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Exploring surplus production models for 3LNO yellowtail flounder: ASPIC sensitivity to changes in survey indices and alternate estimation packages for production models.

by

Dawn Maddock Parsons, Joanne Morgan, Mark Simpson and Brian Healey

Northwest Atlantic Fisheries Centre, Science Branch, Department of Fisheries and Oceans, Canada.
80 East White Hills Road, St. John's, Newfoundland Canada, AlC 5Xl.
Email: dawn.parsons@dfo-mpo.gc.ca

Abstract

Sensitivity of the surplus production model (ASPIC) used in the assessment of yellowtail flounder is explored by systematically shortening the tuning series indices to observe changes in model performance and results. A surplus production model in a Bayesian framework and a surplus production model in continuous time (SPiCT) are also presented. The 2015 accepted assessment model for yellowtail flounder (ASPIC) is insensitive to imposed reductions in the survey indices in the past decade. The SPiCT and Bayesian formulations produce a similar view of the stock history as previous assessments, however the declining trends seen in some indices in recent years are tracked by these production models.

Introduction

A surplus production model has been used to assess yellowtail flounder in NAFO Divisions 3LNO and provide management advice since 2000 (Walsh *et. al.* 2000) There have been recent concerns expressed about the insensitivity of the production model used to assess yellowtail flounder to recent index data. In particular, the ASPIC model results have indicated that the stock has remained stable at a high level in recent years, despite substantial downward trends in recent survey indices. This has led to a request to explore how ASPIC (a non-equilibrium surplus production model incorporating covariates) results and diagnostics are affected by imposing simulated declines in survey indices, and also how the model reacts to removing indices from the start of the time series. The results of this exploration are given here. At the 2017 June meeting of STACFIS, it was also recommended to explore alternate models to describe population parameters and trends in this stock (NAFO, 2017). Results of a Bayesian surplus production model and an alternate state-space surplus production model (SPiCT) are presented.

Methods

ASPIC (A surplus production model incorporating covariates)

The 2015 accepted assessment model formulation using ASPIC (Maddock Parsons *et al.* 2015) was updated with survey and catch information available to 2017 (Table 1). This gave the base model (the updated accepted assessment formulation) that would be best to explore, given that it has two more years or survey and catch (compared to the 2015 assessment) and the decline in the Canadian spring and Spanish spring series were still evident. In order to investigate how results and model diagnostics would respond to imposed declines in survey series, ten input data series were created . In the first data series, a 50% reduction was applied to all tuning indices in the terminal year. The second input dataset had all indices reduced by 50% in the last two years. This 50% reduction was applied successively backwards in time to generate the remaining data series.. The ASPIC model was then fit to each of these datasets with imposed index declines, applying the same formulation of ASPIC to see how the results and diagnostics are affected.

Bayesian surplus production model

A Bayesian production model was applied to the same survey and catch series as those input into the ASPIC update run (with catch and survey indices updated to 2017). For this exploration model, the Schaefer (1954) form of a surplus production model was used:

$$P_t=[P_{t-1}+ r \bullet P_{t-1} (1 - P_{t-1})- C_{t-1}/K] \bullet \eta t$$

Where:

P_{t-1} is exploitable biomass (as a proportion of carrying capacity) for year t-1
C_{t-1} is catch for year t-1
K is carrying capacity (level of stock biomass at equilibrium prior to commencement of a fishery)
r is the intrinsic rate of population growth
ηt is a random variable describing stochasticity in the population dynamics (process error).

The model utilizes biomass proportional to an estimate of K in order to aid mixing of the Markov Chain Monte Carlo (MCMC) samples and to help minimize autocorrelation between each state and K (Meyer and Millar, 1999a, 1999b).

An observation equation is used to relate the unobserved biomass, P_t, to the research vessel survey indices:

$$I_t=q \bullet P_t \bullet \varepsilon_t$$

Where:

q is the catchability parameter
P_t is an estimate of the biomass proportional to K at time t
ε_t is observation error

The full Winbugs model code is included in Appendix 2. The priors on r (mean 0.3 sd 0.1) and carrying capacity, K (mean 150 sd 25) were chosen based on work done in other flatfish stocks.

Priors used in the model were:

Initial population size	Pin~dunif(0.5, 1)	uniform(0.5 to 1)
Intrinsic rate of natural increase	r ~ dlnorm(-1.2567,9.4912)	lognormal (mean, precision)
Carrying capacity	K~dlnorm(4.997,36.4977)	lognormal (mean, precision)
Survey catchability	q ~dgamma(1,1)	gamma(shape, rate)
Process error	sigma ~ dunif(0,5) isigma2= $sigma^{-2}$	uniform(0 to 5)
Observation error	tau~dgamma(1,1) itau2 = 1/tau	gamma(shape, rate)

SPiCT (A stochastic surplus production model in continuous time)

A state-space SPiCT model (Pedersen & Berg 2016) was run with a setup similar to the updated yellowtail flounder ASPIC assessment model. This model estimates process and observation variance parameters from the observed quantities (C_t=catch) and $I_{t,i}$,(survey series) which include observation noise. Unobserved processes B_t (exploitable biomass) and F_t (instantaneous fishing mortality rate) are treated as random effects. No sensitivity analysis or alternate runs were considered.

Results and Discussion

Surplus production model (ASPIC)

Inputs to update the accepted (2015) assessment of yellowtail flounder in NAFO Divisions 3LNO in ASPIC are given in Appendix 1. A version change in ASPIC (from v7.02 to v7.05) was tested to ensure that there were no changes to estimates or results due to the version of ASPIC used. Table 1 and Figure 1 give the catch and survey series that were used in the ASPIC model. The drop in the Canadian spring survey from 2012, and the Spanish series from 2011 have been of particular concern. Table 2 shows the model results for the ASPIC version comparison, which used the 2015 data and model formulation to ensure that the version change did not affect the parameter estimates, and also shows the model results for the base run (updated catch and survey series to 2017). The base case model estimates are very similar to the results from the last assessment, with K estimated to be 141 kt and MSY at 18.94 kt. Overall, the model still seems to fit well, with diagnostics and MSE similar to those of previous assessments. Residuals for survey series are shown in Figure 2. Trends in relative biomass and fishing mortality are also consistent with those from the last assessment. This updated result using ASPIC suggests that no change in relative B or relative F trends have occurred in spite of the survey index declines and nothing in the overall model fit suggests that this result should be rejected. The residuals for the surveys (see Appendix 1) suggest that the surveys are not in agreement with the model estimates, but it is still an arbitrary decision to determine whether to reject or accept a model based on the residual patterns. A retrospective view of the base run (table 3 and figure 3) also shows no change to the perception of stock trajectory as years are removed from the catch and survey indices.

The ASPIC model appears to be insensitive to declines in survey indices observed in recent years, and model fit parameters do not seem to indicate that the model should be rejected for the base run. Several runs were conducted whereby the indices in each year were reduced by 50%, one year at a time, starting with the most recent years and extending for 10 years back in time, while the catch series was maintained. For the first run, then, the 2017 indices were halved and the model parameters were re-estimated; the second run had indices halved for 2017 and 2016, and so on. Model outputs are shown in Table 4 and trends in relative biomass are shown in Figure 4. Some differences in fit parameters and estimates of population parameters are seen (MSE increases from 0.131 to 0.209 as more years are reduced, for example), but estimates of K and MSY remain constant, and biomass in the final year is still estimated to be very high at 1.7 times B_{msy} for all scenarios. Trends in relative biomass (Figure 4) do show some differences in the middle of the time series (around 1996 and 1997) however trends in relative biomass for all exploratory runs are very similar at the end of the time series. It is this stability, even with imposed declines for many years, that causes concern.

To further explore what sort of changes are needed to cause ASPIC outputs to respond to changes in survey indices, several runs were conducted dropping out the beginning years of the surveys and Table 5 shows these model fit and parameter estimates. If eliminating the earlier data from the model provided greater flexibility in fitting recent survey trends, this may lead to using a 'moving window' of more recent data from which population size would be estimated. The catch series was maintained in these exploratory runs. Figure 5 shows the trends in relative biomass ($B_y/B_{msy}= B_{ratio}$) and total biomass, as well as the B_{ratio} for the exploratory run divided by the B_{ratio} of the base run for comparison. Dropping the first years of the survey indices (5 years at a time until a change was seen – specific periods identified in Table 5) does not seem to impact the trends estimated by ASPIC until the series are cropped from the 1970 to 1992 and then estimates change noticeably as indices are dropped for 1994, 1995 and the model no longer tracks trends when indices are shortened to 1997-2017 (1970-1996 points are dropped). The survey series' fit (R^2 for the series) worsens as more and more survey data are removed from the model, however, estimates of K, MSY and other parameter estimates don't change much until the run that dropped 1970-1994. The model seems to be heavily dependent on the Canadian spring survey (related to the nominal catch series) to estimate trends in biomass and population parameters, and model outputs only change when a great deal of data is removed from the model.

Bayesian surplus production model

A surplus production model in a Bayesian framework (Meyer and Millar, 1999a, 1999b) was run using the same indices input into the last accepted assessment for the stock (Table 1 and Fig. 1) updated to 2017. Settings were made to be as close to the ASPIC formulation as possible, and the model script is given in Appendix 2. Estimates of population parameters and some diagnostic information are given in Tables 6 and 7 (2018 Bayesian Run 1).

The model fit and convergence diagnostics were good for all surveys with no apparent trend in process error (see Figs. 6 and 7, Table 7 and Appendix 2 for some of the diagnostics). Posteriors for r and K are updated from their priors (Fig. 6). The production model estimated that an MSY of 18 000 t can be taken from a biomass of 85 400 t at a fishing mortality of 0.21. Intrinsic rate of natural increase (r) is estimated to be 0.42 and carrying capacity (K) 171 000 t. The trends in relative biomass and fishing mortality estimates from the model are given in Figure 7.

The model results from this Bayesian formulation are broadly similar to those estimated from previous ASPIC models for this stock (Table 6), and relative biomass and in 2018 is estimated to be 1.5 times B_{msy} with relative fishing mortality less than 2/3 F_{msy}. The recent downward trajectories of the Canadian and Spanish Spring survey indices are reflected in the estimated trends from this model (eg. B_{ratio} plot in Figure 7) and show the population declining from 2012, although biomass is still estimated to be well above B_{msy}.

A stochastic surplus production model in continuous time (SPiCT)

A SPiCT model (Pedersen & Berg, 2017) was run to compare with the updated ASPIC model for Yellowtail Flounder (base run) and the Bayesian model. The model was set up as close to the ASPIC formulation as possible, and used the same nominal catch series and survey indices. No sensitivity analysis or alternate runs were considered. Input data (nominal catch series, and survey indices) are given in Table 1 and plotted in Figures 1. Diagnostics and results are shown in Figures 8 to 10 and in Appendix 3. The model converged, with the Objective function at an optimum at 101.3. The One Step Ahead (OSA) residuals were not significant different from zero and therefore not biased (Fig. 8). There was also no significant autocorrelation of the residuals. The residuals for catch, the Canadian spring RV survey and the EU-Spain survey were significantly different from an assumption of normality, though this seems to be influenced by large negative outliers. The model estimates r (intrinsic growth-rate parameter) to be 0.34 and K to be 150.5 Kt. Stochastic B_{msy} was calculated as 61.27. F_{msy} was 0.26 and MSY 16.2 (Table 6). Trends in relative biomass and fishing mortality are very similar to the ASPIC and Bayesian model estimates of yellowtail population dynamics.

Summary

The 2015 ASPIC assessment formulation, updated with information up to 2017 was subjected to simulated declines in the survey indices. The model did not show any change in the diagnostics or results which might inform on the imposed declines. Two other surplus production models were run using the same catch series and survey indices for yellowtail flounder, and in both of these models, the estimated biomass trajectory reflects the decline observed in the recent survey indices.

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Table 1. Nominal catch and survey indices used in the exploration runs of ASPIC as well as alternate surplus production models.

Year	Nominal catch (000 t)	Yankee survey (000 t)	Russian survey (000 t)	Campelen spring (000 t)	Campelen fall (000 t)	Spain survey (000 t)
1965	3.13					
1966	7.026					
1967	8.878					
1968	13.34					
1969	15.708					
1970	26.426					
1971	37.342	96.9				
1972	39.259	79.2				
1973	32.815	51.7				
1974	24.313	40.3				
1975	22.894	37.4				
1976	8.057	41.7				
1977	11.638	65.0				
1978	15.466	44.3				
1979	18.351	38.5				
1980	12.377	51.4				
1981	14.68	45.0				
1982	13.319	43.1				
1983	10.473					
1984	16.735		132.0	217.7		
1985	28.963		85.0	146.8		
1986	30.176		42.0	138.2		
1987	16.314		30.0	124.6		
1988	16.158		23.0	81.0		
1989	10.207		44.0	103.8		
1990	13.986		27.0	103.1	65.8	
1991	16.203		27.5	93.4	82.4	
1992	10.762			61.4	64.5	
1993	13.615			93.3	112.8	
1994	2.069			55.6	106.4	
1995	0.067			70.6	129.8	9.3
1996	0.232			175.6	134.3	43.3
1997	0.658			174.9	222.9	38.7
1998	4.386			202.2	231.6	122.6
1999	6.894			365.7	249.9	197.0
2000	11.161			287.5	335.0	144.7
2001	14.145			366.0	475.8	182.7
2002	10.698			199.5	339.7	148.5
2003	13.806			386.5	368.3	136.8
2004	13.354			307.9	374.7	170.0
2005	13.933			388.8	342.7	156.48
2006	0.930			★	305.5	160.1
2007	4.623			443.0	482.4	160.7
2008	11.403			456.9	322.0	160.1
2009	6.168			271.2	237.8	183.4
2010	9.379			394.7	417.2	189.7
2011	5.23			422.9	310.4	203.8
2012	3.684			489.4	357.4	195.6
2013	10.68			397.3	346.1	188.0
2014	7.99			332.1	★	136.5
2015	6.90			★	307.4	140.8
2016	9.33			133.4	286.7	153.7
2017	9.20			214.1	322.2	95.9

The average catch (2013-2017) is included as the 2018 catch in the input file.

★ Canadian surveys in 2006 Spring, 2014 Fall and 2015 Spring were incomplete and results may not be comparable to other years

Table 2. Parameter estimates and model diagnostics comparing ASPIC versions 7.02 and 7.05 using the 2015 assessment formulation and ASPIC model run (v7.03) for the 2018 assessment of Yellowtail founder in NAFO Divs. 3LNO.

	2015 Run 4 **v7.02 catch in 2015 (7400t avg07-14) recommended cc penalty b1/k**	**2015 Rerun in v7.05** **v7.02 catch in 2015 (7400t avg07-14) recommended cc penalty b1/k**	Base Run 2018 Run2 V7.05 catch in 2018 8800t (last 5 years avg) recommended cc penalty b1/k CanS 15 OUT
starting guess B1/K*	**1**	1	1
penalty for B1>K*	**1**	1	1
B1/K	**1.01**	1.01	1.04
K	**145.00**	145.00	141.80
MSY	**18.73**	18.73	18.94
Bmsy	**72.50**	72.50	70.90
Fmsy	**0.258**	0.258	0.267
B/Bmsy	**1.767**	1.767	1.739
Y(Fmsy)	**30.390**	30.390	30.270
Ye	**7.714**	7.714	8.591
F/Fmsy	**0.224**	0.224	0.268
phi	**0.500**	0.500	0.500
q (FC/Spring)	**3.241**	3.241	3.083
q (Yankee)	**1.002**	1.002	1.040
q (Can Fall)	**3.228**	3.228	3.088
q (Russian)	**1.174**	1.174	1.197
q (Spanish)	**1.316**	1.316	1.259
R^2 FC/Spring	**0.868**	0.868	0.700
R^2 Yankee	**0.804**	0.804	0.800
R^2 Can Fall	**0.730**	0.730	0.716
R^2 Russian	**0.553**	0.553	0.550
R^2 Spanish	**0.669**	0.669	0.552
Est contrast index (best=1.0)	**0.891**	0.891	0.883
Est nearness index (best=1.0)	**1.000**	1.000	1.000
Tot Obj Function	**7.137**	7.137	9.337
MSE	**0.083**	0.083	0.098

* This is an input to the model.

Table 3. Model Outputs (ASPIC version 7.05) for retrospective analysis of base run.

	Base Run V7.05 catch in 2018 8800t (last 5 years avg) recommended cc penalty b1/k 2015 Can_S_15OUT	Last Year 2017	2016	2015	2014	2013
starting guess B1/K*	1	1	1	1	1	1
penalty for B1>K*	1	1	1	1	1	1
B1/K	1.04	1.04	1.03	1.01	1.01	1.00
K	142.40	142.50	143.50	144.30	145.10	186.90
MSY	18.89	18.89	18.81	18.78	18.72	18.69
Bmsy	71.22	71.23	71.76	72.15	72.53	72.83
Fmsy	0.265	0.265	0.262	0.260	0.258	0.257
B/Bmsy	1.739	1.742	1.745	1.773	1.761	1.763
Y(Fmsy)	30.180	30.240	30.310	30.550	30.310	30.280
Ye	8.587	8.467	8.126	7.544	7.867	7.820
F/Fmsy	0.268	0.279	0.281	0.208	0.242	0.320
phi	0.500	0.500	0.500	0.500	0.500	0.500
q (FC/Spring)	3.029	3.029	3.094	3.238	3.239	3.268
q (Yankee)	1.031	1.031	1.018	1.010	1.001	0.995
q (Can Fall)	3.070	3.070	3.106	3.183	3.227	3.235
q (Russian)	1.188	1.188	1.181	1.180	1.173	1.169
q (Spanish)	1.253	1.253	1.287	1.302	1.316	1.334
R^2 FC/Spring	0.710	0.700	0.753	0.869	0.868	0.878
R^2 Yankee	0.801	0.801	0.803	0.803	0.804	0.805
R^2 Can Fall	0.717	0.717	0.710	0.717	0.730	0.724
R^2 Russian	0.549	0.549	0.550	0.553	0.553	0.553
R^2 Spanish	0.549	0.549	0.634	0.644	0.669	0.705
Est contrast index (best=1.0)	0.881	0.881	0.885	0.890	0.891	0.892
Est nearness index (best=1.0)	1.000	1.000	1.000	1.000	1.000	1.000
Tot Obj Function	9.195	9.195	8.575	7.252	7.138	7.039
MSE	0.098	0.098	0.094	0.082	0.083	0.084
* This is an input to the model.						

Table 4. Table of ASPIC model fit and population estimates for sensitivity runs in which survey indices were halved over the period start year- 2017, for start years ranging from 2017 back to 2008..

	Base Run 2018 V7.05 catch in 2018 8800t (last 5 years avg) recommended cc penalty b1/k 2015 Can_S_15OUT	Survey indices half from (start year)									
		2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
starting guess B1/K*	1	1	1	1	1	1	1	1	1	1	1
penalty for B1>K*	1	1	1	1	1	1	1	1	1	1	1
B1/K	1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.09	1.11	1.12	1.13
K	142.40	140.40	139.30	138.40	137.90	137.60	137.70	138.10	138.70	139.70	141.30
MSY	18.89	19.04	19.11	19.19	19.22	19.25	19.23	19.19	19.13	19.03	18.90
Bmsy	71.22	70.19	69.66	69.20	68.94	68.79	68.84	69.03	69.35	69.87	70.64
Fmsy	0.265	0.271	0.274	0.277	0.279	0.280	0.279	0.278	0.276	0.272	0.268
B/Bmsy	1.739	1.745	1.746	1.746	1.747	1.747	1.747	1.747	1.746	1.745	1.743
Y(Fmsy)	30.180	30.470	30.580	30.690	30.740	30.770	30.750	30.690	30.590	30.450	30.250
Ye	8.587	8.486	8.490	8.497	8.499	8.498	8.497	8.494	8.488	8.481	8.470
F/Fmsy	0.268	0.276	0.275	0.276	0.273	0.273	0.273	0.274	0.275	0.276	0.278
phi	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
q (FC/Spring)	3.029	3.003	2.919	2.911	2.837	2.747	2.652	2.555	2.457	2.355	2.249
q (Yankee)	1.031	1.058	1.072	1.085	1.092	1.095	1.093	1.085	1.074	1.057	1.033
q (Can Fall)	3.070	2.983	2.878	2.791	2.773	2.668	2.559	2.451	2.343	2.234	2.212
q (Russian)	1.188	1.206	1.211	1.218	1.219	1.215	1.203	1.188	1.169	1.142	1.110
q (Spanish)	1.253	1.213	1.169	1.130	1.092	1.050	1.008	0.967	0.926	0.885	0.844
R^2 FC/Spring	0.710	0.644	0.602	0.603	0.548	0.500	0.467	0.429	0.391	0.349	0.322
R^2 Yankee	0.801	0.798	0.796	0.794	0.793	0.792	0.792	0.793	0.795	0.797	0.799
R^2 Can Fall	0.717	0.643	0.573	0.507	0.512	0.458	0.401	0.351	0.323	0.282	0.250
R^2 Russian	0.549	0.548	0.545	0.543	0.540	0.535	0.528	0.520	0.510	0.498	0.483
R^2 Spanish	0.549	0.437	0.351	0.278	0.219	0.176	0.139	0.115	0.092	0.071	0.045
Est contrast index (best=1.0)	0.881	0.877	0.870	0.866	0.861	0.853	0.843	0.832	0.820	0.807	0.797
Est nearness index (best=1.0)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Tot Obj Function	9.195	12.403	15.499	16.649	17.684	18.392	18.607	18.906	18.777	19.835	19.750
MSE	0.098	0.131	0.163	0.175	0.186	0.194	0.196	0.199	0.198	0.209	0.208

* This is an input to the model.

Table 5. Table of ASPIC model fit and population estimates for sensitivity runs in which survey indices over various time-periods (as per table header) were removed.

	Base run 2018 V7.05 catch in 2018 8800t (last 5 years avg) recommended cc penalty b1/k 2015 Can_S_15OUT	drop series							
		1970-75	1970-80	1970-85	1970-90	1970-1992	1970-1994	1970-1995	1970-1996	1970-1997
starting guess B1/K*	1	1	1	1	1	1	1	1	1	1
penalty for B1>K*	1	1	1	1	1	1	1	1	1	1
B1/K	1.04	1.036	1.037	1.019	1.005	0.5	0.9455	0.5152	0.832	0.6255
K	142.40	141.2	140.8	142.2	141.1	146.7	103.7	81.79	100	100
MSY	18.89	18.97	19.02	18.93	19.03	19.94	22.92	25.98	50	50
Bmsy	71.22	70.72	70.41	71.08	70.54	73.37	51.85	40.89	50	50
Fmsy	0.265	0.2682	0.2701	0.2663	0.2698	0.2717	0.4421	0.6352	1	1
B/Bmsy	1.739	1.74	1.74	1.739	1.741	1.754	1.785	1.811	1.907	1.907
Y(Fmsy)	30.180	30.32	30.39	30.26	30.42	32.04	35.74	39.19	72.66	72.66
Ye	8.587	8.592	8.593	8.588	8.595	8.604	8.81	8.883	8.876	8.877
F/Fmsy	0.268	0.267	0.2662	0.2676	0.2659	0.252	0.2156	0.6352	0.09256	0.09256
phi	0.500	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
q (FC/Spring)	3.029	3.09	3.103	3.061	3.008	2.842	3.844	3.874	3.315	3.428
q (Yankee)	1.031	1.086	0.9392	dropped	dropped					
q (Can Fall)	3.070	3.094	3.105	3.069	3.111	2.942	3.799	4.717	3.395	3.471
q (Russian)	1.188	1.201	1.209	1.027	1.111					
q (Spanish)	1.253	1.26	1.264	1.252	1.256	1.193	1.647	1.988	1.552	1.663
R^2 FC/Spring	0.710	0.701	0.701	0.698	0.629	0.554	0.43	-0.048	-0.042	-0.016
R^2 Yankee	0.801	-0.345	-4.932							
R^2 Can Fall	0.717	0.716	0.717	0.719	0.68	0.576	0.495	0.311	-0.111	-0.087
R^2 Russian	0.549	0.551	0.552	0.229	n=1					
R^2 Spanish	0.549	0.553	0.555	0.55	0.552	0.555	0.672	0.499	-0.082	0.006
Est contrast index (be	0.881	0.8832	0.8838	0.8809	0.8812	0.797	0.9058	0.9256	0.245	0.3731
Est nearness index (b	1.000	1	1	1	1	1	1	1	0.5073	0.251
Tot Obj Function	9.195	9.2883833	9.0485436	8.3992925	7.9305448	7.8275881	5.5114671	5.3421799	6.331924	3.7036126
MSE	0.098	0.1032	0.1065	0.105	0.1149	0.1204	0.09035	0.09211	0.1151	0.07122

* This is an input to the model.

Table 6. Results of surplus production models applied to yellowtail flounder catch and survey indices.

	2015 ASPIC assessment	Base Run 2018 ASPIC updated	2018 Bayesian Run1	2018 SPiCT Run1
Bmsy	72.5	71.22	85.39	61.27
MSY	18.73	18.89	18.00	16.2
Fmsy	0.26	0.27	0.21	0.26
K	145	142	171	151
r		0.54	0.42	0.52
q.Fall	3.24	3.07	2.34	
q.Russian	1.17	1.19	0.85	
q.Spanish	1.32	1.25	0.98	
q.Spring	3.24	3.03	2.21	
q.Yankee	1.00	1.03	0.66	
Pin			0.78	
deviance			1039	
sigma			0.12	
tau.Fall			0.04	
tau.Russian			0.19	
tau.Spanish			0.20	
tau.Spring			0.07	
B_{2018}/B_{msy}	1.8	1.7	1.50	1.7

Table 7. Convergence criteria and diagnostics for two factors, r and sigma (process error) estimated using a Bayesian surplus production model.

		Stats (miniter=1 maxiter=15000 sample=15000) Bin size for caculating Batch SE and (Lag 1) ACF=50									Geweke convergence diag. fraction in 1st window 0.1 fraction in last window 0.5 (between -2 and 2 is good)		Brooks, Gelman, and Rubin Convergence diagnostics (near 1 is good)		
	Chain	Mean	SD	Naïve SE	MC Error	Batch SE	Batch ACF	0.025	0.5	0.975	z-score	p-score	Potential Scale Reduction Factors	Multivariate SRF	Corrected SRF
r	1	0.42	0.06	0.00	0.00	0.00	0.02	0.30	0.42	0.55	-1.514666	0.129857	1.000582	1.000798	0.975
	2	0.42	0.06	0.00	0.00	0.00	0.07	0.30	0.42	0.55	-0.7862093	0.4317449			x 1.000694 1.003299
sigma	1	0.121	0.037	0.000	0.001	0.001	-0.009	0.055	0.119	0.200	-0.7049745	0.4808261			0.975
	2	0.121	0.037	0.000	0.001	0.001	0.007	0.058	0.118	0.202	1.9335688	0.05316617	1.000555	1.000763	x 1.000572 1.003072

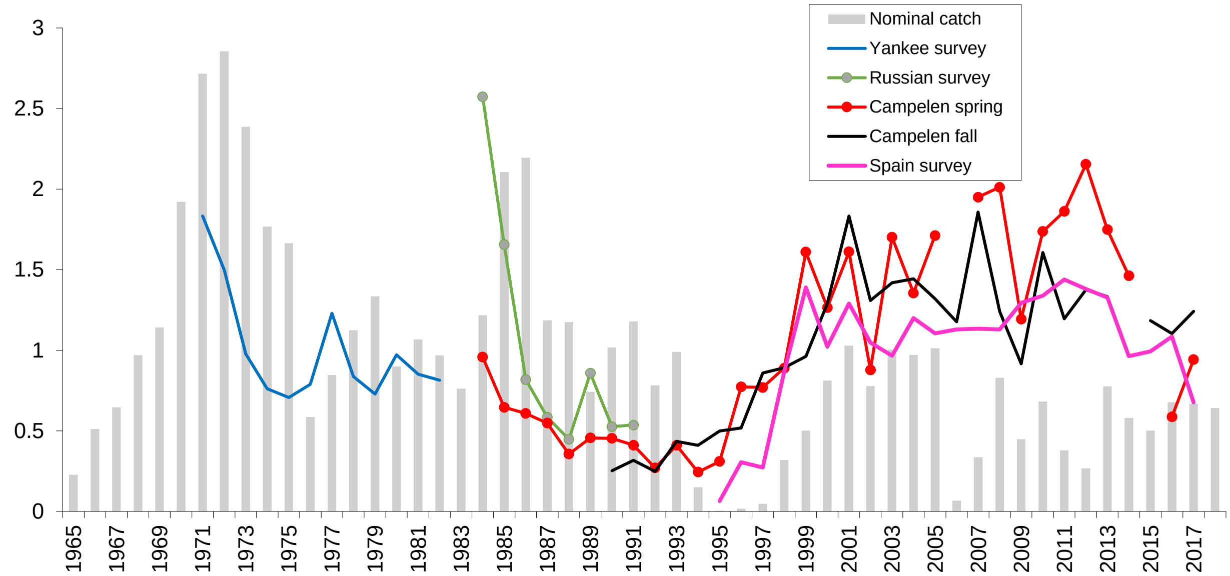

Fig. 1. Nominal catch and survey series scaled to the mean of each series.

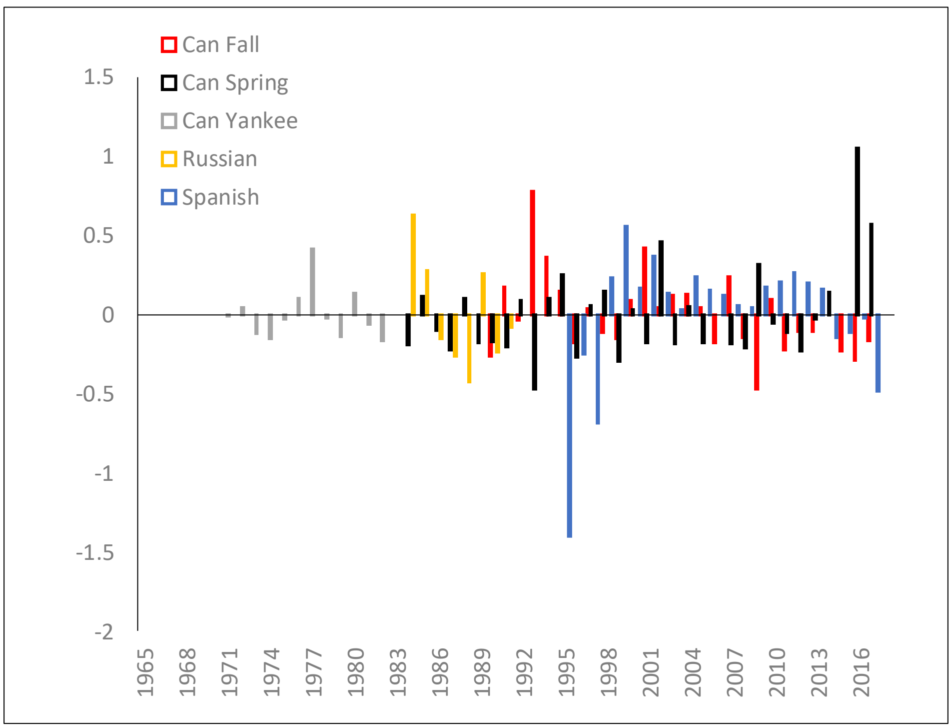

Fig. 2. Residuals (in log scale) for surveys used in ASPIC updated Base Run.

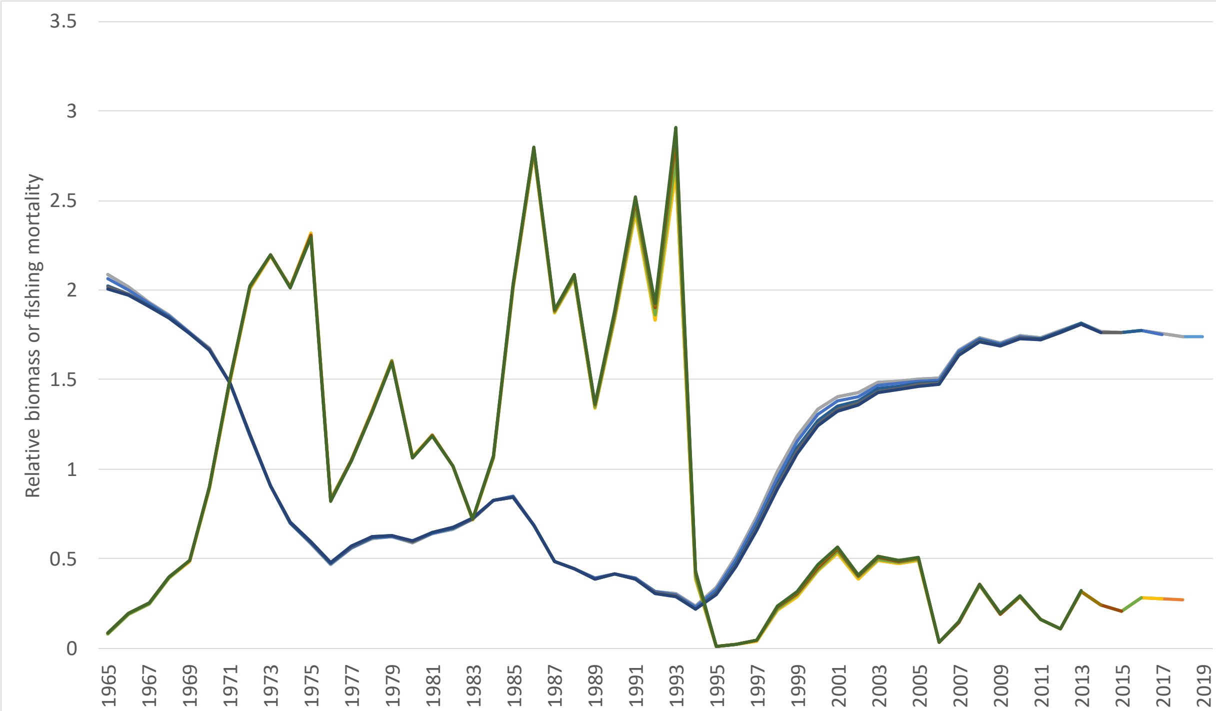

Fig. 3. Retrospective pattern in relative biomass (B/B_{msy}) and relative fishing mortality (F/F_{msy}) for ASPIC base run.

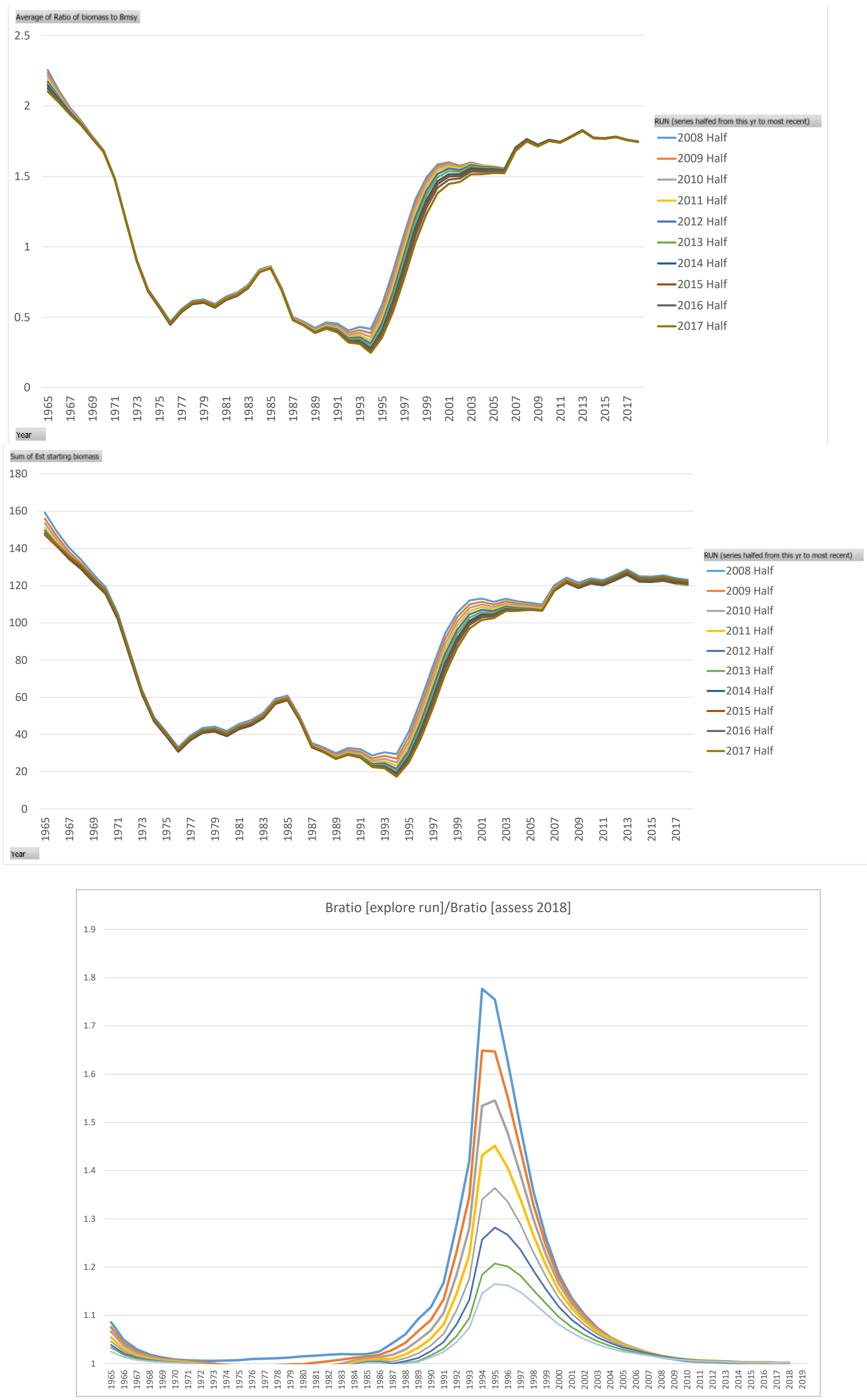

Fig. 4. Trends in relative biomass (B/B_{msy}) (top), starting biomass (middle) and ratio of relative biomass estimates (bottom; comparing individual explorations to base run results) for exploratory runs of ASPIC, imposing known declines of 50% to recent survey indices.

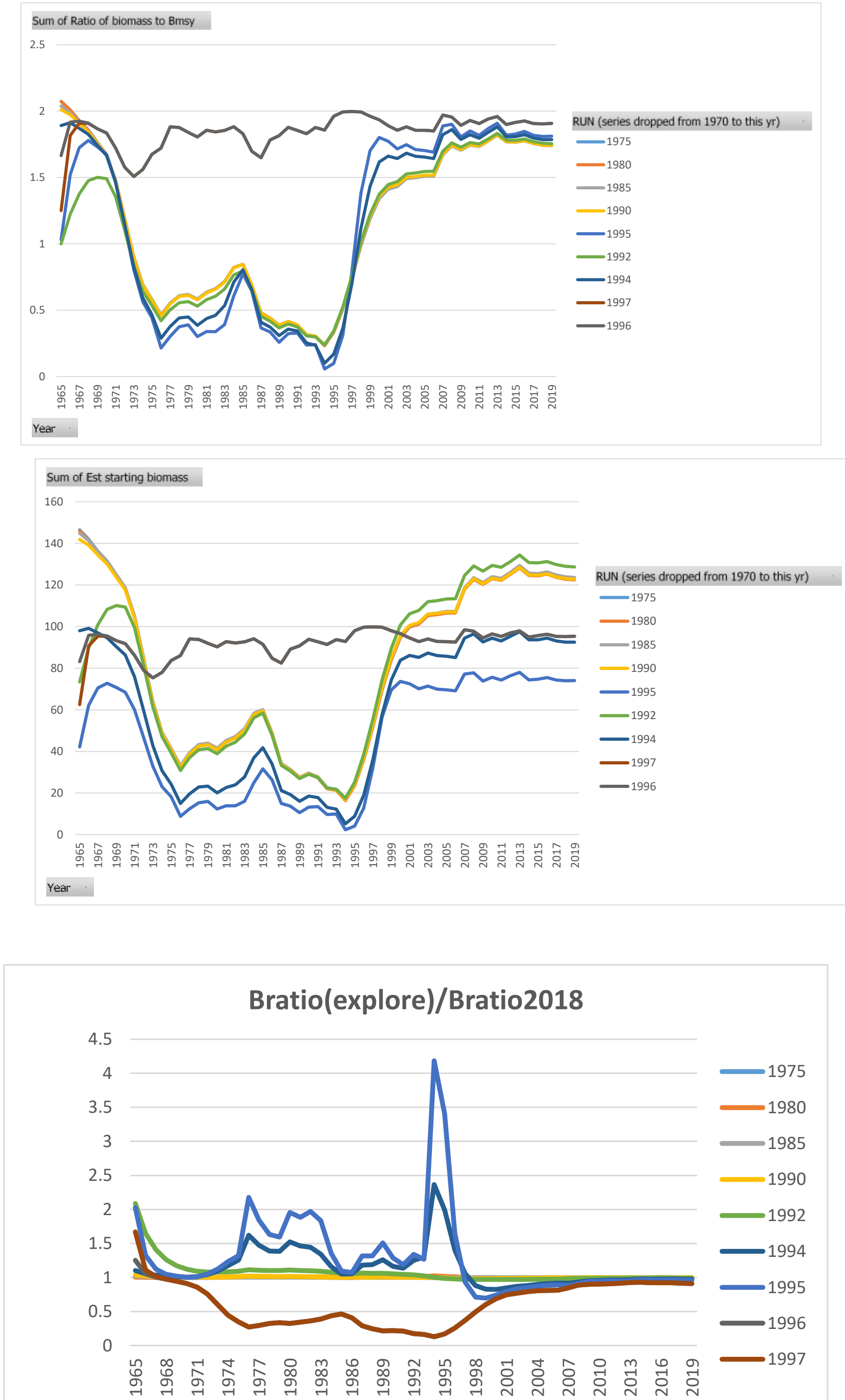

Fig. 5. Trends in relative biomass (B/B_{msy}) (top), starting biomass (middle) and the ratio of relative biomass estimates (bottom; comparing individual explorations to base run results) for exploratory runs of ASPIC, removing years of survey indices from the beginning of the time series. The year in the legend corresponds to the first year of survey data used in each analysis.

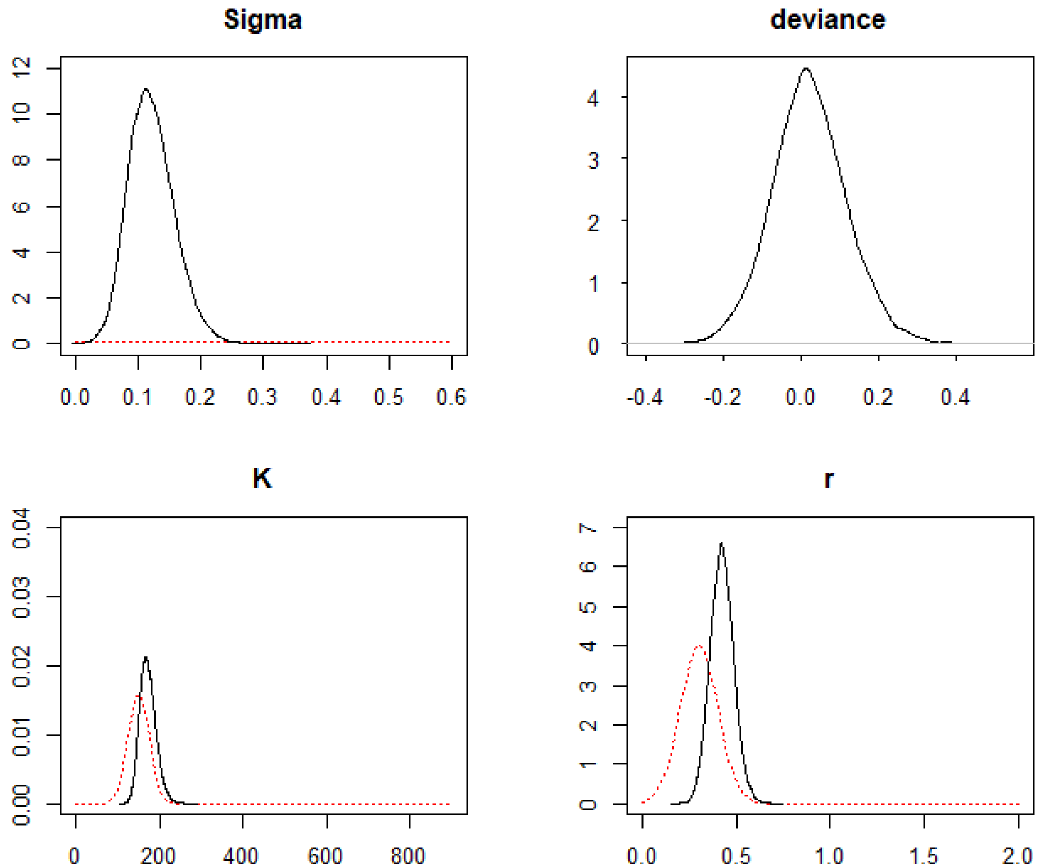

Fig. 6. Priors (red line) and posteriors (black line) for sigma (process error), deviance, carrying capacity (K) and intrinsic rate of growth (r) for the exploratory run of the Bayesian surplus production model.

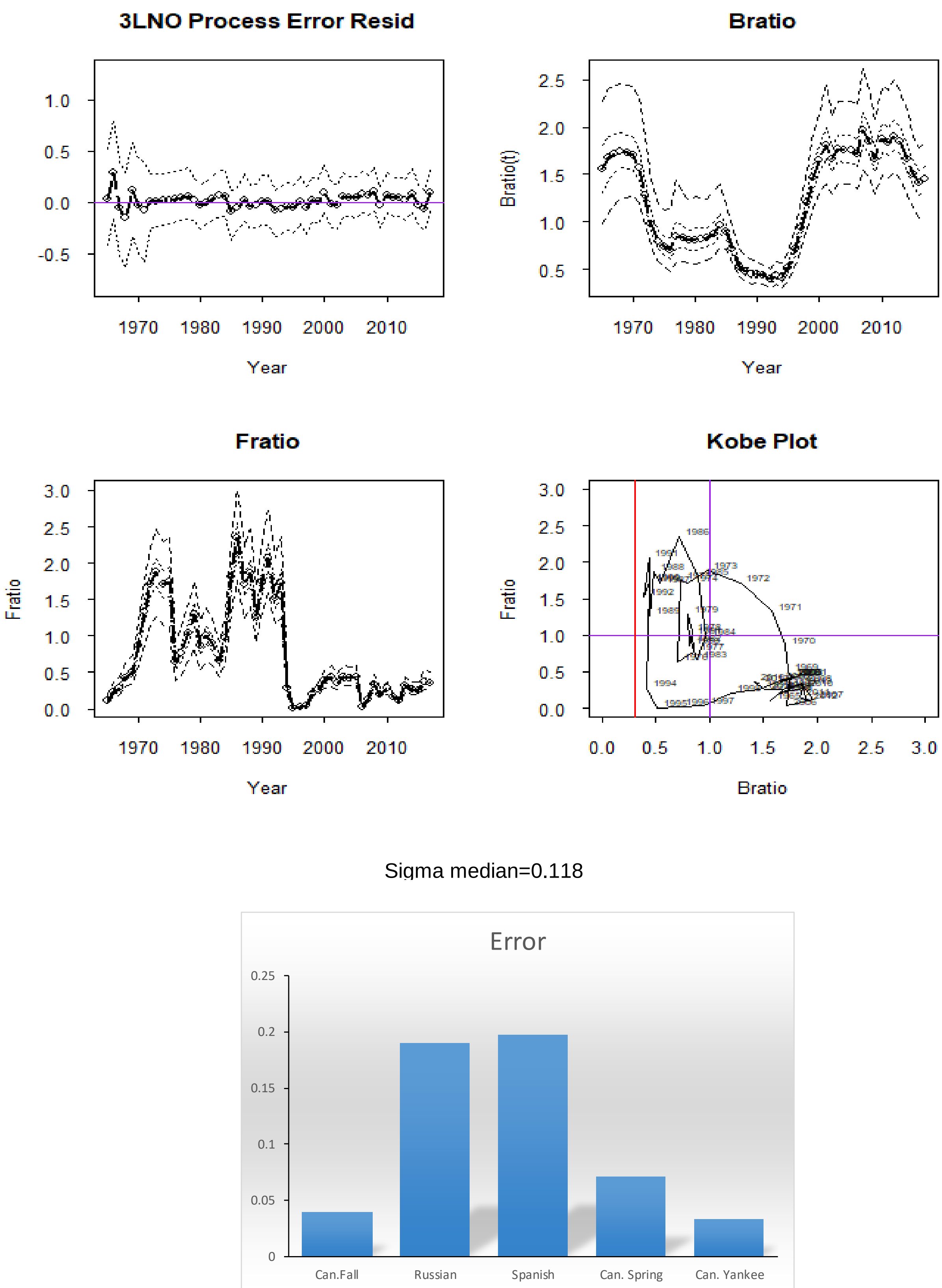

Fig. 7. Diagnostics and outputs for for the exploratory run of the Bayesian surplus production model.

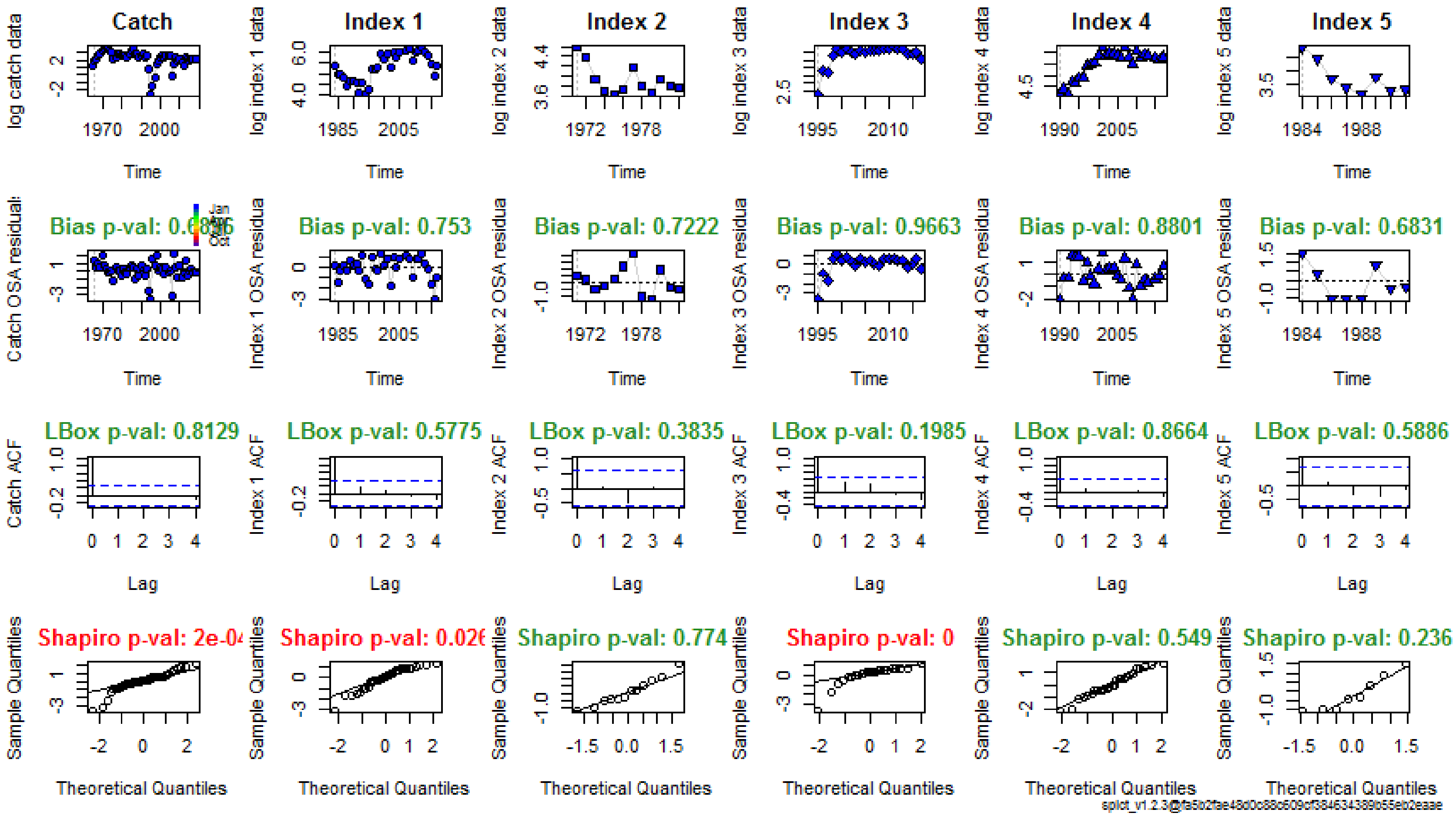

Fig. 8. Diagnostics from a SPiCT model for yellowtail flounder in NAFO Divs. 3LNO. First row shows the log of the input data series; catch and survey indices. Second row has One-step Ahead residuals and a test for bias. Third row indicates the autocorrelation of the residuals. Fourth row indicates the test of normality of the residuals.

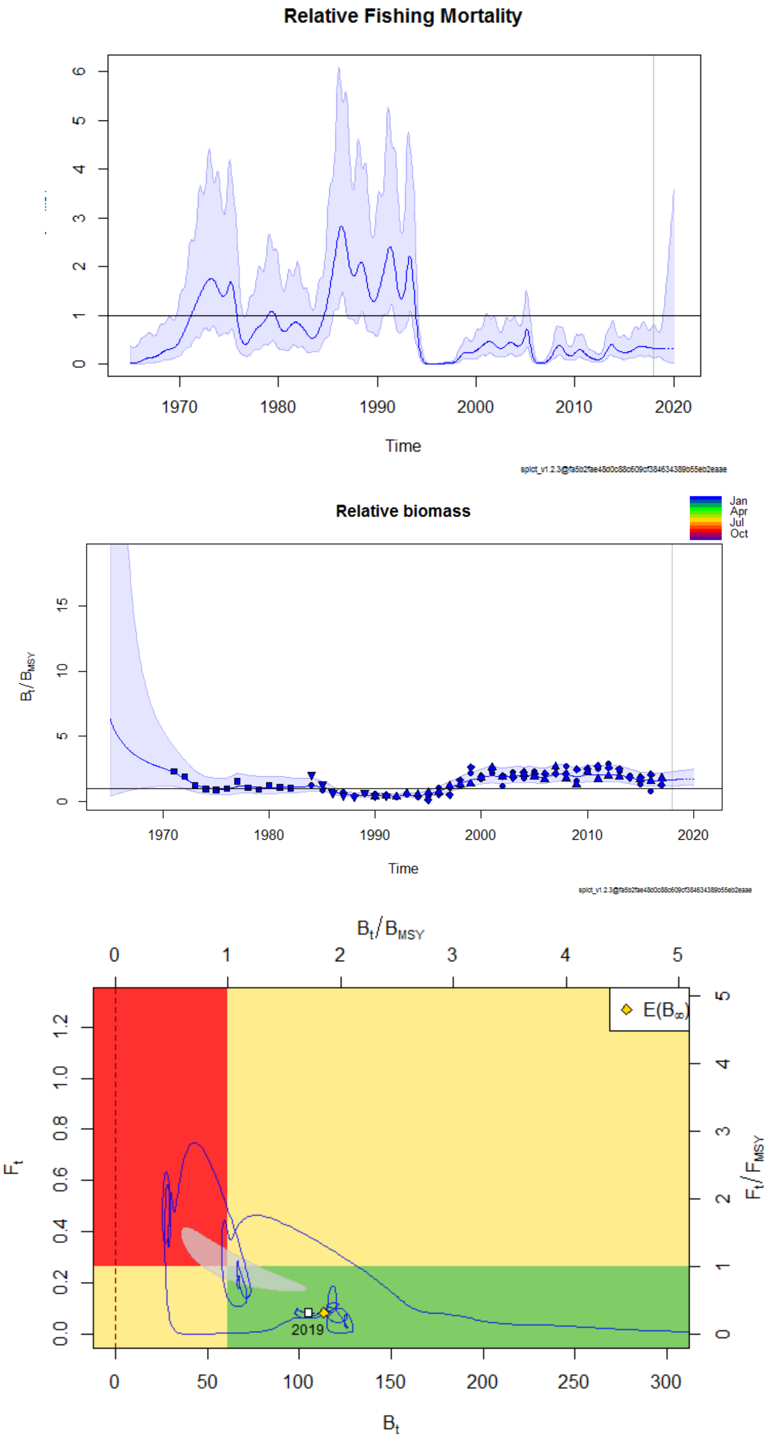

Fig. 9. Plots of the estimated relative fishing mortality(F_t/F_{MSY}), relative biomass (B_t/B_{MSY}), and a combined plot from a SPiCT model for yellowtail flounder in NAFO Divs. 3LNO.

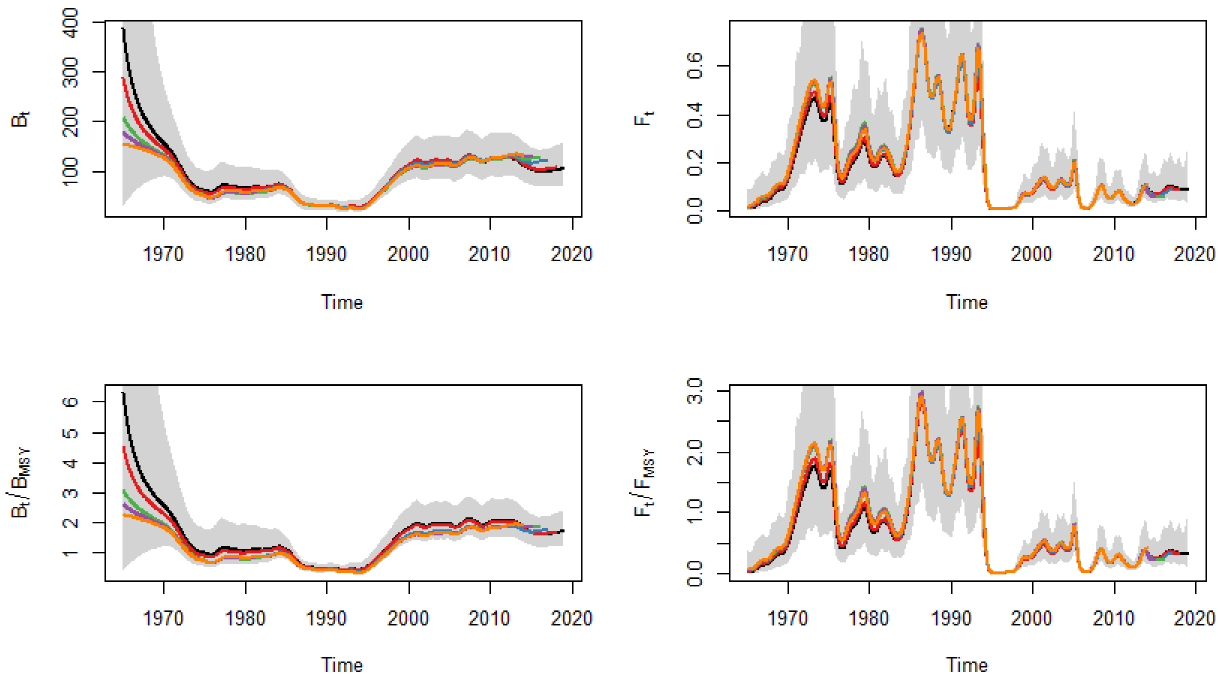

Fig. 10. Retrospective plots of biomass, fishing mortality, relative biomass and relative fishing mortality from a SPiCT model for yellowtail flounder in NAFO Divs. 3LNO.

APPENDIX 1.
Model Inputs

```
ASPIC-V7
"Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2006 2015 Spring 2014 Fall"
# Program mode (FIT/BOT), verbosity, [if BOT] N bootstraps, [opt] user percentile:
BOT 112 2000
# Model shape, conditioning (YLD/EFT), obj. fn. (SSE/LAV/MLE/MAP):
LOGISTIC  YLD  SSE
# N years, N series:
54  5
# Monte Carlo mode (0/1/2), N trials:
0  50000
# Convergence criteria (3 values):
1d-8  3d-8  1.0d-4
# Maximum F, N restarts, [gen. model] N steps/yr:
5.0d0  8  24
# Random seed (large integer):
9114895
# Initial guesses and bounds follow:
# 'B1K', guess, estflag, min, max, ['penalty', penalty], or [priorname, prior params]
B1K    1 1  5.00E-01  3.00E+00  penalty  1
# 'MSY', guess, estflag, min, max, [if MAP] priorname, prior params
MSY    1.30E+01  1  1.00E+00  5.00E+01
# 'Fmsy', guess, estflag, min, max, [if MAP] priorname, prior params
Fmsy   2.00E-01  1  1.00E-02  1.00E+00
# q, guess, estflag, seriesweight, min, max, [if MAP] priorname, prior params
q      3.00E-00  1  1.00E+00  .2   5
q      1.00E-00  1  1.00E+00  .2   2.5
q      3.00E-00  1  1.00E+00  .2   5
q      1.00E-00  1  1.00E+00  .2   2.5
q      3.00E-00  1  1.00E+00  .2   5
DATA
….
```

```
Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring                              Page 1
                                                                                 Tuesday, 05 Jun 2018 at 11:33:29
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 7.05)
                                                                                                FIT program mode
Author:     Michael H. Prager                                                               LOGISTIC model mode
            Prager Consulting                                                                  YLD conditioning
            http://www.mhprager.com                                                            SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium            ASPIC program and user's guide
            surplus-production model.  Fishery Bulletin 92: 374-389.           available gratis at www.mhprager.com

CONTROL PARAMETERS (FROM INPUT FILE)     Input file: D:/...015S/ytail_2018_v7_newcc_penaltyb1_k_avg13_17_dropC15S.a7inp
-----------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                    54           Number of bootstrap trials:                             0
Number of data series:                        5           Objective function:                         Least squares
Relative conv. criterion (simplex):   1.000E-08           Monte Carlo search mode, trials:        0           50000
Relative conv. criterion (restart):   3.000E-08           Random number seed:                               9114895
Relative conv. criterion (effort):    1.000E-04           Identical convergences required in fitting:             8
Maximum F allowed in fitting:             5.000


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                  error code  0
-----------------------------------------------------------------------------------------------------------------------
Normal convergence
Number of restarts required for convergence:     48


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-----------------------------------------------------------------------------------------------------------------------
                                       |
 1  Fishery-catch/Spring biomass       |   1.000
                                       |      32
                                       |
 2  Canadian Yankee Survey             |   0.000   1.000
                                       |       0      12
                                       |
 3  Canadian Fall Survey               |   0.826   0.000   1.000
                                       |      25       0      27
                                       |
 4  Russian Survey                     |   0.933   0.000   1.000   1.000
                                       |       8       0       2       8
                                       |
 5  Spanish Survey Converted biomass...|   0.751   0.000   0.657   0.000   1.000
                                       |      21       0      22       0      23
                                       --------------------------------------------------
                                               1       2       3       4       5


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-----------------------------------------------------------------------------------------------------------------------
Objective function component: label and             Weighted            Weighted      Current     Inv. var.    R-squared
source of variance                                       SSE     N           MSE       weight        weight      in CPUE

Loss(-1)  Unmatched yield                          0.000E+00
Loss(0)   Penalty on B1 > K                        1.807E-03     1           N/A    1.000E+00           N/A
Loss(1)   Fishery-catch/Spring biomass             2.709E+00    32     9.030E-02    1.000E+00     8.379E-01        0.710
Loss(2)   Canadian Yankee Survey                   2.908E-01    12     2.908E-02    1.000E+00     2.602E+00        0.801
Loss(3)   Canadian Fall Survey                     1.724E+00    27     6.896E-02    1.000E+00     1.097E+00        0.717
Loss(4)   Russian Survey                           8.629E-01     8     1.438E-01    1.000E+00     5.261E-01        0.549
Loss(5)   Spanish Survey Converted biomass_2006    3.607E+00    23     1.718E-01    1.000E+00     4.405E-01        0.549
..............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:          9.19536285E+00           9.782E-02    3.128E-01

NOTE: Penalty on B1 > K is nonzero. Sensitivity analysis advised with several fixed B1/K.

Estimated contrast index (good=0.5, best=1.0):        0.8810 ..... Mean of B coverage proportions > and < Bmsy
Estimated nearness index (best=1.0):                  1.0000 ..... Proportional closeness of any B to Bmsy
```

Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 2

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	User guess	2nd guess	Min bound	Max bound	Estim?
B1/K	Starting relative biomass (in 1965)	1.043E+00	1.000E+00	2.555E+00	5.000E-01	3.000E+00	1
MSY	Maximum sustainable yield	1.888E+01	1.300E+01	1.093E+01	1.000E+00	5.000E+01	1
Fmsy	Fishing mortality rate at MSY	2.651E-01	2.000E-01	2.222E-01	1.000E-02	1.000E+00	1
phi	Shape of production curve (Bmsy/K)	0.5000	0.5000	-----	-----	-----	0
q(1)	Fishery-catch/Spring biomass	3.029E+00	3.000E+00	7.500E-01	2.000E-01	5.000E+00	1
q(2)	Canadian Yankee Survey	1.031E+00	1.000E+00	6.159E-01	2.000E-01	2.500E+00	1
q(3)	Canadian Fall Survey	3.070E+00	3.000E+00	1.631E+00	2.000E-01	5.000E+00	1
q(4)	Russian Survey	1.188E+00	1.000E+00	3.843E-01	2.000E-01	2.500E+00	1
q(5)	Spanish Survey Converted biomass_2006	1.253E+00	3.000E+00	1.471E+00	2.000E-01	5.000E+00	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	1.888E+01	----	----
Bmsy	Stock biomass giving MSY	7.122E+01	K/2	K*n**(1/(1-n))
K	Carrying capacity	1.424E+02	2*Bmsy	Bmsy/phi
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2019)/Bmsy	1.738E+00	----	----
F./Fmsy	Ratio: F(2018)/Fmsy	2.684E-01	----	----
Fmsy/F.	Ratio: Fmsy/F(2018)	3.725E+00	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2019	3.018E+01	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	1.599E+00	----	----
Ye.	Equilibrium yield available in 2019	8.587E+00	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	4.548E-01	----	----
---------	Fishing effort rate at MSY in units of each CE or CC series ---------			
fmsy(1)	Fishery-catch/Spring biomass	8.753E-02	Fmsy/q(1)	Fmsy/q(1)

Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 3

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1965	0.021	1.486E+02	1.459E+02	3.130E+00	3.130E+00	-1.877E+00	8.093E-02	2.087E+00
2	1966	0.050	1.436E+02	1.404E+02	7.026E+00	7.026E+00	1.074E+00	1.888E-01	2.017E+00
3	1967	0.066	1.377E+02	1.349E+02	8.878E+00	8.878E+00	3.783E+00	2.482E-01	1.933E+00
4	1968	0.104	1.326E+02	1.289E+02	1.334E+01	1.334E+01	6.503E+00	3.905E-01	1.861E+00
5	1969	0.129	1.257E+02	1.222E+02	1.571E+01	1.571E+01	9.193E+00	4.848E-01	1.765E+00
6	1970	0.236	1.192E+02	1.118E+02	2.643E+01	2.643E+01	1.271E+01	8.919E-01	1.674E+00
7	1971	0.396	1.055E+02	9.425E+01	3.734E+01	3.734E+01	1.678E+01	1.494E+00	1.481E+00
8	1972	0.532	8.494E+01	7.374E+01	3.926E+01	3.926E+01	1.873E+01	2.008E+00	1.193E+00
9	1973	0.582	6.441E+01	5.642E+01	3.281E+01	3.281E+01	1.800E+01	2.194E+00	9.044E-01
10	1974	0.536	4.960E+01	4.540E+01	2.431E+01	2.431E+01	1.638E+01	2.020E+00	6.964E-01
11	1975	0.615	4.166E+01	3.725E+01	2.289E+01	2.289E+01	1.456E+01	2.319E+00	5.850E-01
12	1976	0.221	3.333E+01	3.647E+01	8.057E+00	8.057E+00	1.437E+01	8.333E-01	4.680E-01
13	1977	0.279	3.965E+01	4.166E+01	1.164E+01	1.164E+01	1.562E+01	1.054E+00	5.567E-01
14	1978	0.352	4.363E+01	4.397E+01	1.547E+01	1.547E+01	1.612E+01	1.327E+00	6.127E-01
15	1979	0.427	4.428E+01	4.302E+01	1.835E+01	1.835E+01	1.592E+01	1.609E+00	6.218E-01
16	1980	0.283	4.185E+01	4.372E+01	1.238E+01	1.238E+01	1.606E+01	1.068E+00	5.877E-01
17	1981	0.316	4.554E+01	4.652E+01	1.468E+01	1.468E+01	1.661E+01	1.190E+00	6.394E-01
18	1982	0.270	4.747E+01	4.939E+01	1.332E+01	1.332E+01	1.710E+01	1.017E+00	6.665E-01
19	1983	0.190	5.125E+01	5.500E+01	1.047E+01	1.047E+01	1.789E+01	7.182E-01	7.196E-01
20	1984	0.281	5.867E+01	5.951E+01	1.673E+01	1.673E+01	1.837E+01	1.061E+00	8.237E-01
21	1985	0.533	6.030E+01	5.433E+01	2.896E+01	2.896E+01	1.778E+01	2.011E+00	8.467E-01
22	1986	0.734	4.912E+01	4.113E+01	3.018E+01	3.018E+01	1.544E+01	2.768E+00	6.897E-01
23	1987	0.496	3.439E+01	3.288E+01	1.631E+01	1.631E+01	1.341E+01	1.871E+00	4.828E-01
24	1988	0.547	3.148E+01	2.953E+01	1.616E+01	1.616E+01	1.241E+01	2.064E+00	4.420E-01
25	1989	0.356	2.773E+01	2.871E+01	1.021E+01	1.021E+01	1.215E+01	1.342E+00	3.894E-01
26	1990	0.487	2.967E+01	2.873E+01	1.399E+01	1.399E+01	1.216E+01	1.837E+00	4.166E-01
27	1991	0.646	2.784E+01	2.509E+01	1.620E+01	1.620E+01	1.095E+01	2.436E+00	3.909E-01
28	1992	0.485	2.259E+01	2.217E+01	1.076E+01	1.076E+01	9.924E+00	1.831E+00	3.172E-01
29	1993	0.709	2.176E+01	1.922E+01	1.362E+01	1.362E+01	8.809E+00	2.673E+00	3.055E-01
30	1994	0.102	1.695E+01	2.036E+01	2.070E+00	2.070E+00	9.238E+00	3.834E-01	2.379E-01
31	1995	0.002	2.411E+01	3.002E+01	7.000E-02	7.000E-02	1.251E+01	8.795E-03	3.386E-01
32	1996	0.005	3.656E+01	4.423E+01	2.300E-01	2.300E-01	1.609E+01	1.961E-02	5.133E-01
33	1997	0.011	5.242E+01	6.120E+01	6.600E-01	6.600E-01	1.841E+01	4.068E-02	7.360E-01
34	1998	0.057	7.017E+01	7.743E+01	4.390E+00	4.390E+00	1.867E+01	2.138E-01	9.852E-01
35	1999	0.077	8.445E+01	8.997E+01	6.890E+00	6.890E+00	1.754E+01	2.889E-01	1.186E+00
36	2000	0.114	9.510E+01	9.778E+01	1.116E+01	1.116E+01	1.625E+01	4.305E-01	1.335E+00
37	2001	0.140	1.002E+02	1.010E+02	1.415E+01	1.415E+01	1.559E+01	5.287E-01	1.407E+00
38	2002	0.103	1.016E+02	1.039E+02	1.070E+01	1.070E+01	1.491E+01	3.886E-01	1.427E+00
39	2003	0.130	1.058E+02	1.061E+02	1.381E+01	1.381E+01	1.435E+01	4.908E-01	1.486E+00
40	2004	0.125	1.064E+02	1.068E+02	1.335E+01	1.335E+01	1.417E+01	4.714E-01	1.494E+00
41	2005	0.130	1.072E+02	1.073E+02	1.393E+01	1.393E+01	1.405E+01	4.899E-01	1.505E+00
42	2006	0.008	1.073E+02	1.133E+02	9.300E-01	9.300E-01	1.226E+01	3.097E-02	1.507E+00
43	2007	0.038	1.186E+02	1.213E+02	4.620E+00	4.620E+00	9.549E+00	1.437E-01	1.666E+00
44	2008	0.093	1.236E+02	1.224E+02	1.140E+01	1.140E+01	9.148E+00	3.514E-01	1.735E+00
45	2009	0.050	1.213E+02	1.228E+02	6.170E+00	6.170E+00	8.970E+00	1.895E-01	1.703E+00
46	2010	0.076	1.241E+02	1.237E+02	9.380E+00	9.380E+00	8.626E+00	2.860E-01	1.743E+00
47	2011	0.042	1.234E+02	1.249E+02	5.230E+00	5.230E+00	8.143E+00	1.579E-01	1.732E+00
48	2012	0.029	1.263E+02	1.280E+02	3.680E+00	3.680E+00	6.880E+00	1.084E-01	1.773E+00
49	2013	0.084	1.295E+02	1.275E+02	1.068E+01	1.068E+01	7.078E+00	3.159E-01	1.818E+00
50	2014	0.064	1.259E+02	1.258E+02	7.990E+00	7.990E+00	7.804E+00	2.396E-01	1.767E+00
51	2015	0.055	1.257E+02	1.261E+02	6.900E+00	6.900E+00	7.670E+00	2.064E-01	1.765E+00
52	2016	0.074	1.265E+02	1.257E+02	9.330E+00	9.330E+00	7.850E+00	2.801E-01	1.776E+00
53	2017	0.074	1.250E+02	1.245E+02	9.200E+00	9.200E+00	8.315E+00	2.787E-01	1.755E+00
54	2018	0.071	1.241E+02	1.239E+02	8.820E+00	8.820E+00	8.536E+00	2.684E-01	1.742E+00
55	2019		1.238E+02						1.738E+00

Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 4

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Fishery-catch/Spring biomass

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1965	*	4.419E+02	0.0215	3.130E+00	3.130E+00	0.00000	1.000E+00
2	1966	*	4.251E+02	0.0501	7.026E+00	7.026E+00	0.00000	1.000E+00
3	1967	*	4.086E+02	0.0658	8.878E+00	8.878E+00	0.00000	1.000E+00
4	1968	*	3.903E+02	0.1035	1.334E+01	1.334E+01	0.00000	1.000E+00
5	1969	*	3.701E+02	0.1285	1.571E+01	1.571E+01	0.00000	1.000E+00
6	1970	*	3.385E+02	0.2365	2.643E+01	2.643E+01	0.00000	1.000E+00
7	1971	*	2.855E+02	0.3962	3.734E+01	3.734E+01	0.00000	1.000E+00
8	1972	*	2.233E+02	0.5324	3.926E+01	3.926E+01	0.00000	1.000E+00
9	1973	*	1.709E+02	0.5816	3.281E+01	3.281E+01	0.00000	1.000E+00
10	1974	*	1.375E+02	0.5355	2.431E+01	2.431E+01	0.00000	1.000E+00
11	1975	*	1.128E+02	0.6147	2.289E+01	2.289E+01	0.00000	1.000E+00
12	1976	*	1.105E+02	0.2209	8.057E+00	8.057E+00	0.00000	1.000E+00
13	1977	*	1.262E+02	0.2794	1.164E+01	1.164E+01	0.00000	1.000E+00
14	1978	*	1.332E+02	0.3518	1.547E+01	1.547E+01	0.00000	1.000E+00
15	1979	*	1.303E+02	0.4265	1.835E+01	1.835E+01	0.00000	1.000E+00
16	1980	*	1.324E+02	0.2831	1.238E+01	1.238E+01	0.00000	1.000E+00
17	1981	*	1.409E+02	0.3155	1.468E+01	1.468E+01	0.00000	1.000E+00
18	1982	*	1.496E+02	0.2696	1.332E+01	1.332E+01	0.00000	1.000E+00
19	1983	*	1.666E+02	0.1904	1.047E+01	1.047E+01	0.00000	1.000E+00
20	1984	2.177E+02	1.802E+02	0.2812	1.673E+01	1.673E+01	-0.18884	1.000E+00
21	1985	1.468E+02	1.646E+02	0.5330	2.896E+01	2.896E+01	0.11433	1.000E+00
22	1986	1.382E+02	1.246E+02	0.7338	3.018E+01	3.018E+01	-0.10364	1.000E+00
23	1987	1.246E+02	9.959E+01	0.4960	1.631E+01	1.631E+01	-0.22378	1.000E+00
24	1988	8.098E+01	8.945E+01	0.5472	1.616E+01	1.616E+01	0.09943	1.000E+00
25	1989	1.038E+02	8.695E+01	0.3557	1.021E+01	1.021E+01	-0.17687	1.000E+00
26	1990	1.031E+02	8.702E+01	0.4869	1.399E+01	1.399E+01	-0.16965	1.000E+00
27	1991	9.343E+01	7.598E+01	0.6458	1.620E+01	1.620E+01	-0.20679	1.000E+00
28	1992	6.137E+01	6.713E+01	0.4854	1.076E+01	1.076E+01	0.08977	1.000E+00
29	1993	9.327E+01	5.822E+01	0.7086	1.362E+01	1.362E+01	-0.47132	1.000E+00
30	1994	5.563E+01	6.168E+01	0.1016	2.070E+00	2.070E+00	0.10320	1.000E+00
31	1995	7.062E+01	9.093E+01	0.0023	7.000E-02	7.000E-02	0.25273	1.000E+00
32	1996	1.756E+02	1.340E+02	0.0052	2.300E-01	2.300E-01	-0.27075	1.000E+00
33	1997	1.749E+02	1.854E+02	0.0108	6.600E-01	6.600E-01	0.05780	1.000E+00
34	1998	2.022E+02	2.345E+02	0.0567	4.390E+00	4.390E+00	0.14841	1.000E+00
35	1999	3.657E+02	2.725E+02	0.0766	6.890E+00	6.890E+00	-0.29419	1.000E+00
36	2000	2.870E+02	2.961E+02	0.1141	1.116E+01	1.116E+01	0.03130	1.000E+00
37	2001	3.660E+02	3.058E+02	0.1402	1.415E+01	1.415E+01	-0.17976	1.000E+00
38	2002	1.995E+02	3.146E+02	0.1030	1.070E+01	1.070E+01	0.45536	1.000E+00
39	2003	3.869E+02	3.214E+02	0.1301	1.381E+01	1.381E+01	-0.18542	1.000E+00
40	2004	3.079E+02	3.235E+02	0.1250	1.335E+01	1.335E+01	0.04962	1.000E+00
41	2005	3.888E+02	3.249E+02	0.1299	1.393E+01	1.393E+01	-0.17960	1.000E+00
42	2006	*	3.431E+02	0.0082	9.300E-01	9.300E-01	0.00000	1.000E+00
43	2007	4.430E+02	3.673E+02	0.0381	4.620E+00	4.620E+00	-0.18739	1.000E+00
44	2008	4.569E+02	3.706E+02	0.0932	1.140E+01	1.140E+01	-0.20930	1.000E+00
45	2009	2.712E+02	3.720E+02	0.0502	6.170E+00	6.170E+00	0.31612	1.000E+00
46	2010	3.947E+02	3.747E+02	0.0758	9.380E+00	9.380E+00	-0.05207	1.000E+00
47	2011	4.229E+02	3.784E+02	0.0419	5.230E+00	5.230E+00	-0.11116	1.000E+00
48	2012	4.894E+02	3.877E+02	0.0288	3.680E+00	3.680E+00	-0.23310	1.000E+00
49	2013	3.973E+02	3.862E+02	0.0837	1.068E+01	1.068E+01	-0.02830	1.000E+00
50	2014	3.321E+02	3.809E+02	0.0635	7.990E+00	7.990E+00	0.13718	1.000E+00
51	2015	*	3.819E+02	0.0547	6.900E+00	6.900E+00	0.00000	1.000E+00
52	2016	1.334E+02	3.806E+02	0.0742	9.330E+00	9.330E+00	1.04823	1.000E+00
53	2017	2.141E+02	3.771E+02	0.0739	9.200E+00	9.200E+00	0.56612	1.000E+00
54	2018	*	3.754E+02	0.0712	8.820E+00	8.820E+00	0.00000	1.000E+00

* Asterisk indicates missing value(s).

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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring                           Page 5

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -----------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984    -0.1888                                         ====|
1985     0.1143                                             |==
1986    -0.1036                                           ==|
1987    -0.2238                                         ====|
1988     0.0994                                             |==
1989    -0.1769                                         ====|
1990    -0.1696                                          ===|
1991    -0.2068                                         ====|
1992     0.0898                                             |==
1993    -0.4713                                    =========|
1994     0.1032                                             |==
1995     0.2527                                             |=====
1996    -0.2708                                        =====|
1997     0.0578                                             |=
1998     0.1484                                             |===
1999    -0.2942                                       ======|
2000     0.0313                                             |=
2001    -0.1798                                         ====|
2002     0.4554                                             |=========
2003    -0.1854                                         ====|
2004     0.0496                                             |=
2005    -0.1796                                         ====|
2006     0.0000                                             |
2007    -0.1874                                         ====|
2008    -0.2093                                         ====|
2009     0.3161                                             |======
2010    -0.0521                                            =|
2011    -0.1112                                           ==|
2012    -0.2331                                        =====|
2013    -0.0283                                            =|
2014     0.1372                                             |===
2015     0.0000                                             |
2016     1.0482                                             |=====================
2017     0.5661                                             |===========
2018     0.0000                                             |
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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 6

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Canadian Yankee Survey

Data type I1: Abundance index (annual average) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1965	0.000E+00	0.000E+00	--	*	1.504E+02	0.00000	1.000E+00
2	1966	0.000E+00	0.000E+00	--	*	1.447E+02	0.00000	1.000E+00
3	1967	0.000E+00	0.000E+00	--	*	1.391E+02	0.00000	1.000E+00
4	1968	0.000E+00	0.000E+00	--	*	1.328E+02	0.00000	1.000E+00
5	1969	0.000E+00	0.000E+00	--	*	1.260E+02	0.00000	1.000E+00
6	1970	0.000E+00	0.000E+00	--	*	1.152E+02	0.00000	1.000E+00
7	1971	1.000E+00	1.000E+00	--	9.690E+01	9.717E+01	-0.00277	1.000E+00
8	1972	1.000E+00	1.000E+00	--	7.920E+01	7.602E+01	0.04104	1.000E+00
9	1973	1.000E+00	1.000E+00	--	5.170E+01	5.817E+01	-0.11785	1.000E+00
10	1974	1.000E+00	1.000E+00	--	4.030E+01	4.680E+01	-0.14964	1.000E+00
11	1975	1.000E+00	1.000E+00	--	3.740E+01	3.840E+01	-0.02631	1.000E+00
12	1976	1.000E+00	1.000E+00	--	4.170E+01	3.760E+01	0.10357	1.000E+00
13	1977	1.000E+00	1.000E+00	--	6.500E+01	4.295E+01	0.41438	1.000E+00
14	1978	1.000E+00	1.000E+00	--	4.430E+01	4.533E+01	-0.02290	1.000E+00
15	1979	1.000E+00	1.000E+00	--	3.850E+01	4.436E+01	-0.14157	1.000E+00
16	1980	1.000E+00	1.000E+00	--	5.140E+01	4.507E+01	0.13139	1.000E+00
17	1981	1.000E+00	1.000E+00	--	4.500E+01	4.796E+01	-0.06376	1.000E+00
18	1982	1.000E+00	1.000E+00	--	4.310E+01	5.092E+01	-0.16677	1.000E+00
19	1983	0.000E+00	0.000E+00	--	*	5.670E+01	0.00000	1.000E+00
20	1984	0.000E+00	0.000E+00	--	*	6.135E+01	0.00000	1.000E+00
21	1985	0.000E+00	0.000E+00	--	*	5.601E+01	0.00000	1.000E+00
22	1986	0.000E+00	0.000E+00	--	*	4.240E+01	0.00000	1.000E+00
23	1987	0.000E+00	0.000E+00	--	*	3.390E+01	0.00000	1.000E+00
24	1988	0.000E+00	0.000E+00	--	*	3.045E+01	0.00000	1.000E+00
25	1989	0.000E+00	0.000E+00	--	*	2.960E+01	0.00000	1.000E+00
26	1990	0.000E+00	0.000E+00	--	*	2.962E+01	0.00000	1.000E+00
27	1991	0.000E+00	0.000E+00	--	*	2.586E+01	0.00000	1.000E+00
28	1992	0.000E+00	0.000E+00	--	*	2.285E+01	0.00000	1.000E+00
29	1993	0.000E+00	0.000E+00	--	*	1.982E+01	0.00000	1.000E+00
30	1994	0.000E+00	0.000E+00	--	*	2.099E+01	0.00000	1.000E+00
31	1995	0.000E+00	0.000E+00	--	*	3.095E+01	0.00000	1.000E+00
32	1996	0.000E+00	0.000E+00	--	*	4.560E+01	0.00000	1.000E+00
33	1997	0.000E+00	0.000E+00	--	*	6.309E+01	0.00000	1.000E+00
34	1998	0.000E+00	0.000E+00	--	*	7.983E+01	0.00000	1.000E+00
35	1999	0.000E+00	0.000E+00	--	*	9.275E+01	0.00000	1.000E+00
36	2000	0.000E+00	0.000E+00	--	*	1.008E+02	0.00000	1.000E+00
37	2001	0.000E+00	0.000E+00	--	*	1.041E+02	0.00000	1.000E+00
38	2002	0.000E+00	0.000E+00	--	*	1.071E+02	0.00000	1.000E+00
39	2003	0.000E+00	0.000E+00	--	*	1.094E+02	0.00000	1.000E+00
40	2004	0.000E+00	0.000E+00	--	*	1.101E+02	0.00000	1.000E+00
41	2005	0.000E+00	0.000E+00	--	*	1.106E+02	0.00000	1.000E+00
42	2006	0.000E+00	0.000E+00	--	*	1.168E+02	0.00000	1.000E+00
43	2007	0.000E+00	0.000E+00	--	*	1.250E+02	0.00000	1.000E+00
44	2008	0.000E+00	0.000E+00	--	*	1.261E+02	0.00000	1.000E+00
45	2009	0.000E+00	0.000E+00	--	*	1.266E+02	0.00000	1.000E+00
46	2010	0.000E+00	0.000E+00	--	*	1.275E+02	0.00000	1.000E+00
47	2011	0.000E+00	0.000E+00	--	*	1.288E+02	0.00000	1.000E+00
48	2012	0.000E+00	0.000E+00	--	*	1.320E+02	0.00000	1.000E+00
49	2013	0.000E+00	0.000E+00	--	*	1.315E+02	0.00000	1.000E+00
50	2014	0.000E+00	0.000E+00	--	*	1.297E+02	0.00000	1.000E+00
51	2015	0.000E+00	0.000E+00	--	*	1.300E+02	0.00000	1.000E+00
52	2016	0.000E+00	0.000E+00	--	*	1.295E+02	0.00000	1.000E+00
53	2017	0.000E+00	0.000E+00	--	*	1.284E+02	0.00000	1.000E+00
54	2018	0.000E+00	0.000E+00	--	*	1.278E+02	0.00000	1.000E+00

* Asterisk indicates missing value(s).

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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring                  Page 7

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971    -0.0028                                             |
1972     0.0410                                             |==
1973    -0.1179                                        =====|
1974    -0.1496                                       ======|
1975    -0.0263                                            =|
1976     0.1036                                             |====
1977     0.4144                                             |=================
1978    -0.0229                                            =|
1979    -0.1416                                       ======|
1980     0.1314                                             |=====
1981    -0.0638                                          ===|
1982    -0.1668                                      =======|
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
2012     0.0000                                             |
2013     0.0000                                             |
2014     0.0000                                             |
2015     0.0000                                             |
2016     0.0000                                             |
2017     0.0000                                             |
2018     0.0000                                             |
                   -------------------------------------------------------------------------------------
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RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canadian Fall Survey

Data type I2: Abundance index (end of year) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1965	0.000E+00	0.000E+00	--	*	4.409E+02	0.00000	1.000E+00
2	1966	0.000E+00	0.000E+00	--	*	4.226E+02	0.00000	1.000E+00
3	1967	0.000E+00	0.000E+00	--	*	4.070E+02	0.00000	1.000E+00
4	1968	0.000E+00	0.000E+00	--	*	3.860E+02	0.00000	1.000E+00
5	1969	0.000E+00	0.000E+00	--	*	3.660E+02	0.00000	1.000E+00
6	1970	0.000E+00	0.000E+00	--	*	3.239E+02	0.00000	1.000E+00
7	1971	0.000E+00	0.000E+00	--	*	2.608E+02	0.00000	1.000E+00
8	1972	0.000E+00	0.000E+00	--	*	1.977E+02	0.00000	1.000E+00
9	1973	0.000E+00	0.000E+00	--	*	1.522E+02	0.00000	1.000E+00
10	1974	0.000E+00	0.000E+00	--	*	1.279E+02	0.00000	1.000E+00
11	1975	0.000E+00	0.000E+00	--	*	1.023E+02	0.00000	1.000E+00
12	1976	0.000E+00	0.000E+00	--	*	1.217E+02	0.00000	1.000E+00
13	1977	0.000E+00	0.000E+00	--	*	1.339E+02	0.00000	1.000E+00
14	1978	0.000E+00	0.000E+00	--	*	1.359E+02	0.00000	1.000E+00
15	1979	0.000E+00	0.000E+00	--	*	1.285E+02	0.00000	1.000E+00
16	1980	0.000E+00	0.000E+00	--	*	1.398E+02	0.00000	1.000E+00
17	1981	0.000E+00	0.000E+00	--	*	1.457E+02	0.00000	1.000E+00
18	1982	0.000E+00	0.000E+00	--	*	1.573E+02	0.00000	1.000E+00
19	1983	0.000E+00	0.000E+00	--	*	1.801E+02	0.00000	1.000E+00
20	1984	0.000E+00	0.000E+00	--	*	1.851E+02	0.00000	1.000E+00
21	1985	0.000E+00	0.000E+00	--	*	1.508E+02	0.00000	1.000E+00
22	1986	0.000E+00	0.000E+00	--	*	1.056E+02	0.00000	1.000E+00
23	1987	0.000E+00	0.000E+00	--	*	9.665E+01	0.00000	1.000E+00
24	1988	0.000E+00	0.000E+00	--	*	8.513E+01	0.00000	1.000E+00
25	1989	0.000E+00	0.000E+00	--	*	9.109E+01	0.00000	1.000E+00
26	1990	1.000E+00	1.000E+00	--	6.580E+01	8.547E+01	-0.26159	1.000E+00
27	1991	1.000E+00	1.000E+00	--	8.240E+01	6.936E+01	0.17233	1.000E+00
28	1992	1.000E+00	1.000E+00	--	6.450E+01	6.679E+01	-0.03487	1.000E+00
29	1993	1.000E+00	1.000E+00	--	1.128E+02	5.202E+01	0.77400	1.000E+00
30	1994	1.000E+00	1.000E+00	--	1.064E+02	7.402E+01	0.36282	1.000E+00
31	1995	1.000E+00	1.000E+00	--	1.298E+02	1.122E+02	0.14546	1.000E+00
32	1996	1.000E+00	1.000E+00	--	1.343E+02	1.609E+02	-0.18084	1.000E+00
33	1997	1.000E+00	1.000E+00	--	2.229E+02	2.154E+02	0.03418	1.000E+00
34	1998	1.000E+00	1.000E+00	--	2.316E+02	2.593E+02	-0.11283	1.000E+00
35	1999	1.000E+00	1.000E+00	--	2.499E+02	2.920E+02	-0.15552	1.000E+00
36	2000	1.000E+00	1.000E+00	--	3.350E+02	3.076E+02	0.08542	1.000E+00
37	2001	1.000E+00	1.000E+00	--	4.758E+02	3.120E+02	0.42201	1.000E+00
38	2002	1.000E+00	1.000E+00	--	3.397E+02	3.249E+02	0.04448	1.000E+00
39	2003	1.000E+00	1.000E+00	--	3.683E+02	3.266E+02	0.12026	1.000E+00
40	2004	1.000E+00	1.000E+00	--	3.747E+02	3.291E+02	0.12984	1.000E+00
41	2005	1.000E+00	1.000E+00	--	3.427E+02	3.294E+02	0.03947	1.000E+00
42	2006	1.000E+00	1.000E+00	--	3.055E+02	3.642E+02	-0.17579	1.000E+00
43	2007	1.000E+00	1.000E+00	--	4.824E+02	3.793E+02	0.24033	1.000E+00
44	2008	1.000E+00	1.000E+00	--	3.220E+02	3.724E+02	-0.14550	1.000E+00
45	2009	1.000E+00	1.000E+00	--	2.378E+02	3.810E+02	-0.47143	1.000E+00
46	2010	1.000E+00	1.000E+00	--	4.172E+02	3.787E+02	0.09679	1.000E+00
47	2011	1.000E+00	1.000E+00	--	3.104E+02	3.877E+02	-0.22225	1.000E+00
48	2012	1.000E+00	1.000E+00	--	3.574E+02	3.975E+02	-0.10628	1.000E+00
49	2013	1.000E+00	1.000E+00	--	3.461E+02	3.864E+02	-0.11019	1.000E+00
50	2014	0.000E+00	0.000E+00	--	*	3.858E+02	0.00000	1.000E+00
51	2015	1.000E+00	1.000E+00	--	3.074E+02	3.882E+02	-0.23334	1.000E+00
52	2016	1.000E+00	1.000E+00	--	2.867E+02	3.837E+02	-0.29148	1.000E+00
53	2017	1.000E+00	1.000E+00	--	3.222E+02	3.810E+02	-0.16753	1.000E+00
54	2018	0.000E+00	0.000E+00	--	*	3.801E+02	0.00000	1.000E+00

* Asterisk indicates missing value(s).

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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring                      Page 9

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990    -0.2616                                   ==========|
1991     0.1723                                             |=======
1992    -0.0349                                            =|
1993     0.7740                                             |===============================
1994     0.3628                                             |===============
1995     0.1455                                             |======
1996    -0.1808                                      =======|
1997     0.0342                                             |=
1998    -0.1128                                        =====|
1999    -0.1555                                       ======|
2000     0.0854                                             |===
2001     0.4220                                             |=================
2002     0.0445                                             |==
2003     0.1203                                             |=====
2004     0.1298                                             |=====
2005     0.0395                                             |==
2006    -0.1758                                      =======|
2007     0.2403                                             |==========
2008    -0.1455                                       ======|
2009    -0.4714                          ===================|
2010     0.0968                                             |====
2011    -0.2222                                    =========|
2012    -0.1063                                         ====|
2013    -0.1102                                         ====|
2014     0.0000                                             |
2015    -0.2333                                    =========|
2016    -0.2915                                 ============|
2017    -0.1675                                      =======|
2018     0.0000                                             |
                   ------------------------------------------------------------------------------------
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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page10

RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED) Russian Survey

Data type I1: Abundance index (annual average) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1965	0.000E+00	0.000E+00	--	*	1.734E+02	0.00000	1.000E+00
2	1966	0.000E+00	0.000E+00	--	*	1.668E+02	0.00000	1.000E+00
3	1967	0.000E+00	0.000E+00	--	*	1.603E+02	0.00000	1.000E+00
4	1968	0.000E+00	0.000E+00	--	*	1.531E+02	0.00000	1.000E+00
5	1969	0.000E+00	0.000E+00	--	*	1.452E+02	0.00000	1.000E+00
6	1970	0.000E+00	0.000E+00	--	*	1.328E+02	0.00000	1.000E+00
7	1971	0.000E+00	0.000E+00	--	*	1.120E+02	0.00000	1.000E+00
8	1972	0.000E+00	0.000E+00	--	*	8.762E+01	0.00000	1.000E+00
9	1973	0.000E+00	0.000E+00	--	*	6.705E+01	0.00000	1.000E+00
10	1974	0.000E+00	0.000E+00	--	*	5.395E+01	0.00000	1.000E+00
11	1975	0.000E+00	0.000E+00	--	*	4.426E+01	0.00000	1.000E+00
12	1976	0.000E+00	0.000E+00	--	*	4.334E+01	0.00000	1.000E+00
13	1977	0.000E+00	0.000E+00	--	*	4.951E+01	0.00000	1.000E+00
14	1978	0.000E+00	0.000E+00	--	*	5.225E+01	0.00000	1.000E+00
15	1979	0.000E+00	0.000E+00	--	*	5.113E+01	0.00000	1.000E+00
16	1980	0.000E+00	0.000E+00	--	*	5.195E+01	0.00000	1.000E+00
17	1981	0.000E+00	0.000E+00	--	*	5.529E+01	0.00000	1.000E+00
18	1982	0.000E+00	0.000E+00	--	*	5.870E+01	0.00000	1.000E+00
19	1983	0.000E+00	0.000E+00	--	*	6.536E+01	0.00000	1.000E+00
20	1984	1.000E+00	1.000E+00	--	1.320E+02	7.072E+01	0.62413	1.000E+00
21	1985	1.000E+00	1.000E+00	--	8.500E+01	6.456E+01	0.27500	1.000E+00
22	1986	1.000E+00	1.000E+00	--	4.200E+01	4.887E+01	-0.15156	1.000E+00
23	1987	1.000E+00	1.000E+00	--	3.000E+01	3.907E+01	-0.26428	1.000E+00
24	1988	1.000E+00	1.000E+00	--	2.300E+01	3.509E+01	-0.42252	1.000E+00
25	1989	1.000E+00	1.000E+00	--	4.400E+01	3.411E+01	0.25449	1.000E+00
26	1990	1.000E+00	1.000E+00	--	2.700E+01	3.414E+01	-0.23470	1.000E+00
27	1991	1.000E+00	1.000E+00	--	2.750E+01	2.981E+01	-0.08063	1.000E+00
28	1992	0.000E+00	0.000E+00	--	*	2.634E+01	0.00000	1.000E+00
29	1993	0.000E+00	0.000E+00	--	*	2.284E+01	0.00000	1.000E+00
30	1994	0.000E+00	0.000E+00	--	*	2.420E+01	0.00000	1.000E+00
31	1995	0.000E+00	0.000E+00	--	*	3.567E+01	0.00000	1.000E+00
32	1996	0.000E+00	0.000E+00	--	*	5.256E+01	0.00000	1.000E+00
33	1997	0.000E+00	0.000E+00	--	*	7.273E+01	0.00000	1.000E+00
34	1998	0.000E+00	0.000E+00	--	*	9.202E+01	0.00000	1.000E+00
35	1999	0.000E+00	0.000E+00	--	*	1.069E+02	0.00000	1.000E+00
36	2000	0.000E+00	0.000E+00	--	*	1.162E+02	0.00000	1.000E+00
37	2001	0.000E+00	0.000E+00	--	*	1.200E+02	0.00000	1.000E+00
38	2002	0.000E+00	0.000E+00	--	*	1.234E+02	0.00000	1.000E+00
39	2003	0.000E+00	0.000E+00	--	*	1.261E+02	0.00000	1.000E+00
40	2004	0.000E+00	0.000E+00	--	*	1.269E+02	0.00000	1.000E+00
41	2005	0.000E+00	0.000E+00	--	*	1.275E+02	0.00000	1.000E+00
42	2006	0.000E+00	0.000E+00	--	*	1.346E+02	0.00000	1.000E+00
43	2007	0.000E+00	0.000E+00	--	*	1.441E+02	0.00000	1.000E+00
44	2008	0.000E+00	0.000E+00	--	*	1.454E+02	0.00000	1.000E+00
45	2009	0.000E+00	0.000E+00	--	*	1.459E+02	0.00000	1.000E+00
46	2010	0.000E+00	0.000E+00	--	*	1.470E+02	0.00000	1.000E+00
47	2011	0.000E+00	0.000E+00	--	*	1.485E+02	0.00000	1.000E+00
48	2012	0.000E+00	0.000E+00	--	*	1.521E+02	0.00000	1.000E+00
49	2013	0.000E+00	0.000E+00	--	*	1.515E+02	0.00000	1.000E+00
50	2014	0.000E+00	0.000E+00	--	*	1.495E+02	0.00000	1.000E+00
51	2015	0.000E+00	0.000E+00	--	*	1.499E+02	0.00000	1.000E+00
52	2016	0.000E+00	0.000E+00	--	*	1.493E+02	0.00000	1.000E+00
53	2017	0.000E+00	0.000E+00	--	*	1.479E+02	0.00000	1.000E+00
54	2018	0.000E+00	0.000E+00	--	*	1.473E+02	0.00000	1.000E+00

* Asterisk indicates missing value(s).

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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring                                  Page11

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 4
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.6241                                             |=========================
1985     0.2750                                             |===========
1986    -0.1516                                       ======|
1987    -0.2643                                  ===========|
1988    -0.4225                            =================|
1989     0.2545                                             |==========
1990    -0.2347                                    =========|
1991    -0.0806                                          ===|
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
2005     0.0000                                             |
2006     0.0000                                             |
2007     0.0000                                             |
2008     0.0000                                             |
2009     0.0000                                             |
2010     0.0000                                             |
2011     0.0000                                             |
2012     0.0000                                             |
2013     0.0000                                             |
2014     0.0000                                             |
2015     0.0000                                             |
2016     0.0000                                             |
2017     0.0000                                             |
2018     0.0000                                             |
                   ------------------------------------------------------------------------------------
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Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page12

RESULTS FOR DATA SERIES # 5 (NON-BOOTSTRAPPED) Spanish Survey Converted biomass_2006

Data type I1: Abundance index (annual average) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1965	0.000E+00	0.000E+00	--	*	1.828E+02	0.00000	1.000E+00
2	1966	0.000E+00	0.000E+00	--	*	1.759E+02	0.00000	1.000E+00
3	1967	0.000E+00	0.000E+00	--	*	1.690E+02	0.00000	1.000E+00
4	1968	0.000E+00	0.000E+00	--	*	1.615E+02	0.00000	1.000E+00
5	1969	0.000E+00	0.000E+00	--	*	1.531E+02	0.00000	1.000E+00
6	1970	0.000E+00	0.000E+00	--	*	1.400E+02	0.00000	1.000E+00
7	1971	0.000E+00	0.000E+00	--	*	1.181E+02	0.00000	1.000E+00
8	1972	0.000E+00	0.000E+00	--	*	9.240E+01	0.00000	1.000E+00
9	1973	0.000E+00	0.000E+00	--	*	7.070E+01	0.00000	1.000E+00
10	1974	0.000E+00	0.000E+00	--	*	5.689E+01	0.00000	1.000E+00
11	1975	0.000E+00	0.000E+00	--	*	4.667E+01	0.00000	1.000E+00
12	1976	0.000E+00	0.000E+00	--	*	4.570E+01	0.00000	1.000E+00
13	1977	0.000E+00	0.000E+00	--	*	5.220E+01	0.00000	1.000E+00
14	1978	0.000E+00	0.000E+00	--	*	5.509E+01	0.00000	1.000E+00
15	1979	0.000E+00	0.000E+00	--	*	5.391E+01	0.00000	1.000E+00
16	1980	0.000E+00	0.000E+00	--	*	5.479E+01	0.00000	1.000E+00
17	1981	0.000E+00	0.000E+00	--	*	5.830E+01	0.00000	1.000E+00
18	1982	0.000E+00	0.000E+00	--	*	6.190E+01	0.00000	1.000E+00
19	1983	0.000E+00	0.000E+00	--	*	6.892E+01	0.00000	1.000E+00
20	1984	0.000E+00	0.000E+00	--	*	7.457E+01	0.00000	1.000E+00
21	1985	0.000E+00	0.000E+00	--	*	6.808E+01	0.00000	1.000E+00
22	1986	0.000E+00	0.000E+00	--	*	5.154E+01	0.00000	1.000E+00
23	1987	0.000E+00	0.000E+00	--	*	4.121E+01	0.00000	1.000E+00
24	1988	0.000E+00	0.000E+00	--	*	3.701E+01	0.00000	1.000E+00
25	1989	0.000E+00	0.000E+00	--	*	3.597E+01	0.00000	1.000E+00
26	1990	0.000E+00	0.000E+00	--	*	3.600E+01	0.00000	1.000E+00
27	1991	0.000E+00	0.000E+00	--	*	3.143E+01	0.00000	1.000E+00
28	1992	0.000E+00	0.000E+00	--	*	2.778E+01	0.00000	1.000E+00
29	1993	0.000E+00	0.000E+00	--	*	2.409E+01	0.00000	1.000E+00
30	1994	0.000E+00	0.000E+00	--	*	2.552E+01	0.00000	1.000E+00
31	1995	1.000E+00	1.000E+00	--	9.300E+00	3.762E+01	-1.39750	1.000E+00
32	1996	1.000E+00	1.000E+00	--	4.330E+01	5.543E+01	-0.24689	1.000E+00
33	1997	1.000E+00	1.000E+00	--	3.870E+01	7.669E+01	-0.68394	1.000E+00
34	1998	1.000E+00	1.000E+00	--	1.226E+02	9.703E+01	0.23388	1.000E+00
35	1999	1.000E+00	1.000E+00	--	1.970E+02	1.127E+02	0.55811	1.000E+00
36	2000	1.000E+00	1.000E+00	--	1.447E+02	1.225E+02	0.16633	1.000E+00
37	2001	1.000E+00	1.000E+00	--	1.827E+02	1.265E+02	0.36755	1.000E+00
38	2002	1.000E+00	1.000E+00	--	1.485E+02	1.301E+02	0.13193	1.000E+00
39	2003	1.000E+00	1.000E+00	--	1.368E+02	1.330E+02	0.02825	1.000E+00
40	2004	1.000E+00	1.000E+00	--	1.700E+02	1.338E+02	0.23909	1.000E+00
41	2005	1.000E+00	1.000E+00	--	1.565E+02	1.344E+02	0.15207	1.000E+00
42	2006	1.000E+00	1.000E+00	--	1.601E+02	1.420E+02	0.12031	1.000E+00
43	2007	1.000E+00	1.000E+00	--	1.607E+02	1.520E+02	0.05586	1.000E+00
44	2008	1.000E+00	1.000E+00	--	1.601E+02	1.533E+02	0.04324	1.000E+00
45	2009	1.000E+00	1.000E+00	--	1.834E+02	1.539E+02	0.17533	1.000E+00
46	2010	1.000E+00	1.000E+00	--	1.897E+02	1.550E+02	0.20186	1.000E+00
47	2011	1.000E+00	1.000E+00	--	2.038E+02	1.565E+02	0.26378	1.000E+00
48	2012	1.000E+00	1.000E+00	--	1.956E+02	1.604E+02	0.19844	1.000E+00
49	2013	1.000E+00	1.000E+00	--	1.880E+02	1.598E+02	0.16233	1.000E+00
50	2014	1.000E+00	1.000E+00	--	1.365E+02	1.576E+02	-0.14391	1.000E+00
51	2015	1.000E+00	1.000E+00	--	1.408E+02	1.580E+02	-0.11539	1.000E+00
52	2016	1.000E+00	1.000E+00	--	1.537E+02	1.575E+02	-0.02421	1.000E+00
53	2017	1.000E+00	1.000E+00	--	9.591E+01	1.560E+02	-0.48654	1.000E+00
54	2018	0.000E+00	0.000E+00	--	*	1.553E+02	0.00000	1.000E+00

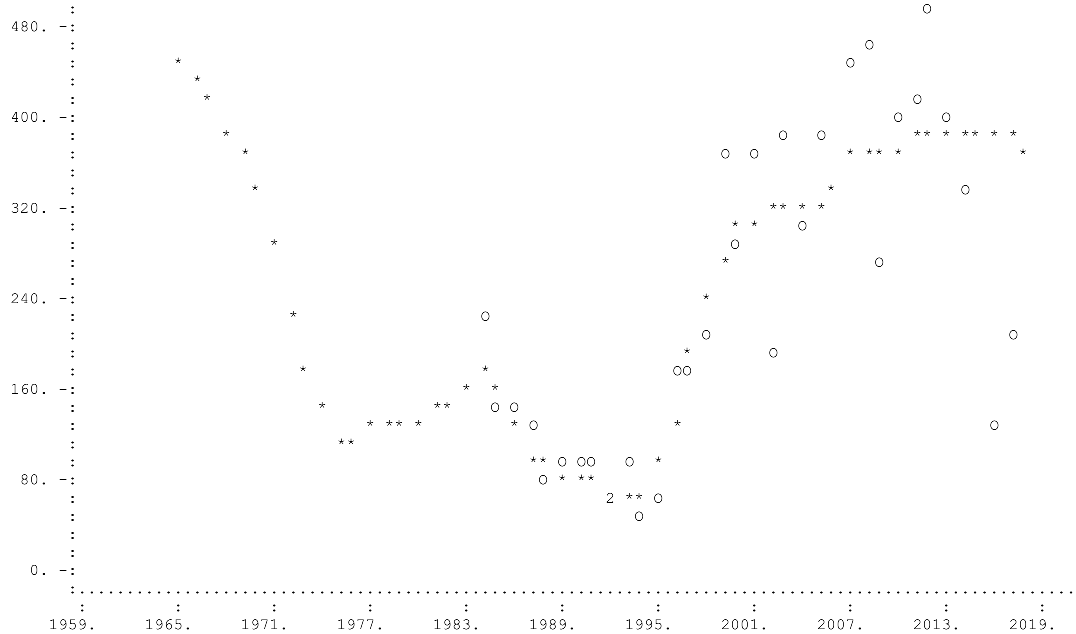
* Asterisk indicates missing value(s).

Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring   Page13

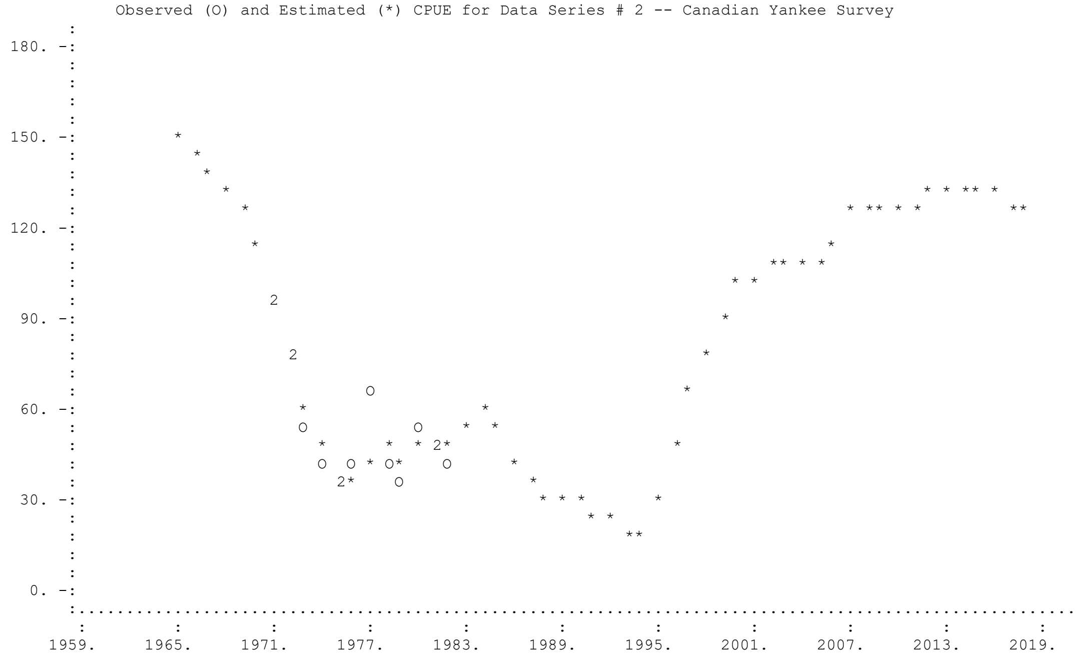
```
UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 5
                   -2       -1.5       -1       -0.5        0        0.5        1       1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1965     0.0000                                             |
1966     0.0000                                             |
1967     0.0000                                             |
1968     0.0000                                             |
1969     0.0000                                             |
1970     0.0000                                             |
1971     0.0000                                             |
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995    -1.3975                 ============================|
1996    -0.2469                                        =====|
1997    -0.6839                               ==============|
1998     0.2339                                             |=====
1999     0.5581                                             |===========
2000     0.1663                                             |===
2001     0.3676                                             |=======
2002     0.1319                                             |===
2003     0.0282                                             |=
2004     0.2391                                             |=====
2005     0.1521                                             |===
2006     0.1203                                             |==
2007     0.0559                                             |=
2008     0.0432                                             |=
2009     0.1753                                             |====
2010     0.2019                                             |====
2011     0.2638                                             |=====
2012     0.1984                                             |====
2013     0.1623                                             |===
2014    -0.1439                                          ===|
2015    -0.1154                                           ==|
2016    -0.0242                                             |
2017    -0.4865                                   ==========|
2018     0.0000                                             |
                   -------------------------------------------------------------------------------------
```

Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 14

Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Fishery-catch/Spring biomass

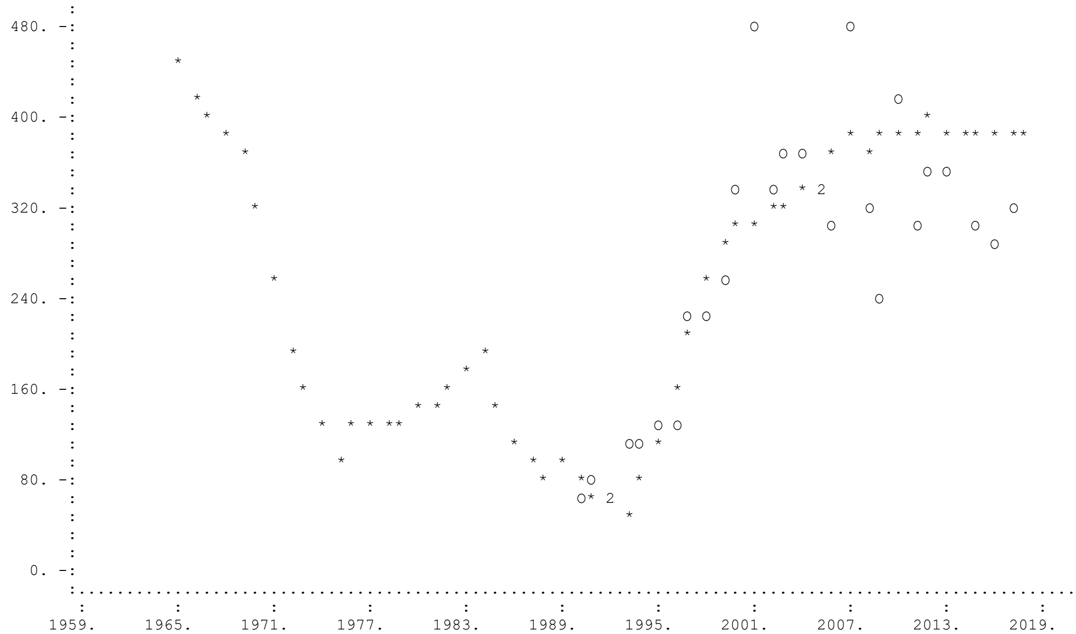


Observed (O) and Estimated (*) CPUE for Data Series # 2 -- Canadian Yankee Survey

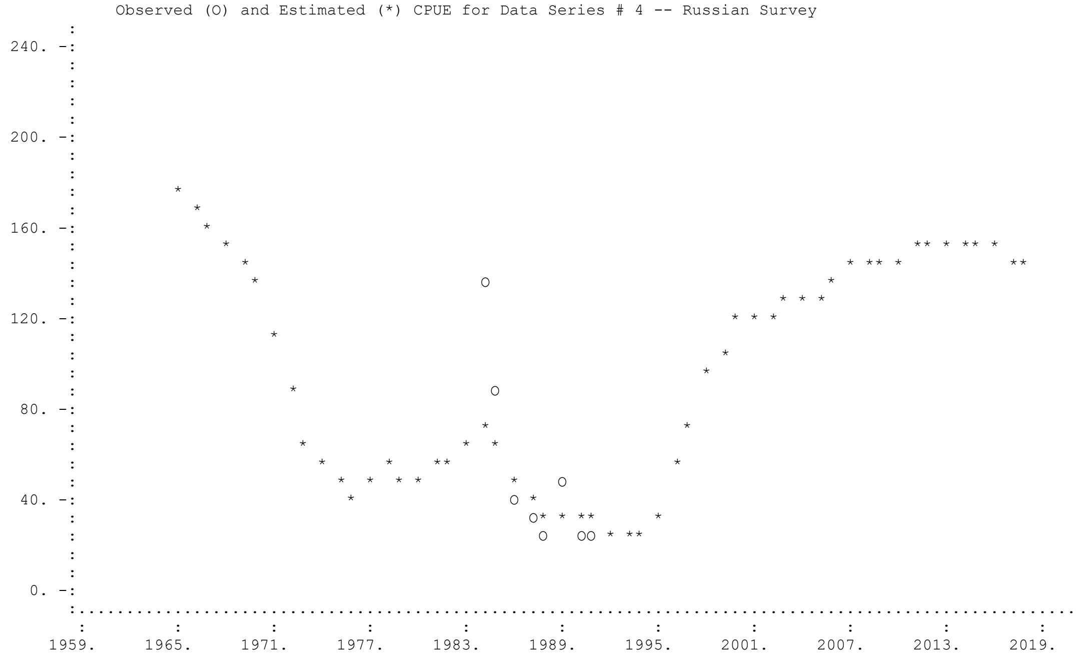


Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring   Page 15

Observed (O) and Estimated (*) CPUE for Data Series # 3 -- Canadian Fall Survey

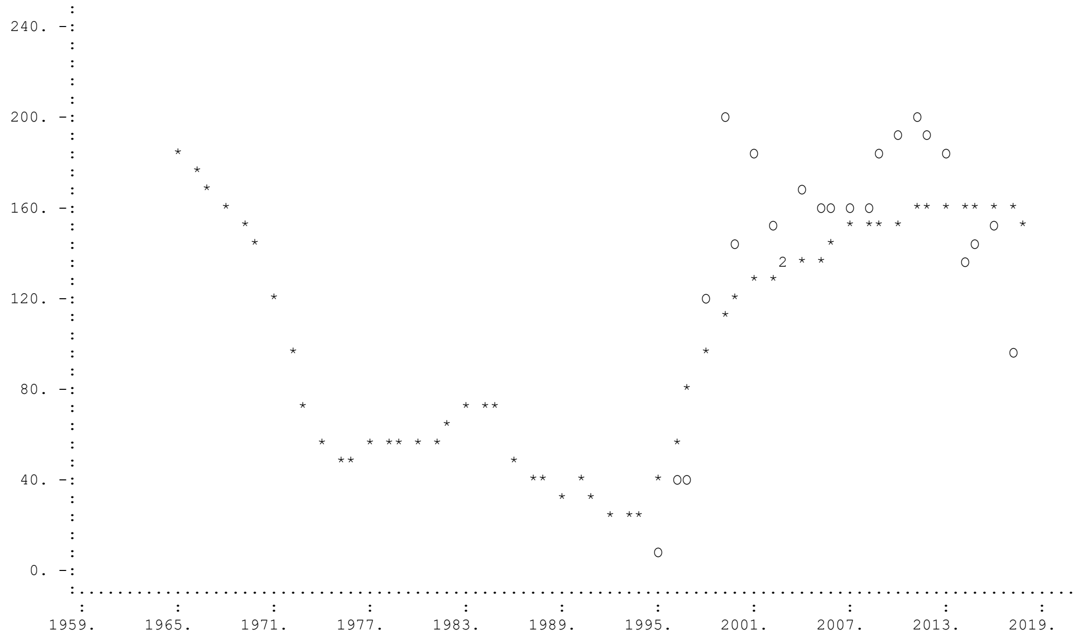


Observed (O) and Estimated (*) CPUE for Data Series # 4 -- Russian Survey

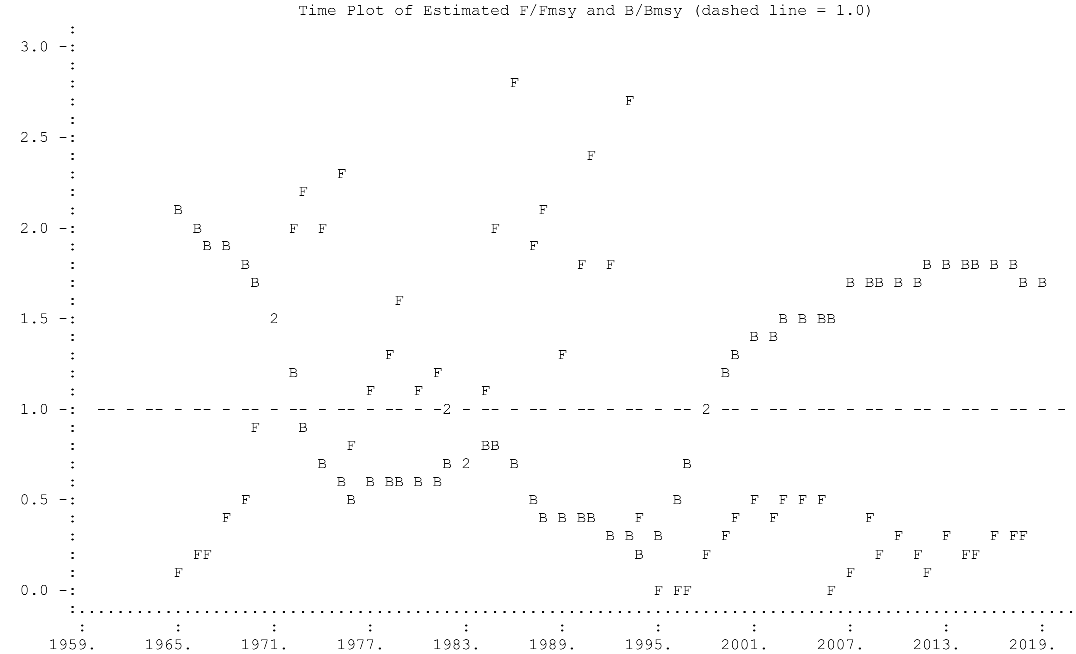


Yellowtail flounder 2018 NAFO catch in 2018 avg 2013-2017 drop Can 2015 Spring Page 16

Observed (O) and Estimated (*) CPUE for Data Series # 5 -- Spanish Survey Converted biomass_2006



Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)



Elapsed time: 0 hours, 0 minutes, 5.328 seconds.

APPENDIX 2

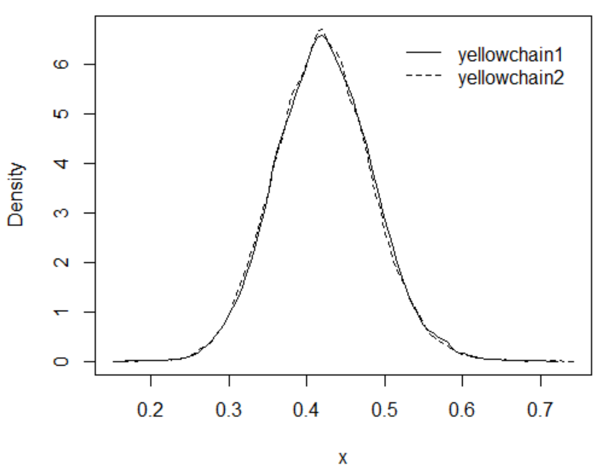
Bayesian Model Specification for trial run of yellowtail flounder in NAFO Divs 3LNO

```
model
{
#prior for r mean 0.3 std 0.1
r ~ dlnorm(-1.2567,9.4912)

# prior distribution of K
#150,25
K~dlnorm(4.997,36.4977)

# prior distribution of q's
q.Spring~dgamma(1,1)
q.Fall~dgamma(1,1)
q.Russian~dgamma(1,1)
q.Spanish~dgamma(1,1)
q.Yankee~dgamma(1,1)

# Prior for process noise, sigma
sigma ~ dunif(0,5)
isigma2 <- pow(sigma, -2)

# Prior for observation errors, tau.
tau.Spring~dgamma(1,1)
itau2.Spring <- 1/tau.Spring
tau.Fall~dgamma(1,1)
itau2.Fall <- 1/tau.Fall
tau.Russian~dgamma(1,1)
itau2.Russian<- 1/tau.Russian
tau.Spanish~dgamma(1,1)
itau2.Spanish <- 1/tau.Spanish
tau.Yankee~dgamma(1,1)
itau2.Yankee <- 1/tau.Yankee

# Prior for initial population size as proportion of K, P[1].
Pin~dunif(0.5, 1)
Pm[1] <- log(Pin)
P[1] ~ dlnorm(Pm[1], isigma2)I(0.001,5)
P.res[1]<-log(P[1])-Pm[1]

# State equation - SP Model.
for (t in 2:(53))   {
Pm[t] <- log(max(P[t-1] + r*P[t-1]*(1-P[t-1]) - L[t-1]/K,
0.0001))
P[t] ~ dlnorm(Pm[t], isigma2)I(0.001,5)
P.res[t]<-log(P[t])-Pm[t]
}

# Observation equations
for (t in 20:(N)) {
Springm[t] <- log(q.Spring* K * P[t])
Spring[t] ~ dlnorm(Springm[t], itau2.Spring)
}

for (t in 26:(N)) {
Fallm[t] <- log(q.Fall* K * P[t])
Fall[t] ~ dlnorm(Fallm[t], itau2.Fall)
}

for (t in 31:(N)) {
Spanishm[t] <- log(q.Spanish* K * P[t])
Spanish[t] ~ dlnorm(Spanishm[t], itau2.Spanish)
}
for (t in 7:(18)) {
Yankeem[t] <- log(q.Yankee* K * P[t])
Yankee[t] ~ dlnorm(Yankeem[t], itau2.Yankee)
}
for (t in 20:(27)) {
Russianm[t] <- log(q.Russian* K * P[t])
Russian[t] ~ dlnorm(Russianm[t], itau2.Russian)
}
# Output. Using the proportion and K to estimate biomass, B.
for(t in 1:N) {
B[t] <- P[t] * K
F[t]<-L[t]/B[t]
}
#Biomass Ratio: Showing what percent the stock would be at if
fished at MSY for a given year, t
for(t in 1:N) {
Bratio[t] <- B[t]/BMSY
}
#F Ratio: indicates the ratio of fishing mortality to that
estimated for FMSY.
#e.g. 1.65=65% higher than that estimated for FMSY
for(t in 1:N) {
Fratio[t] <- F[t]/FMSY
}
# further management parameters and predictions:
MSP <- r*K/4;
FMSY<-r/2
BMSY<-K/2
#Replicate data sets code below here
#generate replicate data sets
for (i in 7:18){
        Yankee.rep[i] ~ dlnorm(Yankeem[i],itau2.Yankee)
        p.smaller.Yankee[i] <- step(log(Yankee[i])-
log(Yankee.rep[i]))
#residuals of log values of replicate data
        res.Yankee.rep[i] <- log(Yankee[i])-
log(Yankee.rep[i])
}
#generate replicate data sets
for (i in 20:N){
        Spring.rep[i] ~ dlnorm(Springm[i],itau2.Spring)
        p.smaller.Spring[i] <- step(log(Spring[i])-
log(Spring.rep[i]))
#residuals of log values of replicate data
        res.Spring.rep[i] <- log(Spring[i])-log(Spring.rep[i])
}
#generate replicate data sets
for (i in 26:N){
        Fall.rep[i] ~ dlnorm(Fallm[i],itau2.Fall)
```

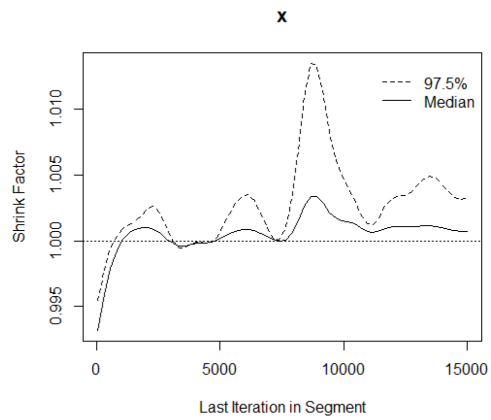
```
        p.smaller.Fall[i] <- step(log(Fall[i])-log(Fall.rep[i]))
#residuals of log values of replicate data
        res.Fall.rep[i] <- log(Fall[i])-log(Fall.rep[i])
}
#generate replicate data sets
for (i in 31:N){
        Spanish.rep[i] ~ dlnorm(Spanishm[i],itau2.Spanish)
        p.smaller.Spanish[i] <- step(log(Spanish[i])-
log(Spanish.rep[i]))
#residuals of log values of replicate data
        res.Spanish.rep[i] <- log(Spanish[i])-
log(Spanish.rep[i])
}
#generate replicate data sets
for (i in 20:27){
        Russian.rep[i] ~ dlnorm(Russianm[i],itau2.Russian)
        p.smaller.Russian[i] <- step(log(Russian[i])-
log(Russian.rep[i]))
#residuals of log values of replicate data
        res.Russian.rep[i] <- log(Russian[i])-
log(Russian.rep[i])
}
} ## END
```

Diagnostics for r

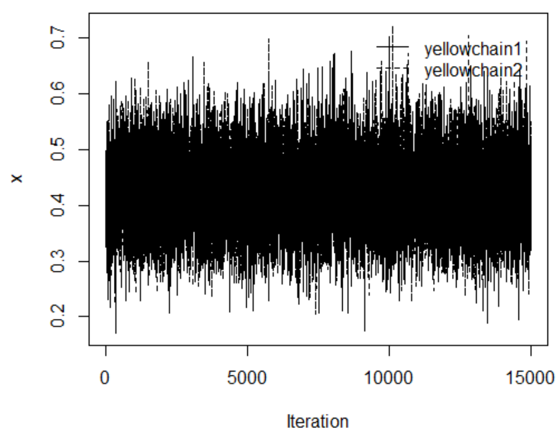
Estimated Posterior Density



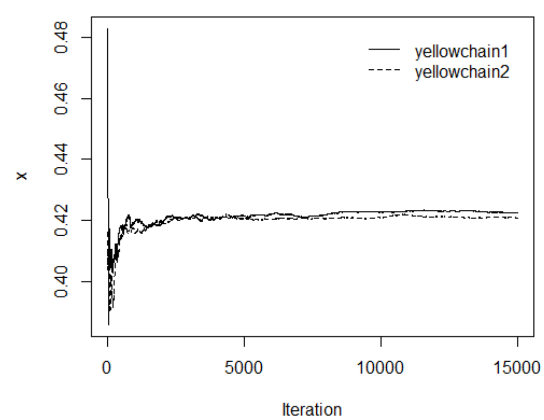
Gelman & Rubin Shrink Factors

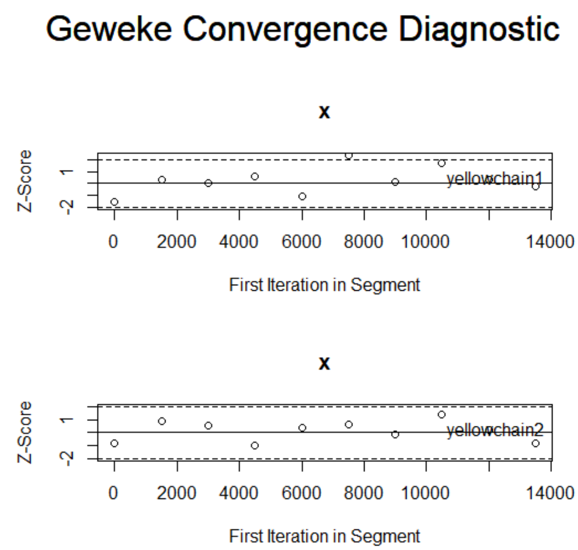


Sampler Trace

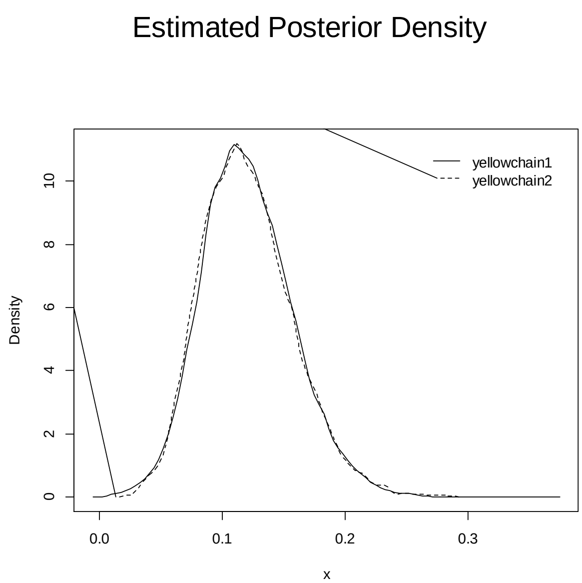


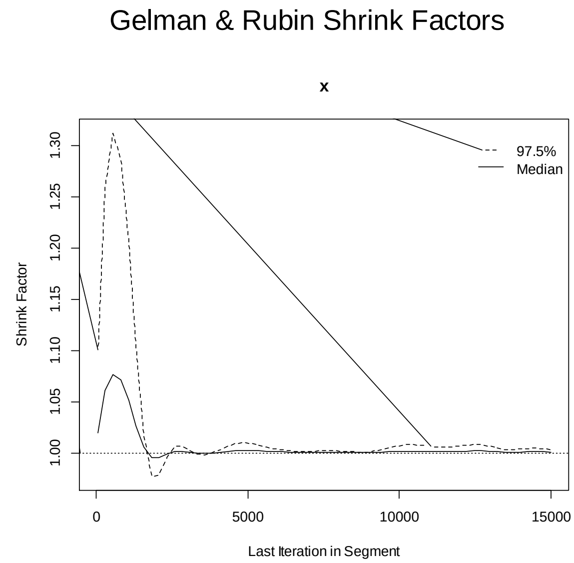
Sampler Running Mean

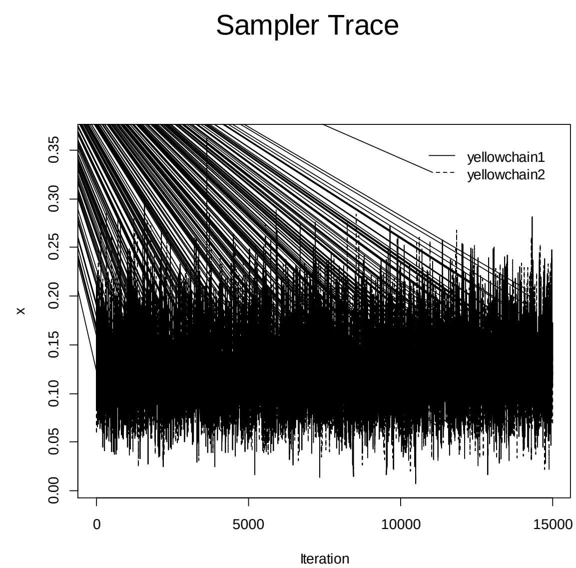


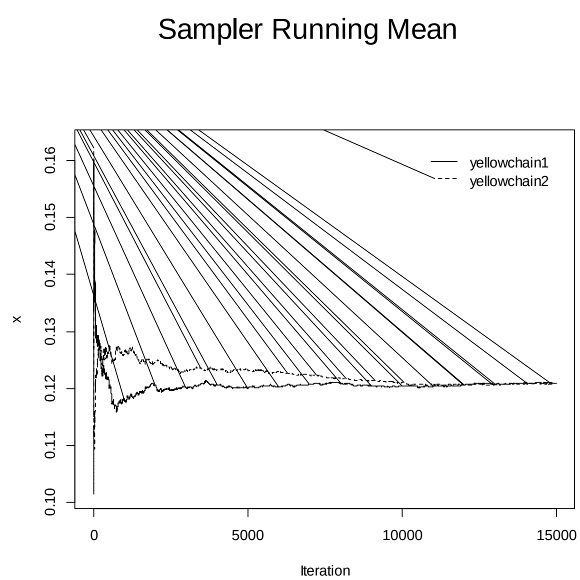


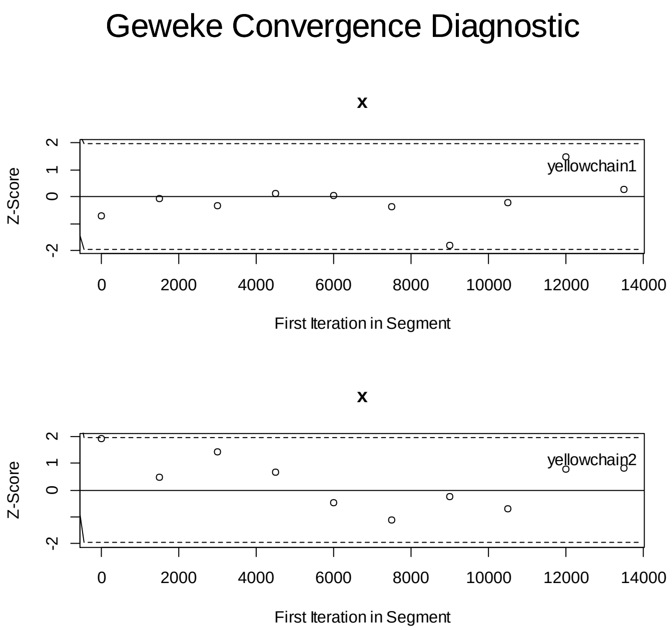
Diagnostics: Process error










Geweke Convergence Diagnostic
x
Z-Score
yellowchain1
First Iteration in Segment
x
Z-Score
yellowchain2
First Iteration in Segment

APPENDIX 3

SPiCT model output(parameter estimates, reference points and predictions)

```
Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 101.2774491
Euler time step (years):  1/16 or 0.0625
Nobs C: 54,  Nobs I1: 33,  Nobs I2: 12,  Nobs I3: 23,  Nobs I4: 27,  Nobs I5: 8
```

Priors

```
     logn  ~  dnorm[log(2), 2^2]
 logalpha  ~  dnorm[log(1), 2^2]
  logbeta  ~  dnorm[log(1), 2^2]
```

Model parameter estimates w 95% CI

```
           estimate       cilow       ciupp    log.est
 alpha1   2.4651796   1.2427037   4.8902328  0.9022647
 alpha2   1.4220171   0.5824047   3.4720402  0.3520764
 alpha3   3.9854310   2.0436936   7.7720361  1.3826455
 alpha4   1.7778448   0.8954449   3.5297895  0.5754018
 alpha5   2.9796493   1.3196282   6.7278872  1.0918056
 beta     0.1033248   0.0182045   0.5864487 -2.2698782
 r        0.3353777   0.1884381   0.5968972 -1.0924980
 rc       0.5294545   0.3699743   0.7576798 -0.6359081
 rold     1.2566600   0.0816122  19.3499794  0.2284574
 m       16.4173991  13.3675624  20.1630622  2.7983417
 K      150.4720383 113.4489162 199.5773524  5.0137773
 q1       2.7712184   2.0199479   3.8019055  1.0192871
 q2       0.6793788   0.4287631   1.0764816 -0.3865764
 q3       1.2227821   0.8617439   1.7350818  0.2011287
 q4       2.9509736   2.1455415   4.0587634  1.0821352
 q5       1.0522476   0.7210163   1.5356450  0.0509285
 n        1.2668802   0.6448442   2.4889508  0.2365573
 sdb      0.1029913   0.0582239   0.1821797 -2.2731107
 sdf      1.0590167   0.8577949   1.3074411  0.0573408
 sdi1     0.2538921   0.1899483   0.3393617 -1.3708461
 sdi2     0.1464554   0.0824394   0.2601814 -1.9210343
 sdi3     0.4104647   0.3003604   0.5609305 -0.8904652
 sdi4     0.1831026   0.1265077   0.2650159 -1.6977089
 sdi5     0.3068780   0.1789942   0.5261294 -1.1813051
 sdc      0.1094226   0.0207520   0.5769721 -2.2125374
         estimate      cilow      ciupp   log.est
 Bmsyd 62.0162848 40.5321742 94.8880649  4.127397
 Fmsyd  0.2647272  0.1849871  0.3788399 -1.329055
 MSYd  16.4173991 13.3675624 20.1630622  2.798342
        estimate      cilow      ciupp   log.est rel.diff.Drp
 Bmsys 61.271138 40.1564237 93.4882133  4.115309 -0.012161471
 Fmsys  0.264036  0.1836081  0.3796945 -1.331670 -0.002617925
 MSYs  16.177270 13.2854165 19.6985970  2.783607 -0.014843608
                  estimate      cilow       ciupp    log.est
 B_2018.00      102.0461840 68.7561439 151.4544457  4.6254255
 F_2018.00        0.0871341  0.0345827   0.2195418 -2.4403069
 B_2018.00/Bmsy   1.6654854  1.2082553   2.2957413  0.5101166
 F_2018.00/Fmsy   0.3300085  0.1339532   0.8130123 -1.1086370
Predictions w 95% CI (inp$msytype: s)
                prediction      cilow       ciupp    log.est
 B_2019.00      105.0086998 69.7148432 158.1704345  4.6540432
 F_2019.00        0.0843145  0.0238365   0.2982377 -2.4732010
 B_2019.00/Bmsy   1.7138363  1.2323212   2.3834977  0.5387343
 F_2019.00/Fmsy   0.3193297  0.0918292   1.1104467 -1.1415311
 Catch_2019.00    8.9511401  1.7921569  44.7075313  2.1917809
 E(B_inf)       113.4165957         NA          NA  4.7310677
```