Application of SPiCT to produce MSY advice for *Nephrops* Functional Unit 25

González Herraiz, I, Gómez Suárez, F.J., Velasco, F., Vázquez, A., Morlán, R., Rincón, M.

INTRODUCTION

Nephrops Functional Unit (FU) 25 (North Galicia) extends among Finisterre and Ortegal capes in the North West of Spain (ICES Division 8c, Figure 1). The species is mostly a by catch of the bottom trawl fleet that targets hake, megrim and monkfish in the area. The exploitation of the FU 25 stock affects the conservation of the large size individuals, which are the most efficient in terms of reproduction. FU 25 *Nephrops* catch has decreased a 98% since 1975 to 2016 (ICES, 2020) and there has also been a contraction of the stock area of 75%. A continuous increase in *Nephrops* mean size since 1983 to 2008 could point out failures in recruitment (ICES, 2020). In the SP-NSGFS Spanish scientific bottom trawl survey *Nephrops* index in the area there are two marked periods, one with higher *Nephrops* yields between 1983 and 1996 and other with lower yields since 1997. ICES advice for this stock has been reducing catch to zero since 2002 (ICES, 2019). The present status of the stock is undesirable (ICES, 2016) and it is considered a stock with an extremely low biomass (ICES, 2017). In 2017 there was established a TAC (total allowable catch) zero for *Nephrops* in division 8c for the triennium 2017-2019 (EU, 2017) and again in 2019 for the period 2020 to 2022 (EU, 2019).

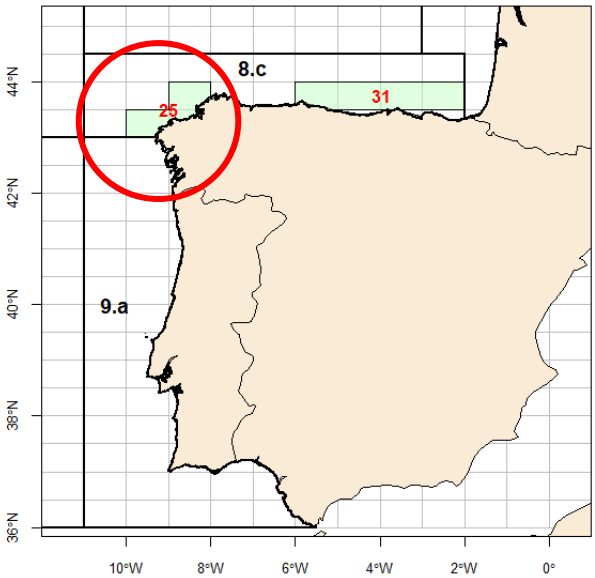

Figure 1 *Nephrops* functional units in Division 8.c. FU 25 covers statistical rectangles 15E0-E1 and 16E1.

In the first part of the 2000 decade the assessment of the stock was analytical using the age-based model XSA (ICES, 2002). Later, in view of the very low levels of landings, the assessment was based in the analysis of the trends of catch per unit effort (CPUE) and catch series (ICEs, 2007). The necessity of establishing reference points of the stock in relation with the maximum sustainable yield (MSY) has encouraged the use of new assessment methods for data limited stocks (DLS) as FU 25 *Nephrops* (ICES, 2020b). In that sense ICES planned a workshop about SPiCT in February 2021 (WKMSYSPiCT). Stochastic surplus Production model In Continuous Time (SPiCT) separates random variability of stock dynamics from error in observed indices of

biomass and also models the dynamics of the fisheries. This enables error in the catch process to be reflected in the uncertainty of estimated model parameters and management quantities. Among data limited methods (DLM), SPiCT could be a suitable tool for the analysis of FU 25 *Nephrops* stock since the stock meets the model assumptions and the model takes into account the long history of the fishery. In 2020 there were two WKMSYSPiCT preparatory meetings. This document shows the results of the appliance of SPiCT to FU 25 *Nephrops* stock after that previous work carried out before WKMSYSPiCT.

MATERIAL AND METHODS

In the WKMSYSPiCT preparatory meetings there was a review of the input data quality and the level of progress in the appliance of SPiCT for each of a list of identified data-poor stocks. There were concrete recommendations for each stock to address problems or improve the appliance of the model.

RESULTS

Data Quality

Catch

Data were collected since 1975 by month. Data were provided by ports authorities and crossed with the information provided by scientific personnel in the ports of landing. The estimation of the catches was reviewed which results in:

- A modification of the catch time series adding some *Nephrops* catches from trips that had an original incorrect gear identification (red figures in Table 1, Figure 2).

- As in the period 2017-2019 there was a *Nephrops* TAC of cero tons in division 8c with a special quota for the FU 25 *Nephrops* sentinel fishery of 2 t by year, the annual catch in this period was estimated following the catch trend of the adjacent FU 26 of West Galicia (green figures in Table 1, Figure 2), which has a parallel evolution and a similar state to FU 25 along the whole time series.

Table 1 FU 25 *Nephrops* previous and new catches series (t) (1975-2019).

Males + Females	Previous FU 25 catches (t)	New FU 25 catches (t)
1975	731	743
1976	559	578
1977	667	828
1978	690	706
1979	475	475
1980	412	532
1981	318	318
1982	431	431
1983	433	433
1984	515	515
1985	477	477

1986	364	398
1987	412	412
1988	445	445
1989	376	405
1990	285	335
1991	453	453
1992	428	428
1993	274	274
1994	245	246
1995	273	275
1996	209	209
1997	219	219
1998	103	103
1999	124	124
2000	81	81
2001	147	147
2002	143	143
2003	89	89
2004	75	75
2005	63	63
2006	62	62
2007	67	67
2008	39	39
2009	23	23
2010	32	34
2011	46	46
2012	9	13
2013	11	11
2014	10	10
2015	14	14
2016	13	13
2017	2	7
2018	2	4
2019	3	13

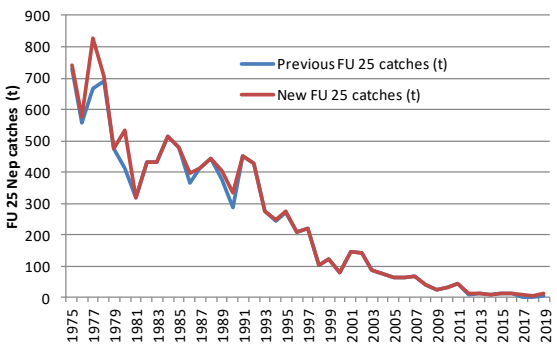

Figure 2 Previous and new FU 25 *Nephrops* catches series (t) 1975-2019.

Abundance index:

In the case of FU 25 *Nephrops* there was recommended to use preferably as abundance index the Spanish bottom trawl scientific survey (SP-NSGFS) *Nephrops* index.

Some issues about the quality of the index were raised, specially related with the existence of two marked and very different periods in the index series, till 1996 and from 1997 (Table 2 and Figure 4).

The original index was calculated with all the hauls carried out in the rectangles of FU 25 (Figure 3, left, blue points). For the February 2021 WKMSYSPiCT, the *Nephrops* area in the FU 25 was estimated with the position of the hauls with *Nephrops* catch from 1983-2020 trawl survey (SP-NSGFS), 1994-2020 Discard programme and 2017-2020 *Nephrops* Sentinels fisheries (Figure 3, green area). Then, the SP-NSGFS index has been recalculated excluding the hauls out of this area (Figure 3, right, white points). This did not change the index trend but increases very slightly the values (Table 2, Figure 4).

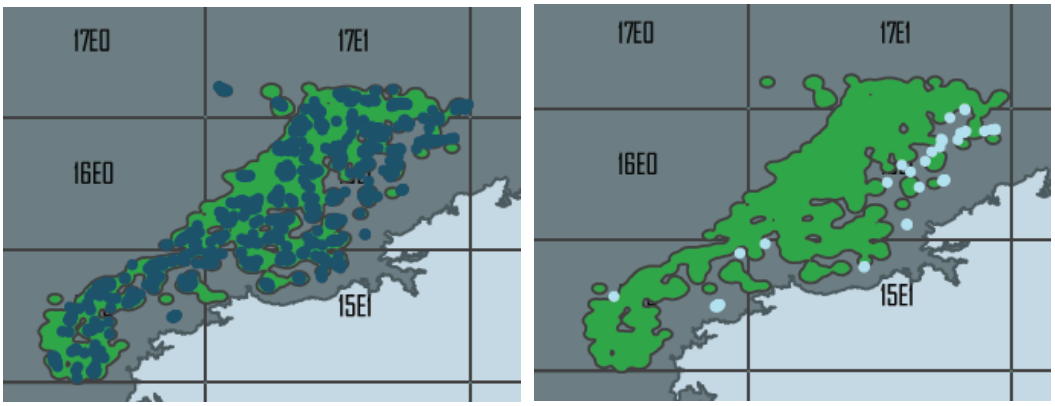

Figure 3 FU 25. *Nephrops* area in green. 1983-2019 survey hauls positions: left - all hauls (blue points), right: hauls out of the *Nephrops* area (white points).

Table 2 FU 25 SP-NSGFS survey *Nephrops* index (g/haul) (1983-2019). Original and recalculated. There was not survey in 1987. Smaller vessel and smaller gear in 1989. New vessel since 2013.

Males + Females	Original	Recalculated
1983	127	127
1984	574	565
1985	266	281
1986	339	353
1987	There was not survey	
1988	399	453
1989	66	81
1990	215	249
1991	1275	1267
1992	471	468
1993	247	256
1994	154	153

1995	496	494
1996	300	288
1997	58	59
1998	69	74
1999	82	87
2000	55	57
2001	87	90
2002	78	81
2003	25	29
2004	41	57
2005	36	48
2006	9	11
2007	11	10
2008	12	13
2009	25	28
2010	47	45
2011	30	59
2012	30	37
2013	67	96
2014	55	80
2015	20	36
2016	52	81
2017	32	47
2018	35	37
2019	51	49

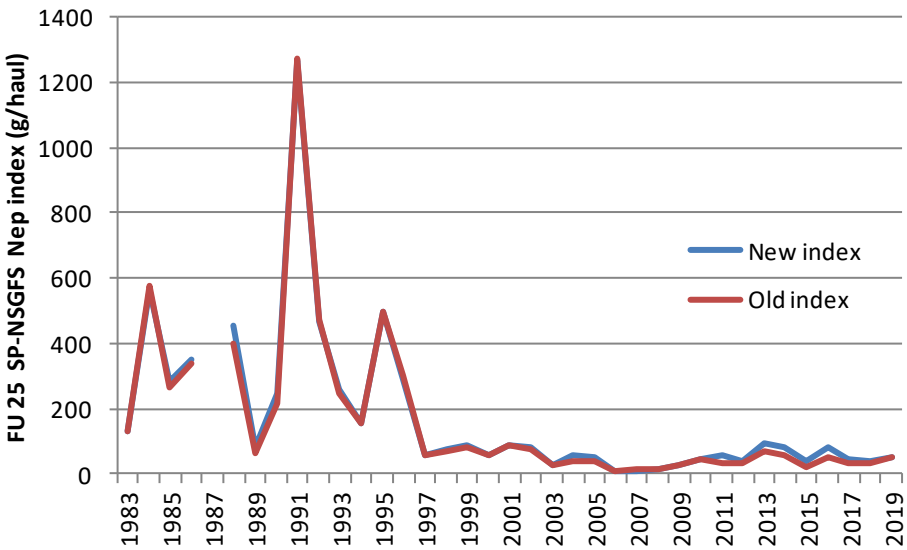

Figure 4 FU 25 SP-NSGFS survey *Nephrops* index (g/haul) 1983-2019. All hauls (original) and only with hauls in the *Nephrops* area (recalculated). There was not survey in 1987. Smaller vessel and smaller gear in 1989. New vessel since 2013.

Other addressed issues were:

- The 1991 value was checked in the raw data and it was right, corresponds to hauls with very high *Nephrops* catch.

- Have there been differences in the sampling design along the survey time series?: In 1997 the survey first depth stratum changed from 30-100 m to 70-120 and the second from 100-200 m to 120-200 m. But this could not affect to the index because there was no *Nephrops* at depths lower than 78 m and the stratum and depth are not taken into account in the *Nephrops* index estimation. *Nephrops* yield is the average of the yields of the hauls within the *Nephrops* area.

- Has the vessel or the gear changed along the survey time series? Does the index take into account the swept area?: The index is the average of the yield in kg/haul, it does not take into account the swept area but the gear, the vessel and the duration of the hauls (30 minutes) have been the same since 1983 to 2012, with the exception of the year 1989 when a smaller vessel and smaller gear were used. After several calibrations, since 2013 a new vessel and gear are used. The gear was similar to the previous except in the mocking, that was bigger and increased the catch of some bottom species but not *Nephrops* catch.

- The number and distribution of the hauls along the survey period have been similar (Figure 5 and Figs. 12.1.5-6abcd of 2020 ICES WGBIE report). Respects to the time of the day of the hauls, the hauls in this survey have always been carried out during the daytime, never at nighttime.

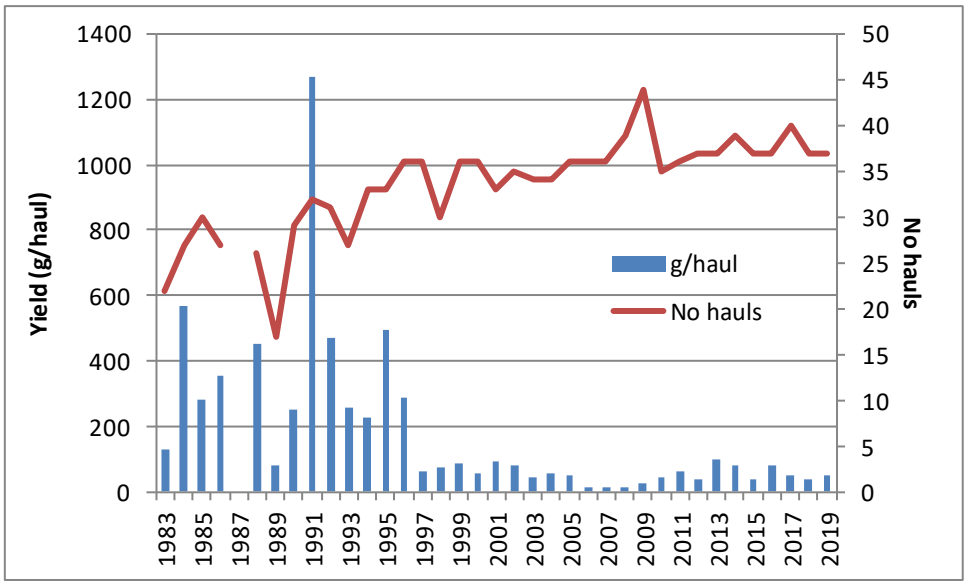

Figure 5 FU 25 SP-NSGFS Survey *Nephrops* index (g/haul). There was no survey in 1987. In 1989 a smaller vessel and smaller gear were used. New vessel since 2013.

SPiCT model

Survey and fishery *Nephrops* mean sizes:

Frequently the mean size of the individuals collected in a scientific survey is smaller than the mean size from the commercial fleet. In that cases trends observed in the scientific survey data could be reflected in the commercial catch one or two years later. The comparison of the survey and commercial mean sizes series of the FU 25 (Fig. 6) shows that in this case it is not necessary to introduce survey time series with one year more than the real, since original series trends match (Figure 6).

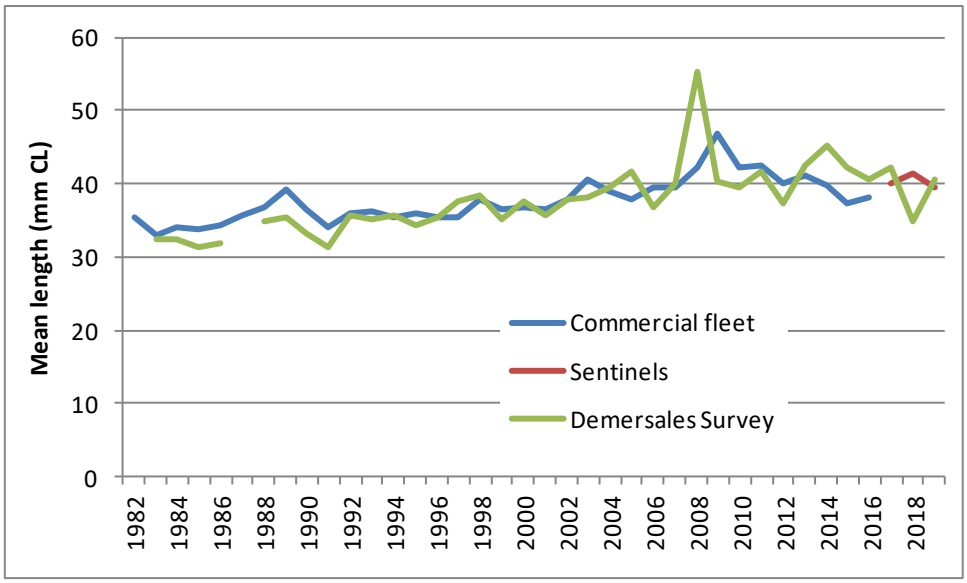

Figure 6 FU 25 *Nephrops* mean size (carapace length in mm) from the commercial fishery, the Sentinel fishery and the SP-NSGFS bottom trawl survey, 1982-2019.

Appliance of the model

Before WKMSYSPiCT, trial runs with males and females data together and quarterly and monthly males data (whole series and since 1997) were done. *Nephrops* total allowable catch (TAC) in this area is established by ICES division, 8c, which contains Functional Unit 25 and FU 31. For the sake of the simplicity, it was decided to carry out the simplest model, annual males and females data together.

The option of using the time series only since 1997 was rejected because does not take into account the oldest levels of reference and history of the stock (catch decreased a 98% from 1977 to 2016 and the stock area has decreased a 75% between 1983 and 2020).

It was decided to eliminate the survey index outlier (1991) (Table 2, Figures 4, 5 and 7).

For better numerical stability the index was scaled to mean 1.

```
> mstd<-function(x) x/mean(x,na.rm=TRUE)

> data$DEM = mstd(data$DEM)
```

The chosen interval was 12 in order to obtain monthly results.

```
> inp$dteuler=1/12
```

A prior for a medium stock depletion level before the beginning of the available data was used.

```
inp$priors$logbkfrac <- c(log(0.5), 1, 1)
```

Other priors were use in order to decrease the confidence intervals of the results.

```
> inp$priors$logalpha <- c(0,0,0)

> inp$priors$logbeta <- c(0,0,0)

> inp$priors$logsdf <- c(log(3), 0.5, 1)

> inp$priors$logsdc <- c(log(0.1), 0.2, 1)

> inp$priors$logn <- c(log(2),0.5,1)

> inp$stdevfacI <- list(c(rep(2, 12), rep(1, length(inp$timeI[[1]]) - 12)))
```

Model results

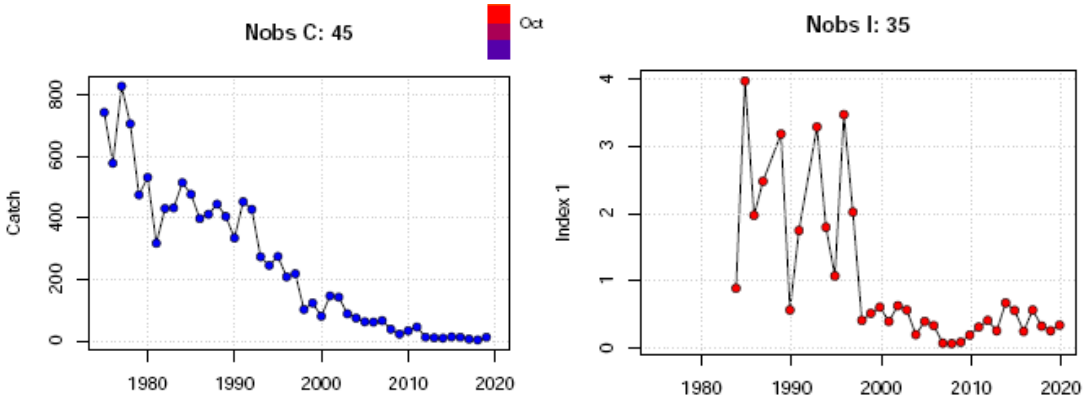

Figure 7 FU 25 *Nephrops* stock. SPiCT model input data. No 1991 value in index graph (right).

The most important outputs of the model are shown in Table 3 and Figure 8.

FU25 biomass in the year 2019 was the 20% of the biomass at maximum sustainable yield (MSY). FU25 fishing mortality in 2019 was a 46% below the fishing mortality at MSY (Table 3).

Table 3 Results of the appliance of SPiCT to FU 25 *Nephrops* stock.

K	8 390 t
B_{msys}	3 004 t
F_{msys}	0.060
MSYs	172 t
B_{2019}/B_{msy}	0.20

F_{2019}/F_{msy}	0.46

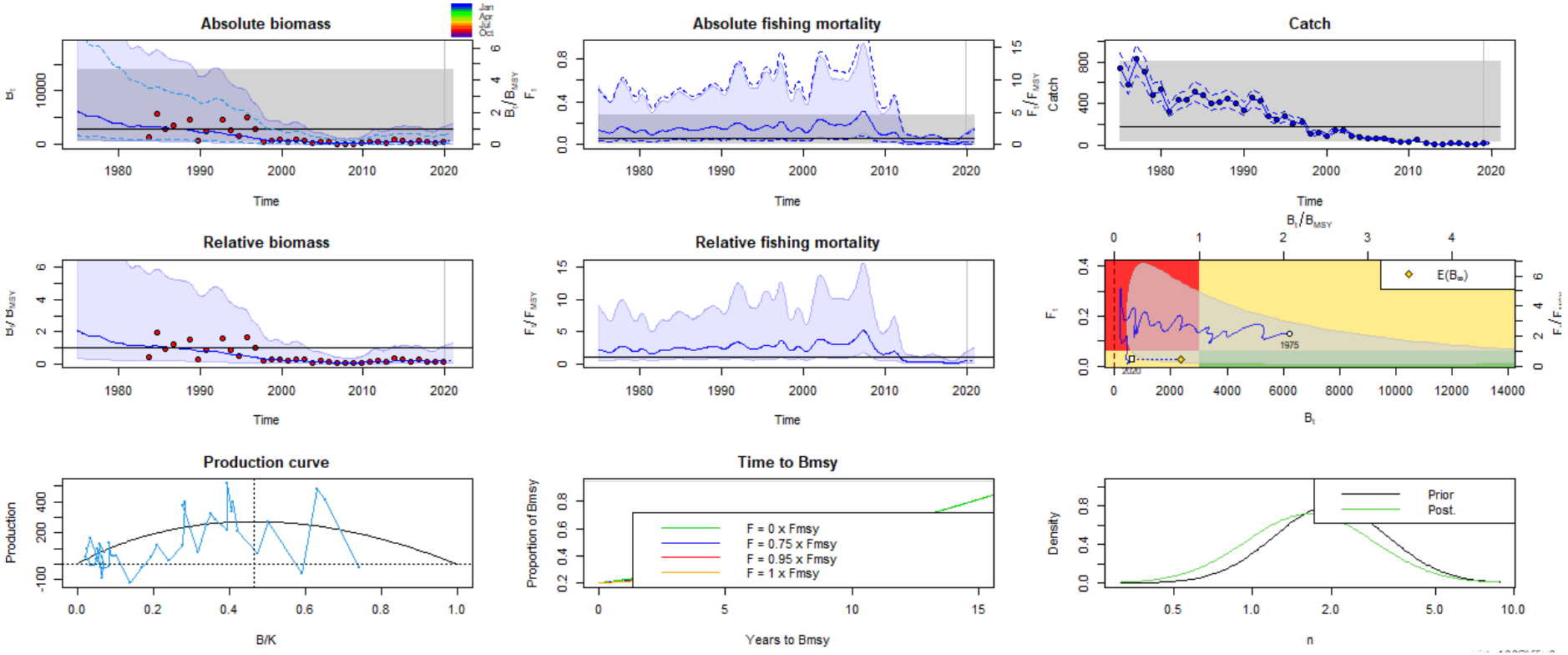

Figure 8 FU 25 *Nephrops* stock. SPiCT model results.

The checklist for the acceptance of the SPiCT assessment is shown in Table 4:

- The model converges,
- the variance of all the model parameters is finite,
- there is not violation of the model assumptions (Figure 9),
- there are consistent patterns in the retrospective analysis (Figure 10),
- the production curve is not skewed,
- the sensitivity to initial parameters is low and
- the main variance parameters is not unrealistically high.

Table 4 Checklist of the model.

Convergence	Yes (0)
Parameters variance finite	TRUE
Model assumptions meet (Diagnosis)	Yes (see figure)
Retrospective match	Yes (see figure)
Production curve skewed	No (0.46)
Sensitivity to initial values	NULL
Uncertainty B_{2019}/B_{msy} CI range order magnitude	Acceptable (2)
Uncertainty F_{2019}/F_{msy} CI range order magnitude	Ok (1)

CONCLUSION

The results of the SPiCT analysis are coincident with what is considered the status of the fu 25 stock (ICES, 2016, 2017).

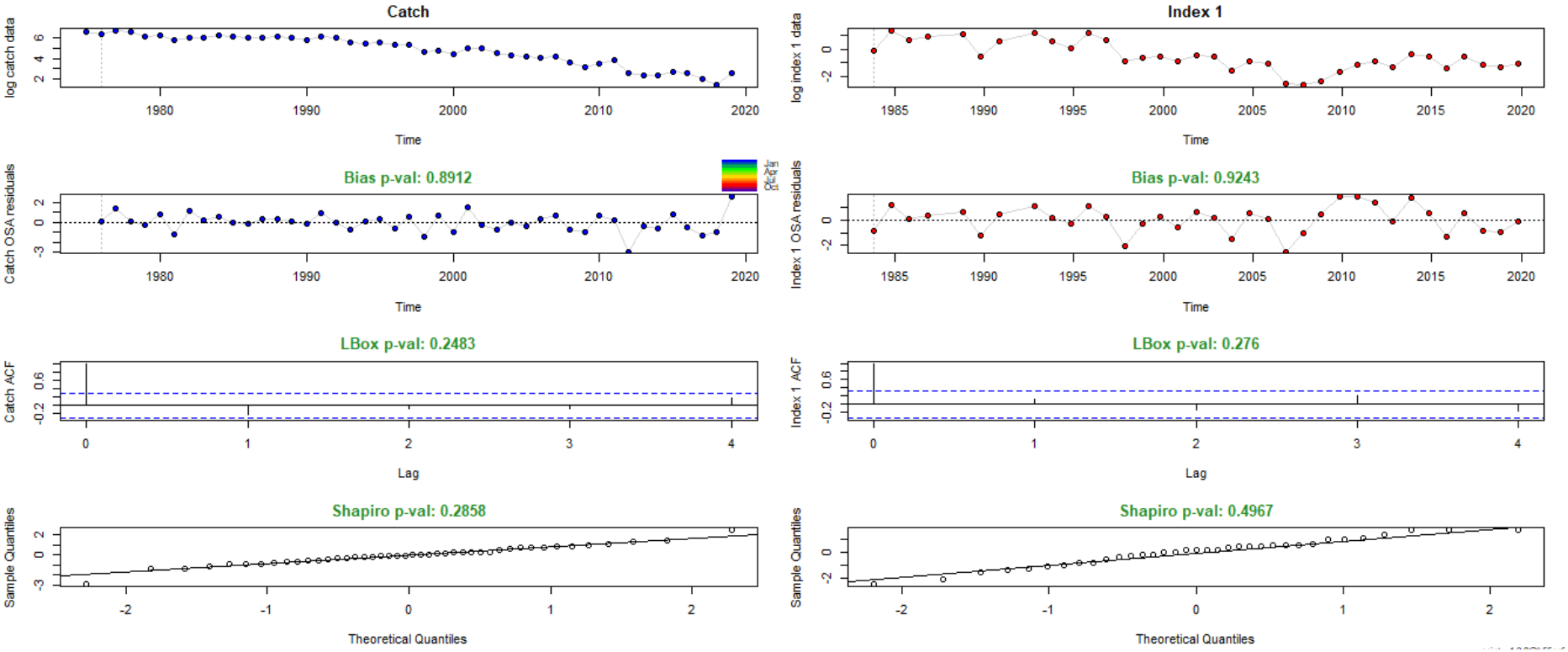

Figure 9 FU 25 *Nephrops* stock. Diagnostics.

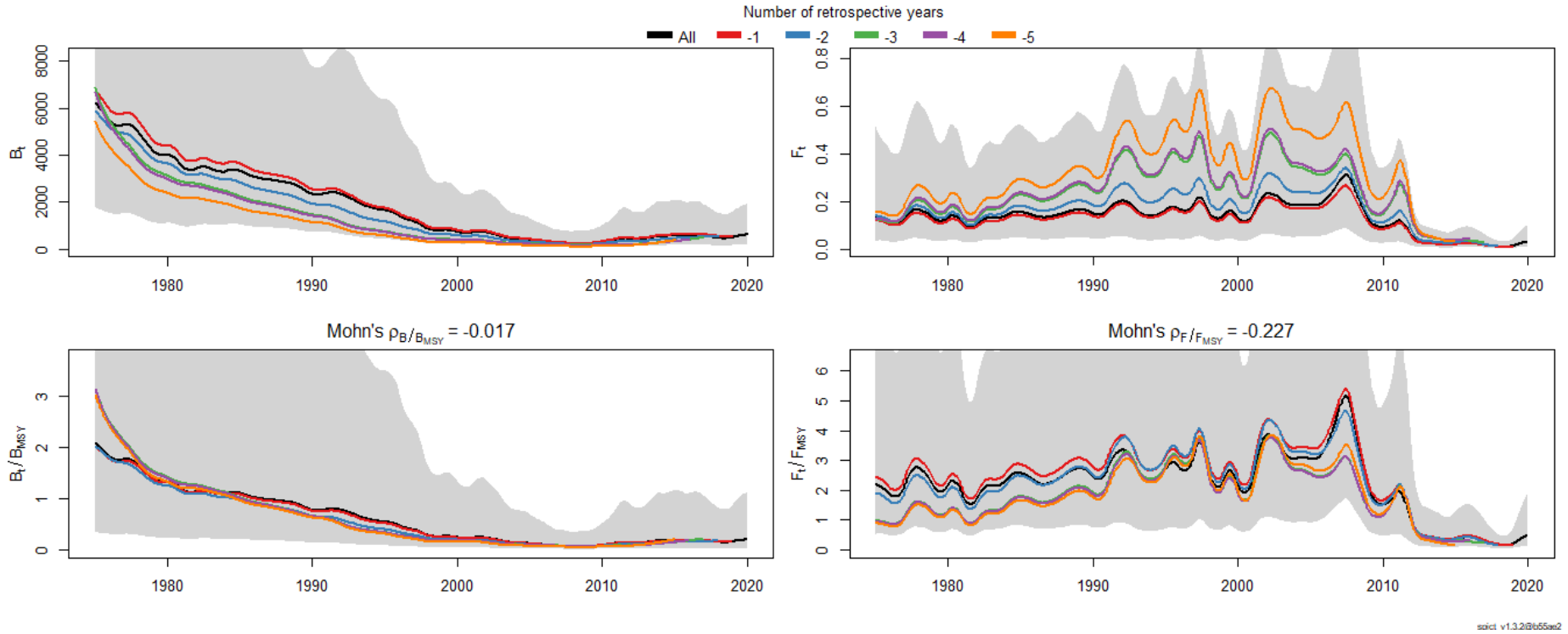

Figure 10 FU 25 *Nephrops* stock. Retrospective analysis.

REFERENCES

EU. 2017. COUNCIL REGULATION (EU) 2017/127 of 20 January 2017 fixing for 2017 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, for Union fishing vessels, in certain non-Union waters. Official Journal of the European Union. 28.1.2017. 1-172 pp.

EU. 2019. REGLAMENTO (UE) 2019/124 DEL CONSEJO de 30 de enero de 2019 por el que se establecen, para 2019, las posibilidades de pesca para determinadas poblaciones y grupos de poblaciones de peces, aplicables en aguas de la Unión y, en el caso de los buques pesqueros de la Unión, en determinadas aguas no pertenecientes a la Unión. Official Journal of the European Union. 31.1. 2019. 1-166 pp.

ICES. 2002. REPORT OF THE Working Group on *Nephrops* Stocks. Advisory Committee on Fishery Management. ICES CM 2002/ACFM:15. Lorient, France. 3–9 April 2002. 396 pp.

ICES. 2007. Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (WGHMM), 8 - 17 May 2007, Vigo, Spain. ICES CM 2007/ACFM:21. 700 pp.

ICES. 2016. EU request to provide a framework for the classification of stock status relative to MSY proxies for selected category 3 and category 4 stocks in ICES subareas 5 to 10. ICES Special Request Advice. Northeast Atlantic Ecoregion. Version 5, 01 December 2016. *In* ICES Advice 2016, Book 5.

ICES. 2017. Report of the ICES Workshop on the Development of Quantitative As-sessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for stocks in categories 3–6 (WKLIFEVI), 3–7 October 2016, Lisbon, Portugal. ICES CM 2016/ACOM:59. 106 pp.

ICES. 2019. Norway lobster (*Nephrops norvegicus*) in Division 8.c, Functional Unit 25 (southern Bay of Biscay and northern Galicia). In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, nep.fu.25, https://doi.org/10.17895/ices.advice.4768

ICES. 2020. Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE). ICES Scientific Reports. 2:49. 845 pp. http://doi.org/10.17895/ices.pub.6033

ICES. 2020b. Workshop on Methodologies for *Nephrops* Reference Points (WKNephrops; outputs from 2019 meeting). ICES Scientific Reports. 2:3. 106 pp. http://doi.org/10.17895/ices.pub.5981