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Estimation of Discard in the Silver Hake Fisheries and a Re-analysis of the Long-Term Yield from the Stocks

by

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Reports of the 17th Stock Assessment Workshop

CRD 94-01 Estimation of Discards in the Silver Hake Fisheries and a Re-analysis of 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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Table of Contents

List of Tables

List of Figures

INTRODUCTION

The silver hake stocks off the northeast coast of the United States have followed a "boom-and-bust" cycle typical of fish stocks that have been heavily exploited. Before 1960, silver hake fishery was composed exclusively of U.S. fleets and only lightly exploited. Exploitation of the U.S. stocks intensified with the arrival of distant-water fleets (DWF) in 1962 and stock biomass declined sharply between 1965 and 1970. Unable to sustain such high rates of exploitation, 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% of the catch comprised age 2-3 fish, and fish older than age 5 almost disappeared from the catch.

While foreign 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. Throughout the last decade, little has changed in the U.S. silver hake fishery and management of these stocks has not been a priority of the regional management councils. Although there are presently no management regulations that pertain to silver hake in the Middle Atlantic and Southern New England regions, a small-mesh fishery, restricted seasonally (June through October) and spatially (SA 522), has been conducted since 1988 over an area of northern Georges Bank known as "Cultivator Shoals" (Almeida *et al.* 1989). Although not unlike the otter trawl fishery that has historically fished in this region, this regulated fishery allows for use of small mesh (2.5 in.) in a region which has minimum mesh size restrictions of 5.5 inches. About the same time, silver hake was also included in the Multispecies Fishery Management Plan in 1988 (under amendment 4).

Recently, a "juvenile whiting" fishery has developed for small silver hake that are exported to Spain and Portugal. Unlike the U.S. whiting market, in which the 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. Exploiting younger ages of fish in the stocks has focused management questions 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), it is important to estimate the selection pattern of the current fishery (total catches) and determine whether a directed fishery for smaller silver hake increases the selectivity toward younger ages. Simultaneously, we must evaluate whether increased effort, and therefore fishing mortality, will likewise be directed into this emerging fishery.

The last analytical assessment of the silver hake stocks off the northeast coast of the United States was conducted in 1990 on data through 1988. Since that time, additional information on research vessel surveys, distribution patterns of adults and juveniles, and updated information on the silver hake fisheries including preliminary estimates of discards have become available. This report compiles updated information relevant for an age-structured assessment. It also presents the results of yield and spawning stock biomass per recruit analyses from catch at age matrices augmented with discards not considered in previous assessments.

STOCK DEFINITION

The silver hake population in U.S. waters is presently assumed to comprise two major stocks (Figure 1): 1) Gulf of Maine-Northern Georges Bank (Div. 5Y, 5Ze; SA 521-522, 561) and 2) Southern Georges Bank-Middle Atlantic (Div. 5Ze, SA 525-526, 562; Div. 5Zw, 6A-6C). These stock definitions represent a change over assessments prior to 1987 and are based on research bottom trawl surveys, U.S. and DWF commercial fishery statistics, and morphometric data collected during bottom trawl surveys in 1978-1979 (Almeida 1987a). 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 farther south (Conover *et al.* 1961; Konstantinov and Noskov 1969). Although the present definition is generally accepted, it is unlikely that these stocks are reproductively isolated nor is it known to what extent exchange between the two stocks occurs.

HISTORY OF THE FISHERY

Silver hake (*Merluccius bilinearis*) is one of the most abundant demersal species inhabiting the northeast continental shelf. Its availability has made it important to both U.S. and Canadian fisheries as well as DWFs. The U.S. fishery for

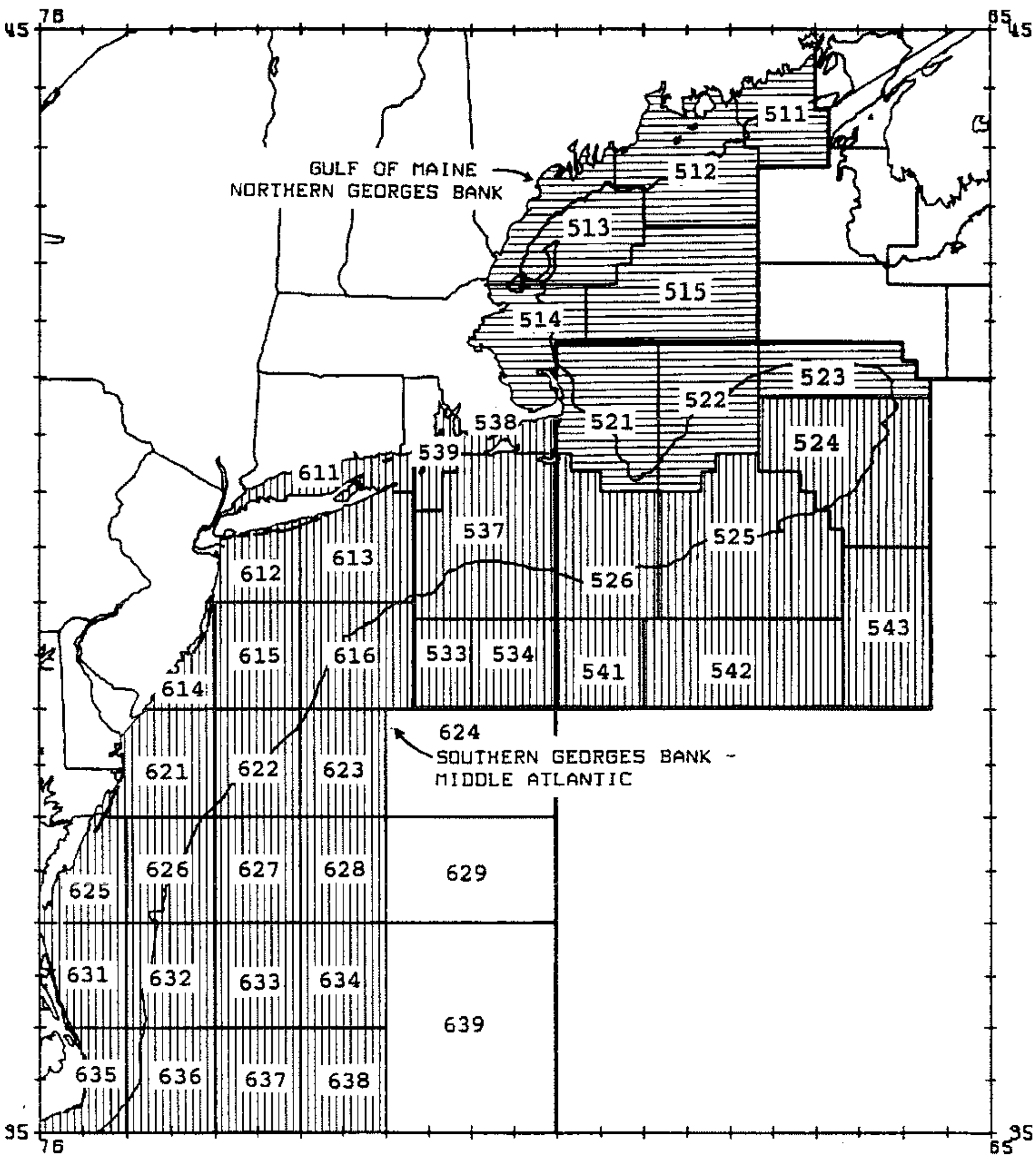

Figure 1. Stock definition of the Gulf of Maine-Northern Georges Bank and the Southern Georges Bank-Middle Atlantic silver hake population in U.S. waters.

silver hake began in the middle 1800s with the principal center of activity located along the Middle Atlantic and New England coasts. Before 1920, silver hake were only lightly exploited and commercial landings rarely totaled 3,000 mt.

The U.S. commercial fishery expanded between 1920 and 1950 with the introduction of otter trawling vessels whose capacity to reach new and productive fishing grounds far surpassed that of more stationary gear. Coupled with technological advances in quick-freezing, automatic scaling machines, and developing markets, landings of silver hake rose to 45,000 mt by 1950 (Fritz 1960).

Between 1955 and 1961, an "industrial fishery" developed in southern New England and landings increased by 30%, averaging 62,000 mt, most of which was taken from the Gulf of Maine-Northern Georges Bank stock. This fishery was conducted primarily by otter trawling vessels fishing inshore waters using small mesh (1.5 in., 40 mm) nets.

Exploitation intensified between 1961 and 1965 with the arrival of DWFs (principally the USSR), and total international landings increased to historic highs; reaching 94,000 mt and 307,000 mt in the Gulf of Maine-Northern Georges Bank and Southern Georges Bank-Middle Atlantic stocks, respectively (Figures 2 and 3). This fleet consisted of factory trawling vessels that were

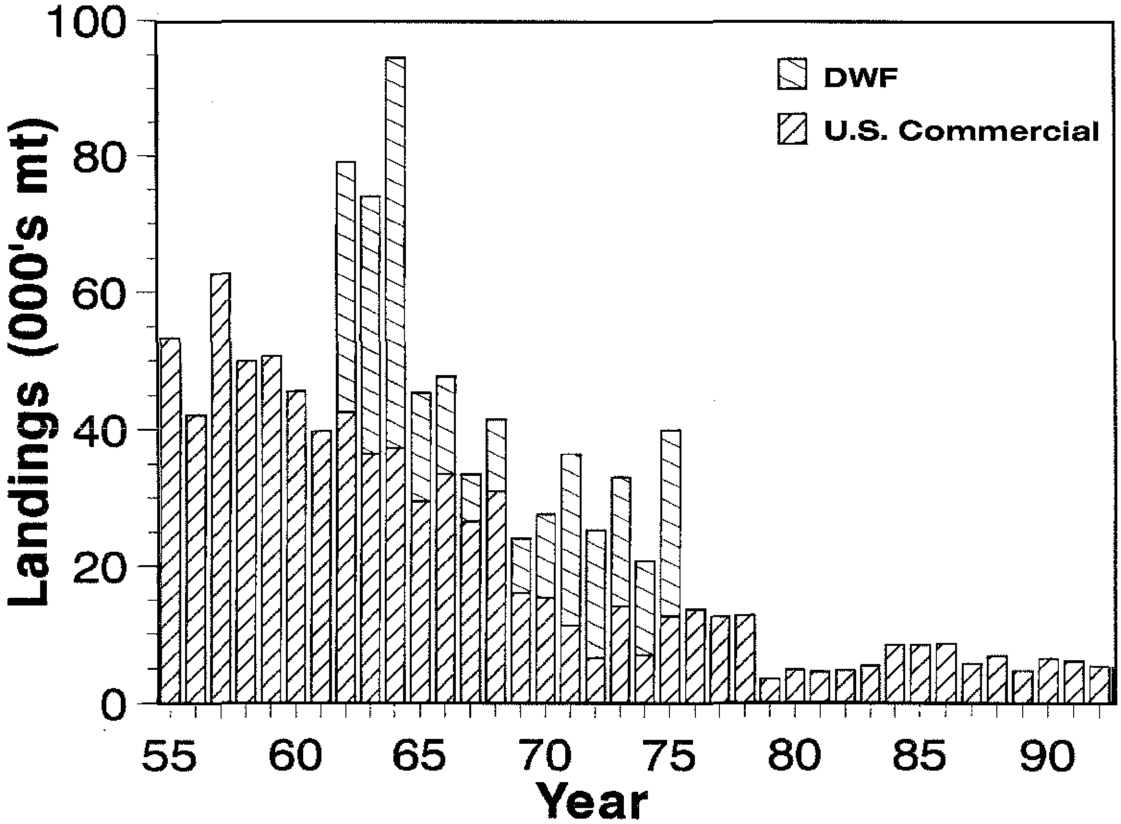

Figure 2. Total landings of silver hake from the Gulf of Maine-Northern Georges Bank stock, 1955-1992.

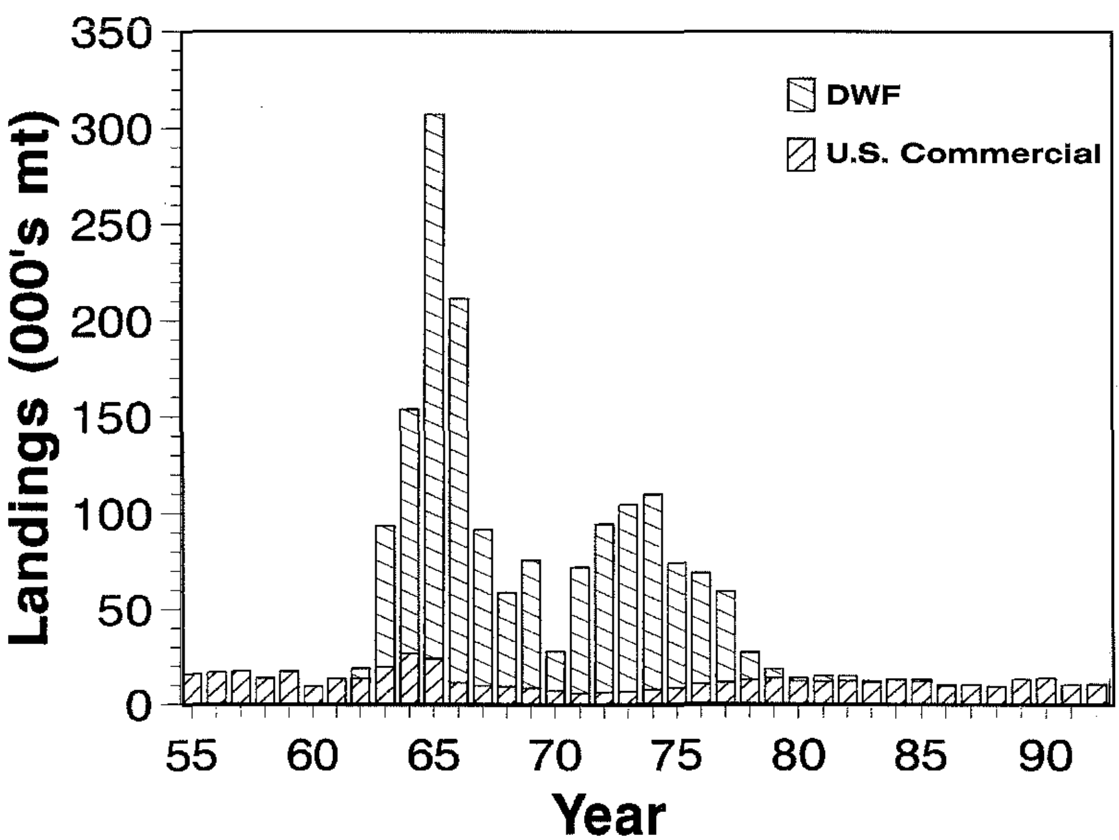

Figure 3. Total landings of silver hake from the Southern Georges Bank-Middle Atlantic stock, 1955-1992.

significantly larger in size (1,000 grt) and fished with smaller mesh (1.5 inch, 40 mm) nets than U.S. fleet vessels (generally vessels were 300 grt, with 2.5 in. mesh nets). As a consequence of such high exploitation, biomass and recruitment from both stocks fell sharply between 1965 and 1970 and total international landings subsequently declined; reaching 23,900 mt (in 1969) and 27,500 mt (in 1970) in the northern and southern stocks, respectively.

After 1972, the majority of landings of silver hake tended to be taken by even smaller mesh nets than previously used by the U.S. fleet, ranging from 1.5 in. (38 mm) to 2.0 in. (51 mm) (Almeida and Anderson 1979). With the inception of the Magnuson Fishery Conservation and Management Act in 1977, the DWF was restricted to a fishing "window" between March 1 and June 30 in a relatively narrow portion of the U.S. continental shelf, and a minimum mesh size regulation of 2.4 in. (60 mm) was imposed. While landings from the Gulf of Maine-Northern Georges Bank stock continued to drop to a historic low of 3,400 mt in 1979, landings from the Southern Georges Bank-Middle Atlantic stock increased again during the early 1970s to 110,000 mt, due to the restrictions imposed on the DWF, but subsequently declined by 1980. This second decline in landings was largely attributed to a 72% drop in silver hake biomass brought about by significant increases in both the size and number of vessels in the U.S. groundfish fleet, as well as technological advances in fishing operations (Anthony 1990). During the last decade, landings from both U.S. silver hake stocks remained fairly stable, but at low levels compared to earlier years of the fishery, averaging 17,500 mt per year. Catches have been taken exclusively by the U.S. fleets, either as bycatch from other groundfish fisheries or through directed fisheries specifically for silver hake.

Table 1. Silver hake landings (mt) from the Gulf of Maine - Northern Georges Bank stock

Gulf of Maine-Northern Georges Bank				
Year	**USSR**	**Other**	**U. S. Commercial**	**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, FRG, GDR, Ireland, Japan, Poland, Romania

GULF OF MAINE-NORTHERN GEORGES BANK

THE FISHERY

Commercial Landings

Total commercial landings in 1992 were 5,302 mt, 12% lower than reported in 1991 and 17% lower than 1990 (Table 1). 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. Short-term trends in U.S. landings between 1980 and 1992 show a steady increase to 8,500 mt in 1986, but an approximate 37% decline between 1986 and 1992.

Recreational Fishery

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

Table 2. United States sampling of commercial silver hake landings by year, quarter and two-digit statistical area from the Gulf of Maine-Northern Georges Bank stock. Values in parentheses in bottom table indicate no samples were taken for given landings

Number of Samples (# Fish Measured)

	Statistical Area 51					Statistical Area52				
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 (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

Sampling Intensity

A summary of the U.S. length frequency sampling of Gulf of Maine (SA 51) and Northern Georges Bank (SA 52) landings during 1982-1992 is presented in Table 2. Samples include both the small round and large round (King) market categories; but virtually all U.S. length samples were collected from otter trawl landings from the unclassified round market category, which generally constitutes more than 90% of the total commercial catch from this stock. United States length frequency sampling in the Gulf of Maine averaged one sample per 130 to 160 mt landed during 1985-1990, but prior to and after this period, sampling has been at a lower intensity (1982-1983: 1 sample per 800 to 960 mt; 1991-1992: 1 sample per 660 to 990 mt). Length frequency sampling of commercial landings from northern Georges Bank 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, an intensity of only 1 sample per 1,600 mt.

Because of the deficiency of length samples taken from landings in the ports (particularly in quarters 3 and 4), it was necessary to use length samples taken from the Domestic Sea Sampling Program (DSSP) data base to derive the catch-at-age matrix for the most recent years. Length frequency samples from sea sampling trips were available from the Gulf of Maine during quarters 3 and 4 and from northern Georges Bank during quarter 3, when landings in the commercial fishery are highest. Only one sea sample was available from northern Georges Bank during quarter 4 in 1992, representing a sampling intensity of 1 per 500 mt. Although fairly close correspondence between the length frequency distributions from sea samples and port samples

Table 3. Landings at age (millions of fish) 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

which were available was observed in some years (*e.g.* quarter 3 in SA 52 in 1989 and 1991), some disparity was seen in other years.

In recent years, length sampling of silver hake commercial landings has become very poor. Although a single length frequency sample (in some cases not even one sample was available) can be used to compute a mean length, at least two are required to compute variance estimates. It is recommended that port sampling coverage for silver hake be increased so that a minimum of two samples are obtained each quarter, from in each area, and for each sample size evaluated. Although it is more desirable to use length frequency samples obtained from a length stratified random sampling design (*i.e.* port samples), in some cases sea samples must be used due to the difficultly in obtaining samples from some ports. Comparison of length distributions between port and sea samples indicated that sea samples cannot directly replace port samples. Therefore, it is further recommended that sea samples be statistically evaluated and potential bias, if any, determined in estimating numbers at length.

Age Composition

The age composition of commercial landings was estimated by applying estimated numbers at length, derived from monthly sea and port sample length frequencies, to age-length keys, derived from research vessel surveys, pooled by calendar quarter. Commercial numbers at length were estimated by dividing quarterly mean weights (obtained by applying silver hake length-weight equations to sample length frequencies) into quarterly commercial landings. Commercial numbers at length were then applied to age-length keys (quarters 1 and 2 applied to the spring survey key; quarters 3 and 4 applied to the autumn survey key) to derive estimates of the numbers at age and summed over quarter to derive the annual catch-at-age matrix (Table 3).

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 (averaging 61% of the total numbers) with significant contributions from age 5. The age composition shifted to younger ages during 1972-1974 (ages 1 and 2 constituting 81% of the total), largely due to the DWF concentrating on the strong 1971 and 1972 year classes. Since 1979, the age composition has shifted towards ages 2 to 3, which have generally constituted at least 64% of the annual totals. In most recent years (1989 to 1992), ages 2 to 3 have constituted at least 70% of the total commercial catch at age. 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 almost complete disappearance of these fish since 1989.

Lack of older ages in the catch-at-age matrix, particularly in recent years, and the need to truncate age distributions makes it difficult to tune the VPA. The use of survey age-length keys to age the commercial catches at length may introduce additional uncertainty into the catch-at-age matrix. Survey age-length keys rarely encompass the full range of length classes found in the commercial catch; this is of particular concern for older ages due to the large overlaps that exist in the size ranges among older aged fish. Therefore, it may be necessary to obtain aging structures from the commercial catches to determine the potential bias that may result in the catch-at-age matrix from using survey age-length keys.

Mean Weights at Age

Mean weights at age in the commercial catch for ages 1 to 6+ during 1955-1992 are given in Table 4 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 Catch Per Effort

Commercial CPUE indices from this stock may be influenced by market conditions (*i.e.* product demand) as much as availability or abundance. Nevertheless, a detailed analysis has been conducted for this stock and is included in this report. United States commercial CPUE indices (catch per unit effort; expressed in metric tons landed per day fished) were calculated by vessel tonnage class (Class 2: 5-50 GRT; Class 3: 51-150 GRT; Class 4: 151-500 GRT) from otter trawl trips in which silver hake constituted 50% or more of the total trip catch by weight. These values are considered "directed trips" and 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 the establishment of the regulated Cultivator Shoals fishery on northern Georges Bank since 1988.

Generally, landings from directed trips have accounted for more than 80% of the total annual catch by weight during the 1973-1992 period, and since 1988 have increased to more than 87% of the total (Table 5). This increase is largely due to the increased landings during the operation of the Cultivator Shoals fishery on northern Georges

Table 4. 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 1	2	3	4	5	6+	Total
Total Commercial Landings Mean Weight (Kilograms) at Age							
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

Bank (SA 52), in which directed trips have accounted for between 46% (1988) and 63% (1991) of the total Gulf of Maine-Northern Georges Bank stock landings. Increases in the directed landings in this fishery since 1988 are also apparent for ton class 3 and 4 vessels. Concurrently, directed landings from the Gulf of Maine have declined over the same period which suggest a shift in directed effort from the Gulf of Maine to the Cultivator Shoals fishery on northern Georges Bank.

Directed U.S. CPUE indices for the Gulf of Maine have generally exhibited an overall declining trend during the 1973-1992 period, but two distinct peaks occurred; one in 1976-1977 and another in 1984-85 (Table 5). This trend is also apparent among vessel class categories, except tonnage class 4 which is only a minor component of the Gulf of Maine fishery. The CPUE indices on northern Georges Bank exhibit a slightly more varied trend and values from tonnage class 3, which have dominated directed landings, have declined slightly between 1973 and 1987. Since 1988, however, CPUE has increased substantially with rates approaching values not observed before in the time series (60.1 mt/day fished in

Table 5. United States commercial landings (L), days fished, and landings per days fished (L/DF), by vessel tonnage class (class 2:5-50 grt; class 3: 51-150 grt; class 4: 151-500 grt), of silver hake from the Gulf of Maine-Northern Georges Bank stock for otter trawl trips in which silver hake constituted 50% or more of the total trip catch by weight [*i.e.*, 'directed trips']

Gulf of Maine (SA 51)

	Class 2			Class 3			Class 4			Total		
YEAR	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF	Trips
1973	4513	652	6.9	2109	179	11.8	-	-	-	6622	8.5	982
1974	2376	458	5.2	860	94	9.1	-	-	-	3235	6.2	822
1975	4097	875	4.7	2562	322	8.0	17	1	17.0	6676	5.9	1266
1976	3789	606	6.3	4750	324	14.7	-	-	-	8538	10.9	940
1977	3314	520	6.4	3544	287	12.3	48	4	12.0	6904	9.4	789
1978	2309	590	3.9	1891	241	7.8	41	4	10.3	4241	5.7	903
1979	778	161	4.8	256	34	7.5	22	1	22.0	1056	5.4	318
1980	1396	318	4.4	964	133	7.2	-	-	-	2360	5.6	510
1981	1590	309	5.1	665	101	6.6	-	-	-	2256	5.6	680
1982	1356	364	3.7	539	95	5.7	2	.5	4.0	1898	4.3	768
1983	2299	477	4.8	1352	154	8.8	-	-	-	3651	6.3	1093
1984	3824	537	7.1	2505	199	12.6	-	-	-	6329	9.3	1269
1985	3233	509	6.4	3109	322	9.7	107	6	17.8	6449	7.9	1381
1986	3000	636	4.7	2848	411	6.9	5	.6	8.3	5853	5.8	1906
1987	1580	492	3.2	1754	351	5.0	3	1	3.0	3338	4.1	1257
1988	1137	411	2.8	1747	389	4.5	-	-	-	2884	3.8	1069
1989	726	318	2.3	506	141	3.6	28	3	9.3	1260	2.8	618
1990	1158	306	3.8	1132	149	7.6	24	3	8.0	2314	5.6	550
1991	965	300	3.2	526	105	5.0	81	19	4.3	1572	4.6	464
1992	955	351	2.7	643	150	4.3	4	1	4.0	1606	3.3	525

Northern Georges Bank (SA 52)

	Class 2			Class 3			Class 4			Total		
YEAR	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF	Trips
1973	530	57	9.3	4312	231	18.7	563	30	18.8	5405	17.8	328
1974	163	37	4.4	1526	111	13.7	417	25	16.7	2105	13.6	191
1975	565	34	16.6	3325	166	20.1	354	13	27.2	4244	20.2	214
1976	493	18	27.4	3170	87	36.4	-	-	-	3663	35.2	144
1977	348	18	19.3	3034	117	25.9	125	4	31.3	3507	25.5	148
1978	313	25	12.5	4827	270	17.9	847	41	20.7	5986	18.0	226
1979	94	6	15.7	306	25	12.2	200	9	22.2	600	16.1	53
1980	245	12	20.3	417	18	23.3	118	4	29.5	779	23.3	77
1981	56	9	6.2	339	34	10.0	-	-	-	395	9.4	68
1982	104	11	9.5	953	38	25.1	227	10	22.7	1283	23.4	95
1983	5	1	5.0	285	18	15.8	171	7	24.4	460	18.9	25
1984	75	7	10.7	248	10	24.8	590	21	28.1	913	25.8	63
1985	48	5	9.6	397	20	19.9	149	16	9.3	593	16.4	69
1986	263	53	5.0	463	36	10.1	134	5	26.8	860	11.1	140
1987	220	45	4.9	773	98	7.9	65	8	8.1	1058	7.3	277
1988	148	27	5.5	1357	73	18.6	1456	30	48.5	2961	32.7	236
1989	111	29	3.8	1097	64	17.1	1593	48	33.2	2801	25.7	262
1990	309	40	7.7	1075	45	23.9	1979	54	36.6	3363	29.9	234
1991	271	41	6.6	1145	48	23.9	2414	29	83.2	3830	60.1	219
1992	64	19	3.4	1088	60	18.1	2018	61	33.1	3170	27.4	230

1991). This is particularly notable in the ton class 4 fleet (Table 5) 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

Table 6. General Linear Model (GLM) standardization coefficients by year grouping and ton class for statistical areas 51 (Gulf of Maine) and 52 (Northern Georges Bank)

	GLM Ton Class Coefficient (S.E.)			Retransformed Coefficient		
	TC3	**TC2**	**TC4**	**TC2**	**TC4**	**Model R^2**
			Statistical Area 52			
1973 - 1982	0	-0.383(0.066)	-0.361(0.140)	0.682	0.679	0.37
1983 - 1987	0	-0.706(0.117)	-0.603(0.284)	0.493	0.547	0.32
1973 - 1987	0	-0.462(0.059)	-0.646(0.130)	0.630	0.524	0.35
1988 - 1992	0	-0.595(0.126)	0.730(0.139)	0.551	2.07	0.45
			Statistical Area 51			
1973 - 1992	0	-0.791(0.019)	-1.088(0.103)	0.453	0.337	0.30

Table 7. Stratified mean number-per-tow (delta estimate) and weight-per-tow (kilograms) for silver hake from Gulf of Maine-Northern Georges Bank stock (strata 20-36, 36-40) from NEFSC spring and autumn bottom trawl surveys

	Spring		Autumn	
Year	**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	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.

tonnage classes were standardized by applying a three factor (year, tonnage class, and area) General Linear Model (GLM) to log CPUE data for all directed otter trawl trips within three different time blocks; 1973-1982, 1983-1987, and 1988-1992, with ton class 3 set as the standard. The models accounted for no less than 32% of the total variation in the CPUE data, with the model applied to the 1988-1992 period accounting for 45% (Table 6).

Results of this analysis suggested that the relative fishing powers (expressed by GLM ton class coefficients) between ton classes 2 and 4 did not differ significantly during the 1973-1982 and 1983-1987 periods, and that both were less than ton class 3.

Retransformed coefficients indicated that ton classes 2 and 4 were only 50 to 68% as efficient as ton class 3 during these time periods (Table 6). However, during the 1988-1992 period, the relative fishing power of ton class 4 vessels was significantly greater than that of either ton class 2 or 3, indicating that ton class 4 vessels were more than 200% efficient. Standardized indices were obtained by dividing the CPUE values by the retransformed GLM ton-class coefficient for the 1973-1987 and 1988-1992 time blocks. Only one time block was used for the GLM analysis on CPUE data from the Gulf of Maine, 1973-1992. Standardized CPUE indices showed relatively consistent trends between the different ton classes and within the different regions (Figure 4a). The 1991 ton class 4 value, although still large relative to adjacent years, is not different from what has been observed during earlier years of the fishery. The overall trend between the Gulf of Maine (51) and northern Georges Bank (52) regions (average of all ton classes weighted by landings) show relatively consistent peaks in the standardized CPUE values, although the magnitude was greater on northern Georges Bank (Figure 4b). Standardized mean (weighted by landings) indices for the entire Gulf of Maine-Northern Georges Bank stock show distinct peaks in CPUE during 1975-1977 and during 1983-1985 (Figure 4b). Most recently, standardized mean CPUE has steadily increased since 1987, peaked in 1991, but has since dropped in 1992.

Research Vessel Abundance Indices

Research vessel bottom trawl surveys have been conducted by NEFSC annually in the autumn since 1963, and in the spring since 1968. Estimates of stratified mean catch per tow in numbers and weight have been used to monitor trends in population size and recruitment and to tune VPA. Spring and autumn survey indices were calculated using Delta distribution estimators (Pennington 1983, Almeida *et al.* 1986) for offshore strata only and the spring indices (1973-1981) adjusted to the #36 Yankee trawl as the standard gear. Stratified mean catch per tow in number and weight for both spring and autumn surveys are given in Table 7 and estimates of number per tow at age since 1973 in Table 8.

The autumn offshore numbers per tow index (0+) declined in the mid- and late 1960s during the period of heavy exploitation by DWF (Figure 4). Numbers per tow increased in both the spring and autumn surveys between 1969 and 1975, due to above average recruitment in the early 1970s, but total abundance subsequently declined during the late 1970s. Trends in population abundance from the NEFSC surveys were largely consistent with standardized commercial CPUE indices (Figure 4b). Numbers per tow in the spring survey varied without trend during the early- to mid 1980s, but increased since 1987, although estimates have been highly variable. The spring index for 1992 is the highest on

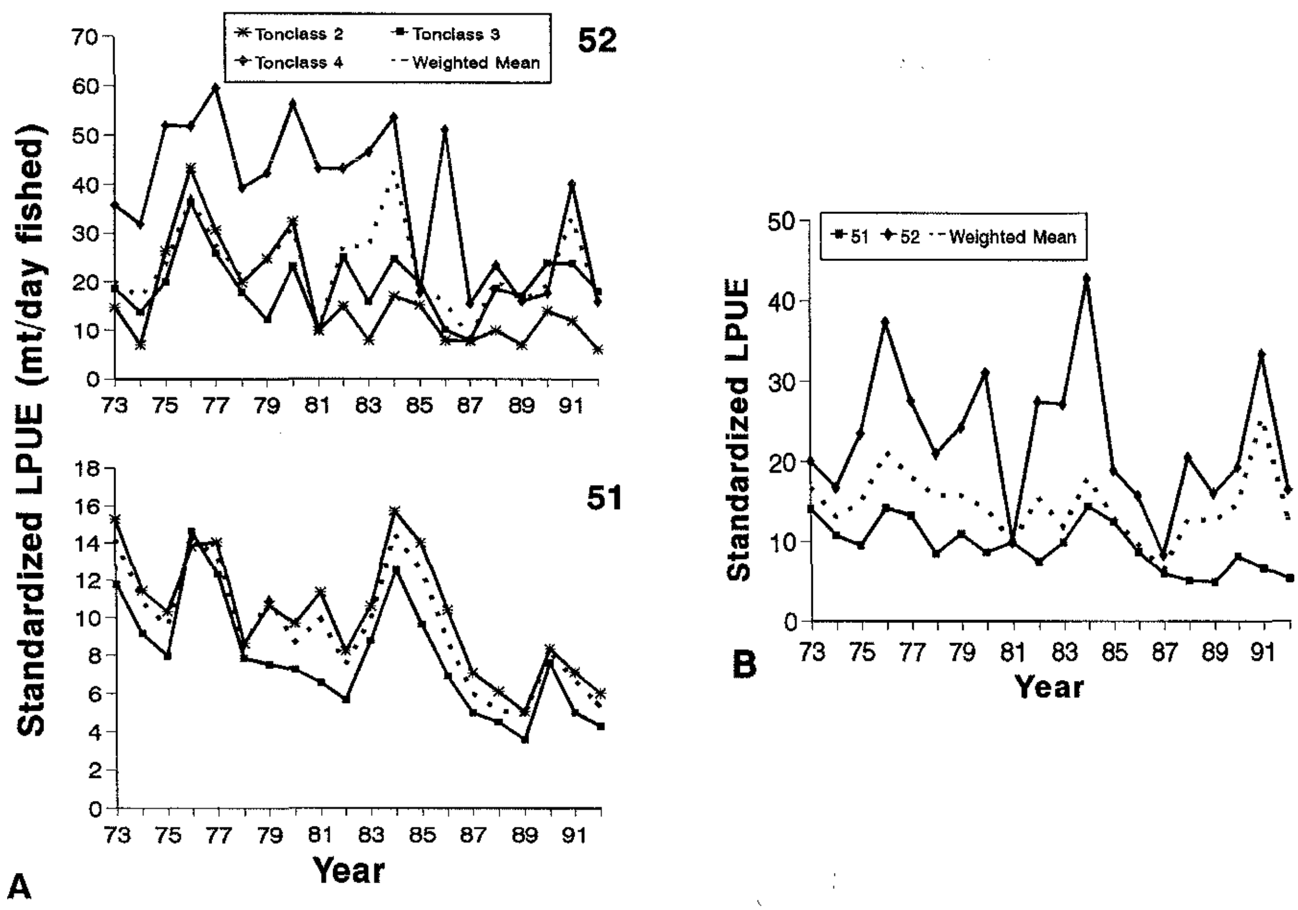

Figure 4. Landings per unit effort (LPUE) standardized for differences in vessel tonnage class fishing power for the Gulf of Maine-Northern Georges Bank silver hake stock. Calculated standardized LPUE indices compared by a) two-digit statistical area (51 and 52) and vessel tonnage class; and b) by statistical area weighted by tonnage class landings.

Table 8. 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 NEFSC spring and autumn 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	5.98	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	38.69	15.11
1977[1]	-	5.00	4.88	4.25	1.71	0.34	0.29	16.63	16.63	11.47	6.59
1978[1]	-	3.57	1.55	0.29	0.16	0.04	0.02	5.64	5.64	2.06	0.51
1979[1]	-	7.06	10.80	0.37	0.07	0.05	0.12	18.55	18.55	11.41	0.61
1980[1]	-	3.67	16.65	5.71	0.40	0.11	0.24	26.92	26.92	23.11	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	8.86	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	7.79	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	38.98	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
					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 catch es to equivalent #36 trawl catches using a .334:1 ratio.

record, at 196.4 fish per tow (Figure 5). The autumn survey indices have steadily increased since 1980 (Figure 5). The autumn index in 1992 was 129.5, also the largest on record since the mid-1960s, and is strongly represented by the 1989, 1990, and 1991 year classes. Juvenile and adult silver hake distributions from U.S. research vessel surveys during 1982-1992 (Figure 6) suggest that silver hake may seasonally migrate across the presently assigned stock boundaries. Such migrations may affect interpretations concerning the indices of abundance. Distributions vary seasonally by size/age and probably in response to hydrographic changes. During the spring, large concentrations of juveniles are observed on northern Georges Bank and in the Gulf of Maine just east of Cape Ann, while the greatest adult concentrations occur along the continental slope of the southeastern rim of Georges Bank (Figure 6). 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 6). Juveniles are widely distributed over all of Georges Bank and into the Middle Atlantic during the autumn. In addition, Figure 6 clearly suggests a general northward

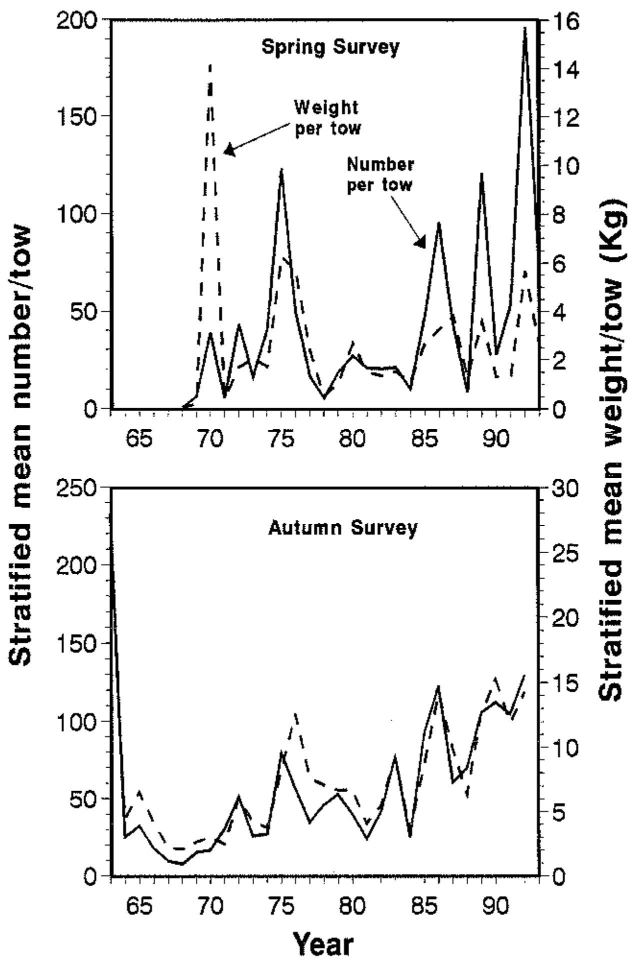

Figure 5. Stratified mean number and weight (kilograms) per tow of Gulf of Maine-Northern Georges Bank silver hake from the NEFSC spring and autumn bottom trawl surveys.

movement of fish from the southern and middle Atlantic areas into southern New England waters during the summer and autumn. It may be equally likely that silver hake migrate across Georges Bank during this season.

The question of interest in the silver hake assessment is whether migrations of fish are occurring across the presently assigned stock boundaries, and if so, to what extent do the indices confound the VPA tuning. Mixing between the stocks and seasonally shifting stock boundaries may lead to a misallocation of landings to the stocks and a mismatch between catch-at-age matrices and survey strata sets between seasons. Therefore, it may be important to investigate further whether stock boundaries have changed and, if so, where should stocks be divided or whether the stocks can be assessed as one unit.

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 M of 0.40 is high, compared with that of other adult gadid fish, given the extensive cannibalism in this stock, it is possible M could be even higher or that the natural mortality rate varies significantly with age.

Total Mortality

Pooled estimates of instantaneous total mortality (Z) were calculated for four time periods encompassed by the NEFSC autumn and spring offshore bottom trawl surveys: 1974-1977, 1979-1982, 1984-1987, and 1989-1992 (Table 9). 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. The geometric mean of the spring and autumn values were also computed. These calculations are given as:

Autumn

$\ln(\Sigma \text{ age } 2+ \text{ for year } i\text{-}1 \text{ to } j\text{-}1 / \Sigma \text{ age } 3+ \text{ for year } i \text{ to } j)$

Spring

$\ln(\Sigma \text{ age } 3+ \text{ for year } i \text{ to } j / \Sigma \text{ age } 4+ \text{ for year } i+1 \text{ to } j+1)$

Pooled estimates indicated that total mortality was lowest during the 1974-1977 period (Z=0.86). Total mortality increased during the next two subsequent periods: 1979-1982 Z=0.97 and 1984-1987 Z=0.90. During the most recent period, 1989-1992, the estimate of Z (0.80) decreased slightly from all earlier periods, although this estimate is provisional. During all periods, estimates of total mortality were lower from autumn survey data than the spring. Except for the most recent period 1989-1992, total mortality has been high (Z>1.0) in the spring survey, but has decreased steadily since 1974. In comparison, total mortality was rather low (Z<0.5) in the autumn survey during the 1974-1977 period, but has since more than doubled.

Table 9. 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	1.59	1.18	0.46	0.06	0.86	0.46
1979-1982	1.26	0.86	0.75	0.35	0.97	0.57
1984-1987	1.17	0.77	0.70	0.30	0.90	0.50
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.

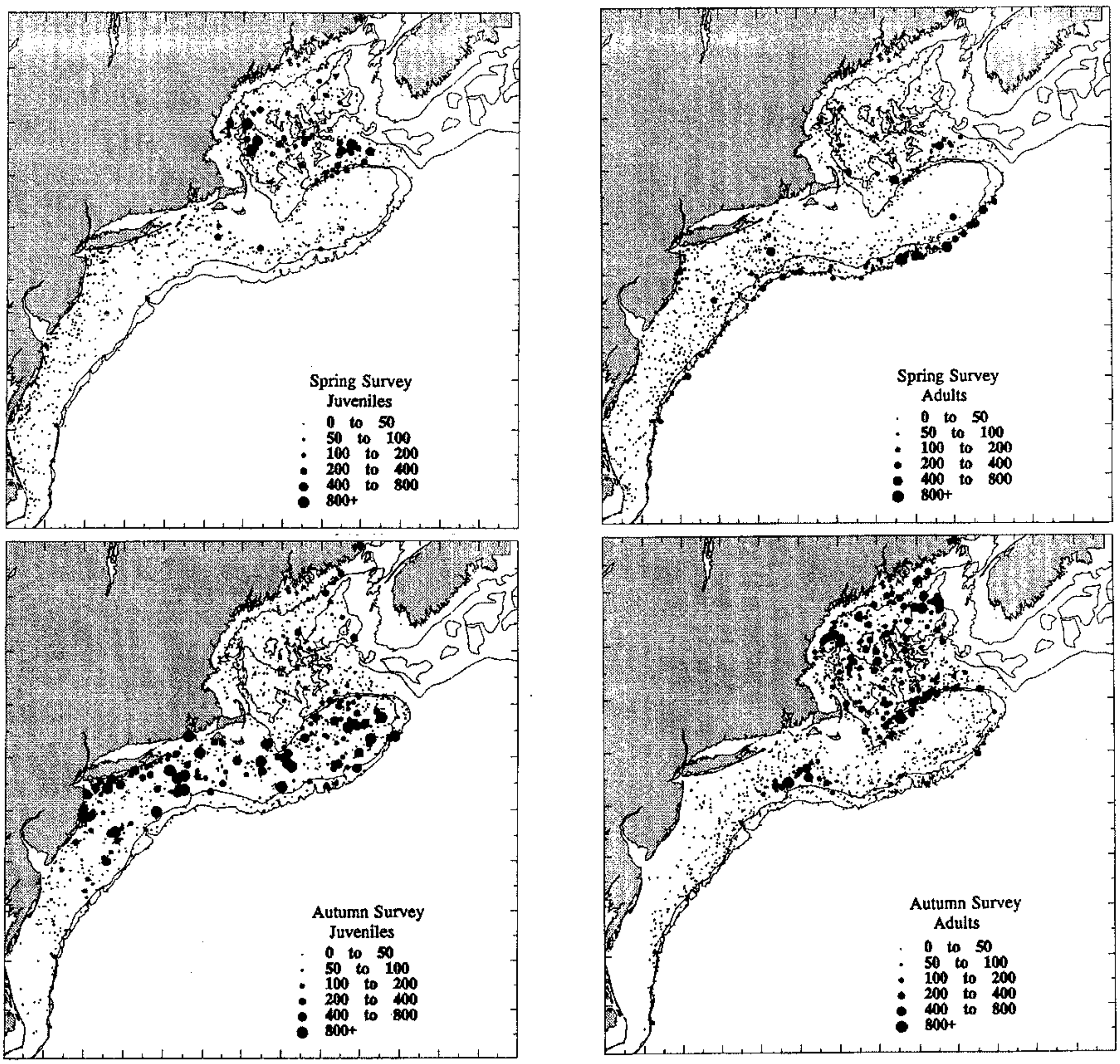

Figure 6. Distribution of juvenile (<18 cm) and adult (>18 cm) silver hake in the NEFSC spring and autumn bottom trawl surveys during 1982-1992. Values shown are numbers of fish per tow.

Table 10. Silver hake landings (mt) from the Southern Georges Bank-Middle Atlantic Stock

Year	USSR	Other[1]	U.S. Commercial	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	-	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, GDR, Italy, Japan, Mexico, Poland, Romania, Spain
[2] Recreational catch estimates taken from Almeida (1987b).

Changes in catchability are a possible explanation for the inconsistency of estimates of total mortality between the spring and autumn surveys. Although both surveys indicated a strong decline in catch per tow between ages 3 and 4, numbers of older fish appear to be less available during the spring survey. This may result from a general offshore movement of adult fish, perhaps beyond the present stock boundaries, during the over-wintering period, which may be evident from concentrations of adults observed on the slope of southeastern Georges Bank (Figure 6).

Table 11. United States sampling of commercial silver hake landings by year, quarter and two-digit statistical area from the Southern Georges Bank - Middle Atlantic stock. Values in parentheses in lower table indicate that no samples were taken for given landings.

Number of Samples (# Fish Measured)

Statistical Area 52

Year	Q1	Q2	Q3	Q4	Σ
1982	-	1(49)	-	-	1
1983	-	1(105)	1(99)	-	2
1984	-	2(156)	-	-	2
1985	-	-	-	-	0
1986	-	-	3(319)	-	3
1987	-	2(201)	1(110)	-	3
1988	-	2(200)	3(303)	-	5
1989	-	2(194)	4(402)	-	6
1990	-	2(199)	-	-	2
1991	1(100)	2(199)	-	-	3
1992	-	3(332)	1(100)	-	4

Statistical Area 53

Year	Q1	Q2	Q3	Q4	Σ
1982	2(587)	3(1002)	2(358)	2(590)	9
1983	2(491)	3(876)	3(772)	4(551)	12
1984	3(267)	3(304)	5(468)	7(680)	18
1985	4(359)	9(887)	10(1002)	7(712)	30
1986	3(300)	8(797)	13(1421)	10(936)	34
1987	6(588)	7(682)	11(1130)	13(1181)	37
1988	3(287)	7(671)	3(291)	9(922)	22
1989	2(204)	7(699)	4(399)	3(299)	16
1990	6(603)	9(911)	6(608)	6(639)	27
1991	3(299)	4(496)	8(900)	4(401)	19
1992	3(375)	-	3(320)	-	6

Statistical Area 61

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

Statistical Area 62

Year	Q1	Q2	Q3	Q4	Σ
1982	-	1(89)	-	-	1
1983	2(342)	1(105)	-	-	3
1984	5(574)	-	-	3(302)	8
1985	1(119)	1(98)	1(89)	1(104)	4
1986	2(208)	-	-	-	2
1987	2(196)	2(202)	-	-	4
1988	1(117)	2(206)	-	-	3
1989	2(105)	-	-	-	2
1990	3(314)	-	-	-	3
1991	-	-	-	-	0
1992	1(102)	-	-	-	1

Annual Sampling Intensity (No. Tons Landed/Sample)

Statistical Area 52

Year	Q1	Q2	Q3	Q4	Σ
1982	(8)	126	245	-	395
1983	(9)	61	381	(3)	316
1984	(1)	22	(392)	(24)	230
1985	(5)	(143)	(212)	(6)	(366)
1986	(20)	(121)	31	(10)	82
1987	(6)	239	565	(10)	378
1988	(45)	202	88	(2)	144
1989	(254)	251	129	(5)	355
1990	(9)	428	(215)	(20)	550
1991	529	494	(42)	(1)	520
1992	(1)	760	645	(1)	732

Statistical Area 53

Year	Q1	Q2	Q3	Q4	Σ
1982	337	783	780	707	668
1983	306	455	940	733	444
1984	193	630	289	205	297
1985	84	223	142	163	164
1986	243	251	105	120	156
1987	184	206	134	72	134
1988	293	236	19	357	146
1989	172	151	280	508	254
1990	213	159	244	214	199
1991	226	316	127	188	169
1992	327	(778)	255	(689)	536

Statistical Area 61

Year	Q1	Q2	Q3	Q4	Σ
1982	471	212	29	115	198
1983	452	180	(6)	(435)	175
1984	138	457	(117)	40	155
1985	114	135	(6)	17	110
1986	73	381	19	90	116
1987	884	158	(49)	211	281
1988	110	189	36	92	111
1989	175	280	40	140	167
1990	148	158	60	84	120
1991	128	331	40	83	125
1992	184	129	170	(972)	205

Statistical Area 62

Year	Q1	Q2	Q3	Q4	Σ
1982	(132)	(37)	-	(1)	170
1983	33	126	-	(3)	65
1984	30	(78)	(117)	2	30
1985	39	41	1	2	22
1986	12	(18)	-	-	21
1987	36	41	-	(4)	39
1988	104	12	-	(1)	43
1989	35	(41)	-	(15)	75
1990	95	(56)	-	(28)	51
1991	(43)	(23)	-	(2)	68
1992	14	(10)	-	(2)	26

Table 12. Landings at age (millions of fish) of silver hake from the Southern Georges Bank-Middle Atlantic Stock, 1955-1992

Year	Age						Total
	1	2	3	4	5	6+	
	Total Commercial Landings (Millions of Fish) at Age						
1955	17.4	9.6	20.0	21.7	8.7	3.0	80.4
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

Table 13. Mean weight (kilograms) at age of total commercial landings of silver hake from the Southern Georges Bank-Middle Atlantic stock, 1955-1992

Year	Age 1	2	3	4	5	6+	Total
	Total Commercial Landings Mean Weight (Kilograms) at Age						
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

SOUTHERN GEORGES BANK-MIDDLE ATLANTIC

THE FISHERY

Commercial Landings

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 10). Landings in 1990 from the U.S. commercial fisheries were the largest since 1966. Since 1980, the U.S. commercial fishery has accounted for at least 80% of the total landings, which have remained steady without trend, averaging 12,000 mt (Figure 3).

Recreational Catches

Recreational catches of silver hake have been reported for this stock but have generally been a minor component of the total catch, averaging

777 mt per year and ranging from 0 to 1,974 mt (Table 10). Details of recreational catch estimates can be found in Almeida (1987b).

Sampling Intensity

A summary of the U.S. length frequency sampling by two-digit statistical area (SA) for which significant commercial landings occur and by quarter during 1982-1992 is given in Table 11. United States length frequency sampling intensity has generally been high in SA 61 and SA 62, and lower in SA 52 and SA 53. Landings taken from SA 62 were generally oversampled (averaging 1 sample per 21-170 mt), particularly since commercial landings from this area are low. In SA 61, length frequency sampling was adequate during 1982-1992, averaging from one sample per 100-280 mt. Sampling in SA 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 SA 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 (Table 11). As for the Gulf of Maine-Northern Georges Bank stock, some disparity was observed between length frequency distributions when comparing port and sea samples. Virtually all U.S. length samples were collected from otter trawl landings from the unclassified round market category, which generally constitutes more than 90% of the total commercial catch from this stock.

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

Age Composition

The age composition of commercial landings was estimated by applying estimated numbers at length derived from monthly sea and port sample length frequencies to age-length keys derived from research vessel surveys, pooled by calendar quarter. Commercial numbers at length were estimated by dividing quarterly mean weights (obtained by applying silver hake length-weight equations to sample length frequencies) into quarterly commercial landings. Commercial numbers at length were then applied to age-length keys (quarters 1 and 2 applied to the spring survey key; quarters 3 and 4 applied to the autumn survey key) to derive estimates of the numbers at age and summed over quarter to derive the annual catch-at-age matrix (Table 12).

Similar shifts in the predominant ages constituting the commercial landings have been observed for this stock since 1955. The age composition of the commercial catch in the 1950s and 1960s was composed of predominantly age 2 to 4 fish (averaging about 86% of the total catch each year). During 1972-1974 the age composition shifted to 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), constituting approximately 90% of the total catch. Since 1979, the commercial catch has been made up of 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.

Mean Weights at Age

Mean weights at age in the commercial catch for ages 1-6+ during 1955-1992 are given in Table 13 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 Catch Per Effort

United States commercial CPUE indices (catch per unit effort; expressed in metric tons landed per day fished) were calculated by vessel tonnage class (Class 2: 5 to 50 grt; Class 3: 51 to 150 grt; Class 4: 151 to 500 grt) from otter trawl trips in which silver hake constituted 50% or more of the total trip catch by weight. These values are considered "directed trips" and have been computed for those areas in which significant silver hake landings occur (Table 14). Since 1980, when U.S. commercial landings constituted the greatest proportion of the total international catch of silver hake, directed landings from U.S. fleets have constituted at least 46% of the total international catch and at least 50% of the total U.S. catch. In recent years, since 1987, landings from

Table 14. United States commercial landings (L), days fished (DF), and landings per days fished (L/DF), by vessel tonnage class (Class 2:5-50 grt; Class 3: 51-150 grt; Class 4: 151-500 grt), of silver hake from the Southern Georges Bank-Middle Atlantic stock for otter trawl trips in which silver hake constituted 50% or more of the total trip catch by weight [*i.e.*, 'directed trips']

Statistical Area 52

	Class 2			Class 3			Class 4			Total		
Year	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF	#Trips
1973	-	-	-	-	-	-	43	2	21.5	43	21.5	1
1974	-	-	-	4	1	4.0	-	-	-	4	4.0	2
1975	-	-	-	51	3	17.0	-	-	-	51	17.0	2
1976	-	-	-	67	3	22.3	-	-	-	67	22.3	3
1977	-	-	-	13	1	13.0	-	-	-	13	13.0	1
1978	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	8	2	4.0	57	2	28.5	68	25.5	5
1980	-	-	-	118	19	6.2	2	1	2.0	119	6.1	32
1981	-	-	-	225	35	6.4	221	28	7.9	446	7.2	34
1982	-	-	-	262	31	8.5	-	-	-	265	8.5	29
1983	-	-	-	514	37	13.9	13	6	2.2	527	13.6	29
1984	-	-	-	399	24	16.6	25	3	8.3	433	16.1	33
1985	13	2	6.5	261	21	12.4	54	5	10.8	328	11.9	29
1986	-	-	-	141	13	10.8	58	6	9.7	199	10.5	19
1987	-	-	-	437	52	8.4	560	32	17.5	1096	13.5	78
1988	-	-	-	277	13	21.3	417	14	29.8	694	26.4	36
1989	-	-	-	825	18	45.8	921	26	35.4	1745	40.3	60
1990	-	-	-	116	11	10.5	942	36	26.2	1059	24.5	54
1991	14	3	4.7	432	28	15.4	1092	27	40.4	1507	33.1	74
1992	-	-	-	414	7	59.1	2498	60	41.6	2912	44.1	88

Statistical Area 53

	Class 2			Class 3			Class 4			Total		
Year	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF	#Trips
1973	268	71	3.8	48	14	3.4	-	-	-	316	3.7	306
1974	583	138	4.2	273	37	7.4	-	-	-	855	5.2	625
1975	659	152	4.3	221	21	10.5	-	-	-	881	5.9	586
1976	1158	212	5.5	321	27	11.9	-	-	-	1479	6.9	836
1977	813	131	6.2	281	18	15.6	-	-	-	1093	8.9	491
1978	997	125	8.0	819	50	16.4	140	4	35.0	1957	13.4	576
1979	1063	173	6.1	1173	125	9.4	48	5	9.6	2285	7.9	946
1980	554	102	5.4	549	66	8.3	10	2	5.0	1113	6.9	616
1981	386	76	5.1	1687	116	14.5	108	14	7.7	2181	12.5	574
1982	291	59	4.9	3347	222	15.1	389	17	22.9	4028	15.1	794
1983	391	70	5.6	2711	233	11.6	735	41	17.9	3837	12.2	853
1984	415	61	6.8	2788	237	11.8	912	51	17.9	4115	12.6	927
1985	263	49	5.4	2803	335	8.4	724	71	10.2	1790	8.5	906
1986	417	75	5.6	2872	365	7.9	1016	95	10.7	4304	8.3	907
1987	421	92	4.6	2610	388	6.7	794	87	9.1	3805	7.0	941
1988	167	47	3.6	1331	179	7.4	595	39	15.3	2092	9.3	503
1989	297	65	4.6	1665	189	8.8	555	60	9.3	2517	8.4	575
1990	383	89	4.3	2007	202	9.9	1298	127	10.2	3688	9.5	794
1991	126	40	3.2	1377	168	8.2	585	80	7.3	2087	7.6	472
1992	51	27	1.9	1193	174	6.9	811	118	6.9	2055	6.7	411

Table 14. Continued

	Statistical Area 61											
	Class 2			Class 3			Class 4			Total		
Year	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF	#Trips
1973	37	7	5.3	21	1	21.0	-	-	-	58	11.0	27
1974	106	20	5.3	35	5	7.0	-	-	-	141	5.7	86
1975	115	26	4.4	23	4	5.8	-	-	-	138	4.6	96
1976	177	23	7.7	92	10	9.2	-	-	-	269	8.2	101
1977	143	16	9.2	157	18	8.7	-	-	-	300	8.9	101
1978	1970	251	7.8	2715	182	14.9	-	-	-	4685	11.9	1174
1979	2033	256	7.9	2962	214	13.8	-	-	-	5002	11.4	1212
1980	2121	242	8.8	2768	217	12.8	-	-	-	4889	11.0	1498
1981	1433	157	9.1	2618	202	13.0	-	-	-	4052	11.6	1235
1982	909	122	7.5	2309	212	10.9	-	-	-	3217	9.9	1161
1983	988	155	6.4	1918	207	9.3	20	2	10.0	2926	8.3	1127
1984	1438	164	8.8	2523	188	13.4	117	5	23.4	4099	12.1	1132
1985	1304	120	10.9	2694	193	14.0	62	9	6.9	4050	12.9	1006
1986	850	141	6.0	2017	292	6.9	67	5	13.4	2934	6.8	862
1987	503	115	4.4	1645	276	6.0	133	15	8.9	2281	5.8	581
1988	463	78	5.9	2909	307	9.5	406	18	22.6	3378	10.4	588
1989	897	138	6.5	3796	274	13.9	177	20	8.9	4870	12.3	862
1990	806	122	6.6	3732	323	11.6	469	64	7.3	5007	10.4	787
1991	408	111	3.7	1745	226	7.7	168	30	5.6	2321	6.9	653
1992	146	79	1.8	999	116	8.6	286	49	5.8	1432	7.4	360

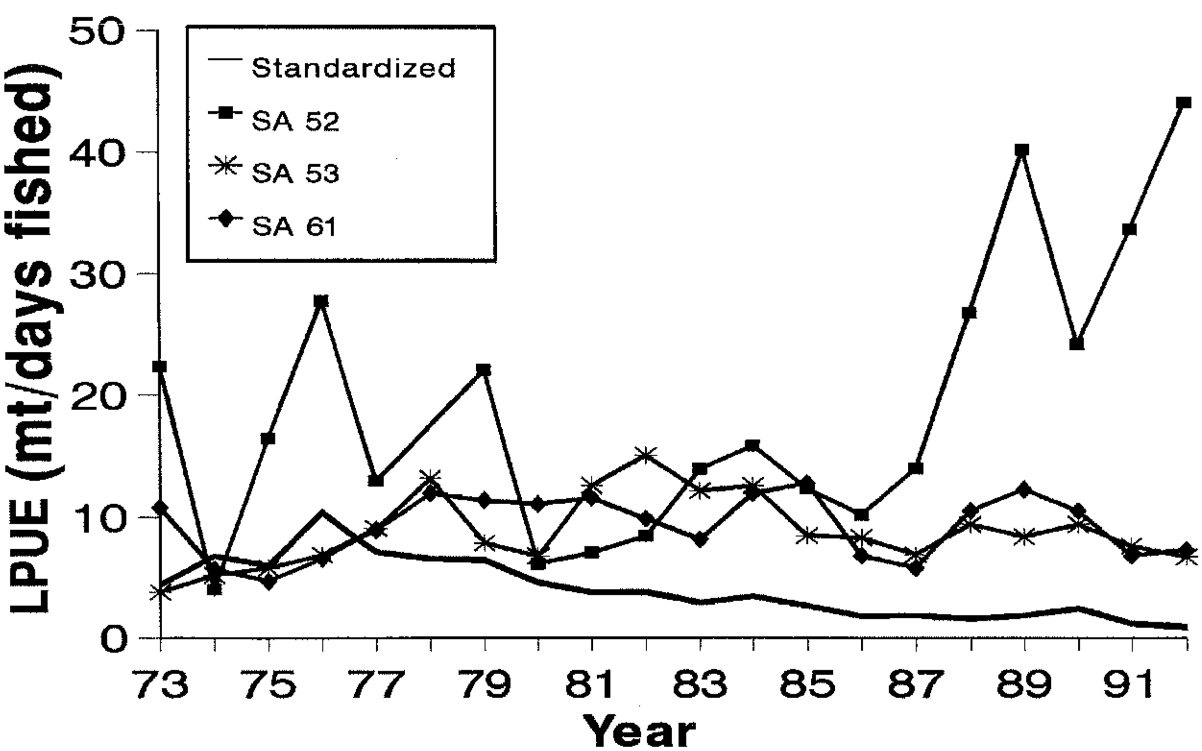

Figure 7. Standardized landings per unit effort (LPUE) for differences in vessel tonnage class fishing power for the Southern Georges Bank-Middle Atlantic stock.

Table 15. 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 spring and autumn 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	65.98	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.

directed trips have increased to at least 60% of the total catch. United States landings from directed trips in SA 53 and SA 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 CPUE indices since the late 1970s from SA 53 and 61 have gradually declined, with peak values during 1981-1984 and another smaller peak during 1988-1990 (Figure 7). Despite decreases in these areas, CPUE in the southern Georges Bank region (SA 52) has steadily increased since 1980.

Commercial CPUE indices were standardized by applying a three-factor (year, tonnage class, and area) GLM to log CPUE data for directed otter trawl trips from 1973 through 1992. The model accounted for just over 30% of the total variation in the data. Retransformed log year coefficients were multiplied by the 1973 base year CPUE to derive standardized indices. Despite increases in the CPUE index from SA 52, the standardized indices that account for area and ton class effects show a declining trend (Figure 7).

Table 16. 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 NEFSC spring and autumn 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
					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.

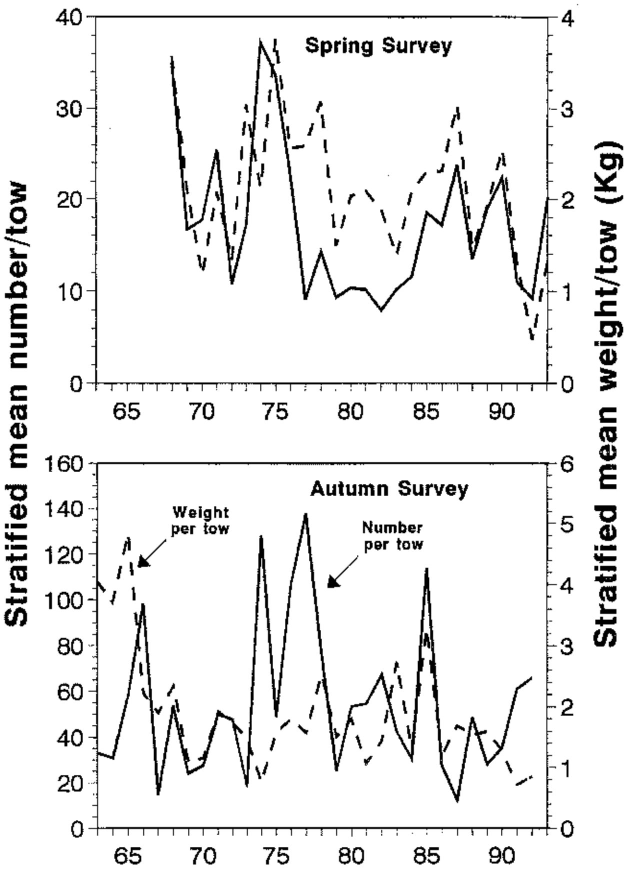

Figure 8. Stratified mean number and weight (kilograms) per tow of Southern Georges Bank-Middle Atlantic silver hake from the NEFSC spring and autumn bottom trawl surveys.

Research Vessel Abundance Indices

Spring and autumn bottom trawl survey indices (linear estimate) are calculated using inshore/offshore data combined and the # 36 Yankee trawl as the standard gear. Surveys that used the # 36 Yankee trawl but did not include inshore strata (spring 1968-1972 and autumn 1963-1973) were adjusted using ratios given in Table 15. See Almeida (1987b) for more details of the calculations of these adjustment coefficients. Stratified mean catch per tow in number and weight for both spring and autumn survey are given in Table 15 and estimates of number per tow at age since 1973 in Table 16.

The spring and autumn survey number per tow indices have been highly 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 this, both sets of indices subsequently declined (Figure 8). Increases in number per tow indices resulted from strong year classes during the mid-1970s and were consistent with trends for the Gulf of Maine-Northern Georges Bank stock during this period. The spring index increased again during 1982-1986, but has shown a generally declining trend through 1993; the

Table 17. 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 rate assumed to be 0.40
[2] Estimates derived from:
Autumn: $\ln(\Sigma$ age 2^+ for year i - 1 to j - 1/Σ age 3^+ for year i to j
Spring: $\ln(\Sigma$ 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 18. 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]		Georges Bank[2]	
	Mesh 1[3]	Mesh 3[4]	Mesh 1	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)	2168)	-
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 codend $\leq$ 3.5 in.)
[4] Mesh category 3 = (mesh codend $\geq$ 5.5 in.)

autumn indices have varied annually without trend since 1980, 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, apply 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 (Table 17).

Pooled estimates indicated that total mortality on this stock was lowest during the earlier periods of the time series; Z=0.77 during 1974-1977 and Z=0.67 during 1979-1982. Total mortality significantly increased in the next two subsequent periods (Table 17); from 0.67 during 1979-1982 to 1.11 during 1984-1987. Total mortality reached its highest value of 1.56 during 1989-1992. Estimates of total mortality were roughly equal between the spring and autumn surveys over all periods.

ESTIMATION OF DISCARDS AND ITS IMPLICATIONS ON YIELD AND SPAWNING STOCK BIOMASS PER RECRUIT

Because discards in the domestic silver hake fishery may be significant (Anderson 1975) an important aspect of this analysis 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 toward younger ages. Simultaneously, the analysis must consider whether increased effort, and therefore fishing mortality, will likewise be directed into this emerging fishery.

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 expansion factor to adjust the cell's discard estimates to fleetwide 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 categories large enough to provide adequate

Table 19. Landings (metric tons) by region and quarter, and number of discarded silver hake 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

		Southern Georges Bank[1]				Southern New England[2]				Middle Atlantic[3]			
Year	Qtr	Landings	Mesh1[4]	Mesh2[5]	Mesh3[6]	Landings	Mesh1	Mesh2	Mesh3	Landings	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	-	-	-
1922													
	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 $\leq$ 3.5 in.)
[5] Mesh Category 2 = (3.5 in. < mesh codend < 5.5 in.)
[6] Mesh Category 3 = (mesh codend $\geq$ 5.5 in.)

samples to stratify temporally and spatially because discard rates are likely to vary by size composition of the fish in the population and operating characteristics of the fleets (*i.e.* mesh size). No statistically based means of deriving strata were used. Because seasonal growth of fish in the population appeared to have an effect on the modal length and size composition of each mesh, quarter was retained as the temporal stratum.

Similarities in the length frequency distributions by mesh and area were used as the basis for defining the spatial stratum and mesh stratum within each stock unit: 1) Gulf of Maine-Northern Georges Bank stock consists of Gulf of Maine Region (SA 511-515) and Northern Georges Bank Region (SA 521-523); and 2) Southern Georges Bank-Middle Atlantic stock consists of Southern Georges Bank region (SA 524-526), Southern New England region (SA 537-613), and Middle Atlantic region (SA 614-636). In addition, meshes were aggregated into mesh categories as follows:

mesh category 1: mesh in codend $\leq$ 3.5 in.,
mesh category 2: 3.5 in. < mesh in codend < 5.5 in.,
mesh category 3: mesh in codend $\geq$ 5.5 inches).

Tables 18 and 19 give number of individual length samples and number of fish measured of discarded silver hake in the DSSP data base by stratum (year, quarter, region, and mesh).

DISCARD ESTIMATOR

The weight (in pounds) of silver hake discarded to days fished was chosen as the discard ratio estimator for the silver hake fishery. In the DSSP, observers who are placed aboard a given vessel for a trip duration record tow-by-tow weight of discards as well as effort data. Although tows are not independent, the trips themselves may be, and trips that caught silver hake were defined as the population of sampling units of interest. This population comprised trips that landed all silver hake, landed and discarded silver hake, and discarded all silver hake. Preliminary computation of discard rates (lb/day fished) indicated that rates were generally much lower for 100% discard trips, which might be expected for a nontargeted fishery, and it would, therefore be desirable to stratify. However, the weighout data base only records effort associated with trips landing silver hake and thus, trips in which the practice of full discarding occurred would not be included in the effort expansion factor. Therefore, 100% discard trips were excluded at the cost of lower overall sample size available for estimation of discard rates. The net effect of this exclusion is higher discard rates for many of the strata, although effort used in the expansion factor will be lower because it excludes effort from trips that discarded the entire catch, probably resulting in an underestimate of total discards.

The trip or sampling unit (a trip that caught silver hake and did not fully discard) comprises a group or cluster of elements that are the observed tows in the DSSP data base containing discard and effort information. The sampling unit (*i.e.* trip) is calculated as:

$$R=\frac{\sum_{1}^{n} y_i}{\sum_{1}^{n} x_i} \tag{1}$$

where y_i = the weight of discarded silver hake in the *ith* observed tow and x_i = the effort expended (days fished) for the *ith* observed tow. Each sampling unit can fall into any cell defined by the above strata or domains (k = 1, 2, ..., n_j) and therefore the population parameter to be estimated is the ratio of means (Cochran 1963) within the *kth* domain;

$$\hat{R}_k=\frac{\sum_{k=1}^{n_j} \frac{y_{jk}}{n_j}}{\sum_{k=1}^{n_j} \frac{x_{jk}}{n_j}}=\frac{\bar{y}_j}{\bar{x}_j} \tag{2}$$

where: $\hat{R}_k$ = discard ratio estimator in the *kth* domain,
y_{jk} = the mean weight of discards over j trips in the *kth* domain,
x_{jk} = the mean effort (days fished) over j trips in the *kth* domain,
n_j = the number of sampling units (trips) that fall into the *kth* domain.

For convenience with subsequent computations, the discard ratio estimator, $\hat{R}_k$, is redefined for the *ith* year, the *jth* region, the *kth* quarter and the *lth* mesh and given as:

$$\hat{R}_{ijkl} \tag{3}$$

Table 20. Mean discard rates (pounds/day fished)[1], coefficients of variation (CV x 100) and sample sizes (N) by defined strata (year, region, quarter and mesh category) for the Gulf of Maine-Northern Georges Bank Stock. Rates are computed from observed tows within trips that caught silver hake but did not discard the entire catch. Values in parentheses represent means computed from strata expanded to yr, stock, half year (*i.e.* quarters 1-2 and quarters 3-4), and mesh category.

	Gulf of Maine[2]						**Northern Georges Bank[3]**					
	Mesh 1[4]			**Mesh 3[5]**			**Mesh 1**			**Mesh 3**		
Year	**X**	**CV**	**N**	**X**	**CV**	**N**	**X**	**CV**	**N**	**X**	**CV**	**N**
1989												
Q1	3126.3	70	7	(4.2)	-	1	380.4	-	1	(4.2)	-	1
Q2	1422.5	43	11	4.2	85	6	5009.3	-	1	(4.2)	-	1
Q3	1290.8	85	8	5.9	50	6	7513.1	66	6	14341	70	8
Q4	2750.2	46	7	8.3	90	2	2034.8	-	1	18649	-	1
1990												
Q1	780.1	36	10	(0.0)	-	1	-	-	-	(0.0)	-	2
Q2	512.2	81	4	0.0	-	1	13895	-	1	(0.0)	-	2
Q3	0.0	-	1	47.6	74	5	678.0	85	5	3406.1	100	3
Q4	830.3	47	9	157.5	88	7	611.3	62	4	(1204)	-	3
1991												
Q1	369.7	28	23	(23.0)	-	3	566.4	-	1	3.3	-	1
Q2	222.2	50	6	65.4	99	4	(386.0)	-	3	1.6	66	2
Q3	134.5	50	7	169.9	96	3	944.5	78	2	6480.4	100	6
Q4	943.5	45	26	70.7	53	12	217.6	-	1	85.3	95	5
1992												
Q1	756.4	32	28	29.3	65	5	1124.0	-	1	51.5	68	5
Q2	913.9	63	4	41.0	81	9	(931.5)	-	3	55.7	90	10
Q3	64.8	63	9	(1251.9)	-	3	905.0	52	5	3602.4	96	5
Q4	2258.2	60	5	84.5	53	7	2717.6	66	3	68.8	58	5

[1] Discard rates are estimated as the ratio of the means (Cochran 1963):

$$R_k = \frac{\sum_{k=1}^{n_j} \frac{y_{jk}}{n_j}}{\sum_{k=1}^{n_j} \frac{x_{jk}}{n_j}} = \frac{\overline{y_j}}{\overline{x_j}}$$

where: R_k = discard ratio estimator in the *kth* strata, y_{jk} = the mean weight of discards over *j* trips in the *kth* strata, x_{jk} = the mean effort (days fished) over *j* trips in the *kth* strata, and n_j = the number of sampling units (trips) that fall into the *kth* strata.

[2] Gulf of Maine region = Statistical Areas 511-515

[3] Georges Bank region = Statistical Areas 521-523

[4] Mesh category 1: mesh codend ≤ 3.5 in.

[5] Mesh category 3: mesh codend ≥ 5.5 in.

and the standard error of $\hat{R}$, is:

$$s(\hat{R}) = \frac{1}{\sqrt{n}\,\overline{X}} \sqrt{\frac{\Sigma y_i^2 - 2\hat{R}\Sigma y_i x_i + \hat{R}^2 \Sigma x_i^2}{n-1}} \quad (4)$$

The sampling distribution of $\hat{R}$ is rather complicated, because both the numerator and denominator vary from sample to sample, and for small samples its distribution is skewed and usually slightly biased (Cochran 1963). Nonetheless, this serves as the best and least biased of the ratio estimators for the present application. Coefficients of variation can be calculated from (4) using, $s(\hat{R})/\hat{R}$*100. Tables 20 and 21 give the estimated mean discard rates (lb discarded/day fished) along with coefficients of variation and sample sizes by strata. Cells in Tables 20 and 21 with values in parentheses (originally missing values for which there was effort associated with that stratum) represent the ratio estimator for strata expanded to year, stock, half year (*i.e.* quarters 1-2 and quarters 3-4), and mesh category.

DISCARD ESTIMATE EXPANSION

The discard rates estimated in the prior section were derived from only a fraction of the total number of trips by vessels within each stratum. To derive fleetwide discard estimates, $\hat{R}$ must be raised by the expansion factor, E, defined as the total days fished for trips that landed silver hake within a given stratum, which is obtained from the *weighout data base*. Total effort was defined as the summation of all days fished for those trips that landed silver hake (Tables A1 and B1 in Appendix 1). While the strata (as defined earlier) for year, region, and quarter can be obtained from all trips in the weighout data base, the strata for mesh can only be obtained from those trips that were interviewed. Therefore, total days fished within a given stratum were allocated to a given mesh category on the basis of the proportion of days fished by mesh category for interviewed trips only (Appendix 1, Tables A2 and B2). In addition, Tables A2 and B2 give the interview coverage (both by trips and days fished) by stratum. It should be noted that trips (and therefore effort) that landed silver hake given here are only a subset of the total number of trips that catch silver hake, because some vessels will discard 100% of silver hake at sea. As stated earlier, 100% discard trips cannot be identified in the weighout data base and therefore 100% discard trips in the DDSP data base were not used in the estimation of discard rates. As such, the present discard estimates are considered minimum estimates. The extent to which these are lower than would be obtained from all trips (and its associated effort) can be inferred to some extent from the proportions of the total days fished in the DSSP data base from trips that did not discard the entire catch of silver hake (Tables A3 and B3 in Appendix 1). Proportions are highly variable, but some pattern appears evident which suggests that most of the total days fished are accounted for by trips not discarding the entire catch for that segment of the fleet using mesh category 1 (ranging from 62% to 100%). Unfortunately, most of the total effort used in the expansion is associated with mesh category 3 from the Gulf of Maine region, where there is generally a lower proportion of the effort from trips not discarding the entire catch.

The total discards (in weight) of silver hake by stratum (Tables 22 and 23) were obtained using

$$W_{ijkl} = \hat{R}_{ijkl} * E_{ijk} * P_{ijkl} \qquad \textbf{(5)}$$

where: W_{ijkl} = total weight of discards (lb) in year i, region j, quarter k, and mesh l;
$\hat{R}_{ijkl}$ = 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.

Total discards (weight) of silver hake in both the northern and southern stock fisheries, although variable by mesh and over years, can comprise a significant proportion of the total landings (Tables 24 and 25). 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. Comparison of discards by mesh suggests that substantial discarding of silver hake by weight in the Gulf of Maine-Northern Georges Bank stock occurs in both the small mesh shrimp and silver hake fisheries (<3.5 in.) and the large mesh (>5.5 in.) groundfish fisheries (Table 24). 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 (Table 25). Here, the overwhelming majority of silver hake discarding by weight occurs in the small mesh fisheries (<3.5 inches). Estimates of total silver hake discarded by weight in the northern stock over the 1989-1992 period are similar to those estimated by Anderson (1975) for the U.S. Gulf of Maine-Northern Georges Bank fishery over the period 1965-1974. Except for rather high estimates from 1971 to 1973 (averaging 8,600 mt), discards ranged between 437 mt and 2,100 mt over the 1965-1970 period. No previous discard estimates have been made for the fisheries in the Southern Georges Bank-Middle Atlantic silver hake stock.

NUMBER OF DISCARDS AT LENGTH AND AGE

The age composition of fish discarded in the silver hake fisheries 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

Table 21. Mean discard rates (pounds/day fished)[1] coefficients of variation (CV x 100) and sample sizes (N) by defined strata (year, region, quarter and mesh category) for the Southern Georges Bank-Middle Atlantic stock. Rates are computed from observed tows within trips that caught silver hake. Values in parentheses represent means computed from expanded strata

Southern Georges Bank[2]

	Mesh1[3]			Mesh2[4]			Mesh3[5]		
Year	**X**	**CV**	**N**	**X**	**CV**	**N**	**X**	**CV**	**N**
1989									
Q1	(7171.6)	-	4	(1483.9)	-	2	(1716.1)	-	4
Q2	(7171.6)	-	4	(1483.9)	-	2	1463.4	153	2
Q3	(2180.3)	-	3	-	-	-	478.0	98	3
Q4	(2180.3)	-	3	-	-	-	(1185.4)	-	4
1990									
Q1	-	-	-	-	-	-	0.0	-	1
Q2	19530	-	1	-	-	-	573.9	96	3
Q3	(3439.5)	-	2	-	-	-	2505.7	88	2
Q4	-	-	-	-	-	-	20.7	77	2
1991									
Q1	1085.5	-	1	-	-	-	2231.9	96	4
Q2	(413.5)	-	5	(683.9)	-	4	1024.1	100	2
Q3	(224.6)	-	4	-	-	-	0.0	-	1
Q4	-	-	-	-	-	-	0.0	-	2
1992									
Q1	913.0	-	1	-	-	-	-	-	-
Q2	(833.5)	-	-	(69.3)	-	3	225.5	95	4
Q3	(3180.4)	-	-	-	-		3075.3	83	3
Q4	-	-	-	-	-	-	-	-	-

Southern New England[6]

	Mesh1[3]			Mesh2[4]			Mesh3[5]		
Year	**X**	**CV**	**N**	**X**	**CV**	**N**	**X**	**CV**	**N**
1989									
Q1	1977.8	89	5	1532.2	82	3	(1716)	-	2
Q2	11207	88	7	1435.6	91	5	-	-	-
Q3	4862.1	66	3	3733.2	87	3	-	-	-
Q4	762.8	66	8	236.4	81	4	1901.7	64	4
1990									
Q1	15.4	100	3	572.5	88	4	2333.3	82	6
Q2	748.0	116	6	20.9	100	2	14100	86	2
Q3	6800	-	1	-	-	-	1361.5	-	1
Q4	78.9	-	1	58.5	-	1	848.9	47	13
1991									
Q1	163.3	45	9	136.9	63	7	186.2	58	6
Q2	644.3	89	5	139.4	73	4	574.2	91	12
Q3	346.3	96	4	2395.2	120	2	3826.6	73	8
Q4	373.8	52	10	708.2	65	12	566.1	48	21
1992									
Q1	160.9	74	7	22.9	98	7	61.1	84	7
Q2	23.0	80	2	(69.3)	-	3	342.6	99	2
Q3	2275.9	-	1	(1057.0)	-	3	2205.0	94	6
Q4	925.4	81	2	1246.0	96	5	2815.1	50	9

Table 21. Continued

	Middle Atlantic[7]								
	Mesh1[3]			Mesh2[4]			Mesh3[5]		
Year	X	CV	N	X	CV	N	X	CV	N
1989									
Q1	676.7	79	7	(1483.9)	-	2	-	-	-
Q2	14825	79	2	(1483.9)	-	2	-	-	-
Q3	(2180.3)	-	3	-	-	-	-	-	-
Q4	915.9	74	2	(1984.8)	-	2	-	-	-
1990									
Q1	702.1	86	3	55.0	125	4	-	-	-
Q2	204.5	66	4	9.1	49	3	-	-	-
Q3	(3439.5)	-	2	-	-	-	-	-	-
Q4	(3439.5)	-	2	(58.5)	-	2	-	-	-
1991									
Q1	60.3	44	10	160.4	84	4	1391.2	81	3
Q2	114.3	-	1	2298.8	100	2	-	-	-
Q3	0.0	-	1	117.9	-	1	(884.8)	-	6
Q4	178.2	58	6	63.3	95	11	141.6	114	7
1992									
Q1	955.6	72	10	8.04	131	5	207.3	47	21
Q2	2115.3	100	5	177.0	-	1	4565.2	-	1
Q3	-	-	-	-	-	-	-	-	-
Q4	8967.2	148	3	1895.4	75	2	70.0	90	8

[1]Discard rates are estimated as the ratio of the means (Cochran 1963):

$$R_k = \frac{\sum_{k=1}^{n_j} \frac{y_{jk}}{n_j}}{\sum_{k=1}^{n_j} \frac{x_{jk}}{n_j}} = \frac{\overline{y_j}}{\overline{x_j}}$$

where; R_k = discard ratio estimator in the *kth* strata, y_{jk} = the mean weight of discards over *j* trips in the *kth* strata, x_{jk} = the mean effort (days fished) over *j* trips in the *kth* strata, and n_j = the number of sampling units (trips) that fall into the *kth* strata.

[2] Southern Georges Bank Region = Statistical Areas 524-526
[3] Mesh category 1: mesh codend ≤ 3.5 in.
[4] Mesh category 2: 3.5 in. < mesh codend < 5.5 in.
[5] Mesh category 3: mesh codend ≥ 5.5 in.
[6] Southern New England Region = Statistical Areas 537-613
[7] Middle Atlantic Region = Statistical Areas 614-636

($W=.00000593L^{3.05}$) to DSSP length frequency samples into the total estimated discarded weight of silver hake by stratum (Appendix 2 Tables A5 and B5). Cells or strata without length frequency samples to compute mean weights were assigned values computed from expanding strata to year, stock, and mesh, and are represented as values in parentheses. 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 1-2 and across quarters 3-4 within each stock and applied to age-length keys (quarters 1-2 applied to the spring survey key; quarters 3-4 applied to the autumn survey key) and summed again over quarter to derive estimates of the number of discards at age by stock.

Table 22. Total discards of silver hake in weight (pounds) and numbers by stratum (year, region, quarter and mesh category) in the Gulf of Maine-Northern Georges Bank stock. Discard in numbers is computed by dividing mean weight into discarded weight. Values of mean weight in parentheses represent means from strata expanded to year, stock, quarter, and mesh category.

	Gulf of Maine						Northern Georges Bank					
	Mesh 1			Mesh 3			Mesh 1			Mesh 3		
Year	**Mean Weight**	**Discard Weight (lb)**	**Discard Number**	**Mean Weight**	**Discard Weight (lb)**	**Discard Number**	**Mean Weight**	**Discard Weight (lb)**	**Discard Numbers**	**Mean Weight**	**Discard Weight (lb)**	**Discard Number**
1989												
Q1	0.087	655,898	7,539,054	0.277	5,990	21,623	0.134	4,679	34,917	0.404	499	1,235
Q2	0.096	552,926	5,759,643	(0.262)	9,751	37,218	0.067	107,199	1,599,985	0.279	1,365	4,894
Q3	0.132	539,813	4,089,489	0.423	12,979	30,682	0.228	590,530	2,590,042	0.222	5,855,512	26,376,180
Q4	0.175	1,617,943	9,245,387	0.295	28,072	95,484	0.222	96,653	435,374	0.330	5,857,588	17,750,267
Totals		3,366,580	26,633,573		71,795	185,007		799,061	4,660,318		11,714,964	44,132,576
1990												
Q1	0.124	346,520	2,794,520	(0.486)	0	0	-	-	-	(0.486)	0	0
Q2	0.192	452,529	2,356,920	(0.486)	0	00.246		234,832	954,603	(0.486)	0	0
Q3	(0.187)	0	0	0.507	76,903	151,681	0.341	276,556	811,015	0.370	866,512	2,341,924
Q4	0.178	1,117,169	6,276,228	1.037	346,736	334,365	0.280	6,724	24,015	(0.486)	270,110	555,782
Totals		1,916,218	11,427,668		423,639	486,046		518,112	1,789,633		1,136,622	2,897,706
1991												
Q1	0.156	328,589	2,106,342	(0.399)	4,659	11,677	0.183	7,760	42,403	1.149	297	258
Q2	0.095	90,258	950,080	(0.399)	119,447	299,365	(0.164)	10,541	64,272	0.399	287	719
Q3	0.157	61,614	392,449	0.521	241,156	462,872	0.174	236,219	1,327,076	0.279	1,814,512	6,503,627
Q4	0.169	634,881	3,756,693	(0.399)	157,470	394,662	0.171	8,312	48,610	(0.399)	20,173	50,560
Totals		1,115,342	7,205,564		522,732	1,168,576		262,832	1,482,361		1,835,269	6,555,164
1992												
Q1	(0.178)	174,653	981,195	(0.613)	19,710	32,154	(0.178)	36,418	204,593	(0.613)	1,716	2,873
Q2	0.195	61,323	314,475	(0.613)	77,146	125,849	(0.178)	15,183	85,300	(0.613)	13,713	22,371
Q3	0.158	40,416	255,796	(0.613)	2,279,084	3,717,918	0.206	448,066	2,175,075	(0.613)	824,229	1,344,583
Q4	0.170	1,982,925	11,664,267	(0.613)	165,730	270,359	0.160	206,538	1,290,860	(0.613)	11,517	18,788
Totals		2,259,317	13,215,733		2,541,670	4,146,280		706,205	3,755,828		851,175	1,388,615

Because the size composition of discards consists of generally smaller silver hake than are taken in the landings the actual numbers of fish discarded can be quite large (Tables 24 and 25). 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 (Table 24). 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 (Table A5). Numbers of discarded silver hake were overwhelmingly greater in the small mesh fisheries (<3.5 in.).

Discarded numbers of silver hake represent the greatest proportion at size and age for smaller and younger fish in the stock, respectively. In the Gulf of Maine-Northern Georges Bank stock, significant discards in numbers occurred generally between 15 and 25 cm (Figure 9) and represented the greatest proportion of age 1 and a smaller but still significant proportion of age 2 fish (Figure 10). Anderson (1975) also found significant numbers of silver hake discarded at age 1 for the 1965-1974 period, but found almost equal numbers of age 0 which were not apparent from estimates here. 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 11). Discarded silver hake dominated numbers at age for age 2 with significant numbers at age 1 and in some years even age 3 (Figure 12).

SELECTION PATTERN AT AGE

An untuned Virtual Population Analysis (Gulland 1965) was applied to the silver hake landings at age and catch at age (landings + discards) matrices to determine the effect on the relative selection pattern at age of the current fishery for silver hake when the landings at age are augmented with discards. Since discard estimates were only available for the years 1989 to 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, first using the silver hake landings at age matrix and then using the catch at age matrix. In both cases, natural mortality (M) was assumed to be 0.4 for both northern and southern silver hake stocks and VPA runs were preformed with varying levels of terminal fishing mortality to derive relative exploitation patterns (Tables A4 and B4 in Appendix 2). In all cases, from low to high terminal F's, convergence was achieved across ages 1-3 by 1989 and to some extent by 1990. In the northern stock, 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 30% 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 45% of the age 3 F.

Sensitivity runs on the catch at age matrices indicated a flat-topped exploitation pattern and increasingly higher fishing mortalities at age with full exploitation on age 3 from high and intermediate terminal F runs for the northern and southern stock, respectively. These were chosen as the most likely exploitation patterns. An average of the 1989-1990 F's at age were then taken because changes in the exploitation pattern between years, particularly when the VPA is applied to the catch at age matrix, suggests that discarding may be affected by year class strength. Thus, the final exploitation pattern (Table 26) indicated as the reference pattern, reflects the effects of discarding from a large year class (1988) and a weaker year class (1989). In addition, subsequent yield per recruit and spawning stock biomass per recruit calculations were also conducted using exploitation patterns other than the reference pattern to account for uncertainty in its estimation as well as possible changes which may result from re-directed fleet effort to younger ages associated with a "juvenile" whiting fishery. Yield and SSB per recruit simulations were conducted on six exploitation patterns; 25% and 50% of the reference pattern and increases of 150%, 175%, and 200% of the reference pattern.

YIELD AND SSB PER RECRUIT

A yield-per-recruit and spawning stock biomass-per-recruit analysis (Thompson and Bell 1934) was conducted to determine the effect on long-term yield of silver hake when losses of fish due to discarding are considered. Losses through wasteful fishing practices such as discarding do not contribute to the fishery's yield, while they can significantly reduce the stock's spawning biomass, resulting in an inaccurate perception of the long-term yield from the stock. Although the

Table 23. Total discards of silver hake in weight (pounds) and numbers by stratum (year, region, quarter and mesh category) in the Southern Georges Bank-Middle Atlantic stock. Discard numbers computed by dividing mean weight into discarded weight. Values of mean weight in parentheses represent means computed from strata expanded to year, stock, quarter and mesh category.

	Mesh 1[1]			Mesh 2[2]			Mesh 3[3]		
	Mean Wt (lb)	**Discard Wt(lb)**	**Discard Number**	**Mean Wt (lb)**	**Discard Wt(lb)**	**Discard Number**	**Mean Wt (lb)**	**Discard Wt(lb)**	**Discard Number**
					Southern Georges Bank				
1989									
Q1	(0.339)	169,967	501,377	(0.336)	23,297	69,337	(0.267)	119,612	447,986
Q2	(0.339)	559,385	1,650,103	0.332	46,446	144,242	0.366	60,146	164,333
Q3	(0.339)	119,917	335,901	-	-	-	0.317	2,342	7,389
Q4	(0.339)	19,187	56,598	-	-	-	(0.267)	16,477	61,712
Total		868,456	2,543,979		69,743	213,579		198,577	681,420
1990									
Q1	-	-	-	-	-	-	(0.287)	0	0
Q2	0.278	1,271,403	4,573,392	-	-	-	(0.287)	59,915	208,764
Q3	(0.294)	57,096	194,203	-	-	-	(0.287)	274,625	956,881
Q4	-	-	-	-	-	-	(0.287)	731	2,546
Totals		1,328,499	4,767,595					335,271	1,168,191
1991									
Q1	(0.282)	65,347	231,727	-	-	-	(0.383)	93,293	243,586
Q2	(0.282)	37,877	134,314	(0.214)	6,839	31,958	(0.383)	89,404	233,431
Q3	(0.282)	2,313	8,203	-	-	-	(0.361)	0	0
Q4	-	-	-	-	-	-	(0.383)	0	0
Totals		105,537	374,244		6,839	31,958		182,697	477,017
1992									
Q1	(0.160)	15,338	95,865	-	-	-	-	-	-
Q2	(0.160)	91,185	569,906	0.205	-	-	(0.230)	12,651	55,002
Q3	(0.160)	90,005	562,533	-	-	-	0.231	114,709	496,574
Q4	-	-	-	-	-	-	-	-	-
Totals		196,528	1,228,304					127,360	551,576
					Southern New England				
1989									
Q1	0.244	2,271,108	9,307,819	0.254	46,272	182,175	0.257	39,299	110,080
Q2	0.235	9,553,627	40,653,730	0.296	216,058	729,925	-	-	-
Q3	0.222	2,287,618	10,304,586	0.297	26,879	90,502	-	-	-
Q4	0.251	948,923	3,780,571	0.336	9,716	28,917	-	-	-
Totals		15,061,276	64,046,706		298,925	1,031,519		39,299	110,080
1990									
Q1	(0.294)	11,103	37,767	0.304	33,320	109,604	0.274	88,432	322,745
Q2	0.176	574,539	3,264,425	(0.341)	4,995	14,648	0.253	1,367,787	5,406,274
Q3	0.178	4,754,560	26,711,011	(0.341)	351	1,029	(0.287)	15,930	55,504
Q4	(0.294)	94,491	321,397	(0.341)	3,762	11,031	(0.287)	48,048	167,414
Totals		5,434,693	30,334,600		42,428	136,312		1,520,197	5,951,937
1991									
Q1	0.266	130,183	489,409	0.180	27,051	150,286	(0.383)	46,308	120,908
Q2	0.282	613,631	2,175,998	(0.214)	7,193	33,612	(0.383)	68,445	178,707
Q3	0.206	225,891	1,096,561	(0.214)	48,862	228,327	0.395	260,591	659,725
Q4	0.278	480,856	1,729,699	0.302	72,307	239,428	0.282	190,266	674,703
Totals		1,450,561	5,491,667		155,413	651,653		565,610	1,634,043
1992									
Q1	(0.160)	198,454	1,240,338	(0.190)	994	4,294	(0.230)	8,640	37,563
Q2	0.173	12,708	73,454	(0.190)	6,854	36,074	(0.230)	94,900	412,610
Q3	0.163	1,386,706	8,303,628	(0.190)	52,110	274,263	(0.230)	82,026	344,647
Q4	0.146	1,251,881	8,574,528	(0.190)	142,169	748,257	0.208	490,235	2,361,706
Totals		2,849,749	18,191,948		202,127	1,062,888		675,801	3,156,526

Table 23. Continued

	Middle Atlantic								
	Mesh 1[1]			Mesh 2[2]			Mesh 3[3]		
	Mean Wt (lb)	**Discard Wt(lb)**	**Discard Number**	**Mean Wt (lb)**	**Discard Wt(lb)**	**Discard Number**	**Mean Wt (lb)**	**Discard Wt(lb)**	**Discard Number**
1989									
Q1	(0.339)	468,073	1,380,747	0.567	359,401	633,863	-	-	-
Q2	0.494	4,337,883	8,781,139	(0.336)	121,828	362,608	-	-	-
Q3	0.095	102,910	1,083,265	-	-	-	-	-	-
Q4	0.356	161,840	454,605	(0.336)	24,612	73,249	-	-	-
Totals		5,070,706	11,699,756		505,841	1,069,720		0	0
1990									
Q1	(0.294)	433,196	1,473,455	(0.341)	21,428	62,839	-	-	-
Q2	0.508	23,886	47,019	(0.341)	760	2,228	-	-	-
Q3	(0.294)	125,198	425,843	-	-	-	-	-	-
Q4	(0.294)	676,550	2,301,189	0.607	995	1,638-	-	-	
Totals		1,258,830	4,247,506		23,183	66,705		0	0
1991									
Q1	0.608	50,917	83,746	0.199	23,900	120,098	(0.383)	35,197	91,899
Q2	(0.282)	36,713	130,189	(0.214)	91,262	426,469	-	-	-
Q3	(0.282)	0	0	(0.214)	837	3,912	0.657	6,548	9,966
Q4	(0.282)	29,403	104,266	(0.214)	2,412	11,270	(0.383)	9,147	23,883
Totals		117,033	318,201		118,411	561,749		50,892	125,748
1992									
Q1	(0.160)	637,290	3,983,060	(0.190)	373	1,963	(0.230)	44,404	193,059
Q2	(0.160)	599,264	3,745,403	(0.190)	8,337	43,879	(0.230)	993,388	4,319,076
Q3	-	-	-	-	-	-	-	-	-
Q4	(0.160)	1,924,361	12,027,257	(0.190)	35,634	187,547	(0.230)	5,509	23,952
Totals		3,160,915	19,755,720		44,344	233,389		1,043,301	4,536,087

quantity of discarding has been estimated, the quantity of landings and extent of targeted effort for fish in the "juvenile" fishery are presently not known. Therefore, the analysis here assumes that the selection pattern that is obtained when discards are used to augment the landings at age matrix is an indication of the selectivity of a fishery that lands juvenile fish. For this analysis, 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. At age two roughly 50% of fish have matured (O'Brien *et al.* 1993). Yield and SSB were calculated for the selection (or exploitation) pattern at age obtained with (catch analysis) and without (landings analysis) discard estimates (taken from the untuned VPA results). Results of this analysis were also compared with another run, which increased the natural mortality rates on younger ages of fish (M=0.80 on age 0, M=0.6 on age 1, and M=0.4 on age 2+) to account for cannibalism of silver hake (Edwards and Bowman 1979) and growth compensatory responses to population density (Ross and Almeida 1986). In addition, yield and SSB analyses were performed using only a few of many other possible exploitation patterns, as given in Table 26.

For the landings analysis, mean weights at age for the application to yield-per-recruit were obtained as the arithmetic average of the landings mean weights at age over the 1989-1992 period (Tables 4 and 13). Mean weights for the catch analysis 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 (Penttilla *et al.* 1989). Input mean weights for yield per recruit analyses are given in Table 27. 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)

Table 24. Total weight and numbers of silver hake discarded by mesh category[1] in the Gulf of Maine-Northern Georges Bank stock.

Year		Discard Weight (lb)	Discard Weight (mt)	Discard Number
1989				
Mesh	1	4,165,641	1,890	31,293,891
	3	11,786,759	5,346	44,317,583
Total		15,952,400	7,236	75,611,474
1990				
Mesh	1	2,434,330	1,104	13,217,301
	3	1,560,261	708	3,383,752
Total		3,994,591	1,812	16,601,053
1991				
Mesh	1	1,378,174	625	8,687,925
	3	2,358,001	1,070	7,723,740
Total		3,736,175	1,695	16,411,665
1992				
Mesh	1	2,965,522	1,345	16,971,561
	3	3,392,845	1,539	5,534,895
Total		6,358,367	2,884	22,506,456

[1] Mesh category 1: mesh codend ≤3.5 in., and mesh category 3: mesh codend ≥ 5.5 in.

Table 25. Total weight and numbers of silver hake discarded by mesh category[1] in the southern Georges Bank-Middle Atlantic stock

Year		Discard Weight (lb)	Discard Weight (mt)	Discard Number
1989				
Mesh	1	21,000,438	9,526	78,290,441
	2	874,509	397	1,607,706
	3	237,876	108	791,500
Total		22,112,823	10,031	80,689,647
1990				
Mesh	1	8,022,022	3,639	39,349,701
	2	65,611	30	203,017
	3	1,855,468	842	7,120,128
Total		9,943,101	4,511	46,672,846
1991				
Mesh	1	1,673,131	759	6,184,112
	2	280,663	127	1,245,360
	3	799,469	363	2,236,808
Total		2,753,263	1,249	9,666,280
1992				
Mesh	1	6,207,192	2,812	39,175,972
	2	246,471	112	1,296,277
	3	1,846,462	838	8,244,189
Total		8,300,125	3,762	48,716,438

[1] Mesh category 1 = mesh codend ≤ 3.5 in.; mesh category 2 = 3.5 in. ≤ mesh codend ≤ 5.5 in.; mesh category 3 = mesh codend ≥ 5.5 in.

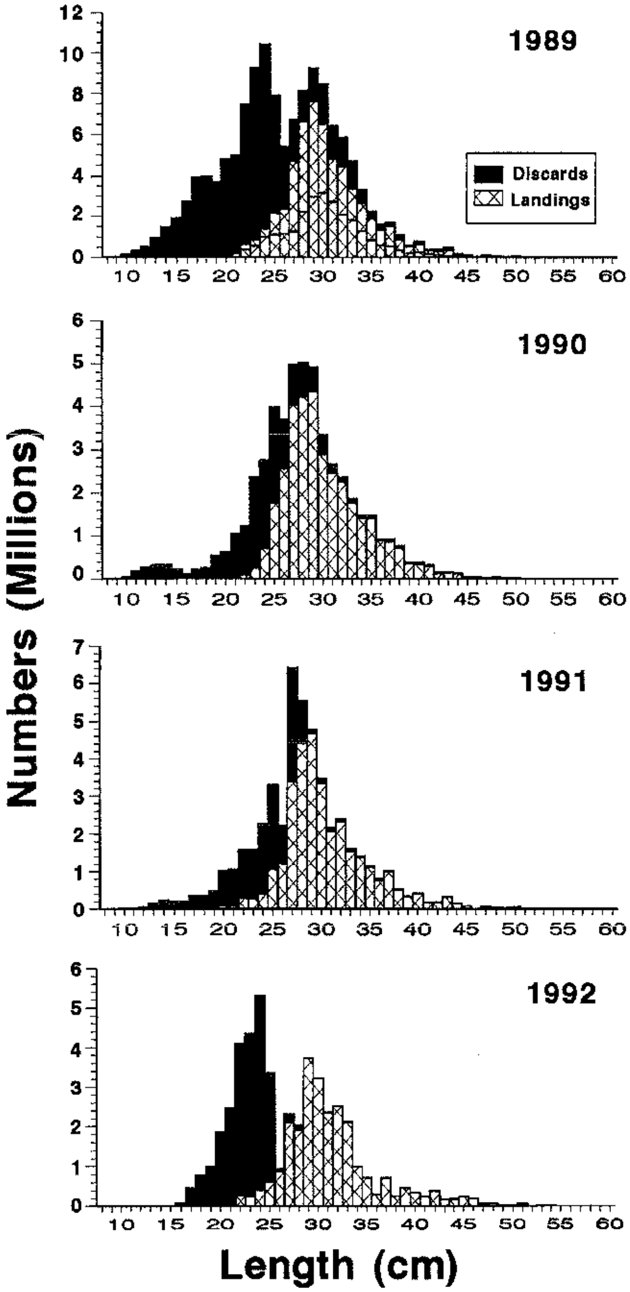

Figure 9. Estimated numbers of landed and discarded silver hake by length from the Gulf of Maine-Northern Georges Bank stock over 1989-1992 period.

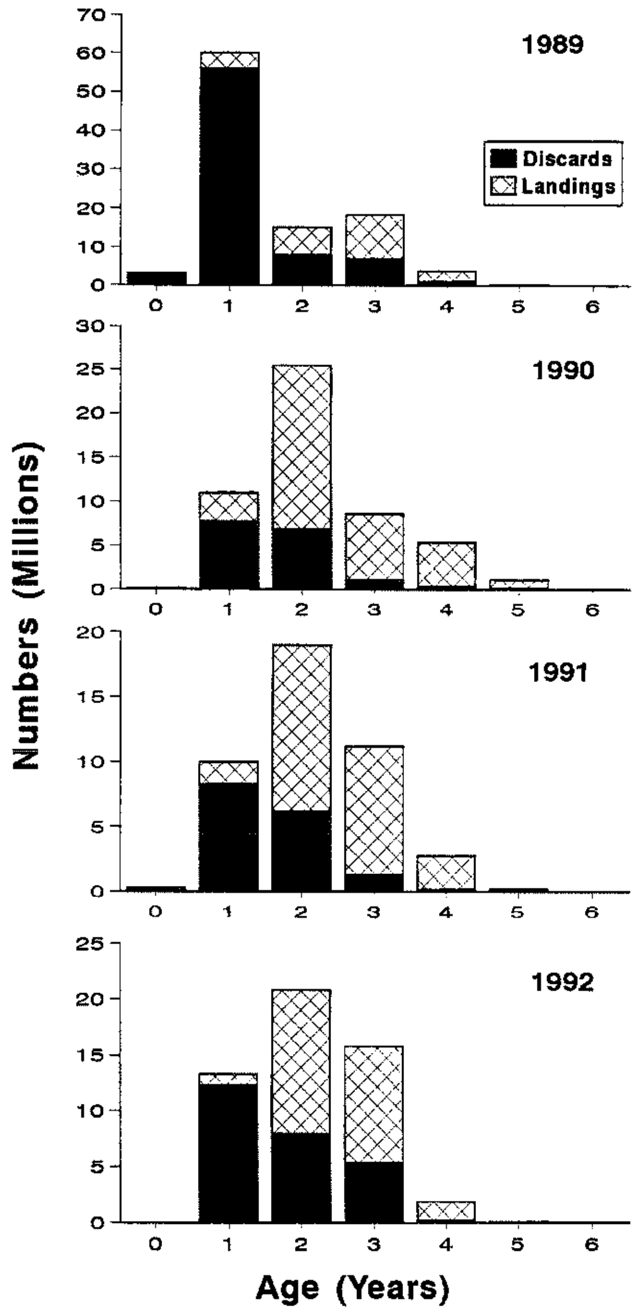

Figure 10. Estimated numbers of landed and discarded silver hake at age from the Gulf of Maine-Northern Georges Bank stock over 1989-1992 period.

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.

Based on the relative selection pattern derived from VPA, when discards are used to augment the catch at age matrix, there was a greater selection for younger fish in the stock (*i.e.* age 1-3), indicative of the possible impact of a "juvenile" silver hake fishery. As a result, yield per recruit analyses suggested that while yield taken from the "juvenile" fishery is higher, yield from the "adult" fisheries on the silver hake stocks is actually lower than when the exploitation pattern accounts for the taking of juvenile fish (Figures 13 and 14). Maximum yield from the northern "adult" silver hake fishery occurred at an F of 0.40 from the catch analysis; a decrease

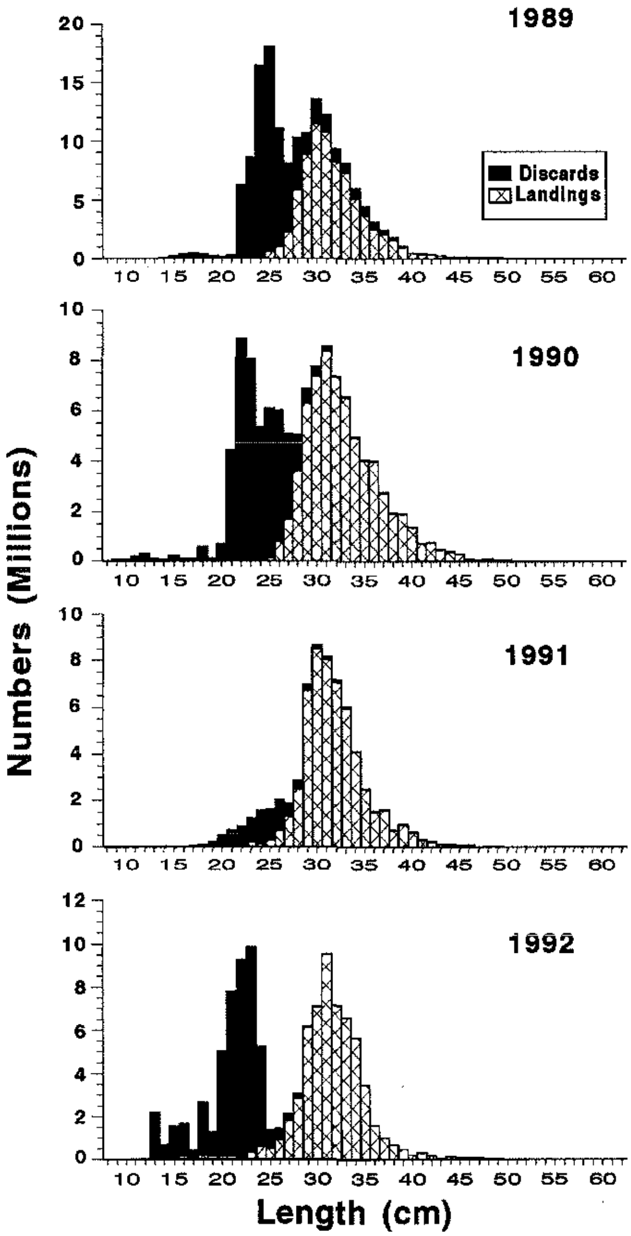

Figure 11. Estimated numbers of landed and discarded silver hake by length from the Southern Georges Bank-Middle Atlantic stock over 1989-1992 period.

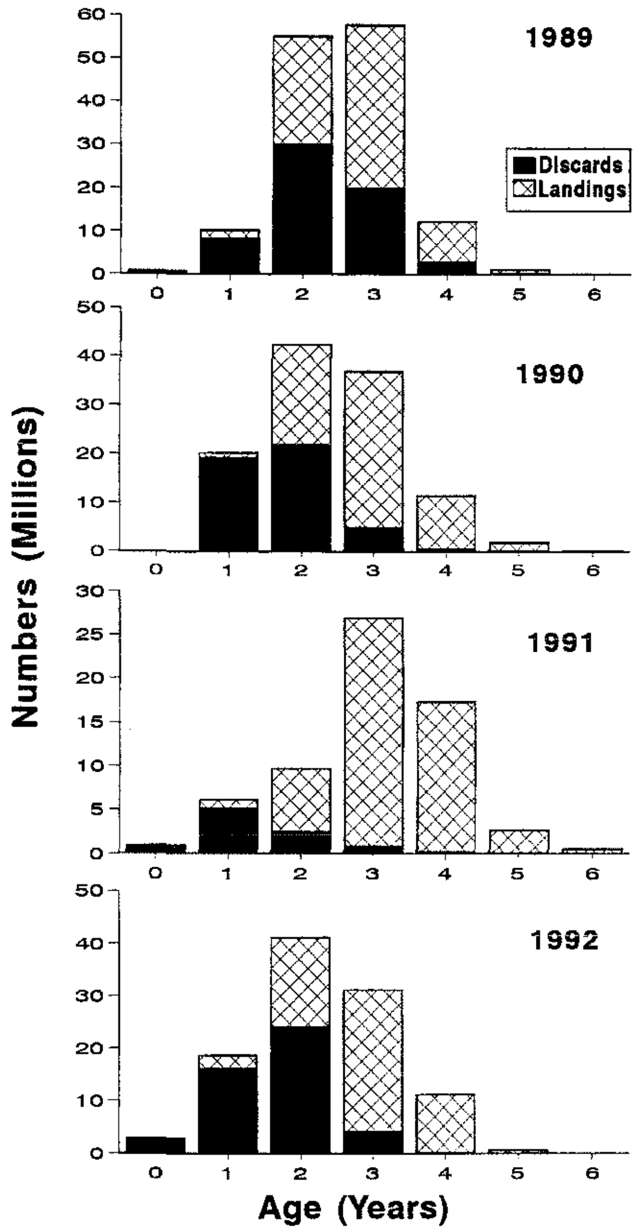

Figure 12. Estimated numbers of landed and discarded silver hake at age from the Southern Georges Bank-Middle Atlantic stock over 1989-1992 period.

from F_{max} of 0.60 from the selection pattern derived from landings at age (See Tables A4 and B4 in Appendix 2). In addition, yield was 15% less at F_{max} when the exploitation pattern was derived from catch at age (Figure 13). Similarly, in the "adult" fishery of the southern stock yield was 18% lower at F_{max} from the catch analysis as compared to the selection pattern derived from landings at age, and F corresponding to maximum yield decreased from an F of 0.75 to 0.60 (Figure 14). Increasing natural mortality on younger ages resulted in an overall decrease in yield by about 50%, without changing the general shape of the yield functions derived from the catch analysis for either stock (Figures 13 and 14). Thus, further analyses using alternate exploitation patterns considered only an M=0.40 that was constant across all ages.

Examination of yield using exploitation patterns other than the reference that was obtained from the VPA applied to the catch at age indicated a significant trade-off between increasing harvest on younger ages of fish in the population and loss of yield to the "adult" fishery. Increasingly

Table 26. Gulf of Maine - Northern Georges Bank and Southern Georges Bank - Middle Atlantic silver hake stock exploitation patterns

	Gulf of Maine - Northern Georges Bank						
Age (yr)	**Landings**	**25%**	**50%**	**Ref.**	**150%**	**175%**	**200%**
1	0.049	0.070	0.141	0.280	0.423	0.492	0.500
2	0.380	0.123	0.247	0.490	0.741	0.864	1.000
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6+	1.000	1.000	1.000	1.000	1.000	1.000	1.000

	Southern Georges Bank - Middle Atlantic Stock						
Age (yr)	**Landings**	**25%**	**50%**	**Ref.**	**150%**	**175%**	**200%**
1	0.011	0.025	0.049	0.099	0.148	0.173	0.350
2	0.245	0.104	0.208	0.417	0.625	0.730	1.000
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6+	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 27. Input mean weights (kilograms) for yield per recruit analyses

	Gulf of Maine- Northern Georges Bank				Southern Georges Bank- Middle Atlantic		
	Avg. Wt.	**(1989-1992)**			**Avg. Wt.**	**(1989-1992)**	
Age	**Landings**	**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] Average weight taken from Tables 4 and 13 over the 1989-1992 period.
[2] From applying length-weight equation ($W=0.00000593L^{3.05}$) to mean length at age from vonBertalanffy growth equations (Penttilla *et al.* 1989).

higher selection (exploitation) of ages 1 and 2 resulted in increasingly greater yield from a "juvenile" fishery, with maximum yield being obtained from lower levels of F as exploitation was increased to 150%, 175% and 200% of the reference pattern (Figures 15 and 16). Yield functions from both the northern and southern "juvenile" components become more asymptotic as exploitation was increased with nearly maximum yield (0.045 kg) occurring at an F of around 2.0. Although yield 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% above the reference pattern maximum yield decreased by nearly 35% (Figure 17 and 18). In addition, F required to achieve maximum yield from the fishery decreased from around 0.6 to 0.3.

These results suggest that a harvesting strat-

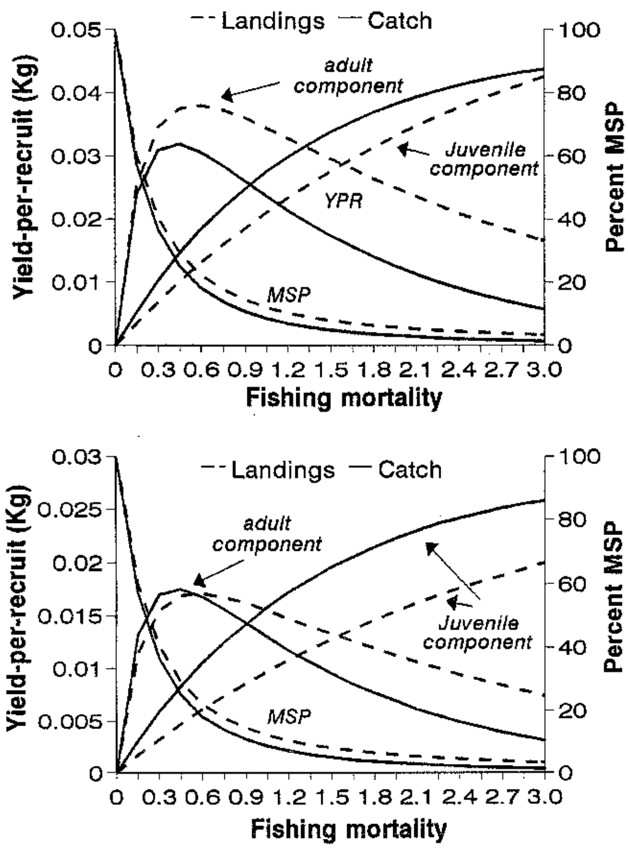

Figure 13. Yield and spawning stock biomass (SSB) per recruit from fisheries on "juvenile" and "adult" components of the Gulf of Maine-Northern Georges Bank silver hake stock. Graphs compare yield and SSB per recruit obtained from exploitation pattern derived from landings and catch at age under two assumed vectors of natural mortality at age: top) M=0.4 constant over all ages; and bottom) M=0.8 on age 0, M=0.6 on age 1, and M=0.4 on ages 2 and above.

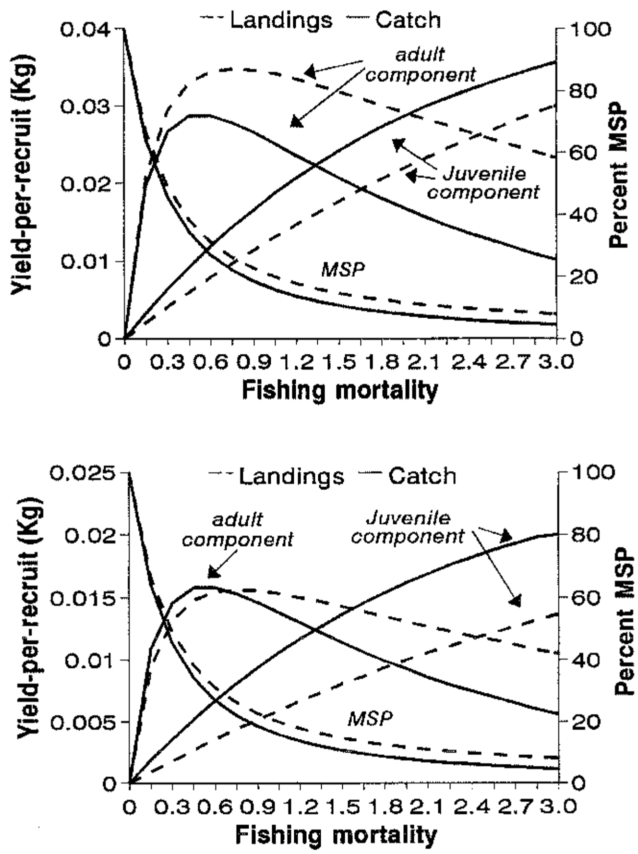

Figure 14. Yield and spawning stock biomass (SSB) per recruit from fisheries on "juvenile" and "adult" components of the Southern Georges Bank-Middle Atlantic silver hake stock. Graphs compare yield and SSB per recruit obtained from an exploitation pattern derived from landings and catch at age under two assumed vectors of natural mortality at age: top) M=0.4 constant over all ages; and bottom) M=0.8 on age 0, M=0.6 on age 1, and M=0.4 on ages 2 and above.

egy directed toward younger ages of fish (as might occur in a "juvenile" whiting fishery) may be incompatible with objectives to maintain an "adult" component that 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 three-quarters of the stock has matured by age 2 (Figure 17 and 18). Fishing mortality rates at 31% and 42% MSP declined from 0.51 to 0.36 and from 0.39 to 0.34, for the northern and southern stocks, respectively, when greater exploitation on juveniles was taken into account using the reference exploitation pattern. If effort is redirected on concentrations of juvenile silver hake 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. It should be emphasized that the length at 50% maturation for either stock is about 23 cm (age 2), and as such increased effort on younger ages (1 and 2) of fish increases the likelihood of driving the population below the minimally accepted MSP threshold.

RESEARCH RECOMMENDATIONS

The following recommendations, which apply to both silver hake stocks, provide future

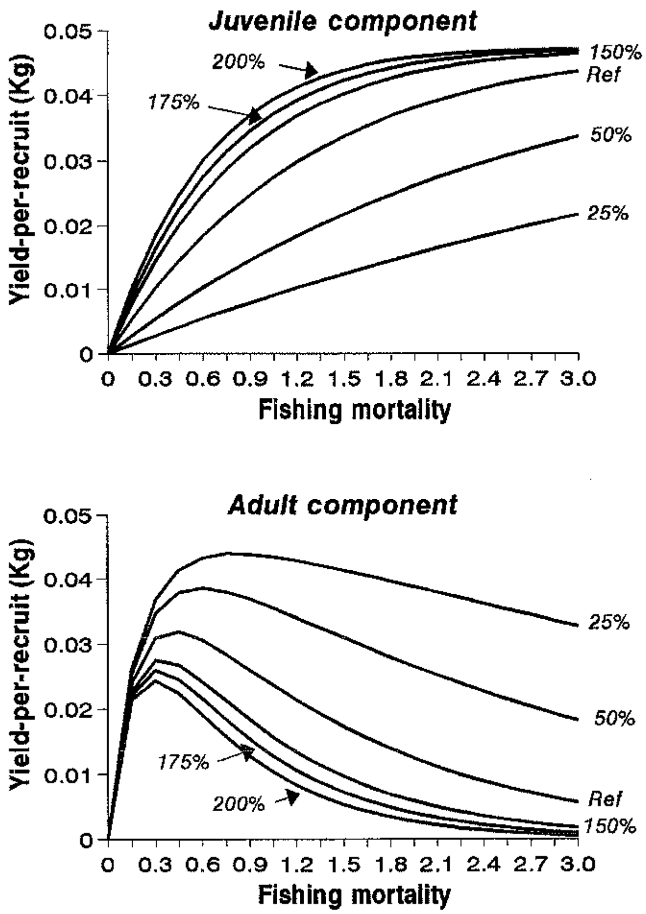

Figure 15. Yield per recruit from fisheries on "juvenile" and "adult" components of the Gulf of Maine-Northern Georges Bank silver hake stock under 25% and 50% of the reference pattern (Ref.) and 150%, 175% and 200% of the reference: 25%) 0.070 and 0.123; 50%) 0.141 and 0.247; Ref.) 0.280 and 0.490; 150%) 0.423 and 0.741; 175%) 0.492 and 0.864; and 200%) 0.500 and 1.000.

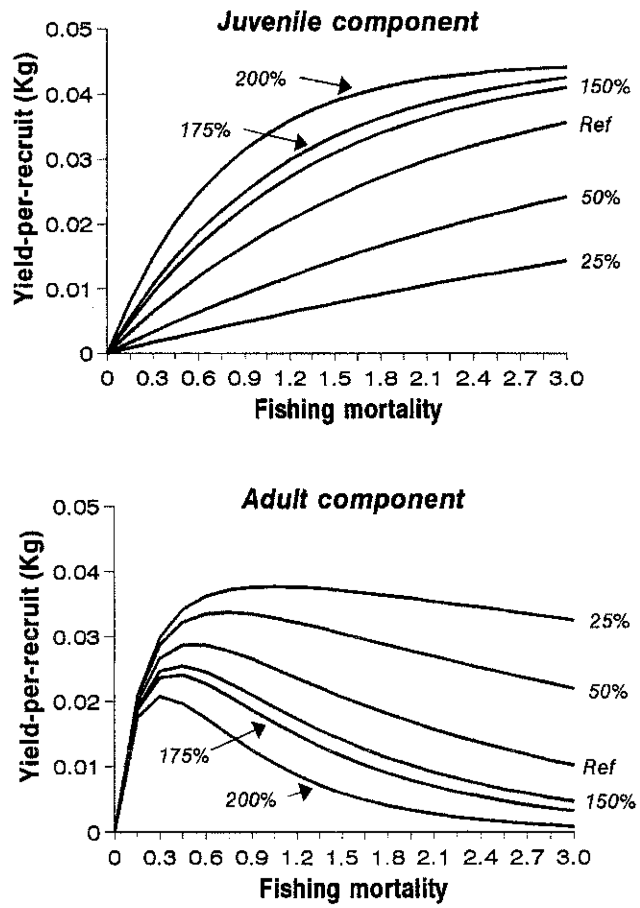

Figure 16. Yield per recruit from fisheries on "juvenile" and "adult" components of the Southern Georges Bank-Middle Atlantic silver hake stock under 25% and 50% of the reference pattern (Ref.) and 150%, 175% and 200% of the reference: 25%) 0.025 and 0.104; 50%) 0.0490 and 0.208; Ref.) 0.099 and 0.417; 150%) 0.148 and 0.625; 175%) 0.173 and 0.730; and 200%) 0.350 and 1.000.

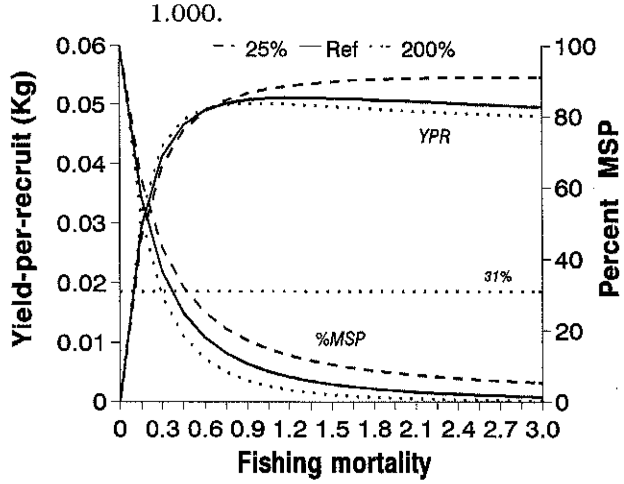

Figure 17. Yield and spawning stock biomass (SSB) per recruit from the Gulf of Maine-Northern Georges Bank silver hake stock under 25% and 200% of the reference (Ref.) exploitation at age 1 and 2: 25%) 0.070 and 0.123; Ref.) 0.280 and 0.490; and 200%) 0.50 and 1.00.

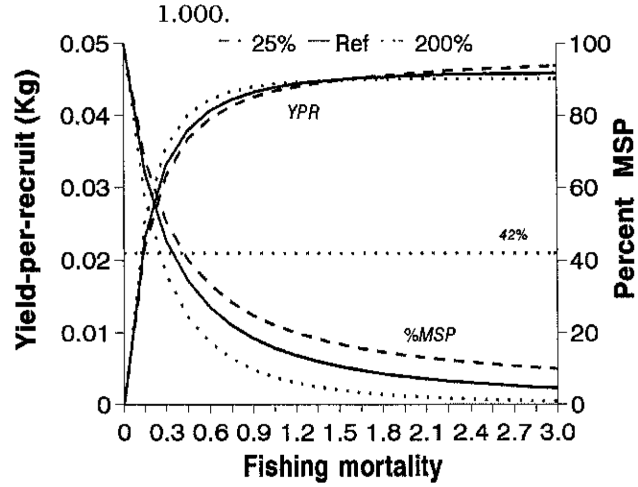

Figure 18. Yield and spawning stock biomass (SSB) per recruit from the Southern Georges Bank-Middle Atlantic silver hake stock under 25% and 200% of the reference (Ref.) exploitation at age 1 and 2: 25%) 0.025 and 0.104; Ref.) 0.099 and 0.417; and 200%) 0.35 and 1.00.

research necessary to resolve the problems noted in the report of SARC17.

1) Re-evaluation of the stock structure of the silver hake resource. The geographic distribution of survey catches of silver hake, particularly juveniles during the autumn, suggests that considerable mixing between the two stocks may occur, particularly for years with large year-classes. The distribution of adult fish also suggests that the stock boundary may shift seasonally, potentially resulting in a misallocation of landings in the catch-at-age matrix to the stocks and a mismatch with the survey strata sets between seasons. Therefore, the most appropriate spatial and temporal aggregation of landings must be determined based on stock boundaries for constructing the catch-at-age matrix.

2) The research survey catch data should be evaluated to a) determine appropriate survey strata sets to apply to catch-at-age matrices from the different stocks and to account for possible differences in spatial distribution between years; and b) determine the effect of transformations (*e.g.*, logarithmic *vs.* delta) in reducing the impact of unusually high numbers in a tow.

3) Inadequate port sampling of silver hake length frequencies as well as use of survey caught fish for constructing age-length keys may introduce additional uncertainty in the catch-at-age matrix. Therefore, port sampling of length frequencies and age structures must be adequate if a reasonable catch-at-age matrix is to be constructed for VPA. Where port sampling is problematic, age structures should be collected from the sea sampling.

4) Preliminary analysis indicated that discarding of silver hake may be substantial. Therefore, the adequacy of the statistical design of the sea sampling data base needs to be evaluated for deriving estimates of silver hake discarding.

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Appendix 1

Supplemental Tables for Estimation of Discards and Implications on Yield and SSB per Recruit

Table A1. Total effort (days fished), number of trips, and landings (pounds) of silver hake by year, region and quarter for the Gulf of Maine-Northern Georges Bank stock

		Gulf of Maine[1]			Northern Georges Bank[2]		
Year		#Trips	Landings (lb)	Days Fished	# Trips	Landings (lb)	Days Fished
1989	Q1	603	384,415	1635.9	69	119,542	131.1
	Q2	1,007	515,401	2,724.2	186	297,763	346.5
	Q3	1,242	1,196,784	2,581.3	388	5,231,049	486.9
	Q4	1,516	1,692,581	3,977.5	255	810,479	361.6
Total		4,368	3,789,181	10,918.9	898	6,458,833	1,326.1
1990	Q1	548	329,589	1,392.1	54	51,549	140.7
	Q2	693	292,076	2,248.7	63	34,113	162.6
	Q3	813	1,383,505	2,699.3	427	7,002,652	662.3
	Q4	1,222	4,377,786	3,547.0	161	588,022	240.4
Total		3,276	6,382,956	9,887.1	705	7,676,336	1,206.0
1991	Q1	644	279,338	1,087.9	74	113,945	103.7
	Q2	648	216,788	2,232.6	86	285,671	206.6
	Q3	1,086	1,203,317	1,877.5	379	7,777,200	530.1
	Q4	2,214	2,705.910	2,900.2	187	758,479	278.1
Total		4,592	4,405,353	8,098.2	726	8,935,295	1,118.5
1992	Q1	620	215,940	903.6	56	150,763	66.6
	Q2	762	65,007	1,948.7	97	113,411	264.1
	Q3	1,359	1,531,790	2,444.2	370	5,923,914	726.2
	Q4	2,102	2,546,229	2,882.6	168	1,142,016	243.4
Total		4,843	4,358,966	8,179.1	691	7,330,104	1,300.3

[1] Gulf of Maine region = Statistical Areas 511-515)
[2] Georges Bank region = Statistical Areas 521-523)

Table B1. Total effort (days fished), number of trips, and landings (pounds) of silver hake by year, region, and quarter for the Southern Georges Bank-Middle Atlantic stock

Year	Southern Georges Bank[1]			Southern New England[2]			Middle Atlantic[3]		
	# Trips	Landings (lb)	Days Fished	# Trips	Landings (lb)	Days Fished	# Trips	Landings (lb)	Days Trips
1989									
Q1	41	560,902	109.1	1,201	5,438,216	1201.3	593	2,025,806	933.9
Q2	101	2,212,241	150.3	1,231	7,767,222	1,003.0	232	936,192	374.7
Q3	52	1,135,478	59.9	720	2,978,218	477.7	12	54,755	47.2
Q4	14	9,995	22.7	1,720	6,196,643	1,298.0	156	288,266	189.1
Total	208	3,918,576	342.0	4,972	22,380,299	3,980.0	993	3,305,019	1,544.9
1990									
Q1	32	20,769	80.1	846	6,454,617	817.1	694	2,633,368	1,006.2
Q2	110	1,887,272	169.5	1,655	8,345,685	1,104.1	198	367,283	200.3
Q3	56	473,467	126.2	948	4,352,282	716.9	50	192,882	36.4
Q4	15	44,161	35.3	1,812	4,972,799	1,318.4	98	259,730	213.7
Total	213	2,425,669	411.1	5,261	24,125,383	3,956.5	1,040	3,453,263	1,457.0
1991									
Q1	73	1,166,155	122.7	1,493	3,431,273	1,266.1	625	2,161,518	1,031.0
Q2	157	2,177,635	212.6	1,617	6,095,114	1,156.0	184	1,119,543	500.4
Q3	23	92,250	64.2	836	2,387,129	740.9	24	116,399	34.2
Q4	7	1,394	13.8	1,708	3,031,962	1,724.6	227	468,498	400.1
Total	260	3,437,434	413.3	5,654	14,945,478	4,887.7	1,060	3,865,958	1,965.7
1992									
Q1	7	3,042	16.8	1,403	2,772,996	1,421.8	554	3,085,864	927.7
Q2	154	5,028,440	171.3	1,065	3,013,229	928.5	327	1,579,798	548.0
Q3	47	1,424,085	65.6	784	1,914,667	695.8	0	0	0
Q4	0	0	0	1,354	2,187,496	1,649.5	208	1,529,139	334.6
Total	208	6,455,567	253.7	4,606	9,888,388	4,695.6	1,089	6,184,801	1,810.3

[1] Southern Georges Bank Region = Statistical Areas 524-526
[2] Southern New England Region = Statistical Areas 537-613
[3] Middle Atlantic Region = Statistical Areas 614-636

Table A2. Total days fished by mesh category[1] within defined strata (year, region, quarter and mesh category) for vessels fishing the Gulf of Maine-Northern Georges Bank stock area expanded by multiplying proportion of days fished by mesh from interviewed trips in weighout data base to total days fished (see Table A1 Appendix 1). Included is fractional interview coverage in Days fished (DF) and by trip.

	Gulf of Maine[2]				Georges Bank[3]			
	Interview Coverage		Days Fished by Mesh Category		Interview Coverage		Days Fished by Mesh Category	
Year	DF	Trip	1	3	DF	Trip	1	3
1989								
Q1	0.11	0.26	209.8	1,426.1	0.33	0.34	12.3	118.8
Q2	0.12	0.26	388.7	2,321.7	0.45	0.34	21.4	325.1
Q3	0.05	0.13	418.2	2,163.1	0.24	0.13	78.6	408.3
Q4	0.04	0.11	588.3	3,382.2	0.15	0.10	47.5	314.1
1990								
Q1	0.10	0.29	444.2	947.9	0.24	0.13	-	140.7
Q2	0.10	0.26	883.6	1,365.2	0.22	0.32	16.9	145.7
Q3	0.05	0.26	1,080.3	1,619.0	0.33	0.60	407.9	254.4
Q4	0.05	0.18	1,345.5	2,201.5	0.20	0.42	11.0	224.4
1991								
Q1	0.03	0.13	888.8	199.1	0.18	0.32	13.7	90.0
Q2	0.03	0.13	406.2	1,826.4	0.19	0.48	27.3	179.3
Q3	0.07	0.18	458.1	1,419.4	0.33	0.60	250.1	280.0
Q4	0.08	0.15	672.9	2,227.3	0.23	0.40	38.2	236.5
1992								
Q1	0.13	0.26	230.9	672.7	0.18	0.29	32.4	34.2
Q2	0.07	0.13	67.1	1,881.6	0.31	0.51	16.3	246.2
Q3	0.11	0.30	623.7	1,820.5	0.17	0.55	495.1	228.8
Q4	0.06	0.16	878.1	1,961.3	0.38	0.55	76.0	167.4

[1] Mesh Category 1: mesh codend $\leq$ 3.5 in. and Mesh Category 3: mesh codend $\geq$ 5.5 in.
[2] Gulf of Maine region = Statistical Areas 511-515
[3] Georges Bank Region = Statistical Areas 521-523

Table B2. Total days fished by mesh category[1] within defined strata (year, region and quarter) for vessels fishing the Southern Georges Bank-Middle Atlantic stock area expanded by multiplying proportion of days fished by mesh from interviewed trips in the weighout data base to total days fished (see Table B1 Appendix 1). Included is fractional interview coverage in days fished (DF) and by trip.

	Southern Georges Bank[2]					**Southern New England[3]**					**Middle Atlantic[4]**				
	Interview Coverage		**Days Fished by Mesh Category**			**Interview Coverage**		**Days Fished by Mesh Category**			**Interview Coverage**		**Days Fished by Mesh Category**		
Year	**DF**	**Trip**	**1**	**2**	**3**	**DF**	**Trip**	**1**	**2**	**3**	**DF**	**Trip**	**1**	**2**	**3**
1989															
Q1	0.48	0.41	23.7	15.7	69.7	0.22	0.30	1148.3	30.2	22.9	0.48	0.55	691.8	242.2	-
Q2	0.46	0.56	78.0	31.3	11.1	0.20	0.34	852.5	150.5	-	0.41	0.50	292.6	82.1	-
Q3	0.61	0.75	55.0	-	4.9	0.32	0.33	470.5	7.2	-	0.06	0.67	47.2	-	-
Q4	0.53	0.50	8.8	-	13.9	0.19	0.29	1244.0	41.2	12.8	0.26	0.40	176.7	12.4	-
1990															
Q1	0.40	0.28	-	-	80.1	0.18	0.30	721.0	58.2	37.9	0.37	0.48	617.0	389.6	-
Q2	0.53	0.63	65.1	-	104.4	0.23	0.39	768.1	239.0	97.0	0.42	0.54	116.8	83.5	-
Q3	0.51	0.50	16.6	-	109.7	0.35	0.36	699.2	6.0	11.7	0.60	0.56	36.4	-	-
Q4	0.53	0.40	-	-	35.3	0.25	0.36	1197.6	64.3	56.6	0.19	0.49	196.7	170	-
1991															
Q1	0.46	0.52	60.2	-	41.8	0.19	0.31	797.2	197.6	248.7	0.37	0.50	844.4	149.0	25.3
Q2	0.42	0.55	91.6	10.0	87.3	0.23	0.40	952.4	51.6	119.2	0.20	0.38	321.2	39.7	-
Q3	0.50	0.52	10.3	-	53.9	0.38	0.33	652.3	20.4	68.1	0.35	0.46	19.7	7.1	7.4
Q4	0.30	0.30	-	-	13.8	0.25	0.24	1286.4	102.1	336.1	0.22	0.47	165.0	38.1	65.0
1992															
Q1	0.21	0.29	16.8	-	-	0.17	0.27	1233.4	43.4	141.4	0.30	0.44	666.9	46.6	214.2
Q2	0.42	0.53	109.4	5.8	56.1	0.20	0.26	552.6	98.9	277.0	0.33	0.47	283.3	47.1	217.6
Q3	0.58	0.68	28.3	-	37.3	0.35	0.30	609.3	49.3	37.2	-	-	-	-	-
Q4	-	-	-	-	-	0.25	0.26	1352.8	114.2	174.5	0.39	0.45	214.6	18.8	78.7

[1] Mesh Category 1: mesh codend $\leq$ 3.5 in, Mesh Category 2: 3.5 in. < mesh codend < 5.5 in., Mesh Category 3 = codend $\geq$ 5.5 in.
[2] Southern Georges Bank region = Statistical Areas 524-526
[3] Southern New England region = Statistical Areaa 537-613
[4] Middle Atlantic region = Statistical Areas 614-636

Table A3. Proportion of the total days fished by strata (year, region, quarter and mesh category[1]) that were from trips in the Domestic Sea Sampling Data Base which did not discard the entire catch of silver hake for the Gulf of Maine-Northern Georges Bank stock

	Gulf of Maine[2] Mesh Category		Georges Bank[3] Mesh Category	
Year	**1**	**3**	**1**	**3**
1989				
Q1	0.63	0.00	1.00	0.00
Q2	0.73	0.40	1.00	0.00
Q3	0.88	0.14	1.00	0.40
Q4	0.69	0.25	1.00	0.10
1990				
Q1	0.62	0.00	-	0.00
Q2	0.68	0.30	1.00	0.00
Q3	1.00	0.68	1.00	0.00
Q4	0.79	0.74	1.00	0.50
1991				
Q1	0.76	0.00	1.00	0.10
Q2	0.64	0.96	1.00	0.15
Q3	1.00	0.10	1.00	0.50
Q4	0.97	0.50	1.00	0.42
1992				
Q1	0.50	0.35	1.00	0.42
Q2	0.60	0.36	1.00	0.99
Q3	1.00	0.00	1.00	0.68
Q4	0.66	0.60	1.00	0.73

[1] Mesh Category 1: Mesh codend $\leq$ 3.5 in.)
Mesh Category 3: Mesh codend $\equiv$ 5.5 in.)
[2] Gulf of Maine region = Statistical Area 511-515
[3] Georges Bank Region = Statistical Area 521-523

Table B3. Proportion of the total days fished by strata (year, region, quarter, and mesh category) that were from trips in the Domestic Sea Sampling Data Base which did not discard the entire catch of silver hake for the Southern Geroges Bank-Middle Atlantic stock

	Southern Georges Bank[1]			**Southern New England**[2]			**Middle Atlantic**[3]		
	Mesh Category[4]			**Mesh Category**			**Mesh Category**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
1989									
Q1	-	-	-	1.00	0.62	0.00	1.00	0.00	-
Q2	-	-	0.25	0.66	0.46	-	0.87	1.00	-
Q3	-	-	0.53	0.77	0.42	-	0.00	-	-
Q4	-	-	-	0.81	1.00	0.95	0.65	1.00	-
1990									
Q1	-	-	0.38	1.00	1.00	0.30	0.43	1.00	-
Q2	-	-	0.40	1.00	0.77	0.55	0.61	0.77	-
Q3	-	-	0.62	1.00	-	1.00	-	-	-
Q4	-	-	0.83	1.00	0.32	0.86	-	0.32	-
1991									
Q1	1.00	-	0.39	1.00	0.73	0.74	0.80	1.00	1.00
Q2	-	-	0.41	1.00	0.42	1.00	0.43	1.00	-
Q3	-	-	0.10	1.00	0.30	1.00	1.00	1.00	-
Q4	-	-	0.78	1.00	0.96	1.00	0.60	1.00	1.00
1992									
Q1	1.00	-	-	1.00	1.00	0.40	0.80	0.36	0.51
Q2	-	-	1.00	1.00	-	1.00	1.00	1.00	1.00
Q3	-	-	1.00	1.00	-	1.00	-	-	-
Q4	-	-	-	1.00	1.00	0.67	1.00	1.00	0.65

[1] Southern Georges Bank Region = Statistical Areas 524-526
[2] Southern New England Region = Statistical Areas 537-613
[3] Middle Atlantic Region = Statistical Areas 614-636
[4] Mesh category 1: mesh codend $\leq$ 3.5 in.
Mesh category 2: 3.5 in. < mesh codend < 5.5 in.
Mesh category 3: mesh codend $\geq$ 5.5 in.

Appendix 2

Estimation of Exploitation Pattern and Yield and SSB per Recruit Analyses

Table A4. Estimation of the relative exploitation pattern at age derived from catch at age for the Gulf of Maine-Northern Georges Bank stock using traditional VPA on three levels of terminal fishing mortality (age 5): 0.25, 0.50, and 1.00. Age 3 is fully recruited, and M is assumed to be 0.40

Age	Year			
	1989	**1990**	**1991**	**Average 1989-1990**
	Terminal Fishing Mortality 0.25			
1	0.564	0.052	0.051	0.308
2	0.772	0.419	0.227	0.596
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	0.250	0.250	0.250	
3+	0.723	1.288	1.110	
	Terminal Fishing Mortality 0.50			
1	0.542	0.066	0.070	0.304
2	0.657	0.428	0.277	0.543
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	0.505	0.505	0.505	
3+	0.876	1.565	1.527	
	Terminal Fishing Mortality 1.00			
1	0.499	0.079	0.088	0.280
2	0.571	0.418	0.321	0.490
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	1.005	1.005	1.005	
3+	1.023	1.795	1.875	

Table B4. Estimation of the relative exploitation pattern at age derived from catch at age for the Southern Georges Bank-Middle Atlantic stock using traditional VPA on three levels of terminal fishing mortality (age 5): 0.50, 1.00, and 1.50. Age 3 is fully recruited, and M is assumed to be 0.40

Age	Year			
	1989	**1990**	**1991**	**Average 1989-1990**
	Terminal Fishing Mortality 0.50			
1	0.053	0.115	0.004	0.084
2	0.483	0.409	0.071	0.446
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	0.500	0.500	0.500	
3+	1.042	0.765	1.228	
	Terminal Fishing Mortality 0.50			
1	0.052	0.146	0.006	0.099
2	0.402	0.432	0.091	0.417
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	1.000	1.000	1.000	
3+	1.279	0.921	1.553	
	Terminal Fishing Mortality 1.50			
1	0.054	0.180	0.009	0.117
2	0.375	0.459	0.110	0.417
3	1.000	1.000	1.000	1.000
4	1.000	1.000	1.000	
5	1.500	1.500	1.500	
3+	1.389	1.003	1.829	

Table A5. Results of yield and SSB per recruit for northern stock

```
   The NEFSC 2-Compartment Yield per Recruit Program - PDBYPRC2
   PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992
             -------------------------------------
             Run Date: 23-11-1993;  Time: 16:21:54.89
SILVER HAKE NORTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A
____________________________________________________________________
Proportion of F before spawning:  .6660
Proportion of M before spawning:  .6660
Natural Mortality is Constant at:  .400
Initial age is: 0 ; Last age is: 6+
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> POLYPR.DAT
```

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
0	.0001	1.0000	.0000	.037	.009
1	.0490	1.0000	.0800	.097	.017
2	.3800	1.0000	.7000	.156	.076
3	1.0000	1.0000	.9900	.222	.177
4	1.0000	1.0000	1.0000	.301	.312
5	1.0000	1.0000	1.0000	.394	.466
6+	1.0000	1.0000	1.0000	.559	.632

```
Summary of Yield per Recruit Analysis for:
SILVER HAKE NORTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A
____________________________________________________________________
 Slope of the Yield/Recruit Curve at F=0.00: -->      .3005
   F level at slope=1/10 of the above slope (F0.1): ----->     .448
     Yield/Recruit corresponding to F0.1: ----->      .0476
 F TO PRODUCE MAXIMUM CATCHW (F-MAX):          NOT FOUND
```

Listing of Yield per Recruit Results for:
SILVER HAKE NORTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A

	FMORT	TOTCTHN	TOTCTHW	JUVCTHN	JUVCTHW	ADLCTHN	ADLCTHW
Fmax	.00	.23371	.05147	.09326	.01356	.14045	.03791
	.00	.00000	.00000	.00000	.00000	.00000	.00000
	.15	.10149	.02901	.02447	.00358	.07702	.02543
	.30	.16105	.04148	.04756	.00694	.11349	.03454
F0.1	.45	.20030	.04758	.06903	.01006	.13127	.03753
	.45	.20081	.04765	.06936	.01010	.13146	.03755
	.60	.22963	.05106	.08994	.01308	.13970	.03798
	.75	.25175	.05312	.10938	.01588	.14238	.03724
	.90	.26946	.05448	.12774	.01851	.14172	.03596
	1.05	.28409	.05543	.14509	.02099	.13899	.03444
	1.20	.29648	.05613	.16150	.02332	.13498	.03281
	1.35	.30719	.05668	.17700	.02551	.13019	.03117
	1.50	.31659	.05711	.19167	.02757	.12493	.02954
	1.65	.32497	.05746	.20554	.02951	.11942	.02795
	1.80	.33250	.05776	.21867	.03134	.11383	.02642
	1.95	.33935	.05801	.23110	.03305	.10825	.02495
	2.10	.34562	.05822	.24287	.03467	.10275	.02355
	2.25	.35140	.05840	.25402	.03619	.09738	.02221
	2.40	.35676	.05856	.26458	.03762	.09218	.02094
	2.55	.36176	.05870	.27459	.03897	.08717	.01974
	2.70	.36644	.05883	.28409	.04024	.08235	.01859
	2.85	.37084	.05894	.29310	.04143	.07775	.01751
	3.00	.37500	.05904	.30164	.04255	.07335	.01649

The NEFSC 2-Compartment Yield per Recruit Program - PDBYPRC2
PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992

Run Date: 1-12-1993; Time: 12:43:19.84
SILVER HAKE NORTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

Proportion of F before spawning: .6660
Proportion of M before spawning: .6660
Natural Mortality is Constant at: .400
Initial age is: 0 ; Last age is: 6+
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> polypr.dat

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
0	.0001	1.0000	.0000	.037	.009
1	.2810	1.0000	.0800	.078	.017
2	.4940	1.0000	.7000	.144	.076
3	1.0000	1.0000	.9900	.218	.177
4	1.0000	1.0000	1.0000	.301	.312
5	1.0000	1.0000	1.0000	.394	.466
6+	1.0000	1.0000	1.0000	.559	.632

Summary of Yield per Recruit Analysis for:
SILVER HAKE NORTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

Slope of the Yield/Recruit Curve at F=0.00: --> .3134
F level at slope=1/10 of the above slope (F0.1): -----> .391
Yield/Recruit corresponding to F0.1: -----> .0448
F level to produce Maximum Yield/Recruit (Fmax): -----> 1.289
Yield/Recruit corresponding to Fmax: -----> .0512

Listing of Yield per Recruit Results for:
SILVER HAKE NORTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

	FMORT	TOTCTHN	TOTCTHW	JUVCTHN	JUVCTHW	ADLCTHN	ADLCTHW
	.00	.00000	.00000	.00000	.00000	.00000	.00000
	.15	.12139	.02947	.04827	.00544	.07313	.02402
	.30	.19423	.04121	.09193	.01028	.10230	.03093
F0.1	.39	.22632	.04485	.11636	.01295	.10995	.03190
	.45	.24396	.04645	.13146	.01458	.11250	.03188
	.60	.28079	.04897	.16729	.01840	.11351	.03057
	.75	.30962	.05022	.19978	.02179	.10984	.02843
	.90	.33309	.05083	.22929	.02479	.10380	.02604
	1.05	.35276	.05112	.25611	.02746	.09665	.02365
	1.20	.36964	.05121	.28052	.02983	.08912	.02138
Fmax	1.29	.37863	.05121	.29401	.03111	.08462	.02010
	1.35	.38436	.05120	.30275	.03193	.08160	.01927
	1.50	.39738	.05111	.32303	.03379	.07435	.01733
	1.65	.40903	.05099	.34155	.03543	.06748	.01556
	1.80	.41955	.05085	.35849	.03689	.06106	.01396
	1.95	.42913	.05069	.37400	.03818	.05513	.01251
	2.10	.43790	.05052	.38822	.03932	.04968	.01121
	2.25	.44598	.05035	.40127	.04032	.04471	.01003
	2.40	.45346	.05019	.41328	.04121	.04018	.00898
	2.55	.46040	.05002	.42433	.04199	.03607	.00803
	2.70	.46688	.04986	.43453	.04268	.03236	.00718
	2.85	.47295	.04970	.44395	.04328	.02900	.00642
	3.00	.47864	.04955	.45266	.04382	.02598	.00574

Table B5. Results of yield and SSB per recruit for southern stock

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 The NEFSC 2-Compartment Yield per Recruit Program - PDBYPRC2
   PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992
            ---------------------------------------
            Run Date: 24-11-1993;  Time: 08:45:21.30
SILVER HAKE SOUTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A
____________________________________________________________________
Proportion of F before spawning:  .5000
Proportion of M before spawning:  .5000
Natural Mortality is Constant at:  .400
Initial age is: 0 ; Last age is: 6+
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> POLYPR.DAT
-----------------------------------------------------------
Age-specific Input data for Yield per Recruit Analysis
-----------------------------------------------------------
 Age | Fish Mort  Nat Mort | Proportion | Average Weights
     |  Pattern    Pattern |   Mature   |  Catch   Stock
-----------------------------------------------------------
  0  |   .0001     1.0000  |    .0000   |   .037    .009
  1  |   .0110     1.0000  |    .0900   |   .091    .012
  2  |   .2450     1.0000  |    .8000   |   .149    .091
  3  |  1.0000     1.0000  |    .9900   |   .187    .216
  4  |  1.0000     1.0000  |   1.0000   |   .238    .348
  5  |  1.0000     1.0000  |   1.0000   |   .322    .442
  6+ |  1.0000     1.0000  |   1.0000   |   .425    .522
Summary of Yield per Recruit Analysis for:
SILVER HAKE SOUTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A
____________________________________________________________________
 Slope of the Yield/Recruit Curve at F=0.00: -->      .2324
   F level at slope=1/10 of the above slope (F0.1): ----->    .498
     Yield/Recruit corresponding to F0.1: ----->      .0402
   F level to produce Maximum Yield/Recruit (Fmax): ----->   8.748
     Yield/Recruit corresponding to Fmax: ----->      .0576
--------------------------------------------------------------------
Listing of Yield per Recruit Results for:
SILVER HAKE SOUTHERN STOCK (LANDINGS) - 1993 UPDATED AVE WTS, FPAT A
--------------------------------------------------------------------
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	FMORT	TOTCTHN	TOTCTHW	JUVCTHN	JUVCTHW	ADLCTHN	ADLCTHW
	.00	.00000	.00000	.00000	.00000	.00000	.00000
	.15	.09333	.02296	.01428	.00207	.07905	.02088
	.30	.14760	.03344	.02807	.00407	.11954	.02936
	.45	.18347	.03900	.04137	.00600	.14210	.03299
F0.1	.50	.19252	.04022	.04551	.00660	.14701	.03362
	.60	.20920	.04231	.05422	.00786	.15498	.03444
	.75	.22873	.04448	.06663	.00966	.16210	.03483
	.90	.24420	.04603	.07860	.01139	.16559	.03465
	1.05	.25685	.04721	.09017	.01306	.16668	.03416
	1.20	.26747	.04815	.10134	.01467	.16613	.03349
	1.35	.27656	.04893	.11213	.01622	.16443	.03271
	1.50	.28449	.04960	.12255	.01772	.16194	.03188
	1.65	.29149	.05018	.13261	.01917	.15888	.03101
	1.80	.29775	.05069	.14233	.02056	.15542	.03012
	1.95	.30341	.05114	.15173	.02191	.15168	.02923
	2.10	.30856	.05155	.16080	.02321	.14776	.02834
	2.25	.31329	.05192	.16957	.02446	.14372	.02746
	2.40	.31767	.05226	.17804	.02567	.13963	.02659
	2.55	.32173	.05257	.18623	.02684	.13550	.02573
	2.70	.32552	.05286	.19414	.02796	.13139	.02489
	2.85	.32908	.05312	.20179	.02905	.12730	.02407
	3.00	.33244	.05337	.20918	.03010	.12326	.02327

The NEFSC 2-Compartment Yield per Recruit Program - PDBYPRC2
PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992

Run Date: 8-12-1993; Time: 11:37:14.00
SILVER HAKE SOUTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

Proportion of F before spawning: .5000
Proportion of M before spawning: .5000
Natural Mortality is Constant at: .400
Initial age is: 0 ; Last age is: 6+
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> POLYPR.DAT

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Stock
0	.0001	1.0000	.0000	.028	.009
1	.0990	1.0000	.0900	.075	.012
2	.4170	1.0000	.8000	.122	.091
3	1.0000	1.0000	.9900	.178	.216
4	1.0000	1.0000	1.0000	.238	.348
5	1.0000	1.0000	1.0000	.322	.442
6+	1.0000	1.0000	1.0000	.425	.522

Summary of Yield per Recruit Analysis for:
SILVER HAKE SOUTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

Slope of the Yield/Recruit Curve at F=0.00: --> .2390
F level at slope=1/10 of the above slope (F0.1): -----> .446
Yield/Recruit corresponding to F0.1: -----> .0379
F level to produce Maximum Yield/Recruit (Fmax): -----> 3.665
Yield/Recruit corresponding to Fmax: -----> .0459

Listing of Yield per Recruit Results for:
SILVER HAKE SOUTHERN STOCK (LANDINGS+DISCARDS) - 1993 UPDATED AVE WT

	FMORT	TOTCTHN	TOTCTHW	JUVCTHN	JUVCTHW	ADLCTHN	ADLCTHW
	.00	.00000	.00000	.00000	.00000	.00000	.00000
	.15	.10635	.02311	.03033	.00332	.07602	.01979
	.30	.16922	.03305	.05866	.00639	.11057	.02666
F0.1	.45	.21055	.03785	.08442	.00917	.12613	.02868
	.45	.21153	.03795	.08512	.00925	.12641	.02870
	.60	.24245	.04061	.10986	.01190	.13259	.02872
	.75	.26637	.04219	.13299	.01436	.13338	.02784
	.90	.28567	.04320	.15463	.01664	.13104	.02656
	1.05	.30173	.04388	.17487	.01875	.12686	.02512
	1.20	.31543	.04436	.19383	.02072	.12160	.02364
	1.35	.32735	.04471	.21159	.02254	.11576	.02217
	1.50	.33787	.04498	.22823	.02423	.10964	.02074
	1.65	.34729	.04518	.24384	.02580	.10345	.01938
	1.80	.35580	.04534	.25847	.02726	.09733	.01809
	1.95	.36357	.04547	.27221	.02861	.09136	.01686
	2.10	.37071	.04557	.28512	.02986	.08559	.01571
	2.25	.37732	.04565	.29725	.03102	.08007	.01463
	2.40	.38346	.04572	.30865	.03210	.07481	.01361
	2.55	.38920	.04577	.31937	.03310	.06982	.01267
	2.70	.39459	.04581	.32947	.03403	.06511	.01178
	2.85	.39966	.04584	.33899	.03489	.06068	.01095
	3.00	.40446	.04587	.34795	.03569	.05650	.01018