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An assessment of the capelin stock in Subarea 2 and Division 3K  
using a sequential capelin abundance model

by

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INTRODUCTION

This paper presents results of an analytical assessment of the status of the Subarea 2 and Div. 3K capelin stock using a sequential capelin abundance model (SCAM 2J3K) (Miller and Carscadden 1979; Carscadden and Miller 1981) and the method of estimating proportions mature-at-age developed by Winters et al. (1980).

Numbers-at-age and mean weight-at-age

Numbers-at-age and mean weight-at-age for 1972-80 are the same as those in Carscadden and Miller (1981). For 1981, data collected by the Foreign Cooperative Sampling Section, Department of Fisheries and Oceans, St. John's, from the USSR experimental capelin fishery provided the basis for estimating numbers- and catch-at-age. The numbers-at-age and mean weight-at-age, 1972-81, are given in Table 1.

Spawning mortality and natural 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

The natural mortality was assumed to be 0.3.

### Estimation of proportions mature-at-age (p)

The method developed by Winters et al. (1980), using catch-per-unit-effort of USSR midwater trawlers, was used to estimate the proportion mature-at-age. This method assumes that estimates of C/E are comparable from year to year. However, there was evidence to suggest that the 1980 estimate was biased upward (Carscadden and Miller 1981; Bakanev 1981). Thus, for this analysis, two methods were used to derive estimates of C/E for 1980. One method assumed that there were no strong year-classes in the capelin population in both 1979 and 1980; hence, the 1980 estimate was the same as the 1979 estimate (1.34 t/hr). The second method assumed that since the 1981 estimates showed an increase over 1979, the 1980 value fell somewhere between the 1979 and 1981 values. For this case, the 1980 C/E value was taken to be 2.51 t/hr. The estimates of C/E are shown in Table 2.

The estimates of p, calculated using the two assumed values of C/E for 1980, are shown in Tables 3 and 4. In some cases, the calculated values of p did not seem reasonable and in these cases, averages of other years were used. This may not be unexpected since in some years, when older ages are less abundant, sampling error may be greater on these ages.

### Partial recruitment

Partial recruitments were calculated in two ways:

- (1) A comparison was made between age-compositions of age 2 and older in the commercial and research catches (Table 5). In this method, ages 5 and 6 were considered to be fully recruited and younger ages indexed to them. A comparison with the two previous years, 1979 and 1980 (Table 5) shows that partial recruitments calculated this way are reasonably consistent from year to year.
- (2) From trial runs of the sequential capelin abundance model, mean values of fishing mortality by age, 1972-77, were calculated. Partial recruitment factors were estimated by indexing ages 2-5 to age 6. Partial recruitments calculated with the two values for C/E for 1980 are shown in Table 6.

### Estimation of fishing mortality

A number of runs of the sequential capelin abundance model were made using the different options of partial recruitment. For each value of the 1980 catch-per-unit-effort (2 values = 1.34 and 2.51), there were two series of estimates of partial recruitment used, one derived from  $F$  values early in the series and one from the comparison of age compositions derived from research vessel and commercial catches. Estimates of total biomass (Sept. 1) and exploitable biomass (Sept. 1), 1972-80, from SCAM were compared to the C/E values shown in Table 2. A summary of the  $r^2$  values,  $F_T$  and 1981 biomass calculated from the model and predicted from the 1981 C/E value is given in Table 7. The best fit, for both exploitable and total biomass, Sept. 1 each year (highest  $r^2$  and closest agreement between calculated and predicted 1981 biomass) occurred at the very low values of  $F_T = 0.01$ . The relationships between C/E and exploitable biomass produced the highest  $r^2$  values but in some cases, there was close agreement between predicted and calculated biomass when C/E and total biomass were compared. The best agreement occurred under the option of 1980 C/E = 2.51 and partial recruitment derived from fishing mortality.

Since in most cases, the different partial recruitments did not severely change the results under each value of 1980 C/E tested, it was decided to combine the series of partial recruitment values for each value of 1980 C/E and present the details of these two options. Summaries of the comparisons between C/E and biomass for these runs are shown in Table 7. Details of the SCAM runs with 1980 C/E = 1.34 and 1980 C/E = 2.51 are given in Tables 8 and 9 respectively. The plots of C/E and exploitable and total biomass for these values of C/E are given in Fig. 1 and 2.

An examination of the two runs in Tables 8 and 9 suggests that the run when C/E = 2.51 might be more meaningful. This run shows the 1973 year-class at age 2 as the strongest year-class in the series which is consistent with observations from age-compositions and previous assessments. In contrast, the option using C/E = 1.34 suggests that the 1971 year-class at age 2 is the strongest year-class in the series. Both options suggest that the 1979 year-class is stronger than any year-class since the 1973 year-class.

Because of the very low values  $F$  in this analysis, the results should be

accepted only with extreme caution. Although changes of 0.01 in the fishing mortality rate are small in the absolute sense, such changes are relatively large in comparison to the F's resulting from this analysis; consequently, estimates of biomass change dramatically with only small changes in F. Nevertheless, the patterns shown in the analysis show an improvement in the capelin stock status in 1981 following a period of low biomass from 1978-80. Again, caution should be exercised in interpretation of these results since an examination of the age composition of the commercial catch and of the catch from the experimental fishery (Fig. 3) reveals a greater dependence on 1- and 2-yr-olds in recent years in spite of the fact that catches are very low. This is probably a result of very weak year-classes being present in the fishery in recent years, such that only young fish are available to the fishery.

#### 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 ( $\times 10^{-3}$ ) in catch and mean weight-at-age (g) for January 1 and September 1 for capelin from Div. 2J3K.

Age/ Year	Numbers									
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	228,420	1,306,440	1,015,200	5,553,990	789,650	157,010	247,465	355,482	102,211	374,293
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	89,372
4	406,380	2,085,270	888,120	733,280	605,650	3,170,380	574,832	11,022	24,464	22,411
5	54,670	262,150	616,150	164,790	77,350	328,780	518,080	15,448	3,641	12,014
6	7,180	14,230	49,280	42,960	16,280	45,070	28,298	14,221	2,441	994

Age/ Year	Weight (Jan. 1)									
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	8.8	8.8	8.8	9.6	8.8	9.5	8.4	8.8	8.1	8.4
3	14.6	16.9	19.8	19.2	17.3	12.8	21.3	14.7	20.1	18.1
4	23.1	23.6	26.9	25.4	28.7	24.8	26.2	19.8	24.4	23.6
5	26.9	25.9	29.2	29.0	32.4	31.5	29.9	24.9	27.9	23.5
6	30.0	26.1	30.2	28.4	32.5	38.2	32.4	27.7	31.6	30.8

Year	Weight (Sept. 1)									
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
2	16.9	19.8	19.2	17.3	12.8	21.3	14.7	20.1	18.1	16.8
3	23.6	26.9	25.4	28.7	24.8	26.2	19.8	24.4	23.6	24.3
4	25.9	29.2	29.0	32.4	31.5	29.9	24.9	27.9	23.5	27.4
5	26.1	30.2	28.4	32.5	38.2	32.4	27.7	31.6	30.8	31.2
6	25.5	31.7	30.4	31.9	43.7	38.0	32.0	34.7	37.0	32.7

Table 2. Catch per hour of USSR trawlers in Div. 2J3K, 1972-81.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Catch/ hour	2.81	3.29	4.56	6.47	5.27	4.14	2.29	1.34	4.57* 1.34 2.51	3.68

\* measured

Table 3. Values of proportions mature-at-age for Div. 2J3K capelin. The 1980 C/E value used was 2.51 t/hr. Values on the left of the diagonal are calculated; values on the right are those used in the analysis.

Year/age	p			
	3	4	5	6
1972	/.19	/.63	/.83	/.93
1973	.12	.47	.76	.97
1974	.19	.47	.68	.79
1975	.22	.83	.89	1.0
1976	.34	.80	.93	1.0
1977	.17	.62	.56/.83	.56/.93
1978	.08	.59	.80	.93
1979	/.19	1.0/.63	.90	.99
1980	/.19	/.63	.35/.83	.59/.93
1981	/.19	/.63	.83	.86

Table 4. Values of p, proportions mature-at-age for Div. 2J2K capelin. The 1980 C/E value used was 1.34 t/hr. Values on the left of the diagonal are calculated; values on the right are those used in the analysis.

Year/age	p			
	3	4	5	6
1972	/.19	/.63	/.84	/.98
1973	.12	.47	.76	.97
1974	.19	.47	.68	.79/.98
1975	.22	.83	.89	1.0
1976	.34	.80	.93	1.0
1977	.17	.62	.56/.84	.56/.98
1978	.08	.61	.80	.93
1979	/.19	1.0/.63	.95	.99
1980	/.19	/.63	.47/.84	.76/.98
1981	/.19	/.63	/.84	.72/.98

Table 5. Commercial and research age compositions (%), ages 2 and older, and partial recruitment calculated from these age compositions, Div. 2J3K capelin, 1979-81.

	Age				
	2	3	4	5	6
<u>1979</u>					
Commercial (C)	80.2	10.7	2.5	3.5	3.2
Research (R)	94.2	3.2	1.0	1.0	0.7
C/R	.85	3.3	2.5	3.5	4.6
Partial Recruitment	.21	.80	.61	1.0	1.0
<u>1980</u>					
Commercial (C)	45.6	40.8	10.9	1.6	1.1
Research (R)	50.3	38.8	7.5	0.6	0.3
C/R	.91	1.05	1.5	2.7	3.7
Partial Recruitment	.28	.33	.47	1.0	1.0
<u>1981</u>					
Commercial (C)	75.0	17.9	4.5	2.4	.2
Research (R)	85.0	11.5	2.4	1.0	.05
C/R	.88	1.6	1.9	2.4	4.8
Partial Recruitment	.24	.44	.53	1.0	1.0

Table 6. Partial recruitment values calculated from fishing mortality estimates, Div. 2J3K capelin at two options of C/E for 1980.

Age	1980 C/E = 1.34	1980 C/E = 2.51
	PR	PR
2	.18	.20
3	.57	.64
4	.71	.73
5	.78	.86
6	1.0	1.0

Table 7. Summary of comparison of runs of SCAM at different options of partial recruitment and 1980 C/E values.

1980 C/E value	PR source	$r^2$ C/E vs Exploitable Biomass (1972-80)	1981 Exploitable Biomass ('000's t)		$r^2$ C/E vs Total Biomass (1972-80)	$F_t$	1981 Exploitable Biomass ('000's t)		$F_t$
			Cal.	Pred.			Calc.	Pred.	
1.34	Mean F's	.81	998	2110	.51	0.01	4221	4854	0.01
1.34	Age compositions	.82	998	2635	.53	0.01	3441	6014	0.01
1.34	Mean of 2 methods	.81	998	2335	.52	0.01	3751	5346	0.01
2.51	Mean F's	.81	998	1865	.53	0.01	3651	3662	0.01
2.51	Age compositions	.78	998	2309	.58	0.01	3441	4232	0.01
2.51	Mean of 2 methods	.80	998	2052	.55	0.01	3449	3899	0.01

Table 8. Details of SCAM run,  $F_T = 0.01$ , under the option of average partial recruitment values and 1980 C/E = 1.34.

TOTAL POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	2102259021.	397956966.	178254926.	287271986.	145891111.	31586997.	41566880.	20981619.	35633651.	228998909.
3	3143937219.	75537607.	293569845.	131088727.	207536636.	107327549.	23250834.	30558097.	15205639.	26300705.
4	4118588023.	90238359.	49454251.	184109584.	78705502.	107451077.	67859987.	15388686.	19362967.	9570359.
5	15524743.	42331362.	39245698.	21749933.	43377930.	19692515.	36341622.	24718053.	5532847.	6951637.
6	4071236.	2827009.	9839937.	10843807.	3157729.	5389474.	3339473.	7208084.	2771441.	1022567.
BIOMASS	6280498.	8078398.	10154785.	10889811.	8641144.	5164848.	3817150.	1753682.	1308666.	2820352.

MATURE POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	27348071.	9064513.	55778270.	28839520.	70562451.	18245682.	1860067.	5806038.	2889071.	4997134.
4	74710454.	42412031.	23243499.	152810963.	62964398.	66619668.	41394593.	9694872.	12198669.	6029326.
5	13040785.	32171835.	26687073.	19357440.	40341472.	16541713.	29073296.	23482151.	4647591.	5839375.
6	3989811.	2742199.	9643138.	10843807.	3157729.	5281684.	3105709.	7136004.	2716012.	1002116.
BIOMASS	2595584.	2058936.	2800145.	5304447.	4437498.	2608537.	2094074.	1059680.	571212.	400831.

TOTAL POPULATION-START OF FISHING (SEPT 1)

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	83722606.	325819606.	145942790.	235198410.	119445539.	25861246.	34032083.	17178297.	29174366.	187488449.
3	101032092.	56272053.	206061892.	89595687.	126534467.	76654826.	17892594.	21449271.	10673108.	18460932.
4	47210558.	45564147.	24970986.	48710571.	22399871.	43494283.	27921588.	6126322.	7708506.	3810014.
5	3181762.	11150224.	12631578.	3662975.	6037576.	4035938.	8510323.	3079165.	1133945.	1424723.
6	417915.	310851.	1010076.	954654.	277996.	553233.	464806.	687246.	284490.	104967.
TOTAL BIOMASS	5115723.	9642009.	9149676.	8368051.	5615337.	4011467.	1800402.	1160719.	1006543.	3750684.
EXPLOIT. BIOMASS	2626866.	2960163.	2563109.	4351689.	3687757.	1840854.	810905.	462706.	557846.	997964.

TOTAL FISHING MORTALITY RATES

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	.003	.004	.007	.025	.007	.006	.008	.022	.004	.002
3	.013	.029	.013	.030	.063	.022	.051	.002	.009	.005
4	.009	.049	.038	.016	.029	.080	.022	.002	.003	.006
5	.018	.025	.053	.048	.014	.089	.066	.005	.003	.009
6	.018	.049	.053	.048	.063	.089	.066	.022	.009	.010

Table 9. Details of SCAM run,  $F_t = 0.01$ , under the option of average partial recruitment values and 1980  $C/E = 2.51$ .

TOTAL POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	2101127910.	223076864.	129272871.	283782421.	82666177.	17360789.	38458873.	20659737.	33666228.	209106532.
3	3142416336.	74699668.	164016613.	94802196.	204951510.	60489706.	12711878.	28255646.	14967182.	24843217.
4	52147363.	89272419.	48889431.	101828295.	56263733.	106025008.	37590387.	8050729.	17900648.	9418911.
5	12725580.	18398258.	38804410.	21491903.	23680264.	13913051.	35819613.	13902466.	2889542.	6424884.
6	2548814.	2392054.	4135818.	10715299.	3118411.	2908767.	2359823.	7097482.	2011935.	551490.
BIOMASS	4592590.	5871277.	6958245.	8058532.	6756481.	4117992.	2726150.	1299340.	1154508.	2596414.

MATURE POPULATION AT START OF YEAR

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	27059103.	8963961.	31163156.	20856483.	69683508.	10283249.	1016950.	5368573.	2843765.	4720211.
4	32852839.	41958040.	22978034.	84517489.	45010984.	65735505.	22178329.	5071959.	11277408.	5933914.
5	10562232.	13982676.	26386997.	19127794.	22022644.	11547833.	28655689.	12512219.	2398320.	5332654.
6	2370397.	2320293.	3267296.	10715299.	3118411.	2705153.	2194636.	7026507.	1871100.	474281.
BIOMASS	1509199.	1564411.	2104312.	3406209.	3312222.	2228960.	1530645.	685531.	458368.	365401.

TOTAL POPULATION-START OF FISHING (SEPT 1)

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	82796530.	182639889.	105839675.	232341396.	67681341.	14213812.	31487462.	16914762.	27563576.	171201948.
3	99964557.	55647827.	115126176.	64794800.	124958323.	43202588.	9782380.	19833140.	10505731.	17437895.
4	20760158.	45076414.	24685791.	26941098.	16012862.	42917036.	15968845.	3205040.	7126348.	3749721.
5	2701065.	4846163.	12489546.	3619520.	3295948.	2953111.	8388081.	2239774.	613319.	1363712.
6	354758.	263025.	998728.	943341.	274535.	404858.	328453.	676701.	280032.	104967.
TOTAL BIOMASS	4375657.	6584119.	6057279.	6899735.	4607595.	2828947.	1297041.	1007594.	943556.	3448656.
EXPLOIT. BIOMASS	2229268.	2496683.	2540073.	4312084.	3644239.	1330174.	570810.	455629.	549068.	998074.

TOTAL FISHING MORTALITY RATES

YEARS AGE	1972.	1973.	1974.	1975.	1976.	1977.	1978.	1979.	1980.	1981.
2	.003	.008	.010	.025	.012	.012	.008	.022	.004	.002
3	.013	.029	.023	.041	.064	.039	.095	.003	.009	.005
4	.021	.050	.039	.029	.041	.081	.039	.004	.004	.006
5	.021	.059	.053	.049	.025	.124	.067	.007	.006	.009
6	.021	.059	.053	.049	.064	.124	.095	.022	.009	.010

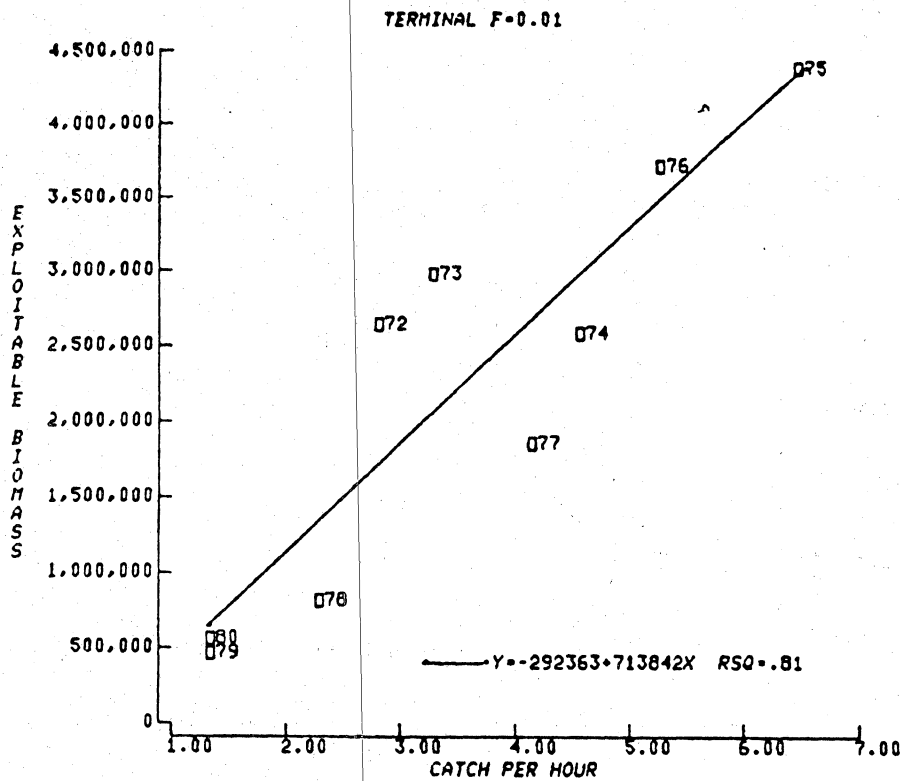
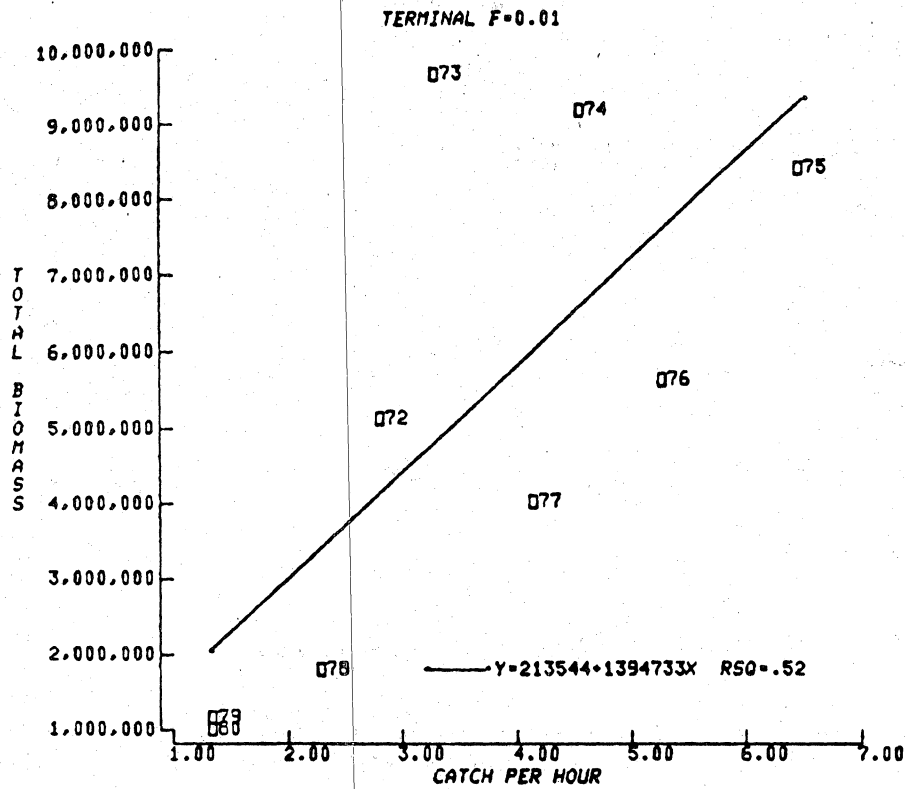


Fig. 1. Total biomass (1972-1980) and exploitable biomass (1972-1980) of capelin (Div. 2J+3K) vs catch per effort, 1980 C/E = 1.34.

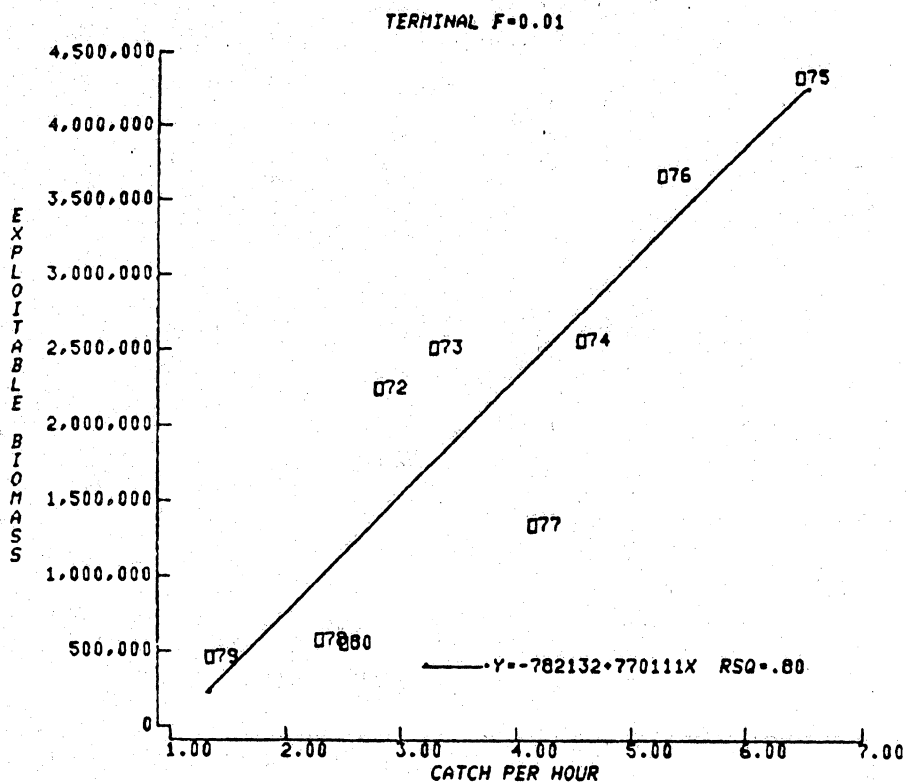
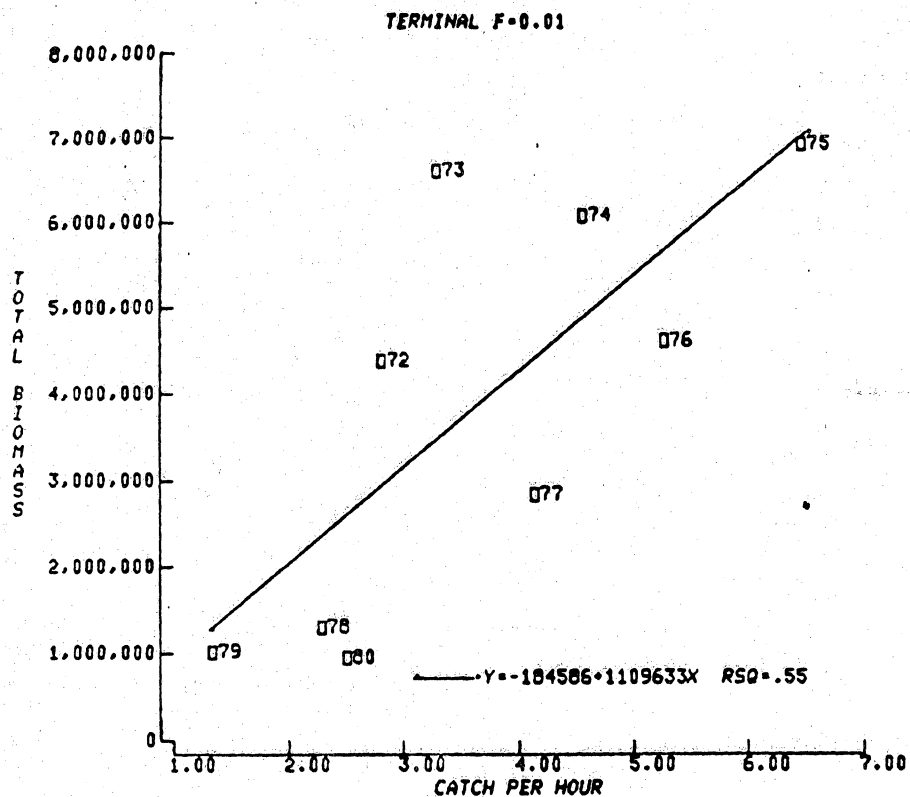


Fig. 2. Total biomass (1972-1980) and exploitable biomass (1972-1980) of capelin (Div. 2J+3K) vs catch per effort, 1980 C/E = 2.51.

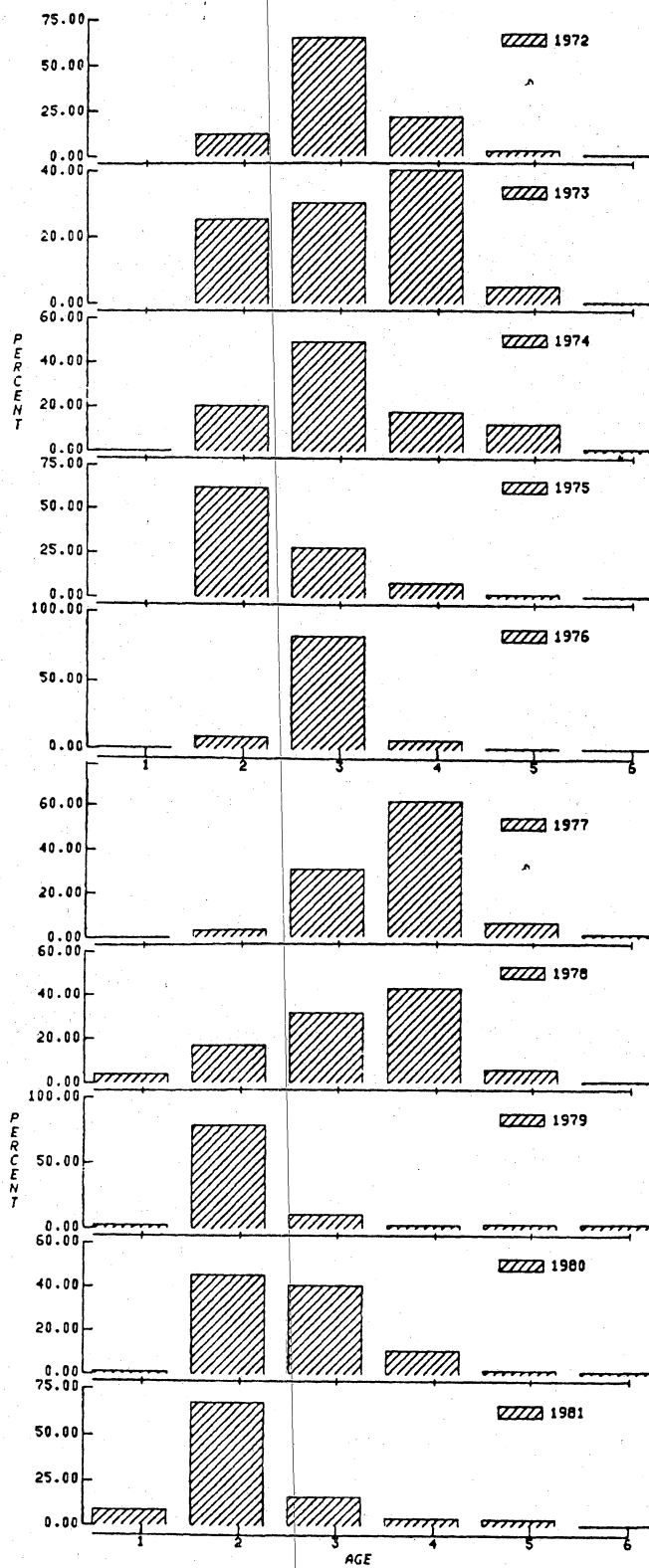


Fig. 3. Age compositions of commercial catch and catch from experimental fishery for capelin in Div. 2J+3K, 1972-1980.

