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Yield-per-recruit Analysis for Cod in Div. 2J3KL

by

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## Abstract

Yield-per-recruit analyses were conducted for Div. 2J3KL cod using various age ranges and average weights at age. The partial recruitment used was that from the most recent assessment and the natural mortality was assumed to be 0.20.  $F_{0.1}$  and  $F_{max}$  values using these data ranged from 0.16 to 0.24 and 0.31 to 0.51 respectively. A range of ages from 1 to 16, with any of the other described parameters, gives an  $F_{0.1}$  value of about 0.20.

## Résumé

On a effectué des analyses du rendement par recrue dans les stocks de morue des divisions 2J3KL, en utilisant divers groupes d'âge et poids moyens selon l'âge. On s'est servi du recrutement partiel provenant de l'évaluation la plus récente et on a postulé une mortalité naturelle de 0,20. Dans ces conditions, les valeurs  $F_{0.1}$  et  $F_{max}$  s'échelonnaient de 0,16 à 0,24 et de 0,31 à 0,51 respectivement. Considérant une fourchette d'âges allant de 1 à 16, et n'importe lequel des autres paramètres décrits, on obtient une valeur  $F_{0.1}$  d'environ 0,20.

### Yield per Recruit Analysis

An  $F_{0.1}$  reference level of 0.20 has been used in the past for projections of catch for NAFO Division 2J3KL cod. Yield-per-recruit analysis for this cod stock using various input parameters are presented in this paper.

The catch at age for 2J3KL cod for the 1962-88 period is given in Table 1. Throughout the 1960s and into the 1970s, substantial numbers of cod of age 16 and older occurred in the commercial fishery; but since the extension of jurisdiction (1977), there have been relatively few cod caught above age 16. For sequential population analysis during the last assessment of this stock (Baird and Bishop, 1989), the maximum age used was 14.

Mean weights at age (Table 2) for this stock indicate that weights were at their lowest in the early 1970s, increased to a high in the late 1970s--early 1980s, and subsequently declined. Illustrations of this for ages 4, 8, and 12 are presented in Figures 1-3 respectively. Three periods were used to obtain input weights at age for yield per recruit analyses: 1973-75, 1979-81, and 1986-88 (Table 3; Figs. 4-6). For each of these weight vectors, subjective smoothing was used to obtain estimates for age 1 and ages greater than 15.

An examination of partial recruitment vectors for approximately the same periods selected for the average weights, indicated little change from the PR used in the most recent assessment. One notable exception was the proportion recruited to the commercial fishing gear at age 7 which was lower in the 1974-75 period than the two subsequent periods (Table 4).

A summary of input parameters used for yield per recruit calculations are as follows:

- (1) Age range: 1-20, 1-16, 1-14
- (2) Average weight at age: 1973-75, 1979-81, 1986-88
- (3) Partial recruitment: Used in most recent assessment for 1988
- (4) Natural mortality: 0.20

The results of these analyses are given in Table 5.  $F_{0.1}$  values range from 0.16 to 0.24 while  $F_{\max}$  values range from 0.31 to 0.51. The parameter with the largest influence on the estimation of the  $F_{0.1}$  and  $F_{\max}$  reference levels was the age range with the range from 1 to 16 giving  $F_{0.1}$  levels similar to those used in the past (Fig. 7).

### References

- Baird, J. W. and C. A. Bishop. 1989. Assessment of the cod stock in NAFO Divisions 2J and 3KL. CAFSAC Res. Doc. 89/6.

TABLE 1. CATCH NUMBERS AT AGE (X 1000) FROM THE COMMERCIAL COD FISHERY IN NAFO DIVISIONS 2J3KL FOR THE PERIOD 1962-88.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
2	301	1446	2872	85	819	790	288	59	6819	33	236	0	473	420
3	8666	5746	19338	5177	14057	15262	6142	4330	18104	12876	6737	3963	3231	3968
4	26194	27577	27603	28709	65992	77873	94291	39626	60102	71557	79809	40785	13201	14101
5	64337	60234	57757	46800	93687	100339	205805	100858	82357	95384	116562	94844	34927	25370
6	58163	118112	60681	66946	62812	96759	150541	163228	101249	98111	76196	59503	74403	34426
7	47314	58996	100147	64360	59312	54996	83808	107509	85696	57865	55984	35464	60539	39105
8	27521	29349	50865	68176	30423	38691	39443	52661	29218	25055	29553	27351	35687	36485
9	20142	15520	20892	33819	23844	17146	23171	19651	10857	11732	11750	14153	18854	13421
10	18036	11612	12264	14913	8762	16084	10984	12370	3825	4470	6393	7566	10492	7514
11	10444	8248	8698	6945	4528	5949	5591	6389	2000	2223	2987	3815	5818	2315
12	9468	4204	6352	3729	2280	3367	5249	4479	1200	1287	1660	2153	2934	1179
13	7778	3942	4989	3948	1825	2108	1939	3004	507	1140	1388	1173	1078	808
14	5785	2933	4036	3730	1186	1529	1334	1557	224	720	725	450	652	372
15	4669	2928	2703	2722	967	685	818	622	214	355	748	278	249	165
16	3888	1737	1456	1859	806	424	610	567	244	474	606	309	338	82
17	3955	1263	1918	575	416	193	127	319	124	124	452	85	162	5
18	2161	1352	1154	971	279	107	89	100	32	128	136	27	113	8
19	232	328	501	183	486	72	83	46	10	148	195	38	45	22
20	403	182	312	226	178	211	26	99	34	78	36	8	20	1
2+	319457	355709	384538	353873	372659	432585	630339	517474	402816	383760	392153	291965	263216	179767
3+	319156	354263	381666	353788	371840	431795	630051	517415	395997	383727	391917	291965	262743	179347
4+	310490	348517	362328	348611	357783	416533	623909	513085	377893	370851	385180	298002	259512	175379
5+	284296	320940	334725	319902	291791	338660	529618	473459	317791	299294	305371	247217	246311	161278
6+	219959	260706	276968	273102	198104	238321	323813	372601	235434	203910	188809	152373	211384	135908
7+	161796	142594	216287	206156	135292	141562	173272	209373	134185	105799	112613	92870	136981	101482
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	
1	15	108	0	0	92	0	0	18	3	0	1	42	25	
3	13767	7128	1323	1152	2554	2185	1702	2585	782	650	831	2329	3106	
4	33727	65510	17556	12361	12025	7172	31286	13616	14871	14824	15219	9217	16482	
5	28049	40462	39206	37493	28814	13191	19003	42602	31760	36614	44168	32340	21273	
6	20898	12107	20319	29202	30016	24800	14397	19028	38624	33922	45869	49061	46761	
7	16811	5397	7711	10982	18017	22014	25435	12044	12503	28006	26025	28469	44072	
8	16022	3396	3078	3460	4830	11848	16930	14701	7246	7050	14722	19505	17461	
9	10931	2730	1530	1300	1217	3175	11936	8934	8910	3836	3104	5818	8526	
10	4637	1381	1083	757	520	779	1923	6341	4227	5162	2000	1346	4699	
11	1462	532	437	560	232	309	338	1018	2536	2905	1977	676	663	
12	631	296	219	183	229	195	156	248	451	1681	1101	873	376	
13	292	149	105	116	56	125	90	90	146	254	574	391	325	
14	251	75	62	51	65	48	153	41	48	107	116	200	194	
15	100	42	40	43	37	14	40	29	41	39	29	37	86	
16	50	21	21	38	13	28	12	11	30	20	18	22	26	
17	40	20	7	7	10	20	13	9	7	17	11	3	5	
18	64	14	8	7	14	5	4	6	7	1	9	1	9	
19	30	2	2	4	4	5	0	2	4	3	2	4	4	
20	20	6	7	9	10	5	0	3	3	5	2	0	4	
2+	147797	139376	92714	97725	98755	85918	123418	121326	122199	135096	155778	150334	163437	
3+	147782	139268	92714	97725	98663	85918	123418	121308	122196	135096	155777	150292	163412	
4+	134015	132140	91391	96573	96109	83733	121716	118723	121414	134446	154946	147963	160306	
5+	100288	66630	73835	84212	84084	76561	90430	105107	106543	119622	139727	138746	143824	
6+	72239	26168	34629	46719	55270	63370	71427	62505	74783	83008	95559	106406	122551	
7+	51341	14061	14310	17517	25254	38570	57030	43477	36159	49086	49690	57345	75790	

TABLE 2. AVERAGE WEIGHT-AT-AGE FROM THE COMMERCIAL COD FISHERY IN NAFO DIVISIONS 2J3KL FOR THE PERIOD 1962-88.

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.00	0.11	0.26	0.25
3	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.44	0.32	0.35	0.45	0.45
4	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.53	0.47	0.68	0.63	0.61
5	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.64	0.71	0.91	0.96	0.93
6	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.08	0.96	1.11	1.18	1.32
7	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.52	1.30	1.27	1.39	1.75
8	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.13	1.80	1.56	1.74	2.07
9	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.86	2.20	2.05	2.21	2.24
10	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.29	2.82	2.75	2.61	2.99
11	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.95	3.19	3.13	3.34	3.67
12	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.12	3.79	3.41	3.66	4.56
13	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	5.00	4.53	4.92	4.78	6.18
14	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	9.32	6.93	4.40	5.20	8.19
15	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	9.40	7.22	6.33	5.20	9.77
16	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	6.89	7.05	5.50	5.46	11.23
17	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	14.67	9.45	7.57	8.51	12.44
18	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	12.04	11.16	11.07	9.24	11.16
19	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	7.62	7.62	7.62	7.62	7.62
20	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	17.46	17.46	17.46	17.46	17.46
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988			
2	0.09	0.00	0.00	0.41	0.00	0.00	0.31	0.34	0.00	0.21	0.32	0.30			
3	0.45	0.40	0.46	0.53	0.55	0.53	0.62	0.59	0.48	0.51	0.43	0.49			
4	0.60	0.72	0.74	0.77	0.78	0.84	0.87	0.88	0.73	0.72	0.66	0.73			
5	0.97	1.04	1.13	1.16	1.17	1.20	1.32	1.20	1.10	1.04	1.03	1.07			
6	1.66	1.58	1.67	1.71	1.64	1.77	1.75	1.79	1.43	1.54	1.32	1.36			
7	2.33	2.46	2.46	2.38	2.23	2.10	2.28	2.28	2.06	1.85	1.87	1.64			
8	2.82	3.26	3.57	3.56	2.86	2.66	2.61	2.71	2.66	2.35	1.93	2.18			
9	3.46	4.05	4.41	5.01	3.81	3.09	3.18	2.96	3.23	2.94	2.80	2.47			
10	3.88	4.46	5.25	5.49	5.32	4.18	3.50	3.65	3.32	3.47	3.51	2.99			
11	4.78	5.02	5.80	6.72	6.29	6.16	4.79	4.28	4.06	3.80	4.80	4.33			
12	6.13	6.72	7.03	7.87	7.06	7.19	7.76	6.19	4.55	4.54	4.64	5.41			
13	7.31	8.10	8.96	8.38	7.32	8.00	9.07	8.39	7.03	5.34	5.74	6.43			
14	8.40	7.42	8.54	10.03	10.01	8.36	9.14	10.26	9.67	7.12	6.13	8.37			
15	8.81	8.20	9.46	11.31	8.99	7.86	10.62	11.44	11.37	11.77	8.53	9.64			
16	11.75	11.26	10.70	13.87	11.54	7.91	10.57	11.61	11.27	11.24	13.51	9.46			
17	10.63	11.61	13.12	10.68	10.48	9.58	13.13	17.47	12.68	14.15	9.10	12.26			
18	12.27	8.92	13.49	16.09	11.15	12.95	15.97	12.94	12.42	16.14	21.77	16.26			
19	7.62	10.57	15.51	12.04	9.82	0.00	9.73	15.21	14.38	12.30	17.66	17.01			
20	17.46	16.00	14.77	11.37	12.59	0.00	15.88	12.81	19.49	15.72	0.00	11.44			

NOTE - AVERAGE WEIGHTS OF 0.00 INDICATE NO CATCH.

Table 3. Mean weights for Div. 2J3KL cod averaged over the three year periods indicated. (Estimates derived from subjective smoothing.)

Age	1973-75 Estimates		1979-81 Estimates		1986-88 Estimates	
1	-	0.15	-	0.30	-	0.20
2	0.19		0.41		0.28	
3	0.37		0.51		0.48	
4	0.59		0.76		0.70	
5	0.86		1.15		1.05	
6	1.08		1.67		1.41	
7	1.32		2.36		1.79	
8	1.70		3.33		2.15	
9	2.15		4.41		2.74	
10	2.73		5.35		3.32	
11	3.22		6.27		4.31	
12	3.62		7.32		4.86	
13	4.74		8.22		5.84	
14	5.51		9.53		7.21	
15	6.25		9.92	10.25	9.98	
16	6.00	7.00	12.04	11.25	11.40	
17	8.51	7.80	11.43	12.00	11.84	12.50
18	10.49	8.50	13.58	12.50	18.06	13.10
19	7.62	8.90	12.46	13.00	15.66	13.50
20	17.46	9.00	12.91	13.00	13.58	13.50

Table 4. Partial recruitments for Div. 2J3KL cod for various time periods indicated.

Age	1974-75	1979-81	1988
3	0.02	0.03	0.02
4	0.14	0.19	0.21
5	0.37	0.46	0.37
6	0.53	0.62	0.58
7	0.69	0.81	0.85
8	1.00	1.00	1.00
9-20	1.00	1.00	1.00

Table 5. Results of a series of yield per recruit analyses for Div. 2J3KL cod.

Years		Age range					
		1-20		1-16		1-14	
		F	Y/R (kg)	F	Y/R (kg)	F	Y/R (kg)
1973-75	F <sub>0.1</sub>	0.169	0.332	0.206	0.333	0.244	0.331
	F <sub>max</sub>	0.385	0.364	0.440	0.362	0.509	0.359
1979-81	F <sub>0.1</sub>	0.170	0.593	0.198	0.591	0.227	0.583
	F <sub>max</sub>	0.311	0.638	0.342	0.631	0.382	0.620
1986-88	F <sub>0.1</sub>	0.158	0.431	0.198	0.428	0.243	0.424
	F <sub>max</sub>	0.340	0.469	0.411	0.465	0.495	0.459

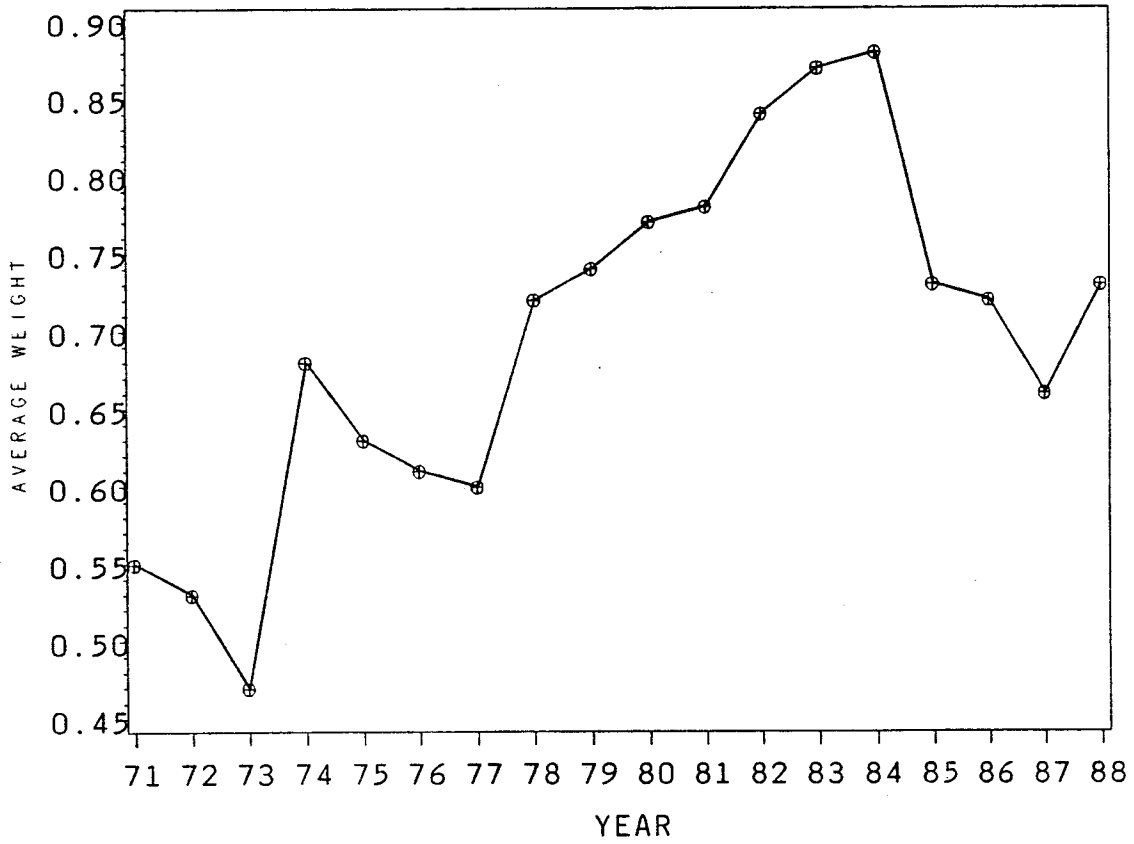


Figure 1. Age 4 average weights for 2J3KL cod (1971-88).

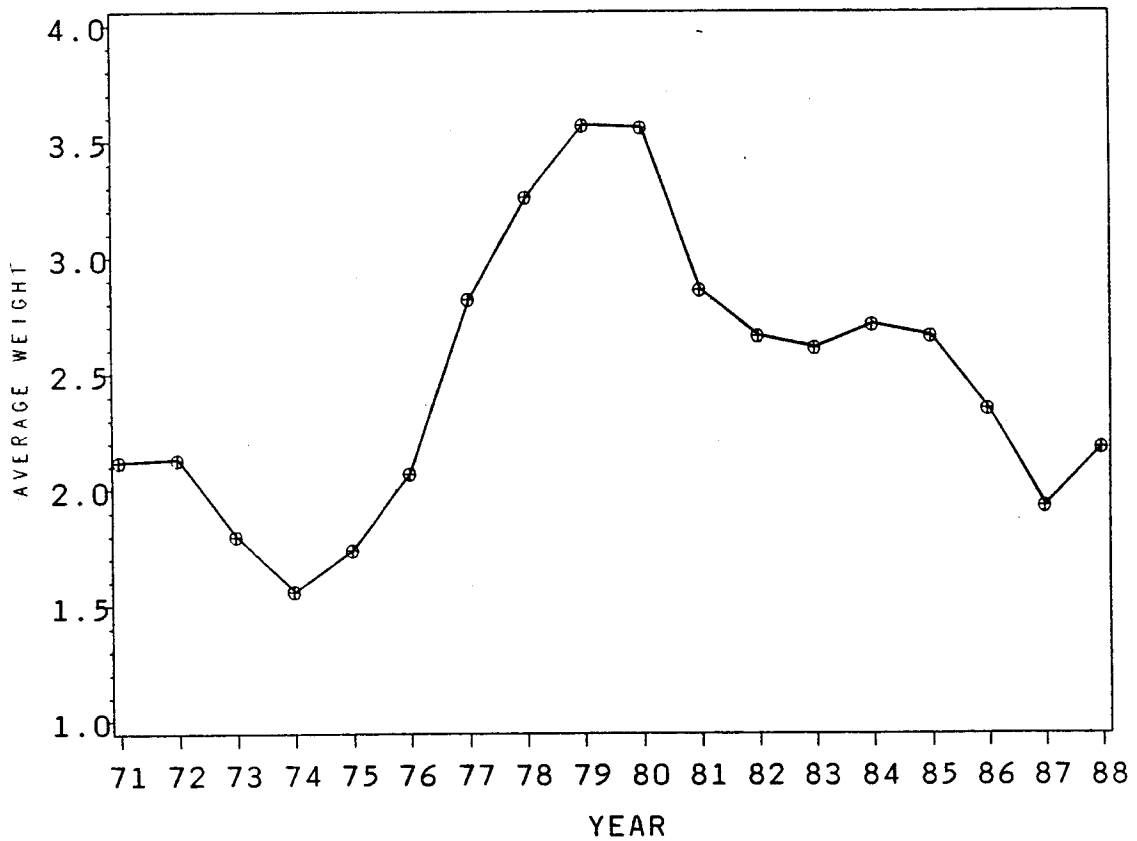


Figure 2. Age 8 average weights for 2J3KL cod (1971-88).



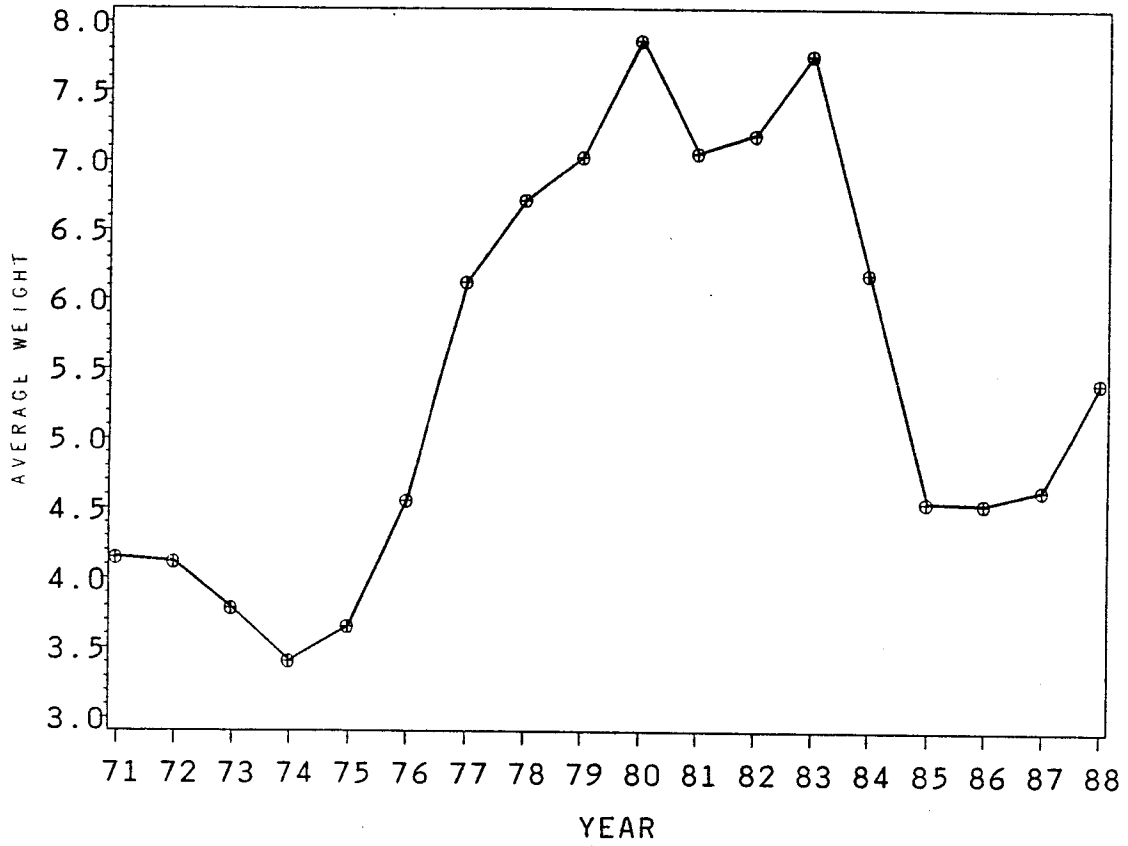


Figure 3. Age 12 average weights for 2J3KL cod (1971-88).

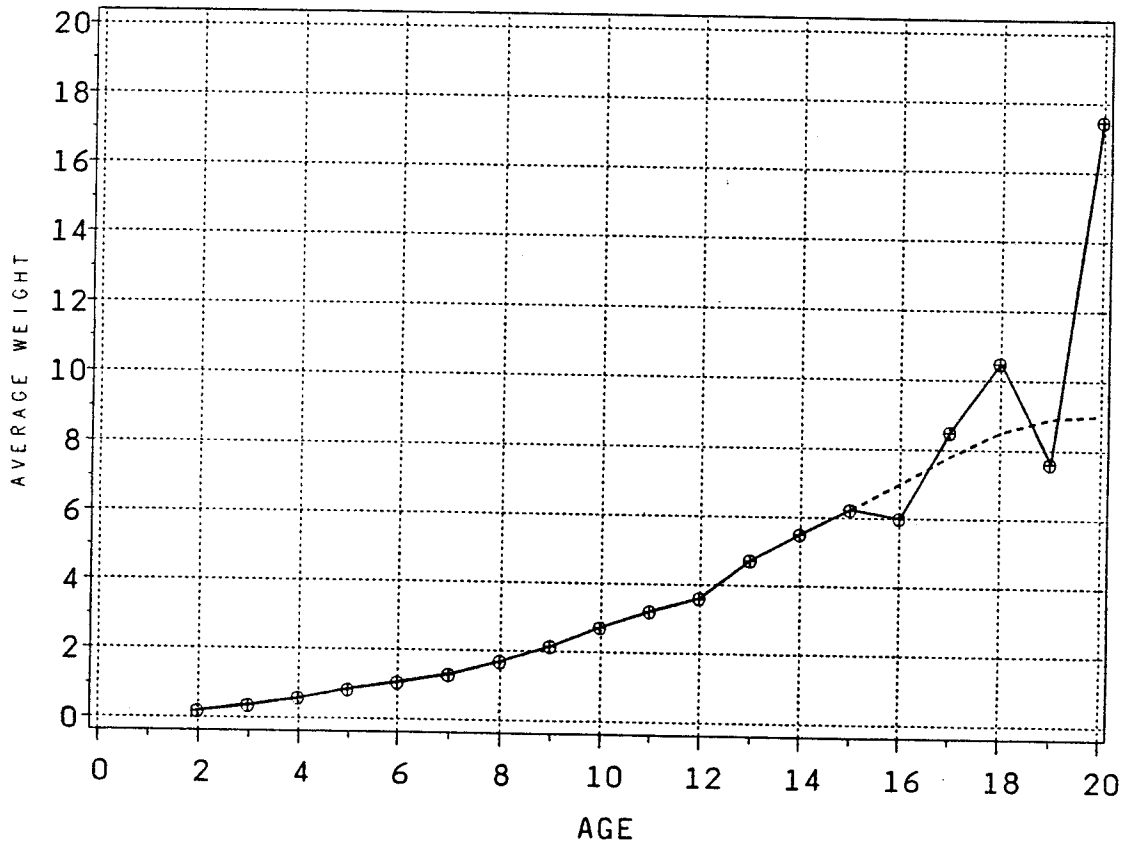


Figure 4. Mean weights for 2J3KL cod averaged for 1973-75.

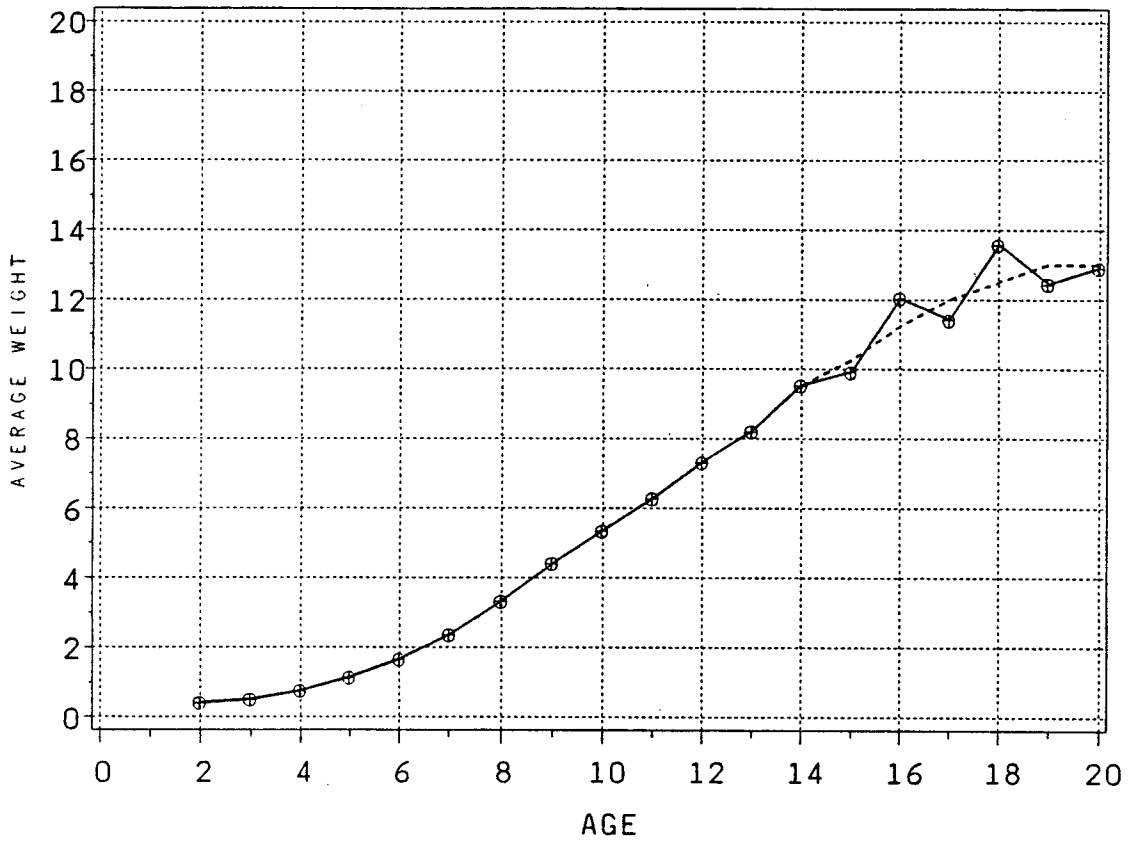


Figure 5 . Mean weights for 2J3KL cod averaged for 1979-81.

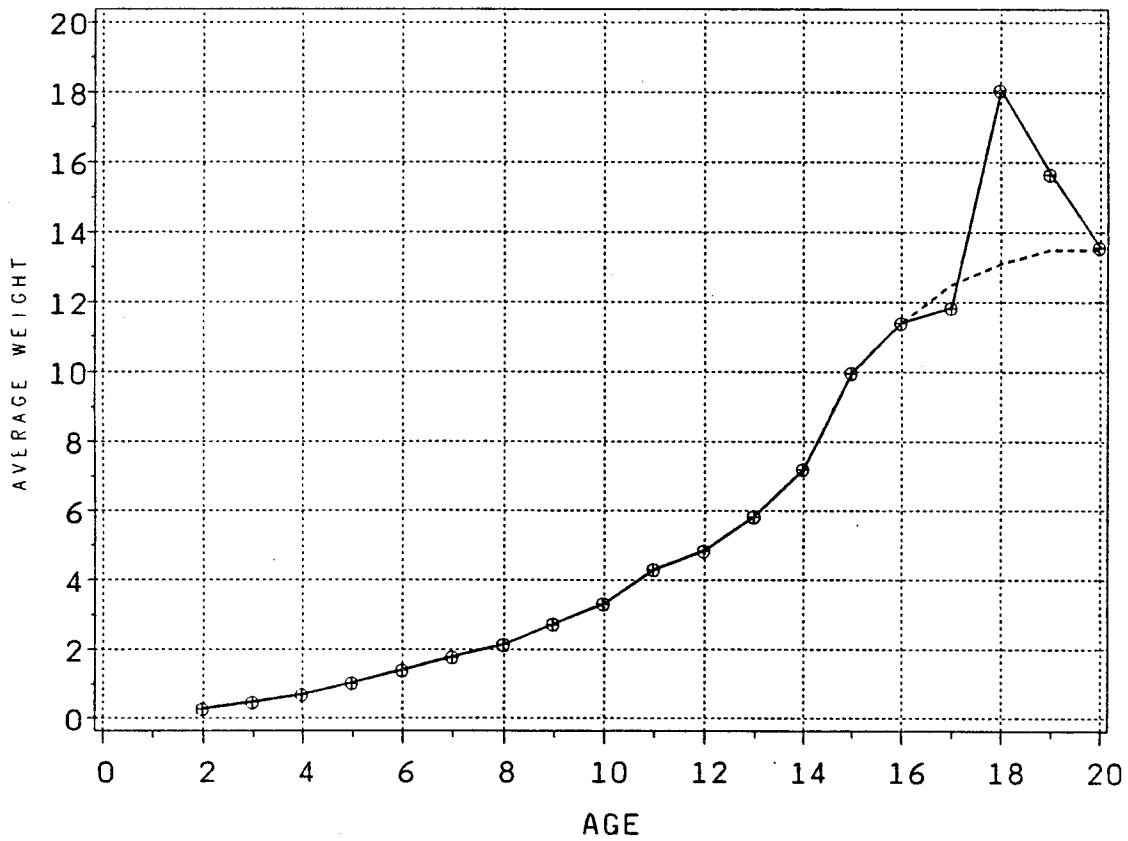


Figure 6 . Mean weights for 2J3KL cod averaged for 1986-88.

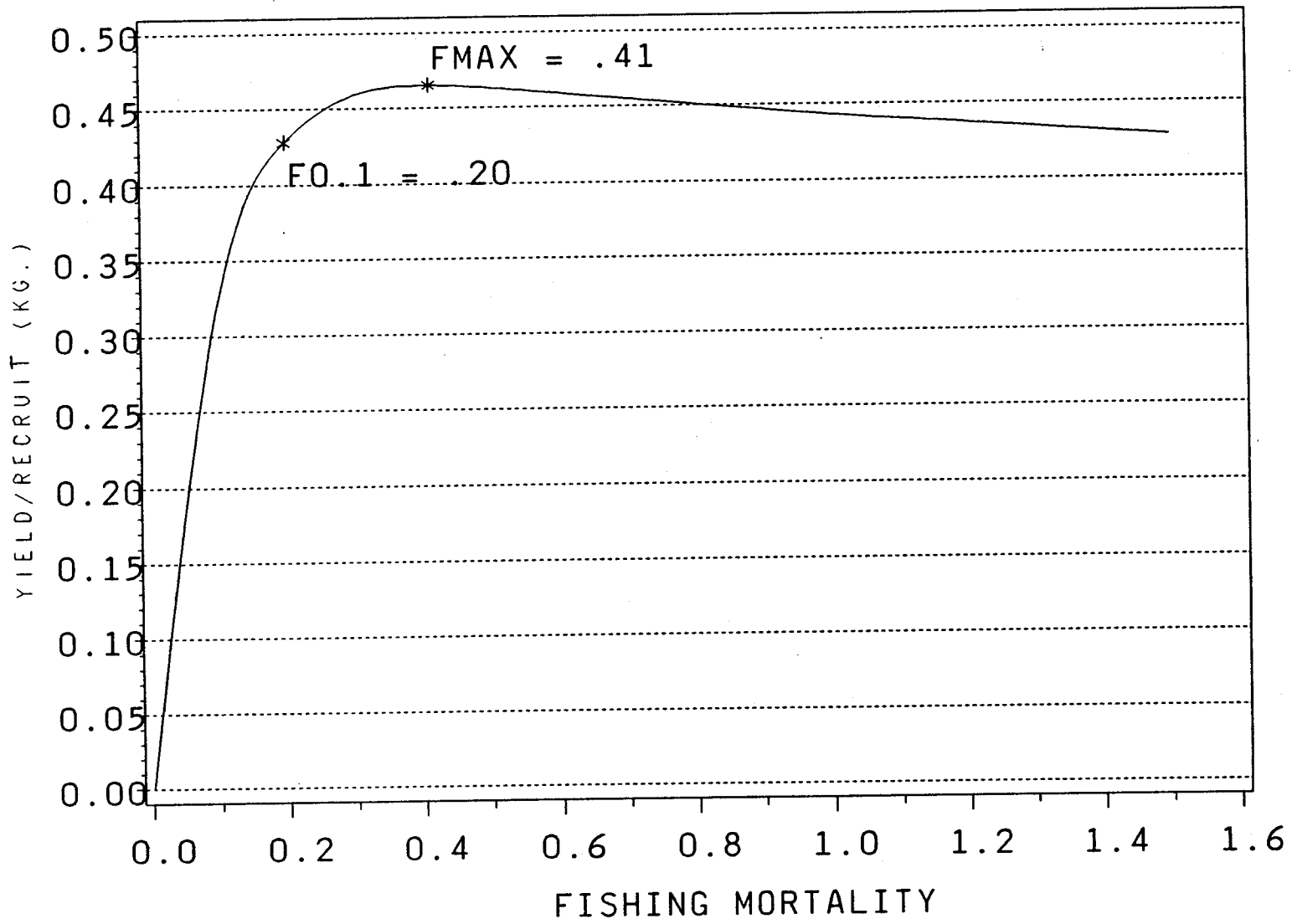


FIG 7. YIELD PER RECRUIT FOR A RANGE OF FISHING MORTALITIES FOR COD IN DIVISIONS 2J3KL.