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Evaluation of Changes in Weight-at-age for Divisions 4VWX Silver Hake, 1983–94

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Abstract

An apparent decrease in weight-at-length and weight-at-age of silver hake (*Merluccius bilinearis*) in 1994 in NAFO Divisions 4VWX was evaluated using Canadian Department of Fisheries and Oceans research survey data. Modal lengths-at-age for ages 1 to 3 over the 1983–94 time period showed a substantial decrease, and values for 1994 were the lowest in the series. Weight-at-length and associated parameters of a length/weight relationship also declined with an implied change in condition factor. Age determination was not identified as a contributing source of the decline and the survey was within a narrow time window. Apparent changes in the timing of spawning in relation to the time of the survey and a higher proportion of fish in post spawning condition were assessed to be the most likely source of changes in total weight. Annual variation in the distribution of silver hake in the Div. 4VWX area, particularly between the Bay of Fundy and Scotian Shelf, could also have been a contributing factor. The analyses indicated that a trend of decreasing weight-at-age had occurred and that mean weights-at-age for recent years were more representative for the current population.

Key words: age, distribution, length, Scotian Shelf, silver hake, weight

Introduction

Weight-at-age is an important element of the fish stock assessment process and variation in weight-at-age has direct implication on the calculation of stock parameters such as total biomass or yield. To reduce the impact of annual variation in weight-at-age, long-term averages are typically used for catch projections. However, this assumes no trend in weight-at-age. If a decreasing (or increasing) trend is observed and if this trend is expected to continue into the near future, then recent mean weights are more appropriate for catch projections.

In the 1994 review of stock status (NAFO, 1994) of silver hake (*Merluccius bilinearis*) in Div. 4VWX it was noted that mean weight-at-age and weight-at-length had shown a "marked drop in 1993 over previous years". Investigation at that time of possible causes for the drop concluded that the low length-weight parameters derived from the 1993 Canadian Department of Fisheries and Oceans summer survey were the source. However, the reason for the low parameters and the extent of any trend in weight-at-age was not resolved, and therefore average mean weights for the 1989–93 commercial fishery were used for the catch projection.

The present study was undertaken to examine weight-at-age and weight-at-length for the 1983–94 time period in order to document trends and to consider possible errors in the data. Timing of the Canadian summer survey, progression of length and age modes of the silver hake through the study period and the maturity composition and distribution of the population were evaluated. Recent changes in Canadian silver hake age determination responsibility and training have been fully documented (Hunt and Bourbonnais, MS 1994; Bourbonnais and Hunt, MS 1995). The authors reported a small bias between readers and therefore age determination was included as a potential factor in the evaluation of trends in weight-at-age.

Materials and Methods

The Canadian summer research surveys through 1983–94 were used as the source of data to ensure consistency in the methodology for data collection and fish measurements. Sampling protocol for these surveys was documented by Strong and Gavaris (MS 1995). These surveys cover the entire Div. 4VWX area from Cape Breton to the Bay of Fundy but, to provide a comparison with commercial fishery distribution, only information relating to the Scotian Shelf was used in the analyses of length and weight.

A length frequency of all fish caught in each representative tow was obtained, and one fish per sex per cm length interval was selected for detailed observations on length, individual weight, maturity stage and age. Therefore, it was necessary to use age/ length keys to derive population estimates. STRAP (Smith and Somerton, 1981) computer software was used for these calculations. The derived population length frequencies-at-age for 1983–94 were examined to compare progression of modal components over time and the assignment to age groups for these components.

Commercial fishery samples, collected at sea by observers, were used to calculate monthly mean length-at-age for the 1989–93 year-classes in the 1992–94 fishery. Growth history for these year-classes was plotted for ages 1 to 3 to evaluate consistency and trends.

The observed mean weight-at-length from research surveys for the 20–35 cm range was used as a subset to assess any trend over the time period and to determine if specific lengths accounted for the trend. Length-weight parameters for the entire observed length range, as well as for the 20–35 subset, were derived using a multiplicative model.

Maturity stage as described by Hunt, 1996, was used to calculate the proportion of the population in pre-spawning condition at the time of the survey. This information was used to estimate the potential influence of gonadal weight on the observed total body weight.

The influence of spatial distribution of the population within the Div. 4VWX geographic area was examined. Annual research survey abundance estimates for each of the Div. 4W, offshore Div. 4X and Bay of Fundy geographic areas were derived and used as a measure of stock distribution.

Results and Discussion

The population length frequency and derived age components for 1983–94 are shown in Fig. 1 for lengths from 6 to 35 cm. Age components are

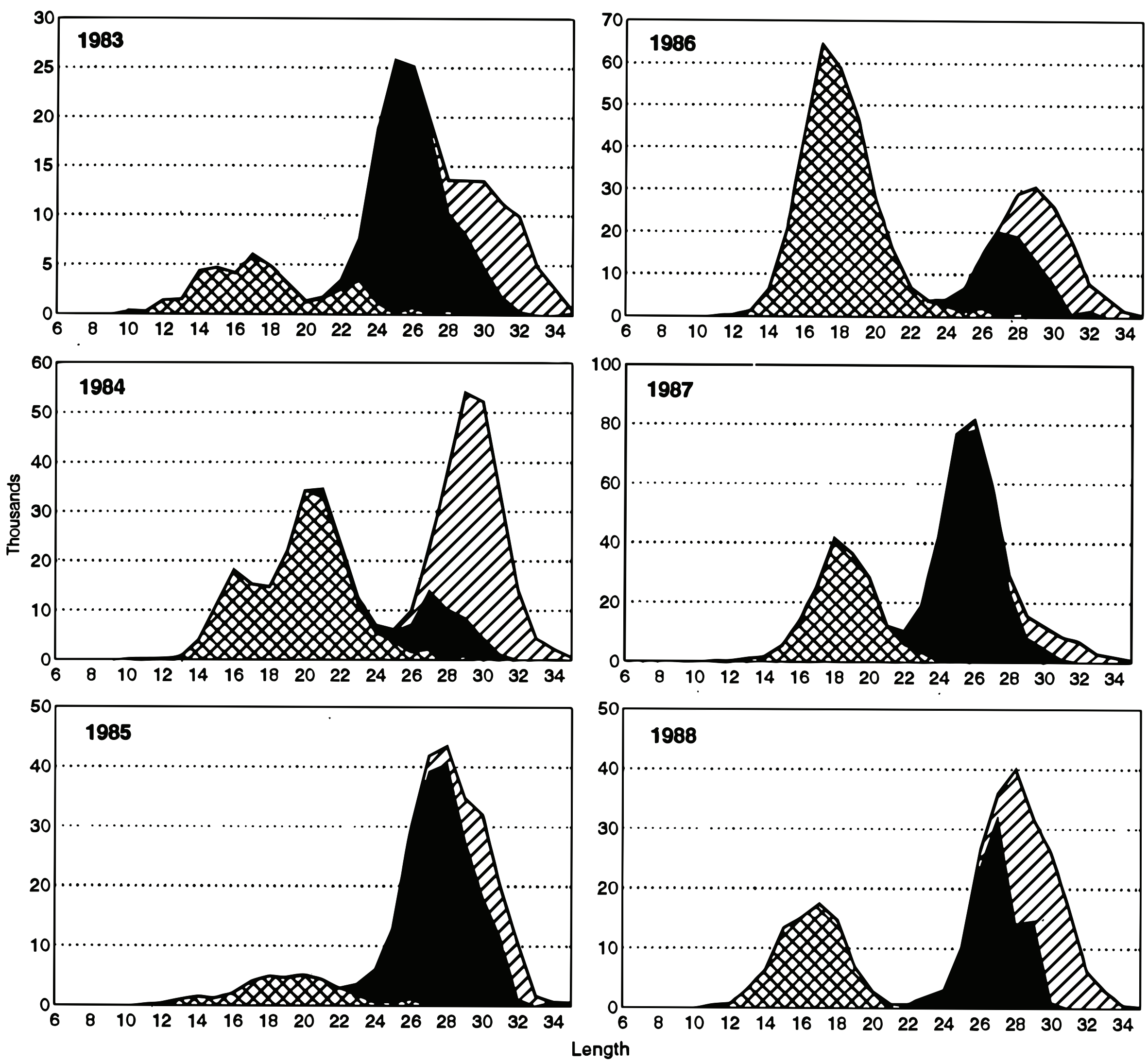

Fig. 1. Population length frequency-at-age of silver hake derived from 1983–94 research surveys. Corresponding age groups shown by cross-hatched (age 1), solid (age 2) and diagonal (age 3) shading.

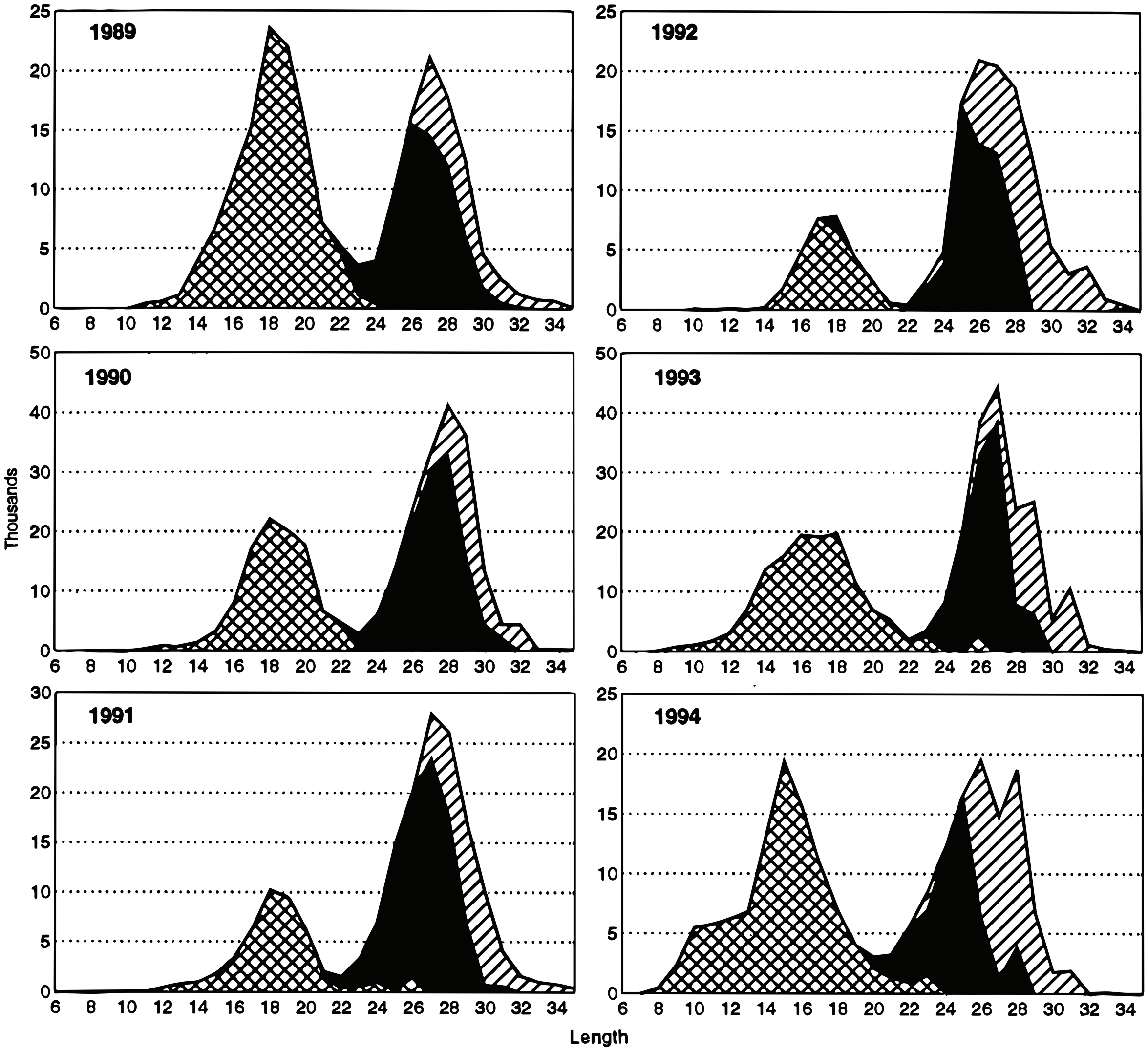

Fig. 1. (Continued). Population length frequency-at-age of silver hake derived from 1983–94 research surveys. Corresponding age groups shown by cross-hatched (age 1), solid (age 2) and diagonal (age 3) shading.

shown as shaded areas with the age 1 component in year *t* progressing at age 2 in year *t*+1 and age 3 in year *t*+2 for ages 1–3. Both the length and age modes appear to follow a logical progression with high abundance in one year reflected in the following year. For example, the very abundant group at 14–22 cm in 1986 (age1) appears as a strong component in 1987 at 22–28 cm (age 2). There do not appear to be many indications of incorrect assignment to age as might be reflected in substantial overlap or discontinuity in distributions.

It is apparent from Fig. 1 that the modal lengths have shown a substantial decrease in recent years and in particular those at age 1 in 1993 and 1994 are the smallest observed. There is also an increase in the number of fish less than 12 cm and in 1994 there is evidence of a bimodal distribution, similar to that seen in 1984 but at much smaller lengths. The variation in the modal length is more evident in Fig. 2 which overlays data for the 1983–94 time series.

Calculated mean length-at-age is given in Table 1 and in Fig. 3. The decrease in size-at-age appears to be most evident in the last three years of the series and occurs for all three age groups. Size-at-age in 1994 is about 2 cm less than the long-term average but the decrease appears to have been gradual with no indication of an abrupt change that might be associated with bias in age determination.

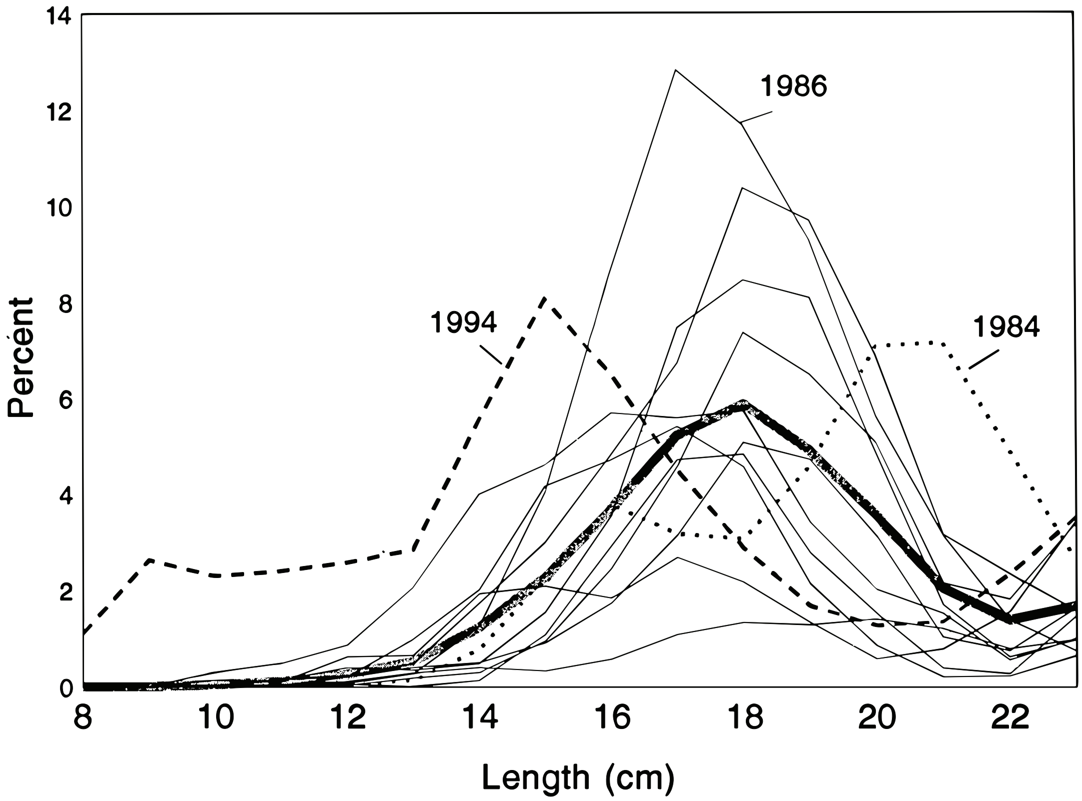

Fig. 2. Population length frequencies of silver hake from research surveys for fish ranging between 10–23 cm.

TABLE 1. Mean length-at-age for males and females combined, from 1983–94 Canadian summer surveys.

Year	Age 1	Age 2	Age 3
1983	17.41	26.12	30.95
1984	19.63	27.26	29.67
1984	18.97	27.70	30.30
1985	17.97	27.61	30.12
1986	18.49	25.78	30.32
1988	16.50	26.86	29.49
1989	18.11	26.61	28.84
1990	18.32	27.05	29.25
1991	18.35	26.44	29.38
1992	17.70	25.75	28.51
1993	16.73	26.25	28.75
1994	14.96	24.46	27.43

Mean length-at-age by month in the 1992–94 commercial fishery for the 1989–93 year-classes is shown in Fig. 4. Growth rate of the cohorts appeared to be consistent with monthly and annual increments. Results were also consistent with those of the research surveys and showed a substantial decrease in size-at-age over the time period. The apparent decrease in the size at age 1 between May and June, 1994 was probably due to the partial recruitment of the smaller mode seen in the 1994 survey data.

Weight-at-length derived from the 1983–94 survey data is shown in Fig. 5. Results indicate a relatively small variation in weight for most of the length range although there is some divergence at

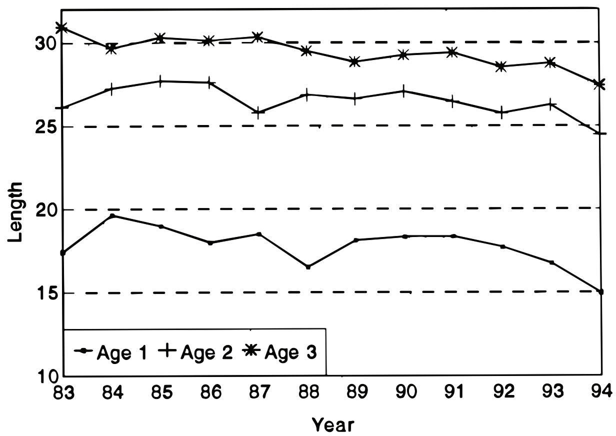

Fig. 3. Mean length-at-age of silver hake from research surveys.

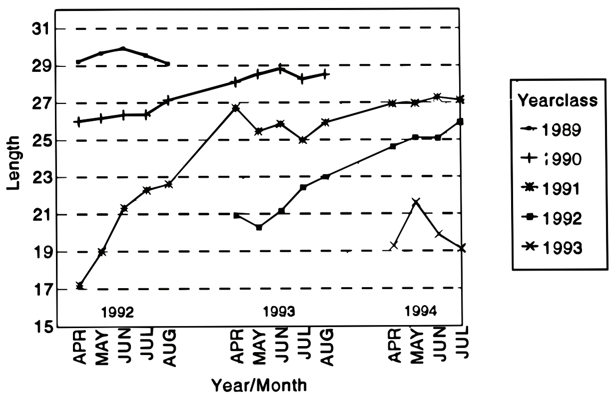

Fig. 4. Monthly mean length-at-age of silver hake from 1992–94 commercial fishery samples.

lengths >45 cm, probably due to small sample size. The observed weight-at-length is shown in Fig. 6 and there was evidence of some strong year effects. In particular, weights in 1990 appeared to be anomalously high while those in 1989 were below average. To investigate if this effect was evident for other species, a similar analysis for cod was completed for 1989 and 1990, but the year effect was not apparent. Data entry and editing were also verified with no evidence of measurement or calibration error. However, 1990 was the first year in which electronic balances were used to weigh fish. These balances provide a more precise measure of weight and also permit weighing of fish less then 50 g.

Annual parameters of the length-weight relationship, for the entire length range and for the 20–35 cm subset, are given in Table 2. The predicated weight at 25 cm using these parameters is also provided and is shown in Fig. 7. As expected, the values for 1989 and 1990 show a very abrupt change from one year to the next. However, the trend of decreasing weight-at-length since 1990 is evident with a slight increase in 1994 over 1993. The mean date of the research surveys is also given in Table 2. Timing of the survey varied between day 184 and 206, but there appeared to be no trend related to the timing of the surveys.

The proportion by maturity stage is shown in Fig. 8 and summarized for pre-spawning fish (stages R1, R2, ripe and spawning) in Fig. 9. The proportion was variable over the time series with some indication of a declining trend after 1991. This

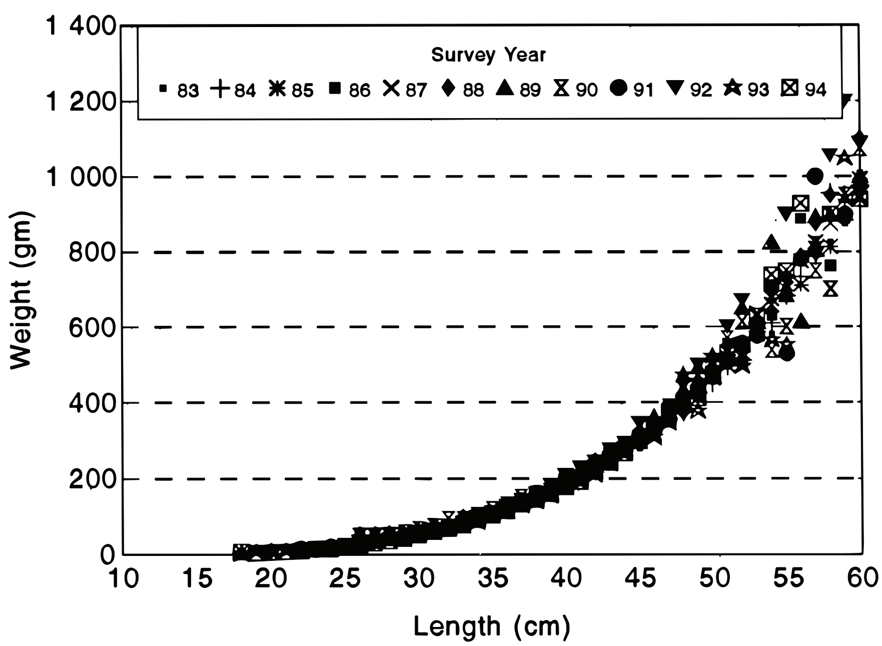

Fig. 5. Weight-at-length of silver hake derived from 1983–94 research surveys.

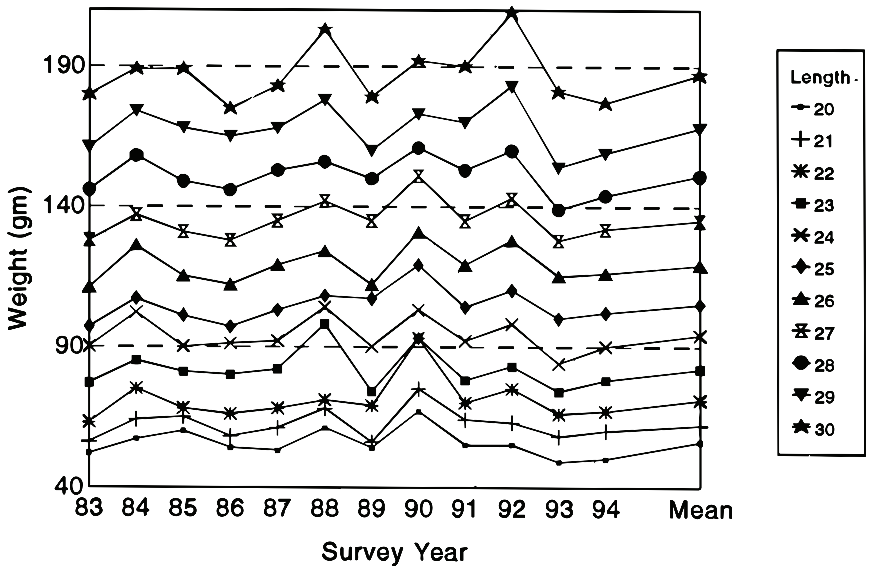

Fig. 6. Mean weight-at-length (20–30 cm) of silver hake from 1983–94 research surveys.

TABLE 2. Mean number of calendar days of the Canadian summer surveys, the estimated length/weight parameters for entire length range (total) and for the 20–35, cm subset (20–35), and the predicted values of weight for a 25 cm fish (weight (gm)) = (EXP a) × (Length (cm))^b.

Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Mean
Calendar days	196	206	195	198	189	195	196	194	195	184	196	195	195
a	-4.971	-4.714	-5.275	-5.091	-4.914	-5.189	-5.377	-4.222	-5.487	-5.754	-5.305	-5.472	-4.970
b^{total}	3.014	2.951	3.104	3.054	3.004	3.097	3.136	2.816	3.166	3.253	3.087	3.150	3.009
$L^{total}_{25\ cm}$	113.4	119.9	112.0	114.5	116.4	119.1	111.7	126.7	110.3	111.9	102.8	106.4	111.8
a	-5.572	-5.010	-5.035	-5.524	-5.439	-4.966	-5.560	-3.894	-5.464	-5.768	-5.646	-5.462	-5.260
b^{20-35}	3.161	3.018	3.013	3.153	3.136	3.015	3.166	2.698	3.147	3.257	3.181	3.132	3.084
L^{20-35}_{25-cm}	99.8	110.5	105.9	101.9	105.0	114.4	102.5	120.3	106.4	111.9	98.8	101.5	106.6

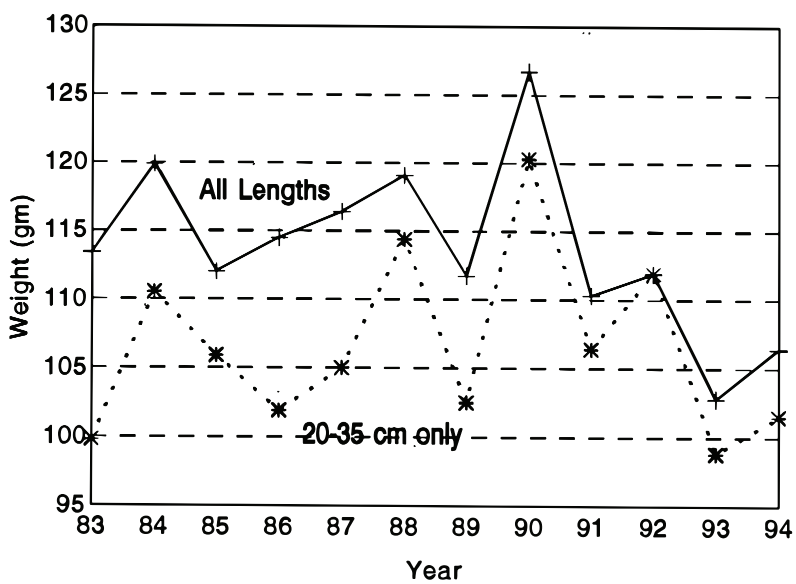

Fig. 7. Calculated weight at a length of 25 cm derived from annual length weight parameters.

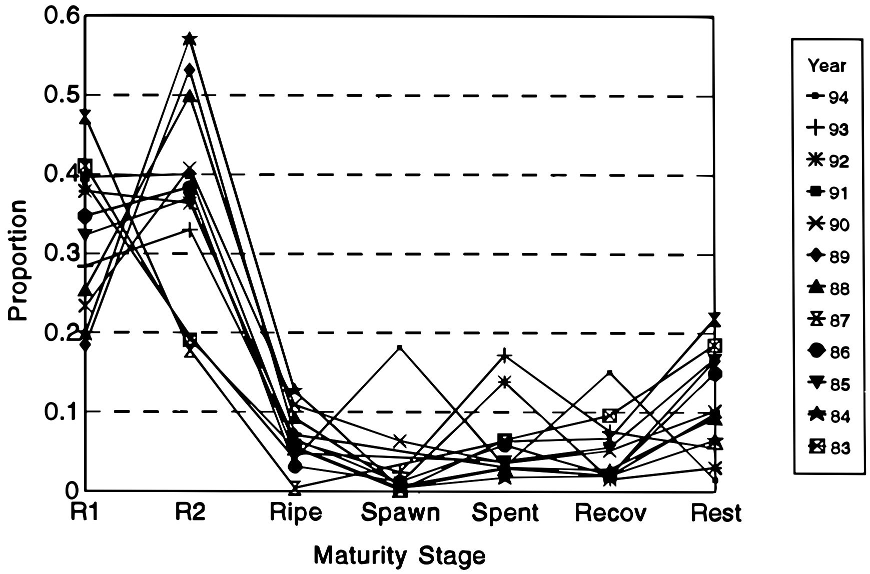

Fig. 8. Annual proportion at maturity stage of mature silver hake observed in research surveys.

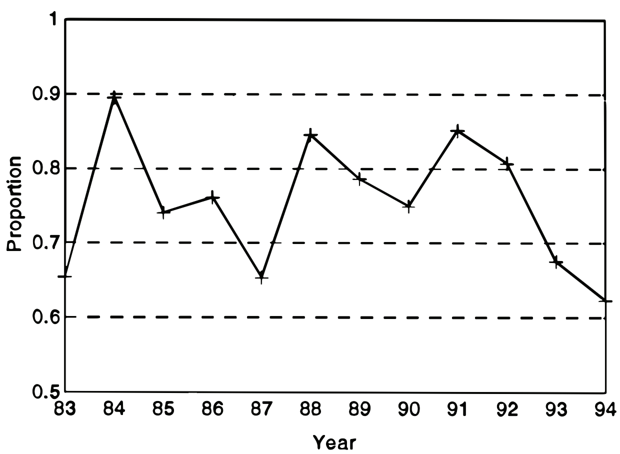

Fig. 9. Proportion of mature silver hake in pre-spawning condition observed in research surveys.

implies that more fish had completed spawning prior to the survey in the recent part of the time series and that the contribution of the gonad to total weight had therefore decreased.

The impact of maturity stage on weight for three length groups (26, 28 30 cm) is shown in Fig. 10. In general, weight-at-length increased as maturity progressed and then declined in the post-spawning stages.

The relative contribution of the three geographic areas is shown in Fig. 11. The Div. 4W area accounted for highest proportion of the abundance in most years but 1983, 1989 and 1992 showed a substantial contribution from the Div. 4X area. The Bay of Fundy typically contributed a small proportion but was above average in 1986 and again in 1993. The influence of area on size-at-age was not investigated, however, the apparent shifts observed could have produced changes in rates of maturation, specific growth rates and condition factors.

Conclusions

Results of this study confirm that a decrease in both size-at-age and weight-at-age of silver hake in the Scotian Shelf area has occurred in recent years. Age determination was not the source of this decrease. The change in size-at-age was consistent with the shift to smaller modal lengths in the length frequency, and the age data matched length modes with good correlation. The decrease in mean length appears to have been gradual rather than abrupt, as might be expected if an ageing bias or error had been introduced. With the analysis with length alone, the decline seen with age as a factor could be traced, and this further reduced the probability of any ageing error.

Changes in the timing of spawning in relation to the summer research surveys appear to be a factor that could result in an apparent reduction in fish total weight.

The apparent anomaly seen in the 1989 and 1990 weight-at-length may be associated with the methodology change from using spring balances

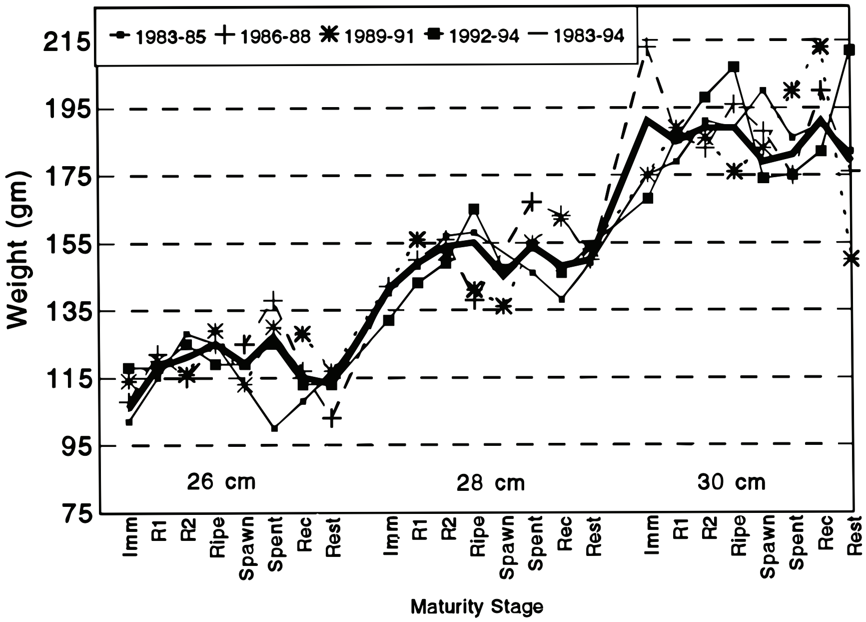

Fig. 10. Mean weight at 26, 28 and 30 cm by maturity stage of silver hake for 1983–85, 1986–88, 1992–94 and the 1983–94 average.

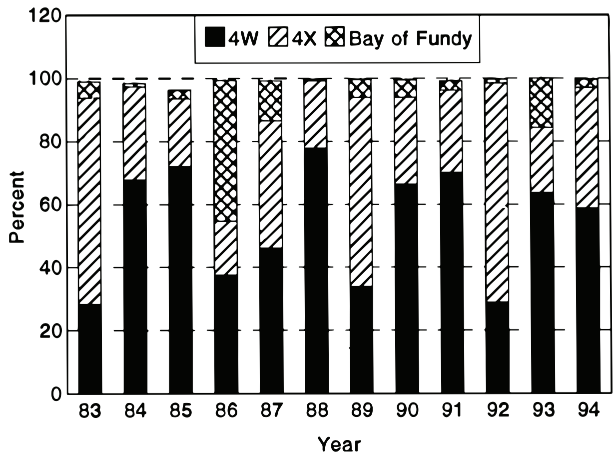

Fig. 11. Proportion of survey estimate of total silver hake abundance by area.

to electronic balances. It would therefore be more appropriate to consider the average weight-at-length derived from post-1990 samples, as these resulted from the use of more accurate electronic balances.

The trend of declining weight-at-age may continue into the near future and therefore the use of more recent average weights-at-age for catch projections is preferred. Using longer term data, and therefore higher values of weights-at-age, would tend to underestimate the exploitation rate at a given yield since a larger number of fish would be required to achieve the cumulative weight.

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