Northwest Atlantic Fisheries Organization

Serial No. N048 NAFO SCR Doc. 80/II/16

SPECIAL MEETING OF SCIENTIFIC COUNCIL - FEBRUARY 1980

An Indirect Method of Estimating Maturation Rates of Cohorts of Capelin

by

G. H. Winters, J. E. Carscadden and D. S. Miller
Department of Fisheries and Oceans, Northwest Atlantic Fisheries Center
P. O. Box 5667, St. John's, Nfld., Canada, A1C 5X1

INTRODUCTION

The development and application of sequential computation models for estimation of year-class strengths and population biomass levels of capelin (Carscadden et al. 1978; Carscadden and Miller 1979; Miller and Carscadden 1979) have contributed substantially to our understanding of recent dynamics in the population status of capelin in the ICNAF Area. However, due to the very high spawning mortalities associated with the reproductive activities of capelin (Winters and Campbell 1974; Carscadden and Miller 1979), estimates of historical population sizes by such SCAM models are highly sensitive to age-and-time-specific maturation parameters. Previous SCAM models have assumed a constant maturation rate for all year-classes. Carscadden and Miller (this meeting) have attempted to calculate cohort maturation rates for 2J-3K capelin from average back-calculated lengths-at-age (Winters 1974a) in combination with empirical data on growth increments of year-classes of capelin from the fall period to the spawning season in 3K. This document presents an alternative method of calculating age-specific maturation rates based on catch-per-unit-effort (CPUE) data for the 2J-3K capelin fishery.

METHODS AND MATERIALS

Although there is little direct information on the seasonal migration patterns of capelin in Div. 2J-3K, a variety of authors (Kovalyov and Kudrin 1973; Winters 1974b; Carscadden 1976; Seliverstov and Serebrov 1979) have suggested a general over-wintering migration from Div. 2J to Div. 3K during the fall period. These conclusions are based mainly on the temporal and spatial distribution of the commercial fleet, complemented by research vessel survey data. Considering that there are no known offshore spawning areas in Div. 3K, one may infer that such migrating fish are predominantly mature, and this conclusion is supported by analyses of maturity data from the commercial fishery (Miller and Carscadden 1979). If this is indeed the case, then the age-compositions of commercial catches in Div. 2J-3K during the fall period should be very similar to the age-compositions of spawning capelin sampled from inshore beaches in Div. 3K. Table 1 indicates that such age-compositions are very similar and suggests rather strongly that the fishery in Div. 2J-3K is based essentially on maturing fish which will spawn inshore during the subsequent summer. Thus one can consider that the rate of recruitment (i.e. partial recruitment rate) is equivalent to the age-specific maturation rate. Given a time series of CPUE data, it is therefore possible to calculate the total instantaneous mortality rate (Z) of a year-class from time t to time t_{+1} from the following formula:

$$Z_t = \ln \left(\frac{CPUE_t \cdot P_{t+1}}{CPUE_{t+1} \cdot P_t}\right) \qquad .... (1)$$

where $CPUE_t$ = Catch rate of a year-class in year t

$CPUE_{t+1}$ = Catch rate of the same year-class in year t+1

P_t = proportion mature of a year-class in year t (equivalent to partial recruitment rate)

P_{t+1} = proportion mature of the same year-class in year t+1

Furthermore, the total mortality rate of a cohort from time t to time t+1 is defined as:

$Z_t = M_t - \ln (P_t e^{-S_t} + (1-P_t))$ .... (2) (Carscadden and Miller 1979)

where M_t = natural mortality rate attributable to causes other than spawning

P_t = proportion mature in year t

S_t = spawning mortality in year t

Z_t = instantaneous mortality rate in year t

If S_t is known for a particular age-group, a series of tables can be constructed from equation (2) relating Z to P for specific values of M. Table 2 provides an illustration of such a tabular array. Since P_{t+1} in equation (1) is known, or assumed, and M_t and S_t for equation (2) are known, then there is a unique solution to equations (1) and (2) for Z_t and P_t. This unique value of P_t then becomes P_{t+1} in the sequential calculation of the cohort's maturation history.

Age-composition data of commercial catches in Div. 2J-3K are available from Carscadden and Miller (this meeting). CPUE data refer to the USSR BMRT-A class as provided by Seliverstov and Serebrov (1979) for the period 1972-78 and by Carscadden (pers. comm.) for 1979. Age-specific spawning mortality are those given by Carscadden and Miller (this meeting).

RESULTS

Catch-per-unit-effort data are shown by age-group for the 1968-77 year-classes in Table 3. Note that in nearly all cases, the CPUE peaks at age-group 3+ (i.e. spawning age-group 4) suggesting that most year-classes have substantially matured by then. Furthermore, the 1973 year-class has the highest CPUE in all age-groups suggesting that it has been the strongest year-class in the past decade and that year-classes since then have been relatively weak.

Table 4 illustrates Z values for the 1968-76 year-classes, unadjusted for changes in partial recruitment from year to year. It suggests that some year-classes are not completely mature until age-group 7 (6+). The two anomalous values (1971 and 1972 year-classes) are probably due to aging errors in the older age-groups and/or biassed sampling particularly as 5+ and 6+ year-olds in 1977. This contention is further supported by the much greater representation of older fish in age-samples from the fall period of 1977 compared with mature spawning capelin in 1978 (Table 1).

Table 5 presents the age-specific P_t values corresponding to the unique solution of equations (1) and (2), based on the CPUE data given in Table 3, assuming M = 0.30 and that all 6+ year-olds are fully mature. The latter assumptions appears quite valid, given the absence of 7+ year-olds in the catch-at-age data and the mean length of 6+ year-olds in relation to length-maturity ogives (Carscadden and Miller, this meeting). A value of P_t = 1.00 was also used for the terminal ages of the 1974 and 1975 year-classes since the Z values for these age-groups were very high.

There is evidently considerable variation in maturation rates between year-classes, particularly in the younger age-groups. The average values derived for the entire period are, however, very consistent with the values assumed by STACRES at its Special Meeting in 1979 (Anon. 1979).

DISCUSSION AND CONCLUSIONS

The above analyses ignore the effect of fishing mortality in the calculation of P_t values from estimates of Z derived from catch rate data. If the assumed value of M were correct, the non-adjustment of Z values to account for the effect of fishing mortality rates would tend to bias upwards the estimates of P_t thereby obtained. Since F values are fairly low in the younger age-groups (2 and 3) (Carscadden and Winters, this meeting) this bias may not be significant. Furthermore, the natural mortality rate (M) has been assumed to be constant during the period of these analyses (1972-79), although during this same period there has been a dramatic attrition in the stock size of 2J3KL cod (Wells, pers. comm.) which predate heavily on capelin. From this perspective M might have been expected to decline during the 1970's. However, fishery removals of capelin increased substantially during the 1970's and thus may have compensated for the decreased predation mortality due to cod. Therefore, the potential bias in the above analyses due to the non-adjustment of Z for F may not be significant, since F could be considered as being included in the constant M value used.

An evaluation of the accuracy of the cohort maturation rates given in Table 5 may be done by a comparison of the age-composition of the spawning capelin as predicted by SCAM (Carscadden and Winters, this meeting) with those observed from actual sampling data of spawning capelin in 3K. The results (Table 6) indicate that the predicted and observed age-compositions are very similar thereby adding confidence in the reliability of the sequential population analyses. A particular reference point is the good agreement in the 1979 relative age-composition, since both age-groups 3 and 4 have been predicted from regression analyses of N_t from SCAM and CPUE data (Carscadden and Winters, this meeting).

REFERENCES

Anon. 1979. Report of Standing Committee on Research and Statistics (STACRES). Special Meeting on Capelin and Squid, February 1979. ICNAF Redbook: 29-46.

Carscadden, J.E. 1976. Biological characteristics of capelin (Mallotus villosus) from Div. 3K and 2J in November 1975. ICNAF Res. Doc. 76/ Vi/62.

Carscadden, J.E., D.S. Miller and G.H. Winters. 1978. Biological aspects of the Div. 3NO Capelin stock in 1977 and a capelin sequential abundance model. ICNAF Res. Doc. 78/VI/52.

Carscadden, J.E. and D.S. Miller. 1979. Biological aspects of capelin for the Division 3LNO stock and a sequential capelin abundance model. ICNAF Res. Doc. 79/II/33 (Revised).

Carscadden, J.E. and D.S. Miller (this meeting). Analytical and acoustic Assessments of Capelin in Div. 2J-3K. NAFO SCR. Doc. 80/II/13.

Carscadden, J.E. and Winters. (this meeting). An alternate method of assessing the NAFO Div. 2J3K capelin stock using SCAM and catch per-unit-effort data. NAFO SCR. Doc. 80/

Kovalyov, S.M. and B.D. Kudrin. 1973. Soviet investigations on capelin in the Grand Newfoundland Bank area in 1972. ICNAF Res. Doc. 73/26, Ser. No. 2959.

Miller, D.S. and J.E. Carscadden. 1979. Biological characteristics and biomass estimates of capelin in ICNAF Div. 2J-3K using a sequential capelin abundance model. ICNAF Res. Doc. 79/II/32.

Seliverstov, A.S. and L.I. Serebrov. 1979. Status of capelin stocks in Divisions 2J and 3K in 1978. ICNAF Res. Doc. 79/II/20.

Winters, G.H. 1974a. Back-calculation of the growth of capelin (Mallotus villosus) in the Newfoundland area. ICNAF Res. Doc. 74/7, Ser. No. 3150, 16 p.

1974b. Rationale for partition of capelin quota in Subareas 2 and 3. ICNAF Res. Doc. 74/12.

Winters, G.H. and J.S. Campbell. 1974. Some biological aspects and population parameters of Grand Bank capelin. ICNAF Res. Doc. 74/76, Ser. No. 3309.

Table 1. Comparison of age-compositions of capelin from the fall fishery in 2J3K (a) with that of mature fish spawning in 3K (b) for the period 1973-79. The fall age-compositions have been incremented by one year.

	Percentage age composition													
	1973		1974		1975		1976		1977		1978		1979	
Age	a	b	a	b	a	b	a	b	a	b	a	b	a	b
3	12	2	25	31	20	40	62	61	9	2	3	27	11	16
4	64	90	30	46	49	53	28	38	83	92	30	33	38	41
5	21	8	40	20	18	5	8	1	7	5	60	38	26	27
6+	3	<1	5	3	13	2	2	<1	1	<1	7	1	25	15
No. Mean	100		200		1020		1219		889		4200		1200	
No. Aged	100		200		1020		1219		889		1268		261	

Table 2. Illustration of changes in Ƶ due to variations in M and P.

	Age 3[a]				Age 4[b]			
	Ƶ when M =				Ƶ when M =			
P	.10	.20	.30	.40	.10	.20	.30	.40
.10	.18	.28	.38	.48	.19	.29	.39	.49
.20	.26	.36	.46	.56	.28	.38	.48	.58
.40	.46	.56	.66	.76	.49	.59	.69	.79
.60	.70	.80	.90	.10	.77	.87	.97	1.07
.80	1.02	1.12	1.22	1.32	1.16	1.26	1.36	1.46
1.00	1.49	1.59	1.69	1.79	1.79	1.89	1.99	2.09

a - spawning mortality = 1.39
b = spawning mortality = 1.69

Table 3. CPUE data for the year-classes 1968-77 as measured by USSR BMRT-A class vessels during the fall fishery in Div. 2J-3K 1972-79. To obtain spawning age, add one year.

	CPUE at age (No/hr. x 10^{-3})				
Year-class	2+	3+	4+	5+	6+
1968			25.25	6.32	1.77
1969		77.05	50.29	22.13	1.40
1970	14.19	37.11	31.90	5.37	0.40
1971	31.51	88.51	23.90	1.88	1.23
1972	36.47	81.06	14.75	8.97	1.23
1973	181.03	181.27	86.53	22.59	1.97
1974	19.24	43.07	25.07	2.14	-
1975	4.29	37.75	1.53	-	-
1976	10.79	6.56	-	-	-
1977	49.28	-	-	-	-
Mean	43.35	69.05	32.40	9.91	1.33

Table 4. Instantaneous total mortality rates (Z) for the year-class 1968-76 calculated from the data given in Table 1.

Year-class	$Z = \ln \left(\frac{CPUE_t}{CPUE_{t+1}} \right)$ 2+/3+	3+/4+	4+/5+	5+/6+
1968			1.39	1.27
1969		0.43	0.82	2.76
1970	-0.96	0.15	1.78	2.60
1971	-1.03	1.31	2.54	.42
1972	-0.80	1.70	0.50	1.99
1973	<-0.01	0.74	1.34	2.44
1974	-0.81	0.54	2.46	-
1975	-2.17	3.21	-	-
1976	-0.04	-	-	-
Mean	-0.83	1.15	1.55	1.91
Spawning Mortality	1.39	1.69	2.23	2.23

Table 5. Maturation rates (P_t) of the 1968-76 cohorts based on the data given in Table 1 and the methodology described in the text (M = 0.30).

Year-class	P_t at age 2+	3+	4+	5+	5+
1968	-	-	.78	0.80	1.00
1969	-	.475	.68	1.00	1.00
1970	.123	.475	.90	1.00	1.00
1971	.191	.840	.93	0.57	1.00
1972	.222	.800	.57	0.94	1.00
1973	.355	.620	.81	0.99	1.00
1974	.177	.620	.99	1.00	
1975	.080	1.00	1.00		
1976	.515	0.69[a]			
Mean	0.24	0.69	0.83	0.90	1.00

a = mean value assumed

Table 6. Comparison of age-composition of mature capelin from SCAM (a) with that of mature fish spawning in Div. 3K (b).

	Percentage age-composition													
	1973		1974		1975		1976		1977		1978		1979	
Age	a	b	a	b	a	b	a	b	a	b	a	b	a	b
3	17	2	36	31	25	40	67	61	15	2	9	27	34	16
4	64	90	36	46	55	53	26	38	79	92	51	33	47	41
5	17	8	27	20	16	5	6	1	6	5	38	38	17	27
6+	1	<1	2	3	4	2	1	<1	1	<1	3	1	3	15