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Report of the Ad hoc Group on Sandeel - II

19-21 October 2009

Copenhagen, Denmark

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive summary

AGSAN2 (chair: T. Jakobsen) met at ICES Headquarters, Copenhagen 19-21 October 2009. The list of participants is given in Annex 1. The group addressed the procedure for real time monitoring in 2010 and made a plan for preparations for a benchmark assessment. The group updated the assessment, standardised the cpue, and revised the formula used for Real Time Monitoring.

As preparation for the benchmark meeting, the group revisited the stock structure, based on modelling of particle drift and other relevant information and agreed on splitting the sandeel in the North Sea into six assessment areas. The group discussed the potential for local depletion of the fishing banks and proposals for management measures to prevent such depletion. The management measures to be introduced in the Norwegian EEZ are described. Data requirements for the benchmark were identified and a detailed plan with commitments for submission of data at certain dates was drawn up (Section 5).

The Working Group recommends that a benchmark meeting is arranged in August 2010, which would be the last possibility if the results are to be applied in the 2011 management and would allow the results of the Norwegian acoustic survey in April-May 2010 to be included in the evaluation.

1 Terms of Reference

ACOM convenes an *ad-hoc* group on North Sea sandeel (AGSAN/2) on 19-21 October 2009 at ICES HQ and chaired by Tore Jakobsen (Norway). The group shall at this meeting:

1) Review and update the procedure for a real time monitoring (RTM) programme for possible use in 2010. This review shall address the criticisms expressed by ICES on the April-May 2009 RTM process.

2) Establish a work plan with the view of benchmarking the North Sea sandeel assessment process. The work plan shall indicate when this benchmark can be held and include commitments for input to the preparations for this benchmark. The benchmark shall cover all elements of the assessment process, i.e. assessment data, model and estimation procedure, projection model and possible in-year TAC revision procedure.

The *ad-hoc* group shall report to ACOM before 3 November 2009.

2 Data

2.1 Commercial catch data

2.1.1 Review available data

2.1.1.1 Total catches (by ICES square/month)

International sandeel catches per square are available from 1994 onwards. Distribution by year, square and month are available from Danish and Norwegian catches only, but as these contribute the large majority of total landings, their distribution are used to predict the monthly distribution of catches of other countries.

The number per tonne of each age group and the distribution of the Danish fishery are used for both Danish and non-Danish catches prior to 1994.

Danish landings of sandeel per square and month from 1989 onwards are known from samples taken by the Fishery Inspectors to measure the species composition and enforce the by-catch regulation. At least one sample (10-15 kg) per 1000 t landings is taken and these samples are used to estimate average species composition by area (ICES rectangles) and month. This species/area/period key is used together with logbook data (spatial distribution) and landings slip data (quantity) to derive the Danish WG estimates of landings of sandeel and by-catch of other species (further information can be found in ICES, 1994/Assess:7; Dalskov, 2002).

Before 1989, only logbook information stating the catch in the directed sandeel fishery is known. As the large majority of the catch in the sandeel fishery consists of sandeel, the distribution of catches in the directed sandeel fishery by square and month is assumed to represent the distribution of sandeel catches.

Total international catches in tonnes can be derived from the report of the Working Group on the assessment of Norway pout and sandeel (ICES 1995) and distributed on squares and months in the particular year according to the distribution of catches derived from logbooks. The development in total catch per area can be seen in Figure 2.1.

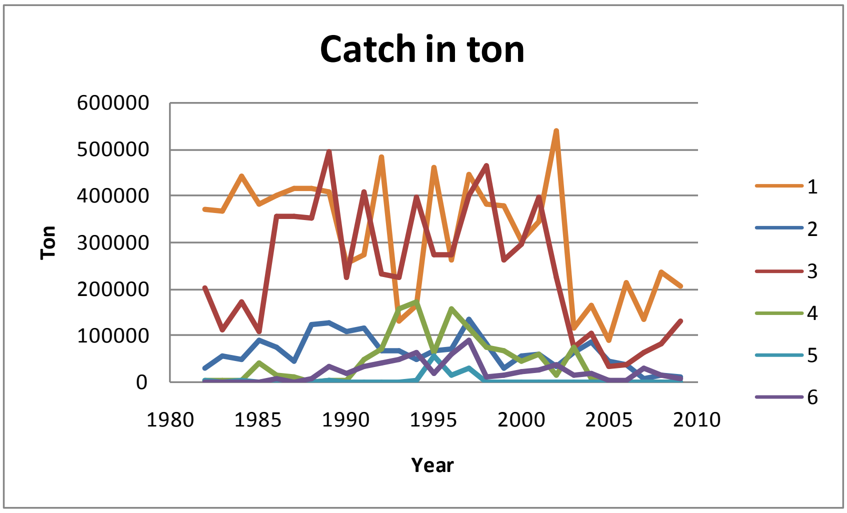

Figure 2.1: Development in total catch per area.

2.1.1.2 Commercial CPUE

Commercial CPUEs from the Danish fishery are available from 1982 onwards. The information includes number of days fished in a square, catches taken (allocated by day to the square where the highest catch was taken), date of landing and size of the vessel.

2.1.1.2.1 Norwegian CPUEs available

Commercial CPUEs for the Norwegian fishery as provided to the annual stock assessment are available from 1982 onwards. Detailed CPUEs in terms of number of days fished in an ICES square, catches taken, date of landing and size of the vessel are available from 2007 onwards.

2.1.1.2.2 Methods for standardization of catch indices

To standardize for differences in catch rates between vessels of different sizes, the median CPUE of a vessel of 200 GT is estimated using a correction factor *b* estimated from logbook data using the model

$$\ln(\hat{CPUE}_{y,V}) = a_y + b_y \ln\left(\frac{V}{200}\right)$$

where index *y* denote year, *V* is vessel size in GT, $\hat{CPUE}_{y,V}$ is median CPUE in the given rectangle, week and year for a vessel size of *V* and *a* and *b* are estimated using general linear models with normal error distribution. Observations used to estimate the parameters are Danish logbook records of catch of sandeel per day (available for the years 1982 to 2009). This standardisation combines the effect of differences in spatial and temporal distribution of effort of different vessel sizes. To avoid this, the correction factor *b* can be estimated in a model comparing vessel sizes in squares and weeks where they co-occurred only:

$$\ln(\hat{CPUE}_{sq,w,y,V}) = a_{sq,w,y} + b_y \ln\left(\frac{V}{200}\right)$$

where the indices *w* and *sq* denote Julian week (Julian day divided by 7) and ICES statistical rectangle, respectively. Estimating the parameters in this model, the difference between vessel sizes explains around 4.5% of the total variation in CPUE (Figure 2.2). As an alternative, the effect of KW was also investigated but this factor explained consistently less than GT (Figure 2.2).

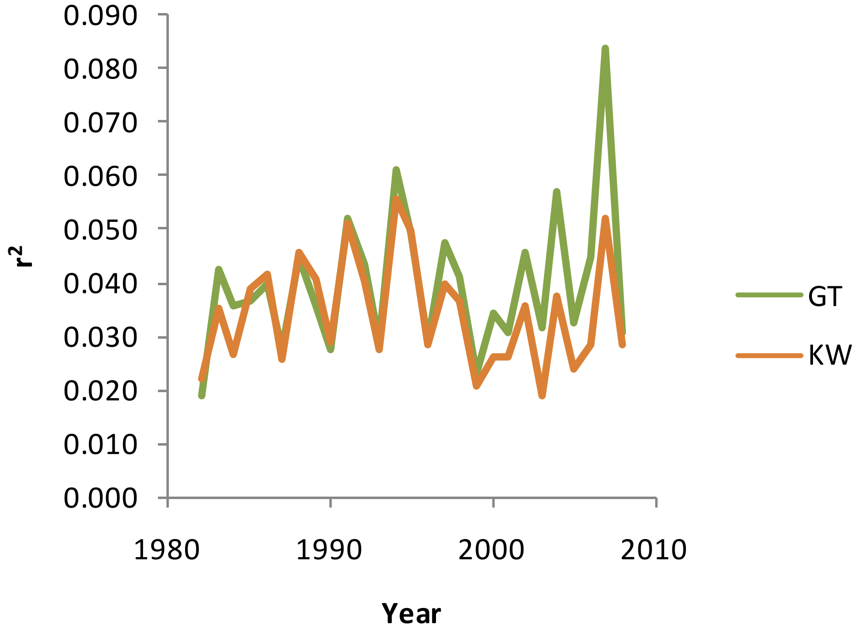

Figure 2.2: The proportion of the variation in CPUE explained by vessel size defined by GT and KW.

2.1.1.2.3 Technical creeping

It is likely that there is technical creeping in the catchability of sandeel to the fishery. However, preliminary investigations showed a significant creep of around 4% per year only in catchability of 1-year olds. This seems to be linked to a general change in catchability around 1999. This is reflected in the current assessment in a separation of the tuning time series of CPUE into two (before and after 1999). The difference may be caused by a change in the fleet as reflected in the mean size of the vessels participating in the fishery (Figure 2.3).

Figure 2.3: Mean vessel size in the fishery (average of fishing trips).

2.1.1.2.4 Reduction in effort

Total effort in the North Sea has decreased severely in recent years (Figure 2.4).

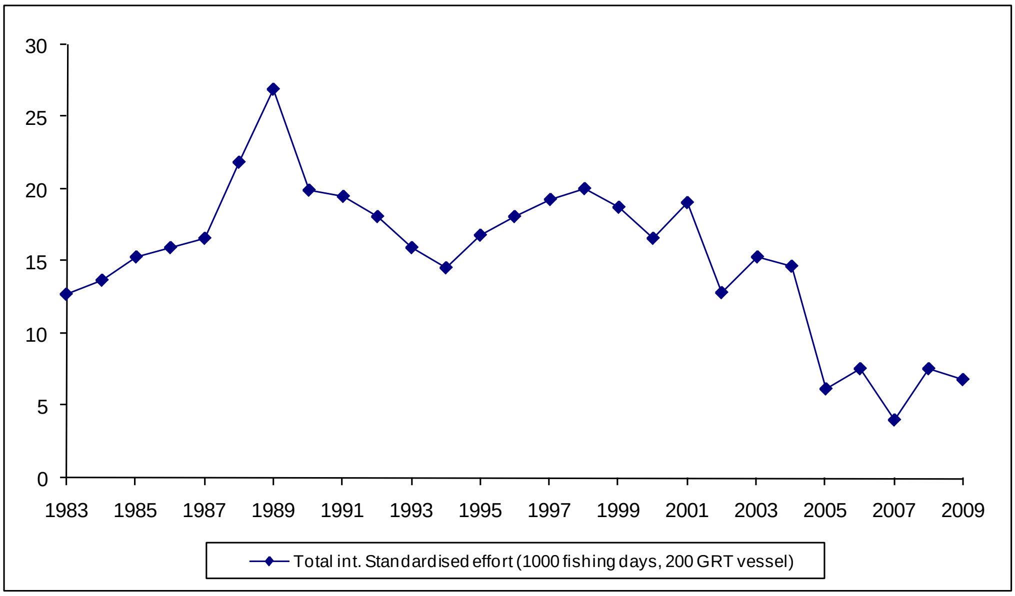

Figure 2.4: Total effort in the North Sea ('000 days) as a function of year.

2.1.1.2.5 Investigations of the shape of the relationship between commercial CPUE and density

There has been some concern expressed on whether commercial CPUE is proportional to abundance. This is a vital assumption in both the current assessment and the real time monitoring system. Besides the question of spatial coverage of the CPUEs investigated in section 2.1.1.2.2, two issues have been raised:

1) Does CPUE at a specific bank reflect abundance at that fishing bank?

2) Will the fishermen detect a reduced abundance through decreases in daily catch rates?

It is difficult to investigate directly whether CPUEs reflect abundance at a fishing bank as there are no commercially independent estimates of abundance. However, a number of indirect methods can be used. Firstly, the lack of movement of settled sandeel should result in a relationship between the number of age 1 in a given year and the number of age 2 the next year. Provided CPUE in numbers at age per time reflects abundance, such a relationship should also be evident between the CPUE of age 1 in a given year and the CPUE of age 2 the next year. Further, within a fishing season, the number of fish in each age group should decrease as the season progresses and fish are removed by both the fishery and natural causes. Provided CPUEs reflect abundance, this decrease should be apparent in CPUEs of each age group. Both hypotheses were investigated using information about individual trawl hauls collected from Danish industrial vessels fishing sandeel since 1999. Each vessel records the exact location and time of shooting and hauling of the trawl, the name of the fishing ground, and an estimate of the total weight of the catch in each individual trawl haul. Further, a sample of between 0.5 and 1 kg fish is collected from each haul. The catch at age in a given haul was estimated combining estimated catch in kg/minute haul time with number per kg of each age group estimated from the length distribution in the haul and age-length keys specific to the particular week and fishing ground. Age distribution was estimated by combining samples of length distribution with age-length keys and age-length keys were produced separately for each fishing ground, where possible using only data from the particular week. If weekly data were insufficient, 2-week periods were used to estimate the age-length key. The method described by Rindorf and Lewy (2001) was used. The number of each age group in the sample was used to estimate the number at age per kg caught. Catch rate in numbers of age a per minute, $CPUE_a$, was estimated by combining catch in tonne per minute with the number of fish of each age per kg. For use in the analysis of year to year mortality, the average catch in numbers per minute of age group a in year y at a given fishing ground, ($\overline{CPUE_{a,y}}$), was estimated when at least 5 samples were taken in the given year (all weeks together).

Relationship between catch rate of a given cohort in subsequent years

The change in CPUE from year to year of a given age a on a given fishing ground was estimated using the model

$$\ln(\overline{CPUE_{a,y}}) = d_a \times \ln(\overline{CPUE_{a-1,y-1}}) + k_a$$

where d and k are constants within age. If catchability is constant and identical for all ages, this model is equivalent to the model

$$CPUE_{a,y} = CPUE_{a-1,y-1}e^{-z}$$

where z is total mortality equal to

$$z = (1 - d_a)\ln(\overline{CPUE_{a-1,y-1}}) - k_a$$

If d_a does not differ from 1, mortality and catchability are density independent and total mortality is equal to $-k_a$. Assuming total mortality to be constant over the years at a given fishing ground, the parameters in this model can be estimated by simple linear regression. Density independent variation in mortality or catchability should result in variation around this relationship, but unless the variation is large (in which case it will not be possible to estimate the slope of the line), this should not bias results. The model was estimated for fishing grounds with at least 5 years sampled, each with average density the previous year ($\overline{CPUE_{a-1,y-1}}$) estimated from at least 5 samples. If the catch rate in the fishery does not reflect the density, the catch rates in subsequent years will be independent and hence the value of d_a would be zero. Unfortunately, estimates of 1-year old mortality cannot be calculated due to the low catchability of 0-year olds.

The decrease between years in catch rate of cohorts was estimated at 4 fishing grounds (N.W. Rough, Rorplads/Berwick bank, Southernmost Rough and Stenkanten v. Sorel, Figure 2.5). At these grounds, a total of 1144 mean catch rates had an estimate of the mean catch rate of the cohort the previous year (Figure 2.6). Slope and intercept (d_a and k_a) differed significantly between grounds and ages ($P<0.0001$ in all cases) and hence the slopes were estimated separately for each age and ground. Of the eight analyses, all revealed a significant positive relationship between current and previous catch rate and in no case did the slope exceed 1 (slopes >1 are indicative of hyperstability in catch rates). Three of the estimates were significantly lower than 1, the lowest value being found for age 3 at Rorplads/Berwick Bank. This was also the analysis which had the lowest range in the observed values of CPUEy-1 (Figure 2.6), and as a low range of observed independent variables may decrease the slope of the regression when the independent variables are not without error (Kendall and Stuart 1961), it is unclear whether the low slope in this case is caused by sampling error.

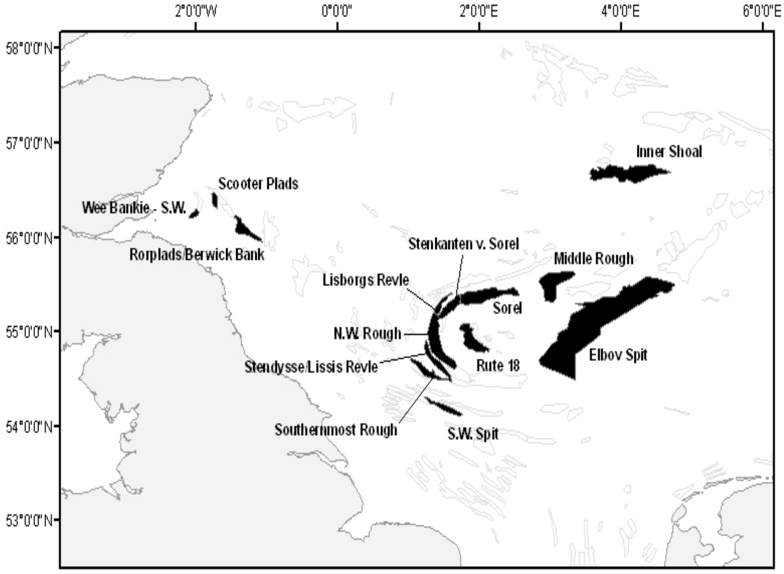

Figure 2.5: Map of fishing grounds used in the analyses. From Jensen et al. 2009.

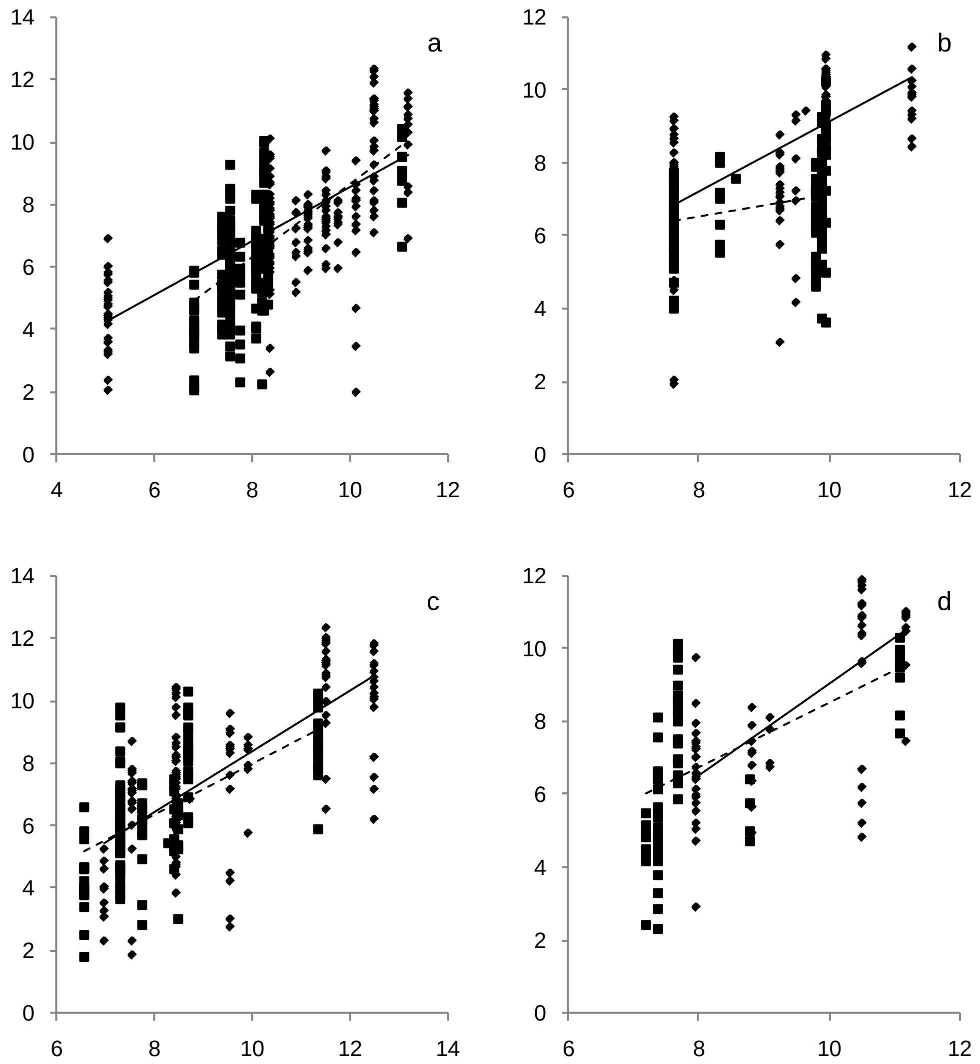

Figure 2.6: Catch rate (catch in numbers per minute) in the current year of 2- (diamonds) and 3+-year olds (squares) as a function of catch rate of 1 year younger fish the preceding year. N. W. Rough (a), Rorplads/Berwick Bank (b), Southernmost Rough (c) and Stenkanten v. Sorel (d). Lines are regression lines of 2 (solid) and 3+ (hatched) -year olds.

Fixing the slope to 1, the intercept, and hence -1 times the density independent total mortality when assuming catchability to be constant, ranges from -0.82 to -2.16, and the estimated common intercept is -1.49 (standard error 0.046). This is significantly higher than the average total mortality over the years 1999 to 2008 of 2-year-olds and older of 1.39 estimated by ICES using single species assessment methods but not significantly different from the total mortality of 1.55 reported by ICES using multispecies assessment (assuming the mortality from age 1 to 2 to be the average of that for the two age groups) (ICES 2008a, b). There is thus reasonable agreement between the fishing ground specific estimates of total mortality and those derived from assessment models. Further, the catch rate of a given cohort was consistent between years as would be expected if CPUE is proportional to local abundance. There was no evidence of hyperstability of catch rates.

Within season decline in catch rate

To investigate whether CPUE declined over the fishing season, the change in average ln(CPUE), $\ln(\widehat{CPUE}_w)$, over the weeks of a given age in a given year and fishing ground was estimated using the model

$$\ln(\widehat{CPUE}_w) = b \times w + h$$

where w is Julian week and b and h are constants describing the combined effect of mortality and changes in availability caused by burying behaviour (b) and the CPUE which could theoretically be obtained in week 0 (h), omitting subscripts of year, age and fishing ground for simplicity. The model was estimated separately for each age, year and fishing ground at fishing grounds and years where a total of at least 5 weeks were sampled. A value of b equal to zero indicates that CPUE does not decrease over the season. This means either that density does not decrease significantly (because of migration into the area or very low mortality rate), that catch rate in the fishery does not reflect density, or that the noise in the data is too large to allow the detection of a decrease.

The change in CPUE over the weeks (b) differed significantly both between fishing grounds, ages and years (P<0.0360). Hence, b was estimated using separate models of each age, year and fishing ground. This resulted in 64 estimates. Of these, 43 (67%) were negative and 21 (49%) of these negative slopes were significant at the 5% level. The distribution of the estimates of b did not differ significantly from those of a normal distribution (P>0.10, Kolmogorov-Smirnov test) and the mean value of b was -0.104 (standard error=0.032), which was significantly negative (P=0.0016, t-test). The r^2 of the models was generally low, ranging from 0 to 0.61 with an average of 0.13. Examples of the relationship in the two cases where more than 50 samples were taken from a fishing ground in a single season are given in Figure 2.1.7.

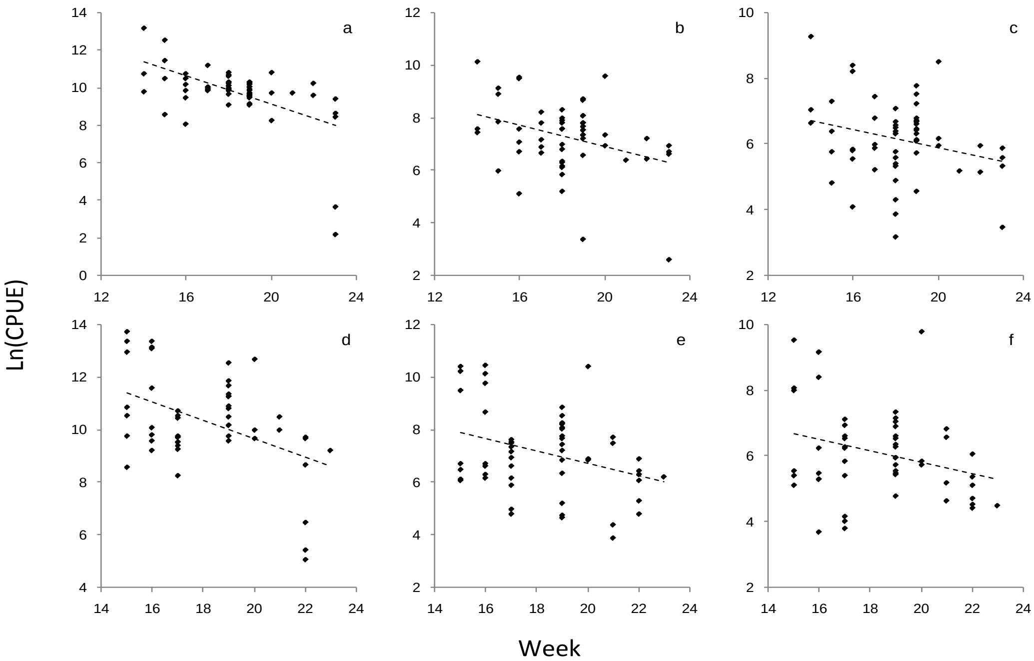

Figure 2.7: Decrease in CPUE (catch in numbers per minute) over the season at two selected fishing grounds in 2006: N. W. Rough (a, b and c) and Southernmost Rough (d, e and f). Age 1 (a and d), 2 (b and e) and 3+ (c and f). Hatched lines are regression lines.

2.1.1.2.6 Investigations of the shape of the relationship between commercial CPUE and density in the Norwegian EEZ

A majority of the Norwegian fishing grounds are considered commercially depleted (Sec. 5.4), i.e. the abundance of sandeel is too low to provide a profitable fishery. In 2007 and 2008 commercially CPUE data were obtained from Norwegian fishing grounds that were depleted by the fleet during one fishing season, namely Inner Shoal East and English Klondyke (Figure 5.4).

There were no landings of sandeel from Inner Shoal East between 2002 and 2006 (Figure 5.3). In 2006 the area was repopulated by new recruitment. Between April 5 and April 23 2007 the Danish and Norwegian fleets landed 11 000 tonnes of I-group sandeel from Inner Shoal East. After April 2007 no sandeel have been fished on this fishing ground, despite being open in 2008 and 24 Norwegian vessels visiting the area. Acoustic surveys in April-May 2007 (after fishery), 2008 and 2009 have confirmed that the abundance of sandeel has remained at a very low level after the fishery in April 2007 (Figure 5.5). During the fishery in April 2007 there was a minor increase in CPUE (Figure 2.8) and vessel size (Figure 2.9). CPUE did not decrease during the last few days of the fishery.

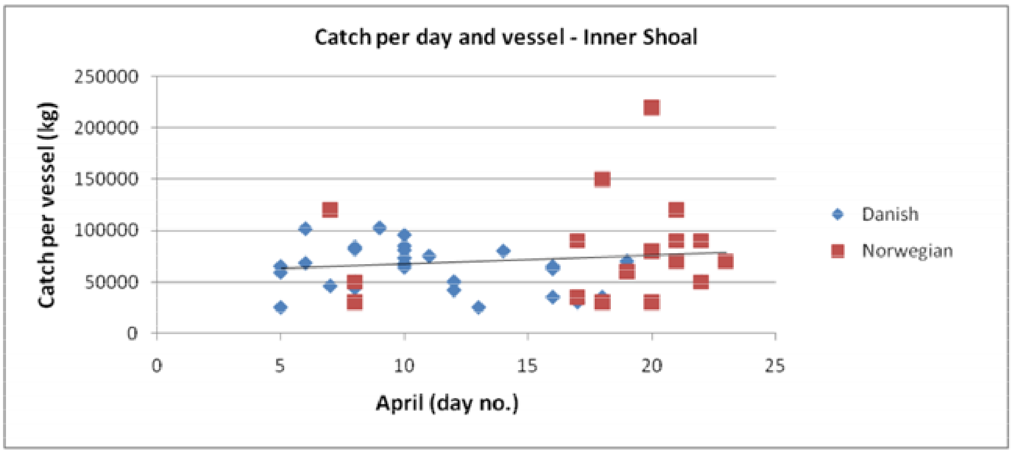

Figure 2.8: Sandeel catches at Inner Shoal East in April 2007. Norwegian data represent landings per day for each vessel, while Danish data are average catches per trip (e.g. if one Danish vessel spent 5 days on Inner Shoal, caught 500 t, left port April 2 and returned to port April 8, this would result in a catch of 100 t on April 5).

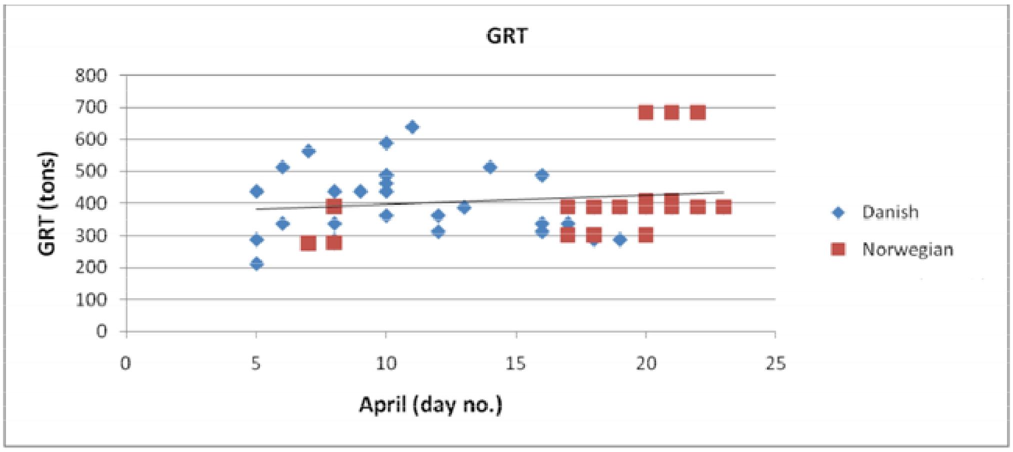

Figure 2.9: Size (GRT) of the vessels fishing at Inner Shoal East in April 2007. Two extraordinary large Norwegian vessels fishing in the end of the period were excluded (also their landings in Figure 2.1.8).

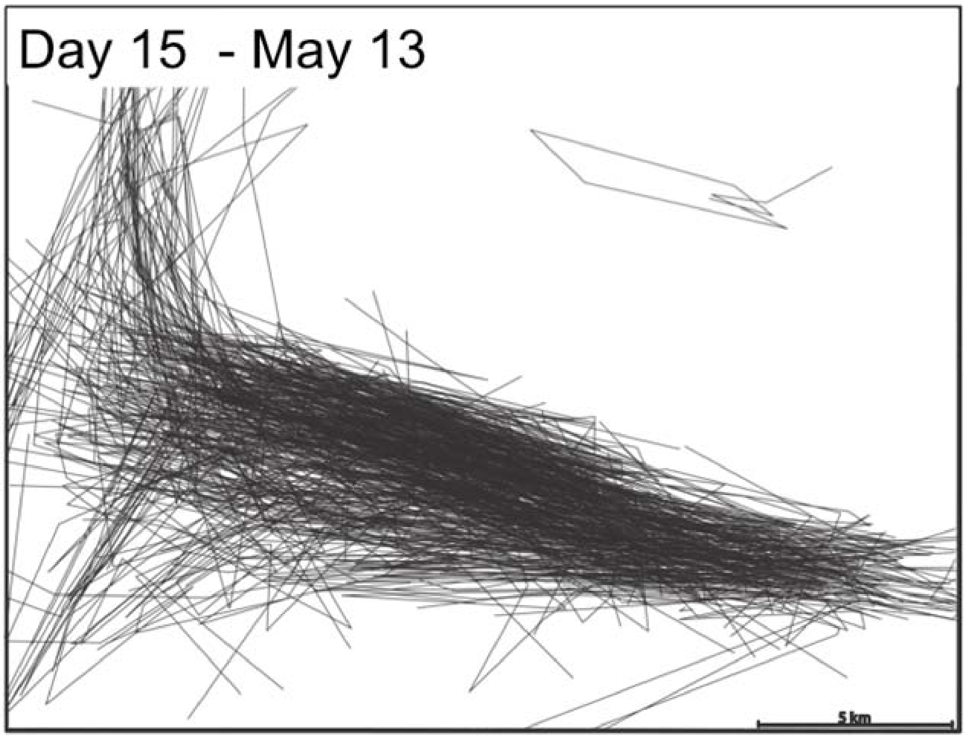

Figure 2.10: Trawl trajectories after 15 days of fishing on English Klondyke. 5 km scale is indicated in the lower right corner. The width of the lines corresponds to approximately 75 m, which is considered realistic.

There were no commercial landings from English Klondyke from 2002 onwards (Figure 5.3). The fishing ground was repopulated by new recruitment in 2006, and high concentrations of I-group sandeel were measured during the acoustic survey in 2007 (Figure 5.5). English Klondyke was closed after the monitoring fishery in 2007, but reopened in 2008, resulting in the second highest annual landings between 1994 and 2008 (Figure 5.5). I-group sandeel contributed to ~20% of the landings in terms of numbers, whereas the remaining 80% was dominated by II-group. 15 days of intensive fishing took place on English Klondyke (Figure 2.7). Two parallel ridges are normally fished on English Klondyke. However, in 2008 sandeel were only caught on the southern ridge, despite many vessels visiting the northern ridge. The fleet started fishing in the western part and moved gradually eastwards.

CPUE in terms of catch per hour of trawling is shown in Figure 2.11a. Except for initially very high catches when only two vessels operated on the fishing ground, there was no marked decrease in CPUE until the very last day of the fishery. There is indication of increased competition as reflected in number of hours of trawling during the 15-day period (Figure 2.11b), whereas the average vessel size decreased (Figure 2.11c).

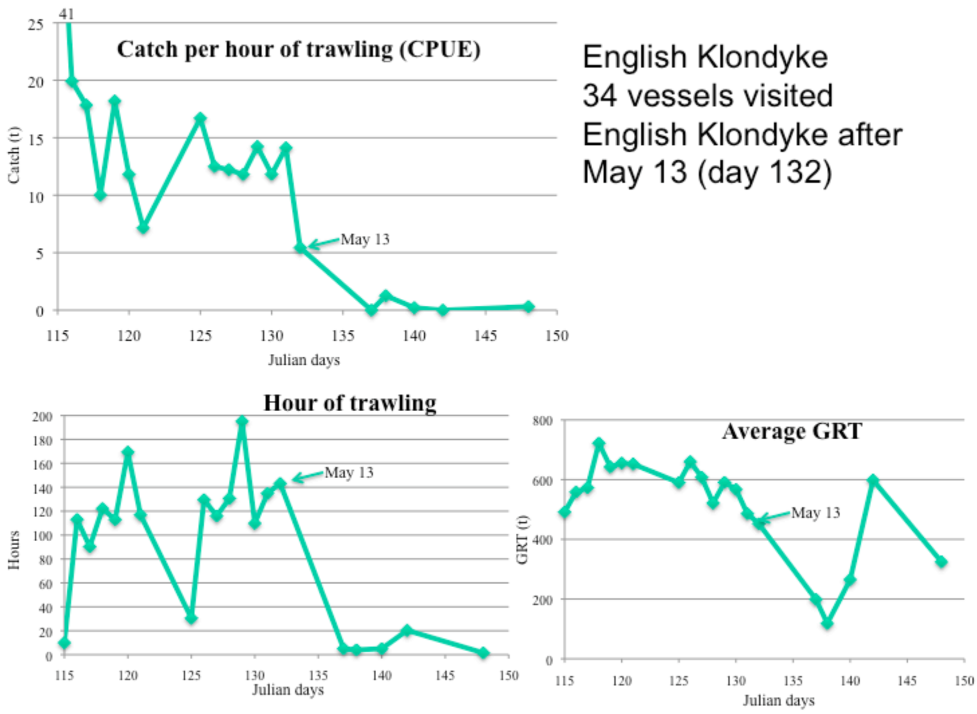

Figure 2.11: a) CPUE in terms of catch per hour of trawling on English Klondyke, b) number of hours of trawling and c) average vessel (GRT). The fishery was closed between day 121 and 125 pending the ICES advice.

34 vessels visited English Klondyke after May 13, of which a few fished for a limited time without catching sandeel (catch on day 142 was taken on the northern ridge a consisted probably of by-catch). In agreement with this, acoustic surveys in 2008 (after May 13) and 2009 measured low abundance of sandeel on English Klondyke (Figure 5.5).

2.1.1.2.7 Conclusion

These results suggest that fishing mortality may drive sandeel fishing grounds to commercial depletion within a few weeks, without CPUE in tonnes being significantly affected. This problem has long been recognised for pelagic schooling species (e.g. Pope 1980; Ulltang 1980). Unfortunately, the investigations of changes in catch in numbers and catch in tonnes over time were performed in different areas of the North Sea. It is therefore not possible for the group to conclude whether the results from either of the investigations are valid for the entire area. Catch rate in numbers at age in the areas investigated (mainly) in the Southern North Sea reflected in most cases the yearly change in abundance, and no bias seemed to be introduced by using the CPUEs as indicators of abundance in these particular areas.

References:

Pope, J. G. 1980. Some consequences for fisheries management of aspects of the behaviour of pelagic fish. Rapp. P.-v. Reun. Cons. Explor. Mer 177, 466-476.

Ulltang, Ø. 1980. Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach Rapp. P.-v. Reun. Cons. Explor. Mer 177, 489-504.

2.1.1.3 Biological data (age/length distributions by ICES square/month)

The coverage of the Danish biological samples follows the distribution of the catches. Sampling intensity has increased over time and has been at a high level since 1999 (Table 2.1). There is insufficient sampling to provide age-based analytical assessments of areas 4 and 5. Further, the number of samples analysed for Area 2 is insufficient in the latter years. Though no current assessment exists, the sampling level in Skagerrak would appear to be sufficient to provide data for age-based analytical assessments.

	Area						
Year	1	2	3	4	5	6	All
1982	25	5	10	0	0	2	42
1983	31	12	14	0	0	2	59
1984	56	4	21	0	2	1	84
1985	32	9	28	10	2	0	81
1986	8	0	25	1	0	1	35
1987	41	3	26	0	0	0	70
1988	14	2	48	0	0	0	64
1989	10	0	17	0	0	3	30
1990	0	0	2	0	0	3	5
1991	7	5	21	1	0	15	49
1992	25	10	35	0	0	20	90
1993	9	12	45	7	0	29	102
1994	6	5	18	2	0	13	44
1995	18	14	13	0	0	11	56
1996	15	11	38	15	0	29	108
1997	9	15	24	5	0	26	79
1998	23	10	32	1	0	8	74
1999	129	21	47	6	1	16	220
2000	28	10	26	33	0	16	113
2001	87	4	76	65	0	19	251
2002	113	15	55	27	0	24	234
2003	92	26	94	89	0	63	364
2004	176	39	78	36	0	46	375
2005	146	24	26	18	0	5	219

2006	204	11	43	2	0	13	273
2007	146	11	66	0	0	38	261
2008	126	4	44	1	0	39	214
2009	112	1	43	0	0	57	213

Table 2.1: Number of biological samples taken from the Danish sandeel fishery (samples with more than 50 length-measured fish only).

In addition to the Danish samples, samples of length distributions of Norwegian catches were taken until 1997 and can be combined with Danish age-length keys to increase the number of biological samples in northern areas. Since 1997, both length distributions and age samples have been taken. The group agreed that these data should be combined with the Danish samples in a common data base. The exchange format will be agreed on after the meeting and the exchange will take place before 1st of January 2010.

2.1.1.4 Combining commercial and biological data

To derive catch at age per area, a revision of the method used to estimate the Danish age distribution of catches was performed to assure that the method was well documented, that results were reproducible and that the highest possible level of precision was obtained. The revision was currently based on Danish data only but it was agreed that the difference between catch composition of Norwegian and Danish was insignificant and samples from both countries should be used in one analysis to estimate the age composition and mean weight in each square. The data delivered by Norway before the 1st of January 2010 will be analysed to derive a common age distribution and mean weight at age for all squares and results will be ready before 1st of March 2010.

2.2 Biological data

2.2.1 Maturity

Present representation of spawning stock size assumes a knife edge age at maturity, whereas recent investigations show size, age as well as regional effects using a logistic regression approach to modelling maturity (Boulcott et al. 2007). A model of the following form was applied:

$$\ln (p/(1-p)) = I + aL + A_i + R_j,$$

where p is the probability of being mature, I is the intercept, a the regression coefficient, L the length in cm, A_i the age effect for age class i, and R_j the regional effect for region j. The published data were primarily derived from biological sampling during the 2004 December dredge survey. A time series (2004-2008) of spatially resolved maturity data from the December dredge survey is held by the Danish institute. It should be considered at the benchmark whether this time series would be appropriate for developing region specific maturity ogives taking into account both size and age.

2.2.2 Natural mortality

Natural mortality of sandeel is estimated in a multispecies model of the North Sea by the ICES WGSAM. The estimated yearly natural mortality is shown in Figure 2.12. It is clear that there has been a significant increase in M since the late 1990s. Further, the average M for ages 2 and 3 used in the current assessment is 0.6, which is lower than the values estimated by WGSAM. Hence, it should be considered at the benchmark whether the M values used should be updated and whether yearly variable values should be used.

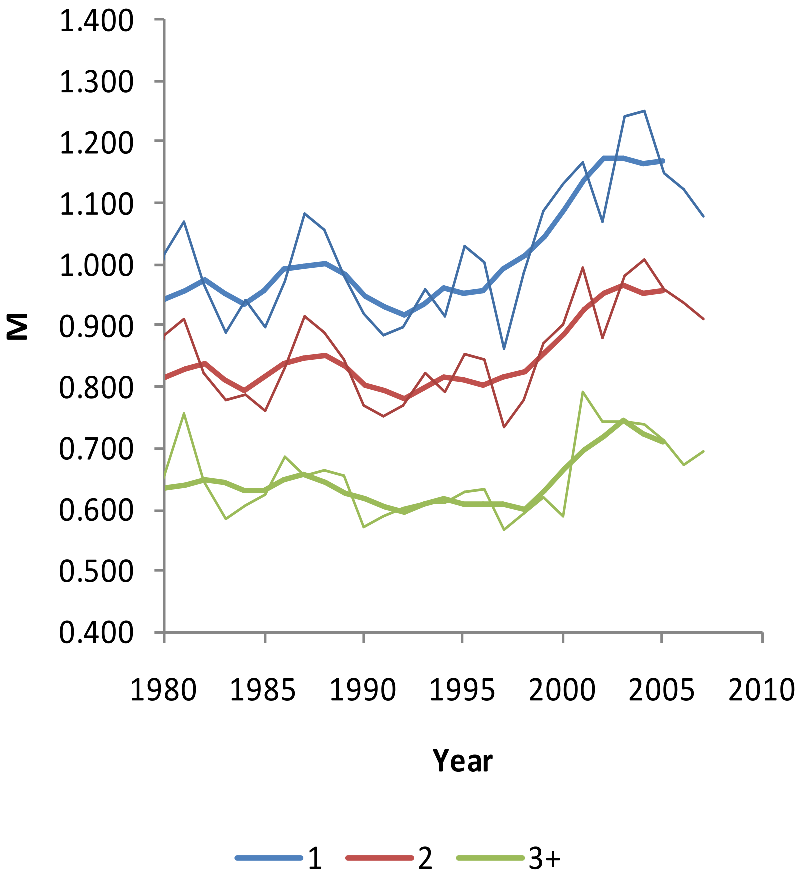

Figure 2.12. Yearly natural mortality for different age groups of sandeel estimated by WGSAM (ICES 2008b). Heavy lines are 5-year moving averages.

References

Boulcott, P., Wright, P. J., Gibb, F. M., Jensen, H., and Gibb, I. M. 2007. Regional variation in maturation of sandeels in the North Sea. – ICES Journal of Marine Science, 64: 369–376.

ICES 2008a. Report of the working group on the assessment of demersal stocks in the North Sea and Skagerrak. ICES CM 2008/ACOM:09

ICES 2008b. Report of the study group on multispecies assessment methods. ICES C.M. 2008/RMC:06

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2.3 Surveys

2.3.1 Dredge survey

Since 2003 DTU-AQUA has used a modified scallop dredge to measure the relative abundance of sandeels in the seabed. The survey is conducted in November/December, after the time 0-group sandeels have been recruited to the adult population and the whole of the population is assumed to reside in the seabed.

Sampling is carried out at fixed positions on known sandeel habitats at some of the most important fishing banks in the North Sea from the Little Fisher Bank in the North Eastern North Sea, to the Dogger Bank area in the south western North Sea. In 2006 additional positions were sampled in the Norwegian EEZ.

The dredge survey has the potential to establish a time series of indices that can be used for tuning the historic assessment, and to estimate the size of the incoming year-class already in January, before the decisions about how the fishery will be managed have to be made.

2.3.2 Acoustic survey

The Institute of Marine Research, Norway has with the support from the Norwegian Research Council started a project which aims to develop a robust acoustic survey to monitor the distribution and abundance of sandeel. An additional objective is to investigate the prey-predator interaction on the sandeel grounds in the spring.

The project period is from January 2008 to December 2010, but acoustic surveys have been carried out in April-May since 2005. However, the data sampled during the two first years are probably not suitable for abundance estimates. For a benchmark meeting in 2010 the survey estimates of number by age by fishing ground in the Norwegian EEZ will be available for 2007-2010.

Expected output:

- Overview of available survey data and their potential use in assessment

3 Real time monitoring of sandeel

The sandeel fishery and stock are in most years dominated by 1-group sandeel for which very little information exists before the fishery is opened. Commercial CPUE is a poor predictor of 0-group recruitment and reliable indices from surveys are not yet available. Therefore, prediction of 1-group abundance in the year following an assessment has a high degree of uncertainty. Since 2004 the information on the 1-group abundance has been obtained from Real Time Monitoring (RTM) of the fishery in the start of the fishery (1st April to around 5th May). The basic idea for RTM is that the observed catch rates in the start of the fishery represents the stock size. The RTM method can be summarise as below:

1) Establish a historical relationship between CPUE of age 1 sandeel in the RTM period and the stock estimate 1st January in the same calendar year.

   a. Extract historical total catch weight and fishing effort
   b. Standardise effort for vessel sizes 50-600 GT
   c. Use biological samples of the catch to estimate proportion age 1 sandeel in the catch
   d. Estimate $CPUE_{RTM}$ (number/days absent for a 200 GT vessel) of 1-group sandeel
   e. Establish a regression: log(assessment $N1_{1.Jan)}$ = a + b *log($CPUE_{RTM}$)

2) Estimate $CPUE_{RTM}$ of age 1 sandeel for the RTM year (2010).

   a. Observed total catch weight and fishing effort
   b. Standardise effort for vessel sizes 50-600 GT
   c. Take biological samples of the catch to estimate proportion age 1 sandeel in the catch
   d. Estimate $CPUE_{RTM}$ of 1-group sandeel
   e. Estimate $N1_{1.Jan}$ from observed CPUE and equation 1e.

3) Predict catches in 2010 from the estimate of the 2009 year-class (N1)

   a. Make an assessment (WGNSSK 2009)
   b. Make a forecast (WGNSSK 2009)
   c. Calculate relation between N_1 and TAC with constraint SSB_{2011} > Bpa
   d. This gives an almost linear relation between N_1 and TAC which can used for setting a TAC, e.g. TAC = a + b * N_1

The present methodology has been unchanged since 2007 and is described in detail in ICES CM 2007/ACFM:38.

3.1 Step 1. Historical relationship between CPUE of age 1 sandeel in April and the stock estimate 1 January

During this meeting the time series for estimating the historical relationship between CPUE of 1-group sandeel and stock estimate was extended by data for 2007-2009. WGNSSK has shown an apparent steep increase in vessel efficiency in 1999 and it was therefore decided to remove earlier years (1991 and 1994) from the time series, such that data from the years 1999-2001 and 2003-2009 were used in the analysis. The 2002 data (2001 year-class) are removed from the time series, based on an earlier decision to leave out years with year classes of more than 300 billions 1-group (Section 6.3.3.4 in ICES Advice 2006, book 6). In case of very large year classes the CPUE does not increase proportionally to the stock size. The catch by hours fishing becomes higher, but handling time of the trawl and transport to and from the fishing ground are almost independent of stock size, such that the catch per days absent (as used in the RTM) flatten for high stock sizes.

3.1.1 Standardise effort for vessel size

Standardization of effort (step 1b in the overview) was made with the assumption that CPUE in a given year is a function of sandeel abundance and vessel size:

1) $CPUE_{y,n} = a_y \times GT_n^b$

or in a log-transformed form:

2) $\log(CPUE_{y,n}) = a_y + b \times \log(GT_n)$

Where $CPUE_{y,n}$ denotes observed CPUE by trip in year y by vessel n; a_y denotes the abundance in year y and GT the vessel size measured as Gross Tonnage (GT). The b value was estimated from GLM analysis of data by trip using “days absent from harbour” as effort.

Effort (and CPUE) was standardized to a 200 GT vessel using the following equation:

$$StdEffort = effort \times \frac{GT^b}{200^b}$$

The estimated b parameter, estimated from cumulative data from the start of the fishing season, is presented in Table 3.1 and Figure 3.1.

3.1.2 Regression between RTM CPUE of 1-group and stock estimate.

Input to the regression (step 1e in the overview) between RTM estimate and stock assessment estimate of age 1 abundance is presented in Table 3.2, and Figure 3.2. The stock estimate (Table 4.3.2.10 in WGNSSK, 2009) is the result of the SPALY assessment, which was selected by ICES as the final assessment.

Estimated parameters for the regression log(assessment $N1_{1.Jan}$) = a + b *log($CPUE_{April}$) are presented in Table 3.3 and Figure 3.3. The regression parameters are mainly determined by the two years (2003 and 2005) with very low CPUE and stock estimates.

3.1.3 Effects of updating the time series.

The b-values for effort standardization estimated this year (Table 3.1) are higher than the b-values estimated in 2007 where e.g. the b-value for week 18 was 0.40 and is now estimated to be 0.55. This indicates that the larger vessels in the size range 50-600 GT have become relatively more efficient, when data from the most recent years are added, and data from the 1991 and 1994 are deleted.

To analyze the effect of the change in b-value, stock numbers were estimated from CPUE from the RTM using the estimated b-values or a fixed value of 0.4. Compared with the stock estimate using the estimated b-values (Table 3.4 upper table) the stock estimate derived using a b-value of 0.4 (Table 3.4 lower table) differs by less than 1-2%. This shows that the RTM is not sensitive to effort standardization. The stable estimate is due to the relatively even and stable distribution of vessels within the selected size range (50-600 GT) used for the analysis.

An additional sensitively test was made to show the effect of updating the time series with the most recent years and keeping the 1991 and 1994 data in the time series. The estimated slope and intercept for the regressions between CPUE 1-group and VPA 1-group becomes slightly higher. For e.g. for week 17 intercept is estimated to 4.11 and slope to 0.43 when 1991 and 1994 are included, while intercept is 4.09 and slope is 0.41 when the two years are excluded. Leaving out the two years therefore result in a lower stock estimate given an estimated $CPUE_{April.}$

3.2 Step 2. Estimation of CPUE of age 1 sandeel in the beginning of the fishing season.

The present Danish sampling scheme for biological samples targets one sample from each landing. In general, smaller vessels have smaller landings from shorter trips compared to the larger vessels, which results in relatively more samples per landed weight of sandeel from the smaller vessels.

Smaller vessels fish more coastal than larger vessels. In 2009 the proportion of 1-group was high in landings from the coastal area (small vessels) and low from the Dogger area (larger vessels). The present sampling will therefore give a biased estimate of the proportion of 1-group in the total landings. In 2009 the problem was identified and an *ad hoc* adjustment was made.

Previously, biological samples by week were raised to total catches by week without considering spatial differences in catches. For 2010 this raising procedure will be changed such that landings and biological samples will be stratified by week and ICES rectangles. Catches in rectangles without samples will be raised using all available biological samples within a week. Step 3. Predicting catches in 2010 from the estimate of the 2009 year-class

ACOM selected the SPALY assessment as the one to present in the ICES advice, whereas WGNSSK suggested an alternative configuration. In this report the TAC calculation is based on the SPALY assessment. The WGNSSK report does not include a TAC calculation based on the SPALY assessment using the RTM approach, so this is presented below.

3.2.1 Relation between CPUE of N_1 from RTM and TAC in 2010.

The TAC in 2010 is a function of the state of the stock for age 2+ and the abundance of 1-group sandeel. The TAC is based on a number of short term forecasts, each using an input recruitment and the constraint that SSB in 2011 should be above Bpa (600 000 t). Without F-reference points for sandeel, this corresponds to the precautionary approach as implemented by ICES. Figure 3.4 below shows the calculated TAC as function of the number of recruits.

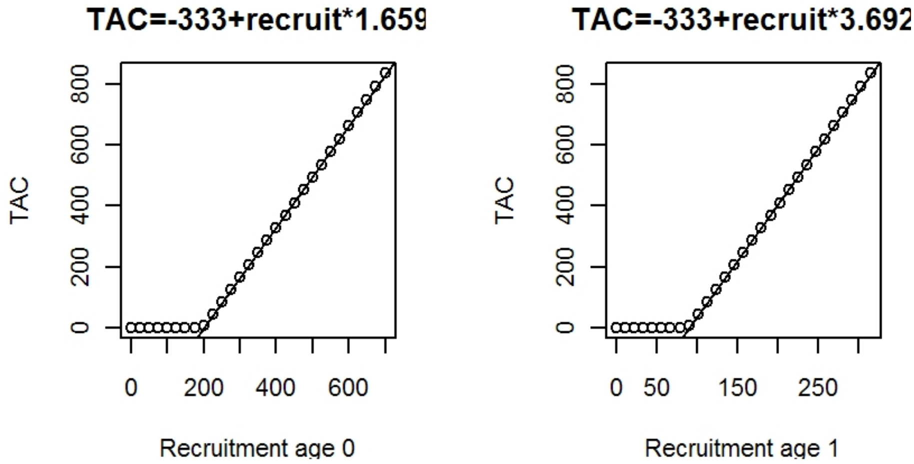


Figure 3.4: Relation between recruitment estimated from the RTM in 2010 and the TAC for 2010. Each "dot" represents a forecast with the constraint of having SSB_{2011} > Bpa. The regression line and parameters approximate the TAC as a function of recruitment.

The figure shows that the relation between recruitment and TAC is almost linear and can be approximated by the relationship:

$TAC_{2010} = - 333 + R_{0,2009} * 1.659$ (1)

where $R_{0,2009}$ is recruitment at age 0 in 2009 and TAC_{2010} is the catch in 2010 that will result in SSB=Bpa in 2011.

The relationship (1) can be translated into a relationship between the stock size of 1-group sandeel in 2010 and the TAC in 2010 that will lead to SSB being 600 000 t in 2011, by projecting age-0 sandeel in second half year of 2009 to age-1 sandeel 1st of January 2010 applying natural mortality of age 0 (M=0.8) for second half year of 2009. This relationship is indicated in Figure 3.4 above and can be expressed by:

$TAC_{2010}= -333 + R_{1,2010} * 3.692$ (2)

where $R_{1,2010}$ is the stock size of age-1 sandeel 1st January 2010.

The recruitment must be given in billions which results in a TAC in 1000 tonnes.

The short term forecast presented by WGNSSK shows that assuming a low (25% per-centile of the long term recruitment), 150 000 t can be taken, leaving an SSB at Bpa in 2011. Such catch is suggested as a preliminary TAC to be used for the RTM period.

As in previous years, an additional TAC-ceiling at 400 000 tonnes is suggested, based on the results from simulation studies (WGNSSK, 2006).

3.2.2 Uncertainties in the assessment and forecast

The ICES (ICES advice book 2009, section 6.4.22) advice expresses concerns about the uncertainties in the assessment: *"The assessment used to provide the stock status assumes equal weight for fleets fishing in the north and south of the North Sea. However in recent years, a decreasing proportion of the effort has been located within the north due to closures in the Norwegian EEZ. The assessment estimates are sensitive to the distribution of effort and exploratory assessments have highlighted that the most recent dynamics of SSB and F are sensitive to these assumptions. The resulting range of biomass estimates in 2009 spans Blim to above Bpa. The advice is based on the assessment procedure as used in previous years."*

As stated above, the range of biomass estimates in 2009 spans B_{lim} to above B_{pa}. ICES have chosen the assessment using the same configuration as last year and this gave a low SSB in 2009 (455 000 tonnes). The final assessment suggested by the WGNSSK gave a higher SSB in 2009. If this assessment is used as basis for the TAC calculation the TAC should be calculated from (WGNSSK 2009):

$$TAC_{2010} = 142 + R_{1,2010} * 3.768 \qquad (3)$$

The main difference between equation 2 and 3 is the intercept value and is due to the state of the stock being estimated differently in the two assessments. With a $R_{1,2010}$ at 100 billions, equation (2) gives a TAC at 36 000 tonnes while equation (3) gives a TAC at 519 000 tonnes (which will be decreased by the cap TAC at 400 000 tonnes). The average R_1 for the period since 2004 is estimated to be around 100 billions.

By comparing the outcome from equation (2) and (3) it is clearly seen that the underlying assessment and forecast is very important for the setting of the TAC. Uncertainties in the RTM estimate of recruitment seems less important.

3.2.3 Adjustment of TAC from the observed mean weight of 1-group

In 2007 and 2008 the equation for setting the TAC included an adjustment term such that a higher mean weight at age (than assumed in the forecast) in the RTM period gave a higher TAC. The justification for such adjustment is that a higher mean weight will require fewer fish to be caught and that each surviving sandeel contributes more to the SSB after the fishery than predicted in the underlying forecast. A prerequisite for such approach is that the mean weight at age for the whole fishery can be predicted from the observed mean weight in the RTM fishery. Analysis of growth of sandeel on individual fishing banks showed that a higher mean weight at the start of the fishing season will lead to a higher mean weight in the end of the season. However, there is no relation between the observed mean weight at age in the RTM period and the mean weight at age in the total international catch (Figure 3.5).

As there is no relation between the mean weight at age during RTM and the mean weight at age in the total international catch, the mean weight adjustment is not included in the suggested equation for TAC calculation in 2010.

3.3 Spatial aspects of RTM

The RTM uses the basic assumption that the historical relation between CPUE and stock estimate from assessment can be used to predict stock size in the RTM year from the observed CPUE. Such assumption requires the same conditions for the fishing fleet in the RTM period as in the historical reference period. In practice this means that the fishery should freely select the banks to fish and CPUE data might not be available for the whole stock distribution area.

Figure 3.6 shows the distribution of the Danish sandeel fishery before and after the RTM period. The spatial distribution of the fishery is based on VMS from the day time with cruising speed 2 to 4 knots for vessels having a trip landing of more than 50% sandeel. The spatial distribution differs between the two periods and the distribution in the RTM period normally only covers part of the total fishing area. A very similar development is found each year, with an early exploitation of the central Dogger, Elbow spit, Tail end Fisher banks and Skagerrak banks, geographically within the rectangular area covered from 37F0 to 40F5 as well as the diagonal of ICES rectangles 41F5, 42F6, 43F7, 43F8 and 44F9. After week 17 fishing effort is spread out to include the narrow banks south of Dogger as well the more costal banks to the south and to the east.

The time series of total international effort and CPUE (Figure 3.7) demonstrates the drastic decline of CPUE in 2003 and a low CPUE in the following two years. The collapse in 2003 was contemporary with relatively high effort. CPUE and fleet capacity can be linked to the distribution of the fleet. Figure 3.8 shows the fishing activity (speed between 2 and 4 knots in the day time) and other activities (Stop: speed less than 1 knot in the day time) by the single VMS signal. Figure 3.8 a, b and c illustrate the widely spread spatial distribution of the fishing fleet in 2003-2005 searching for catches in areas outside traditionally exploited fishing banks. With the reduction in number of vessels and fishing effort from 2005 in combination with a recovering population and increasing CPUE, the fishing operations gradually concentrate more and more on the main fishing banks in 2006-2009 (Figure 3.8 d, e, f, and g). The reduced spatial coverage of the fleet in 2007 is an effect of the early (week 25) closure of the sandeel fishing season that year.

ICES expressed concern about the relatively narrow spatial distribution of sandeel landings in the most recent years, as it can be interpreted as there are very few sandeel outside the fished banks. The presented distribution maps indicate however, that a widely distributed fishing fleet can be linked to a low density of sandeel. Therefore, the observed concentration of the fishing fleets on the main banks, in combination with high CPUE, could more be seen as a favourable stock condition than a shrinking stock.

Table 3.1.: Weekly b parameters (using cumulated data) for effort standardisation

Week	**b-value**
14	0.590
15	0.572
16	0.566
17	0.570
18	0.549
19	0.487
20	0.475
21	0.473
22	0.484
23	0.453
24	0.463
25	0.464
26	0.461

Table 3.2: Input to regression between RTM CPUE of 1-group sandeel and stock estimate. Estimated stock size of 1-group sandeel in billions from the assessment by year, and CPUE (million of age 1 sandeel per day absent for a 200 GT vessel) by year and week.

	Year									
	1999	2000	2001	2003	2004	2005	2006	2007	2008	2009
	stock	stock	stock	stock	stock	stock	stock	stock	stock	stock
	148	196	213	33	115	62	130	86	134	139
	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE
week										
14	5.60	5.88	6.36	0.24	2.64	0.66	3.93	2.82	.	7.00
15	6.27	6.92	7.75	0.29	2.60	0.57	3.96	7.55	8.55	5.95
16	6.07	7.74	8.05	0.38	2.85	0.61	6.24	8.32	9.66	5.47
17	6.96	7.62	8.70	0.45	3.87	0.66	9.99	8.85	12.05	5.75
18	5.81	7.14	8.54	0.52	4.26	0.98	8.25	7.87	10.98	5.39
19	5.69	7.19	8.60	0.56	3.73	1.71	7.72	8.25	11.43	5.48
20	5.24	7.18	9.08	0.57	3.86	2.08	8.98	8.57	12.16	5.78
21	5.10	6.94	8.88	0.60	4.16	2.52	10.03	8.57	12.36	6.02
22	4.91	7.08	8.92	0.61	4.20	2.70	9.28	8.55	11.85	5.89
23	4.46	6.25	8.01	0.58	3.99	2.37	8.51	8.55	11.14	5.88
24	4.36	5.97	7.24	0.56	4.09	2.51	8.07	8.58	11.16	5.82
25	4.01	5.65	6.82	0.51	4.05	2.68	7.84	8.63	9.73	6.84
26	3.83	5.37	6.80	0.51	4.01	2.78	7.41	8.63	9.59	6.99

Table 3.3: Weekly parameters for the regression between observed CPUE of 1-group sandeel during the RTM and stock abundance of 1-group sandeel 1st January in the same calendar year. CPUE estimate in millions per day absent for a 200 GT vessels, the stock assessment N is in billions.

log(assessment N1) = a + b * log ($CPUE_{RTM}$)

Week no.	Intercept	Slope	Adj-rsq
14	4.26	0.50	0.94
15	4.21	0.43	0.80
16	4.14	0.42	0.75
17	4.09	0.41	0.72
18	3.99	0.47	0.74
19	3.91	0.52	0.73
20	3.88	0.52	0.71
21	3.84	0.53	0.69
22	3.82	0.55	0.69
23	3.88	0.54	0.68
24	3.89	0.54	0.66
25	3.92	0.53	0.64
26	3.93	0.53	0.62

Table 3.4.: Historical performance of RTM. Estimated stock size (billions) of 1- group sandeel by week and year from CPUE in RTM. The second line gives the stock assessment estimate.

a) Estimated b-values for effort standardisation

	1999	**2000**	**2001**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	148	**196**	**213**	**33**	**115**	**62**	**130**	**86**	**134**	**139**
week										
14	167	172	178	35	115	58	140	119		187
15	147	153	161	40	101	53	121	159	168	144
16	135	150	152	42	98	51	137	154	164	129
17	131	136	143	43	103	50	152	144	164	121
18	124	137	149	40	108	54	147	144	168	120
19	123	139	152	37	99	66	144	149	177	120
20	115	136	153	36	98	71	153	149	179	121
21	112	131	150	36	100	77	160	147	179	122
22	110	135	153	35	101	79	156	149	179	122
23	109	131	150	36	103	77	155	155	179	127
24	108	128	143	36	105	80	151	156	180	127
25	105	126	139	35	106	85	150	157	168	139
26	103	123	140	36	106	87	146	159	168	142

b) fixed (0.4) b-values for effort standardisation

	1999	**2000**	**2001**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	148	**196**	**213**	**33**	**115**	**62**	**130**	**86**	**134**	**139**
week										
14	165	169	177	35	114	58	136	156		183
15	150	156	164	39	103	52	121	157	165	140
16	137	152	154	41	100	50	139	152	162	128
17	133	138	145	43	105	50	152	143	161	120
18	127	140	152	40	110	53	147	143	164	118
19	125	142	155	36	101	65	144	149	172	118
20	117	138	156	35	100	70	153	148	174	119
21	113	134	152	35	102	76	161	146	175	121
22	111	137	155	34	103	78	157	148	176	120
23	110	132	152	35	105	76	156	154	177	125
24	109	130	144	35	107	79	153	155	178	125
25	105	127	141	35	108	84	151	156	165	138
26	103	125	142	35	108	86	148	157	165	142

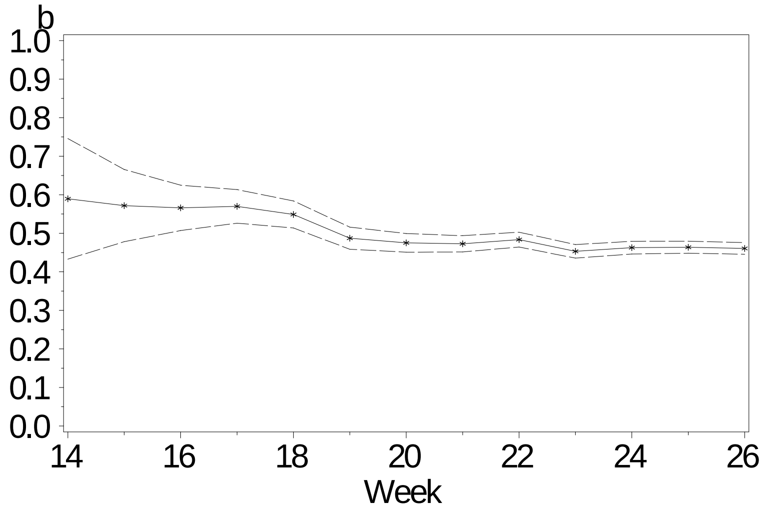


Figure 3.1: Estimate of effort standardisation "b-value" by week and 95% confidence limits.

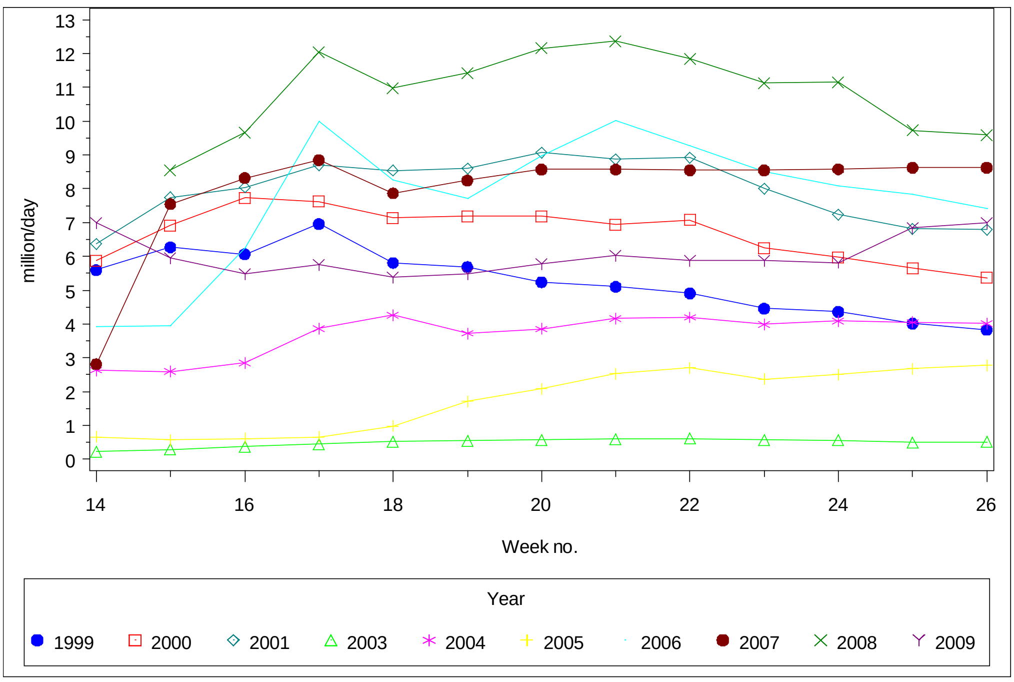


Figure 3.2: RTM estimates of cumulated CPUE (number of 1-group sandeel caught per days absent for a standard 200 GT vessel) by week and year.

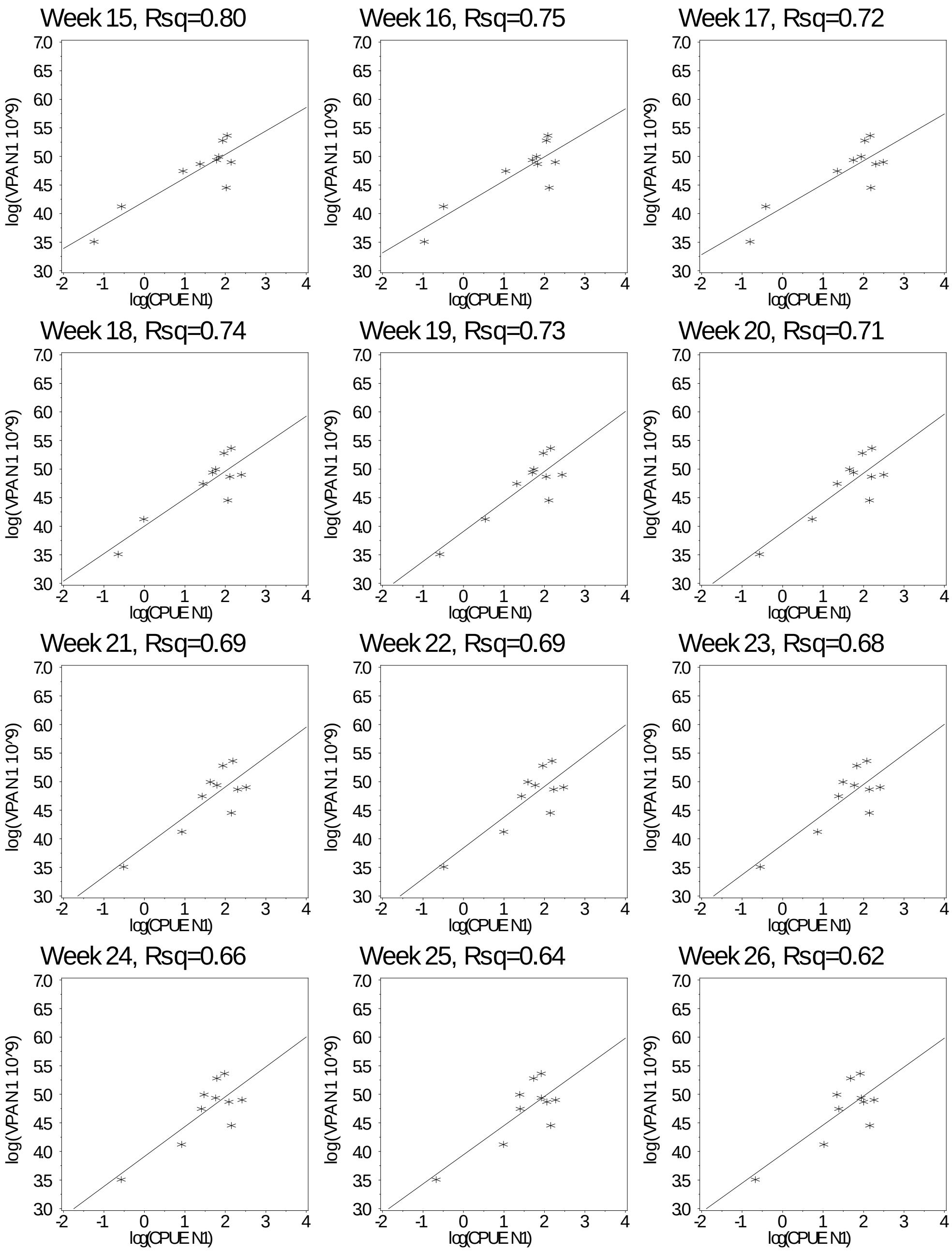


Figure 3.3: Regression analysis of weekly log(VPA-1-group, billions) on cumulative log(CPUE 1-group, millions).

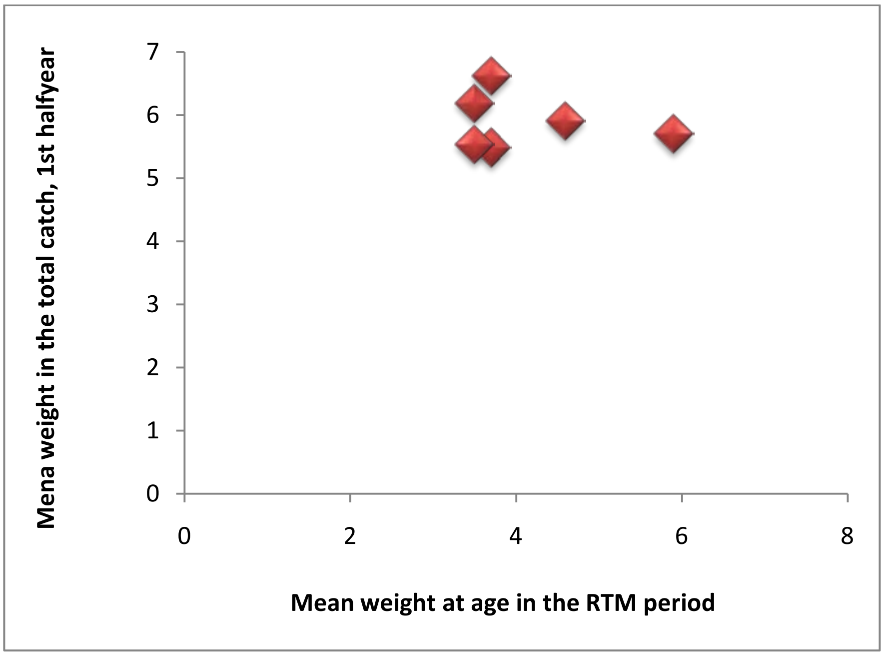


Figure 3.5: Comparison of mean weight at age for 1-group sandeel in the RTM period and in the total international catch at age.

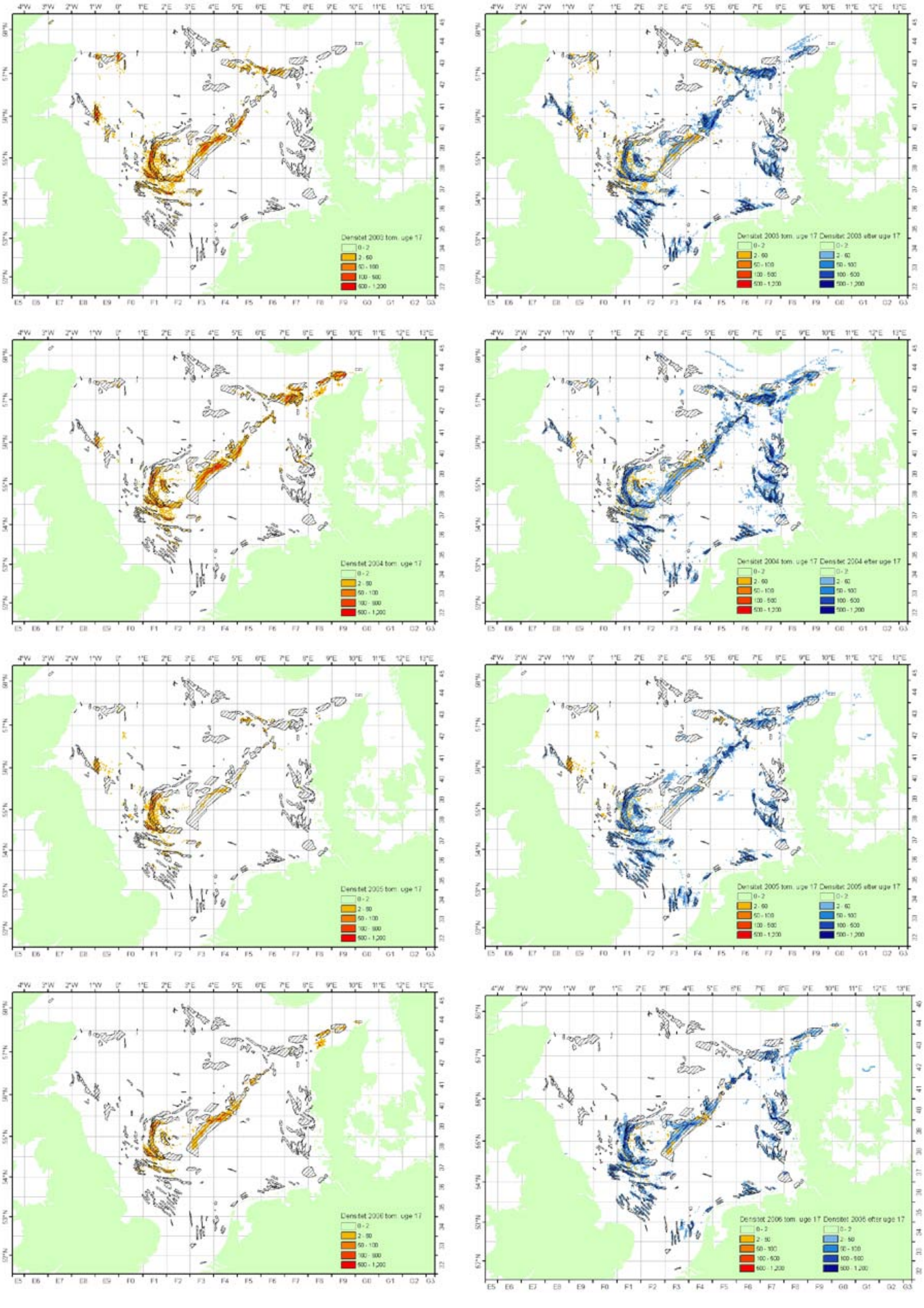


Figure 3.6: Density plots of VMS positions from the sandeel fishery 2003-2008. Left panel yellow cumulated effort until and including week 17, right panel cumulated effort after week 17.

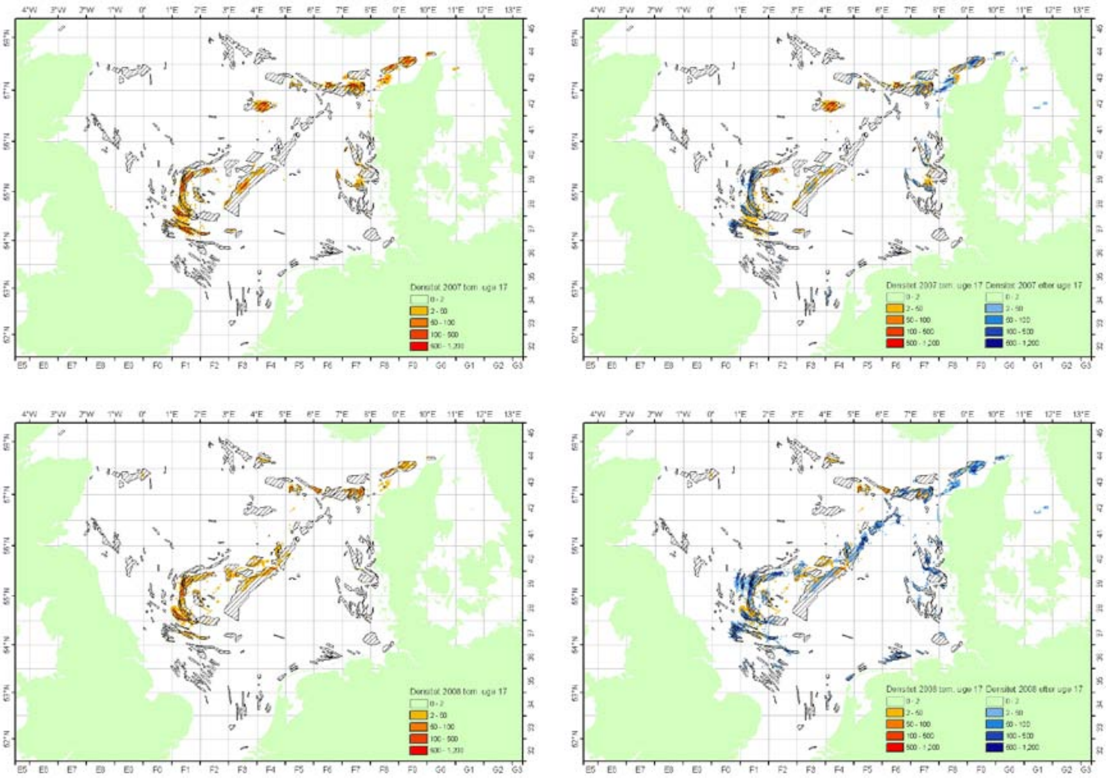


Figure 3.6: (continued). Density plots of VMS positions from the sandeel fishery 2003-2008. Left panel yellow cumulated effort until and including week 17, right panel cumulated effort after week 17.

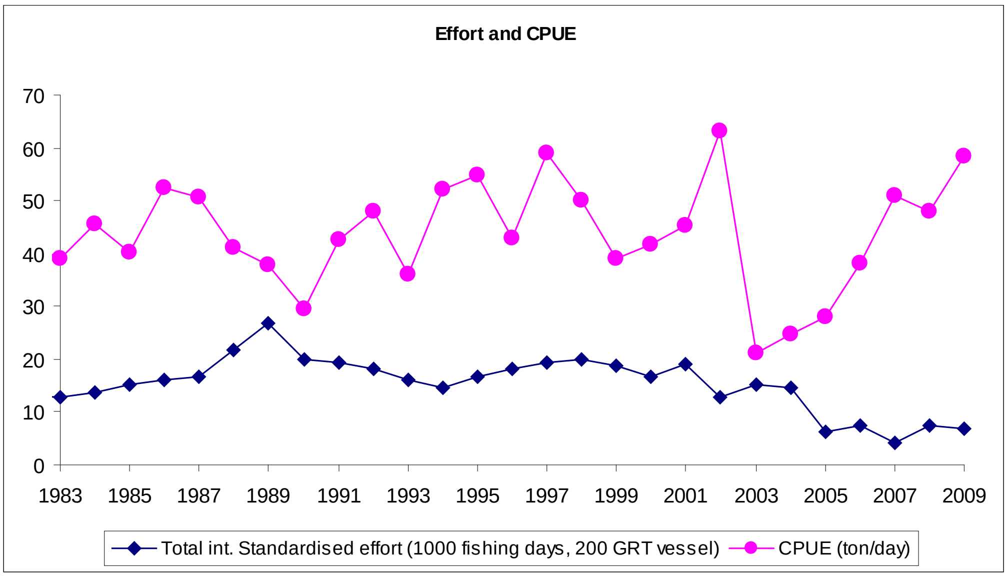
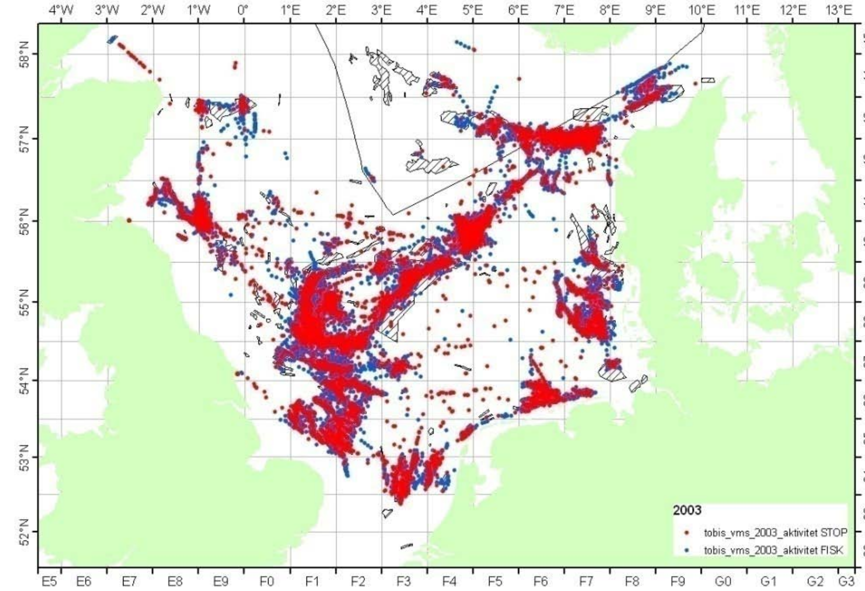


Figure 3.7: SANDEEL in IV. Total international effort and CPUE (source WGNSSK 2009)

a)



b)

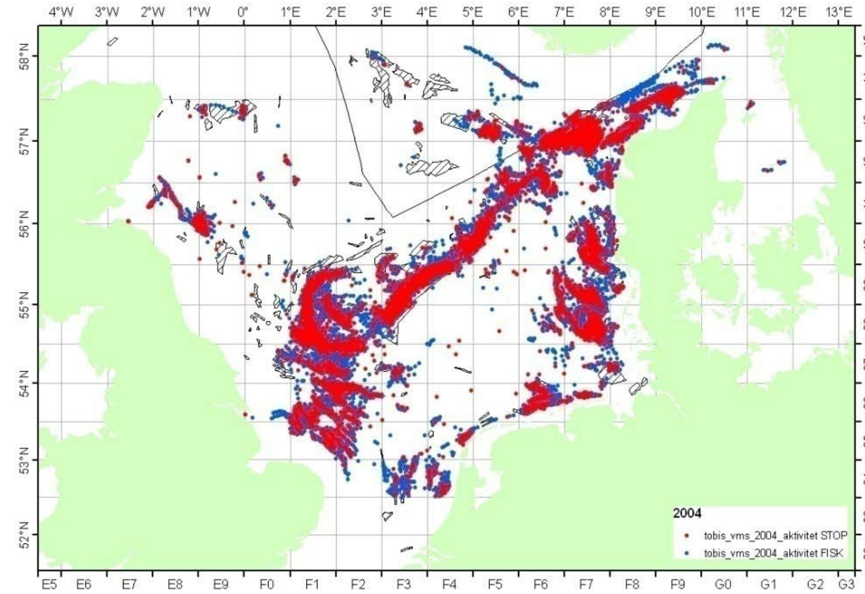
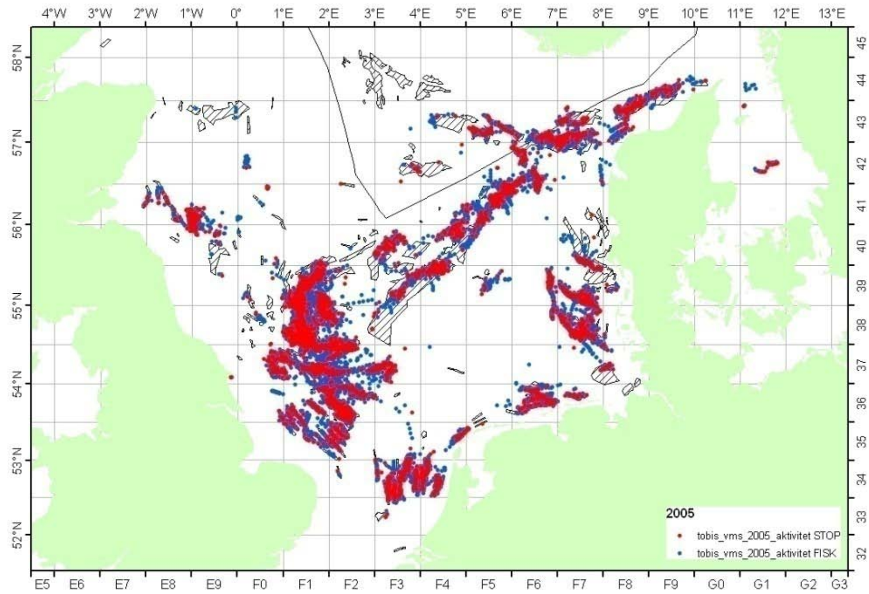


Figure 3.8 a) and b).: Maps of annual effort distribution for the Danish sandeel fishery by year, showing VMS positions with trawling (blue) and stops (red).

c)



d)

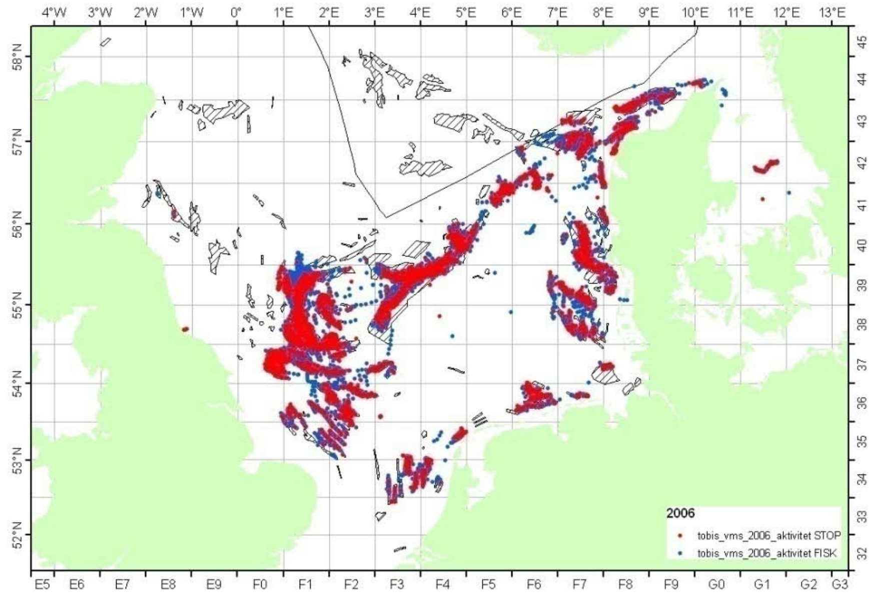
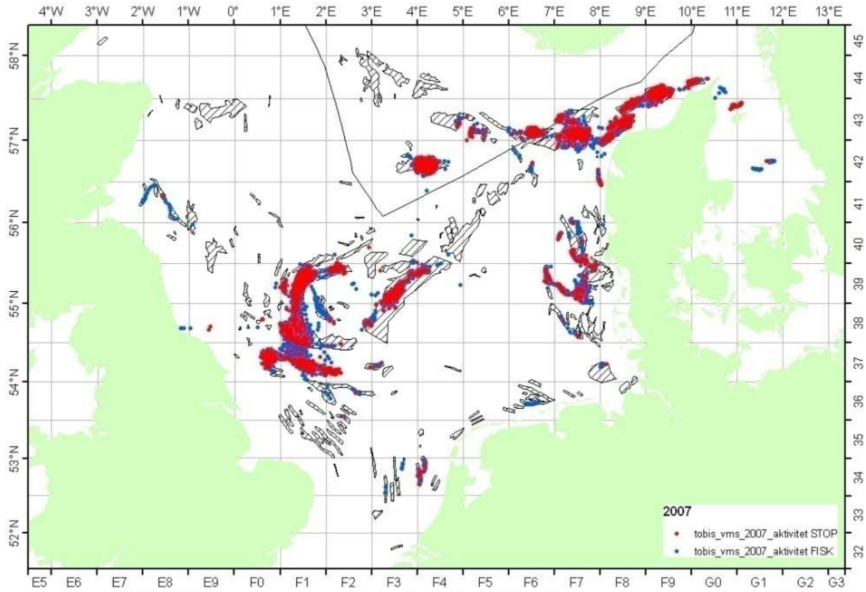


Figure 3.8 c) and d): Maps of annual effort distribution for the Danish sandeel fishery by year, showing VMS positions with trawling (blue) and stops (red).

e)



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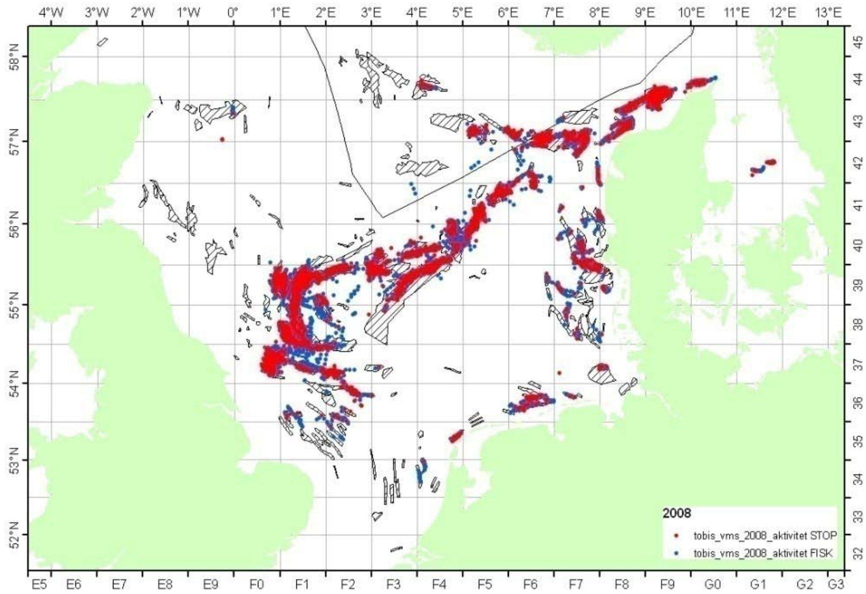

Figure 3.8 e) and f): Maps of annual effort distribution for the Danish sandeel fishery by year, showing VMS positions with trawling (blue) and stops (red).

g)

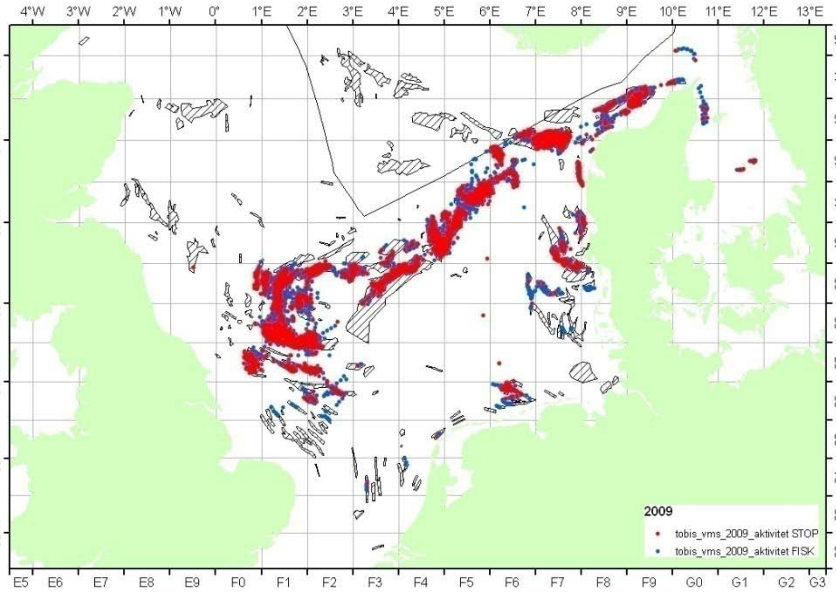

Figure 3.8 g): Map of annual effort distribution for the Danish sandeel fishery by year, showing VMS positions with trawling (blue) and stops (red).

4 Definition of stock assessment units

The sandeel assessment in the ICES Subarea IV (excluding the Shetland area) has assumed a single North Sea stock, but larval drift models and studies on growth differences indicate that the assumption is invalid and that the total stock is divided in several sub-populations. An updated assessment unit definition is therefore needed to make more realistic assessments.

Based on bio-physically coupled models of sandeel larval drift over a 35 years time-series (Christensen et al. 2007, 2008 and 2009) a matrix of larval survival probabilities T_{nm} was constructed for unilateral transport between all pairs (n,m) of 585 individual cells of available sandeel habitat in a 5x5 nm grid of the North Sea south of 59°N.

Habitat connectivity was specifically defined as the hydrodynamic transport probability

$$C_{nm} \sim T_{nm}$$

and used as a similarity measure in the sac (symmetrized agglomerative clustering) analysis, so that the most strongly connected habitats were grouped together.

Starting at the level of individual cells the habitat network is clustered into representative regions based on habitat connectivity derived from the recruitment sensitivity between areas within the habitat network. The habitat connectivity was used for the cluster analysis based on optimizing the degree of self recruitment with respect to habitat division. Central for the optimisation was the recruitment sensitivity:

$$C_{nm} = \frac{1}{v_n} \frac{\partial R_n}{\partial N_m}$$

This relationship tells how much the recruitment R_n in habitat *n* changes, if the stock N_m in habitat *m* changes. It is normalized by the habitat area v_n to make C_{nm} independent of the area of both the habitats *n* and *m*. In this way C_{nm} describes an intrinsic relation between habitats *n* and *m.* Following the chain rule of differential calculus, C_{nm} links management actions *A* directly to recruitment impact, multiplying by $\partial N_m/\partial A$. and summing over *m*.

A sequence of k=2→3→4→5 regions the emergent habitat areas appeared relatively compact in relation to the pattern of sandeel habitats (Figure 4.1). This is a direct consequence of the fact that the hydrodynamic transport kernel exhibits approximative Gaussian distance scaling as the dominant pattern.

The k=3 cluster divisions of the North Sea sandeel habitats were selected for further analysis and recalculated on an ICES rectangle scale basis.

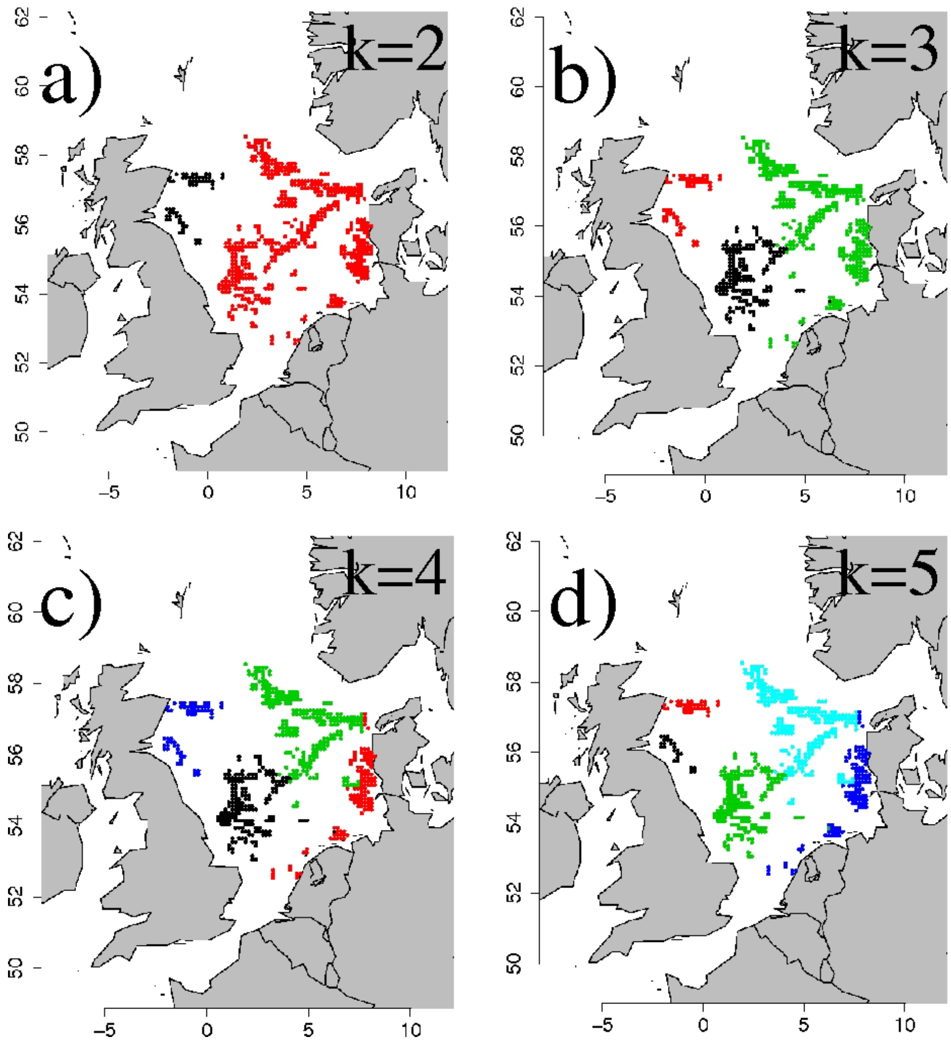

Figure 4.1: Emergent habitat aggregations, generated with the sac algorithm with a) k=2 clusters, b) k=3 clusters, c) k=4 clusters, and d) k=5 clusters.

Based on the presented information, the group agreed that the areas used for assessment should fulfil the following requirements:

1) Reproductively isolated areas should be separate areas. Such areas include the North East coast of Scotland and the Shetland area (Christensen et al. 2008).

2) The easternmost area of the southern North Sea should be a separate assessment area. This area has a different timing of effort allocation (section 2), different species composition (Jensen, 2008) and most likely differences in other biological factors.

3) Skagerrak fishing grounds should be assessed together with the adjacent area in the North Sea. The species composition and commercial CPUE in Skagerrak resembles that of the area in the North Sea bordering the Skagerrak.

4) Northern and southern areas should be assessed separately. The northern and southern parts of the North Sea exhibit large differences in growth, recruitment (preliminary assessments for North and South separately) and maturity (Boulcott et al. 2007).

5) As far as possible, the border between assessment areas should not pass through known fishing banks.

6) Areas should be large enough to account for the fact that the majority of the settling larvae may come from other banks.

A number of areas were considered as assessment areas and their ability to fulfil the listed requirements investigated.

a) One assessment unit

This option was not considered to provide a satisfying solution to any of the requirements.

b) North/south assessment units

Though this division fulfils requirement 4, it does not fulfil 1 and 2 and is therefore not a satisfying solution.

c) Assessment units based on the larval drift models

These areas have biological knowledge to support them and fulfil requirements 1, 2 and 4. It does, however, divide a number of fishing banks in two.

d) Fishing banks used as assessment units

Though this method could protect banks from high pre-spawning fishing mortality, it does not guarantee recruitment at particular fishing banks in subsequent years.

e) Stock units based on the geographical distribution of closed and open areas

There have historically been three closed areas in the North Sea: Shetland, Firth of Forth and the Norwegian EEZ. It is difficult to include large closed areas in assessed areas and special methods therefore need to be used when assessing areas covering both closed and open areas. Practicality could therefore suggest that these areas should be assessed separately as is currently the case with the area around Shetland. However, on their own, these areas fail to fulfil requirements 2 and 4.

4.1 Conclusion

Based on the above requirements, the group considered that the drift model gave a reasonable basis for an area division. The areas suggested by the model fulfils the requirements 1 and 2 but divided some of the fishing grounds. To avoid the division of fishing grounds the group suggested to move the border of the coastal assessment area (former area 2) westward in a number of places. As this left a rather thin strip of squares belonging to the northern area (former area 3) the border of the former area 3 was moved northward. Further, to fulfil requirement 3, the Skagerrak area was joined with the former area 3. The resulting area division is seen in Figure. 4.2 and Table 4.1.

4.2 Management implications

Two of the proposed areas (the Western and the Northern areas) consist of both closed and open areas. The western area cannot be assessed with analytical age-based methods due to lack of data (Table 4.2). The Northern area contains sufficient samples for analytical assessments both in the open area and the closed area in years without area closure. In years with area closure estimates of biomass and recruitment within the closed area are obtained from acoustic surveys. The southern area is sufficiently sampled to allow analytical age-based assessment.

The eastern area has historically been reasonably sampled since 1992, but the sampling in recent years has been sparse.

Table 4.1: Stock assessment areas

Area	
Eastern area	
Northern area	
Southern area	
Western area	
Shetland area	
Viking bank area	

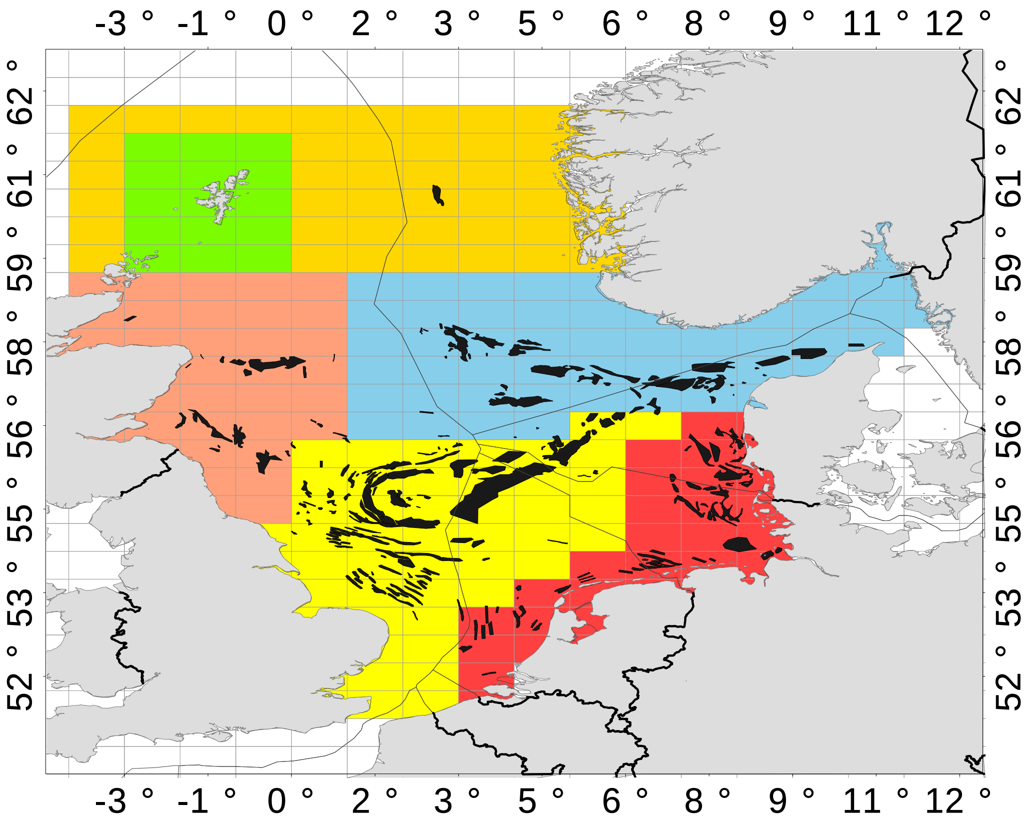

Figure 4.2: Sandeel fishing banks (black areas), EEZ borders, eastern area (red), northern area (blue), southern area (yellow), western area (dark orange), Shetland area (green) and Viking bank area (light orange).

Table 4.2: Number of Danish samples available for each area.

	Area					
Year	1	2	3	4	5	6
1982	33	5	4	0	0	0
1983	36	16	7	0	0	0
1984	63	4	15	0	2	0
1985	50	13	6	10	2	0
1986	14	0	20	1	0	0
1987	45	4	21	0	0	0
1988	15	3	46	0	0	0
1989	17	1	12	0	0	0
1990	1	0	2	0	0	2
1991	16	6	26	1	0	0
1992	40	13	31	0	0	6
1993	13	12	65	7	0	5
1994	13	5	22	2	0	2
1995	20	14	20	0	0	2
1996	21	11	60	15	0	1
1997	15	16	42	5	0	1
1998	31	11	29	1	0	2
1999	156	21	36	6	1	0
2000	39	12	28	33	0	1
2001	144	6	36	65	0	0
2002	131	19	56	27	0	1
2003	109	27	137	89	0	2
2004	216	42	81	36	0	0
2005	167	26	7	18	0	1
2006	243	11	17	2	0	0
2007	151	13	96	0	0	1
2008	149	4	60	1	0	0
2009	144	1	68	0	0	0

Boulcott, P., Wright, P. J., Gibb, F. M., Jensen, H., and Gibb, I. M. 2007. Regional variation in maturation of sandeels in the North Sea. – ICES Journal of Marine Science, 64: 369–376.

Christensen, A., Jensen, H., and Mosegaard, H. (2009). Spatially resolved fish population analysis for designing MPAs: influence on inside and neighbouring habitats. – ICES Journal of Marine Science, 66: 56–63.

Christensen, A., Daevel, U., Jensen, H., Mosegaard, H., St John, M. and Schrum, C. 2008. Sandeel (*Ammodytes marinus*) larval transport patterns in the North Sea from an individual-based hydrodynamic egg and larval model Can. J. Fish. Aquat. Sci. Vol. 65: 1498-1511.

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5 Future management of North Sea sandeel

5.1 Management in 2010

In 2010, the AGSAN2 recommends that the RTM method as described in section 3 is used to set a TAC.

5.2 Management from 2011 onwards

The group proposes that the future management of North Sea sandeel should be based on separate assessments for the areas defined in section 4. To this aim, a benchmark of sandeel assessment in the North Sea is required in August 2010. To assure that the necessary data are available for this benchmark, the group agreed on the following schedule:

A. General

A.1. Stock definition

- Definition of potential assessment areas, AGSAN2009-2, October 2009: Completed

A.2. Fishery

- Description of National fisheries, including changes in gear and in level and distribution of effort submitted to assessment coordinator by country (DK, 1 January 2010)

A.3. Ecosystem aspects

- Update information (literature review) regarding predation etc (DK, 1 June 2010)

B. Data

B.1. Commercial catch

- International Catch data by square submitted (DK, 1 December 2009)
- Total Catch at age by square estimated (DK, 1 March 2010)

B.2. Biological

- Maturity data from dredge survey compiled and available for FishFrame (DK, 1 March 2010)
- Natural mortality estimates from ICES WGSAM (DK, available)
- Length and age samples from Norway compiled and available for Fish-Frame (N, 1 January 2010)

B.3. Surveys

- Dredge survey data (2004-2010) analysed and available for assessment (DK, 1 March 2010)
- Acoustic survey (biomass and number) by fishing bank and age group (2007-2010) available (N, 1 August 2010)

B.4. Commercial CPUE

- Standardised Danish catch rate (or effort) indices (1983-2009) compiled by assessment unit (DK, 1 March 2010)
- Standardised Danish catch rate (or effort) indices (1997-2009) compiled by assessment unit (DK, 1 March 2010)

B.5. Other relevant data

- NA

C. Potential candidate models:

- SXSA: available
- SMS (available)
- Effort Based Model (available)
- Anchovy Model (available)

5.3 Norwegian proposal for sandeel management in 2010 in the Norwegian EEZ

Because a majority of the fishing grounds in the Norwegian EEZ are considered commercially depleted (Sec. 5.4), IMR in Norway considers that the Norwegian sector should not be opened for a commercial sandeel fishery in 2010. However, a limited quota of 20 000 tonnes has been suggested by IMR for an experimental fishery in order to calibrate the acoustic target strength of sandeel. This is a part of an IMR project aiming at increasing the precision of acoustic abundance estimates of sandeel appearing in the water column. The experimental fishery will be restricted to a part of the Vestbank area (Figure 5.1) where relatively high concentrations of sandeel were measured during the acoustic survey in 2009. Based on these abundance estimates IMR considers a quota of 20 000 tonnes not to be detrimental to the local spawning stock. It should also be noted that relatively high concentrations of sandeel were measured in the parts of the Vestbank area that will be closed in 2010.

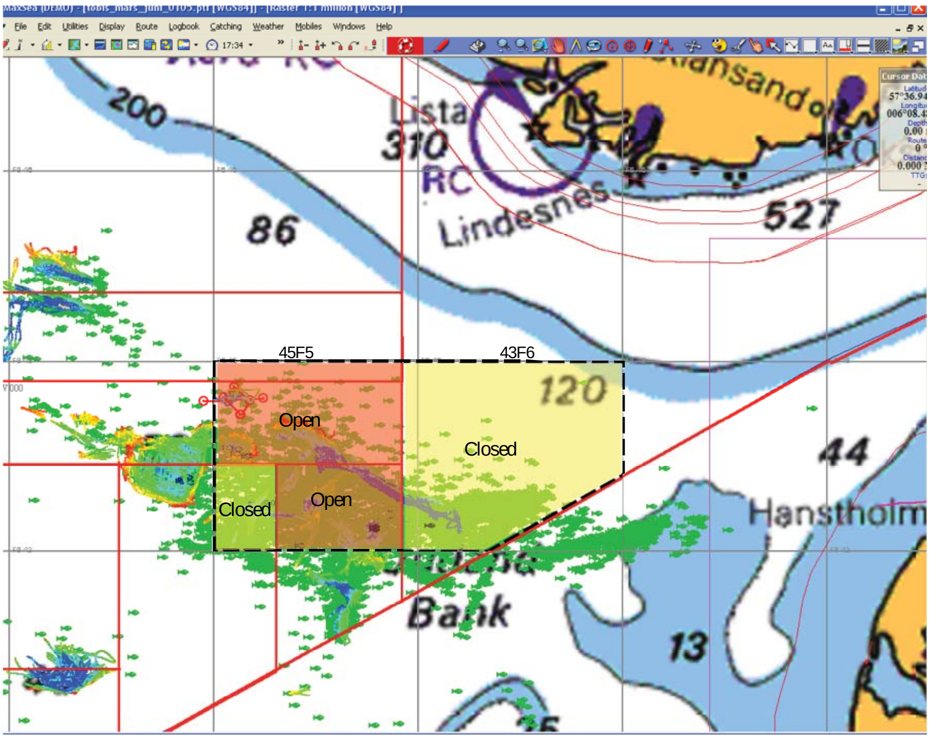

Figure 5.1: A quota of 20 000 tonnes has been suggested for an experimental fishery in the Vestbank area (ICES squares 43F5 and 43F6) in the Norwegian EEZ in 2010. Red squares indicate open fishing areas, green squares closed areas.

Based on the results of the acoustic survey in 2010, a commercial fishery may be considered opened in 2010 on fishing grounds where the local spawning stocks are above predefined limits. Acoustic measurements in 2009 indicate that the Vestbank area is the only fishing ground in the Norwegian EEZ that may be opened for a commercial sandeel fishery in 2010.

5.4 Norwegian proposal for sandeel management from 2011 in the Norwegian EEZ

5.4.1 Background

Landings of sandeel from the North Sea have decreased substantially in recent years. The decrease has been particularly severe in the Norwegian EEZ (Figure 5.2). Several banks have not provided landings for the last 8-12 years (Figure 5.3). These fishing banks are considered commercially depleted, i.e. the concentrations are too low to provide a profitable fishery. For several years after 2001 almost all landings from the Norwegian EEZ came from the Vestbank area (Figure 5.4).

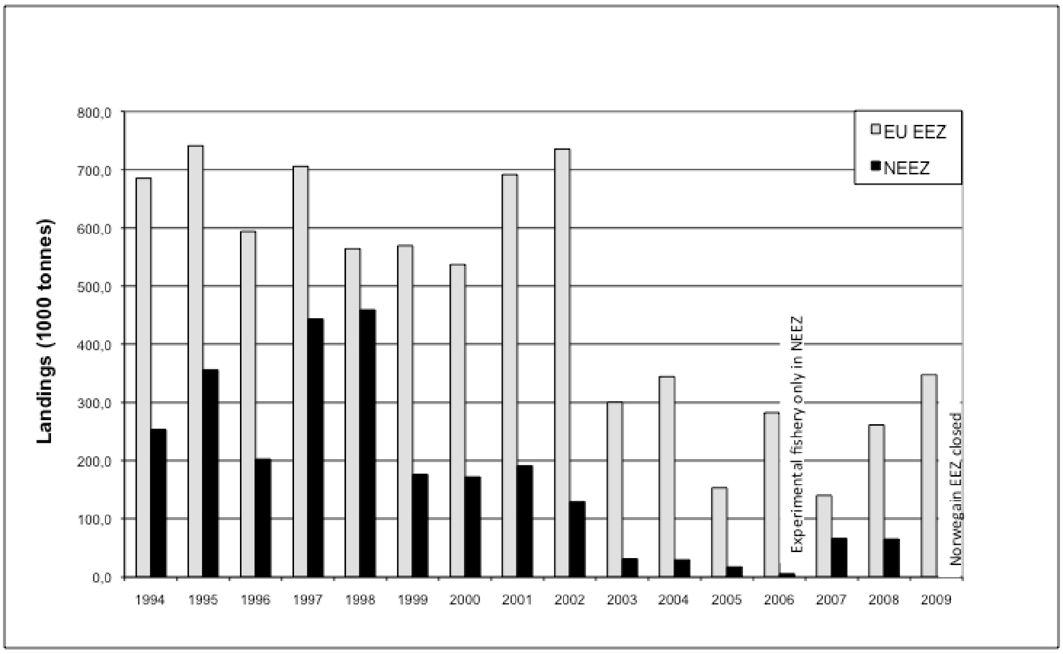

Figure 5.2: Landings of sandeel from the EU and Norwegian EEZ 1994-2009.

Some of the more southerly banks were repopulated by new recruitment in 2006, but commercially depleted again in 2007 or 2008; Inner Shoal East and Outer Shoal were commercially depleted in 2007, and English Klondyke, which was closed after the RTM fishery in 2007, was commercially depleted in 2008. The main concentrations of sandeel in the Norwegian EEZ are again found in the Vestbank area (Figure 5.5). There are high concentrations on Inner Shoal West too, but this is a very small fishing ground. In the Vestbank area and Inner Shoal West there are natural refuges that prevent the fleet from depleting the local sandeel stocks.

Most of the fishing grounds in the Norwegian EEZ were commercially depleted during a period when the assessment suggested that SSB was well above Bpa. In addition, evidence from 2007 and 2008 suggests that fishing grounds can be commercially depleted within a few weeks without marked decreases in CPUE in tonnes (Sec. 2.1.1.2.7).

The commercial depletion of fishing grounds and the long-term implications this may have for the local fishery is of major concern. Because the present management of sandeel has not prevented commercial depletion of the majority of the Norwegian sandeel grounds, the Norwegian Department Fisheries and Coastal Affairs requested the Directorate of Fishery and the Institute of Marine Research, in collaboration with the fishing fleet, to propose an alternative management strategy that may prevent commercial depletion of fishing banks.

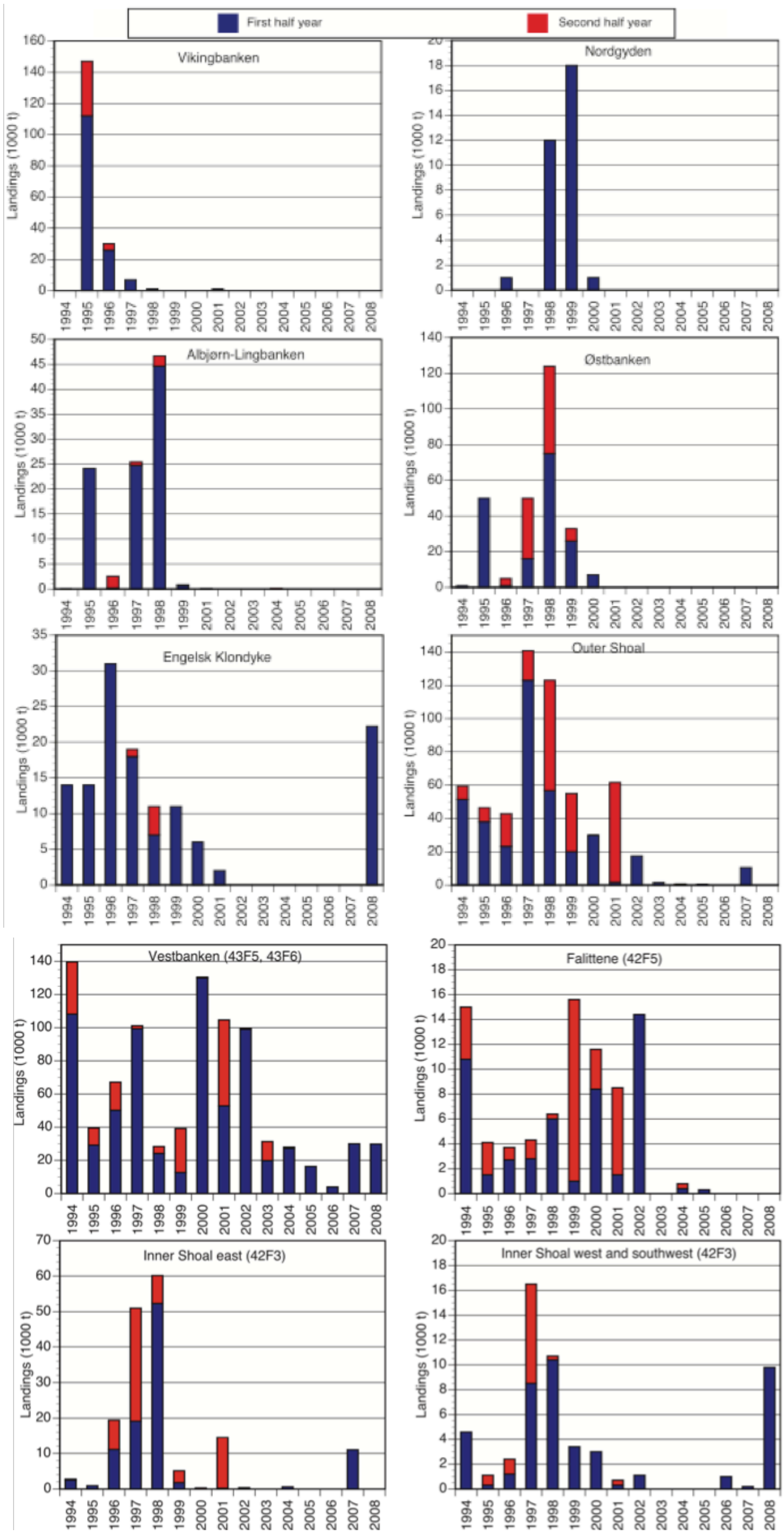

Figure 5.3: Sandeel landings from Norwegian fishing banks 1994-2008 in the first (blue) and second (red) half of the year. Landings in second half are mainly 0-group.

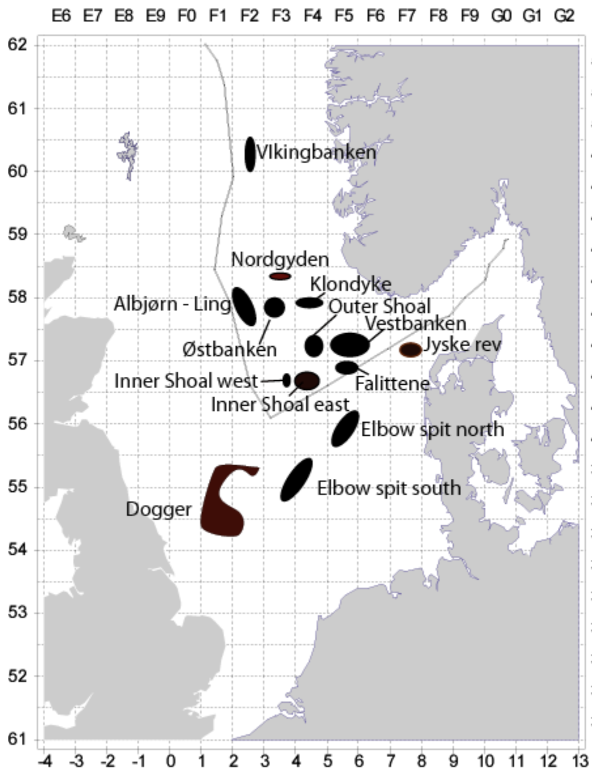

Figure 5.4: Sandeel fishing grounds in the Norwegian EEZ and the main fishing grounds in the EU EEZ.

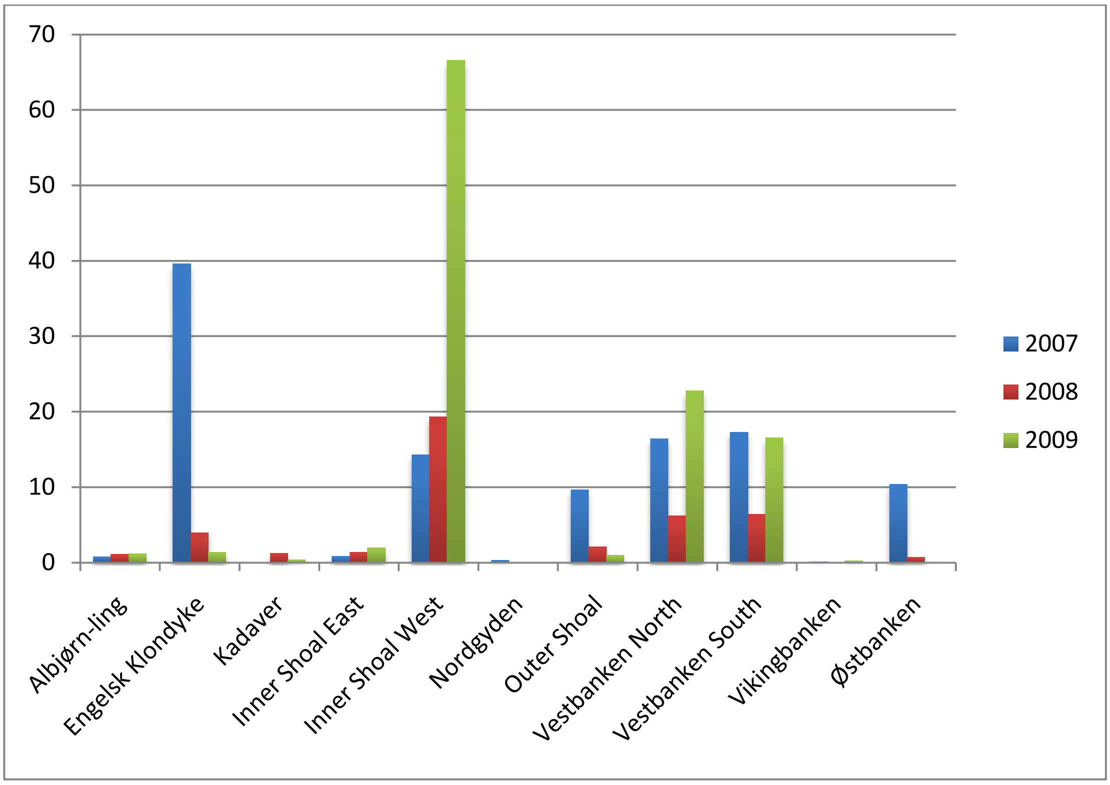

Figure 5.5: Relative densities (sA) of sandeel on various fishing grounds in the Norwegian EEZ in April-May 2007, 2008 and 2009.

5.4.2 Proposed management plan

Main objective: Sandeel will be managed spatially to ensure sustainable local spawning stocks in all areas where sandeel is distributed in the Norwegian EEZ.

Method:

1) The Norwegian EEZ will be divided into areas. Each area will be divided in two sub-areas. The sub-areas will be opened and closed alternately (year to year). If a local spawning stock falls below predefined limits, both sub-areas will be closed.

2) An acoustic survey will be carried out in April-May to measure the abundance of sandeel (I-group and II+-group).

3) Based on results from the acoustic survey propose which area that can be opened for fishing the following year and propose a preliminary TAC for the Norwegian EEZ the following year.

4) Based on the acoustic abundance estimates of I-group, in-season evaluation whether closed area can be re-opened and update the TAC for the rest of the fishing season.

5) Fishing season between April 23 and June 23. The relative late opening is to allow the sandeel to feed and improve the condition, which is very low when the fish emerge from the sand in early spring. The stop date usually coincides with hibernation of I+-group sandeel.

6) Minimum size. If the number of sandeel <10 cm comprise more than 10% of the landings in terms of numbers from a particular fishing ground, the fishing ground will be closed for 7 days and then automatically re-opened.

The proposed method is based on the assumptions that the closed sub-areas will protect sandeel from local depletion and that local spawning stocks are important for local recruitment. Although there are observations in support of both assumptions, neither has been fully tested. Therefore, the proposed management method is an imperative experiment to improve the dismal situation for sandeel in the Norwegian EEZ. The spatial management method will be evaluated after each fishing season.

5.5 Comment from the AGSAN2 on the Norwegian proposal for sandeel management in 2010 and 2011 in the Norwegian EEZ

The group has been informed of the proposed Norwegian future management plan. However, the group was not in a position to evaluate the Norwegian proposal.

Annex 1: Technical Minutes on Section 3

Review of the ICES **Ad hoc Group on Sandeel-II** (AGSAN2) **Report 2009, Section 3.**

Reviewers: Beatriz Roel, Ewen Bell

Review 1

Overall comments

I have participated in AGSAN meetings previously, hence my review of the process looks at consistency through time.

The applied methodology appears to be consistent with that taken before. The only changes have been in the datasets (time scale and raising procedure).

There is a marked difference in the regressions of VPA 1-group and the CPUE 1-group between the 2007 AGSAN report and 2009 AGSAN report. In the earlier report, R-square values were between 0.81 and 0.95 whereas they are now between 0.62 and 0.8. The slope of the regression is also considerably lower and the influence of the two lowest points appears to be even stronger than before in determining the relationship. This means that the recent CPUE values are becoming less correlated to overall stock density. There are several factors which could contribute to this including technical creep in the fleet, changes in fleet structure not accounted for in the standardisation and changing spatial coverage of the monitoring fishery.

Section 3.1.2

3rd line, "Table 3.2" should be "Table 3.3".

It is unclear which assessment results the Group have based their regressions on. WGNSSK proposed a new assessment whereas ACOM chose a SPALY assessment (and this is noted in section 3.3), but the text is ambiguous as to which results have been used.

Short term forecast:

Section 3.3 starts with the comment that ACOM chose a different assessment to that suggested by WGNSSK. The following section then deals with a preliminary short term forecast based upon "assessment results" and the traditional assumption of low (25th centile) recruitment. Again it is unclear whether the assessment basis used was the SPALY run (ACOM's choice) or the WGNSSK alternative.

Review 2

3.1 Reasons for excluding 2002 from the CPUE time-series?

<u>Removal of earlier years from the analysis given increase in efficiency.</u> The parameter a_y in Eq 1 below should subsume both changes in efficiency between years and stock size in year *y*. So, I question the decision of excluding years because of changes in efficiency and suggest doing a sensitivity test by performing the historical CPUE analysis with and without the early years.

3.1.1 Standardisation of effort

Procedure not clear in the report. I guess that CPUE data is input by vessel and trip therefore Eq 1 should be:

$$CPUE_{y,n} = a_y \; GT_n^b$$

Where $CPUE_{y,,n}$ corresponds to catch per unit effort in year *y* and vessel *n*.

3.1.3 Effects of updating the time series

The parameter *b* is estimated from Eq 1 above. The parameter appears estimated with reasonable precision by week 16. There is no point in testing sensitivity to alternative values of this parameter.

3.2 Step 2.

Given the considerations in paragraphs 1 – 3, the proposed stratification of landings: by week and ICES rectangle to be implemented in 2010 seems appropriate.

3.3. Step 3

3.3.2 Uncertainties in the assessment and forecast. The harvest rule, as it stands is very sensitive to the assumptions on distribution of effort made in the assessment. A harvest rule that is robust to those uncertainties needs to be developed and tested by simulation.

3.3.3 Adjustment of TAC from the observed mean weight of 1-group

Mean weight at age in the total catch varies between years and it makes sense to take that into account when computing the TAC. Given results from growth studies on individual fishing banks it may be worthwhile taking the spatial distribution of weight at age into account when trying to predict mean weight at age of the total international catch from estimates in the RTM period.

3.4 Spatial aspects of RTM

The report concludes that current concentration of the fishing fleet on the main banks, in combination with high CPUE, should be seen as indicative of a stock in good condition. Engelhard *et al* (2008) in a study on sandeels behaviour based on survey data collected in the Dogger Bank between 2004 and 2006 compared annual abundance estimates between two areas that differed markedly in sandeel abundance. For the area of high abundance the study showed a similar pattern to the one indicated by the commercial CPUE with a clear increase in abundance in 2006, while the area of low abundance remained consistently so during the period. This highlights the highly localised nature of sandeels distribution with increases in stock abundance reflected primarily on the "best" banks where the habitat offers appropriate conditions for sandeels.

However, commercial CPUE can be kept high even if some of the banks are being depleted because the fleet knows the location of the main banks and would move between them to keep the CPUE at a commercially viable level. This would prove easier under the current conditions of a reduced fleet. Therefore, in present circumstances, high CPUE and concentration of the fishery on the main fishing grounds does not necessarily indicate that the stock is in good condition.

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Annex 3 Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
To hold a Benchmark meeting for Sandeel North Sea in August 2010. Reasoning supporting the need and possiblity for a benchmark are: a. serious doubts that have risen on the quality of the current assessment methodology (covering the whole of the North Sea as one area), b. ICES advice has stipulated the need for area based regional management that is not covered in the current assessment c. insights in the regional subdivisioning of areas from AGSAN-II Planning the preparation of this benchmark is described in section 5 of the AGSAN-II report. The meeting should be held in August in order to be in time for the 2011 assessment and to be able to include the summer survey data collected by Norway.	ACOM