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Mortality rates for 0-Group Silver Hake on the Scotian Shelf

by

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Abstract.-

The Leslie matrix algorithm has been utilized to estimate the mortality rate for the 0th Silver hake year class. Assuming an equilibrium population, the mortality rate obtained indicates about 4 survivors per million eggs in the first year of life.

Introduction.-

The Silver hake, Merluccius bilinearis, is one of the most important groundfish species on the Scotian Shelf (NAFO Div. 4VWX). This population has been systematically studied since 1962, although the first instantaneous natural mortality coefficients for 1+individuals were estimated in 1977.

The goal of this paper is to employ an indirect method in order to estimate the natural mortality rate of the 0th year class, based upon fecundity-at-age data and age specific probabilities of survival derived from a VPA, assuming equilibrium and non equilibrium conditions for the population.

Materials and Methods.-

The fecundity-size relationship of Marí and Ramos (1979) for Scotian Shelf Silver hake was employed. This information is shown in Table 1, together with the instantaneous total mortality rate and the probability of survival. The total mortality rate was obtained from the fishing mortality rate found in Clay (1980) using a natural mortality rate (M=0.4), estimated by Terré and Marí (1977). Fecundity-at-age was calculated by the equation, $F = 15.82\ L^{2.72}$.

The method employed for age determination was that of Marí (1980), as described in the guidelines developed by the ICNAF workshop, and summarized by Hunt (1980).

The survival rate of the 0th year class (P_0) *was estimated by means of the procedure outlined in Vaughan and Saila (1976), for the Atlantic bluefin tuna, deriving the estimate of* P_0 *from a Leslie matrix.*

Results.-

Since 1977, all the Silver hake assessments in the Scotian Shelf employ the value M=0.4 for the age groups 1+, but this value is extremely low for the 0th age group.

By means of the equation:

$$P_0 = \frac{R}{m_i + \sum_{i=1}^{k-1} (m_{i+1}/R^i) \prod_{j=1}^{i} P_j} \quad ------ (1)$$

in which: m_i = *fecundity per individual of age i, i=1, 2, ..., k-1*

P_i = *age specific survival rate, or probability that an individual reaching age i will survive to age i + 1*

R = $n_i(t)/n_i(t-1)$ *(the only positive, real latent root, or dominant latent root, of the Leslie matrix).*

The survival rate P_0 and instantaneous mortality coefficient, M_0, were estimated. The parameter R is related to the intrinsic capacity for population increase, r, by

$$r = \ln R$$

R=1 implies an equilibrium population, $R < 1$ implies an exponentially decaying population, and $R > 1$ implies an exponentially growing population.

The calculations were done in two ways. First, a value of R=1 was assumed (equilibrium population), and the mean survival rate by ages for the period 1970-79, obtained from the table of fishing mortality by ages and years found in Clay (1980), was used to estimate P_0, using equation (1).

The value obtained was:

$$P_0 = 4.37 \times 10^{-6}$$

As $P=e^{-z}$, $z= -\ln (P)$, and since there is no fishing mortality for the 0^{th} age group, $M_0 = -\ln (P_0) = 12.341$.

These results show that there are about four survivors from one million eggs.

Later, a value of P_0 for each year was estimated (assuming an equilibrium population), and the value for M_0 were averaged finding a mean, $\overline{M}_0 = 12,438 \pm 0.354$ (Table 2).

It can be clearly seen that small variations in M_0 give large variations in survival. If both the lower and upper limits or the confidence interval for $\overline{M}_0$ are taken and the corresponding survival rates are found, it can be seen that the value found for the upper limit is about half the value found for the lower limit. These large variations in survival rate from small variations in mortality rates could account for the observed variability in year class abundance.

As the Silver hake population is not really in equilibrium, due to yearly changes in recruitment or fishing effort, a value of R was calculated for each year. Since the calculation of the latent roots of a matrix can be cumbersome, another approach was taken. R is also the ratio of the number of individuals of a given age in the population in two consecutive years $(R=n_i(t)/n_i(t-1))$. Finding the mean R for each year as the ratio $\sum n_i(t)/\sum n_i(t-1)$, a value of P_0 was found for each year using equation (1) and the corresponding values of M_0 were averaged. The mean, $\overline{M}_0=12.559 \pm 0.250$ is not significantly different from the mean value of M_0 found above under the assumption of a stable population (R = 1).

A mean value of R for the period 1970-79 was found (0.95, an exponentially decaying population). Using this value of R in equation (1), a value of $M_0=12.433$ was estimated.

The values found in this paper are higher than those of Vaughan and Saila (1976) for the Atlantic bluefin tuna. Considering the fecundity-at-age of Silver hake and the Atlantic bluefin, the results seem to be logical.

References.-

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Table 1.- Basic data for deriving the Leslie matrix for Silver hake.

Age Class	Length	Instantaneous total mortality rate (Z_X)	Probability of survival [a] (P_X)	Fecundity [b] (M_X)	F_X [c]
0				0	0
1	18.54	0.4931	0.6107	0	72563
2	26.60	1.0351	0.3552	118819	80257
3	33.69	0.9587	0.3834	225748	137579
4	39.93	0.9231	0.3973	358708	202198
5	45.41	0.9978	0.3687	508931	1836430
6+	50.23		0.0000	4980825	

[a] $P_X = N_{X+1} / N_X = \exp(-Z_X)$

[b] $\text{FECUNDITY} = 15.82\ (\text{Length})^{2.72}$

[c] $F_X = P_X M_{X+1}$

Table 2.- Survival rate (P_0)(10^{-6}) and instantaneous natural mortality rate for the period 1970-79.

R	Year	70	71	72	73	74	75	76	77	78	79	MEAN
R=1	P_0	4.83	3.88	5.34	1.10	4.01	5.91	4.61	1.59	2.35	2.00	
	M_0	12.24	12.46	12.14	11.41	12.48	12.03	12.28	13.29	12.95	13.12	12.43
R≠1	P_0	3.23	6.66	3.38	4.31	4.75	3.11	3.11	1.81	3.26	2.08	
	M_0	12.64	11.92	17.59	12.35	12.25	12.68	12.68	13.22	12.63	13.08	12.55