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Year-class Strength in the Scotian Shelf Silver Hake Stock

by

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Introduction

The importance of recruitment estimates in TAC projections for Div. 4VWX silver hake has long been recognized. Ages 2-4 comprise about 90% of the catch by weight. Thus, fish of the 1991 and 1992 yearclasses, which contributed to the 1993 fishery at ages 1 and 2, along with the 1993 yearclass, will essentially support the 1995 fishery.

Information available on yearclass strength includes commercial catch rates at age, Canadian standardized July bottom trawl survey estimates of population numbers at age, and O-group abundance estimates from joint Canada-Russia research vessel surveys in October-November. In the last three years, all of these abundance *estimates were* used to calibrate a sequential population analysis (SPA) using ADAPT. However, the estimates of the most recent yearclass from SPA (age 1 in the *most recent year*) was not accepted as it stood. Following previous practice, judgements were made each year about the strength of this yearclass, and also the yearclass to be recruited at age 1 in the assessment year, based on available indices of abundance. The yearclass recruited at age 1 in the projection year was taken as the geometric mean of past yearclass strengths. Thus, much of the projected catch in the following year continued to depend on these subjective judgements.

In the September 1993 stock assessment (Showell *et al.* 1993) a regression of yearclass abundance at age 1 from SPA on yearclass abundance at age 1 from July RV surveys was used to estimate the strength of the 1991 and 1992 yearclasses for projection purposes. No O-gp survey was conducted for the 1992 yearclass. An element of circularity in this calculation was recognized, as the RV survey age 1 estimates were used to calibrate the SPA, but it nonetheless removed much of the subjectivity from recruitment estimation.

The present paper investigates further how best to use the various estimates of silver hake yearclass strength in population size estimation and projection. An ancillary objective is to evaluate the usefulness of the O-gp survey, as budget cuts to both Russian and Canadian research programmes threaten its continuance.

Methods

The study is based on abundance estimates of the yearclasses 1981-1990 in O-gp surveys, at ages 1-3 in July RV surveys, and in the commercial fishery as evidenced by catch per unit effort (CPUE). As the O-gp survey series begins with the 1981 yearclass, the 1981-90 yearclasses are the only ones for which all estimates are available. The data are derived from Showell *et al.* (1993), except for the addition of data obtained in 1993. Indices of abundance for ages 2 and 3 from the July RV and for ages 1-3 from commercial CPUE were scaled to those of age 1 July RV based on the ratios of the series means, to facilitate graphical comparisons and combination of indices.

Yearclass size estimates from SPA were derived using the same ADAPT formulation as in Showell *et al.* (1993) but with 1993 data added to the calculation.

Results

Data exploration: The data series provide seven estimates of the 1981-90 yearclasses at ages 0-3 (Table 1). There are similar patterns in yearclass strength among the indices, the greatest difference being in estimates of the 1981 yearclass (Fig. 1). The O-gp and RV July age 3 indices show this as the strongest in the series, whereas the other five indices do not. This difference is the primary cause for the lack of correlation between O-gp and age 3 RV indices and the others and for the high correlation between the two indices (Table 2). The remaining five indices are well correlated among themselves, the only non-significant correlation being between CPUE ages 2 and 3.

The weight of evidence would suggest that the 0-gp estimate of the 1981 yearclass is an outlier because the 0-gp index agrees with only one of the six other indices when this yearclass estimate is included. Agreement with the other five indices is good, however, when the 1981 yearclass is excluded (Table 2), whereas agreement with the age 3 RV estimates deteriorates when the 1981 point is excluded. The 1981 0-gp survey marked the implementation of the survey design which has since been standard and the first two yearclass estimates (for 1981 and 1982 yearclasses) subsequently provided to be extreme values. While this may be coincidental, it could be a symptom of methodological problems. The data for these years could usefully be re-examined. In the meantime, however, it was decided to arbitrarily exclude the 0-gp estimates for the 1981 and 1982 yearclass from the data series. Exclusion of the 1982 yearclass estimate, as well as that for the 1981 yearclass, does not greatly change the correlation of the 0-gp series with the others (Table 2), although fewer correlations are significant because there are fewer degrees of freedom. The age 3 RV series is discounted in its entirety in this analysis.

Three yearclass strength indices were calculated for use in subsequent analysis. The two age 1 series were averaged to provide an age 1 index, the age 2 RV and the ages 2 and 3 (averaged) CPUE series were averaged to provide an ages 2 + 3 index, and ages 1 and 2 (averaged) RV and ages 1-3 (averaged) CPUE series were averaged to give an ages 1 + 2 + 3 index (Table 1). This averaging method gives equal weight to RV and CPUE data series. The ages 1 + 2 + 3 index, and the ages 2 + 3 index, were taken as the best estimates of the strengths of 1981-90 yearclasses, independent of SPA. The age 1 index, along with the 0-gp index, was used for recruitment estimation purposes.

Yearclass strength of 1981-90 yearclasses estimated from SPA calibrated with 1981 and 1982 0-gp data removed are virtually identical to those calibrated using all research vessel and commercial catch rate data (Table 1). Indeed, removing the entire 0-gp data set from the calibration changes the results only slightly (less than 5%), and only for most recent yearclasses (Table 1). Removal of the two age 1 indices, as well as the 0-gp indices, also does not change yearclass estimates significantly except for the 1990, which increases by 14%, and the subsequent yearclasses (Table 1).

Yearclass strength forecasting: The SPA estimates derived without using 0-gp and age 1 data in calibration are compared to 0-gp and age 1 indices and regressions calculated to provide a basis for yearclass strength forecasting. This avoids the criticism that the 0-gp and age 1 data are used on both sides of the regression, as in the case when SPA is calibrated using all the data. The 0-gp, age 1, and ages 2 + 3 indices all correlate well with SPA age 1 abundance, as follows:

Regression of SPA age 1 nos. on:	df	r	a	b
0-gp index	6	0.838**	40	0.4103
age 1 index	8	0.876**	74	0.2281
age 2 + 3 index	8	0.864**	51	0.3622

It is not surprising, however, that the 0-gp, age 1, and ages 1 + 2 + 3 indices have similar correlations with estimates from the SPA calibrated using all data, as it has already been shown that SPA estimates do not vary greatly whether or not 0-gp and age 1 data are included in calibration. These regression results are as follows:

Regression of SPA age 1 nos. on:	df	r	a	b	Figure Reference
0-gp index	6	0.823**	38	0.4086	Fig. 2
age 1 index	8	0.904**	70	0.2387	Fig. 3
age 1 + 2 + 3 index	8	0.901**	58	0.3115	

Forecasts of the strength of the 1991-93 yearclasses using the two sets of equations do not differ much:

SPA calibration	Index	Yearclass numbers (X 10^{-7}) at age 1: 1991	1992	1993
Excl. 0-gp and age 1	0-gp	72	-	117
	age 1	89	135	-
Incl. 0-gp and age 1	0-gp	70	-	114
	age 1	86	133	-

In conclusion, including 0-gp and age 1 data in the SPA calibration and also using these for forecasting is acceptable, because the data have little influence on the SPA yearclass strength estimates. The forecasts for the strength of the 1991 yearclass are essentially the same as that provided by the SPA when calibrated using all data. Thus, past practice of accepting the SPA estimate for the penultimate yearclass in the population matrix is supported. However, if the 0-gp and age 1 data are excluded from SPA calibration the 1991 SPA estimate was quite seriously overestimated (Table 1).

Yearclass strength variations: The indices of yearclass strength in each data series have ranges and coefficients of variation (CV), for 1981-90 yearclasses, as follows:

Index	Maximum	Minimum	Max./Min.	C.V.
0-gp	285	43	6.6	45
Age 1	494	50	9.9	84
Ages 2 + 3	391	93	4.2	52
Ages 1 + 2 + 3	437	85	5.1	64
SPA age 1 nos.	188	76	2.5	34

Variation in yearclass strengths is notably less in the SPA estimates than in the other indices. It is notable also that the above regressions between indices all have high intercepts. Two factors which could account for these observations are the SPA retrospective problem, as documented by Showell *et al.* (1993), and age assignment errors.

The retrospective problem would be expected to inflate more recent yearclasses in the SPA. The extent to which this affects the regressions would depend on the distribution of data points. If the most recent, and hence most inflated, estimates are towards the origin this could influence the slope and intercept substantially. However, there is not a strong association between yearclass strength estimates and their chronological sequence (Fig. 2 and 3). Thus, the retrospective problem would not appear to provide the primary explanation for these observations.

It is a feature of SPA that misassignment of ages, which occurs to some degree in the estimation of annual removals at age for all stocks, results in a smoothing of yearclass strength estimates. This reduces the range of estimates and, in particular, inflates the estimates of poor yearclasses. Ageing methodology and length-frequency weighting procedures have historically presented difficulties in silver hake assessments. Thus, errors in estimates of annual removals at age represent a credible explanation of reduced variation in SPA estimates of yearclass strength.

Conclusions

The 0-gp survey provides an index of pre-recruit yearclass strength which is well correlated with SPA yearclass abundance estimates. Indices at age 1 in July RV surveys and from commercial catch rates are also well correlated with SPA estimates. Thus there are two abundance estimates available for each yearclass prior to it making a significant contribution to the fishery, if both surveys continue to be conducted. Recruitment forecasts determine a large part of projected catches and it would therefore appear that continuation of the 0-gp survey is readily justifiable.

The relationships between 0-gp and age 1 recruitment indices and SPA age 1 estimates are not much affected by inclusion or exclusion of age 0 and 1 data in SPA calibration. Thus, the SPA calibration using all data series may as well be used. The 0-gp data for the 1981 yearclass, and possibly also the 1982 yearclass, are aberrant and should be excluded from regressions for yearclass strength forecasting. This is not a novel conclusion. These same data points were excluded from correlation analyses by Rikhter (1993). The 0-gp estimates for 1981 and 1982 yearclasses make no difference to SPA calibration, however. The data for these yearclasses, and from the 0-gp surveys in general, could usefully be reanalysed, now that a time series is available, to see if new estimation procedures can improve the relationships of estimates with other indices.

Despite the good correlations between abundance indices and SPA yearclass strength estimates, a serious bias in these SPA estimates is apparent. Poor yearclasses will be overestimated and good ones underestimated from Fig. 2 and 3, and projections will give overestimates and underestimates, respectively, of potential catches. Confidence limits of the intercept in the 0-group regression (Fig. 2) are wide and include the origin, but the intercept in the age 1 regression (Fig. 3) has narrow confidence bands (±0.2 billion fish) which exclude the origin. The regression of SPA age 1 numbers on the age 1 index (Fig. 3) cannot estimate a yearclass size lower than 0.7 billion fish. Thus, at a yield-per-recruit of 0.06 kg (Waldron *et al.* 1991), the minimum catch at $F_{0.1}$ is about 40,000 t even though no fish are caught in surveys or in the commercial fishery at age 1. This is an important deficiency in the SPA results.

An alternative method of estimating yearclass strength is to use a relationship which goes through the mean of the data points and the origin. The primary assumption here is that the mean yearclass strength from SPA is unbiased. If the ageing errors which cause misallocation of catches to age groups are random, then the mean of SPA age 1 numbers should be unbiased even though the individual estimates are biased. This gives forecasts for yearclass strengths as follows:

	Yearclass strength at age (x 10^{-7})		
Equation	1991	1992	1993
Age 1 no. = 0.63 (0-gp index)	50	-	118
Age 1 no. = 0.65 (age 1 index)	44	172	

This forecasting method, although *ad hoc*, avoids carrying forward into catch projections the biases in SPA, as far as these yearclasses are concerned. Nonetheless, the preferred solution would be to improve the estimates of removals at age used as input to the SPA calculation so that yearclass resolution is improved. This is not only a question of otolith age reading precision but of temporal and spatial stratification used in construction of age-length tables in the derivation of annual estimates of removals at age. A thorough review of estimation procedures for removals at age might prove rewarding.

Acknowledgements

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References

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Table 1. Yearclass strength indices for Scotian Shelf silver hake from Showell *et al.* (1993) updated with 1993 data. Indices for ages 2 and 3 RV July and ages 1-3 CPUE are scaled to those for age 1 RV July based on ratio of means. Yearclass strength from SPA uses same ADAPT formulation as Showell *et al.* (1993) with 1993 removals added to the data series.

	Yearclass												
Parameter	81	82	83	84	85	86	87	88	89	90	91	92	93
0-group no./tow	579	9	232	43	285	198	102	205	132	187	79	-	187
Age 1 RV July	192	114	189	103	553	146	70	172	117	67	45	166	-
Age 2 RV July	167	107	265	129	409	138	98	193	130	86	-	-	-
Age 3 RV July	543	88	185	120	211	62	109	91	120	195	-	-	-
Age 1 CPUE	236	56	501	97	434	79	39	211	39	32	89	364	-
Age 2 CPUE	173	72	159	126	469	91	140	232	122	140	-	-	-
Age 3 CPUE	235	86	294	180	275	186	114	150	96	106	-	-	-
Age 1 + 2 + 3 Index	197	91	273	125	437	130	91	190	105	85	-	-	-
Age 2 + 3 Index	186	93	246	141	391	138	113	192	120	105	-	-	-
Age 1 Index	214	85	345	100	494	113	55	192	78	50	67	265	-
Age 1 SPA Nos. (x 10^{-7})													
- using all data	158	84	138	76	188	82	79	117	96	97	82	266	-
- excluding 0-gp data for '81 & '82 yc	158	84	138	76	188	82	79	117	95	96	80	265	-
- excluding all 0-gp data	158	84	138	76	188	82	79	117	95	93	86	266	-
- excluding all 0-gp + age 1 data	158	84	138	76	188	82	79	117	98	110	108	863	-

Table 2. Correlation (r) matrix for Scotian Shelf silver hake yearclass strength indices from Table 1. (Significance at 5% and 1% levels is indicated by one or two asterisks respectively.)

	0 group	Age 1 RV	Age 2 RV	Age 3 RV	Age 1 CPUE	Age 2 CPUE	Age 3 CPUE
0 group	X	0.385	0.368	0.891**	0.469	0.364	0.587
Age 1 RV	0.385	X	0.895**	0.230	0.719*	0.929**	0.666*
Age 2 RV	0.368	0.895**	X	0.188	0.865**	0.887**	0.793**
Age 3 RV	0.891**	0.230	0.188	X	0.330	0.215	0.445
Age 1 CPUE	0.469	0.719*	0.865**	0.330	X	0.652*	0.906**
Age 2 CPUE	0.364	0.929**	0.887**	0.215	0.652*	X	0.555
Age 3 CPUE	0.587	0.666*	0.793**	0.445	0.906**	0.555	X
0-gp excluding 81 yc		0.640	0.715*	0.538	0.676*	0.676*	0.663
0-gp excluding 81 & 82 yc		0.704	0.740*	0.465	0.695	0.644	0.583

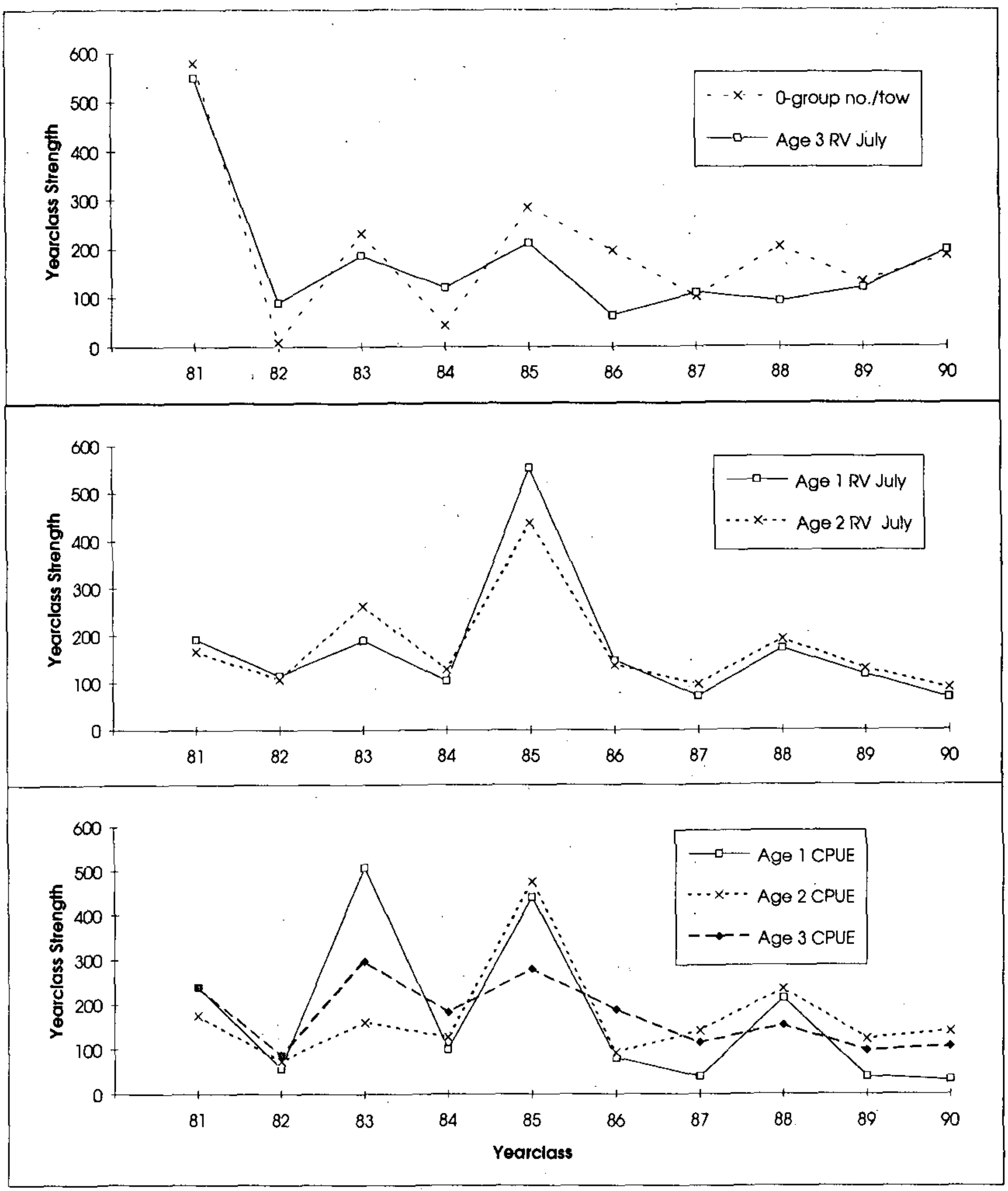

Figure 1: Division 4VWX silver hake research vessel and commercial catch rate indices of yearclass strength.

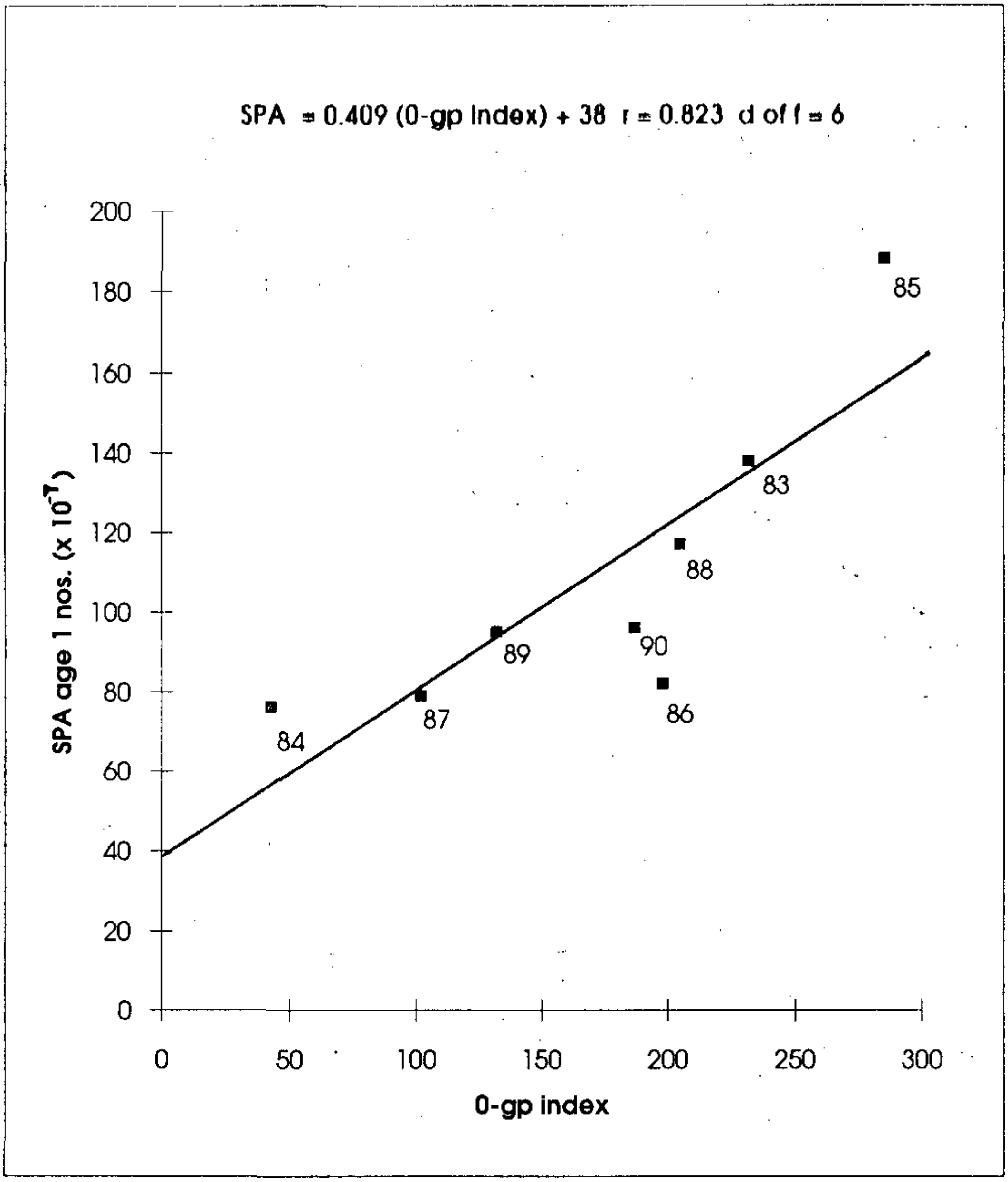

Figure 2: Division 4VWX silver hake: regression of SPA age 1 numbers against the 0-group index, 1983-90 yearclasses. (1981 and 1982 points in 0-group series excluded from SPA calibration.)

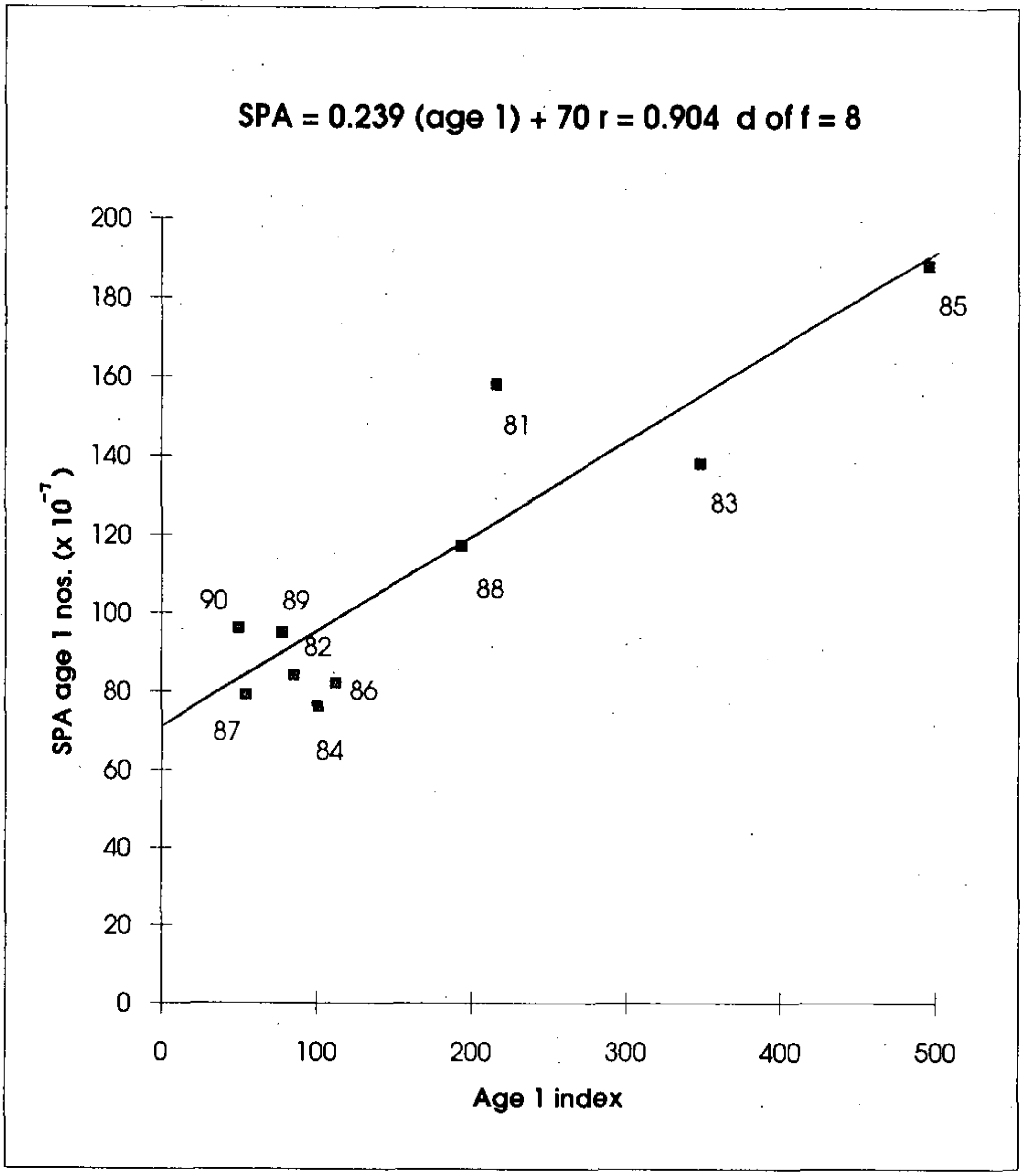

Figure 3: Division 4VWX silver hake: regression of SPA age 1 numbers against the age 1 index. (1981 and 1982 points in 0-group series excluded from SPA calibration.)