APPENDIX A

Development of a Definition of Overfishing for the Gulf of Maine/Northern Georges Bank and Southern Georges Bank/Mid-Atlantic Stocks of Silver Hake

All new FMPs or amendments to existing FMPs are required to contain objective, operational definitions of overfishing, in accordance with the guidelines in Federal Register Final Rule 50 CFR Part 602 (July 24, 1989). The overfishing definitions must address recruitment overfishing at the least, but may also include or substitute other, more restrictive bounds on the fishery (e.g. bounds that are intended to enhance yields). In Amendment #4 to the Northeast Multispecies FMP (MSFMP) it is proposed that the two US stocks of silver hake (whiting) be added to the management unit. This document provides details of the proposed definition of recruitment overfishing for silver hake, the rationale for the definition, and the supporting analysis.

Definition of overfishing

The recommended definition of overfishing for both the Gulf of Maine/Northern Georges Bank and Southern Georges Bank/Mid-Atlantic stocks of silver hake (hereafter refered to as the northern and southern stocks respectively) is:

> "Overfishing is deemed to have occurred or be occurring whenever the four-year running average percent maximum spawning potential (%MSP) is less than the threshold %MSP."
>
> "The current estimate of the threshold %MSP is 31% for the Maine/Northern Georges Bank stock and 42% for the Southern Georges Bank/Mid-Atlantic stock. These numbers are subject to periodic revision as appropriate new scientific information becomes available."

Rationale for the use of a %MSP threshold

There are two main types of biological reference points that could form an appropriate basis for an operational definition of overfishing: a minimum stock size and a maximum fishing mortality rate. Specification of a minimum stock size is problematic for most fish stocks (particularly highly-productive, or highly-variable, stocks) because of the need to partition the variation in stock size into that due to overfishing and that due to environmental factors. Interpretation of a maximum fishing mortality rate is more straightfoward. Candidates for the maximum fishing mortality rate include F0.1 and Fmax, both of which are derived from yield per recruit (YPR) analysis, and Frep (F-replacement), which is derived from the related spawning stock biomass per recruit (SSB/R) analysis combined with spawner-recruit data.

Reference points from YPR analysis are primarily related to growth overfishing, rather than recruitment overfishing. On the other hand, Frep was specifically derived as a reference point defining the threshold of recruitment overfishing. Frep is defined as "the rate of fishing mortality at which year classes are, on average, able to replace themselves". It translates directly into a

%MSP threshold. The only alternative, fully-specified reference points of recruitment overfishing are those derived from theoretical spawner-recruit relationships. Even when such theoretical relationships fit the data well (which is rarely the case, and silver hake is no exception), Frep will generally provide a more conservative estimate of the overfishing threshold.

Since Frep depends on the exploitation pattern (the relative fraction of fish in each age group that is removed by the fishery), it is more convenient to translate it into a related reference point, the replacement SSB/R, in which the age-related pattern of fishing mortality is collapsed into a single number. The replacement SSB/R can then be expressed as a percentage of the maximum possible SSB/R which occurs when there is no fishing. This quantity is called the %MSP.

The proposed definition of overfishing for silver hake is similar to those which have already been adopted for other regulated species in the MSFMP.

Rationale for the use of a running average

There are several advantages to using a running average rather than the most recent estimate alone:

(i) The main objection to the use of a one-year fishing mortality rate to specify overfishing is that it defines the "act of overfishing", but not necessarily the "state of being overfished". Even though a stock is currently being fished below some threshold fishing mortality rate, it may still be judged to be in an "overfished condition" because stock size is extremely low or the age distribution is severly truncated. Low stock size and a truncated age distribution could both be caused by recent high levels of fishing mortality; however, the former phenomenon could also be the result of unfavorable environmental conditions while the latter could be the result of unusually high recruitment. Use of a running average fishing mortality rate is a partial solution for dealing with the overfishing/overfished dichotomy, while at the same time time excluding the confounding effects of environmental conditions and other factors that are probably unrelated to fishing practices.

(ii) The SSB/R model, like the related YPR model, assumes a constant fishing mortality and exploitation pattern throughout the lifespan of a cohort. However, in reality both fishing mortality and the exploitation pattern vary somewhat from year to year. Use of a running average will tend to smooth out the variability in fishing patterns (as well as errors in the estimation of recent fishing mortalities). Moreover, a running average procedure may provide a more reliable means for assessing trends in the data.

(iii) It allows fishery managers to compensate for inadequacies or uncertainties in stock assessments, plan monitoring, enforcement and other factors which have resulted in the targets of previous years being under- or over-shot.

Use of a running average means that an existing overfishing problem cannot be solved simply by achieving the threshold %MSP for a single year. To correct an overfishing condition quickly, it may be necessary to reduce fishing mortality below the level corresponding to the threshold %MSP for several consecutive years. Conversely, fishing mortality rates above the threshold may be allowable occasionally if prior fishing mortality rates have been well below the threshold. This action could not be taken unless it was practical to vary fishing mortality substantially (down as well as up) from one year to the next, in order to ensure that the running average was never exceeded.

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Since highly-productive stocks ought to be able to recover from overfishing more rapidly, the period chosen for calculation of the running average should be related to the life history of the species. Silver hake are considered to be a productive species since they mature early (age 2-3 years) and have a relatively high natural mortality rate (M=0.4). Their potential lifespan is only about eight years (3/M). Although somewhat arbitrary, we have adopted the convention of using half the potential lifespan as the appropriate period for averaging.

Supporting analysis

This analysis uses data from the most recent stock assessment for silver hake, contained in the Stock Assessment Review Committee (SARC) Consensus Summary of Assessments (Report of the 11th NEFC Stock Assessment Workshop) which met at the Northeast Fisheries Center in October, 1990 (NOAA 1990).

Background: Data from commercial silver hake fisheries date back to 1955. A previous silver hake assessment (Almeida 1987) utilized the entire time series; however, due to a change in ageing procedures in 1973, the most recent assessment was restricted to the period from 1973 to the most recent year for which data had been collated (1988). Almeida's assessment suggested that both stocks of silver hake exhibited dramatic declines during the late 1960s (Figs. 1 & 2). Although estimates from the most recent assessment may not be directly comparable, it is likely that both stocks are still at extremely low levels in comparison to their historic highs (Figs. 1 & 2).

Input parameters: Frep (F-replacement) and the corresponding threshold %MSP (percent maximum spawning potential) are calculated from a spawner-recruit (S-R) relationship and a spawning stock biomass per recruit (SSB/R) analysis. The data input to each of these must be from compatible times of year.

Spawner-recruit plots: Using NEFC's method of standardization, VPA population numbers at age on January 1 for each of the years 1973-86 (Table 1) were projected foward to the mid-point of the spawning season (August for the northern stock; June for the southern stock) by multiplying them by:

$$e^{-[P*F(i,t)\ +\ p*M(i,t)]}$$

where P = fraction of fishing mortality within year beforespawning (0.667 for the northern stock, 0.500 for the southern stock)
$F(i,t)$ = fishing mortality for year i and age t (Table 2)
p = fraction of natural mortality within year before spawning (0.667 for the northern stock, 0.500 for the southern stock)
$M(i,t)$ = natural mortality for year i and age t (constant at 0.4).

It was then assumed that commercial weights at age approximate the weights at age applicable during the mid-points of the spawning seasons for each stock (since peak commercial fishing, and therefore peak sampling, occurs during each spawning season; Almeida, pers. comm.). Therefore, the projected numbers were multiplied by the commercial weights at age (Table 3) and the maturities at age (0.0 for age 1, 0.59 for age 2, 0.95 for age 3, and 1.0 for ages 4+) and summed to give annual estimates of spawning stock biomass (SSB). These estimates of SSB were plotted against the corresponding VPA numbers at age 1 (Table 1), using a one-year lag (Figs. 3 and 4). Note that estimates from the most recent years of the VPAs (Table 1) were not included in the analysis. The replacement SSB/R was estimated as the inverse of the slope of the straight line passing through the origin and bissecting the data points (the median).

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SSB/R curves: To conform with the S-R analysis, SSB/R was calculated by projecting the stable age distributions foward by the same amounts (0.667 years for the northern stock, 0.500 years for the southern stock). Other inputs to SSB/R (and YPR) analysis were:

Both stocks: M = 0.4
Age of recruitment = 1
Oldest age = 8 (3/M, no plus group)

Age	1	2	3	4	5	6	7	8
Partial recruitment (northern stock)	.076	.583	1	1	1	1	1	1
Partial recruitment (southern stock)	.069	.468	1	1	1	1	1	1
Weights-at-age (northern stock)	.121	.176	.240	.352	.492	.557	.562	.666
Weights-at-age (southern stock)	.078	.141	.191	.283	.412	.523	.551	.659
Proportion mature (both stocks)	0	.59	.95	1	1	1	1	1

Fraction of fishing mortality within year before spawning =
8/12 for northern stock (August)
6/12 for southern stock (June)
Fraction of natural mortality within year before spawning =
8/12 for northern stock (August)
6/12 for southern stock (June)

The partial recruitments (PRs) were estimated from the fishing mortality rates (Table 2) for the years 1982-86 inclusive, assuming a flat-topped PR with age 3 as the first age of full recruitment. PRs for ages 1 and 2 were calculated by dividing the fishing mortalities for ages 1 and 2 by the pooled fishing mortalities for ages 3-6 (the fishing mortalities tabulated for ages 6 and 7+ in Table 2), and then taking the geometric mean across years. Weights at age were calculated (from Table 3) as unweighted averages across the years 1984-88 inclusive. The maturity ogive was taken from Morse (1979).

Results: The replacement SSB/R was estimated to be 0.13 kg for the northern stock and 0.16 kg for the southern stock. Corresponding estimates of %MSP and Frep were determined by locating the appropriate values of SSB/R in Tables 4 & 5. The values of %MSP were 31% and 42% respectively; and the values of Frep were 0.51and 0.39 respectively (assuming the average PR vectors given in the above text table).

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Current status of silver hake fisheries

The four-year (1985-88) running average of pooled Fs for ages 3-6 (presented as the F estimates for ages 6 and 7+ in Table 2; i.e., the fully-recruited Fs) is 0.76 for the northern stock and 0.71 for the southern stock. If an average PR is calculated for the four most recent years of the VPA (1985-88) using the method outlined in the previous section, the corresponding %MSP is estimated to be approximately 27% for both stocks.

Conclusions

These two stocks of silver hake are unusual in that they are amongst the few examples of fish stocks with values of Frep that approximate F0.1. Based on the above results, which are applicable up to 1988, it appears that both stocks of silver hake were being overfished at that time. Although fishing mortality rates seem to be declining, particularly for the southern stock (Table 2), the SARC warned that this trend should be interpreted with caution. It is likely that current (1990) fishing mortality rates are at least as high as they were in 1988. Thus, management actions such as a regulated minimum allowable mesh size are needed to alleviate the overfishing problem.

References

Almeida, F. P. 1987. Status of the Silver Hake Resource off the Northeast Coast of the United States- 1987. Woods Hole Laboratory Reference Document No. 87-03.

NOAA 1988. Status of the Fishery Resources off the Northeastern United States for 1988. NOAA Technical Memorandum NMFS-F/NEC-63.

NOAA 1990. Report of the 11th NEFC Stock Assessment Workshop: Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, October 1990. Report held at NEFC, Woods Hole, MA.

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Table A1 January 1 population numbers at age (millions) for the northern and southern stocks of silver hake (Tables F4 and F5 from NOAA 1990)

STOCK NUMBERS (Jan 1) in millions - NORTHERN STOCK

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	357.8	398.3	172.1	50.8	38.1	90.1	76.9	48.1	57.3	84.0
2	227.1	212.5	649.3	108.3	32.6	24.0	58.2	51.0	31.4	34.4
3	85.3	77.3	116.5	117.9	56.8	14.8	9.3	36.1	24.5	14.2
4	19.4	37.4	33.5	26.2	58.9	19.6	4.1	4.4	14.3	12.4
5	7.5	9.3	17.5	5.8	10.4	27.3	4.3	1.6	1.3	4.3
6	1.4	3.5	4.0	5.3	1.5	4.5	7.2	1.4	0.7	0.4
7+	1.4	2.8	1.8	0.8	0.6	1.5	1.2	2.7	1.3	1.5
1+	700.0	741.2	994.8	315.0	199.0	181.8	161.3	145.4	130.7	151.1

	1983	1984	1985	1986	1987	1988	1989
1	104.6	60.2	104.7	327.9	38.9	16.9	0.0
2	51.5	68.0	37.9	61.7	217.3	25.6	10.0
3	15.0	23.0	28.0	19.8	29.9	134.8	13.3
4	7.1	6.8	7.4	7.4	6.7	10.9	74.0
5	4.5	3.3	2.1	1.8	1.8	3.2	3.7
6	2.4	1.6	1.4	1.1	0.3	0.5	1.1
7+	1.8	0.0	0.2	0.6	0.0	0.0	0.2
1+	186.2	162.9	181.7	420.3	294.8	192.8	103.0

STOCK NUMBERS (Jan 1) in millions - SOUTHERN STOCK

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	1411.3	1195.7	773.5	214.6	204.7	261.6	178.2	113.9	160.5	159.9
2	866.9	886.4	761.1	514.0	137.5	135.1	160.1	119.5	73.4	93.2
3	334.6	315.0	411.4	409.5	273.6	64.3	68.7	89.3	65.9	29.6
4	81.3	133.2	95.5	153.5	157.6	76.9	36.4	31.9	44.0	20.9
5	23.8	30.5	28.6	22.3	25.0	49.3	27.3	11.2	13.6	14.3
6	3.2	11.9	6.4	3.0	6.4	7.6	22.8	9.0	3.9	5.0
7+	1.7	10.9	3.0	0.5	5.0	2.4	4.3	13.8	4.5	6.0
1+	2724.9	2583.7	2079.5	1317.2	809.9	597.2	497.8	389.3	365.7	328.9

	1983	1984	1985	1986	1987	1988	1989
1	204.9	138.9	178.3	220.4	318.8	167.2	0.0
2	97.0	130.5	87.2	113.3	138.5	209.1	95.9
3	34.3	46.2	50.2	37.1	52.9	72.3	120.9
4	9.8	10.6	12.2	14.8	9.9	20.9	32.0
5	6.4	1.7	2.5	1.9	5.5	1.8	9.2
6	4.3	0.8	0.4	0.4	0.5	0.0	0.8
7+	2.2	0.8	0.4	0.2	0.1	0.1	0.1
1+	360.9	329.5	331.2	388.1	526.1	471.4	258.9

Table A2 Fishing mortality rates for the northern and southern stocks of silver hake (Tables F4 and F5 of NOAA 1990)

FISHING MORTALITY - NORTHERN STOCK

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.1210	0.0685	0.0637	0.0418	0.0595	0.0373	0.0112	0.0283	0.1184	0.0896
2	0.6777	0.2011	0.3487	0.2442	0.3939	0.5476	0.0763	0.3321	0.3961	0.4280
3	0.4251	0.4370	1.0927	0.2941	0.4448	0.8860	0.3585	0.5260	0.4506	0.3881
4	0.3333	0.3574	1.3504	0.5206	0.3695	1.1178	0.5436	0.8194	0.4175	0.4352
5	0.3478	0.4371	0.7991	0.9399	0.4328	0.9271	0.7149	0.4857	0.8393	0.5536
6	0.4135	0.4228	1.1931	0.3572	0.5128	1.0396	0.4913	0.5497	0.4671	0.3959
7+	0.4135	0.4228	1.1931	0.3572	0.5128	1.0396	0.4913	0.5497	0.4671	0.3959

	1983	1984	1985	1986	1987	1988
1	0.0306	0.0628	0.1293	0.0116	0.0138	0.0518
2	0.4070	0.4883	0.2473	0.3247	0.0771	0.2535
3	0.3935	0.7358	0.9343	0.6902	0.6045	0.1999
4	0.3498	0.7753	1.0369	0.9950	0.3467	0.4976
5	0.6179	0.4433	0.2452	1.4523	0.9222	0.4976
6	0.4324	0.7450	0.9557	0.8354	0.5868	0.4976
7+	0.4324	0.7450	0.9557	0.8354	0.5868	0.4976

FISHING MORTALITY - SOUTHERN STOCK

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.0651	0.0783	0.0087	0.0443	0.0136	0.0112	0.0540	0.0394	0.1438	0.0995
2	0.6123	0.3677	0.1932	0.2304	0.3596	0.2762	0.1837	0.1958	0.5095	0.5437
3	0.5271	0.7929	0.5857	0.5549	0.8962	0.4899	0.3475	0.3082	0.7482	0.7011
4	0.5799	1.1379	1.0554	1.4165	0.7619	0.6104	0.4618	0.4522	0.9923	0.7848
5	0.2901	1.1456	1.0650	0.8435	0.7943	0.3705	0.4275	0.4571	0.9960	0.9329
6	0.5309	0.9542	0.7278	0.7645	0.8891	0.5173	0.4524	0.3755	0.7012	0.8191
7+	0.5309	0.9542	0.7278	0.7645	0.8891	0.5173	0.4524	0.3755	0.7012	0.8191

	1983	1984	1985	1986	1987	1988
1	0.0514	0.0654	0.0535	0.0447	0.0217	0.0284
2	0.3418	0.5549	0.4548	0.3625	0.2503	0.1476
3	0.8266	0.9340	0.8250	0.9224	0.5299	0.4151
4	1.3679	1.0629	1.4436	0.5777	1.3048	0.4151
5	1.7248	1.0442	1.3620	1.0084	4.0393	0.4151
6	1.0588	1.0257	0.9927	0.8619	0.7330	0.4151
7+	1.0588	1.0257	0.9927	0.8619	0.7330	0.4151

Table A3 Mean weights at age (kg) from the commercial catch of silver hake from a) the northern stock and b) the southern stock (Tables F3a and F3b from NOAA 1990)

a)

	Age								
Year	1	2	3	4	5	6	7	8	9+
1955	.044	.132	[illegible]	.254	.331	.436	[illegible]	.573	[illegible]
1956	.053	[illegible]	.304	[illegible]	[illegible]	[illegible]	[illegible]	.567	[illegible]
1957	.044	[illegible]	.193	[illegible]	.322	[illegible]	[illegible]	.513	[illegible]
1958	.045	.127	.210	[illegible]	.341	[illegible]	[illegible]	[illegible]	[illegible]
1959	.051	.129	.190	[illegible]	[illegible]	.430	[illegible]	[illegible]	[illegible]
1960	.044	.127	.171	[illegible]	[illegible]	[illegible]	.512	[illegible]	[illegible]
1961	.063	.146	[illegible]	[illegible]	[illegible]	.410	.516	[illegible]	[illegible]
1962	.049	.133	.172	[illegible]	[illegible]	[illegible]	[illegible]	.619	.732
1963	[illegible]	.121	.176	[illegible]	[illegible]	.431	.573	[illegible]	[illegible]
1964	.073	.133	.171	[illegible]	.314	.434	[illegible]	[illegible]	.971
1965	.059	.147	.173	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1966	.065	.144	[illegible]	[illegible]	[illegible]	.427	[illegible]	.772	[illegible]
1967	.072	.153	[illegible]	[illegible]	.317	[illegible]	[illegible]	[illegible]	[illegible]
1968	.070	.161	.222	.276	[illegible]	.307	.442	[illegible]	[illegible]
1969	.044	.154	.301	.271	[illegible]	.373	.442	[illegible]	[illegible]
1970	[illegible]	.118	.178	[illegible]	[illegible]	[illegible]	.444	[illegible]	[illegible]
1971	.077	[illegible]	[illegible]	.311	[illegible]	.344	.437	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	.437	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1973	.119	.173	[illegible]	.414	.472	.344	.463	[illegible]	1.131
1974	.144	.217	.270	.314	[illegible]	[illegible]	[illegible]	1.114	[illegible]
1975	[illegible]	.167	[illegible]	.341	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1976	[illegible]	.162	[illegible]	[illegible]	.422	.472	[illegible]	[illegible]	[illegible]
1977	[illegible]	.172	.321	.277	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1978	.114	[illegible]	[illegible]	.277	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1979	[illegible]	[illegible]	[illegible]	[illegible]	.351	[illegible]	[illegible]	[illegible]	[illegible]
1980	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1981	.113	.167	[illegible]	[illegible]	[illegible]	[illegible]	.410	[illegible]	[illegible]
1982	.117	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1983	[illegible]	.173	[illegible]	.311	[illegible]	.431	[illegible]	[illegible]	[illegible]
1984	[illegible]	.176	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1985	[illegible]	[illegible]	[illegible]	[illegible]	.412	[illegible]	[illegible]	[illegible]	[illegible]
1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.421	[illegible]	[illegible]
1987	[illegible]	.149	.251	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1988	.101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

b)

	Age								
Year	1	2	3	4	5	6	7	8	9+
1955	.044	.091	.162	[illegible]	.307	.432	[illegible]	.462	[illegible]
1956	.034	.076	.154	.323	.314	.438	[illegible]	.444	.777
1957	.042	[illegible]	.157	.324	.326	.445	.512	[illegible]	[illegible]
1958	[illegible]	[illegible]	.152	.313	.310	.409	[illegible]	.462	[illegible]
1959	.033	[illegible]	.154	.327	[illegible]	.439	[illegible]	[illegible]	.973
1960	.047	.076	[illegible]	.316	.317	.443	.567	.782	[illegible]
1961	.077	[illegible]	.164	.317	.331	[illegible]	[illegible]	[illegible]	[illegible]
1962	.067	[illegible]	[illegible]	.315	[illegible]	.441	.444	[illegible]	[illegible]
1963	.076	.103	.161	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1964	.057	.107	.154	.310	.301	[illegible]	[illegible]	.651	[illegible]
1965	.063	.102	.133	[illegible]	[illegible]	.427	.512	.621	[illegible]
1966	[illegible]	[illegible]	.163	[illegible]	.311	.453	[illegible]	[illegible]	[illegible]
1967	.063	.072	[illegible]	[illegible]	[illegible]	.451	[illegible]	[illegible]	[illegible]
1968	[illegible]	[illegible]	[illegible]	[illegible]	.311	[illegible]	[illegible]	.567	[illegible]
1969	.044	.111	[illegible]	[illegible]	[illegible]	[illegible]	.517	[illegible]	[illegible]
1970	.049	[illegible]	.163	[illegible]	[illegible]	[illegible]	.443	[illegible]	[illegible]
1971	.057	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	[illegible]	.372	.451	[illegible]	[illegible]	[illegible]
1973	[illegible]	[illegible]	.251	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1974	.057	[illegible]	[illegible]	[illegible]	[illegible]	.413	[illegible]	[illegible]	[illegible]
1975	.111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1976	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1978	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1979	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.472	[illegible]	[illegible]
1980	[illegible]	[illegible]	.212	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1981	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1982	[illegible]	[illegible]	.210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1983	.113	[illegible]	[illegible]	.351	[illegible]	[illegible]	.512	[illegible]	[illegible]
1984	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1985	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.512	[illegible]	[illegible]
1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.512	[illegible]	[illegible]
1987	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1988	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table A4 Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) results for the northern stock of silver hake

```
              M =   .40    AGES =   1 TO   8

 PROPORTION OF NATURAL MORTALITY PRIOR TO SPAWNING =  .667
 PROPORTION OF FISHING MORTALITY PRIOR TO SPAWNING =  .667

    WEIGHTS AT AGE (catch) =     .120 1.    .180 2.    .240 3.    .350 4.    .490 5.
                                 .560 6.    .560 7.    .670 8.

    WEIGHTS AT AGE (stock) =     .120 1.    .180 2.    .240 3.    .350 4.    .490 5.
                                 .560 6.    .560 7.    .670 8.

    PARTIAL RECRUITMENT =       .0760 1.  .5830 2. 1.0000 3. 1.0000 4. 1.0000 5.
                               1.0000 6. 1.0000 7. 1.0000 8.

    PROPORTION MATURE =         .0000 1.  .5900 2.  .9500 3. 1.0000 4. 1.0000 5.
                               1.0000 6. 1.0000 7. 1.0000 8.
 ............................................... ..........
  FISHING   CATCH   YIELD PER  AVERAGE   SSB PER       %
 MORTALITY   NOS.  RECRUIT KG WT. KG   RECRUIT KG    MSP
     .0000   .0000     .0000    .0000       .4168   100.0000
     .0250   .0335     .0108    .3210       .3877    93.0059
     .0500   .0640     .0202    .3152       .3612    86.6623
     .1000   .1173     .0357    .3042       .3153    75.6550
     .1500   .1621     .0477    .2939       .2772    66.5118
     .2000   .2003     .0570    .2844       .2454    58.8673
     .2500   .2330     .0642    .2757       .2186    52.4344
     .3000   .2614     .0700    .2677       .1958    46.9861
     .3500   .2863     .0745    .2604       .1765    42.3427
     .4000   .3082     .0782    .2537       .1599    38.3608
     .4500   .3278     .0811    .2475       .1456    34.9254
     .5000   .3453     .0835    .2419       .1331    31.9444
     .5500   .3611     .0855    .2367       .1223    29.3430
     .6000   .3755     .0871    .2320       .1128    27.0605
     .6500   .3887     .0885    .2277       .1044    25.0475
     .7000   .4007     .0896    .2237       .0970    23.2633
     .7500   .4119     .0906    .2200       .0903    21.6743
     .8000   .4222     .0915    .2166       .0844    20.2529
     .8500   .4310     .0922    .2135       .0791    18.9760
     .9000   .4408     .0928    .2106       .0743    17.8241
     .9500   .4492     .0934    .2079       .0699    16.7810
    1.0000   .4571     .0939    .2055       .0660    15.8331
    1.0500   .4645     .0944    .2031       .0624    14.9686
    1.1000   .4715     .0948    .2010       .0591    14.1776
    1.1500   .4782     .0952    .1990       .0561    13.4517
    1.2000   .4845     .0955    .1971       .0533    12.7836
    1.2500   .4905     .0958    .1953       .0507    12.1669
    1.3000   .4963     .0961    .1937       .0483    11.5962
    1.3500   .5018     .0964    .1921       .0461    11.0668
    1.4000   .5070     .0967    .1907       .0441    10.5745
    1.4500   .5120     .0969    .1893       .0422    10.1158
    1.5000   .5168     .0972    .1880       .0404     9.6874
    1.5500   .5214     .0974    .1868       .0387     9.2865
    1.6000   .5259     .0976    .1856       .0371     8.9107
    1.6500   .5301     .0978    .1845       .0357     8.5570
    1.7000   .5342     .0980    .1834       .0343     8.2258
    1.7500   .5382     .0982    .1824       .0330     7.9129
    1.8000   .5421     .0984    .1815       .0318     7.6176
    1.8500   .5458     .0985    .1805       .0306     7.3385
    1.9000   .5494     .0987    .1797       .0295     7.0744
    1.9500   .5528     .0989    .1788       .0284     6.8241
    2.0000   .5562     .0990    .1780       .0275     6.5866

 F0.1 =    .4844   F0.1 YIELD =   .0828 kg   SSBPR01  =   .1368
 FMAX = 99.0000   FMAX YIELD =   .1149 kg   SSBPRMAX =   .0000

 %SSB/R (F0.1) =   32.83            %SSB/R (FMAX) =     .00
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Table A5 Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) results for the southern stock of silver hake

```
              M =   .40    AGES =   1 TO   8

PROPORTION OF NATURAL MORTALITY PRIOR TO SPAWNING =  .500
PROPORTION OF FISHING MORTALITY PRIOR TO SPAWNING =  .500

   WEIGHTS AT AGE (catch) =     .080 1.    .140 2.    .190 3.    .280 4.    .410 5.
                                .520 6.    .550 7.    .660 8.

   WEIGHTS AT AGE (stock) =     .080 1.    .140 2.    .190 3.    .280 4.    .410 5.
                                .520 6.    .550 7.    .660 8.

   PARTIAL RECRUITMENT =       .0690 1.  .4600 2. 1.0000 3. 1.0000 4. 1.0000 5.
                              1.0000 6. 1.0000 7. 1.0000 8.

   PROPORTION MATURE =         .0000 1.  .5900 2.  .9500 3. 1.0000 4. 1.0000 5.
                              1.0000 6. 1.0000 7. 1.0000 8.
......................................................... ..........
  FISHING    CATCH   YIELD PER  AVERAGE    SSB PER         %
 MORTALITY    NOS.  RECRUIT KG  WT. KG   RECRUIT KG       MSP
     .0000   .0000     .0000     .0000       .3820     100.0000
     .0250   .0319     .0089     .2804       .3565      93.3246
     .0500   .0609     .0167     .2746       .3333      87.2601
     .1000   .1117     .0294     .2635       .2930      76.7138
     .1500   .1545     .0391     .2533       .2595      67.9294
     .2000   .1910     .0466     .2440       .2314      60.5670
     .2500   .2223     .0523     .2354       .2076      54.3579
     .3000   .2496     .0568     .2276       .1875      49.0886
     .3500   .2734     .0603     .2204       .1703      44.5892
     .4000   .2945     .0630     .2139       .1556      40.7238
     .4500   .3133     .0652     .2080       .1428      37.3830
     .5000   .3302     .0669     .2026       .1317      34.4787
     .5500   .3454     .0683     .1977       .1220      31.9394
     .6000   .3593     .0694     .1932       .1135      29.7070
     .6500   .3720     .0703     .1891       .1059      27.7340
     .7000   .3837     .0711     .1853       .0992      25.9813
     .7500   .3944     .0717     .1819       .0933      24.4166
     .8000   .4044     .0723     .1787       .0879      23.0133
     .8500   .4138     .0727     .1758       .0831      21.7490
     .9000   .4225     .0731     .1731       .0787      20.6053
     .9500   .4307     .0735     .1706       .0747      19.5664
    1.0000   .4383     .0738     .1683       .0711      18.6192
    1.0500   .4456     .0740     .1662       .0678      17.7524
    1.1000   .4525     .0743     .1642       .0648      16.9565
    1.1500   .4590     .0745     .1623       .0620      16.2234
    1.2000   .4652     .0747     .1606       .0594      15.5461
    1.2500   .4711     .0749     .1589       .0570      14.9185
    1.3000   .4767     .0750     .1574       .0548      14.3354
    1.3500   .4821     .0752     .1559       .0527      13.7923
    1.4000   .4873     .0753     .1546       .0507      13.2852
    1.4500   .4922     .0755     .1533       .0489      12.8107
    1.5000   .4970     .0756     .1521       .0472      12.3657
    1.5500   .5015     .0757     .1509       .0456      11.9475
    1.6000   .5059     .0758     .1498       .0441      11.5537
    1.6500   .5102     .0759     .1488       .0427      11.1823
    1.7000   .5143     .0760     .1478       .0414      10.8314
    1.7500   .5182     .0761     .1468       .0401      10.4993
    1.8000   .5220     .0762     .1459       .0389      10.1845
    1.8500   .5257     .0763     .1451       .0378       9.8857
    1.9000   .5293     .0763     .1442       .0367       9.6017
    1.9500   .5328     .0764     .1434       .0356       9.3313
    2.0000   .5362     .0765     .1427       .0347       9.0737

F0.1 =    .4513   F0.1 YIELD =   .0652 kg   SSBPR01  =   .1425
FMAX =  4.7013    FMAX YIELD =   .0779 kg   SSBPRMAX =   .0115

%SSB/R (F0.1) =   37.30               %SSB/R (FMAX) =    3.01
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Figure A1 Trends in spawning stock biomass (SSB) for the northern stock of silver hake - projected data derived from Almeida 1987 (dashed line) and NOAA 1990 (solid line)

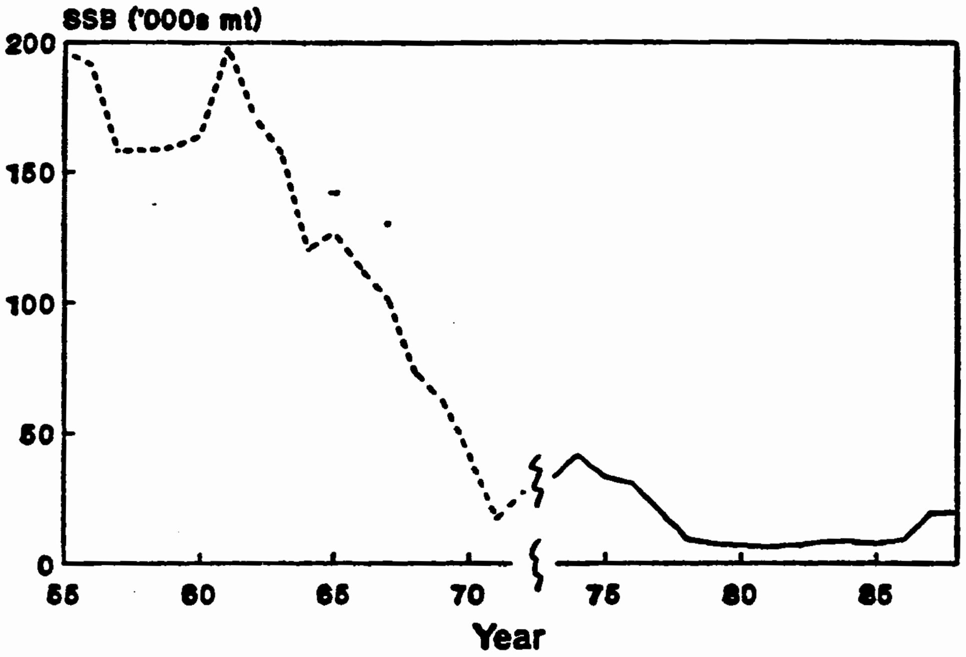

Figure A2 Trends in spawning stock biomass (SSB) for the southern stock of silver hake - projected data derived from Almeida 1987 (dashed line) and NOAA 1990 (solid line)

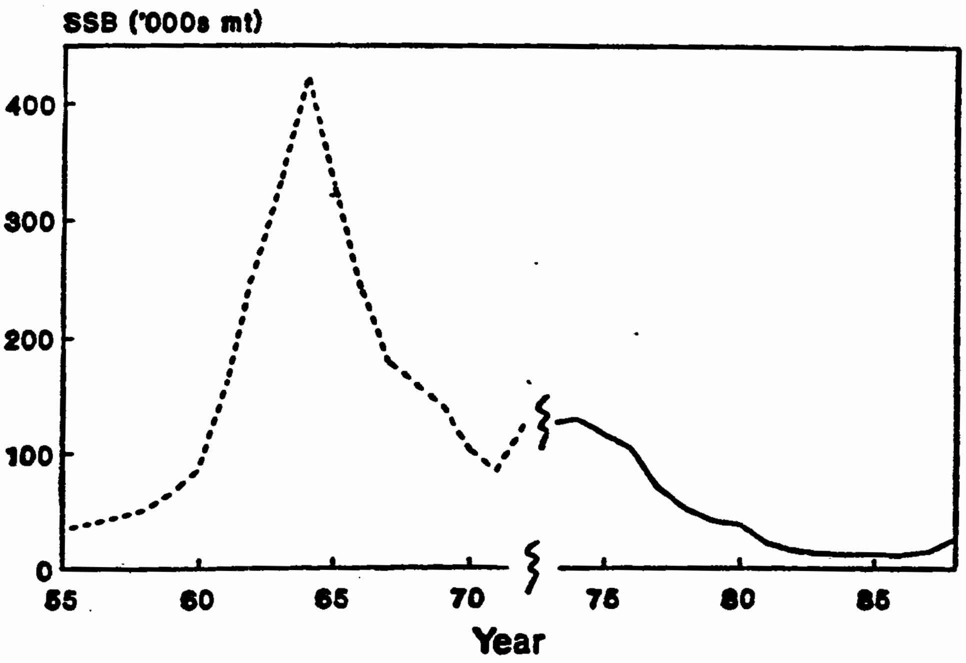

Figure A3 Spawner-recruit data for the 1973-86 year classes of the northern stock of silver hake. The solid line is the line that bisects the data.

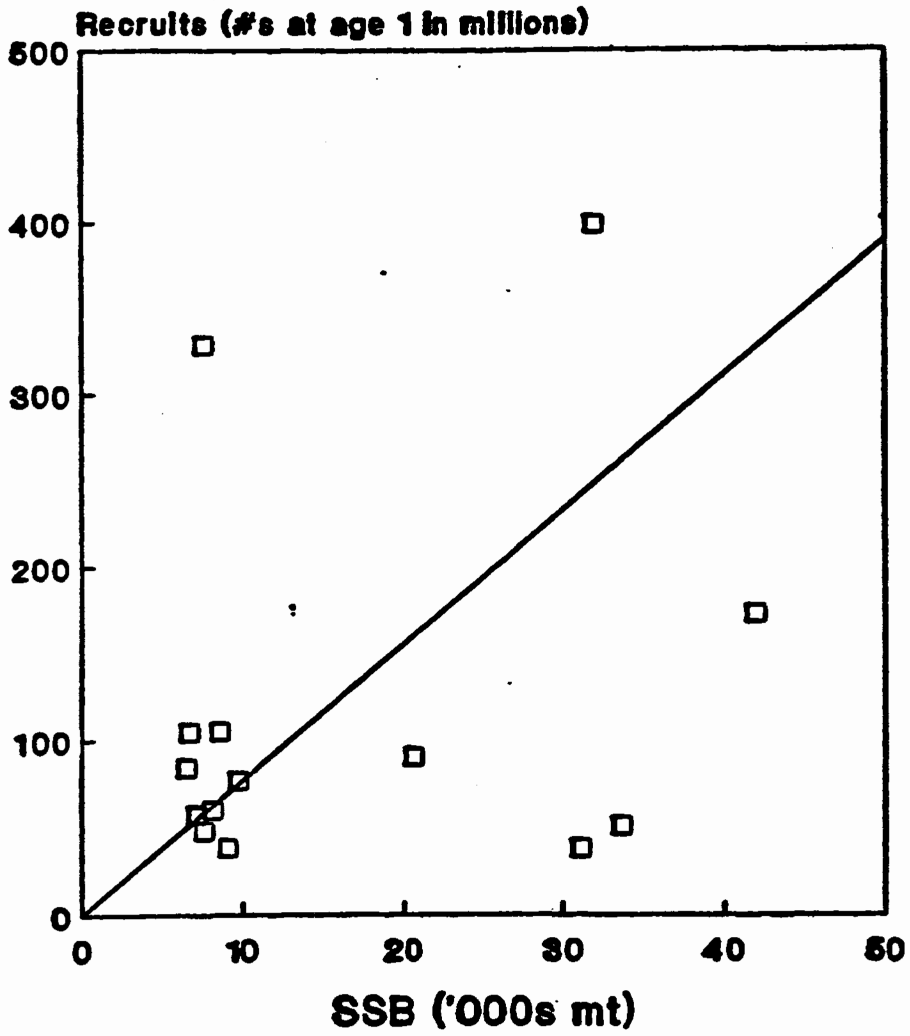

Figure A4 Spawner-recruit data for the 1973-86 year classes of the southern stock of silver hake. The solid line is the line that bisects the data.