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A Preliminary Estimate of Atlantic Cod (*Gadus morhua*) Biomass in West Greenland Offshore Waters (NAFO Subarea 1) for 2006 and Recent Changes in the Spatial Overlap with Northern Shrimp (*Pandalus borealis*)

by

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Abstract

A comparative study of Atlantic cod catches at West Greenland from the German ground fish survey and the Greenland survey for shrimp and fish was carried out. The analysis was restricted to years with sufficient area coverage and regions included in both surveys. A close correlation between the two surveys estimates of cod biomass was found (r^2 = 0.91, P <0.001). Linear regression analysis using data from 14 years revealed that the biomass index of Atlantic cod biomass estimated from the Greenland survey for 2006 would correspond to 22 667 tons in the German survey. This indicates that the biomass of Atlantic cod is still low compared to the 1980s, despite its moderate increase in the most recent years. Furthermore, the geographical distribution of Atlantic cod have become a pronounced southern one, and the impact of Atlantic cod on Northern shrimp through predation appears currently to be small considering the low spatial overlap between the two species.

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 Atlantic 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 and 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 (Storr-Paulsen and Wieland, 2005). It provides a preliminary estimate of Atlantic cod biomass in West Greenland waters for 2006 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 shrimp and fish covers the offshore areas at West Greenland and has been conducted from 1988-2005. 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 (≤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 (Sünksen *et al*., 2005). The survey is designed as a stratified random trawl survey with a minimum of two hauls per stratum. The sampling period is July to September and throughout the entire time period the survey has been conducted by the Greenland Institute of Natural Resources with the research trawler RV *Paamiut*. 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 Wieland and Bergström, 2006 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, 2006).

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 southern NAFO Div. 1E and 1F were not included in the Greenland survey prior to 1992 and in 1993, respectively,
- the northern areas, i.e. NAFO Div. 1B and/or 1C, were not covered in the German survey in 1995, 2001 to 2003 and 2005,
- the number of stations was considered to be insufficient in the German survey in NAFO Div. 1F in 1993, 1999 and 2002, and in NAFO Div. 1D in 1995 and 2002.

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 and 2006 made with the Cosmos trawl to Skjervøy catches from the period 1998-2004 are yet not available. Therefore the 2005 and 2006 estimates were converted preliminarily to the old trawl standard using a size-independent conversion of total catches (Sünksen *et al*., 2006) and an adjustment for the smaller average swept area fished with the old trawl:

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

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 Div. 1A was set to 73°00'N and the southern limit of NAFO Div. 1F was set to 59°30'N considering the main distributional range of the fishery for the two species.

Wieland *et al.* (in prep.) have recently 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 some differences between the two surveys at the upper biomass levels, highly significant correlations ($r^2 = 0.91$, $P < 0.001$, n = 14) between the two data series were found, and the equation obtained by linear regression on a log-log scale (Fig. 2) is:

$$\log\left(Cod\ biomass_{German\ Survey}\right) = 1.0046 + 0.7953 * \log\left(Cod\ biomass_{Greenland\ Survey}\right)$$

Figure 3 shows the geographical distribution of Atlantic cod recorded in the Greenland survey for shrimp and fish in 2006. Dense aggregations of Atlantic cod were found in NAFO Div. 1D, 1E and 1F. In addition, fairly high densities were found in many of the stations taken in NAFO Div. 1C and the southern part of NAFO Div. 1B. This was not the case for stations taken north from the area that is usually covered by the German groundfish survey. Overall estimates of Atlantic cod biomass are 26 718 tons for the entire surveyed area and 25 256 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 16 340 tons.

The regression equation derived from the comparison of the German and the Greenland survey in the previous years gives an estimate of Atlantic cod biomass for 2006 of 22 667 tons in NAFO Div. 1B (south of 67°N) to 1F. This value is quite similar to the index for 2005 derived from the German survey and indicates that the level of Atlantic cod biomass is still much below what has been observed in late 1980s (Fig. 4).

Mean latitude of Atlantic cod landings declined slowly by about 1° latitude from the mid 1950s until the late 1970s followed by a rapid decrease from about 63 to 60°N during the 1980s (Fig. 5a). Mean latitude of Northern shrimp landings fluctuated between 67 and 68°N until the end of the 1980s before a southward extension of the fishery occurred. For the most recent years, mean latitude of survey estimates of stock biomass indicates a pronounced southern distribution of Atlantic cod and a northward shift in the distribution of Northern shrimp (Fig. 5b). Consequently, the spatial overlap between the two species decreased considerably in the years after 2000 indicated by a decline of values of the global index of collocation (GIC) from about 0.5 in the late 1990s to 0.1 in 2005 and 0.2 in 2006 (Fig. 5c). A significant relationship between the GIC and the mean latitude of Atlantic cod survey biomass was found (Fig. 6a). Applying this relationship to the estimates of mean latitude of Atlantic cod landings GIC values between 0.6 and 0.7 were obtained for the years before 1980. This suggests a much higher spatial overlap between Atlantic cod and Northern shrimp throughout most of the earlier years than observed in the past decade (Fig. 6b), and the moderate increase in Atlantic cod biomass in the most recent appears to be almost negligible in respect to predation on Northern shrimp considering the low spatial overlap between the two species (Table 1).

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TABLE 1. Time series of Atlantic cod biomass (*: using mean VPA to survey ratio based on Wieland and Storr-Paulsen, (2004).

Year	Cod biomass VPA (Buch et al. 1984)	Survey (ICES 2006)	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		0.662	1891.5
1954	2848.3		2848.3		0.669	1905.0
1955	2731.4		2731.4		0.666	1818.3
1956	2298.7		2298.7		0.663	1523.1
1957	2037.5		2037.5		0.659	1343.3
1958	1866.2		1866.2		0.656	1223.4
1959	1687.7		1687.7		0.670	1130.5
1960	1823.1		1823.1		0.667	1215.5
1961	1793.9		1793.9		0.666	1195.0
1962	1469.2		1469.2		0.669	983.2
1963	1328.4		1328.4		0.660	876.9
1964	1327.6		1327.6		0.656	871.6
1965	1345.3		1345.3		0.667	897.0
1966	1254.9		1254.9		0.667	837.5
1967	1167.5		1167.5		0.659	769.5
1968	904.9		904.9		0.638	577.5
1969	637.4		637.4		0.621	395.7
1970	442.2		442.2		0.574	253.8
1971	372.8		372.8		0.603	224.6
1972	283.0		283.0		0.657	186.0
1973	179.5		179.5		0.640	114.9
1974	132.1		132.1		0.640	84.5
1975	108.5		108.5		0.632	68.5
1976	228.8		228.8		0.596	136.4
1977	251.7		251.7		0.592	149.1
1978	253.5		253.5		0.655	165.9
1979	217.3		217.3		0.654	142.1
1980	240.4		240.4		0.658	158.1
1981	178.3		178.3		0.626	111.6
1982	190.9	128.5	190.9		0.538	102.6
1983	134.0	82.4	134.0		0.470	62.9
1984	79.0	25.6	79.0		0.493	38.9
1985	51.7	35.7	51.7		0.497	25.7
1986	38.4	86.7	38.4		0.530	20.3
1987	466.7	638.6	466.7		0.616	287.5
1988	481.2	608.0	481.2		0.625	300.8
1989	403.2	333.9	403.2		0.344	138.8
1990		34.4	34.3		0.229	7.9
1991		5.2	5.1		0.262	1.3
1992		0.6	0.6		0.543	0.3
1993		0.4	0.4	0.633	0.648	0.2
1994		0.1	0.1	(0.356)	0.612	0.1
1995		0.1	0.1	(0.120)	0.392	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		0.1
1999		0.2	0.2	0.496		0.1
2000		0.6	0.6	0.643		0.4
2001		2.7	2.7	0.462		1.2
2002		2.1	2.1	0.278		0.6
2003		2.3	2.3	0.398		0.9
2004		6.3	6.3	0.257		1.6
2005		25.2	25.2	0.074		1.9
2006			22.7	0.220		5.0

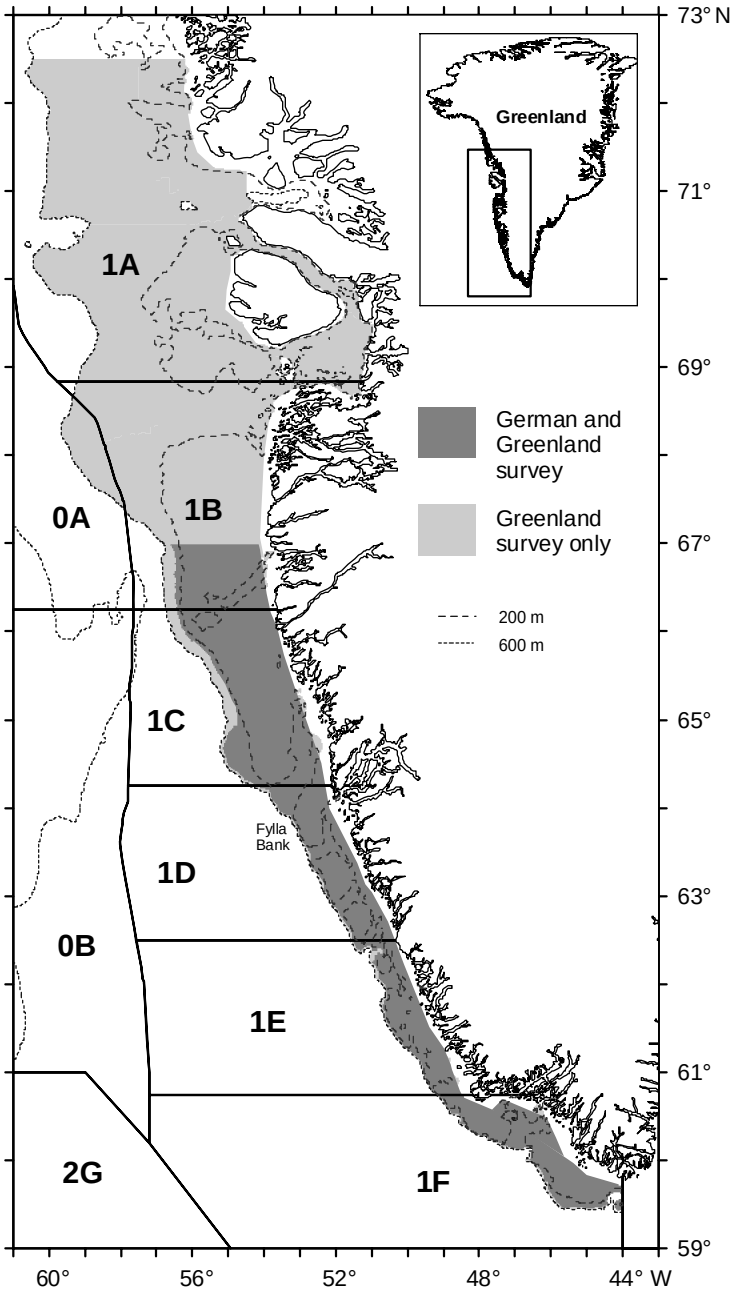

Fig. 1. Survey coverage for the Greenland fish and shrimp survey and the German ground fish survey in West Greenland offshore waters. (*: NAFO Div. 1B and 1C were not covered by the German survey in 1995, in 2001 to 2003 and in 2005).

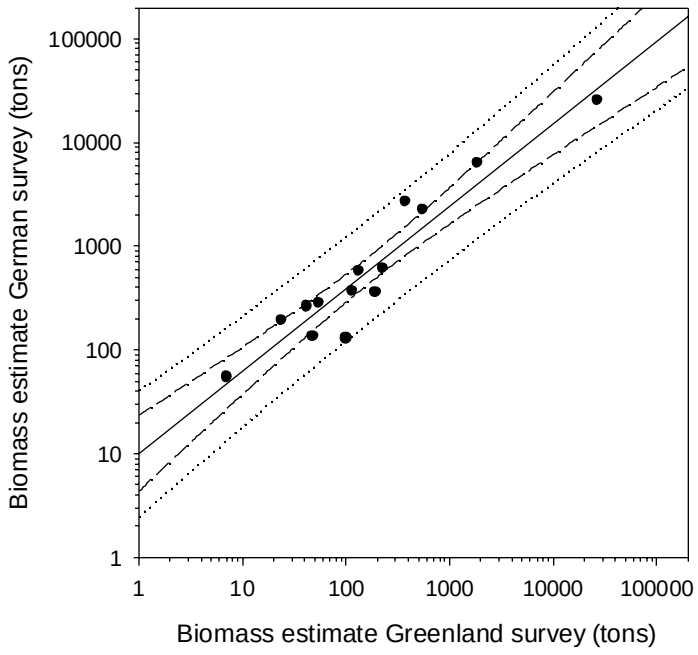

Fig. 2. Relationship between estimates of cod biomass in the overlapping area of the German groundfish survey and the Greenland Bottom Trawl Survey, 1992-2005. Dashed and dotted lines indicate limits of the 95% confidence and prediction intervals, respectively.

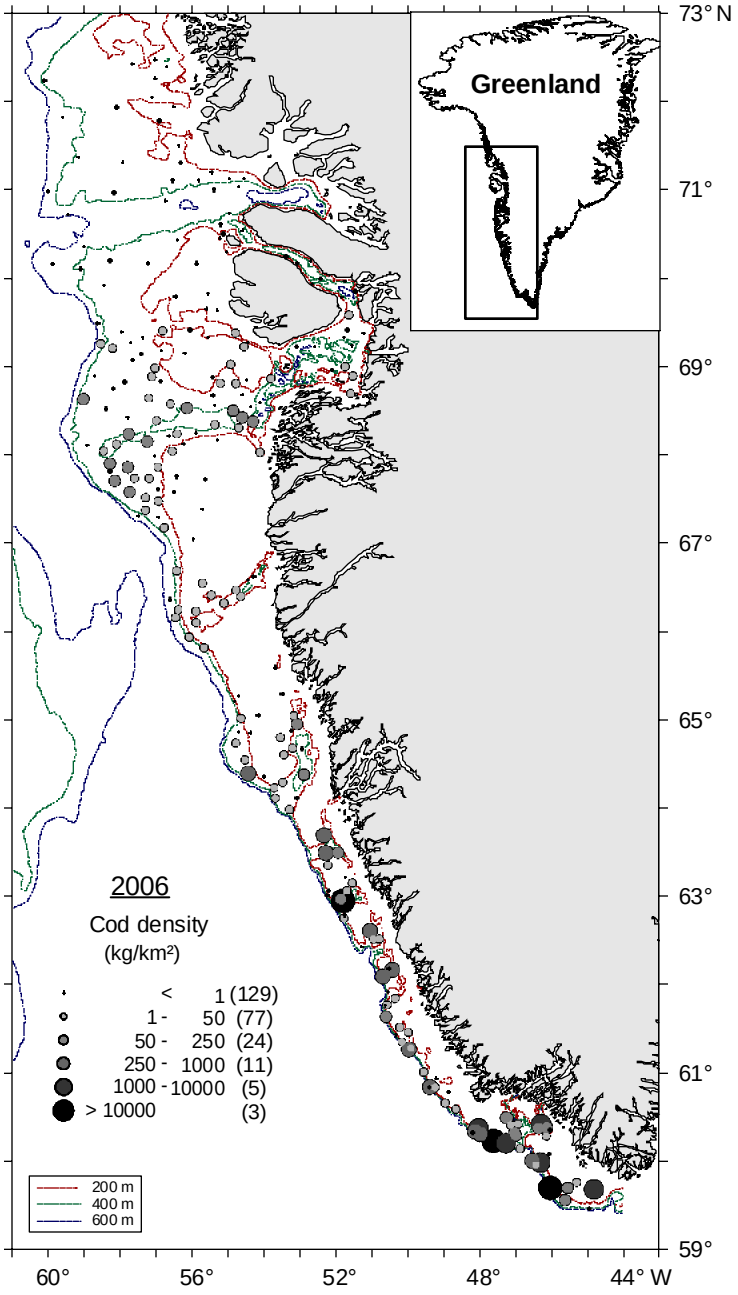

Fig. 3. Geographical distribution of cod density (in kg/h) in the Greenland Bottom Trawl Survey in 2006. Numbers in parentheses denotes number of tows.

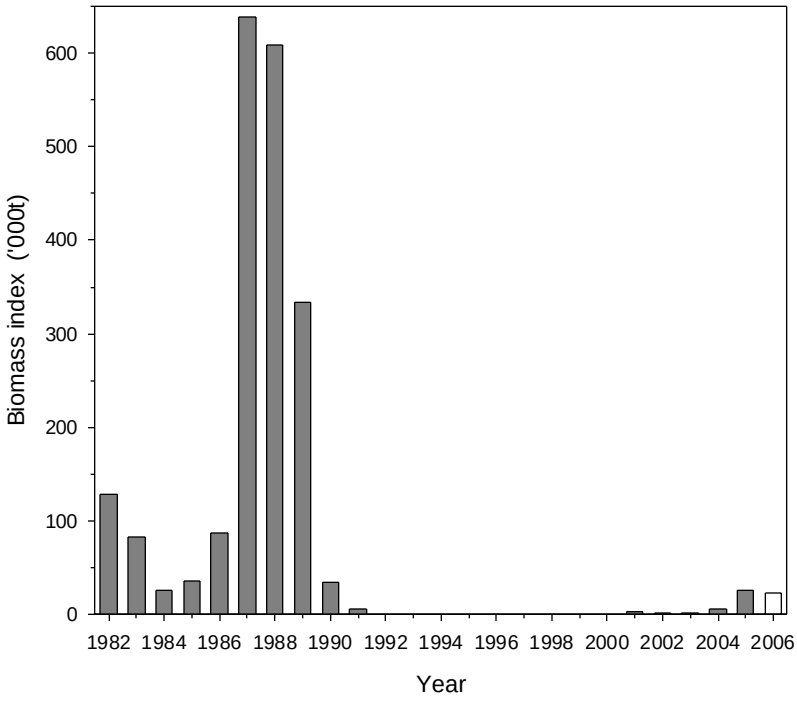

Fig. 4. Survey indices of Atlantic cod biomass for West Greenland offshore waters, 1982-2006 (1982-2005: original estimates from the German groundfish survey; 2006: estimate based on the Greenland Bottom Trawl Survey).

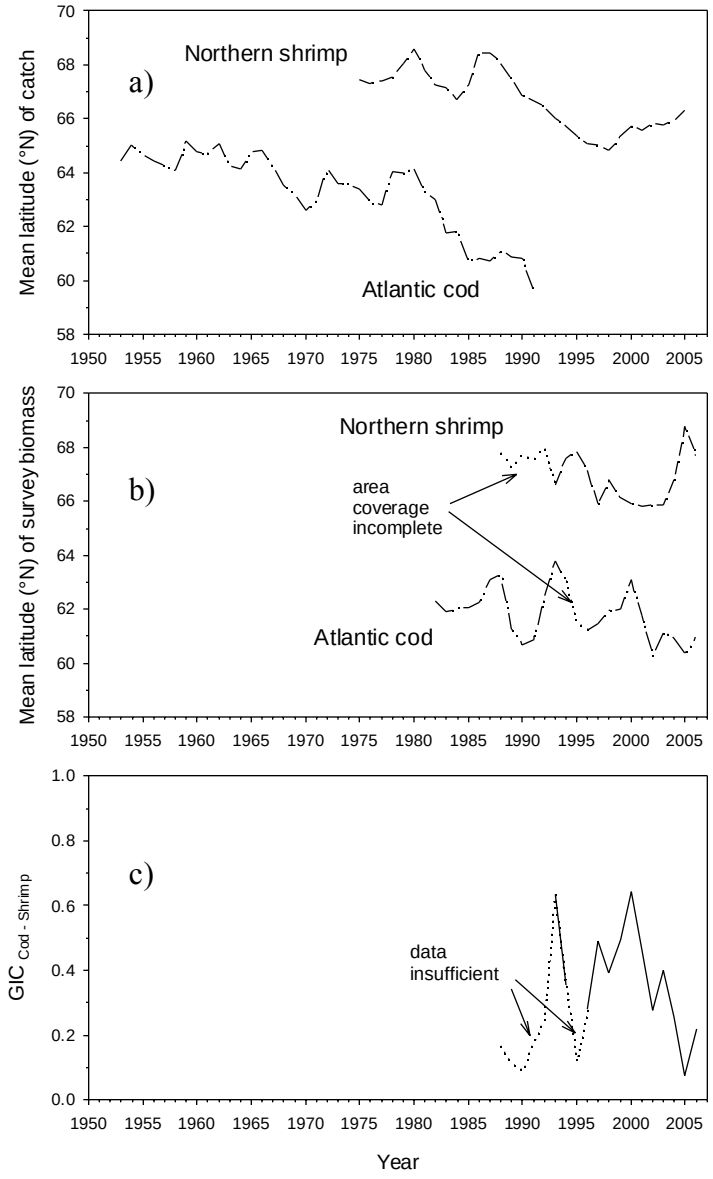

Fig. 5. Time series of mean latitude of commercial catches and survey biomass for Atlantic cod and Northern shrimp, and the global index of collocation (GIC) for the two species based on the survey data (German survey for Atlantic cod and Greenland survey for Northern shrimp, 2006: Greenland survey for both species).

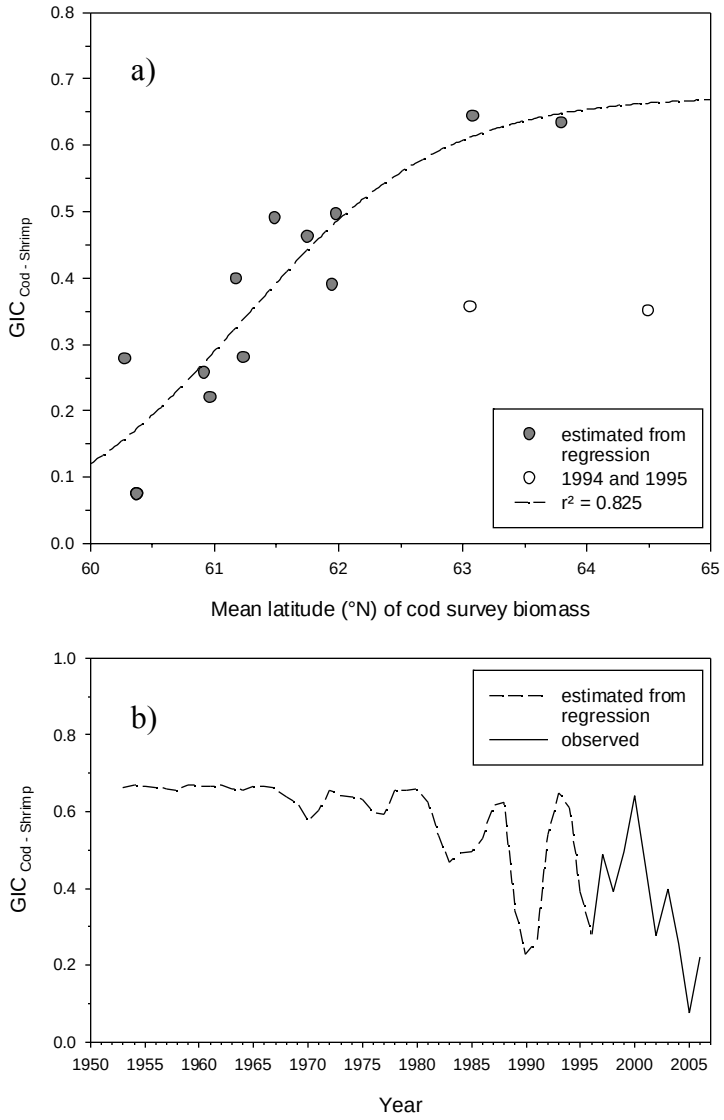

Fig. 6. Comparison of mean latitude of survey biomass for Atlantic cod and the global index of collocation between Atlantic cod and Northern shrimp.