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Application of an Age-Structured Production Model to the Georges Bank Yellowtail Flounder

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ABSTRACT

A Reference Case application of ASPM to the Georges Bank yellowtail flounder, together with three sensitivies, is presented. Strong residual patterns in the fits to survey indices of abundance, particularly to that for the Canadian DFO Spring survey, raise concerns about the compatibility of the population model and these indices. The model fits strongly favour domed over asymptotically flat selectivity. Selectivity assumptions are key to estimates of stock status, with fits to a fully flexible selectivity parameterization indicating the resource to be effectively at its MSY level B^{sp}_{MSY}, whereas imposing asymptotically flat selectivity sees the stock estimated to be below the "overfishing" threshold of $0.5\,B^{sp}_{MSY}$.

INTRODUCTION

This brief document presents results from applications of an ASPM to the Georges Bank yellowtail flounder, particularly to provide an opportunity to compare results to those to be presented for other applications of statistical catch-at-age methodology.

DATA and METHODS

The basic ASPM methodology is as described in Butterworth and Rademeyer (2008). The data used are from Legault *et al*. (2007).

The stock is assumed to be at pre-exploitation equilibrium in 1935. The annual catches from 1935 to 2006 are shown in Table A1. Prior to 1963, the catches do not include discards as those are not available. The natural mortality M is fixed to 0.2 yr^{-1} for the Reference Case. A Ricker stock-recruitment curve is used, with residuals estimated from 1964 to 2006 (σ_R=0.5). The model however extends to a 12+ plus; ages are then grouped (7+ for commercial and 6+ for survey catches-at-age) for comparisons with data in the evaluation of likelihoods. The commercial and survey fishing selectivities are estimated separately for ages 1-6 respectively and are assumed to be invariant throughout the period. The estimated decrease in selectivity from ages 5 to 6 is assumed to continue exponentially to age 12+. This decrease is taken to be the same for the two NMFS surveys.

The model is fit to four survey abundance indices (Table A2) and corresponding catch-at-age data (Table A3). The NMFS spring survey data are split into two indices (with different selectivities and catchability coefficient q) because of changes in gear over the 1973-1981 period. The surveys carried out in spring are taken to correspond to begin-year biomass, and the fall surveys to index mid-year biomass. The model is also fit to the commercial catch-at-age data (Table A4).

The begin-year and mid-year weights-at-age used are given in Tables A5 and A6 respectively, while the maturity-at-age schedule is given in Table A7. In all three cases, the average vector over the whole period available is used pre-1973.

Three sensitivities to the Reference Case ASPM are evaluated:

1) "M=0.4": the natural mortality is fixed to 0.4 instead of 0.2 in the Reference Case;
2) "Flat commercial and survey selectivity": the commercial and survey selectivities are assumed to be flat from age 4+.
3) "Including 30% discards pre-1963": the pre-1963 annual catches are increased by 30% to include discards.

RESULTS

Estimates of key management quantities for the Reference Case ASPM and three sensitivities are listed in Table 1. Fig. 1 plots the spawning biomass and fishing mortality trajectories for the Reference Case ASPM.

The stock is estimated to currently be at B_{MSY} and the current fishing mortality well below F_{MSY}. Figs 2 and 3 show the corresponding fits to survey abundance indices and catch-at-age data respectively. The standardised residuals for the survey abundance indices are also plotted in Fig. 2. The Reference Case commercial and survey selectivities are shown in Fig. 4. A sharp decrease in catchability is estimated from age 5 onwards. The estimated stock-recruitment curve, recruitment and residuals are shown in Fig. 5.

The estimated spawning biomass trajectories for the Reference Case and the three sensitivities are compared in Fig. 6. Fig. 7 plots the standardised commercial catch-at-age residuals for the Reference Case and for the sensitivity with flat commercial and survey selectivity for ages 4 and above.

DISCUSSION

The feature of most concern in these ASPM applications is the clear systematic patterns in the residuals of the fits to the abundance indices (Fig. 2). This is most marked for the Canadian DFO Spring survey, with negative residuals from the mid-1980's to the mid 1990's, and generally positive residuals thereafter. This same pattern is evident also in NMFS Fall and Spring surveys, though it is not too severe in the latter case. Certainly it would be difficult to argue that the population model used is consistent with the abundance index developed from the Canadian survey data (at least).

The data point strongly towards dome shaped selectivity. Forcing asymptotically flat selectivity see fits deteriorate by some 75 log-likelihood points (see Table 1). Further the commercial catch-at-age residuals (see Fig. 7) show a strong systematic pattern for age 6 in these circumstances.

While current F is less than F_{MSY} for all the cases considered in Table 1, the difference is much reduced if asymptotically flat selectivity is imposed. Estimates of the current status of the resource are clearly highly dependent on selectivity assumptions, with B^{sp} being very close to B^{sp}_{MSY} if fully flexible selectivity functions are used, but dropping below the "overfished"/"depleted" threshold of $0.5\,B^{sp}_{MSY}$ if asymptotically flat selectivity is imposed.

REFERENCES

Butterworth DS and Rademeyer RA. 2008. Statistical catch-at-age analysis *vs* ADAPT-VPA: the case of Gulf of Maine cod. This meeting.

Legault CM, Stone HH and Waters C. 2007. Stock assessment of Georges Bank yellowtail flounder for 2007. TRAC Reference Document 2007/05. Available at http://www.mar.dfo-mpo.gc.ca/science/TRAC/trac.html

Table 1: Penalised maximum likelihood estimates of key management quantities for the Reference Case ASPM and three sensitivities. Biomass units are thousand tons. Values shown in bold are fixed on input.

	1) Reference Case	2) M=0.4	3) Flat commercial and survey selectivity	4) Including 30% discards pre-1963
-lnL:overall	79.5	89.5	155.4	79.2
M	**0.20**	**0.40**	**0.20**	**0.20**
h	0.58	0.47	1.15	0.58
γ	**1.00**	**1.00**	**1.00**	**1.00**
K^{sp}	231.5	121.7	76.1	234.0
B^{sp}_{2006}	93.4	57.0	11.2	93.2
B^{sp}_{2006}/K^{sp}	0.40	0.47	0.15	0.40
B^{sp}_{MSY}	97.5	52.2	29.7	98.5
$B^{sp}_{2006}/B^{sp}_{MSY}$	0.96	1.09	0.38	0.95
$MSYL$	0.42	0.43	0.39	0.42
MSY	11.0	10.9	9.5	11.2
F_{MSY}	0.26	0.24	0.28	0.26
F_{2006}	0.06	0.05	0.18	0.06

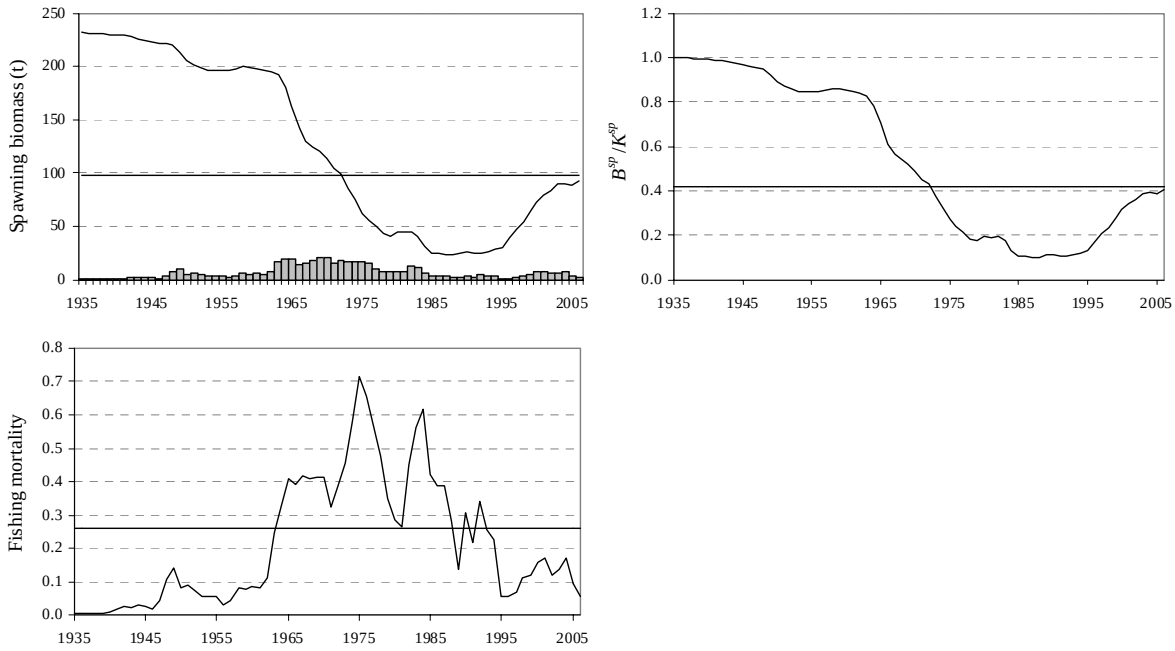

Fig. 1: Penalised maximum likelihood estimates of spawning biomass trajectories (in absolute terms and in terms of pre-exploitation level) and fishing mortality for the ASPM Reference Case. The estimated B^{sp}_{MSY}, *MSYL* and F_{MSY} are also shown. The bar plot shows the annual total landings ('000 t).

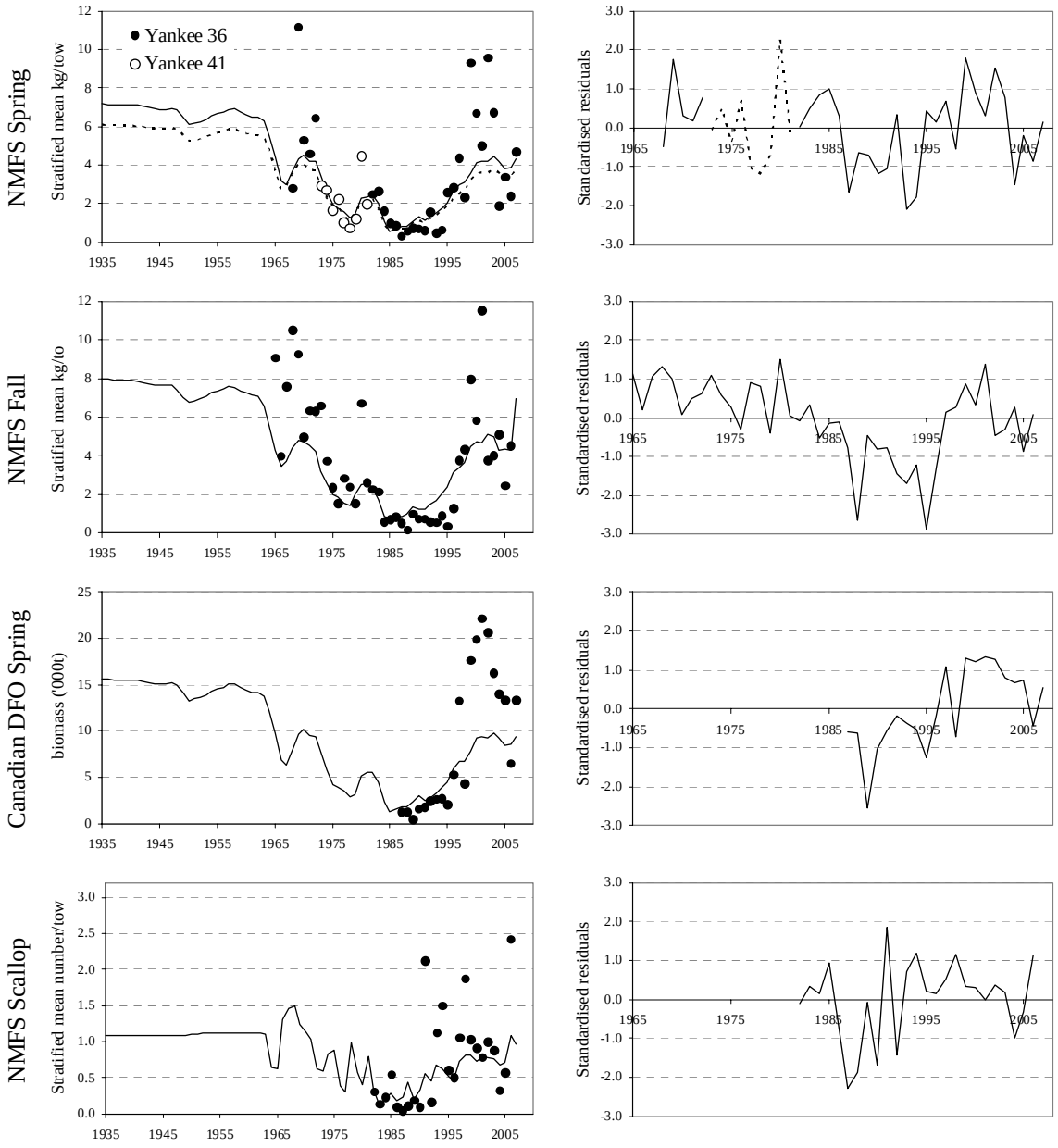

Fig. 2: Reference Case ASPM assessment model fits to the abundance indices and corresponding standardised residuals.

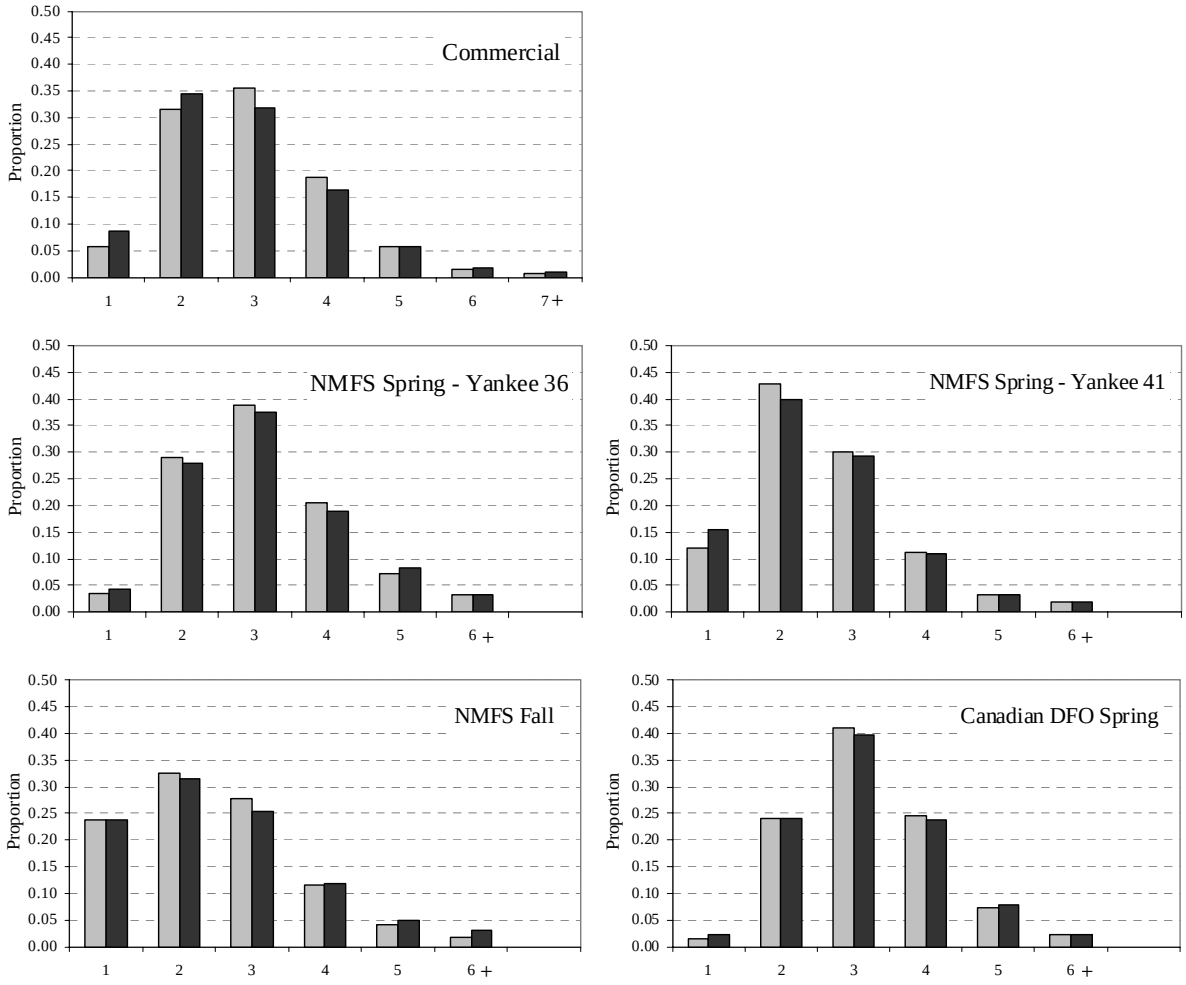

Fig. 3: Reference Case ASPM assessment model fits to the catch-at-age data (survey and commercial averaged over all the years with data for each data set). Light grey bars represent the observed, while black bars represent the predicted catches-at-age.

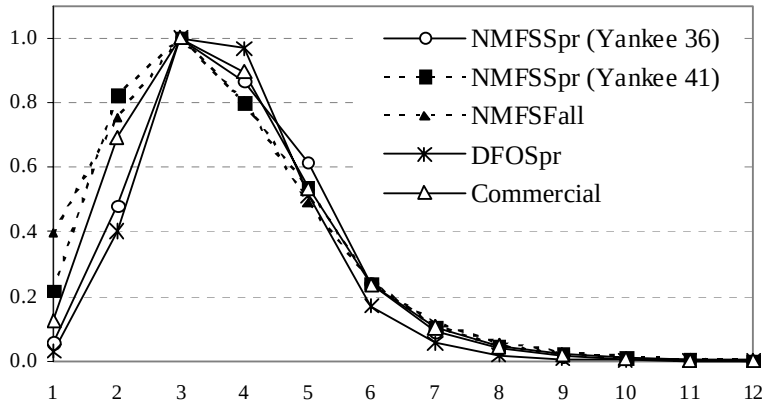

Fig. 4: Commercial and survey selectivities-at-age for the ASPM Reference Case

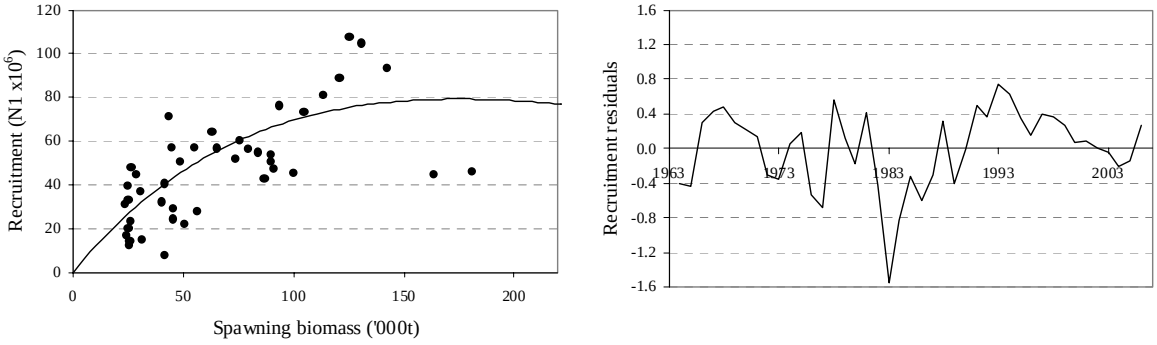

Fig. 5: The estimated stock-recruitment curve and estimated recruitments each year over the period 1964-2006, together with stock-recruitment residuals for the Reference Case ASPM.

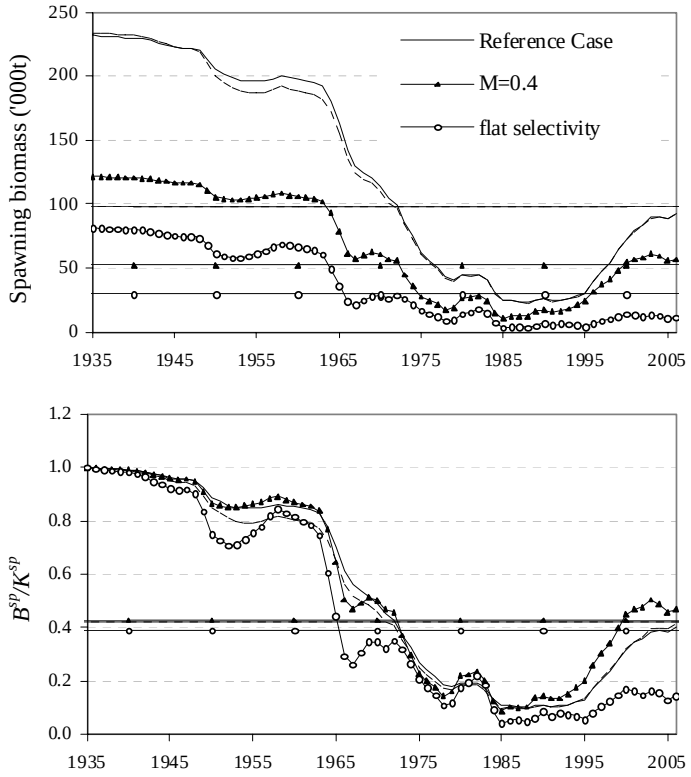

Fig. 6: Comparison of spawning biomass trajectories for the Reference Case ASPM and three sensitivities (the dashed curves are for the sensitivity that includes 30% discards pre-1963).

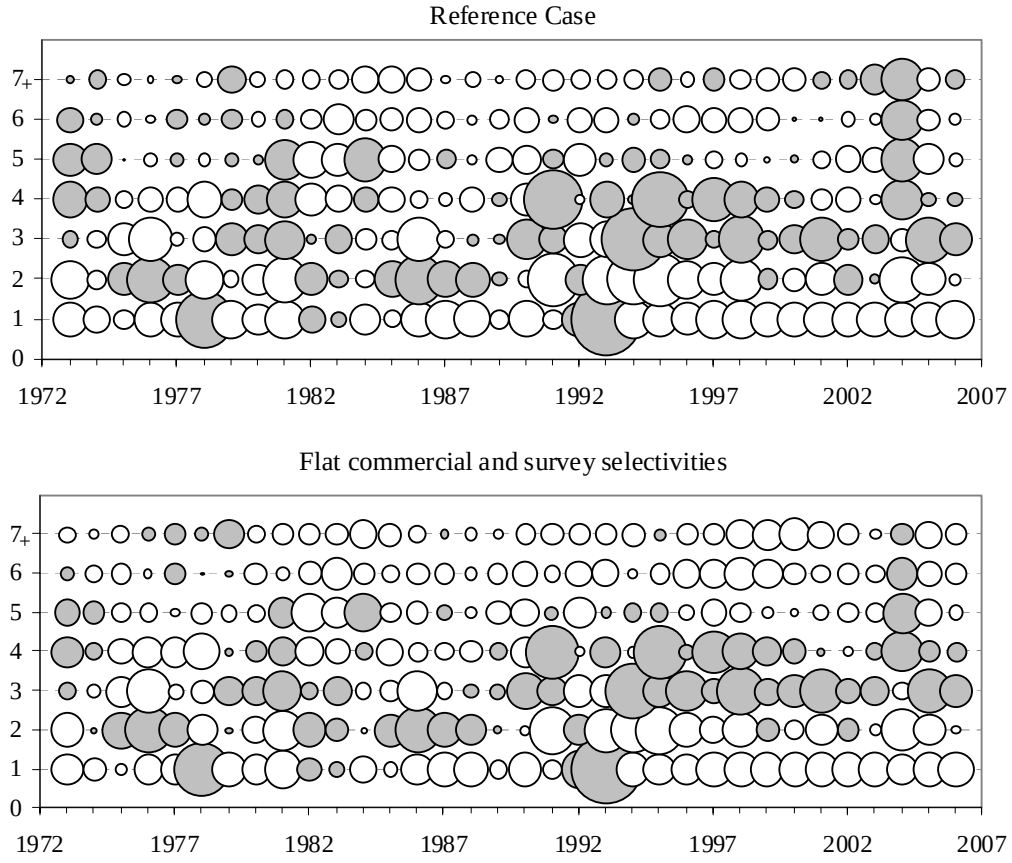

Fig. 7: Bubble plots of the standardised residuals for the commercial catch-at-age data for the ASPM Reference Case and the sensitivity with flat commercial and survey selectivities for age 4+. The size (area) of the bubbles represents the size of the residuals. Grey bubbles represent positive residuals and white bubbles represent negative residuals.

Appendix A – Data used

Table A1: Annual catch (‘000 mt) of Georges Bank yellowtail flounder, including US and Canada landings and discards, as well as foreign landings. Note: discards values are not available pre-1963.

Year	Total catch	Year	Total catch	Year	Total catch	Year	Total catch
1935	0.400	1953	3.900	1971	15.610	1989	1.783
1936	0.400	1954	3.900	1972	18.039	1990	4.089
1937	0.400	1955	3.900	1973	16.953	1991	2.564
1938	0.400	1956	2.200	1974	17.211	1992	5.299
1939	0.500	1957	3.100	1975	16.750	1993	4.300
1940	0.800	1958	6.100	1976	14.988	1994	4.326
1941	1.200	1959	5.500	1977	10.639	1995	1.183
1942	2.100	1960	5.900	1978	6.944	1996	1.682
1943	1.700	1961	5.700	1979	6.935	1997	2.272
1944	2.300	1962	7.700	1980	7.539	1998	3.821
1945	1.900	1963	16.690	1981	6.979	1999	5.038
1946	1.200	1964	19.814	1982	12.520	2000	7.360
1947	3.100	1965	19.448	1983	11.989	2001	7.857
1948	7.700	1966	13.741	1984	6.280	2002	5.915
1949	9.800	1967	15.307	1985	3.267	2003	6.632
1950	5.300	1968	18.321	1986	3.474	2004	7.275
1951	5.800	1969	21.271	1987	3.580	2005	4.088
1952	5.000	1970	21.410	1988	2.759	2006	2.206

Table A2: Survey abundance indices for Georges Bank yellowtail flounder. Note the NMFS spring survey is taken as two surveys due to changes in gear over the 1973-1981 period (in italics in the table).

	NMFS Spring	NMFS Fall	Canada DFO Spring	NMFS Scallop
	stratified mean kg/tow	stratified mean kg/tow	000t	stratified mean number/tow age-1
1963		12.79		
1964		13.63		
1965		9.10		
1966		3.99		
1967		7.58		
1968	2.81	10.53		
1969	11.17	9.28		
1970	5.31	4.98		
1971	4.61	6.36		
1972	6.45	6.33		
1973	*2.94*	6.60		
1974	*2.72*	3.73		
1975	*1.68*	2.36		
1976	*2.27*	1.53		
1977	*1.00*	2.83		
1978	*0.74*	2.38		
1979	*1.23*	1.52		
1980	*4.46*	6.72		
1981	*1.96*	2.62		
1982	2.50	2.27		0.313
1983	2.64	2.13		0.140
1984	1.65	0.59		0.233
1985	0.99	0.71		0.549
1986	0.85	0.82		0.103
1987	0.33	0.51	1.26	0.047
1988	0.57	0.17	1.24	0.116
1989	0.73	0.98	0.47	0.195
1990	0.70	0.72	1.58	0.100
1991	0.63	0.73	1.76	2.117
1992	1.57	0.58	2.48	0.167
1993	0.48	0.55	2.64	1.129
1994	0.66	0.90	2.75	1.503
1995	2.58	0.35	2.03	0.609
1996	2.85	1.30	5.30	0.508
1997	4.36	3.78	13.29	1.062
1998	2.32	4.35	4.29	1.872
1999	9.31	7.97	17.67	1.038
2000	6.70	5.84	19.95	0.912
2001	5.01	11.55	22.16	0.789
2002	9.57	3.76	20.62	1.005
2003	6.72	4.04	16.25	0.880
2004	1.89	5.12	14.01	0.330
2005	3.40	2.46	13.36	0.573
2006	2.42	4.52	6.50	2.422
2007	4.70		13.34	

Table A3a: NMFS spring survey stratified mean number/tow for ages 1 to 12. Note: Values from 1973 to 1981 are in italics because different gear was used over this period.

	1	2	3	4	5	6	7	8	9	10	11	12
1968	0.15	3.36	3.58	0.32	0.08	0.16	0.13	0	0	0	0	0
1969	1.02	9.41	11.12	3.1	1.42	0.45	0.19	0.06	0	0	0	0
1970	0.09	4.49	6.03	2.42	0.57	0.12	0.19	0	0	0	0	0
1971	0.79	3.34	4.62	3.75	0.76	0.23	0.05	0.01	0	0.02	0	0
1972	0.14	7.14	7.2	3.51	1.09	0.05	0.12	0	0	0	0	0
1973	*1.93*	*3.27*	*2.37*	*1.06*	*0.41*	*0.17*	*0.02*	*0.02*	*0*	*0*	*0*	*0*
1974	*0.32*	*2.22*	*1.84*	*1.26*	*0.35*	*0.19*	*0.09*	*0*	*0*	*0*	*0.01*	*0*
1975	*0.42*	*2.94*	*0.86*	*0.3*	*0.21*	*0.07*	*0*	*0.01*	*0*	*0*	*0*	*0*
1976	*1.03*	*4.37*	*1.25*	*0.31*	*0.2*	*0.03*	*0.05*	*0.02*	*0.02*	*0*	*0*	*0*
1977	*0*	*0.67*	*1.13*	*0.38*	*0.07*	*0.01*	*0*	*0*	*0*	*0*	*0*	*0*
1978	*0.94*	*0.8*	*0.51*	*0.22*	*0.03*	*0*	*0.01*	*0*	*0*	*0*	*0*	*0*
1979	*0.28*	*1.93*	*0.39*	*0.33*	*0.06*	*0.05*	*0.04*	*0*	*0*	*0*	*0*	*0*
1980	*0.06*	*4.64*	*5.76*	*0.47*	*0.06*	*0.04*	*0*	*0*	*0*	*0*	*0*	*0*
1981	0.01	1.03	1.78	0.72	0.21	0.06	0	0.03	0	0	0	0
1982	0.05	3.74	1.12	1.02	0.46	0.07	0	0.03	0	0	0	0
1983	0	1.87	2.73	0.53	0.12	0.09	0.06	0.09	0	0	0	0
1984	0	0.09	0.81	0.89	0.83	0.24	0	0	0	0	0	0
1985	0.11	2.2	0.26	0.28	0.15	0	0	0	0	0	0	0
1986	0.03	1.81	0.29	0.06	0.14	0.06	0	0	0	0	0	0
1987	0	0.13	0.11	0.13	0.05	0.05	0	0	0	0	0	0
1988	0.08	0.28	0.37	0.24	0.2	0.03	0	0	0	0	0	0
1989	0.05	0.42	0.74	0.29	0.06	0.02	0.02	0	0	0	0	0
1990	0	0.06	1.11	0.39	0.14	0.01	0.04	0	0	0	0	0
1991	0.44	0	0.25	0.68	0.27	0.02	0	0	0	0	0	0
1992	0	2.01	1.95	0.6	0.19	0	0	0	0	0	0	0
1993	0.05	0.29	0.5	0.32	0.03	0	0	0	0	0	0	0
1994	0	0.62	0.64	0.36	0.15	0.04	0	0	0	0	0	0
1995	0.04	1.18	4.81	1.49	0.64	0.01	0	0	0	0	0	0
1996	0.03	0.99	2.63	2.7	0.61	0.06	0	0	0	0	0	0
1997	0.02	1.17	3.73	4.08	0.7	0.13	0	0	0	0	0	0
1998	0	2.08	1.05	1.16	0.76	0.32	0.03	0	0	0	0	0
1999	0.05	4.75	10.82	2.72	1.62	0.43	0.33	0	0.02	0	0	0
2000	0.18	4.82	7.67	2.91	0.81	0.42	0.1	0	0	0	0	0
2001	0	2.31	6.56	2.41	0.48	0.35	0.1	0	0	0	0	0
2002	0.19	2.41	12.33	4.08	1.74	0.38	0.41	0.09	0	0	0	0
2003	0.2	4.37	6.76	2.88	0.44	0.13	0.54	0.2	0	0	0	0
2004	0.05	0.99	2.18	0.68	0.28	0.11	0.05	0.08	0	0	0	0
2005	0	2.01	5.08	2.4	0.27	0.04	0.05	0.03	0	0	0	0
2006	0.51	0.94	3.52	2.18	0.32	0.08	0	0	0	0	0	0
2007	0.09	5.05	6.26	2.85	0.56	0.11	0.02	0	0	0	0	0

Table A3b: NMFS fall survey stratified mean number/tow for ages 1 to 12.

	1	2	3	4	5	6	7	8	9	10	11	12
1963	14.72	7.9	11.23	1.86	0.5	0.28	0.03	0.16	0.07	0	0	0
1964	1.72	9.72	7.37	6	2.69	0.38	0.09	0.03	0	0	0	0
1965	1.14	5.58	5.47	3.86	1.8	0.16	0.28	0.04	0	0	0	0
1966	8.77	4.78	2.07	0.84	0.09	0.05	0	0	0	0	0	0
1967	9.14	9.31	2.7	1.01	0.31	0.08	0.06	0	0	0	0	0
1968	11.78	11.95	5.76	0.77	0.94	0.06	0	0	0	0	0	0
1969	8.11	10.38	5.86	1.66	0.55	0.15	0.18	0	0	0	0	0
1970	4.61	5.13	3.14	1.95	0.45	0.06	0.02	0	0	0	0	0
1971	3.63	6.95	4.9	2.25	0.55	0.23	0.02	0.02	0	0	0	0
1972	2.42	6.53	4.82	2.1	0.67	0.28	0	0	0	0	0	0
1973	2.49	5.5	5.1	2.94	1.22	0.42	0.17	0	0.03	0	0	0
1974	4.62	2.85	1.52	1.06	0.46	0.25	0.13	0	0	0	0	0
1975	4.63	2.51	0.88	0.57	0.33	0.03	0	0	0	0	0	0.03
1976	0.34	1.93	0.48	0.12	0.12	0.03	0	0.03	0.03	0	0	0
1977	0.93	2.16	1.65	0.62	0.11	0.06	0.04	0.02	0	0	0	0
1978	4.73	1.27	0.77	0.41	0.14	0.01	0	0.02	0	0	0	0
1979	1.31	2	0.32	0.12	0.14	0.04	0.06	0	0.01	0	0	0
1980	0.76	5.09	6.05	0.68	0.22	0.16	0.01	0	0.03	0	0	0
1981	1.58	2.33	1.63	0.5	0.12	0.08	0.01	0	0	0	0	0
1982	2.42	2.19	1.59	0.42	0.09	0	0	0	0	0	0	0
1983	0.11	2.28	1.91	0.47	0.07	0.01	0	0	0.04	0	0	0
1984	0.66	0.4	0.31	2.43	0.09	0.03	0	0.02	0	0	0	0
1985	1.35	0.56	0.16	0.04	0.08	0	0	0	0	0	0	0
1986	0.28	1.11	0.35	0.07	0	0	0	0	0	0	0	0
1987	0.11	0.39	0.4	0.05	0.08	0	0	0	0	0	0	0
1988	0.02	0.21	0.1	0.03	0	0	0	0	0	0	0	0
1989	0.25	1.99	0.77	0.07	0.07	0	0	0	0	0	0	0
1990	0	0.33	1.52	0.28	0.01	0	0	0	0	0	0	0
1991	2.1	0.28	0.44	0.36	0	0	0	0	0	0	0	0
1992	0.15	0.4	0.71	0.16	0.14	0.03	0	0	0	0	0	0
1993	0.84	0.14	0.59	0.54	0	0	0	0	0	0	0	0
1994	1.2	0.22	0.98	0.71	0.26	0.03	0.03	0	0	0	0	0
1995	0.28	0.12	0.35	0.28	0.05	0.01	0	0	0	0	0	0
1996	0.14	0.35	1.87	0.45	0.07	0	0	0	0	0	0	0
1997	1.39	0.53	3.44	2.09	1.07	0.08	0	0	0	0	0	0
1998	1.9	4.82	4.2	1.19	0.3	0.06	0.02	0	0	0	0	0
1999	3.09	8.42	5.73	1.43	1.44	0.26	0	0	0	0	0	0
2000	0.63	1.7	4.81	2.42	0.95	0.8	0.03	0	0	0	0	0
2001	3.52	6.27	8.09	2.6	1.72	0.71	1.33	0	0	0	0	0
2002	2.09	5.75	2.13	0.59	0.28	0	0.03	0.03	0	0	0	0
2003	1.1	5.01	2.81	0.56	0.1	0.09	0.07	0.02	0	0	0	0
2004	0.88	5.51	5.01	2.11	0.92	0.18	0	0	0	0	0	0
2005	0.31	2.1	3.76	0.57	0.23	0	0	0	0	0	0	0
2006	6.19	6.25	3.66	1.17	0.26	0.03	0.01	0	0	0	0	0

Table A3c: Canadian DFO spring survey stratified mean number/tow for ages 1 to 12.

	1	2	3	4	5	6	7	8	9	10	11	12
1988	0	1.59	1.29	0.76	0.3	0.01	0.02	0	0	0	0	0
1989	0.11	0.94	0.58	0.36	0.09	0.01	0.02	0.01	0	0	0	0
1990	0	2.36	3.38	1.06	0.32	0.01	0.02	0	0	0	0	0
1991	0.02	0.86	1.53	3.23	0.72	0	0	0	0	0	0	0
1992	0.06	10.74	3.97	1.03	0.3	0.01	0	0.02	0.01	0	0	0
1993	0.08	2.24	3.26	4.41	1.64	0.05	0.01	0	0	0	0	0
1994	0	6.06	3.46	3.01	0.78	0.13	0.03	0.04	0	0	0	0
1995	0.21	1.19	4.28	2.55	0.79	0.05	0.04	0	0	0	0	0
1996	0.45	6.65	8.58	6.61	1.01	0.09	0.02	0.03	0	0	0	0
1997	0.02	9.78	14.67	17.96	4.32	0.53	0.11	0.09	0	0	0	0
1998	0.89	3.18	4.89	4.5	2.02	0.46	0.03	0.01	0	0.02	0	0
1999	0.16	11.84	27.24	7.95	7.3	2.21	0.34	0.04	0	0	0	0
2000	0.01	9.47	32.9	17.8	5.54	2.96	0.32	0.22	0	0	0	0
2001	0.29	15.18	47.13	13.35	3.7	1.95	0.9	0.1	0	0	0	0
2002	0.09	9.67	33.73	11.27	5.97	1.54	0.95	0.38	0.08	0	0	0
2003	0.07	6.76	27.36	13.45	3.57	0.86	0.62	0.25	0.12	0.04	0	0
2004	0.03	3.6	16.26	9.21	2.27	0.63	0.23	0.46	0.09	0	0	0
2005	0.6	1.6	27.96	20.56	5.7	1.04	0.4	0.1	0.01	0.01	0	0
2006	0	4.89	18.6	6.57	0.82	0.16	0.08	0	0	0	0	0
2007	0.05	12.16	27.71	12.8	2.29	0.22	0.03	0	0	0	0	0

Table A4: Total catches-at-age, including discards (‘000s) for Georges Bank yellowtail flounder.

	1	2	3	4	5	6	7	8	9	10	11	12
1973	359	5175	13565	9473	3815	1285	283	55	23	4	0	0
1974	2368	9500	8294	7658	3643	878	464	106	71	0	0	0
1975	4636	26394	7375	3540	2175	708	327	132	26	14	0	0
1976	635	31938	5502	1426	574	453	304	95	54	11	2	0
1977	378	9094	10567	1846	419	231	134	82	37	10	0	0
1978	9962	3542	4580	1914	540	120	45	16	17	7	6	0
1979	321	10517	3789	1432	623	167	95	31	27	1	3	0
1980	318	3994	9685	1538	352	96	5	11	1	0	0	0
1981	107	1097	5963	4920	854	135	5	2	3	0	0	0
1982	2164	18091	7480	3401	1095	68	20	7	0	0	0	0
1983	703	7998	16661	2476	680	122	13	16	4	0	0	0
1984	514	2018	4535	5043	1796	294	47	39	0	0	0	0
1985	970	4374	1058	818	517	73	8	0	0	0	0	0
1986	179	6402	1127	389	204	80	17	15	0	1	0	0
1987	156	3284	3137	983	192	48	38	26	25	0	0	0
1988	499	3003	1544	846	227	24	26	3	0	0	0	0
1989	190	2175	1121	428	110	18	12	0	0	0	0	0
1990	231	2114	6996	978	140	21	6	0	0	0	0	0
1991	663	147	1491	3011	383	67	4	0	0	0	0	0
1992	2414	9167	2971	1473	603	33	7	1	1	0	0	0
1993	5233	1386	3327	2326	411	84	5	1	0	0	0	0
1994	59	1432	6631	1856	568	95	23	1	0	0	0	0
1995	62	233	1428	986	211	17	23	4	2	0	0	0
1996	54	566	1922	941	234	11	9	3	0	0	0	0
1997	60	745	1502	1827	442	36	55	11	5	0	0	0
1998	64	1496	3224	2134	782	143	26	3	0	2	0	0
1999	37	3694	3583	1731	743	180	34	1	1	0	0	0
2000	155	3840	5985	3120	832	340	43	36	1	0	0	0
2001	284	3065	7622	2824	1093	293	254	23	9	0	0	0
2002	256	4437	3854	1845	670	263	113	62	11	5	0	0
2003	160	3818	4965	2297	777	328	213	93	39	15	1	0
2004	78	1336	3491	4093	2088	919	429	85	73	20	2	0
2005	52	1590	4292	1820	420	143	39	18	0	0	0	0
2006	49	1221	1660	977	367	126	66	18	7	3	0	0

Table A5: Begin-year weight-at-age (kg) for Georges Bank yellowtail flounder. The 2007 values are set equal to the average of the 2004-2006 values.

Year	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.010	0.230	0.401	0.493	0.564	0.645	0.856	1.096	1.100	1.300	1.400	1.500
1974	0.010	0.230	0.415	0.530	0.598	0.660	0.790	1.150	1.100	1.300	1.400	1.500
1975	0.010	0.230	0.410	0.524	0.613	0.684	0.707	0.769	1.100	1.300	1.400	1.500
1976	0.010	0.230	0.415	0.557	0.642	0.709	0.768	0.780	1.100	1.300	1.400	1.500
1977	0.010	0.230	0.404	0.587	0.704	0.800	0.913	0.928	1.100	1.300	1.400	1.500
1978	0.010	0.230	0.418	0.601	0.713	0.839	0.902	1.017	1.100	1.300	1.400	1.500
1979	0.010	0.230	0.381	0.578	0.713	0.823	0.948	0.926	1.100	1.300	1.400	1.500
1980	0.010	0.230	0.403	0.551	0.732	0.878	1.010	1.095	1.100	1.300	1.400	1.500
1981	0.010	0.230	0.397	0.546	0.681	0.818	0.940	1.390	1.100	1.300	1.400	1.500
1982	0.010	0.230	0.403	0.564	0.675	0.868	0.923	1.072	1.100	1.300	1.400	1.500
1983	0.010	0.230	0.364	0.543	0.694	0.853	1.035	1.163	1.100	1.300	1.400	1.500
1984	0.010	0.230	0.335	0.470	0.627	0.741	0.954	1.018	1.100	1.300	1.400	1.500
1985	0.010	0.230	0.347	0.493	0.604	0.723	0.735	1.019	1.100	1.300	1.400	1.500
1986	0.010	0.230	0.442	0.583	0.740	0.844	0.876	0.954	1.100	1.300	1.400	1.500
1987	0.010	0.230	0.423	0.606	0.727	0.921	0.904	0.856	1.100	1.300	1.400	1.500
1988	0.010	0.230	0.425	0.604	0.758	0.904	0.927	1.077	1.100	1.300	1.400	1.500
1989	0.010	0.230	0.413	0.633	0.776	0.905	1.105	0.988	1.100	1.300	1.400	1.500
1990	0.010	0.230	0.359	0.552	0.706	0.826	1.013	1.135	1.100	1.300	1.400	1.500
1991	0.010	0.230	0.327	0.438	0.650	0.767	1.014	1.078	1.100	1.300	1.400	1.500
1992	0.010	0.230	0.294	0.441	0.562	0.891	0.978	1.304	1.100	1.300	1.400	1.500
1993	0.010	0.230	0.333	0.428	0.545	0.741	1.114	1.084	1.100	1.300	1.400	1.500
1994	0.010	0.230	0.315	0.422	0.557	0.676	0.781	1.192	1.100	1.300	1.400	1.500
1995	0.010	0.230	0.300	0.401	0.523	0.689	0.807	0.620	1.100	1.300	1.400	1.500
1996	0.010	0.230	0.318	0.445	0.578	0.731	0.902	1.018	1.100	1.300	1.400	1.500
1997	0.010	0.230	0.351	0.470	0.623	0.777	0.897	1.121	1.100	1.300	1.400	1.500
1998	0.010	0.230	0.378	0.478	0.609	0.789	0.883	1.024	1.100	1.300	1.400	1.500
1999	0.010	0.230	0.404	0.534	0.641	0.788	0.964	1.181	1.100	1.300	1.400	1.500
2000	0.010	0.230	0.421	0.555	0.697	0.832	0.958	1.013	1.100	1.300	1.400	1.500
2001	0.010	0.230	0.416	0.548	0.704	0.879	0.967	1.139	1.100	1.300	1.400	1.500
2002	0.010	0.230	0.410	0.552	0.719	0.891	1.037	1.145	1.100	1.300	1.400	1.500
2003	0.010	0.230	0.427	0.565	0.745	0.885	1.008	1.104	1.100	1.300	1.400	1.500
2004	0.010	0.230	0.396	0.526	0.687	0.857	0.973	1.116	1.100	1.300	1.400	1.500
2005	0.010	0.230	0.361	0.511	0.666	0.835	0.933	1.105	1.100	1.300	1.400	1.500
2006	0.010	0.230	0.381	0.499	0.675	0.834	1.011	1.077	1.100	1.300	1.400	1.500
2007	0.010	0.230	0.379	0.512	0.676	0.842	0.972	1.099	1.100	1.300	1.400	1.500

Table A6: Mean weight-at-age (kg) for the total catch including US and Canadian discards, for Georges Bank yellowtail flounder.

Year	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.101	0.348	0.462	0.527	0.603	0.690	1.063	1.131	1.275	1.389	1.170	1.496
1974	0.115	0.344	0.496	0.607	0.678	0.723	0.904	1.245	1.090	1.377	1.496	1.496
1975	0.113	0.316	0.489	0.554	0.619	0.690	0.691	0.654	1.052	0.812	1.518	1.496
1976	0.108	0.312	0.544	0.635	0.744	0.813	0.854	0.881	1.132	1.363	1.923	1.496
1977	0.116	0.342	0.524	0.633	0.780	0.860	1.026	1.008	0.866	0.913	1.518	1.496
1978	0.102	0.314	0.510	0.690	0.803	0.903	0.947	1.008	1.227	1.581	0.916	1.496
1979	0.114	0.329	0.462	0.656	0.736	0.844	0.995	0.906	1.357	1.734	1.911	1.496
1980	0.101	0.322	0.493	0.656	0.816	1.048	1.208	1.206	1.239	1.377	1.518	1.496
1981	0.122	0.335	0.489	0.604	0.707	0.821	0.844	1.599	1.104	1.377	1.518	1.496
1982	0.115	0.301	0.485	0.650	0.754	1.065	1.037	1.361	1.221	1.377	1.518	1.496
1983	0.140	0.296	0.441	0.607	0.740	0.964	1.005	1.304	1.239	1.377	1.518	1.496
1984	0.162	0.239	0.379	0.500	0.647	0.743	0.944	1.032	1.221	1.377	1.518	1.496
1985	0.181	0.361	0.505	0.642	0.729	0.808	0.728	1.144	1.221	1.377	1.518	1.496
1986	0.181	0.341	0.540	0.674	0.854	0.976	0.950	1.250	1.221	1.686	1.518	1.496
1987	0.121	0.324	0.524	0.680	0.784	0.993	0.838	0.771	0.809	1.377	1.518	1.496
1988	0.103	0.328	0.557	0.696	0.844	1.042	0.865	1.385	1.221	1.377	1.518	1.496
1989	0.100	0.327	0.520	0.720	0.866	0.970	1.172	1.128	1.221	1.377	1.518	1.496
1990	0.105	0.290	0.395	0.585	0.693	0.787	1.057	1.144	1.221	1.377	1.518	1.496
1991	0.121	0.237	0.369	0.486	0.723	0.850	1.306	1.144	1.221	1.377	1.518	1.496
1992	0.101	0.293	0.365	0.526	0.651	1.098	1.125	1.303	1.303	1.377	1.518	1.496
1993	0.100	0.285	0.379	0.501	0.564	0.843	1.130	1.044	1.221	1.377	1.518	1.496
1994	0.195	0.255	0.348	0.469	0.620	0.810	0.723	1.257	1.221	1.377	1.518	1.496
1995	0.167	0.246	0.352	0.463	0.584	0.766	0.805	0.532	0.810	1.377	1.518	1.496
1996	0.140	0.292	0.412	0.563	0.721	0.916	1.062	1.287	1.221	1.377	1.518	1.496
1997	0.206	0.319	0.421	0.537	0.690	0.837	0.878	1.184	1.126	1.377	1.518	1.496
1998	0.184	0.325	0.447	0.543	0.690	0.903	0.932	1.195	1.221	1.473	1.518	1.496
1999	0.190	0.369	0.503	0.638	0.756	0.900	1.030	1.496	1.822	1.377	1.518	1.496
2000	0.220	0.379	0.481	0.613	0.762	0.915	1.020	0.996	1.229	1.377	1.518	1.496
2001	0.225	0.343	0.456	0.624	0.808	1.013	1.023	1.272	1.483	1.377	1.518	1.496
2002	0.263	0.382	0.489	0.668	0.829	0.983	1.062	1.282	1.389	1.433	1.518	1.496
2003	0.226	0.360	0.477	0.652	0.830	0.945	1.033	1.148	1.273	1.432	1.708	1.496
2004	0.194	0.292	0.436	0.581	0.723	0.884	1.001	1.206	1.207	1.306	1.421	1.496
2005	0.129	0.346	0.447	0.599	0.763	0.965	0.984	1.221	1.578	1.578	1.518	1.496
2006	0.110	0.320	0.419	0.557	0.762	0.912	1.058	1.178	1.256	1.202	1.599	1.496

Table A7: Maturity-at-age for the Georges Bank yellowtail flounder.

Year	1	2	3	4	5	6+
1973	0.00	0.42	0.97	1.00	1.00	1.00
1974	0.00	0.45	0.98	1.00	1.00	1.00
1975	0.00	0.45	0.98	1.00	1.00	1.00
1976	0.00	0.45	0.98	1.00	1.00	1.00
1977	0.00	0.45	0.98	1.00	1.00	1.00
1978	0.00	0.45	0.98	1.00	1.00	1.00
1979	0.00	0.45	0.98	1.00	1.00	1.00
1980	0.00	0.45	0.98	1.00	1.00	1.00
1981	0.00	0.49	0.99	1.00	1.00	1.00
1982	0.00	0.49	0.99	1.00	1.00	1.00
1983	0.00	0.49	0.99	1.00	1.00	1.00
1984	0.00	0.93	1.00	1.00	1.00	1.00
1985	0.00	0.93	1.00	1.00	1.00	1.00
1986	0.00	0.93	1.00	1.00	1.00	1.00
1987	0.00	0.93	1.00	1.00	1.00	1.00
1988	0.00	0.93	1.00	1.00	1.00	1.00
1989	0.00	0.93	1.00	1.00	1.00	1.00
1990	0.00	0.93	1.00	1.00	1.00	1.00
1991	0.00	0.93	1.00	1.00	1.00	1.00
1992	0.00	0.52	0.86	1.00	1.00	1.00
1993	0.00	0.52	0.86	1.00	1.00	1.00
1994	0.00	0.52	0.86	1.00	1.00	1.00
1995	0.00	0.52	0.86	1.00	1.00	1.00
1996	0.00	0.52	0.86	1.00	1.00	1.00
1997	0.00	0.52	0.86	1.00	1.00	1.00
1998	0.00	0.52	0.86	1.00	1.00	1.00
1999	0.00	0.52	0.86	1.00	1.00	1.00
2000	0.00	0.52	0.86	1.00	1.00	1.00
2001	0.00	0.52	0.86	1.00	1.00	1.00
2002	0.00	0.52	0.86	1.00	1.00	1.00
2003	0.00	0.52	0.86	1.00	1.00	1.00
2004	0.00	0.52	0.86	1.00	1.00	1.00
2005	0.00	0.52	0.86	1.00	1.00	1.00
2006	0.00	0.52	0.86	1.00	1.00	1.00