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A preliminary estimate of Atlantic cod (*Gadus morhua*) biomass in West Greenland offshore waters (NAFO Subarea 1) for 2012 and recent changes in the spatial overlap with Northern shrimp (*Pandalus borealis*)

by

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Abstract

Catches of Atlantic cod in West Greenland waters were compared between the German ground fish survey and the Greenland survey for shrimp and fish. The analysis was restricted to years with regions included in both surveys. The two survey's estimates of cod biomass were closely correlated ($r^2 = 0.88$, $P < 0.001$). Linear regression analysis using data from 20 years revealed that the biomass index of Atlantic cod biomass estimated from the Greenland survey for 2012 would correspond to 74 344 tons in the German survey. This 2012 offshore biomass of Atlantic cod is the highest seen since 2008, but is only half of the biomass in 2006-2007. The spatial overlap between Atlantic cod and Northern shrimp has decreased in 2012 as the cod biomass was primarily observed in South West Greenland.

Introduction

Hvingel (2002, 2003) has incorporated the effect of cod predation into a model for assessing the stock of Northern shrimp (*Pandalus borealis*) at West Greenland (Hvingel and Kingsley, 2002), and STACFIS and the Scientific Council of NAFO have adopted the results from this model since 2002 (Anon., 2004). No consistent time series of Atlantic cod biomass exist for the different stock components and therefore Hvingel and Kingsley (2002) constructed a cod biomass series for West Greenland based on VPA estimates of stock size for East and West Greenland combined for the period 1955 to 1991 and separate survey indices for East and West Greenland offshore waters available since 1982. From 1993 and forward the time series used in the model was derived from a German offshore cod survey in West Greenland waters alone. This survey is conducted each year in autumn (October-November) and its results are not available at the time the assessment for Northern shrimp is carried out. Instead, information on Atlantic cod abundance and biomass from a Greenland bottom trawl survey for shrimp and fish, which commenced in 1988 and which is carried out in summer (July-September), could be used to assess the actual impact of predation by Atlantic cod on the stock of Northern shrimp. The two surveys, however, do not survey exactly the same area and in some years, area coverage or data sampling has been insufficient in one or the other survey.

Wieland and Storr-Paulsen (2004) compared different time series of Atlantic cod biomass in West Greenland offshore waters and concluded that the approach used by Hvingel and Kingsley (2002) could lead to a substantial overestimation of the impact of predation by Atlantic cod on Northern shrimp. A new time series of Atlantic cod was constructed based on VPA estimates by Buch et al. (1994) and survey indices, which avoids some of the inconsistencies of the data series introduced by Hvingel & Kingsley (2002).

This paper presents an update of a comparison of Atlantic cod biomass estimates from the Greenland survey for shrimp and fish and the German ground fish survey from the last year (Retzel 2011). It provides a preliminary estimate of Atlantic cod biomass in West Greenland waters for 2011 that is comparable to the biomass indices from previous years for the area covered by the German survey. Furthermore, the paper examines changes in the spatial overlap between Atlantic cod and Northern shrimp and suggests an alternative time series of Atlantic cod biomass for consideration in the assessment of Northern shrimp.

Materials and Methods

The Greenland bottom trawl survey for fish and shrimps covers the offshore areas at West Greenland and has been conducted annually from 1988. The area has been expanded through time and since 1992 the survey has covered the area between 72°30'N and 59°15'N (NAFO Division 1A-1F) from the 3 nautical mile limit to the 600 m depth contour (Fig. 1) and the inshore area Disko Bay. The survey area is divided into NAFO Divisions, which are further subdivided into four depth strata ($\leq$ 150 m, 151-200 m, 201-400 m and 401-600 m). The survey was originally designed as a shrimp survey and sampling of fish data was not complete in the period 1988-1991. Since 1992 the sampling of fish has improved and it is now considered as a combined survey for shrimp and fish (Nygaard and Jørgensen, 2011). The survey is designed as a stratified random trawl survey with a minimum of two hauls per stratum. The sampling period is June to August and throughout the entire time period the survey has been conducted by the Greenland Institute of Natural Resources with the research trawler RV *Pâmiut*. Shrimp trawls with a high (10-12 m) vertical opening have been used, which were equipped with a heavy bobbin chain ground gear until 2004 (Skjervøy trawl) or a rockhopper bobbin/rubber disc ground gear since 2005 (Cosmos 2600 trawl). Towing speed has always been about 2.5 knots (see Kingsley 2011 for further details on the survey design).

The German survey is as a stratified random groundfish survey covering the shelf area outside the 3 nautical mile limit and the continental slope down to a depth of 400 m off East and West Greenland between 67°00'N and 59°00'N (ICES area 14 and NAFO Div. 1B-1F, Fig. 1). The Institute for Sea Fisheries, Germany, has conducted this survey annually since 1982. The primary target is cod, and the fishing gear used is a groundfish trawl rigged with a heavy ground gear. Towing speed is 4 knots. The survey provides swept area estimates of abundance (by age) and biomass (all ages pooled) for the East and the West Greenland offshore component, which form the primary basis for the evaluation of the status of the offshore cod stock (ICES, 2012).

Area coverage was incomplete in one or the other surveys the following years and areas:

- NAFO Div. 1A and 1BN have always been covered by the Greenland survey only,
- the northern areas, i.e. 1B and NAFO Div. 1C, were not covered in the German survey in 1995, in 2001 to 2003, in 2005 and 2011,
- In 1995 NAFO Div. 1D were not covered by the German survey.

Consequently, new annual indices of Atlantic cod abundance and biomass were calculated for the Greenland survey for all years since 1992 excluding areas for which no corresponding data have been available from both surveys.

Final factors for converting cod catches from 2005 to 2012 made with the Cosmos trawl to Skjervøy catches from the period 1998-2004 are yet not available. Therefore the 2005 to 2012 estimates were converted preliminarily to the old trawl standard using a size-independent conversion of total catches and an adjustment for the smaller average swept area fished with the old trawl (Nygaard and Jørgensen, 2011):

$$\mathrm{Cod}_{\mathrm{Skjervøy}} = 1/1.78 * 1.15 * \mathrm{Cod}_{\mathrm{Cosmos}} = 0.65 * \mathrm{Cod}_{\mathrm{Cosmos}}.$$

The major difference between the two trawls is the ground gear, and Lewy *et al*. (2004) reported a conversion factor of about 0.5 in such a case, which is close to the value used here.

The changes in the geographical distribution of Atlantic cod and Northern shrimp were examined using both data from the fishery and from the two surveys described above. Commercial catches reported by NAFO Division have been available for Atlantic cod from Horsted (2000) for the period 1953-1991 and for Northern shrimp from Kingsley and Hvingel (2005) for the period 1975-2005. These values were used to calculate mean latitude of the catches based on the mid of the geographical boundaries of the NAFO statistical areas (Fig. 1) weighted by the

aggregated catches. Here, the northern limit of NAFO Division 1A was set to 73°00' N and the southern limit of NAFO Division 1F was set to 59°30' N considering the main distributional range of the fishery for the two species. Wieland et al. (2006) have applied a geostatistical tool, the global index of collocation (GIC) developed by Bez and Rivoirard (2000), to examine the spatial overlap of Atlantic cod and Northern shrimp based on geo-referenced survey data. These results were used to establish a regression between the GIC and the mean latitude of survey biomass of Atlantic cod. This relationship was used to estimate GIC values back in time, i.e. for the periods in which only commercial catch data by NAFO division and no survey data by set were available or the survey appeared to insufficient due to poor area coverage either in the German or the Greenland survey.

Results and Discussion

Atlantic cod biomasses estimated from the Greenland survey were considerably below the estimates from the German survey in the overlapping years and area, and different trawl types and towing speeds might be the major causes for this. Despite pronounced differences between the two surveys at the upper levels of cod biomass, highly significant correlations (r^2 = 0.88, P <0.001, n = 20) between the two data series were found, and the equation obtained by linear regression on a log-log scale (Fig. 2) is:

$$\log\left(Cod\ biomass_{German\ Survey}\right) = 0.928 + 0.908 * \log\left(Cod\ biomass_{Greenland\ Survey}\right)$$

For the most recent years, the survey estimates of stock biomass indicated a pronounced southern distribution of Atlantic cod. In 2011 however increased numbers of small cod (25-30 cm, age 2, YearClass 2009) have been found in the northern NAFO subarea 1B. In 2012 the 2009 YearClass were observed in the southern NAFO subarea 1E and 1F (Tab. 1 and Figure 3) and no longer in the northern NAFO subarea 1B.

Overall estimates of cod biomass are 39 532 tons for the entire surveyed area and 33 990 tons for the reduced area that corresponds to the German survey. Taking into account the change of the trawl in the Greenland survey, the latter value converts to 21 990 tons that is comparable with the old values obtained with the Skjervøy trawl.

The regression equation derived from the comparison of the German and the Greenland survey in the previous years gives an biomass estimate of 74 3449 tons of Atlantic cod to be found by the German survey in fall 2012 in NAFO Div. 1BS (south of 67°N) to 1F (Tab. 2 and Figure 4). The biomass is the highest seen since 2008 in the German survey, but is still low compared to the 2006 and 2007 level where the 2003 year class were found offshore giving rise to biomasses on 160 000 to 170 000 tons respectively.

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Tab. 1: Observed Cod biomass (tons) by survey and area. Greenland survey as observed, i.e. without conversion
-: not covered. +: covered but not to be included in the comparison.

	German survey					Greenlandic survey				
	Stratum					Stratum (without > 400 m depth)				
Year	1BS+1C	1D	1E	1F	Sum	1BS+1C	1D	1E	1F	Sum
1992	337	94	35	257	723	109	118	0	2	229
1993	260	108	72	0	440	30	39	124	5	193
1994	59	28	32	18	137	47	0	1	0	48
1995	-	-	39	19	58	+	+	3	4	7
1996	96	46	44	202	388	15	23	27	49	114
1997	42	22	105	106	275	55	0	0	0	55
1998	77	17	1	46	141	0	47	50	3	100
1999	53	17	143	77	290	6	17	1	0	24
2000	249	188	157	44	638	75	9	2	46	132
2001	-	361	2056	185	2602	+	178	98	100	376
2002	-	178	285	1952	2415	+	1489	42	150	42
2003	-	283	1535	758	2576	+	453	118	46	555
2004	508	639	1196	4245	6588	183	680	685	305	1853
2005	-	1457	3884	21850	27191	+	1317	1047	38765	41129
2006	479	91733	5320	64593	162125	420	5180	545	19111	25256
2007	2408	3644	15694	151432	173178	223	582	471	21091	22367
2008	1745	798	3035	35535	41113	1051	2133	4106	23719	31010
2009	37	1204	1049	1720	4010	458	314	361	308	1441
2010	2024	5091	5736	7804	20655	419	2058	787	2728	5991
2011	-	635	2468	25567	28670	1806	3849	179	3902	9736
2012						1416	226	14104	18244	33990

Tab. 2: Time series of Atlantic cod biomass (tons) (*: using mean VPA to survey ratio based on Wieland & Storr-Paulsen, (2004).

Year	Cod biomass VPA (Buch et al. 1984)	Survey (ICES 2008)	VPA and survey combined *	Spatial overlap GIC Cod - Shr observed	'estimated'	'effective' Cod biomass
1950	4076.5		4076.5			
1951	3722.9		3722.9			
1952	3285.7		3285.7			
1953	2855.3		2855.3		0.692	1977.1
1954	2848.3		2848.3		0.714	2033.9
1955	2731.4		2731.4		0.703	1919.1
1956	2298.7		2298.7		0.693	1592.7
1957	2037.5		2037.5		0.684	1392.9
1958	1866.2		1866.2		0.674	1258.3
1959	1687.7		1687.7		0.719	1212.6
1960	1823.1		1823.1		0.706	1287.3
1961	1793.9		1793.9		0.704	1263.1
1962	1469.2		1469.2		0.716	1051.3
1963	1328.4		1328.4		0.686	911.2
1964	1327.6		1327.6		0.676	898.1
1965	1345.3		1345.3		0.706	950.2
1966	1254.9		1254.9		0.709	889.2
1967	1167.5		1167.5		0.683	797.4
1968	904.9		904.9		0.639	578.1
1969	637.4		637.4		0.611	389.7
1970	442.2		442.2		0.554	244.9
1971	372.8		372.8		0.587	218.7
1972	283.0		283.0		0.678	191.9
1973	179.5		179.5		0.643	115.4
1974	132.1		132.1		0.642	84.7
1975	108.5		108.5		0.629	68.2
1976	228.8		228.8		0.579	132.5
1977	251.7		251.7		0.574	144.5
1978	253.5		253.5		0.672	170.3
1979	217.3		217.3		0.670	145.6
1980	240.4		240.4		0.680	163.4
1981	178.3		178.3		0.619	110.4
1982	190.9	138.0	190.9		0.518	98.8
1983	134.0	80.9	134.0		0.461	61.7
1984	79.0	28.3	79.0		0.479	37.8
1985	51.7	34.1	51.7		0.482	25.0
1986	38.4	75.9	38.4		0.510	19.6
1987	466.7	628.0	466.7		0.604	282.1
1988	481.2	646.7	481.2		0.618	297.3
1989	403.2	332.6	403.2		0.370	149.1
1990		42.1	42.1		0.289	12.2
1991		6.8	6.8		0.313	2.1
1992		0.7	0.7		0.523	0.4
1993		0.4	0.4	0.633	0.658	0.3
1994		0.1	0.1	(0.356)	0.599	0.1
1995		0.1	0.1	(0.120)	0.483	0.0
1996		0.4	0.4	0.280		0.1
1997		0.3	0.3	0.490		0.1
1998		0.1	0.1	0.390		0.0
1999		0.3	0.3	0.496		0.1
2000		0.6	0.6	0.643		0.4
2001		2.6	2.6	0.462		1.2
2002		2.4	2.4	0.278		0.7
2003		2.6	2.6	0.398		1.0
2004		6.6	6.6	0.257		1.7
2005		27.2	27.2	0.074		2.0
2006		162.1	162.1	0.220		35.7
2007		173.2	173.2	0.139		24.0
2008		41.1	41.1	0.156		6.4
2009		4.0	4.0	0.602		2.4
2010		20.7	20.7	0.315		6.5
2011		28.7	28.7	0.888		25.5
2012		74.3	74.3	0.305		22.7

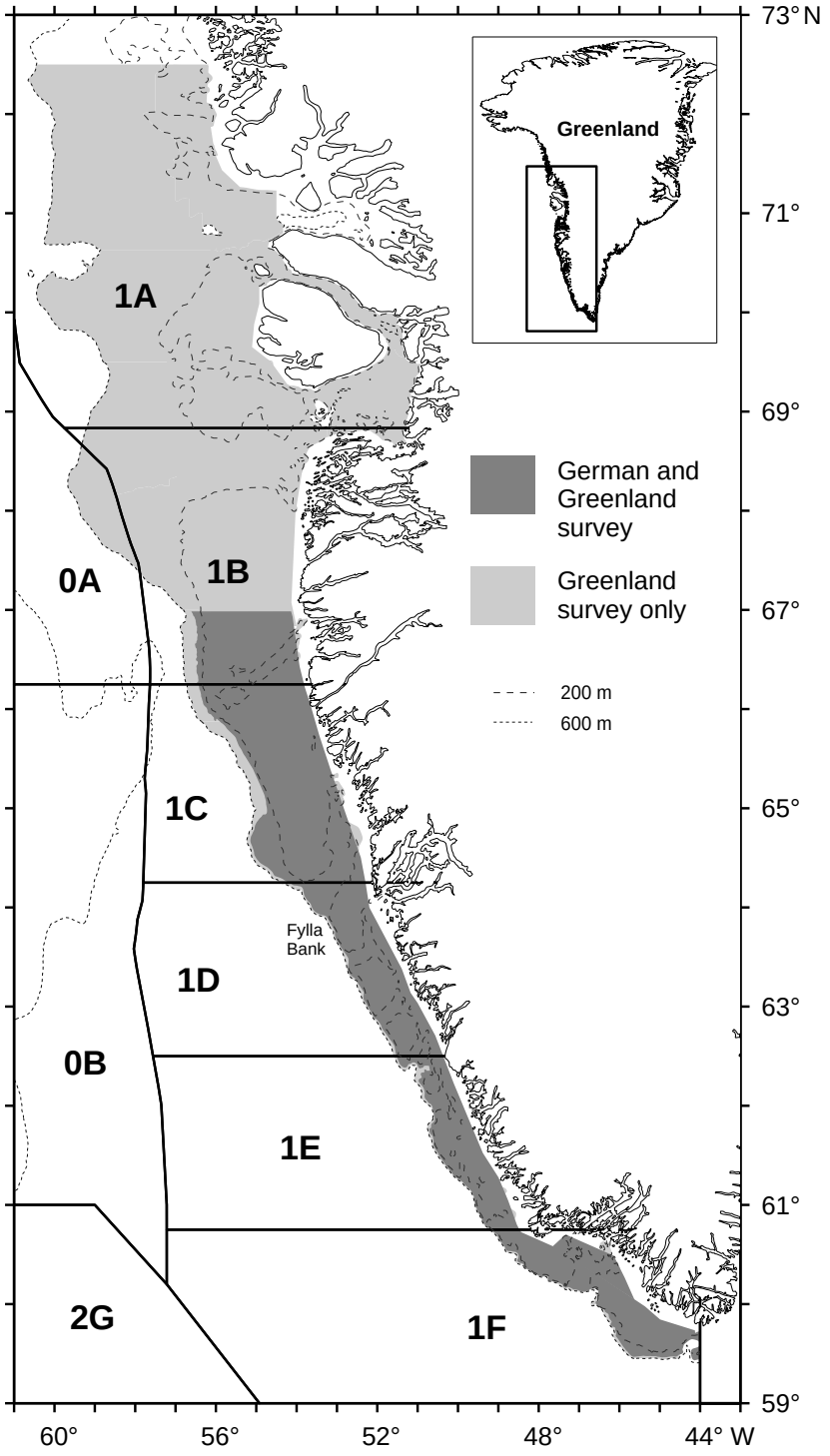

Fig. 1. Survey coverage for the Greenland fish and shrimp survey and the German ground fish survey in West Greenland offshore waters. (*: NAFO divisions 1B and 1C were not covered by the German survey in 1995, in 2001 to 2003, in 2005 and 2011).

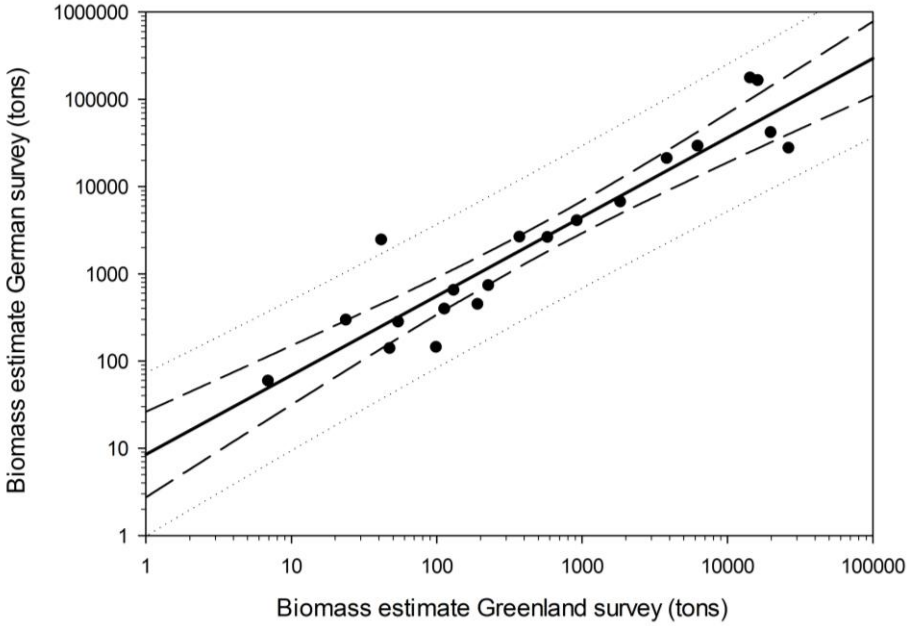

Fig. 2. Relationship between estimates of cod biomass in the overlapping area of the German groundfish survey and the Greenland Bottom Trawl Survey, 1992-2012. Dashed and dotted lines indicate limits of the 95% confidence and prediction intervals, respectively.

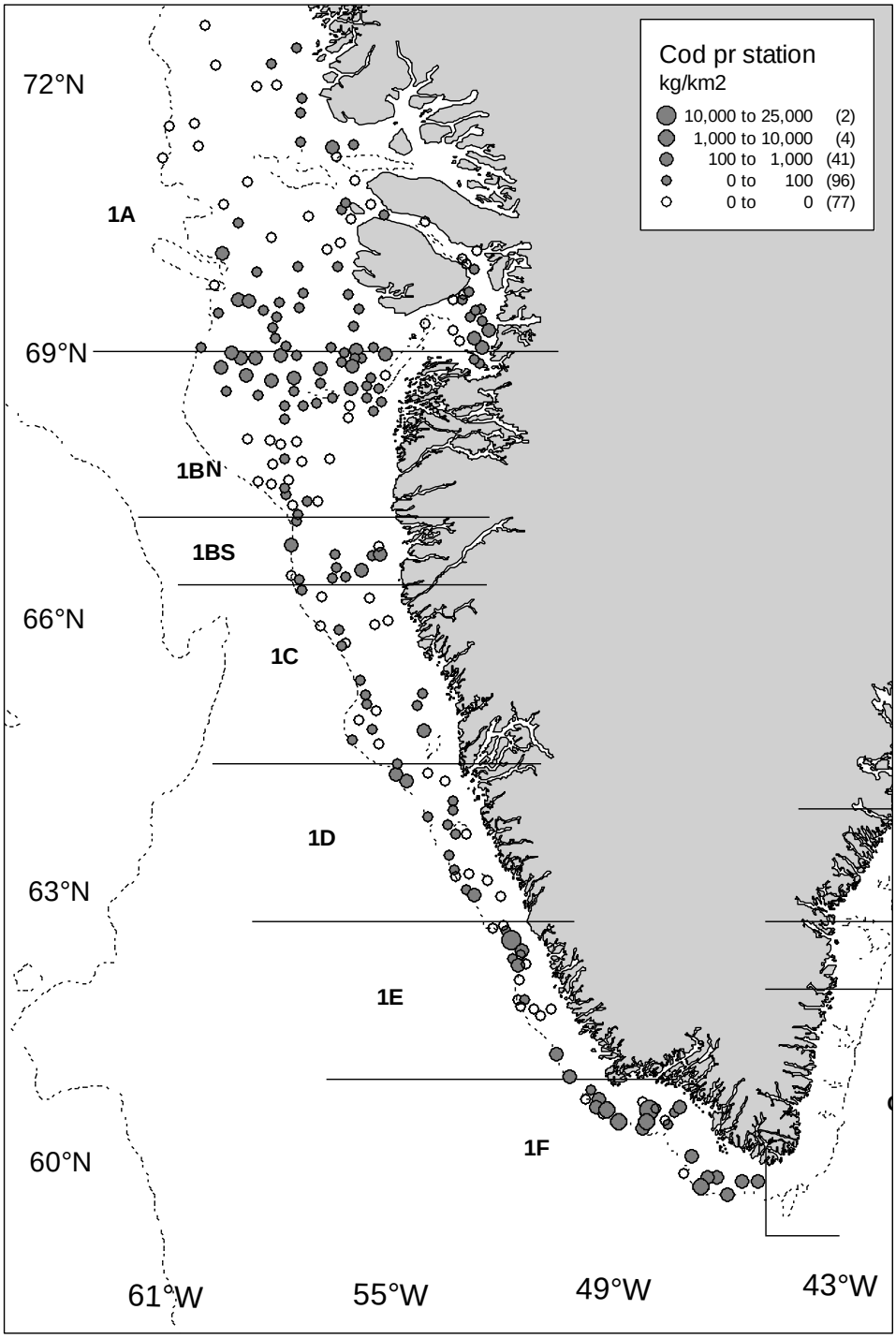

Fig. 3. Geographical distribution of cod density (in kg/km^2) in the Greenland Bottom Trawl Survey in 2012. Numbers in parentheses denotes number of tows.

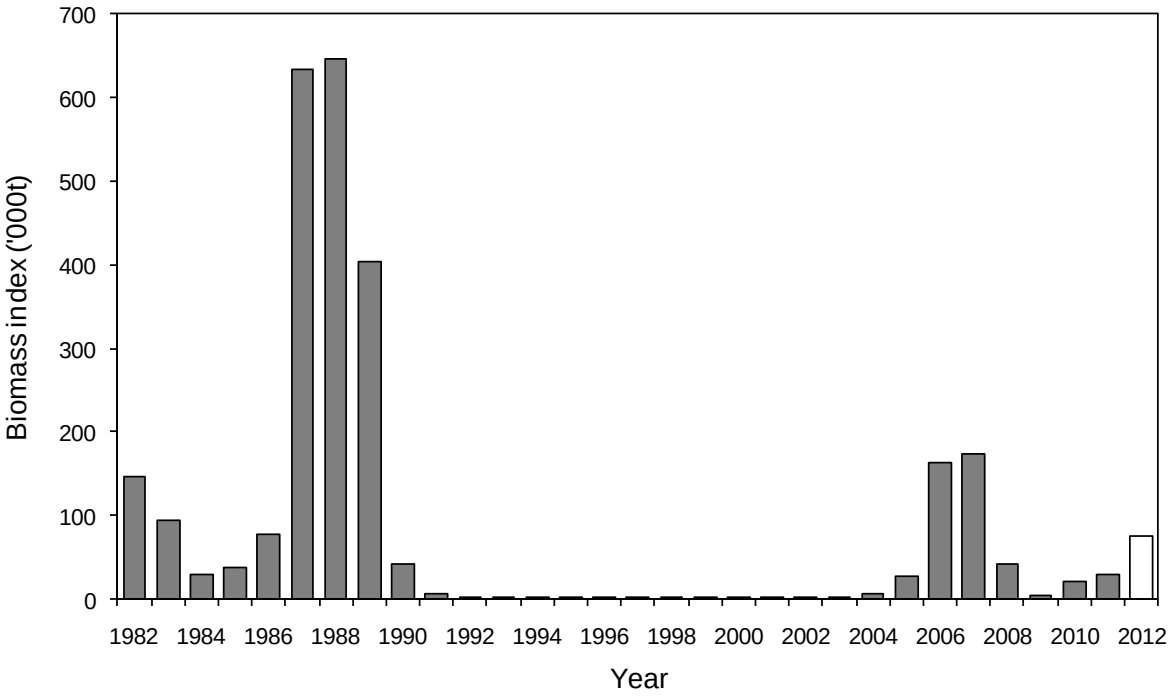

Fig. 4. Survey indices of Atlantic cod biomass for West Greenland offshore waters, 1982-2012 (1982-2011: original estimates from the German groundfish survey; 2012: estimate based on the Greenland Bottom Trawl Survey).