ICES WKWATSUP REPORT 2010

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Report of the Workshop on procedures to establish the appropriate level of the mixed herring TAC (Spring Western Baltic (WBSS) and Autumn Spawning North Sea (NSAS) stocks) in Skagerrak and Kattegat (Division IIIa)

23 - 25 November

ICES Headquarters, Copenhagen

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

The overall outcome of WKWATSUP is a TAC setting procedure alternative to the procedures suggested evaluated by the joint request from the EC Commission and Norway. The WKWATSUP suggest that the TAC should first be set for the WBSS according to the FMSY or FMSY transition framework for WBSS alone. If the NSAS is greatly impacted by management of the WBSS, this rule needs to be re-evaluated. Following this, the fraction taken in the Eastern part of the North Sea (parts of Sub Divisions IVb and IVaE) should be subtracted from the total TAC for the WBSS before sharing the TAC between Division IIIa and Subdivisions 22-24. Subsequently the best estimates of the proportions of the NSAS and WBSS in the catch by fleet should be used to calculate the combined catch options in compliance with the targeted catch for WBSS.

The 50:50 share of the WBSS TAC between Division IIIa and Sub Divisions 22-24 was not specifically evaluated by WKWATSUP. It was viewed as a political choice and thus all evaluations of TAC setting procedures were performed applying a 50:50 share of the TAC between Division IIIa and Sub Divisions 22-24, though using three different approaches as how to include the share taken in the North Sea. The WKWATSUP recommend a seasonal closure of the herring fishery in parts of the Eastern North Sea, however, until such is implemented, the suggested approach by the WKWATSUP mentioned above should be applied.

The WKWATSUP showed that the selection patterns of the C and F fleets were very different and thus choices about the share between Division IIIa and Subdivisions 22-24 are likely to have an impact on the sustainable exploitation of the stock.

The WKWATSUP summarised the existing knowledge on migrations and area distributions for NSAS and WBSS based on literature and recent catch and survey data. The general migration routes are known, however, an end-to-end spatial lifecycle-closure model could be developed, encompassing active migrations of spawning components and larval drift, to investigate the connection, interactions and spatial distribution of herring. There are large amounts of empirical data available with which to verify the model, although the paucity of knowledge about overwintering and feeding locations and processes will challenge its construction.

The WKWATSUP reviewed the sampling for stock proportions in the mixed catches of herring. There was clearly a mis-match between sampling intensity and catch distribution, particularly in relation to the part of the WBSS that migrates into the Eastern North Sea during summer feeding migrations and the WKWATSUP made recommendations as how to improve the sampling scheme.

The methodology currently used to estimate stock proportions at age in the mixed catches of herring was evaluated and recent development using a statistical modelling approach was presented by the WKWATSUP. Some problems are still unresolved, but the group recommends further refinement and peer-review of this approach with an incitement to apply the approach during next HAWG.

1 Terms of reference

The workshop [WKWATSUP] on procedures to establish the appropriate level of the mixed herring TAC (Spring Western Baltic [WBSS] and Autumn Spawning North Sea [NSAS] stocks) in Skagerrak and Kattegat (Division IIIa) will meet (22)23-25 November 2010 at ICES HQ and chaired by Lotte Worsøe Clausen (DTU Aqua, Denmark) to:

1) Collate the available information on the seasonal movements of the WBSS and NSAS stocks;
2) Comment on the reliability of the methods currently used to estimate the proportions of WBSS and NSAS in the catches and suggest improvements that could be made to the sampling methodology in order to increase the precision of the estimates;
3) Evaluate, in the context of the agreed long term plan for NSAS and the suggested harvest control rules for WBSS, the compatibility of the options set out below for setting the mixed TAC in the Skagerrak and Kattegat with the precautionary approach and with the objective of reaching FMSY by 2015;
    a) Adjust the TAC for fleet C in the Skagerrak and Kattegat by the average of the percentage adjustments of the NSAS and the WBSS.
    b) Adjust the TAC for fleet C in the Skagerrak and Kattegat by the average of the percentage adjustments of the NSAS and the WBSS, weighted by the proportions of these stocks in the annual catches from the Skagerrak and Kattegat.
    c) Set the TAC for fleet C in Skagerrak and Kattegat corresponding to the largest percentage reduction or smallest percentage increase in the TACs of the two stocks.
    d) Set the TAC for fleet D in Skagerrak and Kattegat corresponding to the largest percentage reduction, the smallest percentage increase in the TACs of the two stocks or somewhere in between.
    e) For the purposes of these evaluations, it should be assumed that 50% of the TAC for the WBSS will be allocated to Division IIIa and 50% to SD 22-24.
4) Suggest options (if identified) other than a mixed stock TAC that can either replace or supplement the TAC measure and maintain the targets laid down in the management plans for WBSS and NSAS. These options might include seasonal and spatial limitations on catches in the Skagerrak in order to protect one or other component of the mixture.
5) The joint EU-Norway request to ICES on herring in the Skagerrak and Kattegat specified that the evaluations of the options for setting the TAC in the Skagerrak and the Kattegat should be based on the assumption that 50% of the TAC for the Western Baltic spring spawning (WBSS) herring would be allocated to Subdivisions 22-24 in the Baltic and 50% to the Skagerrak.
    a) Advice on whether the 50:50 split of the TAC between the two areas reflects the actual distribution of the catches.

b) Suggest and evaluate alternative options for splitting the WBSS TAC, taking into account the seasonal movements of the stock.

The Workshop shall report to ACOM at the 29 November for consideration by the review and advice drafting group designated by ACOM to deal with this request.

2 Agenda and participation

Tuesday, November 23rd

09:00 – 10:00: Workshop start.

Welcome, agreement on agenda and task sharing, other practical issues

10:00 – 13:00: The Data; ToR 1) Collate the available information on the seasonal movements of the WBSS and NSAS stocks;

Historical split data in place; a model of the WBSS migration is being developed

We need to get a detailed resolution of catch data: Catch by square and quarter for IIIa and IVaE for all countries fishing in the area. Ideally from 1991-present, but we may settle for 2000-present

Historical ‘positive misreporting’: We need to get a better idea of the quantity of this as it may affect our perception of the stock historically (with inputs from stakeholders)

13:00 – 14:00: Lunch

14:00 – 17:00: The Split; ToR 2) Comment on the reliability of the methods currently used to estimate the proportions of WBSS and NSAS in the catches and suggest improvements that could be made to the sampling methodology in order to increase the precision of the estimates

Split-Methodology validated and still under development

Sampling issues revealed through data scrutinizing

Prediction models of mix between NSAS and WBSS resolved on a temporal and spatial scale

Discussion of the biological implications behind the predictions

Discussion of hydrography, larval drift

17:00 – end: Write-up of ToR’s 1) and 2)

Wednesday, November 24th

09:00 – 10:00: Advice:

Tools and Format ; short term forecast, catch options, interpolation table, etc.

Setting up the advice; how do we make the advice calculations transparent and understandable for the outside world? Unifying perceptions of assessment year, intermediate year, prediction of split, etc

10:00 – 13:00: Management Plans; the need to co-manage a mixed TAC:

PelRAC input

Harvest control rule suggested for WBSS (non-paper from EC;)

North Sea long term plan for NSAS

13:00 – 14:00: Lunch

14:00 – 15:30: The mixed TAC; ToR 3). Presentation of WD on the following options:

a) Adjust the TAC for fleet C in the Skagerrak and Kattegat by the average of the percentage adjustments of the NSAS and the WBSS.

b) Adjust the TAC for fleet C in the Skagerrak and Kattegat by the average of the percentage adjustments of the NSAS and the WBSS, weighted by the proportions of these stocks in the annual catches from the Skagerrak and Kattegat.

c) Set the TAC for fleet C in Skagerrak and Kattegat corresponding to the largest percentage reduction or smallest percentage increase in the TACs of the two stocks.

d) Set the TAC for fleet D in Skagerrak and Kattegat corresponding to the largest percentage reduction, the smallest percentage increase in the TACs of the two stocks or somewhere in between.

For the purposes of these evaluations, it should be assumed that 50% of the TAC for the WBSS will be allocated to Division IIIa and 50% to SD 22-24.

Revisit the WKHMP advice on the 50-50 rule in the light of the transition to MSY

Advise on whether the 50:50 split of the TAC between the two areas reflects the actual distribution of the catches.

Suggest and evaluate alternative options for splitting the WBSS TAC, taking into account the seasonal movements of the stock.

15:30 – 16:30: Discussion of the management options in relation to advice; including an including an improved presentation of the advice and management options.

16:30 – end: Write-up of ToR 3)

Thursday, November 25th

09:00 – 10:00: The Future; ToR 4); Suggest options (if identified) other than a mixed stock TAC that can either replace or supplement the TAC measure and maintain the targets laid down in the management plans for WBSS and NSAS. These options might include seasonal and spatial limitations on catches in the Skagerrak in order to protect one or other component of the mixture.

10:00 – 12:00: Revision of the draft report as it stands

12:00 – 13:00: Concluding remarks; allocating missing bits of the report. We have to report to ACOM at the 29 November for consideration by the review and advice drafting group designated by ACOM the report draft need to be done by the end of WKWATSUP.

List of participants can be found in Annex 2.

3 Collation of the available information on the seasonal movements of the WBSS and NSAS stocks (ToR 1)

The available information on the seasonal movements of the WBSS and NSAS stocks is a mixture of literature studies, grey information and catch-observations. This chapter briefly reviews the patterns extracted from these diverse sources of information giving a generalized picture of the stock movements in space and time. The occurrence of different migration patterns based on phenotypic differences of the stocks (and components) is currently thought to adhere to the Adopt-Migrant hypothesis (McQuinn, 1997), where generally stocks mix in the nursery areas and the summer feeding grounds, but migrate with others of their size as the need to spawn approaches. Larvae or isolated migrants (fast-growers or slow-growers) can join other components, and dispersal is more prevalent when established populations become unstable (after collapse or a recruitment boom; McQuinn, 1997; Corten, 2001). Huse *et al.* (2010) suggest with empirical evidence, that major changes in herring migration routes are generally associated with larger than average year classes.

3.1 North Sea autumn Spawners (NSAS)

Our current knowledge of the migrations and mixing of North Sea herring has been recently summarised in Dickey-Collas (2010). The "traditional"view of migrations with the associated assumption that the migrations are fixed (by life stage) is summarised by Cushing and Bridger (1966) and Burd (1978; Figure 3.1.1). However we know that the locations of overwintering change over short and long time scales (Alheit and Hagen, 1996, 1997; Corten, 1999; Huse *et al.,* 2010) and that whilst Harden Jones (1968), Burd (1978), and Corten (2000) assumed that the North Sea herring overwinter to the east of the North Sea, Poulsen (2008) showed that overwintering occurred to the north of the North Sea in the mid 19th century. Evidence from recent catches (2002-2009) suggest that in the last ten years, overwintering has again been in the north of the North Sea (Figure 3.1.2).

Spawning of the main North Sea herring population begins in the north of the North Sea in September and then progresses southwards with time, ceasing in January in the eastern English Channel (Dickey-Collas 2010). Smaller coastal populations tend to spawn in spring. It is during spawning that the stock integrity is thought to be most evident.

North Sea herring use gravel beds (Geffen, 2009). This constraint limits and fixes the spawning location (Figure 3.1.3). These sites must be "upstream" of the nursery grounds (Petitgas, 2010). The number of spawning sites varies with stock size (Schmidt *et al*, 2009) with a decline in the periphery spawning sites at lower biomass. Each component exhibits different dynamics in recruitment and growth (Payne 2010), although the more northern spawning components appear to be influenced by similar environmental drivers compared to the Downs component (Rockmann *et al.*, in press; Fassler *et al*, submitted).

Larval drift is thought to be driven by wind-induced flows (Heath and Rankine, 1988; Heath *et al.*, 1997; Dickey-Collas *et al.,* 2009). In recent years, it is during this phase that the year class strength is determined (Nash and Dickey-Collas, 2005; Payne *et al.*, 2009b). Most post-larvae metamorphose between April and July (Heath and Richardson, 1989). The North Sea is not isolated because larvae originating in the west of Scotland are also introduced by the Scottish coastal current into the northern North

Sea (Heath and Rankine, 1988; Heath 1989). Larvae from spring-spawning herring in the Norwegian fjords and Skagerrak and Kattegat also enter the North Sea. The nursery grounds for the metamorphosed juvenile 0-group fish are mostly in the southern and eastern North Sea (German Bight and Skagerrak). The juveniles appear to remain in these generally mixed waters (and to a lesser degree in other coastal areas) until they are 2 years old (Röckmann *et al*, *in press*). It is here that the most mixing with Western Baltic Spring spawners is thought to occur. It was thought that the juveniles from larger year classes were more likely to mix with WBSS in the Skagerak. Recruiting to the adult population is probably size and maturity dependent (Brophy and Danilowicz, 2003) through active migration to the feeding grounds (Wallace, 1924).

The main feeding time of North Sea herring is April–June (Hardy, 1924; Savage, 1937). Feeding intensity reduces in the build-up to spawning and little feeding occurs over winter (Hardy, 1924). The distribution of feeding shoals correlates to zooplankton abundance (Maravelias and Reid, 1997; Maravelias, 2001). The distribution of the feeding herring is closely associated the southerly incursion of *Calanus* and *Limacina* (Bainbridge and Forsyth, 1972); which are influenced by the Atlantic inflow. In some years, there may be a gradient in the feeding locations by component but this is not true for all years (Bierman *et al.,* 2010). Water depth and herring body length also influence distribution (Guiblin *et al.,* 1996).

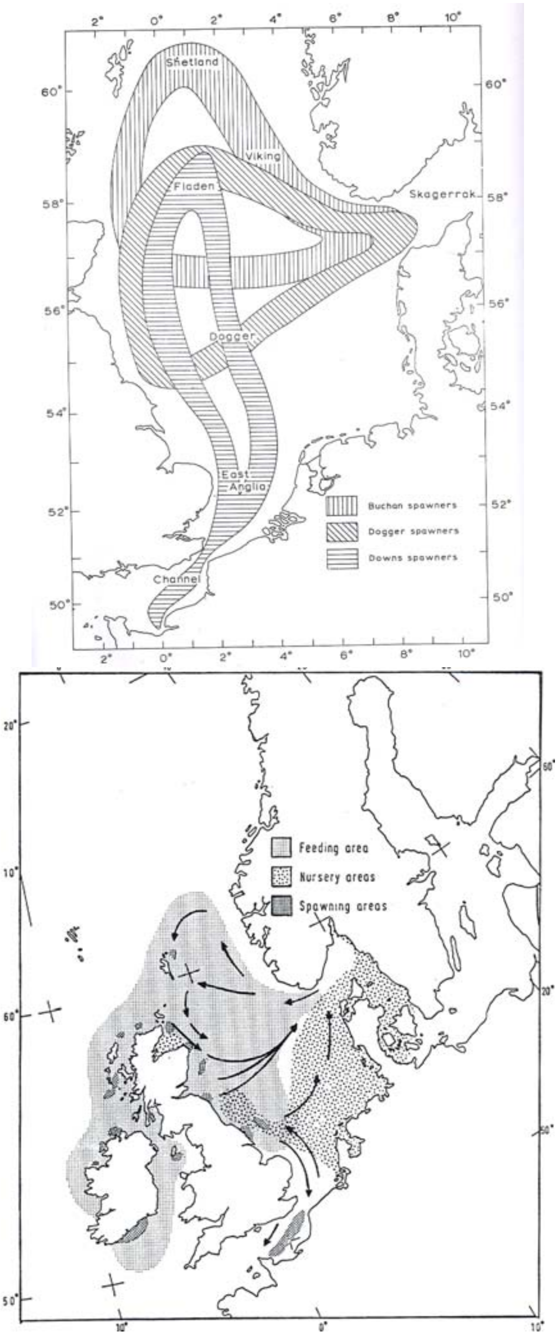


Figure 3.1.1. Schematic of assumed generalised migration patterns of North Sea herring, taken from Cushing and Bridger (1966) and Burd (1978).

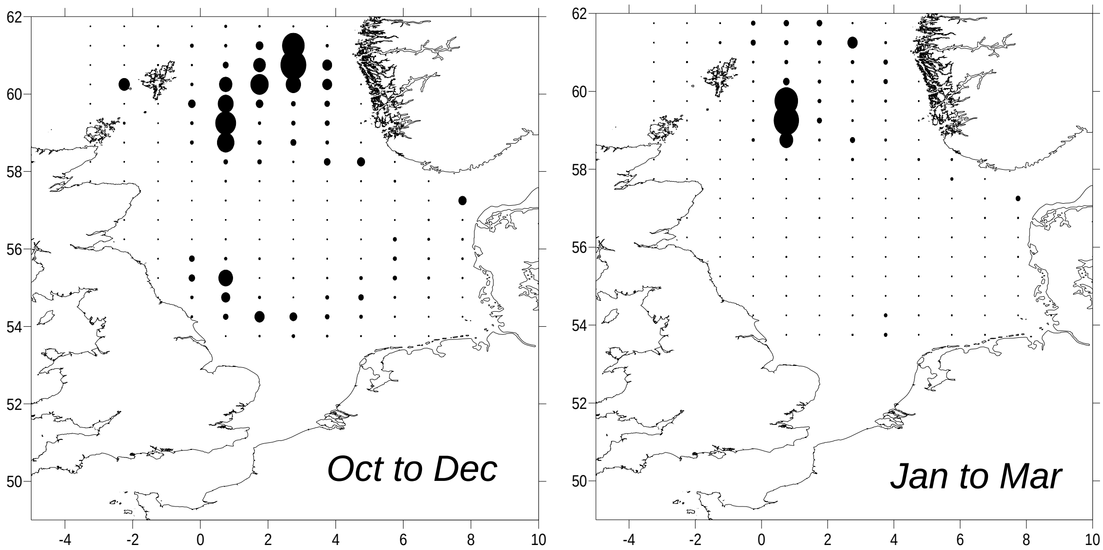


Figure 3.1.2. Overwintering Herring- mean catches of adult herring from 2002 to 2009 in quarter 4 (October to December) and quarter 1 (January to March) in by ICES rectangle in areas IVa and IVb. Catches on migrating Downs herring are shown in the south of IVb in October to December.

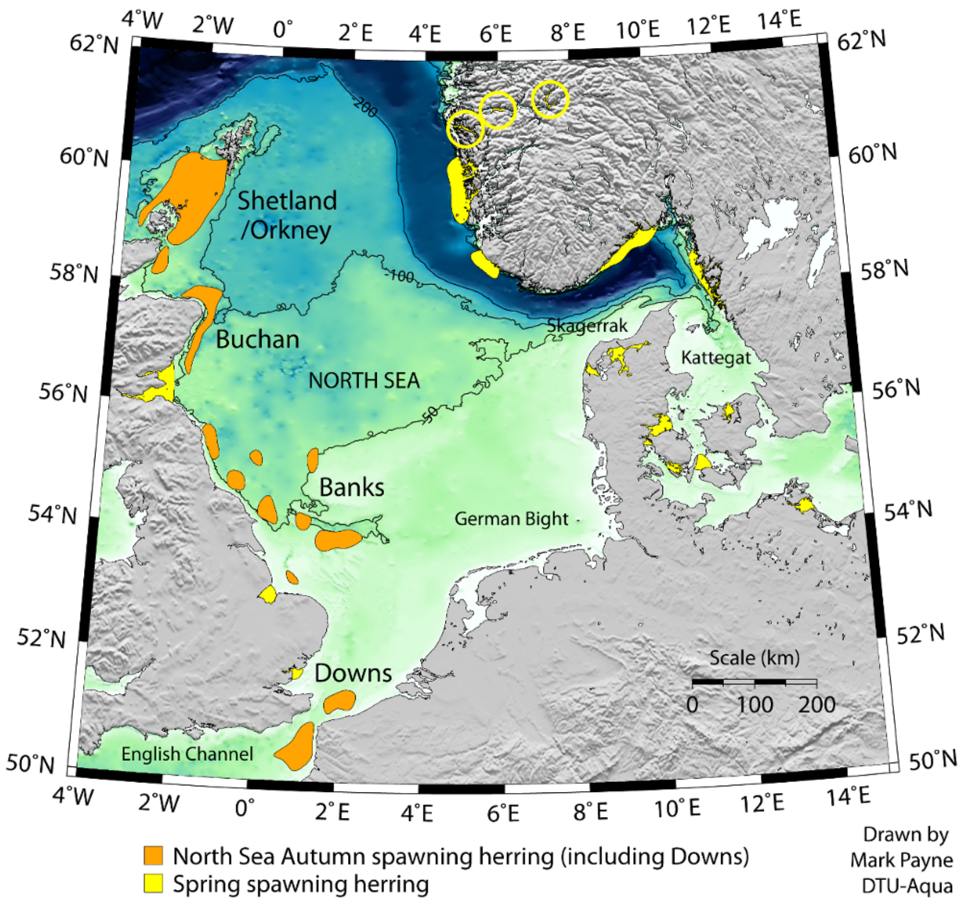


Figure 3.1.3. The current spawning sites of herring in the North Sea and adjacent waters and the location of the four spawning components of North Sea autumn spawning herring. Taken from Dickey-Collas *et al.,* 2010.

3.2 Western Baltic Spring Spawners (WBSS)

The western Baltic has a complex mixture of different herring populations predominantly spawning during spring, but also local spring-, autumn- and winter spawning stock components are found in the area (Bekkevold *et al.*, 2007). The exact proportions of these stocks are hitherto unknown; however, they are observed in the area to some degree and could potentially be important parts of the total amount of herring available for the fishery.

The general patterns of the dynamics of the larger herring populations in the area are qualitatively known (Figure 3.2.1).

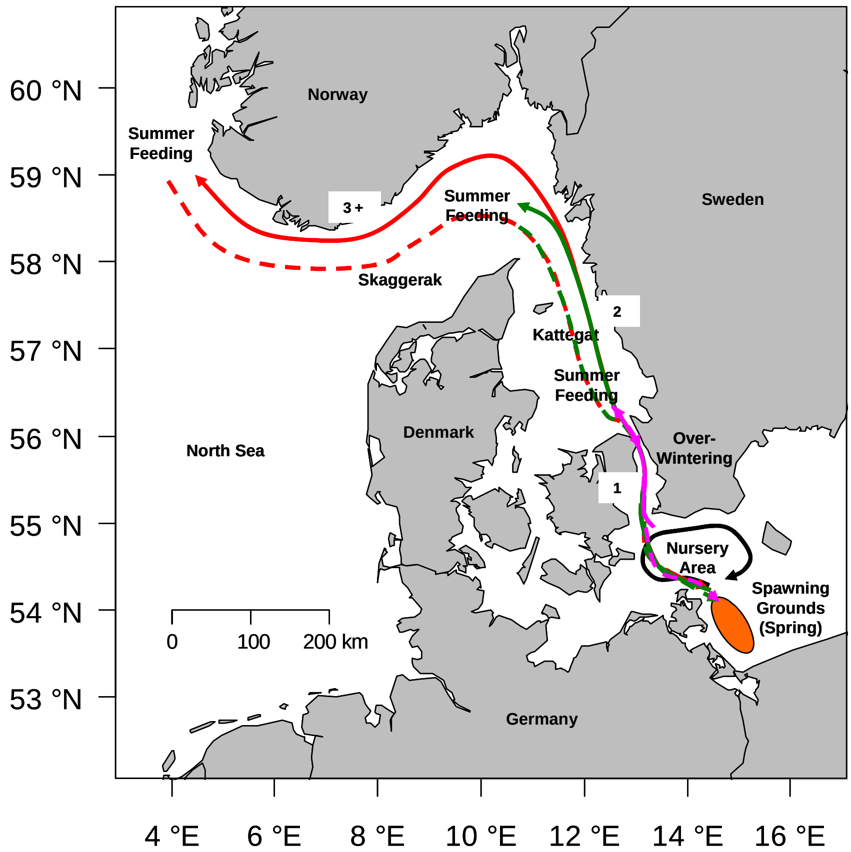


Figure 3.2.1. General migration patterns of the WBSS; the numbers indicates the age-dependent migration pattern (redrawn from M.Payne)

The main spawning area of the WBSS is considered to be Greifswalter Bodden at Rügen Island (Oerberst *et al.*, 2009), where it spawns during March-May. The majority of 2+ ringers migrate out of the area during the 2nd quarter of the year, through the Sound and Belt Sea and propagates into the Western part of the Skagerrak and the Eastern North Sea to feed (Payne 2009). The extend of the migration is age dependent, where the younger individuals migrates up into Kattegat and Skagerrak, the older fish migrates all the way out into the Eastern North Sea (Figure 3.2.1). Towards the end of summer the herring aggregate in the Eastern Skagerrak and Kattegat before they migrate to the main wintering areas in the southern part of the Kattegat, the Sound and the Western Baltic (Anon. 1991/Assess 15; Nielsen *et al.*, 2001). The extent of the migration is age-and season dependent and variable over time (Clausen *et al.*, 2006).

These qualitative patterns had yet to be fully quantified prior to the WKWATSUP, thus the patterns described in the present report suffers from lack of knowledge on the exact migration routes to the feeding area from the southern part of the stock distribution. Efforts have been made to capture the out-migrating herring but with limited success (Clausen, pers.comm).

Sections 4.3 and 4.4 gives a thorough quantitative description of the spatial distribution of the WBSS based on a timeseries of samples of stock affiliation of herring in commercial catches in Subdivision IIIa.

3.3 Conclusions and recommendations

There are some life stages of herring that are well described and easy to monitor with the current series of surveys. However, as described above and in contrast to Norwegian spring spawning herring, there are many life stages whose migration behaviour and associated variability (both interannual and multi-decadal) is unknown. We do however know that juveniles from NSAS and WBSS mix in the Skagerrak and eastern North Sea. We also know that some adult WBSS (generally the older fish though 2 year olds are observed) migrate out into the North Sea to feed. The processes which determine the behaviour, and the dynamics and interactions that result from it, are however difficult to quantify by empirical data alone. For the WBSS in particular, the knowledge of the migration behavior in relation to the feeding into the IIIa is rather limited, possibly due to the nature of this migration as the herring are migrating in small 'patches' and not in collated schools.

An end-to-end spatial lifecycle-closure model can be developed, as done for Norwegian Spring Spawning herring, North Sea cod and haddock, with active migrations of spawning components and larval drift, to investigate the connection, interactions and spatial distribution of herring. It would make sense to construct one such model for both NSAS and WBSS herring. There are large amounts of empirical data available with which to verify the model, although the paucity of knowledge about overwintering and feeding locations and processes will challenge its construction.

4 The reliability of the methods currently used to estimate the proportions of WBSS and NSAS in the catches; suggestion of improvements that could be made to the sampling methodology in order to increase the precision of the estimates; (ToR 2)

The WKWATSUP was asked to evaluate the methodology currently applied for estimation of the stock proportions of WBSS and NSAS in the catches taken in Subdivision IIIa and adjacent areas and suggest potential improvements. This section contains an evaluation of the splitting methods, their background, validation and further development. Secondly this chapter evaluates the sampling of data, particularly in relation to historic misreporting and the sampling coverage both spatially, temporally and in relation to the fishery. Thirdly we describe a modelling approach to predicting the proportions of the NSAS and WBSS in the mixing area.

4.1 Current methodology

4.1.1 Background

The method for separation of the herring stock components has developed the past decade. Prior to 1996, the splitting key used by ICES was calculated from a sample-based mean vertebral count using a cut off algorithm for calculating the proportion WBSS in a sample as MIN(1,MAX(0,(VS_{sample}-55.8)/(56.5-55.8))), where VS_{sample} is the sample mean vertebal count and assuming a population mean VS of 55.8 for WBSS and 56.5 for NSAS respectively. This method is still being used to split samples of Norwegian catches from the transfer area in IVa East. In the period from 1996 to 2001 splitting keys were constructed using information from a combination of vertebral count and otolith microstructure methods (ICES, 2001). From 2001 and onwards, the splitting keys have been constructed solely using the otolith microstructure method which uses visual inspection of season-specific daily increment pattern in the larval otolith, with the exception of the splitting key made for the mixture area in Sub Division IVaE, where vertebral counts currently are the only method used to split the mixed stock (ICES, 2004; Clausen *et al.*, 2007).

The transition from the sample based VS method to the individual based OM method increased precision considerably (Mosegaard and Madsen 1996). The OM method was validated by Clausen *et al*. (2007) and the study showed that the method can discriminate herring with different hatching times, even when a sympatric existence of herring with different spawning times is the case (Brophy and Danilowicz 2002, 2003, Bekkevold *et al.*, 2007). However, different populations with similar spawning periods may not be resolved with the present level of analysis (Mosegaard *et al.*, 2001, Clausen *et al.*, 2007). A change in methodology from VS counts to OM analysis would increase quality in estimated proportion of WBSS and NSAS in Norwegian catches in the IVa East. Although Norwegian spring spawning herring (NSS) exhibit partly overlapping otolith microstructure with WBSS, discrimination of NSS from herring in the North Sea is based on otolith macrostructure and would therefore not influence the results.

Otolith shape analysis has been used to discriminate between populations for a variety of species and for herring this approach has had increasing success with development of imaging techniques and statistical methods. Environmental differences and geographical separation of populations give rise to variation in the shape of otoliths (Messieh 1972; Dowson 1991; Lombarte 1992; Arellano *et al*. 1995). These variations may suggest differences in the spawning area and environment of populations within a species. Both genetic and environmental influences have been reported as important in determining the shape of the otolith and that different genotypes induce important differences in otolith shape (Cardinale *et al*. 2004).

In an early study comparing different herring populations based on both meristic and otolith characters, Messieh (1972) used a combination of comparisons of otolith characters like length, angles between lines joining rostrum, postrostrum and pararostrum to discriminate between herring populations with different spawning times. A further development of this approach was made by Turan (2000) applying a truss network system on otolith shape to successfully discriminate between herring stocks in the North-East Atlantic (Turan 2000).

Using Fourier Series Shape Analysis on Alaskan herring and Northwest Atlantic herring, Bird *et al*. (1986) showed that otolith shape reflects differences in race, however, also differences between yearclasses of the same race (Bird *et al*. 1986). Using the same analysis Groth *et al*. 1988 reports a strong variation in otolith shape between Western Baltic herring with identical spawning time but different ages. Additionally they conclude that as the difference in otolith shape between spring and autumn spawning Western Baltic herring is minor, the separation of these stocks based on otolith shape may be difficult (Groth *et al.*, 1988). Sagittal otoliths have certain morphological features that are laid down early in the ontogeny of the fish (Gago 1993), and measurements of internal otolith shape in adult herring has proven a powerful tool for stock discrimination (Burke *et al*. 2008).

The application of estimates of proportions of herring from different spawning times to the catch or survey data does introduce other statistical challenges. Any use of proportions should include an assessment of classification error and its effects. The effect of relaxing the assumption of perfect classification is that estimates of proportions of the dominant spawner type increase. This is only logical since the most of the misclassified fish will be of the most dominant spawner type. For this reason, estimates change only little when proportions are close to 0.5, but most when one of the components is dominant.

The effect of misclassification is very relevant when either NSAS or WBSS dominate catches or samples. One must not assume that the sample proportions totally represent the "truth" especially if the sampling size is small, one or the other spawner type dominates the catch or misclassification is variable.

Thus, herring stock separation can be done in several ways using meristic characters, otolith microstructure, chemistry or shape, or a combination of all methods. We are currently learning how to use these classifications and the strengths and weaknesses of the approach. Through the history of herring stock separation, the goal has always been to find a fast and reliable method with high robustness and a minimum of reader subjectivity allowing for a high number of observations and thus improved precision. Though all methods applied have had success in separating herring stocks, they vary in precision, objectivity and cost.

4.1.2 Validation

The purpose of classifying individual spawning type is to estimate proportions of the two major stock components by age in catches and surveys from the different areas and seasons. Combining OM with otolith shape and fish meristic characters in a discriminant analysis approach may increase precision of the estimated stock proportions. Validation of the shape and meristic based methodology may be performed using samples of known spawning type (from OM analysis) and classifying random subsets by shape/meristics to test for bias and variation in estimated proportions.

4.1.3 Conclusions

In the present case where distinction between two stocks may be based on genotypic as well as phenotypic expressions of contrasting life history characteristics the chances of successful discrimination are substantial and only depend on sampling effort.

The shift from VS counts to OM individual assignment meant a large increase in precision and a possibility to calibrate other more accessible variables to add information to the classification and estimation of stock proportions.

Analysis of the stock proportions and their sources of variation at different sampling levels is an important tool when planning the optimal sampling strategy for precise estimates of stock proportions at age.

The current VS based estimation of WBSS in catches of herring in the transfer area of IVa East should be combined with an OM calibrated method exploiting differences in meristic characters among stocks such as maturity index, length- weight- age relationships etc. This appears to be a way forward to a more reliable estimate of the catches of WBSS in the North Sea.

4.2 Sampling and modelling

In terms of method reliability, the issue of sampling for biological data for the splitting between NSAS and WBSS is an important factor; without a robust and appropriate sampling strategy, the basis for the splitting is somewhat impaired. The sampling need to be evaluated along two separate lines: the historic misreporting of catches into the IIIa from the North Sea and the actual sampling within the IIIa.

4.2.1 Historical misreporting of catches

The historical misreporting of catches into IIIa has been substantial prior to the implementation of the ITQ system however since 2009 this has no longer been an issue for neither Sweden nor Denmark. In order to have a correct perception of the historic stock properties, a qualitative estimate of the proportions of this misreporting is highly warranted as this potentially would have inflated the perception of the SSB for WBSS, and masking the dynamics in fishing mortality, and thus all countries landing herring from IIIa was asked to give such an estimate:

The Danish reported landings have been corrected for this misreporting each year in the period 2002-2009 based on both grey information from the industry itself, week-by-week evaluation of the fishing trips, and since 2004 also applying VMS data. Prior to 2002 the existing data on total catch by year need to be adjusted by removal of 50% of the reported catches.

The Swedish catches reported in up until 2009 have also been suffering from 'positive misreporting' and thus the total catch data need to be corrected by removal of 20% of the total catch each year in particular catches taken during the 3rd quarter.

The reported catches by the Norwegian fishery in IIIa is thought to be subjected to misreporting as well. However this is not clear what the historic proportion of this misreporting is, potentially it could be rather substantial. The Norwegian fishery directorate is currently looking into this problem, but as of now, no qualitative or quantitative indication of the proportion of herring catches taken outside – and reported into – IIIa can be given.

The German fishery has not been misreporting any catches into IIIa, however, some degree of misreporting 'out' of the IIIa and into the subdivisions 22-24 has occurred the later years (2008 and 2009). However, this is known to the data coordinator for this nation and is corrected prior to submission of the catch data to the HAWG.

The historical misreporting could give rise to analysis of samples not originating from IIIa but from the North Sea. The Danish samples have been scrutinized to remove such samples giving an erroneous impression of the stock proportions, however, it cannot be ruled out that some of the samples of stock composition are subject to this error. It should be noted, that the values of historical misreporting mentioned above are based on anecdotal information from the respective representatives of the National fisheries present during WKWATSUP.

If the full consequence of this historic misreporting is to be examined quantitatively it would be necessary to review the complete catch-at-age matrix for the entire assessment period (1992 to date) or take Bayesian approaches similar to that used for mackerel (Simmonds *et al.,* 2010) or west of Scotland herring (ICES 1997). Either approach would demand resources and involve representatives from the National fisheries and data collectors. It may well be required as it appears that historically more than 70% of the catches allocated to the Division IIIa actually were taken in the North Sea. The uncertainty related to the origin of the historic catch data should however be stated in the Quality of the Assessment and also be dealt with in the Advice following the recent developed 'Traffic light' grading system.

4.2.2 Sampling coverage and sampling scheme

When sampling commercial catches for the biological composition concerning the proportions of the two herring stocks it is crucial that the sampling scheme and coverage mirrors the actual distribution of the fishery. The sampling coverage compared to the reported catches by ICES rectangle over the period 2002-2009 is shown in Figure 4.2.2.1. It is apparent that catches concentrate in the north-western part of area IIIa, while sampling intensity is highest in the north-eastern area.

The sampling for split of catches in the transfer area in Division IVa East was considered insufficient in 2009, with less than 100 individual observations of stock affiliation (ICES 2010) and the data for previous years do also show a lack of coverage of this area (see section 4.1.1 about the challenges of applying the split). In order to get a solid base for estimation of the removal of the SSB by fishery, it is of utmost importance that all parts of the distribution area and the fishery herein are covered by the biological sampling. Thus it is highly recommended that the sampling intensity in Subdivision IVaE and eastern parts of IVb is substantially increased.

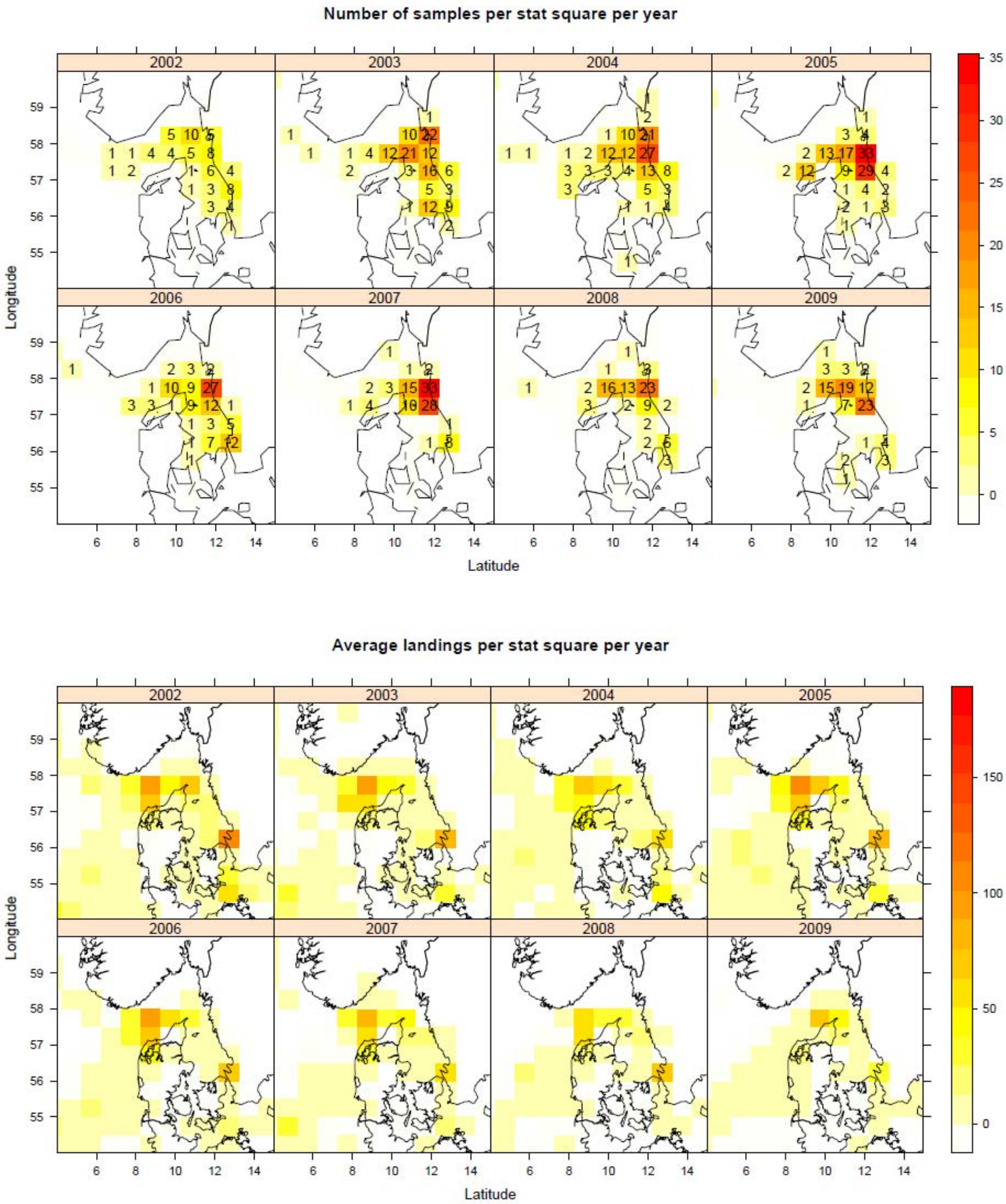


Figure 4.2.2.1: Number of samples by rectangle (upper panel) and average landings in tonnes per year by ICES rectangle (lower panel) over the period 2002-2009.

Through analysis of the historical samples for stock affiliation it became apparent that the sampling scheme for this information differs between Sweden and Denmark, where Sweden take a higher number of samples (giving a potential better spatial and temporal coverage) containing less fish compared to the Danish sampling (Figure 4.2.2.2). It would give a better resolution if the sampling strategy followed by all sampling countries were the one adopted by Sweden, as the spatial mixing of WBSS and NSAS varies within years and this may be better reflected by a broader spatial resolution of sampling data rather then a larger amount of fish samples originating from relatively sparse locations. Based on the results of the split model documented in section 4.3.1, it is evident that the major source of uncertainty in the estimate of the stock mixing proportion p is the variation between samples, and not the variation between fish within a sample. This implies that for a fixed number of sampled fish a higher precision can be expected by taking many samples with few fish in each, than by taking few samples with many fish in each.

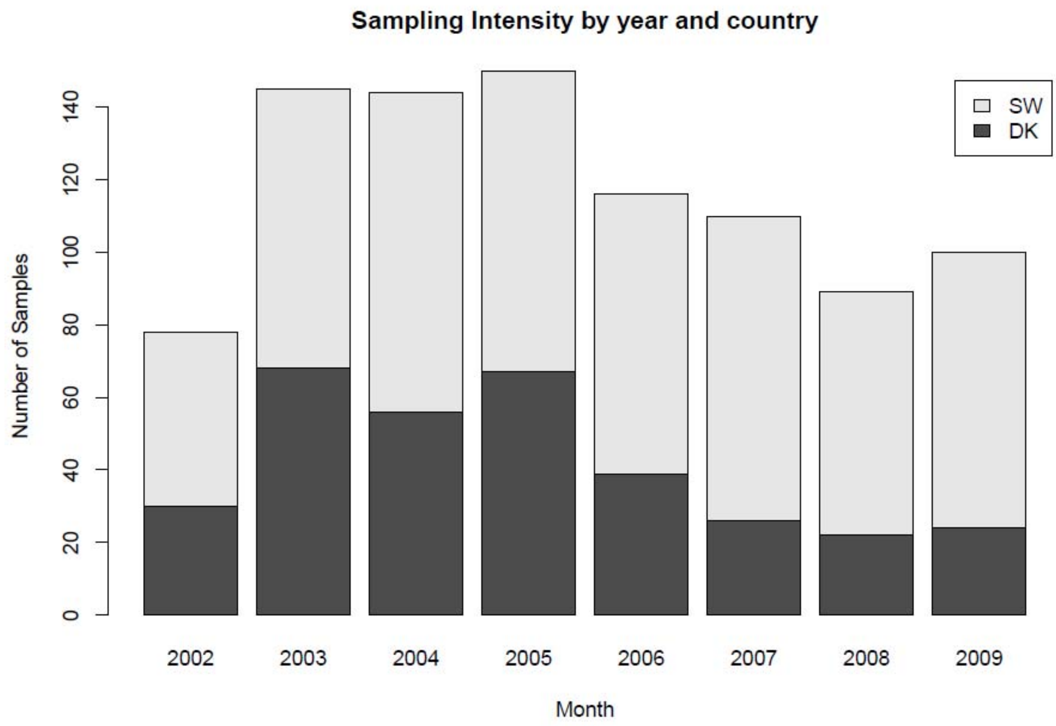


Figure 4.2.2.2: Sampling intensity of Sweden and Denmark in the period 2002-2009.

To illustrate this with the actual between samples variation (variance of 2.86 on logit scale) consider the case where a total of 1000 fish can be sampled with the purpose of estimating stock mixing proportion p in the case where the true p is 0.5. Taking 10 samples with 100 fish in each will result in a standard deviation of 0.5 on the estimated mixing proportion, whereas taking 100 samples with 10 fish in each will result in a standard deviation of 0.2. Figure 4.2.2.4 displays the expected standard deviation as a function of the number of samples (keeping the total number of fish fixed at 1000).

Practical restrictions such as the cost of taking many samples with few fish versus the cost of taking few samples with many fish should naturally also be taken into account. Also the ability to estimate the within sample variability should be preserved, which implies that the number of fish within each sample should be more than one.

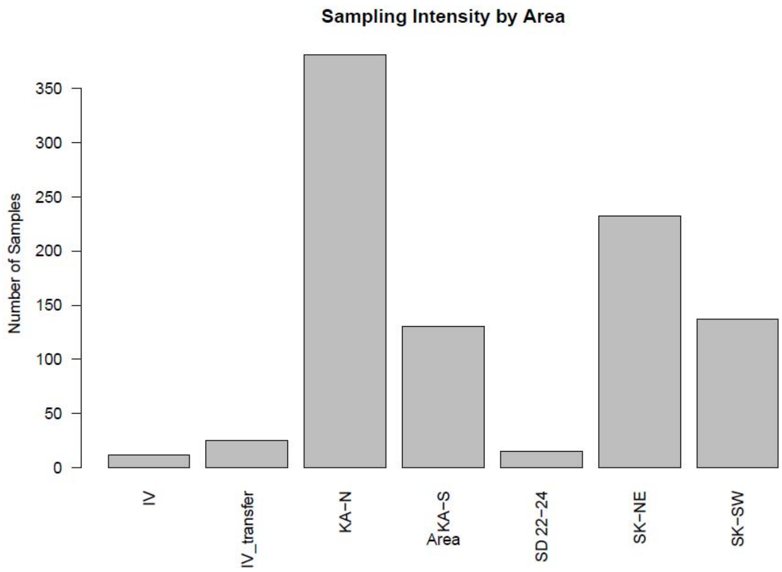


Figure 4.2.2.3: Sampling intensity by area. Legend explanation: IV_transfer=Transfer area in Sub Division IVaE; KA-N= Northern Kattegat; KA-S= Southern Kattegat; SD22-24= Sub Divisions 22-24; SK-NE= North Eastern Skagerrak, SK-SW= South Western Skagerrak (Ulrich et al., 2010).

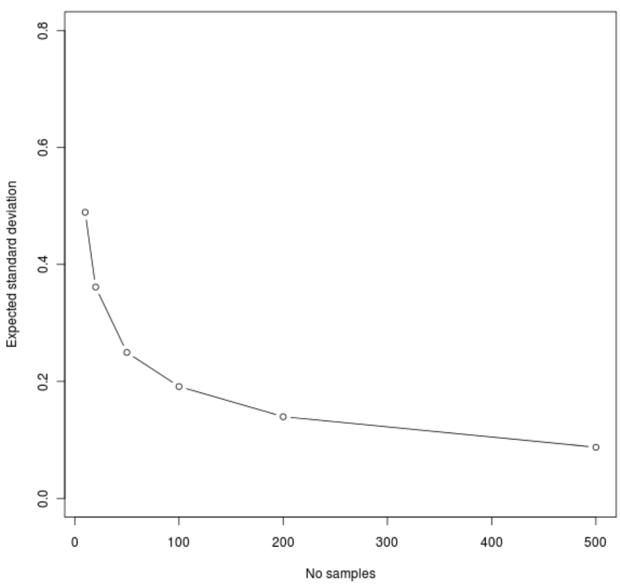


Figure 4.2.2.4. Standard deviation of the estimated logit mixing proportion as a function of the number of samples (keeping the total number of fish fixed at 1000).

Conclusively, the is a space for improvement within area IIIa in order to match the actual fishery pattern The sampling in recent periods very poorly covers the area IVaE (Fig. 4.2.2.3).

The sampling scheme for biological information related to stock affiliation need to be unified following a need for higher resolution in terms of spatial and temporal coverage, but reducing the number of individuals in the samples thus not increasing the workload of the National laboratories by this change in sampling scheme. The suggested change need to be coordinated by the National laboratories through the PGCCDBS following the recommendation from the WKWATSUP.

The presence of local stock components in IIIa may also call for a modification of the current sampling strategy if those components are to be given higher priority to be included in the assessment of the stock mixing in the area. It is however important to notice that the local stock component in IIIa is likely to be less than 5% of the all herring present in the area but more robust estimates should be provided in the future to confirm those estimates.

4.3 Prediction models

Models of stock proportions by age, year, year-class, area, and season describe the effect of differences in recruitment, mortality and migrations, between the stocks and may be used in management scenario evaluation, short and long term predictions as well as input for certain types assessment models. The specific model formulations for prediction of NSAS and WBSS stock proportions in their respective distribution areas apply a GLM approach with a logit transformation of observed proportion in the samples.

The underlying biological assumptions are that juveniles and adults of the two major stocks drift and migrate into the same nursery areas and feeding grounds and form mixed schools depending on encounter rates with co specifics of either stock and retain their mixed aggregations depending on similar habitat related behaviour and subsequent growth pattern.

After hatching NSAS larvae drift from the spawning grounds in the western North Sea to different nursery areas where the juveniles after metamorphosis exhibit a more resident behaviour as in the Division IIIa (see section 3). WBSS larvae exhibit a more restricted dispersion and first after entering the juvenile stage they gradually migrate from the Western Baltic area to the Division IIIa. The different patterns of entry into the mixing area effects the overall proportions in the juvenile stages, but also size differences caused by the lag in hatching time of the two stocks are expected to influence the admixture of local aggregations and schools.

Potential predictions regarding the mixing of NSAS juveniles with the WBSS population re-quires an understanding of the spatial dynamics of the two individual stocks. As discussed above, WBSS herring are generally thought to either reside in this region, or enter through active migration processes. The NSAS juveniles, however, are spawned along the east coast of the British Isles during autumn but are first observed in the Skagerrak and Kattegat areas during the following summer. Potential prediction models must therefore take into account the individual processes, and their variability, that link the spawning and nursery grounds of this stock, and thereby influence the amount if NSAS juveniles in IIIa. Four such processes can readily be identified: the amount and spatial distribution of larvae spawned, survival during the transport phase, passive drift, and active migration. These are each discussed below in turn.

4.4 NSAS herring spawning and productivity of larvae in relation to IIIa

Here we examine whether biological knowledge can aid our understanding of NSAS and WBSS mixing in IIIa, by considering the variability in spawning, mortality rate and transport of North Sea herring larvae and juveniles.

4.4.1 Spawning components of North Sea herring

The NSAS herring stock should be thought of as a collection of individual populations occupying a broad spatial region rather than a single homogenous entity. The known spawning grounds, located along the east coast Great Britain, show fine spatial structure (Dickey-Collas *et al.*, 2010;Figure 3.1.3) and significant events have occurred at the individual bank level (e.g. recolonisation of the Aberdeen bank ground (Corten 1999), loss of the Dogger bank population). However, the individual banks are typically grouped into four spawning components: Orkney-Shetland, Buchan, Banks and Downs.

The individual spawning components have been surveyed on a regular basis by the annual international herring larval survey (IHLS) since the early 1970s (Heath, 1993). These surveys allow us to investigate the dynamics of each component (Payne 2010; Figure 4.4.1).

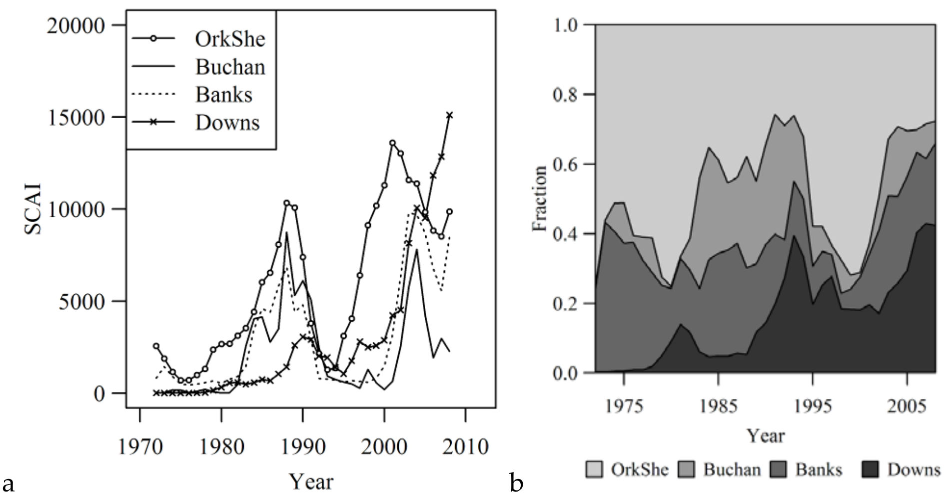


Figure 4.4.1 a) Time series of spawning component abundance index (SCAI) for each individual component in the North Sea Autumn Spawning herring stock b) Time series of the fraction contribution of each spawning component to the total North-Sea Autumn spawning herring stock, as estimated from the spawning component abundance indices (SCAIs). Shaded areas are arranged from top to bottom according to the north-to-south arrangement of the components.

The individual components each follow a broad trend reflecting that of the total stock (i.e. collapse in the late 1970s, peaks in around 1990 and 2000, (Figure 4.3.2)., There also exist appreciable differences especially between the winter-spawning Downs and the other autumn spawning components, leading to the contribution to the stock by each component varying over time (Figure 4.4.1). The Orkney-Shetland component is generally the largest but its contribution has varied between 25% and 80%, whereas, the Downs component has varied from almost negligible in the 1970s to 40% of the stock in recent times.

The variation in the component abundances has important implications for the input of NSAS juveniles into sub-division IIIa. Each component represents a spatially and temporally different starting point for the larvae that are ultimately observed in the Skagerrak as juveniles. In making the transition from spawning ground to nursery ground, the different components will experience different conditions (food availability, temperature, and predation) along the way. Accounting for these differences in both starting points and the number of larvae seeded is therefore critical to predicting the number of individuals that make it to the nursery grounds.

4.4.2 Trends in survival /mortality rates in early stage North Sea herring

The mean mortality rates of newly hatched larvae vary on an inter-annual time-scale, and may also vary in space and between components as well (Fassler *et al*, submitted; Figure 4.4.2a). We also know that for the whole stock the rate of survivorship or larvae to metamorphosis has also changed (Figure 4.4.2b), but it is difficult to investigate the signal of component survival. The survival of juveniles from the pre-metamorphosis stage to the juvenile stage has not shown significant trends over time (Nash and Dickey-Collas 2009; Payne *et al* 2009), although there is some variability about the mean. However, these results are again grouped at the stock level, and there is little or no knowledge about the processes at the component level.

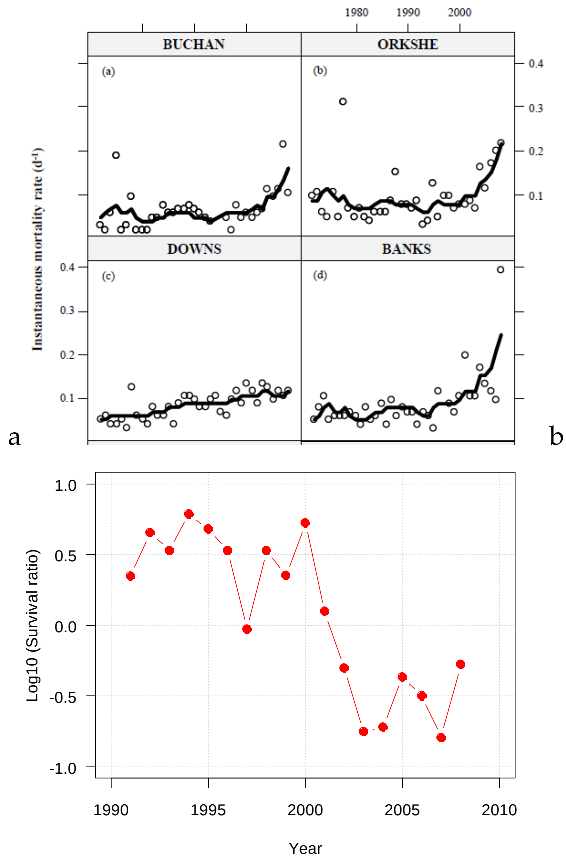


Figure 4.4.2. Mortality and survival of North Sea Autumn Spawned herring larvae as a function of time. a) Newly hatched larvae (taken from Fassler et al., submitted). b) The survival ratio, plotted here on a log10 scale, defined as the ratio of the abundance of early-larvae (as estimated from the multiplicative larval abundance index (MLAI) produced from the international herring larval survey) to that observed in the international bottom trawl survey of age 0 herring (IBTS0).

4.4.3 Delivery of North Sea herring larvae to IIIa

To examine the delivery of larvae from each NSAS component to the eastern North Sea nursery grounds, we need to investigate the transport, growth and survival of the larvae. Oceanographic models can provide insight to many of these processes and here we report on a preliminary investigation into transport from components.

The variability of interannual and intercomponent transport from the spawning grounds to the nursery grounds has been estimated using particle tracking simulations. The IBMlib individual-based modelling library (Christensen and Payne, 2011) was used in a forward-tracking mode to generate particle trajectories, with offline fields from the NORWECOM biogeo-chemical circulation model (Skogen *et al* 1995) providing the underlying oceanographic data-base. Particles representing herring larvae were released on the spawning grounds at times corresponding to the known spawning times and tracked up until the 15th March in the following year. This end date was chosen arbitrarily, as it corresponds approximately to the point where the larvae reach metamorphosis, and therefore start to school and move of their own accord (Gallego 1994): the assumptions about passive planktonic drift inherent in particle-tracking simulations therefore begin to break down at this point.

An example of a particle tracking snapshot at the end of the simulation in 2004 is shown in Figure 4.4.3. In spite of nearly six months of drift time, beginning in August 2003 and running to March 2004, there is still a clear distinction between the distribution of the larvae seeded from the individual component spawning grounds.

An index of the transport efficiency can be generated by considering the number of particles that have been advected into the Skagerrak (here defined as east of 6E and north of 56N) as a function of the total number of particles released. A time series of these proportions (Figure 4.4.4) shows significant interannual variations (in some cases up to three orders of magnitude or more) in the proportions entering IIIa. The transport of particles released at each spawning ground also shows systematic differences between the components (Figure 4.4.5). Particles from the Downs component very rarely reach the Skagerrak before 15th March. The central and northern components reach Skagerrak more frequently, but there is significant variability in the success between years. Particles released on the Banks spawning grounds show a very high degree of interannual variability, whilst the Buchan and Orkney-Shetland grounds show less variability, with the Orkney-Shetland component being the most consistently successful.

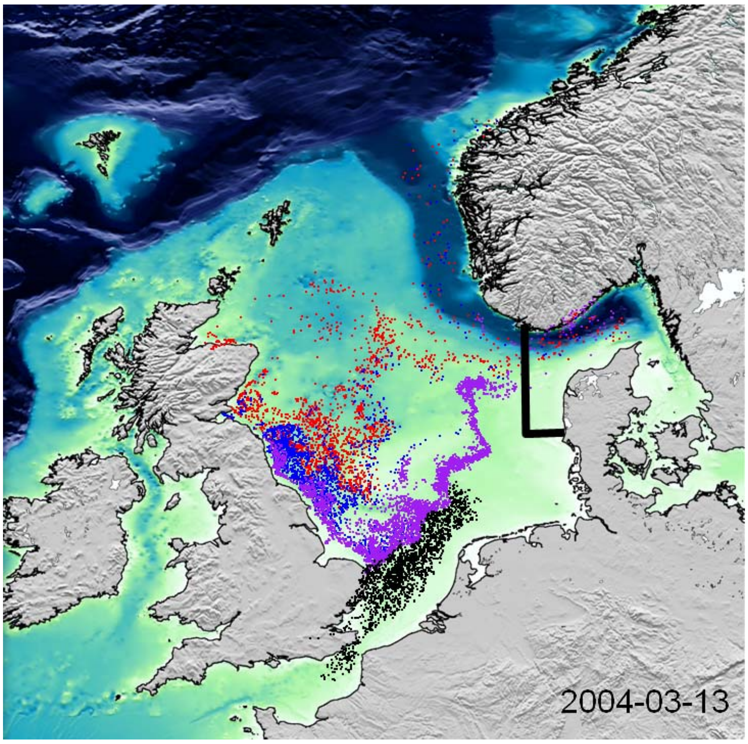


Figure 4.4.3 Particle tracking snapshot corresponding to 13th March 2004. Red points represent Orkney-Shetland spawned particles, blue Buchan particles, purple Banks particles and black Downs particles. The heavy black line at the entrance to the Skagerrak denotes the region used to estimate the particle advection into this region.

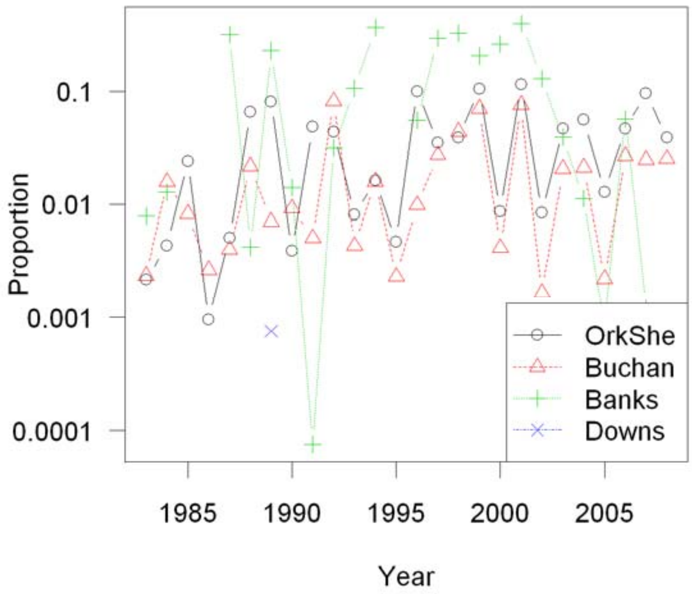


Figure 4.4.4. Delivery to IIIa. Proportion, on a logarithmic scale, of particles released at the various spawning grounds, advected into sub-division IIIa.

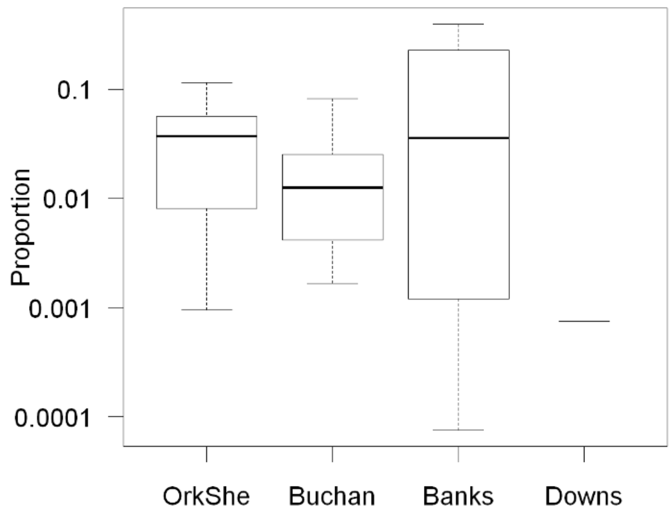


Figure 4.4.5 Box plots showing the distribution (1983-2007) of the proportion of particles re-leased at each spawning component that have been are advected into IIIa by 15th March in the corresponding year.

The particle tracking results serve to characterise the variability in the transport during the larval stages and reflect the modelled distribution of larvae around the time of metamorphosis: however, it is not clear how exactly this relates to the ultimate number and distribution of juveniles that are to be found in the Skagerrak from summer onwards. The particle tracking results presented here were stopped at the 15th March – beyond this point, the onset of schooling and active migratory behaviour is thought to occur, leading to a breakdown of the passive drift assumptions implicit in particle tracking studies. This reemphasises the need to develop demographic and spatial life cycle closure models for herring in the North Sea and western Baltic Sea.

We have examined the transport processes that are thought to influence the input of juveniles from the North Sea Autumn Spawning stock into sub-division IIIa. Transport shows interannual variability, at least at the stock-wide level, and in some cases at the component level. Predicting the input of juveniles into sub-division IIIa requires a further characterisation of these processes. In the current absence of sufficiently complete knowledge, such predictions do not currently seem feasible.

It is, however, possible to identify the outstanding questions that need to be resolved before such predictions can be considered. The first and most pressing need is to understand the link between the end of the larval drift phase, and the observed distribution of juveniles. e.g. At what point does active behaviour start to control the distribution patterns? How much of the transport can be explained by passive drift, and how much by active directed migration (see dickey-Collas *et al*., 2009)?

The second outstanding question relates to the role of survival during the larval stages. It has been shown that the period between the early-larvae and late-larvae stages is critical to determining year class strength of the entire stock (Nash and Dickey-Collas 2005; Payne *et al* 2009). It therefore can be expected that these processes also impact the amount of juvenile NSAS herring, both in total and in the Skagerrak. Given the component-level differences ob-served in drift, larval production and mortality; we require more understanding of the processes before we can predict delivery of herring to IIIa.

Whilst predicting delivery of herring into the IIIa mix is difficult at present; stock specific behaviour and life history traits are well suited parameters for estimating stock proportions in mixed areas, in relation to time (age and season). Whereas variations in spatial distribution of the migrating component (into the IIIa and the Eastern North Sea) and diverging population dynamics of the two stocks may be tracked in the models as year and cohort effects respectively.

4.5 Prediction of the stock proportions

The historic mixing of the two stocks was examined in a statistical framework, in order to quantify both the potential fixed seasonal patterns and the inter-annual variability around them and propose robust standard procedures for forecast and projections. Danish and Swedish samples collected between 2002 and 2009 were used as basic information on the relative proportions of the spawning types composition: given changes in sampling programs and stock identification methods, data prior to 2002 were not considered reliable enough and were thus not included in the dataset. In total, 932 samples, including 29752 fish measured, aged and with identified hatch month, were included. Fish with hatch month between March and June were considered as WBSS, other were pooled and assumed to be NSAS.

Analyses followed to a large extent the approach developed by Bierman *et al.,* (2010) on mixing sub-stocks within the North Sea Herring stock.

Generalized linear mixed models (GLMM) on logit proportion of WBSS in the samples (*split*) were fitted with restricted maximum likelihood (REML) approach, using the glmer function in the lme4 package (Bates & Maechler, 2010) in R (R Core Team, 2010).

Various models were tested, with several combinations of parameters including age, season and area as fixed additive effects and year, yearclass and sample as random effects; Particular attention was dedicated to establishing the most appropriate levels for the plusgroup (from 11+ down to 3+), for the time scale (month, quarter or semester), and for the geographical resolution. This parameter was either considered as categorical variables through grouping the statistical rectangles into various area and subareas definitions, or as continuous data using latitude and longitude. A One-dimensional projection line running through the whole area was also considered.

These various combinations of parameters were compared using an ANOVA. In most cases, the best models could be selected by both the AIC and the BIC criteria. However, in the few cases were the BIC and the AIC were in non-agreement in selecting the best model, the BIC criteria was chosen in order to prioritize the reduction in parameters number.

The final model retained included additive, crossed and random effects as follows:

$$\log(\frac{p}{1-p}) = A_i + Q_j + \beta_1 x + \beta_2 y + \beta_3 x.y + \gamma_{Ai} x + \delta_{Ai} y + U_{key} + U_{year} + U_{cohort} + \varepsilon$$

With p the proportion of WBSS, Ai the age effect from 0 to 4+, Qj the quarter effect, x the centralised longitude, y the centralised latitude, key the sample effect with $U_{key} \sim N(0, \sigma_{key})$, $U_{year} \sim N(0, \sigma_{year})$ and $U_{cohort} \sim N(0, \sigma_{cohort})$.

Most fixed effects were highly significant (Table 4.3.1), and the residuals were independent of the fitted value (Figure 4.3.2).

The actual effect of each coefficient from the GLMM output on the split is inspected using their inverse logit $\frac{e^{coef}}{1+e^{coef}}$, that returns a proportion number between 0 and 1 (Figure 4.3.1). The main outcome of the analysis is the evidence of a clear pattern suggesting increasing proportions of WBSS with age (there is hardly any NSAS in the samples beyond age 3), space (with decreasing proportions with decreasing longitude and increasing latitude, i.e. from SouthEast to NorthWest) and season (with more WBSS in the samples during the second semester compared to the first). Age distribution was also significantly correlated with latitude and longitude.

The analysis of the random effects suggests that a large proportion of the variability is due to the large dispersion of the samples, with a very high σ_{key} (1.69, corresponding to a CV close to 0.5 on the inverse logit). This indicates that the samples are likely not binomially distributed, and may often contain signifcantly more of either spawning type than the average pattern suggests.

On the contrary, the variability from year to year is not particularly high, with $\sigma_{year} = 0.64$ on the logit scale (~ CV=0.28). There has been a decreasing year effect from 2002 to 2007, but this has then reverted and 2009 is the highest positive effect observed.

The cohort effect has also fluctuated over time, with a positive effect of the cohorts born after 2002. This corresponds to the cohorts of low North Sea herring recruitment, which could logically suggest that when the recruitment in the North Sea is poor there is proportionally a lower proportion of NSAS in the area IIIa.

The global spatial pattern by age and quarter can be summarised on the maps Figure 4.3.3.

The same model as above was also fitted for each year individually (though without the U_{year} term and the U_{cohort} term which then is redundant with the age information) , in order to evaluate the potential mismatch between forcing the sample data in a long-term pattern as above, or letting the coefficients reflect more freely the year-to-year variability in the data (Figures 4.3.4 and 4.3.5). Not all yearly models converged properly, and some coefficients were sometimes poorly estimated due to insufficient sampling coverage, in particular for age 0. However, they generally did not exhibit a widely different picture of the main patterns compared to the model fitted on all years.

The observed average split value from the samples across the main regions was compared to the fitted models, both with all years included and with each year fitted individually (Figures 4.3.6 and 4.3.7.). The consistency was in many cases highly satisfying, and particularly for the well sampled strata around the NorthEast Jutland (NorthEastSkagerrak and North Kattegat). However, some particular deviations were also observed, without that these could be linked to a repeated pattern in time and space, or without that this could be easily explained by any other factors than a potential unsufficient sampling in the strata. However, This could potentially bear important consequences, in particular at the edge of the distribution area. Notably, the model captures a very high presence of WBSS during Quarter 4. While this is a sensible outcome for IIIa as the fish are assumed to migrate back across the area towards spawning grounds, this may be erroneous for area IV (Transfer area) as WBSS would have already left this area of summer feeding and should then be less numerous during Quarter 4. But the very low sampling level in this area doesn't allow the model to infer this properly.

Finally, both approaches (Long_term model and yearly models) were applied to the international landings by ICES Rectangle from area IIIa (fleets C andD), using the relative age distribution by area from yearly HAWG reports to evaluate the differences of Catch-At-Age that could enter in the assessment. It is to be noted that due to some discrepancies between the total landings estimated over years by HAWG and the sum of total international landings used here, these figures are not directly comparable to the HAWG figures.

Tables and Figures for this section are found in Annex 3.

4.6 Conclusions and recommendations

There are on average only very small deviations between using the split models or taking the raw average of the samples (Figure 4.3.8), indicating that using the split may not dramatically affect the perception of the catch ratios and subsequent F at age in the assessment for the ages 3 to 6 used for computing the Fbar. However, more differences were observed for ages 0 to 2, where most of the mixing occurs. Furthermore, this apparent consistency hides some larger variations at the Quarter level (Figure 4.3.9).

It was not possible to evaluate the consequences of this split modelling further. It is expected that this work will continue, and a more thorough evaluation should be performed until the next HAWG in spring 2011.

The variance in proportions among samples is very high and therefore a modelling approach to predicting the stock proportions for each fleet in the mixing area is expected to reduce noise and make a more precise prediction of stock proportions than the recent HAWG procedures of a three years' average or values from the preceding year.

The more detailed models including year-class effects may give more robust estimates when proportions are changing due to opposite population trends. Seasonal effects on the other hand may be included when there is a firm knowledge of a shift in the timing of the fishery in the mixing area.

The WK recommends that further effort is put into refining and peer reviewing the modelling approach to estimating stock proportions in catches, to arrive at a robust short term projection of population development at specified catch options. These refinements could include evaluating whether fitting a GAMM on the data would avoid linearity in assumptions accounting for continuity in time and spatial predictors.

5 Setting a mixed TAC in the Skagerrak and Kattegat and the compatibility with the precautionary approach and with the objective of reaching FMSY by 2015 (ToR 3)

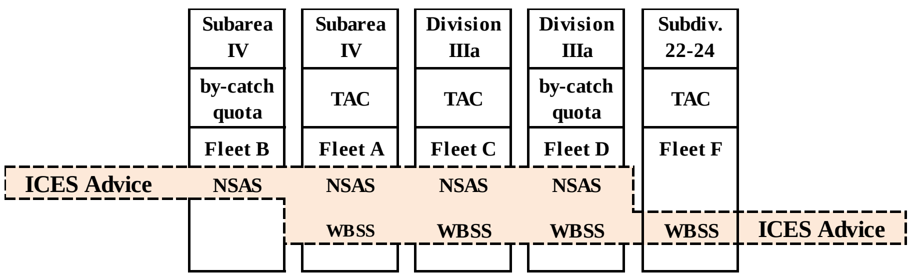
5.1 Introduction

Managing a mixed TAC in IIIa taking into account the above described LTMP's is a paradox not easily accessed. The risk of not adhering to one of the plans when setting the TAC is unavoidably high. Both plans are aiming at the same goal of reaching an FMSY of 0.25, however, they are not always compatible in practise for setting a mixed TAC as each stock is considered individually and their dynamic may diverge. It is likely not to be possible to reach simultaneously all objectives of 1) protect the weaker stock, 2) keep the inter-annual variability in the catch constraint within the agreed boundaries, 3) to reach FMSY and 4) adhere to the assumed split of the TAC between Subdivision 22-24 and Division IIIa.

5.1.1 Introduction of the current advice setting for herring in division IIIa and subdivision 22-24

Advice and Management areas

ICES gives advice on catch options for the entire distribution of the two herring stocks separately, whereas herring is managed by areas:



Forecast Software

Till 2009, short term predictions were made with:

- Multi fleet deterministic Projection (MFDP) Version 1a
- Multifleet Yield per recruit (MFYPR) Version 2a

In 2010, the software for the short term prediction was changed to

- Standard projection routine developed under FLR package ‚Flash' Version 2.0.0

Forecast Basic Input Data (single fleet)

- Population numbers and fishing mortalities derived from catch-at-age analysis
- Estimates of weights at age, natural mortality, maturity at age etc. derived from the input data to the catch-at-age analysis
- Estimates of recruitment during the prediction period

The following input was used in 2010 (HAWG 2010):

2010 (Intermediate year)	Age	N	M	Mat	PF	PM	SWt	Sel	CWt
	0	1627212	0.30	0.00	0.10	0.25	0.000	0.013	0.015
	1	2544477	0.50	0.00	0.10	0.25	0.019	0.234	0.054
	2	365738	0.20	0.20	0.10	0.25	0.058	0.387	0.074
	3	251962	0.20	0.75	0.10	0.25	0.085	0.411	0.095
	4	157474	0.20	0.90	0.10	0.25	0.118	0.450	0.123
	5	113001	0.20	1.00	0.10	0.25	0.146	0.491	0.141
	6	67453	0.20	1.00	0.10	0.25	0.163	0.476	0.158
	7	61531	0.20	1.00	0.10	0.25	0.167	0.450	0.175
	8+	47949	0.20	1.00	0.10	0.25	0.182	0.450	0.192

2011 (Advice year)	Age	N	M	Mat	PF	PM	SWt	Sel	CWt
	0	1627212	0.30	0.00	0.10	0.25	0.000	0.013	0.015
	1	-	0.50	0.00	0.10	0.25	0.019	0.234	0.054
	2	-	0.20	0.20	0.10	0.25	0.058	0.387	0.074
	3	-	0.20	0.75	0.10	0.25	0.085	0.411	0.095
	4	-	0.20	0.90	0.10	0.25	0.118	0.450	0.123
	5	-	0.20	1.00	0.10	0.25	0.146	0.491	0.141
	6	-	0.20	1.00	0.10	0.25	0.163	0.476	0.158
	7	-	0.20	1.00	0.10	0.25	0.167	0.450	0.175
	8+	-	0.20	1.00	0.10	0.25	0.182	0.450	0.192

2012 (Continuation year)	Age	N	M	Mat	PF	PM	SWt	Sel	CWt
	0	1627212	0.30	0.00	0.10	0.25	0.000	0.013	0.015
	1	-	0.50	0.00	0.10	0.25	0.019	0.234	0.054
	2	-	0.20	0.20	0.10	0.25	0.058	0.387	0.074
	3	-	0.20	0.75	0.10	0.25	0.085	0.411	0.095
	4	-	0.20	0.90	0.10	0.25	0.118	0.450	0.123
	5	-	0.20	1.00	0.10	0.25	0.146	0.491	0.141
	6	-	0.20	1.00	0.10	0.25	0.163	0.476	0.158
	7	-	0.20	1.00	0.10	0.25	0.167	0.450	0.175
	8+	-	0.20	1.00	0.10	0.25	0.182	0.450	0.192

Input units are thousands and kg - output in tonnes

MAT = Maturity ogive
PF = Proportion of F before spawning
PM = Proportion of M before spawning
SWt = Weight in stock (kg)
Sel = Exploit. Pattern
CWt = Weight in catch (kg)

$N_{2010,2011,2012}$ Age 0:	**Geometric Mean from ICA (Table 3.6.8) 2004-2008**
N_{2010} Age 1-8+:	**Output from ICA (Table 3.6.15)**
Natural Mortality (M):	**Average for 2007-2009**
Weight in the Catch/Stock (CWt/SWt):	**Average for 2007-2009**
Selection pattern (Sel):	**Average for 2007-2009**

Intermediate Year Assumptions for 2010 (HAWG 2010)

A catch constraint was calculated for the intermediate year based on following assumptions:

- **Transfer of 20 % of the Norwegian quota (fleet C)** from IIIa to the North Sea: 1006 tonnes were subtracted from the TAC in 2009 and 903 t subtracted from the TAC in 2010
- **Misreporting** of catches from the North Sea into Division IIIa is no longer assumed to occur after 2008
- **TAC utilisation by fleet in 2010:**
  - ➢ C- and F-fleet (human consumption) = 100 % (since in 2009 close to the TAC)
  - ➢ D-fleet (small meshed fishery) = 52% (as in 2009)
- **Fractions of the total catch** of WBSS in Division IIIa taken by fleets C and D in 2009 are used for 2010/2011 (fraction of WBSS in fleet F/SD 22-24 is per definition 100 % WBSS herring)

- An additional amount of 3 941 t of WBSS taken in the **transfer area in Division IVaE** in 2009 is used for 2010/2011

The resulting expected catch of WBSS in 2010 (HAWG 2010) following this scheme was:

	2009				2010				
Stock	WBSS	NSAS	WBSS +NSAS	WBSS +NSAS	WBSS +NSAS	WBSS +NSAS	WBSS +NSAS	WBSS proportion	WBSS
Parameter	Catch	Catch	Catch	TAC	TAC	TAC assumed	TAC realised	Catch	Catch
Unit	(t)	(t)	(t)	(t)	(t)	%	(t)	(%)	(t)
A-fleet	3,941		3,941					100	3,941
C-fleet	29,426	5,056	34,482	*36,716	*32,952	100	32,952	85,34	28,120
D-fleet	2,863	1,486	4,349	8,373	7,515	52	3,903	65,83	2,570
F-fleet	31,032		31,032	27,176	22,692	100	22,692	100	22,692
Total	67,262	6,542	73,804	72,265	63,159		59,547		57,323

*After accounting for Norwegian transfer of quota from Division IIIa to the North Sea:
1 006 tonnes in 2009 and 903 tonnes in 2010

Forecast results in 2010 (HAWG 2010)

The short-term prediction multiple option table in 2010 (HAWG 2010) gave following results:

2010 Biomass	SSB	FMult	FBar	Landings
155534	76221	0.9335	0.4267	57323

2011 Biomass	SSB	FMult	FBar	Landings	2012 Biomass	SSB
167670	77285	0.0000	0.0000	0	221776	134789
		0.1000	0.0457	7369	214402	128840
		0.2000	0.0914	14470	207310	123158
		0.3000	0.1371	21311	200491	117730
		0.4000	0.1828	27904	193932	112546
		0.5000	0.2286	34258	187625	107594
		0.6000	0.2743	40382	181558	102864
		0.7000	0.3200	46285	175722	98345
		0.8000	0.3657	51975	170108	94028
		0.9000	0.4114	57462	164708	89904
		1.0000	0.4571	62752	159513	85964
		1.1000	0.5028	67853	154514	82200
		1.2000	0.5485	72773	149704	78604
		1.3000	0.5942	77518	145076	75168
		1.4000	0.6400	82095	140623	71885
		1.5000	0.6857	86511	136337	68748
		1.6000	0.7314	90771	132212	65750
		1.7000	0.7771	94882	128241	62886
		1.8000	0.8228	98849	124420	60149
		1.9000	0.8685	102678	120741	57533
		2.0000	0.9142	106373	117199	55033

Input units are thousands and kg - output in tonnes

The output of the forecast is then transferred to an ‚Interpolation Sheet' (Authors: Sieto Verver/Martin Pastoors (WGNSSK 2004) based on original interpolation sheets made by Rick Officer) in order to get the results for different catch options (e.g. zero catch, +- 15 % TAC, F_{MSY} = 0.25)

Assumption for fleet wise catch for 2011 (HAWG 2010)

The following assumptions for fleet wise catch options were used for 2011 (HAWG 2010):

- TAC distribution by fleet will be equal to 2010
- 20 % of the Norwegian quota in IIIa is transferred to IVa East
- TAC is taken by 100 %
- 2009 proportion of WBSS in the catch by fleet
- 2009 WBSS catch of 3,941 t in IVa East

5.1.2 Co-managing a mixed TAC taking into account current and future LTMP's

The long term management plan for North Sea herring (agreed between the EU and Norway) has been in operation in various forms since 1996 (Simmonds 2009). When adhered to, it has proven itself a useful mechanism to sustain the stock and its exploitation even when the productivity of the stock changes (Dickey-Collas *et al.,* 2010). A similar plan it now proposed for WBSS. It is always problematic to sustainably manage adjacent stocks of different sizes especially if the stocks mix or are exploited by the same fleets (Kell *et al.,* 2009).

Both plans aim at the same goal of exploiting the stocks at an FMSY of 0.25, however, they are not always compatible in practice for setting a mixed TAC. Sustainably exploiting a stock with changes in within stock behaviour or dynamics is difficult if the stock is managed across multiple management areas and yet relative stability between exploiting nations is not allowed to change. Setting a mixed TAC based on the TAC's set under the LTMP's for both stocks could potentially result in a relaxation of the 50-50% allocation rule between area IIIa and 22-24, which would have consequences for relative stability among EU member states and other nations. This would be the case when i.e. the WBSS stock is adjusted by a restriction and the NSAS stock is adjusted by an increase. The subdivisions 22-24 would only be subjected to a restrictive adjustment, whereas the subdivision IIIa would be less influenced by the restriction on the WBSS due to a levelling out by the increasing adjustment for NSAS.

Neither LTMP (NSAS and the proposed WBSS) was developed to account for mixing and joint exploitation by the same fleets. Adhering to the precautionary principle would mean that many of the interactions between NSAS and WBSS in IIIa should be accounted for in the management plans, or at least the LTMP should be made robust to natural variability and mixing in IIIa. At present this is more important to the sustainable exploitation of WBSS, as this is a much smaller stock. In addition the presence of even smaller local stocks in IIIa, needs to be accounted for. Thus it is not a simple act of just merging two LTMP though they aim at the same goal.

A possible solution to at least take the dynamics of the two separate stocks into account could be to take all the stock properties and the variability in the degree of mixing between them in the subdivision IIIa is to assess both stocks simultaneously giving the opportunity to evaluate the future adjustments necessary in unison for the two stocks. Such an alternative model is under development and is further described in Section 6.3.

5.2 Methods applied to assess the mix TAC opportunities for IIIa

The WKWATSUP was asked to evaluate a number of options for assessing the mix TAC opportunities for herring in subdivision IIIa. For the purposes of these evaluations, it needed to be assumed that 50% of the TAC for the WBSS will be allocated to Division IIIa and 50% to SD 22-24. The 50:50 split of the catch options of WBSS between the two areas do not reflect the actual distribution of the catches. Over the past

10 years, in only three occasions (2000, 2002 and 2009) a 50:50 split can be observed in the realized catch.

To be able to evaluate the four ToRs, a short term forecast model was constructed. The details of this model are given below.

5.2.1 The short term forecast procedure for setting TACs for the catches in IIIa and 22-24

The procedure of setting TACs in ICES area IIIa and 22-24 takes into account many different factors, i.e. four different fleets, catches of both Western Baltic Spring Spawning (WBSS) and North Sea Autumn Spawning (NSAS) herring, utilization of TACs and the proportion of NSAS and WBSS that mix in the areas. The flowchart below explains how these different components interact and result in TAC advice for the fleets in ICES area IIIa and 22-24. The flowchart is divided into 5 boxes to being better able to link the explanation below to the process.

Box 1: Each year, an estimation of the WBSS and NSAS stock size is made using a stock assessment model. This model uses information from the catches, surveys and sampling on board commercial vessels, surveys and in harbours. The details of the stock assessment can be found in the stock annex (ICES 2010). The stock size estimation, together with its estimated harvest pattern are used as the starting point for the short term forecast.

Box 2: To derive at a TAC proposal in the forecast year, first the intermediate year (the year where the TAC has already been agreed on) catches need to be resolved. Four different fleets catch WBSS, the A fleet (within the IVaEast area where they take it as a mixture of mainly NSAS and partly WBSS), the C and D fleet (within the IIIa area where they take it as a mixture of mainly WBSS and partly NSAS) and the F fleet (within area 22-24 where they only take WBSS). Each of these fleets target herring taking into account a fleet share of the total TAC. Only part of this TAC is WBSS catches and not all fleets utilize their full TAC fleet share. This results in an estimate of the intermediate year WBSS catches. Given WBSS stock size and these intermediate year catches, the fishing mortality the WBSS stock was exploited at can be estimated.

Box 3: Based on the estimated fishing mortality we can now calculate the survivors from the intermediate year to the forecast year, assuming an incoming year class of 0 year olds. The calculation of the stock size in the forecast year is needed to project catches in the forecast year.

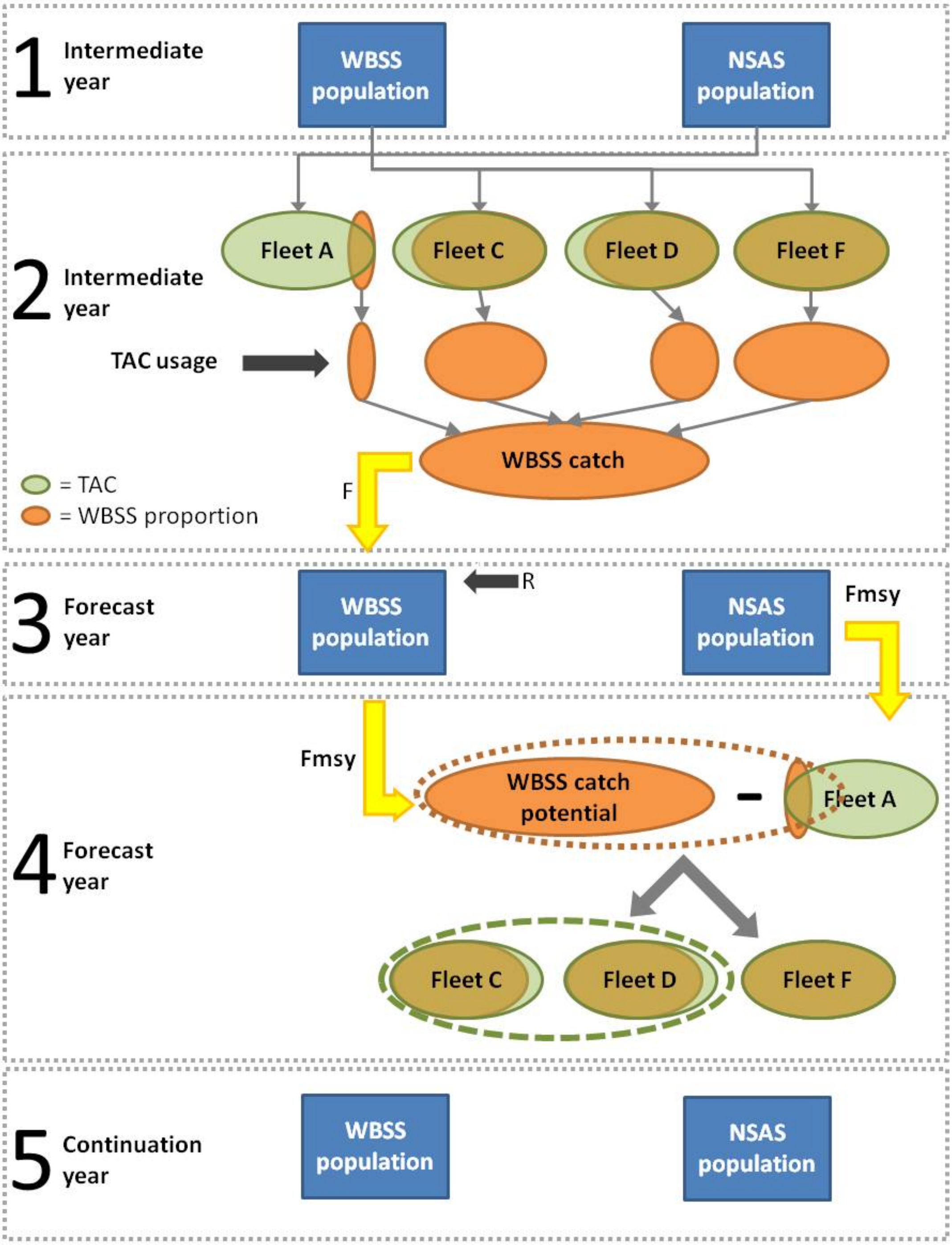
Box 4: The EC targets to g*et al*l stocks exploited at Fmsy by the year 2015. From now until 2015 there is an Fmsy transition period. Therefore, catches of WBSS in forecast year are assumed to be caught at Fmsy levels too, appropriately taking the transition equation into account (see transistion eqn 5.2.1). The potential WBSS catches are used to define the total TAC in ICES area IIIa and 22-24. Therefore, first the WBSS catches taken by the A fleet in the North Sea need to be taken into account. It is up to expert knowledge where these catches are subtracted from (either the C and D fleet share, or the C, D and F fleet shares). It is the intention to split the remainder between the F and the C & D fleet according to a 50% - 50% ratio. To derive the C and D fleet TAC however, a proportion of NSAS needs to be added here because of the mixed fishery on both WBSS and NSAS by these fleets. Therefore, the TAC of the C and D fleet is larger than the proposed catches of WBSS by these fleets. The ratio between the C and D fleet equals to 4:1.

Box 5: The TAC advice from box 4 is taken into the political arena. The result of this will be taken into account to calculate the WBSS population again the year after. Hence, box 5 is similar to box 1.

$$if(SSB < Bpa)\ F_{2011} = \min\left(0.8 * F_{2010} + 0.2 * Fmsy * \frac{SSB_{2010}}{Bpa}, Fpa\right)$$

$$if(SSB \geq Bpa) F_{2011} = \min(0.8 * F_{2010} + 0.2 * Fmsy, Fpa)$$

Equation 5.2.1: The FMSY transition equation applied



5.2.2 Technical details of the short term forecast

Within the short term forecasts assumptions have to be made regarding e.g. expected growth of year classes, maturity development of the fish and the incoming recruits. These details are listed below.

Recruitment in the intermediate to the continuation year is assumed equal to the geometric mean of the level of recruitment in 5 years before the assessment year, i.e. in 2010 this recruitment was calculated as the geometric mean of recruitment over the years 2004 – 2008. A recent study has shown that, with the available data, there is no relationship between stock and recruitment for the WBSS stock, neither did any environmental predictors tested in the analysis give any explanation of the recruitment patterns observed (Cardinale *et al.*, 2009).

All other biological components like natural mortality-at-age, time of spawning, weight-at-age in the stock, maturity-at-age and landing weight-at-age are assumed to be similar to the estimates from the assessment year.

The harvest pattern by fleet (partial F's) is obtained by multiplying the assessed harvest pattern by the proportion of catches at age by the fleet. Partial weights-at-age in the fleet catches are taken as estimated from samples.

The main ages targeted by the combination of the fleets are ages 3-6. These ages are used to calculate the WBSS catch potential following the Fmsy transition framework.

The proportion at age of WBSS and NSAS in ICES area IVaEast, IIIa and 22-24 are calculated using a glmm (see Section 4.3.1). Within the short term forecast, a prediction is made for these three areas taking the center of gravity of the catches by area as the longitude-latitude combination to predict the split. The split proportions are predicted on a quarterly basis and turned into a yearly estimate by weighting the split proportions to the quarterly catches.

Usage of the TAC is taken as the realized catch divided by the TAC in the assessment year. If this proportion is bigger than 1, it is assumed to be 1 in the intermediate and forecast year.

5.2.3 Implementation of the ToRs into the procedure of the short term forecast

ToR-a: the short term forecast procedure is followed as given in the flowchart from box 1 to box 4. However, the TAC of the C-fleet is hereafter reduced by the average of the increase in NSAS TAC and reduction in WBSS TAC in 2010. This averages to a decrease of 7.5% of C fleet TAC.

ToR-b: the short term forecast procedure is followed again as given in the flowchart from box 1 to box 4. In this occasion, not the average change of NSAS and WBSS TAC is taken to modify the C fleet TAC, but the weighted average of these TACs is taken. The catches of WBSS versus catches of NSAS in the IIIa area are used to set this weighting. This results in a reduction of 23% of the C fleet TAC. TACs as proposed by the short term forecast are kept the same for all other fleets.

ToR-c: the short term forecast procedure is followed again as given in the flowchart from box 1 to box 4. Here, the TAC of the C fleet is reduced by 30%. TACs as proposed by the short term forecast are kept the same for all other fleets.

ToR-d: the short term forecast procedure is followed again as given in the flowchart from box 1 to box 4. The TAC of the D fleet is reduced by 30%. TACs as proposed by the short term forecast are kept the same for all other fleets.

The newly derived TACs are used to calculate the fishing mortality by fleet, the WBSS catches by fleet that follow from this fishing mortality and the development in SSB in the forecast and continuation year.

Three different scenarios were evaluated incorporating each of these four ToRs. In the first scenario, it was assumed that the A-fleet would not fish in IVaEast, which automatically results in no catches of WBSS by the A fleet. Both the second as the third scenario deal with the procedure to subtract the A fleet catches from the WBSS catch potential in the forecast year. In the second scenario, it is assumed that the WBSS catch potential is first split 50%-50% to the C & D and F fleet. The A fleet catches are subtracted from the C & D fleet share. In the third scenario, the A fleet catches are subtracted from the total WBSS catch potential and the remainder is hereafter split 50%-50% to the C & D and F fleet.

5.2.4 Interpretation of the ToRs:

At the end of the workshop it became clear that the interpretation of the ToRs was not unambiguous. Several participants from the industry pointed out that another interpretation of the ToRs, different from the interpretation described above, could be given. This difference results in a difference in C and D fleet TACs, For a detailed explanation of this alternative interpretation and its expected implications, see Annex 4.

In the standing interpretation, the WBSS catch potential is split 50:50 to the F and C & D fleet. To calculate the C and D fleet TAC NSAS catch needs to be added to the WBSS catch, because of the mixed nature of these fisheries. This results in a C and D fleet TAC advice. Hereafter, either the C or D fleet TAC is reduced by the percentage described in the ToRs. In e.g. ToR-a the TAC of the C fleet is reduced by 7.5% as the NSAS TAC increases with 15% while the TAC of the F fleet will decrease by 30%.

There will be a quantitative difference between these two interpretations and it should be noted that the alternative interpretation is a less precautionary approach for the WBSS population as it follows the trends in WBSS to a lesser extent.

5.3 Results

Using the framework as described in section 5.2, each of the four ToRs are addressed. As the A fleet forms a special situation in the evaluation, as it takes WBSS catches in IVaEast, three scenarios were designed to evaluate different treatments of the WBSS catches by the A fleet.

In the first scenario, no WBSS catches are taken by the A fleet in IVaEast. In the second scenario, WBSS catches by the A fleet are subtracted from the C & D fleet share after the total WBSS catch potential has been divided over the C & D and F fleet, while in the third scenario the A fleet WBSS catches are first subtracted from the total potential WBSS catches where after the remainder is split over the C, D and F fleets.

In table 5.3.1 the fishing mortality (taken as an average over a specified group of ages), catches and estimated SSB are given for the intermediate year. In all scenario's and under all ToRs, the intermediate year results are the same.

	Fbar 3-6 A	**Fbar 3-6 C**	**Fbar 0-1 D**	**Fbar 3-6 F**	**Fbar 3-6**	**Fbar 0-1**	**Catch A**	**Catch C**	**Catch D**	**Catch F**	**Total Catch**	**SSB 2010**
intermediate year	0.026	0.109	0.026	0.265	0.404	0.097	6308	26978	3156	22692	59134	81595

Table 5.3.1: Statistics on fishing intensity and catch by fleet.

Under the Fmsy transition period, the F target for the forecast year is set at 0.8 * Fbar 3-6 in the intermediate year + 0.2 * Fmsy * SSB2010 / Bpa. This results in an target F for the forecast year of 0.36 Following this F target, the WBSS catch potential in the forecast year amounts to 50782 thousand tonnes.

The tables below show the fishing mortality by fleet as calculated over a selected range of ages (3-6 years old or 0-1 years old). As well, SSB estimation in 2011 and 2012 is given. The second series of tables show the catches by fleet and the TAC under the ToR target. The difference between the catch of e.g. fleet C and its TAC is the amount of NSAS that are assumed to be caught by the C fleet. Hence, the catches in the table are WBSS catches only. As the F fleet takes 50% of the potential WBSS catch, it amounts to 25391 thousand tonnes. However, under scenario 3, the A fleet catches are subtracted from the total potential WBSS catch and hence, the F fleet TAC and catches do not amount up to 50% of the total WBSS potential catch. Under scenario 1, there are no A fleet catches allowed which results in an Fbar and catches of the A fleet of zero. Total catch within one ToR setting can differ because of the handling of the A fleet catches. The A fleet targets different age classes than the C and D fleet. Hence, they can complement each other which results in a combined higher catch. The total catches between ToRs differ because the TACs are changed for the C and D fleet.

The development in SSB shows that a closure of the IVaEast area for WBSS catches would result in the highest increase given the bound on TAC reductions as proposed in ToR a-c. As under ToR d the D fleet, mainly catching juvenile WBSS herring, TAC is reduced, SSB can increase even more on the short term. It is very likely however that this effect will have less effect on the SSB development on the longer term than observed in the short term.

ToR a:

	Fbar 3-6 A	Fbar 3-6 C	Fbar 0-1 D	Fbar 3-6 F	Fbar 3-6	Fbar 0-1	SSB 2011	SSB 2012
Scenario 1	0	0.06	0.026	0.255	0.318	0.07	76067	105289
Scenario 2	0.036	0.043	0.019	0.258	0.34	0.054	75560	103282.2
Scenario 3	0.035	0.051	0.022	0.219	0.307	0.059	75775	105280.2

	Catch A	Catch C	Catch D	Catch F	Catch	TAC A	TAC C	TAC D	TAC F
Scenario 1	0	17214	2406	25391	45011	0	20391.91	5511.327	25390.97
Scenario 2	7116	12568	1757	25391	46832	7419	14901.85	4027.527	25390.97
Scenario 3	7118	14692	2054	21681	45545	7419	17412.75	4706.148	21681.47

ToR b:

	Fbar 3-6 A	Fbar 3-6 C	Fbar 0-1 D	Fbar 3-6 F	Fbar 3-6	Fbar 0-1	SSB 2011	SSB 2012
Scenario 1	0	0.05	0.025	0.254	0.307	0.064	76157	106938.7
Scenario 2	0.036	0.036	0.018	0.257	0.332	0.05	75627	104481.6
Scenario 3	0.035	0.042	0.022	0.217	0.298	0.054	75852	106688.2

	Catch A	Catch C	Catch D	Catch F	Catch	TAC A	TAC C	TAC D	TAC F
Scenario 1	0	14476	2407	25391	42274	0	17148.88	5511.327	25390.97
Scenario 2	7115	10569	1758	25391	44833	7419	12531.93	4027.527	25390.97
Scenario 3	7118	12356	2055	21681	43210	7419	14643.51	4706.148	21681.47

ToR c:

	Fbar 3-6 A	Fbar 3-6 C	Fbar 0-1 D	Fbar 3-6 F	Fbar 3-6	Fbar 0-1	SSB 2011	SSB 2012
Scenario 1	0	0.045	0.025	0.253	0.301	0.061	76205	107813.9
Scenario 2	0.036	0.033	0.018	0.257	0.327	0.048	75662	105117.6
Scenario 3	0.035	0.038	0.022	0.217	0.293	0.052	75893	107434.9

	Catch A	Catch C	Catch D	Catch F	Catch	TAC A	TAC C	TAC D	TAC F
Scenario 1	0	13027	2407	25391	40825	0	15431.71	5511.327	25390.97
Scenario 2	7115	9511	1758	25391	43775	7419	11277.07	4027.527	25390.97
Scenario 3	7117	11119	2055	21681	41972	7419	13177.21	4706.148	21681.47

ToR d:

	Fbar 3-6 A	Fbar 3-6 C	Fbar 0-1 D	Fbar 3-6 F	Fbar 3-6	Fbar 0-1	SSB 2011	SSB 2012
Scenario 1	0	0.065	0.018	0.256	0.323	0.065	76035	104811.8
Scenario 2	0.036	0.047	0.013	0.259	0.343	0.05	75536	102933.1
Scenario 3	0.035	0.055	0.015	0.219	0.311	0.055	75748	104871.3

	Catch A	Catch C	Catch D	Catch F	Catch	TAC A	TAC C	TAC D	TAC F
Scenario 1	0	18606	1684	25391	45681	0	22045.31	3857.929	25390.97
Scenario 2	7116	13585	1230	25391	47322	7419	16110.11	2819.269	25390.97
Scenario 3	7119	15881	1438	21681	46119	7419	18824.59	3294.304	21681.47

5.4 Conclusions

The WKWATSUP did not find any of the above options optimal to manage the mixed stock in Division IIIa, thus the group set up a different management rule for setting such a TAC, which would be compatible with the precautionary approach and with the objective of reaching FMSY by 2015:

- Set the TAC for the WBSS according to the FMSY or FMSY transition framework for WBSS only, do not account for the impact on NSAS. If it appears in the future that the NSAS is greatly impacted by management of the WBSS, this rule needs to be re-evaluated
- The WKWATSUP recommend a seasonal closure of parts of the Eastern North Sea (see section 6.2), however, until till is implemented the WK recommend that the fraction taken in this area should be subtracted from the total TAC for the WBSS before sharing the TAC between Division IIIa and Subdivisions 22-24.
- In the mixing area (Division IIIa), the best estimates of the proportions of the NSAS and WBSS in the catch by fleet should be used to calculate the combined catch options in compliance with the targeted catch for WBSS.

The advice is supported by the short term forecasts displayed in the tables in section 5.3. It is important to underline, that this table do not replace the advice given from ICES for the WBSS stock (ICES 2010), the table was produced using an entirely different model setup and was used to evaluate the ToR's a) to d) under ToR 3.

The WKWATSUP was asked to suggest and evaluate alternative options for splitting the WBSS TAC, taking into account the seasonal movements of the stock. However, the group could not conclude whether to continue applying a 50:50 split between Division IIIa and Subdivisions 22-24 or give any alternatives to this rule. Thus the results displayed in section 5.3 showing short term forecasts under the various management options evaluated by the group are done applying a 50:50 rule under 3 forms.

6 Suggested alternatives to the TAC measure for the mixed herring stock. (ToR 4)

6.1 Introduction

WKWATSUP discussed options other than a mixed stock TAC that could either replace or supplement the TAC measure and maintain the targets laid down in the management plans for WBSS and NSAS. No direct conclusions could be made on this subject; however some options were discussed as potential ways to protect the most vulnerable component of the mixture based on the seasonal spatial pattern of the mixture of the stocks.

6.2 Seasonal or spatial limitations

The extended migration of the older age groups, 2-3+ winter ringers (wr) of WBSS herring out into the Eastern North Sea during summer feeding migrations subjects this part of the stock to additional exploitation. This means that the majority of the SSB will be exploited in Subdivision 22-24, Division IIIa and the eastern part of the North Sea close to the Danish and Norwegian coasts (Figure 6.2.1). From the HERAS summer acoustic survey it is evident that the part of the WBSS migrating out of the

Division IIIa and into the North Sea both encompass 2 wr ('immature') and 3+wr ('mature'), Figure 6.2.1. Although this share does vary between years, it is not an insignificant part of the population.

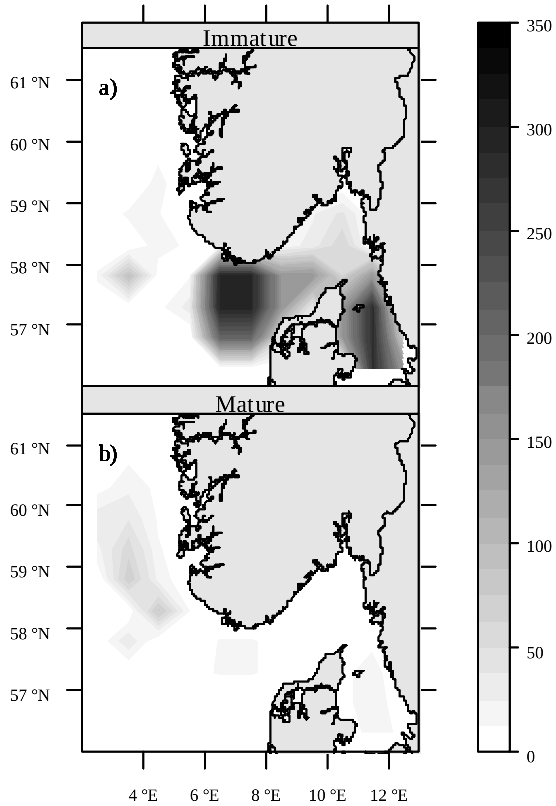


Figure 6.2.1 Integrated distribution maps of WBSS herring in the Skagerrak, Kattegat, and eastern North Sea from the international ERAS in 2005 for (a) immature and (b) mature fish. Note that the abundance scales are not comparable between the two panels (Payne *et al.*, 2009)

A seasonal closure of parts of the Eastern North Sea, covering the distribution area of the farthest migrating WBSS herring would protect an important part of the spawning stock against exploitation during the summer feeding period. This suggestion needs further scientific analysis to define the actual area and the season for a closure, however, WKWATSUP highly recommends this management option for consideration.

The politically decided 50:50 share between IIIa and sub div 22-24 is supposed to uphold the relative stability between the countries exploiting the WBSS stock. However, the selection patterns of the C and F fleets are very different and thus choices about the share between IIIa and sub 22-24 are likely to have an impact on the sustainable exploitation of the stock. There is a risk to take out a higher proportion of the 2 group by the C-fleet if the distribution pattern of the WBSS is following the recent trends where the 2+ group is occurring in high numbers in Division IIIa. Thus alternative shares of the WBSS TAC between IIIa and sub div 22-24 should be investigated, especially with regards to its impact on young fish.

6.3 Alternative TAC setting/Assessment modelling

Presently there is no survey covering the entire distribution area of the WBSS herring at same time of the year (Payne *et al.*, 2009). Taking maximum advantage of positive interaction with the fully covering internationally coordinated acoustic survey in the North Sea, an extension of the summer acoustic survey in Division IIIa (HERAS) to Subdivisions 22-24 would not only improve the precision of the estimated stock proportions in the mixing areas but also greatly add to the development of an integrated assessment of the two stocks within the same model. A full geographical coverage of the HERAS will require substantial resources and solutions drawing on the experience from e.g. the mackerel egg survey may be helpful. Model performance should be evaluated by simulations varying the survey design and frequency e.g. annual, biennial, or triennial to optimise precision of relevant assessment output in relation to necessary resources.

In face of uncertainty, scientific advice should be given based on numbers with reliable confidence intervals, such that it is possible to assess the reliability of that advice. For this purpose, all data which may contain substantial errors should be treated accordingly, and the reliability of model equations should be assessed. Only when all sources of error are taken into account, it is possible to give predictions with reliable confidence intervals.

To accomplish this for the NSAS-WBSS complex, it is necessary to include catches, surveys, split samples and all other observations containing measurement noise in an integrated model.

Preliminary results from a two-stock state-space model was presented, which calculates numbers-at-age for both stocks and fishery mortalities for the North Sea, IIIa (mixing area), and the Western Baltic. This model utilizing catches, surveys and split-samples and estimates the errors on these, all within the same model.

This allows us to predict the split-factor between NSAS and WBSS in IIIa for each age-class in the future, taking into account the ratio of the year-class strengths between the two stocks when predicting the split in IIIa. The model shows (see figure 6.3.1), that the variability in the split observed in IIIa between years may be due to differences in stock-composition, but also due to different proportions of the two stocks being inside IIIa during a year. However, the uncertainties of the splits, and particularly the uncertainty of the proportions of the two stocks that are inside IIIa are quite large especially for the youngest age groups, so it is not possible to predict the split with very high precision using this model. The reason for this may be due to the resolution and precision of the input data, or the model, or some combination of the two. It should still be noted, that the precision of the prediction from this model may very well be better than the current practice, but this has not yet been formally compared.

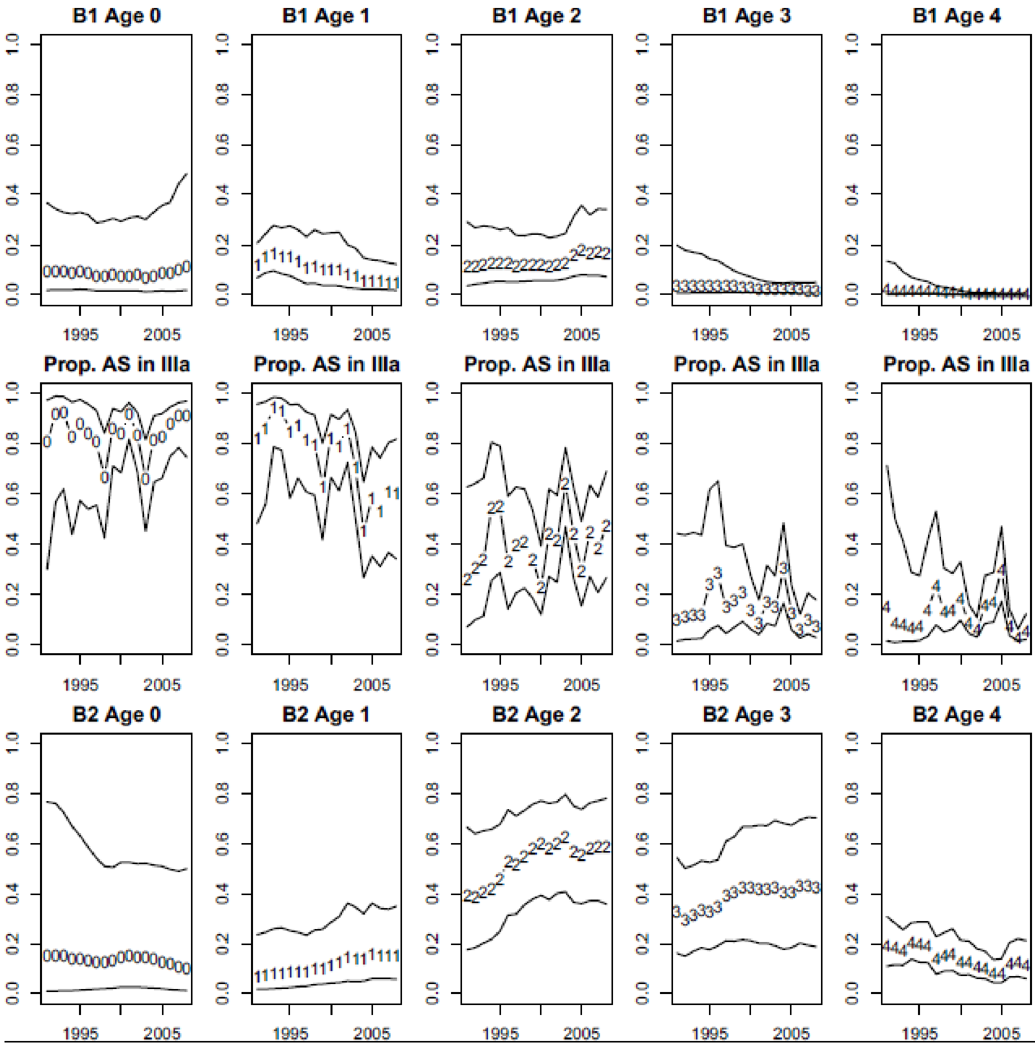


Figure 6.3.1. Proportion of NSAS stock in IIIa during a year (top row), proportion of NSAS in IIIa landings (middle row), and proportion of WBSS stock in IIIa during a year (bottom row). On all plots the 95% confidence interval is included.

6.4 Conclusions

In terms of alternative management strategies for preserving the two stock components in the mixing area, there are some measures, which potentially could aid in maintaining the targets laid down in the management plans for WBSS and NSAS without being direct mixed TAC's. A closure of parts of the Eastern North Sea during the summer feeding migration period for WBSS could protect the part of the SSB which extend the migration route out into this area. This would decrease the exploitation of this important part of the WBSS stock.

Alternative shares of the WBSS TAC between IIIa and sub div 22-24 should be investigated, especially with regards to its impact on young fish. A higher share of the WBSS TAC allocated to Sub Division 22-24 could potentially protect the WBSS stock, however, this need to be scientifically examined and validated before any firm recommendations can be put forward concerning this matter.

In terms of alternative ways to set a precautionary TAC for the mixed stock encompassing both stocks' reference points, other methods than the single stock assessment evaluation are under development and should be considered for future stock assessment of herring in the areas. The preliminary results from a two-stock state-space model shows great potential and this methodology should be investigated further for the NSAS and WBSS assessment.

7 Conclusions

There is a broad empirically based knowledge on the mixing of NSAS and WBSS herring in IIIa and the North Sea. However this is not based on process knowledge and thus it is difficult to predict and simulate the future dynamics of mixing.

Sampling intensity of herring in the eastern North Sea is poor and there is very little information on which to base scientific advice.

The catch at age information for WBSS is highly uncertain. WKWATSUP confirmed widespread misreporting of herring catches into and out of Division IIIa and Subdivisions 22-24 throughout the whole time series. In the most recent years this behaviour has reduced, and the data coordinators for some countries have been adjusting the official catches since 2002. This corruption of the time series weakens the stock assessment and this uncertainty should be addressed. As of now, the information is based on anecdotal information from the Fisheries industry and thus the absolute amounts should be quantified.

The currently applied splitting method for Division IIIa is appropriate, however applying the recently developed "split model" (section 4.5) to the data for prediction of stock proportions may increase the accuracy, transparency and reproducibility of the splitting methodology.

None of suggested management adjustments (in ToR 3) were at the same time compatible with the precautionary principle, exploitation at F_{MSY} and the relative stability of catch allocations. Thus WKWATSUP suggested an alternative:

- Set the TAC for the WBSS according to the FMSY or FMSY transition framework for WBSS alone. If the NSAS is greatly impacted by management of the WBSS, this rule needs to be re-evaluated
- The WKWATSUP recommend a seasonal closure of the herring fishery in parts of the Eastern North Sea (see section 6.2), however, until till is implemented the WK recommends that the fraction taken in this area should be subtracted from the total TAC for the WBSS before sharing the TAC between Division IIIa and Subdivisions 22-24.
- In the mixing area (Division IIIa), the best estimates of the proportions of the NSAS and WBSS in the catch by fleet should be used to calculate the combined catch options in compliance with the targeted catch for WBSS.

The 50:50 share between IIIa and sub div 22-24 was not specifically evaluated. It was viewed as a political choice. WKWATSUP showed that the selection patterns of the C and F fleets were very different and thus choices about the share between Division IIIa and Subdivisions 22-24 are likely to have an impact on the sustainable exploitation of the stock.

There was room for differences as how to interpret the ToR's set by the joint request by the EC commission and Norway and thus the WKWATSUP needed to decide on a common approach. The group decided to apply the approach adopted by ICES when providing advice for WBSS (ICES 2010). This was supported by the representative from the EC commission and thus the group concluded that the ToR's were met and the results and conclusions will answer the request put forward to ICES.

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Annex 1: Recommendations

The WKWATSUP found several recommendations for further action based on the discussions and results from the workshop:

- Initiate studies into the mechanisms and drivers of the summer, feeding migration of WBSS herring into the North Sea.
- Increase and/or redesign sampling for stock proportions in herring catches in ICES area IVa East and IVb and use the Swedish model for sampling in IIIa and 22-24 (many samples with few individuals).
- Expansion of the analysis for stock proportions in the total mixing area of the Eastern part of the North Sea by inclusion of otolith microstructure analysis in addition to the vertebral counts presently used.
- As the uncertainty of the time series of catches reduces the power of the stock assessment to track changes in WBSS herring, efforts should be made to either "correct" the time series or find other stock assessment methods that can cope with this uncertainty. This implies a quantitative estimation of historic misreporting by all Nations that have reported catches of herring in Division IIIa and Subdivisions 22-24.
- The new GLM based split model needs to be evaluated before the end of February 2011, and a working document should be submitted to ICES. ICES will then review the effectiveness and utility of the splitting model. Depending on the results of the review, it is anticipated that the splitting model will be available for HAWG 2011.
- That the EU and Norway when setting the TAC for Division IIIa and Subdivision 22-24 do not consider any of the options in ToR 3, but adapt the suggested procedure by WKWATSUP.
- The WKWATSUP recommend a seasonal closure of parts of the Eastern North Sea (see section 6.2), however, until this is implemented the WK recommend that the frac-tion taken in this area should be subtracted from the total TAC for the WBSS before sharing the TAC between Division IIIa and Subdivisions 22-24.
- As the C and F fleets have such different selection patterns, the 50:50 share between IIIa and sub div 22-24 should be investigated, especially with regards to its impact on young fish.

Recommendation	For follow up by:
1. Follow the guidelines for setting a mixed TAC as stated by WKWATSUP	EC - Norway
2. Increase and/or redesign sampling for spawning date in herring catches in ICES area IVa and IIIa and 22-24	PGCCDBS
3. Quantitative estimation of historic misreporting by all Nations with reported catches of herring in Division IIIa and Subdivisions 22-24.	PGCCDBS/National laboratories reporting to HAWG
4. Evaluate and review of the new GLM based split model. The splitting model should be available for HAWG 2011.	DTU-Aqua authors, ICES review
5. Initiate studies into the mechanisms and drivers of the summer, feeding migration of WBSS herring into the North Sea.	SCICOM?
6. The 50:50 share between IIIa and sub div 22-24 should be investigated, especially with regards to its impact on young fish.	HAWG?

Annex 2: List of participants

Workshop on procedures to establish the appropriate level of the mixed herring TAC (Spring Western Baltic (WBSS) and Autumn Spawning North Sea (NSAS) stocks) in Skagerrak and Kattegat (Division IIIa) (WKWATSUP 2010)

23 – 25 November 2010

Name	Address	Phone/Fax	Email
Lotte Worsøe Clausen (Chair)	DTU Aqua - National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 21362804 Fax +45 33963333	law@aqua.dtu.dk
Fredrik Arrhenius	Swedish Board of Fisheries P.O. Box 423 SE-401 26 Gothenburg Sweden	Phone +46 317430458 Fax +46 317430444	fredrik.arrhenius@fiskeriverket.se
Max Cardinale	Swedish Board of Fisheries Institute of Marine Research, Lysekil P.O. Box 4 SE-453 21 Lysekil Sweden	Phone +46 523 18 750 / 700 Fax +46 523 13977	massimiliano.cardinale@fiskeriverket.se
Aukje Coers	Secretariat Pelagic RAC PO Box 72 2280 AB Rijswijk Netherlands	Phone +31 70 336 9624 Fax +31 70 399 3004	a.coers@pelagic-rac.org
Christian Olesen	Danish Pelagic Producers Organisation P.O. Box 104 9850 Hirtshals Denmark	Phone +45 9894 4239 / +45 40203239	po@pelagisk.dk
Reine Johansson	5105, St. 47115 Dyrön Sweden		mni@yrkesfiskarna.se
Mark Dickey-Collas	Wageningen IMARES P.O. Box 68 NL-1970 AB IJmuiden Netherlands	Phone +31 317 487166 Fax +31 255 56 46 44	mark.dickeycollas@wur.nl
Tomas Gröhsler	Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries Institute for Baltic Sea Fisheries Alter Hafen Süd 2 D-18069 Rostock Germany	Phone +49 381 811 6104 Fax +49 381 811 6199	tomas.groehsler@vti.bund.de
Stina Ø Gmür	Danish Ministry of Food, Agriculture and Fisheries Slotsholmsgade 12 DK-1216 Copenhagen K Denmark	Phone: +45 33 923538	stgm@fvm.dk
Niels Hintzen	Wageningen IMARES P.O. Box 68 NL-1970 AB IJmuiden Netherlands	Phone +31 317 487 090 Fax +31	niels.hintzen@wur.nl

Name	Address	Phone/Fax	Email
Peter Hopkins	European Commission Directorate for Maritime Affairs and Fisheries 200 rue de la Loi B-1049 Brussels Belgium	Phone +32-2 295 11 49	peter.hopkins@ec.europa.eu
Cecilie Kvamme	Institute of Marine Research P.O. Box 1870 N-5817 Bergen Norway	Phone +47 55 23 69 31 Fax +47 55 23 68 30	cecilie.kvamme@imr.no
Jesper Juul Larsen	Danish Fishermen s Association Esbjerg Auktionsgade 2 DK-6700 Esbjerg Denmark	Phone +45 75 15 56 19 Fax Cell: +45 40 18 56 19	jjl@esbjerg-fiskeriforening.dk
Jacob Løvenstjerne	Danish Ministry of Food, Agriculture and Fisheries Slotsholmsgade 12 DK-1216 Copenhagen K Denmark	+45 20 915904	jacl@fvm.dk
Henrik Mosegaard	DTU Aqua - National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33 96 34 61 Fax +45 33 96 33 33	hm@aqua.dtu.dk
Anders Nielsen	DTU Aqua - National Institute of Aquatic Resources Jægersborg Allé 1 DK-2920 Charlottenlund Denmark	Phone +45 33963375	an@aqua.dtu.dk
Mark Payne	DTU Aqua - National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 3396 3474 Fax +45 3396 3333	mpa@aqua.dtu.dk
Norbert Rohlf	Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries Institute for Sea Fisheries Palmaille 9 D-22767 Hamburg Germany	Phone +49 40 38905 166 Fax +49 40 38905 263	norbert.rohlf@vti.bund.de
Dankert Skagen	Fjellveien 96 5019 Bergen Norway	Phone +47 93257452 Fax +47 55 238687	dankert@dwsk.net
Barbara Schoute	International Council for the Exploration of the Sea H. C. Andersens Boulevard 44-46 DK-1553 Copenhagen V Denmark	Phone +45 33 38 67 56 Fax +45	barbara@ices.dk
Clara Ulrich	DTU Aqua – National Institute of Aquatic Resources Jægersborg Allé 1 DK-2920 Charlottenlund Denmark	Phone +45 3396 3395 Fax +45 3396 3333	clu@aqua.dtu.dk

Name	Address	Phone/Fax	Email
Casper Willestofte Berg	DTU Aqua – National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33963433 Fax +45	cbe@aqua.dtu.dk

Annex 3: Tables and Figures for Section 4.

Table 4.3.1. Summary of the GLMM model fitted on split samples

```
> summary(SplitModel)

Generalized linear mixed model fit by the Laplace approximation

Formula: y ~ 0 + age + lat + long + Q + age:lat + age:long + lat:long +      (1
| key) + (1 | year) + (1 | yearclass)

   Data: dd.1.m

  AIC  BIC logLik deviance

 4881 5012  -2418     4837

Random effects:

 Groups    Name        Variance Std.Dev.

 key       (Intercept) 2.86940  1.69393

 yearclass (Intercept) 0.65531  0.80951

 year      (Intercept) 0.41947  0.64767

Number of obs: 2868, groups: key, 925; yearclass, 12; year, 8


Fixed effects:

           Estimate Std. Error z value Pr(>|z|)

age1      -2.464997   0.364139  -6.769 1.29e-11 ***

age0      -5.774506   0.398053 -14.507  < 2e-16 ***

age2       0.004183   0.357736   0.012   0.9907

age3       2.409474   0.365285   6.596 4.22e-11 ***

age4       3.531342   0.381420   9.258  < 2e-16 ***

lat       -2.226399   0.147279 -15.117  < 2e-16 ***

long      -0.106574   0.070411  -1.514   0.1301

Q2         0.255798   0.197639   1.294   0.1956

Q3         2.668511   0.176932  15.082  < 2e-16 ***

Q4         2.667168   0.178886  14.910  < 2e-16 ***

age0:lat   0.198957   0.239806   0.830   0.4067

age2:lat   0.846567   0.127472   6.641 3.11e-11 ***

age3:lat   1.342066   0.182656   7.348 2.02e-13 ***

age4:lat   1.816838   0.216397   8.396  < 2e-16 ***

age0:long  0.326062   0.138132   2.361   0.0182 *

age2:long  0.346978   0.063410   5.472 4.45e-08 ***

age3:long  0.727386   0.079457   9.154  < 2e-16 ***

age4:long  0.900302   0.085278  10.557  < 2e-16 ***

lat:long   0.459213   0.100131   4.586 4.52e-06 ***

---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

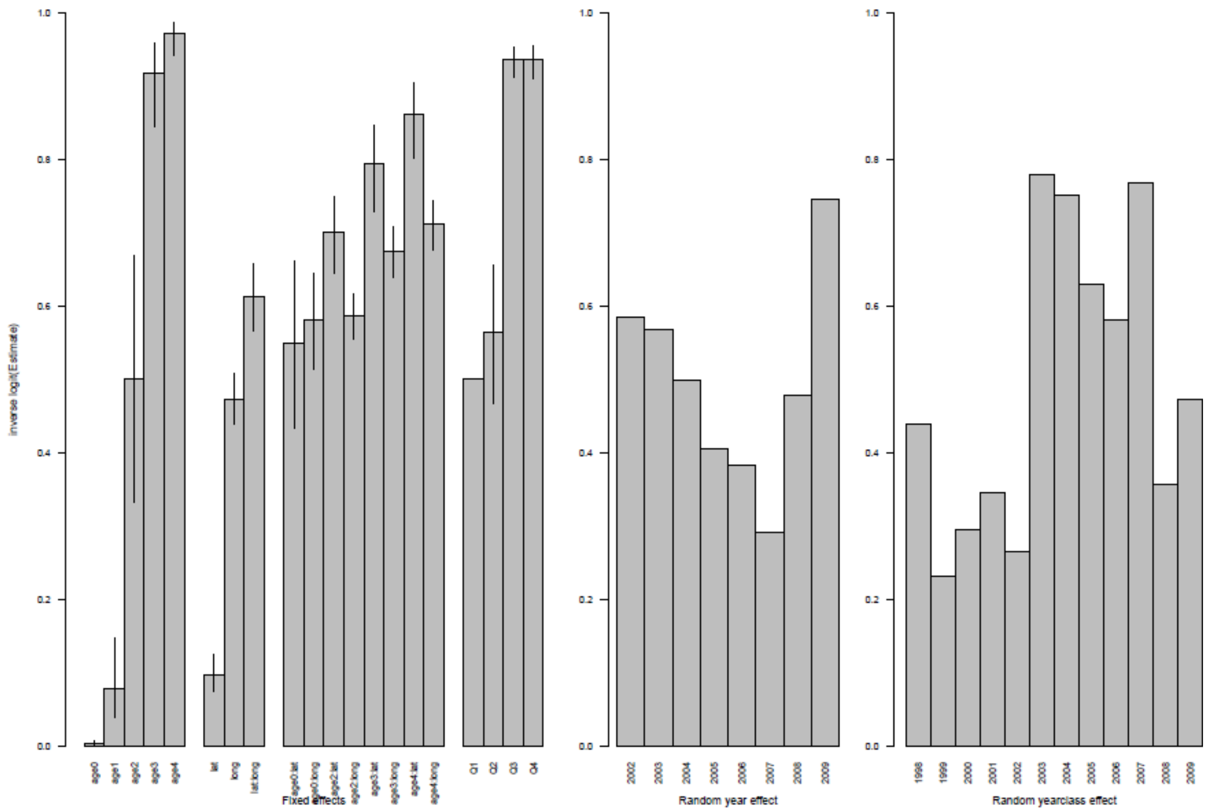

Figure 4.3.1. GLMM analysis of the split samples. InverseLogit values and confidence intervals for the model fitted with all years included.

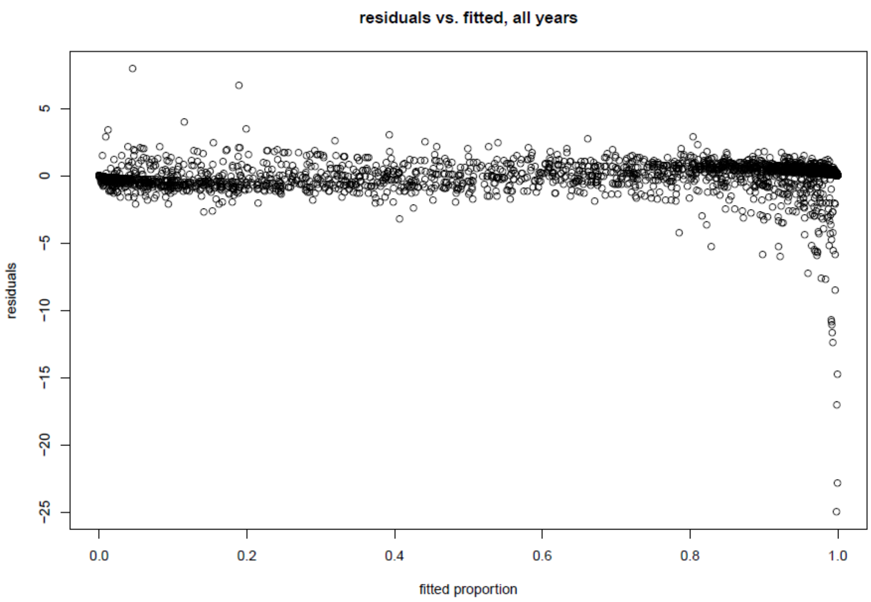

Figure 4.3.2. GLMM analysis of the split samples. Residuals (in logit scale) versus fitted proportion.

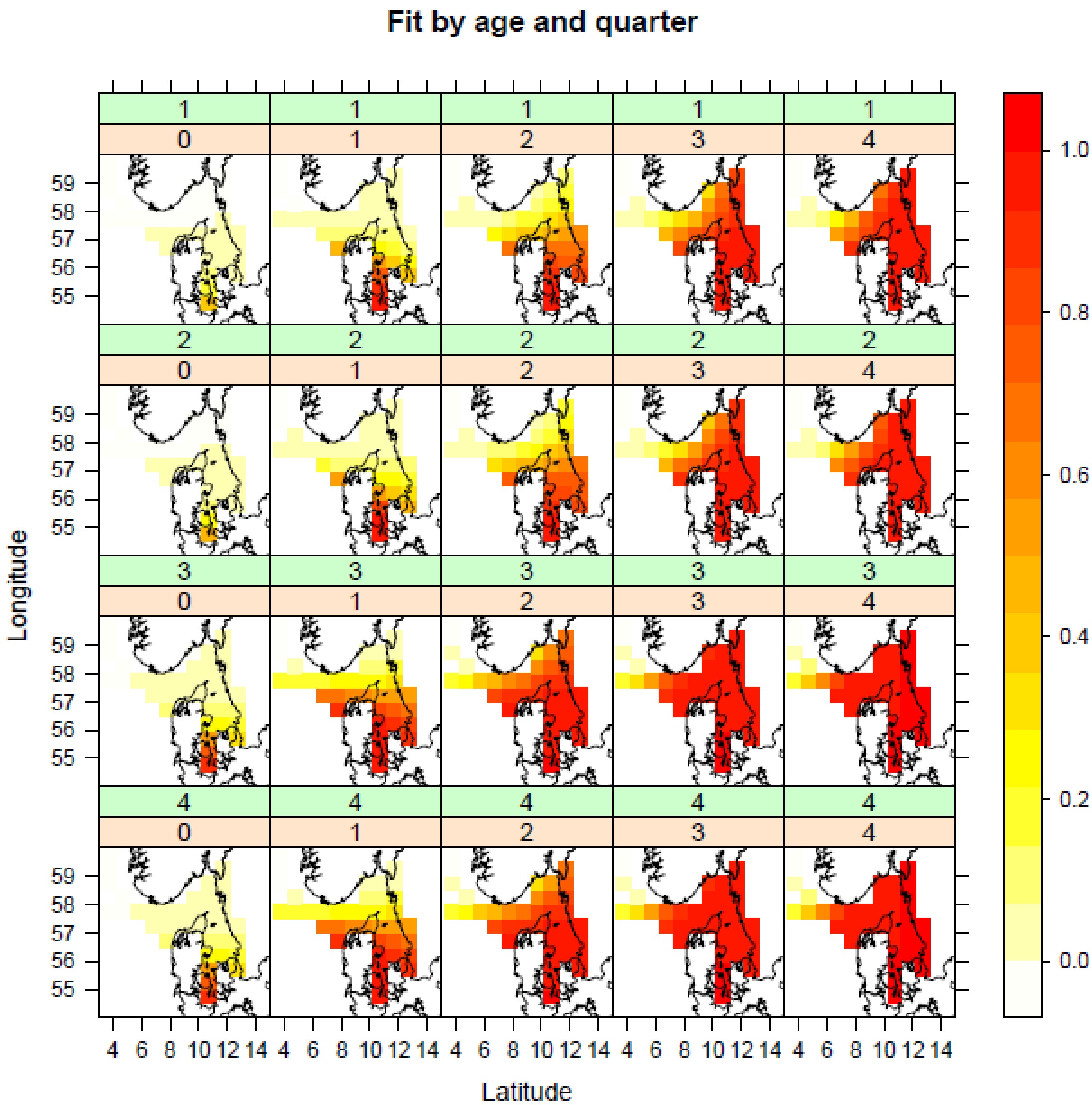

Figure 4.3.3. GLMM analysis of the split samples. Average spatial split pattern by age (in lines) and Quarter (in columns)..

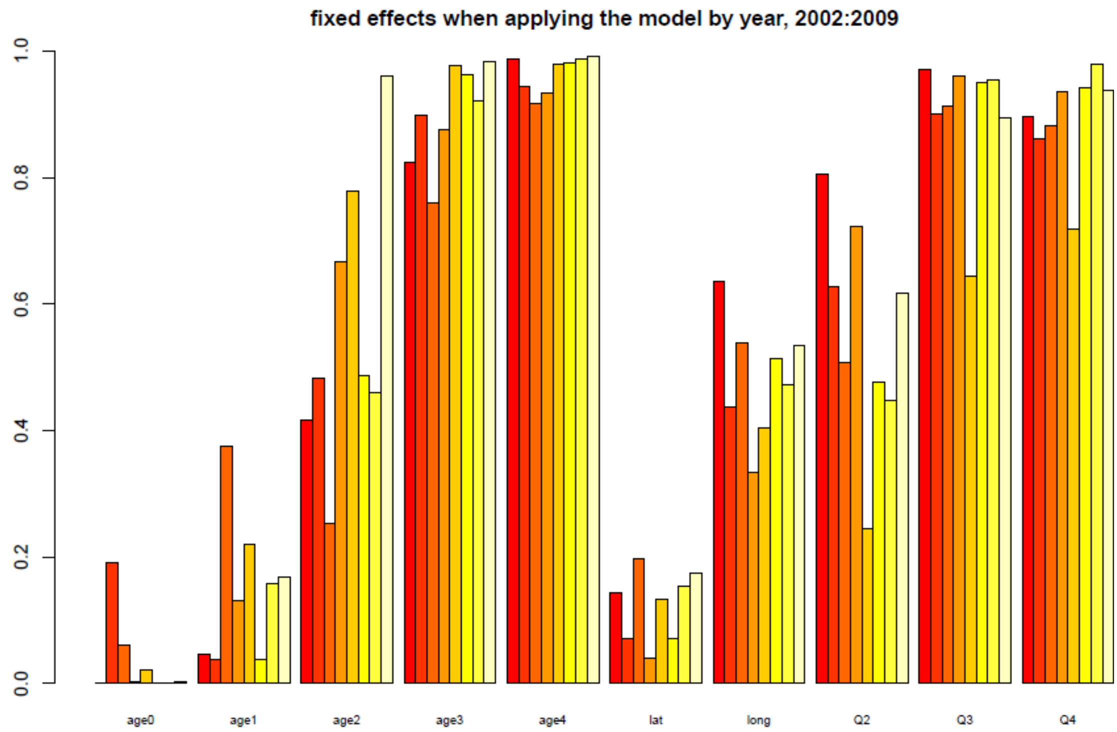

Figure 4.3.4. GLMM analysis of the split samples. InverseLogit values of the single fixed effects for the model fitted with each year individually.

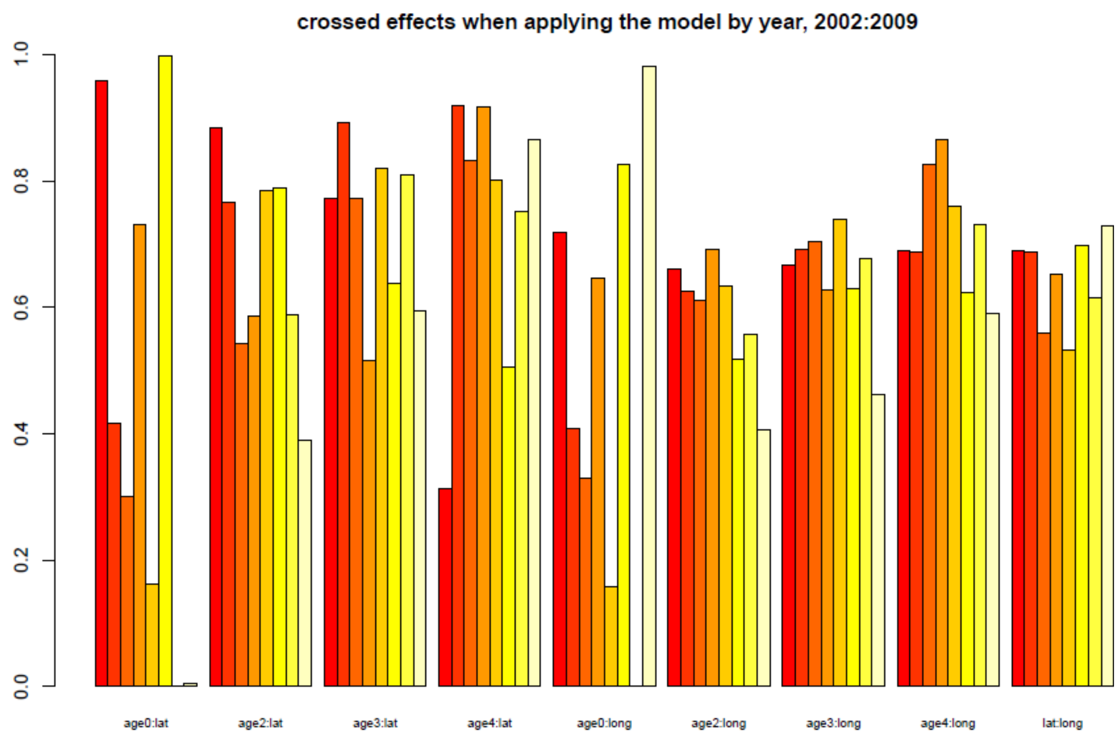

Figure 4.3.5. GLMM analysis of the split samples. InverseLogit value of the fixed crossed effects for the model fitted with each year individually.

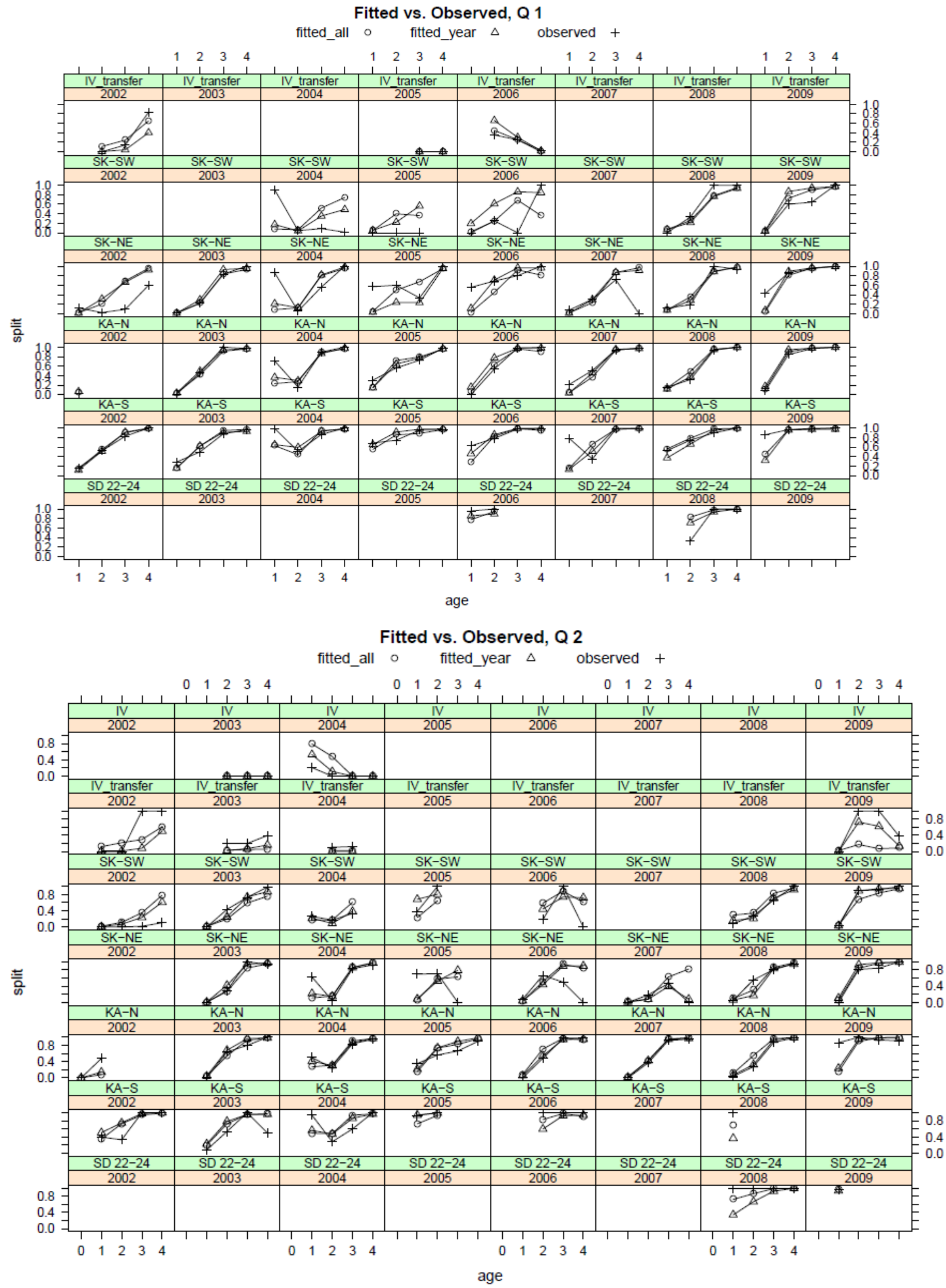

Figure 4.3.6. GLMM analysis of the split samples. Fitted vs. Observed, Quarter 1 and 2.

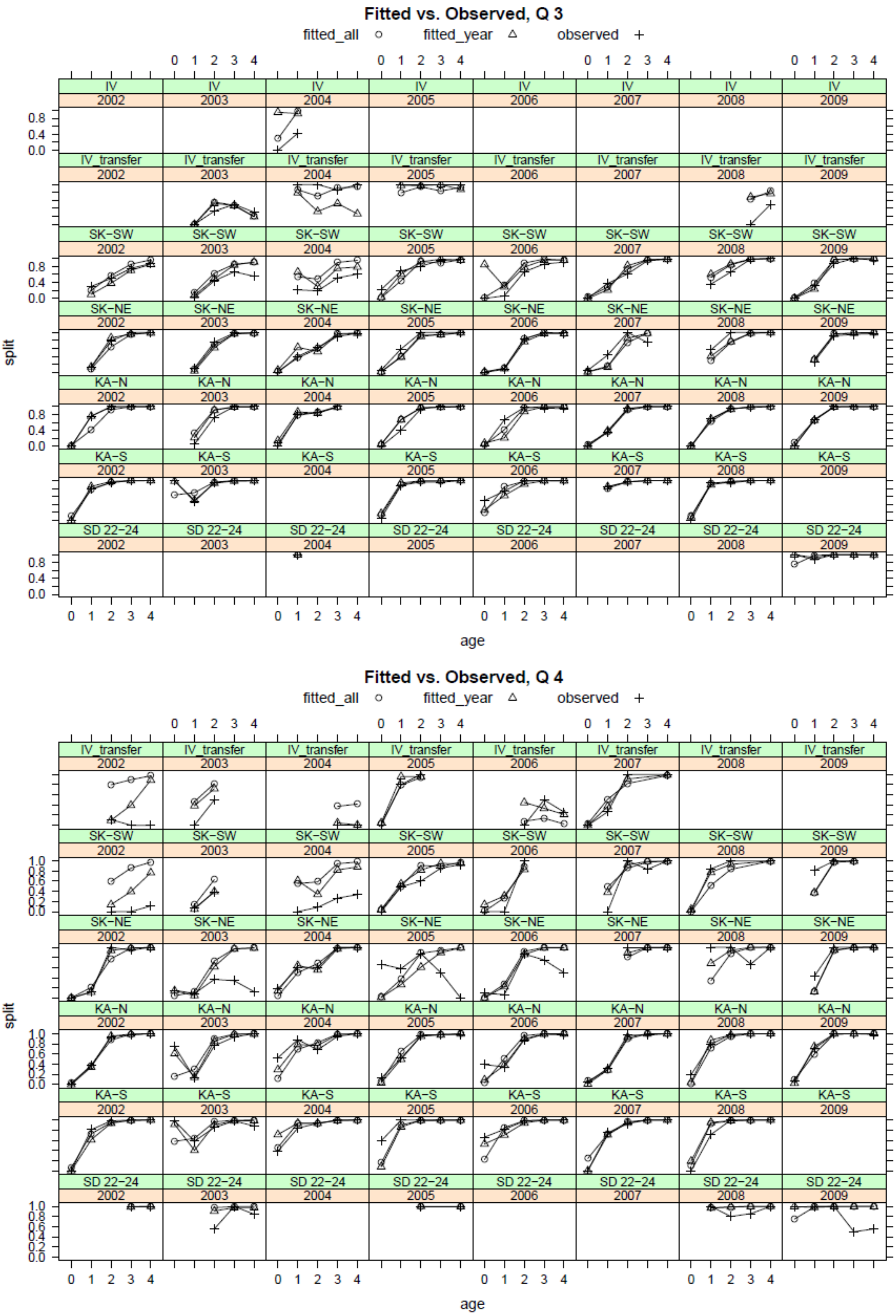

Figure 4.3.7. GLMM analysis of the split samples. Fitted vs. Observed, Quarter 3 and 4.

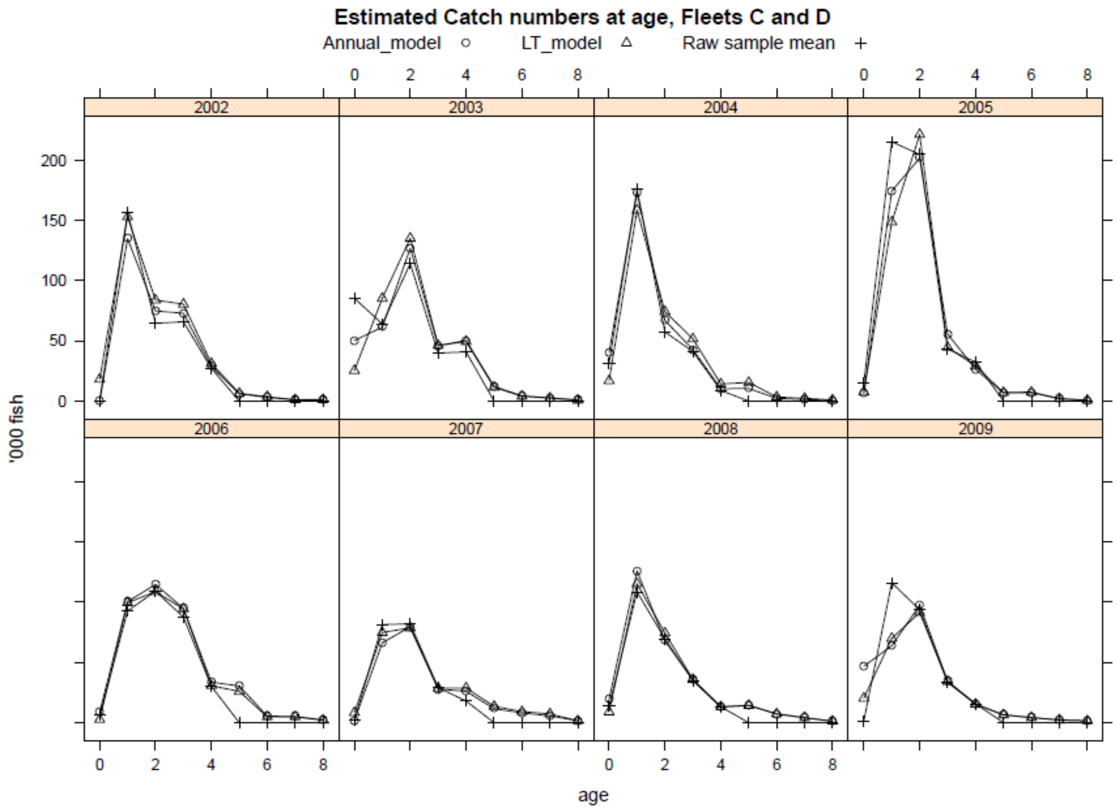

Figure 4.3.8. GLMM analysis of the split samples. WBSS age distribution in area IIIa using the three split approaches, all year.

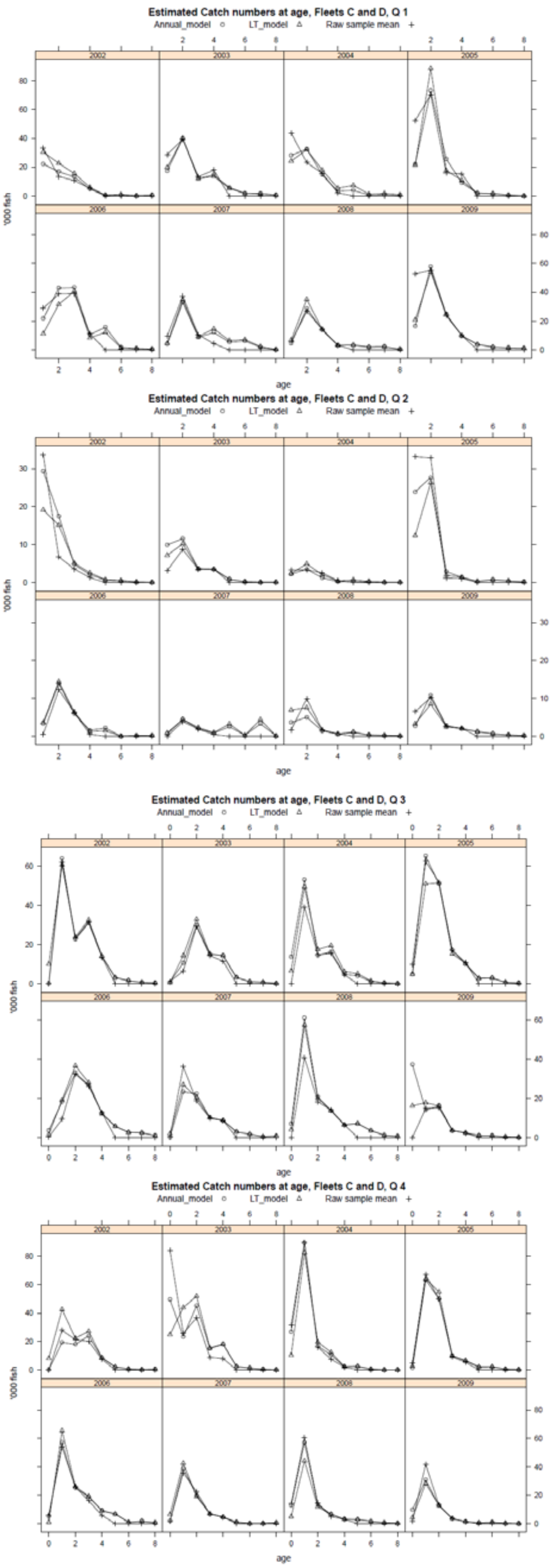

Figure 4.3.9. GLMM analysis of the split samples. WBSS age distribution in area IIIa using the three split approaches, by Quarter.

Annex 4. Possible different interpretations of Terms of Reference

Shortly after the workshop, it became clear that the interpretation of the ToRs was not unambiguous and some participants had had a different interpretation of the Terms of Reference throughout the workshop. Because of this, their expectations of the outcomes had been very different from what was produced. Most importantly, they had expected that the current TAC setting method used by the EU and Norway would be part of the evaluations under ToR-a. amongst others due to time limitations, it was decided not to produce results based on this alternative interpretation at present, but this could be done later, in case that this alternative interpretation was the intended one of EU and Norway. Alternative model runs could then be based on the current TAC-setting methodology (ToR-a') and proposed variations of it (ToR-b' and ToR-c'). This would mean that the model could be adapted in order to follow the below described approach. Step 3 is here described in line with ToR-a' and could thus be replaced by the intended corresponding ToR.

Step 1

- The TAC for the F fleet in 22-24 is fixed.
- Basis is the advice from ICES for WBSS.
- The TAC is set as a tonnage – but referred to as a percentage change compared to the previous year's TAC.

Step 2

- The TAC for the A fleet in the North Sea is agreed between EU and Norway.
- Basis is the advice from ICES for NSAS which follows the LTM plan.
- The TAC is set as a tonnage – but referred to as a percentage change compared to the previous year's TAC.

Step 3

- The average percentage change between the change for the A fleet and the F fleet is calculated.
- The result is used to calculate TAC for the C fleet using this percentage change to the TAC of the previous year.
- The TAC for the C fleet in IIIa is set as a tonnage.

Step 4

- The same percentage change as calculated in step 3 is applied to the TAC for the D-fleet of the previous year to calculate the new D-fleet TAC
- The TAC for the D-fleet is set as a tonnage

The alternative modeling results would be expected to be different most importantly in two ways:

- They will show that the current TAC-setting method leads to the realisation of a fishing mortality higher then the target for WBSS.
- They will show that the political agreement to equally divide WBSS catches between area IIIa and 22-24 will not be possible to be implemented, but in exactly the other way around as the current results show. The WBSS outtake

in IIIa will be predicted to be consequently higher instead of lower then in 22-24.

Note that the anticipated outcomes of this approach do support the workshop's choice to develop an additional TAC setting rule (see section 5), which is to let the WBSS assessment be leading and NSAS following, while area IVa can absorb the rest of the needed TAC change for NSAS, in order to also realise management objectives for NSAS.

The here described alternative interpretation and modeling approach is also not in conflict with the workshop's conclusions and recommendations.

Annex 5 - Technical Minutes for The workshop [WKWATSUP] on procedures to establish the appropriate level of the mixed herring TAC (Spring Western Baltic [WBSS] and Autumn Spawning North Sea [NSAS] stocks) in Skagerrak and Kattegat (Division IIIa) - 23-25 November 2010.

Reviewer:

Dankert W. Skagen

The terms of reference were:

1) Collate the available information on the seasonal movements of the WBSS and NSAS stocks;

2) Comment on the reliability of the methods currently used to estimate the proportions of WBSS and NSAS in the catches and suggest improvements that could be made to the sampling methodology in order to increase the precision of the estimates;

3) Evaluate, in the context of the agreed long term plan for NSAS and the suggested harvest control rules for WBSS, the compatibility of the options set out below for setting the mixed TAC in the Skagerrak and Kattegat with the precautionary approach and with the objective of reaching FMSY by 2015,

for a number of options

4) Suggest options (if identified) other than a mixed stock TAC that can either replace or supplement the TAC measure and maintain the targets laid down in the management plans for WBSS and NSAS. These options might include seasonal and spatial limitations on catches in the Skagerrak in order to protect one or other component of the mixture.

5) The joint EU-Norway request to ICES on herring in the Skagerrak and Kattegat specified that the evaluations of the options for setting the TAC in the Skagerrak and the Kattegat should be based on the assumption that 50% of the TAC for the Western Baltic spring spawning (WBSS) herring would be allocated to Subdivisions 22-24 in the Baltic and 50% to the Skagerrak.

- Advice on whether the 50:50 split of the TAC between the two areas reflects the actual distribution of the catches.
- Suggest and evaluate alternative options for splitting the WBSS TAC, taking into account the seasonal movements of the stock.

In the report, the ToRs 1,2 and 4 are dealt with in separate sections. ToRs 3 and 5 are dealt with together. The report

also has a section with main conclusions and an executive summary. The review is organized the same way.

ToR 1. The report summarizes the existing knowledge on migrations and area distributions for the two stock units, based mostly on literature, but also on recent catch data. For the NSAS, spawning grounds and nursery areas are quite well known, while wintering areas may be variable and do not seem to be confined to the to the southwest of Norway as early literature suggests. WBSS, with main spawning ground in Greifswalder Bodden has feeding migrations into Division IIIa and further into the North-Eastern North Sea. Apparently, the older fish has the longer migrations, while younger fish are mainly confined to Division IIIa.

The report is a fine overview of existing knowledge and the conclusions are sound.

ToR 2. This section addresses three issues:

1) Methods to split the catches in NSAS and WBSS
2) Sampling of material to determine the proportion of each stock, both historic misreporting and current sampling.
3) A statistical prediction model for the 'split' (proportion of WBSS in the mixed catches) that was presented.

An overview of the development of methods to estimate the 'split' (proportion of WBSS) in samples is presented. In subdivision IVaE, vertebrae counts (VC) are still used while otolith microstructure (OM) is used for Division IIIa. The precision can still be improved by combining OM with additional measures. The inference from this section is that for the IVaE, the precision at present is inferior, and can be improved by either introducing OM method or by combining VC with e.g. meristic characters. Separating the various sub-stocks in the WBSS complex may be more problematic.

The report clearly documents a mismatch between sampling intensity and catch distribution. In particular, the North-Western area is poorly sampled, and the IVaE is even worse. Analysis of the data indicate that the major source of uncertainty is the between-samples variance. The point that a large number of small samples gives a better precision than a small number of large samples is highlighted.

The report also has a section outlining the start of the art regarding the drift and survival of NSAS larvae. The variability between years is large, and only partially understood. Hence, reliable predictions of the amount of NSAS growing up in Division IIIa is still not quite feasible.

A statistical modeling approach to predict the proportion of WBSS by area and quarter is presented. Although evaluating the statistical detail is beyond the competence of this reviewer , the approach looks adequate and promising. A by-product is that it highlights the large between-samples variance noted above. Some problems are still unsolved, but the WKWATSUP recommends further refinement and proper peer review of this approach before the next meeting of the HAWG. The reviewer supports this recommendation.

ToR 3 and 5.

The WKWATSUP was asked to evaluate a range of options for setting the mixed TAC in the Skagerrak and Kattegat with respect to the compatibility with the precautionary approach and with the objective of reaching FMSY by 2015. This was to be done in the context of the agreed long term plan for NSAS and the suggested harvest control rules for WBSS.

Both these harvest rules are essentially rules where an overall TAC is derived for each stock separately from an agreed fishing mortality, which is set depending on the SSB. The overall objective is to have a fishing mortality at FMSY for each stock. A further objective is to ensure an equal share of the WBSS catch between Division IIIa and Subdivisions 22-24. The additional objective of the various proposed options is to link the change in the mixed TACs for Division IIIa to the recommended changes in the overall TAC for each of the stocks.

The fishery in IIIa, which exploits a mixture of these stocks, leads to removals that are dependent on the amount of each of the stocks in the area. Hence, it is not meaningful to set a separate TAC for each stock in IIIa, but the amount taken of each stock under a common TAC can be estimated. A complicating factor is that some WBSS is also taken in the North-Eastern North Sea.

The dilemmas this leads to are clearly outlined in the report. The interpretation by the WKWATSUP leads to an altered share between IIIa and 22-24, as the WBSS component of the TAC for IIIa is influenced by the change in TAC also for the NSAS.

The complexity of the proposed options are such that the request may be open to a variety of interpretations. The WKWATSUP decided to chose one that is extensively described and clearly stated in the report. To the reviewer this choice appears sensible. An alternative interpretation that was brought up after the meeting, is outlined in an appendix. To the reviewer, this illustrates that different interpretations of the ToRs will lead to different results, but that the main conclusions in these sections remain unaltered. A better alternative to choosing one plausible interpretation would have been a broad evaluation of possible ways to link changes in local TACs to changes in other TACs. That would be a major task due to the wide range of possible options and the fact that the TACs for the C and D fleets also have implications for the TACs of the A and B fleets in the North Sea. It is also noted that the choice of share between IIIa and 22-24 also relates to the preference for juvenile vs. adult fish. The fishery in IIIa is mostly on ages 0-2 for both stocks.

The evaluation of the plan is restricted to presenting short term predictions for 2011, which demonstrate the immediate consequences of the various options. It also demonstrates that the difference between various options is rather small, in particular with respect to the expected consequences for the stock. The methodology used is standard and properly applied.

For a final comprehensive evaluation of the management plans for both herring stocks, a full Management Plan Evaluation (MPE) would be warranted, in particular to evaluate long term consequences for sustainability and the relation to MSY. To do so, a simulation framework is needed that incorporates both stocks, a model for the mixture of the stocks in IIIa, and management rules that may not be represented in 'off the shelf' software. This is much more than could realistically be expected at this meeting. The present work can be regarded as elements in an incremental approach, where F-based rules previously have been derived and examined with respect to the precautionary approach and MSY objectives on a single stock basis, and the feasibility of rules for the mixing area were examined now with emphasis on short term consequences. Under the present conditions and as parts of a dialogue process, this appears to be a sound approach.

ToR 4

WKWATSUP made two suggestions for alternative management options.

1) A seasonal closure of the Norths-Eastern part of the North Sea would protect older fish and allow some to spawn once more. Although this is logical in qualitative terms, the sampling in that area is very poor and the amounts of WBSS taken in that area is not precisely estimated. The catches in the area are relatively small, but the amount of WBSS present in the area may be substantial according to survey data. The effect on the SSB in the short term is small compared to the option where the predicted amount caught in the North Sea is subtracted from the catch in IIIa and 22-24. Evaluating the long term effects would require more extensive simulation studies. Hence, the effect of such a measure is expected to be beneficial in qualitative terms but is not quite clear in quantitative terms..

2) Due to the conflict between objectives noted above, the WKWATSUP suggests an alternative rule, by which the TAC of WBSS is first derived and distributed on IIIa and 22-24 (after subtracting the assumed amount taken by the A-fleet in the North Sea), and then just calculates the TAC for both stocks together for each fleet in IIIa according to the predicted mixture of the stocks in the area. This ensures that the WBSS stock gets the necessary protection, but would cause problems in a case where the WBSS stock is large and the NSAS stock is small. The WGWATSUP did not attempt to propose a specific solution to that situation, but notes that the management plans may need revision if this problem appears.

Conclusion.

The WKWATSUP has addressed the terms of reference to the extent that was practically possible. Its inferences and conclusions appear sound, and no severe mistakes were detected.