Deliverable D1.3.1:

Channel and North Sea ray stock assessment in a data limited framework

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Introduction

This deliverable (D1.3.1) is part of SUMARiS Interreg project. D1.3.1 provides stock assessment tools and outcomes needed to manage ray species. D1.3.1 science has been coordinated by IFREMER, with a strong involvement from ILVO and Wageningen Marine Research teams.

The lack of reliable data has for a long time been an obstacle to the determination of stock status and the development of appropriate management measures applicable to skates and rays around the world (Stevens *et al.*, 2000). Thus *Rajidae,* which are mostly by-catches from mixed fisheries targeting sole (*Solea solea*) and plaice (*Pleuronectes platessa*) in the Eastern English Channel and the North Sea, EEC-NS (Wiegand *et al.*, 2011), have attracted only limited economic interest and funding for data collection and stock assessment programs until recently as most of by_catches species stocks (Carruthers *et al.*, 2014). However, due to their life histories and trophic position, skates and rays are particularly sensitive to overfishing (Dulvy *et al.* 2001). As top predators, they play an important role in the marine ecosystem top down regulation, so overfishing *Rajidae* would affect the whole ecosystem they are part of (Dulvy *et al.*, 2014). Therefore, the management of *Rajidae* should be supported by appropriate stock assessments.

A multi-species *Rajidae* EU TAC exists in the North Sea (ICES[1] Subarea 4 and Division 2.a) since 1999, and since 2009 a TAC has been set for Subarea 4 and Divisions 3.a, 3.b and 7.d. This TAC applies to seven different species with various life histories and different conservation status. For instance, thornback ray (*Raja clavata*) abundance has decreased during the second half of the 20th century in the North Sea (Walker & Heesen, 1996, Dulvy *et al.*, 2000), while undulate ray (*Raja undulata*) has been on the IUCN (International Union for Conservation of Nature) red list since 2008 and landings were forbidden until 2015. In contrast, recent abundance indices suggest an increase in recruitment for smaller species such are *Leucoraja naevus* and *Raja montagui (*Dulvy *et al.,* 2000*)*. Data available by species are sparse, making analytical stock assessment methods unsuitable. Data Limited Models (DLM) based on historical catch and/or abundance series could provide an alternative to assess *Rajidae* stocks and identify maximum sustainable yield proxies (MSY) (Carruthers *et al.*, 2014).

The objective of the research carried out within D1.3.1 is to develop appropriate methods to assess *Rajidae* stocks, using key information collected during the SUMARiS project as well as DLM-based tools.

[1] International Council for the Exploration of the Sea

1.Review of available data

The main source of information currently used to assess *Rajidae* stocks is extracted from research surveys. These surveys provide time series of abundance indices giving insights on stock dynamics over the last 30 years. Catch data are another requirement to use DLM, and available datasets have been explored thoroughly in this report.

1.1. Species distribution and survey indices

1.1.1 WGEF scientific survey indices

In the ICES Elasmobranch Working Group (WGEF), *Rajidae* abundance indices per species are calculated using information from one up to three scientific surveys depending on the overlap between their area of distribution and the survey coverage (Appendix 1): IBTS (International Bottom Trawl Survey) and NS-BTS (North Sea Bottom Trawl Survey) in the North Sea, CGFS (Channel Groundfish Survey) in the Eastern English Channel. These indices are normalised based on the mean of the indices per species along the time period. Abundance indices per species show positive trends during the last ten years (2009-2019), except for starry ray (*Amblyraja radiata*, RJR), a non-commercial species (Figure 1). ICES TAC advice in year *y* currently builds on the ratio between abundance indices means during the last two years (*y-1*, *y-2*) and indices means for the three previous years (*y*-3, *y*-4, *y*-5) (ICES DLS, 2012).

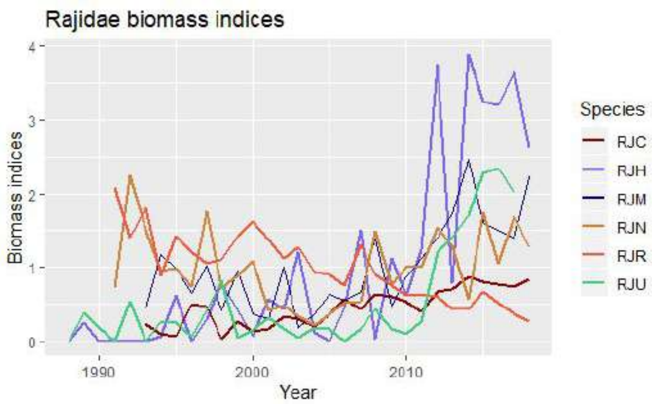

Figure 1 *Rajidae* biomass indices for *Raja clavata* (RJC, surveys: IBTS Q1, IBTS Q3, UK BTS Q3, CGFS Q4), *Raja brachyura* (RJH, surveys: UK BTS Q3, CGFS Q4), *Leucoraja naevus* (RJN, surveys: IBTS Q1, IBTS Q3), *Raja microocellata* (RJE, surveys: CGFS), *Raja montagui* (RJM, surveys: IBTS Q1, IBTS Q3, UK BTS Q3), *Raja undulata* (RJU, survey: CGFS) and, *Amblyraja radiata* (RJR, surveys: IBTS Q, IBTS Q3)

1.1.2. Revised scientific survey indices

A revision of scientific survey biomass indices have been carried out during SUMARiS project. This revision aimed to obtain comparable indices between species so they could be used in a multispecies model. The new indices used IBTS, NS-BTS and CGFS data. They were built using the mean biomass per swept area, species, year, surveys and ICES statistical rectangle. Then biomasses were averaged over rectangle and survey to obtain a stock-wide biomass index per species, taking into account catchability differences between surveys. These biomass indices are non-normalised to allow inter-species comparisons.

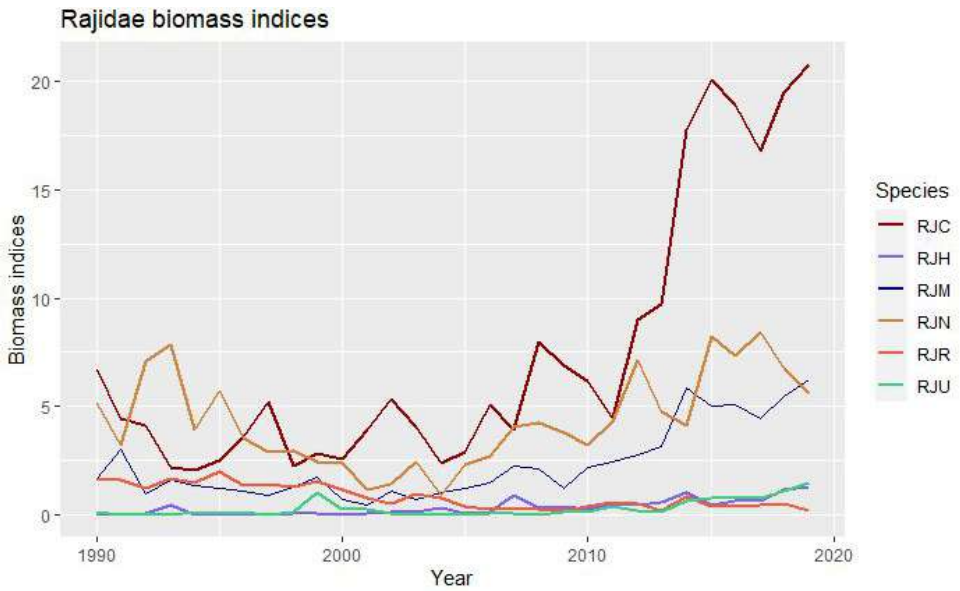

Figure 2 *Rajidae* biomass indices for *Raja clavata* (RJC), *Raja brachyura* (RJH,), *Leucoraja naevus* (RJN), *Raja microocellata* (RJE), *Raja montagui* (RJM), *Raja undulata* (RJU) and, *Amblyraja radiata* (RJR), IBTS, NS-BTS and CGFS data.

1.2. Catch trends

In the SUMARiS study area (EEC-NS), *Rajidae* fisheries represent between 0.1 and 1% of annual landings (in weight). These landings, however, underestimate catches, due to substantial discards at sea. Both landings and discards time series are necessary to feed DLM.

1.2.1. Early period (1900-2008) : aggregated Rajidae landings

Rajidae exploitation in the EEC-NS is not a recent phenomenon, with trade evidence of thornback, spotted and blond rays recorded since at least the sixteenth century (Bennema & Rijnsdorp, 2015). However, the first quantitative information on the level of exploitation of these species only became available in the early 20th century. From 1900 to 2009, landings were aggregated at the *Rajidae* taxonomic level, and these were based on FAO official information. Two exploitation peaks are observable following the two World Wars, an exploitation trend which characterizes most of the commercially exploited fish stocks during this period (Letaconnoux, 1948). Some of the ray species for which landings are currently prohibited, such as *Rostroraja alba* and *Dipturus oxyrhinchus*, were still abundant and commercialized during the first half of the 20th century. Therefore, only the dataset from 1990 to 2008 was considered sufficiently reliable to be used in this study. This period is characterized by a constant decrease of landings from about 5,000t in 1990-1991 to 3,000t in 2008 (Figure 3).

Figure 3 *Rajidae* landings in tonnes from 1950 to 2008, FAO data

Until 1999 in the North Sea, and 2009 in the EEC, *Rajidae* landings were not subject to any regulation. A skates and rays TAC was enforced in the North Sea in 1999, but that was not constraining and had never been reached until 2009 (WGEF, 2019). However, even if the majority of *Rajidae* are landed as bycatch, their economic value cannot be neglected, with an average selling price of 9 euro per kg (FranceAgriMer, France, Rungis Marée-Fraîche, 10/01/2020). This price is consistent across all EEC-NS species. Indeed, most rays are commercialized without any species identification. Consequently, we made the hypothesis that, without any constraining regulation framework during this period, all the *Rajidae* caught at a marketable size were landed, and their discards could be considered as marginal over the period 1950-2008. This hypothesis will be further tested in the multi-specific state space bayesian model.

1.2.2 Recent period (2009-2018): landings and discards per species

Since 2009, the EU has made it legally binding to report *Rajidae* landings at the species level. In addition, the aggregated *Rajidae* TAC has decreased from 6,060t in 1999, for the North Sea only, to 2,755t in 2009 for the EEC-NS. Since 2009, the TAC has been reached almost every year (WGEF, 2019). Catches are mainly composed of thornback rays (*Raja clavata*), which represented 61-81% of total *Rajidae* landings during the 2009-2019 period (Figure 4). Blond rays (*Raja brachyura*) and spotted rays (*Raja montagui*) are the two other major species in terms of overall landings. The undulate ray (*Raja undulata*) is present principally in the EEC, and it is fished only by France, Belgium and the United Kingdom (Figure 5).

Figure 4 Landings per species in tonnes from 2009 to 2018, *Raja clavata* (RJC), *Raja microocellata* (RJE), *Raja brachyura* (RJH), *Raja montagui* (RJM), *Amblyraja radiata* (RJR), *Raja undulata* (RJU), TAC values are represented by the black line.

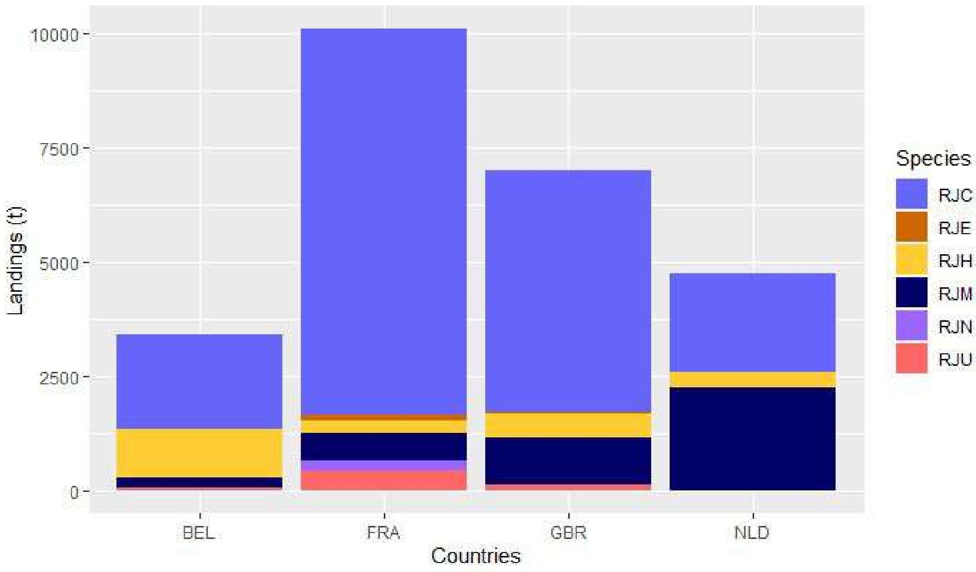

Figure 5 landings per species and country in 2018, Belgium (BEL), Germany (DEU), France (FRA), United Kingdom (GBR), Nederland (NLD), *Raja clavata* (RJC), *Raja microocellata* (RJE), *Raja brachyura* (RJH), *Raja montagui* (RJM), *Amblyraja radiata* (RJR), *Raja undulata* (RJU)

During 2009-2018, more than half of the rays caught by trawlers were discarded. Unfortunately, discards are poorly informed, and a multiple regression, based on the relation between the time spent at sea, the fleet and the amount of discards (Appendix 2) has been applied to infer missing data (Figure 6, Appendix 2).

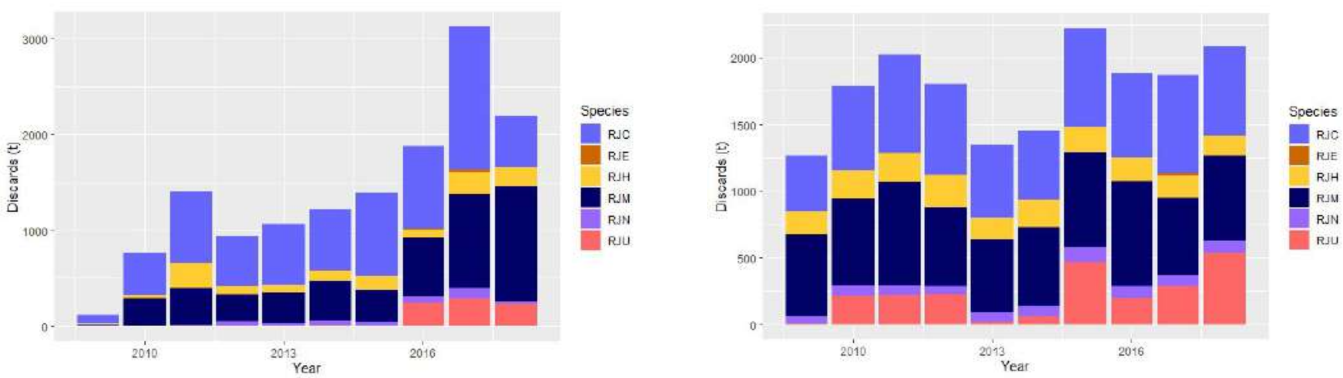

Figure 6 Discard data in tonnes per species and year. Left to right, raw data and multiple regression results

Rajidae species have been subject to an exemption from the EU Landing Obligation (LO) regulation in 2019 as a result of their potentially high survival rate after discarding. Several experiments have been carried out during SUMARiS (WP2) to estimate this survival rate and support the implementation of the LO exemption. Preliminary results and associated literature estimate a survival rate of nearly 50% (Enever *et al.*, 2009, Schram & Molenaar, 2018,). We used this value to estimate catches by adding landings to 50% of the estimated discard amount (Rens *et al.,* 2019).
The existence of a stable TAC has impacted the landing series: catch stayed stable during this period as well, causing an absence of contrast in the catch series data, mainly for *Raja clavata* and *Leucoraja naevus*.

2. DLM choice and associated results

Quota advice for most data-rich stocks is based on analytical assessment methods, which require detailed information on species biology (e.g., age structure) and exploitation parameters, to estimate biomass and fishing mortality levels in relation to target (often MSY-based) reference levels. Consistent with the worldwide implementation of the precautionary approach to fisheries management advice, the number of stocks for which assessments are requested has steadily increased. Because detailed data needed to assess these additional stocks analytically are rarely available (Carruthers *et al.*, 2014), new kinds of assessment models have been developed to determine MSY-based reference point proxies (Carruthers *et al.*, 2012, Froese *et al.*, 2017). Many of these models are based on Bayesian inference (Carruthers *et al.*, 2014, Chrysa & Kuparinen, 2016, Froese *et al.*, 2017). Bayesian inference provides a framework to include prior knowledge, e.g., based on available literature and expert knowledge, through defining prior distributions over the model parameters. In this study, we developed a new stock assessment method in the EEC-NS, by testing a set of DLMs and their robustness to the different hypotheses made on priors and associated errors.

2.1. Species-specific models

Given the data shown previously, only a ten-year time series of species-specific data are available for EEC-NS *Rajidae*. Taking into account this limitation, three DLMs have been considered: the DCAC (Depletion Corrected Average Catch), the CMSY (Catch Maximum Sustainable Yield) and the SPicT (Surplus Production in continuous Time).

2.1.1. DCAC (Depletion Corrected Average Catch)

DCAC is a simple formula based on catch mean derived from a time series (MacCall, 2009). A depletion index is used (ratio between stock level at the end and at the beginning of the time series) as well as an estimation of species' natural mortality, Equations (1) and (2).

$$\frac{W}{Y_{\text{pot}}} = \frac{\Delta B_0}{0.4cMB_0} \quad \text{or} \quad \frac{W}{Y_{\text{pot}}} = \frac{\Delta}{0.4cM}$$

$$Y_{\text{sust}} = \frac{\sum C}{n + W/Y_{\text{pot}}}$$

Equations 1 and 2 *Ysust,* sustainable yield, *C*, catches, *n*, number of years, *W*, depletion indices, *Ypot,* potential yield, *Delta*, difference between initial and final relative biomass, *B0,* initial biomass, *c*, constant, *M*, natural mortality.

We considered the level of exploitation to be similar for all species. The biomass was estimated to be under B_{MSY} at the beginning of the time series and slightly over B_{MSY} at the final time step. Consequently, we used a set of priors for delta comprised between 0.8 and 0.6 for the initial biomass and 0.6 and 0.4 for the final biomass (Table 1). The natural mortality was set at 0.2 for all species with different standard deviations to make the priors more or less informative (Table 1).

Table 1 Priors set for 4 different DCAC models

		2009		2018	
		parameter	standard deviation	parameter	standard deviation
M1	M	0.20	0.10	0.20	0.10
	delta	0.80	0.15	0.60	0.15
	c	1.00	0.20	1.00	0.20
M2	M	0.20	0.05	0.20	0.05
	delta	0.80	0.15	0.60	0.15
	c	1.00	0.20	1.00	0.20
M3	M	0.20	0.10	0.20	0.10
	delta	0.60	0.15	0.40	0.15
	c	1.00	0.20	1.00	0.20
M4	M	0.20	0.05	0.20	0.05
	delta	0.60	0.15	0.40	0.15
	c	1.00	0.20	1.00	0.20

Note that DCAC output Y_{sust} is a proxy of sustainable yield and not an estimation of maximum sustainable yield. Furthermore, the estimation produced by the DCAC is a snapshot estimation that could not be directly updated with new data (MacCall *et al.*, 2009). DCAC results (Table 2) using the DLMTool package produce TAC advice based on sustainable yield proxies. These proxies are close to current TAC recommendations by ICES.

Table 2 DCAC results, catch in tonnes, RJC (Raja clavata), RJH (Raja brachyura), RJN (Leucoraja naevus), RJE (Raja microocellata), RJM (Raja montagui), RJU (Raja undulata), M1 low depletion, 0,1 of mortality standard deviation, M2 low depletion, 0.05 of mortality standard deviation, M3 medium depletion, 0.1 of mortality standard deviation, M4 medium depletion 0.05 of mortality standard deviation.

	M1	M2	M3	M4
RJC	1497	1197	1489	1234
RJH	239	198	244	198
RJN	23	18	23	19
RJE	10	9	10	9
RJM	293	235	291	240
RJU	76	62	76	61
Total	2138	1719	2133	1761

2.1.2. CMSY

CMSY builds on the Schaefer production model (1954), which formulates the biomass at t+1, B_{t+1}, as a function of the biomass at the previous time step, B_t, the intrinsic growth rate r (corresponding to the difference between mortality and reproduction), the carrying capacity of the environment K and the catches at previous time step, C_t (3).

$$B_{t+1} = B_t + r(1 - \frac{B_t}{K})B_t - C_t$$

Equation 3

To use CMSY, priors have to be set on the initial biomass, r and *K* (Froese *et al.*, 2017). The model assumes that only one combination of *r* and *K* best fit biomass and catch data. Bayesian inference using the Markovian chain of Monte Carlo (MCMC) is used to find this combination. This includes an important amount of random simulations to estimate the most likely parameters values, based on priors and collected data. These simulations start with initializers for each parameter. Then parameters values are simulated using the prior distribution input in the model. The probability to obtain these parameters according to the available data is then calculated, and a posterior distribution for each parameter is found. In the case of the CMSY, three Monte Carlo chains were used with an initial set up of 10000 simulations per chain, to obtain the best viable *r* and *K* pair. Once this combination is found, an MSY proxy is calculated using Equation (4).

$$MSY = \frac{rK}{4} \rightarrow log(K) = log(4MSY) + (-1)log(r)$$

Equation 4

We used a set of informative priors for *r*, based on Froese *et al.* (2017). Different prior combinations for the biomass at the beginning of the catch series, 2009, have also been tested (Table 3).

Table 3 Initial and final biomass combinations for CMSY models

	Initial biomass	Final biomass
M1	0.01-0.40	0.20-0.60
M2	0.01-0.40	0.01-0.40
M3	0.20-0.60	0.20-0.60
M4	0.20-0.60	0.50-0.90

CMSY could be applied to all ray species except *Raja microocellata*, for which data were too sparse. All *Rajidae* stocks assessed by CMSY were perceived as overexploited ($F>F_{MSY}$ and $B<B_{MSY}$) using model M2 (very low initial and very low final biomass, Appendix 3). In all other cases, *Raja clavata* and *Leucoraja naevus* had a biomass over B_{MSY} and a fishing mortality under F_{MSY} at the final time step, 2018. *Raja brachyura*, *Raja montagui* and *Raja undulata* are perceived as overexploited using M1 and M3. The range of MSY estimates is

variable, depending on the best prior fit to the production curve, and the [r, k] space coverage (Table 4). Indeed, simulated *r/K* pairs in CMSY are only viable if they meet the following constraints: the biomass is strictly positive, and the biomass ranges for the end and the beginning of the time series has to correspond to its prior range, respectively. Using this approach *r/K* pairs typically result in a triangular-shaped cloud in log-space. Prior's choice consequently had an important impact on the number of viable combinations and cloud shape, allowing or not the full coverage of the *r/K* space.

Table 4: CMSY results for four initial and final biomass combinations, in green smallest confidence interval models, in green broadest confidence interval models

	r	ci r	k	ci k	MSY	ci MSY	Blast	Blast 2,5 %	Blast 97,5 %	F/(r/2)
RJC										
00.1/00.1	0.423	0.362 - 0.495	18	14 - 24	1.900	1.490 - 2.430	0.351 k	0.176	0.398	2.090
00.1/0.2	0.343	0.239 - 0.492	30	17 - 53	2.570	1.710 - 3.870	0.557 k	0.404	0.599	0.978
0.2/0.2	0.282	0.163 - 0.487	30	12 - 74	2.090	1.010 - 4.320	0.529 k	0.274	0.598	1.270
0.2/0.5	0.282	0.163 - 0.487	103	23 - 458	7.270	1.140 - 46.30	0.788 k	0.538	0.897	0.245
RJH										
00.1/00.1	0.282	0.163 - 0.487	9.68	3 - 34	0.683	0.172 - 2.710	0.210 k	0.015	0.394	1.220
00.1/0.2	0.282	0.163 - 0.487	10.4	3 - 34	0.737	0.208 - 2.610	0.398 k	0.209	0.589	0.595
0.2/0.2	0.282	0.163 - 0.487	6.98	2 - 22	0.492	0.150- 1.610	0.440 k	0.213	0.595	0.805
0.2/0.5	0.282	0.163 - 0.487	17.2	4 - 73	1.210	0.210 - 7.030	0.682 k	0.508	0.882	0.211
RJN										
00.1/00.1	0.421	0.358 - 0.495	0.28	0.209 - 0.376	0.030	0.023 - 0.038	0.358 k	0.188	0.398	1.660
00.1/0.2	0.343	0.239 - 0.492	0.461	0.262 - 0.810	0.040	0.027 - 0.059	0.557 k	0.417	0.598	0.794
0.2/0.2	0.341	0.237 - 0.492	0.468	0.264 - 0.831	0.040	0.027 - 0.060	0.530 k	0.368	0.684	0.917
0.2/0.5	0.282	0.163 - 0.487	1.59	0.364 - 6.960	0.112	0.018 - 0.694	0.788 k	0.541	0.897	0.198
RJM										
00.1/00.1	0.282	0.163 - 0.487	12.3	3 - 48	0.867	0.178 - 4.220	0.190 k	0.015	0.394	3.680
00.1/0.2	0.282	0.163 - 0.487	12.7	3 - 47	0.899	0.202 - 4.000	0.414 k	0.209	0.585	1.630
0.2/0.2	0.282	0.163 - 0.487	8.29	2 - 28	0.585	0.155 - 2.210	0.384 k	0.211	0.581	2.700
0.2/0.5	0.346	0.244 - 0.492	11.2	4 - 30	0.970	0.286 - 3.290	0.564 k	0.503	0.700	1.110
RJU										
00.1/00.1	0.282	0.163 - 0.487	12.2	3 - 47	0.857	0.177 - 4.160	0.198 k	0.015	0.394	3.560
00.1/0.2	0.282	0.163 - 0.487	12.5	3- 46	0.879	0.199 - 3.880	0.413 k	0.209	0.587	1.670
0.2/0.2	0.282	0.163 - 0.487	7.93	2 - 27	0.560	0.149 - 2.090	0.375 k	0.211	0.577	2.890
0.2/0.5	0.345	0.241 - 0.492	11.6	4 - 31	1.000	0.292 - 3.420	0.562 k	0.503	0.692	1.080

2.1.3 SPicT (Surplus Production in continuous Time)

SPicT uses the Pella Tomlinson (1969) surplus production model formulation instead of the Schaefer production model (Pedersen & Berg, 2017). A new parameter, *n*, controls the shape of the production curve. When *n* is equal to two, the equation equals the Schaefer production model (5).

$$\frac{dB_t}{dt} = \frac{r}{n-1} B_t \left(1 - \left[\frac{B_t}{K}\right]^{n-1}\right) - F_t B_t$$

Equation 5

Another SPicT specification is the catch formulation, which is divided in two terms: the fishing mortality and the biomass. This new formulation allows the estimation of three reference point proxies (6, 7, 8).

$$B_{MSY} = B^d_{MSY}\left(1 - \frac{1 + F^d_{MSY}(n-2)/2}{F^d_{MSY}(2 - F^d_{MSY})^2}\sigma^2_B\right)$$

$$F_{MSY} = F^d_{MSY} - \frac{(n-1)(1 - F^d_{MSY})}{(2 - F^d_{MSY})^2}\sigma^2_B$$

$$MSY = MSY^d\left(1 - \frac{n/2}{1 - (1 - F^d_{MSY})^2}\sigma^2_B\right)$$

Equations 6, 7 and 8

SPicT features both process and observation errors. The process error corresponds to variability causes not included in the model while observation error represents the difference between the measured biomass and the real biomass. Data required include catch data, one or multiple biomass indices. WGEF actual data were first used (Appendix 4) then we used WGEF revised biomasse indices from 1990 to 2018, and total catch including discards multiple regression estimation results from 2009 to 2018 (Appendix 5). Priors for *n, r* and *K* were necessary. Values used for *r* are the same as values used for CMSY, and *n* has been set to 2 to obtain a Schaefer production model.
Only two parameter combinations for *r* have been tested according to Froese *et al.* (2017) resilience recommendation for CMSY. The model did not converge for *R. brachyura* and *R. undulata* species when taking the less informative prior parameter setting. Consequently, only the most informative resilience setting for revised data is presented here (Table 5). According to SPicT results, the current (2018) biomass of *Raja clavata* was below B_{MSY}. All other species have a biomass superior to the B_{MSY}. However SPicT confidence intervals for all species are broad ranging from an actual biomass under B_{MSY} to biomass over B_{MSY} (Appendix 4). Median fishing mortality of all species was estimated below F_{MSY} for all species, but confidence intervals were also wide. Autocorrelation and normality of the

catch and abundance indices residuals were tested using Ljung-Box and Shapiro tests. Autocorrelation for abundance indices identified for *Raja clavata*. *Raja brachyura* and *Raja montagui* abundance indices residuals were non normally distributed.

Table 5 SPicT results for the main reference point available and associated confidence intervals

	estimate	cilow	ciupp
RJC			
B_2018./Bmsy	0.77	0.22	2.72
F_2018/Fmsy	0.59	0.30	1.17
Bmsy	35 486	4 286	293 784
Fmsy	0.16	0.07	0.37
MSY	5 732	1 466	22 417
RJH			
B_2018/Bmsy	1.22	0.39	3.77
F_2018./Fmsy	0.51	0.04	06.05
Bmsy	5 404	452	6 4555
Fmsy	0.13	0.05	0.37
MSY	719	151	3 416
RJN			
B_2018/Bmsy	1.22	0.65	2.32
F_2018/Fmsy	0.47	0.20	1.11
Bmsy	595	169	2 101
Fmsy	0.19	0.09	0.41
MSY	116	64	212
RJM			
B_2018/Bmsy	1.18	0.56	2.48
F_2018/Fmsy	0.38	0.14	01.02
Bmsy	6 363	1 011	40 049
Fmsy	0.16	0.07	0.35
MSY	1 000	329	3 040
RJU			
B_2018/Bmsy	0.91	<0.01	428.65
F_2018/Fmsy	0.14	<0.01	23.91
Bmsy	70 384	1.64	3 000 000 000
Fmsy	0.03	<0.01	0.50
MSY	-	-	-

2.2. Combined-species model

2.2.1. Method

Another Bayesian approach has been tested allowing the use of a larger amount of data. This approach, termed State Space Bayesian model (SSBM), has first been developed with *Rajidae* fisheries from the Bay of Biscay. It makes hypotheses based on species-specific catch ratios. SSBM estimates the historical catch composition using recent, available species specific data and historical catch data of *Rajidae* (Marandel *et al.*, 2019). This method addresses the issues caused by the relatively short time series available to run the methods shown in Section 2.1.

Six species model did not reach inter and intra chain convergence for the three less abundant species parameters: *Leucoraja naevus, Raja microocellata, and Raja undulata*. A three species only model was constructed to avoid this issue. Less abundant species mean catch over the last ten years have been calculated (2009-2018). These three species did represent on average 5% of the total *Rajidaes* catches. We used this value to reduce the previous total *Rajidaes* catch (1990-2008).

The SSBM we used is based on the Schaefer production model (Marandel *et al.*, 2016, Marandel *et al.*, 2019). SSBM is comparable to CMSY, but accounts for both process and observation error associated with the data, similar to SPicT. The yield at time *t* is equal to the biomass at *time t* divided by the carrying capacity, *K*. The original model was based on landings data only. Considering the important amount of Rajidaes discards we choose to add it in the model (Appendix 5). We calculated an amount of yearly landings and discards based on binomial law integrating a species specific ratio and the observed landings and discards (Equation 9, 10, 11). The ratio par species was calculated by species according to the total biomass in the model and catch (Equation 12 and 13).

$$L_t \sim b(R_t, L_{obs}) \qquad C_t = L_t + D_t$$

$$D_t \sim b(R_t, D_{obs})$$

Equations 9, 10 and 11

$$Y_{t+1} \sim N((r+1) * Y_t - (r * Y_t - C_t), \sigma^2)$$

$$R_{t+1} = \frac{Y_{t+1}}{\Sigma_1^E Y_{t+1}}$$

Equations 12 and 13

Finally the model uses this data in an observation model to simulate biomass indices and observed ratios per species in the catch (Equation 14 and 15).

$$I_{t+1} \sim logN(log(q * Y_{t+1} * K), \tau^2)$$

$$logR_D = log(R_{D_{obs}}) \qquad logR_L = log(R_{L_{obs}})$$

$$P_D \sim logN(logR_D, \tau_{pD})$$

$$P_L \sim logN(logR_L, \tau_{pL})$$

Equations 14 and 15

To fit this model to the data, priors are required for *r, K*, the initial biomass, tau (observation errors), and sigma (process error). This method provides proxies for MSY as well as B_{MSY} Priors used for *r* are the same as those used in the Bay of Biscay as there is no evidence of important differences in ray species biology between the two areas. We selected time series, from 1990 to 2018 to have species specific biomass indices for all species considered. The initial biomass has been set to 0.2 of the unfished biomass for all species, with a standard deviation of 0.1, considering that stocks were already depleted in 1990, after in the post-WWII overfishing period. Finally, semi-informative priors have been set for *K*. All models were run using 800 000 iteration with 400 000 burnin and a thin of 800 iterations. Three discards hypothesis have been made, discards being a constant proportion of the catch, from 1990 to 2018 (M1), or discards have been subject to consistent increase since

2009 with the implementation of a constraining quota. Two reduced discards, hypothesis M2 and M3, have been built with a decrease of discard to 50% 10% of the actual discard to landing proportions (Table 6). To facilitate comparison with SPicT model a SHORT run (M4) has also been tested using data from 2009 to 2018 only.

Table 6 Prior combinations for three species model runs

Run	Species	Catch	Survey	r~Beta mode, SD	Y0~Beta mode, SD	K~Uniform min, max	1/sigma²~Gamma mode, SD	1/tau²~Gamma mode, SD	q~Uniform min, max
M1	*Raja clavata*	1990-2018 full discards	1990-2018	0.105, 0.1	0.2, 0.1	2 000, 800 000	400,1	400,1	0,0.5
	Raja brachyura			0.091, 0.1	0.2, 0.1	500, 200 000		400,1	
	Raja montagui			0.114, 0.1	0.2, 0.1	500, 200 000		400,1	
M2	*Raja clava*	1990-2018 50% discards	1995-2017	-	0.2, 0.1	-	-	-	-
	Raja brachyura			-	0.2, 0.1	-		-	
	Raja montagui			-	0.2, 0.1	-		-	
M3	*Raja clavata*	1990-2018 10% discards	1990-2018	-	0.2, 0.1	-	-	-	-
	Raja brachyura			-	0.2, 0.1	-		-	
	Raja montagui			-	0.2, 0.1	-		-	
M4	*Raja clavata*	2009-2018 full discards	2009-2018	-	0.2, 0.1	-	-	-	-
	Raja brachyura			-	0.2, 0.1	-		-	
	Raja montagui			-	0.2, 0.1	-		-	

2.2.2. Results

Only the first model passed a Gelman and Rubin's convergence test at 1.05, so we would consider the result of this model only. Residuals for species specific catches as well as biomass indices have been compared using Q-Q plots to test model fits. Residuals seems to be more important for the discards than the landings (Appendix 6). Finally the residuals for the abundance indices are good (Appendix 7). Priors and posteriors distributions were different for all estimated parameters. Furthermore no posterior distribution appears to be cut except *Raja montagui* carrying capacity, increasing its range caused model non convergence (Appendix 8).

The error associated with the ratio of each species in the discards is higher for *Raja montagui* than the other species 0.017 again 0.003 and 0.004 for *Raja clavata* and *Raja brachyura* respectively (Table 7). This ratio error is smaller in *Raja montagui* landings. The process error, sigma, associated with the estimation of yearly yield is the most important one.

Table 7 Model parameters posterior mean (RJC, *Raja clavata*, RJH, *Raja brachyura*, RJM, *Raja montagui*)

	RJC	RJH	RJM
Parameters			
K	98 488	18 088	175 666
r	0.180	0.100	0.100
q		0.0004	
Yinit	0.190	0.070	0.080
Error			
sigma		0.050	
Tau		0.003	
TauPropL	0.003	0.008	0.004
TauPropD	0.003	0.004	0.017
Reference points			
MSY	4 383	466	4 405
Bmsy	49 244	9 044	87 833
Blast	55 265	2 747	15 607

SSBM hypothesized a relatively constant ratio between species in catches along this time period (Figure 10). The decrease in catches along the last 29 years is consequently caused by a decrease in *R. clavata* and *R. montagui* catches from 5493 and 760 tons to 2598 and 411 tons in 2018. *R. brachyura* catches stayed relatively stable along the time period, with three peaks in 1993, 2004 and 2007.

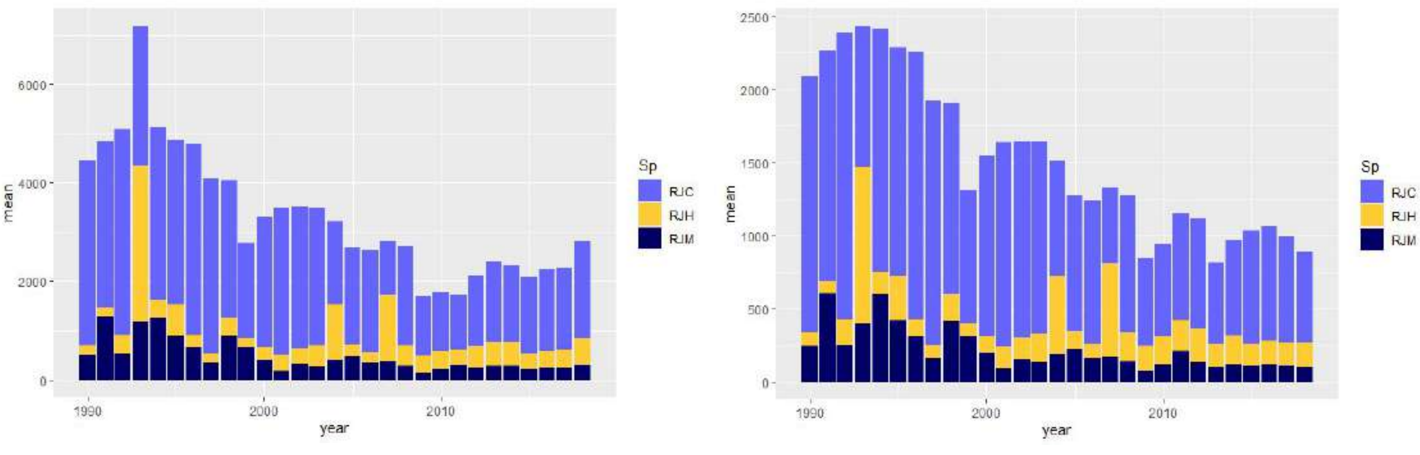

Figure 10 Species total landings in tonnes by year and species total discards in tonnes by year, RJC (*Raja clavata*), RJH (*Raja brachyura*) and RJM (*Raja montagui*)

Abundance indices predicted by the model are stable from 1990 to 2005 and increase for *R. clavata* and *R. montagui* from 2005 to 2015 (Figure 11). *R. brachyura* abundance indices show a slight increase in the last eight years, 2010 to 2018.

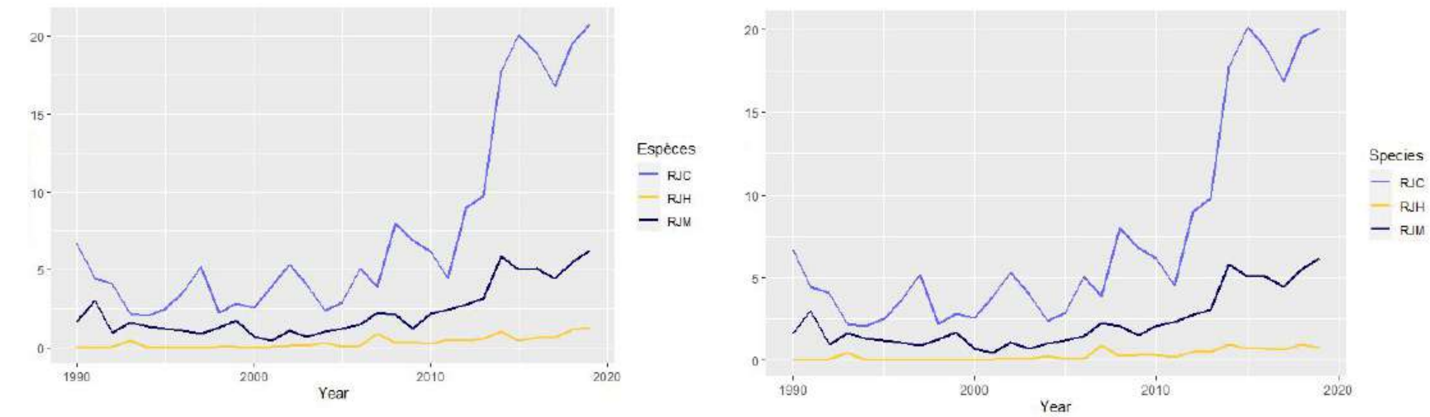

Figure 11 Abundance indices and model calculated relative abundance indices; RJC (*Raja clavata*), RJH (*Raja brachyura*) and RJM (*Raja montagui*).

The model indicates a relative biomass below B_{MSY} for *R. brachyura* and *R. montagui* (Figure 12). However this relative biomass increased for all species over time from 0.39, 0.02 and 0.05 of B_{MSY} in 1990 to 1.12, 0.25 and 0.18 in 2018 for *R. clavata*, *R. brachyura* and *R. montagui* respectively.

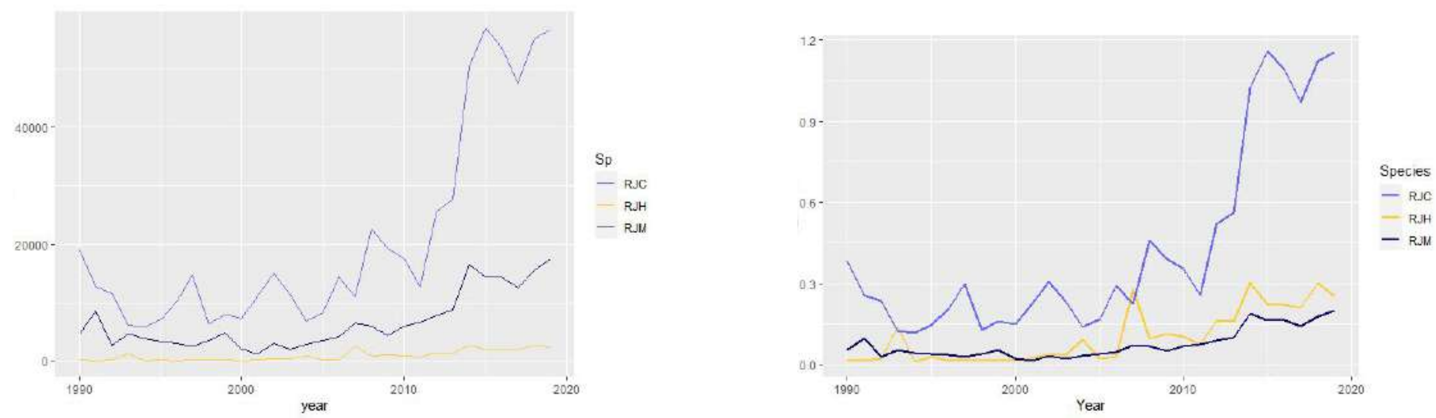

Figure 12 Absolute (in tonnes) and relative biomass of RJC (*Raja clavata*), RJH (*Raja brachyura*) and RJM (*Raja montagui*)

2.3 Model comparison

Maximum Sustainable Yield (MSY) calculated in these models include discards and should not be understood as a possibility for a direct maximal landing proxy. SSBM estimated an MSY of 4 383 tons for *R. clavata*, in 2018 *R. clavata* landings were about 2 218 tons. However considering the discards, *R. clavata* total catches were about 2 768 tons (Figure 13). MSY estimations from SSBM are higher than the one from CMSY and SPicT for *Raja clavata* and *Raja montagui* and smaller for *Raja brachyura* (Table 8)

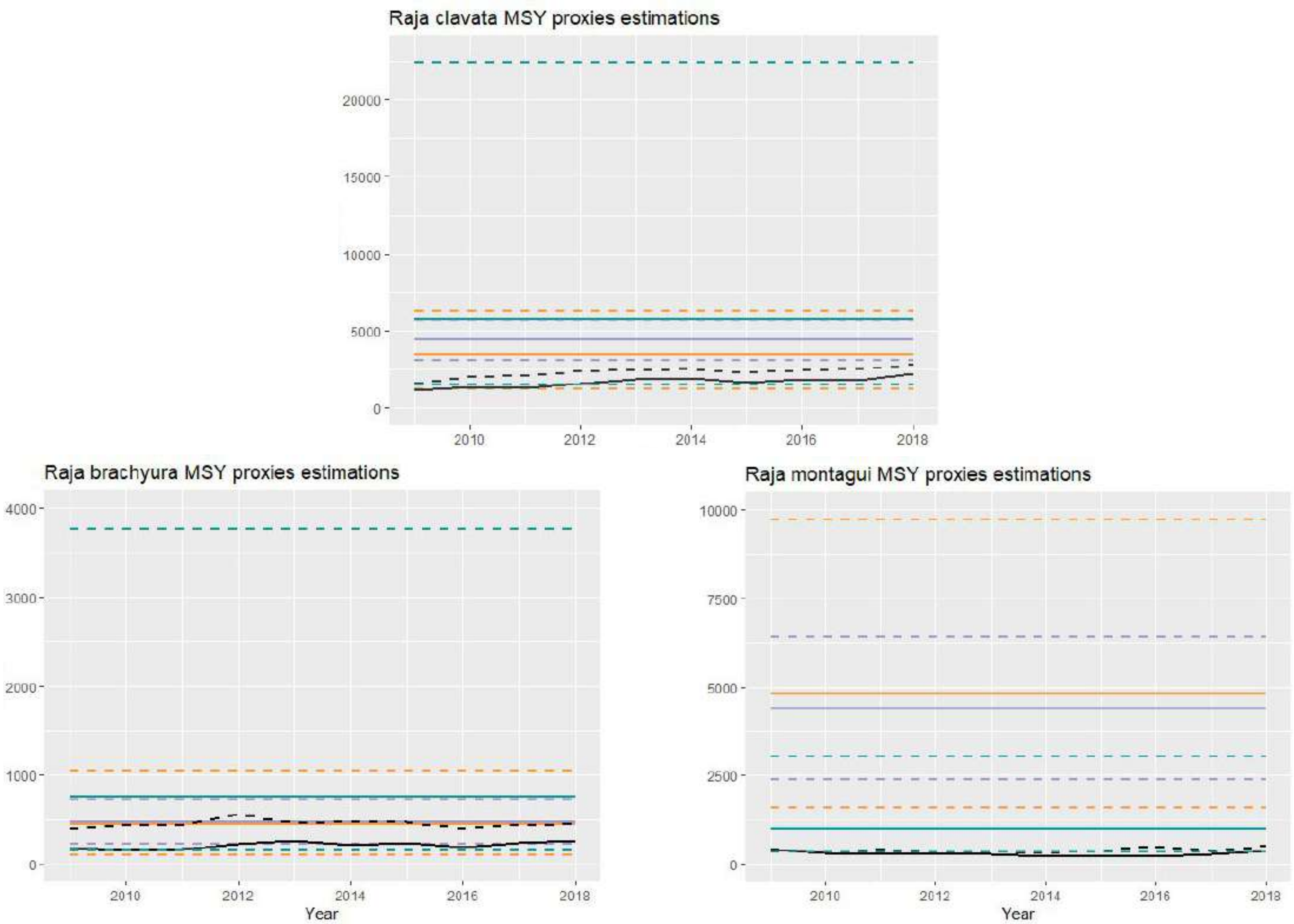

Figure 13 MSY proxies (in tonnes) comparison by species and model, mean value solid line and standard deviation dotted line. Purple: long time series SSBM; orange: short time series SSBM; green: SPicT; black solid line : landings; black dotted line: catches.

Considering the relative biomass and the actual catches compared to the MSY estimated by the models *R. brachyura* is the only species actually overexploited, biomass under B_{MSY} and catches close or over MSY. *R. montagui* catches are currently under MSY, however the actual biomass is evaluated to be under B_{MSY} (Figure 14). Finally *R. clavata* seems to be rebuilding from previous overexploitation, with catches under MSY and biomass over or closed to B_{MSY} (SSBM). *R.clavata* SPicT and SSBM results highlighted the same relative biomass dynamic. However *R. montagui and R. brachyura* relative biomass dynamics follow the same trend for SSBM and SPicT but are lower for the SSBM. Indeed these species carrying capacities are evaluated to be higher in the SSBM than SPicT but both models indicate similar ranges of absolute biomass (Figure 15).

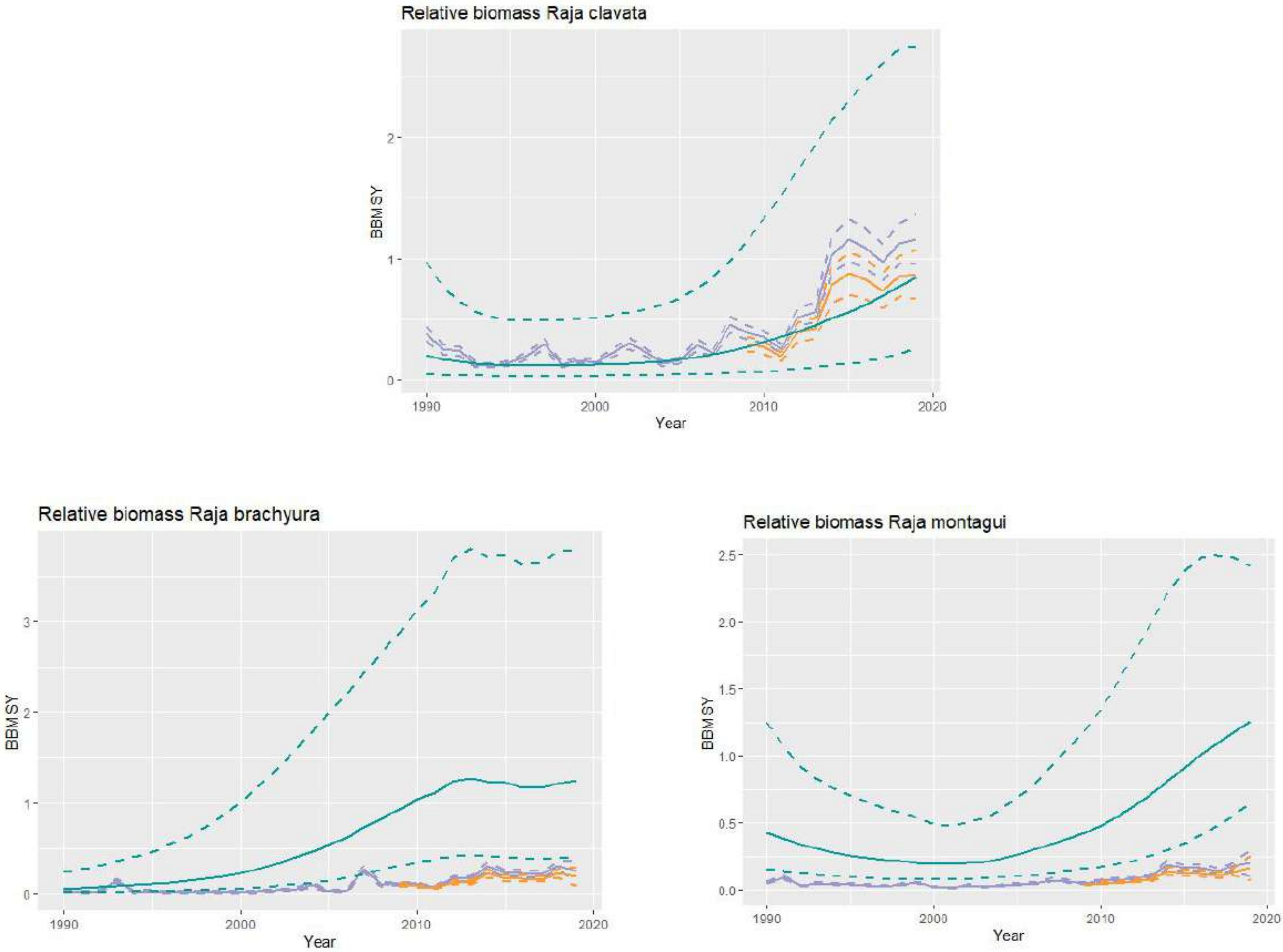

Figure 14 Relative biomass proxies comparison by species and models, mean solid line, standard deviation, dotted line. Purple: long time series SSBM; orange: short time series SSBM; green: SPicT.

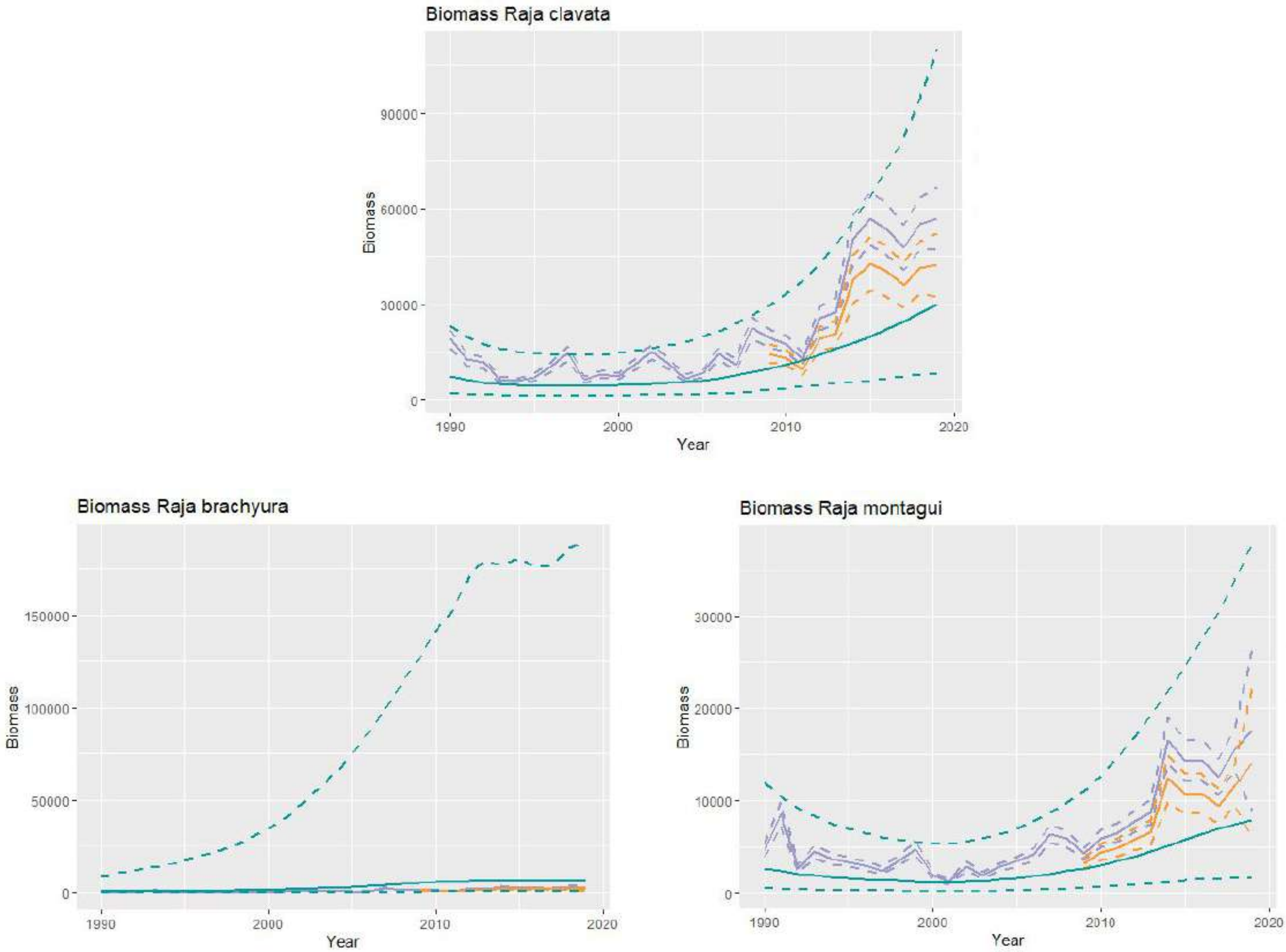

Figure 15 Absolute biomass (in tonnes) proxies comparison by species and models, mean solid line, standard deviation, dotted line. Purple: long time series SSBM; orange: short time series SSBM; green: SPicT.

In conclusion the three production models used indicate a progressive rebuilding of *Rajidae* stocks in the English Channel and North area. However this process is faster for some species than others. Thornback ray stock (*R. clavata*) is presently the most abundant species in the area and currently under or fully exploited depending on the stock assessment methods used. Other *Rajidae* stocks were all evaluated by SSBM assessment method as under B_{MSY} (Table 8). The impact of a longer catch series on stock assessment outputs for these stocks status determination is critical. Differences between stocks in terms of biomass as well as status questioned the actual multispecific management procedures suitability to optimise thornback ray exploitation and other *Rajidae* stocks rebuilding dynamic.

Table 8 MSY (mean and standard deviation) and relative biomass comparison by species and model; RJC (*Raja clavata*), RJH (*Raja brachyura*), RJM (*Raja montagui*), RJN (*Leucoraja naevus*), RJE (*Raja microocellata*), RJU (*Raja undulata*), dark grey for SPicT non convergence issues.

SPECIES		MODELS CMSY	SPicT	SSBM M1	SSBM M4
RJC	MSY	2090 101-4 320	5 732 1 466-22 417	4 383 3 054-5 712	3 436 1 223-6 293
	Blast/Bmsy	1.058	0.77	1.12	0.85
	B2018	-	27 240	55 265	41 498
RJH	MSY	492 15-1 610	719 151-3 416	466 217-715	446 217-715
	Blast/Bmsy	0.88	1.22	0.3	0.23
	B2018	-	6 572	2 747	2 076
RJM	MSY	585 155-2 210	1 000 329-3 040	4 405 2 392-6 418	4 789 1 565-9 723
	Blast/Bmsy	0.768	1.18	0.15	0.16
	B 2018	-	7 491	15 607	14 082
RJN	MSY	40 27-60	116 64-212	-	-
	Blast/Bmsy	01.06	1.22	-	-
	B 2018	-	730	-	-
RJU	MSY	560 149-2 090	-	-	-
	Blast/Bmsy	0.75	0.91	-	-
	B 2018	-	63 740	-	-

3. Perspectives

Determining a set of models to assess ray stocks in the EEC-NS is a preliminary step towards TAC advice setting. The next stages of the advice-giving process will include first the identification of appropriate HCRs (Harvest Control Rules) relating TAC advice to stock status and MSY reference points, considering data and model uncertainties (see Section 3.1). In addition, the variety of operating models used may result in contrasted TAC recommendations, and a final choice must be made (see Section 3.2). Finally, one will need to address how single-stock assessment models such as those presented in D1.3.1 could best inform management when TAC-setting includes all *Rajidae* species (see Section 3.3).

3.1. HCRs identification

HCRs link stock assessment results and reference points with TAC recommendations. Different HCRs could be considered depending on the operating model used and the level of information available for a given stock. In 2017, the WKMSYCat34, Workshop on MSY advice for category 3 and 4 stocks (WKMSYCat34, 2017) provided guidelines to define HCRs adapted to category 3 and 4 stocks (Appendix 9). These categories correspond to data limited stocks, for which catch data or/and abundance indices are available, as is the case for EEC-NS *Rajidae*. Two HCRs have been presented during this workshop, with TAC advice being expressed either as a fishing mortality, or as a catch objective for the following year. These methods have been used during WKLIFE in 2017 (ICES, 2017b) to test these different HCRs within an MSE (Management Strategy Evaluation) framework.

The HCR chosen during this workshop was determined to be adapted to models such as SPicT, which should only be used with category 3 stocks. There are other HCRs suggested in the literature for DLMs. For instance, Froese *et al.* (2011) proposes a HCR that targets a biomass of $1.3B_{MSY}$ and a yield of 0.91MSY. The choice of the most adapted HCR to EEC-NS *Rajidae* stocks will be discussed and the associated risks will be tested within D4.2.1.

3.2. Final model choice

The choice of both an operating model and of a HCR is dependent on the criteria we choose to prioritize as management objectives. The first step is to define potential criteria, whether they be social, economic or biological (Cooke, 1999), which could be contradictory with one another. Thus, it will be necessary to identify the associated risks and the acceptability of measures focusing on one or the other criteria of interest (Bonfil, 2005). Comprehensive MSE (Management Strategy Evaluations) could allow further evaluation of each model and its associated HCRs (Punt *et al.*, 2016, Dutra *et al.*, 2015).

3.3. Global TAC or species specific TAC ?

A SUMARiS conference on potentially relevant management measures for ray stocks in the EEC-NS took place in Canterbury, the 16-17 May 2019. This conference gathered different actors of the project: fisheries industry representatives, scientists, fisheries managers and NGO representatives. The Canterbury conference was followed by a working group, which took place in Ramsgate in September 2019 to revisit the management options and suggest a set of relevant measures. Three possibilities have thus been raised to set a TAC. The first one is to keep a global TAC, as currently. The second option is to set two TACs, one for the thornback ray, and one gathering all other species. Finally, the third option is to keep a global Rajidae TAC, of which 80 % would be allotted to thornback ray catches. These management options will be tested within SUMARiS WP4 (D4.2.1).

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Appendices

Appendix 1

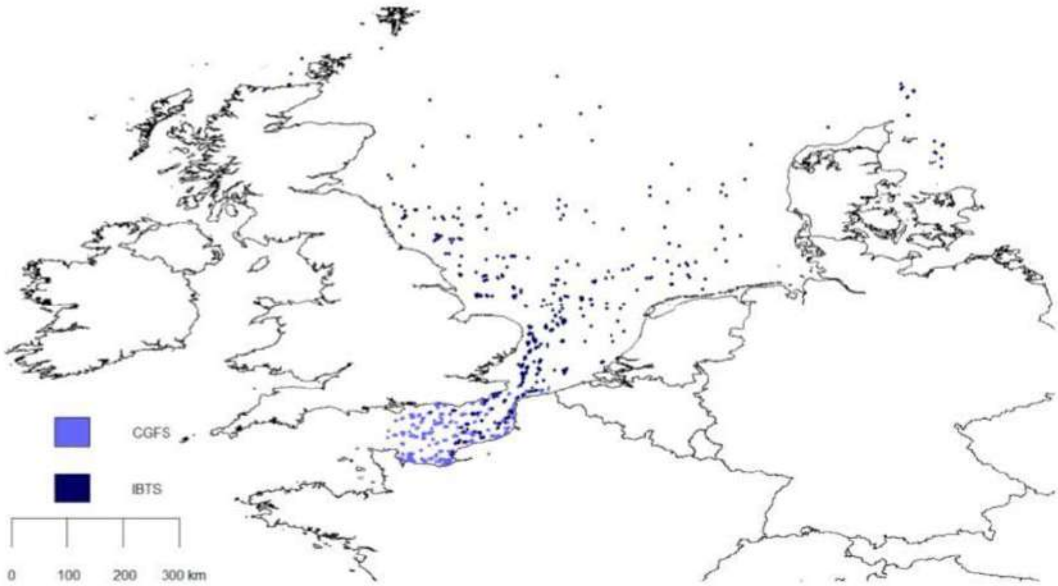


Figure 1 *Raja clavata* distribution map based on European fishery surveys (IBTS and CGFS)

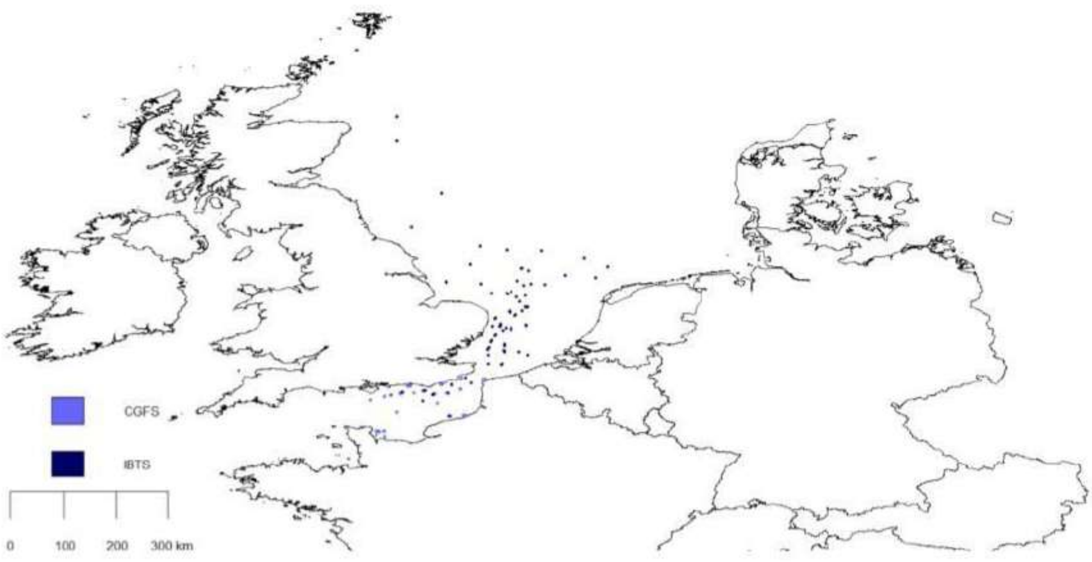


Figure 2 *Raja brachyura* distribution map based on European fishery surveys (IBTS and CGFS)

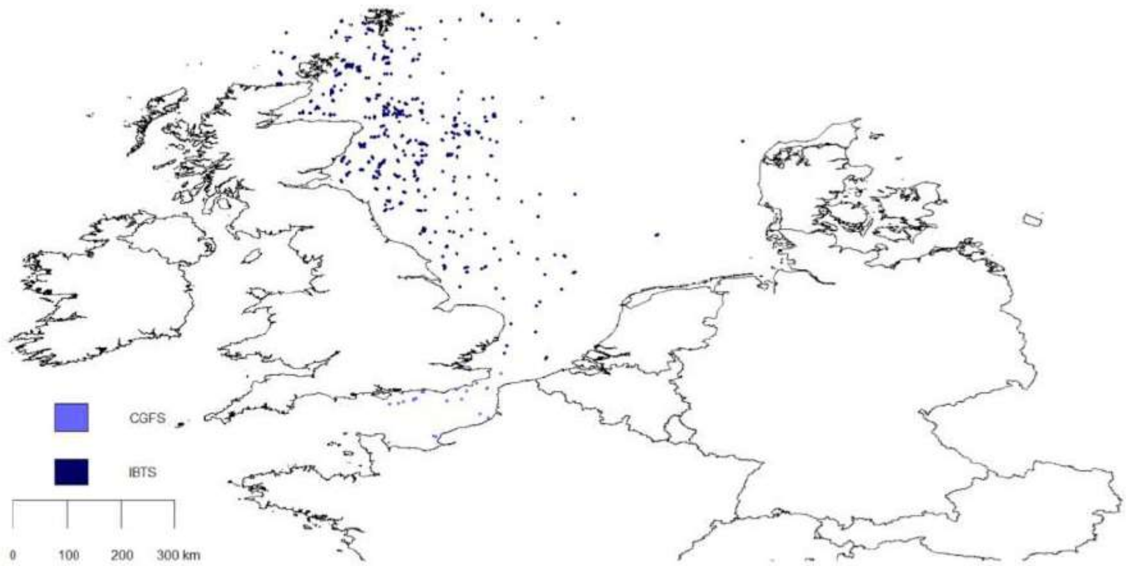


Figure 3 *Leucoraja naevus* distribution map based on European fishery surveys (IBTS and CGFS)

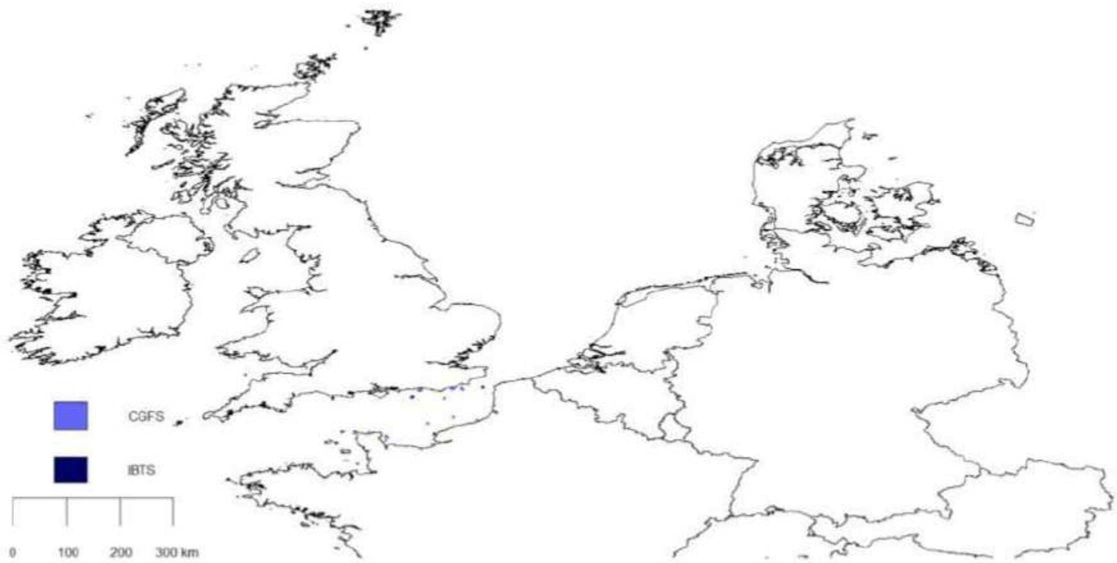


Figure 4 *Raja microocellata* distribution map based on European fishery surveys (IBTS and CGFS)

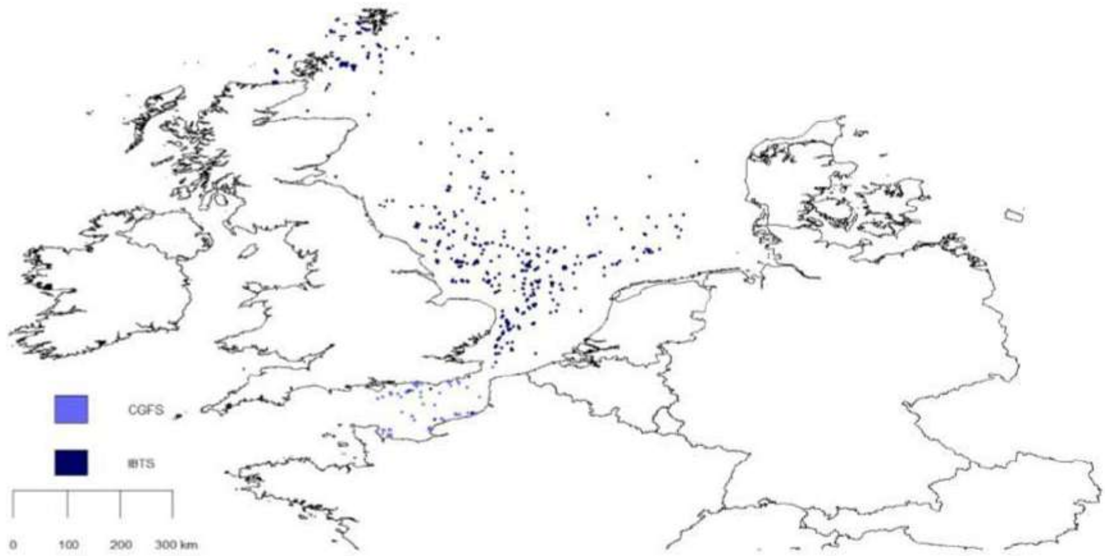


Figure 5 *Raja montagui* distribution map based on European fishery surveys (IBTS and CGFS)

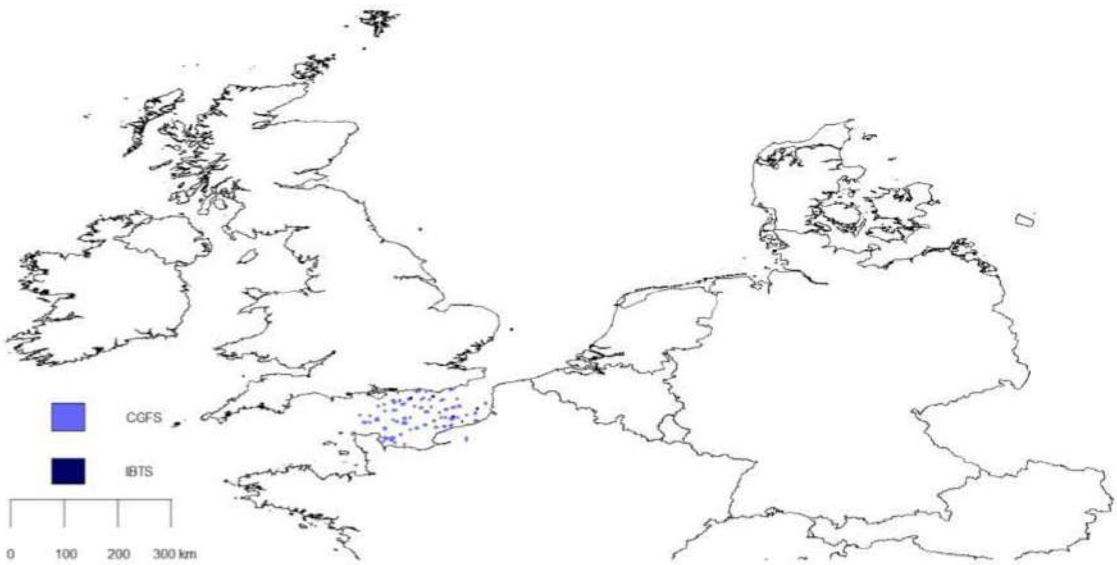


Figure 6 *Raja undulata* distribution map based on European fishery surveys (IBTS and CGFS)

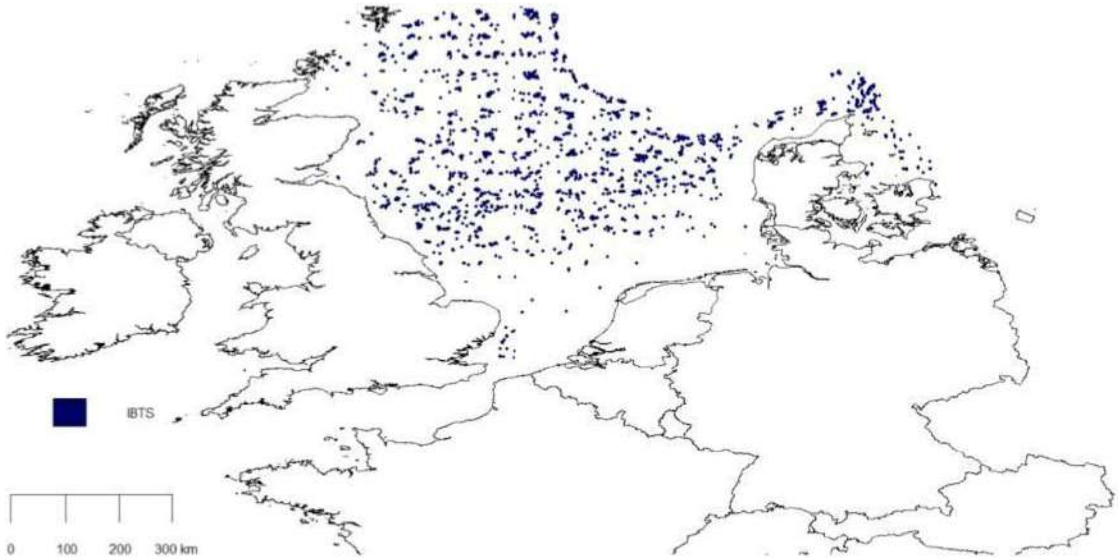


Figure 7 *Amblyraja radiata* distribution map based on European fishery surveys (IBTS and CGFS)

Appendix 2

Table 1 Multiple regression results, Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

RJC (*R. clavata*), RJH (*R. brachyura*), RJN (*L. naevus*), RJM (*R. montagui*), RJU (*R. undulata*), LLS_DEF (demersal set longlines), MIS_MIS (other), OTB_DEF (demersal bottom otter trawl), OTB_DEF_100-119_0_0 (demersal bottom otter trawl mesh size 100-119), OTB_DEF_70-99_0_0 (demersal bottom otter trawl mesh size 70-99), PTB_DEF (demersal pair bottom trawl), SDN_DEF (demersal anchored sein), SSC_DEF (demersal fly sooting seine), TBB_DEF_70-99_0_0 (demersal twin bottom trawl). Regression was possible only when recent discard data was available for different fleets. Shaded cells represent fleets without discard information. Discard information on *Raja microocellata* was too sparse to apply regression.

	SPECIES									
	RJC		RJH		RJN		RJM		RJU	
FLEET	t value	Pr (>| t |)	t value	Pr (>| t |)	t value	Pr (>| t |)	t value	Pr (>| t |)	t value	Pr (>| t |)
LLS_DEF	0.068	0.946	0.000	1.000	0.000	1.000	0.000	1.000		
MIS_MIS	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000		
OTB_DEF	5.738	<0.001***	0.639	0.524	5.061	<0.001 ***	1.304	0.195	2.41	0.037 *
OTB_DEF_100-119_0_0	0.004	0.996					0.014	0.989		
OTB_DEF_70-99_0_0	0.421	0.674	0.714	0.477	0.487	0.628	1.253	0.213		
PTB_DEF	0.056	0.955	0.000	1.000	0.000	1.000	0.000	1.000	0.00	1.000
SDN_DEF	0.000	1.000	0.000	1.000	0.009	0.993				
SSC_DEF	0.426	0.670	0.000	1.000	3.668	<0.001 ***	0.049	0.961		
TBB_DEF_70-99_0_0	8.308	<0.001***	10.902	<0.001***	0.571	0.570	12.048	<0.001***	0.25	0.808

Appendix 3

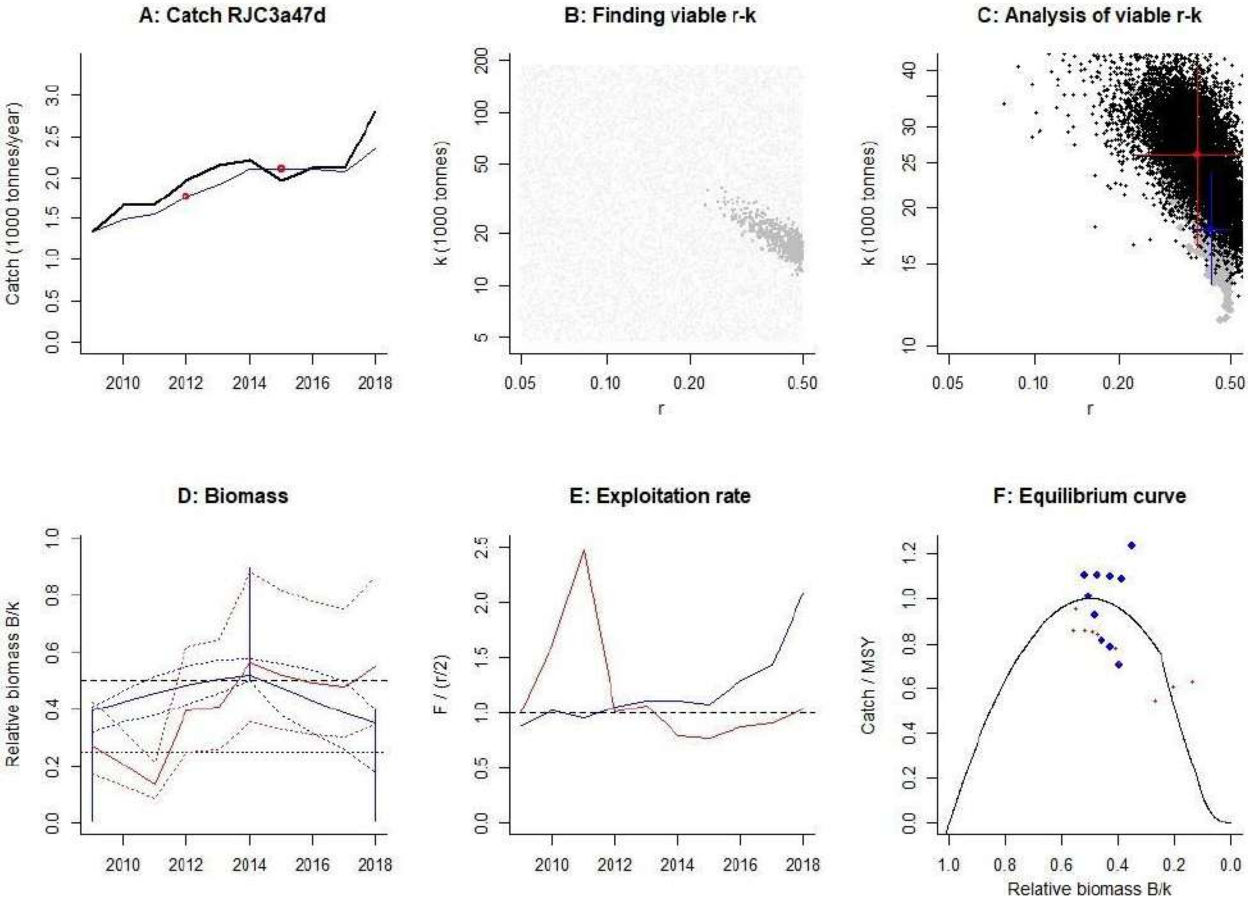


Figure 8 CMSY parameters estimation results *Raja clavata*

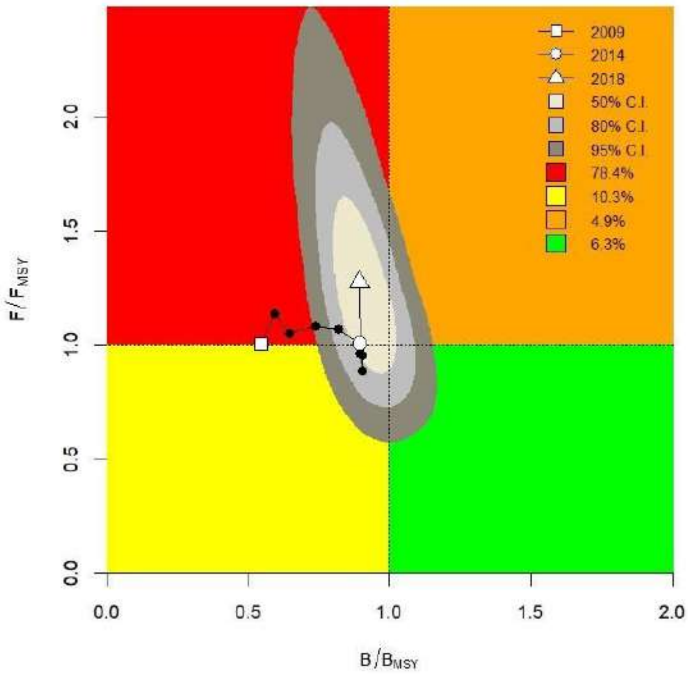


Figure 9 CMSY Kobe plot *Raja clavata*

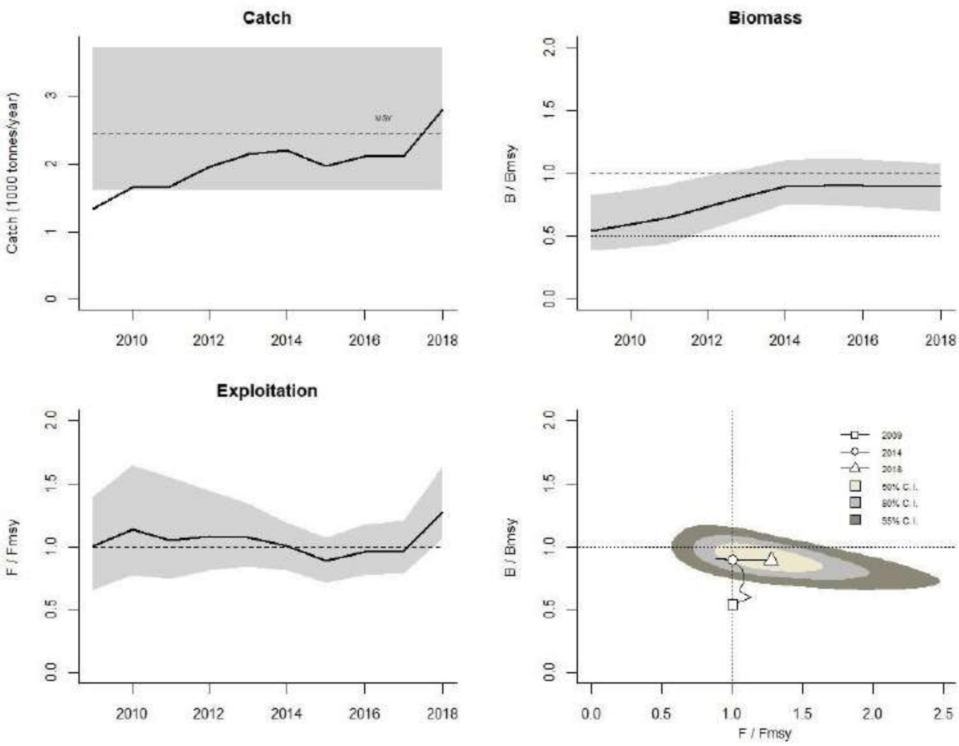


Figure 10 CMSY Biomass and catch trajectories *Raja clavata*

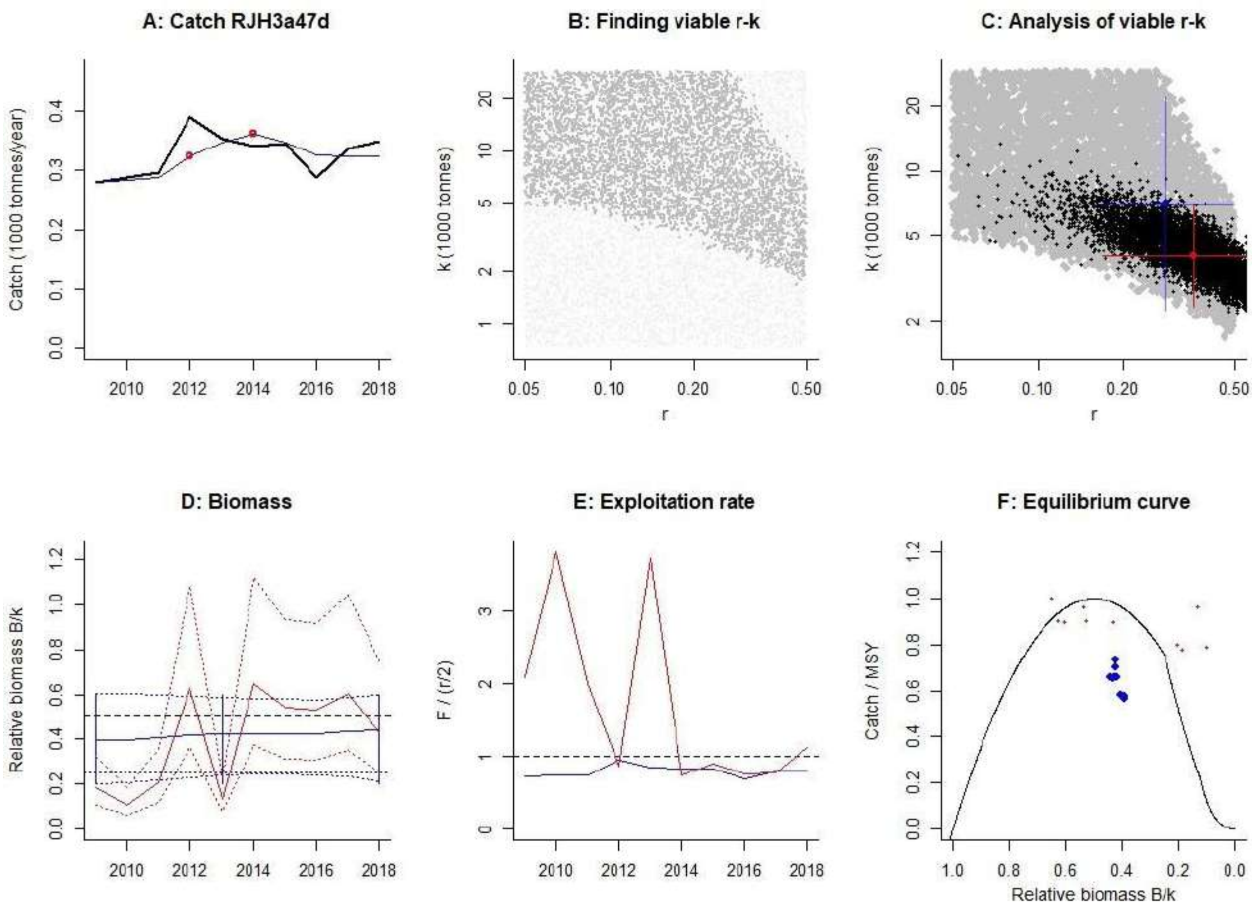


Figure 11 CMSY parameters estimation results *Raja brachyura*

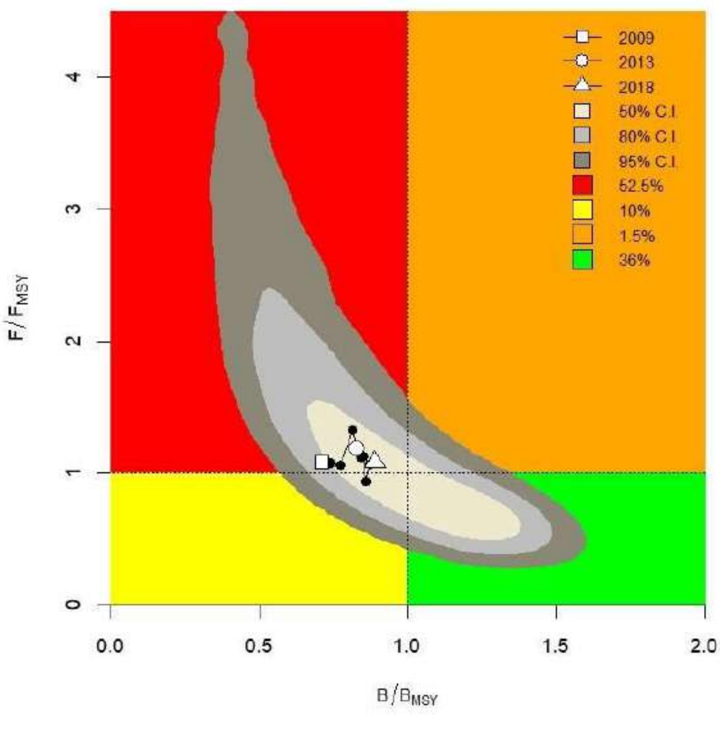


Figure 12 CMSY Kobe plot *Raja brachyura*

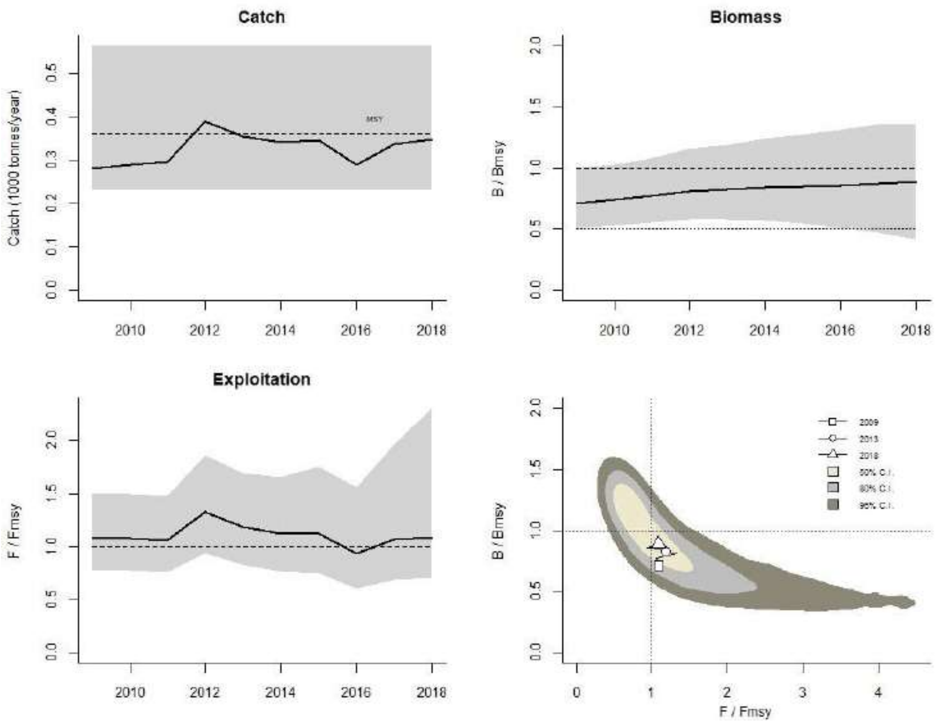


Figure 13 CMSY Biomass and catch trajectories *Raja brachyura*

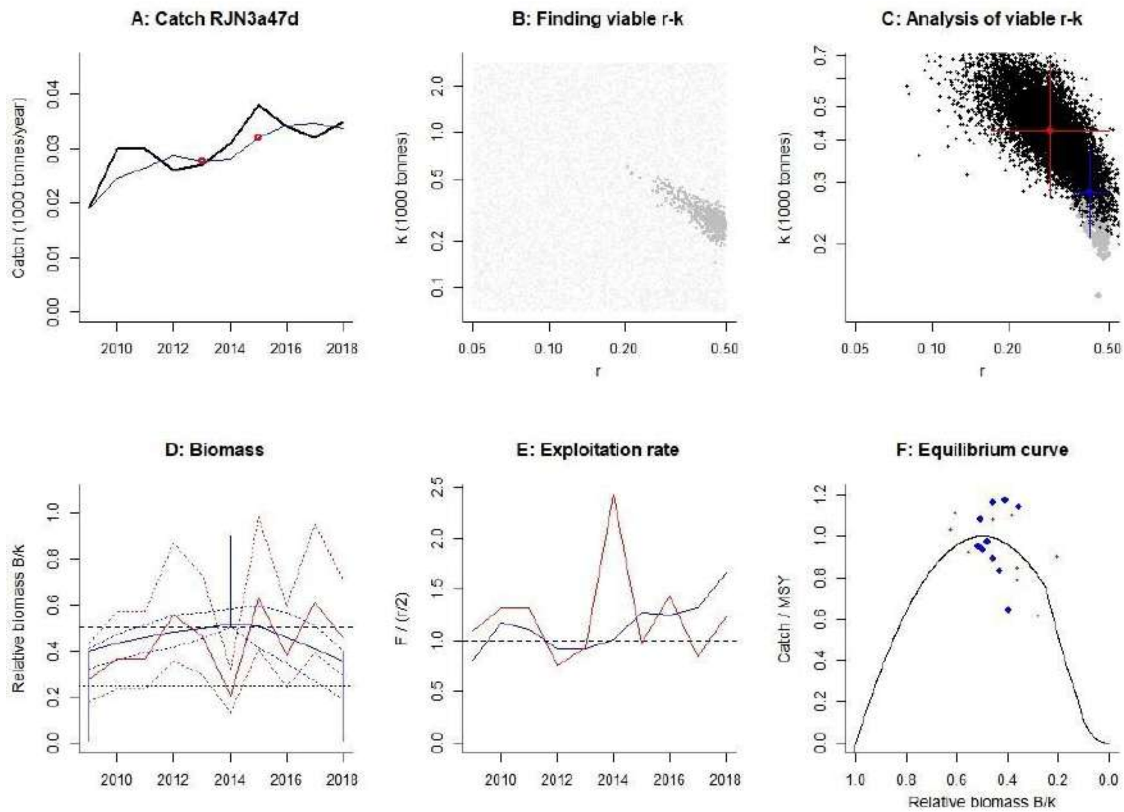


Figure 14 CMSY parameters estimation results *Leucoraja naevus*

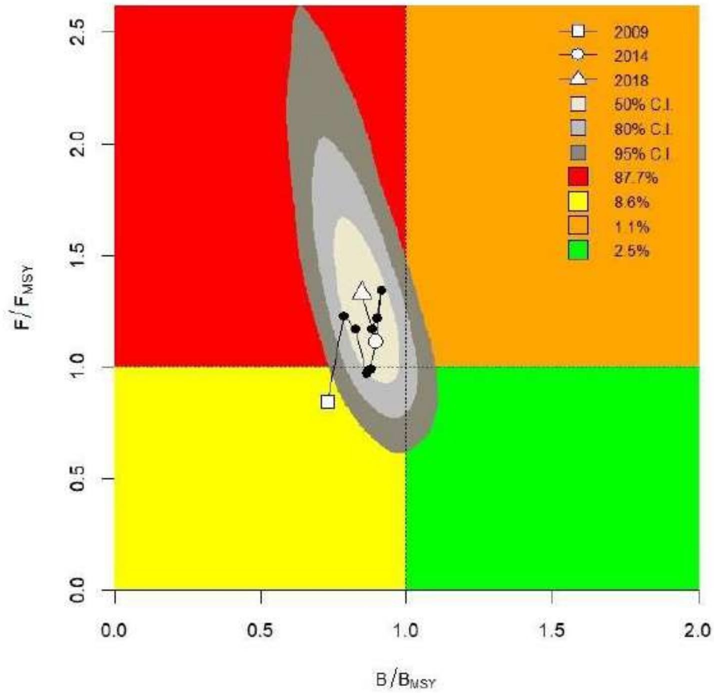


Figure 15 CMSY Kobe plot *Leucoraja naevus*

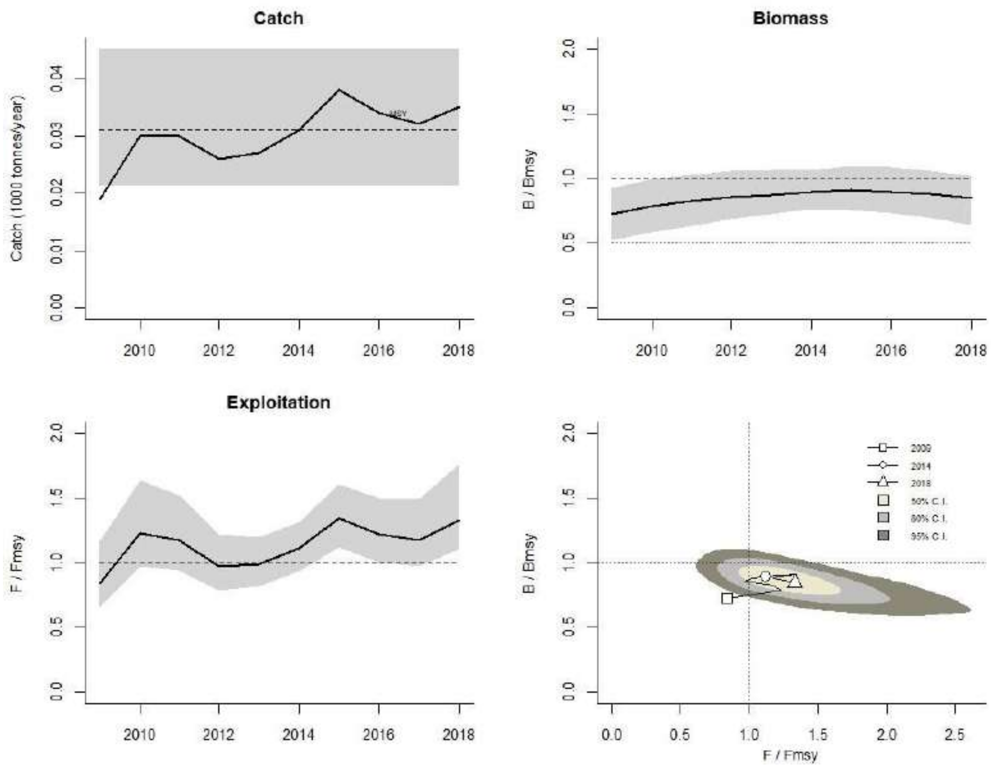


Figure 16 CMSY Biomass and catch trajectories *Leucoraja naevus*

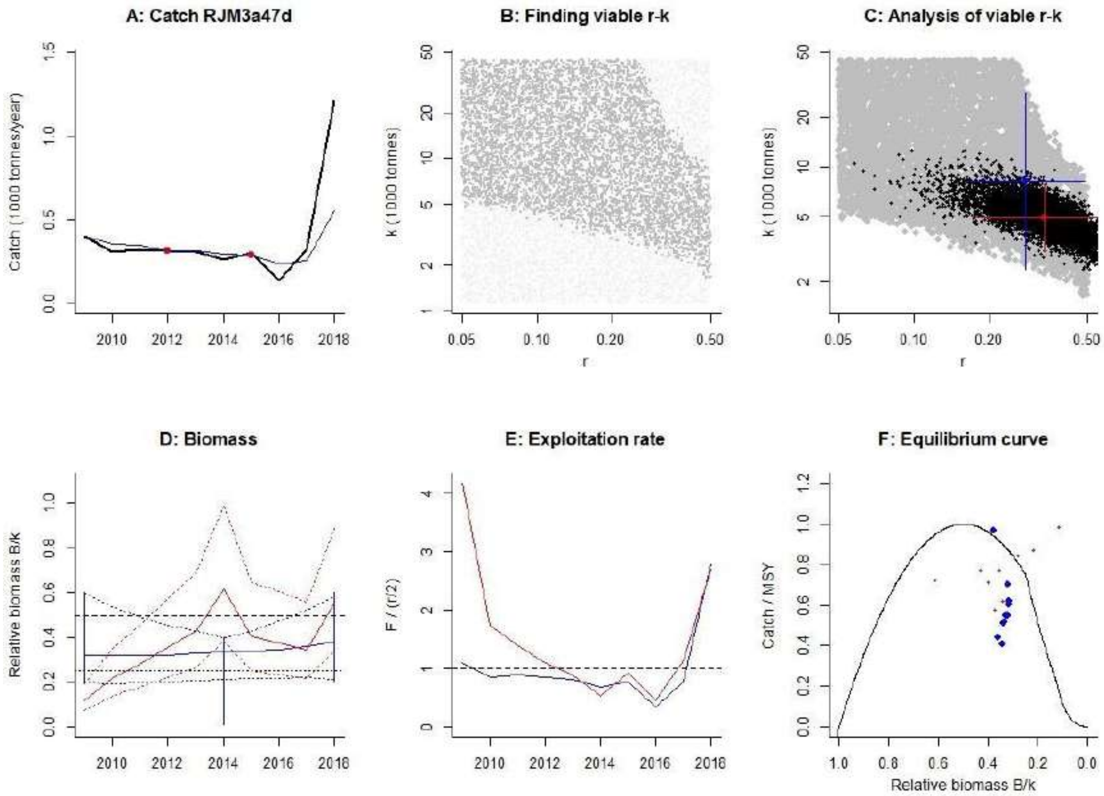


Figure 17 CMSY parameters estimation results *Raja montagui*

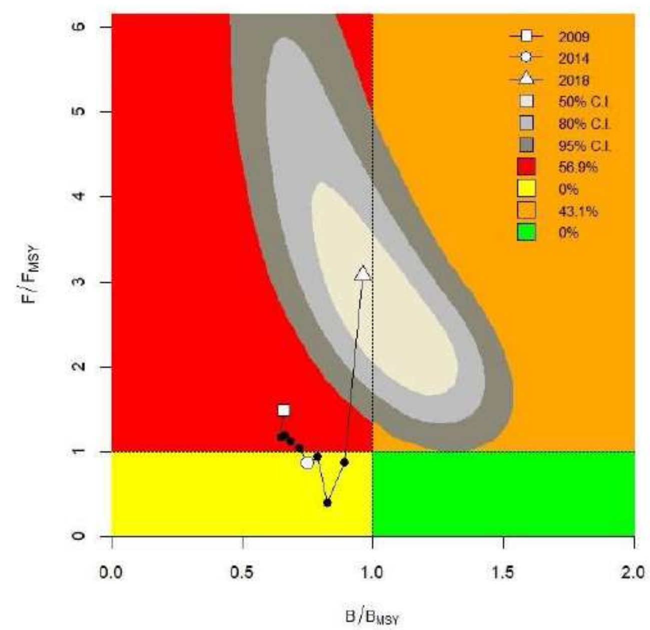


Figure 18 CMSY Kobe plot *Raja montagui*

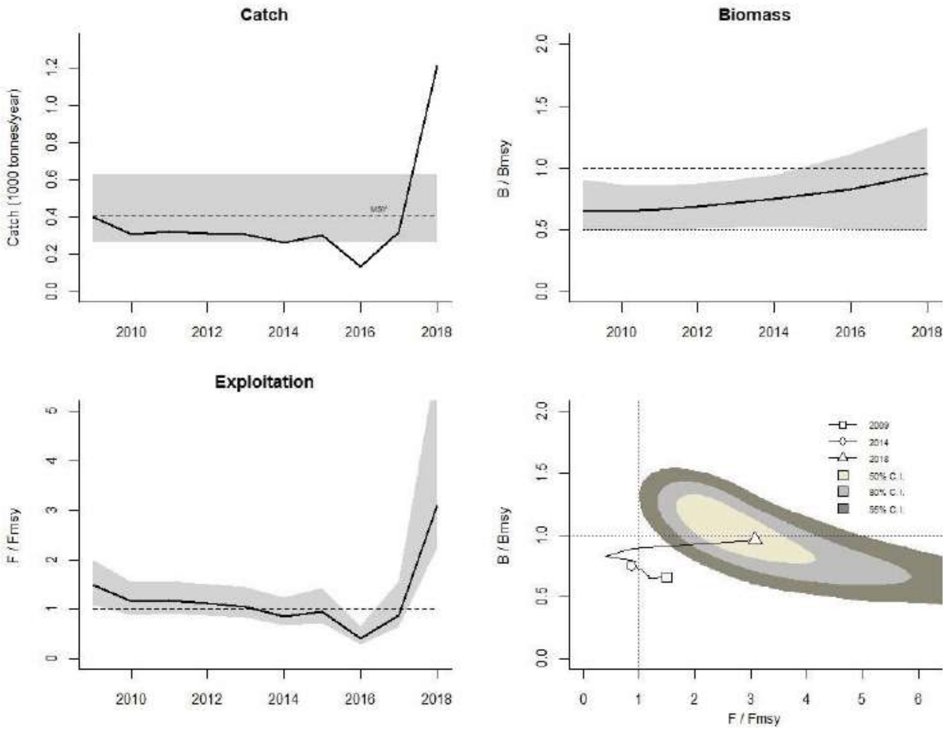


Figure 19 CMSY Biomass and catch trajectories *Raja montagui*

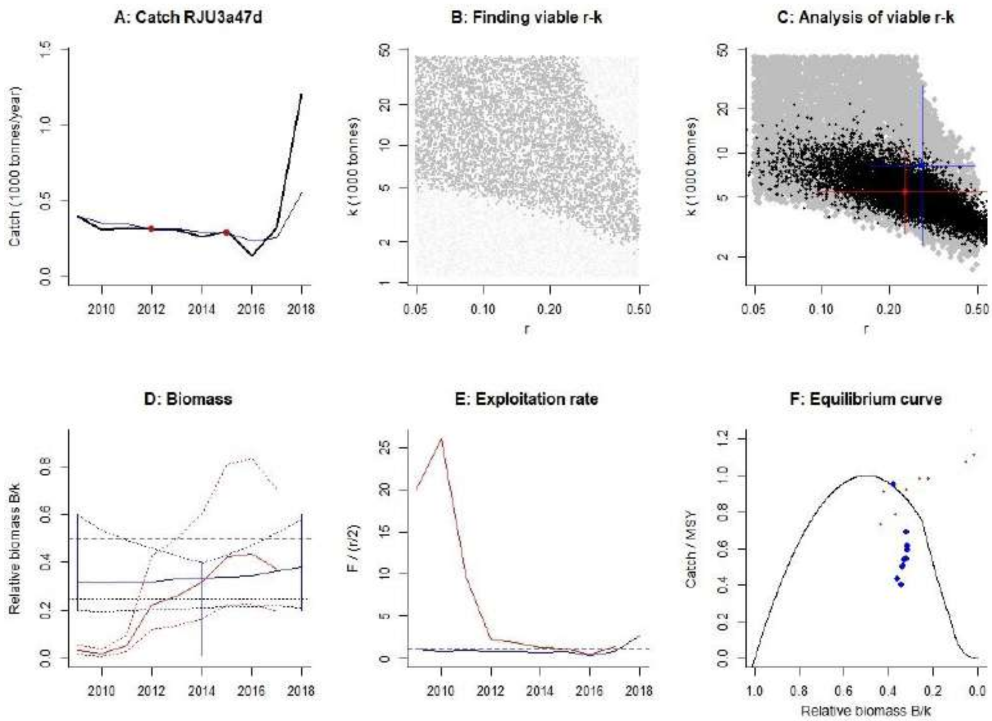


Figure 20 CMSY parameters estimation results *Raja undulata*

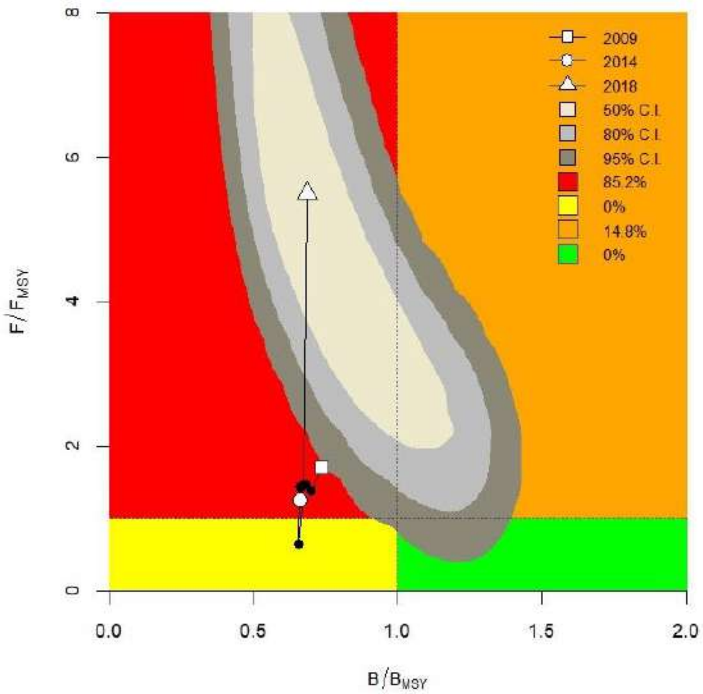


Figure 21 CMSY Kobe plot *Raja undulata*

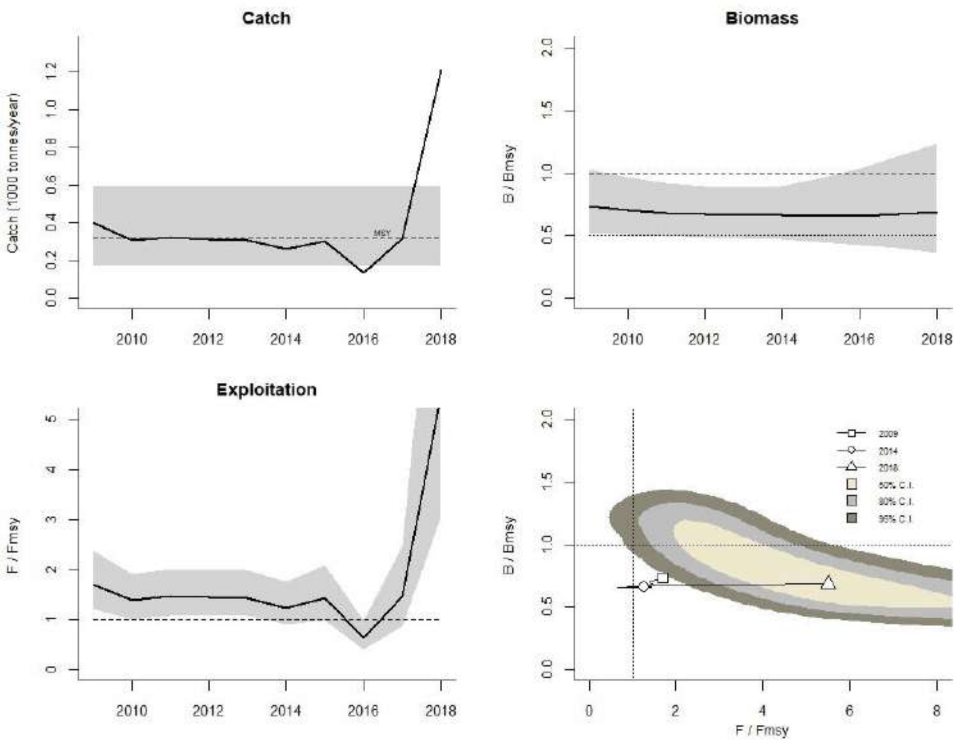


Figure 22 CMSY Biomass and catch trajectories *Raja montagui*

Appendix 4

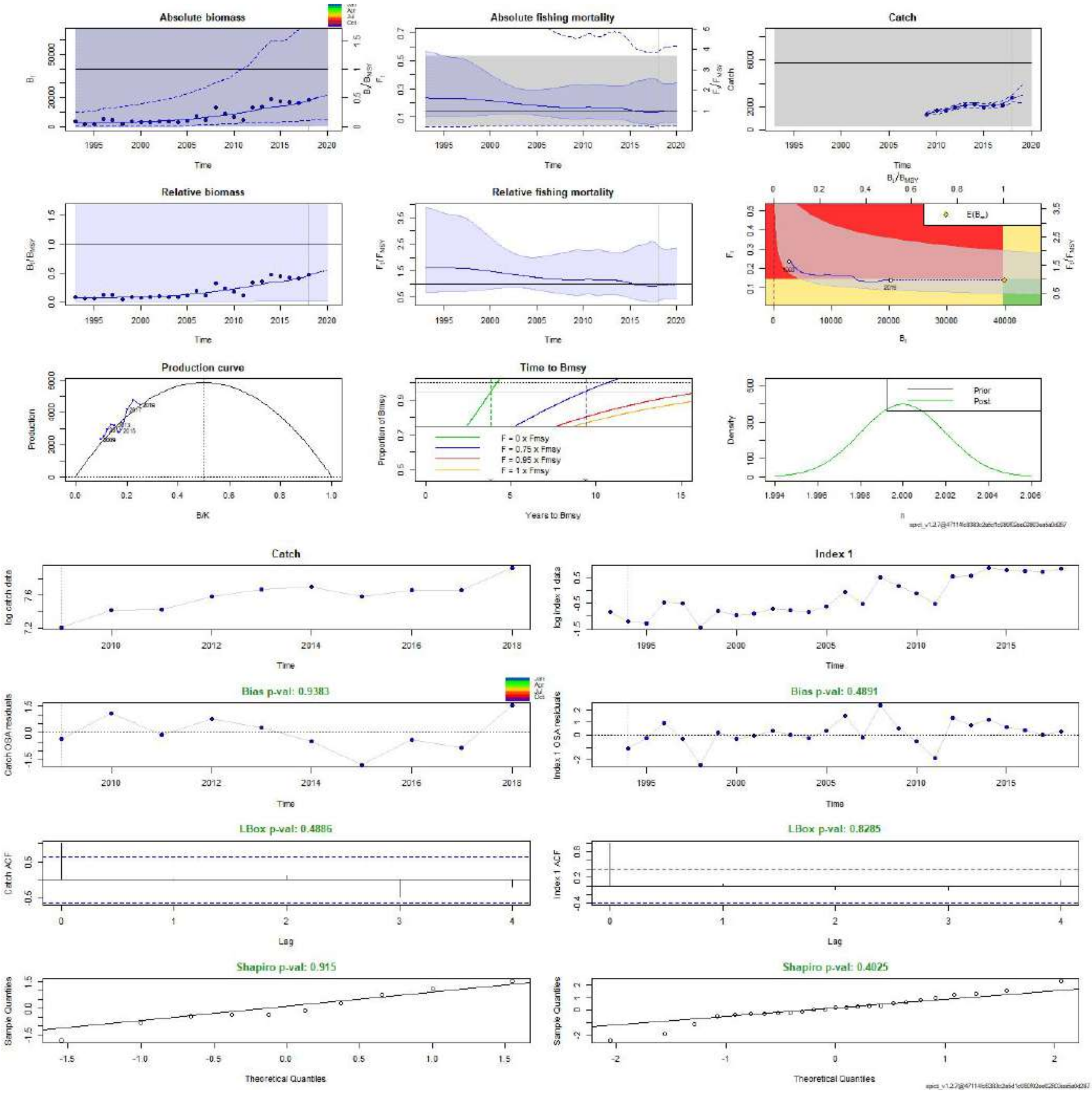


Figure 23 SPicT results, *Raja clavata*

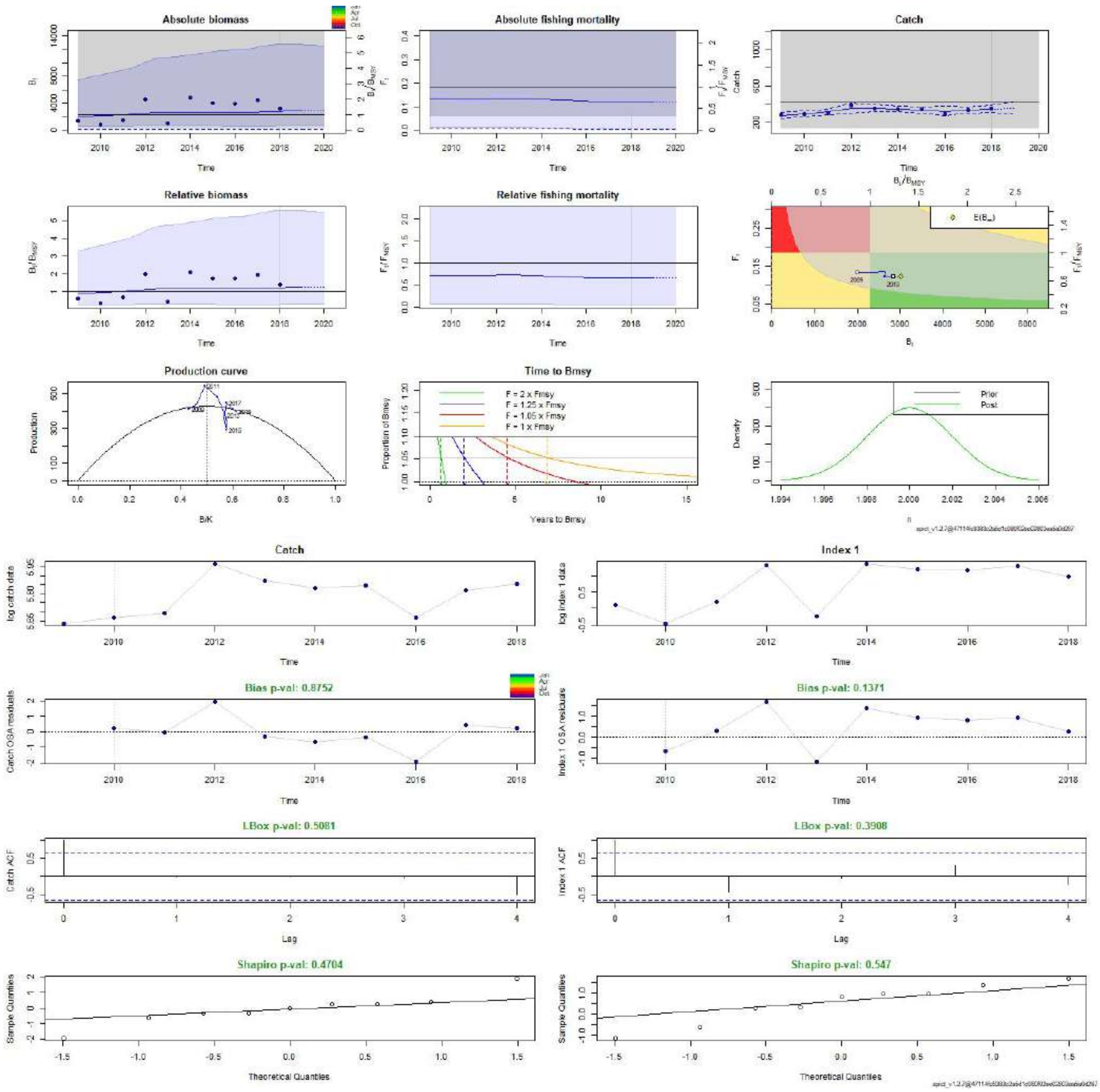


Figure 24 SPicT results, *Raja brachyura*

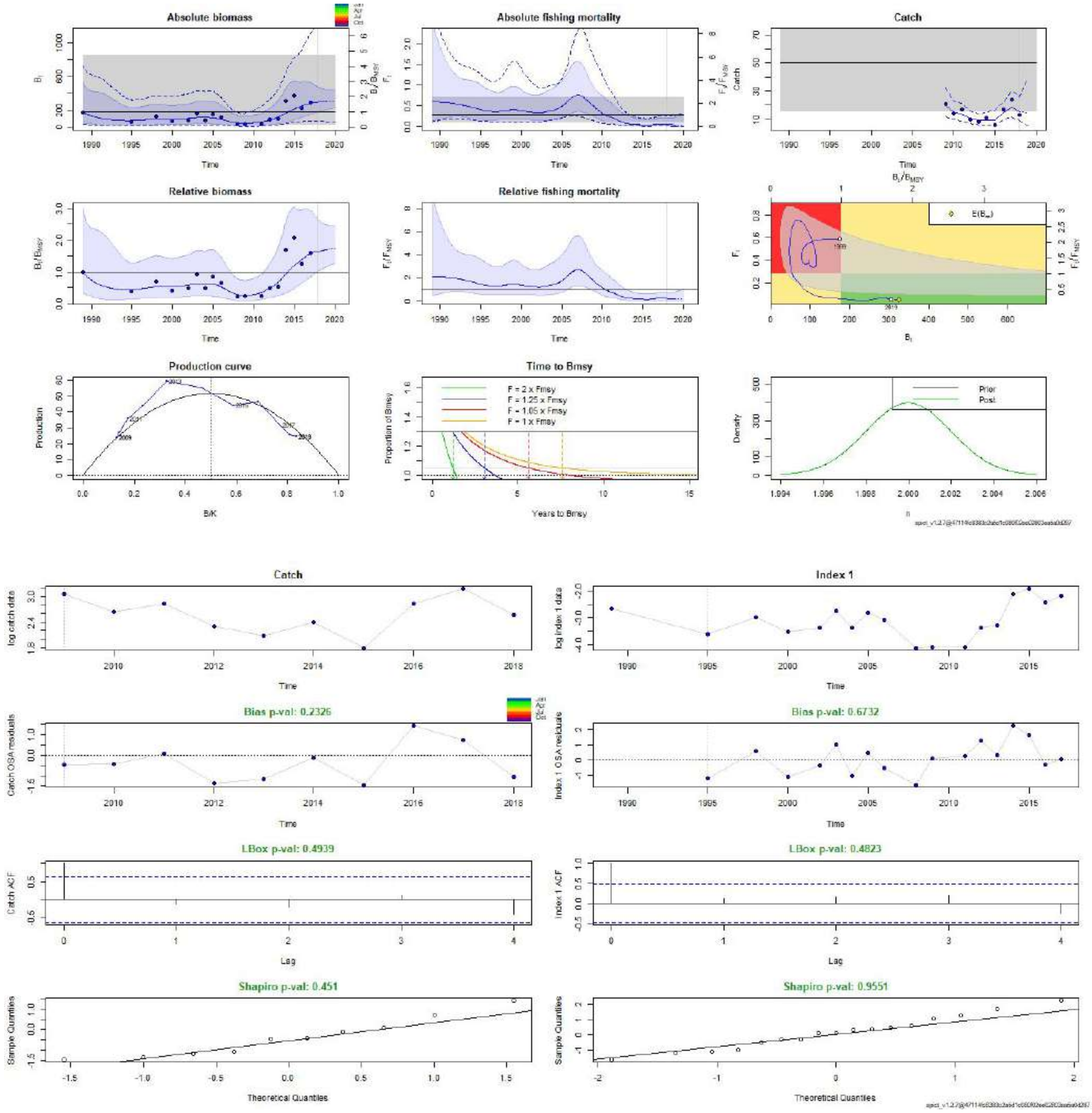


Figure 25 *SPicT results, Raja microocellata*

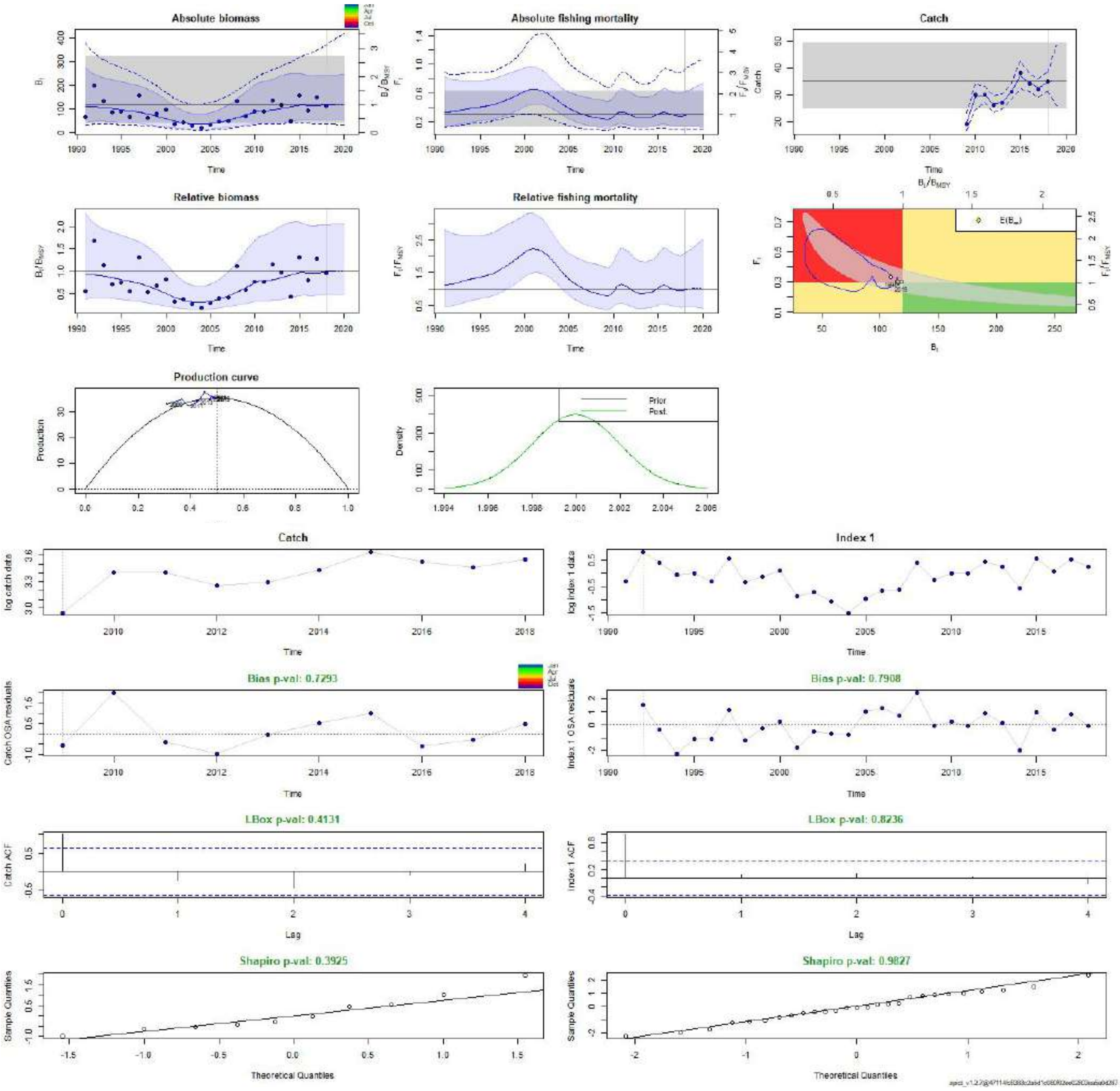


Figure 26 *SPicT results Leucoraja naevus*

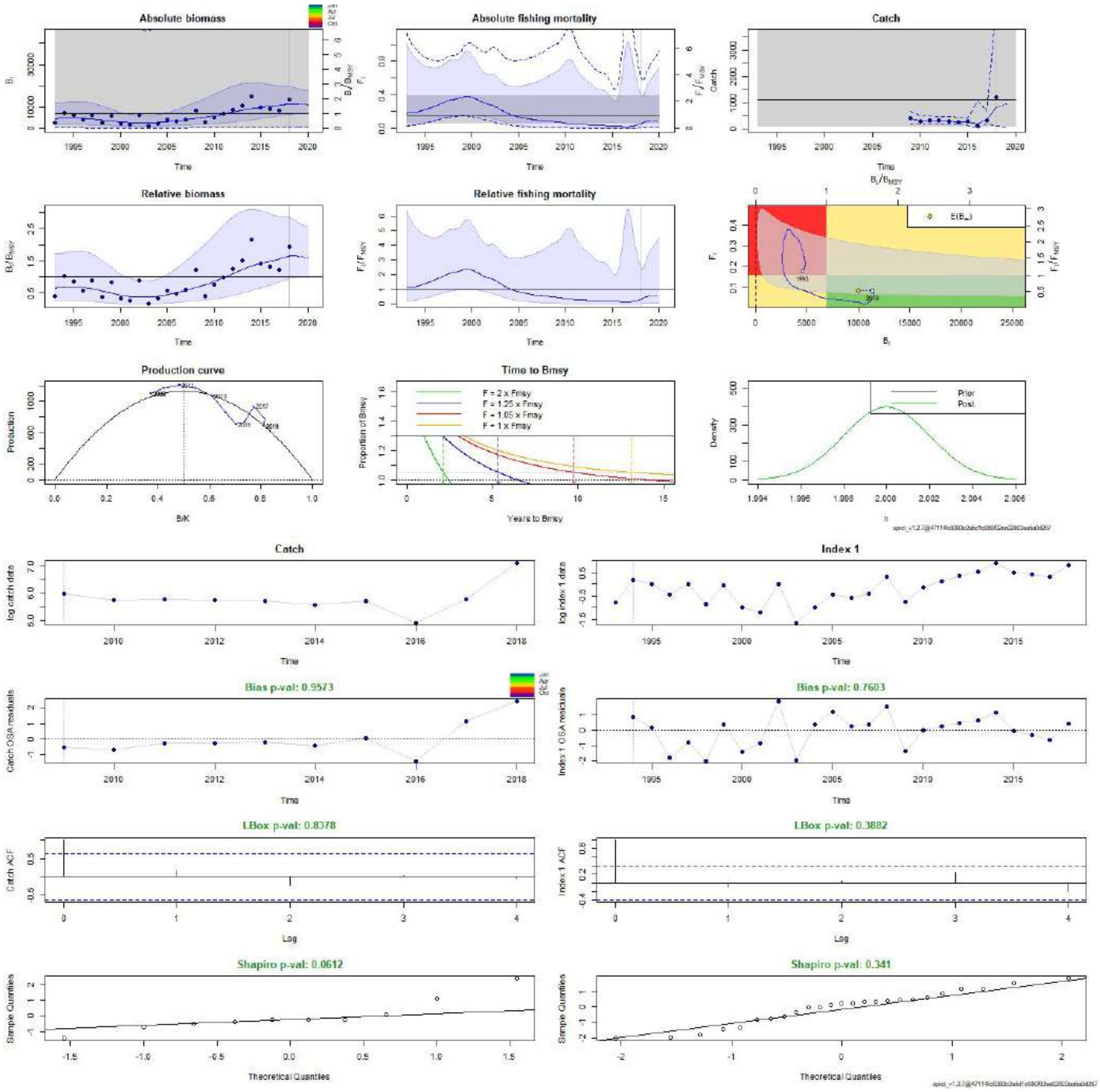


Figure 27 *SPicT results Raja montagui*

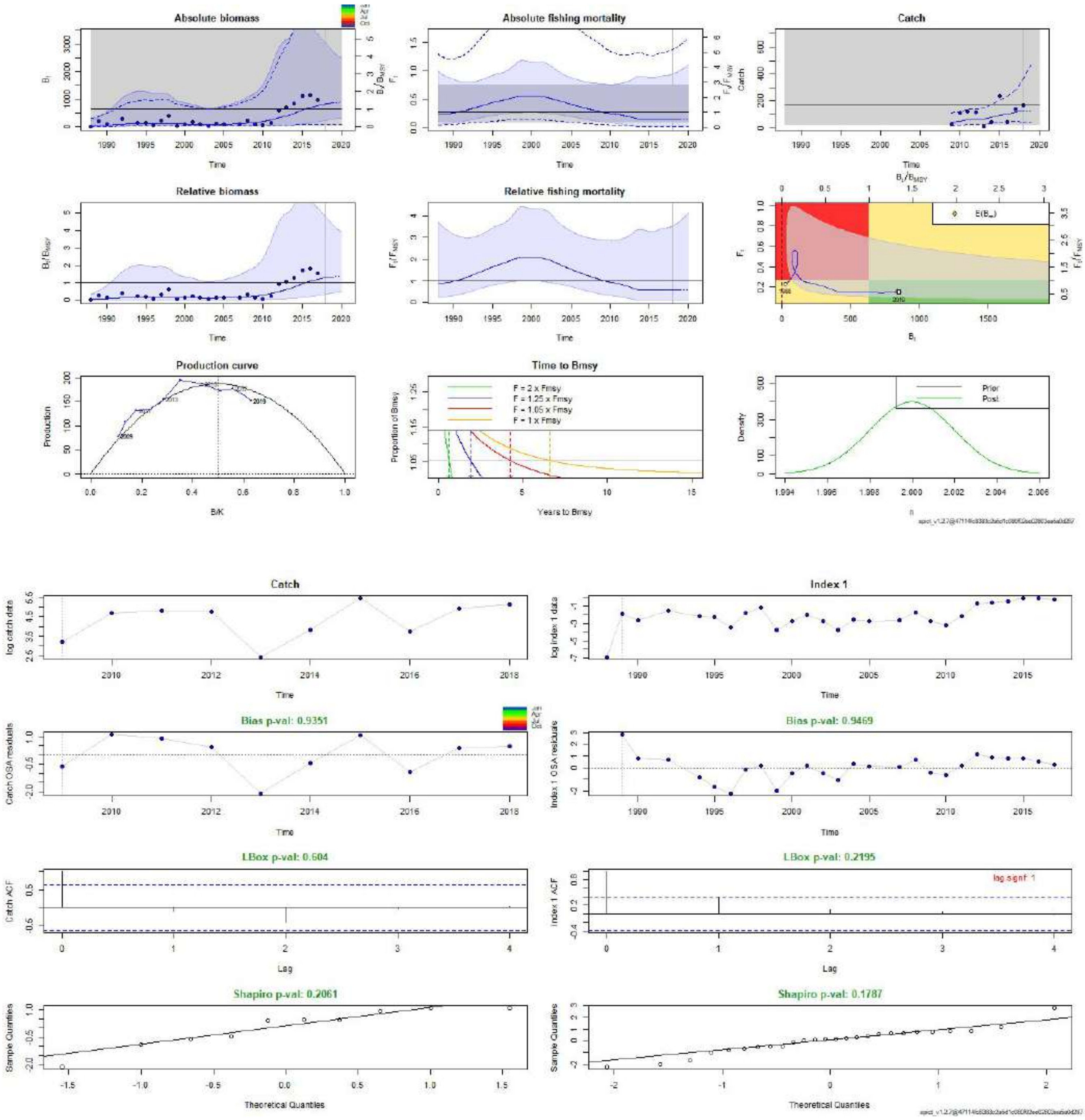
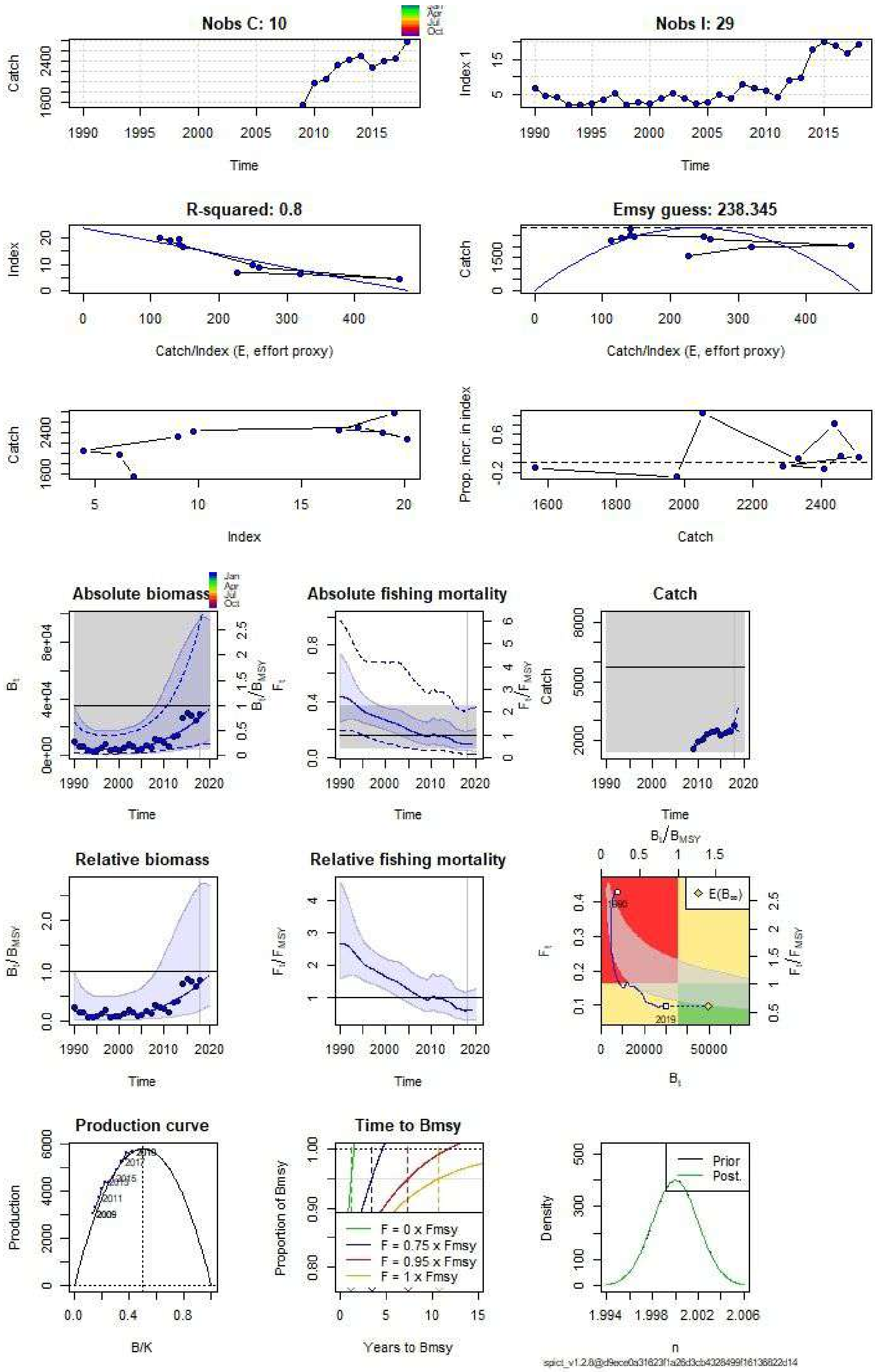


Figure 28 SPicT results *Raja undulata*

Appendix 5



Nobs C: 10
Catch
Time
Nobs I: 29
Index 1
Time
R-squared: 0.8
Index
Catch/Index (E, effort proxy)
Emsy guess: 238.345
Catch
Catch/Index (E, effort proxy)
Catch
Index
Prop. incr. in index
Catch
Absolute biomass
Time
Absolute fishing mortality
Time
Catch
Time
Relative biomass
Time
Relative fishing mortality
Time
E(B∞)
Production curve
Production
B/K
Time to Bmsy
Proportion of Bmsy
F = 0 x Fmsy
F = 0.75 x Fmsy
F = 0.95 x Fmsy
F = 1 x Fmsy
Years to Bmsy
Prior
Post.
Density
n

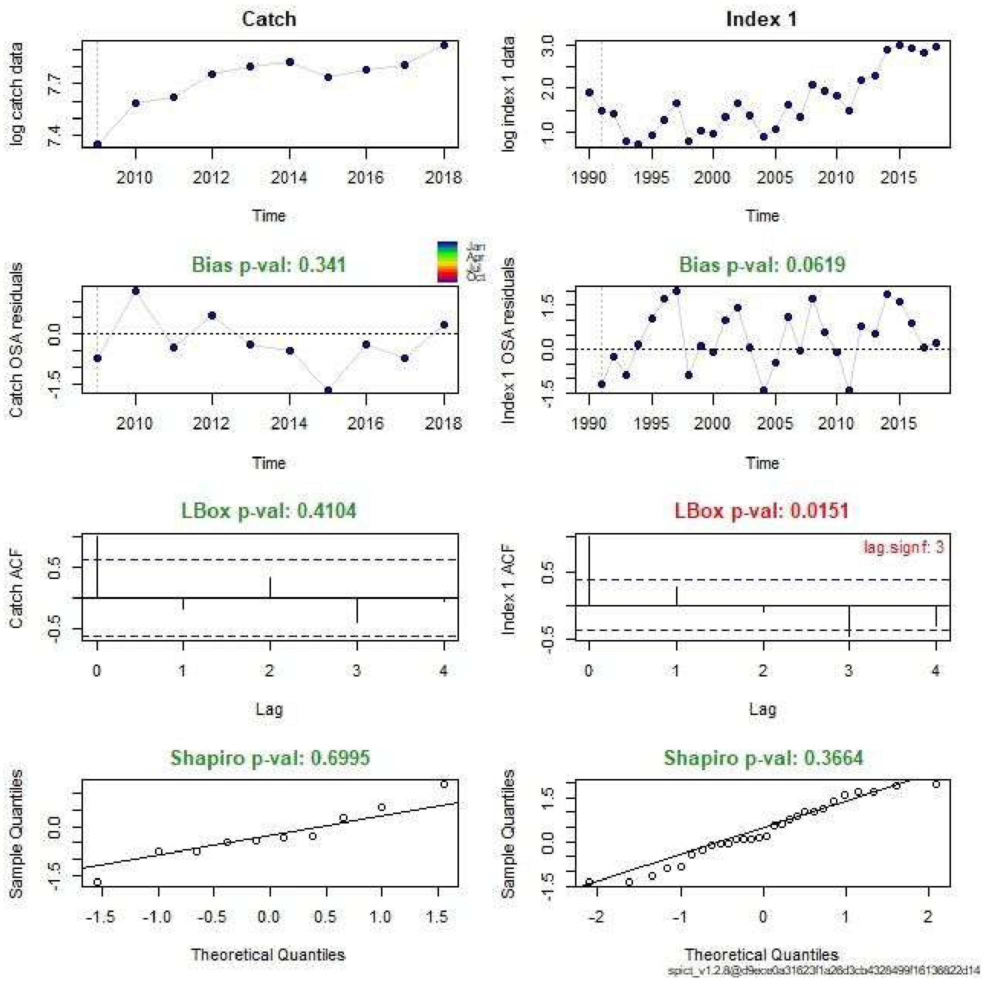
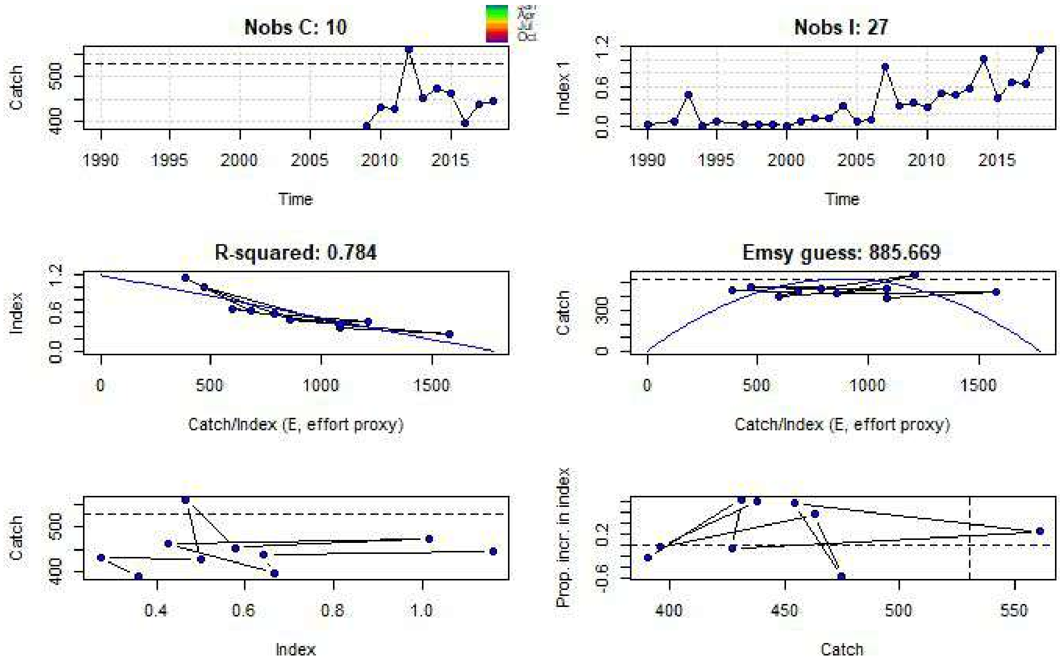


Figure 29 SPicT results, *Raja clavata*



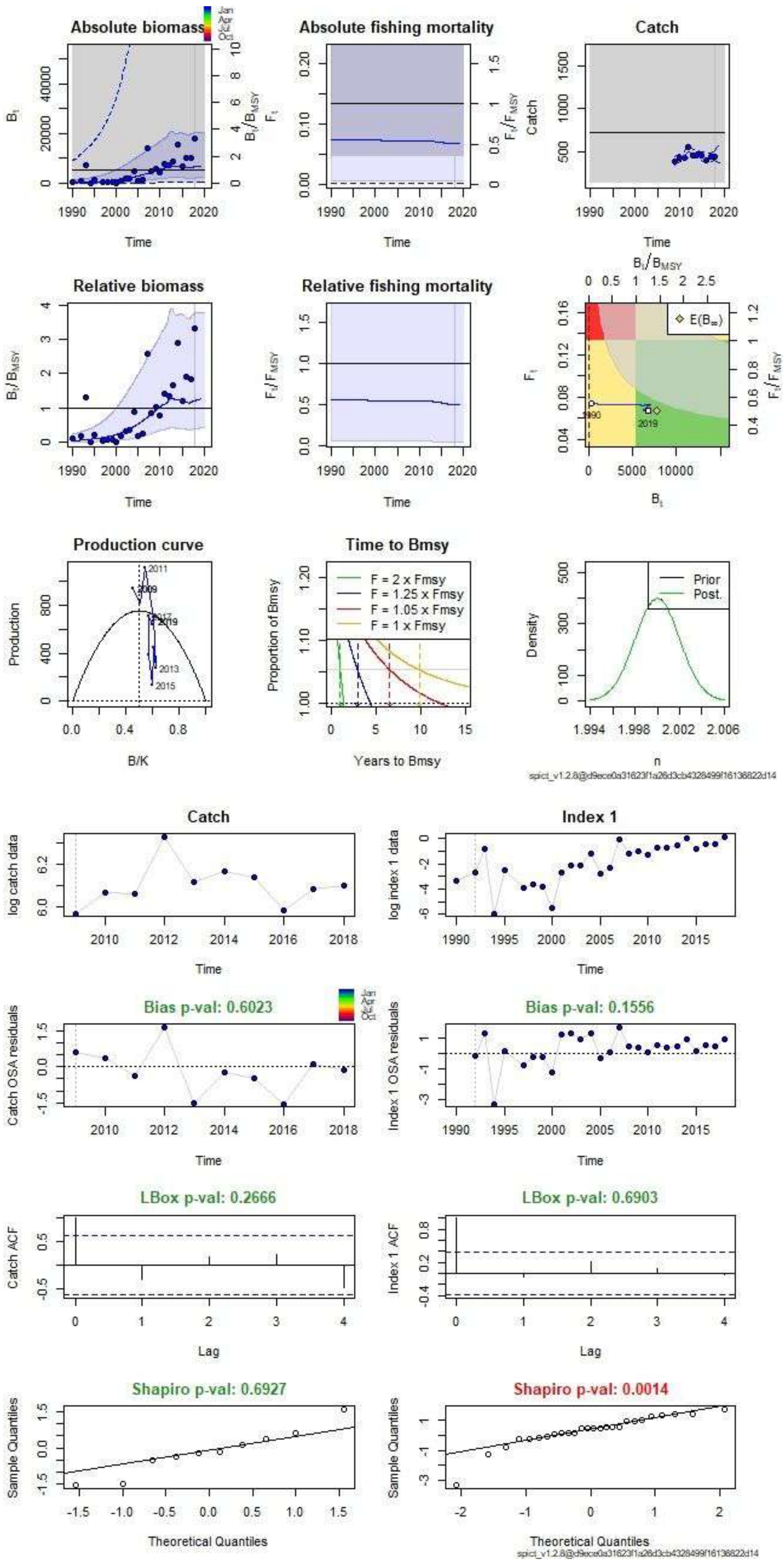
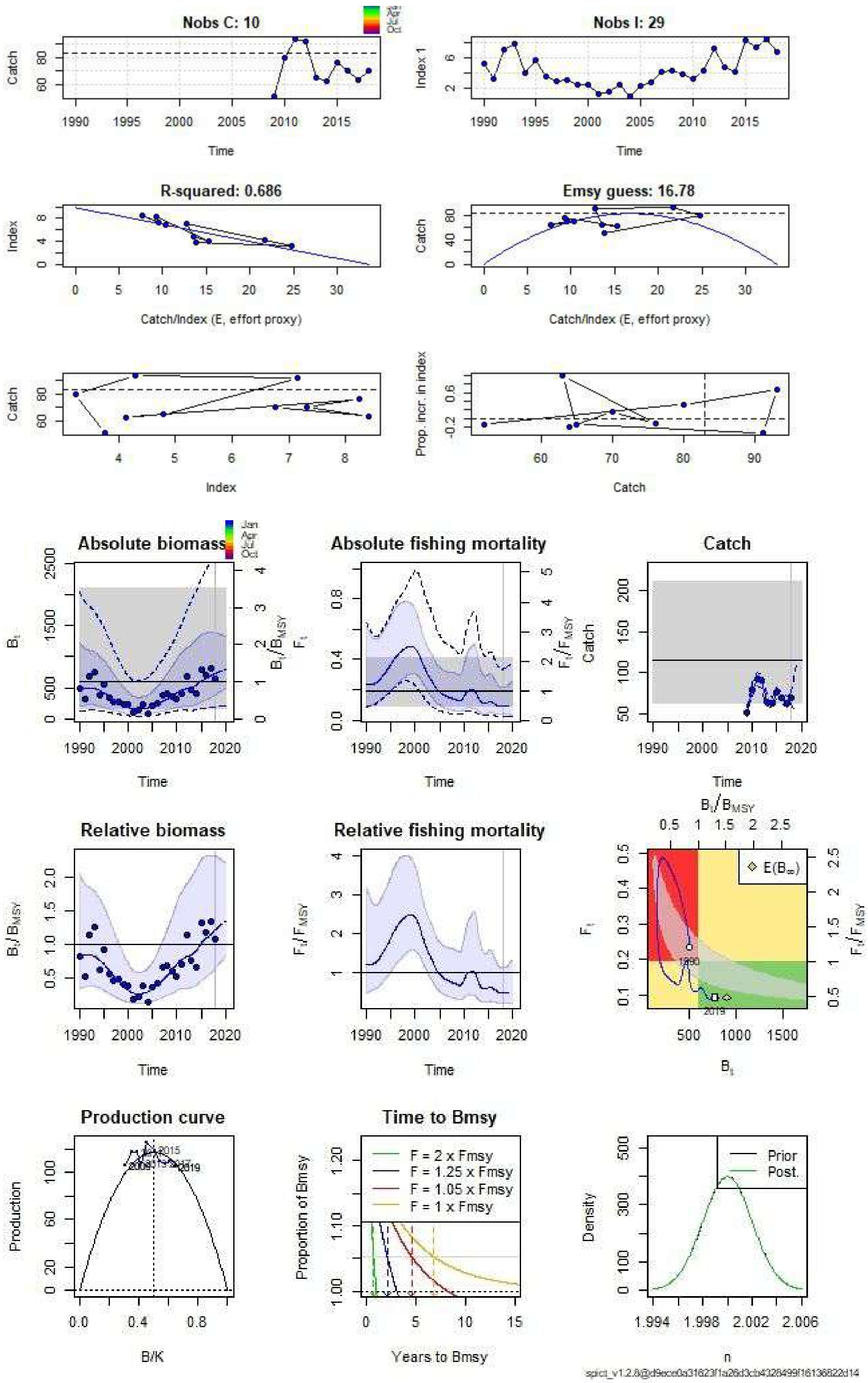


Figure 30 SPicT results, *Raja brachyura*


Nobs C: 10
Catch
Time
Nobs I: 29
Index 1
Time
R-squared: 0.686
Index
Catch/Index (E, effort proxy)
Emsy guess: 16.78
Catch
Catch/Index (E, effort proxy)
Catch
Index
Prop. incr. in index
Catch
Absolute biomass
Jan
Apr
Jul
Oct
Time
Absolute fishing mortality
Time
Catch
Time
Relative biomass
Time
Relative fishing mortality
Time
E(B∞)
1990
2019
Production curve
Production
B/K
Time to Bmsy
F = 2 x Fmsy
F = 1.25 x Fmsy
F = 1.05 x Fmsy
F = 1 x Fmsy
Proportion of Bmsy
Years to Bmsy
Prior
Post.
Density
n

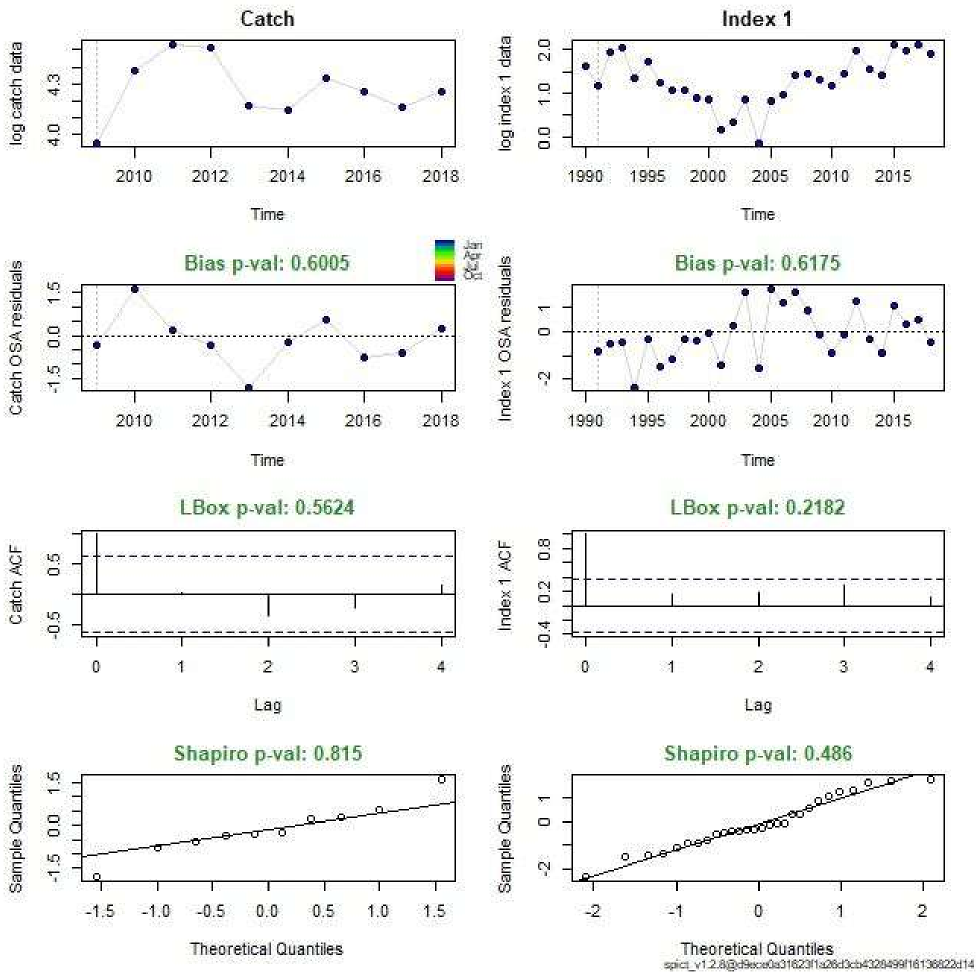
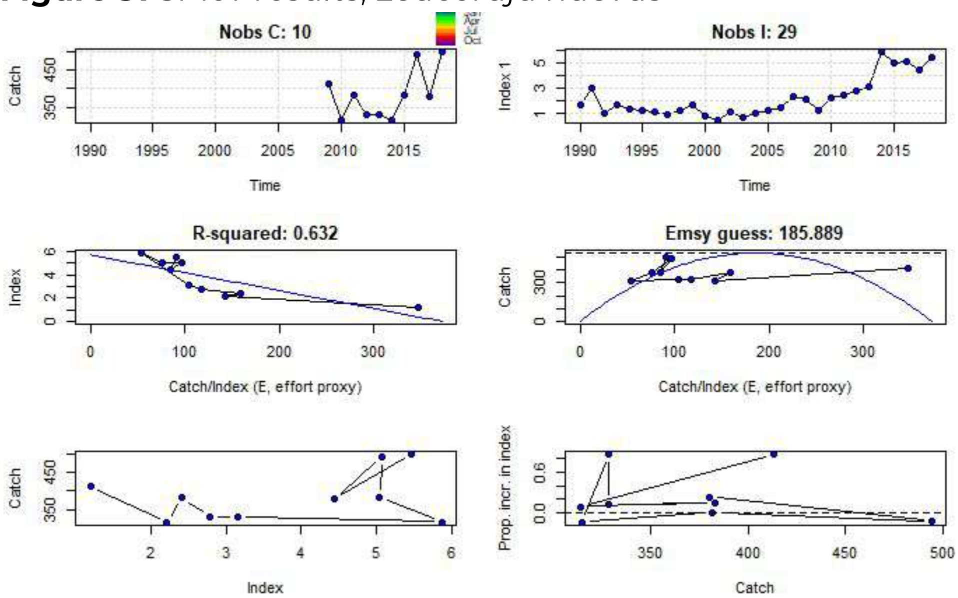


Figure 31 SPicT results, *Leucoraja naevus*



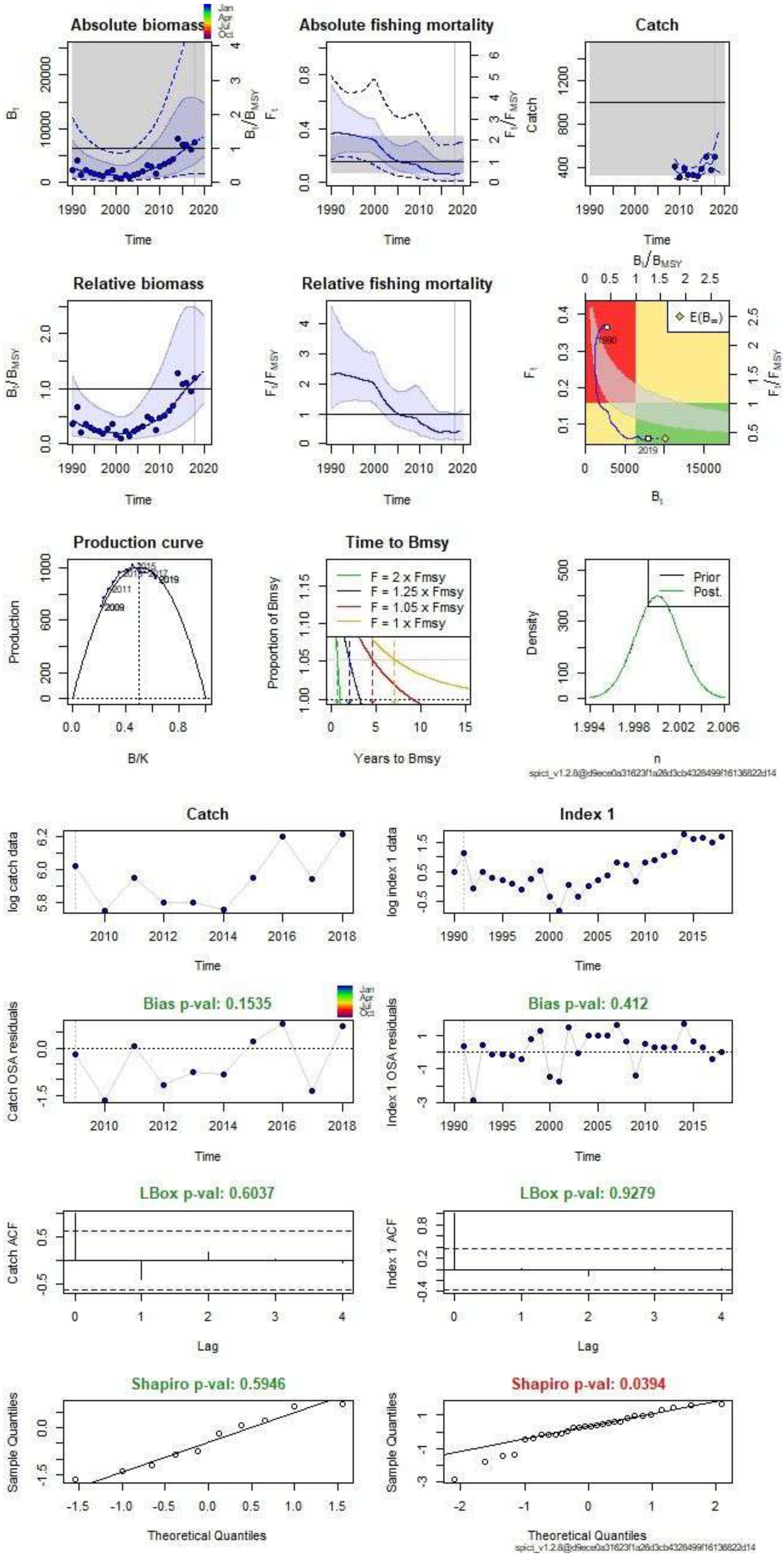
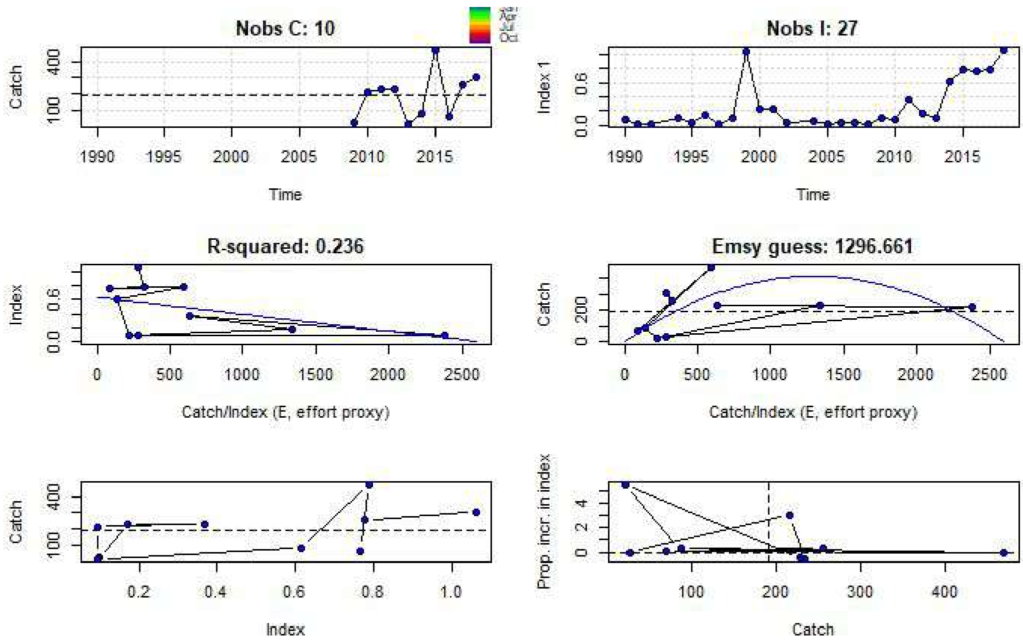
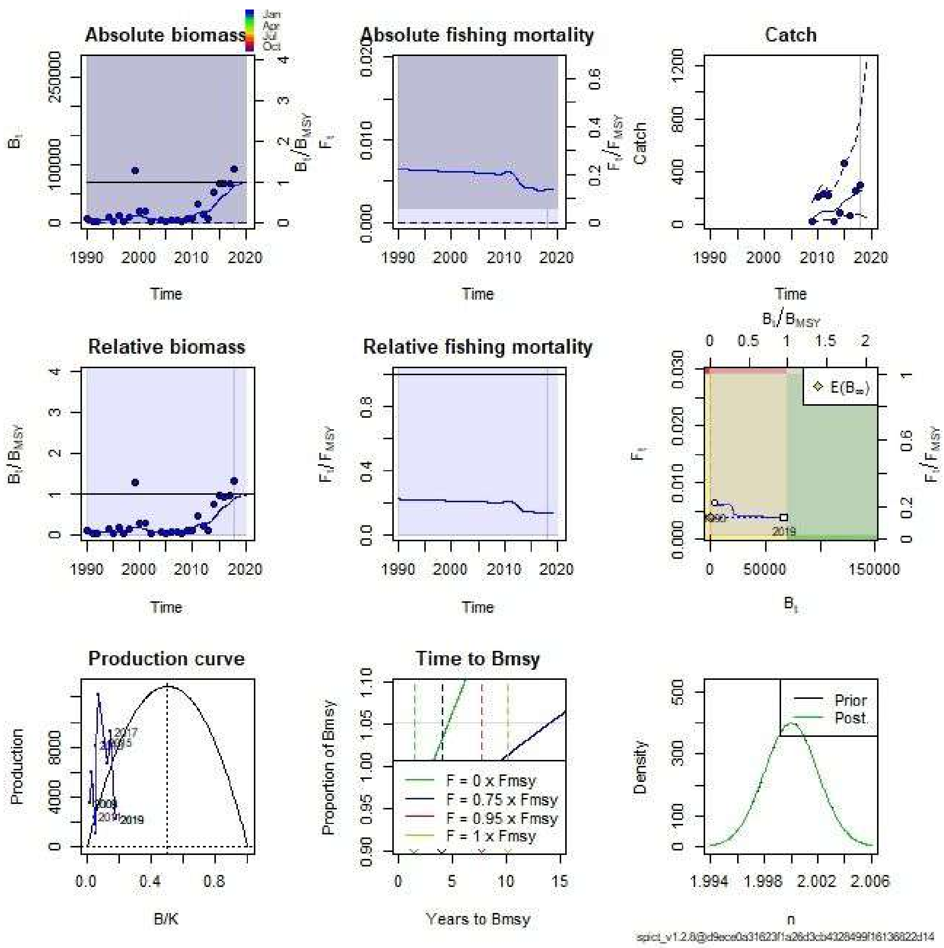


Figure 32 SPicT results, *Raja montagui*


Nobs C: 10
Catch
Time
Nobs I: 27
Index 1
Time
R-squared: 0.236
Index
Catch/Index (E, effort proxy)
Emsy guess: 1296.661
Catch
Catch/Index (E, effort proxy)
Catch
Index
Prop. incr. in index
Catch


Absolute biomass
Absolute fishing mortality
Catch
Time
Relative biomass
Relative fishing mortality
Production curve
Production
B/K
Time to Bmsy
Proportion of Bmsy
Years to Bmsy
F = 0 x Fmsy
F = 0.75 x Fmsy
F = 0.95 x Fmsy
F = 1 x Fmsy
Density
Prior
Post.
n
spict_v1.2.8@d9ece0a31623f1a26d3cb4328499f16136822d14

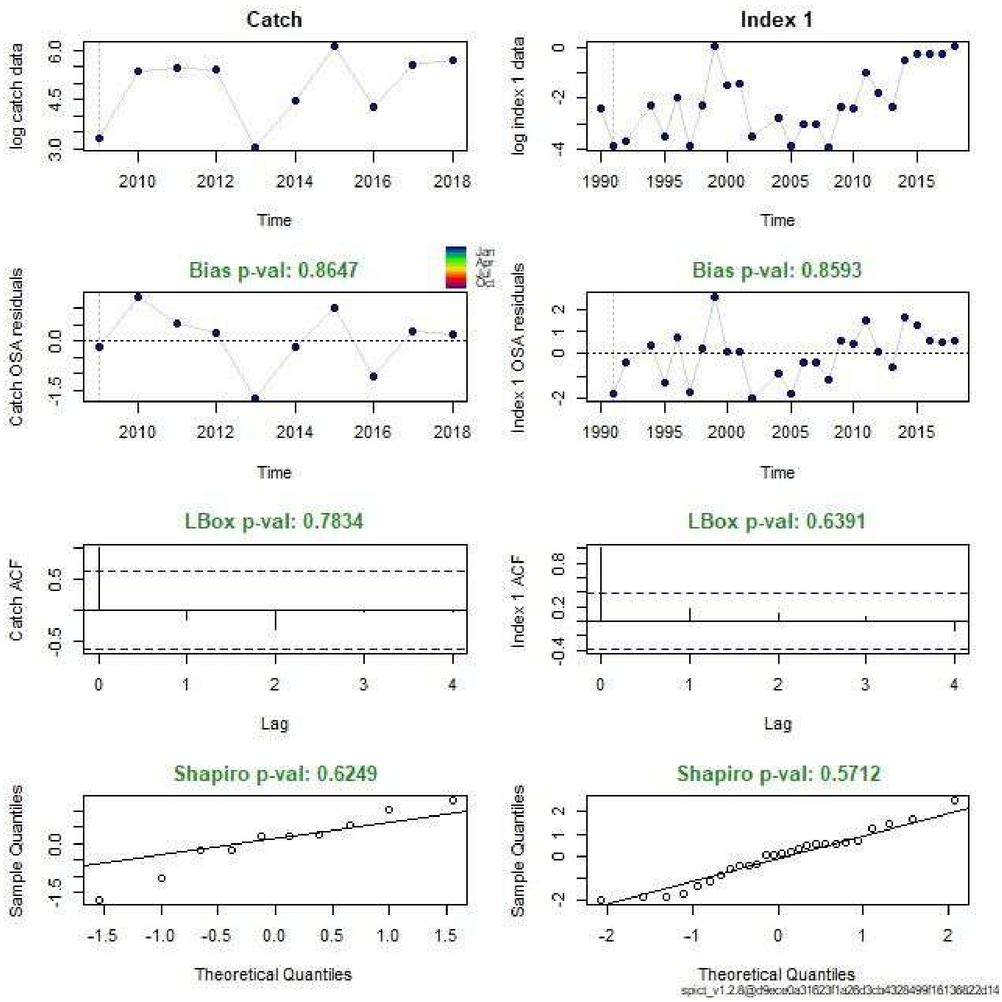


Figure 33 SPicT results, *Raja undulata*

Appendix 6

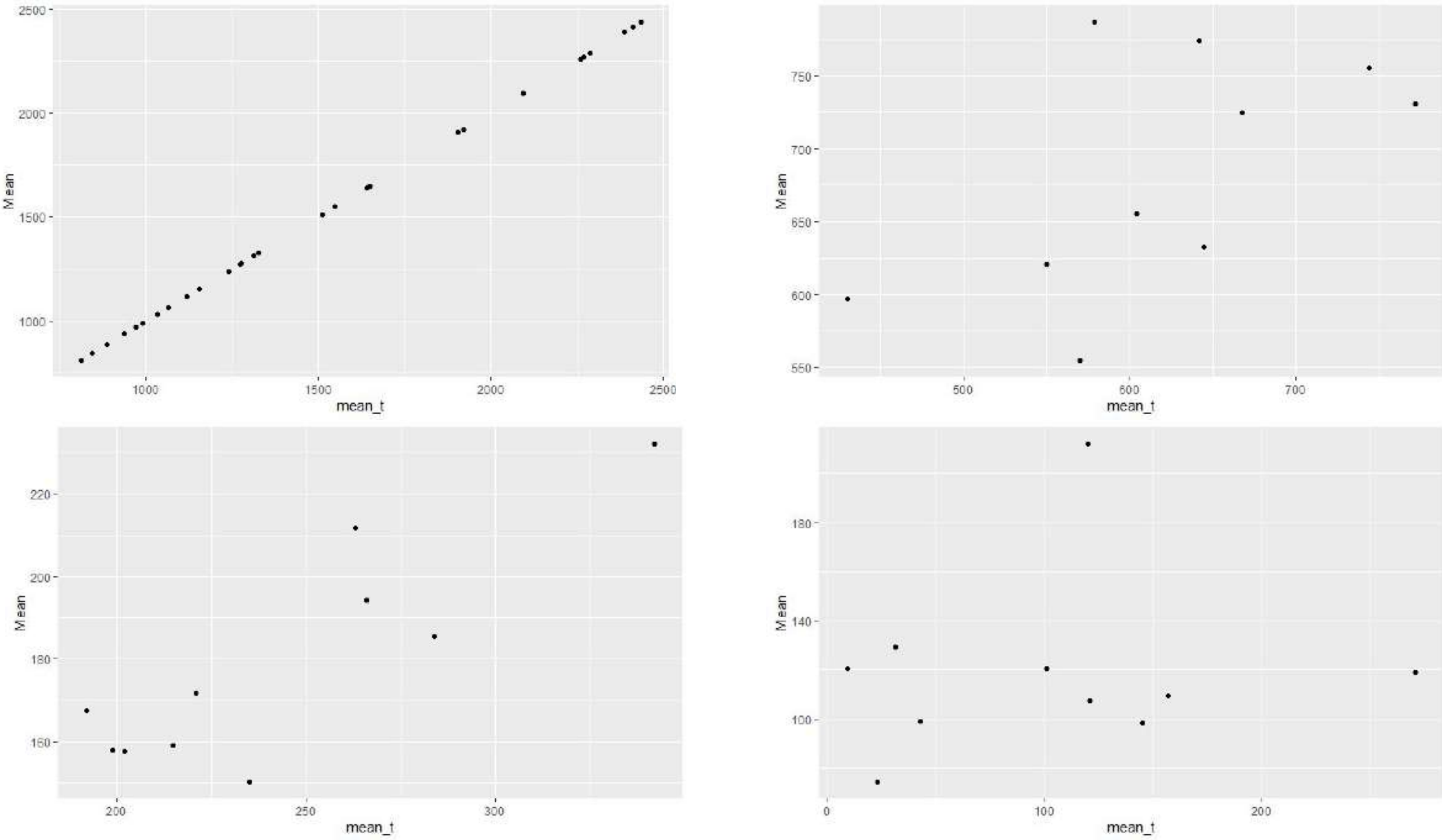


Figure 34 Residuals Discards, from the left to the right and the top to the bottom, all species, *Raja clavata, Raja brachyura* and *Raja montagui M1*

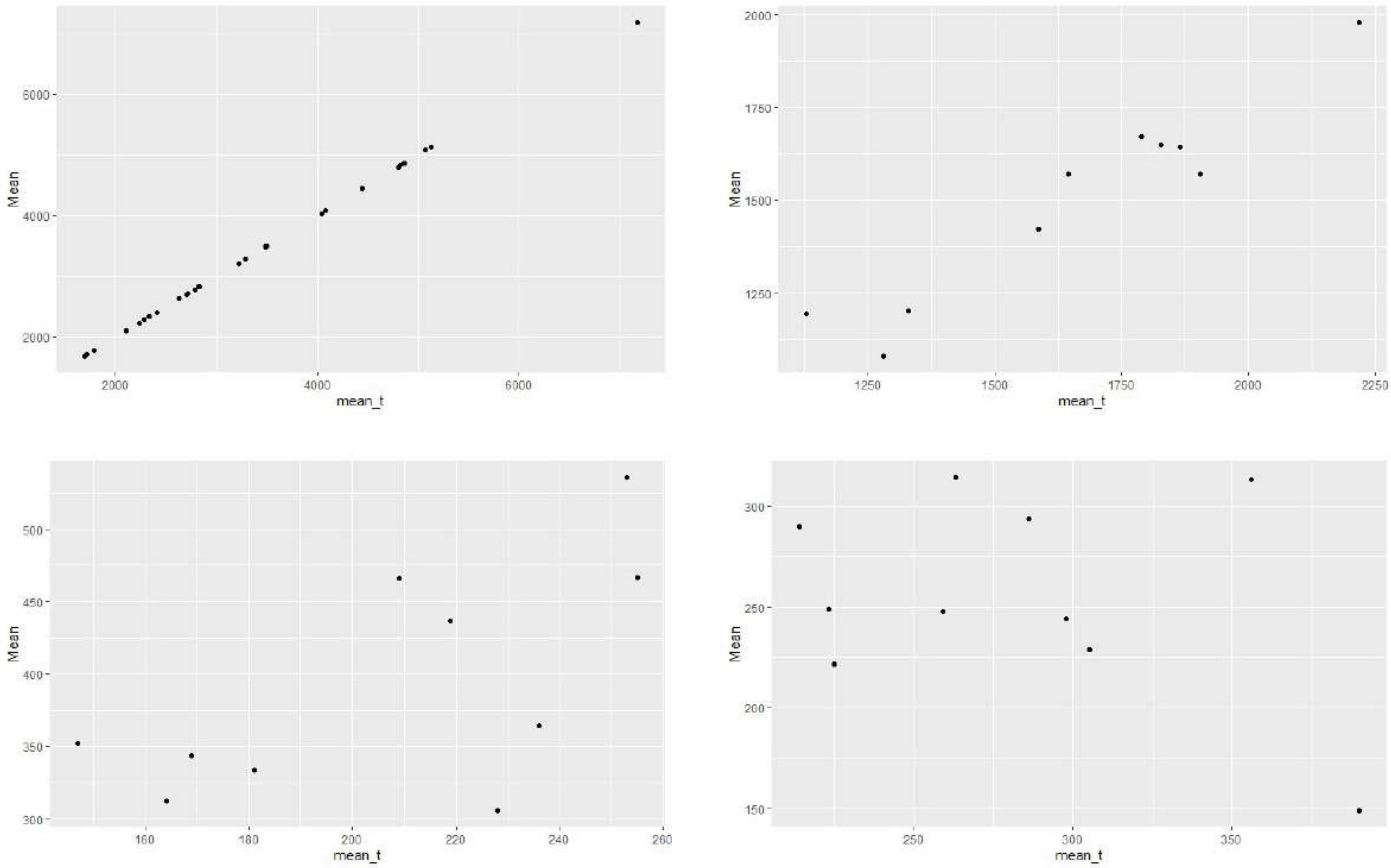


Figure 35 Residuals Landings, from the left to the right and the top to the bottom, all species, *Raja clavata, Raja brachyura* and *Raja montagui*, M1

Appendix 7

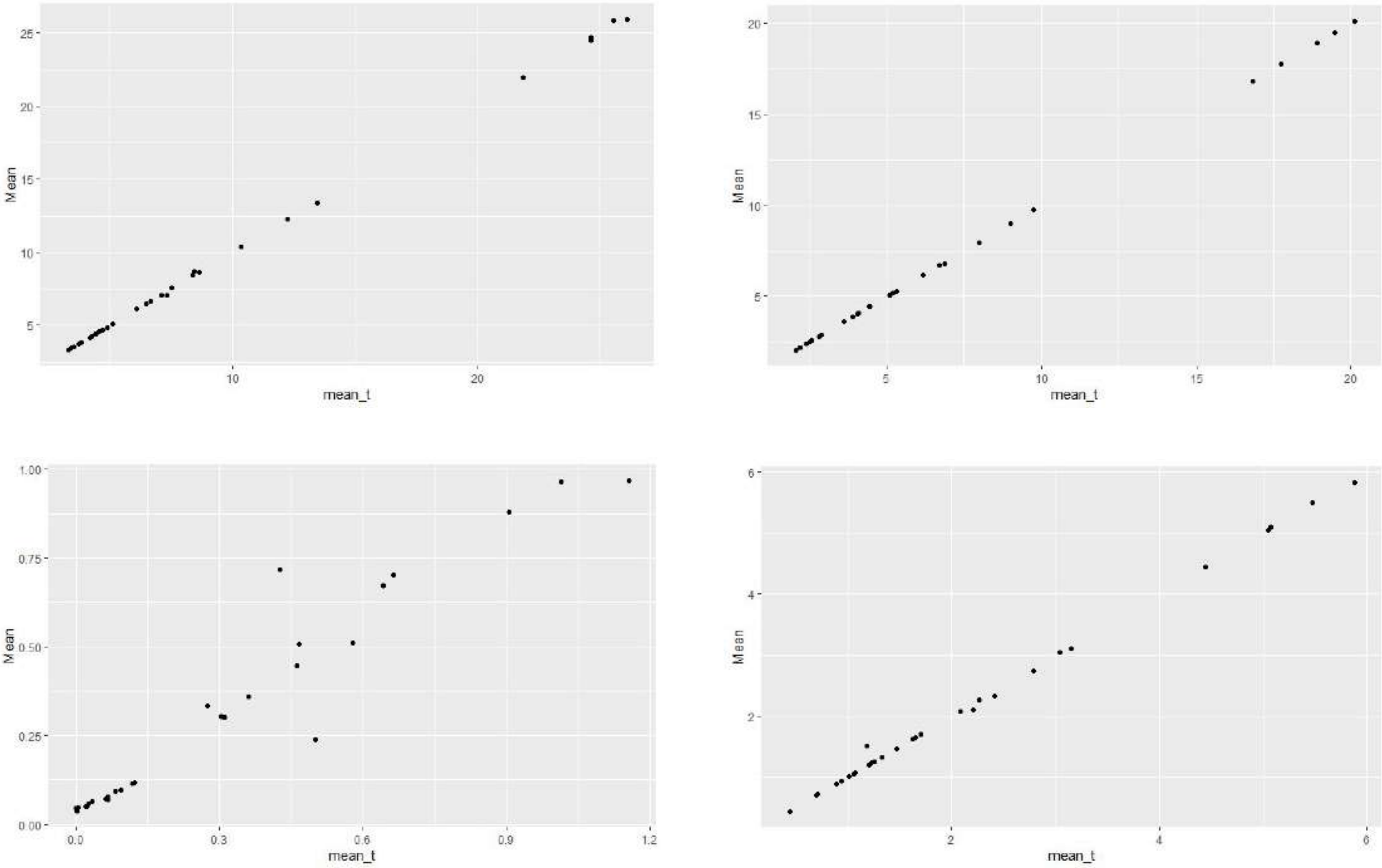
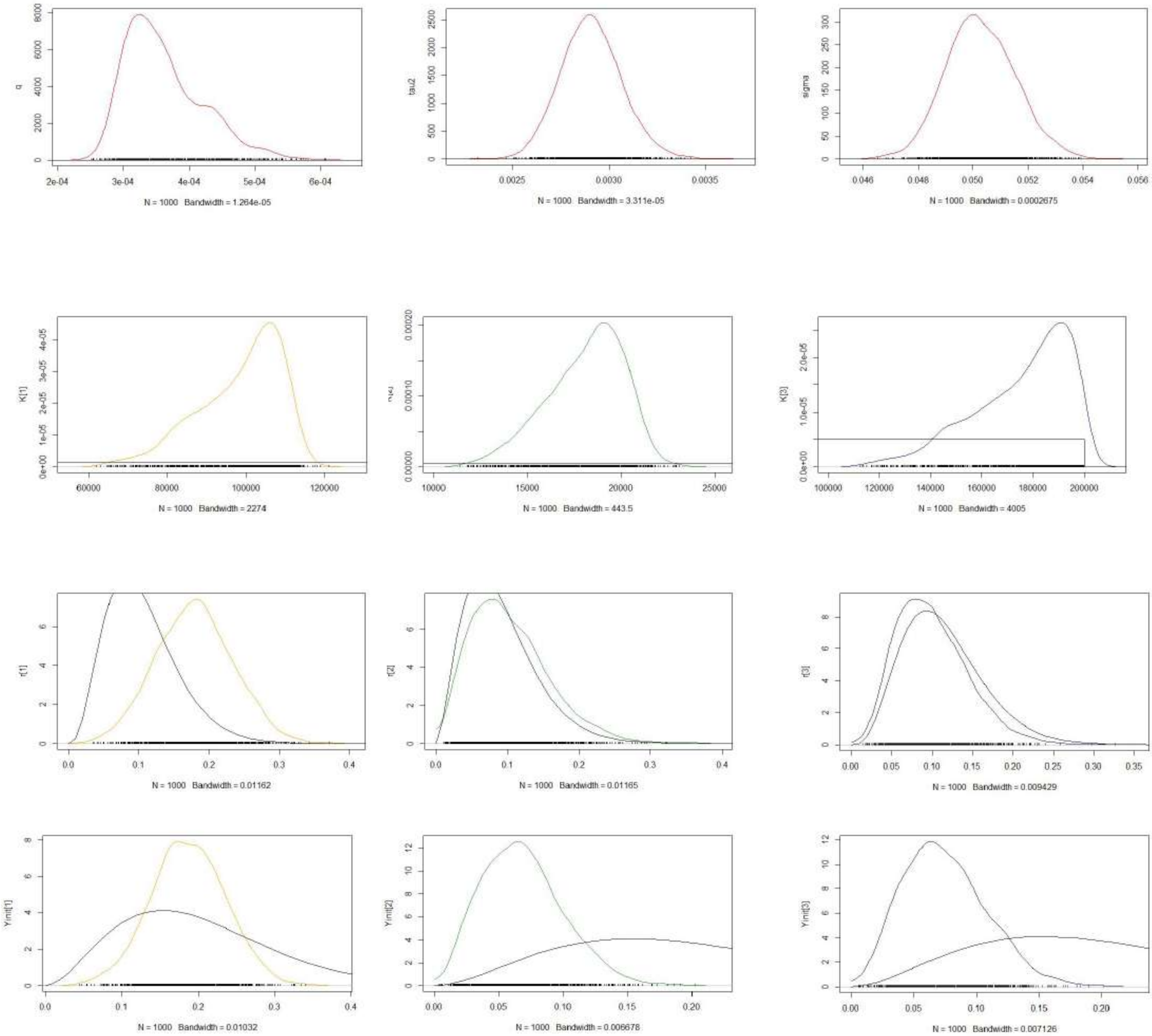


Figure 36 Biomass indices from the left to the right and the top to the bottom, all species, *Raja clavata, Raja brachyura* and *Raja montagui*, M1

Appendix 8


q
N = 1000 Bandwidth = 1.264e-05
tau2
N = 1000 Bandwidth = 3.311e-05
sigma
N = 1000 Bandwidth = 0.0002675
K[1]
N = 1000 Bandwidth = 2274
N = 1000 Bandwidth = 443.5
K[3]
N = 1000 Bandwidth = 4005
f[1]
N = 1000 Bandwidth = 0.01162
f[2]
N = 1000 Bandwidth = 0.01165
f[3]
N = 1000 Bandwidth = 0.009429
Yint[1]
N = 1000 Bandwidth = 0.01032
Yint[2]
N = 1000 Bandwidth = 0.006678
Yint[3]
N = 1000 Bandwidth = 0.007126

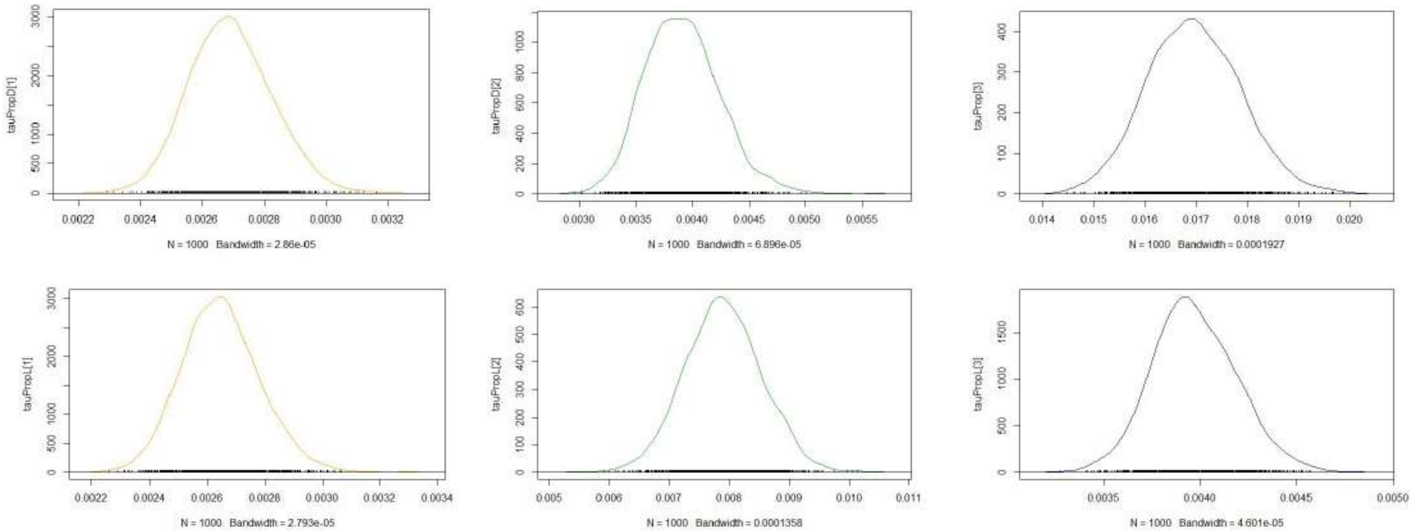


Figure 37 Priors (black line) posterior (yellow: *Raja clavata;* green :*Raja* ; blue: *Raja montagui*) distributions M1, q, catchability, K carrying capacity, Yinit, initial biomass in 1990 and r, intrinsec growth rate.

Appendix 9

ICES stock categories definition

« ICES classifies the stocks into six main categories, based on available data and knowledge, to identify which advice rule to apply when giving advice on fishing opportunities.

• ***Category 1*** – *Stocks with quantitative assessments.* Includes stocks having full analytical assessments and forecasts as well as those with quantitative assessments based on production models.

• ***Category 2*** – *Stocks with analytical assessments and forecasts that are only treated qualitatively.* Includes stocks with quantitative assessments and forecasts that, for a variety of reasons, are considered indicative of trends in fishing mortality, recruitment, and biomass.

• ***Category 3*** – *Stocks for which landings and/or catch and reliable stock size indicator(s) exist.* Includes stocks for which survey or other indices are available that provide reliable indications of trends in stock metrics, such as total mortality, recruitment, and biomass.

• ***Category 4*** – *Stocks for which only reliable catch data are available.* Includes stocks for which a time–series of catch can be used to approximate MSY.

• ***Category 5*** – *Landings-only stocks.* Includes stocks for which only landings data are available.

• ***Category 6*** – *Negligible landings stocks and stocks caught in minor amounts as by-catch.* Includes stocks where landings are negligible in comparison to discards and stocks that are primarily caught as bycatch species in other targeted fisheries. » (WKMSYCat34, 2017)