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Report of the Study Group on Stock Identity and Management Units of Whiting (SGSIMUW)

15–17 MARCH 2005

ABERDEEN, UK

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Conseil International pour l'Exploration de la Mer

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Executive Summary

This meeting operated predominantly as a priming and coordination meeting to initiate the Study Group on Stock Identity and Management Units of Whiting (SGSIMUW) activities. Consequently, it sought to define the inter-sessional work that is required to address the issue of stock structure and the definition of practical management units. Protocols based on survey data and commercial catch data were presented to illustrate the possible means to evaluate the impacts of population structuring on stock assessments. Some of them, e.g. Gadget, are outside the resource-base of the Study Group membership, but others that are also based on spatially disaggregated datasets (from both survey and commercial data) are likely to provide insight into the issue.

Nine working documents were presented at the meeting. Six of these were provided by non-attending contributors and focused on the analysis of various survey series, predominantly the first-quarter International Bottom Trawl Survey (IBTS Q1). The evaluations of the IBTS Q1 indices show the whiting indices to be sensitive to the spatial coverage of the survey and that since 1983, when consistent spatial coverage was first established, a generally coherent set of indices has been produced that is consistent with the corresponding results from catch-at-age analyses. The exception is that for younger ages in particular there are distinct relationships between indices and catch-at-age estimates during two separate periods (1983-1990 and 1991-to date).

Two of the working documents reviewed published information on aspects of North Sea whiting biology relevant to the evaluation of its population structure. Historical information suggests that whiting to the north and south of the Dogger Bank frontal system comprise functionally separate units with only limited movement across the boundary. Although insufficient information exists to confirm any genetic differentiation, the Study Group concluded that there was sufficient information available to support the view of separate stocks for stock assessment and management units but did not, at this meeting, define their boundaries. Current work within one research institute is directed towards resolving the population structure of whiting within the North Sea and between the North Sea and waters to the west of Scotland, but this will not report for two years.

IBTS indices were available to the Study Group at the start of its meeting. The ICES DATRAS data download format was adopted for distribution of the additional English and Scottish survey series to Study Group members for the inter-sessional work. The Study Group Chair will provide a data exchange format to North Sea coastal state institutes for the exchange of commercial catch data with rectangle-based spatial resolution. The completion of survey-based analyses is anticipated prior to the forthcoming meeting of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) (6 September 2005), but the completion of analyses based on spatially-resolved commercial catch data will depend on the availability of those data from national institutes.

1 Introduction

1.1 Participants

A complete list of participants can be found in Annex 1 of this report.

1.2 Terms of Reference

A **Study Group on Stock Identity and Management Units of Whiting** [SGSIMUW] (Chair: Phil Kunzlik, UK) met in Aberdeen, UK from 15–17 March 2005 to:

a. a) review all reported material on the stock identity of whiting in the North Sea and adjacent waters in order to identify the most likely definition of biological stocks of whiting as well as suggest practical management units;
b. b) agree a data exchange format to provide (i) survey data and (ii) commercial landings and discard data, disaggregated by ICES statistical rectangle and quarter for the year to Study Group members. This will be done to provide spatially-structured catch data to which appropriate biological characteristics are or can be attributed (*e.g.*, age compositions) in order to compile assessment datasets nominally derived from the stock definitions determined under ToR (a);
c. c) define an evaluation protocol under which the consequences of assessing multiple stocks or stock sub-units as a single stock can be determined, and allocate responsibilities, as required, between Study Group members.

The SGIMUW will report by 1 May 2005 for the attention of Living Resources Committee, SIMWG and RMC.

1.3 Scientific justification and aims of the Study Group

The assessments of whiting in the North Sea, Irish Sea and West of Scotland has been problematic for many years. Available sources of information include reported landings, estimated discards, and research-vessel surveys. Stock dynamics trends derived from these different sources are often contradictory, making coherent assessments of these stocks extremely difficult. It is possible that the use of incorrect management units is a contributing factor in this situation: it may be that each whiting management unit covers several distinct sub-stocks, which have different and irreconcilable stock dynamics. However, little is currently known of the stock structure of whiting populations in ICES' areas. The aim of SGSIMUW will be to analyse extant data from commercial landings records, research-vessel surveys, tagging studies, and fishery-related information such as industry questionnaires, to determine if there is evidence for sub-stocks, as well as to evaluate stock assessments based on any new management units suggested by the analysis. The consequences in more general terms of assessing multiple stocks will also be investigated.

The Study Group has taken the definition of whiting in the North Sea and adjacent waters from the terms of reference to refer specifically to whiting currently described and assessed by ICES as whiting in the North Sea and eastern Channel (*i.e.*, whiting in ICES subarea IV and Division VIId). The references to participants and linkages to other committees or groups in the ICES resolution that established the Study Group (ICES resolution 2G01 2004), make that the obvious interpretation.

1.4 Conduct of the meeting

As is apparent from its terms of reference, a fundamental role of this meeting is to operate as a pump-priming process to initiate data collation at the appropriate spatial scale to permit relevant analyses to take place, and to bring together and review existing information on the putative stock structure of whiting in the North Sea. Both members and non-members supplied a number of working documents to the Study Group. Contributions from the latter were presented to the best of the Study Group's ability, but the Study Group was conscious of the fact that their authors were not available to contribute to any subsequent discussion.

Working document 1 is presented in full in this report (Sections 2.1–2.3) as it provides the background to the stock assessment issues that led to the formation of the Study Group. Brief highlights are presented of the other working documents along with a short summary of the Study Group's comments on them. The working documents are presented in full in a separate volume.

2 Background

2.1 The fishery

Some of the following description of fisheries that catch whiting in the North Sea and eastern Channel is taken from WGNSSK and ACFM reports, and repeated here for convenience. A map of the relevant ICES divisions is shown in Figure 1.

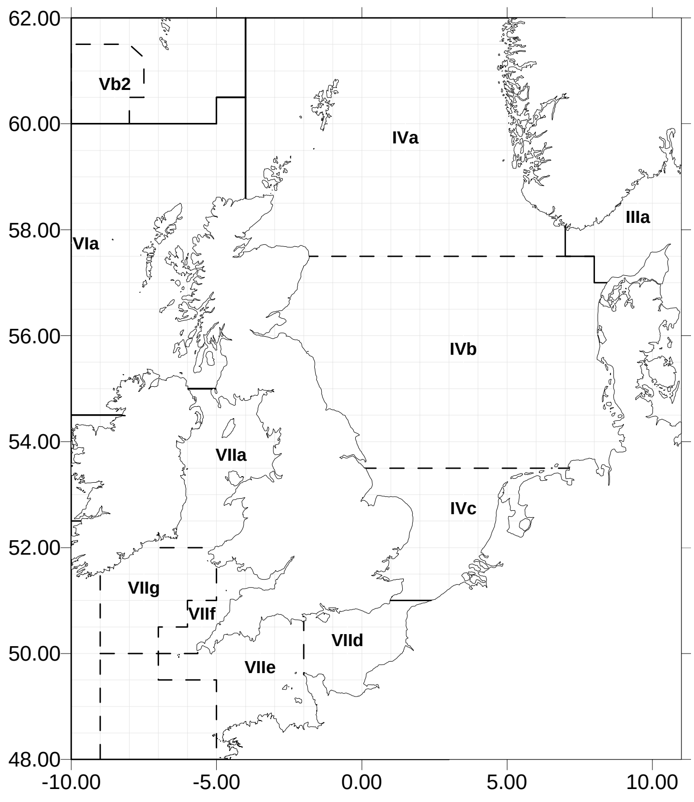

Figure 1: Map of ICES Subareas and Divisions: North Sea (IVa-c), Skagerrak/Kattegat (IIIa), eastern Channel (VIId) and western Channel (VIId).

The demersal fisheries in the North Sea (ICES Subarea IV) can be categorised as a) human consumption fisheries, and b) industrial fisheries which land the majority of their catch for reduction purposes. There are no industrial fisheries in the eastern Channel (ICES Division VIId).

Human consumption demersal fisheries in the areas are mixed fisheries, with different species exploited together in various combinations in different fisheries. For whiting, spatial information on landings suggests three distinct areas of major catch: a northern zone, an area off the eastern English coast, and a southern area extending into the Channel.

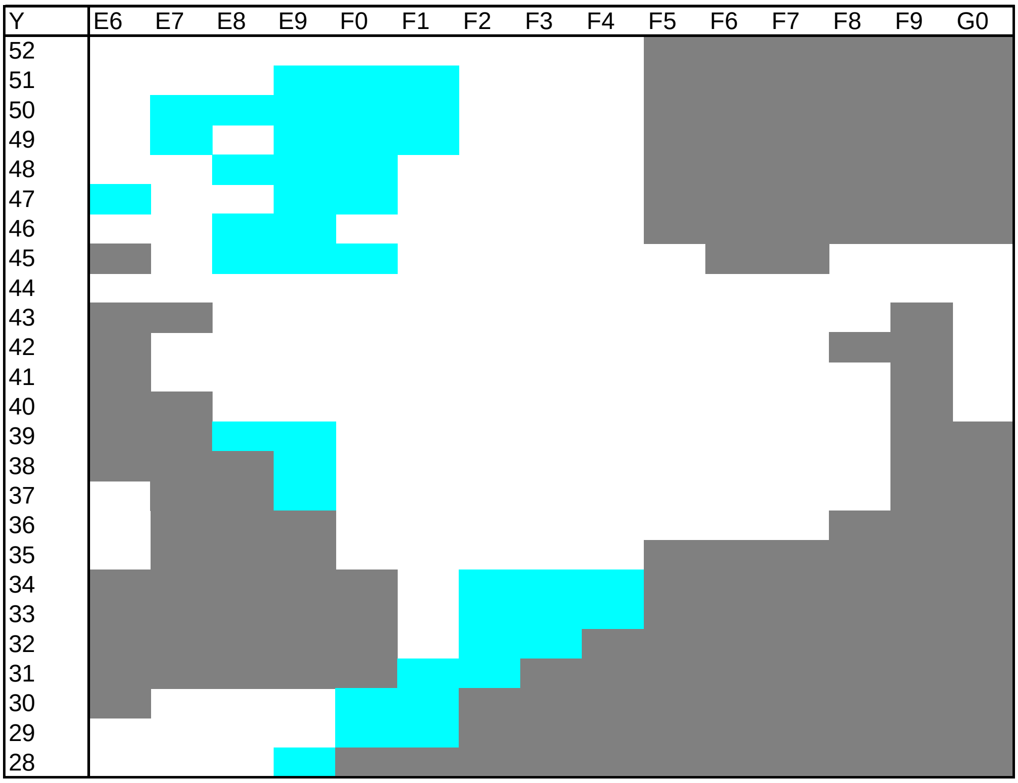

Figure 2: The landings distribution, in 2002, for North Sea, Skagerrak and eastern Channel whiting (from ICES 2004a). Light-shaded rectangles are the highest yielding rectangles and together comprise the rectangles yielding 80% of whiting landings from these areas

In the northern area, roundfish are caught in otter trawl and seine fisheries, currently with a 120mm minimum mesh size. These are mixed demersal fisheries with more specific targeting of individual species in some areas and/or seasons. Cod, haddock and whiting form the predominant roundfish catch in the mixed fisheries, although there can be important bycatches of other species, notably saithe and anglerfish in the northern and eastern North Sea and of *Nephrops* in the more offshore *Nephrops* grounds. The southern whiting fishery uses 80mm nets and is, in part, regulated by catch composition rules.

Whiting also comprise a bycatch in the beam trawl fisheries and the *Nephrops* fisheries, both of which can operate with 80mm mesh sizes depending on area (beam trawls) or gear configuration (*Nephrops* trawls)

The average landings of whiting from areas IV and VIId over the period 1980–1994 were 65.1kt, falling to 28.4kt for the period 1995–2003. Corresponding values for discarded whiting were 42.8kt and 28.3kt. The reduction in landings and discards in recent years can, in part, be explained by increases in minimum mesh sizes for towed demersal roundfish gears in the North Sea for which short-term losses would not be expected to be recovered as long term gains (Kunzlik, 2003). TACs appear to have been unrestrictive except on a localised basis. Northern landings appear to have declined most whilst southern landings have been maintained.

For much of the 1990s, whiting could be caught in the North Sea in a directed whiting fishery using a 90mm codend mesh under a derogation from the 100mm minimum mesh size that was required for the mixed demersal towed gear roundfish fishery.

The North Sea industrial fisheries target sandeel and Norway pout in different areas and seasons. There is bycatch of other species associated with these fisheries and any bycatch landed from the industrial fisheries that is below the minimum landing size for a particular species is recorded as industrial bycatch (fish above the minimum landing size and landed for human consumption are recorded against quota). For whiting, there has been a clear reduction in the industrial bycatch since 1995; the mean value of industrial bycatch has fallen from 31.4kt (1980–1995) to 5.6kt (1996–2003).

2.2 Recent assessment history

ICES assessed whiting in the North Sea and eastern Channel as separate stocks until 1996. Information on stock identity summarised at the 1995 meeting of WGNSSK (ICES, 1996) indicated that whiting in the eastern Channel and southern North Sea shared a greater affinity than existed between whiting in the eastern and western Channel (ICES Division VIIe). It did not address the identity of whiting in the Skagerrak/Kattegat (ICES Division IIIa) relative to the North Sea.

The ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) has frequently commented on the contrast between research vessel survey indices of abundance and the results of catch at age analyses, *e.g.* ICES 1995a. Moreover, it has also commented on a lack of consistency between the first quarter IBTS survey indices, the third quarter Scottish groundfish indices and the third quarter English groundfish surveys. Such differences were further reported by the ICES Study Group on the Evaluation of the Quarterly IBTS Surveys (ICES, 1998) but no exploration of reasons behind the inconsistencies was made. These issues have created a long-standing problem in the stock assessments of North Sea whiting.

For most of the 1990s, and prior to 2001, WGNSSK had used a standard procedure known as extended survivors analysis (XSA, Shepherd, 1999) to reconstruct the historical stock trends for North Sea whiting from commercial catch data whilst regularly exploring other procedures as well. At its meeting in 2001, WGNSSK examined a wide-ranging set of putative assessments based on different procedures and choices of data series (ICES 2002). The outcome of this was a divergent set of results for the terminal years of the assessment, in which estimates of the contemporary size of the stock varied widely. In addition, the whiting assessment was found to be quite sensitive to changes in the XSA configuration. At that meeting WGNSSK selected one model and formulation to provide the key run for the assessment whose results were taken forward into prediction. The selected model (a time-series assessment or TSA, Gudmundsson 1994 and, e.g., Fryer, 2000) was chosen not because it gave the best point estimates for the assessment, but because its confidence limits were considered to best encompass the uncertainty of the various candidate assessments.

Also at that meeting, WGNSSK also held back from presenting a standard catch option forecast table. This was done specifically because of the difficulty it had faced in selecting an appropriate key run for the assessment, arguing that a typical catch option table would not adequately convey the true uncertainty of the forecast. Consequently it presented a probabilistic forecast that indicated, for *status quo* fishing mortality, landings in 2002 with approximate 95% confidence intervals of 15,000t and 70,000t. Despite these concerns of WGNSSK, the ICES Advisory Committee on Fisheries Management (ACFM) presented a standard catch option table to managers (ICES 2001), largely because it was argued that managers, if presented with a probability distribution of catches, would simply select the average of the distribution. So it was felt important for managers to know how that average would vary for different levels of fishing – in other words, that ACFM should present a standard catch options table.

At its subsequent meeting in 2002, WGNSSK again selected the TSA approach to reconstruct the stock history for North Sea whiting (ICES, 2003). It found that attempting to incorporate survey data into the analysis made no statistical difference to the model fit (i.e., no clearly improved or poorer fit could be identified by its goodness-of-fit diagnostics) so, as at its previous meeting, a TSA assessment that excluded survey data was selected as the key run and taken forward into forecast. Due to a change in timing of the WGNSSK meeting, the forecasts were carried out at a later *ad hoc* meeting of the working group at which only a standard catch option table was produced.

At its meeting, in 2003, WGNSSK undertook a considerable re-analysis of the procedures and data used in the assessment (ICES, 2004a). This was thought necessary because a straightforward update of the previous year's TSA assessment suggested a potential problem with retrospective patterning in the results, i.e. the incorporation of data from 2002 had indicated the beginnings of a tendency to under- or over-estimate certain outputs (although such events are difficult to discriminate from noise in the assessment in their early stages). The re-evaluations centred on the choice of survey series to use in the assessment and the sensitivity of the assessment methods to them. The working group settled on an XSA formulation that incorporated three different survey series as the key-run and took it forward into forecasts to produce a standard catch option table.

This approach was rejected by ACFM. This was because the assessment was considered to be very uncertain due to inconsistent trends in the development of the stock as indicated by (i) conflicts between stock indices, and (ii) the high sensitivity of the catch-at-age analysis to annual updates. The TSA approach had previously been used to address this by presenting the results of a probabilistic assessment whose error bounds were considered to best encapsulate the overall uncertainty of the assessment. When even this approach failed to deal adequately with the sensitivity of the analysis, ACFM considered it to be inappropriate simply to fall back on a non-probabilistic assessment with relatively poor diagnostic capabilities.

ACFM failed to pick up in its review of that whiting assessment the fact that WGNSSK had produced a TSA assessment that performed equivalently to the key run XSA. This was achieved by incorporating the three survey indices into the analysis (notwithstanding its previous experience that including the surveys into the TSA made no *statistical* difference to the outcome). However, that TSA assessment was not particularly stable (one had to experiment with different starting values for parameter estimation each time a new year's data were added).

At its 2004 meeting, WGNSSK examined the corresponding survey series disaggregated by reporting area, and also contrasted them to the results of various methods of catch at age analyses (ICES, 2005). It concluded that the catch data, as currently aggregated, did not reflect the stock structure of whiting in the North Sea, and therefore that the catch at age analyses were likely to be inappropriate. Survey data were also subject to these same aggregation problems and therefore that a survey-based assessment using aggregated data was also inappropriate. No assessment was presented to ACFM, although some detailed observations were made and which were reported by ACFM:

- The fishers' North Sea stock survey indicated different stock trends in different roundfish areas of the North Sea. These stock trend perceptions were largely in agreement with IBTS Q1 survey indices aggregated by roundfish area. The fishers' survey suggested a decreasing stock in the north, but an increasing one further south. ACFM suggested that the reduction in catches in the north could be more reflective of recent technical regulation changes (see below) than of any underlying change in stock size.
- Spatial information on landings for 2002 indicated three distinct areas of major catch (Figure 2): a northern zone, an area off the eastern English coast, and a southern area extending into the Channel. The southern whiting fishery uses

80mm nets, whereas the other fisheries are prosecuted by vessels using larger mesh nets. Northern catches have declined most whilst southern landings have been maintained.

- Catches of whiting continued to decline in 2003 to the lowest observed level. However, two of the three available survey indices covering the North Sea area indicated that stock abundance was at or near a historic maximum. Both XSA and TSA models gave a different perception of the stock dependant on whether surveys were used to calibrate the model. There were also considerable within-series discrepancies in apparent stock trends between different sub-units of the assessed area.

2.3 Management history

2.3.1 TACs and quotas

The approximate percentage share of the North Sea whiting TAC is given in Table 1. The TAC for whiting in the eastern Channel is subsumed into the overall TAC for ICES subarea VII (excluding VIIa), where the allocation key shown in Table 2 applies.

TAC and catch figures for the North Sea and eastern channel are given separately in Tables 3 and 4.

Table 1: Approximate national allocations of the EU share of the annual North Sea whiting TAC, as established by Council Regulations 170/83 and 172/83.

COUNTRY[1]	APPROXIMATE QUOTA ALLOCATION (%)[2]
Belgium	3
Denmark	13
Germany	3
France	20
Netherlands	8
United Kingdom	53

[1]Sweden has since been allocated a trivial share of the EU quota, but it does not affect the rounded percentage values given in the Table

[2]in 2005, the EU quota allocation comprised 88% of the TAC as agreed between Norway and the EU.

Table 2: Approximate national allocations of the annual ICES area VII (excluding VIIa) whiting TAC, as established by Council Regulations 170/83 and 172/83

COUNTRY	APPROXIMATE QUOTA ALLOCATION (%)
Belgium	1
France	61
Ireland	28
Netherlands	<0.5
United Kingdom	10

Table 3: North Sea whiting TAC and catch totals (‘000t), 1988–2003.

YEAR	TAC	OFFICIAL LANDINGS	HUMAN CONSUMPTION	INDUSTRIAL BYCATCH	DISCARDS	TOTAL AS USED BY ACFM
1988	120	66	52	49	28	129
1989	115	40	41	43	36	120
1990	125	41	43	51	56	150
1991	141	47	47	38	34	119
1992	135	47	46	27	31	104
1993	120	47	48	20	43	111
1994	100	42	43	10	33	86
1995	81	41	41	27	30	98
1996	67	35	36	5	28	69
1997	74	32	31	6	17	54
1998	60	24	24	3	13	40
1999	44	25	26	5	24	55
2000	30	24	24	9	22	55
2001	30	19	19	7	16	42
2002	32	16	16	7	17	40
2003	16	11	11	3	24	38

Table 4: Eastern Channel (VIId) whiting TAC and catch totals (‘000t), 1988–2003.

YEAR	TAC[1]	OFFICIAL LANDINGS	HUMAN CONSUMPTION	INDUSTRIAL BYCATCH	DISCARDS	TOTAL AS USED BY ACFM
1988		7.8	4.4		n/a	4.4
1989		n/a	4.2		n/a	4.2
1990		n/a	3.5		n/a	3.5
1991		n/a	5.7		n/a	5.7
1992		5.9	5.7		n/a	5.7
1993		5.4	5.2		n/a	5.2
1994		7.1	6.6		n/a	6.6
1995		5.6	5.4		n/a	5.4
1996		5.1	5		n/a	5
1997		4.8	4.6		n/a	4.6
1998		4.8	4.6		n/a	4.6
1999		n/a	4.4		n/a	4.4
2000		6.1	4.3		n/a	4.3
2001		6.6	5.8		n/a	5.8
2002		5.4	5.8		n/a	5.8
2003		6.8	5.7		n/a	5.7

[1]The Division VIId TAC is subsumed within the subarea VII (excluding VIIa) TAC

2.3.2 Technical conservation measures

Whiting in the North Sea have been routinely managed by TAC regulation and technical conservation measures throughout the 1980s and 1990s. Since 2002, fleets catching whiting in association with cod have also been regulated by effort limitation as part of the EU’s days at sea controls aimed at reducing fishing mortality on cod.

The technical conservation measures that have been applied to all fleets catching whiting in all areas during that period are complex and difficult to reconstruct without recourse to numerous technical regulations and amendments to them. Consequently, a restricted outline description of the history of technical conservation measures is given below relating solely to towed demersal roundfish gears catching whiting in the EU part of the North Sea as part of a targeted mixed demersal fishery[1]. Additional but partial information is given for some other fisheries. This information is believed to reflect the general history of technical conservation measures, but due to their complexity, it is difficult to claim categorical accuracy.

From December 1980, nets on all such gears required codends with a minimum diamond mesh size of 80mm. This was subsequently modified in a series of steps starting in January 1987 when the minimum mesh size requirement was increased to 85mm, through January 1989 when it increased to 90mm, to June 1992 when a 100mm minimum mesh size was established (in July 1987 Norway imposed a minimum mesh size of 100mm in Norwegian waters of the North Sea). The technical regulations adopted in 1992 also imposed certain constraints on gear configuration in addition to mesh sizes in the cod. For example, by limiting the number of meshes in the circumference of the codend and the permissible length of a net's extension piece. From 1992 a derogation to fish for whiting with a minimum mesh size of 90mm was permitted. This derogation lapsed in January 2000 when further EU regulations were implemented in an attempt to harmonise technical regulations in the North Sea (EU Council Regulation 850/98). For towed demersal gears targeting roundfish such harmonisation was considered to reflect little change to the *status quo* (ICES, 2000), but due to the very high abundance of the 1999 year class of haddock in the North Sea, additional Scottish legislation was enacted in 2000 in an attempt to reduce the capture of small haddock by use of a square mesh window in the extension piece of nets. Further UK and Scottish legislation was enacted during 2001 to improve further the selection characteristics of towed demersal roundfish gears, and in 2002 additional EU legislation was implemented to increase the minimum mesh size of such gears to 120mm (EU Council Regulation 2056/2001), albeit with a derogation during 2001 that limited the increase to 110mm in certain circumstances.

2.3.3 Minimum landing size

A 27cm minimum landing size (MLS) was introduced for whiting in the North Sea in July 1979. In January 1992 this was reduced to 23cm to reflect the selectivity characteristics of the mesh size derogation in the directed whiting fishery. The UK maintained a 27cm MLS for UK-registered vessels and in 2000 a 27cm MLS was re-established for all nations.

2.4 Physical environment of the North Sea

Whiting are found throughout the North Sea, predominantly to the south of the Norwegian Deep and its extension around the north of the Shetlands (Figure 3). The location and shape of the North Sea, and its topography, result in marked seasonal and regional differences in the vertical structure of the water column and in water movements. Spatial patterns in fish community structure are related to these aspects of the physical environment of the North Sea (Daan *et al*., 1990), and the distribution patterns of whiting appear to be related to depth and temperature structure (see WD2). Some relevant aspects of the hydrography of the North Sea are given here.

The North Sea can be divided into seven geographical areas with different hydrographic and biological conditions (Figure 4, after ICES, 1983). [Note that it is now possible to obtain high-resolution models of water flow, which are being used in projects such as Metacod (see Section 4.3.2) to predict the drift of eggs and larvae from spawning grounds to areas where 0-group fish become demersal].

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[1] Information for the earlier years was provided by Andrew Newton (FRS Marine Laboratory, Aberdeen) in an explanatory memorandum of changes in technical conservation measures to 1994

Most areas of the North Sea are vertically mixed or only slightly stratified during the winter. A strong thermocline is set up in the central and northern North Sea during May and June, becoming more pronounced during summer and autumn and broken down by wind and wave action in late autumn (Knijn *et al*., 1993). The shallow waters of the southern North Sea tend to remain relatively mixed in summer, and steep horizontal temperature and salinity fronts are set up between the mixed and stratified areas in the northern and southern North Sea.

Sea temperatures in the lower water column are likely to be most relevant for the distribution of juvenile and adult demersal fish such as whiting. Patterns of bottom temperature in winter/spring (January to March) and summer/autumn (July to September), for the years 1980–1989, are illustrated in Figures 5 and 6 (from Knijn *et al*., 1993). A strong temperature front separating the mixed and stratified areas in summer and autumn runs roughly along the 50m depth contour to the north of the Dogger Bank between the entrance to the Skagerrak (57°30'N) and Flamborough Head on the English coast (roughly 54°N) and bends northwards along the English and Scottish coasts. Bottom temperatures south of the front reach over 15°C in the most southerly regions of the North Sea and are mostly from 6–8°C in the northern North Sea. In winter, the situation is reversed, with bottom temperatures in the northern North Sea being only slightly lower than in summer, but much colder (<5°C) in the shallow coastal waters of the southern North Sea. A similar seasonal pattern was shown by Gamble *et al*. (1961) from trawl surveys in 1960 and 1961.

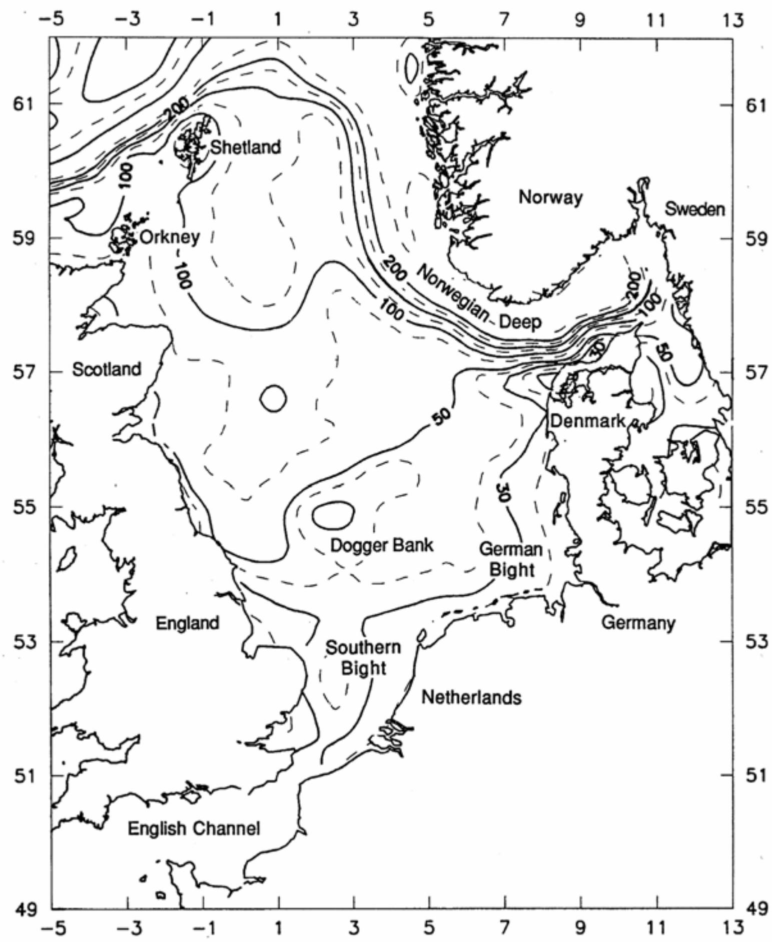

Figure 3: North Sea bathymetry and the location of the Dogger Bank (Reproduced with permission from *ICES Cooperative Research Report,* No. 194 *Atlas of North Sea Fishes,* Knijn *et al,* 1993).

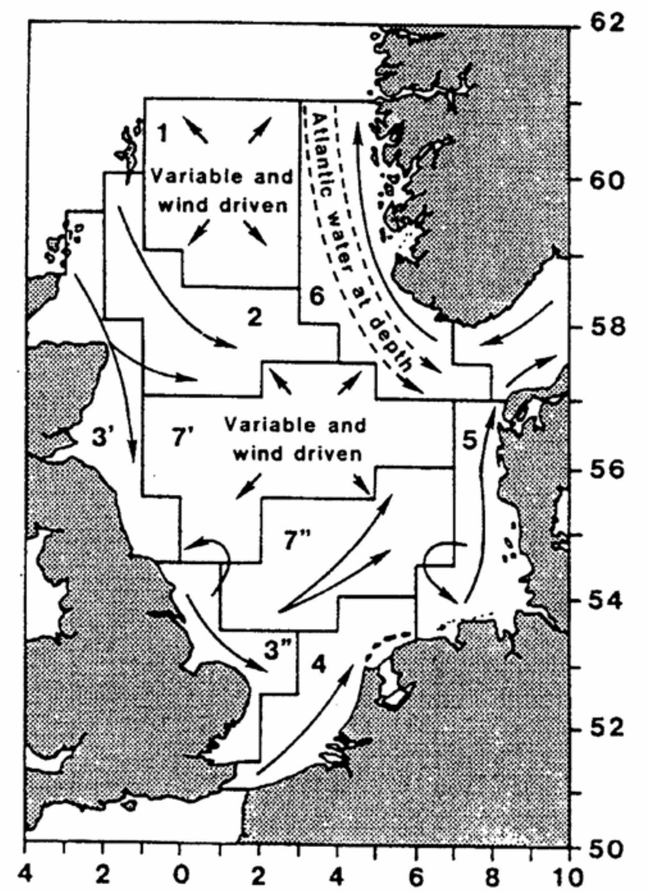

Figure 4: Hydrographical subdivisions in the North Sea (Reproduced with permission from *ICES Cooperative Research Report*, No. 194, *Atlas of North Sea Fishes*, Knijn *et al*, 1993, after Reid *et al.*, 1988)

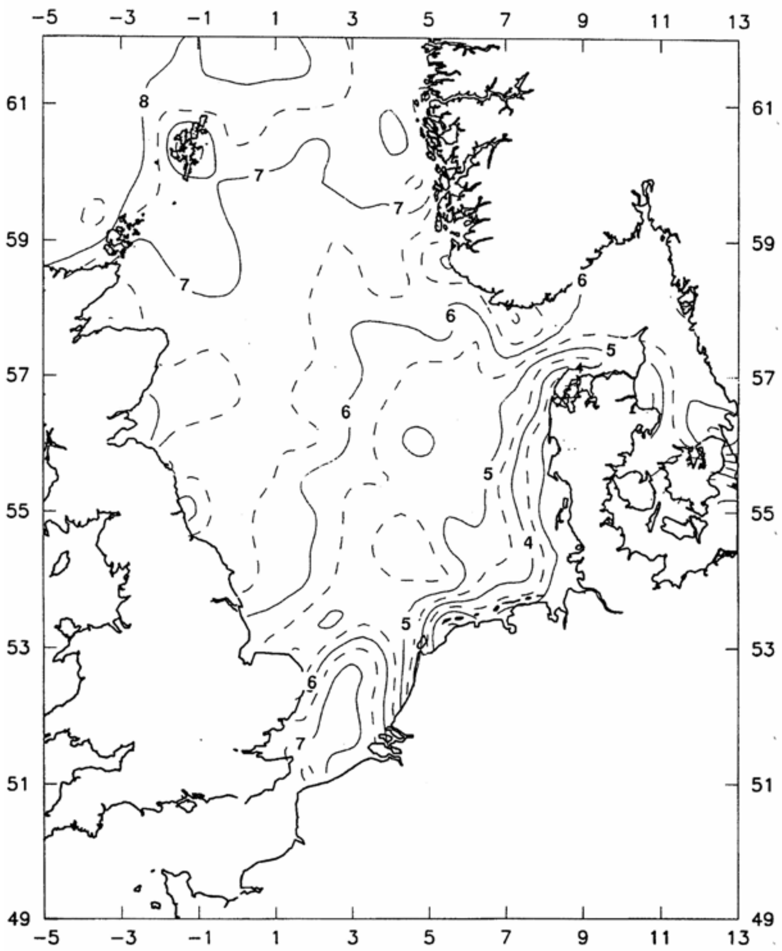

Figure 5: Average bottom temperature (°C) in winter (January-March) during the period 1980–1989 (Reproduced with permission from *ICES Cooperative Research Report,* No. 194, *Atlas of North Sea Fishes,* Knijn *et al,* 1993).

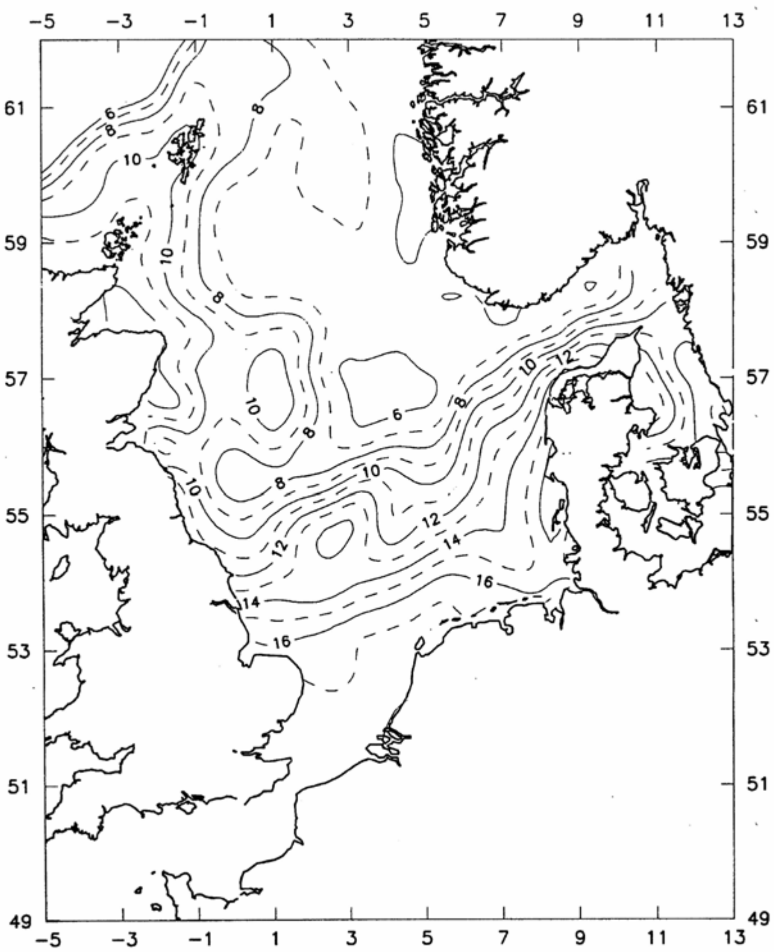

Figure 6: Average bottom temperature (°C) in summer (July-September) during the period 1980–1989 (Reproduced with permission from *ICES Cooperative Research Report,* No. 194, *Atlas of North Sea Fishes,* Knijn *et al,* 1993).

2.5 Study Group comment

The Study Group pointed out, in discussion, that the stock assessment of whiting in VIIa (Irish Sea) shares similar problems with respect to conflicting signals in abundance measures. In that case, English vessels fishing in the eastern Irish Sea have not seen as severe a decline in catch per unit effort (cpue) as has been observed for Northern Ireland vessels fishing in the western Irish Sea. Survey indices of abundance also show different trends in the separate areas; survey cpue in the western area demonstrate a steeper decline than is observed in the eastern area. If mixing does occur between the eastern and western parts of the Irish Sea, it is clearly not at a rate sufficient to balance the distribution of fish. For the North Sea, it has long been postulated that whiting in the northern area comprise a different "grouping" of fish to those in the southern area (see Section 3.2 and WD 2) with some interchange between them. Whether this is incontrovertible, and whether the effect of population structuring in the North Sea is identifiable with respect to survey indices of abundance, and what are the likely consequences of this for stock assessments are questions that the Study Group hopes to resolve.

3 Stock identity and management units

3.1 Introduction

In the course of this chapter reference is made to a number of research vessel surveys carried out in the North Sea. For clarity, a brief description of them is given here.

The first quarter International Bottom Trawl Survey (IBTS Q1) is an internationally co-ordinated, multi-vessel survey. It covers the entire North Sea, with some stations in ICES Division IIIa. Each ICES statistical rectangle is sampled by more than one vessel. It was established in the 1970s, with the gear standardised to the GOV trawl across all participating vessels by 1983.

The third quarter Scottish Groundfish Survey (SGFS) uses a fixed station survey design, covering the north-central and northern North Sea. ICES rectangles are sampled once. From its inception in 1982 until 1997, the gear used was the Aberdeen 48’ trawl. Since then, and on the replacement of the previous vessel in 1998, the gear used has been the GOV trawl and an extended survey area has been introduced in 1999 at a cost that not all rectangles in the survey area are now sampled.

The third quarter English Groundfish Survey (EGFS) is a fixed station survey and has operated since 1977 covering the entire North Sea. Until 1991 it used a Granton trawl, and it has used the GOV trawl since then.

The English and Scottish third quarter surveys also comprise a part of the third quarter IBTS survey (IBTS Q3), although the WGNSSK has tended to use the separate Scottish and English indices in its assessments rather than the combined IBTS Q3 index.

From 1991 to 1995, additional second and fourth quarter co-ordinated surveys were carried out to provide quarterly fish distributions for multispecies and multifleet assessments, and to counterbalance the declining quality of commercial catch data (ICES, 1998). These surveys were not intended to be as rigorously co-ordinated or standardised as the IBTS Q1; each vessel’s series was to be an elemental stand-alone series with inter-vessel calibrations of indices rather than contributing to an undifferentiated dataset as in the IBTS Q1 series.

Distribution charts of whiting abundance at by age are shown in Annex 2 for each of the quarterly IBTS surveys.

3.2 WD 2 — review of North Sea whiting stock structure

3.2.1 Presentation

Published material on distribution, tagging, parasite infestation, meristics and genetics of whiting in the North Sea was examined for information on movement and dispersal of post-settlement whiting in the North Sea. Although there is no clear evidence for genetically distinct populations of whiting residing within the North Sea, tagging studies carried out in coastal and offshore waters of the North Sea by Danish, Scottish and English laboratories since the 1950s have all shown very limited movements of whiting across the boundary between mixed and stratified water (see Section 2.4) in the northern and southern North Sea.

Whiting tagged inshore in the area north of 54°N tended to be recaptured in coastal waters, although there was evidence for a more offshore dispersal of whiting tagged at the Shetlands. Tagging in the 1950s indicated a predominantly northward movement of whiting in the northern North Sea prior to the spawning season, and was thought to be a movement of mature fish towards spawning grounds. Whiting tagged in the northern North Sea have not been recaptured outside of the North Sea.

Whiting tagged in the southern North Sea during winter dispersed widely within the generally shallow waters of the southern North Sea and also into the eastern Channel, indicating mixing of Channel and southern North Sea populations outside the spawning season.

The results of tagging studies have been supported by investigations into spatial patterns of infestation of whiting by external parasites and by myxosporidian parasites in the gall bladder. These indicate marked differences in species compositions of parasites in whiting in the northern and southern North Sea, with intermediate compositions in the central North Sea. This is consistent with limited mixing of whiting between the northern and southern regions.

Vertebral numbers and fin ray counts in whiting show gradients from north to south in the North Sea, and also differences between inshore and offshore samples in the northern North Sea. Mean length at age in whiting tends to be highest in the northern North Sea, and also towards the southern limits of the North Sea. The pattern in the south could be affected by the seasonal influx of whiting from the English Channel shown by tagging.

It is concluded that whiting to the north and south of the Dogger Bank frontal system can be regarded as belonging to functionally separate populations with only limited mixing across this boundary. Movements of whiting occur between the southern North Sea and the eastern Channel. Whiting occurring in English and Scottish coastal waters of the northern North Sea exhibit a relatively slow dispersal offshore, with most tag recaptures from fish tagged inshore having been recorded within 30 miles of the coast. Low tag recapture rates have generally resulted in few data on fish movements beyond the first year after release.

3.2.2 Study Group comment

For reference, Figure 7 shows the IBTS reporting areas for the North Sea along with the 50m and 200m bathymetric contours.

The reviewed works provide a documented background to the basis of the long-held view that whiting in the northern and southern North Sea comprise different stock units with a north-south split across the Dogger Bank. However, it is unlikely that the information provided in the review articles is sufficient to establish a robust argument to delineate different genetic units in the North Sea; the genetic analyses that do suggest differentiation between whiting in the northern and southern area tend to be heavily qualified. Nevertheless, the Study Group believes that there is sufficient information available to support the view for the purpose of stock assessment and fisheries management of the existence of northerly and southerly stock units separated in the region of the Dogger Bank – an area associated in the summer with the separation of mixed and stratified water and roughly approximated by the 50m depth contour. There are more equivocal indications of a third inshore stock unit along the northeastern English and eastern mainland Scottish coasts.

This putative description of stock units will be further examined by the Study Group (see Section 4) with reference to research vessel survey data from the International Bottom Trawl Survey (IBTS), the third quarter English groundfish survey (EGFS) and the third quarter Scottish groundfish survey (SGFS). It will also be taken back for consultation with the fishing community by its representative on the Study Group.

It was further pointed out in discussion, that the IBTS reporting areas were originally identified to reflect relatively homogeneous areas with respect to topographic and hydrographic features; implying that these areas may be of biological significance with respect to stock distribution.

Due to the widespread distribution of whiting, there is little firm evidence to identify the localities of discrete spawning areas. (see Section 3.3) . However, it was noted that in the spring of 2004, an ichthyoplankton survey of the North Sea was carried out in part to map the distribution of gadoid egg production. The results of this are anticipated to be available later in 2005. Although the means now exist to differentiate between early stage eggs of cod, haddock and whiting, these techniques were not applied in earlier studies.

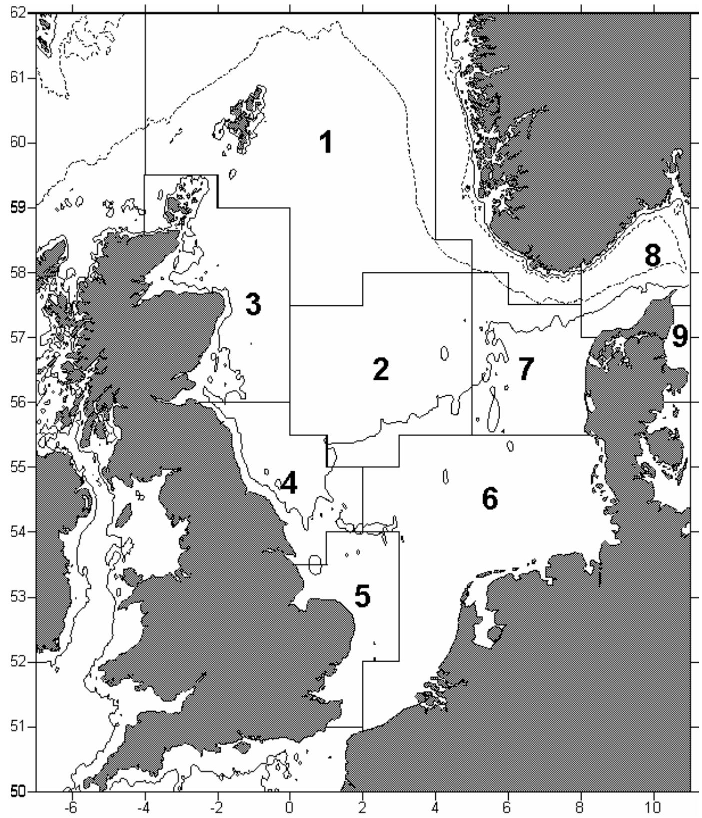

Figure 7: North Sea IBTS roundfish reporting areas. The 200m (dotted line) and 50m (solid line) depth contours are also shown.

3.3 WD 3 — haddock and whiting spawning areas

3.3.1 Presentation

"Metagadoid" is a FRS Marine Laboratory project that aims to establish the degree of reproductive isolation of whiting (and haddock) spawning populations within the North Sea and between the North Sea and waters to the west of Scotland, using microsatellite DNA markers. Extensive sampling has been carried out of whiting from identified spawning areas within the study area and microsatellites are at present being evaluated for their use in the study. Following screening of the samples population structure will be examined within the context of metapopulation theory (e.g., Smedbol *et al*., 2002) to consider the potential of extinction and recolonisation among spawning populations.

Conventional tagging experiments are also being carried out within Metagadoid in conjunction with other inshore fisheries work. The project also aims to carry out data storage tagging experiments; however this has been unsuccessful so far for whiting due to the unsuitability for tagging of samples caught to date.

As part of Metagadoid an internal FRS Marine Laboratory report has been produced (this working document) to identify known spawning grounds of whiting and haddock). Information was taken from the IBTS Q1 sex/maturity/age-length keys from 1990–2000 and the FRS Marine Laboratory historical survey database which is a length-frequency database from 1925–2003 that also contains maturity data from the 1990s. The report shows that historical data relating to spawning grounds is limited, with the timing of the IBTS Q1 survey being too early to cover the full spawning season of whiting.

Coull *et al*. (1998), as part of a fisheries sensitivity report, produced a map of the distribution of whiting spawning grounds in the North Sea and Scottish west coast. Although patchy in occurrence, the main concentrations of spawning whiting in the North Sea were shown: along the Scottish east coast; west of Shetland; Viking Bank; the central North Sea (north and west of Dogger Bank); and in the southern North Sea. This distribution implies quite localised centres of spawning; however, maturity stage sampling carried out by FRS Marine Laboratory in 2003 implies that spawning extends over a much broader area and is widespread throughout the North Sea.

3.3.2 Study Group comment

The Study Group recognises the importance of genetic studies in the identification of population structure although it was also noted that genetic differences are not a requirement for the identification of functionally distinct sub-units given that a small amount of mixing between them may prevent the detection of genetically differentiated populations. It is likely to be two years before the whiting results from Metagadoid are fully available as the analysis of whiting samples has only just begun. The Study Group is unaware of other work currently being undertaken on whiting stock discrimination in the North Sea.

3.4 WD 4 and WD 5 — precision of the IBTS index of whiting spawning biomass

3.4.1 Presentation

The aim of these working documents was to provide a measure of the precision of survey estimates of whiting spawning biomass (SSB) in the North Sea for comparison with those obtained from alternative assessment sources. This was further examined to determine whether there was an obvious “vessel” effect in the survey index of SSB.

The precision of the IBTS Q1 index of whiting spawning biomass was evaluated in various ways:

- The hauls contributing to the survey were split into two sets in each of the years 1983–1985 on the basis of odd and even numbered hauls. The standard deviations of the log-transformed indices were calculated for ages one and two. Using this information and assuming the variability of ages three and above to be equivalent to that at age two, a coefficient of variation (CV) for the SSB index from the full survey was calculated as 9%;
- The standard deviation around the three-year running mean of the full survey SSB, (over the years 1979–2002) was calculated and from this a CV of 6% was found;
- Finally, pairwise comparisons were made between index values for successive age-year pairings. Linear regressions gave high coefficients of determination (R^2) but also high CVs of between 25% and 76%.

The sensitivity of the survey index of SSB to individual vessel effects was examined by the recalculation of the index where any individual vessel’s data were sequentially excluded from the calculation (for the period 1986–1991). It was found that the trends from recalculated indices corresponded well to those of the full dataset.

3.4.2 Study Group comment

The Study Group expressed surprise at the low values obtained for the survey-based SSB CVs given that survey-based data are generally regarded as noisy. Neither was it certain that CVs had been calculated in the most efficient manner given all potential sources of uncertainty in the survey sampling including potential problems with the precision of whiting age determination.

It was reassuring to note the robustness of the SSB index to individual vessel effects in the analysis.

3.5 WD 6 — length distribution of whiting from the IBTS

3.5.1 Presentation

The IBTS mean catch rates in numbers per hour by length class (cm) were calculated for each year and quarter from 1991 Q1 to 1996 Q4. This was done separately for ICES Division IIIa (Skagerrak-Kattegat) and ICES Subarea IV (North Sea). Results showed that 0-group whiting first become available to the IBTS GOV trawl in the third quarter. The mode of the 0-group length distribution in the third quarter varied from 6 cm to 13 cm and between one-fifth and one-half of the 0-groups caught in the third quarter were found in Division IIIa. 0-group fish were again found in this Division in the fourth quarter and, in some years, as 1-group fish in the first and second quarters, although 1-group fish were mostly absent from Division IIIa in the third quarter.

These observations were used to conclude that Division IIIa is a nursery area for North Sea whiting, and should be considered for inclusion in the standard survey area for 0-group whiting in any third or fourth quarter survey, and for 1-group whiting in a first quarter survey. They were also used to conclude that the spawning period of whiting might be more discrete and more variable from year to year than previously considered.

3.5.2 Study Group comment

The Study Group felt that the conclusions drawn from this work needed further supporting evidence. The idea that spawning has taken place at different times in different years can not be justified on the basis of inter-annual variation in the mean lengths of 0-group alone. This is due to the high variation in both the growth of whiting and early-stage mortality of the 0-group.

3.6 WD 7 — conflicting signals in the IBTS, SGFS and EGFS for North Sea whiting

3.6.1 Presentation

This work attempted to account for differences, predominantly for the years 1986–1994, between the Scottish Q3 survey (SGFS), the English Q3 survey (EGFS) and the IBTS Q1 survey.

The IBTS Q1 index was recalculated using data from only those ICES rectangles covered by the SGFS trawl stations (*i.e.* for the north-central and northern North Sea). This modified index was run through the SURBA model together with the standard-area IBTS index and the resultant mean-standardised SSB index series were compared. The qualitative patterns were found to be closely matched. This was used to conclude that there was no area effect behind the conflicting survey series.

Mean-standardised SSB results using IBTS Q2, Q3 and Q4 indices were also compared to the results using the standard-area IBTS Q1 data. The conclusion drawn was that results were consistent between quarters.

On the basis of this, several suggestions were implied as to the likely cause of the conflicting survey indices, including noise in the data; the incorrect correction of Scottish trawl haul duration when moving from one hour to half-hour tows; and changes to the Scottish survey gear.

3.6.2 Study Group comment

The Study Group considers that a comparison between the modelled SSB results is a second-order comparison compared with the pairwise comparisons of index numbers-at-age between surveys. It was reminded that pairwise comparisons between IBTS Q1, Q2, Q3 and Q4 indices for whiting at given ages tend to show weak or negative correlations over the period 1991–1996 (ICES, 1998). However, due to the limited period over which those comparisons were made, and the relative lack of contrast in abundance during that period, a better comparison to make would be of pairwise indices at age between the IBTS Q1 and Q3 surveys over the full time period available. (Section 4.2 gives the Study Group's proposed protocol for survey-based comparisons and analyses).

The working document raises the possibility that the differences seen between the SGFS and IBTS Q1 indices might be due to systematic errors in SGFS data standardisation resulting from a change from one hour to half-hour trawl hauls and uncertainty as to the standardisation of the gear used in the SGFS. The Study Group notes, however, that the change to half-hour hauls in the SGFS occurred in 1998 when the former RV Scotia was replaced by the current vessel of that name; *i.e.* during a period of better agreement between the respective indices. It also noted that the SGFS uniformly used the Aberdeen 48' trawl prior to the change of vessel; *i.e.* this gear was used during the period in which conflicting indices predominantly occur. The SGFS adopted the IBTS Q3 GOV trawl in 1998 and extended its survey area in 1999 at the cost of reduced station coverage. This needs to be taken into account when considering the consistency of surveys after 1997, but does not explain the contrast between survey indices during the period 1986–1994.

3.7 WD 8 — cod stomach content of whiting from 1981 and 1991 'years of the stomach'

3.7.1 Presentation

This work attempted to infer whiting distribution using records of the whiting content of cod stomachs. It was concluded the data were not useful for this purpose in their present form.

3.8 WD 9 — the effects of survey index calculation, and changes in survey coverage on whiting index trends

3.8.1 Presentation

This work considered the impacts of changes in the total coverage of the IBTS survey and the inclusion or removal of data from specific IBTS reporting areas on the level of the overall index. It found that surveys conducted with a reduced-area coverage (as in the years 1980–1982) could lead to an index value that was incommensurate with one derived from the complete area coverage. The requirement is clearly for an index to be calculated from year to year based on consistent area coverage. This was also the conclusion of an earlier EU contract report "Survey-based abundance indices that account for fine spatial scale information for North Sea stocks" (FINE - EU Study 98/029). Consequently, it concludes that due to the relative expansion in survey area coverage in 1983 any preceding index calculations would indicate an incorrect stock trend.

The working document also looked at the relationship between the IBTS Q1 index and the estimated stock numbers at age from a multispecies virtual population analysis (MSVPA), and considered it to be reasonably good. However, it noted that two linear trends were apparent in this relationship, one covering the period 1983–1990 and the second after 1990. It concluded that this was most probably due to different survey methods, and most likely the use of different trawls in the 1980s compared with the years after 1990.

An interesting aspect of this work covered the method by which survey indices are calculated (or at least as implied by their written description). Trawl haul data are raised to the level of ICES statistical rectangles, and the catch rate per rectangle is then averaged within each IBTS roundfish reporting area before being raised to the total area. Averaging within each sampling area purportedly takes the sum of rectangle catch rates and divides by the number of rectangles in the sampling area. This may not correspond to the number of rectangles sampled in that area and, if true, may lead to an underestimate of the area-specific indices.

3.8.2 Study Group comment

At its meeting, the Study Group did not fully agree with the conclusions of this working document, although it was found to be a very useful reference source regarding some of the issues that affect survey index calculations. In particular, the Study Group recognised the importance of its conclusions on the need for consistency of spatial coverage when calculating indices from year to year. To that extent, it seems sensible to exclude consideration of the whiting index prior to 1983. However, from the ICES description of the IBTS Q1 survey on its DATRAS web page this would not at first sight appear to be solely the result of a change in the spatial coverage of the survey at that time as suggested in the working document. The DATRAS web page states that:

“Prior to 1977 there was no standardisation of gear although all ships used bottom trawls with a small mesh cover. In 1977 ICES recommended that all ships should use a GOV trawl as specified by the Institut des Peches Maritimes, Boulogne. A detailed description of the net is to be found in the manual. The GOV trawl has been gradually phased in, e.g. in 1979 only 3 vessels were equipped with the GOV trawl, but by 1983 all 8 nations were using this gear.”

So, according to this, not only did 1983 herald a wider area coverage for the IBTS Q1 survey, but it also appeared to be the first year in which the survey gear was completely standardised to the GOV trawl. In a subsequent discussions on the draft Study Group Report between the Chair of the Study Group and the authors of the working document, the Study Group was informed that the survey gear was not standardised to the GOV trawl by 1983 as indicated on the DATRAS web page, and that in 1984 and 1985 at least one nation was using a different gear. Consequently, differences in spatial sampling do seem likely to be the major explanatory factor for the disjoint indices prior to 1983.

Because of the specific wording in the working document, the Study Group also queried the reasoning behind its suggestion that the two distinct linear trends between the IBTS index and the MSVPA abundance estimates were probably due to different survey methods and the use of different trawls in the periods 1983–1990 compared to the period since 1990. From the available descriptions of survey gears and survey coverage, the Study Group had been unable to confirm any difference in survey methods between these periods. However, after the meeting, it became clear that the authors’ intent was to attribute the differences to changes in the overall performance of vessels and gear between the two periods, particularly with regard to the flux in the composition of vessels that have taken part in the survey over time. The Study Group considers this to be an untested but more plausible explanation for the different linear trends over time.

An important finding from this working document is that when partitioned into different time intervals, the relationship between the IBTS index and MSVPA does appear to be consistent, and is certainly better than when viewed as a single discrete time series. The Study Group noted that the IBTS Q1 index series from 1991 was sufficiently long to be used in assessments without reference to the earlier years’ indices. However, if the index (and its relationship to estimated stock numbers from stock assessments) is susceptible to changes in the survey fleet composition as implied above, then this needs to be explicitly considered before the adoption of a new year’s index into the series. Otherwise, should another shift in the relationship between index and abundance occur, it would be treated inappropriately.

The Study Group felt it would be useful to see whether splitting the assessment region according to the putative sub-unit structure posited in Section 3.2 would remove the anomaly of different relationships over different time periods, and whether it would increase the coherence of all survey series, and this discussion is taken further in Section 4.

The Study Group was very concerned by the apparent anomaly in the calculation of survey indices within IBTS reporting areas identified by this working document. It confirmed the written description of the calculation procedure in the DATRAS manual, and it certainly seems that the divisor in the averaging process is the number of rectangles within the reporting area and not the number of sampled rectangles within it. The Study Group Chair will refer this matter to the IBTS Working Group and the ICES Secretariat for clarification.

4 Protocol to evaluate impacts on assessments

4.1 Introductory comments

One aim of the Study Group is to carry out as full an evaluation as possible of the consistency (or otherwise) of research vessel survey indices of abundance for whiting in the North Sea. It is intended to complete this work prior to the next meeting (6–15 September 2005) of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). The evaluation of assessment units using commercial catch and effort data is more ambitious, reflecting the need to collate spatially disaggregated international catch and fishing effort data. Due to traditional difficulties in eliciting such data, the Study Group cannot give a guaranteed target date for completion of this aspect of its work.

Unlike the previous chapter of the report that was largely compiled on the basis of working document presentations and discussions, this chapter has been compiled on the basis of un-documented, informal presentations and discussions thereof. The next section of this chapter considers the proposed protocols for the evaluation of survey consistency and indications, if any, of homogeneous demographic trends within specific subareas of the North Sea. Following that there is a section on possible ways forward to evaluate the implications for stock assessment and management assuming there to is specific population structuring within the North Sea.

4.2 Survey-based protocols

4.2.1 Analyses of basic indices

For the three available survey series (IBTS Q1; English Q3 – EGFS; Scottish Q3 – SGFS) a simple examination of between-survey consistency would comprise a series of age-specific pairwise scatterplots of indices (suitably transformed if necessary). Indices derived from the entire area of the various surveys' distributions could be examined this way, as well as corresponding indices from subareas within the surveys, e.g.

SGFS (Scottish area)	and	IBTS (IBTS standard area)
SGFS (Scottish area)	and	IBTS (Scottish area)
SGFS (IBTS area 3)	and	IBTS (IBTS area 3)
EGFS (IBTS area 2)	and	IBTS (IBTS area 2)

etc. This would comprise a much-extended analysis along some of the lines explored in working document 7.

The internal consistency of particular surveys can be qualitatively examined by plotting successive cohort catch-curves and looking for obvious discontinuities in them and/or by pairwise plotting of successive-age indices (*i.e.* by plotting catch ratios). This can further be examined by fitting, for example, the separable multiplicative model of Shepherd and Nicholson (1986) in which age, year and year class parameters are estimated. If the residuals from such a model fit are observed to be well balanced this would suggest internally consistent data, providing the model's fundamental assumptions are not violated. For this, or any other approach that assumes constant catchabilities over time, and to ensure the adequacy of the separability assumption, additional diagnostics are available. For example, the log-catch ratios of successive age-year pairings down a cohort should fluctuate synchronously if plotted against age for each year; they need not be parallel, but according to the Working Group on methods of Fish Stock assessment (ICES, 1995b) they only need to follow broadly the same pattern in time.

This model can be also be extended where there is more than one survey, by including an additional survey factor along with (survey * other main effect) interaction terms (ICES, 1995b). For a single survey, the additional factor could index subareas, and the results of model fits evaluated to test for differences in the subarea effects, particularly to determine whether there is homogeneity between specific subareas encompassing the hypothesised distribution of stock sub-units.

4.2.2 Analyses of modelled population trends

4.2.2.1 SURBA

SURBA 3.0 is the most recent implementation of the survey-based separable model of fishing mortality that was first applied to North Sea stocks by Cook (1997; 2004). It is currently under development and has not yet been generally released, but features so far include multiple surveys and analytic estimation of uncertainty in summary outputs.

One potential use of SURBA 3.0 in relation to whiting stock structure in the North Sea could be to determine the consistency between different IBTS roundfish reporting areas in terms of stock dynamics. The methodology might take the following form, as an example:

- Age-structured abundance indices would be generated on the basis of IBTS roundfish reporting areas 1–7. Several sources of data exist for this purpose: the IBTS Q1 and Q3 series from the DATRAS system at ICES, the SGFS series (potentially split at 1998 following vessel and gear changes), and the EGFS series (split at 1992 following gear changes).
- SURBA 3.0 would then be applied to each of the areas in turn. In the absence of other information on survey catchability and variability, the fallback position would be to use constant catchability and age-weightings for each age-year-area combination.
- Summary statistics on Z, relative abundance, and age composition would be collated, and compared between different areas. These comparisons might take the form of simple correlational analyses, or time-series approaches such as dynamic factor analysis (Zuur *et al*., 2003). The aim would be to identify clusters of areas with similar characteristics in terms of survey-based population dynamics.

While not necessarily conclusive, the results of an exercise such as this would provide potentially useful further evidence for the investigation of substock structure in North Sea whiting.

4.2.2.2 Example analysis

The method outlined above was applied to the IBTS Q1 time-series for North Sea whiting (years 1983–2004, ages 1–5). A separate index was generated for each of the nine IBTS sampling areas and the SURBA model was fitted to each in turn. Estimated mean $Z_{2\text{-}4}$, mean-standardised SSB, and mean-standardised recruitment at age 1 from each analysis were compared using bivariate scatterplots: the resultant plot for mean $Z_{2\text{-}4}$ is shown in Figure 8. The correlations between the estimated mean $Z_{2\text{-}4}$ time-series for each area were also calculated. These are given in Table 5, and a crude schematic representation of the links between areas (in terms of significant correlations) is given in Figure 9. These results suggest that there may be a central block (areas 2, 3, 4, 7, 8, 9) with similar characteristics, with areas 1,5 and 6 being distinct from this block and from each other. However, different conclusions arise if SSB or recruitment is used as similarity metrics, and the interpretation of these SURBA fits requires further investigation.

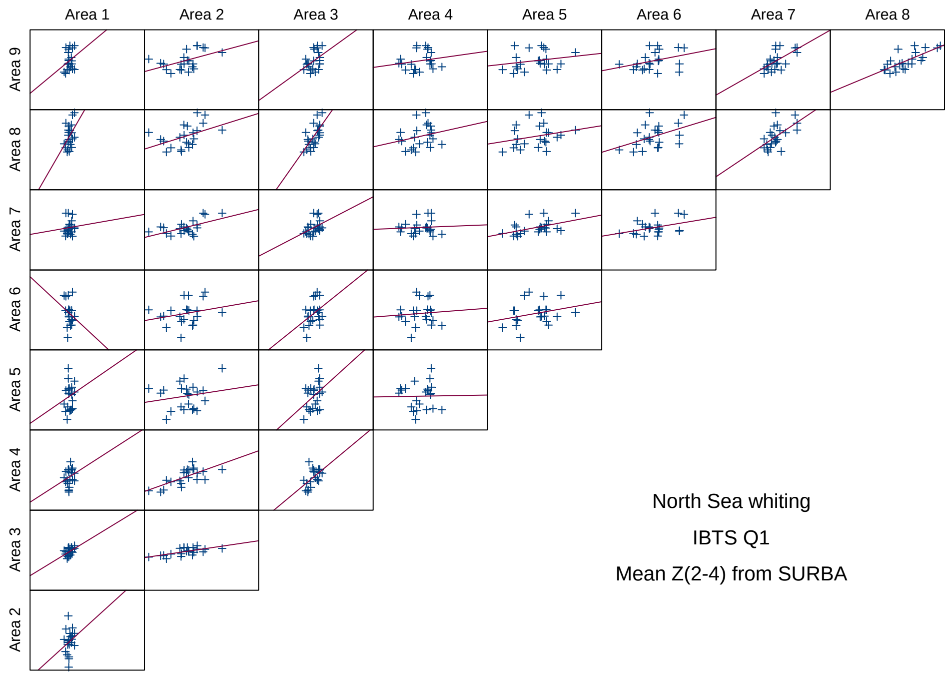

Figure 8: Bivariate scatterplots comparing the estimated mean $Z_{2\text{-}4}$ from SURBA runs on IBTS Q1 indices from each of the nine IBTS sampling areas. Each plot includes the least-squares linear regression fit. Because a common horizontal scale has been used for all graphs and the trend lines are extrapolated beyond the data ranges, the visual representation of the data points and trend lines is distorted in some cases

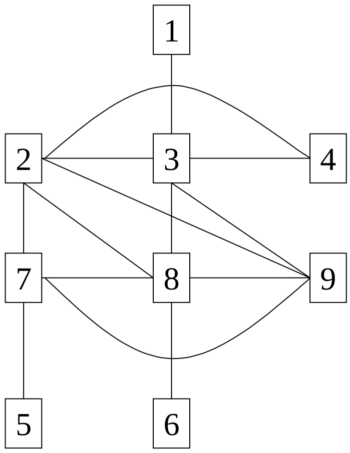

Figure 9: Schematic representation of the significant correlational links between IBTS sampling areas, determined on the basis of SURBA runs on area-disaggregated IBTS Q1 abundance indices. The distances between nodes (representing areas) are not intended to be proportional to the strength of the correlations.

Table 5 Correlations between mean $Z_{2\text{-}4}$ estimates from SURBA runs on IBTS Q1 indices from each of the nine IBTS sampling areas. Bordered boxes indicate significant correlations. A correlation ρ is significant if $\rho \in \left(-2/\sqrt{n}\,, 2/\sqrt{n}\right)$ where $n = 22$ is the number of observations.

				Mean Z (2-4)				
	Area							
Area	1	2	3	4	5	6	7	8
9	0.249	**0.491**	**0.430**	0.189	0.226	0.347	**0.620**	**0.741**
8	0.412	**0.455**	**0.674**	0.237	0.259	**0.444**	**0.584**	
7	0.068	**0.585**	0.406	0.067	**0.496**	0.392		
6	-0.220	0.250	0.379	0.081	0.284			
5	0.146	0.199	0.382	0.017				
4	0.208	**0.699**	**0.532**					
3	**0.439**	**0.647**						
2	0.213							

4.2.3 Analysis of survey age compositions and fishing effort data

The inconsistencies between data series encountered when assessing North Sea whiting as a single stock could be related either to existence of genetic sub-stocks (not yet resolved), barriers to large-scale movement of post-settlement whiting (e.g., the Dogger Bank/thermal front region), or relatively limited dispersal at a smaller spatial scale.

Slow rates of dispersal of whiting, irrespective of any genetic structuring, could lead to locally high rates of fishing mortality and local depletion generated by spatially intensive fisheries. If there was only a very slow immigration of whiting into such areas from surrounding less intensively fished areas, the combined fishery data could indicate higher rates of fishing mortality and population declines not evident in survey data integrated over all areas of the North Sea. If this was indeed occurring, survey data should show spatial patterning of age profiles, and of temporal trends in these profiles, related to spatial patterns of fishing effort in fisheries catching whiting.

The proposed method is to create time-series of survey indices by age group for each of the whiting survey areas (or roundfish areas), and to model these using SURBA to generate smoothed SSB trends and trends in mortality for post-recruit age classes. These trends would be examined in relation to trends in fishing effort for the different fleets in the same areas (where these data can be obtained). The exercise would be repeated for combinations of areas. The existence of stronger correlations at smaller spatial scales could provide evidence for limited spatial dispersal at the scale of the lifespan of whiting. Alternatively, there may be no need to limit aggregation of survey data to roundfish areas. One could define the areas for survey data aggregation to reflect the distribution of fishing effort, *i*.e. by deriving survey indices for discrete areas of high fishing effort and low fishing effort (assuming a relatively stable year-on-year spatial pattern). If age profiles (or SSB trends) are seen to diverge between adjacent areas of high and low fishing effort that is good evidence for limited spatial dispersal — especially if these areas don't fall into different putative sub-stock regions.(This approach may be problematic if fishing effort was found to be spread over small and fragmented areas).

4.3 Stock assessment-based protocols

4.3.1 Gadget

4.3.1.1 Presentation

Gadget is an acronym for the **G**lobally applicable **A**rea **D**is-aggregated **G**eneral **E**cosystem **T**oolbox. Gadget is a statistically-based ecosystem-modelling software tool, and the following overview of it has been extracted from the Gadget web-site, http://www.hafro.is/gadget/.

In a fisheries context, Gadget models can incorporate single or multiple species and take into account both intra- and inter-specific predation. Maturation, reproduction and recruitment can be explicitly modelled, and multiple commercial and survey fleet data can be included. As a statistically-based modelling framework, Gadget incorporates parameter estimation and measures of goodness-of-fit. Of particular interest to the Study Group, is that a single-species model can accommodate multiple stocks, multiple areas and migration between them.

A presentation of the Gadget framework was given to the Study Group with reference to a single-species assessment model for North Sea herring (dst2) that has been developed (http://www.hafro.is/~gunnar/finaldraft.pdf).

4.3.1.2 Study Group comment

The data and modelling requirements for a Gadget implementation of the North Sea whiting fisheries are far beyond the resources of the current Study Group membership. The development of the herring model (REFERENCE), and other North Sea implementations of gadget-based models (*e.g.*, BECAUSE, EU 6th Framework Programme contract 502482) comprise large externally funded research programmes that would have to be emulated. Although BECAUSE includes a work-package based on a multi-species, multi-area model of North Sea fisheries, the aim of that work-package is to examine the effects of rebuilding cod and mackerel (predator) stocks on commercial prey species (including whiting) and non commercial top-predators (*i.e.* sea birds, marine mammals) (http://www.rrz.uni-hamburg.de/BECAUSE/content/case_study_3.html) and it is not focused on population structuring within particular species.

It was pointed out that stock synthesis (Methot, 1989) could be considered an antecedent of Gadget as a single-species assessment model. In a more recent implementation of stock synthesis (Methot, 2000), although most modelling is done within a unit stock, there is the capacity to model up to three areas and to estimate the scale of migration between them. Quoting directly from Methot (2000):

"*In the age model there can be up to three geographic strata (areas). There are two options for distributing fish between the areas: an annual apportionment (vulnerability) approach and a true migration approach.*

In the vulnerability option, the population is apportioned, on an age-specific basis, annually between the areas. Each fishery and survey operates in just one of the areas, and the popula-

tion is completely mixed and re-apportioned at the beginning of the next year. The age-specific population in each area is proportional to the total population because of the complete re-mixing each year, even though all of the fishing mortality may occur in one area.

In the migration approach, an age-specific fraction of the fish in each area migrates annually into each of the other areas. In this approach, effects of an intense fishery in one area initially will primarily affect that area and then slowly affect other areas according to the rate of migration."

This suggests that a synthesis model of North Sea whiting could, in principle, address some of the assessment issues associated with the Study Group's terms of reference. However, as with Gadget, that would be likely to require resources that are unavailable to the Study Group particularly due to the lack of stock synthesis expertise in this region.

4.3.2 Metafor

4.3.2.1 Presentation

Metacod is an EU-funded 5th Framework contract (QLRT-2000-0953) that is investigating the role of population structuring in the maintenance of exploited cod stocks. A principal aim is to evaluate the importance of maintaining the distribution of spatially structured population sub-units, as a common feature of stock decline has been the apparent loss of sub-stocks.

A model that incorporates population structuring, Metafor, has been developed for this purpose. It is a forward-projection model that is less complex than Gadget (it is not a statistical model so it does not estimate parameters by fitting the model to data). It relies on input parameters whose values are established externally, for example, in determining the probabilities of fish spawning at their natal sites or otherwise.

The conceptual basis of Metafor is shown in Figure 10. It assumes a user-specified number of sub-stocks (natal units) where the natal association of an individual is determined by the site at which it is spawned. Egg production is defined by an age-based spawning biomass/egg production function and egg and larval drift result in transport to defined nursery areas. Drift to a larval "sink" imposes a density independent mortality factor and the carrying capacities of nursery sites result in density-dependent mortality factors. Fishing mortality rates vary by stage (immature/mature), and season (spawning/feeding) and can differ between spawning areas and between nursery areas, although a common feeding pool is assumed.

Population structuring is inferred from literature reviews and specific research elements of Metacod, and input values for the state variables are taken from existing project reports (*e.g.*, Stereo), literature reviews and specific analyses (*e.g.*, particle-tracking simulations to infer egg and larval drift and mortality).

4.3.2.2 Study Group comment

Although less complex than Gadget, Metafor requires the values of its "parameters" to be input rather than estimated. Under Metacod, a lot of progress has been made on establishing such values for cod in the North Sea and adjacent waters, but substantial effort is likely to be required to establish them for whiting.

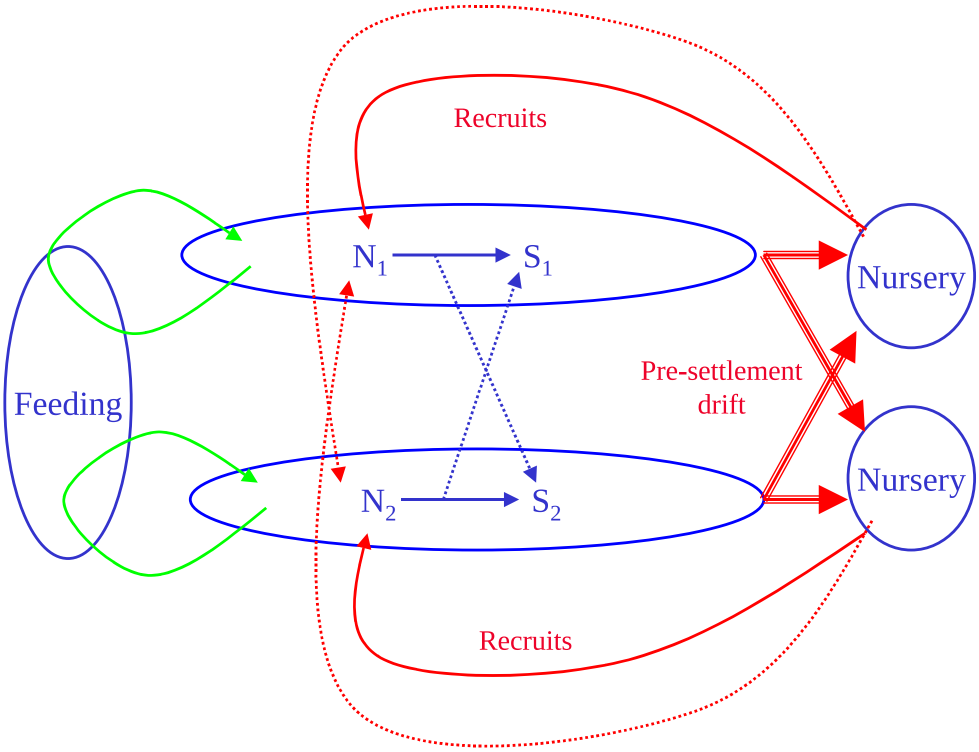

Figure 10: Conceptual outline of the Metafor model.

4.3.3 "What if" analyses

The simplest approach for the Study Group to evaluate the consequential effects of population structuring on stock assessments is through the use of separate, explicit, spatially-disaggregated "standard" assessments, *i.e.* to allocate commercial catches to specific population sub-units as defined by the Study Group and, initially assuming no mixing, to undertake standard ICES catch-at-age analyses on each sub-unit in turn, using area-specific survey indices for calibration. The results from such assessments, summed across units, could then be contrasted against the outcome from a whole area assessment. Assuming that population structuring is a real effect, and that spatially distinct demographic trends occur, then the consistency of the individual assessments, as defined by the available diagnostics (including correlations between abundance estimates and survey indices), would be expected to demonstrate improvements over those from the whole-area assessment.

In addition, less direct inferences could be made. For example, Daan (1991) demonstrated that one possible outcome of erroneously assessing a structured population as if it were a homogeneous unit, is the appearance of a domed exploitation pattern from the whole-area assessment when the true exploitation patterns from the sub-units were flat-topped but at different levels. Daan (*op cit*) concluded that the solution to the inappropriate use of whole-area assessments in a structured system with differential fishing mortalities would be to assess the different units separately, adding that this was rarely a practical proposition. However, the sensitivity of the individual spatially explicit sub-unit assessments to varying degrees of mixing across sub-unit boundaries could be evaluated empirically. It may also be possible to reanalyse existing tag recovery data to obtain better estimates of the actual degree of mixing, using methods such as that proposed by Hilborn (1990).

Although a more *ad hoc* approach than the rigorous statistical methods discussed in Section 4.3.1, the "what-if" approach may be a more pragmatic way forward for the Study Group. Nevertheless, a common issue surrounds all methods of evaluating the effects of population structuring on the assessments and that is the availability of spatially-disaggregated catch data (see Section 5.1.2). The availability of such data over a sufficient time-period is crucial to the application of all such methods.

5 Data requirements and exchange formats

5.1 Introductory comments

5.1.1 Survey data

IBTS indices from each of the quarterly surveys are available (disaggregated by statistical rectangle) from the ICES DATRAS database. Corresponding indices from the EGFS and SGFS need to be distributed to the appropriate Study Group members. The DATRAS download format was an obvious exchange format to use for this purpose. Its structure is a comma-separated text file, with one header row followed by one line of data per sampled statistical rectangle (see Table 6). For the IBTS data, values are given for ages 0 to 10; however, in practice, the older fish are accumulated into a plus group at age 6, with –9 signifying missing values for ages 7 and older.

For ease of processing, all fields need to be included in the exchange files with rectangles attributed to their IBTS area and subareas. National members of the Study Group will ensure distribution of the EGFS and SGFS files in this format by the end of April 2005. A similar structure within an Excel spreadsheet page would be an acceptable alternative means of delivery.

Table 6: Example exchange file format for survey indices.

```
Survey,Year,Quarter, Area, SubArea, SpecCode, species, Age 0,Age 1,Age 2,Age 3,Age 4,Age 5,Age 6,Age 7,Age 8,Age 9,Age
NS-IBTS,1983,1,1,44F0,164758,Merlangius merlangus,0,50.9533,535.7367,669.0233,332.6867,70.6633,0.9967,-9,-9,-9,-9
NS-IBTS,1983,1,1,44F1,164758,Merlangius merlangus,0,37.59,150.54,59.5133,26.1367,7.2567,0.38,-9,-9,-9,-9
NS-IBTS,1983,1,1,49F0,164758,Merlangius merlangus,0,3.36,16.07,44.04,48.28,12.615,2.41,-9,-9,-9,-9
NS-IBTS,1983,1,1,49F1,164758,Merlangius merlangus,0,0.03,0.9,19.84,28.73,8.915,2.44,-9,-9,-9,-9
NS-IBTS,1983,1,1,49F2,164758,Merlangius merlangus,0,0,4.055,14.125,34.72,19.71,12.76,-9,-9,-9,-9
NS-IBTS,1983,1,1,49F3,164758,Merlangius merlangus,0,0,0,34.3,197.945,132.76,93.295,-9,-9,-9,-9
NS-IBTS,1983,1,1,50E8,164758,Merlangius merlangus,0,1.73,38.25,140.73,224.11,111,63.77,-9,-9,-9,-9
NS-IBTS,1983,1,1,50E9,164758,Merlangius merlangus,0,21.345,76.555,91.96,63.05,16.34,1.045,-9,-9,-9,-9
NS-IBTS,1983,1,1,50F0,164758,Merlangius merlangus,0,1.4633,43.6633,302.63,441.0267,181.85,73.1333,-9,-9,-9,-9
NS-IBTS,1983,1,1,50F1,164758,Merlangius merlangus,0,1.455,33.09,209.18,345.115,116.76,33.645,-9,-9,-9,-9
NS-IBTS,1983,1,1,50F2,164758,Merlangius merlangus,0,0,0,0.75,5.9,5.36,3.89,-9,-9,-9,-9
NS-IBTS,1983,1,1,50F3,164758,Merlangius merlangus,0,0,0,5.195,26.18,16.315,11.165,-9,-9,-9,-9
NS-IBTS,1983,1,1,51E8,164758,Merlangius merlangus,0,2,0.605,29.395,104.885,62.23,43.625,-9,-9,-9,-9
NS-IBTS,1983,1,1,51E9,164758,Merlangius merlangus,0,0.105,5.165,23.7,34.755,14.45,7.175,-9,-9,-9,-9
NS-IBTS,1983,1,1,51F0,164758,Merlangius merlangus,0,1.025,8.7,35.615,83.885,52.09,27.92,-9,-9,-9,-9
NS-IBTS,1983,1,1,51F1,164758,Merlangius merlangus,0,0,0.08,1.35,6.51,7.81,4.675,-9,-9,-9,-9
NS-IBTS,1983,1,1,51F2,164758,Merlangius merlangus,0,0.5,1.49,0.23,0.615,0.15,0,-9,-9,-9,-9
NS-IBTS,1983,1,2,39F1,164758,Merlangius merlangus,0,513.58,483.29,58.585,7.18,0.29,0,-9,-9,-9,-9
NS-IBTS,1983,1,2,39F2,164758,Merlangius merlangus,0,90.87,5.975,3.17,0.845,0.1,0,-9,-9,-9,-9
NS-IBTS,1983,1,2,40F0,164758,Merlangius merlangus,0,41.795,93.54,16.2,3.29,1.415,0.14,-9,-9,-9,-9
NS-IBTS,1983,1,2,40F1,164758,Merlangius merlangus,0,86.805,42.805,1.145,0.13,0.04,0,-9,-9,-9,-9
NS-IBTS,1983,1,2,40F2,164758,Merlangius merlangus,0,46.61,11.5667,1.07,0.2833,0.05,0.0167,-9,-9,-9,-9
NS-IBTS,1983,1,2,40F3,164758,Merlangius merlangus,0,30.605,5.55,0.61,0.18,0,0,-9,-9,-9,-9
```

5.1.2 Commercial data

The Study Group will need to undertake some form of spatially disaggregated assessment of commercial catch data (Section 4.3). The fundamental level of spatial disaggregation in the North Sea is the ICES statistical rectangle, and it was recognised in the ICES Resolution that established this Study Group that Coastal states would have to give an undertaking to provide the necessary disaggregated catch and survey data for at least the last 20 years. Due to the full standardisation by gear and area of the IBTS Q1 survey in 1983, an appropriate period for the supply of commercial fisheries data is 1983–2003.

Experience within both ICES and European Union expert groups has demonstrated the difficulty of collating international datasets of catches disaggregated by ICES rectangles even if the information required is simply the weight landed by rectangle. Where this has been achieved, it has been done on an *ad hoc* and often incomplete basis for specific meetings (*e.g.*, EU Expert Group Meeting on Cod Assessment and Technical Measures 28 April–7 May 2003) with no clearly established data exchange format. A separate, but related, issue has been the compilation of fisheries-based data to support the ICES and EU initiatives to move away from stock-based advice to fishery-based advice (*e.g.* ICES, 2004b). This has involved the exchange and collation of new fisheries-based datasets including information on the characteristics defining the fisheries and the biological characteristics of the catches. This has also involved the establishment and refinement of a data exchange format, but one that does not deal with information at the level of the ICES rectangle. More recently, the ICES working group on fish ecology has also had to deal with a request for catch data, from the regional ecosystem study group for the North Sea, with reference for "data on fish individual abundance at length, weight at length, age at length and maturity at length, for all species (both commercial and non-commercial), discards data for all gear types and all fleets, effort data for all gear types and all fleets based on logbook data at the scale of ICES rectangle across the North Sea for the period 1984–2004".

Consequently, national institutes are currently being asked to service requests for data at various levels of aggregation, with no over-arching data exchange format to underpin them. It was not the intention of this Study Group to add to the list of data exchange formats, and it had hoped to use an existing format for its own data request purposes. However, none of the above schemes provide catch-at-age data at the appropriate level of disaggregation for the Study Group. Consequently, the Study Group proposes to request catch-at-age data disaggregated by fleet (or fishery unit) and ICES rectangle according to the format used by DIFRES to supply Danish catch-at-age data to the Study Group. A precise exchange format is not illustrated here. Instead, the Study Group Chair will circulate a more detailed description to coastal state data coordinators by the end of April 2005 as part of the formal request for the provision of commercial fisheries data.

At its most basic, the required data format will comprise a single comma separated text file (or single spreadsheet page) encompassing all fleets/fisheries with a header row comprising "year, quarter, tonnes, effort, rectangle", with a –9 signifying missing data. Where additional information is available, a second corresponding text file (or spreadsheet page) would supply a header row comprising "year, quarter, rectangle, age, numbers, kilogrammes" to provide the age composition of the rectangle catches, and a means to calculate the mean weight at age. At its most complete, a pairing of text files (or spreadsheet pages) would be attributed to separate fleets/fisheries, for example landings from industrial trawl fisheries and age compositions; landings from human consumption fisheries and age compositions; discards from human consumption fisheries and age compositions.

6 Outstanding issues

6.1 Forward workplan

The Study Group agreed to complete the survey-based analyses before the 2005 meeting of WGNSSK (6 September 2005) with the exception of that discussed in Section 4.2.3 "Analysis of survey age compositions and fishing effort", as the Study Group cannot guarantee the availability of the appropriate fishing effort data).

The commercial catch-based evaluations will be undertaken on receipt of the appropriate data from national data co-ordinators. Whereas the Study Group cannot guarantee provision of the appropriate data, every effort will be made to secure them by the end of July 2005.

Although not widely discussed by the Study Group, the possibility remains to reanalyse tag recovery data using methods to evaluate fish movements/mixing that were not available to earlier workers. This will be reviewed within FRS Marine Laboratory with a view to supplying a working paper to the next meeting of WGNSSK.

This meeting of the Study Group has refrained from making any recommendations regarding stock assessment in the light of population structuring, or on management alternatives contingent on their outcomes. Its intention is to provide this only when it reviews both its forthcoming analyses and relevant comments from its parent committee.

6.2 Next meeting

The Study Group will await the outcome of its various analyses (to be considered by correspondence) before deciding whether to request a further meeting. It is possible that its work could be successfully concluded by correspondence. This should be clearer by the time of the 2005 ICES Statutory Meeting at which the appropriate draft resolution would be tabled.

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8 Working documents

WD 1 Kunzlik, P.A. A brief history of the whiting "problem".

WD 2 Armstrong, M. and Brown, B. A brief review of published information on North Sea whiting relevant to stock structure.

WD 3 Gibb, F.M., Wright, P.J., Gibb, I.M. and O'Sullivan, M. Haddock and whiting spawning areas.

WD 4 Sparholt, H. Precision of the IBTS SSB index of whiting.

WD 5 Sparholt, H. More on precision of the IBTS SSB index of whiting.

WD 6 Sparholt, H. Length distribution of whiting from the IBTS.

WD 7 Sparholt, H. Conflicting signals in the IBTS, SGFS and EGFS for North Sea whiting.

WD 8 Sparholt, H. Cod stomach content of whiting from ICES 1981 and 1991 stomach projects.

WD 9 Floeter, J, Kempf, A. and Temming, A. Evaluating the effects of survey index calculation, and changes in survey coverage on whiting IBTS quarter 1 index trends.

Annex 1: List of participants

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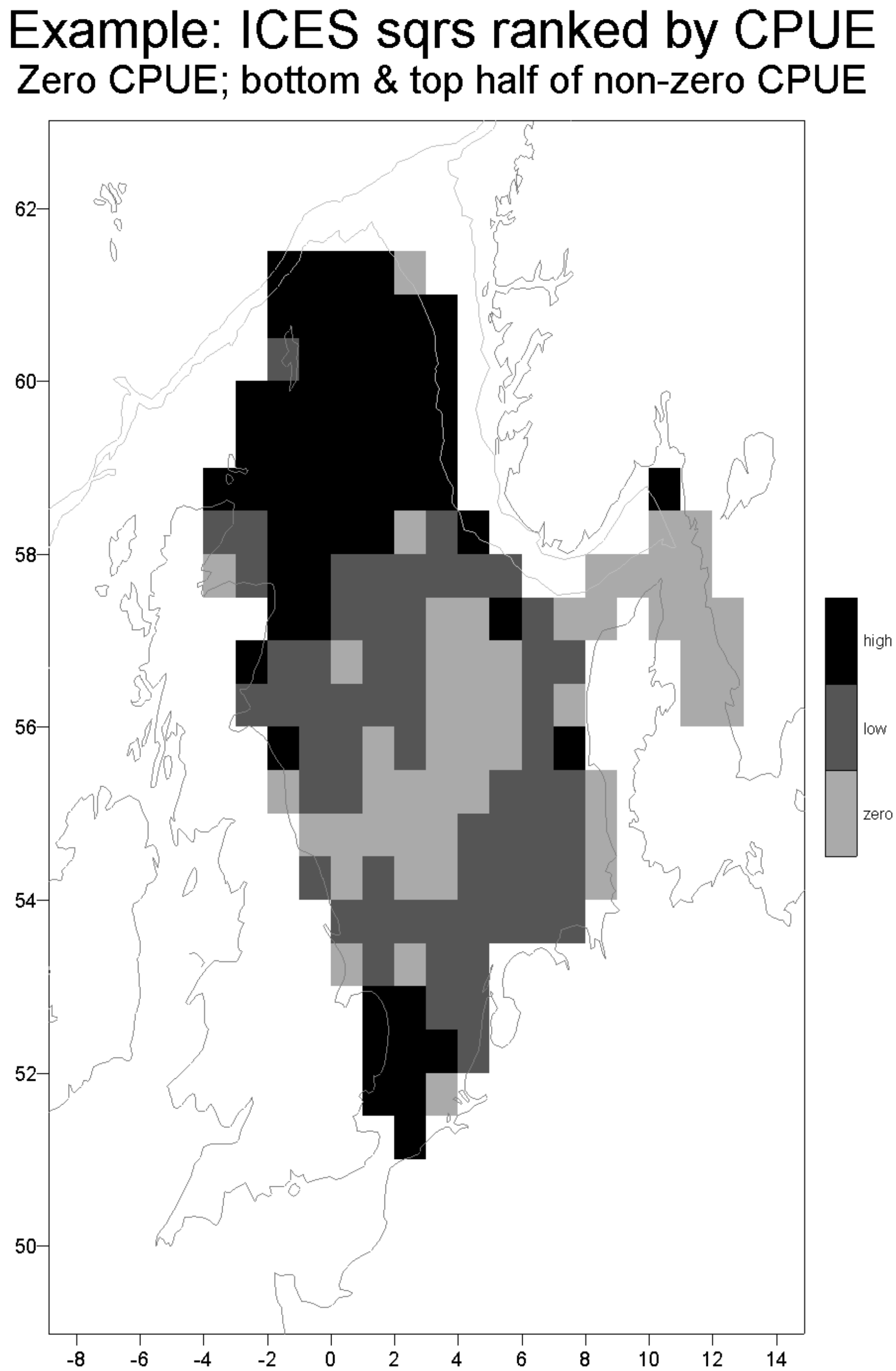
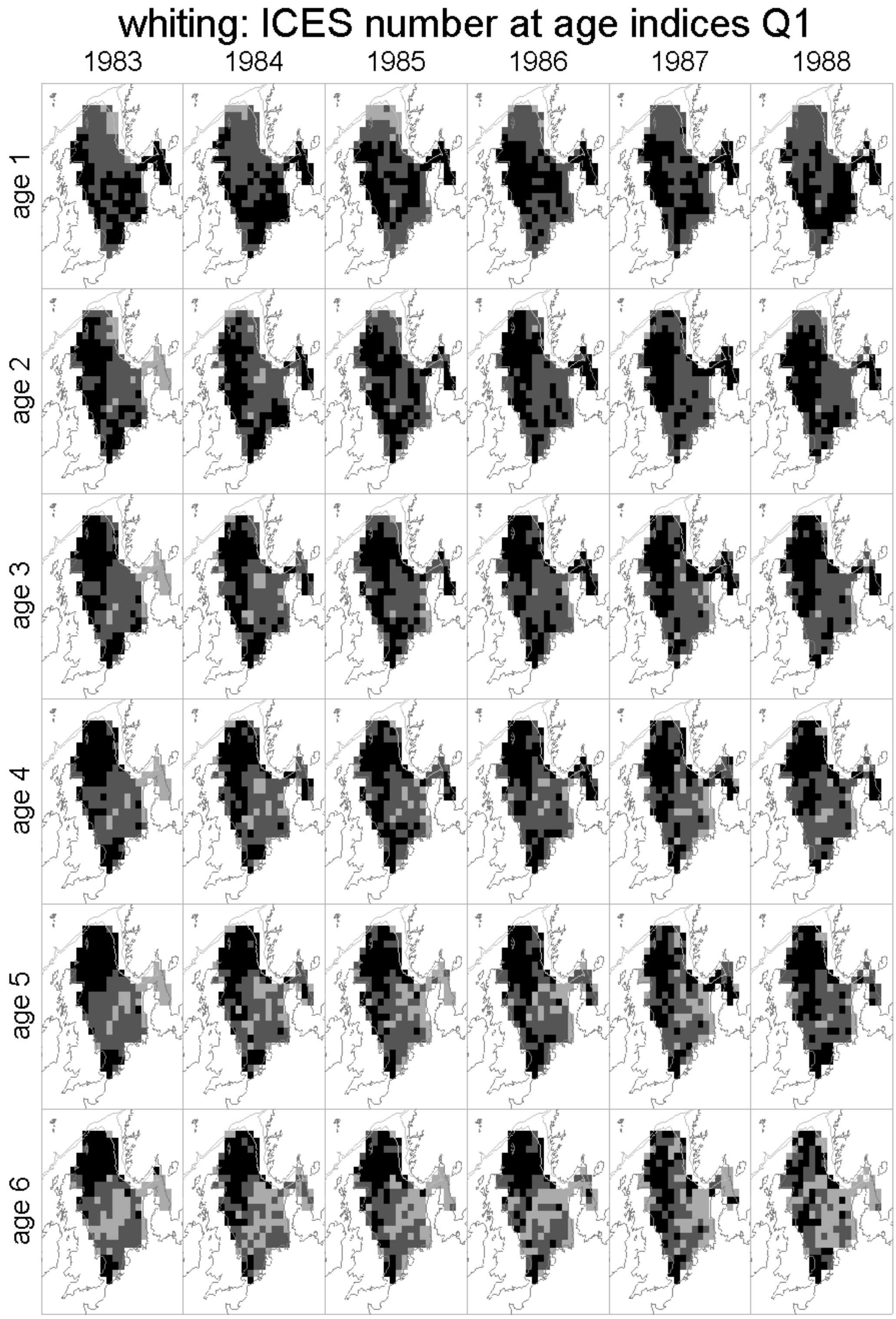
Annex 2: IBTS plots of whiting distribution (Q1–Q4)

The scaling is intended to show the rectangles where zero-catch hauls were taken (light grey) and those that were ranked highest for catch rates (dark grey – top 50% of non-zero rectangles) and lowest (mid-grey – lowest 50% of non-zero rectangles)

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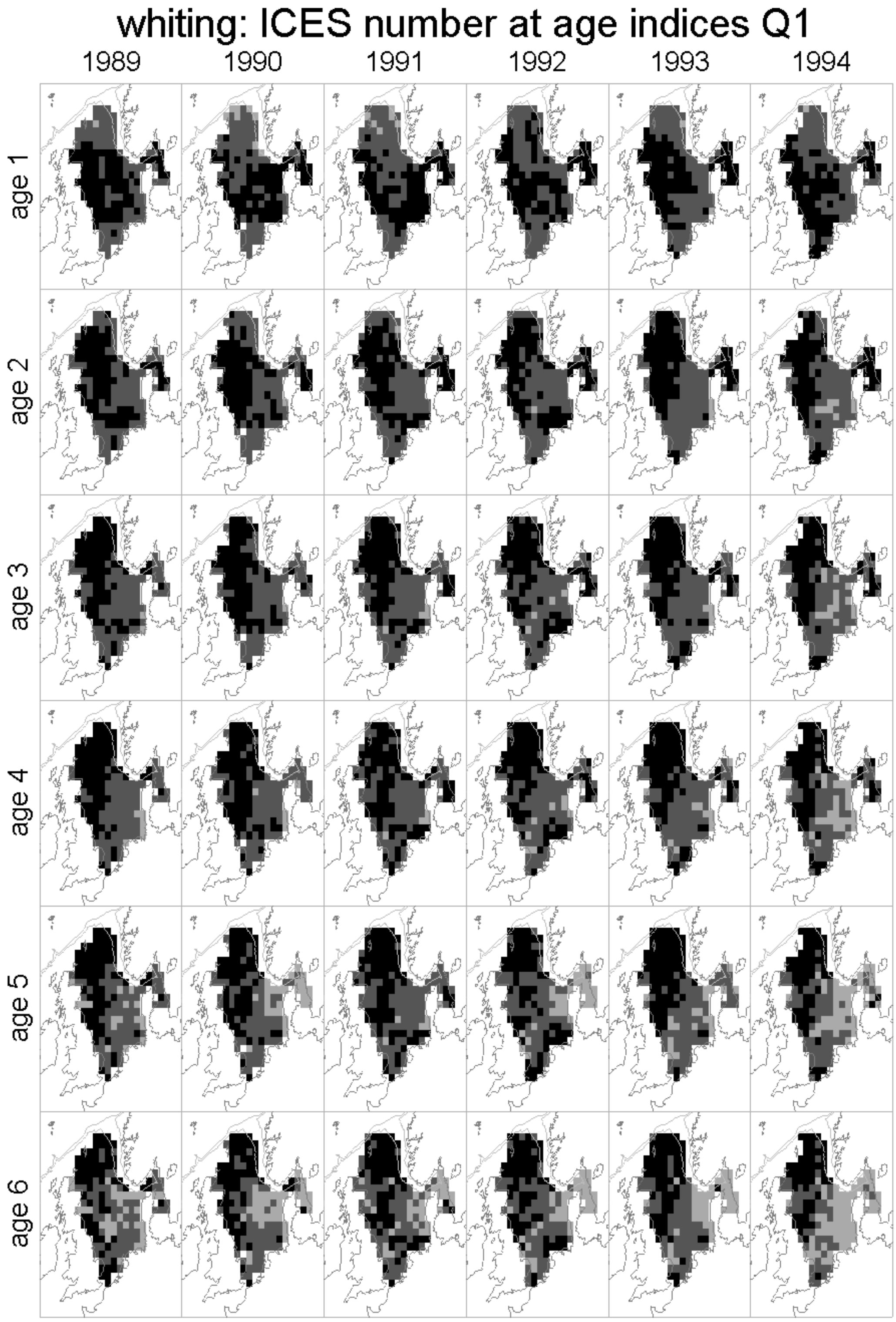
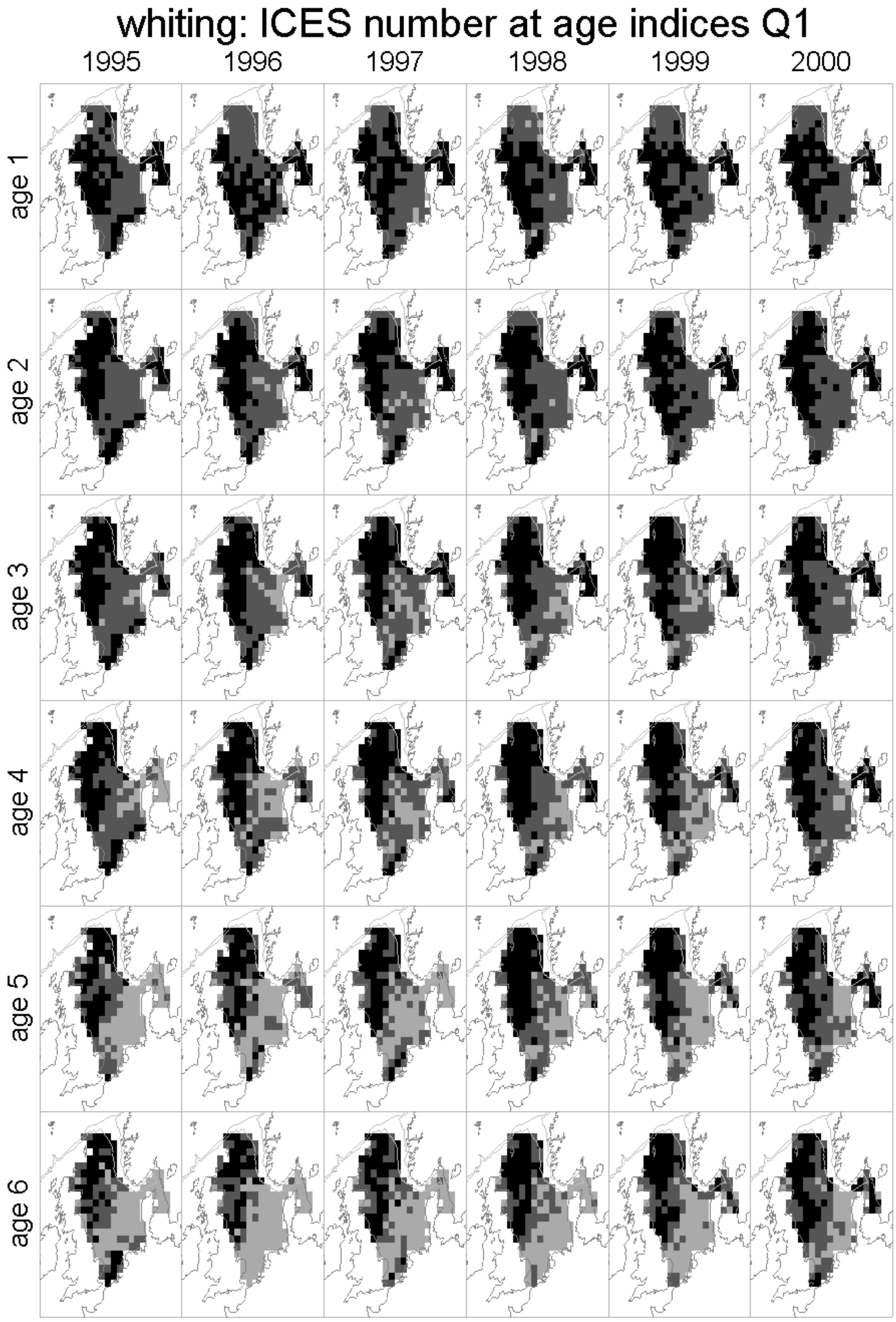
1984
1985
1986
1987
1988
age 1
age 2
age 3
age 4
age 5
age 6



whiting: ICES number at age indices Q1
1989
1990
1991
1992
1993
1994
age 1
age 2
age 3
age 4
age 5
age 6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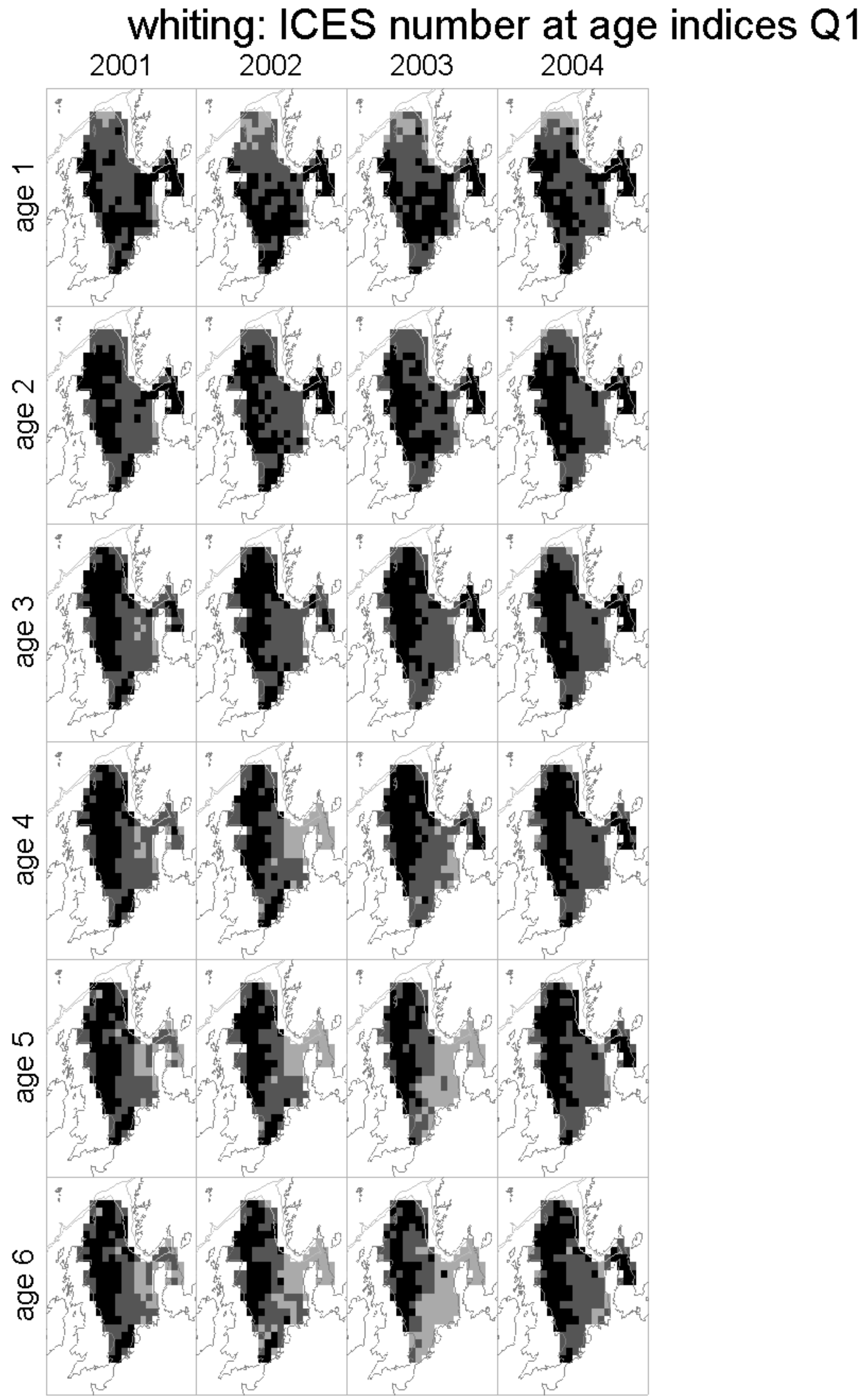
1995
1996
1997
1998
1999
2000
age 1
age 2
age 3
age 4
age 5
age 6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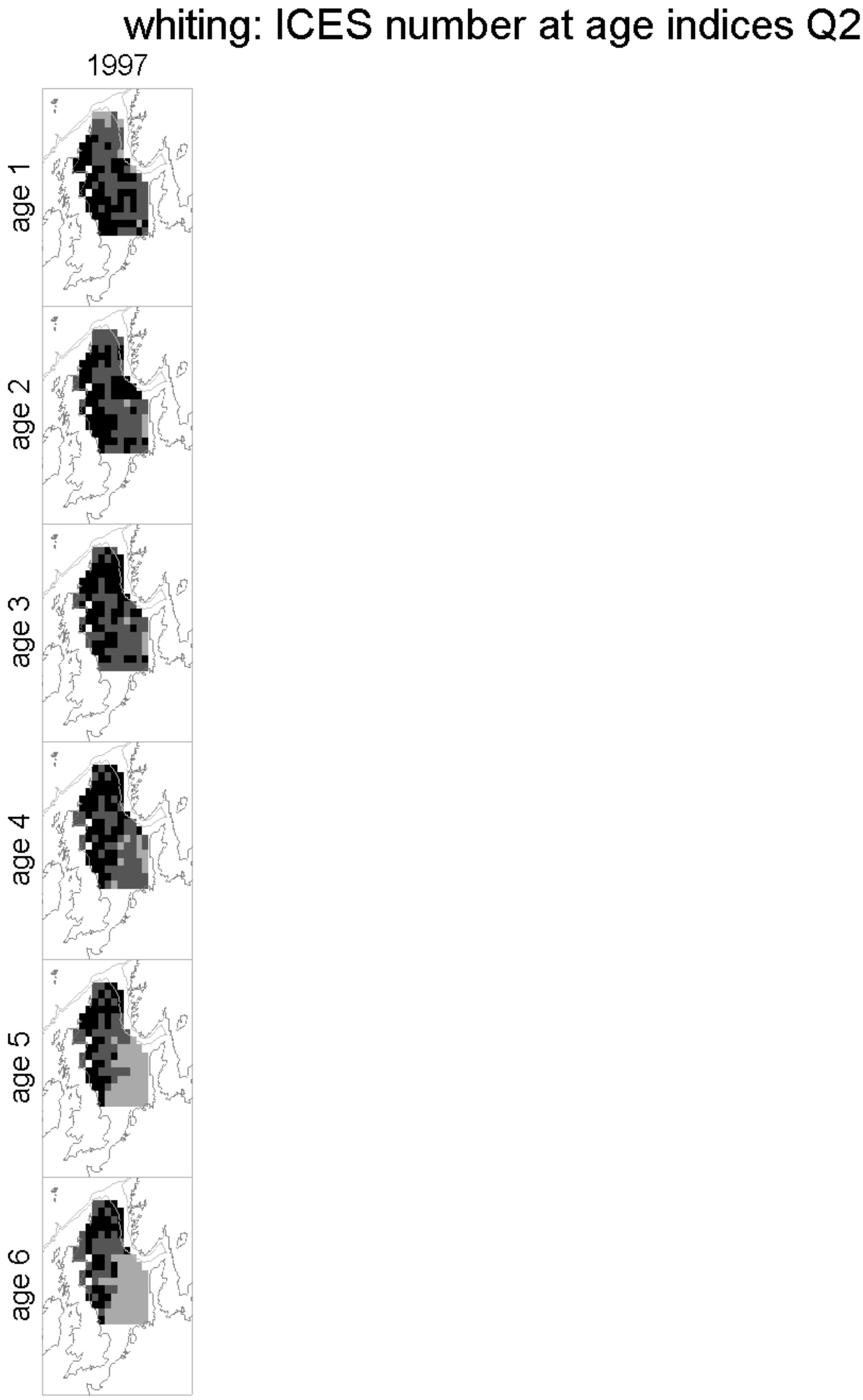
2001
2002
2003
2004
age 1
age 2
age 3
age 4
age 5
age 6


whiting: ICES number at age indices Q2
1991
1992
1993
1994
1995
1996
age 1
age 2
age 3
age 4
age 5
age 6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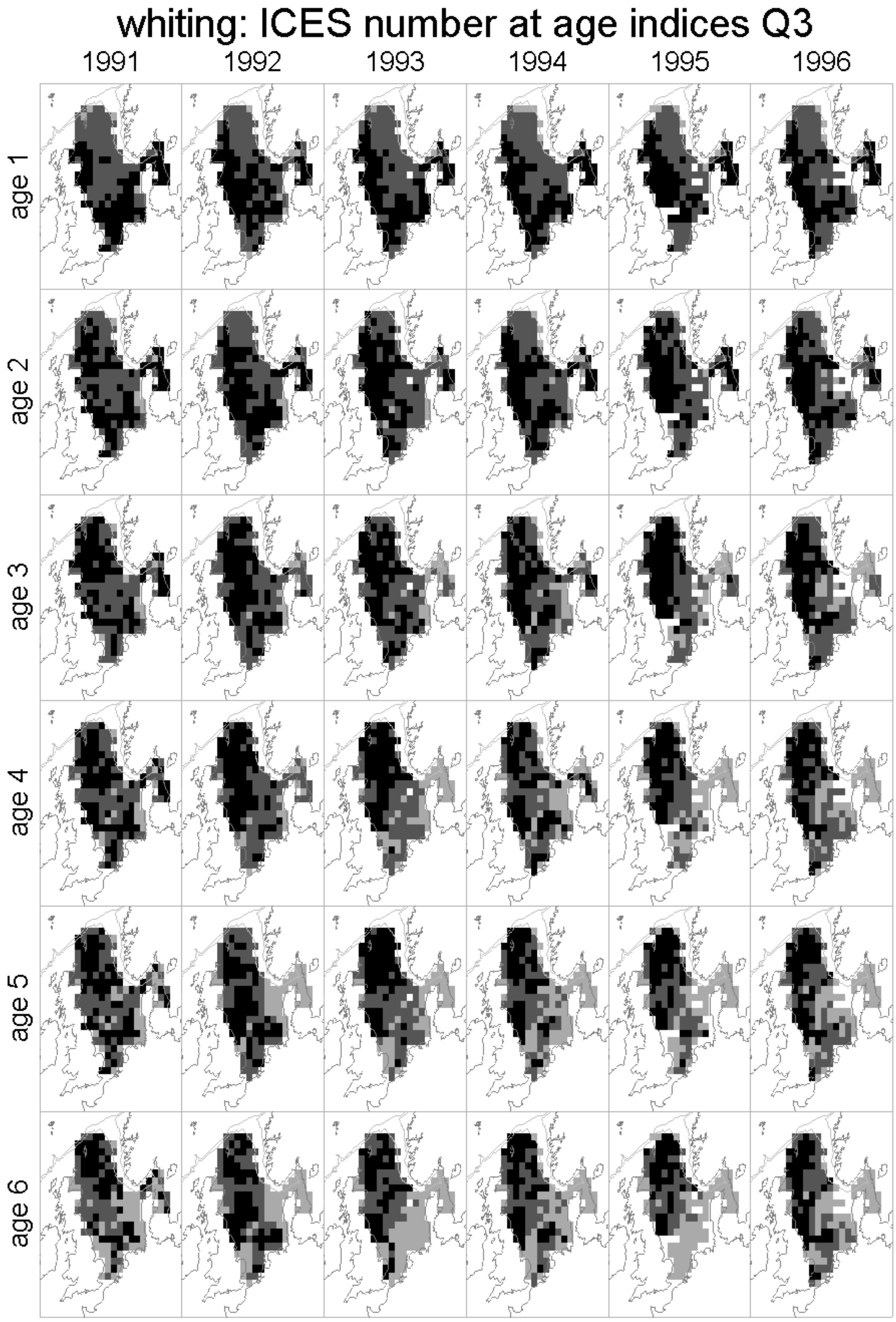
1997
age 1
age 2
age 3
age 4
age 5
age 6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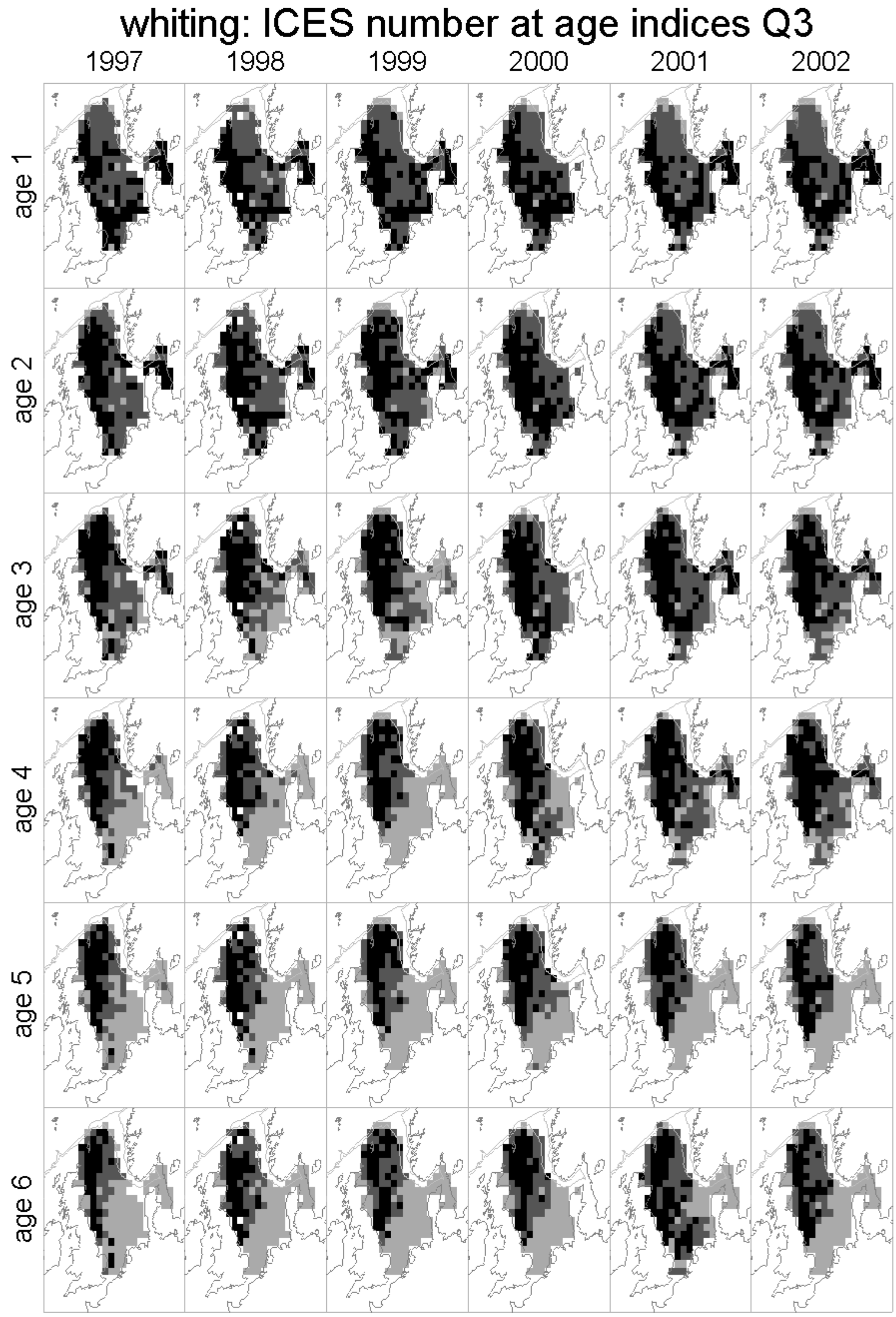
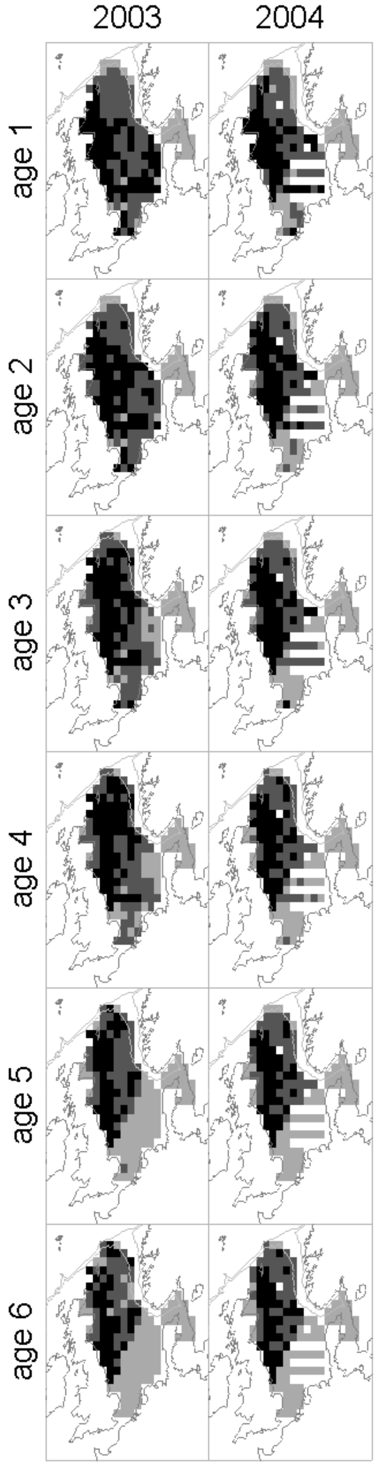
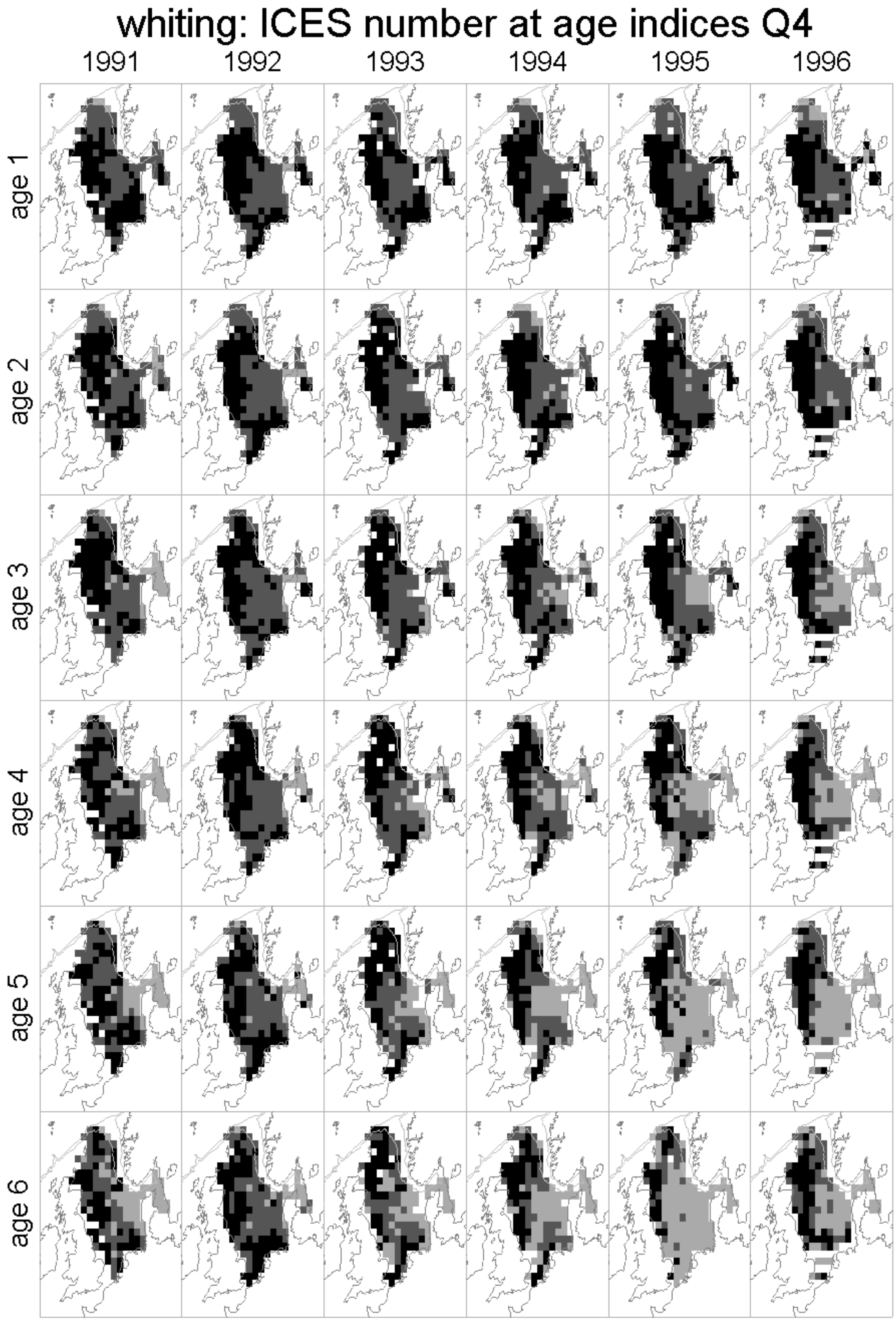
1992
1993
1994
1995
1996
age 1
age 2
age 3
age 4
age 5
age 6


whiting: ICES number at age indices Q3
1997
1998
1999
2000
2001
2002
age 1
age 2
age 3
age 4
age 5
age 6

whiting: ICES number at age indices Q3




whiting: ICES number at age indices Q4
1991
1992
1993
1994
1995
1996
age 1
age 2
age 3
age 4
age 5
age 6


whiting: ICES number at age indices Q4
1997
age 1
age 2
age 3
age 4
age 5
age 6