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Trends in reproductive parameters of North Sea plaice and cod: implications for stock assessment and management advice

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Abstract

In many stock assessments within the ICES area, the proportion of mature fish at age is kept constant at some loosely defined values. However, given that a number of stocks is under severe fishing pressure, we expect that maturity at age changes in a non-random fashion. North Sea plaice and cod are severely over-exploited. In this paper, trends in maturity, sex ratio and age at first maturation of North Sea plaice and cod are analysed based on Dutch market sampling data and International Bottom Trawl Survey (IBTS) data. Implications of the observed trends in maturity at age on stock assessment and management advice are explored. The results indicate that the maturity at age for North Sea plaice and cod, significantly increased in recent years. The implications, as far as they have been analysed in this paper, are that the perception of the current stock may change but that the biological reference points are relatively robust to these changes.

Introduction

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North Sea plaice and cod are two demersal stocks that experience high fishing pressure and are both harvested outside safe biological limits (ICES 2001a). Given the depleted state of these stocks it is all the more important to make sure that the basic biological data and assumptions underlying the stock assessment models (Darby and Flatman 1994; Shepherd 1999) are valid and robust. Stock assessment results are generally presented in terms of fishing mortality and spawning stock biomass (SSB) where the latter is defined as the number of fish at age, times the mean weights at age, times the proportion mature at age. Trends in weight at age have been reported elsewhere (Rijnsdorp and Van Leeuwen 1996; Cook et al. 1999) and will not be investigated here. We want to focus the analysis on the proportion mature at age.

Current practice in many stock assessment working groups within ICES, is to assume a certain proportion mature at age and to keep this constant over years (ICES 2001b). Often the biological basis for the maturity assumptions is at best weak, but sometimes almost absent. However, biological reference points like Fmed, F0.1 and Fmax are to a certain extent dependent on the maturity assumptions because they are related to the stock-recruitment relationship. Therefore, it seems appropriate to investigate the changes in maturity for the two stocks considered here and to explore the implications of those changes on stock assessments and management advice.

Materials en methods

Plaice

Data used in this study comprised samples from commercial landings (market samples) of the Dutch beam trawl fishery. The market samples consist of a fixed number of fish randomly selected from the landings by market category. Apart from the date of landing and the position of the catch, the following data were recorded for each fish: body size (mm), body weight (g), sex, maturity stage and age (years, January 1 as birthday). Age determination was done at the laboratory based on the pattern of growth zones in the otolith assuming that each growth zone corresponds to one year. The ageing method has been validated (Rijnsdorp et al. 1990).

Male and female plaice were considered to be mature when they had reached maturity stage 2-7 in the 1st quarter (Rijnsdorp 1989).

The method to determine the length at first maturation is described below. The analysis was restricted to samples obtained from the spawning period (1^{st} quarter) and from the spawning areas in the southeastern North Sea (between 51oN and 55o30'N and east from 2o E). The sex ratio was estimated from the Dutch market samples over the whole year. The population maturity was then calculated using the proportion males and females mature at age combined with the sex ratio data. To smooth the year-to-year variations in maturity at age, a three-year running mean was used.

Cod

For cod, age and maturity data from the International Bottom Trawl Survey from 1980-2000 were used. Only data from roundfish areas 1-7, collected in the first quarter were analysed (Figure 1). No distinction was made between males and females as they were both included in the dataset.

Length and age at first maturity

The fraction of mature fish at a certain age or length was modelled using a logistic model. In the generalized linear model, the response variable p was defined as:

$$p = n(mature) / (n(mature) + n(immature)). \quad (1)$$

Where p= response variable (fraction mature fish), n=number of mature or immature fish. The response variable p_j has a binomial distribution. A logit function g(m) was used to link the expected value of the response variable (p) to the linear predictor:

$$g(m) = \ln(p/(1-p)). \quad (2)$$

Where g(m) = expected value of fraction of mature fish and m = overall mean.

The size at first maturity in plaice was estimated using the following model:

$$G(m) = a + b\ L \quad (3)$$

For each year separately. The size at 50% maturity is given by: Lmat = a/b;

To predict the fraction of mature cod per roundfish area, the linear predictor for the expected fraction of non-zero catches was defined using the following model:

$$g(m) = m + A + Y + R_i + (A * R_i) + (A * Y) + (Y * R_I) \quad (4)$$

Where A is the age of fish (years), Y is the year of sampling and R is the roundfish area (i=1 to 7). To predict the faction of mature fish for the North Sea, over all roundfish areas, the expected value was weighted for the abundance of cod in each roundfish area. Only age, year and the interaction between age and year were used as explanatory variables.

The procedure was implemented using PROC GENMOD of the SAS software package (SAS 1990). 95% approximate confidence limits of the fitted value were calculated as described in the GENMOD procedure manual. If a term did not reduce deviance significantly (α=0.05), it was removed from the model.

Assessment

For both plaice and cod, XSA assessments (Darby and Flatman 1994) were carried out using the same settings as in the 2000 WG (ICES 2001b), but with new maturity data. A 10-year tuning window was used without tapering. Results were then further investigated using the so-called PA-software (CEFAS 1999) and an equilibrium model analysis (Reeves and Cook 1994; Cook et al. 1999). Biological reference points were calculated and compared with the WG2000 results.

Results

Plaice

Trends in maturity for female plaice are shown in Figure 2, based on the analysis of the 1st-quarter Dutch market sampling data from 1958 to 1999. Maturity at age has increased for ages 3 to 5 over the last 10 years. However, maturity at age 3 appears to have a cyclic nature and maturity in recent years appears to have declined again. The strongest increase in maturity was observed for age 4 where the proportion mature increased from 40% in the 1960's to around 80% in the late 1990's.

Trends in maturity for male plaice could not be analysed because almost all plaice above the minimum landing size of 27cm are mature. For the youngest age groups in the landings, these results will be biased because an important part of these young age-groups are not well represented in the commercial landings. For the subsequent analysis it was assumed that all males from age 2 were mature.

The sex ratio of the stock could not be estimated directly. As a proxy, the sex ratio in the Dutch landings were used as observed in the market samples collected during the whole year. (Figure 3). No apparent trends in sex ratios were observed although there may be a slight increase in the number of females over the recent years. In the youngest age groups represented in the market samples, the proportion males and females are similar. In older age groups the proportion of males declines. The population maturity was estimated taking account of the observed sex ratio and the maturity at age for females (estimated) and males (assumed). Results, indicate the same pattern as for females, but slightly moderated by the inclusion of the males in the population (Figure 4, Table 1). The increases in maturity at age 3 and 4 are still apparent. The overall increase in the percentage mature females at age is related to an overall decrease in the size at which 50% of the females becomes mature (Figure 5).

Differences in SSB between estimates from 'old' and 'new' maturity data, can be observed in periods of a relatively high SSB (e.g. 1960s and 1980s), where the stock is estimated lower when the new maturity data are used (Figure 6). No detectable difference, however, can be found in recent years. The reduced estimates in the two periods of high biomass results in a decrease of the range of estimated SSB values and in a more dome shape Shepherd stock recruitment curve (ICES 1998). The equilibrium analysis for plaice is shown in Figure 7. Since the equilibrium analysis is dependent on the stock recruitment curve, and since these curves are relatively similar when either using the WG estimates of maturity or the 'new' maturity estimates, the results of the equilibrium analysis are also rather similar. Estimates of biological reference points (Table 2) are also similar although the estimate of Floss (Cook 1997), which may be seen as a proxy for Fcrash, is 13% lower when using the new maturity data.

Cod

The analysis of the proportion mature at age for North Sea cod (sexes combined) was based on 44000 individuals collected in the 1st quarter international IBTS surveys over a time-span of 20 years (Table 3). Results of the analysis by roundfish area indicate an increase in the proportion mature, predominantly at ages 3 and 4 (Figure 8). The increase is most clear for roundfish areas 1–5. Age, year and region, as well as the interaction between age*region significantly contribute to the variance (Table 4). The interactions between age*year and between year*region are also significant, but these only explain a minor proportion of the variance.

The maturity at age by roundfish area was transformed into a population estimate of maturity by weighting over the IBTS index values by area and year (Figure 9, Table 5). Since the IBTS data were only available from 1980 onwards, no estimates could be given for maturity before that year. Therefore, the ICES WG estimates were used for this period (ICES 2001b). When both the results for maturity from the logistic model and from the running mean are considered, maturity at age is higher at present than assumed in the ICES WG (Table 6 and Table 7).

As the maturities estimated from the IBTS data tend to be higher compared to the WG estimates of maturity, SSBs are higher when implementing the new series (Figure 10). The estimates of SSB in 1999 ranged from 66000 tonnes (WG2000 data) to 98000 tonnes (using a 3-yr mean maturity). The stock recruitment plots and the equilibrium analysis presented in Figure 11 are very similar and the estimates of biological reference points indicate that both Fmed and Floss are estimated to be higher when using the new maturity data (Table 8). However, as the time series of maturity data only extends from 1980 onwards, the years which could be affected mostly (i.e. the years at high stock numbers as in the early 1970s) could not be included in the analysis and it is likely that a revision of the maturity characteristics for this period may affect the estimated reference points even more.

Discussion

The results presented in this paper indicate that the maturity at age for North Sea plaice and cod, tends to increase in recent years. This is consistent with findings by Cook *et al* (1999) and Bromley (2000).

There are several factors that may be related to the observed changes in maturation in plaice and cod. First, fishing may act as a strong selection factor towards earlier maturation (Rijnsdorp 1993b; Stokes et al. 1993; Law 2000). Second, fishing will reduce the stock biomass and may enhance the food availability per capita, leading to an increase in growth and an earlier maturation (Rijnsdorp 1993a; Trippel 1995). Thirdly, the increase in temperature in the North Sea may explain (part) of the observed change in maturation. For plaice, Rijnsdorp (1993a) showed that both growth and temperature conditions were significantly related to maturation.

Whatever the causes, the observed change in maturation will affect the perception of the trends in spawning stock biomass estimated by VPA and will affect the Stock – Recruitment relationship, which may affect the equilibrium analysis and on the biological reference points. The estimated effect of the changes in maturation explored in this paper should be considered preliminary, because the analysis of the data for both species shows some caveats. A number of caveats should be taken into account. First, the analysis of North Sea plaice, has been restricted to the Dutch market sampling data. As the Dutch fleets generates between 30-60% of the total landings of plaice, this may be regarded as a substantial sample, but there is still a need for a more comprehensive, international analysis (Bromley 2000). Second, the maturity at age for males needs to be revisited, as they are only partly selected by the fishing gear when they are two years old, so that those fish may present a biased sample of the population. Rijnsdorp (1989) showed that in 1985-86, about 50% of the 2-year old males, and 75% of the 3-year old males were sexually mature. As in females, the age at maturation in males has changed since the beginning of the 20th century. Because males become mature at a size that is well below the minimum landing size, no data are available to detect changes in the age at maturation of male plaice in the period over which the VPA results are available. Third, the analysis for North Sea cod has been restricted to the period 1980-1999 whereas the stock-recruit plot for that stock also heavily dominated by the high stock abundances in the early 1970s. Therefore, the effects on the equilibrium analysis may be underestimated if maturity at age in those years differed substantially from the assumed maturity.

Despite these caveats, our study indicates that changes in maturation should be taken into account in the stock assessment carried out annually by the ICES Working Group. Further work on the reconstruction of changes in maturation, and an analysis of the factors underlying these changes may provide a significant improvement of the assessment and the management advice for these stocks.

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References

Bromley, P. J. (2000). Annual variation in the growth and maturity of North Sea plaice - implications for estimating spawning stock biomass (Working Document). WD 4. WGNSSK 2000.

CEFAS (1999). PA Software User's Guide.

Cook, R. M. (1997). The application of a sustainability criterion to demersal stocks in the ICES area. ICES C.M. 1997 / V:7.

Cook, R. M., P. A. Kunzlik, J. R. G. Hislop and D. Poulding (1999). "Models of growth and maturity for North Sea Cod." Journal of the Northwest Atlantic Fishery Science **25**: 91-99.

Darby, C. D. and S. Flatman (1994). Virtual population assessment: version 3.2 (windows/dos) user guide.

ICES (1998). Report of the study group on the precautionary approach to fisheries management. ICES Copenhagen, 3-6 February 1998. **ICES C.M. 1998 / Assess:10. Ref. D**.

ICES (2001a). Report of the ICES advisory committee on fishery management 2000, ICES. **Cooperative Research Report no. ???**

ICES (2001b). Report of the working group on the assessment of demersal stocks in the North Sea and Skagerak. Copenhagen, 3-12 October 2000. **ICES C.M. 2001 / ACFM: 7**.

Law, R. (2000). "Fishing, selection, and phenotypic evolution." ICES Journal of Marine Science **57**: 659-668.

Reeves, S. A. and R. M. Cook (1994). Demersal Assessment Programs (Working Document). WGNSSK 1994.

Rijnsdorp, A. D. (1989). "Maturation of male and female North Sea plaice (Pleuronectes platessa L.)." Journal du Conseil / Conseil International pour l'Exploration de la Mer **46**: 35-51.

Rijnsdorp, A. D. (1993a). "Relationship between juvenile growth and the onset of sexual maturity of female North Sea plaice, Pleuronectes platessa." Canadian Journal of Fisheries and Aquatic Sciences **50**(8): 1617-1631.

Rijnsdorp, A. D. (1993b). Selection differentials of male and female North Sea plaice Pleuronectes platessa L. and changes in maturation and fecundity.In: The exploitation of evolving populations.(T. K. Stokes, J. M. McGlade and R. Law, eds.)**:** 19-36.

Rijnsdorp, A. D. and P. I. Van Leeuwen (1996). "Changes in the growth of North Sea plaice since 1950 and its relation to density, eutrophication, beam trawl effort and temperature." ICES Journal of Marine Science **53**: 1199-1213.

Rijnsdorp, A. D., P. I. Van Leeuwen and T. A. M. Visser (1990). "On the valitity and precision of back-calculation of growth from otoliths of the plaice, Pleuronectes platessa L." Fisheries research **9**: 97-117.

SAS (1990). SAS Technical report P-243, SAS/STAT Software: The GENMOD procedure, SAS Institute Inc., Cary, NC. **Release 6.09.:** 88 pp.

Shepherd, J. G. (1999). "Extended survivors analysis: an improved method for the analysis of catch-at-age data and abundance indices." ICES Journal of Marine Science **56**: 584-591.

Stokes, T. K., J. M. McGlade and R. Law (1993). The exploitation of evolving resources. Lecture Notes in Biomathematics, 99, Springer-Verlag, Berlin.

Trippel, E. (1995). "Age at maturity as a stress indicator in fisheries." BioScience **45**: 759-771.

Table 1 North Sea plaice. Maturity at age using a three year average estimate for ages 2-9. All other values taken from ICES assessment WG.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1957	0	0.38	0.65	0.67	0.80	0.97	0.95	0.98	0.99	1	1	1	1	1	1
1958	0	0.38	0.65	0.67	0.80	0.97	0.95	0.98	0.99	1	1	1	1	1	1
1959	0	0.40	0.60	0.67	0.80	0.97	0.96	0.99	0.99	1	1	1	1	1	1
1960	0	0.39	0.44	0.67	0.82	0.95	0.98	0.98	0.99	1	1	1	1	1	1
1961	0	0.36	0.46	0.68	0.87	0.97	0.99	0.99	0.99	1	1	1	1	1	1
1962	0	0.36	0.48	0.68	0.88	0.97	0.99	1.00	1.00	1	1	1	1	1	1
1963	0	0.41	0.41	0.70	0.86	0.98	0.99	1.00	1.00	1	1	1	1	1	1
1964	0	0.40	0.42	0.69	0.78	0.96	0.97	1.00	1.00	1	1	1	1	1	1
1965	0	0.41	0.33	0.64	0.82	0.96	0.97	0.99	0.97	1	1	1	1	1	1
1966	0	0.23	0.34	0.61	0.83	0.96	0.98	0.99	0.97	1	1	1	1	1	1
1967	0	0.48	0.35	0.59	0.87	0.96	1.00	0.99	0.97	1	1	1	1	1	1
1968	0	0.46	0.45	0.67	0.85	0.93	0.98	0.99	0.99	1	1	1	1	1	1
1969	0	0.58	0.58	0.72	0.87	0.92	0.98	0.99	1.00	1	1	1	1	1	1
1970	0	0.45	0.65	0.79	0.90	0.93	0.98	0.98	1.00	1	1	1	1	1	1
1971	0	0.47	0.69	0.82	0.94	0.97	0.99	0.99	1.00	1	1	1	1	1	1
1972	0	0.52	0.68	0.85	0.96	0.98	0.99	0.99	0.99	1	1	1	1	1	1
1973	0	0.49	0.68	0.84	0.96	0.98	0.99	0.99	1.00	1	1	1	1	1	1
1974	0	0.46	0.64	0.82	0.95	0.98	0.99	0.99	1.00	1	1	1	1	1	1
1975	0	0.50	0.69	0.82	0.95	0.98	0.99	0.99	1.00	1	1	1	1	1	1
1976	0	0.55	0.72	0.83	0.94	0.97	1.00	1.00	1.00	1	1	1	1	1	1
1977	0	0.60	0.78	0.86	0.95	0.97	1.00	1.00	1.00	1	1	1	1	1	1
1978	0	0.61	0.74	0.87	0.95	0.97	1.00	1.00	1.00	1	1	1	1	1	1
1979	0	0.55	0.69	0.88	0.98	0.99	0.99	1.00	1.00	1	1	1	1	1	1
1980	0	0.61	0.68	0.89	0.98	0.99	0.99	1.00	1.00	1	1	1	1	1	1
1981	0	0.49	0.66	0.89	0.98	0.99	0.99	1.00	1.00	1	1	1	1	1	1
1982	0	0.35	0.65	0.88	0.97	0.99	1.00	1.00	0.99	1	1	1	1	1	1
1983	0	0.28	0.59	0.84	0.98	0.99	1.00	1.00	0.99	1	1	1	1	1	1
1984	0	0.33	0.56	0.81	0.97	0.99	1.00	1.00	0.99	1	1	1	1	1	1
1985	0	0.45	0.56	0.80	0.96	0.99	1.00	1.00	1.00	1	1	1	1	1	1
1986	0	0.44	0.55	0.79	0.93	0.99	1.00	1.00	1.00	1	1	1	1	1	1
1987	0	0.42	0.48	0.78	0.93	0.98	1.00	1.00	1.00	1	1	1	1	1	1
1988	0	0.37	0.45	0.74	0.90	0.99	1.00	1.00	1.00	1	1	1	1	1	1
1989	0	0.44	0.46	0.74	0.91	0.99	1.00	1.00	1.00	1	1	1	1	1	1
1990	0	0.48	0.51	0.73	0.89	0.99	1.00	0.99	1.00	1	1	1	1	1	1
1991	0	0.54	0.57	0.76	0.92	0.97	1.00	0.99	1.00	1	1	1	1	1	1
1992	0	0.47	0.62	0.78	0.93	0.96	0.99	0.99	1.00	1	1	1	1	1	1
1993	0	0.48	0.66	0.87	0.96	0.98	0.99	0.99	1.00	1	1	1	1	1	1
1994	0	0.50	0.69	0.92	0.98	1.00	0.99	1.00	1.00	1	1	1	1	1	1
1995	0	0.53	0.69	0.92	0.97	1.00	1.00	0.99	1.00	1	1	1	1	1	1
1996	0	0.52	0.74	0.92	0.98	0.99	1.00	0.99	1.00	1	1	1	1	1	1
1997	0	0.46	0.68	0.90	0.97	0.99	1.00	0.99	1.00	1	1	1	1	1	1
1998	0	0.38	0.61	0.90	0.98	0.99	1.00	1.00	1.00	1	1	1	1	1	1
1999	**0**	**0.33**	**0.53**	**0.88**	**0.98**	**0.99**	**1.00**	**1.00**	**1.00**	**1**	**1**	**1**	**1**	**1**	**1**

Table 2 North Sea plaice. Estimated biological reference points using either the WG2000 data or the new maturity data.

	WG2000	new_mat	%diff
Fmax	0.31	0.31	0%
F0.1	0.15	0.15	0%
Flow	0.19	0.20	10%
Fmed	0.30	0.30	-2%
Fhigh	0.52	0.49	-5%
F35%SPR	0.12	0.12	-2%
Floss	0.45	0.39	-13%

Table 3 North Sea cod. Numbers of individuals analysed per year and roundfish area.

Year	Roundfish area							
	1	2	3	4	5	6	7	Total
1980	610	154	56	150	16	533	243	1762
1981	286	402	237	255	22	1261	229	2692
1982	553	287	223	163	204	624	375	2429
1983	574	245	369	0	55	956	196	2395
1984	427	79	283	109	109	993	46	2046
1985	1199	548	222	546	214	994	259	3982
1986	1159	191	176	34	136	775	24	2495
1987	538	473	327	256	208	1096	27	2925
1988	947	378	305	240	281	700	135	2986
1989	1106	708	314	295	149	593	156	3321
1990	803	432	274	228	59	322	59	2177
1991	302	26	33	7	24	359	256	1007
1992	408	318	220	0	20	172	37	1175
1993	773	317	197	0	11	95	116	1509
1994	221	483	84	259	30	214	59	1350
1995	317	554	157	266	55	391	137	1877
1996	467	278	93	188	69	188	111	1394
1997	414	248	128	244	141	387	104	1666
1998	600	603	195	350	235	705	105	2793
1999	359	268	63	150	121	252	19	1232
2000	191	71	101	216	91	203	36	909
Total	12254	7063	4057	3956	2250	11813	2729	44122

Table 4 North Sea cod. Results logistic regression for the analysis of maturity per Roundfish area.

Source	dF	Deviance	pr>Chi square
Intercept		132216.5	
Age	1	61271.5	<0.0001
Year	1	56214.2	<0.0001
Region	6	41093.5	<0.0001
Age x region	6	35311.2	<0.0001
Age x year	1	35209.7	<0.0001
Year x region	6	32486.8	<0.0001

Table 5 North Sea cod. Results logistic regression for the analysis of maturity over Roundfish areas.

Source	dF	Deviance	pr>Chi square
Intercept		132216.5	
Age	1	61271.5	<0.0001
Year	1	56214.2	<0.0001
Age x year	1	56075.2	<0.0001

Table 6 North Sea cod. Proportion mature at age (3-yr running mean) based on IBTS data (bold) and the ICES WG (ICES 2001b)

	AGE										
YEAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1963	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1964	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1965	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1966	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1967	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1968	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1969	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1970	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1971	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1972	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1973	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1974	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1975	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1976	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1977	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1978	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1979	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1980	0.01	**0.09**	**0.16**	**0.49**	**0.66**	1	1	1	1	1	1
1981	0.01	**0.07**	**0.16**	**0.51**	**0.72**	1	1	1	1	1	1
1982	0.01	**0.03**	**0.20**	**0.58**	**0.88**	1	1	1	1	1	1
1983	0.01	**0.03**	**0.26**	**0.52**	**0.81**	1	1	1	1	1	1
1984	0.01	**0.03**	**0.26**	**0.53**	**0.75**	1	1	1	1	1	1
1985	0.01	**0.09**	**0.25**	**0.48**	**0.69**	1	1	1	1	1	1
1986	0.01	**0.09**	**0.22**	**0.59**	**0.83**	1	1	1	1	1	1
1987	0.01	**0.10**	**0.26**	**0.59**	**0.90**	1	1	1	1	1	1
1988	0.01	**0.08**	**0.31**	**0.64**	**0.91**	1	1	1	1	1	1
1989	0.01	**0.13**	**0.39**	**0.60**	**0.85**	1	1	1	1	1	1
1990	0.01	**0.15**	**0.47**	**0.60**	**0.84**	1	1	1	1	1	1
1991	0.01	**0.19**	**0.49**	**0.67**	**0.85**	1	1	1	1	1	1
1992	0.01	**0.17**	**0.50**	**0.72**	**0.87**	1	1	1	1	1	1
1993	0.01	**0.17**	**0.47**	**0.79**	**0.93**	1	1	1	1	1	1
1994	0.01	**0.12**	**0.46**	**0.74**	**0.96**	1	1	1	1	1	1
1995	0.01	**0.11**	**0.40**	**0.74**	**0.96**	1	1	1	1	1	1
1996	0.01	**0.10**	**0.41**	**0.71**	**0.88**	1	1	1	1	1	1
1997	0.01	**0.09**	**0.41**	**0.70**	**0.85**	1	1	1	1	1	1
1998	0.01	**0.20**	**0.44**	**0.63**	**0.89**	1	1	1	1	1	1
1999	0.01	**0.29**	**0.50**	**0.60**	**0.89**	1	1	1	1	1	1

Table 7 North Sea cod. Proportion mature at age (logistic regression) based on IBTS data (bold) and the ICES WG (ICES 2001b)

	AGE									
YEAR	1	2	3	4	5	6	7	8	9	10	11
1963	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1964	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1965	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1966	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1967	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1968	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1969	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1970	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1971	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1972	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1973	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1974	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1975	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1976	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1977	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1978	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1979	0.01	0.05	0.23	0.62	0.86	1	1	1	1	1	1
1980	0.01	**0.03**	**0.14**	**0.43**	**0.78**	1	1	1	1	1	1
1981	0.01	**0.04**	**0.15**	**0.45**	**0.79**	1	1	1	1	1	1
1982	0.01	**0.04**	**0.16**	**0.47**	**0.81**	1	1	1	1	1	1
1983	0.01	**0.04**	**0.17**	**0.49**	**0.82**	1	1	1	1	1	1
1984	0.01	**0.04**	**0.18**	**0.51**	**0.84**	1	1	1	1	1	1
1985	0.01	**0.04**	**0.19**	**0.54**	**0.85**	1	1	1	1	1	1
1986	0.01	**0.05**	**0.20**	**0.56**	**0.86**	1	1	1	1	1	1
1987	0.01	**0.05**	**0.21**	**0.58**	**0.88**	1	1	1	1	1	1
1988	0.01	**0.05**	**0.22**	**0.60**	**0.89**	1	1	1	1	1	1
1989	0.01	**0.05**	**0.24**	**0.62**	**0.90**	1	1	1	1	1	1
1990	0.01	**0.06**	**0.25**	**0.64**	**0.91**	1	1	1	1	1	1
1991	0.01	**0.06**	**0.26**	**0.66**	**0.91**	1	1	1	1	1	1
1992	0.01	**0.06**	**0.28**	**0.68**	**0.92**	1	1	1	1	1	1
1993	0.01	**0.07**	**0.29**	**0.70**	**0.93**	1	1	1	1	1	1
1994	0.01	**0.07**	**0.31**	**0.71**	**0.93**	1	1	1	1	1	1
1995	0.01	**0.08**	**0.32**	**0.73**	**0.94**	1	1	1	1	1	1
1996	0.01	**0.08**	**0.34**	**0.75**	**0.95**	1	1	1	1	1	1
1997	0.01	**0.08**	**0.35**	**0.76**	**0.95**	1	1	1	1	1	1
1998	0.01	**0.09**	**0.37**	**0.78**	**0.96**	1	1	1	1	1	1
1999	0.01	**0.09**	**0.39**	**0.79**	**0.96**	1	1	1	1	1	1

Table 8 North Sea cod. Estimated biological reference points using either the WG2000 data or the new maturity data (3yr-mean or logit model).

		A	B		
	WG2000	**3yr mean**	**modelled**	**%diff A**	**%diff B**
Fmax	0.23	0.23	0.23	0%	0%
F0.1	0.14	0.14	0.14	0%	0%
Flow	0.48	0.53	0.52	10%	7%
Fmed	0.78	0.95	0.87	22%	11%
Fhigh	1.09	1.59	1.25	46%	15%
F35%SPR	0.16	0.16	0.16	4%	4%
Floss	0.87	0.96	0.95	11%	10%

Figure 1 Map of IBTS roundfish areas.

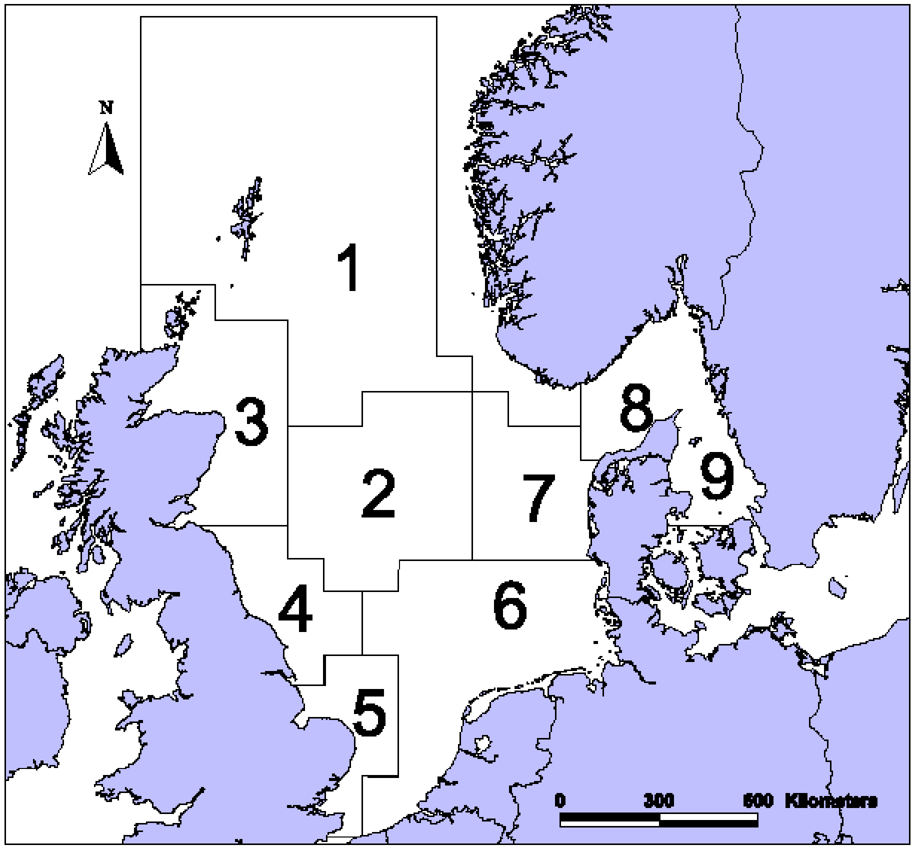


Figure 2. North Sea plaice. Proportion mature females in the North Sea from the Dutch 1st quarter market sampling data. Drawn line is the 3-yr running average. Ages 2-5.

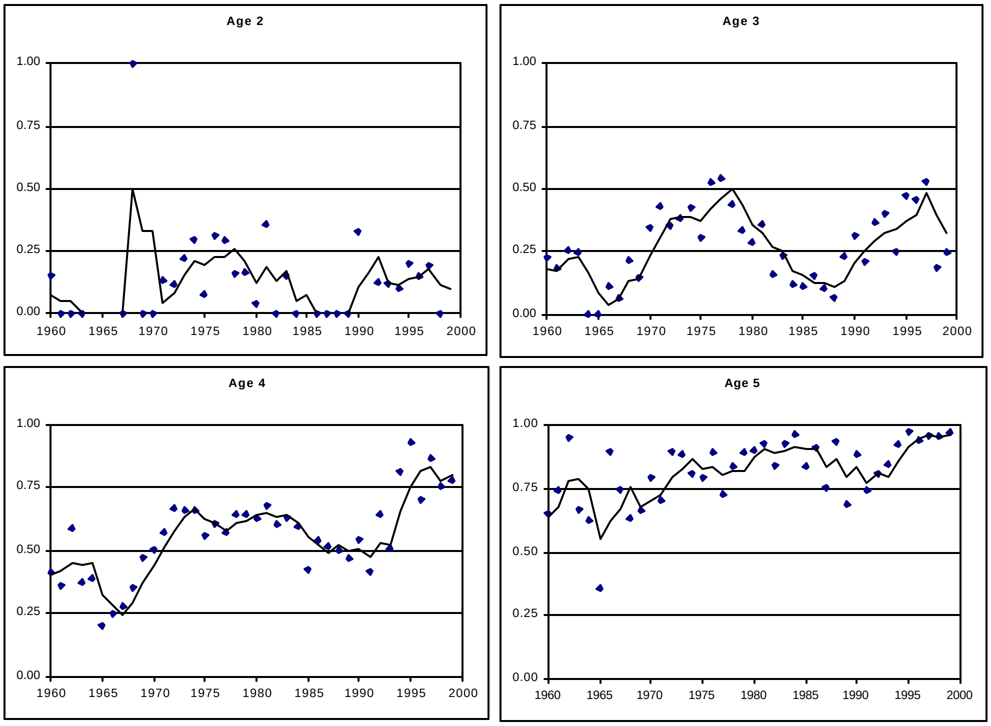


Figure 3. North Sea plaice. Sex ratio as derived from the Dutch market sampling data.

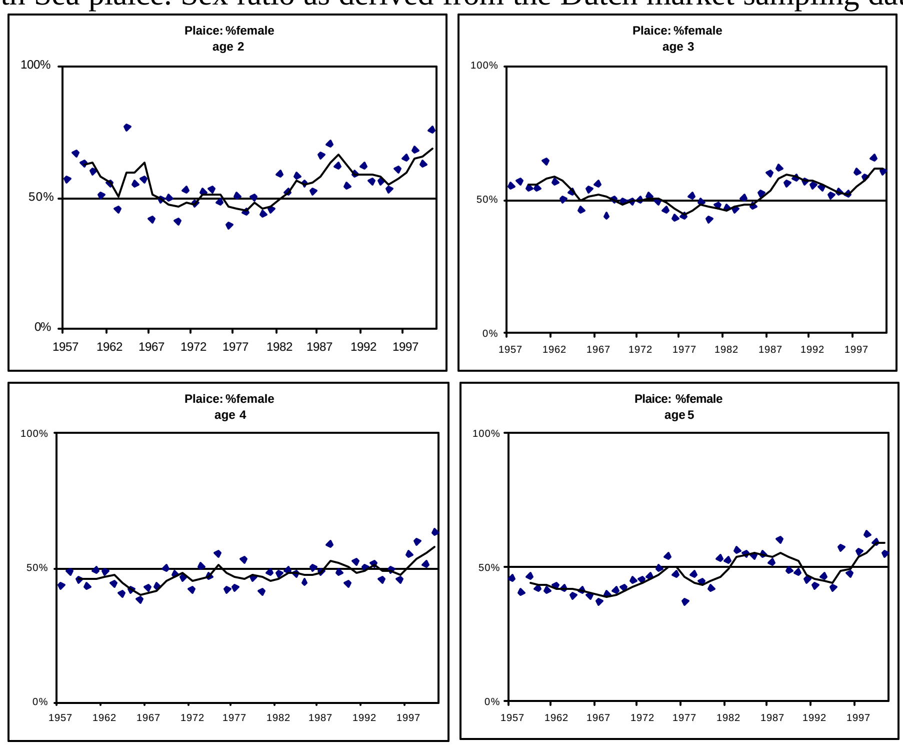


Figure 4. North Sea plaice. Estimated population maturity at age for ages 2 – 5, sexes combined. Dots represent the calculated values by year, the line represents the 3-yr running mean. Red dotted lines indicate the maturity assumed in the ICES assessment of North Sea plaice.

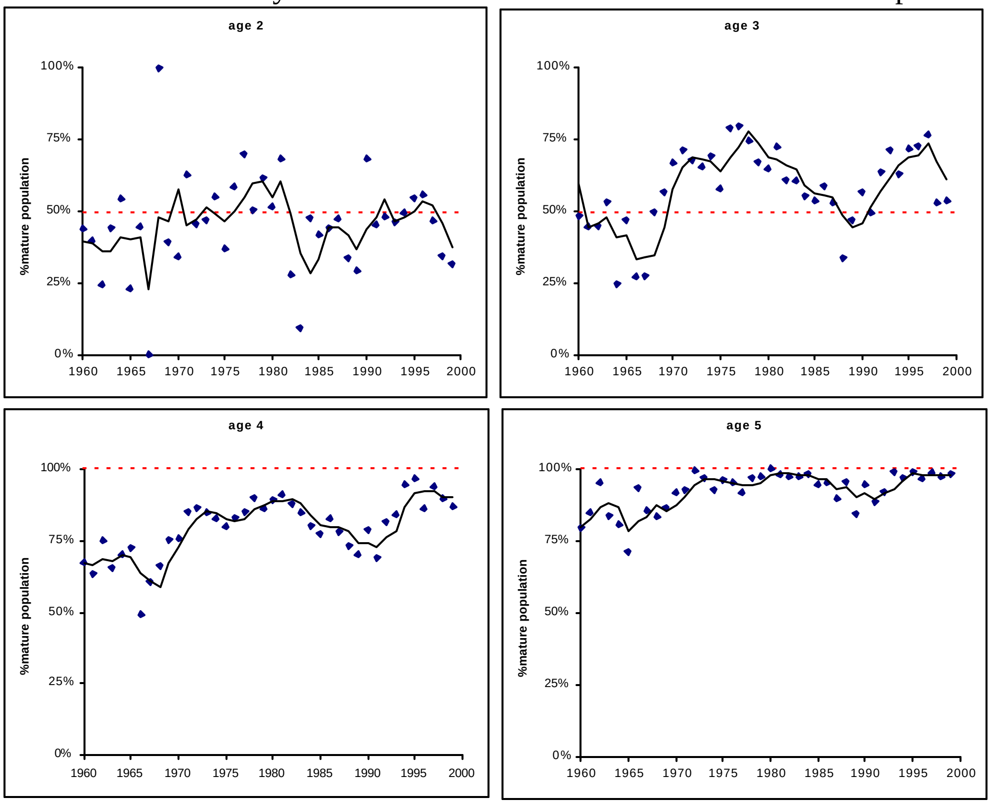


Figure 5 North Sea plaice. Age at 50% maturity in the Southern and German Bight from the Dutch market sampling data.

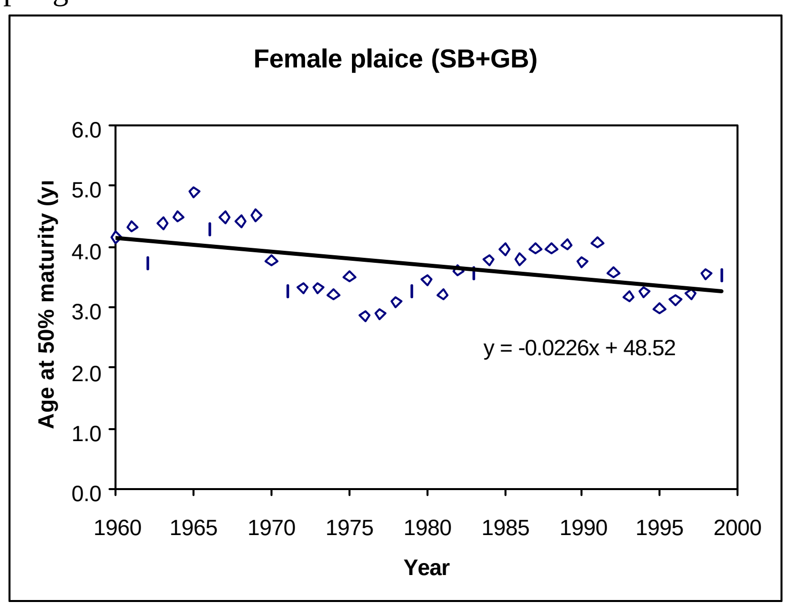
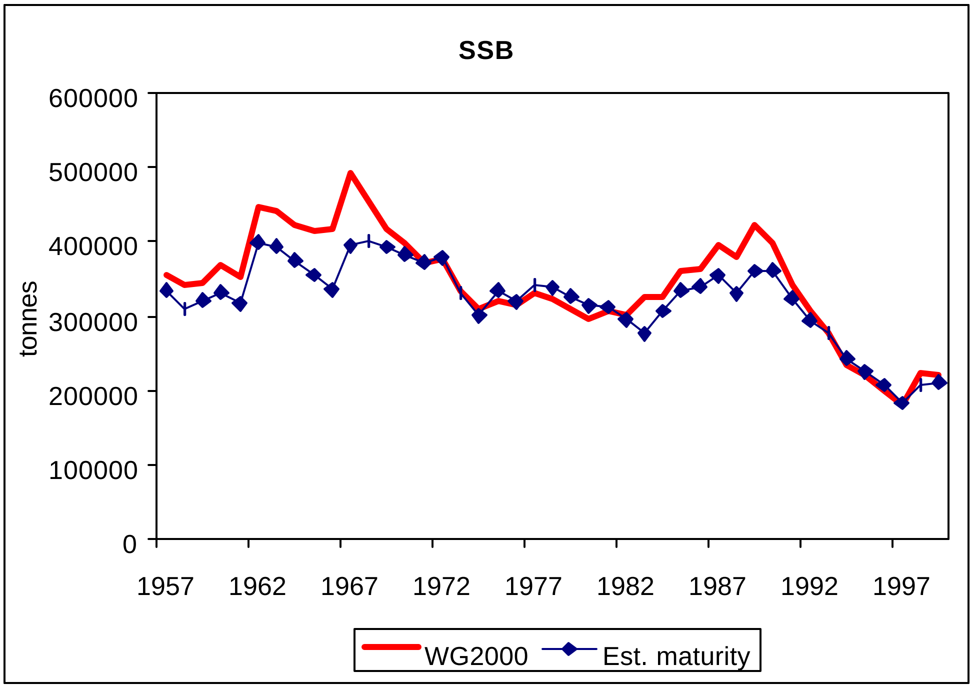


Figure 6 North Sea plaice. Comparison of SSB estimates in de ICES WG2000 assessment and in an assessment using new maturity data. Top: SSB against time. Bottom: SSB against recruits, with Shepherd stock recruitment curves overlaid.



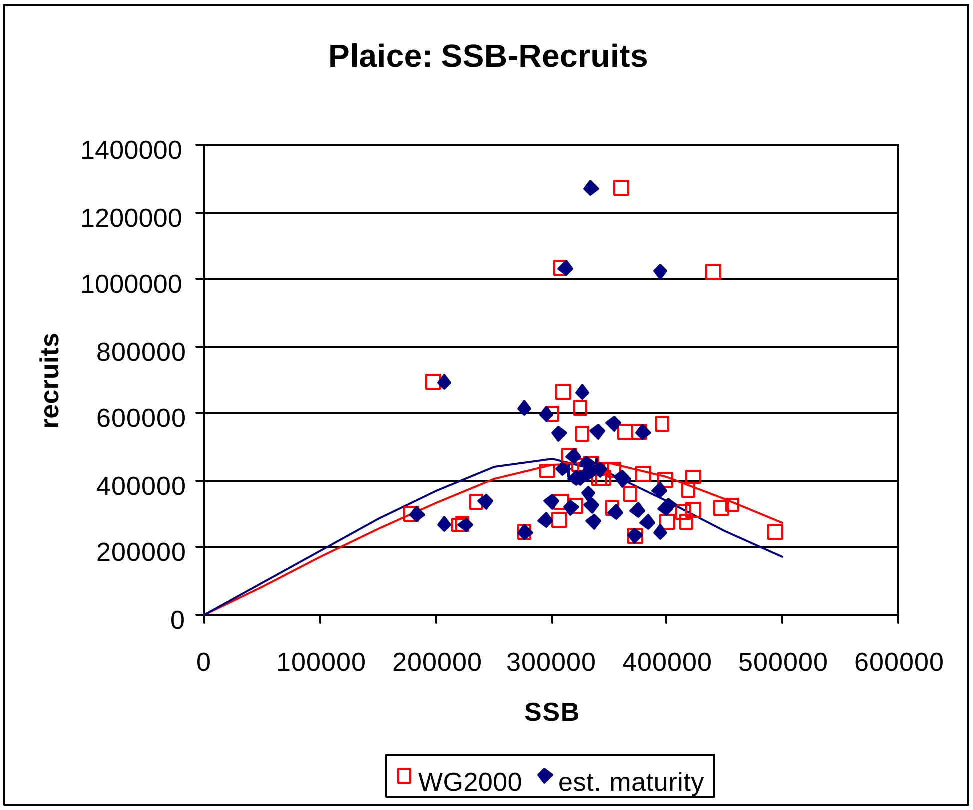
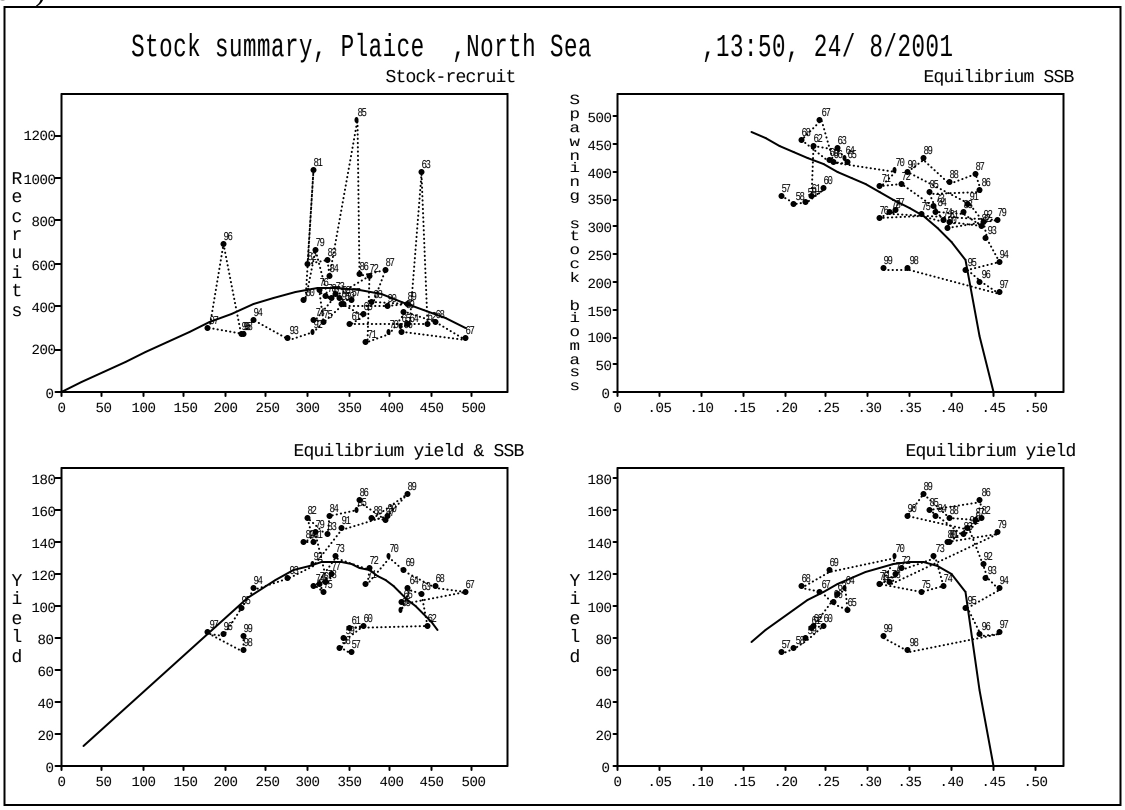


Figure 7 North Sea plaice equilibrium analysis using WG2000 data (top) and new maturity data (bottom)



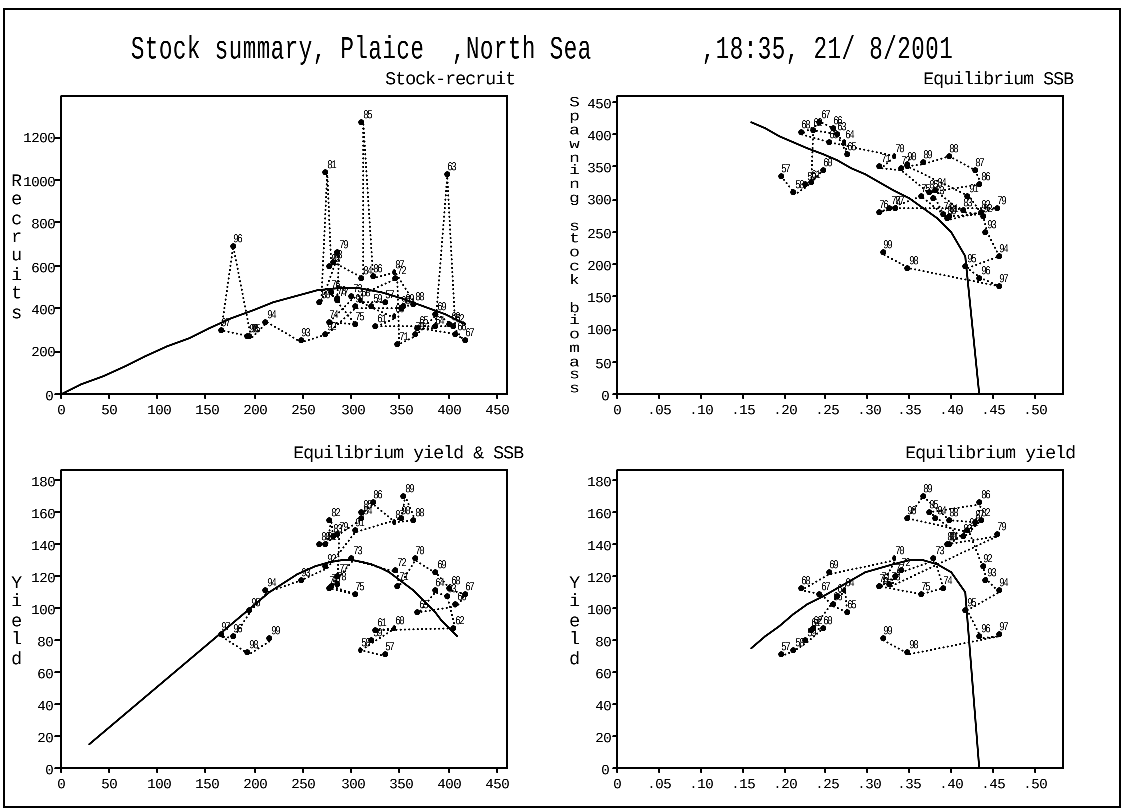


Figure 8 Cod. Maturity at age in the IBTS survey by roundfish (RF) area.

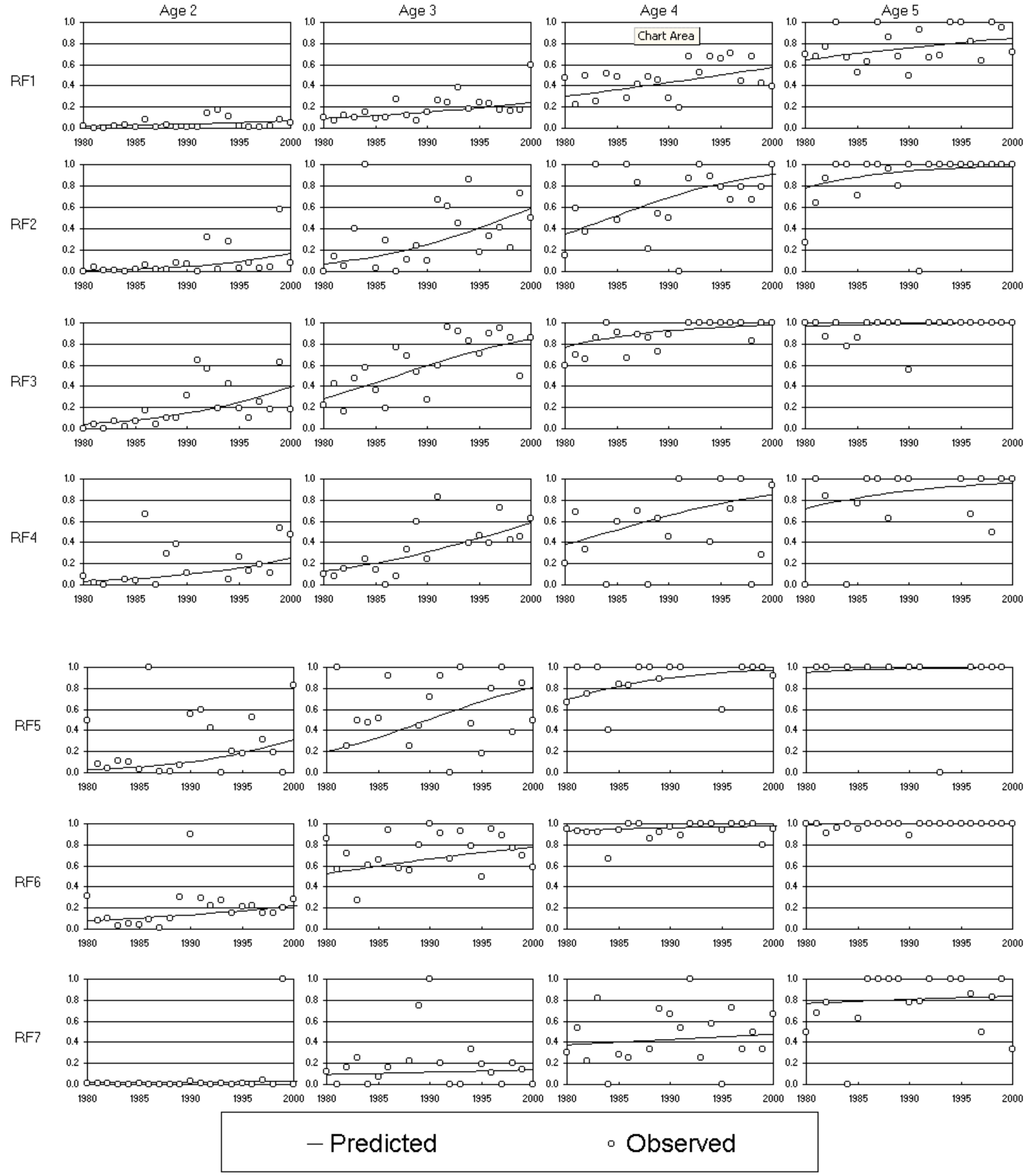
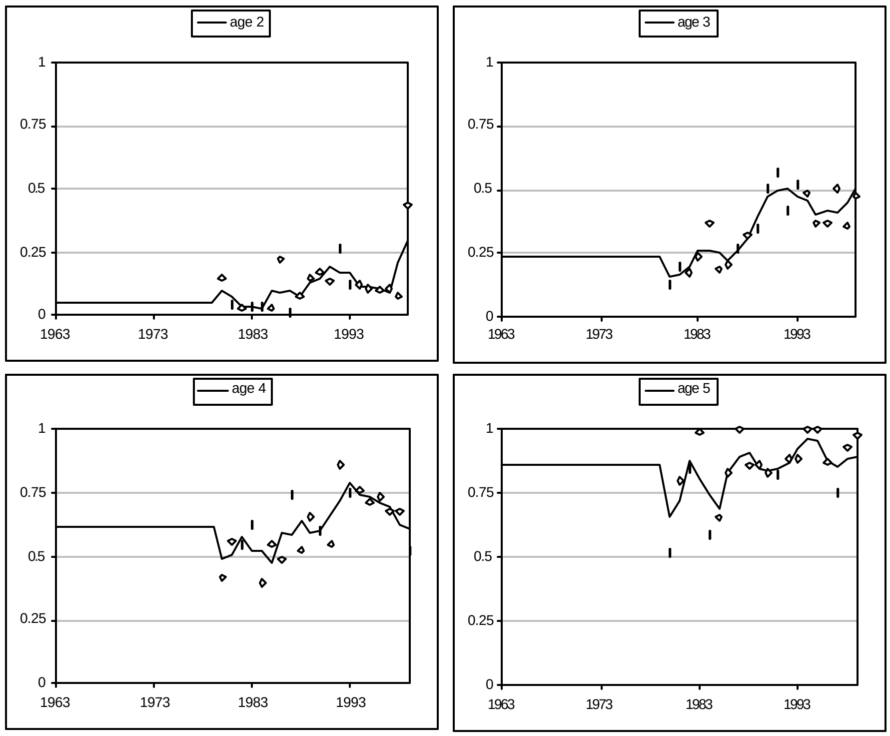


Figure 9 Cod. Time series of maturity at age. Observed and 3-yr running mean maturity (top) and modelled maturity (bottom), each weighted over the index value by RF area.. Maturity before 1980 was taken as the values used by the ICES WG.

3yr mean



Modelled maturity

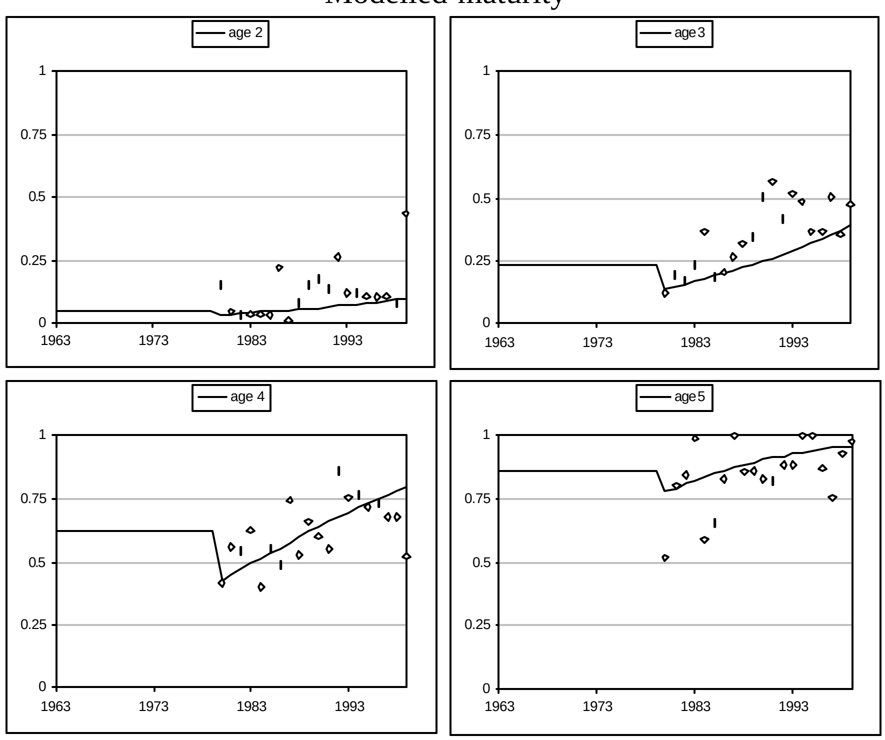


Figure 10 North Sea cod. SSB comparison with three different estimates of maturity

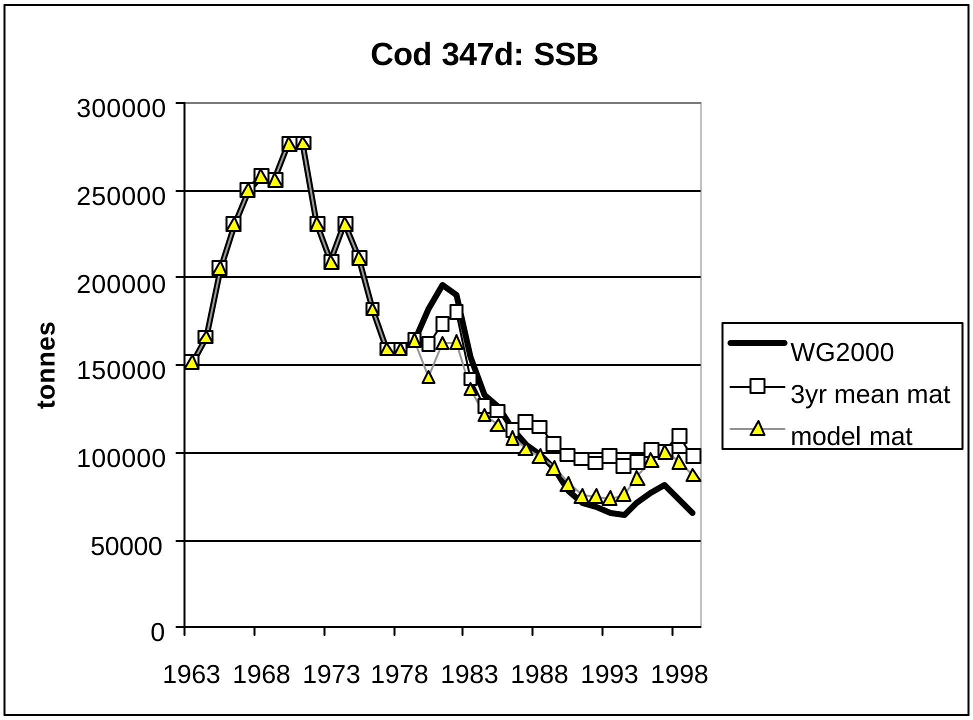
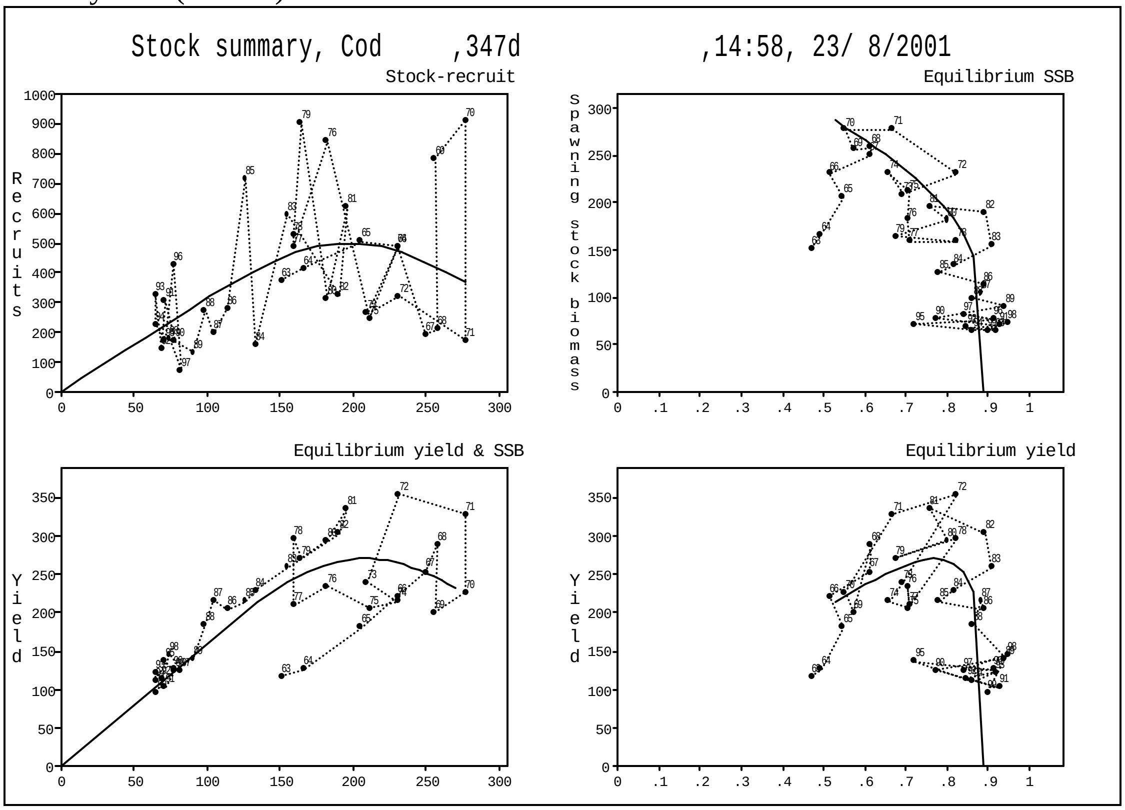
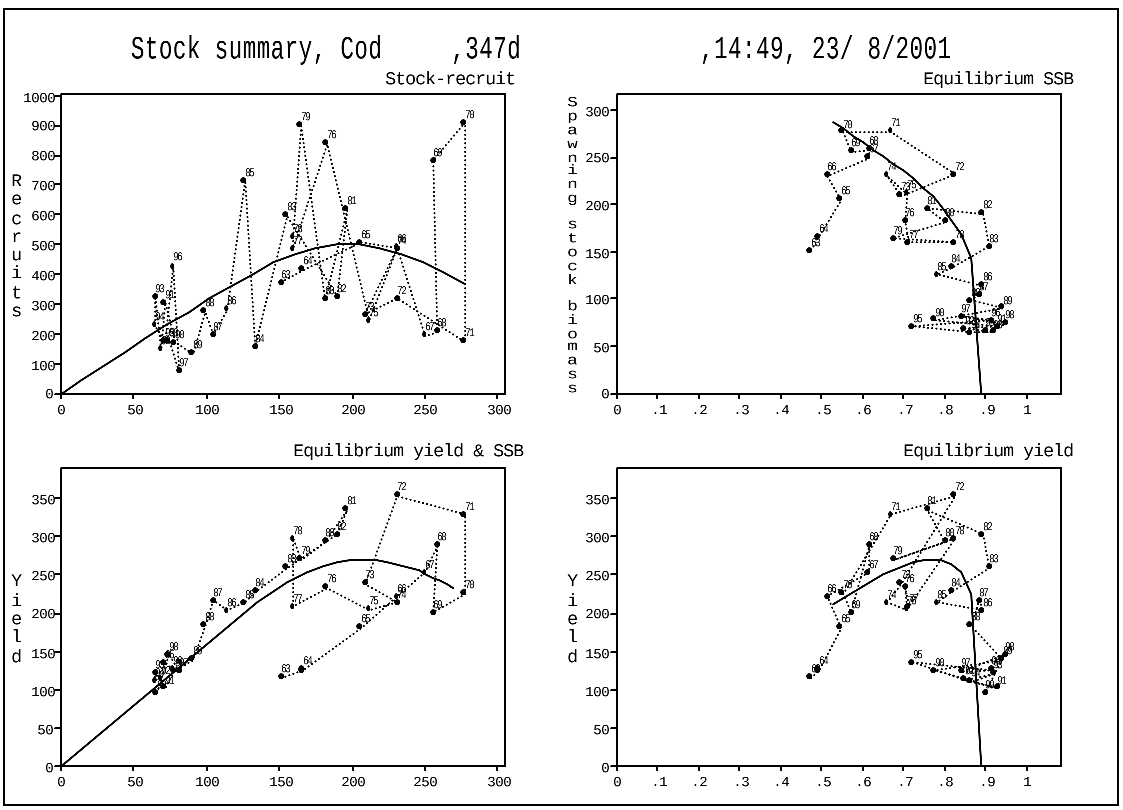


Figure 11 North Sea cod equilibrium analysis using WG2000 data (top) and new 3-yr average maturity data (bottom)



WG2000



3yr mean