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The Distribution of Cod in the North Sea

by

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ABSTRACT

Data for the period 1971-1991 from the International Young Fish Survey are studied to determine possible trends in the abundance of cod in different parts of the North Sea. For the southeastern North Sea, an important nursery area, the relation between abundance of cod and depth, temperature and salinity was studied using data from surveys in October/November (Dutch Groundfish Survey) and in February (International Young Fish Survey).

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INTRODUCTION

This paper is based on data from the International Young Fish Survey (IYFS) which covers the whole North Sea, and the Dutch Groundfish Survey (DGFS) in the southeastern North Sea. After a short introduction of the North Sea cod stock two different 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 North Sea cod.

Data on landings of North Sea cod are available since 1903. From the beginning of this century until the early 1960's total international landings fluctuated between about 60,000 and 130,000 tonnes (Figure 1A). In the 1960's landings increased rapidly and a peak of 340,000 tonnes was reached in 1972. Since 1981 the landings have steadily decreased and more or less reached the pre 1960's level. Landings mainly consist of young fish of age groups 1, 2 and 3. Estimates from Virtual Population Analysis (VPA) of the size of the spawning stock are available since 1963 (Figure 1B). The maximum size of the spawning stock, 270,000 tonnes, was reached in 1970. Spawning stock size has declined more or less steadily since then and is estimated to be around 90,000 tonnes at present. This is well below the level of 150,000 tonnes which is considered to be a 'safe biological limit' for the production of good year classes (Anon., 1988). The cause of the rapid increase in stock size and in landings in the 1960's was a series of very strong year classes which started in 1963 (Daan, 1978). From 1963 onwards the fishing mortality has steadily increased to reach a more or less stable high level of approximately 0.85 since 1980 (Figure 1C). The result of this high fishing mortality is that young cod in the North Sea simply do not get a chance to become mature, which results in the decrease of the size of the spawning stock.

Cod is widely distributed over the North Sea (Figure 2). Data from the International Young Fish Survey in February indicate that age group 1 is usually most abundant in the German Bight, along the Dutch coast and off the coast of northeast England. The distribution of the 2-group is more or less similar but in addition areas of high abundance are found in the northern North Sea. The 3-group is most abundant in the northern North Sea. Cod of 4 years and older occur in a low abundance throughout the North Sea but are almost absent in the shallow parts of the German Bight, and as for the 3-group the highest numbers are found in the northern North Sea.

In this paper changes in abundance in three areas (North, Central and South) of the North Sea are investigated to determine if certain trends in these changes exist and whether the fluctuations in the different areas are correlated.

Buijsse & Daan (1986) analysed 3 year's data (1983-1985) of the International Young Fish Survey for the relation between between depth, temperature and salinity and the abundance of young cod. This study was repeated with a longer data series for the IYFS in winter (February), but also with autumn data from the DGFS (October/November).

MATERIAL AND METHODS

The International Young Fish Survey was held for the first time in 1960 and 1961 and was exclusively aimed at juvenile herring. Only a part of the North Sea was covered. From 1965 onwards the survey was held each year in February. 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. In 1976 a new standard gear after French design was proposed, the GOV, and its introduction was completed in 1978. Haul duration is 30 minutes and trawling is carried out both day and night. The total number of hauls is around 400. Per statistical rectangle (30 x 30 miles) at least 2 hauls are made by two different research vessels. The survey methods are described in Anonymus (1986).

IYFS data for the period 1971-1982 were published in a series of data base reports by Niels Daan (e.g. Daan, 1979). From 1983 onwards, the survey data are stored in the ICES IYFS data base. In this data base hydrographical data are, unfortunately, only available for a limited number of hauls.

The Dutch Groundfish Survey is conducted in October/November and the area covered is restricted to the southeastern North Sea. The main aim of the survey is to provide recruitment indices for cod. The gear and the methods used are the same as for the International Young Fish Survey. The number of hauls per rectangle varies from 1 to 5, with the highest sampling intensity in the coastal area.

IYFS abundance indices were calculated for the years 1971-1991 for the areas North (roundfish sampling area 1 and 3), Central (area 2, 4 and 7) and South (area 5 and 6) as well as for the standard area which comprises most of the North Sea except some coastal rectangles in the German Bight (Figure 3). The standard area is the area used to calculate the 'official' IYFS index for cod as used by the ICES Roundfish Working Group. The indices are calculated by taking the arithmetic mean number at age per hour for all hauls in a certain rectangle and then the arithmetic mean over all rectangles in a certain area.

For the southeastern North Sea, roundfish sampling area 6, data from individual hauls from the IYFS 1981-1989 and DGFS 1981-1990 were used to calculate the mean catch at age per 5m 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 (DGFS) and age groups 1, 2 and 3+ in quarter 1 (IYFS). All data concerning the extreme week year class 1984 were excluded from the analysis. For the 1982 DGFS no temperature or salinity data are available. For each depth, temperature or salinity band the average abundance was calculated (Table 1-3). 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

Changes in abundance in different parts of the North Sea

The changes in abundance of cod in different parts of the North Sea during the last 21 years are shown in different ways in Figures 4 to 7. Figure 4 shows the mean number at age per hour as calculated for areas North, Central and South and for the standard area. In all areas the greatest fluctuations occur in the 1-group. Also the differences in mean number per hour in the three different areas are highest for the 1 group. Annual differences in the 3+ group are relatively small. The mean numbers at age per area were multiplied by the number of rectangles within that area to give the absolute numbers plotted in Figure 5. The contribution of each area to the total absolute number is shown in Figure 6. The bulk of the 1-group is usually caught in area South, but in some years the catches in the Central North Sea dominate. The overall contribution of the three areas to the catch of 2-group cod is roughly equal. Age group 3+ is predominantly caught in area North.

Figure 7 gives 3-year means for the absolute number (as shown in Figure 5). Numbers at age 1 decrease in area South and Central but increase slightly in area North after a minimum in the years '77-'79. The numbers at age 2 fluctuate strongly in the southern North Sea and have decreased to a very low level in the last three years. The 3+ group decreased significantly between the first 2 periods in area South but is rather stable in the rest of the series. The changes in the numbers of the 3+ group definitely do not reflect the strong decrease of the spawning stock which is evident from the VPA (Figure 1C).

Values of r^2 between the three data series are given in Table 4 and similarity plots are shown in Figure 8.

Relation between depth, temperature and salinity an abundance

The average abundance at different depths, temperatures and salinities in quarter 4 and 1 is shown in Figures 9, 10 and 11. Although great annual differences occur some clear

trends exist. In October/November all three age-groups show an increasing abundance with decreasing depth, this tendency is strongest for age 0. In February the 1-group is, again, most abundant in shallow waters, the depth preference of the 2- and 3+ group is less clear due to the high between year variability.

In October/November 0-group fish is most abundant in colder water, whereas 1- and 2-group have a maximum at 12°C. In February the 1-group has again its highest abundance at the lowest temperatures, the 2-group shows a maximum at 3°C and the abundance of the 3+ group increases with increasing temperature.

The 0-group occurs in high densities at low salinities both in autumn and in winter. In the 4th quarter the abundance of 1- and 2-group is highest at salinities of 31 to 33‰, in the first quarter the 2 group still has its highest abundance at 32‰, but the relation between 3+ group and salinity is less pronounced.

DISCUSSION

Although quite significant outliers occur, the pattern in the fluctuations in abundance in different parts of the North Sea is in general rather similar. In the southern North Sea much more 1-group cod is caught than in the northern North Sea. But since the catches of the 2- and 3+ group in the northern North Sea are higher than that of the 1-group in the same area, it can be concluded that either the 1-group in February is not yet completely recruited to the survey gear, or that these fish occur predominantly in areas where it is impossible to fish.
It is rather unexpected that no clear decrease was observed in the catch of the 3+ group. This contradicts the results of the VPA which show a substantial decrease of the spawning stock since 1970 (Anon., 1991). The age groups present in the catch in February mainly consist of individuals of 1, 2 or 3 years old. The catches of the 3+ group as shown in this paper therefore, may not be representative for the size of the spawning stock. Only in the southern North Sea a significant proportion of the 3 group is mature.
The observations on the relation between depth, temperature and salinity are in line with the results of Riley & Parnell (1984) and Buijsse & Daan (1986). In both studies high densities in shallow waters and at low temperatures and low salinities were observed for the youngest age group. For a survey in the Thames estuary in October Riley & Parnell (1984) mention the highest catch rates of 0-group cod in the tidal reaches of the river.
Older fish was found in warmer water than the young ones (Figure 10). For Northeast Arctic cod in the Barents Sea Nakken & Raknes (1987) also found the older age groups consistently in warmer waters. It is not clear what the reasons for these different preferences are. Stay young cod in the area with optimum temperature for feeding/growth, are they escaping predation by other fish, or are the highest densities observed in areas with maximum prey densities? The preference of different age groups for different temperatures is also relevant for the interpretation of 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 0-, 1- and 2-group are observed (Heessen, 1983). The changes in the distribution pattern of 1- and 2-group are very similar: they aggregate in the coastal zone during winter and disperse in north-westerly direction over deeper parts of the central North Sea in summer. This year a series of quarterly International Bottom Trawl Surveys started which are intended to continue for a period of at least 5 years (Anon., 1990). These surveys may provide some interesting material for further studies.

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Table 1. Mean number per hour fishing per year for different age groups in different depth zones, and the number of hauls per year and depth zone.

IYFS, area 6, age 1

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989
5									
10	171.6	21.0		841.8	4.9	18.7	3.0		36.3
15	137.0	32.4	23.7	449.5	7.0	114.6	105.1	10.2	7.7
20	28.2	83.0	17.1	219.9	3.2	30.0	39.9	11.9	3.6
25	124.4	7.4	6.6	39.0	1.0	23.2	14.9	12.4	2.6
30	37.2	110.3	1.1	51.4	1.2	21.9	22.7	8.3	4.3
35	7.5	17.8	27.2	17.1	0.8	145.9	24.5	7.9	9.1
40	5.4	8.5	2.7	8.7	0.5	18.4	82.7	1.3	5.8
45	5.2	15.5	3.8	7.8	1.4	10.0	29.1	5.6	11.1
≥ 50		16.8	9.9	9.6	4.6	1.0	21.7	43.7	26.2

IYFS, area 6, age 2

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989
5									
10	9.4	0.0		2.9	23.9	0.0	0.0		2.4
15	9.0	1.4	20.9	20.7	10.1	1.0	17.2	11.5	32.0
20	19.2	33.8	13.6	19.6	12.8	1.2	4.2	5.5	6.9
25	57.6	4.2	17.8	6.5	117.6	2.0	8.6	0.7	0.9
30	143.5	2.6	1.3	15.3	11.0	1.9	17.1	18.1	5.8
35	32.2	6.7	96.1	1.1	9.1	17.0	29.7	25.8	1.8
40	33.8	9.3	2.1	1.5	8.0	1.6	166.7	0.7	2.1
45	10.9	3.5	3.9	0.2	11.2	0.6	5.5	6.1	1.5
≥ 50		1.9	0.6	0.3	7.7	1.4	84.8	2.2	0.9

IYFS, area 6, age 3

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989
5									
10	0.8	0.0		0.0	1.1	0.0	0.0		16.4
15	0.0	0.0	1.3	1.2	0.1	1.0	0.1	8.9	13.0
20	1.4	2.1	2.1	1.9	2.4	1.9	0.0	12.9	5.5
25	4.2	3.2	1.3	1.7	3.0	1.4	0.3	3.0	2.0
30	3.3	0.4	1.0	2.7	1.0	2.4	0.5	4.0	1.0
35	2.0	4.7	2.5	0.3	0.5	2.0	0.6	14.5	1.6
40	1.6	5.7	1.2	1.0	0.7	0.9	0.9	0.4	0.8
45	2.2	2.9	1.1	0.1	1.9	0.7	0.2	5.6	0.4
≥ 50		0.7	0.0	0.3	0.0	0.6	0.6	0.1	0.9

Number of hauls

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989
5									
10	2	2		3	9	3	4		6
15	4	10	11	15	5	24	18	8	13
20	11	19	23	34	30	30	23	13	15
25	16	15	17	20	25	29	28	13	12
30	7	12	11	15	23	16	17	7	16
35	15	14	6	15	22	28	20	5	9
40	20	29	20	25	28	30	35	21	29
45	15	9	17	10	17	21	14	13	14
≥ 50		6	2	6	7	2	9	2	6

DGFS, area 6, age 0

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5				0.0			15.8			
10	576.0	11.0	240.0	3.0	51.3	151.8	54.7	81.9	36.4	163.8
15	76.0	56.4	290.0	7.1	835.5	383.9	332.0	62.1	20.6	166.2
20	480.7	25.9	352.9	3.5	171.2	43.3	65.1	85.2	30.3	8.9
25	98.3	39.9	14.4	0.2	161.2	34.6	170.4	5.3	22.7	1.6
30		20.9	40.0	0.0	110.0	98.0	5.1	14.1	20.8	0.7
35	50.7	4.0	62.0	3.7	151.6	4.7	8.5	5.2	19.4	1.6
40	6.0	4.9	38.9	0.0	161.5	7.7	4.0	9.4	18.2	0.0
45	2.0	0.0	8.7	0.0	8.5	5.6	1.5	9.4	17.5	
≥ 50	12.0	0.0	1.0	0.0		0.0		0.0	14.0	0.0

DGFS, area 6, age 1

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5				40.1			0.2			
10	402.7	0.5	4.0	74.2	0.2	205.5	0.0	27.5	22.7	53.8
15	336.7	50.6	13.5	197.7	1.3	203.7	583.6	27.5	36.6	13.7
20	68.9	296.0	60.4	475.2	0.8	165.6	86.8	57.6	30.7	2.7
25	27.6	28.4	3.8	187.7	1.1	183.8	255.8	11.9	28.3	3.5
30		4.9	43.2	77.9	14.1	664.2	131.9	28.0	26.3	8.8
35	55.3	39.3	6.6	230.4	3.6	33.3	15.7	17.9	24.6	22.0
40	1.3	31.5	25.4	20.7	6.4	44.2	19.3	10.3	23.2	2.0
45	2.3	14.3	2.8	25.4	11.0	11.0	12.3	9.6	23.1	
≥ 50	0.0	12.0	0.8	2.0		6.0		4.0	14.0	0.0

DGFS, area 6, age 2

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5				3.6			0.0			
10	19.3	1.0	1.7	3.5	0.3	0.9	2.5	3.6	4.4	7.6
15	73.3	0.8	2.1	2.1	2.6	0.0	99.1	4.0	6.1	3.6
20	8.3	4.3	4.9	7.1	4.1	0.8	19.1	6.0	5.6	1.8
25	16.8	0.7	0.7	2.0	2.4	0.5	15.5	1.5	6.4	1.3
30		0.7	10.2	0.6	4.1	1.0	17.2	3.9	5.8	1.5
35	15.6	0.8	1.5	4.2	3.1	0.1	1.9	2.0	4.9	2.9
40	0.0	1.4	1.6	0.4	5.3	0.2	2.6	0.0	4.5	0.4
45	0.7	0.7	0.3	0.5	5.2	0.0	1.0	0.0	4.2	
≥ 50	0.0	0.0	0.5	0.0		0.0		0.0	0.0	0.0

Number of hauls

depth	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5				3			1			
10	1	1	1	7	6	4	3	3	3	5
15	1	4	4	18	16	12	15	14	10	18
20	6	5	13	12	16	18	20	17	18	18
25	7	4	7	9	13	13	8	15	16	15
30		5	4	11	5	6	7	12	5	6
35	6	1	6	10	12	14	18	10	16	14
40	3	8	6	7	10	11	9	14	9	11
45	2	2	6	7	4	7	8	4	7	
≥ 50	1	1	3	1		1		1	2	1

Table 2. Mean number per hour fishing per year for different age groups in different temperature ranges, and the number of hauls per year and depth zone.

IYFS, area 6, age 1

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989
-1						103.6	33.6		
0					7.2	69.7	78.4		
1		78.2		418.3	0.8	22.4	84.5		
2	11.2	143.2	3.7	270.6	0.4	34.6	145.1		
3	35.5	14.9	36.0	433.5	0.3	27.0	22.7		
4	5.1	25.4	12.9	99.3	0.8	20.1	13.0	10.0	31.3
5	2.1	22.2	7.8	30.3	0.3	5.4	10.5	9.4	11.2
6	3.9	97.5	0.0	7.3		7.8		7.7	4.2
7			12.5	24.3		25.7		13.7	7.8
8								22.5	2.0

IYFS, area 6, age 2

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989
-1						0.1	2.9		
0					13.7	0.3	3.0		
1		1.3		0.4	33.4	1.4	7.5		
2	20.7	2.9	3.7	6.9	13.3	1.7	266.4		
3	26.1	9.6	181.2	31.4	134.7	1.1	7.8		
4	21.8	17.3	9.5	7.5	2.3	1.5	38.6	0.9	2.4
5	6.8	2.5	20.4	2.3	1.5	0.7	136.5	8.4	3.5
6	25.3	24.3	0.0	1.5		0.2		5.1	13.4
7			44.6	60.5		2.3		3.3	8.1
8								100.4	15.5

IYFS, area 6, age 3

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989
-1						0.0	0.0		
0					0.1	0.0	0.0		
1		0.2		0.0	1.2	2.0	0.0		
2	0.9	0.0	2.8	0.0	0.4	1.3	1.1		
3	0.9	2.7	12.0	3.8	1.9	1.4	0.2		
4	1.8	3.1	1.9	1.2	0.2	1.2	0.8	3.1	16.7
5	1.8	3.9	1.3	0.6	0.7	0.0	3.3	7.1	5.4
6	0.9	21.6	0.2	1.5		2.4		7.0	5.0
7			10.0	12.5		1.1		13.9	6.5
8								70.3	4.4

DGFS, area 6, *number of hauls*

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989
-1						8	5		
0					20	14	10		
1		11		3	19	30	16		
2	1	9	6	5	19	25	23		
3	6	22	14	14	17	27	35		
4	19	37	37	41	20	33	29	1	6
5	8	6	47	25	7	2	1	9	5
6	1	1	1	6		1		11	33
7			1	1		1		5	9
8								2	1

DGFS, area 6, age 0

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
7										
8	38.0									265.0
9	9.0			0.0		1498.3				
10	314.0		358.0	6.4		146.6	47.9	144.8		634.0
11	115.6		245.7	0.3	1468.7	78.1	203.4	7.9		66.0
12	40.0		102.7	13.2	410.0	46.6	62.6	14.6	21.9	8.8
13			41.5	0.0	277.5		3.8	16.8	22.3	0.0
14				0.0	109.1		0.0		9.3	
15				0.0	91.0				0.0	
16										

DGFS, area 6, age 1

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
7										
8	168.3									23.0
9	0.0			68.6		697.7				
10	94.9		69.3	35.5		99.6	7.8	13.3		8.5
11	36.2		19.8	163.7	0.4	246.3	74.9	8.9		9.5
12	0.0		27.6	561.4	1.2	695.9	342.5	38.4	9.1	19.1
13			18.0	318.7	5.3		61.4	35.8	29.6	4.2
14				79.7	2.9		12.0		24.8	
15				4.0	3.8				2.0	
16										

DGFS, area 6, age 2

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
7										
8	36.7									5.7
9	0.0			4.3		0.0				
10	13.2		2.7	0.6		0.1	0.9	2.1		2.5
11	23.1		1.8	3.3	2.9	0.6	5.2	1.3		3.2
12	0.0		2.6	11.5	3.0	3.4	56.5	4.4	2.0	4.5
13			3.1	0.2	4.0		13.3	2.2	6.6	1.0
14				0.6	2.6		9.0		3.0	
15				0.0	5.9				0.0	
16										

DGFS, area 6, number of hauls

temp	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
7										
8	2									1
9	2			2		2				
10	12		2	7		10	7	14		4
11	5		14	8	6	22	28	24		15
12	1		10	14	16	5	31	39	18	13
13			12	9	15		20	12	30	5
14				16	24		2		35	
15				1	9				1	
16										

Table 3. Mean number per hour fishing per year for different age groups in different salinity ranges, and the number of hauls per year and depth zone.

IYFS, area 6, age 1

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989
26									71.0
27									
28				257.1			2.7		11.0
29		13.0	10.1	375.9		255.9			24.0
30	11.2	25.0	44.8	283.5		381.6		6.9	11.6
31	2.0	9.8	6.9	224.9	0.8	33.9	16.0	3.0	7.2
32	132.4	407.7	25.4	832.4	3.1	27.4	0.0	11.8	4.0
33	4.7	22.5	34.4	361.3	0.7	29.1	0.7	26.0	7.6
34	1.8	9.2	3.3	41.2	0.8	15.0	6.0	2.0	1.2
35			3.3	12.7	0.0	15.3		3.3	28.0

IYFS, area 6, age 2

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989
26									0.0
27									
28				3.9			0.0		0.0
29		0.0	30.6	0.1		1.7			11.2
30	20.7	0.0	34.9	0.5		0.1		5.0	3.9
31	21.5	0.4	11.5	9.9	33.4	1.1	0.0	4.5	75.8
32	25.2	6.9	194.5	61.9	90.1	1.3	0.0	28.7	2.9
33	59.0	19.8	59.7	15.2	9.0	1.7	0.7	0.0	2.0
34	6.3	0.9	4.1	5.1	76.7	1.1	8.8	0.0	0.6
35			0.1	7.7	3.6	0.8		1.3	0.0

IYFS, area 6, age 3

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989
26									0.9
27									
28				1.0			0.0		5.8
29		0.0	7.3	0.0		0.4			2.5
30	0.9	0.0	4.6	0.0		0.0		16.9	4.9
31	2.3	0.0	2.8	1.7	3.1	1.5	0.0	8.5	20.8
32	0.6	0.6	3.7	6.8	2.4	2.0	0.0	6.5	3.7
33	1.2	5.1	8.6	1.8	0.3	0.8	0.0	0.0	2.3
34	1.6	1.1	1.4	0.9	0.9	1.2	0.1	0.5	0.7
35			0.4	5.6	0.4	0.5		1.4	0.0

IYFS, area 6, number of hauls

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989
26									2
27									
28				1			3		2
29		2	1	2		1			1
30	1	2	4	2		3		2	5
31	1	7	7	4	3	17	1	1	5
32	2	3	12	6	5	17	1	2	6
33	2	10	19	9	10	10	3	1	5
34	10	13	48	68	33	29	13	4	12
35			9	3	3	10		3	2

DGFS, area 6, age 0

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
27										
28	76.0					228.3	116.0	177.6		
29			269.6		1280.0	881.1	95.4	104.7	42.9	0.0
30	576.0		520.0		1572.0	18.9	232.0	218.3	44.5	243.0
31	632.0		497.1		532.9	227.7	298.6	33.3	88.2	31.0
32	801.3		186.6		152.5	43.7	174.9	26.7	28.3	293.3
33	146.5		94.8		383.0	69.4	28.5	5.5	23.4	2.4
34	15.1		15.6		33.3	44.9	0.8	8.6	5.6	0.6
35					0.0		0.0		0.0	0.0
36										

DGFS, area 6, age 1

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
27										
28	336.7			297.0		23.7	2.0	82.4		
29			75.7			155.6	5.6	0.7	12.1	2.0
30	402.7		2.0	4.0		44.2	6.9	1.6	47.7	11.0
31	261.3		54.4	390.2		334.7	68.7	16.7	127.9	21.2
32	81.2		25.3	243.7		110.7	659.2	65.8	25.5	5.5
33	99.8		29.3	70.9		321.0	318.8	68.9	30.8	22.4
34	1.2		6.1	32.6		412.3	7.6	11.5	9.3	9.7
35							11.2		16.9	3.6
36										

DGFS, area 6, age 2

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
27										
28	73.3			1.8			6.9	7.1		
29			6.4		4.0		0.4	2.9	7.4	0.0
30	19.3		2.0	0.0	4.2		1.1	1.4	7.6	2.6
31	6.7		3.9	1.1	1.1		11.6	6.0	10.2	3.9
32	37.2		2.1	2.8	5.1		113.8	6.6	5.2	2.2
33	33.8		4.9	1.1	6.2		32.7	2.3	10.7	4.9
34	0.1		1.3	0.8	3.2		1.7	1.6	0.7	5.3
35					1.0		0.9		1.8	0.8
36										

DGFS, area 6, number of hauls

sal	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
27										
28	1			2		1	2	1		
29			1		1	3	3	3	3	1
30	1		1	1	6	4	3	7	2	3
31	1		6	6	7	9	13	8	2	2
32	3		2	7	12	8	14	10	20	10
33	4		9	5	4	6	11	11	11	12
34	11		19	22	23	7	40	43	41	5
35					2		1		3	5
36										

Table 4. Between area correlation for the different age groups: values of r^2 for the log of the absolute number.

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

* $p < 0.05$; ** $p < 0.01$

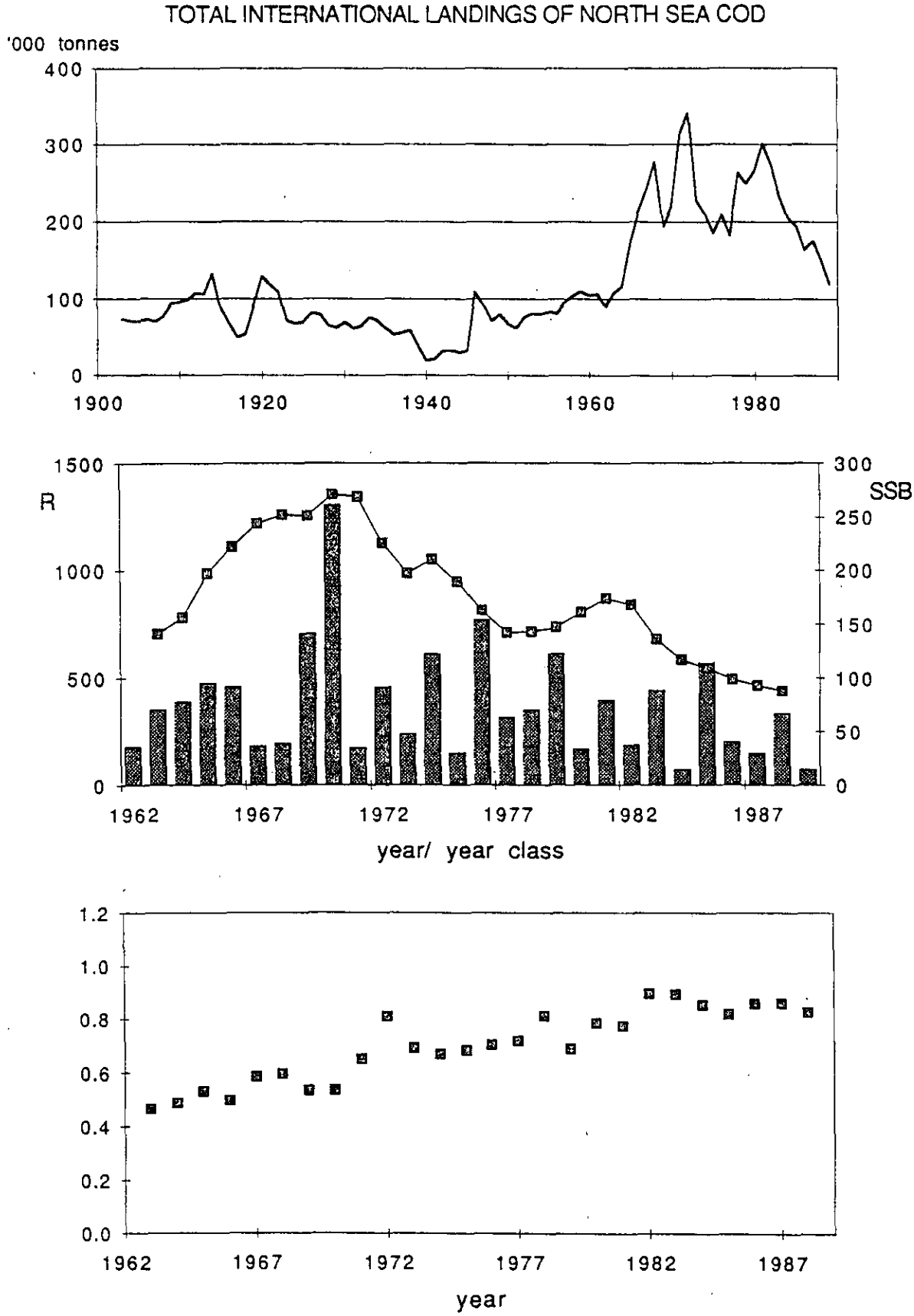

Figure 1. A: Total international landings of North Sea cod since 1903.
B: Recruitment index at age 1, calculated from the number of 1-year olds in the VPA (R in millions) and the 1- and 2-group index from the International Young Fish Survey (updated from Rijnsdorp et al., 1991) and the size of the spawning stock biomass since 1963 (Anon., 1991).
C: Fishing mortality since 1963 (Anon., 1991)

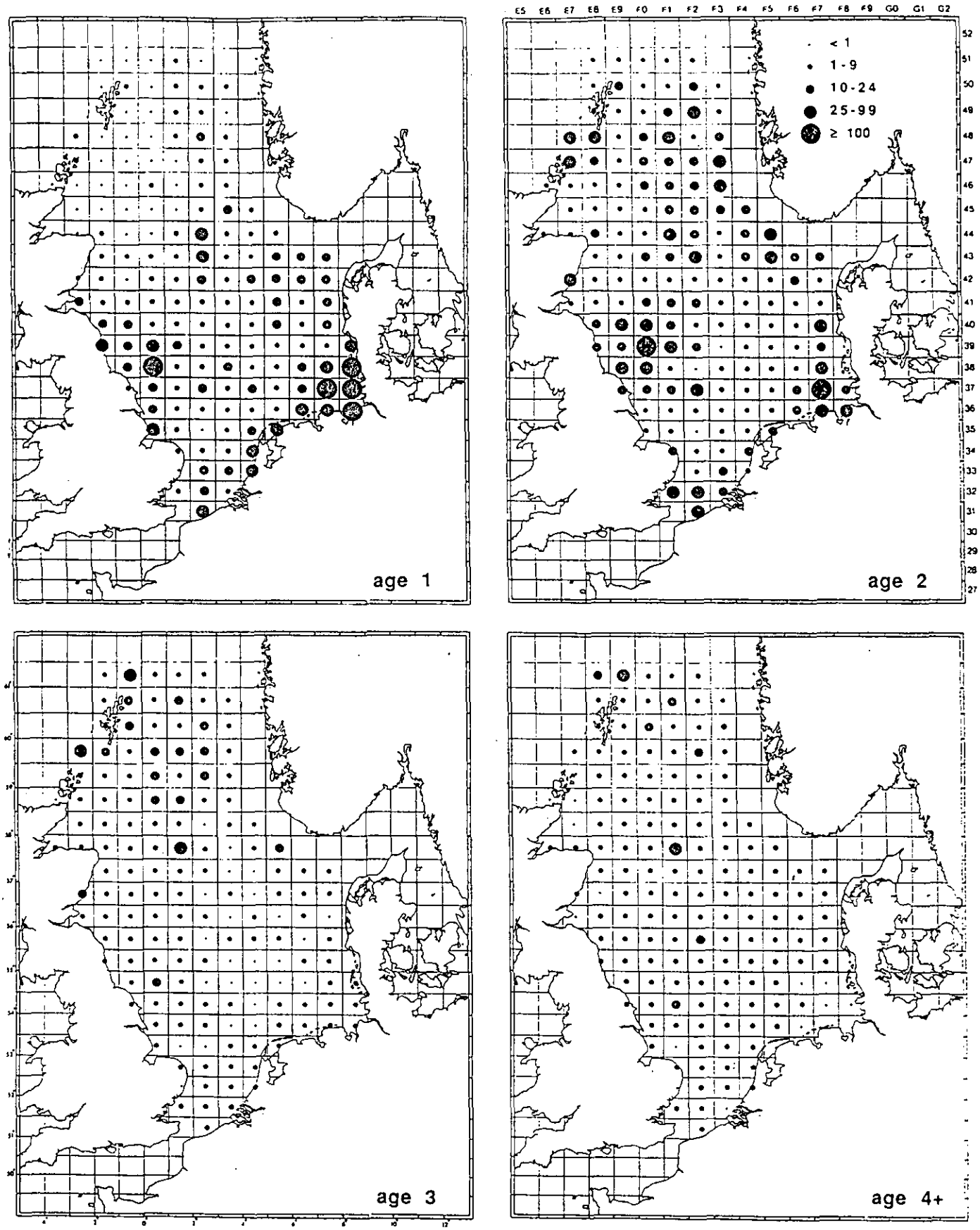

Figure 2. Distribution of 1, 2, 3 and 4+ cod. Average for the period 1983-1987. Data from the International Young Fish Survey.

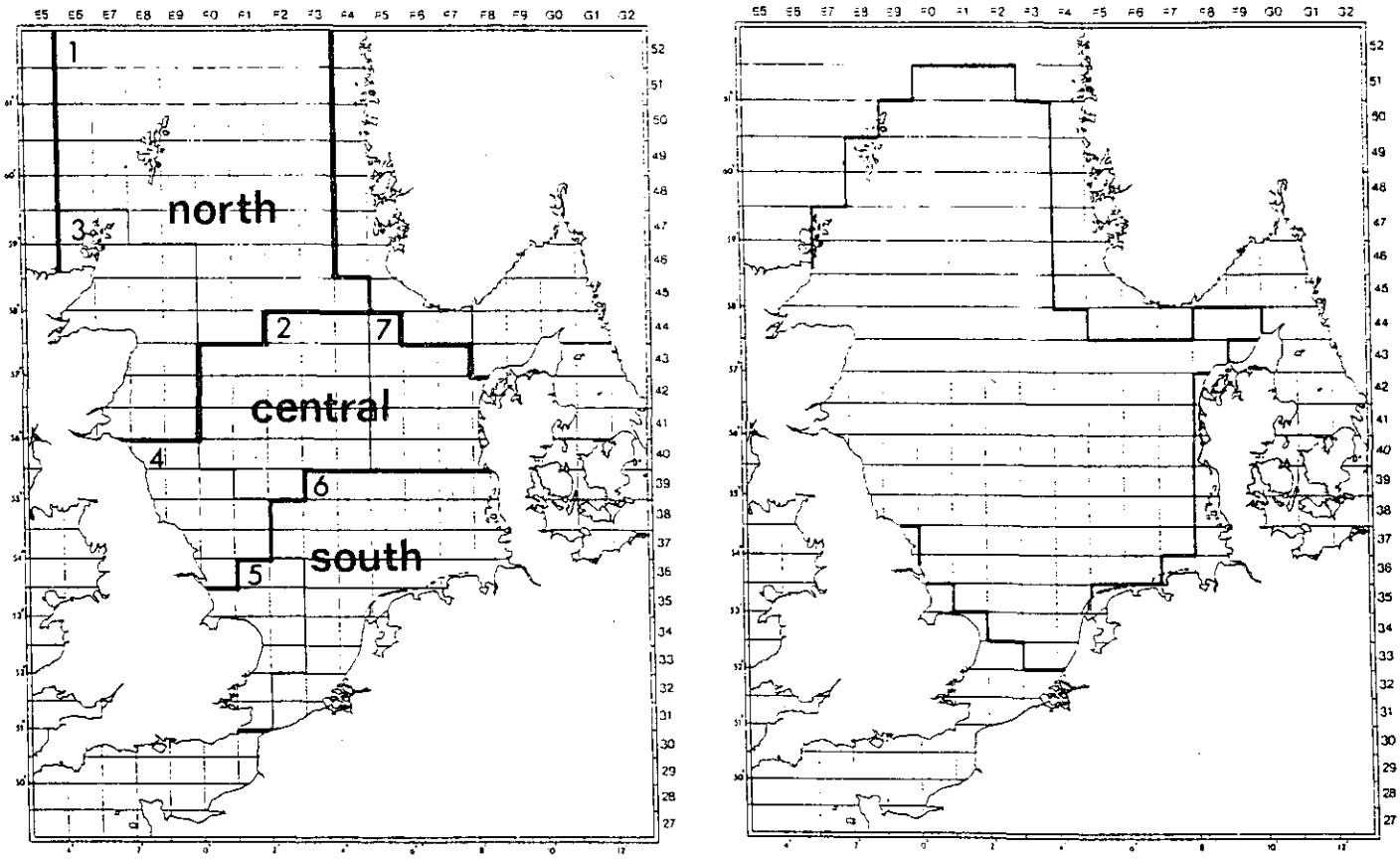

Figure 3. Areas used in the analysis. Left: areas north (roundfish area 1 and 3), central (2, 4 and 7) and south (5 and 6). Right: standard area used for the calculation for the IYFS index of cod.

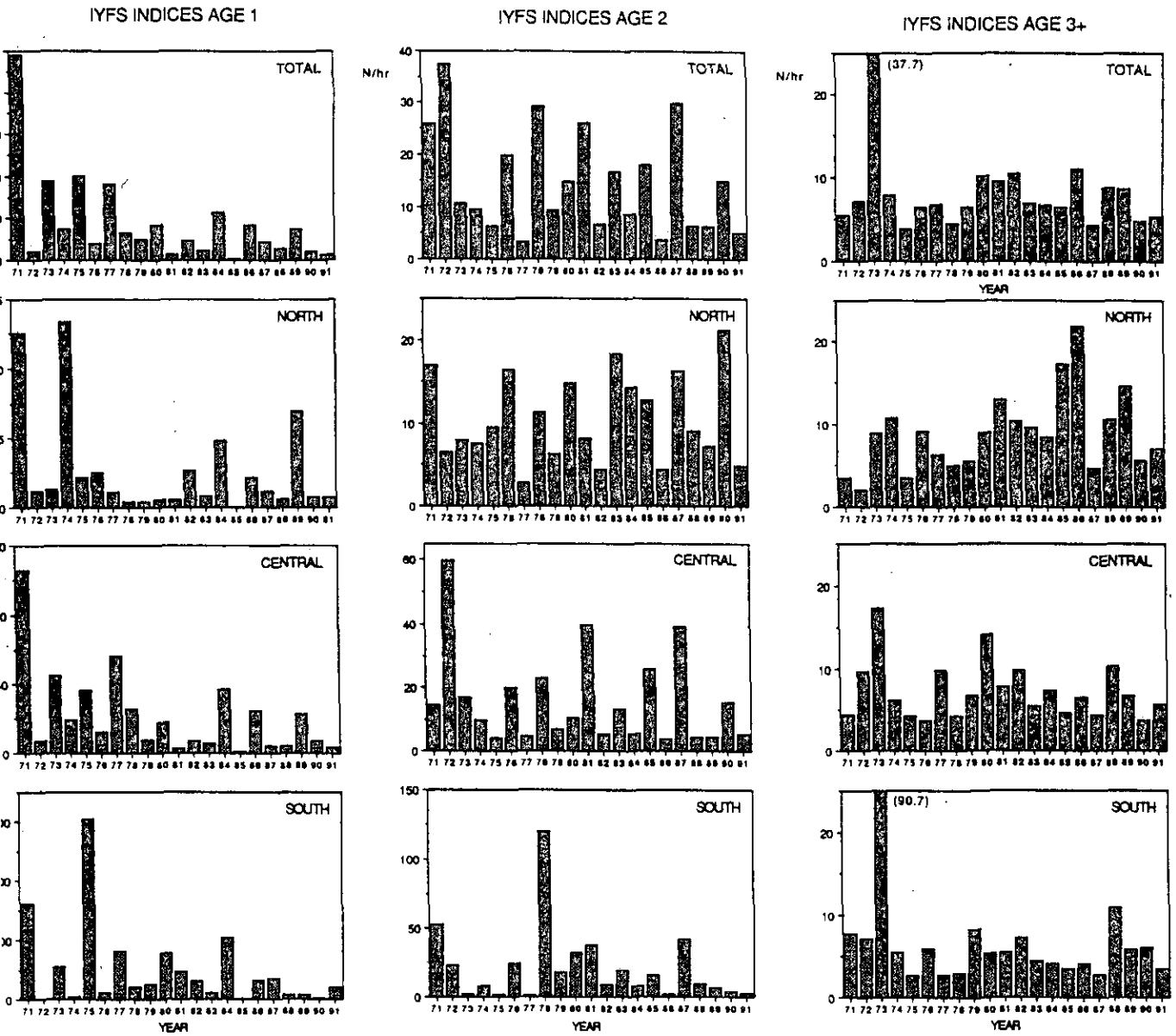

Figure 4. Average catch as mean number per hour fishing per age, for different areas in the International Young Fish Survey in the period 1971-1991. Note that for ages 1 and 2 different scales are used for each area!

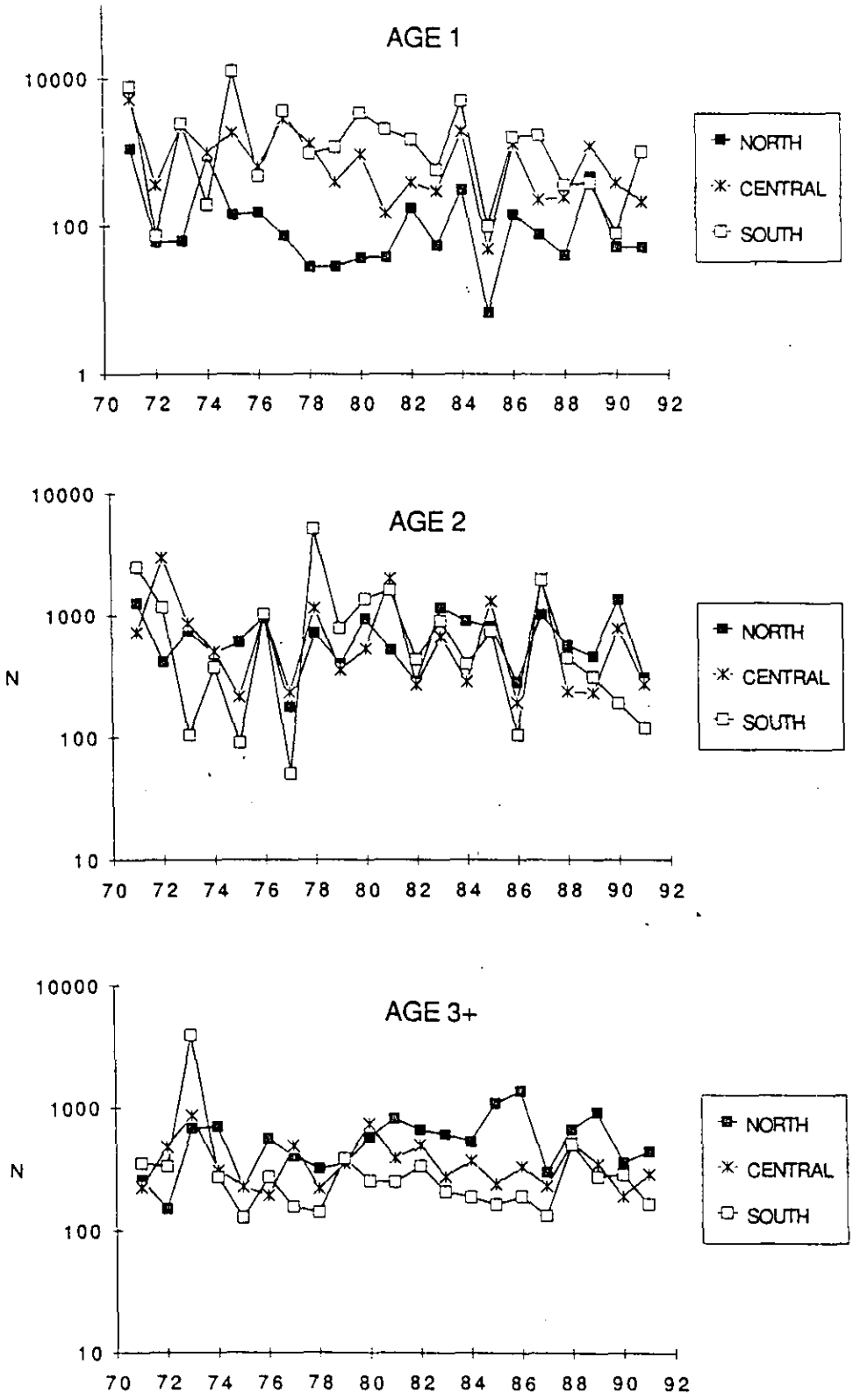

Figure 5. Absolute numbers per age group per area in the International Young Fish Survey.

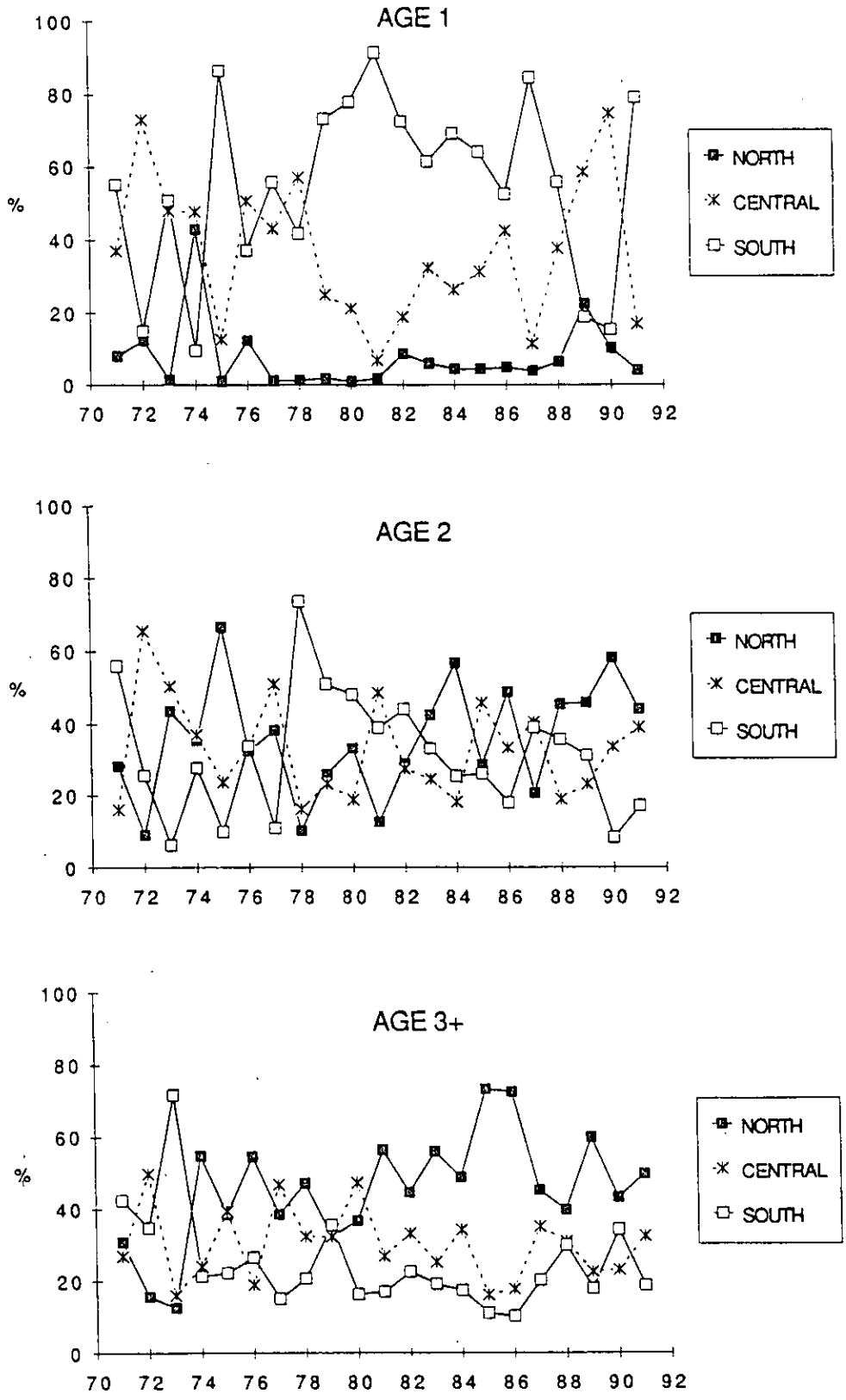

Figure 6. Percentage of the absolute number for each area in the International Young Fish Survey.

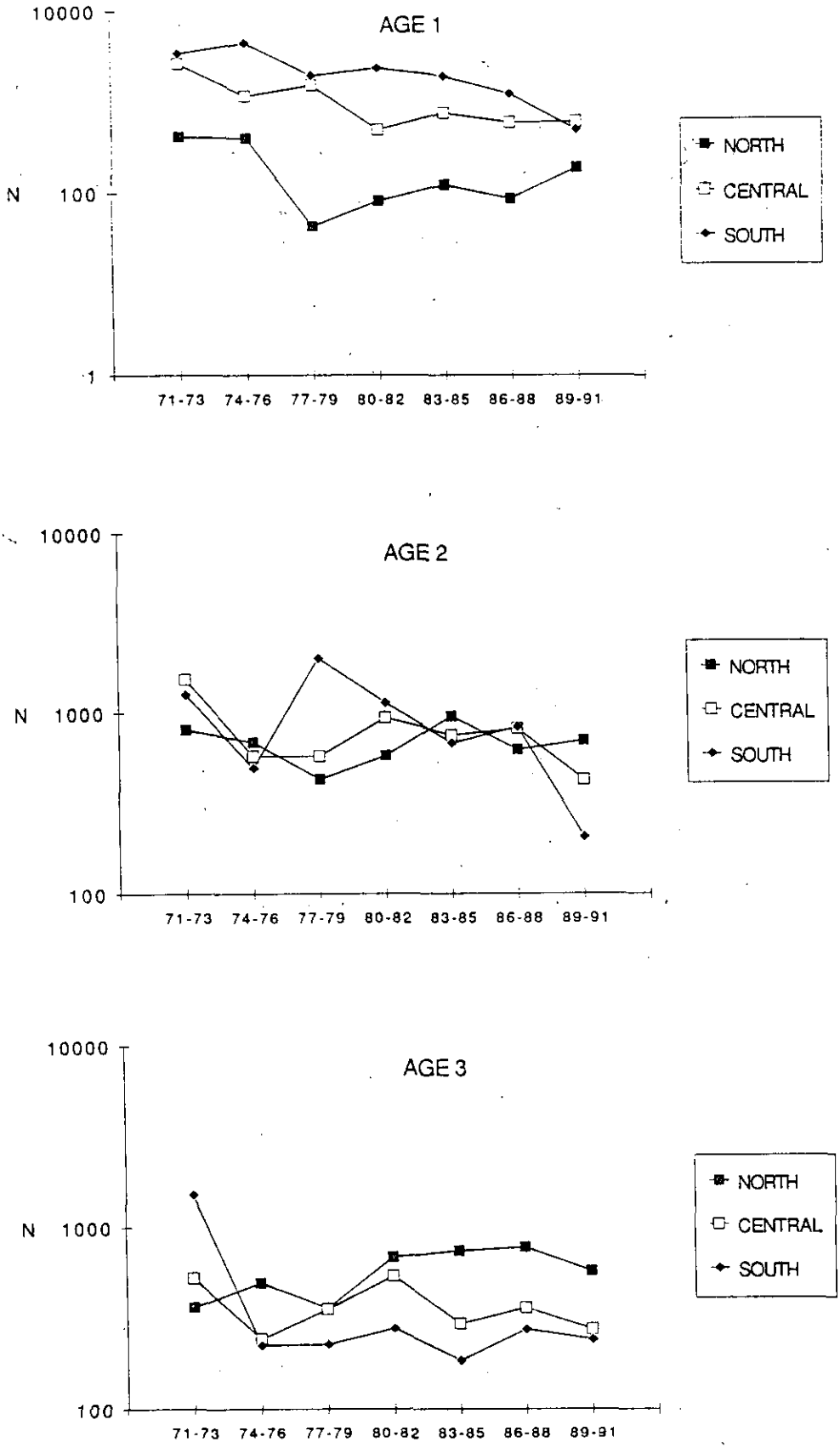

Figure 7. Three year means of the absolute numbers per age group per area as shown in Figure 5.

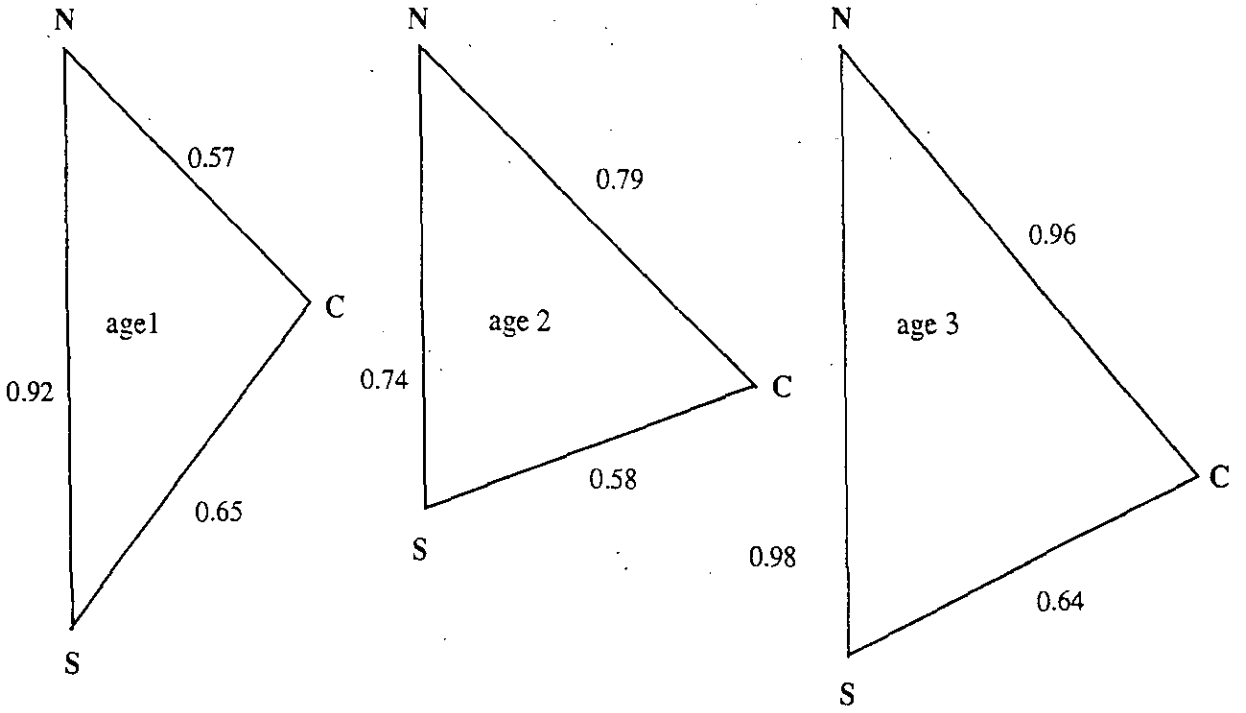

Figure 8. Similarity plots for age groups 1, 2 and 3+. The distance between North, Central and South is $1-r^2$.

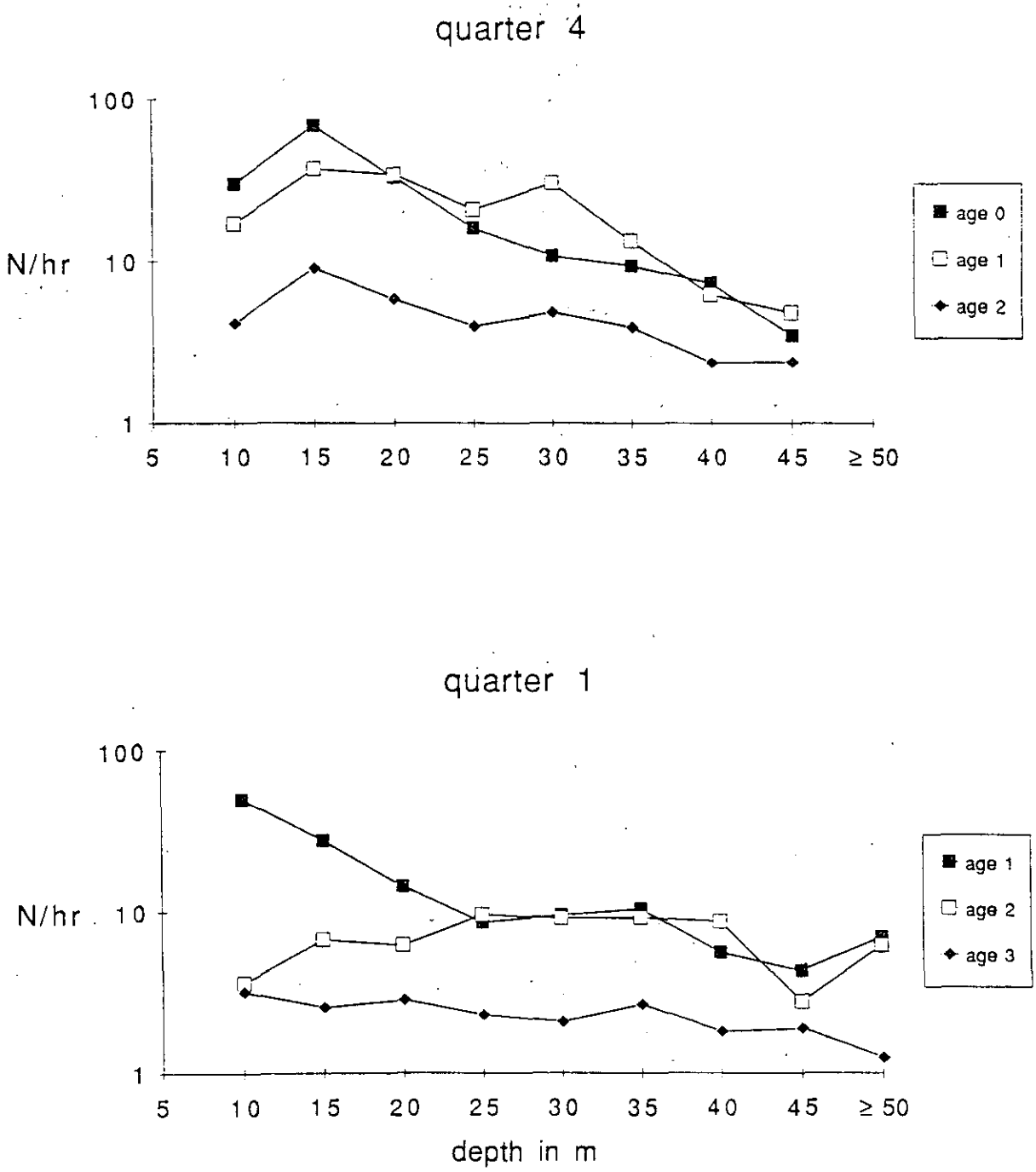

Figure 9. Mean abundance per age group per 5 meter depth zone in quarter 4 and 1 in the southeastern North Sea. Data from the Dutch Groundfish Survey and from the International Young Fish Survey.

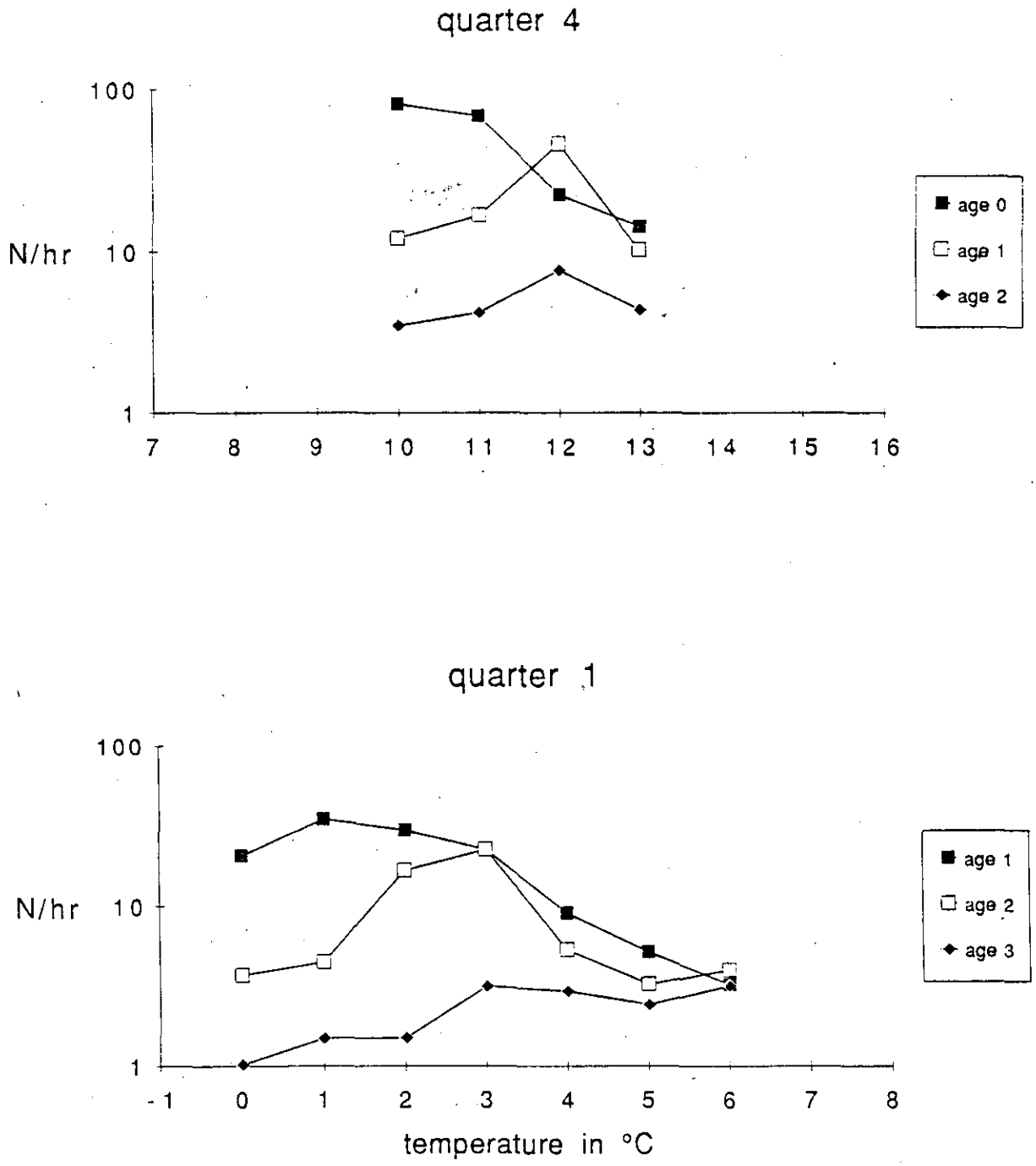

Figure 10. Mean abundance per age group per 1°C temperature zone in quarter 4 and 1 in the southeastern North Sea. Data from the Dutch Groundfish Survey and from the International Young Fish Survey.

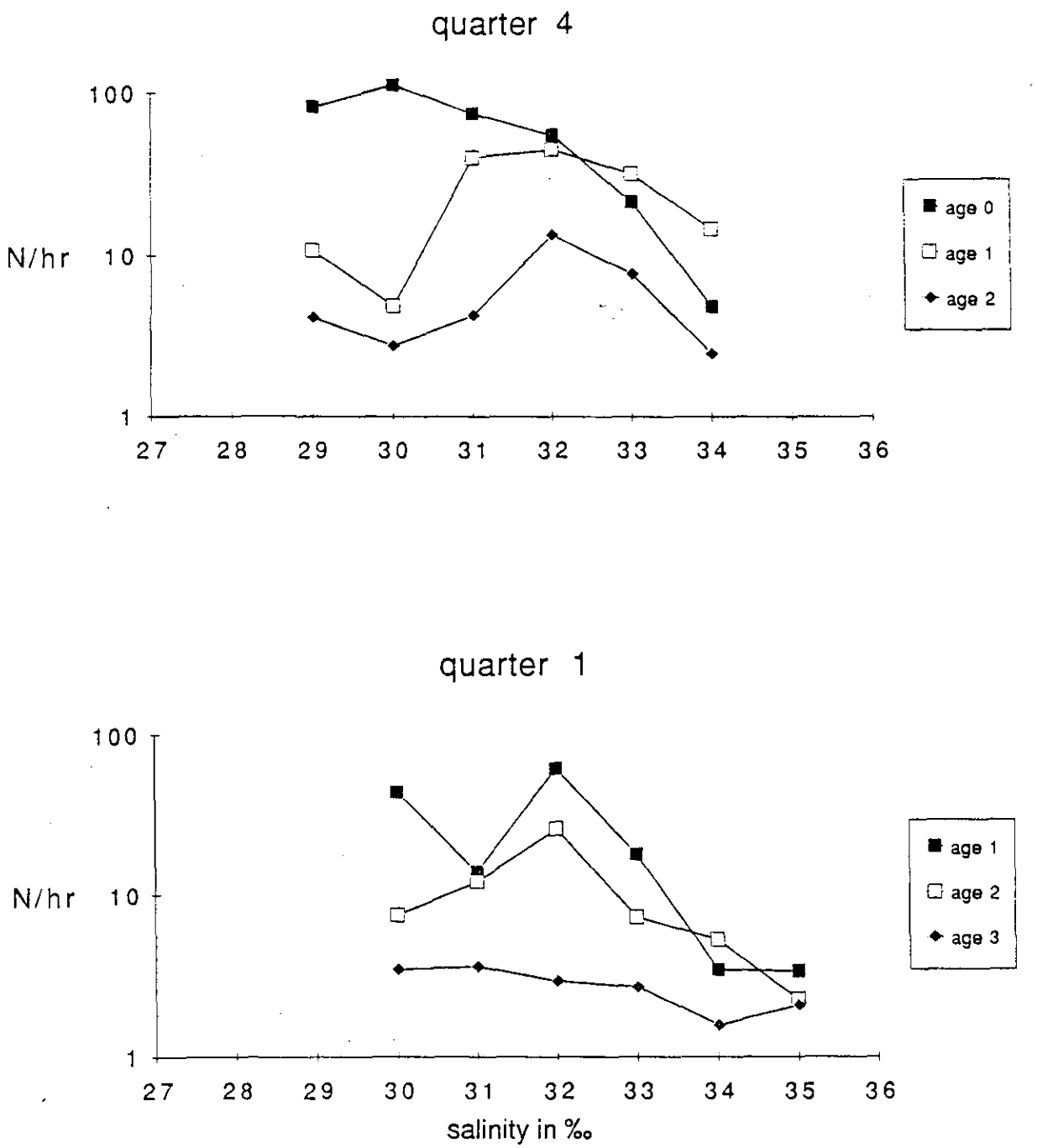

Figure 11. Mean abundance per age group per 1‰ salinity zone in quarter 4 and 1 in the southeastern North Sea. Data from the Dutch Groundfish Survey and from the International Young Fish Survey.