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N O T E
Hydrographic and Atmospheric Conditions Off East Greenland – Their Potential Effect on the Distribution of Shrimp (*Pandalus borealis*)

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Introduction

The purpose of this note is to evaluate hydrographic conditions in the major northern shrimp (*Pandalus borealis*) fishing areas north of 65°N off East Greenland as recommended by NAFO (Anon., 1997), to provide a possible explanation for the apparent southward shift of shrimp aggregations since 1993. *Pandalus borealis* is a circumboreal species, which prefers colder temperatures in the range of 1–6°C (Shumway *et al*., 1985). Warming trends have been associated with population declines in both the Atlantic and Pacific oceans (Clark *et al*., 2000; Anderson, 2000), and temperature is an important determinant of distribution (Koeller, 2000). Consequently it is possible that changes in hydrographic conditions caused the apparent changes in shrimp distributions off east Greenland. The investigation makes use of the large quantity of oceanographic information that has been collected from the area during the 20th Century. Much of this information is now available from various oceano-graphic archives (e.g. World Data Center A, Oceanography, Washington, D.C.) on the Internet.

Material and Methods

Recent hydrographic data were obtained by the German FRV *Walther Herwig* III during the annual autumn bottom trawl surveys off East Greenland. Coverage was confined to the shelf edge and to the adjacent shelf slope area. Since shrimp are caught mostly at depths between 200 m and 300 m (H. Siegstad, Greenland Institute of Natural Resources, Greenland and U. Skuladottir, Marine Research Institute, Iceland, pers. comm.) an analysis of the upper 300 m of the water column was considered appropriate. Information on mean hydrographic conditions in the Denmark Strait area is based on the World Ocean Atlas 1994 available on CD-ROM (NOAA, 1994). A total of 5 933 Nansen and CTD profiles obtained during July–September were examined in a rectangle defined by 60°N, 40°W and 70°N, 20°W. Data analysis, including geostrophic calculations, was achieved with the Ocean Data View software (ODV 4.0, Version 4.0.14) provided by R. Schlitzer, Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven, Germany (http://www.awi-bremerhaven.de/GPH/ODV). Air temperature data from Angmagssalik/East Greenland (65°36'N, 37°40'W) were supplied by the Seewetteramt, Hamburg. Distribution maps of commercial shrimp catches in the Denmark Strait from 1991–98 were obtained from the Greenland Institute of Natural Resources, Nuuk.

Results

The general oceanography of the Denmark Strait region has been widely discussed in the literature (see Stein, 1988 for references). Accordingly two major water masses meet and mix in the area, one of polar, the other of subtropical origin: 1. The East Greenland Current, an extension of the outflow of cold, low saline water from the North Polar Sea, which is confined to the East Greenland shelf area, and 2. The Irminger Current, formed when a major part of the Gulf Stream system flows northwards towards west Iceland, steered by the submarine extension of the Middle Atlantic Ridge system (the Reykjanes Ridge), and is deflected to the west when it meets the sill of the Greenland-Iceland Ridge. This current meets the polar East Greenland Current in the Dohrn Bank region. Both currents flow towards the southwest forming large, meandering features at the interface between the cold and the warm water masses. The Irminger Current has a vertical extension of several hundred metres

whereas the East Greenland Current water mass is confined to the upper 100 m.

Figure 1 shows the abrupt southern shift in commercial shrimp catches in the Denmark Strait between 1992 and 1993, although further southward shifts occurred thereafter. Horizontal summer (July–September) potential temperatures in the area at 100 m and 300 m show a tongue of cold, low saline water of polar origin heading toward Dohrn Bank (Fig. 2).

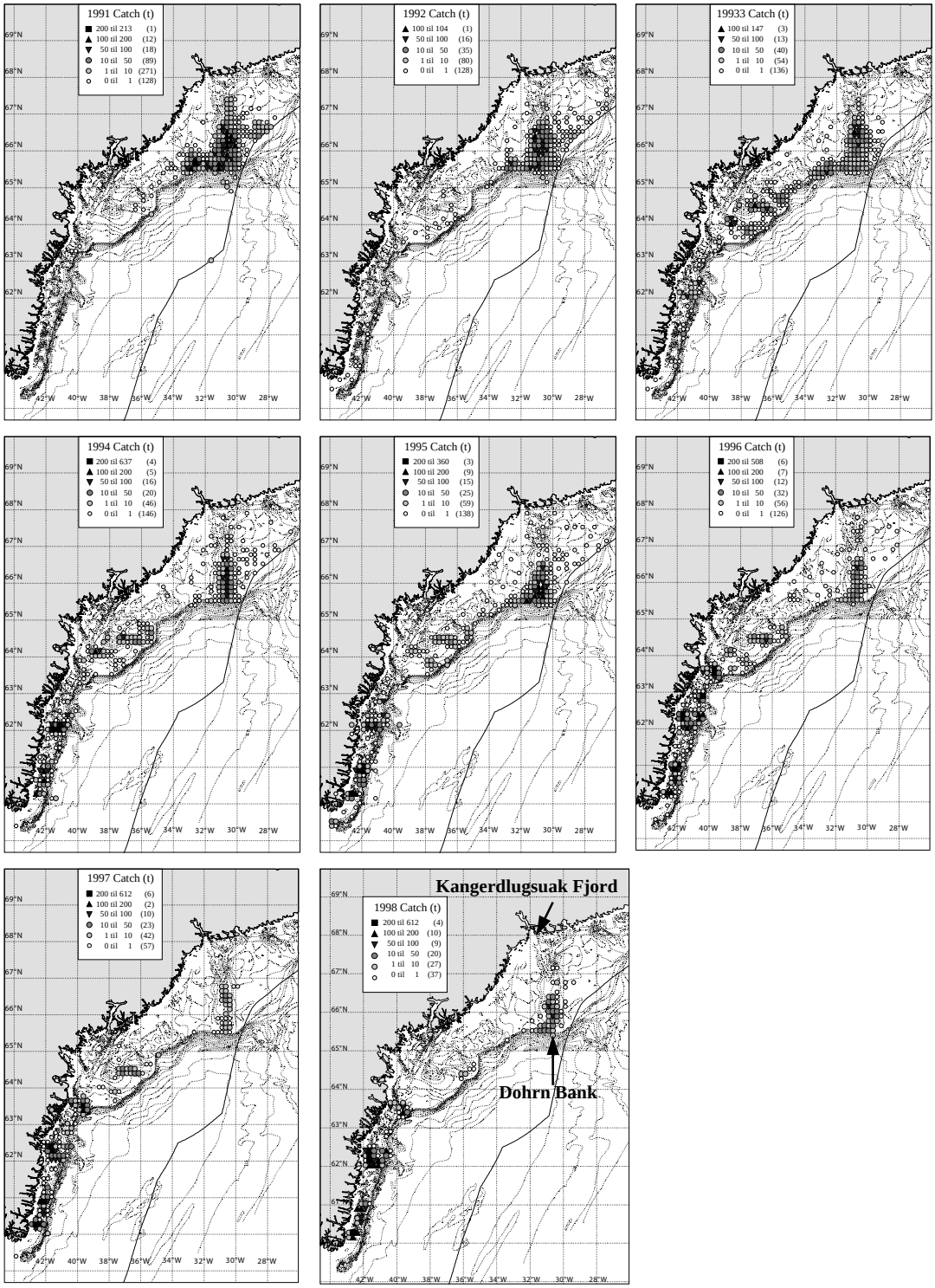

Fig. 1. Distribution of shrimp catches in the Denmark Strait 1991–98.

Vertical temperature fields along a section crossing the Denmark Strait and Kangerdlugsuak fjord in the Dohrn Bank area (Fig. 3) show that the eastern portion is dominated by Irminger water (T > 6°C, S > 34.95 psu). Low salinity water of the polar East Greenland Current dominates the western part at depths <200 m. At 400 m and deeper, bottom water probably consisted of cold, more saline Arctic Intermediate water (e.g. Stein, 1988). Strong thermohaline gradients lead to strong baroclinic activities with geostrophic currents peaking at 150 cm/sec, a value confirmed by direct current meter measurements in the Denmark Strait area (Stein, 1974, 1988).

Potential temperatures along a section of the East Greenland shelf just north of 65°N during the autumn 1992 German bottom trawl survey (Fig. 4, top) show the surface expression of the polar water mass of the East Greenland current. Water properties had changed significantly by September 1993, from cold, low saline, low density polar waters to the warm and saline waters derived from the Irminger Current (Fig. 4, middle). These conditions prevailed until the end of the observation period in 1997 (Fig 4., bottom). There were no cold polar water pockets observed during this period.

Air temperature anomalies for the East Greenland region around 65°N are given in Fig. 5. The data are referenced to the climatic mean from 1961–90, and show the late summer warming (August, September) observed from 1993 onwards.

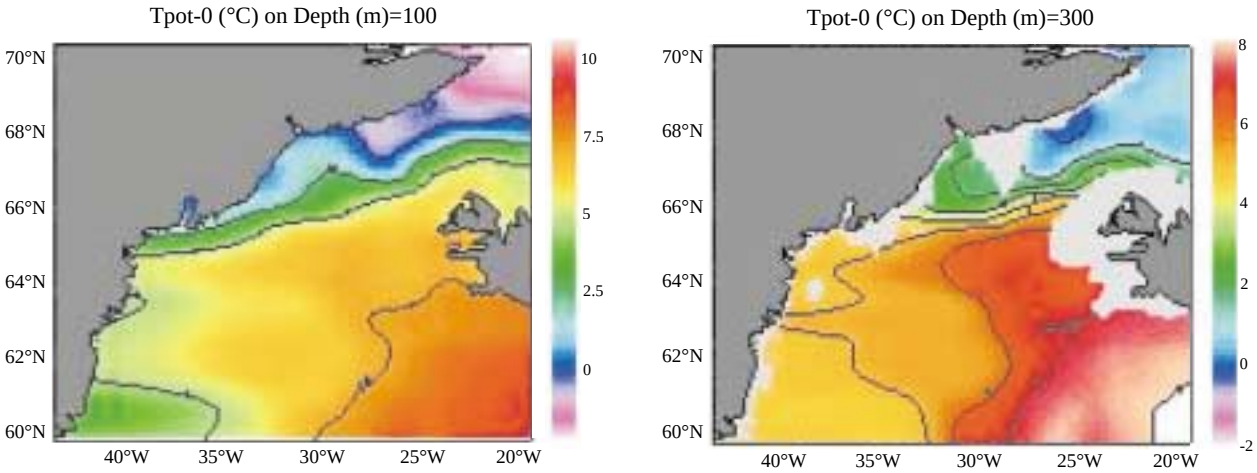

Fig. 2. Long-term mean horizontal distribution of Potential Temperature off East Greenland and in the Denmark Strait area at 100 m and 300 m (July–September).

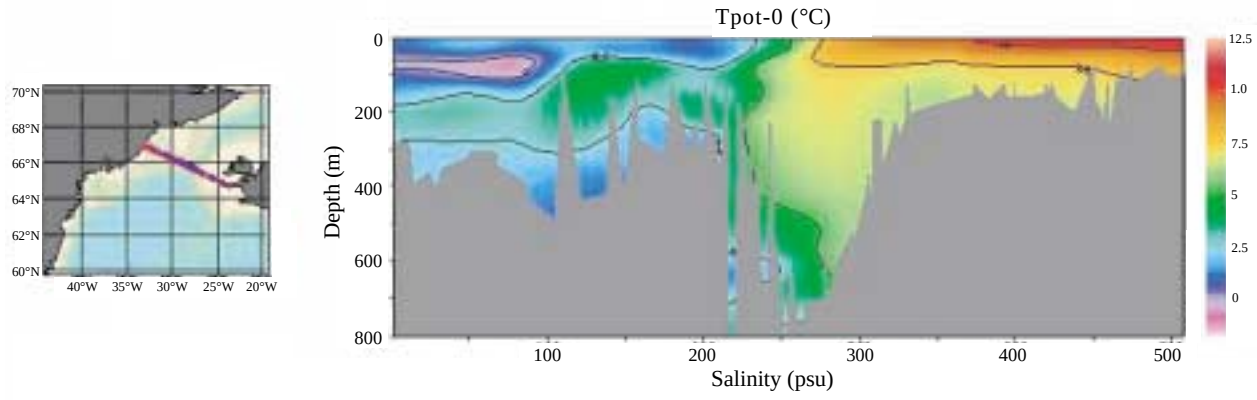

Fig. 3. Vertical distribution of Potential Temperature and Salinity between East Greenland and Iceland in the Dohrn Bank region, based on historical summer (JAS) data.

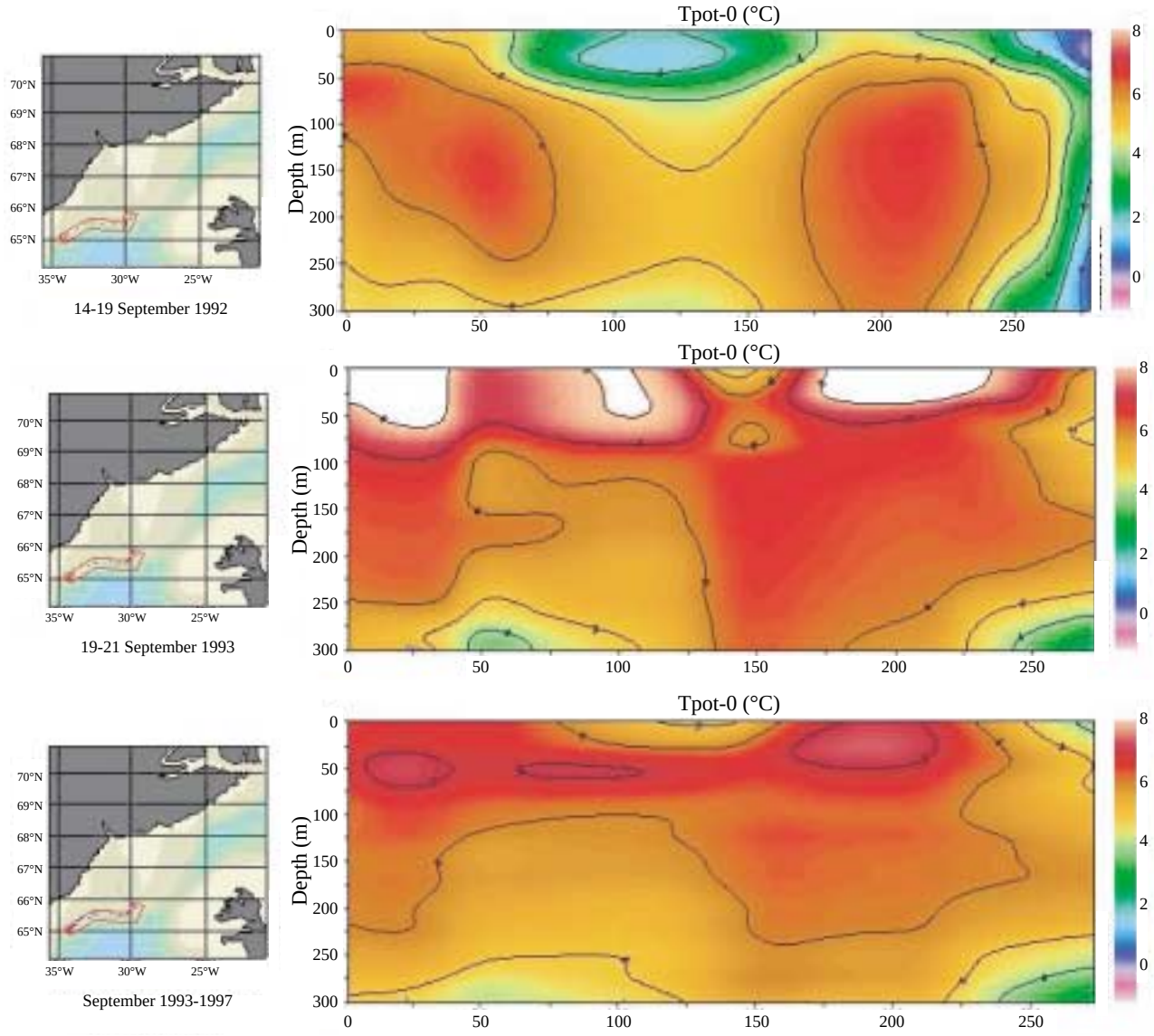

Fig. 4. Vertical distribution of potential temperature north of 65°N on the East Greenland shelf, based on German Bottom trawl station CTD data during 14–19 September, 1992 (top), 19–21 September, 1993 (middle) and during September/October 1993–97.

Discussion

Temperatures increased in the northern region of shrimp *(P. borealis*) distribution (north of 65°N) off East Greenland in 1993 and apparently remained higher relative to the 1989–92 period. Prior to 1993 shrimp catches concentrated in an area of topographic complexity, i.e. the Kangerdlugsuak fjord, which is subject to intense mixing of the polar and subtropical water masses, i.e. East Greenland Current and Irminger Current water. After 1993, the northern area was dominated by warm saline water of Irminger Current origin. Rapid changes in the temperature regime in the area are not unusual and are apparent in satellite images – major changes in the density of the water column can occur on time scales of 10 to 20 days. Atmospheric conditions also suggest a regime shift around 1993 to milder conditions. These results are supported by other studies reporting warming trends in many areas of the Northwest Atlantic during the 1990s (e.g. Drinkwater *et al*., 1999).

It is unclear if shrimp actively migrate from areas of unfavourable environmental conditions, or if strong

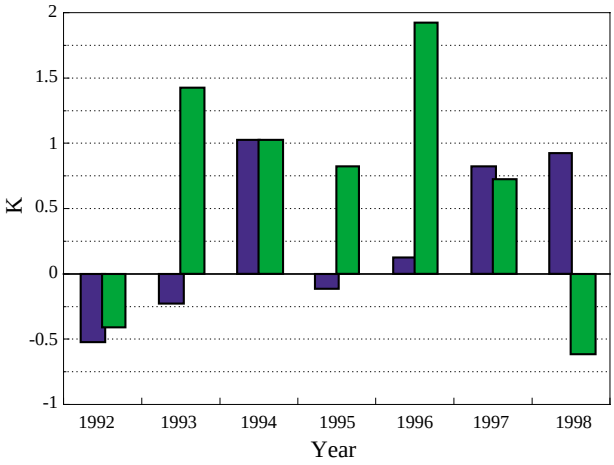

Fig. 5. Air temperature anomalies at Angmagssalik (August, September) 1992–98; mean values: August 3.1°C, September –0.8°C.

currents entrain them. Currents in the Dohrn Bank – Kangerdlugsuak fjord area associated with the renewal of water masses follow the bottom contours where shrimp are found and have high velocities of up to 150 cm/sec (Stein, 1974). Such currents could have moved shrimp relatively quickly in the direction suggested by the rapid shift in commercial catch distributions.

It should be noted that the shift from polar to subtropical water masses in the Dohrn Bank – Kangerdlugsuak fjord area in 1993 did not necessarily cause the concurrent southern shift of commercial shrimp fishing effort, because the latter can be influenced by factors other than *P. borealis* distribution. Clearly, additional studies on the interactions between the distribution of this species and changing atmospheric and oceanographic conditions are needed to fully assess the significance of changes in the distribution of shrimp fishing effort relative to stock status.

References

ANDERSON, J. 2000. Pandalid shrimp as indicators of ecosystem regime shift. *J. Northw. Atl. Fish. Sci.*, **27**: 1–10 (this volume).

ANON. 1997. Northwest Atlantic Fisheries Organization, Scientific Council Reports 1997. p. 238, p. 274.

CLARK, S. H., S. X. CADRIN, D. F. SCHICK, P. J. DIODATI, M. P. ARMSTRONG, and D. MCCARRON. 2000. The Gulf of Maine Northern Shrimp (*Pandalus borealis*) Fishery – a Review of the Record. *J. Northw. Atl. Fish. Sci.*, **27**: 193–226 (this volume).

DRINKWATER, K. F., E. COLBOURNE, and D. GILBERT. MS 2000. Overview of environmental conditions in the Northwest Atlantic in 1999. *NAFO SCR Doc.*, No. 21, Serial No. N4250, 89 p.

KOELLER, P. 2000. Relative Importance of Abiotic and Biotic Factors to the Management of the Northern Shrimp (*Pandalus borealis*) Fishery on the Scotian Shelf. *J. Northw. Atl. Fish. Sci.*, **27**: 21–33 (this volume).

NOAA. 1994. World Ocean Atlas 1994, CD-ROM Data Set Documentation. National Oceanographic Data Center, Ocean Climate Laboratory, Washington, D.C., November 1994.

SHUMWAY, S. E., H. C. PERKINS, D. F. SCHICK, and A. P. STICKNEY. 1985. Synopsis of biological data on the pink shrimp, *Pandalus borealis* Krøyer, 1838. *FAO Fisheries Synopsis*, No. 144, 57 p.

STEIN, M. 1974. Observations on the variability of the outflow of the Greenland Sea through the Denmark Strait. *Ber. Dtsch. Wiss. Komm. Meeresforsch.*, **23**: 337–351.

1988. Variability of Water Masses, Currents and Ice in Denmark Strait. *NAFO Sci. Coun. Studies*, **12**: 71–84.