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Evaluating exceptional circumstances in the context of the Greenland halibut management strategy evaluation based on the 2011 stock assessment

by
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Abstract

A harvest control rule for the management of the NAFO 2+3KLMNO Greenland halibut stock was adopted by Fisheries Commission in September 2010. This rule will be the basis for setting the TAC for the period 2011-2014 after which a full review will be undertaken. However, should "exceptional circumstances" occur such that observed survey and catch data, biological parameters or XSA estimates fall outside the range of values obtained in the management strategy simulations, Fisheries Commission may take over control of TAC setting rather than rely on the rule. This document presents approaches for determining exceptional circumstances and evaluates whether or not exceptional circumstances have occurred based on the June 2011 data for the Greenland halibut stock.

Introduction

NAFO adopted a management strategy (MS) for 2+3KLMNO Greenland halibut in September 2010 for the management of the stock for an initial four-year period (2011 to 2014) following an extensive management strategy evaluation (MSE, Shelton 2011). Allowance was made for Fisheries Commission (FC) to intervene and assume control from the MS should "exceptional circumstances" arise. In its request to Scientific Council (SC) for advice from the June 2011 meeting, FC asked for guidance on what might constitute "exceptional circumstances" and provide advice on whether or not the "exceptional circumstances" provision should be applied (in setting the TAC for 2012).

SC could only provide limited advice from the June 2011 meeting on whether or not the exceptional circumstances provision should be applied because it did not have the distributions of simulated values from the operating models (OMs) on which the HCR was tested to compare with the 2011 assessment results (NAFO SCS Doc. 11/16). Comparisons were however made between updated assessment results and XSA OMs for 5-9 exploitable biomass percentiles because these data were readily available from the September 2010 meeting of WGMSE (NAFO FC Doc. 10/30). It was determined at the June 2011 SC that the 2011 age 5-9 biomass from the updated XSA assessment was within the 5th and 95th percentiles of simulated biomass distribution across all XSA OMs.

SC also felt that it was premature to determine whether exceptional circumstances were occurring because this situation had not yet been defined. A definition of exceptional circumstances in relation to the Greenland halibut MSE have now been developed by WGMSE (NAFO FC Doc. 11/8) and OM simulated values have now been extracted from the XSA-based OMs carried out at WGMSE in September 2010.

Primary indicators are the surveys and the catches (NAFO/FC Doc. 11/8). There is concern when the observed values are outside the range tested in the MSE. The 90% probability interval from the MSE could be considered as a reference. This means that there would be concern if the observed values are below the 5th percentile or above the 95th percentile of MSE simulated values for that year. It is not specifically stated in Annex 4 whether this comparison should be OM by OM or all OMs combined. We suggest that at present this should minimally be done for the CAV XSA OM and SCAA0 OM as well as for all XSA OMs combined and all SCAA OMs combined. SC should give more consideration at the June 2012 meeting on whether this is the right way to do it or if the comparison should be made for each OM separately as was done in evaluating the performance statistics at WGMSE in September 2010 (NAFO/FC Doc. 10/30).

Secondary indicators are data gaps, biological parameters, recruitment, fishing mortality and exploitable biomass (NAFO/FC Doc. 11/8). For recruitment, fishing mortality and exploitable biomass, the comparison should be between the same model (OM) used in the MSE and the model used in the assessment (CAV XSA). This poses a problem because we do not have an update of the SCAA0 assessment for 2011 corresponding to the base case SCAA0 OM.

Information for the above indicators is provided in this WP with the exception of data gaps. With regard to data gaps, what constitutes exceptional circumstances needs to be made more implicit than what is currently available in Annex 4 of the September 2011 WGMSE Report (NAFO/FC Doc. 11/8; e.g. would we still be happy if two surveys were missing in the same year?). We propose that multiple surveys missing in the same year or a single survey missing in consecutive years may constitute exceptional circumstances. The rationale for this proposed criterion is that only single year - single survey data gaps were included in the MSE simulations to test the robustness of the management strategy. Specifically, the HCR computations within the MSE considered the Canadian spring 2006 survey and the Canadian fall 2008 survey as missing values.

Methods and Results

This working paper considers whether or not exceptional circumstances pertain in setting the TAC for 2012 based on the management strategy adopted by NAFO. The data evaluated are from the XSA-based MSE results presented at FC WGMSE in September 2010 (NAFO/FC Doc. 10/30). In addition, new information from the June 2011 stock assessment on survey estimates, biological parameters and XSA results (Healey 2011a,b) is taken into account.

Comparison of XSA-based MSE values with the 2011 assessment values

Primary indicators

Research vessel surveys

The percentiles for MSE generated values for survey biomass (mean weight per tow) for the three research vessel surveys for the period 2010 to 2030 are given for the CAV OM in Table 1 and for the all OMs in Table 2. Figs. 1 and 2 compare these distributions for 2010 with the survey 2010 survey estimates (Healey, 2011a). The intersection of the vertical line with the cumulative distribution gives the probability of achieving the observed survey value in the MSE simulation. None of these lines intersect the cumulative distribution below the 5^{th} percentile or above the 95^{th} percentile, so there is no concern.

Catch data

The percentiles for MSE generated values for commercial catch for the period 2010 to 2030 are given for the CAV OM in Table 3 and for the all OMs in Table 4. Figs. 3 and 4 compare these distributions for 2010-2012 with the observed catch for 2010 and the adopted management strategy harvest control rule generated catches for 2011 and 2012 (Healey, 2011b; Shelton, 2011). The observed 2010 catch is above the MSE simulated distribution for both the CAV OM and all OMs combined. This is a concern and could invalidate the MSE approach and ongoing application of the management strategy. Note that the distribution for 2010 is derived from resampling the TAC overrun multiplier observed between 2004 and 2009 (average of 1.33x) and applying this to the 16kt TAC for 2011. SC estimates that the TAC in 2011 was overrun by a factor of 1.64x (Healey 2011b).

Secondary indicators

Data gaps
There have been no recent data gaps in the survey.

Biological parameters
The information on biological parameters (weights and maturities; Healey 2011b) is consistent with the range of 2010 and 2011 values simulated in the MSE. No new information on natural mortality is available.

Recruitment
The percentiles for projected recruitment for the XSA based CAV OM are given in Table 5 and the cumulative curve for 2010 together with the 2010 estimate from the 2011 assessment (Healey, 2011b) are plotted in Fig. 5. Estimated recruitment is within the empirical 90% CI, so there is no concern.

Fishing mortality
The percentiles for projected fishing mortality (average 5-10) for the XSA based CAV OM are given in Table 6 and the cumulative curve for 2010 together with the 2010 estimate from the 2011 assessment (Healey, 2011b) are plotted in Fig. 6. The assessment estimate is at the 98th percentile of the OM distribution, which is a concern. This high F is a result of the 1.64x TAC overrun in 2010.

Exploitable biomass
The percentiles for projected exploitable biomass for the XSA based CAV OM are given in Table 7 and the cumulative curve for 2010 together with the 2010 and 2011 estimate from the 2011 assessment (Healey, 2011b) are plotted in Fig. 7. The intersection does not occur below the 5th or above the 95th percentile, so there is no concern.

Discussion

Comparisons with most recent data / assessment results

There are concerns in the comparison of the MSE generated values and the assessment estimated values for catch and fishing mortality for 2010 from Healey (2011b). The assessment values are above the 95th percentile of MSE generated values for both the XSA-based OM and all XSA OMs combined with respect to catch and above the XSA-based CAV OM with respect to fishing mortality. This is a consequence of the 2010 TAC overrun being much higher than allowed for in the MSE analysis. In its response to FC request on the Greenland halibut TAC, SC noted "Exceptional circumstances may generally be defined as any event or observation which is outside of the range of possibilities included within the MSE" (SCS Doc. 11/16, p. 29-31).

Applying the general definition above, the 2010 catch, being outside the range simulated in the MSE, *is* an exceptional circumstance. While this is a serious concern, it is not yet clear what the future impact will be on the stock, as reflected by future survey indices, exploitable biomass and recruitment. At this stage it is not suggested that the MSE be abandoned, but the situation be closely monitored during the 2012 annual meeting of SC to determine whether or not the 2013 TAC generated from the HCR should be rejected.

What should SC compare (and how) in addressing future FC requests

Exactly what should be compared, and how, when investigating if exceptional circumstances exist is not yet clearly defined. FC WGMSE has proposed that empirical 90% CIs from the MSE simulations be examined, and values of any indicators outside of this range be identified as an exceptional circumstance. But what to compare? Should each OM be compared individually, the composite distribution across all OMs be compared, or something else? Perhaps the composite distribution should not be used in comparisons, and that a sufficient condition to not invoke exceptional circumstances actions may be that the entire suite of indicators from a single OM be consistent with data and model results.

In MSE, an HCR should be robust across all OMs; that is, all performance statistics should be satisfied (with appropriate risk thresholds). The suite of OMs generally captures a range of potential realities. The broader this range, the greater divergence in population trajectories over the time frame considered. This increases the spread of the composite distribution of results. Yet post-implementation, only one OM can be (most) correct. Thus it may

suffice that reality (whether data or updated assessment model) be consistent with only one OM evaluated in the MSE.

Fig. 8 illustrates a hypothetical example, based on Canadian fall survey data from 1996 – 2010. Survey results were simulated ten years into the future under two assumptions about the survey mean (i.e. consider cases as two OMs). Annual survey values (n=10,000) were drawn from a normal distribution with a CV of 23% (computed from survey data over this period) assuming either:

i) survey mean increases by 3% per annum (starting from 2010 index value), or
ii) survey mean constant (at 2010 index value).

The 90% empirical CIs for each of these scenarios are given by dashed lines. The 90% CI from the composite distribution is illustrated by the shaded grey polygon.

Would a hypothetical index data value of 12.25 in 2013 be exceptional? In this simulation, the probability of the survey being less than this value is p=0 under i), p=0.16 under ii) and p<0.01 for the composite distribution. Hence on an individual OM basis, using the 90% CI rule, this survey would be considered an exceptional circumstance under i) but not ii), and it would also be considered exceptional if looking at the composite distribution.

The best approach on how to conduct comparisons with regard to OMs should be further discussed by SC prior to and during the June 2012 meeting.

Conclusions

Using the FC definition of exceptional circumstances, the 2010 catch (well outside the range tested) is indeed an exceptional circumstance. However, we suggest that the MSE be retained but with careful evaluation of the catch and survey data and the updated XSA assessment in June 2012 in relation to MSE simulations in order to determine whether or not the 2013 TAC generated from the HCR should be rejected.

References

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Table 1. Percentiles for the projected survey biomass (mean weight per tow) under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV).

Canadian Fall Survey

Year	5%	15%	25%	50%	75%	85%	95%
2010	13.21	15.14	15.85	17.41	19.38	20.27	21.34
2011	13.85	15.14	16.03	17.25	19.04	19.84	21.41
2012	13.88	15.46	16.06	17.80	19.02	19.59	21.65
2013	15.15	17.97	18.84	21.22	23.11	24.47	27.69
2014	18.41	20.71	21.57	23.55	25.87	26.72	29.30
2015	19.13	21.21	22.28	24.37	26.50	27.73	30.70
2016	22.74	23.67	24.93	27.68	29.81	31.57	33.95
2017	23.68	25.73	26.78	30.30	33.31	34.84	36.30
2018	21.17	23.43	24.17	27.40	30.44	31.99	33.53
2019	24.45	26.50	27.65	31.10	33.35	35.01	38.69
2020	24.18	27.09	29.32	31.88	35.75	37.34	40.31
2021	23.43	25.72	28.18	30.63	34.07	35.22	38.95
2022	26.14	28.12	29.06	32.26	34.40	35.89	38.00
2023	25.58	27.22	28.43	31.31	34.50	35.64	39.41
2024	25.72	28.00	30.11	33.02	36.56	38.20	40.82
2025	24.21	26.78	29.32	32.35	35.61	38.52	42.67
2026	26.25	28.40	29.91	33.26	36.50	38.92	41.89
2027	22.81	25.01	26.46	30.69	32.79	34.12	36.92
2028	26.56	28.86	30.19	32.47	35.53	37.58	40.21
2029	24.31	26.90	28.98	31.34	35.52	37.11	40.96
2030	25.39	27.87	29.02	31.34	34.80	36.34	39.23

Canadian Spring Survey

Year	5%	15%	25%	50%	75%	85%	95%
2010	0.89	1.00	1.08	1.34	1.66	1.77	2.12
2011	0.85	1.00	1.11	1.39	1.76	1.98	2.31
2012	0.83	0.92	1.05	1.37	1.62	1.79	2.05
2013	0.98	1.29	1.36	1.66	1.92	2.06	2.57
2014	1.19	1.39	1.60	2.13	2.44	2.73	3.34
2015	1.33	1.51	1.78	2.08	2.49	2.73	3.29
2016	1.37	1.72	1.85	2.27	2.64	2.86	3.57
2017	1.65	1.92	2.12	2.61	3.21	3.50	3.89
2018	1.50	1.71	1.80	2.26	2.92	3.26	3.44
2019	1.60	1.92	2.04	2.48	2.91	3.19	3.49
2020	1.67	1.94	2.09	2.53	2.97	3.24	3.95
2021	1.50	1.79	1.99	2.38	2.77	2.95	3.83
2022	1.47	1.88	2.04	2.48	3.06	3.31	3.95
2023	1.66	1.90	2.05	2.62	3.02	3.27	3.94
2024	1.74	1.86	2.01	2.49	3.08	3.38	3.74
2025	1.63	1.90	2.15	2.59	3.18	3.58	3.90
2026	1.48	1.81	1.97	2.52	3.23	3.52	3.89
2027	1.46	1.73	1.92	2.31	2.70	2.99	3.46
2028	1.52	1.78	2.02	2.64	3.17	3.38	3.85
2029	1.49	1.79	1.92	2.39	3.01	3.37	3.82
2030	1.55	1.76	1.96	2.36	2.82	3.08	3.69

EU 0-1400m

Year	5%	15%	25%	50%	75%	85%	95%
2010	18.54	19.62	20.21	21.51	23.49	24.64	26.20
2011	17.39	19.05	20.14	22.18	24.11	24.74	27.06
2012	18.88	20.38	21.75	24.01	26.78	28.01	29.79
2013	19.13	21.38	22.49	24.58	27.59	29.27	32.07
2014	20.00	22.03	23.60	25.82	29.11	31.40	35.28
2015	20.77	22.06	23.03	26.15	28.89	31.78	34.30
2016	21.58	24.56	25.69	27.38	29.85	31.52	36.29
2017	27.32	29.93	30.86	33.35	38.11	39.86	44.39
2018	29.13	31.23	33.06	36.63	40.61	42.17	47.96
2019	33.56	36.25	38.07	41.68	46.24	48.43	56.99
2020	37.02	41.22	43.80	48.91	54.40	56.72	63.03
2021	40.32	43.15	47.52	51.92	57.53	61.09	66.53
2022	40.88	47.47	50.17	55.73	62.73	67.81	74.12
2023	43.49	48.09	51.87	57.26	66.71	70.37	77.05
2024	45.17	48.82	52.05	60.04	65.73	69.58	82.54
2025	44.98	51.16	54.02	61.60	67.39	72.07	81.67
2026	46.86	55.62	60.55	66.91	74.42	78.89	85.43
2027	47.06	53.51	56.08	62.66	71.32	73.14	82.94
2028	41.32	48.65	52.46	58.37	65.08	68.70	74.88
2029	45.07	53.28	55.97	64.11	70.66	74.45	79.05
2030	45.17	52.47	56.15	63.44	70.39	75.40	84.20

Table 2. Percentiles for the projected survey biomass (mean weight per tow) under the adopted Management Strategy for all XSA-based operating models.

Canadian Fall Survey

Year	5%	15%	25%	50%	75%	85%	95%
2010	13.28	14.70	15.55	17.37	19.20	20.25	21.87
2011	13.88	15.08	15.96	17.72	19.72	20.66	22.81
2012	13.94	15.45	16.37	18.13	20.24	21.64	23.41
2013	17.00	18.87	19.99	22.33	25.35	26.98	30.47
2014	19.23	21.28	22.58	25.84	29.55	31.62	36.96
2015	19.79	22.32	23.74	26.92	31.02	34.58	39.28
2016	22.74	24.93	26.68	30.47	37.26	42.02	49.27
2017	23.59	26.54	28.71	33.27	41.26	46.08	54.48
2018	21.96	24.72	26.73	31.10	40.70	45.52	55.80
2019	24.70	27.65	29.48	34.27	45.25	52.09	60.93
2020	25.36	29.22	31.55	36.59	49.47	56.82	66.91
2021	24.47	27.63	29.79	34.77	48.58	55.21	64.85
2022	25.43	28.47	30.62	35.57	49.17	55.64	66.55
2023	25.07	28.16	30.21	36.41	51.16	59.50	69.00
2024	25.46	29.34	31.86	37.33	51.69	60.76	72.43
2025	26.29	29.30	31.40	36.71	50.86	58.57	72.10
2026	27.30	29.85	32.25	38.12	54.98	63.28	75.98
2027	24.15	27.12	29.48	34.94	49.65	56.89	67.73
2028	27.10	30.18	31.96	37.71	52.72	62.50	73.69
2029	25.43	28.95	30.88	36.95	51.05	60.17	71.95
2030	26.08	28.90	30.89	36.55	52.07	60.76	73.09

Canadian Spring Survey

Year	5%	15%	25%	50%	75%	85%	95%
2010	0.88	1.02	1.10	1.34	1.63	1.76	2.04
2011	0.81	1.02	1.11	1.35	1.61	1.78	2.10
2012	0.82	0.96	1.08	1.33	1.65	1.82	2.14
2013	1.07	1.30	1.44	1.71	2.08	2.30	2.76
2014	1.25	1.51	1.68	2.08	2.50	2.75	3.49
2015	1.37	1.63	1.85	2.23	2.77	3.14	3.77
2016	1.55	1.87	2.12	2.61	3.24	3.70	4.43
2017	1.66	2.02	2.28	2.81	3.56	4.15	5.09
2018	1.54	1.87	2.07	2.60	3.39	3.98	5.11
2019	1.64	2.00	2.22	2.77	3.66	4.15	5.41
2020	1.76	2.13	2.33	2.91	3.90	4.44	5.73
2021	1.62	1.92	2.20	2.74	3.54	4.07	5.41
2022	1.62	2.00	2.23	2.78	3.69	4.37	5.36
2023	1.65	2.04	2.28	2.82	3.60	4.15	5.35
2024	1.73	2.01	2.27	2.91	3.73	4.36	5.34
2025	1.66	2.00	2.24	2.90	3.69	4.20	5.35
2026	1.67	2.01	2.28	3.00	3.79	4.46	5.80
2027	1.60	1.92	2.16	2.64	3.44	3.92	4.84
2028	1.65	1.99	2.30	2.88	3.62	4.27	5.45
2029	1.63	1.89	2.17	2.74	3.60	4.04	5.35
2030	1.65	1.99	2.24	2.83	3.64	4.22	5.03

EU 0-1400m

Year	5%	15%	25%	50%	75%	85%	95%
2010	18.31	19.79	20.79	22.59	24.66	25.66	27.55
2011	17.96	19.64	20.81	23.05	25.75	27.57	29.79
2012	18.98	20.91	22.40	25.46	29.47	32.31	35.73
2013	18.59	21.17	22.88	26.37	31.39	34.67	40.11
2014	19.82	22.01	23.93	28.29	34.46	38.33	44.70
2015	19.55	22.20	24.19	28.67	35.12	39.12	45.80
2016	21.41	24.37	26.26	30.93	37.56	42.22	49.24
2017	26.79	29.98	32.78	38.83	49.61	55.12	66.26
2018	28.51	32.11	35.39	42.58	56.85	63.50	79.08
2019	32.49	36.72	39.89	49.81	68.24	77.44	94.92
2020	37.19	42.54	46.13	59.63	84.08	96.92	120.75
2021	38.91	45.05	49.73	65.58	96.42	113.27	149.23
2022	41.28	48.11	52.46	73.06	108.34	134.92	185.10
2023	43.11	49.07	53.82	76.79	118.15	153.23	219.27
2024	44.08	50.28	54.80	81.39	124.54	166.34	237.96
2025	44.84	51.28	56.11	79.00	128.81	171.27	255.03
2026	47.37	54.97	61.01	86.36	142.68	188.08	269.32
2027	45.12	52.50	57.19	82.83	135.73	180.15	262.83
2028	42.17	47.62	53.40	77.40	125.33	164.49	236.59
2029	44.37	52.36	56.82	83.14	139.31	184.29	265.93
2030	45.29	51.48	57.60	85.96	139.49	184.25	265.57

Table 3. Percentiles for the projected catch values under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV).

Catch Year	5%	15%	25%	50%	75%	85%	95%
2010	21.350	21.350	22.225	23.100	24.850	25.375	25.375
2011	16.625	16.625	16.625	16.911	17.366	17.624	17.963
2012	15.794	15.794	15.843	16.300	17.054	17.414	17.866
2013	15.004	15.096	15.237	15.824	16.676	17.118	18.140
2014	14.414	14.703	15.067	15.710	16.529	17.036	18.130
2015	14.716	15.137	15.505	16.239	16.913	17.511	18.678
2016	15.220	15.891	16.102	16.923	17.686	18.315	19.612
2017	15.981	16.662	16.889	17.714	18.524	19.132	20.588
2018	16.696	17.474	17.640	18.514	19.207	20.037	21.291
2019	17.531	18.300	18.398	19.288	20.167	20.967	22.061
2020	18.247	19.025	19.314	20.249	21.062	21.878	23.164
2021	19.089	19.573	20.269	21.160	22.081	22.736	23.985
2022	19.775	20.510	21.108	21.830	22.975	23.662	24.670
2023	20.414	21.185	21.618	22.657	23.556	24.347	25.422
2024	20.731	21.899	22.345	23.583	24.418	25.174	26.439
2025	20.568	22.260	23.052	24.391	25.224	25.825	26.951
2026	20.840	22.574	23.634	24.862	25.898	26.621	27.613
2027	20.823	22.610	23.654	25.007	26.487	27.211	28.850
2028	20.562	22.513	23.354	25.235	26.568	27.351	29.838
2029	20.645	22.221	23.330	24.962	26.476	27.994	30.045
2030	20.884	22.512	23.244	24.884	26.798	27.449	29.589

Table 4. Percentiles for the projected catch values under the adopted Management Strategy for all XSA-based operating models.

Catch Year	5%	15%	25%	50%	75%	85%	95%
2010	21.350	21.350	22.225	22.225	24.850	25.375	25.375
2011	16.625	16.625	16.625	16.965	17.459	17.738	18.059
2012	15.794	15.794	15.843	16.310	17.138	17.508	18.100
2013	15.004	15.018	15.236	15.815	16.747	17.337	18.234
2014	14.389	14.852	15.119	15.822	16.811	17.509	18.606
2015	14.661	15.233	15.670	16.431	17.507	18.162	19.467
2016	15.146	15.880	16.336	17.206	18.329	19.041	20.438
2017	15.810	16.618	17.079	18.027	19.233	19.979	21.418
2018	16.590	17.445	17.899	18.894	20.171	20.951	22.479
2019	17.412	18.219	18.722	19.797	21.133	21.990	23.534
2020	18.192	19.102	19.631	20.715	22.180	23.016	24.711
2021	18.863	19.965	20.521	21.664	23.174	24.128	25.849
2022	19.542	20.755	21.271	22.549	24.177	25.277	27.139
2023	20.211	21.367	22.112	23.427	25.272	26.395	28.465
2024	20.768	22.009	22.759	24.397	26.333	27.449	29.452
2025	21.073	22.474	23.552	25.235	27.368	28.597	30.802
2026	21.131	22.996	23.996	25.962	28.252	29.615	32.082
2027	21.148	22.842	24.045	26.194	29.197	30.759	32.918
2028	21.193	22.811	23.781	26.507	29.674	31.243	34.303
2029	21.105	22.681	23.800	26.645	29.797	31.923	34.154
2030	21.083	22.738	23.835	26.933	30.049	31.913	34.886

Table 5. Percentiles for the projected recruitment values (age 1, thousands) under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV).

Recruits

Year	5%	15%	25%	50%	75%	85%	95%
2010	91133	99286	105736	113731	123178	128811	146539
2011	99583	107142	110270	121502	131524	134516	143530
2012	99874	107175	112017	121880	132344	136977	143644
2013	101958	109593	114384	123191	131718	138194	143540
2014	103215	110930	117438	124553	135062	138775	144425
2015	104595	112308	116816	124321	130272	136589	141567
2016	105360	114077	119946	125499	133201	136911	147159
2017	107504	113390	117346	126750	135448	137791	146065
2018	107554	113654	117355	125840	134662	138738	147714
2019	104015	112359	117047	125008	132667	138926	145875
2020	105549	115724	118624	126072	133176	136926	144674
2021	106060	112749	117387	124772	132902	138570	147664
2022	108375	112344	116614	124106	134318	138191	148169
2023	105258	112706	116298	123591	131154	137569	147892
2024	105260	110184	114681	124212	133422	140218	148435
2025	104529	111071	114904	124180	133453	138950	146083
2026	105602	112445	114961	125248	132574	135916	146117
2027	104568	112512	116827	123849	133899	137587	145502
2028	102495	112335	114721	122813	131335	135263	146362
2029	102689	109139	113515	124283	134503	138682	145284
2030	102186	110220	113620	126053	132597	136739	146660

Table 6. Percentiles for the projected fishing mortality (average 5-10) under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV).

Fishing mortality

Year	5%	15%	25%	50%	75%	85%	95%
2010	0.218	0.236	0.242	0.267	0.298	0.312	0.338
2011	0.178	0.190	0.200	0.217	0.239	0.254	0.271
2012	0.173	0.186	0.192	0.215	0.239	0.247	0.275
2013	0.155	0.168	0.178	0.197	0.219	0.232	0.257
2014	0.149	0.162	0.170	0.188	0.212	0.228	0.256
2015	0.130	0.145	0.156	0.183	0.200	0.211	0.236
2016	0.120	0.129	0.138	0.158	0.171	0.181	0.202
2017	0.112	0.118	0.123	0.136	0.147	0.156	0.175
2018	0.102	0.114	0.117	0.126	0.139	0.145	0.152
2019	0.097	0.106	0.112	0.120	0.134	0.141	0.153
2020	0.095	0.102	0.107	0.117	0.127	0.132	0.140
2021	0.090	0.097	0.103	0.112	0.127	0.132	0.144
2022	0.086	0.094	0.099	0.108	0.122	0.129	0.140
2023	0.078	0.091	0.096	0.111	0.122	0.127	0.137
2024	0.083	0.089	0.094	0.107	0.121	0.123	0.136
2025	0.081	0.086	0.090	0.104	0.116	0.123	0.134
2026	0.083	0.087	0.094	0.103	0.117	0.121	0.137
2027	0.074	0.084	0.088	0.098	0.121	0.128	0.145
2028	0.074	0.080	0.087	0.097	0.112	0.124	0.133
2029	0.068	0.078	0.082	0.098	0.113	0.119	0.147
2030	0.068	0.076	0.086	0.097	0.113	0.118	0.135

Table 7. Percentiles for the projected exploitable biomass under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV).

Year	5%	15%	25%	50%	75%	85%	95%
2010	67253	70732	73075	78490	84367	85883	91608
2011	55603	60489	63163	68090	71444	74258	81487
2012	48179	52814	55496	60662	64407	69210	74044
2013	50172	53466	54855	61372	68509	72930	77967
2014	58887	63018	66292	71301	78611	82276	87384
2015	71671	74959	78239	82572	90963	96361	103306
2016	82535	85584	87636	93270	103193	107278	115816
2017	94659	99958	102289	108954	117484	122225	130801
2018	102255	109354	114292	119569	129975	134093	140662
2019	106371	114233	116946	124523	132300	136220	143815
2020	107046	116738	121304	126915	135219	140526	151269
2021	113321	118423	121941	128255	136680	142695	150907
2022	116163	121101	123944	129443	138666	142106	152141
2023	115571	121590	123833	129852	140914	145732	152462
2024	117760	120721	124737	131571	140906	145470	151582
2025	118154	122428	125718	132929	140787	146507	153610
2026	117181	122952	125345	133997	140181	142794	152269
2027	116908	122466	124898	132355	139740	145392	152988
2028	115207	121536	125952	133094	139356	147071	151971
2029	113115	119873	125959	132858	141364	145815	154001
2030	114287	121776	124969	133213	139967	145642	153439

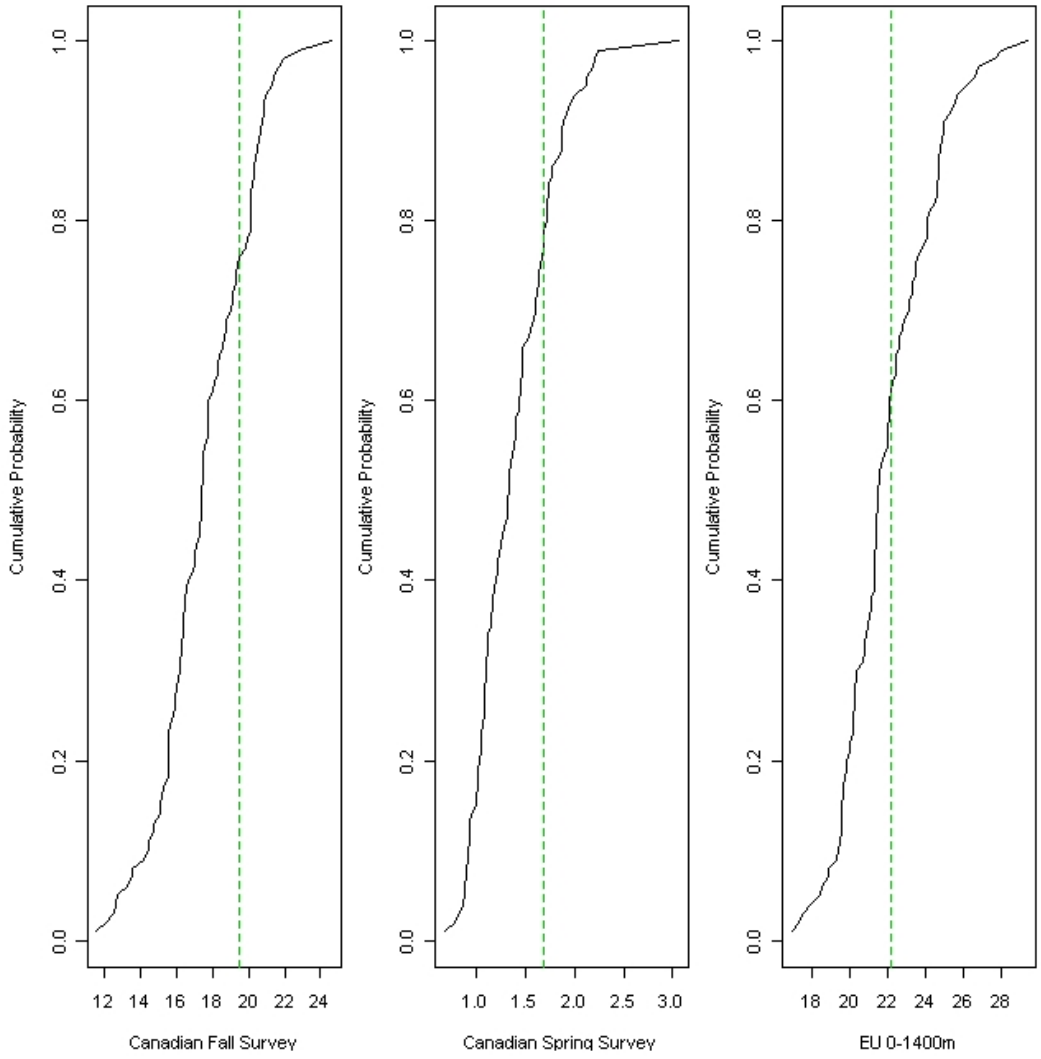

Fig. 1. Cumulative frequency distribution for the projected survey biomass (mean weight per tow) at the beginning of 2010 under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV). Vertical broken lines lines are the results from the 2010 surveys (see Healey, 2011a, for Canadian surveys; Casas and Gonzalez Troncoso, 2011, for EU survey).

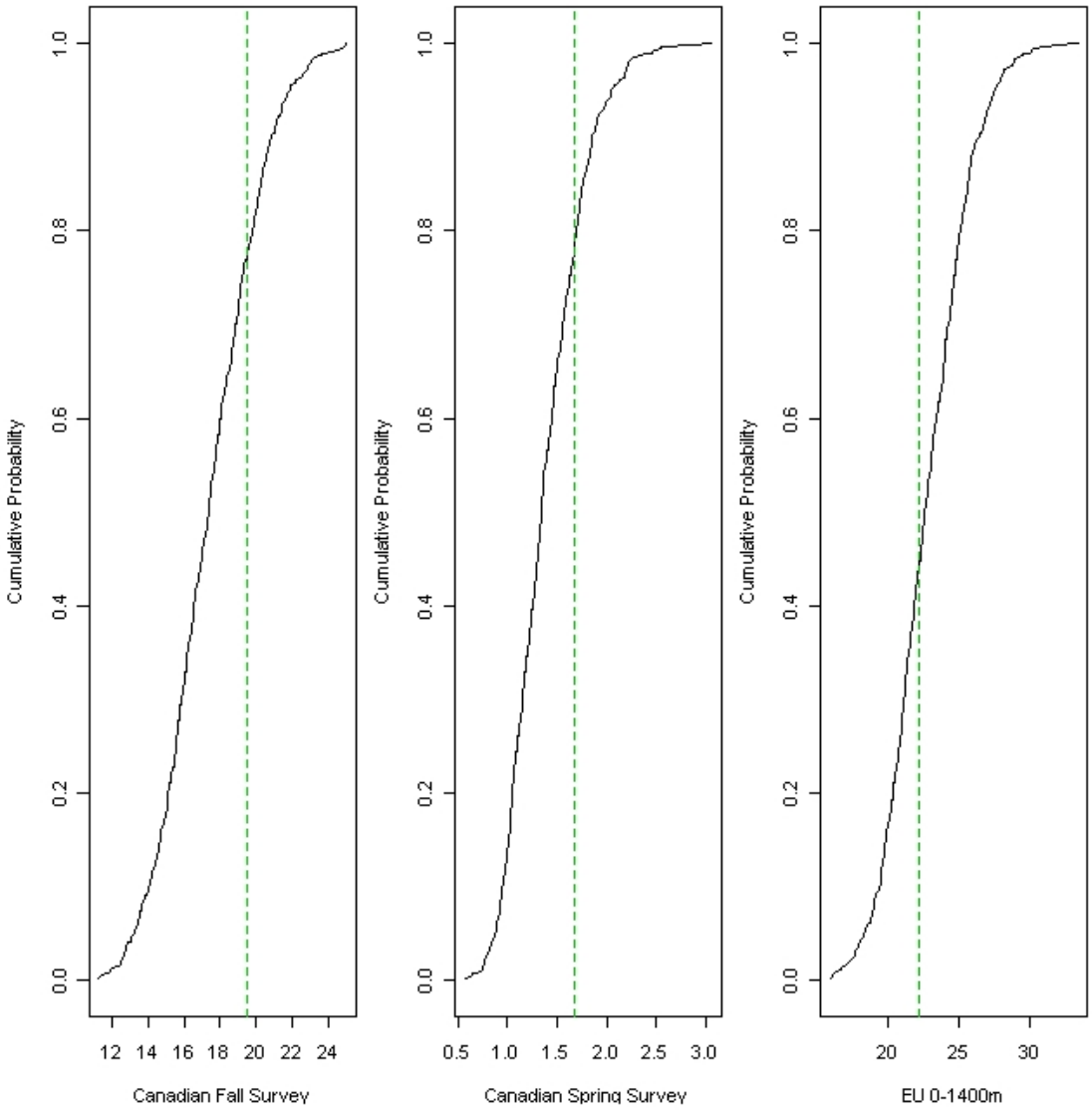

Fig. 2. Cumulative frequency distribution for the projected survey biomass (mean weight per tow) at the beginning of 2010 under the adopted Management Strategy for all XSA-based operating models. Vertical broken lines lines are the results from the 2010 surveys (see Healey, 2011a for Canadian surveys; Casas and Gonzalez Troncoso, 2011, for EU survey).

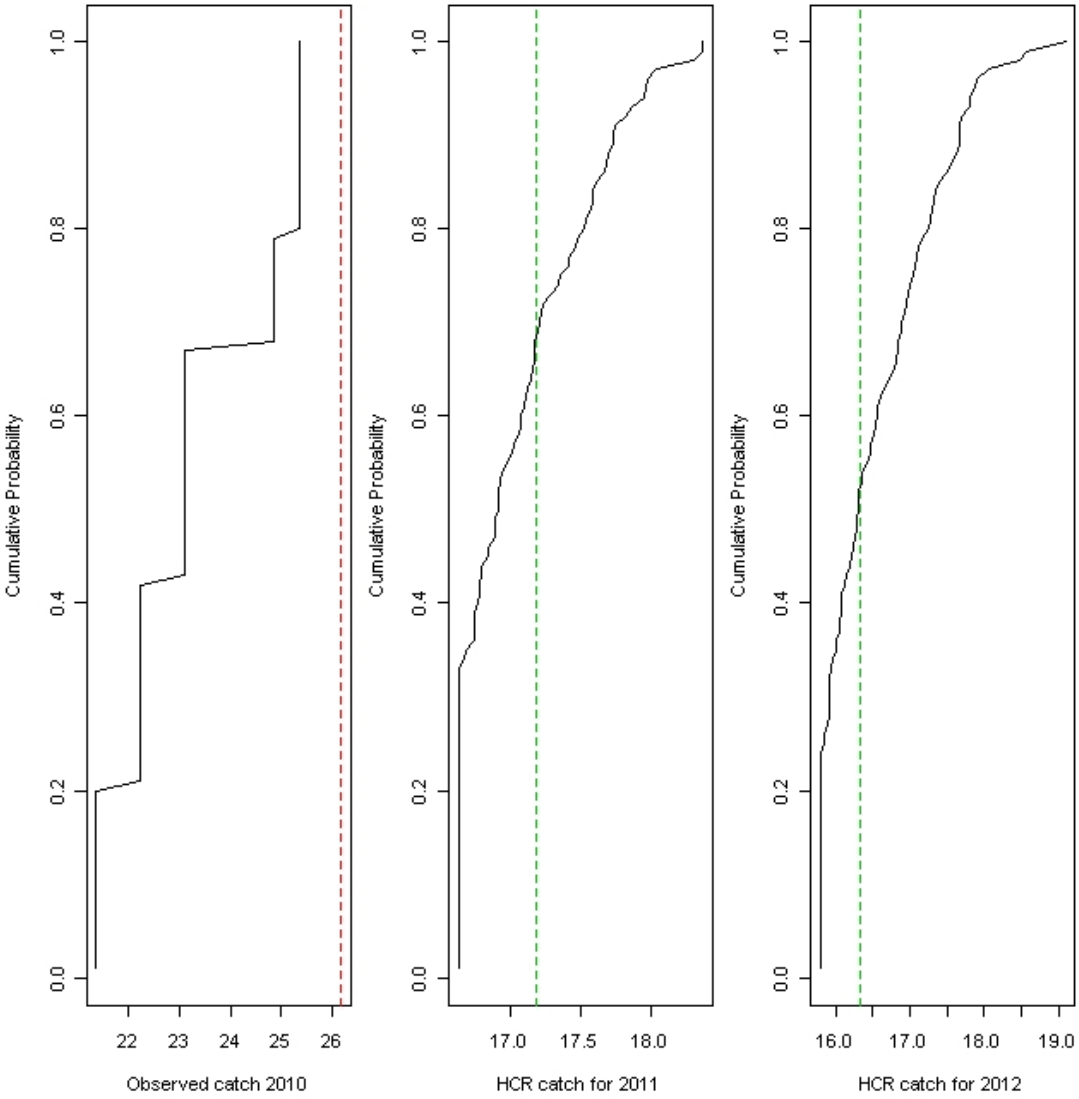

Fig. 3. Cumulative frequency distribution for the projected catch values for 2010 under the adopted Management Strategy for the XSA-based Current Assessment View operating model (CAV). Vertical broken lines lines are the corresponding estimates from the 2011 stock assessment (Healey, 2011b).

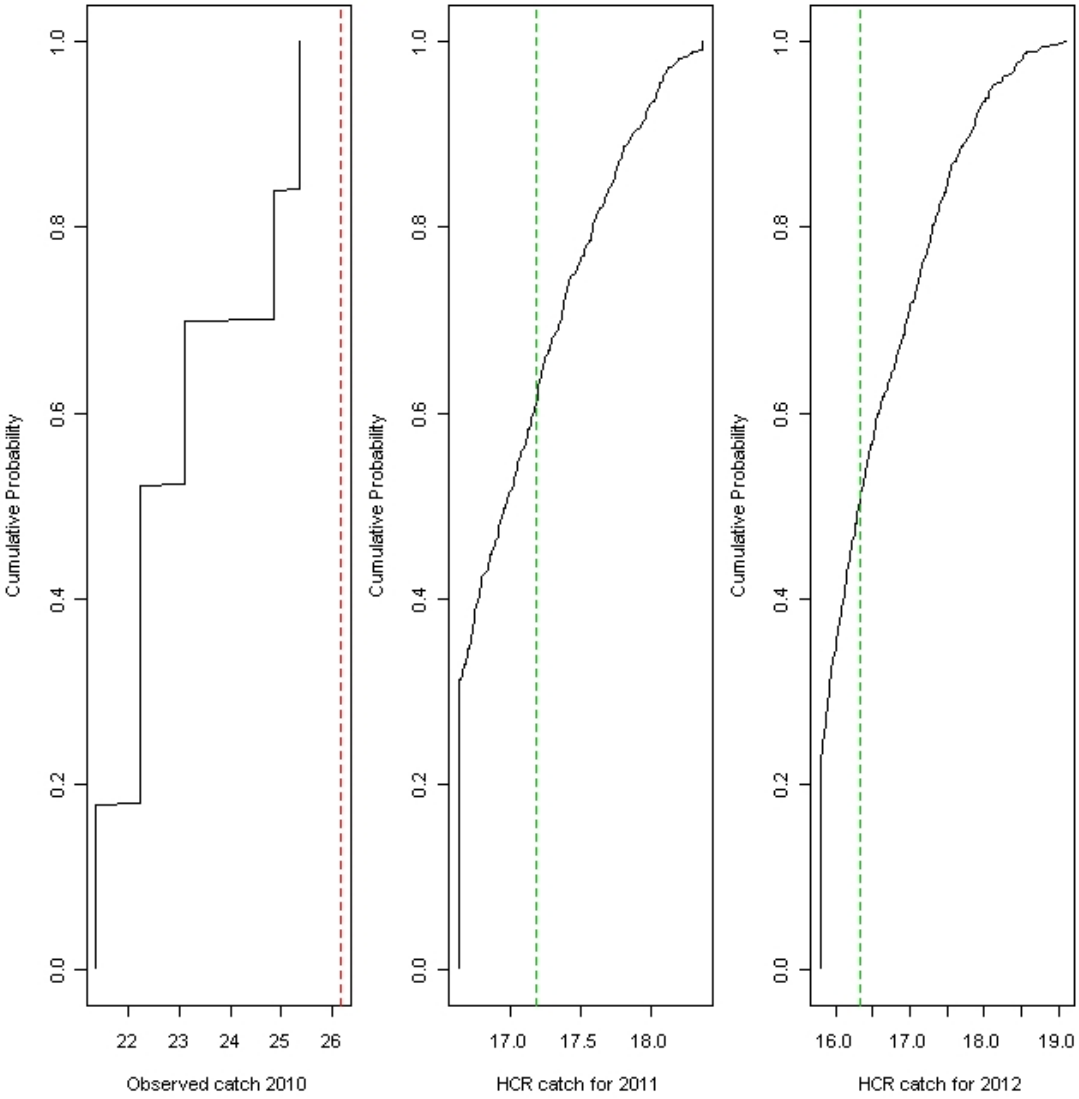

Fig. 4. Cumulative frequency distribution for the projected catch values for 2010 -12 under the adopted Management Strategy for all XSA-based operating models. Vertical broken lines lines are the corresponding estimates from the 2011 stock assessment (Healey, 2011b). For 2011 and 2012 the vertical lines are calculated by applying the adopted management strategy harvest control rule to the observed simulated survey data.

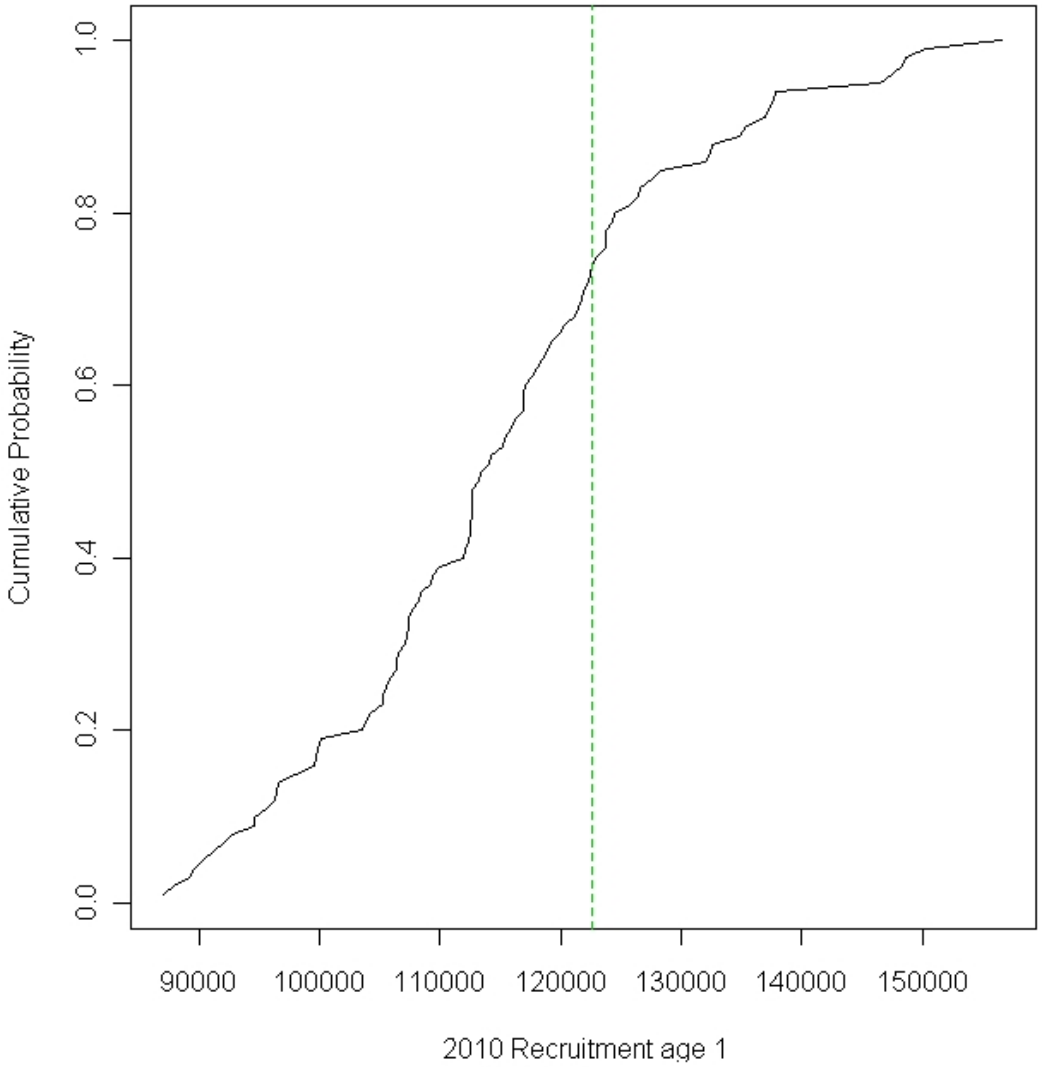

Fig. 5. Cumulative frequency distribution for the projected recruitment (age 1, thousands) at the beginning of 2010 under the adopted Management Strategy for the XSA-based CAV operating models. The vertical broken line represents the corresponding estimate from the 2011 stock assessment (Healey, 2011b).

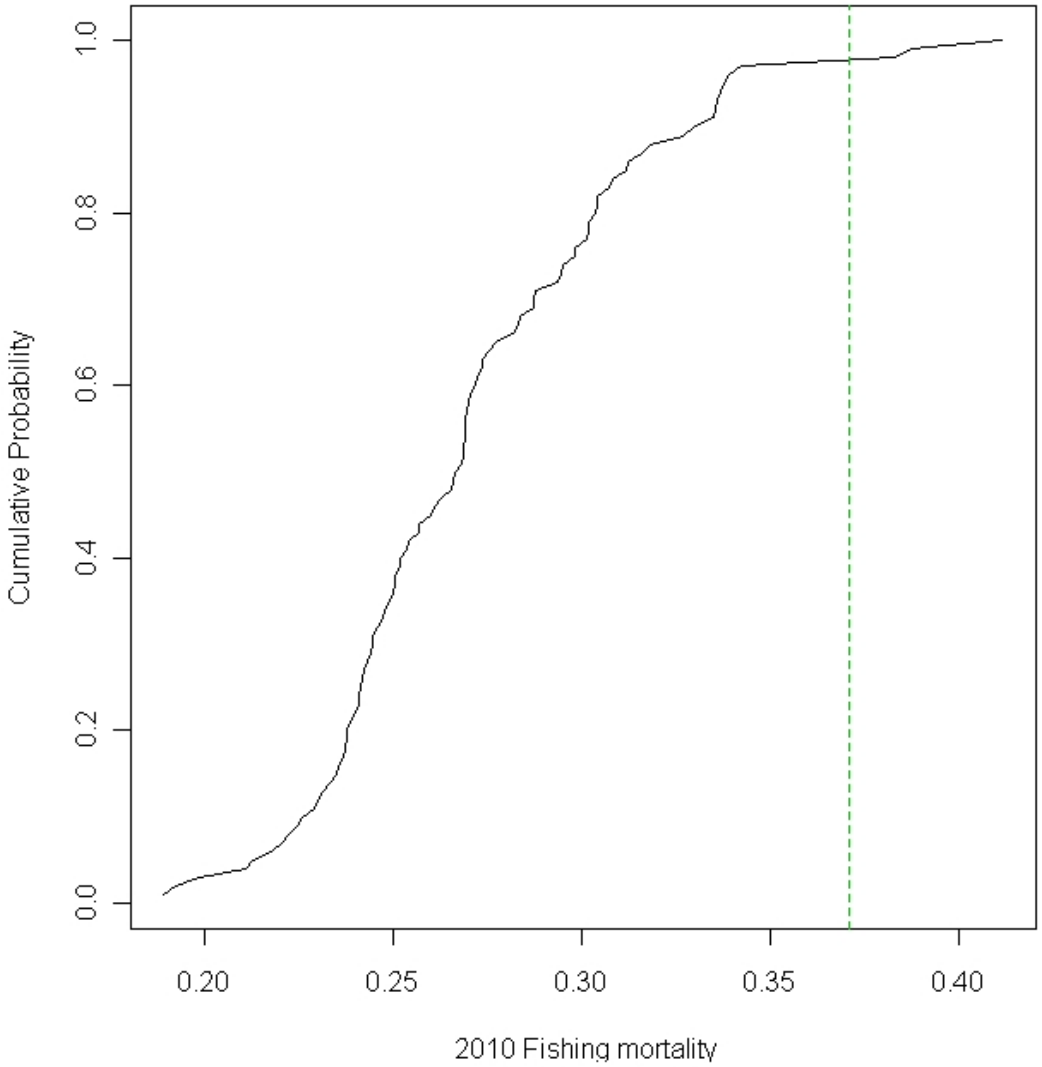

Fig. 6. Cumulative frequency distribution for the projected fishing mortality (average age 5-10) in 2010 under the adopted Management Strategy for the XSA-based CAV operating models. The vertical broken line represents the corresponding estimate from the 2011 stock assessment (Healey, 2011b).

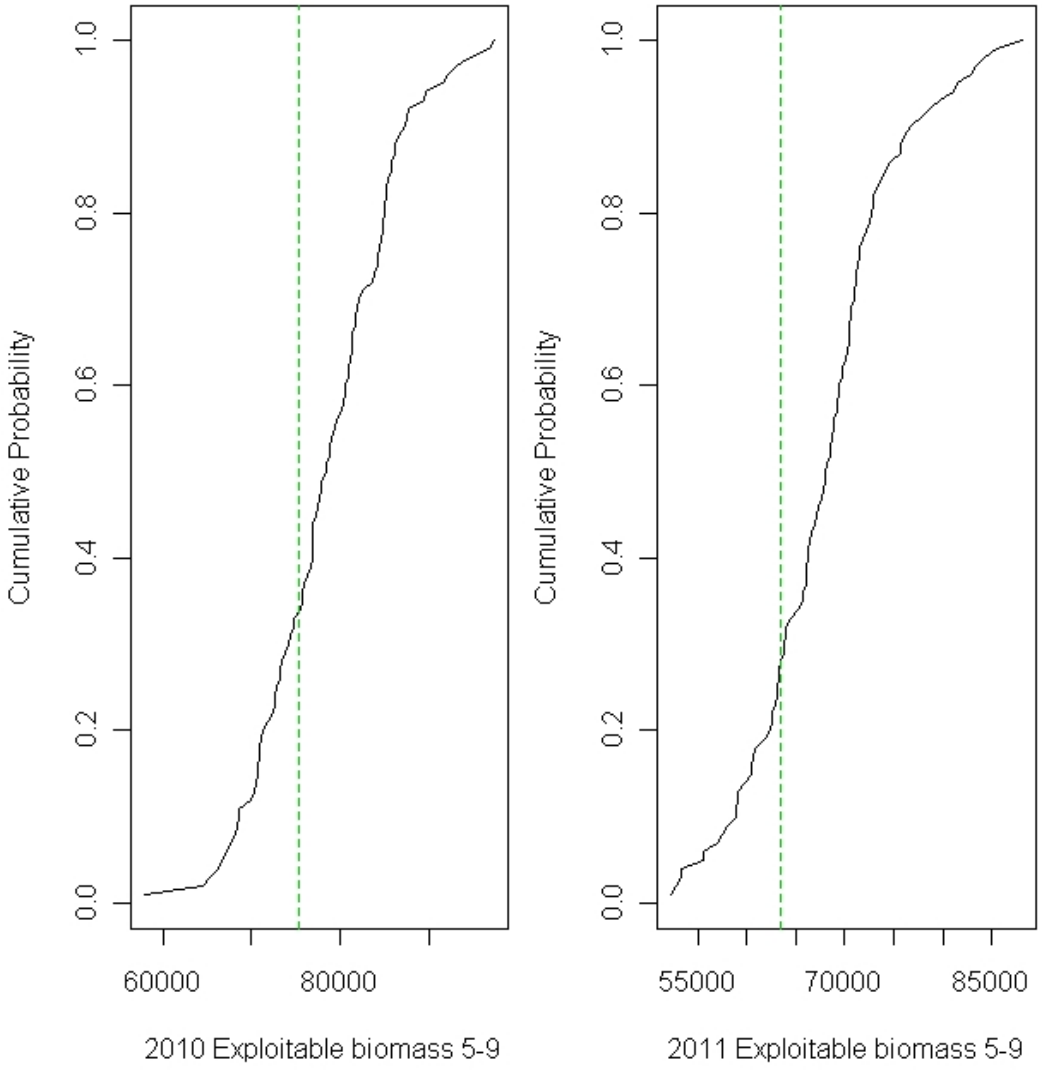

Fig. 7. Cumulative frequency distribution for the projected exploitable biomass (5-9) in 2010 and 2011 under the adopted Management Strategy for the XSA-based CAV operating models. The vertical broken lines represent the corresponding estimate from the 2011 stock assessment (Healey, 2011b).

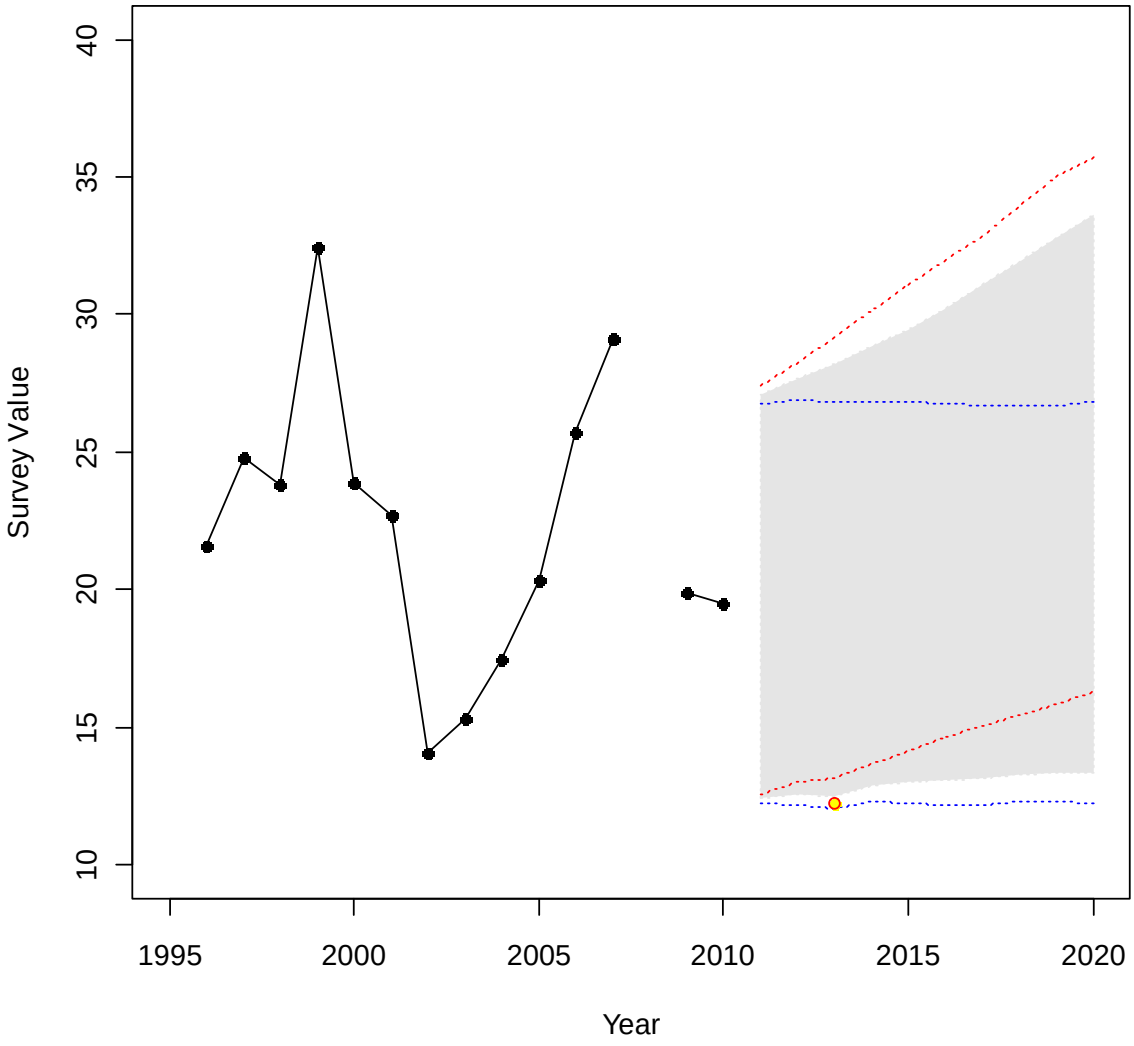

Fig. 8. Illustrative simulation of survey data. Lines/solid circles indicate observed values over 1996-2010 (2008 survey incomplete), dashed lines indicate empirical 90% CIs under two assumptions about the survey mean, and shaded polygon demarcates empirical 90% CI for composite distribution (i.e. both sets of generated data). Open circle in year 2013 is a hypothetical survey value.