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Bottom Temperatures and Possible Effect on Growth and Size at Sex Reversal of Northern Shrimp in West Greenland

by

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Abstract

Temperature data and shrimp samples collected during the stratified-random trawl surveys 1990-99 are analysed. The observed trends and changes in mean temperatures and mean size at sex change of the shrimp are compared and discussed.

Material and Methods

Since 1990 bottom temperatures were recorded at the sampling sites during stratified-random trawl surveys in offshore and inshore West Greenland waters (Carlsson et al., 1999). Until 1994 temperatures were measured by a CTD just before or after each trawling operation, and the recordings from the maximum depths of the profiles were interpreted as bottom temperatures. From 1995 and onwards a temperature recorder mounted on one of the trawl doors has been in use during trawling operations. Temperatures were recorded every 60 seconds along the tracks. For each station a mean temperature along the track was calculated.

Annual mean bottom temperatures were calculated for offshore and inshore regions. An analysis of variance was carried out, relating temperature data to year, region and depth zone.

Samples of shrimp collected from survey catches were sorted by species. Specimens of Northern shrimp *(Pandalus borealis)* were sorted by sexual stage, and the oblique carapace length was measured. Annual overall length frequency distributions for the offshore and the inshore area were calculated by adding mean distributions weighted by stratum. Annual mean size at sex reversal in the offshore and the inshore areas was interpreted as the 50% points in plots of proportion of female shrimp (primiparous and multiparous) of total number of shrimp by length group.

Results and Discussion

Temperature information from all trawl stations were averaged over years (Table 1), regions and depth zones (Fig. 1). A strong positive tendency is seen with an increase of nearly two degrees over the period. In the offshore areas highest temperatures were recorded in 1998, with a slight decline in 1999. In the inshore area the increase continued in 1999. The trend of increasing temperatures is observed in all regions and depth zones. The southermost region (S) has exhibited fairly large variations during the period, being heavily influenced by the strong currents in the Cape Farewell area. The development in the temperatures in the other regions is more parallel apart from a drop in mean temperature in 1995 in region W (mainly in depth zone 200-300 m), and in 1996 in the regions D and N.

A regression analysis of the temperature dependency of year, region and depth zone (Table 2) also shows a clearly increasing temperature over the given range of years, except for a lower temperature in 1995. As expected temperatures are increasing with increasing depth (class variable 'DEPZ', depth zones). The regions C and N have fairly low bottom temperatures, being influenced by the cold, arctic current from northwest. Region D (inshore area) exhibits the lowest temperatures. The region F (shallow water areas offshore) is not consistently fitting into the model as the temperatures are heavily influenced by surface heating and local currents over the banks.

These observations are in good agreement with temperatures measured in a hydrographic standard station in the Fylla Bank area (Fig. 2, E. Buch, unpubl.).

Fig. 3 shows examples of the S-shaped plots of proportion of female shrimp per carapace length group from the inshore survey 1996 to 1999. Carapace length at 50% sex change can be easily read from the plots. Fig. 4 shows the mean carapace length at sex change and mean annual bottom temperatures in offshore and inshore areas.

Offshore mean carapace length at sex reversal show a decline from 1988 to 1990, followed by an increase back to the level of 1988 in 1992, and a stable mean size up to 1997. Between 1997 and 1998 the mean size decreased about 1 mm, followed by an increase by 0.5 mm in 1999. Inshore mean size at sex reversal show an increasing trend from 1991 to 1995, stability from 1995 to 1998 and a decrease of about one mm carapace length from 1998 to 1999.

Overall mean bottom temperatures show stability or a slightly increasing trend from 1990 to 1996, followed by a drastic increase from 1996 to 1998. The decrease in mean length at sex reversal in the offshore area between 1997 and 1998 might be correlated with the relatively high bottom temperature in 1997, i.e. that higher temperatures at this level directly or indirectly causes increased growth in Northern shrimp. According to Fig. 1 the mean bottom temperature in the inshore areas (Disko Bay and Vaigat) is generally following the trend in the offshore area, but about one centigrade below the offshore average. Accordingly the rise in temperature to or above 3° C in the inshore area was delayed a year in relation to the offshore area. The significant drop in mean size at sex reversal from 1997 to 1998 in the offshore areas and from 1998 to 1999 in the inshore area indicates, that sex reversal is correlated to temperature.

From 1987 to 1990 there was a decline in mean surface temperature at the hydrographic standard station on Fylla Bank (Fig. 2). In shrimp samples from the same period (from 1988, when the first offshore survey was performed, to 1990) mean size at sex change dropped more than one mm carapace length. If the Fylla Bank surface temperatures are related to bottom temperatures, the correlation between temperature and mean size at sex change is not consistent with what is seen in later years. However, from 1989 and in the following years, a very large year class of Northern shrimp – noted as the 1985 year class - totally dominated overall size distributions in the stock, and the size at sex change may have been more dependant on the relative number of females to males in the stock rather than to temperature relationships.

References

Carlsson, D. M., P. Kanneworff, and M. C. S. Kingsley. 1999. Stratified-random trawl survey for shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1999. NAFO SCR Doc. 99/109, Serial No. N4189.

Table 1. Mean temperatures for all regions in depths between 150 and 600 m.

	TEMPERATURE					
YEAR	MEAN	N	STD	CV	MIN	MAX
1990	1.62	51	0.99	60.73	-0.01	4.24
1991	1.66	215	0.85	51.10	-0.17	4.90
1992	1.94	181	0.94	48.37	0.26	4.79
1993	2.06	171	1.16	56.36	-0.10	5.01
1994	2.08	167	1.09	52.32	0.34	5.03
1995	1.84	195	1.01	54.80	-0.22	4.50
1996	2.21	166	1.28	57.94	-0.01	5.66
1997	3.17	257	1.12	35.49	0.09	5.82
1998	3.55	228	1.05	29.53	0.76	5.88
1999	3.46	314	0.92	26.73	1.63	5.81

Table 2. Result from the regression analysis (SAS, GLM) of temperature dependency of year, depth zone and geographical area.

Class Level Information

Class	Levels	Values
YEAR	10	90 91 92 93 94 95 96 97 98 99
DEPZ	4	1 2 3 4
REGION	6	C D F N S W

Number of observations in data set = 1945

Dependent Variable: TEMPERAT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	1973.21338611	116.07137565	189.00	0.0001
Error	1927	1183.44771541	0.61413997		
Corrected Total	1944	3156.66110153			

R-Square	C.V.	Root MSE	TEMPERAT Mean
0.625095	30.94742	0.78367083	2.53226530

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	9	1061.98719748	117.99857750	192.14	0.0001
DEPZ	3	306.26607392	102.08869131	166.23	0.0001
REGION	5	604.96011471	120.99202294	197.01	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	9	814.53861150	90.50429017	147.37	0.0001
DEPZ	3	437.59315018	145.86438339	237.51	0.0001
REGION	5	604.96011471	120.99202294	197.01	0.0001

<table>
<tr><th>Parameter</th><th></th><th>Estimate</th><th>T for H0: Parameter=0</th><th>Pr > |T|</th><th>Std Error of Estimate</th></tr>
<tr><td>INTERCEPT</td><td></td><td>4.100401551 B</td><td>69.45</td><td>0.0001</td><td>0.05904053</td></tr>
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<tr><td></td><td>99</td><td>0.000000000 B</td><td>.</td><td>.</td><td>.</td></tr>
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<tr><td></td><td>2</td><td>-0.813162292 B</td><td>-16.03</td><td>0.0001</td><td>0.05074212</td></tr>
<tr><td></td><td>3</td><td>-0.179963164 B</td><td>-3.71</td><td>0.0002</td><td>0.04856458</td></tr>
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<tr><td></td><td>D</td><td>-1.056071683 B</td><td>-21.02</td><td>0.0001</td><td>0.05024263</td></tr>
<tr><td></td><td>F</td><td>0.419414448 B</td><td>0.53</td><td>0.5940</td><td>0.78672259</td></tr>
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<tr><td></td><td>S</td><td>1.729883888 B</td><td>16.94</td><td>0.0001</td><td>0.10210908</td></tr>
<tr><td></td><td>W</td><td>0.000000000 B</td><td>.</td><td>.</td><td>.</td></tr>
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NOTE: The X'X matrix has been found to be singular and a generalised inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

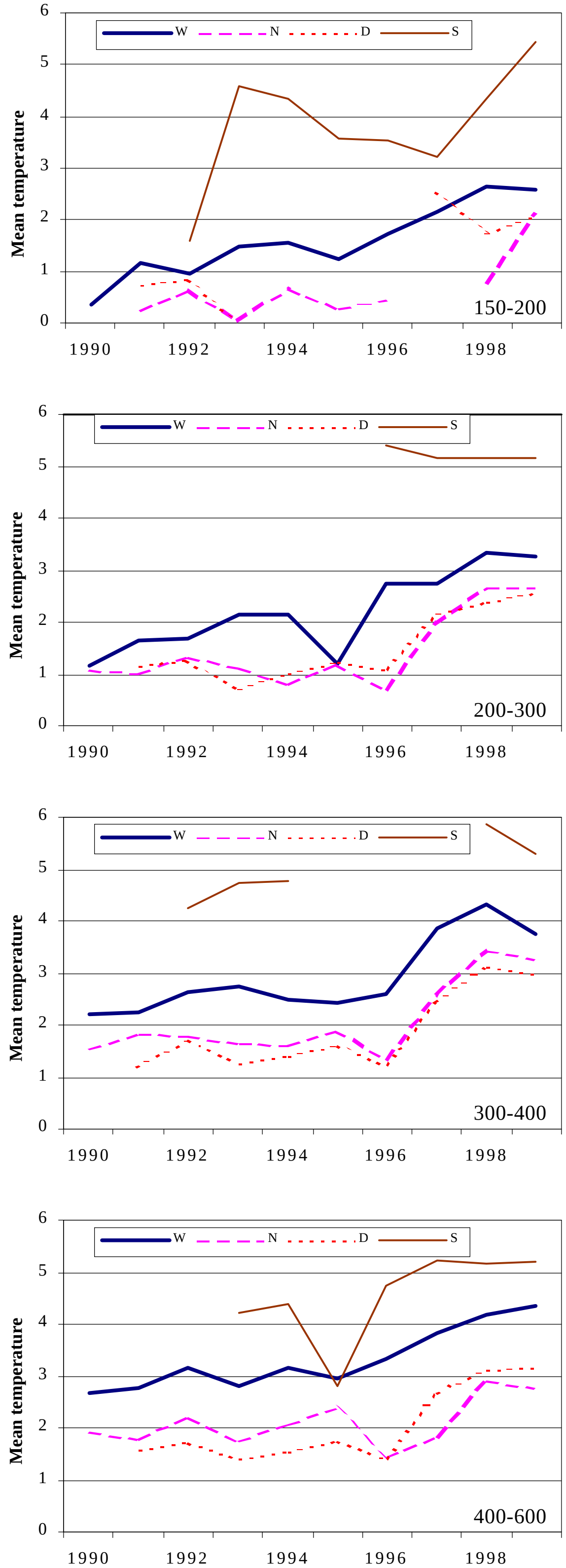

Figure 1. Mean temperatures in four regions at West Greenland 1990-99. The temperatures are shown separately for the four depth zones.

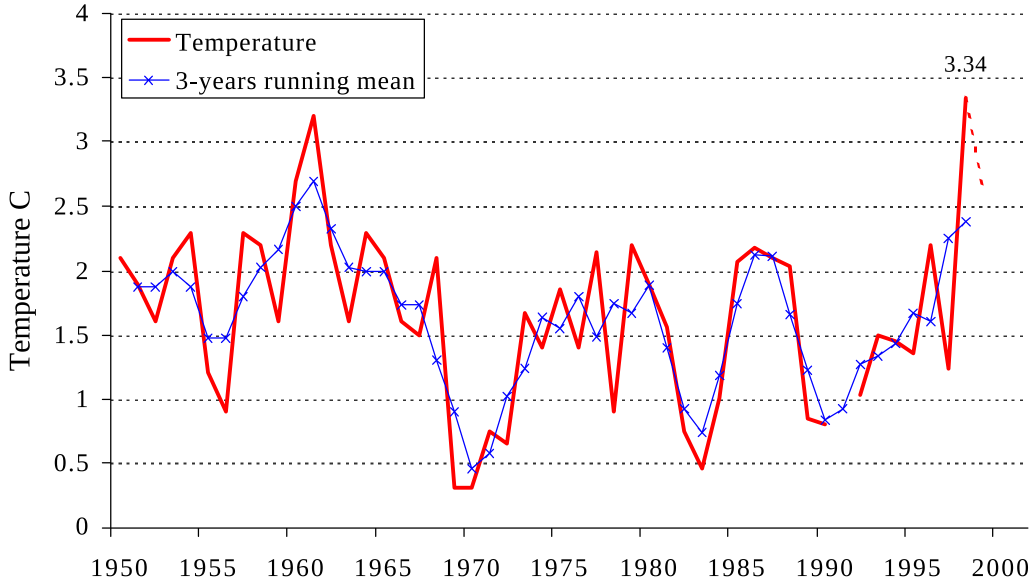

Figure 2. Mean surface (0-50 m) temperature over Fylla Bank 1950-1999 (E. Buch, unpubl.).

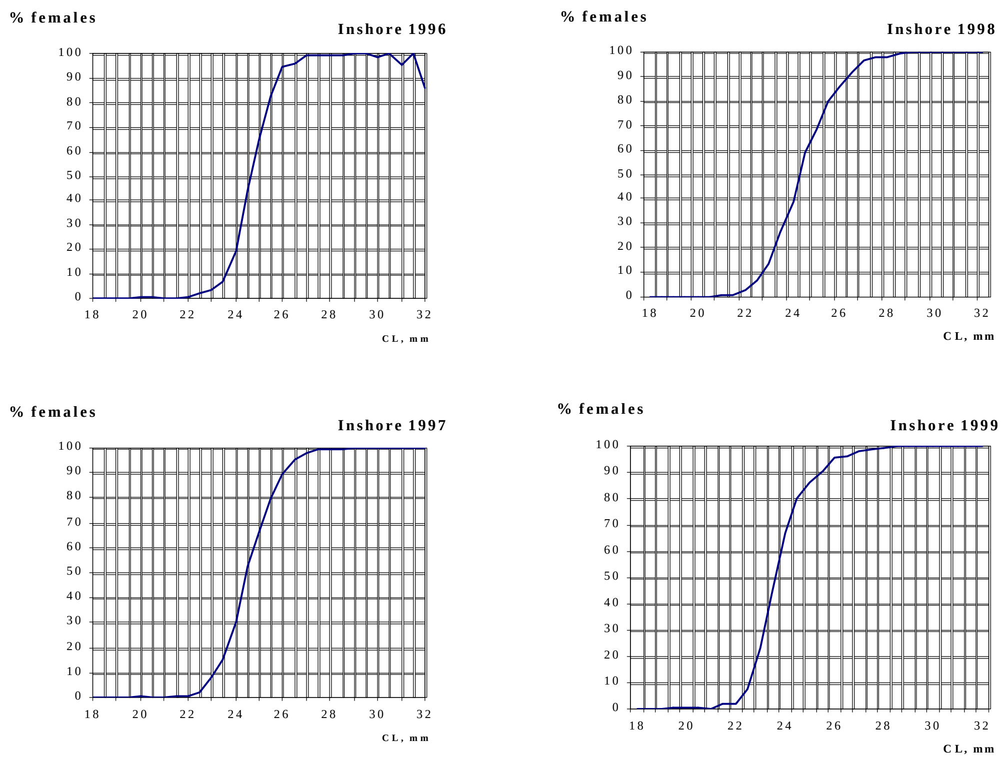

Figure 3. Plot of proportions of female shrimp per length group (mm CL), inshore area 1996-1999.

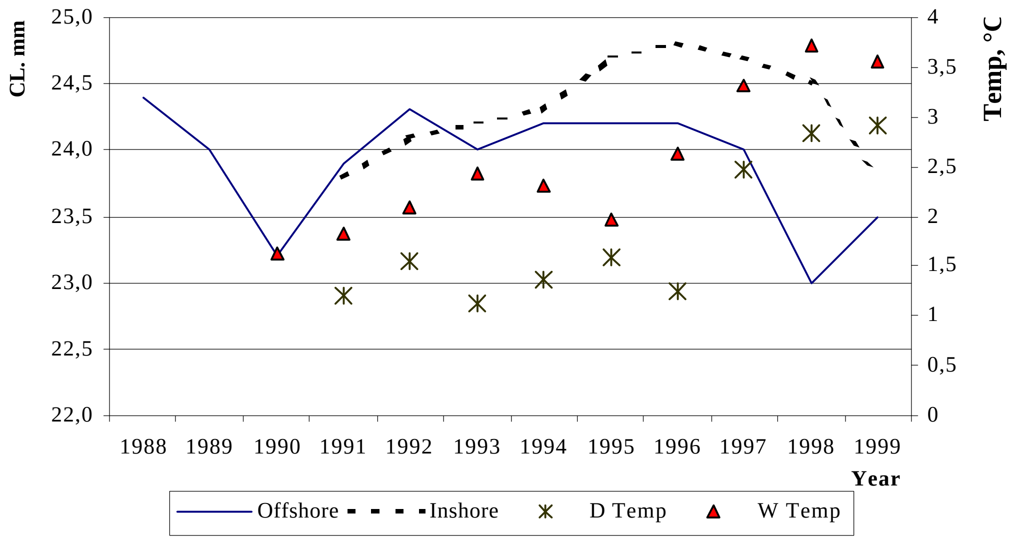

Figure 4. Mean length at sex change (curves) for shrimp and average temperatures (markers) in offshore and inshore areas.