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Assessment of Atlantic Wolffish (*Anarhichas lupus* L.) off West and East Greenland, 1982-98

by

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Abstract

Stock abundance varied without a pronounced trend in terms of numbers and spawning stock size in numbers between 17-43 million and 9-24 million, repectively. The abundance off East Greenland peaked during the four most recent years while the stock component off West Greenland contributed reduced parts. In contrast, the stock biomass and spawning stock biomass decreased almost continuously by 75% from 27 000 and 18 000 tons to 5 500 tons and 4 000 tons in 1993, respectively. The total biomass and spawning stock biomass estimates of the four most recent years averaged at a higher level of 8 400 and 6 700 tons, respectively.

During 1982-90, the mean age decreased by 50% from 8 to 4 years with a higher reduction off West Greenland. The mean age remained relatively stable at this low level since then. The correlation between total mortality Z and the aggregated catch of shrimp and cod in NAFO Sub-area 1 and ICES Div. XIVb reveals that the Atlantic wolffish stock is subject to by-catches. The continued higher mortality off West Greenland after the collapse of the cod fishery in the early 90s might be caused by the shrimp fishery.

The current fishing mortality (F5-11, 1995-1998) is indicated to be at the level of F_{max} and likely to be caused by catches taken in the shrimp fishery off West Greenland. However, the above average recruitment and the low mortality rates off East Greenland allowed recently the SSB index to increase from the lowest level observed to the 17 years average and the MSY estimate. The potential of the stock to recover from low SSB seems to indicate, that the stock is within safe biological limits.

The Atlantic wolffish off Greenland was found to grow slower in length and weight and to mature later as any other investigated stock in the North Atlantic.

Introduction

The exploitation of Atlantic wolffish in Greenland waters has not been of high 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 Atlantic wolffish 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 (Möller, 1998). Individual size is given in terms of length and weight. Maturity data were

used for estimation of spawing stock size in numbers and biomass. Management reference points are presented in order to reflect the status of the stock.

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 Atlantic wolffish. 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.

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.

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, total and gutted weight was measured with a precision of 5 grams. Weight (g) at age calculations were based on the regression $f(x)=0.0071x^{3.0572}$, x=length (cm), which was determined on the basis of 2 481 individual measurements.

Age determinations were based on length-stratified otolith (sagitta) collections in 1997 and conducted using transmitted light. Annuli were counted under a binocular microscope after mounting the otoliths on glass plate and

grinding them to the larval nucleus. In 1997, 1 433 individual age determinations were available. The age-length key was used to convert length compositions to agedisaggegated data for all years 1982-98.

Maturity at age was determined from visual observations. The results are considered reliable because the survey was conducted just before the spawning season (autumn spawner).

Results and Discussion

Tables 4 and 5 list abundance and biomass indices by stratum, West and East Greenland and total in 1982-98. The estimates of the spawning stock size in numbers and weight are listed in Tables 9 and 10. Trends of the stock estimates and their mature parts for West and East Greenland are shown in Figures 2 and 3, respectively. These Figures illustrate that the stock abundance varied without a pronounced trend in terms of numbers and spawning stock size in numbers between 17-43 million and 9-24 million, repectively. The abundance off East Greenland peaked during the four most recent years while the stock component off West Greenland contributed reduced parts. During 1995-98, estimates of abundance and spawning stock in numbers averaged at a level of 34 and 19 million. In contrast, the stock biomass and spawning stock biomass decreased almost continuously by 75% from 27 000 and 18 000 tons to 5 500 tons and 4 000 tons in 1993, respectively (Rätz, 1998). The total biomass and spawning stock biomass estimates of the four most recent years averaged at a higher level of 8 400 and 6 700 tons, respectively.

Age disaggregated abundance and biomass indices and their mature proportions are listed in Tables 6-10. During 1982-90, the age structure in the stock shrunk considerably. The mean age decreased by 50% from 8 to 4 years with a higher reduction off West Greenland. The mean age remained relatively stable at this low level since then (Fig. 4). Resulting total mortality estimates Z are given in Tables 11-13 and illustrated in Figure 5 as 3-years running means to avoid year effects in catchability. The comparison with the aggregated catch of shrimp and cod in NAFO Sub-area 1 and ICES Div. XIVb reveals higher mortality rates during years with high catches. This correlation indicates, that the Atlantic wolffish stock is subject to by-catches. The continued higher mortality off West Greenland after the collapse of the cod fishery in the early 90s might be caused by the shrimp fishery. During 1995-98, the mean total mortality amounted to 0.47.

The yield and spawning stock weight per recruit analysis is illustrated in Figure 6, respective input parameters being specified in Table 14. The fishing mortality vector Fbar was derived from the total mortality coefficients Z for ages 5-11 subtracting a natural mortality M=0.15 (long-lived species). Fishing mortality of for ages 12-17 were derived from a linear regression and assumed to be 1.0 for older ages (flat top selection). Weight at age was estimated from the v. Bertalanffy growth function and the length-weight regression described further down. The proportion mature at age is used as observed. $F_{0.1}$ was estimated to amount to 0.18 and F_{max} to 0.37, respectively.

Figure 7 illustrates the recruitment at age 3 plotted against the spawning stock biomass index as listed in Tables 8 and 10 and fitted to the Ricker recruitment model. The few points available indicates a negative slope of the function for the entire range of SSB observed. The high number of recruits at age 3 produced since the mid 90s mainly off East Greenland will recruit to the SSB as indicated by the most recent increase in SSB to the level of the 17 years mean.

The coefficients a and k of the Ricker recruitment model were used in combination with the yield per recruit analysis to estimate the fishing mortality F_{msy} and SSB_{msy} at maximum sustainable yield. The sustainable yield estimates as a function of fishing mortality and SSB index are illustrated in Figures 8 and 9. F_{msy} was estimated to amount to 0.65 while SSBmsy index amounted to 6 500 tons. As the Ricker coefficients are poorly estimated based on few observations, these values should be taken with care and are expected to change significantly as the fit of the Ricker function improves with additional points.

The estimated management references in terms of fishing mortality and SSB are summarised in Table 15. The current fishing mortality (F5-11, 1995-1998) is indicated to be at the level of F_{max}. and likely to be caused by catches taken in the shrimp fishery off West Greenland. However, the above average recruitment and the low mortality rates off East Greenland allowed recently the SSB index to increase from the lowest level observed to the 17 years average and the MSY estimate. The potential of the stock to recover from low SSB seems to indicate, that the stock is within safe biological limits.

Length-weight and total weight-gutted weight regressions are specified in Figures 10 and 11 to enable conversion.

The growth of Atlantic wolffish in Greenland waters is illustrated in Figure 12. The Atlantic wolffish was found to grow slower in length and weight as any other investigated stock in the North Atlantic (Möller, 1998). Figure 13 displays the maturity ogive for both sexes combined as distinct differences were absent. According to this information, 75% percent of the fish at age 5 (mean length is 27 cm) were found to be mature before they are selected by the fishery. Although this is the latest maturity among the North Atlantic stocks (Möller, 1998), the first spawing at small sizes before exploitation and the care for eggs and larvae might cause the Atlantic wolffish recruitment success off Greenland at low or average SSB.

References

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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 *A. lupus*. Abundance indices (1000) for West, East Greenland and total by stratum, 1982-98. Confidence intervals (CI) are given in per cent of the statified mean at 95% level of significance. () incorrect due to incomplete sampling. () 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	11113	2955	3457	2313	1822	458	945			832		483		606	23062	1921	24982	23
1983	7567	3186	1720	485	1471	211	786			463	171	912		1849	15426	3395	18821	24
(1984)	5777	1277	1542	185	1382	111	750		1236			2806		2749	11024	6791	17816	26
1985	5369	2718	1419	370	955	999	907		1994	2851	386	3399		4236	12738	12866	25603	19
1986	4961	1704	1967	635	1500	511	811			1660	347	2448		6842	12090	11297	23387	19
1987	5328	1644	888		1023		691		4534	3714	632	4342		6847	9575	20068	29642	15
1988	4927	1834	895	449	1136	555	758		1824	4955	271	2798		4208	10553	14056	24609	21
1989	3675	673	1669	516	2901		1130		1249	2079	472	1629		3685	10564	9113	19677	21
1990	3511	1076	1981	295	1899		1066	612	2113	1182	622	2003		5337	10440	11256	21696	17
1991	2838	1010	968	756	2593	639	562	494	3231	2563	448	1621		2276	9861	10139	20000	21
(1992)	3015	376	1509	937	3360	916	948	2107						5438	13168	5438	18606	26
1993	4723	1712	703	426	574	326	385		1232	5380	112	5379		4451	8848	16553	25401	28
(1994)	1545	1196	1725	567	1225	153	4515	1047						5521	11972	5521	17492	48
1995					1349	563	529	705	2044	3976	600	5901		5052	3146	17573	20719	26
1996	715	942	254	381	2574	622	799	1075	4815	4211	1299	13103		8815	7360	32244	39604	21
1997	3001	1279	1126	335	3771	1149	1538	2863	4413	5124		11264		7489	15062	28289	43351	30
1998	3083	957	783	653	1990	620	1009	1047	3048	2251	237	7678		8430	10142	21644	31786	21

Table 5 *A. lupus*. Biomass indices (tons) for West, East Greenland and total by stratum, 1982-98. Confidence intervals (CI) are given in per cent of the statified mean at 95% level of significance. () incorrect due to incomplete sampling. () 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	9908	2974	5203	3926	2273	475	1240			853		203		207	26000	1263	27262	31
1983	3661	3442	2084	471	1769	271	1086			369	65	522		922	12786	1878	14664	31
(1984)	3089	673	1283	189	820	71	871		600			1208		753	6997	2561	9557	24
1985	1837	1134	1020	200	581	557	632		698	1329	65	1107		2157	5961	5356	11317	16
1986	1783	912	1441	434	973	458	768			794	96	990		3731	6768	5611	12379	16
1987	2191	521	573		1048		616		1626	1704	83	1684		4511	4950	9608	14558	16
1988	1102	384	797	298	882	341	696		849	1804	39	787		2561	4499	6040	10539	16
1989	687	222	620	246	1750		1037		437	900	133	803		1689	4564	3962	8526	19
1990	708	177	496	111	655		660	320	800	650	136	553		1895	3127	4034	7161	16
1991	456	166	160	161	674	148	249	214	1207	678	159	624		955	2228	3622	5850	20
(1992)	436	79	322	237	831	200	231	630						2221	2967	2221	5188	27
1993	646	314	101	80	130	67	108		402	1235	22	1122		1446	1447	4227	5674	22
(1994)	218	209	376	97	285	26	865	171						2290	2246	2290	4536	42
1995					248	68	131	114	592	794	101	2611		1808	561	5907	6467	25
1996	61	261	42	68	486	114	169	238	1232	972	412	4615		2451	1441	9681	11122	19
1997	306	239	89	77	665	164	352	372	859	731		2705		2304	2264	6599	8863	24
1998	361	194	125	146	287	97	175	266	306	328	129	1808		2864	1649	5435	7084	16

Table 6 *A. lupus*, 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+	TOTAL	Mean
1982	13	91	219	930	1492	2152	1774	2093	2827	2211	2071	1995	2471	20339	7,9
1983	0	43	261	1184	1798	2302	1712	1537	1713	1141	1002	895	1041	14629	6,8
1984	4	98	320	1343	1663	1828	1307	1078	971	647	506	422	400	10587	6,0
1985	115	194	229	1000	1820	2669	2089	1674	1171	748	392	258	246	12605	5,9
1986	84	532	608	1141	1397	2113	1754	1487	1149	757	440	282	220	11964	5,7
1987	191	740	703	1262	1069	1214	1020	938	851	601	447	297	200	9533	5,4
1988	170	859	833	2065	1472	1052	796	913	858	611	424	274	175	10502	5,0
1989	100	627	808	1831	1607	1527	1004	846	745	539	392	268	213	10507	5,1
1990	189	1258	1157	2014	1499	1388	899	667	532	349	206	123	94	10375	4,3
1991	674	1052	943	2022	1731	1432	824	484	300	170	77	48	50	9807	3,8
1992	181	1339	1288	3196	2638	2111	1140	625	371	184	72	41	26	13212	3,9
1993	111	1511	1400	2039	1377	1128	636	323	139	97	28	14	27	8830	3,4
1994	88	974	1730	3442	2237	1638	902	484	245	144	51	23	18	11976	3,8
1995	5	291	366	899	683	422	206	124	74	41	13	16	7	3147	3,8
1996	228	500	699	1832	1496	1216	671	366	191	106	29	19	19	7372	4,0
1997	738	2394	1907	3567	2601	1864	960	545	256	153	42	23	25	15075	3,4
1998	563	1598	1256	2314	1618	1183	675	385	204	134	61	28	42	10061	3,4

Table 7 *A. lupus*, East Greenland. Age disaggregate abundance indices (1000) and mean age, 1982-1998.
() incomplete sampling.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12+	TOTAL	Mean
1982	0	37	67	221	247	267	209	156	189	120	106	83	149	1851	6,4
1983	0	10	70	367	604	669	455	337	237	199	140	102	103	3293	5,9
(1984)	5	369	406	1133	1170	1265	804	503	367	251	202	134	171	6780	5,1
1985	332	731	737	1853	2057	2163	1454	1140	920	582	351	240	197	12757	5,1
1986	15	244	388	1380	1852	2131	1521	1220	968	642	415	298	228	11302	5,7
1987	59	421	897	2913	3308	3550	2546	1966	1579	1052	713	543	394	19941	5,6
1988	518	951	874	2133	2077	2151	1461	1126	852	653	472	342	250	13860	5,0
1989	6	298	435	1105	1406	1603	1151	959	754	530	341	227	268	9083	5,7
1990	334	1570	1004	1503	1460	1545	1116	855	642	465	335	191	157	11177	4,6
1991	164	815	836	1877	1753	1529	1006	705	533	371	221	167	136	10113	4,7
(1992)	59	202	315	705	905	1050	670	536	369	264	174	144	57	5450	5,3
1993	705	1398	1226	3182	3157	2748	1554	1035	684	436	212	140	68	16545	4,2
(1994)	116	402	284	660	819	994	750	587	408	235	113	79	41	5488	5,0
1995	77	870	1225	3205	3507	3305	1961	1259	804	565	335	231	200	17544	4,8
1996	238	2114	2571	6036	5773	5768	3620	2446	1566	944	587	364	204	32231	4,6
1997	607	2353	2357	5100	4858	4864	3029	1923	1305	850	500	345	192	28283	4,5
1998	1011	2755	1683	3341	3382	3373	2146	1499	1030	660	358	229	150	21617	4,3

Table 8 *A. lupus*, Greenland (total). Age disaggregate abundance indices (1000) and mean age, 1982-1998.
() incomplete sampling.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12+	TOTAL	Mean
1982	13	128	286	1151	1739	2419	1983	2249	3016	2331	2177	2078	2620	22190	7,8
1983	0	53	331	1551	2402	2971	2167	1874	1950	1340	1142	997	1144	17922	6,7
(1984)	9	467	726	2476	2833	3093	2111	1581	1338	898	708	556	571	17367	5,7
1985	447	925	966	2853	3877	4832	3543	2814	2091	1330	743	498	443	25362	5,5
1986	99	776	996	2521	3249	4244	3275	2707	2117	1399	855	580	448	23266	5,7
1987	250	1161	1600	4175	4377	4764	3566	2904	2430	1653	1160	840	594	29474	5,5
1988	688	1810	1707	4198	3549	3203	2257	2039	1710	1264	896	616	425	24362	5,0
1989	106	925	1243	2936	3013	3130	2155	1805	1499	1069	733	495	481	19590	5,4
1990	523	2828	2161	3517	2959	2933	2015	1522	1174	814	541	314	251	21552	4,4
1991	838	1867	1779	3899	3484	2961	1830	1189	833	541	298	215	186	19920	4,2
(1992)	240	2034	3287	5193	4951	3765	2422	1470	942	557	328	180	123	25488	4,2
1993	816	2909	2626	5221	4534	3876	2190	1358	823	533	240	154	95	25375	4,0
(1994)	204	1939	4032	5809	5481	4197	2906	1663	1045	654	385	199	101	28612	4,2
1995	82	1264	2628	4818	5836	4759	2963	1806	1099	702	417	262	212	26846	4,6
1996	466	2614	3270	7868	7269	6984	4291	2812	1757	1050	616	383	223	39603	4,5
1997	1345	4747	4264	8667	7459	6728	3989	2468	1561	1003	542	368	217	43358	4,1
1998	1574	4353	2939	5655	5000	4556	2821	1884	1234	794	419	257	192	31678	4,0

Table 9 *A. lupus*, Greenland (total). Spawning stock indices in numbers (1000), 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12+	TOTAL
1982	0	0	0	184	1269	2225	1963	2227	3016	2331	2177	2078	2620	20090
1983	0	0	0	248	1753	2733	2145	1855	1950	1340	1142	997	1144	15307
1984	0	0	0	396	2068	2846	2090	1565	1338	898	708	556	571	13036
1985	0	0	0	456	2830	4445	3508	2786	2091	1330	743	498	443	19130
1986	0	0	0	403	2372	3904	3242	2680	2117	1399	855	580	448	18000
1987	0	0	0	668	3195	4383	3530	2875	2430	1653	1160	840	594	21328
1988	0	0	0	672	2591	2947	2234	2019	1710	1264	896	616	425	15374
1989	0	0	0	470	2199	2880	2133	1787	1499	1069	733	495	481	13746
1990	0	0	0	563	2160	2698	1995	1507	1174	814	541	314	251	12017
1991	0	0	0	624	2543	2724	1812	1177	833	541	298	215	186	10953
1992	0	0	0	624	2586	2908	1792	1149	740	448	246	185	83	10761
1993	0	0	0	835	3310	3566	2168	1344	823	533	240	154	95	13068
1994	0	0	0	656	2231	2421	1635	1060	653	379	164	102	59	9360
1995	0	0	0	657	3059	3429	2145	1369	878	606	348	247	207	12945
1996	0	0	0	1259	5306	6425	4248	2784	1757	1050	616	383	223	24051
1997	0	0	0	1387	5445	6190	3949	2443	1561	1003	542	368	217	23105
1998	0	0	0	905	3650	4192	2793	1865	1234	794	419	257	192	16301

Table 10 *A. lupus*, Greenland (total). Spawning stock biomass indices (tons), 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12+	TOTAL
1982	0	0	0	18	237	628	766	1483	3088	2494	2612	2772	4359	18457
1983	0	0	0	25	314	727	768	1059	1757	1305	1362	1314	1838	10469
1984	0	0	0	38	339	714	715	847	1113	799	810	696	903	6974
1985	0	0	0	43	495	1196	1277	1460	1518	1071	800	584	647	9091
1986	0	0	0	36	434	1070	1203	1471	1505	1133	904	672	621	9049
1987	0	0	0	57	530	1166	1274	1590	1813	1441	1264	990	842	10967
1988	0	0	0	54	383	731	800	1161	1322	1117	983	731	582	7864
1989	0	0	0	41	348	714	751	997	1135	926	794	584	712	7002
1990	0	0	0	44	335	677	688	815	852	687	572	353	333	5356
1991	0	0	0	52	366	629	587	584	571	438	315	249	262	4053
1992	0	0	0	53	385	672	555	539	486	339	261	209	99	3598
1993	0	0	0	68	490	817	659	631	548	398	240	161	113	4125
1994	0	0	0	53	317	567	540	486	402	273	170	117	71	2996
1995	0	0	0	56	456	802	671	663	655	494	377	296	298	4768
1996	0	0	0	106	812	1548	1376	1328	1170	805	659	438	277	8519
1997	0	0	0	114	811	1417	1244	1165	1040	759	552	418	274	7794
1998	0	0	0	74	544	1002	922	918	822	626	440	287	262	5897

Table 11 *A. lupus*, West Greenland (total). Total mortality coefficients Z, 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	Mean 5-11	3 Years Running Mean
1982-83	-1,20	-1,05	-1,69	-0,66	-0,43	0,23	0,14	0,20	0,91	0,79	0,84	0,65	0,54	
1983-84		-2,01	-1,64	-0,34	-0,02	0,57	0,46	0,46	0,97	0,81	0,86	0,81	0,71	0,49
1984-85	-3,88	-0,85	-1,14	-0,30	-0,47	-0,13	-0,25	-0,08	0,26	0,50	0,67	0,54	0,22	0,43
1985-86	-1,53	-1,14	-1,61	-0,33	-0,15	0,42	0,34	0,38	0,44	0,53	0,33	0,16	0,37	0,38
1986-87	-2,18	-0,28	-0,73	0,07	0,14	0,73	0,63	0,56	0,65	0,53	0,39	0,34	0,55	0,42
1987-88	-1,50	-0,12	-1,08	-0,15	0,02	0,42	0,11	0,09	0,33	0,35	0,49	0,53	0,33	0,38
1988-89	-1,31	0,06	-0,79	0,25	-0,04	0,05	-0,06	0,20	0,46	0,44	0,46	0,25	0,26	0,45
1989-90	-2,53	-0,61	-0,91	0,20	0,15	0,53	0,41	0,46	0,76	0,96	1,16	1,05	0,76	0,67
1990-91	-1,72	0,29	-0,56	0,15	0,05	0,52	0,62	0,80	1,14	1,51	1,46	0,90	0,99	0,74
1991-92	-0,69	-0,20	-1,22	-0,27	-0,20	0,23	0,28	0,27	0,49	0,86	0,63	0,61	0,48	0,93
1992-93	-2,12	-0,04	-0,46	0,84	0,85	1,20	1,26	1,50	1,34	1,88	1,64	0,42	1,32	0,66
1993-94	-2,17	-0,14	-0,90	-0,09	-0,17	0,22	0,27	0,28	-0,04	0,64	0,20	-0,25	0,19	1,10
1994-95	-1,20	0,98	0,65	1,62	1,67	2,07	1,98	1,88	1,79	2,40	1,16	1,19	1,78	0,56
1995-96	-4,61	-0,88	-1,61	-0,51	-0,58	-0,46	-0,57	-0,43	-0,36	0,35	-0,38	-0,17	-0,29	0,59
1996-97	-2,35	-1,34	-1,63	-0,35	-0,22	0,24	0,21	0,36	0,22	0,93	0,23	-0,27	0,27	0,20
1997-98	-0,77	0,65	-0,19	0,79	0,79	1,02	0,91	0,98	0,65	0,92	0,41	-0,60	0,61	
Mean	-1,98	-0,42	-0,97	0,06	0,09	0,49	0,42	0,49	0,63	0,90	0,66	0,38	0,57	

Table 12 *A. lupus*, East Greenland (total). Total mortality coefficients Z, 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	Mean 5-11	3 Years Running Mean
1982-83		-0,64	-1,70	-1,01	-1,00	-0,53	-0,48	-0,42	-0,05	-0,15	0,04	-0,22	-0,26	
1983-84		-3,70	-2,78	-1,16	-0,74	-0,18	-0,10	-0,09	-0,06	-0,01	0,04	-0,52	-0,13	-0,25
1984-85	-4,98	-0,69	-1,52	-0,60	-0,61	-0,14	-0,35	-0,60	-0,46	-0,34	-0,17	-0,39	-0,35	-0,08
1985-86	0,31	0,63	-0,63	0,00	-0,04	0,35	0,18	0,16	0,36	0,34	0,16	0,05	0,23	-0,11
1986-87	-3,33	-1,30	-2,02	-0,87	-0,65	-0,18	-0,26	-0,26	-0,08	-0,10	-0,27	-0,28	-0,20	0,28
1987-88	-2,78	-0,73	-0,87	0,34	0,43	0,89	0,82	0,84	0,88	0,80	0,73	0,78	0,82	0,37
1988-89	0,55	0,78	-0,23	0,42	0,26	0,63	0,42	0,40	0,47	0,65	0,73	0,24	0,51	0,58
1989-90	-5,57	-1,21	-1,24	-0,28	-0,09	0,36	0,30	0,40	0,48	0,46	0,58	0,37	0,42	0,49
1990-91	-0,89	0,63	-0,63	-0,15	-0,05	0,43	0,46	0,47	0,55	0,74	0,70	0,34	0,53	0,56
1991-92	-0,21	0,95	0,17	0,73	0,51	0,83	0,63	0,65	0,70	0,76	0,43	1,07	0,72	0,41
1992-93	-3,17	-1,80	-2,31	-1,50	-1,11	-0,39	-0,43	-0,24	-0,17	0,22	0,22	0,75	-0,01	0,61
1993-94	0,56	1,59	0,62	1,36	1,16	1,30	0,97	0,93	1,07	1,35	0,99	1,23	1,12	0,19
1994-95	-2,01	-1,11	-2,42	-1,67	-1,40	-0,68	-0,52	-0,31	-0,33	-0,35	-0,72	-0,93	-0,55	0,16
1995-96	-3,31	-1,08	-1,59	-0,59	-0,50	-0,09	-0,22	-0,22	-0,16	-0,04	-0,08	0,12	-0,10	-0,01
1996-97	-2,29	-0,11	-0,68	0,22	0,17	0,64	0,63	0,63	0,61	0,64	0,53	0,64	0,62	0,43
1997-98	-1,51	0,34	-0,35	0,41	0,36	0,82	0,70	0,62	0,68	0,86	0,78	0,83	0,76	
Mean	-2,05	-0,47	-1,14	-0,27	-0,21	0,25	0,17	0,19	0,28	0,36	0,29	0,26	0,26	

Table 13 *A. lupus*, Greenland (total). Total mortality coefficients Z, 1982-98.

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	Mean 5-11	3 Years Running Mean
1982-83	-1,41	-0,95	-1,69	-0,74	-0,54	0,11	0,06	0,14	0,81	0,71	0,78	0,60	0,46	
1983-84		-2,62	-2,01	-0,60	-0,25	0,34	0,32	0,34	0,78	0,64	0,72	0,56	0,53	0,33
1984-85	-4,63	-0,73	-1,37	-0,45	-0,53	-0,14	-0,29	-0,28	0,01	0,19	0,35	0,23	0,01	0,28
1985-86	-0,55	-0,07	-0,96	-0,13	-0,09	0,39	0,27	0,28	0,40	0,44	0,25	0,11	0,31	0,14
1986-87	-2,46	-0,72	-1,43	-0,55	-0,38	0,17	0,12	0,11	0,25	0,19	0,02	-0,02	0,12	0,35
1987-88	-1,98	-0,39	-0,96	0,16	0,31	0,75	0,56	0,53	0,65	0,61	0,63	0,68	0,63	0,38
1988-89	-0,30	0,38	-0,54	0,33	0,13	0,40	0,22	0,31	0,47	0,54	0,59	0,25	0,40	0,54
1989-90	-3,28	-0,85	-1,04	-0,01	0,03	0,44	0,35	0,43	0,61	0,68	0,85	0,68	0,58	0,55
1990-91	-1,27	0,46	-0,59	0,01	0,00	0,47	0,53	0,60	0,77	1,00	0,92	0,52	0,69	0,55
1991-92	-0,89	-0,57	-1,07	-0,24	-0,08	0,20	0,22	0,23	0,40	0,50	0,50	0,56	0,37	0,57
1992-93	-2,49	-0,26	-0,46	0,14	0,24	0,54	0,58	0,58	0,57	0,84	0,76	0,64	0,64	0,43
1993-94	-0,87	-0,33	-0,79	-0,05	0,08	0,29	0,28	0,26	0,23	0,33	0,19	0,42	0,28	0,42
1994-95	-1,82	-0,30	-0,18	0,00	0,14	0,35	0,48	0,41	0,40	0,45	0,38	-0,06	0,34	0,24
1995-96	-3,46	-0,95	-1,10	-0,41	-0,18	0,10	0,05	0,03	0,05	0,13	0,09	0,16	0,09	0,33
1996-97	-2,32	-0,49	-0,97	0,05	0,08	0,56	0,55	0,59	0,56	0,66	0,52	0,57	0,57	0,47
1997-98	-1,17	0,48	-0,28	0,55	0,49	0,87	0,75	0,69	0,68	0,87	0,75	0,65	0,75	
Mean	-1,93	-0,49	-0,97	-0,12	-0,03	0,37	0,31	0,33	0,48	0,55	0,52	0,41	0,42	

Table 14 *A. lupus*, Greenland (total). Input parameters and estimation of management reference points. Fbar is derived from total mortality coefficients Z 1982-97 minus natural mortality M=0.15 including ages 3-11. Fishing mortalities for ages 12-17 were estimated from a linear regression and assumed to be at the level of 1.0 for older ages (flat top selection). Weight at ages were estimated from the v. Bertalanffy growth function. Maturity ogive represents the observed values.

age	Weight at age (kg)	prop. mature	Fbar	M
3	0.083	0.16	0	0.15
4	0.150	0.73	0	0.15
5	0.178	0.92	0.22	0.15
6	0.266	0.99	0.17	0.15
7	0.372	0.99	0.20	0.15
8	0.492	1	0.33	0.15
9	0.626	1	0.40	0.15
10	0.770	1	0.35	0.15
11	0.922	1	0.46	0.15
12	1.081	1	0.62	0.15
13	1.245	1	0.70	0.15
14	1.411	1	0.79	0.15
15	1.578	1	0.87	0.15
16	1.745	1	0.95	0.15
17	1.911	1	1.00	0.15
18	2.074	1	1.00	0.15
19	2.234	1	1.00	0.15
20	2.390	1	1.00	0.15
21	2.542	1	1.00	0.15
22	2.688	1	1.00	0.15
23	2.830	1	1.00	0.15
24	2.965	1	1.00	0.15
25	3.095	1	1.00	0.15
26	3.220	1	1.00	0.15
27	3.338	1	1.00	0.15
28	3.451	1	1.00	0.15
29	3.559	1	1.00	0.15
30	3.660	1	1.00	0.15

Table 15 *A. lupus*, Greenland. Management reference points for fishing mortality and spawning stock biomass.

	Fishing mortality F	SSB
F (0,1)	0,18	
F (max)	0,37	
F (msy)	0,65	
Z 1995-98	0,47	
SSB msy (index)		6500
SSB 1982-98 (index)		7500
SSB loss (index)		4100
SSB 1995-98		6750

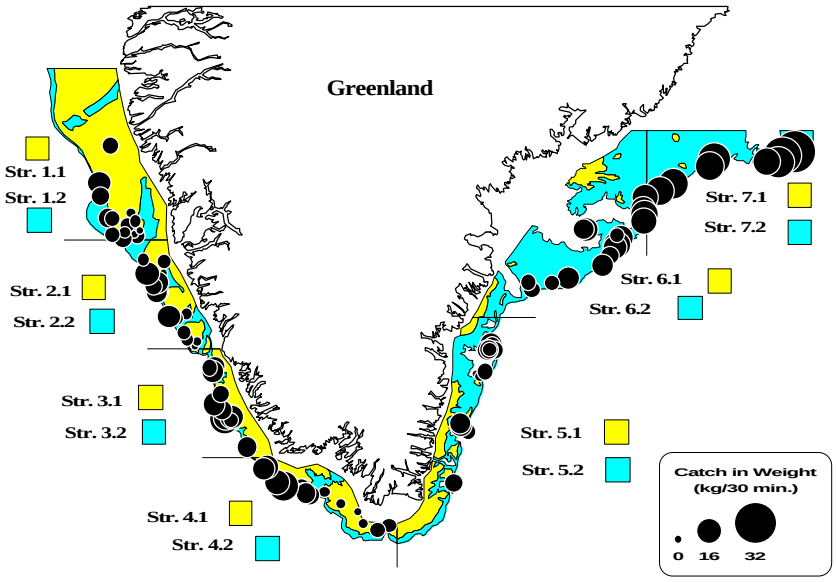

Fig. 1 Stratification of the survey area as specified in Table 2, positions of halus carried out in 1998 and catches of Atlantic wolffish.

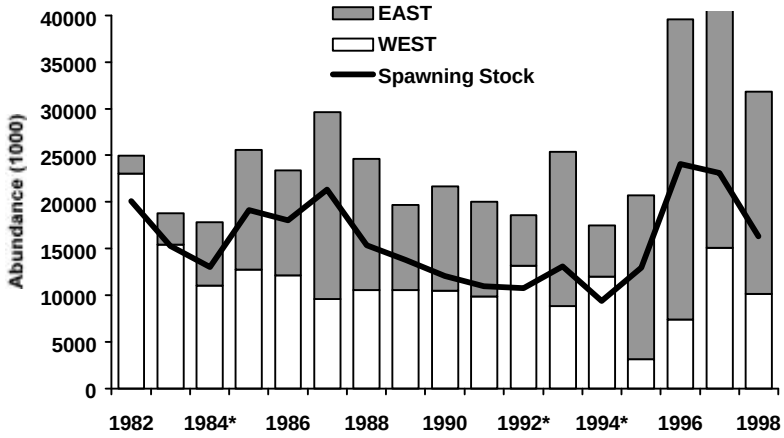

Fig. 2 *A. lupus*. Aggregated survey abundance indices for West and East Greenland and spawning stock size as listed in Tables 4 and 9, 1982-98. *) incomplete survey coverage.

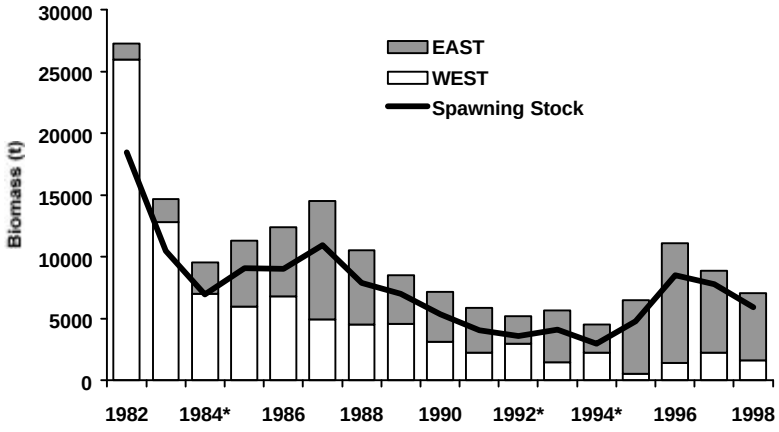

Fig. 3 *A. lupus*. Aggregated survey biomass indices for West and East Greenland and spawning stock size as listed in Tables 5 and 10, 1982-98. *) incomplete survey coverage.

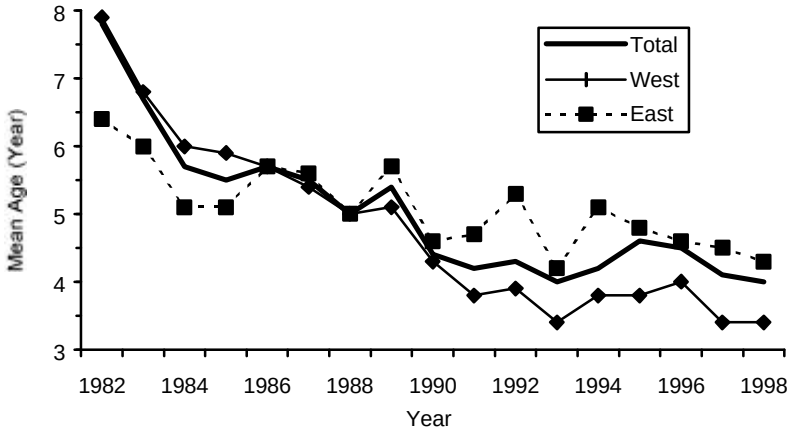

Fig. 4 *A. lupus*. Trend in mean age for West, East Greenland and total as listed in Tables 6-8, 1982-98.

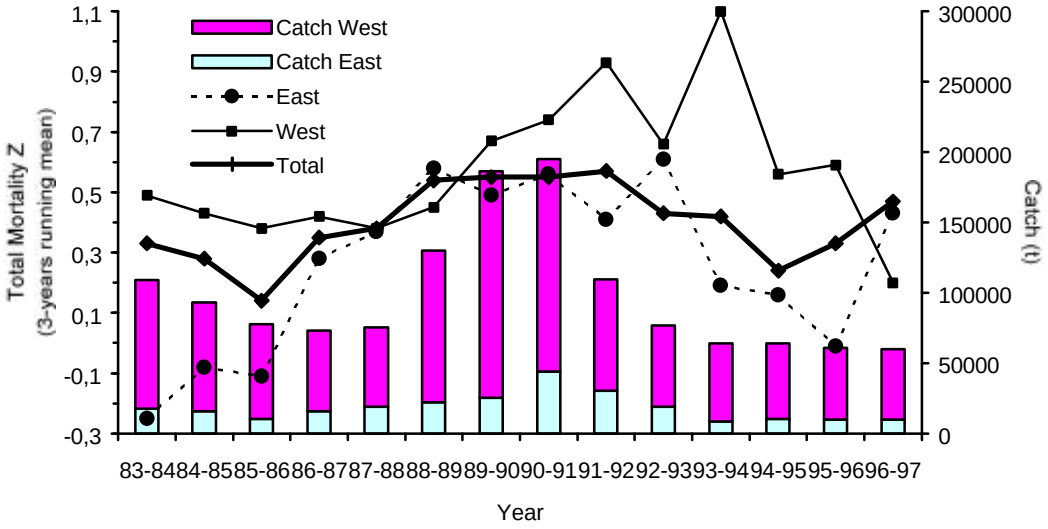

Fig. 5 *A. lupus*, Greenland. Trends in total mortality Z for ages 5-11 (3-years running means) and commercial catches (shrimp and cod aggregated) for West, East Greenland and total (NAFO 1 and ICES XIVb), 1983-1997.

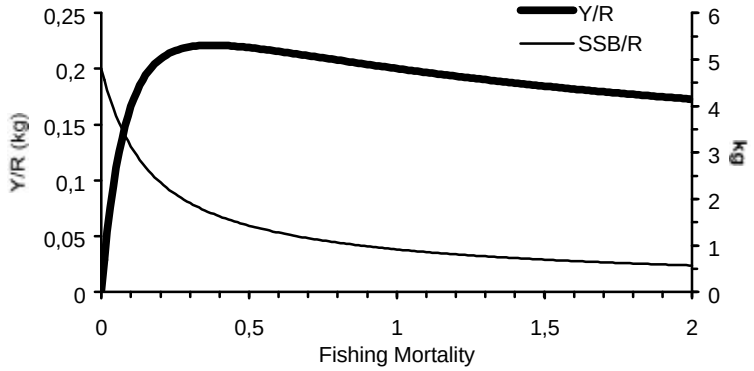

Fig. 6 *A. lupus*, Greenland (total). Yield and spawning stock per recruit as a function of fishing mortality. Input parameters are listed in Table 14.

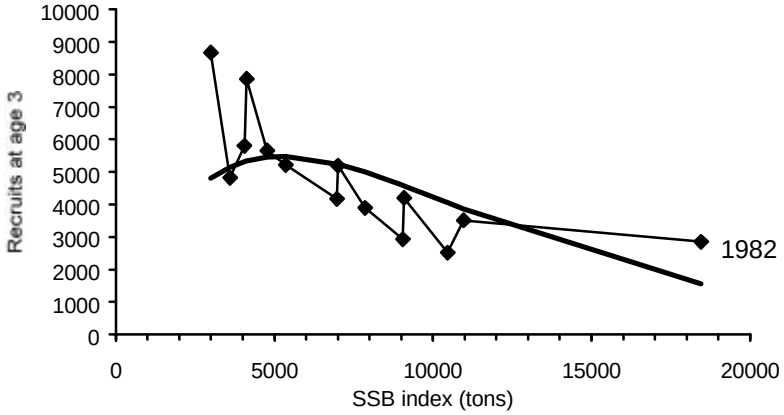

Fig. 7 *A. lupus*, Greenland (total). Ricker SSB-Recruitment relation, 1982-1995. Values are listed in Tables 8 and 10. Recr=a*SSB*exp(-SSB/k), a=2.8305, b=5264.5.

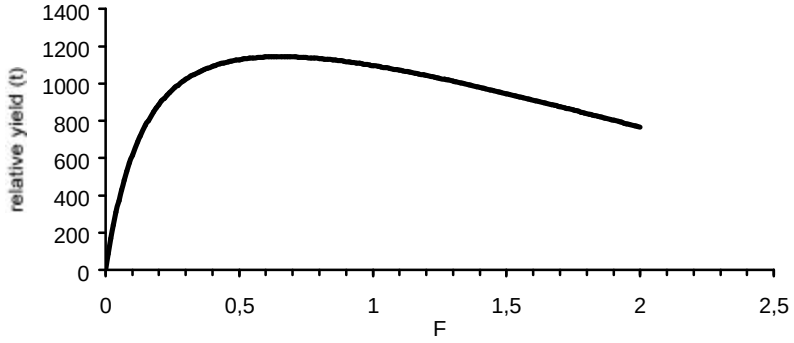

Fig. 8 *A. lupus*, Greenland. Sustainable yield as a function of fishing mortality as based on yield per recruit and the coefficients of the Ricker function. Fmsy=0.65.

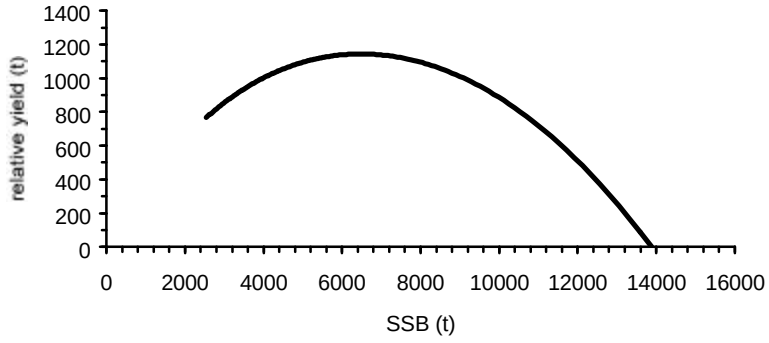

Fig. 9 *A. lupus*, Greenland. Sustainable yield as a function of spawning stock biomass as based on yield per recruit and the coefficients of the Ricker function. SSBmsy=6 498 t.

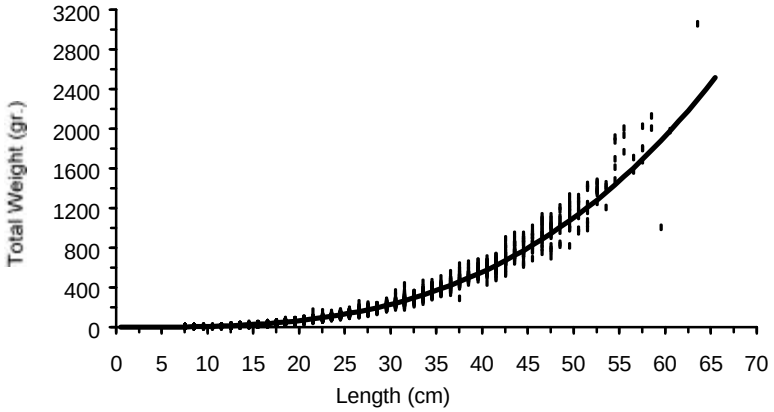

Fig. 10 *A. lupus*, Greenland. Length-weight relation. $W = 0.0071 * L^{3,0572}$, $r^2 = 0.99$.

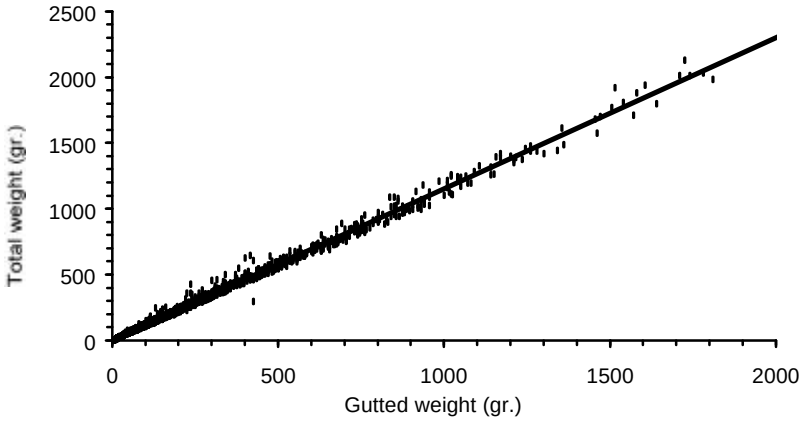

Fig. 11 *A. lupus*, Greenland. Total-Gutted weight relation. $TW = 2.3454+1.14888x$, $r^2 = 0.99$.

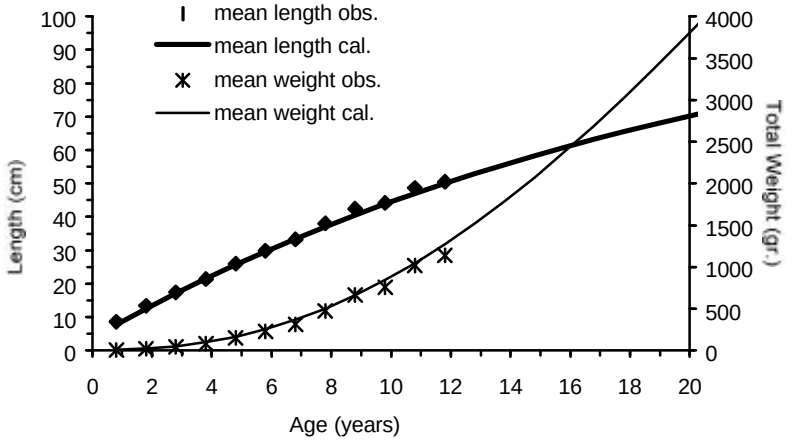

Fig. 12 *A. lupus*, Greenland. Mean length and weight at age as listed in Table 14 and v. Bertalanffy growth functions. L(t)=114.5(1-exp(-0.0458(t+0.74))).

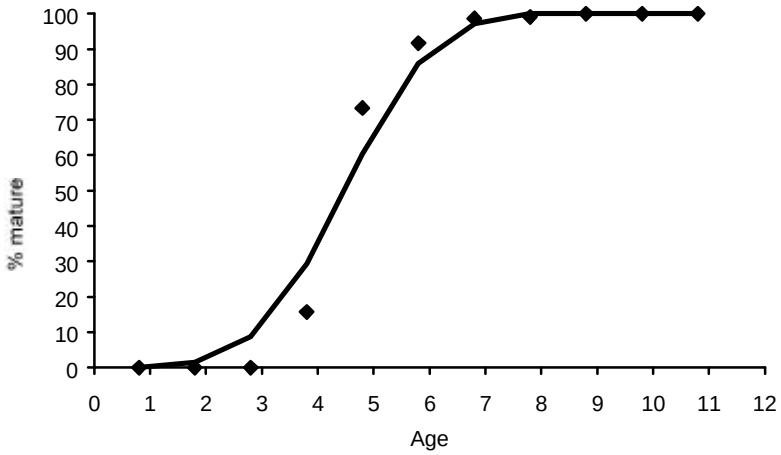

Fig. 13 *A. lupus*, Greenland. Maturiy at age for both sexes combined as listed in Table 14 and fitted logistic function.