ICES WGISDAA REPORT 2016

Interim Report of the working Group on Improving use of Survey Data for Assessment and Advice (WGISDAA)

Hamburg, Germany

12–14 July 2016

International Council for
the Exploration of the Sea

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Executive summary

The Working Group on Improving use of Survey Data for Assessment and Advice (WGISDAA) met at the Thünen Institute in Hamburg from 12 to 14 July 2016.

ICES assessment Working Groups (WG) were not represented at the meeting so no work could be conducted in relation to addressing concerns with survey information specific to a particular assessment (TOR a). Instead, the group focused on reviewing the methodology for combining survey indices for the Pacific Halibut assessment. A size based Generalized Linear Mixed Model (GLMM) estimating spatial and temporal autocorrelation provides a credible solution to the problem of discontinuous (spatially and temporally) indices coming from surveys with different gears for use in assessments. To further strengthen the argument for a modelled solution, it would help to test the robustness of the index model using independent data or boot-strapping to look for systematic residuals indicative of process error, examine and compare the performance of the modelled index with other methods of index inclusions/spatial disaggregation of models for the credibility of the expected stock dynamics, and finally to try to quantify the differences in uncertainty between the different options and the effect on the effective sample size in likelihood based assessments.

Collaborative work between the survey WGs and WGISDAA (TOR b) continued on the questions of maintaining time-series consistency under increased budgetary pressure and a substantial increase in the extent of the spawning habitat currently used by the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) and the recent difficulty in isolating the herring stock components in the MIK survey (IBTSWG[1], WGALES[2]) using the historically appropriate discriminate function.

This year's mackerel egg survey data are currently being processed and additional efforts were made to increase the survey coverage in order to provide the necessary data to make a thorough evaluation of the variance components. In the meantime, the WG reviewed a spawning habitat model using environmental information to describe the temporal variability of spawning, showing promise in guiding efficient survey implementation in real time. Some spatially unrealistic patterns of spawning prediction require a more detailed analysis as do the variation in interannual variability to adequately assess opportunity for improving survey index precision while avoiding potential biases. Lastly, there is a concern that recent increases in the SSB may have led to more marginal habitats being used for spawning resulting in the spatial extent of egg distribution irrespective of the modelled changes in environmental conditions.

Historic data from the MIK net are still throwing up some problems and inconsistencies in data treatment. While this is being sorted the WG examined the most recent data for developments in the distribution of Herring larvae in the first quarter. The data suggested that the problem of the northward expansion of the winter spawned larvae was most severe in 2016. Opportunities for using alternate data sources to improve the stock component identification in MIK-net survey data are being explored.

Upcoming issues associated with the use of survey data in benchmarks (TOR c) relate to recent and possible future change options in the Q3IBTS survey. In 2015, the

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1 International Bottom Trawl Survey Working Group (IBTSWG)
2 Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES)

IBTSWG implemented changes to the tow duration for replicate tows within a rectangle in order to increase the number of replicates and extend survey coverage in rectangles that were not routinely covered. They provided preliminary analyses of their finding on the effect of tow duration in commercial species and the effect on species richness, which WGISDAA reviewed. The group concluded that the data examined did not suggest significant effects of the change in tow duration, but pointed out that the power was very low and the analyses did not consider the effect of reduced tows on the age-length-keys. The group recommended changes to the analyses to increase power and an extension of data to rarer and larger individuals more likely to be affected by the change will be implemented next year with the addition of the 2016 data.

The Workshop to Plan and Integrate Monitoring Program in the North Sea in the 3rd quarter (WKPIMP) proposed a redesign of the Q3IBTS survey in order to provide a broader ecosystem perspective to the current Data Collection Framework (DCF) monitoring requirements. WGISDAA examined the concept of the design and found it a useful approach for those objectives. The group addressed the request for information as to how such a redesign would affect the current stock assessment process and how to minimize the risk of breaking the current time-series for target species. At the abundance level, most species showed a consistent distribution with the strata proposed by WKPIMP so likely there would only be a small effect on the central tendency since the historic data could be post stratified. What is less clear is the effect on variance due to reduced sample numbers particularly at the older ages. WGISDDA will hope to address this issue by simulations intersessionally.

1 Administrative details

Working Group name
Working Group on Improving use of Survey Data for Assessment and Advice (WGISDAA)
Year of Appointment within the current cycle: 2015
Reporting year within the current cycle (1, 2 or 3): 2
Chair(s):
Sven Kupschus, UK
Meeting venue:
Hamburg, Germany
Meeting dates:
12–14 July 2016

2 Terms of Reference a) – z)

ToR DESCRIPTORS	DESCRIPTION	BACKGROUND	SCIENCE PLAN TOPICS ADDRESSED	DURATION	EXPECTED DELIVERABLES
New a)	To work together with assessment working groups to provide resolution to assessment issues prioritized by the assessment working groups	Specific resolutions to individual assessment issues with a report to feedback into the assessment, or where necessary into the benchmark process. In addition, cataloguing and classification of issues and review of methods used to resolve problems in order to provide "self-help" options to resolve similar issues in other assessments.			
New b)	To work together with survey working groups to provide	Specific resolutions to individual survey issues with a report to feedback into the survey			

	resolution to problems associated with index calculations, survey design changes (proposed or realized) to ensure efficient and effective use of survey resources.	working group. In addition cataloguing and classification of issues and review of the methods used to resolve them in order to provide "self-help" options for survey working groups.			
c	Initiate with ACOM and secretariat a process to identify upcoming issues associated with the use of survey data in benchmarks. This should be initiated as soon as the benchmark process is started	Survey data issues, as in ToR a, are often critical in the benchmarking process. WGISDAA can advise best if involved in this process from the start, can collaborate with the operators and present conclusions at the benchmark	4.1., 5.1., 5.2	As required	Reports and presentations to the appropriate Benchmark workshop

3   Summary of Work plan

Year 1	Initiate process eliciting advice requests from other elements of the ICES system; assessment, survey and benchmarking groups. Identify priorities within requests, and set up meeting and personnel accordingly
Year 2	Continue and update process eliciting advice requests from other elements of the ICES system; assessment, survey and benchmarking groups. Identify priorities within requests, and set up meeting and personnel accordingly
Year 3	As in year 2, plus appraisal of the success of the process, and make proposals for changes and any continuation

4   List of Outcomes and Achievements of the WG in this delivery period

1) Recommendations to the Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES) and the Herring Assessment Working Group for the Area South of 62°N (HAWG), with respect to methods to be applied to the MIK index to improve the robustness of the index used in the North Sea

Herring assessment and the utility of the index given the assumptions in the assessment.

2) Advice to the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS) on using a modelling approach to improves the efficiency and design of the monitoring program supporting the mackerel and horse mackerel egg production indices in view of the temporal and spatial expanding spawning distribution.

3) Examination of method for combining survey indices where spatial and temporal deployment of effort is not consistent. The GLMM method derives an index by using the autocorrelative structures in the data at different scales/periods to account for missing information assuming independence between the scales examined. Where this assumption holds true the method can provide a single-stock wide index for assessment purposes avoiding potential conflicts between different indices within the assessment.

4) The WG examined the scientific basis for the redesign of the Q3IBTS survey proposed by WKPIMP. The approach is sound, and abundance information does not suggest that this should cause much disruption to the index series; however, more work is needed to determine the effect of reduced sample numbers on the age-length-keys and the variance estimates. This information will be fed back to the Working Group on Integrating Surveys for the Ecosystem Approach (WGISUR).

5) The IBTSWG requested advice on their evaluation of the effect of a change in tow duration on the index and potential biodiversity indicators. WGIS-DAA suggested that the analysis currently has low power and suggested some alternatives that could provide a more effective means of determining the effects.

5   Progress report on ToRs and workplan

The WG addressed the following issues:

5.1   Geostatistical modelling to compensate for spatial and temporal variability of distribution of fish, survey gear differences, and sampling effort

Frequently multiple fisheries independent surveys cover or partially cover the extent of a stock of interest. Usually, the primary purpose of these surveys vary so that they differ in spatial and/or temporal coverage, in gear and/or vessel and potentially survey design. As a consequence, indices of abundance from different surveys can show differing trends and worse, they may conflict within a stock assessment model that does not appropriately account for these differences.

Effects of gear and vessel are adequately accommodated in most modern assessment models by estimating selectivity and catchability parameters independently for each survey. Developing spatially explicit models is now also possible, but efforts are often hampered by a lack of historic data at the appropriate spatial resolution. An alternative approach is to combine all survey data and construct an overall index of abundance that accounts for the differences in survey gear/boat (selectivity and catchability) and survey spatio-temporal coverage. This is often done through what is called a catch per unit of effort (cpue) standardization (Maunder and Punt, 2004). cpue standardization

starts from the simple assumption that cpue is proportional (q) to abundance (B_t) with some observation error (e^{ε_t}).

$$\text{cpue}_t = qB_t e^{\varepsilon_t} \quad \text{with } e^{\varepsilon_t} \sim N(0, \sigma^2) \tag{1}$$

However, catchability is seldom constant over time and space and varies depending on the gear, location, time of the day, etc. (Wilberg *et al.*, 2010). Moreover, many environmental covariates can affect the underlying species distribution (biomass) (Whittaker *et al.*, 1973). Therefore, changes in catch rates are often modelled as a function of covariates that we think affect them.

$$\text{cpue}_t = q_t B_t e^{\varepsilon_t} \approx \text{f(covariates)}\, e^{\varepsilon_t} \tag{2}$$

Spatio-temporal dependence has received much attention over the last decades as it is innate to many ecological processes as both exogenous (e.g. climate, habitat) and endogenous (e.g. dispersal, predation) drivers of species distributions vary through time and space (Legendre, 1993; Hoeting, 2009; Cressie and Wikle, 2011) which influence catch rates in the end. Traditionally, spatial dependence has been incorporated in cpue analysis in the form of spatial grids (Ono *et al.*, 2015). But the effects are rarely homogenous within grids (depending on the size of grid and species of interest). Therefore, spatial dependence is now preferably modelled as a continuous distribution over space by the use of spatial covariance structure, therefore allowing the analysis at the haul by haul level accounting for variation at appropriate spatial scales (Dormann, 2007). Temporal correlations, e.g. consistent distribution of a species over years, can be modelled by the use of autoregressive (AR), moving averages (MA) or autoregressive moving average (ARIMA) effects using techniques common to ecology, economics and engineering (Box *et al.*, 2016). Where such relationships exist, it is possible to compensate for missing data within the space-time array (DeYoung *et al.*, 2008; Perretti *et al.*, 2013).

There is however at least one remaining issue in cpue standardization and it is related to the problem of gear selectivity and catchability. If we ignore the age and/or size structure of the cpue data, there isn't an easy way to incorporate the differences in survey catchability and selectivity in the model as its effect is confounded with changes in underlying species size/age composition (moreover, gear selectivity can sometimes be quite different in shape). One approach to simplifying this problem is to divide the analysis by size groups (or age groups as in Berg and Kristensen, 2012 or Berg *et al.*, 2014). In doing so, differences in gear selectivity and catchability by group can be more easily modelled (by a constant through linear approximation) than over the whole size range, therefore increasing model accuracy i.e. $\overline{q'_{s,g}}$ in equation 3 is more accurate than $\overline{q''_s}$ in equation 4 as it is based on smaller size range.

$$CPUE_{s,g,t} = \left(\sum_{l \in g} q_{s,l} S_{s,l} B_{s,l}\right) e^{\varepsilon_{s,g,t}} \approx \overline{q'_{s,g}} B_{s,g} e^{\varepsilon_{s,g,t}} \tag{3}$$

$$CPUE_{s,t} = \left(\sum_{l=1}^{n} q_{s,l} S_{s,l} B_{s,l}\right) e^{\varepsilon_{s,t}} \approx \overline{q''_s} B_s e^{\varepsilon_{s,t}} \tag{4}$$

In the above equations, q is the catchability coefficient, S is the survey gear selectivity, B is the species biomass, and the subscript s, g, t, l stand for survey, size group, time, and fish size, respectively.

The final step in a cpue standardization is to produce an index of abundance. One approach is to calculate it based on the sum of standardized prediction over the assumed range of the species (Thorson *et al.*, 2015). An advantage of this approach is we can

explore if there is any perceivable shift in the species distribution (e.g. center of gravity, distribution envelope) in addition to the variation in the index of abundance. Alternatively, the model could account for known shift in species distribution in calculating the final index of abundance. The resulting index of abundance by size (or age) group could then be readily incorporated into a stock assessment as a global index of abundance (or recruitment index if analysing small size groups).

To address the problem associated with combining multiple indices of abundance, works have been undertaken at the University of Washington on developing a cpue standardization model by size class that incorporates multiple survey data with different gears, space and time coverage to create an overall index of abundance. Pacific halibut (*Hippoglosomus stenolepis*) was chosen as a case study to illustrate the method.

Pacific halibut is one of the world's largest right-eye-flounder (up to 250 kg and 2.5 m) that is widely distributed along the Pacific Northeast from Northern California to the Alaska Bering Sea (Stewart *et al.*, 2016). The species has been exploited over a century and the average annual removals approximated 40 000 t (ranging between 20 000 to 60 000 t) (Stewart *et al.*, 2016) with a value exceeding 100 million $ in recent years (Fissel *et al.*, 2015). The species has been managed by the International Pacific Halibut Commission (IPHC) for nearly 100 years and stock assessment has been conducted annually since 1991. Many sources of data go into the assessment (both fishery-independent and dependent data) including some age and length composition data, survey indices of abundances, estimates of commercial and recreational catch and discard (Stewart and Monnahan, 2016). However, many challenges still remain in the assessment (Stewart *et al.*, 2016). Among others, recruitment variability is a significant source of uncertainty in estimating the stock status. One reason is that there is a lag of six to ten years in seeing any effect of recruitment in both the commercial fishery (as the legal capture size limit is 81.3 cm) and the setline survey abundance index and age composition data (which uses the same gear as the commercial fishery). The current abundance index from Alaska Bering Sea (BS), used in the assessment, provides some information about young halibut (thus recruitment) as it captures smaller fish than the setline survey but it is not representative at the coast-wide level and is based on an analysis that aggregated all size groups. By combining all bottom survey throughout Alaska (i.e. BS, Gulf of Alaska (GOA) and Aleutian Islands (AI)) and performing a cpue standardization focused on small size groups, one can develop an index of abundance specific to younger halibut (i.e. a recruitment index) that could be potentially useful in informing the coast-wide recruitment strength in the stock assessment model.

The cpue standardization model is based on a delta GLMM model by size group that account for spatio-temporal autocorrelation structure (spatial correlation is modelled via the Matérn covariance matrix while temporal correlation is modelled using a first order autoregressive process (AR1)) and the effect of other covariates such as year, survey region, depth and sea surface temperature. The final index of abundance by size group is determine by summing the standardized predictions (removing for the region specific difference in catchability) over a 1x1 km spatial grid overlaid across the survey region. Predictions were limited to the alpha shape (shape defining algorithm, a generalization of the convex-hull algorithm) of all survey points in order to prevent extrapolating much outside the area that have been surveyed in the past. In this sense, the derived index of abundance is representative of the young halibut abundance within the survey area. Nonetheless, sensitivity test to the choice of prediction area (one limited to the survey region and one extending beyond the survey region) did not show qualitative difference in the final index of abundance.
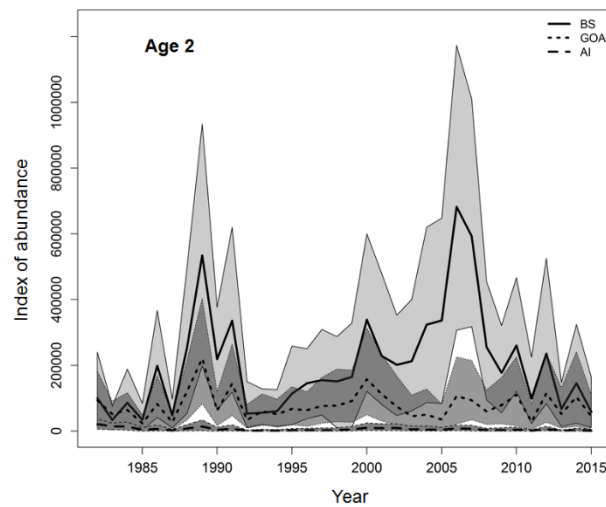
Figure 6.1.1: Index of abundance of young halibut (roughly age 2) across Alaska regions (i.e. BS, GOA, and AI) between 1982 and 2015 with the 75% credible interval.

The results of the analysis suggest that the young halibut (approximately age 2) is mostly found in the BS region and that the AI has a minimal contribution to the young halibut stock (Figure 6.1.1). Moreover, BS shows the largest fluctuation (in magnitude) in young halibut index over the years while GOA has a more stable index. In addition, there are two noticeable peaks in young halibut abundance across Alaska: 1990 (which is equivalent to a 1988 age-0 recruit) and 2007–2008 (equivalent to a 2005–2006 age-0 recruit). The 1988 recruitment peak is a well-known event that is also estimated in the stock assessment. However, the 2005–2006 peak is not apparent in the assessment. Looking at the regional contribution on the overall young halibut abundance in Alaska, the 1988 peak was observed both in the BS and in the GOA. However, the 2005–2006 peak was mostly evident in BS but not in GOA. When calculating the correlation between the scaled recruitment estimates from the latest assessment (Stewart and Martell, 2016) and the lagged scaled young halibut abundance index by region, correlation was as high as 0.6 when using the index within GOA but reduced to lower than 0.4 when using the index from the other regions or Alaska-wide. This suggests that the current assessment might be missing some source of recruitment that is coming from or generated within the BS. While this might be true, the current analysis is not able to inform about the contribution of the young halibut population across Alaska to the halibut spawning biomass that is the main target of the commercial fishery in Alaska.

Finally, WGISDAA stresses the need to explore and keep developing modelling approaches to analyse the combined haul-by-haul data from multiple surveys to detect spatio-temporal changes in distribution-at-size (or age). Such analysis could be useful in designing future survey (e.g. decision on extending or not survey area) but also lead to the development of stock-wide indices of abundance that are less biased and sensitive to the differences in survey spatio-temporal asynchrony and gear selectivity. Such development could help reducing subjective decisions in stock assessment whereby a lack of understanding of survey differences (such as spatio-temporal coverage and gear selectivity) frequently lead to the exclusion of one index vs. another (as in the case of NS cod) or down-weighting an index of abundance based on its divergence from other indices or assessment estimates.

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5.2 Effect of tow duration on catch rates and species richness in the 3Q NS-IBTS in 2015

In response to recent discussion of survey efficiency and spatial coverage, IBTSWG agreed in 2015 to reduce the nominal tow duration from 30 min to 15 min for about 50% of the tows in the 3rd quarter 2015 in the North Sea. The short tows were evenly distributed in the survey area in ICES Division 4 (North Sea) and the allocation was balanced with at least one tow in each rectangle with the standard tow duration of 30 min. However, since one country (England) preferred to keep its survey unchanged, the allocation of the short tows to the different countries was unbalanced and ranged from 53 to 76% for the other participants (Denmark, Germany, Norway, and Scotland). Comparisons of catch rates by species and age and fish species richness from the short and the long tows were discussed in several working documents during the 2016 IBTSWG meeting (ICES 2016). The objective of this approach was to:

- Extend area coverage and increase sampling intensity in the north and northwestern part of the North Sea by Norway and Scotland,

- Conduct a second tow in rectangles which otherwise would had been sampled only by one tow (more balanced effort distribution),

- Allow Denmark to conduct additional stations in the Skagerrak (ICES Division 3a) for comparison with Sweden which originally is the only country in that area, and

- Facilitate an analysis on how much time can be saved for other work, i.e. moving towards an ecosystem survey, if all tows would be 15 min without degrading the quality of the abundance indices for target species (as they are used in stock assessments) and without increasing the number of total survey days.

Except for catch rates of age 1 Norway pout and the species richness no significant effect of tow duration were reported in the working documents presented at the 2016 IBTSWG. However, all the analyses had a lower power and the number of observations was considered too low for deriving conclusive results. Based on this, IBTSWG adopted a continuation of the use short and long tows in 3Q 2016 with just minor modification of the set up compared to the previous year.

WGISDAA evaluated these results and conducted some additional analysis on the effect of tow duration on catch rates for cod and whiting using the identical datasets and the same initial model formulation (subscript for haul omitted):

$g(\mu) = s(Depth) + s(Time\ of\ day) + s(Lon, Lat) + s(Tow\ duration) + f(Vessel) + offset(log(Swept\ area))$

where the expected response μ is N_{Age} per haul.

5.2.1 Tow duration and catch rates of gadoids

GAM's with a negative binominal distribution were used in the analyses for cod, whiting, haddock, and Norway pout. For cod and whiting, tow duration was considered a continuous variable and modelled with a smoothing function, but lowest uncertainty was observed at medium tow durations where only few observations have been available. This appears to be unrealistic and when using a Poisson distribution this phenomenon disappeared and the lowest uncertainty was recorded at the tails, i.e. around 15 and 30 min tow duration (Figure 6.2.1.1), and this makes much more sense.

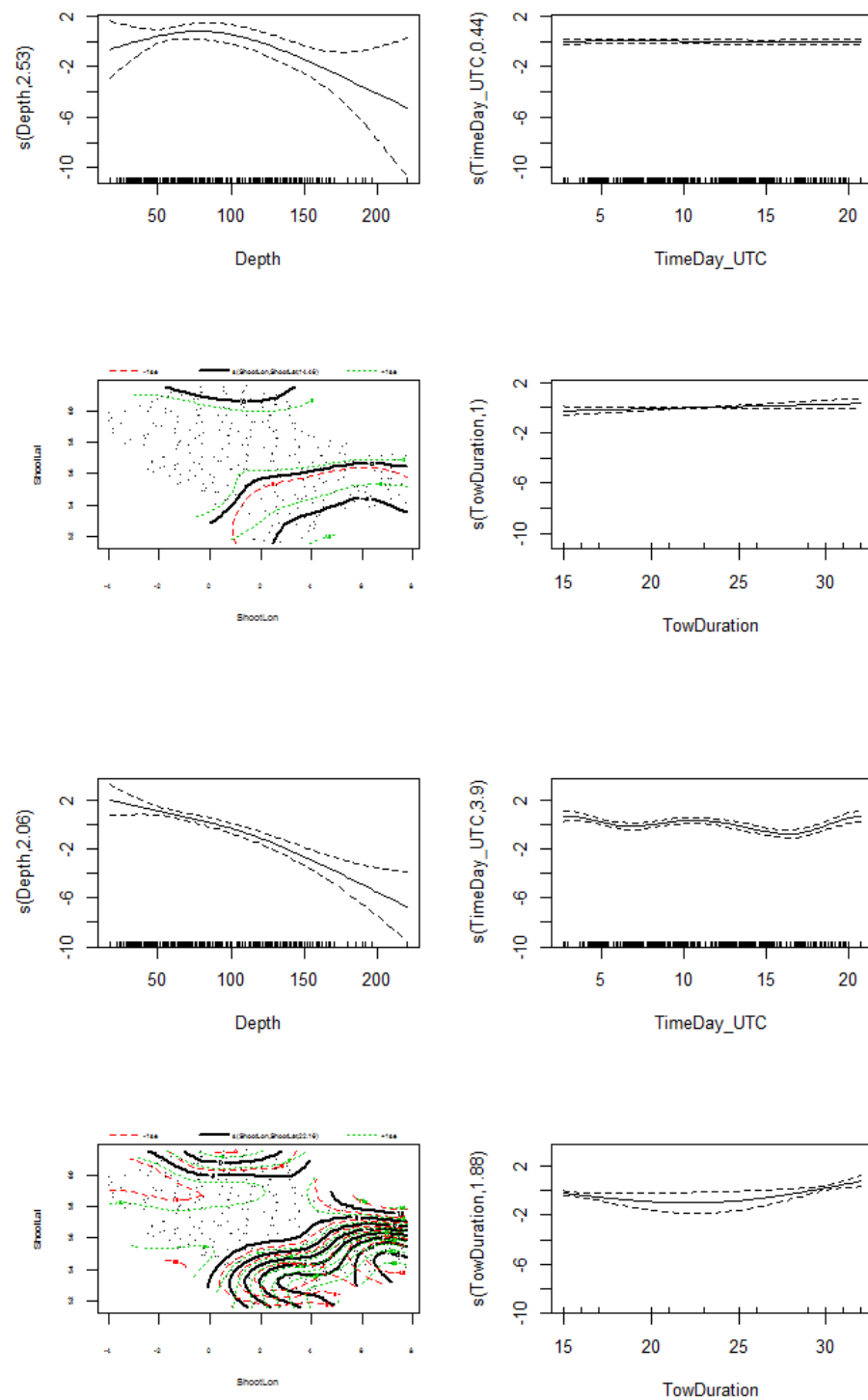**Figure 6.2.1.1: Response plots showing the effect of the smoothing functions on the catches of Cod age 1 (Time of Day with cyclical smoother and k=3, position (2D smother) with k=25). Upper panel: Negative binominal GAM (Significant covariates: Depth and position, Lower panel: Poisson GAM (Significant covariates: Vessel (factor), depth, time of day, position and tow duration).**
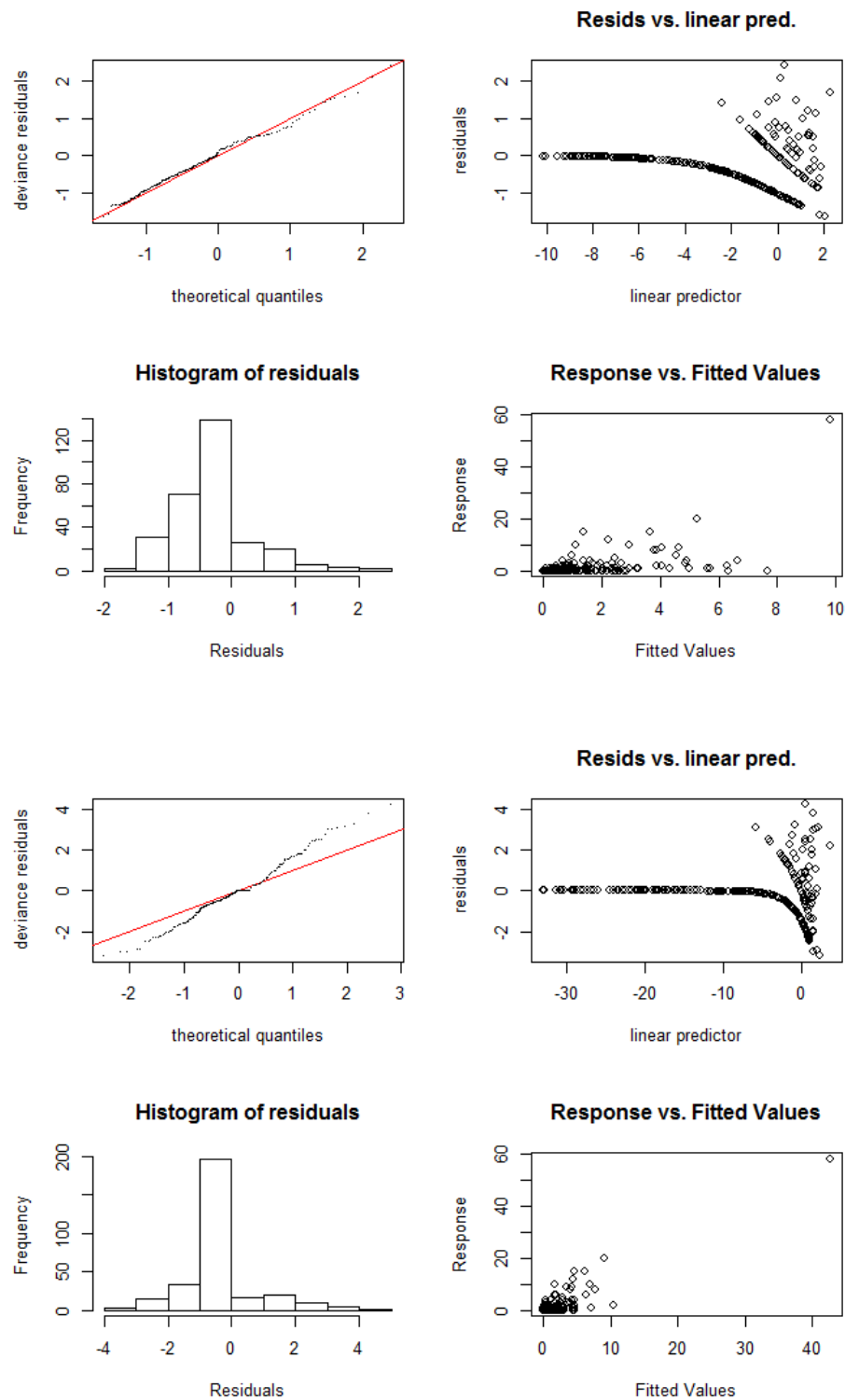
Figure 6.2.1.2. Diagnostics for the Cod age 1 models from Figure 6.2.1.1. Upper panel: Negative binominal GAM (Theta: -0.76, Deviance explained: 61.3%, AIC: 573.81, AICc: 567.99), Lower panel: Poisson GAM (Deviance explained: 66.7%, AIC: 684.26, AICc: 693.82).

However, since the frequency distribution is strongly bimodal with the by far most values between 15 and 16 min or between 29 and 32 min, this variable should be modelled as a categorical one, i.e. "short" vs. "long" tow, and estimated the degree of freedoms in the GAM as it had already been done for haddock and Norway pout.

WGISDAA considers that Negative binominal distribution is most appropriate for species exhibiting schooling while the Poisson distribution may work better for species or age groups that are not too rare or show a highly patchy distribution. Both distributions can be applied to count data, but for new analyses, the Poisson distribution appears to be preferable unless clear indication for overdispersion is encountered (Theta values roughly < 10). A comparison of the model diagnostics for both likelihood functions is shown in Figure 6.2.1.2, and here the AICc comparison would support the negative binominal model. When using tow duration as a categorical variable no change in the effect of the covariates were found except that the effect of short and long tows became also not significant in the Poisson model for cod age 1.

The following issues should be considered for future analyses:

- Use of AICc (Akaike information criterion corrected for small sample sizes) as a model selection tool. AICc is more adapted than AIC for small dataset (and converges to AIC values as the number of data increases). Information criterion is often used in the literature to choose between covariates combination and likelihood functions,

- Consider residual structure, the estimated degree of freedom from the smooth terms, and the biological plausibility/realism of the estimated effects (and the estimated confidence interval).

WGISDAA examined further the question about the effect of tow duration on the observation of older age class (e.g. cod age 5) and suggests using a binomial model instead of modelling the low catch rates explicitly (Figure 6.2.1.3). However, the model had very little power to detect the effect of tow duration because of the scarcity of the age groups and the small number of observations. More importantly, WGISDAA winders the importance of these older age classes for stock assessment. Therefore, it would matter whether we catch more or less of these age 5+ fish with shorter tow duration. However, given current levels of cod abundance it is unlikely that there will be sufficient power in the analysis to detect statistically significant differences. The effects of changing tow duration on the assessment in case of future recovery of the stock are very difficult to predict.
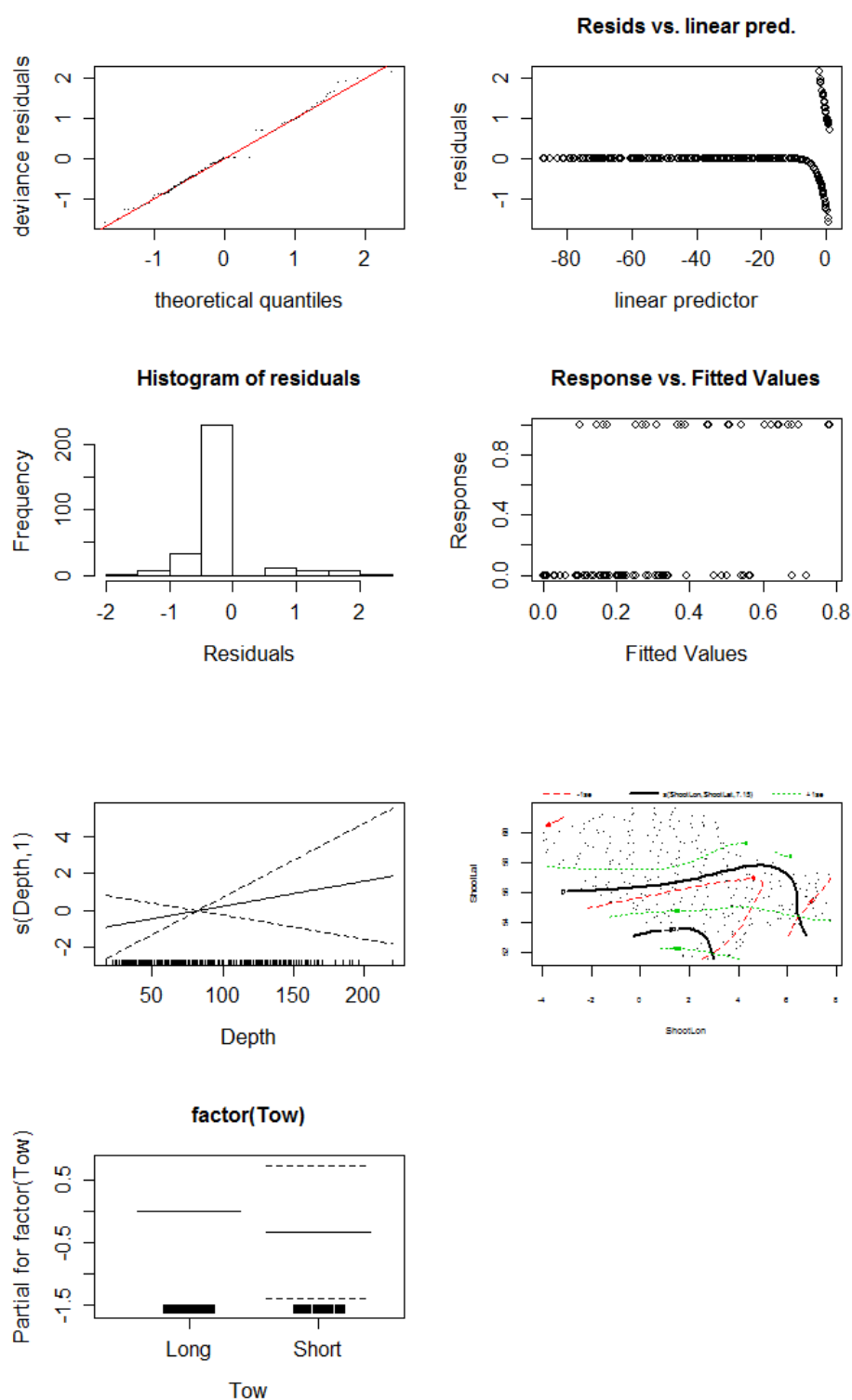
Figure 6.2.1.3. Diagnostics and response plots for a presence/absence GAM for cod age 5.

5.2.2 Tow duration and species richness

IBTSWG reported that species richness in the 3Q NS-IBTS 2015 was lower in the short than in the long tows. This was based on an analysis considering 84 fish species or species groups. The analysis was done at a time when the submissions from the different countries had not completely been quality checked. While some unusual records

reported for the long tows have been confirmed in the meantime (e.g. *Scomber japonicus* and *Sarda sarda*) other are not (e.g. *Trigla lyra*). However, in total 12 'species' were found only in the long tows and other 7 'species' were only found in the short tows, and for the remaining 'species' occurring in both tow durations the number of tows in which they have been found did apparently not differ very much.

Species identification may differ between countries, e.g. *Mustelus mustelus* and *M. asterias* are not necessarily distinguished by all teams within and between vessels, and the allocation was tow durations between countries was unbalanced. Here, it might have an effect that England did 100% long tows while the second country in the respective rectangles did only short tows. Similarly, the distribution of long and short tows between potentially different habitats was not controlled.

WGISDAA considers the result of the applied Welsch test surprising i.e. was a one-tail test used? In that case, the hypothesis needs to be reformulated to H0: number of species in short tows is not lower than in long tows. Furthermore, WGISDAA thinks that it may be more effective to replace it with a GLM (with gamma or other error distribution) with tow duration as a categorical covariate and potentially habitat types as another covariate.

WGISDAA thinks that the species accumulation curve with the use of permutation is a reasonable approach but there is a danger of extrapolating the accumulation curve beyond the number of tows that has been observed. It is therefore recommended to compare this biodiversity analysis with species diversity based on a longer survey time-series or a recent year with 100% long tows.

References

ICES 2016. First Interim Report of the International Bottom Trawl Survey Working Group (IBTSWG), 4-8 April 2016, Sète, France. ICES CM 2016/SSGIECOM:24. 292 pp.

5.3 Two-meter Midwater Ring trawl (MIK) sampling for O-winter ring herring larvae in the North Sea during the first Quarter of the year in conjunction with the International Bottom-trawl Survey (IBTS).

5.3.1 Update on the MIK herring larvae survey presented during the meeting.

The MIK survey provides an abundance index for large herring larvae (around and > 20 mm SL) that is used as a recruitment index for North Sea herring. It takes place during first quarter IBTS. Catches are standardized to abundance of herring larvae per m² and from those values an index for larval abundance is calculated for the entire survey area.

Only the offspring of the autumn spawning components (Orkney/Shetlands, Buchan, and Banks) are considered for the index because those components have dominated the North Sea stock in the past and larvae of the winter spawning Downs component have not passed the stage of high and variable mortality. When the index calculation algorithm was formulated, it was assumed that small Downs larvae are only abundant south of 54°N. Consequently, only for stations south of that latitude, an exception rule is implemented. The mean larval length for each of those stations is calculated, and if that value is < 20 mm all data from that station are excluded from the index calculation (for a more detailed description, see last year's WGISDAA report, ICES 2015a).

With the increasing importance of the Downs component in total North Sea herring SSB it became apparent that the current algorithm for calculating the MIK herring larvae index became more likely to produce biased results. In addition, small larvae drifting beyond that boundary may cause problems in the index calculation. This was particularly true for the 2014 MIK survey when large numbers of small herring larvae, assumed to be originating from the Downs component resulted in an extraordinarily high MIK index (Figure 6.3.1.1).

That problem has again been dramatically highlighted during the 2016 Q1 IBTS. A large advection of herring larvae originating from the Downs component to waters west of Denmark again led to another apparently severely biased MIK index.
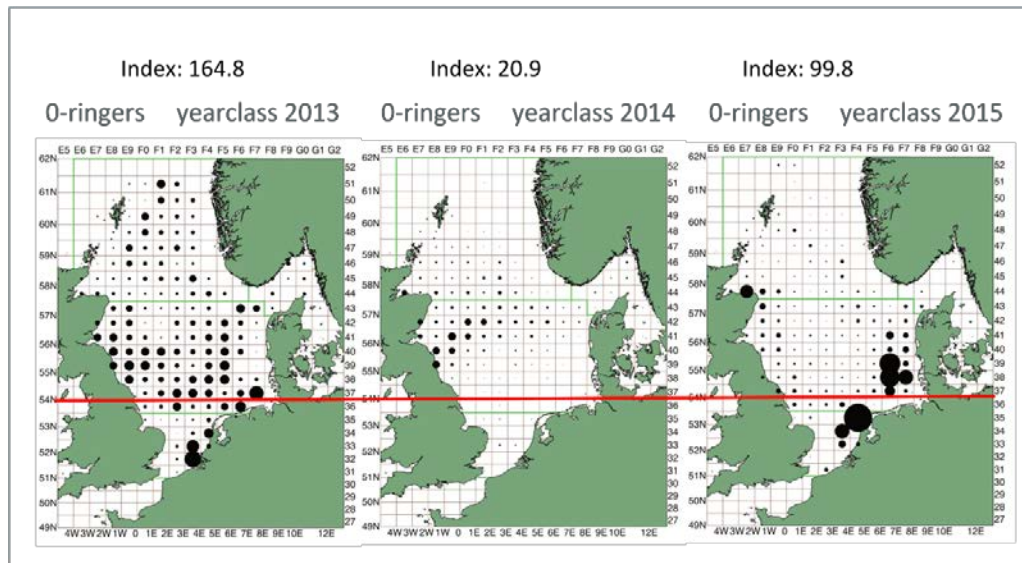
Figure 6.3.1.1: Examples of 3 consecutive years (2014–2016) of MIK index results for North Sea herring larvae. The distribution of the mean herring larvae abundance per each ICES rectangle is shown. Note the high abundances of the 2015 year class north 54°N (red line) in the eastern part of the North Sea. All of those correspond to the high advection of small larvae from the Downs component.

During last year's meeting of WGISDAA, these issues were thoroughly discussed and the working group recommended that in the first place the Herring Assessment Working Group (HAWG) should evaluate the importance of the MIK index for the assessment of the North Sea herring stock. HAWG discussed the recommendation and concluded that the index is still needed for recruitment forecasts and that HAWG will not refrain from using the index in future. Therefore, HAWG also recommended the implementation of a workshop especially dedicated to resolving the issues with the MIK survey. That workshop (Workshop on Herring Larvae Surveys, data needs and execution, WKHERLARS) will be held in November 2016 at IMARES, IJmuiden, the Netherlands. The workshop will also consider the recommendations of this Working Group that were made last year: **a.:** the revision of the exclusion criterion making better use of the extensive length information that is already existent in the data, and **b.:** make use of drift models that are currently in development in order to determine the potential contribution of the single-stock components to the MIK index. An outline of the proposed modelling approach is given in the following chapter.

In addition, the HAWG has recommended another Workshop for 2017 (Workshop on Stock Identification and allocation of catches of herring to stocks [WKSPLIT]), which

has the goal of providing methodologies and protocols for identifying the various herring stocks (or substocks), which co-occur in samples, catches or areas of the Northeast Atlantic. The workshop will explore a variety of otolith (shape, primary increments etc.) and genetic techniques. The relevance to the larvae in the North Sea region will be techniques to separate out the various components or substocks in the MIK samples.

WGISDAA stressed that after revision of the MIK index the then newly established time-series of recruitment indices for the northern components needs to be evaluated by HAWG with respect to its validity in a combined stock assessment.

5.3.2   Outline of the drift modelling

The autumn spawning herring in the North Sea and adjacent west of Scotland and Ireland span three ICES assessment and management areas (North Sea, 6a North (6aN) and 6a South (6aS)). Their principal nursery areas are coastal and inshore with the largest of these being in the German Bight and the Skagerrak area. Both of these locations probably contain mixtures of young herring from different origins. According to Saville and Bailey (1980), herring from the west coast of Scotland (an adjacent management area) are found on NS nursery grounds and Heath (1989) showed the transport of larvae eastward from the west of the British Isles in to the North Sea. Evidence of west coast juveniles in the North Sea was reported by Saville and Bailey (1980, see Saville, 1971), and Campbell *et al.* (2007). Some NS herring larvae also get caught in the Norwegian coastal current (Fossum and Moksness, 1993) and are probably advected into Norwegian fjords.

Prior to the collapse in the 1970s (Dickey-Collas *et al.*, 2010) the herring in the North Sea were comprised of a number of stocks (Corten, 2013). Currently the North Sea complex is managed as one stock (ICES 2015b), although at least four major components (Orkney/ Shetland, Buchan, Banks, and Downs) are recognized (Hufnagl *et al.*, 2015). The current assessment model used for North Sea herring (ICES 2015b) is capable of including substock Spawning-stock biomasses (SSB) information to provide a more spatially explicit assessment (Hintzen and Payne, ICES HAWG, pers. comm.).

The principal questions addressed in this section cover potential issues related to the substocks within the North Sea ('Is it possible to distinguish the four principal subcomponents (Orkney/Shetland, Buchan, Banks, and Downs) within the MIK data and the extent of ingress of larvae from the adjacent Division 6 (west of Scotland) caught in the MIK survey ?).

Exploratory modelling has been undertaken by the Institute of Marine Research (IMR, Norway) and will form part of an application for further funding to undertake an international initiative to develop the models further.

The particle tracking modeling: The Hydrodynamic model, ROMS (Regional Ocean Modelling System, http://myroms.org), is a well-validated model results for the Norwegian Seas, 4 km horizontal resolution (Lien *et al.,* 2014). The particle-tracking model applied is the main Lagrangian trajectory-model used at IMR. The simulations assumed passive drift in fixed levels, distributed evenly between 0 and 50 m, initialized at known spawning grounds (Figure 6.3.2.1) within observed spawning periods.
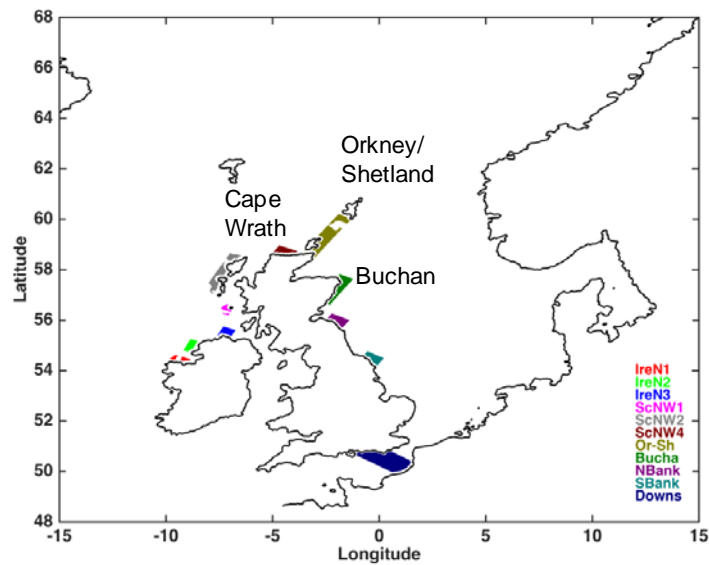
Figure 6.3.2.1: Location of main herring spawning grounds around the British Isles which are relevant to studies concerning larvae in the North Sea during January-March. These locations were used as the starting points for the particle tracking modelling.

Selected model outputs

The model runs were stopped at approximately the midpoint date of the annual 1st Quarter IBTS MIK survey. The raw distributions of larvae at that time can be displayed as shown in Figure 6.3.2.2. In all cases examined there was considerable mixing of larvae from the different spawning grounds, indicating that a sample in a particular ICES rectangle would have a mixture of larvae.
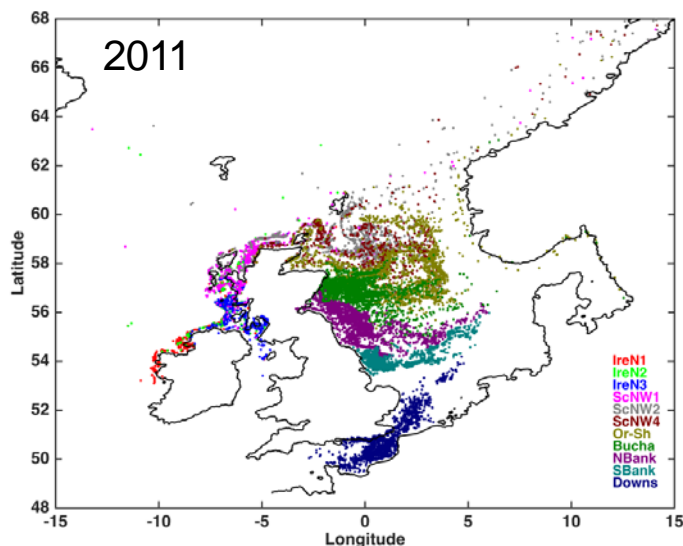

Figure 6.3.2.2: Distribution of particles (herring larvae) in March 2011 (2010 year class) at the time of the MIK survey as suggested by the particle tracking model. Points are colour coded by their origin (spawning ground, see Figure 6.3.2.1).

Another presentation of the data is to show the distribution of larvae by spawning ground at the time of the MIK survey in Figure 6.3.2.3.
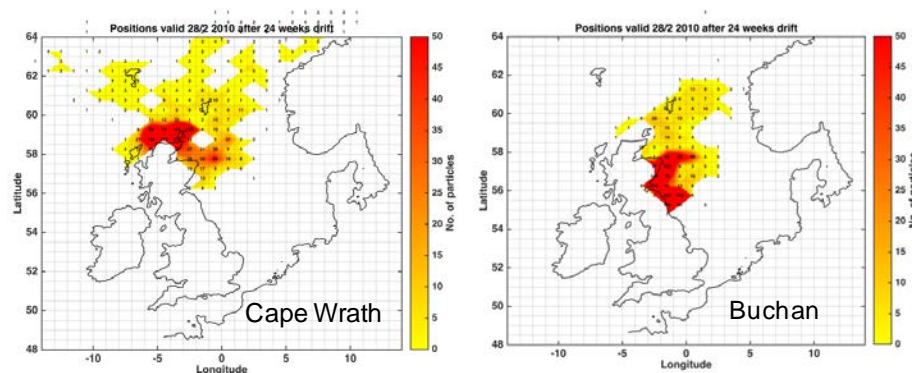
Figure 6.3.2.3. Distribution of larvae, by ICES statistical rectangle, at the time of the 2010 MIK survey, of herring larvae from the particle tracking modelling. Larvae originating in spawning grounds off Cape Wrath (left) and Buchan (right).

There is a possibility that the particle tracking results could be used for determining the contributions of each of the spawning grounds to the overall MIK recruitment index. An example for a selection of four ICES statistical rectangles in the north central North Sea is given in Figure 6.3.2.4.
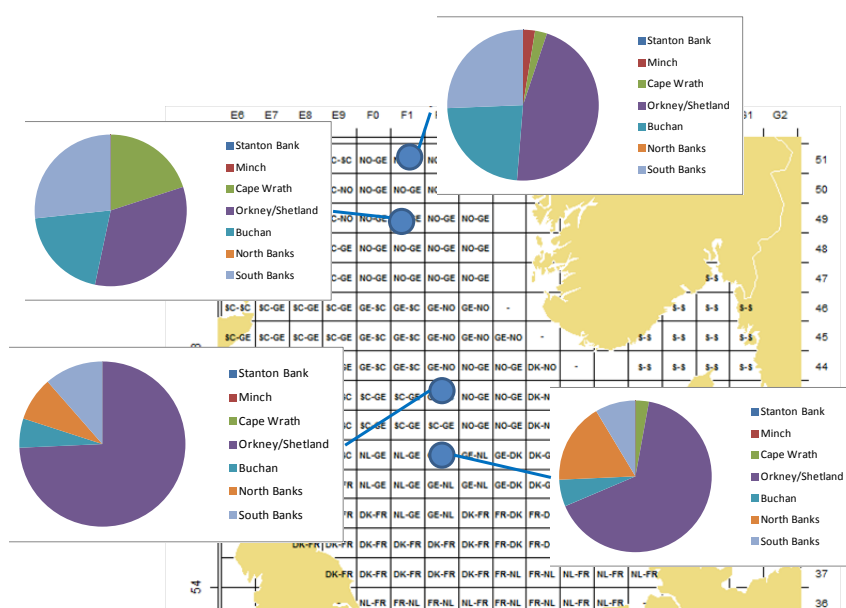

Figure *6.3.2.4:* Proportion of larvae in selected ICES statistical rectangles from each of the known spawning grounds as estimated from the particle drift modelling.

The model outputs show the reduced contributions from the north and west of Scotland (Minch and Cape Wrath) from northwest to the south and east. Likewise, the large contribution from the Orkney/Shetland spawning grounds to the north with an increase in contributions from Buchan and Banks to the south and east.

5.3.3   Recommendations for future calculation and protocols in the estimation of MIK indices of herring recruitment in the North Sea

The new index calculation algorithm should follow a 2-phase approach: in a first phase, each year in the short time between the MIK survey and annual meeting of the Herring Assessment Working Group, a preliminary MIK index should be calculated based on simple, fixed rules. Larvae of Downs origin should be excluded. The samples of all

stations should be used while an exclusion rule is only applied to length classes within each sample. That exclusion rule should only apply at stations in an area where the occurrence of Downs larvae is most likely. For a preliminary index, the boundary shall be a fixed, but not necessarily straight line. In a second phase and prior to the HAWG meeting in the following year, the index will be refined based on modelling results. Accordingly, the index calculation will follow 3 steps:

1) Redefine the area where exclusion rules for larvae of Downs origin apply.

2) Inclusion of larvae greater than 18 mm in areas where currently the rule is if the mean length of larvae at a station is < 20 mm all data from that station are to be excluded from inclusion in to the index value.

   The 18 mm minimum size, should exclude any 'Downs' larvae but will allow larvae from the other spawning grounds to be included in the index calculation. The drift modelling indicates that larvae originating in spawning grounds other than the Downs can occur south of 54°N. The length class of 18 mm does not yet represent fixed value and is subject to revision by WKHERLARS;

3) Utilize the drift modelling results to inform any decisions in the southeastern part of the North Sea as to the likelihood of areas being significantly influenced by winter spawned (Downs) larvae.

   These data will provide additional support for any decision made in 1) and 2) above, either for fixing cut off values for both, larval size and geographic boundary, in calculating a preliminary index, but also for their revision while providing a final index in each year. Further refinements in the modelling framework e.g. more realistic spawning times, growth rates and mortality rates will provide more conclusive support for the decisions concerning inclusion in to the index and origins of larvae.

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5.4 The mackerel and horse mackerel egg surveys in the Atlantic

5.4.1 Adaptions to the 2016 survey

During its 2014 meeting, the Working Group on Mackerel and horse mackerel Egg Surveys (WGMEGS) asked WGISDAA for support in conducting the Atlantic mackerel and horse mackerel eggs survey while taking account of the extension of both spawning area and season at limited survey resources without creating a biased SSB index.

The mackerel egg survey (MEGS) is carried out triennially and delivers the only fishery-independent data for the assessment of Northeast Atlantic mackerel and horse mackerel. Total annual egg production is calculated from counts of freshly spawned eggs taken from tows with Gulf VII type samplers. Plankton samples are taken on stations on predefined zonal transects every full half degree latitude using the alternate transect strategy, i.e. during the first half of each cruise the assigned survey area is sampled on every other transect and the remaining transects filled in during the second half. In addition, survey participants are requested to follow an adaptive strategy while following their transects, i.e. each transect should only be finished after encountering zero counts of freshly spawned mackerel eggs. Total annual egg production (TAEP) is then calculated from stage 1 egg abundance data. With the fecundity values estimated during the same survey, the TAEP of mackerel is then converted into an SSB value for mackerel, which is used an index in the assessment. For horse mackerel, the TAEP is used directly as an index for SSB in the assessment (for more details see last year's WGISDAA report, ICES 2015a).

Extension of the spawning time and area at limited survey resources necessitated leaving out of every other transects in order to achieve a full coverage. Additionally, it also became increasingly difficult to represent the annual egg production for both target species of the survey, mackerel and horse mackerel, as their time of peak spawning appears to drift further apart. This raised concern that the current survey design will not be able to provide reliable and defendable estimates of TAEP and SSB for mackerel and TAEP for horse mackerel, in future.

During its 2015 meeting, WGISDAA recommended that WGMEGS should consider investigating temporal and spatial variability of mackerel and horse mackerel egg production and to estimate the contribution of northwestern spawning extension to total annual egg production. This should indicate areas where effort savings could be made that have minimal impact on the precision and accuracy of the index. WGMEGS should also replace the double zero rule for transect termination by a more meaningful one.

WGMEGS was in the middle of survey preparation for 2016 when WGISDAA's recommendations were published. The last recommendation, however, was adopted for this year's survey. No participating country would, thus, be forced to conduct an unnecessarily long transect at the cost of having less survey time available for the core spawning area. Thorough sampling in the core area was considered by WGISDAA being of higher importance for an unbiased SSB index than a full coverage of the total spawning area. WGMEGS was also able to recruit new survey participants for a better coverage of both survey area and time. The necessary ship time will be provided by the pelagic

fishing industry at the cost of scientific quota. Need to discuss the efficacy and utility of this once results are available.

5.4.2 Prediction of egg production distribution w.r.t. spatial and temporal dynamics of environmental parameters.

A detailed study on the spatial and temporal variability of mackerel egg production was conducted by Mark Payne (DTU-Aqua, Denmark) in order to predict egg production in survey years facilitating real-time advice for the mackerel egg survey design. An outline of that model is given in the following chapter. That study could also be utilized for a more detailed look into egg production variability and contribution of the northwestern spawning extension to TAEP.

The model predicts presence or absence of mackerel egg production and, in case of presence, the daily egg productions by area. Covariates used were SST, primary production, bathymetry and daylength. Other covariates were volume filtered and gear-type. Applied models were binomial GAM (presence/absence) and zero inflated Poisson GAM (daily egg production). As input data, all survey years between 1992 and 2013 were used. When applied to the different survey years (1992–2013), the model had an overall capability of predicting more the 75% of either presence or absence of egg production correctly. The model was then applied to the current MEGS (2016) in order to assist survey planning. Per each survey period, the probability of encountering mackerel production as well as its magnitude was modelled and compared with the survey plan. While the major spawning areas appeared to be well covered by the survey plan over all of the spawning season, the model results also highlighted areas (e.g. in the Northwest south of Iceland and close to the Faroese) where survey effort may become disproportionately high with respect to the area's contribution to the total annual egg production. Other areas, particularly in the Cantabrian Sea, were not covered at all during a later period, despite a high probability of considerable egg production there (http://www.staff.dtu.dk/mpay/Talks).

5.4.3 Recommendations

The working group supports the environmentally based approach and suggests:

In order to test the quality of the model, the working group stressed that it would be worthwhile to test whether the prediction of the northwestern expansion of the spawning area in the years 2010 and 2013 could have been achieved with the current environmental model setup. While one of the major reasons for the expansion appears to be the increase of the spawning stock size, SSB itself is not included in the model. Conditional on this assumption, the working group concluded that expansion or contraction of the spawning area is unlikely to be reliably predicted with the current model alone. The model would also benefit from estimation of the amount of spatial autocorrelation of residuals and further verification particularly where predictions diverge from historic perceptions.

5.5 Potential effect of a Q3–IBTS redesign by WKPIMP on commercial fisheries indices for stock assessment.

Background:

WGISUR requested information regarding methods that would make it possible to maintain time-series of important commercial species assessed in ICES stock assessments while altering the survey design and effort levels in the North Sea Q3 IBTS to

develop a more ecosystem integrated approach. The WG was unable to offer general advice on this question because of the extremely wide range of options for change. Without further specific information as to the desired changes, the response would need to be too extensive and time consuming. Instead, the WG decided to use the draft proposal developed by WKPIMP 2016 as a starting basis for assessing the appropriateness of the design and the possible consequences on the delivery of survey information for stock assessments.

Survey designs:

Current design: The current Q3-IBTS design is based on a systematic design based on ICES rectangles in which sampling is conducted randomly, with most rectangles having replicate samples from different vessels. Practically at least sampling within rectangles has been less than random with several countries/ships returning to the identical tow positions year after year due to concerns over gear damage at other possible locations.

Proposed design:

The new survey design is planning to use the same GOV gear currently used and envisions no change to the spatial extent of the survey area, simplifying the maintenance of time-series significantly. The intention is to stratify the area into ecologically relevant strata abandoning the current rectangle based systematic design for a random design for a substantial number of possible safe towing positions.

Qualitative determination of effects and means to quantify likely impact on assessments:

Most indices used in stock assessments based on the Q3-IBTS survey simply use the mean abundance at length in a rectangle adjusted to an hourly tow and converted to the mean abundance at age using age length keys for the associated species-specific ALK areas. The resultant rectangle abundance is then summed by age over the species-specific survey area to derive the annual age based index. This method assumes that all rectangles are sampled, so where intended effort levels are insufficient to cover all rectangles in all years the new design will fail to produce values consistent with the historic time-series. WGISDAA qualitatively examined the data available in the current design to examine if there may be potential alternate methods of index calculation that would be consistent across both designs, with the following conclusions:

Plots of cpue at each station over the last 11 years for the important stocks assessment species in which the Q3-IBTS data are or could reasonably be used were examined for coherence with the proposed stratification scheme (some examples shown in Figure 6.5.1). Variability of total abundance within strata generally seems to be lower than variability between strata. The stratification scheme does not appear to be ideal for all species at current abundances. The differences in the distribution of individual species suggest that no one stratification would be ideal for all 10 species at reasonable effort levels, but the proposed scheme with possible modifications is likely to be considerable more efficient than a completely random design. If YEAR and Stratum variance components are orthogonal and station abundances within a stratum are more or less random, then it should be possible to derive continuous time-series of abundance using the GLM approach despite the change in survey design. WGISDAA should derive quantitative descriptions of the variance components for each species for the proposed design are required for the abundance estimates.

Considering abundance alone may be insufficient to evaluate the effect of design changes, because some indices are used at age. Since the major change in the survey design, at least on an initial examination appears to be the overall change in effort, it is necessary to examine if such reduced effort would still provide sufficient randomly collected otolith samples to reflect the relative abundance of age-at-length. For those stocks where the current index merely represents the sum of the rectangle abundance it is likely that a decrease in effort will merely decrease the precision of estimates, particularly for older rare ages. Some of this could be compensated by larger subsamples of otoliths at length. However, where lengths themselves become rarer due to fewer samples increases in stochasticity are unavoidable. Fewer larger samples (longer duration) may be an option if but may lack the independence of otolith samples. Generally, we would expect a decrease in precision with a substantial decrease in effort. Dependent on the appropriateness of the current roundfish ALK strata vs. the new ecosystem strata historic estimates of trend may change and precision of estimates under the new design may be slightly lower.

The Q3-IBTS cod index already uses annual regression methods to derive the index. Unlike the other index method, it does not assume orthogonality between distribution in time and space. Instead, it assumes that samples are collected randomly, and that covariates used (location and ship, for example) are uncorrelated. These assumptions may be violated in historic data and the effect of this should be tested. For the future collections, the proposed plan is much more consistent with the way the data are analysed currently specifically attempting to reduce the correlation between different variables in the design and maintaining randomness wherever possible. Potential disadvantages of the new design would be that the distance between stations is likely to be much more variable than in the systematic design so that the spatial smoothing may be more imprecise. The problem may be exacerbated for the age information particularly for rarer ages. WGISDAA attempted to bootstrap the current dataset using the index methodology at different effort levels to try to identify the contribution of these effects to the uncertainty in the index. There were insufficient resources available to complete this work prior to the WG, but the necessary tasks were identified and discussed at the WG. It is hoped that this work can be completed intersessionally.
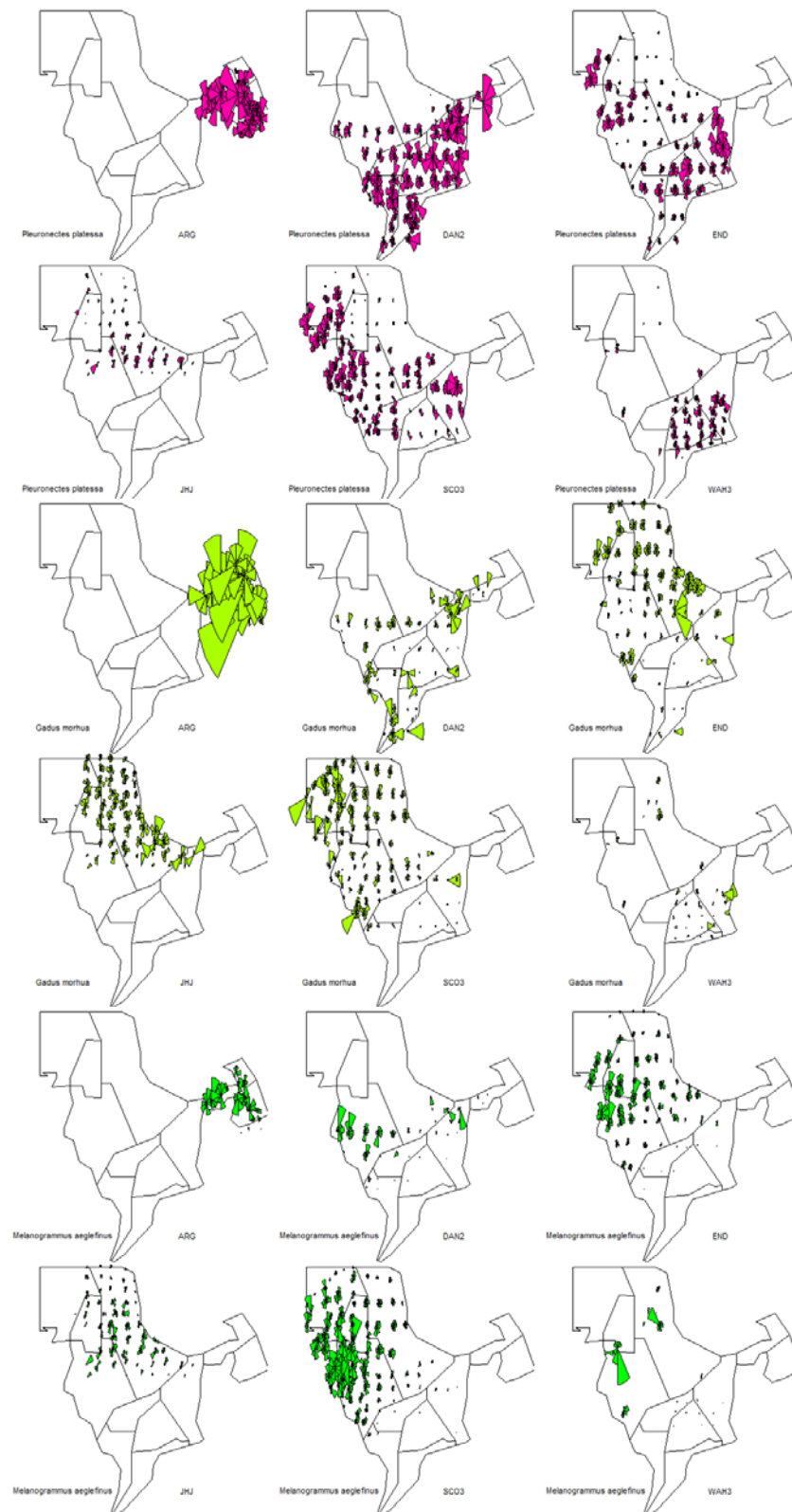
Figure 6.5.1: 11-year IBTS survey abundance plots by vessel, overlaid on the stratification scheme recommended by WKPIMP. Pie-slices represent the 11 years (2005–2015 clockwise starting at 12:00) with the radius of the slice proportional to the square root of cpue. Plaice (top) indicate a temporally stable pattern with low variability within strata. Cod (middle also indicate a reasonable coherence with the strata, but also indicate some temporally random large catches spread across the coastal strata. Haddock (bottom) are consistently encountered in greatest abundance in the NW also showing occasional large catches, but temporally consistent suggesting cohort effects.

6 Revisions to the work plan and justification

No revisions made this year.

7 Next meetings

The third and final meeting of WGISDAA in this period of multi-annual TOR's will meet at ICES Headquarters, Copenhagen 11–13 July 2017. There is an offer for an alternate venue in Seattle but this would require moving the meeting to the 6–8 June 2017. A final decision will be made in 2017 once next year's WG schedule is made available to ensure that there are no clashes for participants.

Annex 1: List of participants

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