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Report of the Study Group on the evaluation of assessment and management strategies of the western herring stocks (SGHERWAY)

7-11 December 2009

Aberdeen, UK

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

The ICES Study Group on the evaluation of assessment and management strategies of the western herring stocks [SGHERWAY] met in Aberdeen, UK, from 7-11 December 2009. The chair was Emma Hatfield (UK) and 8 people in total attended, from five nations.

The report addresses the ToRs, in turn, and discusses the work required to allow us to produce a set of full results for the deliberation of ACOM in July 2010.

During the meeting, progress was made towards determining the best settings for the combined assessment of the three herring stocks (VIaN, VIaS/VIIb,c and VIIaN). The dataset was updated fully and a number of different assessment runs were carried out to explore the combined dataset. The selection on the oldest age, the reference age and a number of data combinations using different surveys and ages were explored. It was found that the only way to improve the retrospective pattern is to remove survey years prior to 1998. The VIaN assessment uses all ages and all years in the VIaN survey time-series. Further work is still required here and there is no basis, as yet, from which to offer advice from the combined assessment.

A second synoptic survey of the Malin and Hebrides shelf areas was carried out in 2009. The area was surveyed in June/July by vessels from Scotland, Northern Ireland and the Republic of Ireland. The data from Northern Ireland were not available in time to be included herein. The Malin Shelf estimate, without the Northern Irish survey results, of SSB was 593 000 tonnes and 2 647 million fish compared to the 2008 estimates of 826 000 tonnes and 4 007 million fish. The results are, again, largely dominated by the VIaN estimate. The development of this synoptic acoustic survey will allow survey coverage of all areas in which mixing of the various western herring stocks is thought to occur, and create a more apposite tuning index which may be used in a combined assessment.

The modelling approach developed for the 2009 SGHERWAY meeting is different from the approach taken in 2008, with the main focus on sustainable management targets to maintain each spawning component in a healthy state. The distinction between mixing populations and non-mixing fisheries are consecutively evaluated. This approach is complex and has taken a lot of time to develop; no clear results can be presented as yet as time was constraining. However, during development of the model, many new insights have led to the confidence that the modelling approach will represent, in clear detail, the processes occurring in the area. Additionally, the model gives new insights in the processes that might play an important role in driving the populations such as the level of mixing and the accuracy of correctly identifying the spawning origin. This study intends to calculate the risk of depletion for each of the stocks under a number of management scenarios. By varying the levels of fishing mortality, we will be able to comment on safe management targets for the combination of these stocks.

1 Participation and Terms of Reference

The ICES SGHERWAY met in Aberdeen, UK from 7-11 December 2009. The participants were:

Steven Beggs	UK [Northern Ireland]
Afra Egan	Ireland
Clementine Harma	Ireland
Emma Hatfield [Chair]	UK [Scotland]
Niels Hintzen	The Netherlands
Beatriz Roel	UK [England and Wales]
Norbert Rohlf	Germany
John Simmonds	Italy

Contact details for each participant are given in Annex 1.

Taking into account the results of WESTHER in relation to VIaN, VIaS and VIIaN stocks, SGHERWAY met to:

a) evaluate the utility of a synoptic acoustic survey in the summer for the Hebrides, Malin and Irish shelf areas, in conjunction with WGIPS surveys of VIaN and the North Sea;

b) explore a combined assessment of the three stocks and investigate its utility for advisory purposes;

c) evaluate, through simulation, alternative management strategies for the metapopulation of VIaN, VIaS and VIIaN and the best way to maintain each spawning component in a healthy state.

2 Progress against ToRs

2.1 Evaluation of the utility of a synoptic acoustic survey in the summer for the Hebrides, Malin and Irish shelf areas, in conjunction with WGIPS surveys of VIaN and the North Sea

The Study Group was asked to evaluate the utility of a synoptic acoustic survey in summer for the Hebrides, Malin and Irish shelf areas, in conjunction with the WGIPS surveys of VIaN and the North Sea. This evaluation is based on results of a combined survey programme in 2008 and 2009, and an analysis of time-series of existing surveys in the area.

2.1.1 2009 Malin Shelf acoustic survey results

The synoptic survey of what is currently considered the Malin Shelf metapopulation of herring was carried out for the second time in 2009, with participating vessels from Scotland (FV "Quantus"), Northern Ireland (RV "Corystes") and Ireland (RV "Celtic Explorer"). The three vessel survey was an extension of the existing west of Scotland time-series to cover ICES divisions VIaS and VIIb *("Celtic Explorer")* and the Clyde and North Channel ("Corystes").

Planned transect interlacing between Scotland and Ireland (55.5°N - 56.5°N) and Ireland and Northern Ireland (east of 7°W in the North Channel) was not possible as Ireland was not granted permission to enter UK waters. Temporal synchrony was achieved between the Scottish and Irish vessels in the western area but a time-lag was again noted with the RV "Corystes" in the North Channel and its approaches. This time-lag needs to be addressed in 2010 to ensure close harmony between surveys.

Table 2.1.1.1. Component surveys of the Malin Shelf metapopulation, conducted in 2009.

Vessel	Period	Area	Rectangles
"Celtic Explorer" (IR)	3 July – 22 July	53°-56°N ,12°-7°W	35D8-D9, 36D8-D9, 37D9-E1, 38D9-E1, 39E0-E2, 40E0-E2
"Quantus" (SCO)	29 June – 18 July	55°30'-60°30'N, 4°-10°W	41E0-E3, 42E0-E3, 43E0-E3, 44E0-E3, 45E0-E4, 46E2-E5, 47E2-E5, 48E4-E5, 49E5
"Corystes" (NIR)	12 July-16 July	Clyde/North Channel	40E 3–40E5, 39E3-E5, 38E4

At the time of the WGIPS meeting (end January 2010), no survey results were available from the RV "Corystes" survey and thus results from the survey covering the southeastern part of VIaN, the Firth of Clyde and the North Channel cannot be given here. The Malin Shelf estimate of SSB reported in 2009 covers the west of Scotland herring stock in Division VIaN and the stock in Division VIaS/VIIb,c. The survey results were combined in the same manner as those in the North Sea, with weighting applied to individual survey estimates at ICES statistical rectangle according to the amount of survey effort (Figure 2.1.1.1) in the rectangle measured in nautical miles.

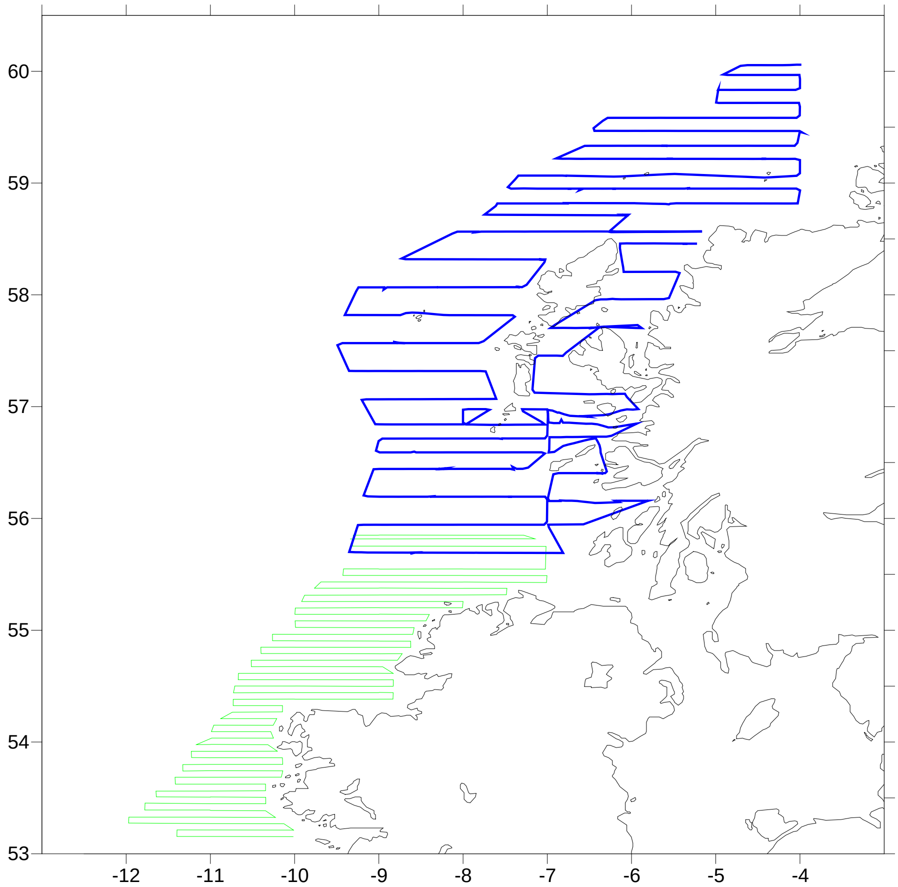


Figure 2.1.1.1. Cruise tracks for the Malin Shelf survey June/July 2009. Cruise tracks (green RV "Celtic Explorer" (Republic of Ireland); blue FV "Quantus" (Scotland)).

The Malin Shelf estimate of SSB was 593 000 tonnes and 2 647 million fish and is again largely dominated (98%) by the west of Scotland estimate (Table 2.1.1.2). The 2008 RV "Corystes" survey caught only immature fish and therefore contributed no mature biomass to the SSB estimate. It appears to be the same in 2009 (P-J. Schön, AFBINI Belfast, UK personal communication).

Table 2.1.1.2. Total numbers (millions of fish) and biomass (thousands of tonnes) of Malin Shelf herring in the area surveyed in the acoustic surveys July 2009, with mean weights, mean lengths and fraction mature by age ring. N.B. without the RV "Corystes" survey values which might be likely to inflate the numbers and biomass of small, immature herring.

AGE (RING)	NUMBERS	BIOMASS	MATURITY	WEIGHT (G)	LENGTH (CM)
0					
1	773	45	0.00	58.9	18.6
2	265	38	0.67	143.3	24.5
3	274	56	0.99	204.1	27.4
4	444	98	1.00	222.1	28.2
5	380	89	1.00	233.0	28.6
6	225	52	1.00	231.5	28.6
7	193	45	1.00	232.4	28.6
8	500	116	1.00	232.3	28.6
9+	456	109	1.00	238.2	28.8
Immature	863	55		63.8	19.0
Mature	2 647	593		224.1	28.3
Total	3 510	648	0.75	184.7	26.0

The west of Scotland estimates of SSB are 579 000 tonnes and 2 560 million herring. These are lower compared to the estimates from the previous year, which were the second highest in the time-series. Once again the west of Scotland survey did not detect many immature fish this year. The youngest year class observed in the survey represents the strongest of the past four years. To ensure that the west of Scotland results were consistent with the time-series, they were derived from squares above 56°N only.

The density distribution of Malin Shelf herring in 2009 from two of the three surveys is given in Figure 2.1.1.2.

The spatial distribution of Malin Shelf herring in 2008 and 2009 is given in Figure 2.1.1.3. In general, the spatial distribution is highly comparable between both years, with a somewhat more pronounced preference of northern latitudes in 2009.

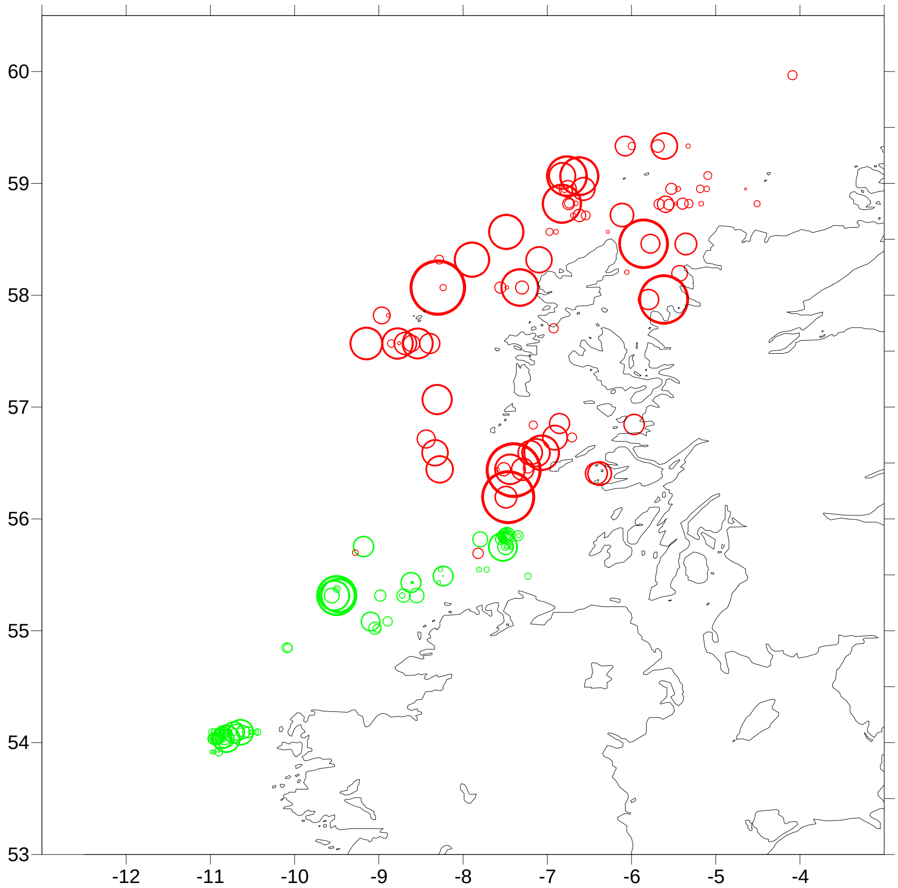


Figure 2.1.1.2. Post plot of the distribution of total herring nautical area scattering coefficient (NASC) values (circle size is proportional to NASC but only within a survey) obtained from the two hydroacoustic surveys carried out in June/July 2009. Relative NASC comparisons are approximate and scaled to a maximum value of 7 500. Red circles FV "Quantus" and green circles RV Celtic Explorer.

The corresponding distribution for immature herring is shown in Figure 2.1.1.4. Results for 2009 are influenced by the lack of survey estimates for the North Channel, which is anticipated to yield higher quantities of immature herring. Therefore, the annual estimates are not really comparable. However, the general pattern is obvious from the Figure.

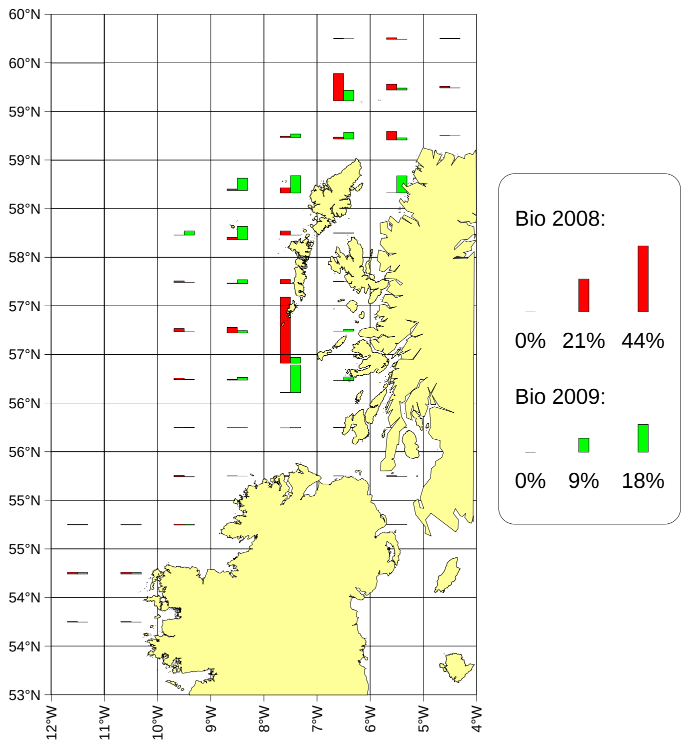


Figure 2.1.1.3. Comparison of herring spawning biomass (1 000 t) per rectangle in 2008 and 2009. The biomass per rectangle is given as percentage of total SSB for each specific year.

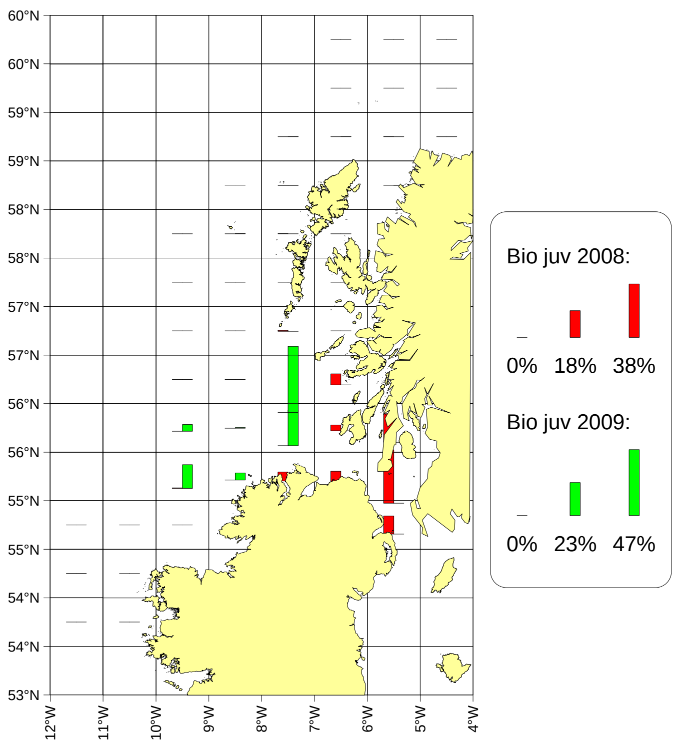


Figure 2.1.1.4. Comparison of biomass of immature herring (1 000 t) per rectangle in 2008 and 2009. The biomass per rectangle is given as percentage of total biomass of immature fish for each specific year.

2.1.2 Coordination for the Malin Shelf Survey in 2010

It was proposed that a subgroup should be established during WGIPS meetings to coordinate planning, effort allocation and logistics for this area. SGHERWAY has requested that additional sampling be undertaken during the 2010 survey within the Malin Shelf area.

1) Ireland has agreed that they will extend their survey area to 57°N to accommodate SGHERWAY's request.

2) The collection of additional morphological and biological samples to provide a possible split of the population components was discussed by the members of the Malin Shelf subgroup present at WGIPS. Ireland stated that they could accommodate the requirements if protocols could be made available detailing the techniques and equipment required. Scotland felt that the additional sampling might prove difficult unless additional staff could be physically accommodated on the charter vessel to carry out the tasks. Northern Ireland has not yet responded to the request. Ireland was appointed as survey coordinator in 2010 by the participants in the Malin Shelf surveys. They should maintain contact between vessels at sea; communicate and coordinate planning of cruise tracks, transect interlacing areas, temporal progression and survey effort in the planning phase and communicate plans to WGIPS chair.

3) It was proposed that a two day post-cruise meeting should be established soon after the survey to compile and collate combined survey data and to upload it to FishFrame. The meeting would allow members to evaluate survey data and discuss issues arising from the survey and conclude on recommendations to improve survey precision.

2.1.3 Evaluation of the Malin Shelf Survey

The new survey programme may provide a time-series for tuning a joint assessment of the Malin Shelf stock complex. However, such a time-series will not be available for a number of years. Until a time-series of Malin Shelf surveys is available, the current assessments can continue uninterrupted. If a new combined series became available it would have to be evaluated for its utility in tuning. Such work could not take place before 4 or 5 years of data are available. It should be noted that work in developing a new survey programme does not interfere with the tuning index time-series for any current stock.

The VIaS/VIIb,c sub-survey may provide a tuning index for that stock component, in time. A summer survey is considered a better index, because the fish are less contagiously distributed. However, it is unclear what the spatial extent of that stock is during summer.

It remains unclear to what extent fish from one stock are being registered in another stock area. It is likely that a proportion of the fish registered in the VIaN survey belong to the other two stocks. It is also possible that VIIaN and Firth of Clyde fish may be registered in VIaS (Morrison and Bruce, 1981).

2.1.4 Time series of existing surveys

In 2008 and 2009 the Malin shelf survey was carried out extending the areas south of 56°N. This survey gives estimates of abundance in the area 53° N to 56° N on the shelf area to the west of Ireland and Scotland. The archive of acoustic survey data for the ICES coordinated surveys in North Sea, Kattegat, Skagerrak, and VIa includes two years when the survey was carried out south to 53°N. The proportions of herring by age found south of 56°N in the four survey years (1995, 1996, 2008 and 2009) are compared below (Table 2.1.4.1). This indicates that larger proportions of young fish are found south of 56°N compared with adults. There is considerable variability between years.

Table 2.1.4.1. Percentage of estimate of area VIa found south of 56°N from acoustic surveys (Ages 1–9 by number, Biomass and SSB by weight). N.B. the 2008 data include the Northern Irish (RV "Corystes") survey; 2009 data are still preliminary and without the RV "Corystes" survey values which are likely to inflate the numbers and biomass of small, immature herring.

Age	1995	1996	2008	2009
1	74%	92%	89%	55%
2	26%	15%	38%	29%
3	28%	2%	9%	3%
4	15%	1%	7%	1%
5	5%	5%	6%	0%
6	11%	1%	5%	0%
7	8%	3%	0%	1%
8	4%	5%	0%	0%
9	30%	10%	0%	0%
SSB	25%	3%	6%	2%
Biomass	20%	8%	15%	6%

Survey and catch comparisons

Comparisons of the age compositions of catch numbers-at-age from commercial catches and survey data are presented below. Plots are presented comparing the VIaN canum, VIaS/VIIb,c canum, combined canum (VIaN, VIaS/VIIb,c and VIIaN) and the VIaN acoustic survey.

Good agreement between the VIaN survey and fishery was observed in about 10 out of 19 years. In 2 years there is some agreement at older ages but poor agreement at younger ages. In the most recent years agreement has been low, with mismatch between the most abundant age classes. The differences are mainly in younger (1 and 2-winter ring) fish. Good agreement between the VIaN survey and the combined catch-numbers-at-age (CNAA) was only found in 7 out the 19 years. The combined CNAA tends to differ both in young and older ages. Less agreement is seen between the VIaS/VIIb,c CNAA and the combined survey.

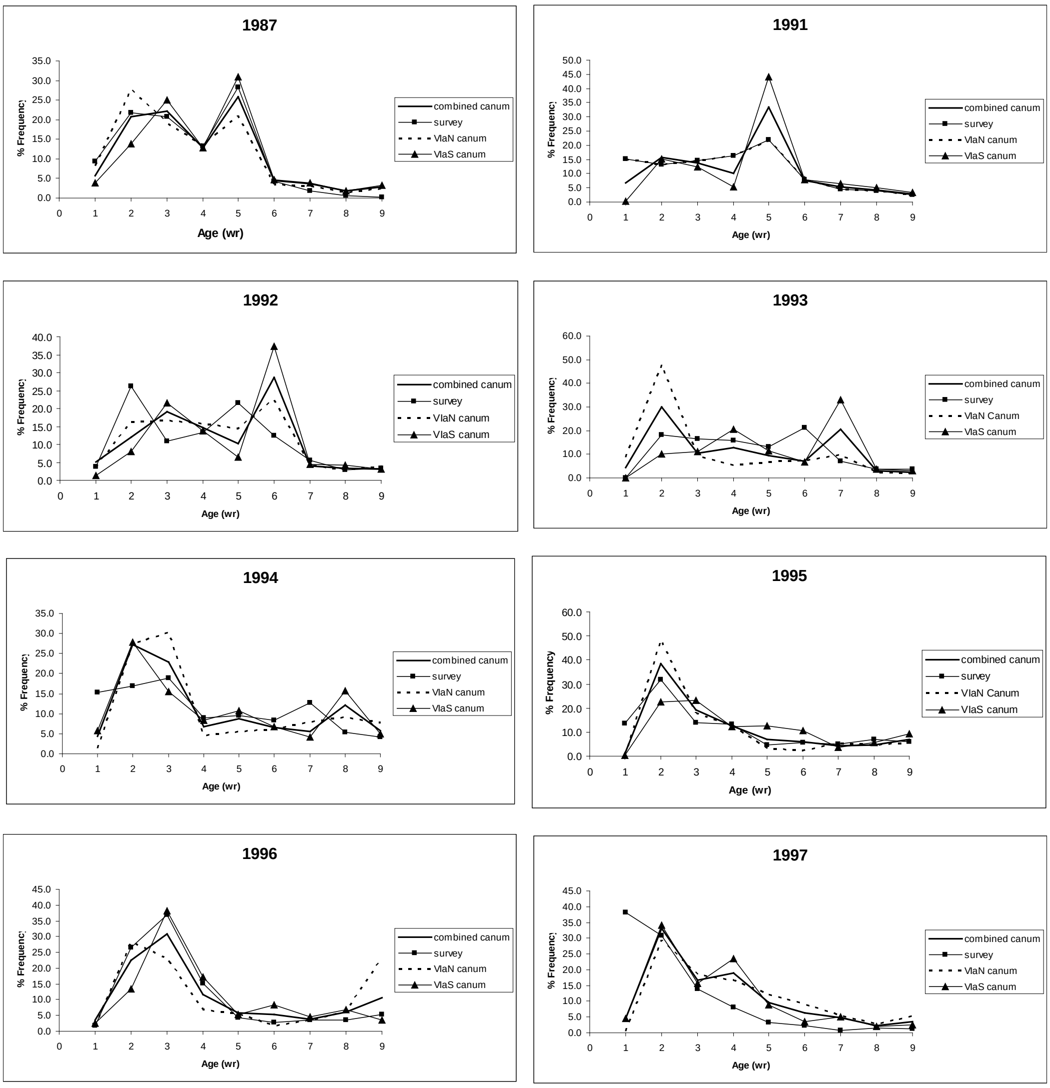


Figure 2.1.3.1. Percentage age composition in VIaN acoustic survey, VIaN and VIaS/VIIb.c catch numbers-at-age (CNAA) and combined Malin Shelf CNAA. Age in winter rings.

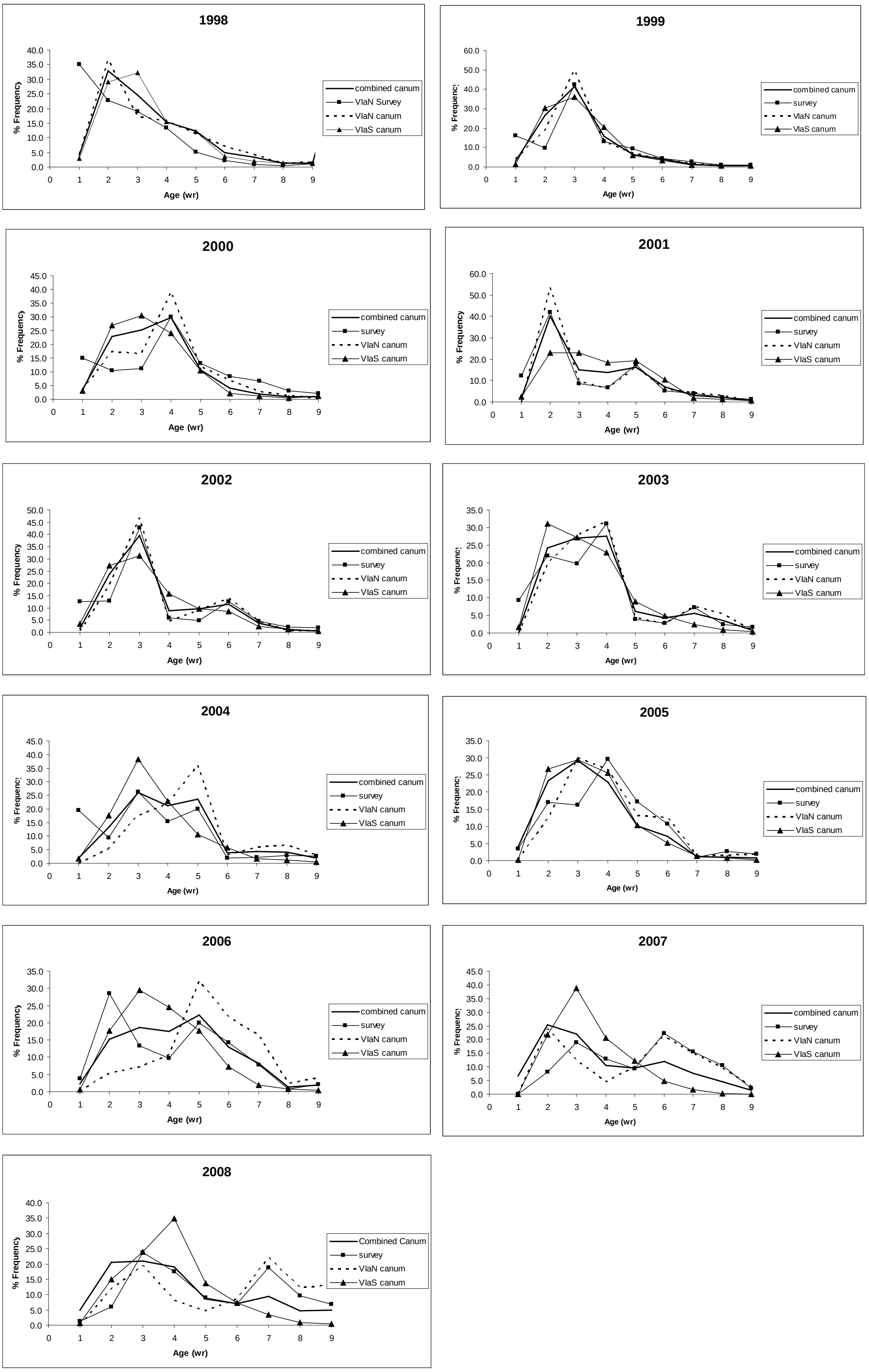


Figure 2.1.3.1 (continued). Percentage age composition in VIaN acoustic survey, VIaN and VIaS/VIIb.c catch numbers-at-age (CNAA) and combined Malin Shelf CNAA. Age in winter rings.

Substantial herring abundance south of 57°N was found from 1993 to 1999 and from 2002 to 2003 (presented in the 2008 SGHERWAY report (ICES 2008)), and again in 2008 and 2009 (Figures 2.1.1.3 and 2.1.1.4). The strong 1981 year class present in VIaS/VIIb,c can be seen in the VIaN survey and the CNAA. The strong 1985 year class also present in VIaS/VIIb,c was evident in the combined CNAA. It was also picked up by the VIaN survey but not to the same extent. Interestingly, both the strong 1981 and 1985 year classes from VIaS/VIIb,c were also strongly evident in the catch numbers-at-age for VIaN from 1987 to 1994 (data in ICES files). Either these cohorts were also strong in the VIaN stock, or they were mixing with local fish in the fishery in that area.

These comparisons illustrate that there is not full coherence between the existing VIaN survey and the VIaN catch numbers-at-age. However, the coherence with the survey and combined Malin Shelf CNAA is lower. There is evidence that fish from the more southern stocks occur in the VIaN area. Further work is required to quantify the extent of this mixing.

2.1.5 Time series of existing surveys

In 2008 and 2009 the Malin Shelf survey was carried out extending the areas south of 56°N. This survey gives estimates of abundance in the area 53°N to 56°N on the shelf area to the west of Ireland and Scotland. The archive of acoustic survey data for the ICES coordinated surveys in North Sea, Kattegat, Skagerrak, and VIa includes two years when the survey was carried out south to 53°N. The proportions of herring by age found south of 56°N in the four survey years (1995, 1996, 2008 and 2009) are compared below (Table 2.1.4.1). This indicates that larger proportions of young fish are found south of 56°N compared with adults. There is considerable variability between years. Note that the 2008 estimate includes North Channel results.

Table 2.1.4.1. Percentage of estimate of area VIa found south of 56°N from acoustic surveys (Ages 1–9 by number, Biomass and SSB by weight.)

Age	1995	1996	2008	2009
1	74%	92%	89%	55%
2	26%	15%	38%	29%
3	28%	2%	9%	3%
4	15%	1%	7%	1%
5	5%	5%	6%	0%
6	11%	1%	5%	0%
7	8%	3%	0%	1%
8	4%	5%	0%	0%
9	30%	10%	0%	0%
SSB	25%	3%	6%	2%
Biomass	20%	8%	15%	6%

2.1.6 Irish Sea herring coverage issues

There is evidence from historical scientific surveys, records of historical herring fisheries and tagging studies that herring are present throughout the Irish Sea during summer. This in turn suggests that the combined Malin Shelf survey described above may not fully contain the VIIaN herring stock at that time.

ICES (1994) provides an overview of the various sources of information which suggest that the Irish Sea acts as a nursery area and summer feeding ground for herring from both the Irish Sea (VIIaN) and Celtic Sea/VIIj stocks. Groundfish surveys of the northern part of the Irish Sea carried out between 1991 and 1993 showed young herring to be widespread in the area during June (Figures 2.1.5.1 and 2.1.5.2).

Large scale historical acoustic surveys of the area carried out in July 1991 and 1992 were designed to estimate the total stock size of the Manx and Mourne (the VIIaN spawning components) herring over summer feeding areas (Table 2.1.5.1; Armstrong 1992; Armstrong *et al.*, 1993). The emerging distribution patterns of herring detected during the surveys (Figures 2.1.5.3 and 2.1.5.4) reflected the early season fishery that had been carried out for centuries off the west coast of the Isle of Man (ICES, 1994). The summer acoustic surveys were discontinued as it was evident that they did not cover the whole stock, with an influx of larger herring, a proportion of which may migrate into the Irish Sea from Division VIa and the Clyde, occurring nearer spawning time. A comparison between the length structures of herring taken inshore on the west coast of the Isle of Man during the August 1993 survey with the length frequency of the Manx spawning aggregation a month later showed a much greater average size in the latter survey. (ICES, 1994).

Table 2.1.5.1. Summary of acoustic survey information for VIIaN from historical acoustic surveys in 1991 and 1992. Small clupeoids include sprat and 0-ring herring unless otherwise stated. CVs are approximate. Biomass in tonnes.

Year	Area	Dates	Herring biomass	CV	Composition	Small clupeoids biomass	CV	Total biomass estimate**
1991	Western Irish Sea	26 July – 8 Aug	12,760	0.23	1+ ringers	66 0001	0.20	20 250
1992	Western Irish Sea + IOM east coast	20 – 31 July	17,490	0.19	1+ ringers	43 200	0.25	23 240

**** Source ICA output (HAWG, 2007)**

[1] sprat only

Historical reports of the herring fisheries state that from about June each year, aggregations of prespawning herring started to congregate inshore along the northwest coast of the Isle of Man. Traditionally catches of this component of the Irish Sea stock reached a peak around July-August. The fish then moved offshore to be joined by older herring. The fish would then migrate around the south of the Isle of Man and onto the Douglas Bank spawning beds to the east of the island (ICES, 1994).

It is acknowledged that these sources of data are historical and not recent. However, the seasonality of herring spawning (autumn) in this area has not changed dramatically since the early 1990s (see Dickey-Collas *et al.*, 2001). It is therefore assumed that the juvenile life history will also be similar.

Tagging studies have been carried out in the Clyde area and the Irish Sea to get more information on the movements of Irish Sea herring. In the mid to late 1970s tagging was carried out in the Clyde (Morrison and Bruce, 1981). This study showed that both Manx and Mourne herring move to the Clyde area. These herring then emigrate from the Clyde to their respective spawning sites between late May and late August. It has also been shown that mixing between Celtic Sea and Irish Sea juvenile herring occurs in the Irish Sea (Brophy and Danilowicz, 2002). The results from a tagging experiment carried out in the Irish Sea were reported by Molloy *et al.* (1993). Approximately 10

000 1-ring and 2-ring herring were tagged and released in July 1991 west of the Isle of Man. 47% of the fish were recaptured around the Isle of Man, 10% off the County Down coast (Mourne herring), while the remainder, about 41%, were captured in the Celtic Sea or migrating to that area (Molloy *et al.*, 1993), suggesting that the links between Irish Sea and Celtic Sea herring stocks were extensive. A recent study has shown that, for herring sampled in Irish Sea in September, the biomass of "autumn" type spawning herring in the Irish Sea can be overestimated by a factor of 2 if the mixing of "winter" spawning stocks is not accounted for (Beggs *et al.*, 2009). If this was the case during the 1991 and 1992 July surveys then the summer Irish Sea herring biomass might have been lower than reported. In the Beggs *et al.* (2009) study the "winter" spawning type fish identified were assumed to originate in the Celtic Sea based on Brophy and Danilowicz's (2002) findings.

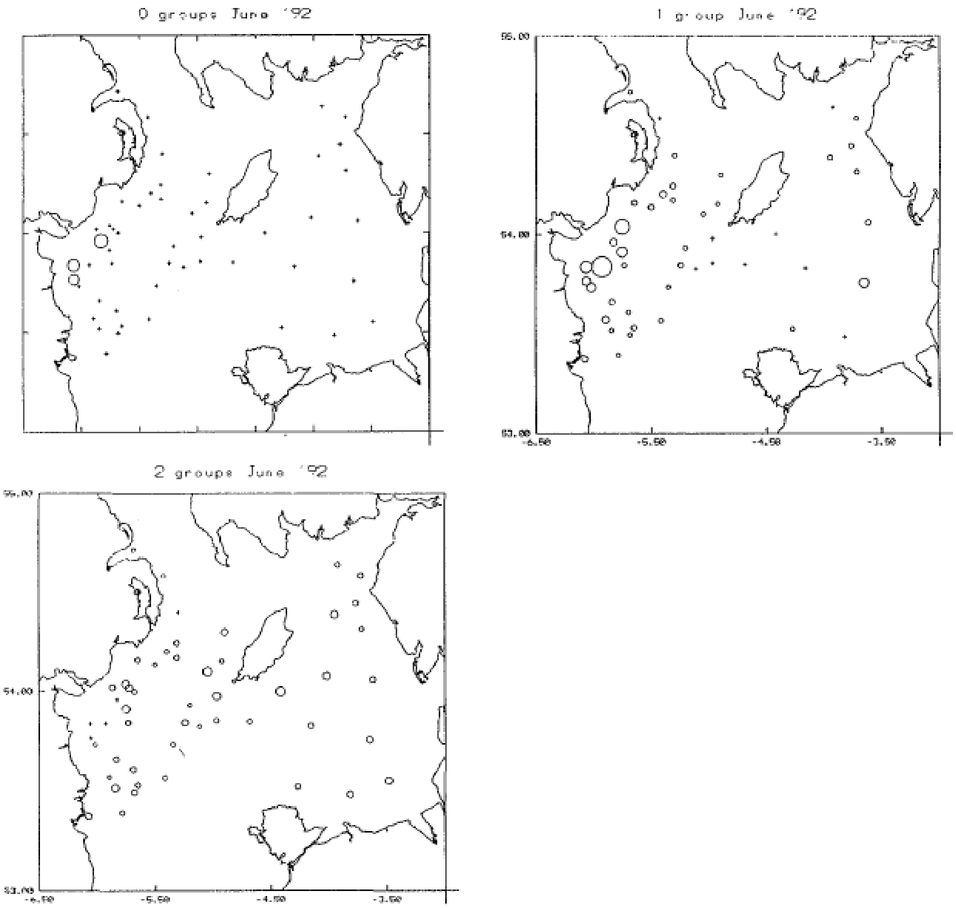


Figure 2.1.5.1. Catch rates of 0-ring, 1-ring and 2-ring herring in the Irish Sea during the June 1992 groundfish survey. (+ = zero catches; reproduced from ICES 1994).

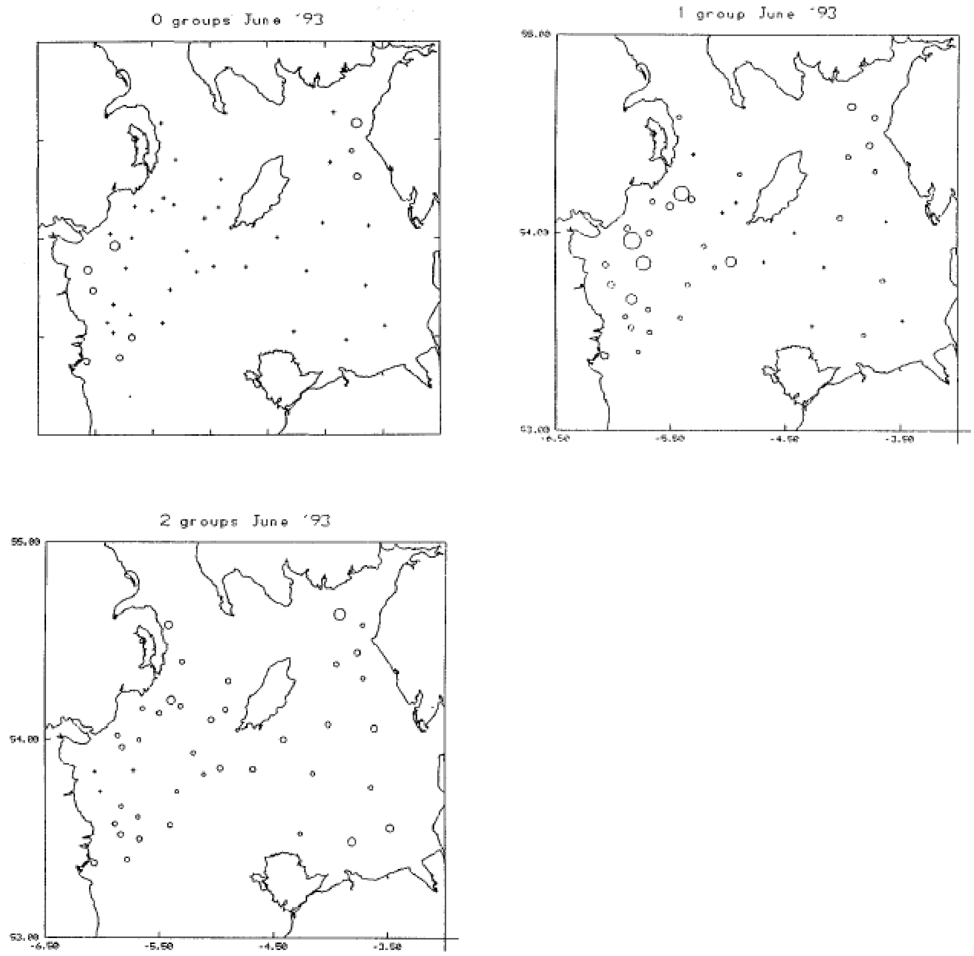


Figure 2.1.5.2. Catch rates of 0-ring, 1-ring and 2-ring herring in the Irish Sea during the June 1993 groundfish survey. (+ = zero catches; reproduced from ICES 1994).

The studies that have been carried out show that Irish Sea herring are dispersed throughout the Irish Sea in July when the Malin shelf survey is carried out. Therefore, in summary, it is possible that the "Malin Shelf" combined summer survey which does not survey the Irish Sea will underestimate the Irish Sea component of that combined survey. However, work needs to be done to unequivocally determine if the perception of 20 years ago is still relevant today.

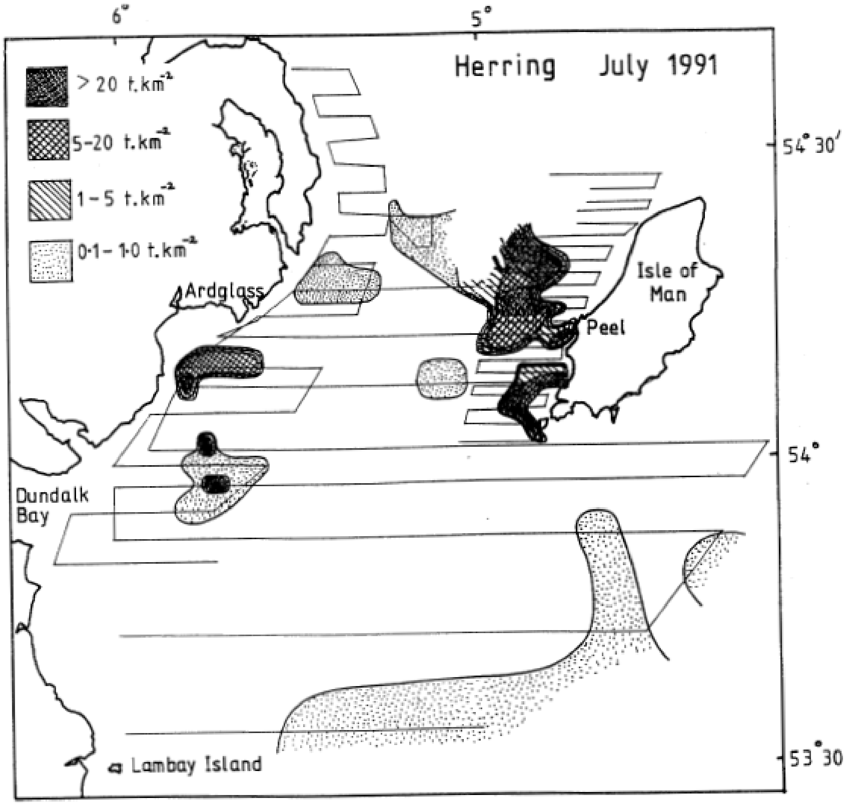


Figure 2.1.5.3. Density distribution of herring in Irish Sea during the July 1991 acoustic survey (reproduced from ICES, 1992).

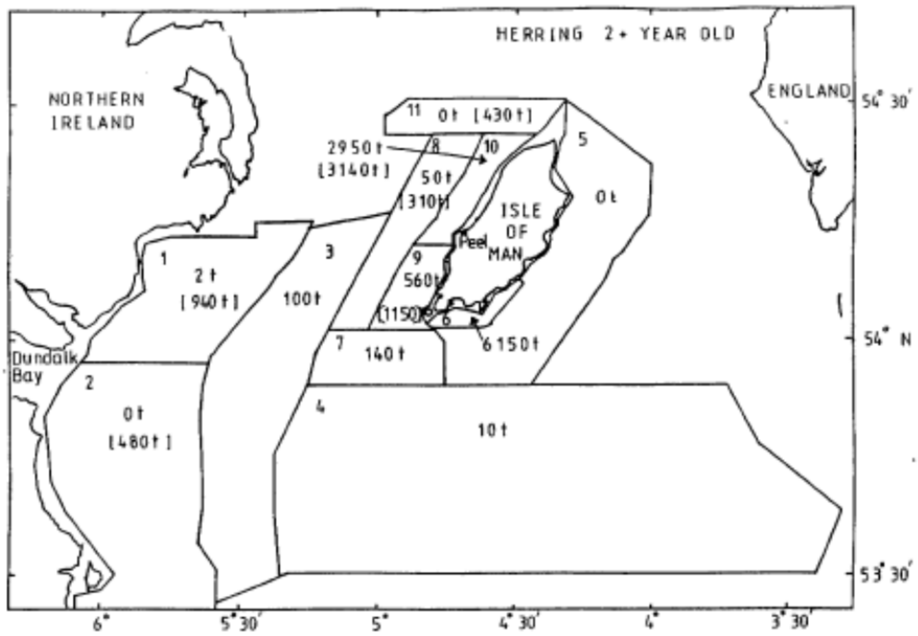


Figure 2.1.5.4. Biomass indices of 2+ ring herring during the July 1992 acoustic survey, by survey stratum (reproduced from ICES, 1993).

2.2 A west coast MIK survey

In 2007, after discussion with representatives of the Scottish Pelagic Fishermen's Association, it was decided within the then FRS (now Marine Scotland – Science) to instigate a survey of 0-ringer herring during the west coast 1st quarter International Bottom Trawl Survey (IBTS) to determine whether it could provide information of use to the VIaN herring assessment as a putative tuning index.

The 0-ringer index derived from the 1st quarter North Sea IBTS provides a very strong signal of year-class strength of North Sea herring. In the North Sea the 0-ring larvae result from the previous autumn and winter's spawning production. The 1st quarter IBTS in the North Sea started out as a young herring survey in 1966, with the objective of obtaining annual recruitment indices (abundance of 1-ringers in the 1st quarter) for the combined North Sea herring stock. It has been carried out every year since, and currently the survey provides recruitment indices not only for herring, but for roundfish species as well. During night-time, additional sampling of herring larvae (0-ringers) is carried out using small, fine-meshed nets. From 1977 to 1991 a small midwater trawl (IKMT) was used, but as a consequence of poor catchability of this gear the standard gear was changed. Since 1991, a 2 metre Methot Isaacs–Kidd ring-net (MIK) has been used for sampling. The total abundance of herring larvae in the survey area is used as an estimate of 0-ringer abundance of the stock.

There is currently a quarter 1 IBTS survey to the west of Scotland but, historically, no MIK net sampling has been carried out during this survey. The VIaN herring stock lacks a recruitment index, with the only fishery-independent information in the assessment coming from the July acoustic survey; this only catches adults, aged 2+. The acoustic survey does not encounter recruits, or even juveniles, to enable a recruitment index to be developed with sufficient precision.

It was thought, then, that a MIK net survey during the west coast 1st quarter IBTS might provide a reasonable index of recruitment as it does in the North Sea. The herring stock in VIaN is predominantly composed of autumn spawners (as in the North Sea) and a quarter 1 MIK net survey would be able to catch overwintered 0-ringers, if they are present, and thus give a recruitment index. However, there are issues with the entrainment of herring larvae from the VIaN stock into the North Sea as passive drift in the prevailing currents (Figure 2.2.1). There are similar issues of drift of herring from VIaS/VIIb into VIaN.

2.2.1 The surveys

A MIK net survey was carried out in both 2008 and 2009, during the west coast 1st quarter IBTS on FRV *Scotia*, from 1 – 21 March 2008, and from 9 - 29 March 2009, from west of the Orkney Islands to the north of Ireland.

During these surveys the MIK net was used to sample plankton in the hours of darkness after the day's bottom-trawling had been completed. The purpose of these exploratory investigations was to measure the abundance and distribution of pre-metamorphic herring larvae. At least one MIK haul was planned for every statistical rectangle that was fished with a bottom-trawl in daylight hours.

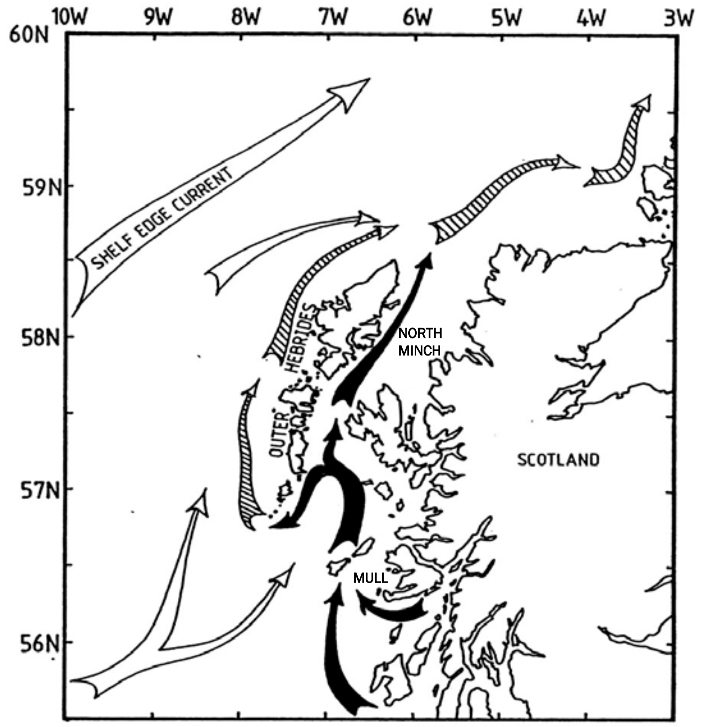


Figure 2.2.1. Schematic of mean current circulation over the west of Scotland shelf. Open arrows represent flow of high salinity Atlantic Ocean water (>35.1 ‰); filled arrows represent flow of coastal water (<34.8 ‰), and hatched arrows represent flow of mixed coastal/Atlantic water. Reproduced with permission from Heath (1989).

2.2.2 Results

In 2008, "Scotia" completed 67 MIK hauls, and in 2009 there were 63 MIK hauls. The catch in each haul was analysed for herring larvae and these larvae were measured and preserved in 4% buffered formaldehyde. All clupeoid larvae caught were identified as herring. Herring larvae were caught in 38 of the 67 hauls in 2008 and in 19 of the 63 hauls in 2009.

Figure 2.2.2.1 shows the differences in abundance in the areas surveyed. In 2008, the maximum abundance was 6.65 larvae per square metre (m^2), caught off the north coast of Ireland. The mean number of larvae caught was 0.633 per m^2; this has a fairly high variance. The majority of the herring larvae were caught in the South Minch, around the Inner Hebrides, and to the north of Ireland, whereas the offshore areas showed little or no abundance, especially in the northwest.

In 2009, a similar distribution picture was observed. The maximum abundance was 29.94 larvae per m^2, caught off the north coast of Ireland. The mean number of larvae caught was 0.734 per m^2; which also has a high variance.

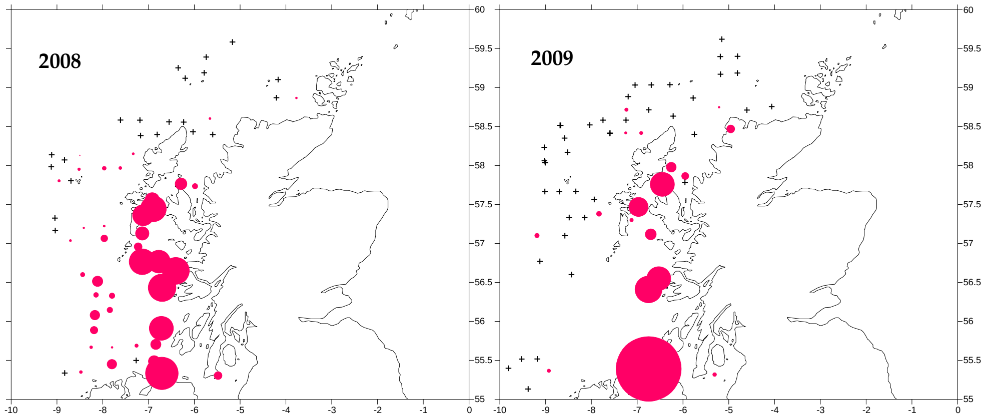


Figure 2.2.2.1. Abundance of herring larvae in the 2008 and 2009 1st quarter west coast MIK net surveys. Bubbles are scaled to the maximum value of 6.65 larvae per m2 in 2008. + indicates zero values.

Figure 2.2.2.2 shows the distribution of mean lengths of the herring larvae. In 2008 the overall mean length was 16.5 mm which is lower than the mean of 21.84 mm of the North Sea herring larvae caught in February 2008, in the northern North Sea, with the same sampling equipment. The average length in all hauls, bar two, was below 20 mm. Five hauls contained larvae of ≥25 mm. These larger larvae were found off the northwest of Scotland, in the Minches and off the north coast of Ireland. In 2009 the overall mean length was 16.3 mm which is lower than the 21.64 mm of the North Sea herring larvae caught in February 2009, in the northern North Sea, with the same sampling equipment. Again, five hauls contained larvae of ≥25 mm. These larger larvae were found off the northwest of Scotland, in the North Minch, to the west of Mull and just off the north coast of Ireland. The average length in all hauls, bar one, was below 20 mm.

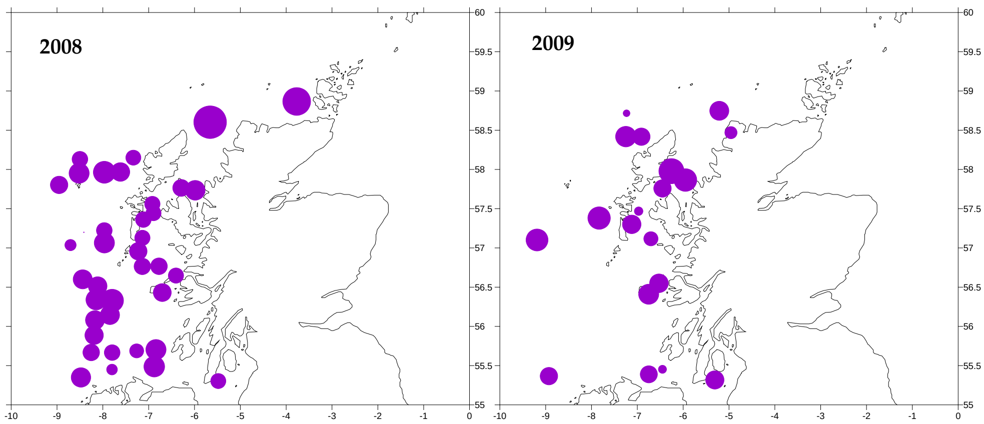


Figure 2.2.2.2. Mean length of herring larvae in the 2008 and 2009 1st quarter west coast MIK net surveys. Bubbles are scaled from the minimum mean value of 11 mm to the maximum mean value of 29 mm.

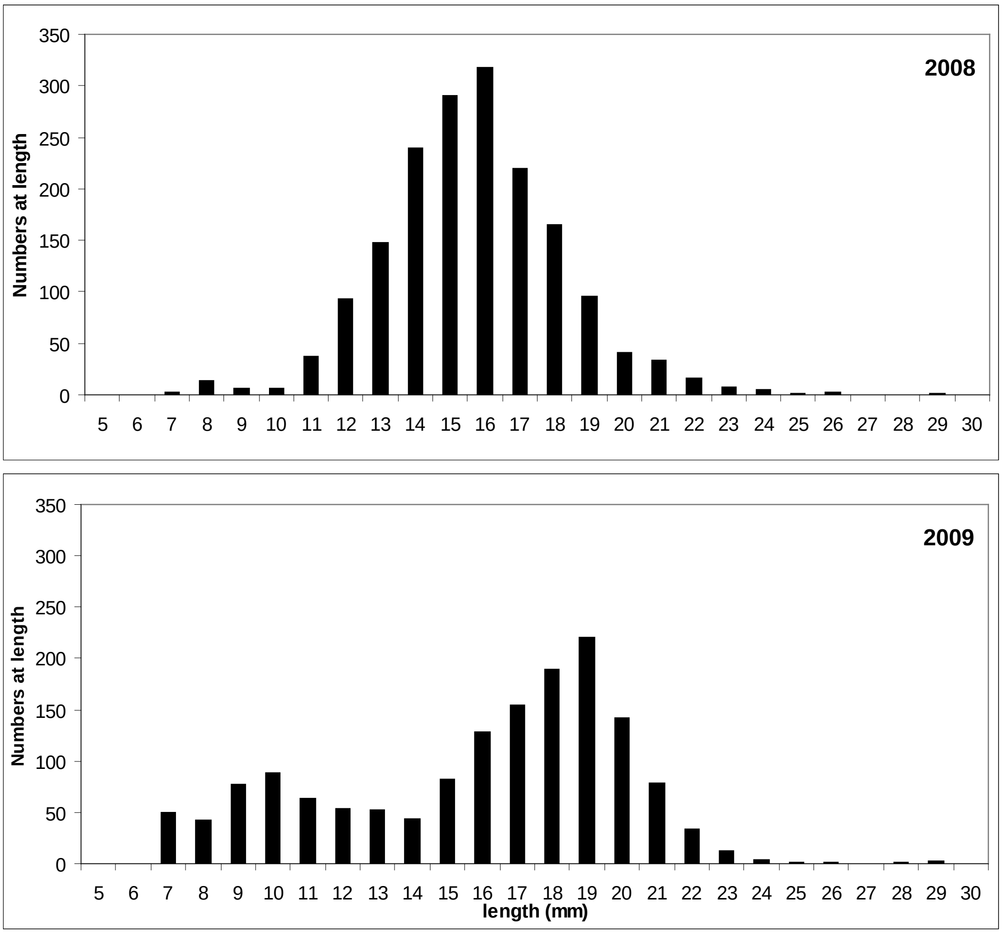


Figure 2.2.2.3. Length-frequency distribution of herring larvae in the 2008 and 2009 1st quarter west coast MIK net surveys.

Figure 2.2.2.3 shows the length–frequency distribution in both survey years. In both years the minimum length caught was 7 mm and the maximum was 29 mm. However, the length distribution is quite different. In 2008 there was a unimodal distribution with a mode at 16 mm whereas 2009 showed a very clear bimodal distribution with clear modes at 10 and 19 mm.

2.2.3 Larvae spawning identity

The question is where do these larvae originate? To determine this simplistically, hatch-dates can be back-calculated using a few assumptions on hatch length and growth rates.

A hatch length of 6.2 mm was used, based on Heath and MacLachlan (1987) and month-specific growth rates were taken from Table 3 in Munk *et al.* (1991) for their region 1a (northwestern North Sea). The February growth rate was used for dates beyond February and a linear interpolation between January and November was used to estimate December growth, as it was not measured in Munk *et al.* (1991). From the time it would take to grow at those rates up to a length of 29 mm, in 2008, the maximum age was assumed to be 145 days, and only 4% of larvae sampled were 112 days or older ($\geq$ 20 mm length). In 2009, again, the maximum age was assumed to be 145 days, whereas approximately 18% of larvae sampled were 112 days or older.

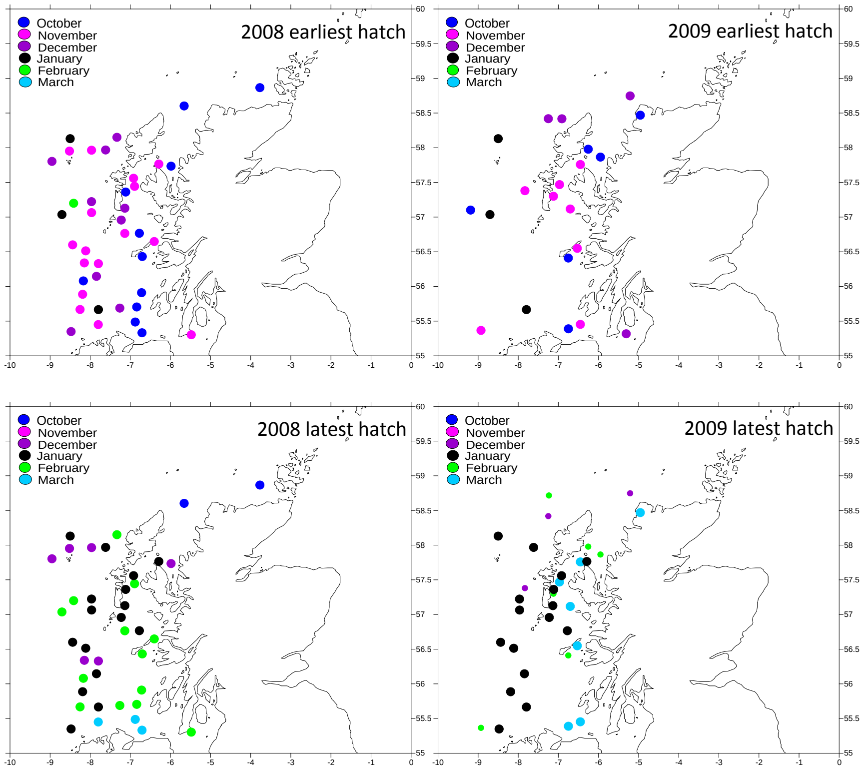


Figure 2.2.3.1. Back-calculated earliest and latest months of hatch for herring larvae in the 2008 and 2009 1st quarter west coast MIK net surveys.

Given the sampling period in 2008 (2 - 19 March) and the range of ages in the samples, the earliest any of the sampled larvae could have hatched was 14 October 2007. For 2009, with a sampling period 9 – 29 March, the earliest any of the sampled larvae could have hatched was 27 October 2008. Note, however, that Munk *et al.* (1991) stated that their growth rates could have been overestimated somewhat, so the actual hatch dates could be earlier than predicted. The largest larvae seen in both surveys, ≥25 mm, were all hatched on, or soon after, the earliest hatch dates and comprise the majority of the dark blue circles in the minimum hatch date distributions (two upper panels) in Figure 2.2.3.1 (above). In 2008, only 0.2% of the larvae caught were hatched within the survey period. In 2009, however, 5% of those caught were hatched within the survey period.

In 2008 the modal size was 16 mm, with 66% of the sampled larvae at or below this size. This equates to an approximate age of 80 days, with hatch dates for the modal size ranging from 13 – 30 December 2007, given the survey dates. Assuming egg duration of 3 weeks this implies a spawning period for the most commonly encountered larvae size from late November to mid December 2007. No account is taken of between-stage mortality and these hatching and spawning times are merely indicative. In 2009, the picture was slightly more complex, given the bimodal size distribution. For the 10 mm mode, 17% of the sampled larvae were at or below this size. This equates to an approximate age of 29 days, hatch dates ranging from 11 – 24 February 2009 and an approximate spawning period from late January to early February 2009. The second mode, at 19 mm, equates to an approximate age of 104 days. 65% of sampled larvae in 2009 were between 11 and 19 mm. An age of 104 days equates to hatch dates ranging from 28 November to 12 December 2008 over the period surveyed and an approximate spawning period from early to late November 2008.

Some preliminary exploratory backwards particle tracking simulations were performed but these did not provide an informative spawning area location, as a consequence of the deterministic nature of the model.

2.2.4 Conclusions

In both 2008 and 2009 the majority of the larvae caught were likely to be from winter spawning events from November onwards, with evidence of spawning activity into February (from back-calculated hatch dates in March). The VIaN herring stock now spawns predominantly from August to October (Rankine, 1986) but there is evidence of some winter/spring-spawning in the area (Bowman, 1922; Heath, 1984) VIaN autumn-spawned herring larvae do not appear to be present in the two MIK surveys carried out in 2008 and 2009. Given that larvae surveys carried out in the area from 1973 to 1993 demonstrated the entrainment of herring larvae from the VIaN stock into the North Sea as passive drift in the prevailing currents (Figure 2.2.1; Heath 1989) this might be expected. It does, however, confirm that drift characteristics in play during the previously surveyed period are still in place. Herring from the north and northwest of Ireland are known to have an extended spawning period, from late September to March (Anon., 1994; Molloy, 1983). Molloy and Barnwall (1988) suggested that herring from Donegal and further south drift north towards the Scottish coast. Evidence from the parasitic load of juvenile herring from the Scottish west coast sea lochs from two studies, in the mid 1980s (MacKenzie, 1985) and more recently, from 200 2–2005 (Campbell *et al.*, 2007), suggests very strongly that this drift pattern occurs from the north and northwest of Ireland and has been doing so for at least the last 20 years. The hydrodynamics of the region would tend to advect larvae away from the coastal north and northwest of Ireland in a northerly and easterly direction towards the Minches and Hebrides (Figure 2.2.1), giving the distribution seen clearly in this survey. It is likely, therefore, that the majority of the larvae present in both 2008 and 2009 are from spawning events in VIaS and possibly VIIb.

Several studies have given expected rates of movement away from the VIaN spawning grounds (reviewed in Heath, 1989). It may, therefore, be possible to determine (model) where one might expect the VIaN larvae to be at the time of the North Sea MIK surveys and quantify them. In fact preliminary research, using 'back-tracking' in a particle tracking model using the North Sea MIK samples indicates that larvae found in the northern North Sea during the quarter 1 IBTS MIK survey probably originated from the west coast of Scotland (M. Payne, DTU Aqua, Denmark personal communication). This research is 'ongoing' and the results should be available in the latter half of 2010. Therefore, it might then be the possible to combine data from the west coast, and relevant parts of the North Sea, MIK surveys to produce an index of larvae abundance that could be used as a recruitment index, as done for the North Sea (see ICES, 2009a). This will be investigated. The one caveat to the presence of west coast of Scotland larvae occurring in the North Sea is that there is limited research evidence currently available as to whether these larvae recruit back to the west coast of Scotland (Campbell *et al.* 2007) and as such remain part of the VIaN stock.

It has been requested within SGHERWAY that the Marine Scotland-Science, Marine Laboratory Aberdeen should continue to perform these surveys. Given that they cover the spawning period of herring in VIaS and VIIb, there might be utility in this survey as an index of larvae abundance for that area if a time-series is allowed to build up.

2.3 Exploration of a combined assessment of the three stocks and an investigation of its utility for advisory purposes

In order to facilitate a common assessment of the various stock units that constitute the Malin Shelf metapopulation, a common dataset was compiled in 2008. This dataset was extended in 2009 to include the Clyde data and the most recent catch and survey data. The combined assessment data covers 1961–2008. Full details on how the data were combined are presented in the 2008 SGHERWAY report (ICES, 2008). The Clyde data were compiled as follows:

Data used were supplied by the Marine Lab. in Aberdeen. These were found to correspond to the combination of two datasets available to SGHERWAY in 2008. These two datasets represented native Clyde spring spawners (SS) and immigrant autumn spawners (AS). These combined data also correspond to data presented in HAWG 2005.

It was noted that the sum of products (canum*weca) for the combined Clyde data were in excess of reported landings for the stock, presented in HAWG 2005. There was no evidence of duplication of the catches from the Clyde in the other assessments (Dickey-Collas, Molloy, Nash and Simmonds personal communications). Therefore, the combined Clyde AS and SS canums were scaled to the reported catches from HAWG 2005. These data were then added to the Malin Shelf 2008 canum.

Mean weights in the catch in the new (2009) Malin Shelf dataset were re-weighted using the new canums, including Clyde data, and updated to 2008. The re-weighting was done by multiplying the new combined catch numbers-at-age (including Clyde) by the VIaN mean weights-at-age then dividing the products by the new combined catch numbers-at-age. Stock weights and acoustic survey abundance indices were as used for VIaN (HAWG, 2009).

Table 2.3.1. Description of time-series for Malin Shelf Metapolulation of herring.

UNIT	DESCRIPTION	YEARS
VIaN (incl. Moray Firth juvenile historic fishery)	ICES Files	1970–2008
VIaS/VIIb,c	ICES Files	1970–2008
VIIaN	ICES Files	1961–2008
Clyde	ICES 1978; Bailey *et al.*, 1986; ICES, 2005	1960–2005
VIaN (incl. Moray Firth juvenile historic fishery)	Data revision 2003, raised	196 1–1969
VIaS	Segregated from VIa, using allocation keys from 2003 revision of VIaN assessment data	196 1–1970
VIIb,c	Only catch in tonnes available	196 7–1970

The catch numbers-at-age were mean-standardized and are presented in Figure 2.3.1 below. Two of the strongest year classes visible are 1981 and 1985 which were also picked up in the VIaS fishery. The strong 1963 and 1969 year classes which were seen in the VIaN fishery can also be seen.

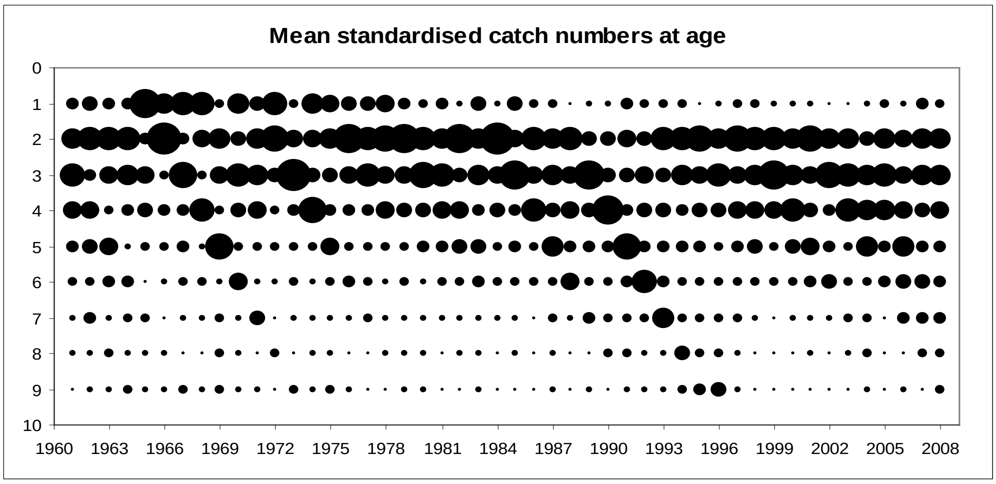


Figure 2.3.1. Catch numbers-at-age for the combined series, including the Clyde, 196 1–2008

2.3.1 Combined Assessment

2.3.1.1 Data Available

The available data for the three areas which make up this metapopulation are given in the text table below. The combined dataset runs from 196 1–2008 and uses ages 1 - 9+.

	VIaN	VIaS/VIIb,c	VIIaN	Clyde
Time Series	1957 - 2008	1970 - 2008	1961 - 2008	1961 - 2001
Age Range	1 - 9+	1 - 9+	1 - 8+	1 - 10+
Surveys	Acoustic 1987, 1991 - 2008	No survey	Acoustic 1994 - 2008 Larvae 1983 - 2008	

2.3.1.2 Assessment

A number of different assessment runs were carried out to explore the combined dataset. Full details of the settings tested in each run are presented in the table below. Run 18 is considered the best run because it improves the diagnostics of this exploratory assessment.

Table 2.3.1.1. Exploratory assessment runs performed.

	Catch Data	Survey Time Series	Survey ages	Separable Period	Reference Age	Selection at oldest age
SPALY Run	1961-2008	1987-2008	1-9	8	4	1
1	1961-2008	1987-2008	1-9	8	4	0.7
2	1961-2008	1987-2008	1-9	8	4	0.85
3	1961-2008	1987-2008	1-9	8	4	1
4	1961-2008	1987-2008	1-9	8	4	1.15
5	1961-2008	1987-2008	1-9	8	4	1.3
6	1961-2008	1987-2008	1-9	8	3	1
7	1961-2008	1987-2008	1-9	8	3	0.7
8	1961-2008	1991-2008	1-9	8	4	1
9	1961-2008	1992-2008	1-9	8	4	1
10	1961-2008	1993-2008	1-9	8	4	1
11	1961-2008	1994-2008	1-9	8	4	1
12	1961-2008	1995-2008	1-9	8	4	1
13	1961-2008	1996-2008	1-9	8	4	1
14	1961-2008	1997-2008	1-9	8	4	1
15	1961-2008	1997-2008	1-9	8	4	1
16	1961-2008	1998-2008	1-9	8	4	1
17	1961-2008	1999-2008	1-9	8	4	1
18	**1961-2008**	**1998-2008**	**3-6**	**8**	**4**	**1**
19	1961-2008	1998-2008	2-7	8	4	1
20	1961-2008	1998-2008	2-6	8	4	1
21	1961-2008	1987-2008	3-6	8	4	1
22	1970-2008	1987-2008	1-9	8	4	1
23	VIaS and VIaN only	1987-2008	1-9	8	4	1
24	VIaS VIaN and Clyde only	1987-2008	1-9	8	4	1

SPALY run

The first run carried out was an update of the run conducted at the 2008 meeting. The dataset was extended to include the 2008 survey and catch data as well as the Clyde data. The assessment performed uses an Integrated Catch at Age analysis method (ICA), embedded within the FLR software, using the R platform (R Development Core Team 2008), with the same settings as the 2009 VIaN assessment (ICES, 2009a). The stock summary and the diagnostics from this run (SPALY) are presented in Figures 2.3.1.1 to 2.3.1.8 below. The separable period was 8 years and selection was fixed at 1.0 relative to age 4. The diagnostics do not show much change from the run carried out in 2008.

Examination of the diagnostics (Figures 2.3.1.2 – 2.3.1.8) shows that the observed and fitted time-series are noisy for younger ages. It can also be seen that from age 5 to age 9 there is a mismatch between the fitted index and the observed index. This may be because the acoustic survey did not pick up the strong 1985 year class evident in the combined catch data (Figure 2.3.1).

The VIaN survey in 2008 had a greater spread of ages than in previous years with higher amounts of older ages. This leads to low agreement in the diagnostics from the older ages in 2008. The survey age classes encountered on this survey vary from year-to-year, with year class estimates one year higher than the previous year. Oscillations in the biomass estimate are also seen. The imprecision is almost certainly driven by the year-to-year variability of the distribution of the stock and the contagious distribution of herring within the survey area (Fernandes *et al.*, 2003).

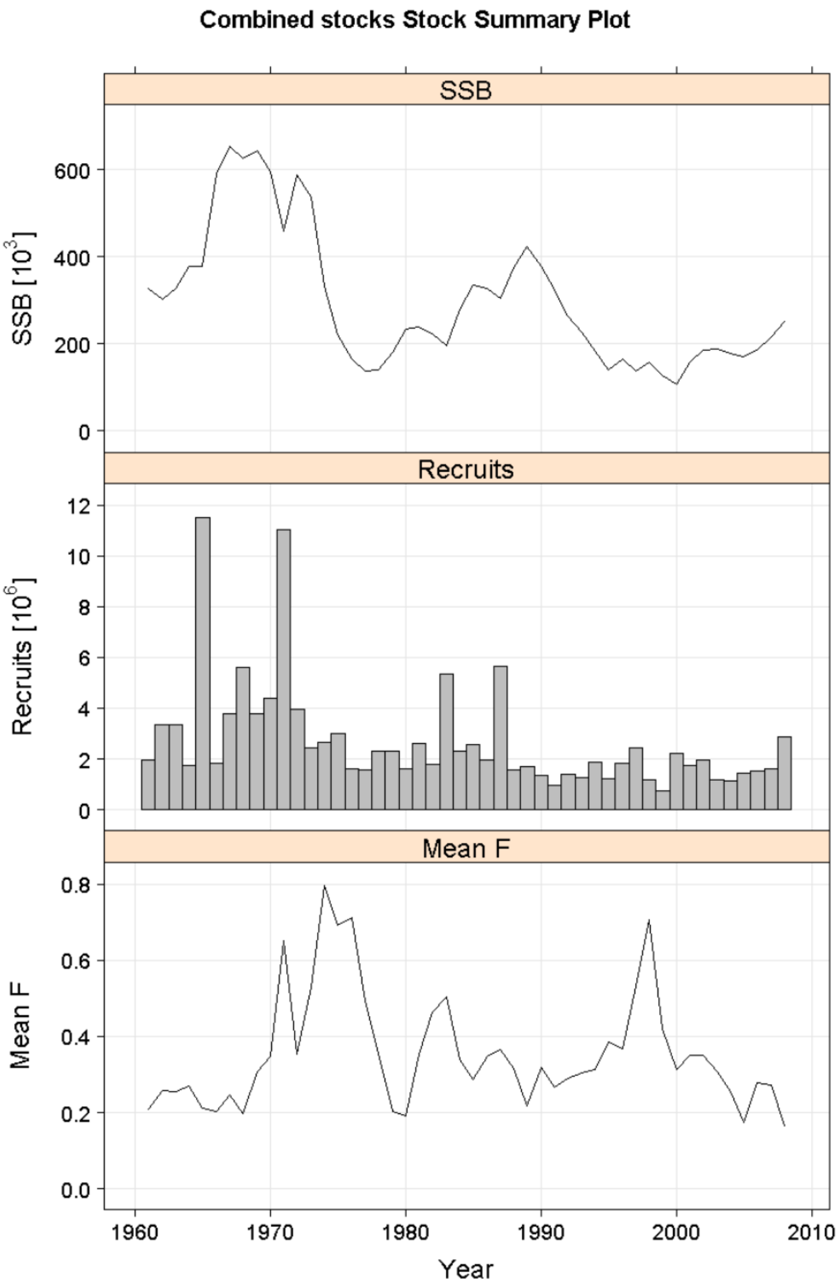


Figure 2.3.1.1. Combined Assessment SPALY run. SSB, Recruits and Mean F ages 3–6.

The catch and survey residuals are presented in Figures 2.3.1.7 and 2.3.1.8 and do not show any clear year or age effects, other than the 2005 effect in the log catch residuals. Figure 2.3.1.9 shows the otolith plot which shows the results of parametric bootstrapping and represents the uncertainty of the fit to the assessment model.

An analytical retrospective was carried out. Analytical retrospectives are carried out in stock assessments to evaluate assessment quality. However, this method only provides a measure of the internal consistency of the methodology that is used (Payne *et al.*, 2009a). A poor retrospective pattern can be seen in Figure 2.3.1.10. SSB and recruitment tend to be overestimated and mean F underestimated. The addition of the Clyde data and most recent year did not improve this pattern. However the retrospective bias is much lower in the recent period than in the early 2000s, and is comparable to many other ICES assessments.

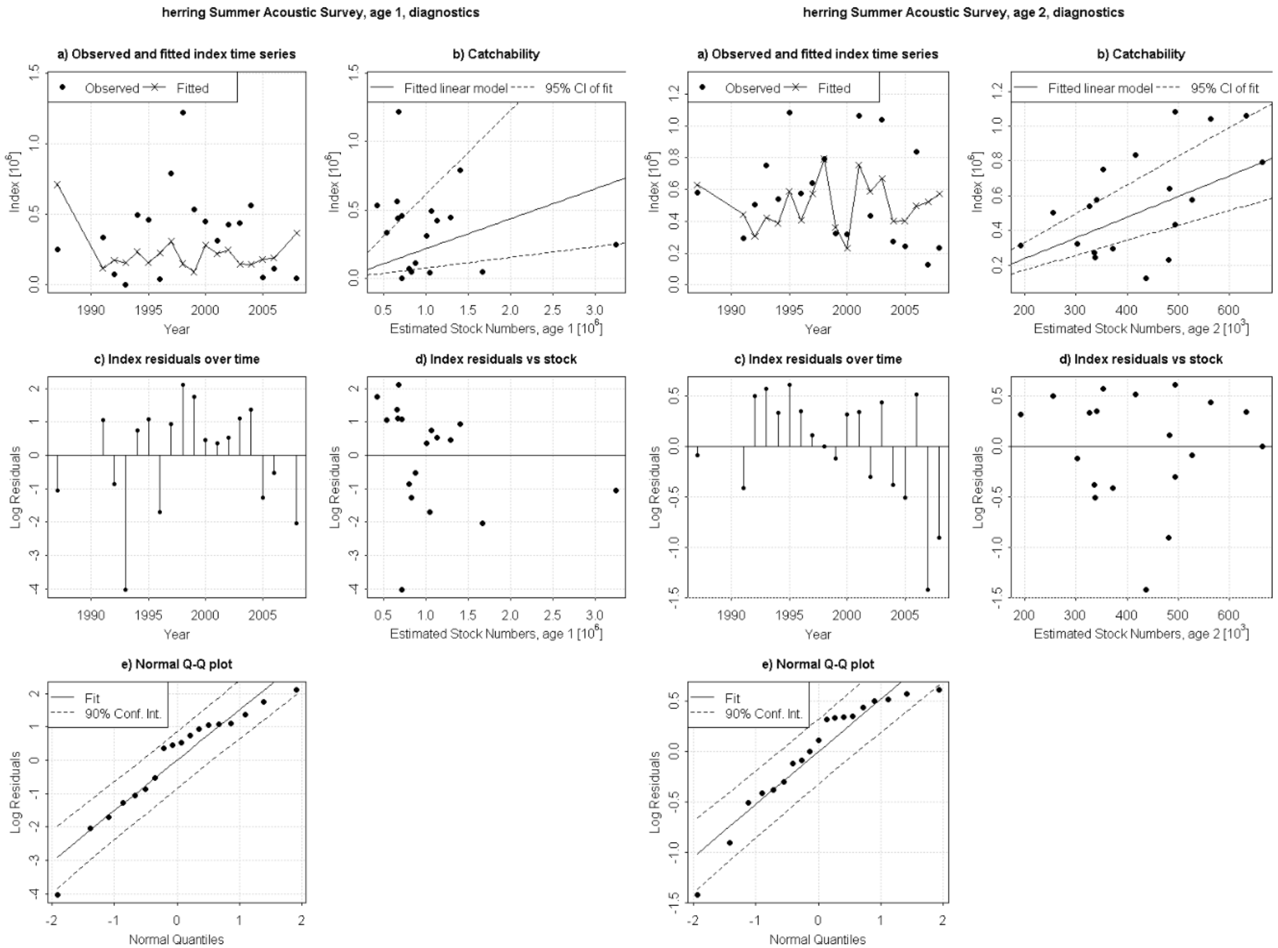
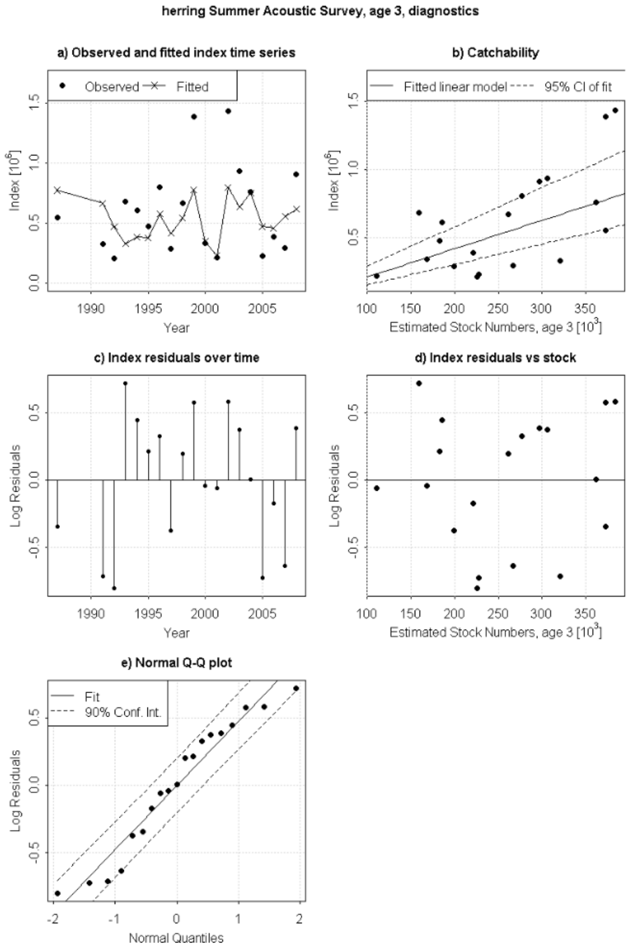


Figure 2.3.1.2. Combined Assessment SPALY run. Diagnostics of the VIaN acoustic survey fit at 1 wr (left) and 2 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatter plot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).



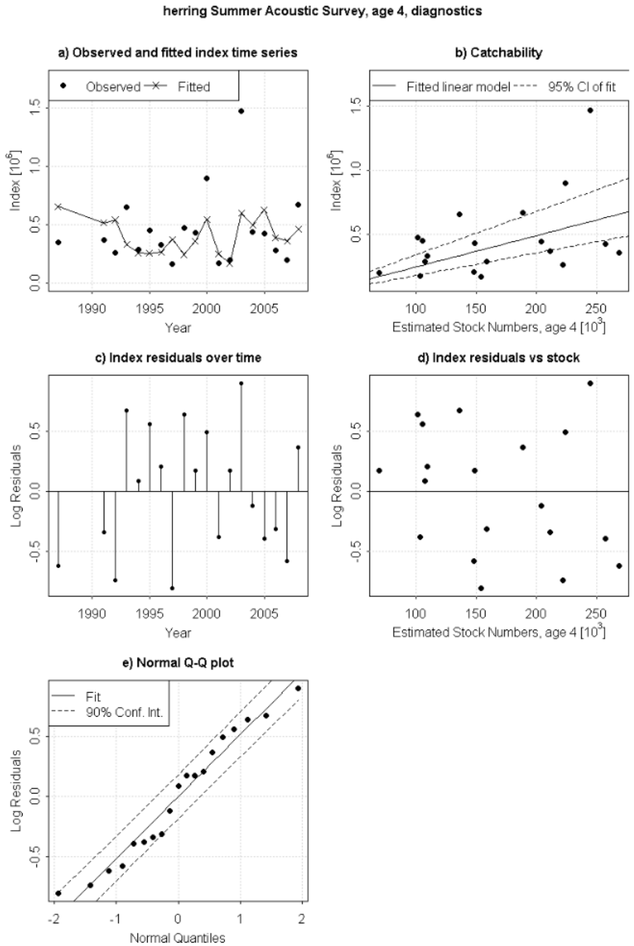


Figure 2.3.1.3. Combined Assessment SPALY run. Diagnostics of the VIaN acoustic survey fit at 3 wr (left) and 4 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatter plot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

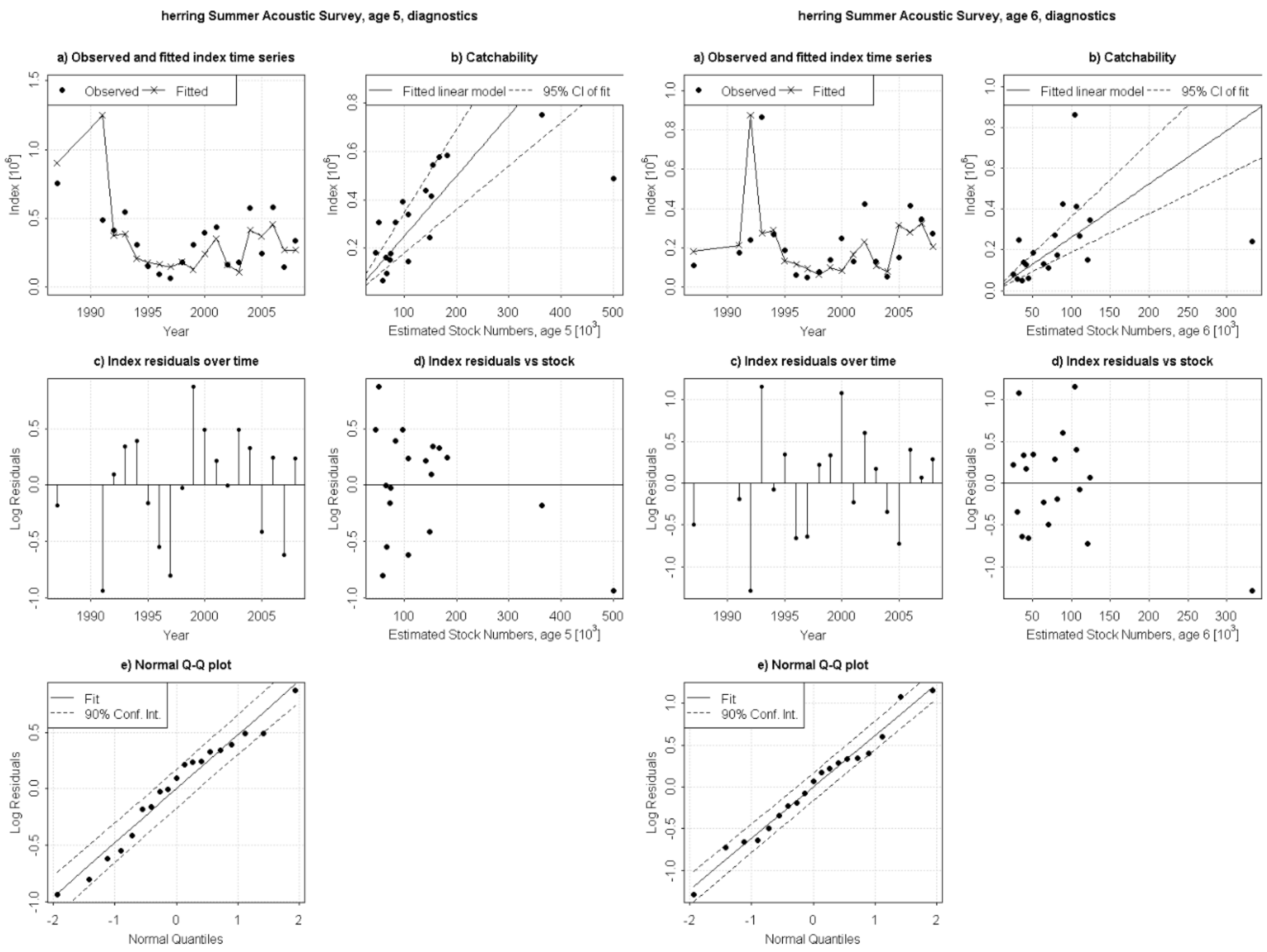


Figure 2.3.1.4. Combined Assessment SPALY run. Diagnostics of the VIaN acoustic survey fit at 5 wr (left) and 6 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatter plot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

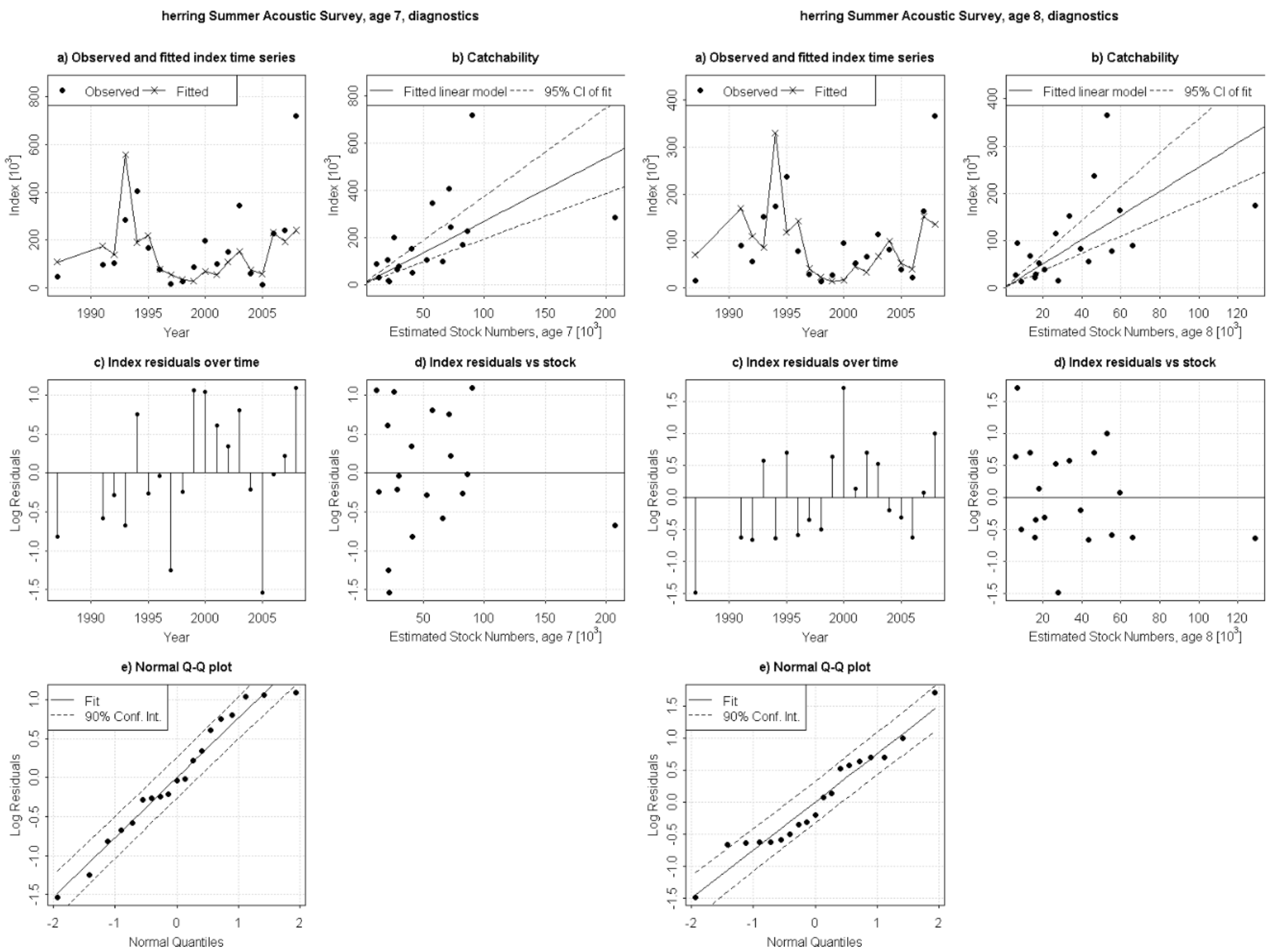


Figure 2.3.1.5. Combined Assessment SPALY run. Diagnostics of the VIaN acoustic survey fit at 7 wr (left) and 8 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatter plot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

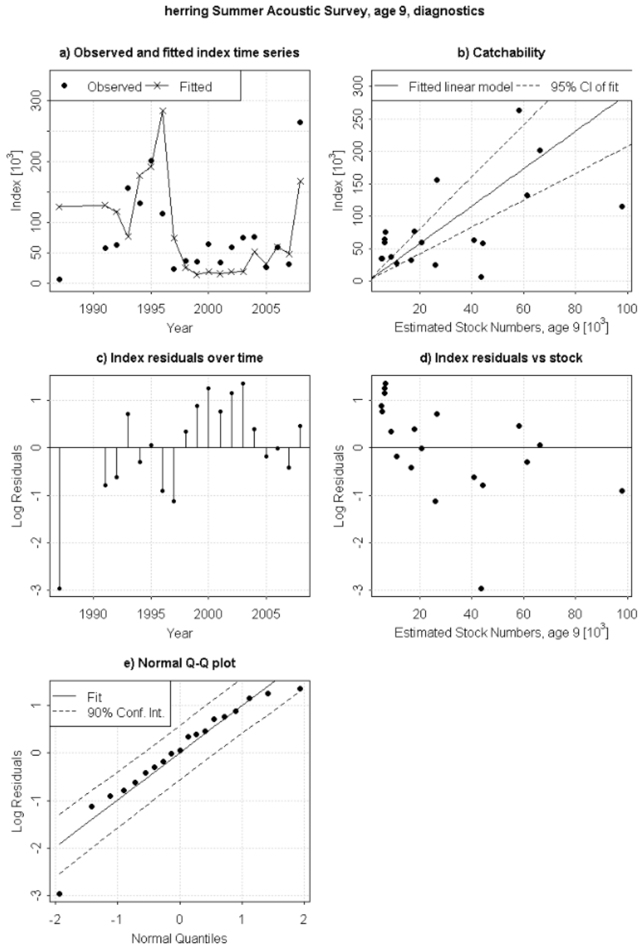


Figure 2.3.1.6. Combined Assessment SPALY run. Diagnostics of the VIaN acoustic survey fit at 9 wr from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatterplot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal QQ plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

Further exploratory analyses

The selection on the oldest age and the choice of reference age were examined. Examination of catch curves shows that the main ages for full recruitment are 2 and 3 ringers and therefore reference ages of 3 and 4 were tested in the assessment. Selection on the oldest age was also examined with values ranging from 0.7 to 1.3 used. A range of values was examined because it is believed that the stocks in VIaN, VIaS/VIIb,c and VIIaN are exploited at different levels which would equate to a dome-shaped selection in a combined assessment. The reason for this is that fish exploited at a higher level would only form a small component of the exploited stock at older ages, whereas fish exploited at a lower level would form a larger component of the exploited stock at older ages.

Changes could be seen in the catch diagnostics with a selection value of 0.7 and a reduced reference age of 3. This gave the most dome shaped pattern (Figure 2.3.1.11). A flat topped selection pattern can be seen if selection is set at 1.3 and the reference age is 3 (Figure 2.3.1.11). An upward facing selection can be seen if a higher value for selection (1.3) and a reference age of 4 is chosen (Figure 2.3.1.12). However, these runs did not change the remaining diagnostics with a poor retrospective pattern observed each time.

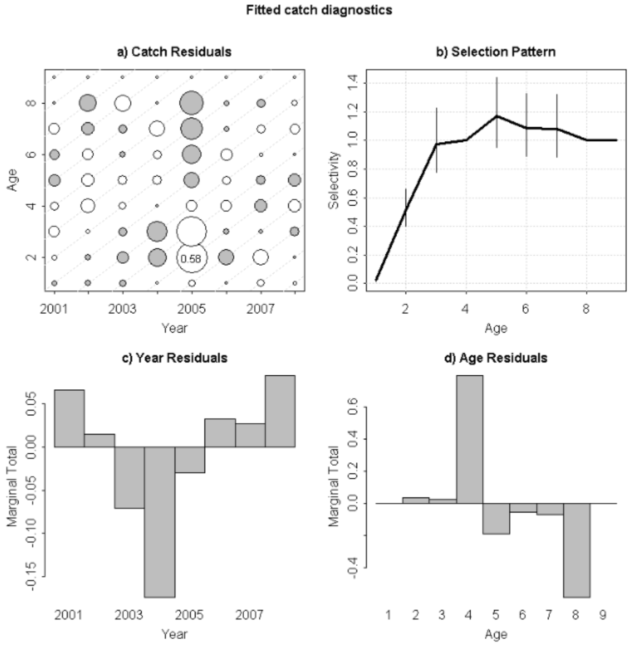


Figure 2.3.1.7. Combined Assessment SPALY run. Catch diagnostics from FLICA. a) Bubble plot of log catch residuals by age (weighting applied) and year. Grey bubbles correspond to negative log residuals. The largest residual is given. b) Estimated selection parameters (relative to 4 wr) with 95% confidence intervals. c): Marginal totals of residuals by year. d). Marginal totals of residuals by age (wr).

The poor retrospective pattern produced in each scenario may be as a result of the partial coverage of the single tuning series used. In most years this survey does not extend as far as VIaS. In 1994, 1995 and 1996 a summer survey was carried out in VIaS/VIIb,c. In 2008 the first synoptic survey covering the whole area was carried out and its utility will be further investigated. This survey was again carried out in 2009 and a total estimate produced by WGIPS. Once this additional year of survey data becomes available, additional assessments will be carried out which will include these data.

Adjusting the settings of the assessment had little impact on the diagnostics. The assessment is not sensitive to the choice of setting. In order to determine if the choice of data were causing this poor retrospective pattern, runs were carried out which removed both survey and catch data.

In order to see if an improved retrospective pattern could be attained; a number of data combinations were tested by removing surveys one year at a time and also removing ages one at a time. It was found that the only way to improve the retrospective pattern is to remove survey years prior to 1998. The assessment was run using surveys from 199 8–2008 and tuned only using ages 3–6. The main reasons why data would be excluded would be if the survey timing changed between years and only certain years were comparable, or specific ages were not picked up by the survey. The VIaN assessment uses all ages and all years in the VIaN survey time-series.

This inclusion of additional catch from VIaS/VIIb,c and VIIaN (SPALY run) improved the catchability of the survey as calculated by the assessment. The difference between the survey and modelled abundances (the catchability) is less than for the VIaN assessment. The catchability of the VIaN acoustic survey in the combined assessment SPALY run was around 2. When the survey ages and years are removed (Run 18) this catchability increases to around 3. In the VIaN assessment, this survey has a catchability of about 4, which is higher than in other herring assessments (Celtic Sea, North Sea and Irish Sea). The combined assessment (SPALY run) could be expected to encompass more of the interstock variability. When survey data are removed the catchability increases because less of the variability is accounted for.

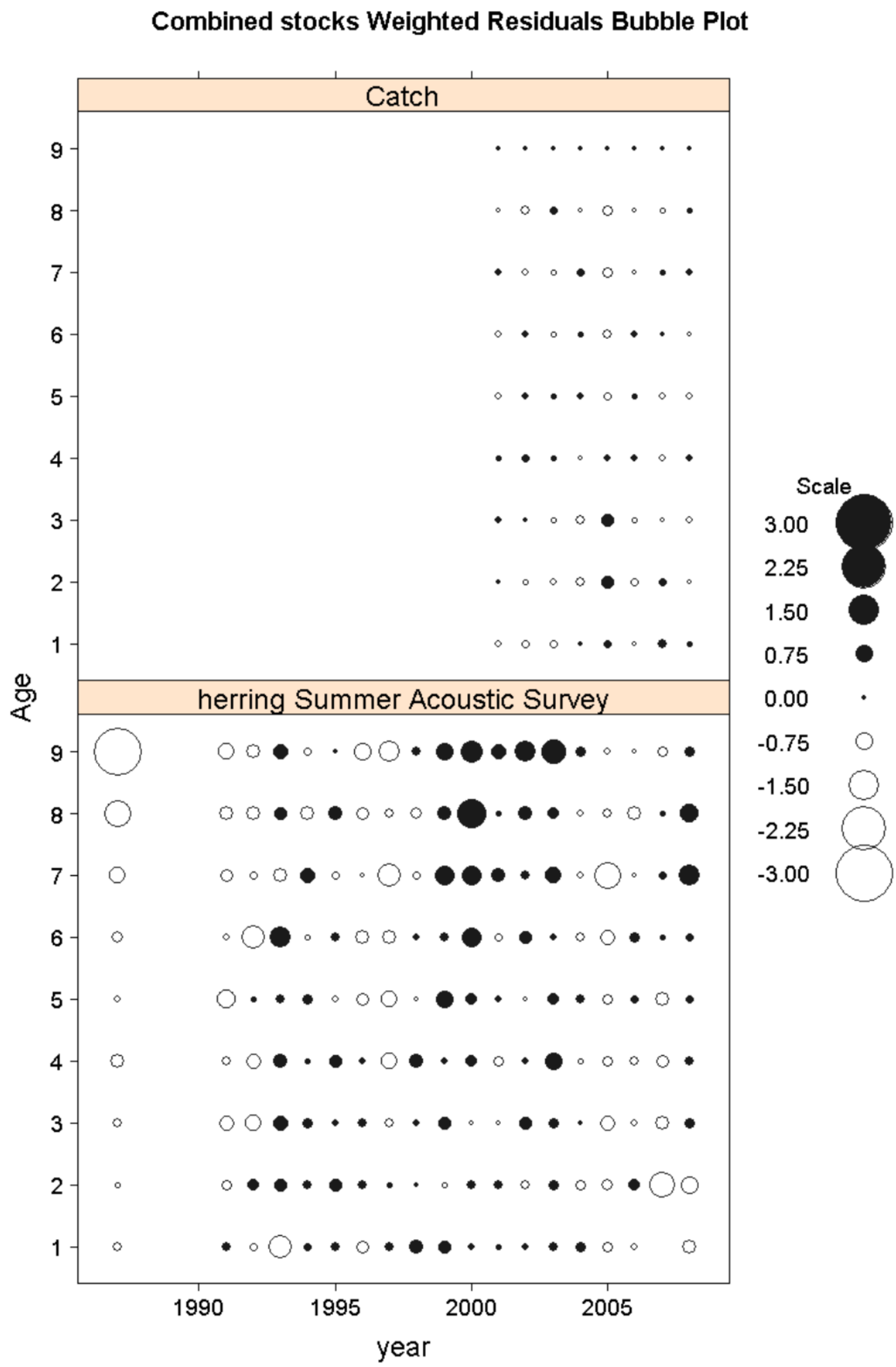


Figure 2.3.1.8. Combined Assessment SPALY run. Catch and survey residuals from the VIaN Summer acoustic survey.

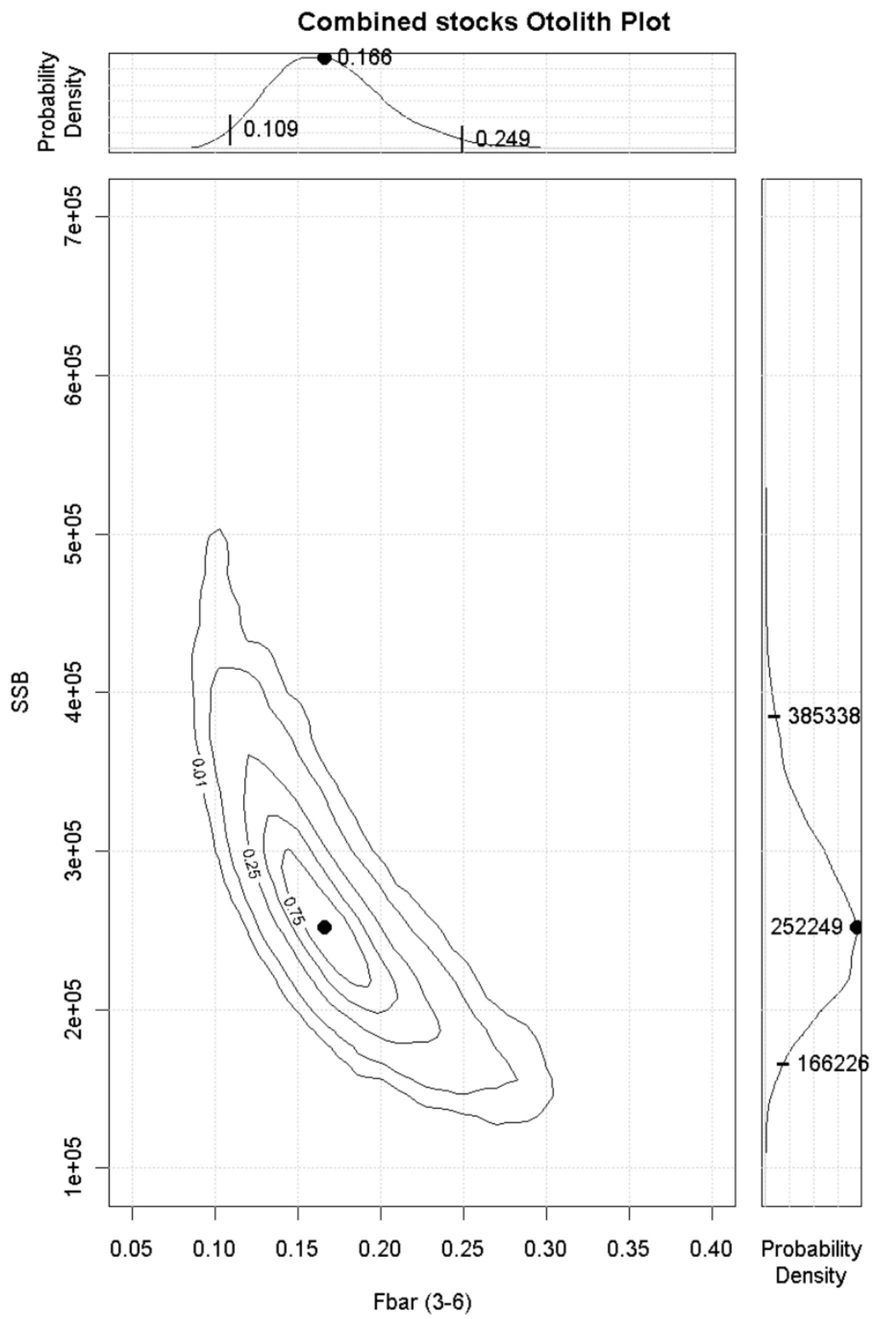


Figure 2.3.1.9. Combined Assessment SPALY run "Otolith" plot. Results of parametric bootstrapping from FLICA. The main figure depicts the uncertainty in the estimated spawning-stock biomass and average fishing mortality, and their correlation. Contour lines give the 1%, 5%, 25%, 50% and 75% confidence intervals for the two estimated parameters and are estimated from a parametric bootstrap based on the variance covariance matrix in the parameters returned by FLICA. The plots to the right and top of the main plot give the probability distribution in the SSB and mean fishing mortality respectively. The SSB and fishing mortality estimated by the method is plotted on all three plots with a heavy dot. 95% confidence intervals, with their corresponding values, are given on the plots to the right and top of the main plot.

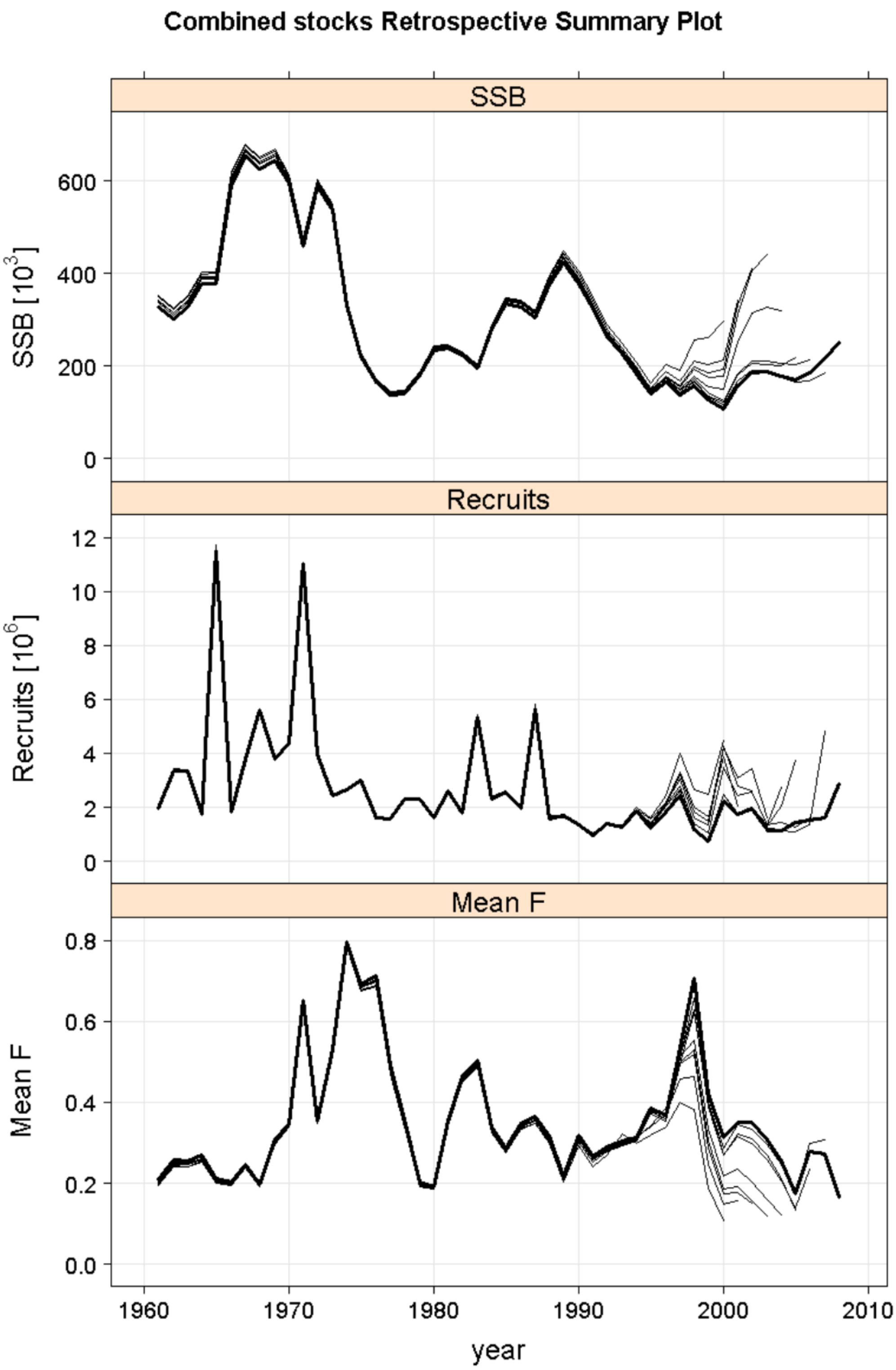


Figure 2.3.1.10. Retrospective pattern in the combined assessment SPALY run.

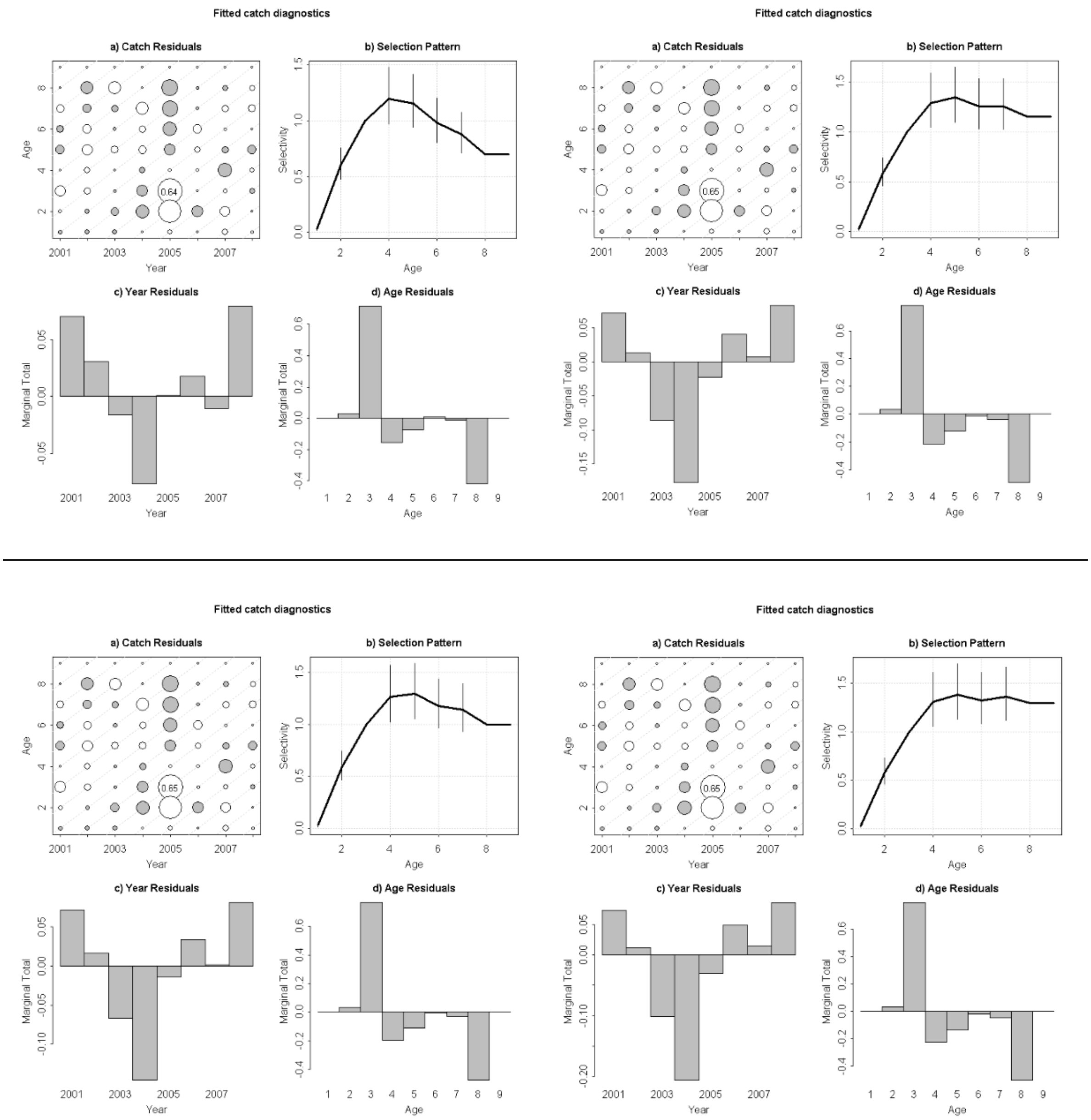


Figure 2.3.1.11. Combined Assessment catch diagnostics. Explorations using a reference age of 3 and changing the selection on the oldest age. Top left 0.7 Top Right 1.0 Bottom left 1.15 Bottom Right 1.3.

The stock summary plot and diagnostics from this run (Run 18) are presented in Figures 2.3.1.13 – 2.3.1.16 below. There is still uncertainty in the retrospective regarding the estimates of F but clear improvements can be seen in SSB and recruitment. The results of the parametric bootstrapping are presented in Figure 2.3.1.18. This run shows a greater range of F values and a lower range of SSB values than the SPALY run. The point estimate for F is considerably higher than the SPALY run (0.287 vs. 0.166) and the SSB estimate is 38% lower (156 871 tonnes vs. 252 249 tonnes).

Each run shows a similar pattern for SSB, Mean F and Recruitment. The magnitude and location of the catch residuals is similar also with 2005 showing the largest residuals in each scenario. The residuals produced are smaller overall than from single-stock assessments.

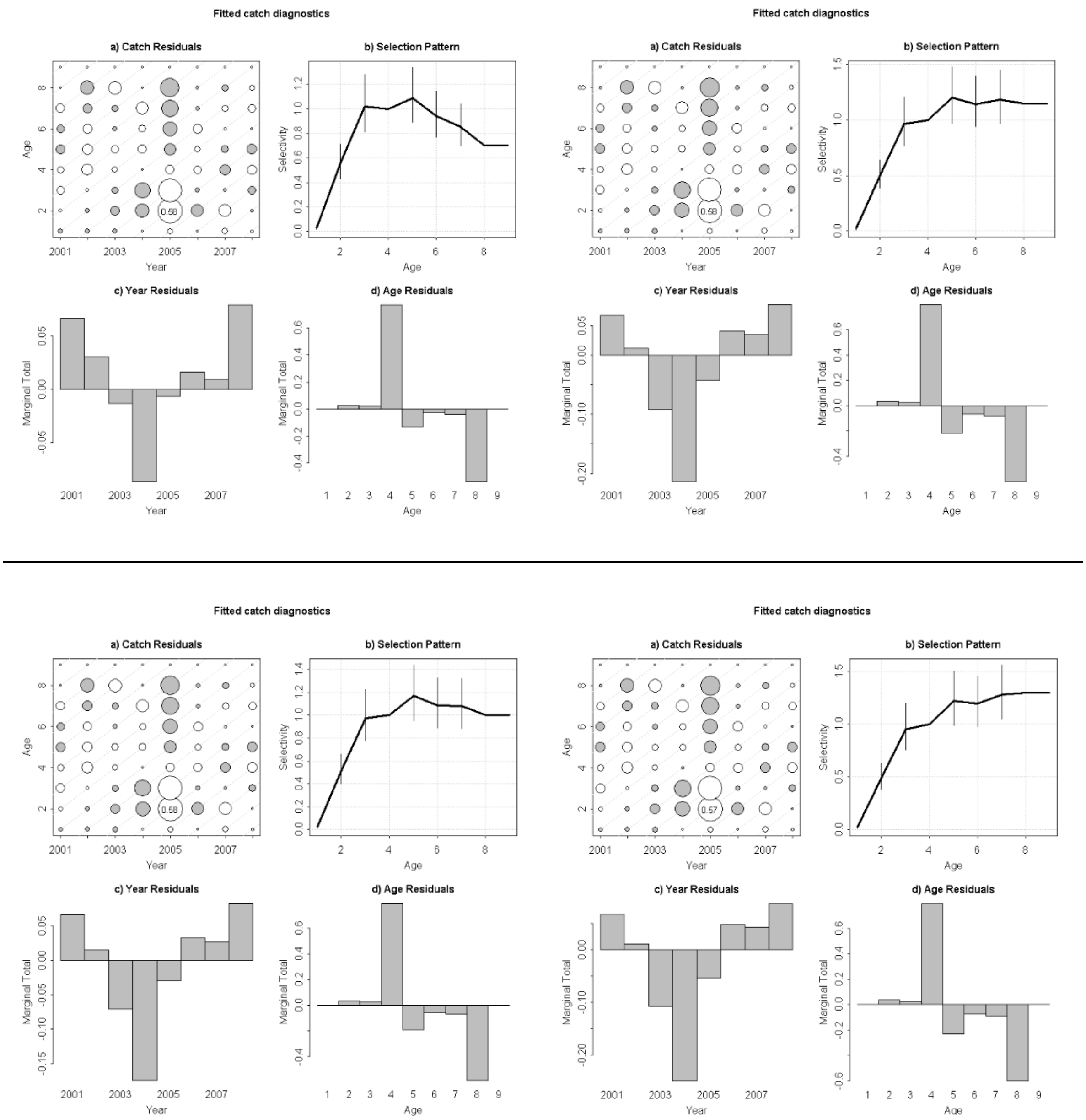


Figure 2.3.1.12. Combined Assessment catch diagnostics. Explorations using a reference age of 4 and changing the selection on the oldest age. Top left 0.7 Top Right 1.0 Bottom left 1.15 Bottom Right 1.3.

The combined assessment is a first step in a process. Some of the findings of the assessment are encouraging, but further work is required before the assessment could be used as a basis for the formulation of management advice.

Future work on this combined assessment will involve:

- using a tuning series that covers a greater proportion of the area. Surveys were carried out in 1994, 1995 and 1996 and the current WGIPS coordinated surveys that were carried out in 2008 and 2009. These five years of data can be used as a tuning series in further exploratory assessments
- as shown by Simmonds (2009), adaptive models often overemphasize information from older age groups that are potentially noisy. ICA does this and can lead to a poor retrospective performance. Using *a priori* weights based on precision reduces this problem and contributes to a more reliable assessment. Using a different weighting system on this combined assessment may improve the assessment
- investigating further the reasons for the retrospective bias

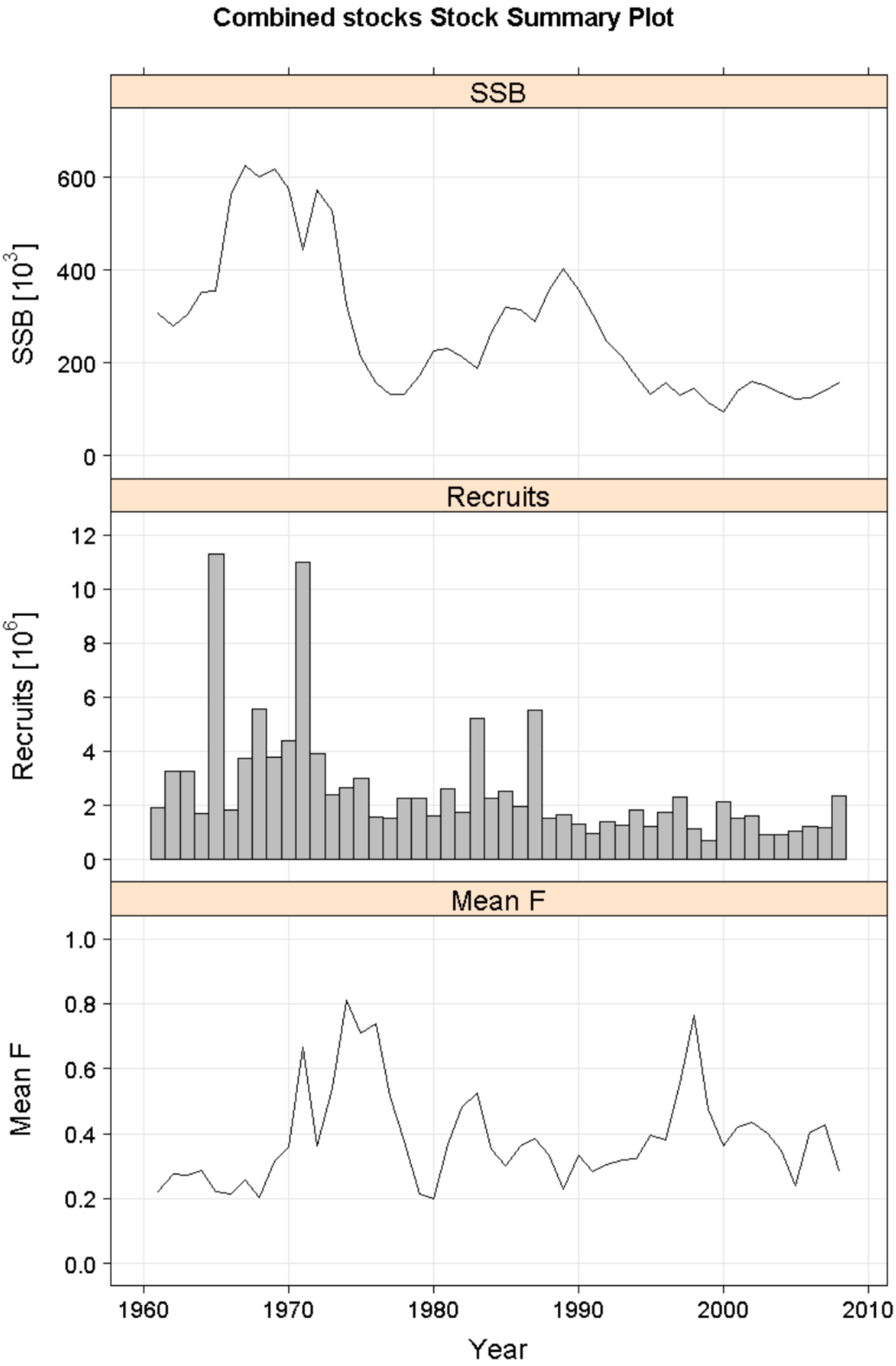


Figure 2.3.1.13. Combined Assessment "Best Run" (Run 18). SSB, Recruits and Mean F ages 3–6.

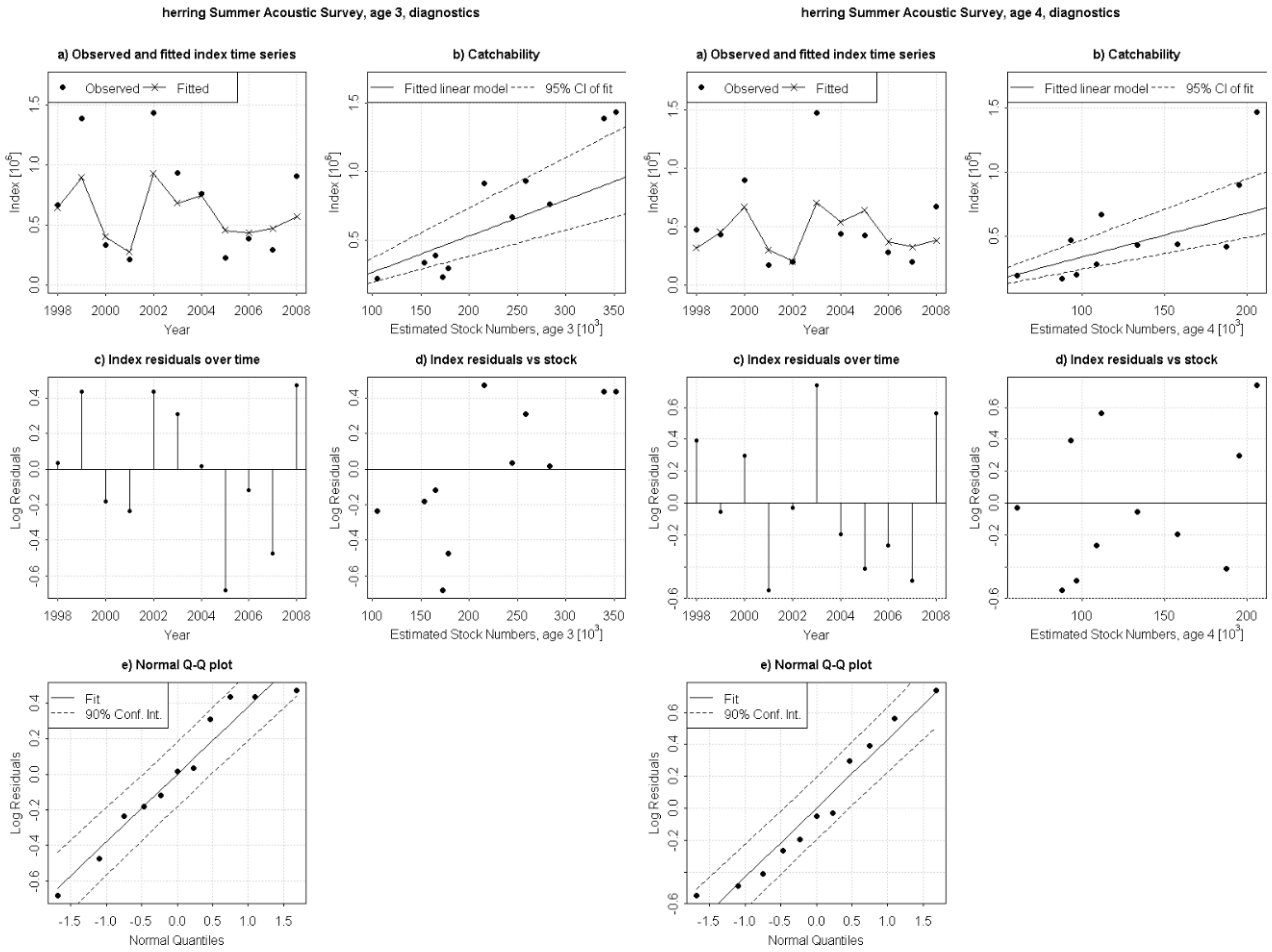


Figure 2.3.1.14. Combined Assessment Run 18. Diagnostics of the VIaN acoustic survey fit at 3 wr (left) and 4 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatter plot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

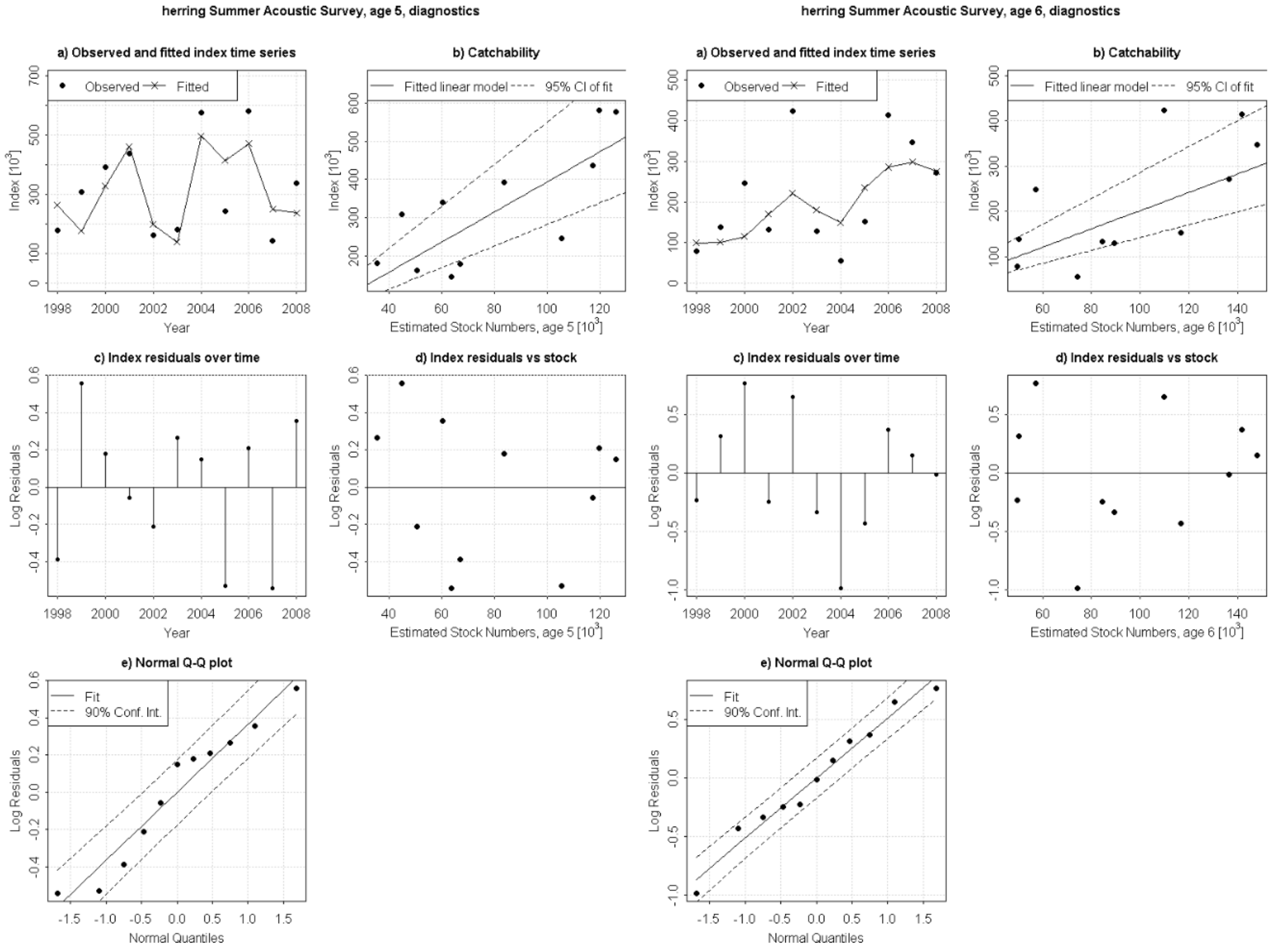


Figure 2.3.1.15. Combined Assessment Run 18. Diagnostics of the VIaN acoustic survey fit at 5 wr (left) and 6 wr (right) from the FLICA assessment. a) Comparison of observed (points) and fitted (line) index value. b) Scatterplot of index observations vs. FLICA estimates of stock numbers-at-age. Fitted catchability (linear model – solid line), with 95% confidence interval (dotted line). c) Log residuals of catchability model fitted by FLICA as a function of time. d). Log residuals from the catchability model against stock size at age estimated by the FLICA assessment method. e). Normal Q-Q plot of log residuals (points) with fitted linear regression (solid line) and 90% confidence interval for predication (dotted line).

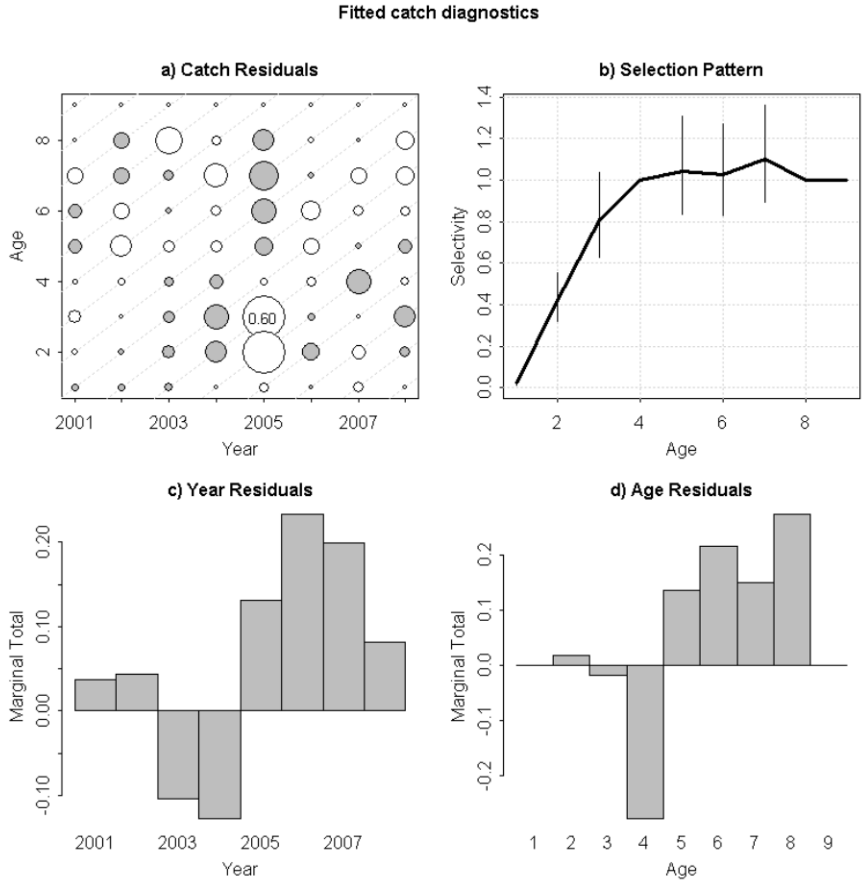


Figure 2.3.1.16. Combined Assessment Run 18. Catch diagnostics from FLICA. a) Bubble plot of log catch residuals by age (weighting applied) and year. Grey bubbles correspond to negative log residuals. The largest residual is given. b) Estimated selection parameters (relative to 4 wr) with 95% confidence intervals. c): Marginal totals of residuals by year. d). Marginal totals of residuals by age (wr).

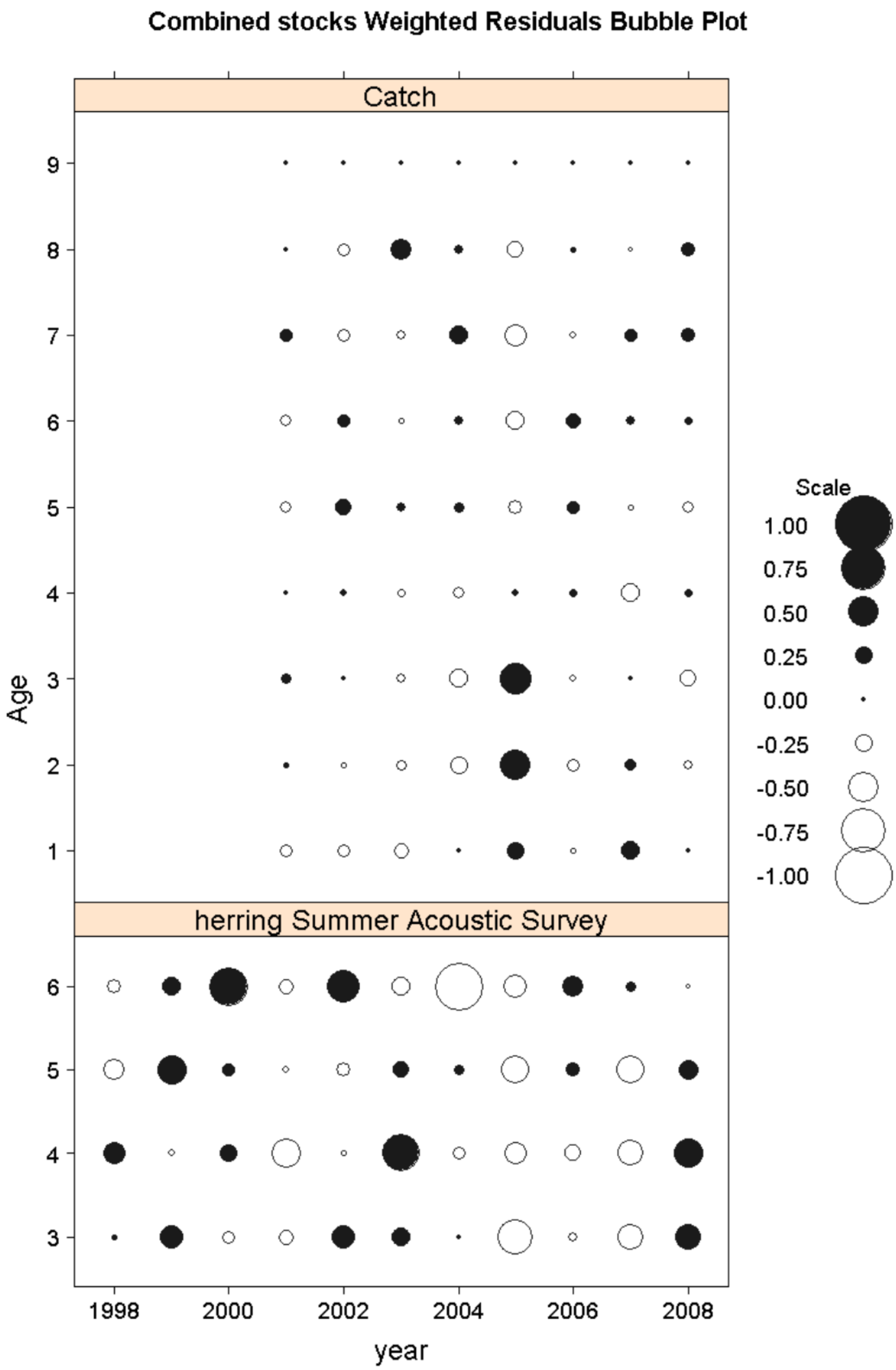


Figure 2.3.1.17. Combined Assessment Run 18. Catch and Survey residuals from the VIaN Summer acoustic survey.

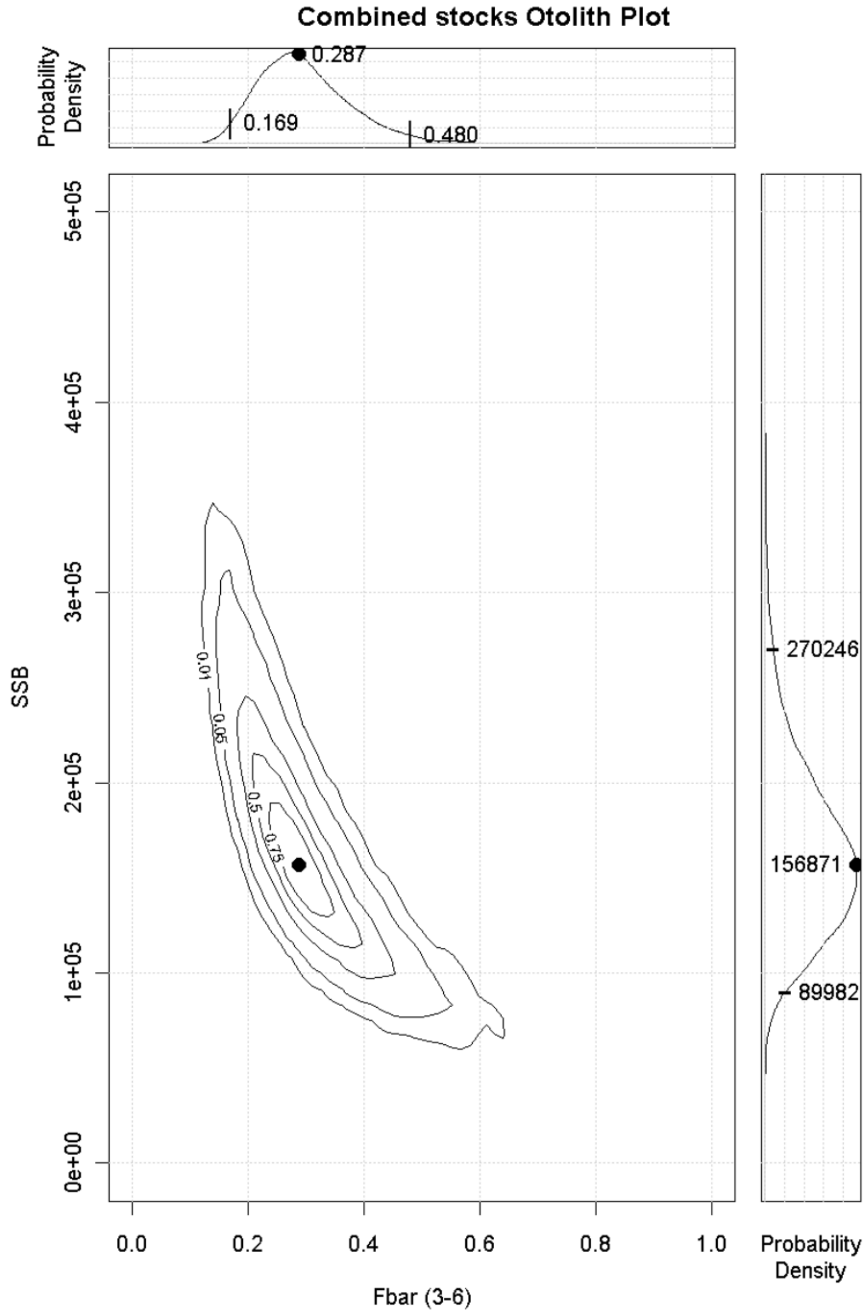


Figure 2.3.1.18. Combined Assessment Run 18 "Otolith" plot. Results of parametric bootstrapping from FLICA. The main figure depicts the uncertainty in the estimated spawning-stock biomass and average fishing mortality, and their correlation. Contour lines give the 1%, 5%, 25%, 50% and 75% confidence intervals for the two estimated parameters and are estimated from a parametric bootstrap based on the variance covariance matrix in the parameters returned by FLICA. The plots to the right and top of the main plot give the probability distribution in the SSB and mean fishing mortality respectively. The SSB and fishing mortality estimated by the method is plotted on all three plots with a heavy dot. 95% confidence intervals, with their corresponding values, are given on the plots to the right and top of the main plot.

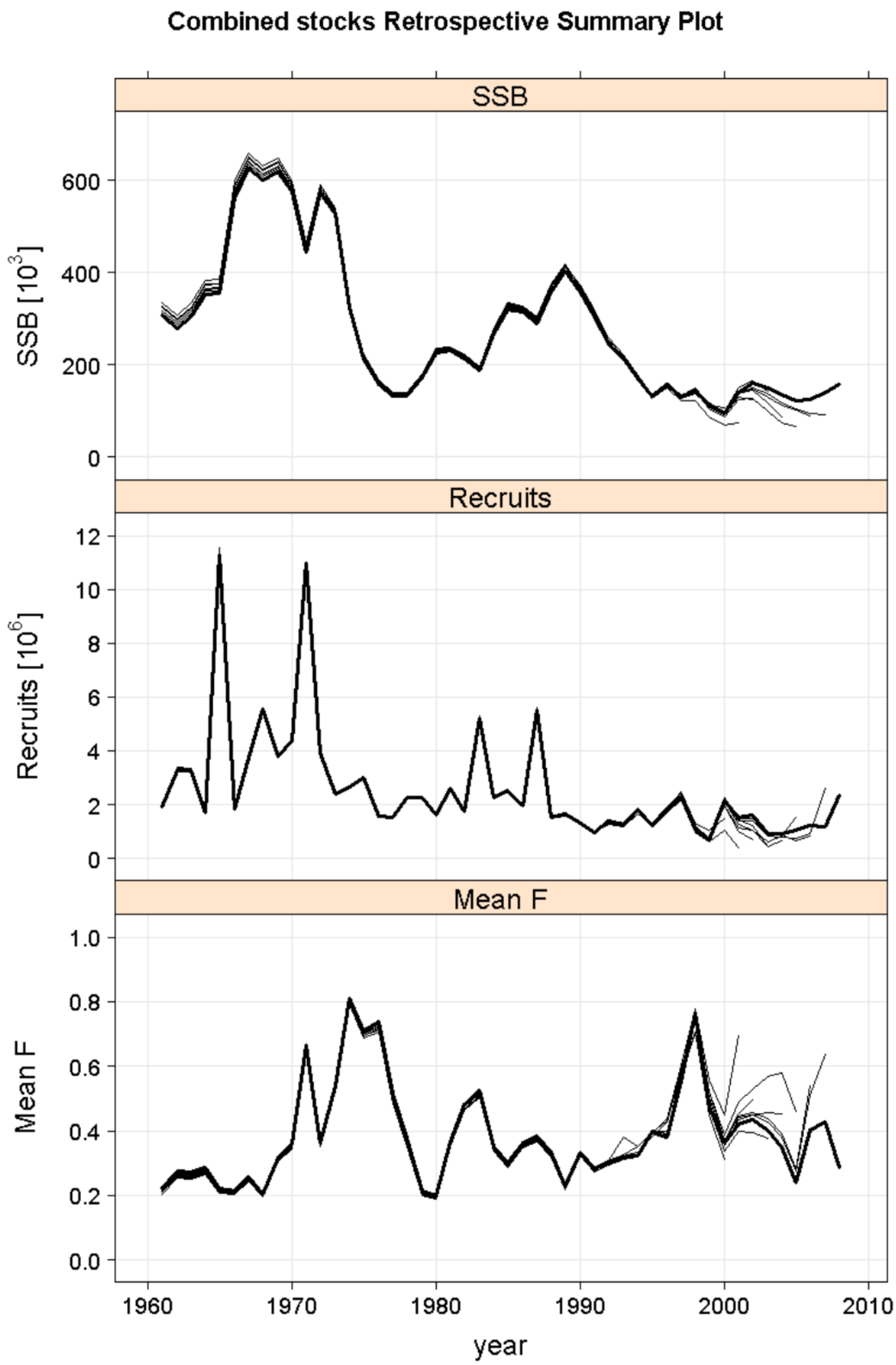


Figure 2.3.1.19. Retrospective pattern in the combined assessment Run 18.

2.4 Evaluation, through simulation, alternative management strategies for the metapopulation of VIaN, VIaS and VIIaN and the best way to maintain each spawning component in a healthy state

2.4.1 Introduction

Within the 2008 SGHERWAY meeting, an approach was developed based on paper by Kell *et al.* (2009). The approach was used to evaluate if drastic changes in stock size could be detected in catch statistics. As these changes were hardly detectable, it was decided that it was unlikely that the approach would result in an answer to ToR c. Hence, the setup of the evaluation changed. The modelling approach developed for the 2009 SGHERWAY meeting is described in the material and methods section below. The main differences from the 2008 approach lie in the research questions asked. The question changed from whether drastic changes in stock size could be observed into what can be sustainable management targets to maintain each spawning component in a healthy state. With this change in question, the model that should give insight into the possible answers to this question changed as well. To be able to evaluate management strategies, the model setup had to change into a 'Management Strategy Evaluation' type of model, where results obtained within the model feed directly back into the model. The general concept of the Kell *et al.* (2009) model, modified to fit the 2008 SGHERWAY work, is still the backbone of the modelling approach at present where the distinctions between mixing populations and non-mixing fisheries are consecutively evaluated.

This approach is complex and has taken a lot of time to develop; no clear results can be presented as yet as time was constraining. However, the general idea behind the modelling is presented in the results section, and we discuss the answers most likely to be obtained from this exercise. In addition, a short description of the steps to take prior to the SGHERWAY 2010 meetings is given.

2.4.2 Material and Methods:

The implications of different herring populations mixing during feeding time, and the inability to distinguish the spawning origin of these populations for management are evaluated within a simulation framework. Here we coherently model [1] the biological populations of four spawning components of herring west of the British Isles: VIaN, VIaS/VIIb,c, Irish Sea (VIIaN) and Celtic Sea herring (Celtic Sea/VIIj), [2] the four different fisheries targeting these populations, [3] the collection of fisheries-independent data-based on surveys, [4] the stock assessment procedure to identify the perceived status of the four biological components which is used to [5] set management targets. These procedures are modelled including feedback loops where, over time, the outcomes of management actions affect the biological population the year after, which in its turn affects the fishery and management.

Key elements in this simulation are related to the way surveys sample information on each spawning component and how this information is used within the assessments, as well as information on the extent of population mixing during the feeding season. As it is currently impossible to clearly distinguish spawning origin, survey catches are allocated with a particular level of uncertainty to each population. At the same time it is unknown what proportions of the VIaN, VIaS/VIIb,c and VIIaN populations mix during feeding time and hence it is unknown to what extent they are available to the individual fisheries in those three management areas. These elements contribute most to the sensitivity of the management and hence its ability to be precautionary. To contrast the results of the VIaN, VIaS/VIIb,c and VIIaN population mixing behaviour against a non-mixing population, the Celtic Sea/VIIj population has been included in the modelling framework.

Within the simulation we make a distinction between the concept of a stock and a biological component. We assume that the biological component represents the truth while a stock is a perceived view of the truth generated through the catches of a fleet and survey indices, which might be inaccurate or biased due to uncertain survey measures or population mixing.

[1] Biological populations

The biological populations of the four different ICES areas, VIaN, VIaS/VIIb,c, VIIaN and Celtic Sea/VIIj are assumed to each represent the spawning population. During spawning they only occupy the area they are named after, while during the feeding season parts can migrate to other areas where they are susceptible to the fishery active within that area. The age-structured populations are assumed not to immigrate/emigrate between spawning populations. Each year, recruits are added to the population, based on a segmented regression function, which represents the relation between the potential spawning biomass and the number of offspring produced. It is assumed that the amount of recruits produced depends on the productivity of the system. As productivity is known to change considerably over time (Payne *et al.*, 2009b), the magnitudes in recruitment vary as well. Hence, specific year ranges (see Table 2.4.1) have been selected which are thought to be similar to the current productivity levels. This should prevent the prediction of too optimistic or too pessimistic offspring productions. The simulated extent of mixing has, however, implications for recruitment. If, e.g. the VIaS/VIIb,c population has always contributed to the VIaN catch, it is likely that the VIaN population has always been overestimated. However, Recruitment (R), which has been observed by the surveys are the recruits solely produced by the unmixed-stock. Hence, to account for the overestimation of population size, but with respect to the number of recruits produced, the Stock-Recruitment Relationship (SRR) has to be adapted as lower Spawning Stock Biomasses (SSB) now produced the Recruitment (R). To what extent the SRR relationship has to be adapted depends on the level of mixing. As well, this level of mixing is bound. Obviously, if all catches in VIaN originate in the VIaS/VIIb,c and VIIaN populations, there would be no VIaN population and hence the observed recruits would have emerged spontaneously. In calculating the catch originating from the VIaN recruits, and hence assuming some level of mixing of the VIaS/VIIb,c, and VIIaN population, we gain insight into realistic levels of mixing (See Table 2.4.2)

Within a cohort, survival from one year to the next depends on natural mortality and fishing mortality generated by the different fleets the populations are susceptible to. It is assumed that the catches of the fleets are taken exactly and that fishing mortality can therefore be calculated without error. Natural mortality, fecundity, time of spawning, and weight-at-age are taken from the 2008 assessment results (ICES, 2009a). Starting numbers-at-age are taken as the estimated stock numbers from the stock assessments for the years 2005, 1998, 2000 and 2005 for the VIaN, VIaS/VIIb,c, VIIaN and Celtic Sea/VIIj herring populations respectively. These years were assumed to represent the last year in which there was confidence in the accuracy of estimated stock numbers. All timelines of the populations are aligned to range from 1977 to 2005. Note that due to the shift in timelines, time-correlation between stocks has disappeared.

The dynamics of the biological populations are projected 20 years forward in time to study the difference in perception of the stock vs. the underlying biological truth.

Table 2.4.1. Year classes assumed to be produced during system productivity levels similar to current levels.

Population	Year classes
VIaN	1989–2006
VIaS/VIIb,c	1970–1980,1986–1998
VIIaN	1963–2005
Celtic Sea/VIIj	1960–2005

Table 2.4.2. Example of the number of recruits that would be produced by each spawning component under different levels of mixing. If mixing is higher (higher percentages in column 2 and 3), the VIaN stock is overestimated and the number of recruits that can be produced reduces.

Per cent of Catch from VIaN Recruits	% of VIaS recruits moved from VIaS/VIIb,c to VIaN	% VIIaN recruits moved from VIIaN to VIaN	Recruitment in VIaS/VIIb,c	Recruitment in VIaN	Recruitment in VIIaN	Total Recruitment
100%	0%	0%	62.7	62.3	17.9	143
97%	3%	3%	64.3	60.2	18.4	143
93%	5%	5%	66.0	58.0	18.9	143
89%	8%	8%	67.8	55.7	19.4	143
86%	10%	10%	69.7	53.3	19.9	143
81%	13%	13%	71.7	50.7	20.5	143
77%	15%	15%	73.8	48.0	21.1	143
73%	18%	18%	76.0	45.2	21.7	143
68%	20%	20%	78.4	42.1	22.4	143
62%	23%	23%	80.9	38.8	23.1	143
57%	25%	25%	83.6	35.4	23.9	143
51%	28%	28%	86.5	31.7	24.7	143
44%	30%	30%	89.6	27.7	25.6	143
38%	33%	33%	92.9	23.4	26.6	143
30%	35%	35%	96.5	18.8	27.6	143
22%	38%	38%	100.3	13.9	28.7	143
14%	40%	40%	104.5	8.5	29.9	143
4%	43%	43%	109.1	2.6	31.2	143
0%	44%	44%	111.1	0.0	31.8	143

[2] The fishery

Within each of the four management areas, a fishery targets the biological populations during the feeding season when mixing between populations occurs. Hence, each fishery has only the availability to the fish present in the management area they are active in. Due to mixing, it is possible that a fishery has more than one population available to it, while others might have less than one population available to it. The latter scenario results from a proportion of that population having migrated into a different fishery area. In total then, the combination of the four fisheries (i.e. those occurring in VIaN, VIaS/VIIb,c, VIIaN and Celtic Sea/VIIj) target 100% of each population. The catches of these fisheries are defined by the Baranov catch equation and depend on the available numbers-at-age, selectivity pattern of the catch, the catchability of the fishery, natural mortality and the amount of effort allocated during a year.

Landings are assumed to equal the catches as discarding is not simulated. Landing weights for the projection period are taken as the mean weight–at-age over the most recent 10 historical years. Selectivity for the projected period of 20 years is assumed to be similar to the pattern as fitted by the assessment in the last appropriate year. Error has been added to vary selectivity from year-to-year. These errors are obtained from selectivity residuals in the 2008 assessments. The residuals represent observed vs. fitted ratios (trimmed to minimum and maximum values of 2 standard deviations from the mean at age), where final selectivity equals the selectivity-at-age multiplied by error-at-age. Catchability is assumed to be 1 for the whole time-series for all fleets.

[3] The surveys

Four different herring surveys have been performed in the area west of the British Isles. Three of them are acoustic surveys on the VIaN, VIIaN and Celtic Sea/VIIj populations running from 1991, 1994 and 1995 onwards respectively. The fourth survey is a larval survey in VIIaN undertaken by Northern Ireland, running since 1993. A sufficiently long survey time-series is not yet available to estimate the stock size of the VIaS/VIIb,c component.

Within the simulation framework, only two surveys are designed: (1) an acoustic Malin Shelf survey targets the combined metapopulation of VIaN, VIaS/VIIb,c and VIIaN during its summer mixing over the Hebrides and Malin shelves and reports on all ages; (2) an acoustic survey on the Celtic Sea/VIIj population which also reports on all ages. These surveys estimate an absolute abundance of the populations. As the VIaN, VIaS/VIIb,c and VIIaN stocks are separately managed, the Malin Shelf survey has to be split into proportions allocating survey samples to the different stocks. However, due to the difficulty of distinguishing spawning origin, the splitting procedure has the potential to incorrectly allocate a sample to e.g. the VIaS/VIIb,c population while it actually belonged to the VIaN population, and vice versa. This process is described by the ‘confusion’ matrix. Within this matrix (Table 2.4.3), the proportion correctly identified per stock, and the transfers from each stock to the three others is given. As the survey on the Celtic Sea/VIIj is only targeting this one population, there is no incorrect allocation of survey samples. In addition to the accuracy of allocation, the number of samples taken during the survey determines the age structure of the individual surveys. In the case of many samples, the number-at-age patterns will approximate the true age pattern in the populations rather well. However, when a small number of samples are taken, the age structure might be distorted. Error is added to the derived age structures for each survey. These errors are obtained from survey residuals in the individual 2008 assessments. The residuals represent observed vs. fitted ratios (trimmed to minimum and maximum values of 2 standard deviations from the mean at age), where the final survey index equals the numbers-at-age multiplied by error-at-age. As the survey design is completely different from the historic survey setup, index numbers–at- age for all surveys are generated in retrospect according to the methods described above.

The effects of both incorrect splitting and the number of samples taken during a survey on management will be evaluated by testing varying levels of ‘confusion’ and sampling size.

Table 2.4.3. 'Confusion' matrix. Values on the diagonal indicate the proportion of samples that is correctly identified. All other values indicate the proportion of incorrectly identified samples which are allocated to the other named spawning components.

		Allocation			
	Population	VIaN	VIaS/VIIb,c	VIIaN	Celtic Sea/VIIj
Origin	VIaN	0.8	0.1	0.1	0
	VIaS/VIIb,c	0.1	0.8	0.1	0
	VIIaN	0.1	0.1	0.8	0
	Celtic Sea/VIIj	0	0	0	1

[4] The stock assessment procedure

The perception of the stock status is generated through the explicit inclusion of a stock assessment in the simulation, which is based on fishery-independent (surveys) and fishery-dependent (landings) data. By combining population parameters, catches and survey indices, all information sources necessary to perform an assessment are available. The biological parameters contributing to the perception of the stock are management area specific. Hence, only population x contributes to the biological parameters of stock x whereas the catches in fishery x can originate in different populations. To what extent the survey indices originate in different populations depends on the accuracy of the splitting procedure and sample size of the surveys. The assessment performed uses an Integrated Catch at Age analysis method (ICA), embedded within the FLR software, using the R platform (R Development Core Team 2008). Within the assessment, stock numbers-at-age, as well as the harvest patterns, are estimated by minimizing the likelihood function (see Patterson (1998) for a more technical description).

[5] Management

The results of the assessment are used within the management routine. For this, the stock is projected forward 2 years in time, assuming constant recruitment (geometric mean of recruitment over the past 5 years) and weights-at-age equal to the moving average over the last 2 years. Management targets are set to the proposed TAC for the intermediate year as obtained from the projections the year before, and to an F-target for the forecast year. Three different management targets have been evaluated: maintain harvest mortality over the targeted age-groups at 0.2, 0.3 or 0.4. In the first year of the projected period, no assumptions have been made on a TAC proposition. Hence, the TAC applied in this year equals the proposed TAC directly derived from the F management target which is set at 0.2, 0.3 or 0.4. Based on the proposed TAC, the effort necessary to actually catch this amount can be calculated. However, where the TAC has been based on the stock's dynamics, the effort is calculated based on the numbers available to the fishery, and hence is directly linked to the population sizes and the level of mixing during the feeding season.

The effort projected for year $y+1$ is deployed the year after to generate a catch. Based on this catch the fishing mortality within that year can be computed. This permits a full-feedback analysis of the management strategy evaluation. In total each scenario is repeated 100 times as the uncertainty in the different processes might encompass a range of possible outcomes. These repetitions are used to evaluate whether a certain management scenario is precautionary (less than 5% of the runs may fall below B_{lim}) or not.

2.4.2.1 Scenario descriptions

In total four different processes are varied to evaluate whether management of the four populations is precautionary or not:

1. the number of samples taken in the Malin Shelf survey
2. the accuracy of correctly splitting the Malin Shelf survey into three different survey indices as given in the confusion matrix
3. the level of mixing between populations (see Appendix 1 for a detailed description)
4. the management target for the forecasted year

[1] As a baseline, 1500 samples are taken during one survey season. This number approximates to the number of fish one would expect to be sampled in the synoptic acoustic Malin Shelf survey in an average year. Furthermore, both a halving and a doubling of this number will be used to evaluate management.

[2] When new methods might become available, the accuracy of correctly splitting the survey and fisheries catches might increase. For the survey splitting this implies that the diagonal values in the confusion matrix might increase towards 1. Hence, three extra scenarios are executed with diagonal values of 0.9 and 1, while also a worst-case scenario will be evaluated with diagonal values up to 0.7.

[3] Several hypotheses of mixing during the feeding season were considered for stocks in VIaN, VIaS/VIIb,c and VIIaN. As low levels of mixing already have major implications for the restructuring of the SRR, values up to 25% mixing belong to the highest chosen during these scenarios.

[4] Three different management targets have been chosen to evaluate management. Fs of 0.2, 0.3 and 0.4 have been selected as it is assumed that these levels approximate respectively very precautionary to rather unprecautionary management targets.

2.4.3 Results

During the 2009 meeting only one scenario was investigated by the group. As the model setup is complex, its results are difficult to interpret. Hence, a lot of time was invested to evaluate whether the model was working properly and in line with what should be sensible regarding the historic behaviour of the populations.

The scenario run had [1] 1000 samples in the Malin Shelf survey, [2] the accuracy of splitting the survey as given in Table 2.4.3, [3] mixing of 25% over all ages for the VIaS/VIIb,c and VIIaN populations within the VIaN area and [4] a management target equal to F= 0.2 y^{-1}.

Figure 2.4.1 indicates that reality (biology) and the perception (assessment) diverges from the start of the projection period onwards. Most likely this is caused by the survey indices where abundance estimates for the VIaN, VIaS/VIIb,c and VIIaN populations are not correct due to low levels of sampling and the effect of misclassifying spawning origin. A similar effect was found by Kell *et al.* (2009), where the assessment (XSA) estimates were negatively biased in the case where the populations suffered greater mortality than suggested by the catch data and were positively biased when the reverse was true. The difference between assessment and biology in the Celtic Sea/VIIj herring needs further investigation. This population does not mix during feeding time within different areas, and hence, should be managed without large error. The difference between the VIIaN biology and assessment is large, and can most likely be explained by the low starting point at the start of the projection period.

Figure 2.4.2 indicates how the SRR should be adapted under the assumption of 20% mixing of the VIaS/VIIb,c and the VIIaN populations with the VIaN population in the VIaN management area. The change is largest for both the VIaS/VIIb,c and VIaN populations as these are bigger in size than the VIIaN population.

2.4.4 Discussion

Results presented are still preliminary. However, during development of the model, many new insights have led to the confidence that the modelling approach will represent, in clear detail, the current processes occurring in the area. Additionally, the model gave new insights in what processes might play an important role driving the populations. Currently these two processes are defined as the level of mixing and the accuracy of correctly identifying the spawning origin.

The implications on assumptions of levels of mixing are important. If mixing of VIaS/VIIb,c and VIIaN is assumed to equal 25% for both populations, this implies that only 57% of the perceived VIaN population is really existing in the VIaN area. If mixing has been present in the long history, the abundance of the VIaN herring stock has been overestimated for many years. In turn, this affects the estimated productivity of the population, as now the much lower population size has produced the same amount of offspring as was perceived to be produced by the assumed bigger population (recruitment estimates do not change as they are picked up by the surveys). The converse is true for the VIaS/VIIb,c and VIIaN populations. This insight especially might result in better management advice, as the processes that drive the populations begin to be better understood.

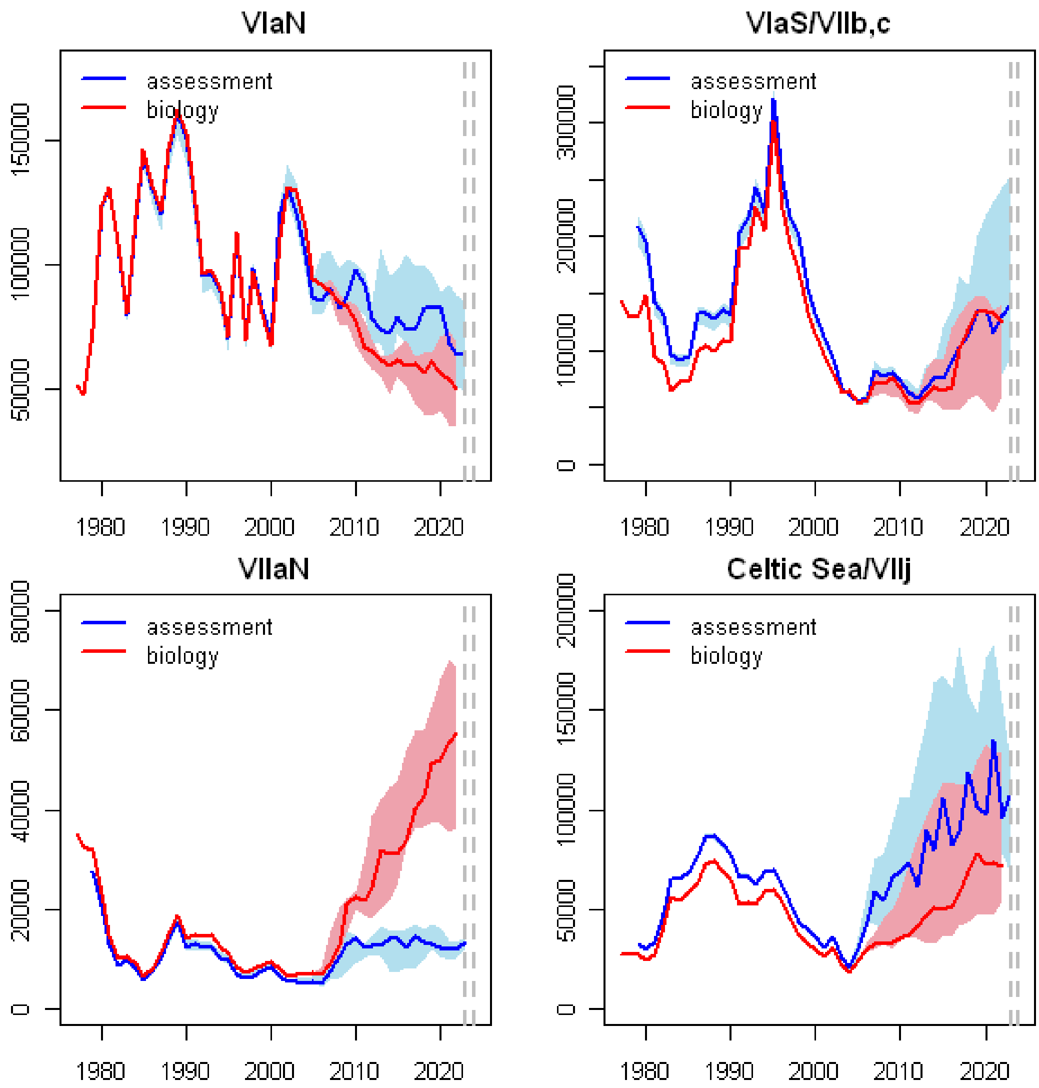


Figure 2.4.1. Overview of spawning-stock biomass of the four herring populations and assessment results. The red lines indicate the simulated biological populations. The blue lines indicate the development of the perceived population, i.e. the assessed stock. The shaded areas originate at the first year all data are simulated (the future period) in 2005. As variation in different biological processes is taken into account, a range of outcomes could be possible. The range of outcomes obtained from the simulations is given in the shaded areas for both the biological population and the assessment results.

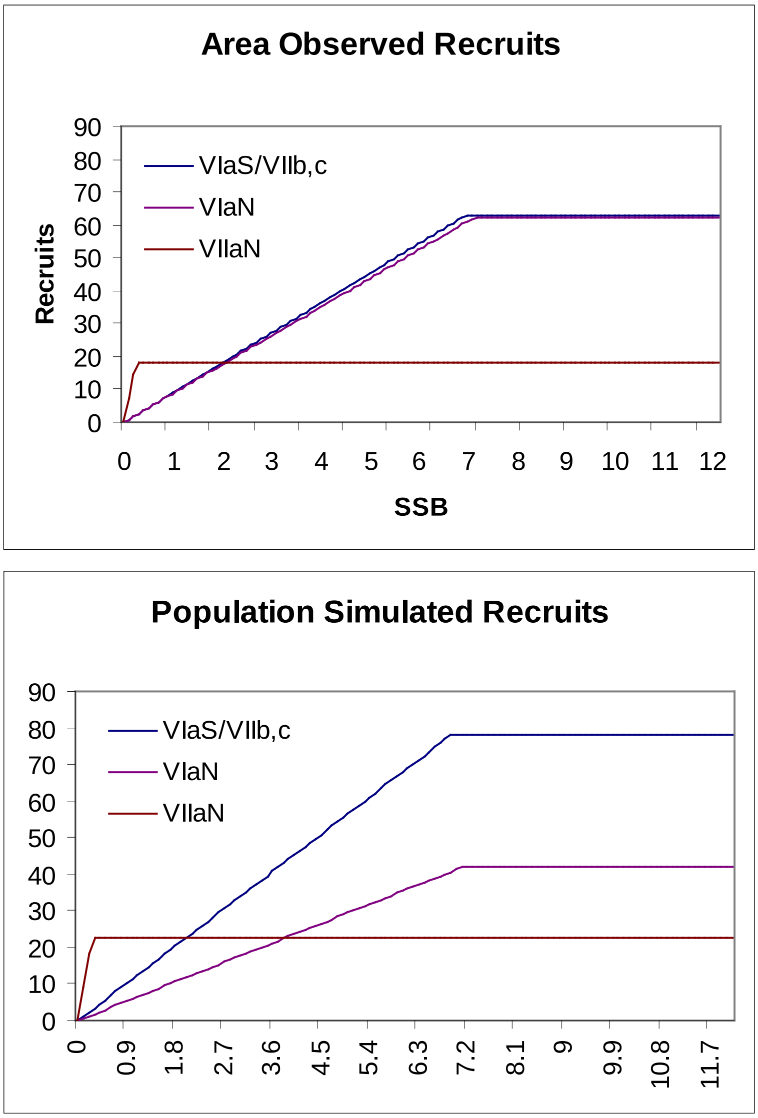


Figure 2.4.2. Observed recruit models by area, Simulated models assuming 20% transfer from VIaS and Irish Sea into VIaN.

Additionally, the model has already given an insight into how the misidentification of spawning origin can alter survey indices and hence the management of the three stocks, VIaN, VIaS/VIIb,c and VIIaN. Under the current 'confusion' strategy, where spawning origin is correctly identified in 80% of the cases, the smaller stocks, e.g. VIIaN, get much higher survey indices than would be correct considering the population size. This is because the two other large populations, VIaN and VIaS/VIIb,c, contribute 10% each to the index for VIIaN. However, the 20% transfer of misidentification of VIIaN into VIaN and VIaS/VIIb,c is less than the combined 20% transfer of VIaN and VIaS/VIIb,c into VIIaN, and hence results in a larger index for VIIaN. A small simulation study will investigate what number of Malin Shelf Survey samples given the levels of 'confusion' may provide unbiased estimates. This could quantify the appropriate number of samples that should be taken in case the Malin Shelf Survey is seen as part of the best management strategy possible. Newly designed techniques that identify spawning origin to a higher level of accuracy might solve part of the problem of 'confusion'. The effects on management of these technical improvements can be quantified through such a study.

Although little is known about the level of mixing of the populations, the estimates of 'confusion' and number of samples taken during the Malin Shelf Survey are accurate. Combined with the well known biological characteristics of the fish, and the management of the fisheries, the model should be representative for the actual situation. This study intends to calculate the risk of depletion for each of the stocks under a number of management scenarios. By varying the levels of fishing mortality targets, we will be able to comment on safe management targets for the combination of these stocks.

2.4.5 Future work

In preparation for the first of the two 2010 SGHERWAY meetings, different scenarios will be run to be discussed during the meeting. The first scenario will encompass no variation in any process at all. This should identify any problems remaining within the modelling approach, as there should be no difference in the historic periods between the populations and the assessment results. Additionally, the Celtic Sea/VIIj management evaluation should be very much in line with the development of the true biological population.

The list of planned scenarios contains differences in settings of:

1) the 'confusion' matrix: with 100%, 90% and 70% accurate identifications

2) the availability of each population to the fisheries will be varied. This is based on the mixing levels described

3) within each scenario, an F management target has to be set. As a lower bound, the value of 0.2 has been chosen while an F of 0.4 is regarded as the upper bound. These values range according to the perception of being very safe (0.2) to rather unsafe (0.4) in the long term

4) the setup of the Malin Shelf Survey will be varied. In the baseline run, we will use 2 different surveys in the whole area. One Malin Shelf Survey covering the VIaN, VIaS/VIIb,c and VIIaN mixing, and a second to cover the Celtic Sea/VIIj area. In other scenarios the Malin Shelf Survey will be split to cover only the VIaN and VIaS/VIIb,c area while another survey covers VIIaN

5) different sample sizes in the Malin Shelf Survey will be evaluated

The combination of these settings will result in a large number of results indicating whether there is a chance to deplete a stock. The chance to deplete a stock should be lower than the precautionary approach (5% chance that a stock over a time span reaches levels below B_{lim}).

As we have already indicated that starting conditions might influence the development of the populations, and hence their sensitivity to changes in management, we will vary the point in time where the projection period will start as well.

2.5 Towards the production of a spawning ground map

It was decided that the SGHERWAY meeting provided a valuable opportunity to draw together several data sources to produce a map of spawning grounds for the herring stocks in VIaN, VIaS/VIIb,c, VIIaN and the Celtic Sea/VIIj. Several reviews have been done of herring spawning grounds in the area (e.g. ICES 1994; Breslin 1998; Molloy 2006). Spawning grounds have been defined using a number of data sources, including: grab surveys on spawning grounds (e.g. Bowers 1969; Parrish *et al.*, 1969), presence of recently hatched larvae (reviewed in Heath 1993), the presence of herring eggs in haddock stomachs (e.g. Bowman 1922) and the capture of mature adult fish from both commercial boats and surveys.

To produce a map we chose to restrict our data to time-series of survey data that could be built up as layers in ArcGIS. The data we intend to investigate are:

a) larvae survey time-series of VIaN and VIaS/VIIb

b) larvae surveys of Celtic Sea, 1978 to 1985 and 1989 and 1990

c) larvae surveys in the Irish Sea

d) Scottish west coast IBTS data where reasonable proportions of spawners are shown

e) Scottish west coast MIK surveys 2008 and 2009 – numbers of larvae ≤ 7 mm to show recent spawning activity

f) Celtic Sea acoustic survey and Q1 VIaS acoustic survey

g) Q1 VIaS and Celtic Sea groundfish surveys where reasonable proportions of spawners are shown

A spawning ground map will be available for the final SGHERWAY report.

2.5.1 Larvae survey time-series of VIaN and VIaS/VIIb

Historical information on the distribution and abundance of herring larvae in areas VIaN, VIaS and VIIb is available from the ICES coordinated herring larvae surveys in the North Sea and adjacent waters, which were conducted from 1972 onwards. These surveys are designed to catch newly hatched and foraging larvae during and early after the spawning season. Surveys are carried out in specific time periods and areas, following autumn/winter spawning activity of herring from north to south. At a given station grid oblique tows with plankton samplers are done at 5 knots ship speed. The number of herring larvae caught is estimated and all larvae are length measured. Data are stored in data files and give information on number of larvae in the size range of 5 - 24 mm. Only newly hatched larvae <10 mm total length are considered for the index calculation.

The main purpose of the herring larvae surveys is to provide quantitative estimates of the abundance of herring larvae which can be used as a relative index of changes in the spawning stock size of the specific herring stocks. Details of the survey methodology and the index calculation can be found in the manual of the IHLS programme (ICES, 2009b) and in Rohlf *et al.* (1998).

While these surveys are still prosecuted in the North Sea, the time-series for area VIaS/VIIb stopped in 1989 and for VIaN in 1993. In the years before, surveys focused on hatching of larvae of autumn spawning herring. Most surveys were done in September and October. The temporal coverage for the period 1972 to 1993 is given in Figure 2.5.1.1.

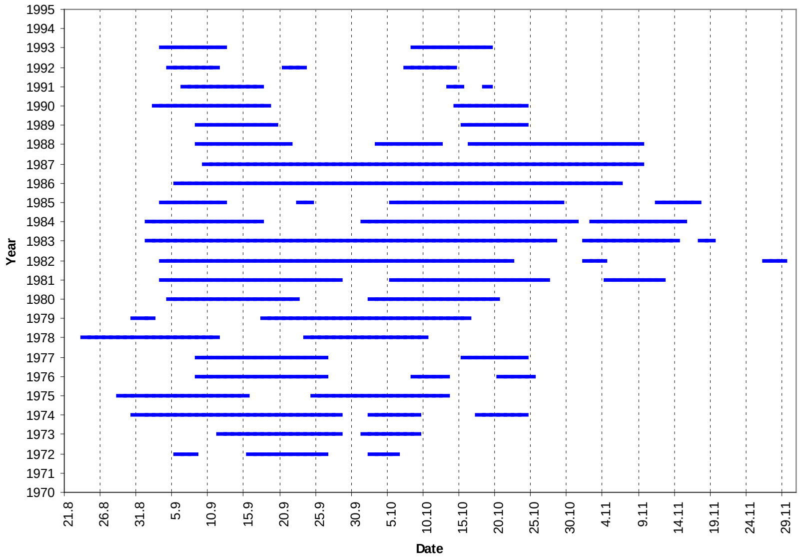


Figure 2.5.1.1. Temporal coverage of the herring larvae surveys in VIaN and VIaS for the period 1972 – 1993. Dates are given where samples are available. This does not necessarily correspond to days-at-sea in the surveys.

With the aim of describing the spawning grounds of autumn spawning herring stocks in the Malin Shelf area, the mean abundance of larvae <10 mm is plotted by year in Figures 2.5.1.2 – 2.5.1.7. The mean abundance for the period 1981–1991 is calculated and given in Figure 2.5.1.7. Larger quantities of newly hatched larvae are found at the banks north of Scotland, around Rona, the Outer Hebrides, at Donegal Bank and west of Achill Island.

However, is should be noted that these results show only tendencies. Firstly, there is no information from winter or spring spawners included. Second, the hatching size of herring larvae is about 6 - 7 mm, and foraging larvae are subject to drift. The figures focus on larvae <10 mm, and thus the resulting distribution pattern may be influenced by drifted larvae to a certain degree.

Rankine (1986) suggested that a size of ≤7 mm length should be used to delineate spawning grounds off the Scottish coast as the larvae would be around one day old and not had the opportunity to drift away from the spawning grounds to any extent. He also suggested that densities of >500 larvae per square metre should be used to indicate the main spawning grounds. A study following this approach is initiated and results will be presented at next SGHERWAY meeting.

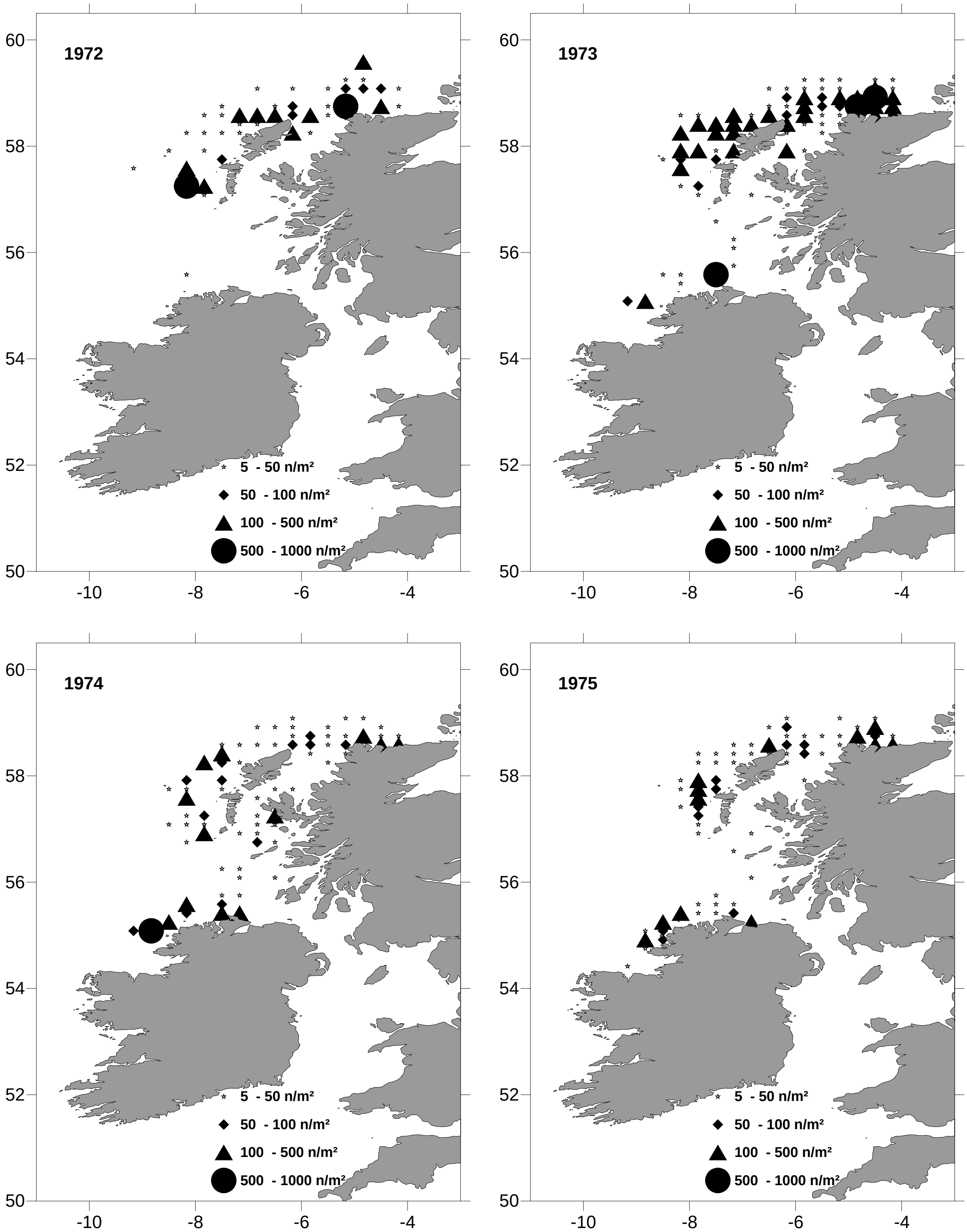


Figure 2.5.1.2. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel.

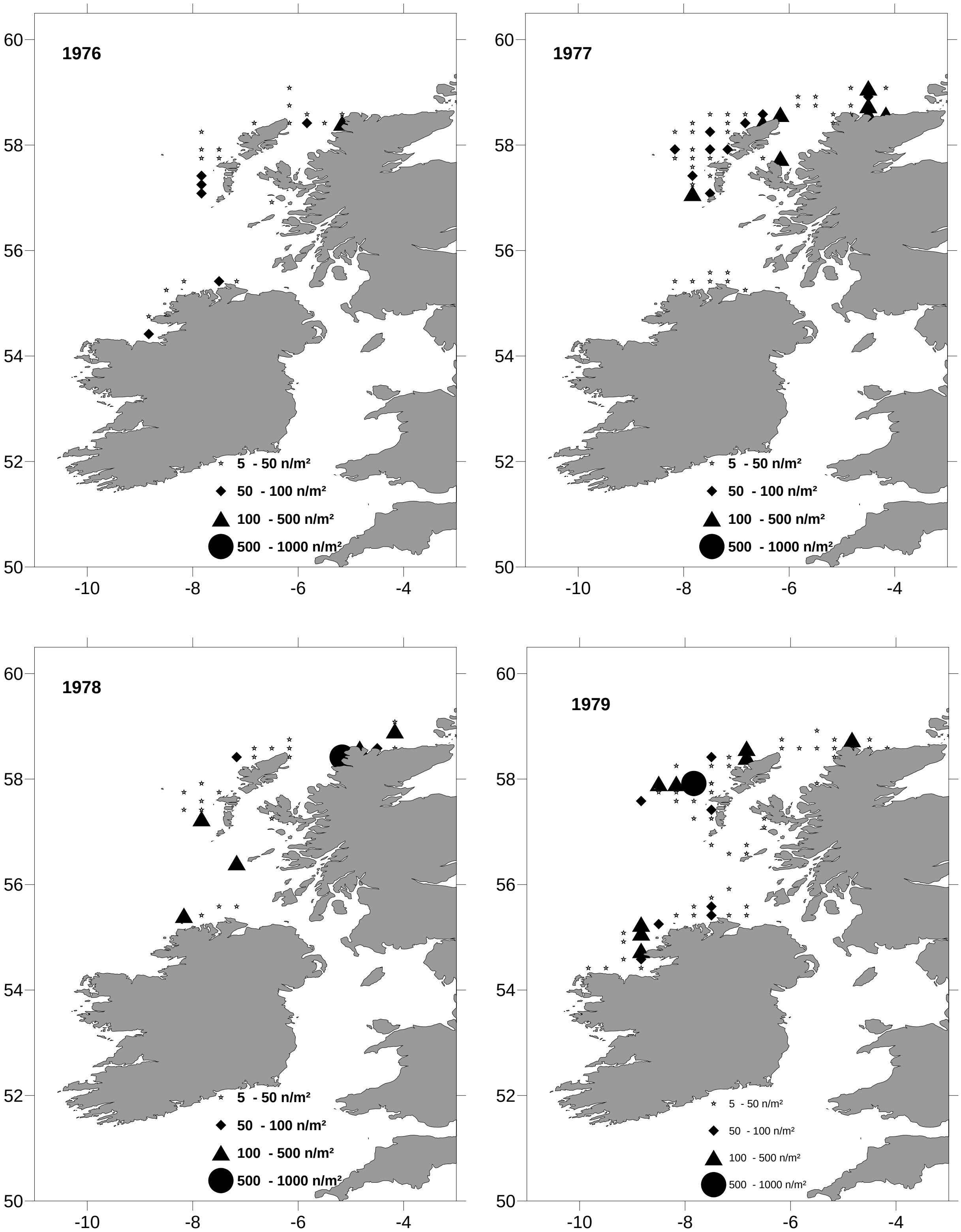


Figure 2.5.1.3. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel.

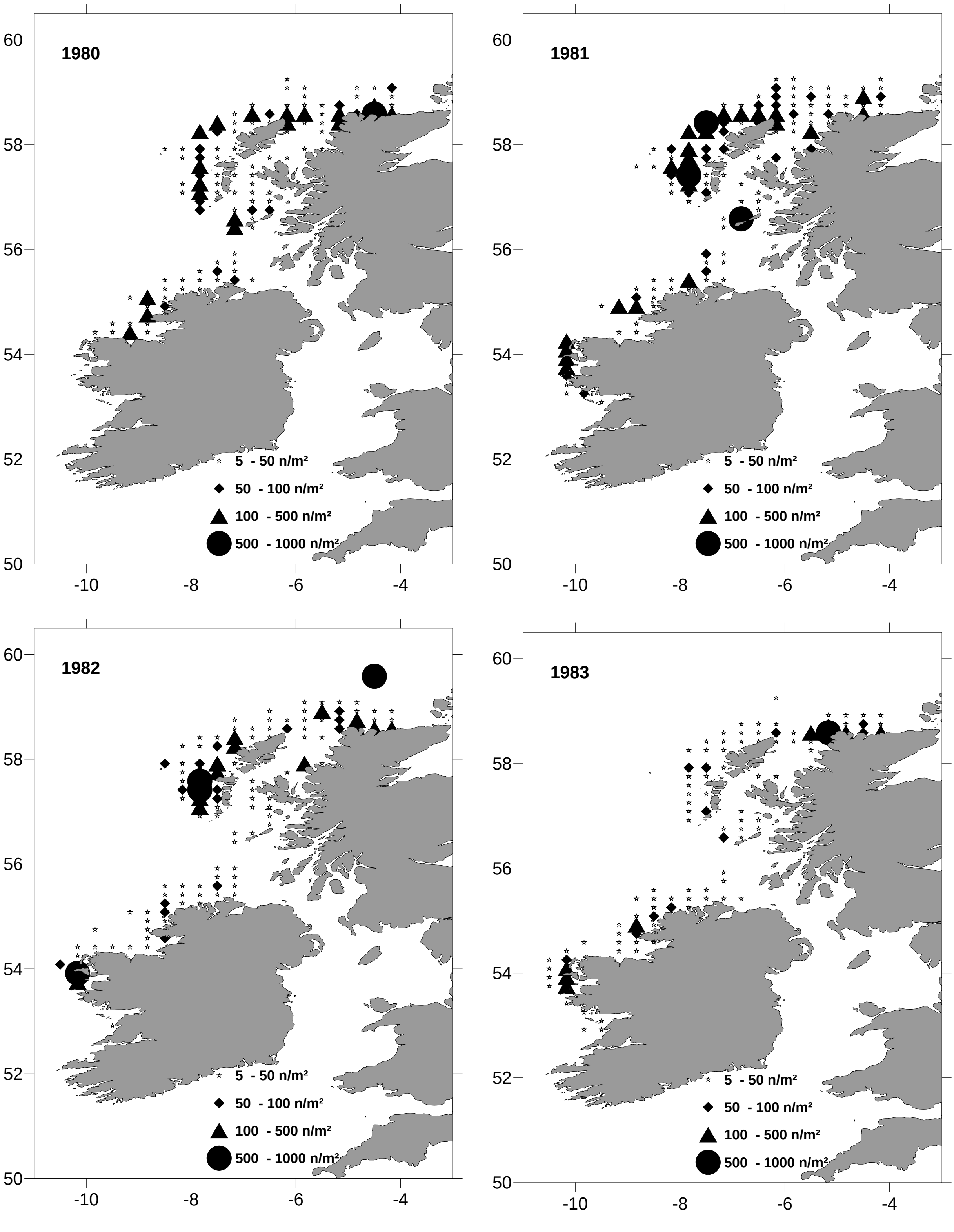


Figure 2.5.1.4. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel.

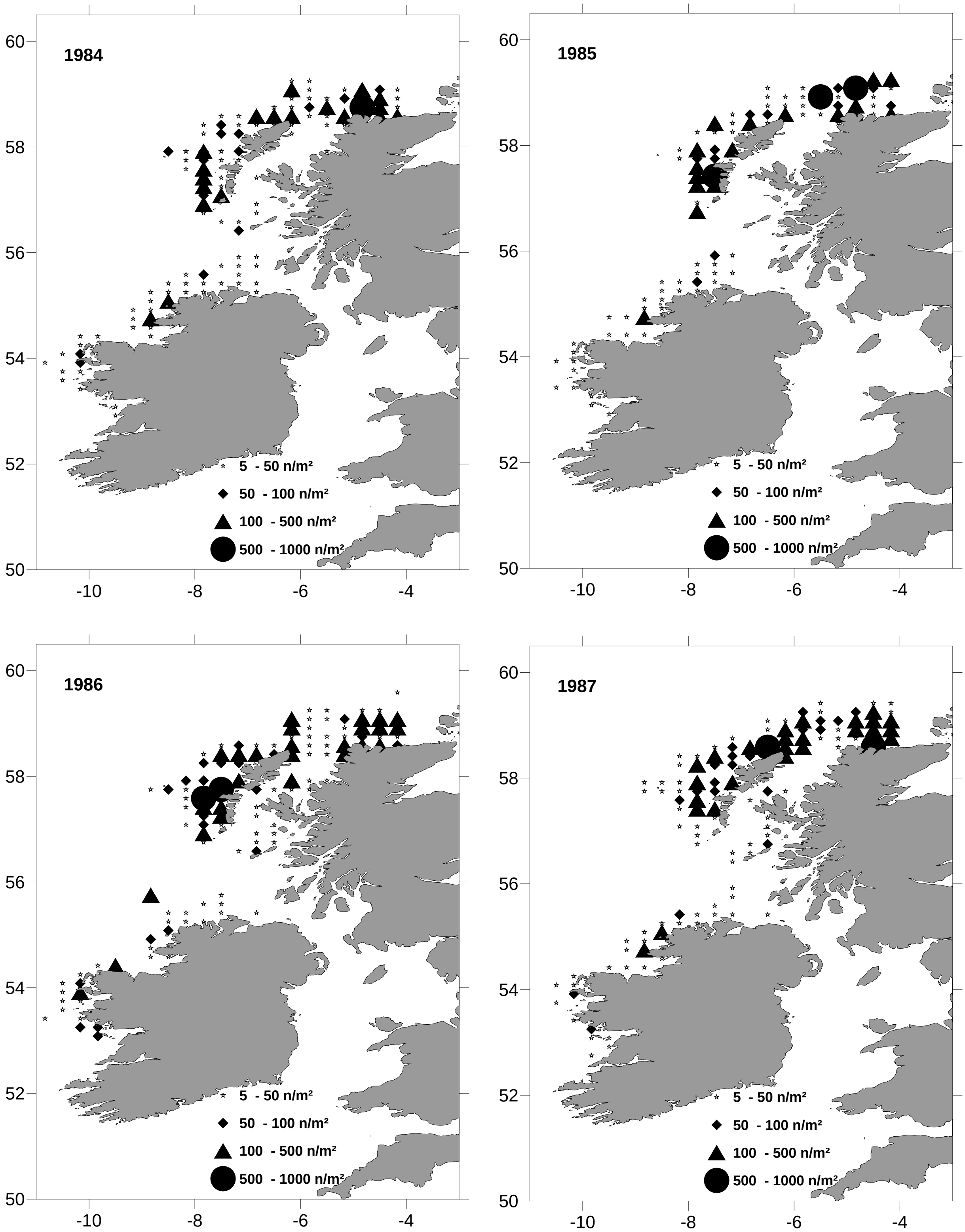


Figure 2.5.1.5. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel.

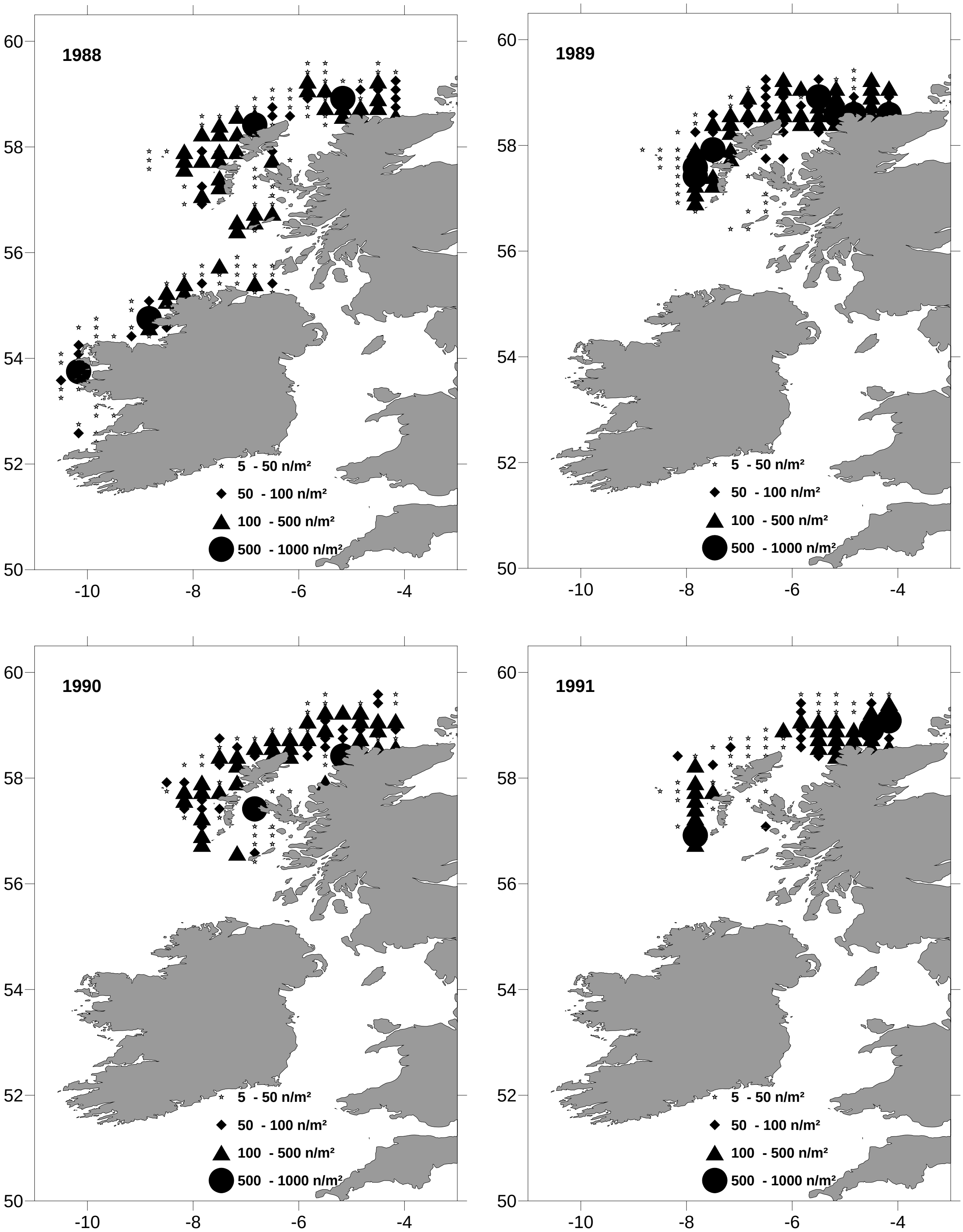


Figure 2.5.1.6. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel. Note that the survey in VIaS/VIIb was discontinued in 1989.

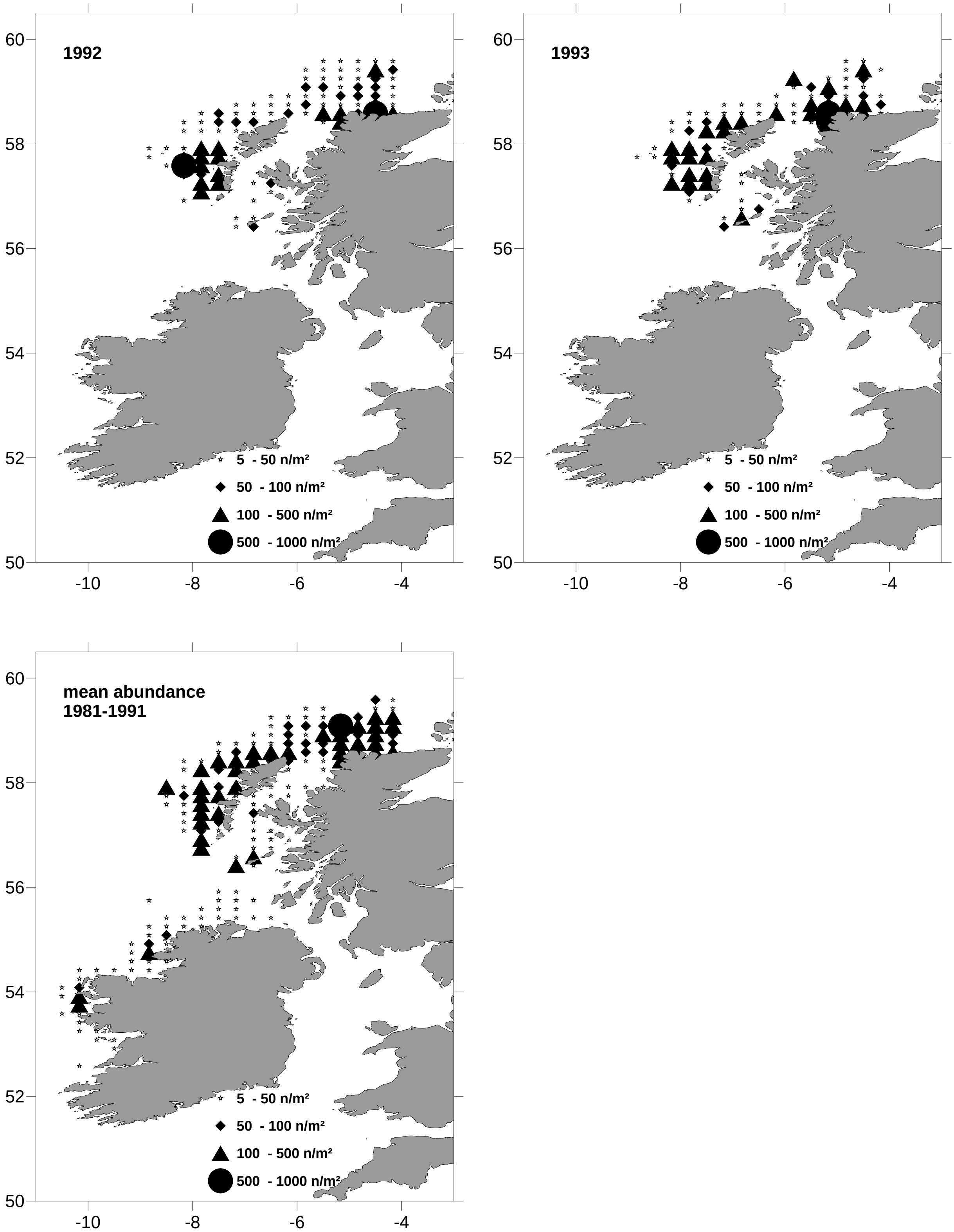


Figure 2.5.1.7. Mean abundance of herring larvae <10 mm (n/m²) as obtained from larvae surveys in VIaN and VIaS/VIIb. Stations yielding <5 larvae/m² are not shown. The survey year is indicated in each panel. Note that the survey in VIaS/VIIb was discontinued in 1989.

2.5.1.1 Drift path of foraging larvae

The movement of foraging (i.e. post yolk-sac) larvae can be estimated by tracking the centre of gravity of observed larvae from the surveys. There are some prerequisites, which seem to be fulfilled here. The domain must be sufficient to capture the overall distribution of larvae and the time of the surveys must cover the whole spawning period.

Data for the area west of Scotland were used from the international herring larvae database from years 1972 to 1993. These include larvae north of 56°N and around the shelf up to 4°W. The centre of gravity was calculated by year for three size groups (<10 mm; 10 – 15 mm; >15 mm). The centre of gravity of different sizes of larvae is indicative of the general drift (Figure 2.5.1.8).

There is considerable scatter among years, but the overall mean motion moves north-east at around 24 nautical miles between length groups. It takes the larvae approximately two weeks to growth from one size group into the other (assuming constant daily growth rates of 0.35 mm). This gives an average movement of 0.06 knots, implying around 40 days to travel the 60 Nautical miles across to the north of Scotland.

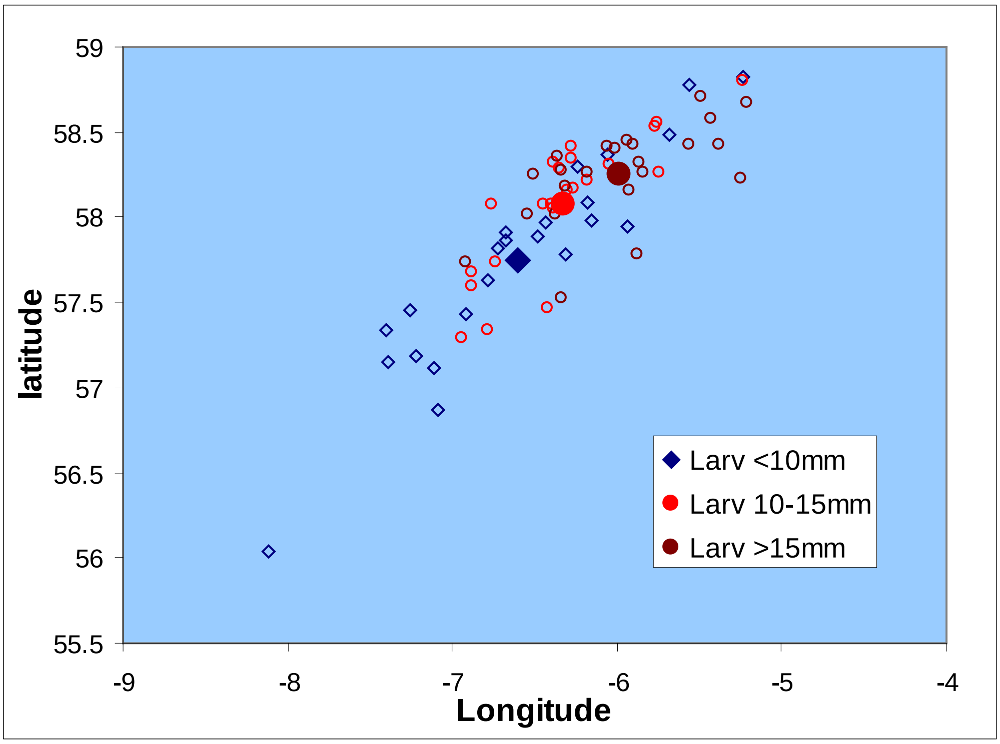


Figure 2.5.1.8. The centre of gravity of larval abundance in the area north of 56°N and west of 4°W to the west of Scotland by size group for the period 1972–1993.

2.5.2 Larvae surveys of Celtic Sea, 1978 to 1985 and 1989 and 1990

Herring larvae surveys were carried out in the Celtic Sea from 1978 to 1985 with further surveys carried out in 1989 and partial surveys in 1990. The larvae distribution by month is presented in Figure 2.5.2.1. These surveys provided information on the timing of spawning and on the location of the main spawning events as well as on the size of autumn and winter spawning components of the stock. The larvae surveys carried out after the fishery reopened in 1982 showed an increase in the spawning stock (Molloy 1995). The surveys covered the south coast and stations were positioned 8 nautical miles apart in a grid formation. A Gulf III sampler, with 275 µm mesh was used to collect the samples (Grainger *et al.*, 1982).

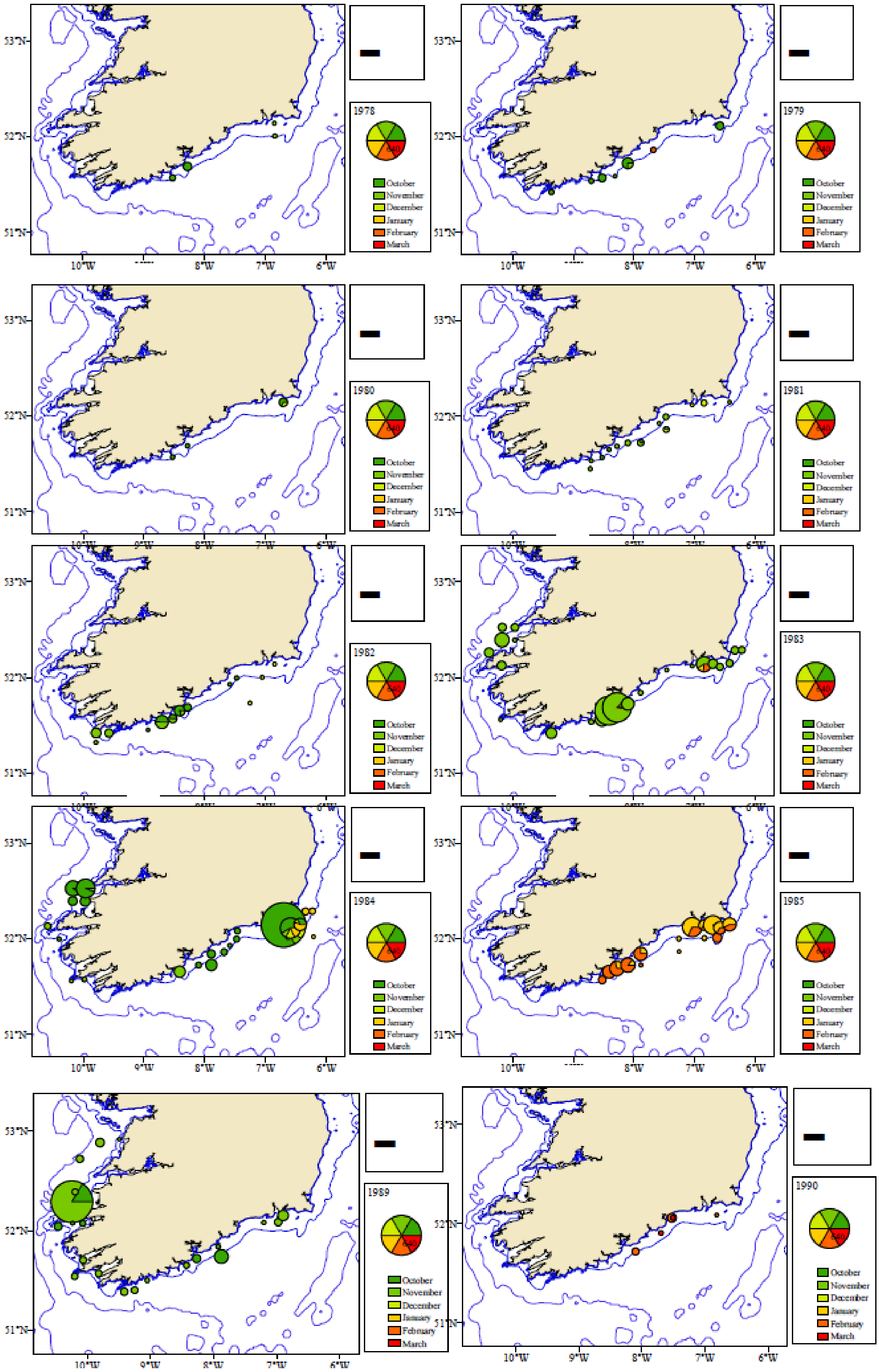


Figure 2.5.2.1. Summary of herring larvae distribution (<10 mm larvae) by month from Celtic Sea Larvae surveys.

2.5.3 Larvae surveys in the Irish Sea

Herring larvae surveys of the northern Irish Sea (ICES area VIIaN) have been carried out by the Agri-Food and Biosciences Institute (AFBI), formerly the Department of Agriculture and Rural Development for Northern Ireland (DARD), in November each year since 1993. The surveys have been carried out onboard the RV "Corystes" since 2005 and prior to that on the smaller RV "Lough Foyle".

Sampling is carried out on a systematic grid of stations covering the spawning grounds and surrounding regions in the NE and NW Irish Sea (Figure 2.5.3.1). Larvae are sampled using a Gulf-VII high-speed plankton sampler with 280 µm mesh net. Mean catch-rates (nos.m^{-2}) are calculated over stations to give separate indices of abundance for the NE and NW Irish Sea. Larvae production rates (standardized to a larva of 6 mm), and birth-date distributions, are computed based on the mean density of larvae by length class. A growth rate of 0.35 mm day^{-1} and instantaneous mortality of 0.14 day^{-1} were assumed based on estimates made in 1993–1997.

The results for 2009 indicate a similar distribution pattern to previous years, with highest abundance of herring larvae to the east and north of the Isle of Man (Figure 2.5.3.2). The point estimate of production in the northeastern Irish Sea for 2009 (1.69 x 10^{12} larvae) was below the time-series average. The index is used as an indicator of spawning-stock biomass in the exploratory assessment of Irish Sea herring by the Herring Assessment Working Group (HAWG).

The 2010 survey is scheduled to take place 8–19 November.

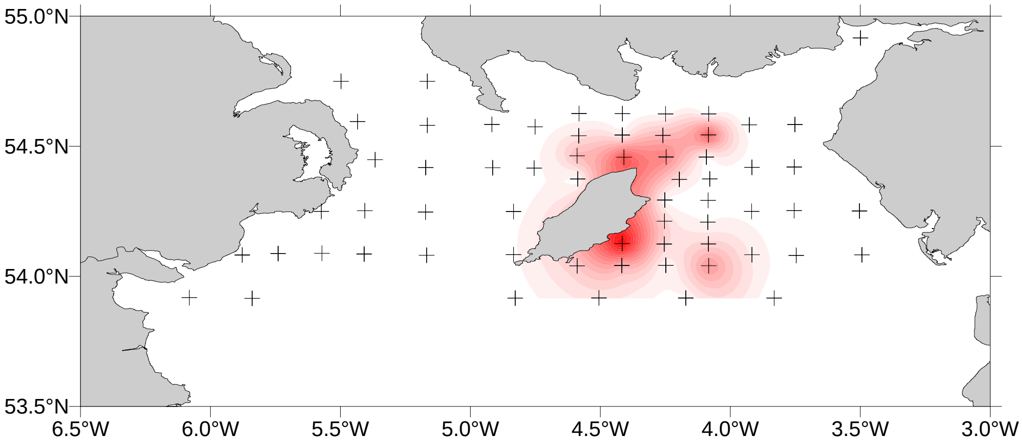


Figure 2.5.3.1. Estimates of larval herring abundance in the northern Irish Sea in 2009. Crosses indicate sampling stations. Areas of shading are proportional to larvae abundance (maximum = 182 per m2).

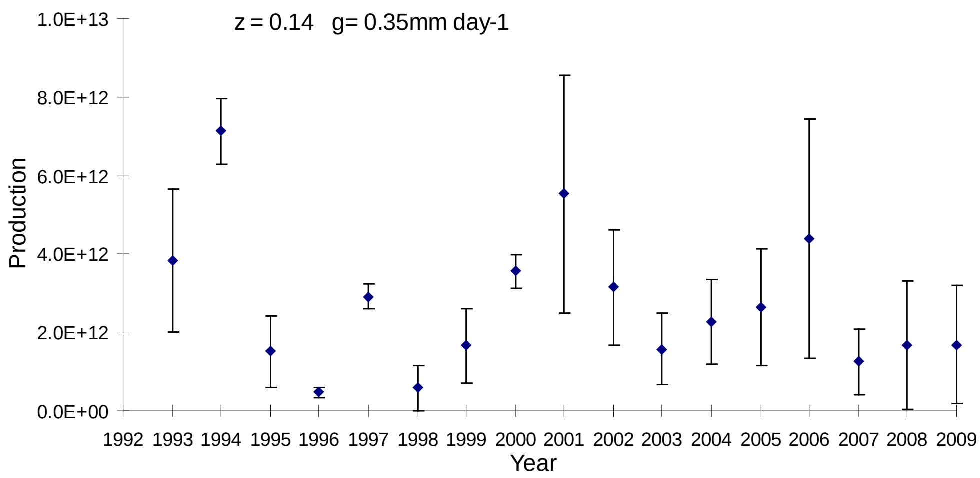


Figure 2.5.3.2. Estimates of herring larvae production in the NE Irish Sea from 1993 to 2009. Error bars denote 1 standard error (calculated from coefficients of variation of the estimates of abundance, but not including uncertainty in growth or mortality).

2.5.4 Scottish west coast IBTS time-series

International Bottom Trawl Surveys (IBTS) have been carried out by the Marine Laboratory, Aberdeen, off the west coast of Scotland and north of Ireland since 1986 in quarter 1 and since 1997 in quarter 4. Herring have been caught in 790 hauls across the 24 year time-series in Q1 (to 2009) and in 523 hauls across the 13 year time-series in Q4 (to 2008). It is known that herring spawn across winter and spring in the area and it might therefore be possible to find evidence of this spawning activity in these surveys. However, these surveys do not catch many herring in each haul and fewer still are sampled for biological data (across the time-series, Q1 average 30 herring per haul, Q4 average 13 herring per haul).

An examination of maturity data showed that, for the IBTS time-series in both quarters, the maximum percentage mature (equivalent to stage 6 on the 8 stage scale) in any haul was 3.93. Using a cut off point of 1% mature gave one data point in the Q4 survey (1.02% mature in one haul) and four from the Q1 survey (1.24 to 3.93% mature in one haul; Figure 2.5.4.1). We know herring are benthic spawners in very specific areas and the IBTS survey does not necessarily fish in those areas. However, for example, the herring haul in the Clyde was taken on 14 March 1994. This is in the vicinity of the Ballantrae Bank spawning area, in the middle of the spawning period for Clyde spring-spawning herring (February to April: Bailey *et al.*, 1986) but only 3.5% of the herring within that haul were mature. The Scottish west coast IBTS always samples within the ICES statistical rectangle that contains Ballantrae Bank. However, the Bank area is only some 3 miles (east to west) by 9 miles (north to south) in area and extends from the coast seawards (Stubbs and Lawrie, 1962) with depths over the bank of 12 – 18 m. It is unlikely that surveys tows would be carried out so close to the coast. However, one might still expect to see reasonable aggregations of mature herring in the vicinity of a known spawning area at spawning time and the fact that so few mature herring were present throughout the time-series would suggest that these surveys are not of use as an indicator of spawning grounds in the area.

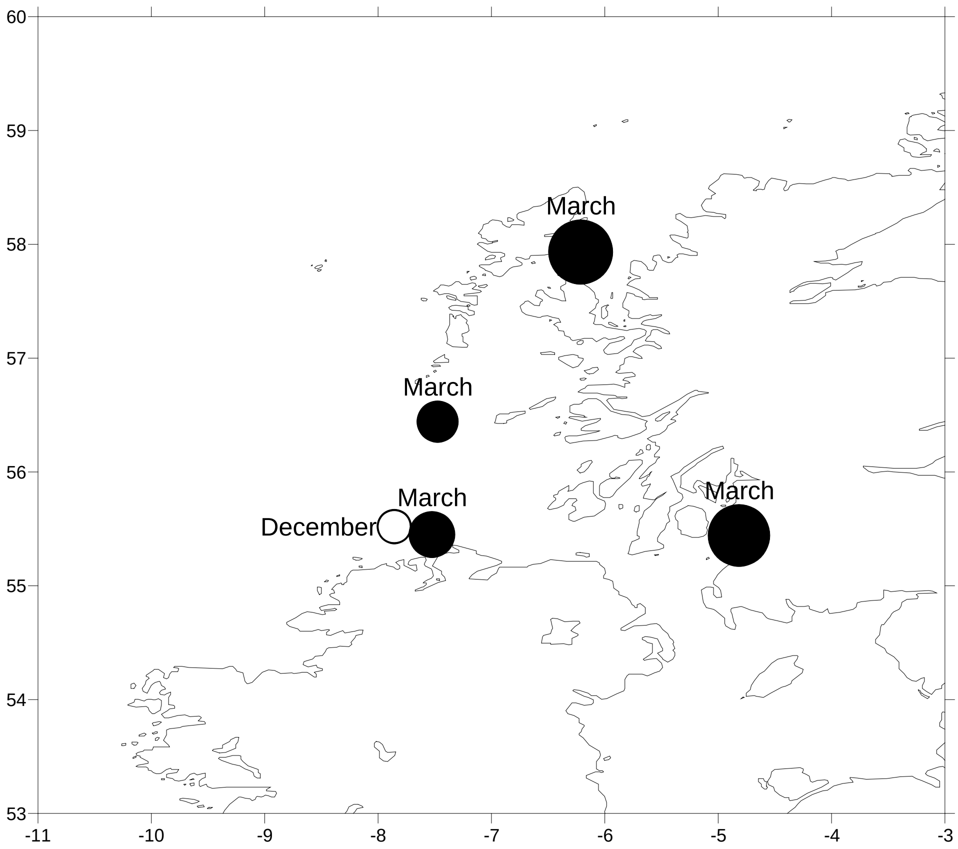


Figure 2.5.4.1. Map showing the position of the five hauls in the Q1 (1986 to 2009) and Q4 (1997 to 2008) west coast IBTS surveys where more than 1% of mature herring were found. Bubbles are scaled from a minimum of 1% to a maximum of 4%.

2.5.5 Scottish west coast MIK surveys 2008 and 2009

For the two west coast MIK surveys, if larvae were to be mapped on the same basis as the North Sea herring larvae survey where only herring <10 mm are used then 2.5% of larvae in 2008 and 11.1% of larvae in 2009 would be included as evidence of recently hatched herring. However, the MIK is designed to sample larger herring larvae. The North Sea MIK net survey samples overwintered herring larvae, not recently hatched ones. In 2009, in the Marine Lab. Aberdeen component of the North Sea MIK survey, no herring less than 11 mm were caught and the 11 mm larvae comprised less than 0.1% of the total larvae caught. The modal length was 23 mm. In contrast, the northern parts of the North Sea herring larvae survey in 2008 (in Orkney/Shetland (O/S) and Buchan (Bu)) that would contribute to the 2009 MIK in 2009 had modes of 7 mm (O/S) and 8 mm (Bu). The proportion of 2008 O/S larvae <10 mm was 91% and of Bu larvae was 83%.

It may be that a cut-off greater than <10 mm could be used to define to define spawning grounds for spring-spawning herring. Certainly, in the North Sea calculations, <11 mm is used for winter spawning component because hatch length is larger, 7 – 8 mm in the English Channel, than for autumn spawned larvae. However, it has been demonstrated that, in the Firth of Clyde at least, spring spawned larvae hatch in the same size range as autumn spawned North Sea herring (Rankine *et al.*, 1990). Expert advice on this will be sought at the 2010 Herring Assessment Working Group (HAWG).

2.5.6 Other Surveys

Other survey data will be explored such as the acoustic and groundfish surveys carried out in the Celtic Sea and northwest of Ireland to see if additional information on spawning grounds can be obtained.

2.5.7 Gravel bed distribution

Data were not available to the 2009 SGHERWAY meeting. They will be available in 2010.

3 References

Anon. 1978. Working paper for ICES Herring Assessment Working Group 28–30 September 1978.

Anon. 1994. Study Group on Herring Assessment and Biology in the Irish Sea and Adjacent Waters. ICES CM 1994/H:5. 69 pp.

Armstrong, M.J. 1992. Research surveys of Irish Sea herring and sprat in 1991. Working Document: 1992 ICES Herring Assessment Working Group.

Armstrong, M.J., Clarke, W.J., and Burns, C.A. 1993. Research surveys of Irish Sea herring and sprat in 1992. Working Document: 1993 ICES Herring Assessment Working Group.

Bailey, R.S., McKay, J.A., Morrison, J.A., and Walsh, M. 1986. The biology and management of herring and other pelagic fish stocks in the Firth of Clyde. Proc. Roy. Soc. Edinburgh, 90B: 407–422.

Beggs, S., Schon, P-J., McCurdy, W., Peel, J., McCorriston, P., and McCausland, I. 2009. Seasonal Origin of 1-ring+ Herring in the Irish Sea (VIIaN) Management Area During the Annual Acoustic Survey. Working Document: 2009 ICES Herring Assessment Working Group.

Bowers, A.B. 1969. Spawning beds of Manx autumn herring. J. Fish. Biol., 1: 355–359.

Bowman, A. 1922. Spawny haddocks. The occurrence of "spawny" haddock and the locus and extent of herring spawning grounds. Fisheries, Scotland, Scientific Investigations, 4 (April, 1923). 15 pp.

Brophy, D., and Danilowicz, B.S. 2002. Tracing populations of Atlantic herring (*Clupea harengus* L.) in the Irish and Celtic Seas using otolith microstructure. ICES J. Mar. Sci., 59: 1305–1313.

Campbell, N. Cross, M.A., Chubb, J.C., Cunningham, C.O., Hatfield, E.M.C., and MacKenzie, K. 2007. Spatial and temporal variations in parasite prevalence and infracommunity structure in herring (*Clupea harengus* L.) caught to the west of the British Isles and in the North and Baltic Seas: implications for fisheries science. Journal of Helminthology (2007) 81, 137–146.

Dickey-Collas, M., Nash, R.D.M., and Brown, J. 2001. The location of spawning of Irish Sea herring (*Clupea harengus*). J. Mar. Biol. Ass. UK, 81: 713–714.

Fernandes, P.G., Reid, D.G., and Copland, P.J. 2003. The use of commercial vessels for Acoustic Assessments of herring on the west coast of Scotland. Working document for the ICES Working Group on Fisheries Acoustic, Science and Technology 2003, Bergen, Norway. 12 pp.

Grainger, R.J., Barnwall, E., and Cullen, A. 1982. Herring larval surveys in the Celtic Sea in 1981/82. ICES CM H:38: 16 pp.

Heath, M.R. 1984. Report on an acoustic survey carried out in the northern part of Division VIa on herring and mackerel. ICES CM 1984/H:62. 38 pp.

Heath, M. 1989. Transport of larval herring (*Clupea harengus* L.) by the Scottish Coastal Current. Rapp. P.-v. Reun. Cons. Int. Explor. Mer, 191: 85–91.

Heath, M.R. 1993. An evaluation and review of the ICES herring larval surveys in the North Sea and adjacent waters. Bull. Mar. Sci., 53: 795–817.

Heath, M.R., and MacLachlan, P. 1987. Dispersion and mortality of yolk-sac herring (*Clupea harengus* L.) from a spawning round to the west of the Outer Hebrides. J. Plank. Res., 9: 613–630.

ICES. 1980. Herring Assessment Working Group for the Area South of 62ºN (HAWG). ICES CM 1980/H:4. 128 pp.

ICES. 1992. Report of the Herring Assessment Working Group for the Area South of 62°N. ICES Document CM 1992/Assess:11. 180 pp.

ICES. 1993. Report of the Herring Assessment Working Group for the Area South of 62°N. ICES Document CM 1993/Assess:15. 252 pp.

ICES. 1994. Report of the Study Group on Herring assessment and Biology in the Irish Sea and Adjacent Waters. ICES Document CM 1994/H:5. 69 pp.

ICES. 2004. Herring Assessment Working Group for the Area South of 62ºN (HAWG). ICES CM 2004/ACFM: 18. 551 pp.

ICES. 2005. Herring Assessment Working Group for the Area South of 62ºN (HAWG). ICES CM 2005/ACFM: 16. 609 pp.

ICES. 2008. Report of the Herring Assessment Working Group South of 62ºN (HAWG). Copenhagen, ICES CM/2008/ACOM:02: 601 pp.

ICES. 2008 Report of the Study Group on the Evaluation of Assessment and Management of the western herring stocks (SGHERWAY). ICES CM 2008/RMC:08. 46 pp.

ICES. 2009a. Report of the Herring Assessment Working Group South of 62ºN (HAWG). Copenhagen, ICES CM/2008/ACOM:02. 601 pp.

ICES. 2009b. Report of the Planning Group of International Pelagic Surveys (PGIPS), 20–23 January 2009, Aberdeen, Scotland, UK. ICES CM 2009/LRC:02. 217 pp.

Kell, L.T., Dickey-Collas, M., Hintzen, N.T., Nash, R.D.M. Pilling G.M., and Roel B.A. 2009. Lumpers or splitters? Evaluating recovery and management plans for metapopulations of herring. ICES J. Mar. Sci., 66: 1776–1783.

MacKenzie, K. 1985. Relationships between the herring, *Clupea harengus* L., and its parasites. Adv. Mar. Biol., 24: 263–319.

Molloy, J. 1983. The occurrence of winter and spring spawning herring off the northwest coast of Ireland. ICES CM 1983/H:60. 11 pp.

Molloy, J. 1995. The Irish herring fisheries in the twentieth century: their assessment and management. Occasional Papers in Irish Science and Technology, Royal Dublin Society: 1–16.

Molloy, J. 2006. The Herring Fisheries of Ireland (1995–2005), Biology, Research, Development and Assessment. Marine Institute. 235 pp.

Molloy, J., and Barnwall, E. 1988. Herring larval surveys off the west and north west coasts. Dept. of Mar. Fishery Leaflet 142.

Molloy, J., Barnwall, E., and Morrison, J. 1993. Herring Tagging Experiments around Ireland in 1991. Dep. of Mar. Dublin., Fish. Leaf. No. 154.

Morrison, J.A., Bruce, T. (1981) Scottish herring tagging experiments in the Firth of Clyde 1975–1979 and evidence of affinity between Clyde herring and those in adjacent areas. ICES CM 1981/H:53.

Munk, P., Heath, M., and Skaarup, B. 1991. Regional and seasonal differences in growth of larval North Sea herring (*Clupea harengus* L.) estimated by otolith microstructure analysis. Cont. Shelf Res., 11:641–654.

Parrish, B.B., Saville, A., Craig, R.E., Baxter, I.G., and Priestley, R. 1959. Observations on herring spawning and larval distributions in the Firth of Clyde in 1958. J. mar. biol. Ass. UK, 38: 445–453.

Patterson, K.R. 1999. Integrated Catch at Age Analyses Version 1.4. Report No. 28, S.F. Research.

Payne, M.R., Clausen, L.W., and Mosegaard, H. 2009a. Finding the signal in the noise: objective data- selection criteria improve the assessment of western Baltic spring-spawning herring. ICES J. Mar. Sci., 66: 1673–1680.

Payne, M.R., Hatfield, E.M.C., Dickey-Collas, M., Falkenhaug, T., Gallego, A., Gröger, J., Licandro, P., Llope, M., Munk, P., Röckmann, C., Schmidt, J.O., and Nash, R.D.M. 2009b. Recruitment in a changing environment: the 2000s North Sea herring recruitment failure. ICES J. Mar. Sci., 66: 272–277.

R Development Core Team. 2008. R: A language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing.

Rankine, P.W. 1986. Herring spawning grounds around the Scottish coast. ICES CM 1986/H: 15. 11 pp.

Rankine, P W., Cargill, L.H., and Morrison, J.A. 1990. Variation in the hatching length of spring-spawned herring larvae (*Clupea harengus* L.) on Ballantrae Bank in the Firth of Clyde. J. du Conseil, 46: 333–339.

Rohlf, N.; Gröger, J., and D. Schnack. 1998. Effects of calculation procedure and reduced sampling effort on abundance indices of herring larvae as measure of spawning stock size. ICES CM 1998/ BB:04. 40pp.

Simmonds, E.J. 2009. Evaluation of the quality of the North Sea Herring Assessment. ICES J. Mar. Sci., 66: 1814–1822.

Stubbs, A.R., and Lawrie, R.G.G. 1962. ASDIC as an aid to spawning ground investigations. J. du Conseil, 27: 248–260.

Appendix 1

The level of mixing is inversely related to the availability of a population to the fishery. An availability of 100% indicates no mixing of that population in different management areas.

Availability of population 1–4 to the fishery in %			
FISHERY 1 (VIaN)			
Pop 1	**Pop 2**	**Pop 3**	**Pop 4**
100	25	25	0
FISHERY 2 (VIaS/VIIb,c)			
Pop 1	**Pop 2**	**Pop 3**	**Pop 4**
0	75	0	0
FISHERY 3 (Irish Sea)			
Pop 1	**Pop 2**	**Pop 3**	**Pop 4**
0	0	75	0
FISHERY 4 (Celtic Sea)			
Pop 1	**Pop 2**	**Pop 3**	**Pop 4**
0	0	0	100

Annex 1: List of participants

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Annex 2: SGHERWAY terms of reference for the next meeting

The Study Group on the evaluation of assessment and management strategies of the western herring stocks (SGHERWAY) chaired by Emma Hatfield, UK will meet at ICES Copenhagen, Denmark, 24–26 March 2010, and in Dublin, Ireland, 14–18 June, 2010 to:

a) Evaluate the utility of a synoptic acoustic survey in summer for the Hebrides, Malin and Irish shelf areas, in conjunction with WGIPS surveys of VIaN and the North Sea;

b) Explore a combined assessment of the three stocks and investigate its utility for advisory purposes;

c) Evaluate, through simulation, alternative management strategies for the metapopulation of VIaN, VIaS and VIIaN, considering the maintenance of each spawning component in a healthy state.

SGHERWAY will report by 30 July 2010 (via SSGSUE) for the attention of SCICOM and ACOM.

Supporting information

Priority	It is expected that this work will resolve issues surrounding the assessment and management of the herring stocks to the west of the British Isles. Its impact is expected to be high and consequently this work is considered to have a very high priority.
Scientific Justification	The EU funded project WESTHER evaluated the uncertain stock identity of herring stocks to the west of the British Isles. Its results suggested a rearrangement of the stocks as they are currently assessed and these results now need to be taken forward into the assessment and management process. We recognize the need to provide sound management advice for the western herring areas, and in particular the importance of ensuring as far as possible that there is no depletion of local components. HAWG noted that WESTHER was not funded to evaluate the extent of mixing in the fisheries or to evaluate alternate management strategies for the area. Currently it is unclear what management regime would provide the most cost-effective method for successful management and what data would be needed to support this management. We consider that it is necessary to move towards an integrated management plan for this area through a series of iterations involving the following steps :- • Investigation of combined assessment of the three currently assessed stocks, VIaN, VIaS and VIIaN (to be called the Malin Shelf stock), including an investigation of the utility of a combined acoustic survey. • Examination of alternative management strategies based on their ability to deliver protection to local populations and provide cost-effective information applicable for management of the two proposed stock units of herring to the west of the British Isles (Malin Shelf and Celtic Sea). • Amendment of existing, or development of new, cost-effective assessment and data collection schemes which will be required to support this management. SGHERWAY supports directly ICES Goals 1, 3 and 4 in the action plan,

	specifically 1.11, 3.4, 4.1, 4.2, 4.3 and 4.15.
Resource Requirements	It is proposed that these would constitute the final two meetings of SGHERWAY. It is intended that there would be 8–10 participants, meeting for 3 and 5 days respectively, with intersessional work required.
Participants	Herring biologists and scientists experienced in assessment and management strategy evaluation, from Ireland, Norway, The Netherlands, and the UK have agreed to attend the study group.
Secretariat Facilities	None, other than formatting and publishing of the final report.
Financial:	There are virtually no financial implications
Linkages To Advisory Committees	The study group will provide information to ACOM. This group feeds into the advisory process.
Linkages To other Committees or Groups	This SG is essential to the work of HAWG and will have clear links to WGIPS and SGSUE.
Linkages to other Organisations	None

Annex 4: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. That the Marine Scotland-Science, Marine Laboratory Aberdeen should continue to perform the west coast MIK surveys. Given that they cover the spawning period of herring in VIaS and VIIb, there might be utility in this survey as an index of larvae abundance for that area if a time-series is allowed to build up.	Marine Scotland – Science: Fishery Management Programme
2. That all efforts should be made to hold a two day post-cruise meeting soon after the combined Malin Shelf survey to compile and collate combined survey data and to upload it to FishFrame. The meeting would allow members to evaluate survey data and discuss issues arising from the survey and conclude on recommendations to improve survey precision.	WGIPS