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A Note on the Timing of Hatching of Northern Shrimp, (*Pandalus borealis* Krøyer, 1861) off West Greenland (NAFO Area 1D, 1C and 1B)

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Abstract

Estimates of the span and the mode of hatching time of Northern shrimp, (*Pandalus borealis*) in West Greenland waters are presented based on samples from commercial trawl catches. Results based on frequency variations of "berried" females and females in "breeding dress" indicate that hatching starts as early as in mid February and commences until mid May with a mode between the last week in March and the first week in April. This is earlier than previously observed and may possibly be caused by the documented strong influence of warm Atlantic water in the Davies Strait during 2005.

Introduction

Determination of fecundity and the timing of spawning and hatching are important to stock management of *P. borealis* and hence a considerable amount of information on the reproductive biology of this species, throughout its distribution, is available in the literature (Bergstrøm, 2000).

No published reports, however, gives detailed and comprehensive information on the reproductive biology and life cycle of the Northern Shrimp in Greenland waters. The only available information in the literature was summarised by Horsted in 1978 ((Horsted, 1978a) that gave some results from Tunugdliarfik Fjord (data from 1953-1954), the Godthaab Deep and Sukkertoppen Deep (data from 1971-1976) and from the Disko Bay area (only summer data from periods 1947-1954, 1963-1964, 1974-1976). The results in Horsteds' report are based on combinations of data from different years and somewhat inconsistent categorizations of female reproductive stages.

Generally *Pandalus borealis* has, as most of its congeners, a seasonal reproductive cycle with mating taking place during the autumn months and hatching occurring once a year, normally in the spring or early summer. Eggs are generally extruded during late summer to early autumn and are carried on the pleopods until spring. However, especially in the northern parts of the species geographical range, deviations from a yearly spawning pattern have been reported. For example Teigsmark (1983) reported a biannual spawning pattern for *P. borealis* in parts of the Barents Sea. Indications of such a biannual spawning are also present in data from the West Greenland shrimp survey time series but has not as of yet been formally analysed and reported.

Already Rasmussen (1953), in his classical study of the population biology and life cycles of *P. borealis* along the Norwegian coast, recognized the relationship between temperature and the duration of the reproductive cycle in this species. He stated that "the general rule seems to be that the colder the environment, the earlier the spawning and the longer the ovigerous period". Rasmussen's early insight has been supported by several later authors, most recently by (Bergstrøm, 2000). In this latter account, the strength of the relationship between ambient temperature and the duration of the reproductive cycle was illustrated by the combination of a reported inverse relationship between temperature and the duration of oogenesis in *P. borealis* in laboratory experiments (Stickney and Perkins, 1980) and (Shumway *et al*., 1985) and correlative results based on field data (Bergström, 1991b) and the presence of a strong negative correlation between the duration of the ovigerous period and ambient average temperature (Bergstrøm 2000)

These aspects of the *Pandalus* reproductive biology combined with reports of temperature variability and temperature increases in West Greenland shrimp habitats ((Buch *et al*., 1994)and (Hvid Ribergaard, 2006)) combined, generally motivates experimental work and also work towards the accumulation of more detailed regional information on temporal and spatial variability in the reproduction biology of this species.

Against this background this paper presents some preliminary results on the timing of hatching of eggs in *P. borealis* in the Greenland sectors of NAFO Areas 1D, 1C and 1B. The results presented here are based on samples from commercial catches graciously provided by the trawler fleet owned and operated by "Polar Sea food" in Nuuk. I also briefly compare and discuss these results in relation to previously reported information concerning timing of hatching in *P. borealis* North Atlantic distribution area.

Material and Methods

Study area and sample distribution

Sampling dates are given in Table 1 and the geographic distribution of samples for this report is shown in Fig. 1. The trawls that were used to obtain samples for this report were, Royal Greenland special 3300 mesh, 200 mm-50 mm, grid 22 mm, cod end 43 mm, Vonin 3300/20 codend: 43mm, grid Cosmos 244x1.50 22 m/m and RGS 3306/20 200 mm, fornet "bellow" 50 m/m grid 22 m/2.

Table 1. List of ship and sampling dates

Ship	Date
M/TR Polar Nattoralik	15-Feb-2006
M/TR Polar Nattoralik	15-Feb-2006
M/TR Polar Amaroq	17-Feb-2006
M/TR Polar Nanok	18-Feb-2006
M/TR Nanoq Trawl	27-Feb-2006
M/TR Polar Timmiarmiut	1-Mar-2006
M/TR Polar Amaroq	9-Mar-2006
M/TR Polar Nanoq	15-Mar-2006
M/TR Polar Amaroq	16-Mar-2006
M/TR Polar Amaroq	1-Apr-2006
M/TR Polar Amaroq	25-Apr-2006
M/TR Polar Nattoralik	27-Apr-2006
M/TR Polar Nattoralik	29-Apr-2006
M/TR Polar Timmiarmiut	6-May-2006
M/TR Polar Amaroq	7-May-2006
M/TR Polar Amaroq	14-May-2006
M/TR Nanoq	19-May-2006

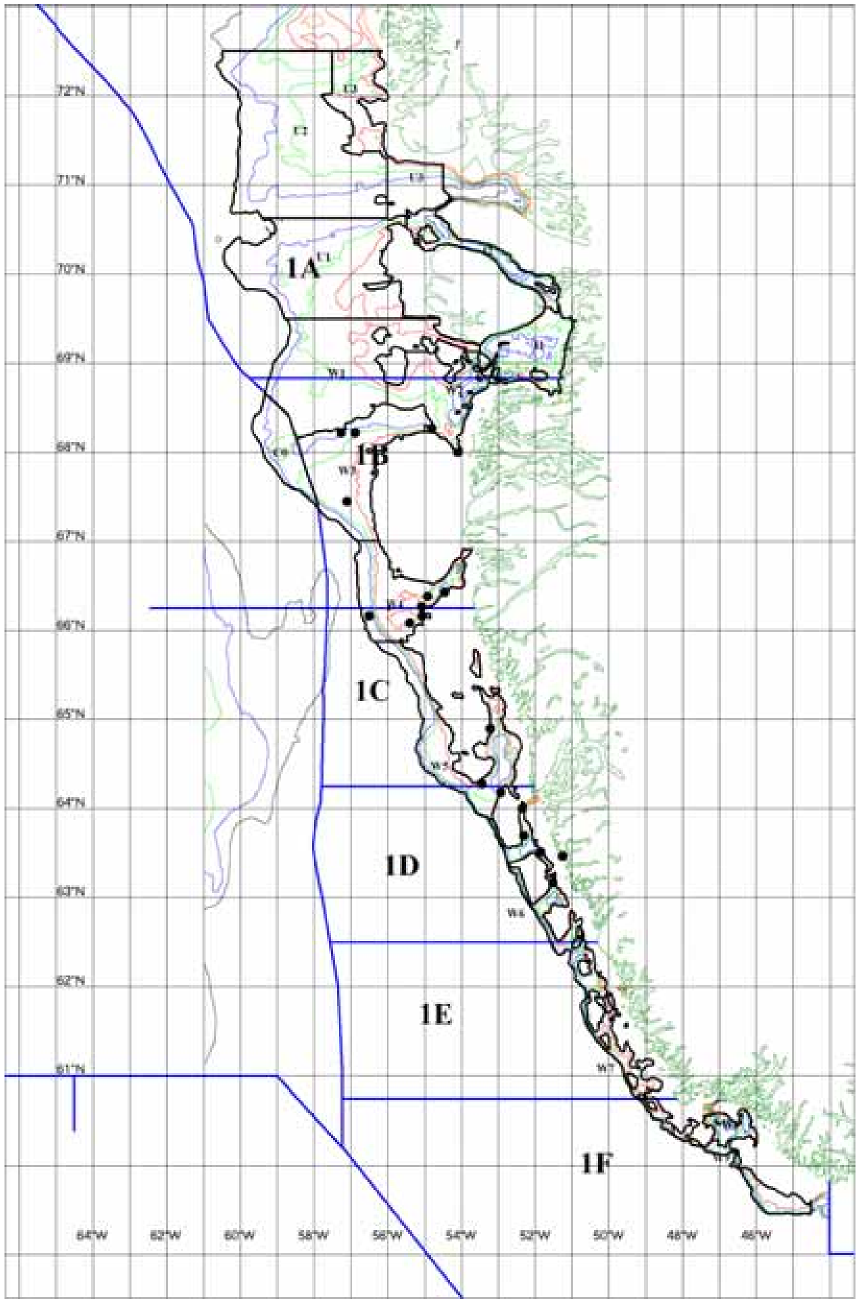

Fig. 1. Map showing the geographic position of sampling locations.

Sample analyses

Samples, typically weighing between 5,5 and 6,5 kg wet weight, were collected from the unsorted catch onboard the trawlers before the entire catch was transferred to the trawl tank. These samples were frozen at sea and brought to the lab for further analysis. From each of the samples a random sub-sample of between 250-400 specimens were analysed for this study. All specimens of Northern shrimp were grouped into males, primiparous and multiparous females based on their sexual characteristics as defined by Allen (1959) and McCrary (1971). Oblique carapace length (CL) of each specimen was furthermore measured to the nearest 0.1 mm using slide callipers and females were sorted in the categories "with head roe", "berried", and "in breeding dress".

- "Females with head roe" are those were the green female gonad is clearly visible through the carapace

- "Berried females" are those carrying embryos attached to setae on their pleopods. Embryos at an early stage of development have no eyespots while those close to hatching have. Consequently berried females were subdivided into those carrying eggs with "eyespots" and into those with no "eyespots".
- "Females in breeding dress" are those females still retaining the setae on which the embryos were attached but have no remaining embryos.

Calculations

For this study I calculated the relative frequencies of berried females and females in breeding dress and plotted them against sampling date. The present data set only includes samples where both categories were present simultaneously.

Previous reports (Bergström, 1991b; Bergstrøm, 2000) indicate that hatching in *P. borealis* stocks show a modal progression over time. The frequency of berried females decreases with time while the frequency of females in breeding dress increases proportionally. Against that background I fitted linear regression lines (with a 95% confidence interval) to the observed proportions of these two categories at date based on the simplistic assumption that, over the short time spans in question here, the frequency of berried females decreases in a linear fashion with time and that the frequency of females in breeding dress is a mirror image of this pattern. Linear models were chosen instead of sigmoid models for simplicity since fitting of sigmoid models to the short time span and few data points at hand does not give more or more reliable information. The date were the two regressed lines cross each other then represents a date at which 50% of the females have hatched their embryos-assuming the timing of hatching is uni-modal and symmetric. The time interval for the mode of hatching following this assumption should then be between the dates corresponding to where the min and the max of the 95% confidence interval of the two respective lines cross the relative frequency 0.5.

Results

All berried females in the samples had embryos with eyespots, indicating 100 % fertilization success. Females in "breeding dress" were found as early as in mid February in both the middle latitude strata W4 and the southernmost strataW6 and as early as in February-March in the northernmost strata W2 (Fig. 1). Hatching appears to have been finished by mid May (Fig. 2). According to the reasoning illustrated in Fig. 2 most shrimp hatched their embryos between the last week in March and the first week of April in West Greenland waters.

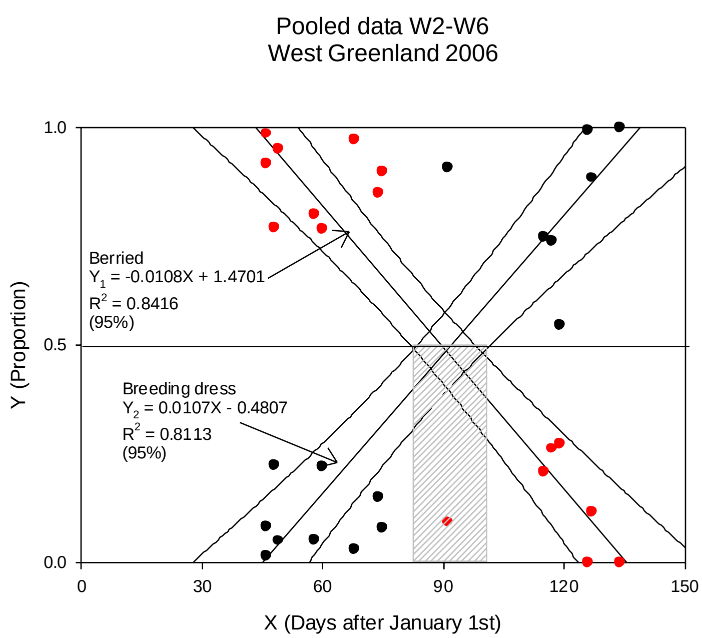

Fig 1. Observed and fitted linear regression lines with 95% confidence intervals of proportions of "Berried females" and females in "Breeding dress" from West Greenland 2005. Crosshatched block indicates the estimated time span of the modal hatching date.

Discussion

Generally the present data set is small and hence only tentative conclusions can be drawn. Nevertheless results indicate that hatching in the spring 2006 peaked between the last week of March and the first week of April in West Greenland waters (68°30'N and 63°N). Compared to the hatching times (April-May) indicated by (Horsted, 1978b) for both the Tunugdliarfik Fjord (~61°N) and Godthaab Deep and Sukkertoppen Deep (~64°-65°N) this is about one month earlier than previously observed. Further comparisons with earlier reported results from other *P. borealis* stocks shows that the timing of hatching is very similar to those dates reported from the North Sea, Skagerak, Western Norway-Northern Norway and the Gulf of Maine (Table 2). No strong conclusions can be drawn based on the present data but these results raise questions about the reasons behind the apparent advancement of hatching time in Northern shrimp off West Greenland. Speculatively this observation may be explained by the observed strong influence of Atlantic water in the Davies Strait during 2005 (Hvid Ribergaard, 2006).

Table 2 Reported hatching times for *Pandalus borealis.*

Area	Hatching period	Ann. av. temperature T (°C)	Reference
S. Barents Sea	May	2	(Teigsmark, 1983)
Central Barents Sea	May	1	(Teigsmark, 1983)
N. and E. Barents Sea	May-June	0	(Teigsmark, 1983)
Svalbard, Isfjord	May	1	(Nilssen and Hopkins, 1991)
	April-May	1	(Nilssen and Hopkins, 1991)
Balsfjord (≈69°15N) (Norway)	March-April	2	((Thomassen, 1977)
Balsfjord (≈69°15N)	March-April	2	(Hopkins and Nilssen, 1990)
Balsfjord (≈69°15N)	March-April	2	(Hopkins and Nilssen, 1990)
Brands fjord (≈64°15N) (Norway)	March-April	6-8 (≈7)	(Rasmussen, 1953)
Vestlandet (≈61°N) (Norway)	April		(Rasmussen, 1953)
Torungen ground (≈58°30N) (Norway, Skagerrak)	March-April	≈7	(Rasmussen, 1953)
Oslofjorden (Norway)	March-April	7.1	(Rasmussen, 1953)
Gullmarsfjorden (Sweden)	March	4-6	(Bergström, 1992a)
North Sea off Northumberland	March-April	8	(Allen, 1959)
Snæfellsnes (Iceland)	May	6	(Skúladóttir *et al.*, 1991)
Isafjardardjup(Iceland)	May	4,5	(Skúladóttir *et al.*, 1991)
North coast of Iceland			
Grimsey (Iceland)	March-May	1.2	(Skúladóttir *et al.*, 1991)
Nordurkantur (Iceland)	April-Jun	0	
Davis strait	April-June		(Carlsson, pers. comm.)
Hopedale Channel (Canada)		3	(Parsons, pers. comm.)
Cartwright channel(Canada)		3	(Parsons, pers. comm.).
Hawke Channel(Canada)		3	(Parsons, pers. comm.).
St. Anthony(Canada)		3	(Parsons, pers. comm.)
Funk Island(Canada)		3	(Parsons, pers. comm.)
Flemish Cap		5	(Parsons, pers. comm.)
Gulf of Maine (U.S)	March-April	5	(Haynes and Wigley, 1969)
	March		(Apollonio *et al*., 1986)

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