ANNUAL MEETING - JUNE 1972

Virtual population assessments of cod in
ICNAF Divisions 3K and 3L

R. Wells
Fisheries Research Board of Canada
Biological Station, St. John's, Newfoundland

Introduction

As part of a continuing effort to assess the state of various cod stocks in ICNAF Subareas 2 and 3, virtual population assessments were made of cod in ICNAF Divisions 3K and 3L and in 3KL (Divisions 3K and 3L combined). Data were taken from the ICNAF Sampling Yearbooks and Statistical Bulletins for the years 1955-70 for Division 3L and for 1961-70 for Division 3K. Data prior to 1961 for the 3K inshore fishery were scanty. Age keys for the inshore catches were available in the files of the St. John's laboratory.

Materials and methods

Length compositions of the otter-trawl landings for each division for each year were derived in a manner identical to that used by Pinhorn (1971) for Division 2J cod. It consisted of adjusting the length frequencies by country and month to the numbers caught and then combining these by quarters. Age-length keys for each quarter available were then applied to the length frequencies to provide numbers caught at each age by quarter and these were combined into yearly totals. Catches by inshore gears were treated in the same way and added to the offshore catches to arrive at the annual numbers caught by age in Divisions 3K and 3L (Tables 1 and 3). These tables were combined for the period 1961-70 to produce the numbers caught at each age by year in Division 3KL (Table 5).

The virtual population technique as outlined by Schumacher (1970) and used by Pinhorn (1971) was applied to the data of these 3 tables. An estimate of natural mortality of 0.2 was used for all areas. Initial E values were 0.8, 0.7 and 0.8 for Divisions 3K, 3L and 3KL respectively.

Results

Fishing mortalities

Estimates of F for cod at each age by year are shown in Tables 2, 4 and 6 for Divisions 3K, 3L and 3KL. Full recruitment took place at age 7. The fishing mortality at age 3 was low. Yield per recruit values were calculated incorporating the partial recruitment shown in the tables. Yield per recruit values at various levels of F are shown in Fig. 1.

Division 3K

The maximum yield per recruit was available at an F = 0.3. Yields
of at least 95% of the maximum value could be obtained at levels of F from
0.2 to 0.6. Values of F were within this range for all years considered
except 1968. Interpolated values (Fig. 2) for 1969 and 1970 were also
within this range.

Division 3L

The maximum yield per recruit was available at an F = 0.3. Yields
of at least 95% of the maximum value could be obtained at levels of F from
0.2 to 0.5. Values of F exceeding this range were those of 1964, 1967, and
also of the interpolated values (Fig. 2) for 1969 and 1970.

Division 3KL

The maximum yield per recruit was available at an F = 0.3. Yields
of at least 95% of the maximum value could be obtained at levels of F from
0.2 to 0.5. Values of F exceeding this range were those of 1964, 1967 and
1968. Interpolated values (Fig. 2) for 1969 and 1970 were within this range.

Stock sizes

Numbers of cod present at the beginning of the year are shown in
Tables 7-10. In each division the total stock size has remained fairly
stable or even increased. In Table 10, where stock sizes have been averaged
for 4-year periods, it is apparent that the numbers of the older age groups
have declined, but that stock sizes have been maintained by good recruitment.

Discussion and conclusions

Fishing mortality of cod off the northern and eastern coasts of
Newfoundland in recent years are probably somewhat beyond that required to
obtain the maximum yield. Increases in fishing effort are not likely to
result in increased long-term yield. Older age groups have been reduced
but the stock size has been maintained by good recruitment. The fishery
has therefore become more vulnerable to the fluctuations in strength of
new year-classes entering the fishery.

References

Pinhorn, A.T. 1971. Virtual population assessment of ICNAF Division 2J cod.
Res. Bull. int. Comm. Northw. Atlant. Fish., No. 8: 75-85.

Schumacher, A. 1971. Fishing mortality and stock size in West Greenland cod.
Res. Bull. int. Comm. Northw. Atlant. Fish., No. 8: 15-19.

Table 1. Numbers of cod (000's) caught at each age by year during the period 1961-70 in ICNAF Division 3K. Age compositions were derived by applying age-length keys to length compositions.

Age	Year									
	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
2	-	98	611	2481	22	204	637	288	7	163
3	446	2638	2304	15556	734	3445	4747	1327	54	1543
4	5619	7145	8153	10639	4592	10611	16692	6999	3258	9630
5	9818	17025	20543	18981	8713	14908	16610	21909	10225	14846
6	8459	11654	30443	17033	10423	7683	15015	21733	14290	19413
7	5529	6694	18377	27693	8365	5361	8871	20467	13291	14477
8	5561	4590	6777	12356	5975	3686	5174	7467	11355	4349
9	4392	2415	2806	6502	1673	3305	1627	7665	3555	1564
10	2451	1973	2384	3411	990	1543	1902	2936	3006	997
11	2020	832	1346	1960	518	1401	821	858	1573	628
12	1996	1316	1020	1242	376	968	595	1516	847	307
13	1136	756	482	888	460	507	530	976	472	110
14	1242	634	551	737	244	428	299	681	675	92
15	1127	744	480	549	222	291	176	486	392	94
16	478	367	314	224	94	416	145	304	387	41
17	188	603	201	283	49	38	50	110	174	41
18	86	229	101	253	80	91	44	74	26	-
19	25	87	44	41	22	55	18	77	28	4
20	2	69	80	5	12	126	94	19	49	12
21	-	37	29	16	5	2	5	41	20	10
22	9	7	-	79	1	4	28	38	36	14
23	2	40	3	21	21	-	-	-	23	23
24	-	5	-	-	-	3	-	-	-	-
25	-	-	1	-	1	3	-	-	-	-
26	-	-	-	8	-	1	-	-	-	-
	50586	59958	97050	120958	43592	55080	74080	95971	63743	68358

Table 2. Fishing mortality estimates of cod at each age by year during the period 1961-68 in ICNAF Division 3K.

Age	Year								Average	Change in F with age as % of average F in the ages 7-13
	1961	1962	1963	1964	1965	1966	1967	1968		
2	-	.001	.004	.02	<.001	.001	.004	.0002	.002	1
3	.005	.02	.02	.10	.005	.02	.03	.01	.026	7
4	.04	.07	.08	.14	.04	.11	.12	.05	.081	22
5	.11	.15	.30	.28	.16	.18	.24	.23	.206	55
6	.17	.18	.42	.43	.24	.21	.28	.58	.314	84
7	.19	.20	.49	.85	.39	.19	.41	.76	.435	100
8	.28	.24	.31	.74	.44	.30	.28	.73	.415	100
9	.31	.19	.23	.56	.20	.46	.21	.89	.381	100
10	.32	.22	.28	.47	.15	.29	.54	.73	.375	100
11	.29	.17	.23	.39	.12	.32	.25	.50	.284	100
12	.42	.31	.32	.34	.12	.33	.22	1.04	.388	100
13	.35	.27	.18	.50	.20	.23	.30	.65	.335	100
Average ages 7-13	.31	.23	.29	.55	.23	.30	.32	.76	.373	
Landings	92	88	123	152	73	90	102	157		

Table 3. Numbers of cod (000's) caught at each age by year during the period 1955-70 in ICNAF Division 3L. Age compositions were derived by applying age-length keys to length compositions.

Age	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1	-	-	-	-	78	16	-	79	-	-	-	-	-	-	-	-
2	-	-	8	51	1120	166	-	211	724	204	59	286	90	2929	50	6255
3	143	153	538	1428	1629	2860	1005	5902	1799	1920	3894	3684	4351	59719	3439	10820
4	3235	2066	2036	6504	17690	15000	12250	17476	10958	12094	17157	28813	20800	100377	25549	40131
5	8869	7822	7410	12530	11515	31436	19939	26771	20964	17054	23658	39073	30134	43027	56431	38028
6	13497	12325	7247	10780	13984	15779	21399	13409	25159	17791	20791	19206	34316	14300	51190	30308
7	13172	18284	7298	5188	12474	8354	6026	16801	11003	18294	19827	11495	19129	3990	21737	19739
8	22915	13053	8542	5951	5723	6758	4604	6138	8303	9791	11215	6856	14859	1938	5717	6554
9	7069	20742	7879	3667	4426	2163	3360	4774	3572	7165	4192	2571	7691	811	1278	2100
10	5226	4517	14163	3833	3853	2676	1996	3932	2366	4342	3783	1516	7356	646	801	972
11	2139	3821	6746	6054	2571	2880	1682	1707	1448	2749	1282	1220	2225	406	419	509
12	1173	2039	5795	2428	4589	3105	969	1532	968	2711	713	139	1751	325	271	420
13	1778	1013	3817	1595	902	5583	1313	720	785	1939	1008	403	597	25	504	155
14	693	1014	1644	496	1100	1059	959	784	684	1891	649	251	878	6	59	69
15	645	753	1385	404	667	1136	509	656	329	1148	512	462	378	8*	12	85
16	712	819	763	374	194	641	146	107	361	560	415	99	70	-	15	88
17	140	187	531	328	286	366	108	160	100	1183	335	316	29	-	10	35
18	95	147	372	243	121	435	66	30	60	427	324	109	47	-	-	31
19	81	35	189	108	263	295	48	11	14	170	55	367	27	-	-	6
20	39	52	63	15	51	302	30	4	25	230	165	34	65	-	2	22
21	18	14	30	2	14	107	25	7	11	52	46	54	30	-	-	20
22	1	4	29	2	5	34	28	9	14	-	58	34	-	-	-	2
23	-	-	11	-	-	2	43	-	1	-	20	8	14	-	6	9
24	-	-	6	-	1	30	-	-	9	-	69	13	7	-	1	-
25	6	-	1	-	-	35	-	-	-	-	10	-	5	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	26
	81646	88860	76503	61981	83256	101218	76505	101220	89657	101715	110237	117013	144849	228507	167491	156384

* > 15

F 5

Table 4. Fishing mortality estimates of cod at each age by year during the period 1955-68 in ICNAF Division 3L.

Age	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average	Change in F with age as % of average F in the ages 7-13
2	-	-	<.001	<.001	.004	.001	-	.001	.004	.001	<.001	.001	<.001	.006	.002	0.4
3	.001	.001	.005	.006	.01	.01	.006	.04	.01	.01	.02	.01	.01	.01	.02	3
4	.04	.02	.02	.07	.10	.12	.07	.12	.09	.10	.11	.15	.07	.23	.12	26
5	.10	.12	.08	.16	.16	.26	.23	.22	.21	.19	.30	.38	.23	.53	.29	63
6	.15	.20	.15	.16	.26	.33	.28	.24	.33	.28	.38	.42	.67	.60	.40	88
7	.19	.32	.17	.15	.27	.24	.20	.37	.32	.42	.58	.38	.97	.66	.49	100
8	.20	.29	.24	.20	.24	.23	.20	.32	.32	.52	.50	.41	1.25	.55	.51	100
9	.20	.28	.28	.15	.22	.13	.17	.33	.31	.50	.44	.20	1.13	.50	.45	100
10	.18	.19	.31	.21	.24	.20	.17	.30	.27	.77	.53	.28	1.50	.32	.52	100
11	.13	.19	.48	.21	.21	.28	.18	.22	.17	.58	.54	.32	.88	.52	.43	100
12	.15	.18	.50	.32	.24	.41	.14	.25	.19	.55	.29	.10	1.07	.38	.37	100
13	.24	.19	.57	.25	.19	.51	.30	.15	.20	.72	.41	.27	.83	.57	.43	100
Average ages 7-13	.18	.23	.36	.21	.23	.29	.19	.28	.25	.58	.47	.28	1.09	.50	.46	
Landings	158	187	161	106	133	162	146	164	156	215	186	181	258	266		

F 6

Table 5. Numbers of cod (000's) caught at each age by year during the period 1961-70 in ICNAF Divisions 3K and 3L combined.* Age compositions were derived by applying age-length keys to length compositions.

Age	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1		79								
2		309	1335	2685	81	490	727	288	57	6418
3	1451	8540	4103	17476	4628	7129	9098	4256	3493	12363
4	17869	24621	19111	22733	21749	39424	37492	66718	28807	49761
5	29757	43796	41507	36035	32371	53981	46744	122286	66656	52874
6	29858	25063	55602	34824	31214	26889	49331	64760	65480	49721
7	11555	23495	29380	45987	28192	16856	28000	34767	35028	34216
8	10165	10728	15080	22147	17190	10542	20033	11457	17072	10903
9	7752	7189	6378	13667	5865	5876	9318	9603	4833	3664
10	4447	5905	4750	7753	4773	3059	9258	3747	3807	1969
11	3702	2539	2794	4709	1800	2621	3046	1504	1992	1137
12	2965	2848	1988	3953	1089	1107	2346	1922	1118	727
13	2449	1476	1267	2827	1468	910	1127	1301	976	265
14	2201	1418	1235	2628	893	679	1177	706	734	161
15	1636	1400	809	1697	734	753	554	492	404	179
16	624	474	675	784	509	515	215	304	402	129
17	296	763	301	1466	384	354	79	110	184	76
18	152	259	161	680	404	200	91	74	26	31
19	73	98	58	211	77	422	45	77	28	10
20	32	73	105	235	177	160	159	19	51	34
21	25	44	40	68	51	56	35	41	20	30
22	37	16	14	79	59	38	28	38	36	16
23	45	40	4	21	41	8	14		29	32
24	-	5	9	-	69	16	7		1	
25			1	-	11	3	5			
26				8		5				
30										26
	127091	161178	186707	222673	153829	172093	218929	324470	231234	224742

Table 6. Fishing mortality estimates of cod at each age during the period 1961-66 in ICNAF Divisions 3K and 3L combined.*

Age	1961	1962	1963	1964	1965	1966	1967	1968	Average	Change in F with age as % of average F in the ages 7-13
2	-	.001	.003	.01	<.001	.001	.002	.0004	.002	0.5
3	.004	.03	.02	.05	.01	.01	.02	.01	.02	4
4	.05	.10	.08	.12	.08	.14	.08	.17	.10	24
5	.17	.18	.25	.23	.25	.29	.25	.43	.26	60
6	.23	.21	.37	.35	.32	.34	.48	.64	.37	86
7	.20	.29	.41	.61	.52	.29	.70	.76	.47	100
8	.24	.28	.31	.62	.49	.37	.67	.71	.46	100
9	.25	.26	.27	.52	.33	.31	.66	.81	.43	100
10	.24	.30	.28	.60	.35	.29	1.13	.62	.48	100
11	.23	.21	.23	.50	.27	.33	.53	.55	.36	100
12	.26	.28	.25	.57	.20	.26	.54	.78	.39	100
13	.33	.20	.19	.67	.43	.25	.46	.66	.40	100
Average ages 7-13	.25	.26	.28	.58	.37	.30	.67	.70	.43	
Landings	238	252	279	367	259	271	360	423		

*Division 3KL

Table 7. Numbers of cod (millions) present in the stock at the beginning of the year in ICNAF Division 3K, 1961-68.

Age	Year							
	1961	1962	1963	1964	1965	1966	1967	1968
4	158	98	117	96	131	122	158	149
5	104	129	88	87	64	101	84	118
6	60	77	96	53	53	45	68	55
7	35	41	53	52	28	34	29	42
8	25	24	28	26	18	16	23	16
9	18	15	15	17	10	10	9	14
10	10	11	11	10	8	7	5	6
11	9	6	7	7	5	6	4	2
12	6	5	4	5	4	4	3	3
13	4	3	3	2	3	3	2	2
14	5	2	2	2	1	2	2	1
15	3	3	1	1	1	1	1	1
15+	3	6	5	3	2	2	2	2
Ages 4-15+	440	420	430	361	328	353	390	411

Table 8. Numbers of cod (millions) present in the stock at the beginning of the year in ICNAF Division 3L, 1955-68.

Age	Year													
	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
4	91	122	126	101	210	146	228	161	135	151	177	201	335	355
5	103	74	99	92	83	151	106	151	123	107	102	134	161	263
6	107	75	56	80	66	61	96	69	98	80	73	61	76	105
7	64	74	51	41	57	43	36	60	44	58	49	40	33	32
8	39	57	44	36	29	36	28	25	33	26	31	22	22	10
9	429	93	35	29	24	19	24	19	15	20	13	16	12	5
10	35	29	36	22	20	16	14	16	11	9	10	7	10	3
11	19	24	19	35	15	13	11	10	10	7	3	5	4	2
12	9	14	16	10	23	10	8	8	6	7	3	2	3	1
13	9		9	5	6	15	6	6	5	4	3	2	1	1
14	6	6	4	4	5	4	8	3	4	3	2	2	1	
15	5	4	4	2	3	3	2	5	2	3	1	1	-	-
15+	7	8	7	6	5	7	5	2	4	5	4	4	2	-
Ages 4-15+	1043	586	528	466	546	524	572	535	490	480	471	497	660	777

Table 9. Numbers of cod (millions) present in the stock at the beginning of the year in ICNAF Divisions 3K and 3L combined* 1961-68.

Age	Year							
	1961	1962	1963	1964	1965	1966	1967	1968
4	404	306	264	202	310	374	589	438
5	209	304	209	200	161	236	234	395
6	160	145	199	130	125	102	143	149
7	70	103	96	111	75	74	60	71
8	52	48	62	52	49	37	45	25
9	39	34	30	37	23	24	21	19
10	23	25	22	19	18	13	15	9
11	20	15	15	13	8	10	8	4
12	14	13	10	10	7	5	6	4
13	10	9	8	6	5	4	3	3
14	12	6	6	5	3	2	3	2
15	6	8	3	4	2	1	1	1
15+	6	8	8	7	6	6	3	1
Ages 4-15+	1025	1024	932	796	792	888	1131	1121

Table 10. Average numbers of cod (millions) present in the stock at the beginning of the year in 4-year periods in ICNAF Divisions 3L, 3K, and 3K and 3L combined* The figures for 3K and 3L combined were derived separately from the individual Divisions 3K and 3L figures.

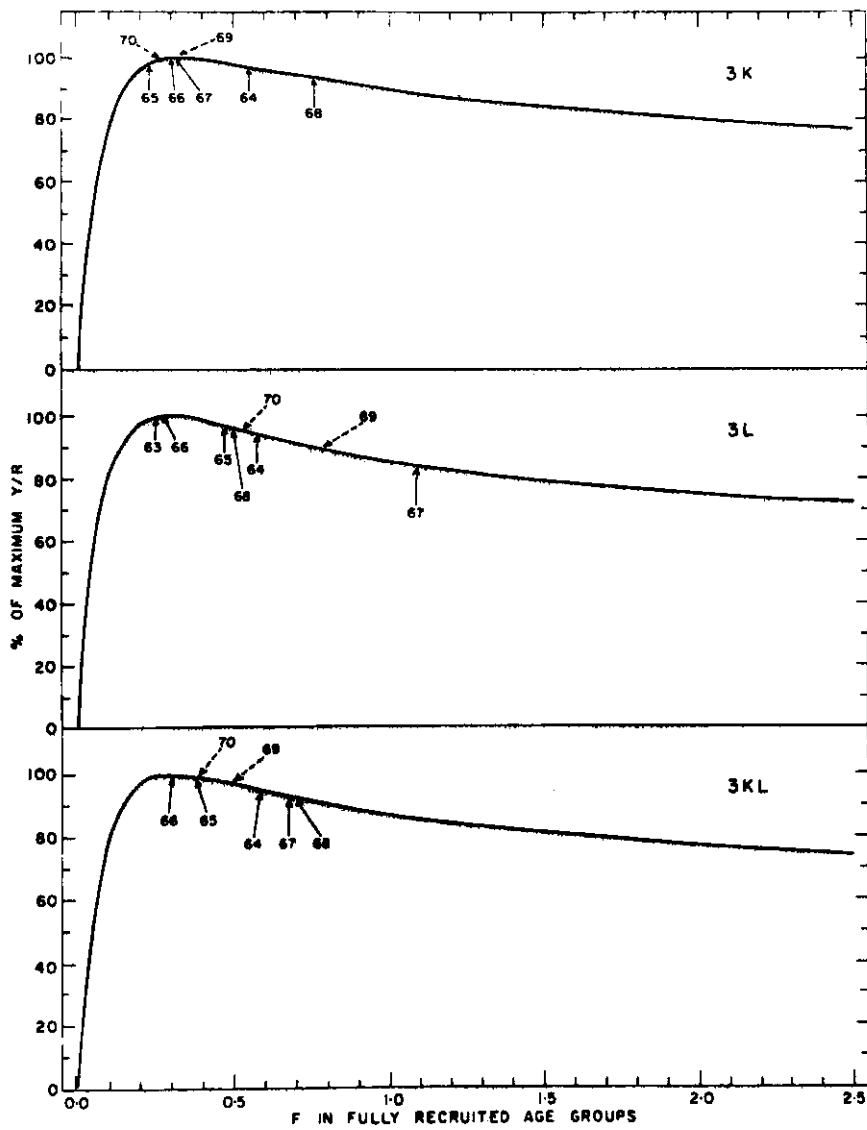| Age	3L			3K		3KL	
	1957-60	1961-64	1965-68	1961-64	1965-68	1961-64	1965-68
4	146	169	267	117	140	294	428
5	106	122	165	102	92	231	257
6	66	86	79	72	68	159	130
7	48	50	39	45	33	95	70
8	36	28	21	26	18	54	39
9	27	20	12	16	11	35	22
10	29	13	8	11	7	22	14
11	21	10	4	7	4	16	8
12	15	7	2	5	4	12	6
13	10	5	2	3	3	8	4
14	4	5	1	-	2	7	3
15	3	3	1	2	1	5	1
15+	6	4	3	4	2	7	4
Total	517	522	604	410	385	945	986

*Division 3KL

F 9

Fig. 1. Yield per recruit values for cod in ICNAF Divisions 3K, 3L and 3KL.
Arrows indicate levels of F in various years. Dashed arrows are F values
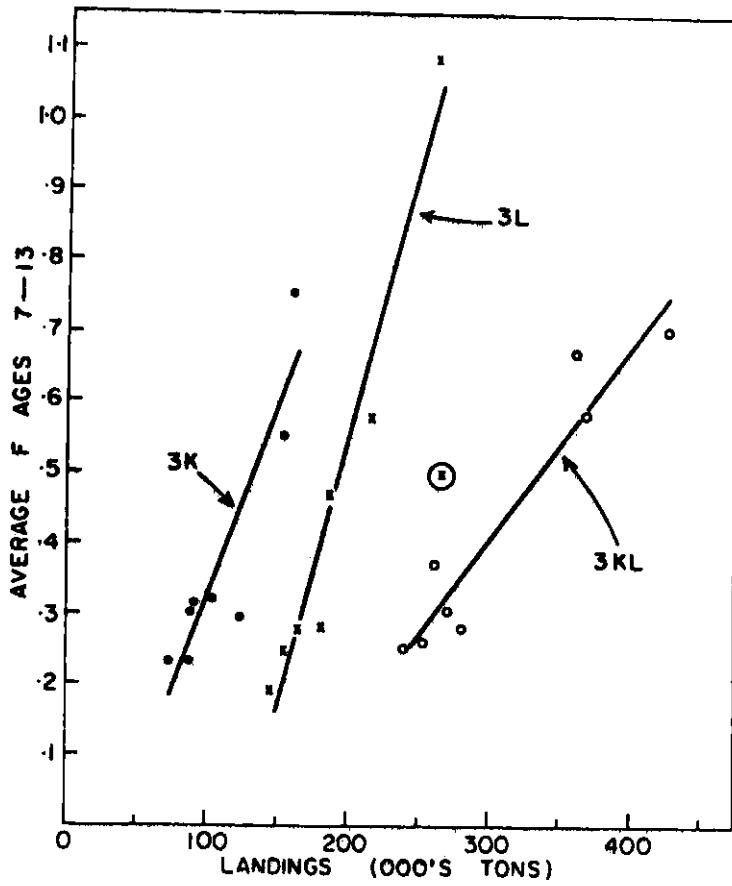for 1969 and 1970 estimated on the basis of catch.

Fig. 2. Straight line fits of fishing mortality with landings in ICNAF
Divisions 3K, 3L and 3KL.

F 11