Northeast Fisheries Science Center Reference Document 05-14

*41st Northeast Regional Stock Assessment Workshop (41st SAW)*

# 41st SAW Assessment Report

First Issued September 2005
Revised and Reissued August 2006

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05-10 **41st SAW Assessment Summary Report.** By 41st Northeast Regional Stock Assessment Workshop. August 2005.

05-11 **Expanding Opportunities in Oceanic and Atmospheric Sciences III: Proceedings of the Third National Conference to Strengthen the Links among HBMSCUs, NOAA, Business, and Graduate Studies in Marine and Atmospheric Sciences.** By A. Jearld, Jr., and D. Peloquin, compilers. August 2005.

05-12 **Total Bycatch Estimate of Loggerhead Turtles (*Caretta caretta*) in the 2004 Atlantic Sea Scallop (*Placopecten magellanicus*) Fishery.** By K.T. Murray. August 2005.

05-13 **Assessment of 19 Northeast Groundfish Stocks through 2004: 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August 2005.** By R.K. Mayo and M. Terceiro, editors. September 2005.

Northeast Fisheries Science Center Reference Document 05-14

*A Report of the 41st Northeast Regional Stock Assessment Workshop (41st SAW)*

# 41st SAW Assessment Report

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

First Issued September 2005
Revised and Reissued August 2006

# Northeast Fisheries Science Center Reference Documents

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**This document's publication history** is as follows: manuscript submitted for review September 26, 2005; manuscript accepted through technical review September 27, 2005; manuscript accepted through policy review September 28, 2005; final copy submitted for publication September 29, 2005; revision submited August 22, 2006. This document may be cited as:

41st Northeast Regional Stock Assessment Workshop (41st SAW). 41st SAW assessment report. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 05-14; 237 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

**The stock assessments which are the subject of this document** were peer reviewed by a panel of assessment experts known as the Stock Assessment Review Committee (SARC). Panelists were provided by the Center for Independent Experts (CIE), University of Miami. Reports from the SARC panelists and a summary report from the SARC Chairman can be found at *http://www.nefsc.noaa.gov/nefsc/saw*.

# Assessment Report (41st SAW/SARC)

## Table of Contents

**INTRODUCTION TO SAW-41 ASSESSMENT REPORT ........ 1**

**A. SUMMER FLOUNDER ........ 7**
EXECUTIVE SUMMARY ........ 7
1.0 INTRODUCTION ........ 9
2.0 SUMMER FLOUNDER ASSESSMENT SUMMARY FOR 2005 ........ 10
3.0 BIOLOGICAL REFERENCE POINTS FOR SUMMER FLOUNDER ........ 14
Introduction ........ 14
Estimation Methodology ........ 15
Fishery and research survey input data for summer flounder ........ 17
Results: Empirical Non-parametric Approach ........ 20
Results: Parametric Model Approach ........ 20
SDWG Reference Point Advice ........ 22
4.0 RESEARCH RECOMMENDATIONS FOR SUMMER FLOUNDER ........ 23
5.0 LITERATURE CITED ........ 27
SUMMER FLOUNDER TABLES ........ 30
SUMMER FLOUNDER FIGURES ........ 37

**B. ASSESSMENT OF BLUEFISH ........ 53**
EXECUTIVE SUMMARY ........ 53
1.0 TERMS OF REFERENCE ........ 54
2.0 INTRODUCTION ........ 54
2.1 Life History ........ 55
2.2 Growth ........ 55
2.3 Reproduction ........ 56
2.4 Stock Definitions ........ 56
2.5 Habitat Description ........ 56
3.0 DESCRIPTION OF FISHERIES ........ 56
3.1 Commercial Fishery ........ 56
3.2 Recreational Fishery ........ 57
4.0 TERM OF REFERENCE #1: Evaluate adequacy, appropriateness, and uncertainty of fishery-dependent and fishery-independent data used in the assessment ........ 57
4.1 Commercial Data ........ 57
4.2 Commercial Discards or Bycatch ........ 59
4.3 Recreational Data ........ 60
4.4 Fishery-Independent Surveys ........ 62
4.5 General Survey Results ........ 67
4.6 Data Discussion ........ 67
5.0 TERM OF REFERENCE #2: Evaluate adequacy and appropriateness of models used to assess the species and to estimate population benchmarks ........ 68

6.0 TERM OF REFERENCE #3: Evaluate and either update or re-estimate biological reference points as appropriate ........ 69
7.0 TERM OF REFERENCE #4: Estimate and evaluate stock status (biomass) and fishery status (fishing mortality rate) ........ 69
7.1 ADAPT model ........ 69
7.2 Age-Structured Assessment Program (ASAP) ........ 70
8.0 CONCLUSIONS ........ 71
9.0 RESEARCH RECOMMENDATIONS FROM SAW 39 PANEL ........ 71
10.0 TERM OF REFERENCE #5: Research Recommendations ........ 75
11.0 LITERATURE CITED ........ 76
BLUEFISH TABLES ........ 81
BLUEFISH FIGURES ........ 108
APPENDIX I - Other Models Tested for bluefish ........ 130
APPENDIX II – Other surveys that capture bluefish ........ 135

**C. ASSESSMENT OF GOLDEN TILEFISH ........ 138**
EXECUTIVE SUMMARY ........ 138
1.0 INTRODUCTION ........ 141
2.0 DATA SOURCES ........ 141
Commercial catch data ........ 141
Commercial discard data ........ 142
Commercial CPUE data ........ 142
Commercial market category and size composition data ........ 144
Recreational data ........ 145
NEFSC Trawl survey data ........ 145
3.0 MORTALITY AND STOCK SIZE ESTIMATES ........ 146
Surplus production model ........ 146
Catch-Length Model Mortality Estimates ........ 147
An Index Method (AIM) ........ 147
Lagged Recruitment Survival Growth (LRSG) Model ........ 148
Yield and Spawning Stock Biomass per Recruit ........ 149
4.0 Biomass and Fishing Mortality Projections ........ 150
5.0 CONCLUSIONS ........ 150
6.0 SOURCES OF UNCERTAINTY ........ 151
7.0 RESEARCH RECOMMENDATIONS ........ 152
8.0 REFERENCES ........ 154
TILEFISH TABLES ........ 156
TILEFISH FIGURES ........ 170
APPENDIX C1: Working Group Comments ........ 218
APPENDIX C2: NEFSC Weighout CPUE GLM model ........ 220
APPENDIX C3: NEFSC VTR CPUE GLM model ........ 223
APPENDIX C4: ASPIC Run 13 with Bootstrap ........ 225
APPENDIX C5: AIM Model results ........ 234
APPENDIX C6: Length-based YPR ........ 237

# INTRODUCTION TO SAW-41 ASSESSMENT REPORT

The Northeast Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Regions managers.

Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) is now a smaller panel (3 panelists and a chair) with panelists provided by the University of Miami's Independent System for Peer Review (CIE). Second, the SARC no longer provides management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees) formulate management advice, given that an assessment has been accepted by the SARC.

Reports that are produced following the SAW/SARC-41 meeting include: An *Assessment Summary Report* - a brief summary of the assessment results in a format useful to managers; this *Assessment Report* – a detailed account of the assessments for each stock; and SARC panelists reports – one for each panelist and a separate report from the SARC chair summarizing the individual panelist reports.

The 42nd SARC was convened in Woods Hole at the Northeast Fisheries Science Center, June 6 - 10, 2005 to review assessments of summer flounder, bluefish and tilefish. The reviews were based on detailed assessment reports produced by the SAW Southern Demersal Working Group for summer flounder and tilefish and the ASMFC Technical Committee/Assessment Subcommittee for bluefish. A panelist list, meeting agenda, list of working group meetings and a list of attendees are provided in Tables 1 – 4, respectively.

In overview, the SARC accepted the summer flounder and tilefish assessments. The SARC-41 reviewers all accepted the summer flounder and tilefish assessments as sufficient to serve as a basis for providing scientific advice to managers. For the bluefish assessment, however, the SARC members were divided as to the acceptability of the assessment. One reviewer rejected the bluefish assessment. The other two reviewers felt that the bluefish assessment was adequate, but that the assessment results needed to be treated with great caution. All three reviewers felt that the bluefish assessment was weak with respect to the quality of input data, certain aspects of the modeling, and lack of progress on Research Recommendations from the previous SARC. The reviewers spent considerable time discussing the weaknesses of the bluefish assessment; as a consequence, little time was spent discussing whether the updated biological reference points, the estimates of current biomass and fishing mortality rate, and the determination of bluefish stock status were correct. All reviewers believe that this assessment could be improved. Bluefish were also reviewed in June, 2004 by SARC-39, and that assessment was rejected.

Table 1. 41st Stock Assessment Review Committee Panel.

**The 41st Northeast Regional**
**Stock Assessment Review Committee**
**(41st SARC)**

**Stephen H. Clark Conference Room – Northeast Fisheries Science Center**
**Woods Hole, Massachusetts**

**June 6 – 10, 2005**

**SARC Chairman:**

**Cynthia Jones**
**Old Dominion University**
**Virginia, USA (CIE)**

**SARC Panelists:**

**Patrick Cordue**
**Innovative Solutions Limited**
**Wellington, New Zealand (CIE)**

**Olav Godø**
**Inst. of Marine Research**
**Bergen, Norway (CIE)**

**John Wheeler**
**DFO**
**Newfoundland, Canada (CIE)**

Table 2. Agenda, 41st Stock Assessment Review Committee Meeting.

Northeast Regional Stock Assessment Workshop (SAW 41)
**Stock Assessment Review Committee (SARC) Meeting**

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

June 6 – 10, 2005

**AGENDA**

| TOPIC | PRESENTER | SARC LEADER | RAPPORTEUR |
|---|---|---|---|
| **MONDAY, 6 June (1:00 – 5:00 PM)……………………………………………………** | | | |
| Opening | | | |
| Welcome | **James Weinberg**, SAW Chairman | | |
| Introduction | **Cynthia Jones**, SARC Chairman | | |
| Agenda | | | |
| Conduct of Meeting | | | |
| Summer Flounder (A) | **Mark Terceiro** | **Patrick Cordue** | **Kathy Sosebee** |
| SARC Discussion | **Cynthia Jones** | | |
| **Tuesday, 7 June (8:30 AM – 12:00)……………………………………………………** | | | |
| Bluefish (B) | **Jessica Coakley** | **Olav Godø** | **Gary Shepherd** |
| SARC Discussion | **Cynthia Jones** | | |
| **Tuesday, 7 June (1:15 – 5:00 PM)……………………………………………………** | | | |
| Golden Tilefish (C) | **Paul Nitschke** | **John Wheeler** | **Laurel Col** |
| SARC Discussion | **Cynthia Jones** | | |

**Wednesday, 8 June (8:30 AM – 12:00) ………………………………………………**

| | | | |
|---|---|---|---|
| Revisit Assessments, if needed. | **TBA** | TBA | **TBA** |
| SARC Discussion | **Cynthia Jones** | | |

**Wednesday, 8 June (1:15 PM – 5:00) ………………………………………………**

SARC Report writing (closed)

**Thursday, 9 June (8:30 AM – ) ………………………………………………**

SARC Report writing (closed)

Table 3. 41st Stock Assessment Workshop, list of working groups and meetings.

| Assessment Group | Chair | Species | Meeting Date/Place |
|---|---|---|---|
| SAW Southern Demersal Working Group | Mark Terceiro, NMFS NEFSC | **Summer flounder** | May 10-11,2005<br>Woods Hole |

Chris Batsavage, NCDMF
Jeffrey Brust, NJDFW
Steve Cadrin, NMFS NEFSC
Paul Caruso, MADMF
Greg DiDomenico, GSSA/NFI-SMC
Toni Kerns, ASMFC
Janine Laroux, NMFS Contract Observer
Paul Nitschke, NMFS NEFSC
Chris Moore, MAFMC
Brian Murphy, RIDFW
David Simpson, CTDEP
Katherine Sosebee, NMFS NEFSC
Susan Wigley, NMFS NEFSC
Richard Wong, DEDFW
Najih Lazar, RIDFW
Anne Mooney, NYDEC
Don Byrne, NJDFW
Stew Michels, DEDFW
Steve Doctor, MDDNR
Chris Bonzak, VIMS
Rob O'Reilly, VMRC

| Assessment Group | Chair | Species | Meeting Date/Place |
|---|---|---|---|
| SAW Southern Demersal Working Group | Ralph Mayo, NMFS NEFSC | **Tilefish** | May 3-6, 2005<br>Woods Hole |

Larry A. Alade ,UMES/NEFSC
Jon Brodziak, NEFSC
Steve Cadrin, NEFSC
Laurel Col, NEFSC
Dan Farnhan, F/V Kimberly
Brian Hooker, NERO
Chris Legault, NEFSC
Ralph Mayo, NEFSC (Acting Chair)
Jose´ Montañez, MAFMC
Josh Moser, NEFSC
Paul Nitschke, NEFSC (Assessment Lead)
John Nolan, F/V Seacapture
Laurie Nolan, Industry
Michael Palmer, NEFSC
Paul Rago, NEFSC
Anne Richards, NEFSC
Barbara Rountree, NEFSC
Gary Shepherd, NEFSC
Katherine Sosebee, NEFSC
Steve Turner, SEFSC
Susan Wigley, NEFSC

ASMFC Technical Committee/Assessment Subcommittee
Jessica Coakley, MAFMC
**Bluefish** April 28,2005
Providence, RI

| | |
|---|---|
| Jessica Coakley, Chair, MAFMC | Brandon Muffley, NJ DEP |
| Gary Shepherd, NEFSC | Rich Wong, DE DMF |
| Doug Grout, NH Dept. Fish and Wildlife | Rob O'Reilly, VA Marine Res. Comm. |
| Paul Caruso, MA DMF | Beth Burns, NC Div. Mar. Fish. |
| Laura M. Lee, ASMFC | Mark Collins, SC DNR |
| Brian Murphy, RI DMF | Rich McBride, FL Fish & Wildl. Cons. Comm. |
| Kurt Gottschall, CT DEP | Julie Nygard, ASMFC |
| Alice Weber, NY DEP | |

Table 4. 41st Stock Assessment Review Committee, List of Attendees

| | |
|---|---|
| Paul Caruso, MA DMF | Gary Shepherd, NEFSC |
| Jessica Coakley, MAFMC | Julie Nygard, ASMFC |
| Susan Wigley, NEFSC | Laura M. Lee, ASMFC |
| Stacy Kubis, NEFSC | Brian Murphy, RIDFW |
| Laurel Col, NEFSC | Katherine Sosebee, NEFSC |
| Ralph Mayo, NEFSC | Mark Terceiro, NEFSC |
| Russell Brown, NEFSC | Bonnie VanPelt, NMFS-NERO |
| Josh Moser, NEFSC | Laurie Nolan, Industry/MAFMC |
| Toni Kerns, ASMFC | |
| Paul Nitschke, NEFSC | |

**A. SUMMER FLOUNDER**
**Stock Assessment Update**
**And Biological Reference Point Estimation**

**A report of the**
**SAW Southern Demersal Working Group (SDWG), SAW-41**

**Mark Terceiro, Chairman**
**National Marine Fisheries Service**
**Northeast Fisheries Science Center**
**166 Water Street**
**Woods Hole, MA 02543**

## EXECUTIVE SUMMARY

The Terms of Reference (ToR) for SAW 41 were completed as summarized below:

1) Update the summer flounder assessment models (i.e. ADAPT VPA and AGEPRO projection) using the same configurations as those used in the 2004 SAW Southern Demersal Working Group (WG) assessment update.

*The assessment was updated using fishery catches through 2004, survey indices through 2004/2005, and the same ADAPT VPA and AGEPRO model configurations as in the 2004 update. Fully recruited fishing mortality (ages 3-5) was estimated by ADAPT VPA to be 0.40 in 2004, above the current overfishing definition reference point ($F_{threshold} = F_{max}$ = 0.26) and above the updated estimate of $F_{threshold}$ = 0.276. Total stock biomass on Jan. 1, 2005 was estimated to be 54,900 mt, slightly above the biomass threshold (53,200 mt). Forecasts indicate that the currently specified TAL of 13,744 mt (30.3 million lbs) in 2005 will result in a median F in 2005 = 0.40, and the currently specified TAL of 14,969 mt (33.0 million lbs) in 2006 will result in a median F in 2006 = 0.41.*

2) Estimate biological reference points derived by yield and SSB per recruit analysis and by stock-recruitment modeling, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.

3) Consider the recommendations of the MAFMC Science and Statistical Committee (SSC) 2001 peer review of the summer flounder Overfishing Definition in developing the analyses described in ToR 2. The major recommendations were to explore other proxies (besides $F_{max}$) to $F_{MSY}$, to continue stock-recruitment model development as additional stock-recruit estimates become available, and to monitor and utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) as they become available.

*The SDWG updated the biological reference points for summer flounder using both parametric and empirical non-parametric approaches to derive $F_{MSY}$ and $B_{MSY}$ or their* *proxies, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. The SDWG also followed the recommendations of the MAFMC SSC 2001 Overfishing Definition review to utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) in estimating the biological reference points. The mean weights in the catch and stock, maturity schedule, and partial recruitment pattern have been updated and broadened to include data from 1992-2004. This covers the year range for individually measured and weighed fish sampled in NEFSC research surveys, and includes the latest fishery data available. Also in line with the SSC 2001 recommendations, stock-recruitment estimates were updated to include the results of the current assessment update.*

*The SDWG recommended adoption of biological reference points from the empirical non-parametric approach for summer flounder. Updated FMP biological reference points would be* $F_{MSY} = F_{max} = 0.276$*, MSY = 19,072 mt (42.0 million lbs), and* $TSB_{MSY} = 92,645$ *mt (204.2 million lbs; Table 3-4). The biomass threshold of* $0.5*TSB_{MSY} = 46,323$ *mt (102.1 million lbs).*

4) Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in previous SARC and WG reviewed assessments.

*Of the thirteen Research Recommendations (RR) listed in the 2003 assessment, significant progress or completion has been achieved for seven items (RRs # 1, 2, 6, 7, 8, 9, & 10). There has been little or no progress made for the remaining six research recommendations (RRs # 3, 4, 5, 11, 12, & 13). Five new research recommendations were developed during the 2005 SDWG meeting.*

## 1.0 INTRODUCTION

The following Terms of Reference were addressed for summer flounder:

1) Update the summer flounder assessment models (i.e. ADAPT VPA and AGEPRO projection) using the same configurations as those used in the 2004 SAW Southern Demersal Working Group (WG) assessment update.

*WG Response: This ToR was completed; see Section 2) Summer Flounder Assessment Summary for 2005. The updated assessment results were used as inputs for the models used in responding to ToR 2 & 3.*

2) Estimate biological reference points derived by yield and SSB per recruit analysis and by stock-recruitment modeling, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish.

*WG Response: This ToR was completed, and the results were used in formulating WG recommendations for updated values in Section 3) Biological Reference Points for Summer Flounder.*

3) Consider the recommendations of the MAFMC Science and Statistical Committee (SSC) 2001 peer review of the summer flounder Overfishing Definition in developing the analyses described in ToR 2. The major recommendations were to explore other proxies (besides $F_{max}$) to $F_{MSY}$, to continue stock-recruitment model development as additional stock-recruit estimates become available, and to monitor and utilize new data on the population dynamics of summer flounder (e.g., age, growth, and maturity) as they become available.

*WG Response: This ToR was completed, as direct estimates of $F_{MSY}$ were calculated from stock-recruitment models, and updated information on the population dynamics of summer flounder (1992-2004) were included as inputs to the models presented in Section 3) Biological Reference Points for Summer Flounder.*

4) Review, evaluate and report on the status of the SARC/Working Group research recommendations offered in previous SARC and WG reviewed assessments.

*WG Response: This ToR was completed; see Section 4) Research Recommendations for Summer Flounder.*

## 2.0 SUMMER FLOUNDER ASSESSMENT SUMMARY FOR 2005

**State of Stock:** The summer flounder stock is not overfished, but overfishing is occurring relative to the biological reference points. The fishing mortality rate has declined from 1.32 in 1994 to 0.40 in 2004 (Figure 2-1). The 80% confidence interval for F in 2004 ranges from 0.34 to 0.49. Retrospective analysis shows that the current assessment method tends to underestimate recent fishing mortality rates (Figure 2-4). The overfishing reference point $F_{threshold}$ (= $F_{max}$ ) was previously estimated to be 0.263 (Terceiro 1999; MAFMC 1999) (Figures 2-1, 2-3). For the present assessment, the updated estimate of $F_{threshold}$ (= $F_{max}$ ) is 0.276 (Figures 2-1, 2-3) .

Total stock biomass (TSB) has increased substantially since 1989, and was estimated to be 54,900 mt on January 1, 2005. The 80% confidence interval for total stock biomass on January 1, 2005 ranged from 49,300 to 62,100 mt. The biomass threshold reference point (½$TSB_{MSY}$ ) was previously estimated to be 53,200 mt (Terceiro 1999; MAFMC 1999) (Figures 2-2, 2-3). For the present assessment, the updated estimate of the biomass threshold (½$TSB_{MSY}$ ) is 46,323 mt (Figures 2-2, 2-3).

Spawning stock biomass (SSB; Age 0+) declined 72% from 1983 to 1989 (18,800 mt to 5,200 mt), but with improved recruitment and decreased fishing mortality has increased to 38,600 mt in 2004 (Figure 2-2). Retrospective analysis shows a tendency to overestimate the SSB in the most recent years (Figure 2-4). The age structure of the spawning stock has expanded, with 75% at ages 2 and older, and 16% at ages 5 and older (Figure 2-5).

The arithmetic average recruitment from 1982 to 2004 is 38 million fish at age 0, with a median of 33 million fish. The 2004 year class is currently estimated to be at the median of 33 million fish (Figure 2-2, 2-6). Retrospective analysis shows that the current assessment method tends to overestimate the abundance of age 0 fish in the most recent years (Figure 2-4).

**Forecasts for 2005-2006:** Stochastic forecasts were conducted, incorporated uncertainty in 2005 stock sizes from survey variability, and assumed current discard to landings proportions. If landings in 2005 are 13,744 mt (30.2 million lbs) and discards are 1,269 mt (2.8 million lbs), the forecasts estimate a median F in 2005 = 0.40 and a median total stock biomass on January 1, 2006 of 59,900 mt, above the biomass threshold of ½$TSB_{MSY}$ = 53,200 mt. (Figure 2-3). Landings of 14,969 mt (33.0 million lbs) and discards of 1,400 mt (3.1 million lbs) in 2006 provide a median F in 2006 = 0.41 and a median total stock biomass level on January 1, 2007 of 63,800 mt (Figure 2-3). A subsequent reduction in fishing mortality in 2007 to F = 0.263, the reference point, is forecast to yield landings of 10,853 mt (23.9 million lbs).

**Forecast Table: 2005 Landings = 13,744 mt**
**2005-2007 median recruitment from 1982-2004 VPA estimates (33.1million)**

Forecast medians (landings, discards, and total stock biomass (TSB) in '000 mt)

| 2005 | | | | 2006 | | | | 2007 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TSB | F | Land | Disc | TSB | F | Land | Disc | TSB | F | Land | Disc |
| 54.9 | 0.40 | 13.7 | 1.3 | 59.9 | 0.41 | 15.0 | 1.4 | 63.8 | 0.26 | 10.9 | 1.0 |

**Catch and Status Table (weights in '000 mt, recruitment in millions, arithmetic means): Summer Flounder**

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Max[2] | Min[2] | Mean[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| Commercial landings | 5.1 | 4.8 | 5.1 | 5.0 | 6.6 | 6.5 | 7.8 | 17.1 | 4.0 | 8.3 |
| Commercial discards | 0.4 | 1.5 | 0.7 | 0.5 | 0.4 | 0.5 | 0.2 | 1.5 | 0.2 | 0.7 |
| Recreational landings | 5.7 | 3.8 | 7.1 | 5.3 | 3.6 | 5.3 | 4.8 | 12.7 | 1.4 | 5.3 |
| Recreational discards | 0.5 | 0.7 | 0.9 | 1.2 | 0.7 | 0.7 | 1.0 | 1.2 | 0.1 | 0.5 |
| Catch used in assessment | 11.7 | 10.8 | 13.8 | 12.0 | 11.3 | 13.0 | 13.8 | 26.5 | 8.0 | 14.6 |
| Commercial quota | 4.9 | 4.9 | 4.9 | 4.6 | 6.6 | 6.3 | 7.6 | | | |
| Recreational harvest limit | 3.4 | 3.4 | 3.4 | 3.3 | 4.4 | 4.2 | 5.1 | | | |
| | | | | | | | | | | |
| Spawning stock biomass[1] | 17.8 | 16.5 | 19.4 | 25.5 | 29.4 | 36.4 | 38.6 | 38.6 | 5.2 | 16.5 |
| Recruitment (age 0) | 31.0 | 29.4 | 35.9 | 32.8 | 38.1 | 27.5 | 33.1 | 80.3 | 13.0 | 38.0 |
| Total stock biomass[3] | 32.0 | 29.1 | 27.9 | 31.4 | 39.5 | 46.4 | 53.1 | 53.1 | 16.1 | 32.7 |
| F (ages 3-5) | 0.97 | 0.99 | 0.86 | 0.65 | 0.46 | 0.43 | 0.40 | 2.07 | 0.40 | 1.32 |
| Exploitation rate | 57% | 58% | 53% | 44% | 34% | 33% | 30% | 82% | 23% | 68% |

[1]At the peak of the spawning season (i.e., on November 1), ages 0-7+ . [2]Over period 1982-2004 [3]On January 1

**Stock Distribution and Identification:** The Mid-Atlantic Fishery Management Council (MAFMC) and Atlantic States Marine Fisheries Commission (ASMFC) Fishery Management Plan for summer flounder defines the management unit as all summer flounder from the southern border of North Carolina northeast to the US-Canada border. For assessment purposes, the definition of Wilk et al. (1980) of a unit stock extending from Cape Hatteras north to New England has been accepted in this and previous assessments (NEFSC 2002a). A recent summer flounder genetics study, which revealed no population subdivision at Cape Hatteras (Jones and Quattro 1999), is consistent with the definition of the current management unit. A recent consideration of summer flounder stock structure incorporating new tagging data concluded that evidence supported the existence of stocks north and south of Cape Hatteras, with the stock north of Cape Hatteras possibly composed of two distinct spawning aggregations, off New Jersey and Virginia-North Carolina (Kraus and Musick, 2003). The conclusions of Kraus and Musick (2003) are consistent with the current assessment unit.

**Catches:** Total landings peaked in 1983 at 26,100 mt. During the late 1980s and into 1990, landings declined markedly, reaching 4,200 mt in the commercial fishery in 1990 and 1,400 mt in the recreational fishery in 1989. Total landings were only 6,500 mt in 1990. Reported 2004 landings in the commercial fishery were 7,748 mt, about 2% over the adjusted commercial quota.

Commercial discard losses are estimated from fishery observer data and have recently constituted 5%-10% of the total commercial catch, assuming a discard mortality rate of 80%. Estimated 2004 landings in the recreational fishery were 4,841 mt, about 5% under the recreational harvest limit. Recreational discard losses have recently comprised 10%-15% of the total recreational catch, assuming a discard mortality rate of 10%. Total commercial and recreational landings in 2004 were 12,589 mt, and total catch was estimated at 13,832 mt (Figure 2-1).

**Data and Assessment:** An analytical assessment (VPA) of commercial and recreational total catch at age (landings plus discards) was conducted. The natural mortality rate (M) was assumed to be 0.2. Indices of recruitment and stock abundance from NEFSC winter, spring, and autumn; Massachusetts spring and autumn; Rhode Island; Connecticut spring and autumn; Delaware; and New Jersey trawl surveys were used in VPA tuning in an ADAPT framework (NFT 2005). Recruitment indices from surveys conducted by the states of North Carolina, Virginia, and Maryland were also used in the VPA tuning. The current VPA tuning configuration is the same as that in the 2002 SAW 35 (NEFSC 2002a) and in the 2003 and 2004 SAW Southern Demersal Working Group assessments (Terceiro 2003, SDWG 2004).

**Biological Reference Points:** Biological reference points for summer flounder are based on a yield per recruit model (Thompson and Bell 1934). The yield per recruit analysis conducted for the 1999 assessment (Terceiro 1999) indicated that $F_{max}$ = 0.263, which was used as a proxy for $F_{threshold}$ (Figure 2-3). No value for $F_{target}$ has been defined for summer flounder. The current Fishery Management Plan (FMP) Amendment 12 stock biomass reference points were estimated as the product of yield per recruit (0.552 kg per recruit) and total stock biomass per recruit (2.813 kg per recruit) at $F_{max}$ = 0.263, and median recruitment of 37.8 million fish per year (1982-1998; from Terceiro (1999)). Yield at $F_{max}$, used as a proxy for MSY, was estimated to be 20,900 mt (46 million lbs), and the corresponding stock biomass, used as a proxy for $B_{MSY,}$ was estimated to be 106,400 mt (235 million lbs; Figure 2-3). In the review of the 2002 stock assessment, SARC 35 concluded that updating these reference points was not warranted at that time (NEFSC 2002a).

For present assessment, updated input data (1992-2004 average mean weights, maturities, and partial recruitment) were used to revise the yield and biomass per recruit analysis. The updated 1982-2004 VPA provided an estimate of median recruitment for summer flounder of 33.1 million age 0 fish. The revised estimates of the biological reference points are $F_{MSY} = F_{max}$ = 0.276, MSY = 19,072 mt (42.0 million lbs), and $TSB_{MSY}$ = 92,645 mt (204.2 million lbs). The revised estimate of the biomass threshold, ½$TSB_{MSY,}$ is 46,323 mt (102.1 million lbs).

**Fishing Mortality:** Fishing mortality calculated from the average of the currently fully recruited ages (3-5) was high during 1982-1997, varying between 0.9 and 2.2 (55%-83% exploitation), far in excess of the Amendment 12 overfishing definition, $F_{threshold} = F_{max}$ = 0.26 (21% exploitation; Figure 2-1). The fishing mortality rate has declined substantially since 1997 and was estimated to be 0.40 (30% exploitation) in 2004. The 80% confidence interval for F in 2004 ranged from 0.34 to 0.49. Retrospective analysis shows that the current assessment method tends to underestimate recent fishing mortality rates (Figure 2-4).

**Total Stock Biomass**: Total stock biomass has increased substantially since 1989, and in 2005 total stock biomass was estimated to be 54,900 mt, slightly above the Amendment 12 biomass threshold (Figures 2-2, 2-3). The 80% confidence interval for total stock biomass in 2005 ranged from 49,300 to 62,100 mt.

**Recruitment:** The arithmetic average recruitment from 1982 to 2004 is 38 million fish at age 0, with a median of 33 million fish. The 1982 and 1983 year classes are the largest in the VPA time series, at 74 and 80 million fish. Recruitment declined from 1983 to 1988, with the 1988 year class the weakest at only 13 million fish. Recruitment since 1988 has generally improved. The 2003 year class is currently estimated to be below average at 27 million fish. The 2004 year class is currently estimated to be at the median of 33 million fish (Figures 2-2, 2-6). Retrospective analysis shows that the current assessment method tends to overestimate the abundance of age 0 fish in the most recent years (Figure 2-4).

**Spawning Stock Biomass:** Spawning stock biomass (SSB; Age 0+) declined 72% from 1983 to 1989 (18,800 mt to 5,200 mt), but with improved recruitment and decreased fishing mortality has increased to 38,600 mt in 2004 (Figure 2-2). Retrospective analysis shows a tendency to overestimate the SSB in the most recent years (Figure 2-4). The age structure of the spawning stock has expanded, with 75% at ages 2 and older, and 16% at ages 5 and older (Figure 2-5). Under equilibrium conditions and at $F_{max}$ = 0.263 from Amendment 12, about 85% of the spawning stock biomass would be expected to be ages 2 and older, with 50% at ages 5 and older (Figure 2-5). Similar results for the long-term population structure are derived using the updated $F_{max}$ = 0.276.

**Special comments: Major sources of assessment uncertainty**

1) There is persistent retrospective underestimation of fishing mortality in the assessment.

2) The landings from the commercial fisheries used in this assessment assume no under reporting of summer flounder landings. Therefore, reported landings from the commercial fisheries should be considered minimal estimates.

3) The recreational fishery landings and discards used in the assessment are estimates developed from the Marine Recreational Fishery Statistics Survey (MRFSS). While the estimates of summer flounder catch are among the most precise produced by the MRFSS, they are subject to possible error. The proportional standard error (PSE) of estimates of summer flounder total landings in numbers has averaged 7%, ranging from 26% in 1982 to 3% in 1996, during 1982-2004.

4) The length and age composition of the recreational discards are based on data from a limited geographic area (Long Island, New York, 1988-1992; Connecticut, 1997-2004, New York party boats 2000-2004, ALS releases focused in New York and New Jersey, 1999-2004). Sampling of recreational fishery discards on an annual, synoptic basis is needed.

5) The allocation of commercial landings to water area and the measure of commercial fishing effort used in the estimate of discards both rely on information self-reported by commercial fishermen in Vessel Trip Reports (VTR), which are subject to possible error.

## 3.0 BIOLOGICAL REFERENCE POINTS FOR SUMMER FLOUNDER

### Introduction

The calculation of biological reference points for summer flounder based on yield per recruit analysis using the Thompson and Bell (1934) model was first detailed in the 1990 Stock Assessment Workshop (SAW) 11 assessment (NEFC 1990). The 1990 analysis estimated that $F_{max}$ = 0.23. In the 1997 SAW 25 assessment (NEFSC 1997), an updated yield per recruit analysis reflecting the partial recruitment pattern and mean weights at age for 1995-1996 estimated that $F_{max}$ = 0.24. The analysis in the Terceiro (1999) assessment, reflecting partial recruitment and mean weights at age for 1997-1998, estimated that $F_{max}$ = 0.263.

The Overfishing Definition Review Panel (Applegate *et al.* 1998) recommended that the Mid-Atlantic Fishery Management Council (MAFMC) base MSY proxy reference points on yield per recruit analysis, and this recommendation was adopted in formulating the FMP Amendment 12 Overfishing Definition (MAFMC 1999). These reference points were based on the 1999 assessment (Terceiro 1999) and followed what would later be described as the "empirical non-parametric approach," detailed below (NEFSC 2002b). The 1999 assessment yield per recruit analysis indicated that $F_{threshold}$ = $F_{max}$ = 0.263, yield per recruit (YPR) at $F_{max}$ was 0.55219 kg/recruit, and January 1 biomass per recruit (BPR) at $F_{max}$ was 2.8127 kg/recruit. The median number of summer flounder recruits estimated from the 1999 Virtual Population Analysis (VPA) for 1982-1998 was 37.844 million age-0 fish. Based on this median recruitment level, maximum sustainable yield (MSY) was estimated to be 20,897 mt (46 million lbs) at a total stock biomass ($B_{MSY}$) of 106,444 mt (235 million lbs). The biomass threshold, one-half $B_{MSY}$, was therefore estimated to be 53,222 mt (118 million lbs). The Terceiro (1999) reference points were retained in the 2000 SAW 31 assessment (NEFSC 2000) because of the stability of the input data and resulting biological reference point estimates.

The MAFMC Science and Statistical Committee (SSC) conducted a peer review of the summer flounder Overfishing Definition in concert with the 2001 assessment update (MAFMC 2001a, b). The SSC reviewed six analyses to estimate biological reference points for summer flounder conducted by members of the Atlantic States Marine Fisheries Commission (ASMFC) Summer Flounder Biological Reference Point Working Group. After considerable discussion, the SSC decided that although the new analyses conducted by the ASMFC Working Group had resulted in a wide range of estimates, they did not provide a reliable alternative set of reference points for summer flounder. The SSC therefore recommended that $F_{target}$ remain $F_{max}$ = 0.263 because a better estimate had not been established by any of the new analyses. The SSC also reviewed the biomass target ($B_{MSY}$) and threshold (one-half $B_{MSY}$) components of the Overfishing Definition and concluded that the new analyses did not justify an alternative estimate of $B_{MSY.}$

The SSC endorsed the recommendations of SAW 31 which stated that "the use of $F_{max}$ as a proxy for $F_{MSY}$ should be reconsidered as more information on the dynamics of growth in relation to biomass and the shape of the stock recruitment function become available" (NEFSC 2000). The SSC agreed that additional years of stock and recruitment data should be collected and encouraged further model development, including model evaluation through simulation studies. They also encouraged the evaluation of alternative proxies for biological reference points that might be more appropriate for an early maturing species like summer flounder and the development and evaluation of management strategies for fisheries where $B_{MSY}$ is unknown. The SSC indicated that as the stock size increases, population dynamic processes that could reflect density dependent mechanisms should be more closely monitored and corresponding analyses should be expanded, i.e., rates of size and age, maturity, fecundity, and egg viability should be closely monitored as potential indicators of compensation at higher stock sizes. Finally, the committee recommended that potential environmental influences on recruitment, including oceanographic changes and predation mortality, should be reevaluated as additional recruitment data become available.

As a result of the SSC peer review (MAFMC 2001a) the Terceiro (1999) reference points were retained in the 2001 stock assessment (MAFMC 2001b). In the review of the 2002 stock assessment (NEFSC 2002a), SAW 35 concluded that revision of the reference points was not warranted at that time due to the continuing stability of the input data and resulting reference point estimates. The Terceiro (1999) reference points were retained in the 2003 (Terceiro 2003) and 2004 (SDWG 2004) assessment updates.

The SAW Southern Demersal Working Group (SDWG), the scientific body responsible for the summer flounder assessment, has continued to monitor the biological characteristics of the stock in accordance with SARC and SSC recommendations. This work updates the biological reference points for summer flounder based on the 2005 assessment update using fishery data through 2004 and research survey data through 2004/2005.

**Estimation Methodology**

The SDWG updated the biological reference points for summer flounder using both parametric and empirical non-parametric approaches to derive $F_{MSY}$ and $B_{MSY}$ or their proxies, following the procedures adopted by the 2002 Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (BRPWG; NEFSC 2002b). Note that the remainder of this **Estimation Methodology** section closely paraphrases pages 14-26 of the 2002 BRPWG report, with interspersed references specific to summer flounder.

The two approaches were applied so as to be potentially complimentary and supportive and because using both should build confidence in the results. Where results differ appreciably, the results of the empirical approach were used as a component in final model selection. Automatic objective application of these techniques is often compromised by lack of sufficient observation on stock and recruitment over a range of biomass to provide suitable contrast. Thus it is often necessary to extrapolate beyond the range of observation and to infer the shape of the stock recruit relationship from limited and variable observations. The 2001 MAFMC SSC review of summer flounder reference points also noted this concern (MAFMC 2001a).

*The empirical non-parametric approach* was to evaluate various statistical moments (mean, variance, percentiles) of the observed series of recruitment data and apply the estimated biomass or yield per recruit associated with common F reference points to derive the implied spawning or total biomass and equilibrium yield. The yield and biomass per recruit models were fit using the NOAA Fisheries Toolbox (NFT) YPR version 2.6 software (NFT 2004a). A loess smoother (tension = 0.5) was fit to the scatter plot of stock-recruitment estimates as a visual guide to any trend in the relationship. If the trend was flat (implying that the observed recruitment variation was density independent), then the mean or median recruitment was chosen for the biomass and yield calculations. For summer flounder the median recruitment estimated by ADAPT VPA was used in the biomass calculations at fishing mortality reference points for consistency with the method used to calculate the FMP Amendment 12 reference points. In addition to performing the calculation at $F_{max}$, this work for summer flounder also followed the 2002 BRPWG guideline (NEFSC 2002b) to use a $B_{MSY}$ proxy calculated from the spawning biomass per recruit at $F_{40\%}$. The empirical, non-parametric approach assumes that compensatory mechanisms such as impaired growth, maturity, or recruit survival are negligible over the range of biomass considered.

*The parametric approach* used fitted parametric stock-recruitment models along with yield and spawning biomass per recruit information to calculate MSY-based reference points following the procedure of Sissenwine and Shepherd (1987). Stock-recruitment models were fit using the NFT SRFIT version 6.0.3 software (NFT 2004b) and evaluated using the approach described in Brodziak et al. (2001) and Brodziak and Legault (2005). For summer flounder, both compensatory Beverton-Holt (Beverton and Holt 1957, Mace and Doohan 1988) and over-compensatory Ricker stock-recruit models (Ricker 1954) were fit using maximum likelihood estimation. The stochastic component of the models was represented by a multiplicative lognormal or an autoregressive, multiplicative lognormal error structure with a lag of one year. The autoregressive term was included to model serial correlation in random environmental variation, because this allowed successive recruitments to be correlated when the potential effects of environmental forcing were indicated (e.g., periods of good recruitment followed by periods of poor recruitment, regardless of the influence of the stock). Finally, the modeling framework allowed Bayesian priors on Beverton-Holt curve steepness ($z_{max}$, the ratio of recruitment (R) at 20% of the maximum observed SSB ($S_{max}$) to the R at $S_{max}$ ; Myers et al. 1999), Ricker slope at the curve origin, and unfished recruitment (Brodziak at al. 2001; NEFSC 2002b, Brodziak and Legault 2005).

For each of the candidate stock-recruit models, a hierarchy of criteria was applied to determine whether the maximum likelihood mode fits were consistent with auxiliary information and with respect to model goodness of fit measures. A priori, it was required that the estimated MLE from the model fit satisfied the first- and second- order derivative conditions required for a strict maximum (i.e., the gradient of the log likelihood is identically zero at the MLE; Hessian matrix of the second derivatives of the negative log likelihood is positive definite). In addition to satisfying these derivative conditions, each model was required to satisfy the following six criteria to be considered credible:

1) Parameter estimates must not lie on the boundary of their feasible range of values
2) The estimate of MSY lies within the range of observed landings
3) The estimate of $S_{MSY}$ is not substantially greater than the nonparametric proxy estimate
4) The estimate of $F_{MSY}$ is not substantially greater than the value of $F_{max}$
5) The dominant frequencies for the autoregressive parameter, if applicable, lie within the range of one-half of the length of the stock-recruitment time series (implying the influence of environmental forcing within the length of the observed stock-recruitment time series)
6) The estimate of recruitment at $S_{MAX}$, the maximum spawning stock size proxy input to the stock-recruitment model, is consistent with the value of recruitment used to compute the nonparametric proxy estimate of $S_{MSY}$

Next, for the subset of parametric models that satisfied these criteria,, Akaike's Information Criteria (AIC) was used to assign relative probabilities to each model based on likelihood values, and the resulting model likelihood ratios calculated and compared using Bayes Theorem to judge the most likely model (odds ratio test; the posterior probability that each model represents the true state of nature). In the absence of any prior information on the credibility of candidate models, equal prior probability was assumed. Models that did not satisfy derivative condition or one or more of the hierarchal criteria were assigned a prior probability of zero and eliminated from further consideration (Brodziak et al., 2001, NEFSC 2002b).

**Fishery and research survey input data for summer flounder**

In the 1990 SAW 11 yield and biomass per recruit analysis (NEFC 1990), mean weights at age in the catch and stock were based on fishery mean weights at age (catch number weighted average of commercial and recreational landed weights at age) for ages 0-8, 1982-1988. The 1990 analysis assumed a natural mortality rate of M = 0.2, based an assumed maximum age of about 15 years (Anthony 1982; Penttila et al. 1989). No commercial or research survey estimates for ages 9-15 were available, so a Gomphertz model relating age and weight was fit to the age 0-8 mean weight age estimates to develop mean weights for ages 9-15 ($W_t = W_0 * \exp(G(1-\exp(-gt)))$)(Table 3-1) . Maturity at age was estimated from NEFSC Autumn survey data for 1978-1989. Peak spawning was estimated to occur on November 1 (0.83 years). Combined maturities indicated the following estimated percentages mature at age: 38% for age 0, 72% for age 1, 90% for age 2, 97% for age 3, 99% for age 4, and 100% for ages 5 and older. The partial recruitment vector for the 1990 SAW 11 analysis was developed from a separable virtual population analysis (SVPA) employing catch at age data for 1982-1988, with the reference age set at age 2 and selection at age 4 set at 1.0. The analysis indicated the following selection percentages at age: 5% at age 0, 50% at age 1, and 100% at ages 2 and older (Table 3-2). As noted in the **Introduction**, the yield and biomass per recruit analysis was updated in the 1999 assessment (Terceiro 1999) using the mean weights at age in the catch and partial recruitment pattern for 1997-1998. Mean weights from the catch and spawning biomass were recalculated for ages 0-8 only; the mean weights from the 1990 analysis were retained for ages 9-15. Mean weights at age on January 1 were estimated from the mid-year catch weights using the Rivard equations (Rivard 1982) to provide input for the calculation of total stock biomass per recruit. Maturities at ages 0-2 were the same as in the 1990 SAW 11 analysis, while maturities at ages 3 and 4 were rounded up to 100% (Tables 3-1, 3-2). The 1999 analysis was reviewed in the subsequent assessments (NEFSC 2000; MAFMC 2001b; NEFSC 2002a; Terceiro 2003, SDWG 2004) and the results retained as the basis for biological reference points due to the continuing stability of the input data and resulting parameter estimates (Tables 3-3, 3-4).

In this work, the mean weights at age in the catch and stock, maturity schedule, and partial recruitment pattern have been updated and broadened to include data from 1992-2004. This covers the year range for individually measured and weighed fish sampled in NEFSC research surveys. These NEFSC research survey data have been used to develop estimates of mean weights at age for fish in the total (January 1) and spawning (November 1) biomass and for the maturity schedule. Summer flounder spawning takes place during the annual southern and offshore migration during the autumn and winter months, with peak activity occurring in October and November (O'Brien et al. 1993). Spawning stock biomass mean weights at age and observed proportions mature at age were therefore estimated from NEFSC autumn survey (1992-2004; September-October) individual fish samples (Tables 3-1, 3-2; Figures 3-1, 3-2). Total stock biomass (January 1) mean weights at age were estimated from the NEFSC winter survey (1993-2004; February) individual fish samples (Table 3-2; Figures 3-1, 3-3). Cumulative sample sizes at age for the 1992/1993-2004 period were as follows:

Age

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7+ | Total |
|---|---|---|---|---|---|---|---|---|---|
| Autumn weights and maturities | 696 | 2,150 | 1,467 | 489 | 132 | 64 | 29 | 14 | 5,041 |
| Winter Weights | 0 | 2,250 | 4,428 | 2,421 | 1,270 | 527 | 225 | 172 | 11,293 |

Estimates of the mean weights in the catch have been developed as in previous assessments, using samples from the commercial and recreational fishery landings and discards at length and age and quarterly length-weight relationships from Lux and Porter (1966), for the1992-2004 period (Tables 3-1, 3-2; Figures 3-1, 3-4). Annual commercial landings length sample sizes averaged 7,398 fish per year in NEFSC samples (88,776 total) and 17,823 fish per year (213,887 total) in NCDMF samples. Annual commercial discard length sample sizes averaged 3,688 fish per year in NEFSC (44,259 total). Annual recreational landings length samples sizes averaged 4,335 fish per year (52,024 total) in NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) samples and 764 fish per year (3,054 total) in New York Department of Environmental Conservation (NYDEC) samples (2000-2003). Annual recreational discard length samples sizes averaged 1,354 fish per year (5,416 total) in NYDEP samples (2000-2003). Annual commercial landings age sample sizes averaged 1,922 fish per year in NEFSC samples (23,064 total) and 490 fish per year (5,880 total) in NCDMF samples; while recreational fishery age sample sizes averaged 1,093 fish per year (2,185 total) in NYDEC samples (2002-2003). With all data sources combined, the mean weights at age in the catch (landings and discards) for the period 1992-2004 were derived from a cumulative length sample total of 407,297 fish and cumulative age sample total of 31,129 fish.

As in previous work for older aged fish with very limited or missing samples, Gomphertz functions based on younger ages were used to estimate mean weights for the older ages (NEFSC Winter survey ages 1-11 for Jan1 Bio ages 12-15; n = 11,293 fish, $W_0 = 0.0926$, $G = 4.0758$, $g = 0.2929$, $p < 0.0001$; NEFSC Autumn survey ages 0-8 for catch and Nov 1 SSB ages 9-15, n = 4601 fish, $W_0 = 0.1959$, $G = 3.5480$, $g = 0.2662$, $p < 0.0001$). Also, for the 2005 SAW 41 catch at age 8, the Nov 1 SSB weight (NEFSC Autumn Survey) was substituted due to low sample numbers from the fisheries. For the 2005 SAW 41 Jan 1 Bio at age 0, the Nov 1 SSB weight at age 0 was substituted since no age 0 fish are taken in the NEFSC Winter survey (Table 3-1).

The partial recruitment pattern has been calculated from fishing mortality rate estimates from the SDWG 2005 assessment NFT ADAPT VPA for 1992-2004 (See Section 2: Assessment Update and Table 3-2). The SDWG considered shorter time periods over which to calculate the partial recruitment pattern, in order to reflect the most recent changes in regulations that might impact partial recruitment. However, the average partial recruitment, and thus the estimated yield and biomass per recruit, was not very sensitive to the period of years included in the averaging. There was practically no change in partial recruitment for ages 0, 1, and 3 and older for the three periods examined (1992-2004 as compared to 1997-2004 or 2002-2004). The partial selection for age 2 fish varied from ~60% to ~80%, depending on the year range selected. Further, the partial recruitment pattern (partial fishing mortality at age) in the most recent years of the summer flounder VPA often change and eventually stabilize at higher values as those estimates pass into the converged portion of the VPA, a function of VPA convergence properties and the current pattern of retrospective bias in the assessment. Thus, the SDWG used the same time periods for the partial recruitment as for the mean weights and maturities at age.

The 2002 BRPWG (NEFSC 2002b) fit stock-recruitment models to data sets for some of the New England groundfish stocks which included "hindcast" estimates of spawning stock and recruitment – estimates derived from NEFSC survey data for years before the start of the respective VPA time series. These "hindcast" estimates were developed in an attempt to enlarge the stock-recruit data sets and include estimates beyond the range of the VPA estimates, thus providing greater contrast in the data used to fit stock-recruitment models. In the 2001 SSC peer review for summer flounder (MAFMC 2001a), "hindcast" estimates for summer flounder were also developed for stock-recruitment model work. The "hindcast" estimates were of limited utility in the 2001 modeling work because the longest available series of research survey indices of spawning stock (NEFSC Spring survey biomass per tow: 1969-2000) and recruitment (MD DNR index of age-0 summer flounder: 1972-2000) did not provides estimates outside the range of the VPA estimates and so failed to increase the contrast in the stock-recruitment data, therefore providing essentially the same stock-recruitment model results. The "hindcast" exercise was attempted again in the preliminary stages of this work, by incorporating the updated VPA estimates and most recent survey indices. While the relationships between the survey indices and VPA estimates continue to be statistically significant (NEFSC biomass: VPA SSB, $r^2 = 0.70$, $p < 0.01$; MDDNR age-0: VPA age-0; $r^2 = 0.41$, $p<0.05$), the pre-VPA "hindcast" estimates of spawning stock and recruitment remain within the range of the VPA estimates and therefore provide similar stock-recruitment model results, and so use of "hindcast" estimates was not continued in developing the current suite of parametric model comparisons. Therefore, the SDWG 2005 assessment NFT ADAPT VPA 1982-2004 time series of stock-recruit estimates was used as input in fitting parametric stock-recruit models (See Section 2: Assessment Update; Table 3-5; Figure 3-5).

For the Bayesian priors, the Beverton-Holt model steepness (and Ricker model slope starting values were set at mean = 0.8 and standard error = 0.1, reflecting the values reported in Myers et al. (1999) for Pleuronectid flounders (Beverton-Holt steepness mean = 0.8, standard error = 0.09; Ricker slope mean = 0.79, standard error = 0.18). Recruitment priors approximated the 1982-2004 ADAPT VPA time series of stock-recruit estimates, with mean of 40 million fish and standard error of 10 million fish.

**Results: Empirical Non-parametric Approach**

The yield per recruit analysis indicated that Fmax = 0.276 (the FMP Amendment 12 proxy for $F_{MSY}$), and $F_{40\%}$ = 0.181 (the 2002 BRPWG [NEFSC 2002b] recommended proxy for $F_{MSY}$). Yield per Recruit (Y/R) at $F_{max}$ was estimated to be 0.576 kg, Spawning Stock Biomass per Recruit (SSB/R) at $F_{max}$ was estimated to be 2.466 kg, and Total Stock Biomass per Recruit (TSB/R) at $F_{max}$ was estimated to be 2.798 kg. Yield per Recruit at $F_{40\%}$ was estimated to be 0.553 kg, SSB/R at $F_{40\%}$ was estimated to be 3.477 kg, and TSB/R at $F_{40\%}$ was estimated to be 3.748 kg (Table 3-3).

Given that the loess smoother (tension = 0.5) indicted no trend in recruitment with spawning stock size, the recruitment at age 0 estimates from the 2005 ADAPT VPA for the entire time series (1982-2004) were used to calculate the equilibrium biomass ($SSB_{MSY}$, $B_{MSY}$) and yields (MSY) in the empirical non-parametric approach (Figure 3-5). Median recruitment was estimated to be 33.111 million fish (mean of 37.951 million fish). The product of the median recruitment and Y/R at $F_{max}$ was 19,072 mt (current FMP Amendment 12 proxy for MSY), SSB at $F_{max}$ was calculated at 81,652 mt, and TSB at $F_{max}$ was calculated at 92,645 mt (current FMP Amendment 12 proxy for $B_{MSY}$). The product of the median recruitment and Y/R at $F_{40\%}$ was 18,310 mt, SSB at $F_{40\%}$ was calculated at 115,127 mt, and Total Biomass at $F_{40\%}$ was calculated at 124,100 mt.

New FMP biological reference points derived from the empirical non-parametric approach would be $F_{MSY} = F_{max}$ =0.276, MSY = 19,072 mt (42.0 million lbs), and $TSB_{MSY}$ = 92,645 mt (204.2 million lbs), where the estimate of MSY includes commercial and recreational landings and discards. The biomass threshold of 0.5* $TSB_{MSY}$ = 46,323 mt (102.1 million lbs). A comparison with the biological reference points from the 1990 SAW 11 assessment (NEFC 1990) and 1999 Assessment/FMP Amendment 12 (Terceiro 1999; MAFMC 1999) is provided in Table 3-4.

**Results: Parametric Model Approach**

Maximum likelihood fits of 12 parametric stock-recruitment models to the summer flounder VPA estimates for 1982-2004 are listed in Table 3-6. The model acronyms are: BH = Beverton-Holt, ABH = Beverton-Holt with autoregressive errors, RBH = Beverton-Holt with recruitment prior, SBH = Beverton-Holt with steepness prior, ARBH = Beverton-Holt with autoregressive errors and recruitment prior, ASBH = Beverton-Holt with autoregressive errors and steepness prior, RSBH = Beverton-Holt with recruitment and steepness priors, ARSBH = Beverton-Holt with autoregressive errors and both recruitment and steepness priors, RK = Ricker model, ARK = Ricker model with autoregressive errors, SRK = Ricker model with slope prior, ASRK = Ricker model with autoregressive errors and slope prior. The six hierarchical criteria were applied to each of the models to determine the set of candidate models.

The first criterion (i.e., feasible parameter estimates) was not satisfied by any of the Ricker model configurations, which either provided estimates of $F_{MSY}$ (> 1.0) that greatly exceed $F_{max}$ (0.27) or infeasible estimates of $S_{MSY}$ (either very large or very small). All of the Beverton-Holt models satisfied the first through fourth criteria, with estimates of MSY within the range of observed landings (i.e., 20,000-30,000 mt), estimates of $S_{MSY}$ comparable to the empirical non-parametric approach estimate (95,000-105,000 mt), estimates of $F_{MSY}$ (~0.25-0.26) comparable to the values of $F_{max}$ (0.23-0.27), and estimates of the Beverton-Holt steepness parameter (~0.98-1.00) that were similar to the Bayesian prior (mean = 0.8, standard error = 0.1) for other flatfish stocks, although outside the $\pm$1 standard error interval.

The four Beverton-Holt models incorporating autoregressive errors all provided dominant power spectrum frequencies greater (~25 years or more) than one-half the length of the relatively short stock-recruitment time series for summer flounder (one-half of 22 years = 11 years), and so failed to satisfy the fifth criterion since this result implies a period of environmental forcing greater than the length of the stock-recruitment time series (Figure 3-6). The four remaining Beverton-Holt models (BH, RBH, SBH, and RSBH) all satisfied the sixth criteria, providing estimates of recruitment at $S_{max}$ ($R_{max}$, ~ 40 million fish) consistent with the value of recruitment (~33 million fish) used to compute the empirical non-parametric estimate of $S_{MSY}$. The four remaining models also had very similar corrected AIC values and parameter estimates. To aid in the selection of the most likely model, the four models were assigned equal prior probability (i.e., 0.250), and the model likelihood ratios compared using Bayes Theorem to compute the posterior probability that each model represents the true state of nature (Brodziak et al. 2001, NEFSC 2002b). Since the AIC value for the BH model (Beverton-Holt without priors) was very slightly lower than the other models, the odds ratio of the BH model being true compared to the others was also slightly better (i.e., 0.1% more likely than the RBH, 4% more likely than the RSBH, and 7% more likely than the SBH), and so the BH configuration was selected as the most likely model (Table 3-7).

The standardized residual plot of the fit of the BH model to the summer flounder stock-recruitment data shows that the residuals lie within $\pm$two standard deviations of zero, with the exception of the 1983 and 1988 year classes, which are the largest and smallest recruitments of the time series (Figure 3-7). The BH model stock-recruitment plot shows that recruitment values near $SSB_{MSY}$ are about 40 million fish, about 20% higher than the median of 33 million fish from the observed VPA recruitment series (Figure 3-8). Parameter uncertainty plots show 5000 Markov Chain Monte Carlo (MCMC) sample estimates of MSY, $S_{MSY}$, and $F_{MSY}$ drawn from the posterior distribution of the MLE for the BH model (Figure 3-9). Overall, the point estimates of MSY and $S_{MSY}$ were slightly lower, and $F_{MSY}$ slightly higher, than the medians of the MCMC samples. New FMP biological reference points from the BH model would be $F_{MSY}$ = 0.254, MSY = 23,193 mt (51.1 million lbs), and $SSB_{MSY}$ = 106,435 mt (234.6 million lbs), where the estimate of MSY includes commercial and recreational landings and discards (Table 3-6; Figure

3-10). If expressed in terms of SSB, the biomass threshold of 0.5*$SSB_{MSY}$ would be 53,218 mt (117.3 million lbs).

**SDWG Reference Point Advice**

The BH model fits the observed stock-recruitment data well, and reference points are comparable to those derived from the empirical non-parametric approach. However, the quantity of observed stock-recruitment data is limited (22 years), and the data during the early part of the time series, when the SSB was at the lowest observed levels, indicates a level of recruitment near the estimated $R_{max}$, and exerts a high degree of leverage on the estimation of the model parameters (Figure 3-8). This leverage results in a high value (0.984) for the subsequently calculated steepness of the BH curve, which is outside of the $\pm$ one standard interval of Myers et al. (1999) estimate for Pleuronectid flatfish (0.8 $\pm$ 0.1). The BH model results suggest that summer flounder SSB could fall to very low levels (<2,000 mt) and still produce recruitment near that produced at $SSB_{MSY}$. This may not be a reasonable assumption for the long term, given the recent stock-recruitment history of the stock (i.e., production of a very poor year class in 1988). The BH model estimated parameters may prove to be sensitive to subsequent additional years of S-R data, especially if they accumulate at higher levels of SSB and recruitment in the near term. The BH model fit may also be sensitive to the magnitude of recently estimated spawning stock and recruitment, given the recent retrospective pattern of overestimation of stock size evident in the assessment. The SDWG recognizes that the limited time series of observed stock-recruitment data impacts both reference point estimation approaches (empirical non-parametric and parametric stock-recruitment model) in terms of the potential spawning stock biomass and recruitment levels that might be realized from the stock if fished at fishing mortality rates in the 0.2-0.3 range over the long term. Given these concerns, the SDWG advises that the current BH model estimates are not suitable for use as biological reference points for summer flounder.

The SDWG updated the input data (1992-2004 averages of mean weights, maturities, and partial recruitment) for yield and biomass per recruit analysis. The updated 1982-2004 VPA provided an estimate of median recruitment for summer flounder of 33.111 million age 0 fish. The SDWG recommends adoption of biological reference points from the empirical non-parametric approach for summer flounder. Updated FMP biological reference points would be $F_{MSY} = F_{max} = 0.276$, MSY = 19,072 mt (42.0 million lbs), and $TSB_{MSY}$ = 92,645 mt (204.2 million lbs; Table 3-4). The biomass threshold of 0.5*$TSB_{MSY}$ = 46,323 mt (102.1 million lbs).

## 4.0 RESEARCH RECOMMENDATIONS FOR SUMMER FLOUNDER

**The following major data and analytic needs for future assessments were identified in the SARC 35 review of the 2002 assessment (NEFSC 2002a) and in the SDWG assessment updates for 2003 and 2004 (Terceiro 2003; SDWG 2004):**

1) Expand the NEFSC fishery observer program for summer flounder, with special emphasis on a) comprehensive areal and temporal coverage, b) adequate length and age sampling, and c) continued sampling after commercial fishery areal and seasonal quotas are reached and fisheries are limited or closed, and d) sampling of summer flounder discard in the scallop dredge fishery. Maintaining adequate observer coverage will be especially important in order to monitor a) the effects of implementation of gear and closed/exempted area regulations, both in terms of the response of the stock and the fishermen, b) potential continuing changes in "directivity" in the summer flounder fishery, as a results of changes in stock levels and regulations, and c) discards of summer flounder in the commercial fishery once quota levels have been attained and the summer flounder fishery is closed or restricted by trip limits.

*WG Response: Observer sampling intensity has improved since 2001. Attempts are made to maintain coverage of otter trawl fishing even after summer flounder quotas have been filled.*

2) Evaluate the amount of observer data needed to reliably estimate discards of summer flounder in all components of the fishery

*WG Response: The NEFSC Population Dynamics Branch has developed an optimization algorithm to calculate sampling levels adequate to reliably estimate summer flounder discards and then allocate observer sea days across gear types, mesh sizes, regions, and trip lengths to define trips participating in various fisheries. This tool has been used to allocate Observer sea days since May 2004. Sea days are allocated across three gear types (otter trawl, gillnet and scallop dredge). Otter trawl and gillnet trips have been classified into four mesh size categories: Small (less than 3.99 inch mesh); Medium (between 3.99 and 5.49 inch mesh); Large (between 5.5 and 7.99 inch mesh) and XLarge (8.0 inch mesh or greater). Additionally, trips have been classified into six geographical regions: vessel leaving from ports located within Maine and New Hampshire (ME_NH); Massachusetts (N_MA, excluding Bristol county); Connecticut, RI, and Bristol county, MA (SNE); New Jersey - New York (NJ/NY); Maryland and Delaware (MD/DE); Virginia and North Carolina (VA/NC).*

3) Conduct further research to better determine the discard mortality rate of recreational and commercial fishery summer flounder discards.

*WG Response: the assessment continues to rely on commercial industry advisors for an assumption of the commercial fishery discard mortality rate (80%). The results of three research programs completed in the late 1990s are averaged to provide the recreational fishery discard mortality rate (10%). Clearly, further research is needed to improve the commercial rate assumption.*

4) Develop a program to annually sample the length and age frequency of summer flounder discards from the recreational fishery.

*WG Response: To date, programs are in place only in New York (NYDEC Party Boat Survey) and Connecticut (CTDEP Volunteer Anglers) to sample the biological characteristics recreational discards. So, progress has been made, but more synoptic data are needed.*

5) RIDFW monthly fixed station survey length frequencies are currently converted to age using length cut-offs points. Investigate the utility of applying the appropriate NEFSC or MADMF age-length keys to convert the RIDFW monthly fixed station survey lengths to age.

*WG Response: This recommendation has not yet been addressed by the RIDFW.*

6) Explore the possibility of weighting survey indices used in VPA calibration by the areal coverage (e.g., in square kilometers) of the respective seasonal surveys.

*WG Response: This recommendation was addressed in the 2004 assessment update (SDWG 2004), and the SDWG found that results from two areal weighted runs were nearly identical (due to the large NEFSC areal weights) and very similar to their respective unweighted runs. The SDWG therefore recommended retention of the 2003 tuning index selection process and configuration, which essentially gives greatest weight to the initially best fitting indices, in the 2004 assessment update (SDWG 2004). That recommendation was also implemented in the 2005 assessment update.*

7) Explore the sensitivity of the VPA calibration to the addition of 1 and/or a small constant to values of survey series with "true zeros."

*WG Response: This recommendation was addressed in the 2004 assessment update (SDWG 2004). This recommendation stems from the nature of the ADAPT VPA tuning (calibration) algorithm, which includes natural logarithm (ln) transformation (i.e., assumption of a lognormal error distribution) of the input survey abundance indices prior to calibration. Some of the tuning series in the assessment include several "true zero" observations (as contrasted with years for which no sampling was performed) in their time series. Since "zeros" are treated as missing values in the ADAPT computations, a constant value of 1 was added to every value in these series to enable use of these "true zeros" as observations. The choice of the value of 1 as the additive constant was made by the previous WGs based on recommendations from traditional statistical texts for ln-transformation of data. However, more recent statistical literature provides guidance on the objective selection of the appropriate value of the additive constant based on the statistical properties (skew and kurtosis) of the series to be ln-transformed. Briefly, the method consists of 1) addition of a range of constants from very large (e.g., 1,000) to very small (e.g., 0.0001) to the original values in the series, 2) ln-transformation of the modified series, 3) calculation of the skewness and kurtosis of the modified series, and 4) summation of the absolute value of the skewness and kurtosis (providing the statistic "g") of the modified series. The additive constant that minimizes the statistic "g" for a given series of data is the one that best minimizes the effect of outliers and normalizes residuals from the lognormal error distribution, hence best adhering to the assumption of the lognormal distribution. Studies using both empirical and simulated indices of abundance indicate that for "small value" (e.g. < 1.0 fish per tow) summer flounder survey time series, the value of "g" appears on average to be best minimized by the additive constant value equal to 0.10. Thus, use of 0.10 as the additive constant for those "small value" series provides a transformation of the calibration data that best matches the assumed error distribution. The SDWG* *therefore recommended use of the revised, varying additive constants in the 2004 assessment update (SDWG 2004). That recommendation was also implemented in the 2005 assessment update.*

8) Statistically analyze changes in mean weights at age in the catch and NEFSC surveys. Determine if using mean weights at age in the survey are more appropriate for estimating the $B_{MSY}$ proxy. Explore the sensitivity of the mean weights of the catch and partial recruitment pattern from a longer time series (1997 to 2001) to the re-estimated $B_{MSY}$ proxy. As the NEFSC fall survey age structure expands, investigate the use of survey mean weights at age for stock weights at age in yield per recruit, VPA, and projection analyses.

*WG Response: This recommendation has been addressed in the 2005 SDWG Response to SAW 41 ToRs 2 and 3.*

9) Monitor changes in life history (growth and maturity) as the stock rebuilds.

*WG Response: This recommendation has been addressed in the 2005 SDWG Response to SAW 41 ToRs 2 and 3.*

10) Evaluate use of a forward calculating age-structured model for comparison with VPA. Forward models would facilitate use of expanding age/sex structure and allow inclusion of historical data. If sex-specific assessments are explored, the implications on YPR should also be investigated.

*WG Response: Work to address this recommendation is underway (use of ASAP model), and will be a component of the next benchmark assessment.*

11) Explore the sensitivity of the VPA results to separating the summer flounder stock into multiple components.

*WG Response: This recommendation has not yet been addressed by the SDWG.*

12) Evaluate trends in the regional components of the NEFSC surveys and contrast with the state surveys that potentially index components of the stock.

*WG Response: This recommendation has not yet been addressed by the SDWG.*

13) Use NEFSC fishery observer age-length keys for 1994 and later years (as they become available) to supplement NEFSC survey data in aging the commercial fishery discard.

*WG Response: This recommendation has not been addressed by the SDWG, as the age data are not yet available.*

**The following major data and analytic needs for future assessments were identified by the SDWG in completing the 2005 assessment update:**

1) Initiate an age structure exchange between the NEFSC and all interested state agencies and academic institutions, with a goal of completing the laboratory work and a summary report by May 1, 2006.

2) Complete the NEFSC comparison study between scales and otoliths as aging structures for summer flounder, and prepare a summary report by May 1, 2006.

3) Develop a long term protocol to sample otoliths from summer flounder caught in the recreational and commercial fisheries (e.g., purchase samples; as a component of Research Set-Aside projects; as Cooperative Research with industry).

4) Develop a long term protocol to correct summer flounder scale ages using a more limited sample of otolith ages.

5) Explore statistical methods to develop “combined” survey abundance indices (by age if possible) from state agency survey data, for use in calibration of analytical assessment models.

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**SUMMER FLOUNDER TABLES**

Table 3-1. Input data for summer flounder yield per recruit analyses: mean weights at age. Weights in italics estimated from Gomphertz function and/or Rivard equations. For 2005 SAW 41 catch at age 8, the Nov 1 SSB weight (NEFSC Autumn Survey) was substituted due to low sample numbers from the fisheries. For 2005 SAW 41 Jan 1 Bio at age 0, the Nov 1 SSB weight at age 0 was substituted since no age 0 fish are taken in the Winter survey.

| | 1990 SAW 11 | | 1999 Assessment | | | 2005 SAW 41 | | |
|---|---|---|---|---|---|---|---|---|
| Age | Catch | Nov 1 SSB | Jan 1 Bio | Catch | Nov 1 SSB | Jan 1 Bio | Catch | Nov 1 SSB |
| 0 | 0.237 | 0.237 | 0.170 | 0.234 | 0.234 | 0.184 | 0.221 | 0.184 |
| 1 | 0.432 | 0.432 | 0.353 | 0.471 | 0.471 | 0.241 | 0.499 | 0.469 |
| 2 | 0.642 | 0.642 | 0.556 | 0.643 | 0.643 | 0.577 | 0.684 | 0.817 |
| 3 | 1.164 | 1.164 | 0.722 | 0.862 | 0.862 | 0.980 | 1.049 | 1.402 |
| 4 | 1.811 | 1.811 | 1.111 | 1.277 | 1.277 | 1.539 | 1.489 | 1.953 |
| 5 | 2.449 | 2.449 | 1.860 | 2.330 | 2.330 | 2.136 | 2.217 | 2.946 |
| 6 | 3.074 | 3.074 | 2.337 | 2.565 | 2.565 | 2.680 | 2.745 | 3.073 |
| 7 | 3.434 | 3.434 | 3.130 | 3.537 | 3.537 | 3.245 | 3.515 | 3.630 |
| 8 | 4.380 | 4.380 | 4.120 | 4.592 | 4.592 | 3.576 | 4.515 | 4.515 |
| 9 | *4.841* | *4.841* | *4.671* | *4.841* | *4.841* | 3.780 | *4.926* | *4.926* |
| 10 | *5.336* | *5.336* | *5.162* | *5.336* | *5.336* | 4.672 | *5.313* | *5.313* |
| 11 | *5.767* | *5.767* | *5.590* | *5.767* | *5.767* | 5.020 | *5.630* | *5.630* |
| 12 | *6.135* | *6.135* | *5.957* | *6.135* | *6.135* | 5.360 | *5.885* | *5.885* |
| 13 | *6.445* | *6.445* | *6.266* | *6.445* | *6.445* | *5.553* | *6.089* | *6.089* |
| 14 | *6.704* | *6.704* | *6.525* | *6.704* | *6.704* | *5.674* | *6.249* | *6.249* |
| 15 | *6.917* | *6.917* | *6.738* | *6.917* | *6.917* | *5.765* | *6.375* | *6.375* |

Table 3-2. Input data for summer flounder yield per recruit analyses: percent mature and partial recruitment (percent selection) at age.

| | 1990 SAW 11 | | 1999 Assessment | | 2005 SAW 41 | |
|---|---|---|---|---|---|---|
| Age | Percent Mature | Partial Recruit. | Percent Mature | Partial Recruit. | Percent Mature | Partial Recruit. |
| 0 | 38 | 5 | 38 | 1 | 38 | 1 |
| 1 | 72 | 50 | 72 | 18 | 91 | 19 |
| 2 | 90 | 100 | 90 | 62 | 98 | 77 |
| 3 | 97 | 100 | 100 | 100 | 100 | 100 |
| 4 | 99 | 100 | 100 | 100 | 100 | 100 |
| 5 | 100 | 100 | 100 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 |
| 7 | 100 | 100 | 100 | 100 | 100 | 100 |
| 8 | 100 | 100 | 100 | 100 | 100 | 100 |
| 9 | 100 | 100 | 100 | 100 | 100 | 100 |
| 10 | 100 | 100 | 100 | 100 | 100 | 100 |
| 11 | 100 | 100 | 100 | 100 | 100 | 100 |
| 12 | 100 | 100 | 100 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 |
| 14 | 100 | 100 | 100 | 100 | 100 | 100 |
| 15 | 100 | 100 | 100 | 100 | 100 | 100 |

Table 3-3. Summary results for summer flounder yield per recruit analyses. Yield per Recruit (Y/R), Spawning Biomass per Recruit (SSB/R) and Total Stock Biomass per Recruit (TSB/R) in kilograms.

| | 1990 SAW 11 | 1999 Assessment | 2005 SAW 41 |
|---|---|---|---|
| Fmax | 0.232 | 0.263 | 0.276 |
| F40% | 0.150 | 0.167 | 0.181 |
| | | | |
| Y/R @ Fmax | 0.574 | 0.552 | 0.576 |
| SSB/R @ Fmax | 2.107 | 2.139 | 2.466 |
| TSB/R @ Fmax | not calculated | 2.813 | 2.798 |
| | | | |
| Y/R@ F40% | 0.540 | 0.524 | 0.553 |
| SSB/R @ F40% | 3.275 | 3.111 | 3.477 |
| TSB/R @ F40% | not calculated | 3.853 | 3.748 |

Table 3-4. Summary results for summer flounder empirical non-parametric biological reference point calculations. Maximum Sustainable Yield (MSY), Spawning Stock Biomass at MSY ($SSB_{MSY}$), and Total Stock Biomass at MSY ($TSB_{MSY}$) in metric tons.

| | 1990 SAW 11 | 1999 Assessment | 2005 SAW 41 |
|---|---|---|---|
| Recruitment Year Range | 1982-1987 | 1982-1998 | 1982-2004 |
| Median Recruitment (000s) | 58,440 | 37,844 | 33,111 |
| Y @ Fmax (MSY) | 33,545 | 20,897 | 19,072 |
| SSB @ Fmax ($SSB_{MSY}$) | 123,133 | 80,948 | 81,652 |
| TSB @ Fmax ($TSB_{MSY}$) | not calculated | 106,444 | 92,645 |
| Y @ F40% (MSY) | 31,558 | 19,830 | 18,310 |
| SSB @ F40% ($SSB_{MSY}$) | 191,391 | 117,733 | 115,127 |
| TSB @ F40% ($TSB_{MSY}$) | not calculated | 145,813 | 124,100 |

Table 3-5. Input spawning stock biomass (metric tons; ages 0-7+) and recruitment (millions of age 0 fish) data for summer flounder parametric stock-recruitment models._

| Year Class | Spawning Stock Biomass | Recruitment |
|---|---|---|
| | | |
| 1983 | 17,501 | 80,323 |
| 1984 | 18,837 | 48,380 |
| 1985 | 16,087 | 48,579 |
| 1986 | 14,972 | 53,444 |
| 1987 | 13,934 | 43,921 |
| 1988 | 14,424 | 13,033 |
| 1989 | 8,130 | 27,270 |
| 1990 | 5,217 | 30,352 |
| 1991 | 7,453 | 28,686 |
| 1992 | 6,007 | 32,315 |
| 1993 | 7,303 | 33,158 |
| 1994 | 9,249 | 35,251 |
| 1995 | 11,960 | 38,679 |
| 1996 | 15,611 | 28,244 |
| 1997 | 15,886 | 29,089 |
| 1998 | 15,669 | 31,046 |
| 1999 | 17,794 | 29,417 |
| 2000 | 16,497 | 35,871 |
| 2001 | 19,381 | 33,831 |
| 2002 | 25,544 | 38,133 |
| 2003 | 29,415 | 27,478 |
| 2004 | 36,696 | 33,111 |

Table 3-6. Stock-recruitment model comparisons for summer flounder. MSY and $S_{MSY}$ in 000s metric tons.

| **Model** | **BH** | **ABH** | **RBH** | **SBH** | **ARBH** | **ASBH** | **RSBH** | **ARSB** | **RK** | **ARK** | **SRK** | **ASRK** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of data points | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Number of parameters | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 4 |
| Negative log likelihood | 84.520 | 83.379 | 87.742 | 84.751 | 86.636 | 83.849 | 87.997 | 87.072 | 85.015 | 84.483 | 122.85 | 90.690 |
| Bias corrected AIC | ***176.37*** | 177.11 | 176.37 | 176.51 | 177.13 | 177.42 | 176.44 | 177.39 | 177.36 | 179.31 | 246.66 | 190.49 |
| **Parameter estimates** | | | | | | | | | | | | |
| $F_{MSY}$ | ***0.254*** | 0.262 | 0.254 | 0.252 | 0.260 | 0.256 | 0.252 | 0.256 | 1.360 | 1.414 | 0.272 | 0.252 |
| $S_{MSY}$ | ***106.4*** | 95.5 | 106.1 | 112.7 | 98.1 | 106.2 | 110.4 | 105.6 | 20.7 | 20.3 | 101,45 | 10.7 |
| MSY | ***23.2*** | 21.4 | 23.1 | 24.4 | 21.9 | 23.3 | 23.9 | 23.2 | 17.8 | 17.9 | 23,488 | 2.3 |
| Alpha | ***40.6*** | 36.9 | 40.5 | 43.0 | 37.9 | 40.8 | 42.0 | 40.5 | 1.876 | 1.906 | 0.098 | 4.54e- |
| Beta | ***1.506*** | 5.09e- | 1.467 | 2.375 | 0.238 | 1.445 | 2.094 | 1.376 | -0.059 | -0.060 | -9.99e- | -0.092 |
| steepness | ***0.984*** | 1.000 | 0.984 | 0.976 | 0.997 | 0.984 | 0.978 | 0.985 | n/a | n/a | n/a | n/a |
| $R_{max}$ | ***39.4*** | 36.9 | 39.3 | 41.1 | 37.7 | 39.6 | 40.4 | 39.4 | 17.3 | 16.8 | 55.1 | 0.5 |
| Prior mean steepness; | n/a | n/a | n/a | 0.8 | n/a | 0.8 | 0.8 | 0.8 | n/a | n/a | 0.8 | 0.8 |
| Prior se steepness; slope | n/a | n/a | n/a | 0.1 | n/a | 0.1 | 0.1 | 0.1 | n/a | n/a | 0.1 | 0.1 |
| Prior mean recruitment | n/a | n/a | 40 | n/a | 40 | n/a | 40 | 40 | n/a | n/a | n/a | n/a |
| Prior se recruitment | n/a | n/a | 10 | n/a | 10 | n/a | 10 | 10 | n/a | n/a | n/a | n/a |
| Sigma | n/a | 0.340 | 0.328 | 0.329 | 0.339 | 0.332 | 0.328 | 0.332 | 0.336 | 0.338 | 0.890 | 3.153 |
| Phi | n/a | 0.408 | n/a | n/a | 0.397 | 0.336 | n/a | 0.339 | n/a | 0.247 | n/a | 0.993 |
| Sigmaw | n/a | 0.311 | n/a | n/a | 0.311 | 0.313 | n/a | 0.313 | n/a | 0.327 | n/a | 0.384 |
| last log-residual R | n/a | -0.109 | n/a | n/a | -4.563 | -0.169 | n/a | -0.165 | n/a | 5.497 | n/a | 3.239 |
| expected lognormal error | 1.055 | 1.060 | 1.055 | 1.056 | 1.059 | 1.057 | 1.055 | 1.057 | 1.058 | 1.059 | 1.486 | 144.58 |

Table 3-7. Posterior probability and odds ratio tests for the most likely stock-recruitment models for summer flounder.

| S-R Model | **BH** | RBH | SBH | RSBH |
|---|---|---|---|---|
| Number of data points | **22** | 22 | 22 | 22 |
| Number of parameters | **3** | 3 | 3 | 3 |
| Bias-corrected AIC | **175.373** | 176.374 | 176.512 | 176.446 |
| Prior Probability | **0.250** | 0.250 | 0.250 | 0.250 |
| Model AIC Ratio | **1.072** | 1.071 | 1.000 | 1.034 |
| Normalized (Unity) Likelihood | **0.257** | 0.257 | 0.239 | 0.247 |
| Posterior Probability | **0.257** | 0.257 | 0.239 | 0.247 |
| Odds Ratio for Most Likely Model | **1.000** | 1.001 | 1.072 | 1.037 |
| | **Most Likely Model** | | | |

SUMMER FLOUNDER FIGURES

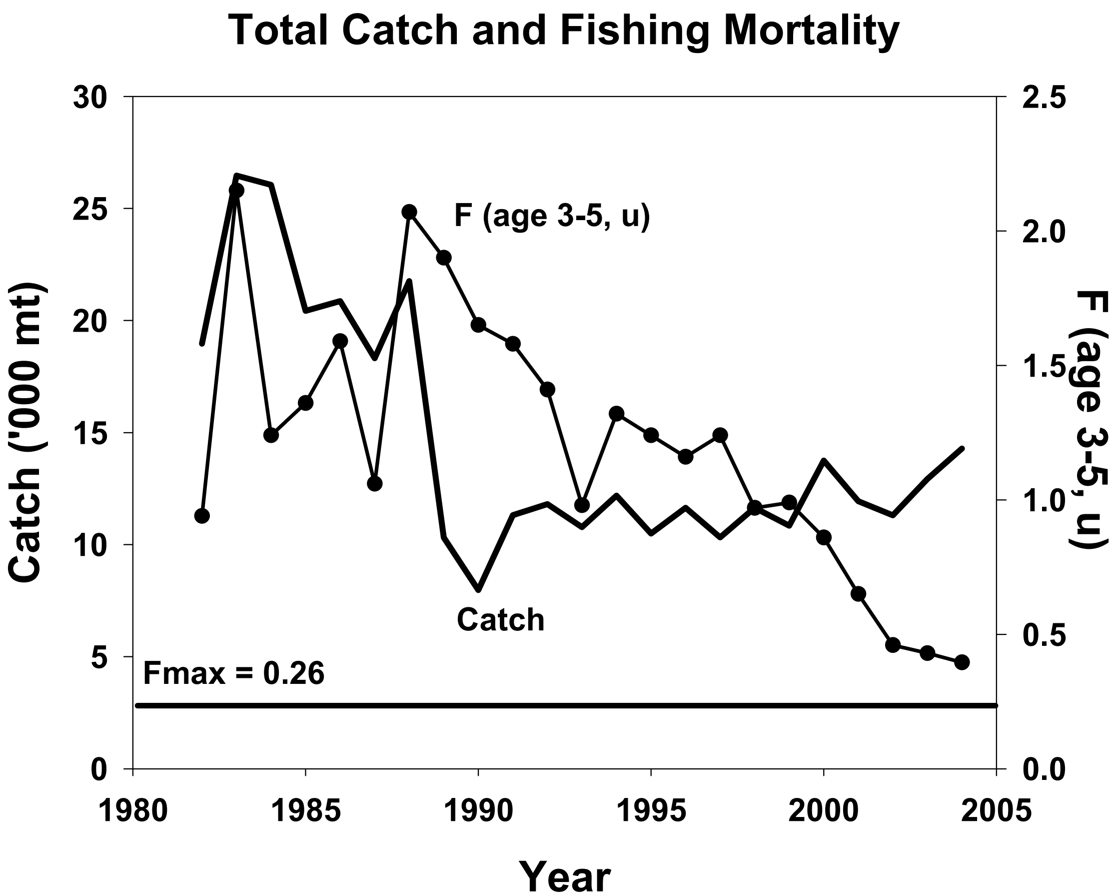



Figure 2-1. Total catch (landings and discards, thousands of metric tons) and fishing mortality rate (F, ages 3-5, unweighted) for summer flounder.

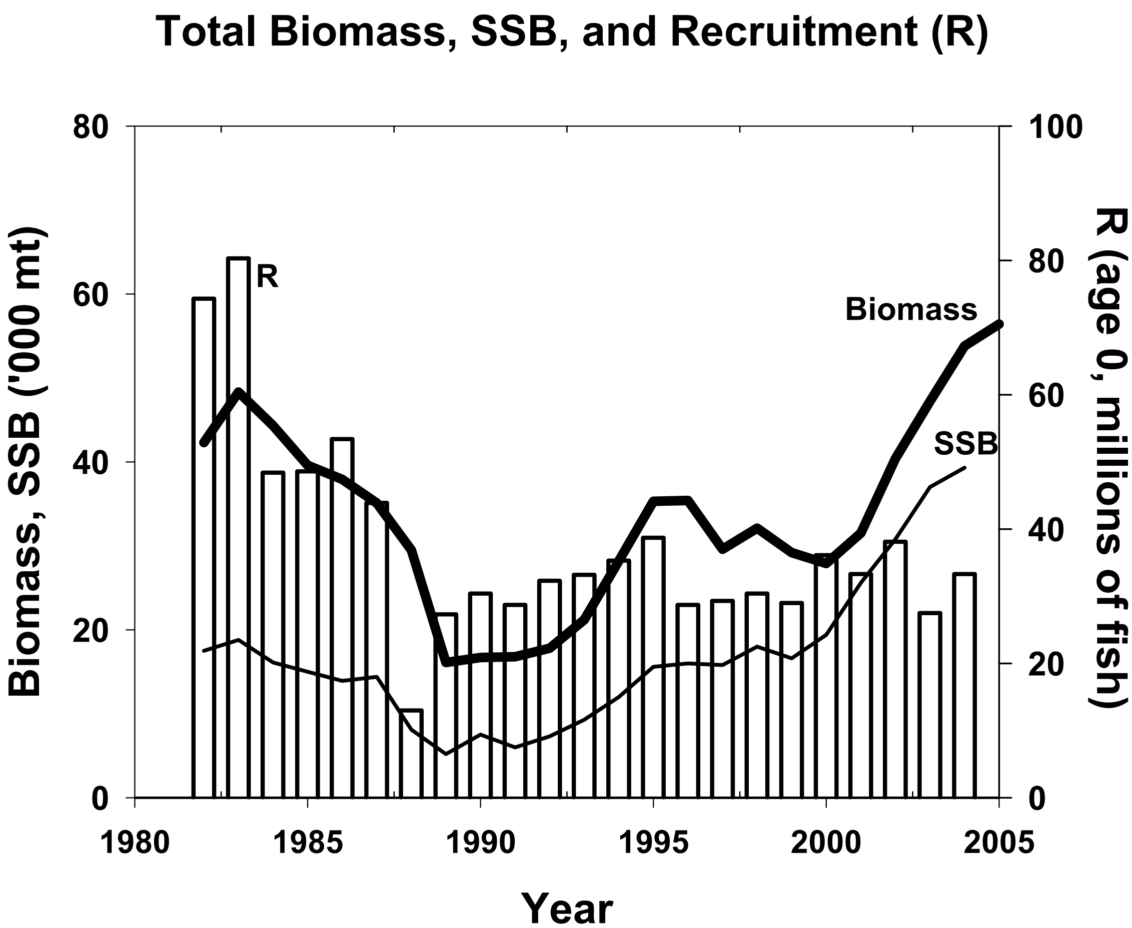
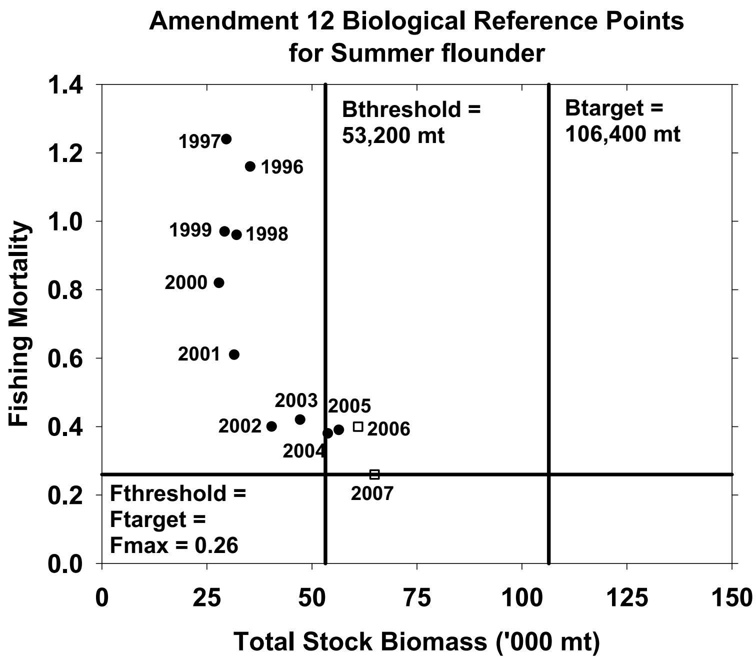



Figure 2-2. Total stock biomass ('000 mt; thick line), spawning stock biomass (SSB, '000 mt; thin line), and recruitment (millions of fish at age-0; bars) for summer flounder.



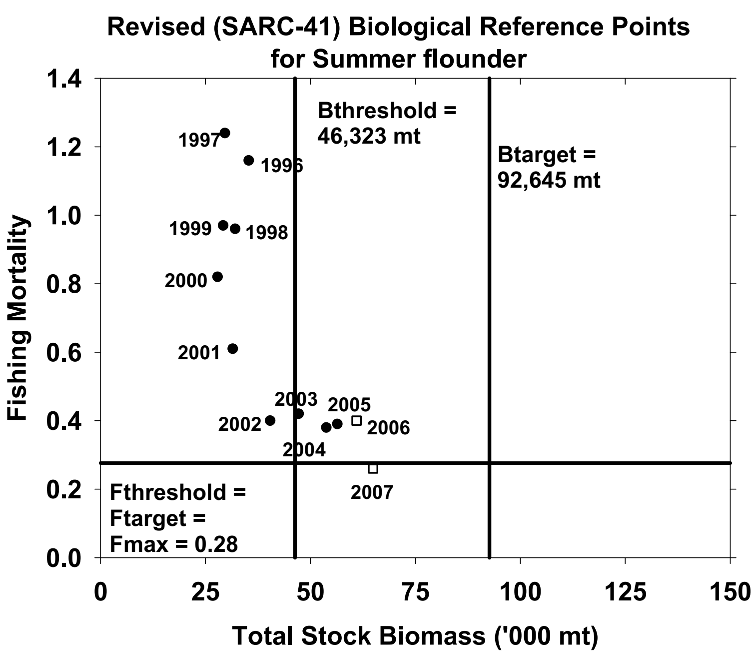




Figure 2-3. Estimates of Biological Reference Points, biomass and F.

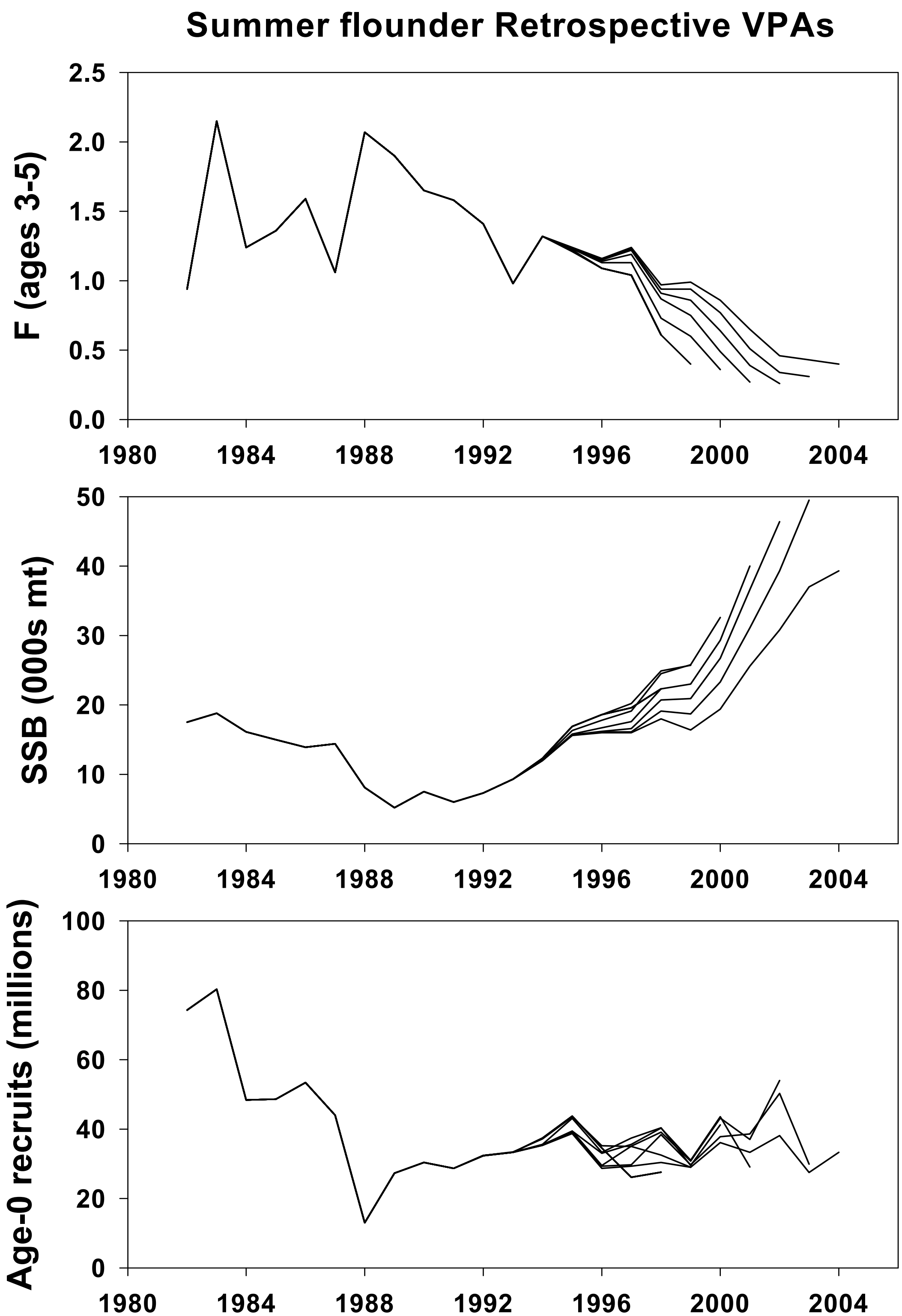



Figure 2-4. Retrospective VPAs for summer flounder.

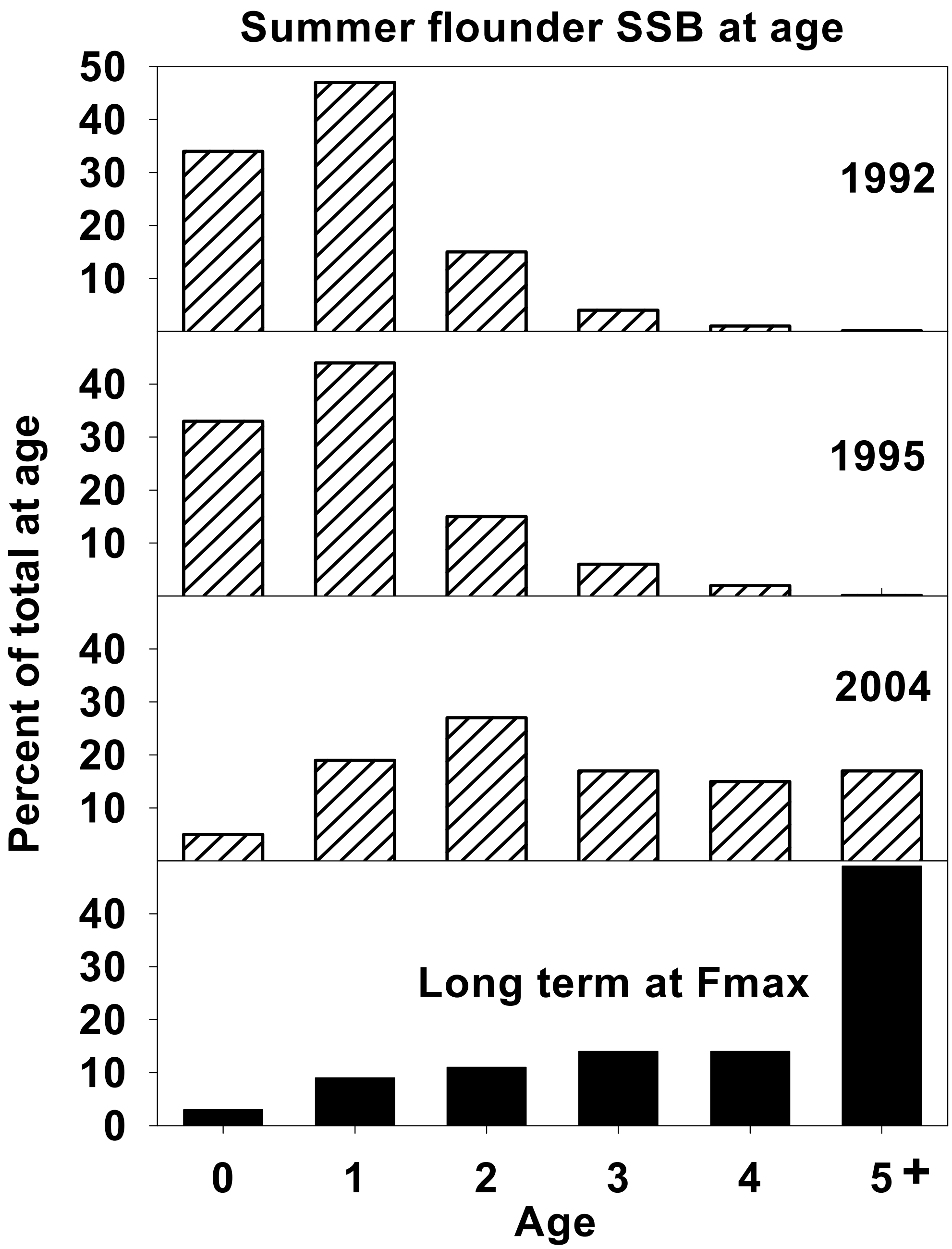



Figure 2-5. Percent of summer flounder spawning stock biomass (SSB) at age in 1992, 1995, 2004 and long-term at Fmax = 0.263. Similar long-term results are derived using updated Fmax = 0.276.

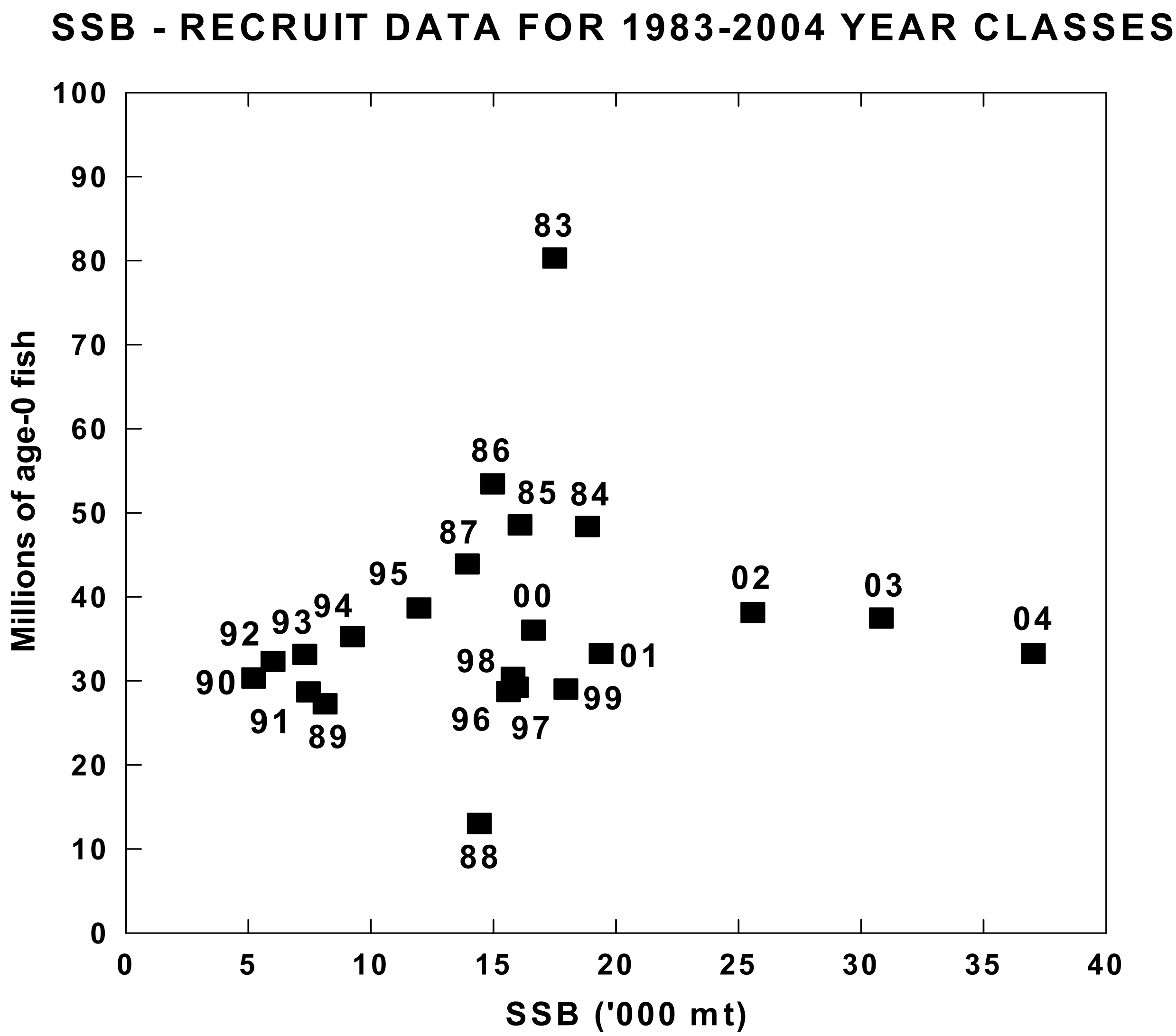



Figure 2-6. VPA spawning stock biomass and recruitment estimates for summer flounder.

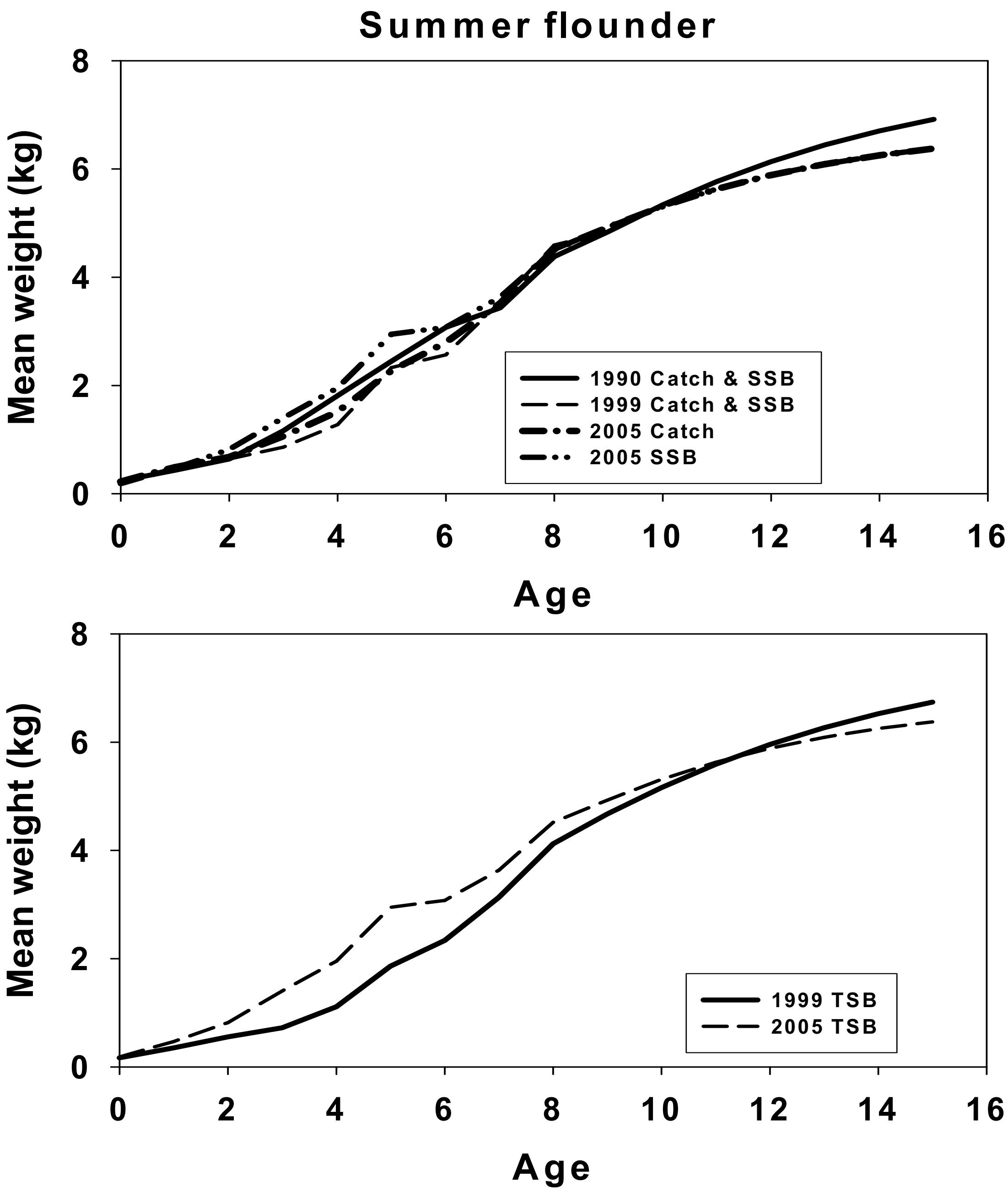



Figure 3-1. Mean weights at age for summer flounder yield and biomass per recruit analyses.

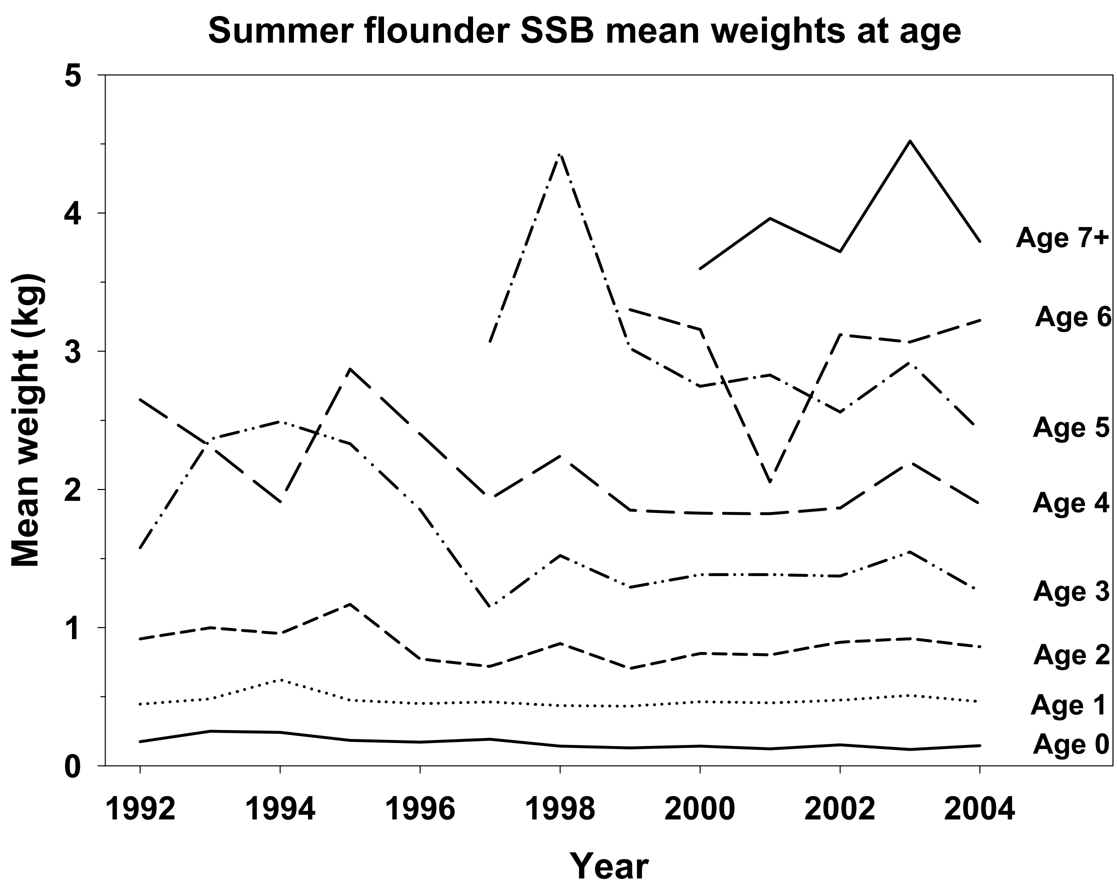



Figure 3-2. Trends in mean weight at age in the spawning stock of summer flounder: NEFSC Autumn survey 1992-2004.

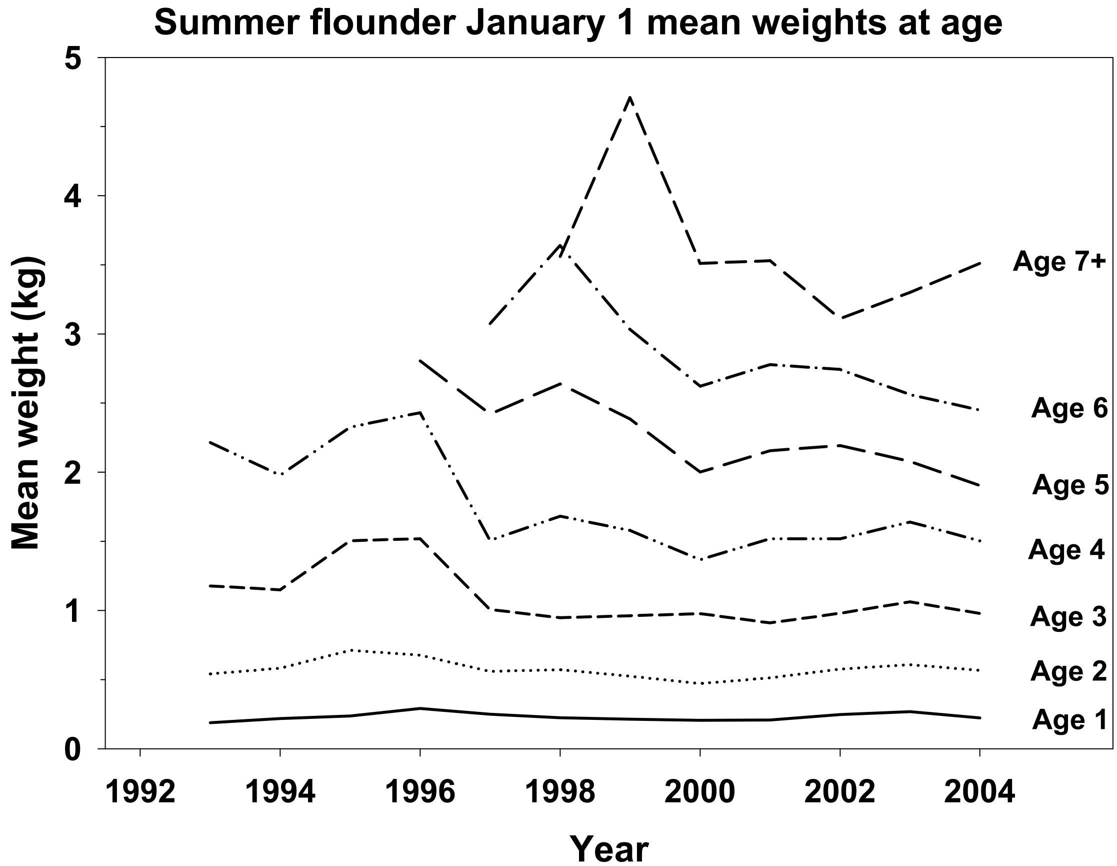



Figure 3-3. Trends in mean weight at age on January 1 for summer flounder: NEFSC Winter survey 1993-2004.

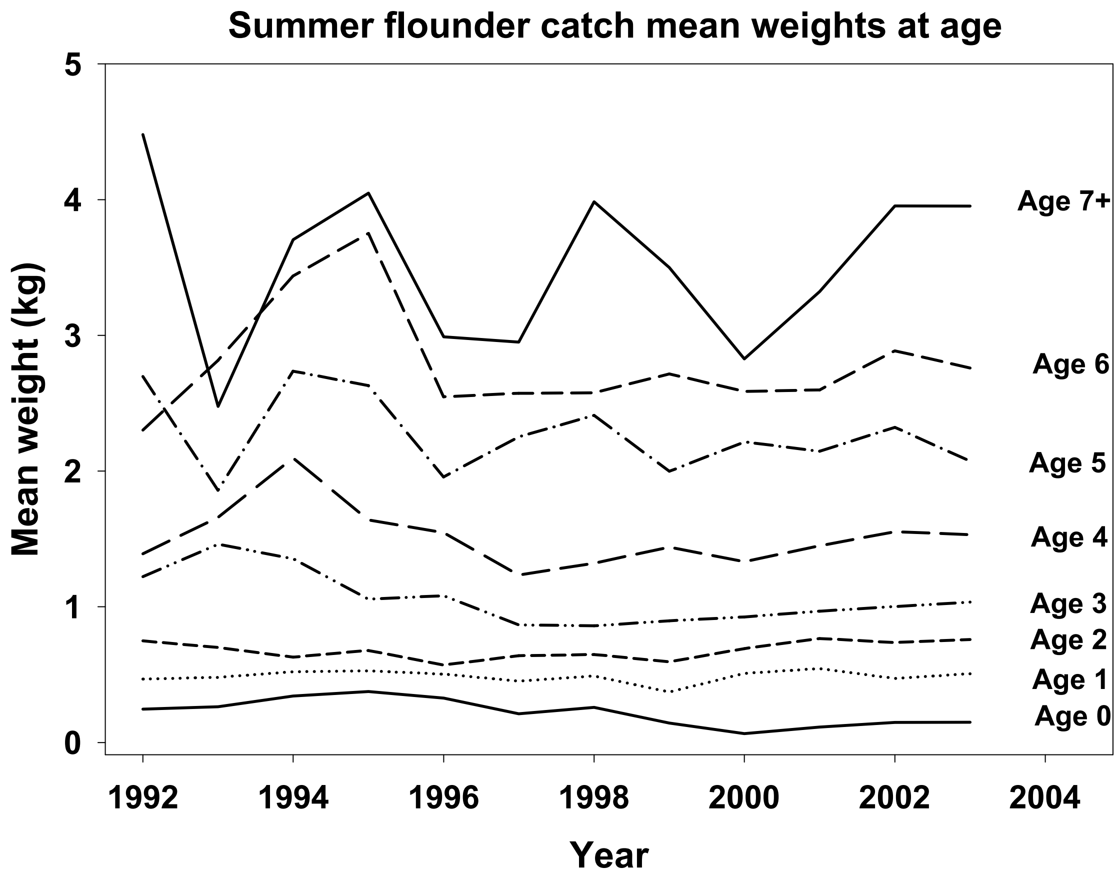



Figure 3-4. Trends in mean weight at age in the total catch of summer flounder.

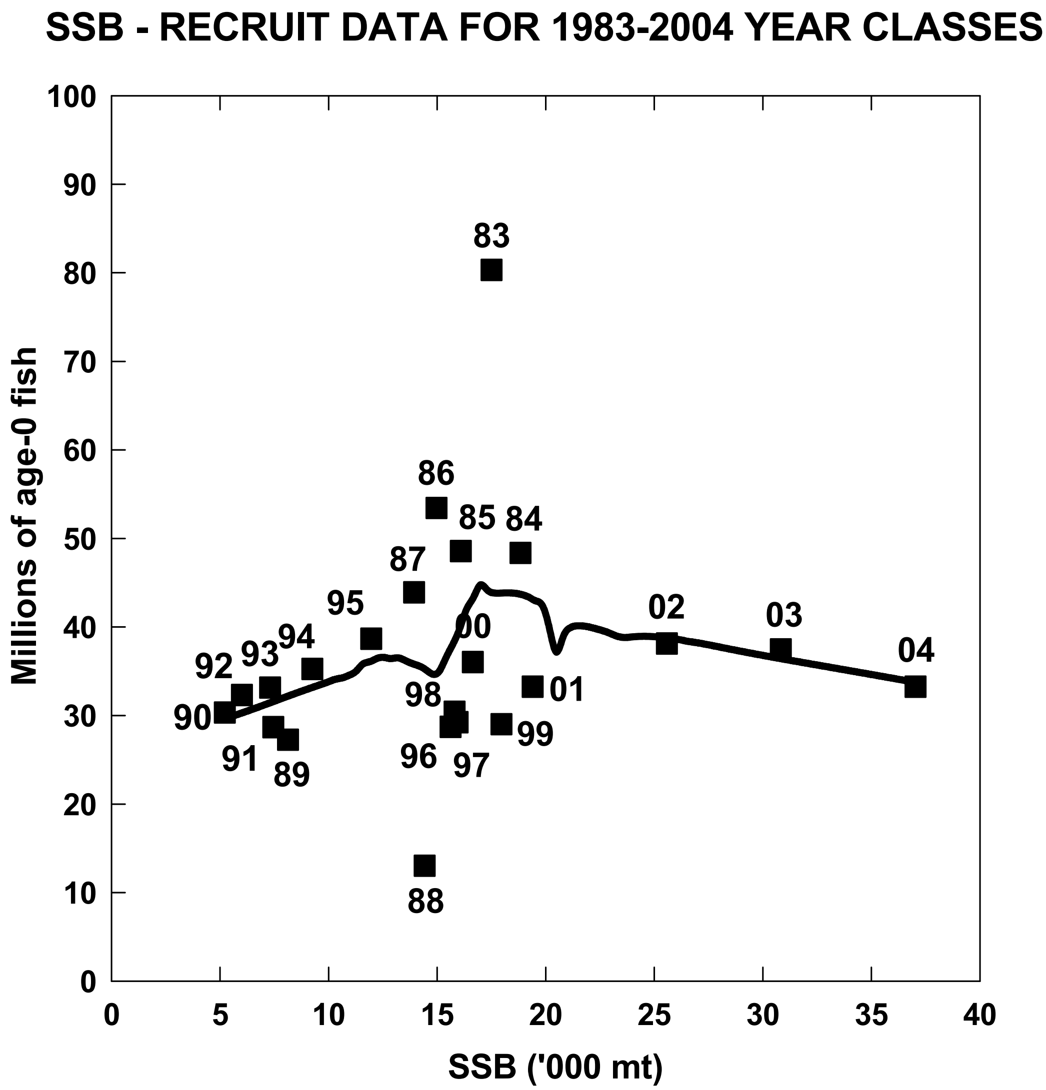



Figure 3-5. VPA spawning stock biomass and recruitment estimates for summer flounder. Smoother in the plot is loess with tension = 0.5.

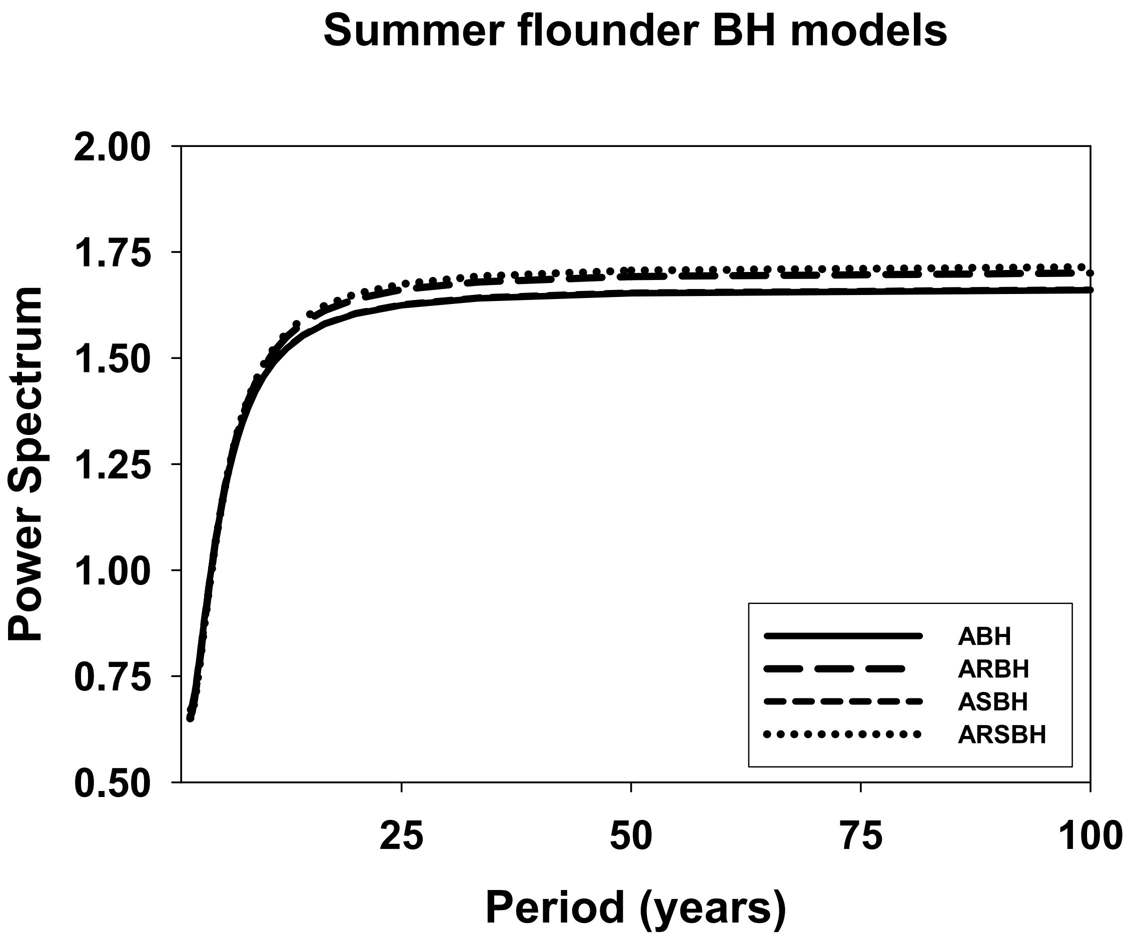



Figure 3-6. Summer flounder periodicity of environmental forcing for autoregressive BH stock-recruitment models.

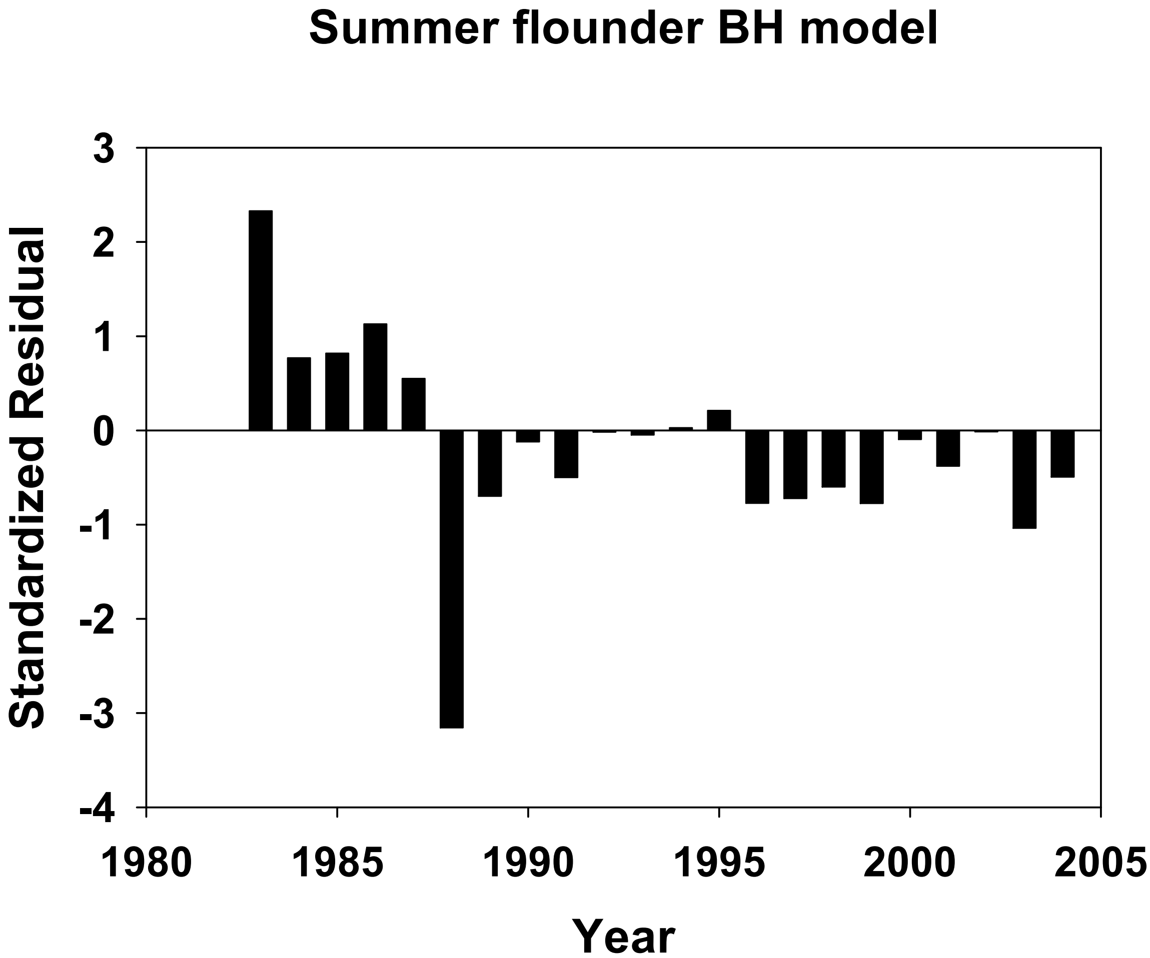



Figure 3-7. Summer flounder standardized residuals for the BH stock-recruitment model.

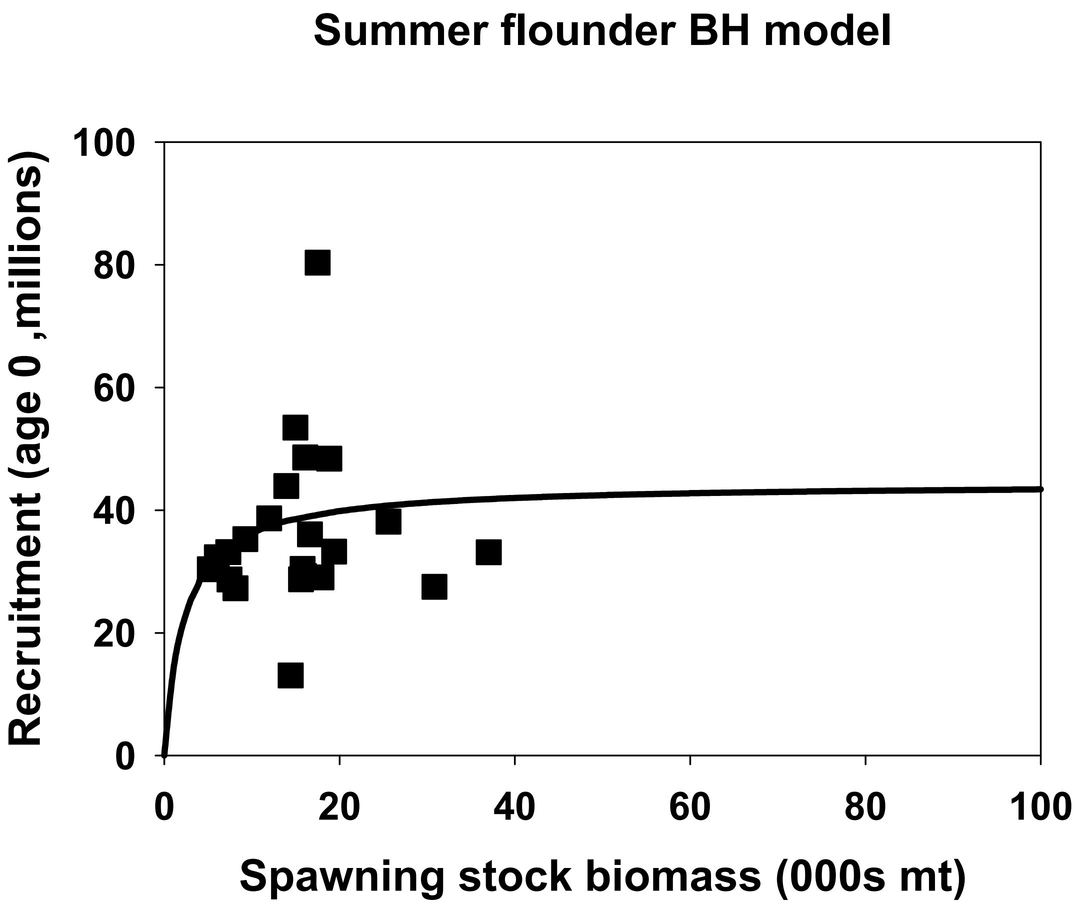



Figure 3-8. Summer flounder stock-recruitment relationship for the BH model.

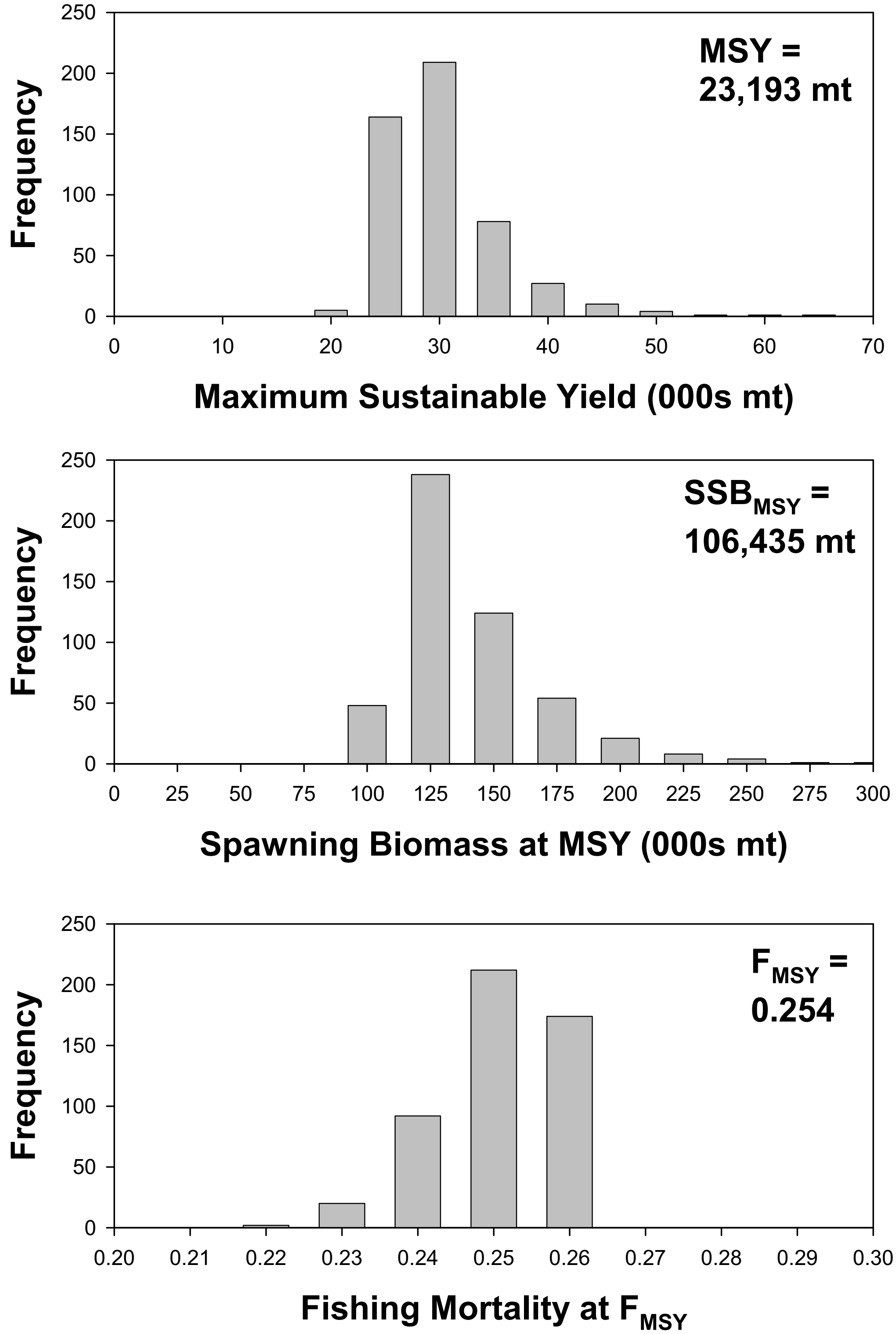



Figure 3-9. Summer flounder posterior distribution of MSY, $SSB_{MSY}$, and $F_{MSY}$ for the most likley parametric BH stock-recruitment model fit.

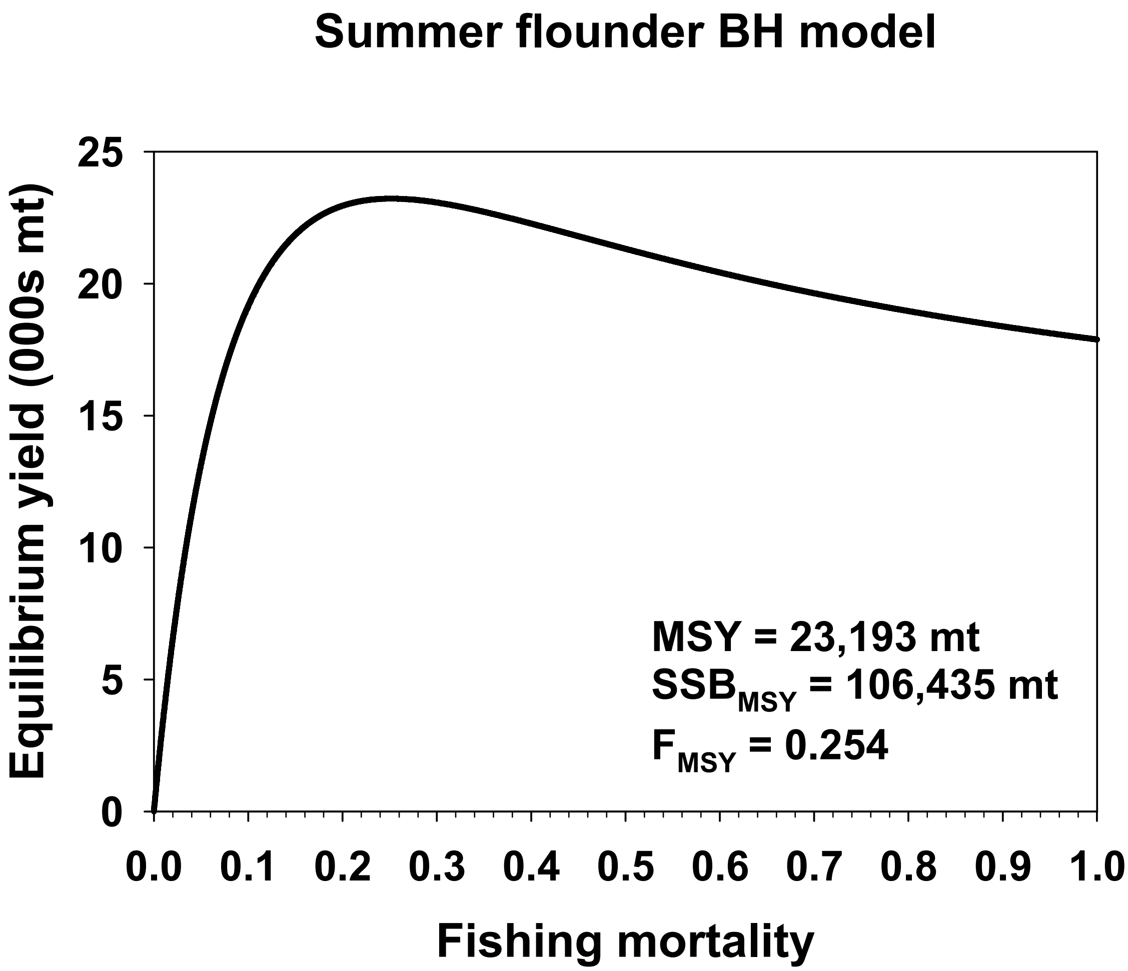



Figure 3-10. Summer flounder equilibrium yield versus F for the BH stock-recruitment model.

## B. ASSESSMENT OF BLUEFISH
## (SAW/SARC-41)

### A report of the
### ASMFC Technical Committee/Assessment Subcommittee, SAW-41

### EXECUTIVE SUMMARY

Bluefish, *Pomatomus saltatrix*, is a migratory pelagic species found in most temperate and tropical marine waters throughout the world. Along the U.S. Atlantic Coast, bluefish commonly occur in estuarine and continental shelf waters. Bluefish are a schooling species that migrate in response to seasonal changes, moving north and inshore during the spring and south and offshore in the late autumn. The Atlantic bluefish fishery is believed to exploit a single stock or population of fish.

Bluefish is one of the most sought after species in the recreational fisheries along the Atlantic Coast. In 2004, recreational anglers along the Atlantic Coast harvested over 6.9 thousand metric tons (mt) of bluefish, second only to striped bass (11.7 thousand mt harvested). Recreational catch of bluefish has averaged over 19 thousand mt since 1982. Landings from the commercial bluefish fishery have been consistently lower than the recreational catch. Regional variations in commercial fishing activity are linked to the seasonal migration of bluefish. Bluefish are most abundant in the North and Mid-Atlantic from late spring to early fall, when the majority of commercial fishing activity for bluefish in these areas occurs. In the late fall and winter, bluefish move southward and landings peak in the South Atlantic region. Annually, the majority of commercial landings are taken in the Mid- and South Atlantic regions where approximately 87% of the coastwide total landings have occurred since 1950.

The Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fisheries Management Council (MAFMC) jointly manage bluefish under Amendment 1 to the Bluefish Fishery Management Plan (FMP). The FMP defines the management unit as bluefish occurring in U.S. waters of the western Atlantic Ocean and is considered a single stock of fish. The FMP allows a state-by-state commercial quota system and recreational harvest limit to reduce fishing mortality. ASMFC and MAFMC adjust both quotas annually by the specification setting process. Overfishing definitions are based on $F_{msy}$ and $B_{msy}$.

The Bluefish Technical Committee examined the quality of the commercial, recreational, and age data for use in an analytical model. The committee felt the level of sampling by gear and market grade from North Carolina and Virginia was adequate to characterize the length distribution of Atlantic coast bluefish landings. The level of commercial sampling in certain time periods was low, however the committee felt there was enough information covering the entire time series to capture the trends in size for landings since 1982. The Committee concluded that the recreational landings information was adequate for use in a bluefish assessment. Recreational discard estimates were also sufficient although there remains a lack of discard length information. Age information, although relatively sparse in some years, was determined adequate to characterize bluefish catch and indices.

The Committee decided an age-structured model was the best approach given the available data and suggestions from previous SAW reports. The committee felt that a VPA model produced satisfactory results, but the assumption of no error in the catch-at-age matrix and the ADAPT method of modeling selectivity could produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was used as the primary assessment tool. The ability of the ASAP model to allow error in the catch-at-age as well as the assumption of separability into year and age components makes it better suited to handle the selectivity patterns and catch data from the bluefish fishery.

The biological reference points established in Amendment 1 were based on the results of a biomass-dynamic model, ASPIC, which had been used to assess the bluefish stock in the past several years. New reference points are proposed based on the results of the catch at age model. The model software estimates $F_{msy}$ = 0.19. Biomass reference points were developed by applying ASAP model results to a Thompson-Bell Yield-Per-Recruit model. The Shepherd-Sissenwine approach was used to estimate $B_{MSY}$ at 147,052 mt; the current estimate of bluefish stock biomass is 104,136 mt. The ASAP model estimated $F_{MULT}$ in 2004 to equal 0.149. The ASAP model results lead to the conclusion that the Atlantic stock of bluefish is not experiencing overfishing. The current FMP defines the overfished threshold as ½Bmsy which equals 53,751 mt. The current biomass estimate implies that bluefish are not overfished.

## 1.0 TERMS OF REFERENCE

1. Evaluate adequacy, appropriateness, and uncertainty of fishery-dependent and fishery-independent data used in the assessment.
2. Evaluate adequacy and appropriateness of models used to assess the stock and to estimate population benchmarks.
3. Evaluate and/or update biological reference points as appropriate.
4. Estimate and evaluate stock status (biomass) and fishery status (fishing mortality rates).
    a. Is the stock overfished?
    b. Is overfishing occurring?
5. Develop recommendations for improving data collection and for future research.

## 2.0 INTRODUCTION

The Atlantic States Marine Fisheries Commission (ASMFC) and Mid-Atlantic Fishery Management Council (MAFMC) jointly developed the Fishery Management Plan (FMP) for the bluefish fishery and adopted the plan in 1989 (ASMFC 1989; Moore 1989). The

Secretary of Commerce approved the FMP in March 1990. The FMP defines the management unit as bluefish (*Pomatomus saltatrix*) in U.S. waters of the western Atlantic Ocean.

The ASMFC and MAFMC approved Amendment 1 to the FMP in October 1998 and the National Marine Fisheries Service (NMFS) published the final rule to implement the Amendment 1 measures in July 2000 (MAFMC and ASMFC 1998). Amendment 1 implemented an annual coastwide quota to control bluefish landings. The ASMFC and MAFMC adjust the quota and harvest limit annually using the specification setting process detailed in Amendment 1. The recreational fishery is allocated 83% of the entire quota. Coastwide, the commercial fishery is limited to 17% of the total allowable landings each year. The commercial quota can be increased if it is anticipated that the recreational fishery will not land their entire allocation for the upcoming year. The coastwide commercial quota is divided into individual state-by-state quotas based on landings from 1981-1989.

### 2.1 Life History

Bluefish, *Pomatomus saltatrix*, is a coastal, pelagic species found in temperate and tropical marine waters throughout the world (Goodbred and Graves 1996; Juanes et al. 1996). Bluefish spawn in offshore waters (Kendall and Walford 1979; Kendall and Naplin 1981). Larvae develop into juveniles in continental shelf waters and eventually move to estuarine and nearshore shelf habitats (Marks and Conover 1993; Hare and Cowen 1994; Able and Fahay 1998; Able et al. 2003). Bluefish are highly migratory along the U.S. Atlantic coast and are found north of the Carolinas only in warmer months (Beaumariage 1969; Lund and Maltezos 1970).

### 2.2 Growth

Several studies show bluefish to be a moderately long-lived fish with a maximum age of 14 years (Hamer 1959; Lassiter 1962; Richards 1976; Barger 1990; Chiarella and Conover 1990; Terceiro and Ross 1993; Austin et al. 1999; Salerno et al. 2001; Sipe and Chittenden 2002). Bluefish up to 88 centimeter (cm) fork length (FL) have been aged (Chiarella and Conover 1990; Salerno et al. 2001). Terceiro and Ross (1993) noted considerable variation in mean bluefish size-at-age. Scale ages have been used to estimate von Bertalanffy growth parameters (Lassiter 1962; Barger 1990; Terceiro and Ross 1993; Salerno et al. 2001). The values for $L_\infty$ from these studies (87-128 cm FL) match closely to the largest individuals in catch data. Growth rates do not differ between sexes (Hamer 1959; Salerno et al. 2001).

Bluefish grow nearly one-third of their maximum length in their first year (Richards 1976; Wilk 1977). Variation in growth rates or size-at-age arise among young bluefish from the appearance of intra-annual cohorts. Lassiter (1962) identified a spring-spawned cohort and a summer-spawned cohort from the bimodal appearance of size at Annulus I for fish aged from North Carolina. As the cohorts appellations imply, the seasonal cohorts differ in age by two to three months. Summer-spawned larvae and juveniles grow faster than spring-spawned larvae and juveniles (McBride and Conover 1991). Size differences at annual age diminish greatly after three to four years (Lassiter 1962).

### 2.3 Reproduction

Bluefish spawn offshore in the western North Atlantic Ocean, from approximately Massachusetts to Florida (Norcross et al. 1974; Kendall and Walford 1979; Kendall and Naplin 1981; Collins and Stender 1987). In addition to the spring and summer cohorts identified by Lassiter (1962), Collins and Stender (1987) identified a fall-spawned cohort, demonstrating an expansive and prolonged bluefish spawning season. Individual bluefish are thought to be highly iteroparous but no specific information is published for spawning frequency or batch fecundity.

### 2.4 Stock Definitions

Bluefish in the western North Atlantic is managed as a single stock (NEFSC 1997; Fahay et al. 1999). Genetic data support a unit stock hypothesis (Graves et al. 1992; Goodbred and Graves 1996; Davidson 2002). For management purposes, the ASMFC and MAFMC define the management unit as the portion of the stock occurring along the Atlantic Coast from Maine to the east coast of Florida.

### 2.5 Habitat Description

Adult and juvenile bluefish are found primarily in waters less than 20 meters (m) deep along the Atlantic coast (Fahay et al. 1999). Adults use both inshore and offshore areas of the coast and favor warmer water temperatures although they are found in a variety of hydrographic environments (Ross 1991; Fahay et al. 1999). Temperature and photoperiod are the principal factors directing activity, migrations, and distribution of adult bluefish (Olla and Studholme 1971).

## 3.0 DESCRIPTION OF FISHERIES

### 3.1 Commercial Fishery

Commercial landings from the bluefish fishery have been consistently lower than the recreational catch (Table 1; Figure 1). Gill nets are the dominant commercial gear used to target bluefish and account for over 40% of the bluefish commercial landings from 1950 to 2003. Other commercial gears including hook & line, pound nets, seines, and trawls, collectively account for approximately 50% of the commercial landings.

Regional variations in commercial fishing activity are linked to the seasonal migration of bluefish. The majority of commercial fishing activity in the North and Mid-Atlantic occurs from late spring to early fall when bluefish are most abundant in these areas. As water temperatures decrease in late fall and winter, bluefish migrate south. Peak landings in the South Atlantic occur in late fall and winter. The majority of commercial landings are taken in the South and Mid-Atlantic regions (Table 2). Since 1950, approximately 87% of the coastwide total landings have been taken in these regions.

Commercial landings decreased from 7,500 mt in 1981 to 3,300 mt in 1999 (Table 1; Figure 1). Commercial landings have been regulated by quota since implementation of Amendment 1 in 2000. In 2000 and 2001, landings increased to approximately 3,600 mt and 3,900 mt, respectively, but declined again in 2002 and 2003 to at 3,100 mt and 3,400 mt, respectively (Table 1; Figure 1). Preliminary landing estimates for 2004 increased to 3,800 mt (Table 1).

### 3.2 Recreational Fishery

Bluefish is a highly sought after species in the recreational fisheries along the Atlantic Coast. Recreational catch of bluefish has averaged over 19,000 metric tons (mt) since 1981 (Table 1, Figure 2). In 2004, recreational anglers along the Atlantic Coast harvested over 6,800 mt of bluefish. Most of the recreational activity occurs from July to October, when almost 70% of the bluefish harvest is taken (Figure 3) . Most of the recreational catch of bluefish is taken in the North and Mid-Atlantic states (New York to Virginia) (Table 3). Recreational landings decreased from 43,500 mt in 1981 to a low of 5,379 mt in 1999. Since 1999, landings and numbers have fluctuated from about 6,200 mt to about 8,000 mt. Landings in 2004 were 6,870 mt (Table 1; Figure 2).

## 4.0 TERM OF REFERENCE #1: Evaluate adequacy, appropriateness, and uncertainty of fishery-dependent and fishery-independent data used in the assessment.

This bluefish assessment is an extension of the stock analysis reviewed in 1997 and accepted at SAW-23. The Bluefish Stock Assessment Working Group therefore concluded that information through 1995, the final year in the SAW-23 assessment, was adequate for use in an age-based assessment model. Expanded numbers at length for commercial and recreational fisheries were subsequently updated through 1996. Data from 1997 to present were assembled and reviewed for adequacy by the current working group.

### 4.1 Commercial Data

Commercial fisheries landings data for states between North Carolina and Maine are collected via the NMFS dealer mandatory reporting system. Beginning in June 2004, an electronic dealer reporting was initiated in the northeast. The states of Florida, Georgia, and South Carolina use a trip ticket system.

#### 4.1.1 Commercial Biological Sampling

Commercial length data from 1997 to 2004 were expanded based on four regions of sampling: Maine to Maryland, Virginia, North Carolina, and South Carolina to Florida.

##### 4.1.1.1 Maine to Maryland

Biological samples collected by NMFS were used to expand landings by year, quarter, gear, and market category. Length data were measured to the nearest cm FL and total landings in weight in pounds (lbs). Lengths were converted to weights using a seasonal length-weight equation across all years. Missing information in cells was replaced by mean weights in adjoining cells (e.g. among gears by market category, quarter). If no appropriate information was collected within a year, overall cell mean weights were substituted from the 1997 to 2004 period.

Sampling levels, landings and samples per 100 lbs of landings are presented in Tables 4 to 6. Since 1997, sampling in this region has averaged only 1,766 lengths per year (1,376 excluding the 4,500 lengths from 2004). The seasonal distribution of samples varied by year, although in general few samples were collected during the first quarter. Similarly, all market grades were not sampled equally among seasons or years.

#### 4.1.1.2 Virginia

The Virginia Marine Resources Commission's (VMRC) Stock Assessment Program (SAP) has collected finfish biological data (length, weight, sex, and age) since 1988. At most sites, bluefish are sampled from 50-pound boxes of landed fish that have been graded, boxed, and iced. At sites associated with pound net or haul seine landings, bluefish are intercepted after they have been graded by market category and weighed. A 50-pound box (or partial box) of graded fish from all available species market categories (*i.e.* small, medium, large, and unclassified) are chosen for determination of length, weight, and sex information. In most cases, the entire 50-pound box of fish graded by species market category is sampled to account for within-box variation (see Chittenden et al. 1990).

Each fish is measured for size (total length and usually weight). Weight is measured to the nearest 0.1 lbs; total length is measured to the nearest millimeter (mm), accurate to 2.5 mm, using electronic Limnoterra Fish Measuring Boards. Fork length is measured on a subsample basis. All fish, except those with damaged tails, are measured for total length from the tip of the snout to the end of the tail fin.

Ancillary data collected for each biological sample includes species grade or market category, harvest area, gear type used, and total catch by species market category. Biological data collections are generally stratified by season, area, gear type, and market grade. Numbers of fish sampled depends on availability but range from roughly 5,000 (1989-1992) to about 2,000 (2000-2003). Sampling intensity ranged from 25.8 lbs per 1,000 lbs of landings (2003) to 4.5 lbs sampled per 1,000 lbs of landings (1995) from 1989 to 2003. Generally, a greater proportion of the landings are sampled during years of lower landings. A summary of samples collected, landings and sampling per unit weight are provided in Tables 4 to 6.

#### 4.1.1.3 North Carolina

Commercial bluefish landings are monitored through the North Carolina trip ticket program (1994-present) (NCDMF 2004). Under this program, licensed fishermen can only sell commercial catch to licensed North Carolina Division of Marine Fisheries (NCDMF) fish dealers. The dealer is required to complete a trip ticket every time licensed fishermen land fish. Trip tickets capture data on gears used, area fished, species harvested, and total weights of each individual species landed, by market grade. Trip tickets are submitted to NCDMF monthly.

Fishery-dependent sampling of NC commercial fisheries has been ongoing since 1982. Predominant gears sampled include: ocean sink nets, estuarine gill nets, winter trawls, long haul seines/swipe nets, beach haul seines, and pound nets. From the fishery-dependent data, NCDMF derives length and weight estimates by market grade for almost all of the commercial landings except catches by shrimp trawls, pots, long line, gigs, fyke nets, hand harvest, trolling, and rod & reel. Landings from these unsampled or 'other' commercial gears combined represent 0.2-1.1% of the 1997-2004 landings. Length frequency distributions from all sampled commercial gear were combined to represent landings by these other gears.

Bluefish length frequency samples, by gear, for both the market and bait components were obtained from dealers with a sample representing the landings from an individual trip. Sampling was done by market category as fish were culled at the dealers. Length distributions (and aggregate weights) from sampled trips by gear and market grade were expanded by respective landings, gear, and market grade. Length frequency distributions were combined to represent total landings, by gear, market grade, quarter, and year.

Length frequency distributions, by gear, market grade, quarter, and year, were used to proportion the total number of individuals harvested into numbers at length. Due to the lack of available data for the jumbo market grade, large and jumbo market grades were combined. When length information was insufficient, data from bluefish caught from inside waters by long haul seines, estuarine gill nets, or pound nets, or the ocean beach seine fishery, were substituted for each other.

Bait was defined as the part of the catch not marketed for human consumption, but sold for crab or fish pot bait, industrial uses, or discarded. Bait landings were estimated bi-annually by applying the bi-annual ratio of marketable to bait species sampled in the fish house to the reported marketable landings. The total number of bait individuals by fishery was derived by dividing the estimate of bait landings by the mean weight of a bait individual for each fishery, for each bi-annual period. A summary of samples collected and sampling per unit weight are provided in Tables 4 to 6. Since 1997, NC has averaged 7,650 length measurements per year covering all seasons and market grades.

#### 4.1.1.4 Florida

Biological data collection for the bluefish fishery from Florida to North Carolina was sparse. Florida Department of Environmental Protection (FLDEP) collected 724 lengths from a variety of gear types since 1998 (although 4,321 fish were measured between 1993 and 1997 prior to a change in fishery regulations). The length distribution among periods was similar to NC medium grade bluefish, consequently the NC medium length distribution was used to expand semi-annual FL landings (Figure 4).

Expanded commercial fisheries length frequencies among all sampling programs are presented in Figure 5.

### 4.2 Commercial Discards or Bycatch

The SAW-23 assessment concluded that commercial discards were minimal and not estimable based on available data. The bluefish stock assessment working group concluded that discard estimates for the Atlantic coast were not possible and likely insignificant for several reasons. First, there is no minimum fish size in the commercial fishery. Second, the average commercial quota for the 1994-2003 period was approximately 10 million lbs while an average 8.1 million lbs was landed in the same time period. Third, the bluefish FMP allows states with a surplus quota to transfer a portion or the entire quota to a state that has or will reach its quota. Finally, Amendment 1 allows quota transfer from the recreational fishery to the commercial fishery.

### 4.3 Recreational Data

Recreational fishery statistics for bluefish caught along the Atlantic Coast were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS). The MRFSS estimates are divided into three catch types:

1) Fish brought to the dock in whole form and are identified and measured by trained interviewers are classified as landings (Type A).
2) Fish that are not in whole form (*e.g.* bait, filleted, released dead) when brought to the dock are classified as discards (Type B1). Discards are reported to the interviewer but identified by the angler.
3) Fish released alive (Type B2) are identified by the angler and reported to the interviewer.

The sum of types A and B1 provides an estimate of total harvest for the recreational fishery. Total recreational catch is the sum of the three catch types (A + B1 + B2). Estimates of weight provided by MRFSS are minimum values and may not accurately reflect the true total weight that was landed or harvested. This bias is more common with large or rarely caught species.

Length and weight measurements of type A catch are collected as part of the MRFSS intercept survey program (Figure 6). The intercept survey collects catch and demographic information from recreational anglers who have just completed fishing. Sampling is stratified by state, mode (shore, private/rental, or charter/party), and two month wave, with a minimum of 30 intercepts per stratum. Numbers, weights, and lengths are recorded by species as part of the intercept interview. The intensity of length frequency sampling for bluefish from the recreational fishery was calculated on the basis hundreds of pounds landed per length measurement (NEFSC 1994a, 1994b, 1997). Sampling intensity by wave is presented in Table 7 for 1997 to 2004. Because there is no minimum size, the working group assumed that bluefish recreational discards had the same size distribution as landed fish. As in previous bluefish stock assessments, a discard mortality rate of 15% was assumed for type B2 catches based on Malchoff (1995) and as modified by the ASMFC Bluefish Technical Committee (NEFSC 1997).

#### 4.3.1 Recreational Catch Rates

The MRFSS intercept and catch estimate data were used to develop a fishery-dependent time series of catch-per-unit-effort (CPUE). Recreational fishing effort was defined as those trips that either caught or targeted bluefish (*i.e.* variable 'PRIM1' or 'PRIM2' in MRFSS intercept files). Bluefish catch was also divided by the number of participants per trip to produce catch per angler trip as a measure of effort. The different measurements of effort had little effect on the time series trends (Figure 7). Based on the recommendation of previous SARC reviews, the CPUE time series was modeled in a general linear model framework using a negative binomial transformation of log catch rates (per trip) (Terceiro 2003). Significant variables in the model include year, wave, area, mode of fishing, and number of fishing days in the previous 12 months as recalled by anglers. Re-transformed year estimates from the GLM model were used as the recreational CPUE time series. A comparison of CPUE series before and after GLM modeling is shown in Figure 7. The amount of information available as covariates in the GLM is limited and has had little influence on the time series. .

#### 4.3.2 Age Data

NCDMF age data were available for bluefish aged by scales (1983-1996; n=5,639) and otoliths (1996-2000; n=2,067). The majority of the age structures were collected from fishery-dependent sampling, but a few recreationally caught bluefish were also aged. Age data were also provided for age structures (scales, whole, and sectioned otoliths) collected from various northeast states (1996; n=295). The northeast samples were collected from commercial and recreational gear (hook & line, trawl, seine, and gill nets).

In 1997, VMRC established a cooperative fish ageing lab with Old Dominion University's Center for Quantitative Fisheries Ecology (CQFE) Laboratory. The CQFE Lab age harvest from Virginia's marine fisheries and provide the data to VMRC for management purposes. Otolith-based age data were available for bluefish from 1998-2004. Collection of age samples was based on a quota by inch interval. The Virginia time series (1998-2004) contains age information by gear, sex, market category, and location from approximately 2,500 samples, from sectioned otoliths only.

The bluefish stock assessment working group reviewed the NC age data and concluded that there was a shift in ageing protocol after 1997. From 1998 on, the time of annuli formation appears to be the criteria for birth date rather than January 1. Consequently the spring age data from 1998-2004 were incompatible with other available age data and could not be modified without supplemental information. Therefore, only age keys provided by VA from 1998 to 2004 were applied to commercial and recreational fisheries.

Several studies document the problems with bluefish ageing information, specifically problems with using scales to accurately age bluefish. False annuli, rejuvenated scales, identifying annuli on scales from larger fish, different annuli counts between scales from the same fish, and the timing of the first annulus formation can all cause inaccuracies (Lassiter 1962; Richards 1976; NCDMF 2000). The divergence between scale ages and otolith ages occurs beyond age-6 (E. Robillard, CQFE, pers. comm. 2005). Therefore the catch-at-age matrices were truncated to a 6+ category to reduce ageing error associated with scale ages in the 1982-1997 time period.

The SAW-23 review expressed concern that use of a single age key collected in NC may not be representative of the coastal stock (NEFSC 1997). Salerno et al. (2001) examined age data collected along the Atlantic coast in the NEFSC autumn trawl survey and compared the scale ages with the North Carolina commercial ages and concluded that the NC ages were representative of Atlantic coast bluefish. Other studies have used age-length information from commercial and recreational fisheries and fishery-independent surveys and have shown similar bluefish growth parameter estimates from Maine to North Carolina, providing further evidence that North Carolina age data are representative of the Atlantic Coast (VMRC 1999, 2000, 2001).

In years with a limited number of ages available, seasonal age keys were combined across years. Spring age keys were developed for 1997 (n=228), 1998-2001 combined (n=62), 2002 (n=282), and 2003 (n=226). Spring 2004 (n=41) was a combination of 2003 and 2004 (Table 8). Fall age keys were developed for 1997 (n=217), 1998-1999 combined (n=337), 2000-2001 combined (n=412), 2002 (n=395), 2003 (n=214), and 2003-2004 combined (n=380) (Table 8). To fill gaps in the keys, the working group assumed that length bordered by lengths with only one age group were similar. Lengths with no available information were filled from an age key for the combined 1997-2003 period. Indices were divided by age using survey specific age data if available (CT 1984-1998 and NMFS 1997-1998), otherwise the general age key was applied.

Commercial catch at age and recreational catch at age were combined for the 1982 to 2004 catch at age matrix (Table 9). Age data was also used to calculate mean weights at age (Table 10). Recreational CPUE estimates were also partitioned into ages (Table 11) based on the proportion of each age group in the recreational catch at age matrix

### 4.4 Fishery-Independent Surveys

Fishery-independent surveys from Florida to New Hampshire were reviewed for this assessment. Survey methods include estuarine and nearshore bottom trawl and beach seine surveys. The surveys caught predominantly age-0 and age-1 bluefish (< 30 cm FL). Bluefish catch was generally low and large catches were sporadic. Indices of relative abundance were calculated based on constraints of catch size, time, and location of sampling. Several surveys sample monthly or bi-monthly. The working group evaluated the timing of each survey and chose the period that had the highest availability of bluefish to the survey gear (Table 12).

#### 4.4.1 Northeast Fisheries Science Center (NEFSC) Fall Inshore Trawl Survey

The NEFSC has conducted bottom trawl surveys over a large portion of the Atlantic shelf since 1963 (Avarovitz 1981). Sampling sites are randomly selected from within depth-defined strata; both inshore and offshore strata are sampled. The surveys run in the spring, fall, and winter seasons. The surveys cover areas from 5 to 200 fathoms deep, from Cape Hatteras, North Carolina to Canadian waters. The trawling locations are allocated according to a stratified-random sampling design. Strata 1-46 are assigned to the fall inshore survey for stations from Cape Hatteras to Cape Cod. The research vessels F/RV *Albatross IV* and the F/RV *Delaware II* are used exclusively to conduct these surveys. A small-mesh cod-end liner (1/2 inch mesh) is used to retain pre-recruits. Bluefish are seen more commonly in the fall survey and from inshore sites. Mean number per tow and mean weight per tow from the 1975-2004 fall inshore survey were calculated (Table 13; Table 14). Mean number per tow at length since 1982 were divided into age categories using NEFSC ages prior to 1996 (Table 15). Age keys developed from VA data were used for 1997 to 2004. The majority of bluefish caught in the fall are age-0 or age-1. The index shows a large cohort present in 1981, 1984, and 1989. The index has been well below the time series average since 1989, although the 2003 index was slightly above average (Table 13).

#### 4.4.2 NEFSC Fall Offshore Trawl Survey

NMFS fall survey data from 1975 to 2004 were also used to calculate stratified mean number per tow and mean weight per tow (Table 13). Age expansion was done as discussed for the inshore strata (Table 15). Catch rates in the offshore strata were considerably lower and varied without trend.

#### 4.4.3 Massachusetts Division of Marine Fisheries Inshore Bottom Trawl Survey

The Massachusetts Division of Marine Fisheries (MADMF) started sampling inshore state waters in 1978 using a bi-annual seasonal bottom trawl survey. The survey design is random stratified using strata based on geographic area and depth zone. Bluefish are rarely observed in the spring component of the survey and the majority of bluefish caught during the fall survey are young-of-year (<25 cm), with most catches representing the second or summer cohort fish. Arithmetic and geometric mean numbers and length frequencies for young-of-year are available for the 1978 to 2003 time period. Survey indices depict larger than average year-classes in 1987, 1991, 1997, and 1998. Recent year-class indices (2000-2002) are lower than average (Table 13).

#### 4.4.4 Rhode Island Marine Fisheries Trawl Surveys

The Rhode Island Division of Fish and Wildlife's (RIDFW) Marine Fisheries Section initiated a seasonal trawl survey in 1979 to monitor recreationally important finfish stocks in Narragansett Bay, Rhode Island Sound, and Block Island Sound. The survey employs a stratified random, stratified fixed design and records aggregate weight by species, abundance, individual length measurements, and various physical data. In 1990, a monthly component was added to the survey, which includes 13 fixed stations in Narragansett Bay. Abundance indices were calculated from 1981-2004.

Age-0 fish dominate bluefish catch in the RIDFW seasonal survey during the fall component of the survey. The spring component rarely catches bluefish. The average abundance index for the RIDFW survey was 14.1 fish/tow. Relative abundance was below average from 1981-1993, ranging from 1.3 to 13.0 fish/tow. Relative abundance was highest in 1994 (36.9 fish/tow), 1997 (72.2 fish/tow), 1998 (46.7 fish/tow), and 1999 (61.2 fish/tow) before dropping to below average in the early 2000s. The lowest abundance index occurred in 2003 (0.9 fish/tow) and the most recent index (2004) is below average at 5.5 fish/tow (Table 13; Table 14).

#### 4.4.5 Connecticut DEP Long Island Sound Trawl Survey

The Connecticut Department of Environmental Protection's (CTDEP) Marine Fisheries Division has conducted the Long Island Sound Trawl Survey (LISTS) since 1984. The LISTS was designed to collect long-term fishery-independent data from the Connecticut and New York waters of Long Island Sound. The LISTS employs a stratified-random sampling design using strata based on depth interval (0-9.0 m, 9.1-18.2 m, 18.3-27.3 m or, 27.4+ m) and bottom type (mud, sand, or transitional). Sampling is currently divided into spring (April, May, and June) and fall (September and October) periods. Forty tows are sampled monthly (120 in the spring, 80 in the fall) using a 14 m otter trawl (9.1 m headrope, 14 m footrope). Species are sorted, weighed, and counted and all or a sub-sample of primary species are measured to nearest cm FL. Scales are removed from a sub-sample for ageing purposes. The LISTS has not aged bluefish since 1988, however, scales from 2,469 bluefish were collected and aged from 1984 to 1988. Geometric mean number per tow estimates were developed from the September tows as an index of bluefish abundance. Mean number per tow at age since 1988 were developed using NC or VA age keys (Table 15).

The LISTS has collected 150,091 bluefish from 4,869 tows since 1984. The survey is one of the few inshore state fishery-independent surveys that consistently capture adult bluefish during the fall period. The LISTS calculates two geometric mean count and weight indices for the fall survey: an age-0 index (fish less than 30 cm) which average 17.37 bluefish (2.34 kg/tow) and an age-1+ index which averages 3.60 fish per tow (5.71 kg/tow). The surveys age-0 abundance initially was low during the startup years of the survey then varied around average levels from the late 80s to 1996. A three-year period of high abundance was observed from 1997 to 1999 after which abundance decreased to average levels. The age-1+ bluefish index declined steadily from above average levels in 1985 to 1.92 fish/tow in 1989. A large increase in abundance was seen in 1990 and again in 1992. A precipitous decline occurred for the next seven years to 0.86/tow in1999, the lowest abundance recorded. Abundance of age-1+ bluefish increased for the next three years to average levels in 2002. However, recent large catches of adult bluefish during the fall of 2004 resulted in a 21-year record high abundance (in numbers) that was five times higher than that seen just a year earlier and the second highest biomass index in the survey (Table 13; Table 14). Many of these fish ranged from 37 cm to 41 cm FL, however, catches of fish up to 70 cm FL were common in 2004.

#### 4.4.6 New York DEC Small Mesh Trawl Survey

The New York Department of Environmental Conservation's (NYSDEC) Small Mesh Trawl Survey started in 1987. The survey area is divided into 77 sampling blocks located in the Peconic estuary in eastern Long Island. Each year from May to October, sixteen stations are randomly chosen each week and sampled by an otter trawl (16 foot shrimp trawl with small mesh liner) and towed for 10 minutes.

Catches of bluefish, which peak in August and September, consist almost entirely of young-of-the-year (52 to 250 mm FL). The highest observed catches occurred in the late 1980s, with a smaller peak in the mid-1990s. Catches of young-of-the-year have been well below average and declining in recent years (Table 13). A geometric mean number per tow was calculated from August and September tows as an index of bluefish abundance.

#### 4.4.7 New York DEC Beach Seine Survey

In 1984, the NYSDEC initiated a beach seine survey, which was designed to target age-1 striped bass. The survey uses a 200 foot beach seine to sample about 175 sets per year from May through October at fixed stations within western Long Island bays, primarily Little Neck, Manhasset, and Jamaica bays.

Catches of bluefish are predominantly young-of-the-year and usually reach their highest abundance in July and August. An index of bluefish abundance was based on August hauls. Catches of young-of-the-year were highest in the late 1980s, 2000, and 2001. Catches of young-of-the-year have been below average in 2003 and 2004 (Table 13).

#### 4.4.8 New Jersey DFW Ocean Stock Assessment Program

The New Jersey Division of Fish and Wildlife (NJDFW) Bureau of Marine Fisheries initiated the Ocean Stock Assessment Program in 1989 to monitor the abundance and distribution of marine recreational fishes in the state's nearshore coastal waters. The survey uses a stratified random design and is conducted five times per year in January, April, June, August, and October. The survey samples waters from Sandy Hook to the entrance of the Delaware Bay.

Typically, few to no bluefish are collected during the January and April surveys. Annual numbers of bluefish per tow range from 0.3 to 10.6. The highest years of abundance were 1989 (10.6 bluefish per tow), 1994 (8.1), and 2002 (7.8). The lowest years of abundance were 2001 (0.3) and 1993 (0.9). Sizes range from 3 to 81 cm FL. The majority (75%) of bluefish were less than 31 cm FL. Indices of bluefish abundance and biomass was calculated as the geometric mean per tow from the October data (Table 13; Table 14). Indices were further divided into age groups by applying the generalized age keys to survey length data (Table 15). Indices at ages greater than 2 prior to 1998 were unavailable.

#### 4.4.9 Delaware DFW Juvenile Trawl Survey

Delaware's Department of Natural Resources and Environmental Control (DNREC) Division of Fish and Wildlife's juvenile trawl survey targets juvenile fish and shellfish. This program was initiated in 1980 to monitor distribution, relative abundance, and year-class strength. The survey conducts monthly sampling from April to October at fixed stations in the Delaware Bay and River. Tows conducted during September were used to estimate an index of abundance as the geometric mean number per tow (Table 13).

#### 4.4.10 Delaware DFW Adult Trawl Survey

The DNREC Division of Fish and Wildlife began an adult trawl survey in 1966. The survey was discontinued in 1971, started again in 1979, discontinued after 1984, and finally resumed again in 1990. The aim is intended to track temporal trends in abundance and distribution and to characterize the size composition of select species. Trawl tows are carried out monthly from March to December at fixed stations in the Delaware Bay. Large numbers of bluefish are not common, but bluefish do occur in the catches, peaking in the fall. Tows from August to October were used to calculate the geometric mean number per tow and biomass per tow as indices of bluefish abundance (Table 13; Table 14). Abundance indices were further divided into age groups (Table 15). Only fish age 0 to age 2 were included due to samples sizes.

#### 4.4.11 Maryland DNR Juvenile Striped Bass Seine Survey

The Maryland Department of Natural Resources' (MD DNR) Juvenile Striped Bass Seine Survey has documented annual year-class success and relative abundance of many fish species in Chesapeake Bay since 1954. Juvenile striped bass indices are developed from sampling at 22 fixed stations located in major spawning areas in Maryland's portion of the Chesapeake Bay. A subset of 13 sample sites was selected for the development of a juvenile bluefish index from 1981 to present. Other sites were excluded on the basis that bluefish were rarely, if ever, captured there. Each site is visited monthly, from July to September, and two samples are collected.

Samples are collected with a 30.5 m x 1.24 m bagless beach seine of untreated 6.4 mm bar mesh set by hand. Selected fish species are separated into age-0 and age-1+ groups. Ages are assigned from length frequencies and verified through scale examination. A random sub-sample of 30 age-0 fish is measured per site, per month. All other finfish are identified to species and counted. Additional data collected at each site include: time of first haul, maximum distance from shore, surface water temperature, surface salinity, primary and secondary bottom substrates, percent submerged aquatic vegetation, dissolved oxygen, pH, and turbidity.

Effort was slightly variable prior to 1994 because sites were occasionally lost to beach erosion, bulk heading, or proliferation of bay grasses. The number of samples has been constant (n=75) since 1994, and sample sites were standardized in 1997. Samples collected in July were used to generate an index of bluefish abundance (Table 13).

#### 4.4.12 VIMS Juvenile Bluefish Seine Survey

Virginia Institute of Marine Science (VIMS) developed a program to survey the abundance of juvenile bluefish in the waters along the bay and ocean sides of Virginia's Eastern Shore. Data are collected in waters with depths up to 1.5 m. The survey was started as an extension of the striped bass beach seine survey and was granted funding in 1994. A seine is used to sample fixed stations from June to October. Data collected in September are used to calculate an index of bluefish abundance as the geometric mean number per haul (Table 13).

#### 4.4.13 SEAMAP

The Southeast Area Monitoring and Assessment Program (SEAMAP) fishery-independent trawl survey has sampled the coastal zone of the South Atlantic Bight between Cape Hatteras, North Carolina and Cape Canaveral, Florida since 1989. The R/V Lady Lisa is used to conduct sampling. Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1-hour after sunrise to 1-hour before sunset). Stations are randomly selected from a pool of stations within each stratum. Beginning in 2001, the number of stations sampled in each stratum was determined by optimal allocation stations within fourteen shallow water strata in both summer and the fall. A total of 52 stations were sampled from 1990 to 2000 and increased to 57 after 2000. Sampling stations are delineated by the 4 m depth contour inshore and the 10 m depth contour offshore. In 2001, sampling stations in deeper strata were eliminated in order to intensify sampling in the shallower depth zone. Sampling occurs in spring (early April - mid-May), summer (mid-July - early August), and fall (October - mid-November). SEAMAP collects biological information for 27 priority species and the contents of each net are sorted separately to species. In every collection, each of the priority species is weighed collectively and individuals are measured to the nearest centimeter. Sub-sampling is used when catch of a priority species is too large to measure every individual.

Indices determined in this study were based on young-of-the-year bluefish (<25 cm FL) collected from inshore strata during April. Also, samples from south of 30°N were eliminated from analyses due to low and sporadic catches of bluefish in the southern range of the survey. Although older bluefish are occasionally collected, age-0 fish greatly predominate. The indices suggest above average age 0 abundance in 1991,1992 and 1995 (Table 13; Table 14)

### 4.5 General Survey Results

The seasonality of bluefish spawning results in two annual cohorts often referred to as the spring cohort and summer cohort (Chiarella and Conover 1990). Young-of-the-year survey indices were partitioned into cohort based on size (summer cohort = 1-13 cm, spring cohort = 14-25 cm) (Table 16).

The fishery-independent surveys sample components of the bluefish stock with distinct seasonal migration patterns that vary by fish age. State and federal fisheries-independent survey data were normalized to compare trends among young-of-the-year indices (Figure 8). Correlations among cohorts and programs were examined, resulting in 210 comparisons (Table 17). Among the comparisons, 17 of 210 possible combinations had R-values exceeding 0.5. However, 50% (105 of 210) were negatively correlated with another index (Table 17).

Because the state indices measure temporal and spatial components of a migratory stock, the size and contributions of these components to the total stock cannot be quantified.

### 4.6 Data Discussion

The Bluefish Technical Committee evaluated the quality of the commercial, recreational, and age data for use in an analytical model. The highest amount of commercial sampling since 1997 occurred in the North Carolina and Virginia region, which also accounted for the highest proportion of landings. The committee felt the sampling amounts by gear and market grade were adequate to represent the length distribution of Atlantic coast bluefish landings. The amount of commercial sampling in the mid-1990s was poor (see SAW-23 report), however, it was believed that here was enough information covering the entire time series to capture the trends in size for landings since 1982.

The length sampling of recreational landings has remained relatively stable at about 3,000 to 4,000 fish per year from 1997 to 2004 (Table 7). Since bluefish landings are not rare events, intercepts likely provide representative information to characterize length distributions. The MRFSS provides a survey estimate with proportional standard error estimates. The average PSE values since 1994 for bluefish (4.2) was comparable to other species such as summer flounder (3.9) and striped bass (5.3). The Committee concluded that the recreational landings information was adequate for use in a bluefish assessment. Recreational discard estimates were also considered adequate although there remains a lack of discard length information.

Age information, although relatively sparse in some years, was determined to be adequate to characterize bluefish catch and indices. Bluefish growth is dominated by the increase in size at age-0 and age-1. The fast growth results in very strong signals within the length distributions with little overlap between cohorts. The committee accepted the recommendation of researchers that ages beyond age-6 based on scales may underestimate the true age. The committee concluded that although there may be some error introduced into analytical models due to combining age data across years it was not likely a fatal flaw in this instance.

Most state agencies between Massachusetts and Florida conduct some type of annual survey of marine finfish. Examination of the survey results did not reveal any consistent signal of bluefish abundance or biomass indices among programs. There appears to be several issues that create problems with bluefish survey data. First, the type of gear used in available survey programs (trawls or beach seines) is generally inefficient for catching bluefish, particularly once the fish reach a larger size and can easily evade the gear. The second problem is the wide-distribution of the bluefish stock along the Atlantic coast. Finally, there appears to be a partitioning of fish by size, with smaller fish most common inshore and larger fish most common in deeper offshore areas. Consequently, state coastal surveys tend to miss larger fish that are beyond the survey area. In addition, during the fall survey period individual state programs only sample a limited part of the population. The NEFSC inshore survey reduces some of the problem associated with temporal coverage, although there remains the issue of catchability of larger fish.

The relationship among age-0 bluefish indices from different programs may be further confounded by the strength of the juvenile cohort (spring vs. summer) that is being sampled. The correlations suggest that summer cohorts may produce similar signals among the northeastern states surveys, but with little correlation among spring cohorts. The mix of the spring and summer cohorts within an age-0 index may produce indices without a clear signal of abundance trends.

The Technical Committee concluded that although there was inherent uncertainty in the data, the data was adequate for use in an analytical model. The greatest area of uncertainty was in the accuracy of survey indices in following population trends. The committee felt that the recreational CPUE, although a fishery-dependent index, provided the greatest spatial coverage and had the least problem with catchability of larger fish. The approach was to evaluate the utility of each survey index based on their performance within a model framework.

## 5.0 TERM OF REFERENCE #2: Evaluate adequacy and appropriateness of models used to assess the species and to estimate population benchmarks.

After reviewing several model types such as the modified Delury model, a surplus production model, a VPA and catch-at-age models, the Committee concluded that age-based models such as a catch-at-age model or VPA model were most appropriate for a bluefish assessment (see appendix I for details on rejected models). The bluefish data were truncated to an age-6+ category to reduce the influence of ageing error. In addition, the catch-at-age distribution in past assessments has been identified as having a bimodal distribution, which was reduced with inclusion of more ages into a plus group.

The NFT ADAPT version of VPA was used as an initial model. The model is configured such that a partial recruitment vector is input for use in estimation of terminal year + 1 *F* and N. However, estimation of the oldest true age in the matrix in prior years does not account for a dome (or bimodal) shaped partial recruitment (PR) vector. An *F*-ratio other than 1 for calculation of the plus group *F* can help adjust for non-flat topped PR in the plus group. The ADAPT model was setup to use averaging within years rather than across years to avoid some issues associated with any bimodal PR.

The Committee concluded that although the VPA produced satisfactory results, the assumption of no error in the catch-at-age matrix and the way ADAPT handles selectivity may produce misleading results. Therefore, a catch-at-age model, ASAP from the NFT models, was chosen as the primary assessment tool. The ability of the ASAP model to allow error in the catch-at-age as well as the assumption of separability into year and age components makes it better suited to handle the selectivity patterns and catch data from the bluefish fishery. However, there is no diagnostic metric that allows direct comparison between ADAPT and ASAP models.

## 6.0 TERM OF REFERENCE #3: Evaluate and either update or re-estimate biological reference points as appropriate.

The biological reference points in the FMP were based on a surplus production model that was rejected during the SAW 39 review. Therefore there are no currently accepted reference points for Atlantic coast bluefish.

New biological reference points were developed for comparison to current stock status. The preferred ASAP model output estimated $F_{MSY}$=0.19 (Table 18). The model also estimated $F_{MAX}$ = 0.28, $F_{0.1}$ = 0.18 and $F_{30\%}$ as 0.28 (Table 18). Alternative reference points were calculated with an age based Thompson-Bell yield-per-recruit model (Figure 9). Partial recruitment values were based on the average 1982-2003 ASAP selectivity estimates. The model was extended to age-7+ with a selectivity of 1.0. $F_{MAX}$ was estimated at 0.25, $F_{0.1}$ = 0.17 and $F_{30\%}$ as 0.26 (Table 18). The current $F$ of 0.146 is below $F_{MSY}$ as well as alternative reference points. Therefore, it is concluded that bluefish are not experiencing overfishing.

Recruitment and spawning stock biomass are both estimated in the ASAP model and these values used to fit a Beverton-Holt S/R relationship. The parameters for bluefish were alpha = 35426.6 and beta = 41159.4 with a steepness of 0.740 (Figure 10). In addition, SSB at msy was estimated equal to 142,104 mt. Using the SSB/R and B/R estimates from the Thompson-Bell model, we used the Shepherd/Sissenwine approach to calculate $B_{msy}$ as 147,052 mt (Table 18). The current FMP defines overfished status as biomass below ½ $B_{msy}$ which would be equal to 73,526 mt (Table 18). Therefore, with the current estimate of biomass equal to 104,136 mt, bluefish would not be considered overfished.

## 7.0 TERM OF REFERENCE #4: Estimate and evaluate stock status (biomass) and fishery status (fishing mortality rate). Is the stock overfished; is overfishing occurring?

### 7.1 ADAPT model

The initial bluefish model was the ADAPT VPA using a catch-at-age matrix from 1982 to 2004 through age-6+. The SAW-17 review of a bluefish assessment suggested that values of $M$ should range from 0.2-0.25 instead of $M$=0.35 (NEFSC 1994a). Since the oldest aged bluefish is 14, an $M$ of 0.2 was appropriate, using $M$=3/oldest age. The initial input PR was bimodal with a maximum value at age-1 of 1.0 and age-5 value of 0.74. The *F* ratio was set at 1.4 to create a higher *F* in the age-6+ group, forcing the model towards a bimodal *F* pattern. Full *F* was calculated as an average of *F* from age-2 to age-4 (since age-5 *F* was based on oldest true age estimation and age-6+ was function of the oldest true age).

Maturity at age was held constant over time as 0 at age-0, 0.25 at age-1, 0.75 at age-2 and 1.0 thereafter. Following initial runs including all available indices, the tuning indices were truncated based on proportional variance contributions to the overall model variance. The final tuning indices were limited to those with adults present (NEFSC inshore (age-0 – age-6+), CT trawl indices (age-0 – age-6+), NJ trawl indices (age-0 – age-2), DE adult trawl indices (age-0 – age-2), Rec CPUE (age-0 – age-6+), and the SEAMAP series to include an age-0 recruitment series from the South Atlantic Bight. Tuning was made to mid-year population size.

Results of the ADAPT indicate a reasonable fit to the model with a CV around the population estimates of 0.43 (age-0), 0.38 (age-1), 0.27 (age-3 and age-4) and 0.28 (age-5). The model fit to the indices tended to miss the abrupt peaks in the time series. The residual patterns for Rec CPUE age-1 and age-2 had a trend over time. However, when indices were removed from the model they had little influence on the results (the population CVs increased to 0.30 for age-3 – age-5). The fishing mortality rate in 2004 was estimated to be $F_{2004}$=0.12, a decline from 0.23 in 2001 (Table 19). Population size estimates increased steadily from 52,940 in 1998 to 97,216 in 2004 (using a geometric mean recruitment estimate since 2000) (Table 20) and biomass estimates increased from 47,900 mt in 2000 to 90,400 mt in 2004 (Table 21). Bootstrapped abundance estimates produced an 80% confidence interval of 78,793 to 108,963 thousand fish and a January 1 biomass distribution of 86,000 mt to 140,900 mt (Figure 11). Similar bounds in *F* estimates ranged from 0.10 to 0.16 (Figure 11). The model configuration had no retrospective pattern in the *F* or population estimates (Figure 12)

### 7.2 Age-Structured Assessment Program (ASAP)

The input values from ADAPT were used as initial values for the ASAP model. ASAP allows selectivity and catchability patterns to vary over time. The model was structured to allow greater deviations from the indices than from the catch-at-age data. A selectivity pattern was fitted to the data and held constant for the periods 1982-1990,1991-1998 and 1999-2004. Recruitment was allowed to deviate from the fitted model after the 4$^{th}$ year.

The final model configuration resulted in a residual sum of squares of 0.0035 and a likelihood value of 7.058 (Table 22). When the model is allowed to vary selectivity to fit catch data, the resulting selectivity pattern was similar to the backcalculated PR in the ADAPT results and did not vary over time. The model closely predicted catch at age for the combined time series and annual catch when compared to the observed catch (Figure 13). Annual catch at age predictions were less accurate, particularly in years with unusually high or low age-0 and age-1 catch (Figure 14).

Predicted indices vary from observed estimates, in part because of the weighting schemes used in the model. Predicted indices are generally smoothed over time relative to observed values (Figure 15). Negative log-likelihood values were minimized for recreational CPUE at age, CT age-0 and DE age-1 (Figure 16). Similar to ADAPT, the early part of the REC age 1 time series was under-estimated. Overall the residual patterns scattered distributions with the exception of time trends in age 1 and age 2 recreational CPUE indices (Figure 17)

Fishing mortality estimates in ASAP are based on a separability assumption. $F_{\mathrm{MULT}}$ is the estimate of full F. The 2004 $F_{\mathrm{MULT}}$ value equals 0.149 (Table 23) . The trend in $F$ has steadily declined since 1991 when $F$ reached 0.41 (Figure 18). The time series of $F$ from the VPA shows less variability since 1990, bounded between 0.1 and 0.23. If the average VPA F for ages 1-4 is compared to ASAP average F for the same ages, the resulting $F$ trends between the two models are very similar.

January 1st population sizes show a general increase in overall abundance since 1997 (Table 24; Figure 19). Abundance estimates peaked in 1982 at 176 million fish, declined to 57 million in the mid-1990s and has since increased to 92 million fish (Table 19). Biomass estimates peaked in 1982 at 229,000 mt, then declined to 65,000 mt by 1997 before increasing to the 2004 level of 104,000 mt (Table 25; Figure 20). The magnitude of population estimates are similar to those produced in the VPA.

## 8.0 CONCLUSIONS

The Bluefish Technical Committee concluded that the results of the ASAP model were the best representation of the Atlantic coast bluefish population. There was some trade-off in the goodness of fit between the catch-at-age and survey indices in the model, but the overall model results were considered acceptable. The results also corresponded well to ADAPT model results. Although the agreement between models did not validate either model, it indicates that there was some signal in the data that could produce consistent output in two models with different assumptions. The model results lead to the conclusion that the Atlantic stock of bluefish is not experiencing overfishing nor is it overfished.

## 9.0 RESEARCH RECOMMENDATIONS FROM SAW 39 PANEL

### Data

Release Mortality

- The mortality of bluefish released by anglers is a key parameter because of the large proportion now released alive, and should be the subject of a more detailed investigation. This should include effect of any potentially significant factors such as fish size, sex, method of capture, and season.
    - No new studies have been conducted since SAW 39.

Recreational Catch Rate

- Recreational catch rate is important, so the data should be collected in a manner that allows analysis of changes in angler behavior, composition, technology, or other factors that influence both the statistical distribution of individual catch rate and changes in catchability over time.

- Data collection made under the MRFSS program with a standard sampling protocol. That protocol has not been changed.

- Terceiro (2003) has done much of the groundwork needed to develop a recreational catch rate abundance index. Poisson quasi-likelihood may be the simplest error model to apply. If possible, all trips should be used, and targeting should be allowed for as factor in the GLM.
  - The Terceiro method was used in calculation of recreational catch rates for the current analysis.

Catchability

- An assumption of constant catchability in recreational catch rates is likely to give an optimistic view of the state of the stock unless there has been a significant increase in less efficient anglers over time, and must remain an issue of concern that needs to be addressed externally to the model, through a more comprehensive analysis of recreational catch data.
  - The change in angler efficiency is partially addressed through use of the GLM model. However, a lack of angler specific information prohibits detailed analysis of changes in catchability.

Indices

- Catch rate and survey indices should both continue to be used for assessment purposes, if possible. However, models other than a catch rate index should at least be considered.
  - Recreational catch rates and survey indices were used in the current assessment, which is a forward-projecting age-structured model.

- There is a need for an integrated analysis of the many different research surveys for juvenile bluefish. The surveys cover different regions using different gear types and provide data on 0- and 1-group bluefish. It is recommended that serious consideration be given to convening a workshop to evaluate: 1) the quality of the individual data sets; 2) the potential ability of the surveys to index bluefish abundance at age in the areas surveyed; 3) coherence of trends in localized surveys with trends in nearby stations of the larger scale surveys; and 4) methods for standardizing and combining data from small-scale intensive surveys with large-scale less spatially intensive surveys, to give improved indices of recruitment. Such a workshop would require consolidation of raw survey data from the different surveys into common databases.
  - An attempt was made to consolidate state survey data into a single comprehensive index. Available data limited progress on the analysis at this time. It has been suggested to the ASMFC that a workshop to conduct this consider this approach is warranted.

Age Data

- Age composition data should be collected to allow continued development of fully age-structured assessment models, particularly in light of the unusual selectivity patterns estimated from earlier catch-at-age analyses.
  - Data collection continues but limited efforts have been made towards generating coast wide age information.

Maturity

- Maturity ogives need to be constructed and presented in future assessments.
    - This has not been done to date.

Tagging Studies

- The feasibility of using tagging studies to estimate mortality, selectivity and movements, as well as to determine tag retention, should be investigated.
    - A manuscript regarding a tagging study of bluefish along the Atlantic coast is currently in review.

Catch Data

- Catches should not be presumed to be exact, but can be fitted through some likelihood function for discrepancies between observed and estimated catch in the population model. The likelihood can use the standard error of the catch estimate.
    - This has been addressed through the use of the ASAP model.

Use of GLM

- Care should be taken when using a GLM index approach that information relevant to changes in stock size is not mistakenly removed. A better approach might be to integrate the GLM into a population model.
    - Only the recreational CPUE was subjected to a GLM analysis in this assessment. Fisheries independent indices were modeled by the assessment model.
    - 

International Work

- Stock assessment methods applied to bluefish elsewhere in the world should be evaluated for applicability to the NE US situation.
    - An extensive search of international work found a recent assessment of bluefish conducted in Queensland, Australia had potential applicability to the US East Coast situation. Leigh and O'Neill (2004) applied three different stock assessment models to data collected from the Australian east coast tailor fishery to evaluate stock status. Results of a surplus production model were considered unreliable. The main concerns with the outcome of the various model scenarios were parameter estimates that were unrealistic for tailor, the surplus production method's inability to model partial selectivity of mature fish, and convergence on local minima. An age-structured model and a fully integrated age-length model were also evaluated. The age-length model structured the population by both length and age. The development of the age-length model was prompted by a desire to capture the observed changes in length-at-age of tailor over the years. Unlike the strictly age-structured model, this model is able to directly fit observed length frequencies rather than first converting them to ages. Ageing data are applied only in years when age data are available, instead of extrapolating to years with missing age data.
    - The current data available for the US east coast bluefish stock could support development of an age-length model. Commercial and recreational fishery length samples are available back to 1982 and at least seven fishery-independent surveys have collected 20 or more years of

length data on bluefish. North Carolina has 13 years of age data based on scales and 5 years of otolith-based ages. Virginia has been processing otolith ages since 1998. Application of a fully integrated model could incorporate all these data and avoid some of the disadvantages of age-structured analyses. It would not be necessary to combine age-length keys across years, or even gear type depending on the model configuration. Other advantages include ability to model selectivity patterns as a function of size, incorporation of variation in size-at-age, and ability to include an explicit growth function.

  - Leigh, G.M. and M.F. O'Neill. 2004. Stock assessment of the Queensland-New South Wales Tailor Fishery (*Pomatomus saltatrix*). Queensland Department of Primary Industries and Fisheries QI04065.

Intermediate Models

- Pending ability to apply full age-structured methods, the use of partially age-structured methods such as the Collie-Sissenwine model is recommended to allow explicit incorporation of survey estimates for 0- and 1-group fish, so estimating the contribution of recruitment to annual production. This would require that the commercial fishery and recreational catches and cpue be disaggregated into recruits and older fish. The effect of poor data on discards of young bluefish in the commercial fishery on such an analysis requires evaluation.
  - A Collie-Sissenwine model was attempted in this assessment (see appendix). However, it was not successful for various reasons. A modification of the model structure in future work may eliminate the issues identified.

Model Optimization

- Global search algorithms (e.g. genetic algorithms) should be used for parameters if an ASPIC model is used in future.
  - ASPIC was not the model of choice in this assessment. Recent changes have been made to the search algorithm in the NFT ASPIC software.

Management

- As the current assessment has been rejected, and the status of the stock is unknown, the total allowable landings specification should continue at current value.
  - Management has been status quo since the assessment was rejected.

- Reducing fishing mortality to allow the abundance indices to increase could provide useful information on the productivity of the stock. A much-improved assessment may be obtained when a recovery has taken place.
  - No action taken.

## 10.0 TERM OF REFERENCE #5: Research Recommendations

**Commercial Data**

- Increase sampling of size and age composition by gear type and statistical area
- Target landings for biological data collection and increase intensity of sampling for biological data.

**Recreational Data**

- Increase sampling of size and age composition by gear type and statistical area
- Target landings for biological data collection and increase intensity of sampling for biological data.

**Ageing Data**

- Complete a scale-otolith comparison study
- Conduct study or workshop to address discrepancies between estimated bluefish age from scales and otoliths and the chronological age. Examine issues of inter- and intra-reader variation in interpretation of ages
- Examine the feasibility of each state collecting samples of hard parts for ageing, with one or two laboratories interpreting the annuli for consistency.

**Fishery-Independent Data**

- Continue research on species interactions and predator-prey relationships
- Examine alternative weighting schemes for the available fishery-independent surveys (*e.g.* area, inverse variance, N, etc.)
- Investigate the feasibility of alternative survey methods that target bluefish across all age classes to create a more representative fishery-independent index of abundance
- Initiate sampling of offshore populations in winter months
- Conduct research on influences on recruitment including pathways of larval bluefish
- Initiate coastal surf zone seine study to provide more complete indices of juvenile abundance.

**Models, Inputs, and Outputs**

- Explore a tag based assessment and associated costs compared to age based assessments
- Determine if a tag based assessment could supplement or replace other assessment techniques
- Continue to examine alternative models including a forward projection catch-at-age model.

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## BLUEFISH TABLES


Table 1. Summary of Atlantic coast bluefish commercial and recreational catch.
Table 2. Bluefish Atlantic coast commercial landings (mt) by state.
Table 3. Bluefish Atlantic coast recreational landings and discards in numbers (000s), by state.
Table 4. Number of bluefish sampled from commercial fisheries, 1997-2004
Table 5. Commercial Landings (lbs) 1997-2004 by period and market category.
Table 6. Relative Commercial Sampling (fish measured per 100 lbs landed) 1997-2004
Table 7. Sampling intensity of bluefish length collected from the recreational fishery, by wave, Maine to Florida (east coast).
Table 8. Age sample sizes used in development of age length keys. Spring 1998-2004 VA only. 1997 NC. Autumn 1999-2000 includes VA and NC data.
Table 9. Total Atlantic coast bluefish catch at age (000s). CAA for 1982 to 1996 adjusted from SAW 23 to reflect updated landings estimates.
Table 10. Total Atlantic coast bluefish weight at age (lbs). 1996 estimates set equal to 1995
Table 11. Bluefish recreational CPUE at age using re-transformed GLM indices.
Table 12. Seasonal distribution of fisheries independent surveys evaluated. Highlighted months were chosen.
Table 13. Mean number per tow or haul from fisheries independent surveys evaluated.
Table 14. Mean weight (kg) per tow or haul from fisheries independent surveys evaluated.
Table 15. Fisheries independent mean number per tow at age.
Table 16. Fisheries independent indices of age-0 bluefish by cohort as determined from length distributions.
Table 17. Correlations among juvenile indices by cohort group.
Table 18. Atlantic coast bluefish biological reference points.
Table19. Fishing mortality at age estimates from ADAPT model.
Table 20. January 1 population size estimates (000s) from the ADAPT model.
Table 21. Population biomass estimates (000s lbs) from ADAPT model
Table 22. Diagnostic information from preferred ASAP model run.
Table 23. Fishing mortality at age estimates from ASAP catch at age model.
Table 24. January 1 population size estimates (000s) from the ASAP model.
Table 25. Population biomass estimates (000s lbs) from ASAP model

Table 1. Summary of Atlantic coast bluefish commercial and recreational catch.

| Year | Commercial Landings (mt) | Commercial Landings (000 lbs) | Commercial Landings (000s) | Recreational Landings (000s) | Recreational Discards (000s) | Recreational Discards (000s) | Recreational Catch (000s) | Recreational Landings (mt) | Recreational Discards (mt) | Recreational Catch (mt) | Total Catch (000s) | Total Catch (mt) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1974** | 4,538 | 10,005 | | | | (assumes 15% | | | | | | |
| **1975** | 4,402 | 9,705 | | | | release mortality) | | | assumes same | | | |
| **1976** | 4,546 | 10,022 | | | | | | | mean wt | | | |
| **1977** | 4,802 | 10,587 | | | | | | | as landings | | | |
| **1978** | 4,986 | 10,992 | | | | | | | | | | |
| **1979** | 5,693 | 12,551 | | | | | | | | | | |
| **1980** | 6,857 | 15,117 | | | | | | | | | | |
| **1981** | 7,465 | 16,457 | | | | | | | | | | |
| **1982** | 6,997 | 15,426 | 7,699 | 23,724 | 3,497 | 525 | 24,248 | 37900 | 838 | 38,738 | 31,947 | 45,735 |
| **1983** | 7,166 | 15,798 | 5,556 | 24,884 | 5,254 | 788 | 25,672 | 41159 | 1,304 | 42,463 | 31,228 | 49,629 |
| **1984** | 5,380 | 11,861 | 5,849 | 20,798 | 5,710 | 857 | 21,654 | 31089 | 1,280 | 32,369 | 27,503 | 37,749 |
| **1985** | 6,122 | 13,497 | 4,340 | 19,246 | 3,228 | 484 | 19,730 | 24035 | 605 | 24,640 | 24,070 | 30,762 |
| **1986** | 6,651 | 14,663 | 6,658 | 24,441 | 5,970 | 895 | 25,336 | 43607 | 1,598 | 45,205 | 31,994 | 51,856 |
| **1987** | 6,578 | 14,502 | 4,467 | 21,076 | 6,527 | 979 | 22,055 | 36255 | 1,684 | 37,939 | 26,522 | 44,517 |
| **1988** | 7,161 | 15,787 | 3,805 | 9,905 | 3,460 | 519 | 10,424 | 22773 | 1,193 | 23,966 | 14,229 | 31,127 |
| **1989** | 4,740 | 10,450 | 2,978 | 13,600 | 5,037 | 756 | 14,356 | 18772 | 1,043 | 19,815 | 17,334 | 24,555 |
| **1990** | 6,250 | 13,779 | 3,605 | 11,365 | 5,081 | 762 | 12,127 | 14750 | 989 | 15,739 | 15,732 | 21,989 |
| **1991** | 6,160 | 13,580 | 7,747 | 11,943 | 6,349 | 952 | 12,895 | 16153 | 1,288 | 17,441 | 20,642 | 23,601 |
| **1992** | 5,205 | 11,475 | 10,063 | 7,158 | 4,242 | 636 | 7,794 | 12031 | 1,070 | 13,101 | 17,857 | 18,306 |
| **1993** | 4,808 | 10,600 | 1,969 | 5,725 | 4,200 | 630 | 6,355 | 9979 | 1,098 | 11,077 | 8,324 | 15,885 |
| **1994** | 4,304 | 9,489 | 2,325 | 5,768 | 6,152 | 923 | 6,691 | 7884 | 1,261 | 9,145 | 9,016 | 13,449 |
| **1995** | 3,628 | 7,998 | 2,068 | 5,168 | 5,326 | 799 | 5,967 | 7303 | 1,129 | 8,432 | 8,035 | 12,060 |
| **1996** | 4,113 | 9,068 | 1,842 | 4,205 | 5,316 | 797 | 5,002 | 6276 | 1,190 | 7,466 | 6,844 | 11,579 |
| **1997** | 4,064 | 8,960 | 2,955 | 5,413 | 7,161 | 1,074 | 6,487 | 7730 | 1,534 | 9,264 | 9,443 | 13,328 |
| **1998** | 3,741 | 8,246 | 3,161 | 4,202 | 5,002 | 750 | 4,952 | 6585 | 1,176 | 7,761 | 8,113 | 11,501 |
| **1999** | 3,334 | 7,351 | 2,411 | 3,682 | 7,806 | 1,171 | 4,853 | 5379 | 1,711 | 7,090 | 7,264 | 10,424 |
| **2000** | 3,659 | 8,066 | 2,662 | 4,897 | 11,363 | 1,705 | 6,602 | 6196 | 2,157 | 8,353 | 9,264 | 12,011 |
| **2001** | 3,945 | 8,698 | 2,823 | 6,663 | 13,749 | 2,062 | 8,726 | 7533 | 2,332 | 9,865 | 11,549 | 13,810 |
| **2002** | 3,119 | 6,876 | 2,142 | 5,300 | 9,917 | 1,488 | 6,788 | 6596 | 1,851 | 8,447 | 8,930 | 11,566 |
| **2003** | 3,359 | 7,406 | 2,161 | 6,045 | 8,996 | 1,349 | 7,395 | 7967 | 1,778 | 9,745 | 9,555 | 13,105 |
| **2004** | 3,783 | 7,200 | 1,847 | 6,939 | 11,739 | 1,761 | 8,700 | 6870 | 1,743 | 8,613 | 10,547 | 12,396 |

Table 2. Bluefish Atlantic coast commercial landings (mt) by state.

| Year | ME | NH | MA | RI | CT | NY | NJ | DE | MD | VA | NC | SC | GA | FL | mt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1950 | | | 27.8 | 25.4 | 9.5 | 57.7 | 587.7 | 9.4 | 47.8 | 141.4 | 576.9 | 4.7 | | 448.9 | 1,937.2 |
| 1951 | | | 12.9 | 16.7 | 24.8 | 86.7 | 499.1 | 2.2 | 38.4 | 81.3 | 420.0 | 5.3 | | 649.2 | 1,836.6 |
| 1952 | | | 0.4 | 21.9 | 40.8 | 94.3 | 653.0 | 0.4 | 50.4 | 65.2 | 334.2 | 5.0 | | 505.8 | 1,771.4 |
| 1953 | | | 13.6 | 36.4 | 25.2 | 73.7 | 409.4 | 1.1 | 20.9 | 79.4 | 245.7 | 3.2 | | 500.6 | 1,409.2 |
| 1954 | | | 14.0 | 41.6 | 11.0 | 182.1 | 572.0 | 1.0 | 40.4 | 83.8 | 146.6 | 3.6 | | 364.9 | 1,461.0 |
| 1955 | | | 16.8 | 14.2 | 14.3 | 212.7 | 460.3 | 1.2 | 28.7 | 99.7 | 197.3 | 17.7 | | 459.4 | 1,522.3 |
| 1956 | | | 8.7 | 21.2 | 5.9 | 168.2 | 502.9 | 1.5 | 46.0 | 101.6 | 287.1 | 24.2 | | 349.7 | 1,517.0 |
| 1957 | | | 11.2 | 26.9 | 8.6 | 189.7 | 415.7 | 1.9 | 42.0 | 87.5 | 370.1 | 32.4 | | 502.2 | 1,688.2 |
| 1958 | | | 1.4 | 4.5 | 1.0 | 52.3 | 41.2 | 2.8 | 14.7 | 70.6 | 198.2 | 1.1 | | 383.3 | 771.1 |
| 1959 | | | 2.4 | 8.9 | 2.6 | 118.7 | 170.4 | 2.0 | 13.5 | 82.8 | 335.8 | 0.6 | | 582.2 | 1,319.9 |
| 1960 | | | 6.9 | 15.5 | 2.5 | 187.9 | 200.9 | 0.2 | 4.7 | 59.1 | 278.7 | 0.1 | | 494.5 | 1,251.0 |
| 1961 | | | 8.1 | 22.2 | 4.9 | 229.2 | 209.3 | | 8.6 | 133.2 | 341.3 | 0.4 | 0.2 | 444.2 | 1,401.6 |
| 1962 | | | 15.5 | 49.6 | 14.3 | 344.0 | 495.1 | 3.7 | 28.9 | 237.8 | 433.0 | 2.1 | | 631.8 | 2,255.8 |
| 1963 | | | 21.5 | 37.2 | 23.5 | 316.0 | 373.3 | 9.7 | 18.9 | 286.9 | 368.5 | 51.7 | | 618.1 | 2,125.3 |
| 1964 | | | 18.9 | 41.0 | 27.4 | 306.2 | 245.5 | | 2.9 | 179.2 | 233.5 | 143.5 | | 545.1 | 1,743.2 |
| 1965 | | | 64.7 | 49.0 | 27.0 | 470.0 | 394.7 | 0.1 | 3.2 | 93.2 | 319.2 | 38.3 | | 387.7 | 1,847.1 |
| 1966 | | | 57.5 | 32.6 | 25.2 | 423.2 | 457.3 | 0.4 | 7.7 | 109.5 | 372.1 | 71.8 | 0.2 | 614.0 | 2,171.5 |
| 1967 | | | 31.9 | 36.1 | 28.2 | 249.5 | 227.8 | 0.1 | 7.9 | 54.5 | 402.7 | 21.6 | | 610.8 | 1,671.1 |
| 1968 | | | 39.5 | 36.9 | 28.2 | 261.3 | 346.9 | 0.2 | 63.9 | 109.4 | 395.7 | 10.8 | | 866.7 | 2,159.5 |
| 1969 | | | 68.2 | 56.1 | 37.8 | 507.8 | 308.6 | | 24.4 | 101.2 | 395.1 | 2.4 | | 943.6 | 2,445.2 |
| 1970 | | | 76.7 | 146.3 | 38.4 | 726.5 | 482.4 | | 31.4 | 292.7 | 224.9 | 3.8 | | 928.1 | 2,951.2 |
| 1971 | | 0.7 | 124.2 | 122.9 | 37.5 | 549.2 | 444.1 | | 64.1 | 277.0 | 262.1 | 5.9 | | 737.2 | 2,624.9 |
| 1972 | | | 168.9 | 141.9 | 22.4 | 455.0 | 368.1 | 0.3 | 26.5 | 551.6 | 529.6 | | | 850.8 | 3,115.1 |
| 1973 | 26.8 | | 252.1 | 126.0 | 43.7 | 640.2 | 402.6 | 1.2 | 124.8 | 1,317.8 | 910.9 | 1.4 | | 718.0 | 4,565.5 |
| 1974 | 13.4 | | 177.0 | 121.0 | 40.3 | 484.0 | 455.0 | 2.7 | 253.6 | 1,423.1 | 990.4 | 0.1 | | 577.3 | 4,537.9 |
| 1975 | 5.2 | | 249.3 | 173.0 | 6.7 | 403.3 | 581.1 | 6.8 | 125.5 | 1,490.2 | 896.0 | 1.0 | 0.2 | 463.2 | 4,401.5 |
| 1976 | 0.2 | | 204.1 | 109.7 | 10.5 | 272.1 | 580.6 | 5.3 | 232.7 | 1,890.1 | 614.9 | 0.4 | | 625.8 | 4,546.4 |
| 1977 | 0.1 | 0.1 | 228.5 | 111.0 | 5.6 | 447.1 | 634.1 | 14.6 | 237.6 | 1,437.5 | 1,057.5 | 4.6 | 0.3 | 622.9 | 4,801.5 |
| 1978 | 14.7 | 1.1 | 361.9 | 169.6 | 24.8 | 792.1 | 718.9 | 18.3 | 147.2 | 1,243.1 | 883.6 | 4.4 | 0.1 | 605.8 | 4,985.6 |
| 1979 | 30.5 | 0.2 | 257.0 | 146.6 | 23.1 | 731.0 | 720.8 | 22.9 | 144.7 | 1,389.9 | 1,544.8 | 5.9 | 0.1 | 675.4 | 5,692.9 |
| 1980 | 43.6 | 0.6 | 314.5 | 165.6 | 22.4 | 674.9 | 635.3 | 74.4 | 198.1 | 1,277.8 | 2,469.2 | 1.5 | | 978.9 | 6,856.8 |
| 1981 | 41.0 | 20.5 | 372.1 | 160.4 | 141.5 | 580.7 | 832.1 | 88.9 | 188.5 | 1,061.6 | 2,997.0 | 1.3 | 0.5 | 978.7 | 7,464.8 |
| 1982 | 74.8 | 30.3 | 406.1 | 270.5 | 136.1 | 781.4 | 898.5 | 231.8 | 131.1 | 1,176.2 | 1,945.9 | 2.8 | 0.3 | 910.8 | 6,996.6 |
| 1983 | 77.1 | 13.9 | 453.6 | 235.6 | 31.5 | 765.3 | 873.0 | 131.7 | 149.8 | 689.4 | 3,060.5 | 5.1 | 0.1 | 679.8 | 7,166.4 |
| 1984 | 22.0 | 8.0 | 318.3 | 462.3 | 45.3 | 742.1 | 767.3 | 71.3 | 83.9 | 525.2 | 1,614.5 | 0.6 | | 719.1 | 5,379.9 |
| 1985 | 41.0 | 10.3 | 362.2 | 767.8 | 82.4 | 967.6 | 902.0 | 85.3 | 231.0 | 749.8 | 1,633.9 | 0.2 | | 288.5 | 6,122.0 |
| 1986 | 46.9 | 27.7 | 708.6 | 518.4 | 86.2 | 733.6 | 1,362.3 | 181.5 | 207.0 | 686.4 | 1,561.9 | 1.3 | 0.8 | 528.6 | 6,651.2 |
| 1987 | 47.9 | 58.0 | 361.6 | 537.4 | 79.7 | 709.7 | 1,148.4 | 160.8 | 164.9 | 536.3 | 2,068.8 | 1.5 | 1.2 | 702.2 | 6,578.4 |
| 1988 | 4.0 | 10.4 | 365.7 | 464.4 | 46.3 | 510.4 | 1,126.5 | 94.9 | 467.8 | 1,186.4 | 2,285.6 | 1.6 | 0.3 | 597.1 | 7,161.4 |
| 1989 | 34.4 | 62.2 | 562.3 | 549.7 | 88.0 | 256.2 | 717.8 | 47.3 | 125.1 | 349.5 | 1,492.8 | 1.2 | | 453.4 | 4,739.9 |
| 1990 | 24.5 | 89.4 | 546.1 | 537.4 | 81.2 | 731.2 | 984.8 | 65.3 | 129.4 | 495.0 | 2,075.9 | 0.5 | | 488.9 | 6,249.6 |
| 1991 | 56.7 | 57.7 | 343.0 | 676.1 | 116.8 | 716.0 | 1,110.2 | 153.1 | 105.8 | 373.5 | 1,777.9 | 0.6 | | 672.5 | 6,159.9 |
| 1992 | 39.2 | 103.5 | 376.3 | 703.1 | 121.9 | 677.1 | 997.0 | 42.0 | 93.6 | 269.1 | 1,287.8 | 0.3 | 0.1 | 494.2 | 5,205.2 |
| 1993 | 8.3 | 73.7 | 288.5 | 542.0 | 61.0 | 702.6 | 994.0 | 13.4 | 60.5 | 294.7 | 1,226.4 | 0.1 | | 543.1 | 4,808.3 |
| 1994 | 24.5 | 124.8 | 543.2 | 409.0 | 68.9 | 667.6 | 858.2 | 15.6 | 74.7 | 284.7 | 808.5 | 0.8 | | 423.4 | 4,303.9 |
| 1995 | 8.8 | 84.8 | 252.9 | 350.2 | 53.2 | 590.3 | 384.5 | 16.6 | 48.8 | 243.7 | 1,365.4 | | | 228.6 | 3,627.8 |
| 1996 | 5.5 | 72.5 | 409.2 | 291.1 | 45.9 | 719.8 | 731.0 | | | 279.4 | 1,496.3 | 0.9 | | 60.9 | 4,112.5 |
| 1997 | 1.2 | 28.3 | 197.0 | 270.6 | 32.7 | 682.5 | 559.3 | 13.3 | | 335.5 | 1,815.3 | | | 128.6 | 4,064.3 |
| 1998 | | 7.5 | 164.9 | 258.8 | 25.5 | 716.0 | 627.4 | 12.5 | 84.1 | 360.5 | 1,326.8 | | | 154.5 | 3,738.5 |
| 1999 | - | 5.5 | 186.4 | 272.3 | 24.1 | 644.7 | 490.0 | 8.9 | 65.9 | 223.1 | 1,252.4 | | 0.2 | 156.3 | 3,329.8 |
| 2000 | 0.1 | 10.9 | 128.1 | 157.6 | 15.2 | 843.9 | 608.5 | 13.2 | 38.2 | 241.7 | 1,525.3 | | | 64.2 | 3,646.9 |
| 2001 | | 5.3 | 158.1 | 219.3 | 20.8 | 624.3 | 583.6 | 8.5 | 59.2 | 358.8 | 1,844.3 | 0.2 | | 62.7 | 3,945.1 |
| 2002 | 0.4 | 2.4 | 184.5 | 254.6 | 24.6 | 669.1 | 601.0 | 20.8 | 51.5 | 215.6 | 1,054.2 | | | 37.1 | 3,115.8 |
| 2003 | 0.3 | 3.9 | 150.2 | 189.6 | 20.3 | 707.6 | 459.2 | 13.9 | 24.0 | 171.5 | 1,574.0 | 0.1 | | 44.8 | 3,359.4 |
| 2004 | | | | | | | | | | | | | | | |

Table 3. Bluefish Atlantic coast recreational landings and discards in numbers (000s), by state.

**Landings**

| | ME | NH | MA | RI | CT | NY | NJ | DE | MD | VA | NC | SC | GA | FL (east) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1982** | 9 | 1 | 667 | 2,869 | 5,451 | 3,128 | 2,936 | 235 | 2,166 | 1,078 | 2,927 | 476 | 37 | 1,744 | 23,724 |
| **1983** | 39 | 5 | 1,451 | 3,741 | 1,208 | 5,426 | 3,953 | 341 | 2,124 | 577 | 4,311 | 148 | 100 | 1,459 | 24,884 |
| **1984** | 0 | 6 | 795 | 746 | 3,272 | 5,822 | 2,941 | 203 | 1,737 | 455 | 2,197 | 279 | 180 | 2,166 | 20,798 |
| **1985** | 46 | - | 431 | 1,478 | 3,135 | 3,760 | 2,683 | 120 | 3,642 | 650 | 1,754 | 431 | 20 | 1,096 | 19,246 |
| **1986** | 149 | 66 | 2,244 | 1,874 | 2,515 | 6,914 | 4,808 | 161 | 2,064 | 850 | 1,679 | 157 | 19 | 940 | 24,441 |
| **1987** | 289 | 74 | 1,420 | 825 | 2,535 | 5,386 | 4,727 | 100 | 2,241 | 565 | 1,738 | 164 | 44 | 967 | 21,076 |
| **1988** | 63 | 32 | 693 | 440 | 664 | 1,454 | 1,754 | 255 | 1,229 | 437 | 1,822 | 87 | 8 | 968 | 9,905 |
| **1989** | 38 | 23 | 412 | 487 | 1,468 | 3,984 | 2,889 | 324 | 711 | 707 | 1,605 | 226 | 16 | 711 | 13,600 |
| **1990** | 47 | 27 | 416 | 447 | 1,034 | 2,738 | 2,177 | 242 | 707 | 743 | 2,229 | 76 | 43 | 439 | 11,365 |
| **1991** | 115 | 41 | 840 | 441 | 1,729 | 3,471 | 2,012 | 147 | 953 | 666 | 821 | 39 | 24 | 643 | 11,943 |
| **1992** | 95 | 24 | 345 | 250 | 1,185 | 1,196 | 1,908 | 189 | 367 | 163 | 682 | 33 | 8 | 715 | 7,158 |
| **1993** | 29 | 28 | 511 | 188 | 825 | 1,440 | 656 | 138 | 217 | 66 | 723 | 81 | 5 | 818 | 5,725 |
| **1994** | 66 | 18 | 434 | 297 | 512 | 1,605 | 941 | 120 | 473 | 231 | 452 | 118 | 4 | 497 | 5,768 |
| **1995** | 9 | 12 | 405 | 126 | 608 | 1,042 | 1,243 | 183 | 285 | 213 | 387 | 154 | 15 | 487 | 5,168 |
| **1996** | 10 | 3 | 285 | 361 | 624 | 545 | 957 | 136 | 346 | 324 | 299 | 55 | 4 | 256 | 4,205 |
| **1997** | 13 | 25 | 316 | 412 | 519 | 816 | 942 | 159 | 433 | 447 | 742 | 89 | 5 | 494 | 5,413 |
| **1998** | 2 | 3 | 237 | 194 | 387 | 768 | 817 | 150 | 284 | 223 | 527 | 171 | 22 | 418 | 4,202 |
| **1999** | 8 | 4 | 197 | 330 | 440 | 710 | 809 | 84 | 167 | 134 | 518 | 34 | 12 | 235 | 3,682 |
| **2000** | - | 1 | 221 | 280 | 390 | 718 | 1,236 | 132 | 344 | 150 | 878 | 88 | 20 | 439 | 4,897 |
| **2001** | 15 | 8 | 357 | 365 | 716 | 1,005 | 1,431 | 102 | 429 | 261 | 1,266 | 118 | 10 | 581 | 6,663 |
| **2002** | 24 | 19 | 229 | 325 | 569 | 751 | 1,321 | 117 | 199 | 131 | 777 | 79 | 2 | 759 | 5,300 |
| **2003** | 14 | 8 | 374 | 334 | 458 | 1,147 | 1,571 | 89 | 214 | 172 | 953 | 66 | 1 | 644 | 6,045 |
| **2004** | 18 | 22 | 426 | 273 | 552 | 1,442 | 1,818 | 133 | 318 | 256 | 1,057 | 119 | 1 | 504 | 6,939 |

**Discards**

| | ME | NH | MA | RI | CT | NY | NJ | DE | MD | VA | NC | SC | GA | FL (east) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1982** | 3 | - | 59 | 152 | 886 | 197 | 346 | 47 | 690 | 452 | 301 | 107 | 53 | 204 | 3,497 |
| **1983** | 2 | 1 | 636 | 42 | 64 | 1,743 | 784 | 36 | 711 | 170 | 765 | 17 | 67 | 214 | 5,254 |
| **1984** | - | - | 354 | 55 | 257 | 2,570 | 709 | 89 | 512 | 138 | 242 | 77 | 37 | 671 | 5,710 |
| **1985** | 8 | 1 | 160 | 123 | 327 | 955 | 537 | 34 | 257 | 118 | 333 | 182 | 38 | 155 | 3,228 |
| **1986** | 25 | 23 | 1,318 | 71 | 155 | 1,852 | 1,162 | 44 | 287 | 315 | 449 | 48 | 29 | 192 | 5,970 |
| **1987** | 191 | 8 | 639 | 268 | 291 | 1,879 | 1,697 | 64 | 478 | 181 | 545 | 47 | 33 | 206 | 6,527 |
| **1988** | 23 | 2 | 298 | 70 | 27 | 735 | 437 | 35 | 266 | 715 | 550 | 64 | 7 | 229 | 3,460 |
| **1989** | 5 | 17 | 266 | 86 | 131 | 1,474 | 1,084 | 191 | 446 | 294 | 750 | 145 | 22 | 127 | 5,037 |
| **1990** | 36 | 6 | 308 | 317 | 228 | 1,262 | 1,062 | 104 | 388 | 280 | 728 | 66 | 132 | 165 | 5,081 |
| **1991** | 327 | 24 | 579 | 195 | 552 | 1,367 | 1,545 | 59 | 369 | 451 | 551 | 17 | 66 | 246 | 6,349 |
| **1992** | 67 | 13 | 451 | 235 | 415 | 784 | 536 | 122 | 99 | 278 | 796 | 16 | 44 | 388 | 4,242 |
| **1993** | 18 | 22 | 390 | 153 | 261 | 975 | 561 | 105 | 194 | 163 | 784 | 56 | 22 | 495 | 4,200 |
| **1994** | 52 | 8 | 350 | 201 | 282 | 1,171 | 894 | 46 | 246 | 462 | 1,481 | 140 | 20 | 799 | 6,152 |
| **1995** | 5 | 7 | 585 | 70 | 171 | 719 | 637 | 127 | 273 | 417 | 1,201 | 221 | 85 | 808 | 5,326 |
| **1996** | 57 | 3 | 467 | 439 | 367 | 661 | 959 | 83 | 465 | 420 | 736 | 86 | 26 | 547 | 5,316 |
| **1997** | 83 | 3 | 644 | 320 | 293 | 898 | 849 | 193 | 891 | 662 | 1,149 | 197 | 20 | 956 | 7,161 |
| **1998** | - | 1 | 510 | 203 | 405 | 589 | 702 | 275 | 492 | 405 | 534 | 200 | 71 | 615 | 5,002 |
| **1999** | 20 | 5 | 397 | 784 | 744 | 1,156 | 1,824 | 323 | 605 | 228 | 986 | 59 | 14 | 661 | 7,806 |
| **2000** | 4 | 1 | 596 | 497 | 863 | 2,629 | 1,907 | 303 | 1,150 | 321 | 1,630 | 182 | 79 | 1,201 | 11,363 |
| **2001** | 40 | 14 | 948 | 893 | 1,429 | 2,543 | 2,056 | 221 | 1,074 | 625 | 2,329 | 152 | 48 | 1,376 | 13,749 |
| **2002** | 42 | 14 | 628 | 801 | 662 | 1,017 | 2,168 | 435 | 577 | 382 | 1,610 | 163 | 26 | 1,392 | 9,917 |
| **2003** | 23 | 17 | 1,019 | 932 | 542 | 1,305 | 1,913 | 120 | 518 | 340 | 1,416 | 215 | 23 | 622 | 9,004 |
| **2004** | 39 | 10 | 1,490 | 749 | 1,015 | 1,848 | 2,333 | 319 | 669 | 510 | 1,930 | 352 | 17 | 457 | 11,740 |

Table 4. Number of bluefish sampled from commercial fisheries, 1997-2004

**Maine to Maryland**

| Year | | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | sum |
|---|---|---|---|---|---|---|
| **1997** | small | | | 200 | 106 | |
| | med | 100 | 83 | 69 | 156 | |
| | large | | 200 | 104 | 59 | |
| | unclassified | | 59 | 37 | 77 | 1,250 |
| **1998** | small | | | 545 | | |
| | med | | 115 | | 213 | |
| | large | | 100 | 295 | | |
| | unclassified | | | 202 | 36 | 1,506 |
| **1999** | small | | 133 | 205 | | |
| | med | | | 62 | | |
| | large | | 446 | 58 | | |
| | unclassified | | 741 | | 106 | 1,751 |
| **2000** | small | | | 202 | | |
| | med | 100 | | | | |
| | large | 101 | 292 | 115 | | |
| | unclassified | 14 | 207 | 144 | 53 | 1,228 |
| **2001** | small | | | 190 | | |
| | med | | 100 | | 86 | |
| | large | | | 102 | 200 | |
| | unclassified | | 183 | 325 | 71 | 1,257 |
| **2002** | small | 29 | | 173 | 205 | |
| | med | | 130 | 200 | | |
| | large | | 162 | | | |
| | unclassified | | 82 | 199 | 29 | 1,209 |
| **2003** | small | | | | | |
| | med | | 296 | | 111 | |
| | large | | 308 | 259 | 20 | |
| | unclassified | | 235 | 201 | | 1,430 |
| **2004** | small | | | 82 | 99 | |
| | med | | | | 212 | |
| | large | | 410 | 338 | 220 | |
| | unclassified | | 796 | 1,310 | 1,031 | 4,498 |

**Virginia**

| Year | | Jan-Jun | Jul-Dec | sum |
|---|---|---|---|---|
| **1997** | small | 39 | 214 | |
| | med | 851 | 1,562 | |
| | large | 39 | 45 | |
| | unclassified | 739 | 736 | 4,225 |
| **1998** | small | 644 | 444 | |
| | med | 543 | 674 | |
| | large | 80 | 141 | |
| | unclassified | 443 | 642 | 3,611 |
| **1999** | small | 225 | 263 | |
| | med | 523 | 741 | |
| | large | 469 | 513 | |
| | unclassified | 78 | 267 | 3,079 |
| **2000** | small | 228 | 487 | |
| | med | 1,609 | 1,775 | |
| | large | 107 | 107 | |
| | unclassified | 188 | 390 | 4,891 |
| **2001** | small | 621 | 340 | |
| | med | 483 | 401 | |
| | large | 304 | 304 | |
| | unclassified | 465 | 337 | 3,255 |
| **2002** | small | 638 | 599 | |
| | med | 585 | 1,854 | |
| | large | 571 | 511 | |
| | unclassified | 363 | 533 | 5,654 |
| **2003** | small | 238 | 535 | |
| | med | 704 | 798 | |
| | large | 517 | 636 | |
| | unclassified | 485 | 226 | 4,139 |
| **2004** | small | 874 | 728 | |
| | med | 318 | 366 | |
| | large | 100 | 106 | |
| | unclassified | 42 | 330 | 2,864 |

**North Carolina**

| Year | | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | sum |
|---|---|---|---|---|---|---|
| **1997** | small | | 585 | 322 | 103 | |
| | med | 195 | 382 | 296 | 428 | |
| | large | 225 | 16 | 1 | 183 | |
| | unclassified | 163 | 543 | 337 | 134 | 3,913 |
| **1998** | small | 21 | 120 | 193 | - | |
| | med | 189 | 1,383 | 491 | 193 | |
| | large | 459 | 108 | - | 220 | |
| | unclassified | 142 | 121 | 215 | 138 | 3,993 |
| **1999** | small | 3 | 46 | 34 | 71 | |
| | med | 1,311 | 1,893 | 434 | 56 | |
| | large | 1,605 | 116 | 43 | 262 | |
| | unclassified | 14 | 351 | 88 | 61 | 6,388 |
| **2000** | small | 137 | 180 | 45 | 45 | |
| | med | 190 | 1,013 | 1,196 | 837 | |
| | large | 1,784 | 817 | | 289 | |
| | unclassified | 419 | 547 | 253 | 339 | 8,091 |
| **2001** | small | 517 | 390 | 222 | 71 | |
| | med | 1,995 | 2,277 | 602 | 105 | |
| | large | 2,133 | 859 | 2 | 258 | |
| | unclassified | 64 | 1,038 | 401 | 150 | 11,084 |
| **2002** | small | 138 | 252 | 72 | 200 | |
| | med | 1,282 | 397 | 808 | 472 | |
| | large | 1,245 | 697 | 78 | 507 | |
| | unclassified | 798 | 423 | 397 | 174 | 7,940 |
| **2003** | small | 308 | 210 | 35 | 2 | |
| | med | 535 | 1,117 | 626 | 256 | |
| | large | 2,050 | 982 | | 352 | |
| | unclassified | 74 | 706 | 296 | 112 | 7,661 |
| **2004** | small | 180 | 266 | 20 | 72 | |
| | med | 1,600 | 589 | 526 | 953 | |
| | large | 1,704 | 1,337 | 34 | 813 | |
| | unclassified | 135 | 542 | 500 | 221 | 9,492 |

**NC Bait Fishery**

| | Jan-Jun | Jul-Dec | sum |
|---|---|---|---|
| **1997** | 91 | 203 | 294 |
| **1998** | 298 | 189 | 487 |
| **1999** | 49 | 422 | 471 |
| **2000** | 64 | 132 | 196 |
| **2001** | 369 | 221 | 590 |
| **2002** | 36 | 272 | 308 |
| **2003** | 84 | 114 | 198 |
| **2004** | 40 | 74 | 114 |

Table 5. Commercial Landings (lbs) 1997-2004 by period and market category.

**Maine to Maryland**

| Year | Category | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec |
|---|---|---|---|---|---|
| **1997** | small | 3,695 | 14,141 | 154,541 | 110,241 |
| | med | 11,518 | 118,090 | 277,440 | 219,531 |
| | large | 2,698 | 209,369 | 133,583 | 152,033 |
| | unclassified | 16,640 | 464,768 | 1,376,305 | 767,592 |
| **1998** | small | 3,079 | 57,835 | 281,823 | 142,208 |
| | med | 1,440 | 146,177 | 191,597 | 286,039 |
| | large | 713 | 149,937 | 199,127 | 195,526 |
| | unclassified | 7,035 | 517,516 | 1,152,656 | 849,453 |
| **1999** | small | 1,018 | 46,824 | 133,366 | 87,347 |
| | med | 2,993 | 143,095 | 115,502 | 167,659 |
| | large | 7,574 | 213,049 | 113,921 | 338,687 |
| | unclassified | 12,437 | 536,672 | 1,213,209 | 609,587 |
| **2000** | small | 2,507 | 19,981 | 181,189 | 115,596 |
| | med | 9,474 | 99,906 | 112,652 | 196,955 |
| | large | 8,403 | 323,479 | 454,581 | 265,733 |
| | unclassified | 3,379 | 601,200 | 1,114,944 | 492,573 |
| **2001** | small | 322 | 9,289 | 93,506 | 104,163 |
| | med | 2,476 | 274,137 | 159,410 | 139,296 |
| | large | 6,826 | 456,436 | 199,838 | 232,986 |
| | unclassified | 1,681 | 578,576 | 1,017,276 | 425,346 |
| **2002** | small | 6,747 | 24,477 | 217,447 | 177,921 |
| | med | 12,658 | 447,093 | 133,368 | 130,594 |
| | large | 25,784 | 452,286 | 116,171 | 163,468 |
| | unclassified | 19,756 | 547,697 | 1,035,984 | 476,146 |
| **2003** | small | 1,191 | 15,807 | 48,405 | 39,659 |
| | med | 6,349 | 200,954 | 185,263 | 267,065 |
| | large | 177 | 232,656 | 241,607 | 220,684 |
| | unclassified | 3,216 | 518,530 | 902,272 | 575,081 |
| **2004** | small | 8,580 | 16,895 | 88,661 | 52,718 |
| | med | 618 | 307,278 | 320,655 | 264,529 |
| | large | 4,666 | 394,904 | 433,748 | 283,542 |
| | unclassified | 126 | 258,965 | 671,507 | 553,357 |

**Virginia**

| Year | Category | Jan-Jun | Jul-Dec |
|---|---|---|---|
| 1997 | small | 1,928 | 11,916 |
| | med | 9,235 | 62,468 |
| | large | 4,493 | 44,091 |
| | unclassified | 68,434 | 447,676 |
| 1998 | small | 1,545 | 11,148 |
| | med | 34,911 | 55,139 |
| | large | 8,675 | 62,996 |
| | unclassified | 109,317 | 334,446 |
| 1999 | small | 3,068 | 7,932 |
| | med | 26,456 | 19,497 |
| | large | 4,761 | 7,932 |
| | unclassified | 65,618 | 247,130 |
| 2000 | small | 3,869 | 5,493 |
| | med | 12,893 | 53,210 |
| | large | 14,182 | 9,162 |
| | unclassified | 59,171 | 322,492 |
| 2001 | small | 2,599 | 7,183 |
| | med | 35,435 | 48,310 |
| | large | 2,190 | 31,436 |
| | unclassified | 174,923 | 446,704 |
| 2002 | small | 135 | 5,800 |
| | med | 10,305 | 47,245 |
| | large | 5,320 | 2,906 |
| | unclassified | 69,092 | 289,733 |
| 2003 | small | 29 | 3,319 |
| | med | 29,428 | 24,866 |
| | large | 1,236 | 8,424 |
| | unclassified | 94,715 | 182,781 |
| 2004 | small | 80 | 4,187 |
| | med | 4,815 | 49,144 |
| | large | 4,987 | 60,210 |
| | unclassified | 32,955 | 254,445 |

**North Carolina**

| Year | Category | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec |
|---|---|---|---|---|---|
| **1997** | small | 20,107 | 57,263 | 28,700 | 50,354 |
| | med | 178,225 | 286,149 | 160,727 | 276,594 |
| | large | 1,636,777 | 130,059 | 15,541 | 1,164,687 |
| | unclassified | 257 | 1,957 | 2,601 | 17,077 |
| **1998** | small | 16,083 | 55,566 | 9,003 | 34,478 |
| | med | 265,073 | 529,851 | 80,201 | 207,573 |
| | large | 1,266,661 | 155,667 | 7,366 | 251,657 |
| | unclassified | 32,002 | 17,689 | 3,007 | 2,925 |
| **1999** | small | 6,551 | 30,150 | 6,609 | 10,385 |
| | med | 539,873 | 323,615 | 55,077 | 24,994 |
| | large | 1,383,285 | 266,671 | 2,936 | 61,108 |
| | unclassified | 1,761 | 40,245 | 1,092 | 552 |
| **2000** | small | 6,647 | 32,420 | 19,420 | 16,800 |
| | med | 33,911 | 164,172 | 145,319 | 329,330 |
| | large | 1,876,457 | 603,066 | 6,059 | 103,046 |
| | unclassified | 493 | 7,526 | 2,761 | 12,168 |
| **2001** | small | 16,829 | 34,968 | 18,824 | 20,654 |
| | med | 694,722 | 340,709 | 100,452 | 47,896 |
| | large | 1,829,400 | 460,128 | 4,519 | 427,291 |
| | unclassified | 10,402 | 42,816 | 7,784 | 2,337 |
| **2002** | small | 9,657 | 20,067 | 10,774 | 19,228 |
| | med | 249,253 | 95,284 | 78,592 | 108,066 |
| | large | 1,103,802 | 141,567 | 24,547 | 426,096 |
| | unclassified | 1,623 | 16,436 | 6,591 | 4,326 |
| **2003** | small | 25,251 | 29,979 | 4,228 | 4,155 |
| | med | 448,955 | 388,941 | 106,044 | 78,913 |
| | large | 1,258,917 | 422,787 | 2,245 | 585,668 |
| | unclassified | 4,635 | 45,378 | 11,171 | 13,786 |
| **2004** | small | 4,466 | 20,881 | 10,771 | 10,830 |
| | med | 391,836 | 308,364 | 103,616 | 202,771 |
| | large | 1,477,056 | 418,753 | 11,567 | 723,008 |
| | unclassified | 31,016 | 8,897 | 4,117 | 17,874 |

**NC Bait Fishery-(Estimated Landings)**

| | Jan-Jun | Jul-Dec |
|---|---|---|
| 1997 | 10,966 | 36,006 |
| 1998 | 8,038 | 21,881 |
| 1999 | 51,720 | 22,348 |
| 2000 | 16,909 | 12,621 |
| 2001 | 47,337 | 10,827 |
| 2002 | 1,488 | 11,876 |
| 2003 | 8,316 | 14,279 |
| 2004 | 15,935 | 10,185 |

Table 6. Relative Commercial Sampling (fish measured per 100 lbs landed) 1997-2004

| Year | Size | Maine to Maryland Jan-Mar | Maine to Maryland Apr-Jun | Maine to Maryland Jul-Sep | Maine to Maryland Oct-Dec | Virginia Jan-Jun | Virginia Jul-Dec | North Carolina Jan-Mar | North Carolina Apr-Jun | North Carolina Jul-Sep | North Carolina Oct-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | small | - | - | 0.13 | 0.10 | 2.02 | 1.80 | - | 1.02 | 1.12 | 0.20 |
| | med | 0.87 | 0.07 | 0.02 | 0.07 | 9.21 | 2.50 | 0.11 | 0.13 | 0.18 | 0.15 |
| | large | - | 0.10 | 0.08 | 0.04 | 0.87 | 0.10 | 0.01 | 0.01 | 0.01 | 0.02 |
| | unclassified | - | 0.01 | 0.00 | 0.01 | 1.08 | 0.16 | 63.42 | 27.75 | 12.96 | 0.78 |
| 1998 | small | - | - | 0.19 | - | 41.68 | 3.98 | 0.13 | 0.22 | 2.14 | - |
| | med | - | 0.08 | - | 0.07 | 1.56 | 1.22 | 0.07 | 0.26 | 0.61 | 0.09 |
| | large | - | 0.07 | 0.15 | - | 0.92 | 0.22 | 0.04 | 0.07 | - | 0.09 |
| | unclassified | - | - | 0.02 | 0.00 | 0.41 | 0.19 | 0.44 | 0.68 | 7.15 | 4.72 |
| 1999 | small | - | 0.28 | 0.15 | - | 7.33 | 3.32 | 0.05 | 0.15 | 0.51 | 0.68 |
| | med | - | - | 0.05 | - | 1.98 | 3.80 | 0.24 | 0.58 | 0.79 | 0.22 |
| | large | - | 0.21 | 0.05 | - | 9.85 | 6.47 | 0.12 | 0.04 | 1.46 | 0.43 |
| | unclassified | - | 0.14 | - | 0.02 | 0.12 | 0.11 | 0.80 | 0.87 | 8.06 | 11.05 |
| 2000 | small | - | - | 0.11 | - | 5.89 | 8.87 | 2.06 | 0.56 | 0.23 | 0.27 |
| | med | 1.06 | - | - | - | 12.48 | 3.34 | 0.56 | 0.62 | 0.82 | 0.25 |
| | large | 1.20 | 0.09 | 0.03 | - | 0.75 | 1.17 | 0.10 | 0.14 | - | 0.28 |
| | unclassified | 0.41 | 0.03 | 0.01 | 0.01 | 0.32 | 0.12 | 84.99 | 7.27 | 9.16 | 2.79 |
| 2001 | small | - | - | 0.20 | - | 23.89 | 4.73 | 3.07 | 1.12 | 1.18 | 0.34 |
| | med | - | 0.04 | - | 0.06 | 1.36 | 0.83 | 0.29 | 0.67 | 0.60 | 0.22 |
| | large | - | - | 0.05 | 0.09 | 13.88 | 0.97 | 0.12 | 0.19 | 0.04 | 0.06 |
| | unclassified | - | 0.03 | 0.03 | 0.02 | 0.27 | 0.08 | 0.62 | 2.42 | 5.15 | 6.42 |
| 2002 | small | 0.43 | - | 0.08 | 0.12 | 472.59 | 10.33 | 1.43 | 1.26 | 0.67 | 1.04 |
| | med | - | 0.03 | 0.15 | - | 5.68 | 3.92 | 0.51 | 0.42 | 1.03 | 0.44 |
| | large | - | 0.04 | - | - | 10.73 | 17.58 | 0.11 | 0.49 | 0.32 | 0.12 |
| | unclassified | - | 0.01 | 0.02 | 0.01 | 0.53 | 0.18 | 49.17 | 2.57 | 6.02 | 4.02 |
| 2003 | small | - | - | - | - | 820.69 | 16.12 | 1.22 | 0.70 | 0.83 | 0.05 |
| | med | - | 0.15 | - | 0.04 | 2.39 | 3.21 | 0.12 | 0.29 | 0.59 | 0.32 |
| | large | - | 0.13 | 0.11 | 0.01 | 41.83 | 7.55 | 0.16 | 0.23 | - | 0.06 |
| | unclassified | - | 0.05 | 0.02 | - | 0.51 | 0.12 | 1.60 | 1.56 | 2.65 | 0.81 |
| 2004 | small | - | - | 0.09 | 0.19 | 1,092.08 | 17.39 | 4.03 | 1.27 | 0.19 | 0.66 |
| | med | - | - | - | 0.08 | 6.60 | 0.74 | 0.41 | 0.19 | 0.51 | 0.47 |
| | large | - | 0.10 | 0.08 | 0.08 | 2.01 | 0.18 | 0.12 | 0.32 | 0.29 | 0.11 |
| | unclassified | - | 0.31 | 0.20 | 0.19 | 0.13 | 0.13 | 0.44 | 6.09 | 12.14 | 1.24 |

**NC Bait Fishery**

| | Jan-Jun | Jul-Dec |
|---|---|---|
| 1997 | 0.83 | 0.56 |
| 1998 | 3.71 | 0.86 |
| 1999 | 0.09 | 1.89 |
| 2000 | 0.38 | 1.05 |
| 2001 | 0.78 | 2.04 |
| 2002 | 2.42 | 2.29 |
| 2003 | 1.01 | 0.80 |
| 2004 | 0.25 | 0.73 |

Table 7. Sampling intensity of bluefish length collected from the recreational fishery, by wave, Maine to Florida (east coast).

Samples collected (# fish measured)

| wave | Year 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| Jan-Feb | 16 | 12 | 68 | 38 | 64 | 49 | 81 | 22 |
| Mar-Apr | 115 | 292 | 283 | 201 | 261 | 127 | 188 | 94 |
| May-Jun | 680 | 911 | 636 | 577 | 1,100 | 579 | 1,183 | 910 |
| Jul-Aug | 1,575 | 937 | 571 | 563 | 1,255 | 863 | 910 | 1,577 |
| Sep-Oct | 1,363 | 915 | 702 | 825 | 1,366 | 1,306 | 820 | 1,632 |
| Nov-Dec | 643 | 286 | 223 | 167 | 278 | 352 | 309 | 319 |
| total | 4,392 | 3,353 | 2,483 | 2,371 | 4,324 | 3,276 | 3,491 | 4,554 |

Landings (00s lbs)

| wave | Year 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| Jan-Feb | 1,163 | 1,638 | 714 | 1,430 | 2,325 | 1,451 | 1,564 | 2,014 |
| Mar-Apr | 1,968 | 4,102 | 3,719 | 1,754 | 4,712 | 2,237 | 2,935 | 4,610 |
| May-Jun | 22,781 | 28,133 | 19,622 | 22,152 | 30,387 | 20,644 | 43,281 | 31,685 |
| Jul-Aug | 44,753 | 50,075 | 15,134 | 37,119 | 46,930 | 20,909 | 32,042 | 46,060 |
| Sep-Oct | 47,640 | 30,267 | 39,774 | 38,538 | 38,885 | 49,632 | 41,629 | 55,144 |
| Nov-Dec | 24,713 | 9,125 | 3,568 | 5,065 | 9,059 | 18,842 | 9,908 | 11,942 |
| total | 143,018 | 123,340 | 82,531 | 106,058 | 132,298 | 113,715 | 131,359 | 151,455 |

Samples per 00 lbs landed

| wave | Year 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|
| Jan-Feb | 0.014 | 0.007 | 0.095 | 0.027 | 0.028 | 0.034 | 0.052 | 0.011 |
| Mar-Apr | 0.058 | 0.071 | 0.076 | 0.115 | 0.055 | 0.057 | 0.064 | 0.020 |
| May-Jun | 0.030 | 0.032 | 0.032 | 0.026 | 0.036 | 0.028 | 0.027 | 0.029 |
| Jul-Aug | 0.035 | 0.019 | 0.038 | 0.015 | 0.027 | 0.041 | 0.028 | 0.034 |
| Sep-Oct | 0.029 | 0.030 | 0.018 | 0.021 | 0.035 | 0.026 | 0.020 | 0.030 |
| Nov-Dec | 0.026 | 0.031 | 0.063 | 0.033 | 0.031 | 0.019 | 0.031 | 0.027 |
| total | 0.031 | 0.027 | 0.030 | 0.022 | 0.033 | 0.029 | 0.027 | 0.030 |

Table 8. Age sample sizes used in development of age length keys.
Spring 1998-2004 VA only. 1997 NC. Autumn 1999-2000 includes VA and NC data.

| Spring | 0 | 1 | 2 | 3 | 4 | 5 | 6+ | total |
|---|---|---|---|---|---|---|---|---|
| 1997 | - | 101 | 76 | 19 | 9 | 7 | 16 | 228 |
| 1998 | - | | | | | | | 0 |
| 1999 | - | | | | | | | 0 |
| 2000 | - | | | | | | | 0 |
| 2001 | - | 12 | 32 | 2 | 2 | 3 | 11 | 62 |
| 2002 | - | 103 | 85 | 6 | 8 | 42 | 38 | 282 |
| 2003 | - | | 147 | 4 | 13 | 17 | 45 | 226 |
| 2004 | - | 82 | 131 | 23 | 3 | | 2 | 241 |

| Autumn | 0 | 1 | 2 | 3 | 4 | 5 | 6+ | |
|---|---|---|---|---|---|---|---|---|
| 1997 | 65 | 128 | 14 | 1 | | | 9 | 217 |
| 1998 | | | | | | | | 0 |
| 1999 | 85 | 134 | 59 | 7 | 1 | 2 | 49 | 337 |
| 2000 | 21 | 108 | 10 | | | | 1 | 140 |
| 2001 | | 116 | 109 | | 2 | 5 | 40 | 272 |
| 2002 | 7 | 319 | 56 | 5 | 1 | 2 | 5 | 395 |
| 2003 | 34 | 51 | 12 | | 6 | 41 | 70 | 214 |
| 2004 | | 132 | 28 | 6 | | | | 166 |

Table 9. Total Atlantic coast bluefish catch at age (000s). CAA for 1982 to 1996 adjusted from SAW 23 to reflect updated landings estimates.

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6+ |
| 1982 | 11,158 | 9,746 | 2,848 | 2,435 | 797 | 1,217 | 3,746 |
| 1983 | 4,783 | 7,661 | 8,675 | 3,024 | 972 | 1,326 | 4,787 |
| 1984 | 7,140 | 6,799 | 6,686 | 2,046 | 898 | 745 | 3,190 |
| 1985 | 4,680 | 6,462 | 5,776 | 2,928 | 1,325 | 520 | 2,378 |
| 1986 | 5,172 | 8,045 | 8,719 | 2,813 | 1,060 | 1,705 | 4,479 |
| 1987 | 3,122 | 5,419 | 5,180 | 5,750 | 2,008 | 1,085 | 3,959 |
| 1988 | 1,708 | 2,081 | 2,517 | 1,591 | 1,985 | 1,599 | 2,748 |
| 1989 | 3,468 | 5,671 | 3,227 | 990 | 398 | 1,173 | 2,407 |
| 1990 | 2,721 | 7,198 | 1,851 | 691 | 382 | 428 | 2,461 |
| 1991 | 3,710 | 5,292 | 7,332 | 1,619 | 315 | 225 | 2,149 |
| 1992 | 2,118 | 9,527 | 1,739 | 2,407 | 596 | 478 | 993 |
| 1993 | 1,196 | 2,073 | 1,575 | 592 | 1,036 | 665 | 1,187 |
| 1994 | 1,971 | 3,144 | 1,313 | 368 | 297 | 850 | 1,073 |
| 1995 | 1,904 | 3,257 | 733 | 130 | 203 | 686 | 1,122 |
| 1996 | 1,713 | 2,151 | 632 | 204 | 209 | 538 | 1,398 |
| 1997 | 1,634 | 4,299 | 1,496 | 511 | 197 | 93 | 1,212 |
| 1998 | 683 | 2,754 | 2,786 | 861 | 261 | 308 | 459 |
| 1999 | 1,638 | 1,946 | 2,097 | 573 | 175 | 353 | 483 |
| 2000 | 667 | 4,396 | 2,693 | 718 | 97 | 536 | 156 |
| 2001 | 1,414 | 4,467 | 3,466 | 1,152 | 198 | 608 | 243 |
| 2002 | 587 | 5,146 | 1,662 | 543 | 340 | 237 | 416 |
| 2003 | 819 | 2,646 | 3,974 | 774 | 378 | 320 | 644 |
| 2004 | 421 | 5,149 | 2,222 | 1,226 | 425 | 461 | 644 |

Table 10. Total Atlantic coast bluefish weight at age (kg).
1996 estimates set equal to 1995

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6+** |
| **1982** | 0.14 | 0.49 | 1.52 | 2.05 | 3.20 | 4.23 | 6.57 |
| **1983** | 0.10 | 0.42 | 0.99 | 2.15 | 3.16 | 4.42 | 6.72 |
| **1984** | 0.10 | 0.41 | 0.93 | 1.83 | 2.91 | 4.48 | 7.19 |
| **1985** | 0.10 | 0.40 | 0.97 | 1.93 | 2.82 | 3.99 | 6.42 |
| **1986** | 0.12 | 0.49 | 1.20 | 2.32 | 3.15 | 4.30 | 6.28 |
| **1987** | 0.12 | 0.30 | 1.18 | 2.02 | 2.96 | 3.93 | 5.92 |
| **1988** | 0.17 | 0.40 | 1.00 | 2.05 | 2.84 | 3.56 | 5.59 |
| **1989** | 0.13 | 0.30 | 1.06 | 2.12 | 3.64 | 4.11 | 5.76 |
| **1990** | 0.21 | 0.50 | 0.88 | 1.73 | 3.24 | 4.18 | 5.27 |
| **1991** | 0.14 | 0.33 | 0.70 | 1.73 | 2.81 | 3.96 | 5.78 |
| **1992** | 0.16 | 0.39 | 1.04 | 1.89 | 2.80 | 3.30 | 6.08 |
| **1993** | 0.18 | 0.59 | 0.95 | 2.46 | 2.73 | 3.24 | 6.18 |
| **1994** | 0.12 | 0.40 | 0.90 | 1.88 | 3.04 | 3.76 | 6.15 |
| **1995** | 0.17 | 0.44 | 0.98 | 1.73 | 2.85 | 4.06 | 5.66 |
| **1996** | 0.17 | 0.44 | 0.98 | 1.73 | 2.85 | 4.06 | 5.66 |
| **1997** | 0.13 | 0.51 | 1.04 | 2.22 | 3.06 | 4.11 | 5.58 |
| **1998** | 0.19 | 0.60 | 0.94 | 2.35 | 3.40 | 4.02 | 6.04 |
| **1999** | 0.14 | 0.53 | 0.92 | 2.09 | 3.43 | 4.10 | 5.75 |
| **2000** | 0.17 | 0.46 | 1.00 | 2.72 | 3.51 | 3.61 | 6.02 |
| **2001** | 0.16 | 0.44 | 0.91 | 2.52 | 3.87 | 3.88 | 5.55 |
| **2002** | 0.17 | 0.55 | 1.17 | 2.29 | 2.90 | 3.78 | 5.08 |
| **2003** | 0.12 | 0.56 | 1.00 | 2.17 | 2.64 | 3.66 | 4.65 |
| **2004** | 0.08 | 0.45 | 1.32 | 2.14 | 3.27 | 3.75 | 4.64 |

Table 11. Bluefish recreational CPUE at age using re-transformed GLM indices.

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| year | 0 | 1 | 2 | 3 | 4 | 5 | 6+ |
| 1982 | 0.109 | 0.099 | 0.027 | 0.021 | 0.010 | 0.015 | 0.047 |
| 1983 | 0.042 | 0.061 | 0.067 | 0.026 | 0.009 | 0.011 | 0.044 |
| 1984 | 0.094 | 0.075 | 0.060 | 0.027 | 0.012 | 0.009 | 0.045 |
| 1985 | 0.071 | 0.087 | 0.087 | 0.045 | 0.016 | 0.008 | 0.035 |
| 1986 | 0.053 | 0.066 | 0.082 | 0.034 | 0.013 | 0.018 | 0.052 |
| 1987 | 0.035 | 0.064 | 0.063 | 0.065 | 0.023 | 0.014 | 0.052 |
| 1988 | 0.023 | 0.027 | 0.031 | 0.023 | 0.028 | 0.023 | 0.043 |
| 1989 | 0.056 | 0.085 | 0.043 | 0.016 | 0.005 | 0.014 | 0.038 |
| 1990 | 0.038 | 0.115 | 0.033 | 0.012 | 0.006 | 0.005 | 0.029 |
| 1991 | 0.047 | 0.059 | 0.060 | 0.028 | 0.005 | 0.003 | 0.029 |
| 1992 | 0.016 | 0.050 | 0.034 | 0.054 | 0.013 | 0.004 | 0.024 |
| 1993 | 0.022 | 0.049 | 0.023 | 0.013 | 0.024 | 0.016 | 0.016 |
| 1994 | 0.044 | 0.066 | 0.030 | 0.010 | 0.006 | 0.013 | 0.019 |
| 1995 | 0.029 | 0.092 | 0.017 | 0.004 | 0.006 | 0.017 | 0.014 |
| 1996 | 0.059 | 0.065 | 0.018 | 0.007 | 0.007 | 0.008 | 0.024 |
| 1997 | 0.051 | 0.102 | 0.035 | 0.011 | 0.004 | 0.002 | 0.029 |
| 1998 | 0.031 | 0.077 | 0.067 | 0.029 | 0.010 | 0.007 | 0.018 |
| 1999 | 0.116 | 0.098 | 0.071 | 0.029 | 0.008 | 0.009 | 0.017 |
| 2000 | 0.035 | 0.182 | 0.089 | 0.028 | 0.003 | 0.012 | 0.007 |
| 2001 | 0.062 | 0.162 | 0.098 | 0.036 | 0.006 | 0.012 | 0.009 |
| 2002 | 0.031 | 0.223 | 0.068 | 0.021 | 0.005 | 0.006 | 0.016 |
| 2003 | 0.035 | 0.096 | 0.135 | 0.025 | 0.008 | 0.010 | 0.020 |
| 2004 | 0.018 | 0.157 | 0.088 | 0.051 | 0.013 | 0.016 | 0.024 |

Table 12. Seasonal distribution of fisheries independent surveys evaluated. Highlighted months were chosen.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MA trawl** | | | | | | | | | **x** | | | |
| **RI trawl** | | | | | | | | | **x** | | | |
| **CT trawl** | | | | x | x | x | | | **x** | x | | |
| **NY trawl** | | | | | x | x | x | **x** | **x** | x | | |
| **NY beach** | | | | | | x | x | **x** | x | x | | |
| **NJ trawl** | x | | | x | | x | | x | | **x** | | |
| **DE juv trawl** | | | | | | x | x | x | **x** | x | | |
| **DE adult trawl** | | | x | x | x | x | x | **x** | **x** | **x** | x | |
| **MD beach seine** | | | | | | | **x** | x | x | | | |
| **VA blue seine** | | | | | x | x | x | x | **x** | x | | |
| **NMFS inshore** | | | x | x | | | | | **x** | **x** | | |
| **NMFS offshore** | | | x | x | | | | | **x** | **x** | | |
| **SEAMAP** | | | | **x** | x | | x | x | | x | x | |

Table 13. Mean number per tow or haul from fisheries independent surveys evaluated.

| | Massachusetts Bottom Trawl Survey | Rhode Island Trawl Survey | Connecticut LI Sound Trawl Survey | New York Small Trawl Survey | New York Beach Seine Survey | New Jersey Ocean Trawl Survey | Delaware Adult trawl Survey | Delaware Juvenile Trawl Survey | Maryland Beach Seine Survey | Virginia Juvenile Beach Seine Survey | SEAMAP | NEFSC Autumn inshore Trawl Survey | NEFSC Autumn offshore Trawl Survey |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1966** | | | | | | | 0.259 | | | | | | |
| **1967** | | | | | | | 0.171 | | | | | | |
| **1968** | | | | | | | 0.047 | | | | | | |
| **1969** | | | | | | | 0.074 | | | | | | |
| **1970** | | | | | | | 0.235 | | | | | | |
| **1971** | | | | | | | 0.357 | | | | | | |
| **1972** | | | | | | | | | | | | | |
| **1973** | | | | | | | | | | | | | |
| **1974** | | | | | | | 0.260 | | | | | | |
| **1975** | | | | | | | | | | | | 10.043 | 0.290 |
| **1976** | | | | | | | | | | | | 64.983 | 0.549 |
| **1977** | | | | | | | | | | | | 97.032 | 0.365 |
| **1978** | 0.354 | | | | | | | | | | | 15.929 | 0.174 |
| **1979** | 0.059 | | | | | | 0.573 | | | | | 53.599 | 0.241 |
| **1980** | 0.605 | | | | | | 0.705 | 0.026 | | | | 44.624 | 0.154 |
| **1981** | 1.372 | 0.940 | | | | | 0.596 | 0.000 | 0.166 | | | 287.869 | 0.716 |
| **1982** | 0.010 | 0.706 | | | | | 0.379 | 0.020 | 0.584 | | | 29.706 | 0.282 |
| **1983** | 0.268 | 0.845 | | | | | 0.297 | 0.061 | 0.526 | | | 25.852 | 0.277 |
| **1984** | 1.094 | 3.526 | 54.068 | | 8.723 | | 0.377 | 0.122 | 0.289 | | | 124.003 | 0.225 |
| **1985** | 0.566 | 0.996 | 39.933 | | 2.130 | | | 0.000 | 0.375 | | | 28.748 | 0.676 |
| **1986** | 1.507 | 2.950 | 9.808 | | 10.897 | | | 0.387 | 0.091 | | | 22.165 | 0.268 |
| **1987** | 4.114 | 6.714 | 18.230 | 0.764 | 6.683 | | | 0.121 | 0.142 | | | 10.068 | 0.278 |
| **1988** | 0.611 | 1.719 | 15.411 | 0.538 | 6.533 | 25.324 | | 0.477 | 0.066 | | | 9.636 | 0.142 |
| **1989** | 0.174 | 1.311 | 51.410 | 0.518 | 15.264 | 6.381 | | 0.341 | 0.311 | | | 239.204 | 0.390 |
| **1990** | 0.324 | 0.927 | 32.739 | 0.318 | 7.306 | 3.834 | 0.759 | 0.088 | 0.238 | | 4.531 | 9.945 | 0.239 |
| **1991** | 5.442 | 5.179 | 44.362 | 0.352 | 13.545 | 12.784 | 0.394 | 0.194 | 0.121 | | 6.808 | 8.111 | 0.089 |
| **1992** | 0.000 | 0.594 | 30.306 | 0.125 | 6.200 | 3.172 | 0.240 | 0.292 | 0.109 | | 5.098 | 7.312 | 0.252 |
| **1993** | 1.604 | 1.598 | 30.582 | 0.114 | 2.959 | 2.278 | 0.629 | 0.072 | 0.039 | | 0.828 | 1.336 | 0.214 |
| **1994** | 0.580 | 8.419 | 33.339 | 0.200 | 3.102 | 8.362 | 0.320 | 0.104 | 0.083 | 1.211 | 0.966 | 7.426 | 0.324 |
| **1995** | 0.596 | 2.791 | 35.574 | 0.425 | 2.826 | 4.846 | 0.623 | 0.138 | 0.063 | 0.341 | 7.083 | 13.576 | 0.587 |
| **1996** | 0.093 | 2.753 | 44.471 | 0.546 | 5.055 | 2.149 | 0.796 | 0.225 | 0.083 | 0.084 | 2.161 | 11.704 | 0.071 |
| **1997** | 16.501 | 7.371 | 41.805 | 0.179 | 9.577 | 2.526 | 0.546 | 0.532 | 0.582 | 0.554 | 2.630 | 5.007 | 0.152 |
| **1998** | 10.779 | 14.660 | 37.021 | 0.234 | 2.054 | 4.982 | 0.696 | 0.236 | 0.120 | 0.399 | 1.674 | 5.316 | 0.185 |
| **1999** | 1.797 | 18.749 | 51.216 | 0.444 | 2.256 | 1.616 | 1.091 | 0.266 | 0.151 | 0.723 | 1.604 | 16.934 | 0.384 |
| **2000** | 0.172 | 0.594 | 27.895 | 0.310 | 3.816 | 1.808 | 0.548 | 0.381 | 0.205 | 0.197 | 1.344 | 4.197 | 0.339 |
| **2001** | 0.175 | 2.726 | 38.895 | 0.078 | 13.280 | 0.778 | 1.273 | 0.385 | 0.247 | 0.296 | 0.448 | 9.748 | 0.221 |
| **2002** | 0.135 | 3.393 | 18.214 | 0.095 | 3.253 | 9.642 | 0.968 | 0.321 | 0.080 | 0.811 | 0.929 | 9.104 | 0.193 |
| **2003** | 0.110 | 0.295 | 28.525 | 0.019 | 3.159 | 5.971 | 0.269 | 0.055 | 0.173 | | 1.517 | 51.784 | 0.288 |
| **2004** | | 2.322 | 29.130 | 0.021 | 2.804 | 3.302 | 0.927 | 0.053 | | | | 12.857 | 0.361 |
| **Average** | 1.886 | 3.837 | 33.949 | 0.293 | 6.258 | 5.868 | 0.515 | 0.196 | 0.211 | 0.513 | 2.687 | 41.261 | 0.298 |

Table 14. Mean weight (kg) per tow or haul from fisheries independent surveys evaluated.

| | Rhode Island Trawl Survey | Connecticut LI Sound Trawl Survey | New Jersey Ocean Trawl Survey | Delaware Adult trawl Survey | SEAMAP | NEFSC Autumn inshore Trawl Survey |
|---|---|---|---|---|---|---|
| **1966** | | | | 0.000 | | |
| **1967** | | | | 0.000 | | |
| **1968** | | | | 0.000 | | |
| **1969** | | | | 0.000 | | |
| **1970** | | | | 0.000 | | |
| **1971** | | | | 0.000 | | |
| **1972** | | | | | | |
| **1973** | | | | | | |
| **1974** | | | | 0.000 | | |
| **1975** | | | | | | 6.108 |
| **1976** | | | | | | 6.914 |
| **1977** | | | | | | 8.418 |
| **1978** | | | | | | 7.156 |
| **1979** | | | | 0.393 | | 8.662 |
| **1980** | | | | 0.365 | | 6.957 |
| **1981** | 0.136 | | | 0.386 | | 20.983 |
| **1982** | 0.077 | | | 0.269 | | 3.894 |
| **1983** | 0.148 | | | 0.179 | | 4.074 |
| **1984** | 0.714 | 0.000 | | 0.158 | | 9.654 |
| **1985** | 0.214 | 0.000 | | | | 4.200 |
| **1986** | 0.346 | 0.000 | | | | 3.857 |
| **1987** | 0.721 | 0.000 | | | | 3.008 |
| **1988** | 0.274 | 0.000 | 12.956 | | | 1.504 |
| **1989** | 0.204 | 0.000 | 3.417 | | | 11.681 |
| **1990** | 0.239 | 0.000 | 1.609 | 0.440 | 0.860 | 3.051 |
| **1991** | 0.669 | 0.000 | 2.031 | 0.134 | 1.106 | 1.520 |
| **1992** | 0.273 | 14.125 | 1.211 | 0.123 | 0.891 | 1.327 |
| **1993** | 0.343 | 11.376 | 1.013 | 0.346 | 0.145 | 0.656 |
| **1994** | 0.791 | 6.650 | 1.555 | 0.178 | 0.273 | 1.611 |
| **1995** | 0.185 | 11.081 | 1.282 | 0.294 | 1.248 | 2.184 |
| **1996** | 0.584 | 8.352 | 0.684 | 0.373 | 0.382 | 2.473 |
| **1997** | 0.616 | 5.977 | 0.701 | 0.241 | 0.559 | 1.079 |
| **1998** | 0.438 | 5.004 | 3.207 | 0.444 | 0.319 | 1.054 |
| **1999** | 1.189 | 6.755 | 0.624 | 0.377 | 0.357 | 2.696 |
| **2000** | 0.120 | 8.093 | 1.070 | 0.241 | 0.285 | 1.152 |
| **2001** | 0.288 | 7.224 | 0.404 | 0.627 | 0.101 | 1.612 |
| **2002** | 0.597 | 5.843 | 3.142 | 0.798 | 0.258 | 1.668 |
| **2003** | 0.117 | 8.991 | 1.912 | 0.127 | 0.262 | 3.281 |
| **2004** | 0.688 | 16.390 | 1.538 | 0.503 | | |
| **Average** | 0.415 | 5.517 | 2.256 | 0.250 | 0.503 | 4.567 |

Table 15. Fisheries independent mean number per tow at age.

**NMFS Inshore survey mean number per tow (re-transformed ln values) at age.**

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** |
| **1981** | 181.869 | 104.537 | 0.622 | 0.513 | 0.109 | 0.000 | 0.219 |
| **1982** | 18.768 | 10.788 | 0.064 | 0.053 | 0.011 | 0.000 | 0.023 |
| **1983** | 8.189 | 16.695 | 0.845 | 0.034 | 0.004 | 0.017 | 0.068 |
| **1984** | 81.356 | 40.869 | 1.257 | 0.201 | 0.120 | 0.052 | 0.147 |
| **1985** | 17.473 | 9.703 | 0.925 | 0.428 | 0.096 | 0.036 | 0.088 |
| **1986** | 21.055 | 0.923 | 0.042 | 0.060 | 0.024 | 0.028 | 0.033 |
| **1987** | 7.589 | 1.768 | 0.167 | 0.238 | 0.098 | 0.049 | 0.158 |
| **1988** | 9.493 | 0.067 | 0.009 | 0.010 | 0.028 | 0.006 | 0.023 |
| **1989** | 237.573 | 1.254 | 0.113 | 0.130 | 0.000 | 0.014 | 0.119 |
| **1990** | 6.186 | 3.637 | 0.006 | 0.016 | 0.016 | 0.000 | 0.084 |
| **1991** | 7.878 | 0.154 | 0.050 | 0.026 | 0.001 | 0.000 | 0.001 |
| **1992** | 6.625 | 0.637 | 0.016 | 0.022 | 0.002 | 0.002 | 0.008 |
| **1993** | 1.109 | 0.123 | 0.044 | 0.003 | 0.034 | 0.023 | 0.000 |
| **1994** | 6.580 | 0.760 | 0.010 | 0.019 | 0.030 | 0.021 | 0.006 |
| **1995** | 9.222 | 4.122 | 0.115 | 0.015 | 0.015 | 0.025 | 0.062 |
| **1996** | 9.643 | 1.638 | 0.211 | 0.144 | 0.027 | 0.021 | 0.019 |
| **1997** | 4.179 | 0.482 | 0.217 | 0.107 | 0.002 | 0.007 | 0.013 |
| **1998** | 4.793 | 0.387 | 0.074 | 0.045 | 0.017 | 0.000 | 0.000 |
| **1999** | 15.266 | 1.528 | 0.061 | 0.051 | 0.018 | 0.002 | 0.008 |
| **2000** | 2.485 | 1.517 | 0.157 | 0.017 | 0.015 | 0.006 | 0.000 |
| **2001** | 8.819 | 0.754 | 0.148 | 0.020 | 0.002 | 0.001 | 0.003 |
| **2002** | 7.815 | 1.210 | 0.042 | 0.037 | 0.000 | 0.000 | 0.000 |
| **2003** | 48.332 | 3.085 | 0.277 | 0.019 | 0.006 | 0.022 | 0.043 |
| **2004** | 7.0484 | 5.3070 | 0.3717 | 0.0788 | 0.0078 | 0.0119 | 0.0314 |

**NMFS Offshore survey mean number per tow (re-transformed ln values) at age**

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** |
| **1982** | 0.010 | 0.064 | 0.051 | 0.056 | 0.018 | 0.019 | 0.065 |
| **1983** | 0.013 | 0.024 | 0.064 | 0.084 | 0.019 | 0.022 | 0.050 |
| **1984** | 0.065 | 0.045 | 0.025 | 0.029 | 0.010 | 0.019 | 0.031 |
| **1985** | 0.084 | 0.198 | 0.232 | 0.050 | 0.023 | 0.025 | 0.064 |
| **1986** | 0.025 | 0.044 | 0.031 | 0.030 | 0.020 | 0.028 | 0.090 |
| **1987** | 0.001 | 0.006 | 0.014 | 0.042 | 0.045 | 0.026 | 0.145 |
| **1988** | 0.001 | 0.001 | 0.001 | 0.006 | 0.014 | 0.023 | 0.097 |
| **1989** | 0.135 | 0.232 | 0.000 | 0.000 | 0.001 | 0.006 | 0.015 |
| **1990** | 0.059 | 0.063 | 0.001 | 0.001 | 0.006 | 0.014 | 0.096 |
| **1991** | 0.001 | 0.008 | 0.011 | 0.022 | 0.006 | 0.001 | 0.040 |
| **1992** | 0.001 | 0.008 | 0.008 | 0.076 | 0.059 | 0.044 | 0.057 |
| **1993** | 0.000 | 0.000 | 0.000 | 0.051 | 0.099 | 0.019 | 0.045 |
| **1994** | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.166 | 0.132 |
| **1995** | 0.151 | 0.117 | 0.020 | 0.071 | 0.046 | 0.122 | 0.060 |
| **1996** | 0.000 | 0.000 | 0.015 | 0.007 | 0.004 | 0.036 | 0.009 |
| **1997** | 0.030 | 0.000 | 0.000 | 0.013 | 0.027 | 0.051 | 0.030 |
| **1998** | 0.037 | 0.032 | 0.005 | 0.034 | 0.043 | 0.012 | 0.021 |
| **1999** | 0.018 | 0.037 | 0.044 | 0.057 | 0.098 | 0.048 | 0.083 |
| **2000** | 0.003 | 0.252 | 0.022 | 0.027 | 0.009 | 0.011 | 0.015 |
| **2001** | 0.003 | 0.042 | 0.037 | 0.090 | 0.015 | 0.015 | 0.020 |
| **2002** | 0.000 | 0.011 | 0.025 | 0.075 | 0.033 | 0.025 | 0.024 |
| **2003** | 0.197 | 0.060 | 0.007 | 0.005 | 0.002 | 0.008 | 0.010 |
| **2004** | 0.000 | 0.056 | 0.054 | 0.077 | 0.033 | 0.071 | 0.070 |

**Connecticut Long Island trawl survey geometric mean number per tow at age.**

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** |
| **1984** | 52.101 | 0.800 | 0.760 | 0.298 | 0.054 | 0.014 | 0.041 |
| **1985** | 36.368 | 1.573 | 1.075 | 0.498 | 0.244 | 0.044 | 0.131 |
| **1986** | 8.727 | 0.547 | 0.352 | 0.083 | 0.053 | 0.028 | 0.018 |
| **1987** | 14.357 | 2.229 | 0.951 | 0.279 | 0.213 | 0.131 | 0.070 |
| **1988** | 13.122 | 0.851 | 0.567 | 0.358 | 0.234 | 0.173 | 0.106 |
| **1989** | 47.873 | 1.900 | 0.732 | 0.205 | 0.347 | 0.282 | 0.072 |
| **1990** | 28.027 | 3.499 | 0.742 | 0.106 | 0.141 | 0.200 | 0.024 |
| **1991** | 36.482 | 5.233 | 2.078 | 0.194 | 0.135 | 0.164 | 0.075 |
| **1992** | 24.585 | 3.359 | 1.750 | 0.172 | 0.152 | 0.283 | 0.005 |
| **1993** | 25.810 | 1.241 | 2.161 | 0.877 | 0.385 | 0.107 | 0.000 |
| **1994** | 30.018 | 1.410 | 0.752 | 0.512 | 0.386 | 0.251 | 0.010 |
| **1995** | 26.588 | 6.967 | 1.313 | 0.303 | 0.168 | 0.202 | 0.034 |
| **1996** | 42.334 | 0.491 | 1.031 | 0.360 | 0.060 | 0.036 | 0.159 |
| **1997** | 40.413 | 0.586 | 0.536 | 0.140 | 0.051 | 0.022 | 0.058 |
| **1998** | 34.831 | 1.453 | 0.512 | 0.130 | 0.058 | 0.011 | 0.025 |
| **1999** | 44.950 | 5.617 | 0.287 | 0.188 | 0.046 | 0.049 | 0.079 |
| **2000** | 22.593 | 3.652 | 1.408 | 0.178 | 0.021 | 0.016 | 0.029 |
| **2001** | 34.050 | 2.294 | 2.180 | 0.283 | 0.026 | 0.021 | 0.042 |
| **2002** | 12.419 | 4.926 | 0.578 | 0.135 | 0.045 | 0.048 | 0.063 |
| **2003** | 27.307 | 0.357 | 0.655 | 0.104 | 0.024 | 0.034 | 0.044 |
| **2004** | 20.134 | 3.944 | 3.315 | 1.336 | 0.071 | 0.160 | 0.171 |

Table 15. (cont.) Fisheries independent mean number per tow at age.

**NJ Ocean Trawl survey geometric mean number per tow at age.**

| | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** |
| **1988** | 23.969 | 0.378 | 0.002 | | | | |
| **1989** | 5.327 | 0.411 | 0.020 | | | | |
| **1990** | 3.636 | 0.183 | 0.003 | | | | |
| **1991** | 12.459 | 0.029 | 0.067 | | | | |
| **1992** | 2.700 | 0.419 | 0.029 | | | | |
| **1993** | 2.065 | 0.070 | 0.090 | | | | |
| **1994** | 8.323 | 0.172 | 0.012 | | | | |
| **1995** | 4.560 | 0.215 | 0.045 | | | | |
| **1996** | 2.017 | 0.078 | 0.012 | | | | |
| **1997** | 2.440 | 0.046 | 0.021 | | | | |
| **1998** | 4.196 | 0.408 | 0.233 | 0.111 | 0.020 | 0.003 | 0.010 |
| **1999** | 1.322 | 0.270 | 0.027 | 0.001 | 0.000 | 0.000 | 0.000 |
| **2000** | 1.308 | 0.366 | 0.095 | 0.036 | 0.002 | 0.000 | 0.000 |
| **2001** | 0.523 | 0.089 | 0.117 | 0.012 | 0.009 | 0.009 | 0.019 |
| **2002** | 6.649 | 2.911 | 0.064 | 0.011 | 0.003 | 0.003 | 0.000 |
| **2003** | 5.723 | 0.165 | 0.065 | 0.004 | 0.002 | 0.004 | 0.009 |
| **2004** | 2.182 | 0.708 | 0.322 | 0.033 | 0.012 | 0.027 | 0.020 |

**DE Adult Trawl survey geometric mean number per tow at age.**

| | Age | | |
|---|---|---|---|
| **year** | **0** | **1** | **2** |
| **1990** | 0.299 | 0.450 | 0.009 |
| **1991** | 0.135 | 0.254 | 0.000 |
| **1992** | 0.000 | 0.237 | 0.003 |
| **1993** | 0.436 | 0.301 | 0.037 |
| **1994** | 0.005 | 0.314 | 0.000 |
| **1995** | 0.168 | 0.438 | 0.017 |
| **1996** | 0.436 | 0.337 | 0.023 |
| **1997** | 0.218 | 0.308 | 0.020 |
| **1998** | 0.191 | 0.439 | 0.066 |
| **1999** | 0.722 | 0.355 | 0.014 |
| **2000** | 0.205 | 0.309 | 0.034 |
| **2001** | 0.839 | 0.395 | 0.040 |
| **2002** | 0.444 | 0.509 | 0.016 |
| **2003** | 0.000 | 0.260 | 0.009 |
| **2004** | 0.281 | 0.631 | 0.015 |

Table 16. Fisheries independent indices of age-0 bluefish by cohort as determined from length distributions.

**spring and summer cohorts (not survey period)**

division by length
summer = 1-13 cm
spring=14-25 cm
(unless otherwise obvious breaks in length frequency for upper end of spring)

| age 0 | Massachusetts Bottom Trawl Survey | | Rhode Island Trawl Survey | | Connecticut LI Sound Trawl Survey | | New York Small Trawl Survey | | New Jersey Ocean Trawl Survey | | Delaware Adult trawl Survey | | Delaware Juvenile Trawl Survey | | VA Juvenile Beach Seine Survey | SEAMAP survey | NMFS Fall Inshore Survey | | NMFS Fall Offshore Survey | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | spring | summer | spring | summer | spring | summer | spring | summer | spring | summer | spring | summer | spring | summer | summer | summer | spring | summer | spring | summer |
| **1975** | | | | | | | | | | | | | | | | | 8.585 | 0.157 | 0.046 | 0.000 |
| **1976** | | | | | | | | | | | | | | | | | 58.751 | 2.427 | 0.284 | 0.000 |
| **1977** | | | | | | | | | | | | | | | | | 92.383 | 3.174 | 0.219 | 0.017 |
| **1978** | 0.104 | 0.250 | | | | | | | | | | | | | | | 6.835 | 1.696 | 0.002 | 0.000 |
| **1979** | 0.011 | 0.048 | | | | | | | | | 0.367 | 0.000 | | | | | 49.922 | 0.828 | 0.003 | 0.000 |
| **1980** | 0.000 | 0.605 | | | | | | | | | 0.302 | 0.000 | 0.026 | 0.000 | | | 35.993 | 3.875 | 0.026 | 0.000 |
| **1981** | 0.173 | 1.199 | 0.678 | 0.263 | | | | | | | 0.072 | 0.000 | 0.000 | 0.000 | | | 261.778 | 13.787 | 0.645 | 0.000 |
| **1982** | 0.000 | 0.011 | 0.151 | 0.555 | | | | | | | 0.067 | 0.000 | 0.020 | 0.000 | | | 25.722 | 1.445 | 0.005 | 0.000 |
| **1983** | 0.194 | 0.073 | 0.680 | 0.165 | | | | | | | 0.000 | 0.000 | 0.020 | 0.020 | | | 22.711 | 0.656 | 0.069 | 0.000 |
| **1984** | 0.725 | 0.368 | 3.375 | 0.141 | 41.071 | 10.831 | | | | | 0.157 | 0.000 | 0.082 | 0.041 | | | 109.917 | 6.642 | 0.104 | 0.000 |
| **1985** | 0.319 | 0.247 | 0.402 | 0.507 | 34.328 | 1.341 | | | | | | | 0.000 | 0.000 | | | 22.747 | 1.291 | 0.131 | 0.000 |
| **1986** | 1.226 | 0.281 | 1.854 | 1.029 | 7.531 | 0.305 | | | | | | | 0.290 | 0.097 | | | 17.791 | 3.190 | 0.060 | 0.000 |
| **1987** | 0.373 | 3.741 | 4.796 | 1.907 | 11.778 | 3.720 | 0.442 | 0.318 | | | | | 0.100 | 0.020 | | | 7.254 | 0.131 | 0.000 | 0.000 |
| **1988** | 0.258 | 0.353 | 1.018 | 0.692 | 11.150 | 3.049 | 0.362 | 0.176 | 10.016 | 13.953 | | | 0.143 | 0.334 | | | 3.061 | 6.374 | 0.000 | 0.000 |
| **1989** | 0.035 | 0.139 | 1.109 | 0.179 | 44.069 | 4.890 | 0.265 | 0.253 | 4.659 | 0.666 | | | 0.052 | 0.288 | | | 216.002 | 14.577 | 0.351 | 0.000 |
| **1990** | 0.021 | 0.304 | 0.665 | 0.229 | 25.514 | 1.293 | 0.183 | 0.135 | 3.495 | 0.136 | 0.276 | 0.000 | 0.035 | 0.053 | | 4.531 | 4.166 | 1.768 | 0.116 | 0.000 |
| **1991** | 0.216 | 5.226 | 1.545 | 3.547 | 30.842 | 7.066 | 0.262 | 0.090 | 2.998 | 9.525 | 0.158 | 0.000 | 0.123 | 0.053 | | 6.808 | 7.761 | 0.047 | 0.007 | 0.000 |
| **1992** | 0.000 | 0.000 | 0.041 | 0.483 | 15.590 | 7.094 | 0.048 | 0.068 | 0.873 | 1.847 | 0.000 | 0.000 | 0.102 | 0.190 | | 5.098 | 1.231 | 5.374 | 0.000 | 0.000 |
| **1993** | 0.648 | 0.956 | 1.119 | 0.445 | 23.866 | 3.271 | 0.101 | 0.013 | 1.869 | 0.197 | 0.441 | 0.000 | 0.054 | 0.018 | | 0.828 | 0.968 | 0.046 | 0.000 | 0.000 |
| **1994** | 0.440 | 0.140 | 4.090 | 4.329 | 17.025 | 14.900 | 0.116 | 0.084 | 1.999 | 6.327 | 0.000 | 0.000 | 0.035 | 0.069 | 1.199 | 0.966 | 3.671 | 2.739 | 0.000 | 0.000 |
| **1995** | 0.042 | 0.554 | 0.113 | 2.669 | 25.200 | 6.369 | 0.300 | 0.125 | 3.439 | 1.160 | 0.161 | 0.000 | 0.069 | 0.069 | 0.341 | 7.083 | 5.268 | 3.613 | 0.034 | 0.024 |
| **1996** | 0.036 | 0.057 | 2.686 | 0.033 | 41.862 | 0.475 | 0.289 | 0.257 | 1.796 | 0.236 | 0.381 | 0.000 | 0.225 | 0.000 | 0.075 | 2.161 | 9.157 | 0.155 | 0.000 | 0.000 |
| **1997** | 0.118 | 16.383 | 0.805 | 6.563 | 12.251 | 28.164 | 0.079 | 0.100 | 1.247 | 1.193 | 0.211 | 0.000 | 0.208 | 0.324 | 0.554 | 2.630 | 2.363 | 1.801 | 0.022 | 0.008 |
| **1998** | 0.424 | 10.356 | 0.876 | 13.768 | 11.457 | 24.353 | 0.018 | 0.212 | 1.826 | 2.478 | 0.226 | 0.000 | 0.029 | 0.206 | 0.399 | 1.674 | 2.628 | 2.178 | 0.028 | 0.000 |
| **1999** | 0.362 | 1.435 | 1.602 | 17.117 | 36.130 | 14.169 | 0.016 | 0.428 | 1.111 | 0.333 | 0.873 | 0.034 | 0.100 | 0.166 | 0.712 | 1.604 | 11.897 | 3.791 | 0.022 | 0.000 |
| **2000** | 0.091 | 0.081 | 0.111 | 0.477 | 24.718 | 1.258 | 0.163 | 0.144 | 1.242 | 0.295 | 0.219 | 0.044 | 0.030 | 0.350 | 0.197 | 1.344 | 1.804 | 0.770 | 0.000 | 0.000 |
| **2001** | 0.112 | 0.064 | 0.166 | 2.478 | 29.749 | 5.911 | 0.063 | 0.010 | 0.255 | 0.304 | 0.861 | 0.047 | 0.160 | 0.224 | 0.296 | 0.448 | 3.390 | 5.686 | 0.000 | 0.000 |
| **2002** | 0.037 | 0.099 | 0.225 | 2.978 | 12.579 | 3.015 | 0.005 | 0.090 | 6.642 | 1.610 | 0.562 | 0.000 | 0.092 | 0.214 | 0.802 | 0.929 | 2.448 | 5.693 | 0.000 | 0.000 |
| **2003** | 0.111 | 0.000 | 0.134 | 0.081 | 25.630 | 1.710 | 0.012 | 0.000 | 3.786 | 2.052 | 0.073 | 0.000 | 0.018 | 0.037 | - | 1.517 | 27.846 | 21.886 | 0.235 | 0.000 |
| **2004** | 0.033 | 0.256 | 0.116 | 1.963 | | | 0.008 | 0.008 | 2.167 | 0.339 | 0.456 | 0.000 | 0.053 | 0.000 | 0.440 | | 6.076 | 1.768 | 0.000 | 0.000 |

Table 17. Correlations among juvenile indices by cohort group.

| Survey | cohort | MA trawl spring | MA trawl summer | RI trawl spring | RI trawl summer | CT trawl spring | CT trawl summer | NY trawl spring | NY trawl summer | NJ trawl spring | NJ trawl summer | DE Adult trawl spring | DE Adult trawl summer | DE Juv Trawl spring | DE Juv Trawl summer | VA Seine summer | SEAMAP summer | NMFS Inshore spring | NMFS Inshore summer | NMFS Offshore spring | REC CPUE age 0 | REC CPUE age 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MA trawl | spring | 1.00 | | | | | | | | | | | | | | | | | | | | |
| MA trawl | summer | 0.01 | 1.00 | | | | | | | | | | | | | | | | | | | |
| RI trawl | spring | 0.46 | 0.03 | 1.00 | | | | | | | | | | | | | | | | | | |
| RI trawl | summer | 0.10 | 0.50 | 0.06 | 1.00 | | | | | | | | | | | | | | | | | |
| CT trawl | spring | -0.23 | -0.35 | 0.02 | -0.11 | 1.00 | | | | | | | | | | | | | | | | |
| CT trawl | summer | 0.03 | 0.82 | 0.10 | 0.71 | -0.22 | 1.00 | | | | | | | | | | | | | | | |
| NY trawl | spring | -0.05 | -0.13 | 0.48 | -0.42 | 0.11 | -0.39 | 1.00 | | | | | | | | | | | | | | |
| NY trawl | summer | 0.11 | 0.06 | 0.45 | 0.51 | 0.26 | 0.12 | 0.35 | 1.00 | | | | | | | | | | | | | |
| NJ trawl | spring | -0.11 | -0.23 | -0.09 | -0.28 | -0.25 | -0.34 | 0.45 | 0.03 | 1.00 | | | | | | | | | | | | |
| NJ trawl | summer | 0.22 | 0.02 | 0.28 | -0.07 | -0.35 | 0.00 | 0.45 | -0.07 | 0.62 | 1.00 | | | | | | | | | | | |
| DE Adult trawl | spring | 0.06 | -0.06 | -0.09 | 0.43 | 0.29 | -0.09 | -0.27 | 0.37 | -0.12 | -0.44 | 1.00 | | | | | | | | | | |
| DE Adult trawl | summer | -0.08 | -0.17 | -0.21 | 0.24 | 0.25 | -0.13 | -0.17 | 0.22 | -0.49 | -0.33 | 0.63 | 1.00 | | | | | | | | | |
| DE Juv Trawl | spring | 0.34 | 0.23 | 0.21 | 0.03 | -0.21 | 0.02 | 0.22 | 0.13 | -0.04 | 0.12 | 0.40 | 0.11 | 1.00 | | | | | | | | |
| DE Juv Trawl | summer | -0.21 | 0.32 | -0.33 | 0.25 | -0.26 | 0.31 | -0.17 | 0.05 | 0.21 | 0.13 | 0.29 | 0.55 | 0.20 | 1.00 | | | | | | | |
| VA Seine | summer | 0.57 | -0.01 | 0.49 | 0.30 | -0.46 | 0.35 | -0.49 | -0.07 | 0.31 | 0.78 | -0.13 | -0.28 | -0.35 | -0.09 | 1.00 | | | | | | |
| SEAMAP | summer | -0.39 | 0.06 | -0.18 | -0.16 | 0.09 | -0.08 | 0.62 | -0.01 | 0.14 | 0.36 | -0.44 | -0.38 | 0.06 | -0.26 | -0.26 | 1.00 | | | | | |
| NMFS Inshore | spring | 0.01 | -0.17 | 0.11 | -0.21 | 0.56 | -0.06 | 0.18 | 0.24 | 0.19 | -0.14 | -0.20 | -0.16 | -0.15 | 0.11 | -0.07 | -0.05 | 1.00 | | | | |
| NMFS Inshore | summer | -0.15 | -0.22 | -0.21 | -0.14 | 0.19 | -0.14 | -0.24 | -0.20 | 0.32 | -0.02 | -0.06 | -0.03 | -0.15 | 0.18 | 0.38 | -0.18 | 0.51 | 1.00 | | | |
| NMFS Offshore | spring | -0.07 | -0.17 | -0.13 | -0.23 | 0.46 | -0.18 | 0.01 | 0.04 | 0.20 | -0.20 | -0.27 | -0.24 | -0.30 | -0.01 | -0.08 | 0.03 | 0.80 | 0.72 | 1.00 | | |
| REC CPUE | age 0 | 0.12 | -0.09 | 0.14 | 0.28 | 0.61 | 0.17 | -0.17 | 0.58 | -0.33 | -0.24 | 0.32 | 0.27 | 0.01 | -0.22 | 0.10 | -0.22 | 0.29 | -0.04 | 0.10 | 1.00 | |
| REC CPUE | age 1 | -0.35 | -0.07 | -0.39 | 0.06 | 0.01 | -0.09 | -0.41 | -0.16 | -0.07 | -0.46 | 0.47 | 0.52 | -0.11 | 0.35 | -0.05 | -0.37 | -0.08 | 0.08 | -0.04 | 0.07 | 1.00 |

Table 18. Atlantic coast bluefish biological reference points. Biomass in mt.

**ASAP** Reference Points using final year selectivity scales Max=1.0

| Ref pt | F | slope to plot on SRR |
|---|---|---|
| F0.1 | 0.177 | 0.184 |
| Fmax | 0.276 | 0.264 |
| F30%SPR | 0.279 | 0.267 |
| F40%SPR | 0.199 | 0.200 |
| **Fmsy** | **0.190** | 0.193 |
| Foy | 0.143 | ------ |
| Fcurrent | 0.146 | 0.162 |
| | | |
| SSmsy | 142,104 | 313,285,320 |
| Rmsy | 30,777 | |
| | | |
| SSoy | 180,341 | |
| MSY | 18,483 | |
| OY | 17,881 | |
| | | |
| SSmsy_ratio | 0.487 | |
| Fmsy_ratio | 0.769 | |
| Bmsy ratio | 0.701 | |

**Thompson-Bell YPR**

| age 0 | 1982-2003 PR Time series average |
|---|---|
| 0 | 0.337 |
| 1 | 0.996 |
| 2 | 0.934 |
| 3 | 0.468 |
| 4 | 0.337 |
| 5 | 0.696 |
| 6 | 0.910 |
| 7+ | 1.000 |

| | F | Catch Wt (YPR) | SSB/R | % MSP |
|---|---|---|---|---|
| **F max** | 0.254 | 0.722 | 3.04 | 30.3 |
| **F 0.1** | 0.173 | 0.689 | 4.29 | 42.9 |
| **$F_{30\%}$** | 0.257 | 0.722 | 3.00 | 30.0 |
| **Fmsy** | 0.190 | | 3.97 | |
| **Bmsy** | **147,052** (from stock/recruit and recruitment at F=0.19) | | | |

| | |
|---|---|
| $F_{msy}$ = | **0.19** |
| $F_{2004}$ = | **0.15** |
| $B_{msy}$ = | **147,052** |
| 1/2 $B_{msy}$ = | **73,526** |
| $B_{2004}$ = | **104,136** |

Table19. Fishing mortality at age estimates from ADAPT model.

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** | **$F_{2-4}$** |
| **1982** | 0.274 | 0.274 | 0.280 | 0.378 | 0.152 | 0.270 | 0.378 | 0.270 |
| **1983** | 0.112 | 0.307 | 0.417 | 0.540 | 0.254 | 0.404 | 0.565 | 0.404 |
| **1984** | 0.138 | 0.230 | 0.480 | 0.162 | 0.303 | 0.315 | 0.441 | 0.315 |
| **1985** | 0.152 | 0.179 | 0.312 | 0.400 | 0.150 | 0.287 | 0.402 | 0.287 |
| **1986** | 0.282 | 0.420 | 0.387 | 0.246 | 0.246 | 0.293 | 0.410 | 0.293 |
| **1987** | 0.159 | 0.536 | 0.527 | 0.479 | 0.278 | 0.428 | 0.599 | 0.428 |
| **1988** | 0.059 | 0.152 | 0.515 | 0.302 | 0.301 | 0.373 | 0.522 | 0.373 |
| **1989** | 0.087 | 0.281 | 0.370 | 0.392 | 0.114 | 0.292 | 0.409 | 0.292 |
| **1990** | 0.090 | 0.261 | 0.139 | 0.125 | 0.257 | 0.174 | 0.243 | 0.174 |
| **1991** | 0.132 | 0.252 | 0.462 | 0.173 | 0.077 | 0.237 | 0.332 | 0.237 |
| **1992** | 0.262 | 0.576 | 0.123 | 0.270 | 0.089 | 0.160 | 0.224 | 0.160 |
| **1993** | 0.112 | 0.441 | 0.172 | 0.056 | 0.178 | 0.135 | 0.190 | 0.135 |
| **1994** | 0.149 | 0.473 | 0.559 | 0.055 | 0.036 | 0.217 | 0.303 | 0.217 |
| **1995** | 0.121 | 0.391 | 0.190 | 0.096 | 0.039 | 0.108 | 0.152 | 0.108 |
| **1996** | 0.087 | 0.194 | 0.121 | 0.074 | 0.219 | 0.138 | 0.193 | 0.138 |
| **1997** | 0.116 | 0.327 | 0.201 | 0.136 | 0.095 | 0.144 | 0.201 | 0.144 |
| **1998** | 0.043 | 0.290 | 0.365 | 0.170 | 0.095 | 0.210 | 0.294 | 0.210 |
| **1999** | 0.068 | 0.165 | 0.374 | 0.118 | 0.047 | 0.180 | 0.252 | 0.180 |
| **2000** | 0.036 | 0.261 | 0.360 | 0.211 | 0.026 | 0.199 | 0.279 | 0.199 |
| **2001** | 0.039 | 0.349 | 0.338 | 0.257 | 0.083 | 0.226 | 0.317 | 0.226 |
| **2002** | 0.022 | 0.191 | 0.211 | 0.081 | 0.112 | 0.135 | 0.188 | 0.135 |
| **2003** | 0.020 | 0.133 | 0.221 | 0.144 | 0.074 | 0.146 | 0.205 | 0.146 |
| **2004** | 0.028 | 0.170 | 0.158 | 0.098 | 0.110 | 0.128 | 0.179 | 0.122 |

Table 20. January 1 population size estimates (000s) from the ADAPT model.

| year | Age 0 | 1 | 2 | 3 | 4 | 5 | 6+ | Total |
|---|---|---|---|---|---|---|---|---|
| 1982 | 51,171 | 44,730 | 12,803 | 8,487 | 6,219 | 5,648 | 13,049 | 142,107 |
| 1983 | 49,712 | 31,862 | 27,857 | 7,922 | 4,763 | 4,373 | 12,118 | 138,606 |
| 1984 | 60,939 | 36,388 | 19,201 | 15,025 | 3,778 | 3,025 | 9,800 | 148,157 |
| 1985 | 36,564 | 43,458 | 23,674 | 9,728 | 10,459 | 2,286 | 7,868 | 134,037 |
| 1986 | 23,121 | 25,719 | 29,760 | 14,191 | 5,337 | 7,369 | 14,584 | 120,081 |
| 1987 | 23,321 | 14,279 | 13,840 | 16,539 | 9,088 | 3,416 | 9,598 | 90,082 |
| 1988 | 32,968 | 16,281 | 6,839 | 6,693 | 8,388 | 5,635 | 7,392 | 84,195 |
| 1989 | 45,852 | 25,451 | 11,455 | 3,345 | 4,050 | 5,083 | 7,860 | 103,095 |
| 1990 | 34,854 | 34,412 | 15,738 | 6,481 | 1,850 | 2,957 | 12,534 | 108,827 |
| 1991 | 33,128 | 26,082 | 21,700 | 11,217 | 4,683 | 1,171 | 8,343 | 106,325 |
| 1992 | 10,101 | 23,780 | 16,593 | 11,194 | 7,726 | 3,550 | 5,428 | 78,372 |
| 1993 | 12,475 | 6,365 | 10,945 | 12,018 | 7,000 | 5,787 | 7,562 | 62,153 |
| 1994 | 15,639 | 9,135 | 3,353 | 7,542 | 9,306 | 4,798 | 4,505 | 54,277 |
| 1995 | 18,468 | 11,029 | 4,661 | 1,570 | 5,843 | 7,351 | 8,766 | 57,687 |
| 1996 | 22,568 | 13,404 | 6,107 | 3,156 | 1,167 | 4,600 | 8,755 | 59,757 |
| 1997 | 16,475 | 16,933 | 9,037 | 4,430 | 2,400 | 768 | 7,314 | 57,357 |
| 1998 | 17,940 | 12,015 | 10,000 | 6,052 | 3,167 | 1,788 | 1,977 | 52,940 |
| 1999 | 27,464 | 14,071 | 7,362 | 5,686 | 4,179 | 2,357 | 2,385 | 63,504 |
| 2000 | 21,048 | 21,007 | 9,767 | 4,145 | 4,139 | 3,264 | 704 | 64,074 |
| 2001 | 41,289 | 16,630 | 13,245 | 5,578 | 2,747 | 3,301 | 985 | 83,775 |
| 2002 | 29,237 | 32,528 | 9,604 | 7,731 | 3,531 | 2,071 | 2,664 | 87,365 |
| 2003 | 45,106 | 23,407 | 21,998 | 6,367 | 5,840 | 2,584 | 3,822 | 109,124 |
| 2004 | 16,545 | 36,190 | 16,780 | 14,433 | 4,515 | 4,440 | 4,313 | 97,216 |
| 2005 | 28,548 | 13,166 | 24,991 | 11,736 | 10,712 | 3,313 | 6,149 | 98,616 |

Table 21. Population biomass estimates (MT) from ADAPT model

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **Total** |
| **1982** | 4,135 | 15,418 | 16,363 | 14,014 | 16,938 | 20,786 | 64,698 | 152,351 |
| **1983** | 2,456 | 7,726 | 19,403 | 14,321 | 12,122 | 16,441 | 67,582 | 140,050 |
| **1984** | 3,047 | 7,369 | 12,000 | 20,224 | 9,451 | 11,387 | 55,368 | 118,845 |
| **1985** | 1,653 | 8,692 | 14,929 | 13,033 | 23,759 | 7,790 | 39,758 | 109,614 |
| **1986** | 1,755 | 5,694 | 20,618 | 21,289 | 13,161 | 25,669 | 70,701 | 158,886 |
| **1987** | 1,532 | 2,709 | 10,524 | 25,750 | 23,815 | 12,015 | 47,836 | 124,181 |
| **1988** | 4,220 | 3,567 | 3,746 | 10,410 | 20,090 | 18,304 | 34,171 | 94,508 |
| **1989** | 3,040 | 5,747 | 7,459 | 4,870 | 11,064 | 17,358 | 37,100 | 86,637 |
| **1990** | 5,838 | 8,775 | 8,086 | 8,776 | 4,848 | 11,532 | 56,078 | 103,934 |
| **1991** | 2,779 | 6,865 | 12,838 | 13,840 | 10,325 | 4,196 | 41,423 | 92,267 |
| **1992** | 841 | 5,557 | 9,720 | 12,876 | 17,003 | 10,814 | 27,721 | 84,533 |
| **1993** | 1,506 | 1,955 | 6,662 | 19,223 | 15,901 | 17,424 | 36,905 | 99,576 |
| **1994** | 981 | 2,451 | 2,443 | 10,079 | 25,448 | 15,365 | 18,437 | 75,204 |
| **1995** | 1,952 | 2,534 | 2,918 | 1,959 | 13,525 | 25,818 | 41,166 | 89,873 |
| **1996** | 2,214 | 3,666 | 4,010 | 4,109 | 2,592 | 15,644 | 41,114 | 73,350 |
| **1997** | 997 | 4,985 | 6,114 | 6,534 | 5,522 | 2,628 | 33,643 | 60,423 |
| **1998** | 2,042 | 3,356 | 6,924 | 9,461 | 8,700 | 6,270 | 10,638 | 47,391 |
| **1999** | 2,120 | 4,465 | 5,470 | 7,970 | 11,865 | 8,801 | 12,328 | 53,019 |
| **2000** | 2,225 | 5,332 | 7,111 | 6,557 | 11,210 | 11,485 | 3,968 | 47,888 |
| **2001** | 3,563 | 4,548 | 8,570 | 8,856 | 8,914 | 12,183 | 5,346 | 51,980 |
| **2002** | 2,740 | 9,648 | 6,891 | 11,160 | 9,545 | 7,919 | 12,415 | 60,317 |
| **2003** | 2,797 | 7,221 | 16,314 | 10,145 | 14,359 | 8,419 | 15,707 | 74,962 |
| **2004** | 455 | 8,410 | 14,427 | 21,114 | 12,027 | 13,971 | 20,010 | 90,415 |

Table 22. Diagnostic information from preferred ASAP model run.

| Component | Residual Sum Squares | Number Obs | Index Lambda | Likelihood value |
|---|---|---|---|---|
| Catch_Fleet_Total | 0.0035 | 23 | 2000 | 7.058 |
| CAA_proportions | N/A | 161 | see_below | 203.9 |

objective function = 10116.6

| Component | Residual Sum Squares | Number Obs | Index Lambda | Likelihood value |
|---|---|---|---|---|
| NEFSC 0 | 16.26 | 23 | 50 | 406.470 |
| NEFSC 1 | 31.98 | 23 | 50 | 799.479 |
| NEFSC 2 | 32.35 | 23 | 50 | 808.701 |
| NEFSC 3 | 21.98 | 23 | 50 | 549.431 |
| NEFSC 4 | 25.34 | 21 | 50 | 633.618 |
| NEFSC 5 | 17.08 | 18 | 50 | 427.067 |
| NEFSC 6 | 25.04 | 19 | 50 | 625.882 |
| DE 0 | 17.51 | 13 | 50 | 437.674 |
| DE 1 | 1.97 | 15 | 50 | 49.229 |
| DE 2 | 8.29 | 13 | 50 | 207.237 |
| NJ 0 | 14.46 | 17 | 50 | 361.496 |
| NJ 1 | 15.78 | 17 | 50 | 394.376 |
| NJ 2 | 23.95 | 17 | 50 | 598.866 |
| CT 0 | 4.81 | 21 | 50 | 120.240 |
| CT 1 | 17.05 | 21 | 50 | 426.235 |
| CT 2 | 10.16 | 21 | 50 | 254.104 |
| CT 3 | 12.35 | 21 | 50 | 308.684 |
| CT 4 | 18.79 | 21 | 50 | 469.680 |
| CT 5 | 24.95 | 21 | 50 | 623.822 |
| CT 6 | 13.83 | 20 | 50 | 345.860 |
| Rec CPUE 0 | 3.65 | 23 | 50 | 91.235 |
| Rec CPUE 1 | 6.07 | 23 | 50 | 151.709 |
| Rec CPUE 2 | 4.65 | 23 | 50 | 116.340 |
| Rec CPUE 3 | 3.72 | 23 | 50 | 92.924 |
| Rec CPUE 4 | 4.32 | 23 | 50 | 107.904 |
| Rec CPUE 5 | 4.61 | 23 | 50 | 115.254 |
| Rec CPUE 6 | 2.68 | 23 | 50 | 67.015 |
| SEAMAP | 12.90 | 14 | 50 | 322.448 |
| Index_Fit_Total | 396.52 | 563 | 1400 | 9912.980 |

Table 23. Fishing mortality at age estimates from ASAP catch at age model.

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **year** | **0** | **1** | **2** | **3** | **4** | **5** | **6+** | **F mult** |
| **1982** | 0.094 | 0.279 | 0.263 | 0.133 | 0.096 | 0.194 | 0.255 | 0.279 |
| **1983** | 0.105 | 0.311 | 0.293 | 0.148 | 0.106 | 0.216 | 0.284 | 0.311 |
| **1984** | 0.094 | 0.277 | 0.261 | 0.132 | 0.095 | 0.192 | 0.254 | 0.277 |
| **1985** | 0.089 | 0.263 | 0.247 | 0.125 | 0.090 | 0.182 | 0.240 | 0.263 |
| **1986** | 0.145 | 0.429 | 0.404 | 0.204 | 0.147 | 0.297 | 0.392 | 0.429 |
| **1987** | 0.155 | 0.458 | 0.431 | 0.218 | 0.157 | 0.318 | 0.419 | 0.458 |
| **1988** | 0.137 | 0.406 | 0.383 | 0.193 | 0.139 | 0.282 | 0.372 | 0.406 |
| **1989** | 0.118 | 0.349 | 0.328 | 0.166 | 0.119 | 0.242 | 0.319 | 0.349 |
| **1990** | 0.108 | 0.320 | 0.301 | 0.152 | 0.110 | 0.222 | 0.293 | 0.320 |
| **1991** | 0.139 | 0.411 | 0.387 | 0.196 | 0.141 | 0.285 | 0.376 | 0.411 |
| **1992** | 0.117 | 0.346 | 0.326 | 0.165 | 0.119 | 0.240 | 0.317 | 0.346 |
| **1993** | 0.113 | 0.333 | 0.314 | 0.159 | 0.114 | 0.231 | 0.305 | 0.333 |
| **1994** | 0.103 | 0.304 | 0.286 | 0.145 | 0.104 | 0.211 | 0.278 | 0.304 |
| **1995** | 0.084 | 0.248 | 0.233 | 0.118 | 0.085 | 0.172 | 0.227 | 0.248 |
| **1996** | 0.082 | 0.241 | 0.227 | 0.115 | 0.083 | 0.167 | 0.221 | 0.241 |
| **1997** | 0.095 | 0.280 | 0.264 | 0.133 | 0.096 | 0.194 | 0.256 | 0.280 |
| **1998** | 0.077 | 0.229 | 0.216 | 0.109 | 0.078 | 0.159 | 0.210 | 0.229 |
| **1999** | 0.068 | 0.201 | 0.189 | 0.096 | 0.069 | 0.140 | 0.184 | 0.201 |
| **2000** | 0.068 | 0.200 | 0.189 | 0.095 | 0.069 | 0.139 | 0.183 | 0.200 |
| **2001** | 0.076 | 0.223 | 0.210 | 0.106 | 0.077 | 0.155 | 0.204 | 0.223 |
| **2002** | 0.060 | 0.176 | 0.166 | 0.084 | 0.060 | 0.122 | 0.161 | 0.176 |
| **2003** | 0.065 | 0.191 | 0.180 | 0.091 | 0.066 | 0.133 | 0.175 | 0.191 |
| **2004** | 0.049 | 0.146 | 0.138 | 0.070 | 0.050 | 0.102 | 0.134 | 0.146 |
| | | | | | | | | |
| **selectivity at age** | 0.338 | 1.000 | 0.942 | 0.476 | 0.343 | 0.694 | 0.915 | |

Table 24. January 1 population size estimates (000s) from the ASAP model.

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| year | 0 | 1 | 2 | 3 | 4 | 5 | 6+ | Total |
| **1982** | 61,381 | 50,364 | 14,431 | 6,956 | 6,952 | 14,105 | 21,385 | 175,573 |
| **1983** | 48,325 | 45,730 | 31,202 | 9,087 | 4,987 | 5,173 | 23,083 | 167,586 |
| **1984** | 52,904 | 35,618 | 27,444 | 19,066 | 6,417 | 3,671 | 17,638 | 162,757 |
| **1985** | 31,079 | 39,437 | 22,103 | 17,308 | 13,681 | 4,778 | 13,686 | 142,071 |
| **1986** | 23,235 | 23,281 | 24,827 | 14,129 | 12,504 | 10,236 | 12,070 | 120,281 |
| **1987** | 16,488 | 16,455 | 12,418 | 13,577 | 9,433 | 8,839 | 12,902 | 90,112 |
| **1988** | 22,043 | 11,561 | 8,522 | 6,605 | 8,938 | 6,601 | 12,214 | 76,484 |
| **1989** | 50,783 | 15,729 | 6,306 | 4,759 | 4,457 | 6,367 | 10,973 | 99,374 |
| **1990** | 23,044 | 36,951 | 9,087 | 3,718 | 3,301 | 3,238 | 10,622 | 89,960 |
| **1991** | 26,916 | 16,932 | 21,973 | 5,505 | 2,614 | 2,422 | 8,614 | 84,975 |
| **1992** | 13,379 | 19,175 | 9,190 | 12,214 | 3,706 | 1,859 | 6,332 | 65,855 |
| **1993** | 15,932 | 9,744 | 11,108 | 5,432 | 8,481 | 2,695 | 4,975 | 58,367 |
| **1994** | 18,428 | 11,654 | 5,718 | 6,646 | 3,795 | 6,195 | 4,755 | 57,191 |
| **1995** | 18,179 | 13,615 | 7,044 | 3,518 | 4,709 | 2,800 | 7,058 | 56,922 |
| **1996** | 18,458 | 13,687 | 8,701 | 4,567 | 2,560 | 3,542 | 6,537 | 58,052 |
| **1997** | 16,362 | 13,929 | 8,806 | 5,677 | 3,334 | 1,930 | 6,746 | 56,783 |
| **1998** | 24,271 | 12,185 | 8,617 | 5,537 | 4,068 | 2,480 | 5,575 | 62,732 |
| **1999** | 27,884 | 18,390 | 7,934 | 5,686 | 4,065 | 3,079 | 5,434 | 72,472 |
| **2000** | 16,711 | 21,328 | 12,314 | 5,375 | 4,231 | 3,107 | 5,893 | 68,958 |
| **2001** | 34,542 | 12,785 | 14,291 | 8,348 | 4,000 | 3,234 | 6,230 | 83,429 |
| **2002** | 27,780 | 26,221 | 8,372 | 9,480 | 6,145 | 3,034 | 6,425 | 87,457 |
| **2003** | 41,561 | 21,429 | 18,004 | 5,807 | 7,138 | 4,737 | 6,677 | 105,353 |
| **2004** | 15,850 | 31,893 | 14,488 | 12,309 | 4,340 | 5,473 | 7,984 | 92,337 |

Table 25. Population biomass estimates (MT) from ASAP model

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| year | 0 | 1 | 2 | 3 | 4 | 5 | 6+ | Total |
| 1982 | 4,960 | 17,360 | 18,444 | 11,485 | 18,933 | 51,909 | 106,028 | 229,120 |
| 1983 | 2,387 | 11,089 | 21,733 | 16,426 | 12,692 | 19,448 | 128,733 | 212,508 |
| 1984 | 2,645 | 7,213 | 17,152 | 25,664 | 16,052 | 13,817 | 99,649 | 182,192 |
| 1985 | 1,405 | 7,888 | 13,938 | 23,188 | 31,078 | 16,281 | 69,157 | 162,934 |
| 1986 | 1,764 | 5,154 | 17,200 | 21,196 | 30,834 | 35,657 | 58,514 | 170,318 |
| 1987 | 1,083 | 3,122 | 9,442 | 21,138 | 24,719 | 31,090 | 64,303 | 154,897 |
| 1988 | 2,822 | 2,533 | 4,668 | 10,273 | 21,407 | 21,443 | 56,461 | 119,605 |
| 1989 | 3,367 | 3,552 | 4,106 | 6,929 | 12,175 | 21,742 | 51,793 | 103,664 |
| 1990 | 3,860 | 9,422 | 4,669 | 5,034 | 8,649 | 12,627 | 47,525 | 91,787 |
| 1991 | 2,258 | 4,457 | 12,999 | 6,792 | 5,763 | 8,678 | 42,769 | 83,716 |
| 1992 | 1,114 | 4,481 | 5,383 | 14,049 | 8,156 | 5,662 | 32,339 | 71,185 |
| 1993 | 1,923 | 2,993 | 6,761 | 8,688 | 19,266 | 8,114 | 24,279 | 72,025 |
| 1994 | 1,156 | 3,127 | 4,166 | 8,882 | 10,378 | 19,839 | 19,459 | 67,007 |
| 1995 | 1,921 | 3,128 | 4,410 | 4,389 | 10,901 | 9,835 | 33,144 | 67,728 |
| 1996 | 1,811 | 3,743 | 5,713 | 5,946 | 5,685 | 12,046 | 30,700 | 65,644 |
| 1997 | 990 | 4,100 | 5,958 | 8,374 | 7,671 | 6,603 | 31,031 | 64,727 |
| 1998 | 2,763 | 3,403 | 5,966 | 8,657 | 11,174 | 8,695 | 29,999 | 70,657 |
| 1999 | 2,152 | 5,835 | 5,895 | 7,970 | 11,542 | 11,497 | 28,086 | 72,978 |
| 2000 | 1,767 | 5,413 | 8,965 | 8,503 | 11,458 | 10,932 | 33,218 | 80,255 |
| 2001 | 2,981 | 3,496 | 9,247 | 13,253 | 12,981 | 11,935 | 33,814 | 87,707 |
| 2002 | 2,603 | 7,777 | 6,007 | 13,685 | 16,611 | 11,600 | 29,944 | 88,228 |
| 2003 | 2,577 | 6,611 | 13,352 | 9,253 | 17,551 | 15,432 | 27,439 | 92,216 |
| 2004 | 436 | 7,411 | 12,457 | 18,007 | 11,562 | 17,222 | 37,041 | 104,136 |

## BLUEFISH FIGURES

**List of Figures**


Figure 1. Times series of bluefish commercial landings (mt) along the Atlantic coast.
Figure 2. Times series of bluefish recreational landings (000s) along the Atlantic coast.
Figure 3. Average ( $\pm$1 std dev) bluefish recreational catch, by wave, 1982-2004.
Figure 4. Frequency distribution of Florida commercial samples (1998-2003) and North Carolina length frequency for medium market grade landingsfor 1998-2003 combined.
Figure 5. Length distribution of Atlantic coast bluefish commercial landings.
Figure 6. Length distributions of Atlantic coast bluefish recreational landings.
Figure 7. Bluefish recreational catch per effort from MFRSS estimates.
Figure 8. Age 0 spring and summer cohort by survey program, 1975-2004. Indices standardized to the series mean.
Figure 9. Yield per recruit and %SPR from Thompson-Bell yield per recruit model.
Figure 10. Stock- recruitment relationship for Atlantic coast bluefish fit to a Beverton-Holt S/R model. Stock and recruit estimates from ASAP model output.
Figure 11. Residuals of survey index fits from ADAPT model, by index.
Figure 12. Bootstap distributions and cumulative frequencies from ADAPT model, based on 1000 bootstrap runs. A) Jan 1 population size (number of fish (000s)); B) mean biomass (000s lbs) ; C) Spawning biomass (000s lbs)
Figure 13. Results from retrospective analysis of fishing mortality and population estimates in ADAPT model.
Figure 14. Predicted vs. observed annual catch at age from ASAP catch at age model.
Figure 15. Predicted vs. observed catch at age from ASAP catch at age model, by year. (Note that ages have been re-scaled to age+1 (age1=age0, etc.)).
Figure 16 . Observed (blue) vs. predicted (red) indices at age by survey from the ASAP catch at age model results.
Figure 17. Likelihood values by index from preferred ASAP model run.

Figure 18. $F_{mult}$ estimates from ASAP and $F_{age\ 2\text{-}4}$ from ADAPT (vpa) models. Bottom figure includes VPA F x ASAP selectivity for comparison purposes.
Figure 19. January 1 population abundance estimates from ASAP catch at age model and ADAPT VPA.
Figure 20. Biomass esimates (mt) from ASAP catch at age model and ADAPT vpa model.

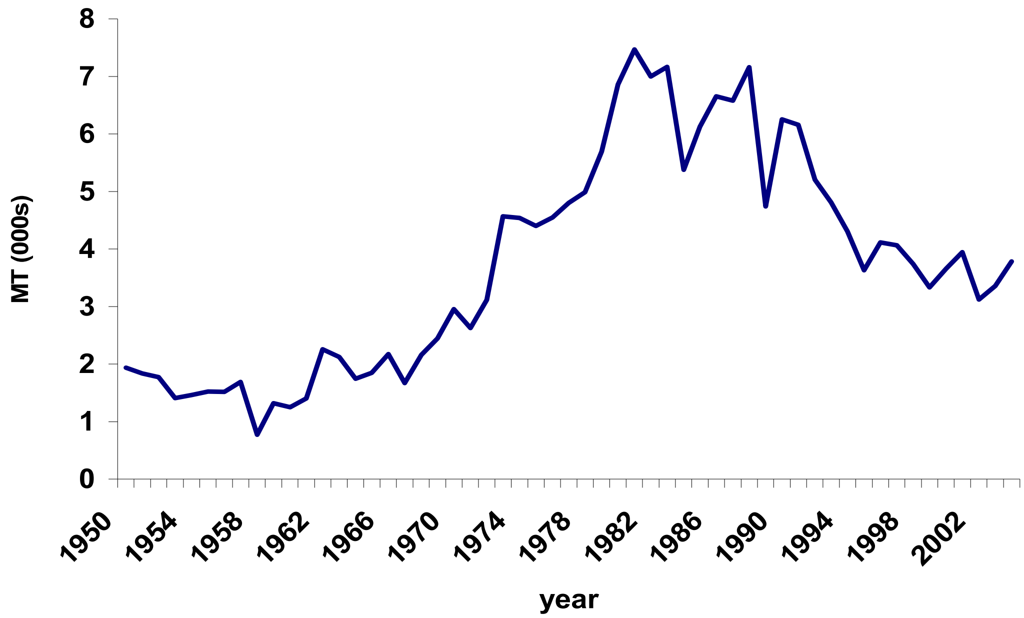



Figure 1. Times series of bluefish commercial landings (mt) along the Atlantic coast.

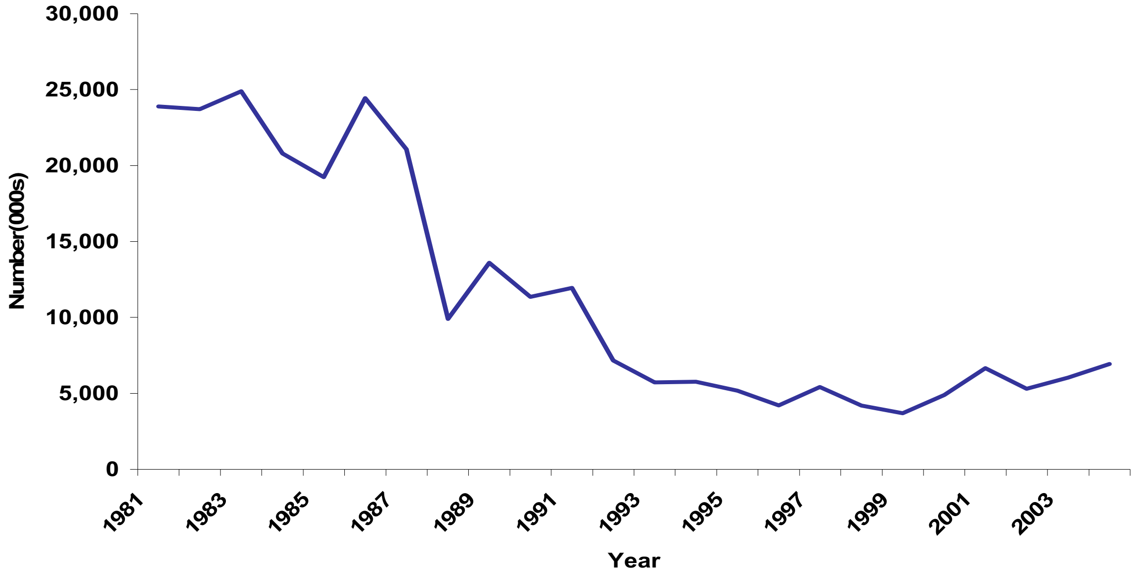



Figure 2. Times series of bluefish recreational landings (000s) along the Atlantic coast.

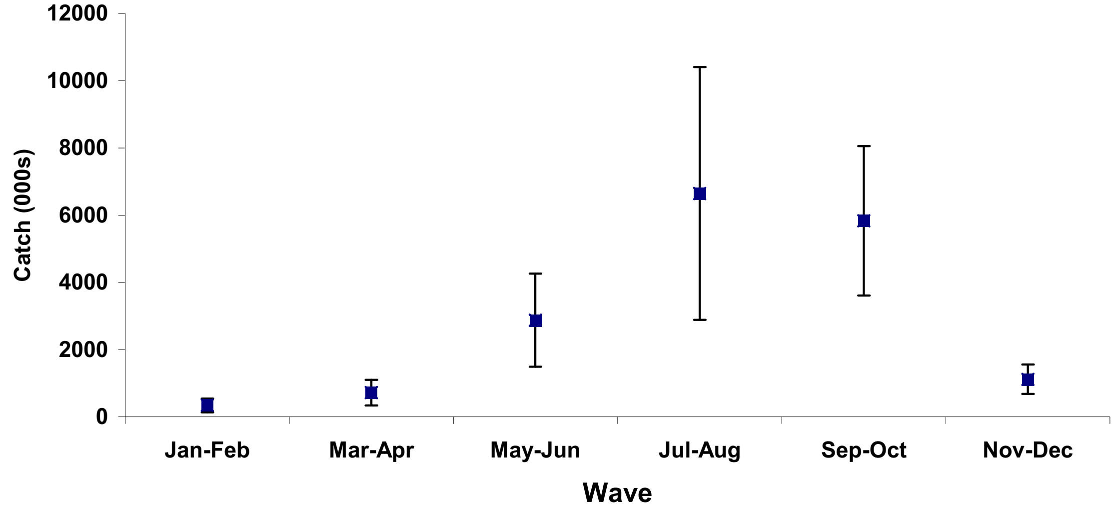
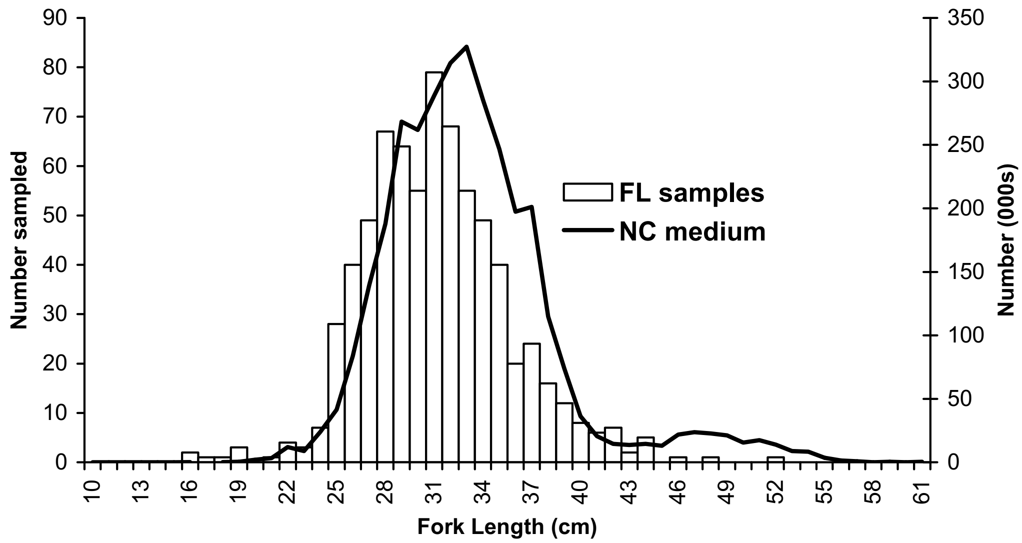



Figure 3 . Average ( ±1 std dev) bluefish recreational catch, by wave, 1982-2004.

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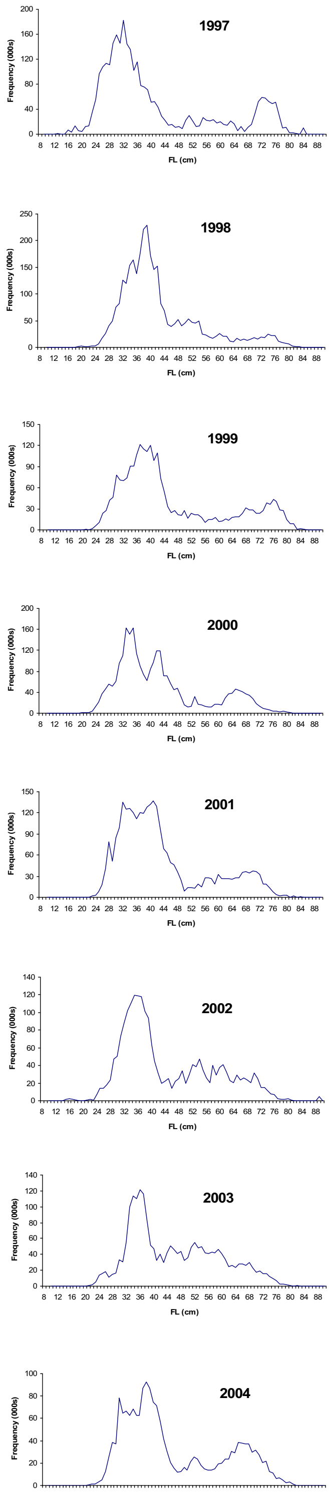



Figure 5. Length distribution of Atlantic coast bluefish commercial landings.

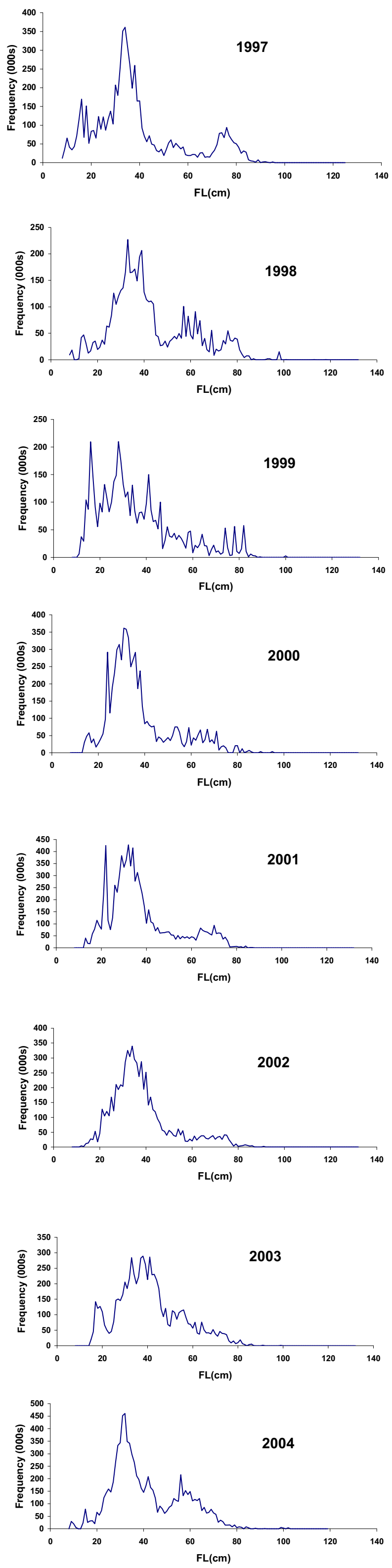
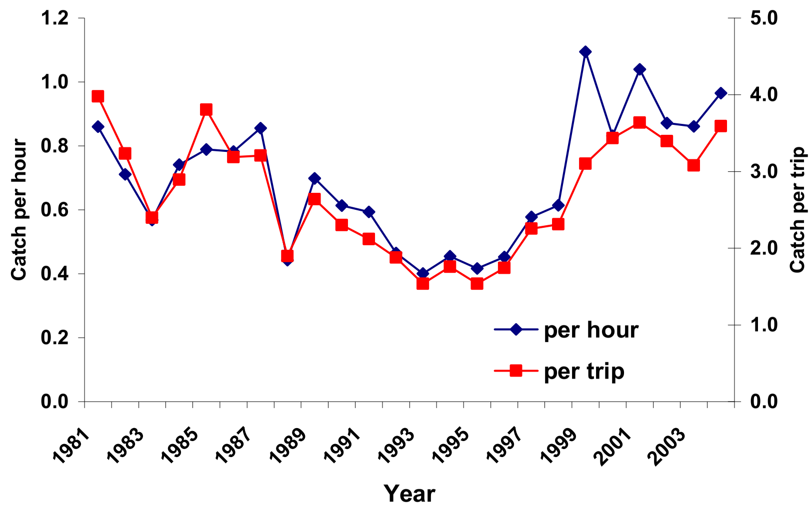



Figure 6. Length distributions of Atlantic coast bluefish recreational landings.



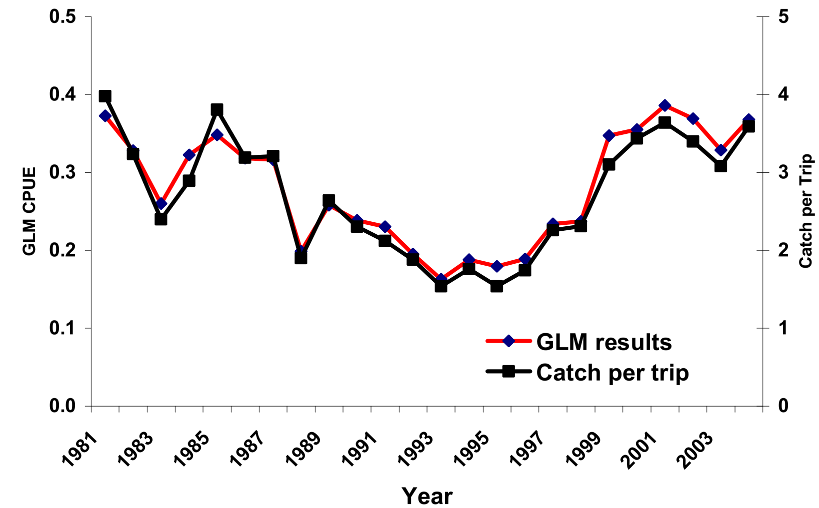
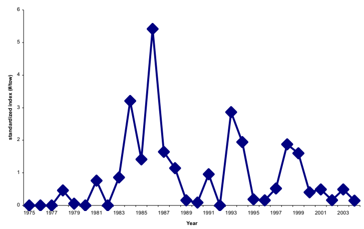



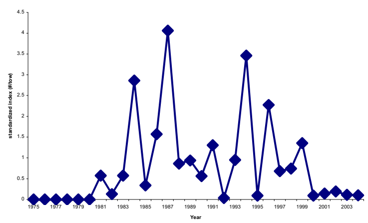

Figure 7. Bluefish recreational catch per effort from MFRSS estimates.

## Spring cohorts

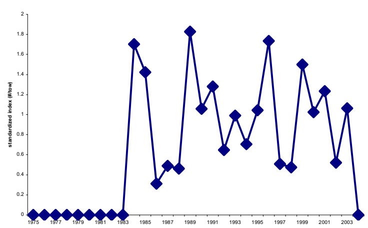
### MA fall trawl survey



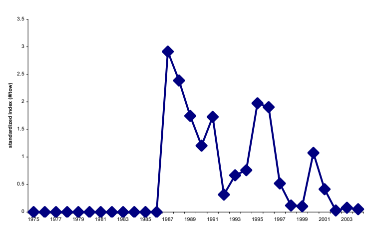
### RI trawl survey



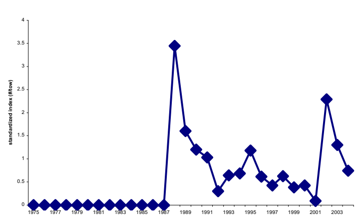
### CT trawl survey



### NY trawl survey



### NJ trawl survey



## Summer cohorts

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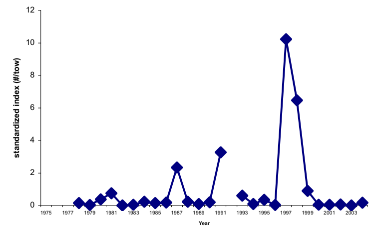
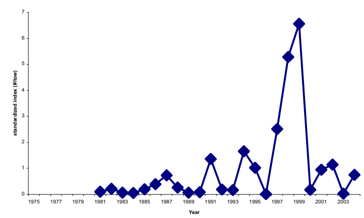
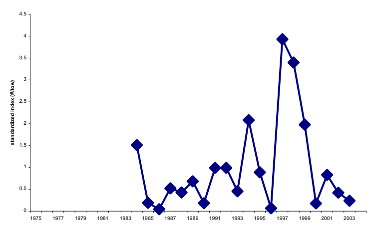


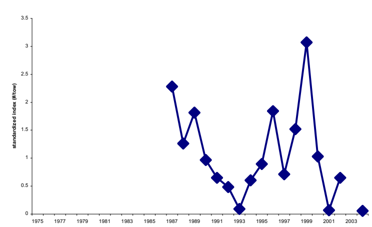

### RI trawl survey



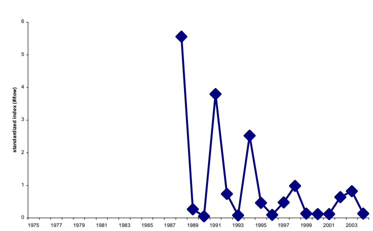
### CT trawl survey



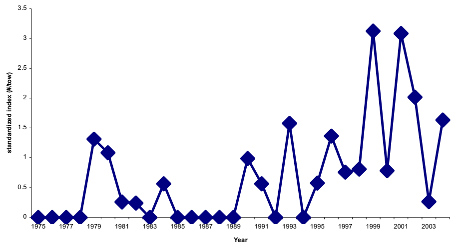
### NY trawl survey



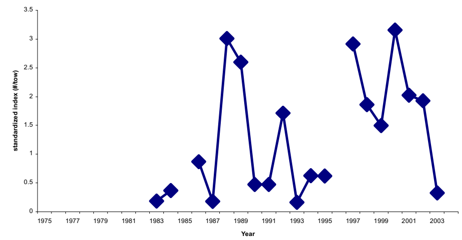
### NJ trawl survey



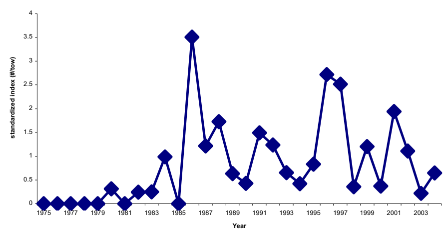
**DE adult survey**



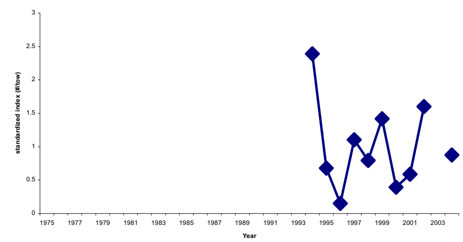
**DE juvenile survey**



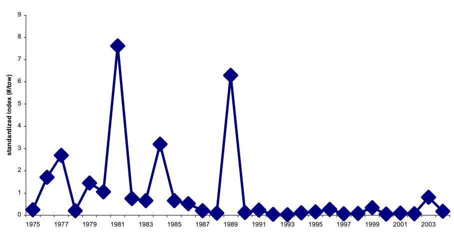
**DE juvenile survey**



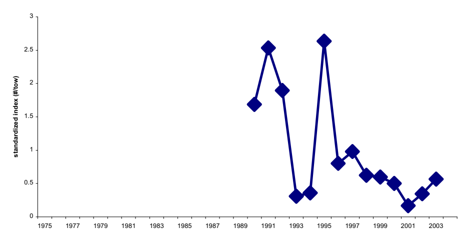
**VA Beach seine survey**



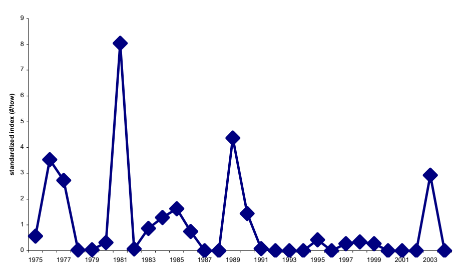
**NMFS Fall inshore**



**SEAMAP**



**NMFS Fall offshore**



**NMFS Fall inshore**

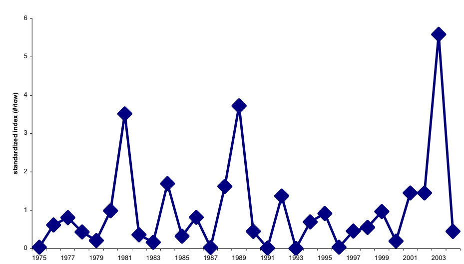


Figure 8. Age 0 spring and summer cohort by survey program, 1975-2004.
Indices standardized to the series mean.

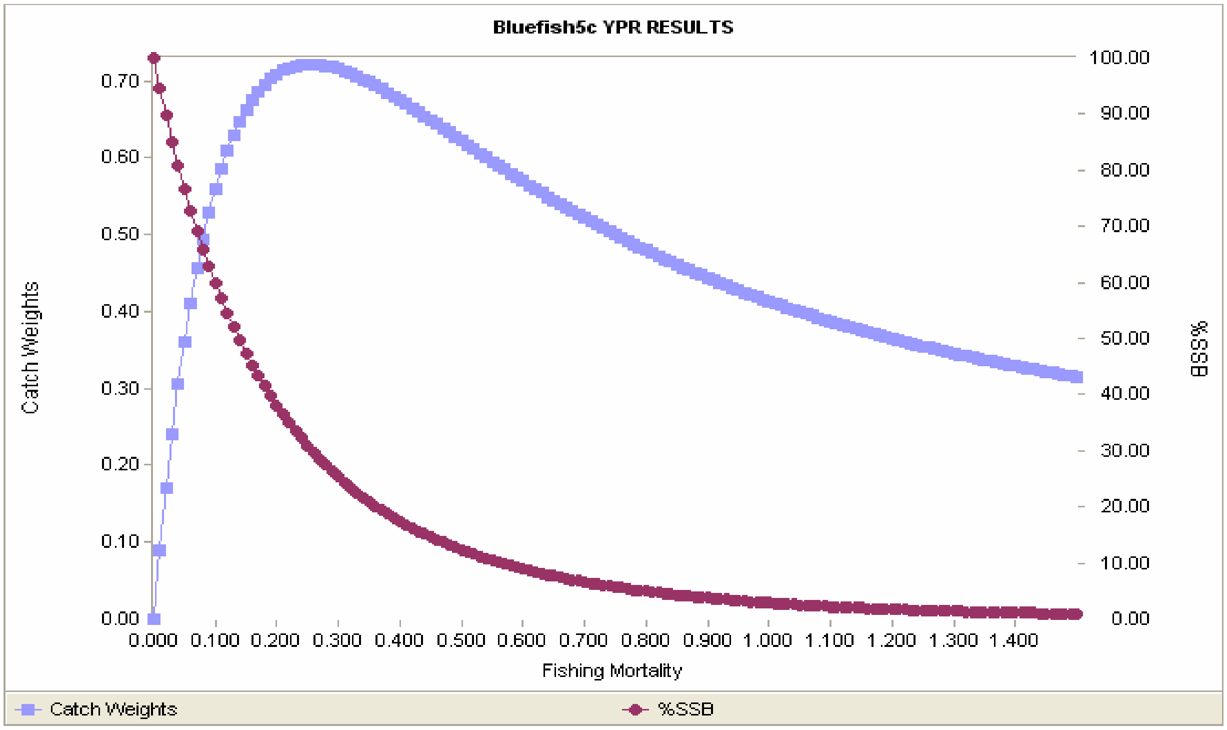



Figure 9. Yield per recruit and %SPR from Thompson-Bell yield per recruit model.

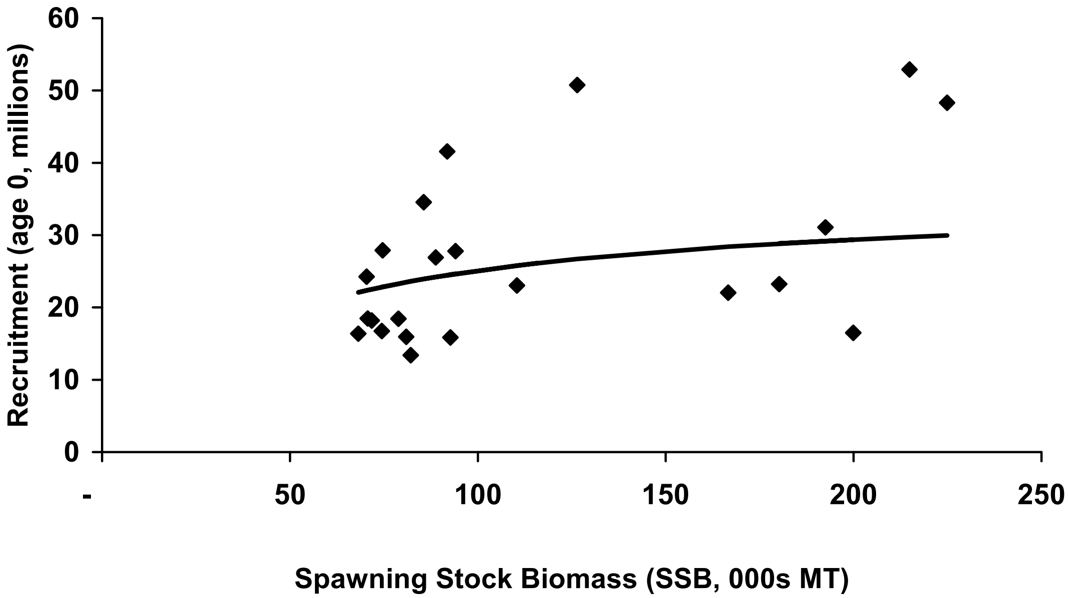



Figure 10. Stock-recruitment relationship for Atlantic coast bluefish fit to a Beverton-Holt S/R model. Stock and recruit estimates from ASAP model output.

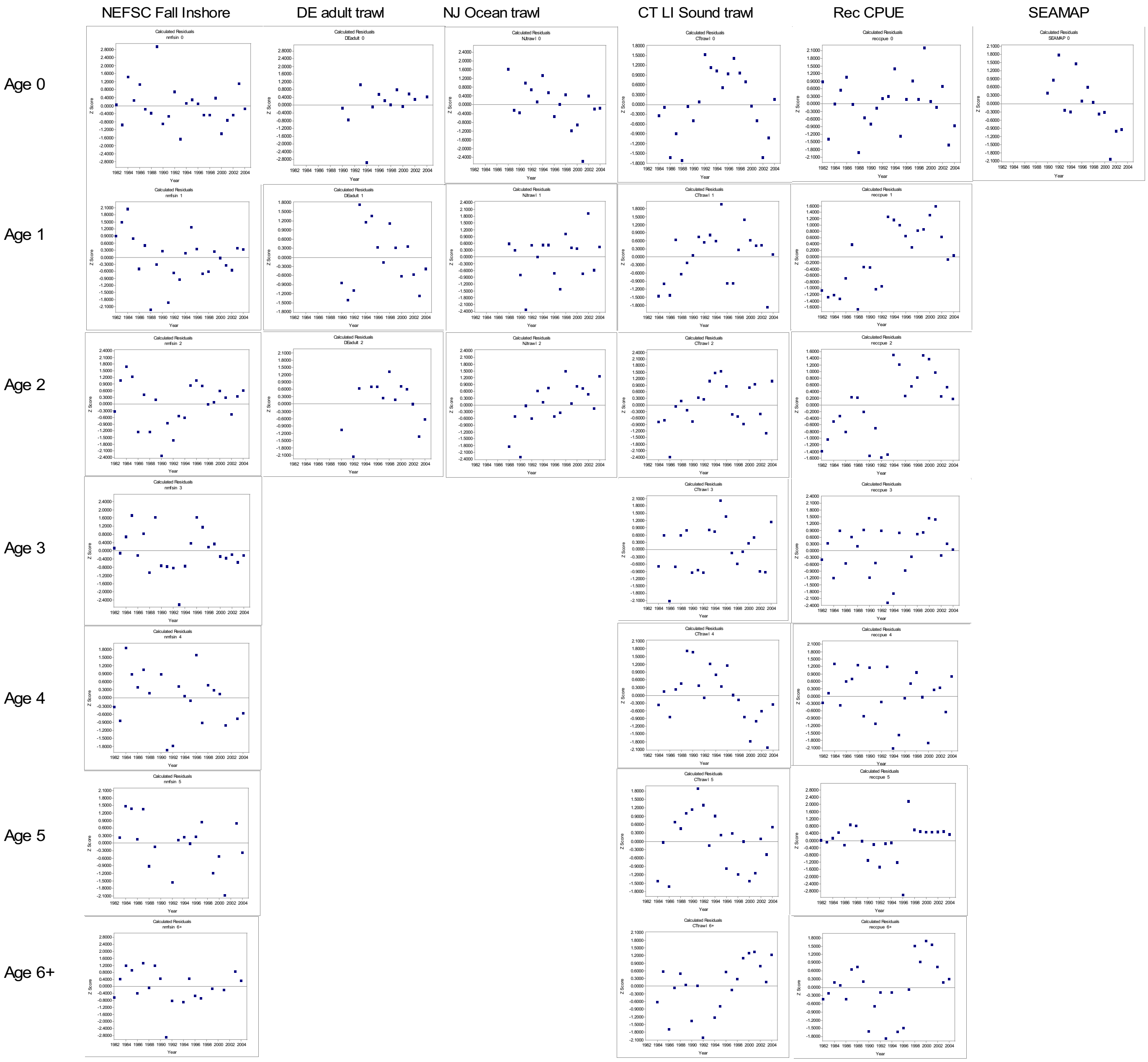



Figure 11. Residuals of survey index fits from ADAPT model, by index.

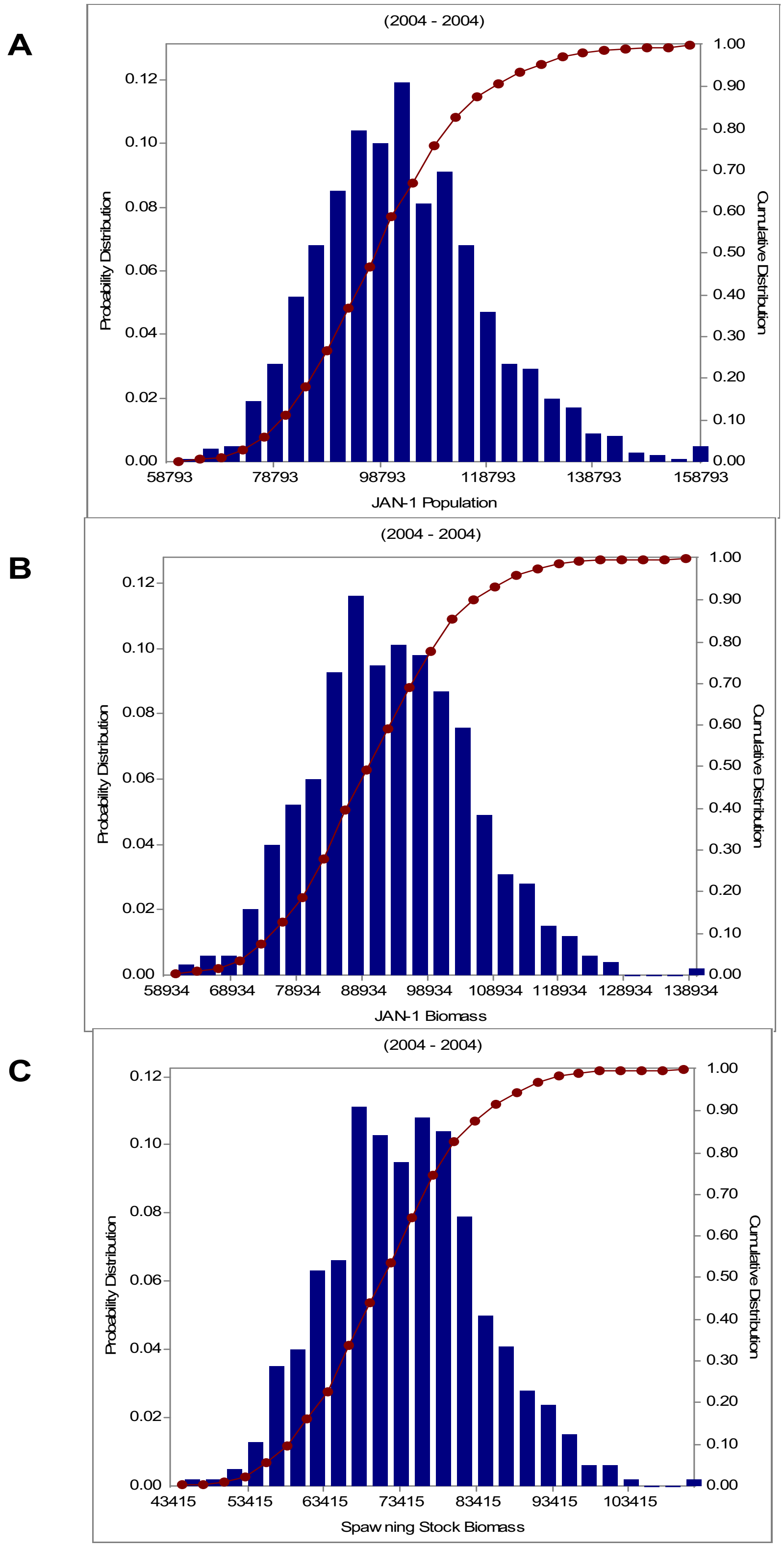



Figure 12. Bootstrap distributions and cumulative frequencies from ADAPT model, based on 1000 bootstrap runs. A) Jan 1 population size (numbers of fish (000s)) ; B) mean biomass (mt) C) spawning biomass (mt).

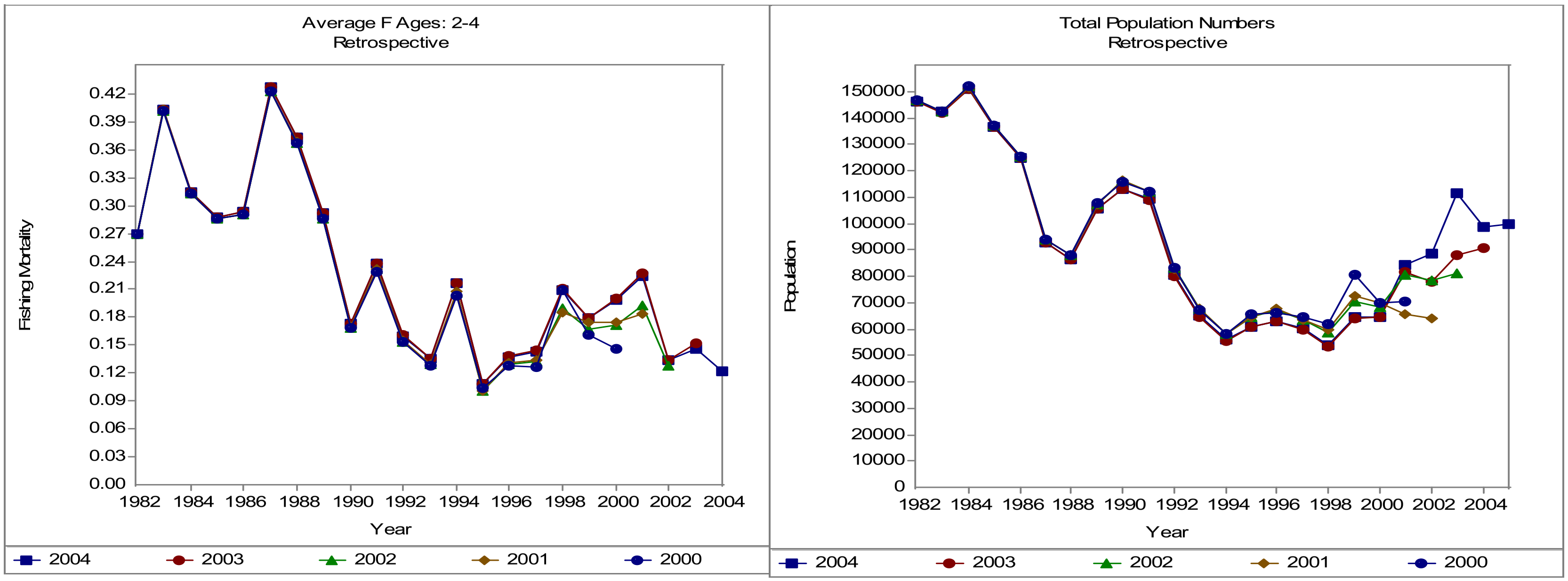



Figure 13. Results from retrospective analysis of fishing mortality and population estimates in ADAPT model.

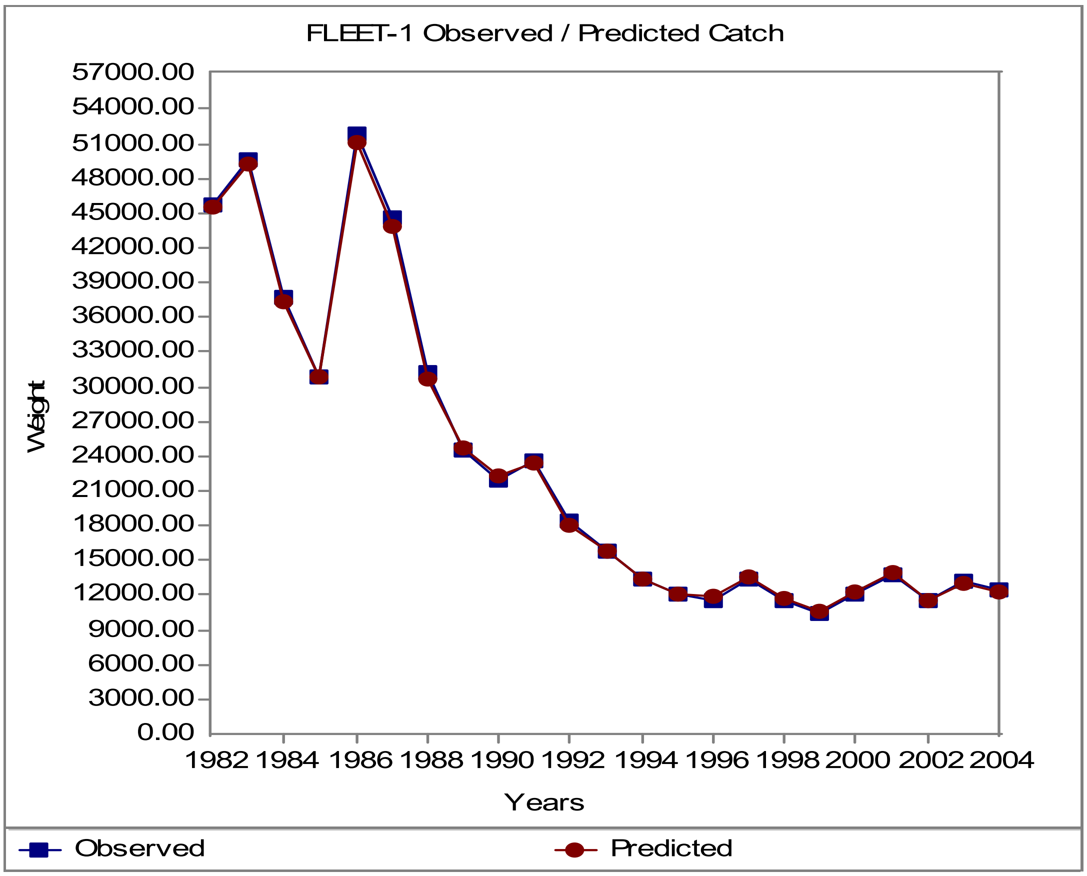



Figure 14. Predicted vs. observed annual catch at age from ASAP catch at age model.

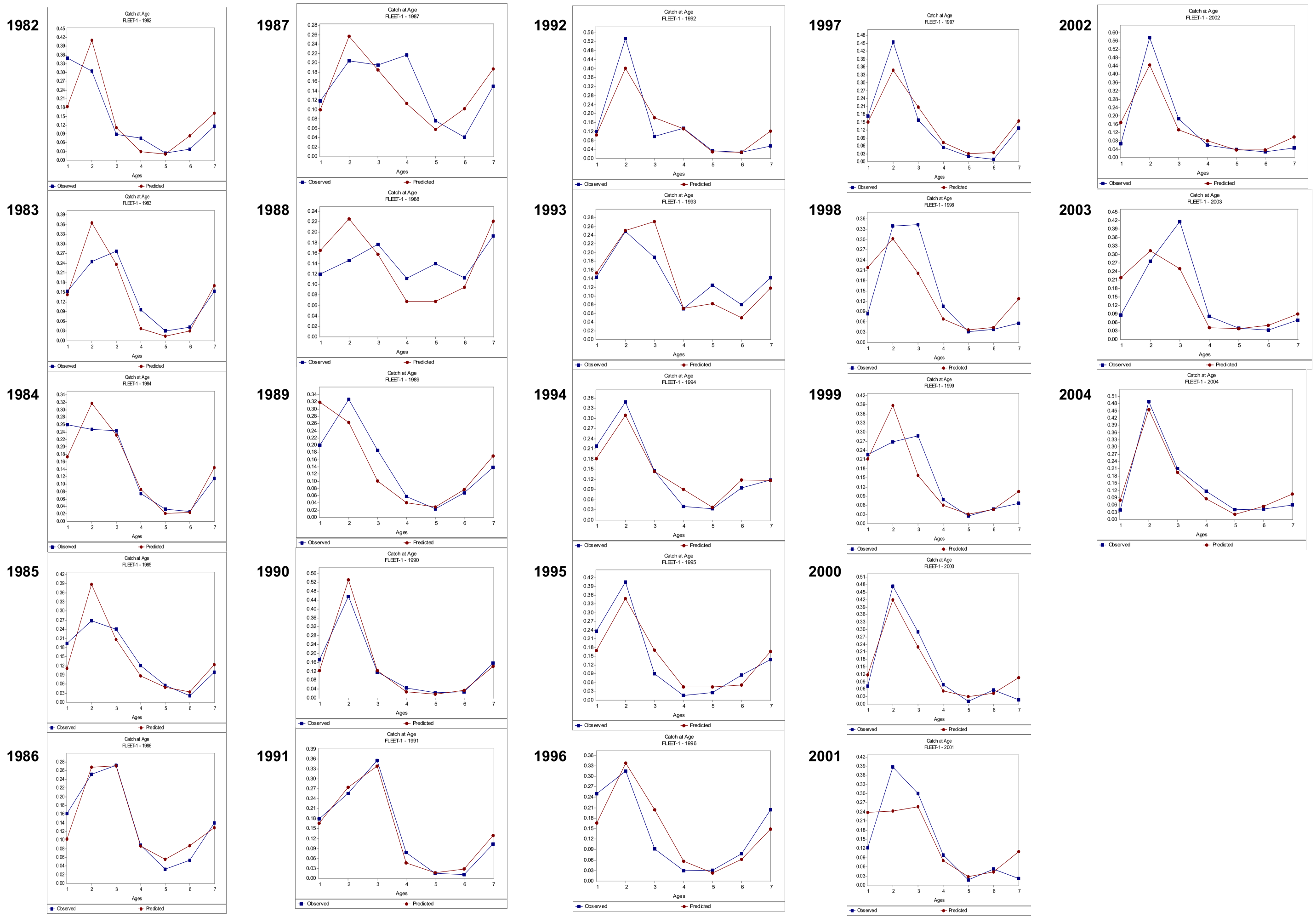



Figure 15. Predicted vs. observed catch at age from ASAP catch at age model, by year. (Note that ages on graph have been re-scaled to age +1 (age 1=age 0, etc.)

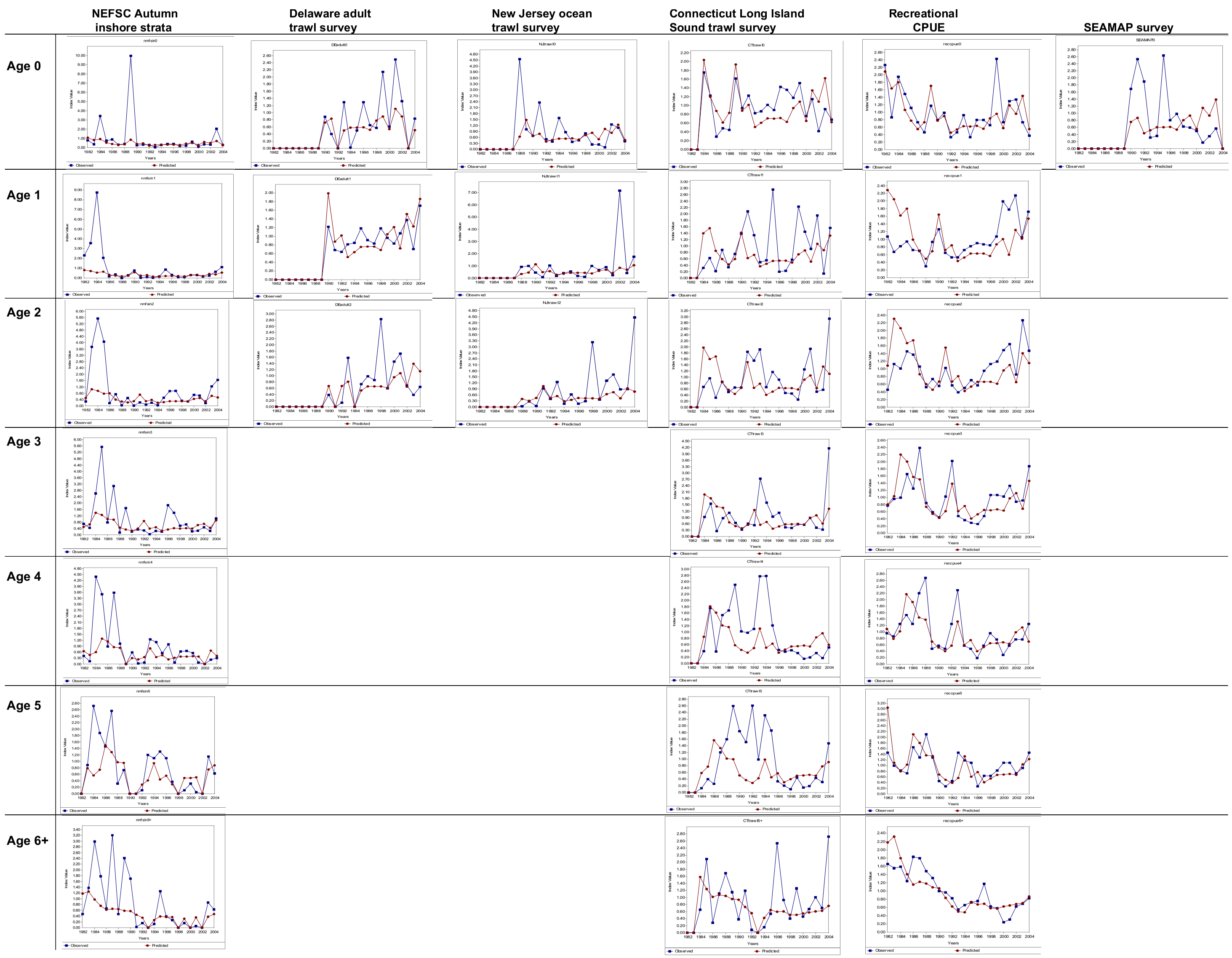



Figure 16 . Observed (blue) vs. predicted (red) indices at age by survey from the ASAP catch at age model results.

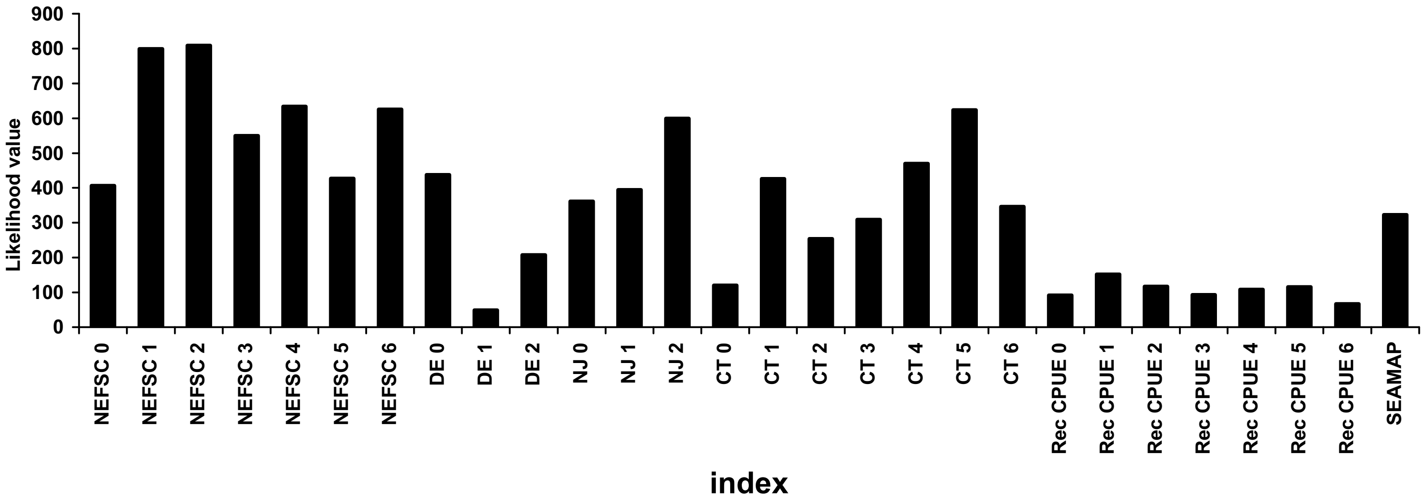



Figure 17. Likelihood values by index from preferred ASAP model run.

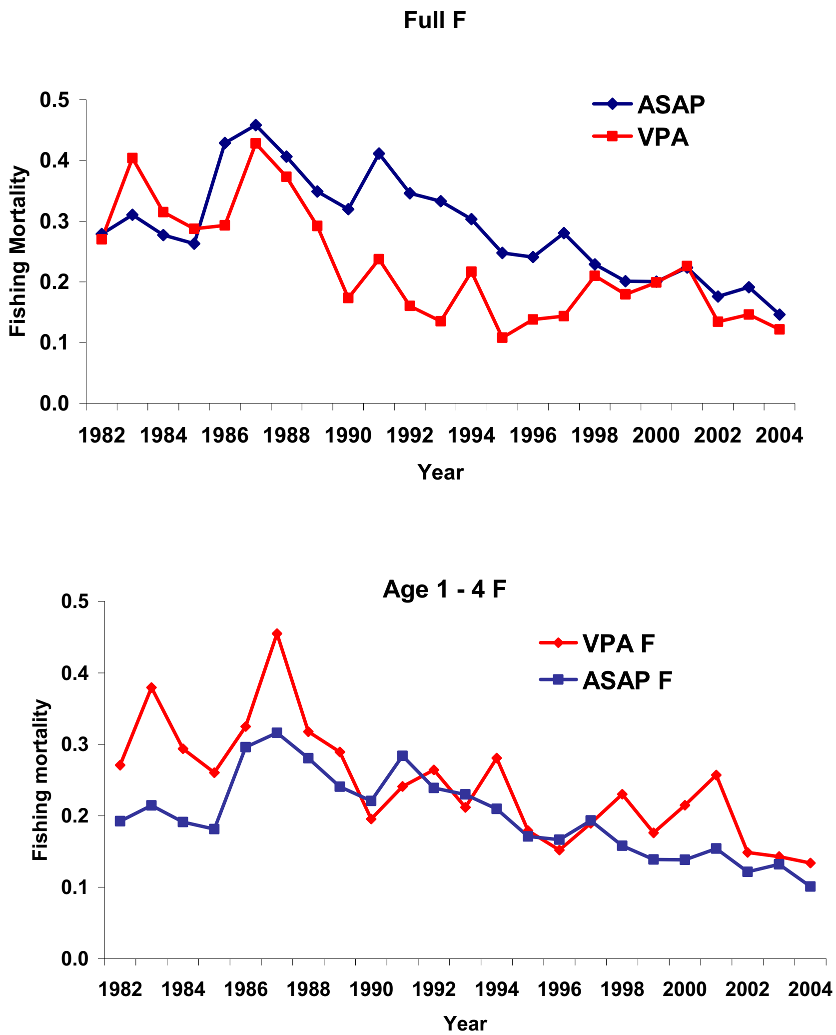



Figure 18. $F_{mult}$ estimates from ASAP and $F_{age\ 2\text{-}4}$ from ADAPT (vpa) models. Bottom figure includes age 1 to 4 average F for VPA and ASAP.

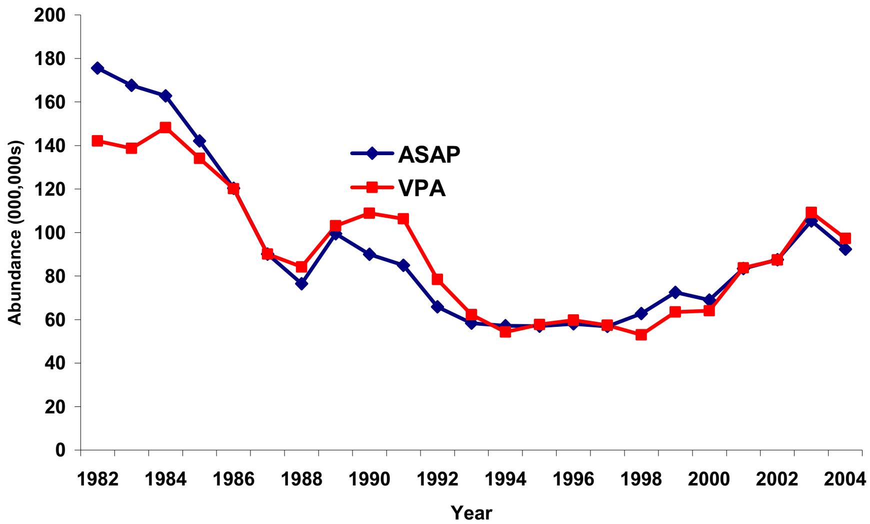



Figure 19. January 1 population abundance estimates from ASAP catch at age model and ADAPT VPA.

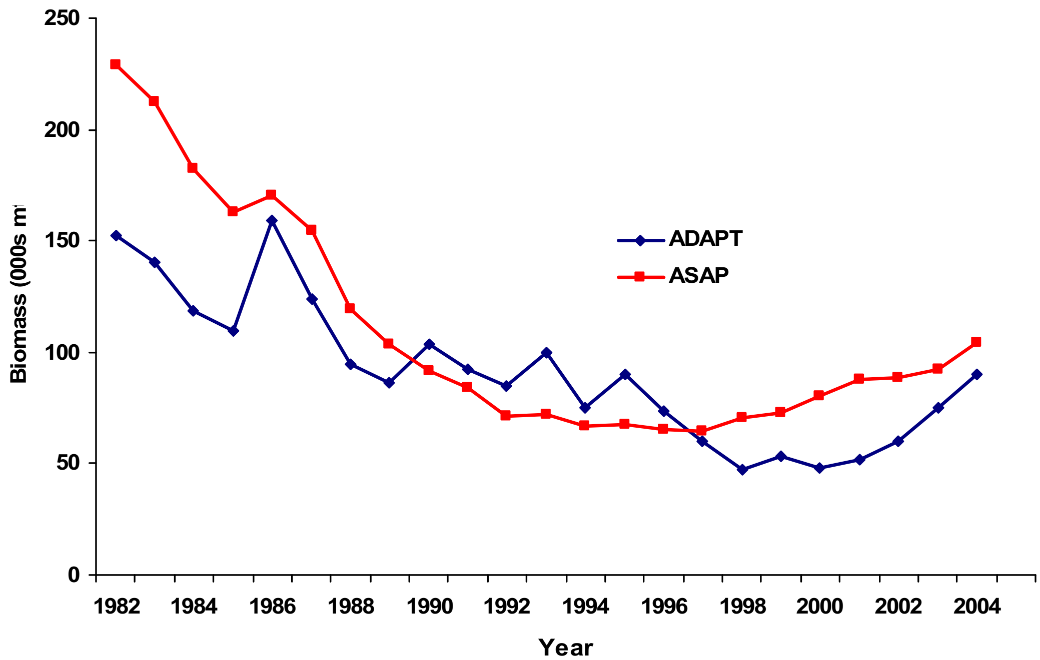



Figure 20. Biomass estimates (mt) from ASAP catch at age model and ADAPT vpa model.

## APPENDIX I - Other Models Tested for bluefish

The Bluefish Technical Committee evaluated several models for their appropriateness for assessing bluefish populations. The previous assessment used a surplus production model (ASPIC) which reviewers felt produced inadequate results as structured. The shortcomings of the survey data limited the model to the recreational CPUE series as the only index with adequate spatial coverage and size distribution. A re-examination of the model using this correct CPUE series did not resolve the problems of the previous assessment. The model solution remained unstable with slight changes in the starting values. The committee chose not to use the production model in the current bluefish assessment.

### Overview of Modified Delury (Catch-Survey) Model

The modified Delury or catch-survey model estimates a catchability coefficient to convert observed relative abundance indices to absolute abundance and fishing mortality rates (Collie and Sissenwine 1983; Conser and Idoine 1992; Collie and Kruse 1998). The model requires annual indices of population size in numbers for two life history stages (i.e., recruit and fully-recruited) estimated by research surveys, total annual fishery landings and discards in numbers, information on the partial recruitment of recruit size fish to the fully-recruited life stage (to partition $F$), and an estimate of instantaneous natural mortality. Other data needed are mean weights for each life stage and the relative selectivity of each life stage to the survey gear.

The modified Delury model is based on the equation:

$$N_{0,y+1} = (N_{0,y} + R_{0,y} - C_y)\, e^{-M}$$

where $N_{0,y+1}$ = fully-recruited stock size at the beginning of the year

$N_{0,y}$ = fully-recruited stock size at the beginning of the previous year

$R_{0,y}$ = recruitment in the previous year

$C_y$ = catch

$M$ = natural mortality

The equation assumes that a recruit is any animal smaller than the minimum size vulnerable to the fishery at the beginning of the survey year, and that will be fully-recruited to the fishery by the end of the survey year.

The catchability coefficient, calculated as

$$n'_{y'} = q_n N_{0y} e^{\eta t}$$

and

$$r'_{y'} = q_r R_{0y} e^{\delta t}$$

where $r'_y$ = observed research indices of recruit bluefish

$n'_y$ = observed research indices of fully-recruited bluefish

q = catchability coefficient of the research survey gear

$e^{\eta t}$ = log normally distributed random variable that represents survey measurement errors for recruits

$e^{\delta t}$ = log normally distributed random variable that represents survey measurement errors for fully-recruited indices

relates survey indices of abundance to absolute stock sizes.

Total mortality, $Z$, is estimated as

$$Z_{R+N,y} = \log_e\left[\frac{N_{0y} + R_{0y}}{N_{0,y+1}}\right]$$

Fishing mortality is calculated by solving the following equation for $F$

$$F=Z_{R+N,y}-M$$

or by using a harvest rate method

$$U_y = (C_y + Di) / ((R_y + N_y) * EXP(-M_y *(T_f - T_s)))$$

and then calculate $F$ from $U$ by trial using

$$U=F*(1-EXP(-Z))/Z$$

where $U$ = harvest rate

$C$ = landings

$D$ = discards

$T_s$ = timing of survey

$T_f$ = timing of catch.

### Delury Data Inputs and Results

#### MRFSS

The MRFSS CPUE index from 1982-2003 was transformed using a negative binomial transformation for all trips that targeted bluefish and non-targeted catch, and was partitioned into an age-0 (recruit) and age-1+ (fully-recruited) index to provide a measure of encounters with bluefish where A+B1+B2 = total catch. The timing of the survey and catch during the year was 0.58, which corresponds to peak catches and landings of bluefish. Natural mortality was included as 0.20. The total removals, as coastwide landings (A+B1) and discards (15% of B2), were included along with individual weights for recruits and fully-recruited fish from the MRFSS survey and commercial and recreational removals. The bootstrapping option was set at 2000.

#### Results with MRFSS Data

While recruit and fully recruited indices correlated relatively well, fully recruited CPUE and catch correlated poorly. Estimates of *F* were unreasonable and produced some negative estimates over the time series. Catchability was extremely low and estimates of stock size were unreasonable with the age-0 and age-1+ stock sizes equal in some years.

#### NEFSC Bottom Trawl Survey

The NEFSC trawl survey from 1982-2003, calculated as a geometric mean, was partitioned into an age-0 (recruit) and age-1+ (fully recruited) index to provide a measure of encounters with bluefish. The timing of the survey was 0.75 and peak catch during the year was 0.58. All other parameters are the same as for the model runs using MRFSS data. Age-0 bluefish were split into two spring and summer cohorts, with each index paired with the fully recruited index for additional model runs.

#### Results with NEFSC Bottom Trawl Survey

There was weak correlation between the recruit and fully recruited indices; and indices and catch. Estimates of *F* were unreasonable and produced some negative estimates over the time series. Estimates of stock size and biomass appeared unreasonable with the age-0 and age-1+ stock sizes equal in some years. In all cases the model was not able to complete all 2000 bootstraps without error.

### Modified Delury Conclusions

The Bluefish Technical Committee rejected the modified-Delury model for two main reasons. First, the model assumes that recruits are not exposed to *F* until they are fully recruited. The bluefish fishery cannot meet this assumption. Second, there are weak relationships between recruit and fully recruited indices; and between indices and catch. The weak relationships may potentially be due to *F* on recruits and weak adult index values. Most surveys are not designed to adequately sample adult bluefish.

### ASPIC Model

The ASPIC program (version 5.05) was used to estimate population biomass and fishing mortality for the Atlantic coast bluefish stock. ASPIC is a non-equilibrium surplus production model that can fit several catch-effort or abundance data series and has been used in the past several bluefish stock assessments and serves as the basis for the current FMP. The results of an ASPIC model for bluefish were reviewed in SARC 39 (June 2004) and it was concluded that the model was unstable and the calibration data was inappropriate. The Technical Committee revised the fisheries-dependent and catch data series for a re-evaluation of the production model. The model was fit to the 1982 – 2004 time series of bluefish total catch from along Atlantic Coast.

**ASPIC Model Calibration**

**Input Series**

The data series used in the ASPIC model included a fishery-independent index of relative biomass and a fishery-dependent series of weight-based catch-per-unit-effort. Annual estimates of bluefish weight per tow calculated from the NEFSC fall inshore survey for the 1982 - 2004 time period provided the fishery-independent biomass index. The fishery-dependent series was generated from the MRFSS intercept and catch estimate data as described in Section 4.2.1. The re-transformed year estimates from the GLM model were used for the recreational CPUE index.

**Output/Results**

**Parameter Estimates**

The bluefish stock was modeled using 1982 as the start year. The population growth rate, *r*, was estimated at 0.20. Carrying capacity, *K*, was estimated at 4,341,000 mt. The value of maximum sustainable yield, MSY, was 219,300 mt and the corresponding biomass, $B_{MSY}$, was 2,170,000 mt based on the optimum model results. The fishing mortality associated with the maximum sustainable yield, $F_{MSY}$, was estimated to be 0.10. Fishing mortality in 2004 was estimated at a value of $F_{2004}$=0.12. In 2005, the starting year biomass was predicted as $B_{2005}$=110,900.

**Goodness of Fit of Model Used**

Prager et. al. (1996) provided indicators of potential reliability of the fitted model, based on measures of contrast within the data. One is a coverage index, which indicates how widely stock biomass has varied between 0 and *K*, the carrying capacity. The coverage index ranges from 0 (least reliable) to 2 (most reliable). The nearness index indicates how closely a modeled stock has approached the biomass level producing MSY. This index ranges from 0 (least reliable) to 1 (most reliable). The optimum fit of the bluefish biomass-dynamic model yielded a coverage index of 0.03 and a nearness value of 0.54.

**Precision of Parameter Estimates**

Bootstrap trials (500 times) were run to provide an indication of the bias associated with the parameter estimates. The bootstrap parameter estimates were then used to calculate 80% confidence intervals (Prager 1994). Bootstrap results indicate that model parameters were estimated moderately to poorly. For example, the bootstrap analysis suggests there is an 80% probability that MSY is between 17,170 and 484,400 mt. The value for $F_{MSY}$ estimated by ASPIC has an 80% probability of lying between 0.049 and 0.14.

**Summary of ASPIC Model**

The working group felt the results of the ASPIC assessment were unreliable and not suitable to serve as the basis for management decisions. First, the ASPIC model assumed that the NEFSC autumn inshore bottom trawl survey index was representative of the available bluefish biomass, following methodology used in previous assessment work (Lazar and Gibson 2002; Lee 2003). As identified in the previous review, the NEFSC biomass index has been assumed to represent the average biomass for the respective years. The NEFSC length samples indicate that over 90% of the bluefish caught in the autumn inshore survey are less than 40-cm fork length, and therefore mostly age-0 and age-1 fish. Age samples from the commercial and recreational fisheries provide evidence that the ages observed in the fisheries are not limited to age-0 and age-1 fish (Boreman 1983; NEFSC 1994a, 1994b, 1997). As such, the NEFSC autumn inshore survey may be more suitable as a recruitment index than an index representative of the annual average fishable biomass (Boreman 1983; NEFSC 1994b). Additionally, there was a low correlation between the NEFSC index and recreational CPUE series (0.305).

There is also a lack of contrast in the catch and index data, as indicated by the low coverage index value. This points to poor information content in the data and contributes to higher imprecision of parameter estimates in the bootstrap analysis.

As a result of the problems encountered in the present iteration of the analysis, the Technical Committee dismissed the production model as the primary assessment model.

## APPENDIX II – Other surveys that capture bluefish

### New Hampshire

**NHFG Estuarine Juvenile Finfish Seine Survey**

The New Hampshire Fish and Game's (NHFG) Marine Fisheries Division developed an Estuarine Juvenile Finfish Seine Survey in 1997 to monitor the abundance of juvenile finfish in the state's estuaries. The seine survey samples fixed stations in the Great Bay Estuary and Hampton Harbor on a monthly basis from June to November. Bluefish have only been encountered in this survey during the months of July, August, and September. All of the fish were less than 21 cm in length indicating they were young-of-the-year. Significant numbers of bluefish were only observed in three years of this survey: 1999 – 76 bluefish were caught; 2000 – 7 bluefish were caught; and 2001 – 53 bluefish were caught.

### New Jersey

**NJDFW Delaware River Striped Bass Recruitment Survey**

The NJDFW Bureau of Marine Fisheries Delaware River Recruitment Survey monitors young-of-year striped bass found from the Salem Power Plant up to Newbold Island near Trenton, NJ. The survey, which began in 1980, provides an annual recruitment index for striped bass in the Delaware River. A 100-foot beach seine samples 32 fixed stations, bi-monthly, from late June through early November. The river is divided into three regions, each characterized by a distinct habitat type. Numbers of bluefish caught for the survey season range from 7 to 194. Distribution of juvenile bluefish caught in the survey usually depends on the amount of rainfall and sizes have ranged from 31 to 338 mm FL. The highest years of abundance were 1997, 1999, and 2001. The lowest years of abundance were 1996, 1994, and 2003. The majority bluefish catches occurred in the lower part of the river.

**NJDFW Delaware Bay Finfish Trawl Survey**

The NJDFW initiated a trawl survey in 1991 to survey finfish occurring in the shallow waters of the Delaware Bay. Eleven fixed stations are sampled monthly from April through October. Bluefish caught in the surveys have ranged in size from 34 to 259 mm FL. The survey has caught 82 bluefish in 937 samples. Numbers of bluefish caught for the survey season range from 1 to 24.

### Virginia

**VIMS Juvenile Finfish & Blue Crab Trawl Survey**

The Virginia Institute of Marine Science's (VIMS) Juvenile Finfish and Blue Crab Trawl Survey was started in 1955 to monitor seasonal trends of important juvenile fish and invertebrates. The survey design includes both fixed and stratified random stations, which are sampled monthly throughout the year. Sampling occurs in the Lower Chesapeake Bay and the Lower James, York, and Rappahannock Rivers.

**VIMS Juvenile Striped Bass Seine Survey**

VIMS started the juvenile striped bass seine survey in 1967 to monitor annual recruitment of juvenile striped bass occurring in the lower Chesapeake Bay. The survey is the second longest abundance index for striped bass in the U.S. Fixed stations along the shores of the James, York, and Rappahannock rivers are sampled monthly from July to September.

### North Carolina

**NCDMF Juvenile Trawl Survey**

NCDMF has conducted a juvenile fish trawl survey during May and June since 1979. The survey samples fixed stations from the Cape Fear River to the mouth of Albemarle and Currituck Sounds at depths <2 meters. One-minute tows are carried out using a trawl with a 3.2 m headrope and 3.2 mm (0.13 in) mesh cod end. Indices of abundance developed from this survey using data for shrimp, croaker, and spot have shown good correlation with landings for those species, but catches of bluefish were typically low. Catches ranged from 1-20 bluefish annually and fish ranged from 4-28 cm size classes. Arithmetic mean CPUEs ranged from 0.01-0.30 (1979-2004).

**North Carolina Pamlico Sound Trawl Survey**

NCDMF Pamlico Sound Trawl Survey began in 1987 and was initially designed to provide a long-term fishery-independent database for the waters of the Pamlico Sound, eastern Albemarle Sound and the lower Neuse and Pamlico rivers. However, in 1990 the Albemarle Sound sampling in March and December was eliminated, and sampling now occurs only in the Pamlico Sound and associated rivers and bays in June and September. From 1987-1989, a mongoose or falcon trawl was used for comparison with SEAMAP data of inshore and offshore catches. From 1990 to the present, fifty-two randomly selected stations (grids) are sampled over a two-week period, usually the second and third week of the month in both June and September. The stations sampled are randomly selected from strata based upon depth and geographic location. There are seven designated strata: Neuse River, Pamlico River, Pungo River, shallow (6-12 ft) and deep (>12 ft) Pamlico Sound east of Bluff Shoal, and shallow and deep Pamlico Sound west of Bluff Shoal. A minimum of three stations are maintained in each strata and a minimum of 104 stations are trawled every year. Tow duration is 20 minutes at 2.5 knots using the R/V Carolina Coast pulling double rigged demersal mongoose trawls (9.1 m headrope, 1.0 m x 0.6 m doors, 2.2 cm bar mesh body, 1.9 cm bar mesh cod end and a 100 mesh tailbag extension. All species are sorted and a total number and weight is recorded for each species. For target species, 30-60 individuals are measured and total weights are measured. The two catches from each tow are combined to form a single sample in an effort to reduce variability. The total number of bluefish caught annually ranged from 26 (1995) to 324 (2004), and in length from 4-42 cm size classes. Arithmetic mean CPUEs for 2003 (2.39) and 2004 (2.34) notably higher than in previous years.

**North Carolina Pamlico Sound Independent Gill Net Survey**

The Pamlico Sound Independent Gill Net Survey was initiated on March 1, 2001 and field sampling began in May 2001. The primary objective of the project is to provide independent relative abundance indices for key estuarine species in Pamlico Sound and adjacent rivers that can be incorporated into stock assessments and used to improve bycatch estimates, evaluate management measures, and evaluate habitat usage. A stratified random sampling design is used and each region is divided into four areas of similar sizes. The creation of areas assured that samples were distributed evenly throughout each region. Each of the four areas by region was sampled twice a month. The SAS procedure PLAN was used to randomly select sampling grids within each area. For each of the grids selected, both the shallow and deep strata were sampled with separate gangs of nets. A gang of nets consisted of 30-yard segments of 3, 3 ½, 4, 4 ½, 5, 5 ½, 6, and 6½ inch stretched mesh, for a total of 240 yards of nets.

Segment 1 was conducted during May 2001-June 2002, and Segments 2 & 3 were conducted during July-June 2003, 2004. Excluding menhaden, bluefish were the second most abundant species encountered and only exceeded by spot. The annual index of relative abundance or catch per unit effort (CPUE) was calculated as the number of fish at length per 12-hour soak time per 240 yards (gang) of net for both regions and strata combined. The total area of each region by strata was quantified using the one-minute by one-minute grid system and then used to weight the observed catches for calculating the abundance indices. Annual weighted catch per unit effort (CPUE) estimates and weighted catch per unit effort length distributions were calculated. Bluefish CPUE was 5.87 (1,512), 3.66 (1,293), & 4.92 (1,498) during Segments 1,2,3, respectively, and bluefish were the third most abundant species collected during each segment. A wide range of size classes were represented, as bluefish caught ranged from 122-765 mm FL.

## C. ASSESSMENT OF GOLDEN TILEFISH (*Lopholatilus chamaeleonticeps)* in the Middle Atlantic-Southern New England Region

A Report of the
Southern Demersal Working Group
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, MA 02543

## EXECUTIVE SUMMARY

Terms of Reference (TOR):

1. *Characterize the commercial catch including landings and discards. Characterize recreational landings.*
This TOR was completed. See Section 2.0.

2. *Estimate fishing mortality and total stock biomass for the current year and characterize the uncertainty of those estimates*.
This TOR was completed. See Section 3.0.

3. *Evaluate and either update or re-estimate biological reference points as appropriate*.
This TOR was completed. See Section 3.0.

4. *Where appropriate, estimate a constant TAC and/or TAL based on stock status for years following the terminal assessment year.* This TOR is covered in TOR 5.

5. *If projections are possible,*

a) *provide seven year projections of stock status under various TAC strategies and*

b) *evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.*

This TOR was not carried out because of concerns related to the wide variance and substantial bias in the projection realizations. See Section 4.0.

6. *Review, evaluate and report on the status of the research recommendations offered in the 1999 Science and Statistical committee reviewed assessment.*
This TOR was completed. See Section 7.0.

The current status for this stock is based on the ASPIC surplus production model employed in the past 2 assessments. The model is calibrated with CPUE series, as there are no fishery-independent sources of information on trends in population abundance. While the Working Group expressed concern about the projection phase of this analysis, we agreed to accept the estimates of current fishing mortality and biomass and associated reference points.

Total commercial landings (live weight) increased from less than 125 metric tons (mt) during 1967-1972 to more than 3,900 mt in 1979 and 1980. Annual landings have ranged between 666 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt (ranging from 506 to 874 mt). An annual quota of 905 mt was implemented in November of 2001. During the late 1970s and early 1980s Barnegat, NJ was the principal tilefish port; more recently Montauk, NY has accounted for most of the landings.

Three different series of longline effort data were analyzed. The first series was developed by Turner (1986) who used a general linear modeling approach to standardize tilefish effort during 1973-1982 measured in kg per tub (0.9 km of groundline with a hook every 3.7 m) of longline fished obtained from logbooks of tilefish fishermen. Two additional CPUE series were calculated from the NEFSC weighout (1979-1993) and the VTR (1995-2004) systems. The number of vessels targeting tilefish has declined over the time series; during 1995-2002, five vessels accounted for more than 70 percent of the total tilefish landings. The length of a targeted tilefish trip had been generally increasing until the mid 1990s. Since then there appears to have been a trend towards shortening of the tilefish trips.

Six market categories exist in the database. From smallest to largest they are: small, kitten, medium, large and extra large as well as an unclassified category. The proportion of landings in the kittens and small market categories increased in 1995 and 1996. Evidence of two strong recruitment events can be seen tracking through these market categories. The proportion of large market category has declined since the early 1980s. Commercial length sampling has been inadequate over most of the time series. However some commercial length sampling occurred in the mid to late 1990s. More recently there has been a substantial increase in the commercial length sampling in 2003 and 2004.

A small recreational fishery occurred briefly in the mid 1970s (< 100 mt annually) but subsequent recreational catches have been quite low for the last 25 years (i.e., less than 1 mt caught annually). Directed tilefish trips are rare. Since 2000, only 2 trips in the MRFSS data had tilefish reported as the primary target species.

Thirteen different configurations of the ASPIC model were examined. The accepted formulation began the analysis in 1973, separated the Turner, weighout and VTR CPUE into three series and fixed the $B1/B_{msy}$ ratio at 1 as the final run (run 13). The surplus production model indicates that the tilefish stock biomass in 2005 has improved since the last assessment in 1998. Total biomass in 2005 is estimated to be 72% of $B_{msy}$ and fishing mortality in 2004 is estimated to be 87% of $F_{msy}$. Biological reference points did not change greatly from the 1998 assessment. $B_{msy}$ is estimated to be 9,384 mt and $F_{msy}$ is estimated to be 0.21.

Results from several alternative models were also examined. Results from An Index Method (AIM) model also suggest that relative F is below the point that corresponds with a replacement ratio of 1 (stock replacement). MSY and Yield per recruit based biological reference points did not change greatly from the 1998 assessment. The Lagged Recruitment Survival Growth (LRSG) model produced results similar to the ASPIC surplus production model calibrated with the single linked CPUE series. However commercial length data indicate that increases in total biomass are predominantly due to a strong 1999 year class. Most of the commercial catch over the 2002-2004 period was derived from this year class.

Several ASPIC projections employing a constant TAC strategy, including the current TAC of 905 mt were examined Each of these analyses exhibited wide variance and substantial bias and, in many cases, produced estimates of biomass and F at maximum or minimum model boundary conditions. The projections are too uncertain to form the basis for evaluating likely biomass recovery schedules relative to $B_{msy}$ under various TAC strategies. The Working Group does note, however, that stock biomass in 2005 (72% of $B_{msy}$) is above that projected for 2005 in the 1998 assessment (59% of $B_{msy}$). Thus, the existing TAC of 905 mt appears to have sufficiently constrained F to allow stock biomass to increase towards $B_{msy}$.

There are two major sources of uncertainty affecting our perception of current stock status. The biomass-based models (ASPIC, AIM and LRSG) use the CPUE series as an index of population size. The Working Group considered these models and expressed concerns over whether the CPUE in this fishery may be as much a reflection of changes in fishing practices and changes in spatial distribution of the fish rather than fluctuations in population size. The catch-length model attempts to reconcile recent fishing mortality rates with a less than expected representation of larger fish in the catch. Because there are no fishery-independent data on trends in population biomass and size structure, the model must assume that the length composition of the catch will represent the extent of large fish in the population assuming a flat topped partial recruitment pattern. Working Group comments are included as Appendix C1.

## 1.0 INTRODUCTION

Golden tilefish, *Lopholatilus chamaeleonticeps*, inhabit the outer continental shelf from Nova Scotia to South America, and are relatively abundant in the Southern New England to Mid-Atlantic region at depths of 80 to 440 m. Tilefish have a narrow temperature preference of 9 to 14 C. Their temperature preference limits their range to a narrow band along the upper slope of the continental shelf where temperatures vary by only a few degrees over the year. They are generally found in and around submarine canyons where they occupy burrows in the sedimentary substrate. Tilefish are relatively slow growing and long-lived, with a maximum observed age of 46 years and a maximum length of 110 cm for females and 39 years and 112 cm for males (Turner 1986). At lengths exceeding 70 cm, the predorsal adipose flap, characteristic of this species, is larger in males and can be used to distinguish the sexes. Tilefish of both sexes are mature at ages between 5 and 7 years (Grimes et. al. 1988).

Golden Tilefish was first assessed at SARC 16 in 1992 (NEFSC 1993). The Stock Assessment Review Committee (SARC) accepted a non-equilibrium surplus production model (ASPIC). The ASPIC model estimated biomass-based fishing mortality (F) in 1992 to be 3-times higher than $F_{msy}$, and the 1992 total stock biomass to be about 40% of $B_{msy}$. The intrinsic rate of increase (r) was estimated at 0.22.

The Science and Statistical (S&S) Committee reviewed an updated tilefish assessment in 1999. Total biomass in 1998 was estimated to be 2,936 mt, which was 35% of $B_{msy}$ = 8,448 mt. Fishing mortality was estimated to be 0.45 in 1998, which was about 2-times higher than $F_{msy}$ = 0.22. The intrinsic rate of increase (r) was estimated to be 0.45. These results were used in the development of the Tilefish Fishery Management Plan (Mid-Atlantic Fishery Management Council 2000). The Mid-Atlantic Fishery Management Council implemented the Tilefish Fishery Management Plan (FMP) in November of 2001. Rebuilding of the tilefish stock to $B_{msy}$ was based on a ten-year constant harvest quota of 905 mt.

**TOR 1*: Characterize the commercial catch including landings and discards. Characterize recreational landings.***

## 2.0 DATA SOURCES

### Commercial catch data

Total commercial landings (live weight) increased from less than 125 mt during 1967-1972 to more than 3,900 mt in 1979 and 1980 (Table C1, Figure C1). Landings stabilized at about 2,000 mt during 1982-1986. An increase in landings occurred in 1987 to 3,200 mt but subsequently declined to 450 mt in 1989. Annual landings have ranged between 454 and 1,838 mt from 1988 to 1998. Landings from 1999 to 2002 were below 900 mt (ranging from 506 to 874 mt). An annual quota of 905 mt was implemented in November of 2001. Landings in 2003 and 2004 were over the quota at 1,130 and 1,182 mt respectively. Over 75% of the landings came from Statistical Areas 537 and 616 since

1991 (Table C2). Since the 1980s, over 85% of the commercial landings of tilefish in the MA-SNE region have been taken in the longline fishery (Table C3, Figure C2). During the late 1970s and early 1980s Barnegat, NJ was the principal tilefish port; more recently Montauk, NY has accounted for most of the landings. The shift in landings can be seen in the proportion of the landings by state in Table C4 and Figure C3. In the late 1970s and earlier 1980s a greater proportion of the landings were taken in quarters 1 and 2 (Table C5, Figure C4). Recent landings have been relatively constant over the year.

**Commercial discard data**

Very little discarding (< 1%) of tilefish was reported in the vessel trip report (VTR) from longline vessels that target tilefish and there is little reported discarding of tilefish in the trawl fishery in the VTR data (Table C6). The highest trawl reported total discard of tilefish was 13 mt in 2003. Observer trawl data did not produce a reliable discard estimates for tilefish. Discard to kept ratios for trawl trips that either kept or discarded tilefish in the observer data varied from 0 in 1993 to 1.4 in 2001 (Table C7). Since 1989, twelve of the sixteen years had less than 15 trips sampled that caught tilefish.

**Commercial CPUE data**

Analyses of catch (landings) and effort data were confined to the longline fishery since directed tilefish effort occurs in this fishery (e.g. the remainder of tilefish landings are taken as bycatch in the trawl fishery). Most longline trips that catch tilefish fall into two categories: (a) trips in which tilefish comprise greater than 90% of the trip catch by weight and (b) trips in which tilefish accounted for less than 10% of the catch. Effort was considered directed for tilefish when at least 75% of the catch from a trip consisted of tilefish (NEFSC 1993).

Three different series of longline effort data were analyzed. The first series was developed by Turner (1986) who used a general linear modeling approach to standardize tilefish effort during 1973-1982 measured in kg per tub (0.9 km of groundline with a hook every 3.7 m) of longline obtained from logbooks of tilefish fishermen. Two additional CPUE series were calculated from the NEFSC weighout (1979-1993) and the VTR (1995-2004) systems as well as a combined 1979-2004 series. Effort from the weighout data was derived by port agents' interviews with vessel captains whereas effort from the VTR systems comes directly from mandatory logbook data. In this assessment and in the 1998 tilefish assessment we used Days absent as the best available effort metric. In the 1998 assessment an effort metric based on Days fished (average hours fished per set / 24 * number of sets in trip) was not used because effort data were missing in many of the logbooks and the effort data were collected on a trip basis as opposed to a haul by haul basis. For this assessment effort was calculated as:

Effort = Days absent - Number of trips,

where, Days absent = (time & date landed - time & date sailed).
For some trips, the reported days absent were calculated to be a single day. This was considered unlikely, as a directed tilefish trip requires time for a vessel to steam to near the edge of the continental shelf, time for fishing, and return trip time (Grimes et al.

1980). Thus, to produce a realistic effort metric based on days absent, a one day steam time for each trip (or the number of trips) was subtracted from days absents and therefore only trips with days absent greater than one day were used.

The NEFSC Weighout and VTR CPUE series were standardized using a general linear model (GLM) incorporating year and individual vessel effects (Mayo et al. 1994). The CPUE was standardized to an individual longline vessel and the year 1984; the same year used in the last assessment. For the VTR series the year 2000 was used as the standard. Model coefficients were back-transformed to a linear scale after correcting for transformation bias (Granger and Newbold 1977). The full GLM output for the Weighout CPUE series is included as Appendix C2 and the full GLM output for the VTR CPUE series is included as Appendix C3.

The number of vessels targeting tilefish has declined over the time series (Table C8, Figure C5); during 1995-2002, five vessels accounted for more than 70 percent of the total tilefish landings (Table C9, Figure C6). In 2003 and 2004 there appears to be an increase in the number of vessels targeting tilefish. The length of a targeted tilefish trip had been generally increasing until the mid 1990s. Since then there appears to have been a trend towards decreasing trip length (Figure C5). In the weighout data the small number of interview is a source of concern; very little interview data exists at the beginning of the time series (Table C8, Figure C7). The 5 dominant tilefish vessels make up almost all of the VTR data with the exception of 2004 when there appears to be more vessels targeting tilefish (Figure C6). In some years there were higher total landings reported in the VTR data than the Dealer data for the 5 dominant tilefish vessels.

The number of targeted tilefish trips declined in the early 1980s while trip length increased (Figures C5 and C8). More recently the number of trips became relatively stable as trip length decreased. The interaction between the number of vessels, the length of a trip and the number of trips can be seen in the total days absent trend in Figure C8. Total days absent remained relatively stable in the early 1980s, but then declined at the end of the weighout series (1979-1994). In the beginning of the VTR series (1994-2004) days absent increased through 1998 but declined thereafter. Figure C8 also shows that a smaller fraction of the total landings were included in the calculation of CPUE compared to the VTR series.

Figure C9 illustrates difference between the nominal CPUE and vessel standardized (GLM) CPUE with the weighout and VTR data combined. A large increase in CPUE can be seen in both series in recent years. CPUE trends are similar for most vessels that targeted tilefish (Figure C10). The sensitivity of the GLM model to sporadic vessels entering the CPUE series was tested by limiting the CPUE data set to vessels that were represented for at least 2 years, 3 years, 4 years, 5 years, and 6 years (Figures C11 to C15). This trimming of the data had very little influence on the resulting standardized GLM CPUE trend (Figure C16).

Very little CPUE data exist for New York vessels in the 1979-1994 weighout series despite the shift in landing from New Jersey to New York before the start of the VTR series in 1994. The small amount of overlap between the weighout and VTR series is illustrated in Figures C17 and C18. Splitting the weighout and VTR CPUE series can be justified by the differences in the way effort was measured and difference in the tilefish fleet between the series. In breaking up the series we omitted 1994 because there were very little CPUE data. The sparse 1994 data that existed came mostly from the weighout system in the first quarter of the year. Very similar trends exist in the four years of overlap between Turner (1986) CPUE and the weighout series (Figure C19).

A month vessel interaction was significant but explained only a small amount of the total sum of squares (6%*).* Adding a month - vessel interaction term to the GLM model had very little influence on the results (Figure C20). In addition, limiting the VTR series to the 5 dominant tilefish vessels also had little influence on GLM results. The GLM output for the weighout and VTR CPUE series standardized for individual vessel effects can be seen in Appendix C2 and C3.

Since 1979, the tilefish industry has changed from using cotton twine to steel cables for the backbone and from J hooks to circle hooks. In light of possible changes in catchability associated with these changes in fishing gear, the working group considered that it would be best to use the three available indices separately rather than combined into one or two series. The earliest series (Turner 1986) covered 1973-1982 when gear construction and configuration was thought to be relatively consistent. The Weightout series (1979-1993) overlapped the earlier series for four years and showed similar patterns (Figure C19) and is based primarily on catch rates from New Jersey vessels. The VTR (1995-2004) series is based primarily on information from New York vessels.

**Commercial market category and size composition data**

Six market categories exist in the database. From smallest to largest they are: small, kitten, medium, large and extra large as well as an unclassified category. In 1996 and 1997, the reporting of tilefish by market categories increased, with the proportion of unclassified catch declining to less than 20% (Table C10, Figure C21). The proportion of landings in the small and kitten market categories increased in 1995 and 1996. Small and kitten market categories had similar length distributions and samples were combined. Evidence of several strong recruitment events can be seen tracking through the market category proportions (Figures C21 and C22). The proportion of the large market category has declined since the early 1980s (Figure C22). Landings data obtained directly from the New York tilefish industry shows a similar decline in the proportion of the large market category between 1980 and 1990 (Figure C23).

Since 2000 commercial length samples from New York were measured in total length. All other commercial tilefish were measured in fork length. In 2005 port agents measured both total and fork length from 345 fish to determine a total to fork length conversion (Figure C24). A 45 cm fish has about a 2 cm difference between total and fork length. All total length measurement were converted to fork length using the total length to fork length regression.

Extensive size sampling was conducted in 1976-1982 (Grimes *et al.* 1980, Turner 1986) however that data are not available by market category. Since then commercial length sampling has been inadequate in most years (Table C10). However some commercial length sampling occurred in the mid to late 1990s. More recently there has been a substantial increase in the commercial length sampling in 2003 and 2004 (Table C10). Commercial length sampling in New York has also increased since the last assessment in 1998. The large and medium market category length frequencies appear to have been relatively stable for years when more than 100 fish were measured (Figures C25 and C26). However the small market category exhibits shifts in the size distribution in certain years as strong year classes move through the fishery (Figure C27). The tracking of a year class can be seen as the cohort grows over the year in 2002 and 2003 (Figure C28).

The loligo-scup small mesh trawl fishery catches smaller tilefish than longline gear. This can be seen in many of the length frequency distributions of smalls and kittens for the trawl gear (Figure C29). Therefore trawl length frequency distribution where not used to characterize the catch (Table C11). Longline tilefish fishermen often receive forecasts from the draggers of when a strong year class will be entering the fishery.

Commercial length frequencies were expanded for years where sufficient length data exist (1995-1999 and 2002-2004) (Table C10). The large length frequency samples from 1996 to 1998 were used to calculate the 1995 to 1999 expanded numbers at length while the large length samples from 2001 and 2003 were used to calculate the 2002 expanded numbers at length. Evidence of strong 1993 and 1999 year classes can be seen in the expanded numbers at length in the years when length data existed (1995-1999 and 2002-2004) (Figure C30). The matching of modes in the length frequency with ages was done using the Turner (1986) aging study. At the end of 2004 the 1999 year class can be seen growing into the medium market category (Figure C30). In recent years it appears that most of the catch is made up of this 1999 year class. An increase in the landings and CPUE can be seen when the 1993 and 1999 year classes recruit to the longline fishery.

Recently 1,409 commercial lengths were taken from 17 hauls on 3 tilefish longline observer trips from three different vessels (October 2004, November 2004, and January 2005) (Figure C31). The observer length frequency data show slightly larger fish than in the expanded commercial length data, which could be explained by growth of the cohort since the trips were done at the end of the year (Figure C32). A comparison between recent commercial expanded length data to commercial length data collected by Turner et al. (1983) from 1974-1982 shows a shift in the landings to smaller fish (Figure C33).

### Recreational data

A small recreational fishery occurred briefly in the mid 1970s (< 100 mt annually, Turner 1986) but subsequent recreational catches have been quite low for the last 25 years (i.e., less than 1 mt caught annually) (Table C12). Party and charter boat vessel trip reports also show low numbers of tilefish being caught since 1994 (Table C13). Directed tilefish trips are rare. Since 2000, only 2 trips in the MRFSS data had tilefish reported as the primary target species.

### NEFSC Trawl survey data

Only a few fish per survey are caught during NEFSC bottom trawl surveys. This survey time series is not useful as an index of abundance for tilefish.

**TOR 2:** ***Estimate fishing mortality and total stock biomass for the current year and characterize the uncertainty of those estimates.***

**TOR 3:** ***Evaluate and either update or re-estimate biological reference points as appropriate.***

## 3.0 MORTALITY AND STOCK SIZE ESTIMATES

### Surplus production model

The ASPIC surplus production model (Prager 1994; 1995) was the primary model used to determine fishing mortality, stock biomass and biological reference points ($F_{msy}$, and $B_{msy}$). Results of sensitivity runs with 13 different configurations of the ASPIC model were examined (Table C14). A comparison of runs 1-2, 3-4, 5-6, and 7-8 provides information on the effect of splitting the weighout and VTR CPUE series. Runs 3-4, and 5-6 also extend the landings time series in the past before the existence of CPUE data. Runs 3-4 extended landings to the end of World War II (1945) when effort was thought to be low and runs 5-6 extended the landings to the beginning of the landings time series (1916). A comparison of runs 7-8 with runs 1-2 evaluates the effect of using a GLM to standardize CPUE. Runs 9 through 11 reduced the increase in CPUE at the end of the VTR series to determine the sensitivity of recent increases in CPUE to the model results (Figure C34). Run 12 examines the effect of using a single CPUE series by combining Turner and the weighout/VTR CPUE series. Turner and weighout-based CPUE indices were combined using a regression on the four years of overlap between the indices (1979-1982) (Figure C35). Run 13 fixed the $B1/B_{msy}$ ratio at 1.

Splitting of the weighout and VTR CPUE series did not have a strong effect on the model results. Extending the landings time series used in the model back to 1916 or 1945 when CPUE data do not exist also did not appear to influence the results. The use of a CPUE series standardized for vessels effects (GLM) produced little change in the results. Sensitivity runs that lowered the CPUE at the end of the VTR CPUE series had more of an influence on model results. Reducing the increase in CPUE at the end of the time series generally lowers the estimate of the intrinsic rate of increase. The sensitivity run that combined all of the CPUE series into a single index (run 12) provided a high estimate of the intrinsic rate of increase (r = 0.63). Large fluctuations in the $B1/B_{msy}$ ratio between the model runs did not have a large influence on model results. The Working Group accepted the formulation that began the analysis in 1973, separated the Turner, weighout and VTR CPUE into three series and fixed the $B1/B_{msy}$ ratio at 1 as the final run (run 13). The solution obtained from the final run was bootstrapped (1000 iterations) to obtain estimates of precision and bias. The complete ASPIC model output with bootstrap results is included as Appendix C4.

The surplus production model indicates that the tilefish stock biomass in 2005 has improved since the last assessment in 1998. Total biomass in 2005 is estimated to be

72% of $B_{msy}$, and fishing mortality in 2004 is estimated to be 87% of $F_{msy}$ (Figure C36). Biological reference points did not change greatly from the 1998 assessment. $B_{msy}$ is estimated to be 9,384 mt and $F_{msy}$ is estimated to be 0.21 (Figure C37). Bootstrap iterations show highly variable estimates of 2005 total biomass to $B_{msy}$ ratios (80% confidence intervals from 0.5 to 1.2) and 2004 F to $F_{msy}$ ratios (80% confidence intervals from 0.5 to 1.3) (Figure C38, Appendix C4).

## Catch-Length Model Mortality Estimates

A length-based fishing mortality estimate in the 1998 assessment for the 1996-1997 period was 0.65 using the Hoenig (1987) method and 1.12 using the Beverton and Holt (1957) method (Nitschke et al. 1998). In the present assessment a catch-length forward projection model was developed in an attempt to produce more accurate fishing mortality estimates based on growth and size information in the catch. Testing of the model produced reasonable results on a simulated population of tilefish when recruitment does not have a strong trend over time and the average growth is known. However the model could not fit both the catch length frequency and total landings data in the tilefish assessment. The model produced an unrealistic increase in F at the end of the time series. Substantial changes to model inputs (natural mortality, partial recruitment, and/or growth rate) were needed to eliminate the fitting conflict. The catch-length model was not considered as the primary model for determining stock status at this time because of the fitting problems and the uncertainty about the partial recruitment, natural mortality and growth. The expanded length frequency data for 2002-2004 indicates that most of the commercial landings were taken from a single year class (1999) comprising of relatively young fish (age 5 in 2004).

The longline tilefish fleet targets strong year classes by fishing areas where the catch rates are high. Spatial segregation of the stock by size and changes in fishing practices to keep catch rates high can result in a dome shaped partial recruitment pattern. The shape and changes over time of a possible dome is unknown. Assuming that natural mortality and growth are relatively well known, a severe dome shaped partial recruitment pattern is needed to allow fishing mortality to match the F trend seen in the ASPIC model. Conversely, if a flat top partial recruitment pattern is more likely to occur in the fishery, recent catches should have comprised more larger fish than were observed to allow the catch-length model to estimate a declining fishing mortality rate at the end of the time series. Although uncertainty in the input data and the paucity of length data from the fishery precluded the use of the catch-length model at this time, the model still calls attention to the lack of large fish seen in the catch in recent years for a stock which is thought to have a relatively low fishing mortality rate in recent years.

## An Index Method (AIM)

An Index Method (AIM, NOAA Fisheries Toolbox V1.4.1) was used as an additional indicator of stock status. The Index Method can only accommodate a single CPUE series so the combined index was employed. AIM uses a statistical fitting procedure to determine the relationship between indices and landings to calculate a relative F. A replacement ratio is estimated by dividing the annual CPUE index by a moving average of the previous five years of that index. At a replacement ratio of 1 the stock is sustained at the same level as the previous five years. At a level above 1 the stock is increasing and at a level below 1 the stock is declining. A relative F is calculated by dividing the catch by the three-point moving average of the catch rates centered on the year in which that catch occurred. The relative F needed to maintain the population can be computed from the plot comparing the relative F with the replacement ratio (Figure C39).

For tilefish, the replacement ratio has been increasing since 2001 and has been above 1.0 since 2002, and the current estimate of relative F for 2004 is well below the point corresponding to the replacement ratio of 1.0 (Figure C40, Appendix C5). This model indicates that relative F has declined in recent years (Figure C40).

**Lagged Recruitment Survival Growth (LRSG) Model**

A lagged-recruitment survival growth (LRSG) model (Hilborn and Mangel 1997) was developed for tilefish. This simple model includes a time lag for recruitment (L) and a lumped survival-growth parameter for biomass (s). The model was fit using catch biomass and combined catch-per-unit effort (CPUE) series during 1973-2004. The recruitment time lag was 4 years. Recruited biomass in year T+1 ($B_{T+1}$, age-4+) was derived from previous biomass, recruiting biomass ($R_T$), and catch ($C_T$) via

$$B_{T+1} = s \cdot B_T + R_T - C_T$$

Recruitment biomass was modeled using a Beverton-Holt curve with a time lag of L=4 years

$$R_T = \frac{B_{T-L}}{a + b \cdot B_{T-L}}$$

In the likelihood for CPUE, model observation errors were assumed to be iid (independent and identically distributed) multiplicative lognormal distributions with constant variance. CPUE was assumed proportional to age-4+ biomass raised to an exponent ($\delta$). In practice, there was insufficient information to estimate $\delta$ and it was set

$$CPUE_T = q \cdot \left(B_T\right)^{\delta}$$

to unity.

Prior distributions were assumed to be uninformative, with the exception of stock-recruitment steepness. Broad uniform prior distributions were used for the initial biomass ($B_0$), survival (s), catchability (q), exponent ($\delta$), and error variance ($\sigma^2$) parameters. A uniform prior of [0.2, 1] was initially used for the stock-recruitment steepness parameter (z). This initial model configuration led to a highest posterior density point estimate of z=0.88 indicating a highly resilient stock. However, the Hessian matrix for this model solution had a high condition number indicating substantial collinearity among parameters. As a result, an informative truncated Gaussian prior for steepness was developed using the meta-analysis of Myers et al. (1999). Steepness estimates from the nearest taxonomic grouping were used to set the mean steepness for the prior. In this case, the closest group was striped bass (*Morone saxatalis*) with a steepness of z=0.82. The coefficient of variation for the steepness prior was assumed to be 20%. Realized steepness values constrained to be in the interval [0.2, 1.0].

The combined CPUE series was used, because the current configuration of the model allows only one index of abundance. The LRSG model provided a reasonable fit to the CPUE series (Figure C41). Standardized residuals (Figure C42) were smaller than 1.5 and they exhibited a moderate alternating high-low pattern across blocks of several years. Relative biomass estimates ($B/B_{msy}$) indicated that the tilefish stock had been fished down in the 1970s-1980s (Figure C43) and has moderately increased since then. Recent biomass estimates appear to be at or above the $B_{msy}$ estimate obtained from this model. Relative exploitation rate estimates ($H/H_{msy}$) indicated that the tilefish stock experienced periods of overfishing during the 1980s-1990s (Figure C44). Recent exploitation rates appear to be relatively low but increasing. Overall the LRSG modeling results are more similar to the results obtained from the ASPIC model calibrated with the single linked CPUE series.

**Yield and Spawning Stock Biomass per Recruit**

Biological reference points from the Thompson-Bell yield per recruit (YPR) model (Thompson and Bell 1934) were not updated from the last assessment since updated data for the YPR analysis does not exist. However a value of $F_{max}$ was calculated from the Catch-length model. A length based YPR analysis (NOAA Fisheries Toolbox V1.2.1) was also performed for comparison to $F_{max}$ estimates derived from the Catch-length model and the original 1998 YPR analysis. The proportions mature-at-age and length were derived from estimates of maturity in 1978 and 1982 provided by Grimes et al. (1988) (Figure C45). In the 1998 YPR analysis the partial recruitment and weight at age was taken from the yield per recruit analysis (Ricker model) in Turner (1986). Von Bertalanffy growth parameters, a length weight relationship and a partial recruitment vector based on the landings length frequencies are used in the catch-length model and length based YPR model. The 1998 yield per recruit analysis provided an estimate of $F_{max}$ = 0.143, the length based YPR model provided an estimate of 0.138 (Figure C46, Appendix C6) and the catch-length model estimated an $F_{max}$ of 0.142 (Figure C47). The predicted length and age distribution at $F_{max}$ from the catch-length model is shown in Figure C48.

**TOR 4:** ***Where appropriate, estimate a constant TAC and/or TAL based on stock status for years following the terminal assessment year.***

**TOR 5:** ***If projections are possible,***

***a) provide seven year projections of stock status under various TAC strategies and***

***b) evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.***

## 4.0 Biomass and Fishing Mortality Projections

The Working Group examined several ASPIC projections employing a constant TAC strategy, including the current TAC of 905 mt. Each of these analyses exhibited wide variance and substantial bias and, in many cases, produced estimates of biomass and F at maximum or minimum model boundary conditions. The Working Group, therefore, concluded that the projections are too uncertain to form the basis for evaluating likely biomass recovery schedules relative to Bmsy under various TAC strategies. We do note, however, that stock biomass in 2005 (72% of $B_{msy}$) is above that projected for 2005 in the 1998 assessment (59% of $B_{msy}$). Thus, the existing TAC of 905 mt appears to have sufficiently constrained F to allow stock biomass to increase towards $B_{msy}$.

## 5.0 CONCLUSIONS

The Working Group accepted the ASPIC model solution but the projection results were considered too uncertain to form the basis for evaluating likely biomass recovery schedules relative to $B_{msy}$ under various TAC strategies. The surplus production model indicates that the tilefish stock biomass in 2005 has improved since the last assessment in 1998. Total biomass in 2005 was estimated to be 72% of $B_{msy}$ and fishing mortality in 2004 was estimated to be 87% of $F_{msy}$. MSY and Yield per recruit based biological reference points did not change greatly from the 1998 assessment. Results from the AIM model suggest that relative F is below the point that corresponds with a replacement ratio of 1.0 (stock replacement) and the LRSG model produced results similar to the ASPIC surplus production model. The AIM and LRSG require a single index of abundance. The ASPIC model, which allows for the separation of the CPUE indices, was used as the base model for status determination given the changes in commercial gear over time. However commercial length data indicate that improvements in total biomass are predominantly due to a strong 1999 year class. Most of the commercial catch was derived from this year class over the 2002-2004 period.

The partial recruitment pattern is unknown for the tilefish longline fishery because targeting of year classes to increase catch rates and market conditions will influence the size of fish landed. The price on the large market category in this fishery is particularly sensitive to the quantity of large fish landed. However there is still concern that fishing mortality may be higher than estimated by the surplus production model due to the relative lack of larger/older fish seen in the catch. The inability to characterize the actual partial recruitment pattern, the possibility of unknown refuge effects due to conflicts with lobster and trawl gear and effects of targeting incoming year classes introduce considerable uncertainty in interpreting CPUE from this fishery as a measure of stock abundance. Thus, there is concern that CPUE at the end of the series may be increasing faster than stock biomass. CPUE and catch length frequency data in this fishery may be as much a reflection of changes in fishing practices and the spatial distribution of the fish rather than fluctuations in population size.

With regard to the yield per recruit-based reference points and the results from the catch-length model, there is an issue of how appropriate it is to assume a flat top partial recruitment pattern given anecdotal information that the tilefish fleet will target single year classes and will optimize profits by fishing an area where the catch rates are higher on fish in the small and medium market category as opposed to an area (greater depth) where more valuable larger fish can be caught at a lower catch rate.

## 6.0 SOURCES OF UNCERTAINTY

There are two major sources of uncertainty affecting our perception of current stock status. The biomass-based models (ASPIC, AIM and LRSG) use the CPUE series as an index of population size. The Working Group considered these models and expressed concerns over whether the CPUE in this fishery may be as much a reflection of changes in fishing practices and changes in spatial distribution of the fish rather than fluctuations in population size. The catch-length model attempts to reconcile recent fishing mortality rates with a less than expected representation of larger fish in the catch. Because there are no fishery-independent data on trends in population biomass and size structure, the model must assume that the length composition of the catch will represent the extent of large fish in the population assuming a flat topped partial recruitment pattern. Specific sources of uncertainty are:

1) The effort metric (days absent) in the Weighout and VTR CPUE is a crude measure of effort and could be improved by collecting information (number and size of hooks, length of main line, soak time, time of day, depth fished and area fished) on a haul by haul basis and not by a trip basis.

2) The production models and index method (AIM) do not consider size or age structure of the population.

3) Sparse commercial length frequency sampling in many years.

4) The possible existence of a dome shaped partial recruitment pattern in the longline fishery depending on hook size and/or fishery practice such as areas/depth fished.

5) Possible shifts in growth relative to the Turner (1986) study and maturity at age/size from the Grimes *et al.* (1988) early 1980s study with increases in fishing mortality in the 1990s.

6) Effects of fishing on spawning success for a species that possesses sexual dimorphic growth and size specific competition for baited hooks.

7) Effects of fish behavior and fishing practice on the CPUE index as an assumed measure of population size.

8) Uncertainty in projections based on wide variance and substantial bias estimates.

## 7.0 RESEARCH RECOMMENDATIONS

1) Conduct a hook selectivity study to determine partial recruitment changes with hook size. Determine catch rates by hook size. Update data on growth, maturity, size structure, and sex ratios at length.

2) Collect data on spatial distribution and population size structure. This can help answer the question of the existence of a possible dome shaped partial recruitment pattern where larger fish are less vulnerable to the fishery due to spatial segregation by size.

3) Continue to develop the forward projecting catch-length model as additional length data becomes available. Investigate the influence of adding a tuning index of abundance and model estimated partial recruitment (logistic) to the catch-length model.

4) Collect appropriate effort metrics (number and size of hooks, length of main line, soak time, time of day, area fished) on a haul basis to estimate commercial CPUE.

5) Initiate a study to examine the effects of density dependence on life history parameters between the 1978-82 period and present.

6) Increased observer coverage in the tilefish fishery to obtain additional length data.

7) Develop a bioeconomic model to calculate maximum economic yield per recruit.

**TOR 6: Review, evaluate and report on the status of the research recommendations offered in the 1999 Science and Statistical committee reviewed assessment.**

**Research recommendations from 1999 Science and Statistical Committee review**

1) Ensure that market category distributions accurately reflect the landings.

This is not really a research recommendation. The catch-length model assumes that landings from all market categories are accurately accounted for and that the length frequency distributions for a market category are stable over time. Sampling of the commercial lengths has improved over the last two years.

2) Ensure that length frequency sampling is proportional to landings by market category.

This is not really a research recommendation. Commercial length sampling has been sporadic over the time series. In particular length samples from the large market category have been lacking. However commercial length sampling improved in 2003 and 2004.

3) Increase and ensure adequate length sampling coverage of the fishery.

Commercial length sampling improved in 2003 and 2004.

4) Update age- and length- weight relationships.

This TOR has not been addressed. Question why length-weight relationships would change. Growth data for tilefish should be updated and will be collected in a planned 2005-2006 hook selectivity study.

5) Update the maturity-at-age, weight-at-age, and partial recruitment patterns.

This TOR has not been addressed. Maturity and partial recruitment data will also be collected in the 2005-2006 hook selectivity study.

6) Develop fork length to total length conversion factors for the estimation of total length to weight relationships.

This work is in progress. Port agents are collecting data.

7) Incorporate auxiliary data to estimate r independent of the ASPIC model.

This TOR has not been addressed. Question if this can be done or should be done.

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**TILEFISH TABLES**

Table C1. Landings of tilefish in live metric tons from 1915-2004. Landings in 1915-1972 are from Freeman and Turner (1977), 1973-1989 are from the general canvas data, 1990-1993 are from the weighout system, 1994-2003 are from the dealer reported data, and 2004 is from dealer electronic reporting. - indicates missing data.

| year | mt | year | mt |
|---|---|---|---|
| 1915 | 148 | 1960 | 1,064 |
| 1916 | 4,501 | 1961 | 388 |
| 1917 | 1,338 | 1962 | 291 |
| 1918 | 157 | 1963 | 121 |
| 1919 | 92 | 1964 | 596 |
| 1920 | 5 | 1965 | 614 |
| 1921 | 523 | 1966 | 438 |
| 1922 | 525 | 1967 | 50 |
| 1923 | 623 | 1968 | 32 |
| 1924 | 682 | 1969 | 33 |
| 1925 | 461 | 1970 | 61 |
| 1926 | 904 | 1971 | 66 |
| 1927 | 1,264 | 1972 | 122 |
| 1928 | 1,076 | 1973 | 394 |
| 1929 | 2,096 | 1974 | 586 |
| 1930 | 1,858 | 1975 | 710 |
| 1931 | 1,206 | 1976 | 1,010 |
| 1932 | 961 | 1977 | 2,082 |
| 1933 | 688 | 1978 | 3,257 |
| 1934 | - | 1979 | 3,968 |
| 1935 | 1,204 | 1980 | 3,889 |
| 1936 | - | 1981 | 3,499 |
| 1937 | 1,101 | 1982 | 1,990 |
| 1938 | 533 | 1983 | 1,876 |
| 1939 | 402 | 1984 | 2,009 |
| 1940 | 269 | 1985 | 1,961 |
| 1941 | - | 1986 | 1,950 |
| 1942 | 62 | 1987 | 3,210 |
| 1943 | 8 | 1988 | 1,361 |
| 1944 | 22 | 1989 | 454 |
| 1945 | 40 | 1990 | 874 |
| 1946 | 129 | 1991 | 1,189 |
| 1947 | 191 | 1992 | 1,653 |
| 1948 | 465 | 1993 | 1,838 |
| 1949 | 582 | 1994 | 786 |
| 1950 | 1,089 | 1995 | 666 |
| 1951 | 1,031 | 1996 | 1,121 |
| 1952 | 964 | 1997 | 1,810 |
| 1953 | 1,439 | 1998 | 1,342 |
| 1954 | 1,582 | 1999 | 525 |
| 1955 | 1,629 | 2000 | 506 |
| 1956 | 707 | 2001 | 874 |
| 1957 | 252 | 2002 | 851 |
| 1958 | 672 | 2003 | 1,130 |
| 1959 | 380 | 2004 | 1,182 |

Table C2. Percent landings by statistical area. Landings before 1990 are taken from the general canvas data. Percent landings after 1993 are estimated from vessel trip reports.

| year | unknown | 626 | 622 | 616 | 537 | 526 | 525 | other |
|---|---|---|---|---|---|---|---|---|
| 1962 | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1963 | 65% | 0% | 0% | 0% | 4% | 28% | 0% | 3% |
| 1964 | 83% | 0% | 0% | 0% | 4% | 14% | 0% | 0% |
| 1965 | 83% | 0% | 0% | 0% | 1% | 16% | 0% | 0% |
| 1966 | 97% | 0% | 0% | 0% | 0% | 1% | 1% | 0% |
| 1967 | 96% | 0% | 0% | 0% | 0% | 4% | 0% | 0% |
| 1968 | 96% | 0% | 0% | 0% | 1% | 0% | 0% | 3% |
| 1969 | 93% | 0% | 0% | 0% | 2% | 4% | 0% | 1% |
| 1970 | 87% | 0% | 0% | 0% | 8% | 5% | 0% | 0% |
| 1971 | 99% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1972 | 92% | 0% | 0% | 1% | 1% | 0% | 0% | 6% |
| 1973 | 0% | 0% | 0% | 62% | 16% | 0% | 0% | 21% |
| 1974 | 0% | 0% | 0% | 51% | 27% | 0% | 0% | 22% |
| 1975 | 0% | 0% | 0% | 48% | 34% | 8% | 0% | 10% |
| 1976 | 0% | 0% | 0% | 58% | 28% | 13% | 0% | 1% |
| 1977 | 1% | 0% | 0% | 44% | 32% | 22% | 0% | 1% |
| 1978 | 0% | 0% | 0% | 29% | 40% | 31% | 0% | 0% |
| 1979 | 0% | 0% | 0% | 18% | 37% | 45% | 0% | 0% |
| 1980 | 0% | 0% | 0% | 22% | 34% | 44% | 0% | 0% |
| 1981 | 0% | 0% | 0% | 28% | 37% | 35% | 0% | 0% |
| 1982 | 0% | 0% | 0% | 19% | 52% | 27% | 0% | 2% |
| 1983 | 0% | 1% | 0% | 22% | 54% | 23% | 0% | 0% |
| 1984 | 0% | 1% | 3% | 9% | 53% | 34% | 0% | 1% |
| 1985 | 0% | 0% | 2% | 25% | 33% | 38% | 2% | 1% |
| 1986 | 0% | 0% | 1% | 28% | 44% | 25% | 3% | 1% |
| 1987 | 0% | 0% | 0% | 12% | 53% | 32% | 1% | 2% |
| 1988 | 0% | 1% | 2% | 21% | 41% | 32% | 0% | 2% |
| 1989 | 0% | 0% | 1% | 63% | 9% | 26% | 1% | 1% |
| 1990 | 0% | 2% | 0% | 15% | 14% | 36% | 0% | 33% |
| 1991 | 0% | 0% | 1% | 64% | 25% | 1% | 0% | 10% |
| 1992 | 0% | 0% | 1% | 22% | 70% | 5% | 1% | 1% |
| 1993 | 0% | 0% | 2% | 14% | 72% | 7% | 3% | 2% |
| 1994 | 3% | 0% | 0% | 10% | 71% | 0% | 7% | 9% |
| 1995 | 1% | 0% | 0% | 7% | 90% | 0% | 1% | 1% |
| 1996 | 21% | 0% | 0% | 27% | 49% | 0% | 0% | 3% |
| 1997 | 23% | 0% | 0% | 16% | 57% | 0% | 0% | 3% |
| 1998 | 17% | 0% | 0% | 9% | 66% | 1% | 1% | 7% |
| 1999 | 3% | 0% | 0% | 34% | 55% | 0% | 0% | 7% |
| 2000 | 0% | 0% | 0% | 41% | 50% | 2% | 1% | 6% |
| 2001 | 0% | 0% | 0% | 66% | 26% | 2% | 0% | 5% |
| 2002 | 0% | 0% | 0% | 50% | 44% | 0% | 1% | 5% |
| 2003 | 1% | 0% | 0% | 49% | 39% | 1% | 1% | 10% |
| 2004 | 0% | 0% | 0% | 21% | 63% | 1% | 2% | 14% |

Table C 3. Landings of tilefish (mt, live) by gear. Number of length measurements are in parentheses. Landing berfore 1990 are from the general canvas data. Percent by gear per year are also given.

| Year | Gear | | | | | | Total | Percent by Gear | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | longline | | trawl | | other | | | longline | trawl | other |
| 1962 | | | 167 | | 2 | | 169 | 0% | 99% | 1% |
| 1963 | | | 121 | | | | 121 | 0% | 100% | 0% |
| 1964 | | | 596 | | | | 596 | 0% | 100% | 0% |
| 1965 | | | 614 | | | | 614 | 0% | 100% | 0% |
| 1966 | | | 437 | | | | 437 | 0% | 100% | 0% |
| 1967 | | | 51 | | | | 51 | 0% | 100% | 0% |
| 1968 | | | 30 | | | | 30 | 0% | 100% | 0% |
| 1969 | | | 30 | | | | 30 | 0% | 100% | 0% |
| 1970 | | | 57 | | 1 | | 58 | 0% | 99% | 1% |
| 1971 | | | 62 | | 1 | | 62 | 0% | 99% | 1% |
| 1972 | 93 | | 26 | | 2 | | 121 | 77% | 21% | 2% |
| 1973 | 370 | | 24 | | 1 | | 394 | 94% | 6% | 0% |
| 1974 | 531 | | 33 | | 22 | | 586 | 91% | 6% | 4% |
| 1975 | 588 | | 111 | | 11 | | 710 | 83% | 16% | 2% |
| 1976 | 950 | | 58 | | 1 | | 1,010 | 94% | 6% | 0% |
| 1977 | 1,772 | | 309 | | 1 | | 2,082 | 85% | 15% | 0% |
| 1978 | 2,938 | | 309 | | 10 | | 3,257 | 90% | 9% | 0% |
| 1979 | 3,362 | | 449 | | 156 | | 3,968 | 85% | 11% | 4% |
| 1980 | 3,794 | | 94 | (37) | 0 | | 3,889 | 98% | 2% | 0% |
| 1981 | 3,366 | (25) | 128 | | 5 | | 3,499 | 96% | 4% | 0% |
| 1982 | 1,935 | | 49 | (87) | 6 | | 1,990 | 97% | 2% | 0% |
| 1983 | 1,857 | (158) | 8 | | 11 | | 1,876 | 99% | 0% | 1% |
| 1984 | 2,003 | (116) | 6 | | 1 | | 2,009 | 100% | 0% | 0% |
| 1985 | 1,929 | (410) | 31 | | 0 | | 1,961 | 98% | 2% | 0% |
| 1986 | 1,874 | (177) | 76 | | 0 | | 1,950 | 96% | 4% | 0% |
| 1987 | 3,029 | (292) | 180 | (291) | 0 | | 3,210 | 94% | 6% | 0% |
| 1988 | 1,319 | (98) | 42 | | | | 1,361 | 97% | 3% | 0% |
| 1989 | 421 | | 33 | | 0 | | 454 | 93% | 7% | 0% |
| 1990 | 852 | | 22 | | 0 | | 874 | 97% | 2% | 0% |
| 1991 | 1,164 | | 25 | | 0 | | 1,189 | 98% | 2% | 0% |
| 1992 | 1,497 | (36) | 155 | | 0 | | 1,653 | 91% | 9% | 0% |
| 1993 | 1,597 | | 241 | (100) | 0 | | 1,838 | 87% | 13% | 0% |
| 1994 | 764 | | 22 | | 0 | | 786 | 97% | 3% | 0% |
| 1995 | 617 | (432) | 47 | | 2 | | 666 | 93% | 7% | 0% |
| 1996 | 1,009 | (548) | 111 | (107) | 0 | | 1,121 | 90% | 10% | 0% |
| 1997 | 1,699 | (1,763) | 80 | (216) | 30 | | 1,810 | 94% | 4% | 2% |
| 1998 | 1,179 | (710) | 142 | (290) | 21 | | 1,342 | 88% | 11% | 2% |
| 1999 | 466 | (360) | 29 | | 31 | (11) | 525 | 89% | 6% | 6% |
| 2000 | 451 | (143) | 45 | | 11 | | 506 | 89% | 9% | 2% |
| 2001 | 811 | (217) | 62 | (103) | 2 | | 874 | 93% | 7% | 0% |
| 2002 | 757 | (637) | 84 | (482) | 10 | | 851 | 89% | 10% | 1% |
| 2003 | 987 | (3,303) | 131 | (274) | 13 | | 1,130 | 87% | 12% | 1% |
| 2004 | 507 | (1,532) | 191 | (411) | 484 | (8) | 1,182 | 43% | 16% | 41% |

Table C4. Landings of tilefish (mt, live) by state. Number of length measurements are in parentheses. Landings before 1990 are from general canvas data. Percent by state per year are also given.

| Year | ME | MA | RI | NY | NJ | other | Total | Percent by State ME | MA | RI | NY | NJ | other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 0 | 28 | 31 | 57 | 42 | 12 | 169 | 0% | 16% | 18% | 34% | 25% | 7% |
| 1963 | 0 | 42 | 46 | 13 | 14 | 6 | 121 | 0% | 35% | 38% | 10% | 12% | 5% |
| 1964 | 0 | 102 | 424 | 37 | 30 | 2 | 596 | 0% | 17% | 71% | 6% | 5% | 0% |
| 1965 | 0 | 106 | 478 | 20 | 9 | 2 | 614 | 0% | 17% | 78% | 3% | 1% | 0% |
| 1966 | 0 | 13 | 366 | 55 | 3 | 2 | 437 | 0% | 3% | 84% | 13% | 1% | 0% |
| 1967 | 0 | 2 | 27 | 8 | 8 | 5 | 51 | 0% | 4% | 54% | 16% | 17% | 9% |
| 1968 | 0 | 1 | 23 | 3 | 3 | 0 | 30 | 0% | 4% | 76% | 9% | 11% | 0% |
| 1969 | 0 | 2 | 13 | 4 | 10 | 0 | 30 | 0% | 7% | 44% | 15% | 35% | 0% |
| 1970 | 0 | 8 | 36 | 3 | 10 | 1 | 58 | 0% | 13% | 62% | 5% | 17% | 2% |
| 1971 | 0 | 0 | 21 | 25 | 15 | 1 | 62 | 0% | 1% | 34% | 40% | 24% | 2% |
| 1972 | 0 | 2 | 3 | 6 | 111 | 0 | 121 | 0% | 1% | 2% | 5% | 92% | 0% |
| 1973 | 0 | 51 | 17 | 3 | 323 | 0 | 394 | 0% | 13% | 4% | 1% | 82% | 0% |
| 1974 | 0 | 163 | 21 | 22 | 380 | 0 | 586 | 0% | 28% | 4% | 4% | 65% | 0% |
| 1975 | 0 | 174 | 101 | 2 | 434 | 0 | 710 | 0% | 24% | 14% | 0% | 61% | 0% |
| 1976 | 0 | 212 | 56 | 23 | 718 | 0 | 1,010 | 0% | 21% | 6% | 2% | 71% | 0% |
| 1977 | 0 | 84 | 354 | 314 | 1,331 | 0 | 2,082 | 0% | 4% | 17% | 15% | 64% | 0% |
| 1978 | 0 | 95 | 292 | 969 | 1,900 | 0 | 3,257 | 0% | 3% | 9% | 30% | 58% | 0% |
| 1979 | 0 | 22 | 432 | 1,365 | 2,148 | 0 | 3,968 | 0% | 1% | 11% | 34% | 54% | 0% |
| 1980 | 0 | 1 | 87 (37) | 1,451 | 2,348 | 2 | 3,889 (37) | 0% | 0% | 2% | 37% | 60% | 0% |
| 1981 | 0 | 6 | 126 | 1,284 (25) | 2,083 | 1 | 3,499 | 0% | 0% | 4% | 37% | 60% | 0% |
| 1982 | 6 | 5 | 42 (87) | 643 | 1,288 | 6 | 1,990 (87) | 0% | 0% | 2% | 32% | 65% | 0% |
| 1983 | 0 | 12 | 7 | 844 (158) | 1,001 | 12 | 1,876 | 0% | 1% | 0% | 45% | 53% | 1% |
| 1984 | 0 | 1 | 5 | 1,094 | 898 (116) | 11 | 2,009 (116) | 0% | 0% | 0% | 54% | 45% | 1% |
| 1985 | 2 | 10 | 207 (247) | 958 | 777 (163) | 6 | 1,961 (410) | 0% | 0% | 11% | 49% | 40% | 0% |
| 1986 | 3 | 1 | 183 (70) | 1,076 (107) | 687 | 1 | 1,950 (177) | 0% | 0% | 9% | 55% | 35% | 0% |
| 1987 | 0 | 7 | 269 (380) | 1,996 | 924 (203) | 13 | 3,210 (583) | 0% | 0% | 8% | 62% | 29% | 0% |
| 1988 | 0 | 33 | 100 (98) | 868 | 353 | 6 | 1,361 (98) | 0% | 2% | 7% | 64% | 26% | 0% |
| 1989 | 0 | 1 | 28 | 249 | 174 | 1 | 454 | 0% | 0% | 6% | 55% | 38% | 0% |
| 1990 | 7 | 7 | 19 | 606 | 232 | 3 | 874 | 1% | 1% | 2% | 69% | 27% | 0% |
| 1991 | 4 | 1 | 19 | 720 | 444 | 1 | 1,189 | 0% | 0% | 2% | 61% | 37% | 0% |
| 1992 | 8 | 3 | 146 | 963 (36) | 530 | 3 | 1,653 | 0% | 0% | 9% | 58% | 32% | 0% |
| 1993 | 59 | 14 | 276 (100) | 1,003 | 485 | 1 | 1,838 (100) | 3% | 1% | 15% | 55% | 26% | 0% |
| 1994 | 25 | 3 | 51 | 580 | 127 | 0 | 786 | 3% | 0% | 6% | 74% | 16% | 0% |
| 1995 | 8 | 1 | 29 | 551 (432) | 76 | 1 | 666 (432) | 1% | 0% | 4% | 83% | 11% | 0% |
| 1996 | 6 (108) | 0 | 88 (219) | 914 | 106 (328) | 6 | 1,121 (655) | 1% | 0% | 8% | 82% | 9% | 1% |
| 1997 | 13 (244) | 0 | 65 (422) | 1,494 (159) | 196 (1,154) | 41 | 1,810 (1,979) | 1% | 0% | 4% | 83% | 11% | 2% |
| 1998 | 15 | 4 | 251 (320) | 890 (74) | 155 (606) | 27 | 1,342 (1,000) | 1% | 0% | 19% | 66% | 12% | 2% |
| 1999 | 3 | 2 | 86 (212) | 362 | 43 (159) | 30 | 525 (371) | 1% | 0% | 16% | 69% | 8% | 6% |
| 2000 | 7 | 0 | 62 | 415 (143) | 16 | 5 | 506 (143) | 1% | 0% | 12% | 82% | 3% | 1% |
| 2001 | 0 | 0 | 33 (103) | 832 (217) | 4 | 4 | 874 (320) | 0% | 0% | 4% | 95% | 0% | 0% |
| 2002 | 4 | 9 | 72 (482) | 722 (637) | 32 | 11 | 851 (1,119) | 0% | 1% | 8% | 85% | 4% | 1% |
| 2003 | 2 (343) | 12 | 105 (167) | 796 (1,862) | 208 (1,205) | 7 | 1,130 (3,577) | 0% | 1% | 9% | 70% | 18% | 1% |
| 2004 | 0 (31) | 117 (19) | 136 (345) | 601 (351) | 318 (1,205) | 10 | 1,182 (1,951) | 0% | 10% | 12% | 51% | 27% | 1% |

Table C5. Landings of tilefish (mt, live) by quarter. Number of length measurements are in parentheses. General canvas data are not included. Percent by quarter per year are also given.

| | Quarter | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | | 2 | | 3 | | 4 | | Total | 1 | 2 | 3 | 4 |
| 1977 | 1,017 | | 961 | | 93 | | 12 | | 2,082 | 49% | 46% | 4% | 1% |
| 1978 | 905 | | 1,128 | | 432 | | 793 | | 3,257 | 28% | 35% | 13% | 24% |
| 1979 | 1,351 | | 1,055 | | 538 | | 1,024 | | 3,968 | 34% | 27% | 14% | 26% |
| 1980 | 1,524 | | 1,263 | (37) | 505 | | 596 | | 3,889 | 39% | 32% | 13% | 15% |
| 1981 | 1,352 | | 1,091 | | 474 | | 581 | (25) | 3,499 | 39% | 31% | 14% | 17% |
| 1982 | 1,028 | (87) | 433 | | 239 | | 289 | | 1,990 | 52% | 22% | 12% | 15% |
| 1983 | 577 | (119) | 726 | | 289 | (39) | 284 | | 1,876 | 31% | 39% | 15% | 15% |
| 1984 | 1,032 | | 491 | (116) | 293 | | 193 | | 2,009 | 51% | 24% | 15% | 10% |
| 1985 | 551 | (340) | 632 | (70) | 496 | | 281 | | 1,961 | 28% | 32% | 25% | 14% |
| 1986 | 542 | (107) | 597 | (70) | 437 | | 374 | | 1,950 | 28% | 31% | 22% | 19% |
| 1987 | 1,048 | (481) | 873 | | 723 | (102) | 565 | | 3,210 | 33% | 27% | 23% | 18% |
| 1988 | 737 | | 292 | (98) | 160 | | 172 | | 1,361 | 54% | 21% | 12% | 13% |
| 1989 | 147 | | 61 | | 78 | | 167 | | 454 | 32% | 13% | 17% | 37% |
| 1990 | 258 | | 243 | | 184 | | 189 | | 874 | 29% | 28% | 21% | 22% |
| 1991 | 326 | | 437 | | 182 | | 244 | | 1,189 | 27% | 37% | 15% | 21% |
| 1992 | 424 | | 434 | | 401 | | 394 | (36) | 1,653 | 26% | 26% | 24% | 24% |
| 1993 | 634 | (100) | 664 | | 267 | | 273 | | 1,838 | 34% | 36% | 15% | 15% |
| 1994 | 301 | | 275 | | 73 | | 138 | | 786 | 38% | 35% | 9% | 18% |
| 1995 | 214 | (432) | 148 | | 109 | | 195 | | 666 | 32% | 22% | 16% | 29% |
| 1996 | 366 | (215) | 215 | | 231 | | 308 | (440) | 1,121 | 33% | 19% | 21% | 28% |
| 1997 | 441 | (808) | 574 | (906) | 373 | (80) | 421 | (185) | 1,810 | 24% | 32% | 21% | 23% |
| 1998 | 539 | (324) | 362 | (517) | 229 | (104) | 212 | (55) | 1,342 | 40% | 27% | 17% | 16% |
| 1999 | 163 | (150) | 146 | (10) | 120 | (102) | 96 | (109) | 525 | 31% | 28% | 23% | 18% |
| 2000 | 143 | | 141 | (143) | 77 | | 144 | | 506 | 28% | 28% | 15% | 28% |
| 2001 | 191 | | 236 | | 223 | | 224 | (320) | 874 | 22% | 27% | 25% | 26% |
| 2002 | 287 | (619) | 195 | (100) | 181 | (217) | 188 | (183) | 851 | 34% | 23% | 21% | 22% |
| 2003 | 305 | (480) | 299 | (407) | 247 | (1,641) | 280 | (1,049) | 1,130 | 27% | 26% | 22% | 25% |
| 2004 | 504 | (1,711) | 272 | (240) | 182 | | 223 | | 1,182 | 43% | 23% | 15% | 19% |

Table C6. Total VTR trawl kept and discarded tilefish in live kg. Ratios of discarded to kept are also shown.

| year | kept | discard | d/k ratio |
|---|---|---|---|
| 1994 | 3,090 | 113 | 0.037 |
| 1995 | 14,637 | 98 | 0.007 |
| 1996 | 90,405 | 656 | 0.007 |
| 1997 | 75,321 | 260 | 0.003 |
| 1998 | 121,042 | 206 | 0.002 |
| 1999 | 31,501 | 74 | 0.002 |
| 2000 | 20,785 | 0 | 0.000 |
| 2001 | 51,055 | 538 | 0.011 |
| 2002 | 69,722 | 2,053 | 0.029 |
| 2003 | 135,058 | 13,024 | 0.096 |
| 2004 | 222,540 | 273 | 0.001 |

Table C7. Observer trawl trips which either kept and/or discarded tilefish in kgs. Discard to kept ratio, the number of trips and observed hauls are also shown.

| year | discard kgs | kept kgs | d/k ratio | No. trips | No. hauls |
|---|---|---|---|---|---|
| 1989 | 114 | 131 | 0.88 | 8 | 43 |
| 1990 | 9 | 85 | 0.11 | 4 | 11 |
| 1991 | 252 | 446 | 0.57 | 19 | 69 |
| 1992 | 182 | 855 | 0.21 | 22 | 84 |
| 1993 | 21 | 4,619 | 0.00 | 13 | 77 |
| 1994 | 14 | 119 | 0.11 | 7 | 23 |
| 1995 | 20 | 23 | 0.90 | 6 | 13 |
| 1996 | 56 | 1,515 | 0.04 | 11 | 53 |
| 1997 | 195 | 1,080 | 0.18 | 13 | 71 |
| 1998 | 45 | 518 | 0.09 | 11 | 92 |
| 1999 | 31 | 152 | 0.20 | 14 | 47 |
| 2000 | 116 | 112 | 1.04 | 8 | 25 |
| 2001 | 653 | 455 | 1.43 | 10 | 54 |
| 2002 | 5 | 58 | 0.08 | 3 | 6 |
| 2003 | 271 | 1,206 | 0.22 | 15 | 65 |
| 2004 | 250 | 1,592 | 0.16 | 30 | 160 |

Table C8. Total commercial and vessel trip report (VTR) landings in live mt and the commercial catch-per-unit effort (CPUE) data used for tilefish. Dealer landings before 1990 are from the general canvas data. CPUE data from 1979 to the first half of 1994 are from the NEFSC weighout database, while data in the second half of 1994 to 2004 are from the VTR system (below the dotted line). Effort data are limited to longline trips which targeted tilefish (= or >75% of the landings were tilefish) and where data existed for the days absent. Nominal CPUE series are calculated using landed weight per days absent minus one day steam time per trip. Da represents days absent.

| | Weighout | | Commerical CPUE data subset | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | & Dealer | vtr | interview | No. | % interview | No. | subset | days | No. | da per | nominal |
| year | landings | landings | landings | interviews | trips | vessels | landings | absent | trips | trip | cpue |
| 1979 | 3,968 | | 0.0 | 0 | 0.0% | 20 | 1,807 | 1,187 | 330 | 3.6 | 1.93 |
| 1980 | 3,889 | | 0.8 | 1 | 0.3% | 18 | 2,153 | 1,390 | 396 | 3.5 | 1.99 |
| 1981 | 3,499 | | 35.0 | 4 | 1.2% | 21 | 1,971 | 1,262 | 333 | 3.8 | 1.95 |
| 1982 | 1,990 | | 90.7 | 13 | 5.7% | 18 | 1,267 | 1,282 | 229 | 5.6 | 1.10 |
| 1983 | 1,876 | | 85.8 | 16 | 8.9% | 21 | 1,013 | 1,451 | 179 | 8.1 | 0.73 |
| 1984 | 2,009 | | 140.1 | 25 | 18.2% | 20 | 878 | 1,252 | 138 | 9.1 | 0.72 |
| 1985 | 1,961 | | 297.1 | 64 | 30.6% | 25 | 933 | 1,671 | 209 | 8.0 | 0.59 |
| 1986 | 1,950 | | 120.7 | 31 | 16.5% | 23 | 767 | 1,186 | 188 | 6.3 | 0.71 |
| 1987 | 3,210 | | 198.5 | 38 | 18.5% | 30 | 1,014 | 1,343 | 206 | 6.5 | 0.82 |
| 1988 | 1,361 | | 148.2 | 30 | 19.4% | 23 | 422 | 846 | 154 | 5.5 | 0.56 |
| 1989 | 454 | | 92.8 | 11 | 15.7% | 11 | 165 | 399 | 70 | 5.7 | 0.46 |
| 1990 | 874 | | 32.4 | 8 | 11.9% | 11 | 241 | 556 | 68 | 8.2 | 0.45 |
| 1991 | 1,189 | | 0.8 | 3 | 2.8% | 7 | 444 | 961 | 107 | 9.0 | 0.48 |
| 1992 | 1,653 | | 58.0 | 9 | 8.6% | 13 | 587 | 969 | 105 | 9.2 | 0.62 |
| 1993 | 1,838 | | 71.9 | 11 | 10.5% | 10 | 571 | 959 | 105 | 9.1 | 0.61 |
| 1994 | - | | 0 | 0 | 0.0% | 7 | 127 | 385 | 42 | 9.2 | 0.34 |
| 1994 | 786 | 31 | | | | 4 | 53 | 150 | 18 | 8.3 | 0.37 |
| 1995 | 666 | 549 | | | | 5 | 470 | 964 | 100 | 9.6 | 0.50 |
| 1996 | 1,121 | 865 | | | | 8 | 822 | 1,318 | 134 | 9.8 | 0.64 |
| 1997 | 1,810 | 1,439 | | | | 6 | 1,427 | 1,332 | 133 | 10.0 | 1.09 |
| 1998 | 1,342 | 1,068 | | | | 9 | 1,034 | 1,517 | 158 | 9.6 | 0.70 |
| 1999 | 525 | 527 | | | | 10 | 516 | 1,185 | 133 | 8.9 | 0.45 |
| 2000 | 506 | 446 | | | | 11 | 427 | 942 | 111 | 8.5 | 0.47 |
| 2001 | 874 | 705 | | | | 8 | 691 | 1,046 | 116 | 9.0 | 0.68 |
| 2002 | 851 | 724 | | | | 8 | 712 | 951 | 114 | 8.3 | 0.78 |
| 2003 | 1,130 | 790 | | | | 7 | 788 | 691 | 101 | 6.8 | 1.22 |
| 2004 | 1,182 | 1,137 | | | | 13 | 1,118 | 750 | 126 | 6.0 | 1.64 |

Table C9. Dealer and VTR tilefish total landings (live metric tons) compared to the total landings from the five dominant tilefish vessels. Percent of five dominant vessels to the total are also shown. Difference between the dealer and VTR data are calculated.

| year | Dealer total (live mt) | Dealer top 5 vessels | Dealer % landing of top 5 vessels to total | VTR total (live mt) | VTR top 5 vessels | VTR % landing of top 5 vessels to total | Dealer total minus vtr total | Dealer top 5 minus vtr top 5 |
|---|---|---|---|---|---|---|---|---|
| 1994 | 786 | 485 | 62% | 31 | 17 | 57% | 755 | 467 |
| 1995 | 666 | 522 | 78% | 549 | 538 | 98% | 117 | -16 |
| 1996 | 1,121 | 803 | 72% | 865 | 799 | 92% | 256 | 4 |
| 1997 | 1,810 | 1,292 | 71% | 1,439 | 1,416 | 98% | 371 | -123 |
| 1998 | 1,342 | 948 | 71% | 1,068 | 1,003 | 94% | 274 | -55 |
| 1999 | 525 | 399 | 76% | 527 | 486 | 92% | -2 | -87 |
| 2000 | 506 | 459 | 91% | 446 | 428 | 96% | 60 | 31 |
| 2001 | 874 | 817 | 93% | 705 | 684 | 97% | 169 | 133 |
| 2002 | 851 | 722 | 85% | 724 | 687 | 95% | 127 | 35 |
| 2003 | 1,130 | 726 | 64% | 790 | 732 | 93% | 340 | -6 |
| 2004 | 1,182 | 584 | 49% | 1,137 | 622 | 55% | 45 | -38 |

Table C10. Landing by market category. Number of length measurements are in parentheses. Percent by market category redistributes the unclassified category by the proportion of the other categories.

| | | | | | | | | | | Percent by market cat | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | large | | medium | | small | | unclassified | | total | lg | md | sm |
| 1980 | 0 | | 0 | | 0 | | 3,889 | (37) | 3,889 | - | - | - |
| 1981 | 0 | | 0 | | 0 | | 3,499 | (25) | 3,499 | - | - | - |
| 1982 | 18 | | 9 | | 6 | | 1,957 | (87) | 1,990 | 55% | 28% | 18% |
| 1983 | 13 | (119) | 7 | (39) | 2 | | 1,854 | | 1,876 | 59% | 31% | 10% |
| 1984 | 49 | | 47 | | 18 | | 1,895 | (116) | 2,009 | 43% | 41% | 16% |
| 1985 | 218 | | 206 | (247) | 111 | | 1,426 | (163) | 1,961 | 41% | 38% | 21% |
| 1986 | 359 | (49) | 223 | (58) | 168 | | 1,200 | | 1,950 | 48% | 30% | 22% |
| 1987 | 300 | | 663 | (393) | 134 | | 2,113 | (190) | 3,210 | 27% | 60% | 12% |
| 1988 | 120 | | 161 | (98) | 36 | | 1,043 | | 1,361 | 38% | 51% | 11% |
| 1989 | 47 | | 27 | | 33 | | 347 | | 454 | 44% | 25% | 31% |
| 1990 | 46 | | 103 | | 37 | | 688 | | 874 | 25% | 55% | 20% |
| 1991 | 85 | | 154 | | 59 | | 892 | | 1,189 | 29% | 52% | 20% |
| 1992 | 86 | | 87 | | 328 | | 1,151 | (36) | 1,653 | 17% | 17% | 65% |
| 1993 | 70 | | 206 | (100) | 368 | | 1,193 | | 1,838 | 11% | 32% | 57% |
| 1994 | 61 | | 89 | | 19 | | 617 | | 786 | 36% | 53% | 12% |
| 1995 | 93 | | 88 | (208) | 99 | (244) | 386 | | 666 | 33% | 31% | 35% |
| 1996 | 158 | (136) | 149 | (100) | 593 | (419) | 221 | | 1,121 | 18% | 17% | 66% |
| 1997 | 112 | (95) | 260 | (688) | 1,130 | (1,174) | 307 | (22) | 1,810 | 7% | 17% | 75% |
| 1998 | 110 | (101) | 699 | (407) | 474 | (473) | 58 | (19) | 1,342 | 9% | 54% | 37% |
| 1999 | 115 | | 201 | (155) | 181 | (211) | 29 | (5) | 525 | 23% | 40% | 36% |
| 2000 | 124 | | 153 | (79) | 210 | (64) | 18 | | 506 | 25% | 31% | 43% |
| 2001 | 131 | (25) | 160 | (100) | 564 | (195) | 19 | | 874 | 15% | 19% | 66% |
| 2002 | 132 | | 311 | (130) | 369 | (989) | 40 | | 851 | 16% | 38% | 45% |
| 2003 | 141 | (498) | 162 | (1,354) | 793 | (1,725) | 35 | | 1,130 | 13% | 15% | 72% |
| 2004 | 136 | (106) | 520 | (870) | 395 | (932) | 130 | (43) | 1,182 | 13% | 49% | 38% |

Table C11. Trawl landing by market category. Number of trawl length measurements are in parentheses. Percent by market category redistributes the unclassified category by the proportion of the other categories.

| year | large | medium | | small | | unclassified | | total | Percent by market cat lg | md | sm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 2 | 7 | | 9 | | 4 | | 22 | 12% | 38% | 51% |
| 1995 | 9 | 10 | | 22 | | 7 | | 47 | 22% | 24% | 54% |
| 1996 | 5 | 4 | | 72 | (107) | 31 | | 111 | 6% | 4% | 90% |
| 1997 | 4 | 4 | | 40 | (216) | 31 | | 80 | 9% | 9% | 82% |
| 1998 | 7 | 48 | | 41 | (271) | 45 | (19) | 142 | 7% | 50% | 42% |
| 1999 | 6 | 7 | | 10 | | 7 | | 29 | 27% | 30% | 43% |
| 2000 | 11 | 10 | | 16 | | 6 | | 45 | 30% | 27% | 43% |
| 2001 | 13 | 7 | | 27 | (103) | 14 | | 62 | 28% | 15% | 57% |
| 2002 | 3 | 20 | | 47 | (482) | 15 | | 84 | 4% | 28% | 68% |
| 2003 | 2 | 12 | (100) | 85 | (174) | 32 | | 131 | 2% | 12% | 86% |
| 2004 | 4 | 55 | (95) | 82 | (316) | 49 | (43) | 191 | 3% | 39% | 58% |

Table C12. Recreational Golden tilefish data from the Marine Recreational Fishery Statistics Survey (MRFSS).

| year | number fish measured | landed no. A and B1 | Released B2 | A and B1 kg |
|---|---|---|---|---|
| 1982 | 0 | 984 | 0 | 98 |
| 1983 | 0 | 0 | 0 | 0 |
| 1984 | 0 | 0 | 0 | 0 |
| 1985 | 0 | 0 | 0 | 0 |
| 1986 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 0 |
| 1988 | 0 | 0 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 |
| 1990 | 0 | 0 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 | 0 |
| 1994 | 0 | 608 | 0 | 0 |
| 1995 | 0 | 0 | 0 | 0 |
| 1996 | 0 | 10,167 | 0 | 0 |
| 1997 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 0 |
| 2000 | 0 | 0 | 0 | 0 |
| 2001 | 0 | 148 | 0 | 0 |
| 2002 | 0 | 20,068 | 1,338 | 0 |
| 2003 | 18 | 722 | 0 | 2,126 |
| 2004 | 3 | 90 | 0 | 206 |

Table C13. Number of tilefish reported in the Party/charter vessel trip reports.

| year | ME | MD | NH | NJ | NY | NC | RI | VA | other | total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 275 | 0 | 636 | 0 | 0 | 0 | 0 | 0 | 0 | 911 |
| 1995 | 0 | 0 | 0 | 0 | 176 | 0 | 541 | 0 | 0 | 717 |
| 1996 | 0 | 0 | 0 | 0 | 81 | 0 | 0 | 0 | 0 | 81 |
| 1997 | 0 | 0 | 0 | 0 | 380 | 0 | 0 | 0 | 20 | 400 |
| 1998 | 0 | 0 | 0 | 0 | 121 | 52 | 102 | 0 | 20 | 295 |
| 1999 | 0 | 6 | 0 | 0 | 88 | 34 | 1 | 0 | 0 | 129 |
| 2000 | 0 | 0 | 0 | 39 | 108 | 139 | 0 | 0 | 0 | 286 |
| 2001 | 0 | 0 | 0 | 100 | 122 | 1,164 | 0 | 0 | 0 | 1,386 |
| 2002 | 0 | 0 | 0 | 383 | 425 | 0 | 0 | 0 | 0 | 808 |
| 2003 | 0 | 0 | 0 | 905 | 71 | 0 | 3 | 0 | 15 | 994 |
| 2004 | 0 | 0 | 0 | 225 | 0 | 0 | 0 | 27 | 12 | 264 |

Table C14. Comparison of 13 different ASPIC model runs for tilefish. Runs 1-2, 3-4, 5-6, and 7-8 split the weighout and VTR CPUE series. Runs 3-4, and 5-6 extend the landings time series in the past before the existence of CPUE data. Runs 7-8 uses the nominal weighout and VTR CPUE indices. Runs 9 through 11 reduced the increase in CPUE at the end of the VTR series to determine the sensitivity of recent increases in CPUE. Run 12 examines the effect of using a single CPUE series by combining Turner and the weighout/VTR CPUE series. Runs which combine indices use the weighout label to report the combined index $r^2$ and q. Run 13 fixed the B1/Bmsy ratio at 1 and was used as base run.

| run | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | | | | | | | nominal CPUE | nominal CPUE | vtr cpue no increase in last 3 years | vtr cpue no increase in last 2 years | vtr cpue decrease 2003 & 2004 CPUE | single CPUE Series | fix B1/Bmsy ratio to 1 |
| Start year | 1973 | 1973 | 1945 | 1945 | 1916 | 1916 | 1973 | 1973 | 1973 | 1973 | 1973 | 1973 | 1973 |
| Number of CPUE series | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 3 |
| $r^2$ (Turner) | 0.39 | 0.55 | 0.48 | 0.53 | 0.50 | 0.53 | 0.55 | 0.57 | 0.60 | 0.57 | 0.58 | - | 0.18 |
| $r^2$ (Weighout) | 0.73 | 0.72 | 0.73 | 0.72 | 0.72 | 0.71 | 0.68 | 0.68 | 0.70 | 0.72 | 0.71 | 0.87 | 0.70 |
| $r^2$ (VTR) | - | 0.51 | - | 0.51 | - | 0.51 | - | 0.45 | 0.14 | 0.47 | 0.36 | - | 0.54 |
| B1/Bmsy | 4.61 | 2.12 | 1.08 | 5.39 | 10.51 | 8.46 | 2.25 | 2.19 | 2.44 | 2.19 | 2.28 | 2.51 | 1.00 |
| MSY (live, mt) | 1.87 | 1.83 | 1.94 | 1.84 | 1.92 | 1.84 | 1.87 | 1.75 | 1.56 | 1.76 | 1.69 | 2.14 | 1.99 |
| r | 0.47 | 0.42 | 0.47 | 0.42 | 0.47 | 0.42 | 0.45 | 0.38 | 0.30 | 0.39 | 0.35 | 0.63 | 0.42 |
| K (mt) | 15.87 | 17.39 | 16.30 | 17.42 | 16.51 | 17.44 | 16.82 | 18.40 | 20.54 | 18.17 | 19.12 | 13.67 | 18.77 |
| $B_{msy}$ (live, mt) | 7.93 | 8.69 | 8.15 | 8.71 | 8.26 | 8.72 | 8.41 | 9.20 | 10.27 | 9.09 | 9.56 | 6.84 | 9.38 |
| $F_{msy}$ (live, mt) | 0.24 | 0.21 | 0.24 | 0.21 | 0.23 | 0.21 | 0.22 | 0.19 | 0.15 | 0.19 | 0.18 | 0.31 | 0.21 |
| q (Turner's) | 0.008 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 | 0.008 | 0.007 | 0.008 | 0.007 | - | 0.010 |
| q (Weighout) | 0.235 | 0.217 | 0.241 | 0.218 | 0.235 | 0.184 | 0.162 | 0.139 | 0.160 | 0.200 | 0.183 | 0.31 | 0.225 |
| q (VTR) | - | 0.379 | - | 0.384 | - | 0.382 | - | 0.157 | 0.307 | 0.344 | 0.329 | - | 0.392 |
| B(2005)/Bmsy | 0.81 | 0.77 | 0.79 | 0.76 | 0.77 | 0.76 | 0.91 | 0.77 | 0.51 | 0.71 | 0.63 | 0.82 | 0.715 |
| F(2004)/Fmsy | 0.82 | 0.87 | 0.81 | 0.87 | 0.83 | 0.87 | 0.73 | 0.91 | 1.57 | 1.03 | 1.21 | 0.73 | 0.870 |

## TILEFISH FIGURES

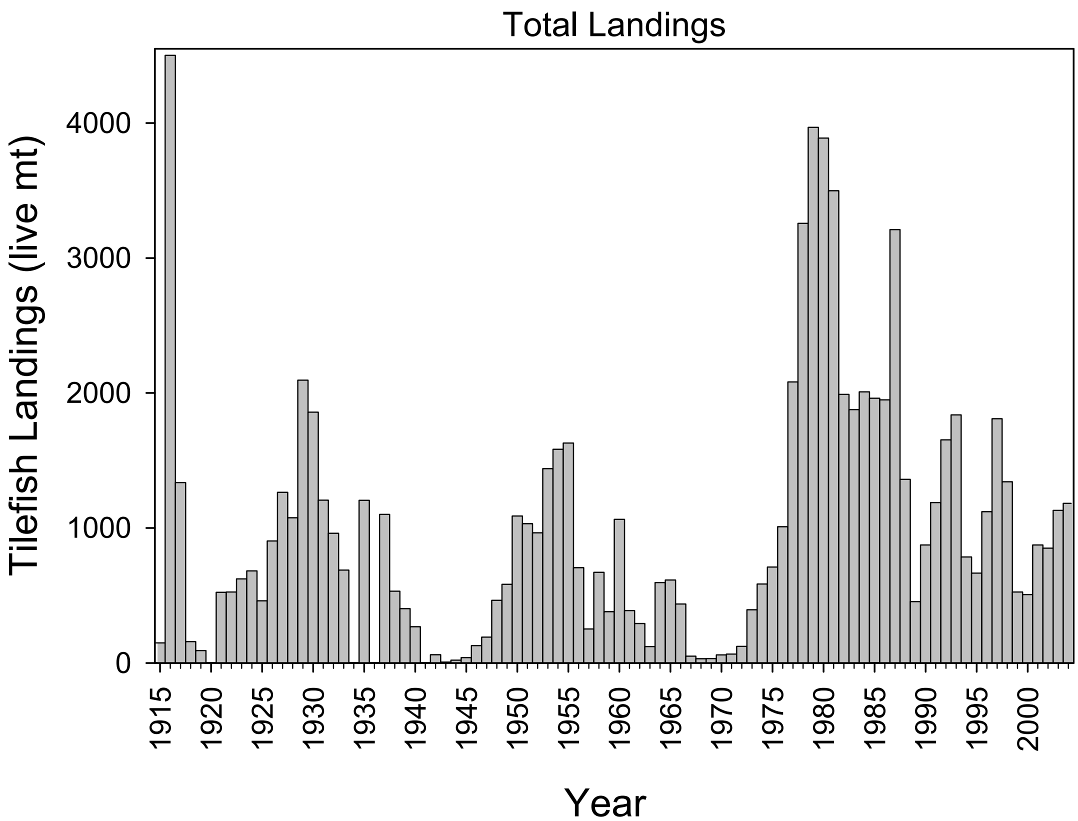



Figure C1. Landings of tilefish in metric tons from 1915-2004. Landings in 1915-1972 are from Freeman and Turner (1977),1973-1989 are from the general canvas data, 1990-1993 are from the weighout system, 1994-2003 are from the dealer reported data, and 2004 is from dealer electronic reportings.

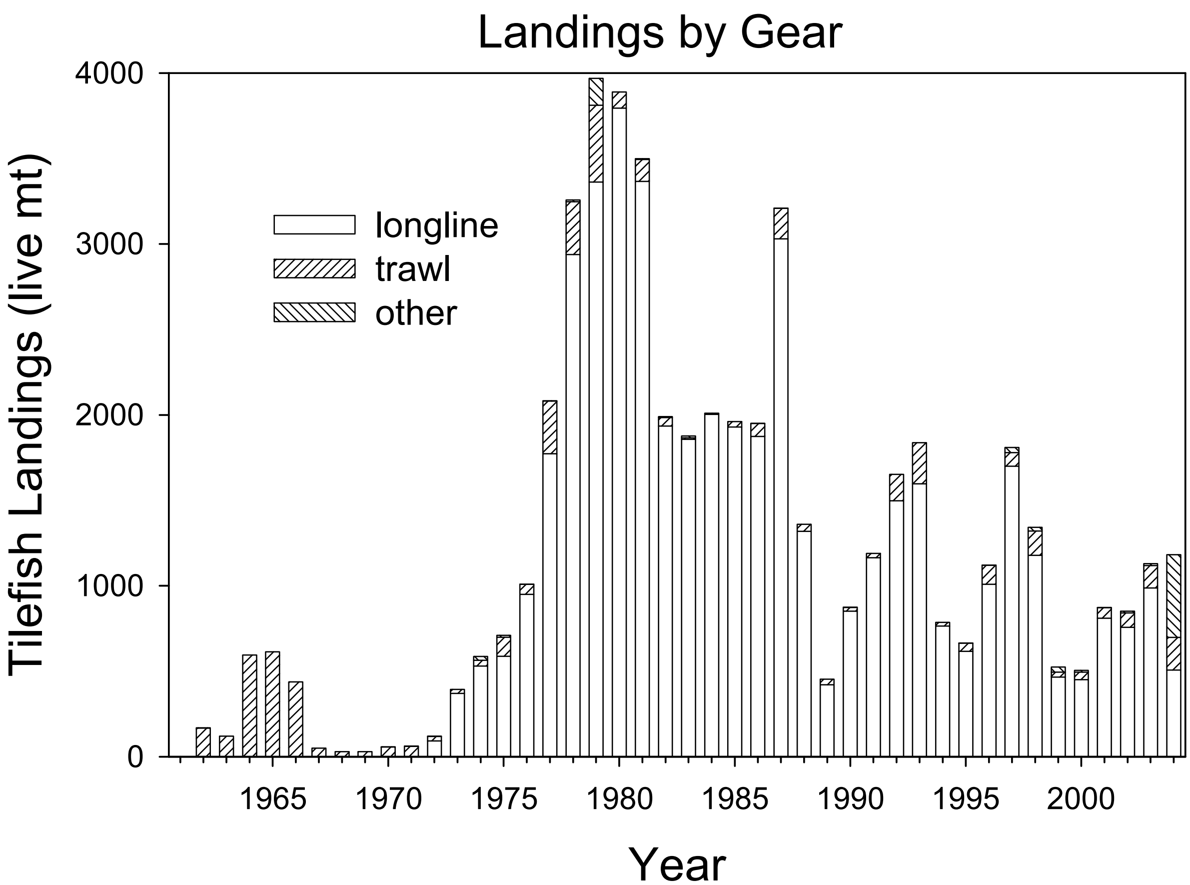



Figure C2. Landings of tilefish (mt, live) by gear. Landing berfore 1990 are from the general canvas data.

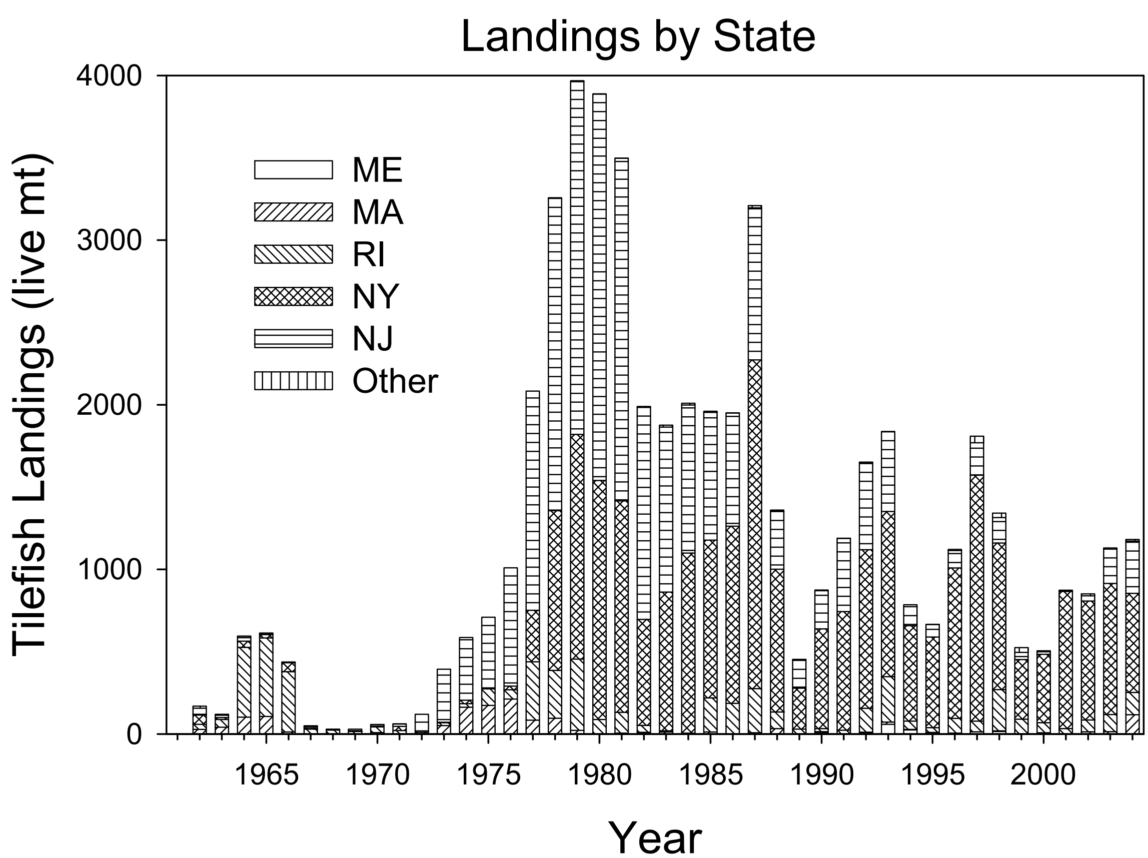



Figure C3. Landings of tilefish (mt, live) by State. Landings berfore 1990 are from the general canvas data.

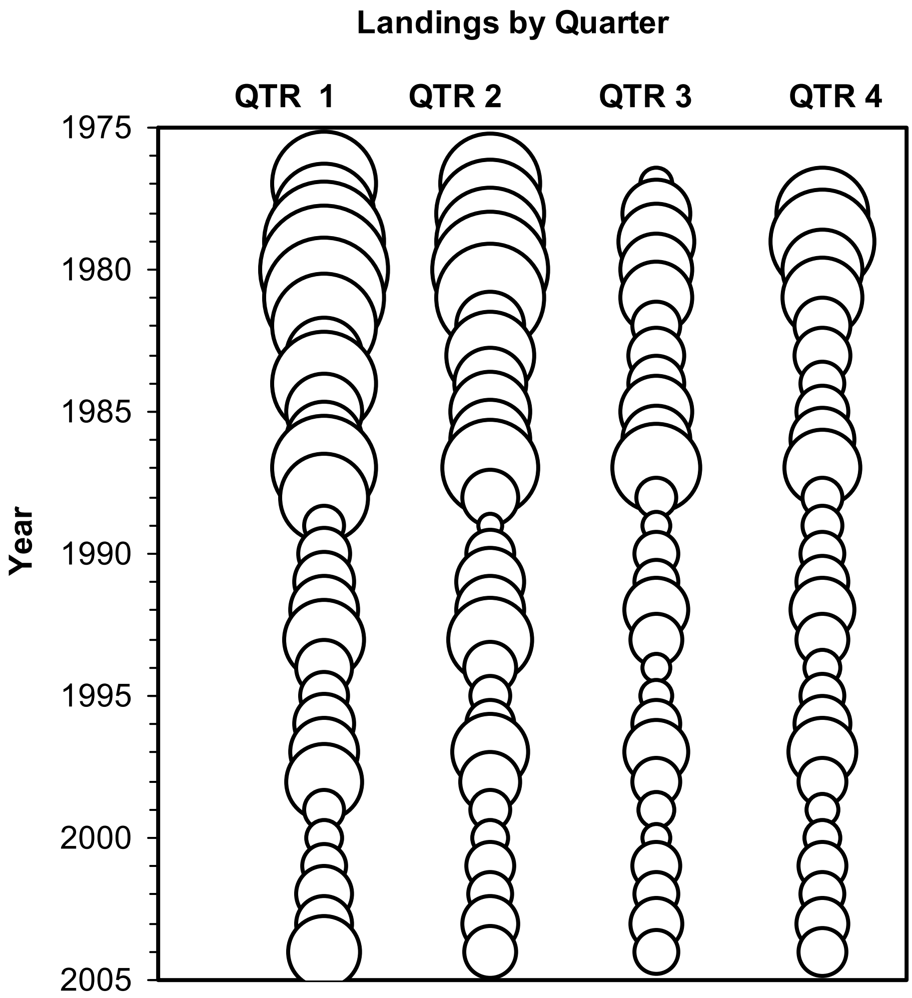



Figure C4. Bubble plot of Golden tilefish landings by quarter.

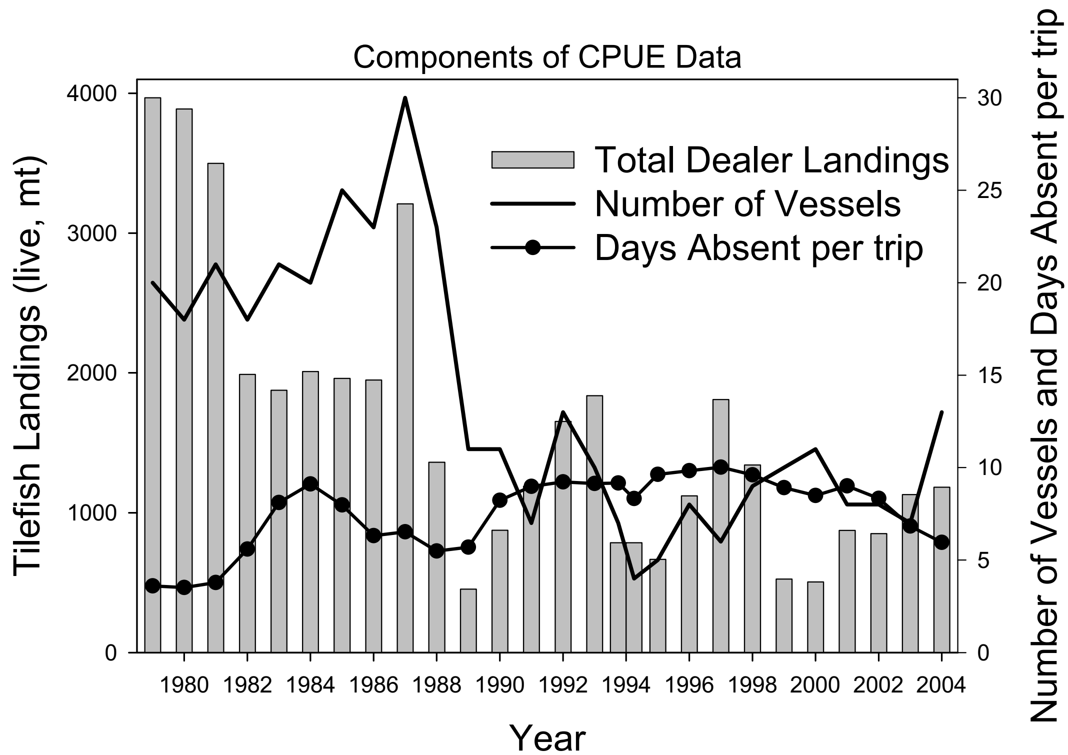



Figure C5. Number of vessels and length of trip (days absent per trip) for trips targeting tilefish (= or >75% tilefish) from 1979-2004. Total Dealer landings are also shown. Year 1994 is split by weighout and VTR data.

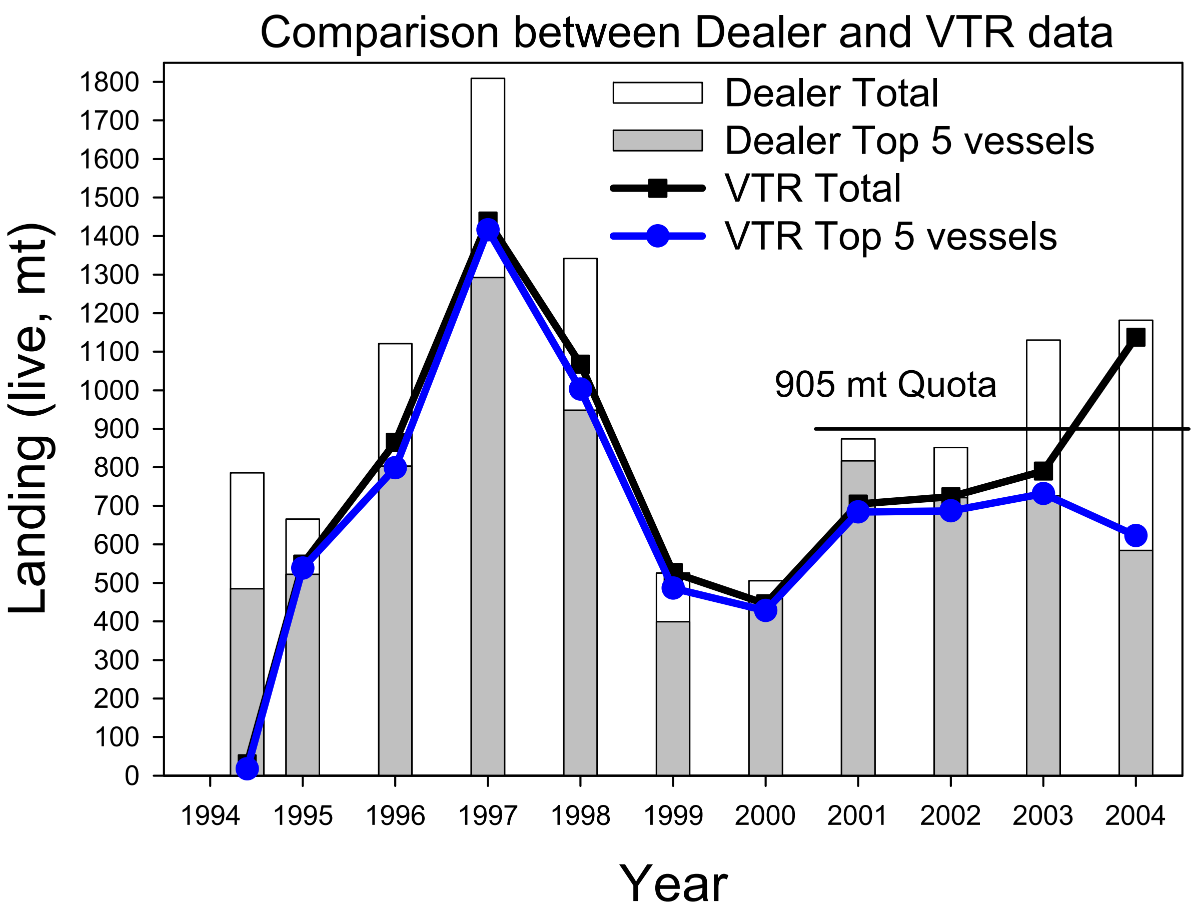



Figure C6. Comparison of dealer and VTR total landings in live metric tons. Total landings limited to the five dominant tilefish vessel are also shown.

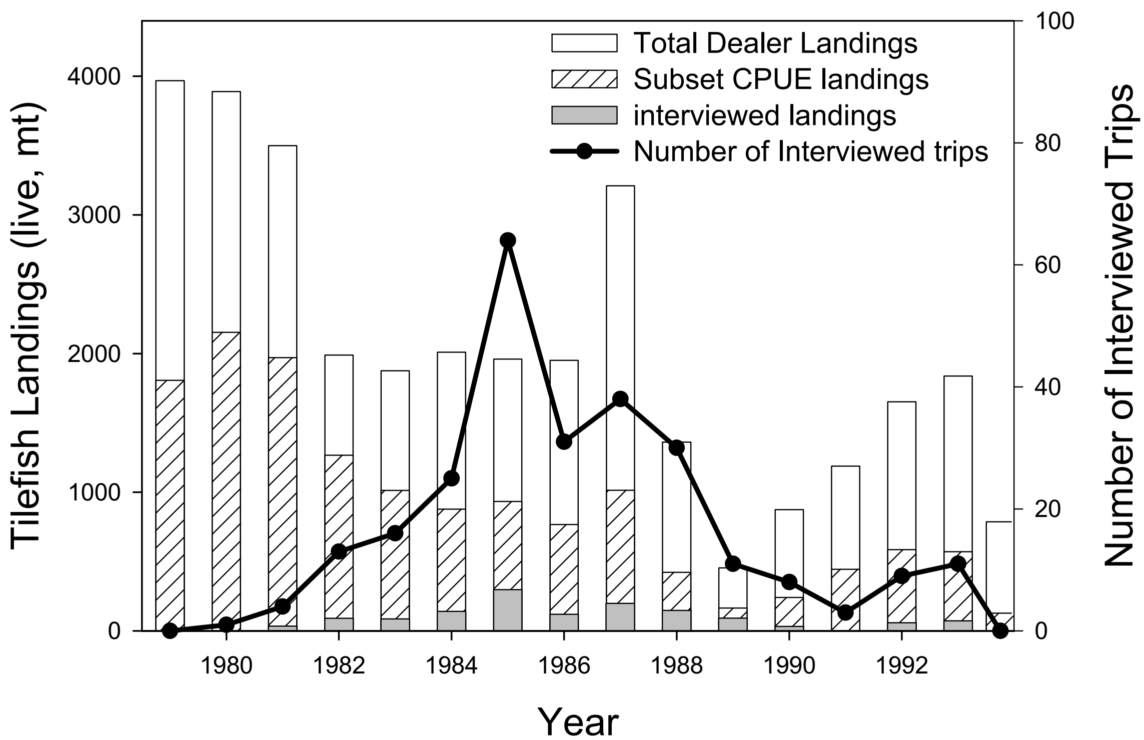



Figure C7. Number of interviewed trips and interviewed landings for trips targeting tilefish (= or >75% tilefish) for the weighout data from 1979-1994. Total weighout landings and the subset landings used in CPUE estimate are also shown.

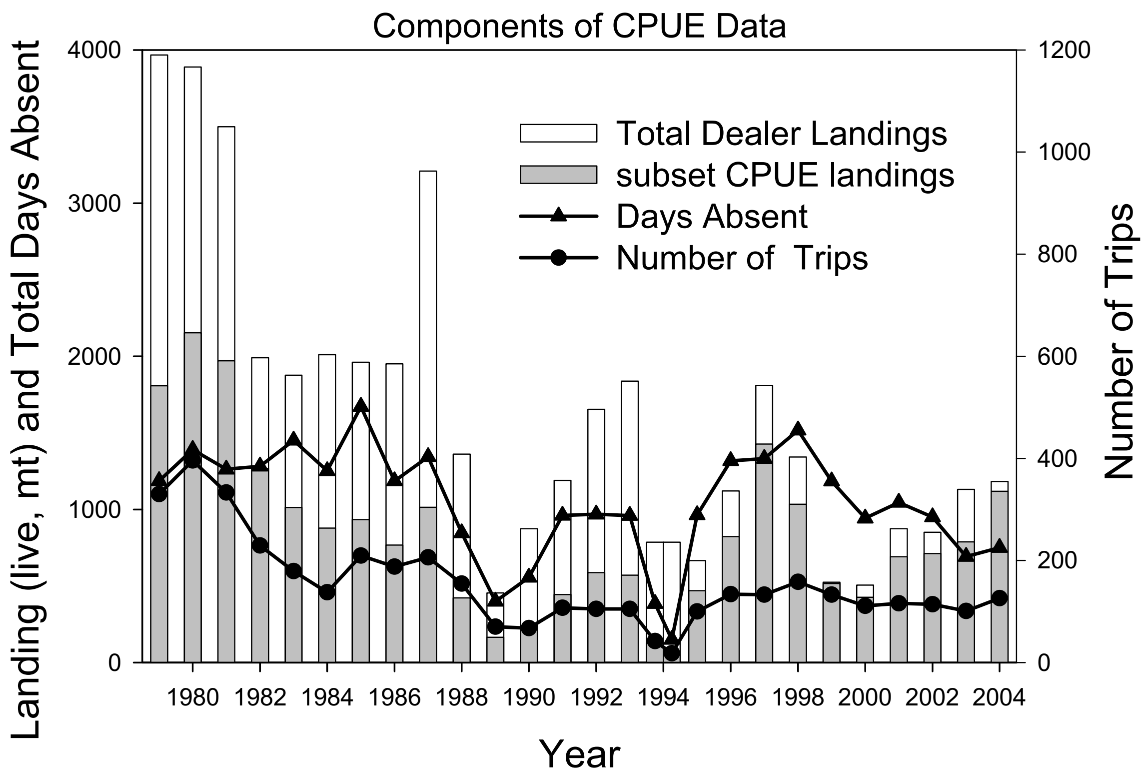



Figure C8. Total number of trips and days absent for trips targeting tilefish (= or >75% tilefish) from 1979-2004. Total Dealer and CPUE subset landings are also shown. Year 1994 is split by weighout and VTR data.

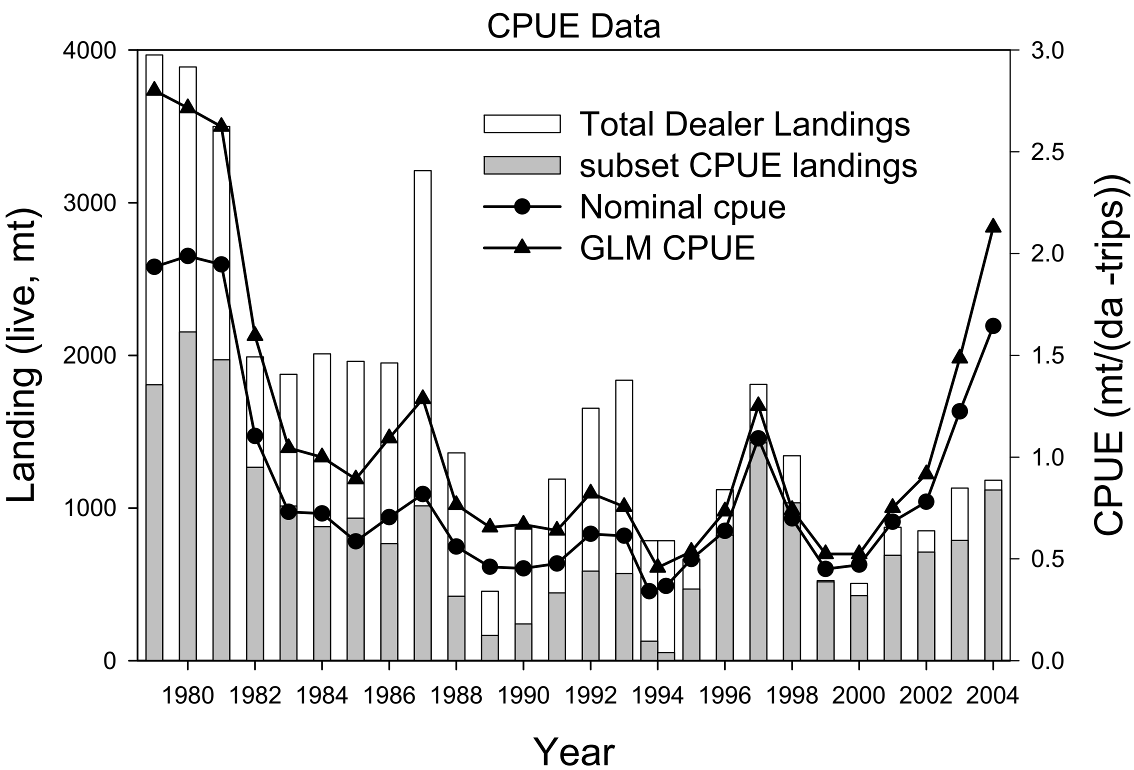



Figure C9. Nominal CPUE (1994 split by weighout and VTR series) and vessel standardized CPUE (GLM) for trips targeting tilefish (= or >75% tilefish) from 1979-2004. Total Dealer and CPUE subset landings are also shown. Year 1994 is split by the weighout and VTR data for the landings and nominal CPUE series.

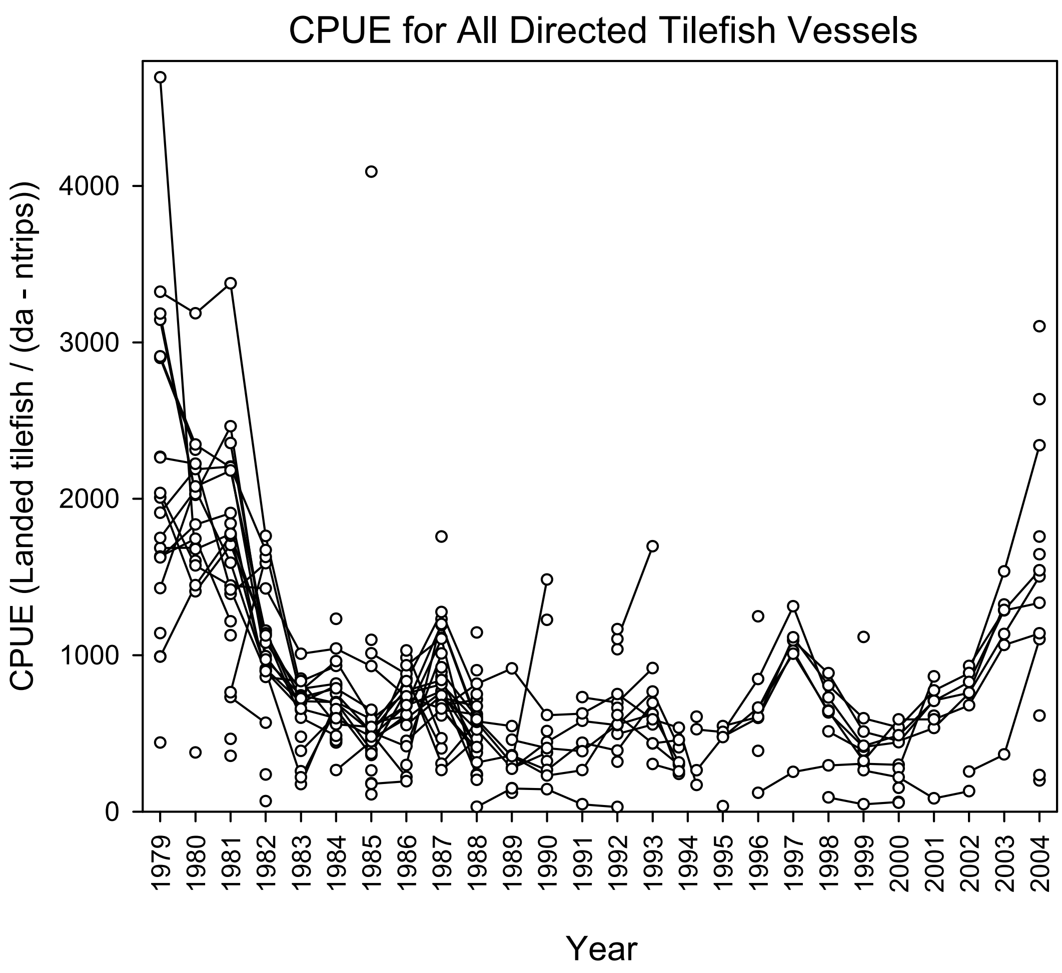



Figure C10. All individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004.

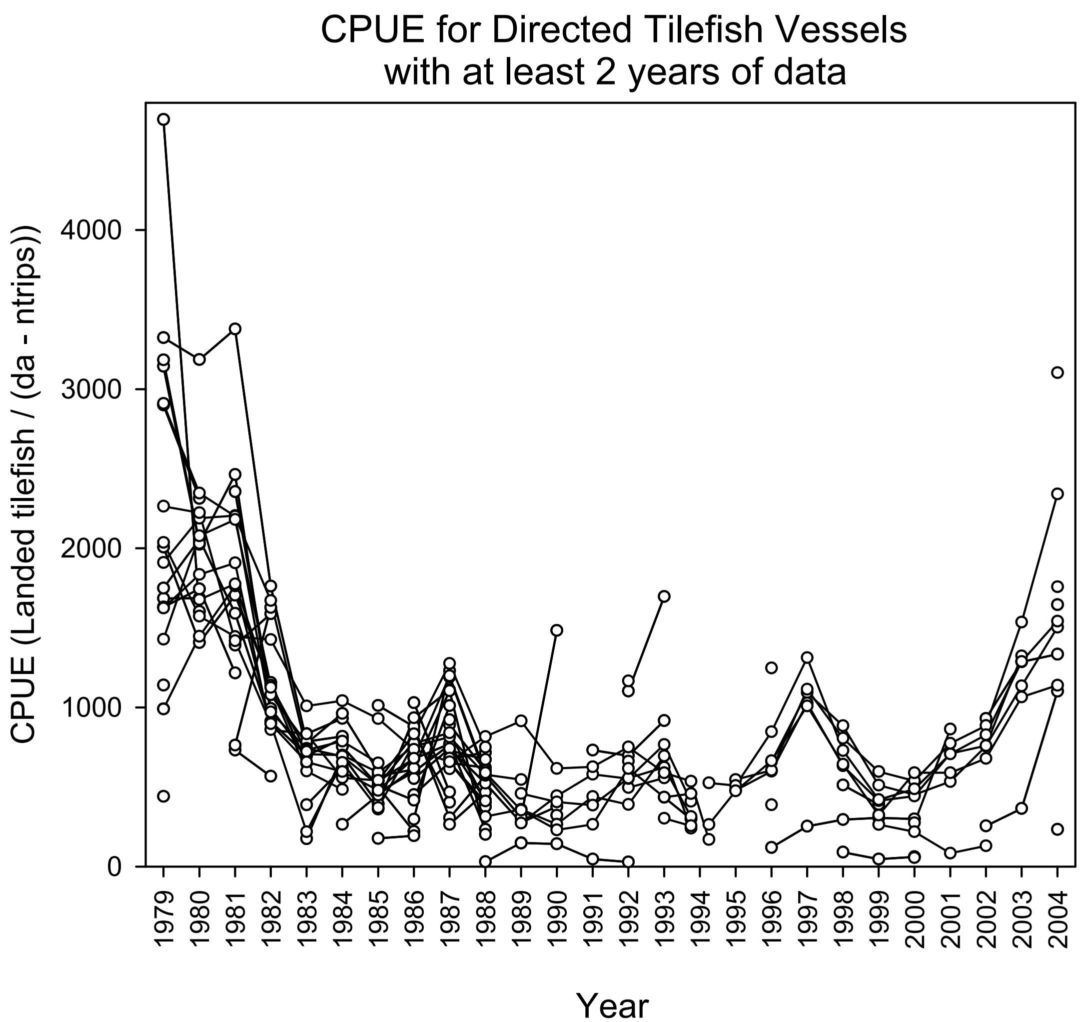



Figure C11. Individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004 with at least 2 years of data.

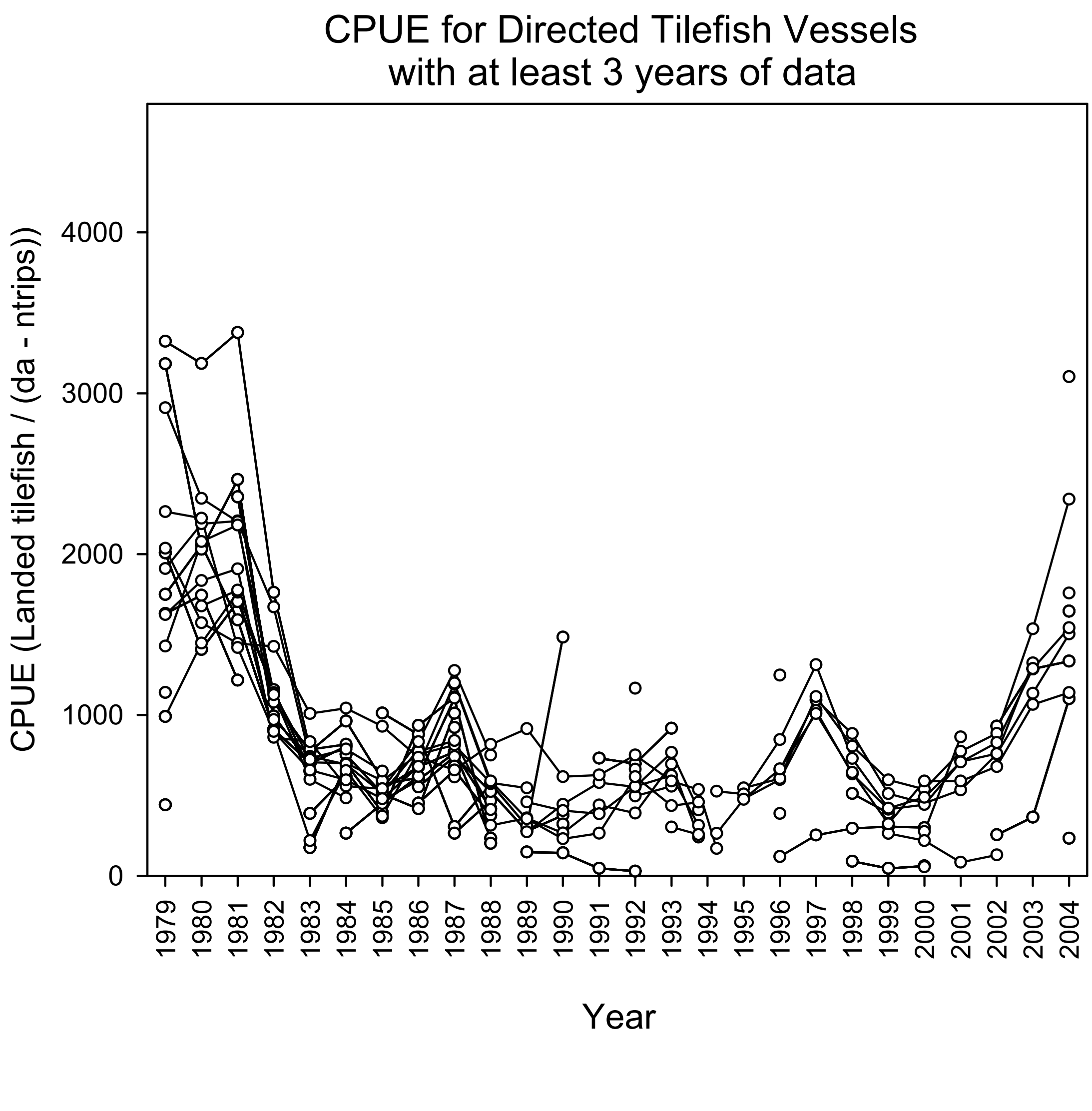



Figure C12. Individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004 with at least 3 years of data.

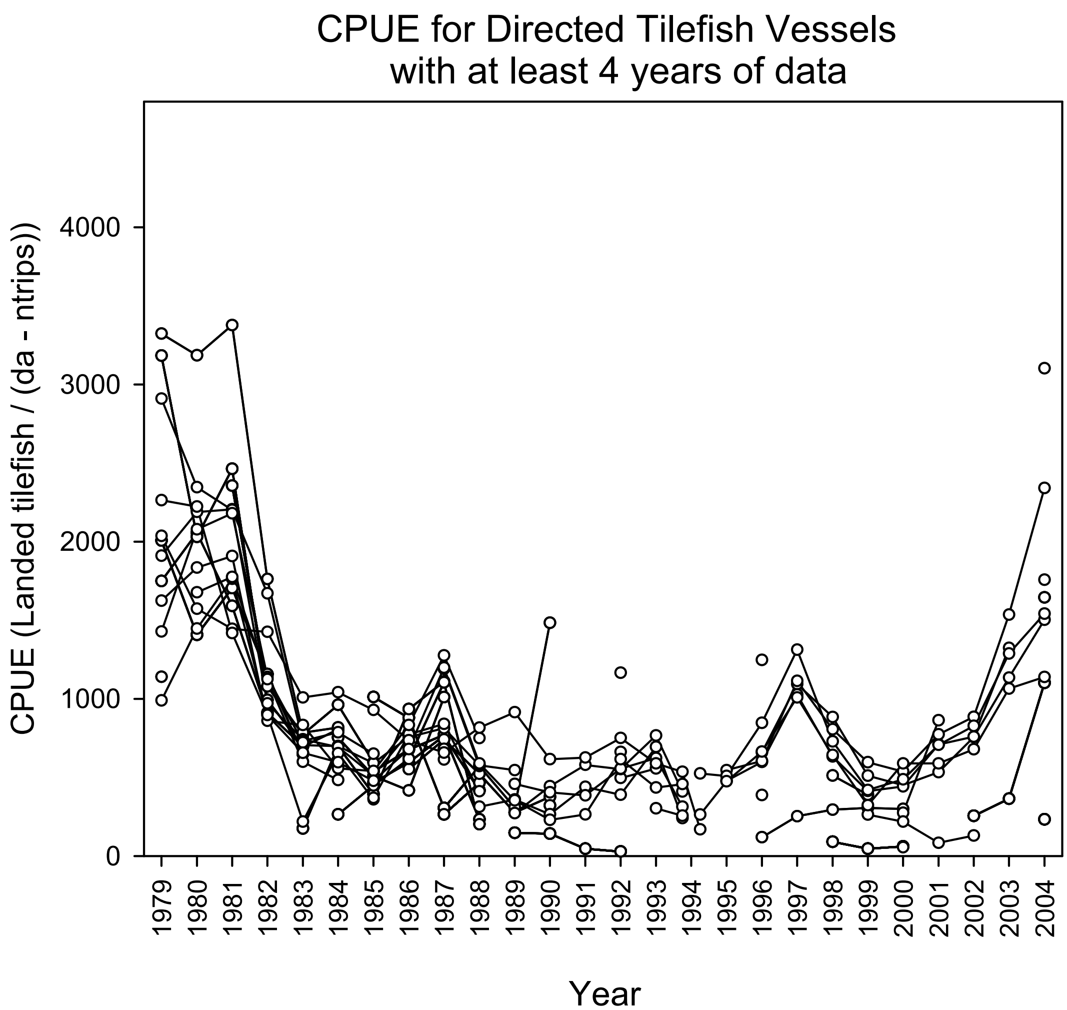



Figure C13. Individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004 with at least 4 years of data.

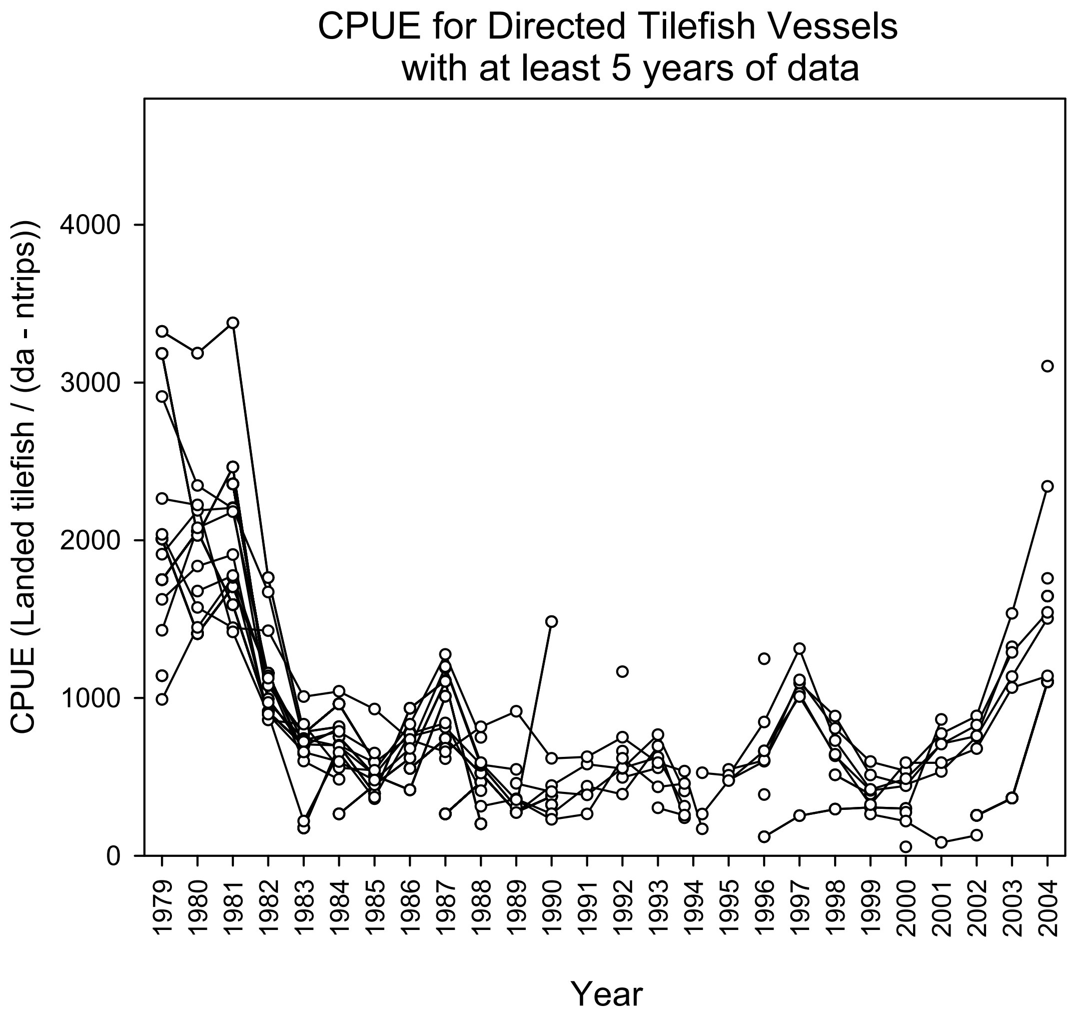



Figure C14. Individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004 with at least 5 years of data.

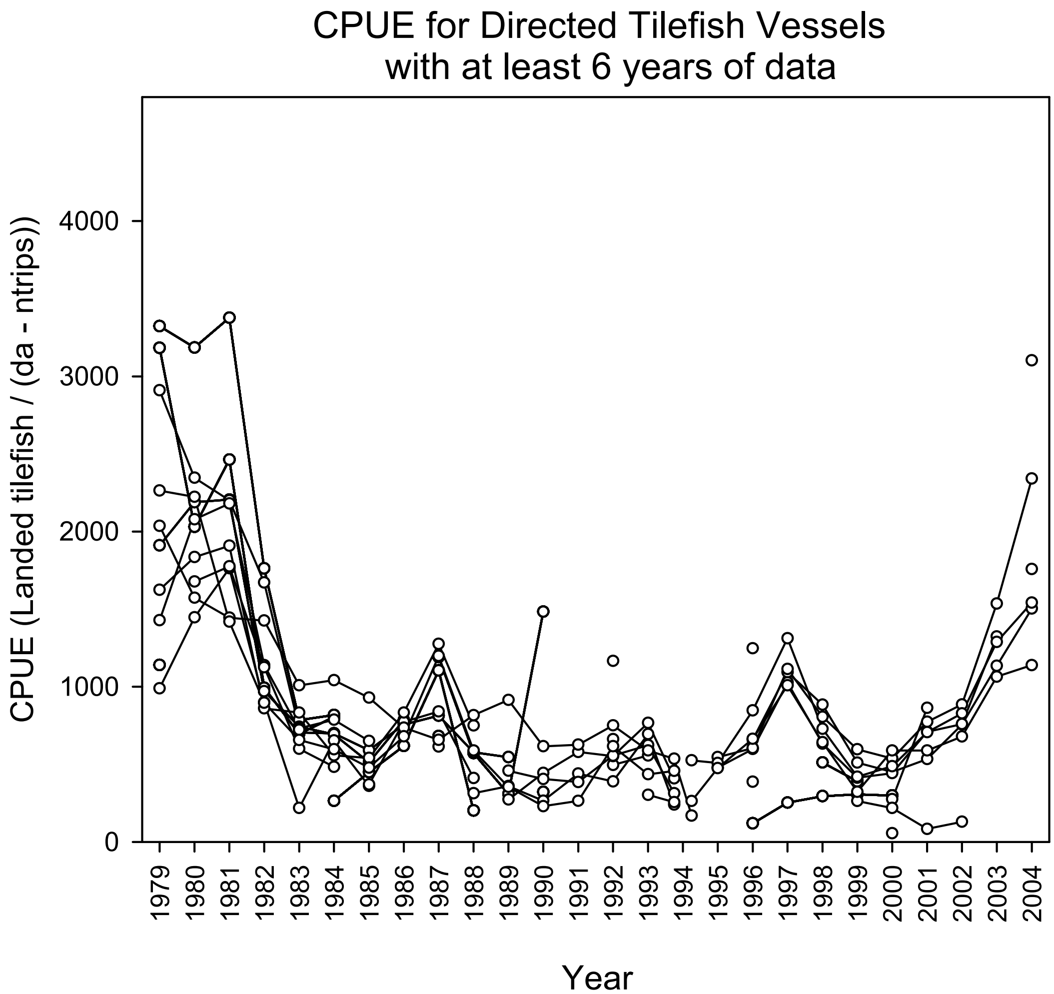



Figure C15. Individual tilefish vessel CPUE data for trips targeting tilefish (= or >75% tilefish) from 1979-2004 with at least 6 years of data.

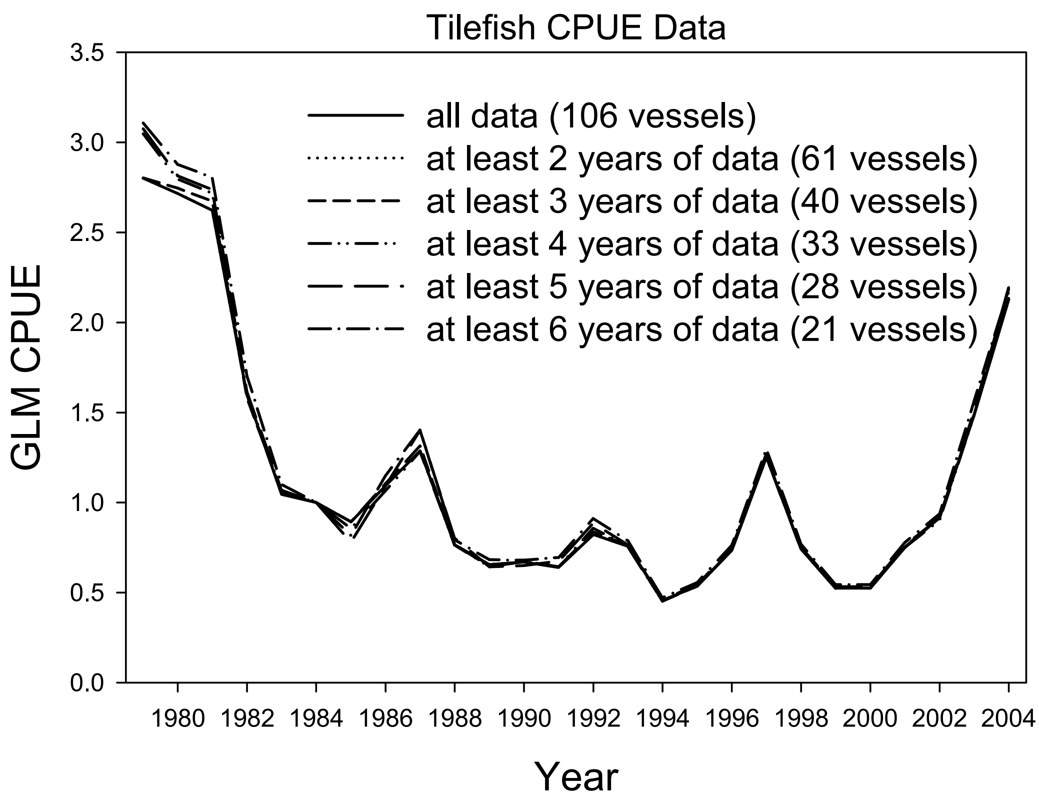



Figure C16. Sensitivity of the GLM (weighout and VTR combined) to the triming of vessels with different amonts of data.


Figure C17. Depiction of individual vessels (rows) targeting tilefish over the weighout and VTR series. Year 1994 is split by the two series. Below the horizontal line are vessels which are predominantly found in the VTR series.

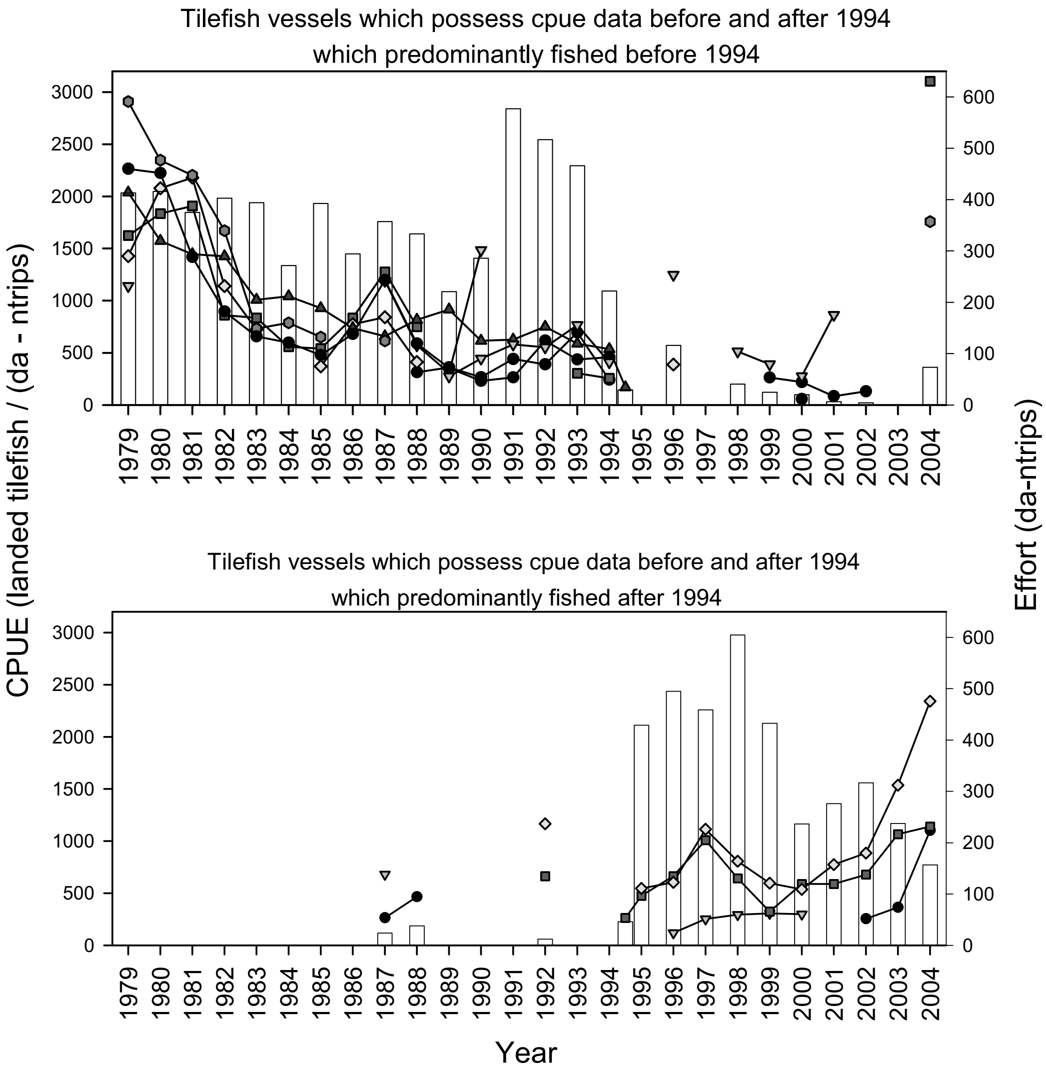



Figure C18. Individual tilefish vessel CPUE and effort data (Bars) for trips targeting tilefish (= or >75% tilefish) from 1979-2004 which are found in both the weighout and VTR series. Top graph are vessels found predominantly in the weighout series. Bottom graph are vessels found predominantly in the VTR series.

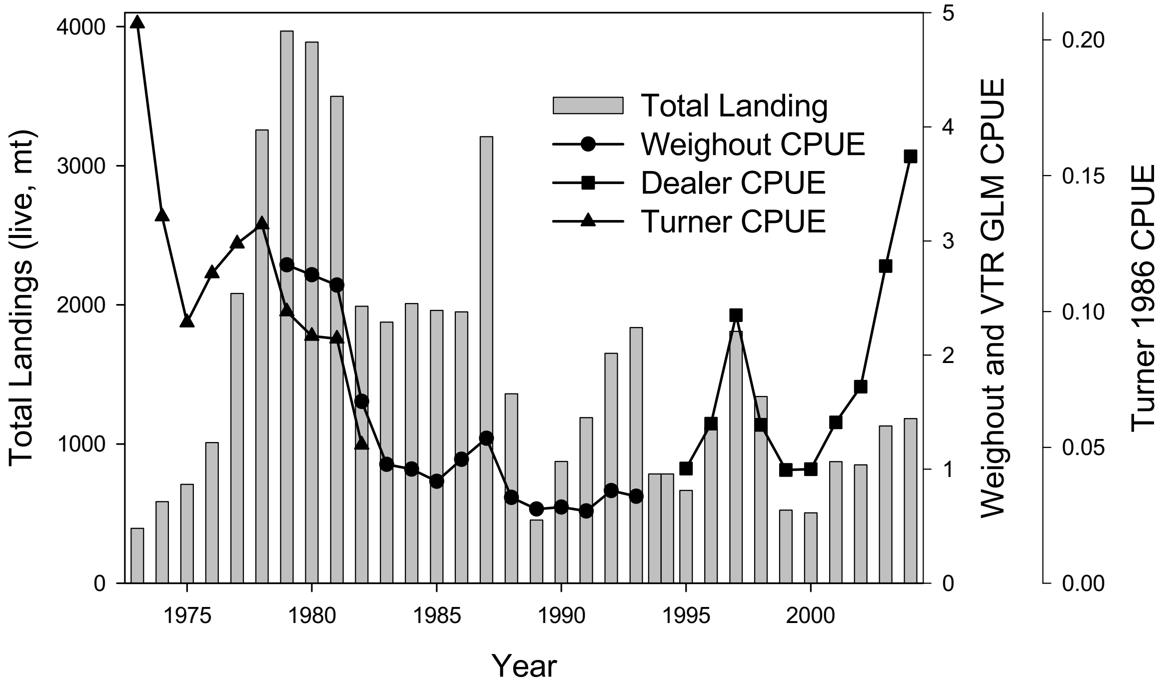



Figure C19. GLM CPUE for the weighout and VTR data split into two series. Four years of overlap between Turner and the weighout CPUE series can be seen. Total Dealer landings are also shown.

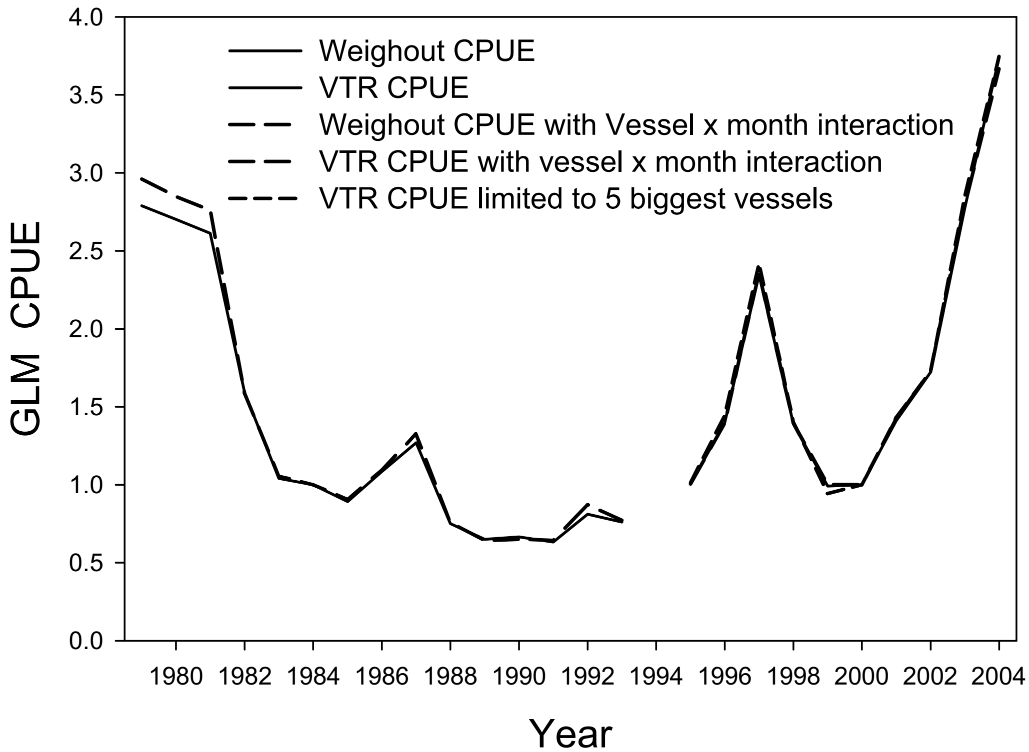



Figure C20. Standardized CPUE (GLM) data with the weighout and VTR data split into two series. GLM CPUE estimates with vessel-month interaction and a GLM limited to the five dominant vessels for the VTR data are also shown.

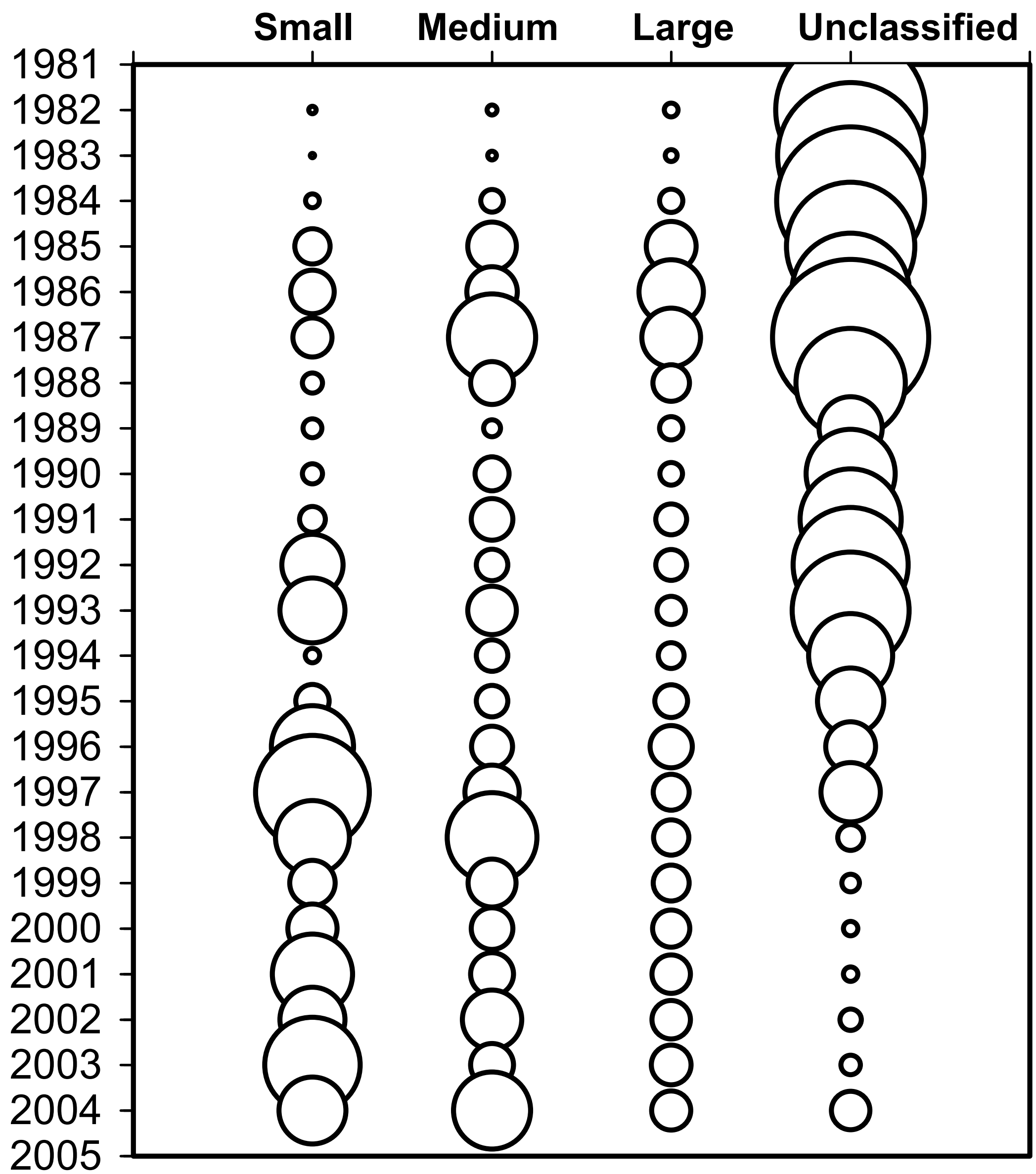
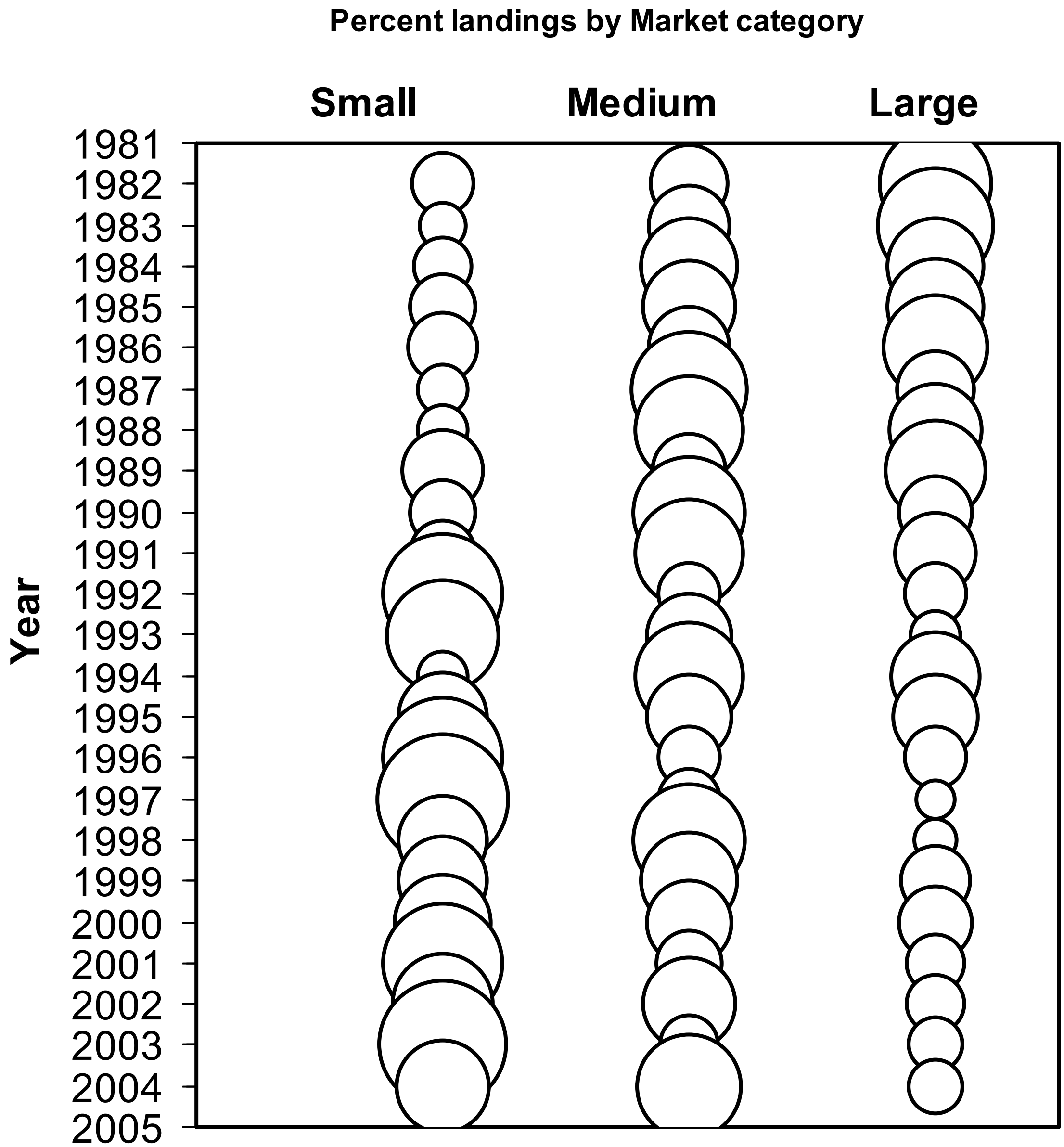



Figure C21. Bubble plot of Golden tilefish landings by market category.



Percent landings by Market category
Small
Medium
Large
Year
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

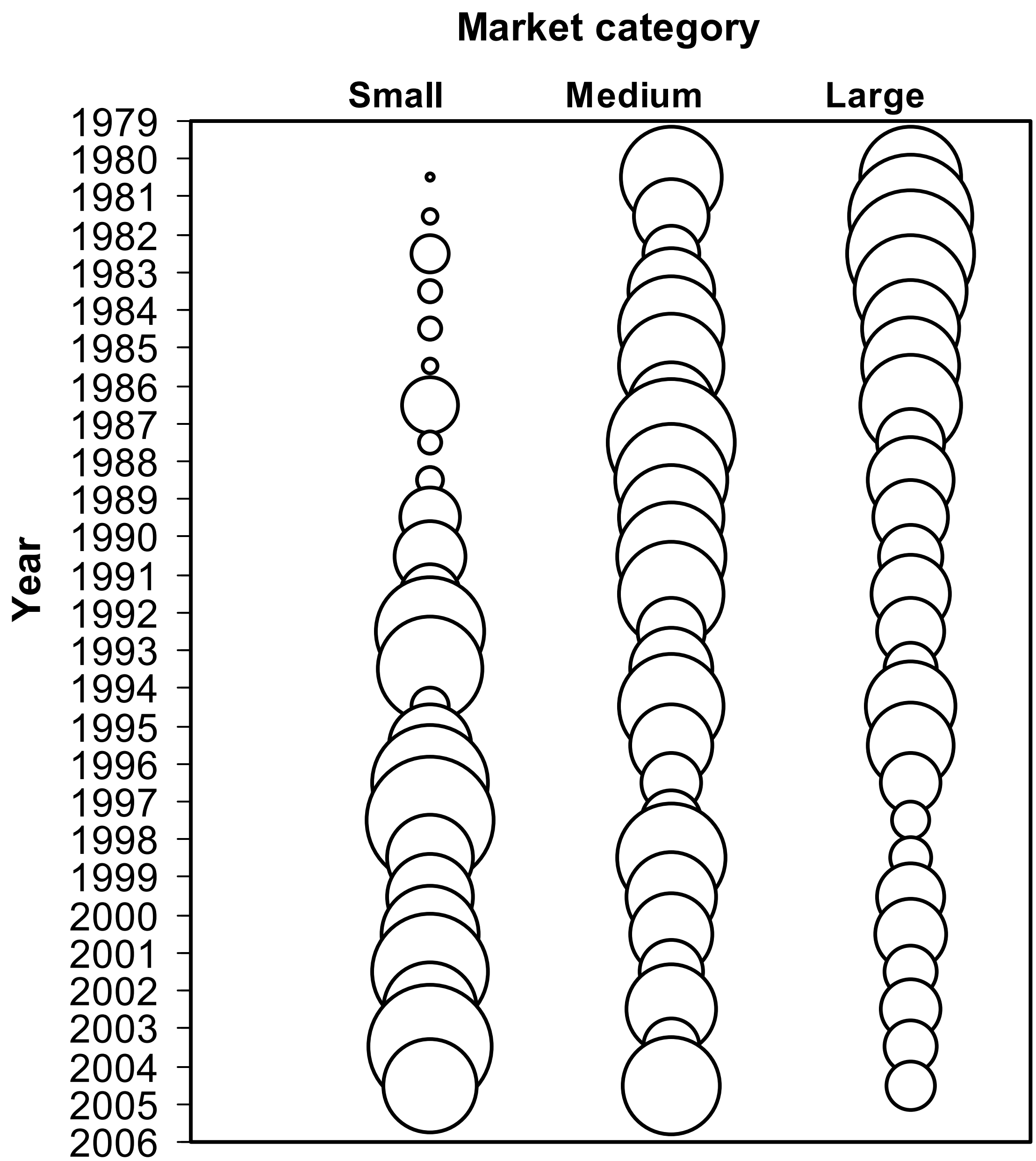



Figure C23. Bubble plot of percent Golden tilefish longline landings by market category. Data from 1980 to 1990 comes from New York tilefish fishermen. Data form 1991-2003 was taken from the dealer data. Data form 2004 are from dealer electronic reporting. Unclassified landings were redistributed according to the other market categories.

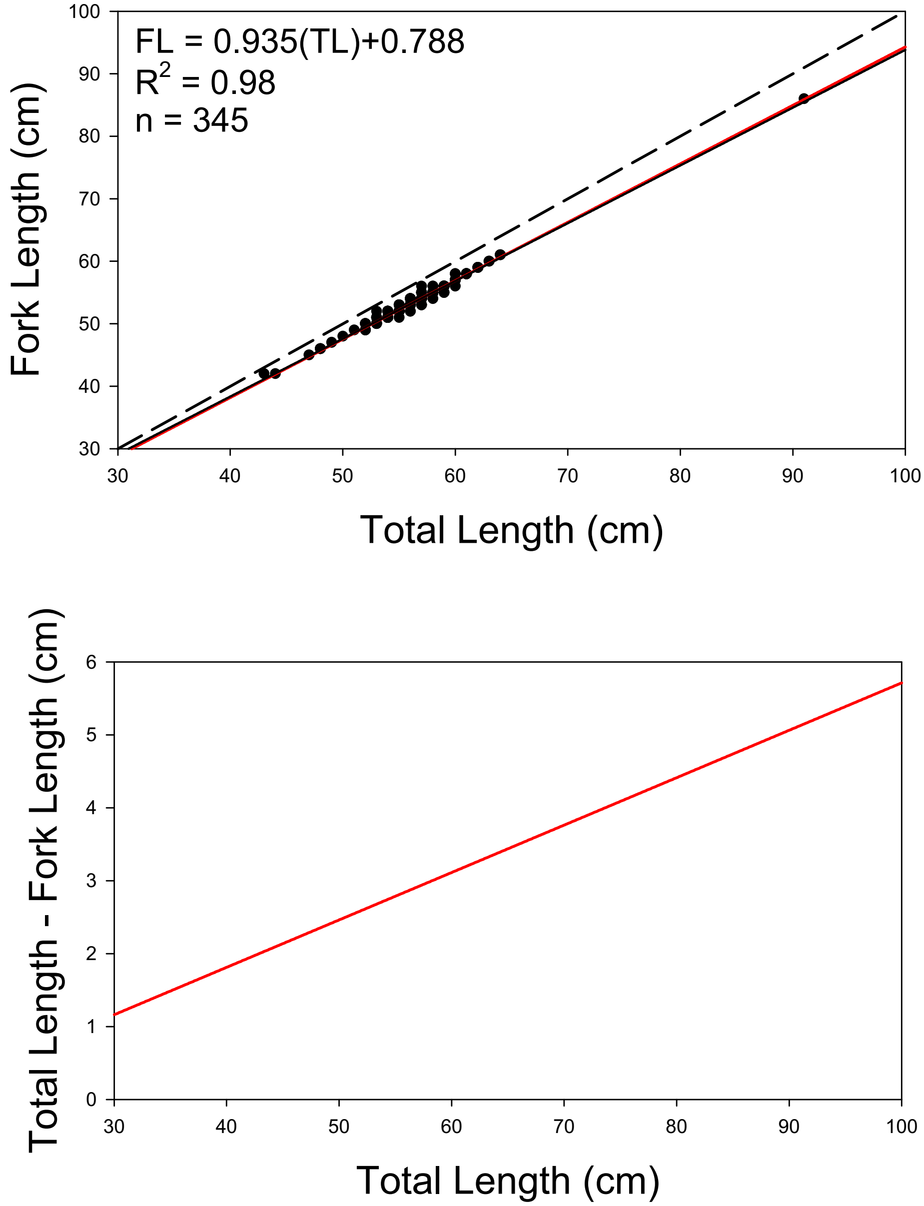



Figure C24. Top graph shows the estimated regression between total and fork length for Golden tilefish for data collected in 2005. Bottom graph illustrates the difference between the two measurements.

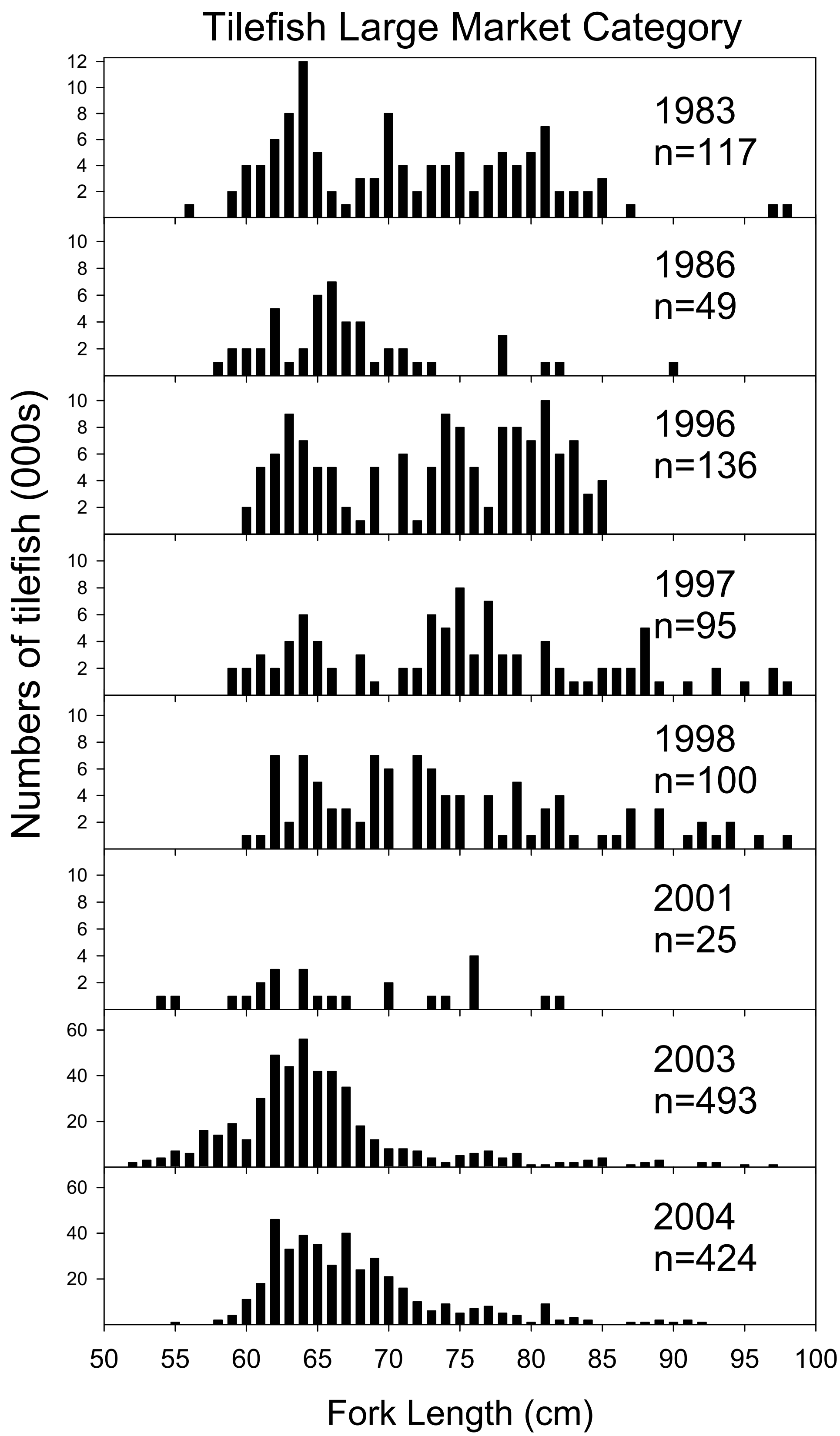



Figure C25. Large tilefish market category length frequency distributions by year. Lengths from New York from 2000 to 2004 were converted to fork length.

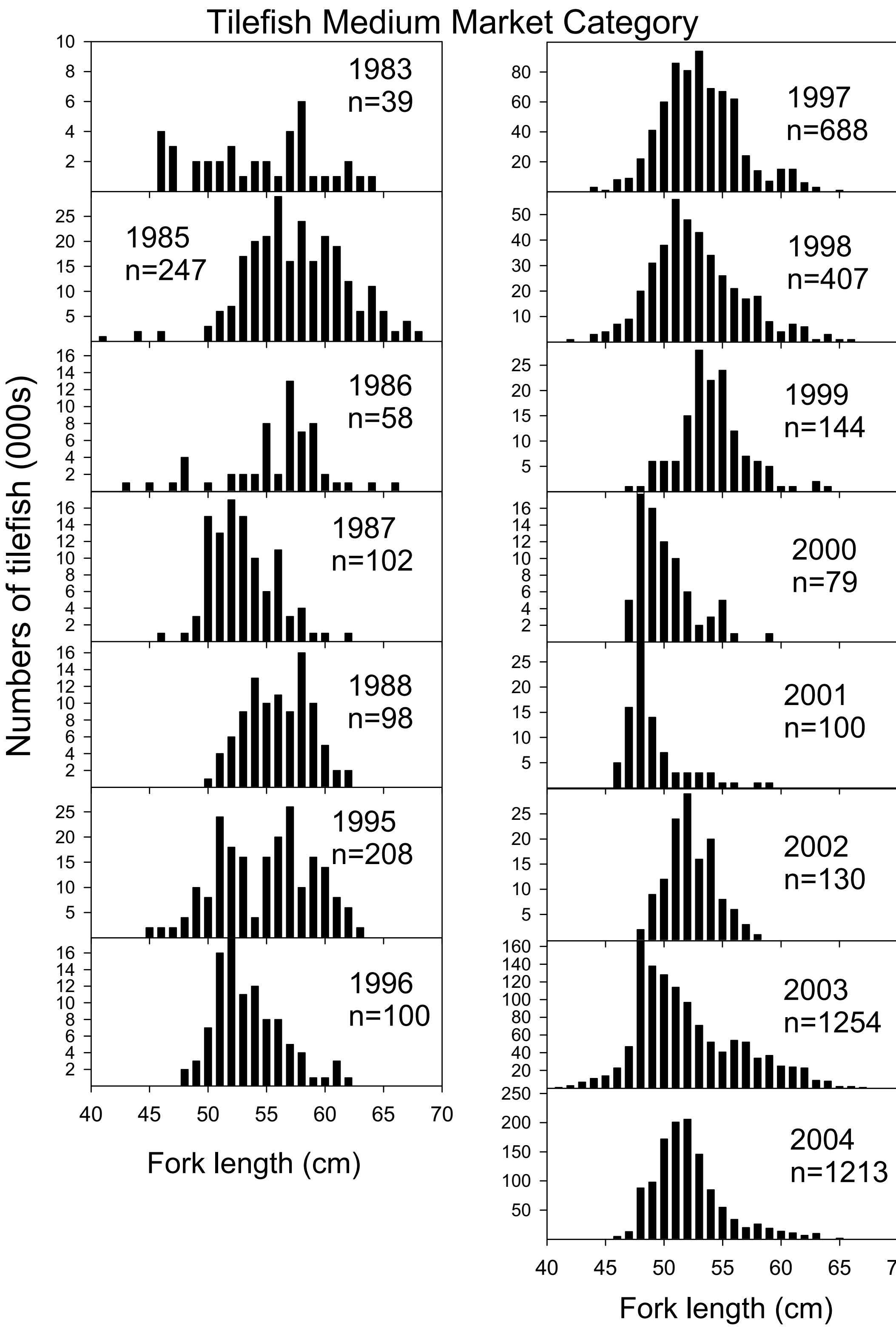



Figure C26. Medium tilefish market category length frequency distributions by year. Lengths from New York from 2000 to 2004 were converted to fork length.

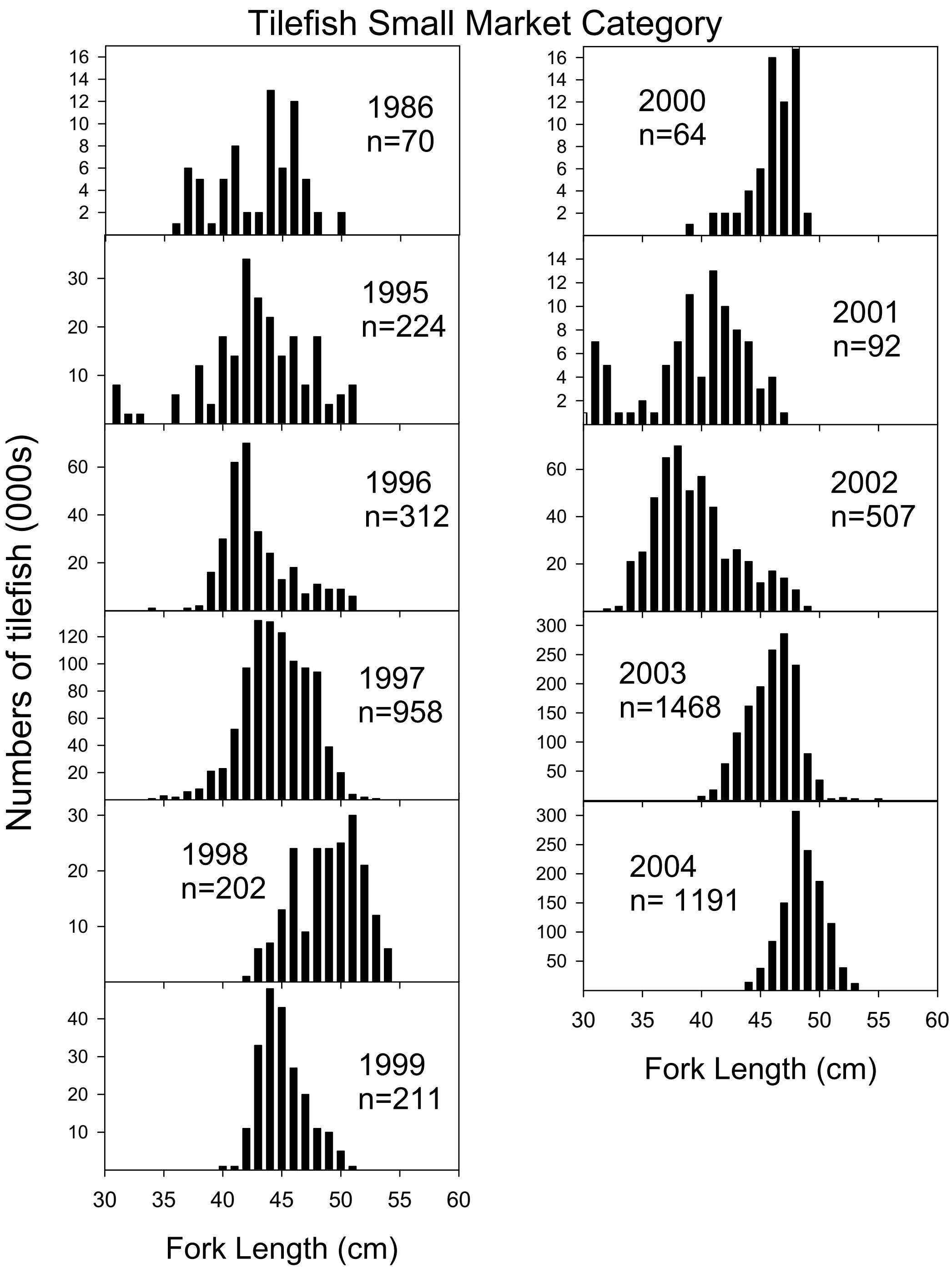



Figure C27. Small tilefish market category length frequency distributions by year. Lengths from New York from 2000 to 2004 were converted to fork length.

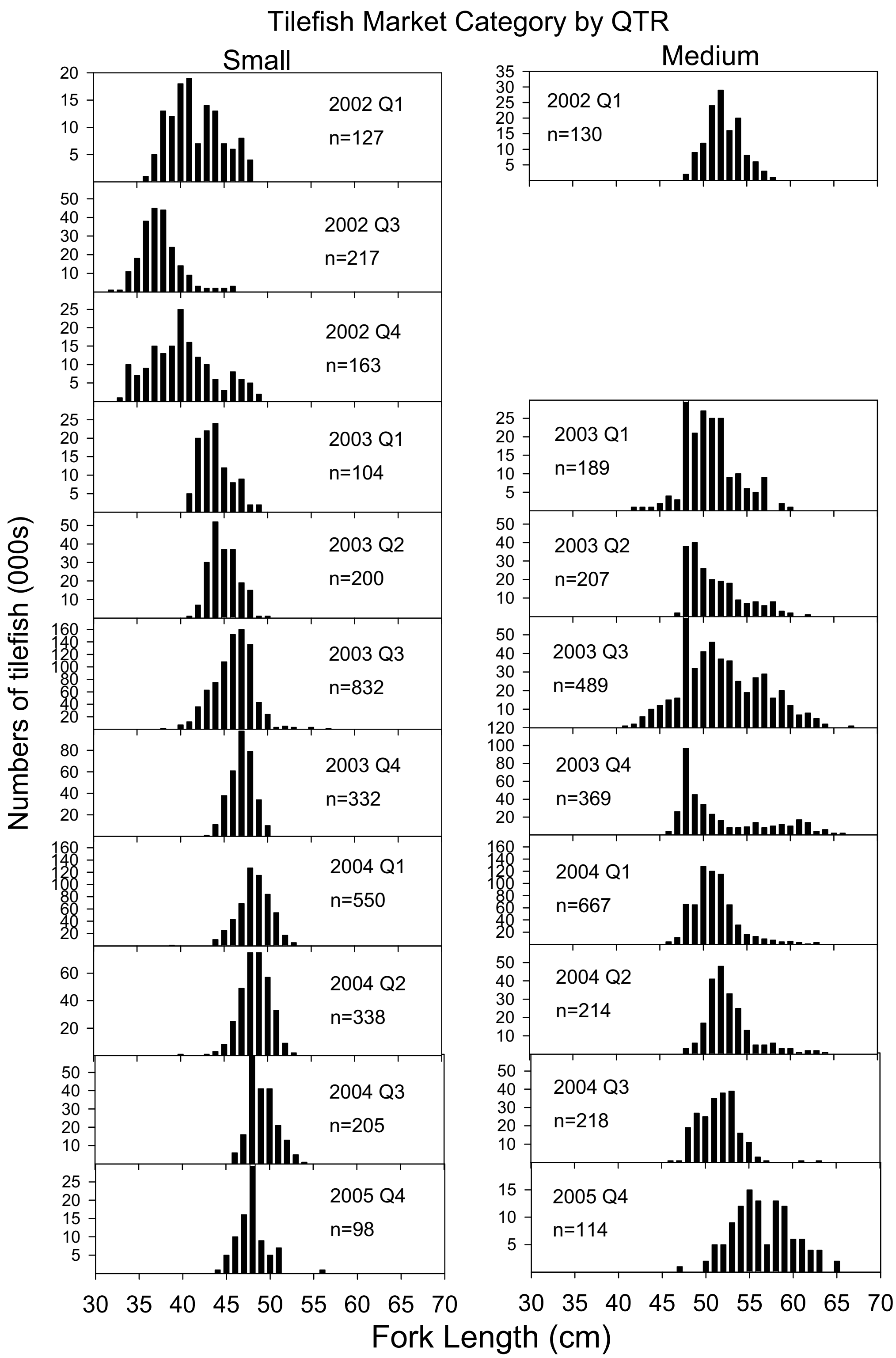



Figure C28. Small and medium tilefish market category length frequency distributions by quarter. Lengths from New York from 2000 to 2004 were converted to fork length.

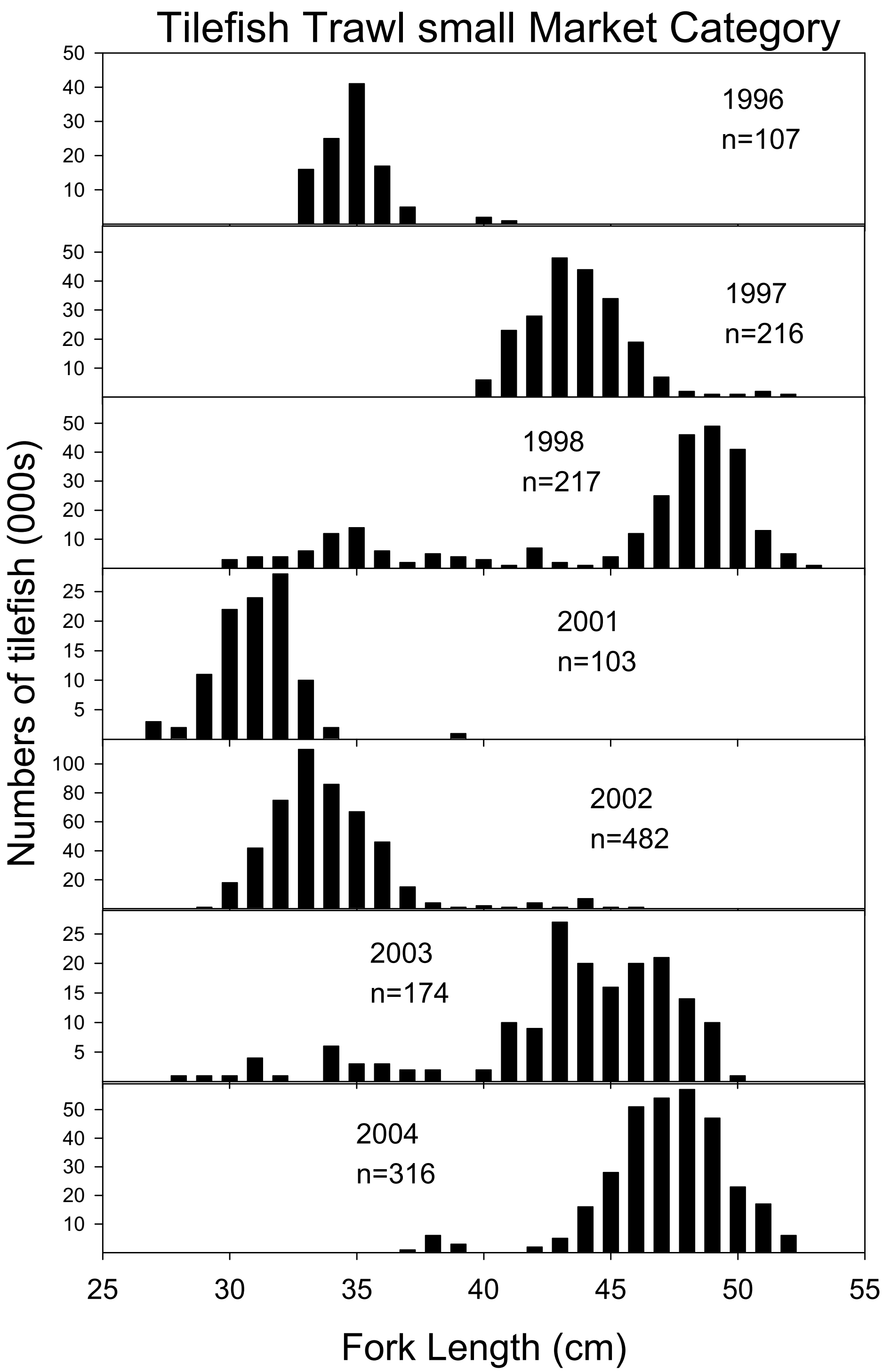



Figure C29. Trawl small tilefish market category length frequency distributions by year. Lengths from New York from 2000 to 2004 were converted to fork length.

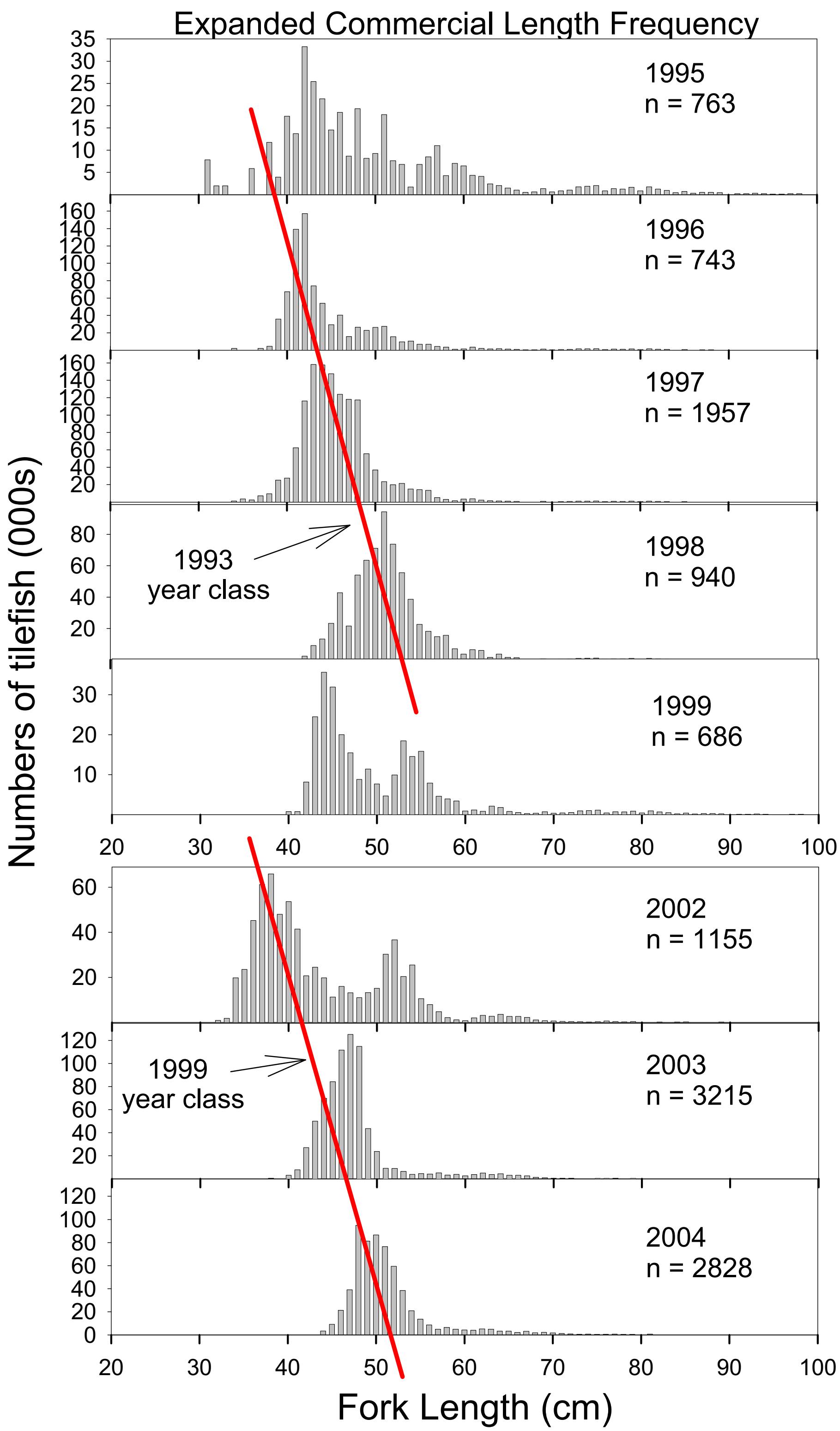



Figure C30. Expanded catch length frequency distributions by year. Large market category lengths used from 1995 to 1999 were taken from years 1996, 1997, and 1998. Large lengths for 2002 when taken from large lengths in 2001 and 2003.

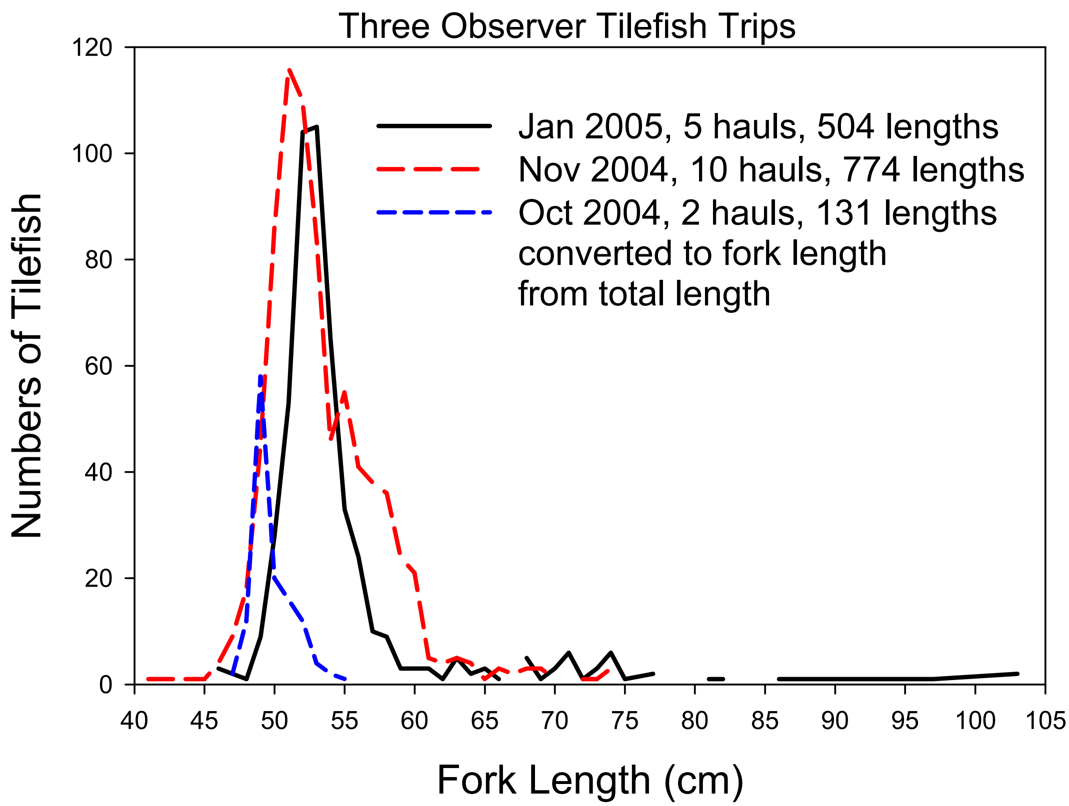



Figure C31. Observer Length frequency distributions from three longline tilefish trips.

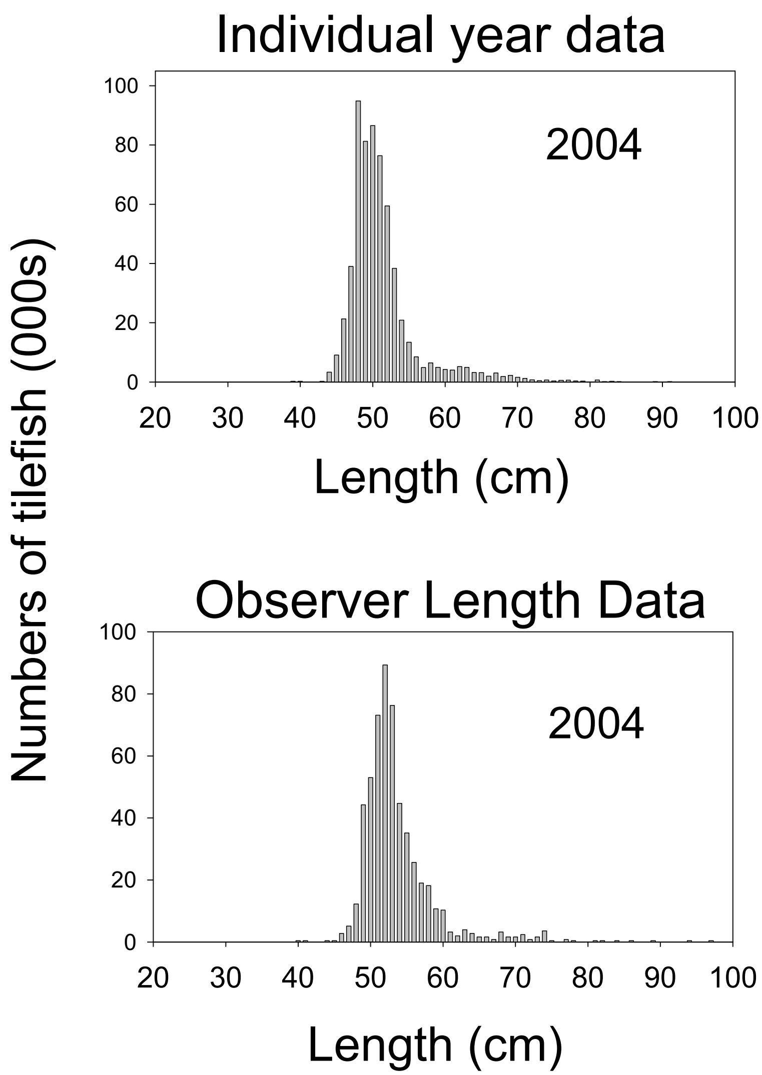



Figure C32. Comparison of expanded length frequency distributions for 2004.

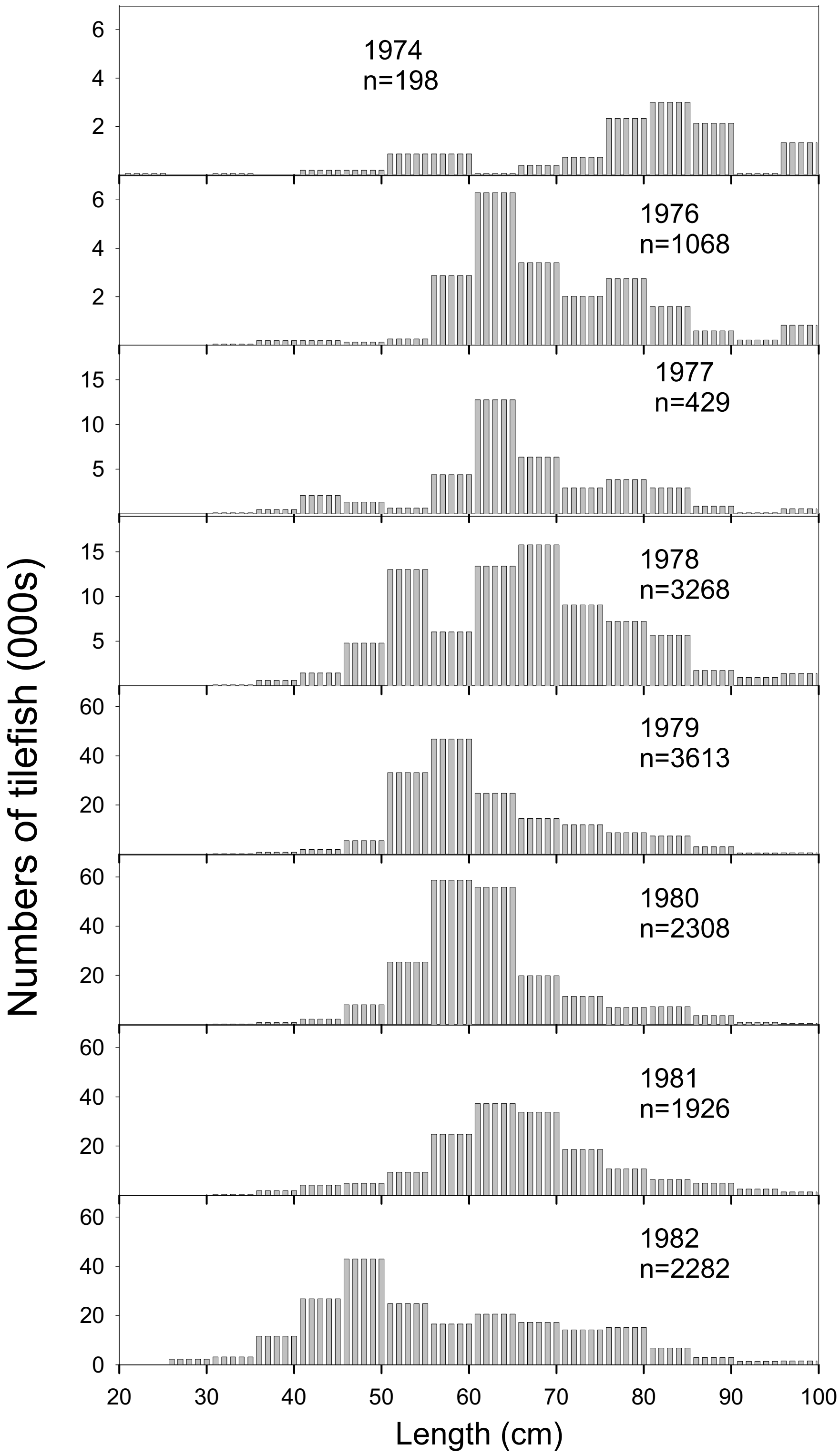



Figure C33. Expanded length frequency distributions using Turner (1986) length samples by 5 cm intervals. Hudson Canyon and Southern New England samples were combined.

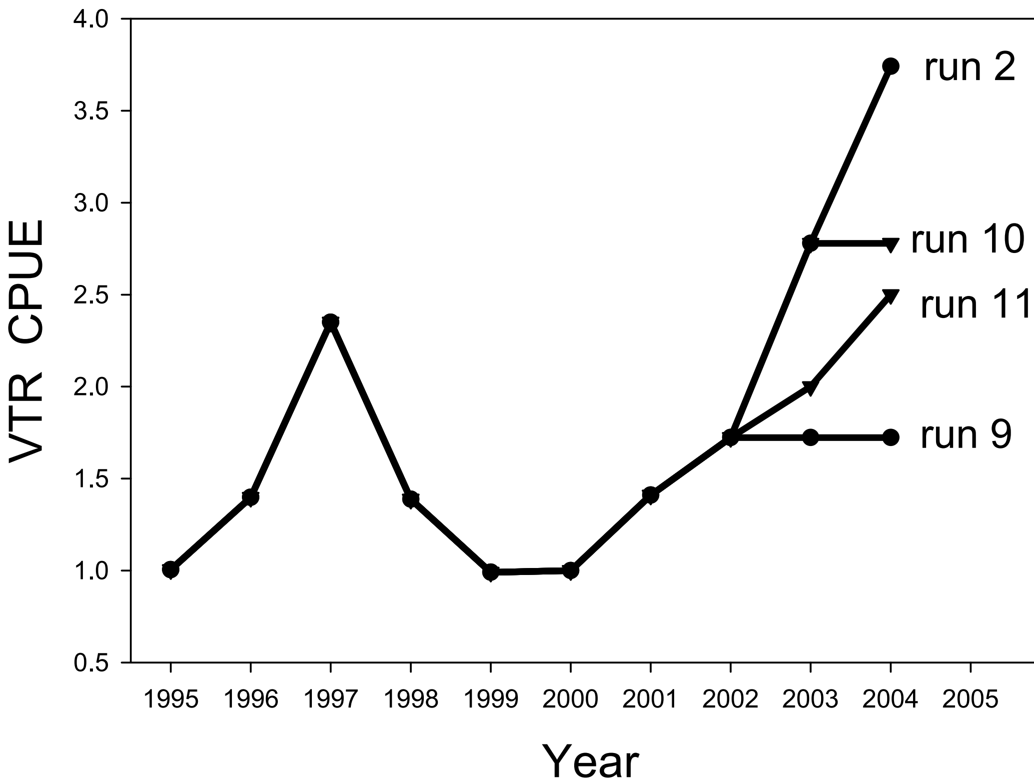



Figure C34. The actual VTR CPUE (run 2) and CPUE with lowered CPUE at the end of the time sereis used to determine sensitivity of the recent increase in CPUE in the ASPIC model.

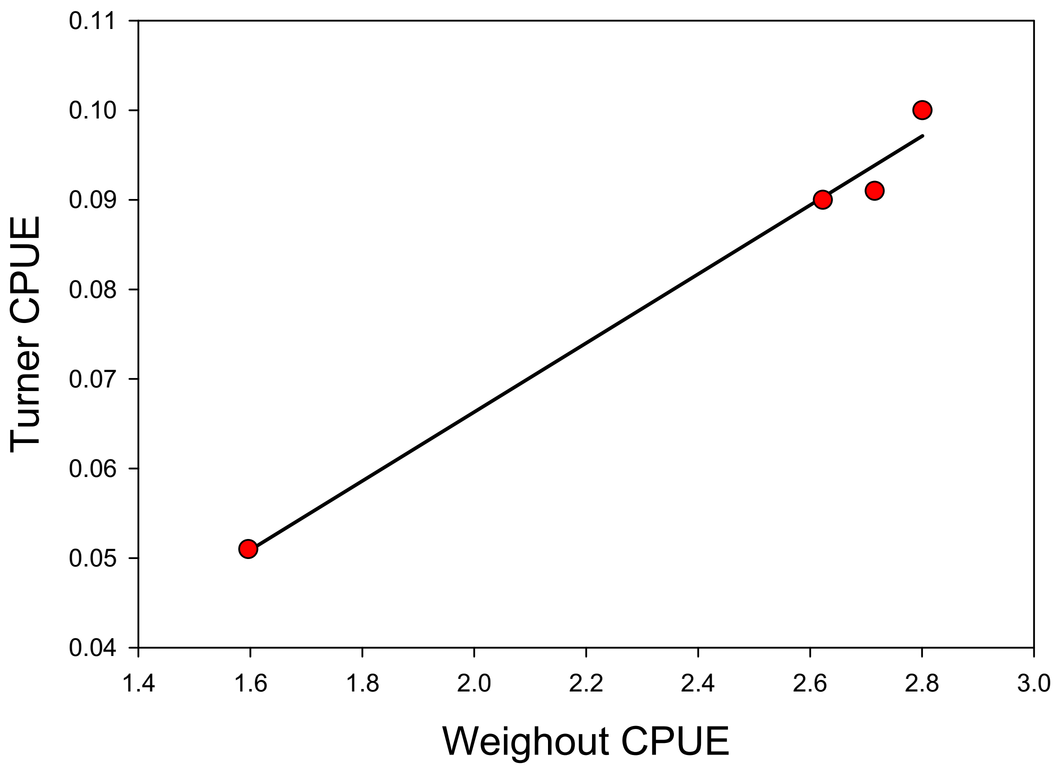



Figure C35. Regression (forced through zero) between the weighout CPUE and Turner CPUE using the four years of overlapping data (1979-1982). Regression was used to combine Turner and NEFSC series used in the AIM and LRSG model.

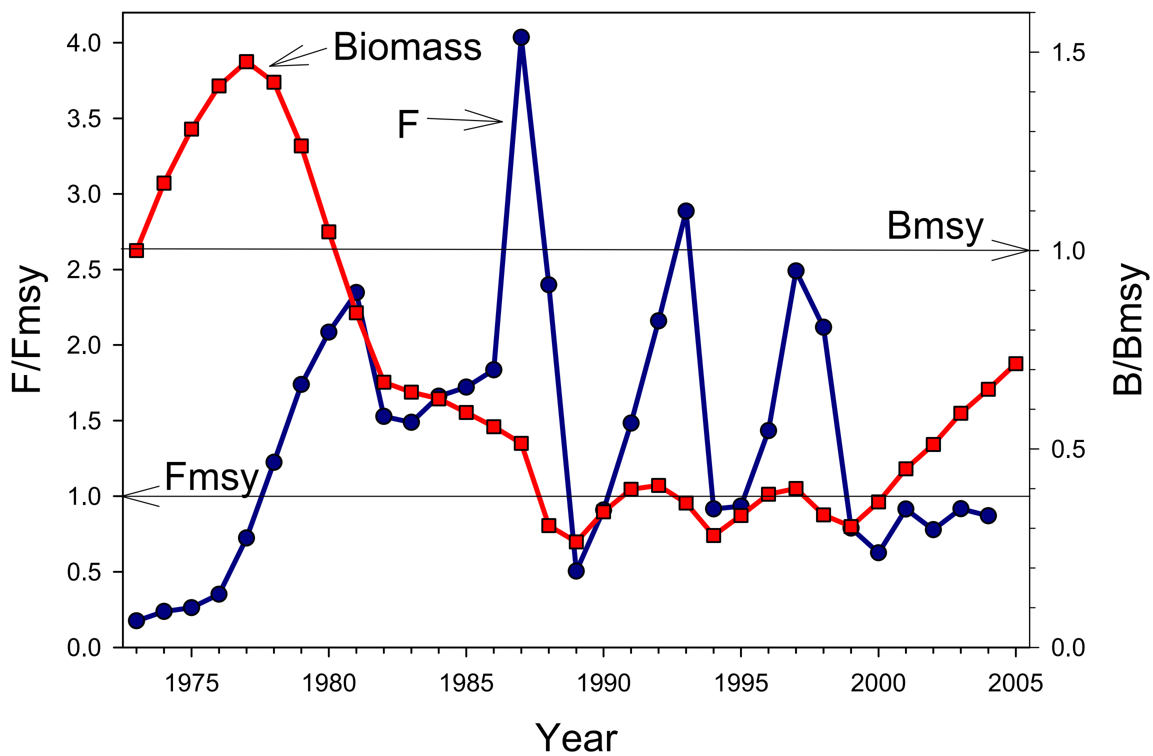



Figure C36. Trends in F/Fmsy and B/Bmsy ratios for the base ASPIC run 13 which fix the B1/Bmsy ratio at 1 and used three CPUE series (Turner, weighout, and VTR).

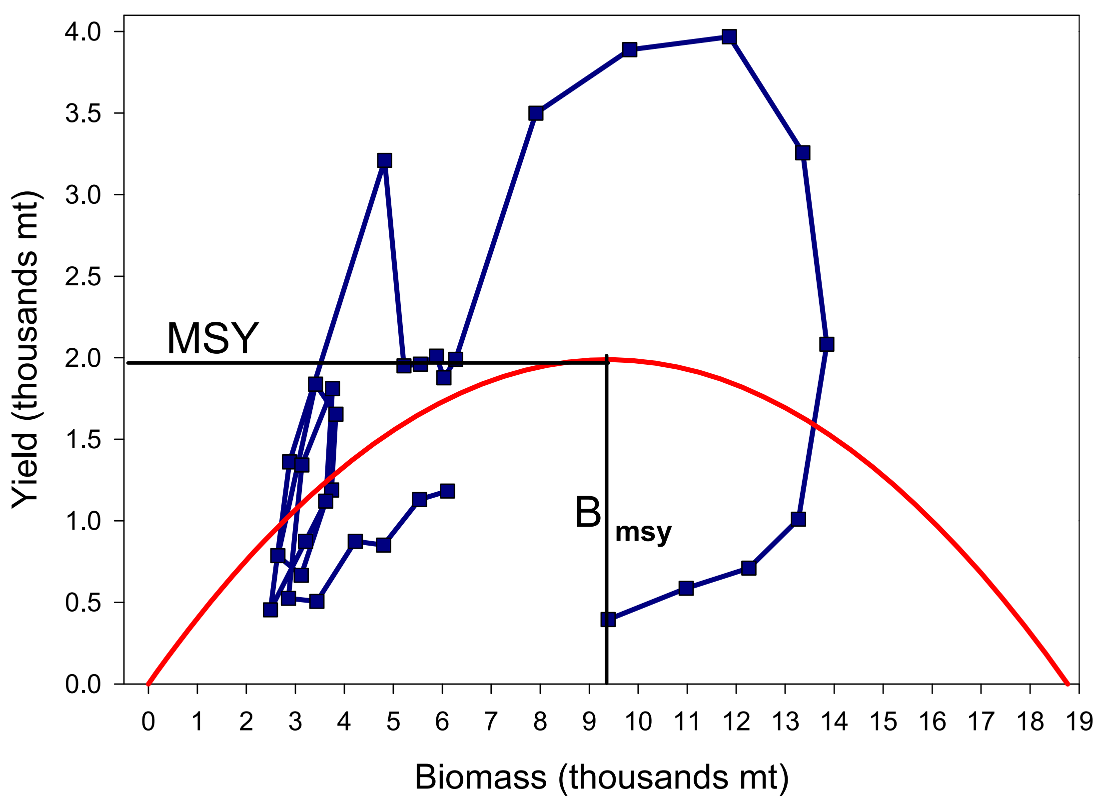
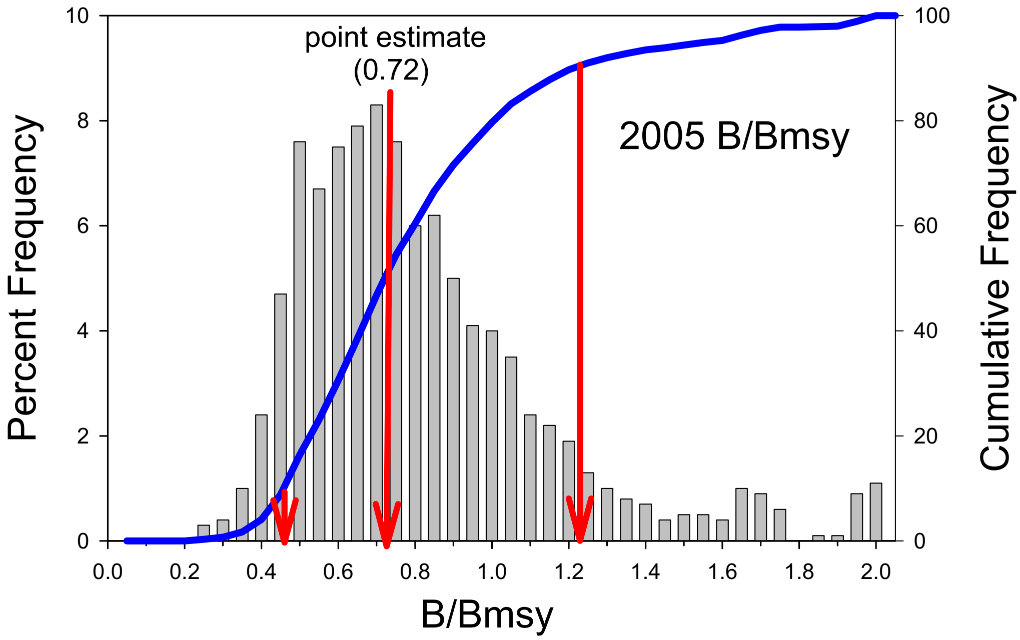



Figure C37. Observed and predicted equilibrium yield with biomass for the ASPIC model base run 13.



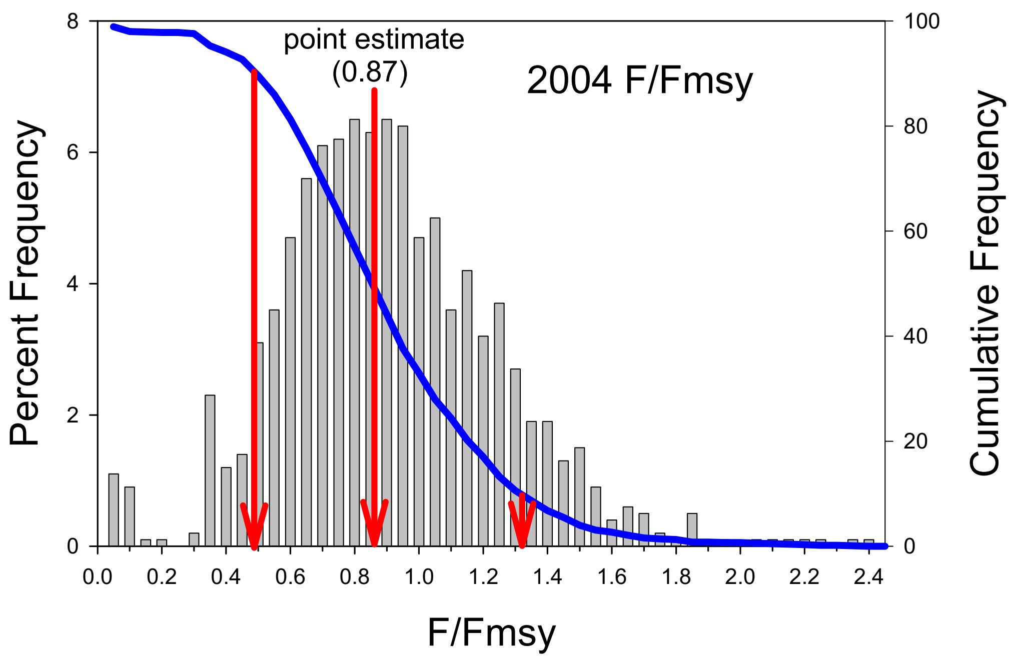




Figure C38. Precision of estimates of total stock biomass to $B_{msy}$ ratios and fishing mortality to $F_{msy}$ ratios for Golden tilefish. Vertical bars display the range of the boostrap estimates. The percent confidence limits can be taken of the cumulative frequency curve.

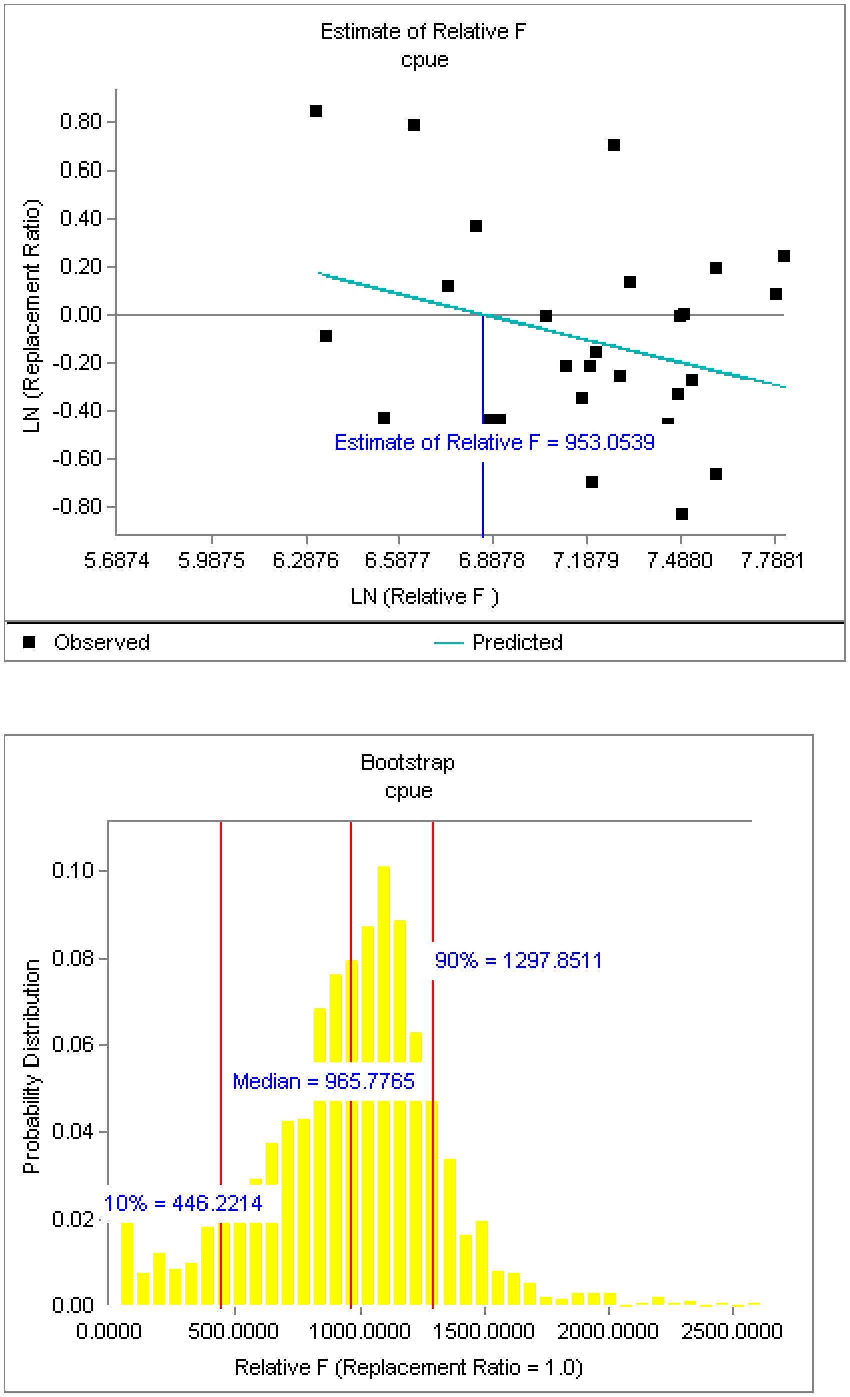



Figure C39. Aim model using combined Turner, NEFSC weighout and VTR CPUE (1973-2004). Top graph is the relationship between relative F and the replacement ratio. Bottom graph is the bootstrap distribution of relative Fs.

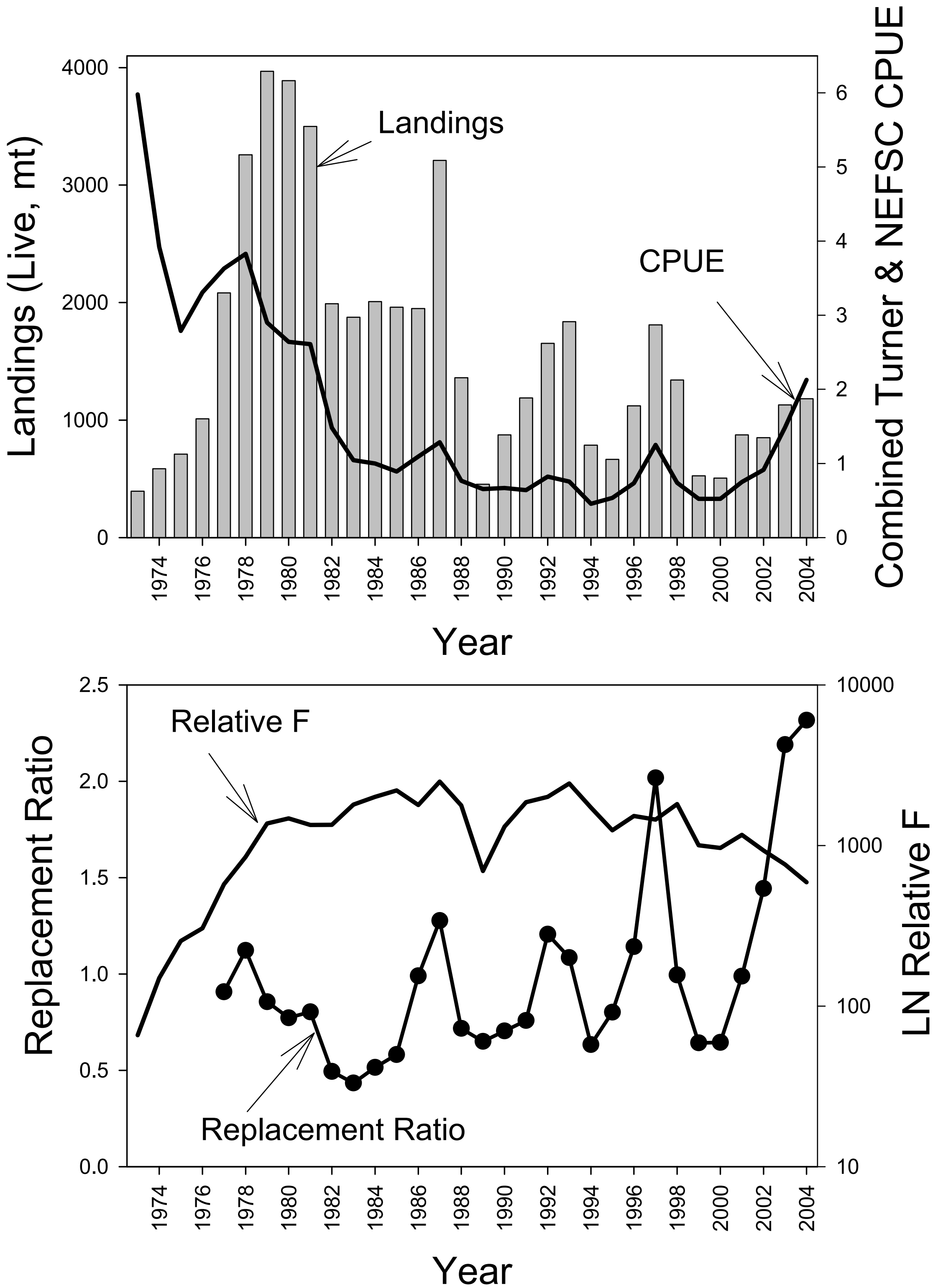



Figure C40. AIM model results using Turner and NEFSC commercial CPUE series combined.

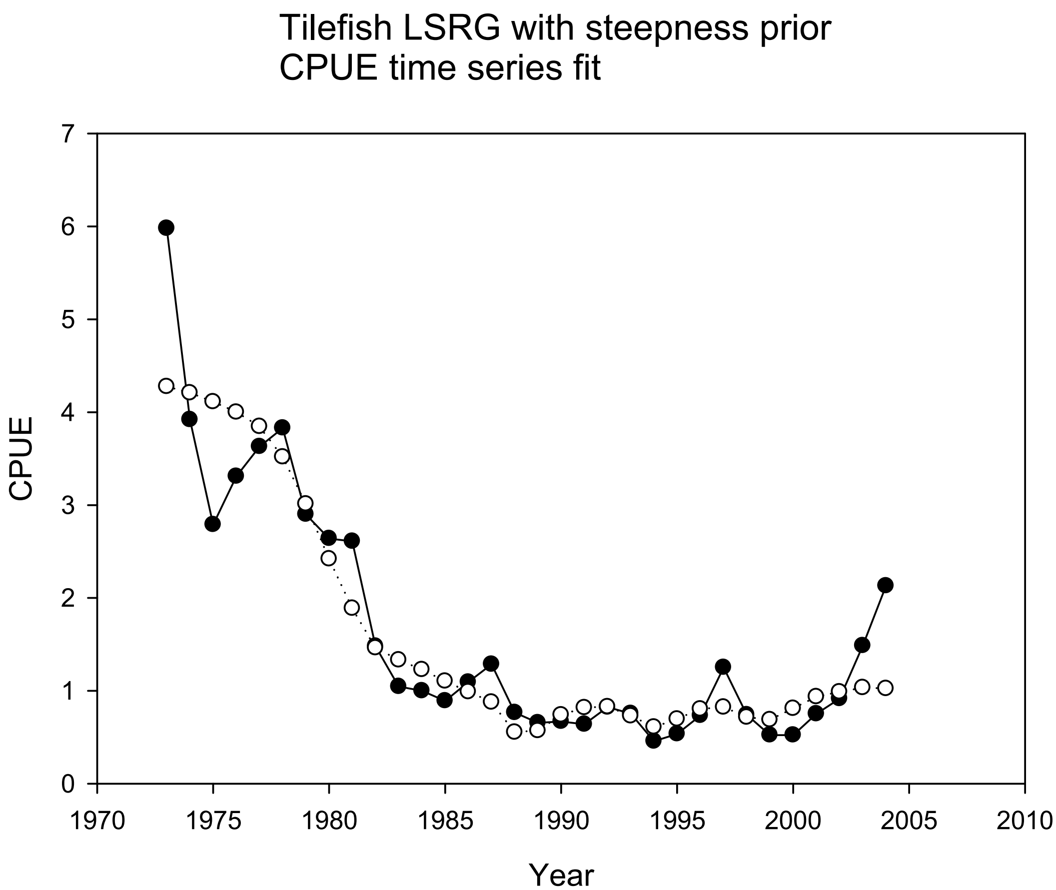



Figure C41. Observed and predicted CPUE from the LRSG model with a steepness prior.

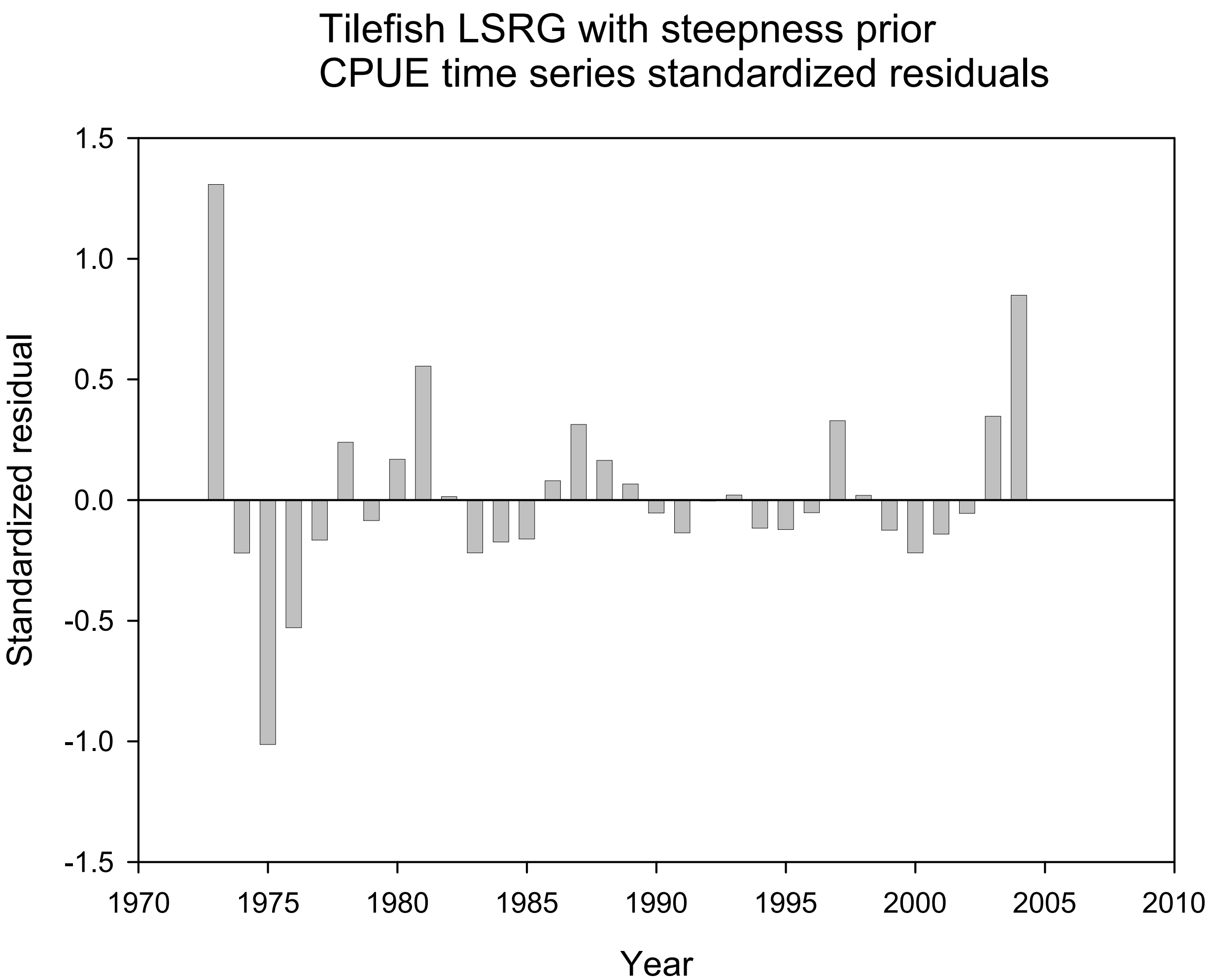



Figure C42. Standardized residuals form the LRSG model with a steepness prior.

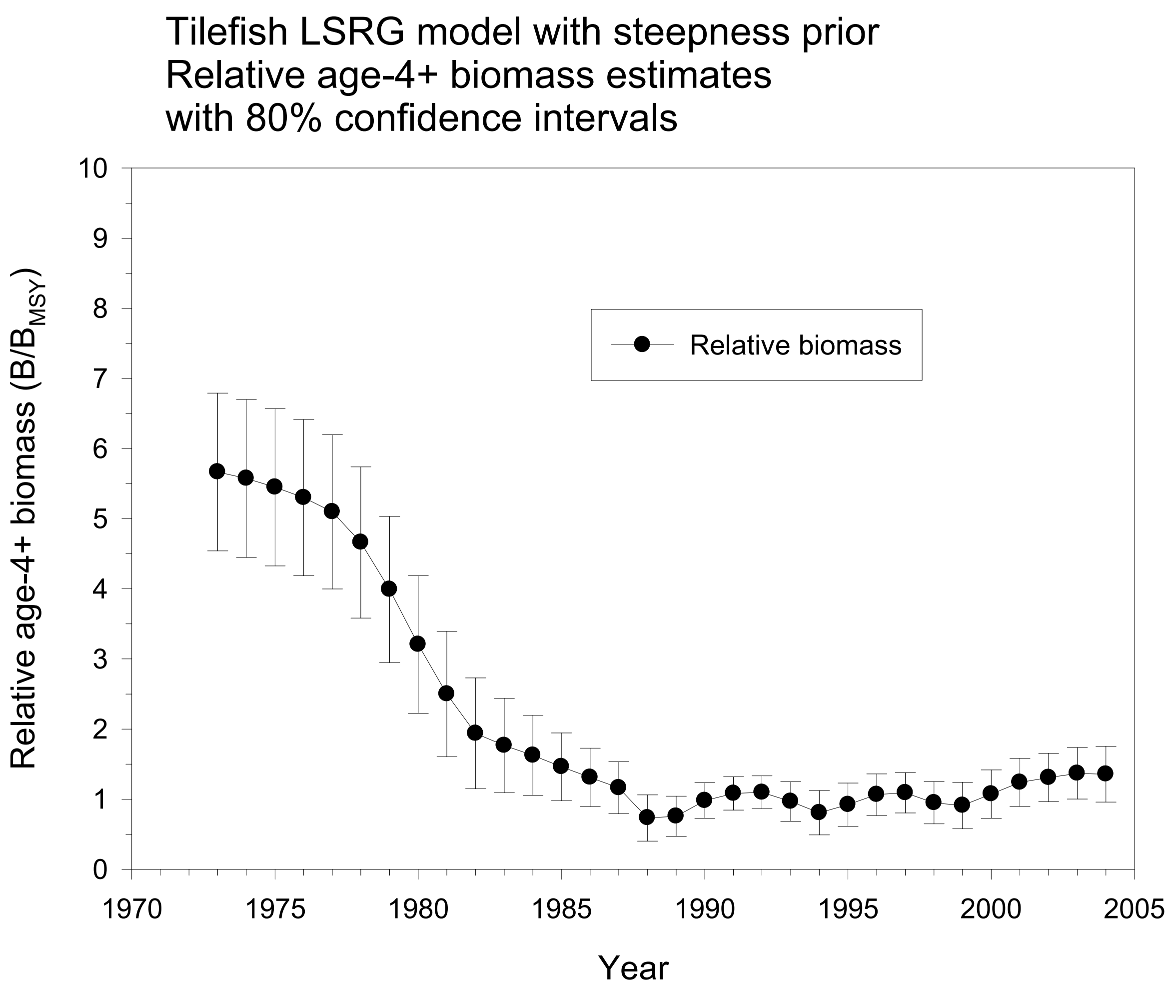



Figure C43. Relative biomass estimates from the LRSG model with a steepness prior.

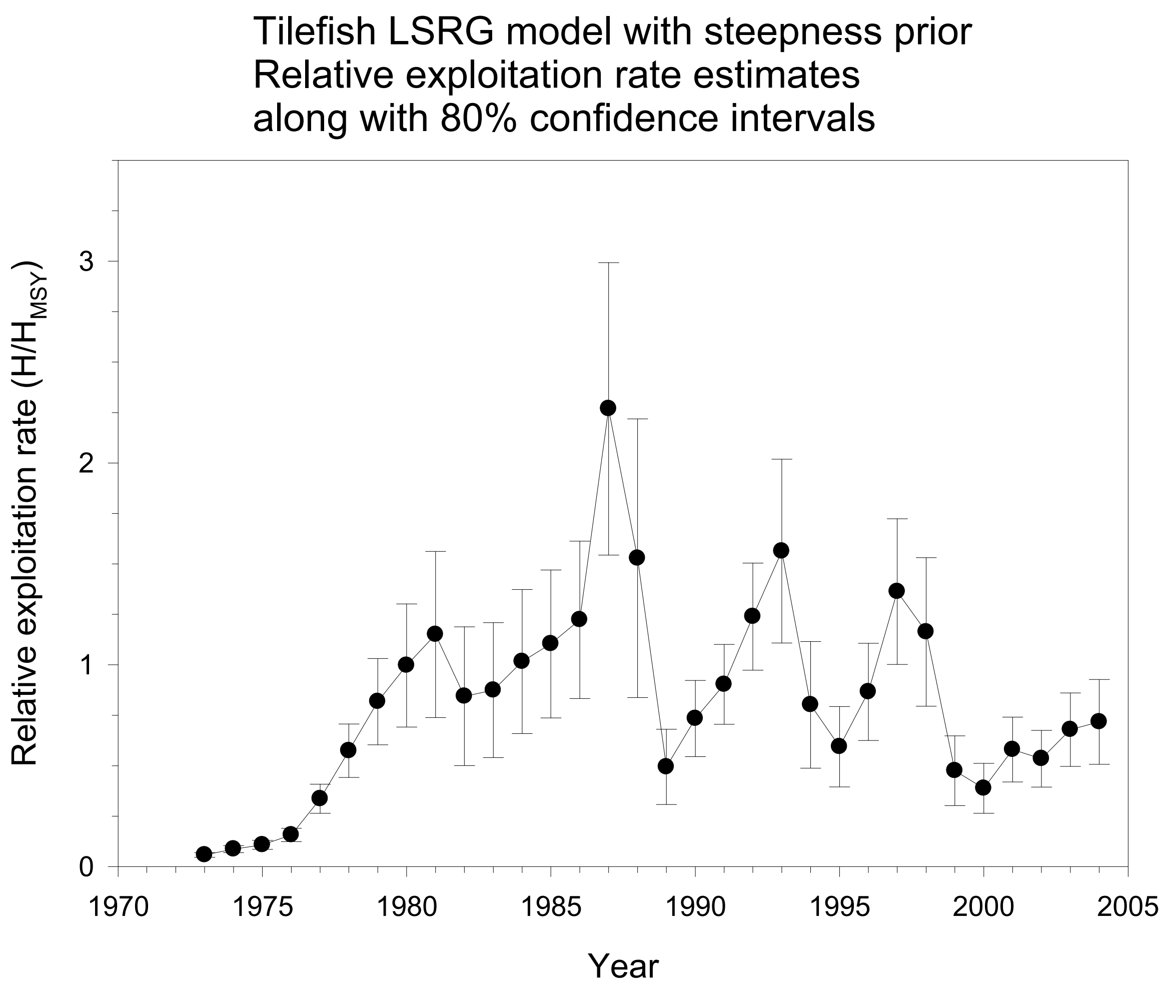



Figure C44. Relative harvest rate estimates from the LRSG model with a steepness prior.

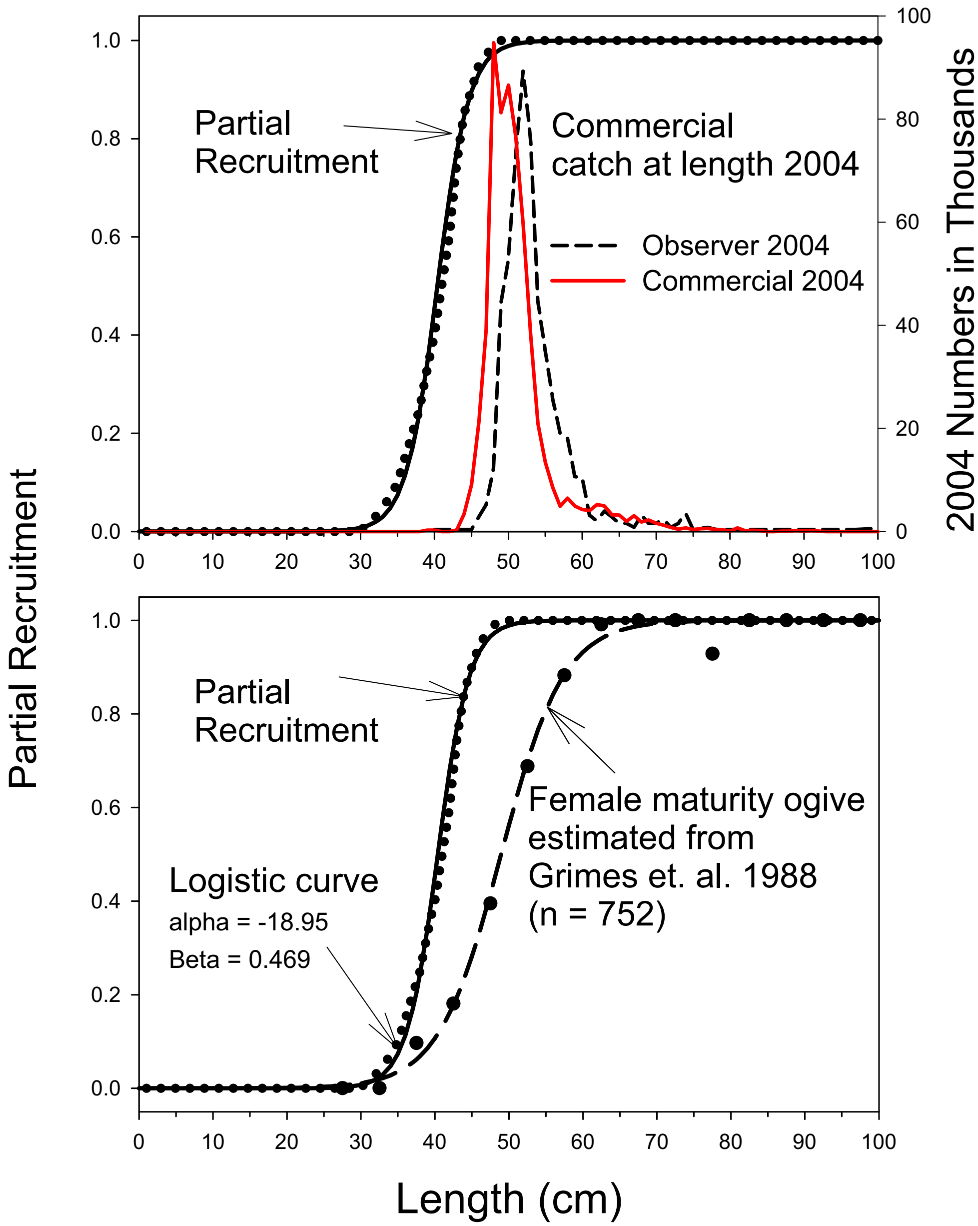



Figure C45. Top graph shows the partial recruitment and commercial/observer estimates of the expanded length frequency distributions for 2004. Bottom graph shows the maturity ogive from Grimes et. al. (1988) and the estimated logistic curve for the partial recruitment.

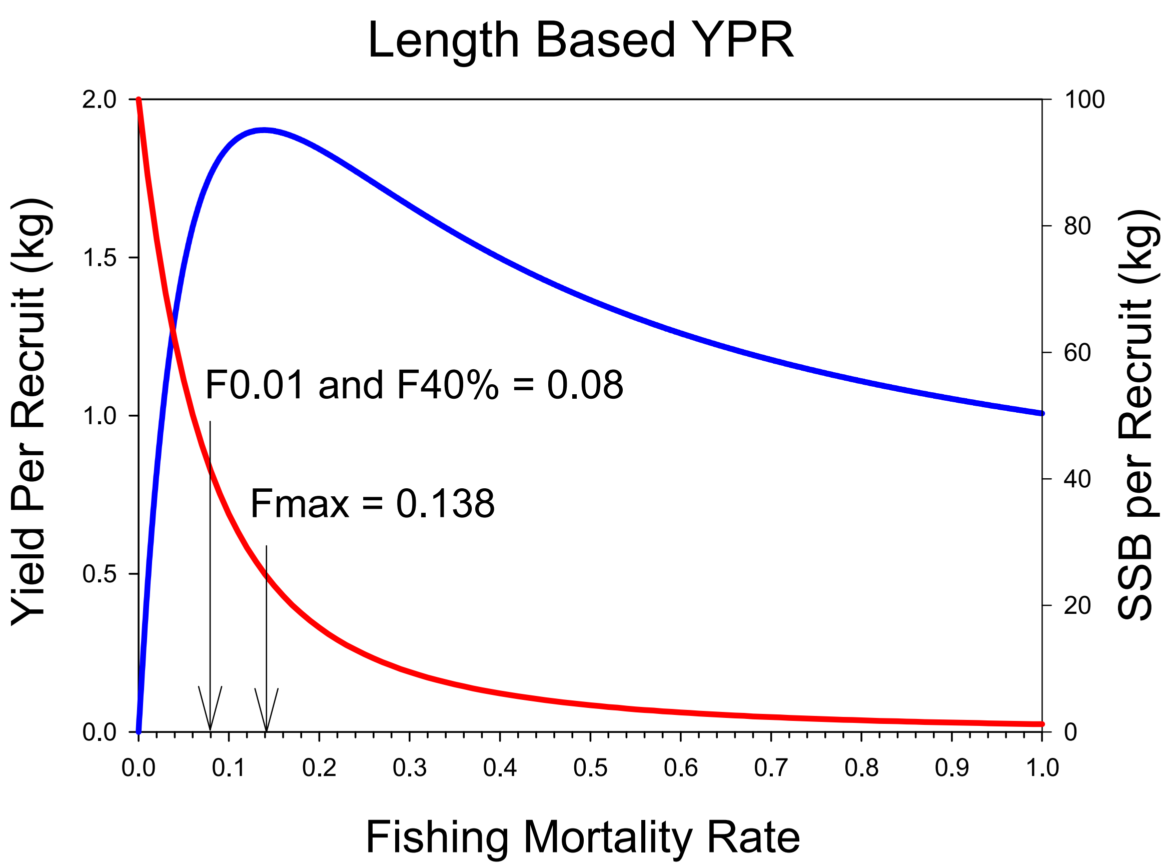



Figure C46. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) from the length based YPR analysis for Golden tilefish.

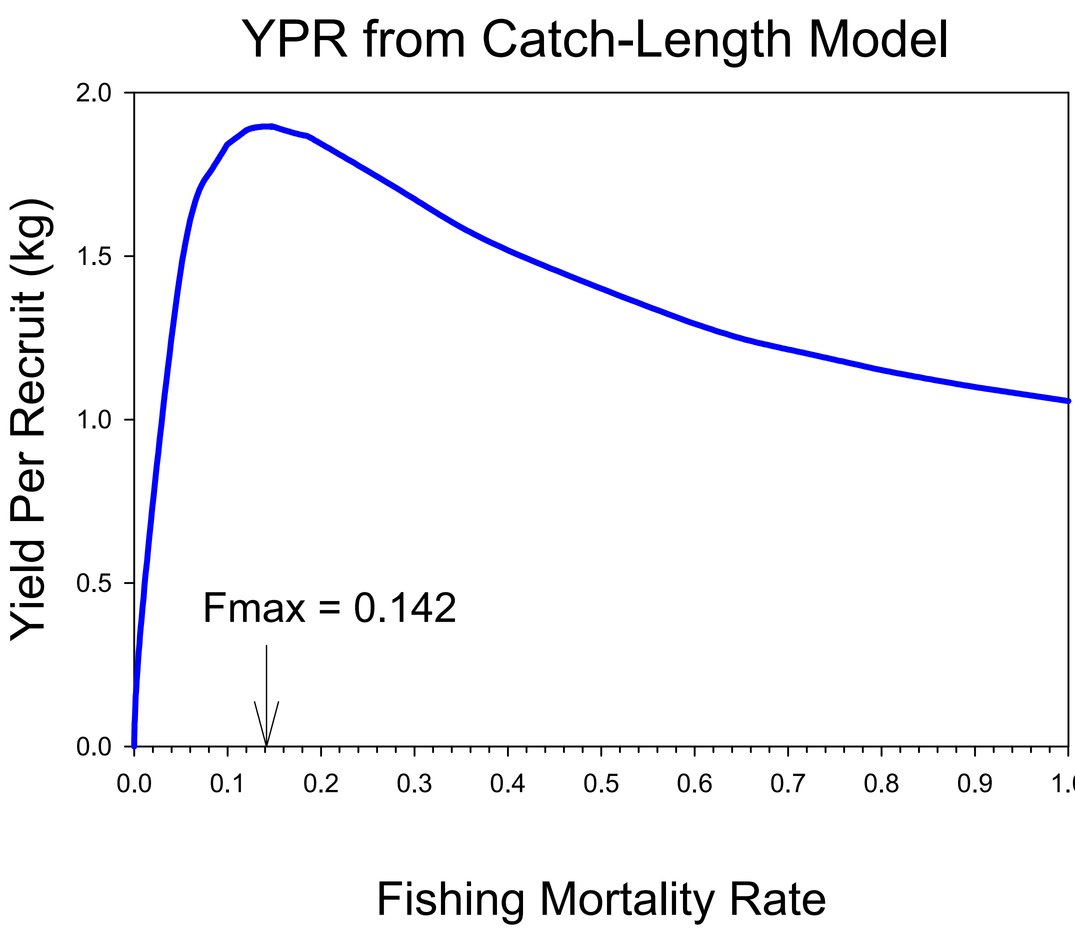



Figure C47.  Yield per recruit (YPR) from the catch-length model for Golden tilefish.

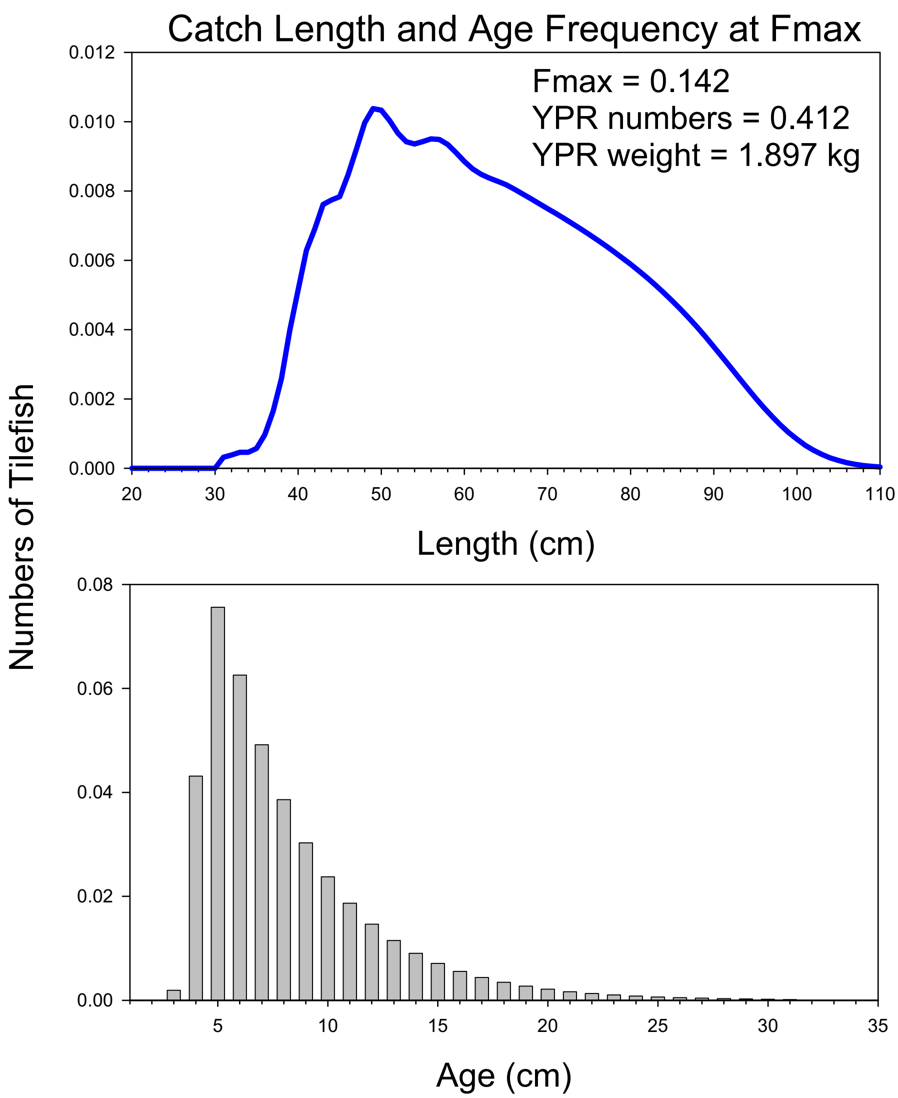



Figure C48. Predicted catch and age frequency at Fmax (0.142) using the catch-length model for Golden tilefish.

## APPENDIX C1: Working Group Comments

The Working Group discussed the recreational data presented and questioned how 8800 trips could only catch 90 tilefish. It was noted that many tuna trips will fish for tilefish and may have listed tilefish as a secondary target. A request was made to limit the data to only trips that caught tilefish and trips that reported tilefish as a primary target. This reduced the number of trips to 2004. It was decided that the number of trips was not very meaningful given that tilefish catch in the recreational fishery appears to be a sporadic event. The recreational catch is currently not directly incorporated into the assessment but may become more of an issue as the stock recovers.

The Working Group discussed the CPUE series and decided to use the data as three separate series. The Turner series was estimated using different methodology than the later data. The weighout series and the VTR series were derived using the same methodology but the data in each part were collected in a different way. Looking at the vessels that have been in the fishery over time was very useful in the decision to keep the two series separate. Prior to 1994, vessels from New York were not in the weighout database individually. After 1994, they reported through the VTR system.

There were also concerns from the Working Group over changes in gear technology and fishing behavior over the time of the assessment. These changes may mask changes in abundance.

The Working Group reviewed several formulations of the ASPIC model. The group decided to use CPUE as three series and start the model in 1973. The formulations with the longer time series did not add anything to the more recent time frame. The group decided to fix the B1 ratio at 1 because the stock was not likely at carrying capacity in 1973 as the fishery had been occurring since 1916.

The Working Group reviewed two other models that gave slightly more optimistic views of the status of the stock, the AIM model and the LRSG model. Both models were promising for this stock but used a single CPUE series. The time trend of the LSRG model was similar to that of the ASPIC model run with a single CPUE series.

A Catch-at-length model was presented to the Working Group. The assumption of constant recruitment was discussed and may be a possible reason that the model does not fit the data very well and results in a spike of fishing mortality at the end of the time series. From the simulation work, an increase in fishing mortality can occur if you have both an increasing trend in fishing mortality and an increasing trend in recruitment. The length frequencies in the catch may or may not be an accurate reflection of the population length frequency, but may have more to do with fishing practices to maximize profit. The trawl length composition is not included in the model and may contribute to the lack of fit. Trawl catches of tilefish are generally smaller than those of longlines.

A length-based yield-per-recruit model was examined which confirmed a previous age-based YPR. The partial recruitment (PR) vector used may or may not reflect the fishery PR. If the fishery PR is dome-shaped then $F_{max}$ may come closer to the $F_{msy}$ of the ASPIC model. The PR may also be changing from year to year based on market considerations. A bio-economic model that maximizes economic yield per recruit may be a useful tool.

The Working Group noted several signals coming out of the data. The current length frequency of the commercial catch is truncated relative to the 1970s length frequencies, but they were never as wide as expected from the maximum size of tilefish. The trawl catches are increasing, which may either be a sign of increased recruitment or increased allocation in recent years. The landings by vessels directing for tilefish have seen an increase in large animals indicating good stock size. Most of the models presented show some increase in biomass in recent years. Areas with increased amounts of offshore lobster gear may have created closed areas and refuges for the larger animals.

The Working Group discussed the uncertainty in the projections and whether to use the bias-corrected estimates or the ordinary estimates. It was decided to use the ordinary estimates for two sets of projections. The first would be a status quo catch of 905 mt and the second would be 905 mt for 2005 and then a constant catch that would allow the stock to recover to $B_{msy}$ by 2011. Discussion also occurred as to the unusual erratic behavior of this particular projection. It may be that the large increase in CPUE in the last two years is causing the model to have more uncertainty causing a large estimate of bias. It was suggested to try starting the model projections at 2002. The Working Group considered these projections to be too uncertain to form the basis of TAC advice.

## Research Recommendations

Research Recommendations from 1998 Science and Statistical Committee review

1) Ensure that market category distributions accurately reflect the landings.
2) Ensure that length frequency sampling is proportional to landings by market category.
3) Increase and ensure adequate length sampling coverage of the fishery
4) Update age- and length-weight relationships.
5) Update the maturity-at-age, weight-at-age, and partial recruitment patterns.
6) Develop fork length to total length conversion factors for the estimation of total length to weight relationships
7) Incorporate auxiliary data to estimate r independent of the ASPIC model.

The Working Group noted that sampling has improved for 2003 and 2004. This addresses 1, 2, and 3. A hook selectivity study is planned for 2005-2006 and data will be collected to address 4 and 5. Work is in progress collecting total length and fork length data to address 6. Nothing has been done to date to address 7.

# APPENDIX C2: NEFSC Weighout CPUE GLM model

```
The SAS System
14:00 Thursday, March 31, 2005   1
The GLM Procedure
                                                      Class Level Information
Class       Levels  Values

lndyear         15  1979 1980 1981 1982 1983 1985 1986 1987 1988 1989 1990 1991 1992 1993 9999

permit          92        delete permit numbers
Number of observations    1897
The SAS System
14:00 Thursday, March 31, 2005   2

The GLM Procedure
 Dependent Variable: LNCPUE

                                           Sum of
Source                      DF            Squares     Mean Square    F Value    Pr > F
Model                      105         743.569869        7.081618      23.67    <.0001
Error                     1791         535.787323        0.299155

Corrected Total           1896        1279.357192

R-Square     Coeff Var      Root MSE    LNCPUE Mean
0.581206      8.116663      0.546951       6.738619

Source                      DF        Type I SS     Mean Square    F Value    Pr > F
lndyear                     14      566.9637531      40.4974109     135.37    <.0001
permit                      91      176.6061156       1.9407265       6.49    <.0001

Source                      DF      Type III SS     Mean Square    F Value    Pr > F
lndyear                     14      281.1521083      20.0822934      67.13    <.0001
permit                      91      176.6061156       1.9407265       6.49    <.0001

                                              Standard
Parameter              Estimate                  Error    t Value    Pr > |t|

Intercept           6.232567267 B      0.11429828      54.53      <.0001
lndyear   1979      1.022878443 B      0.07430951      13.77      <.0001
lndyear   1980      0.991305758 B      0.07181247      13.80      <.0001
lndyear   1981      0.957632235 B      0.07168379      13.36      <.0001
lndyear   1982      0.461931590 B      0.07359297       6.28      <.0001
lndyear   1983      0.036989477 B      0.07511938       0.49      0.6225
lndyear   1985     -0.116577906 B      0.07301030      -1.60      0.1105
lndyear   1986      0.078237855 B      0.07992860       0.98      0.3278
lndyear   1987      0.235247667 B      0.07689409       3.06      0.0023
lndyear   1988     -0.290869711 B      0.08580020      -3.39      0.0007
lndyear   1989     -0.437414680 B      0.11355219      -3.85      0.0001
lndyear   1990     -0.412418009 B      0.10524248      -3.92      <.0001
lndyear   1991     -0.462210977 B      0.09637704      -4.80      <.0001
lndyear   1992     -0.213720208 B      0.09349023      -2.29      0.0224
lndyear   1993     -0.277906028 B      0.09113548      -3.05      0.0023
lndyear   9999      0.000000000 B       .               .          .
permit    -         0.053877941 B      0.39953947       0.13      0.8927
permit    -         0.290799259 B      0.40217631       0.72      0.4697
permit    -         2.200653904 B      0.55660933       3.95      <.0001
permit    -        -0.720065816 B      0.33062733      -2.18      0.0295
permit    -         1.204048080 B      0.23673422       5.09      <.0001
permit    -        -0.918838210 B      0.55660933      -1.65      0.0990
permit    -         0.884977111 B      0.55660933       1.59      0.1120
permit    -         0.089186369 B      0.13030426       0.68      0.4938
permit    -         0.351073875 B      0.55660933       0.63      0.5283
permit    -        -0.474685588 B      0.40127024      -1.18      0.2370
permit    -        -1.051239079 B      0.55796370      -1.88      0.0597
permit    -         0.883791874 B      0.55876605       1.58      0.1139
permit    -         0.042036558 B      0.15197217       0.28      0.7821
```

| | | | | | | |
|---|---|---|---|---|---|---|
| permit | - | -2.501448583 | B | 0.55827964 | -4.48 | <.0001 |
| permit | - | 0.450272193 | B | 0.12822212 | 3.51 | 0.0005 |
| permit | - | 0.471191134 | B | 0.55809344 | 0.84 | 0.3986 |
| permit | - | -0.050060896 | B | 0.14723604 | -0.34 | 0.7339 |
| permit | - | -0.138317903 | B | 0.24734699 | -0.56 | 0.5761 |
| permit | - | 0.288864363 | B | 0.40301160 | 0.72 | 0.4736 |
| permit | - | -0.719753788 | B | 0.55856606 | -1.29 | 0.1977 |
| permit | - | 0.539895149 | B | 0.20257954 | 2.67 | 0.0078 |
| permit | - | 0.200325406 | B | 0.14810284 | 1.35 | 0.1764 |
| permit | - | 0.166798650 | B | 0.13012707 | 1.28 | 0.2001 |
| permit | - | 0.171959971 | B | 0.11302093 | 1.52 | 0.1283 |
| permit | - | 0.231976547 | B | 0.12244851 | 1.89 | 0.0583 |
| permit | - | 0.024125664 | B | 0.13432034 | 0.18 | 0.8575 |
| permit | - | 0.094051267 | B | 0.16446785 | 0.57 | 0.5675 |
| permit | - | 0.371090946 | B | 0.17507191 | 2.12 | 0.0342 |
| permit | - | 0.068525060 | B | 0.15621988 | 0.44 | 0.6610 |
| permit | - | 0.291237884 | B | 0.55606608 | 0.52 | 0.6005 |
| permit | - | 0.250774748 | B | 0.19444954 | 1.29 | 0.1973 |
| permit | - | -1.365464039 | B | 0.19254217 | -7.09 | <.0001 |
| permit | - | 0.202892095 | B | 0.11692497 | 1.74 | 0.0829 |
| permit | - | -0.150565146 | B | 0.55660933 | -0.27 | 0.7868 |
| permit | - | -1.227887492 | B | 0.55827964 | -2.20 | 0.0280 |
| permit | - | -1.316984788 | B | 0.55796370 | -2.36 | 0.0184 |
| permit | - | 0.055682092 | B | 0.55606608 | 0.10 | 0.9202 |
| permit | - | 0.476788308 | B | 0.56089822 | 0.85 | 0.3954 |
| permit | - | -1.513147475 | B | 0.22407363 | -6.75 | <.0001 |
| permit | - | 0.925030445 | B | 0.56089822 | 1.65 | 0.0993 |
| permit | - | -0.260880622 | B | 0.40623775 | -0.64 | 0.5208 |
| permit | - | 0.277147040 | B | 0.11033921 | 2.51 | 0.0121 |
| permit | - | -0.894403775 | B | 0.26894018 | -3.33 | 0.0009 |
| permit | - | -0.087797738 | B | 0.21953680 | -0.40 | 0.6893 |
| permit | - | 0.002668324 | B | 0.19877790 | 0.01 | 0.9893 |
| permit | - | 0.496364007 | B | 0.10872728 | 4.57 | <.0001 |
| permit | - | -0.163600190 | B | 0.55796370 | -0.29 | 0.7694 |
| permit | - | 0.467983305 | B | 0.12033347 | 3.89 | 0.0001 |
| permit | - | 0.024708856 | B | 0.13276574 | 0.19 | 0.8524 |
| permit | - | -1.665756882 | B | 0.40275435 | -4.14 | <.0001 |
| permit | - | -0.008289609 | B | 0.21203679 | -0.04 | 0.9688 |
| permit | - | 0.422212817 | B | 0.56253472 | 0.75 | 0.4530 |
| permit | - | -0.994541917 | B | 0.41068120 | -2.42 | 0.0155 |
| permit | - | 0.640814312 | B | 0.17122800 | 3.74 | 0.0002 |
| permit | - | 0.289229697 | B | 0.11245469 | 2.57 | 0.0102 |
| permit | - | 0.232020794 | B | 0.11406216 | 2.03 | 0.0421 |
| permit | - | 0.435287696 | B | 0.23285239 | 1.87 | 0.0617 |
| permit | - | -0.093362255 | B | 0.55876605 | -0.17 | 0.8673 |
| permit | - | 0.565119319 | B | 0.29382393 | 1.92 | 0.0546 |
| permit | - | 0.185883996 | B | 0.10864670 | 1.71 | 0.0873 |
| permit | - | 0.383628924 | B | 0.26777330 | 1.43 | 0.1521 |
| permit | - | -0.429338431 | B | 0.15476255 | -2.77 | 0.0056 |
| permit | - | 0.941153790 | B | 0.26751142 | 3.52 | 0.0004 |
| permit | - | -0.144900138 | B | 0.55876605 | -0.26 | 0.7954 |
| permit | - | -0.018365360 | B | 0.39831869 | -0.05 | 0.9632 |
| permit | - | 0.233109656 | B | 0.24325318 | 0.96 | 0.3380 |
| permit | - | 0.579583698 | B | 0.55656992 | 1.04 | 0.2979 |
| permit | - | 0.280357477 | B | 0.14815327 | 1.89 | 0.0586 |
| permit | - | -0.220190021 | B | 0.33549831 | -0.66 | 0.5117 |
| permit | - | 0.477244382 | B | 0.17126647 | 2.79 | 0.0054 |
| permit | - | 0.586558492 | B | 0.29544304 | 1.99 | 0.0473 |
| permit | - | 1.003951166 | B | 0.55606608 | 1.81 | 0.0712 |
| permit | - | 0.882877530 | B | 0.33498687 | 2.64 | 0.0085 |
| permit | - | 0.191509700 | B | 0.24286878 | 0.79 | 0.4305 |
| permit | - | 0.297364159 | B | 0.29099874 | 1.02 | 0.3070 |
| permit | - | 0.283495433 | B | 0.12957609 | 2.19 | 0.0288 |
| permit | - | 1.042813481 | B | 0.56089822 | 1.86 | 0.0632 |
| permit | - | -0.065468315 | B | 0.19188028 | -0.34 | 0.7330 |
| permit | - | -0.153684912 | B | 0.40328873 | -0.38 | 0.7032 |
| permit | - | 0.036432483 | B | 0.15621610 | 0.23 | 0.8156 |
| permit | - | 0.099929826 | B | 0.29223882 | 0.34 | 0.7324 |

| | | | | | | |
|---|---|---|---|---|---|---|
| permit | - | 0.224377910 | B | 0.11753056 | 1.91 | 0.0564 |
| permit | - | 0.334472400 | B | 0.29263852 | 1.14 | 0.2532 |
| permit | - | 0.346528767 | B | 0.39933585 | 0.87 | 0.3856 |
| permit | - | 0.131354900 | B | 0.17613902 | 0.75 | 0.4559 |
| permit | - | 0.056859718 | B | 0.15272950 | 0.37 | 0.7097 |
| permit | - | -1.420176111 | B | 0.55660933 | -2.55 | 0.0108 |
| permit | - | -1.054505031 | B | 0.33062733 | -3.19 | 0.0015 |
| permit | - | 1.290671749 | B | 0.56253472 | 2.29 | 0.0219 |
| permit | - | -0.545675103 | B | 0.55660933 | -0.98 | 0.3270 |
| permit | - | 0.722755358 | B | 0.12789264 | 5.65 | <.0001 |
| permit | - | 0.000000000 | B | . | . | . |

## APPENDIX C3: NEFSC VTR CPUE GLM model

```
The SAS System
14:00 Thursday, March 31, 2005   6

The GLM Procedure
                                                                  Class Level Information
Class       Levels  Values

lndyear         10  1995 1996 1997 1998 1999 2001 2002 2003 2004 9999

permit          25 delete permit numbers

Number of observations    1226
The SAS System
14:00 Thursday, March 31, 2005   7

The GLM Procedure

Dependent Variable: LNCPUE

                                        Sum of
Source                      DF         Squares     Mean Square    F Value    Pr > F
Model                       33     331.2333689      10.0373748      54.83    <.0001
Error                     1192     218.2168857       0.1830679
Corrected Total           1225     549.4502547

R-Square     Coeff Var      Root MSE    LNCPUE Mean
0.602845      6.542155      0.427864       6.540113

Source                      DF       Type I SS     Mean Square    F Value    Pr > F
lndyear                      9     228.8146560      25.4238507     138.88    <.0001
permit                      24     102.4187130       4.2674464      23.31    <.0001

Source                      DF     Type III SS     Mean Square    F Value    Pr > F
lndyear                      9     174.3859974      19.3762219     105.84    <.0001
permit                      24     102.4187130       4.2674464      23.31    <.0001

                                           Standard
Parameter                Estimate             Error    t Value    Pr > |t|

Intercept         5.113658653 B      0.25524735      20.03      <.0001
lndyear   1995    0.003251958 B      0.06064188       0.05      0.9572
lndyear   1996    0.333649416 B      0.05686636       5.87      <.0001
lndyear   1997    0.852841891 B      0.05578225      15.29      <.0001
lndyear   1998    0.326173101 B      0.05434864       6.00      <.0001
lndyear   1999   -0.010167260 B      0.05602196      -0.18      0.8560
lndyear   2001    0.341776436 B      0.05753438       5.94      <.0001
lndyear   2002    0.542159089 B      0.05809594       9.33      <.0001
lndyear   2003    1.020162126 B      0.06030139      16.92      <.0001
lndyear   2004    1.317256060 B      0.06425412      20.50      <.0001
lndyear   9999    0.000000000 B       .                .         .
permit    -       0.961909899 B      0.49808246       1.93      0.0537
permit    -      -1.056374914 B      0.31554991      -3.35      0.0008
permit    -      -1.126161751 B      0.39058488      -2.88      0.0040
permit    -      -0.219682088 B      0.39583474      -0.55      0.5790
permit    -       1.031794240 B      0.49773781       2.07      0.0384
permit    -      -0.105358649 B      0.31694803      -0.33      0.7396
permit    -       0.196988940 B      0.27462680       0.72      0.4733
permit    -       0.783944131 B      0.30800139       2.55      0.0110
permit    -       1.417322553 B      0.30254575       4.68      <.0001
permit    -       0.066578059 B      0.26406366       0.25      0.8010
permit    -       0.872233511 B      0.25449976       3.43      0.0006
permit    -       1.470460556 B      0.31246790       4.71      <.0001
permit    -       0.858064274 B      0.26325314       3.26      0.0011
permit    -       0.482304252 B      0.29211263       1.65      0.0990
```

```
permit    -       1.011645989 B      0.28165476       3.59      0.0003
permit    -       1.914340963 B      0.49796734       3.84      0.0001
permit    -       0.933575330 B      0.25354360       3.68      0.0002
permit    -      -1.099661139 B      0.49821588      -2.21      0.0275
permit    -       0.944271665 B      0.25359215       3.72      0.0002
permit    -       1.163582345 B      0.35355219       3.29      0.0010
permit    -       1.140939563 B      0.25261419       4.52      <.0001
permit    -      -1.595414622 B      0.49850958      -3.20      0.0014
permit    -       0.891670841 B      0.28966550       3.08      0.0021
permit    -       1.075896536 B      0.25270683       4.26      <.0001
permit    -       0.000000000 B       .                .         .

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve
the normal equations.  Terms whose estimates are followed by the letter 'B' are not uniquely
estimable.
```

# APPENDIX C4: ASPIC Run 13 with Bootstrap

```
TILEFISH -- three series                                                       Page 1
                                                                    04 May 2005 at 08:31.18
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.93)        BOT Mode
Author: Michael H. Prager; NOAA/NMFS/S.E. Fisheries Science Center        ASPIC User's Manual
        101 Pivers Island Road; Beaufort, North Carolina  28516  USA        is available gratis
                                                                            from the author.
Ref:    Prager, M. H.  1994.  A suite of extensions to a nonequilibrium
        surplus-production model.  Fishery Bulletin 92: 374-389.


CONTROL PARAMETERS USED (FROM INPUT FILE)
----------------------------------------------------------------------------------------------------
Number of years analyzed:                     32       Number of bootstrap trials:        1000
Number of data series:                         3       Lower bound on MSY:              1.000E-01
Objective function computed:           in effort       Upper bound on MSY:              9.000E+01
Relative conv. criterion (simplex):    1.000E-08       Lower bound on r:                1.000E-01
Relative conv. criterion (restart):    3.000E-08       Upper bound on r:                1.000E+02

Relative conv. criterion (effort):     1.000E-04       Random number seed:              973142085
Maximum F allowed in fitting:              5.000       Monte Carlo search mode, trials: 1  50000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                   code  0
------------------------------------------------------------------------------------------------------
Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------
                                       |
 1  weighout cpue                      |   1.000
                                       |      15
                                       |
 2  turner                             |   0.994   1.000
                                       |       4      10
                                       |
 3  vtr                                |   0.000   0.000   1.000
                                       |       0       0      10
                                       --------------------------------------------------
                                               1       2       3


GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS
------------------------------------------------------------------------------------------------------
                                          Weighted          Weighted    Current   Suggested   R-squared
Loss component number and title             SSE       N        MSE      weight     weight      in CPUE

Loss(-1)  SSE in yield                    0.000E+00
Loss( 0)  Penalty for B1R > 2             0.000E+00    1      N/A     0.000E+00     N/A
Loss( 1)  weighout cpue                   1.254E+00   15  9.647E-02  1.000E+00  9.982E-01    0.703
Loss( 2)  turner                          6.714E-01   10  8.393E-02  1.000E+00  1.147E+00    0.180
Loss( 3)  vtr                             9.007E-01   10  1.126E-01  1.000E+00  8.553E-01    0.538
TOTAL OBJECTIVE FUNCTION:              2.82613812E+00

Number of restarts required for convergence:              18
Est. B/Bmsy coverage index (0 worst, 2 best):          1.2109 <These two measures are defined in Prager
Est. B/Bmsy nearness index (0 worst, 1 best):          1.0000 < et al. (1996), Trans. A.F.S. 125:729

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
------------------------------------------------------------------------------------------------------
Parameter                                     Estimate     Starting guess    Estimated   User guess

B1R       Starting B/Bmsy, year 1973          1.000E+00       1.000E+00          0           1
MSY       Maximum sustainable yield           1.988E+00       3.000E+00          1           1
r         Intrinsic rate of increase          4.237E-01       3.000E-01          1           1
........  Catchability coefficients by fishery:
q( 1)     weighout cpue                       2.245E-01       3.000E-02          1           1
```

| | | | | | |
|---|---|---|---|---|---|
| q( 2) | turner | 1.033E-02 | 3.000E-02 | 1 | 1 |
| q( 3) | vtr | 3.921E-01 | 3.000E-02 | 1 | 1 |

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | quantity | Estimate | Formula | Related |
|---|---|---|---|---|
| MSY | Maximum sustainable yield | 1.988E+00 | Kr/4 | |
| K | Maximum stock biomass | 1.877E+01 | | |
| Bmsy | Stock biomass at MSY | 9.384E+00 | K/2 | |
| Fmsy | Fishing mortality at MSY | 2.118E-01 | r/2 | |
| F(0.1) | Management benchmark | 1.906E-01 | 0.9*Fmsy | |
| Y(0.1) | Equilibrium yield at F(0.1) | 1.968E+00 | 0.99*MSY | |
| B./Bmsy | Ratio of B(2005) to Bmsy | 7.153E-01 | | |
| F./Fmsy | Ratio of F(2004) to Fmsy | 8.703E-01 | | |
| F01-mult | Ratio of F(0.1) to F(2004) | 1.034E+00 | | |
| Ye./MSY | Proportion of MSY avail in 2005 | 9.189E-01 | 2*Br-Br^2 | Ye(2005) = 1.827E+00 |
| ........ | Fishing effort at MSY in units of each fishery: | | | |
| fmsy( 1) | weighout cpue | 9.434E-01 | r/2q( 1) | f(0.1) = 8.491E-01 |



ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

| Obs | Year or ID | Estimated total F mort | Estimated starting biomass | Estimated average biomass | Observed total yield | Model total yield | Estimated surplus production | Ratio of F mort to Fmsy | Ratio of biomass to Bmsy |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 0.037 | 9.384E+00 | 1.064E+01 | 3.940E-01 | 3.940E-01 | 1.985E+00 | 1.748E-01 | 1.000E+00 |
| 2 | 1974 | 0.050 | 1.098E+01 | 1.163E+01 | 5.860E-01 | 5.860E-01 | 1.870E+00 | 2.378E-01 | 1.170E+00 |
| 3 | 1975 | 0.056 | 1.226E+01 | 1.278E+01 | 7.100E-01 | 7.100E-01 | 1.725E+00 | 2.622E-01 | 1.306E+00 |
| 4 | 1976 | 0.074 | 1.327E+01 | 1.358E+01 | 1.010E+00 | 1.010E+00 | 1.590E+00 | 3.512E-01 | 1.415E+00 |
| 5 | 1977 | 0.153 | 1.385E+01 | 1.359E+01 | 2.082E+00 | 2.082E+00 | 1.587E+00 | 7.231E-01 | 1.476E+00 |
| 6 | 1978 | 0.259 | 1.336E+01 | 1.256E+01 | 3.257E+00 | 3.257E+00 | 1.756E+00 | 1.224E+00 | 1.424E+00 |
| 7 | 1979 | 0.368 | 1.186E+01 | 1.077E+01 | 3.968E+00 | 3.968E+00 | 1.937E+00 | 1.739E+00 | 1.264E+00 |
| 8 | 1980 | 0.442 | 9.828E+00 | 8.804E+00 | 3.889E+00 | 3.889E+00 | 1.973E+00 | 2.085E+00 | 1.047E+00 |
| 9 | 1981 | 0.497 | 7.912E+00 | 7.039E+00 | 3.499E+00 | 3.499E+00 | 1.859E+00 | 2.347E+00 | 8.432E-01 |
| 10 | 1982 | 0.324 | 6.272E+00 | 6.149E+00 | 1.990E+00 | 1.990E+00 | 1.752E+00 | 1.528E+00 | 6.684E-01 |
| 11 | 1983 | 0.315 | 6.034E+00 | 5.954E+00 | 1.877E+00 | 1.877E+00 | 1.722E+00 | 1.488E+00 | 6.430E-01 |
| 12 | 1984 | 0.352 | 5.879E+00 | 5.711E+00 | 2.009E+00 | 2.009E+00 | 1.683E+00 | 1.661E+00 | 6.265E-01 |
| 13 | 1985 | 0.364 | 5.553E+00 | 5.380E+00 | 1.961E+00 | 1.961E+00 | 1.626E+00 | 1.721E+00 | 5.917E-01 |
| 14 | 1986 | 0.389 | 5.218E+00 | 5.015E+00 | 1.950E+00 | 1.950E+00 | 1.557E+00 | 1.836E+00 | 5.560E-01 |
| 15 | 1987 | 0.855 | 4.824E+00 | 3.755E+00 | 3.210E+00 | 3.210E+00 | 1.266E+00 | 4.035E+00 | 5.141E-01 |
| 16 | 1988 | 0.508 | 2.880E+00 | 2.679E+00 | 1.361E+00 | 1.361E+00 | 9.728E-01 | 2.398E+00 | 3.069E-01 |
| 17 | 1989 | 0.107 | 2.492E+00 | 4.249E+00 | 4.540E-01 | 4.540E-01 | 1.171E+00 | 5.044E-01 | 2.655E-01 |
| 18 | 1990 | 0.192 | 3.208E+00 | 4.544E+00 | 8.740E-01 | 8.740E-01 | 1.404E+00 | 9.081E-01 | 3.419E-01 |
| 19 | 1991 | 0.314 | 3.739E+00 | 3.785E+00 | 1.189E+00 | 1.189E+00 | 1.280E+00 | 1.483E+00 | 3.984E-01 |
| 20 | 1992 | 0.457 | 3.830E+00 | 3.615E+00 | 1.653E+00 | 1.653E+00 | 1.236E+00 | 2.159E+00 | 4.081E-01 |
| 21 | 1993 | 0.611 | 3.413E+00 | 3.008E+00 | 1.838E+00 | 1.838E+00 | 1.069E+00 | 2.885E+00 | 3.637E-01 |
| 22 | 1994 | 0.194 | 2.644E+00 | 4.055E+00 | 7.860E-01 | 7.860E-01 | 1.260E+00 | 9.151E-01 | 2.817E-01 |
| 23 | 1995 | 0.198 | 3.118E+00 | 3.367E+00 | 6.660E-01 | 6.660E-01 | 1.170E+00 | 9.338E-01 | 3.322E-01 |
| 24 | 1996 | 0.304 | 3.622E+00 | 3.690E+00 | 1.121E+00 | 1.121E+00 | 1.256E+00 | 1.434E+00 | 3.860E-01 |
| 25 | 1997 | 0.527 | 3.757E+00 | 3.432E+00 | 1.810E+00 | 1.810E+00 | 1.187E+00 | 2.490E+00 | 4.003E-01 |
| 26 | 1998 | 0.448 | 3.134E+00 | 2.992E+00 | 1.342E+00 | 1.342E+00 | 1.065E+00 | 2.117E+00 | 3.340E-01 |
| 27 | 1999 | 0.167 | 2.858E+00 | 3.144E+00 | 5.250E-01 | 5.250E-01 | 1.108E+00 | 7.884E-01 | 3.045E-01 |
| 28 | 2000 | 0.132 | 3.441E+00 | 3.825E+00 | 5.060E-01 | 5.060E-01 | 1.289E+00 | 6.246E-01 | 3.667E-01 |
| 29 | 2001 | 0.194 | 4.224E+00 | 4.511E+00 | 8.740E-01 | 8.740E-01 | 1.451E+00 | 9.146E-01 | 4.501E-01 |
| 30 | 2002 | 0.165 | 4.801E+00 | 5.167E+00 | 8.510E-01 | 8.510E-01 | 1.585E+00 | 7.776E-01 | 5.116E-01 |
| 31 | 2003 | 0.194 | 5.535E+00 | 5.822E+00 | 1.130E+00 | 1.130E+00 | 1.701E+00 | 9.162E-01 | 5.899E-01 |
| 32 | 2004 | 0.184 | 6.106E+00 | 6.412E+00 | 1.182E+00 | 1.182E+00 | 1.788E+00 | 8.703E-01 | 6.507E-01 |
| 33 | 2005 | | 6.712E+00 | | | | | | 7.153E-01 |

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) weighout cpue

Data type CC: CPUE-catch series Series weight: 1.000

| Obs | Year | Observed CPUE | Estimated CPUE | Estim F | Observed yield | Model yield | Resid in log scale | Resid in log yield |
|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | * | 2.390E+00 | 0.0370 | 3.940E-01 | 3.940E-01 | 0.00000 | 0.000E+00 |
| 2 | 1974 | * | 2.612E+00 | 0.0504 | 5.860E-01 | 5.860E-01 | 0.00000 | 0.000E+00 |
| 3 | 1975 | * | 2.871E+00 | 0.0555 | 7.100E-01 | 7.100E-01 | 0.00000 | 0.000E+00 |
| 4 | 1976 | * | 3.049E+00 | 0.0744 | 1.010E+00 | 1.010E+00 | 0.00000 | 0.000E+00 |
| 5 | 1977 | * | 3.052E+00 | 0.1532 | 2.082E+00 | 2.082E+00 | 0.00000 | 0.000E+00 |
| 6 | 1978 | * | 2.820E+00 | 0.2593 | 3.257E+00 | 3.257E+00 | 0.00000 | 0.000E+00 |
| 7 | 1979 | 2.789E+00 | 2.419E+00 | 0.3684 | 3.968E+00 | 3.968E+00 | -0.14252 | |
| 8 | 1980 | 2.702E+00 | 1.977E+00 | 0.4417 | 3.889E+00 | 3.889E+00 | -0.31247 | |
| 9 | 1981 | 2.612E+00 | 1.581E+00 | 0.4971 | 3.499E+00 | 3.499E+00 | -0.50235 | |
| 10 | 1982 | 1.591E+00 | 1.381E+00 | 0.3236 | 1.990E+00 | 1.990E+00 | -0.14170 | |
| 11 | 1983 | 1.041E+00 | 1.337E+00 | 0.3152 | 1.877E+00 | 1.877E+00 | 0.25023 | |
| 12 | 1984 | 1.000E+00 | 1.282E+00 | 0.3518 | 2.009E+00 | 2.009E+00 | 0.24870 | |
| 13 | 1985 | 8.920E-01 | 1.208E+00 | 0.3645 | 1.961E+00 | 1.961E+00 | 0.30335 | |
| 14 | 1986 | 1.085E+00 | 1.126E+00 | 0.3889 | 1.950E+00 | 1.950E+00 | 0.03713 | |
| 15 | 1987 | 1.269E+00 | 8.433E-01 | 0.8548 | 3.210E+00 | 3.210E+00 | -0.40870 | |
| 16 | 1988 | 7.500E-01 | 6.016E-01 | 0.5080 | 1.361E+00 | 1.361E+00 | -0.22042 | |
| 17 | 1989 | 6.500E-01 | 9.540E-01 | 0.1069 | 4.540E-01 | 4.540E-01 | 0.38373 | |
| 18 | 1990 | 6.660E-01 | 1.020E+00 | 0.1924 | 8.740E-01 | 8.740E-01 | 0.42649 | |
| 19 | 1991 | 6.330E-01 | 8.499E-01 | 0.3142 | 1.189E+00 | 1.189E+00 | 0.29460 | |
| 20 | 1992 | 8.110E-01 | 8.116E-01 | 0.4573 | 1.653E+00 | 1.653E+00 | 0.00080 | |
| 21 | 1993 | 7.610E-01 | 6.754E-01 | 0.6111 | 1.838E+00 | 1.838E+00 | -0.11934 | |
| 22 | 1994 | * | 9.104E-01 | 0.1939 | 7.860E-01 | 7.860E-01 | 0.00000 | 0.000E+00 |
| 23 | 1995 | * | 7.560E-01 | 0.1978 | 6.660E-01 | 6.660E-01 | 0.00000 | 0.000E+00 |
| 24 | 1996 | * | 8.285E-01 | 0.3038 | 1.121E+00 | 1.121E+00 | 0.00000 | 0.000E+00 |
| 25 | 1997 | * | 7.707E-01 | 0.5274 | 1.810E+00 | 1.810E+00 | 0.00000 | 0.000E+00 |
| 26 | 1998 | * | 6.719E-01 | 0.4485 | 1.342E+00 | 1.342E+00 | 0.00000 | 0.000E+00 |
| 27 | 1999 | * | 7.059E-01 | 0.1670 | 5.250E-01 | 5.250E-01 | 0.00000 | 0.000E+00 |
| 28 | 2000 | * | 8.588E-01 | 0.1323 | 5.060E-01 | 5.060E-01 | 0.00000 | 0.000E+00 |
| 29 | 2001 | * | 1.013E+00 | 0.1937 | 8.740E-01 | 8.740E-01 | 0.00000 | 0.000E+00 |
| 30 | 2002 | * | 1.160E+00 | 0.1647 | 8.510E-01 | 8.510E-01 | 0.00000 | 0.000E+00 |
| 31 | 2003 | * | 1.307E+00 | 0.1941 | 1.130E+00 | 1.130E+00 | 0.00000 | 0.000E+00 |
| 32 | 2004 | * | 1.440E+00 | 0.1844 | 1.182E+00 | 1.182E+00 | 0.00000 | 0.000E+00 |

* Asterisk indicates missing value(s).

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UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                  -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75      1
                   |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual   ----------------------------------------------------------------------------------
1973     0.0000                                            |
1974     0.0000                                            |
1975     0.0000                                            |
1976     0.0000                                            |
1977     0.0000                                            |
1978     0.0000                                            |
1979    -0.1425                                      ======|
1980    -0.3125                                ============|
1981    -0.5023                        ====================|
1982    -0.1417                                      ======|
1983     0.2502                                            |==========
1984     0.2487                                            |==========
1985     0.3034                                            |============
1986     0.0371                                            |=
1987    -0.4087                            ================|
1988    -0.2204                                   =========|
1989     0.3837                                            |===============
1990     0.4265                                            |=================
1991     0.2946                                            |============
1992     0.0008                                            |
1993    -0.1193                                       =====|
1994     0.0000                                            |
1995     0.0000                                            |
1996     0.0000                                            |
1997     0.0000                                            |
1998     0.0000                                            |
1999     0.0000                                            |
2000     0.0000                                            |
2001     0.0000                                            |
2002     0.0000                                            |
2003     0.0000                                            |
2004     0.0000                                            |
                  ---------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) turner

Data type I1: Year-average biomass index Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Resid in index |
|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 1.000E+00 | 1.000E+00 | 0.0 | 2.060E-01 | 1.100E-01 | 0.62756 | 9.602E-02 |
| 2 | 1974 | 1.000E+00 | 1.000E+00 | 0.0 | 1.350E-01 | 1.202E-01 | 0.11598 | 1.478E-02 |
| 3 | 1975 | 1.000E+00 | 1.000E+00 | 0.0 | 9.600E-02 | 1.321E-01 | -0.31930 | -3.611E-02 |
| 4 | 1976 | 1.000E+00 | 1.000E+00 | 0.0 | 1.140E-01 | 1.403E-01 | -0.20760 | -2.630E-02 |
| 5 | 1977 | 1.000E+00 | 1.000E+00 | 0.0 | 1.250E-01 | 1.405E-01 | -0.11666 | -1.547E-02 |
| 6 | 1978 | 1.000E+00 | 1.000E+00 | 0.0 | 1.320E-01 | 1.298E-01 | 0.01694 | 2.217E-03 |
| 7 | 1979 | 1.000E+00 | 1.000E+00 | 0.0 | 1.000E-01 | 1.113E-01 | -0.10706 | -1.130E-02 |
| 8 | 1980 | 1.000E+00 | 1.000E+00 | 0.0 | 9.100E-02 | 9.098E-02 | 0.00027 | 2.474E-05 |
| 9 | 1981 | 1.000E+00 | 1.000E+00 | 0.0 | 9.000E-02 | 7.274E-02 | 0.21297 | 1.726E-02 |
| 10 | 1982 | 1.000E+00 | 1.000E+00 | 0.0 | 5.100E-02 | 6.354E-02 | -0.21990 | -1.254E-02 |
| 11 | 1983 | 0.000E+00 | 0.000E+00 | 0.0 | * | 6.153E-02 | 0.00000 | 0.0 |
| 12 | 1984 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.901E-02 | 0.00000 | 0.0 |
| 13 | 1985 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.560E-02 | 0.00000 | 0.0 |
| 14 | 1986 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.182E-02 | 0.00000 | 0.0 |
| 15 | 1987 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.881E-02 | 0.00000 | 0.0 |
| 16 | 1988 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.769E-02 | 0.00000 | 0.0 |
| 17 | 1989 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.390E-02 | 0.00000 | 0.0 |
| 18 | 1990 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.695E-02 | 0.00000 | 0.0 |
| 19 | 1991 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.911E-02 | 0.00000 | 0.0 |
| 20 | 1992 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.735E-02 | 0.00000 | 0.0 |
| 21 | 1993 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.108E-02 | 0.00000 | 0.0 |
| 22 | 1994 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.190E-02 | 0.00000 | 0.0 |
| 23 | 1995 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.479E-02 | 0.00000 | 0.0 |
| 24 | 1996 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.813E-02 | 0.00000 | 0.0 |
| 25 | 1997 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.547E-02 | 0.00000 | 0.0 |
| 26 | 1998 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.092E-02 | 0.00000 | 0.0 |
| 27 | 1999 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.249E-02 | 0.00000 | 0.0 |
| 28 | 2000 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.952E-02 | 0.00000 | 0.0 |
| 29 | 2001 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.662E-02 | 0.00000 | 0.0 |
| 30 | 2002 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.339E-02 | 0.00000 | 0.0 |
| 31 | 2003 | 0.000E+00 | 0.000E+00 | 0.0 | * | 6.017E-02 | 0.00000 | 0.0 |
| 32 | 2004 | 0.000E+00 | 0.000E+00 | 0.0 | * | 6.626E-02 | 0.00000 | 0.0 |

* Asterisk indicates missing value(s).

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UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5     -0.25       0        0.25      0.5       0.75      1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -----------------------------------------------------------------------------------
1973     0.6276                                            |=========================
1974     0.1160                                            |=====
1975    -0.3193                               =============|
1976    -0.2076                                    ========|
1977    -0.1167                                       =====|
1978     0.0169                                            |=
1979    -0.1071                                        ====|
1980     0.0003                                            |
1981     0.2130                                            |=========
1982    -0.2199                                   =========|
1983     0.0000                                            |
1984     0.0000                                            |
1985     0.0000                                            |
1986     0.0000                                            |
1987     0.0000                                            |
1988     0.0000                                            |
1989     0.0000                                            |
1990     0.0000                                            |
1991     0.0000                                            |
1992     0.0000                                            |
1993     0.0000                                            |
1994     0.0000                                            |
1995     0.0000                                            |
1996     0.0000                                            |
1997     0.0000                                            |
1998     0.0000                                            |
1999     0.0000                                            |
2000     0.0000                                            |
2001     0.0000                                            |
2002     0.0000                                            |
2003     0.0000                                            |
2004     0.0000                                            |
                   -----------------------------------------------------------------------------------
```

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) vtr

Data type I1: Year-average biomass index Series weight: 1.000

| Obs | Year | Observed effort | Estimated effort | Estim F | Observed index | Model index | Resid in log index | Resid in index |
|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.173E+00 | 0.00000 | 0.0 |
| 2 | 1974 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.562E+00 | 0.00000 | 0.0 |
| 3 | 1975 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.013E+00 | 0.00000 | 0.0 |
| 4 | 1976 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.324E+00 | 0.00000 | 0.0 |
| 5 | 1977 | 0.000E+00 | 0.000E+00 | 0.0 | * | 5.330E+00 | 0.00000 | 0.0 |
| 6 | 1978 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.925E+00 | 0.00000 | 0.0 |
| 7 | 1979 | 0.000E+00 | 0.000E+00 | 0.0 | * | 4.223E+00 | 0.00000 | 0.0 |
| 8 | 1980 | 0.000E+00 | 0.000E+00 | 0.0 | * | 3.452E+00 | 0.00000 | 0.0 |
| 9 | 1981 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.760E+00 | 0.00000 | 0.0 |
| 10 | 1982 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.411E+00 | 0.00000 | 0.0 |
| 11 | 1983 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.335E+00 | 0.00000 | 0.0 |
| 12 | 1984 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.239E+00 | 0.00000 | 0.0 |
| 13 | 1985 | 0.000E+00 | 0.000E+00 | 0.0 | * | 2.110E+00 | 0.00000 | 0.0 |
| 14 | 1986 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.966E+00 | 0.00000 | 0.0 |
| 15 | 1987 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.473E+00 | 0.00000 | 0.0 |
| 16 | 1988 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.051E+00 | 0.00000 | 0.0 |
| 17 | 1989 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.666E+00 | 0.00000 | 0.0 |
| 18 | 1990 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.782E+00 | 0.00000 | 0.0 |
| 19 | 1991 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.484E+00 | 0.00000 | 0.0 |
| 20 | 1992 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.417E+00 | 0.00000 | 0.0 |
| 21 | 1993 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.179E+00 | 0.00000 | 0.0 |
| 22 | 1994 | 0.000E+00 | 0.000E+00 | 0.0 | * | 1.590E+00 | 0.00000 | 0.0 |
| 23 | 1995 | 1.000E+00 | 1.000E+00 | 0.0 | 1.005E+00 | 1.320E+00 | -0.27275 | -3.151E-01 |
| 24 | 1996 | 1.000E+00 | 1.000E+00 | 0.0 | 1.398E+00 | 1.447E+00 | -0.03433 | -4.883E-02 |
| 25 | 1997 | 1.000E+00 | 1.000E+00 | 0.0 | 2.350E+00 | 1.346E+00 | 0.55746 | 1.004E+00 |
| 26 | 1998 | 1.000E+00 | 1.000E+00 | 0.0 | 1.388E+00 | 1.173E+00 | 0.16805 | 2.147E-01 |
| 27 | 1999 | 1.000E+00 | 1.000E+00 | 0.0 | 9.910E-01 | 1.233E+00 | -0.21823 | -2.417E-01 |
| 28 | 2000 | 1.000E+00 | 1.000E+00 | 0.0 | 1.000E+00 | 1.500E+00 | -0.40524 | -4.997E-01 |
| 29 | 2001 | 1.000E+00 | 1.000E+00 | 0.0 | 1.410E+00 | 1.769E+00 | -0.22676 | -3.589E-01 |
| 30 | 2002 | 1.000E+00 | 1.000E+00 | 0.0 | 1.723E+00 | 2.026E+00 | -0.16195 | -3.029E-01 |
| 31 | 2003 | 1.000E+00 | 1.000E+00 | 0.0 | 2.779E+00 | 2.283E+00 | 0.19659 | 4.960E-01 |
| 32 | 2004 | 1.000E+00 | 1.000E+00 | 0.0 | 3.741E+00 | 2.514E+00 | 0.39744 | 1.227E+00 |

* Asterisk indicates missing value(s).

```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ----------------------------------------------------------------------------------
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995    -0.2728                                  ===========|
1996    -0.0343                                            =|
1997     0.5575                                             |======================
1998     0.1681                                             |=======
1999    -0.2182                                    =========|
2000    -0.4052                             ================|
2001    -0.2268                                    =========|
2002    -0.1619                                       ======|
2003     0.1966                                             |========
2004     0.3974                                             |================
                   ---------------------------------------------------------------------------------
```

RESULTS OF BOOTSTRAPPED ANALYSIS

| Param name | Point estimate | Estimated bias | Relative bias | Approx 80% lower CL | Approx 80% upper CL | Approx 50% lower CL | Approx 50% upper CL | Inter-quartile range | Relative IQ range |
|---|---|---|---|---|---|---|---|---|---|
| B1/Bmsy | 1.000E+00 | -7.798E-10 | 0.00% | 1.000E+00 | 1.000E+00 | 1.000E+00 | 1.000E+00 | 4.293E-10 | 0.000 |
| K | 1.877E+01 | -1.096E+00 | -5.84% | 1.632E+01 | 2.649E+01 | 1.803E+01 | 2.302E+01 | 4.990E+00 | 0.266 |
| r | 4.237E-01 | 1.179E+00 | 278.33% | 2.675E-01 | 5.115E-01 | 3.272E-01 | 4.478E-01 | 1.206E-01 | 0.285 |
| q(1) | 2.245E-01 | 2.937E-02 | 13.08% | 1.476E-01 | 2.702E-01 | 1.795E-01 | 2.426E-01 | 6.313E-02 | 0.281 |
| q(2) | 1.033E-02 | 2.189E-03 | 21.19% | 7.588E-03 | 1.186E-02 | 8.500E-03 | 1.088E-02 | 2.380E-03 | 0.230 |
| q(3) | 3.921E-01 | 5.745E-02 | 14.65% | 1.980E-01 | 5.707E-01 | 2.622E-01 | 4.644E-01 | 2.022E-01 | 0.516 |
| MSY | 1.988E+00 | 6.862E-01 | 34.52% | 1.793E+00 | 2.092E+00 | 1.869E+00 | 2.024E+00 | 1.552E-01 | 0.078 |
| Ye(2005) | 1.827E+00 | -8.667E-02 | -4.74% | 1.395E+00 | 2.085E+00 | 1.641E+00 | 1.996E+00 | 3.552E-01 | 0.194 |
| Bmsy | 9.384E+00 | -5.482E-01 | -5.84% | 8.160E+00 | 1.325E+01 | 9.015E+00 | 1.151E+01 | 2.495E+00 | 0.266 |
| Fmsy | 2.118E-01 | 5.896E-01 | 278.33% | 1.337E-01 | 2.557E-01 | 1.636E-01 | 2.239E-01 | 6.030E-02 | 0.285 |
| fmsy(1) | 9.434E-01 | 1.083E+00 | 114.80% | 8.198E-01 | 1.031E+00 | 8.627E-01 | 9.743E-01 | 1.117E-01 | 0.118 |
| fmsy(2) | 2.050E+01 | 1.210E+01 | 59.05% | 1.702E+01 | 2.361E+01 | 1.840E+01 | 2.188E+01 | 3.485E+00 | 0.170 |
| fmsy(3) | 5.403E-01 | 8.430E-01 | 156.04% | 4.071E-01 | 8.735E-01 | 4.658E-01 | 6.768E-01 | 2.111E-01 | 0.391 |
| F(0.1) | 1.906E-01 | 5.306E-01 | 250.50% | 1.204E-01 | 2.302E-01 | 1.472E-01 | 2.015E-01 | 5.427E-02 | 0.285 |
| Y(0.1) | 1.968E+00 | 6.793E-01 | 34.17% | 1.775E+00 | 2.071E+00 | 1.850E+00 | 2.004E+00 | 1.536E-01 | 0.078 |
| B/Bmsy | 7.153E-01 | 8.117E-02 | 11.35% | 4.507E-01 | 1.171E+00 | 5.497E-01 | 9.135E-01 | 3.638E-01 | 0.509 |
| F/Fmsy | 8.703E-01 | 1.169E-02 | 1.34% | 5.173E-01 | 1.352E+00 | 6.803E-01 | 1.129E+00 | 4.489E-01 | 0.516 |
| Y-ratio | 9.189E-01 | -7.335E-02 | -7.98% | 7.242E-01 | 9.989E-01 | 8.406E-01 | 9.887E-01 | 1.481E-01 | 0.161 |
| f0.1(1) | 8.491E-01 | 9.747E-01 | 103.32% | 7.378E-01 | 9.277E-01 | 7.764E-01 | 8.769E-01 | 1.005E-01 | 0.118 |
| f0.1(2) | 1.845E+01 | 1.089E+01 | 53.14% | 1.532E+01 | 2.125E+01 | 1.656E+01 | 1.969E+01 | 3.136E+00 | 0.170 |
| f0.1(3) | 4.862E-01 | 7.587E-01 | 140.44% | 3.664E-01 | 7.861E-01 | 4.192E-01 | 6.091E-01 | 1.900E-01 | 0.391 |
| q2/q1 | 4.602E-02 | 1.685E-03 | 3.66% | 3.792E-02 | 5.511E-02 | 4.172E-02 | 5.007E-02 | 8.349E-03 | 0.181 |
| q3/q1 | 1.746E+00 | 4.235E-02 | 2.43% | 1.134E+00 | 2.350E+00 | 1.431E+00 | 2.042E+00 | 6.116E-01 | 0.350 |

NOTES ON BOOTSTRAPPED ESTIMATES

- The bootstrapped results shown were computed from 1000 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- Estimates of bias and relative bias are known to be highly imprecise and may not be informative.

| | |
|---|---|
| Trials replaced for lack of convergence: | 2 |
| Trials replaced for MSY out-of-bounds: | 6 |
| Trials replaced for r out-of-bounds: | 3 |
| Residual-adjustment factor: | 1.0801 |

## APPENDIX C5: AIM Model results

## (Combined NEFSC Weighout, VTR and Turner CPUE)

AIM Summary Report

Input File: C:\NIT\TILE\SARC41\AIM\TILECOMB3.DAT

Report Date: 27-Apr-05
Report Time: 15:44

First Year: 1973
Last Year: 2004
Number of Years: 32

Number of Indices: 1

| | |
|---|---|
| Number of Years for Smoothing Abundance Indices: | 4 |
| Number of Years for Smoothing Relative F: | 1 |
| Number of Realizations for Randomization Test: | 2000 |
| Number of Bootstrap Iterations: | 2000 |
| Random Number Generation Seed: | 123456 |
| Number of Lags for Auto & Cross-correlation: | 15 |

Relative F Smoothing Method is Lagged

| | Catch | cpue |
|---|---|---|
| 1973 | 3.9400E+02 | 5.9800E+00 |
| 1974 | 5.8600E+02 | 3.9200E+00 |
| 1975 | 7.1000E+02 | 2.7900E+00 |
| 1976 | 1.0100E+03 | 3.3100E+00 |
| 1977 | 2.0820E+03 | 3.6300E+00 |
| 1978 | 3.2570E+03 | 3.8300E+00 |
| 1979 | 3.9680E+03 | 2.9000E+00 |
| 1980 | 3.8890E+03 | 2.6400E+00 |
| 1981 | 3.4990E+03 | 2.6100E+00 |
| 1982 | 1.9900E+03 | 1.4800E+00 |
| 1983 | 1.8760E+03 | 1.0450E+00 |
| 1984 | 2.0090E+03 | 1.0000E+00 |
| 1985 | 1.9610E+03 | 8.9200E-01 |
| 1986 | 1.9500E+03 | 1.0930E+00 |
| 1987 | 3.2100E+03 | 1.2860E+00 |
| 1988 | 1.3610E+03 | 7.6600E-01 |
| 1989 | 4.5400E+02 | 6.5600E-01 |
| 1990 | 8.7400E+02 | 6.6900E-01 |
| 1991 | 1.1890E+03 | 6.4000E-01 |
| 1992 | 1.6530E+03 | 8.2300E-01 |
| 1993 | 1.8380E+03 | 7.5600E-01 |
| 1994 | 7.8600E+02 | 4.5700E-01 |
| 1995 | 6.6600E+02 | 5.3600E-01 |
| 1996 | 1.1210E+03 | 7.3400E-01 |
| 1997 | 1.8100E+03 | 1.2520E+00 |
| 1998 | 1.3420E+03 | 7.4100E-01 |
| 1999 | 5.2500E+02 | 5.2400E-01 |
| 2000 | 5.0600E+02 | 5.2400E-01 |
| 2001 | 8.7400E+02 | 7.5100E-01 |
| 2002 | 8.5100E+02 | 9.1600E-01 |
| 2003 | 1.1300E+03 | 1.4860E+00 |
| 2004 | 1.1820E+03 | 2.1290E+00 |

Base Case Results

cpue

Replacement Ratio    Relative F

| | | |
|---|---|---|
| 1973 | N/A | 65.8862876 |
| 1974 | N/A | 149.4897959 |
| 1975 | N/A | 254.4802867 |
| 1976 | N/A | 305.1359517 |
| 1977 | 0.9075000 | 573.5537190 |
| 1978 | 1.1223443 | 850.3916449 |
| 1979 | 0.8554572 | 1368.2758621 |
| 1980 | 0.7724945 | 1473.1060606 |
| 1981 | 0.8030769 | 1340.6130268 |
| 1982 | 0.4941569 | 1344.5945946 |
| 1983 | 0.4340602 | 1795.2153110 |
| 1984 | 0.5144695 | 2009.0000000 |
| 1985 | 0.5815811 | 2198.4304933 |
| 1986 | 0.9898121 | 1784.0805124 |
| 1987 | 1.2764268 | 2496.1119751 |
| 1988 | 0.7173964 | 1776.7624021 |
| 1989 | 0.6499876 | 692.0731707 |
| 1990 | 0.7040253 | 1306.4275037 |
| 1991 | 0.7580693 | 1857.8125000 |
| 1992 | 1.2054193 | 2008.5054678 |
| 1993 | 1.0846485 | 2431.2169312 |
| 1994 | 0.6329640 | 1719.9124726 |
| 1995 | 0.8011958 | 1242.5373134 |
| 1996 | 1.1415241 | 1527.2479564 |
| 1997 | 2.0169150 | 1445.6869010 |
| 1998 | 0.9949648 | 1811.0661269 |
| 1999 | 0.6423537 | 1001.9083969 |
| 2000 | 0.6447247 | 965.6488550 |
| 2001 | 0.9878329 | 1163.7816245 |
| 2002 | 1.4425197 | 929.0393013 |
| 2003 | 2.1893186 | 760.4306864 |
| 2004 | 2.3160185 | 555.1902302 |

Simple Regression Results

LN(Replacement Ratio) = A + B * LN(Relative F)

cpue

| Coefficient | A | B |
|---|---|---|
| Estimated Value | 2.1716E+00 | -3.1657E-01 |
| Std Error Coeff | 1.3898E+00 | 1.9275E-01 |
| t Statistic | 1.5626E+00 | -1.6424E+00 |
| p-Value (2 Sided) | 1.3025E-01 | 1.1255E-01 |
| Variance Inflation Factor | 3.1191E+02 | 1.0000E+00 |

Relative F (for ln(Replacement Ratio = 0) = 9.530539E+02

Analysis of Variance

| | |
|---|---|
| Degrees of Freedom for Regression | 1.0000E+00 |
| Degrees of Freedom for Error | 2.6000E+01 |
| Total Degrees of Freedom | 2.7000E+01 |
| Sum of Squares for Regression | 4.6770E-01 |
| Sum of Squares for Error | 4.5080E+00 |
| Total Sum of Squares | 4.9757E+00 |
| Regression Mean Square | 4.6770E-01 |
| Error Mean Square | 1.7338E-01 |
| F-Statistic | 2.6975E+00 |
| p-Value | 1.1255E-01 |
| R Squared (percent) | 9.3998E+00 |
| Adjusted R Squared (percent) | 5.9152E+00 |
| Estimated Standard deviation of model error | 4.1639E-01 |
| Mean of response (dependent) variable | -1.0730E-01 |
| Coefficient of Variation (percent) | -3.8808E+02 |

Least Absolute Value Regression Results

```
LN(Replacement Ratio) = A + B * LN(Relative F)
cpue

Coefficient                         A               B
Estimated Value                     8.1748E-01    -1.4398E-01
Sum of Absolute Value of Error   = 9.1166E+00

Relative F (for ln(Replacement Ratio = 0) = 2.922861E+02
```

## APPENDIX C6: Length-based YPR

```
##    Length Based Yield Per Recruit Model
##    Version 1.2
##    Date & Time of Run: 22 Apr 2005   16:57
##    Input File Name: c:\nit\tile\sarc41\ypr\tlenypr-log2.dat

 Model Title: tilefish

 Fishing Mortality Upper Bound             =     2.0000
 Fishing Mortality Calculation Increment   =     0.0001
 Fishing Mortality Printing Increment      =       0.01

 Natural Mortality                         =     0.1000

 Starting Length                           =     1.0000
 Ending Age of Projection (Years)          =    35.0000
 Age Step Increment                        =     0.1000

 Length Units                              = Centimeters
 Weight Units                              = Kilograms

 Von Bertalanffy Growth Equation Parameters
 L-Infinity                                =    97.6000
 K                                         =     0.1620

 Length-Weight Equation Parameters
 Ln(A)                                     =   -12.3114
 B                                         =     3.2835

 Fishery Mortality Selectivity
 Single Logistic Equation Parameters
 Alpha                                     =   -18.9569
 Beta                                      =     0.4693
 L-50 (Calculated)                         =    40.3896

 Matural Mortality Selectivity
 Natural Mortality is Constant with Value  =     0.1000

 Maturity Ogive Equation Parameters
 Alpha                                     =   -11.6211
 Beta                                      =     0.2374
 L-50 (Calculated)                         =    48.9618


 Reference Point        F           YPR          SSBR         TSBR
 F Zero              0.00000      0.00000     51.53361     53.26153
 F-01                0.08470      1.78983     20.34513     21.96114
 F-Max               0.13870      1.90241     12.95707     14.51105
 F at   40 %MSP      0.08320      1.78180     20.62892     22.24674
```

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