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CMP projections under XSA in comparison to the SCAA baseline (OM0)

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Summary

As an illustrative exercise, the CMP testing framework is applied to an Operating Model provided by an XSA assessment to show how this may be done. Results are reported for the CMP1 candidate management procedure, and performance statistics indicate reasonable robustness compared to those for the SCAA OM0. The results given should, however, not be over-interpreted as the XSA assessment used is not necessarily agreed and accepted at this time.

Introduction

It is important not to confuse an assessment method (e.g. SCAA, SAM-style, XSA) used to provide Operating Models (OMs) for CMP testing (for Greenland halibut) with the broadly agreed common projection specifications used to generate future data and performance statistics, as are set out in Appendix B of Rademeyer and Butterworth (2017).

This document provides an example to show how results from XSA can be used in this manner to provide such performance statistics for the CMP1 candidate management procedure (though given that the XSA results available did not provide all the information required, a few further assumptions had to be made, as detailed below)..

Although comparative results for the SCAA OM0 baseline are also shown, given that the XSA results were obtained merely to provide an example and do not necessarily constitute an agreed and accepted implementation of XSA at this time, these comparison should be regarded as illustrative rather than definitive.

Data

Numbers-at-age, fishing mortality-at-age and catchability-at-age for each of the four surveys, as estimated for the XSA "run4" have been kindly provided by Brian Healey (pers. commn). These results are listed in Appendix A.

Methods

Projections into the future under a specific CMP are evaluated using steps 1-7 in Appendix B of Rademeyer and Butterworth (2017). Given, however, limitations associated with the XSA information available, the following modifications and further assumptions have been made.

Step 1: Begin-year numbers at age

The components of the numbers-at-age vector at the start of 2016 ($N_{2016,a}$: a = 2,…, m) are given in Table App.A.1. The 2016 recruitment ($N_{2016,1}$) is not available and is therefore computed from the stock-recruitment curve (see step 4 for details on the estimation of the stock-recruit parameters):

$$N_{2016,1} = \frac{\alpha B_{2015}^{sp}}{\beta + B_{2015}^{sp}} \quad (1)$$

Error is included for all ages to allow for estimation imprecision in the assessment:

$$N_{2016,a} \rightarrow N_{2016,a} e^{\varepsilon_a} \quad (2)$$

where ε_a is generated from the variance-covariance matrix obtained from the SCAA baseline OM0, as this information is not available for the XSA assessment in question. Note that this variance-covariance matrix is for ln$N_{2016,a}$, i.e the same *relative* error size is assumed, which makes allowance for scale differences between the XSA and OM0 results.

Step 2: Catch

These numbers-at-age are projected one year forward at a time given a catch for the year concerned as for the SCAA projections. This requires specification of how the catch is disaggregated by age to obtain $C_{y,a}$, and how future recruitments are specified, which is set out in Step 3 below.

Step 3: Catch-at-age (by number)

The past commercial selectivity function is computed from the fishing mortality-at-age:

$$S_{y,a} = \frac{F_{y,a}}{F_y} \quad (3)$$

where F_y is the maximum fishing mortality over ages 1 to 10+ for year y.

Future commercial selectivity is taken to be the average of the last five years (2011 to 2015):

$$S_a^{fut} = \frac{\sum_{y=2011}^{2015} S_{y,a}}{5} \quad (4)$$

Step 4: Recruitment

Future recruitments are provided by a Beverton-Holt stock-recruitment relationship:

$$R_y = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} e^{(\varphi_y - (\sigma_R)^2/2)} \quad (5)$$

where

α is the asymptotic recruitment, computed as the average of the 1975-2010 recruitment values, excluding the values associated with the lowest 20% of the spawning biomasses;

$$\beta = \frac{b_0(1-h)}{5h-1} \quad (6)$$

with

$$b_0 = r_0 \sum_{a=1}^{m-1} f_a w_{y,a}^{strt} e^{-\sum_{a'=1}^{a-1} M_{a'}} + f_m w_{y,m}^{strt} \frac{e^{-\sum_{a'=1}^{m-1} M_{a'}}}{1-e^{-M_m}} \quad (7)$$

and

$$r_0 = \frac{\alpha(5h-1)}{4h} \quad (8)$$

The steepness parameter h is taken as 0.99 for a reasonable representation of the spawning biomass and recruitment estimates from the XSA (see Figure 1).

As with the SCAA projections, log-normal fluctuations are introduced by generating φ_y factors which also take account of autocorrelation:

$$\varphi_y = \rho\varphi_{y-1} + \sqrt{1-\rho^2}\lambda_y$$

with λ_y from $N(0,(\sigma_R)^2)$ where σ_R is input (0.4) and ρ is fixed at 0.5 (based on results from the SCAA baseline assessment).

Step5:

The information obtained in Step 1 is used to generate values of the abundance indices I_{2016}^i (in terms of biomass or of numbers), and similarly for following years. The EU survey is assumed to continue sampling the 0-1400m depth zone. Indices of abundance in future years will not be exactly proportional to true abundance, as they are subject to observation error. Log-normal observation error is therefore appended to the expected value of the abundance index evaluated, i.e.:

$$I_y^i = q^i B_y^i e^{\varepsilon_y^i} \quad (9)$$

with

ε_y^i from $N\left(0,\left(\sigma^i\right)^2\right)$

where

B_y^i is the biomass available to the survey:

$$B_y^i = \sum_{a=0}^{m} w_{y,a}^i S_a^i N_{y,a} e^{-Z_{y,a}T^i/12} \quad (10)$$

The survey selectivities are computed from the estimated catchability-at-age (Table App.A.3):

$$S_a^i = \frac{q_a^i}{\max(q_a^i)} \tag{11}$$

They are assumed to remain unchanged over the projection period.

The constant of proportionality q^i and residual standard deviation σ^i have been estimated directly from the XSA outputs:

$$\sigma^i = \sqrt{\frac{1}{n^i}\sum_y \left(lnI_y^i - ln\left(q^i B_y^i\right)\right)^2} \tag{12}$$

The constant of proportionality q^i for survey biomass index *i* is estimated by its maximum likelihood value:

$$lnq^i = \frac{1}{n^i}\sum_y\left(lnI_y^i - lnB_y^i\right) \tag{13}$$

Step 6:

Given the new survey indices I_y^i compute TAC_{y+1} using the CMP (aside from the fixed values assumed for 2016 to 2018).

Step 7:

Steps 1-6 are repeated for each future year in turn for as long a period as desired, and at the end of that period the performance of the CMP under review is assessed by considering statistics such as the average catch taken over the period and the final spawning biomass of the resource.

The results reported here are for CMP1 with comparable results for the SCAA baseline OM0.

Results[1]

Assessment

Assessment results are compared for the XSA and SCAA OM0 baseline in Figure 2 and Table 1.

CMP projections

Medians and lower 5%iles for projected catch, spawning and exploitable biomass are compared for the SCAA baseline OM0 and XSA under CMP1 in Figure 3. The corresponding performance measures are given in Table 2, with some of the performance measures compared graphically in Figure 4.

[1] Subsequent to the meeting at which this document was presented, a glitch was found in the projection code used which introduces some changes to the results given here. This matter is detailed further in footnote 1 of document **NAFO SCR Doc. 17-026REV.** As indicated in that footnote, these changes would not be of particular consequence for the differences in the results presented for different OMs and the associated inferences.

Discussion

As stated in the Introduction, this is an illustrative rather than a definitive exercise and comparison, so it would be inappropriate to draw over-firm conclusions from the results. Discussion here is therefore limited to a few broad points only.

- A value of steepness *h*=0.99 seems rather high for the stock-recruitment function for XSA, but the results of that assessment do indicate that a high recruitment can be maintained down to relatively rather low values of spawning biomass (Figure 1).
- Spawning biomass is much lower in absolute terms for XSA than for OM0, but exploitable biomass and recruitment estimates are not greatly dissimilar in scale (Figure 2).
- Broadly speaking, the performances for CMP1 under XSA and OM0 are quite similar (Table 2 and Figures 2, 3 and 4).
- The important differences appears mainly to be in the B_{low} statistic (Figure 4), but this is unsurprising since the XSA projections start at a lower fraction of B_{MSY} than do those for the SCAA OM0. Nevertheless CMP1 secures acceptable resource recovery (Figures 3 and 4).

References

NAFO. 2017. Report of the NAFO Joint Fisheries Commission-Scientific Council Working Group on Risk-Based Management Strategies (WG-RBMS), 25-27 April 2017, Holiday Inn, Falmouth, MA, USA. NAFO document NAFO/FC-SC Doc. 17-xx. xx pp.

Rademeyer R.A. and Butterworth D.S. 2017. Results for Initial Candidate Management Procedure Testing for Greenland Halibut. NAFO document: SCR Doc 17-026.

Table 1: Comparison of SCAA baseline OM0 and XSA results.

	OM0	XSA
h	**0.80**	**0.99**
M	**0.12**	**0.12**
K^{sp}	880.50	558.67
$B^{sp}{}_{1960}$	901.26	-
$B^{sp}{}_{1975}$	577.45	52.41
$B^{sp}{}_{2015}$	133.58	2.93
$B^{sp}{}_{2015}/K^{sp}$	0.15	0.01
$B^{sp}{}_{2015}/B^{sp}{}_{1975}$	0.23	0.06
$B^{5\text{-}9}{}_{1975}$	173.10	140.70
$B^{5\text{-}9}{}_{2015}$	109.19	67.93
$B^{5\text{-}9}{}_{2015}/B^{5\text{-}9}{}_{1975}$	0.63	0.48
	σ index	σ index
Can. Fall 2J3K	0.19	0.26
EU 3M 0-700m	0.29	0.40
EU 3M 0-1400m	0.20	0.21
Can. Spring 3LNO	0.52	0.54
MSY	26.86	35.72
F_{MSY}	0.39	0.37
$F^{5\text{-}9}{}_{MSY}$	0.22	0.18
$B^{sp}{}_{MSY}$	182.54	82.58
$B^{sp}{}_{MSY}/K^{sp}$	0.21	0.15
$B^{sp}{}_{2015}/B^{sp}{}_{MSY}$	0.73	0.04
$B^{5\text{-}9}{}_{MSY}$	123.25	115.40
$B^{5\text{-}9}{}_{2015}/B^{5\text{-}9}{}_{MSY}$	0.89	0.59

Table 2: Performance measures for CMP1 for the SCAA baseline OM0 and XSA; the pink highlights show instances where desired performance criterion specified by the Falmouth RBMS meeting (NAFO 2017) has not been met.

Management objective	1. Restore to within a prescribed period of time or maintain at Bmsy			2. The risk of failure to meet the Bmsy target and interim biomass targets within a prescribed period of time should be kept moderately low			3. Low risk of exceedin g F_{msy}	4. Very low risk of going below an established threshold				5. Maximize yield in the short, medium and long term		6. The risk of steep decline of stock biomass should be kept moderately low		7. Keep inter annual TAC variation below "an established threshold"
Perf. stats	$B^{5\text{-}9}_{2037}/B^{5\text{-}9}_{msy}$	$B^{5\text{-}9}_{2037} < B^{5\text{-}9}_{msy}$	$B^{5\text{-}9}_{2037} < 0.8B^{5\text{-}9}_{msy}$	$B^{5\text{-}9}_{lowest}/B^{5\text{-}9}_{msy}$	$B^{5\text{-}9}_{2022} < B^{5\text{-}9}_{2018}$		$(F_{2018\text{-}2037} > F_{msy}) > 0.3$	$B^{sp}_{2037}/B^{sp}_{2018}$	$B^{5\text{-}9}_{2037}/B^{5\text{-}9}_{2018}$	$(B^{5\text{-}9}_{2018\text{-}2037} < 0.3B^{5\text{-}9}_{msy}) > 0.1$	$B^{5\text{-}9}_{lowest}/B^{5\text{-}9}_{msy} < 0.3$	avC: 2018-2020	avC: 2018-2037	$B^{5\text{-}9}_{2037} < 0.75B^{5\text{-}9}_{2018}$		AAV: 2018-2037
	median (90%PI)	Proportion	Proportion	median (90%PI)	Proportion		Count	median (90%PI)	median (90%PI)	Count	Proportion	median (90%PI)	median (90%PI)	Proportion		median (90%PI)
Criteria		<=0.5	<=0.25		<Ω	Ω					<=0.1			<β	β	
OM0	1.00 (0.45; 1.83)	0.49	0.22	0.81 (0.42; 1.07)	0.31	0.25	5	1.35 (0.56; 2.53)	0.89 (0.35; 1.59)	0	0.00	15.39 (15.10; 15.81)	21.85 (17.36; 29.02)	0.02	0.25	3.64 (1.38; 6.50)
XSA	1.06 (0.68; 1.83)	0.42	0.12	0.63 (0.48; 0.86)	0.18	0.25	0	4.44 (2.02; 10.11)	1.47 (0.65; 2.95)	0	0.00	15.37 (15.12; 15.74)	24.10 (18.84; 30.87)	0.01	0.15	5.15 (3.15; 7.25)

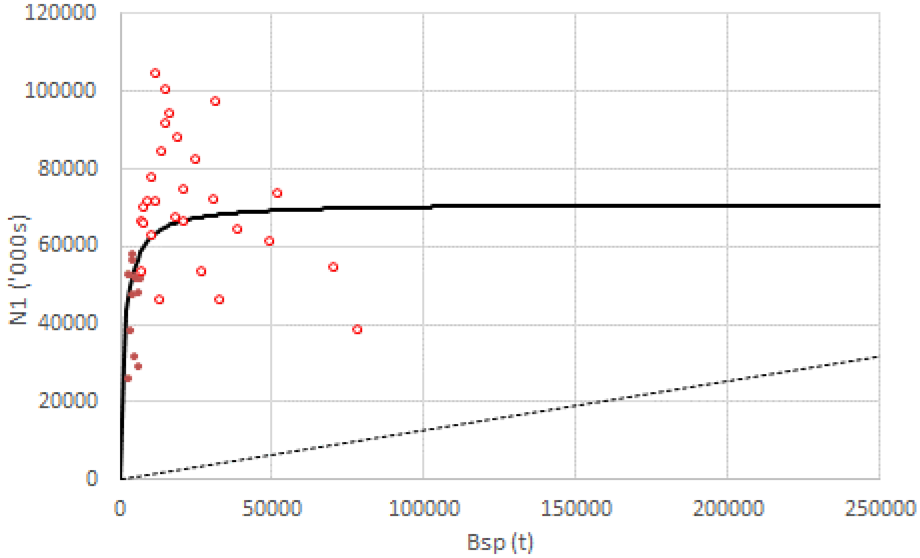

Fig. 1. The estimated stock-recruitment curve for *h*=0.99 compared to the XSA spawning biomass and recruitment estimates. The open dots have been used in the estimation of the asymptotic recruitment. The dotted line through the origin is the replacement line

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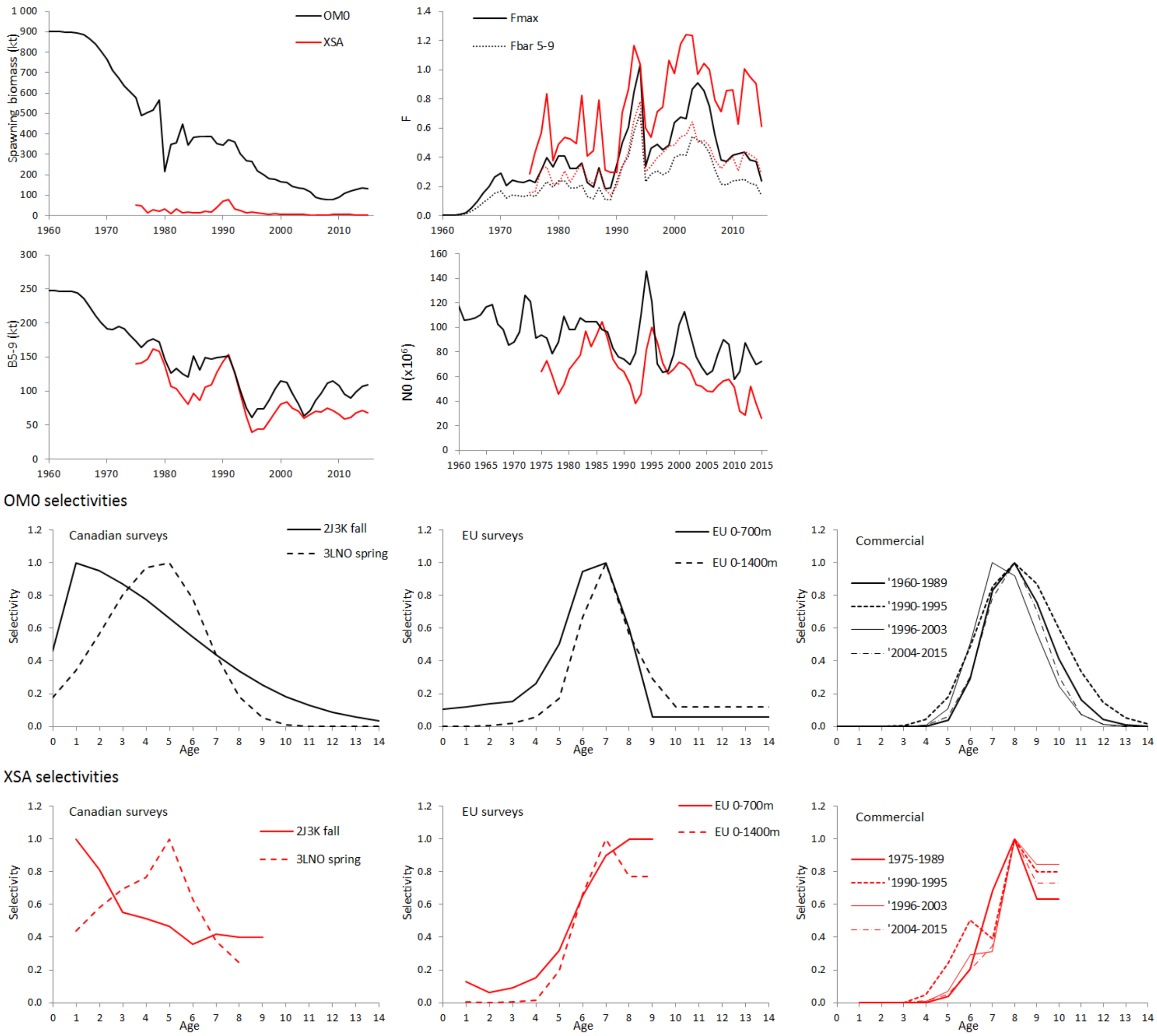

Fig.2. Comparison of the results for the SCAA baseline (OM0) assessment with those for XSA "run4".

Fig. 3. Projected median and lower 5%iles for catch, spawning and exploitable biomass (both relative to B_{MSY}) and F/F_{MSY} (for which the upper 5%iles are plotted instead of lower 5%iles) for the SCAA baseline OM0 and XSA “run4”under CMP1.

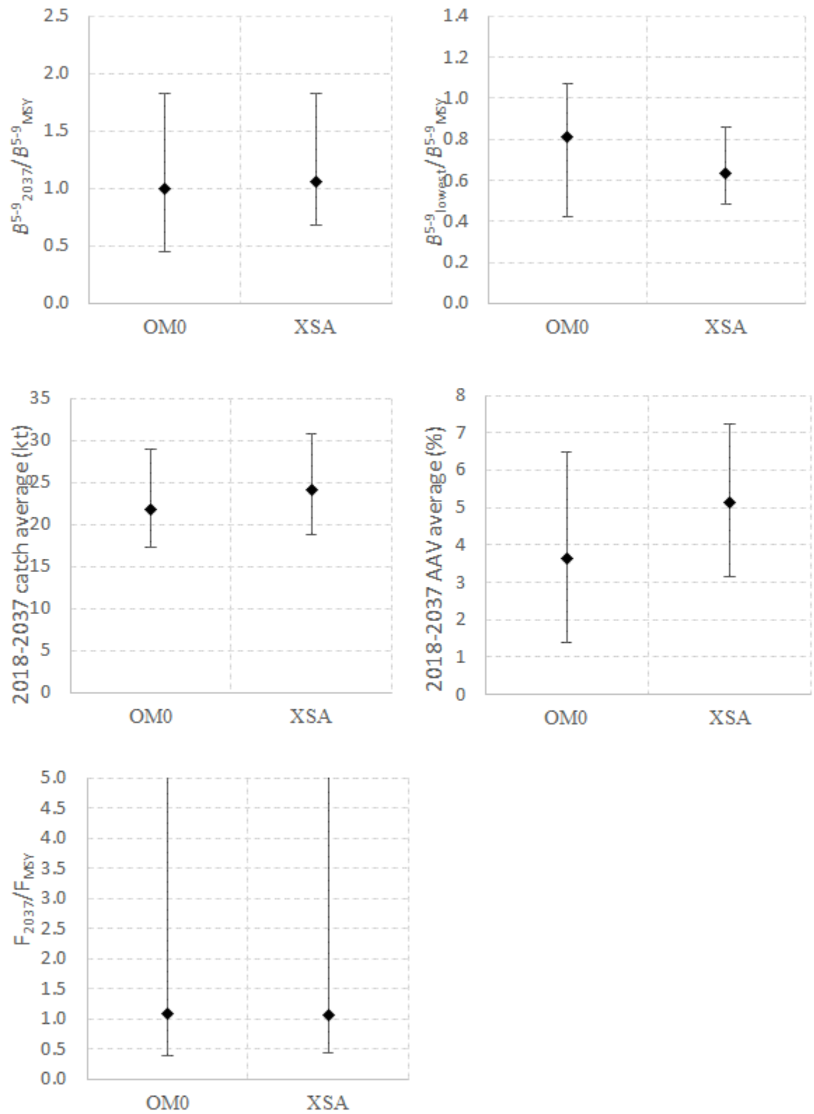

Fig. 4. Projected median and 90% PIs for a series of performance statistics for the SCAA baseline OM0 and XSA “run4” under CMP1.

Appendix A – XSA outputs

Table App.A.1: XSA "run4" numbers-at-age (in thousands).

	1	2	3	4	5	6	7	8	9	10+
1975	64142	97533	83813	74629	36059	29744	24540	29734	23620	18391
1976	73151	56889	86504	74335	66190	31667	23725	16350	21704	19803
1977	60956	64879	50456	76722	65929	58689	27512	18000	9403	4988
1978	45810	54063	57543	44751	68047	57971	47333	14232	9046	9453
1979	53226	40629	47949	51036	39690	57544	43491	33533	5487	6289
1980	65912	47207	36035	42527	45265	32955	42818	26496	23962	22338
1981	71704	58459	41869	31960	37718	39949	27264	29359	14384	4655
1982	77571	63596	51848	37134	28346	32640	31178	14946	15255	12404
1983	97201	68799	56404	45985	32935	24887	26784	21701	7829	4273
1984	84242	86209	61020	50026	40785	28551	18723	14526	12171	6217
1985	93757	74716	76461	54120	44369	35324	23134	11102	5649	3846
1986	104456	83155	66267	67815	48000	37484	26330	14949	6551	4631
1987	91228	92644	73752	58773	60146	42308	31136	17315	8464	6215
1988	74257	80912	82168	65412	52127	53216	35733	17252	6942	5412
1989	67042	65860	71762	72876	58015	45954	44198	24030	11176	12703
1990	63860	59461	58413	63647	64635	51284	38885	32156	17288	23410
1991	54113	56639	52737	51808	56361	56289	39121	22592	21403	23195
1992	38262	47994	50234	46774	45742	47292	42619	22311	9870	9599
1993	45854	33936	42567	44554	40483	36633	31658	18363	8294	7855
1994	82030	40669	30098	37753	38565	26892	17490	11394	5062	4667
1995	99993	72754	36070	26695	28403	18665	8957	5019	3759	5092
1996	87966	88685	64527	31991	23372	23918	14348	4930	2446	3573
1997	71211	78019	78657	57230	28195	19167	16319	6711	2570	3357
1998	62449	63159	69196	69762	50443	23214	13073	7369	2924	2471
1999	65948	55388	56017	61372	61354	41372	15497	6145	3096	2900
2000	71424	58491	49124	49683	54152	52392	31396	5635	1878	2549
2001	69810	63347	51877	43570	43809	46118	34617	7904	1891	2539
2002	65637	61916	56184	46010	38221	36747	29448	9869	2157	2489
2003	53284	58215	54915	49796	40356	32334	25774	9561	2531	1722
2004	52279	47259	51632	48514	42960	31563	18579	7072	2467	2178
2005	47975	46367	41915	45777	42183	34277	20238	6550	2386	1528
2006	47549	42550	41124	37137	40098	35857	24751	8237	2046	1168
2007	52830	42172	37739	36464	32735	33804	25728	10516	2689	1704
2008	56228	46856	37403	33471	32258	28496	26466	11600	4228	1722
2009	57643	49869	41557	33173	29659	28188	22155	13400	5054	2181
2010	51640	51125	44230	36858	29365	25857	22062	11361	5032	1970
2011	31657	45801	45344	39229	32553	25267	18152	9017	4265	2419
2012	28846	28077	40622	39811	34143	27567	18548	9265	4275	2435
2013	51817	25584	24902	34883	34645	28415	21227	9276	3010	1328
2014	38266	45957	22691	21967	30486	28876	20635	13276	3170	1072
2015	26018	33939	40760	20013	19235	25997	22015	12854	4767	1000
2016	0	23076	30101	36096	17666	16656	21892	15724	6178	3325

Table App.A.2: XSA "run4" fishing mortality-at-age.

	1	2	3	4	5	6	7	8	9	10+
1975	0	0	0	0	0.0099	0.1061	0.2861	0.1948	0.1961	0.1961
1976	0	0	0	0	0.0003	0.0207	0.1562	0.4332	0.2038	0.2038
1977	0	0	0	0	0.0086	0.0951	0.5391	0.5680	0.4023	0.4023
1978	0	0	0	0	0.0477	0.1674	0.2247	0.8330	0.4099	0.4099
1979	0	0	0	0	0.0660	0.1756	0.3756	0.2160	0.2564	0.2564
1980	0	0	0	0	0.0049	0.0696	0.2574	0.4908	0.2734	0.2734
1981	0	0	0	0	0.0246	0.1279	0.4811	0.5347	0.3826	0.3826
1982	0	0	0	0	0.0101	0.0777	0.2423	0.5267	0.2831	0.2831
1983	0	0	0	0	0.0229	0.1646	0.4919	0.4583	0.3729	0.3729
1984	0	0	0	0	0.0238	0.0904	0.4026	0.8245	0.4409	0.4409
1985	0	0	0	0	0.0486	0.1739	0.3166	0.4076	0.3003	0.3003
1986	0	0	0	0	0.0062	0.0656	0.2991	0.4488	0.2720	0.2720
1987	0	0	0	0	0.0024	0.0489	0.2991	0.7940	0.4395	0.4395
1988	0	0	0	0	0.0060	0.0657	0.2991	0.3141	0.2194	0.2194
1989	0	0	0	0	0.0033	0.0470	0.2991	0.2093	0.1518	0.1518
1990	0	0	0	0.0016	0.0183	0.1507	0.2991	0.2871	0.2878	0.2878
1991	0	0	0	0.0045	0.0554	0.1582	0.2991	0.7081	0.4377	0.4377
1992	0	0	0	0.0245	0.1021	0.2813	0.2991	0.8696	0.6275	0.6275
1993	0	0	0	0.0244	0.2890	0.6193	0.2991	1.1685	0.9022	0.9022
1994	0	0	0	0.1646	0.6057	0.9794	0.2991	0.9889	1.0391	1.0391
1995	0	0	0	0.0129	0.0519	0.1430	0.2991	0.5990	0.4067	0.4067
1996	0	0	0	0.0063	0.0784	0.2623	0.2991	0.5315	0.5363	0.5363
1997	0	0	0	0.0062	0.0744	0.2626	0.2991	0.7107	0.6361	0.6361
1998	0	0	0	0.0084	0.0782	0.2841	0.2991	0.7473	0.7362	0.7362
1999	0	0	0	0.0052	0.0379	0.1559	0.2991	1.0655	0.8418	0.8418
2000	0	0	0	0.0058	0.0406	0.2944	0.2991	0.9719	0.7989	0.7989
2001	0	0	0	0.0110	0.0558	0.3286	0.2991	1.1789	0.8373	0.8373
2002	0	0	0.0007	0.0111	0.0473	0.2347	0.2991	1.2408	0.9480	0.9480
2003	0	0	0.0039	0.0277	0.1258	0.4341	0.2991	1.2348	1.1305	1.1305
2004	0	0	0.0003	0.0198	0.1058	0.3244	0.2991	0.9664	0.8270	0.8270
2005	0	0	0.0010	0.0125	0.0425	0.2056	0.2991	1.0436	0.9873	0.9873
2006	0	0	0.0003	0.0062	0.0508	0.2120	0.2991	0.9995	0.8329	0.8329
2007	0	0	0	0.0026	0.0187	0.1247	0.2991	0.7912	0.6649	0.6649
2008	0	0	0	0.0009	0.0149	0.1317	0.2991	0.7108	0.4540	0.4540
2009	0	0	0	0.0020	0.0172	0.1251	0.2991	0.8594	0.5267	0.5267
2010	0	0	0	0.0042	0.0303	0.2338	0.2991	0.8598	0.5984	0.5984
2011	0	0	0.0101	0.0189	0.0462	0.1892	0.2991	0.6264	0.3747	0.3747
2012	0	0	0.0323	0.0190	0.0636	0.1413	0.2991	1.0043	0.6828	0.6828
2013	0	0	0.0054	0.0147	0.0621	0.2000	0.2991	0.9537	0.5898	0.5898
2014	0	0	0.0056	0.0128	0.0393	0.1513	0.2991	0.9042	0.5801	0.5801
2015	0	0	0.0015	0.0047	0.0240	0.0518	0.2991	0.6127	0.4307	0.4307

Table App.A.3: XSA “run4” survey catchability-at-age.

	Canadian Fall 2J3K	EU 3M 0-700m	EU 3M 0-1400m	Canadian Spring 3LNO
1	0.000666747	0.000058137	0.000002824	0.000013359
2	0.000540725	0.000028070	0.000001518	0.000017650
3	0.000366541	0.000042420	0.000002060	0.000021215
4	0.000343439	0.000070542	0.000008013	0.000023378
5	0.000311441	0.000145229	0.000094058	0.000030457
6	0.000237273	0.000297886	0.000316148	0.000019208
7	0.000279698	0.000408753	0.000479676	0.000011424
8	0.000267685	0.000455689	0.000370595	0.000007431
9	0.000267685	0.000455689	0.000370595	0.000000000
10+	0.000000000	0.000000000	0.000000000	0.000000000