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Relevance of Some Environmental Parameters to Distribution Patterns of Groundfish and Implications for Reasonable Survey Design: Case Study Atlantic Cod off Greenland

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Introduction

The effects of environmental parameters on fish distribution patterns have been targeted frequently in fishery science. Concerning the recently depleted status of numerous demersal fish stocks and a consistent lack of commercial fishery data, results of groundfish surveys have gained in significance for fish stock assessment purposes (Doubleday, 1981). One primary use of the analysis of changes in the environment and their consequences in fish distribution is to create reasonable stratified survey designs in order to improve the precision of resulting abundance estimates.

Since the taking up of regular investigations in fisheries biology in the 1920s, much attention has been directed at the occurrence of Atlantic cod (*Gadus morhua*) in relation to environmental conditions. The majority of contributions deal with climatic effects on migration or recruitment success in terms of large geographic or temporal scales (Jensen, 1939; Hansen, 1949; Bratberg and Hylen, 1964; Meyer, 1964; Stein and Messtorff, 1990). In contrast, the present analysis is focused on possible impacts of environmental parameters in terms of near bottom temperature, depth and position on the spatial distribution patterns of Atlantic cod off West and East Greenland, based on groundfish survey data covering a relatively short period of 14 years from 1982 until 1995 and in a limited survey area. The results are discussed in order to assess their relevance in relation to appropriate survey designs.

Material and Methods

Since 1982, the demersal fish assemblage off West and East Greenland (NAFO Division 1 and ICES Subarea XIV) has been monitored annually by German groundfish surveys. The survey strategy was designed for cod as the target species. The survey area was the continental slope off West and East Greenland south of 67°N from the 3-mile offshore line down to the 400 m isobath. Positions of hauls were randomly selected within trawlable areas and are illustrated in Fig. 1.

During 1982-95, 2 245 successful sets were carried out, the numbers of valid sets by year are listed in Table 1. In 1984, 1992, 1994 and 1995, the survey area was not covered adequately due to technical problems. The catches of Atlantic cod (*Gadus morhua* L.) in numbers were raised to abundance per nautical square mile. Gear parameters used for converting and a detailed description of the survey method are given by Rätz (1996).

As a standard procedure, near bottom temperatures were measured directly before or after trawling in the vicinity of the swept area by a CTD-sonde with a precision of a hundredth °C. Table 1 lists the available numbers of temperature values by year. During the 14-year time series, a total of 1 847 measurements were conducted (82% of the hauls). Numerical values of catch positions (longitude and latitude) were converted to decimals and the mean depth was determined from the average of the minimum and maximum recorded depths during an individual haul.

In order to avoid pronounced year effects, individual cod abundance estimates in numbers per nautical square mile derived from trawl catches were standardized by division using the stratified means. Temperature measurements were standardized by division using the weighted means (by survey area) for the same reason. Table 1 lists the means on which standardizations are based.

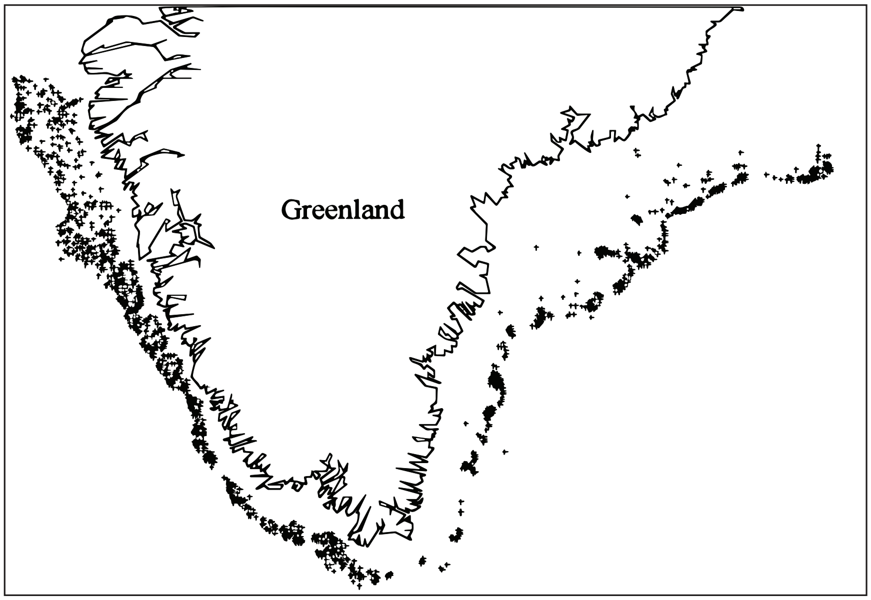

Fig. 1. Study area showing positions of the 2 245 survey hauls conducted through 1982–95.

TABLE 1. Number of valid sets, stratified mean cod abundance (adopted from Rätz, 1996), number of temperature measurements and weighted mean near bottom temperature over the 14-year study period.

Year	Valid Sets	Stratified Mean Cod Abundance (nm^2)	No. of Temperature Measurements	Weighted Mean Temperature (°C)
1982	136	2 679	92	3.138
1983	203	1 553	148	3.012
1984	145	622	115	2.698
1985	219	1 915	218	4.181
1986	214	4 295	207	4.136
1987	212	22 102	142	3.782
1988	238	17 353	218	3.958
1989	205	12 024	161	3.296
1990	174	1 596	151	3.460
1991	170	406	81	3.558
1992	53	72	49	3.490
1993	108	126	105	3.597
1994	84	37	76	3.620
1995	84	199	84	3.862

Results

The survey coverage of the shelf and continental slope off Greenland from the 3-mile limit down to the 400 m isobath are shown in Fig. 1. Because of rough trawling grounds and extremely steep slopes, the survey area off East Greenland had been covered less evenly. The geographic distribution of the hauls also shows that the majority of the effort was concentrated on the banks and outer slopes, while the inshore areas were often found non-trawlable.

Figure 2 shows the scatter plot of 1 847 individual observations between relative cod abundance values and the relative near bottom temperature. During 1982–95, an enormous variation in relative cod abundance between 0 and 60 times of the stratified mean was observed. Looking at the data plot, there was no evidence for the existence of a linear trend as being specified by the parameters of correlation.

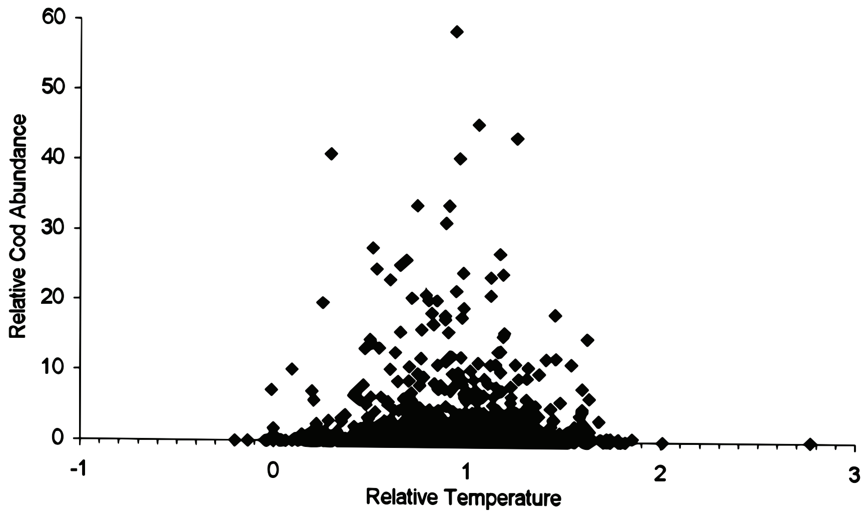

Fig. 2. Relation between relative abundance (standardized by stratified means) of Atlantic cod off Greenland and relative near bottom temperature (standardized by-weighted means) in the survey conducted through 1982–95. The parameters of correlation were: n = 1 847, r = -0.056, r^2 = 0.003.

However, there seemed to be a sign of a preference around the weighted mean temperatures when all available data were considered.

The scatter plot between relative cod abundance and the mean depth on a haul by haul basis is illustrated in Fig. 3. In spite of highly variable catches which cause a poor confidence, a clear negative trend with increasing depth was evident. Only 4% of the variation in relative cod abundance was explained by the depth factor. The majority of high values of relative abundance were observed at shallower soundings, mainly at less than 250 m.

The latitude seemed also to contribute significantly to the relative cod abundance. Both variables are plotted in Fig. 4. The general lack of high abundance values north of 65°N resulted in a significant negative trend. A similar effect was found regarding the longitude (Fig. 5), explaining also 1% of the observed variation. The bulk of high relative abundance values was concentrated at West Greenland at a longitude >44°W with a few exceptions only. The low confidence related to the position of the hauls resulted again from the high variation in the relative cod abundance.

Discussion

Some essential underlying assumptions for the assessment of cod abundance and environmental conditions were not met by the groundfish surveys off Greenland. The most important deviation was the restriction of haul distribution to trawlable areas located mainly on the top of the banks and to their outer slopes. No information on cod distribution was available from vast non-trawlable areas. Another restriction was that all results refer to the autumn season. It is noted that the patterns of cod distribution may change considerably before or after the survey time. Further, observations were made only in the near bottom layer and the surveys were not designed to give any accounts of what happened in the pelagic water column. A possible year-class or age group effect might also have contributed to the results, since single cohorts were known to have dominated the stock structure during some years. Godø and Wespestad (MS 1991) found pronounced age effects in cod distribution patterns and hence found different availability to their survey gear.

The pronounced changes in cod abundance and near bottom temperatures require standardizations of the observations when interannual effects need to be excluded. Since 1982, the stratified mean cod abundance varied by a factor of 600, the maximum values were observed during 1987 to 1989. In 1991,

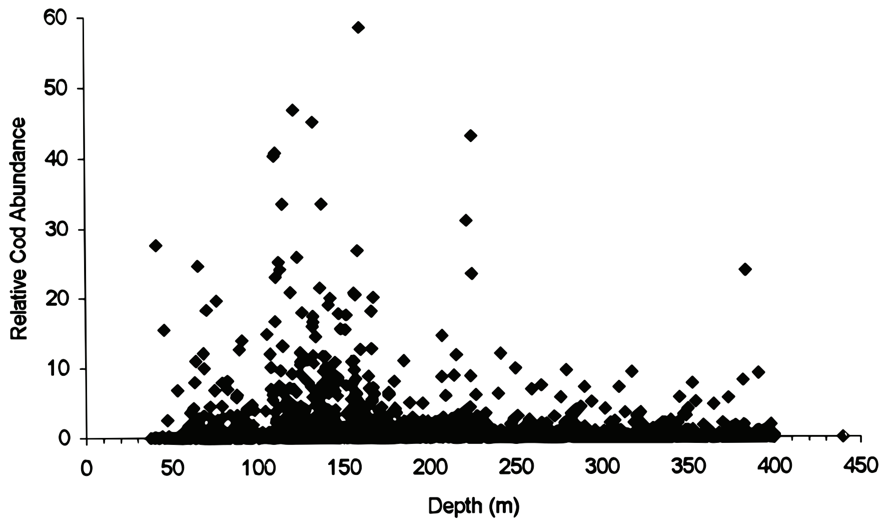

Fig. 3. Relation between relative abundance (standardized by stratified means) of Atlantic cod off Greenland and mean depth in the survey conducted through 1982–95. The parameters of correlation were: n = 2 245, r^2 = -0.190, r^2 = 0.036.

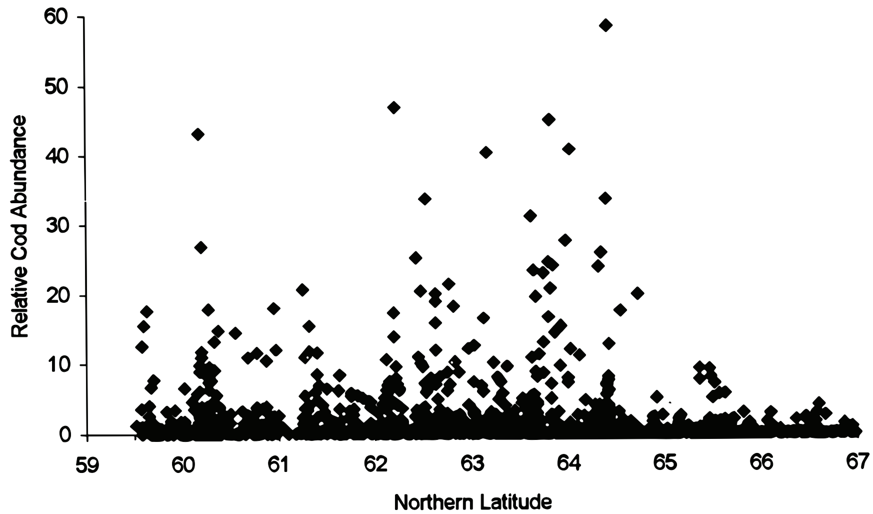

Fig. 4. Relation between relative abundance (standardized by stratified means) of Atlantic cod off Greenland and northern latitude (in decimals) in the survey conducted through 1982–95. The parameters of correlation were: n = 2 245, r = -0.117, r^2 = 0.014.

the stock collapsed to an extremely low level, and has not shown any signs of recovery since then (Rätz, MS 1996). The variation in the weighted mean temperature was much lower with the minimum of 2.7°C observed in 1984 followed by the maximum exceeding 4.1°C in 1985 and 1986. During 1986–95, the near bottom temperature averaged around 3.3–3.9°C and has displayed a slight increasing trend since 1990. These indications of the hydrographic conditions are consistent with the results from measurements taken at oceanographic standard sections (Stein, 1996).

The data analyzed revealed no evidence of a close relationship between the near bottom temperature and cod abundance, both variables being standardized to the stratified and weighted means. Consequently,

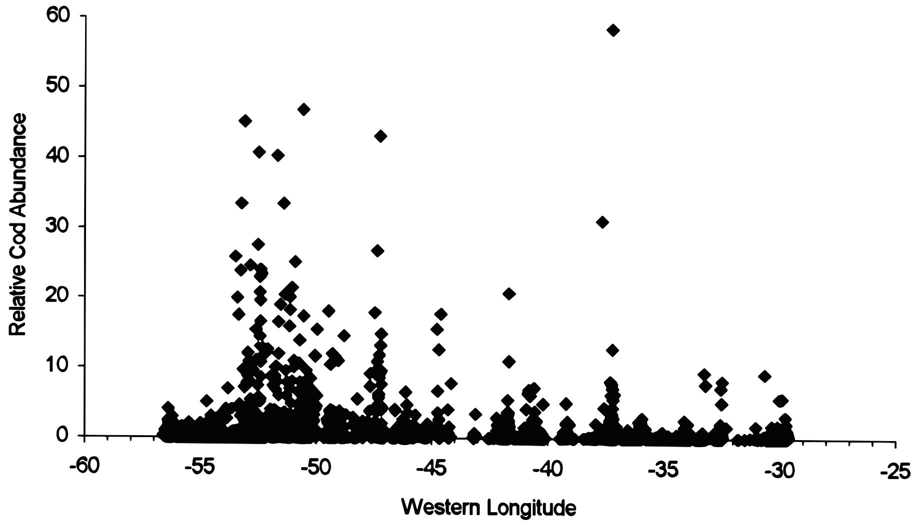

Fig. 5. Relation between relative abundance (standardized by stratified means) of Atlantic cod off Greenland and western longitude (in decimals) in the survey conducted through 1982–95. The parameters of correlation were: n = 2 245, r = -0.110, r^2 = 0.012.

near bottom temperatures are not expected to serve as a meaningful factor for a stratification of the survey area. However, strong positive or negative deviations from the mean temperature seem to be avoided by cod. This result confirms earlier findings by Bratberg and Hylen (1964) describing maximum catches in the temperature interval 2.6–3.5°C, while water masses with temperatures below 1.5°C and above 4°C gave smaller yields. Rasmussen (1954, 1955) and Hatchery *et al*. (1954) obtained highest catches for temperatures between 0.8°C and 3.2°C.

Whereas a linear trend of temperature and relative abundance of cod was found to be insignificant, linear numerical relations of both depth and the geographic position were identified. The depth was found to be the most important parameter in relation to the relative occurrence of cod off Greenland. Based on the 14-year experience, cod seem to prefer shallower soundings of less than 250 m in depth. Consequently, the 250 m isobath appeared to be the most appropriate subdivision for stratum construction. The preference of cod to occur west of 44°W and south of 65°N also resulted in significant patterns.

In agreement as well with findings for other groundfish in other surveys (Smith and Gavaris, 1993), a reasonable stratification for Atlantic cod off Greenland should be based on depth as well as the spatial factors. Considering the low confidence of these relations, the error reduction in the assessment of the stratified mean should generally be expected to be low. The high variations in the survey catches do not allow for a geographic analysis on a small scale, and this complicates the concept of the ideal stratum definition based on a homogenous frequency distribution (Cochran, 1953).

References

BRATBERG, E., and A. HYLEN. 1964. A Study of the relationship between the water temperature and the concentration of cod in West Greenland waters. *Fiskeridir. Skrifter*, **13**(7): 1–26.

COCHRAN, W. G. 1953. Sampling techniques. John Wiley & Sons Inc. New York: 1–330.

DOUBLEDAY W. G. 1981. Manual on Groundfish Surveys in the Northwest Atlantic. *NAFO Sci. Coun. Studies*, **2**: 7–55.

GODØ, O. R., and V. G. WESPESTAD. MS 1991. Monitoring changes in abundance of gadoids with varying availability to surveys. *ICES C.M. Doc.*, No. G:76:1–30.

HANSEN, P. M. 1949. Studies on the biology of cod in Greenland waters. *ICES Rapp. Proc.-Verb.*, **123**: 1–77.

HATCHERY, H. B., F. HERMANN, and W. B. DAILEY. 1954. The waters of the ICNAF Convention Area. *ICNAF Ann. Proc.*, **4**: 67–102.

JENSEN, Ad. S. 1939. Concerning a change of climate during recent decades in the Arctic and Subarctic Regions, from Greenland in the west to Eurasia in the east, and contemporary biological and geophysical changes. *Det Kgl. Danske Selskabs Aarsskrift*, Kopenhagen: 7–19.

MEYER, A. 1964. Zusammenhang zwischen Eisdrift, atmosphärischer Zirkulation und Fischerei im Bereich der Fangplätze vor der südostgrönländischen Küste während der ersten Jahreshälfte. *Arch. Fischereiwiss.*, **15**: 1–16.

RASSMUSSEN, B. 1954. On the Norwegian pelagic long line fishery in the Holsteinborg Deep–1953. *ICNAF Ann. Proc.*, **4**: 40–45.

1955. Norwegian research report for 1954. Notes on the composition of the catch by Norwegian long liners off West Greenland 1954. *ICNAF Ann. Proc.*, **5**: 43–49.

RÄTZ, H.-J. MS 1996. Groundfish survey results 1982–95 and length and age structure of German landings 1952–93 for cod off Greenland (offshore component). *ICES North Western Working Group Paper*, No. 9, 32 p.

1996. Efficiency of geographical and depth stratification in error reduction of groundfish survey results: case study Atlantic cod off Greenland. *NAFO Sci. Coun. Studies*, **28**: 65–71 (this issue).

SMITH, S. J., and S. GAVARIS. 1993. Improving the precision of abundance estimates of eastern Scotian Shelf Atlantic cod from bottom trawl surveys. *North Am. J. Fish.Management*, **13**: 35–47.

STEIN, M. 1996. Environmental overview of the northern Atlantic Area–with focus on Greenland. *NAFO Sci. Coun. Studies*, **24**: 29–39.

STEIN, M., and J. MESSTORFF. 1990. Relationship of fluctuations in cod recruitments off West Greenland to long-term variations of the physical environment. *NAFO Sci. Coun. Studies*, **14**: 39–40.