WORKING GROUP FOR THE BAY OF BISCAY AND THE IBERIAN WATERS ECOREGION (WGBIE)

VOLUME 3 | ISSUE 48

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 3 | Issue 48

WORKING GROUP FOR THE BAY OF BISCAY AND THE IBERIAN WATERS ECOREGION (WGBIE)

Recommended format for purpose of citation:

ICES. 2021. Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE). ICES Scientific Reports. 3:48. 1101 pp. https://doi.org/10.17895/ices.pub.8212

Editors

Cristina Silva • Maria Ching Villanueva

Authors

Esther Abad • Santiago Cerviño López • Mickael Drogou • Spyros Fifas • Dorleta Garcia • Hans Gerritsen Isabel González Herraiz • Maria Grazia Pennino • Ane Iriondo • Francisco Izquierdo Tarín • Eoghan Kelly Jean-Baptiste Lecomte • Catarina Maia • Teresa Moura • Lisa Readdy • Paz Sampedro Pastor • Bárbara Serra-Pereira • Cristina Silva • Agurtzane Urtizberea Ijurco • Youen Vermard • Yolanda Vila Gordillo Maria Ching Villanueva • Mathieu Woillez

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Section contents

8 Sole in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

Solea solea – sol.27.8c9a

8.1 General biology

Common sole (*Solea solea*) spawning takes place in winter/early spring and varies with latitude starting earlier in the south (Vinagre, 2007). Larvae migrate to estuaries where juveniles concentrate until they reach approximately 2 years of age and move to deeper waters. In Portuguese waters, sole length of first maturity is estimated as 25 cm for males and 27 cm for females (Jardim *et al.*, 2011). Sole is a nocturnal predator and therefore more susceptible to be captured by fisheries at night than in daytime. It feeds on polychaetes, molluscs and amphipods. *S. solea* is abundant in the Tagus estuary and uses this habitat as its nursery ground (Cabral and Costa, 1999).

Growth studies based on *S. solea* otoliths readings in the Portuguese coast indicate L_{inf} of 52.1 cm for females and 45.7 cm for males. The growth coefficient estimate for females (k = 0.23) was slightly higher than for males (k = 0.21) and t_0 was estimated at −0.11 and 1.57 for females and males, respectively (Teixeira and Cabral, 2010). Maximum length observed between 2004 and 2011 from the landings sampling program (PNAB-DCF) attained 60 cm. According to Vinagre (2007), *S. solea* off the Portuguese coast presents higher growth-rates compared with the northern European coasts.

8.2 Stock identity and possible assessment areas

There is no clear information to support the definition of the common sole stock for ICES subdivisions 8.c and 9.a.

8.3 Management regulations (TACs, minimum landing size)

The minimum landing size of sole is 24 cm. There are other regulations regarding the mesh size for trammel and trawlnets, fishing grounds and vessels size. Sole is under the Landing Obligation in divisions 8.a, 8.b, 8.d, and 8.e (all bottom-trawls, mesh sizes between 70 mm and 100 mm, all beam trawls, mesh sizes between 70 mm and 100 mm and all trammel and gillnets, mesh size larger or equal to 100 mm) and in Division 9.a (all trammelnets and gillnets, mesh size larger or equal to 100 mm). In Portugal, all sole catches from all gears and mesh sizes are under the Landing Obligation (more restrictively than required by European regulations).

Management of all sole species is made under a combined species TAC which prevents effective control of the single-species exploitation rates and could lead to the overexploitation of either species. For the period 2011–2020, *Solea solea* represented on average 56% of the total catches of sole species, while *Solea senegalensis* represented on average 24%, *Pegusa lascaris* 19%, and *Solea spp.* only 1% (Table 8.3.1).

8.4 Fisheries data

Table 8.4.1 presents common sole catches for divisions 8.c and 9.a., as well as landings for the other sole species (*S. senegalensis, Pegusa lascaris,* and *Solea spp.*). Discards are considered negligible (< 1%) and therefore, from there on, the words catch or landings can be used indistinctly.

There is evidence of misidentification problems in Portuguese official statistics regarding sole species (i.e. *Solea solea*, *Solea senegalensis,* and *Pegusa lascaris*) (Dinis *et al*., 2020). During the WKWEST benchmark (ICES, 2021), using data from the Data Collection Framework (DCF) sampling program, Portuguese catches were proportionally divided by sole species applying the species weight proportion to the total weight of *Soleidae* in each year, landing port, and semester and using a simple random sampling estimator, following Figueiredo *et al*. (2020). Details on data available and catch estimation procedures can be found in Annex 2 of the working document Pennino *et al*. (2021). At the moment the new Portuguese catches are considered reliable.

Reviewed catches reported in InterCatch are now available from 2009 to 2020 by Spain and France and from 2011 to 2020 by Portugal (Figure 8.4.1). Information on discards indicates that discarding can be considered negligible (< 1%) (Figure 8.4.2). Presently, only damaged specimens are discarded, while specimens under the minimum conservation reference size are landed under the landing obligation (in negligible numbers).

The majority of catches are from ICES Division 9.a (Figure 8.4.3). The two main fleets that fish this stock are the polyvalent fleet from Portugal (i.e. "MIS_MIS_0_0_0") and the trammelnet fleet from Spain (i.e. "GRT_DEF_60-79_0_0") (Figure 8.4.4). The distribution of the catches is almost homogenous along the year for the two main countries (i.e. Portugal and Spain), as well as for the main fleets.

In InterCatch, data on length-frequency distribution are available for the years 2011–2020 (Figure 8.4.5). The majority of the data are from the polyvalent fleet (i.e. métier "MIS_MIS_0_0_0") from Portugal and the distribution seems to be homogeneous in the last years. Market sampling in Portuguese ports during 2020 was affected by the COVID-19 pandemic, resulting in the sampling suspension during the period March-June and resumption after that. In order to overcome the decrease in the amount of data collected by the National sampling program PNAB/DCF, samples were collected under the Project "Pequena Pesca na Costa Ocidental Portuguesa - PPCENTRO" (ref: MAR-01.03.02-FEAMP-0007) were also used to estimate landings by species and length frequency distribution.

For the WKWEST benchmark an official data call was issued for this stock to get all the possible data, not only for the common sole (*S. solea*) but also for the other sole species, i.e. *Solea senegalensis, Pegusa lascaris,* and *Solea spp.* (Figure 8.4.6) due to misassignment problems identified in official statistics.

During the benchmark, Spanish landings of *S. senegalensis, P. lascaris* and *Solea spp*. were available for the period 2009–2019, while from Portugal for 2011 to 2019. No French data on these species were available.

For Portugal, as for the catches of *S.solea*, also the catches of *S. senegalensis, P. lascaris* and *Solea spp.* were proportionally split by sole species applying the species weight proportion to the total weight of *Soleidae* in each year, landing port, and semester and using a simple random sampling estimator, following Figueiredo *et al*. (2020) (ICES, 2021).

8.4.1 Survey data, recruit series

Two biomass indices are available for this stock, a standardized commercial Landing Per Unit Effort (LPUE) from Portugal and a standardized biomass index from the Spanish IBTS-Q4 bottom-trawl survey (G2784).

8.4.1.1 Standardized biomass index from the Spanish IBTS-Q4 bottom trawl survey (G2784)

Common sole data were collected during the Spanish IBTS-Q4 bottom trawl survey (G2784) performed by the Instituto Español de Oceanografía (IEO) in autumn (September and October) between 2000 and 2020. Surveys were conducted on the northern continental shelf of the Iberian Peninsula (ICES divisions 8.c and the northern part of 9.a) which has a total surface area of almost 18 000 km^2. Surveys were performed using a stratified sampling design based on depth with three depth strata: 70–120 m, 121–200 m, and 201–500 m. Sampling stations consisted of 30 min trawling hauls located within each stratum at the beginning of the design. The gear used is the baka 44/60 and the survey follows the protocol of the International Bottom Trawl Survey Working Group (IBTSWG) of ICES (ICES, 2017).

However, the common sole is a species with a biological bathymetric range between 0 and 200 meters in the Iberian Atlantic waters. The Spanish IBTS-Q4 (G2784) only covers partially the common sole bathymetric range and the resultant abundance index is probably underestimated. For this reason, and with the aim to correct this sampling bias, a hurdle Bayesian spatio-temporal was applied to this dataset.

Two response variables were analysed in order to characterize the spatio-temporal behaviour of common sole individuals. Firstly, a presence/absence variable was considered to measure the probability of the species occurrence. Secondly, the weight by haul (kg) was used as an indicator of the conditional-to-presence abundance of the species.

As an environmental variable, we used depth. Bathymetry values were retrieved from the European Marine Observation and Data Network (EMODnet, http://www.emodnet.eu/) with a spatial resolution of 0.02 x 0.02 decimal degrees (20 m).

Models were fitted using the integrated nested Laplace approximation approach INLA (Rue *et al*., 2009) in the R software (R Core Team, 2021). The spatial component was modelled using the spatial partial differential equations (SPDE) module (Lindgren *et al*., 2011) of INLA and implementing a multivariate Gaussian distribution with zero mean and a Matérn covariance matrix (Muñoz *et al*., 2013).

As spatio-temporal structure, we used the progressive one (Paradinas *et al*., 2017, 2020), which contains an autoregressive ϱ parameter that controls the degree of autocorrelation between consecutive years. This ϱ parameter is bounded to [0, 1], where parameter values close to 0 represent more opportunistic behaviours and parameter values close to 1 represent more persistent distributions over time. In addition, an extra-temporal effect g(t) was added using a second-order random walk (RW2) before allowing non-linear effects. In the presence of bathymetric and spatial autocorrelation terms, g(t) can be regarded as a spatially standardized stock size temporal trend.

Occurrence (Y_{st}) was modelled using a Bernoulli distribution and conditional-to-presence abundance (Z_{st}) using a gamma distribution, which is a probability distribution that captures the overdispersion of continuous data. The means of both variables were modelled through the logit and log link functions respectively to the bathymetric and spatio-temporal effects as:

$$Y_{st} \sim \mathrm{Ber}(\pi_{st}) \quad (1)$$
$$Z_{st} \sim \mathrm{Gamma}(\mu_{st}, \phi)$$
$$\mathrm{logit}(\pi_{st}) = \alpha(Y) + f(ds) + g(t) + U_{st}(Y)$$
$$\log(\mu_{st}) = \alpha(Z) + \theta f(ds) + \eta g(t) + U_{st}(Z)$$

where π_{st} represents the probability of occurrence at location *s* at time *t* and μ_{st} and ϕ are the mean and dispersion of common sole conditional-to-presence abundance. The linear predictors, which contain the effects that link the parameters π_{st} and μ_{st}, include: $\alpha(Y)$ and $\alpha(Z)$, terms that represent the intercepts of each variable respectively; ds corresponds to the depth at location s, being f(ds) the bathymetric effect modelled as a second-order random walk (RW2) smooth function parameterized as unknown values f = (f0,… fi-1)t at *i* = 14 equidistant values of ds, with hyperparameter σ representing the variance of the f(ds) model. In the same way, g(t) corresponds to the temporal trend fitted through a RW2 effect over the years. The terms f(ds) and g(t) are shared between both predictors and multiplied by θ and η in the conditional-to-presence abundance model to allow for differences in scales between both predictors (i.e. the logit transformed probability and the logarithm of the conditional-to-presence abundance); $U_{st}(Y)$ and $U_{st}(Z)$ refer to the progressive spatio-temporal structures of common sole occurrence and conditional-to-presence abundance respectively.

Following the Bayesian approach, penalised complexity priors (i.e. PC priors, weak informative priors; Simpson *et al.*, 2017) were assigned so that the probability of the spatial effect range being smaller than 0.5 degrees was 0.05, and the probability of the spatial effect variance being larger than 0.5 was 0.5. PC priors were also used for the variance of the bathymetric and the temporal trend RW2 effects. Specifically, the size of these effects was constrained by setting a 0.05 probability that sigma was greater than 0.5 and 1 respectively. Sensitivity analysis for the selection of priors was performed by testing different priors and verifying that the posterior distributions were consistent and concentrated comfortably within the support of the priors.

From this analysis, we obtained a new spatio-temporal abundance index (Figure 8.5.1).

8.4.1.2 Landings Per Unit Effort (LPUE) from Portugal

Portuguese LPUE estimates rely on fishery-dependent data derived from the polyvalent fleet and are based on the estimated *S. solea* landed weight by fishing trip. The analysis was restricted to the most important landing ports in terms of *S. solea* landed weight: Viana do Castelo, Matosinhos, Aveiro, Peniche and Setúbal. The Portuguese polyvalent fleet segment comprises multi-gear/multispecies fisheries, usually licensed to operate with more than one fishing gear (most commonly gill and trammelnets, longlines and traps), that can be deployed in the same trip, targeting different species. The period considered in the present study extends from 2011 to 2020.

The dataset was subset to trips with positive landings of the species. The LPUE standardization procedure was done via the adjustment of a General Linear Model (GLM) to the matrix data, where the response variable was the *S. solea* landed weight by trip (unit effort) and was fitted with a Gamma distribution. Several variables were evaluated as a candidate to be included in the model: region, landing port, year, semester, quarter, month and vessel size group (< 9 m and > 9 m).

All the explanatory variables were considered categorical variables. The function "*bestglm*" implemented in R software, used to select the best subset of explanatory variables (McLeod and Xu, 2010), is based on a variety of information criteria and their comparison following a simple exhaustive search algorithm (Morgan and Tatar, 1972). The diagnostic plots, distribution of residuals and the quantile-quantile (Q-Q) plots, were used to assess model fitting. Changes in deviance explained by the selected model and the proportions of deviance explained to the total explained deviance were determined and used as indicative of r2. Finally, annual estimates of LPUE and the corresponding standard error were determined using estimated marginal means with the R package "*emmeans*" (Lenth, 2016, 2020).

The final model explained 86% of the variability and included as explanatory variables the year, the month, the landing port and the vessel size. The final LPUE index is presented in Figure 8.5.2. Finally, it is worth mentioning that sensitivity tests were carried out on this dataset to assess the sensibility of the model to a possible increase or reduction of the weight per trip by 25% for data from 2020. Results highlighted that the model performed well and consequently consistent outputs were obtained with the original dataset.

8.5 Biological sampling

Existing biological sampling is based on fishery data from commercial vessel landings.

8.5.1 Population biology parameters and a summary of other research

Solea solea maturity ogives by sex, length-weight relationship, sex-ratio by length are based on port sampling and are available from 2012 for Division 9.a (Jardim, *et al.,* 2011).

8.6 Assessment

8.6.1 Length based indicators (LBI) method

The assessment of this stock is provided using the Length Based Indicators (LBI) method, as approved during the recent benchmark (ICES, 2021). Length-based indicators are calculated from length-frequency distributions obtained from catch or landings and compared to appropriate reference levels derived from life-history parameters. These indicators are related to conservation, optimal yield and length distribution relative to expectations under maximum sustainable yield (MSY) and thus can provide an overall perception of the stock status (ICES, 2018).

For the LBI implementation, life-history parameters considered were:

- M/K = 1.41, derived from M = 0.31 (from Cerim *et al*., 2020) and K = 0.22 (assuming the mean value of both sexes with K = 0.23 for females and K = 0.21 for males from Teixeira and Cabral (2010)).
- L_∞ = 48.9 cm (corresponding to the mean of females L_∞ = 52.1 cm and males L_∞ = 45.7 cm, from Teixeira and Cabral (2010)).
- L_{mat} or L_{50} = 26 cm (the mean L_{50} was computed with males L_{50} = 25 cm and females L_{50} = 27 cm from Jardim *et al*. (2011)).
- Length–weight relationship parameters a = 0.00759 and b = 3.06 (Bayesian length-weight model based on LWR estimates for this species (Froese *et al*., 2014)).

The LBI method was adjusted using the above values and defined as the reference model. A sensitivity analysis of the parameters L_∞, M/K and $L_{50\%}$ (around the literature/reference values) was also carried out overestimating and underestimating them by 5 and 10%.

From the reference model, we can conclude that the stock is exploited at the MSY level and the optimal yield is attained (Table 8.8.1 and Figure 8.8.1). Immature individuals are well preserved whereas the proportion of mega-spawners is low, although it has been increased in the last years.

Finally, the sensitivity analysis shows that (Figure 8.8.2):

- L_∞: overestimation of this parameter leads to a decrease in the proportion of mega-spawners and also affects the MSY indicator, although this indicator is red for some years it is not worrisome since its values are close to 1. Underestimation leads to the opposite situation, the proportion of mega-spawners increases attaining values above the threshold of 0.3.
- M/K: the conclusions are similar to the ones derived from the reference model (although under overestimation the proportion of mega-spawners increase and is larger or close to the threshold of 0.3).
- L_{50}: overestimation leads to a decrease in the values of the indicators related to the conservation of immatures.

Although in the WKWEST benchmark (ICES, 2021) it was advised that the LBI is the preferred method for this stock, the LBSPR and MLZ were also computed for this stock to check if all the data-poor methods agree on the stock status. However, results of the LBSPR and MLZ should be taken with care once not all the assumptions of these methods are fully accomplished by this stock.

8.6.2 Length-based spawning potential ratio (LBSPR)

The values of the life-history parameters derived from a literature review are the following ones:

- M = 0.31 (by Cerim *et al.*, 2020), K = 0.22 (from Teixeira and Cabral, 2010, assuming the mean value of both sexes, as mentioned for LBI method) and consequently M/K = 1.41.
- L_∞ = 48.9 cm (see LBI method).
- L_{50} = 26 cm (see LBI method).
- L_{95} = 27.5 cm (derived from Bay of Biscay sole, i.e. sol.27.8ab Stock Annex).

The LFDs are the same used for the LBI method.

The SPR values for this stock vary from a minimum of 0.28 in 2015 to a maximum of 0.41 in 2019 (Figure 8.8.3). The SPR value for 2020 is 0.34. Overall the trend of the SPR is increasing and within the recommended range of 0.30–0.40.

8.6.3 Mean length-based mortality estimators (MLZ)

The Then *et al.* (2018) MLZ method was applied for this stock. Then *et al.* (2018) developed a new formulation of the Gedamke-Hoenig estimator (Gedamke and Hoenig, 2006), which uses additional information from a time-series of fishing effort to estimate the catchability coefficient q and the natural mortality rate M and thus year-specific total and fishing mortality rates.

The values of the life-history parameters derived from a literature review are the following:

- K = 0.22 (see LBI method).
- L_∞ = 48.9 cm (see LBI method).

The effort time-series was derived from the ratio of the catch and the commercial LPUE series of Portugal. It is worth noting that this time-series of effort only covers Portugal and thus it is not representative of the entire effort applied to this stock.

The output from the model indicates that the fishing mortality estimates range from a maximum of 0.38 at the beginning of the time-series (2012) to a minimum of 0.24 in 2013 (Figure 8.8.4). The value of F for 2020 is 0.27. Overall, the F time-series shows a decreasing pattern.

In addition, the Yield-Per-Recruit (YPR) estimations produce a F_{max} of 1.04 and $F_{0.1}$ of 0.32 (Figure 8.8.5).

8.7 General problems

Solea solea (SOL) is officially reported to ICES from Spain and France to the EWG through InterCatch by Division since 2009 and from 2011 by Portugal. For the other *Soleidae* species is distributed in 8.c and 9.a, namely *Solea senegalensis*, *Pegusa lascaris* and *Solea spp*. the information is not officially reported to ICES but it was required for the benchmark of the *S. solea* in 2021. The advice is provided for *Solea solea* while for the others species the reported landings for the period 2011 to 2020 were revised during the benchmark.

8.8 References

Cabral H. and Costa, M.J. 1999. Differential use of nursery areas within the Tagus estuary by sympatric soles, *Solea solea* and *Solea senegalensis*. Environmental Biology of Fishes 56: 389–397,1999.

Cerim, H. and Ateş, C. 2020. Age, growth and length-weight relations of common sole (*Solea solea* Linnaeus, 1758) from Southern Aegean Sea. Aquatic Sciences and Engineering, 35(2), 36–42.

Dinis, D,, Maia, C., Figueiredo, I. and Moreno, A. 2020. Information on *Soleidae* species landings from mainland Portugal. In ICES, 2020 (this report). Working Group for the Bay of Biscay and the Iberian Waters Ecoregion (WGBIE), Working Document 18.

Figueiredo, I., Maia, C., Lagarto, N. and Serra-Pereira, B. 2020. Bycatch estimation of Rajiformes in multispecies and multigear fisheries. Fisheries Research. 232: 105727.

Froese, R., Thorson, J.T. and Reyes, R.B., Jr (2014), A Bayesian approach for estimating length-weight relationships in fishes. J. Appl. Ichthyol., 30: 78–85. https://doi.org/10.1111/jai.12299.

Gedamke, T., and Hoenig, J.M. 2006. Estimating Mortality from Mean Length Data in Non-equilibrium Situations, with Application to the Assessment of Goosefish. Trans. Amer. Fish. Soc., 135:476–487.

ICES. 2017. Interim Report of the International Bottom Trawl Survey Working Group. IBTSWG Report 2017 27–31 March 2017. ICES CM 2017/SSGIEOM:01. 337 pp.

ICES. 2018. ICES reference points for stocks in categories 3 and 4. ICES Technical Guidelines. http://ices.dk/sites/pub/Publication%20Reports/Guidelines%20and%20Policies/16.04.03.02_Category_3-4_Reference_Points.pdf.

ICES. 2021. Benchmark Workshop on selected stocks in the Western Waters in 2021 (WKWEST). ICES Scientific Reports. 3:31. 504 pp. https://doi.org/10.17895/ices.pub.8137.

Jardim, E., Alpoim, R., Silva, C., Fernandes, A.C., Chaves, C., Dias, M., Prista, N. and Costa, A.M. 2011. Portuguese data provided to WGHMM for stock assessment in 2011. Working document presented in WGHMM (ICES, 2011) and WGNEW (ICES, 2012) Reports.

Lenth, Russell V. 2016. Least-Squares Means: The R Package lsmeans. Journal of Statistical Software, 69(1), 1–33. doi:10.18637/jss.v069.i01.

Lenth, Russell V. 2020. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.4.5. https://CRAN.R-project.org/package=emmeans.

Lindgren, F., Rue, H., Lindström, J. 2011. An explicit link between Gaussian fields and Gaussian Markov random fields: the stochastic partial differential equation approach. J R Stat Soc B Methods 73: 423–498.

Morgan, J.A., and Tatar J.F. 1972. Calculation of the Residual Sum of Squares for all Possible Regressions. Technometrics, 14, 317–325.

McLeod, A.I., and Xu, C. 2010. bestglm: Best Subset GLM. URL http://CRAN.Rproject.org/package=bestglm.

Muñoz, F., Pennino, M. G., Conesa, D., López-Quílez, A., and Bellido, J. M. 2013. Esti-mation and prediction of the spatial occurrence of fish species using Bayesian latent Gaussian models. Stochastic Environmental Research and Risk Assessment, 27(5), 1171–1180.

Paradinas, I., Conesa, D., López-Quílez, A. and Bellido, J.M. 2017. Spatio-temporal model structures with shared components for semi-continuous species distribution modelling. Spat Stat, 22:434–450.

Paradinas, I., Conesa, D., López-Quílez, A., Esteban, A., Martín López, L.M., Bellido, J.M. and Pennino, M.G. 2020. Assessing the spatio-temporal persistence of fish distri-butions: a case study on red mullet (Mullus surmuletus and M. barbatus) in the west-ern Mediterranean. Marine Ecology Progress Series. In Press.

Pennino, M.G., Maia, C., Rocha, A., Silva, C., Figueiredo, I., Cousido, M., Izquierdo, F., Cerviñol, S., Velasco, F., Teruel Gomes, J. and Rodrígues, J. 2021. Common sole (Solea solea) stock in ICES divisions 8c9a. Data compilation and preliminary assessment. Working document presented during the Data Compilation Meeting to of the ICES WKWEST2021.

R Core Team. 2021. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Rue, H., Martino, S. and Chopin, N. 2009. Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. J. R. Statist. Soc. B. 71 (2): 319–392.

Simpson, D., Rue, H., Riebler, A., Martins, T.G., Sorbye, S.H., *et al*. 2017. Penalising model component complexity: A principled, practical approach to constructing priors. Stat Sci, 32(1):1–28.

Teixeira, C M. and Cabral, H.N. 2010. Comparative analysis of the diet, growth and reproduction of the soles, Solea, solea and Solea senegalensis, occurring in sympatry along the Portuguese coast. Journal of the Marine Biological Association of the United Kingdom. 90(5): 995–1003.

Then, A.Y., Hoenig, J.M., and Huynh, Q.C. 2018. `Estimating fishing and natural mortality rates, and catchability coefficient, from a series of observations on mean length and fishing effort'. VIMS Articles. 749. https://scholarworks.wm.edu/vimsarticles/749.

Vinagre, C.M.B. 2007. Ecology of the juveniles of the soles, Solea solea (Linnaeus, 1758) and Solea senegalensis Kaup, 1858, in the Tagus estuary. Tese de Doutoramento em Biologia, especialidade Biologia Marinha e Aquacultura, 214 p.

8.9 Tables and figures

Table 8.3.1. Percentage of *S. Solea*, *S. senegalensis*, *Pegusa lascaris* and *Solea spp.* in the total landed weight of sole species from 2009–2020.

Year	*S. solea*	*S. senegalensis*	*P. lascaris*	*Solea spp*
2009*	100	0	0	0
2010*	100	0	0	0
2011	48	28	22	2
2012	47	25	26	2
2013	52	20	26	2
2014	53	28	18	1
2015	66	20	13	1
2016	69	18	13	0
2017	65	20	14	1
2018	62	25	13	1
2019	54	25	21	0
2020	50	29	21	0

Table 8.4.1. Catches (in tonnes) of *S. Solea, S. senegalensis, Pegusa lascaris* and Solea spp. from 2009–2020.

Year	*S. solea*	*S. senegalensis*	*P. lascaris*	*Solea spp.*	Total catch
2009*	190				190
2010*	247				247
2011	447	261	206	14	928
2012	354	191	200	14	759
2013	448	171	219	17	855
2014	458	243	156	10	867
2015	521	161	101	5	787
2016	485	126	94	2	707
2017	491	147	107	5	751
2018	431	171	92	5	698
2019	399	186	159	1	745
2020	431	248	183	1	864

*** No Portuguese data available in 2009 and 2010.**

Table 8.8.1. Traffic light indicator table for the LBI analysis.

	Conservation				Optimizing Yield	MSY
Year	Lc/Lmat	L25%/Lmat	Lmax5%/L∞	Pmega	Lmean/Lopt	Lmean/LF = M
2011	1.10	1.10	0.94	0.13	1.00	0.99
2012	0.83	1.02	0.90	0.17	0.96	1.12
2013	1.02	1.10	0.89	0.14	0.99	1.01
2014	1.02	1.10	0.91	0.15	0.99	1.02
2015	1.06	1.10	0.88	0.12	0.98	0.98
2016	0.87	0.98	0.93	0.17	0.95	1.08
2017	1.10	1.13	0.91	0.15	1.02	1.00
2018	1.02	1.10	0.93	0.18	1.00	1.03
2019	1.13	1.17	0.94	0.23	1.05	1.01
2020	1.06	1.10	0.89	0.20	1.03	1.03

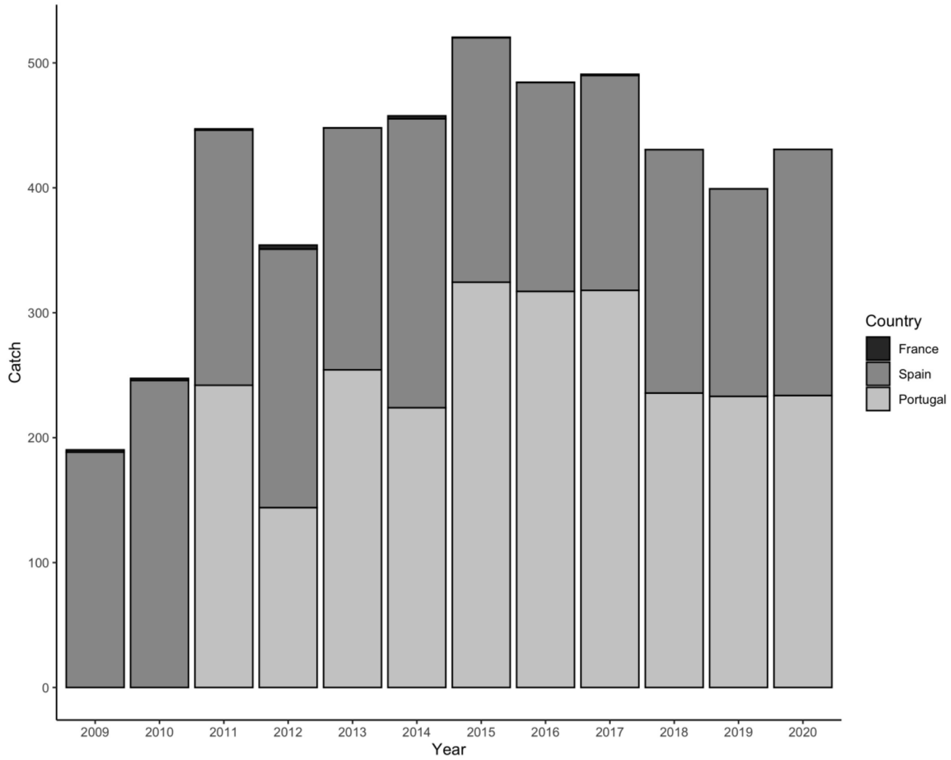

Figure 8.4.1. Catches for *Solea solea* in the ICES divisions 8.c and 9.a by country from 2009 to 2020. Source: InterCatch. Note that in 2009–2010 no Portuguese data were available.

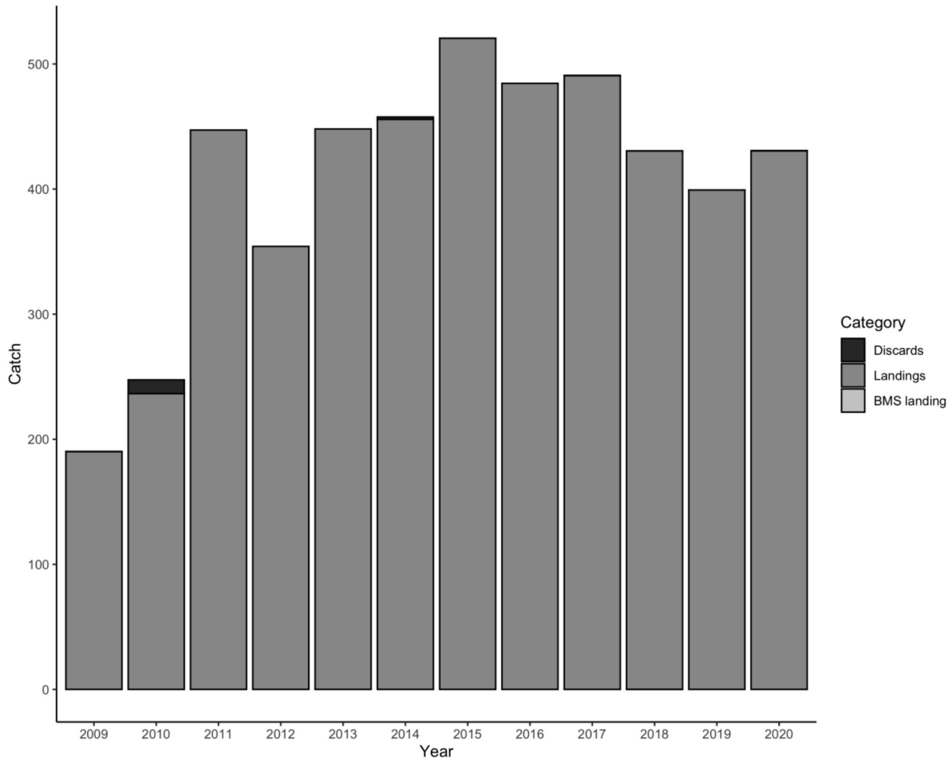

Figure 8.4.2. Catches for *Solea solea* by category (landings, discards, and BMS landing) in the ICES divisions 8.c and 9.a for Spain and France (2009–2020) and Portugal (2011–2020). Source data: InterCatch.

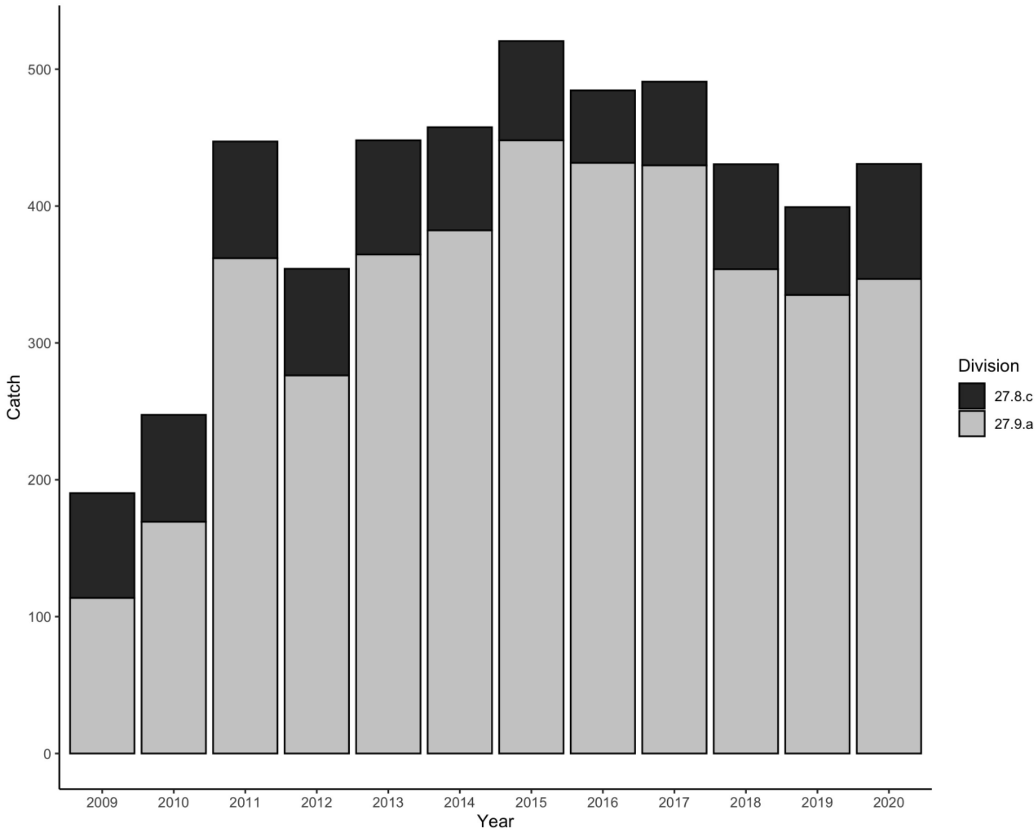

Figure 8.4.3. Catches for *Solea solea* by ICES divisions 8.c and 9.a for Spain and France (2009–2020) and Portugal (2011–2020). Source data: InterCatch.

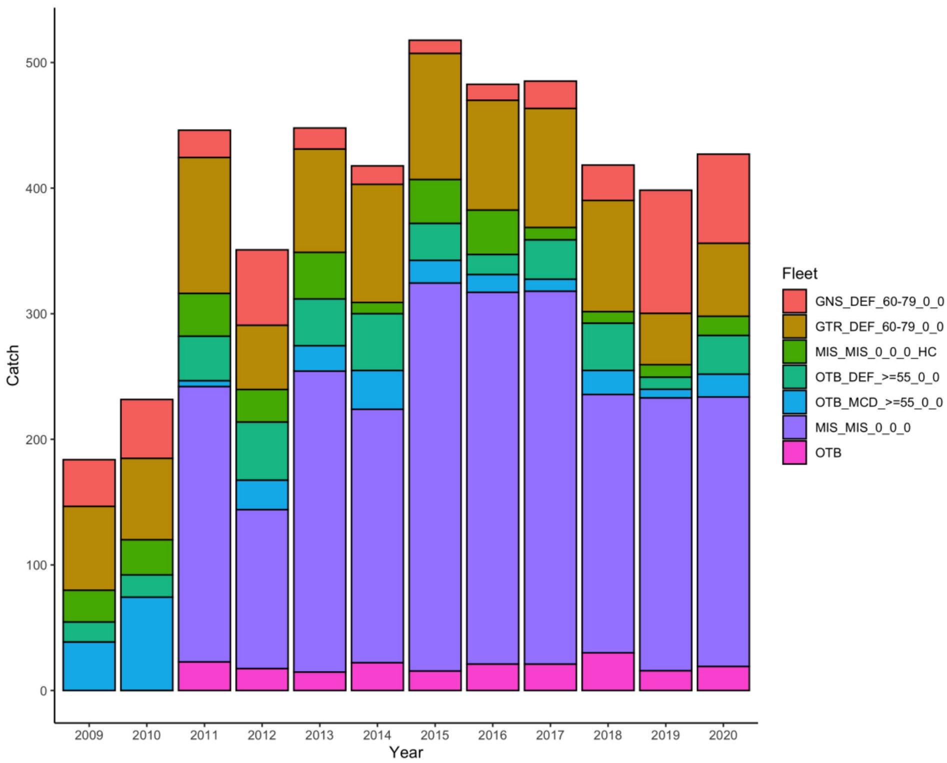

Figure 8.4.4. Catches for *Solea solea* by the main fleet in the ICES divisions 8.c and 9.a for Spain and France (2009–2020) and Portugal (2011–2020). Source data: InterCatch.

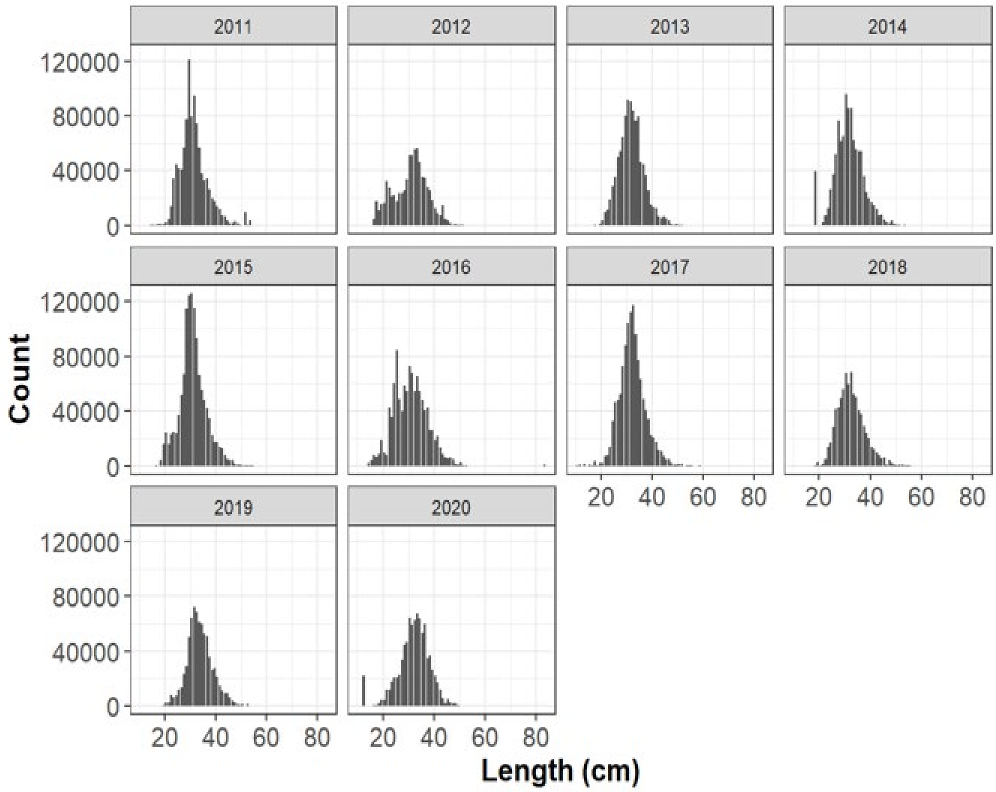

Figure 8.4.5. Annual length frequency distribution of catches for *Solea solea* in the ICES divisions 8.c and 9.a for the period 2011–2020, for Portugal and Spain. Source data: InterCatch.

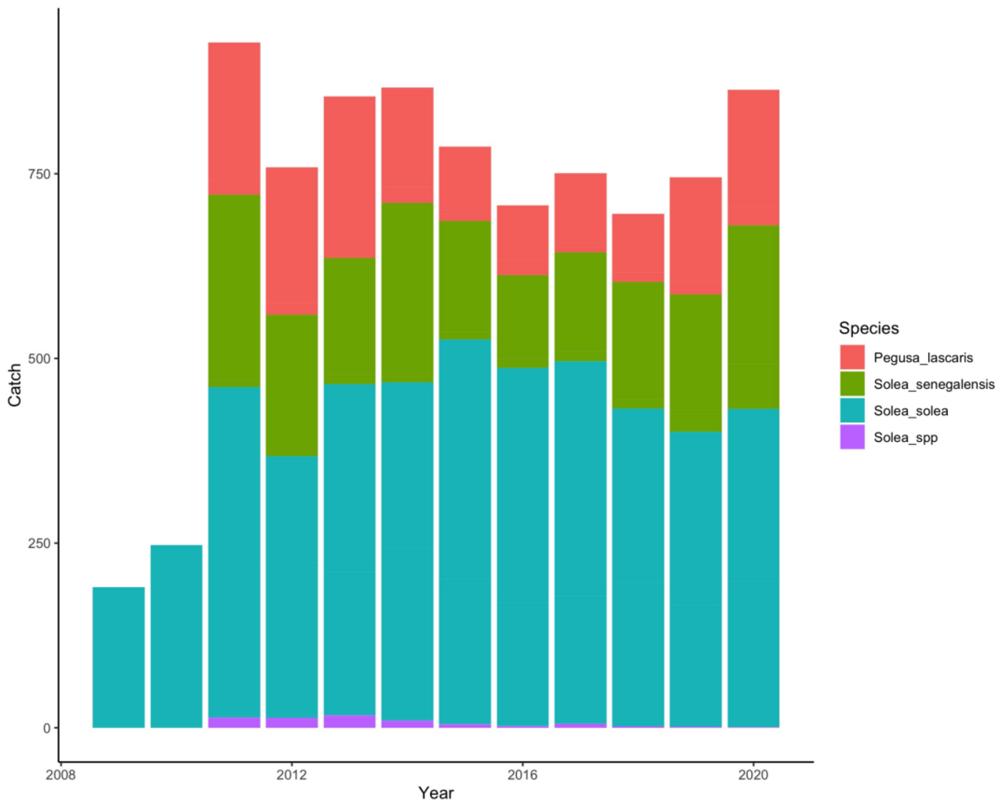

Figure 8.4.6. Sole species landings for divisions 8.c and 9.a. Data are from Spain and Portugal together. Please note that in 2009–2010 no Portuguese data were available.

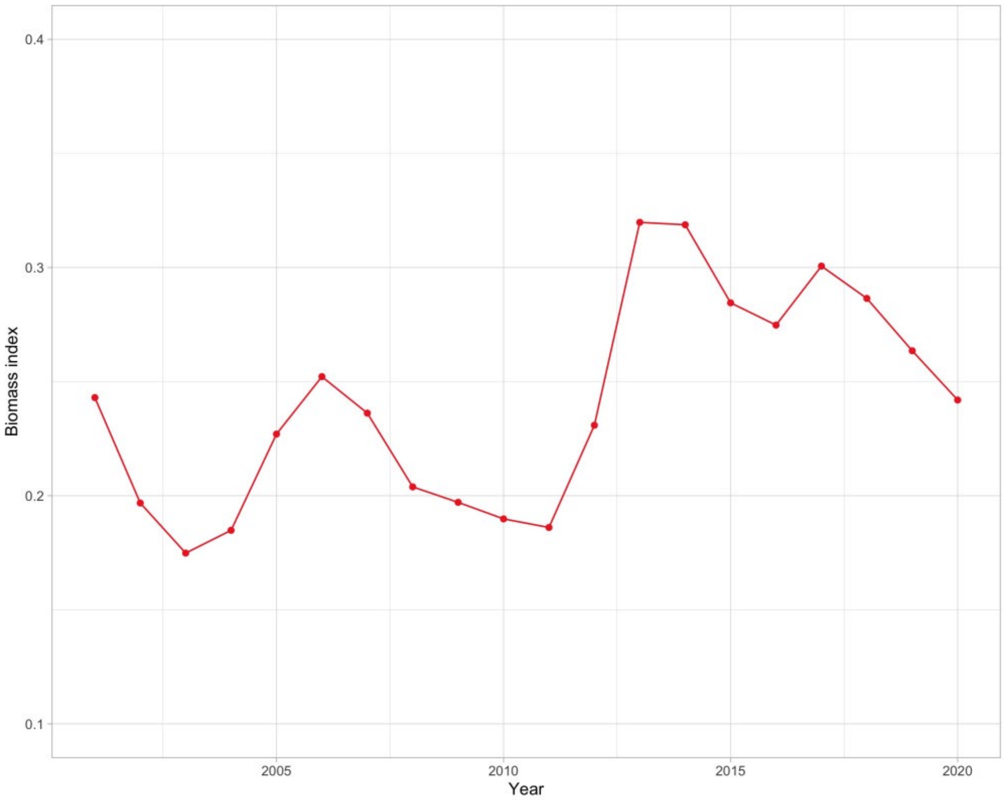

Figure 8.5.1. Temporal trend of the spatio-temporal biomass index for the G2784 for *Solea solea*.

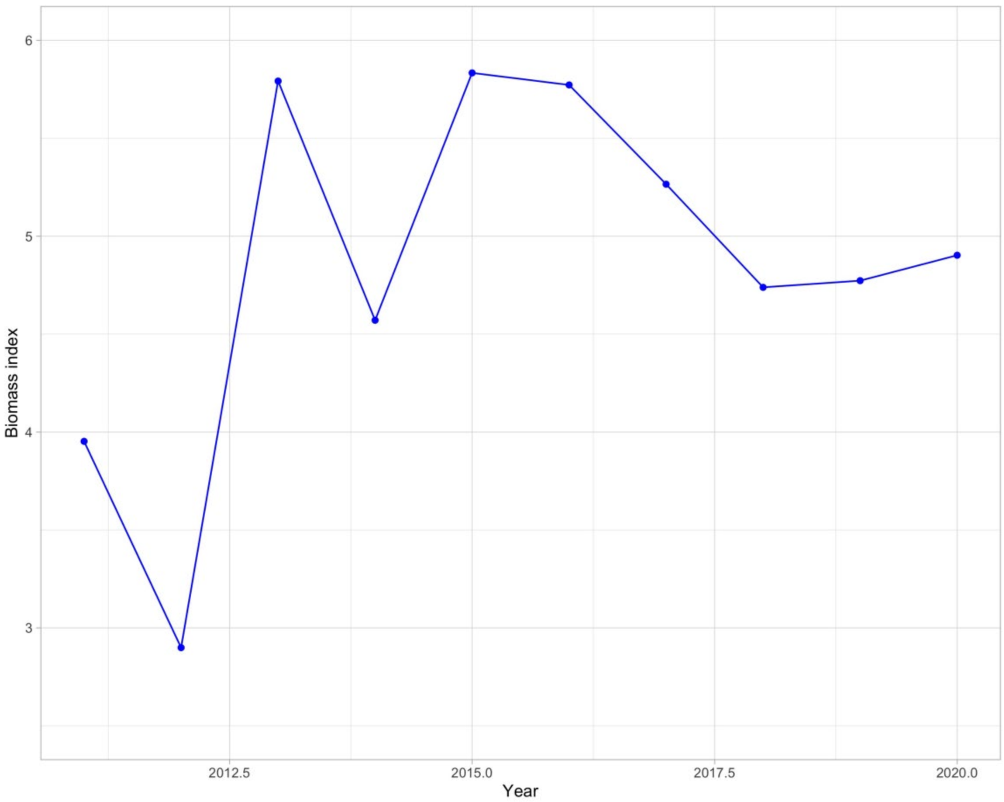

Figure 8.5.2. Standardized commercial LPUE of the Portuguese polyvalent fleet in ICES Subdivision 9.a for *Solea solea* (2011–2020).

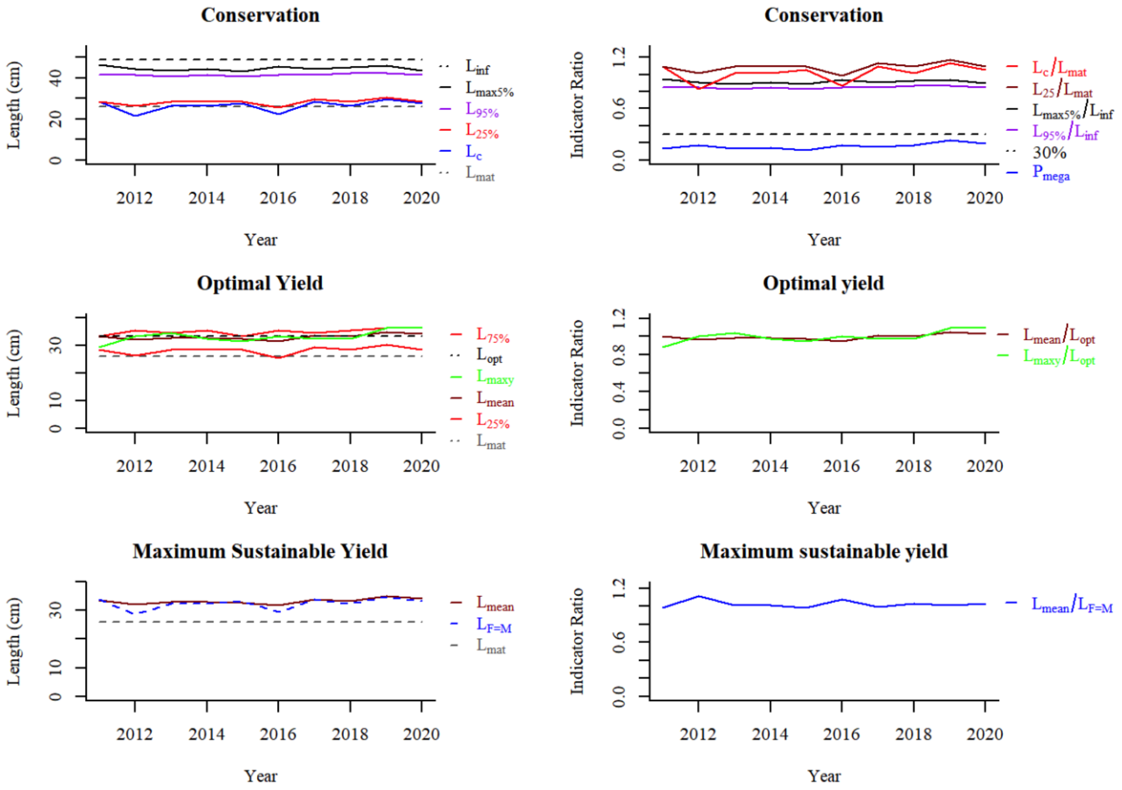

Figure 8.8.1. LBI indicators for *Solea solea* (2011–2020).

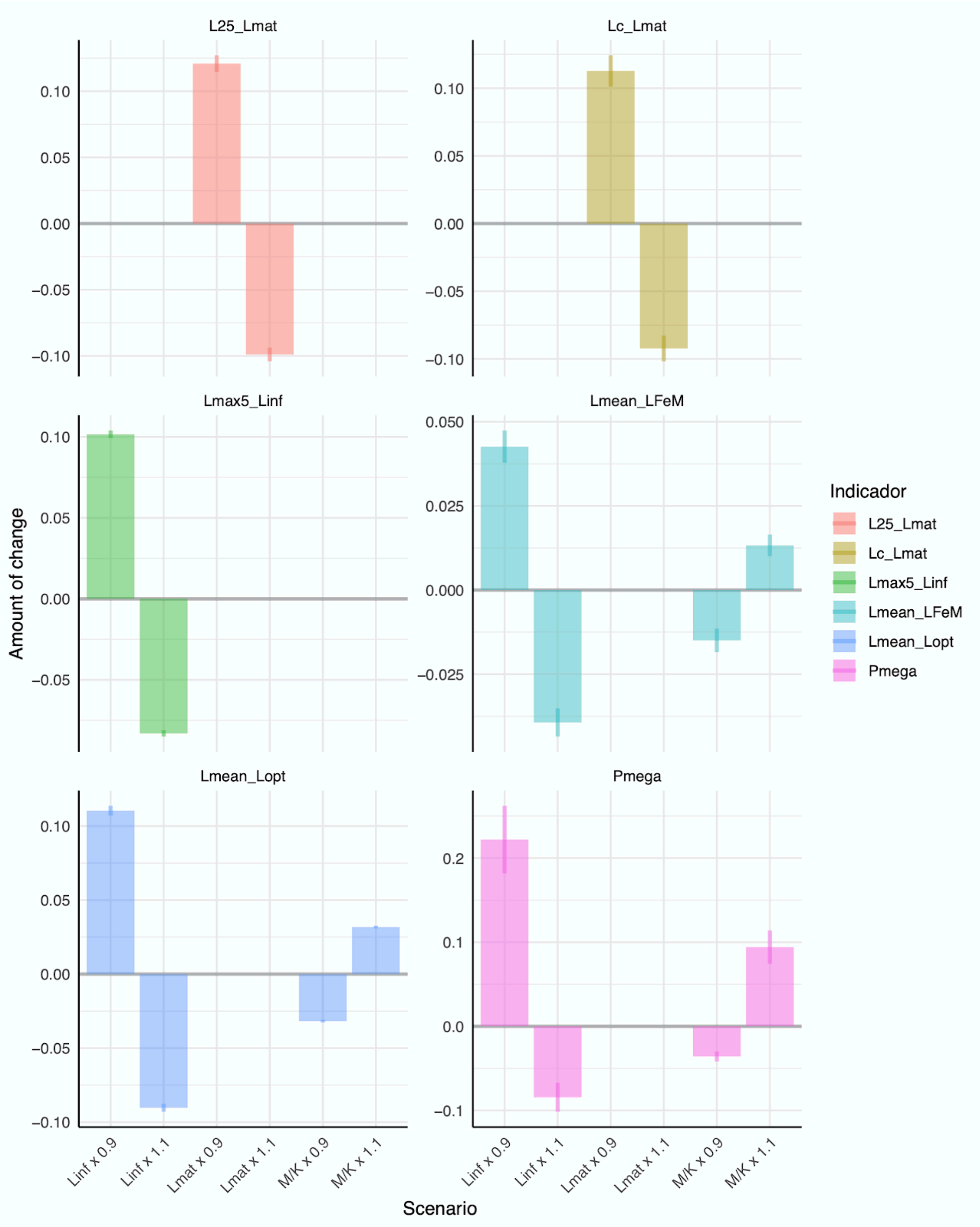

Figure 8.8.2. LBI sensitive analysis using underestimation and overestimation of L_{inf}, M/K and L_{50} parameters with respect the selected model values. The 95% confidence limits are represented through a vertical line.

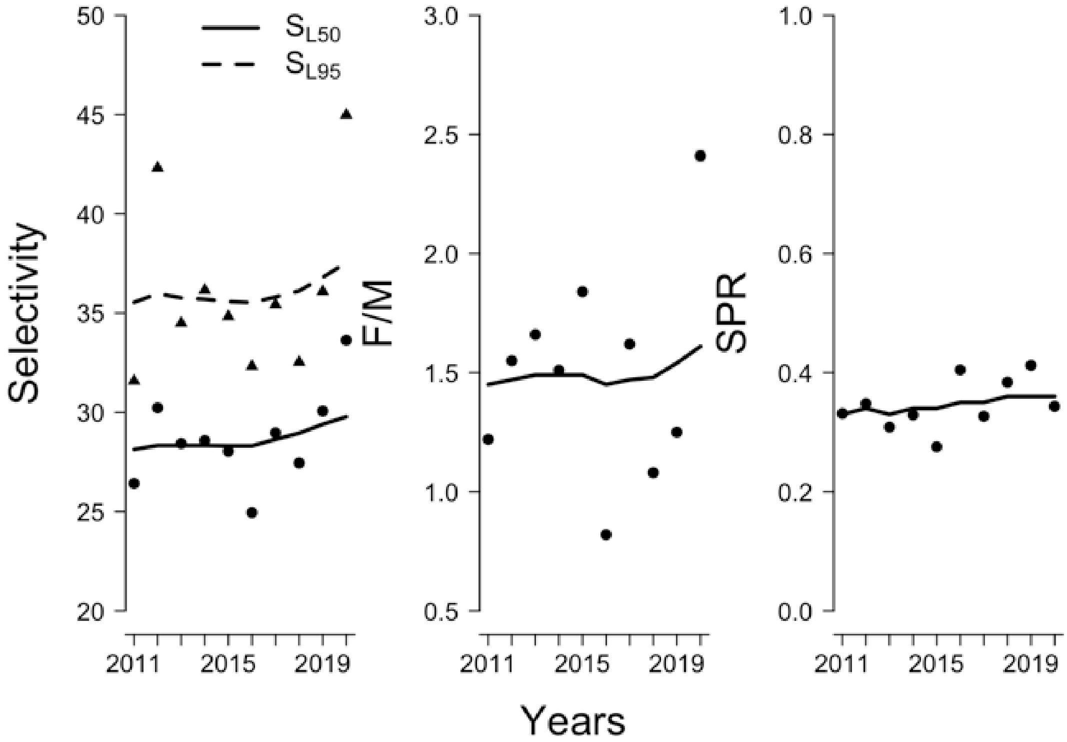

Figure 8.8.3. Results of the LBSPR method applied to *S. solea* in 2011–2020.

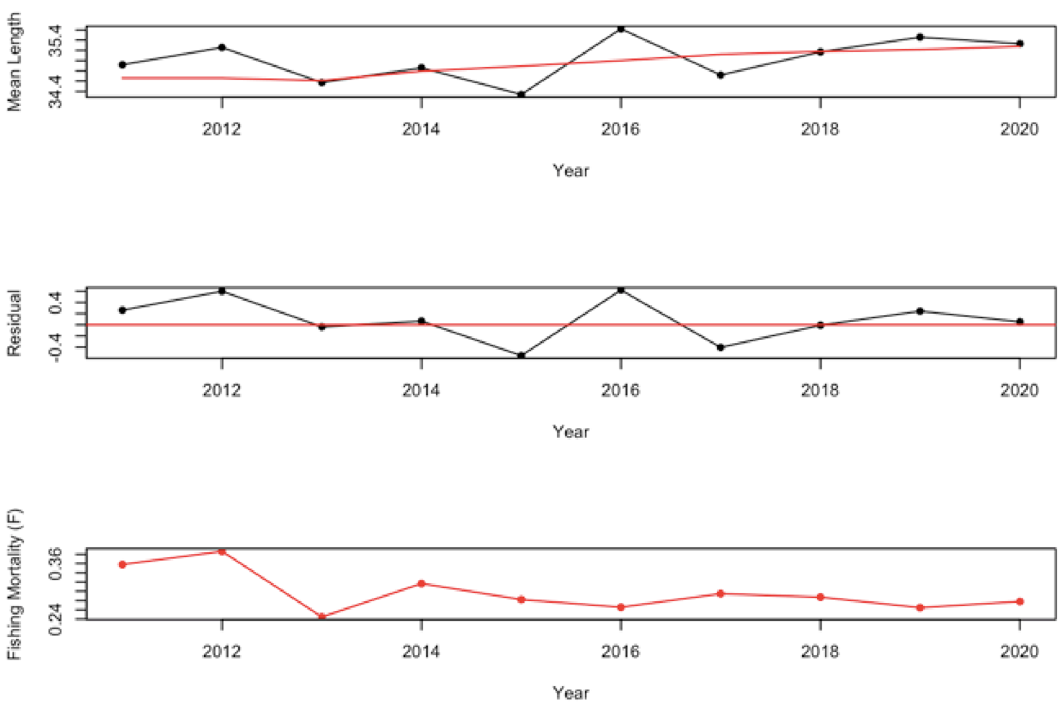

Figure 8.8.4. Fishing mortality trend computed using the MLZ model for *S. solea* in 2011–2020.

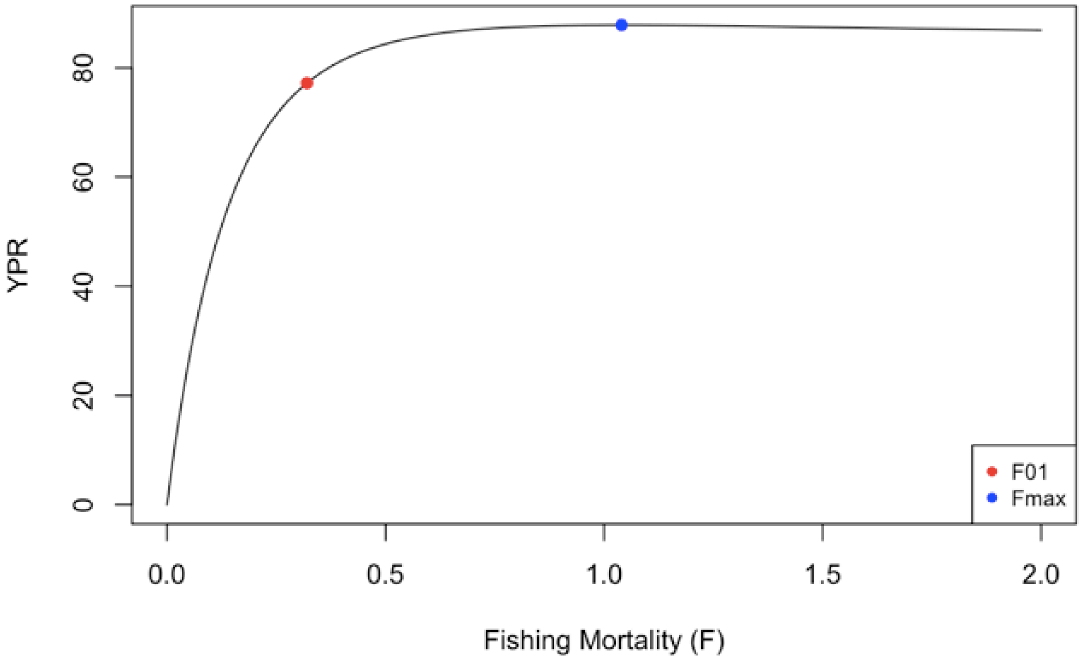

Figure 8.8.5. Yield-per-recruits approximation obtained with the MLZ methods for *S.solea* 2011–2020.