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Analytical Assessment of the Capelin Stock
in Subarea 2 + Div. 3K using SCAM

by

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INTRODUCTION

In 1972, the first large offshore capelin catches were reported from NAFO Subarea 2 + Div. 3K. Catches peaked in 1976 at 216,000 tons and declined to 10,000 tons in 1979. In 1974, a TAC of 110,000 tons was established for this stock. This TAC was increased to 300,000 tons in 1975 and remained at that level until 1978. Evidence of poor recruitment in the stock prompted a reduction of the TAC in 1979 to 75,000 tons and a complete closure of the offshore commercial fishery in 1980. However, a small experimental fishery conducted by three Soviet trawlers under special licence was allowed in 1980.

This paper presents results of an analytical assessment of the status of this capelin stock using a sequential capelin abundance model (SCAM 2J3K) and the method of estimating proportions mature-at-age developed by Miller and Carscadden (1979) and Winters et al. (1980), respectively.

The Model - SCAM 2J3K

The original SCAM 2J3K (Miller and Carscadden 1979) has been changed such that fishing is incomplete on the final age. Now for all ages $\mu = \frac{F}{F + MDF} (1 - e^{-F-MDF})$.

Numbers-at-age and Mean Weight-at-age

Numbers-at-age and mean weight-at-age from 1972-1979 are the same as those in Carscadden and Miller (1980). During 1980, an experimental fishery with three Soviet vessels was conducted and personnel from Foreign Cooperative Sampling Section observed this fishery. Data collected from this program formed the basis for numbers-at-age (Table 1) and mean weight-at-age for 1980 (Table 2).

Spawning Mortality

Spawning mortality for ages 3-6 was from Carscadden and Miller (1980).

<u>Age</u>	<u>Spawning Mortality</u>
3	1.39
4	1.69
5	2.23
6	2.23

Estimation of Proportions Mature-at-age (p)

Estimates of p (Table 3) were derived using the method derived by Winters et al. (1980). Where data were not available, averages for p were used. The values of p for 1980 did not fit the pattern of previous years and were considered to be in error probably because of biased catch-per-effort data. As a result, averages of the years 1973-1979 were used for 1972 and 1980.

Partial Recruitment and Fishing Mortality

Two methods were used to calculate partial recruitment and fishing mortality.

Method 1

A number of runs of SCAM were made at various levels of terminal fishing mortality (F_T). Mean values of fishing mortality at age were calculated for the early years of the series (1972-1976). Partial recruitment values were then estimated by expressing the mean F 's as a fraction of the largest mean F . These partial recruitment values were:

<u>Age</u>	<u>Partial Recruitment</u>
2	.13
3	.38
4	.53
5	1.0
6	1.0

A number of runs of SCAM were made using the above partial recruitment factors and a series of F_T 's ranging from 0.01 to 0.4. Regressions were calculated using exploitable capelin biomass on September 1 and catch-per-hour of USSR trawlers (Table 4). Exploitable capelin biomass on September 1 was calculated by multiplying calculated population numbers-at-age by a calculated partial recruitment factor for each age. This partial recruitment factor was estimated by expressing F at age each year as a proportion of the highest F in that year.

In all runs of the model, the 1980 point did not fit the trends of biomass and catch-per-effort. It was felt that the catch rate estimate for 1980 was biased upward (see discussion) and for this reason, the 1980 point was not used in the regression. The best fit occurred with $F_T = 0.3$ (Fig. 1). Details of the run of the SCAM at this level of F_T are given in Table 5.

The results of this run of the model suggest that the 1973 year-class was the strongest in the series with the 1969 year-class second in strength and the 1978 year-class third. The 1974-1977 year-classes were relatively low resulting in declining biomass from 1977-1979. The 1980 biomass on September 1 was estimated to be 745,185 tons although only 168,518 tons was exploitable (as calculated in this paper) due to the large numbers of small and presumably immature 2+ fish.

Method 2

In this method partial recruitment factors were estimated by comparing the age-composition of research and commercial catches of age 2+ and older capelin in 1977-1980 (Table 6). An examination of age-composition in the research samples in 1977 and 1978 showed an approximate correspondence to age-compositions on September 1 in those years predicted from runs of SCAM. However, in both cases, the proportions of 2+ fish in the research samples were much lower than older fish although in the calculated age-compositions, the proportions of 2+ fish were higher. This suggests that the research net does not provide a reliable age-composition of the entire population. Using the estimated age-compositions in SCAM, the age-compositions of the research samples in 1977 and 1978 were adjusted to be comparable to the calculated age-compositions in SCAM. These calculations suggested that the age 2+ fish were undersampled by a factor of 3.88 times in 1977 and 3.76 times in 1978. Thus, the age-composition of capelin in the research samples in 1980 was adjusted using the factor calculated for undersampling of age 2+ in 1977 and 1978 (Table 6). Partial recruitment factors were then calculated based on age-compositions of commercial and adjusted research samples (Table 6).

A number of runs of SCAM were made using these partial recruitment factors and a series of F 's ranging from 0.01 to 0.4. Again regressions using exploitable capelin biomass on September 1 and catch-per-hour of USSR trawlers were calculated omitting the 1980 point. The best fit occurred when $F_T = 0.03$ (Fig. 2). Details of this run are given in Table 7.

The results from this analysis suggest that the 1973 year-class is the largest, followed in strength by the 1969 and 1978 year-classes. The 1974-1977 year-classes were relatively weak contributing to declining biomasses in the 1977-1979 period. The biomass on September 1, 1980 was estimated to be relatively large, 1,177,016 tons, due mainly to the size of the 1978 year-class.

DISCUSSION

The two methods used in the SCAM runs differ only in the calculation of partial recruitment and serve to illustrate the critical importance of this factor in estimating year-class abundance in the most recent year. Even though the F_T 's are the same, the predicted strengths of the 1978 year-class are 33.7×10^9 fish. These estimates suggest that the 1978 year-class is the third largest in the series.

The estimate of catch-per-hour is also of critical importance in determining the biomass estimate in the most recent year. Since the 1978 year-class makes up the bulk of the 1980 biomass on September 1, catch-per-hour is also important in the estimate of the strength of this year-class.

The estimates of catch-per-hour in 1980 came from three Soviet vessels fishing capelin in Div. 2J during part of September and October. It is our understanding that during earlier years of the fishery the capelin fleet was larger and operated in Div. 2J early in the fall and gradually moved into Div. 3K to fish capelin that would normally overwinter in this area. Thus, the pattern of the 1980 fishery was different from earlier years of the fishery. It is possible that such a small number of vessels operating in 1980 could have maintained a good catch rate on a localized group of capelin over a relatively short fishing period. This would provide an estimate of C/E that is biased upward in relation to other years and would provide no information on that portion of the stock occurring in other areas.

The acoustic survey conducted by Canada in late October-early November 1980 found very few capelin in both Div. 2J and 3K although a large area was surveyed. The acoustic survey conducted in 1979 also detected few capelin although reports in 1980 suggested that concentrations of capelin spawning inshore in that year were larger than in 1979. The only empirical information available to us on recruiting year-classes in Subarea 3 comes from the Canadian acoustic survey in Div. 3L in June when concentrations of both the 1978 and 1979 year-classes were detected.

All of this information suggests two possibilities: that the stock is low but probably improving or that the status of the stock has already improved and the acoustics surveys in 1979 and 1980 failed to detect capelin because of abnormal distribution during the time of the surveys.

Because of the conflicting evidence and the sensitivity of the estimate of the 1978 year-class to the partial recruitment factor and catch/effort estimate of 1980, the authors suggest that the estimates of the size of the 1978 year-class may be optimistic. A cautious approach should be taken when projecting from the estimates in this paper.

REFERENCES

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- Winters, G.H., J.E. Carscadden, and D.S. Miller. 1980. An indirect method of estimating maturation rates of cohorts of capelin. NAFO SCR Doc. 80/II/16, Ser. No. N048, 6 p.

Table 1. Numbers-at-age of capelin in catch in Div. 2J3K, 1972-1980.

Age	Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	228,420	1,306,440	1,015,200	5,553,990	789,650	157,010	247,465	355,482	102,211
3	1,240,140	1,538,840	2,463,850	2,486,910	7,409,420	1,578,100	842,792	47,307	91,543
4	406,380	2,085,270	888,120	733,280	605,650	3,170,380	574,832	11,022	24,464
5	54,670	262,150	616,150	164,790	77,350	328,780	518,080	15,448	3,641
6	7,180	14,230	49,280	42,960	16,280	45,070	28,298	14,221	2,441

Table 2. Mean weights (g) of capelin at age at beginning of the year (January 1) and during fishing.

Age	January 1								
	Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	8.8	8.8	8.8	9.6	8.8	9.5	8.4	8.8	8.1
3	14.6	16.9	19.8	19.2	17.3	12.8	21.3	14.7	20.1
4	23.1	23.6	26.9	25.4	28.7	24.8	26.2	19.8	24.4
5	26.9	25.9	29.2	29.0	32.4	31.5	29.9	24.9	27.9
6	30.0	26.1	30.2	28.4	32.5	38.2	32.4	27.7	31.6

Age	During fishing								
	Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	16.9	19.8	19.2	17.3	12.8	21.3	14.7	20.1	18.1
3	23.6	26.9	25.4	28.7	24.8	26.2	19.8	24.4	23.6
4	25.9	29.2	29.0	32.4	31.5	29.9	24.9	27.9	23.5
5	26.1	30.2	28.4	32.5	38.2	32.4	27.7	31.6	30.8
6	25.5	31.7	30.4	31.9	43.7	38.0	32.0	34.7	37.0

Table 3. Estimates of proportions of capelin mature-at-age (p) for Div. 2J3K capelin stock. Mean values were used in 1972 and 1980.

Year	Age			
	3	4	5	6
1972	.18	.67	.78	.87
1973	.12	.47	.76	.81
1974	.19	.47	.68	.79
1975	.22	.83	.89	1.0
1976	.34	.80	.93	1.0
1977	.17	.62	.56	.56
1978	.08	.58	.80	.93
1979	.14	.94	.86	.99
1980	.36	.13	.22	.42
Mean values 1973-1979	.18	.67	.78	.87

Table 4. Catch-per-hour of USSR trawlers operating in Div. 2J3K capelin fishery, 1972-1980.

[illegible]

Table 5. Results of SCAM with $F_T = 0.03$ and partial recruitment factors of 0.13, 0.38, 0.53, 1.0, 1.0 for ages 2-6, respectively.
TOTAL POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.
2	52194912.	53032533.	42059585.	224422999.	22247628.	7700815.	9343104.	16633245.	33702196.
3	60542688.	38449570.	38045602.	30193482.	160977195.	15730672.	5555650.	6686094.	11984290.
4	24492397.	37609906.	24454739.	21822845.	16310735.	81765801.	8667393.	3068657.	4387464.
5	2426912.	7844461.	15202730.	10328566.	4527922.	3625181.	26937567.	2838022.	520224.
6	433255.	494393.	1620667.	3842337.	1417383.	496787.	1031350.	5215569.	474083.
BIOMASS	1987294.	2220153.	2274123.	3697127.	3641572.	2435473.	1262752.	520556.	650421.

MATURE POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.
2	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	10897684.	4613949.	7228664.	6642566.	54732339.	2674214.	444452.	936053.	2157172.
4	16409905.	17676657.	11493728.	18112962.	13048588.	50694797.	5027089.	2884538.	2939601.
5	1892991.	5961790.	10337855.	9192424.	4210988.	2030101.	21550053.	2440699.	405775.
6	376932.	400458.	1280327.	3842337.	1417383.	278201.	959155.	5163414.	412452.
BIOMASS	600404.	660007.	792840.	963309.	1503862.	1366036.	816600.	274674.	139440.

TOTAL POPULATION-START OF FISHING (SEPT 1)

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.
2	42733580.	43419366.	34435476.	183742011.	18214817.	6304894.	7649487.	13618149.	27593024.
3	42868208.	28643166.	26704884.	20636448.	98147309.	11235065.	4275330.	4898621.	8485666.
4	9096459.	18990408.	12347957.	5773753.	4642094.	33097341.	3739881.	586516.	1629501.
5	603790.	2066257.	4893134.	1739467.	630221.	1484665.	6308122.	540172.	129426.
6	79297.	112162.	391363.	338267.	124782.	203455.	143549.	497272.	86770.
BIOMASS	1987266.	2250681.	1848418.	4025396.	2842956.	1474098.	469551.	443940.	745185.
BIOMASS	484486.	1047604.	983657.	1516168.	1613489.	643502.	244825.	334512.	168518.

TOTAL FISHING MORTALITY RATES

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.
2	.006	.032	.031	.032	.047	.027	.035	.028	.004
3	.031	.058	.102	.135	.083	.159	.232	.010	.011
4	.048	.122	.079	.143	.147	.106	.176	.020	.016
5	.100	.143	.142	.105	.138	.264	.090	.031	.030
6	.100	.143	.142	.143	.147	.264	.232	.031	.030

Table 7. Results of SCAM with $F_T = 0.03$ and partial recruitment factors of 0.07, 0.35, 0.79, 1.0, 1.0 for ages 2-6, respectively.

TOTAL POPULATION AT START OF YEAR

YEARS AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	52194912	53032533	42059585	224422999	22247628	7700815	6425579	18012101	62534457
3	60542688	38449570	38045602	30193482	160977185	15730672	5555650	4524932	13005768
4	24492397	37609906	24454739	21822845	16310735	81765801	8667393	3068657	2954761
5	2426912	7844461	15202730	10328566	4527922	3625181	26937567	2838022	520224
6	433255	494393	1620667	3842337	1417383	496787	1031350	5215569	474083
BIOMASS	1987294	2220153	2274123	3697127	3641572	2435473	1238245	500920	869536

MATURE POPULATION AT START OF YEAR

YEARS AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	0	0	0	0	0	0	0	0	0
3	10897684	4613949	7228664	6642566	54732239	2674214	444452	633490	2341038
4	16409905	17676657	11493728	18112962	13048588	50694797	5027089	2884538	1979690
5	1892991	5961790	10337855	9192424	4210968	2030101	21550053	2440699	405775
6	376932	400458	1280327	3842337	1417383	278201	959155	5163414	412452
BIOMASS	600404	660007	792840	963309	1503862	1366036	816600	270226	119714

TOTAL POPULATION-START OF FISHING (SEPT 1)

YEARS AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	42733580	43419366	34435476	183742011	18214817	6304894	5260819	14747061	51198883
3	42868208	28643166	26704884	20636448	98147309	11235065	4275330	3315228	9208940
4	9096459	18990408	12347957	5773753	4642094	33097341	3739881	586516	1097396
5	603790	2066257	4893134	1739467	630221	1484665	6308122	540172	129426
6	79297	112162	391363	338267	124782	203455	143549	497272	86770
BIOMASS	1987266	2250681	1848418	4025396	2842956	1474098	434437	427996	1177016
BIOMASS	484486	1047604	983657	1516168	1613489	643502	244946	334337	168505

TOTAL FISHING MORTALITY RATES

YEARS AGE	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	.006	.032	.031	.032	.047	.027	.051	.026	.002
3	.031	.058	.102	.135	.083	.159	.232	.015	.011
4	.048	.122	.079	.143	.147	.106	.176	.020	.024
5	.100	.143	.142	.105	.138	.264	.090	.031	.030
6	.100	.143	.142	.143	.147	.264	.232	.031	.030

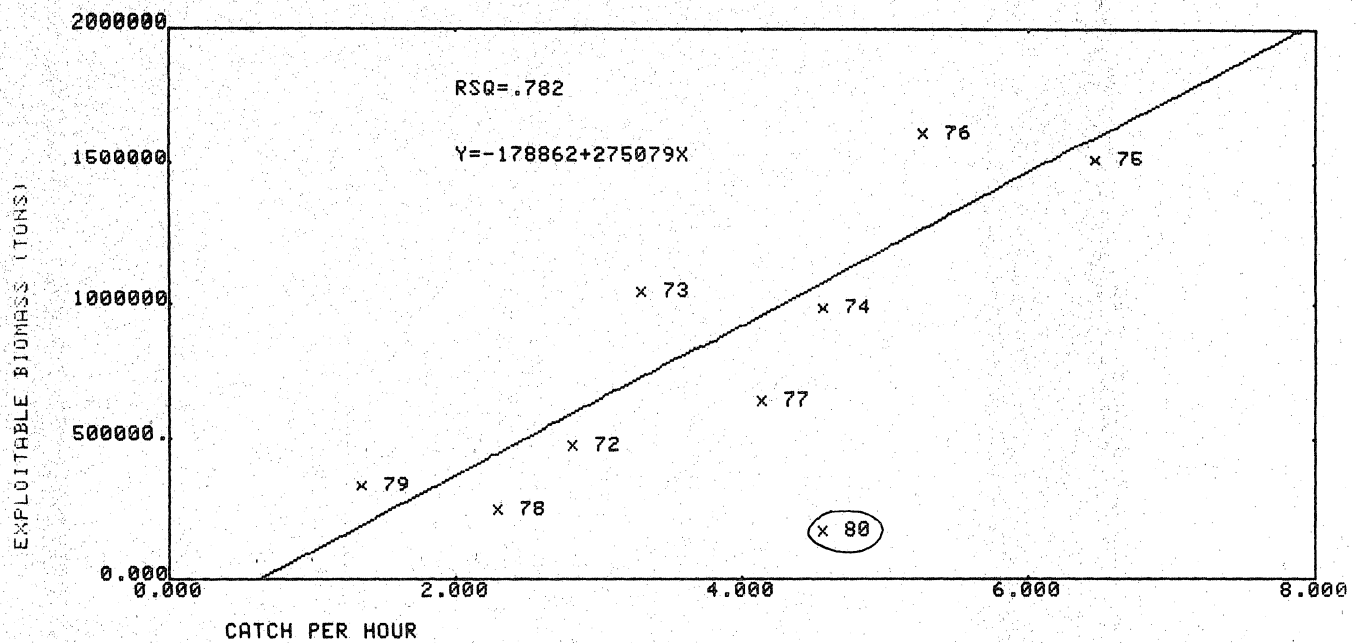


Fig. 1. Relationship between exploitable capelin biomass on Sept. 1 and catch-per-hour when $F_T = 0.03$ and selection factors are 0.13, 0.38, 0.3, 1.0, 1.0 at ages 2-6, respectively.

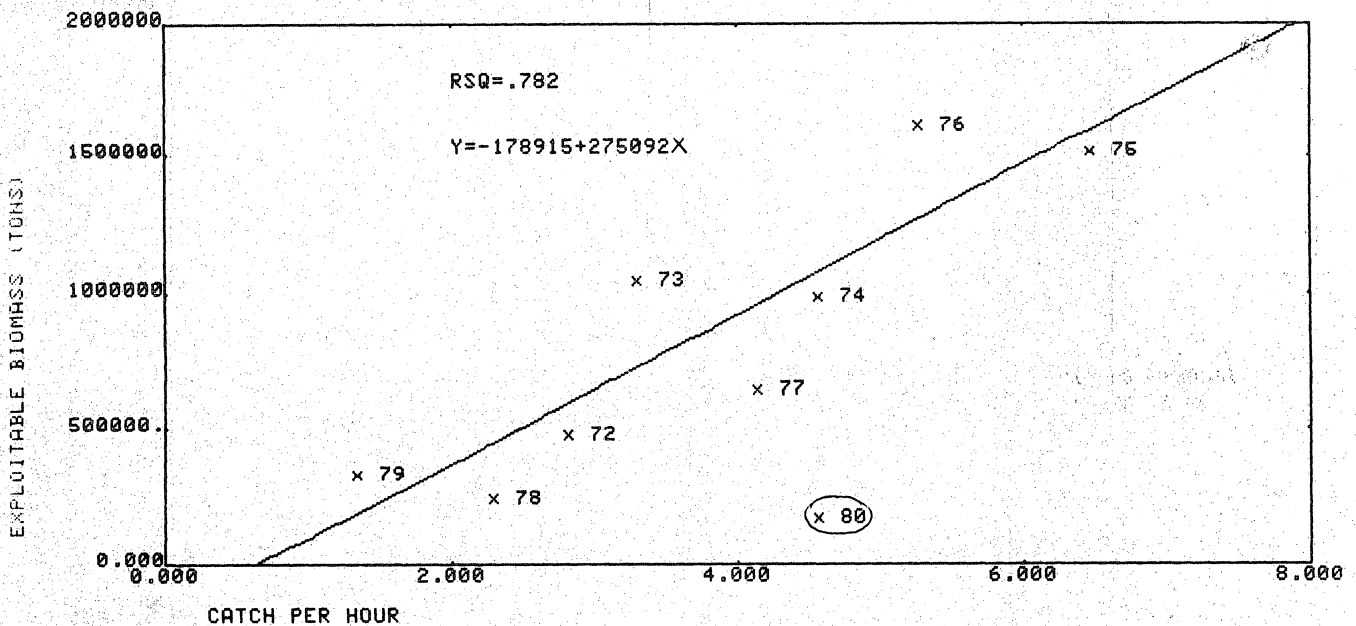


Fig. 2. Relationship between exploitable capelin biomass on Sept. 1 and catch-per-hour when $F_T = 0.03$ and selection factors are 0.07, 0.35, 0.79, 1.0, 1.0 at ages 2-6, respectively.