Applying a stochastic surplus production model (SPiCT) to Pollack *(Pollachius pollachius*) stock in ICES Area 8 and division 9a. Data compilation and preliminary assessment.

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Summary

The Bay of Biscay and Atlantic Iberian Waters pollack stock, pol.27.89a, is considered as a data-limited stock and it is classified as category 5 stock, as only landings data were available. There is no assessment for pollack in this area. Since 2012, ICES provides scientific advice for pol.27.89a applying the precautionary approach. A stochastic surplus production model (SPiCT) was applied to pol.27.89a using as input data the commercial landings time-series 1986-2018 and the new available information of the commercial LPUE index FR-GN90-8a-2S for the time-series 2005-2018. Different combinations of settings of the model and values of priors for the initial biomass depletion (log_bkfrac) and the shape of the production model (log_n) were explored. A Base Case model converged and was stable, and the perception was that the relative biomass and fishing mortality were within safe biological limits. However, there are some concerns due to the model only converges by setting very informative priors on BK fraction and the shape of the production model.

1. Introduction

Pollachius pollachius (Linnaeus, 1758) is restricted to the Northeast Atlantic with a main distribution from the Portuguese continental coast northwards around the British Isles, into the Skagerrak and along the Norwegian coast where it is fairly common up to the Lofoten Islands. Pollack is bentho-pelagic. Outside the breeding season, it does not form large schools, but it is rarely solitary. During reproduction, individuals come together in dense formations. Juveniles live along the coast at least during their first two years; they move offshore, gaining depth (40 to 100 m) during their third year (Moreau, 1964; Quéro and Vayne, 1997). According to Moreau (1964) reproduction occurs at maximum depths of 150 m.

Data from the fishery indicate three main areas of exploitation, so based on a pragmatic approach three different stock units are distinguish (ICES, 2012): the southern European Atlantic shelf (ICES Subarea 8 and Division 9a), the Celtic Seas (ICES Subareas 6 and 7), and the North Sea (ICES Subarea 4, including Divisions 7d and 3a).

Pol.27.89a is mainly exploited by France and Spain, with minor contribution to landings from Portugal. In the last 10 years, France was responsible for 77% of the commercial landings of the stock and Spain for 18%. In recent years, netters and longliners are catching the 54% and 35% of landings, respectively. Trawl and other gears catch the remaining 21% of landings.

Although it is known that the recreational catches may be considerable, they have not been quantified.

The last management advice for pol.27.89a was provided in 2019, and ICES advised that commercial landings should be no more than 1131 tones in each of the years 2020 and 2021.

The first objective of this study was to compile and evaluate the available data of pol.27.89a in order to apply a stochastic production model in continuous time (SPiCT) (Pedersen and Berg, 2007). The second objective was to test different model configurations and values of priors to achieve a robust model for Pollack.

2. Material and Methods

Compilation of available data

Commercial Landings. A time-series of landings has been obtained from EuroStat, the statistical office of the European Union, since 1950; however, data show much more reliable from 1977 onwards. At the same time, the National laboratories of countries with pollack catches have provided more detailed data of landings, disaggregated by gear, since 2001. Since 2015, official data by country are uploaded to the InterCatch data-base.

The time series of commercial landings available by country and area for the period 1985-2019 (Table 1). The values recorded for Spain in 1985 are considered too high to be realistic, and it is recommended they not be taken into account. There is a missing value in the series for France in 1999. In order to complete the series, a value for France in 1999 was calculated as the average of the previous and next year of French landings, resulting in 1125 t. The assumed total landings for the stock in 1999 are 1282 t.

Discards. Discard data are available for the main countries and gears from 2015 to 2019 (Table 2). Data were extracted from InterCatch database. Discards represented an average of 2.5% of total commercial catches and, following the ICES guidelines, they can be considered negligible.

Surveys. Pollack abundance indices result negligible in the groundfish surveys developed in the area (French, Spanish and Portuguese surveys). The bottoms preferred for this species (wrecks and rocky bottoms) makes that trawl surveys are probably not very well suited for monitoring this species.

Table 1. Commercial landings by area for each country participating in the fishery. Values are in tonnes.

Year	Subarea 8				Division 9.a		Total official	Unallocated	Total
	Belgium	Spain	France	UK	Spain	Portugal			
1985*	0	2304*	2769	23	636*	0	5732	0	5732
1986	0	437	2127	5	237	0	2806	0	2806
1987	0	584	2022	1	308	3	2918	0	2918
1988	3	476	1761	6	329	7	2582	0	2582
1989	13	214	1682	4	57	3	1973	0	1973
1990	14	194	1662	2	27	1	1900	0	1900
1991	1	221	1867	1	76	2	2168	0	2168
1992	2	154	1735	0	65	2	1958	0	1958
1993	3	135	1327	0	47	1	1513	0	1513
1994	3	157	1764	0	28	3	1955	0	1955
1995	6	153	1457	2	59	2	1679	0	1679
1996	8	137	1164	0	43	2	1354	0	1354
1997	2	152	1167	1	54	2	1378	0	1378
1998	1	152	956	0	55	1	1165	0	1165
1999**	0	120	na**	0	36	1	157**	0	157
2000	0	121	1294	0	49	15	1479	0	1479
2001	0	346	1278	0	81	41	1746	0	1746
2002	0	170	1722	0	35	45	1972	0	1972
2003	0	142	1450	1	39	31	1663	0	1663
2004	0	211	1343	0	90	12	1656	70	1726
2005	0	306	1552	0	132	0	1990	-4	1986
2006	0	251	1596	171	102	0	2120	6	2126
2007	0	198	1375	62	103	5	1743	104	1847
2008	0	265	1732	64	128	31	2220	93	2313
2009	0	218	1371	41	68	3	1701	111	1812
2010	0	265	1170	44	91	2	1572	110	1682
2011	0	322	1475	27	104	2	1930	102	2032
2012	0	159	1131	2	139	2	1433	87	1520
2013	0	251	1346	8	110	3	1718	93	1811
2014	0	185	1612	19	93	1	1910	49	1959
2015	0	195	1244	37	78	18	1573	37	1610
2016	0	186	1292	25	111	28	1642	19	1661
2017	0	128	1219	0	95	38	1480	1	1481
2018	0	135	1220	0	12	33	1512	0	1512
2019	0	174	1189	0	143	57	1562	0	1562

* Unrealistic values for Spanish landings in 1985.** French data is not available for 1999.

Table 2. Discards by country and gear. Values are in tonnes.

	France			Spain			Portugal
Year	Nets	Trawl	Lines	Lines	Nets	Trawl	Trawl
2015	28.1	0	0	0	3.5	0	0
2016	83.1	5.4	4.3	0	0.4	0	0
2017	18.6	0	0	0	0	0	0
2018	38.7	0	0	0	0	2.8	0
2019	8.2	0	6.1	0	0	0	0

Commercial LPUE. A commercial abundance index for pollack for the French gillnet fleet in division 8a (Léauté *et al*. 2018) was provided to the WGBIE2019 for years 2005 to 2015. The index includes information for fishing sequences performed with gillnets of mesh size >= 90 mm and acting during the 2nd semester of the year (FR-GN90-8a-2S). An update of the index was provided to the WGWIDE2020 to cover the period 2016 to 2018 (Caill-Milly et al. 2020). Thus, the FR-GN90-8a-2S index is available from 2005 to 2018. The landings of the selected fleet represent an average of 7.5% of the total landings of the stock. Landings of this fleet have fluctuated between 54 and 178 t recorded in 2008 and 2014, respectively. Since 2014, there is a decreasing trend in landings. The effort unit is the fishing sequence, a combination of vessel, gear, statistical rectangle, and day. After an increasing period, between 2011 and 2016, effort of FR-GN90-8a-2S has decreased in the last two years. The LPUE showed a decreasing trend in the last 7 years, declining from 197 Kg/Fs in 2011 to 112 Kg/Fs in 2018.

The size range of sampled landings of FR-GN90-8a-2S represent the length composition of the exploited population. The mean fork length of Pollack over the 14 years was 56 cm, and the size range was 30 – 97 cm.

At the moment of writing this document the values for 2019 are not available, but it is expected that they were ready for the data compilation meeting of WKMSYSPICT.

Table 3. Time series of the biomass index FR-GN90-8a-2S. The representativeness of the index in terms of landings is shown in the last column.

Year	Landings (kg)	Effort (Fishing sequence)	LPUE (kg/Fs)	% Stock Landings
2005	105638	918	115.1	5.3
2006	52672	794	66.3	2.5
2007	124141	961	129.2	6.7
2008	144019	1117	128.9	6.2
2009	112862	907	124.4	6.2
2010	92146	854	107.9	5.5
2011	157098	799	196.6	7.7
2012	163350	937	174.3	10.7
2013	161663	1033	156.5	8.9
2014	178039	1187	150.0	9.1
2015	167710	1166	143.8	10.4
2016	149680	1242	120.5	9.0
2017	136618	1118	122.2	9.2
2018	111191	995	111.7	7.4

Length composition of landings

A set of length compositions of commercial landings, annual and gear-combined, for the period 2010-2019 were compiled from information from ROMELIGO project (2010-2014) (ICES, 2019) and from InterCatch (2015-2019). However, the metier's coverage of the length sampling has changed from year to year and the sampling level has been extremely low in the last two years.

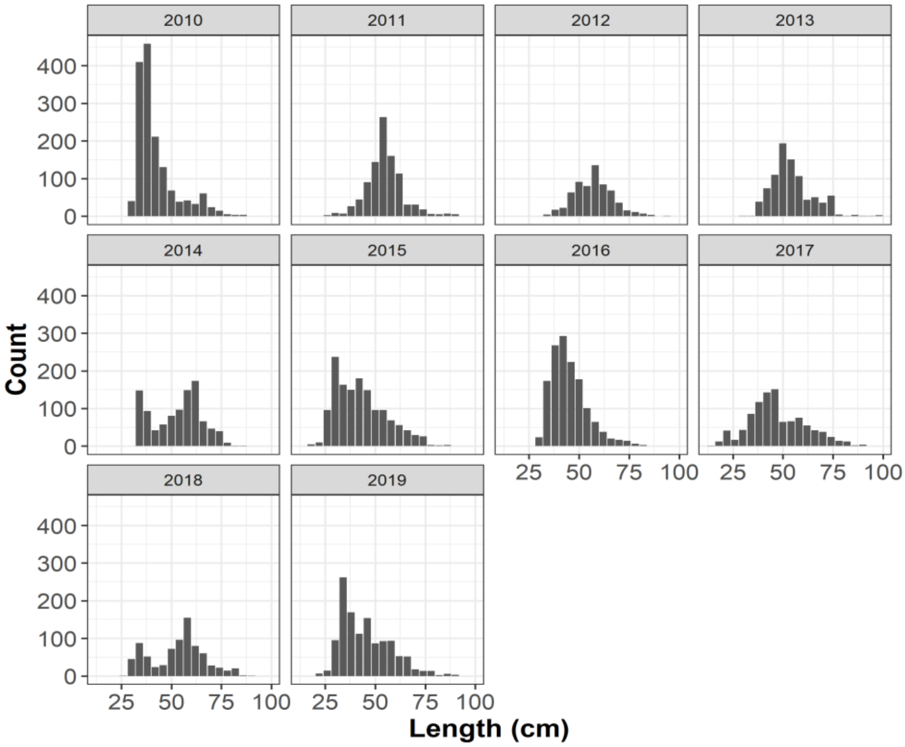

Figure 1. Length composition of landings for pol.27.89a.

Application of SPiCT

As a new index of biomass is available for pollack, it is possible to move to a full biomass dynamic model (like SPiCT, ASPIC…). The model selected was the SPiCT and different configurations of the model were tested to achieve the convergence.

Six main scenarios were defined attending to time-series used and priors defined. The *Scenario 1* uses the whole time series of catches and the default priors of SPiCT. Three *Scenarios 2* are applied to a shorten series of catches 2005-2018, accompanying the biomass index, with three alternative sets of priors. *Scenarios 3 to 6* are implemented to the whole time series of catches and they test alternative values of priors for the parameter B/K and the shape parameter.

Prior distributions for the initial biomass depletion (B/K) and the production shape parameter (n) were used to represent existing knowledge about the likely values of these model parameters. Traditional knowledge and the records found at the EuroStat indicate that this stock was commercially exploited, at least, 30 years before the time-series of landings data starts. So, it is might be assumed that B_0 was lower than carrying capacity (K). The following informative priors B_{1986}/K were tested: c(log(0.3), 0.5) and c(log(0.5), 0.5).

Different options for the shape parameter were explored. As a first approach, the symmetric form of Schaefer (*n* fixed at 2) was assumed. Based on the meta-analysis carried out by Thorson et al. (2012), intermediate values between Schaefer (n=2) and Fox model (n=1) were used as mean of the prior distribution of n.

The sensitivity of the Base case model results to the priors assumed was evaluated. There were performed 12 runs derived for the combination of 4 different prior distribution for log_bkfrac: Base Case (mean=log(0.3),sd=0.5), HighMean (mean=log(0.8),sd=1), LowMean (mean=log(0.1),sd=1) and HighSD (mean=log(0.1),sd=0.5), and 3 prior distribution for log_n: Base Case (mean=log(2.5),sd=0.5), LowMean (mean=log(0.9),sd=1) and HighMean (mean=log(2.5),sd=1)

3. Results

Selected data to fit SPiCT model

Time series of annual commercial landings (1986-2018) and the time series of biomass index FR-GN90-8a-2S (2005-2018) were selected to use as input data of the SPiCT (Figure 2). There is no data available to perform a seasonal model. The forthcoming availability of the biomass data for 2019 for the first meeting of WKMSYSPICT, will enlarge the time series of input data in one year.

The catch series shows a decreasing trend from 1987 to 1998, after that there is an increasing period achieving 2000 t in 2002. Since this year, catches range between 1500 and 2000 t. As catch data for 1999 was estimated, this data will be implemented with an uncertainty of 2 times higher than the uncertainty used for the rest of the years.

The FR-GN90-8a-2S index ranges between a minimum of 66 kg/fishing sequence recorded in 2006 to a maximum of 197 kg/fishing sequence in 2011. The last 7 years a decreasing trend is observed.

Two issues are going to make a challenge to achieve a robust fit of the model. The first one is that the overlapped period for the series Catch and Index is short, only 14 years. That means that the information provided by the input data might be not enough to fit a model, and the second one is that there is a lack of contrast in the last 19 years of the catch series.

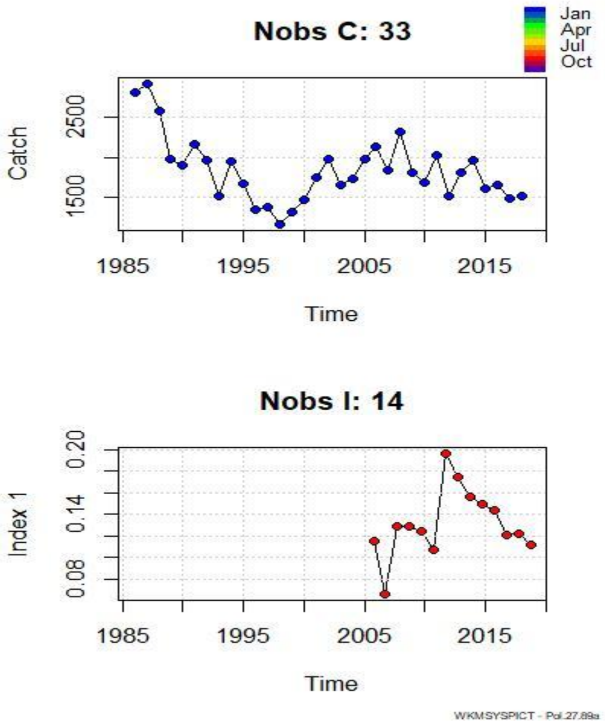

Figure 2. Input data of SPiCT.

Model fitting and Diagnostics

Scenarios 1 to 5 did not achieve the convergence (Table 4). The short catch series (2005-2018), used in the scenario 2, does not show any contrast making no possible the convergence. Fixing the shape parameter at 2 (*Schaefer* model) did not improve the convergence nor assuming the mean prior for log_bkfrac = log(0.5) with standard deviation=0.5.

The scenario 6 uses strong priors on log_bkfrac, mean=log(0.3) and sd=0.5, and on log_n, mean=log(1.5) and sd=0.5. The model converged and realistic results were obtained (Figure 3, Table 5). Through the SPiCT standard diagnostics, it was tested if—for both the catch and LPUE fits—the mean of the one-step-ahead residuals was different from zero, if there was empirical autocorrelation in the residuals, and if the residuals were not normally distributed. No violations of these three assumptions were observed (Figure 4). Additionally, the robustness of model fit to the addition of new observations was checked with a retrospective analysis of re-fitting the model after removing the 1–5 last years of the empirical observations. The estimates of B and F were inside the confidence intervals (Figure 5) and Mohn's rho value was < 0.1 in all cases. The robustness of the model to initial values was tested with 30 trials. The 18 trials that converged obtained the same estimates. The scenario 6 is considered as the Base Case scenario to provide preliminary results for pollack stock status. The status of stock in 2019 was above the B_{MSY} (1.15) and below the F_{MSY} (0.73) (Table 5).

Table 4. Scenarios Overview

Scenario	Catch Time Series	Biomass Index Series	Uncertainty	Priors	Diagnostics
Scenario 1	1986-2018	2005-2018	Catch1999	default	does not converge
Scenario 2.0	2005-2018	2005-2018	Catch1999	default	does not converge
Scenario 2.1	2005-2018	2005-2018	Catch1999	log_n (log(2), 0.001)	does not converge
Scenario 2.2	2005-2018	2005-2018	Catch1999	log_bkfrac (log(0.5), 0.5)	does not converge
Scenario 3	1986-2018	2005-2018	Catch1999	log_n (log(2), 0.001) log_bkfrac (log(0.5), 0.5) and	does not converge
Scenario 4	1986-2018	2005-2018	Catch1999	log_n (log(2), 0.001)	does not converge
Scenario 5	1986-2018	2005-2018	Catch1999	log_bkfrac(log(0.3), 0.5)	does not converge
Scenario 6 = Base Case	1986-2018	2005-2018	Catch1999	log_bkfrac(log(0.3), 0.5) and log_n (log(1.5), 0.5)	Converge, good diagnostics, retro, initial.parameters

Table 5. Scenario 6 (Base Case). Estimates and 95% confidence intervals of model parameters. Reference points and current states.

Model Parameters

	estimate	cilow	ciupp
alpha	2.64	0.71	9.73
beta	1.19	0.29	4.93
r	0.29	0.08	1.14
rc	0.53	0.17	1.65
rold	2.51	0	7297.92
m	1863	1516	2290
K	18251	5704	58393
q	1.59E-05	4.00E-06	6.20E-05
n	1.12	0.45	2.76
sdb	0.09	0.03	0.25
sdf	0.08	0.02	0.26
sdi	0.23	0.14	0.37
sdc	0.09	0.06	0.15

Reference Points

	estimate	cilow	ciupp
Bmsys	7030	2222	22236
Fmsys	0.26	0.08	0.83
MSYs	1846	1505	2265

States	estimate	cilow	ciupp
B_2018.94	8074	1989	32775
F_2018.94	0.19	0.05	0.81
B_2018.94/Bmsy	1.15	0.39	3.4
F_2018.94/Fmsy	0.73	0.21	2.57

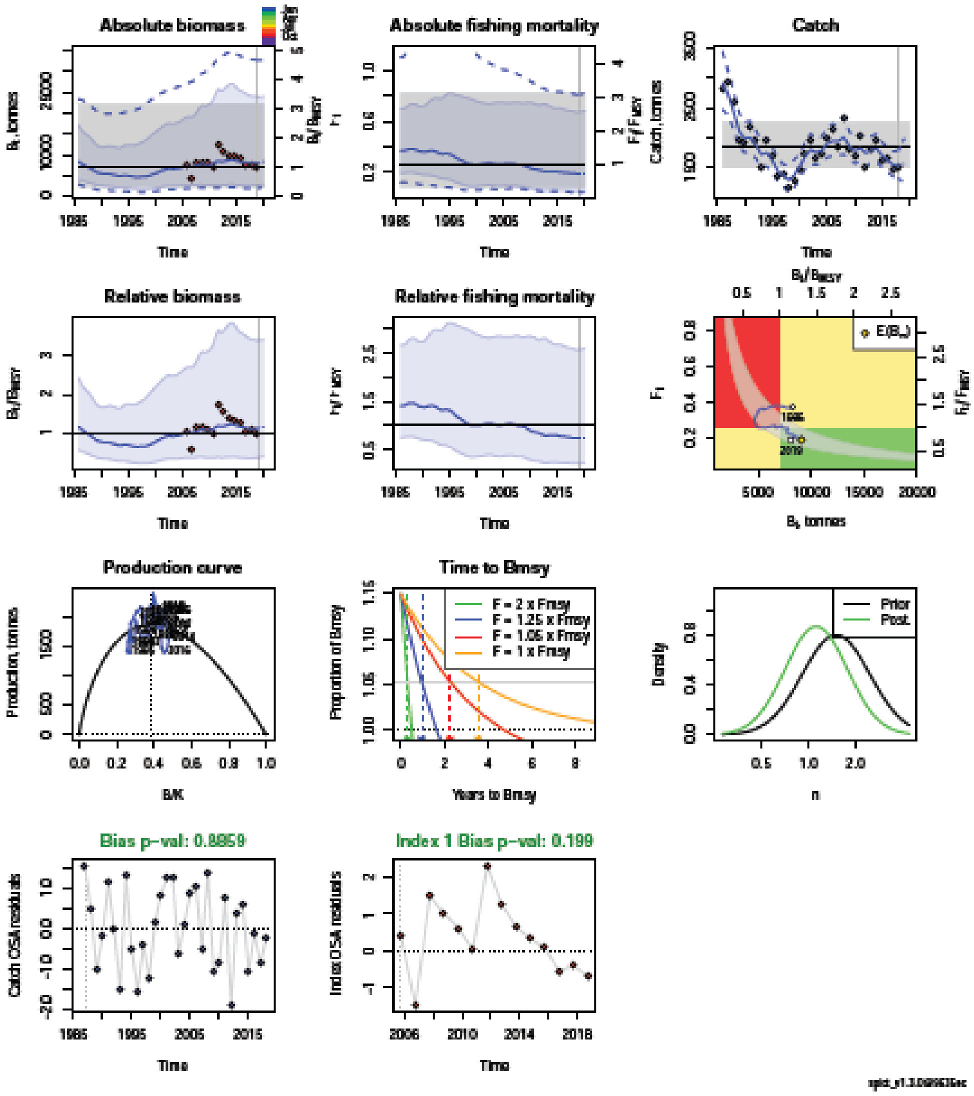

Figure 3. Scenario 6 (Base Case). Results of the model fit.

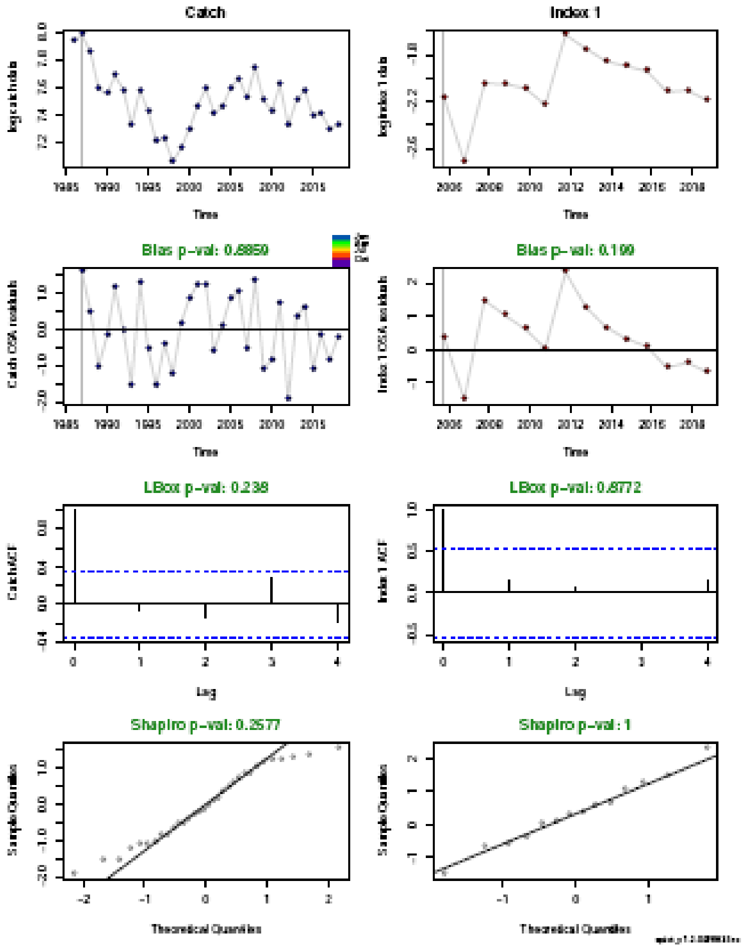

Figure 4. Scenario 6 (Base Case). Model diagnostics.

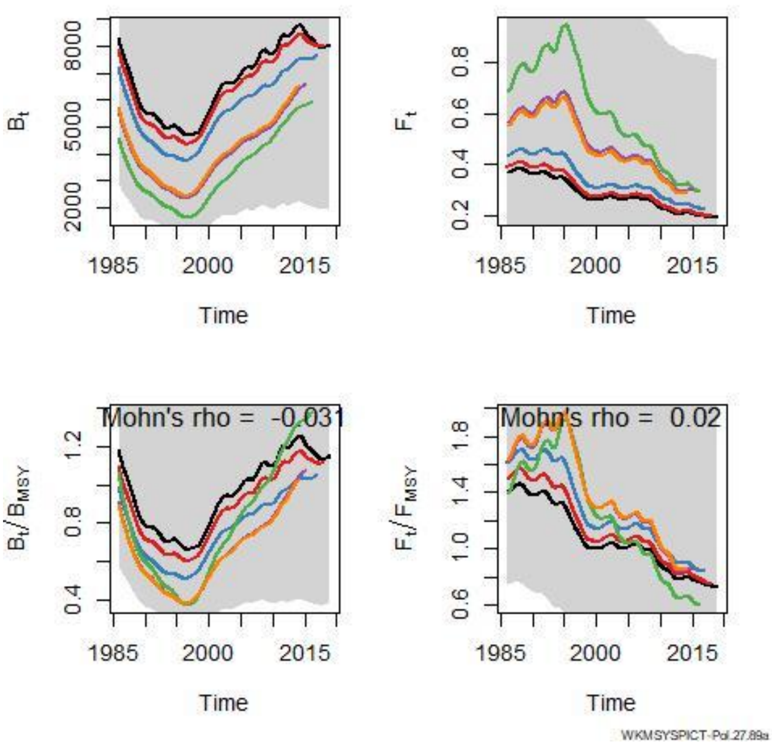

Figure 5. Scenario 6 (Base Case). Retrospective analysis. Estimates of biomass and fishing mortality, and their respective relative values, with 95% confidence regions. Mohn's rho number is indicated for relative quantities of biomass and fishing mortality.

Sensitivity to alternative prior distribution for log_bkfrac and log_n

From the 12 runs performed only 4 converged (Table 6). None of the runs with a high mean of log_bkfrac or with a standard deviation of 1 converged. The three runs that assumed the prior distribution of log_bkfrac of the Base Case with different prior distributions for log_n, converged. Estimates of biomass (B/Bmsy) and fishing mortality rate (F/Fmsy) for the sensitivity analyses differed by at most -7% and 11%, respectively from the Base Case model. These scenarios resulted in the same status for B_{2019}/B_{MSY} and F_{2019}/F_{MSY} for pollack. Although the run assuming a low mean for log_bkfrac (0.1) and low mean for log_n (0.1) achieved the convergence, the results were no reliable.

4. Discussion

The data available for pol.27.89a, the catch time-series and the biomass index FR-GN90-8a-2S, allow fitting a model assessment using SPiCT. The Base Case appears to be stable and give the perception of the stock being exploited bellow F_{MSY} and that the biomass is above B_{MSY}. However, there are some concerns due the model only converges assuming very informative priors on the initial biomass depletion and on the production shape parameter.

Table 6. Sensitivity analysis for priors of log_bkfrac and log_n.

Prior log_bkfrac	Prior log_n	Convergence	Type Convergence	Objective Function	n	BKfrac	K	MSY	Fmsy	Bmsy	BBmsy	BBmsy cilow	BBmsy ciupp	FFmsy	FFmsy cilow	FFmsy ciupp
Base Case (log(0.3), 0.5)	Base Case (log(1.5), 0.5)	0	5	-4.0	1.12	0.39	18251	1846	0.26	7030	1.15	0.39	3.40	0.73	0.21	2.57
	LowMean (log(0.9), 1)	0	4	-3.9	0.61	0.28	23817	1810	0.27	6654	1.07	0.28	4.15	0.80	0.18	3.61
	HighMean (log(2.4), 1)	0	4	-3.2	0.93	0.35	19017	1858	0.28	6698	1.19	0.21	6.67	0.70	0.09	5.35
HighMean (log(0.8, 1)	Baseline (log(1.5), 0.5)	1	8	-11.7	1.28	0.41	12697	1922	0.37	5169	1.35	0.02	103.32	0.58	0.00	113.72
	LowMean (log(0.9), 1)	1	8	-11.2	1.25	0.41	12884	1938	0.37	5172	1.35	0.00	504.76	0.58	0.00	733.59
	HighMean (log(2.4), 1)	1	8	-9.1	1.49	0.44	11982	1915	0.37	5213	1.40	0.69	2.84	0.56	0.24	1.32
LowMean (log(0.1), 1)	Baseline (log(1.5), 0.5)	1	8	-4.7	1.1	0.39	15052	1970	0.34	5759	1.41	1.21	1.65	0.55	0.47	0.65
	LowMean (log(0.9), 1)	0	5	-2.6	0.44	0.23	54692	1960	0.16	12432	0.48	0.03	9.02	1.67	0.14	19.97
	HighMean (log(2.4), 1)	1	8	-9.5	0.98	0.36	15510	1968	0.35	5608	1.49	0.00	421746	0.53	0.00	1937446
HighSD (log(0.3), 1)	Baseline (log(1.5), 0.5)	1	8	-9.4	1.25	0.41	12518	1912	0.38	5066	1.42	0.79	2.56	0.56	0.27	1.15
	LowMean (log(0.9), 1)	1	8	-9.9	1.22	0.40	12487	1912	0.38	4988	1.42	0.30	6.73	0.56	0.08	3.83
	HighMean (log(2.4), 1)	failed														

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