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Assessment of American Plaice (*Hippoglossoides platessoides*) in NAFO Subarea 1 and ICES Div. XIVb Based on Survey Indices, 1982-98

by

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Abstract

Stock abundance and biomass indices decreased from 100 million individuals and 20 000 tons during the early 1980s to 50 million individuals and 5 000 tons in 1998. This decrease was caused by the stock reduction off West Greenland while the abundance off East Greenland remained fairly stable. The age structure of the stock component off West Greenland shrunk significantly by more than 2 years from an average age of 8 years in 1982 to a constant level below 6 years since 1990. The decrease of the spawning stock in number and weight off West Greenland is drastic and exceeded the level of 80 %.

The spawning stock-recruitment relation indicates a significantly reduced recruitment potential for SSB index<3 000 t, a possible candidate for a SSB_{pa} value (mbal) for the West Greenland stock component. Since 1990, the SSB index remained below the 3 000 t level and consequently outside the safe biological level. $F_{0.1}$ and F_{max} amounted to 0.14 and 0.23, F_{msy} amounted to 0.1 and SSB_{msy} to 3 000 t, respectively. The current mortality rates are indicated to significantly exceed sustainable levels. The low productivity of the stock can be explained by the slow growth and poor condition as a consequence of the sub-arctic environment. Furthermore, the American plaice off West Greenland displays a very late and slow maturation which indicates a high sensitivity to increased mortality rates.

Introduction

The exploitation of American plaice in Greenland waters has not been of any commercial importance during the past two decades but is considered to reflect the bottom trawl fishing effects as a dominant species in the demersal fish assemblage and by-catch. This paper presents estimates of American plaice stock abundance and biomass indices disaggregated by age groups as derived from annual groundfish surveys commenced in 1982, the only regular source of quantitative information from the traditional fishing grounds off West and East Greenland south of 67° northern latitude. Individual size is given in terms of length and weight. Maturity data were used for estimation of spawing stock size in numbers and biomass.

Materials and Methods

Abundance, biomass estimates and length structures were derived from annual groundfish surveys covering shelf areas and the continental slope off West and East Greenland. Surveys commenced in 1982 and were primarily designed for the assessment of cod. Because of favourable weather and ice conditions and to avoid spawning concentrations, autumn was chosen for the time of the surveys. These were carried out by the research vessel (R/V) WALTHER HERWIG (II) throughout most of the time period. In 1984 R/V ANTON DOHRN was used and she was replaced by the new R/V WALTHER HERWIG III since 1994, respectively.

The fishing gear used was a standardized 140-feet bottom trawl, its net frame rigged with heavy ground gear because of the rough nature of the fishing grounds. A small mesh liner (10mm) was used inside the cod end. The horizontal distance between wing-ends was 25 m at 300 m depth, the vertical net opening being 4 m. In 1994, smaller Polyvalent doors (4.5 m^2, 1,500 kg) were used for the first time to reduce net damages due to overspread caused by bigger doors (6 m^2, 1,700 kg), which have been used earlier. All calculations of abundance and biomass indices were based on the 'swept area' method using 22 m horizontal net opening as trawl parameter, i. e. the constructional width specified by the manufacturer. The towing time was normally 30 min. at a speed of 4.5 knots. Trawl parameters are listed in Table 1. Hauls which received net damage or became hangup after less than 15 minutes were rejected. Some hauls of the 1987 and 1988 surveys were also included although their towing time had been intentionally reduced to 10 minutes because of the expected large cod catches as observed from echo sounder traces.

Fish were identified to species or lowest taxonomic level and the catch in number and weight was recorded. Total fish lengths were measured to cm below. Weight (g) at age calculations were based on the regression $f(x)=0.0036105x^{3.253315}$, x=length (cm), which was determined on the basis of 1 589 individual measurements.

The surveys were primarily designed for the assessment of cod. In order to reduce the error of abundance estimates, the subdivision of shelf areas and the continental slope into different geographic and depth strata was required due to a pronounced heterogeneity of cod distribution. The survey area was thus split into seven geographic strata. Each stratum was itself subdivided into two depth strata covering the 0-200 m and 201-400 m zones. Figure 1 and Table 2 indicate the names of the 14 strata, their geographic boundaries, depth ranges and areas in nautical square miles (nm^2). All strata were limited at the 3 mile offshore line.

The applied strategy was to distribute the sampling effort according both to the stratum areas and to cod abundance. Consequently, fifty percent of the hauls were allocated proportionally to strata by stratum area while the other fifty percent were apportioned on the basis of a review of the historical mean cod abundance/nm^2, all hauls being randomly distributed within trawlable areas of the various strata. Non-trawlable areas were mainly located inshore. During 1982-98, 2 521 successful sets were carried out, the numbers of valid sets by year and stratum being listed in Table 3. Apart from stratum 7.2 (Dohrn Bank), East Greenland strata were not covered adequately in 1984, 1992 and 1994 due to technical problems. In 1995, the survey area off West Greenland was incompletely covered for the first time again due to technical problems. Only 50 % of the strata of West Greenland were covered, namely the southern strata 3.1, 3.2, 4.1, and 4.2. Stratum 7.1 has a very low area and therefore never been covered. Since 1996, the entire survey area was covered. Figure 1 shows the positions of hauls conducted during the most recent survey.

Stratified abundance estimates were calculated from catch-per-tow data using the stratum areas as weighting factor (Cochran, 1953; Saville, 1977). Strata with less than five valid sets were rejected from the calculation. The coefficient of catchability was set arbitrarily at 1.0, implying that estimates are merely indices of abundance and biomass. Respective confidence intervals (CI) were set at the 95% level of significance of the stratified mean.

Conversion of length compositions 1982-98 into age disaggregated abundance was based on a length-stratified otolith (sagitta) collection from West Greenland only comprising 954 age determinations conducted in 1994 (Lloret, 1997). Only West Greenland length compositions were converted to age compositions due to expected growth differences between West and East Greenland. Thin sections were cutted through the central part of the

otoliths after they have been embedded into black polyester resin. Annuli were counted under a binocular microscope using transmitted light.

Maturity at age was determined from visual observations (Lloret, 1997). However, the results should be interpreted carefully since the surveys were conducted in autumn when a high proportion of the gonads displayed resting stages. During this season, it was often difficult to distinguish immature from mature American plaice. The data recorded in 1994 were used to estimate the trend in spawning stock size in numbers and weight.

In order to investigate the productivity, the spawning stock biomass (SSB) data in year n were plotted against the strength of the year classes at age 3 in year n-3, and the Ricker model (Ricker, 1975) was fitted. Various management references for biomass and fishing mortality are proposed based on yield and spawning stock biomass per recruit analysis and equilibrium analysis. The parameters used are given in Table 10. Natural mortality coefficients by age were set to M=0.1 and the fishing mortality vector was derived from a linear regression model fitted to the mean total mortality minus natural mortality including ages 0-11 as derived from the survey results. The models used the calculated length and weight at age vectors as input values to allow for an extension of the age range to age 20 years.

Results and Discussion

Figure 1 illustrates the survey area and splitting into strata and shows the trawl position and catch rates observed during the most recent survey in 1998. The catch rates peaked at 20 kg/0.5h.

Tables 4 and 5 list abundance and biomass indices by stratum, West and East Greenland and total in 1982-98. Indices varied significantly between strata and years. Trends of the abundance and biomass estimates for West and East Greenland are shown in Figures 2 and 3, respectively. These figures illustrate the negative trend in stock abundance and biomass from 100 million individuals and 20 000 tons during the early 80s to 50 million individuals and 5 000 tons in 1998. This decrease was caused by the stock reduction off West Greenland while the abundance off East Greenland remained fairly stable.

The age disaggregated abundance for West Greenland 1982-98 is given in Table 6. The age structure of the stock component off West Greenland shrunk significantly by more than 2 years from an average age of 8 years in 1982 to a constant level below 6 years since 1990 (Fig. 4). Age disaggregated spawning stock abundance and biomass indices are listed in Tables 7 and 8, respectively. The decrease of the spawning stock in number and weight off West Greenland is drastic and exceeded the level of 80 % (Fig. 2 and 3).

For West Greenland estimates of total mortality coefficients Z are given in Table 9. Despite the high variation it can be seen in Figure 4 that the mean Zs off West Greenland were higher during the 90s when the coefficient often exceeded the level of 1.0.

The productivity of the stock component off West Greenland is illustrated in Figures 6-9. The Ricker curve indicates a significantly reduced recruitment potential for SSB index<3 000 t, a possible candidate for a SSB_{pa} value (mbal) for the West Greenland stock component. Since 1990, the SSB index remained below the 3 000 t level (Tab. 8, Fig. 3) and consequently outside the safe biological level. $F_{0.1}$ and F_{max} are very low and amounted to 0.14 and 0.23, respectively (Fig. 7). The selectivity of the survey gear is probably very similar to the selectivity of the small meshed shrimp trawls used by the commercial fleet, which have been demonstrated to effectively catch juvenile fish. The resulting F_{msy} amounted to 0.1 and SSB_{msy} 3 000 t (Fig. 8 and 9), respectively. The current mortality rates, which might be attributed to the unknown by-catches in the shrimp fishery or increased natural mortality rates, are indicated to significantly exceed sustainable levels (Tab. 11). The low productivity of the stock can be explained by the slow growth and poor condition as a consequence of the sub-arctic environment. Furthermore, the American plaice off West Greenland displays a very late and slow maturation which indicates a high sensitivity to increased mortality rates. Likely differences in growth and maturation prevented a more detailed analysis for the East Greenland stock component which did not display indications for negative changes in abundance or composition.

Acknowledgement

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Table 1. Trawl parameters of the survey.

Gear	140-feet bottom trawl
Horizontal net opening	22 m
Standard trawling speed	4.5 kn
Towing time	30 minutes
Coefficient of catchability	1.0

Table 2. Specification of strata.

Stratum	geographic boundaries				depth	area
	south	north	east	west	(m)	(nm^2)
1.1	64°15'N	67°00'N	50°00'W	57°00'W	1-200	6805
1.2	64°15'N	67°00'N	50°00'W	57°00'W	201-400	1881
2.1	62°30'N	64°15'N	50°00'W	55°00'W	1-200	2350
2.2	62°30'N	64°15'N	50°00'W	55°00'W	201-400	1018
3.1	60°45'N	62°30'N	48°00'W	53°00'W	1-200	1938
3.2	60°45'N	62°30'N	48°00'W	53°00'W	201-400	742
4.1	59°00'N	60°45'N	44°00'W	50°00'W	1-200	2568
4.2	59°00'N	60°45'N	44°00'W	50°00'W	201-400	971
5.1	59°00'N	63°00'N	40°00'W	44°00'W	1-200	2468
5.2	59°00'N	63°00'N	40°00'W	44°00'W	201-400	3126
6.1	63°00'N	66°00'N	35°00'W	41°00'W	1-200	1120
6.2	63°00'N	66°00'N	35°00'W	41°00'W	201-400	7795
7.1	64°45'N	67°00'N	29°00'W	35°00'W	1-200	92
7.2	64°45'N	67°00'N	29°00'W	35°00'W	201-400	4589
Sum						37463

Table 3. Numbers of valid hauls by stratum and total and weighted (by stratum area) mean near bottom temperature, 1982-98.

Year	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2	7.1	7.2	Sum
1982	20	11	16	7	9	6	13	2	1	10	3	12	1	25	136
1983	26	11	25	11	17	5	18	4	3	19	10	36	0	18	203
1984	25	13	26	8	18	6	21	4	5	4	2	8	0	5	145
1985	10	8	26	10	17	5	21	4	5	21	14	50	0	28	219
1986	27	9	21	9	16	7	18	3	3	15	14	37	1	34	214
1987	25	11	21	4	18	3	21	3	19	16	13	40	0	18	212
1988	34	21	28	5	18	5	18	2	21	8	13	39	0	26	238
1989	26	14	30	9	8	3	25	3	17	18	12	29	0	11	205
1990	19	7	23	8	16	3	21	6	18	19	6	15	0	13	174
1991	19	11	23	7	12	6	14	5	8	11	10	28	0	16	170
1992	6	6	6	5	6	6	7	5	0	0	0	0	0	6	53
1993	9	6	9	6	10	8	7	0	9	6	6	18	0	14	108
1994	16	13	13	8	10	6	7	5	0	0	0	0	0	6	84
1995	0	0	3	0	10	7	10	5	8	6	6	17	0	12	84
1996	5	5	8	5	12	5	10	5	7	9	5	13	0	9	98
1997	5	6	5	5	6	5	8	5	5	5	4	8	0	8	75
1998	9	5	10	7	11	6	10	5	5	8	6	12	0	9	103

Table 4. *H. platessoides*. Abundance indices (1000) for West, East Greenland and total by stratum, 1982-98. Confidence intervals (CI) are given in per cent of the stratified mean at 95% level of significance. () incorrect due to incomplete sampling.

YEAR	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2	7.1	7.2	WEST	EAST	TOTAL	CI
1982	31582	5092	29598	5735	2843	2133	1043			913		1091		2942	78026	4946	82972	30
1983	46601	6482	55493	2871	2725	461	811			1097	209	2791		7269	115443	11366	126810	49
1984	18251	6258	53766	4366	2928	2244	1792		1311			2806		3813	89606	7930	97536	43
1985	21388	5974	22819	6185	2632	239	3161		1883	2823	422	7031		5966	62398	18125	80523	23
1986	22035	11393	58741	9556	2936	2388	4463			1816	186	10367		5108	111511	17477	128988	39
1987	23321	3314	26226		2357		1030		2416	5636	293	6758		2698	56247	17802	74050	26
1988	10963	3476	8025	5698	3566	800	1035		417	1638	180	8629		2808	33563	13673	47236	18
1989	9370	4454	11362	3775	8764		1446		723	638	304	4607		3653	39171	9924	49095	28
1990	8615	6465	8227	2614	1083		1492	606	995	1994	440	6415		5612	29103	15457	44560	25
1991	7826	4537	5168	1899	1517	639	1248	952	1328	3914	1240	8894		6966	23785	22342	46126	17
1992	8527	4996	3020	2704	1233	1707	1744	175						6695	24105	6695	30800	28
1993	5859	3284	1201	1212	632	694	398		1735	3995	1110	17921		4993	13280	29753	43034	17
1994	2212	3525	1488	1514	624	282	1661	189						2492	11495	2492	13987	21
1995					891	1189	1019	785	1293	3839	1558	21974		4249	3885	32913	36798	18
1996	3716	1337	956	1424	1946	772	1566	472	3549	4367	5842	25778		6773	12189	46309	58499	17
1997	8656	3262	2585	3543	2973	1288	2427	109	1920	2995		23845		4548	24842	33307	58149	21
1998	6254	3956	5654	2873	1767	865	2296	204	1792	2735	244	20563		2423	23869	27757	51626	17

Table 5. *H. platessoides*. Biomass indices (tons) for West, East Greenland and total by stratum, 1982-98. Confidence intervals (CI) are given in per cent of the stratified mean at 95% level of significance. () incorrect due to incomplete sampling.

YEAR	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	6.1	6.2	7.1	7.2	WEST	EAST	TOTAL	CI
1982	6050	946	7797	1151	919	376	157			266		210		684	17396	1160	18556	32
1983	7451	1155	11771	607	1008	88	167			341	53	748		2189	22247	3331	25577	41
1984	1701	762	8662	807	607	387	365		239			569		941	13291	1749	15040	45
1985	1939	600	3861	1062	519	49	321		328	653	68	1037		1597	8352	3684	12035	22
1986	2150	1147	8429	1385	703	452	460			844	45	2619		1868	14728	5376	20103	30
1987	3130	339	5471		645		229		992	1103	62	1247		798	9814	4203	14016	30
1988	919	293	1699	807	814	137	236		79	435	28	1582		753	4905	2876	7782	19
1989	517	297	1476	371	2120		288		111	116	54	850		739	5069	1869	6937	40
1990	395	397	1220	314	213		288	221	180	422	75	1076		918	3047	2671	5718	22
1991	347	399	486	260	266	125	187	173	212	1422	262	1746		1569	2243	5212	7455	18
1992	578	419	228	183	151	250	152	25						1065	1987	1065	3052	26
1993	327	222	82	102	66	70	26		175	419	159	2385		849	895	3987	4882	17
1994	143	416	134	143	64	34	108	28						629	1069	629	1698	25
1995					70	154	123	58	133	525	246	3274		835	405	5014	5419	20
1996	211	100	66	164	159	78	149	38	316	522	1195	3983		1161	964	7177	8141	22
1997	490	265	209	343	353	168	185	7	193	306		3874		1019	2020	5392	7412	27
1998	306	252	355	244	186	122	185	19	146	147	38	2791		500	1670	3621	5291	20

Table 6. *H. platessoides*, West Greenland. Age disaggregate abundance indices (1000) and mean age, 1982-1998.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	TOTAL	Mean
1982	0	40	44	1490	3268	4148	12958	13394	13550	8720	5569	3714	380	1534	606	2516	71931	7.8
1983	0	40	51	3390	8180	9167	25760	22653	17906	10836	5044	3233	333	1455	570	2012	110630	7.1
1984	0	110	131	4043	8042	7677	20473	17076	13948	8900	3778	1981	300	991	295	749	88494	6.9
1985	0	360	406	3736	6719	5761	13829	11085	8675	5104	2501	1526	238	818	275	552	61585	6.7
1986	0	146	263	7478	14622	12164	28043	20393	13197	7111	3021	1792	257	1152	327	781	110747	6.4
1987	0	321	392	2717	4576	4228	11373	10125	8725	5535	3134	1972	284	911	289	851	55433	7.1
1988	0	354	357	2822	3904	2745	6454	5560	4544	2741	1545	987	120	465	148	410	33156	6.6
1989	0	158	356	3807	5604	3414	7440	6262	5234	3059	1522	867	108	455	158	325	38769	6.4
1990	0	306	501	4615	6324	2853	4927	3615	2758	1671	711	353	64	171	51	121	29041	5.6
1991	0	682	451	3559	4390	2355	4547	3265	2177	1117	440	235	26	145	43	144	23576	5.6
1992	0	469	585	3236	4190	2571	4964	3672	2351	1227	422	187	18	91	18	86	24087	5.6
1993	0	181	370	2495	2804	1369	2474	1680	1056	503	173	79	1	58	20	17	13280	5.3
1994	0	149	90	1659	2550	1275	2150	1537	1102	546	200	88	9	75	16	32	11478	5.6
1995	0	15	30	324	539	425	953	690	448	230	103	54	6	35	5	31	3888	6.2
1996	0	182	261	1478	2439	1470	2635	1799	1081	574	146	63	14	43	9	20	12214	5.5
1997	0	139	229	3613	5422	2825	4920	3408	2252	1127	365	142	16	119	17	23	24617	5.5
1998	0	1036	207	3306	5175	2859	4842	3184	1869	844	248	90	8	78	11	10	23767	5.3

Table 7. *H. platessoides*, West Greenland. Spawning stock indices in numbers (1000), 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	TOTAL
1982	0	0	9	596	1307	2074	7775	9376	10840	7848	5012	3714	380	1534	606	2516	53587
1983	0	0	10	1356	3272	4584	15456	15857	14325	9752	4540	3233	333	1455	570	2012	76755
1984	0	0	26	1617	3217	3839	12284	11953	11158	8010	3400	1981	300	991	295	749	59820
1985	0	0	81	1494	2688	2881	8297	7759	6940	4594	2251	1526	238	818	275	552	40394
1986	0	0	53	2991	5849	6082	16826	14275	10558	6400	2719	1792	257	1152	327	781	70062
1987	0	0	78	1087	1830	2114	6824	7087	6980	4981	2821	1972	284	911	289	851	38109
1988	0	0	71	1129	1562	1373	3872	3892	3635	2467	1390	987	120	465	148	410	21521
1989	0	0	71	1523	2242	1707	4464	4383	4187	2753	1370	867	108	455	158	325	24613
1990	0	0	100	1846	2530	1427	2956	2530	2206	1504	640	353	64	171	51	121	16499
1991	0	0	90	1424	1756	1178	2728	2285	1742	1005	396	235	26	145	43	144	13197
1992	0	0	117	1294	1676	1286	2978	2570	1881	1104	380	187	18	91	18	86	13686
1993	0	0	74	998	1122	685	1484	1176	845	453	156	79	1	58	20	17	7168
1994	0	0	18	664	1020	638	1290	1076	882	491	180	88	9	75	16	32	6479
1995	0	0	6	130	216	213	572	483	358	207	93	54	6	35	5	31	2409
1996	0	0	52	591	976	735	1581	1259	865	517	131	63	14	43	9	20	6856
1997	0	0	46	1445	2169	1413	2952	2386	1802	1014	328	142	16	119	17	23	13872
1998	0	0	41	1322	2070	1430	2905	2229	1495	760	223	90	8	78	11	10	12672

Table 8. *H. platessoides*, West Greenland. Spawning stock biomass indices (tons), 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14+	TOTAL
1982	0	0	0	20	61	176	902	1359	1995	1585	1438	1274	125	445	220	1004	10604
1983	0	0	0	49	160	358	1499	1950	2292	1755	1267	1122	110	386	207	803	11958
1984	0	0	0	52	138	280	1192	1446	1808	1474	881	642	99	255	107	299	8673
1985	0	0	1	46	113	190	730	877	1097	877	603	494	79	219	100	220	5646
1986	0	0	1	96	246	395	1346	1428	1489	1101	729	581	85	272	119	312	8200
1987	0	0	1	28	75	159	689	900	1187	971	787	651	94	249	105	340	6236
1988	0	0	1	26	56	89	356	471	603	476	392	326	40	126	54	164	3180
1989	0	0	1	37	74	102	397	522	687	520	359	281	36	123	57	130	3326
1990	0	0	1	41	73	68	231	271	340	287	161	111	21	43	19	48	1715
1991	0	0	1	30	56	64	207	226	242	173	102	76	9	35	16	57	1294
1992	0	0	1	30	57	71	226	249	250	183	95	57	6	18	7	34	1284
1993	0	0	1	21	34	34	105	109	111	75	38	25	0	14	7	7	581
1994	0	0	0	16	31	31	97	111	130	85	44	27	3	18	6	13	612
1995	0	0	0	4	9	13	44	47	49	35	25	17	2	8	2	12	267
1996	0	0	0	16	33	38	114	117	112	84	32	20	5	8	3	8	590
1997	0	0	0	36	67	71	221	236	249	172	80	46	5	27	6	9	1225
1998	0	0	0	36	70	69	192	194	185	126	53	28	3	16	4	4	980

Table 9. *H. platessoides*, West Greenland. Total mortality coefficients for ages 4-11.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean 4-11
1982-83		-0.24	-4.34	-1.70	-1.03	-1.83	-0.56	-0.29	0.22	0.55	0.54	2.41	-1.34	0.99	-1.20	0.00
1983-84		-1.19	-4.37	-0.86	0.06	-0.80	0.41	0.48	0.70	1.05	0.93	2.38	-1.09	1.60	-0.27	0.65
1984-85		-1.31	-3.35	-0.51	0.33	-0.59	0.61	0.68	1.01	1.27	0.91	2.12	-1.00	1.28	-0.63	0.79
1985-86		0.31	-2.91	-1.36	-0.59	-1.58	-0.39	-0.17	0.20	0.52	0.33	1.78	-1.58	0.92	-1.04	0.01
1986-87		-0.99	-2.34	0.49	1.24	0.07	1.02	0.85	0.87	0.82	0.43	1.84	-1.27	1.38	-0.96	0.89
1987-88		-0.11	-1.97	-0.36	0.51	-0.42	0.72	0.80	1.16	1.28	1.16	2.80	-0.49	1.82	-0.35	1.00
1988-89		-0.01	-2.37	-0.69	0.13	-1.00	0.03	0.06	0.40	0.59	0.58	2.21	-1.33	1.08	-0.79	0.38
1989-90		-1.15	-2.56	-0.51	0.68	-0.37	0.72	0.82	1.14	1.46	1.46	2.61	-0.46	2.19	0.27	1.06
1990-91		-0.39	-1.96	0.05	0.99	-0.47	0.41	0.51	0.90	1.33	1.11	2.61	-0.82	1.38	-1.04	0.92
1991-92		0.15	-1.97	-0.16	0.54	-0.75	0.21	0.33	0.57	0.97	0.86	2.57	-1.25	2.09	-0.69	0.66
1992-93		0.24	-1.45	0.14	1.12	0.04	1.08	1.25	1.54	1.96	1.68	5.23	-1.17	1.52	0.06	1.74
1993-94		0.70	-1.50	-0.02	0.79	-0.45	0.48	0.42	0.66	0.92	0.68	2.17	-4.32	1.29	-0.47	0.71
1994-95		1.60	-1.28	1.12	1.79	0.29	1.14	1.23	1.57	1.67	1.31	2.69	-1.36	2.71	-0.66	1.46
1995-96		-2.86	-3.90	-2.02	-1.00	-1.82	-0.64	-0.45	-0.25	0.45	0.49	1.35	-1.97	1.36	-1.39	-0.23
1996-97		-0.23	-2.63	-1.30	-0.15	-1.21	-0.26	-0.22	-0.04	0.45	0.03	1.37	-2.14	0.93	-0.94	0.00
1997-98		-0.40	-2.67	-0.36	0.64	-0.54	0.44	0.60	0.98	1.51	1.40	2.88	-1.58	2.38	0.53	0.99
Mean			-2.60	-0.50	0.38	-0.71	0.34	0.43	0.73	1.05	0.87	2.44	-1.45	1.56	-0.60	0.69

Table 10. *H. platessoides*, West Greenland. Input parameters for production models: mean length observed and calculated, mean weight observed and calculated, and proportion mature at ages 0-20 for both sexes combined. Fishing mortality for ages 3 to 10 was derived from a linear regression model over the mean total mortality 1982-97 (Tab. 11) minus natural mortality.

v. Bertalanffy growth function in length:	f(x)=41.4*(1-exp(-0.113(x-0.5)))
Length-weight relationship (Lloret, 1995):	f(x)=0.0036105*x^3.253315
Fishing mortality (linear model age 0-11)	f(x)=-0.451+0.141x

Age	Length (cm) Observed	Length (cm) calculated	Weight (g.) observed	Weight (g.) calculated	Prop. mature	Natural Mortality	Fishing Mortality
0.8		1.4		0	0		
1.8	8.2	5.7	3	1	0		
2.8	11.2	9.5	9	5	0.2		
3.8	15.5	12.9	27	15	0.4	0.1	0.00
4.8	16.6	15.9	34	29	0.4	0.1	0.11
5.8	18.5	18.7	48	49	0.5	0.1	0.26
6.8	20.4	21.1	66	73	0.6	0.1	0.40
7.8	22.2	23.3	87	101	0.7	0.1	0.54
8.8	24.8	25.2	124	131	0.8	0.1	0.68
9.8	27.1	26.9	166	162	0.9	0.1	0.82
10.8	30.2	28.5	236	195	0.9	0.1	0.96
11.8	33	29.9	315	227	1	0.1	1.00
12.8	33.5	31.1	330	259	1	0.1	1.00
13.8	28.7	32.2	200	290	1	0.1	1.00
14.8	34.5	33.2	363	320	1	0.1	1.00
15.8	35.5	34.1	399	348	1	0.1	1.00
16.8		34.8		375	1	0.1	1.00
17.8		35.5		400	1	0.1	1.00
18.8		36.2		424	1	0.1	1.00
19.8		36.7		446	1	0.1	1.00
20.8		37.2		466	1	0.1	1.00

Table 11. *H. platessoides*, West Greenland. Mean total mortality coefficient for ages 4-11 and years 1982-98 and some resulting management references for fishing mortality and biomass.

	Value
Mean Z ages 4-11, 1982-98	0.69
$F_{0.1}$	0.14
F_{max}	0.23
F_{msy}	0.10
SSB index 1991-98	<1 500 t
SSB_{msy} index	3 000 t
SSB_{pa} index (mbal)	3 000 t

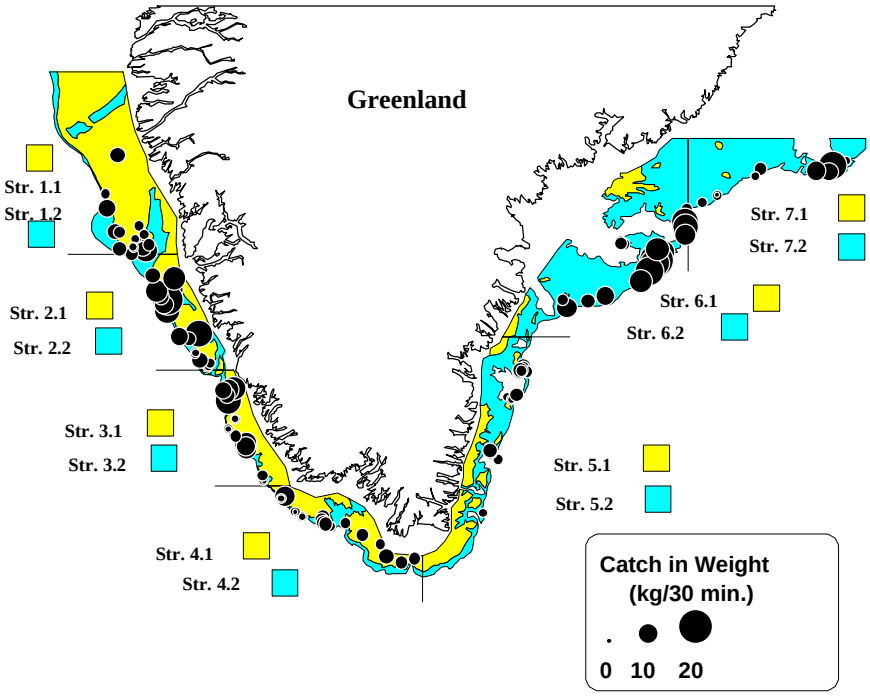

Fig. 1. Stratification of the survey area as specified in Table 2, positions of hauls carried out in 1998 and catches of American plaice.

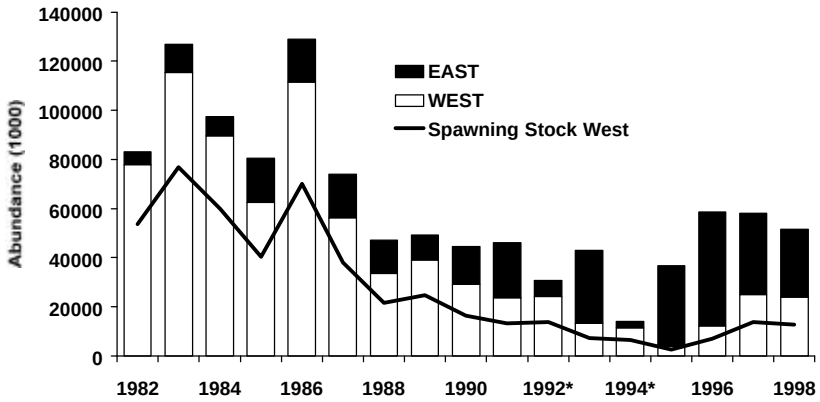

Fig. 2. *H. platessoides*, Greenland. Aggregated survey abundance indices and spawning stock size (West Greenland only) as listed in Tables 4 and 10, 1982-98. *) incomplete survey coverage off East Greenland.

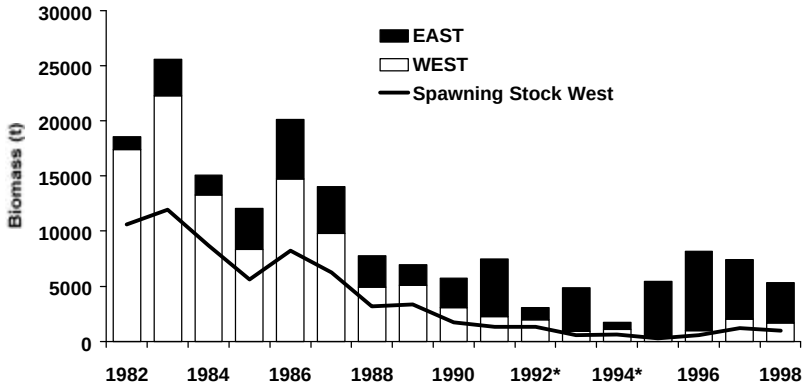

Fig. 3. *H. platessoides*, Greenland. Aggregated survey biomass indices and spawning stock size (West Greenland only) as listed in Tables 5 and 11, 1982-98. *) incomplete survey coverage off East Greenland.

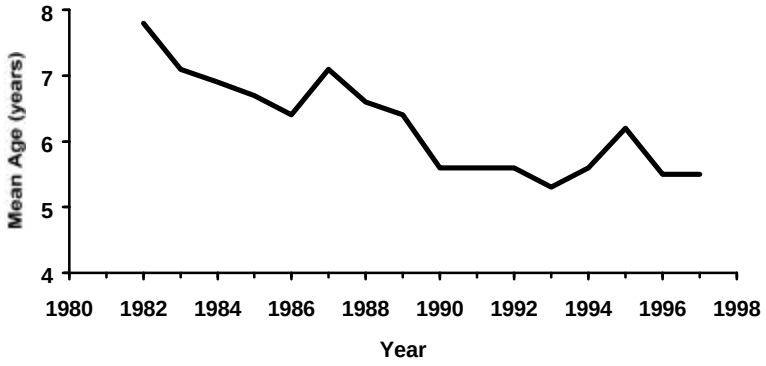

Fig. 4. *H. platessoides*, West Greenland. Mean age of the stock as listed in Table 6, 1982-98.

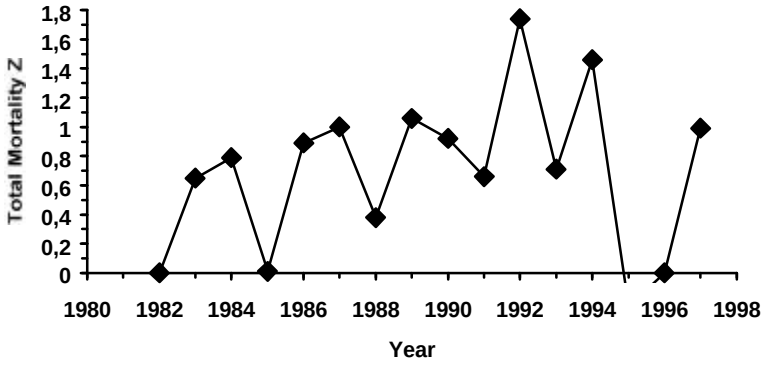

Fig. 5. *H. platessoides*, West Greenland. Mean total mortality coefficient Z for ages 4-11 as listed in Table 12, 1982-98.

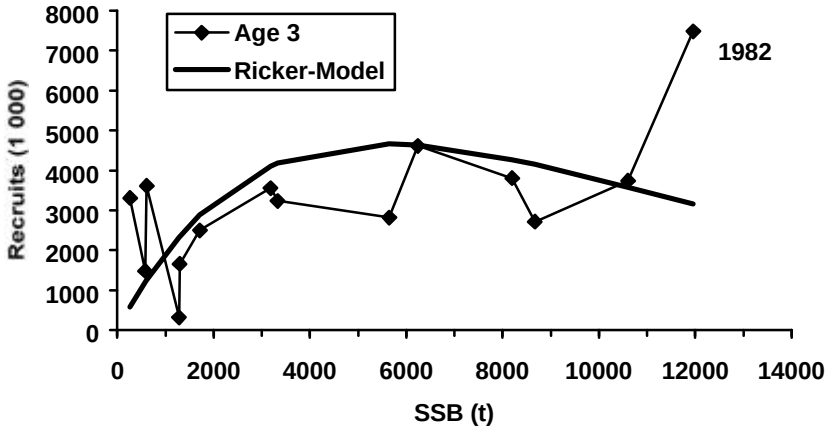

Fig. 6. *H. platessoides*, West Greenland. Ricker recruitment-SSB function (West Greenland only, f(x)=2.2916*x*Exp(-x/5534.3002)) as listed in Tables 6 and 8, 1982-95.

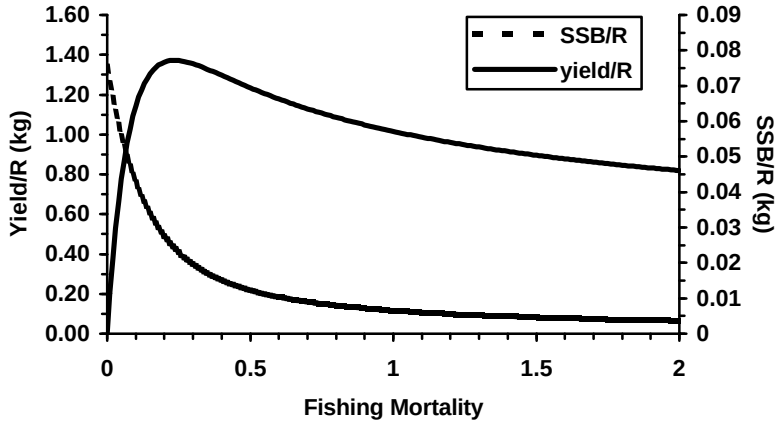

Fig. 7. *H. platessoides*, West Greenland. Yield and SSB per recruit analysis as listed in Table 9. $F_{0.1}$=0.14; F_{max} = 0.23

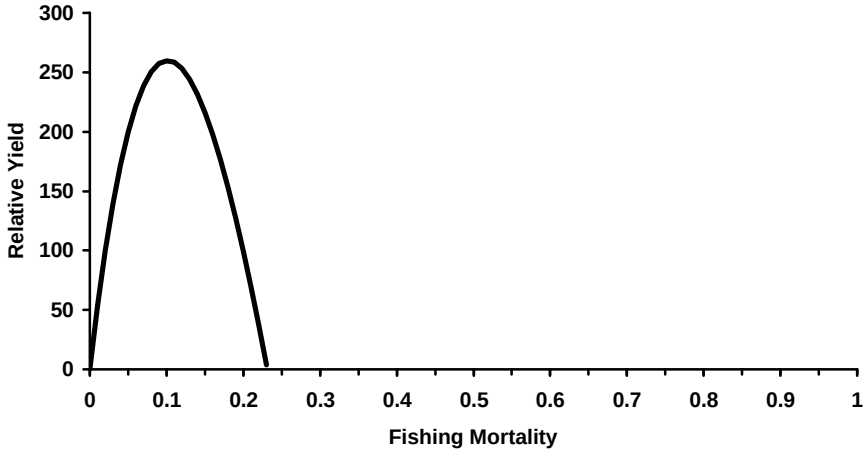

Fig. 8. *H. platessoides*, F_{msy} and equilibrium yield analysis based on YPR and Ricker coefficients as given in Figure 6. F_{msy} = 0.10

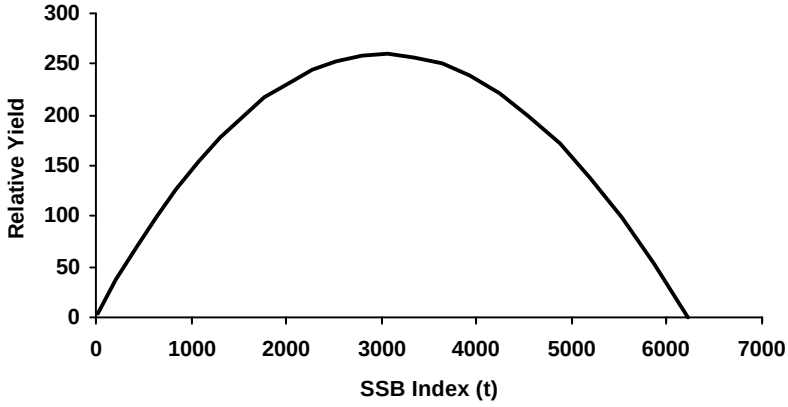

Fig. 9 *H. platessoides*, F_{msy} and equilibrium yield analysis based on YPR and Ricker coefficients as given in Figure 6. F_{msy}=0.10