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On Environment and Reproduction of the West Greenland Shrimp Stock (Pandalus borealis Kr.) North of 71°N (NAFO Division 1A)

by

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INTRODUCTION.

In 1985 the Greenland Home Rule Administration started an exploratory fishery for shrimp (Pandalus borealis Kr.) in West Greenland waters north of 70°52.5'N. Nominal catches in 1985 and 1986 amounted to 4,349 tons and 11,045 tons respectively.

At a meeting in 1987 biologists of the STACFIS Committee were unable to decide, whether the stock north of 71°N depends on larval drift or movement of adult or juvenile shrimp from southern areas or if the stock is self-sustaining.

This paper presents the few facts available on temperature and stock conditions which may be of importance to maintenance of the shrimp stock in question. Furthermore, an outline of larval abundance and current pattern in a potential supply area, i.e. waters around Disko island, is given. On the background of this information, stock reproduction and the possibility of a northerly drift of larvae from southern areas are discussed.

BASIC PROBLEMS.

Until the trial fishery was initiated by three trawlers in 1984 there had been no commercial exploitation of the West Greenland shrimp stock north of 71°N. Also, very little scientific work had been carried out in the area since the 'Godthaab Expedition' in 1928, and accordingly, the biological knowledge of these northern shrimp (Pandalus borealis Kr.) populations was no more than a few dots on a map of the species' area of distribution.

Because of the fishery, which has increased substantially since 1985, the 'dots' have multiplied and expanded to cover a greater area (Lund 1987). Furthermore, shrimp samples have become available to the 'Greenland Fisheries Research Institute', so we now have an impression of the density and of the composition of the stock (ibid.)

At the January 1987 Meeting, the STACFIS Committee was 'unable to discern a significant difference between stocks' from areas south and north of 71°N (Anon 1987). However, three possibilities pertaining to the maintenance of the stock north of 71°N were inferred from the preliminary data and shrimp samples:

The shrimp north of 71°N may

1) constitute a separate, self-sustaining stock, or
2) represent a northward extension of southern stocks, or
3) a combination of both.

The immediate question therefore is whether this stock meets the requirements of reproductive independency, or if its level of reproduction is such that its continuous existence depends wholly or partly upon larval in-flow or immigration of adult shrimps. Further, a probable dependency raises the question whether current conditions permit larval drift between stocks.

INFORMATION ON SHRIMP AND ENVIRONMENTAL CONDITIONS.

SHRIMP.

Field examinations of berried females in Tugtorqortoq (73°30'N) and Søndre Upernavik (72°10'N) fishing areas (figure 1) in 1986 showed that perhaps more than 50% of the superficially located eggs were dead by September; also, a substantial fraction of the eggs inside the egg-masses were dead. About fifty percent of the females, many of which had spawned at an earlier time (as indicated by the lack of sternal spines), did not carry eggs in the autumn of 1986, nor did they show developing head roe (Lund 1987).

Logbook data from 27 trawlers were analysed to show the overall distribution of trawling hours and mean catch rates in 1986. Mean CPUE-values decline almost linearly from 71°N and northwards as a function of distance (fig. 2).

SHRIMP LARVAE.

Annual plankton surveys, carried out by Greenland Fisheries Research Institute in June-July, provide provisional data on larval densities. Data on larval densities around Disko island are available for the period from 1980 to 1982 (as are data on current pattern), while data on larval densities south of Disko are available for the period from 1977 to 1983.

Numbers of larvae appear to be consistently low at most offshore stations.

In 1980 low densities were found in Disko Bay, while very high densities were found in the northern part of the Vaigat (figure 3: *).

In 1981 rather low densities were found all around Disko island.

In 1982 very high densities were found all around Disko island - excepting offshore stations west of the island.

WATER TEMPERATURE.

Temperature measurements made by the 'Godthaab Expedition' (Riis-Carstensen 1936) show low positive or even negative near bottom temperatures in waters north of Disko island in late July (table 1). In the water layer between 75 m and 200 m temperatures were below -1°C. Below 200 m temperatures were generally above 0°C, but nowhere did they exceed 1°C.

No information is available concerning the further development of the temperature regime so far north, and the long term average bottom temperature remains unknown.

CURRENT CONDITIONS AROUND DISKO ISLAND.

The following outline of current conditions in the areas around Disko island (figure 3) is based on Sloth (1983) Kiilerich (1939, 1943), and Andersen (1981).

The waters around Disko island are influenced by three water masses mainly: The relatively warm Irminger component of the northerly West Greenland Current, counterclockwise eddies from the cold Baffin Current, and low salinity surface water discharging from Disko Bay.

Current pattern in the mouth of Disko Bay is heavily influenced by bottom topography (figures 3 and 4). Upon reaching Store Hellefiske Bank from the south the West Greenland Current is rather slow. The current flows across Store Hellefiske Bank, and part of it turns towards Disko Bay by way of the rather narrow east-west oriented channel running between Disko Bank and the northern edge of Store Hellefiske Bank. The current passes a treshold (383 m) north-east of Store Hellefiske Bank and flows towards Disko Bay through the deep basin (max. depth 920 m) that runs in a north-easterly direction between Egedesminde and Disko Bank. However, the current does not enter the bay through the continuation of the basin running between and past Kronprinsens Ejland and Hunde Ejland. In this area current is weak and of varying directions. Also, observations made in mid summer point to the exsistence of a counterclockwise eddy in the middle of the basin. Rather it seems that the main part of the surface flow entering the bay passes along the southern part of the bay, between Egedesminde and Hunde Ejland, where an easterly net current of about 0.12 m s^{-1} has been measured (July-August).

Having entered Disko Bay the surface current describes a cyclonic motion, causing surface water to leave the bay mainly as a low saline current (because of admixed run-off from land) flowing west or south-west past Godhavn and south of or across Disko Bank. However, during times of intense circulation in the bay, surface water may also discharge through the Vaigat.

It appears that the Vaigat, which Kiilerich (1939, 1943) and Andersen (1981) considered an outlet mainly, may only function as such when the component of the West Greenland Current entering the bay is strong. This is usually not the case until fall, when current velocity in the Vaigat may rise to 0.3-0.4 m s^{-1} (upper 200 meters - September; Kiilerich 1939). At times of very weak circulation in the bay (spring and summer period) surface water may enter Disko Bay via the Vaigat - i.e. southerly current in the Vaigat - and south of Disko island. In July 1980 current was northerly in the Vaigat, while in 1981 and 1982 it was southerly (figure 4).

Current pattern outside the Disko Bay entrance is influenced by the West Greenland Current, the Baffin Current and water discharging from Disko Bay. The southern part of this area is touched upon above.

The comparatively shallow area off Godhavn is of a very variable hydrography, because of the interaction between the West Greenland Current, the out-going current flowing west, and swift tidal currents. Thus, the out-going current flowing west past Godhavn is often forced back into the bay by rising tides off Godhavn (Andersen 1981). Also, in the area between Disko island and Disko Bank (Godhavn Rende) current velocity and speed is very variable, while further west current is stronger and primarily directed north-west.

North of Disko Bank the surface current shows undulating easterly movements towards Disko island (figure 4), but the predominant direction of the current is northerly. However, during spring and summer current is slow and of varying direction west of Disko island (max. velocity about 0.03 m s^{-1}; Sloth 1983), as the part of the West Greenland Current that continues past the entrance to Disko Bay passes beneath the fresher surface layers flowing out from Disko Bay. Current velocity does not increase until fall (max. velocity abt. 0.10 m s^{-1}).

Next to nothing is known of near shore current conditions north of 71°N - except that overall direction is northerly.

DISCUSSION.

Reproductive potential and temperature.

Water temperature is generally believed to be one major factor governing the distribution and population dynamics of *Pandalus borealis* stocks (Nunes 1984, Rasmussen 1953, Shumway et al. 1985, Teigsmark 1983). Taking the whole area of distribution into consideration, it appears that the 'optimum temperature' range, as well as the lower range of temperature in which reproduction is severely affected, varies between populations living in different waters (Nunes 1984, Berenboym 1982, Teigsmark 1983).

No data are available as regards the effect of low temperatures on reproduction of Greenland shrimp stocks. Accordingly, defining a lower temperature limit at which *Pandalus borealis* populations at Greenland are unable to reproduce is difficult, because in doing so one will have to draw inferences from populations which may not be comparable to the Greenland populations. Also, most of the evidence is circumstantial, as regards temperatures which are of interest in this connection (i.e. below 1°C), in that most (laboratory) studies dealing with reproduction have considered temperatures well above 1°C only. Among the studies (i.e. populations) available there is probably least risk of reaching wrong conclusions if characteristics of thermal tolerance of Greenland shrimp populations are inferred from observations made on Barents Sea populations. The latter appear to be rather robust and to be living under similar environmental conditions (as compared to Gulf of Maine (e.g. Stickney 1981) and Pacific (e.g. Nunes 1984) populations).

Temperatures below 0°C apparently do not prevent populations in the Barents Sea from spawning (Berenboym 1982, Rasmussen 1953, Teigsmark 1983), but there is no doubt that egg formation and larval development are negatively influenced by temperatures even below 1°C Berenboim 1982, Teigsmark 1983). In the Barents Sea Berenboim (1982) found 'a direct relationship between the long-term average temperature near the bottom in May, when hatching of the larvae takes place, and the reproductive potential of the shrimp population.' Reproduction of populations living in areas where the long-term average temperature near the bottom in May was below 1°C were considered dependent on immigration of individuals from the outside. The degree of dependency increased with decreasing temperature until at -1°C reproduction was totally dependent on individuals (larvae) immigrating from warmer areas.

The inability of the populations to reproduce themselves was considered to result mainly from the combined effects of reduced numbers of egg-bearing females and egg-losses and death of embryos during the time of incubation (Berenboym 1982). These findings are consistent with indications of low temperature effects mentioned by other authors (Nunes 1984, Teigsmark 1983, Squires 1968)

It may be mentioned that low temperatures during the ovigerous period do not seem to lower the viability of surviving larvae. However, low temperatures excert a negative effect on larval physiology, which shows as a lengthened larval phase; the number of, and the period between, instars increases, causing a lengthening of the larval phase (Nunes 1984). This eventually may increase exposure to predation. Also, larvae may be exposed to more periods of starvation, but as larvae of Pandalus borealis seem to be highly resistant to starvation (Nunes 1984) this may be of minor importance.

No quantitative observations are available for Greenland shrimp stocks as regards the above-mentioned characteristics. However, compared to the stock in NAFO Division 1B, conditions of reproduction do seem to be below optimum in the northern area, as suggested by the relatively high incidence of dead eggs and the low frequency of berried females. In NAFO Div. 1B almost 90% of females were berried or had head roe in August 1986 (Carlsson & Kanneworff 1987) as compared to 50% in the northern area.

This difference between stocks may be caused by differences of temperature. North of 71°N temperatures are below 1°C in August (at depths of 260-400 m, table 1), while west and north west of Store Hellefiske Bank temperatures are above 2.0°C at comparable depths (Riis-Carstensen 1936 and unpublished data).

On the basis of this one may assume that the reproductive capacity of the northern stock is below that of the southern stock. Using the terminology of Berenboym (1982), one would be reluctant to classify the northern stock as 'independent', i.e. completely self- sustaining. Some supply of shrimp from the outside may be essential to the continuous existence of this stock.

Mean catch rates in fishing areas declined almost linearly in a northerly direction (figure 2). This may imply that

1) reproduction declines in a northerly direction, and/or that

2) shrimp in the northern area emigrate in a southerly direction, and/or that

3) the presence of shrimp in northern areas depends on a supply of larvae or juvenile/adult shrimp from more southern areas.

It must be stressed that data is scarce, but present knowledge does not suggest that reproduction or conditions of importance to reproduction decline in a northerly direction inside the northern area. Thus, temperature, fecundity, egg mortality, and the fraction of berried females do not <u>seem</u> to vary concurrently with mean CPUE values.

No information is available as regards the incidence of dead eggs in the two southernmost fishing areas, Svarten Huk (71°30'N) and Uummannaq (71°N - figure 1), or as regards the fraction of egg carrying females in Uummannaq fishing area. Therefore, it is possible that the 'populations' in these southern areas to some extent are able to supply northern areas with larvae or adult shrimp. At the present time this cannot be evaluated, though, because data is lacking.

There is hardly any way of testing the possibility that the stock north of 71°N is replenished by shrimp immigrating from areas south of this latitude - as there is at present no way of detecting a southerly emigration from the northern area.

This being the case one may in stead consider the possible significance of a northerly flow of larvae from more southern populations, i.e. the stock south of Disko Island. With a planktonic life which may last 3-4 months or longer (Horsted et al. 1978; Lysy 1978), larvae are excellent units of dispersal, which by surface currents may be carried far from their place of hatching.

<u>Larval distribution</u>

The observations on larvae do not allow definite conclusions concerning the overall distribution of larvae, as the surveys have covered a relatively short period of the larval phase. The main hatching period in the Davis Strait is March-April (Horsted 1978), which leaves a period of at least 1.5 month between the time of hatching and the time of investigation. We do not know anything for certain about the geographical distribution of larvae in the time interval on either side of the survey period.

Compared to offshore areas, Disko Bay and the Vaigat frequently have a relatively large stock of larvae, so these waters do make up a potential supply area for a more northern shrimp stock.

Furthermore, the observations on larval densities seem to imply either that production of larvae is relatively high in Disko Bay and in the Vaigat, and/or that larvae from offshore banks are 'dammed-up' in Disko Bay.

Current pattern and the apparent absence of larvae in offshore areas in June-July may suggest that the Disko Bay, and the mouth of Disko Bay in particular, are centres as regards larval 'traffic'. Pandalus borealis larvae from offshore populations probably hatch on the banks or in near shore waters and disperse in the upper water layers, at depths which do not exceed the thickness of the surface current (Chaput 1984; Horsted & Smidt 1956; Lysy 1979). It is therefore to be expected that a large number of larvae come into contact with the West Greenland Current. The high densities of larvae that on occasion have been observed in the areas mentioned above may reflect current mediated transport of larvae. Thus, larvae from the offshore stock south of Disko Bay (and from Disko Bay itself) may accumulate in the eddies inside the bay or in the basin south of Godhavn.

Most likely the eddies themselves are not main areas of settling, given the great depths. It is to be expected, though, that large scale settling takes place near the Disko Bay entrance, because the combination of shallow areas and complicated flow patterns with counteracting currents, which provide ideal conditions for settling (Berenboim et al. 1980), is amply present in the area. A local dominance of juvenile shrimp found in Disko Rende (Carlsson,D.M. - personal communication) may support this wiev.

Larval flow?

Northward transportation of larvae past Disko Bay must take place west of Disko island and/or through the Vaigat. None of these routes seems to be of major importance in the light of current pattern. Larvae may, of course, be carried past Disko Bay by offshore currents or they may enter the bay and leave again by the surface current flowing south of Disko island. However, the great variability of current speed and direction west of Disko island and the abundance of suitable conditions for settling in the mouth of Disko Bay do not suggest that substantial numbers of larvae are carried past Disko island.

Northerly larval flow through the Vaigat was earlier suggested by Horsted et al. (1978), but this route may be of minor importance, because current velocity is low and often of a southerly direction during the summer period. High larval densities have been observed in the northern part of the Vaigat at both northerly (1980) and southerly (1982) currents. This may imply that larvae observed here during the summer are of local origin and not a manifestation of a current mediated transport of larvae from Disko Bay. However, in years of northerly current, larvae hatched in this area might contribute to the stock north of 71°N (especially if unfavourable environmental conditions prolong the larval phase), but this does not seem to be the rule.

CONCLUSION.

Preliminary data and observations suggest that a supply of immigrating individuals is essential to the continuous exsistence of the shrimp stock in Greenland waters north of 71°N - at least it seems to be as regards the northern part of this stock. Immigrations may occur by migrating adult shrimp or by larval flow.

One cannot exclude the possibility that juvenile or adult shrimp immigrate from more southern areas. At present this is beyond detection, though.

The mouth of Disko Bay and Disko Bay itself may be very important as far as larval flow from the stock south of Disko is concerned. Furthermore, it seems that inshore areas around Disko island, including the Vaigat, make up a potential supply area for more northern shrimp populations.

Current pattern and velocities during a considerable proportion of the larval period (i.e. spring and summer) do not seem to favour major annual flow of larvae from areas south of Disko island or from Disko Bay to the areas north of 71°N.

Present data are too scant for drawing definite conclusions as to a northerly flow of larvae past Disko island or as to a northerly migration of adult shrimp to areas north of 71oN. This inevitably leads to the conclusion that, in order to get past mere hypothesizing, we need quantitative information on abiotic factors and stock features mentioned above, i.e. temperature, egg mortality, etc. Quantitative information on the reproductive potential of the northern stock must be obtained by monitoring the frequency of berried females and the survival rate of embryos. To get a measure of the relative reproductive potential of this stock, it is necessary that the same information is obtained for shrimp stocks of known high reproductive potential.

Furthermore, if an accurate picture of the larval drift is to be established, we may need to know the current pattern on a smaller scale, but more important, we will need more than a superficial knowledge of the distribution and abundance of pelagic shrimp larvae.

References.

Andersen, O.G. Norden (1981): The annual cycle of temperature, salinity, currents, and water masses in Disko Bugt and adjacent waters, West Greenland.
Meddr Grønland, Biosci. 5: 33 pp.

Anon (1987): Report of Standing Committee on Fishery Science (STACFIS).
NAFO Scientific Council Reports 1987.

Berenboim, I.B., A.Yu. Lysy, L.I. Serebrov (1980): On distribution, stock state and regulation measures of shrimp (Pandalus borealis Krøyer) fishery in the Barents Sea.
ICES C.M. 1980/K:15.

Berenboim, I.B. (1982): Reproduction of the shrimp Pandalus borealis in the Barents Sea.
Oceanology, 22(1): 85-89.

Carlsson, D.M., P. Kanneworff (1987): The Shrimp Fishery in NAFO Subarea 1 in 1985 and 1986.
NAFO SCR Doc. 87/08, Serial No. N1276.

Chaput,G.J. (1984): Distribution and abundance of decapod larvae from Labrador with special emphasis on the distribution, abundance, development and growth of Pandalus borealis.
Report, LGL Limited for Department of Fisheries and Oceans Department of Supply and Services.

Horsted, Sv.Aa. (1978): The Life Cycle of Shrimp, Pandalus borealis Kr., in Greenland Waters in Relation to the Potential Yield.
ICNAF Sel. Pap., 4:51-60.

Horsted, S.Aa., P. Johansen, E. Smidt (1978): On the possible drift of shrimp larvae in the Davis Strait.
ICNAF Res. Doc. 78/XI/93, Serial No. 5309.

Horsted, Sv.Aa., E. Smidt (1956): The deep sea prawn (Pandalus borealis Kr.) in Greenland waters.
Medd. Danm. Fisk.- og Havunders., N.S. 1, 11: 1-118.

Kiilerich, A.B. (1939): The Godthaab Expedition 1928. A Theoretical Treatment of the Hydrographical Observation Material.
Meddelelser om Grønland, 78(5), 149 pp.

Kiilerich, A.B. (1943): The Hydrography of the West Greenland Fishing Banks.
Medd. Komm. Danm. Fisk.- og Havunders., Ser.Hydrografi, 3(3), 1-45.

Lund, H. (1987): Trial Fishery for Shrimp (Pandalus borealis Kr.) in West Greenland Waters North of 70.52.5'N in 1986.
NAFO SCR Doc. 87/07, Serial No. N1275.

Lysy, A.Y. (1978): Investigations on deepwater shrimp larvae (Pandalus borealis Kr.) in the Norwegian and Barents Seas in 1978.
Annales Biologique, 35: 253-255.

Lysy, A.Y. (1979): Distribution of deepwater shrimp (Pandalus borealis) larvae in the Norwegian and Barents Seas in 1979.
Annales Biologique, 36: 198-200.

Nunes, P. (1984): Reproductive and larval biology of northern shrimp, Pandalus borealis Krøyer, in relation to temperature.
Doctoral dissertation. University of Alaska, Fairbanks.

Rasmussen, B. (1953): On the Geographical Variation in Growth and Sexual Development of the Deep Sea Prawn (Pandalus borealis Kr.).
Reports on Norwegian Fishery and Marine Investigations, Vol. X, no. 3.

Riis-Carstensen, E. (1936): The Godthaab Expedition 1928. The hydrographic work and material.
Meddelelser om Grønland, Vol. 78, No.3.

Shumway, S., 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 (NOAA Technical Report NMFS 30).

Sloth, P. (1983): Hydrografi i Disko Bugt 1980-82.
University of Copenhagen (thesis).

Squires, H.J. (1968): Relation of temperature to growth and self-propagation of Pandalus borealis in Newfoundland.
FOA Fish. Rep. No. 57, Vol. 2.

Stickney, A.P. (1981): Laboratory studies of the development and survival of Pandalus borealis eggs in the Gulf of Maine.
In: Frady, T. (ed.): Proceedings of the International Pandalid Shrimp Symposium, Sea Grant Report 81-3, June 1981, pp.395-405.

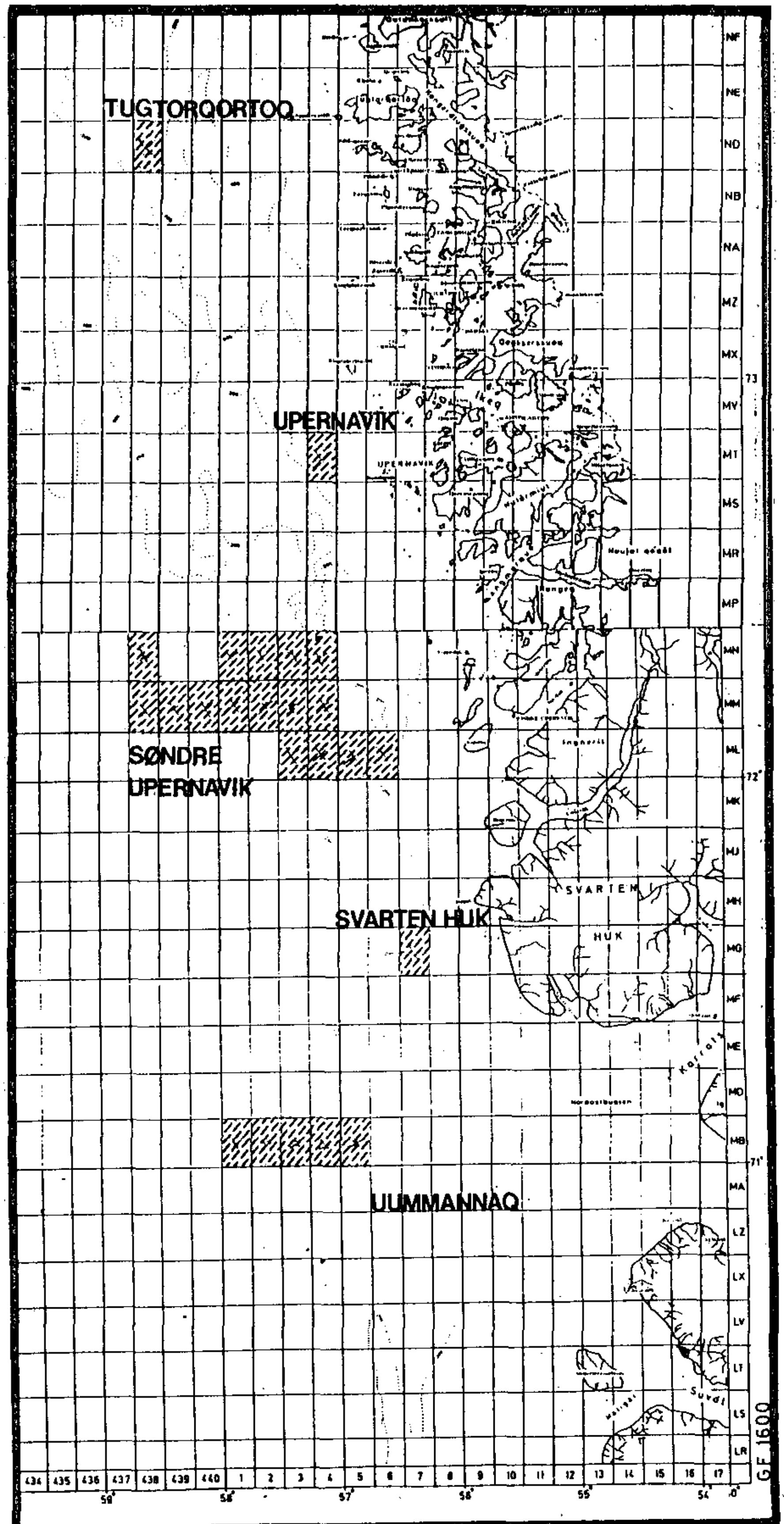
Teigsmark, G. (1983): Populations of the deep-sea shrimp (Pandalus borealis Krøyer) in the Barents Sea.
Fisk Dir. Skr. Ser. HavUnders ., 17: 377-430 (1983)

TEMPERATURE MEASUREMENTS MADE BY THE GODTHAAB EXPEDITION.

(Riis-Carstensen 1936)

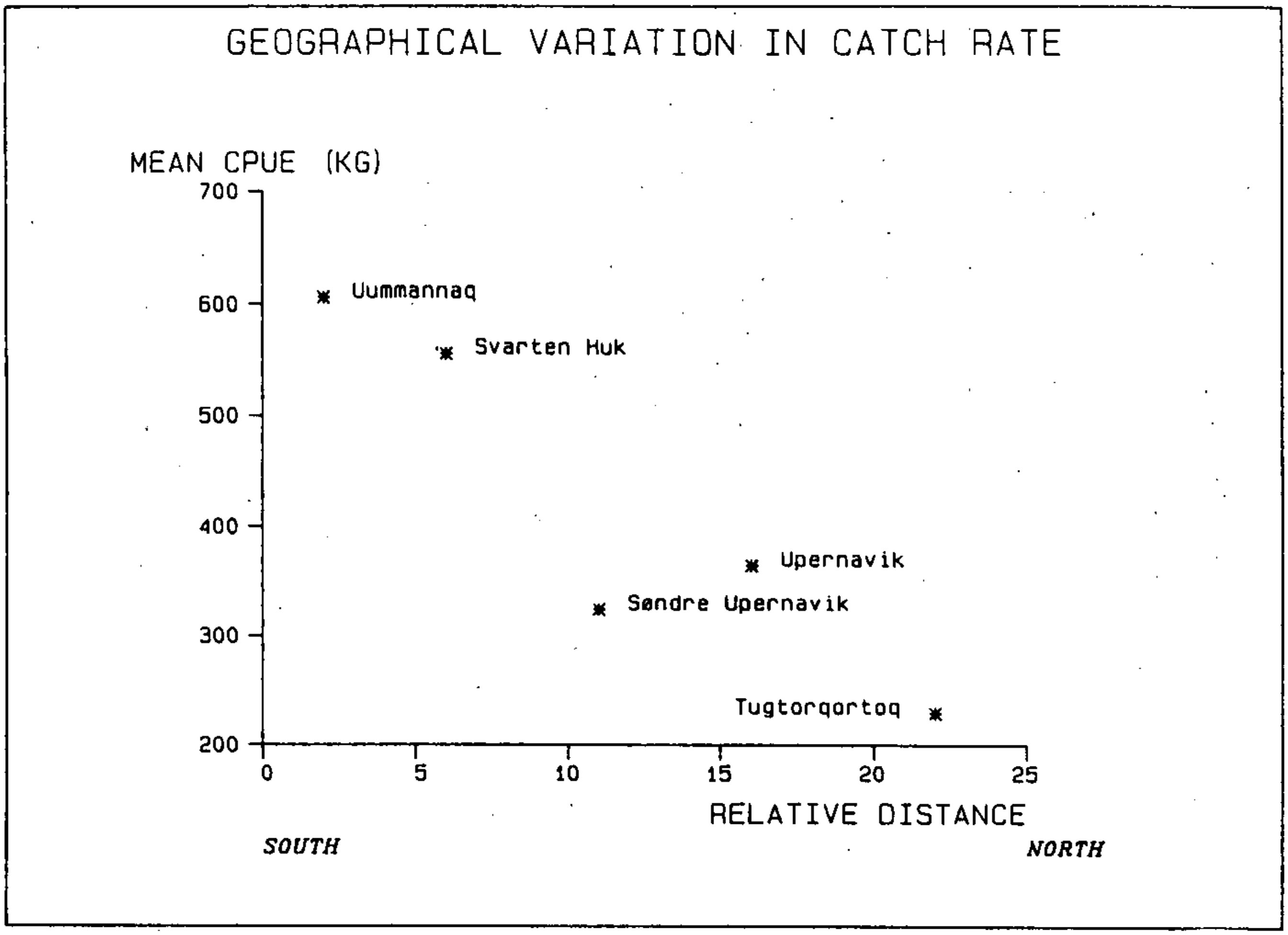
ST.NO.	DATE	POSITION	DEPTH	TEMP. (°C).
47	13/7	69°41.2'N	0	4.10
		55°01'W	5	17
			10	3.80
			20	1.09
			40	-0.06
	max. depth	80 m	70	-0.10
48	13/7	69°41.3'N	0	4.29
		55°30'W	10	2.64
			25	0.07
			50	-0.42
			75	-0.26
	max. depth	120 m	110	-0.20
49	13/7	69°42.8'N	0	5.05
		56°20'W	10	4.89
			25	0.94
			50	-0.23
			75	-0.60
			100	-0.51
	max. depth	160 m	150	-0.17
50	13/7	69°44.4'N	0	4.10
		57°22'W	10	3.60
			25	0.64
			50	-1.60
			75	-1.56
			100	-0.91
			150	0.65
	max. depth	215 m	200	1.20
60	21/7	72°30'N	0	5.26
		59°02.5'W	10	3.67
			25	-0.18
			50	-1.64
			75	-1.71
			100	-1.21
	max. depth	245 m	225	-0.03
61	21/7	72°33.5'N	0	4.20
		57°36'W	10	3.86
			25	0.64
			50	-0.95
			75	-1.16
			100	-1.09
	max. depth	190 m	175	-0.41
62	21/7	72°37'N	0	4.55
		56°31'W	10	48
			25	2.84
			50	0.22
			75	-0.60
			100	-0.69
	max. depth	230 m	215	-0.11
63	27/7	72°56'N	0	3.21
		56°55'W	5	02
			10	2.86
			15	68
			25	10
			50	0.28
			75	-0.22
			100	-0.21
			200	-0.20
			300	0.35
	max. depth	410 m	390	47
64	28/7	73°12'N	0	4.56
		58°08'W	10	37
			25	-0.11
			50	-1.19
			75	-1.62
			100	-1.67
			200	-0.13
			300	0.29
			500	98
	max. depth	850 m	820	47
65	28/7	73°30.8'N	0	3.86
		59°36'W	10	65
			25	-0.31
			50	-0.96
			75	-0.75
			100	-0.69
	max. depth	225 m	200	-0.12
66	28/7	73°49.2'N	0	-0.61
		61°10'W	5	-0.69
			10	-0.15
			15	-0.84
			25	-1.45
			50	-1.69
			75	-1.69
			100	-1.52
			200	-0.16
			300	0.79
	max. depth	490 m	475	83
67	29/7	74°05'N	0	1.98
		59°54'W	10	-0.13
			25	-1.36
			50	-1.67
			75	-1.25
			100	-0.91
			200	-0.26
			300	0.65
	max. depth	540 m	500	80
68	29/7	74°20'N	0	4.39
		58°38'W	10	3.19
			25	-0.26
			50	-0.88
			75	-1.02
			100	-0.65
			200	-0.13
	max. depth	384 m	370	0.95
69	29/7	74°28'N	0	1.70
		58°04'W	10	3.81
			25	-0.47
			50	-1.12
			75	-1.15
			100	-0.90
			200	-0.08
			300	0.26
	max. depth	465 m	450	59

Table 1



FISHING AREAS IN GREENLAND WATERS NORTH OF 71°N (defined as statistical units in which fishing effort was 100 hours and above in 1986: hatched squares).

Figure 1.



Names refer to fishing areas north of 71oN.

Figure 2.

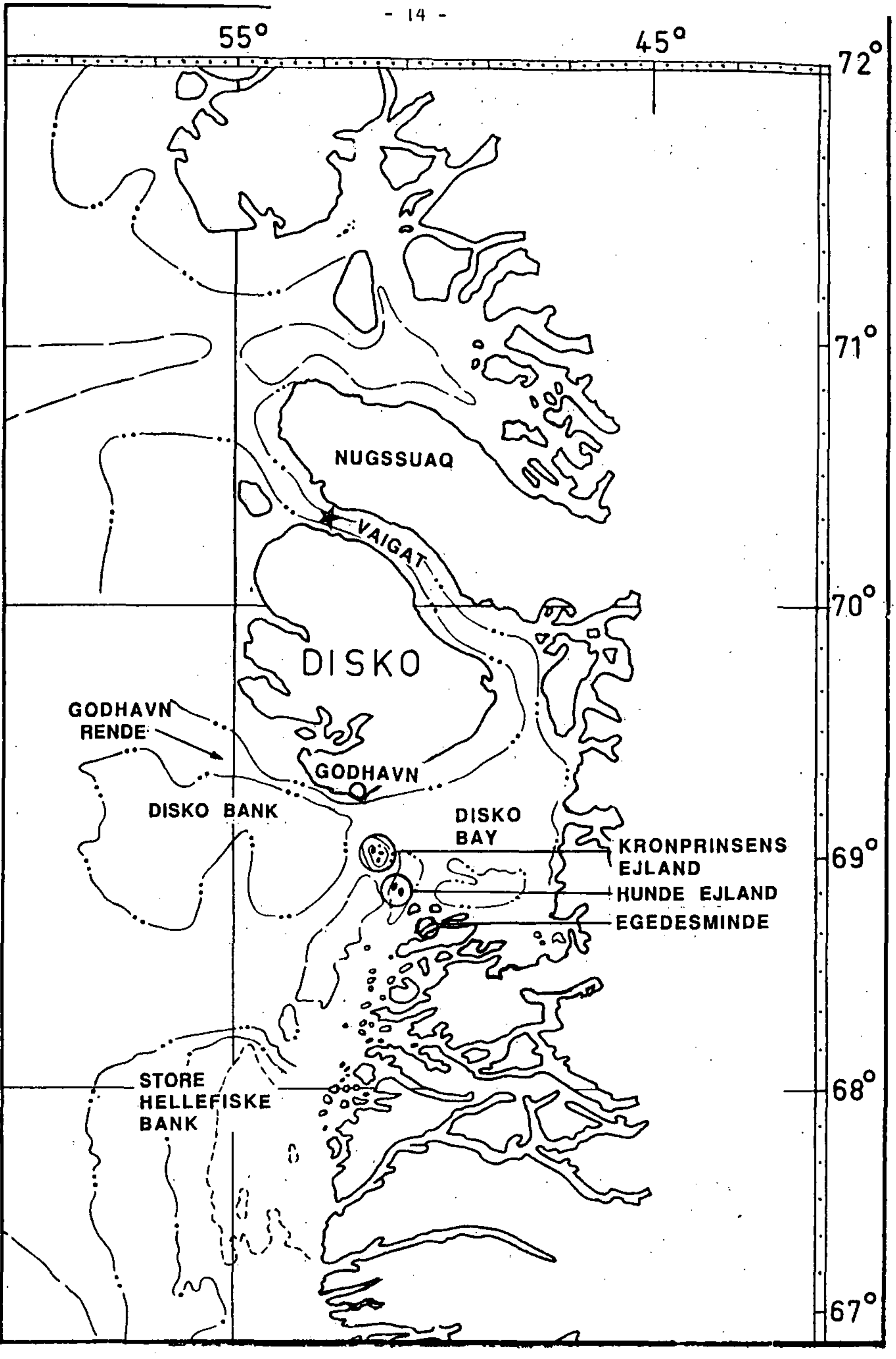
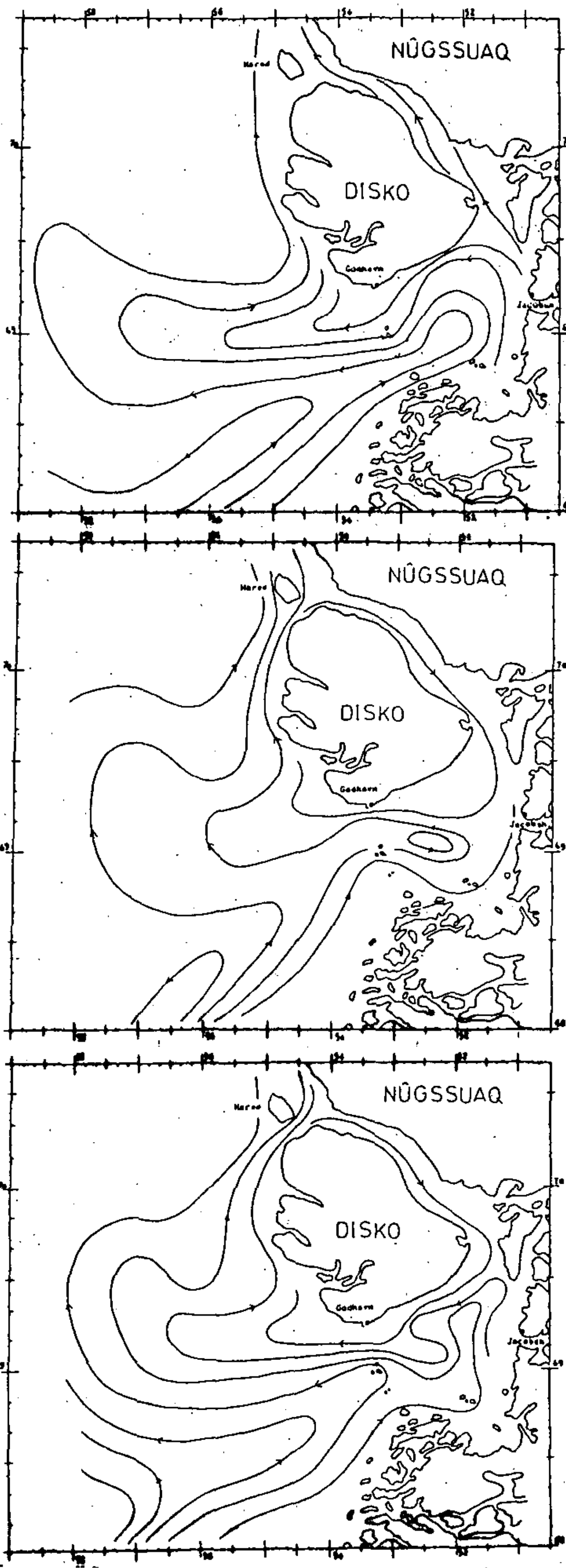

55°
45°
72°
71°
70°
69°
68°
67°
NUGSSUAQ
VAIGAT
DISKO
GODHAVN RENDE
GODHAVN
DISKO BANK
DISKO BAY
KRONPRINSENS EJLAND
HUNDE EJLAND
EGEDESMINDE
STORE HELLEFISKE BANK

Figure 3

GEOSTROPHICAL CURRENTS AROUND DISKO (from Sloth 1983).



July 1980

July 1981

July 1982

Figure 4.