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The Importance of Atlantic Cod (*Gadus morhua*) Predation on Northern Shrimp (*Pandalus borealis*) in Greenland Waters 2005

by

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Abstract

In the most recent years signs of recovery in the offshore cod stock are evident in West Greenland waters and concerns have been raised on the effects of cod predation on the Northern shrimp stock. Since the Atlantic cod stock in the West Greenland offshore waters decreased in the late 1960s and collapsed in the beginning of the 1990s the main commercial fishing effort has been put towards the shrimp fishery. To expose the potential importance of cod predation of Northern shrimp in Greenland offshore waters 686 cod stomachs were in 2005 analysed to determine prey choice in relation to cod distribution. The condition indexes of cod sampled during the summer and fall survey and condition indexes from East and West Greenland were also compared. Cod in the northern NAFO Division (1A-1B) had a higher frequency of occurrence of Northern shrimp in their diet and a lower occurrence of fish as prey than observed in the southern NAFO Division (1F). Cod sampled in the summer survey had a significantly (P<0.001) better condition in the southern area (Fulton K= 0.89) than in the northern areas (Fulton K= 0.79). Differences in summer and fall samples (Fulton K= 0.95 and K=0.99 for East and West Greenland waters, respectively) revealed that condition levels increased in the fall concurrent with a higher proportion of fish and a lower proportion of Northern shrimp in the diet.

Introduction

During the last five decades exploitation of two species have contributed to the main part of the Greenland economy; the Atlantic cod (*Gadus morhua*) in 1960s-1980s and the Northern shrimp (*Pandalus borealis*) from 1980s to the present. Close linkages between Atlantic cod and Northern shrimp populations have been described for various parts of the North Atlantic (Worm and Myers, 2003). Short-term responses, i.e. with time lags of less than 2 or 3 years, of stock size of Northern shrimp to changes in Atlantic cod biomass have been documented in the Barents Sea and Icelandic waters (Berenboim *et al*., 2000, Stefánsson *et al*., 1998, Wieland *at al*., 2006). Furthermore, it has been concluded that a reduction in predation by Atlantic cod has contributed to the increase in Northern shrimp biomass of Newfoundland and Labrador (Lilly *et al*., 2000).

After large fluctuations of Atlantic cod were observed during the 1970s and 1980s, cod almost disappeared from West Greenland waters in the beginning of the 1990s (Buch *et al*., 1994). An indication of some recovery of Atlantic cod was first observed after 2003 when survey catch rates increased slightly at southwest Greenland. In 2005 the survey abundance estimate was the highest in 15 years and 17% of the level in 1987, the record high in the survey time series (ICES, 2006). Indices of Northern shrimp stock size fluctuated during the late 1970s and the early 1980s, were relatively stable at a low level and increased to record high values in the end of the 1990s (Kingsley and Hvingel, 2005, Wieland and Bergström, 2005). The increase in Northern shrimp biomass was preceded by a couple of years of increasing recruitment. It has been suggested that an increase in sea temperature in the mid 1990s has been beneficial for survival and growth of juvenile Northern shrimp (Wieland, 2005).

The Northern shrimp stock has since 2002 been assessed with a Bayesian framework model taking cod predation into account (Hvingel and Kingsley, 2006). This model estimated a yearly consumption of shrimp by cod to be relatively constant between 30 and 80 000 t from 1956 to 1983. The estimation declined after 1960 but in the late 1980s cod consumption increased dramatically to around 100 000 t for a couple of years during a period of an increase in cod biomass. After nearly no estimated consumption of shrimps in the last 15 years the estimated cod predation increased from about 2 000 t in 2004 to 30 000 t in 2005 (Kingsley and Hvingel, 2005). The spatial distribution of cod has changed dramatically since the late 1980s, when predation by cod on shrimp was large in comparison to the present.

In 1987, only 5% of the total cod abundance was located in East Greenland waters whereas, 56% of the abundance was located in East Greenland waters in 2005 (ICES, 2006). Furthermore, the distribution of cod at West Greenland has been an extremely southern one with 80% of the total biomass found in NAFO Div. 1F in 2005 (ICES, 2006). At the same time the shrimp abundance has shifted to a more northerly distribution (Wieland *et al*., in prep.; Wieland and Sünksen, 2006), and it is therefore believed that the change in spatial distribution compared to earlier periods has reduced the importance of cod predation upon the Northern shrimp stock in West Greenland waters.

In the present study, predation by the Atlantic cod on the Northern shrimp, was explored from stomachs sampled in West and East Greenland waters compiled from two surveys in the summer and fall of 2005.

Material and Methods

Survey information

Stomachs of Atlantic cod were gathered during two different stratified-random bottom trawl surveys. These were a Greenland survey for shrimp and fish carried out in the summer by the Greenland Institute of Natural Resources (GNIR) with R/V *Paamiut* and a German groundfish survey conducted with R/V *Walter Herwig* in autumn (October-November) by the Institute of Sea Fisheries Hamburg (ISH), both surveys were carried out in 2005.

The GNIR survey for fish and shrimp covers the West Greenland shelf between 72°30' N and 59°30' N down to depths of 600 m (Fig. 1). The fishing gear is a rubber disc / bobbin rock-hopper trawl which has a vertical opening of about 14 m and is towed at a speed of 2.5 knots. The primary objective of the survey is to provide an estimate of the fishable biomass of Northern shrimp, and although the survey is considered to be less efficient for Atlantic cod it provides an index of cod abundance.

The ISH survey covers the shelf area outside the 3 nautical mile limit and the continental slope down to a depth of 400 m between 64°15' N and 59°30' N (Fig. 1) off West Greenland and between 66°00' N and 59°30' N in East Greenland waters. The fishing gear is a standardized 140 feet bottom trawl with a vertical opening of about 4 m and is towed at a speed of 4 knots. This survey is primarily designed for Atlantic cod.

In all 556 and 130 cod stomachs were sampled during the surveys with RV *Paamiut* and RV *Walter Herwi*g, respectively. Total length of the fish was measured to the nearest cm and their weight noted (± 5 g.). Fish showing evidence of regurgitation were not used and therefore not included in further analysis. The remaining fish were sexed and gutted and stomachs were removed and frozen within one hour.

Stomachs sampled in the summer were analysed according to NAFO Divisions were Division. Due to the low number of samples from the northern Div. 1A they were pooled with Div. 1B. The samples gathered in the fall survey were pooled into two groups West- and East Greenland waters, as sample sizes were to small to be analysed according to NAFO Divisions (West Greenland) or subdivisions of ICES area 14B (East Greenland).

Laboratory analysis

In the laboratory stomachs were slowly thawed at 10°C and opened with scissors. The degree of stomach fullness (0-3) was visually evaluated according to the amount of prey items and the appearance of the stomach inner wall. The prey items in the stomachs were determined to the lowest possible taxonomic level according to the degree of digestion and placed in one of 12 prey categories.

21% (28 stomachs) and 11% (59 stomachs) sampled on the R/V *Walter Herwig* and R/V *Paamiut*, respectively, were empty and not included in further analysis.

Category	Stomach wall characteristics
0	Completely empty, with many creases inside
1	Similar to "0" but less creased. Few items prey
2	Stomach stretched and wall thinner than "1" with very few creases and some prey
3	Stomach entirely filled. Wall thin and no creases.

Condition index

Simple condition indices (Fultons *K*- index and CF) were calculated as a proxy for the energy reserve of the cod (ex. Schwalme and Chouinard, 1999; Lloret and Rätz, 2000; Rätz and Lloret, 2003);

$$K = 100 * (W/L^3)$$

where *W* denotes wet weight (g) of the fish and *L* is total length (cm) assuming isomeric growth. If the assumption of isometric growth (b=3) is seriously violated this condition measure is inappropriate. Furthermore, CF was calculated based on the exact relation between the weight and length (Fig. 2).

$$CF = 100 * (W/L^b)$$

where *b* denotes the regression coefficient between *ln* (weight) and ln (length). In this study *b* was found to be 2.988 (r^2=0.96) and 3.03 (r^2=0.95) for the summer and fall survey data, respectively. The relationship between the condition indices were r^2= 0.999 for both data sets.

The fish were grouped in 10 cm length categories with 'group 0' ranking from 5-15 cm. and the largest 'group 9' larger than 100 cm.

Data analysis of stomach contents

In relation to the stomach content analysis the following parameters were estimated:

a) Relative frequency of occurrence (*F*) is the number of cod stomachs with prey items, *i*, as the percentage of the total number of cod stomachs. The occurrence of different prey taxa in a stomach was determined when at least one individual of a taxonomic group was present and thus indicated how many predators that had eaten a particular prey or prey group (Andersen *et al.*, 2005; Mello and Rose, 2005).

$$F = N_i/N_t$$

where N_i is the number of stomachs containing prey *i* and N_t is the total number of stomachs containing prey.

b) Prey specific abundance (*A*) with the use of both wet (A_{ww}) and dry (A_{dw}) weight of prey.

$$A = (\Sigma W_i)/(\Sigma W_{it})$$

where W_i is the total weight of prey in a given category and W_{it} is the total weight of prey in all stomachs containing prey. There was a significantly high relation between wet and dry weight.

c) Mean partial fullness index (PFI)

$$PFI = 1/N * \Sigma (W_{if} / (L_f)^3 * 10^4)$$

where *N* is the number of fish, W_{if} is the weight of prey *i* in fish *f* and L_f is the length in cm of fish *f* (Nielsen and Andersen, 2001).

d) Mean total fullness index (*TFI*)

$$TFI= 1/N * \Sigma (W_f/(L_f)^3 * 10^4)$$

where N is the number of fish, W_f is the weight of total stomach content for fish f and L_f is the length in cm of fish f (Nielsen and Andersen, 2001,).

Statistics

A one-way ANOVA on ranks as was used to analyse the difference between medians in length, weight and condition index (Fultons *K* and *CV*) in NAFO Divisions, as data were not normally distributed.

Results

Empty stomachs were found in all NAFO Divisions but no obvious trend in comparisons between Divisions was apparent (Fig. 3). On average empty stomachs amounted to 10.6% (between 8-16%) of all stomachs in the summer survey and 22% in the fall survey (between 18.2-28.6%) and thus there was a relatively higher proportion of empty cod stomachs in the fall than of cod collected in the summer survey: An effect that could be caused by the time of year the surveys were conducted (Table 1). Furthermore, in the summer sampling the proportion of empty stomachs decreased with increasing fish size (Fig. 3) whereas this effect was not seen in the fall survey.

Condition

A significant difference in length and weight (P<0.001) of cod along the west coast was observed as cod in the southern NAFO divisions were significantly longer and heavier than cod caught in the northern NAFO divisions.

In the fall survey the condition level of cod was relatively higher than cod from the summer survey with a mean level of 0.99 (S.D.± 0.37) in West Greenland and 0.95 (S.D.± 0.13) in East Greenland waters (Table 1 and Table 2).

Furthermore, the condition of cod (Fultons *K* index and *CF*) was significantly better (P<0.001) in the more southerly NAFO Divisions (Table 3). The average condition on the west coast was 0.85 (S.D.± 0.19) with the lowest levels in the northern regions and the highest levels in the south.

Condition factors were tested to be independent of length groups.

Stomach content

The relative importance of Northern shrimp in the cod diet decreased from North to South. This was illustrated as the relative frequency of occurrence of shrimp in stomachs (F) (Fig. 4) and the proportion of Northern shrimp prey by weights (wet and dry) progressively decreased from North to South (Fig. 5 and 6). On average 40% of the cod stomachs contained Northern shrimps in NAFO 1B in comparison to only 8% in NAFO division 1F. However, the variation (S.D) between fish is relatively high, as a number of fish stomachs do not contain shrimp (Fig. 7). When assessing the importance of prey by weight (dry and wet) the trend is even more pronounced as approximately 86% of the total wet and dry weight, found in stomachs in NAFO division 1B contains Northern shrimp in comparison to 1.82% and 1.22% for wet and dry weight, respectively in NAFO division 1F (Table 3).

Cods sampled in South Greenland contained a greater variation of different prey items, in particular fish such as capelin and other fish species (sand eel, cod and redfish) increased in importance (Table 3 and Fig. 8). The decreasing proportion of Northern shrimp and increasing importance of fish prey was even more pronounced in the autumn survey. None of the cod stomachs sampled in East Greenland water contained Northern shrimp while more than 70% of the stomachs contained fish. In the West Greenland fall survey (NAFO 1D-1F pooled) only 5% of the prey by weight was made up of Northern shrimp while 15% of the diet was made up of fish (Table 2).

Discussion

Stomach content

The present results show that the primary food sources of Atlantic cod in West Greenland offshore waters are very dependent on latitude and time of year. Northern shrimp and krill had a major importance in the diet of cod in the northern most areas (*F* = 42% and 50%, respectively) whereas capelin and other fish species were nearly almost absent (0% and 2%, respectively) as prey items. In contrast, the diet of cod in the southern areas showed fish as the major food component (9% capelin and 40% other fish species, respectively) whereas the frequency of Northern shrimp and krill was lower (14% and 22%, respectively). These findings are in accordance with earlier investigations of cod diets conducted in offshore West Greenland waters by Grunwald and Köster (1995). Their investigations showed that more than 80% of the cod diet by wet weight in the northern areas (NAFO Div. 1B/1C) was made up of shrimp while less than 5% of the cod diets contained shrimp in the southerly NAFO Div. 1F in July-August. Furthermore, capelin and other fish species contributed less than 15% of the diet in the northern regions yet capelin made up 45% of the total wet weight in the southern NAFO Div. 1F. Their investigation was carried out in 1989-1992 when there was a greater overlap in the distribution of cod and Northern shrimp than observed in 2005 (Fig. 9). Wieland *et al.* (in prep.) as well as Wieland and Sünksen (2006) showed that the spatial overlap between the Northern shrimp and the cod distribution has changed throughout the years, and that the spatial overlap in 2005 was at a record low with Northern shrimp reaching a weighted mean latitude at approximately 69°N and cod at 61°N. These findings together with the present investigation indicate that although consumption of northern shrimp does take place in the northern areas, the abundance of cod in this area is very low. In contrast, cod is more abundant in the southern regions yet their diet contains a lower proportion of Northern shrimp. In all, this would suggest that the total consumption of Northern shrimp by cod at West Greenland has been of minor importance in 2005.

Condition

The higher condition levels observed in this studies fall survey compared to the levels found during summer corresponds well with other investigations showing maximum levels of condition factors occur from September to December and the lowest levels are generally observed in the spring just after spawning (Llambert and Dutil 1997). Lloret and Rätz (2000) analysed cod condition in West Greenland in the years 1982-1998 from a fall survey, with a mean Fultons *K* at 0.89 ranging from 0.82 (S.D.± 0.15) in the start of the period to a maximum of 0.94 (S.D.± 0.12) in 1997. A comparative analysis of fish condition on 10 stocks in the Atlantic revealed that the stock in West Greenland water was amongst those with the lowest mean condition (Rätz and Lloret, 2003). The condition levels observed in the fall survey of this study was above the level of the entire period investigated by Rätz and Lloret (2003), indicating that the mean condition of cod was good in the Greenland offshore cod stock in 2005. Condition levels of cod in the northern areas observed in the summer were also relatively high compared to levels measured in earlier studies, while the levels in the northern areas were amongst the lowest (Llambert and Dutil, 1997; Dutil *et al*., 2003). Lloret and Rätz (2000) found a positive correlation between mean annual condition factors and weighted mean temperatures. In 2005 recorded water temperatures reached a record high (Stein, 2005), which could be one explanation for the generally high condition achieved in 2005.

The ratio of fish prey compared to invertebrate prey in the diet, could also explain the relatively high condition in cod. A low ratio of fish to invertebrates in the diet is believed to be an important reason for slow growth of cod in the Western Gulf of St. Lawrence compared to other stocks (Waiwood and Majkowski, 1984). This inference is based on the assumption that invertebrates are energetically inferior to fish as food for cod. Increased fish consumption has been correlated with improved growth rate in southern Gulf cod; once in the mid 1950s with increased herring consumption (Kohler, 1964) and again in the late 1960s when improved growth in cod coincided with increased consumption of capelin (Waiwood, 1986). It has previously been shown that capelin and capelin eggs made up the main food source for cod (*F* = 57%) in the inshore areas of West Greenland waters (Nielsen and Andersen 2001). This trend was also observed in inshore cod sampled in June 2005 as capelin was found at a high frequency of occurrence (F=70%) in their diet (Schack and Hedeholm, 2005). The high value in the latter study was probably caused by the large aggregations of spawning capelin in the fjords at this time of year (Friis-Rødel and Kanneworff, 2002). The mean condition of cod in the study of Schack and Hedeholm (2005) was also high (0.98) supporting the theory that a high ratio of fish in the diet increases fitness.

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Table 1. Prey categories and prey specific abundance using wet weight (A_{ww}) and dry weight (A_{dw}) respectively and frequency of occurrence (F), mean partial fullness index (PFI) for the total survey area (West Greenland). As a fish can have fed on more than 1 prey item F is not summing up to 1. n is the total numbers of stomachs sampled incl. the empty.

	(n=556)	RV	Paamiut		(n=130)	RV	Walther	Herwig
Prey categories	F	A_{ww}(%)	A_{dw}(%)	PFI	F	A_{ww}(%)	A_{dw}(%)	PFI
Prey species								
Pandalus borealis	0.106	14.40	10.64	2.673	0.039	0.28	0.57	0.540
Pandalus montagui	0.066	6.72	6.63	2.345	0.441	7.21	0.17	0.032
Euphausiidae sp.	0.070	10.79	7.00	1.835	0.539	0.83	4.65	4.627
Mallotus villotus	0.038	4.13	3.80	0.239	0.059	0.21	0.14	0.014
Fish sp	0.354	30.37	35.36	1.798	0.225	66.03	68.58	4.996
Crustacea sp	0.004	0.64	0.39	0.043	0.010	0.07	0.04	0.029
Polychaetes sp.	0.003	0.38	0.28	0.048	0.039	0.04	0.05	0.068
Gonatus sp.	0.012	2.10	1.16	0.128	0.029	0.29	0.23	0.567
Amphipods	0.068	11.30	6.75	0.976	0.000	0.00	0.00	0.000
Cottidae sp.	0.005	0.26	0.50	0.016	0.000	0.00	0.00	0.000
Unidentified species	0.275	18.92	27.47	0.964	0.275	25.03	25.56	2.932
Mean length		32.98				40.74		
Mean weight		0.45				0.86		
Min. length		11				19		
Max. length		82				108		
Empty stomachs%		10.6				22.0		
Fultons K		0.850	(±0.19)			0.967		
CF		0.806	(±0.18)			0.870		
TFI		8.34				13.80		

Table 2. Same as table 1 but from the fall survey with RV *Walter Herwig* in West and East Greenland waters.

	(n=88)	Walter	Herwig	West	(n=42)	Walter	Herwig	East
Prey categories	F	A_{ww}(%)	A_{dw}(%)	PFI	F	A_{ww}(%)	A_{dw}(%)	PFI
Prey species								
Pandalus borealis	0.056	5.45	4.68	0.765	0.000	0.00	0.00	0.000
Pandalus montagui	0.000	0.00	0.00	0.000	0.067	0.31	0.20	0.109
Euphausiidae sp.	0.569	35.06	29.34	6.127	0.467	2.09	1.20	1.028
Mallotus villotus	0.000	0.00	0.00	0.000	0.200	4.86	0.16	0.047
Fish sp	0.153	32.65	33.84	3.293	0.367	68.71	73.43	9.082
Crustacea sp	0.000	0.00	0.00	0.000	0.033	0.08	0.05	0.099
Polychaetes sp.	0.042	0.34	0.45	0.096	0.033	0.00	0.00	0.000
Gonatus sp.	0.042	1.93	1.87	0.803	0.000	0.00	0.00	0.000
Amphipods	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000
Cottidae sp.	0.000	0.00	0.00	0.000	0.000	0.00	0.00	0.000
Unidentified species	0.264	24.56	29.82	2.245	0.300	23.95	24.97	4.579
Mean length		54.46				31.63		
Mean weight		3.194				0.371		
Min. length		25				20		
Max. length		108				61		
Empty stomachs%		18.2				28.6		
Fultons K		0.99	(±0.37)			0.95	(±0.13)	
CF		0.87	(±0.33)			0.87	(±0.11)	
TFI		13.33				14.94		

Table 3. Same as table 1 but summer survey with RV *Paamiut* divided on NAFO Divisions at West Greenland.

Prey species	NAFO 1B				1C				1D				1E				1F			
	(n=58)				(n= 101)				(n= 115)				(n= 124)				(n=158)			
	F	PFI	A_{ww}	A_{dw}	F	PFI	A_{ww}	A_{dw}	F	PFI	A_{ww}	A_{dw}	F	PFI	A_{ww}	A_{dw}	F	PFI	A_{ww}	A_{dw}
Pandalus borealis	0.42	8.19	86.0	86.6	0.25	5.20	51.8	50.0	0.14	1.84	23.4	21.8	0.07	5.78	6.47	6.30	0.14	9.82	1.82	1.22
Pandalus montagui	0.02	0.26	1.28	1.14	0.00	0.00	0.00	0.00	0.21	1.99	19.1	39.5	0.2	8.82	30.5	30.6	0.01	0.1	0.81	0.59
Euphausiidae sp.	0.50	2.10	8.86	8.31	0.61	3.96	22.3	20.3	0.49	3.43	33.1	17.9	0.47	3.52	17.5	16.8	0.22	0.56	4.42	2.70
Mallotus villotus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.48	4.90	6.67	0.09	2.29	5.58	4.25
Fish sp	0.02	0.21	2.62	2.62	0.00	0.00	0.00	0.00	0.06	0.34	4.84	6.43	0.09	1.37	31.8	31.5	0.40	4.28	41.26	44.5
Crustacea sp	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.01	0.03	0.13	0.14	0.00	0.00	0.00	0.00	0.16	0.30	1.03	0.55
Polychaetes sp.	0.02	0.01	0.13	0.09	0.07	0.21	2.08	1.93	0.00	0.00	0.00	0.00	0.04	0.03	0.35	0.35	0.06	0.02	0.17	0.11
Gonatus sp.	0.00	0.00	0.00	0.00	0.01	0.03	0.26	0.23	0.02	0.01	0.06	0.04	0.05	0.45	2.77	2.21	0.04	0.18	2.71	1.24
Amphipods	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	2.10	17.2	12.3	0.24	1.27	4.80	4.12	0.46	4.25	15.2	8.00
Cottidae sp.	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.14	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.01	0.04	0.42	0.70
Unidentified sp.	0.12	0.32	1.08	1.23	0.25	2.22	23.5	27.4	0.13	0.36	2.10	1.88	0.08	0.15	0.95	1.40	0.34	1.44	26.6	36.1
Mean length			29.88				31.43				27.95				29.65				41.09	
Mean weight			0.27				0.29				0.22				0.3				0.88	
Min. length			11				14				14				18				14	
Empty stomachs%			10.3				11.9				7.0				16.1				8.2	
Max. length			50				55				47				60				82	
Fultons K			0.789				0.848				0.832				0.889				0.89	
CV			0.749				0.805				0.79				0.835				0.841	
TFI			2.34				11.64				10.08				17.08				14.38	

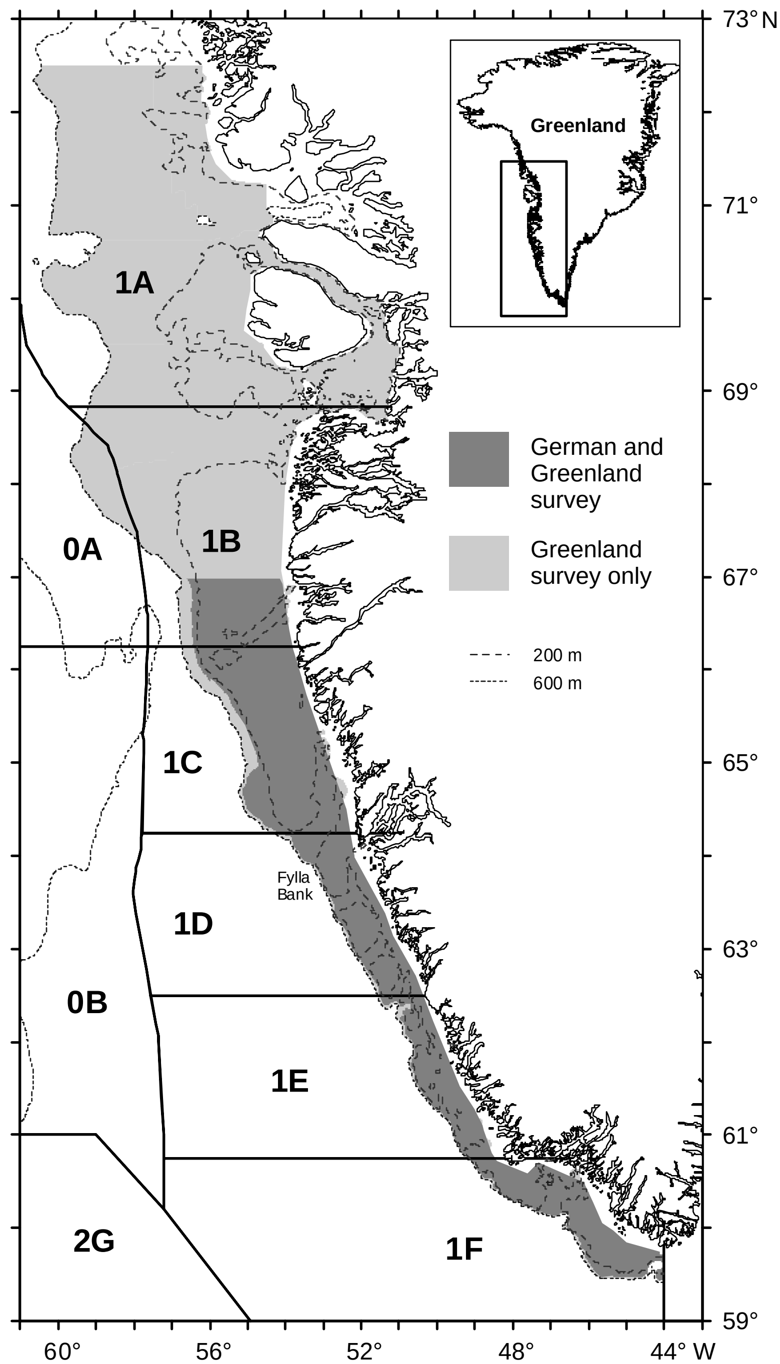

Fig. 1. NAFO statistical Divisions and area coverage of the German groundfish survey and the Greenland survey for shrimp and fish off West Greenland.

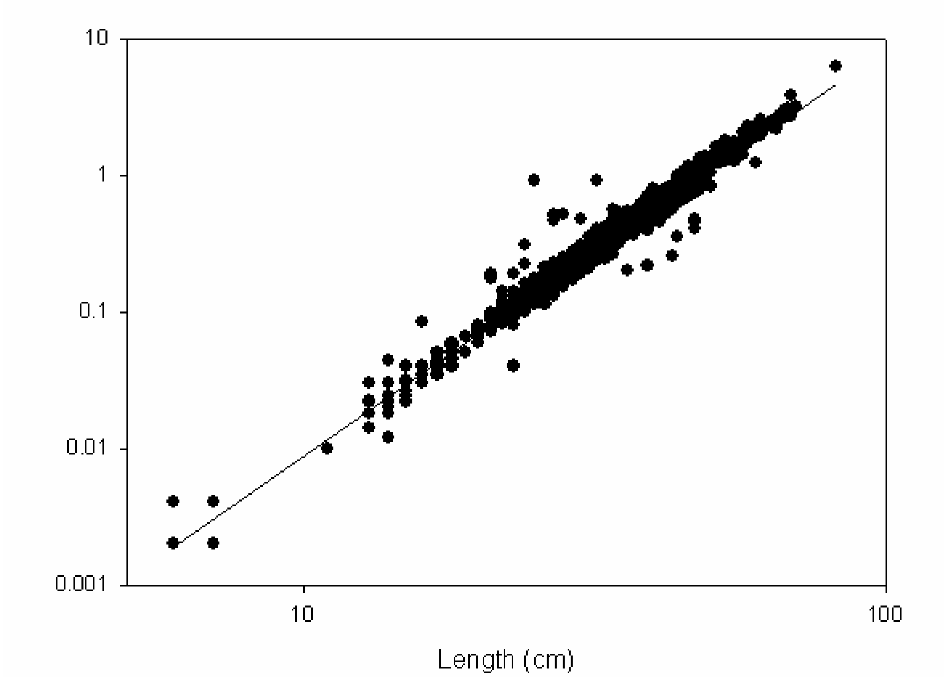

Fig. 2. Log relation between length and weight of cod in the Greenland summer survey 2005.

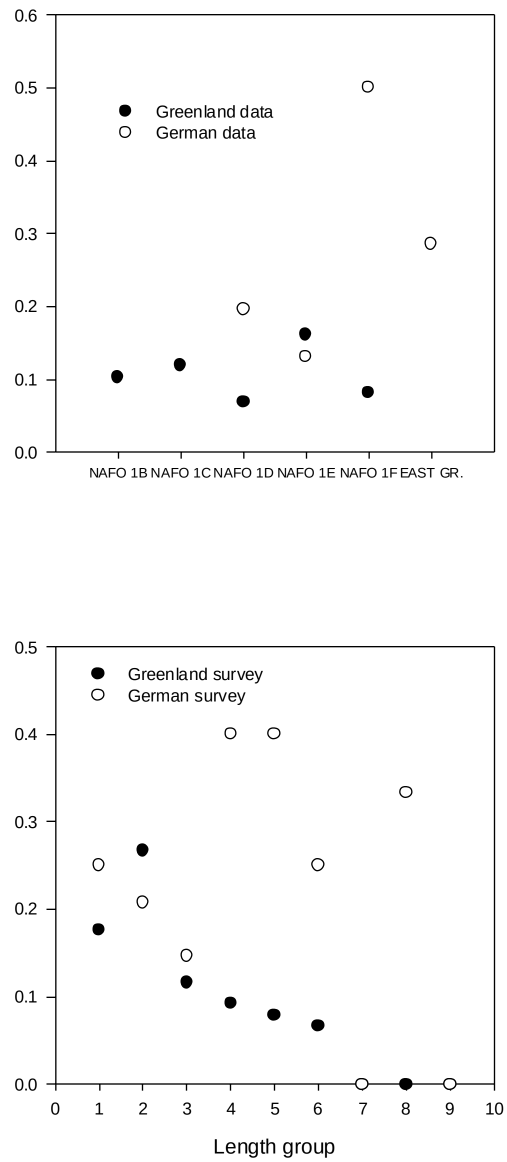

Fig. 3. Proportion of empty cod stomachs in relation to length groups at West Greenland (Greenland survey) and for East and West Greenland combined (German survey).

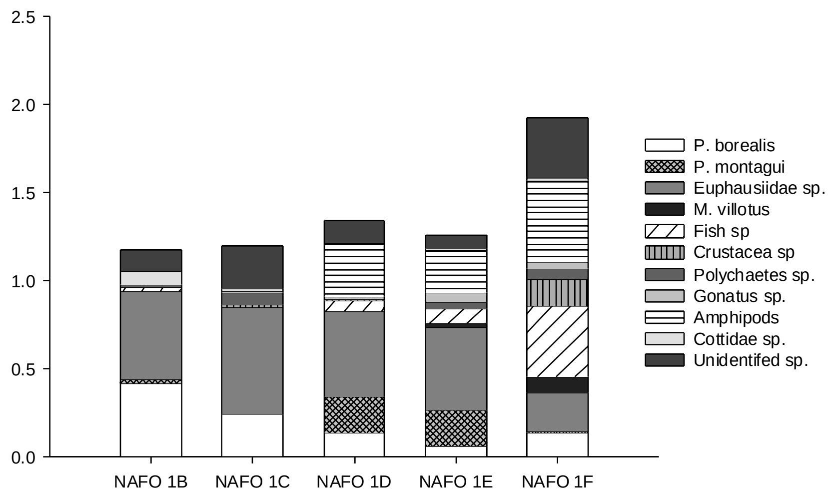

Fig. 4. *F*-parameter for cod in the different NAFO Divisions. The values do not sum up to one as it reflects how many of the stomach that continued the different prey and one stomach can continue more than one prey item.

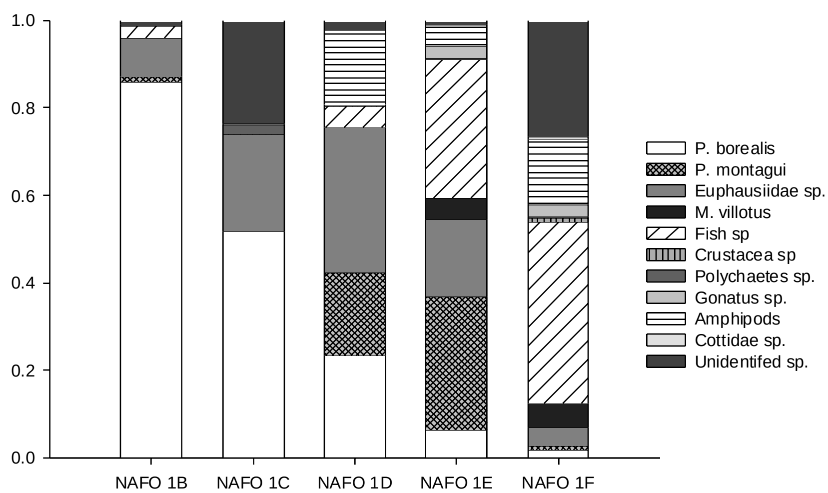

Fig. 5. Proportion of different species in wet weight in cod stomachs derived from NAFO Div. 1B-1F.

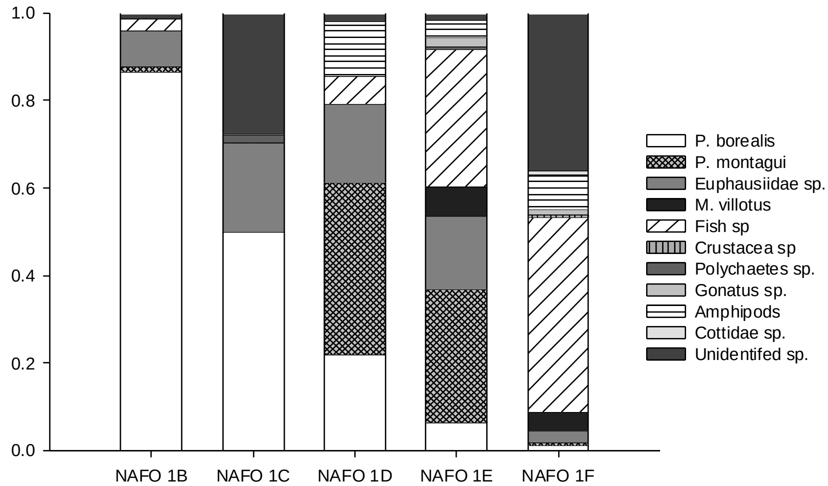

Fig. 6 Proportion of different species in dry weight in cod stomachs derived from NAFO Div. 1B-1F.

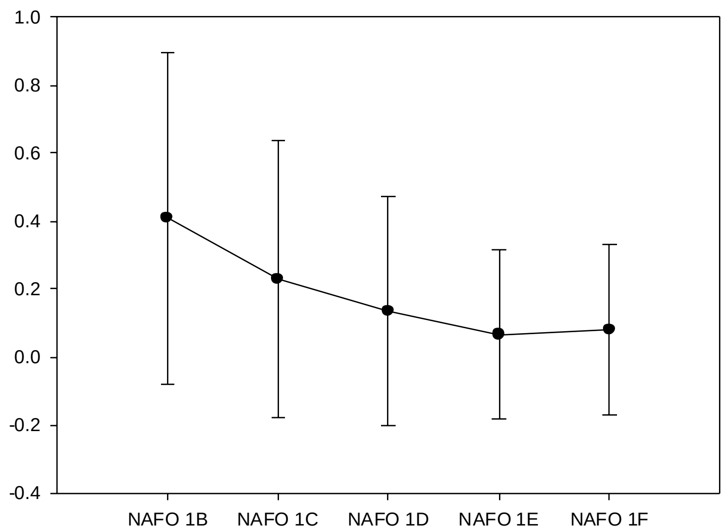

Fig. 7. Proportion (±1 SD) of *P. borealis* in total prey in cod stomach in NAFO Div. (1B-1F).

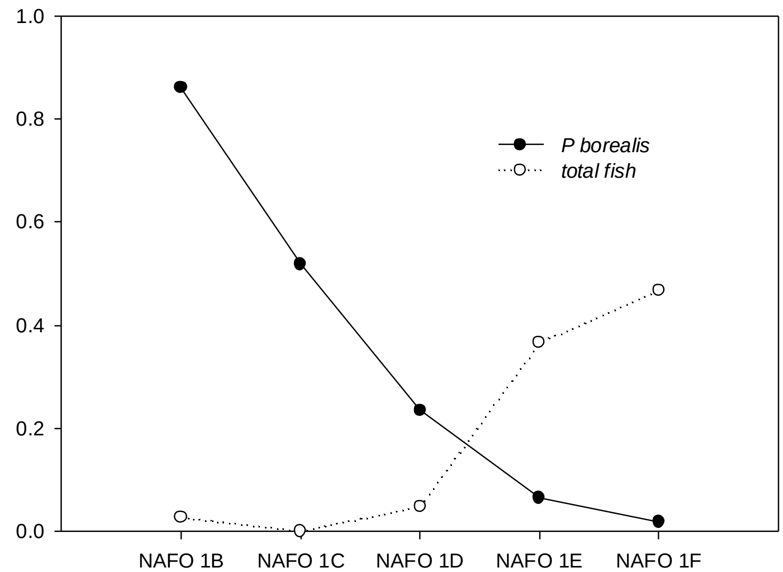

Fig. 8. Changes of mean proportion (A_{ww}, wet weight) of *P. borealis* and total fish in cod stomachs along the West Greenland coast.

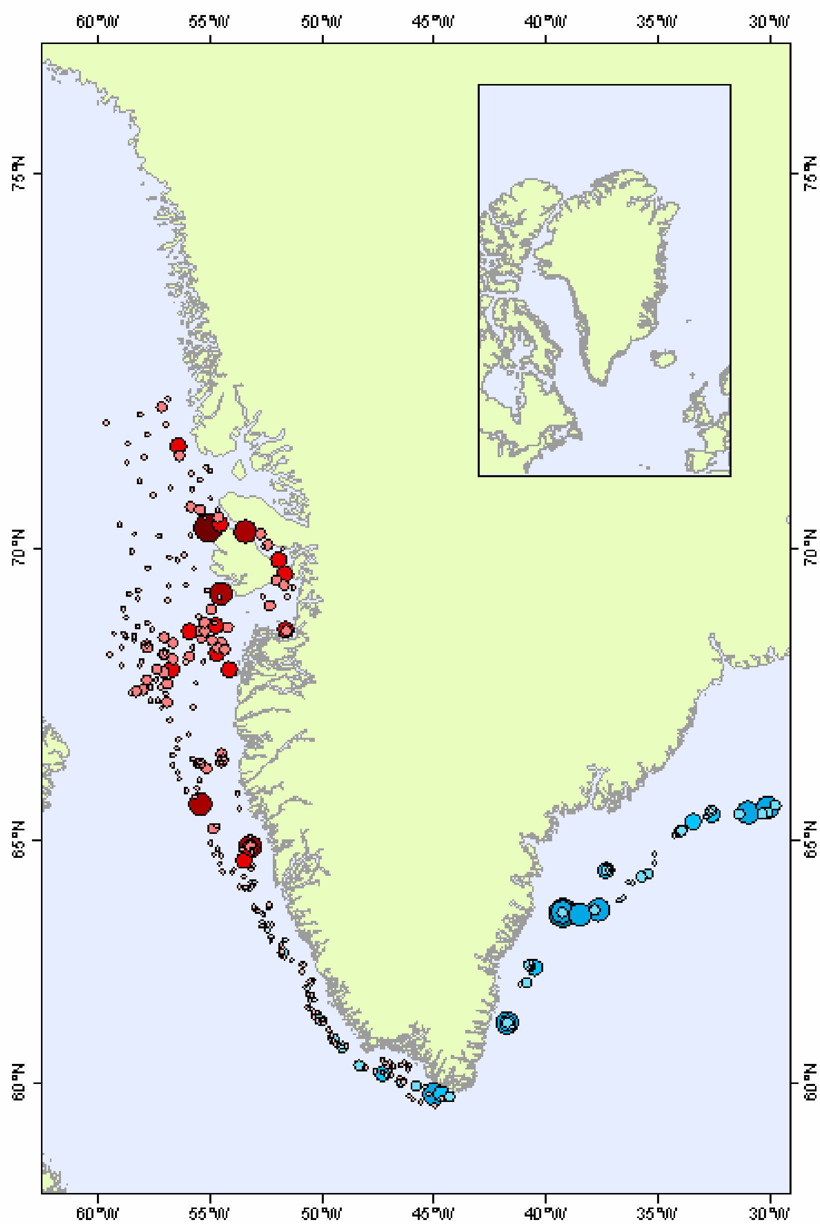

Fig. 9. The distribution of Atlantic cod (blue) at East and West Greenland and Northern shrimp (red) at West Greenland according to survey information by the Federal research institute Hamburg and the Greenland institute of Natural Resources, respectively, in 2005 (Note: no survey information available for the distribution of Northern shrimp at East Greenland; size of symbols and colour intensity refers to biomass density).