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ICES COORDINATED ACOUSTIC SURVEY OF ICES DIVISIONS IIIa, IVa, IVb AND Via (NORTH) 2002 Results and long term trends

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ABSTRACT

Six surveys were carried out during late June and July covering most of the continental shelf north of 54°N in the North Sea and to the west of Scotland to a northern limit of 62°N. The eastern edge of the survey area was bounded by the Norwegian and Danish, Swedish and German coasts, and to the west by the shelf edge between 200 and 400 m depth. The surveys are reported individually in the report of the planning group for herring surveys, and a combined report has been prepared from the data from all surveys. The combined survey results provide spatial distributions of herring abundance by number and biomass at age by statistical rectangle; and distributions of mean weight and fraction mature at age. The estimates of North Sea autumn spawning herring are consistent with previous years at 2.9 million tonnes and 17,200 million herring. The survey also shows two exceptional year classes of herring (the 1998 and 2000 year classes) in the North Sea, which is consistent with the observation of exceptionally large year classes observed in the MIK and IBTS surveys. The estimates of Western Baltic spring spawning herring SSB are 255,000 tonnes and 2.9 millions (Table 2) and show a large increase compared with the previous year. The Western Baltic survey produces a rather noisy signal but the indications are of a stock that is higher now than between 1996 to 2000. The West of Scotland survey estimates of 548,000 tonnes and 2,900 million and shows the high 1995 year class again this year. The 1998 year class now (3 ring) is also a large one. Total adult mortality shows much lower mortality than last year (0.1 compared to 0.5) but the mean mortality over the last 4 years has been 0.3: this is consistent with the 2002 assessment that the stock is lightly exploited.

The overall time series of abundance by age from 1989 to 2002 are summarised by simple models describing the spatial distribution over time. The changes over time with latitude, longitude and area occupied are compared with changes in abundance.

INTRODUCTION

Six surveys were carried out during late June and July covering most of the continental shelf north of 54oN in the North Sea and 56oN to the west of Scotland to a northern limit of 62oN.

The eastern edge of the survey area is bounded by the Norwegian, Danish, Swedish and German coasts, and to the west by the shelf edge at approximately 200 m depth. The surveys are reported individually in appendices IIa-f of the report of the planning group for herring surveys (ICES, 2003). The vessels, areas and dates of cruises are given below and in Figure 1:

Vessel	Period	Area
Charter west Scotland	01 July – 21 July	56°- 60°N, 3° - 7° W
G.O. Sars	27 June – 20 July	56°30'- 62° N, 2° - 6° E
Scotia	27 June – 17 July	58°- 62° N, 4° W - 2° E
Tridens	24 June – 19 July	54°30 – 58° N, west of 3° E
Walther Herwig III	21 June – 12 July	53° 30' - 57° N, east England / 3° E
Dana	25 June – 8 July	North of 57° N, east of 6° E

The data have been combined to provide an overall estimate. Estimates of numbers at age, maturity stage and mean weights at age are calculated as weighted means of individual survey estimates by ICES statistical rectangle. The weighting applied is proportional to the length of survey track for each vessel that has covered each statistical rectangle. The data have been combined and estimates of North Sea autumn spawning herring, Western Baltic spring spawning herring, and West of Scotland (VIa_{north}) herring are shown in Tables 1-3.

METHODS

The acoustic surveys were carried out using Simrad EK60, EK500 or EY500 38 kHz sounder echo-integrator with transducers mounted on the hull, drop keel and towed bodies. Further data analysis was carried out using either BI500, Echoview or Echoann software. The survey track was selected to cover the area giving a basic sampling intensity over the whole area based on the limits of herring densities found in previous years. A transect spacing of 15 nautical miles was used in most parts of the area with the exception of some relatively high density sections east of Orkney, east and west of Shetland, and in the Skaggerak where short additional transects were carried out at 7.5 nmi spacing.

The following target strength to fish length relationships have been used to analyse the data:

herring	TS = 20 log L - 71.2 dB
sprat	TS = 20 log L -71.2 dB
gadoids	TS = 20 log L - 67.5 dB
mackerel	TS = 21.7 log L - 84.9 dB

Combined Acoustic Survey Results for 2002

The estimates of North Sea autumn spawning herring SSB are 2.9 million tonnes and 17,200 millions herring (Table 1). The North Sea survey is consistent with previous years, giving a total adult mortality of about 0.39 over the last 3 years, which is similar to the estimates from the assessment (0.45). The SSB rose from 2.4 million tonnes in 2001 (Table 4) to 2.9 million tonnes in 2002. The survey also shows two exceptional year classes of herring (the 1998 and 2000 year classes) in the North Sea, which is consistent with the observation of exceptionally large year classes observed in the MIK and IBTS surveys (ICES 2001a). The 2002 acoustic survey indicates that the abundance of these year classes are similar and about six times that of the preceding (1997) year class.

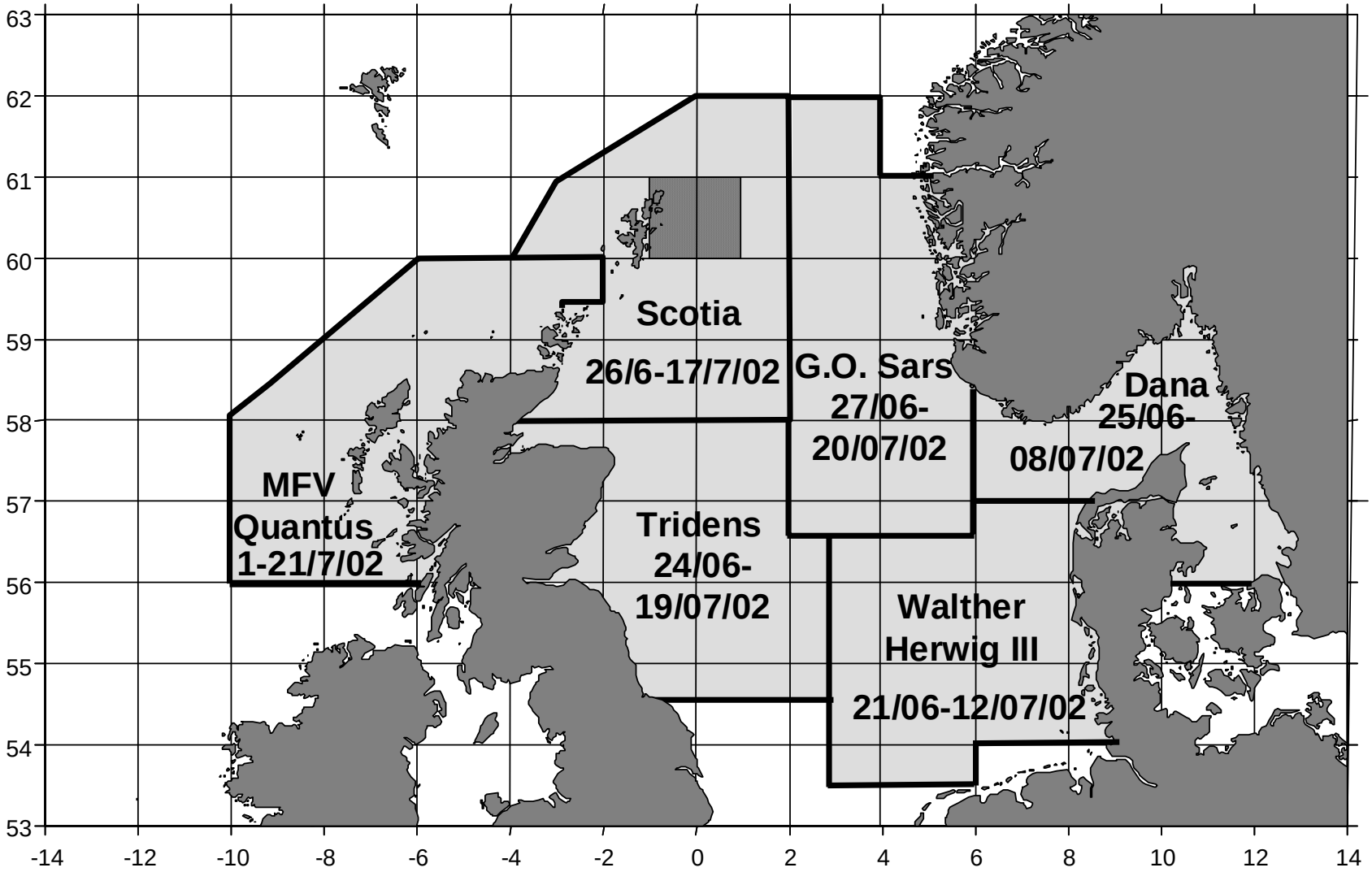

Figure 1 Survey area layouts and dates for all participating vessels in the 2002 acoustic survey of the North Sea and adjacent areas. Heavily shaded areas indicate areas of overlap.

Table 1 Total numbers (millions of fish) and biomass (thousands of tonnes) of North Sea autumn spawning herring in the area surveyed in the acoustic surveys July 2002, with mean weights, mean lengths and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	weight(g)	Length (cm)
0	7428.8	41.0	0.00	6	9.3
1	23054.9	1031.9	0.06	45	18.1
2	4875.1	673.0	0.86	138	24.7
3	8220.6	1421.0	0.97	172	26.4
4	1390.0	270.8	1.00	194	27.4
5	794.6	178.6	1.00	224	28.6
6	1031.2	254.7	1.00	247	29.4
7	244.4	63.8	1.00	261	29.9
8	121.0	33.8	1.00	280	30.6
9+	149.5	37.2	1.00	249	29.2
Immature	30075.6	1058.2			
Mature	17234.5	2947.5			
Total	47310.1	4005.7			

Table 2 Total numbers (millions of fish) and biomass (thousands of tonnes) of Western Baltic spring spawning herring in the area surveyed in the acoustic surveys July 2002, with mean weights, mean length and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	weight(g)	length (cm)
0	22.4	0.2	0.00		
1	3346.2	138.5	0.05	41	18.4
2	1576.6	107.8	0.56	68	21.4
3	1392.8	126.9	0.82	91.1	23.4
4	524.3	55.9	1.00	106.6	24.5
5	87.5	12.8	1.00	145.8	26.8
6	39.5	7.4	1.00	186.5	28.3
7	17.8	3.5	1.00	198.7	28.3
8	5.9	1.2	1.00	200.8	29.2
9+	11.2	2.0	1.00	174.2	28.7
Immature	4149.8	200.6			
Mature	2874.5	255.5			
Total	7024.3	456.0			

Table 3 Total numbers (millions of fish) and biomass (thousands of tonnes) of autumn spawning of West of Scotland herring in the area surveyed in the acoustic surveys July 2002, with mean weights, mean lengths and fraction mature by age ring.

Age (ring)	Numbers	Biomass	Maturity	weight(g)	Length (cm)
0					
1	424.7	26.2	0.00	62	19.0
2	436.0	66.7	0.92	153	25.4
3	1436.9	255.0	1.00	177	26.6
4	199.8	39.6	1.00	198	27.6
5	161.7	34.3	1.00	212	28.2
6	424.3	91.4	1.00	215	28.3
7	152.3	34.3	1.00	225	28.7
8.00	67.5	16.4	1.00	243	29.4
9+	59.5	15.4	1.00	259	30.0
Immature	459.9	30.6			
Mature	2903.0	548.8			
Total	3362.9	579.4			

The estimates of Western Baltic spring spawning herring SSB are 255,000 tonnes and 2.9 millions (Table 2) and show a large increase compared with previous years. This survey produces a rather noisy signal but the indications are of a stock that is higher now than between 1996 to 2000. The year classes that are newly detected in the survey @ 3 & 4ring are larger than recent year classes

Table 4 Estimates of North Sea autumn spawners (millions) at age from acoustic surveys, 1984-2002. For 1984-1986 the estimates are the sum of those from the Division IVa summer survey, the Division IVb autumn survey, and the Divisions IVc, VIId winter survey. The 1987 to 2002 estimates are from the summer survey in Divisions IVa,b and IIIa excluding estimates of Division IIIa/Baltic spring spawners. For 1999 and 2000 the Kattegat was excluded from the results because it was not surveyed. Smoothed Z are those estimated over 2 years providing an estimate of mortality that is less noisy.

Year/age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	551	726	1,639	13,736	6,431	6,333	6,249	3,182	6,351	10,399	3,646	4,202	6,198	9,416	4,449	5,087	24,735	6,837	23,055
2	3,194	2,789	3,206	4,303	4,202	3,726	2,971	2,834	4,179	3,710	3,280	3,799	4,557	6,363	5,747	3,078	2,922	12,290	4,875
3	1,005	1,433	1,637	955	1,732	3,751	3,530	1,501	1,633	1,855	957	2,056	2,824	3,287	2,520	4,725	2,156	3,083	8,220
4	394	323	833	657	528	1,612	3,370	2,102	1,397	909	429	656	1,087	1,696	1,625	1,116	3,139	1,462	1,390
5	158	113	135	368	349	488	1,349	1,984	1,510	795	363	272	311	692.1	982.4	506.4	1,006	1,676	794.6
6	44	41	36	77	174	281	395	748	1,311	788	321	175	98.7	259.2	445.2	313.6	482.5	449.6	1,031
7	52	17	24	38	43	120	211	262	474	546	238	135	82.8	78.6	170.3	138.6	266.4	169.6	244.4
8	39	23	6	11	23	44	134	112	155	178	220	110	132.9	78.3	45.2	54.3	120.4	97.7	121.0
9+	41	19	8	20	14	22	43	56	163	116	132	84	206	158.3	121.4	87.2	97.2	58.9	149.5
Total	5,478	5,484	7,542	20,165	13,496	16,377	18,262	12,781	17,173	19,326	13,003	11,220	18,786	22,028	16,104	15,107	34,928	26,124	39,881
$Z_{2+/3+}$	.	0.92	0.57	1.02	0.81	0.11	0.11	0.57	0.37	0.74	1.21	0.53	0.43	0.40	0.76	0.52	0.32	0.38	0.47
Smooth $Z_{2+/3+}$	.	.	0.73	0.76	0.91	0.30	0.11	0.25	0.46	0.52	0.94	0.80	0.48	0.41	0.55	0.63	0.41	0.35	0.42
SSB ('000 t)	807	697	942	817	897	1,637	2,174	1,874	1,545	1,216	1,035	1,082	1446.2	1,780	1,792	1,534	1,833	2,622	2,948

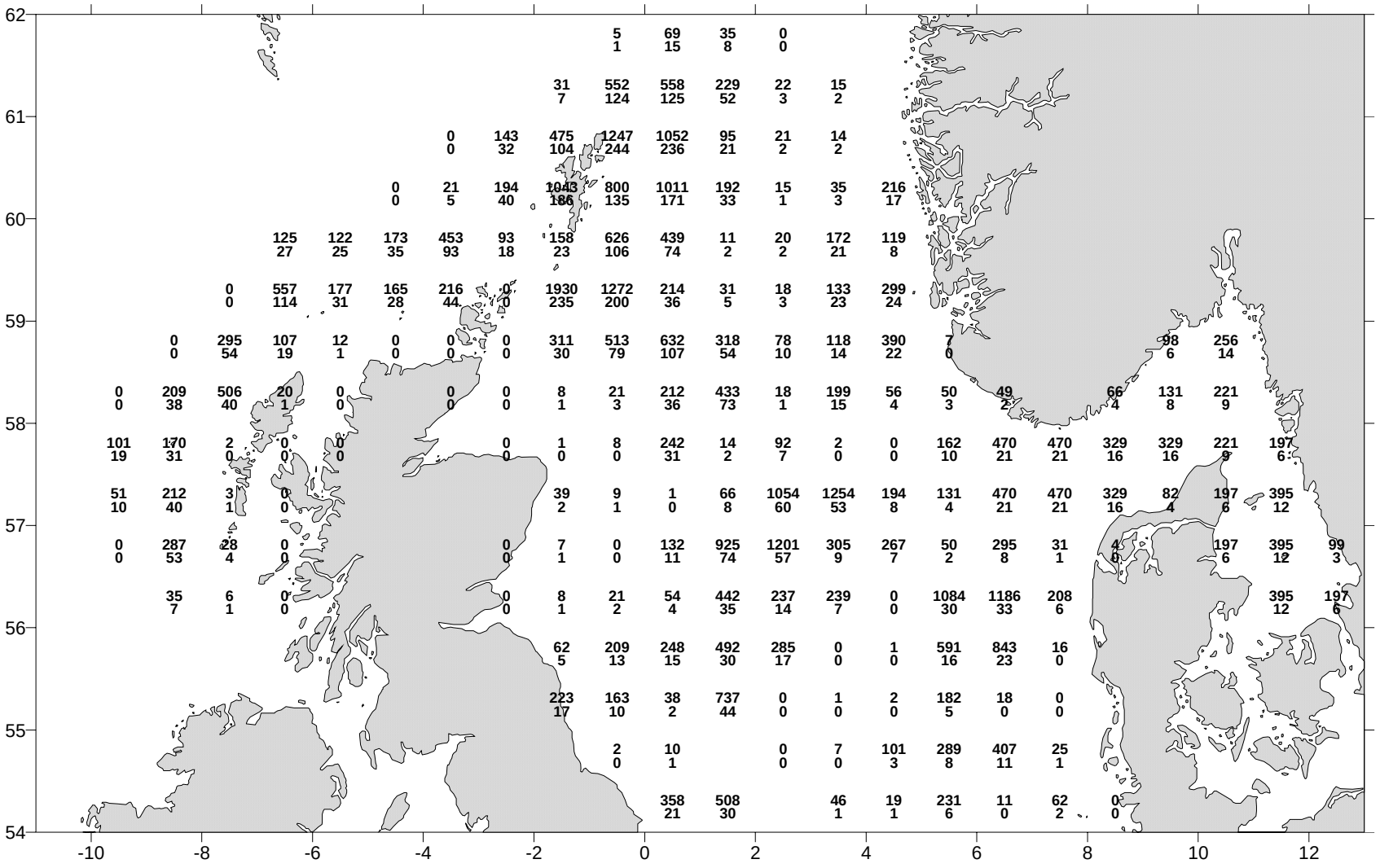

Figure 2 Abundance of Autumn spawning herring from combined acoustic survey July 2002. Numbers (millions) (upper figure) and biomass (thousands of tonnes) (lower figure).

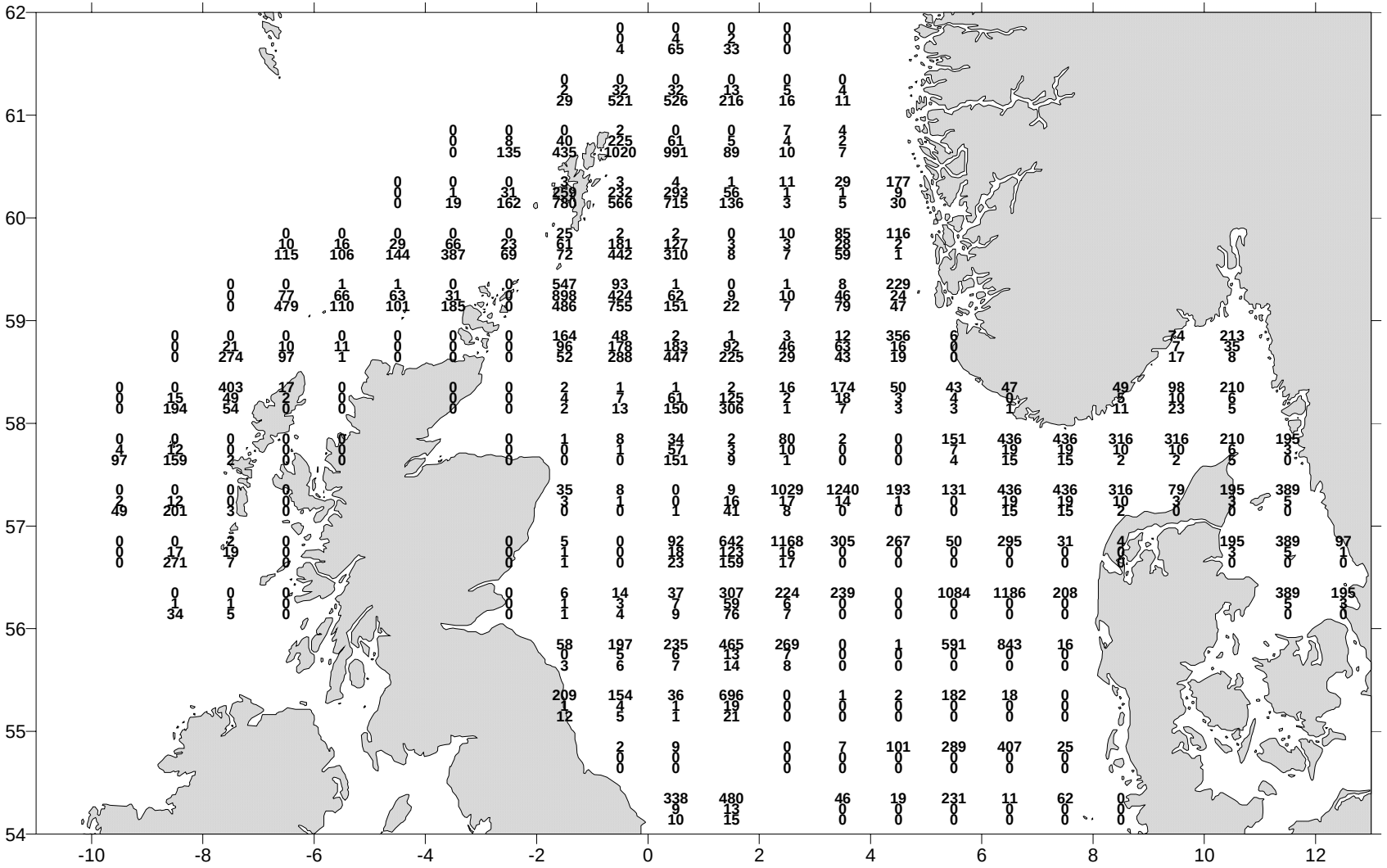

Figure 3 Numbers (millions) of Autumn spawning herring from combined acoustic survey June - July 2002. 1 ring (upper figure), 2 ring (centre figure), 3+ (lower figure).

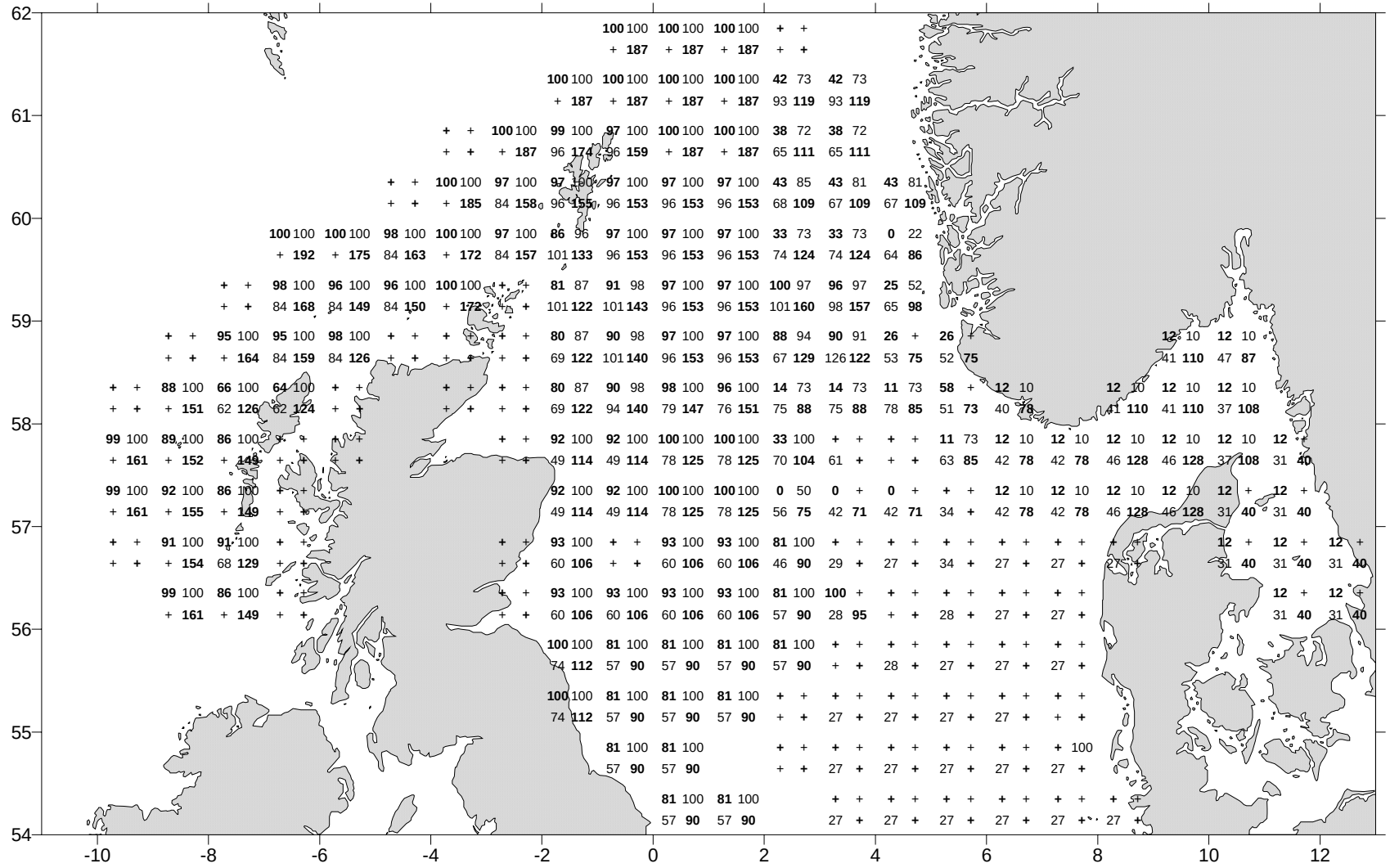

Figure 4 Mean weight & maturity of Autumn spawning herring from combined acoustic survey June - July 2002. Four numbers per ICES rectangle, fraction mature (upper) 2 ring (left), 3 ring (right), mean weights (lower) 1 ring (left), 2 ring (right), 0 indicates measured fraction mature, + indicates surveyed with zero abundance ,blank indicates an unsurveyed rectangle.

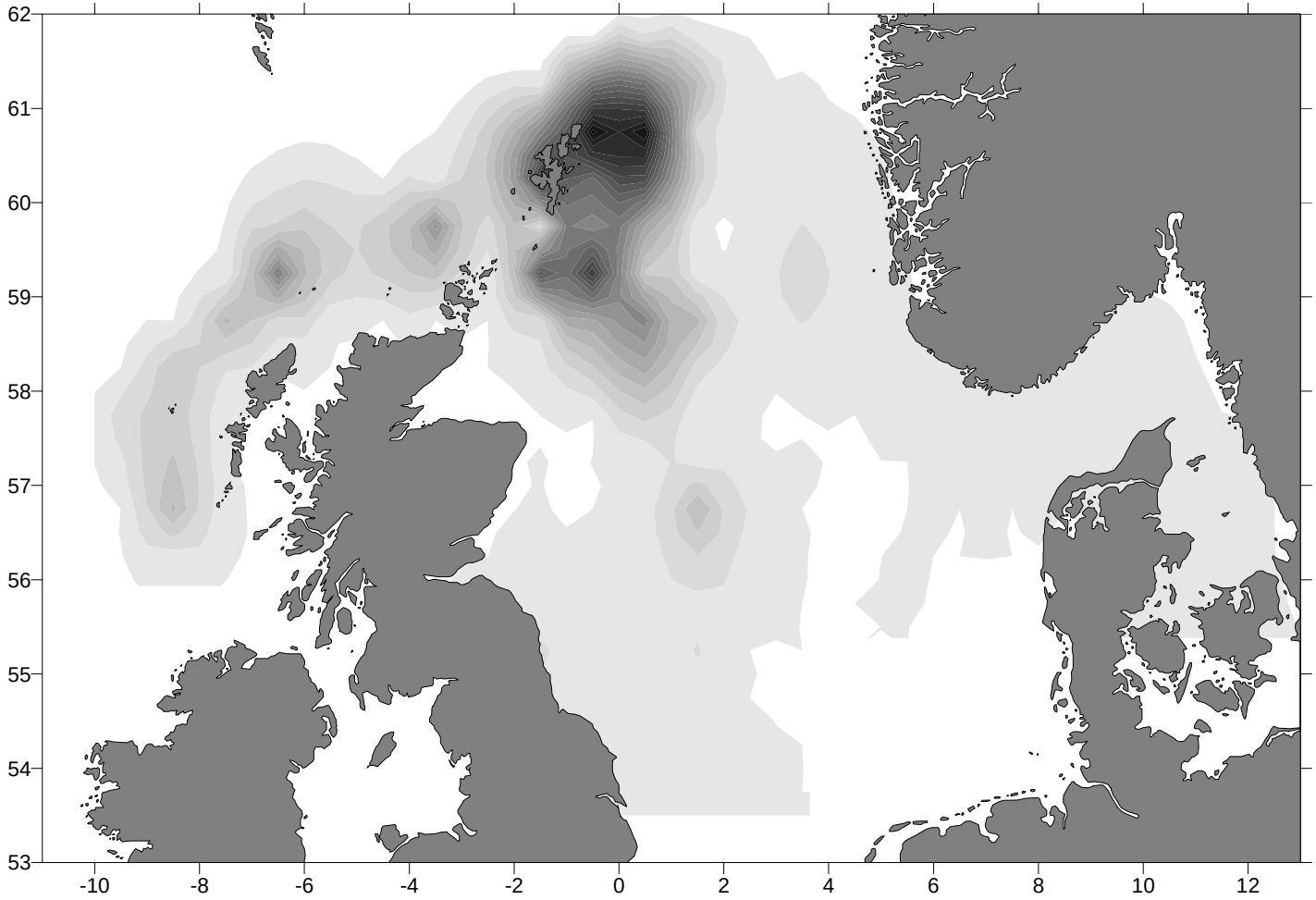

Figure 5 Biomass of mature autumn spawning herring from combined acoustic survey June -July 2002.

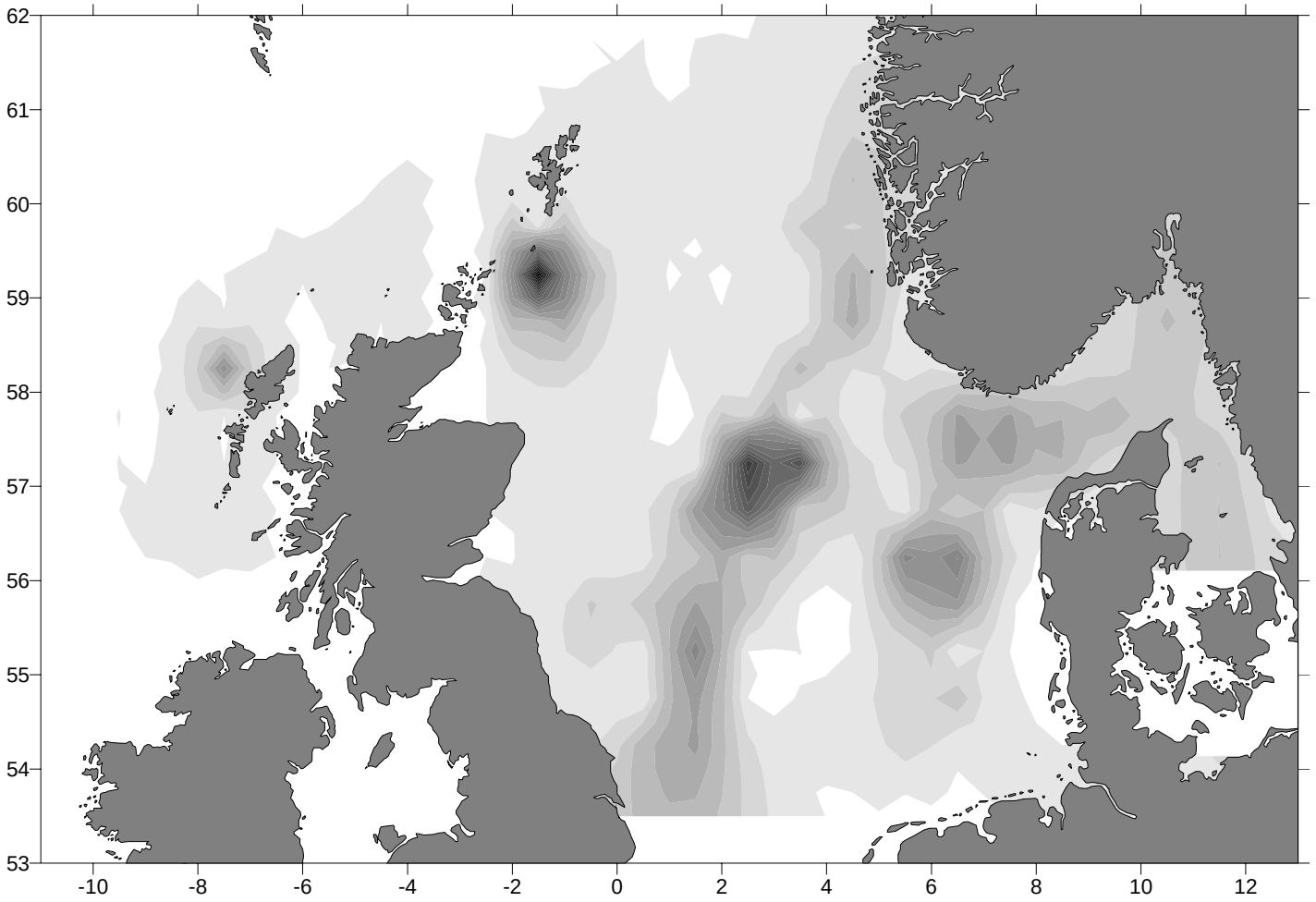

Figure 6 Biomass of immature autumn spawning herring from combined acoustic survey June -July 2002.

Table 5 Numbers (millions) of Western Baltic Spring Spawning herring at age (rings) from acoustic surveys 1989 to 2002. The 1999 survey was incomplete due to the lack of participation by RV DANA.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0		31		3,853	372	964								
1		135		277	103	5	2,199	1,091	128	138	1367	1509	66	3346
2	1,105	1,497	1,864	2,092	2,768	413	1,887	1,005	715	1,682	1143	1891	641	1576
3	714	549	1,927	1,799	1,274	935	1,022	247	787	901	523	674	452	1392
4	317	319	866	1,593	598	501	1,270	141	166	282	135	364	153	524
5	81	110	350	556	434	239	255	119	67	111	28	186	96	88
6	51	24	88	197	154	186	174	37	69	51	3	56	38	40
7	16	10	72	122	63	62	39	20	80	31	2	7	23	18
8+	4	5	10	20	13	34	21	13	77	53	1	10	12	19
Total	2,288	2,680	5,177	10,509	5,779	3,339	6,867	2,673	2,088	3,248	3,201	4,696	1,481	7,002
3+ group	1,183	1,017	3,313	4,287	2,536	1,957	2,781	577	1,245	1,428	691	1,295	774	2,081

Table 6 Numbers at age (millions) and SSB of West of Scotland Autumn Spawning herring at age (rings) from acoustic surveys 1987, 1991 to 2002. #In 1997 the survey was carried out one month early in June as opposed to July when all the other surveys were carried out

Age	**1987**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997#**	**1998**
1	249.1	338.3	74.3	2.8	494.2	441.2	41.2	792.3	1,221.7
2	578.4	294.5	503.4	750.3	542.1	1,103.4	576.5	641.9	794.6
3	551.1	327.9	211.0	681.2	607.7	473.2	802.5	286.2	666.8
4	353.1	367.8	258.1	653.1	285.6	450.3	329.1	167.0	471.1
5	752.6	488.3	414.8	544.0	306.8	153.0	95.4	66.1	179.1
6	111.6	176.3	240.1	865.2	268.1	187.1	60.6	49.5	79.3
7	48.1	98.7	105.7	284.1	406.8	169.1	77.4	16.3	28.1
8	15.9	89.8	56.7	151.7	173.7	236.5	78.2	29.0	13.9
9+	6.5	58.0	63.4	156.2	131.9	201.5	114.8	24.4	36.8
SSB:	273.0	452.0	351.5	866.2	533.7	452.1	370.3	140.9	375.9

Age	**1999**	**2000**	**2001**	**2002**
1	534.2	447.6	313.1	424.7
2	322.4	316.2	1,062.0	436.0
3	1,388.8	337.1	217.7	1,436.9
4	432.0	899.5	172.8	199.8
5	308.0	393.4	437.5	161.7
6	138.7	247.6	132.6	424.3
7	86.5	199.5	102.8	152.3
8	27.6	95.0	52.4	67.5
9+	35.4	65.0	34.7	59.5
SSB:	460.2	500.5	359.2	548.8

The West of Scotland estimates of SSB are 548,000 tonnes and 2,900 millions (Table 3), and show the high 1995 year class again this year (Table 6). The 1998 year class now 3 ring is also a large one. Total adult mortality shows much lower mortality than last year (0.1 compared to 0.5) but the mean mortality over the last 4 years has been 0.3: this is consistent with the 2002 assessment that the stock is lightly exploited (ICES 2002). The survey indicates a fairly steady rise in stock over the last 4 years.

The spatial distributions of the abundance (numbers and biomass) of autumn spawning herring are shown in Figure 2. The distribution of numbers by age are shown in Figure 3 for 1 ring, 2 ring and 3+ ring autumn spawning herring. The survey provides estimates of maturity and weight at age: the mean weight at age for 1 and 2 ring herring along with the proportion mature for 2 and 3 ring herring are shown in Figure 4. The spatial distribution of mature and immature autumn spawning herring is shown in Figures 5 & 6 respectively. The spatial distributions of the abundance (numbers and biomass) of Western Baltic spring spawning herring are shown in Figure 7. The distribution of numbers by age are shown in Figure 8 for 1 ring, 2 ring and 3+ ring. The mean weight at age for 1 and 2 ring herring along with the proportion mature for 2 and 3 ring herring are shown in Figure 9. The spatial distribution of mature and immature Western Baltic spring spawning herring is shown in Figures 10 & 11 respectively.

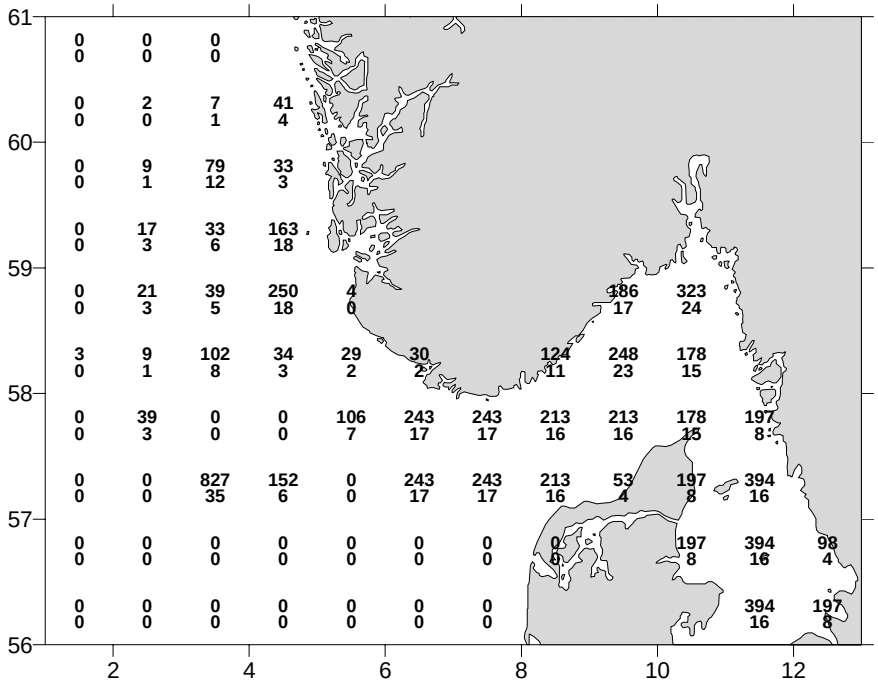

Figure 7 Numbers (millions) (upper) and biomass (thousands of tonnes) (lower) of Western Baltic spring spawning herring from combined acoustic survey June - July 2002.

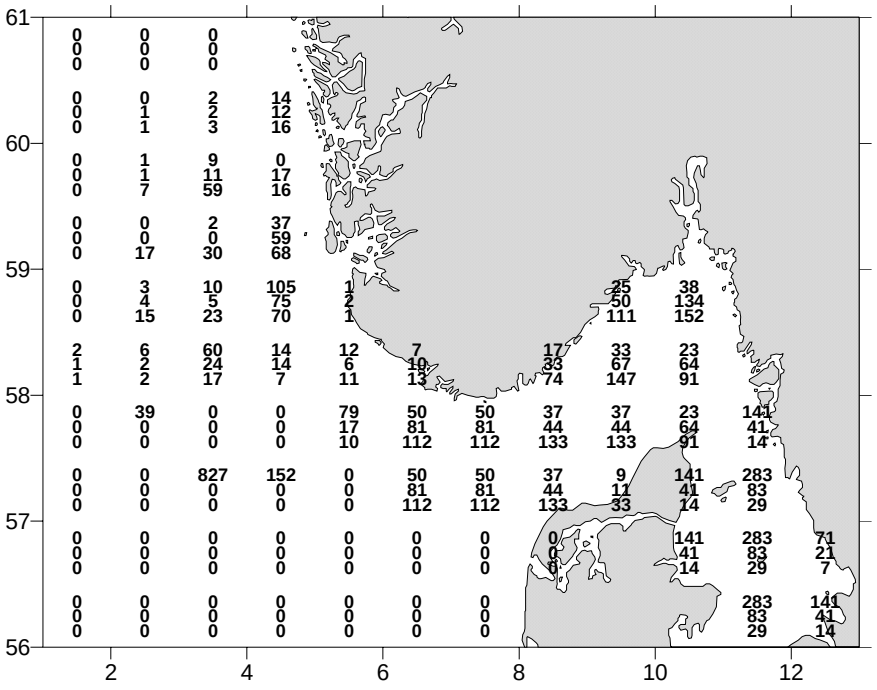

Figure 8 Numbers (millions) of Western Baltic spring spawning herring from combined acoustic survey June - July 2002. 1 ring (upper figure), 2 ring (centre figure), 3+ (lower figure).

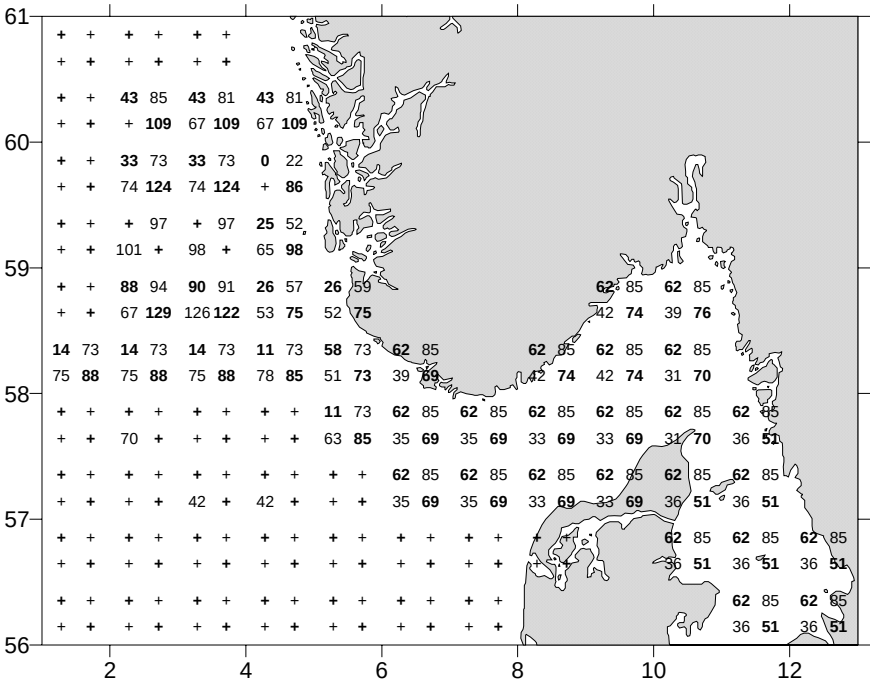

Figure 9 Mean weight & maturity of Western Baltic spring spawning herring from combined acoustic survey June - July 2002. Four values per ICES rectangle, fraction mature (upper),2 ring (left), 3 ring (right), mean weights (lower),1 ring (left) ,2 ring (right) ,0 indicates measured fraction mature, + indicates surveyed with zero abundance blank indicates an unsurveyed rectangle.

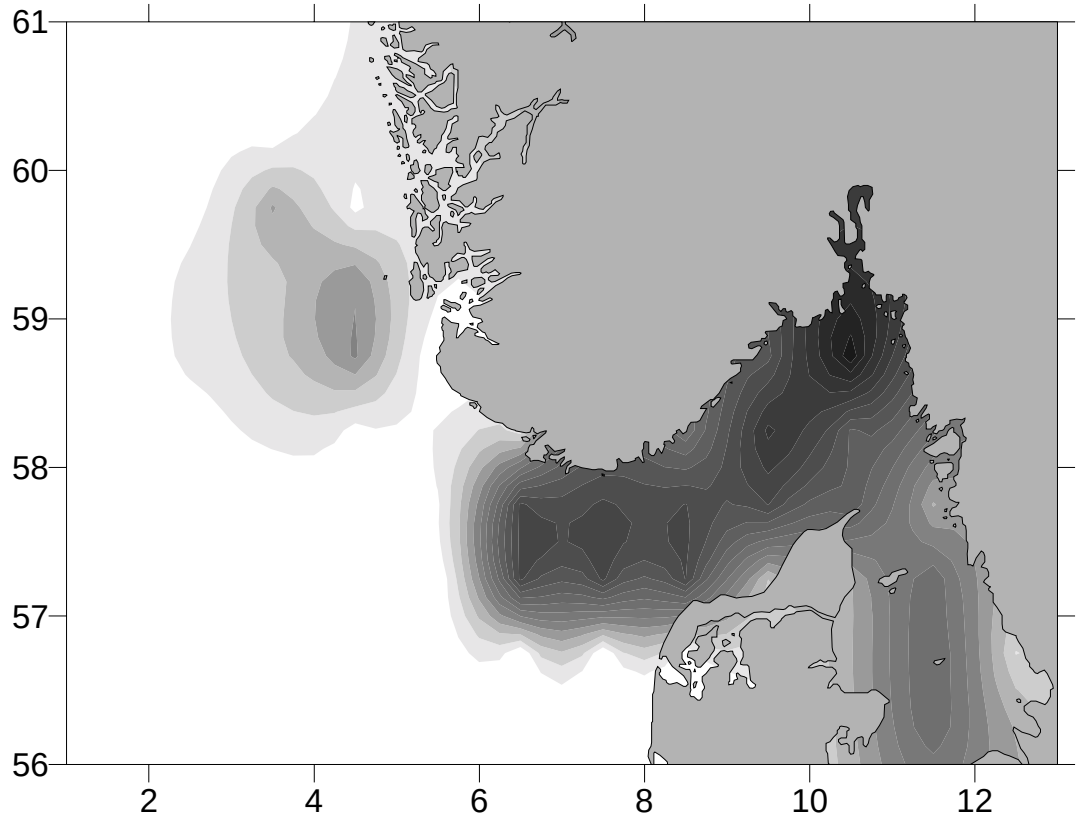

Figure 10 Abundance of mature Western Baltic spring spawning herring from combined acoustic survey July 2002. Numbers of herring .

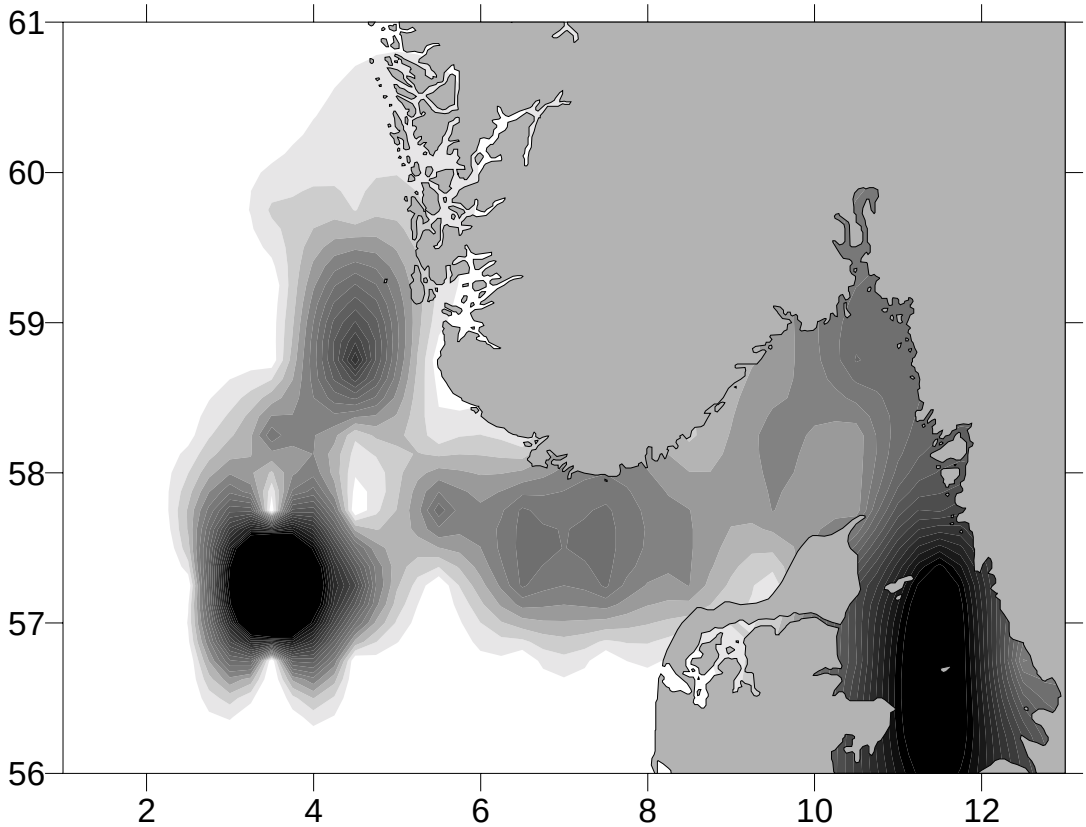

Figure 11 Abundance of immature Western Baltic spring spawning herring from combined acoustic survey July 2002. Numbers of herring .

Combined Acoustic Survey Results for North Sea herring 1989 to 2002

The time series of survey data by ICES Statistical rectangle level has been analyses for the period 1989 to 2002. Changes in distribution are summarised pictorially as colour represented spatial distributions with changes in time shown as movies and through graphs showing median values and 90% intervals derived from bootstrap analysis. The intervals on the centre of gravity and maturity are derived from bootstrap of the local means of ICES statistical rectangle observations from the acoustic survey. The data are effectively samples from a uniform intensity systematic survey, thus the intervals derived from bootstrap will slightly over estimate the true interval width for a systematic survey. So the results presented here are conservative. Figures 10 and 11 show the average spatial distribution at age 1 to 9+ and illustrates the northward and westward movement by age. This is shown pictorially in figure 10 and as intervals on the centre of gravity by age in Figure 11. This shows a well defined change of location for herring in July as it they grow older. Figures 12 and 13 show spatial changes in maturity at age 2 for 1989 to 2002. Figure 12 shows the change in spatial distribution pictorially and Figure 13 gives the fraction mature in the population at age 2 and 3. These show the high maturity fraction in then early years, the dramatic reduction in fraction mature in 1992 and the rapid recovery to an intermediate level in 1995 and then subsequently by 2001 to the levels seen pre-1992. Patterson 1996 estimated increased natural mortality for herring in 1992 and 1993 due to ichthyophonus disease. Its interesting to postulate that this was the cause of the reduced maturity in 1992 and 1993. In addition it may also be postulated that early spawners had a higher probability of contracting the disease and dying thus removing a higher proportion of early spawners leading to the reduction in fraction mature over the subsequent years. There are in any case clear differences in fraction mature over time. Figures 14 and 15 show the spatial distribution of adults 1989 to 2002. Figure 14 shows the spatial distribution pictorially and Figure 15 shows the change in centre of gravity of the adult population with clear movements south in 1991 and then north again in 1995 with eastwards movement in 1993/4 and westwards in 1999. Figures 16 and 17 show the spatial distribution of juvenile herring ages 1 and older. Figure 16 shows the distribution pictorially and Figure 17 shows 90% intervals on the centre of gravity suggesting little systematic movement with rapid fluctuation from year to year. Figure 18 shows the change in spatial distribution of mean weight at age.

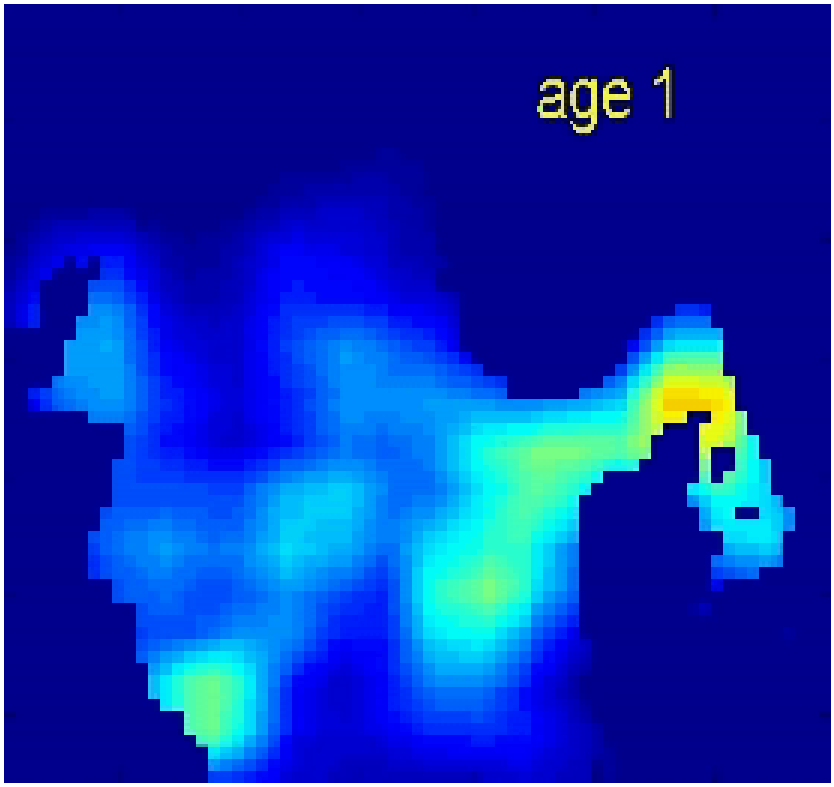

Figure 10 The average spatial distribution at age 1 to 9+ for all years 1989-2002. Blue through to red represents low to high densities **(left click to play movie herage89-02.avi which should be on the same directory as this pdf file)**

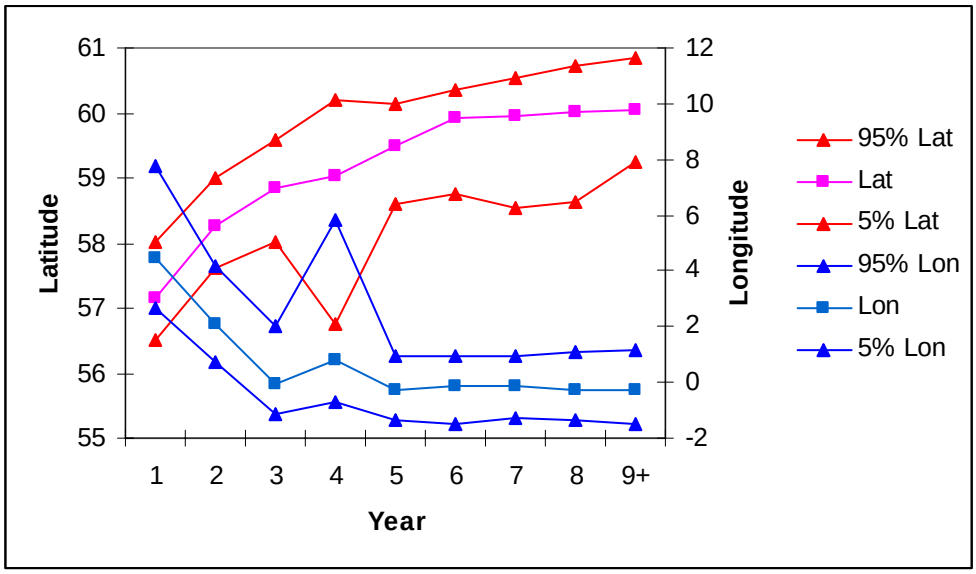

Figure 11 The centre of gravity by age with 90% interval ages 1-9+ showing clear change in location with age in July. Age 1 should be treated with caution from due to poor area coverage 1989 to1995.

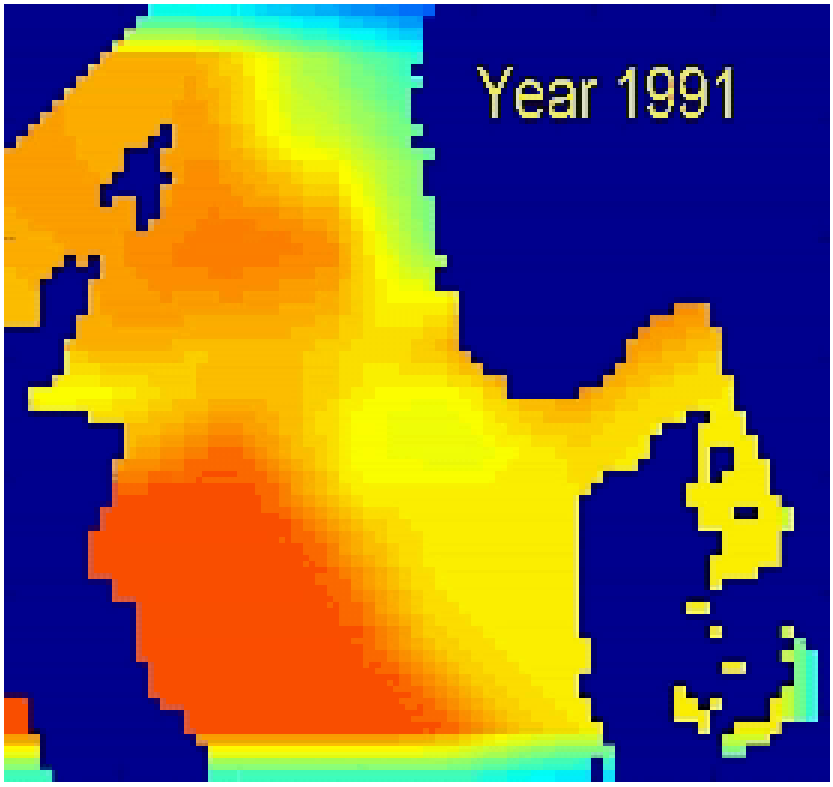

Figure 12 Spatial changes in fraction mature at age 2 for 1989 to 2002 Blue through to red represents low to high fractions mature **(left click to play movie mather89-02.avi which should be on the same directory as this pdf file)**

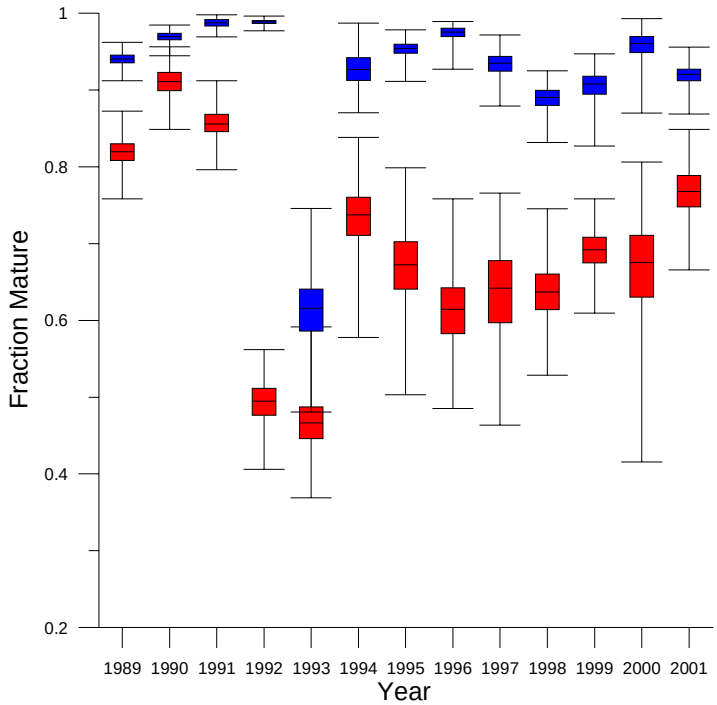

Figure 13 The fraction mature as 90% intervals in the population at age 2 ring (red) and 3 ring (blue) from 1989 to 2001.

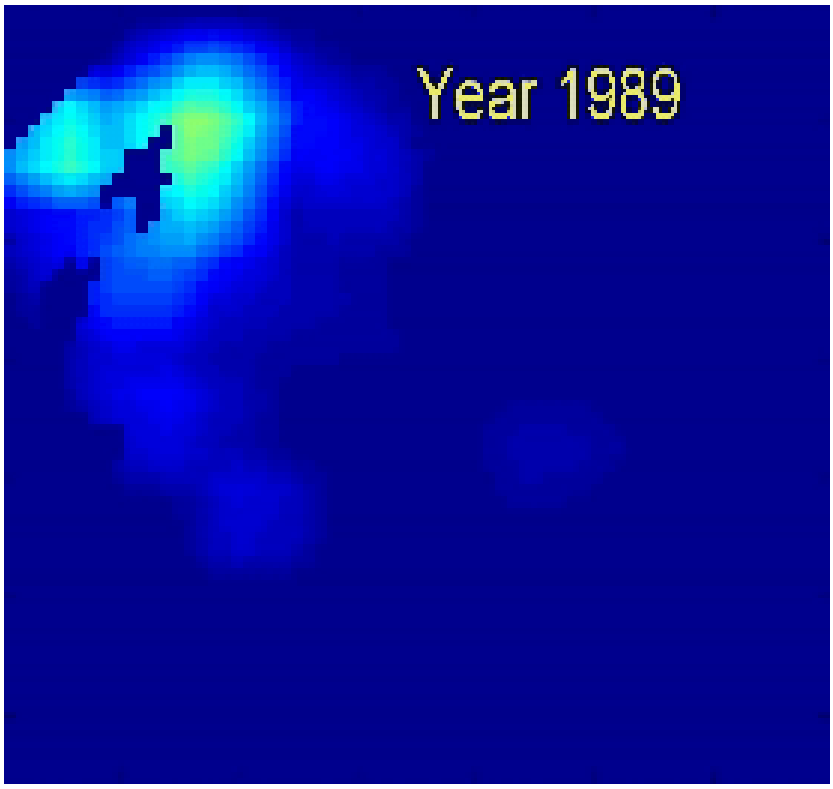

Figure 14 The spatial distribution of adults 1989 to 2002 Blue through to red represents low to high densities **(left click to play movie adulther89-02.avi which should be on the same directory as this pdf file)**

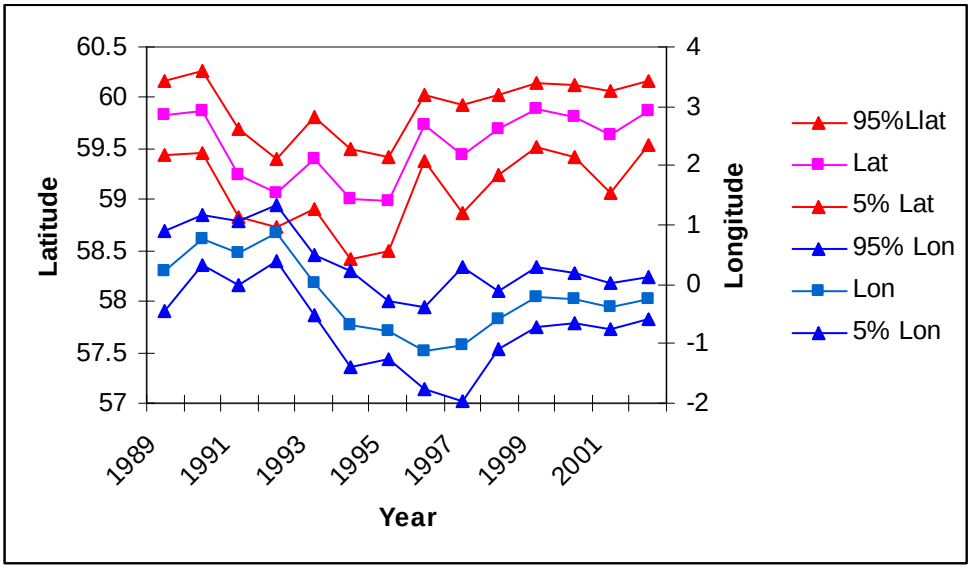

Figure 15 The change in centre of gravity of the adult population with clear movements south in 1991 and north in 1995 eastwards movement in 1992-3 and westwards in 1999.

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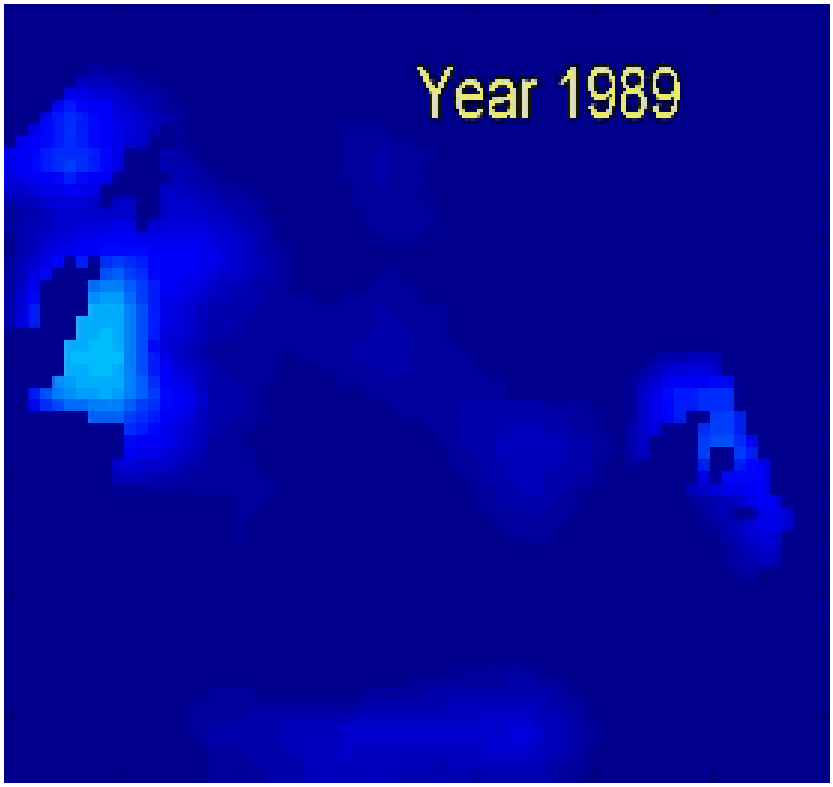

Figure 16 The spatial distribution of juvenile herring ages 1 and older Blue through to red represents low to high densities **(left click to play movie juvher89-02.avi which should be on the same directory as this pdf file)**

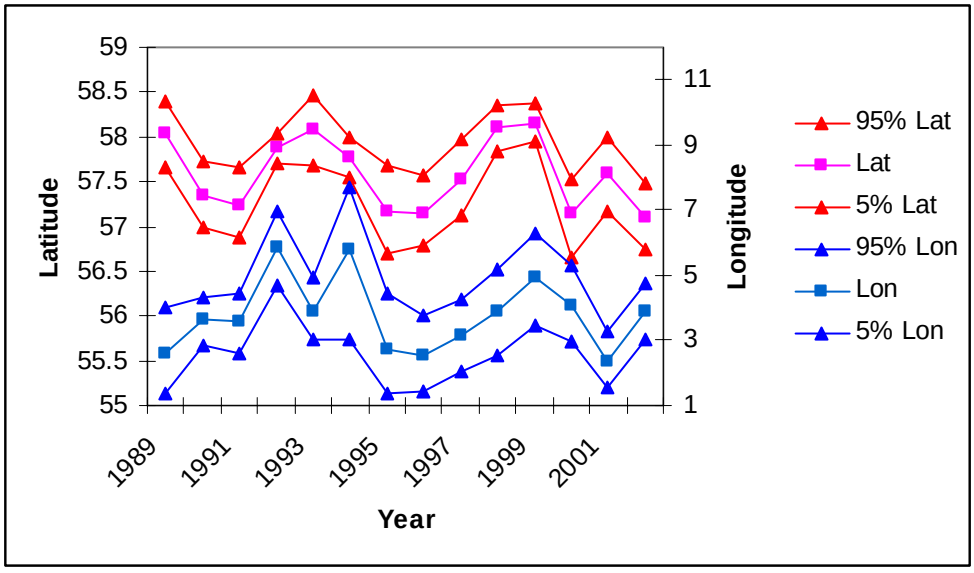

Figure 17 shows 90% intervals on the centre of gravity of juveniles with little trend over time but some rapid fluctuation from year to year.

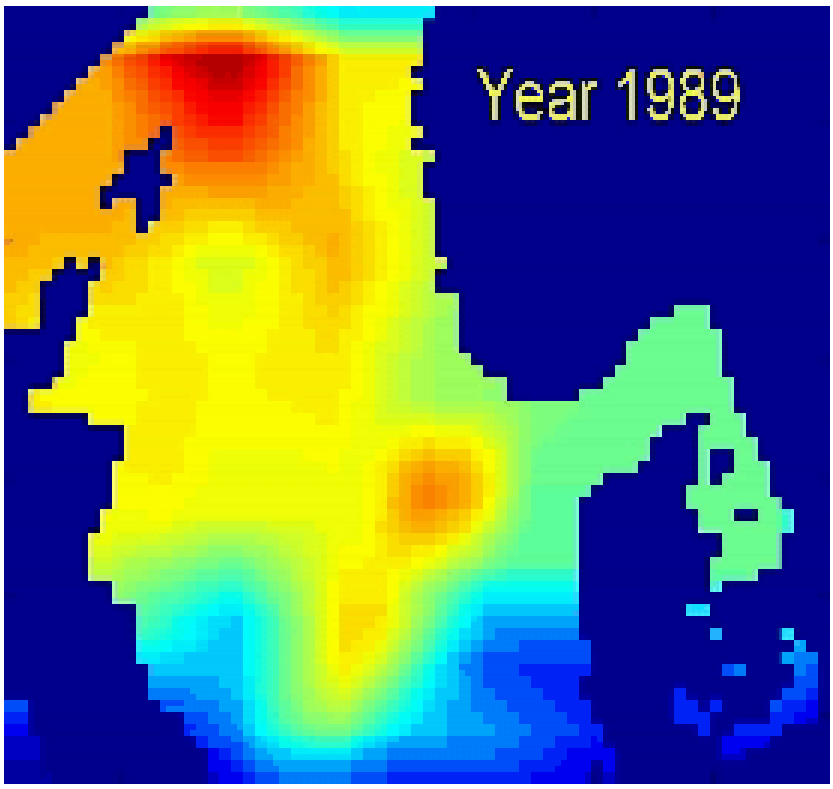

Figure 18 The change in spatial distribution of mean weight at age 2 Blue through to red represents low to high mean weights at age 2 **(left click to play movie mwt2her89-02.avi which should be on the same directory as this pdf file)**

DISCUSSION

These results suggest that the survey is capable of determining real differences in location by age and by year, and differences in the fraction mature at 2 and 3 ring. These may be compared with the spawning stock biomass and the yearclass strength expressed as abundance at 0 group. The estimates of yearclass strength and stock biomass are taken from the 2003 assessment reported in the HAWG report (ICES 2003). Different year classes appear to grow differently and different proportions reach maturity at age 2 and 3. Fast growing year classes seem to mature in higher proportions at age 2 ring (Figure 19a). High spawning stock sizes are linked to high proportions of mature 2 ring herring but this may be only because the 2 ring herring form part of the SSB. Big year classes have a higher proportion of 2 ring herring maturing (Figure 19c). The growth of year classes does not seem to be affected by stock size or year class strength (Figure 20). It can be seen that the herring spawning stock is more northerly and more easterly in July when the population is larger (Figure 21). Though during the period 1989 to 2002 the location in July, population size, yearclass growth rate and fraction mature have little influence on the subsequent year class strength at 0 group (Figure 22). While this is true for the period 1989-2002 it should be remembered however, that the North Sea herring population has a well established stock recruitment relationship with reduced recruitment at reduced stock size (ICES 2003).

However, the stock did not appear to have been reduced sufficiently in 1994-96 to affect recruitment.

This information suggests that early life history success resulting in big year classes then provides faster development to early maturity. This suggests that over the range of abundances and stock movements seen in the period 1989 to 2002 there has been nothing about stock size or year class size or location, all of which have changed substantially, to limit development. The implications are that the most important controlling factors for development of North Sea herring occur in the first two to three months of life.

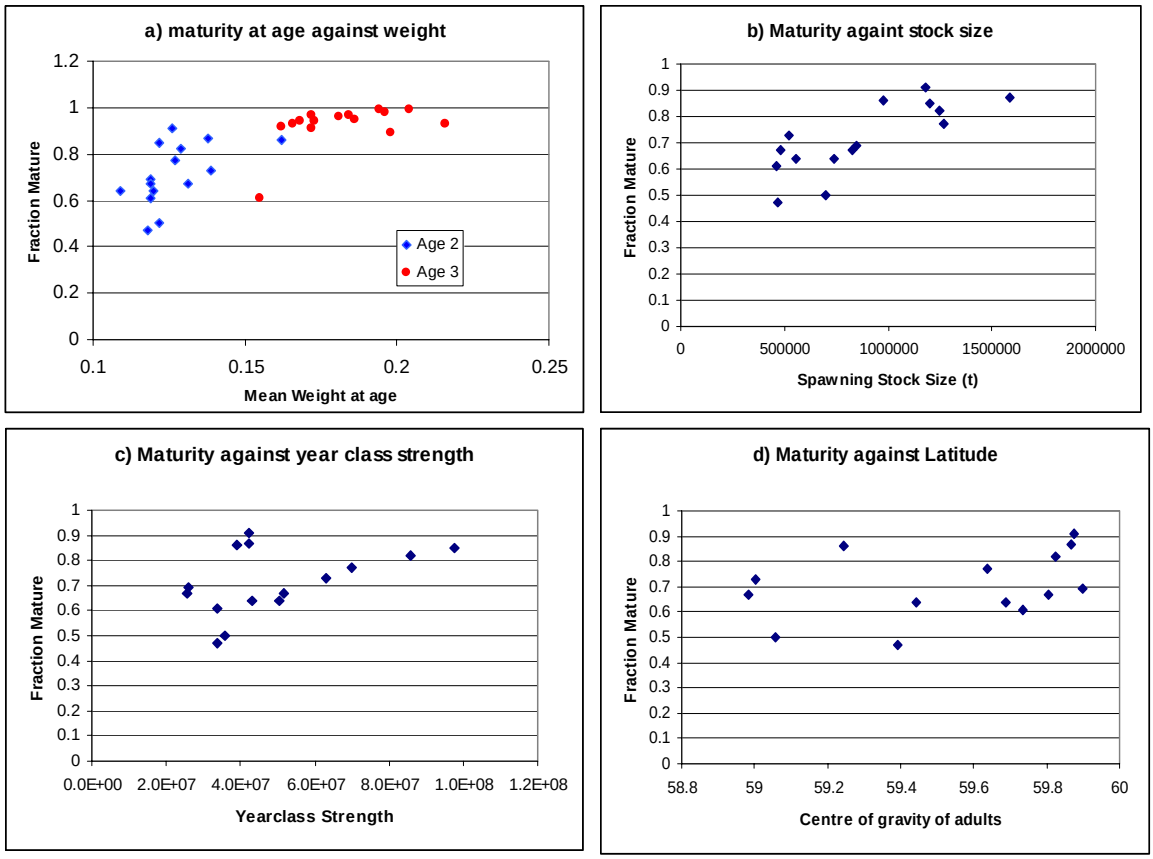

Figure 19 Fraction of Maturing herring. a) fraction mature (ages 2 and 3 ring) against mean weight at age, b) fraction mature age 2 ring against stock size, c) fraction mature at age 2 ring against yearclass strength, and d) fraction mature against latitude of the stock.

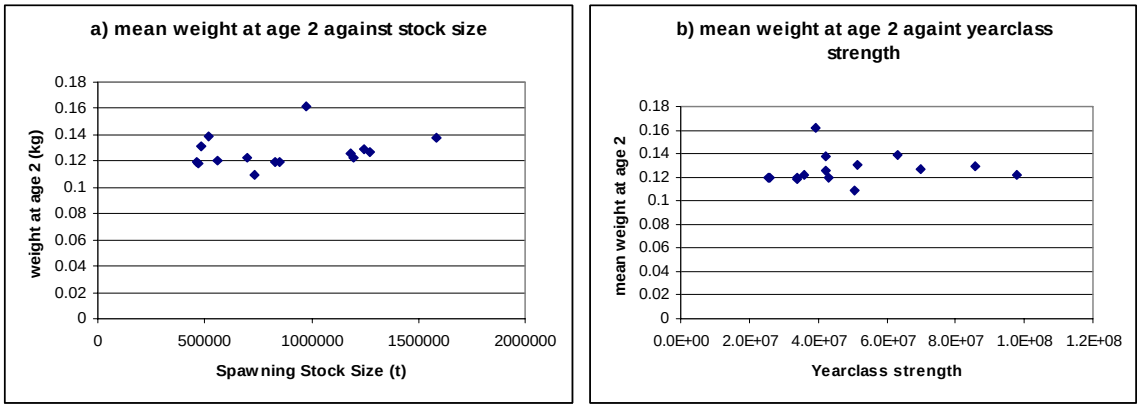

Figure 20 Mean Weight of 2 ring herring. a) Mean weight at age 2 against stock size, b) Mean weight at age 2 yearclass strength.

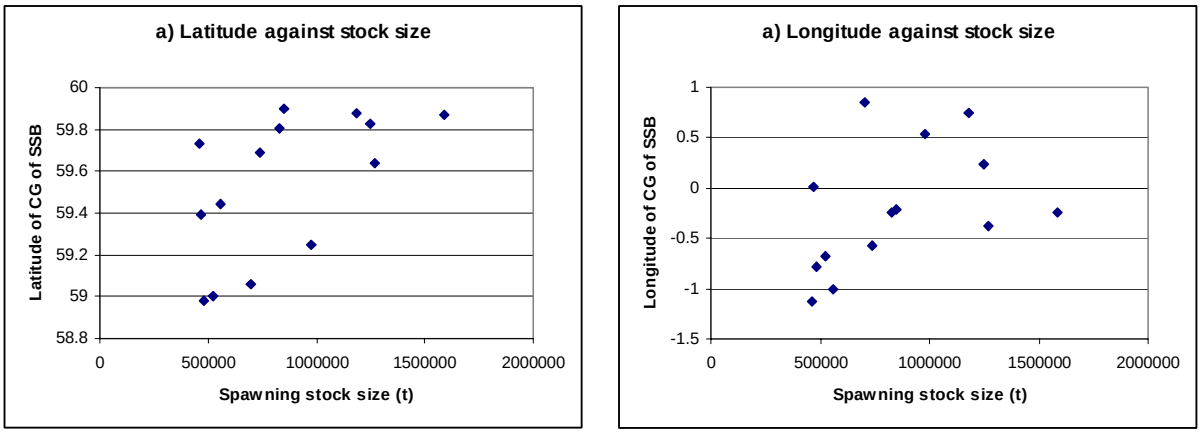

Figure 21 Location of stock with stock size; a) latitude with stock size and b) longitude with stock size

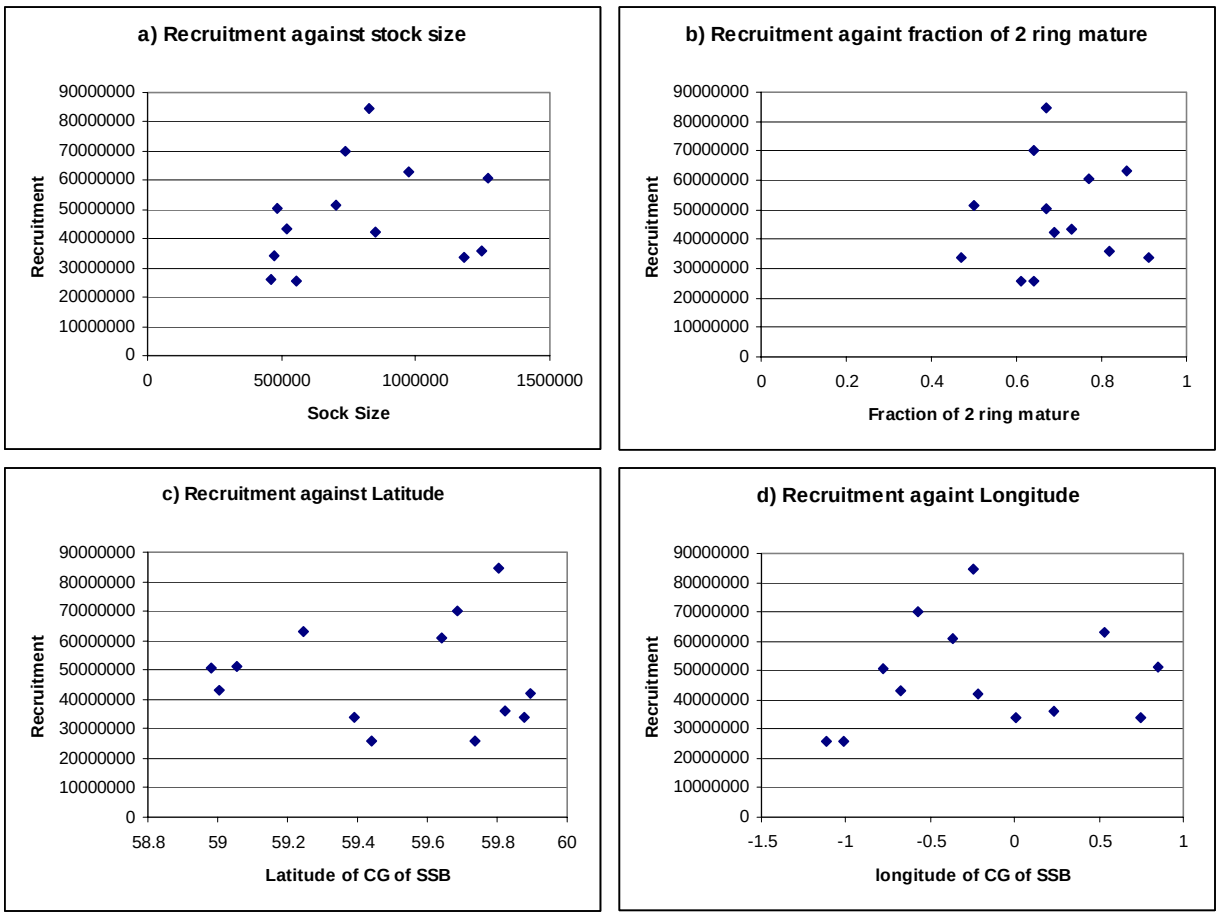

Figure 22 Recruitment: a) dependence of recruitment on stock size (SSB) from 1989-2002, b) dependence of recruitment on fraction if incoming 2 ring maturity 1989-2002, c&d) dependence of recruitment on location 1989 to 2002

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