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ADDITIONAL ANALYSES ON THE STOCK ASSESSMENT OF NORTHEAST ATLANTIC PORBEAGLE (*Lamna nasus*) USING THE SPiCT SURPLUS PRODUCTION MODEL

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SUMMARY

In 2022, ICES and ICCAT aimed to jointly assess the northeast Atlantic porbeagle stock, which was last assessed in 2009. The SPiCT runs used the 3 indices reviewed by the Working Group on Elasmobranch Fishes (WKELASMO), and included the historical Spanish longline index that was used in the 2009 assessment. The proposed SPiCT run uses all available indices of abundance. Comparisons were made between the proposed SPiCT run and JABBA run applying similar model settings. Both models indicated that the northeast porbeagle stock is still overfished, but experiencing very low fishing mortality at present. However, those results differ in the level of depletion, SPiCT results being slightly more pessimistic compared to the JABBA results, likely due to the assumptions of process error, the variance of indices, and structural model estimation, among others. It is suggested that integrating both model results will provide a more comprehensive evaluation of the stock assessment uncertainty for providing management advice. It is recommended to reactive monitoring programs to confirm the recovery trends of the stock.

RÉSUMÉ

En 2022, le CIEM et l'ICCAT avaient pour objectif d'évaluer ensemble le stock de requin-taupe commun de l'Atlantique Nord-Est, dont la dernière évaluation remonte à 2009. Les scénarios SPiCT ont utilisé les 3 indices examinés par le Groupe de travail sur les élasmobranches (WKELASMO) et ont inclus l'indice historique de la palangre espagnole qui a été utilisé dans l'évaluation de 2009. Le scénario SPiCT proposé utilise tous les indices d'abondance disponibles. Des comparaisons ont été faites entre le scénario SPiCT proposé et le scénario JABBA en utilisant des configurations de modèle similaires. Les deux modèles indiquent que le stock de requin-taupe commun du Nord-Est est toujours surexploité mais qu'il connaît actuellement une très faible mortalité par pêche. Cependant, ces résultats diffèrent en ce qui concerne le niveau d'épuisement, les résultats de SPiCT étant légèrement plus pessimistes que ceux de JABBA, probablement en raison des postulats d'erreur de processus, de la variance des indices et de l'estimation du modèle structurel, entre autres. Il est suggéré que l'intégration des résultats des deux modèles fournira une évaluation plus complète de l'incertitude de l'évaluation du stock pour fournir un avis de gestion. Il est recommandé de réactiver les programmes de surveillance afin de confirmer les tendances du rétablissement du stock.

RESUMEN

En 2022, ICES e ICCAT se pusieron como objetivo evaluar conjuntamente el stock de marrajo sardinero del Atlántico nordeste, cuya última evaluación fue en 2009. Los ensayos SPiCT utilizaron los tres índices revisados por el Grupo de trabajo sobre peces elasmobranquios (WKELASMO) e incluyeron el índice histórico del palangre español que se utilizó en la evaluación de 2009. El ensayo SPiCT propuesto utiliza todos los índices de abundancia disponibles. Se han realizado comparaciones entre el ensayo SPiCT propuesto y el ensayo de JABBA aplicando configuraciones de modelo similares. Ambos modelos indicaban que el stock

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de marrajo sardinero del noreste sigue estando sobrepescado, pero que actualmente experimenta una mortalidad por pesca muy baja. Sin embargo, esos resultados difieren en el nivel de merma, siendo los resultados de SPiCT ligeramente más pesimistas en comparación con los de JABBA, probablemente debido a los supuestos de error del proceso, la varianza de los índices y la estimación del modelo estructural, entre otras cosas. Se sugiere que la integración de los resultados de ambos modelos proporcionará una evaluación más completa de la incertidumbre de la evaluación de stock para proporcionar asesoramiento de ordenación. Se recomienda reactivar los programas de seguimiento para confirmar las tendencias de recuperación del stock.

KEYWORDS

Northeast Atlantic porbeagle, stock status, biomass dynamic model, SPiCT, model diagnostics, uncertainty.

1. Introduction

The previous stock assessment for the Northeast Atlantic porbeagle stock was carried out in a joint ICES and ICCAT meeting in 2009 (Anon., 2010). The assessment took place again in 2021/2022. In a series of meetings, the catch series, biological parameters, stock structure, and indices of abundance were reviewed and agreed upon by the WKELASMO Group as input for the stock assessment. A working document "SPiCT runs for the northeast Atlantic porbeagle" (Biais, 2022) using the French longline (FRA-LL), the Norway longline (NOR-LL), and the Survey composite index (Survey), has been provided with the initial assessment results.

This document presents additional analyses on the stock assessment results for Northeast Atlantic porbeagle stock based on SPiCT Surplus Production Model software including the historical Spanish longline index (1986-2007) that was reviewed and applied in the 2009 stock assessment. This study aims to complement the results presented in the working document by Biais (2022). Data input, software, and the R-script code are provided on the meeting's SharePoint site. In addition, a comparison of the SPiCT and Just Another Bayesian Biomass Assessment (JABBA, Winker et al., 2018) results for those models considered the best fit is presented and discussed.

2. Material and Methods

2.1. Fishery data

Fishery catch data for northeast porbeagle were made available by ICES/ICCAT and reviewed by WKELASMO during the data preparatory meeting (ICES 2022) for the period 1926-2020 (**Figure 1**). During the data preparatory meeting, the Group reviewed three indices of abundance, including two new series, the Norway historic longline series (NOR-LL) from 1950 to 1972 (missing 3 years 1965-67) that covers a wider spatial area of the stock and the main fishery during this period, just after the major peak of catches of porbeagle in 1947 (Biais 2022a). A longline composite survey index (2018-2019) that has been extended back in time with commercial longline data (2000-2009) is the only index of abundance available after the full no-retention management policy implemented after 2010 (Biais, 2022b). The third index reviewed was the updated French longline CPUE (FRA-LL) that targeted porbeagle from 1972 to 2009 and covers the Bay of Biscay and the Celtic Sea (Biais 2022c). For this additional analysis in this document, the assessment evaluation also included the Spanish longline index (SPA-LL) used during the 2009 assessment (Anon. 2010; Mejuto et al., 2010). The SPA-LL index comes from the surface longline fishery that targets swordfish in the North Atlantic but catches porbeagle as bycatch, this index has larger geographical coverage and was reviewed during the 2009 assessment (Anon. 2010). Input data including catch and indices series were available from the WKELASMO SharePoint Data folder. **Figure 2** shows the available indices of abundance used for this analysis.

2.2. Model specifications and sensitivity runs

The additional analyses presented here were done with the SPiCT R package software version 1.3.5 available at https://github.com/DTUAqua/spict (Pedersen and Berg, 2017) under the R-Studio 2022.02.0 version (Pederson et al., 2021). An initial run to replicate exactly the results presented in the ICES WKELASMO working document SPiCT runs for the northeast Atlantic porbeagle (Biais 2022) was performed to generate results as shown in Table

5 of the working document for all 5 scenarios. Following the conclusions from the working document, we use run # 5 as the reference for further comparisons. Briefly, run # 5 of Biais (2022) working document settings were as follows:

- Catch series 1926-2020
- Schaefer surplus model (*n*=2) function with a standard deviation of 0.5
- Prior for r = 0.059 with a standard deviation of 0.2 to reach CI close to 0.037 – 0.081 as reported from Cortes and Semba (2020)
- Catch uncertainty set 5 times higher for the 2010-2020 period compared to the 1926-2009 period.
- Index series include the French longline index (1972-2009), Norway longline index (1950-1964, 1968-1972), and the extended survey index (2000-2009, 2018-2019). Commercial fisheries indices (FRA-LL, NOR-LL) were set a mid-year, while the survey index was set to May. All indices in biomass units and with standard error input as the index standard error estimated and scaled to the minimum value of the series.
- Prior for the initial biomass (1926) relative to carrying capacity K was set at 0.99 with an std of 0.2.

The additional analyses evaluated in this document were set as follows:

1. Run **Ref**: Including the Spanish longline index 1986 - 2007 as presented in the 2009 stock assessment. All other settings are the same as the reference run described above.
2. Sensitivity runs:

   - S1 Terminal year 2010 = same as Run **Ref**, but end catch and index series in 2010.
   - S2 Terminal year 2015 = same as Run **Ref**, but end catch and index series in 2015.
   - S3 Higher r prior assumptions = increase the mean r prior by a factor of three (3*0.059) same standard error of 0.2 as Run **Ref**.
   - S4 Low standard error for the Survey index = assuming a higher precision of the composite survey index (0.5 * se Index) compared to the fisheries dependent CPUE series.

The addition of the Spanish longline bycatch index is to provide the model with further information from a fishery targeting swordfish and blue sharks with a wider distribution in the North Atlantic region that had wider season coverage than the porbeagle target fisheries. This index was used in the 2009 assessment and would allow for a more comparable evaluation of the results between 2009 and the present assessment. The sensitivity runs with terminal years 2010 and 2015 try to address the very limited information in the model since 2010 when due to management regulations, catches of porbeagle were nearly zero, therefore there are no fishery-dependent indices of abundance, and the survey index is limited to 2-year observations (2018, 2019). Sensitivity runs also evaluated alternative weighting for indices of abundance, assuming higher precision of the composite survey index, or higher relative uncertainty for the bycatch index. However, after the comparison, the Spanish LL index coefficient of variance (mean CV = 89%) is double compared to the other indices (range from 29% to 46%), therefore no sensitivity run was done.

2.3. Model diagnostics

Model fit and results were evaluated following the guidelines of the SPiCT software developers (Pedersen et al., 2021), and consistent with diagnostics summarized in the Biais (2022) working document. Briefly, a) model run convergence (e.g. fitoptconvergence equals 0), b) all variance parameters of the model are estimated and finite (all(is.finite(fit$sd)) = TRUE), c) no violation of model assumptions based on one-step-ahead residuals (bias, auto-correlation, normality) *p*-values not-significant (>0.05), d) consistent patterns in the retrospective analysis, e) realistic shape of the surplus production curve, with estimated values of B_{MSY}/K between 0.1 and 0.9 (calc.bmsyk(fit)), e) realistic relative variance parameters (logsdb, logsdc, logsdi, logsdf) with credible intervals for B/B_{MSY} and F/F_{MSY} that should not span more than 1 order of magnitude (calc.om(fit)), and f) check that initial values do not influence the parameter estimates (fit$check.ini$resmat).

Plots of residuals, one-step ahead (OSA) residual diagnostics, trends of biomass and fishing mortality, and production curves were produced.

3. Results and Discussion

The initial run (S0) successfully replicated run#5 from the Biais (2022) Working Document**.** All other runs and sensitivity scenarios were modifications of the run **Ref** that included the SPA-LL bycatch index. **Table 1** presents a summary of the results from the different scenarios including the run specifications, catch series, indices of abundance included, estimates of the production shape parameter *n*, carrying capacity (*K*), intrinsic growth rate *r*, relative biomass (B_{ty}/B_{MSY}), and fishing mortality (F_{ty}/F_{MSY}) stocks status at terminal year, and estimates of stochastic reference points of B_{MSY}, F_{MSY} and MSY with 2,5% and 97,5% credible confidence bounds.

All runs converged and estimated finite parameters, the full descriptions of diagnostics are provided in **Table 2**. The initial **Ref** run showed high Mohn's rho value for the estimates of B/B_{MSY}, that was slightly improved for the sensitivity runs S4 using alternative weighting for indices of abundance. Based on the results from the sensitivity runs, the initial **Ref** run was updated to generate a SPiCT Final Model (**FM**) proposal, that included all four indices of abundance available, namely the three fishery dependent CPUEs i.e. the French longline target index, the Norway longline target index, the Spanish longline bycatch index, and the fourth index the composite Survey index. This model used the catch series 1926-2020, and the following priors of surplus function shape parameter *n* (mean = log(2), se = 0.5), initial fraction of biomass in 1926 near carrying capacity *K* (mean = 0.99 , se = 0.2), and informative prior for the intrinsic growth rate *r* (mean = 0.059, se = 0.2). **Table 3** shows the indices of abundance in biomass units and their respective estimated standard error (se) and coefficient of variance (CV).

For the **FM** run proposal, diagnostic plots are provided in **Figure 3**, the Shapiro test for normality of the catch data fail to pass, a feature that is common for all SPiCT runs where very low catches depart from the normality test, these corresponding to the years 1940, and after 2012, when catches drop to almost zero. The Shapiro test t for normality of residuals also fails for the Spa LL index. This result does not invalidate the model runs. All other residual tests and diagnostics passed.

The SPiCT **FM** model median posterior of the intrinsic growth rate *r* of 0.0607 (0.0416 – 0.08885) is very similar to the informative prior (**Table 2**, **Figure 4**), as is the posterior of the initial biomass fraction. The production curve is left-skewed as expected for this species, with an inflection point at *B/K* of about 0.35 and an estimated production function parameter *n* of 1.109 (0.649 – 1.895).

The trends of biomass and fishing mortality are provided in **Figure 5**. The northeast porbeagle stock biomass shows a continued decline from 1926 until about 2012 when started to reverse this trend and an increase in biomass has been observed since then. In 1926, biomass was about carrying capacity (*K* = 57,952 t) declining rapidly until 1938 when catches plummeted. This was followed by a slight recovery of biomass, but as catches increased again in the 1950s, biomass dropped below the estimate of B_{MSY} (B_{MSY} = 20,736 t) and continued decreasing, reaching very low values by the mid-1980s. The stock biomass continued with low values until 2011 when catches stopped, and the biomass then started to recover slowly. By 2020, the stock biomass is still below B_{MSY}, (B_{2020}/B_{MYS} = 0.47) or about 16% of the carrying capacity (B_{2020}/K = 0.165). Trends of fishing mortality showed in general a fishing pressure well above the estimates of F_{MSY} (F_{MSY} = 0.054) for most of the time series. After 2011 fishing mortality has drastically decreased to low values and by 2020 is estimated at 1.6% of F_{MSY} (F_{2020}/F_{MYS} = 0.016) (**Table 1**). The Kobe phase plot (**Figure 5**) shows the relative historic trend of biomass and fishing mortality, indicating the overexploitation of the stock for most of the time series until the 2010s when fishing mortality decreased and the stock was no longer experiencing overfishing, but with the stock remaining still in an overfished status.

The retrospective pattern of the **FM** model is shown in **Figure 6**. The trends show a slight deviation of the biomass trend when it removes the last year of data, the estimates of the Mohn's rho parameter are slightly outside the rule of thumb range (-0.2 to 0.3) from long-live species as proposed by Hurtado et al. (2016) (**Table 2**). However, all estimated retrospective trends are within the estimated confidence bounds for biomass and fishing mortality of the model with all years.

In general, all SPiCT runs show similar trends and results of declining stock biomass for the northeast porbeagle stock since the 1930s with catches well above the sustainable levels that drove the stock to very low biomass levels by the 1980s, and only after catches has been suspended around 2010, the stock has showed a slow recovery. **Figure 7** summarizes the estimated parameters of all runs, providing the median and 95% credible intervals for each scenario. Scenarios S1 and S2, with different terminal years (2010 and 2015, respectively) show that by 2010 the stock was at low biomass and experiencing high fishing mortality, a situation that shifted in 2015 and continues in 2020. Estimates of absolute biomass *K* and B_{MSY} show a consistent median value at about 60 thousand t and 20 thousand t, respectively with overlapping confidence bounds. Only the scenario with the high *r*-value (S3), showed low estimated values of *K*, as would be expected. Similarly, estimates of MSY are about 1.1 thousand tons, with ranges between 600 to 1,800 t, exception of the scenario of high *r*-value (S3) (**Figure 7**). This scenario of high *r*-value (S3) also showed a different shape of the production curve, with an *n* parameter estimated just above 2, indicating more of a Shaefer production model type.

The results of the SPiCT model were compared to the JABBA model run S2 full presented in the working document Ortiz et al. (2022). Both SPiCT and JABBA are state-space production models and used the same input data of catch and indices of abundance and overall prior information regarding the fraction of initial biomass (1926), and intrinsic growth rate *r*. However, they differed in several settings and assumptions such as the standard error of *r*, being less informative in the JABBA runs, an informative prior for the process error in JABBA. **Table 4** presents a summary of the estimates from both the SPiCT FM model, and the JABBA full model considered both as the best fit model in each platform for the northeast porbeagle evaluation. In general, JABBA estimated a lower median intrinsic growth rate *r* compared to SPiCT, with higher median estimates of absolute biomass (*K*, B_{MSY}, and MSY) for the JABBA run and similar estimates of F_{MSY}. Yet the estimates of variability overlap for most parameters. The stock status in 2020 is similar, e.g. overfishing is not occurring with low fishing mortality (1.6%, 1.2%, respectively) compared to F_{MSY}. And the stock is overfished (e.g. Biomass 2022 < B_{MSY}), however, SPiCT estimates the stock about 47% of B_{MSY}, while JABBA estimates the stock about 51%.

In summary, both model SPiCT and JABBA indicated that the northeast porbeagle stock is still overfished and experiencing very low fishing mortality at present. They differ in the level of depletion, being slightly more pessimistic with the SPiCT results. Both models suggest that maximum sustainable yield (MSY) is about 1,200 t but differ in the absolute estimates of *K* and B_{MSY}. These differences in the models' results are likely associated with the assumptions of process error, the variance of indices, and structural model estimation among others. It is suggested, therefore, averaging across both models to provide a more comprehensive evaluation of the stock assessment uncertainty for providing a management advice. There is, however, high uncertainty in the recent trends of the stock as in the last decade (2010-2020) there are only two survey observations, and no other information on the relative abundance of the stock. Therefore, it is strongly recommended to reactive monitoring programs to confirm the recovery trends of the stock.

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Table 1. Model specifications of alternative productivity and variance parameters used in the SPiCT runs and sensitivity analysis. Estimates, stock status, and stochastic reference points include the median estimate and the 2.5% and 97.5% credible intervals. See text for further details.

Run ID	Scenario	Catch	Index Biomass	Estimates			Stock status		Stochastic Ref Points		
				n	*K*	*r*	B2020/BMSY	F2020/FMSY	BSMY	FMSY	MSY
S0	*Run 5 WD Biais 2022*	1926-2020	FRA-LL, NOR-LL, Survey	1.099 (0.615 - 1.963)	59,595 (28,433 - 124,910)	0.061 (0.042 - 0.089)	0.475 (0.166 - 1.360)	0.016 (0.004 - 0.065)	19,870 (8,504 - 46,429)	0.055 (0.029 - 0.105)	1,086 (0,586 - 2,014)
Ref	*4 index 1926-2020*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	1.109 (0.649 - 1.895)	59,177 (31,390 - 111,564)	0.061 (0.042 - 0.088)	0.470 (0.184 - 1.202)	0.016 (0.004 - 0.062)	20,736 (9,897 - 43,449)	0.054 (0.031 - 0.095)	1,122 (0,656 - 1,920)
S1	*Terminal year 2010*	1926-2010	FRA-LL, NOR-LL, Survey, SPA-LL	0.910 (0.564 - 1.468)	54,537 (31,550 - 94,271)	0.062 (0.043 - 0.090)	0.177 (0.077 - 0.407)	1.936 (0.816 - 4.597)	17,827 (9,302 - 34,163)	0.069 (0.042 - 0.112)	1,222 (0,773 - 1,931)
S2	*Terminal year 2015*	1926-2015	FRA-LL, NOR-LL, Survey, SPA-LL	1.010 (0.562 - 1.813)	56,922 (31,381 - 103,253)	0.061 (0.042 - 0.090)	0.311 (0.121 - 0.804)	0.100 (0.017 - 0.583)	19,374 (9,511 - 39,465)	0.061 (0.033 - 0.113)	1,179 (0,703 - 1,977)
S3	*high r prior (3* r)*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	2.056 (1.242 - 3.403)	42,787 (24,263 - 75,453)	0.170 (0.116 - 0.249)	0.485 (0.187 - 1.263)	0.011 (0.003 - 0.047)	19,952 (10,352 - 38,458)	0.077 (0.044 - 0.133)	1,516 (0,911 - 2,524)
S4	*low se Survey idx*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	1.109 (0.647 - 1.902)	59,242 (31,093 - 112,876)	0.061 (0.042 - 0.089)	0.468 (0.181 - 1.211)	0.016 (0.004 - 0.063)	20,676 (9,762 - 43,792)	0.054 (0.031 - 0.096)	1,119 (0,649 - 1,930)
FM	*Final Model Proposal*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	1.109 (0.649 - 1.895)	59,177 (31,390 - 111,564)	0.061 (0.042 - 0.088)	0.470 (0.184 - 1.202)	0.016 (0.004 - 0.062)	20,736 (9,897 - 43,449)	0.054 (0.031 - 0.095)	1,122 (0,656 - 1,920)

Table 2. Summary of diagnostics tests and retrospective results from the SPiCT run and sensitivity analysis from the northeast porbeagle evaluation. The retrospective Monh's rho estimate parameters are provided in the last column. Hurtado et al. (2015) reported Monh's rho estimates should fall within the range of -0.2 to 0.3 for long-live species.

				Diagnostics									Retrospective
Run ID	**Scenario**	**Catch**	**Index Biomass**	**Convergence**	**Parameters finite sd**	***Bmsy/K***	***Relative Par***	***low***	***estimate***	***upp***	***range***	***order magnitude***	**Monh's rho**
S0	*Run 5 WD Biais 2022*	1926-2020	FRA-LL, NOR-LL, Survey	Yes	TRUE	0.3845756	*B/Bmsy*	0.166	0.475	1.360	1.194	1	0.331
							F/Fmsy	0.004	0.016	0.065	0.061	1	-0.135
Ref	*4 index 1926-2020*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.3817181	*B/Bmsy*	0.184	0.470	1.202	1.019	1	0.403
							F/Fmsy	0.004	0.016	0.062	0.058	1	-0.199
S1	*Terminal year 2010*	1926-2010	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.348784	*B/Bmsy*	0.077	0.177	0.407	0.330	1	0.019
							F/Fmsy	0.816	1.936	4.597	3.781	1	-0.032
S2	*Terminal year 2015*	1926-2015	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.3576256	*B/Bmsy*	0.121	0.311	0.804	0.683	0	0.071
							F/Fmsy	0.017	0.100	0.583	0.565	1	0.654
S3	*high r prior (3* r)*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.5074022	*B/Bmsy*	0.187	0.485	1.263	1.076	1	4.356
							F/Fmsy	0.003	0.011	0.047	0.044	1	-0.967
S4	*low se Survey idx*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.3825877	*B/Bmsy*	0.181	0.468	1.211	1.030	1	0.402
							F/Fmsy	0.004	0.016	0.063	0.059	1	-0.197
FM	*Final Model Proposal*	1926-2020	FRA-LL, NOR-LL, Survey, SPA-LL	Yes	TRUE	0.3819258	*B/Bmsy*	0.184	0.470	1.202	1.019	1	0.403
							F/Fmsy	0.004	0.016	0.062	0.058	1	-0.199

Table 3. Summary of indices of abundance inputs used in the SPiCT runs and sensitivity analysis. The index represents the estimated relative biomass value, the standard error, se, and coefficient of variance (CV). Year indicates the time of the year associated with each index in the model.

NOR-LL				FRA-LL				SPA-LL				Survey			
Year	Index	se	CV	Year	Index	se	CV	Year	Index	se	CV	Year	Index	se	CV
1950.5	2526.412	777.308	31%	1972.5	1219.27	386.68	32%	1986.5	0.661	0.55524	84%	2000.42	214.396	98.363	46%
1951.5	696.01	331.84	48%	1973.5	913.39	216.93	24%	1987.5	0.292	0.30368	104%	2001.42	292.733	127.813	44%
1952.5	2781.324	1244.646	45%	1974.5	1036.56	259.47	25%	1988.5	2.28	1.6872	74%	2002.42	170.221	71.858	42%
1953.5	1172.64	565.04	48%	1975.5	1177.89	278.46	24%	1989.5	0.961	0.71114	74%	2003.42	163.742	67.146	41%
1954.5	1952.568	621.528	32%	1976.5	1110.31	256.83	23%	1990.5	0.683	0.60787	89%	2004.42	146.661	61.845	42%
1955.5	1498.938	445.356	30%	1977.5	981.92	232.84	24%	1991.5	1.456	1.13568	78%	2005.42	84.816	45.353	53%
1956.5	1613.253	481.641	30%	1978.5	690.07	181.69	26%	1992.5	0.389	0.38511	99%	2006.42	297.445	146.661	49%
1957.5	1375.47	359.658	26%	1979.5	756.27	184.56	24%	1993.5	0.491	0.48118	98%	2007.42	461.187	206.739	45%
1958.5	857.31	203.49	24%	1980.5	507.66	120.98	24%	1994.5	1.846	1.45834	79%	2008.42	597.246	272.118	46%
1959.5	807.279	190.179	24%	1981.5	583.83	138.93	24%	1995.5	0.33	0.3267	99%	2009.42	245.024	113.088	46%
1960.5	1420.86	300.9	21%	1982.5	530.61	129.78	24%	1996.5	0.34	0.2652	78%	2018.42	377.622	188.811	50%
1961.5	682.395	154.715	23%	1983.5	346	83.4	24%	1997.5	0.699	0.55221	79%	2019.42	262.384	136.896	52%
1962.5	414.032	103.508	25%	1984.5	363.25	91.77	25%	1998.5	0.421	0.39995	95%				
1963.5	417.366	116.289	28%	1985.5	450.38	128.78	29%	1999.5	0.169	0.15041	89%				
1964.5	643.15	334.875	52%	1986.5	466.24	126.03	27%	2000.5	0.419	0.35615	85%				
1968.5	516.78	168.48	33%	1987.5	616.35	171.86	28%	2001.5	0.35	0.287	82%				
1969.5	1117.06	317.14	28%	1988.5	818.62	221.17	27%	2002.5	2.874	1.95432	68%				
1970.5	456.29	304.784	67%	1989.5	745.39	211.1	28%	2003.5	3.445	2.6182	76%				
1971.5	796.48	432.06	54%	1990.5	736.89	204.04	28%	2004.5	0.537	0.5907	110%				
1972.5	452.746	168.783	37%	1991.5	400.09	109.34	27%	2005.5	1.236	1.3596	110%				
				1992.5	795.9	221.84	28%	2006.5	1.969	1.75241	89%				
				1993.5	630.25	167.11	27%	2007.5	0.152	0.18696	123%				
				1994.5	682.23	172.6	25%								
				1995.5	495.33	130.39	26%								
				1996.5	628.19	182.88	29%								
				1997.5	464.02	129.68	28%								
				1998.5	704.11	226.89	32%								
				1999.5	1070.76	330.46	31%								
				2000.5	509.93	147.12	29%								
				2001.5	437.17	123.96	28%								
				2002.5	538.23	154.78	29%								
				2003.5	534.24	160.11	30%								
				2004.5	440.17	136.47	31%								
				2005.5	424.48	164.03	39%								
				2006.5	603.95	221.45	37%								
				2007.5	542.88	210.49	39%								
				2008.5	718.17	282.66	39%								
				2009.5	452	244.02	54%								

Table 4. Summary comparing the estimates from two surplus production model runs SPiCT final model proposal (FM) in this document and the JABBA full model (Ortiz et al., 2022) for the northeast porbeagle stock evaluation.

	SPiCT FM			**Jabba Full**		
Estimates	Median	2.50%	97.50%	Median	2.50%	97.50%
K	59,177	31,390	111,564	61,275	38,247	126,950
r	0.0607	0.0416	0.0885	0.0517	0.0288	0.0797
ψ *(psi)*				0.9287	0.6864	0.9972
σ_{proc}				0.1180	0.0560	0.1930
F_{MSY}	0.054	0.031	0.095	0.051	0.028	0.079
B_{MSY}	20,736.5	9,896.6	43,449.4	22,676.3	14,154.4	46,981.0
MSY	1,122.4	656.1	1,920.1	1,166.0	721.9	1,870.0
B_{1926}/K				0.910	0.640	1.160
B_{2020}/K	0.165	0.150	0.180	0.189	0.074	0.391
$B_{2020}/B_{\mathrm{MSY}}$	0.470	0.184	1.202	0.511	0.201	1.057
$F_{2020}/F_{\mathrm{MSY}}$	0.016	0.004	0.062	0.012	0.006	0.028

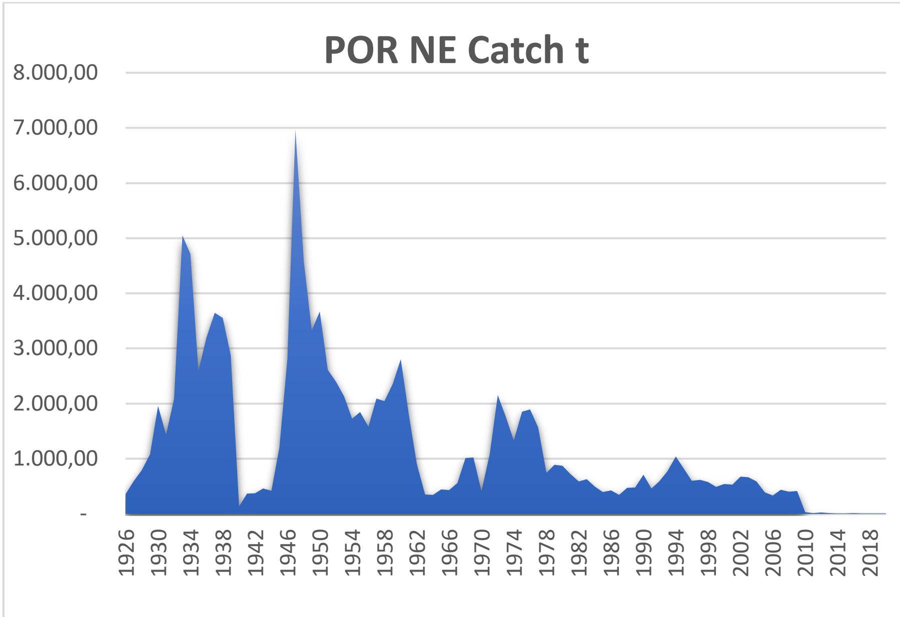

Figure 1. Catch time series 1926 – 2020 in metric tons (t) for the northeast Atlantic porbeagle.

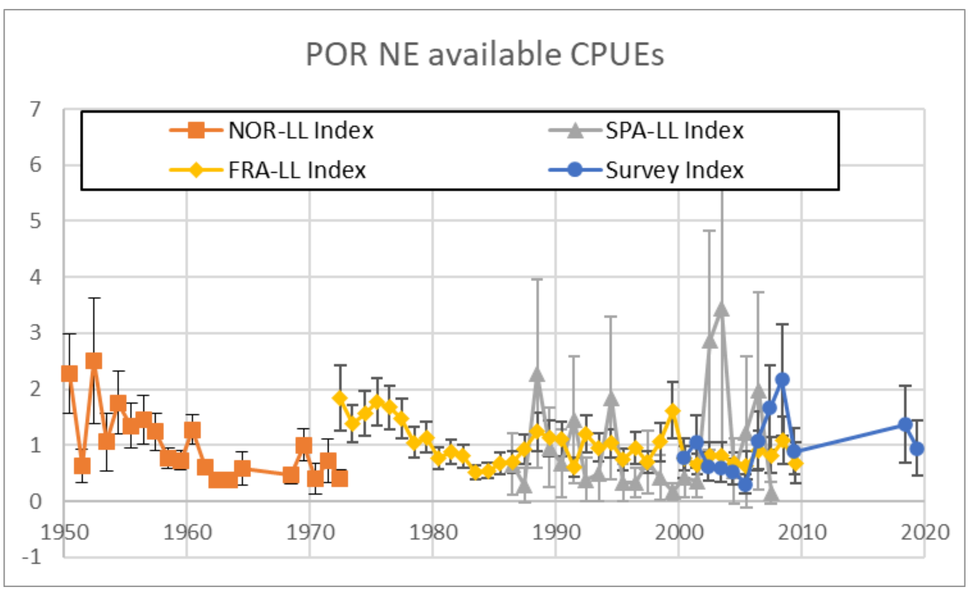

Figure 2. Time-series of relative indices of abundance considered in the additional SPiCT stock assessment for northeast porbeagle scaled to their respective mean. Error bars represent the $\pm$ 1 standard error (se) of the standard index.

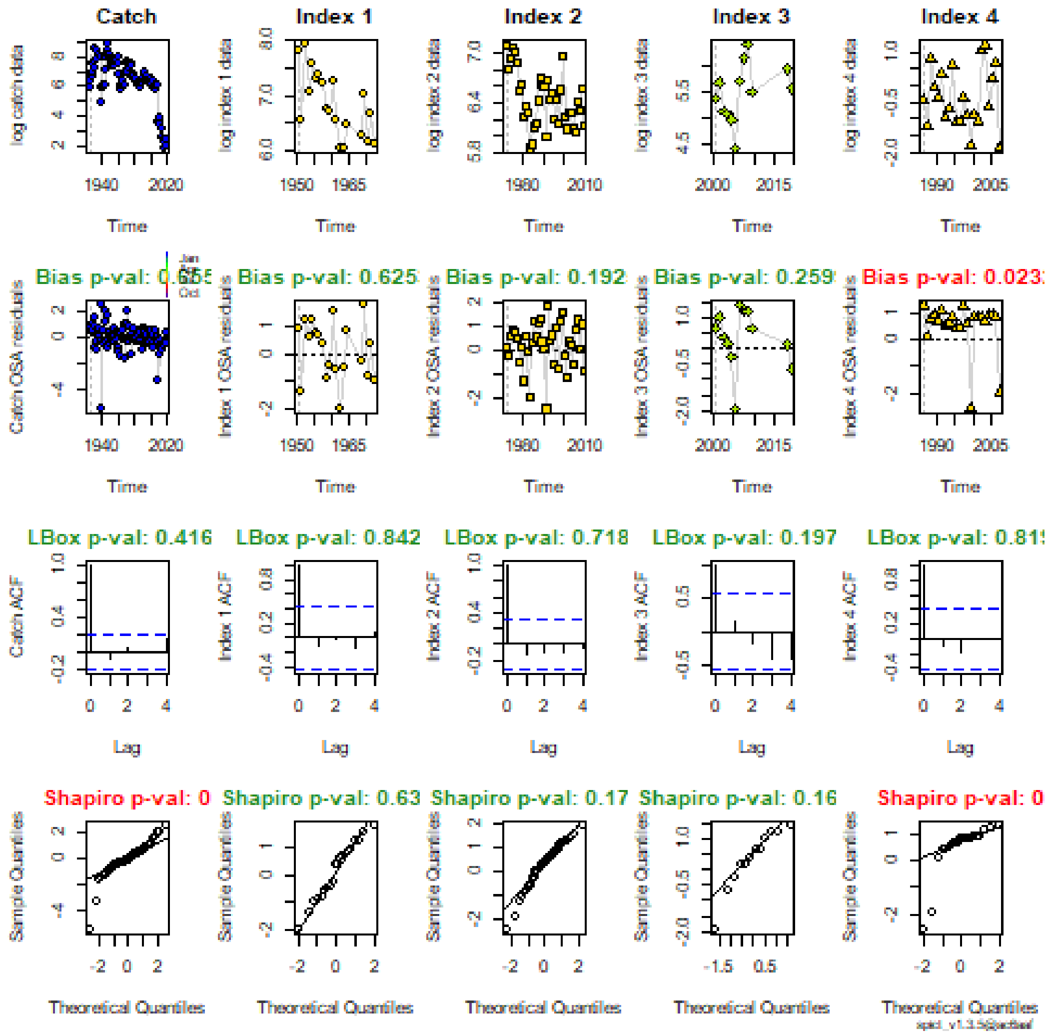

Figure 3. Diagnostic plots from the SPiCT run final model (FM) proposal for the northeast porbeagle stock. Log of the input data series (Catch, NOR-LL index 1, FRA-LL index 2, Survey index 3, SPA-LL index 4) (top row), one-step at head (OSA) residuals with *p*-value of a test for bias (2nd row), empirical autocorrelation (ACF) of the residuals (3rd row), and test for normality of the residuals (Shapiro and QQ-plot) with *p*-value (bottom row).

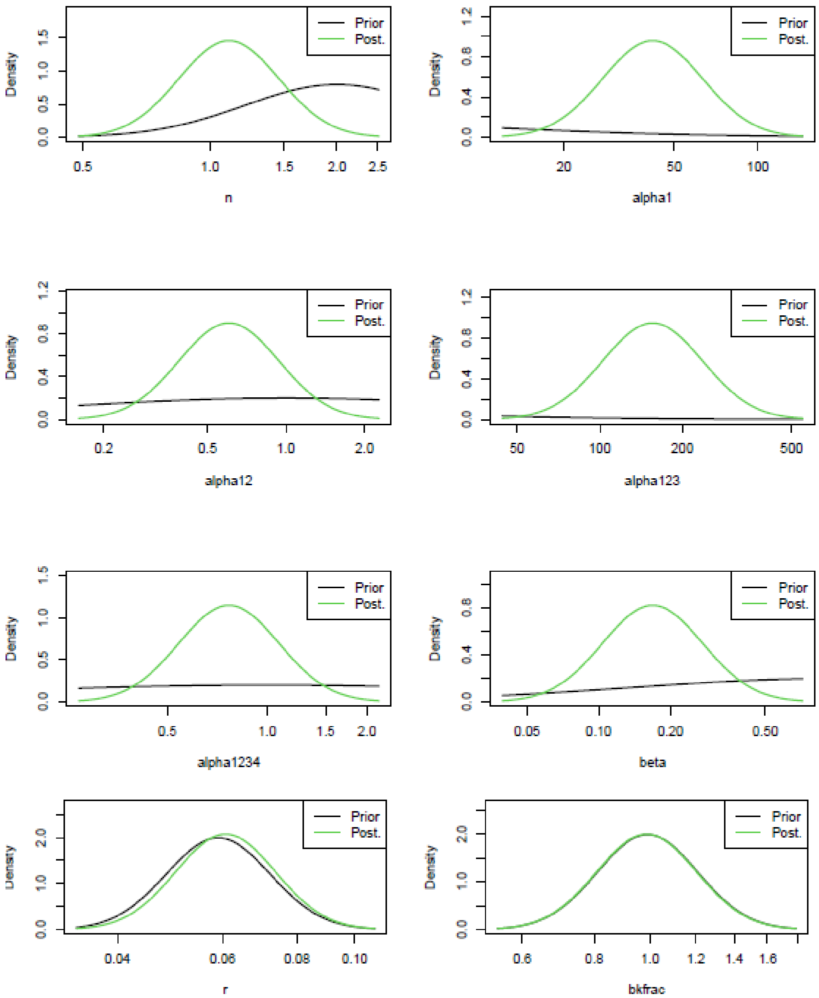

Figure 4. Plots of distributions of priors (black line) and posteriors (green line) for the estimated parameter of the SPiCT run final model (FM) proposal. Parameter of production model (n), intrinsic growth rate (r), biomass fraction at start of series (bkfrac), and alpha noise ratios parameters for each index of abundance.

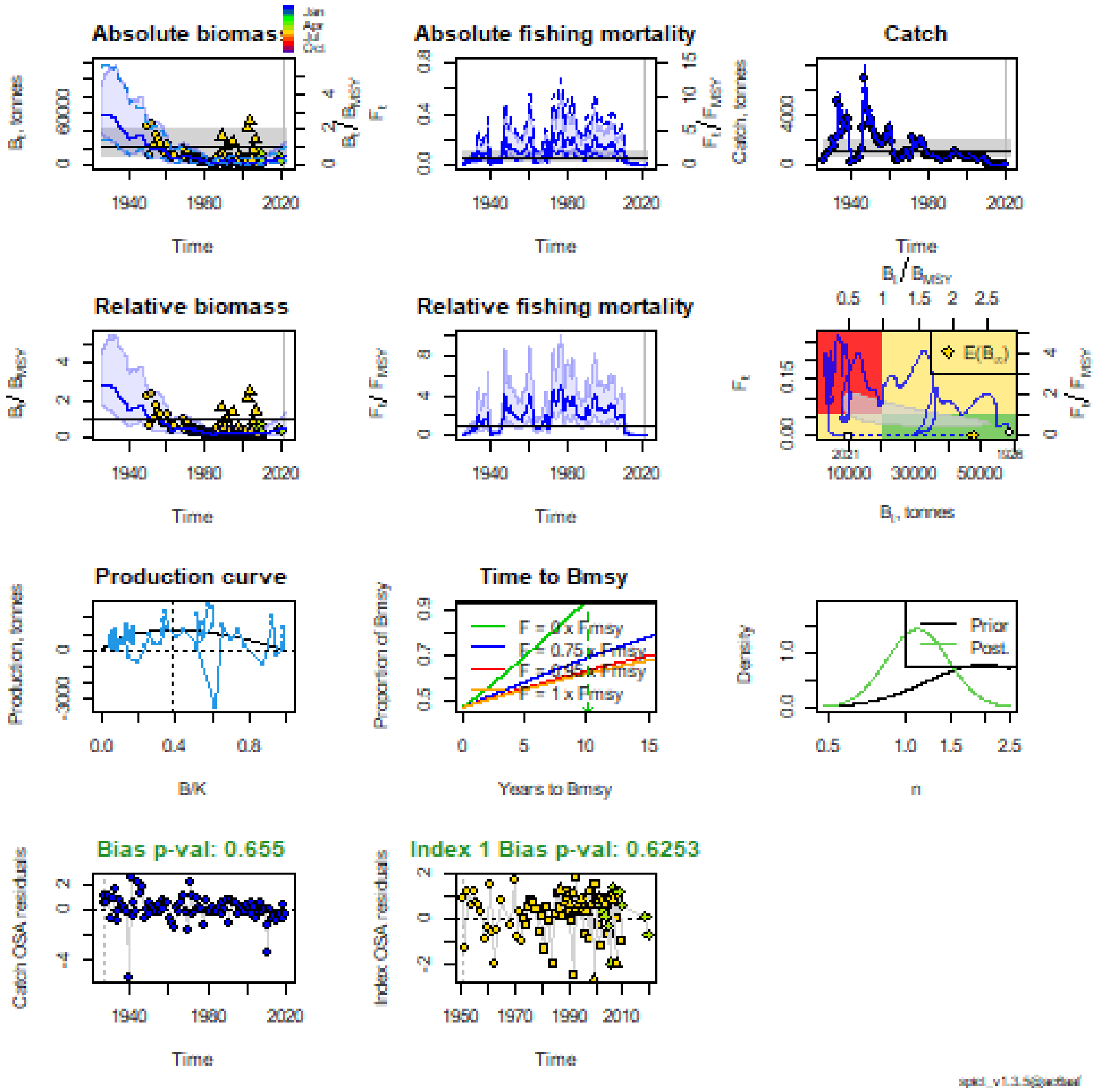

Figure 5. Plot of SPiCT fit run FM proposal estimates for the northeast porbeagle stock. Estimates of biomass, fishing mortality, catch, relative biomass, and relative fishing mortality (blue solid lines). Blue dash lines and shades denote estimates of 95%. Estimates of reference points (B_{MSY}, F_{MSY}, MSY) are shown in black lines, while 95% CIs of reference points are shown in gray shade areas. Kobe phase plot with stock trajectory

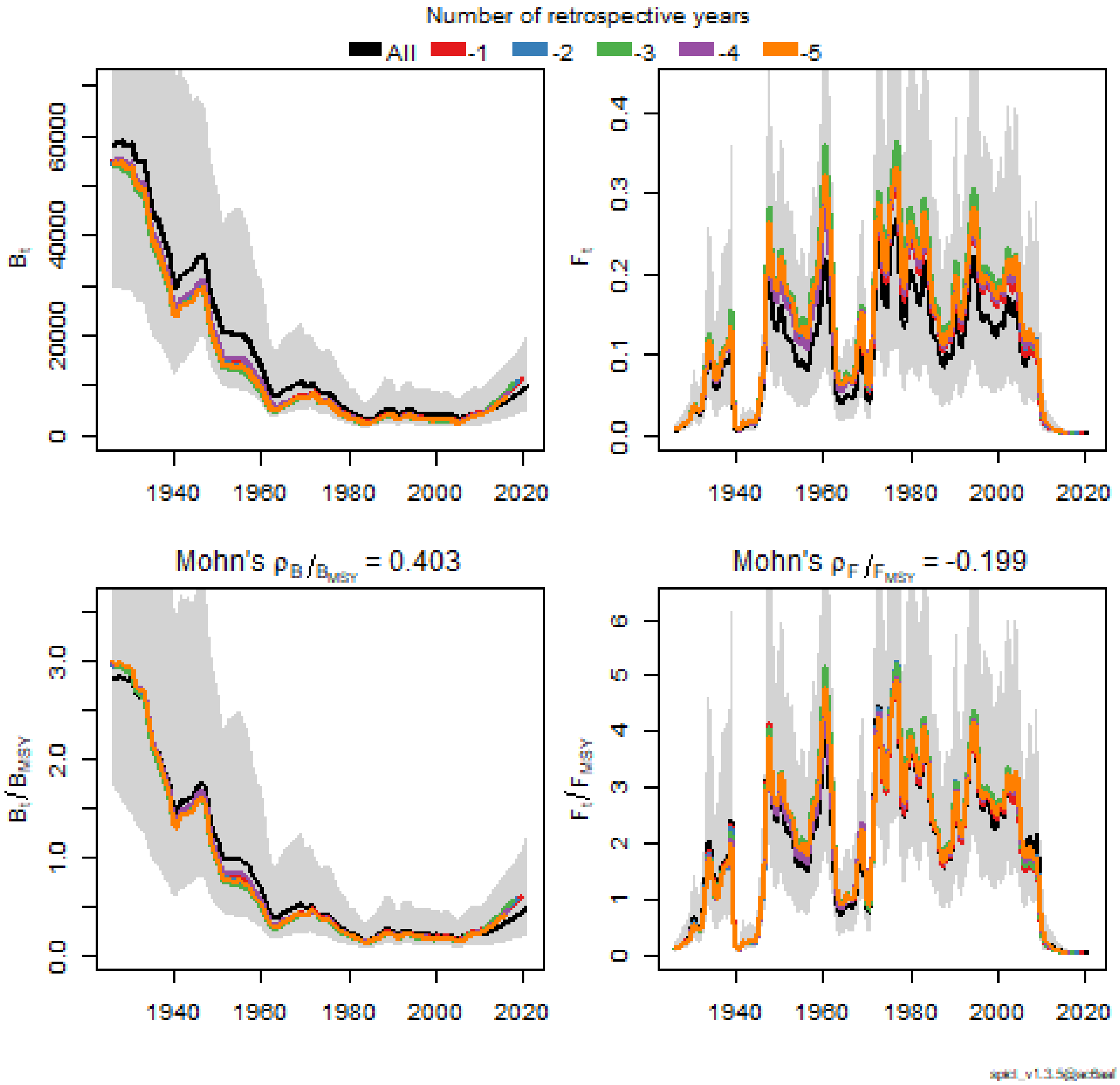

Figure 6. Retrospective plots for the SPiCT run FM proposal for the northeast porbeagle stock. Each color line indicates an estimate of biomass, fishing mortality, or relative biomass and fishing mortality when peeling off the indicated number of years (1 to 5). Shade areas are the 95% CI for the All-years (black line) estimates. And estimates of the Mohn's rho parameter for the relative biomass and fishing mortality.

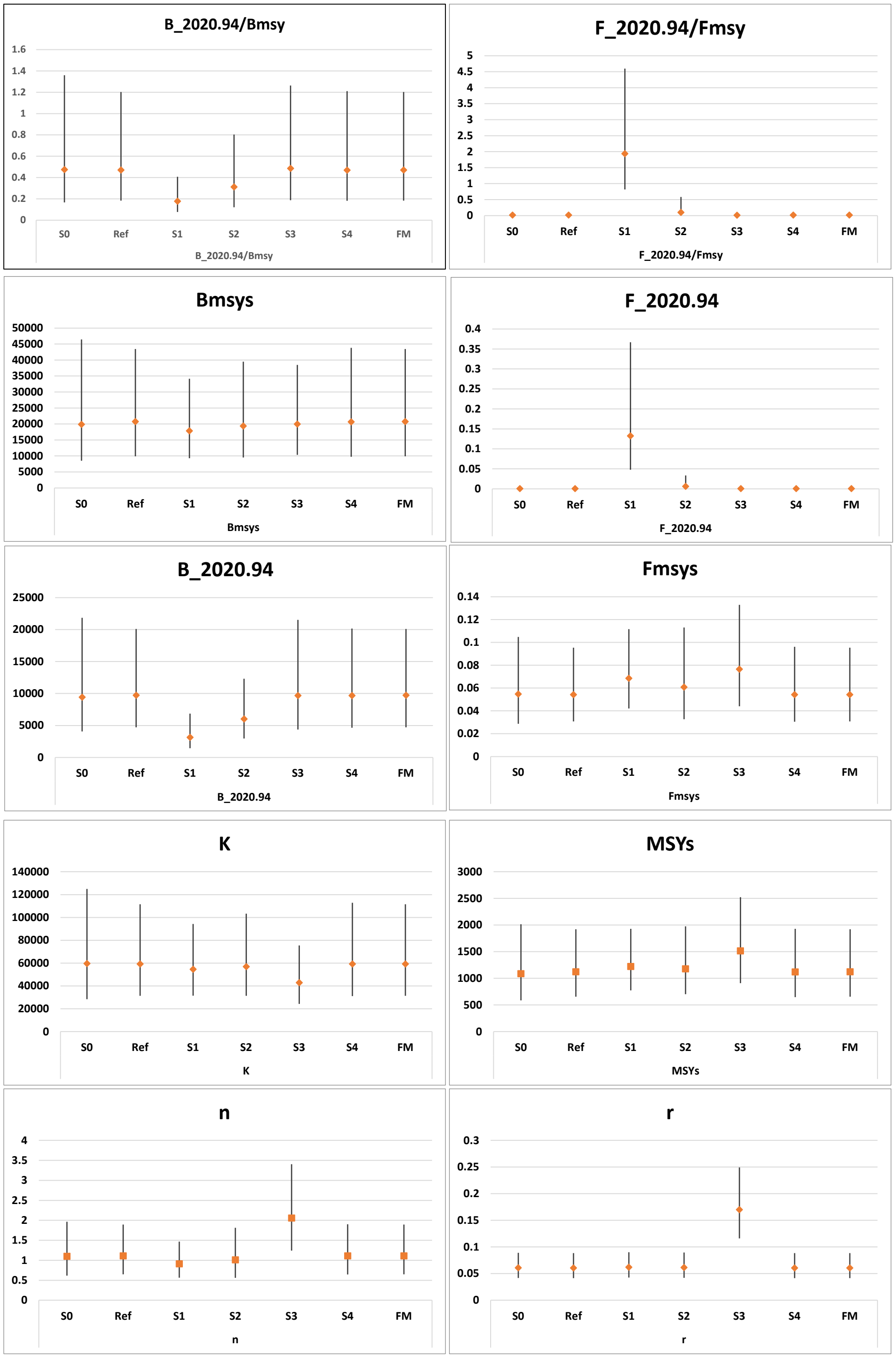

Figure 7. Summary estimates of parameters from the SPiCT model run for northeast porbeagle stock. Estimates of biomass at terminal year (B_2020), relative biomass at terminal year (B_2020/B_{MSY}), Fishing mortality at terminal year (F_2020), relative fishing mortality (F_2020/F_{MSY}), B_{MSY}, F_{MSY}, *K*, MSY, production shape parameter (*n*), and intrinsic growth rate *r*. Point estimates (marker) and 95% CI (vertical lines) are provided for each scenario (see **Table 1** for details).