2003 Coleraine assessment of the Icelandic cod stock

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Background

Coleraine is a generalized statistical catch at age model, developed at the University of Washington (Hilborn et al. 2001). The model generates the population structure in the first year from parameters and then uses the Baranov catch equation and a chosen form of recruitment to calculate the rest of the age-structured population history. The annual recruitment can be modelled as free parameters, deterministic Beverton-Holt, or an intermediate where large deviations from Beverton-Holt are penalized. Gear selectivity is modelled with an asymmetric normal curve.

The objective function is a product of likelihood components, which are based on the model fit to biomass indices and the catch at age data. Furthermore, the objective function is modified by penalties when informative Bayesian priors for any parameters are supplied. The model is programmed in the AD Model Builder language, which has built-in C++ libraries to perform the function optimization. Coleraine has mainly been used in New Zealand as well as in modelling workshops with simulated data, although this is the fourth Icelandic cod assessment using Coleraine (Hilborn et al. 2000, Magnusson 2001, 2002).

Data

The data were received in email attachments from Hafro: landed catch 1971–2003, commercial catch at age 1971–2002, weight at age 1971–2003, and spring trawl survey indices 1985–2002. Residual diagnosis of initial model runs led to the decision to pool ages 10 and older into a plus group, but the oldest age has traditionally been 14 years. The autumn trawl survey was not used in this year's Coleraine assessment.

Model

A total of 49 parameters are estimated in the model, and 44 of those determine the initial age structure and annual recruitment. The other 5 parameters are spring survey q and two selectivity parameters (age at full selectivity and left hand decline) for each gear: commercial fleet and spring survey.

Several constants have to be arbitrarily chosen to weight the different likelihood components. These constants are recruitment variability, biomass index CV, and effective sample sizes for the catch at age data. Recruitment variability was set at high a high value ($\sigma = 1.0$), which makes the estimated recruitment virtually independent of the Beverton-Holt function. Natural mortality rate was assumed to be 0.2. The spawning season data (weight and maturity) was used outside the model, and the biomass of 4+ year olds was used as the default model output instead of spawning biomass.

MCMC algorithm was used to estimate confidence bounds around derived parameters, 1000 samples from a chain of 1 million. Percentiles from this sample, 5%, 25%, 50%, 75%, and 95%, were used to summarize the posterior distribution.

Results

Fit to data

The survey biomass index (Fig. 1) shows a noticable decline between 1985 and 1995, with smaller fluctuations since then. The catch at age data are fitted reasonably well by the model (Figs. 2–3), via the estimated selectivity ogives (Fig. 4) of the survey and commercial fishery.

Confidence bounds

The cohort sizes are well defined (Fig. 5) by the catch at age data, with 1973, 1983, and 1984 being the strongest yearclasses, and 1996, 2001, and 1991 being the weakest. The biomass of 4+ year olds (Fig. 6) in the beginning of 2003 is estimated as 809 thousand tonnes, a considerable increase from the year before. This point estimate falls close to the median of the MCMC posterior distribution (Fig. 7). The biomass increase is mainly due to recruitment from the 1997–2000 cohorts, which are of average strength in contrast to the weak recruitment in 1994–1996.

Forward projections

Forward projections (Fig. 8) indicate that the 25% harvest control rule should lead to gradual rebuilding of the stock, possibliy levelling off around one million tons.

Retrospective analysis

Retrospective analysis shows that the model fit is consistent when parts of the data are removed stepwise. The model fits all show the same long-term trends, with the biomass declining from around 1500 thousand t in the late 1970s down to around 750 thousand t in the 1990s (Fig. 9), with the fishing mortality rate meandering around 0.5 (Fig. 10). This corresponds to around 32% annual removals from the fishable biomass (Table 1).

Residual diagnosis

As seen in Fig. 1, the observed survey biomass index fluctuates more than the predicted biomass. This can also be portrayed as a positive correlation between the observed survey biomass index and the standardized residuals (Fig. 11). Among possible causes are violations of survey assumptions and/or that the model is not reflecting the true population dynamics. Large residuals from the model fit to catch at age are mainly around the age classes 2–7, both in absolute terms (Figs. 2–3) and for the robust multinomial likelihood. When the residuals are standardized with log(obs/fit), however, it becomes clear that the oldest ages (10+) are consistently overestimated by the model (Figs. 12–13). Among possible causes are underestimation of natural mortality and/or that the fitted selectivity curve is not reflecting the true fishery dynamics.

Discussion

The current age distribution has some important implications for the management of the stock, given the low recruitment in 1986–1996, followed by larger cohorts spawned in 1997–2000. Although the biomass of 4+ year olds is increasing, the spawning biomass is at a low level and it will take a few years until the 1997–2000 cohorts start contributing fully to the spawning . Another concern, perhaps equally important, is that while these cohorts are young there is going to be an unusually high proportion of undersize fish in the catch.

References

Hilborn, R., A. Magnusson, and B. Ernst. 2000. Coleraine assessment of the Icelandic cod fishery. Annex 5 in J.A. Pope (ed.) An overview of additional studies made on Icelandic cod, summer 2000. Working Group Paper presented to Hafrannsóknastofnunin.

Hilborn, R., M. Maunder, A. Parma, B. Ernst, J. Payne, and P. Starr. 2001. Coleraine: A generalized age-structured stock assessment model. User's manual 2.0. Univ. Wash. School Aquat. Fish. Sci. Rep. 0116.

Magnusson, A. 2001. Coleraine úttekt á íslenska þorskstofninum [Coleraine assessment of the Icelandic cod stock]. Report submitted to the Marine Research Institute.

Magnusson, A. 2002. Coleraine assessment of the Icelandic cod stock. ICES ACFM Northwestern Working Group Doc. 29.

Figures

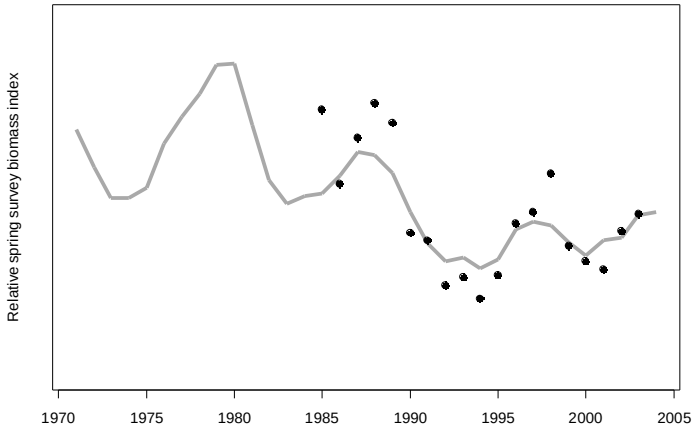

Figure 1. Model fit (line) to observed spring survey biomass index (points).

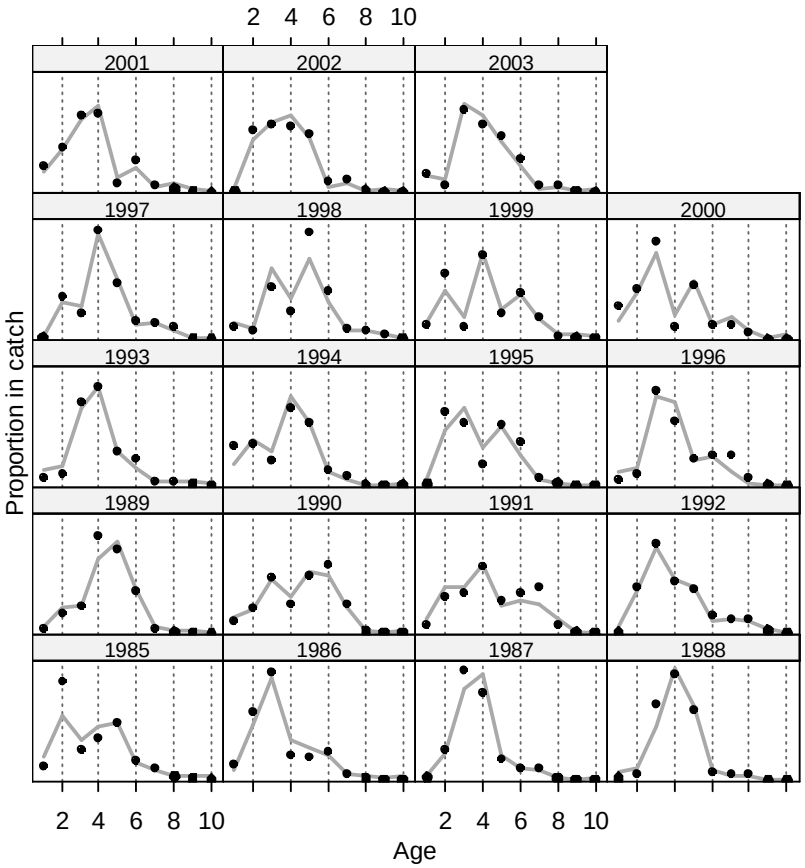

Figure 2. Model fit (line) to observed spring survey catch at age 1985-2003 (points).

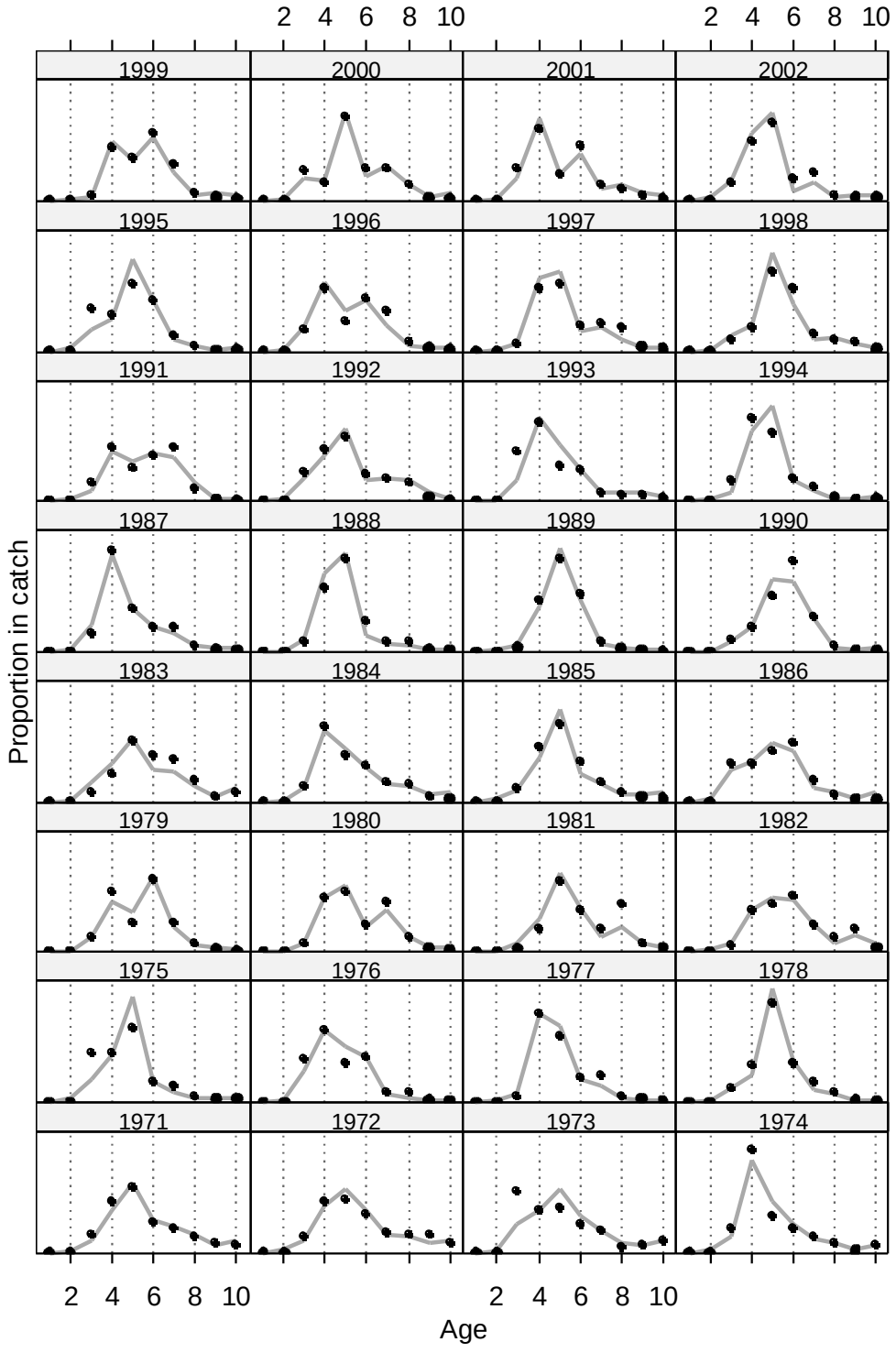

Figure 3. Model fit (line) to observed commercial catch at age 1971-2002 (points).

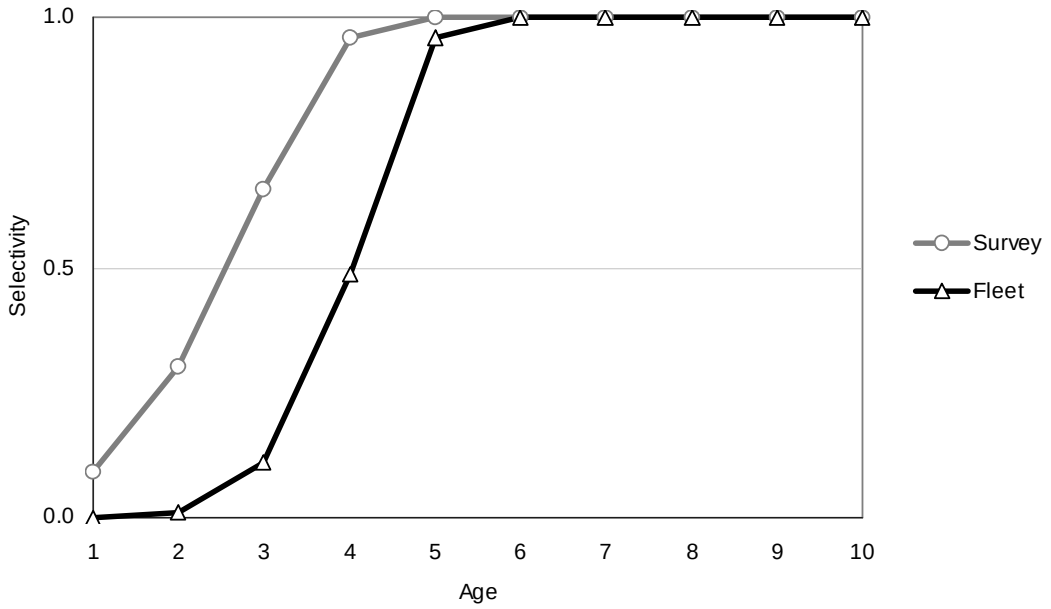

Figure 4. Estimated selectivity ogives.

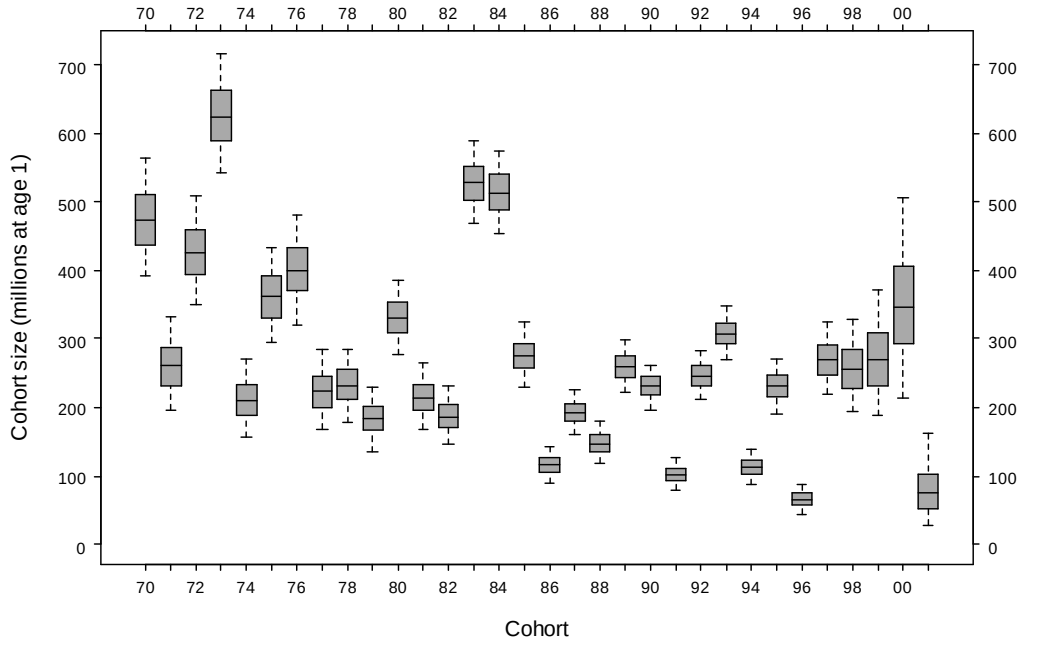

Figure 5. Estimated cohort size. The 5th, 25th, 50th, 75th, and 95th percentiles are shown.

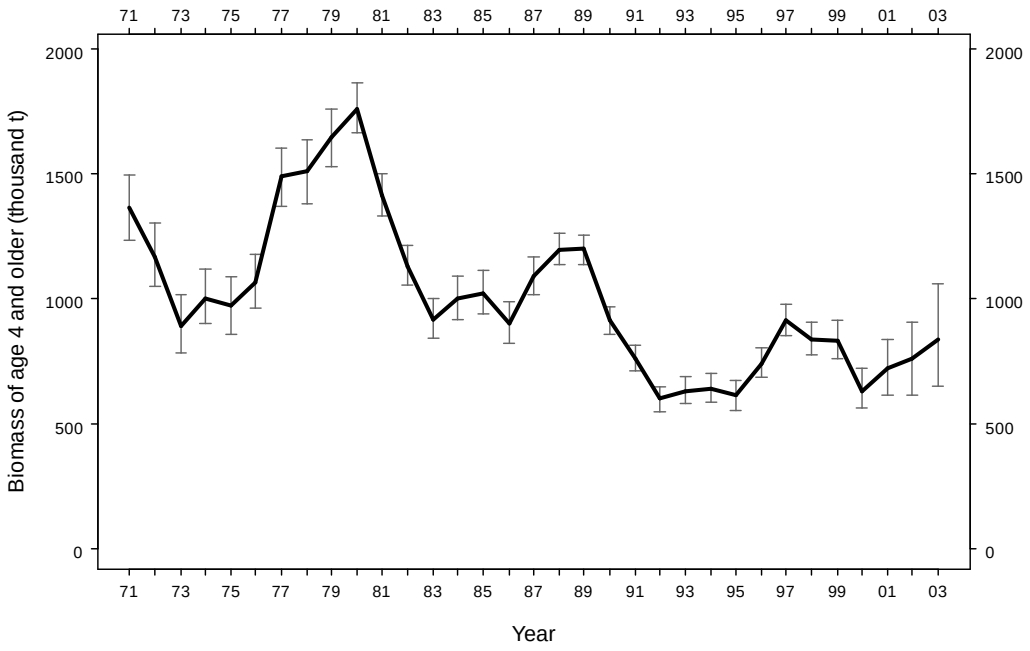

Figure 6. Estimated biomass trajectory. The 5th, 50th, and 95th percentiles are shown.

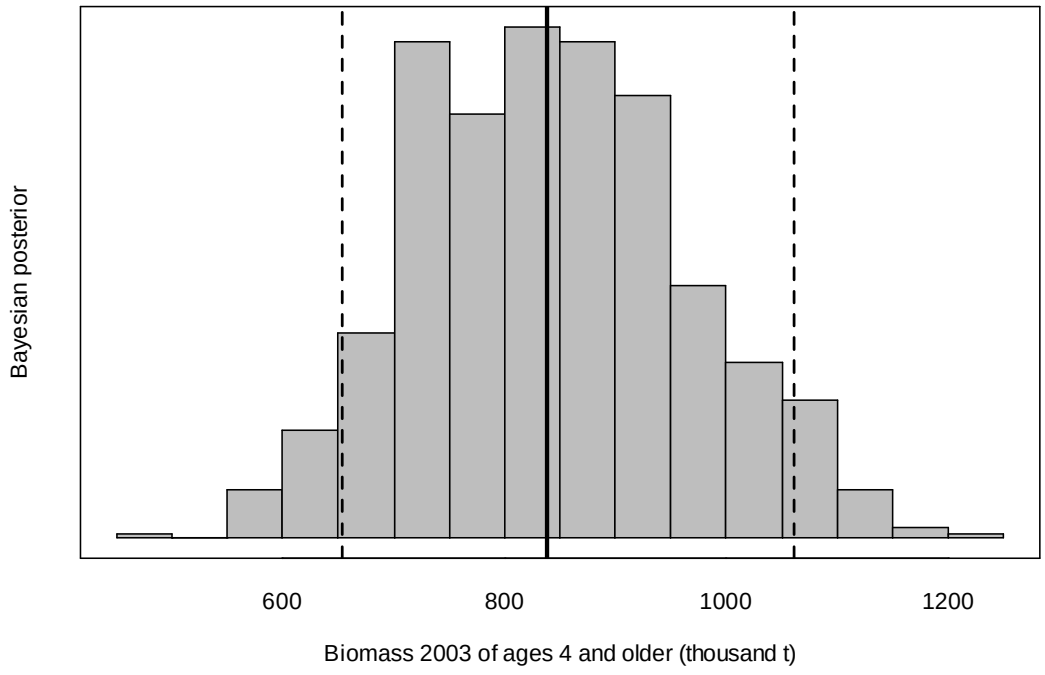

Figure 7. Likelihood profile of biomass 2003. The 5th, 50th, and 95th percentiles are shown.

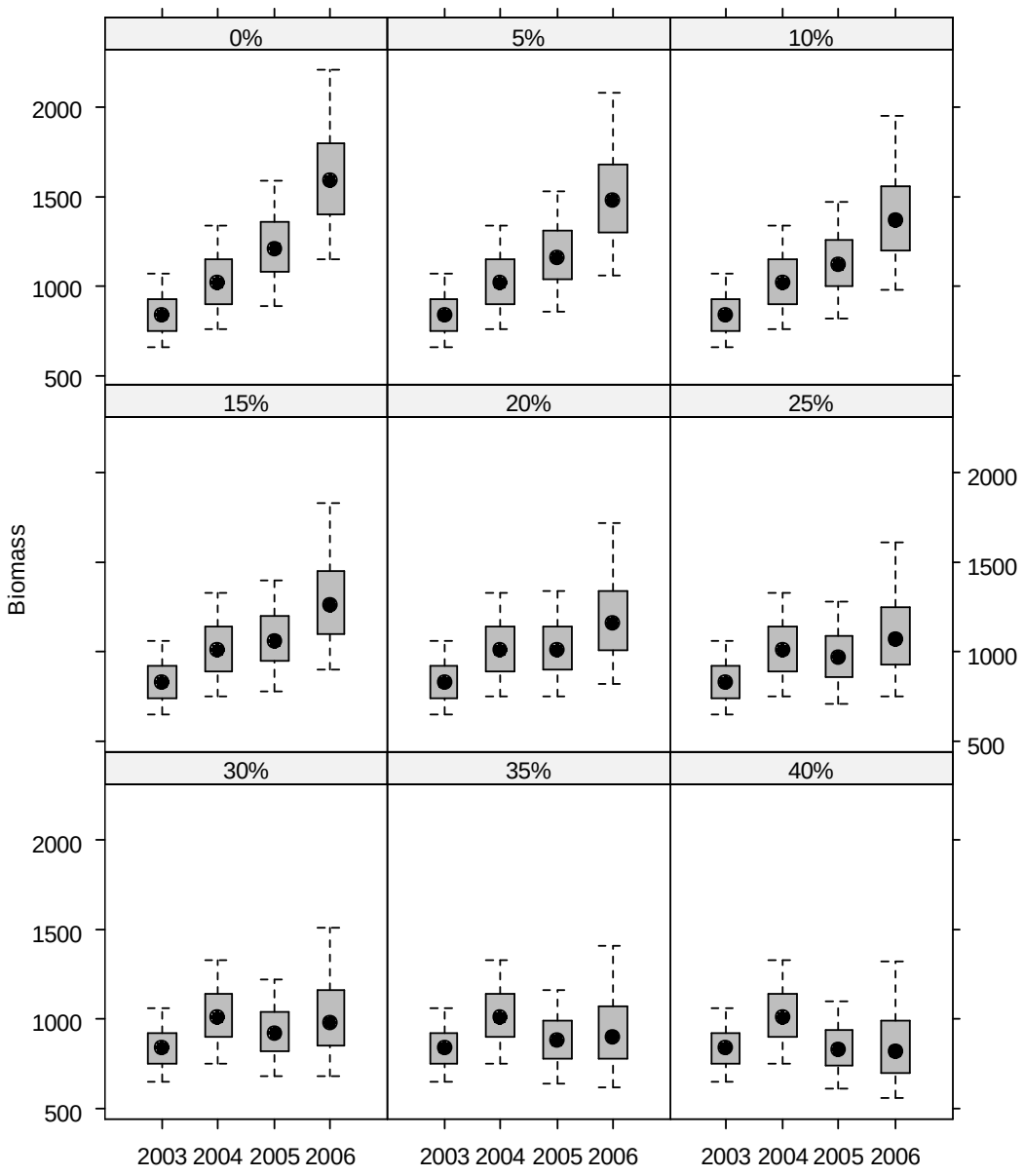

Figure 8. Forward projections with different harvest control rules (adopted rule is 25%). The 5th, 25th, 50th, 75th, and 95th percentiles are shown.

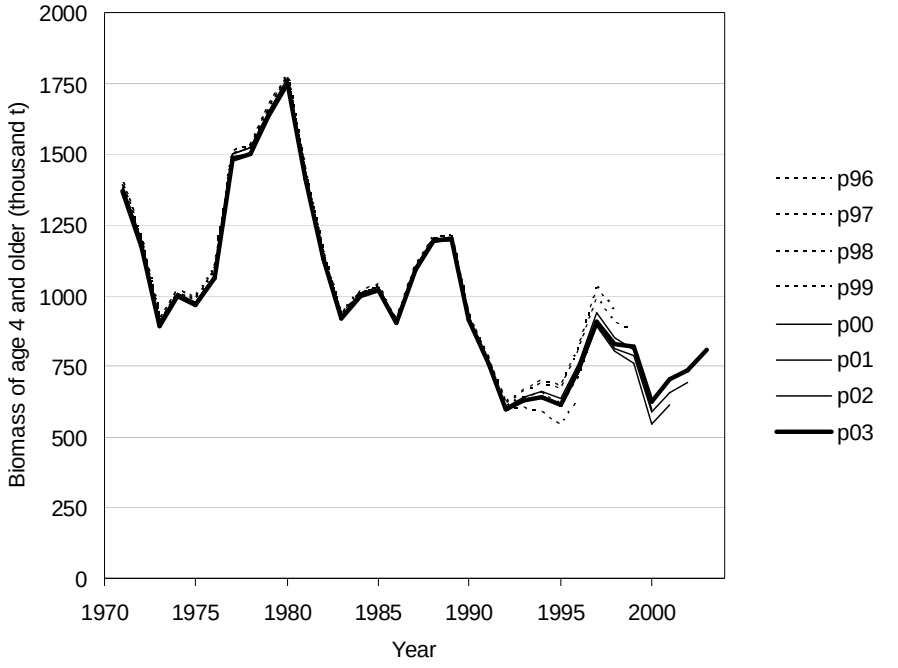

Figure 9. Retrospective analysis of biomass. Dataset p96 includes data that were available in the 1996 assessment, and dataset p03 includes all data used in this year's assessment.

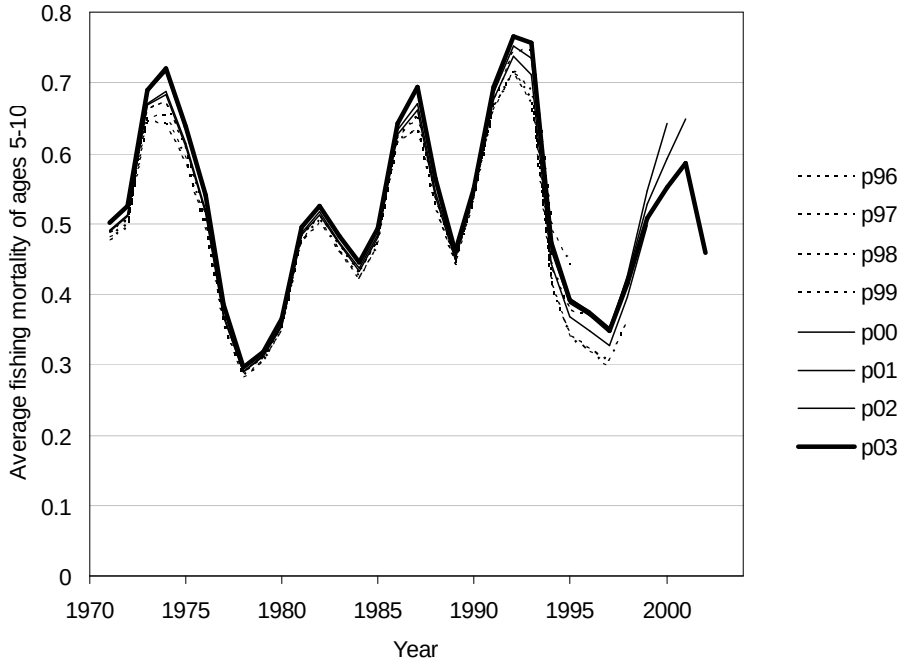

Figure 10. Retrospective analysis of fishing mortality. Dataset p96 includes data that were available in the 1996 assessment, and dataset p03 includes all data used in this year's assessment.

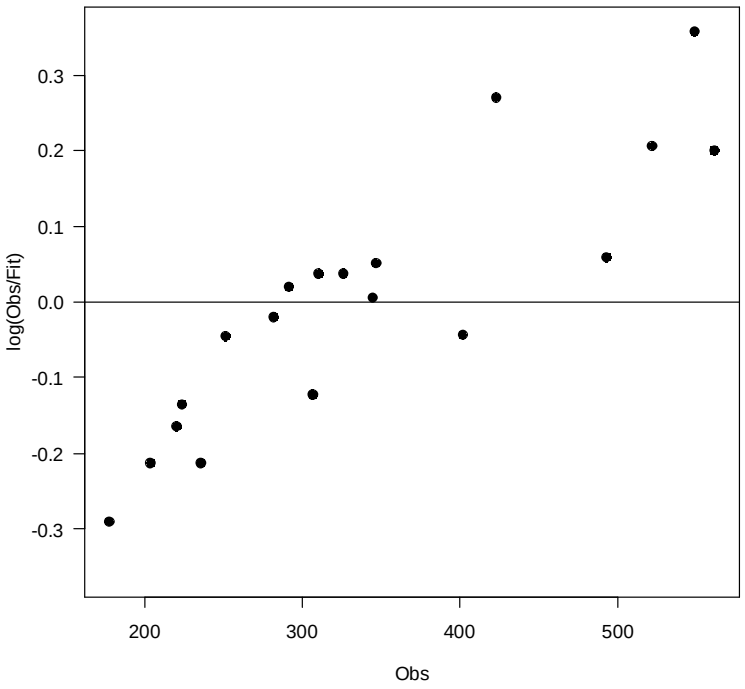

Figure 11. Standardized residuals from model fit to survey biomass index, plotted on observed values.

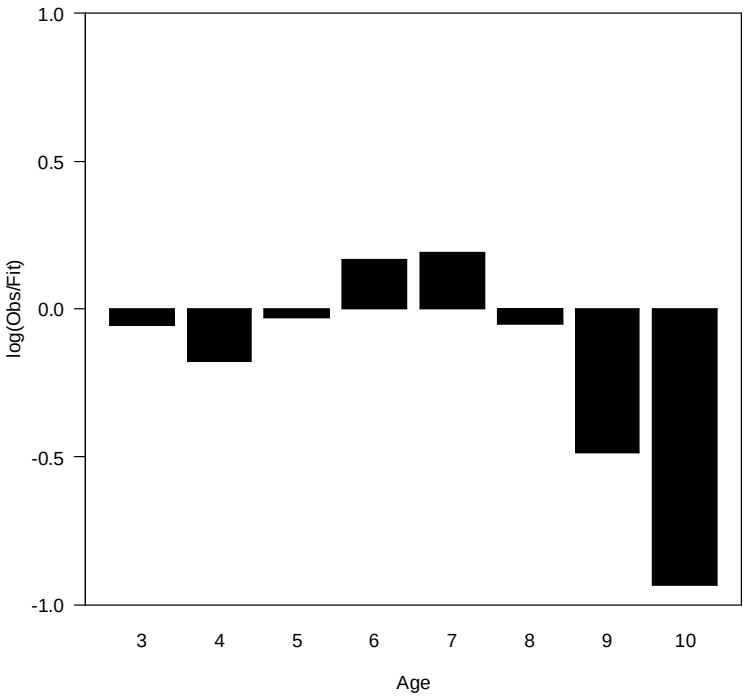

Figure 12. Standardized residuals from model fit to survey catch at age, plotted on age.

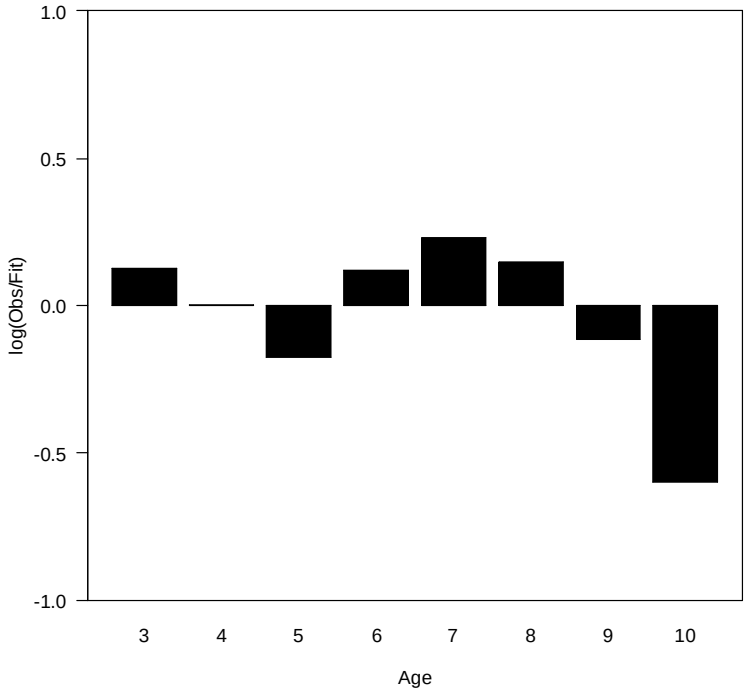

Figure 13. Standardized residuals of model fit to commercial catch at age, plotted on age.

Tables

Table 1. Landed catch, estimated biomass (age 4 and older), and estimated fraction removed annually.

Year	Catch	Biomass	Fraction
1971	453 052	1 370 000	33%
1972	398 528	1 170 000	34%
1973	383 446	894 552	43%
1974	374 770	999 547	37%
1975	370 991	966 587	38%
1976	347 849	1 060 000	33%
1977	340 050	1 480 000	23%
1978	330 390	1 500 000	22%
1979	368 064	1 630 000	23%
1980	434 344	1 750 000	25%
1981	468 659	1 410 000	33%
1982	388 387	1 130 000	34%
1983	300 056	918 667	33%
1984	283 822	1 000 000	28%
1985	325 267	1 020 000	32%
1986	368 633	900 452	41%
1987	392 257	1 090 000	36%
1988	378 076	1 190 000	32%
1989	355 954	1 200 000	30%
1990	335 390	912 646	37%
1991	308 560	762 816	40%
1992	267 767	598 591	45%
1993	251 979	630 708	40%
1994	178 809	642 020	28%
1995	169 424	613 469	28%
1996	181 658	737 990	25%
1997	203 153	906 160	22%
1998	242 632	828 555	29%
1999	260 052	817 466	32%
2000	235 654	623 002	38%
2001	235 098	700 825	34%
2002	208 830	737 061	28%
2002	210 000*	808 611	26%

*: assumed for forward projections

Appendix

Table A. Estimated numbers at age matrix (millions of individuals).

	1	2	3	4	5	6	7	8	9	10
1971	472	173	163	136	113	51	42	28	12	18
1972	263	387	141	127	89	57	25	21	14	15
1973	426	215	315	110	83	44	27	12	10	14
1974	629	349	175	244	68	35	18	11	5	10
1975	208	515	284	135	149	28	14	7	4	6
1976	360	170	419	220	85	66	12	6	3	4
1977	401	295	139	328	143	42	31	6	3	3
1978	230	328	241	109	226	81	23	17	3	3
1979	234	188	268	191	78	139	49	14	11	4
1980	186	192	154	213	136	47	82	29	8	9
1981	329	153	157	122	148	78	27	47	16	10
1982	213	269	124	123	80	75	39	13	23	13
1983	186	174	219	97	80	40	36	19	6	17
1984	530	152	142	172	65	41	20	18	9	12
1985	510	434	124	112	116	35	22	10	9	11
1986	277	418	354	97	74	59	17	11	5	10
1987	118	227	340	274	61	33	25	7	5	7
1988	193	96	185	263	169	26	13	10	3	5
1989	146	158	78	144	170	81	12	6	5	3
1990	260	120	129	62	96	89	42	6	3	4
1991	232	213	98	100	40	47	42	19	3	3
1992	103	190	173	76	62	17	19	17	8	3
1993	242	85	155	134	46	25	6	7	6	4
1994	302	198	69	119	81	18	9	2	3	4
1995	113	247	162	54	80	42	9	5	1	3
1996	227	92	202	128	37	45	23	5	3	3
1997	67	186	75	159	89	21	25	13	3	3
1998	266	54	151	60	112	52	12	14	7	3
1999	256	218	44	119	41	61	28	7	8	6
2000	263	209	177	35	79	20	30	14	3	7
2001	344	216	171	138	23	38	10	14	6	5
2002	88	281	176	133	89	11	17	4	6	5
2003	310	72	229	138	89	47	5	9	2	6