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ASSESSMENTS OF THE NORTH-EAST ARCTIC AND NORTH SEA  
STOCKS OF SAITHE TAKING INTO ACCOUNT MIGRATION

by

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ABSTRACT

Tagging experiments have shown that there is a substantial migration of young saithe from the Norwegian coast north of  $62^{\circ}\text{N}$  to the North Sea. Assessments of the North-East Arctic and North Sea Stocks of saithe were made assuming that all 1-4 year old saithe caught between  $62^{\circ}$  and  $64^{\circ}\text{N}$  would have recruited to the North Sea stock. The new assessments give a decrease in the level of recruitment to the North-East Arctic stock and an increase to the North Sea stock. The exploitation of the North-East Arctic stock is close to  $F_{\text{max}}$ , whereas the North Sea stock is subject to considerable growth overfishing. Reduction in the exploitation of young saithe between  $62^{\circ}$  and  $64^{\circ}\text{N}$  will benefit chiefly the North Sea stock.

INTRODUCTION

Migration of fish between areas assumed to represent different stocks is a problem both for stock assessments and fishery management. In the North Sea region, migration between the North Sea and adjacent areas is common, but in most cases the data do not give a sufficient basis for quantifying the migration. In stock assessments migration is therefore usually either ignored or the effect of it is eliminated by assuming

that the fish in the areas concerned belong to the same stock. Neither procedure is satisfactory if there in fact are two or more different stocks in the areas.

In the Saithe Working Group, assessments have been made assuming that there is one self-contained stock in Sub-areas I and II and another in Sub-area IV and Division IIIa (Anon. 1981). However, recent tagging experiments have shown that there is a very substantial migration of immature saithe from part of the coastal area north of  $62^{\circ}\text{N}$  to the North Sea (Jakobsen 1978, 1981). This is contrary to the results of tagging experiments in the same area in 1955-58 which showed a basically northward migration (Olsen 1959, Anon. 1965). The present migration pattern may therefore be temporary. However, this pattern appears to have been stable at least for 10 years and clearly introduces a bias in the assessments. Therefore, assessments of the North Sea and North-East Arctic stocks of saithe have been made using information obtained from the tagging experiments to revise the data bases and thus eliminating at least some of the bias caused by migration in the traditional assessments.

#### CHANGES IN THE DATA-BASES

The rate of migration of immature saithe from the Norwegian coast to the North Sea is very high just north of  $62^{\circ}\text{N}$  and then gradually decreases northward along the coast (Jakobsen 1978, 1981). From north of the Lofoten Islands (about  $68^{\circ}\text{N}$ ) it appears to be negligible. If the rate of migration had been the same from the whole coastal area north of  $62^{\circ}\text{N}$ , it might have been possible to estimate an emigration rate from the North-East Arctic. However, the fact that the rate of migration to the North Sea differs between different coastal areas precludes this possibility because the geographical distribution of immature saithe north of  $62^{\circ}\text{N}$  is not sufficiently well known. Thus, it is not known how large proportion of each year class north of  $62^{\circ}\text{N}$  is found in the area south of  $68^{\circ}\text{N}$  from which there is a significant migration to the North Sea. If the

number of fish of each year class migrating to the North Sea had been known, the effect on the North Sea stock might have been calculated (Ulltang 1977) but this again requires an estimate of the emigration rate from the North-East Arctic.

An alternative approach to the problem is to assume that all or a given proportion of immature saithe caught in an area on the Norwegian coast north of  $62^{\circ}$  would eventually have migrated to the North Sea. The Norwegian statistics give landings separately for the area between  $62^{\circ}$  and  $64^{\circ}$ N and also for the area between  $64^{\circ}$  and  $67^{\circ}$ N. The rate of migration to the North Sea from the latter area is substantial, but difficult to estimate. It is clearly higher from the southern part of this area than from the northern part (Jakobsen 1978, 1981) and it is not certain that all the fish migrating southward will go as far as the North Sea. From the area between  $62^{\circ}$  and  $64^{\circ}$ N the rate of migration to the North Sea is very high and the low number of recoveries north of the tagging area also indicates that recruitment to the North-East Arctic spawning stock from this area is low.

Thus, from the assessments it was assumed that all saithe of ages 1-4 caught between  $62^{\circ}$  and  $64^{\circ}$ N would eventually have migrated to the North Sea. This represents an overestimate of migration from that area. However, this was compensated for by not assuming any migration from areas further north. In view of the results of the most recent tagging experiments (Jakobsen 1981) this would seem to represent an underestimate of the migration. However, catches of young saithe between  $64^{\circ}$  and  $67^{\circ}$ N have generally been only about half the level of catches between  $62^{\circ}$  and  $64^{\circ}$ N and the estimate of migration from the southernmost area is therefore most important to the assessments.

The tagging experiments between  $62^{\circ}$  and  $64^{\circ}$ N have been carried out on predominantly 2-4 year old fish. The migration of 5 year old fish from the area is virtually unknown and as some of the saithe mature at this age (Reinsch 1976), the 5 year old fish remaining in the area may join the spawning saithe coming from

the north, which also may contribute to the catch of 5 year olds in the area. The change in the data-bases was therefore restricted to catches of 1-4 year old saithe in the area between  $62^{\circ}$  and  $64^{\circ}$ N which was transferred from the North-East Arctic to the North Sea catch-at-age data base. This is equivalent to extending the area of the North Sea stock north to  $64^{\circ}$ N as far as 1-4 year old saithe is concerned, and reducing the area of the North-East Arctic stock correspondingly.

The data bases were changed only back to 1970 because of inadequate Norwegian catch statistics in earlier years. In addition to the Norwegian fisheries, there has also been other fleets in the area with Germany (Fed. Rep. of) taking the highest catches. These include catches taken at the Halten Bank, i.e. at about  $65^{\circ}$ N, which could not be separated from the others. However, the catches of 1-4 year old saithe are insignificant compared to the Norwegian ones.

For the assessments, also weight-at-age for ages 1-4 had to be adjusted because the young saithe caught in the area between  $62^{\circ}$  and  $64^{\circ}$ N on the average has a lower weight-at-age than the averages both for the North Sea and the North-East Arctic.

Input Fs in 1980 for age groups 5-14 were the same as used in the Saithe Working Group. For the age groups 1-4 the change in the catch-at-age data required a revision of input Fs. This was done by using the same principles as in the Working Group assessments.

## RESULTS

The input catch-at-age and results of the VPA are given in Tables 1-6. The input F-values at 1-4 are lower for the North-East Arctic and higher for the North Sea stock than those used in the Working Group. The transfer of catches from one area to another do not necessarily produce a corresponding change in F-levels. However, considering that immature saithe is heavily fished by purse seiners and to some extent trawlers on the

Norwegian coast between  $62^{\circ}$  and  $64^{\circ}\text{N}$ , it seems reasonable to expect that the exploitation rate on the younger age groups is higher in this area higher in the rest of the North-East Arctic and also higher than in the North Sea. The change from the Working Group assessments in the level of  $F_s$  for ages 1-4 in the historical series, i.e. increase in the North Sea and decrease in the North-East Arctic, seems to support this. However, the traditional assessments ignore migration and therefore do not give "true" levels of  $F$  and the comparison is not totally relevant.

The most striking difference from the traditional assessments is in the level of recruitment. For the North-East Arctic there is a reduction of 24% and for the North Sea an increase of 29% in the average of the year-classes 1969-76. However, the sum of recruitment in the two stocks remains virtually the same. The spawning stocks are of course unchanged, all the input data to estimate them being the same as in the Working Group.

Yield calculations based on the 1980 exploitation patterns are shown in Fig. 1. For the North-East Arctic stock  $F_{80}=0.95 \cdot F_{\text{max}}$ , whereas in the Working Group assessment  $F_{80}=1.18 \cdot F_{\text{max}}$ . For the North Sea stock  $F_{80}=1.59 \cdot F_{\text{max}}$  compared to  $F_{80}=1.46 \cdot F_{\text{max}}$  in the Working Group. The implications of these assessments can be summed up as follows:

1. The present rate of exploitation in the North-East Arctic stock of saithe is close to  $F_{\text{max}}$ .
2. Regulation measures aiming at a further reduction of the exploitation (e.g. to  $F_{0.1}$ ) or an increase of the spawning stock will to a large extent have to be made effective north of  $64^{\circ}\text{N}$ .
3. The North Sea stock is subject to considerable growth overfishing.
4. Regulation measures aiming at a decrease in exploitation of young saithe between  $62^{\circ}$  and  $64^{\circ}\text{N}$  will benefit chiefly the North Sea stock.

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Table 1. North-East Arctic Saithe.

VIRTUAL POPULATION ANALYSIS

CATCH IN NUMBERS

UNIT: THOUSANDS

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	0	0	0	0	0	0	0	0	48	80	0
2	4815	2818	1172	1416	9040	39381	24101	1731	15940	7780	11791
3	57078	38482	28504	60705	21471	49241	88426	67217	35392	47045	12727
4	50406	52946	32421	19961	35743	9100	27174	28532	21161	16550	23782
5	13987	26961	29346	26911	15671	16366	7947	10140	12476	14127	7066
6	16189	9556	10186	16031	20419	4436	8712	2062	4534	4400	7595
7	5122	9592	5616	7114	12148	7808	3435	4332	1468	2901	3071
8	7950	2901	3547	3935	4802	6789	3212	1456	1848	963	2043
9	2504	4352	1865	2871	3258	2914	2679	1606	938	1356	155
10	3697	2195	2140	2610	2505	2350	1724	963	976	438	878
11	1096	5156	1229	1565	1456	1937	1091	463	655	305	429
12	757	1303	796	791	1444	1245	852	244	681	281	453
13	523	554	531	812	452	459	489	211	284	168	253
14	276	232	261	442	263	260	140	58	196	222	252
15+	347	465	552	314	246	239	308	158	299	216	246
TOTAL	144547	155295	117746	145478	128878	142525	170290	119175	96896	96807	70741

Table 2. North Sea Saithe.

VIRTUAL POPULATION ANALYSIS

CATCH IN NUMBERS

UNIT: THOUSANDS

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	626	887	457	4425	3670	311	260	2707	2956	1721	658
2	23989	27171	30870	42728	26869	174766	55175	42924	46788	37513	16130
3	45579	106659	76968	65306	75991	62878	260284	54399	43081	24985	47655
4	87434	59682	82501	39025	40087	26176	54813	56986	34203	21554	21640
5	12391	30151	25124	24725	12451	9028	9852	12914	17251	12843	9421
6	10874	3717	20826	15345	20595	6717	5111	4684	3787	6878	6007
7	3779	3874	5655	8058	14504	12660	3309	3173	1162	2641	4224
8	1996	2682	3113	1798	5028	8656	4840	2902	1069	873	934
9	600	1808	1901	1267	1427	3299	2978	707	707	470	705
10	326	403	1110	1025	809	1100	1068	1895	736	282	349
11	86	225	265	579	412	616	420	875	640	402	536
12	59	51	126	261	222	254	253	342	415	343	230
13	26	18	25	87	152	275	121	347	213	157	160
14	26	18	68	37	30	77	161	123	95	154	104
15+	27	31	49	21	27	25	66	129	108	101	584
TOTAL	185618	237335	245038	2681	202234	246838	396751	187700	153191	110917	109135

Table 3. North-East Arctic Saithe.

VIRTUAL POPULATION ANALYSIS

FISHING MORTALITY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.02	0.02	0.01	0.02	0.05	0.16	0.10	0.01	0.08	0.15	0.08
3	0.16	0.20	0.29	0.40	0.47	0.41	0.62	0.41	0.45	0.37	0.38
4	0.40	0.36	0.26	0.34	0.43	0.37	0.42	0.41	0.22	0.39	0.32
5	0.23	0.38	0.35	0.37	0.48	0.36	0.65	0.27	0.32	0.22	0.29
6	0.33	0.24	0.24	0.35	0.53	0.24	0.33	0.35	0.19	0.18	0.18
7	0.22	0.33	0.21	0.27	0.45	0.39	0.30	0.27	0.45	0.18	0.18
8	0.38	0.19	0.19	0.23	0.29	0.49	0.28	0.20	0.18	0.61	0.18
9	0.24	0.37	0.18	0.23	0.30	0.29	0.36	0.22	0.19	0.19	0.18
10	0.35	0.35	0.31	0.41	0.35	0.37	0.28	0.21	0.20	0.13	0.18
11	0.19	0.57	0.34	0.40	0.42	0.46	0.29	0.11	0.22	0.09	0.18
12	0.33	0.37	0.28	0.38	0.79	0.79	0.37	0.10	0.24	0.74	0.18
13	0.26	0.25	0.15	0.50	0.37	0.63	0.85	0.15	0.16	0.09	0.18
14	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.22	0.20	0.18	0.18
15+	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.22	0.20	0.18	0.18
F(5-10),U	0.29	0.31	0.25	0.31	0.40	0.36	0.37	0.25	0.25	0.25	0.20
F(5-10),L	0.28	0.32	0.28	0.32	0.45	0.36	0.38	0.26	0.26	0.21	0.21

Table 4. North Sea Saithe.

VIRTUAL POPULATION ANALYSIS

FISHING MORTALITY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.01	0.00
2	0.06	0.12	0.16	0.27	0.17	0.21	0.25	0.26	0.31	0.21	0.15
3	0.18	0.37	0.54	0.54	0.75	0.46	1.05	0.44	0.46	0.27	0.45
4	0.36	0.41	0.55	0.54	0.81	0.65	0.97	0.69	0.55	0.44	0.40
5	0.38	0.38	0.27	0.31	0.38	0.42	0.52	0.64	0.46	0.42	0.35
6	0.45	0.19	0.50	0.24	0.47	0.37	0.45	0.51	0.39	0.33	0.35
7	0.28	0.29	0.24	0.37	0.50	0.60	0.31	0.57	0.22	0.52	0.35
8	0.23	0.34	0.34	0.22	0.42	0.65	0.48	0.49	0.38	0.26	0.35
9	0.25	0.35	0.42	0.28	0.28	0.53	0.46	0.78	0.21	0.28	0.35
10	0.34	0.24	0.35	0.42	0.28	0.36	0.33	0.60	0.37	0.12	0.35
11	0.25	0.41	0.25	0.31	0.30	0.36	0.22	0.49	0.42	0.35	0.35
12	0.17	0.23	0.45	0.41	0.14	0.31	0.25	0.28	0.46	0.42	0.35
13	0.27	0.07	0.17	0.35	0.38	0.38	0.24	0.62	0.29	0.31	0.35
14	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.35	0.35	0.35
15+	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.35	0.35	0.35
F(5-10),U	0.32	0.30	0.37	0.32	0.34	0.48	0.43	0.40	0.34	0.32	0.35
F(5-10),L	0.32	0.34	0.35	0.31	0.44	0.50	0.45	0.60	0.41	0.38	0.35



Table 5. North-East Arctic Saithe.

VIRTUAL POPULATION ANALYSIS

STOCK SIZE IN NUMBERS

1 JANUARY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1970-1977
1	190030	305031	95542	251191	365098	357112	161762	272082	70359	206485	0*****		249781
2	285448	155584	249739	78059	205658	299408	292379	132440	222762	67474	168983	0	212359
3	273248	229357	124836	203410	62631	160279	209052	217643	100869	168002	44138	127715	185124
4	168338	190312	153137	76581	112059	37032	86996	92579	117885	55764	95309	24713	114004
5	75842	92587	108274	96219	44768	59687	18056	46849	50198	77470	30821	56663	67785
6	64009	49507	51603	62470	54614	22609	34171	7681	29238	29888	50718	18882	45333
7	28063	37860	31934	35085	36744	26429	14520	20150	4437	19855	20508	34684	28598
8	27583	18366	22379	21090	20690	19191	14650	8800	12601	2316	13643	14024	19091
9	17688	15447	12475	15128	13726	12623	9629	9090	5894	8653	1035	9330	12594
10	13644	8135	8739	8493	9803	8310	7715	5478	5997	3981	5863	708	8790
11	6906	7851	4689	5232	4612	5775	4694	4766	3618	4031	2865	4010	5566
12	2955	4667	3621	2735	2879	2487	2992	2862	3485	2373	3025	1959	3150
13	1555	1739	2651	2249	1529	1070	926	1685	2123	2240	1689	2069	1676
14	1169	983	1106	1872	1114	864	465	323	1189	1482	1683	1155	987
15+	1470	1970	2253	1330	1042	795	1024	880	1814	1442	1643	2274	1345
TOTAL	1152948	1119396	872728	859147	937568	1008611	859612	823306	644469	646458	447923		
SPAWN. ST.	235884	239112	249675	249905	191522	159840	108822	108563	120595	153733	133492		

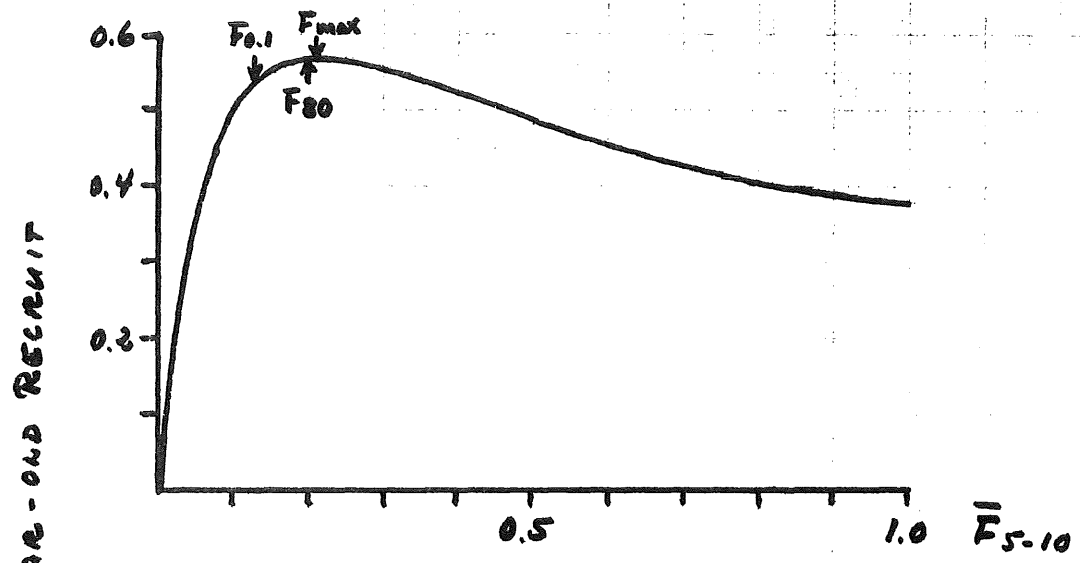
Table 6: North Sea Saithe.

VIRTUAL POPULATION ANALYSIS

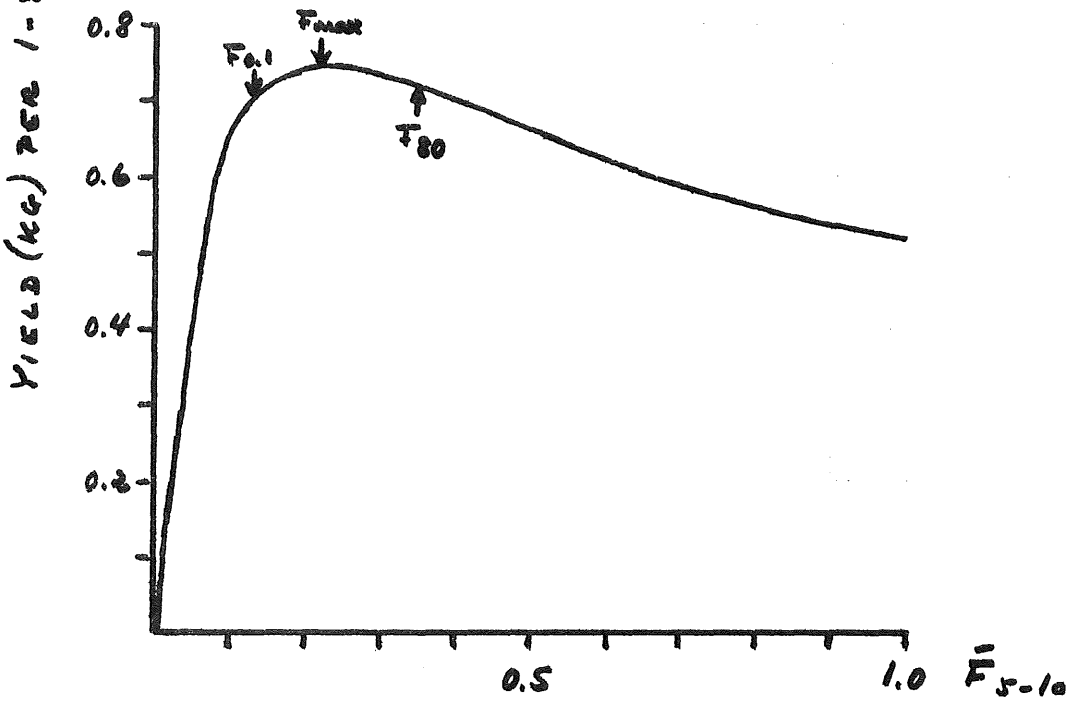
STOCK SIZE IN NUMBERS

1 JANUARY

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1970-1977
1	356220	289772	292483	318577	807773	520697	249774	237743	268459	157563	305390*****		356410
2	486937	274708	239933	239032	256783	637674	262284	203754	192703	217144	127447	249438	327137
3	286795	377021	200474	165368	157267	186014	435111	166906	128214	115515	144014	89811	246861
4	222015	195560	212938	95779	78714	60949	95927	125087	87869	66351	71945	75782	135796
5	42577	103518	106359	100488	43017	28711	26501	29801	51515	41326	34994	39483	60746
6	32725	23737	57707	66449	66054	24061	15408	12874	12856	26711	22313	20190	36627
7	16762	17043	16087	28589	40609	30708	13668	8032	6344	7126	15696	12674	21437
8	10731	10326	10471	9903	16772	20253	13818	8217	3737	4148	3469	9052	12486
9	5174	6990	6045	3779	6489	8730	8843	6976	4127	2100	2611	2002	6628
10	1245	2059	4059	3244	3592	4030	4193	4570	2620	2742	1296	1507	3379
11	428	777	1523	2359	1736	2214	2312	2474	2047	1484	1991	748	1696
12	426	273	595	845	1411	1051	1259	1515	1241	1162	854	1149	897
13	122	296	178	210	437	955	652	803	933	644	594	493	457
14	110	76	226	123	100	256	535	409	353	572	386	343	229
15+	114	131	163	70	90	83	219	429	401	375	1426	1046	162
TOTAL	1440387	1301636	1145041	1074	1473760	1346333	1129885	8095	762918	644703	734421		
SPAWN. ST.	108415	165176	203252	278059	173726	121051	87389	76099	86173	88331	85627		



NORTH-EAST ARCTIC



NORTH SEA

FIG. 1. YIELD PER RECRUIT