Northeast Fisheries Science Center Reference Document 94-06

Report of the 17th Northeast Regional Stock Assessment Workshop

Stock Assessment Review Committee (SARC)

Consensus Summary of Assessments

NOAA/National Marine Fisheries Service
Northeast Fisheries Science Center
Environmental Processes Division
Woods Hole, MA 02543-1097

January 1994

The 17th Northeast Regional Stock Assessment Workshop is documented in seven separate reports, listed below. The Northeast Fisheries Science Center Reference Documents are a series of informal reports produced by the Center for timely transmission of results obtained through work at NEFSC labs. The documents are reviewed internally before publication, but are not considered formal literature. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these reports. To obtain additional copies of this report or other Center Reference Documents contact, Information Services Unit, Northeast Fisheries Science Center, Woods Hole, MA 02543 (508-548-5123, ext. 260 or 378).

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Reports of the 17th Stock Assessment Workshop (17th SAW)

CRD 94-01 Estimation of Discards in the Silver Hake Fisheries and its Implications on the Long-Term Yield of the Stocks
by T. Helser and R. Mayo

CRD 94-02 Assessment of Yellowtail Flounder *Pleuronectes ferrugineus*, 1993
by P. Rago, W. Gabriel, and M. Lambert

CRD 94-03 Stock Assessment of Atlantic Butterfish, *Peprilus triacanthus*, in the Northwest Atlantic During 1992
by J. Brodziak

CRD 94-04 Stock Assessment of Long-Finned Squid, *Loligo pealei*, in the Northwest Atlantic During 1992
by J. Brodziak

CRD 94-05 Stock Assessment of Short-Finned Squid, *Illex illecebrosus*, in the Northwest Atlantic During 1992
J. Brodziak and L. Hendrickson

CRD 94-06 Report of the 17th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee Consensus Summary of Assessments

CRD 94-07 Report of the 17th Northeast Regional Stock Assessment Workshop, The Plenary

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) Meeting of the 17th Northeast Regional Stock Assessment Workshop (17th SAW) was held during 29 November - 4 December 1993 at the Northeast Fisheries Science Center, Woods Hole, Massachusetts. Dr. Vaughn Anthony (NEFSC) chaired the 14-member SARC (Table 1). Two SARC members were from outside the region (Seattle, Washington and Canada). Nearly 50 other individuals also attended (Table 2). The agenda for the meeting is presented in Table 3.

OPENING

The Chairman reviewed the current SAW structure (Figure 1) and functions of the SAW Steering Committee (Table 4), clarified the responsibilities of the SARC and its Subcommittees (Table 5), and discussed how he planned to conduct the meeting. He reviewed the SAW documentation and when material would be due. In addition to carefully reviewing the species/stock assessments, the SARC would produce a "Consensus Summary of Assessments" document (SARC Report), that would include research recommendations for each species reviewed, designate any materials for publication, draft an "Advisory Report on Stock Status" (Advisory Report) for managers, and review the terms of reference for the Assessments Methods Subcommittee.

The Chairman reviewed the responsibilities of the Subcommittee chairs, rapporteurs, and the editor of the Advisory Report (Terry Smith), as well as the responsibilities of the SARC Leaders. The Subcommittee chairs are responsible for the presentation of assessments, selection of rapporteurs for Subcommittee reports, the first draft of their section of the SARC Report, and the first draft of the Advisory Report (especially tables and figures). The rapporteurs are responsible for both drafts of the SARC Report, including research recommendations, and the first draft of the Advisory Report. The editor is responsible for two drafts of the Advisory Report. SARC leaders were designated to ensure that the final documents appropriately reflect the consensus of the SARC. The SARC Leaders would work with Rapporteurs to develop the final draft of the SARC Report and with Terry Smith and Rapporteurs to develop the final draft of the Advisory Report. The Leaders would also make sure that all research recommendations for assigned species would be properly documented.

Table 1. SAW-17 SARC composition

Chair NEFSC Chief Scientific Advisor

Vaughn Anthony

Four *ad hoc* assessment members chosen by the Chair

Frank Almeida
Kevin Friedland
Steve Murawski
Fred Serchuk

One person from NMFS Northeast Regional Office

Pete Colosi

One person from each Regional Fishery Management Council

Andy Applegate, NEFMC **Tom Hoff,** MAFMC

Atlantic States Marine Fisheries Commission /State personnel

Lisa Kline, ASMFC
Steve Correia, Massachusetts
David Simpson, Connecticut

One scientist from:

Canada	M. Christina Annand, Department of Fisheries and Oceans
Academia	**John Boreman,** UMA/NOAA CMER
Other Region	**Grant Thompson**, AKFSC

The SAWs Coordinator is responsible for the organization and overall coordination of the meeting, meeting materials, and meeting reports. The Coordinator also drafts the meeting overview and other business section of the SARC report.

To insure that all procedures and timing were well understood, the SARC Chairman tabled a 20 page document concerning the above topics.

AGENDA AND REPORTS

The SARC agenda included nine species/stocks (seven first priority and two second priority) and the terms of reference for the Assessments Methods Subcommittee. Reviewed were analyses for two stocks of silver hake (Gulf of Maine - Northern Georges Bank and Southern

Table 2. List of all participants

National Marine Fisheries Service

Northeast Fisheries Science Center

Frank Almeida
Vaughn Anthony
John Boreman
Jon Brodziak
Ray Conser
Kevin Friedland
Wendy Gabriel
Ruth Haas-Castro
Dan Hayes
Tom Helser
Lisa Hendrickson
Joseph Idoine
John Kocik
Marjorie Lambert
Ralph Mayo
Tom Morrissey
Steve Murawski
Helen Mustafa
Loretta O'Brien
Bill Overholtz
Paul Rago
Anne Richards
Fred Serchuk
Terry Smith
Katherine Sosebee
Mark Terceiro
Jim Weinberg

Northeast Regional Office

Peter Colosi

Office of Research and Environmental Information

Andy Rosenberg

Alaska Fisheries Science Center

Grant Thompson

Mid-Atlantic Fishery Management Council

Tom Hoff

New England Fishery Management Council

Andrew Applegate

Atlantic States Marine Fisheries Commission

Lisa Kline

Connecticut Department of Environmental Protection

Dave Simpson
Vic Creco

Massachusetts Division of Marine Fisheries

Steve Cadrin
Steve Correia
Tom Currier
Jessica Harris
Arnold Howe
Dan McKiernan
David Pierce

New York Division of Marine Resources

John Mason

Rhode Island Division of Fish and Wildlife

Mark Gibson

Department of Fisheries and Oceans, Canada

Chris Annand

Conservation Law Foundation

Eleanor Dorsey

East Coast Fish. Association

Erling Berg

F/V Flicka, F/V Dyrsten

Lars Axelsson

Georges Bank - Middle Atlantic), Southern New England yellowtail flounder, bluefish, butterfish, and long- and short-finned squid. Time, however, was insufficient to allow a review of the second priority species. A chart of U.S. commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 2.

Analyses were submitted to the SARC in the form of Subcommittee Reports developed in a series of meetings (Table 6). Material from Subcommittee reports form the basis of this report. In addition, the SARC reviewed separate working papers containing detailed supporting material for the Subcommittee reports. Five of the working papers reviewed were recommended for publication in the NEFSC Reference Document series (Table 7).

In addition, the SARC prepared a draft Advi-

Table 3. Agenda for the 17th Northeast Regional Stock Assessment Workshop (SAW-17), Stock Assessment Review Committee (SARC) Meeting

Woods Hole, Massachusetts
November 29 - 4 December 1993

AGENDA

Monday, November 29 (9:00 AM - 6:00 PM)

Opening	Chairman, V. Anthony
Welcome	
Agenda	
Conduct of meeting	
Assessment Methods Subcommittee	R. Conser
Review Terms of Reference from SAW-16	

SPECIES/STOCK	SUBCOMMITTEE	RAPPORTEUR	SARC LEADER & PRESENTER
First Priority			
Silver Hake	No. Demersal		
GoM-NGB (A)	R. Mayo	J. Idoine	G. Thompson
SGB-Mid-Atl (B)		J. Idoine	G. Thompson
Tuesday, November 30 (9:00 AM - 6:00 PM)			
Yellowtail Flounder	So. Demersal		
So. New England (C)	W. Gabriel	P. Rago	K. Friedland
Bluefish (D)	Pelagic/Coastal	M. Terceiro	J. Kocik/L. Kline
Review available report sections (SARC and Advisory Reports)			
Wednesday, December 1 (9:00 AM - 6:00 PM)			
Butterfish (E)	Invertebrate	J. Brodziak	J. Weinberg/T. Hoff
Squid	Invertebrate		
Long-finned (F)	J. Brodziak	A. Richards	J. Boreman
Short-finned (G)		A. Richards	C. Annand
Review available report sections (SARC and Advisory Reports)			
Thursday, December 2 (9:00 AM - 6:00 PM)			
Review all sections of the SARC and Advisory Reports (1st priority)			
Complete SARC Report sections			
Complete Advisory Report sectionsEditor, T.P. Smith			
Friday, December 3 (9:00 AM - 6:00 PM)			
Second Priority			
Cod No. Demersal			
Georges Bank (H)	R. Mayo	G. Shepherd	P. Colosi
Yellowtail Flounder	So. Demersal		
Georges Bank (I)	W. Gabriel	P. Rago	A. Applegate
Review 2nd priority sections (SARC and Advisory Reports)			
Assessment Methods Subcommittee	R. Conser		
Terms of Reference (J)			
Complete SARC Report sections			
Complete Advisory Report sectionsEditor, T.P. Smith			

Saturday, December 4 (9:00 AM - 6:00 PM) IF NECESSARY

Finalize sections of SARC and Advisory Reports
Complete any other unfinished business

sory Report on Stock Status for the species/ stocks reviewed. Information in the Advisory report was compiled according to the format approved by the SAW Steering Committee. The draft Advisory Report will be provided to the Steering Committee two weeks prior to the SAW Plenary Meeting scheduled to be held on 24 - 25 January 1994, in conjunction the Mid-Atlantic Fishery Management Council meeting in Ocean City, MD. The final version of the Advisory Report will be included in the Report of the 17th SAW Plenary (NEFSC Reference Document 94-07).

GENERAL DISCUSSION HIGHLIGHTS

Assessment Methods

The SARC thoroughly discussed the terms of reference for the Assessment Methods Subcommittee. The summary on pages 121 - 122 of this report is based on that discussion. As the ADAPT framework is adaptive to a variety of data on particular species and has a central role in age-based assessments performed in the region, it is critical to convene an ADAPT tutorial to explain the method and use of the program to all who may wish to use it. Members of state fisheries organizations, in particular, should participate in the tutorial. The NEFSC should take the responsibility to convene the tutorial, as it would not be productive to have this activity among the terms of reference of the Assessment Methods Subcommittee. It was agreed that the documentation of some basic version of the ADAPT software should be a "high priority" and recommended that the Assessment Methods Subcommittee specify what should be included in a standard user-friendly, version of the software so that action could be taken to develop such a package as soon as possible.

Silver Hake

The silver hake assessment addressed the juvenile fishery in addition to the stated terms of reference. However, the analyses, for both the southern and northern stocks, were plagued by a number of problems which are reflected in the research recommendations. Some of these recommendations must be met in order to make progress in the assessment of these stocks.

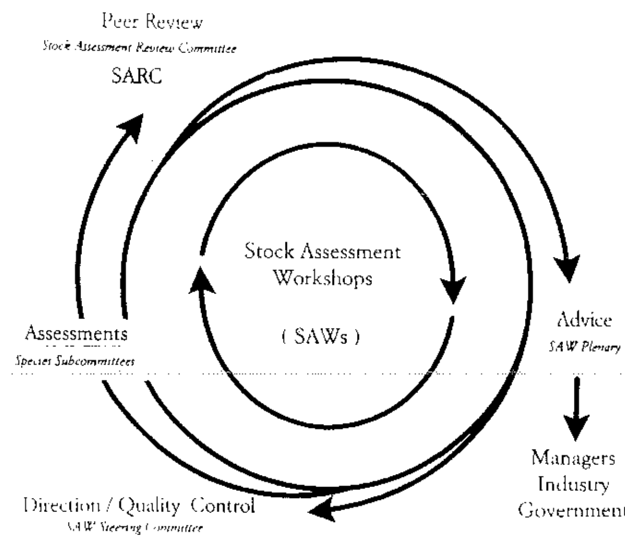

Figure 1. SAW structure.

Bluefish

Only three out of five of the terms of reference for bluefish were met. Although several approaches to the assessment of bluefish were discussed at the Subcommittee level, none was tabled for SARC review. After considerable debate, it was concluded that it would be worthwhile for the Subcommittee to meet once again to try to develop an agreed-upon assessment before the Plenary Meeting. This Subcommittee had met twice already (see Table 6) but, after discussion, members felt that considerable progress could be made, given one more meeting. Such a meeting in the midst of a SAW process is an exception to the procedure developed by the Steering Committee. To guarantee joint assessment and solid peer review, however, the Steering Committee did agree that another meeting should be held, because of the importance of the bluefish at this time and the promise of success made by the scientists. The Pelagic/Coastal Subcommittee met at Woods Hole on 5 January and a special SARC meeting was arranged for 11 January 1994. The scientists could not agree, however, even on the basics of an assessment and the special SARC meeting was canceled.

Yellowtail Flounder

A new diagnostic approach and smoothing procedure were implemented in the assessment on Southern New England yellowtail flounder. A

Table 4. Steering Committee functions

- Attend the SAW Plenary and discuss management advice
- Set priorities for review of the 48 stocks in the region, allocate resources (people and funding), and oversee the assessment and advice process
- Select species/stocks to review at the next SARC
- Set terms of reference for assessments
- Set dates and places for SARC and SAW Plenary meetings
- Evaluate sufficiency and style of SARC Advisory Reports and additional communication required
- Set Subcommittees in force and functioning

Table 5. Clarification of responsibilities of the SARC and its Subcommittees as well as the SARC procedure in general

- Subcommittee reports should be drafted as sections for the SARC Report, to be approved by the SARC.
- Subcommittee working papers should be forwarded to SARC members two weeks before the SARC meeting. More lead time may be needed for SARC members not familiar with specific species under review.
- Relative to Subcommittee workloads, in addition to the species terms of reference, the general guidance is to do what can reasonably be done on the basis of a "normal" workday. The Steering Committee is not always the best judge as to how much work is involved or how to handle the workload.
- As the SARC is responsible for all assessment advice, the review of details is contingent on the particular assessment.
- If there is no indication that stock status has changed from a previous assessment, or is not about to change, then the SARC could report this as the only advice for that stock.
- Subcommittees should submit all tables and figures required for the Advisory document in the standard format.
- It is not desirable for Rapporteurs to be SARC members. Rapporteurs from outside the SARC (NEFSC or states) may be appointed to allow the SARC members to fully participate in all SARC discussions. Although Rapporteurs use their ability to interpret, SARC members make the final judgement. An additional Rapporteur (editor) will coordinate the production of the Advisory Report to assure continuity from stock to stock within the agreed-upon format.

detailed description of the approach and methods can be found in the Northeast Fisheries Science Center Reference Document 94-02.

Squid

Recent research on the age and growth of long-finned *(Loligo)* squid indicates that the life span of the species is less than one year. Unlike previous assessments, which assumed a longer life span, the assessment of this species was based on the new findings. For short-lived species such as long- and short-finned squid and butterfish, the SARC concluded that a real-time assessment/management system should be contemplated to ensure that adequate levels of spawning stock are achieved for these species. A Plan Development Team approach was suggested for the development of such a system. In connection

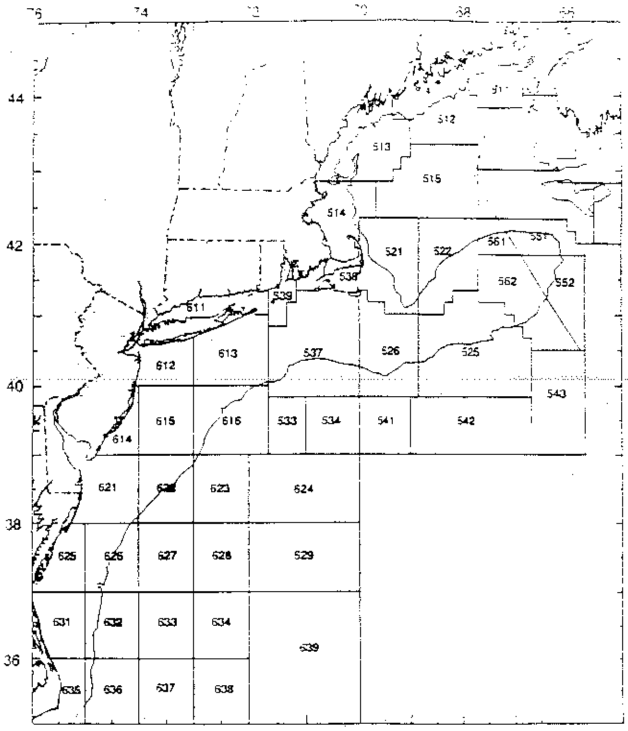

Figure 2. U.S. commercial statistical areas used to report landings in the Northwest Atlantic.

Table 7. NEFSC Reference Documents associated with the 17th Northeast Regional Stock Assessment Workshop (17th SAW)

Number	Title/Author(s)
CRD 94-01	Estimation of Discards in the Silver Hake Fisheries and its Implications on the Long-Term Yield of the Stocks by T. Helser and R. Mayo
CRD 94-02	Assessment of Yellowtail Flounder *Pleuronectes ferrugineus*, 1993 by P. Rago, W. Gabriel, and M. Lambert
CRD 94-03	Stock Assessment of Atlantic Butterfish, *Peprilus triacanthus*, in the Northwest Atlantic During 1992 by J. Brodziak
CRD 94-04	Stock Assessment of Long-Finned Squid, *Loligo pealei*, in the Northwest Atlantic During 1992 by J. Brodziak
CRD 94-05	Stock Assessment of Short-Finned Squid, *Illex illecebrosus*, in the Northwest Atlantic During 1992 by J. Brodziak
CRD 94-06	Report of the 17th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee Consensus Summary of Assessments
CRD 94-07	Report of the 17th Northeast Regional Stock Assessment Workshop, The Plenary

with this issue, the Report of the Working Group on Methods of Fish Stock Assessment (ICES 1993) was summarized for the SARC's information. The ICES report provides examples of successful assessment and management procedures for short-lived species.

General

Several other items, common to a number of species, were noted during the meeting:

- As sea sampling data are used for discard estimation, it was suggested that the SARC address the issue of sea sampling coverage generically, for all species, rather than on the species by species basis. This would, most importantly, involve a formal examination of the sea sampling survey design.

- The age structure approach to developing assessments was discussed in connection with at least two species before the SARC. The method requires much more complete biological data base than is currently available for these species, so attention should be paid to the caveats in the reports.

- In some cases, major assessment difficulties were directly related to the fact that the ADAPT framework was not accessible to most assessment scientists outside NEFSC. This emphasized the point that an ADAPT tutorial is badly needed along with the development of user-friendly ADAPT software.

- Compatible management, in addition to co-operative research, with Canada was recommended for transboundary species such as silver hake and short-finned squid.

- Some meeting participants indicated concern about how the transfer of the Statistics Program from NEFSC to NERO would affect stock assessments since the program plans to stop biological sampling at the ports.

Two fishermen attended the meeting and contributed to discussion of butterfish and the squids.

The timing of and species to review at SAWs 18 and 19, as well as the conduct of SARC meetings was discussed. These discussions are summarized under other business.

Table 6. Subcommittee Meetings, participants, and analyses prepared

Subcommittee/ Participants	Meeting Date(s) and Places(s)	Analyses Prepared
Northern Demersal	8 - 12 November 1993	Silver hake
A. Applegate, NEFMC	Woods Hole, MA	(2 stocks)
D. Hayes, NEFSC		GB Cod
T. Helser, NEFSC		
T. Hoff, MAFMC		
J. Mason, NY DEC		
R. Mayo, NEFSC (Chair)		
L. O'Brien, NEFSC		
F. Serchuk, NEFSC		
K. Sosebee, NEFSC		
S. Wigley, NEFSC		
Southern Demersal	2 - 5 November 1993	Yellowtail Flounder
A. Applegate, NEFMC	Woods Hole, MA	(2 stocks)
R. Conser		
W. Gabriel (Chair)		
M. Lambert		
P. Rago		
Pelagic/Coastal	25 - 26 October 1993	Bluefish
J. Buckler, SUNY	Old Lyme, CT	
V. Crecco, CT DEP		
M. Gibson, RI DFW	16 November 1993	
D. Hayes, NEFSC	Old Lyme, CT	
C. Moore, MAFMC		
S. Murawski, NEFSC (Chair)		
W. Overholtz, NEFSC		
J. Ross, NC DMF		
L. Rugolo, MD DNR		
M. Terceiro, NEFSC		
Special Meeting	5 January 1994	
V. Crecco, DT DEP	Woods Hole, MA	
M. Gibson, RI DFW		
C. Moore, MAFMC		
W. Overholtz, NEFSC		
F. Serchuk, NEFSC (Act. Chair)		
T.P. Smith, NEFSC		
M. Terceiro, NEFSC		
Invertebrate	27 - 29 October 1993	Long-finned squid
J. Brodziak, NEFSC	Dover, DE	Short-finned squid
T. Hoff, MAFMC		Butterfish
A. Lange, MD DNR		
R. Seagraves, MAFMC		
F. Serchuk, NEFSC (Chair)		
J. Weinberg, NEFSC		

SILVER HAKE
A. GULF OF MAINE-NORTHERN GEORGES BANK STOCK
B. SOUTHERN GEORGES BANK-MIDDLE ATLANTIC

TERMS OF REFERENCE

The following terms of reference were addressed:

a. Update the analytical assessments of the Gulf of Maine-Northern Georges Bank and Southern Georges Bank-Middle Atlantic silver hake stocks through 1992. If possible, include estimates of discards in the catch-at-age matrix.

b. Evaluate catchability differences for silver hake between the '36 Yankee' and '41 Yankee' survey trawls, and determine the most appropriate conversion factor between the two nets. Standardize the spring survey indices and use the standardized indices in the VPA tuning.

c. Provide any new information on the natural mortality rate of silver hake, with reference to whether the natural mortality rate used in previous assessments (M=0.40) is still reasonable.

d. Review past biological reference points.

e. Examine the effects of a newly developed fishery on juvenile silver hake (< 18 cm).

OVERVIEW

The silver hake stocks off the northeast coast of the United States have followed a trajectory typical of fish stocks that have been heavily exploited. Before 1960, silver hake fishery was exploited only by U.S. fleets. Exploitation intensified with the arrival of distant-water fleets (DWF) in 1962, and stock biomass declined sharply between 1965 and 1970. Total international landings fell by the late 1970s to historic lows. In addition, the age composition became highly truncated to younger ages: from a fishery whose landings were dominated by ages 3 to 5 with ages up to 10 years, to one in which more than 64 percent of the landings comprised age 2 to 3 fish.

While DWF fishing activity for silver hake in U.S. waters was either greatly reduced or ceased altogether by the late-1970s, U.S. landings have not increased and remain at low but stable levels compared to earlier years of the fishery. A small-mesh fishery, restricted seasonally (June through October) and spatially (SA 522), has been conducted over an area of northern Georges Bank known as Cultivator Shoals. Provisions in Amendment 4 of the Multispecies Fishery Management Plan (FMP) allow the use of small mesh in a region that has minimum mesh size restrictions of 5.5 in. More recently, a "juvenile whiting" fishery has developed for small silver hake as an export product to Spain and Portugal. Unlike the U.S. whiting market, where product demand is for larger silver hake (age 2 and 3), the export market demand is for small silver hake (7 to 9 in.) presumably in their first or second year of life. By exploiting younger ages of fish in the stocks the question of concern to management focuses on the affects of a "juvenile whiting" fishery on the long-term yield of the silver hake stocks. Because discards in the domestic silver hake fishery may be significant (Anderson 1975) an important consideration deals with estimating the selection pattern of the current fishery (total catches) and determining whether a directed fishery for smaller silver hake increases the selectivity towards younger ages. Simultaneously, we considered whether increased effort and, therefore, fishing mortality will likewise be directed into this emerging fishery.

The silver hake population in U.S. waters is presently assumed to comprise two major stocks (Figure AB1): 1) Gulf of Maine-Northern Georges Bank (Div. 5Y; 5Ze, SA 521-522, 561) and 2) Southern George Bank-Middle Atlantic (Div. 5Ze, SA 525-526, 562; Div. 5Zw, 6A-6C). These stock definitions represent a change from assessments prior to 1987 and are based on research bottom trawl surveys, U.S. and distant-water fleet commercial fishery statistics, and morphometric data collected during bottom trawl surveys in 1978-1979 (Almeida 1987). Other studies suggest similar distinctions between silver hake populations in the northern and southern regions of the northeast U.S. continental shelf, but have placed the dividing line further south (Conover *et al.* 1961; Konstantinov and Noskov 1969). Although the present definition is generally accepted, it is

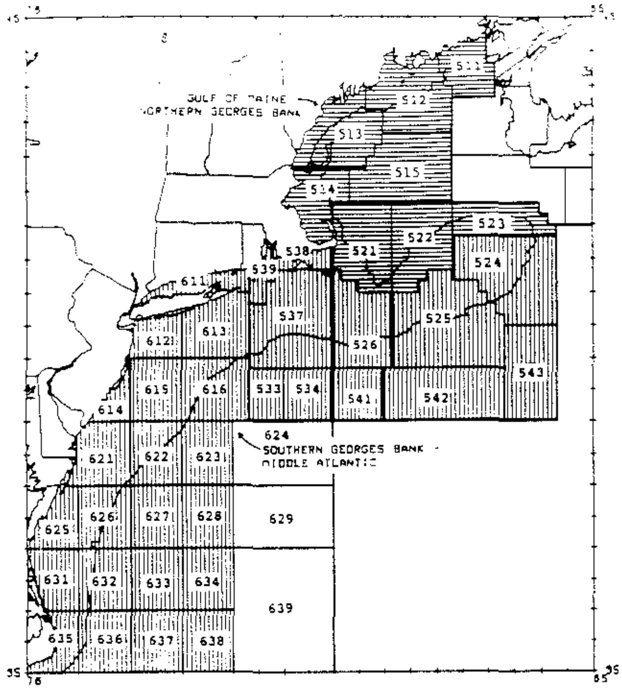

Figure AB1. Stock definition of the Gulf of Maine-Northern Georges Bank and the Southern Georges Bank-Middle Atlantic silver hake population in U.S. waters.

unlikely that these stocks are reproductively isolated nor is it known to what extent exchange between the two stocks occurs.

Juvenile and adult silver hake distributions from U.S. research vessel surveys during 1982-1992 (Figure AB2) suggest that silver hake may seasonally migrate across the presently assigned stock boundaries. Distributions vary seasonally by size/age and probably in response to hydrographic changes. During the spring, dense concentrations of juveniles are observed on northern Georges Bank and in the Gulf of Maine just east of Cape Ann, while during the autumn they are widely distributed over all of Georges Bank. Also during the spring, large concentrations of adults occur along the continental slope of the southeastern rim of Georges Bank. Distributions shift significantly by the autumn; the large concentrations of adults, formerly on southern Georges Bank, are absent and adults appear in significant numbers on northern Georges Bank and in the Gulf of Maine (Figure AB2). In addition, silver hake show a general northward movement from the southern and middle Atlantic into southern New England waters which occurs during the summer and autumn. Thus, it may be equally likely that silver hake migrate across Georges Bank.

The impact of the boundary used to separate the northern and southern silver hake stocks on the respective landings at age matrices is greatest in the area of the Cultivator Shoals fishery on Georges Bank. In this area of likely mixing between the northern and southern stocks, all of the catch is allocated to the northern stock under the present definition. Therefore, it may be important to investigate further the question of where to divide the stocks or whether the stocks can be assessed as one unit.

A. GULF OF MAINE-NORTHERN GEORGES BANK STOCK

The Fishery

Commercial Landings

Before 1955, silver hake in the Gulf of Maine and Georges Bank were only lightly exploited. Between 1955 and 1961, an "industrial fishery" developed in Southern New England and landings of silver hake increased, averaging 62,000 mt, most of which was taken from the Gulf of Maine-Northern Georges Bank Stock (Table A1). Exploitation intensified between 1961 and 1965 with the arrival of the DWF (principally the USSR), and total international landings increased to historic highs, reaching 94,500 mt (Figure A1). Total international landings from the Gulf of Maine-Northern Georges Bank stock subsequently declined to a time series low of 3,400 mt in 1979. Since the late 1970s, silver hake have been taken exclusively by U.S. vessels and landings have been fairly stable but at low levels compared to earlier years of the fishery, averaging 6,000 mt.

Total commercial landings in 1992 were 5,302 mt, 12% lower than reported in 1991 and 17% lower than 1990 (Table A1). Short-term trends in U.S. landings between 1980 and 1992 show a steady increase to 8,500 mt in 1986, but a decline in more recent years, approximately 37%, between 1986 and 1992.

Recreational Fishery

No estimates of the recreational catches are available for this stock, but these catches are considered to be insignificant.

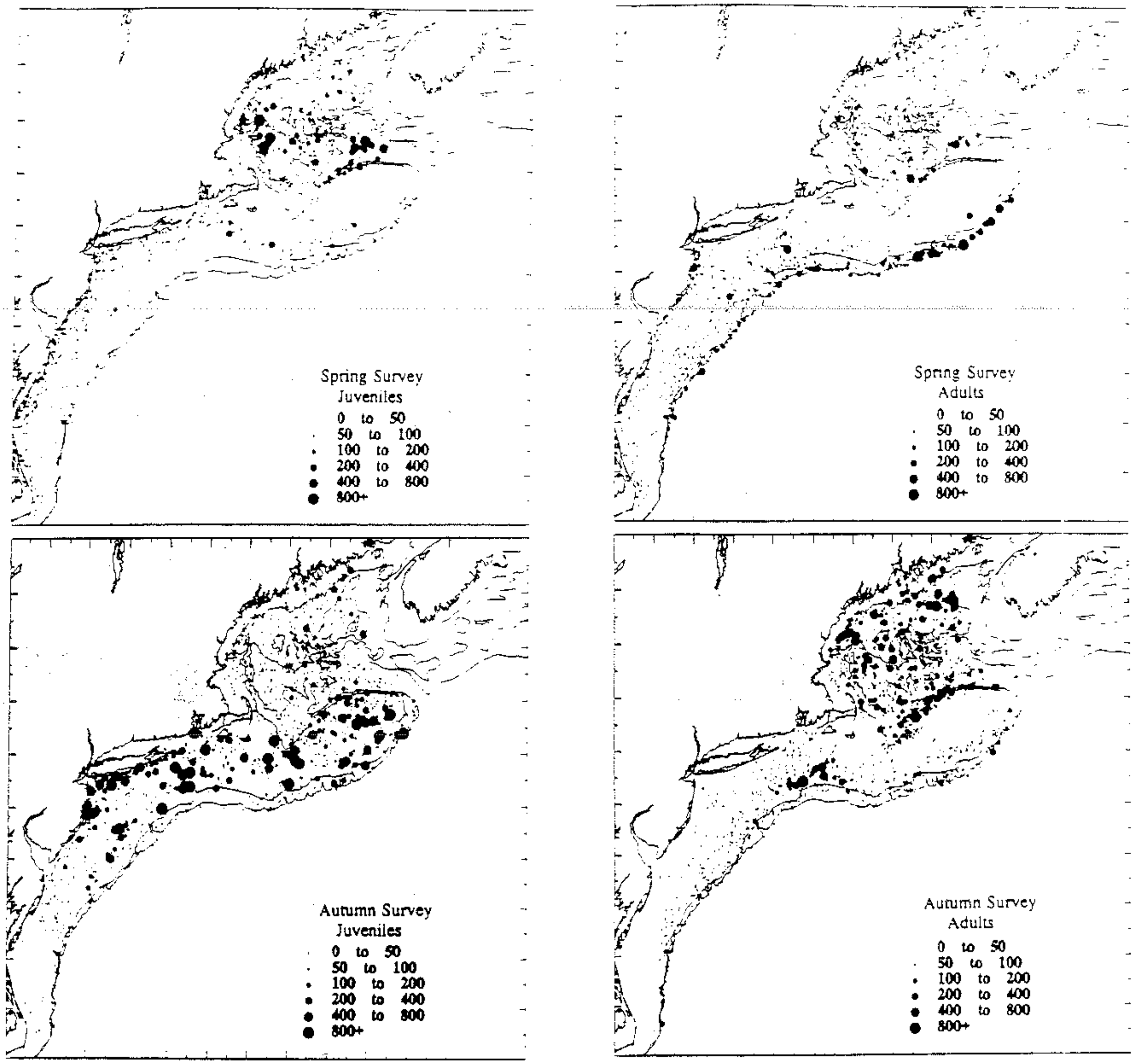

Figure AB2. Distribution of juvenile (<18 cm) and adult (>18 cm) silver hake in the NEFSC spring and autumn bottom trawl surveys during 1982-1992. Values shown are numbers of fish per tow.

Sampling Intensity

United States length-frequency sampling in the Gulf of Maine (SA 51) averaged one sample per 130 to 160 mt landed during 1985-1990 (Table A2), but prior to and after this period sampling has been at a much lower intensity (1982-1983: 1 sample per 800 to 960 mt; 1991 to 1992: 1 sample per 660 to 990 mt). Length-frequency sampling of commercial landings from northern Georges Bank (SA 52) averaged one sample per 160 to 350 mt during 1982-1989, but since 1990 sampling intensity has decreased substantially (1 sample per 500 mt in 1990-1991). In 1992, only two length-frequency samples were taken from 3,300 mt landed from northern Georges Bank.

Commercial Landings at Age

Strong shifts in the predominant age of commercial landings have occurred since 1955. During 1955-1971, commercial landings were dominated by age 3 and 4 silver hake (Table A3) with significant contributions from age 5, after which the age composition shifted to younger

Table A1. U.S. silver hake landings (mt) from the Gulf of Maine - Northern Georges Bank stock

Year	USSR	Other	US Comm.	Total[1]
1955	-	-	53,361	53,361
1956	-	-	42,150	42,150
1957	-	-	62,750	62,750
1958	-	-	49,903	49,903
1959	-	-	50,608	50,608
1960	-	-	45,543	45,543
1961	-	-	39,688	39,688
1962	36,575	-	42,427	79,002
1963	37,525	-	36,399	73,924
1964	57,240	-	37,222	94,462
1965	15,793	-	29,449	45,242
1966	14,239	-	33,477	47,716
1967	6,879	3	26,489	33,371
1968	10,434	72	30,873	41,379
1969	7,813	234	15,917	23,964
1970	12,279	26	15,223	27,528
1971	23,674	1,569	11,158	36,401
1972	16,469	2,315	6,440	25,224
1973	17,847	239	13,997	32,083
1974	13,476	299	6,905	20,680
1975	25,456	1,852	12,566	39,874
1976	65	86	13,483	13,634
1977	2	-	12,455	12,457
1978	-	-	12,609	12,609
1979	-	-	3,415	3,415
1980	-	-	4,730	4,730
1981	-	-	4,416	4,416
1982	-	-	4,656	4,656
1983	-	-	5,310	5,310
1984	-	-	8,289	8,289
1985	-	-	8,297	8,297
1986	-	-	8,502	8,502
1987	-	-	5,658	5,658
1988	-	-	6,767	6,767
1989	-	-	4,646	4,646
1990	-	-	6,379	6,379
1991	-	-	6,053	6,053
1992	-	-	5,302	5,302

[1] Includes Bulgaria, Canada, Cuba, Federal Republic of Germany, German Democratic Republic, Ireland, Japan, Poland, Romania

ages during 1972-1974, largely due to the DWF concentrating on the strong 1971 and 1972 year classes. Since 1979, the age composition has shifted toward ages 2 to 3, which have generally composed at least 64% of the total annually. Since 1955, the age composition of the commercial landings has become highly truncated, with a gradual decrease in the numbers of fish age 6 and greater during 1972-1986, and a complete disappearance since 1989.

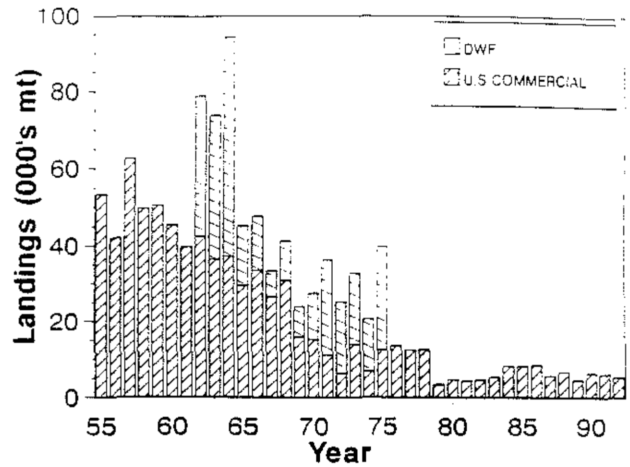

Figure A1. Total landings of silver hake from the Gulf of Maine-Northern Georges Bank stock, 1955-1992.

Commercial Mean Weights at Age

Mean weights at age in the commercial landings for ages 1 to 6+ during 1955-1992 are given in Table A4 and, based on landings patterns, are considered mid-year values. Only slight variations in mean weight at age are apparent among years during 1955-1992 and are related to variations in year class strengths as they become recruited to the fishery. No trends in mean weights during the 1955-1992 period are evident.

Stock Abundance and Biomass Indices

Commercial Landings Per Unit Effort

United States commercial landings per unit effort indices (LPUE, expressed in metric tons landed per day fished) were calculated by tonnage class from otter trawl trips in which silver hake constituted 50% or more of the total trip landings by weight. These values are considered "directed trips." They have been calculated for the Gulf of Maine (SA 51) and northern Georges Bank (SA 52) separately because the fisheries differ between these areas, and because of regulated Cultivator Shoals fishery on northern Georges Bank established in 1988.

Directed U.S. LPUE indices for the Gulf of Maine have generally exhibited an overall declining trend during the 1973-1992 period, but two

Table A2. United States sampling of commercial silver hake landings from the Gulf of Maine-Northern Georges Bank stock

Number of Samples (# Fish Measured)

	Statistical Area 51					Statistical Area 52				
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Σ**	**Q1**	**Q2**	**Q3**	**Q4**	**Σ**
1982	-	-	2(744)	2(365)	4	-	-	4(1015)	-	4
1983	1(90)	-	4(1352)	-	5	-	1(120)	2(418)	-	3
1984	-	3(433)	10(1232)	6(593)	19	-	-	5(523)	-	5
1985	2(289)	2(300)	14(2008)	10(1165)	28	-	-	1(107)	1(134)	2
1986	7(727)	4(458)	12(1259)	16(1780)	39	-	1(79	)6(629)	1(101)	7
1987	-	2(223)	6(687)	19(2292)	27	-	1(144)	7(731)	-	8
1988	2(199)	2(208)	11(1158)	11(1278)	27	-	1(101)	11(1091)	1(120)	13
1989	5(561)	2(208)	-	-	7	-	1(100)	10(1034)	2(212)	13
1990	4(466)	-	3(330)	4(410)	11	-	-	6(627)	-	6
1991	-	1(103)	1(173)	1(235)	3	-	-	7(824)	1(129)	8
1992	-	-	1(73)	1(85)	2	-	1(105)	1(104)	-	2

Annual Sampling Intensity[1]
(No. Tons Landed/Sample)

	Statistical Area 51					Statistical Area 52				
Year	**Q1**	**Q2**	**Q3**	**Q4**	**Σ**	**Q1**	**Q2**	**Q3**	**Q4**	**Σ**
1982	(156)	(202)	660	790	814	(3)	(15)	309	(154)	352
1983	176	(530)	534	(1,961)	960	(10)	11	225	(49)	173
1984	(167)	75	305	649	386	(5)	(5)	166	(112)	191
1985	270	283	246	305	272	(11)	(17)	298	361	344
1986	103	130	240	191	184	(213)	93	121	289	189
1987	(247)	242	195	129	161	(77)	27	127	(309)	162
1988	221	270	98	142	134	(136)	97	223	481	243
1989	35	115	(543)	(768)	245	(54)	135	237	184	225
1990	37	(128)	209	497	263	(23)	(15)	529	(267)	580
1991	(127)	98	546	1228	666	(52)	(130)	504	344	507
1992	(98)	(30)	695	1155	989	(68)	51	2687	(518)	1,662

[1] Values in parenthesis for annual samplin gintensity indicate no samples taken for landings given.

distinct peaks occurred; one in 1976-77 and another in 1984-85. The LPUE indices on northern Georges Bank exhibit a slightly more varied trend, and values from tonnage class 3 (which have dominated directed landings) declined slightly between 1973 and 1987. Since 1988, however, LPUE has increased substantially with rates approaching values not observed before in the time series (60.1 mt/day fished in 1991). This is particularly notable in the ton class 4 fleet and suggests a significant change in the fishing power of those vessels, which have participated in the regulated small-mesh Cultivator Shoals fishery since 1988.

To account for changes in the fishing power of the ton class 4 fleet on northern Georges Bank, the relative fishing power between the various tonnage classes were standardized by applying a three-factor (year, tonnage class, and area) GLM to log LPUE data for all directed otter trawl trips.

Standardized LPUE indices appear to show relatively consistent trends between the different ton classes and within the different regions (Figure A2). The overall trend between the different regions (average of all ton classes weighted by landings) shows relatively consistent peaks in the standardized LPUE values, although the magnitude was greater on northern Georges Bank (Figure A2). The standardized mean (weighted by landings) indices for the entire Gulf of Maine-Northern Georges Bank stock show distinct peaks in LPUE during 1975-1977 and during 1983-

Table A3. Landings (millions of fish) at age of silver hake from the Gulf of Maine-Northern Georges Bank Stock, 1955-1992

Year	Age						Total
	1	2	3	4	5	6+	
1955	17.0	19.9	50.2	69.2	30.4	25.0	211.7
1956	16.2	12.7	36.5	61.2	26.4	17.1	170.1
1957	52.8	19.5	58.8	84.8	41.6	29.0	286.5
1958	20.9	20.2	40.1	57.6	28.4	26.9	194.1
1959	10.1	30.0	58.2	54.2	26.8	23.3	202.6
1960	4.4	37.7	76.2	53.2	20.8	16.7	209.0
1961	1.1	23.2	59.7	51.5	18.9	14.8	169.2
1962	2.6	33.5	127.2	122.8	47.4	21.6	355.1
1963	14.9	48.3	136.9	103.0	29.2	18.7	351.0
1964	1.4	46.6	133.1	123.4	50.2	40.0	394.7
1965	4.0	23.9	84.2	54.0	18.3	14.8	199.2
1966	5.3	20.3	82.6	70.9	19.8	12.8	211.7
1967	0.7	5.3	32.5	54.9	20.3	9.3	123.0
1968	1.3	4.0	25.8	49.5	36.5	21.5	138.6
1969	3.1	10.6	16.8	21.3	16.2	17.0	85.0
1970	24.8	16.0	32.4	34.1	13.4	14.4	135.1
1971	4.0	24.3	73.8	49.8	19.8	12.7	184.4
1972	78.2	44.5	18.2	4.2	2.2	1.3	148.6
1973	33.4	91.5	24.2	4.5	1.8	0.8	156.2
1974	21.6	31.7	22.4	9.2	2.7	1.8	89.4
1975	8.7	60.1	63.4	20.3	7.9	3.4	163.8
1976	1.7	19.2	24.6	8.7	2.9	1.5	58.6
1977	1.8	8.7	22.6	14.9	3.0	0.7	51.7
1978	2.7	8.3	7.1	10.8	13.5	3.2	45.6
1979	0.7	3.5	2.3	1.4	1.8	2.7	12.4
1980	1.1	11.8	12.1	2.0	0.5	1.5	29.0
1981	4.9	8.4	7.4	4.0	0.6	0.6	25.9
1982	5.9	9.8	2.9	3.0	2.2	0.5	24.3
1983	2.6	14.1	4.0	1.8	1.7	1.0	25.2
1984	3.0	21.5	9.8	3.0	1.0	0.7	39.0
1985	10.4	6.8	13.9	3.9	0.4	0.8	36.2
1986	3.1	14.0	8.1	3.8	1.1	0.8	30.9
1987	0.5	13.2	11.1	1.6	0.9	0.1	27.4
1988	0.7	4.7	20.0	4.5	1.3	0.2	31.4
1989	4.2	7.0	11.3	2.6	0.2	0.0	25.5
1990	3.2	18.6	7.5	5.0	0.9	0.1	35.4
1991	1.7	17.4	9.9	2.6	0.2	0.0	31.8
1992	1.0	12.8	10.4	1.7	0.1	0.0	25.9

1985. Most recently, standardized mean LPUE has steadily increased since 1987, but declined in 1992.

Research Vessel Survey Indices

Spring and autumn survey indices were calculated using Delta distribution estimators for offshore strata only and spring 1973-1981 indices were adjusted to the #36 Yankee trawl as the standard gear. Stratified mean catch-per-tow in number and weight from U.S. spring and autumn bottom trawl surveys are given in Table A5 and estimates of number-per-tow at age since 1973 in Table A6.

The autumn offshore number per tow index (0+) declined in the mid- and late 1960s during the period of heavy exploitation by the DWF (Figure A3). Between 1969 and 1975, number per tow increased in both the spring and autumn surveys due to above average recruitment in the mid 1970s, but subsequently declined during the late 1970s. These trends in population abundance from the NEFSC surveys were largely consistent with standardized commercial LPUE indices (Figure A2). Number per tow in the spring survey varied without trend during the early- to

Table A4. Mean weight (kilograms) at age of total commercial landings of silver hake from the Gulf of Maine-Northern Georges Bank Stock, 1955-1992

Year	Age						Total
	1	2	3	4	5	6+	
1955	0.046	0.132	0.200	0.258	0.331	0.481	0.252
1956	0.055	0.128	0.204	0.260	0.326	0.462	0.249
1957	0.064	0.120	0.193	0.260	0.322	0.425	0.226
1958	0.045	0.127	0.210	0.282	0.341	0.449	0.257
1959	0.051	0.129	0.190	0.269	0.348	0.485	0.250
1960	0.064	0.129	0.171	0.233	0.320	0.495	0.218
1961	0.065	0.146	0.186	0.239	0.303	0.483	0.235
1962	0.069	0.135	0.172	0.229	0.303	0.460	0.222
1963	0.080	0.121	0.176	0.229	0.308	0.555	0.211
1964	0.075	0.123	0.171	0.228	0.316	0.548	0.239
1965	0.059	0.147	0.175	0.233	0.320	0.560	0.227
1966	0.065	0.144	0.183	0.229	0.298	0.566	0.226
1967	0.072	0.155	0.218	0.266	0.317	0.478	0.272
1968	0.070	0.161	0.222	0.278	0.323	0.439	0.299
1969	0.064	0.154	0.201	0.291	0.325	0.439	0.284
1970	0.060	0.118	0.178	0.232	0.304	0.442	0.203
1971	0.077	0.122	0.165	0.211	0.262	0.413	0.197
1972	0.089	0.195	0.310	0.437	0.494	0.695	0.169
1973	0.119	0.173	0.262	0.414	0.472	0.806	0.189
1974	0.144	0.217	0.270	0.314	0.563	0.617	0.241
1975	0.102	0.167	0.238	0.361	0.484	0.721	0.242
1976	0.102	0.162	0.237	0.295	0.422	0.668	0.237
1977	0.120	0.172	0.221	0.277	0.403	0.588	0.241
1978	0.114	0.196	0.232	0.277	0.329	0.509	0.277
1979	0.104	0.139	0.201	0.258	0.351	0.373	0.244
1980	0.094	0.134	0.164	0.206	0.283	0.453	0.169
1981	0.115	0.147	0.188	0.215	0.238	0.460	0.173
1982	0.117	0.159	0.197	0.271	0.289	0.525	0.186
1983	0.129	0.175	0.249	0.311	0.310	0.453	0.212
1984	0.126	0.176	0.242	0.368	0.404	0.334	0.212
1985	0.142	0.200	0.256	0.325	0.412	0.606	0.230
1986	0.145	0.214	0.270	0.376	0.538	0.549	0.262
1987	0.092	0.149	0.251	0.321	0.578	0.568	0.215
1988	0.101	0.139	0.181	0.368	0.526	0.779	0.218
1989	0.096	0.162	0.203	0.258	0.378	0.786	0.180
1990	0.108	0.150	0.218	0.244	0.361	0.428	0.180
1991	0.094	0.156	0.225	0.317	0.420	0.464	0.212
1992	0.088	0.154	0.243	0.385	0.418	0.559	0.204

mid-1980s, but increased since 1987, although estimates have been highly variable. The spring index for 1992 is the highest on record, at 196.4 fish per tow. The autumn survey index in 1992 is also the largest on record and is strongly influenced by the 1989, 1990, and 1991 year classes.

Mortality

Natural Mortality

Instantaneous natural mortality (M) for the Gulf of Maine-Northern Georges Bank stock is assumed to be 0.40. Substantial changes in the age composition of the stock (*i.e.* substantial numbers of age 8 and 9+ during the earlier history of the fishery) may suggest that M has also changed. Although an adult M of 0.40 is high compared to other gadids, given the extensive cannibalism in this stock it is possible M could be even higher and that the natural mortality rates varies significantly with age.

Total Mortality

Pooled estimates of instantaneous total mortality (Z) were calculated for four time periods

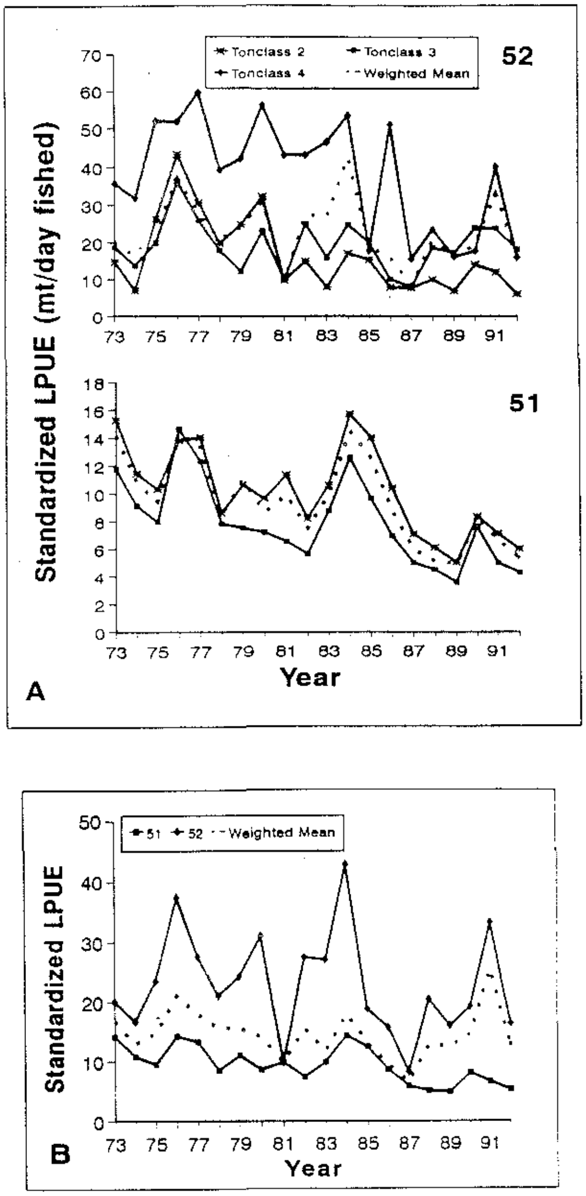

Figure A2. Landings per unit effort (LPUE) standardized for differences in vessel tonnage class fishing power for the Gulf of Maine-Northern Georges Bank silver hake stock. Calculated standardized LPUE indices compared by a) two-digit statistical area (51 and 52) and vessel tonnage class; and b) by statistical area weighted by tonnage class landings.

encompassed by the NEFSC autumn and spring offshore bottom trawl surveys: 1974-1977, 1979-1982, 1984-1987, and 1989-1992 (Table A7). Total mortality was calculated from survey catch-per-tow in numbers at age for fully recruited age groups (age 2+) by the $\log_e$ ratio of the pooled age 2+/age 3+ indices in the autumn surveys, and the pooled age 3+/age 4+ indices in the spring surveys.

Table A5. Stratified mean number-per-tow (delta estimate) and weight-per-tow (kg) for silver hake from the Gulf of Maine-Northern Georges Bank stock (strata 20-36, 36-40) from NEFSC autumn and spring bottom trawl surveys

Year	Spring		Autumn	
	No./Tow	Wt./Tow	No./Tow	Wt./Tow
1963	-	-	232.92	25.42
1964	-	-	25.19	4.44
1965	-	-	32.26	6.50
1966	-	-	17.79	4.12
1967	-	-	9.42	2.16
1968	0.52	0.04	7.50	2.05
1969	6.37	0.19	15.29	2.63
1970	38.70	14.13	16.74	3.03
1971	5.71	0.41	30.41	2.47
1972	43.31	1.70	51.59	6.09
1973[1]	16.34	2.01	25.80	4.15
1974[1]	40.65	1.73	27.21	3.76
1975[1]	123.00	6.26	79.37	8.23
1976[1]	49.28	5.69	56.34	12.63
1977[1]	16.63	2.38	34.62	7.59
1978[1]	5.64	0.52	46.01	7.07
1979[1]	18.55	1.04	52.96	6.65
1980[1]	26.92	2.67	39.63	6.66
1981[1]	20.73	1.49	23.99	4.06
1982	20.23	1.35	41.55	5.45
1983	20.87	1.51	77.08	9.20
1984	10.39	1.09	24.84	3.62
1985	47.39	2.64	92.70	8.58
1986	95.42	3.25	122.94	14.19
1987	42.14	3.80	60.60	9.84
1988	8.39	1.26	69.75	6.32
1989	120.79	3.57	105.71	12.55
1990	27.62	1.29	112.39	15.25
1991	53.59	1.38	104.59	11.89
1992	196.38	5.66	129.51	14.25
1993	68.58	2.50	N/A[2]	N/A[2]

[1] Adjusted from #41 trawl catches to equivalent #36 trawl catches using a .334:1 ratio.
[2] Estimates from autumn bottom trawl survey not available.

Pooled estimates indicated that total mortality has been relatively stable since 1973, ranging from 0.8 to 1.0.

Estimates of Stock Size and Fishing Mortality

Virtual Population Analysis Calibration

The ADAPT framework (Parrack 1986; Gavaris 1988; Conser and Powers 1990) was used in an attempt to calibrate VPA stock sizes and derive estimates of terminal F values in 1992. Several

Table A6. Stratified mean number-per-tow (delta estimate) at age for silver hake from the Gulf of Maine-Northern Georges Bank Stock (strata 20-36, 36-40) from NEFC autumn and spring bottom trawl surveys

Year	Age										
	0	1	2	3	4	5	6+	0+	1+	2+	3+
					Spring Survey						
1973[1]	-	4.64	10.46	1.05	0.13	0.05	0.01	16.34	16.34	11.70	1.24
1974[1]	-	34.59	3.62	1.73	0.39	0.11	0.13	40.65	40.65	6.06	2.36
1975[1]	-	56.51	57.52	7.29	1.23	0.40	0.05	123.00	123.00	66.49	8.97
1976[1]	-	10.53	23.58	12.78	1.48	0.51	0.34	49.28	49.28	38.75	15.11
1977[1]	-	5.00	4.88	4.25	1.71	0.34	0.29	16.63	16.63	11.63	6.59
1978[1]	-	3.57	1.55	0.29	0.16	0.04	0.02	5.64	5.64	2.07	0.51
1979[1]	-	7.06	10.80	0.37	0.07	0.05	0.12	18.55	18.55	11.49	0.61
1980[1]	-	3.67	16.65	5.71	0.40	0.11	0.24	26.92	26.92	23.25	6.46
1981[1]	-	9.92	5.70	3.69	1.17	0.17	0.07	20.73	20.73	10.81	5.11
1982	-	11.32	5.77	1.64	0.77	0.54	0.14	20.23	20.23	8.91	3.09
1983	-	10.85	8.40	0.89	0.28	0.30	0.13	20.87	20.87	10.02	1.62
1984	-	3.80	5.28	0.98	0.11	0.08	0.11	10.39	10.39	6.59	1.28
1985	-	39.49	4.13	2.36	0.92	0.20	0.18	47.39	47.39	7.90	3.66
1986	-	87.10	5.81	1.74	0.57	0.14	0.06	95.42	95.42	8.32	2.51
1987	-	3.12	34.85	3.37	0.47	0.25	0.04	42.14	42.14	39.02	4.13
1988	-	0.93	1.76	4.92	0.61	0.12	0.05	8.39	8.39	7.46	5.70
1989	-	114.98	3.39	0.73	1.57	0.12	0.00	120.79	120.79	5.81	2.42
1990	-	15.37	10.06	1.64	0.33	0.19	0.03	27.62	27.62	12.25	2.19
1991	-	45.97	5.53	1.45	0.59	0.05	0.00	53.59	53.59	7.62	2.09
1992	-	137.14	49.83	7.06	2.16	0.19	0.00	196.38	196.38	59.24	9.41
1993	-	-	-	-	-	-	-	68.58	-	-	-
					Autumn Survey						
1973	5.87	7.20	8.51	3.24	0.48	0.32	0.18	25.80	19.93	12.73	4.22
1974	18.30	3.56	2.97	1.80	0.25	0.22	0.11	27.21	8.91	5.35	2.38
1975	18.36	17.41	32.09	7.61	2.39	0.87	0.64	79.37	61.01	43.60	11.51
1976	6.48	3.26	14.61	20.36	8.60	1.40	1.63	56.34	49.86	46.60	31.99
1977	2.66	3.03	6.05	13.05	8.21	1.34	0.28	34.62	31.96	28.93	22.88
1978	19.65	5.22	4.77	3.39	4.92	6.46	1.60	46.01	26.36	21.14	16.37
1979	1.16	28.44	17.35	2.06	0.96	1.19	1.80	52.96	51.80	23.36	6.01
1980	5.47	3.56	12.11	11.89	2.73	1.02	0.85	39.63	34.16	30.60	18.29
1981	1.33	7.66	4.07	5.19	3.95	0.75	1.04	23.99	22.66	15.00	10.93
1982	9.59	14.46	8.63	3.18	2.67	2.57	0.45	41.55	31.96	17.50	8.87
1983	1.45	43.04	29.76	1.22	0.59	0.63	0.39	77.08	75.63	32.59	2.83
1984	8.42	6.02	7.38	2.23	0.50	0.18	0.11	24.84	16.42	10.40	3.02
1985	37.59	43.00	3.97	6.61	1.41	0.09	0.03	92.70	55.11	12.11	8.14
1986	14.52	87.78	6.34	11.58	2.45	0.20	0.07	122.94	108.42	20.64	14.30
1987	1.88	3.30	43.32	10.15	1.03	0.85	0.07	60.60	58.72	55.42	12.10
1988	39.59	4.06	6.30	18.26	1.40	0.14	0.00	69.75	30.16	26.10	19.80
1989	16.47	59.03	13.83	14.78	1.48	0.11	0.01	105.71	89.24	30.21	16.38
1990	16.86	21.02	53.95	13.71	6.18	0.67	0.00	112.39	95.53	74.51	20.56
1991	24.05	37.55	30.23	10.67	1.99	0.10	0.00	104.59	80.54	42.99	12.76
1992	18.65	46.62	49.47	14.25	0.52	0.00	0.00	129.51	110.86	64.24	14.77

[1] Adjusted from #41 trawl catches to equivalent #36 trawl catches using a .334:1 ratio.

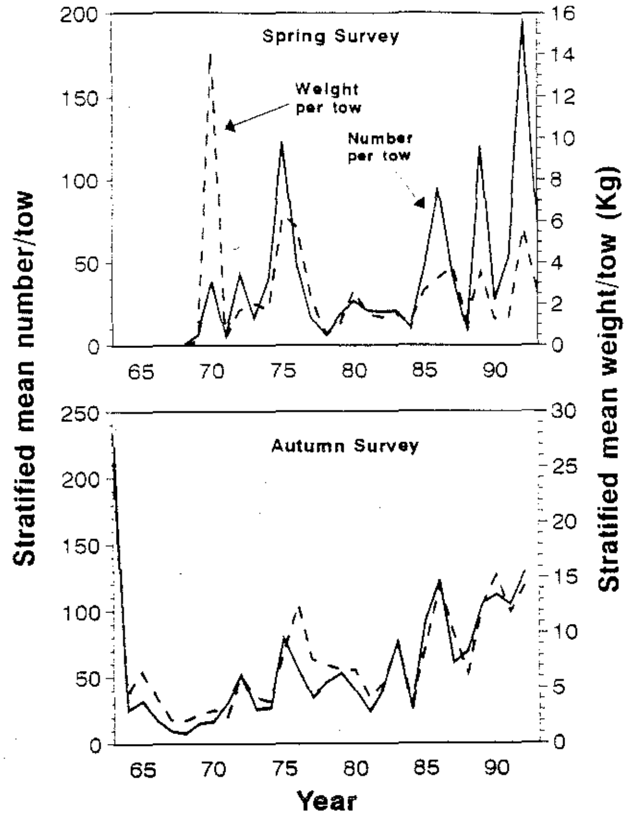

Figure A3. Stratified mean number and weight (kg) per tow of Gulf of Maine-Northern Georges Bank silver hake from the NEFSC spring and autumn bottom trawl surveys.

ADAPT runs were made using the same formulation but with different combinations of spring and fall indices. Two causes for concern from these analyses were: 1) the indices' q's for the autumn and the spring showed inconsistent patterns, with q's increasing at age in the autumn and q's decreasing at age in the spring, and 2) the autumn survey indices (ages 2 to 5+) showed strong residual patterns that were negative in the earlier years (1973-1975) and positive in more recent years.

These ADAPT results indicated that the estimated F's in 1992 were largely invariant to the different sets of tuning indices, ranging from F=0.10 to 0.14. Regardless of which ADAPT results are chosen, F on the fully recruited ages was estimated to decrease by an order of magnitude since 1988 (from F=1.6 to 0.14). Since landings have declined only slightly since 1988 and there is no real indication that effort has declined, it seems improbable that F could have declined as drastically as indicated by these results.

The reasons for the extremely low values of F in 1992 are not completely clear. However, a number of possible explanations include: 1) recent increasing trends in survey population abundance in combination with the temporal trends in the residuals from the ADAPT results, may have inflated stock sizes (as seen as high positive residuals in recent years from the ADAPT results) and therefore artificially lower F's; 2) uncertainty in the landings-at-age matrix from the use of survey age-length keys to age the commercial

Table A7. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for the Gulf of Maine-Northern Georges Bank silver hake stock derived from NEFSC offshore spring and autumn bottom trawl survey data[2]

Gulf of Maine - Northern Georges Bank

Time Period	**Spring**		**Autumn**		**Geometric Mean**	
	Z	**F**	**Z**	**F**	**Z**	**F**
1974 - 1977	1.64	1.24	0.46	0.06	0.87	0.47
1979 - 1982	1.30	0.90	0.75	0.35	0.98	0.58
1984 - 1987	1.19	0.79	0.70	0.30	0.91	0.51
1989 - 1992	0.64[3]	0.24[3]	0.99	0.59	0.80[3]	0.40[3]

[1]Instantaneous natural mortality (m) assumed to be 0.40.
[2]Estimates derived from: Autumn, ln (Σ age 2+ for year i-1 to j-1/Σ age 3+ for year i to j.
Spring, ln (Σ age 3+ for year i to j/Σ age 4+ for year i+1 to j+1.
[3] Provisional estimate; does not include spring 1993 survey abundance estimates.

Table B1. United States silver hake landings (mt) from the Southern Georges Bank-Middle Atlantic Stock

Year	USSR	Other[1]	US Comm.	U.S. Recreational[2]	Total
1955	-	-	12,489	1,353	15,717
1956	-	-	13,417	1,454	16,564
1957	-	-	15,476	1,677	17,153
1958	-	-	12,156	1,317	13,473
1959	-	-	15,439	1,673	17,112
1960	-	-	8,306	900	9,206
1961	-	-	11,918	1,291	13,209
1962	5,325	-	12,097	1,311	18,733
1963	74,023	-	18,252	1,107	93,382
1964	127,036	-	25,000	1,518	153,584
1965	283,366	-	22,406	1,359	307,131
1966	200,058	-	10,571	641	211,270
1967	81,711	38	8,957	543	91,249
1968	48,392	1,030	8,447	627	58,496
1969	66,151	1,245	7,601	564	75,561
1970	19,762	871	6,404	475	27,512
1971	64,902	1,442	5,163	383	71,890
1972	85,416	2,965	5,561	412	94,396
1973	95,606	2,383	6,146	458	104,593
1974	99,215	2,897	7,213	538	109,863
1975	63,425	2,387	8,342	99	74,253
1976	53,707	4,600	9,581	853	68,741
1977	46,305	1,545	9,484	1,974	59,308
1978	13,390	963	11,410	1,369	27,132
1979	3,075	1,802	13,087	411	18,375
1980	-	1,698	11,731	117	13,546
1981	-	3,043	11,718	65	14,826
1982	-	2,397	11,908	256	14,561
1983	-	620	11,520	+[4]	12,140
1984	-	412	12,731	+	13,143
1985	-	1,321	11,820	23	13,164
1986	-	550	9,479	94	10,123
1987	-	2	10,053	68	10,121
1988	-	-	9,187	8	9,194
1989	-	-	13,169	-	13,169
1990	-	-	13,615	-	13,615
1991	-	-	10,093	-	10,093
1992	-	-	10,288	-	10,288

[1] Includes Bulgaria, Cuba, German Democratic Republic, Italy, Japan, Mexico, Poland, Romania, Spain

[2] Recreational catch estimates taken from Almeida (1987)

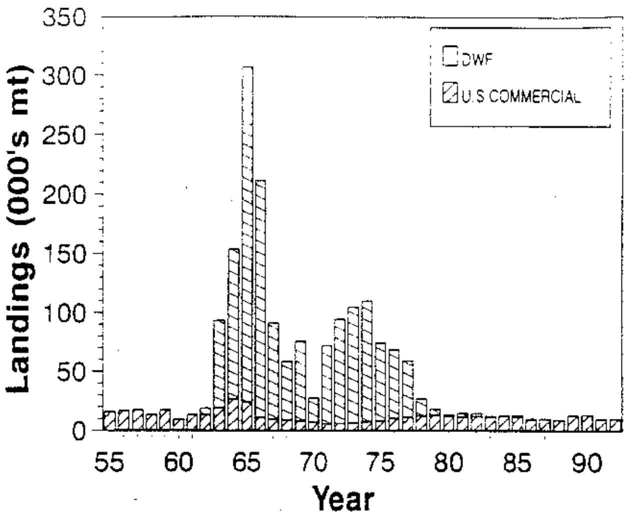

Figure B1. Total landings of silver hake from the Southern Georges Bank-Middle Atlantic stock, 1955-1992.

landings and poor sampling of commercial landings, particularly in recent years which required the use of sea samples; and 3) mixing of the Gulf of Maine-Northern Georges Bank and the Southern Georges Bank-Middle Atlantic stocks and its effect on the survey indices that are used to tune the VPA.

B. SOUTHERN GEORGES BANK-MIDDLE ATLANTIC

The Fishery

Commercial Landings

Landings from the Southern Georges Bank-Middle Atlantic silver hake stock were taken exclusively by U.S. vessels before 1960. Exploitation intensified between 1961 and 1965 with the arrival of the DWF (principally the USSR) and total international landings increased to 307,000 mt (Figure B1), the historic high. Total international landings from the Southern Georges Bank-Middle Atlantic stock dropped markedly between 1965 and 1969, increased again during the early 1970s, and subsequently declined. While foreign fleets fishing for silver hake in U.S. waters were either greatly reduced or eliminated altogether by the late-1970s, U.S. landings have not increased and remain at lows levels compared to earlier years of the fishery.

Total commercial landings from this stock in 1992 were 10,300 mt, a slight increase over 1991 and approximately 24% lower than the 13,600 mt reported for 1990 (Table B1). In 1990 the U.S. commercial fisheries had the largest landings since 1966, and international landinds were the largest since 1982. Since 1980, the U.S. commercial fishery has accounted for at least 80% of the total, which has remained without trend, averaging 12,000 mt (Figure B1).

Recreational Catches

Recreational catches of silver hake have been reported for this stock but have been generally a minor component of the total, averaging 777 mt per year and ranging from 0 to 1,974 mt (Table B1). Details of recreational catch estimates can be found in Almeida (1987).

Sampling Intensity

Length frequencies taken from Division 62 were generally oversampled (averaging 1 sample per 21 to 170 mt), particularly since commercial landings from this area are low (Table B2). In division 61, length frequency sampling was adequate during 1982-1992, averaging one sample per 100 to 280 mt. Sampling in division 53 averaged one sample per 150 to 290 mt during 1984-1991, but decreased prior to 1984 and in 1992 (1982-1984: 1 sample per 450 to 660 mt; 1992: 1 sample per 500 mt). Sampling has been generally poor in division 52, particularly since 1988, averaging one sample per 350 to 730 mt. Length frequency samples from sea sampling trips during 1989-1992 were also available and used to augment port sample length frequencies.

Sampling recommendations as discussed for the Gulf of Maine-Northern Georges Bank stock should be applied.

Commercial Landings at Age

Similar shifts in the predominant ages composing the commercial landings have been observed for this stock since 1955 (Table B3). The commercial landings in the 1950s and 1960s were predominantly composed of age 2 to 4 fish (averaging about 86% of the total each year). During 1972-1974 the age composition shifted to

Table B2. United States sampling of commercial silver hake landings from the Southern Georges Bank - Middle Atlantic stock

Number of Samples (# Fish Measured)

Year	Statistical Area 52 Q1	Q2	Q3	Q4	Σ	Statistical Area 53 Q1	Q2	Q3	Q4	Σ
1982	-	1(49)	-	-	1	2(587)	3(1002)	2(358)	2(590)	9
1983	-	1(105)	1(99)	-	2	2(491)	3(876)	3(772)	4(551)	12
1984	-	2(156)	-	-	2	3(267)	3(304)	5(468)	7(680)	18
1985	-	-	-	-	0	4(359)	9(887)	10(1002)	7(712)	30
1986	-	-	3(319)	-	3	3(300)	8(797)	13(1421)	10(936)	34
1987	-	2(201)	1(110)	-	3	6(588)	7(682)	11(1130)	13(1181)	37
1988	-	2(200)	3(303)	-	5	3(287)	7(671)	3(291)	9(922)	2
1989	-	2(194)	4(402)	-	6	2(204)	7(699)	4(399)	3(299)	16
1990	-	2(199)	-	-	2	6(603)	9(911)	6(608)	6(639)	27
1991	1(100)	2(199)	-	-	3	3(299)	4(496)	8(900)	4(401)	19
1992	-	3(332)	1(100)	-	4	3(375)	-	3(320)	-	6

Year	61 Q1	Q2	Q3	Q4	Σ	62 Q1	Q2	Q3	Q4	Σ
1982	4(1157)	5(726)	1(89)	8(1749)	18	-	1(89)	-	-	1
1983	8(2312)	5(658)	-	5(1081)	18	2(342)	1(105)	-	-	3
1984	19(1974)	3(325)	-	6(574)	28	5(574)	-	-	3(302)	8
1985	25(2818)	11(1111)	-	4(414)	40	1(119)	1(98)	1(89)	1(104)	4
1986	19(1965)	5(496)	4(417)	5(493)	33	2(208)	-	-	-	2
1987	21(2402)	9(900)	-	2(200)	13	2(196)	2(202)-	-	4	
1988	24(2582)	8(802)	6(600)	8(806)	46	1(117)	2(206)	-	-	3
1989	17(1706)	8(902)	6(601)	10(997)	41	2(105)	-	-	-	2
1990	19(1927)	14(1394)	10(1016)	13(1306)	56	3(314)	-	-	-	3
1991	14(1406)	6(599)	3(302)	10(991)	33	-	-	-	-	0
1992	9(890)	10(1006)	1(202)	-	20	1(102)	-	-	-	1

Annual Sampling Intensity[1] (No. Tons Landed/Sample)

Year	52 Q1	Q2	Q3	Q4	Σ	53 Q1	Q2	Q3	Q4	Σ
1982	(8)	126	245	-	395	337	783	780	707	668
1983	(9)	61	381	(3)	316	306	455	940	733	444
1984	(1)	22	(392)	(24)	230	193	630	289	205	297
1985	(5)	(143)	(212)	(6)	(366)	84	223	142	163	164
1986	(20)	(121)	31	(10)	82	243	251	105	120	156
1987	(6)	239	565	(10)	378	184	206	134	72	134
1988	(45)	202	88	(2)	144	293	236	19	357	146
1989	(254)	251	129	(5)	355	172	151	280	508	254
1990	(9)	428	(215)	(20)	550	213	159	244	214	199
1991	529	494	(42)	(1)	520	226	316	127	188	169
1992	(1)	760	645	(1)	732	327	(778)	255	(689)	536

Year	61 Q1	Q2	Q3	Q4	Σ	62 Q1	Q2	Q3	Q4	Σ
1982	471	212	29	115	198	(132)	(37)	-	(1)	170
1983	452	180	(6)	(435)	175	33	126	-	(3)	65
1984	138	457	(117)	40	155	30	(78)	(117)	2	30
1985	114	135	(6)	17	110	39	41	1	2	22
1986	73	381	19	90	116	12	(18)	-	-	21
1987	884	158	(49)	211	281	36	41	-	(4)	39
1988	110	189	36	92	111	104	12	-	(1)	43
1989	175	280	40	140	167	35	(41)	-	(15)	75
1990	148	158	60	84	120	95	(56)	-	(28)	51
1991	128	331	40	83	125	(43)	(23)	-	(2)	68
1992	184	129	170	(972)	205	14	(10)	-	(2)	26

[1] Values in parenthesis for annual sampling intensity indicate that no samples were taken for given landings.

Table B3. Commercial landings (millions of fish) at age of silver hake from the Southern Georges Bank-Middle Atlantic Stock, 1955-1992

Year	Age						Total
	1	2	3	4	5	6+	
1955	17.4	9.6	20.0	21.7	8.7	3.0	0.4
1956	61.9	46.6	20.4	15.2	5.4	2.3	151.8
1957	2.4	22.2	31.3	22.6	9.6	4.0	92.1
1958	20.6	27.8	24.8	15.5	5.4	2.3	96.4
1959	11.8	11.4	36.6	24.7	8.7	2.9	96.1
1960	12.0	17.0	12.7	10.6	4.9	3.0	60.2
1961	0.4	6.2	26.2	21.5	5.5	3.0	62.8
1962	0.5	6.6	31.7	34.6	10.1	4.3	87.8
1963	6.5	33.8	171.7	196.2	53.5	12.4	474.1
1964	18.4	65.3	286.8	271.5	85.1	35.5	762.6
1965	46.9	203.7	901.7	553.0	75.1	26.6	1807.0
1966	18.7	359.8	507.6	289.7	77.8	42.2	1295.8
1967	15.7	121.5	216.3	154.9	30.8	12.1	551.3
1968	9.7	24.5	143.4	90.8	29.0	17.7	315.1
1969	1.8	20.0	111.0	100.6	40.7	28.5	302.6
1970	41.8	25.1	17.3	32.6	23.1	15.6	155.5
1971	8.0	41.3	92.3	79.0	44.4	50.1	315.1
1972	134.0	174.1	111.9	33.0	5.0	2.8	460.8
1973	72.8	325.0	112.9	29.3	4.9	1.7	546.6
1974	73.7	223.3	141.2	74.1	17.2	11.7	541.2
1975	5.5	106.6	149.3	51.0	19.8	4.0	336.2
1976	7.6	86.6	142.8	95.2	10.4	1.5	344.1
1977	2.6	34.0	132.6	68.8	11.2	5.6	254.8
1978	2.2	26.7	20.4	28.0	12.5	3.3	93.1
1979	8.1	22.0	17.3	8.0	10.4	8.1	73.9
1980	3.6	17.4	19.4	9.5	4.4	6.1	60.4
1981	17.6	24.0	28.4	16.1	5.0	3.5	94.6
1982	12.4	32.0	12.2	9.3	8.1	4.2	78.2
1983	8.4	23.0	16.7	6.0	4.3	3.5	61.9
1984	7.2	45.5	23.0	5.7	0.9	0.8	83.1
1985	7.6	26.1	23.1	7.6	1.5	0.4	66.3
1986	11.3	28.2	18.3	5.3	1.0	0.3	64.4
1987	5.6	25.1	17.8	5.9	4.5	0.2	59.1
1988	3.4	23.5	20.1	5.8	0.5	0.0	53.3
1989	1.8	25.0	37.7	9.4	0.8	0.0	74.7
1990	1.0	20.2	31.8	11.0	1.8	0.1	65.9
1991	0.9	7.2	26.1	17.1	2.6	0.5	54.4
1992	2.5	17.1	27.2	11.1	0.6	0.0	58.5

younger fish (ages 1 to 3), due to several strong year classes recruiting to the fishery. As those year classes grew through the fishery during 1975-1978, the age composition again shifted toward older fish (age 2 to 4), which constituted approximately 90% of the total. Since 1979, the commercial landings have been made up primarily of age 2 to 3 fish (about 65% of the total each year), and since 1988 significant contributions have been made by age 4 fish.

Commercial Mean Weights at Age

Mean weights at age in the commercial landings for ages 1 to 6+ during 1955-1992 are given in Table B4 and, based on landings patterns, are considered mid-year values. During the 1955-1992 period, mean weights at age varied annually, but without consistent trend.

Stock Abundance and Biomass Indices

Commercial Landings Per Unit Effort

United States commercial LPUE indices (landings per unit effort; expressed in metric tons landed per day fished) were calculated, by ton-

Table B4. Mean weight (kilograms) at age of commercial landings of silver hake from the Southern Georges Bank-Middle Atlantic stock, 1955-1992

Year	Age						Total
	1	2	3	4	5	6+	
1955	0.044	0.101	0.162	0.222	0.307	0.477	0.173
1956	0.034	0.074	0.154	0.223	0.316	0.490	0.098
1957	0.062	0.085	0.157	0.224	0.326	0.501	0.186
1958	0.060	0.088	0.152	0.215	0.310	0.457	0.140
1959	0.035	0.105	0.156	0.227	0.333	0.463	0.179
1960	0.047	0.074	0.159	0.216	0.317	0.525	0.154
1961	0.077	0.105	0.164	0.217	0.331	0.591	0.211
1962	0.067	0.106	0.157	0.215	0.300	0.594	0.213
1963	0.076	0.103	0.161	0.209	0.286	0.468	0.198
1964	0.057	0.107	0.154	0.210	0.301	0.530	0.201
1965	0.063	0.102	0.153	0.199	0.300	0.486	0.170
1966	0.058	0.089	0.143	0.207	0.311	0.512	0.163
1967	0.045	0.092	0.149	0.204	0.300	0.516	0.165
1968	0.046	0.096	0.138	0.194	0.311	0.526	0.186
1969	0.064	0.111	0.189	0.243	0.308	0.553	0.251
1970	0.049	0.093	0.163	0.209	0.270	0.478	0.178
1971	0.057	0.096	0.152	0.204	0.280	0.517	0.231
1972	0.092	0.201	0.274	0.370	0.372	0.537	0.203
1973	0.096	0.167	0.251	0.300	0.393	0.542	0.185
1974	0.057	0.178	0.225	0.302	0.325	0.526	0.203
1975	0.111	0.141	0.199	0.332	0.468	0.710	0.221
1976	0.064	0.168	0.195	0.228	0.453	0.563	0.204
1977	0.066	0.168	0.213	0.257	0.376	0.590	0.233
1978	0.081	0.192	0.286	0.344	0.333	0.468	0.284
1979	0.081	0.183	0.243	0.287	0.396	0.380	0.249
1980	0.103	0.194	0.212	0.263	0.315	0.499	0.245
1981	0.060	0.144	0.220	0.255	0.265	0.498	0.190
1982	0.106	0.158	0.210	0.246	0.298	0.421	0.197
1983	0.113	0.167	0.207	0.251	0.285	0.406	0.200
1984	0.044	0.138	0.183	0.304	0.324	0.483	0.159
1985	0.089	0.147	0.214	0.354	0.520	0.507	0.198
1986	0.078	0.133	0.193	0.268	0.385	0.579	0.158
1987	0.119	0.135	0.187	0.214	0.466	0.416	0.183
1988	0.061	0.153	0.176	0.275	0.367	0.425	0.171
1989	0.103	0.149	0.190	0.239	0.361	0.425	0.184
1990	0.125	0.157	0.207	0.272	0.335	0.435	0.260
1991	0.079	0.138	0.172	0.210	0.307	0.415	0.205
1992	0.058	0.151	0.177	0.229	0.284	0.425	0.209

nage class, from otter trawl trips in which silver hake constituted 50% or more of the total trip landed by weight. These values are considered "directed trips" and have been computed for those divisions in which significant silver hake landings occur. United States landings from directed trips in divisions 53 and 61 have varied annually but generally without trend since the late 1970s. However since the early 1980s, commercial landings from directed trips have increased in the southern Georges Bank area (SA 52), primarily from the ton class 4 fleet.

United States directed commercial LPUE indices from divisions 53 and 61 have gradually declined since the late 1970s, with peak values during 1981-1984 and another smaller peak during 1988-1990 (Figure B2). Despite decreases in these areas, LPUE in the southern Georges Bank region (SA 52) has increased since 1980.

Commercial LPUE indices were standardized by applying a three-factor (year, tonnage class, and area) General Linear Model (GLM) to log LPUE data for directed trips otter trawl trips from 1973 through 1992. Standardized indices that have accounted for area and ton class effects show an overall declining trend (Figure B2).

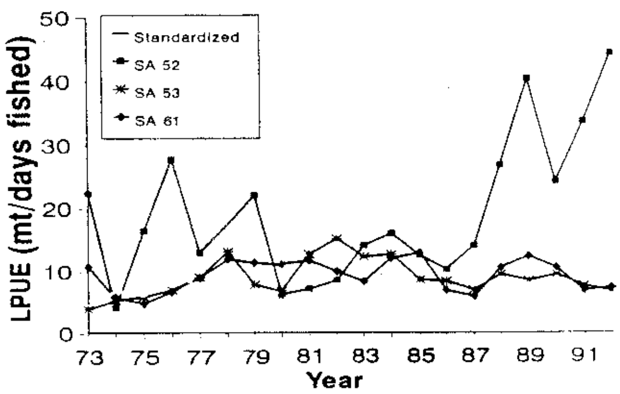

Figure B2. Landings per unit effort (LPUE) standardized for differences in vessel tonnage class fishing power for the Southern Georges Bank-Middle Atlantic silver hake stock.

Research Vessel Survey Indices

Spring and autumn survey indices were calculated using Delta distribution estimators for offshore strata only and spring 1973-1981 indices were adjusted to the #36 Yankee trawl as the standard gear. Stratified mean catch per tow in number for both spring and autumn surveys are given in Table B5 and estimates of number per tow at age in Table B6.

The spring and autumn survey number per tow indices have been variable and have generally shown inconsistent trends in population abundance, except during 1973-1978. During this period, the number per tow indices increased, reaching a series high in 1974 and in 1977 for the spring and autumn surveys, respectively, after which both set of indices subsequently declined (Figure B3). This resulted from strong year classes during the mid-1970s and was consistent with trends occurring in the Gulf of Maine-Northern Georges Bank stock during the same period. The spring index increased again during 1985-1989, but declined through 1992; since 1980 autumn indices have generally varied without trend except for an unusually high index in 1985.

Mortality

Natural Mortality

Instantaneous natural mortality (M) for the Southern Georges Bank-Middle Atlantic stock is assumed to be 0.40. Changes in natural mortality rates over time and varying by age as was discussed for the Gulf of Maine-Northern Georges Bank stock also applies here.

Total Mortality

Estimates of instantaneous total mortality (Z) were calculated in the same manner as for the Gulf of Maine-Northern Georges Bank stock and values were obtained for the same time periods. Pooled estimates indicated that total mortality on this stock increased from 0.7 to 0.8 during 1974-1982, to 1.1 during 1984-1987 and further to 1.6 during 1989-1992 (Table B7). Estimates of total mortality were roughly equal between spring and autumn surveys.

Estimates of Stock Size and Fishing Mortality

Virtual Population Analysis Calibration

The ADAPT framework (Parrack 1986; Gavaris 1988; Conser and Powers 1990) was used in an attempt to calibrate VPA stock sizes and derive estimates of terminal F values in 1992. As with the Gulf of Maine-Northern Georges Bank stock, temporal trends in the residuals were observed in both surveys in earlier years (1973-1976); however, the spring survey indices (ages 2 to 5+) showed particularly strong trends. Additionally, the spring and autumn surveys have shown inconsistent trends in recent years; observed spring indices were larger than expected (resulting in large positive residuals) while the observed autumn indices were smaller than expected (resulting in large negative residuals).

The above ADAPT results indicated that the estimated F's in 1992 were extremely variable to different sets of tuning indices and formulations, ranging from F=0.79 to 4.8. The variability in the fully recruited F in 1992 is not only driven by the inconsistency between the spring and autumn surveys, but by the within survey variability in the observed indices. It is not clear whether one index should be chosen over the another; *i.e.*, omission of spring indices which showed strong temporal trends in the residuals lead to extreme values of F in 1992. The reasons for the extremely high values of F in 1992 are not completely clear; however, a number of possible explanations include: 1) large positive residuals on age 2 indices

Table B5. Stratified mean number-per-tow and weight-per-tow (kilograms) for silver hake from the Southern Georges Bank-Middle Atlantic stock (offshore strata 1-19, 61-76; inshore strata 1-46, 52, 55) from NEFSC autumn and spring bottom trawl surveys

	Spring			Autumn	
Year	No./Tow	Wt./Tow	Year	No./Tow	Wt./Tow
1963	-	-	1963[4,5]	33.26	4.05
1964	-	-	1964[4,5]	30.76	3.21
1965	-	-	1965[4,5]	58.56	4.84
1966	-	-	1966[4,5]	98.52	2.22
1967	-	-	1967[4]	14.81	1.90
1968[1]	35.10	3.57	1968[4]	53.74	2.34
1969[1]	16.68	2.09	1969[4]	24.14	1.09
1970[1]	17.75	1.17	1970[4]	27.72	1.16
1971[1]	25.44	2.08	1971[4]	50.07	1.92
1972[1]	10.75	1.33	1972[4]	47.74	1.74
1973[2]	17.23	3.04	1973[4]	18.38	1.48
1974[2]	37.21	2.13	1974	127.95	0.76
1975[2]	33.70	3.76	1975	48.90	1.59
1976[3]	22.82	2.56	1976	106.90	1.80
1977[3]	9.13	2.59	1977	137.59	1.58
1978[3]	14.24	3.08	1978	77.31	2.53
1979[3]	9.34	1.49	1979	25.26	1.51
1980[3]	10.38	2.04	1980	53.49	1.80
1981[3]	10.12	2.09	1981	54.65	1.07
1982	7.97	1.88	1982	67.44	1.44
1983	10.18	1.38	1983	42.68	2.73
1984	11.51	2.09	1984	30.50	1.32
1985	18.83	2.30	1985	113.90	3.29
1986	17.16	2.31	1986	27.84	1.20
1987	23.74	3.04	1987	12.45	1.68
1988	13.47	1.46	1988	48.68	1.54
1989	19.03	1.93	1989	28.13	1.60
1990	22.41	2.55	1990	35.36	1.29
1991	10.92	1.29	1991	61.23	0.72
1992	9.22	0.48	1992	61.23	0.72
1993	20.22	1.33	1993	N/A[6]	N/A[6]

[1] Adjusted from offshore #36 trawl catches to equivalent inshore-offshore #36 trawl catches using a .960:1 ratio.
[2] Adjusted from offshore #41 trawl catches to equivalent inshore-offshore #36 trawl catches using a .320:1 ratio.
[3] Adjusted from offshore #41 trawl catches to equivalent inshore-offshore #36 trawl catches using a .334:1 ratio.
[4] Adjusted from offshore #36 trawl catches to equivalent inshore-offshore #36 trawl catches using a .890:1 ratio.
[5] Strata 1-19 only.
[6] Estimates from autumn bottom trawl survey not available.

and large negative residuals on age 4 indices in recent years from ADAPT results, may have inflated stock sizes at age 1 and deflated stock sizes at age 4 and, therefore, artificially increased Fs; 2) uncertainty in the landings-at-age matrix from the use of survey age-length keys to age the commercial landings composition and poor sampling of commercial landings, particularly in recent years, which required the use of sea samples; and 3) mixing of the Gulf of Maine-Northern Georges Bank and the Southern Georges Bank-Middle Atlantic stocks and its effect on the survey indices that are used to tune the VPA.

Effects of Discarding onYield and Spawning Stock-Biomass-Per-Recruit Analyses

Methods

To estimate the selection pattern of the current fishery for silver hake, the landings-at-age matrix was augmented to account for the numbers of silver hake at age discarded at sea. This required: 1) a discard estimator for each cell within defined temporal and spatial strata; 2) an

Table B6. Stratified mean number-per-tow (linear estimate) at age for silver hake from the Southern Georges Bank-Middle Atlantic Stock (offshore strata 1-19, 61-76; inshore strata 1-46, 52, 55) from NEFC autumn and spring bottom trawl surveys.

Year	Age										
	0	1	2	3	4	5	6+	0+	1+	2+	3+
					Spring Survey						
1973[1]	-	5.65	6.96	3.33	1.07	0.11	0.11	17.23	17.23	11.58	4.62
1974[1]	-	28.40	2.19	3.55	2.06	0.69	0.32	37.21	37.21	8.81	6.62
1975[1]	-	17.38	4.57	8.64	2.38	0.66	0.07	33.70	33.70	16.32	11.75
1976[2]	-	12.08	5.15	3.40	1.70	0.37	0.12	22.82	22.82	10.74	5.59
1977[2]	-	1.42	1.24	3.69	2.05	0.42	0.31	9.13	9.13	7.71	6.47
1978[2]	-	6.24	2.84	1.53	2.22	1.05	0.36	14.24	14.24	8.00	5.16
1979[2]	-	5.18	1.44	1.00	0.47	0.72	0.53	9.34	9.34	4.16	2.72
1980[2]	-	3.60	3.07	2.10	0.79	0.25	0.57	10.38	10.38	6.78	3.71
1981[2]	-	3.69	1.84	2.01	1.37	0.64	0.57	10.12	10.12	6.43	4.59
1982	-	1.31	3.11	1.02	1.03	0.86	0.64	7.97	7.97	6.66	3.55
1983	-	4.12	3.83	1.08	0.58	0.24	0.33	10.18	10.18	6.06	2.23
1984	-	2.47	5.74	2.39	0.59	0.13	0.19	11.51	11.51	9.04	3.30
1985	-	8.91	3.98	3.99	1.41	0.35	0.19	18.83	18.83	9.92	5.94
1986	-	3.35	9.57	2.19	1.74	0.27	0.04	17.16	17.16	13.81	4.24
1987	-	3.53	13.09	5.17	1.28	0.64	0.03	23.74	23.74	20.21	7.12
1988	-	4.58	2.42	5.57	0.84	0.06	0.00	13.47	13.47	8.89	6.47
1989	-	6.46	4.62	6.59	1.26	0.08	0.02	19.03	19.03	12.57	7.95
1990	-	3.35	12.10	5.74	1.04	0.17	0.01	22.41	22.41	19.06	6.96
1991	-	3.03	1.49	3.61	2.23	0.45	0.11	10.92	10.92	7.89	6.40
1992	-	6.13	1.14	1.37	0.55	0.03	0.00	9.22	9.22	3.09	1.95
1993	-	-	-	-	-	-	-	20.22	20.22	-	-
					Autumn Survey						
1973[3]	10.51	2.89	3.09	1.32	0.37	0.19	0.01	18.38	7.87	4.98	1.89
1974	121.59	4.19	1.58	0.45	0.10	0.04	0.00	127.95	6.36	2.17	0.59
1975	40.81	3.78	2.16	1.32	0.54	0.18	0.11	48.90	8.09	4.31	2.15
1976	95.46	2.49	4.92	2.62	0.91	0.24	0.26	106.90	11.44	8.95	4.03
1977	128.39	3.63	1.44	2.82	0.96	0.21	0.14	137.59	9.20	5.57	4.13
1978	57.05	9.46	4.20	2.76	2.50	1.13	0.21	77.31	20.26	10.80	6.60
1979	18.72	2.01	1.75	1.27	0.62	0.45	0.44	25.26	6.54	4.53	2.78
1980	42.85	3.74	1.39	3.34	1.04	0.50	0.63	53.49	10.64	6.90	5.51
1981	49.19	2.42	0.77	1.16	0.83	0.19	0.09	54.65	5.46	3.04	2.27
1982	60.74	2.85	2.28	0.91	0.39	0.17	0.10	67.44	6.70	3.85	1.57
1983	27.48	8.68	3.91	1.93	0.38	0.18	0.12	42.68	15.20	6.52	2.61
1984	22.23	4.79	2.29	0.92	0.24	0.03	0.00	30.50	8.27	3.48	1.19
1985	89.94	16.30	3.53	3.13	0.88	0.07	0.05	113.90	23.96	7.66	4.13
1986	19.96	4.95	2.21	0.50	0.16	0.06	0.00	27.84	7.88	2.93	0.72
1987	0.72	4.62	6.42	0.49	0.15	0.05	0.00	12.45	11.73	7.11	0.69
1988	36.94	3.29	7.56	0.82	0.07	0.00	0.00	48.68	11.74	8.45	0.89
1989	17.92	2.34	5.65	2.03	0.16	0.03	0.00	28.13	10.21	7.87	2.22
1990	27.68	1.12	5.12	1.07	0.30	0.07	0.00	35.36	7.68	6.56	1.44
1991	57.47	0.52	2.06	0.98	0.19	0.01	0.00	61.23	3.76	3.24	1.18
1992	59.11	3.38	3.03	0.42	0.04	0.00	0.00	65.98	6.87	3.49	0.46

[1] Adjusted from offshore #41 trawl catches to equivalent inshore-offshore #36 trawl catches using a .320:1 ratio.
[2] Adjusted from offshore #41 trawl catches to equivalent inshore-offshore #36 trawl catches using a .334:1 ratio.
[3] Adjusted from offshore #36 trawl catches to equivalent inshore-offshore #36 trawl catches using a .890:1 ratio.

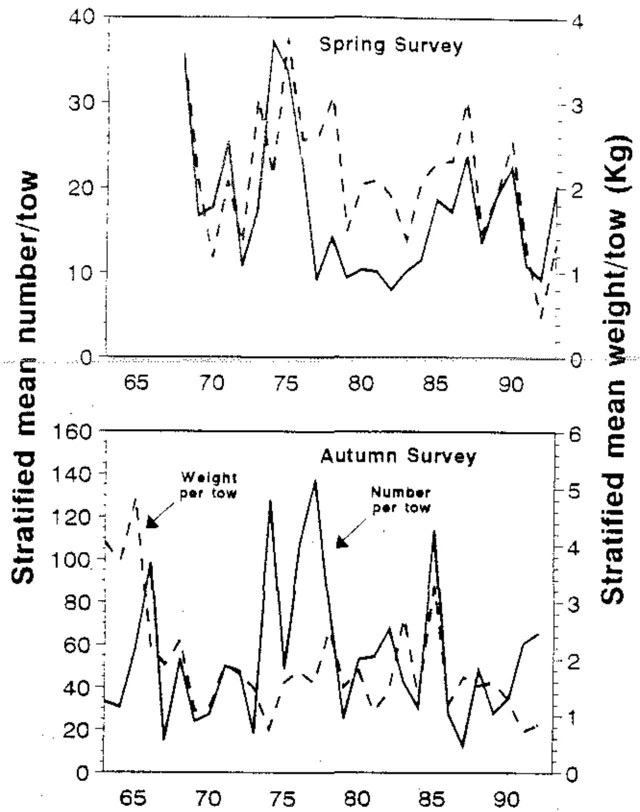

Figure B3. Stratified mean number and weight (kilograms) per tow of Southern Georges Bank-Middle Atlantic silver hake from the NEFSC spring and autumn bottom trawl surveys.

expansion factor to adjust the cell's discard estimates to fleet wide estimate of discards by strata; and 3) samples of the size composition of discards by strata from which the average weight can be used to estimate numbers of fish discarded by length and age. It is assumed that fishing patterns and recorded weight and size composition of discards from observed trips in the *Domestic Sea Sampling Program* (DSSP) are representative of the overall fishing fleet.

Statistical areas and meshes were aggregated into large enough categories to obtain minimum adequate samples to stratify temporally and spatially, because discard rates are likely to vary owing to the size composition of the fish in the population and operations of the fleets (*i.e.* mesh size). In addition, meshes were aggregated into mesh categories as follows: mesh category 1 (mesh cod end <= 3.5 inches), mesh category 2 (3.5 < mesh cod end < 5.5), mesh category 3 (mesh cod end => 5.5 in). Tables A8 and B8 show data on discarded silver hake in the DSSP data base: the number of individual length samples and numbers of fish measured by strata (year, quarter, region, and mesh).

Discard Estimate Expansion

The weight (in pounds) of silver hake discarded to days fished was chosen as the ratio

Table B7. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for the Southern Georges Bank - Middle Atlantic silver hake stock derived from NEFSC offshore spring and autumn bottom trawl survey data[2].

Time Period	Spring		Autumn		Geometric Mean	
	Z	F	Z	F	Z	F
1974 - 1977	0.95	0.55	0.63	0.23	0.77	0.37
1979 - 1982	0.62	0.22	0.73	0.33	0.67	0.27
1984 - 1987	1.10	0.70	1.12	0.72	1.11	0.71
1989 - 1992	1.54[3]	1.14[3]	1.59	1.19	1.56[3]	1.16[3]

[1] Instantaneous natural mortality (m) assumed to be 0.40.

[2] Estimates derived from: Autumn, ln (Σ age 2^+ for year i-1 to j-1 / Σ age 3^+ for year i to j.
Spring, ln (Σ age 3^+ for year i to j / Σ age 4^+ for year i+1 to j+1.

[3] Provisional estimate; does not include spring 1993 survey abundance estimates.

discard estimator for the silver hake fishery (Helser 1993). Only those sea sampling trips for which some silver hake were landed were used to compute the discard rates, *i.e.*, trips in which all silver hake were discarded were excluded from the calculations.

The discard rates so estimated were derived from only a fraction of the total number trips made by vessels within each stratum. To derive fleet-wide discard estimates, the discard rate was raised by the expansion factor, *E*, defined as the total days fished of trips that landed silver hake within a given stratum (Helser, 1993). Total effort was defined as the summation of all days fished for those trips during which silver hake were landed. Because some trips that catch silver hake discard 100% of them (*i.e.*, landings are 0), the present discard rates are considered minimum estimates.

The total discards (in weight) of silver hake by stratum were obtained using:

$$W_{ijkl} = R_{ijkl} * E_{ijk} * P_{ijkl} \quad (1)$$

where:

W_{ijkl} = total weight of discards (lb) in year i region j quarter k and mesh l

R_{ijkl} = mean discard estimator in year i region j quarter k and mesh l

E_{ijk} = the total effort (days fished) in year i region j, and quarter k, and

P_{ijkl} = proportion of total effort from interviewed trips in year i region j, quarter k, and mesh l.

Numbers of Discards at Length and Age

The age composition of discarded silver hake in the fishery was estimated by applying estimated numbers of discards at length derived from DSSP length frequency samples to age-length keys derived from NEFSC research vessel surveys, pooled by calendar quarter. Discarded numbers were estimated by dividing mean weights obtained by applying a length-weight equation ($W = .00000593L^{3.05}$) to DSSP length frequency samples into the total discard estimate. Total numbers discarded were then multiplied back into proportions at length by stratum to derive numbers at length. Numbers at length were summed across mesh categories, across regions, and across quarters 1 to 2 and across quarters 3 to 4 and applied to age-length keys (quarters 1 to 2 applied to the spring survey key; quarters 3 to 4 applied to the autumn survey key) and summed again over quarter to derive estimates of the numbers of discards at age. Total numbers discarded at length are shown in Figures A4 and B4 and numbers at age in Figures A5 and B5.

Estimated discards of silver hake ranged from 26% (1,695 mt in 1991) to 156% (7,236 mt in 1989) of total Gulf of Maine-Northern Georges Bank landings over the 1989-1992 period for which data were available. In the Southern Georges Bank-Middle Atlantic silver hake stock discards ranged from 12% (1,249 mt in 1991) to 76% (10,000 mt in 1989) of total landings. Numbers of silver hake discarded ranged from 47% (16.6 million in 1990) to 296% (75.6 million in 1989) of the total numbers landed in the fisheries in the Gulf of Maine-Northern Georges Bank stock. In the Southern Georges Bank-Middle Atlantic stock fisheries, numbers discarded ranged between 18% (9.7 million in 1991) to 108% (80.7 million in 1989) of the total numbers of silver hake landed.

In the Gulf of Maine-Northern Georges Bank stock significant discards in numbers occurred generally between 15 and 25 cm (Figure A4) and represented the greatest proportion of age 1 and a smaller but still significant proportion of age 2 fish (Figure A5). The size composition of discarded silver hake in the Southern Georges Bank-Middle Atlantic fisheries, although slightly larger in size compared to the northern stock, were clearly of a smaller size composition than the landings; with significant numbers between 21 and 30 cm (Figure B4). Discarded silver hake dominated in number at age for age 1 with significant numbers at age 2 and in some years even age 3 (Figure B5).

Selection Pattern at Age

Estimated numbers of discards-at-age (from 1989-1990) were added to the numbers landed-at-age to develop an estimated catch-at-age matrix for those years. An untuned Virtual Population Analysis (Gulland 1965) was applied to the silver hake landings-at- age and catch-at-age matrices to determine the effect of discarding on the exploitation pattern. Since discard estimates were only available for the years 1989-1992, the VPA was run and examined to determine the extent to which estimates of fishing mortality at age had converged over the 1989-1992 period. For both stocks, natural mortality (M) was assumed to be 0.4 and VPA runs were performed with varying levels of terminal fishing mortality. In all cases, from low to high terminal F's, convergence was achieved across ages 1 to 3 by 1989 and to some extent by 1990. In the northern

Table A8. Number of length samples (# fish measured) of discarded silver hake in U.S. domestic Sea Sampling Program (DSSP) by defined strata (year, region, quarter and mesh category) for the Gulf of Maine-Northern Georges Bank Stock

Year Qtr	Gulf of Maine[1] Mesh 1[3]	Gulf of Maine[1] Mesh 3[4]	Georges Bank[2] Mesh 1	Georges Bank[2] Mesh 3
1989				
Q1	17 (2323)	5 (236)	-	6 (244)
Q2	11 (1763)	-	2 (1602)	5 (213)
Q3	8 (976)	6 (154)	16 (1927)	36 (3103)
Q4	10 (1134)	5 (195)	2 (251)	14 (719)
1990				
Q1	8 (928)	-	-	-
Q2	3 (293)	-	1 (84)	-
Q3	-	2 (87)	2 (257)	9 (531)
Q4	3 (341)	3 (108)	2 168)	-
1991				
Q1	7 (700)	-	1 (109)	2 (31)
Q2	3 (386)	-	-	-
Q3	7 (643)	3 (150)	5 (466)	2 (347)
Q4	46 (6183)	-	4 (424)	-
1992				
Q1	-	-	-	-
Q2	1 (100)	-	-	-
Q3	12 (804)	-	20 (1280)	-
Q4	11 (1169)	-	9 (635)	-

[1]Gulf of Maine Region = (statistical area 511-515)
[2]Georges Bank Region = (statistical area 521-523)
[3]Mesh category 1 = (mesh cod end <= 3.5 inches)
[4]Mesh category 3 = (mesh cod end => 5.5 inches)

stock (see table in the next column), inclusion of the discards in the catch at age increased the F at age 1 from about 5 to 7% of the age 3 F (assumed full) to about 45% (see 200% column) of the age 3 F. In the southern stock, F at age 1 remained low relative to the age 3 F, but F at age 2 increased from about 25% of the age 3 F to about 42% of the age 3 F.

Sensitivity runs at various terminal F's indicated a flat-topped exploitation pattern from age 3 and older. The exploitation pattern given below, indicated as the reference pattern, reflects the average conditions in 1989 and 1990 for each stock. To examine possible results from effort being redirected toward younger ages associated with a "juvenile" whiting fishery, these reference patterns were compared to patterns representing 25% and 200% of this estimate in yield and spawning stock biomass per recruit analyses.

Gulf of Maine - Northern Georges Bank Stock

Age	Exploitation Pattern: Landings	1989 25%	1990 Ref.	200%
1	0.049	0.070	0.280	0.500
2	0.380	0.123	0.490	1.000
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000
6+	1.000	1.000	1.000	1.000

Southern Georges Bank - Middle Atlantic Stock

Age	Exploitation Pattern: Landings	1989 25%	1990 Ref.	200%
1	0.011	0.025	0.099	0.350
2	0.245	0.104	0.417	1.000
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000
6+	1.000	1.000	1.000	1.000

Yield and Spawning Stock Biomass-per-Recruit

Yield-per-recruit and spawning stock biomass-per-recruit analyses (Thompson and Bell 1934) were conducted to determine the affect on the long-term yield of the silver hake stocks. Yield and spawning stock biomass (SSB) per recruit were accumulated separately over both the "juvenile" and the "adult" life history phases of a cohorts entire life span and used to examine the likely outcome of harvesting for both a juvenile (ages 0 through 2) and adult (age 3+) silver hake fishery. Yield and SSB was calculated for the reference exploitation pattern at age obtained with and without discard estimates (taken from the untuned VPA results) as described earlier, using the 1989-1990 discard estimates.

Mean weights at age were calculated as the average of the mean weights from the landings and discards at age matrices weighted by numbers at age over the 1989-1992 period. Stock weights used in the subsequent analysis were taken as the weight from the length-weight equation applied to mean lengths at age derived from von Bertalanffy growth equations Pentilla *et al.* 1989). Input mean weights for yield per recruit analyses are given in the table at the bottom of page 29.

Table B8. Landings (metric tons) by region and quarter and number of length samples (# fish measured) from U.S. Domestic Sea Sampling Program (DSSP) by defined strata (year, region, quarter and mesh category) for the Southern Georges Bank-Middle Atlantic Stock.

Year	**Southern Georges Bank**[1]				**Southern New England**[2]				**Middle Atlantic**[3]			
Qtr	**Land. (mt)**	**Mesh1**[4]	**Mesh2**[5]	**Mesh3**[6]	**Land. (mt)**	**Mesh1**	**Mesh2**	**Mesh3**	**Land. (mt)**	**Mesh1**	**Mesh2**	**Mesh3**
1989												
Q1	254	-	-	-	2467	2(201)	2(202)	3(11)	919	4(405)	5(224)	4(108)
Q2	1003	-	1(105)	3(158)	3523	2(19)	6(553)	2(202)	425	5(526)	-	-
Q3	515	1(25)	-	5(363)	1351	1(91)	3(299)	2(207)	25	1(89)	-	-
Q4	4.5	-	-	-	2811	5(358)	-	5(570)	131	1(102)	-	-
1990												
Q1	9.4	-	-	-	2928	-	3(272)	6(579)	1194	-	-6(630)	
Q2	856	4(377)	-	-	3786	2(176)	-	3(299)	167	2(156)	-	-
Q3	215	-	-	-	1974	1(57)	-	-	87	-	-	-
Q4	20	-	-	-	2256	-	-	-	118	-	1(38)	-
1991												
Q1	529	-	-	-	1556	3(169)	3(313)	-	980	1(23)	2(152)	-
Q2	988	-	-	-	2765	-	-	-	508	-	-	-
Q3	42	-	-	2(9)	1083	1(63)	-	9(541)	53	-	-	1(20)
Q4	<1	-	-	-	1375	1(23)	3(144)	1(112)	213	-	-	-
1992												
Q1	1.4	-	-	-	1258	-	--	1400	-	-	-	
Q2	2281	-	-	-	1367	1(20)	-	-	716	-	-	-
Q3	646	-	1(70)	-	868	1(69)	-	2(158)	0	-	-	-
Q4	0	-	-	-	992	1(54)	-	2(62)	694	-	-	-

[1] Southern Georges Bank region = (statistical area 524-526)
[2] Southern New England region = (statistical area 536-613)
[3] Middle Atlantic region = (statistical area 614-636)
[4] Mesh Category 1 = (mesh codend < = 3.5 inches)
[5] Mesh Category 2 = (3.5< mesh codend <5.5 inches)
[6] Mesh Category 3 = (mesh codend = >5.5 inches)

Gulf of Maine - Northern Georges Bank Southern Georges Bank- Middle Atlantic

	Ave. weight (1989 - 1992)				**Ave. weight (1989-1992**		
Age	**Landings**[1]	**Catch**	**Stock**[2]	**Age**	**Landings**	**Catch**	**Stock**
1	0.097	0.078	0.017	1	0.091	0.075	0.012
2	0.156	0.144	0.076	2	0.149	0.122	0.091
3	0.222	0.218	0.177	3	0.187	0.178	0.216
4	0.301	0.301	0.311	4	0.238	0.238	0.348
5	0.394	0.394	0.466	5	0.322	0.322	0.442
6+	0.559	0.559	0.632	6+	0.425	0.425	0.522

[1] Taken from Helser (1993) 1989-1992 period.
[2] From applying length-weight equation ($W=0.00000593L^{3.05}$) to mean length at age from von Bertalanffy growth equations (Pentilla *et al.* 1989).

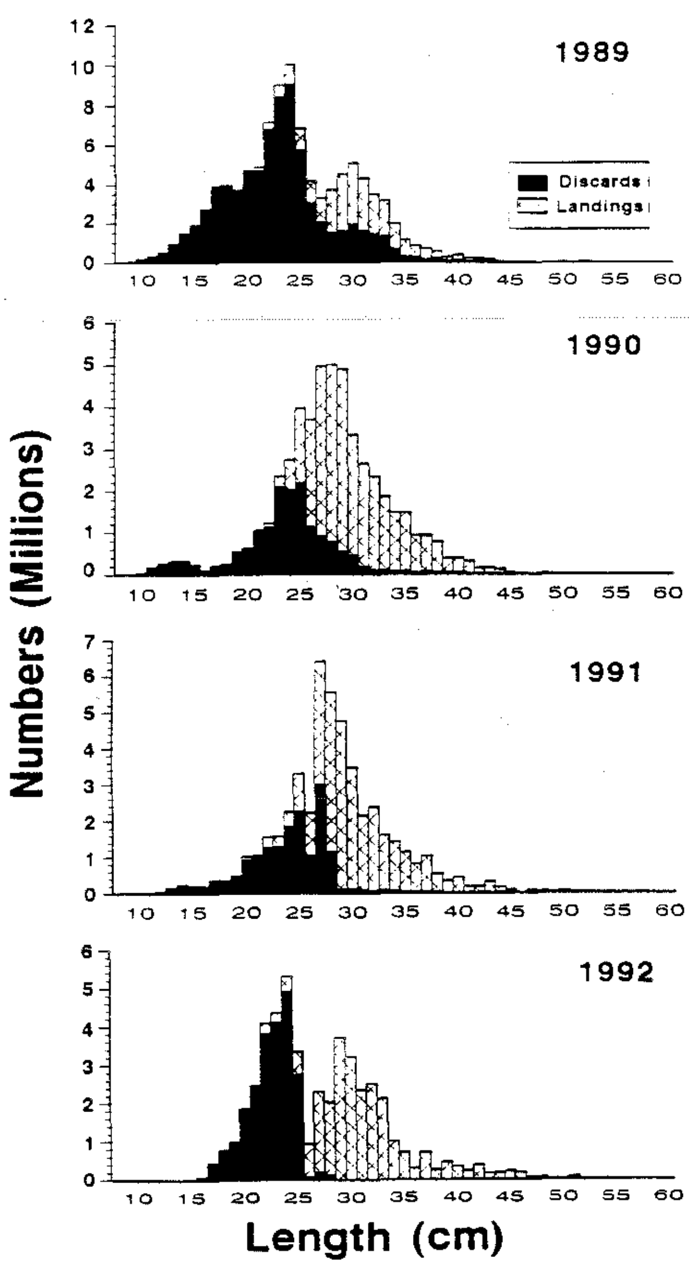

Figure A4. Estimated numbers of landed and discarded silver hake by length from the Gulf of Maine-Northern Georges Bank stock over the 1989-1992 period.

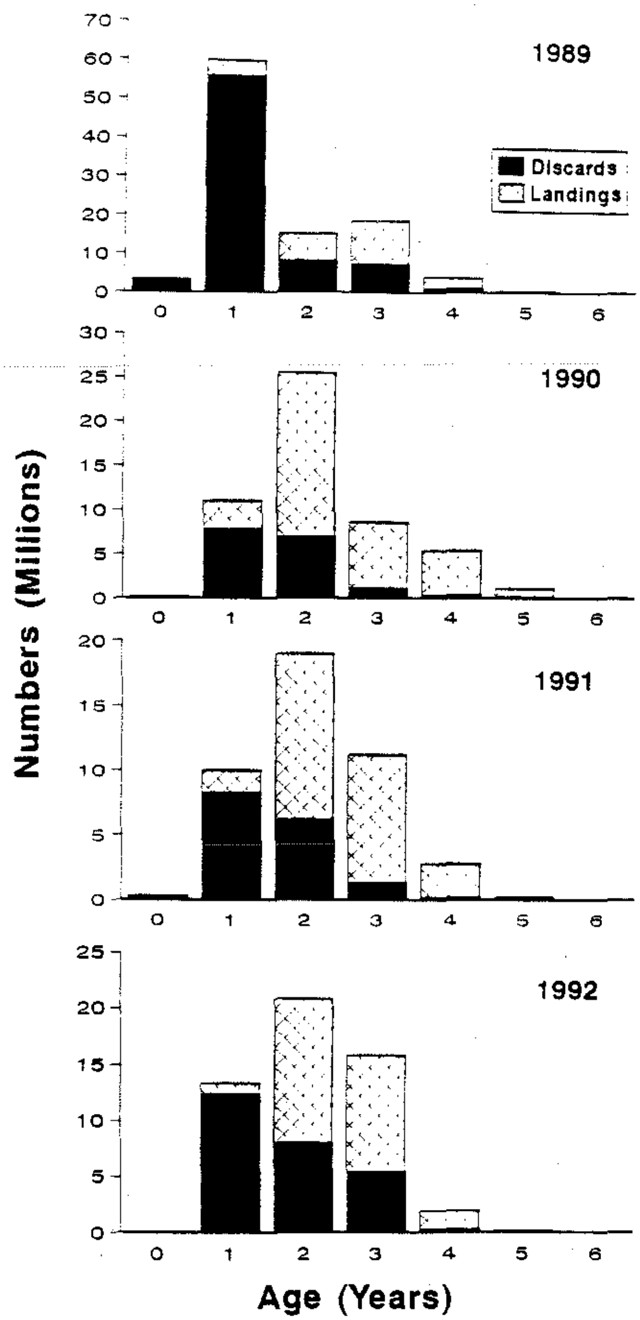

Figure A5. Estimated numbers of landed and discarded silver hake at age from the Gulf of Maine-Northern Georges Bank stock over the 1989-1992 period.

The maturation ogives at age of northern and southern silver hake stocks for application of the spawning stock biomass-per-recruit analyses were taken from O'Brien *et al.* (1993). All initialization parameters were set equal for each stock and for the landings and catch analyses: 1) natural mortality (M) was assumed to be 0.40 and equal for all ages; and 2) proportion of F and M before spawning was set to 0.66 and 0.50 for the northern and southern stocks, respectively.

Examination of yield per recruit from exploitation patterns obtained from the VPA indicated a significant trade off between increasing harvest on younger ages of fish in the population andloss of yield per recruit to the "adult" fishery (Figures A6 and B6). Increasingly higher selection (exploitation) of ages 1 and 2 resulted in increasingly greater yield per recruit from a "juvenile" fishery, with maximum yield per recruit being obtained from lower levels of F as exploitation was in-

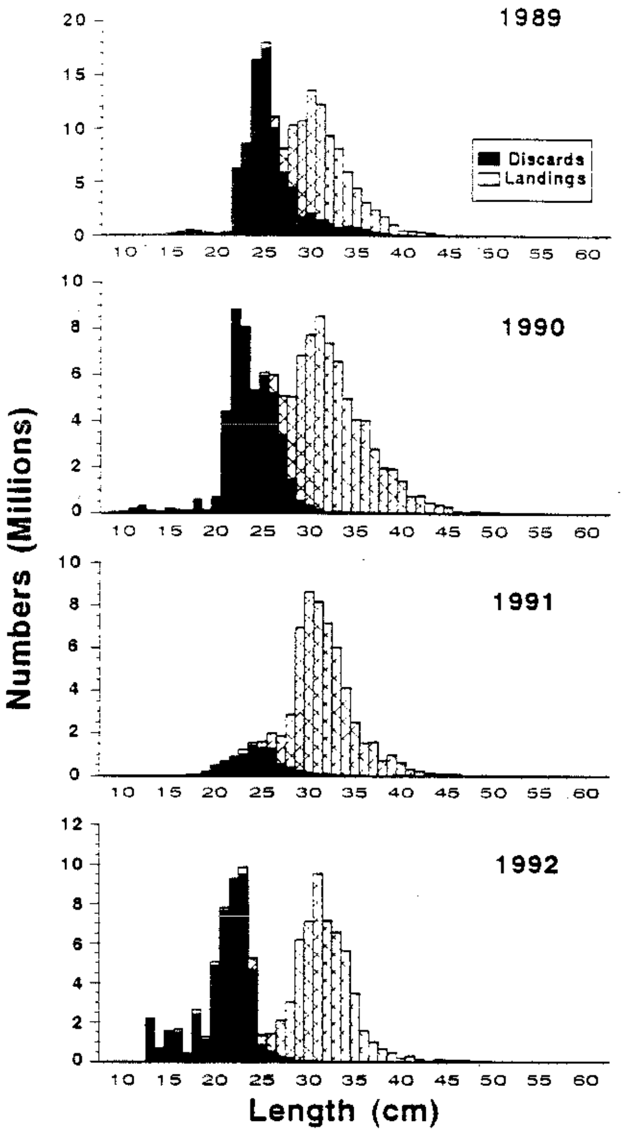

Figure B4. Estimated numbers of landed and discarded silver hake by length from the Southern Georges Bank-Middle Atlantic stock over the 1989-1992 period.

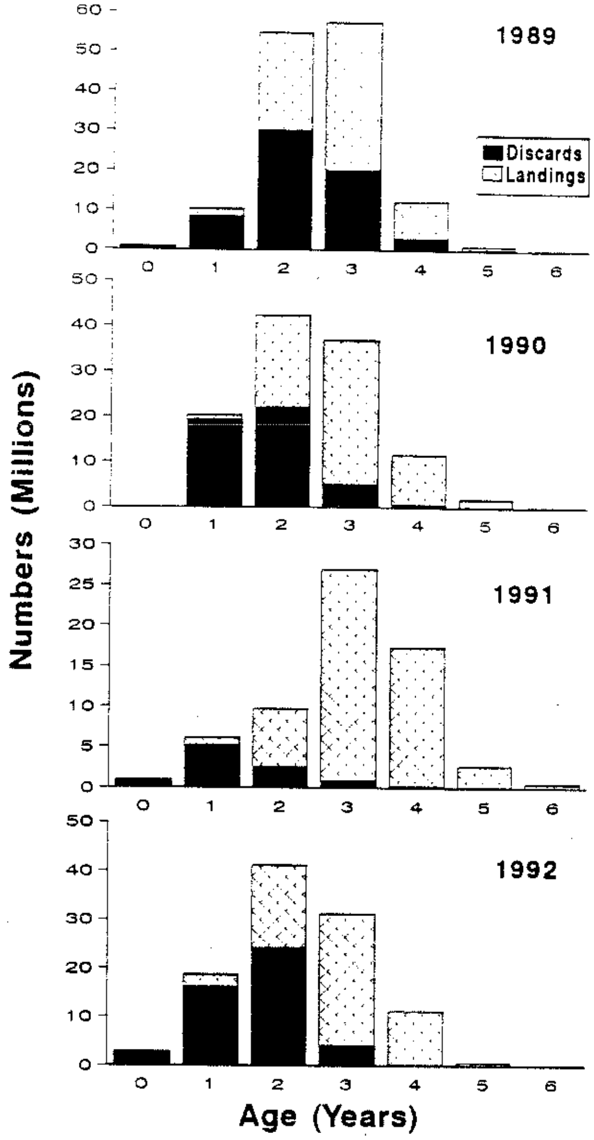

Figure B5. Estimated numbers of landed and discarded silver hake at age from the Southern Georges Bank-Middle Atlantic stock over the 1989-1992 period.

creased to 200% of the reference pattern. Yield per recruit becomes more asymptotic as exploitation was increased. Although yield per recruit increased from the "juvenile" component with increasing exploitation on younger ages, it resulted in a significant adverse effect on an "adult" fishery; as selection on ages 1 and 2 was increased to 200% of the reference pattern maximum yield per recruit decreased by nearly 35%. In addition, F required to achieve maximum yield per recruit from the fishery decreased from around 0.6 to 0.3.

These results suggest that a harvesting strategy directed toward younger ages of fish (as might occur in a "juvenile" whiting fishery) may be incompatible with objectives to maintain an "adult" component which has traditionally supported the silver hake fishery. While overall yield to the "adult" fishery was significantly reduced using the different series of exploitation scenarios in this analysis, percent maximum spawning potential (currently used as the overfishing definition) did not decrease as much as might be expected, probably because most of the stock has matured by age 2 (Figures A7 and B7). Fishing mortality rates at 31% and 42% MSP declined from 0.51 to 0.36 and 0.39 to 0.34, for the northern and southern stocks respectively, when discard mortality was taken into account using the reference exploitation pattern. If effort is targeted on con-

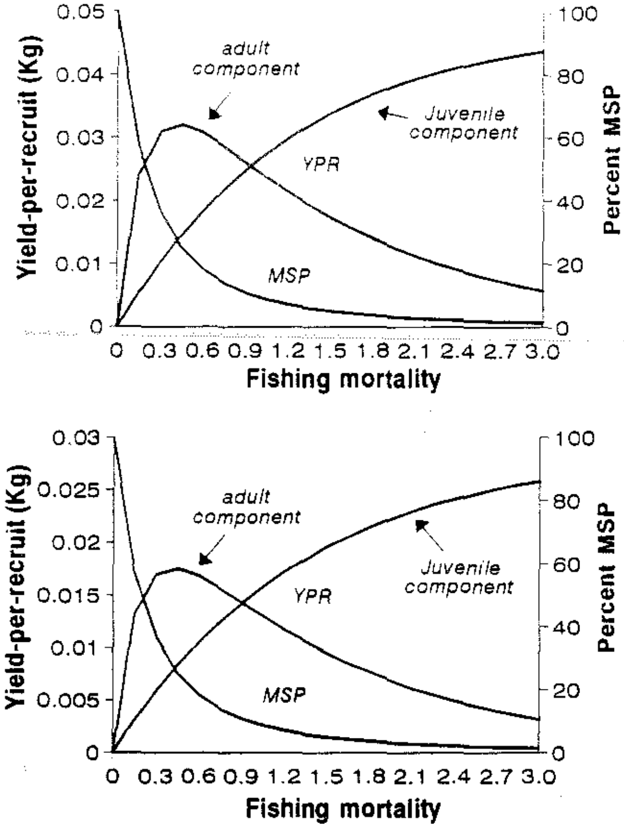

Figure A6. Yield and percent maximum spawning potential (MSP) per recruit from fisheries on "juvenile" and "adult" components of the Gulf of Maine-Northern Georges Bank silver hake stock. Graphs compare yield and MSP per recruit obtained from exploitation pattern derived from catch at age under two assumed vectors of natural mortality at age: top graph, M=0.4 constant over all ages; bottom graph, M=0.8 on age 0, M=0.6 on age 1, and M=0.4 on ages 2 and above.

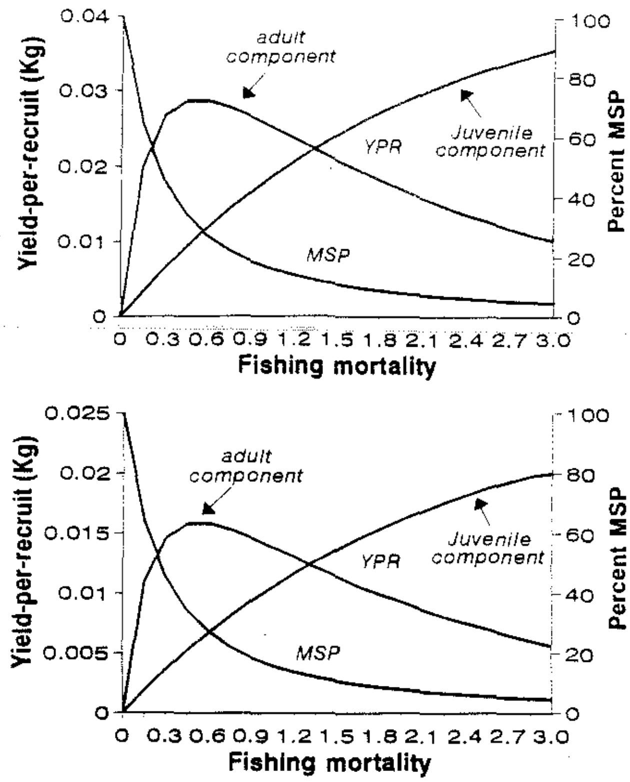

Figure B6. Yield and percent maximum spawning potential (MSP) per recruit from fisheries on "juvenile" and "adult" components of the Southern Georges-Bank-Middle Atlantic silver hake stock. Graphs compare yield and MSP per recruit obtained from exploitation pattern derived from catch at age under two assumed vectors of natural mortality at age: top graph, M=0.4 constant over all ages; bottom graph, M=0.8 on age 0, M=0.6 on age 1, and M=0.4 on ages 2 and above.

targeted on concentrations of juveniles as indicated by the 200% exploitation pattern, F at 31% MSP decreases to 0.29 and F at 42% MSP decreases to 0.25 for the northern and southern stocks respectively.

Subcommittee Comments

Preliminary analyses were presented on the level of discards for a range of mesh sizes from the sea sampling database for 1989 to 1992. Although these samples indicate that discard rates can be substantial, such estimates should be viewed as preliminary due to the spotty spatial and temporal coverage in the sea sampling program. Further, it should be noted that reliable discard estimates can only be obtained from a statistically based sampling program.

Sampling of commercial landings since 1982 was reviewed. Sampling has frequently been spotty, particularly during 1992 when only 4 samples for the entire year were available from port samples. Also, age structures were not available directly from port samples, but age-length keys were derived from survey-captured fish. Both of these factors contribute to variability and potential bias in landings at age for recent years. The length frequency of silver hake measured in the sea sampling program were compared to that obtained in port sampling. Although good agreement was seen in some years (*e.g.*, statistical area 52 in quarter 2 of 1989),

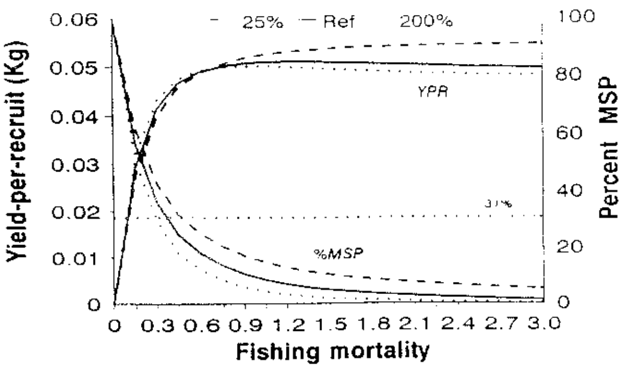

Figure A7. Yield and percent maximum spawning potential (MSP) per recruit from the Gulf of Maine-Northern Georges Bank silver hake stock under 25% and 200% of the reference (Ref.) exploitation at age 1 and 2: 25%) 0.070 and 0.123; Ref.)0.280 and 0.490; and 200%) 0.50 and 1.00.

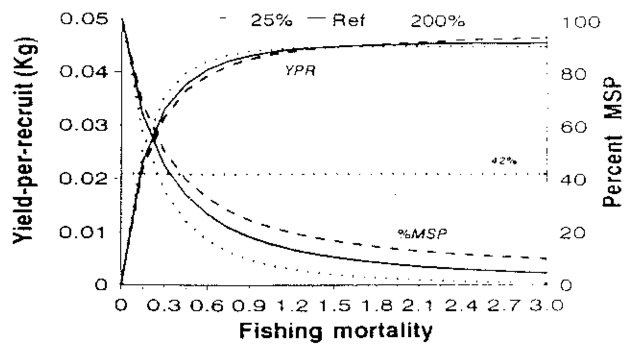

Figure B7. Yield and percent maximum spawning potential (MSP) per recruit from the Southern Georges Bank-Middle Atlantic silver hake stock under 25% and 200% of the reference (Ref.) exploitation at age 1 and 2: 25%) 0.025 and 0.104; Ref.)0.099 and 0.417; and 200%) 0.35 and 1.00.

some disparity was observed in other years (*e.g.*, statistical area 52 in quarter 4 of 1991). The subcommittee also notes that because the sea sampling data are unaudited, the data must be scrutinized prior to use.

Regarding the landings at age matrix, the subcommittee noted that cohorts that appeared strong in the survey did not appear to track well through the landings matrix. The cause of this problem is unknown, but could result from imprecision due to sampling variation, errors introduced by using survey-derived age length keys for the commercial landings, or to other factors such as mixing between the two stocks.

Commercial LPUE indices derived from nominal landings over days fished by ton class, as well as GLM analyses of LPUE indicated different trends between different size vessels. In particular, the LPUE of ton class 4 vessels in recent years has increased greatly relative to ton class 2 and 3 boats. This increase is nnevident beginning in 1988, coincident with the initiation of the Cultivator Shoals fishery. As such, the reliability of commercial LPUE measures as indices of abundance was questioned.

Spring and autumn research survey indices for both stocks show considerable interannual variability resulting in difficulty in tracking cohorts through time. For both surveys, the subcommittee noted a strong decline in catch/tow between ages 3 and 4, suggesting high mortality on these age groups or changes in catchability to the survey. Mortality rates estimated from the surveys show conflicting trends between the two seasonal surveys for the northern stock. Estimates of Z from the spring survey have been high since 1974 (*i.e.*, $Z>1.0$), and have declined during the past four 4-year time periods. Estimates of Z from the autumn survey, however, were less than 1.0, and have shown a steady increase since 1974.

Discussions of ADAPT results for both the northern and southern stocks concluded that none of the results were reliable in estimating current stock size and fishing mortality. Further, the subcommittee felt that the problems observed could occur for a number of reasons including:

- The boundaries between these stocks are uncertain. Evidence presented on the geographical distribution of survey catches of silver hake, particularly juveniles in the autumn, suggests that considerable mixing between these stocks may occur. The distribution of adult fish also suggests that the stock boundary may shift seasonally, potentially resulting in a misallocation of landings to the stocks and a mismatch between stock boundaries and survey strata sets between seasons.
- Sampling variation in the landings at age matrix, and possible errors introduced by using survey-captured fish for commercial age-length keys in recent years could be significant. Since the ADAPT procedure assumes that errors in the landings at age matrix are negligible, violations of this assumption may result in patterns among the residuals and unreliable results.

- Variation in the distribution of silver hake in bottom trawl surveys and changes in gear used could result in trends in residuals.

General Comments

Biological Sampling

Lack of adequate biological samples affected the assessment of silver hake; problems were mainly associated with inadequate port sampling. In 1992, only four silver hake samples were taken from the commercial landings of the northern stock. In three cases, these samples were of king whiting (large silver hake), although this size group comprises a very small fraction of the total catch.

Sea Sampling

Sea sampling data were used in the silver hake assessments to estimate discards. When the available data were stratified spatially and seasonally within each year, the number of observations within each cell in was usually quite low. Further, incomplete coverage of the commercial fishery by sea sampled trips often led to missing cells when the stratification was too fine-scale. This often led to high variance on the discard estimates and/or problems with imbalanced designs when attempting ANOVAs.

Because of the various gears and mesh sizes in use in the Northeast mixed groundfish fishery, discards within each component must be estimated separately. Expansion to total discards must be performed using some fishery-based raising factor such as total catch or effort. Often, the commercial weighout data are insufficient to allocate total catch by factors such as mesh size which is needed to determine the proportion of sea sample coverage to total activity within each gear/mesh stratum.

Lack of sea sampling coverage prior to 1989 requires the use of other measures as a surrogate for the sea sampling data based, in part, on relationships determined from the 1989-1992 period. In some cases research vessel survey data can be used to approximate the discard, but this approach requires several assumptions regarding the distribution of fish and fishing activity with respect to the survey sampling design.

The subcommittee has reservations about the general use of sea sampling data for discard estimation without regard to the above caveats. We would like to request that the SARC address the issue of sea sampling coverage generically for all species rather than on the species by species basis that has prevailed in the past.

Research Recommendations

- The subcommittee strongly recommends that the stock structure of this resource be closely examined in order to determine the most appropriate aggregation of landings at age and survey data.
- The subcommittee recommends that the survey series be evaluated to 1) determine appropriate strata sets to account for possible differences in distribution between years 2) determine evidence of mixing between stocks 3) determine effect of transformations (*e.g.*, logarithmic or delta) in reducing the impact of unusually high tows.
- The subcommittee recommends that the adequacy of the statistical design of the sea sampling program for estimating discards of silver hake be evaluated. The subcommittee notes that this evaluation should be done across several species and that sampling designs need to reflect the priorities given to each species.
- Sea sampling is not yet substitutable for port sampling. Thus, port samples for length composition are essential to estimate landings at age. Since age-structures collected in the survey do not adequately cover commercially caught fish, the subcommittee recommends that age structures be collected from either the port sampling or sea sampling programs.
- The subcommittee recommends that the spring and summer Canadian surveys be evaluated for use as tuning indices and as indicators of silver hake geographical distribution.
- The developing fishery for juvenile silver hake should be carefully monitored to establish whether it is targeting concentrations of small fish or simply landing catches that otherwise would have been discarded. From a scientific basis it would be beneficial to take observers aboard trips that target juvenile silver hake, optimally when participating in

an experimental fisheries program. This data collection effort is needed to accumulate catch statistics, measure the length composition of landings and discards, and provide adequate sea sampling to determine discard rates.

- There is a need for a market category designation and adequate sampling for small silver hake (<18cm) to properly quantify the magnitude of the landings of these juvenile fish.
- MARMAP data should be examined to gain information on egg and larval silver hake distribution with respect to aggregation of spawning adults.

REFERENCES

Almeida, F.P. 1987a. Stock definition of silver hake in the New England-Middle Atlantic area. *North Am. J. Fish. Manage.* 7:169-186.

Almeida, F.P. 1987b. Status of the silver hake resources off the northeast coast of the United States. Woods Hole, MA: *NOAA/NMFS/NEFC Lab Ref. Doc.* 87-03.

Anderson, E.D. 1975. Assessment of the ICNAF Division 5Y silver hake stock. *ICNAF* [International Commission for the Northwest Atlantic Fisheries] *Res. Doc* 79/62, Serial Number 3544.

Conover, J.T., R.L. Fritz, and M. Viera. 1961. A morphometric study of silver hake. *U.S. Fish and Wildl. Serv.* SSR 368.

Conser, R.J. and J.E. Powers. 1990. Extensions of the ADAPT VPA tuning method designed to facilitate assessment work on tuna and swordfish stocks. *ICCAT* [International Commission for the Conservation of Atlantic Tunas] *Coll. Vol. Sci. Papers* 32:461-467

Gavaris, S. 1988. An adaptive framework for the estimation of population size. *CAFSAC* [Canadian Atlantic Fisheries Scientific Advisory Committee] *Res. Doc.* 88/29.

Gulland, J.A. 1965. Estimation of mortality rates. Annex to Arctic Fisheries Working Group Report (Hamburg, Jan. 1965). *ICES* [International Council for Exploration of the Sea] *C. M. Doc.* 3 (mimeo).

Helser, T.E. 1993. Estimation of discards in the silver hake fisheries and its implications on the long-term yield of the Stocks. Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 94-01.

Konstantinov, K.G. and A.S. Noskov. 1969. USSR Research Report, 1968. *ICNAF* [International Commission for the Northwest Atlantic Fisheries] *Res. Doc* 69/17, Serial No. 2224.

O'Brien, L., J. Burnett, and R.K. Mayo. 1993. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990. *NOAA Tech. Rep. NMFS* 113.

Parrack, M.L. 1986. A method of analyzing catches and abundance indices from a fishery. *ICCAT* [International Commission for the Conservation of Atlantic Tunas] *Coll. Vol. Sci. Papers* 24:209-211.

Pentilla, J.A, G.A. Nelson, and J.M. Burnett, III. 1989. Guidelines for estimating lengths at age for 18 northwest Atlantic finfish and shellfish species. *NOAA Tech. Mem. NMFS-F/NEC* 66.

Thompson, W.F., and F.H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effects of changes in fishing intensity upon total yield and yield per unit of gear. *Rep. Int. Fish.* (Pacific Halibut) *Comm.* 8.

C. SOUTHERN NEW ENGLAND YELLOWTAIL FLOUNDER

TERMS OF REFERENCE

After the Sixteenth Stock Assessment Workshop (SAW 16), the Steering Committee set the following terms of reference:

a. Assess the status of Southern New England yellowtail flounder through 1992 and characterize the variability of stock abundance and fishing mortality rates.

b. Provide 1994 projected estimates of catch and 1995 SSB options at various levels of F.

The SARC noted several new approaches for assessment methodology within this assessment. These include application of a cumulative logistic model for estimation of age-specific retention rates by pooled fishery years, graphical methods for examination of tuning indices and VPA model residuals, and a stochastic stock projection technique for short term forecasting. These approaches, described in Rago, *et al.* (in prep), may prove useful in other age-structured assessments.

INTRODUCTION

A unit stock of Southern New England yellowtail flounder extending between Nantucket Shoals and Long Island has been defined, based on results of tagging experiments and studies of parasite infestations. Some intermixing occurs with stocks on Georges Bank and off Cape Cod (Royce, *et al.* 1959; Lux 1963). The stock distribution is represented by U.S. Statistical Reporting Areas 526 and 537-539 and Northeast Fisheries Science Center (NEFSC) offshore bottom trawl survey strata 5, 6, 9 and 10.

Yellowtail flounder were managed under the International Commission for Northwest Atlantic Fisheries (ICNAF), with nationally-allocated catch quotas in 1971-1976. With the implementation of the Magnusson Fisheries and Conservation Act in 1976, yellowtail flounder were managed under the New England Fishery Management Council's Fishery Management Plan (FMP) for Atlantic Groundfish from 1977-1982. From September 1982 - September 1986, the species was managed under the Interim Plan, which included a minimum possession size of 28 cm (11 in.). The New England Multispecies FMP then imposed minimum sizes of 30 cm (12 in.), later revised to 33 cm (13 in.) under Amendment 5, effective September 1989.

Yellowtail flounder became an important component of the domestic demersal fishery in the early 1930s as abundance of winter flounder declined (Royce, *et al.* 1959). Total landings rose from about 10,000 mt in 1938 to about 38,000 mt in 1942, but declined in the 1950s, with most landings from the southern New England stock. Some recovery was observed in the 1960s, and

Table C1. Commercial landings of yellowtail flounder (thousands of metric tons) from Southern New England (U.S. Statistical Reporting Areas 526, 537-539) as reported by NEFSC weighout, state bulletin and canvas data (U.S.), and by ICNAF/NAFO or estimated by Brown and Hennemuth 1971 (foreign)

Year	U.S.	Foreign	Total
1960	8.3	-	8.3
1961	12.3	-	12.3
1962	13.3	-	13.3
1963	22.3	0.2	22.5
1964	19.5	-	19.5
1965	19.4	1.4	20.8
1966	17.6	0.7	18.3
1967	15.3	2.8	18.1
1968	18.2	3.5	21.7
1969	15.6	17.6	33.2
1970	15.2	2.5	17.7
1971	8.6	0.3	8.9
1972	8.5	3.0	11.5
1973	7.2	0.2	7.4
1974	6.4	0.1	6.5
1975	3.2	-	3.2
1976	1.6	<0.1	1.6
1977	2.8	<0.1	2.8
1978	2.3	-	2.3
1979	5.3	-	5.3
1980	6.0	-	6.0
1981	4.7	-	4.7
1982	10.3	-	10.3
1983	17.0	-	17.0
1984	7.9	-	7.9
1985	2.7	-	2.7
1986	3.3	-	3.3
1987	1.6	-	1.6
1988	0.9	-	0.9
1989	2.5	-	2.5
1990	8.0	-	8.0
1991	3.9	-	3.9
1992	1.4	-	1.4

Table C2. Commercial landings at age of yellowtail flounder (thousands), Southern New England (U.S. Statistical Reporting Areas 526, 537-539), 1973-1992

Year	1	2	3	4	5	6	7	8	Total
1973	28	2570	7169	4630	1716	1517	257	55	17942
1974	130	1766	3922	5053	2500	950	1021	196	15538
1975	170	2352	1496	973	1257	549	308	163	7268
1976	0	1396	898	245	337	391	167	188	3622
1977	66	2039	3931	392	205	253	123	160	7169
1978	21	3209	1488	1025	165	34	44	28	6014
1978	19	4972	8252	1033	428	96	24	0	14824
1980	119	4557	6324	3619	472	117	19	12	15239
1981	0	2732	6418	2449	884	128	14	0	12625
1982	56	17414	12788	1741	404	78	7	0	32488
1983	57	13823	33242	3347	376	129	35	7	51016
1984	45	2624	13902	6587	740	244	7	14	24163
1985	166	3984	1496	1312	774	135	27	4	7898
1986	39	5926	2882	561	324	119	21	1	9873
1987	72	1370	2014	803	139	47	8	1	4454
1988	0	1154	504	407	101	17	6	0	2189
1989	0	5213	1269	280	41	3	0	0	6806
1990	0	415	18476	1352	68	5	0	0	20316
1991	0	253	2230	6606	81	1	17	0	9188
1992	0	301	896	1687	246	10	3	0	3143

estimated landings from the stock peaked at 33,200 mt in 1969, including a foreign fishery that also harvested the stock between 1965-1974. Landings declined to 1,600 mt by 1976. Although landings briefly averaged 13,500 mt in 1982-1983, they quickly declined to a new record low level of 900 mt in 1988. A second quick increase in landings to 8,000 mt in 1990 was also short-lived.

In 1992, total commercial landings were 1,400 mt, 500 mt above the 1988 record-low level, and the second-lowest level in the landings history of the stock (1935) (Table C1). There is no recreational fishery for this stock.

Landings Data

Commercial landings for 1973-1992 were derived from the NEFSC commercial landings files by stock area (U.S. Statistical Reporting Areas 526, 537-539). A landings-at-age matrix (Table C2) was developed from quarterly length samples and age-length keys from the commercial fishery as described in Conser, *et al.* (1990).

Landings Per Unit Effort

A general linear model (GLM) was fitted to landings and data collected by interview from trips reporting otter trawl landings of yellowtail flounder in the NEFSC weighout data base, 1973-1992 (Table C3). Year, calendar quarter, statistical area and tonnage class (one digit) were included as explanatory variables. Models including year-quarter, year-area and year-tonnage class interactions indicated that although statistically significant, addition of these interaction effects did not improve model fit substantially (*e.g.*, changes in R^2 from 0.30 to 0.34, with F levels of interaction effects one to two orders of magnitude smaller than main effects. Effort was standardized relative to tonnage class 4, quarter 4, area 539, 1992.

As reflected by the low values of R^2, effect of standardization of southern New England effort was minimal (Figure C1). Effort increased from low levels in 1976 to reach high levels in 1983-1986, before dropping sharply by 1988. A second, higher peak followed in 1990, and effort in 1992 dropped to just below 1983-1986 levels.

Retransformed year coefficients provided LPUE-based indices of abundance (Figure C2). Because the largest bias correction changed the retransformed value by only 0.1, bias correction was omitted. The index declined to low levels between 1975-1978, increased abruptly in 1979, peaked in 1983 and then declined rapidly. It remained at very low levels from 1984-1989, increasing briefly in 1990-1991, then reaching the second lowest level in the series in 1992.

Table C3. General Linear Model of commercial landings per day fished, Southern New England yellowtail flounder, 1973-1992, all otter trawl trips landing yellowtail flounder; raw and standardized effort (days fished)

SOUTHERN NEW ENGLAND ALL TRIPS
YEAR TC QTR AREA MODEL

General Linear Models Procedure

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	27	29528.70194731	1093.65562768	384.64	0.0001
Error	24752	70377.23964754	2.84329507		
Corrected Total	24779	99905.94159484			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.295565	-209.2428	1.68620730	-0.80586160

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	19	18318.62912448	964.13837497	339.09	0.0001
TC	2	647.21186765	323.60593383	113.81	0.0001
QTR	3	3746.52085535	1248.84028512	439.22	0.0001
AREA	3	4945.30027623	1648.43342541	579.76	0.0001

Parameter		Estimate	T for HO PArameter = 0	Pr > |T|	Std. Error of Estimate	Effort Raw	Effort Standardized
INTERCEPT		-3.059844345 B	-37.93	0.0001	0.08066421	4024.5	12595.8
	73	2.504344277 B	30.78	0.0001	0.08136161	3985.5	12163.1
	74	2.044176703 B	23.83	0.0001	0.08576459	3129.2	9613.1
	75	1.437375238 B	16.41	0.0001	0.08761736	2185.8	6421.2
	76	1.166022859 B	11.80	0.0001	0.09877896	2525.6	7256.3
	77	1.751490345 B	21.62	0.0001	0.08099934	2985.7	8009.7
	78	1.383929675 B	17.22	0.0001	0.08038340	3474.1	8506.9
	79	2.383667723 B	30.61	0.0001	0.07787105	3759.4	11667.2
	80	2.273453081 B	28.87	0.0001	0.07875817	3307.8	8426.3
	81	2.365619494 B	28.98	0.0001	0.08162966	4279.5	10405.3
	82	2.515141498 B	32.19	0.0001	0.07812460	6775.0	17870.7
	83	2.710039649 B	36.37	0.0001	0.07451482	6749.1	19169.4
	84	1.660875861 B	21.93	0.0001	0.07573459	6115.6	17231.3
	85	0.471066233 B	6.03	0.0001	0.07817293	5860.7	16211.9
	86	0.619008115 B	7.71	0.0001	0.08028403	4023.3	11356.3
	87	0.294022793 B	3.51	0.0004	0.08368602	3479.5	8815.0
	88	-0.072747502 B	-0.84	0.4032	0.08702168	5167.0	15374.0
	89	0.266527144 B	3.22	0.0013	0.08283181	8652.2	27966.0
	90	1.350158462 B	17.75	0.0001	0.07605249	6675.1	21159.6
	91	0.943573559 B	11.64	0.0001	0.08102960	5356.1	14605.7
	92	0.000000000 B	.	.	.		
TC	2	-0.471197765 B	-8.85	0.0001	0.05324481		
	3	0.025010997 B	0.57	0.5679	0.04379570		
	4	0.000000000 B	.	.	.		
QTR	1	0.790950593 B	27.82	0.0001	0.02843535		
	2	0.001325153 B	0.04	0.9657	0.03078819		
	3	-0.162366598 B	-4.91	0.0001	0.03309455		
	4	0.000000000 B	.	.	.		
AREA	526	1.079795774 B	31.20	0.0001	0.03460707		
	537	0.348962897 B	10.51	0.0001	0.03321196		
	538	-1.384298493 B	-14.69	0.0001	0.09426144		
	539	0.000000000 B	.	.	.		

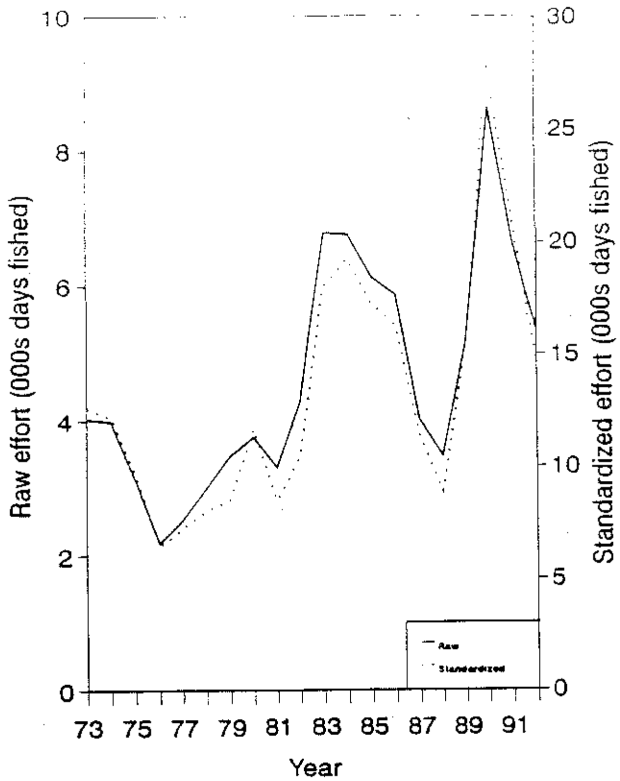

Figure C1. Otter trawl effort, Southern New England yellowtail flounder, raw and standardized days fished, all trips landing yellowtail flounder, 1973-1992.

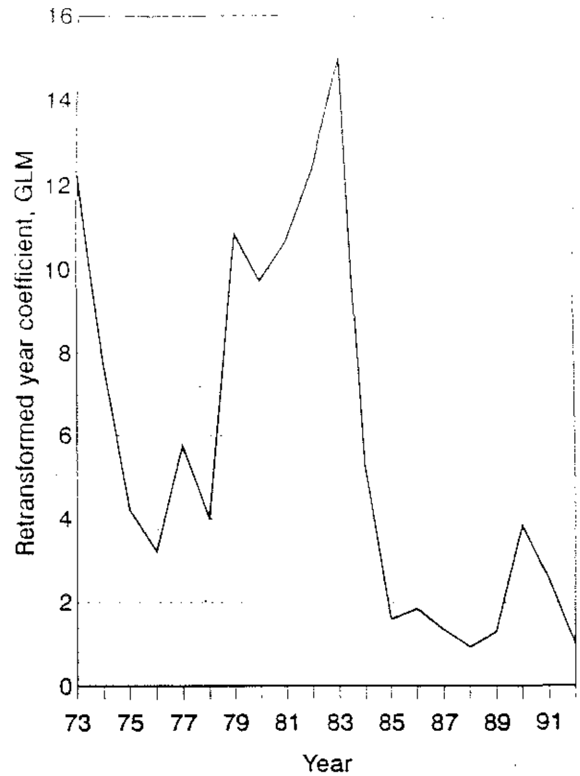

Figure C2. Standardized index of abundance from commercial landings per unit effort data, Southern New England yellowtail flounder, 1973-1992.

Discard Data

A wide variety of methodologies were employed to estimate numbers of yellowtail flounder discarded by age group. In many instances the estimates fluctuated widely by year and quarter within year. Such fluctuations include sampling variability and process error (or alternatively, model misspecification). To reduce these effects of this variation, Conser, *et al.* (1991) used nonlinear least squares to fit a cumulative logistic function to estimated discard fractions by age group within a cohort (year class). The cumulative logistic function has several attractive properties for smoothing discard data. First, it is bounded by zero and one, as are the observed input data. Second, the function is monotonically increasing, thereby modeling the general tendency of fisheries to become increasingly efficient at capturing older and larger fish. Finally, the parameters correspond to easily interpreted concepts of 50% retention and the rate of increase in retention with age.

The general logistic model for retention can be written as:

$$R = 1 - \frac{1}{1+\exp\left(-\frac{K_{50} - Age}{a}\right)} \quad (1)$$

where R is fraction of catch retained, K_{50} is the age at 50% retention, a is the slope of the regression and Age is the age group.

Equation 1 was fit to cohorts (year class) in Conser, *et al.* (1991) for the 1970 to 1988 year classes. Smoothing along cohorts was based on the general premise that strong year classes tend to "attract" fishing effort, thereby increasing the rate of discarding at earlier ages. In other words, high rates of discarding become feasible for fishermen when high levels of landings can be obtained from a cohort. When estimated discard proportions from the 1991 and 1992 fishery years were appended to the cohort-based approach, the statistical fitting procedure produced erratic results. In some instances the retention proportions were lower in 1991 and 1992 than in previous years for the same cohort. These results suggested that a fishery year approach would be more appropriate. In particular, the implementation of a 13 in. size limit in 1989 would be expected to have a marked effect on discarding rates. Equation 1 was applied to pooled years and generalized to allow for testing of differences among pooled fishery years.

To compare two groups the model was generalized as :

(2) $$R = 1 - \frac{1}{1+\exp\left(-\frac{K_{50} + \beta X - Age}{a + \gamma X}\right)}$$

where X is dummy variable equal to 0 for observations in group 1 and equal to 1 for group 2, β and γ are parameters related to the group effect on K_{50} and a, respectively. Equation 2 can easily be generalized to more than two groups by adding more dummy variables. Equation 2 was applied to pooled data for the 1985-1988 and 1989-1992 fishery year groups. Statistical significance of the K_{50}, a, β, and γ parameters was approximated by computing the 95% confidence bounds using the asymptotic standard error of the estimates. Reduced parameter models were selected when the approximate confidence interval overlapped with zero. The following text table summarizes the model estimates and approximate confidence intervals.

Corrected R^2	Parameter	Est.	Approx. 95% C.I.
0.83356	K	2.234	[2.1281, 2.3393]
	β	1.238	[1.0054, 1.4702]
	a	0.2029	[0.1186, 0.2872]
	γ	0.6435	[0.4139, 0.8731]

Results suggested that the four-parameter model, with a significant period effect on both K_{50} and a, was appropriate. Changes in minimum size regulations, growth rates, or fishing patterns may have effected significant changes in K_{50} and a. The statistical fit for this stock is summarized in Figure C3. Analyses of residuals suggested no significant departure from normality.

Overall, the cumulative logistic function was judged to be an effective means of aggregating and smoothing the age specific retention rates. Additional work is needed to apply the model to fishery years prior to 1985. Statistical testing of similar management measures in previous years should also be conducted. Smoothing models are appropriate for discard rates in view of the noisy and potentially biased estimates associated with nonrepresentative sea-sampling, imprecise interview data, and reliance on the survey data for estimation of the true population length at age.

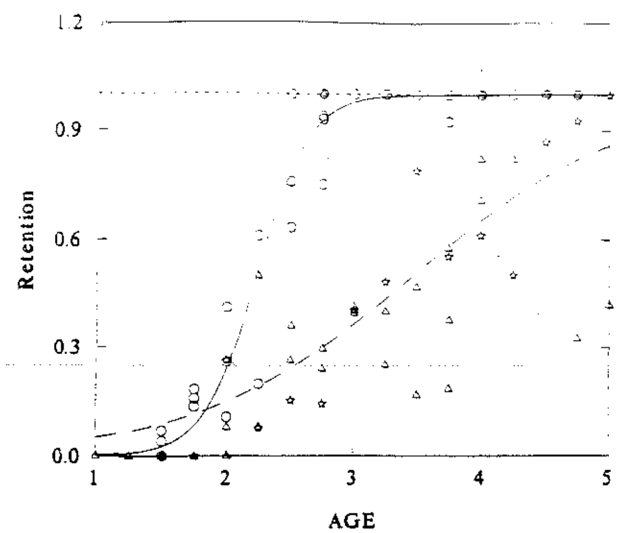

Figure C3. Observed age-specific retention rates and smoothed values for 1985-1992 for the Southern New England stock of yellowtail flounder. Circles denote observations from 1985-1988: the solid lijne is the smoothed prediction from the nonlinear fit of the cumulative logistic distribution function: Reten = 1 - 1/(1+exp(-(2.2368 - Age)/0.2029)). Triangles represent observed retention rates for 1989-1992. Rates for the 1987 year class within this period are indicated by stars. Retention function is: Reten = 1 - 1/(1+exp(-(3.47 - Age)/0.8464)).

The SARC discussed potential reasons for the change in retention pattern in 1989-1992 relative to 1985-1988. The decline in proportion retained at age in 1989-1992 could be due to implementation of higher minimum fish size (13 in. *vs* 12 in.) after 1989, a change in growth patterns, or a combination of the two factors. Although a decline in mean length at age was observed from research survey catches, mean weights at age in landings do not appear to be changing. But of course, mean weights in the landings should increase for age groups not fully vulnerable to the length limit, unless the length-weight relationship has changed over time. Consequently, further study of the potential interaction between fishing mortality and growth rates is warranted.

When landings (L) were available for a given age class, the smoothed retention function was

Table C4. Estimated discard at age of yellowtail flounder (thousands), Southern New England, 1973-1992

Year	Age								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1973	160	2486	1130	43	0	0	0	0	3819
1974	728	26568	793	45	0	0	0	0	28134
1975	8670	1427	1	10	0	0	0	0	10108
1976	214	5203	14	0	0	0	0	0	5431
1977	5376	2732	42	0	0	0	0	0	8150
1978	8677	10102	7	0	0	0	0	0	18786
1979	185	14253	119	0	0	0	0	0	14557
1980	869	5441	18	0	0	0	0	0	6328
1981	38	4013	319	0	0	0	0	0	4370
1982	113	17716	905	3	0	0	0	0	18737
1983	2469	4607	5373	17	0	0	0	0	12466
1984	465	3107	941	74	0	0	0	0	4587
1985	2064	3031	20	0	0	0	0	0	5115
1986	423	3754	39	0	0	0	0	0	4216
1987	1518	2034	19	0	0	0	0	0	3572
1988	5899	896	4	0	0	0	0	0	6798
1989	24	14002	1834	131	6	0	0	0	15996
1990	192	1633	23709	673	11	0	0	0	26217
1991	445	1354	2820	2883	12	0	0	0	7514
1992	477	1152	1086	659	33	0	0	0	3408

Table C5. Total catch at age of yellowtail flounder (thousands), Southern New England, 1973-1992

Year	Age								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1973	188	5056	8299	4673	1716	1517	257	55	21761
1974	858	28334	4715	5098	2500	950	1021	196	43672
1975	8840	3779	1497	983	1257	549	308	163	17376
1976	214	6599	912	245	337	391	167	188	9053
1977	5442	4771	3973	392	205	253	123	160	15319
1978	8698	13311	1495	1025	165	34	44	28	24800
1979	204	19225	8371	1033	428	96	24	0	29381
1980	988	9998	6342	3619	472	117	19	12	21567
1981	38	6745	6737	2449	884	128	14	0	16995
1982	169	35130	13693	1744	404	78	7	0	51225
1983	2526	18430	38615	3364	376	129	35	7	63482
1984	510	5731	14843	6661	740	244	7	14	28750
1985	2230	7015	1516	1312	774	135	27	4	13013
1986	462	9680	2921	561	324	119	21	1	14089
1987	1590	3404	2033	803	139	47	8	1	8026
1988	5899	2050	508	407	101	17	6	0	8987
1989	24	19215	3103	411	47	3	0	0	22802
1990	192	2048	42185	2025	79	5	0	0	46533
1991	445	1607	5050	9489	93	1	17	0	16702
1992	477	1453	1982	2347	279	11	3	0	6551

used to estimate discards (D) as $D = L/R - L$. When landings data were not available, other procedures incorporating research length distribution data (Conser, *et al.*, 1991; Rago, *et al.*, in prep.) were used to impute the number of fish caught, but not landed.

Commercial landings (Table C2) and discard at age (Table C4) were summed to provide a total

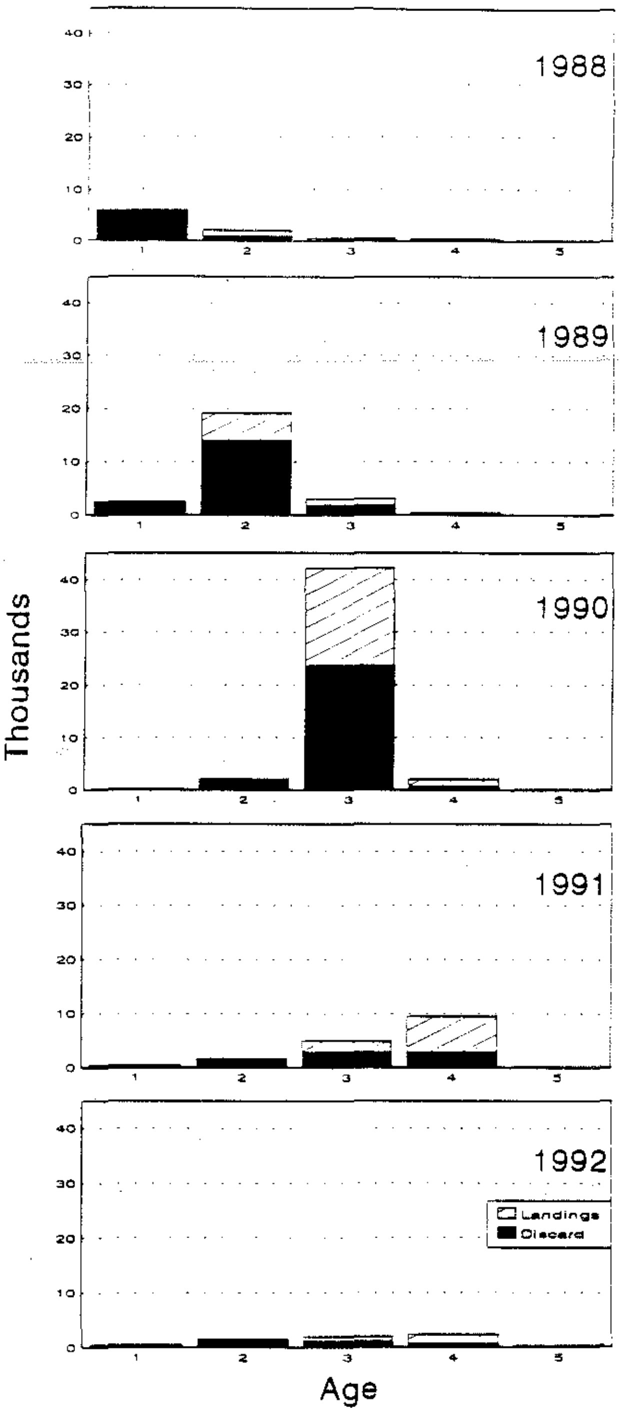

Figure C4. Age composition of commercial landings and discards, Southern New England yellowtail flounder, 1988-1992.

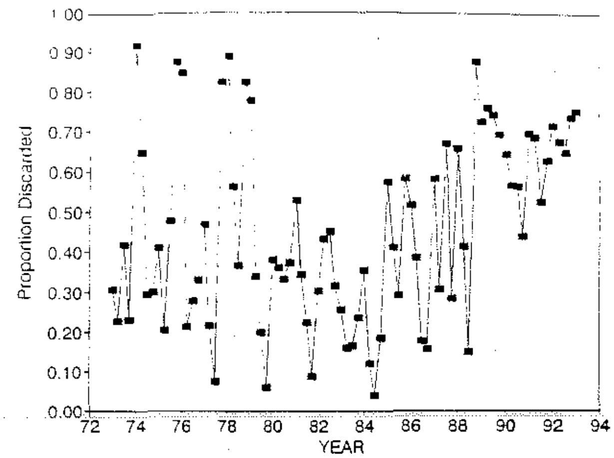

Figure C5. Proportion of total catch aged 1 to 3 discarded quarterly, Southern New England yellowtail flounder, 1973-1993.

catch-at-age matrix (Table C5, Figure C4). The proportion of catch derived from discards is summarized in Figure C5. From 1989-1991, landings were dominated by the 1987 year class. Age 1 fish were absent from landings since 1988, which may have been reinforced by minimum size regulations implemented in 1989. The age structure of the landings has continued to become more truncated. Between 1977 and 1986, landings of fish age 5 and older averaged 665,000 annually (3.25% of total landings, average). Between 1987-1992, an average of 143,000 fish age 5 and older were landed per year (1.57% of total landings, average). Mean weight in the landings is summarized in Table C6.

STOCK ABUNDANCE INDICES

Indices of age-specific stratified mean catch per tow (Figure C6) were available from NEFSC spring and autumn bottom trawl surveys (Table C7, 1968-1993; Table C8, 1963-1992; respectively) and from NEFSC scallop surveys (Table C9, 1982-1992). Aggregate indices in 1992 were the lowest in the time series for autumn trawl and scallop surveys. The aggregate index in the 1993 spring survey was the second lowest in the time series. Age-specific indices generally indicated relatively weak year classes since 1989. Age distributions in trawl survey catches have become more truncated over the past ten years, with few or no catches of fish aged 5 or older. The SARC noted the absence of statistical adjustment for the effects of vessel (*Albatross IV vs Delaware II*) and otter trawl door changes over the course of the fall and spring surveys. Although the statistical adjustment factors are small (<15%), and do not affect the conclusions of the assessment, the SARC suggested adjustment

Table C6. Mean weight (kilograms) at age of Southern New England yellowtail flounder in landings, 1973-1992

Year	Age 1	2	3	4	5	6	7+
1973	0.210	0.298	0.381	0.420	0.430	0.506	0.611
1974	0.203	0.308	0.359	0.429	0.477	0.476	0.518
1975	0.218	0.290	0.385	0.439	0.436	0.469	0.515
1976	-	0.303	0.427	0.528	0.533	0.568	0.603
1977	0.215	0.284	0.385	0.521	0.529	0.484	0.612
1978	0.234	0.296	0.402	0.543	0.710	0.791	0.677
1979	0.189	0.301	0.366	0.476	0.590	0.684	0.679
1980	0.206	0.281	0.384	0.499	0.690	0.891	1.182
1981	0.140	0.262	0.343	0.484	0.619	0.664	0.476
1982	0.226	0.263	0.354	0.502	0.661	0.821	0.956
1983	0.175	0.262	0.341	0.499	0.671	0.829	0.838
1984	0.182	0.239	0.298	0.388	0.497	0.652	0.724
1985	0.183	0.264	0.370	0.428	0.541	0.620	0.867
1986	0.186	0.285	0.335	0.470	0.598	0.617	0.804
1987	0.247	0.268	0.361	0.412	0.542	0.595	0.905
1988	-	0.293	0.398	0.501	0.664	0.936	0.937
1989	-	0.337	0.389	0.546	0.736	0.959	1.278
1990	-	0.327	0.378	0.461	0.800	0.884	0.781
1991	-	0.336	0.379	0.426	0.715	1.530	0.599
1992	-	0.347	0.386	0.460	0.631	0.802	1.432

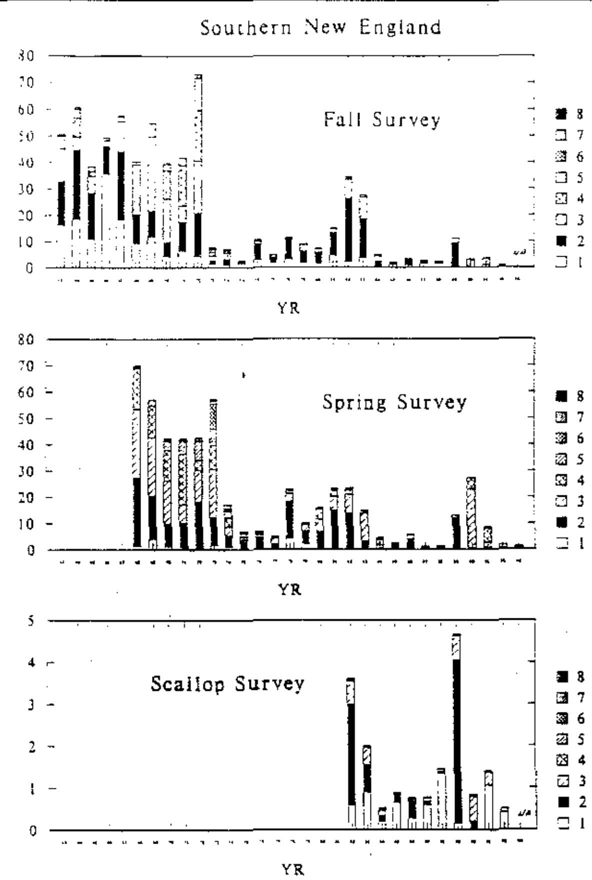

Figure C6. Number by age group of yellowtail flounder caught per tow during NEFSC fall (1963-1992), spring (1968-1993), and scallop (1982-1992) research surveys in Southern New England.

in future assessments. A newly-released version of the survey analysis program (SURVAN 6.0) will make these adjustments automatically.

The SARC also noted that comparisons among age-specific survey indices revealed highly significant correlations within and between years, especially for the fall and spring surveys (Rago, *et al.* in prep). These results suggest that the NEFSC survey data provide a coherent set of tuning indices for Virtual Population Analysis (VPA).

Northeast Fisheries Science Center Winter Trawl Survey

The NEFSC winter trawl survey, implemented in early 1992, is designed to improve sampling of flatfishes through gear modification (elimination of roller gear, use of longer sweeps in front of doors) and survey timing (during period of potential offshore concentration). For yellowtail flounder, winter survey performance varied widely between the two years examined, 1992-1993, as well as when compared with other surveys (Table C10). The total number of stations within survey strata was comparable to that for spring and fall surveys for Southern New England. However, the placement of stations in 1993 appeared to

Table C7. NESFC spring trawl survey mean number of Southern New England yellowtail flounder per tow at age (NEFSC offshore strata 5, 6, 9 and 10)

Year	Age 1	2	3	4	5	6	7	8	Total
1968	1.362	25.999	26.158	15.575	0.726	0.138	0.055	0	70.013
1969	4.182	16.284	22.345	12.029	2.082	0.234	0	0	57.156
1970	1.218	8.745	16.364	11.587	3.333	0.898	0.193	0.079	42.417
1971	0.874	9.281	6.983	19.397	4.971	0.793	0.009	0.009	42.317
1972	0.403	17.905	12.078	3.767	7.224	1.115	0.211	0	42.703
1973	1.877	10.488	18.340	9.053	6.147	9.514	1.183	0.658	57.260
1974	1.070	4.288	3.355	3.650	2.376	0.856	1.390	0.278	17.263
1975	0.809	2.244	0.721	1.110	1.169	0.679	0.047	0.211	6.990
1976	0.037	4.702	0.761	0.361	0.435	0.361	0.227	0.073	6.957
1977	0.296	1.804	2.244	0.239	0.249	0.116	0.035	0.148	5.131
1978	4.275	14.113	2.924	1.032	0.270	0.052	0.068	0.199	22.933
1979	2.224	4.843	2.512	0.510	0.159	0	0	0.012	10.260
1980	0.534	6.208	4.729	3.911	0.420	0.168	0.008	0.056	16.034
1981	0.344	14.634	5.243	2.170	0.788	0.079	0	0	23.258
1982	0.321	13.548	7.193	1.794	0.583	0.179	0.019	0	23.637
1983	0.074	3.197	10.587	0.868	0.256	0	0	0	14.982
1984	0	0.410	1.351	2.141	0.545	0.183	0	0	4.630
1985	0.561	0.744	0.417	0.201	0.454	0.093	0	0	2.470
1986	0.037	4.083	1.492	0.308	0.073	0.036	0	0	6.029
1987	0	0.198	0.919	0.144	0	0	0	0	1.261
1988	0.327	0.692	0.177	0.245	0.127	0	0	0	1.568
1989	0.178	12.127	0.710	0.078	0	0	0	0	13.093
1990	0.107	0.433	22.346	4.464	0.036	0	0	0	27.386
1991	0.552	0.363	1.850	5.275	0.600	0.130	0	0	8.770
1992	0.037	0.115	0.322	1.414	0	0	0	0	1.888
1993	0.037	0.579	0.203	0.547	0.039	0	0	0	1.405

leave areas southeast of Nantucket unsampled. These areas may provide higher catches, based on some spring survey distribution information. Consequently, some differences between years (*e.g.*, the higher proportion of stations with yellowtail flounder in 1992 *vs* 1993) may be due to station distribution, although the continued decline in stock size may also be important.

For Southern New England, the winter survey produced higher catch rates in weight and number than spring and autumn surveys in adjoining seasons, although coefficients of variation were generally higher than for spring survey results. The survey captured some age 1 fish. Results based on the first year would appear promising, but it is difficult to determine if the change in performance in 1993 were due to inherent interannual variability for a survey in this season, lower sampling intensity, changing spatial distribution of sampling (or stock) in the second year, or declining stock conditions. This inconsistency will likewise make evaluation of this index's performance in tuning virtual population analyses difficult.

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY

Virtual Population Analysis

Virtual population analyses were tuned by estimating numbers at age surviving after the terminal year, and age-specific survey catchabilities, using weighted non-linear least squares fitting procedures (ADAPT, Gavaris 1988; Conser and Powers 1990). Survivors at ages 1 to 3 and 5 (1993) were estimated as were catchabilities for NEFSC spring survey catch/tow indices of age 1 to 4 and 5+ abundance, NEFSC scallop survey catch/tow indices of age 1 to 3 and 4+ abundance, and NEFSC autumn survey catch/tow indices of age 1 to 3 and 4+ abundance. Spring survey indices were compared with 1 January stock sizes at ages 1 to 4 and 5+ while scallop and autumn survey indices were compared with mid-year stock sizes at age 1 to 3 and 4+. The survey indices in the objective function were weighted to reduce the effect of

Table C8. NEFSC autumn trawl survey mean number of Southern New England yellowtail flounder per tow at age (NEFSC offshore strata 5, 6, 9 and 10)

	Age								
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1963	16.228	16.531	12.262	4.779	0.541	0.124	0	0.082	50.547
1964	18.466	26.190	4.804	7.132	3.265	0.908	0	0	60.765
1965	10.845	17.533	6.370	1.754	1.776	0.127	0	0.074	38.479
1966	35.496	10.710	1.947	1.022	0.189	0	0	0	49.364
1967	18.440	25.540	11.243	1.587	0.387	0.065	0.131	0	57.393
1968	9.250	10.944	18.738	1.183	0.094	0	0	0	40.209
1969	11.870	9.741	27.755	5.206	0.093	0.041	0.041	0	54.747
1970	4.227	5.521	16.341	10.624	2.514	0.426	0.073	0	39.726
1971	6.351	10.900	6.244	15.138	2.694	0.216	0.161	0	41.704
1972	4.209	16.496	19.716	18.847	12.288	1.680	0.044	0	73.280
1973	1.415	1.303	1.823	1.344	1.017	0.866	0.174	0	7.942
1974	0.997	1.678	0.554	2.275	0.956	0.401	0.195	0.076	7.132
1975	1.624	0.423	0.218	0.27	0.274	0	0.085	0	2.894
1976	2.977	6.009	0.719	0.072	0.114	0.296	0.347	0.155	10.689
1977	1.696	2.194	0.798	0.051	0.044	0.109	0.075	0	4.967
1978	3.131	7.328	0.434	0.378	0.041	0.009	0.076	0.031	11.428
1979	1.730	4.371	2.446	0.374	0.041	0.040	0	0	9.002
1980	1.411	4.345	1.159	0.411	0	0	0	0	7.326
1981	4.536	8.625	1.354	0.322	0.077	0.059	0	0	14.973
1982	2.139	24.075	7.109	0.840	0.335	0	0	0	34.498
1983	3.756	14.718	8.261	0.718	0.060	0	0.041	0	27.554
1984	0.589	1.817	1.967	0.540	0	0	0	0	4.913
1985	1.198	0.526	0.189	0.144	0	0	0	0	2.057
1986	0.972	1.982	0.429	0.103	0	0	0	0	3.486
1987	1.515	0.674	0.558	0.047	0.037	0	0.037	0	2.868
1988	1.484	0.457	0.203	0.229	0.056	0	0	0	2.429
1989	0	9.416	1.647	0.077	0	0	0	0	11.140
1990	0	0.114	2.818	0.318	0	0	0	0	3.250
1991	0.944	0.258	2.011	0.533	0	0	0	0	3.746
1992	0.261	0.037	0.111	0.443	0	0	0	0	0.852

Table C9. NESFC scallop survey mean number of Southern New England yellowtail flounder per tow at age

	Age								
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1982	0.584	2.404	0.559	0.054	0.013	0	0	0	3.614
1983	0.891	0.652	0.417	0.038	0	0	0	0	1.998
1984	0.205	0.130	0.127	0.033	0.031	0	0	0	0.526
1985	0.647	0.180	0.027	0.023	0.010	0	0	0	0.887
1986	0.282	0.395	0.051	0.028	0	0	0	0	0.756
1987	0.601	0.086	0.075	0.011	0.006	0	0.004	0	0.783
1988	1.343	0.047	0.054	0.008	0.001	0	0	0	1.453
1989	0.169	3.878	0.576	0.039	0.014	0	0	0	4.676
1990	0.026	0.180	0.592	0.038	0	0	0	0	0.836
1991	1.060	0.007	0.295	0.040	0	0	0	0	1.402
1992	0.411	0	0.012	0.086	0	0	0	0	0.509

Table C10. Summary of the NEFSC survey data fpr yellowtail flounder - Southern New England stock 1991-1993 (offshore strata 5-6, 9-10, 33-48)

Survey	Total # Stations in Strata	Percent Stations with YT	Strata Mean kg/tow	CV	Strata Mean #/tow	CV	Mean Length (cm)	Length Range (cm)	Largest Tow (kg)	Largest Tow (#)
Spring 1991	26	0.73	2.79	13.2	8.77	12.7	31.72	9-49	8.5	29
Scallop 1991	52	0.031	-	-	1.43	33.7	23.35	3-38	-	12
Autumn 1991	26	0.54	1.01	29.2	3.75	33.0	30.52	20-40	4.5	24
Winter 1992	28	0.72	4.33	20.2	12.23	20.3	33.26	8-46	24.6	71
Spring 1992	25	0.56	0.65	30.9	1.93	31.1	32.66	9-42	4.5	14
Scallop 1992	52	0.15	-	-	0.51	37.2	23.97	16-42	-	6
Autumn 1992	26	0.23	0.23	48.4	0.85	47.5	31.27	23-40	2.7	10
Winter 1993	24	0.46	1.97	45.6	8.07	43.7	27.21	7-44	24.1	81

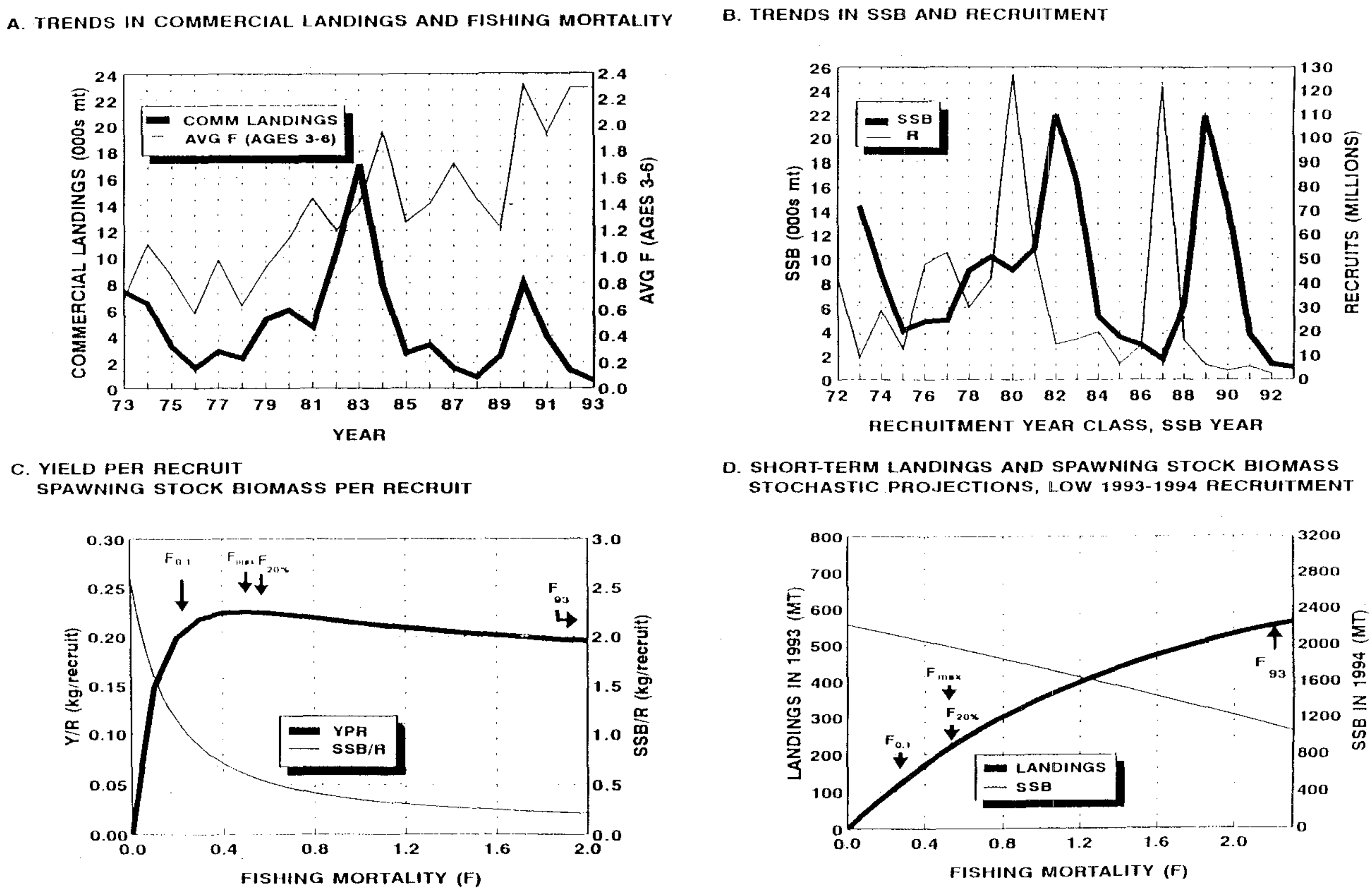

Figure C7. Southern New England yellowtail flounder. A. Trends in commercial lanings and fishing mortality, 1973-1993. B. Trends in spawning stock biomass and recruitment, 1972-1993. C. Yield and spawning stock biomass per recruit. D. Short-term landings and spawning stock biomass stochastic projections, low 1993-1994 recruitment.

Table C11. Results of ADAPT tuning, virtual population analysis, Southern New England yellowtail flounder

A) Stock Numbers

STOCK NUMBERS (Jan 1) in millions - SNE92

	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	42.145	9.228	28.861	12.907	47.568	52.417	30.089	41.941	126.926
2	15.231	34.335	6.779	15.631	10.374	34.021	35.045	24.450	33.445
3	19.879	7.895	2.475	2.132	6.826	4.177	15.811	11.298	10.972
4	10.104	8.765	2.197	0.671	0.922	1.994	2.068	5.370	3.512
5	3.811	4.045	2.564	0.909	0.327	0.400	0.706	0.760	1.123
6	3.443	1.567	1.048	0.961	0.439	0.082	0.178	0.192	0.195
7	0.703	1.968	0.885	0.861	0.484	0.170	0.043	0.049	0.021
1+	95.316	67.803	44.809	34.072	66.939	93.261	83.940	84.060	176.195

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	53.147	14.584	16.731	19.837	6.969	13.984	121.881	16.378	6.019
2	103.884	43.359	9.654	13.236	14.223	5.287	10.010	94.450	13.387
3	21.280	53.266	18.823	2.719	4.489	2.886	1.249	6.341	59.942
4	2.888	5.032	8.670	1.982	0.854	1.032	0.523	0.563	2.384
5	0.661	0.786	1.077	1.071	0.435	0.192	0.119	0.060	0.089
6	0.119	0.175	0.304	0.212	0.177	0.063	0.031	0.006	0.007
7	0.011	0.056	0.024	0.048	0.032	0.012	0.011	0.000	0.000
1+	181.989	117.258	55.283	39.104	27.179	23.456	133.824	117.797	81.828

	1991	1992	1993
1	3.689	5.402	2.483
2	4.754	2.618	3.991
3	9.107	2.438	0.829
4	10.906	2.887	0.203
5	0.119	0.343	0.240
6	0.001	0.014	0.029
7	0.022	0.004	0.001
1+	28.599	13.705	7.776

Summaries for ages 1, 2-7, 3-7, 4-7, 5-7

	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	42.145	9.228	28.861	12.907	47.568	52.417	30.089	41.941	126.926
2-7	53.171	58.576	15.948	21.165	19.372	40.844	53.851	42.119	49.269
3-7	37.941	24.240	9.169	5.535	8.998	6.823	18.806	17.669	15.824
4-7	18.062	16.345	6.695	3.402	2.172	2.646	2.995	6.371	4.852
5-7	7.957	7.580	4.498	2.731	1.250	0.652	0.927	1.001	1.339

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	53.147	14.584	16.731	19.837	6.969	13.984	121.881	16.378	6.019
2-7	128.842	102.674	38.552	19.267	20.210	9.473	11.943	101.420	75.809
3-7	24.959	59.315	28.898	6.031	5.987	4.185	1.933	6.970	62.422
4-7	3.679	6.049	10.074	3.312	1.498	1.299	0.684	0.629	2.480
5-7	0.790	1.017	1.404	1.331	0.644	0.267	0.161	0.066	0.096

	1991	1992	1993
1	3.689	5.402	2.483
2-7	24.910	8.303	5.293
3-7	20.156	5.685	1.301
4-7	11.049	3.247	0.473
5-7	0.143	0.360	0.270

Table C11. Continued

B) Fishing Mortality

FISHING MORTALITY - SNE92

	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.0049	0.1085	0.4132	0.0185	0.1352	0.2026	0.0075	0.0264	0.0003
2	0.4571	2.4300	0.9566	0.6285	0.7097	0.5663	0.9320	0.6013	0.2522
3	0.6189	1.0791	1.1046	0.6385	1.0304	0.5032	0.8798	0.9683	1.1347
4	0.7155	1.0293	0.6831	0.5185	0.6353	0.8391	0.8011	1.3650	1.4705
5	0.6885	1.1501	0.7809	0.5271	1.1806	0.6069	1.1037	1.1582	2.0441
6	0.6663	1.1086	0.8674	0.5971	1.0122	0.6099	0.9013	1.1219	1.3043
7	0.6663	1.1086	0.8674	0.5971	1.0122	0.6099	0.9013	1.1219	1.3043

	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0.0035	0.2125	0.0343	0.1327	0.0761	0.1343	0.0550	0.0016	0.0359
2	0.4680	0.6344	1.0673	0.8813	1.3949	1.2431	0.2566	0.2547	0.1852
3	1.2419	1.6154	2.0512	0.9579	1.2698	1.5072	0.5970	0.7784	1.5041
4	1.1012	1.3421	1.8912	1.3157	1.2944	1.9632	1.9607	1.6450	2.7947
5	1.1290	0.7512	1.4254	1.6024	1.7297	1.6175	2.8224	1.9734	3.9963
6	1.2745	1.6800	2.1949	1.2178	1.3648	1.7258	0.9253	0.8530	1.6344
7	1.2745	1.6800	2.1949	1.2178	1.3648	1.7258	0.9253	0.8530	1.6344

	1991	1992
1	0.1431	0.1027
2	0.4678	0.9504
3	0.9488	2.2871
4	3.2588	2.2871
5	1.9767	2.2871
6	1.7461	2.2871
7	1.7461	2.2871

Avg F for ages 1, 2-7, 3-7, 4-7, 5-7

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.0049	0.1085	0.4132	0.0185	0.1352	0.2026	0.0075	0.0264	0.0003	0.0035
2-7	0.6354	1.3176	0.8767	0.5845	0.9300	0.6225	0.9199	1.0561	1.2517	1.0815
3-7	0.6711	1.0951	0.8607	0.5757	0.9741	0.6338	0.9174	1.1471	1.4516	1.2042
4-7	0.6842	1.0991	0.7997	0.5600	0.9600	0.6665	0.9269	1.1917	1.5308	1.1948
5-7	0.6737	1.1224	0.8386	0.5738	1.0683	0.6089	0.9688	1.1340	1.5509	1.2260

	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	0.2125	0.0343	0.1327	0.0761	0.1343	0.0550	0.0016	0.0359	0.1431
2-7	1.2838	1.8042	1.1988	1.4031	1.6304	1.2479	1.0596	1.9582	1.6907
3-7	1.4137	1.9515	1.2623	1.4047	1.7079	1.4461	1.2205	2.3128	1.9353
4-7	1.3633	1.9266	1.3384	1.4384	1.7581	1.6584	1.3311	2.5150	2.1819
5-7	1.3704	1.9384	1.3460	1.4865	1.6897	1.5577	1.2264	2.4217	1.8229

	1992
1	0.1027
2-7	2.0643
3-7	2.2871
4-7	2.2871
5-7	2.2871

Table C11. Continued

C.) Spawning Stock Biomass

SSB AT THE START OF THE SPAWNING SEASON - males & females (1000s MT)

■	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1 ■	1.056	0.214	0.633	0.349	1.156	1.348	0.678	1.022	2.125	1.434
2 ■	2.554	2.616	0.898	2.482	1.492	5.415	4.870	3.641	5.371	15.306
3 ■	5.277	1.630	0.542	0.629	1.542	1.228	3.616	2.613	2.115	4.048
4 ■	2.898	2.253	0.668	0.263	0.339	0.702	0.648	1.396	0.847	0.843
5 ■	1.132	1.099	0.743	0.358	0.097	0.203	0.242	0.298	0.273	0.251
6 ■	1.214	0.432	0.315	0.392	0.128	0.046	0.077	0.098	0.069	0.053
7 ■	0.300	0.591	0.292	0.373	0.179	0.082	0.019	0.034	0.005	0.005
1+■	14.431	8.835	4.092	4.845	4.934	9.024	10.151	9.102	10.806	21.941

■	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1 ■	0.279	0.359	0.411	0.150	0.391	3.847	0.609	0.213	0.086	0.103
2 ■	5.938	1.007	1.648	1.543	0.575	1.794	19.488	2.759	0.698	0.379
3 ■	8.354	2.151	0.608	0.799	0.501	0.349	1.608	10.916	1.858	0.311
4 ■	1.321	1.407	0.451	0.215	0.173	0.107	0.142	0.315	1.068	0.440
5 ■	0.355	0.272	0.273	0.116	0.049	0.022	0.018	0.012	0.033	0.073
6 ■	0.066	0.073	0.073	0.057	0.017	0.018	0.004	0.003	0.001	0.004
7 ■	0.021	0.006	0.023	0.013	0.005	0.006	0.000	0.000	0.006	0.002
1+■	16.334	5.276	3.487	2.894	1.710	6.144	21.869	14.219	3.749	1.312

The above SSBs by age (a) and year (y) are calculated following the algorithm used in the NEFSC projection program, i.e.

$$SSB(a,y) = W(a,y) \times P(a,y) \times N(a,y) \times \exp[-Z(a,y)]$$

where $Z(a,y) = 0.4167 \times M(a,y) + 0.4167 \times F(a,y)$
$N(a,y)$ - Jan 1 stock size estimates (males & females)
$P(a,y)$ - proportion mature (generally females)
$W(a,y)$ - weight at age at the beginning of the spawning season

The $W(a,y)$ are assumed to be the same as the mid-year weight at age estimates (see "WT AT AGE" table in input section).

highly variable or inconsistent survey indices. Catch at ages 7 and 8 were combined in a plus group. The input exploitation pattern reflected full recruitment at age 3, as in previous assessments (*e.g.*, Conser, *et al.* 1991). Fishing mortality for ages 7+ was assumed equal to fishing mortality for age 6 fish. Instantaneous natural mortality (M) was assumed to equal 0.2, as in previous assessments. The partial recruitment vector for the terminal year was taken from Conser, *et al.* (1991); age-specific partial recruitment values were assigned as 0.02 and 0.35 for ages 1 and 2 and 1 for ages 3 to 7. The SARC suggested further examination of the partial recruitment vector, particularly for changes in recent years.

Fishing mortality levels obtained from virtual population analysis have remained within high ranges observed previously (F=1.6 from 1990 estimates, Conser, *et al.* 1991, Figure 7), although reliability of the estimates has deteriorated. There is no analytic evidence of any decline in fishing mortality since 1990 (Table C11). Exploitation rates may possibly be near 85% in 1992 (comparable to 75% as estimated in the 1990 assessment for 1990). The age structure in the stock and catches has been reduced to the point that results of virtual population analyses are compromised.

Estimates of 1992 fishing mortality were fairly insensitive to alternative definitions of plus groups as ages 5+ or 6+. Designation of a 5+ group implies fishing mortality for the fully-recruited portion of the stock is defined primarily by fishing mortality on age 3 in any year in these analyses. Examination of the residual errors using influence and LOWESS smoothing (Rago, *et al.*, in prep.) revealed no significant departure from the ADAPT model assumptions.

Stock size in numbers, although imprecisely estimated, reflected a continuous decline since the appearance of the 1987 year class (Table C11). Stock numbers in 1992 were close to if not the lowest in the 1973-1992 time series. Spawning stock biomass likewise appeared low, comparable to record-low levels in 1986-1987 (Figure C7, C8). In 1992, the contribution of the 1987 year class to the stock numbers and spawning stock biomass was negligible.

The three most recent year classes, 1989-1990, were the smallest of the 1973-1992 series, estimated at about 6, 4 and 5.5 million, respectively (Figure C7). The abundance of the 1992 year class in 1993 was estimated using 1993

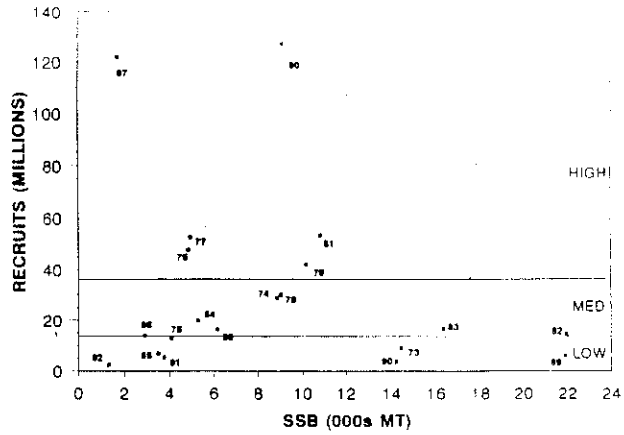

Figure C8. Spawning stock biomass (thousands of metric tons) and recruitment (millions), Southern New England yellowtail flounder, 1973-1992. Points are labeled by year class. Observations serving as the basis for high, medium, and low recruitment used in stochastic projections are separated by soild lines.

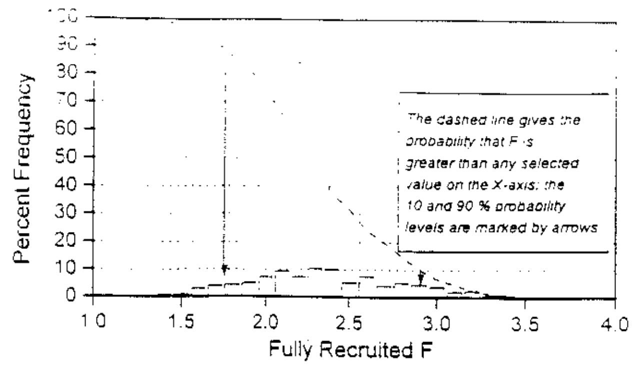

Figure C10. Precision of the estimates of fishing mortality for Southern New England yellowtail flounder derived from a statistical procedure known as bootstrap. The vertical bars give the range and probability of individual values within that range. The dashed line gives the probability that F is less than any selected value on the x-axis.

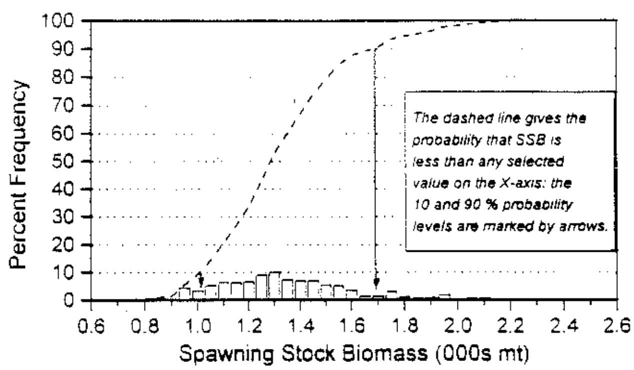

Figure C9. Precision of the estimates of spawning stock biomass for Southern New England yellowtail flounder derived from a statistical procedure known as bootstrap. The vertical bars give the range and probability of individual values within that range. The dashed line gives the probability that SSB is less than any selected value on the x-axis.

spring survey data and the associated catchability coefficient estimated from the ADAPT procedures. The year class was estimated to be about 2.5 million, but with extremely low precision (approximate coefficient of variation of 133%).

Precision of estimates of survivors (1993) was low, although comparable with that of the previous assessment. Approximate coefficients of variation ranged between 50 and 55% for estimates of numbers at age, 1993, except for age 1. Previously, approximated coefficients of variation ranged between 44 and 76% (age 1 not estimated). Estimates were biased 19% high for age 2 and 5 to 6% for older ages. To address the low precision of the estimates, 500 bootstrap replicates were conducted. Bootstrapped estimates of coefficients of variation for stock sizes at ages 2, 3, and 4 to 7+ in 1993 were 84%, 62% and 55%, after correcting estimates for bias. The 1993 age 1 value was extremely poorly estimated, with coefficients of variation exceeding 300% and bias exceeding 100%.

Spawning stock biomass at the start of the 1992 spawning season (1300 mt) was estimated with little bias, and a coefficient of variation of 20%. The entire distribution of spawning stock biomass estimates was below 2300 mt., *i.e*, the probability that spawning stock biomass exceeded 2300 mt in 1993 less than 1 in 500 (Figure 9).

A coefficient of variation of 20% was associated with the estimate of fully-recruited F in the terminal year, based on bootstrap analysis. The lowest bootstrap realization of fully-recruited F was 1.20, *i.e.*, the probability of F being less than 1.2 was less than 1 in 500 (Figure C10). Coefficients of variation for F at ages 1 and 2 were 68% and 38%, respectively.

Table C12. Input parameters and projection results for Southern New England yellowtail flounder, landings, discard and spawning stock biomass (000 mt). Stock size in 1993 is based on results of bootstrap replications. Recruitment is drawn randomly from a pool of high, medium or low observations from the virtual population time series. Results are averaged over 500 replications. Proportion of F, M before spawning =0.4167 (peak spawning 1 May). Mean weights at age from 1992 landings and discard at age.

Age	Fishing Mortality Pattern	Proportion Landed	Proportion Mature	Mean Weight Catch	Mean Weight Landings	Mean Weight Discards
1	0.02	0.090	0.13	0.167	0.301	0.167
2	0.35	0.244	0.74	0.316	0.347	0.308
3	1.00	0.512	0.98	0.367	0.386	0.351
4	1.00	0.773	1.00	0.430	0.460	0.353
5	1.00	0.900	1.00	0.597	0.631	0.344
6	1.00	1.000	1.00	0.779	0.802	0.276
7	1.00	1.000	1.00	1.409	1.432	0.276

			1993			1994			1995		
F_{93}	$F_{94\text{-}95}$	Rec.	Land.	Disc.	SSB	Land.	Disc.	SSB	Land.	Disc.	SSB
2.3	2.3	High	564	744	1052	603	1197	2262	2686	6999	9860
(SQ)	(SQ)	Med	564	744	1052	550	900	1315	1011	2209	3034
	Low		564	744	1052	535	819	1053	548	894	1157
2.3	2.1	High				572	1112	2312	2554	6539	10231
(SQ)	(-10%)	Med				524	843	1363	989	2091	3177
	Low					510	769	1101	557	864	1237
2.3	1.1	High				403	714	2548	1850	4338	11983
(SQ)	(-50%)	Med				377	563	1592	835	1468	3930
	Low					369	522	1327	550	675	1714
2.3	0.5	High				213	349	2758	1032	2164	13636
(SQ)	(F_{20}%)	Med				202	284	1797	542	781	4775
	Low					198	265	1531	406	399	2336

Yield per Recruit and Spawning Stock Biomass per Recruit Analyses

Biological reference points were calculated in 1990 based on a Thompson-Bell model (Conser, *et al.* 1991)(Figure 7). Analyses were not revised in this assessment because the partial recruitment vector may vary over the short-term as a function of stock and year class abundance; and no trend in weight at age was observable. Based on the 1990 analysis, $F_{0.1}$ = 0.22, F_{max} = 0.48 and $F_{20\%}$ = 0.49. Proportion discarded at age was based on fitted retention curves (Figure C3).

Short-Term Projections

Because of the uncertainty in estimates of numbers at age in 1993, a stochastic projection was undertaken. Each of the 500 realized population vectors at age in 1993 from ADAPT bootstrap runs was projected forward through 1995 under an F option of interest. Three levels of recruitment were considered for each F option. For the high recruitment option, recruitments in 1993-1995 for each iteration were drawn randomly from a pool of the top 33% of estimated recruitment values from 1973-1992 (Figure 8), consisting of seven values between 41.9 and 126.9 million. For medium and low recruitment, recruitment was drawn randomly from pools containing middle and lower 33% of observed recruitment values, each containing seven values between 14.0 and 30.0 million and 2.5 and 12.9 million, respectively.

Four F options were considered:

	F_{1993}	F_{1994}	F_{1995}
1. Status quo	2.3	2.3	2.3
2. Status quo, reduced 10% in 1994-95	2.3	2.1	2.1
3. Status quo, reduced 50% in 1994-95	2.3	1.1	1.1
4. $F_{20\%MSP}$ in 1994-95	2.3	0.5	0.5

Mean landings, discard and spawning stock biomass resulting from the 500 realizations are summarized by F option, recruitment level and year in Table C12.

Partial recruitment for the projection was set equal to that used in VPA (described in Conser, *et al.*, 1991). Weights at age were based on observed values for 1992. Total catch at age was apportioned between landings and discard based on estimated ratios of discard to catch, 1989-1992, estimated from the retention curve (Figure C3).

Landings and spawning stock biomass levels in 1993 were predicted to decline to new record low levels under all options and recruitment scenarios (below 600 mt and 1000 mt, respectively). In 1994, landings remained at or below 600 mt in all cases, and continued to decline under medium and low recruitment scenarios, to about 200 mt when F was reduced to $F_{20\%}$. By 1995, three consecutive years of high recruitment could increase spawning stock biomass to 10,000 to 14,500 mt, with highest spawning stock biomass from most restrictive F option. If recruitment is assumed to be totally independent of spawning stock biomass, the probability of 3 consecutive years of high recruitment would be $(0.33)^3$ =0.04. If recruitment is dependent on spawning stock biomass, the probability of three consecutive "high" recruitment levels would be substantially less. Medium recruitment would produce spawning stock biomasses ranging from 3,000 to 5,000 mt, while low recruitment would maintain spawning stock biomass at or below 2,500 mt, although with slight increases under more restrictive fishing mortality options. Under three consecutive years of medium recruitment, landings could range from 540 mt ($F_{20\%}$) to 1,000 mt ($F_{2.3}$), with associated spawning stock biomasses of 4,800 mt to 3,000 mt.

The SARC noted that the projection methodology incorporated the uncertainty of the estimates of stock size, and partially accounted for the uncertainty in future recruitment. Alternative formulations of recruitment stochasticity, including incorporation of a stock-recruitment function, should be examined.

SUMMARY

1. Stock abundance is at record-low levels, based on results of research vessel surveys, and virtual population analyses.

2. Stock abundance has declined continuously since the recruitment of the 1987 year class. This year class is absent or insignificant in age-structured indices of abundance and landings in 1992.

3. The three most recent year classes, 1989-1991, appear to be among the poorest observed over the 1973-1992 period examined here. From initial indications of the NESFC spring survey, the 1992 year class is likely to be below average.

4. The age structure of the stock has become truncated in recent years to contain few or no fish older than age 5.

5. Fishing mortality rates are well in excess of biological reference levels, with exploitation rates of approximately 85%.

6. Traditional analytic techniques including virtual population analysis, and separable models are compromised for this stock by truncated age structure in the stock, and likely changing fishery targeting patterns with year class strength or regulation. Precision of assessment results is declining with stock status.

RESEARCH RECOMMENDATIONS

- Evaluate potential changes in growth, sex ratios and maturity related to increased fishing pressure, decreasing stock size, and possibly, water temperature.

- Evaluate potential bias in length frequency distributions and age-length keys arising from cluster sampling by sex.

- Develop sea sampling coverage to allow direct estimation of discards for all seasons of the fishery.

- Investigate alternative models for population assessment.

REFERENCES

Brown, B. E. and R. C. Hennemuth. 1971. Assessment of the yellowtail flounder fishery in Subarea 5. ICNAF [International Commission for Northwest Atlantic Fisheries] *Res. Doc.* 71/14, Serial No. 2599 (mimeo).

Conser, R. J., L. O'Brien and W. J. Overholtz. 1991. Stock assessment of the Georges Bank and Southern New England yellowtail flounder stocks. Woods Hole, MA: NOAA/NMFS/NEFSC. *Lab. Ref. Doc.* 91-12, Appendix.

Conser, R. J. and J. E. Powers. 1990. Extension of the ADAPT VPA tuning method designed to facilitate assessment work on tuna and swordfish stocks. *ICCAT* [International Commission for Conservat ion of Atlantic Tunas] *Coll. Vol. Sci. Pap.* 32:461-467.

Gavaris, S. 1988. An adaptive framework for the estimation of population size. *CAFSAC* [Canadian Atlantic Fisheries Scientific Advisory Committee] *Res. Doc.* 88/29.

Lux, F. E. 1963. Identification of New England yellowtail flounder groups. *Fish. Bull.* (U.S.) 63:1-10.

Rago, P., W. Gabriel, and M. Lambert. In prep. Assessment of yellowtail flounder (*Pleueronectes ferrugineus*), 1993. NOAA/NMFS/NEFSC Ref. Doc.

Royce, W. F., R. J. Buller and E. D. Premetz. 1959. Decline of the yellowtail flounder (*Limanda ferruginea*) off New England. *Fish. Bull.* (U.S.) 146: 169-267.

D. BLUEFISH

TERMS OF REFERENCE

The following terms of reference were established for bluefish by the Steering Committee:

a. Agree on standard aging methodology and/or length-based aging methods for bluefish.

b. Compile catch at age for commercial and recreational bluefish fisheries from Maine to Florida.

c. Compile research catch per tow indices for bluefish from available state and federal surveys from Maine to Florida.

d. Assess the status of bluefish through 1992 and characterize the variability of stock abundance and fishing mortality rates. Review past biological reference points and update as necessary.

e. Provide 1994 projected estimates of catch and 1995 SSB options at various levels of F.

The Stock Assessment Workshop (SAW) Pelagic/Coastal Subcommittee met on October 25-26, 1993 and on November 16, 1993 at the Connecticut Division of Marine Fisheries in Old Lyme, Conn. to initiate a reassessment of the status of Atlantic coast bluefish in response to direction from the SAW Steering Committee. At the October meeting, the Subcommittee considered terms of reference A-C, and developed a consistent series of catch at age data and fishery independent survey indices. Results of the initial meeting and associated data are included in this report. Based on the acceptance of the catch at age matrix, the data were distributed to Subcommittee in early November for analysis with retrospective techniques including ADAPT tuning of VPA (Parrack 1986, Gavaris 1988, Conser and Powers 1990) and CAGEAN (Deriso, *et al.* 1985; catch-age analysis). At the November meeting, several trial runs using both methods were considered, using different underlying assumptions and combinations of tuning indices, but the Subcommittee was unable to reach a consensus on estimates of stock size and fishing mortality rates. Therefore, terms of reference D and E were not met.

INTRODUCTION

Bluefish *(Pomatomus saltatrix)* are found along the U.S. Atlantic coast from Maine to Florida, migrating northward from the South Atlantic Bight in the spring and returning southward in the late fall. They are the target of a major recreational fishery along the Atlantic coast, with catches averaging 44,200 mt per year during 1979 to 1992. For the same period, the commercial landings of bluefish, mainly by otter trawls, averaged 6,300 mt per year. The management unit for the Fishery Management Plan (FMP) for the Bluefish Fishery, developed jointly by the Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC), has been defined as the entire bluefish population along the Atlantic Coast of the United States (MAFMC 1990).

Atlantic coast bluefish exhibit fast growth during the first two years of life, attaining fork lengths of over 40 cm by age 2 (Hamer 1959, Lassiter 1962, Richards 1976, Wilk 1977). They may reach ages of at least 12 years and sizes in excess of 100 cm fork length and 14 kg in weight. About fifty percent of bluefish reach sexual maturity by the second year of life, and they are fully mature by age 2 (Wilk 1977). Spawning occurs during two major periods: March and April in the South Atlantic Bight near the inner edge of the Gulf Stream, with a peak about 1 April; and June through September in the Mid-Atlantic Bight, with a peak about 1 August (Wilk 1977, Kendall and Walford 1979, Nyman and Conover 1988). Some spawning also occurs in the South Atlantic Bight during the fall and into early winter (September through January; McBride, *et al.* 1993).

Lund and Maltezos (1970) used analysis of mark and recapture data to conclude that several bluefish populations are present along the Atlantic coast. Wilk (1977) suggested that two populations of bluefish, corresponding to the major spawning groups, exist along the Atlantic coast. Chiarella and Conover (1990) presented evidence that fish from the major spawning groups mix extensively during their lifespan, as summer spawning fish were observed to originate from both spring- and summer-spawned cohorts, and concluded that year classes of bluefish therefore consist of varying proportions of seasonal cohorts. Graves, *et al.* (1992) used analysis of mitochondrial DNA to investigate the genetic basis of stock structure of bluefish along the Atlantic coast, and were unable to detect significant genetic differences among spring- and summer-spawned bluefish. Graves, et al. (1992) concluded that bluefish along the mid-Atlantic coast comprise a single genetic stock.

In anticipation of a fisheries management plan to regulate commercial and recreational catches of Atlantic coast bluefish, the ASMFC and the MAFMC, in cooperation with the National Marine Fisheries Service (NMFS), began work on stock assessment in 1986. Length frequency data collected by the Northeast Fisheries Science Center (NEFSC) (bottom trawls, 1974-1986) and NMFS Marine Recreational Fishery Statistics Survey (MRFSS) (1979-1985) was available for analytical assessment (*i.e.*, virtual population analysis). However, no consistent time series of geographically comprehensive age-length keys were available for estimating age frequency from length frequency data. Therefore, an age-length key (hereafter referred to as the ASMFC pooled key) was developed by pooling data collected by the fisheries agencies of several Atlantic coast states from 1982 to 1986 (Crecco, et al. 1987, Terceiro 1987).

There were concerns about the potential for biased results using the ASMFC pooled key, due to influence of interannual variation in growth, recruitment, or mortality rate, given the broad temporal and geographic scale over which the age-length data were collected (Westrheim and Ricker 1978). As a result, no consensus was reached on the utility of the ASMFC pooled key, catch at age data, or subsequent analyses presented in Crecco, et al. (1987) and Terceiro (1987).

Following implementation of the bluefish FMP in 1990, stock assessment work for bluefish was renewed by ASMFC. A yield-per-recruit analysis was developed to provide new biological reference points. Parameters of the von Bertalanffy growth function ($L_t = L_{inf}[1 - e^{-K(t-t0)}]$), derived from weighted mean calculated lengths at annulus formation presented in NOAA (1989), were used as an expedient alternative to the ASMFC pooled key to age MRFSS sample bluefish length frequency data by cohort slicing (*i.e.*, solving for t in the von Bertalanffy growth equation, given L_{inf}, L_t, K, and t_0). Length at age, weight at age, and partial recruitment vectors for the yield-per-recruit analysis were developed from this version of the MRFSS length-age data.

Reviews of this yield-per-recruit analysis at the Eleventh NEFSC Stock Assessment Workshop (NEFSC 1990) noted that variation in mean lengths at age and subsequently derived growth parameters, likely inherent when data from several disparate sources are considered, could lead to biased results from cohort slicing. The Eleventh NEFSC Stock Assessment Workshop (NEFSC 1990) recommended testing alternative methods, such as mixture of distributions methods, and data sources in lieu of a time-series of age-length keys for the estimation of bluefish ages from length frequency data. Terceiro and Ross (1993) compared the utility of two simple methods for estimating bluefish ages from length-frequency data (cohort slicing using growth parameters, and application of a pooled age-length key) with two more rigorous statistical methods (the iterated age-length key method of Kimura and Chikuni (1987), and the MULTIFAN method of Fournier, *et al.* (1990)). Terceiro and Ross (1993) found that MULTIFAN was the best alternative to a time series of fishery-specific age-length keys for the estimation of Atlantic coast bluefish ages from length data.

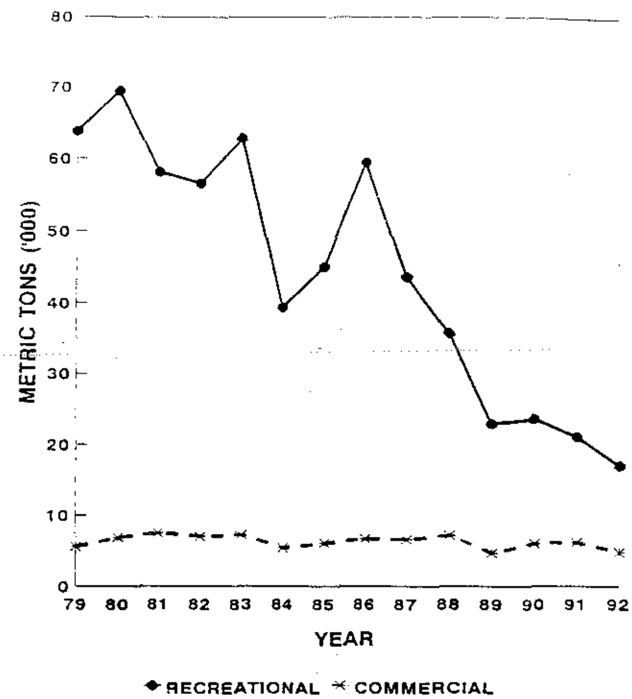

Figure D1. Trends in recreational catch (includes catch type B2, fish released alive) and commercial landings for bluefish, Maine to Florida, 1979-1992.

FISHERY DATA

Commercial Landings

Total U.S. commercial landings of bluefish from Maine to Florida peaked in 1981 at nearly 7,500 mt (16 million pounds, Table D1, Figure

Table D1. Estimated bluefish catch: commercial landings, recreational landings, recreational catch, and foreign landings, Maine to Florida, east coast (metric tons). Recreational landings include catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 25% of type B2 (fish released alive, assuming a 25% discard mortality rate). Recreational catch includes catch types A and B1, plus all catch type B2. Total landings include commercial landings, recreational landings, and foreign landings. Total catch includes commercial landings, recreational catch, and foreign landings.

Year Landings	Commercial Landings	Foreign Landings	Recreational[1] Catch	Recreational[1] Landings	Total Catch	Total
1960	1,251	0	N/A	11,475	N/A	12,726
1961	1,401	0	N/A	N/A	N/A	N/A
1962	2,256	0	N/A	N/A	N/A	N/A
1963	2,123	0	N/A	N/A	N/A	N/A
1964	1,743	0	N/A	N/A	N/A	N/A
1965	1,847	0	N/A	20,528	N/A	22,375
1966	2,172	0	N/A	N/A	N/A	N/A
1967	1,671	0	N/A	N/A	N/A	N/A
1968	2,159	0	N/A	N/A	N/A	N/A
1969	2,445	0	N/A	N/A	N/A	N/A
1970	2,952	0	N/A	27,024	N/A	29,976
1971	2,624	23	N/A	N/A	N/A	N/A
1972	3,115	18	N/A	N/A	N/A	N/A
1973	4,556	214	N/A	N/A	N/A	N/A
1974	4,538	99	N/A	N/A	N/A	N/A
1975	4,502	103	N/A	N/A	N/A	N/A
1976	4,547	1	N/A	N/A	N/A	N/A
1977	4,802	4	N/A	N/A	N/A	N/A
1978	5,629	35	N/A	N/A	N/A	N/A
1979	4,983	28	59,168	63,759	64,179	68,770
1980	6,858	23	64,559	69,612	71,440	76,493
1981	7,466	71	50,197	58,216	57,734	65,753
1982	6,996	77	52,133	56,573	59,206	63,646
1983	7,166	33	55,464	62,859	62,663	70,058
1984	5,381	68	33,389	39,327	38,838	44,776
1985	6,124	18	40,833	44,977	46,975	51,119
1986	6,657	28	51,151	59,365	57,836	66,050
1987	6,579	2	35,952	43,479	42,533	50,060
1988	7,162	0	28,575	35,666	35,737	42,828
1989	4,740	0	18,225	22,965	22,965	27,705
1990	6,246	0	18,223	23,705	24,469	29,951
1991	6,160	0	15,280	21,067	21,440	27,227
1992	5,024	0	12,241	16,994	17,265	22,018

[1] Marine Angling Survey estimates, adjusted as per Boreman (1983) - these surveys used a different methodology than the MRFSS, and are not directly comparable to recreational catch estimates since 1979.

D1). The reported landings in 1992 of about 5,024 mt (about 11 million pounds) were an 18% decrease from 1991. Large variability in bluefish landings exist among the states, over time, but generally the states of North Carolina, Virginia, New Jersey, New York, Florida, Rhode Island, and Massachusetts have accounted for more than 90% of the commercial landings (Table D2).

Northeast Region Commercial Fishery

A summary of length frequency and age sampling of bluefish landings sampled by the NEFSC commercial fishery weighout system in the Northeast Region (NER; Maine to Virginia) is presented in Table D3. For comparability with the manner in which length frequency sampling in the recre-

Table D2. Bluefish commercial landings by state (metric tons), 1979-1992

Year	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
1979	15	1	362	170	25	792	719	18	147	1243	884	1	*	606	4983
1980	44	1	315	166	22	675	635	74	198	1278	2469	1	0	978	6858
1981	44	20	371	160	142	581	832	89	188	1061	2998	1	*	978	7466
1982	75	30	406	270	136	781	898	232	131	1176	1946	4	*	911	6996
1983	77	14	454	235	31	765	873	132	150	689	3060	5	0	680	7166
1984	22	8	318	462	45	742	767	71	83	525	1614	1	0	719	5381
1985	41	10	362	767	82	968	902	85	231	749	1635	*	0	288	6124
1986	48	28	709	518	86	733	1362	181	207	686	1565	4	1	528	6657
1987	47	58	362	537	79	709	1149	161	165	536	2069	1	1	702	6579
1988	4	10	366	464	46	510	1126	95	468	1186	2286	1	1	596	7162
1989	35	62	562	549	88	256	718	47	125	349	1493	1	0	453	4740
1990	24	89	546	537	81	731	984	65	129	491	2077	*	0	488	6246
1991	56	58	343	676	117	716	1110	153	106	373	1778	*	0	672	6160
1992	39	103	215	703	112	675	997	42	93	269	1288	1	0	487	5024

Source: unpublished NMFS General Canvas data.
* = less than 1 mt; na = not available;
Note: numbers may not total due to rounding and preliminary nature of 1992 data by state

Table D3. Summary of NEFSC sampling of the NER (ME-VA) commercial fishery for bluefish, 1982-1992. Age samples are currently archived. NEFSC weighout landings are those characterized directly by length frequency sample data. Total NER landings include weighout plus general canvas data. Length frequency distributions based on NEFSC weighout landings are raised to NER total landings.

Year	Samples	Lengths	Ages	NEFSC Weightout Landings (mt)	NER Total Landings (mt)	Sampling Intensity (Total mt/100 lengths)
1982	9	942	141	1,622	4,135	439
1983	20	1,900	401	1,515	3,420	180
1984	22	2,045	456	1,477	3,043	149
1985	18	1,581	376	2,087	4,197	265
1986	20	1,838	445	3,411	4,558	248
1987	11	1,105	250	2,847	3,803	344
1988	20	1,961	450	2,401	4,225	215
1989	6	590	150	1,953	2,791	473
1990	4	402	52	2,765	3,677	915
1991	2	201	51	2,792	3,708	1845
1992	4	400	50	2,839	3,248	812

ational fishery has been evaluated, sampling intensity is expressed in terms of metric tons of total NER landings per 100 fish lengths measured. The sampling is proportionally stratified by market category and fishing gear, with the sampling distribution generally reflecting the distribution of weighout landings by market category and gear. Sampling intensity has been in general low, deteriorated since 1988, and was very poor during 1990-1992.

Length composition of the NER commercial landings for 1982-1992 was estimated annually for pooled market categories and statistical areas, using standard NEFSC procedures (length frequency samples converted to mean weights by length-weight relationships; mean weights in turn divided into landings to calculate numbers at length; Table D4). Length compositions were estimated by gear type when samples were adequate (1983-1988). The NER commercial landings at length matrix does not include the landings from states not participating in the NEFSC weighout system (*e.g.*, North Carolina to Florida).

No age data from NER fisheries are available for conversion of the NER landings at length, although the age structures (scales) are archived. For this assessment, the Subcommittee compared the mean weights in the NER fishery with those from the North Carolina (N.C.) winter fisheries (gillnet and otter trawl) as a means of judging the applicability of North Carolina Division of Marine Fisheries (NC DMF) commercial winter fishery age-length keys for aging NER commercial fishery lengths. The Subcommittee judged that mean weights in the fisheries were similar, and so NC DMF commercial winter fishery annual age-length keys were used to convert NER commercial fishery length data to age. For 1990-1992, the NER commercial fishery length sampling was judged to be inadequate to provide a reliable sample of the landings (Table D3). To overcome this deficiency, the N.C. commercial winter fishery proportions at age were applied to the NER commercial fishery landings to estimate landings at age (Tables D4-D5).

North Carolina Commercial Fishery

The N.C. commercial fishery accounts for about one-third (30 to 35%) of the commercial landings along the Atlantic coast. A separate landings at age matrix for this component of the commercial fishery was developed from NC DMF length-age frequency sampling data. The NC DMF program sampled the commercial fishery landings at a rate of about 100 mt of landings per 25 ages during 1982-1992 (Table D6). Lengths

Table D4. Northeast region (Maine to Virginia) commercial fishery landings at age for bluefish (thousands of fish). The 1982-1989 lengths were converted to age using NC DMF annual age-length keys from the North Carolina winter fishery. The 1990-1992 landings were assumed to have the same age composition as the North Carolina winter fishery landings.

	Age												Total
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
1982	505	994	848	846	51	56	49	14	4	0	0	0	3368
1983	2	364	1498	369	68	27	43	31	15	2	0	3	2422
1984	247	1184	2358	195	29	19	12	10	3	1	0	0	4059
1985	83	640	790	375	400	40	53	60	40	20	0	1	2503
1986	74	2069	2025	70	32	139	87	35	21	9	0	0	4561
1987	0	47	488	1064	292	22	44	25	10	0	0	0	1993
1988	230	318	717	323	398	220	98	75	23	9	9	0	2420
1989	49	490	713	53	62	201	113	60	26	0	4	0	1770
1990	341	624	71	37	53	110	376	105	137	4	0	0	1858
1991	569	1017	2465	10	15	48	86	163	86	1	1	0	4461
1992	976	4858	203	124	42	202	2	2	3	2	0	0	6414

Table D5. Northeast region (Maine to Virginia) commercial fishery landings mean weights at age (kilograms) for bluefish

	Age											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1982	0.198	0.621	1.159	1.979	2.853	4.511	5.297	5.684	5.194			
1983	0.416	0.852	0.981	1.980	3.054	4.296	5.715	6.354	6.751	7.870		7.449
1984	0.422	0.610	0.682	1.561	2.381	4.410	5.331	6.068	6.378	7.030		
1985	0.430	0.562	0.882	2.113	2.787	3.552	5.276	6.174	6.407	6.755		7.247
1986	0.583	0.689	0.727	2.024	3.199	4.201	4.621	5.398	6.284	6.816		
1987	0.427	0.771	0.992	1.897	2.575	3.976	5.088	5.615	5.887			
1988	0.270	0.428	0.856	1.686	2.769	3.507	4.368	5.017	5.858	6.192	5.645	
1989	0.347	0.509	0.649	1.947	3.552	4.042	4.162	4.719	5.580		7.247	
1990	0.343	0.569	0.864	1.782	2.591	3.565	3.854	4.040	4.710	7.710		
1991	0.334	0.300	0.502	1.782	3.251	3.578	4.435	5.421	5.252	7.710	8.000	
1992	0.214	0.381	1.113	1.745	2.333	2.980	4.145	4.731	4.981	7.710		

Table D6. Summary of NC DMF sampling of the North Carolina commercial fishery for bluefish, 1982-1992

Year	Sampled Ages	North Carolina Commercial Landings (mt)	Sampling Intensity (mt/25 ages)
1982	490	1,946	99
1983	596	3,060	129
1984	854	1,614	47
1985	548	1,635	75
1986	437	1,565	89
1987	381	2,069	136
1988	346	2,286	166
1989	320	1,493	117
1990	372	2,077	140
1991	279	1,778	159
1992	606	1,288	53

and ages are sampled from the summer pound net, summer long haul seine, winter gill net, and winter trawl fisheries, and separate matrices were developed for each, before summing to provide an estimate of total N.C. commercial fishery landings at age and mean weights at age (Tables D7-D8).

Commercial Discards

Data on bluefish catch have been collected by the NEFSC sea sampling program in the Gulf of Maine groundfish gillnet fishery and the Southern New England/Mid-Atlantic otter trawl fishery for 1989-1992. The Subcommittee found these data indicated that in both fisheries, discards have comprised less than 10% of the total catch per trip. Length frequency sampling has been inconsistent, and the data are not adequate to develop an estimate of either total discard or discard at length for the 1989-1992 period.

Commercial Fishery-based Indices of Abundance

A General Linear Model (GLM; SAS 1989) standardized index of abundance for bluefish was developed based on NER commercial otter trawl fishery weighout data for 1982-1992. An initial model including year, state, calendar quarter, 3-digit statistical area, and tonnage class explained 31% of the variation in log-transformed otter trawl landings per trip (mt per days fished), but interaction terms between state/area and quarter/area were statistically significant and nearly as important as the main effects, and some empty cells were present. Aggregating areas to 2-digit divisions reduced the magnitude of the interaction terms, but they still were nearly as important as the main effects, and empty cells remained. A final main effects model incorporating year, state, calendar quarter, and tonnage class had no empty cells, minor potential interaction terms, and explained 25% of the variation in log-transformed otter trawl landings per trip. This index indicated a pattern of decreasing stock size from 1985 to 1988, with a stable level since 1989 (Table D9, Figure D2). Proportions at age from the NER fishery (in weight) were applied to this index to develop an age-disaggregated index for VPA tuning (after division by mean weights to provide an index in numbers (Table D10).

GLM standardized indices of abundance have also been developed from total catch per trip data (landings plus discard, metric tons per days fished) for trips sampled in the otter trawl and sink gillnet groundfish fisheries. Significant main effects (other than year) were calendar quarter and individual vessel in both models. The year effect was not significant in the gillnet fishery model, suggesting no effect of stock biomass on CPUE, although this model was significant and explained a large proportion (41%) of the variation in log-transformed catch per trip. The otter trawl model also did not have a significant (at the 1% level) year effect, although R^2 = 0.51. The Subcommittee judged that neither index of abundance based on sea sampling data gave a reliable estimate of bluefish stock abundance.

Recreational Catch and Effort

Summary fishery statistics collected by the MRFSS are presented in Tables D11-D16. The 1992 recreational fishery total catch (catch type

Table D7. North Carolina commercial fishery landings at age for bluefish. This matrix is a sum of component matrices from the North Carolina landings from pound nets, long haul seines, gill nets, and trawls. Landings from South Carolina, Georgia, and Florida are included in the gillnet landings.

	Age												Total
	0	1	2	3	4	5	6	7	8	9	10	11	
1982	2621	1464	42	17	4	17	45	57	42	18	3	1	4331
1983	647	1277	592	66	51	190	191	86	32	1	0	0	3134
1984	553	583	308	20	36	145	79	45	19	0	2	0	1790
1985	551	922	56	19	38	55	127	39	25	4	0	1	1837
1986	870	744	178	4	24	126	64	51	27	9	1	0	2097
1987	699	894	323	146	105	82	151	60	12	3	0	0	2474
1988	287	323	163	38	100	182	14	224	50	3	0	0	1385
1989	300	424	92	33	78	173	46	44	12	5	0	0	1208
1990	430	721	87	24	33	68	232	65	84	2	0	0	1747
1991	505	977	1562	6	9	28	50	95	50	1	1	0	3283
1992	511	2798	156	63	20	98	1	1	1	1	0	0	3649

Table D8. North Carolina commercial fishery mean weights at age for bluefish

	Age											
	0	1	2	3	4	5	6	7	8	9	10	11
1982	0.307	0.603	2.357	1.597	3.123	4.293	5.100	5.468	6.221	7.000	6.928	7.710
1983	0.236	0.391	0.903	1.866	2.852	3.931	4.733	5.104	5.936	7.000		
1984	0.249	0.489	0.840	1.330	3.393	4.655	5.467	5.835	6.506		6.500	
1985	0.207	0.404	0.759	1.816	2.545	4.530	4.729	5.734	5.981	6.800		7.710
1986	0.308	0.487	0.860	2.602	3.275	3.944	4.235	4.608	6.015	6.009	6.123	
1987	0.217	0.316	0.924	1.617	3.246	4.035	4.837	5.197	6.250	7.250		
1988	0.288	0.533	0.842	1.745	2.445	3.386	6.100	4.960	5.350	6.500		
1989	0.280	0.487	0.734	1.819	3.130	4.261	4.705	5.398	5.670	4.989		
1990	0.255	0.599	0.932	1.821	2.598	3.566	3.854	4.041	4.710	7.700		
1991	0.271	0.350	0.526	1.764	3.251	3.578	4.432	5.421	5.252	7.710	6.928	
1992	0.212	0.375	0.960	1.725	2.333	2.980	4.145	4.731	4.981	7.710		

Table D9. General Linear Model (GLM) standardization of NER commercial otter trawl fishery (1982-1992) landings per trip (mt per day fished), for all trips landings any bluefish. Variation in log-transformed landings per trip (LNCPUE) is modeled with year (YR), state (ST), quarter (QTR), and tonnage class (TC), as main effects, with no interactions. The corrected, retransformed YR parameter estimates are indices of stock biomass.

Dependent variable: LNCPUE

SOURCE	DF	SS	MSE	F	PR > F	R-SQUARE
Model	22	33468.7	1521.3	600.89	0.0001	0.25
Error	40628	102860.3	2.5			
Total	40650	136329.0				

Model SS

VARIABLE	DF	TYPE III SS	F	PR > F
YR	10	720.0	28.4	0.0001
ST	7	14218.5	802.3	0.0001
QTR	3	9604.7	1264.6	0.0001
TC	2	3586.2	708.2	0.0001

Corrected, retransformed YR parameter estimates

	Estimate	Lower 95% CI	Upper 95% CI
1982	1.279	1.185	1.381
1983	1.001	0.932	1.089
1984	1.154	1.072	1.243
1985	1.453	1.356	1.558
1986	1.225	1.141	1.316
1987	1.103	1.025	1.187
1988	0.923	0.856	0.995
1989	1.005	0.931	1.085
1990	1.037	0.960	1.121
1991	1.079	1.005	1.160
1992	1.000		

A: fish landed and available for sampling, plus type B1: fish landed but not available for sampling, plus type B2: fish released alive) was about 17,000 mt (37.5 million lb), well below the 1979-1991 average of 46,300 mt (102 million lb; Tables D1 and D11, Figure D1). The share of total catch taken by the recreational sector was 77% in 1992. The proportion of fish released alive has increased since 1979, peaking at 37.3% of total catch in 1992 (Table D11).

The number of directed bluefish trips (those catching bluefish, or with bluefish indicated as a target species but with zero catch) was estimated by applying the proportion of sampled trips targeting bluefish by two-month sampling wave/state/fishing mode/fishing area (distance from shore) strata to the estimated number of fishing trips for all species in those strata (Table D14, Figure D3). Nominal catch per trip in number and weight (Tables D15-D16) was calculated from the total catch estimates. These indices of abundance indicate a steady decline in bluefish stock size and biomass since 1979. On a regional and fishing mode basis, these nominal indices of abundance have declined at higher rates in the North Atlantic region (Maine-Conn.) than in the

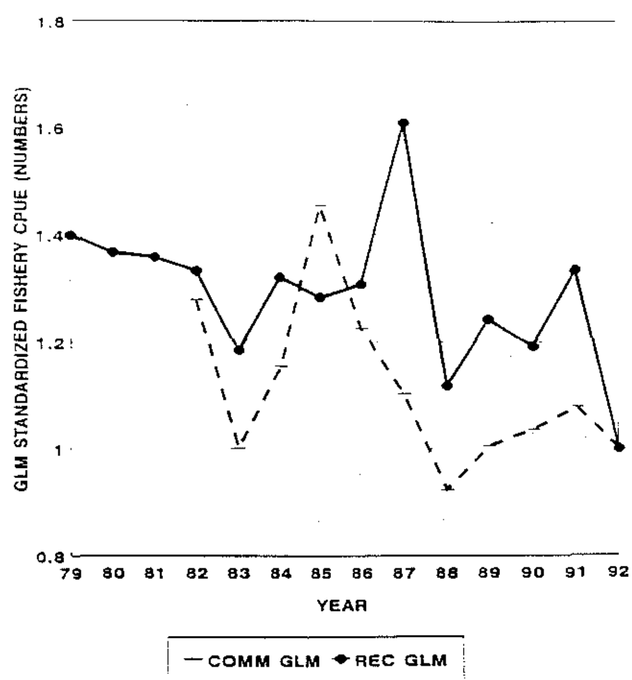

Figure D2. Indices of stock abundance for bluefish, based on recreational and commercial fishery General Linear Model (GLM) standardized catch (numbers) per unit effort.

Table D10. General Linear Model (GLM) standardized index of abundance at age (in numbers) for bluefish from the NER commercial otter trawl fishery

	Age											
	0	1	2	3	4	5	6	7	8	9	10	11
1982	0.200	0.394	0.336	0.335	0.020	0.022	0.019	0.006	0.002	0.000	0.000	0.000
1983	0.001	0.108	0.445	0.110	0.020	0.008	0.013	0.009	0.004	0.001	0.000	0.001
1984	0.108	0.518	1.033	0.085	0.013	0.008	0.005	0.004	0.001	0.000	0.000	0.000
1985	0.042	0.322	0.398	0.189	0.202	0.020	0.026	0.030	0.020	0.010	0.000	0.001
1986	0.024	0.682	0.667	0.023	0.010	0.046	0.029	0.012	0.007	0.003	0.000	0.000
1987	0.000	0.015	0.156	0.340	0.094	0.007	0.014	0.008	0.003	0.000	0.000	0.000
1988	0.046	0.063	0.143	0.064	0.079	0.044	0.019	0.015	0.005	0.002	0.002	0.000
1989	0.018	0.177	0.258	0.019	0.023	0.073	0.041	0.022	0.009	0.000	0.001	0.000
1990	0.185	0.224	0.021	0.014	0.018	0.033	0.101	0.028	0.035	0.001	0.000	0.000
1991	0.444	0.459	0.592	0.003	0.012	0.023	0.025	0.041	0.021	0.001	0.000	0.000
1992	0.503	0.682	0.104	0.126	0.042	0.061	0.001	0.001	0.001	0.000	0.000	0.000

Mid-Atlantic (N.Y.-Vir.) and South Atlantic (N.C.-Fla.) regions. This may imply that the availability of bluefish to anglers in New England waters has declined relative to the more southern waters (Figures D4-D5).

The length frequency sampling intensity for the recreational fishery for bluefish was calculated on a metric tons of total catch per 100 lengths measured basis. Sampling intensity has not met the generally accepted target of 200 mt per 100 lengths measured, and in most years has been very poor relative to this target level (Burns, *et al.* 1983)(Table D17). The length composition of the recreational catch during 1979-1992 was estimated by two-month sampling period (wave), state, fishing mode (shore and boat), and fishing area (inland and territorial sea, EEZ) strata by merging MRFSS intercept length frequency samples with estimated type A, B1, and B2 catches. Catch types B1 and B2 were assumed to have the same length frequency distribution as catch type A, and catch type B2 was assumed to have a hooking (discard) mortality rate of 25%, based on analogy with species such as striped bass (Diodati 1991), black sea bass (Bugley and Shepherd 1991), and Pacific halibut (IPHC 1988). The length frequencies of the recreational catches in 1980 (highest level of recreational catch since implementation of the MRFSS in 1979), 1987 (average level of recreational catch in MRFSS time series), and 1992 (most recent year, lowest level of recreational catch in MRFSS time series) are presented in Figure D6.

No age structures are sampled by the MRFSS from fish captured in the recreational fishery. The Subcommittee considered two options for converting recreational lengths to ages: 1) using MULTIFAN (Fournier, *et al.* 1990), a mixture of distributions method for resolving ages from length frequencies using maximum likelihood methods, and incorporating consideration of growth patterns, or 2) application of NC DMF commercial fishery annual age length keys. An initial comparison for three years (1983, 1987, and 1992) suggested the results would be comparable for ages 0 to 3, with some divergence at older ages. The MULTIFAN method tended to convert larger lengths to ages based on the mean pattern of growth (which is influenced strongly by the growth pattern evident for the younger ages) and to form a large "plus group." The NC DMF keys tended to provide a smoother decline in numbers at age, improved coherence of strong and weak cohorts at age 5 and older, and a broader distribution at older ages.

The Subcommittee performed a comparison of Connecticut Department of Marine Fisheries (CT DMF) trawl survey age-length keys for 1984-1987 with the NC DMF commercial keys using the method of Hayes (1993) to determine if application of those keys would cause a serious bias in conversion of lengths to age if applied to

Table D11. Estimated total number (thousands) of bluefish caught by recreational fishermen, MRFSS 1979-1992. Shore fishing mode includes catch taken from beaches, banks, and man-made structures; boat fishing mode includes catch taken from party/charter and private/rental boats. For annual totals, numbers of fish released alive (catch type B2) is also totaled and expressed as a percentage of the total catch. Total landed includes catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 25% of type B2 (fish released alive, assuming a 25% discard mortality rate).

Region/ Mode	Year													
	1979	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	1883	3359	2176	3898	7010	2656	2120	2211	2345	600	425	1189	2301	1015
Boat	3444	4064	6907	6398	6756	3686	5812	8435	4686	2030	1628	1830	2709	2218
Total	5327	7423	9083	10296	13766	6342	7932	10646	7031	2630	2053	3019	5010	3233
Mid (New York-Virginia)														
Shore	3409	7628	5902	3095	5085	6228	3926	6187	3801	1019	4458	2198	4594	1011
Boat	20897	19486	11855	11882	13758	11077	9718	12192	13910	8362	7421	7579	5268	4840
Total	24306	27114	17757	14977	18843	17305	13644	18379	17711	9381	11879	9777	9862	5851
South (North Carolina-Florida)														
Shore	3565	2816	3302	3258	3134	3309	2608	1895	1662	2393	2095	2288	1161	1379
Boat	2548	4445	1859	4413	6894	2862	2842	1206	1553	1778	1151	1644	981	1435
Total	6113	7261	5161	7671	10028	6171	5450	3101	3215	4171	3246	3932	2142	2814
All Regions														
Shore	8857	13803	11380	10251	15229	12193	8654	10293	7808	4012	6978	5675	8056	3405
Boat	26889	27995	20621	22693	27408	17625	18372	21833	20149	12170	10200	11053	8958	8493
Total	35746	41798	32001	32944	42637	29818	27026	32126	27957	16182	17178	16728	17014	11898
Total B2	3440	4032	5874	3441	6679	6005	3316	5930	6449	4290	4729	5158	6233	4435
Percent B2	9.9	9.6	18.4	10.4	15.7	20.1	12.3	18.5	23.1	26.5	27.5	30.8	36.6	37.3
Total Landed	33166	38774	27596	30363	37628	25314	24539	27679	23120	12965	13631	12860	12339	8572

Table D12. Estimated total weight (mt) of bluefish caught by recreational fishermen, MRFSS 1979-1992. Shore fishing mode includes catch taken from beaches, banks, and man-made structures; boat fishing mode includes catch taken from party/charter and private/rental boats. For annual totals, weight of fish released alive (catch type B2) is also totaled and expressed as a percentage of the total catch. Total landed includes catch type A (fish landed and available for sampling), type B1 (fish landed but not available for sampling), and 25% of type B2 (fish released alive, assuming a 25% discard mortality rate).

	Year													
Region/ Mode	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	936	1010	825	762	3302	497	1377	2844	1209	943	892	2295	2713	1298
Boat	10201	11580	24111	26030	18993	9048	13373	26276	12186	7388	5776	5393	6413	5658
Total	11137	12590	24936	26792	22295	9545	14750	29120	13395	8331	6668	7688	9126	6956
Mid (New York-Virginia)														
Shore	1225	3747	2004	964	3071	1002	2048	3786	1244	652	1214	1245	1649	509
Boat	45483	46422	26295	24061	22016	21743	19668	23389	25635	22307	12377	12592	8043	7299
Total	46708	50169	28299	25025	25087	22745	21716	27175	26879	22959	13591	13837	9692	7808
South (North Carolina-Florida)														
Shore	2121	2172	4240	1232	2334	2103	1395	1605	1427	2380	1501	1228	1172	1065
Boat	3793	4681	741	3524	13143	4934	7116	1465	1778	1996	1205	952	1077	1165
Total	5914	6853	4981	4756	15477	7037	8511	3071	3205	4376	2706	2180	2249	2230
All Regions														
Shore	4282	6929	7069	2958	8707	3602	4820	8235	3880	3975	3607	4768	5534	2872
Boat	59477	62683	51146	53615	54152	35725	40157	51129	39599	31691	19358	18937	15533	14122
Total	63759	69612	58216	56573	62859	39327	44977	59365	43479	35666	22965	23705	21067	16994
Total B2	6137	6713	10684	5908	9845	7921	5518	10959	10028	9455	6323	7309	7716	6333
Percent B2	9.9	9.6	18.4	10.4	15.7	20.1	12.3	18.5	23.1	26.5	27.5	30.8	36.6	37.3
Total Landed	59168	64559	50197	52133	55464	33389	40833	51151	35952	28575	18225	18223	15280	12241

Table D13. Estimated mean weight per fish (kilograms), MRFSS 1979-1992. Shore fishing mode includes fish taken from beaches, banks, and man-made structures; boat fishing mode includes fish taken from party/charter and private/rental boats.

Region/ Mode	**Year**													
	1979	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	0.497	0.301	0.379	0.195	0.471	0.187	0.650	1.286	0.516	1.572	2.099	1.930	1.179	1.279
Boat	2.962	2.849	3.491	4.068	2.811	2.455	2.301	3.115	2.601	3.639	3.548	2.947	2.367	2.551
All	2.091	1.696	2.745	2.602	1.620	1.505	1.860	2.735	1.905	3.168	3.248	2.547	1.822	2.152
Mid (New York-Virginia)														
Shore	0.359	0.491	0.340	0.311	0.604	0.161	0.522	0.612	0.327	0.640	0.272	0.566	0.359	0.503
Boat	2.177	2.339	2.218	2.025	1.600	1.963	2.024	1.918	1.843	2.668	1.668	1.661	1.527	1.508
All	1.922	1.850	1.594	1.673	1.331	1.314	1.592	1.479	1.518	2.447	1.144	1.415	0.983	1.334
South (North Carolina-Florida)														
Shore	0.595	0.771	1.284	0.378	0.745	0.636	0.535	0.847	0.859	0.995	0.716	0.537	1.009	0.772
Boat	1.489	1.053	0.399	0.799	1.906	1.724	2.504	1.215	1.145	1.123	1.047	0.579	1.098	0.812
All	0.967	0.944	0.965	0.620	1.543	1.140	1.562	0.990	0.997	1.049	0.834	0.554	1.050	0.792
All Regions														
Shore	0.483	0.502	0.621	0.289	0.572	0.295	0.557	0.800	0.497	0.991	0.517	0.840	0.687	0.843
Boat	2.212	2.239	2.480	2.363	1.976	2.207	2.186	2.342	1.965	2.604	1.898	1.713	1.734	1.663
All	1.784	1.665	1.819	1.717	1.474	1.319	1.664	1.848	1.555	2.204	1.337	1.417	1.238	1.428

Table D14. Estimated total number (thousands) of fishing trips for bluefish (trips with bluefish catch or bluefish indicated as a target species), summarized by subregion/mode, MRFSS 1979-1992. Shore fishing mode includes fishing from beaches, bank, and man-made structures; boat fishing mode includes fishing from party/charter and private/rental boats.

	Year													
Region/ Mode	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	478	382	534	628	1212	596	644	1168	790	820	399	1037	1646	1337
Boat	775	1149	1077	907	1842	1029	1873	2228	1379	1328	1063	1274	1393	1462
Total	1253	1531	1611	1535	3054	1625	2517	3396	2169	2148	1462	2311	3039	2799
Mid (New York-Virginia)														
Shore	1667	2718	1403	2080	2004	1650	1779	2087	1357	1218	1519	1326	1471	1089
Boat	4813	7728	3398	3847	4167	3813	2974	4155	4119	3089	2922	2900	2049	2443
Total	6480	9946	4801	5927	6171	5463	4753	6242	5476	4307	4441	4226	3520	3532
South (North Carolina-Florida)														
Shore	1540	878	2053	1560	2077	2364	2240	1221	916	1651	1773	1484	1228	1288
Boat	939	1348	658	1382	1461	1617	1515	537	681	1107	807	1019	679	846
Total	2479	2226	2711	2942	3538	3981	3755	1758	1597	2758	2580	2503	1907	2134
All Regions														
Shore	3685	3978	3990	4268	5293	4610	4663	4476	3063	3689	3691	3847	4345	3714
Boat	6527	9725	5133	6136	7470	6459	6362	6920	6179	5524	4792	5193	4121	4751
Total	10212	13703	9123	10404	12763	11069	11025	11396	9242	9213	8483	9040	8466	8465

Table D15. Estimated catch per unit effort (number/trip) for bluefish, MRFSS 1979-1992 (trips with bluefish catch or bluefish indicated as a target species). Shore fishing mode includes catch taken from beaches, banks, and man-made structures; boat fishing mode includes catch taken from party/charter and private/rental boats.

Region/	Year													
Mode	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	3.939	8.793	4.075	6.207	5.784	4.456	3.292	1.893	2.968	0.732	1.065	1.147	1.398	0.759
Boat	4.444	3.537	6.413	7.054	3.668	3.582	3.103	3.786	3.398	1.529	1.532	1.436	1.945	1.517
Total	4.251	4.848	5.638	6.707	4.508	3.903	3.151	3.135	3.242	1.224	1.404	1.306	1.649	1.155
Mid (New York-Virginia)														
Shore	2.045	2.806	4.207	1.488	2.537	3.775	2.207	2.965	2.801	0.837	2.935	1.658	3.123	0.928
Boat	4.342	2.696	3.489	3.089	3.302	2.905	3.268	2.934	3.377	2.707	2.540	2.613	2.571	1.981
Total	3.751	2.726	3.699	2.527	3.053	3.168	2.871	2.944	3.234	2.178	2.675	2.314	2.802	1.657
South (North Carolina-Florida)														
Shore	2.315	3.207	1.608	2.088	1.509	1.400	1.164	1.552	1.814	1.449	1.182	1.542	0.945	1.071
Boat	2.714	3.297	2.825	3.193	4.719	1.770	1.876	2.246	2.280	1.606	1.426	1.613	1.445	1.696
Total	2.466	3.262	1.904	2.607	2.834	1.550	1.451	1.764	2.013	1.512	1.258	1.571	1.123	1.319
All Regions														
Shore	2.404	3.470	2.852	2.402	2.877	2.645	1.856	2.300	2.549	1.088	1.891	1.475	1.854	0.917
Boat	4.120	2.879	4.017	3.698	3.669	2.729	2.888	3.155	3.261	2.203	2.129	2.128	2.174	1.788
Total	3.500	3.050	3.508	3.166	3.341	2.694	2.451	2.819	3.025	1.756	2.025	1.850	2.010	1.406

Table D16. Estimated catch per unit effort (kilograms per trip) for bluefish, MRFSS 1979-1992 (trips with bluefish catch or bluefish indicated as a target species). Shore fishing mode includes catch taken from beaches, banks, and man-made structures; boat fishing mode includes catch taken from party/charter and private/rental boats.

Region/ Mode	**Year**													
	1979	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
North (Maine-Connecticut)														
Shore	1.958	2.644	1.545	1.213	2.724	0.834	2.138	2.435	1.530	1.150	2.236	2.213	1.648	0.971
Boat	13.163	10.078	22.387	28.699	10.311	8.793	7.140	11.794	8.837	5.563	5.434	4.233	4.604	3.870
Total	8.888	8.223	15.479	17.454	7.300	5.874	5.860	8.575	6.176	3.878	4.561	3.327	3.003	2.485
Mid (New York-Virginia)														
Shore	0.735	1.379	1.428	0.463	1.532	0.607	1.151	1.814	0.917	0.535	0.799	0.939	1.121	0.467
Boat	9.450	6.423	7.738	6.254	5.283	5.702	6.613	5.629	6.224	7.221	4.236	4.342	3.925	2.988
Total	7.208	5.044	5.894	4.222	4.065	4.163	4.569	4.354	4.909	5.331	3.060	3.274	2.753	2.211
South (North Carolina-Florida)														
Shore	1.377	2.474	2.065	0.790	1.124	0.890	0.623	1.314	1.558	1.442	0.847	0.827	0.954	0.827
Boat	4.039	3.473	1.126	2.550	8.996	3.051	4.697	2.728	2.611	1.803	1.493	0.934	1.586	1.377
Total	2.386	3.079	1.837	1.617	4.375	1.768	2.267	1.746	2.007	1.587	1.049	0.871	1.179	1.045
All Regions														
Shore	1.162	1.742	1.772	0.693	1.645	0.781	1.034	1.840	1.267	1.078	0.977	1.239	1.274	0.773
Boat	9.112	6.446	9.964	8.738	7.249	5.531	6.312	7.389	6.409	5.737	4.040	3.647	3.769	2.972
Total	6.244	5.080	6.381	5.438	4.925	3.553	4.080	5.209	4.705	3.871	2.707	2.622	2.488	2.008

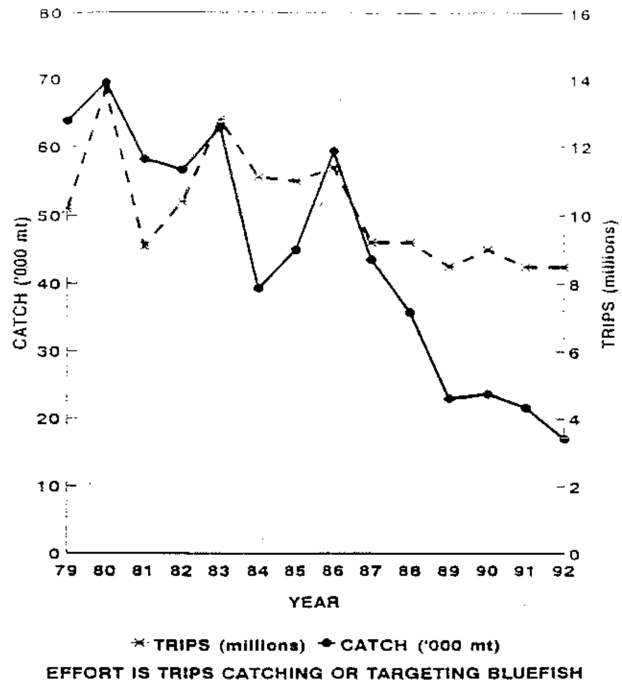

Figure D3. Trends in recreational catch and effort for bluefish, Maine to Florida, 1989-1992. Catch includes fish released alive (catch type B2), effort is trips catching or targeting bluefish.

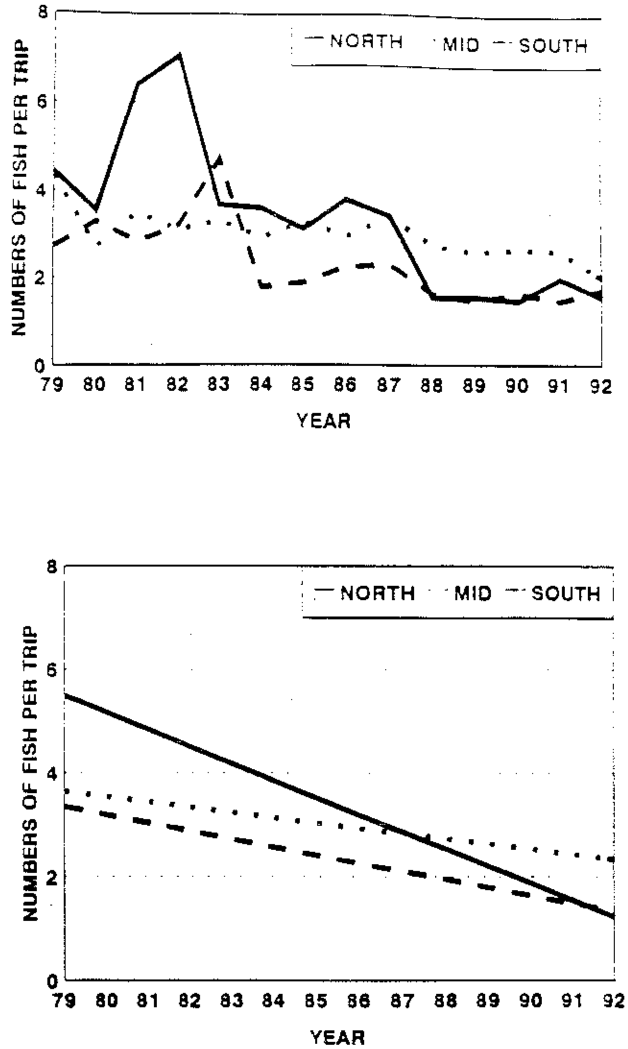

Figure D4. Trends in nominal recreational catch per trip (CPUE) for bluefish for anglers fishing from boats in the North Atlantic (Maine-Connecticut), Mid-Atlantic (New York-Virginia) and South Atlantic Regions (North Carolina-Florida). Top panel shows nominal CPUE, bottom panel shows linear regression line over the time series.

recreational fishery length frequencies. The method computes the probability of obtaining the observed difference between proportions at age for a given length interval in the age-length key by random chance. The method suggested no serious bias would be caused if the annual NC DMF age-length keys were used to age the recreational length data.

For further comparison, the recreational lengths were converted to age using both methods to develop parallel recreational catch at age and mean weights at age matrices, and thus parallel total (commercial and recreational) catch at age and mean weights at ages matrices, for the 1982-1992 time series. After considering the results of application of the Hayes method (1993) and upon inspection of the catch at age matrices developed with the alternative length to age conversion methods, the Subcommittee judged the use of the NC DMF keys to be the preferred approach, and adopted the catch at age matrices compiled with the keys as the best estimate of recreational catch at age (Tables D18-D19).

Recreational Fishery-based CPUE Indices

In addition to the nominal indices derived from estimated catch and effort statistics (described above), the intercept sample data from the MRFSS 1979-1992 were used directly to develop an index of abundance. The Subcommittee suggested a revision of previous analyses to include not only those trips catching bluefish, but also those with zero catch which targeted

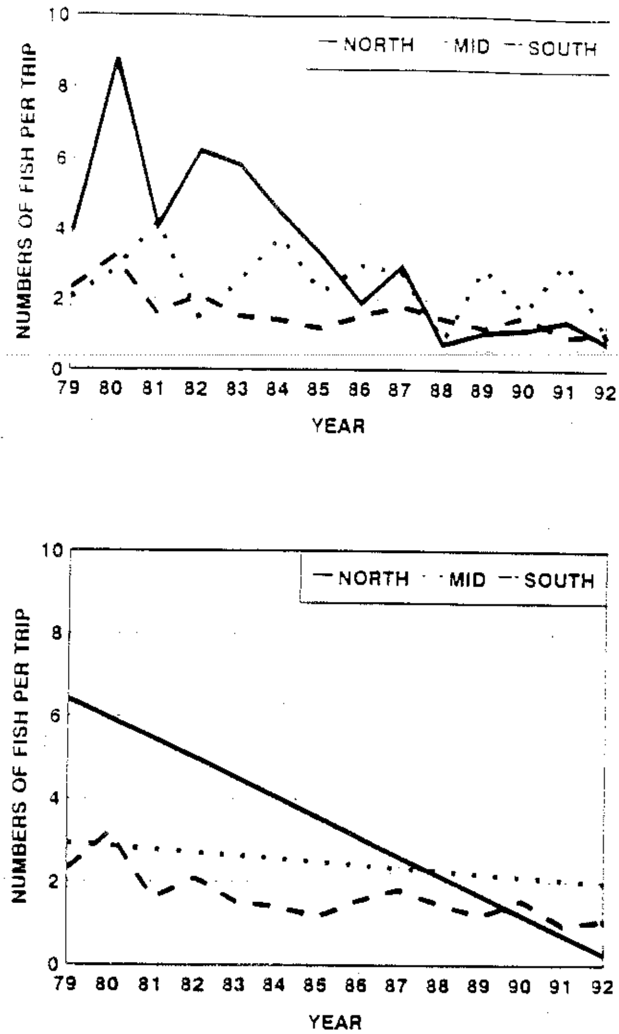

Figure D5. Trends in nominal recreational catch per trip (CPUE) for bluefish for anglers fishing from shore in the North Atlantic (Maine-Connecticut), Mid-Atlantic (New York-Virginia) and South Atlantic Regions (North Carolina-Florida). Top panel shows nominal CPUE, bottom panel shows linear regression line over the time series.

bluefish as the primary or secondary species sought. A GLM analysis was used to model the variation in MRFSS intercept log-transformed catch per trip for all intercepts coastwide, and produce a standardized index of stock numbers based on year category regression coefficients. A main effects (year, state, two-month sampling wave, and fishing mode) model accounted for about 9% of the variation in intercept catch per trip. This standardized index suggests a general decline in bluefish abundance since 1979 (Table D20, Figure D2). Age-disaggregated indices for VPA tuning were calculated by applying propor-

Table D17. Summary of MRFSS sampling of the recreational fishery for bluefish, 1979-1992

Year	Lengths	Estimated Total Catch (mt)	Sampling Intensity (mt/ 100 lengths)
1979	6,883	63,759	926
1980	10,825	69,612	643
1981	5,221	58,216	1,115
1982	3,835	56,573	1,479
1983	5,322	62,859	1,181
1984	4,206	39,327	935
1985	6,699	44,977	671
1986	4,952	59,365	1,199
1987	5,325	43,479	817
1988	2,762	35,666	1,291
1989	8,009	22,965	287
1990	7,189	23,705	330
1991	6,705	21,066	314
1992	5,120	16,994	332

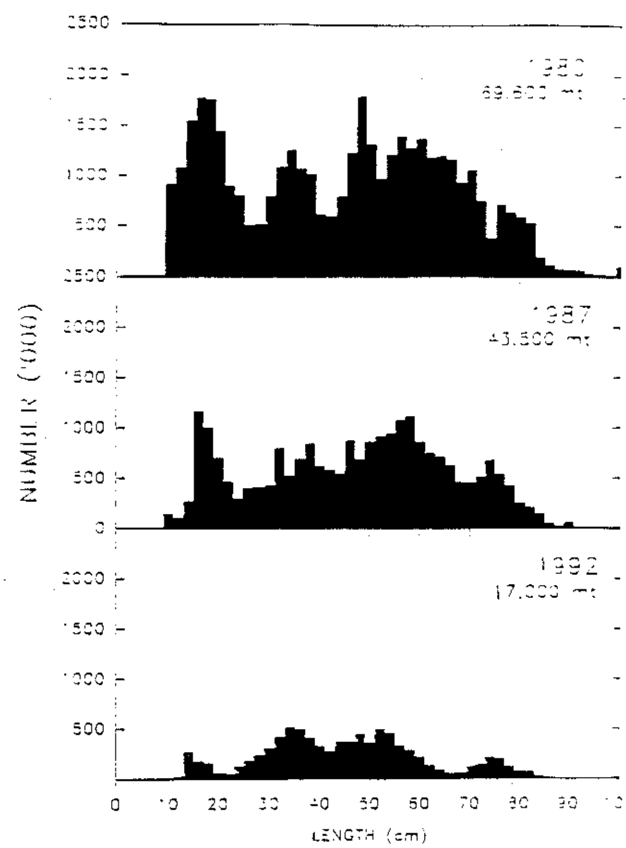

Figure D6. Length frequency distribution of bluefish in the recreational fishery for 1980, 1987, and 1992. Includes catch type B2 (catch released alive) assuming a hooking (discard) mortality rate of 25%.

Table D18. Recreational fishery (Maine to Florida) catch at age (thousands) for bluefish. Catch type B2 (catch released alive) included with a hooking mortality rate of 25%. Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age													
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1982	9178	9669	2516	1966	805	1212	1427	1181	953	1140	175	83	57	30363
1983	8559	8361	8469	2980	1179	1506	2569	1607	921	1071	127	216	64	37628
1984	7377	5789	4642	1927	900	725	948	975	717	1015	107	128	64	25314
1985	4633	5629	5419	3413	1038	636	1415	728	732	779	60	0	58	24539
1986	5930	4704	6876	3244	1111	1474	1159	927	1318	905	31	0	0	27679
1987	2510	4662	4575	4779	1721	1039	1584	1054	661	501	34	0	0	23120
1988	1464	2307	2585	1374	1368	1023	696	825	562	514	181	12	55	12965
1989	2774	4503	2367	946	245	765	627	556	514	273	37	7	19	13631
1990	1967	6205	1798	681	322	280	574	287	315	411	8	8	4	12860
1991	2448	3169	3151	1532	291	149	421	632	384	131	17	11	4	12339
1992	631	2255	1717	2275	528	180	176	317	320	159	6	6	2	8572

Table D19. Recreational fishery (Maine to Florida) mean weights at age (kilograms) for bluefish. Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age												
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1982	0.094	0.429	1.674	2.107	3.178	4.304	5.097	5.831	6.576	8.582	7.756	8.260	8.187
1983	0.057	0.383	0.971	2.205	3.168	4.591	5.718	6.261	6.854	8.744	8.404	7.916	8.404
1984	0.078	0.348	1.022	1.866	2.932	4.505	5.696	6.297	7.195	8.418	7.209	8.404	8.404
1985	0.085	0.362	1.014	1.890	2.810	4.073	5.198	6.158	6.892	8.327	8.404		7.812
1986	0.059	0.405	1.395	2.303	3.156	4.392	4.848	5.674	6.819	7.557	7.812		
1987	0.089	0.287	1.222	2.068	3.011	3.917	4.990	5.908	6.525	8.652	7.812		
1988	0.169	0.388	0.996	1.967	2.817	3.710	4.795	5.358	6.134	7.655	6.360	8.404	7.877
1989	0.111	0.269	1.206	2.167	3.826	4.099	4.824	5.596	6.117	7.805	7.901	7.247	8.203
1990	0.186	0.483	0.879	1.727	3.421	4.585	5.159	5.652	5.946	7.447	8.404	8.404	8.404
1991	0.072	0.333	0.916	1.737	2.790	4.133	5.139	5.882	6.338	7.659	7.635	7.532	8.042
1992	0.055	0.434	1.002	1.878	2.849	3.821	5.132	5.805	5.962	7.876	7.980	7.980	8.404

Table D20. General Linear Model (GLM) of recreational fishery (MRFSS 1979-1992) intercept catch (types A+B1+B2) per trip data to develop standardized index of abundance. Includes trips with bluefish catch and trips with zero bluefish catch but which targeted bluefish. Variation in log-transformed catch per trip (LOGCA) is modeled with year (YR), state (ST), two-month sampling period (WAVE) and fishing mode (MODE) as main effects, with no interactions. The corrected, retransformed YR parameter estimates are indices of stock numbers (total number of fish caught per trip).

Dependent variable: LOGCA

Source	DF	SS	MSE	F	PR > F	R-Square
Model	33	6024.1	182.6	259.6	0.0001	0.09
Error	86649	60939.9	0.7			
Total	86682	66964.0				

MODEL SS

Variable	DF	Type III SS	F	PR > F
YR	13	955.9	104.6	0.0001
ST	13	1854.5	202.8	0.0001
WAVE	5	136.1	38.7	0.0001
MODE	2	2166.4	1540.2	0.0001

Corrected, retransformed YR parameter estimates

	Estimate	Lower 95% CI	Upper 95% CI
1979	1.400	1.356	1.445
1980	1.369	1.329	1.409
1981	1.358	1.313	1.404
1982	1.332	1.285	1.380
1983	1.184	1.146	1.223
1984	1.320	1.274	1.368
1985	1.282	1.243	1.321
1986	1.307	1.267	1.349
1987	1.608	1.559	1.659
1988	1.118	1.084	1.153
1989	1.242	1.209	1.275
1990	1.192	1.160	1.225
1991	1.334	1.298	1.370
1992	1.000		

tions at age from the recreational fishery (using NC DMF keys) to the annual aggregate indices (Table D21).

Total Catch Composition at Age

NER commercial landings, N.C. commercial landings, and recreational fishery catch (landings plus release mortalities) at age matrices were summed to provide an estimate of total catch at age of bluefish, 1982-1992. Mean weights at age in the total catch were calculated as a weighted mean (by number) of the mean weights at age in the component fisheries (Tables D22-D23).

RESEARCH SURVEY ABUNDANCE AND BIOMASS INDICES

NEFSC Fall Inshore

Long-term trends in bluefish abundance were derived from a stratified random bottom trawl survey conducted by NEFSC between Cape Hatteras and Nova Scotia. Catches of bluefish in spring surveys and in offshore strata are low and sporadic. Bluefish are caught consistently in relatively large numbers during the fall survey, in inshore strata (Tables D24-D26). Generally, over 90% of the bluefish caught in the fall inshore

Table D21. General Linear Model (GLM) standardized index of abundance at age from the recreational fishery (MRFSS 1982-1992). Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age												
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1982	0.407	0.429	0.112	0.086	0.026	0.050	0.063	0.052	0.042	0.051	0.008	0.004	0.003
1983	0.269	0.263	0.266	0.094	0.037	0.047	0.081	0.051	0.029	0.034	0.004	0.007	0.002
1984	0.387	0.304	0.244	0.100	0.041	0.036	0.050	0.051	0.038	0.053	0.006	0.007	0.003
1985	0.245	0.298	0.287	0.176	0.044	0.034	0.075	0.038	0.039	0.041	0.003	0.000	0.003
1986	0.286	0.227	0.332	0.146	0.043	0.064	0.056	0.045	0.064	0.044	0.002	0.000	0.000
1987	0.180	0.335	0.329	0.311	0.113	0.064	0.114	0.076	0.048	0.036	0.002	0.000	0.000
1988	0.131	0.207	0.232	0.108	0.113	0.072	0.062	0.074	0.050	0.046	0.016	0.001	0.005
1989	0.255	0.415	0.218	0.084	0.020	0.064	0.056	0.051	0.047	0.025	0.003	0.001	0.002
1990	0.183	0.579	0.168	0.062	0.025	0.025	0.054	0.027	0.029	0.038	0.001	0.001	0.000
1991	0.266	0.344	0.342	0.165	0.026	0.016	0.046	0.069	0.042	0.014	0.002	0.001	0.000
1992	0.075	0.267	0.203	0.264	0.057	0.016	0.021	0.038	0.038	0.019	0.001	0.001	0.000

Table 22. Total commercial landings and recreational catch at age for bluefish. Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age													
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1982	12304	12127	3406	2829	861	1285	1520	1253	1000	1159	178	84	57	38063
1983	9208	10002	10559	3416	1298	1723	2803	1724	967	1074	128	218	64	43184
1984	8178	7556	7308	2142	965	888	1039	1030	739	1016	109	128	64	31162
1985	5268	7191	6264	3807	1476	731	1594	827	797	804	60	3	58	28880
1986	6874	7516	9079	3318	1165	1739	1310	1013	1367	923	33	0	0	34337
1987	3209	5604	5386	5989	2118	1143	1778	1139	684	503	34	0	0	27587
1988	1981	2948	3465	1736	1866	1425	807	1124	635	526	190	12	55	16770
1989	3123	5417	3172	1032	386	1139	785	660	552	277	42	7	19	16610
1990	2737	7551	1956	742	408	457	1182	457	537	417	8	8	4	16465
1991	3521	5163	7178	1547	315	225	558	890	520	132	20	11	4	20084
1992	2117	9911	2076	2462	591	480	179	320	324	162	6	6	2	18635

survey are less than 40 cm fork length, and therefore mainly age 0 and age 1 fish. For 1982-1992, lengths were converted to ages using the corresponding annual NC DMF commercial fishery age-length keys. The NEFSC survey suggests that strong year classes of bluefish recruited to the stock in 1977, 1981, 1984, 1986, 1988, and 1989. The series indicates that poor recruitment occurred in 1974, 1978, 1983, 1987, 1990, and 1993 (Tables D24 and D26, Figure D7).

Rhode Island DFW

A standardized bottom trawl survey has been conducted during the fall months in Narragansett Bay and state waters of Rhode Island Sound by the Rhode Island Division of Fish and Wildlife (RI DFW) since 1979. An index of age 0 bluefish abundance developed from this survey (mean number per tow less than 30 cm) indicated strong year classes in 1984, 1987, and 1991, with very weak year classes in 1979 and 1992. The RI DFW has also conducted a beach seine survey consisting of 15 stations sampled during June-October since 1986. An age-0 index developed from those data indicated strong year classes in 1987, 1990, and 1991, with the poorest year classes in 1992 and 1993 (Table D27, Figure D7).

Connecticut DEP

A fall (September-October) bottom trawl survey conducted by the Connecticut Department of Environmental Protection (CT DEP) catches bluefish over the full range of lengths in the stock. These data suggest that strong year classes recruited to the stock in 1984-1986, and 1989, with poor year classes in 1987, 1988 and 1993 (Table D28, Figure D7).

Delaware DFW

The Delaware Division of Fish and Wildlife (DE DFW) has conducted a standardized bottom trawl survey (30 ft headrope trawl with 0.5 in. stretch mesh) since 1980. A recruitment index (age 0, fish less than 30 cm) has been developed from these data for the 1980 to 1992 year classes. The index incorporates data collected from June through October (arithmetic mean number per tow), with age 0 bluefish separated from older fish by visual inspection of the length frequency. This index suggests that strongest year classes recruited to the stock in 1988 and 1989, with poorest recruitment in 1981 and 1991 (Table D29, Figure D7).

Virginia Institute of Marine Science

The Virginia Institute of Marine Science (VIMS) has conducted a juvenile fish survey using trawl gear in Virginia rivers since 1955. A index of recruitment developed from these data suggests that since 1979, strongest year classes recruited to the bluefish stock in 1981, 1984, 1989, and 1990, and poorest year classes in 1979-1980, 1985-1987, and 1991. Results are incomplete for 1993. VIMS also conducts a haul seine survey targeting juvenile striped bass in Chesapeake Bay. An index of age 0 abundance for bluefish from this survey indicates strong year classes recruiting in 1983, 1985, 1987, 1991, and 1993, with poor year classes in 1986 and 1992 (Table D30, Figure D7).

North Carolina DMF

The NC DMF has conducted a juvenile fish trawl survey, which samples fixed stations from the Cape Fear River to the mouth of Albermarle and Currituck Sounds at depths < 2 m, during May and June since 1979. One minute tows are made using a trawl with a 3.2 m headrope and 3.2 mm (0.13 in.) mesh codend. Indices of abundance developed from this survey using data for shrimp, croaker, and spot have shown good correlation with landings for those species. For age-0 bluefish, the NC DMF juvenile fish trawl survey suggests that strong year classes recruited to the stock in 1981, 1987, and 1989, with the poorest year classes recruiting in 1984, 1986, and 1992.

A recently established survey has sampled the Neuse and Pamlico Rivers and Pamlico Sound at depths > 2 m since 1987. This survey uses a demersal trawl rigged with a 9.1 m headrope and 1.9 cm (0.75 in.) mesh codend. An index of age-0 bluefish abundance developed from these survey data suggests that the best year classes of bluefish recruited in 1990 and 1991 (Table D31, Figure D7).

Table D23. Total commercial landings and recreational catch mean weights at age (kilograms) for bluefish. Lengths converted to age using NC DMF commercial fishery annual age-length keys.

	Age												
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1982	0.143	0.465	1.554	2.066	3.158	4.313	5.104	5.812	6.556	8.557	7.743	8.251	8.187
1983	0.070	0.401	0.968	2.174	3.149	4.514	5.651	6.205	6.823	8.740	8.374	7.909	8.376
1984	0.100	0.400	0.904	1.833	2.932	4.527	5.674	6.275	7.174	8.416	7.171	8.404	8.404
1985	0.103	0.385	0.995	1.912	2.797	4.079	5.164	6.140	6.839	8.279	8.356	7.473	7.812
1986	0.097	0.491	1.235	2.298	3.160	4.344	4.803	5.611	6.795	7.534	7.672		
1987	0.117	0.296	1.183	2.027	2.962	3.927	4.979	5.865	6.511	8.644	7.812		
1988	0.198	0.408	0.960	1.909	2.787	3.638	4.765	5.256	6.062	7.623	6.327	8.404	7.877
1989	0.131	0.308	1.067	2.144	3.641	4.113	4.722	5.504	6.082	7.758	7.815	7.228	8.203
1990	0.216	0.501	0.881	1.732	3.246	4.189	4.488	5.053	5.436	7.451	8.404	8.404	8.404
1991	0.143	0.330	0.689	1.738	2.826	3.944	4.966	5.748	6.055	7.659	7.631	7.509	8.042
1992	0.166	0.391	1.010	1.867	2.794	3.296	5.116	5.796	5.950	7.873	7.869	7.869	8.404

Table D24. Stratified mean number per tow of bluefish from Cape Cod to Cape Hatteras (inshore strata 1-46) from NEFSC autumn inshore bottom trawl survey

Year	Mean	95% Confidence Interval Low	95% Confidence Interval High	Coefficient of Variation
1974	9.830	5.335	14.326	25.3
1975	14.223	0.351	28.094	49.8
1976	43.944	26.723	61.164	20.0
1977	58.332	15.189	101.474	37.7
1978	14.550	11.105	17.995	12.1
1979	45.528	29.678	61.379	17.8
1980	37.605	13.482	61.729	32.7
1981	107.368	69.352	145.384	18.1
1982	34.246	15.066	53.425	28.6
1983	21.006	6.738	35.425	28.6
1984	59.841	39.575	80.108	17.3
1985	17.736	12.135	23.336	16.1
1986	40.748	-1.037	82.533	52.3
1987	7.444	2.958	11.933	30.8
1988	30.468	-16.489	77.424	78.6
1989	91.273	46.512	136.035	25.0
1990	9.321	5.099	13.543	23.1
1991	15.797	5.670	25.923	32.7
1992	17.865	14.467	21.264	9.7
1993	1.911			

Note: 1993 index is preliminary

Table 25. Stratified mean weight per tow (kilograms) of bluefish from Cape Cod to Cape Hatteras (inshore strata 1-46) from NEFSC autumn inshore bottom trawl survey

Year	Mean	95% Confidence Interval Low	95% Confidence Interval High	Coefficient of Variation
1974	1.475	0.783	2.166	23.9
1975	5.581	1.868	9.293	33.9
1976	5.724	3.765	7.682	17.5
1977	6.546	2.785	10.307	29.3
1978	5.875	4.843	6.906	9.0
1979	7.443	5.604	9.282	12.6
1980	7.031	2.430	11.633	33.4
1981	13.183	9.517	16.849	14.2
1982	4.823	2.484	7.161	24.7
1983	3.958	1.609	6.307	30.3
1984	7.682	5.960	9.404	11.4
1985	3.451	2.658	4.244	11.7
1986	3.913	1.860	5.966	26.8
1987	2.703	1.940	3.467	14.4
1988	1.982	0.379	3.585	41.3
1989	9.132	3.456	14.808	31.7
1990	2.513	1.488	3.358	20.8
1991	2.063	1.109	3.017	23.6
1992	1.363	0.931	1.795	16.2
1993	n/a			

Table D26. Stratified mean number per tow of bluefish at age*: NMFS NEFSC Autumn Inshore Bottom Trawl Survey, Cape Cod to Cape Hatteras (strata 1-46), 1982-1993

Year	Age 0	1	2	3	4	5	6	7	8+	Total
1982	21.632	12.434	0.074	0.061	0.013	0.000	0.002	0.004	0.020	34.246
1983	6.654	13.566	0.687	0.028	0.003	0.014	0.023	0.011	0.021	21.006
1984	39.210	19.697	0.606	0.097	0.058	0.025	0.031	0.033	0.007	59.841
1985	10.770	5.981	0.570	0.264	0.059	0.022	0.026	0.018	0.010	17.736
1986	31.524	8.514	0.448	0.080	0.053	0.039	0.031	0.019	0.033	40.748
1987	1.996	4.670	0.346	0.150	0.069	0.032	0.073	0.044	0.030	7.444
1988	28.733	1.421	0.077	0.018	0.032	0.055	0.033	0.025	0.050	30.468
1989	51.015	40.007	0.130	0.026	0.008	0.031	0.026	0.018	0.012	91.273
1990	4.614	4.369	0.225	0.009	0.013	0.015	0.026	0.017	0.033	9.321
1991	8.856	6.603	0.210	0.089	0.026	0.007	0.001	0.001	0.000	15.797
1992	14.181	3.399	0.169	0.066	0.020	0.003	0.006	0.007	0.009	17.865
1993	0.598	1.138	0.083	0.044	0.011	0.014	0.011	0.003	0.002	1.911

* Aged using annual NC DMF age-length keys from NC commercial fisheries, 1993 NC DMF keys used to age 1992 NEFSC lengths.

Summary of Recruitment Trends in Research Surveys

Indices of abundance for bluefish from research surveys were used to qualitatively detect recent trends in recruitment. Most surveys agreed that the best recent year classes recruited in 1984 and 1989, with relatively poor year classes in 1992 and 1993 (Figure D7).

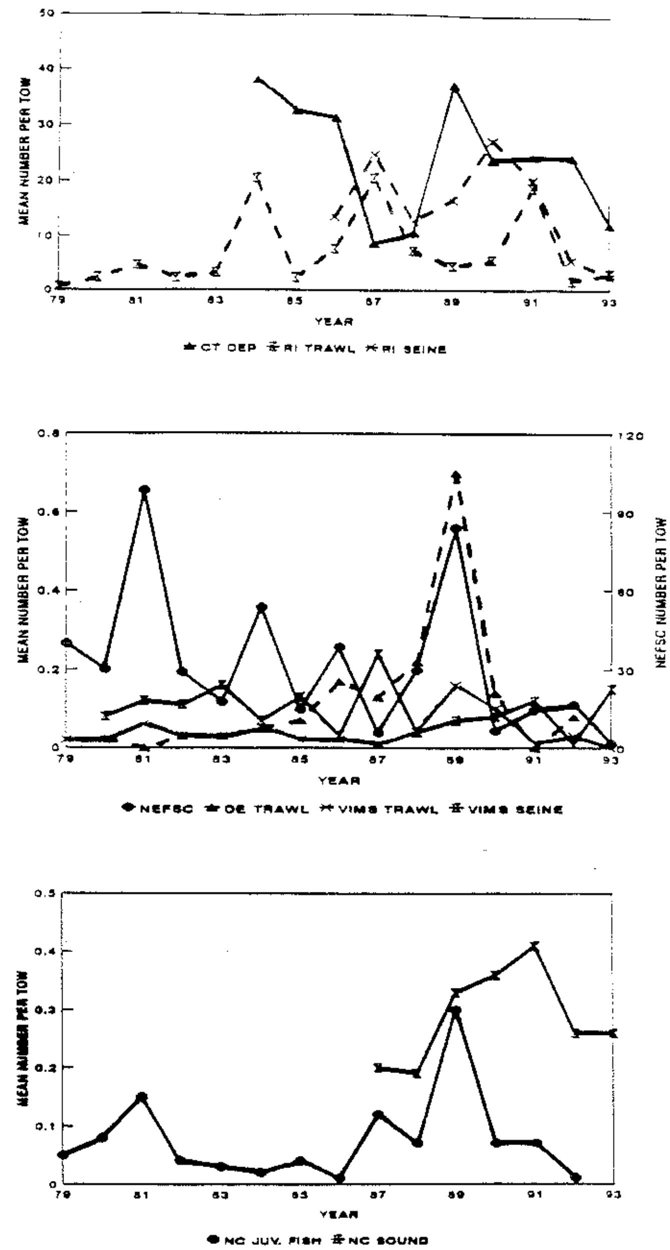

Figure D7. Indices of recruitment (age 0) for bluefish from research trawl surveys.

ASSESSMENT RESULTS

The Subcommittee was unable to reach a consensus on the status of the bluefish stock, but the SARC recognized that the data and analyses that were presented by the Subcommittee represented an interim step in the development of an age-structured assessment. However, the SARC also felt that it was necessary to review the data and analyses presented by the Subcommittee that addressed terms of reference A-C, and to make a statement concerning the status of the stock.

The SARC noted that total catches have declined from a peak of 76,500 mt in 1980 to only 22,000 mt in 1992. Most of the decline has been due to a general decrease in recreational catch. Commercial catches have remained stable (Figure D1). Recreational fishing effort has declined from the peak level in 1980, but has been stable during 1987-1992 (Figure D3). Recent indices of age-0 bluefish abundance from NEFSC, Rhode Island, Connecticut, Delaware, Virginia, and North Carolina research surveys indicated recruitment was strong in 1984 and 1989, and relatively poor in 1992 and 1993 (Figure D7). Indices of stock abundance available from fisheries data suggest a general decline from record high bluefish stock biomass levels since 1979 (Figure D2). Indices of abundance have declined at higher rates in more northern waters, implying that availability of bluefish in New England waters (Maine-Conn.) has declined relative to the Mid-Atlantic (N.Y.-Vir.) and South Atlantic (N.C.-Fla.) regions (Figures D4-D5). Current levels of stock biomass are probably similar to levels that occurred prior to the increase of the stock in the 1970s. The SARC concluded the bluefish stock was at a medium level of historic abundance (1960-1993) and is probably fully exploited.

The declining trend in recreational catch combined with relatively low recruitment since 1989 will likely result in lower recreational catches in 1994. Commercial catches have been stable in recent years. The reasons for the differential trends in the fisheries are not well understood, but probably reflect changes in availability and targeting of local concentrations of bluefish. The SARC concluded that a reduction of the fishing mortality rate on bluefish could be used to reduce the rate of decline of stock abundance.

SARC COMMENTS

The SARC debated at length the appropriateness of various assumptions and analytical techniques used in the bluefish assessment. Various definitions of directed recreational fishing effort for deriving CPUE measures were discussed. These included defining directed effort as only those trips catching bluefish, versus considering both trips catching fish as well as those that target bluefish but have zero catch. Development of an analytical assessment for bluefish is critically dependent on abundance-at-age indices from the recreational survey.

The natural mortality rate for bluefish has previously been assumed to be 0.35, based on the scarcity of fish older than age 8 in available length-age data, and an assumed maximum age of 12 years. Current length-age data (*i.e.*, the NC DMF age-length keys) indicate that significant numbers of fish at least 12 years old are present in the catch and it seems likely that bluefish reach ages older than 12 years. The SARC suggested that values of M for bluefish in the range of 0.2 to 0.25 might be more appropriate.

The Subcommittee has not yet tabled an analytical assessment, since there is considerable debate as to the most appropriate assessment technique and assumptions such as natural mortality rate. The SARC expressed concern that the Subcommittee may not reach a consensus on these issues and that if a single analytical assessment cannot be agreed upon by the Subcommittee, that the SARC assume the role of arbiter. It was agreed that the SARC could, in theory, provide valuable external review when a Subcommittee could not reach a consensus. The Subcommittee members present concluded that

Table D27. Mean number per tow of age 0 bluefish (less than 30 cm) from A) RI DFW fall trawl survey in Narragansett Bay and Rhode Island Sound and B) RI DFW beach seine survey in Narragansett Bay.

A) Trawl survey

Year	Mean
1979	0.61
1980	2.39
1981	4.67
1982	2.23
1983	3.20
1984	20.57
1985	2.32
1986	7.68
1987	20.60
1988	7.31
1989	4.44
1990	5.54
1991	18.74
1992	1.62
1993	3.04
Mean	7.00

B) Seine survey

Year	Mean
1986	13.6
1987	24.9
1988	12.8
1989	16.5
1990	27.3
1991	20.1
1992	5.4
1993	2.4
Mean	15.4

Table 28. Mean number per tow of bluefish at age: Connecticut trawl survey (April-November). Fish from the 1988-1993 surveys were aged by application of pooled 1984-1987 CT DEP age-length key.

Year	Age									
	0	1	2	3	4	5	6	7	8+	Total
1984	38.41	0.59	0.56	0.22	0.04	0.01	0.02	0.01	0.00	39.86
1985	32.83	1.42	0.97	0.45	0.22	0.04	0.05	0.06	0.008	36.05
1986	31.45	1.97	1.27	0.30	0.19	0.10	0.04	0.02	0.006	35.35
1987	8.76	1.36	0.58	0.17	0.13	0.08	0.04	0.00	0.003	11.12
1988	10.64	0.69	0.46	0.29	0.19	0.14	0.08	0.003	0.003	12.50
1989	37.30	1.48	0.57	0.16	0.27	0.22	0.05	0.006	0.00	40.06
1990	23.79	2.97	0.63	0.09	0.12	0.17	0.02	0.00	0.00	27.79
1991	24.40	3.50	1.39	0.13	0.09	0.11	0.05	0.00	0.00	29.67
1992	24.30	3.32	1.73	0.17	0.15	0.28	0.005	0.00	0.00	29.96
1993	12.06	0.58	1.01	0.41	0.18	0.05	0.00	0.00	0.00	14.29

Table D29. Mean number per tow of age 0 bluefish (less than 30 cm) from DE DFW summer trawl survey in Delaware Bay

Year	Mean
1980	0.02
1981	0.00
1982	0.03
1983	0.03
1984	0.05
1985	0.07
1986	0.17
1987	0.13
1988	0.22
1989	0.70
1990	0.14
1991	0.00
1992	0.08
Mean	0.13

it was possible to reach consensus and table an analytical assessment for bluefish incorporating the useful comments by the SARC concerning data and assumptions. The SARC review is based on indices of abundance from commercial and recreational fisheries and research vessel surveys. In particular, the evaluation of the level of exploitation is tenuous and will be improved by more definitive results from analytical assessments. With SARC concurrence, the Subcommittee will continue the development of analytical assessments with a goal of tabling an agreed-upon assessment in January 1994.

The SARC Pelagic/Coastal Subcommittee met on 5 January 1994 to review new assessment analyses of bluefish (completed after the SAW-17 SARC meeting in early December 1993) and to reach a consensus on best estimates of stock size and fishing mortality rates. The Subcommittee reviewed results from three different assessment models (ADAPT VPA, DeLury, and CAGEAN), evaluated fishery and research survey selectivity patterns, examined alternative yield per recruit analyses, and discussed the adequacy and appropriateness of various indices of stock abundance and fishing effort. Although a number of issues were resolved during the meeting, the Subcommittee was unable to agree upon a definitive assessment, and hence unable to provide consensus of best estimates of stock abundance and fishing mortality.

Table D30. Mean number per tow of age 0 bluefish (less than 30 cm) from A) VIMS trawl survey in Chesapeake Bay and B) VIMS juvenile striped bass haul seine survey in Chesapeake Bay.

A) Trawl Survey

Year	Number of Fish	Tows	Mean/ Tow
1974	8	747	0.01
1975	9	787	0.01
1976	78	1187	0.07
1977	44	868	0.05
1978	37	1130	0.03
1979	16	813	0.02
1980	11	561	0.02
1981	28	489	0.06
1982	17	587	0.03
1983	14	482	0.03
1984	25	475	0.05
1985	5	310	0.02
1986	6	374	0.02
1987	4	334	0.01
1988	39	889	0.04
1989	131	840	0.16
1990	79	827	0.10
1991	7	768	0.01
1992	27	765	0.03
1993	0	310	0.00
mean	29	677	0.04

B) Seine Survey

Year	Number of Fish	Number of Hauls	Mean/ Tow
1980	7	89	0.08
1981	14	116	0.12
1982	12	106	0.11
1983	16	102	0.16
1984	7	106	0.07
1985	19	142	0.13
1986	4	144	0.03
1987	34	144	0.24
1988	7	180	0.04
1989	13	180	0.07
1990	14	180	0.08
1991	22	180	0.12
1992	2	180	0.01
1993	27	180	0.15
mean	14	145	0.10

Table D31. Mean number per tow of age 0 bluefish from NC DMF juvenile fish trawl survey, and B) NC DMF trawl survey in Pamlico Sound

A) Juvenile fish trawl

Year	Mean
1979	0.05
1980	0.08
1981	0.15
1982	0.04
1983	0.03
1984	0.02
1985	0.04
1986	0.01
1987	0.12
1988	0.07
1989	0.30
1990	0.07
1991	0.07
1992	0.01
mean	0.08

B) Pamlico Sound trawl

Year	Mean
1987	0.20
1988	0.19
1989	0.33
1990	0.36
1991	0.41
1992	0.26
1993	0.26
mean	0.29

The Subcommittee believes that both the DeLury and CAGEAN models offer promise in developing a definitive, quantitative assessment of bluefish. However, further Subcommittee analyses examining the assumptions and input sensitivity of these models are required before accepting any of the results. The Subcommittee envisages that these analyses can be completed by mid-February 1994.

RESEARCH RECOMMENDATIONS

- The intensity of biological sampling of the NER commercial and coastwide recreational fisheries (expressed as mt/100 lengths) has historically been low, and has worsened since 1989 for the NER commercial fishery. The SARC recommends increased biological sampling of the NER commercial and recreational fisheries, and the collection of age samples from the recreational fishery.

- There are some inconsistent patterns in mean weights at age across years (*e.g.*, during 1990-1992, ages 0-2). Some of these patterns may be due to changing contributions of different gears, which exploit certain age groups of fish at different times of the year, or due to inadequate sampling. The SARC suggests using sums-of-product checks, examination of sample mean length/weight at age data, or other appropriate analytical methods to investigate potential errors. Presentation of catch at age, mean length at age, and mean weight at age matrices for each of the four NC commercial fisheries (summer pound net, summer haul seine, winter gill net, and winter trawl) may help clarify why these inconsistencies are present. Mean length at age matrices for the NER commercial and recreational fisheries should also be presented in the assessment.

- A great deal of discussion was undertaken regarding the appropriate measure of effort for the recreational fishery. The SARC decided that the Subcommittee could enhance the present method of calculating recreational effort by examining alternate definitions of recreational fishing effort. The Subcommittee should readdress effective effort in the future to better reflect the question of targeting. The Subcommittee should present measures of CPUE under different assumptions of effective effort to allow evaluation of the sensitivity of results.

- The question of the units of effort expended in the recreational CPUE was also raised, i.e. whether catch per trip is a realistic measure when trips may be of variable duration. The SARC recommends that the Subcommittee assess these topics and explore the potential effect of these parameters.

- Concerns were raised by the committee over the adequacy of data to provide meaningful catch at age models. The SARC suggested that perhaps other models could provide a better analysis given the variability and reliability of the underlying data. The SARC recommends that the Subcommittee examine the current age-structured approach to see if it is appropriate given the low level of biological sampling of the NER commercial and coastwide recreational fisheries. It may be beneficial to explore other methods such as length-based and modified DeLury models in determining the best alternative.

- Many difficulties evident in this assessment reflect the unavailability of a version of the ADAPT VPA that can be used by a wider spectrum of assessment scientists. The SARC supports development of a user-friendly version of the ADAPT VPA software and a tutorial on using the method.

REFERENCES

Bugley, K., and G. Shepherd. 1991. Effect of catch-and-release angling on the survival ofblack sea bass. *North Am. J. Fish. Manage.* 11:468-471.

Burns, T.S., R. Schultz, and B.E. Brown. 1983. The commercial catch sampling program inthe northeastern United States. *In* Doubleday, W.G. and D. Rivard, eds., Sampling commercial catches of marine fish and invertebrates. *Can. Spec. Publ. Fish. Aquat. Sci.* 66.

Chiarella, L.A., and D.O. Conover. 1990. Spawning season and first-year growth of adult bluefish from the New York Bight. *Trans. Am. Fish. Soc.* 119:455-462.

Conser, R.J., and J.E. Powers. 1990. Extension of the ADAPT VPA tuning method designed to facilitate assessment work on tuna and swordfish stocks. *ICCAT* [International Commission for Conservation of Atlantic Tunas] *Coll. Vol. Sci. Pap.* 32: 461-467.

Crecco, V., M. Terceiro, and C. Moore. 1987. A stock assessment of Atlantic coast bluefish, *Pomatomus saltatrix.* Special report prepared for the Atlantic States Marine Fisheries Commission, Washington, D.C.

Deriso, R.B., T.J. Quinn II, and P.R. Neal. 1985. Catch-age analysis with auxiliary information. *Can. J. Fish. Aquat. Sci.* 42:815-824.

Diodati, P.J. 1991. Estimating mortality of hooked and released striped bass. USDOC/NOA A/NMFS/NER Emergency Striped Bass Study Final Report Massachusetts. Manuscript.

Fournier, D.A., J.R. Sibert, J.Majkowski, and J. Hampton. 1990. MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna *(Thunnus maccoyii). Can. J. Fish. Aquat. Sci.* 47:301-317.

Gavaris, S. 1988. An adaptive framework for the estimation of population size. *CAFSAC* [Canadian Atlantic Fisheries Scientific Advisory Committee] *Res. Doc.* 88/29.

Graves, J.E., J.R. McDowell, A.M. Beardsley, and D.R. Scoles. 1992. Stock structure of the bluefish *Pomatomus saltatrix* along themid-Atlantic coast. *Fish. Bull. (U.S.).* 90:703-710.

Hamer, P.E. 1959. Age and growth studies of bluefish *(Pomatomus saltatrix)* of the New York Bight. Unpublished Master's thesis. Rutgers University, New Brunswick, New Jersey.

Hayes, D.B. 1993. A statistical method for evaluating differences between age-length keys with application to Georges Bank haddock, Melanogrammus aeglefinus. *Fishery Bulletin (U.S.)* 91:550-557.

IPHC. 1988. Annual Report, 1987. Seattle, Washington: International Pacific Halibut Commission.

Kendall, A.W., Jr., and L.A. Walford. 1979. Sources and distribution of bluefish, *Pomatomus saltatrix,* larvae and juveniles off the East Coast of the United States. *Fish. Bull. (U.S.)* 77:213-277.

Kimura, D.K., and S. Chikuni. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. *Biometrics* 43:23-35.

Lassiter, R.R. 1962. Life history aspects of the bluefish, *Pomatomus saltatrix* Linnaeus, from the coast of North Carolina. Unpublished Master's thesis. North Carolina State College, Raleigh, North Carolina.

Lund, W.A., and G.C. Maltezos. 1970. Movements and migrations of the bluefish, *Pomatomus saltatrix,* tagged in the waters of New York and southern New England. *Trans. Am. Fish. Soc.* 99:719-725.

MAFMC. 1990. Fishery management plan for the bluefish fishery. Dover, Delaware: Mid-Atlantic Fishery Management Council.

McBride, R.S., J.L. Ross, and D.O. Conover. 1993. Recruitment of bluefish *Pomatomus saltatrix* to estuaries of the U.S. South Atlantic Bight. *Fish. Bull. (U.S.)* 91: 389-395.

NEFSC. 1990. Report of the Eleventh NEFSC Stock Assessment Workshop, Fall 1990. Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc. 90-09.*

NOAA. 1989. Guidelines for estimating lengths at age for 18 northwest Atlantic finfish and shellfish species. *NOAA Tech. Memo. NMFS-F/NEC*-66.

Nyman, R.M., and D.O. Conover. 1988. The relation between spawning season and the recruitment of young-of-the-year bluefish, *Pomatomus saltatrix*, to New York. *Fish. Bull. (U.S.)* 86:237-250.

Parrack, M.L. 1986. A method of analyzing catches and abundance *indices* from a fishery. *ICCAT* [International Commission for Conservation of Atlantic Tunas] *Coll. Sci. Pap.* 24:209-221.

Richards, S.W. 1976. Age, growth, and food of the bluefish *(Pomatomus saltatrix)* from east-central Long Island Sound from July through November 1975. *Trans. Am. Fish. Soc.* 105:523-525.

SAS. 1989. SAS user's guide, version 6, fourth edition, volume 2. SAS Institute, Inc. Cary,NC.

Terceiro, M. 1987. Status of Atlantic coast bluefish - 1987. Woods Hole, MA: NOAA/NMFS/NEFC. *Lab. Ref. Doc.* 87-10.

Terceiro, M., and J.L. Ross. 1993. A comparison of alternative methods for the estimation of age from length data for Atlantic coast bluefish *(Pomatomus saltatrix)*. *Fish. Bull. (U.S.)* 91:534-549.

Westrheim, S.J., and W.E. Ricker. 1978. Bias in using an age-length key to estimate age-frequency distributions. *J. Fish. Res. Bd. Can.* 35:184-185.

Wilk, S.J. 1977. Biological and fisheries data on bluefish, *Pomatomus saltatrix* (Linnaeus). Highlands, NJ: NOAA/NMFS/NEFC. *Sandy Hook Laboratory Technical Series Report* 11.

E. ATLANTIC BUTTERFISH

TERMS OF REFERENCE

The following terms of reference were addressed:

a. Compute revised research vessel survey indices and evaluate the stock with respect to survey-based management reference points

b. Develop CPUE series based on GLM models incorporating area, vessel, and percent directed fishing

c. Assess the role of discards in the fishery

d. Review MSY

INTRODUCTION

Atlantic butterfish (*Peprilus triacanthus*) range from Newfoundland to Florida and are found in commercially-exploitable concentrations between Cape Hatteras and Southern New England. For management purposes, the butterfish population in waters north of Cape Hatteras is assumed to constitute a unit stock. This stock migrates inshore and northward during the summer and offshore and southward during the winter in response to seasonal changes in water temperature on the shelf.

DESCRIPTION OF THE FISHERY

Atlantic butterfish have been landed by domestic fishermen since the 1800s, and from 1920 to 1962 the annual domestic harvest has averaged 3,500 mt per year. Foreign landings began in the mid-1960s and averaged 8,000 mt during 1965-1976 (Table E1). Total annual landings peaked in 1973 at 19,500 mt but since 1977 have ranged between 2,000 mt and 12,400 mt. From 1977 to 1987 (when foreign fishing was being phased out), annual landings of butterfish averaged 6,100 mt. Since 1988, annual landings (solely U.S.) have averaged 2,500 mt per year.

In 1992, butterfish landings totaled 2,700 mt in 1992, 25% higher than in 1991, but still among the lowest domestic harvests since 1978. Nearly half (45%) of the 1992 landings was taken from Southern New England waters (Statistical Area 53, Figure 2, page 6), and landings from Southern New England and the New York Bight (Area 61) accounted for over 75% of the 1992 total (Table E2). Temporally, 48% of the 1992 harvest was taken in January and February. Landings patterns in 1992 were similar to those in recent years.

Table E1. Landings (metric tons) of Atlantic butterfish (*Peprilus triacanthus*) from Cape Hatteras to the Gulf of Maine, 1965 to 1992

Year	United States	Foreign	Total
1965	3,340	749	4,089
1966	2,615	3,865	6,480
1967	2,452	2,316	4,768
1968	1,804	5,437	7,241
1969	2,438	15,073	17,511
1970	1,869	9,028	10,897
1971	1,570	6,238	7,853
1972	819	5,671	6,490
1973	1,557	17,847	19,454
1974	2,528	10,337	12,865
1975	2,088	9,077	11,165
1976	1,528	10,353	11,881
1977	1,448	3,205	4,653
1978	3,676	1,326	5,002
1979	2,831	840	3,671
1980	5,356	879	6,235
1981	4,855	936	5,791
1982	9,060	631	9,691
1983	4,905	630	5,535
1984	11,972	429	12,401
1985	4,739	804	5,543
1986	4,418	164	4,582
1987	4,508	0	4,508
1988	2,001	0	2,001
1989	3,203	1	3,204
1990	2,298	3	2,301
1991	2,189	0	2,189
1992	2,678	0	2,678
1993[1]	2,679		2,679
Average			
1965-76	2,051	7,999	10,050
1977-87	5,252	895	6,147
1988-92	2,474	1	2,475
1965-92	3,384	3,920	7,167

[1] Predicted

Based on provisional January-October 1993 landings data, total butterfish landings in 1993 are projected to be 2,700 mt.

Butterfish are managed by the Mid-Atlantic Fishery Management Council under provisions of the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan. In 1992, the maximum optimum yield and the allowable biological catch for butterfish were each set at 16,000 mt, and the domestic allowable harvest was set at 10,000 mt (MAFMC 1991). Identical specifications pertain in 1993 and 1994 (MAFMC 1992).

DATA SOURCES

Commercial U.S. landings data from 1989 through 1992 were taken from the NEMFIS data base and general canvass sources. Landings data for 1965 to 1988 were provided in the Report of the 10th SAW (NEFSC 1990). Effort data used in the analysis of domestic LPUE from 1982-1992 were extracted from the NEMFIS data base. Domestic observer data used to quantify discarding of butterfish were taken from the NEFSC Domestic Sea Sampling Program data base.

A multiplicative GLM model (Gavaris 1980) was used to standardize fishing effort (in terms of days absent) during 1982-1992 in the U.S. otter trawl fishery for butterfish (Brodziak 1993). A main effects model was used with year, area, and tonnage class as factors (R^2 = 0.34) (Table E3). Month was initially included as a factor but contributed little to the Type III sum of squares, and was thus subsequently excluded to avoid overparameterization of the model (Searle 1987).

As in previous assessments (NEFSC 1990), indices of relative abundance of butterfish were derived from NEFSC spring and autumn bottom trawl surveys conducted from Cape Hatteras to Georges Bank [offshore strata 1-14, 16, 19-20, 23, 25, and 61-76; inshore strata 1-46] (Grosslein 1969; Azarovitz 1981).

ASSESSMENT RESULTS

Abundance and Mortality

Standardized fishing effort (in terms of days absent) increased in 1992 while standardized LPUE slightly declined (Table E3, Figure E1). The LPUE and standardized abundance indices were highest during 1982-1984. The lowest values in both series have occurred in recent years (*i.e.*, from 1988 onward). Effort has fluctuated without trend since 1984.

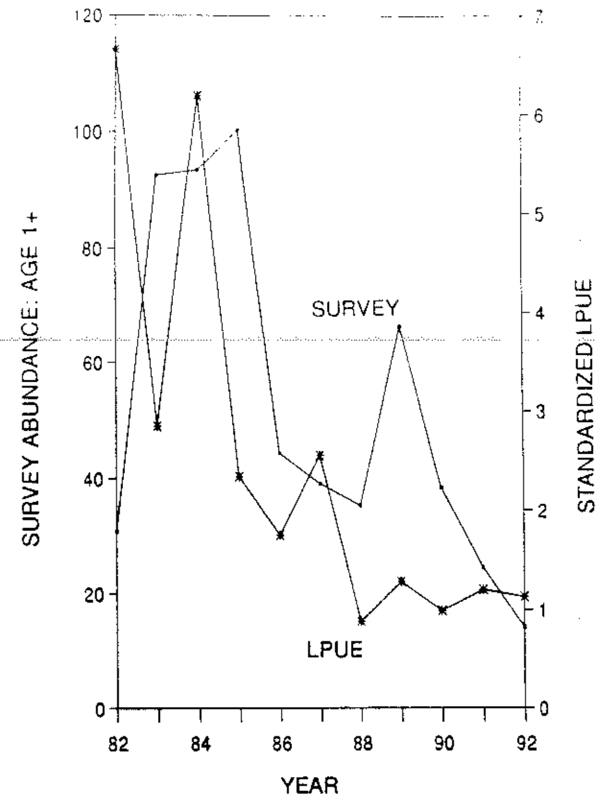

Figure E1. Comparison of butterfish recruit abundance per survey tow and standardized LPUE from 1982-1992.

NEFSC research survey indices indicate that butterfish stock abundance was low during the late 1960s-early 1970s but high during 1979-1985 and 1988-1990 (Tables E4 and E5; Figure E2). The most recent indices (spring 1992-1993; autumn 1991-1992) indicate a decline in abundance and biomass from 1990; the autumn 1992 weight-per-tow index and the age 1+ number-per-tow index were among the lowest values in the survey time series (Table E5). The spring 1993 weight-per-tow index was also among the lowest ever observed (Table E4).

In contrast to the total stock indices, survey pre-recruit (age 0) indices have remained high in recent years (Table E5). Prerecruit indices in autumn 1988-1990 were among the highest on record, and the 1991 and 1992 prerecruit values were average and 40% above-average, respec-

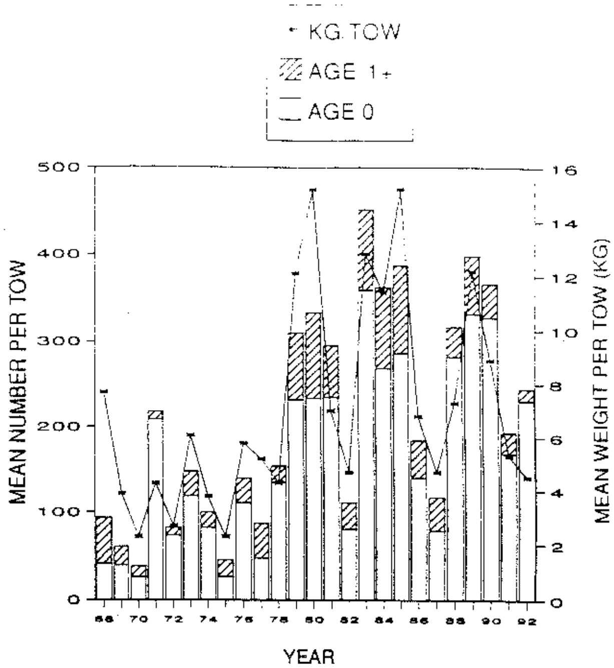

Figure E2. Abundance and weight per tow of butterfish from the NEFSC Fall bottom trawl survey.

tively. Thus, despite declines in the adult (age 1+) stock, butterfish recruitment has continued to be good.

Estimates of total instantaneous mortality (Z) for butterfish (Table E6) were calculated from NEFSC autumn survey number per tow at age indices (Table E5) by:

$$Z = \ln\left(\frac{N_{age-1}(t-1)}{N_{age}(t)}\right) \quad (1)$$

Total mortality rates for all age groups appear to have increased in recent years. Values of Z during 1989-1992 for age 0 fish are the highest on record, and the 1989-1991 values for age 1 butterfish are among the highest. Age 2 fish have displayed very high Z's from 1986 onward.

Discard Rates

Domestic observer data collected by the NEFSC Sea Sampling Program were used to quantify discarding of butterfish caught with bottom otter trawl gear during 1989 to 1992. Monthly observations on butterfish discards from a total of 159 tows were pooled across trips and years (Table E7). Monthly discard ratios (percentage of total catch discarded) range from 69% to 100% (Table E8). However, the quantities of butterfish kept in all months is very low, suggesting that the available sea sampling data are not representative of the directed fishery for butterfish (where much larger quantities kept would be expected). Further evaluation of the precision and design of the sea sampling program in adequately characterizing butterfish discards (by fishery) is needed, before attempting to estimate the absolute magnitude of discards. A previous report on butterfish (Waring 1986) noted that "very high discard rates (30 to 100%) were observed by NMFS port agents during mid-1983-1985".

Biological Reference Points

Overfishing for butterfish is defined to occur when the three-year moving average of prerecruits from the NEFSC autumn bottom trawl survey is below the first quartile of this series. For the purpose of applying the definition in 1992, 1993, and 1994, the lowest quartile consists of the seven lowest age 0 indices (Table E5); the three-year moving average of the prerecruit series must be less than the largest index in this quartile for overfishing to occur. Given the 1992 autumn age 0 index of 230.3 (Table E5), the three-year moving prerecruit average in 1992 was 242.3. If the 1993 and 1994 prerecruit indices are both 0, the corresponding three-year moving averages would be 132.9 and 76.8, respectively. The largest prerecruit index in the lower quartile of values during 1992, 1993, and 1994 would correspond to 78.59, 73.20, and 47.73. Thus, according to the overfishing definition, butterfish were not overfished in 1992, and will not be overfished in 1993 and 1994.

No new information was available that could be used as a basis for changing the current MSY.

Murawksi and Waring (1979) estimated that $F_{0.1}$ for Atlantic butterfish was 0.47, 0.69, 0.96, and 1.38 for mesh sizes of 30, 60, 80, and 100 mm, respectively, provided that instantaneous natural mortality was 0.8 yr^{-1}. Corresponding estimates of F_{max} were 0.71, 1.33, and greater than 2.50 for mesh sizes of 30, 60, and 80 or 100 mm, respectively. A high natural mortality rate, such as 0.8, has a large influence on the magnitudes of reference points such as $F_{0.1}$ and F_{max}. This reduces the proportional impact of fishery-related mortality (*i.e.*, landings and discards) on

Table E2. Atlantic butterfish (*Peprilus triacanthus*) landings (metric tons) in 1992, by 2-digit statistical area and month

Area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Totals
51	0.51	-	-	-	-	0.01	0.02	-	0.04	0.09	0.48	0.01	1.15
52	0.01	88.70	21.00	58.45	8.59	13.13	1.13	1.23	1.36	2.90	0.13	0.31	196.94
53	535.00	218.33	32.04	20.41	29.78	73.31	11.63	26.44	66.41	48.12	29.80	113.13	1204.40
56	-	-	-	-	-	0.17	2.19	-	-	-	-	-	2.36
61	155.06	271.27	103.87	28.54	24.83	46.72	23.48	23.82	30.08	31.47	63.33	43.23	845.70
62	2.68	3.69	12.76	4.94	2.94	35.50	13.16	15.33	99.21	60.94	83.38	28.31	362.83
63	0.01	0.01	0.03	-	-	0.01	-	-	0.68	37.19	26.49	-	64.42
Totals	693.27	582.00	169.70	112.33	66.14	168.85	51.61	66.82	197.78	180.71	203.60	184.98	2677.80
%	26%	22%	6%	4%	2%	6%	2%	2%	7%	7%	8%	7%	
Avg % 1990-92	22%	16%	8%	4%	3%	5%	2%	5%	12%	10%	6%	7%	

Table E3. Standardized fishing effort (days absent) and standardized landings-per-day absent (LPUE) for the U.S. otter trawl fishery for Atlantic butterfish (*Peprilus triacanthus*), 1982 - 1992. The U.S. otter trawl fishery is defined as trips landing butterfish during January-March and September-December from Statistical Areas 526, 537, 539, 613, 616, 621, or 622.

Year	Domestic LPUE[1] (mt/day absent)	Standardized fishing effort (days absent)	Standardized abundance index[2]
1982	6.65	1005.7	1.00
1983	2.85	990.3	0.43
1984	6.19	1595.8	0.93
1985	2.35	1356.9	0.35
1986	1.75	1829.7	0.26
1987	2.56	1361.0	0.38
1988	0.88	1532.3	0.13
1989	1.28	1560.2	0.19
1990	0.99	1404.7	0.15
1991	1.20	1143.4	0.18
1992	1.13	1676.1	0.17
Average 1982-92	2.53	1405.1	

[1] For trips used in the general linear model, the ratio of total landings (mt) to standardized fishing effort.
[2] Ratio of annual LPUE to LPUE in 1982.

the magnitudes of the reference points. Waring and Anderson (1983) estimated $F_{0.1}$ for butterfish at 1.60. This value is based on data that was collected over a decade ago; thus, an updated estimate of $F_{0.1}$ based on current exploitation patterns is needed.

DISCUSSION

Since 1987, butterfish landings have averaged 2,500 mt per year - only 25% of the Domestic

Table E4. Stratified mean catch per tow in numbers and weight (kilograms) of Atlantic butterfish from NEFSC spring bottom trawl surveys, Cape Hatteras to Georges Bank (Strata 1-14, 16, 19, 20, 23, 25, 61-76), 1968 - 1993

Year	Mean Number/ Tow	(CV%)	Mean Number/ Tow	(CV%)
1968	33	(59%)	2.0	(63%)
1969	31	(80%)	3.1	(83%)
1970	10	(29%)	0.5	(30%)
1971	22	(56%)	0.8	(41%)
1972	228	(96%)	6.6	(92%)
1973	69	(33%)	5.4	(40%)
1974	25	(49%)	1.7	(48%)
1975	121	(20%)	4.0	(19%)
1976	31	(44%)	1.3	(29%)
1977	7	(34%)	0.6	(33%)
1978	5	(29%)	0.3	(32%)
1979	13	(36%)	1.0	(42%)
1980	58	(24%)	3.2	(26%)
1981	44	(21%)	2.5	(30%)
1982	49	(42%)	2.5	(42%)
1983	65	(42%)	3.9	(67%)
1984	16	(42%)	0.7	(37%)
1985	38	(45%)	1.6	(40%)
1986	66	(46%)	2.8	(41%)
1987	16	(40%)	0.6	(31%)
1988	13	(38%)	0.5	(30%)
1989	32	(81%)	0.8	(67%)
1990	9	(45%)	0.4	(39%)
1991	28	(71%)	1.0	(59%)
1992	27	(40%)	0.8	(32%)
1993	18	(21%)	0.6	(21%)
Average 1968-92	42	(46%)	1.9	(44%)

Table E5. Stratified mean numbers per tow at age and stratified mean weight (kilograms) per tow of Atlantic butterfish (*Peprilus triacanthus*) in NEFSC autumn bottom trawl surveys, Cape Hatteras to Georges Bank (offshore strata 1-14, 16, 19-20, 23, 25, and 61-76; inshore strata 1-46), 1968 - 1992

Year	Age					Total	Age 1+	Mean Wt Wt Per Tow	3-Year Mean of Age 0
	0	1	2	3	4				
1968	41.28	50.59	1.64	0.10	0.00	93.61	52.3	7.7	-
1969	39.48	18.82	2.12	0.16	0.00	60.58	21.1	3.9	-
1970	26.43	11.24	0.86	0.10	0.00	38.63	12.2	2.3	35.73
1971	208.85	8.76	0.70	0.24	0.00	218.55	9.6	4.3	91.58
1972	73.20	8.34	0.31	0.05	0.00	81.90	8.7	2.7	102.82
1973	119.10	27.73	1.50	0.07	0.00	148.40	29.3	6.1	133.71
1974	82.13	15.96	1.74	0.37	0.00	100.20	18.0	3.8	91.47
1975	26.34	17.54	1.71	0.15	0.00	45.74	19.4	2.3	75.85
1976	110.63	26.50	2.12	0.33	0.00	139.58	29.0	5.8	73.03
1977	47.73	32.78	6.22	0.24	0.00	86.97	39.3	5.2	61.56
1978	134.96	7.96	10.18	1.05	0.00	154.15	19.2	4.3	97.77
1979	231.51	73.01	4.85	0.18	0.00	309.55	78.1	12.1	138.06
1980	233.19	80.42	18.82	0.73	0.04	333.20	100.0	15.2	199.88
1981	234.55	47.14	12.88	0.29	0.01	294.87	60.3	7.0	233.08
1982	80.31	26.12	4.73	0.14	0.14	111.44	30.7	4.7	182.68
1983	358.77	78.49	10.70	3.25	0.07	451.28	92.5	12.8	224.54
1984	268.60	79.55	11.07	2.79	0.00	362.01	93.4	11.4	235.89
1985	286.26	85.69	12.40	2.27	0.09	386.71	100.4	15.2	304.54
1986	140.16	29.75	12.19	1.96	0.33	184.39	44.3	6.8	231.67
1987	78.59	31.55	7.17	0.25	0.00	117.56	39.0	4.7	168.33
1988	282.28	21.59	13.29	0.20	0.00	317.36	35.1	7.3	167.01
1989	332.31	49.95	15.05	1.03	0.00	398.34	66.0	12.2	231.06
1990	328.29	33.35	3.89	0.95	0.00	366.57	38.3	8.9	314.29
1991	168.38	20.53	3.60	0.29	0.00	192.80	24.4	5.3	276.32
1992	230.26	9.54	4.51	0.09	0.00	244.40	14.1	4.5	242.31
1968-91 Average	163.89	36.81	6.66	0.72	0.03	208.10	44.2	7.2	

Allowable Harvest of 10,000 mt - and well below historical yields (Table E1). Japanese demand for butterfish exports has decreased in recent years (MAFMC 1992), and this has probably had a negative impact on butterfish landings. Since 1987, commercial LPUE has remained low while standardized fishing effort has remained relatively stable (Table E3). Butterfish abundance, based on both NEFSC age 1+ survey indices and commercial LPUE indices, was lower in 1991-1992 than during the 1982-1987 period (Figure E2).

Research survey indices (Table E5) suggest that butterfish survival to age 2 has declined since 1990. Estimates of total mortality derived from these indices suggest that age 0 butterfish mortality rates have increased since 1989, and that age 2 mortality has been high since 1987 (Table E6). Despite the recent decline in the adult stock (Table E5), the abundance of prerecruits has remained above average since 1987.

While survey data indicate that abundance of butterfish prerecruits has remained high, estimates of survival among older ages has decreased. This may reflect one or more of the following: an increase in the rate of natural mortality in recent years, an increase in discard mortality, a reduction in availability of older individuals relative to younger individuals. Given this uncertainty, estimates of Z as well as F from the survey data are unreliable.

Overall, it appears that the butterfish stock is at a low to medium biomass level. While exploitation rates could not be determined, butterfish are underexploited relative to management targets. An increase in landings seems unlikely unless market demand improves.

Table E6. Estimates of age-specific instantaneous total mortality rates (Z) for Atlantic butterfish (*Peprilus triacanthus*) derived from the NEFSC autumn bottom trawl surveys, 1968 - 1992

Year	Age-0	Age-1	Age-2	Age-3
1968/69	0.79	3.17	2.33	-[1]
1969/70	1.26	3.09	3.05	-[1]
1970/71	1.10	2.78	1.28	-[1]
1971/72	3.22	3.34	2.64	-[1]
1972/73	0.97	1.72	1.49	-[1]
1973/74	2.01	2.77	1.40	-[1]
1974/75	1.54	2.23	2.45	-[1]
1975/76	-[2]	2.11	1.65	-[1]
1976/77	1.22	1.45	2.18	-[1]
1977/78	1.79	1.17	1.78	-[1]
1978/79	0.61	0.50	4.04	-[1]
1979/80	1.06	1.36	1.89	1.50
1980/81	1.60	1.83	4.17	4.29
1981/82	2.19	2.30	4.52	0.73
1982/83	0.02	0.89	0.38	0.69
1983/84	1.51	1.96	1.34	-[1]
1984/85	1.14	1.86	1.58	3.43
1985/86	2.26	1.95	1.84	1.93
1986/87	1.49	1.42	3.89	-[1]
1987/88	1.29	0.86	3.58	-[1]
1988/89	1.73	0.36	2.56	-[1]
1989/90	2.30	2.55	2.76	-[1]
1990/91	2.77	2.23	2.60	-[1]
1991/92	2.87	1.52	3.69	-[1]
Average 1968-91	1.47	1.91	2.41	-[1]

[1] No total mortality estimate was made for this age group.
[2] Infeasible estimate.

RESEARCH RECOMMENDATIONS

- Given that butterfish is a short-lived species, new approaches to the assessment and management of the stock may be required. A more adaptive, real-time assessment/management system will be needed to attain full exploitation of the stock while, at the same time, ensuring that adequate levels of spawning stock are achieved. Examples of the types of assessment and management procedures that have proved successful for short-lived species are provided in the 1993 report of the ICES Working Group on Methods of Fish Stock Assessment (ICES 1993).

- Data need to be collected to make reliable estimates of discards, particularly discards associated with the directed fishery. The design and/or implementation of the Sea Sampling program needs to be improved so that data are collected from all components of the fishing fleet. Data currently available from the NEFSC sea sampling program are not adequate because most of data appear to come from trips in which butterfish was not the target species.

- The exploitation pattern and levels of discarding need to be estimated to allow revised computation of exploitation rates and biological reference points such as $F_{0.1}$ and F_{max}.

REFERENCES

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. *In* Doubleday, W.G. and Rivard, D., eds. Bottom trawl surveys. *Can. Spcl. Pub. Fish. Aquat. Sci.* 58:62-67.

Brodziak, J. 1993. Stock assessment for Atlantic butterfish, *Peprilus triacanthus*, in the Northwest Atlantic during 1992. Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 94-03.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci.* 37: 2272-2275.

Grosslein, M.D. 1969. Groundfish survey program of the BCF Woods Hole. *Commer. Fish. Rev.* 31(8-9): 22-35.

ICES. 1993. Report of the Working Group on Methods of Fish Stock Assessment, Copenhagen, 3-10 February 1993. *ICES* [International Council for Exploration of the Sea] C.M. 1993/Assess:12.

MAFAC [Mid-Atlantic Fishery Management Council]. 1991. 1992 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for atlantic mackerel, *Loligo, Illex,* and butterfish. Dover, DE: MAFAC. MAFAC [Mid-Atlantic Fishery Management Council]. 1992. 1993-1994 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for Atlantic mackerel, *Loligo, Illex,* and butterfish. Dover, DE: MAFMC. Murawski, S. and G. Waring.

Table E7. Monthly Atlantic butterfish trips (T) and catches (C, metric tons) from bottom otter trawl trips recorded in the NEFSC Sea Sampling database, 1989-92

	Area																					
	521		522		526		537		538		539		611		613		616		621		622	
Month	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**
Jan							1	0.953									4	3.133				
Feb																	3	0.634			2	0.021
Mar							2	0.005									2	0.025				
Apr																	1	0.084	1	0.096	1	0.210
May									2	0.040	1	0.227	1	0.186	1	0.055			4	0.091		
Jun	1	0*					2	0	1	0	1	0.093			1	0			3	0.157		
Jul							1	0.111											4	0.384		
Aug					1	0.014	2	0.029														
Sep			1	0.077			6	5.910	1	0.448	1	0.003							3	0.048		
Oct							4	1.517			3	0.085			4	0.307	1	0.266	3	0.072		
Nov							2	2.386			4	0.361			1	0.034	1	0.261				
Dec											1	0.160					5	3.044				
All	1	0	1	0.077	1	0.014	20	10.911	4	0.488	11	0.929	1	0.186	7	0.396	17	7.448	18	0.849	3	0.232

* Catches of 0 are due to rounding

Table E8. Monthly catches and discards (mt) of Atlantic butterfish (*Peprilus triacanthus*) from bottom otter trawl trips in the NEFSC Sea Sampling Program database, 1989 - 1992

Month	Weight Discarded (mt)	Weight Kept (mt)	Discard Ratio[1]
Jan	3.040	1.046	.744
Feb	.634	.021	.968
Mar	.031	.000	1.000
Apr	.373	.018	.954
May	.548	.051	.915
Jun	.250	.000	1.000
Jul	.495	.000	1.000
Aug	.036	.006	.837
Sep	6.477	.009	.999
Oct	1.543	.704	.687
Nov	3.008	.034	.989
Dec	3.204	.000	1.000
Total	19.640	1.889	.912

[1] Ratio of weight discarded to total weight kept and discarded.

1979. A population assessment of butterfish, *Peprilus triacanthus*, in the Northwest Atlantic Ocean. *Trans. Am. Fish. Soc.* 108: 427-439.

NEFSC. 1990. Report of the Spring 1990 NEFC Stock Assessment Workshop (Tenth SAW). Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 90-07.

NEFSC. 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop (14th SAW). Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 92-07.

Searle, S.R. 1987. Linear models for Unbalanced Data. New York: John Wiley and Sons, New York, New York.

Waring, G.T., and E.D. Anderson. 1983. Status of the northwestern Atlantic butterfish stock - 1983. Woods Hole, MA: NOAA/NMFS/NEFC. *Lab. Ref. Doc.* 81-41.

Waring, G.T. 1986. An analysis of spatial differences in size composition and abundance of butterfish, *Peprilus triacanthus*, off the northeast United States. Woods Hole, MA: NOAA/NMFS/NEFC. *Lab. Ref. Doc.* 86-04.

F. LONG-FINNED SQUID

TERMS OF REFERENCE

Terms of reference for *Loligo pealei* were finalized by the SAW Steering Committee in September 1993 [see Report of the 16th Northeast Regional Stock Assessment Workshop (16th SAW), The Plenary, NEFSC Ref. Doc. 93-19: p. 52-54]. The assessments of *Loligo* was designated by the Steering Group as '1st priority' - indicating that all terms of reference should be met. The following terms of reference, provided by the SAW Steering Committee, were addressed:

a. Provide updated calculation of yield and spawning stock biomass per recruit and other standard biological reference points.

b. Provide updated minimum biomass and recruitment estimates based on areal expansion of research vessel survey data.

c. Continue development of DeLury population estimators based on research vessel survey and commercial CPUE and length composition data.

d. Recalculate CPUE series based on general linear models, by vessel size class, area, and season. Investigate the predictability of fishery success from research vessel surveys.

e. Review MSY.

INTRODUCTION

Long-finned squid (*Loligo pealei*)[1] are distributed in shelf and slope waters extending from Newfoundland, Canada (Dawe *et al.* 1990) to the Gulf of Venezuela (Summers 1983). Previous assessments assumed a lifespan of at most three years (USDOC 1988) based upon analyses of length frequency data (Verrill 1882; Mesnil 1977; Lange and Sissenwine 1980). However, inferences about the age and growth of squids based on length frequency analyses must be regarded with caution unless they are accompanied by supplementary age data (Caddy 1991) because (i) squid growth rates exhibit high variability and can vary with season, food availability, temperature, and population density; (ii) squid populations can be composed of several broods or microcohorts that have different growth and survival rates; (iii) if separate microcohorts enter the sampled population at successive times, modal analysis of length frequency data sampled from a mixture of microcohorts will not represent the true growth rate. Research on the age and growth of several species of squid based on counts of daily statolith growth increments (e.g., Lipinski 1978; Spratt 1979; Dawe *et al.* 1985; Lipinski 1986; Yang *et al.* 1986; Jackson 1990; Rodhouse and Hatfield 1990; Jereb *et al.* 1991; Jackson and Choat 1992; Jackson *et al.* 1993) indicates that statolith aging is useful technique. Statolith aging of *Loligo pealei* indicates that this species has a lifespan of less than 1 year (Macy 1992; Macy MS, Figure F1) and that spawning occurs during the winter (Figure F2). As a result, the previous hypothesis that *Loligo* have a cross-over life cycle (Mesnil 1977) with spawning peaks in the spring and fall and protracted spawning during the summer has been replaced with the working hypothesis that *Loligo* are an annual, semelparous species that has the capacity to spawn throughout the year.

At present, collaborative research between the NEFSC and the University of Rhode Island is being conducted to examine seasonal and spatial patterns of growth and to further validate the one day-one ring hypothesis of statolith increment formation in *Loligo pealei*. *Loligo* are assumed to constitute a unit stock throughout their range of commercial exploitation in the Northwest Atlantic, and the stock unit consists of all *Loligo* within U.S. jurisdiction outside the Gulf of Mexico and the Caribbean Sea (MAFMC 1990).

DESCRIPTION OF THE FISHERY

The domestic fishery for *Loligo* off the Northeastern United States began in the late 1800s with squid being primarily used as bait. From 1928 to 1967, annual squid landings from Maine to North Carolina (including *Illex illecebrosus* landings) averaged roughly 2,000 mt. A directed foreign fishery for *Loligo* developed in 1967 and exploited *Loligo* throughout the 1970s and early 1980s (Table F1). Total annual landings averaged 20,400 mt from 1967-1986 with a peak of 37,600 mt in 1973. In 1987, foreign fishing effort ceased, and annual domestic landings have aver-

[1] For brevity, *Loligo pealei* is referred to as *Loligo* whenever possible

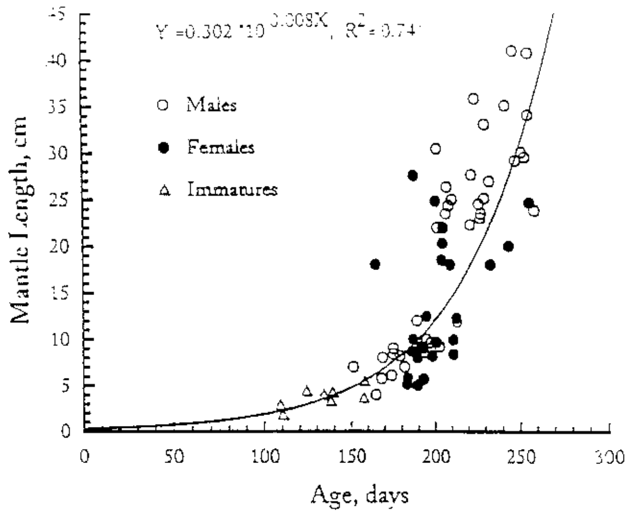

Figure F1. Size at age of *Loligo pealei* based on counts of daily statolith increments from Macy (MS).

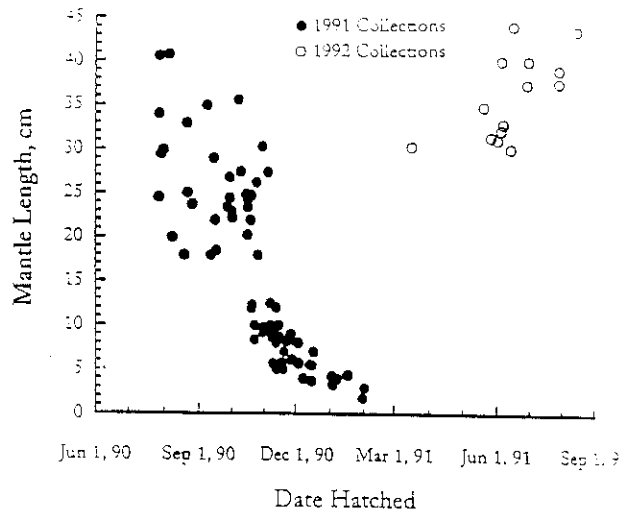

Figure F2. Hatching dates of *Loligo pealei* from Macy (MS).

Table F1. Annual *Loligo pealei* landings (metric tons) from the Northwest Atlantic (Cape Hatteras to Gulf of Maine) the U.S.[1] and foreign fleets, 1963 to 1993

Year	U.S.	Foreign	Total
1963	1,294	0	1,294
1964	576	2	578
1965	709	99	808
1966	772	226	948
1967	547	1,130	1,167
1968	1,084	2,327	3,411
1969	899	8,643	9,542
1970	653	16,732	17,385
1971	727	17,442	18,169
1972	725	29,009	29,734
1973	1,105	36,508	37,613
1974	2,274	32,576	34,850
1975	1,621	32,180	33,801
1976	3,602	21,682	25,284
1977	1,088	15,586	16,674
1978	1,291	9,355	10,646
1979	4,252	13,068	17,320
1980	3,996	19,750	23,746
1981	2,316	20,212	22,528
1982	5,464	15,805	21,269
1983	15,943	11,720	27,663
1984	11,592	11,031	22,623
1985	10,155	6,549	16,704
1986	13,292	4,598	17,890
1987	11,475	2	11,477
1988	19,072	3	19,075
1989	23,650	5	23,655
1990	14,954	0	14,954
1991	19,409	0	19,409
1992	18,172	0	18,172
1993[2]	22,900	0	22,900

[1] Includes joint venture landings made by U.S. vessels
[2] Predicted

aged 17,800 mt during 1987-1992.

In 1992, *Loligo* landings (5,708 fishing trips) totaled 18,172 mt with an exvessel value of $23,342,000 and an average price of $1.28 per kg ($0.58 per lb). Nearly half of the 1992 harvest (8,112 mt; 45%) was taken from one statistical area (SA 616); six statistical areas (SA 616, 537, 613, 622, 612, and 526) accounted for 87% of the total landings (Table F2). Temporally, 81% of the 1992 landings occurred in winter and autumn (Jan-Apr; Oct-Dec).

Nearly all landings (99%) were made with bottom otter trawl gear (Table F3). The small-vessel (5 to 50 GRT) fishery - prosecuted in inshore areas between May-July - accounted for 1% (150 mt) of the 1992 otter trawl landings, while the large-vessel (51 to 900 GRT) fishery - occurring primarily in offshore waters during November-April - accounted for 99% (15,590 mt) (Table F4; Figure F3). Historically (1982-1992), the inshore fishery has accounted for as much as 35% of the U.S. catch (e.g., in 1983); since 1985, however, the inshore fishery has accounted for a very much smaller proportion (1-8%) of the annual landings (Table F4).

Based on provisional January-October 1993 landings data, total *Loligo* landings in 1993 are projected to be about 22,900 mt, 26% higher than in 1992 (Table F1).

Loligo are managed by the Mid-Atlantic Fishery Management Council under provisions of the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan. In 1992, the maximum optimum yield was 44,000 mt, the allowable biological catch was 37,000 mt and the domestic allowable harvest was 34,000 mt (MAFMC 1991).

Table F2. *Loligo* squid landings (metric tons) in 1992, by area and month

Area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Totals
513	-	-	-	-	0.2	0.3	-	-	-	-	-	-	0.5
514	-	-	-	-	0.3	-	0.0	-	0.1	0.5	1.6	0.1	2.8
521	0.1	-	-	-	0.2	0.0	-	0.9	0.0	0.2	0.2	0.0	1.8
522	-	-	-	-	0.0	-	3.8	0.0	-	4.8	-	-	8.6
525	-	-	-	-	1.5	0.3	-	-	-	-	-	-	1.7
526	-	3.2	265.2	276.0	2.7	1.6	13.1	145.6	0.9	0.1	0.1	0.5	708.9
537	351.4	227.4	353.9	357.9	125.8	54.0	302.2	266.6	77.2	465.6	260.5	294.4	3136.8
538	-	-	-	1.5	368.2	2.6	8.1	1.0	0.3	2.6	1.1	-	385.5
539	12.2	0.2	-	1.6	57.8	49.7	18.0	15.9	8.5	34.7	99.9	99.5	398.1
611	9.5	9.5	1.6	29.6	44.4	38.6	50.6	39.0	20.2	27.0	3.0	2.7	275.7
612	81.8	3.8	0.7	0.1	80.1	108.5	267.0	123.3	0.6	24.4	7.9	23.3	721.4
613	64.8	4.0	12.4	121.4	74.5	87.4	117.3	202.8	101.8	246.7	522.2	68.1	1623.4
614	0.1	-	-	1.3	0.3	6.9	1.2	14.2	0.3	0.0	0.0	-	24.4
615	4.8	2.3	0.0	2.9	-	104.2	10.5	19.6	-	-	-	244.8	389.1
616	809.7	2293.8	1458.7	622.0	133.2	117.2	81.9	-	25.8	177.9	966.9	1425.1	8112.2
621	3.2	3.5	0.5	2.1	3.6	27.0	19.7	1.0	0.3	1.4	1.3	3.4	67.0
622	172.5	44.5	552.2	362.9	2.4	0.0	-	0.3	2.7	10.4	72.1	288.3	1508.3
623	-	24.5	18.1	-	-	-	-	-	-	-	-	-	42.6
625	0.1	-	-	-	0.0	-	0.0	-	-	0.2	0.9	0.7	1.9
626	6.6	11.4	74.9	99.5	0.0	-	-	0.5	2.4	47.5	30.4	16.7	289.8
631	1.3	0.5	4.6	0.0	-	-	-	-	-	0.1	0.5	0.3	7.3
632	1.3	2.3	2.8	0.4	-	-	-	-	5.0	216.0	234.5	-	462.2
635	1.6	-	-	-	-	-	-	-	-	-	-	0.3	1.9
Totals	1521.1	2630.7	2745.7	1879.1	895.2	598.1	893.3	830.9	246.2	1260.1	2203.2	2468.3	18171.9
%	8	14	15	10	5	3	5	5	1	7	12	14	
Avg % (1982-92)	6	6	7	6	19	10	7	6	4	9	9	9	

Table F3. Summary of *Loligo pealei* landings (mt) by fishing gear within the NEMFIS database, 1982 - 1992

Year	Bottom Otter Trawl	Floating Trap	Pound Net	Paired Mid-Water Otter Trawl	Other	Total
1982	2445	1	75	1	3	2525
1983	8266	23	2	2	439	8732
1984	6649	67	438	0	4	7158
1985	6217	359	281	2	5	6864
1986	10867	77	522	11	35	11512
1987	9688	96	552	1	6	10343
1988	16811	649	1007	84	11	18562
1989	22416	450	725	55	5	23651
1990	14354	306	280	9	4	14953
1991	18849	318	161	44	37	19409
1992	17911	44	116	20	81	18172

For 1993 and 1994, the allowable biological catch and domestic allowable harvests have been increased to 44,000 mt (MAFMC 1992).

DATA SOURCES

Commercial landings data for 1992 were derived from the NEMFIS data base and general canvas sources. Landings data for 1989 to 1991 were reported at the 12th and 14th SAWs (NEFSC 1991, 1992), while landings data for 1963-1988 were given in the Report of the 10th SAW (NEFSC 1990). Effort data used in the analysis of domestic LPUE from 1982 to 1992 were derived from the NEMFIS data base.

Numbers of *Loligo* landed by the commercial fishery during 1982 - 1992 (Table F5) were estimated using NEFSC commercial size frequency sampling data.

Multiplicative GLM main effects models (Gavaris 1980) was used to standardize fishing effort (days fished) and landings per unit of effort (LPUE) in both the small-vessel and large-vessel fisheries for *Loligo* during 1982 to 1992 (Brodziak MS 1993). In the small-vessel analysis, year and area were used as factors to standardize fishing effort (R^2=.45) (Table F6; Figure F4). In the large-vessel analysis, fishing effort was standardized using year, tonnage class, quarter, and area as factors (R^2=.24) (Table F7; Figure F5). In both analyses, standardized LPUE (ratio of fleet landings to standardized effort) and a standardized abundance index (ratio of annual LPUE to LPUE in 1982) were calculated.

Research survey indices of relative abundance of *Loligo* offshore (depth > 27 m) were derived from NEFSC spring (1967-1993) and autumn (1967-1992) bottom trawl surveys conducted from Cape Hatteras to Georges Bank [offshore strata 1-23, 25, and 61-76] (Grosslein 1969; Azarovitz 1981). In previous *Loligo* assessments, NEFSC survey catches were adjusted to a standard tow duration of 30 minutes. However, results from a regression analysis of *Loligo* catch (kilograms) per tow on tow duration indicated that tow duration has no significant effect on *Loligo* catches (Table F8). As a result, both spring and autumn NEFSC bottom trawl survey time series were recomputed without the tow standardization option (Tables F9 and F10).

Indices of relative abundance of *Loligo* inshore were computed from Commonwealth of Massachusetts spring inshore bottom trawl surveys conducted during 1982 to 1993 (Table F11).

ASSESSMENT RESULTS

Relative Abundance

Standardized fishing effort and LPUE for the small-vessel fishery declined sharply in 1992 (Table F6), while effort and LPUE slightly increased in the large-vessel fishery (Table F7). In the small-vessel fleet, LPUE and standardized fishing effort have declined markedly since 1988. Small-vessel LPUE in 1992 was a record-low, while small-vessel effort in 1992 was the second-lowest in the 11-year time series (Table F6; Figure F4). In the large-vessel fleet, LPUE and standardized fishing effort have markedly increased since the early 1980s; in 1992, large-vessel LPUE and fishing effort were the second-highest on record (Table F7; Figure F5).

Spring and autumn NEFSC survey indices of *Loligo* abundance in 1992 were somewhat dis-

Table F4. Summary of landings (metric tons) by small vessel and large vessel components of the U.S. *Loligo pealei* fishing fleet that were used to compute standardized fishing effort, 1982 to 1992

Year	Small Vessel	Large Vessel	Subtotal[1]	Total[2]
1982	275 (13%)[3]	1820 (87%)	2095 (38%)[4]	5464
1983	1639 (21%)	6263 (79%)	7902 (50%)	15943
1984	684 (11%)	5523 (89%)	6207 (54%)	11592
1985	159 (3%)	4949 (97%)	5108 (50%)	10155
1986	603 (6%)	9075 (94%)	9678 (73%)	13292
1987	421 (5%)	7949 (95%)	8370 (73%)	11475
1988	925 (7%)	12507 (93%)	13432 (70%)	19072
1989	797 (5%)	16420 (95%)	17217 (73%)	23655
1990	455 (4%)	11259 (96%)	11714 (78%)	14954
1991	504 (3%)	14933 (97%)	15437 (80%)	19409
1992	150 (1%)	15740 (99%)	15890 (87%)	18177

[1] Total landings of small and large vessel trips that were used to standardize fishing effort.
[2] Total landings by U.S. vessels. This total includes joint venture landings made by U.S. vessels.
[3] Percentage of small and large vessel landings total.
[4] Small and large vessel landings as a percentage of total U.S. landings.

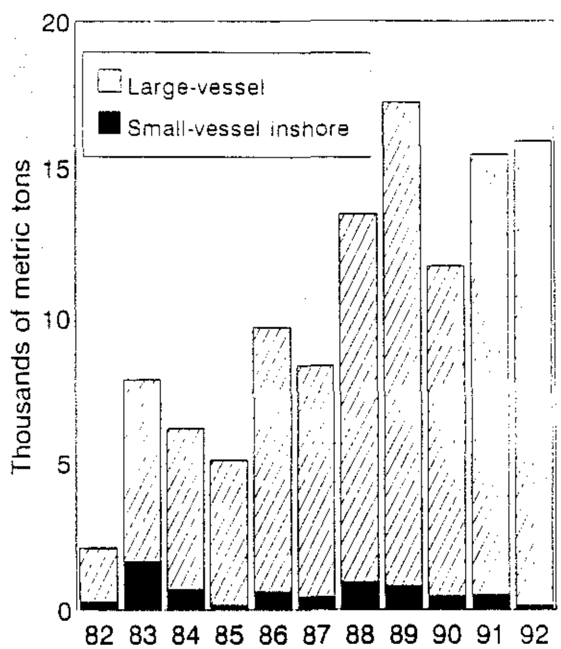

Figure F3. Annual landings in the small-vessel inshore and large-vessel fisheries for *Loligo pealei*.

parate (Tables F9 and F10). The 1992 spring number-per-tow index was slightly above average, but 50% less than the high 1991 index. Similarly, the spring 1992 weight-per-tow index was equal to the average, but 40% lower than the 1991 value. Based on these results, *Loligo* abundance during the 1992 spring/summer inshore fishery was expected to be average - and well below that in 1991.

In contrast, the NEFSC autumn 1992 number-per-tow index was the largest in the survey time series (about 2.5 times higher than the long-term average) due to a record-high level of prerecruits (Table F10). However, the autumn 1992 weight-per-tow index was 35% below the mean and less than half of the 1991 index. The record-high prerecruit index (Table F10) suggested that a large cohort would be recruiting to the offshore fishery during Winter of 1993. This cohort was also expected to generate elevated catch-per-tow indices in the 1993 NEFSC spring survey, if landings during the winter fishery were not substantial.

However, *Loligo* catch-per-tow indices in the spring 1993 survey were sharply lower than in 1992 and well below the long-term means (Table F9). These results suggested that *Loligo* abundance during the 1993 spring/summer inshore fishery would be no higher - and perhaps much lower - than in 1992.

The 1992 and 1993 Massachusetts inshore spring survey catch-per-tow indices were the lowest ever recorded (Table F11). Although the 1993 indices were higher than in 1992, these still suggested that inshore abundance of *Loligo* in

Table F5. Total numbers and mean weights of *Loligo pealei* landed in the Northwest Atlantic from 1982 to 1992

Year	Total Number (thousands)	Mean Weight (g)
1982	162,231	131
1983	216,122	128
1984	183,213	123
1985	151,739	110
1986	139,173	129
1987	106,720	108
1988	194,430	98
1989	195,167	118
1990	113,828	138
1991	144,180	134
1992	137,508	128
Average 1982-91	160,680	122

southern New England during 1993 would be well below average.

Absolute Abundance

Minimum estimates of absolute biomass and numbers (total and pre-recruits) of *Loligo* on the Northeast U.S. continental shelf from Cape Hatteras to the Gulf of Maine were calculated by areal expansion of NEFSC autumn bottom trawl indices obtained during 1982 to 1992 (Table F12). These estimates (Table F13) were based upon areal expansion of *Loligo* catches in offshore survey strata 1-30, 33-40, and 61-76 (Cape Hatteras to Gulf of Maine) and inshore survey strata 1-55 (Cape Hatteras to Cape Cod). These estimates require three assumptions: (i) catchability of *Loligo* is constant in space and time; (ii) catchability is equal for all sizes of *Loligo*; (iii) all *Loligo* within the area swept by the survey gear are captured. Thus, these estimates are likely to be biased low because these assumptions are unlikely to hold.

Loligo have a tendency to disperse vertically upward in the water column at night (Summers 1968, 1969). This behavior reduces availability to bottom trawl gear and will cause the area-swept estimates of population size derived from the NEFSC research vessel surveys to be under-estimates - since survey tows are made round-the-clock during both day and night. Analysis of autumn 1967-1991 survey catches of *Loligo* taken in tows during day, dawn-dusk, and at night suggest that diurnally-adjusted, area-swept es-

Table F6. Standardized fishing effort and standardized landings-per-unit of effort (LPUE) for the U.S. small-vessel, inshore otter trawl fishery for long-finned squid (*Loligo pealei*), 1982-1992. The U.S. small-vessel, inshore fishery is defined as trips by tonnage class 2 vessels landing *Loligo* during May, June, and July from Statistical Areas 537, 538, 539, 611, 612, 613, or 621.

Year	Domestic LPUE (mt/ day fished)	Standardized Fishing Effort (days fished)	Standardized Abundance Index[2]
1982	3.02	91.2	1.00
1983	7.81	210.0	2.59
1984	5.47	125.0	1.81
1985	2.08	76.4	0.69
1986	5.34	112.9	1.77
1987	3.02	139.3	1.00
1988	4.71	196.3	1.56
1989	4.32	184.4	1.43
1990	3.03	150.1	1.00
1991	3.31	152.4	1.10
1992	1.75	85.6	0.58
Average 1982-91	4.21	143.8	

[1] For trips used in the general linear model, the ratio of total landings (mt) to standardized fishing effort.
[2] Ratio of annual LPUE to LPUE in 1982.

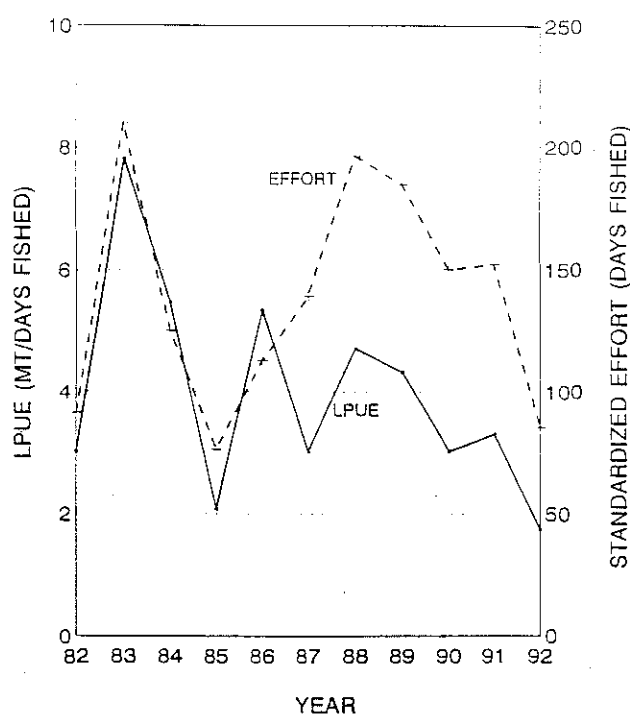

Figure F4. Annual LPUE and effort in the small-vessel inshore fishery for *Loligo pealei*.

Table F7. Long-finned squid (*Loligo pealei*) domestic landings (metric tons) per days fished (LPUE) and days fished for the large vessel (tonnage classes 3 and 4) fishery (statistical areas 526, 537, 538, 539, 612, 613, 615, 616, 621, 622, 626, and 632) during 1982 to 1992

Year	Domestic LPUE[1] (mt/ days fished)	Standardized Effort (days fished)	Standardized Abundance Index[2]
1982	3.88	469.3	1.00
1983	7.27	861.0	1.87
1984	5.70	968.7	1.47
1985	4.00	1235.8	1.03
1986	3.79	2397.5	.98
1987	4.55	1748.1	1.17
1988	6.81	1837.7	1.76
1989	8.34	1969.7	2.15
1990	6.33	1777.5	1.63
1991	7.09	2107.6	1.83
1992	7.21	2183.6	1.86
Average 1982-91	5.78	1537.3	

[1] Ratio of total landings (mt) to standardized effort for trips used in the general linear model.
[2] Ratio of annual LPUE and LPUE in 1982.

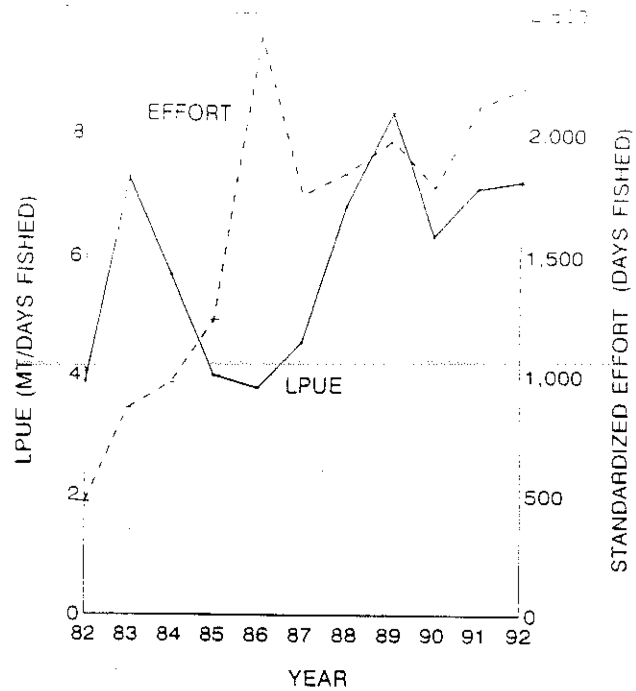

Figure F5. Annual LPUE and effort in the large-vessel fishery for *Loligo pealei*.

Table F8. Estimated linear relationship between weight per tow of *Loligo pealei* (CATCHWT) and tow duration (DUR) during the NEFSC Fall survey, 1967-1991

Model: CATCHWT = DUR
Dependent Variable: CATCHWT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	1	175.648	175.648	0.442	0.5062
Error	3486	1385400.431	397.418		
C Total	3487	1385576.079			

Root MSE	19.935	R-square	0.0001
Dep Mean	9.131	Adj R-sq	-0.0002
C.V.	218.323		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.917	12.359	0.074	0.9408
DUR	1	0.274	0.413	0.665	0.5062

Table F9. Stratified mean catch per tow in numbers and weight (kiolgrams) of *Loligo pealei* in NEFSC spring bottom trawl surveys, Cape Hatteras to Georges Bank (Strata 1-23, 25, and 61-76), 1967 - 1992. Mean number per tow indices are presented for all sizes of *Loligo*, for pre-recruits (≤ 8 cm), and for recruits (> 8 cm).

Year	All CV[1]	Prerecruit	Recruit	Kg/Tow	Mean Weight per Squid (g)
1968	26.9 (25%)	5.7	21.1	1.4	53
1969	14.8 (21%)	2.0	12.8	1.2	82
1970	26.6 (22%)	17.7	8.9	.9	34
1971	35.0 (24%)	20.3	14.7	1.6	46
1972	65.2 (21%)	37.0	28.2	3.2	49
1973	42.4 (27%)	19.2	23.2	2.9	67
1974	231.2 (30%)	196.0	35.3	4.1	18
1975	166.6 (31%)	126.0	40.6	4.2	25
1976	200.1 (17%)	153.6	46.5	5.2	26
1977	18.8 (30%)	10.0	8.8	.8	42
1978	49.1 (34%)	36.0	13.2	1.5	30
1979	113.8 (34%)	95.5	18.4	2.3	20
1980	54.6 (34%)	39.6	15.0	1.9	35
1981	48.1 (27%)	28.1	20.0	1.9	40
1982	70.6 (27%)	50.0	22.6	2.1	30
1983	46.9 (24%)	17.5	29.4	2.1	44
1984	78.1 (31%)	54.0	24.1	2.6	33
1985	83.4 (21%)	61.5	22.0	2.4	28
1986	99.6 (24%)	70.8	28.8	2.9	30
1987	31.0 (16%)	12.7	18.3	2.1	67
1988	130.1 (28%)	94.7	35.4	3.6	28
1989	153.0 (30%)	92.4	60.6	5.2	34
1990	136.2 (23%)	102.6	33.6	3.7	27
1991	181.2 (24%)	131.7	49.4	4.5	25
1992	90.4 (30%)	69.9	20.5	2.7	30
1993	46.5 (28%)	26.3	20.2	1.8	40
1968-91 Average	87.7 (26%)	61.7	26.1	2.7	38

[1] Coefficient of variation for the all sizes index.

timates may be 50-85% higher than the non-adjusted estimates provided in Table F13. However, more work is needed to thoroughly evaluate day-night differences, including possible size-related differences in diurnal catchability between prerecruit and recruit animals. More work is needed to evalute the effects of this behavior upon relative abundance indices.

Provisional estimates of annual surplus production of *Loligo* during 1982-1992 indicate similar trends in biomass as those from the area-swept method. Estimates of virgin biomass and MSY from the surplus production model were relatively sensitive to the assumed values of catchability (q) and stock resilience (A). Further work in examining the assumptions and application of the model for *Loligo* is warranted.

OVERFISHING DEFINITION

Overfishing for *Loligo* is defined to occur when the three-year moving average of prerecruits from the NEFSC autumn bottom trawl survey is below the first quartile of this series. For the purpose of applying the overfishing definition in 1992, 1993, and 1994, the lowest quartile of values consists of the seven lowest prerecruit indices (Table F10); the three-year moving average of the prerecruit series must be less than the largest index in this quartile for overfishing to occur (Table F14). Given the record-high 1992 autumn prerecruit index (755.8), the three-year moving prerecruit average in 1992 was 412.4. If the 1993 and 1994 prerecruit indices are both 0, the corresponding three-year moving averages

Table F10. Stratified mean catch per tow in numbers and weight (kiolgrams) of *Loligo pealei* in NEFSC autumn bottom trawl surveys, Cape Hatteras to Georges Bank (Strata 1-23, 25, and 61-76), 1967 - 1992. Mean number per tow indices are presented for all sizes of *Loligo*, for prerecruits (≤ 8 cm), and for recruits (> 8 cm).

Year	All Sizes (CV)[1]	Prerecruits	Recruit	Kg/Tow	Mean Weight (g) Per Squid
1967	143.1 (22%)	123.4	19.6	4.1	29
1968	187.7 (13%)	118.8	68.9	7.6	41
1969	252.3 (15%)	160.1	92.2	10.2	40
1970	90.9 (14%)	54.1	36.9	3.3	36
1971	173.6 (15%)	141.7	31.9	3.2	18
1972	288.6 (18%)	220.1	68.4	6.9	24
1973	395.6 (15%)	275.4	120.2	11.4	29
1974	267.7 (18%)	186.4	81.2	8.7	32
1975	653.3 (20%)	543.0	110.3	11.4	17
1976	436.7 (14%)	321.4	115.3	12.0	28
1977	413.1 (13%)	316.6	96.6	8.5	21
1978	153.3 (16%)	99.2	54.2	4.5	29
1979	205.9 (15%)	166.4	39.5	4.0	19
1980	387.2 (16%)	297.5	89.7	8.3	22
1981	241.3 (15%)	171.5	69.8	6.1	25
1982	270.9 (22%)	216.4	54.5	5.8	21
1983	384.7 (15%)	261.8	122.9	11.6	30
1984	316.4 (17%)	160.4	155.9	12.8	41
1985	460.2 (15%)	322.2	138.0	13.1	28
1986	459.6 (16%)	364.6	95.0	8.9	19
1987	59.8 (14%)	33.9	25.9	2.2	37
1988	405.3 (16%)	316.0	89.3	7.7	19
1989	450.6 (15%)	291.3	159.3	11.9	26
1990	385.8 (14%)	286.6	99.2	9.2	24
1991	321.0 (11%)	194.7	126.3	11.0	34
1992	788.9 (30%)	755.8	33.1	5.3	7
1993[2]	190.8 -	124.3	66.5	5.1	27
1967-1992 Average	312.2 (16%)	225.7	86.4	8.2	28

[1] Coefficient of variation for the all sizes index.
[2] Provisional survey indices.

would be 316.8 and 251.9, respectively. The largest prerecruit index in the lower quartile of values during 1992, 1993, and 1994 would correspond to 160.1, 141.7, and 123.4. Thus, according to the overfishing definition, *Loligo* were not overfished in 1992, and will not be overfished in 1993 and 1994. The provisional 1993 prerecruit index of 124.3 indicates that the minimum three-year moving average in 1995 would be 41.4, provided that 1994 and 1995 pre-recruit indices were 0. If this were the case, the largest index in the lowest quartile would be 123.4. Therefore it is possible that *Loligo* could be overfished in 1995 given the low provisional index in 1993.

YIELD AND SPAWNING STOCK BIOMASS PER RECRUIT

A yield per recruit analysis was performed for *Loligo* using recently developed information on the age and growth of *Loligo* using daily statolith growth increments (Macy 1992; Macy MS). These findings indicate that *Loligo* is an annual species

Table F11. Stratified mean catch per tow in numbers and weight (kg) of *Loligo pealei* in Commonwealth of Massachusetts spring inshore bottom trawl surveys, south of Provincetown, Massachusetts, 1982 - 1993. The mean weight (grams) per squid caught is also given.

Year	Number Per Tow (CV)	Kilograms Per Tow (CV)	Mean Weight Per Squid (g)
1982	15.5 (30%)	1.3 (46%)	81
1983	85.8 (23%)	6.7 (37%)	78
1984	61.9 (19%)	4.3 (26%)	70
1985	113.3 (26%)	7.0 (23%)	62
1986	48.9 (14%)	6.2 (17%)	126
1987	59.8 (20%)	5.9 (22%)	98
1988	255.5 (23%)	15.9 (24%)	62
1989	64.9 (19%)	5.5 (21%)	85
1990	136.3 (15%)	8.9 (15%)	65
1991	43.2 (24%)	4.3 (26%)	99
1992	10.8 (27%)	1.2 (33%)	109
1993	22.5 (19%)	3.4 (20%)	149
1982-92 Average	81.4 (22%)	6.1 (26%)	85

that grows rapidly - and is not as long-lived as previously thought (Verrill 1882; Mesnil 1977; Lange and Sissenwine 1980).

Input data for a Thompson-Bell yield per recruit analysis (Ricker 1975), using a monthly time step, were derived from a sample of 87 *Loligo* collected during spring and winter of 1991. Animals ranged in size from 2 cm to 44 cm in dorsal-mantle length, and from 3.6 to 9.7 months in age (Macy, *pers. comm.*). Instantaneous natural mortality for *Loligo* was estimated to be M = 4.1 (Hoenig 1983), and knife-edged recruitment was assumed to occur at an age of 3 months (9 cm dorsal-mantle length).

For the spawning stock biomass per recruit analysis (Gabriel *et al.* 1989), sexual maturity was assumed to be knife-edged and to occur at an age of 7 months (approximately 20 cm dorsal-mantle length), based on the observations of Mesnil (1977, Figure 2, 20-month cycle) on Georges Bank and the observations of Macy (1980) within Rhode Island waters during April to June. Recruits were assumed to be fully susceptible to natural and fishing mortality prior to spawning.

Results of the monthly yield and spawning stock biomass per recruit calculations (Table F.15; Figure F6) indicate that in units of month^{-1}, $F_{0.1}$ = 0.16 and F_{max} = 0.26 (in units of year^{-1}, $F_{0.1}$=1.92 and F_{max}=3.12). These estimates of **monthly fishing mortality reference points** are 47% and 76%, respectively, of monthly natural mortality (M_m = 0.34), and suggest that fishing mortality should be kept below natural mortality for this stock.

Estimates of the total potential yield from a Fall-spawned *Loligo* cohort were calculated based upon the average cohort size during 1982 to 1992. Although a definitive estimate (in absolute numbers) of the size of an average cohort is not available, a provisional diurnally-adjusted value of 2.20 billion recruits was calculated using

Table F12. Stratified mean catch per tow in numbers and weight (kg) of *Loligo pealei* in NEFSC autumn bottom trawl surveys, Cape Hatteras to the Gulf of Maine (offshore strata 1-30, 33-40 and 61-76; inshore strata 1-55), 1982 - 1992. Mean number per tow indices are presented for all sizes of *Loligo*, for prerecruits (≤ 8 cm), and for recruits (> 8 cm).

Year	All Sizes	CV[1]	Prerecruit	Recruit	Mean Weight Per Squid (g)	Kg/Tow	(CV[1])
1982	185.5	(19%)	152.3	33.2	20	3.6	(15%)
1983	270.1	(13%)	193.4	76.7	27	7.3	(14%)
1984	191.3	(16%)	100.4	90.9	39	7.5	(15%)
1985	280.7	(14%)	197.2	83.5	28	7.9	(13%)
1986	287.1	(15%)	230.4	56.7	19	5.3	(13%)
1987	41.9	(12%)	25.0	16.9	34	1.4	(14%)
1988	333.0	(11%)	276.0	57.0	16	5.2	(11%)
1989	281.6	(14%)	187.2	97.4	25	7.1	(17%)
1990	239.7	(13%)	178.7	61.0	24	5.7	(10%)
1991	226.1	(9%)	146.8	79.3	31	6.9	(12%)
1992	504.0	(27%)	479.7	24.3	7	3.4	(16%)
Average 1982-91	233.7	(14%)	168.7	65.2	26	5.8	(14%)

[1] Coefficient of variation for the all sizes index

Table F13. Area-swept estimates of *Loligo pealei* population size in the Cape Hatteras to Gulf of Maine region, 1982 - 1992. Estimates were derived by areal expansion of autumn NEFSC survey catch per tow indices and are expressed as total biomass (metric tons), total numbers (billions) and numbers of prerecruits (billions).

Year	Total Biomass	Total Numbers	Number of Prerecruits
1982	25,800	1.32	1.08
1983	51,000	1.89	1.35
1984	53,500	1.36	0.71
1985	56,700	2.02	1.42
1986	38,000	2.05	1.65
1987	10,000	0.29	0.17
1988	36,000	2.32	1.92
1989	49,800	1.97	1.31
1990	39,800	1.68	1.25
1991	48,600	1.59	1.03
1992	23,900	3.53	3.36
Average 1982-91	40,900	1.65	1.19

Table F14. Three-year moving average of the *Loligo pealei* prerecruit number per tow index from the NEFSC fall bottom trawl survey, 1969-92. a. ordered by year; b ordered by index value. * = upper bound of lower quartile for 1993-1995.

a.Year	Average[1] Prerecruit Number per Tow	b. Year	Average[1] Prerecruit Number per Tow	
1969	134.1	1970	111.0	
1970	111.0	1971	118.6	
1971	118.6	1969	134.1	
1972	138.6	1972	138.6	
1973	212.4	1980	187.7	
1974	227.3	1979	194.0	
1975	334.9	1981	211.8	*
1976	350.3	1973	212.4	
1977	393.7	1984	212.9	
1978	245.7	1989	213.7	
1979	194.0	1983	216.6	
1980	187.7	1974	227.3	
1981	211.8	1982	228.5	
1982	228.5	1988	238.2	
1983	216.6	1987	240.2	
1984	212.9	1978	245.7	
1985	248.1	1985	248.1	
1986	282.4	1991	257.5	
1987	240.2	1986	282.4	
1988	238.2	1990	298.0	
1989	213.7	1975	334.9	
1990	298.0	1976	350.3	
1991	257.5	1993	358.3	
1992	412.4	1977	393.7	
1993[2]	358.3	1992	412.4	

[1] Average of pre-recruit index in years T, T-1, and T-2, where T is the current year.
[2] Provisional.

NEFSC autumn survey data. At F_{max}, the potential yield (MSY) from such a cohort would be 35,900 mt (Table F16). Based on the 95% confidence interval associated with the mean cohort size of 2.2 billion squid (1.38 billion, lower 95% limit; 3.02 billion, upper 95% limit), the potential yield from an average cohort ranges from 22,500 to 49,200 mt (Table F16).

Sensitivity analyses evaluating the impact on MSY of misestimation of M (from the assumed value of M_m = 0.34) indicate that a 20% increase in M_m would lower MSY by 30%, while a 20% reduction in M_m would increase MSY by 56% (Table F16).

STOCK AND RECRUITMENT

Cross-correlations were computed between NEFSC spring and autumn survey indices (prerecruit and recruit number-per-tow indices) to examine possible lagged associations (Table F17). The pre-recruit and recruit series were used as approximate measures of juvenile and adult abundance. Significant positive cross-correlations were found between: (1) the spring and autumn recruit indices with no lag; (2) the spring recruit indices lagged by one year and the autumn prerecruit indices; (3) the spring recruit and spring prerecruit indices with no lag; and (4) the spring pre-recruit indices lagged by one year and the autumn prerecruit indices. Overall, the cross-correlation analyses suggest that the spring and autumn indices contain useful information about linkages between spawning stock and juvenile abundance in *Loligo*. The biological basis for these relationships, however, needs to be explored.

PREDICTION OF FISHERY SUCCESS

Potential associations between research survey indices and fishery success were examined by correlation analysis of NEFSC spring and autumn pre-recruit and recruit indices and Massachusetts spring survey indices with small-

Table F15. Yield and spawning stock biomass per recruit analyses for *Loligo pealei*

Proportion of F before spawning: 1.0000
Proportion of M before spawning: 1.0000
Natural mortality is constant at: 0.3400
Initial age is: 1 month; Last age is: 10 months
Last age is a PLUS group
Input data from file named: loligo.dat

Age-specific (in months) Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Stock	Weights Catch
1	0.0000	1.0000	0.0000	0.0110	0.0110
2	0.0000	1.0000	0.0000	0.0170	0.0170
3	1.0000	1.0000	0.0000	0.0280	0.0280
4	1.0000	1.0000	0.0000	0.0450	0.0450
5	1.0000	1.0000	0.0000	0.0720	0.0720
6	1.0000	1.0000	0.0000	0.1160	0.1160
7	1.0000	1.0000	1.0000	0.1860	0.1860
8	1.0000	1.0000	1.0000	0.3000	0.3000
9	1.0000	1.0000	1.0000	0.4820	0.4820
10+	1.0000	1.0000	1.0000	0.7750	0.7750

Summary of Yield per Recruit Analysis for: ***Loligo pealei***

The slope of the yield per recruit curve at F=0:	0.237245
F level at slope=1/10 of the above slope (F0.1):	**0.158424**
Yield/Recruit corresponding to F0.1:	0.015332
F level to produce Maximum Yield/Recruit (Fmax):	**0.259548**
Yield/Recruit corresponding to Fmax:	0.016274

Listing of Yield per Recruit Results for: ***Loligo pealei***

FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	%MSP
0.000	0.00000	0.00000	3.4695	0.3030	0.3211	0.1493	100.00
0.050	0.06495	0.00865	3.2805	0.2319	0.2232	0.0977	65.41
0.100	0.11514	0.01301	3.1350	0.1840	0.1577	0.0652	43.64
0.150	0.15509	0.01512	3.0196	0.1506	0.1129	0.0442	29.59
0.200	0.18764	0.01601	2.9259	0.1267	0.0816	0.0304	20.34
0.250	0.21467	0.01627	2.8485	0.1092	0.0595	0.0211	14.15
0.300	0.23748	0.01620	2.7835	0.0962	0.0437	0.0148	9.94
0.350	0.25698	0.01597	2.7282	0.0863	0.0323	0.0105	7.04
0.400	0.27385	0.01569	2.6807	0.0786	0.0240	0.0075	5.03
0.450	0.28858	0.01538	2.6394	0.0725	0.0179	0.0054	3.62
0.500	0.30156	0.01509	2.6032	0.0677	0.0134	0.0039	2.62
0.550	0.31308	0.01483	2.5714	0.0638	0.0100	0.0028	1.91
0.600	0.32337	0.01459	2.5431	0.0606	0.0076	0.0021	1.40
0.650	0.33263	0.01437	2.5179	0.0579	0.0057	0.0015	1.03
0.700	0.34099	0.01419	2.4953	0.0557	0.0043	0.0011	0.76
0.750	0.34859	0.01402	2.4750	0.0538	0.0033	0.0008	0.56
0.800	0.35552	0.01388	2.4566	0.0522	0.0025	0.0006	0.42
0.850	0.36187	0.01376	2.4399	0.0508	0.0019	0.0005	0.31
0.900	0.36771	0.01365	2.4247	0.0496	0.0014	0.0003	0.23
0.950	0.37309	0.01356	2.4108	0.0485	0.0011	0.0003	0.18
1.000	0.37807	0.01348	2.3981	0.0476	0.0008	0.0002	0.13

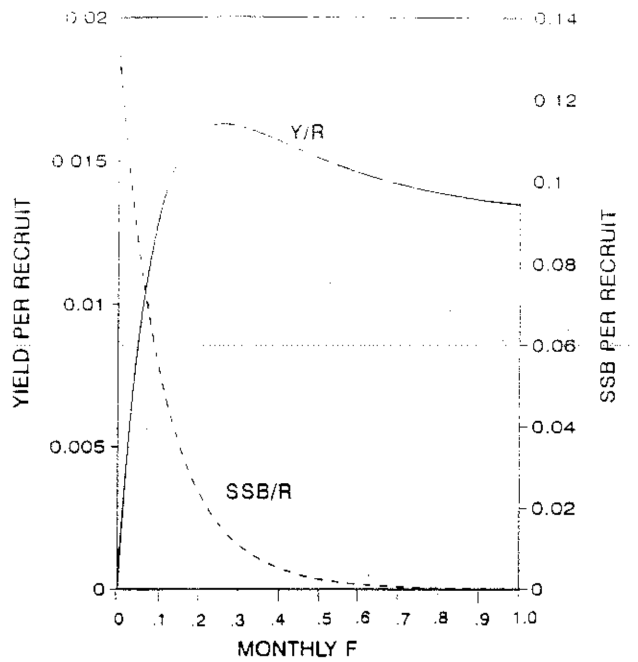

Figure F6. Relationship between monthly fishing mortality (F), yield per recruit (Y/R) and spawning stock biomass per recruit (SSB/R) for *Loligo pealei*.

Table F16. Cross-correlations between standardized indices of *Loligo pealei* abundance from the NEFSC bottom trawl surveys, 1967-1992. Spring (SR) and Fall (FR) recruit indices are approximate measures of relative adult abundance, while Spring (SP) and Fall (FP) prerecruit indices are approximate measures of relative juvenile abundance. An index (I) lagged by k years is denoted by I(-k).

Indices	Cross-correlation
{FR(-1), SR}	0.11
{FR, SR}	0.59[1]
{FR(1), SR}	0.35
{FR(-1), SP}	0.28
{FR, SP}	0.28
{FR(1), SP}	0.25
{FR(-1), FP}	0.26
{FR, FP}	0.23
{FR(1), FP}	0.19
{SR(-1), FP}	0.55[1]
{SR, FP}	0.28
{SR(1), FP}	0.25
{SR(-1), SP}	0.31
SR, SP}	0.71[1]
{SR(1), SP}	0.36
{SP(-1), FP}	0.66[1]
{SP, FP}	0.32
{SP(1), FP}	0.19

[1] Significantly different from 0 for $\alpha = 0.05$.

Table F17. Effect of changes in monthly instantaneous natural mortality rate (M_m) on maximum yield per recruit (YPR) and maximum sustainable yield (MSY) for *Loligo pealei*. Confidence limits (CL) on MSY are also provided and are based on the 95% confidence limits associated with the estimate of average recruitment.

% Change in M_m	% Change in YPR	MSY Lower 95% CL (mt)	MSY Point Estimate (mt)	MSY Upper 95% CL (mt)
25%	-36%	14,500	23,100	31,700
20%	-30%	15,800	25,100	34,500
15%	-24%	17,100	27,200	37,400
10%	-17%	18,600	29,700	40,800
5%	-9%	20,400	32,500	44,700
0%	0%	22,500	35,900	49,200
-5%	11%	24,900	39,700	54,500
-10%	23%	27,700	44,200	60,700
-15%	38%	31,000	49,500	67,900
-20%	55%	34,900	55,600	76,400
-25%	75%	39,400	62,900	86,300

vessel and large-vessel LPUE values during 1982 to 1992. No significant correlations were found between any of the research survey indices and small-vessel LPUE. In contrast, large-vessel LPUE was significantly positively correlated with spring prerecruit and recruit indices.

A number of potential predictors of fishery success were explored using linear regression, and some were provisionally found to be statistically significant. These analyses should continue and give proper consideration for lag effects between the timing of the surveys and the seasonality of the fisheries.

DISCUSSION

In 1992, several indices of relative abundance (small-vessel LPUE, and NEFSC and Commonwealth of Massachusetts spring survey indices) indicated that *Loligo* abundance was below average (Tables F6, F9, and F11). The LPUE in the small-vessel, inshore fishery in 1992 was a record-low (Table F6), and effort markedly dropped - presumably in response to poor landings success. In contrast, LPUE in the large-vessel fishery remained high in 1992, and large-vessel effort increased to near-record levels (Table F7).

The autumn 1992 pre-recruit index was the largest on record (Table F10) and suggests that a large cohort would be available to the offshore fishery in Winter 1993. Provisional *Loligo* landings during the first four months of 1993 were 13,300 mt, 67% above the corresponding period in 1992, and projected total landings in 1993 are expected to be 25,400 mt, a record-high domestic catch. The high landings during the first quarter of 1993, combined with the record-high autumn 1992 pre-recruit index, are indicative of the rapid growth and recruitment of *Loligo* to the offshore fishery. However, the 1993 NEFSC spring survey indices did not reflect a high abundance of *Loligo*; in fact, the spring 1993 indices were among the lowest in the past decade. While the low spring indices might be due to the impact of the large Winter 1993 fishery, other factors affecting the relationship between autumn and spring survey abundance indices must be explored further (particularly since the correlation between autumn prerecruit indices and the subsequent spring recruit indices was not found to be significant).

New yield per recruit calculations based on an annual life cycle for *Loligo* indicate that, for an estimated Fall cohort of average size (2.2 billion animals), a maximum yield of 36,000 mt in yield could be realized. However, there are many uncertainties with the input parameters used in the yield per recruit and spawning stock biomass analyses - and these need to be resolved as quickly as possible as the current MSY level of 44,000 mt (based on a 2-year life span) now appears to be too high. The YPR and SSB/R analyses do not account for discard mortality, density-dependent mortality due to cannibalism, seasonal fluctuations in growth, or potential fluctuations in natural mortality due to variability in predation pressure or environmental factors. As such, the 36,000 mt should not be viewed as an annual harvest target - but more of an initial, rough upper bound on the sustainable yield from a cohort. In years of low *Loligo* biomass, however, this level of landings would likely result in severe reductions in SSB.

During 1973-1976 when fishing for *Loligo* was unrestricted, total annual landings averaged about 33,000 mt (with a peak catch of 38,000 mt in 1973). During this period, both spring and autumn NEFSC survey indices were among the highest on record. However, since 1976, annual landings have been much lower - suggesting that yields above 30,000 mt may only be attainable during years of very high abundance.

Given that *Loligo* is now considered to be an annual semelparous species, the potential for recruitment overfishing may be substantial since only a single cohort exist at any one time and animals recruit to the fishery and the spawning stock within the same year. Failure to ensure an adequate annual level of spawning escapement can jeopardize both the stock and the fishery.

There are clear advantages to operating a real time management procedure for stocks of species that have a short (annual) life cycle. Such systems have been successfully implemented in a number of fisheries around the world (see ICES 1993). However, it is important that managers be aware that both the scientific and administrative requirements for real time management may be substantially different from those used for resources which are managed under more traditional systems.

The components of a real time management system are;

1) An assessment of data from previous years to determine the management target for the coming year. This target should be in terms of fishing mortality rate and fishing effort. If prerecruit surveys are available then the target fishing mortality rate and the projected biomass can be used to make an initial estimate of the coming seasons catch.

2) A monitoring program that obtains fishery information, e.g. catches and effort, on a fine time and spatial scale.

3) An interim assessment(s) procedure using the fishery information to date and additional survey data as it becomes available. The interim assessments are used to monitor the progress of the resource through the season and to adjust the regulations to account for new information on the incoming stock. For example, if an interim assessment indicated that recruitment had been particularly poor in a given year, the fishery may be closed early to protect spawners. Alternatively, if a very large year class was available, additional catch or a longer season might lift unnecessary constraints on the industry.

4) An agreed procedure for expanding or reducing the amount of catch or effort allowed in a given season. The rules for expanding or contracting the fishery should be agreed beforehand, so that arguments over particular actions are minimized at the time when that action is needed. The procedure should only be changed between seasons, not during the season.

These elements will require a substantial amount of development by managers and scientists. A Plan Development Team could serve as a useful vehicle for the development of such a real time system for squid and other short-lived stocks.

SOURCES OF UNCERTAINTY

Estimation of absolute biomass from area-swept and diurnally-adjusted area-swept methods are likely to be sensitive to the assumption that catchability of prerecruit and recruits is 100% during daylight hours, and to any differences in vertical migration patterns between prerecruits and recruits.

The provisional recalculation of MSY based on maximum yield per recruit and average recruitment does not account for discard mortality, density-dependent mortality due to cannibalism, seasonal fluctuations in growth, or potential fluctuations in natural mortality due to variability in predation pressure or environmental factors.

Discarding of *Loligo* may be an important source of fishing-induced mortality. However, data currently available from the NEFSC sea sampling program are inadequate to evaluate this. No sea sampling trips have been conducted on freezer-trawler vessels fishing for *Loligo*.

Many of the analyses which are predicated on a life span for *Loligo* of one year must be considered provisional as age and growth studies are still in progress.

RESEARCH RECOMMENDATIONS

- Collaborative research between the NEFSC and the University of Rhode Island that is being conducted to examine seasonal and spatial patterns of growth and to further validate the one day-one ring hypothesis of statolith increment formation in *Loligo pealei* should be continued and completed as soon as possible. This information is critical to the assessment and to planned revisions to the FMP.

- If *Loligo* is an annual species, new approaches to the assessment and management of the stock will be required. A more adaptive, real-time assessment/management system will be needed to attain full exploitation of the stock while, at the same time, ensuring that adequate levels of spawning stock are achieved (Rosenberg *et al.* 1990). Examples of the types of assessment and management procedures that have proved successful for short-lived species are provided in the 1993 report of the ICES Working Group on Methods of Fish Stock Assessment (ICES 1993).

- Once the 1993 landings data become available, the relationship between the record-high autumn 1992 survey prerecruit index and large-vessel LPUE should be examined.

- Collection of *Loligo* maturity data during NEFSC bottom trawl surveys should be initiated in order to determine seasonal maturation rates, and to quantify the spatial/temporal patterns in spawning activity.

- Surplus production models to estimate *Loligo* population size and fishing mortality should incorporate the new information about *Loligo* age and growth.

- Thus, alternative definitions of overfishing for *Loligo*, possibly based on a minimum biomass threshold or a minimum proportional escapement level, should be investigated. Future assessment research should investigate stock-recruitment relationships for *Loligo*. The calculation of risk-averse levels of spawning escapement should also be possible when more quantitative information on the age and growth, maturation, and timing of spawning for *Loligo* becomes available.

- Evaluate possible shifts in availability of *Loligo* between offshore and inshore areas, and potential influences of temperature on distribution patterns.
- Examine the influence of cannibalism on estimates of natural mortality, potential yield and spawner-recruit relations.
- Standardize survey indices for size-specific variation in catchability.
- Significant improvements in the *Loligo* assessment require the present studies on age and growth to be completed. The SARC does not anticipate that such information will be available before spring 1995.

REFERENCES

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. *In*: Doubleday, W.G. and Rivard, D., eds. Bottom trawl surveys. *Can. Spcl. Sci. Publ. Fish. Aquat. Sci.* 58:62-67.

Brodziak, J. 1993 MS. Stock assessment for long-finned squid, *Loligo pealei*, in the Northwest Atlantic during 1992. Working paper prepared for the 17th SAW SARC, NEFSC, Woods Hole, MA, November 1994.

Caddy, J.F. 1991. Daily rings on squid statoliths: an opportunity to test standard population models? *In* Jereb, P., S. Ragonese, and S. von Boletzky, eds., Squid age determination using statoliths. Proceedings of the International Workshop held at the Instituto di Technologia della Pesce e del Pescato (ITPP-CNR), Mazara del Vallo, Italy, 9-14 October 1989. *NTR-ITPP Spcl. Pub.* 1: 53-66.

Dawe, E.G., R.K. O'Dor, P.H. Odense, and G.V. Hurley. 1985. Validation and application of an ageing technique for short-finned squid (*Illex illecebrosus*). *J. Northw. Atl. Fish. Sci.* 6:107-116.

Dawe, E.G., J.C. Shears, N.E. Balch, and R.K. O'Dor. 1990. Occurrence, size, and sexual maturity of long-finned squid (*Loligo pealei*) at Nova Scotia and Newfoundland, Canada. *Can. J. Fish. Aquat. Sci.* 47: 1830-1835.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci.* 37: 2272-2275.

Gabriel, W.L., M.P. Sissenwine, and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. *N. Amer. J. Fish. Mgmt.* 9: 383-391.

Grosslein, M.D. 1969. Groundfish survey program of the BCF Woods Hole. *Commer. Fish. Rev.* 31(8-9): 22-35.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. *Fish. Bull.* 82: 898-902.

ICES. 1993. Report of the Working Group on Methods of Fish Stock Assessment, Copenhagen, 3-10 February 1993. *ICES* [International Council for Exploration of the Sea] *C. M.* 1993/Assess: 12.

Jackson, G.D. 1990. Age and growth of the tropical nearshore loliginid squid *Sepioteuthis lessoniana* determined from statolith growth-ring analysis. *Fish. Bull. (U.S.)* 88:113-118.

Jackson, G.D. and J.H. Choat. 1992. Growth in tropical cephalopods: an analysis based on statolith microstructure. *Can. J. Fish. Aquat. Sci.* 49:218-228.

Jackson, G.D., A.I. Arkhipkin, V.A. Bizikov, and R.T. Hanlon. 1993. Laboratory and field corroboration of age and growth from statoliths and gladii of the loliginid squid *Sepioteuthis lessoniana* (Mollusca: Cephalopoda). *In* Okutani, T., R.K. O'Dor, and T. Kubodera, eds., Recent advances in Cephalopod Fisheries Biology, p.189-199. Tokyo: Tokai University Press.

Jereb, P., S. Ragonese, and S. von Boletzky, eds. 1991. Squid age determination using statoliths. Proceedings of the International Workshop held at the Instituto di Technologia della Pesce e del Pescato (ITPP-CNR), Mazara del Vallo, Italy, 9-14 October 1989. *NTR-ITPP Spcl. Pub.* 1.

Lange, A.M.T., and M.P. Sissenwine. 1980. Biological considerations relevant to the management of squid, *Loligo pealei* and *Illex illecebrosus* of the Northwest Atlantic. *Mar. Fish. Rev.* 42(7-8):23-38.

Lipinski, M. 1978. The age of squid, *Illex illecebrosus*, from their statoliths. *ICNAF* [International Commission for Northwest *Atlantic* Fisheries] *Res. Doc.* 78/II/15.

Lipinski, M. 1986. Methods for the validation of squid age from statoliths. *J. Mar. Biol. Assoc. UK* 66:505:526.

Macy, W.K., III. 1980. The ecology of the common squid *Loligo pealei* Le Sueur, 1821 in Rhode Island waters. Kingston, RI: University of Rhode Island. Ph.D. thesis.

Macy, W.K., III. 1992. Preliminary age determination of the squid, *Loligo pealei*, using digital imaging. *ICES* [International Council for Exploration of the Sea] *C. M.* 1992/K:, 9 p.

Macy, W.K., III. (MS, in press). Digital image processing to age long-finned squid using statoliths. Proceedings of the Otolith Symposium, 1993, University of South Carolina.

Mesnil, B. 1977. Growth and life cycle of squid, *Loligo pealei* and *Illex illecebrosus*, from the Northwest Atlantic. *ICNAF* [International Commission for Northwest Atlantic Fisheries] *Sel. Pap.* 2:55-69.

MAFMC [Mid-Atlantic Fishery Management Council]. 1990. Amendment 3 to the fishery management plan for the Atlantic mackerel, squid, and butterfish fisheries. Dover, DE: MAFMC.

MAFMC [Mid-Atlantic Fishery Management Council]. 1991. 1992 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for Atlantic mackerel, *Loligo*, *Illex*, and butterfish. Dover, DE:MAFMC.

MAFMC [Mid-Atlantic Fishery Management Council]. 1992. 1993-1994 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for Atlantic mackerel, *Loligo*, *Illex*, and butterfish. Dover, DE:MAFMC.

NEFSC [Northeast Fisheries Science Center]. 1990. Report of the Spring 1990 NEFC Stock Assessment Workshop (Tenth SAW). Woods Hole, MA: NOAA/NMFS/NEFC. *Ref. Doc.* 90-07.

NEFSC. 1991. Report of the Twelfth Northeast Regional Stock Assessment Workshop (12th SAW), Spring 1991. Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 91-03.

NEFSC. 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop (14th SAW). Woods Hole, MA: NOAA/NMFS/NEFSC. *Ref. Doc.* 92-07: 140 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board. Can.* 191:

Rodhouse, P.G., and E.M.C. Hatfield. 1990. Age determination in squid using statolith growth increments. *Fish. Res.* 8:323-334.

Rosenberg, A.A., G.P. Kirkwood, J.A. Crombie, and J.R. Beddington. 1990. The assessment of stocks of annual squid species. *Fish. Res.* 8: 335-349.

Spratt, J.D. 1979. Age and growth of the market squid *Loligo opalescens* Berry, froms. *CALCOFI Repts.* 20:58-64.

Summers, W.C. 1968. The growth and size distribution of current year class *Loligo pealei*. *Biol. Bull.* 135(2): 366-377.

Summers, W.C. 1969. Winter population of *Loligo pealei* in the Mid-Atlantic Bight. *Biol. Bull.* 137(1): 202-216.

Summers, W.C. 1983. *Loligo pealei*. *In* Cephalopod Life Cycles, Vol. I., p. 115-142. London: Academic Press.

USDOC. 1988. Status of fishery resources off the Northeastern United States for 1988. *NOAA Tech. Mem. NMFS-F/NEC*-63: 135 p.

Verrill, A.E. 1882. The cephalopods of the northeastern coast of America. Part II. *Trans. Connecticut Academy Sci.* 5.

Yang, W.T., R.F. Hixon, P.E. Turk, M.E. Krejci, W.H. Hulet, and R.T. Hanlon. 1986., behavior, and sexual maturation of the market squid, *Loligo opalescens*, cultured through the life cycle. *Fish. Bull. (U.S.)* 84:771-798.

G. SHORT-FINNED SQUID

TERMS OF REFERENCE

a. Compute revised research vessel survey indices from spring and autumn surveys. Estimate minimum stock sizes from area-swept calculations. Evaluate the stock with respect to survey-based management reference points.

b. Estimate catch in numbers by cohort.

c. Examine times-series CPUE data based on GLM formulations.

d. Provide updated projections of yield and stock size based on current fishery patterns. Evaluate the stock relative to management reference points.

e. Review MSY.

INTRODUCTION

The short-finned squid (*Illex illecebrosus*)[1] population is assumed to constitute a unit stock throughout its range of commercial exploitation from Cape Hatteras to Newfoundland. *Illex* are capable of long-distance migrations (Dawe *et al.* 1981), and major *Illex* spawning grounds have been identified south of Cape Hatteras (Rowell and Trites 1985), although spawning may occur in other areas as well.

Previous assessments assumed a two-year cross-over lifecycle based upon analyses of length frequency data (Verrill 1882; Mesnil 1977; Lange and Sissenwine 1980). However, inferences about the age and growth of squids based on length frequency analyses must be regarded with caution unless they are accompanied by supplementary age data (Caddy 1991) because (i) squid growth rates exhibit high variability and can vary with season, food availability, temperature, and population density; (ii) squid populations can be composed of several broods or microcohorts that have different growth and survival rates; (iii) if separate microcohorts enter the sampled population at successive times, modal analysis of length frequency data sampled from a mixture of microcohorts will not represent the true growth rate. Research on the age and growth of several species of squid based on counts of daily statolith growth increments (*e.g.*, Lipinski 1978; Spratt 1979; Dawe *et al.* 1985; Lipinski 1986; Yang *et al.* 1986; Jackson 1990; Rodhouse and Hatfield 1990; Jereb *et al.* 1991; Jackson and Choat 1992; Jackson *et al.* 1993) indicates that statolith aging is useful technique. Recent research on the age and growth of *Illex* based on counts of daily statolith growth increments indicate a lifespan of less than 300 days (Dawe *et al.* 1985; Dawe and Beck 1992; see Figure G1), therefore this assessment adopts the working hypothesis that Illex illecebrosus is an annual, semelparous species.

DESCRIPTION OF THE FISHERY

Domestic landings of *Illex* began in the 1800s as a bait fishery. From 1928 to 1967, annual squid landings from Maine to North Carolina (including *Loligo pealei*) averaged about 2000 mt. A directed foreign fishery for *Illex* developed in 1972 off the northeast coast of the United States and continued through 1982. During this 11 year period, total annual *Illex* landings (Cape Hatteras to the Gulf of Maine) averaged 19,250 mt, with the foreign fishery accounting for 95% of the total (Table G1; Figure G2). Since 1983, annual landings have ranged between 2000 and 17,800 mt, and have averaged 9400 mt. Foreign landings in 1983-1986 represent landings in the U.S. joint venture fishery, which ended in 1987.

Within the total stock area of *Illex* (NAFO Subareas 2-6), landings peaked in 1979 at 180,000 mt but have since been very much lower, ranging between 2800 and 22,200 mt during 1983-1991 (Figure G2).

In 1992, U.S. *Illex* landings (416 trips) totaled a record-high 17,827 mt with an exvessel value of $9.7 million and an average price of $0.54 per kg ($0.25 per lb). Nearly two-thirds of the 1992 harvest (11,207 mt; 63%) was taken from one statistical area (SA 622); three statistical areas (SA 622, 626, and 632) accounted for 96% of the total landings (Table G2). Temporally, 94% of the 1992 landings were taken during June through October.

Virtually all the 1992 landings (99.9%) were taken with bottom otter trawl gear (356 trips). Other gear (shrimp trawls, paired trawls, and sea scallop dredges) accounted for less than 0.1% of the landings (60 trips).

[1] For brevity, *Illex illecebrosus* is subsequently referred to as *Illex* wherever possible.

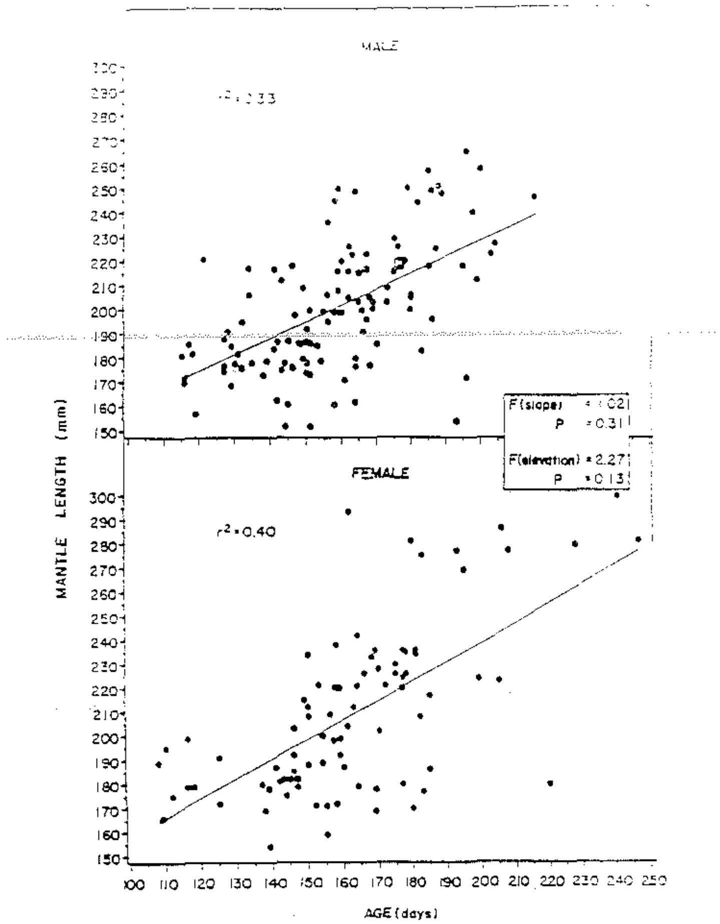

Figure G1. Linear regressions of *Illex illecebrosus* dorsal mantle length on age, by sex, with results of analysis of covariance for effect of sex, for all short-finned squid aged in Dawe and Beck (1992)

Based on provisional January-September 1993 landings data, total *Illex* landings for the U.S from Cape Hatteras to the Gulf of Maine in 1993 are projected to be 14,800 mt, about 17% lower than in 1992.

Illex are managed by the Mid-Atlantic Fishery Management Council under provisions of the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan. In 1992, the maximum optimum yield, the allowable biological catch, and the domestic allowable harvest were each specified as 30,000 mt (MAFMC 1991). Identical specifications pertain in 1993 and 1994 (MAFMC 1992).

DATA SOURCES

Commercial U.S. landings data from 1989 through 1992 were derived from the NEMFIS data base and general canvas sources. Landings

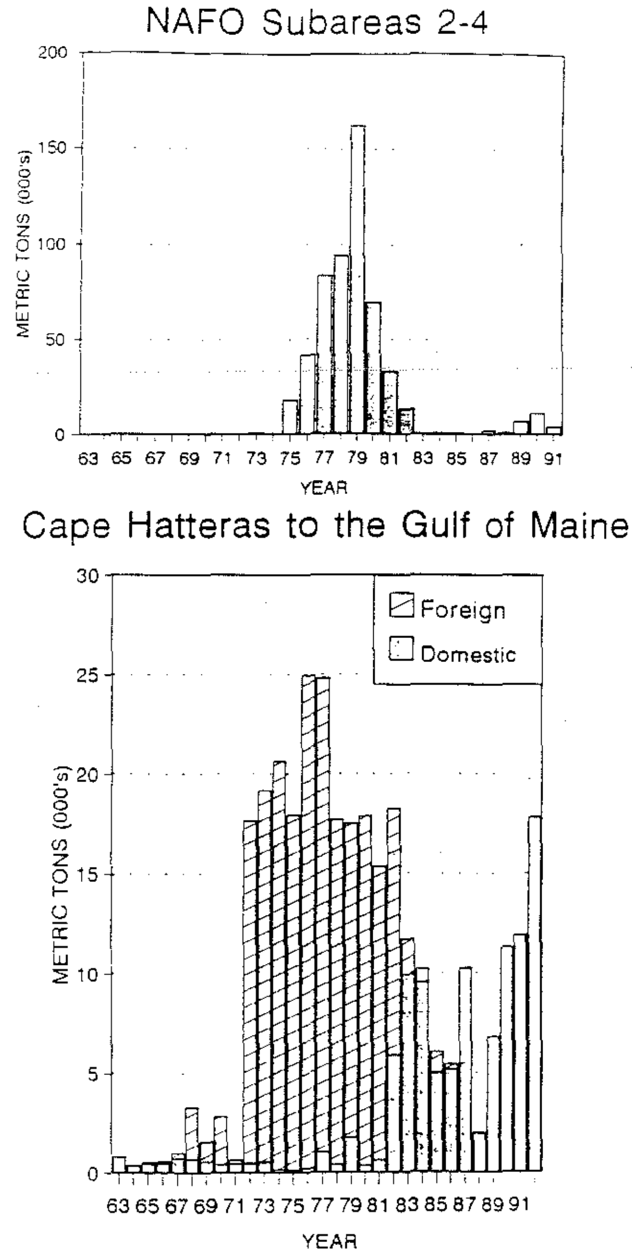

Figure G2. *Illex illecebrosus* landings (metric tons), 1963-1992. ICNAF squid landings not reported by species prior to 1973. NAFO landings for 1989-91 are provisional.

data for 1963-1988 were provided in the Report of the 10th SAW (NEFSC 1990). Effort data used in the analysis of domestic LPUE from 1982 to 1992 were extracted from the NEMFIS database. Landings data from NAFO Subareas 2, 3, and 4 during 1973-1988 were obtained from ICNAF and NAFO Statistical Bulletins.

Numbers of *Illex* landed by the commercial fishery during 1982 - 1992 (Table G3) were estimated using NEFSC commercial size frequency sampling data.

A multiplicative GLM model (Gavaris 1980) was used to standardize fishing effort during

Table G1. Short-finned squid (*Illex illecebrosus*) landings (metric tons) from Cape Hatteras to the Gulf of Maine during 1963 to 1993, and *Illex* landings from NAFO Subareas 2, 3, and 4, inclusive, during 1973 to 1991[1,2]

Year	Cape Hatteras to the Gulf of Maine			NAFO Areas 2-4	All Areas
	Domestic	Foreign	Subtotal	Subtotal	Total
1963	810	0	810	-[1]	810
1964	358	2	360	-[1]	360
1965	444	78	522	-[1]	522
1966	452	118	570	-[1]	570
1967	707	285	992	-[1]	992
1968	678	2,593	3,271	-[1]	3,271
1969	562	975	1,537	-[1]	1,537
1970	408	2,418	2,826	-[1]	2,826
1971	455	159	614	-[1]	614
1972	472	17,169	17,641	-[1]	17,641
1973	530	18,625	19,155	641	19,796
1974	148	20,480	20,628	283	20,911
1975	107	17,819	17,926	17,696	35,622
1976	229	24,707	24,936	41,767	66,703
1977	1,024	23,771	24,795	83,480	108,275
1978	385	17,310	17,695	94,064	111,759
1979	1,780	15,742	17,522	162,092	179,614
1980	349	17,529	17,878	69,606	87,484
1981	631	14,723	15,354	32,862	48,216
1982	5,902	12,350	18,252	12,908	31,160
1983	9,944	1,776	11,720	421	12,141
1984	9,547	676	10,223	715	10,938
1985	4,997	1,053	6,050	673	6,723
1986	5,176	250	5,422	111	5,533
1987	10,260	0	10,260	1,694	11,954
1988	1,966	1	1,967	846	2,813
1989	6,801	0	6,801	6,537	13,338
1990	11,316	0	11,316	10,867	22,183
1991	11,908	0	11,908	3,838	15,746
1992	17,827	0	17,827	-[2]	17,827
1993[3]	14,800				
Average					
1963-92	3,540	7,020	10,560	-[1]	28,597
1973-82	1,109	18,306	19,414	51,540	70,954
1983-89	6,956	537	7,493	1,571	9,064
1990-92	13,691	0	13,691	7,353[2]	18,592

[1] ICNAF squid landings were not reported by species before 1973
[2] Provisional Illex landings from NAFO Subareas 2,3, and 4 in 1992 are not yet available
[3] Predicted

1982-1992 in the U.S. otter trawl fishery for *Illex* (Brodziak MS 1993). The GLM had the same form as that used in the last *Illex* assessment (NEFSC 1992); *i.e.*, a main effects model was employed with year, tonnage class, and area used as factors to standardize fishing effort ($R^2 = 0.75$) (Table G4). In addition to calculating standardized effort, standardized LPUE (ratio of landings to standardized effort) and a standardized abundance index (ratio of annual LPUE to LPUE in 1982) were also computed.

Research survey indices of relative *Illex* abundance were derived from NEFSC spring (1968-1993) and autumn (1967-1992) bottom trawl

Table G2. *Illex* squid landings in 1992, by area and month

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
513	0.3	-	-	-	-	-	0.1	-	-	0.1	0.1	-	0.7	<1%
514	-	-	-	-	-	-	-	-	-	-	0.8	-	0.8	<1%
522	-	-	-	-	-	-	-	0.2	-	-	-	-	0.2	<1%
526	-	0.2	4.8	23.7	-	-	-	-	-	-	-	-	28.7	<1%
537	-	-	-	16.3	10.6	49.9	-	3.2	11.4	0.7	0.3	3.7	96.0	1%
612	-	-	-	-	-	1.5	-	-	-	-	-	-	1.5	<1%
613	0.9	-	-	-	-	-	-	-	-	0.6	-	-	1.6	<1%
614	-	-	-	-	-	-	-	0.1	-	-	-	-	0.1	<1%
615	1.2	0.7	-	-	-	-	-	-	-	-	-	2.1	3.9	<1%
616	0.1	12.1	10.9	0.6	-	447.3	-	-	-	-	132.0	27.0	630.0	4%
621	0.1	-	-	-	-	-	-	0.1	-	-	-	-	0.2	<1%
622	2.1	-	13.0	45.5	696.8	3433.4	2560.6	2025.0	1365.1	1047.7	6.9	11.0	11207.0	63%
623	-	-	0.9	-	-	-	-	-	-	-	-	-	0.9	<1%
626	-	0.8	0.1	0.3	-	-	1409.0	2382.9	227.8	69.3	-	-	4090.1	23%
632	-	-	-	-	-	-	-	-	812.1	907.1	46.1	-	1765.3	10%
Total	4.8	13.7	29.7	86.3	707.3	3932.1	3969.7	4411.6	2416.4	2025.4	186.2	43.8	17827.0	
%	<1%	<1%	<1%	<1%	4%	22%	22%	25%	14%	11%	1%	<1%		
Avg % 1988-92	<1%	<1%	<1%	<1%	1%	11%	25%	31%	24%	7%	1%	<1%		
Avg % 1982-92	<1%	<1%	<1%	<1%	4%	16%	27%	26%	22%	5%	<1%	<1%		

Table G3. Total numbers of *Illex illecebrosus* landed (millions) from Cape Hatteras to the Gulf of Maine during 1982 to 1992.

Year	Mean Weight (g)	Total Landings (mt)	Number of *Illex* Landed (millions)
1982	154	18,252	118.6
1983	130	11,720	90.2
1984	128	10,223	79.8
1985	130	6,050	46.4
1986	110	5,422	49.4
1987	132	10,260	77.4
1988	139	1,967	14.1
1989	126	6,802	54.0
1990	126	11,316	89.7
1991	140	11,929	85.2
1992	128	17,827	139.7
Average 1982-92	131	10,161	77.4

Table G4. Standardized fishing effort and standardized landings-per-unit of effort (LPUE) for the U.S. otter trawl fishery for short-finned squid (*Illex illecebrosus*), 1982 - 1992

Year	Domestic LPUE[1] (mt/day fished)	Standardized Fishing Effort[2] (days fished)	Standardized Abundance Index[3]
1982	22.9	153(258)	1.00
1983	20.5	69(485)	0.90
1984	45.5	72(210)	1.99
1985	20.0	58(250)	0.87
1986	37.0	116(140)	1.62
1987	54.3	119(189)	2.37
1988	52.9	37	2.31
1989	60.4	113	2.64
1990	29.4	385	1.28
1991	43.7	272	1.91
1992	33.9	526	1.48
Average 1982-92	38.2	175	(260)

[1] For trips used in the general linear model, the ratio of total landings (mt) to standardized fishing effort.
[2] Effort for 1982-1987 (in parentheses) has been prorated to account for U.S. joint venture landings.
[3] Ratio of annual LPUE to LPUE in 1982.

surveys conducted in the Mid-Atlantic through Georges Bank regions [offshore strata 1-23, 25, and 67-76] (Tables G5 and G6).

ASSESSMENT RESULTS

Relative Abundance

Standardized fishing effort for *Illex* increased sharply in 1992 to a record-high level (Table G4). Although large interannual changes in *Illex* effort are not uncommon, effort has trended upward since 1988 (Figure G3). The LPUE and standardized abundance indices were highest during 1987-1989. The LPUE values in 1991 and 1992 were about 30% lower than the peak values, but near the time series average.

NEFSC research survey indices indicate a cyclical pattern in *Illex* abundance over the past 25 years (Tables G5 and G6). Periods of low indices (1967-1974 and 1982-1986) have been followed by periods of very high abundance indices (1975-1981 and 1988-1990). The most recent indices (spring 1992-1993; autumn 1991-1992), however, are neither high nor low, but about near the long-term average. Such periods of intermediate *Illex* abundance have not previously been observed in the surveys (Figure G4).

The spring indices do not exhibit the high/low abundance pattern of the fall indices. The lack of concordance between the spring and fall indices is likely due to the low availability of the stock to the spring survey.

Absolute Abundance

Minimum stock size estimates (numbers and biomass) of *Illex* in the Cape Hatteras-Gulf of Maine region were derived by areal expansion of NEFSC autumn bottom trawl survey indices, 1967-1992 (Table G7). For 1967-1992, indices based on all offshore survey strata in the Cape Hatteras-Gulf of Maine region were used (offshore strata 1-30, 33-40 and 61-76). During 1982-1992, inshore survey strata (1-55) were also included in calculating the indices; comparable inshore data for 1967-1981 were not available. However, inshore strata contribute less than 0.2% to the estimated population size of *Illex* in any year.

Since the area-swept estimates are based on the survey indices, temporal patterns of abundance are the same. However, in years in which autumn survey abundance indices are low (1967-1974; 1982-1986), the minimum biomass estimates are in almost all cases less than the landings. This suggests that further work is

Table G5. Stratified mean catch per tow in numbers and weight (kg) of *Illex illecebrosus* in NEFSC spring bottom trawl surveys, Cape Hatteras to Georges Bank (Strata 1-23, 25, and 61-76), 1968 - 1993. Mean number per tow indices are presented for all sizes of *Illex*, for prerecruits (≤10 cm), and for recruits (> 10 cm).

Year	All Sizes (CV[1])	Pre-recruit	Recruit	Kg/Tow
1968	0.21 (49%)	0.00	0.21	0.02
1969	2.60 (50%)	2.30	0.30	0.04
1970	0.88 (42%)	0.24	0.64	0.04
1971	0.10 (37%)	0.01	0.09	0.01
1972	0.03 (39%)	0.01	0.03	0.01
1973	0.05 (52%)	0.00	0.05	0.01
1974	1.16 (38%)	0.10	1.05	0.07
1975	0.27 (33%)	0.13	0.14	0.02
1976	0.35 (24%)	0.01	0.34	0.03
1977	0.32 (18%)	0.20	0.12	0.02
1978	1.35 (47%)	0.02	1.32	0.07
1979	0.93 (25%)	0.16	0.78	0.08
1980	0.63 (22%)	0.22	0.42	0.04
1981	1.74 (31%)	0.09	1.65	0.10
1982	1.22 (24%)	0.02	1.20	0.08
1983	0.11 (28%)	0.02	0.09	0.01
1984	0.40 (70%)	0.35	0.05	0.01
1985	1.47 (77%)	1.25	0.22	0.04
1986	0.35 (68%)	0.29	0.06	0.01
1987	0.50 (41%)	0.28	0.22	0.02
1988	0.20 (43%)	0.10	0.11	0.01
1989	0.47 (31%)	0.01	0.47	0.05
1990	0.64 (36%)	0.04	0.60	0.03
1991	1.92 (41%)	0.43	1.49	0.08
1992	0.88 (31%)	0.17	0.71	0.03
1993	0.60 (22%)	0.02	0.58	0.04
Average 1968-92	0.75 (40%)	0.26	0.49	0.04

[1] Coefficient of variation for the all sizes index.

Table G6. Stratified mean catch per tow in numbers and weight (kg) of *Illex illecebrosus* in NEFSC autumn bottom trawl surveys, Cape Hatteras to Georges Bank (Strata 1-23, 25, and 61-76), 1967 - 1992. Mean number per tow indices are presented for all sizes of *Illex*, for prerecruits (≤10 cm), and for recruits (> 10 cm).

Year	All Sizes (CV[1])	Pre-recruit	Recruit	Kg/Tow
1967	2.1 (21%)	0.1	2.0	0.3
1968	2.3 (24%)	0.2	2.1	0.4
1969	0.8 (28%)	0.1	0.7	0.1
1970	3.4 (29%)	1.5	1.9	0.3
1971	1.9 (10%)	0.3	1.6	0.4
1972	3.5 (29%)	1.1	2.4	0.4
1973	1.3 (19%)	0.1	1.2	0.2
1974	3.0 (55%)	1.8	1.2	0.2
1975	12.4 (53%)	6.2	6.2	1.1
1976	30.9 (27%)	0.6	30.3	10.0
1977	15.8 (21%)	1.1	14.7	4.7
1978	29.4 (22%)	5.1	24.3	6.3
1979	32.8 (16%)	2.6	30.2	9.0
1980	17.1 (19%)	0.7	16.5	3.6
1981	61.9 (41%)	0.4	61.5	20.0
1982	4.6 (15%)	1.1	3.5	0.6
1983	2.8 (15%)	0.2	2.6	0.3
1984	6.4 (18%)	0.4	5.9	0.7
1985	2.0 (13%)	0.3	1.6	0.2
1986	3.2 (18%)	0.5	2.7	0.3
1987	30.0 (42%)	1.3	28.7	2.7
1988	24.0 (17%)	0.7	23.3	2.9
1989	22.2 (27%)	1.9	20.3	2.3
1990	24.5 (10%)	1.2	23.3	2.9
1991	8.6 (15%)	0.4	8.2	1.0
1992	12.3 (15%)	3.3	9.0	1.1
Average 1967-91	13.9 (24%)	1.2	12.7	2.8

[1] Coefficient of variation for the all sizes index.

needed to evaluate the catchability and availability of *Illex* to the survey gear, and whether the areas surveyed for *Illex* are appropriate. Furthermore, since *Illex* is an annual species with a rapid growth rate, standing stock estimates should be adjusted to account for body-weight growth.

OVERFISHING DEFINITION

Overfishing for *Illex* is defined to occur when the three-year moving average of prerecruits from the NEFSC autumn bottom trawl survey is below the first quartile of this series. For the purpose of applying the overfishing definition in 1992, 1993, and 1994, the lowest quartile of values consists of the seven lowest prerecruit indices (Table G6); the three-year moving average of the prerecruit series must be less than the largest index in this quartile for overfishing to occur. Given the high 1992 autumn prerecruit index (3.3; third-highest in the survey time series), the three-year moving prerecruit average in 1992 was 1.6. If the 1993 and 1994 prerecruit indices are both 0, the corresponding three-year moving averages would be 1.2 and 1.1, respectively (Table G8). The largest prerecruit index in the lower quartile of values during 1992, 1993, and 1994 would correspond to 0.3, 0.3, and 0.2. Thus, according to the overfishing definition, *Illex* were not overfished in 1992, and will not be overfished in 1993 and 1994.

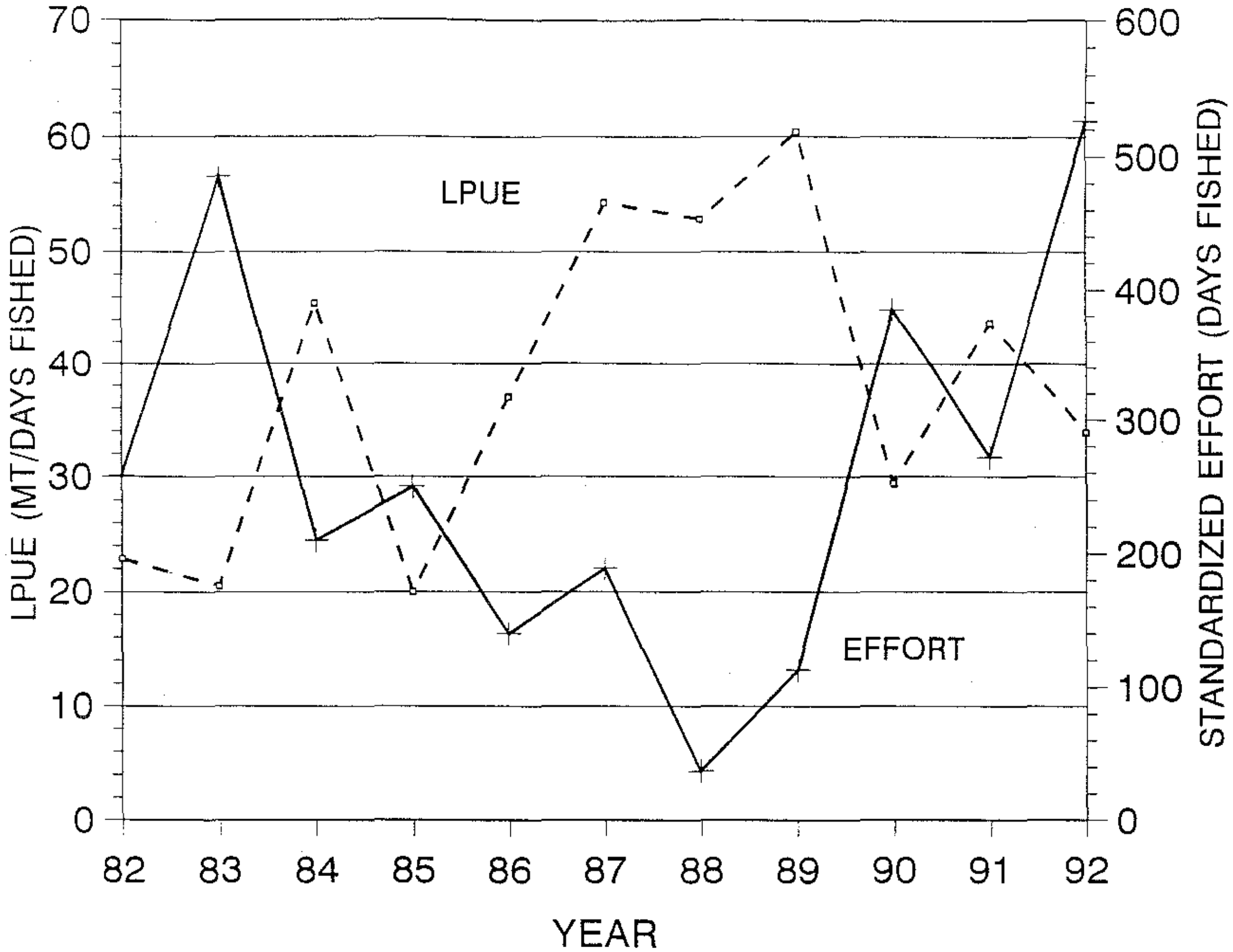

Figure G3. Annual standardized fishing effort and LPUE for *Illex illecebrosus* fishery, 1982-1992.

YIELD AND SPAWNING STOCK BIOMASS

No new information is available on yield per recruit or spawning stock biomass per recruit for *Illex*. However, previous calculations (e.g., Lange and Sissenwine 1980) were based on a two-year, crossover life cycle. *Illex* is now considered to be an annual species and thus re-evaluation of life history dynamics, biological reference points, and MSY is clearly warranted. Because of the transboundary distribution of Illex, these analyses need to be done in collaboration with Canadian scientists.

DISCUSSION

Both commercial LPUE and research survey indices indicate that *Illex* abundance was low in the mid-1980s, high during 1987-1989, and is presently at an intermediate level. The low abundance of *Illex* during the mid-1980s may have been the result of intensive fishing pressure between 1977 and 1980 when annual landings from the stock (NAFO Areas 2-6) averaged over 120,000 mt (Table G1). Subsequently (until 1987), landings in NAFO Subareas 2-4 and research survey indices of abundance markedly declined.

Domestic landings of *Illex* were a record-high in 1992 (17,800 mt) and are projected to be 14,800 mt in 1993, the second-highest U.S. landings level. However, fishing effort markedly increased in 1992 (nearly double that in 1991) while commercial LPUE declined. Since recent survey indices indicate a medium level of stock abundance, annual domestic landings above the 1990-1992 average (13,700 mt) are probably not sustainable during the next several years.

Illex recruitment to fishery areas within the

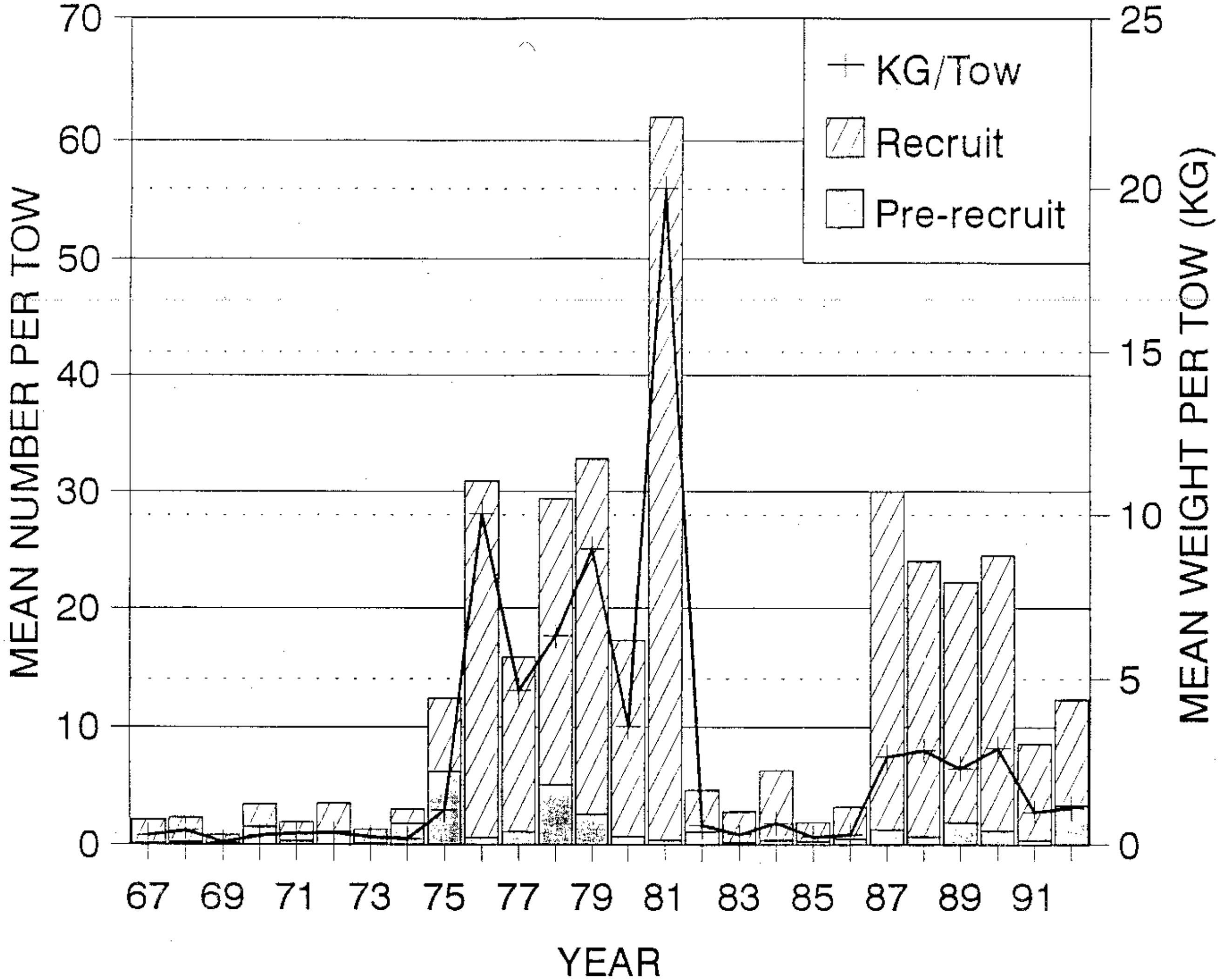

Figure G4. Stratified mean number and weight per tow of *Illex illecebrosus* fom the NEFSC bottom trawl survey, 1967-1992.

U.S. EEZ appears to be episodic, alternating between high and low states. This may reflect the influence of environmental factors or, alternatively, overcompensation. Given this variability, landings projections are difficult to make and are imprecise.

SOURCES OF UNDERTAINTY

A substantial proportion of the Illex stock is probably distributed outside NEFSC survey areas in most years. To the extent this proportion varies, changes in abundance are difficult to separate shifts in availability to the survey. Since area-swept estimates are based on expansion to the survey area rather than the entire stock area, the estimates are expected to underestimate biomass.

Availability of *Illex* to the commercial fishery and to the research survey may vary substantially in response to environmental conditions and predation pressure. Because the U.S. EEZ lies near the edge of *Illex* distribution in the Northwest Atlantic, the response of the stock to localized fishing patterns may be difficult to discern from variability in recruitment and migration patterns to inshore areas.

RESEARCH RECOMMENDATIONS

1 Present studies on the life history dynamics of *Illex* need to be examined so that new assessment analyses - incorporating annual life history parameters - can be conducted. Biological reference points and MSY will need to be recalculated based on this new information.

Table G7. Area-swept estimates of minimum biomass (metric tons) and minimum population size (millions of animals) of *Illex* squid between Cape Hatteras and the Gulf of Maine, derived from NEFSC fall bottom trawl surveys, 1967-1992.

Year	Minimum Biomass	Standard Deviation	Minimum Population Size	Standard Deviation
1967	1542	(270)	10.3	(2.0)
1968	2141	(357)	11.0	(2.4)
1969	493	(129)	4.0	(1.0)
1970	1798	(271)	16.4	(4.2)
1971	2343	(362)	11.4	(1.3)
1972	2106	(334)	17.1	(4.4)
1973	2328	(600)	9.6	(2.3)
1974	2917	(1179)	20.4	(8.3)
1975	9686	(1569)	67.8	(28.7)
1976	48453	(10751)	151.3	(34.2)
1977	24110	(5029)	81.3	(15.9)
1978	29496	(7385)	134.4	(26.5)
1979	48112	(6393)	165.3	(23.0)
1980	21703	(4100)	90.8	(14.9)
1981	74503	(29610)	236.6	(81.6)
1982	3780	(430)	24.2	(3.1)
1983	1525	(188)	11.2	(1.7)
1984	3483	(640)	30.4	(5.1)
1985	2107	(377)	14.2	(1.9)
1986	1799	(284)	15.3	(2.3)
1987	11729	(4371)	127.1	(50.9)
1988	23153	(8444)	195.0	(80.6)
1989	12450	(2936)	109.6	(25.8)
1990	17936	(1543)	131.9	(12.0)
1991	5400	(682)	43.6	(5.8)
1992	5259	(599)	53.5	(7.3)
Average	13860	(3417)	68.6	(17.2)

- Given that *Illex* is an annual species, new approaches to the assessment and management of the stock will be required. A more adaptive, real-time assessment/management system will be needed to attain full exploitation of the stock while, at the same time, ensuring that adequate levels of spawning stock are achieved (Rosenberg *et al.* 1990). Examples of the types of assessment and management procedures that have proved successful for short-lived species are provided in the 1993 report of the ICES Working Group on Methods of Fish Stock Assessment (ICES 1993).

- Collection of *Illex* maturity data during NEFSC bottom trawl surveys should be initiated in order to determine seasonal maturation rates, and to quantify the spatial/temporal patterns in spawning activity.

- Relationships between *Illex* distribution/reproduction and environmental factors (*i.e.*, sea surface temperature) should be investigated. The use of remote sensing data may be helpful in this work.

- Alternative definitions of overfishing for *Illex*, possibly based on a minimum biomass threshold or a minimum proportional escapement level, should be investigated. Future assessment research should investigate stock-recruitment relationships for *Illex*. The calculation of risk-averse levels of spawning escapement should also be possible when more quantitative information on the age and growth, maturation, and timing of spawning for *Illex* becomes available.

- *Illex* is a transboundary stock between the U.S. and Canada. A joint assessment approach, involving US and Canadian scientists, is strongly recommended.

Table G8. Three-year moving average of the Illex illecebrosus pre-recruit number per tow index from the NEFSC fall bottom trawl survey, 1969-1992

Year	Average[1] Prerecruit Number per Tow
1969	0.1
1970	0.6
1971	0.6
1972	0.9
1973	0.5
1974	1.0
1975	2.7
1976	2.9
1977	2.7
1978	2.3
1979	2.9
1980	2.8
1981	1.2
1982	0.7
1983	0.6
1984	0.6
1985	0.3
1986	0.4
1987	0.7
1988	0.8
1989	1.3
1990	1.3
1991	1.2
1992	1.6
1993[2]	1.3

[1] Average of prerecruit index in years T, T-1, and T-2, where T is the current year.
[2] Provisional

- Until further analyses based on an annual life cycle have been completed, revisions to the Illex assessment will not be significant.

REFERENCES

Brodziak, J. 1993 MS. Stock assessment for short-finned squid, *Illex illecebrosus*, in the Northwest Atlantic during 1992. Working paper prepared for the 17th SAW SARC, NEFSC, Woods Hole, MA.

Dawe, E.G., P.C. Beck, H.J. Drew, and G.H. Winters. 1981. Long-distance migration of a short-finned squid, *Illex illecebrosus*. *J. Northw. Atl. Sci.* 2: 75-76.

Dawe, E.G., R.K. O'Dor, P.H. Odense, and G.V. Hurley. 1985. Validation and application of an aging technique for short-finned squid (*Illex illecebrosus*). *J. Northw. Atl. Fish. Sci.* 6: 107-116.

Dawe, E.G. and P.C. Beck. 1992. Population structure, growth, and sexual maturation of short-finned squid at Newfoundland, Canada, based on statolith analysis. *ICES* [International Council for Exploration of the Sea] *C. M.* 1993/K:33.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci.* 37:2272-2275.

ICES. 1993. Report of the Working Group on Methods of Fish Stock Assessment, Copenhagen, 3-10 February 1993. *ICES* [International Council for Exploration of the Sea] *C. M.* 1993/Assess:12.

Lange, A.M.T., and M.P. Sissenwine. 1980. Biological considerations relevant to the management of squid, *Loligo pealei* and *Illex illecebrosus* of the Northwest Atlantic. *Mar. Fish. Rev.* 42(7-8): 23-38.

MAFMC [Mid-Atlantic Fishery Management Council]. 1991. 1992 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for Atlantic mackerel, *Loligo*, *Illex*, and butterfish. Dover, DE: MAFMC.

MAFMC [Mid-Atlantic Fishery Management Council]. 1992. 1993-1994 Allowable biological catch, optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing recommendations for Atlantic mackerel, *Loligo*, *Illex*, and butterfish. Dover, DE: MAFMC.

NEFSC. 1990. Report of the Spring 1990 NEFC Stock Assessment Workshop (Tenth SAW). Woods Hole, MA: NOAA/NMFS/NEFC. *Lab. Ref. Doc.* 90-07.

Rosenberg, A.A., G.P. Kirkwood, J.A. Crombie, and J.R. Beddington. 1990. The assessment of stocks of annual squid species. *Fish. Res.* 8: 335-349.

Rowell, T., and R. Trites. 1985. Distribution of larval and juvenile *Illex* in the Blake Plateau region. *Vie Milieu* 35(3):149-161.

ASSESSMENT METHODS SUBCOMMITTEE TERMS OF REFERENCE

Candidate terms of reference for the Assessment Methods Subcommittee were tabled at SARC 16 in June 1993 (16th SAW SARC Report pages 113 - 114). Due to lack of time, however, these terms of reference were not discussed during the SARC 16 meeting. The SARC reviewed the terms of reference during this meeting, established priorities, and discussed several general issues regarding assessment methods software development and support.

The role of the Assessment Methods Subcommittee within the overall SARC process was reviewed, *i.e.*:

(1) to address the practical methodological and statistical problems encountered by the species oriented subcommittees in the course of carrying out their respective assessments;

(2) to suggest alternative procedures or methods to address these problems;

(3) to evaluate new assessment methods (*e.g.* methods developed elsewhere) and make recommendations regarding their usage in SAW/SARC assessments; and

(4) to develop new assessment methods, as needed, to address recurring problems or to improve the quality and precision of SAW/SARC assessments.

The terms of reference for the Assessment Methods Subcommittee should be closely tied to the ongoing work within the species oriented subcommittees. Members of the Methods Subcommittee also serve as members of one of the species oriented subcommittees, and will participate fully in the ongoing assessment work. Outside experts should be invited to participate in the Methods Subcommittee meetings.

The candidate terms of reference evolved from three sources:

(1) Suggestions tabled during the SARC 16 Meeting (June 1993).

(2) Items that by implication must be examined to address the above issues.

(3) Suggestions that arose during SARC 15 and earlier meetings.

The SARC noted that there are several constraints governing the number and scope of the terms of reference that can be undertaken at a single meeting of the Methods Subcommittee, *i.e.*

(a) Subcommittee Meeting duration limited to 5 days or so.

(b) Intensive computing work needed to address most issues.

Much of it will need to be done during the Subcommittee meeting.

(c) Assimilation of results, report writing, etc. during meeting.

(d) Background and interests of Subcommittee members.

The candidate terms of reference are summarized below and include, in parentheses, the specific concerns of the SARC at this time.

(1) Potential biases in SARC assessment results (including, among other things, investigation of implications of uncertainty in the catch at age matrix)

(2) Methods for medium-term stochastic projections ***

(3) Multiple indices of abundance within the DeLury model ***

(4) CPUE-based indices of abundance for VPA tuning *** (including, among other things, methods of construction of fishery dependent indices of abundance)

(5) Calibration of recruitment indices

(6) Effects of outliers in survey data (including, among other things, methods of construction of resource survey indices of abundance)

(7) Sensitivity of ADAPT results to multiple indices ***

(8) Extending the time series of stock-recruitment data

(9) ADAPT tutorial ***

The items labeled with asterisks were identified as priority items by the SAW Steering Committee at its August 1993 meeting. Additionally, Item (9) was added to the original list of candidate terms of reference by the Steering Committee.

Item (9), the ADAPT tutorial, was discussed at length by the SARC. Given its central role in all of the age-structured assessments carried out in the Region, the SARC agreed that an ADAPT tutorial should be held, perhaps as early as February 1994. However, given that few of the current Methods Subcommittee members have expertise with the ADAPT framework, the SARC does not feel that an ADAPT tutorial would be a productive term of reference for the Subcommittee as a whole. The SARC recommends that the Center take on this responsibility instead, thereby allowing the Methods Subcommittee to take on other pressing items from the candidate terms of reference list.

Ideally, an ADAPT tutorial should cover:

(a) Background and history

(b) Data requirements for its use

(c) Description of the methodology and assumptions

(d) Use of model diagnostics in designing the appropriate ADAPT formulation

(e) Interpretation of the output

(f) Hands-on usage of user-friendly ADAPT software

An ADAPT tutorial, covering items (a) through (e), above, should be held two days in the near future. Dr. Steve Murawski was requested to look into the interest of potential participants and to set a date for the tutorial. However, user-friendly ADAPT software is not available within the Center, and given the complexity of the ADAPT framework, will take considerable time and resources to develop. The SARC recommends that the Center develop user-friendly ADAPT software, as well as appropriate software for all other assessment methods regularly used for within the Region, and that Item (f), above, be covered in a follow-up tutorial after the user-friendly software has been written. Further, the Methods Subcommittee should contribute to this effort by formulating detailed design specifications for ADAPT and other methods software. These specifications should emphasize user-friendliness and maintainability using state-of-the-art, modular programming techniques.

With regard to the other candidate terms of reference, above, the SARC agreed that Items (1) and (2) should be given the highest priority. Bias considerations (including retrospective analysis) should be included routinely in all assessments presented to the SARC (Item 1). Often this is not done because of technical and software problems that could be addressed productively by the Methods Subcommittee. Similarly, assessments should routinely include stochastic projections (*i.e.* projections that take uncertainty into account), and advice on how best do such projections could be rendered by the Subcommittee.

The SARC agreed that candidate terms of reference (3) and (5), are priority items, but with less importance than terms of reference (1) and (2). The other candidate terms of reference were considered useful for the Subcommittee to consider, but with a lower priority than those mentioned above. In summary, there are three priority groupings for the Methods Subcommittee:

1st Priority:	Candidate terms of reference (1), (2), and ADAPT software design.
2nd Priority:	Candidate terms of reference (3) and (5)
3rd Priority:	Candidate terms of reference (4), (6), (7) and (8)

The SARC felt that the Subcommittee should meet and address the first priority candidate terms of reference -- (1) Potential biases in SARC assessment results and (2) Methods for medium-term stochastic projections -- as well as ADAPT software design, before May, 1994.

The SARC also briefly discussed whether the Methods Subcommittee should be asked to quantify the potential impact on assessment results of the modifications in port sampling protocol that are currently being considered within the Region. The SARC agreed that although the effects may be important, it is premature to ask the Subcommittee to evaluate them quantitatively until the new protocols are in place and data are available for analysis.

OTHER BUSINESS

FUTURE SAWS

The Chairman reported that the SAW Steering Committee met on 21 September 1993. At that meeting, dates were set for the two sessions of the 18th Northeast Regional Stock Assessment Workshop (SAW-18) and five species were suggested for assessment during SAW-18. A number of species to review at SAW-19 were also discussed.

- SAW-18 Stock Assessment Review Committee (SARC) Meeting
  20 - 24 June 1994
  NEFSC, Woods Hole, MA

- SAW-18 Plenary Meeting
  In Conjunction with the NEFMC Meeting
  9 August 1994
  King's Grant Inn, Danvers, MA

- Suggested agenda for SAW-18 SARC
  Review analyses for mackerel, witch flounder, summer flounder, dogfish, and lobster

- SAW-19
  Although dates have not yet been set for the SAW-19 sessions, species discussed for possible review at SAW-19 SARC include cod, scallops, white hake, scup, and black sea bass; and possibly shad, and river herring.

In discussion of this information at the SARC meeting, it was indicated that there would not be much new material to present on lobster at the time of SAW-18 and members suggested that the lobster be replaced by scallop. Because there was not enough time at the SAW-17 SARC meeting to review Georges Bank cod and Georges Bank yellowtail flounder (second priority), cod (two stocks) and yellowtail flounder (two stocks), as well as haddock and white hake (suggested to be more important to review at this time than cod), be considered for the SAW-19. As it is becoming obvious that the SARC can comfortably manage to review only five species/stocks at a week long meeting, an optimum group of species was identified to include cod (two stocks), yellowtail flounder (two stocks), and haddock.

It was suggested to hold the SAW-17 Plenary meetings during two days, beginning in the afternoon of the first day.

The question of meeting dates for SARC meetings in general was debated. Although SARC meetings are slipping too far into the spring and fall seasons, considering the responsibilities of people concerned, June and November were currently determined to be the best months for the SARC to meet after all. This may not be changed in the near future. The best week in November remains to be the week after Thanksgiving. One suggestion was to hold meetings from Tuesday to the following Wednesday, taking only Sunday off. The possibility of holding three SARC meetings a year was also voiced.

The Steering Committee is scheduled to meet again on 15 February 1994 to reevaluate the species to review *vis a vis* the most current management needs, confirm the agenda for SAW-18, and set the dates for SAW-19. The Chairman will present the SARC's comments and suggestions at that meeting.

It was noted, with great apprehension, that the SARC may have to revisit all the fisheries every year in the future, as status reports will be required to effectively monitor species under new regulations such as those concerning groundfish.

CONDUCT OF THE SARC

The conduct of the SARC was discussed to some extent at the end of the meeting. Generally it was suggested that SARC meetings must be more efficient and interesting in order for people to want to participate. Specific comments by individuals are summarized below. Please note that these are individual comments and do not reflect a consensus of the SARC members. The SARC Chair, in fact, strongly disagrees with some of these comments.

- Re-examine the objectives of the SARC, *i.e.*, peer review of assessments, development of the technical report, and development of advice.

- Separate peer review from report writing tasks. After all, SARC's primary responsibility is to identify the information that should go into its reports (Consensus Summary of Assessments and the Advisory Report on Stock

Status). Reports can be edited and reviewed by SARC members after the meeting.

- Develop a standard protocol for conducting meetings, as the only reference to conducting SARC meetings, available to date, is the 15th SAW Plenary report.
- The responsibilities of the SARC, the Rapporteurs, and SARC Leaders should be more thoroughly described in the Chairman's memo prior to each SARC meeting.
- The Chairman's introductory notes should have been sent to SARC members and the Rapporteurs prior to the meeting.
- The SARC Leader for each species/stock should keep notes and review exactly what changes need to be made in a report at the end of each presentation.
- Have one person do all the figures to assure consistency in format, or provide more guidance regarding preparation of figures.
- Subdivide the SARC for the purpose of quality control and formatting documentation, then, assemble for the last two days to agree on documents.
- Better frame or formulate the terms of reference. For example, there was no reference to the silver hake juvenile fishery this time.
- Get Steering Committee approval of the terms of reference sooner, as Subcommittees would benefit from more lead time.
- Subcommittee drafts should more closely resemble the sections of the SARC report.
- Subcommittees should take more lead time to get information together to better meet SARC reporting needs. (This time Subcommittees held their meetings too close (in terms of time) to the SARC meeting.)
- Subcommittee presentations should consist of summaries of data and identified problems.
- Take into consideration that new analyses and methods need more careful review, thus, requiring more SARC time than established ones.
- Reduce the number of species the SARC should review at a meeting.
- The SARC meeting program should include seminars, *e.g.*, assessment techniques such as an ADAPT workshop, or invited speakers like Bill Macy whose research on squid was relevant to the *Loligo* assessment.

Finally, it was noted that as the current SAW structure is quite new, it may be too soon to say how effective it is and should go through another cycle before it is evaluated.

REVIEW PROCESSES IN OTHER REGIONS

Chris Annand described the assessment review process in Canada where a more restricted group of assessment scientists participate. Meetings are not open and fishermen and academics do not participate, although fishermen are consulted prior to meetings. The most current material, basically tables, is presented for review. One person writes the advisory report, which the committee reviews one week after the meeting. All graphs are prepared by one person, assuring consistency in format.

Terry Smith discussed the review system in the North Pacific where analyses on 30 to 40 species are presented to a group of assessment scientists. Summaries are prepared and presented on an individual basis, the chair has the option to limit discussion and a draft is completed at the end of the meeting. Under this system species get three levels of review: 1) from a Planning Team, including biologists and social scientists from the states, academia, and the fisheries centers; 2) from persons responsible for certain species, includes state people; and, 3) from a Team Consensus. The quality of assessments in that region, however, is not as consistent as in the Northeast.

The 17th Northeast Regional Stock Assessment Workshop is documented in seven separate reports, listed below. The Northeast Fisheries Science Center Reference Documents are a series of informal reports produced by the Center for timely transmission of results obtained through work at NEFSC labs. The documents are reviewed internally before publication, but are not considered formal literature. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these reports. To obtain additional copies of this report or other Center Reference Documents contact, Information Services Unit, Northeast Fisheries Science Center, Woods Hole, MA 02543 (508-548-5123, ext. 260 or 378).

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Reports of the 17th Stock Assessment Workshop (17th SAW)

CRD 94-01 Estimation of Discards in the Silver Hake Fisheries and its Implications on the Long-Term Yield of the Stocks
by T. Helser and R. Mayo

CRD 94-02 Assessment of Yellowtail Flounder *Pleuronectes ferrugineus*, 1993
by P. Rago, W. Gabriel, and M. Lambert

CRD 94-03 Stock Assessment of Atlantic Butterfish, *Peprilus triacanthus*, in the Northwest Atlantic During 1992
by J. Brodziak

CRD 94-04 Stock Assessment of Long-Finned Squid, *Loligo pealei*, in the Northwest Atlantic During 1992
by J. Brodziak

CRD 94-05 Stock Assessment of Short-Finned Squid, *Illex illecebrosus*, in the Northwest Atlantic During 1992
J. Brodziak and L. Hendrickson

CRD 94-06 Report of the 17th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee Consensus Summary of Assessments

CRD 94-07 Report of the 17th Northeast Regional Stock Assessment Workshop, The Plenary