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The Distribution of Cod (*Gadus morhua*) in the North Sea

Henk J. L. Heessen
Netherlands Institute for Fisheries Research, P. O. Box 68
1970 AB IJmuiden, The Netherlands

Abstract

Cod (*Gadus morhua*) distribution data for the period 1971–91 from the International Young Fish Survey conducted in February, and the period 1981–91 from the Dutch Groundfish Survey conducted in October/November, were studied to determine possible trends in their abundance in different parts of the North Sea. Cod were widely distributed. Age groups 0 and 1 were most abundant in the German Bight, along the Dutch coast and northeast coast of England, while the age groups 3 and 4 were most abundant in the northern North Sea. For the southeastern North Sea, an important nursery area, the relation between abundance of cod and depth, temperature and salinity was studied. Although annual differences were pronounced, age groups 0 to 3 showed decreasing abundance with increasing depths with the tendency strongest for age group 0. The younger age groups also had highest densities at low temperature and low salinities, while the older fish were found in warmer water. These age specific differences in distribution were relevant to interpreting data from surveys.

Key words: Cod, *Gadus morhua*, depth, distribution, long term trends, North Sea, salinity, temperature

Introduction

Data on landings of North Sea cod (*Gadus morhua*) are available since 1903. From the beginning of this century until the early-1960s, the total international landings fluctuated between about 60 000 and 130 000 tons (Fig. 1). In the 1960s landings increased rapidly and a peak of 340 000 tons was reached in 1972. Since 1981 the landings have steadily decreased and have been approaching the pre-1960s level during the most recent years. The maximum size of the spawning stock, estimated by Virtual Population Analysis back to 1963 peaked in 1970 at 270 000 tons and has declined more or less steadily since then. The rapid increase in stock size and in landings in the 1960s was caused by a series of very strong year-classes which started in 1963 (Daan, 1978). From 1963 onwards the fishing mortality steadily increased to reach the high level of approximately 0.85 since 1980 (Fig. 1). The result of this high fishing mortality is that stock and catches are dominated by age 1 to 3 cod, and that the spawning stock at present is well below the safe biological level for the production of good year-classes (Anon., 1988).

In this paper, after a short introduction to the North Sea cod stock, two topics are discussed: firstly the changes in abundance of cod in different parts of the North Sea during the last 20 years, and secondly the relation between depth, temperature and salinity and the abundance of young cod in the southeastern part of the North Sea, an important nursery area. For studying changes in relative abundance, the North Sea has been split in three areas (North, Central and South) (Fig. 2) to determine if certain trends in these changes exist and whether the fluctuations in the different areas are correlated.

Material and Methods

This paper is based on data from the International Young Fish Survey (IYFS) covering the whole North Sea (Daan, 1979; Anon., MS 1990), and the Dutch Groundfish Survey (DGFS) which is restricted to the southeastern North Sea (Anon., MS 1990).

An international research vessel survey aimed primarily at establishing the distribution of young herring was carried out for the first time in 1960. From 1965, an annual International Young Herring Survey was carried out in February. During these surveys only that part of the North Sea where juvenile herring could be expected was covered. Over the years the objectives of the survey were broadened to include sampling of young gadoids and the area covered was extended to include the whole North Sea, Skagerrak and Kattegat, and the survey was renamed the IYFS. In 1976 a new standard gear after a French design, the GOV, was proposed and its introduction was completed in 1978. Haul duration was 30 min. and trawling was carried out both day and night. The total number of hauls was around 400 per statistical rectangle (30 x 30 miles), and at least two hauls were made by two different research vessels. The survey methods are described in Anon. (MS 1986).

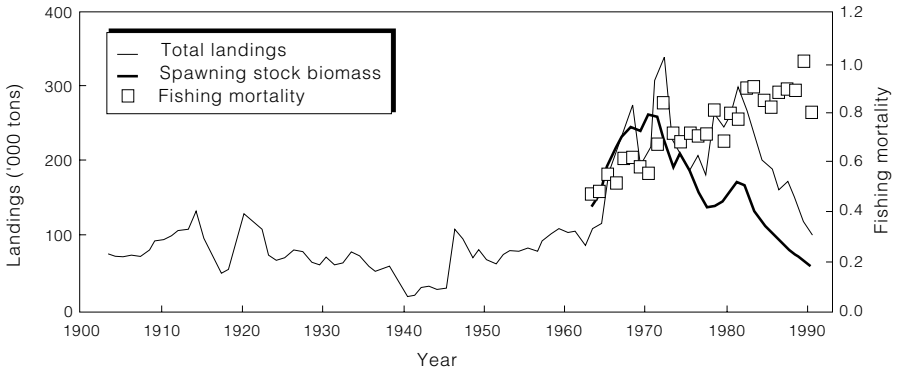

Fig. 1. Total international landings of North Sea cod, the size of the spawning stock biomass (Anon., MS 1991), and fishing mortality (Anon., MS 1991).

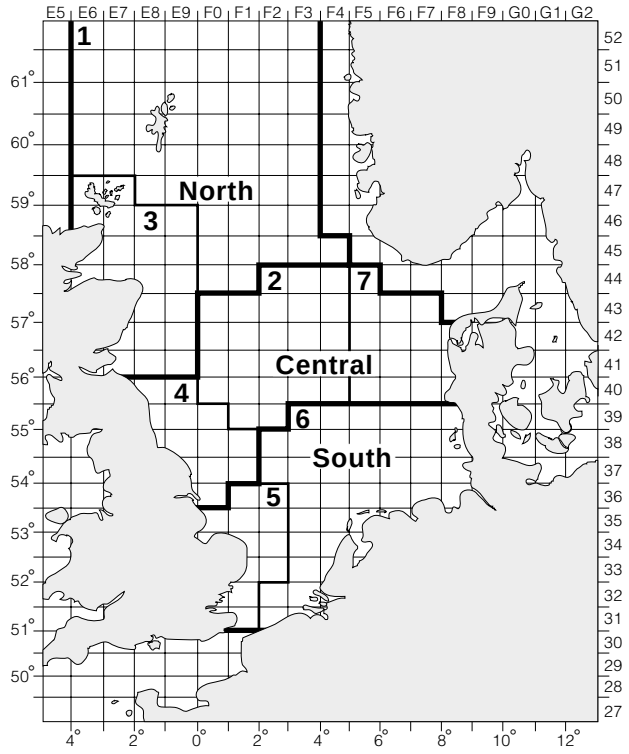

Fig. 2. Areas used in the analysis: North (roundfish sampling areas 1 and 3, Central (2, 4 and 7) and South

The DGFS has been conducted in October/November since 1981 with area covered restricted to the southeastern North Sea. The main aim of the survey was to provide recruitment indices for cod. The gear and methods used are the same as for the IYFS. The number of hauls per rectangle varied from 1 to 5, with the highest sampling intensity in the coastal area.

Using survey data from October/November (DGFS) and data from February (IYFS) the relation between depth, temperature and salinity and the abundance of young cod was studied.

IYFS abundance indices were calculated for age groups 1, 2 and 3+ for the years 1971–91 for the areas North (roundfish sampling area 1 and 3), Central (area 2, 4 and 7) and South (area 5 and 6) (Fig. 2). The indices were calculated by taking the arithmetic mean number-at-age per hour for all hauls within a rectangle and finally the arithmetic mean over all rectangles in the whole area was calcu-

lated. These area means per hour were multiplied by the number of rectangles within each area to give an index of the absolute numbers.

For the southeastern North Sea, roundfish sampling area 6 (Fig. 2), data from individual hauls from the IYFS 1981–89 and DGFS 1981–90 were used to calculate the mean catch-at-age per 5 m depth bands, 1°C temperature bands and 1‰ salinity bands for each year. This was done for age groups 0, 1 and 2 in the 4th quarter of the year (DGFS), and age groups 1, 2 and 3 in the 1st quarter of the year (IYFS). All data concerning the extreme poor year-class of 1984 were excluded from the analysis. For the 1982 DGFS, no temperature or salinity data were available. For each depth, temperature or salinity band the average abundance was calculated. This annual average was divided by the mean catch-at-age in area 6 for that particular year to exclude the influence of year-class strength as much as possible.

Results

Cod was widely distributed over the North Sea (Fig. 3). Data from the IYFS in February indicated that age group 1 was usually most abundant in the German Bight, along the Dutch coast and off the coast of northeast England. The distribution of the age group 2 was largely similar, but in addition, areas of high abundance were found in the northern part. The age group 3 was most abundant in the northern North Sea. Cod of 4 years and older had a similar distribution but were notably absent in the shallow parts of the German Bight.

The changes in abundance of cod in different parts of the North Sea during the last 21 years are shown in Fig. 4. The bulk of age group 1 was usually caught in the southern part of the North Sea, but in some years the catches in the central North Sea dominated. The overall contribution of the three areas to the catch of age group 2 was roughly equal. Age group 3+ was predominantly caught in area North.

Values of r^2 between the three data series are given in Table 1 and similarity plots are shown in Fig. 5. For age 1, the fluctuations in North and Central areas were correlated and so were those in areas Central and South. For age 2 the fluctuations in all three areas were significantly correlated. For age 3+, significant correlation was found only between the areas South and Central.

Figure 6 shows the average abundance at different depths, temperatures and salinities. Although great annual differences occurred some clear trends existed. In the 4th quarter, all three age-groups 0, 1 and 2 showed a decreasing abundance with increasing depth; this tendency was strongest for age 0. Also in the 1st quarter, the youngest age group was most abundant in shallow waters, the depth distribution of the age 2 and age 3+ groups showed less clear trends due to the high between-year variability.

In the 4th quarter the 0-group fish was most abundant in colder water, whereas age groups 1 and 2 had maximum abundance at 12°C. In the 1st quarter the age group 1 had again its highest abundance at the lowest temperatures, the age group 2 showed maximum abundance at 3°C. The abundance of the age group 3+ increased with increasing temperature.

The 0-group occurred in high densities at low salinities both in autumn and in winter. In the 4th quarter the abundance of age group 1 and 2 was highest at salinities of 31–33‰. In the 1st quarter the age group 2 still had its highest abundance at 32‰, but the relationship between age group 3+ and salinity was less pronounced.

Discussion

Although there was a high annual variability, the pattern in the fluctuations in abundance of young cod in different parts of the North Sea was in general rather similar. Recruits originated from widely distributed spawning areas and the synchronous recruitment in different parts of the North Sea would be a reflection of the annual similarities in the environment.

In the southern North Sea much more age group 1 cod were caught than in the northern North Sea. The catches of the age groups 2 and 3+ in the northern North Sea were, however, higher than that of the age group 1 in the same area. It can be concluded that either the age group 1 in February was not yet completely recruited to the survey gear, or that these fish occurred predominantly in areas where it was impossible to fish and that they dispersed later over a wider area. In the North Sea, 0-group cod change from its pelagic to its demersal phase somewhere between June and autumn, and in February all age group 1 cod are demersal. The use of the standard GOV trawl with its rather light ground-rope is strongly recommended in the IYFS. Quite often, however, bobbins are used to prevent gear damage on rough grounds, which holds particularly for the northern North Sea. It is known that the abundance of young cod may be severely underestimated when trawls equipped with heavy roller gear are used since young cod can escape under the ground-rope (Ehrich, MS 1987; Engås and Godø, 1989). Recruitment from other nursery areas is rather

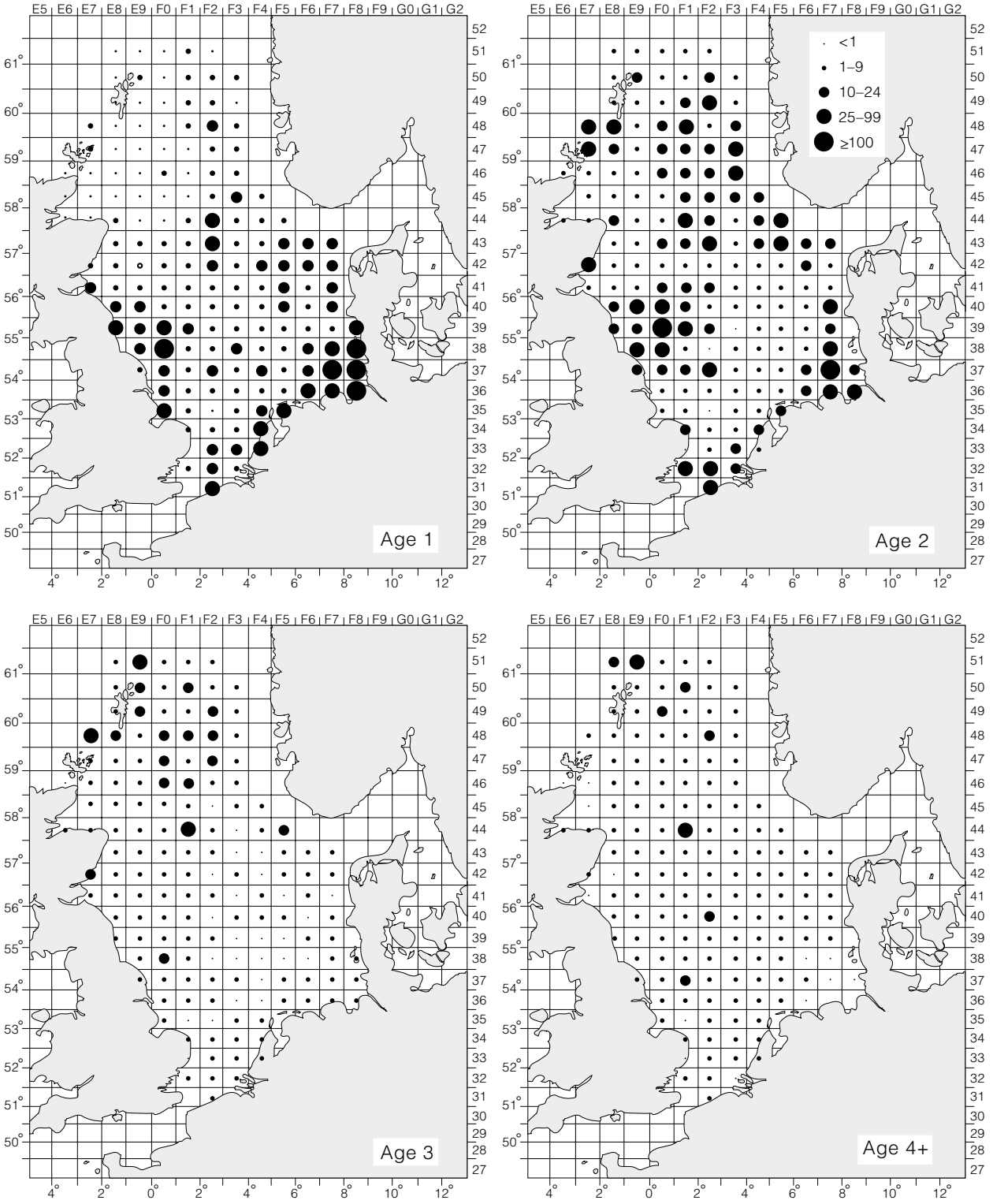

Fig. 3. Distribution of age groups 1, 2, 3 and 4+ cod as mean number per hour fishing. Average for the period 1983–87 from the International Young Fish Survey.

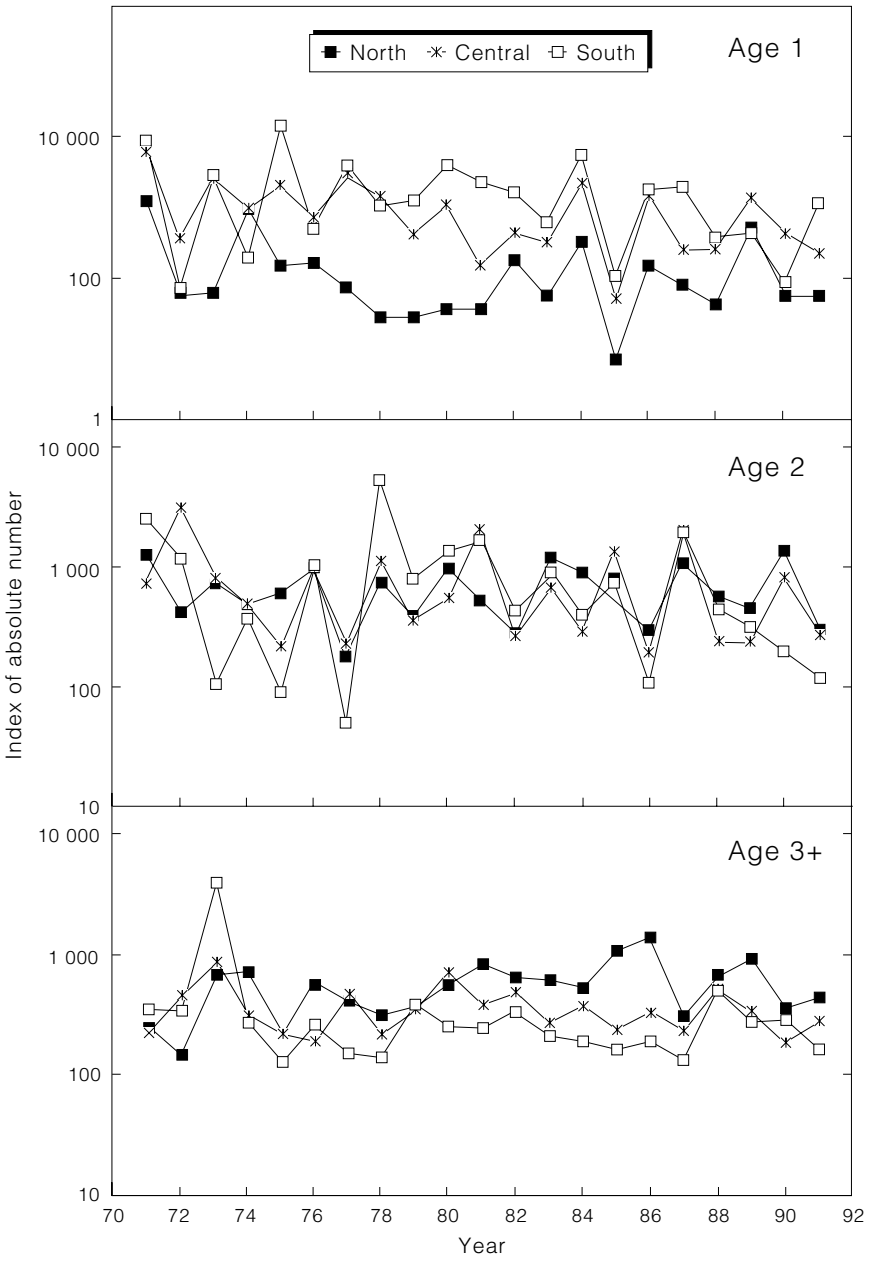

Fig. 4. The mean number-at-age per hour multiplied by the number of rectangles within the area, as an index of the absolute numbers per area. Data from the International Young Fish Survey.

unlikely since migration is known to be limited to distances usually less than 100 miles (Anon., MS 1970 and MS 1971).

The observations on the relation between depth, temperature and salinity are in line with the results of Riley and Parnell (1984) and Buijsse and Daan (MS 1986). In those studies high densities in shallow waters, at low temperatures and low salinities were observed for the youngest age group. In a survey in the Thames estuary in October, Riley and Parnell (1984) also found the highest catch rates of 0-group cod in the tidal reaches of the river.

Older fish were found in warmer water than the young ones (Fig. 6). For Northeast Arctic cod in the Barents Sea, Nakken and Raknes (1987) also found the older age groups consistently in warmer waters. It is not clear what the reasons for these different preferences are. Is it that young cod stay in the area

TABLE 1. Between-area correlation for cod abundance of different age groups. Values are the r^2 for the log of the absolute numbers as plotted in Fig. 4. Log values were used to stabilize the variance.

Areas	Age 1	Age 2	Age 3
North-Central	0.429**	0.212*	0.043
Central-South	0.350**	0.421**	0.362**
North-South	0.082	0.258**	0.019

* P <0.05; ** P <0.01

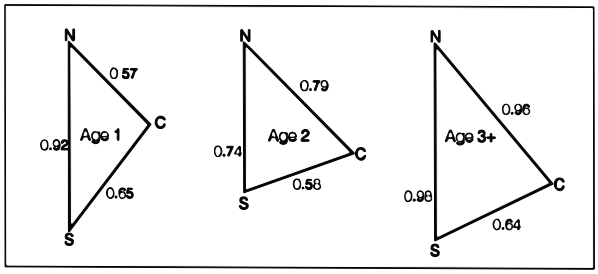

Fig. 5. Similarity plots for cod age groups 1, 2 and 3+. The distance between North (N), Central (C) Central and South (S) is $1-r^2$.

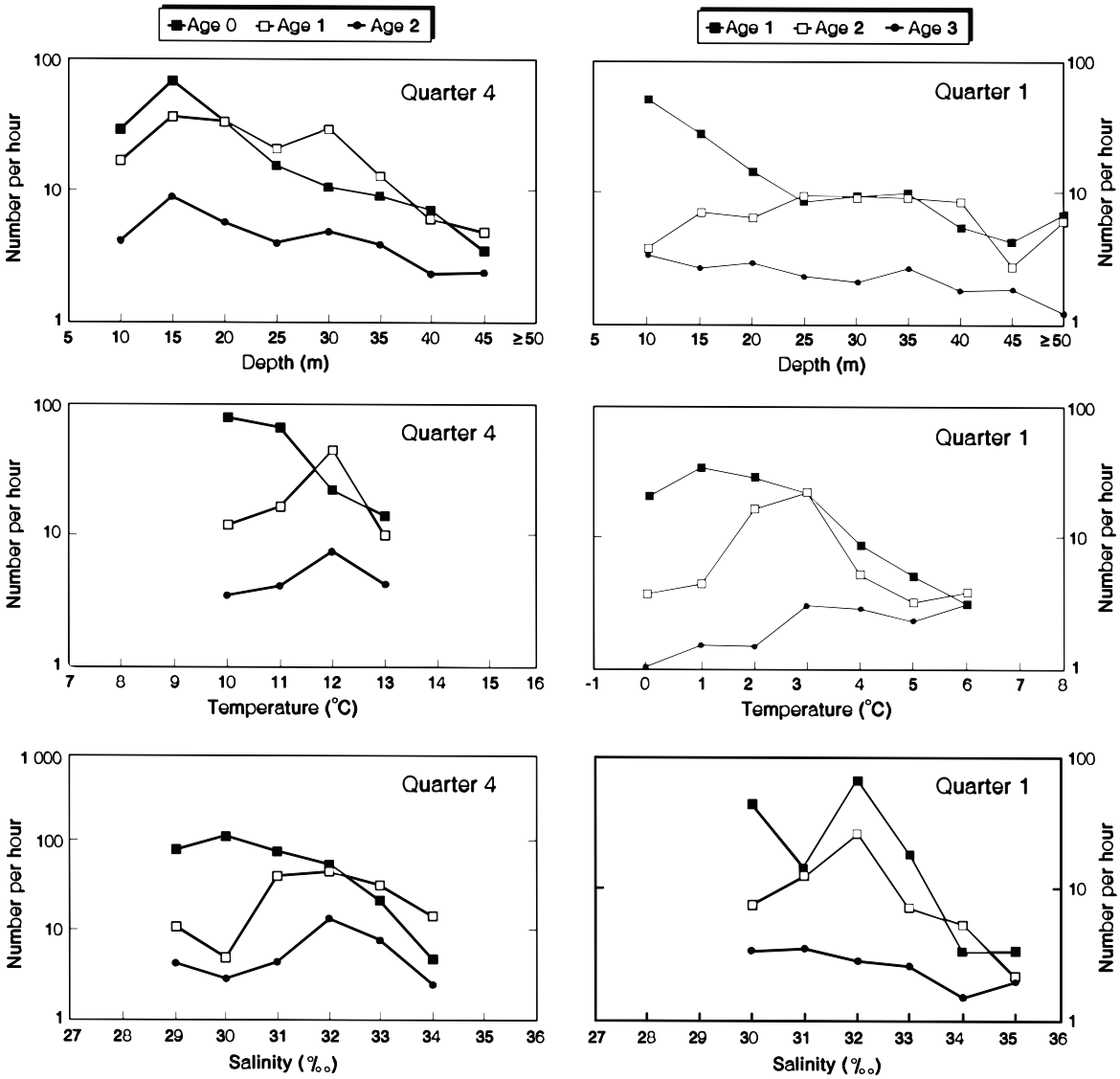

Fig. 6. Mean abundance of age groups 0, 1, 2 and 3 in the 1st quarter and the 4th quarter in the southeastern North Sea plotted against 5 m depth bands, 1°C temperature bands and 1‰ salinity bands. Data from the Dutch Groundfish Survey and from the International Young Fish Survey.

with optimum temperature for feeding/growth, or are they escaping predation by other fish, or are the highest densities observed in areas with maximum prey densities? Nevertheless, the preference of different age groups for different temperatures is relevant for the interpretation of data from many cod surveys, including for example stomach content data.

Although depth, temperature and salinity are interrelated, this was not taken into account in this study. It would also be very interesting to follow the relation between distribution and temperature and salinity in the course of the year. In the southeastern North Sea clear seasonal changes in the distribution of groups 0, 1 and 2 have been observed (Heessen, MS 1983). The changes in the distribution pattern of groups 1 and 2 are very similar: they aggregate in the coastal zone during winter and disperse in a northwesterly direction over deeper parts of the central North Sea in summer. In 1991 a series of quarterly International Bottom Trawl Surveys were started and are intended to continue for a period of at least 5 years (Anon., MS 1990). These surveys will provide interesting material for further studies.

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