Common sole (*Solea solea*) stock in ICES divisions 8c9a. Data compilation and preliminary assessment.

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Background

The common sole (*Solea solea*, Linnaeus, 1758) is a species of flatfish which is widely distributed in Northeast Atlantic shelf waters, from the northwest of Africa to southern Norway, including the North Sea, the western Baltic and the Mediterranean Sea. Inhabiting sandy and muddy bottoms (Quero et al., 1986), this species is generally targeted by multi-species fleets (gillnetters and trawlers) and has traditionally been considered of great relevance due to its high commercial value (Teixeira and Cabral, 2010).
The life cycle of common sole is complex and presents different ontogenetic migrations (Tanner et al., 2017). Common sole spawn in coastal waters at depths ranging from 30 to 100 m (van der Land, 1991). The spawning period is commonly between February and May, although it can occur in early winter in warmer areas. The development of the larvae is temperature-dependent and takes place in shallow waters (Tanner et al., 2017). It is during transport from spawning areas to coastal nurseries that the larvae metamorphose into benthic life (Marchand, 1993). Nursery areas are generally located within estuaries where juveniles of common sole spend up to 2 years in a residence phase before returning to the adult feeding and spawning areas on the continental shelf (e.g., Vasconcelos et al., 2010).

The unit management of the common sole stock in the Iberian Atlantic waters includes the ICES Subdivision 8.c and 9.a. where both the Portuguese and Spanish fleets operate. In this area common sole is target mainly by multi-species fleets using as main fishing gears trammel and gill nets.

The minimum landing size of sole is 24 cm. There are other regulations regarding the mesh size for trammel and trawl nets, fishing grounds and vessel's size. Sole is under the Landing Obligation in Divisions 8.abde (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 gill nets, mesh size larger or equal to 100 mm) and in Division 9.a (all trammel nets and gill nets, mesh size larger or equal to 100 mm). In Portugal all catches of sole from all gears and mesh sizes are under the Landing Obligation (more restrictively than required by European regulations).

The common sole stock, sol8c9a, is considered as a data-limited stock and it is classified as category 5 stock, as only catches data were available. There is no analytical assessment for sole in this area. Since 2012, ICES provides scientific advice for this stock applying the precautionary approach. A precautionary buffer was applied in 2018 (≥20% reduction in catch relative to 2014-2016 average) and in 2019 (same catch value advised as 2018) with an advises that catches should be no more than 502 tones (2020-2021).
The advice and assessment are provided only for common sole species. The management of all sole species is provided under a unique combined Total Allowable Catch (TAC).

The EU multiannual plan (MAP; EU, 2019) for stocks in the Western Waters and adjacent waters applies to this stock. The MAP stipulates that when the F_{MSY} ranges are not available, fishing opportunities should be based on the best available scientific advice.
At the moment this stock is going to be benchmarked in the WKWEST21 (Data meeting: 1-4 December 2020; Assessment meeting: in February 2021) as well as the WKMSYSPiCT21. For the WKWEST21 an official data call was requested for this stock to get all the possible data, not only for the common sole (*S. Solea*) but also for the other sole species *Solea senegalensis*, *Pegusa lascaris* and sole spp.

Data

Catches

From the recent data call, catches for *S. solea* are available in InterCatch from 2009 to 2019 (Figure 1). Information on discards indicates that discarding can be considered negligible (< 1%).
For the years 2009-2010, only catches from Spain and France were available (Figure 2), while for the other years (2011-2019) catches are available for the three countries (i.e., Portugal, Spain and France).
During the WGBIE2020, Portuguese's colleagues highlight that catches from Portugal have a problem of misidentification in some ports with the three species (Dinis et al., 2020).
For this benchmark, using data from the Data Collection Framework (DCF) sampling, 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) (see details in annex 1).
At the moment the new data are considered reliable.

From the "*Historical Nominal Catches from 2000-2010, Source: Eurostat/ICES database on catch statistics - ICES 2011, Copenhagen. Version 26-06-2019*" dataset, catches are available for *S. sole* for 2000-2010 but some years data were reported only by Portugal, others by Spain and for this reason are considered possible underestimated (Figure 3).

When catches are analyzed by division it is possible to see that the majority of them are in the Area 9a (Figure 4).
Different métiers fish this stock (Figure 5). However, when the proportion of the catches by fleet on the total catches is computed (Table 1) it is possible to see that there are two main métiers that catch this stock, the "MIS_MIS_0_0_0" from Portugal and "GRT_DEF_60-79_0_0" from Spain (Figure 6).

When catches are analyzed by quarter it is possible to see that the distribution is almost homogenous along the year (Figure 7), also for the two main countries (i.e. Portugal and Spain) (Figure 8), as well as for the main métiers (Figure 9).

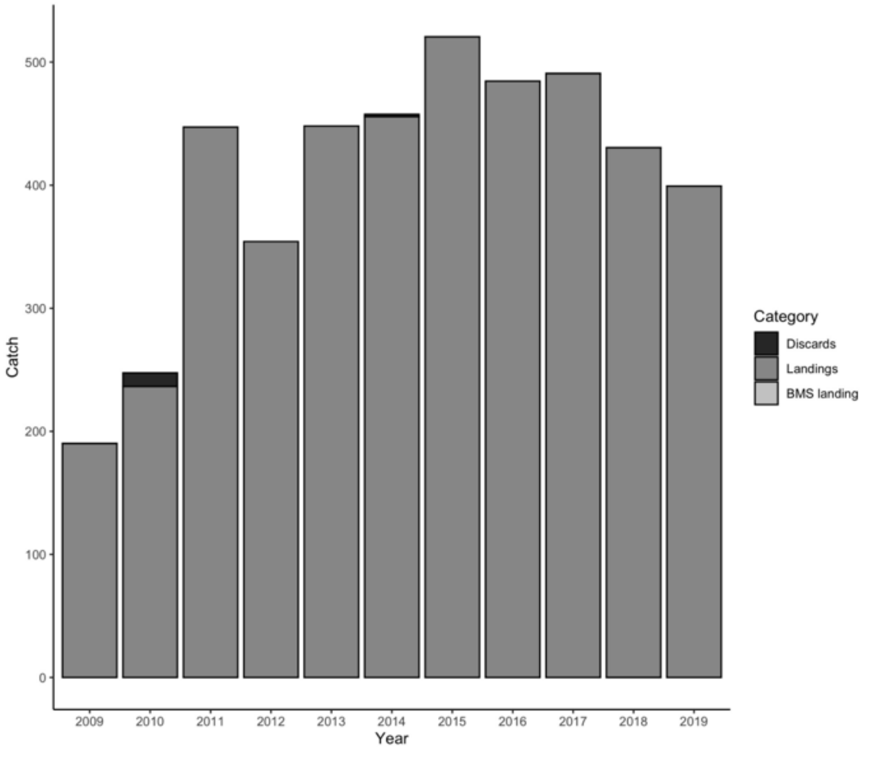

Figure 1: Catches for *Solea solea* by category in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

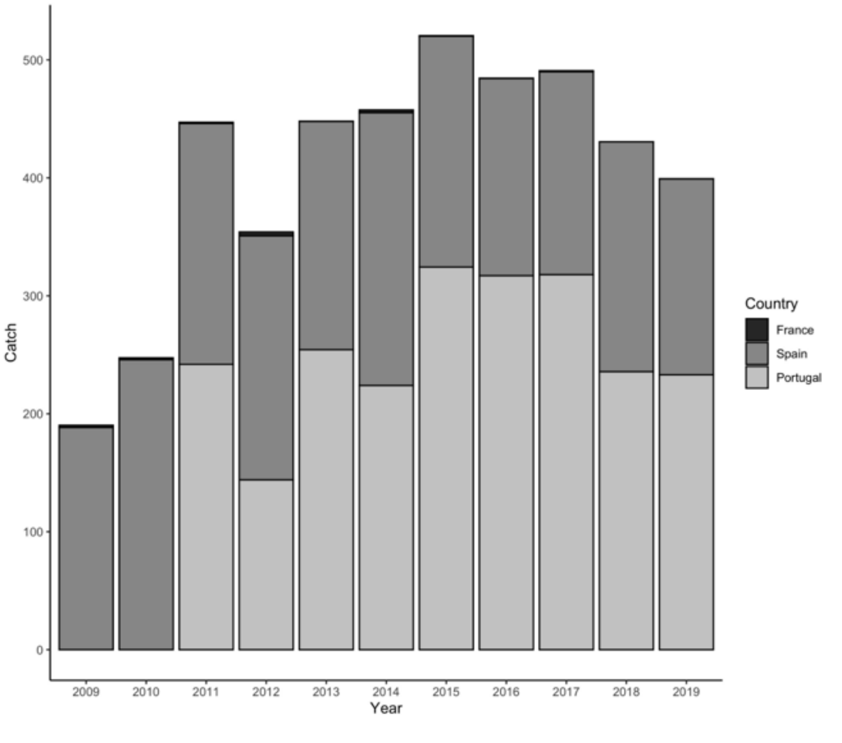

Figure 2: Catches for *Solea solea* by country in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

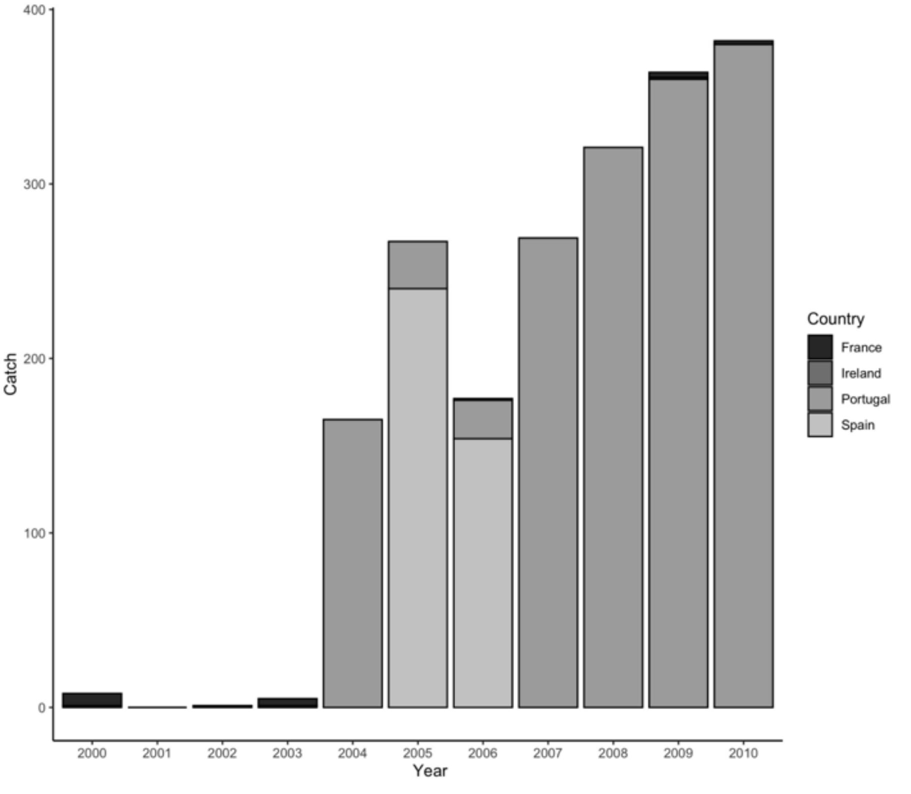

Figure 3: Catches for *Solea solea* by country in the ICES divisions 8c9a for Portugal, Spain, Ireland and France from 2000 to 2010. Source data: Eurostat/ICES database on catch statistics.

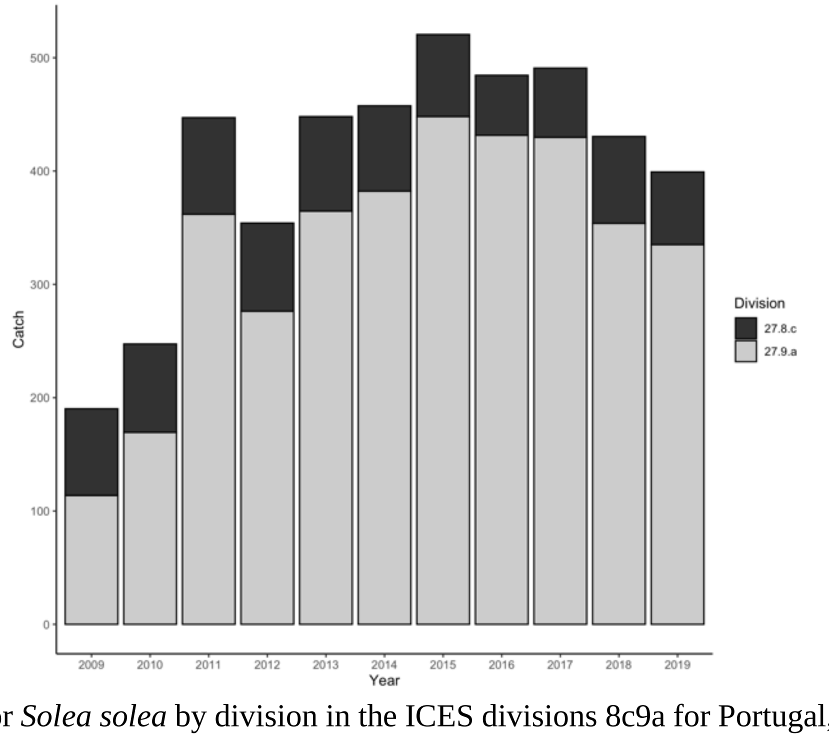

Figure 4: Catches for *Solea solea* by division in the ICES divisions 8c9a for Portugal, Spain, Ireland and France from 2000 to 2010. Source data: Eurostat/ICES database on catch statistics.

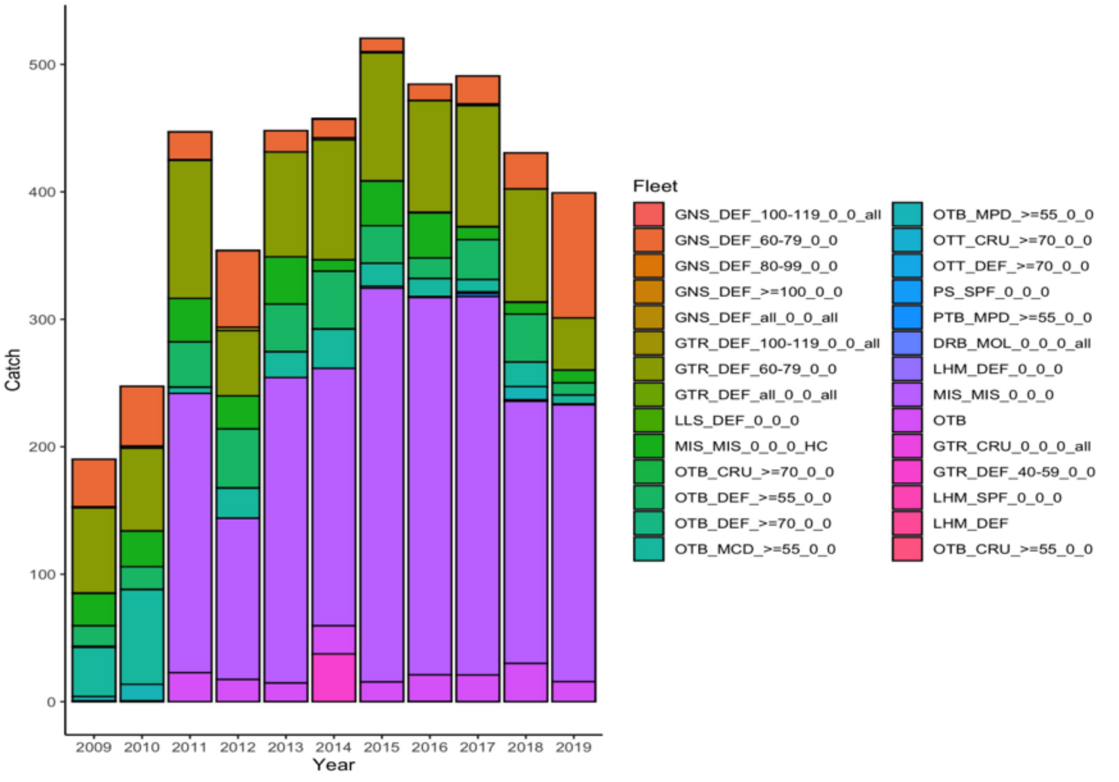

Figure 5: Catches for *Solea solea* by fleet in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

Table 1: Proportion of the catches by metier with respect the total catches by year.

Metier	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
GNS_DEF100_119_0_0_all	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GNS_DEF_all_0_0_all	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GNS_DEF_60-79_0_0	**0.05**	**0.17**	**0.04**	**0.03**	**0.02**	**0.03**	**0.04**	**0.07**	**0.25**
GTR_DEF100-119_0_0_all	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GTR_DEF_60-79_0_0	**0.24**	**0.14**	**0.18**	**0.21**	**0.19**	**0.18**	**0.19**	**0.21**	**0.10**
GTR_DEF_40-59_0_0	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
GTR_CRU_0_0_0_all	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTB_CRU_>=70_0_0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTB_DEF_>=55_0_0	0.08	0.13	0.08	0.10	0.06	0.03	0.06	0.09	0.02
OTB_DEF_>=70_0_0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTB_MCD_>=55_0_0	0.01	0.07	0.05	0.07	0.03	0.03	0.02	0.04	0.02
OTB_MPD_>=55_0_0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
OTB	0.05	0.05	0.03	0.05	0.03	0.04	0.04	0.07	0.04
OTT_DEF_>=70_0_0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OTT_CRU_>=70_0_0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MIS_MIS_0_0_0_HC	0.08	0.07	0.08	0.02	0.07	0.07	0.02	0.02	0.02
MIS_MIS_0_0_0	**0.49**	**0.36**	**0.53**	**0.44**	**0.59**	**0.61**	**0.60**	**0.48**	**0.54**

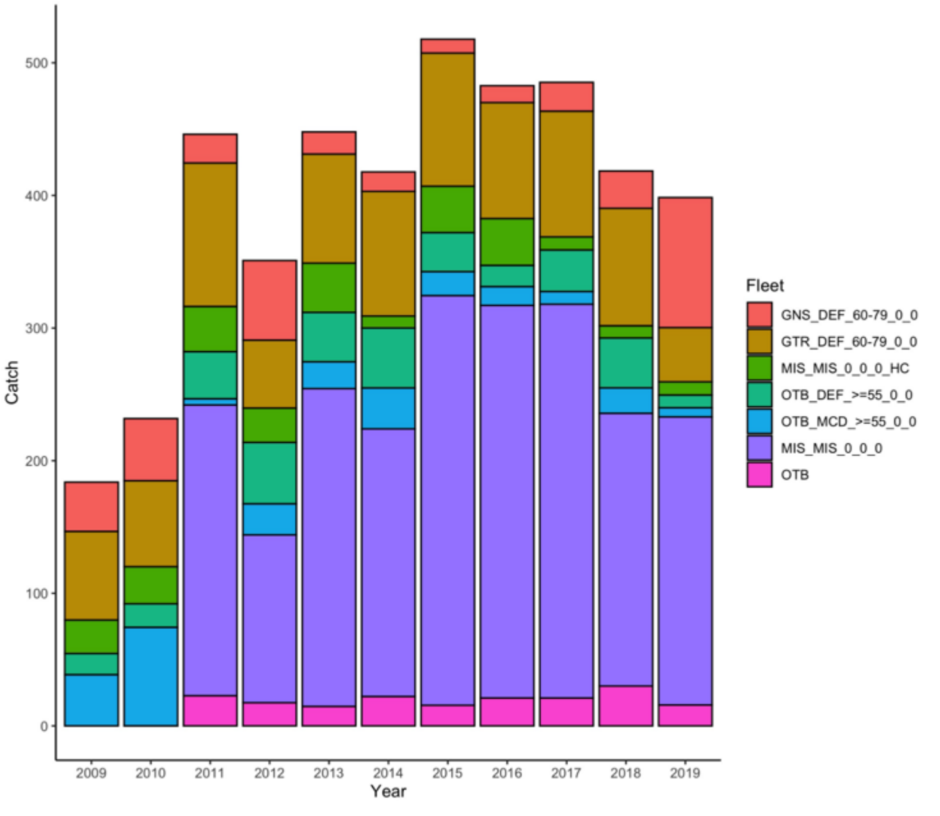

Figure 6: Catches for *Solea solea* by the main fleet in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

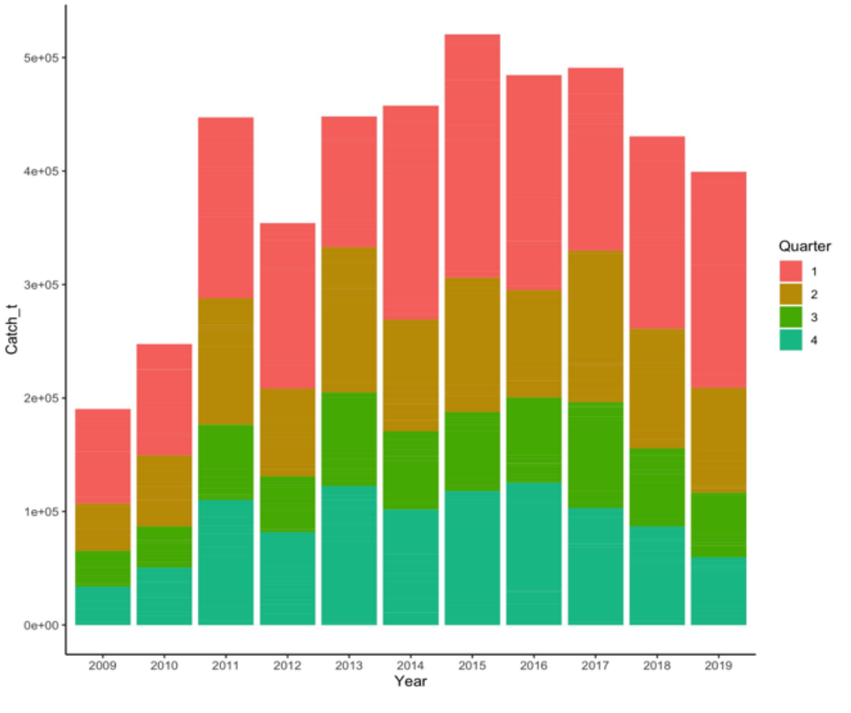

Figure 7: Catches for *Solea solea* by quarter in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

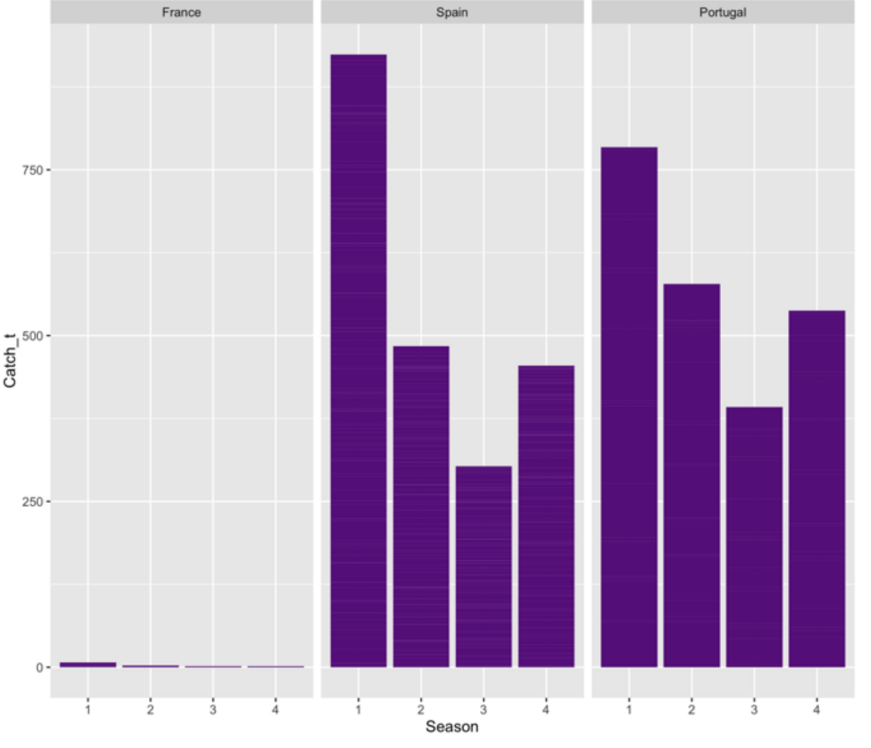

Figure 8: Catches for *Solea solea* by quarter and country in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

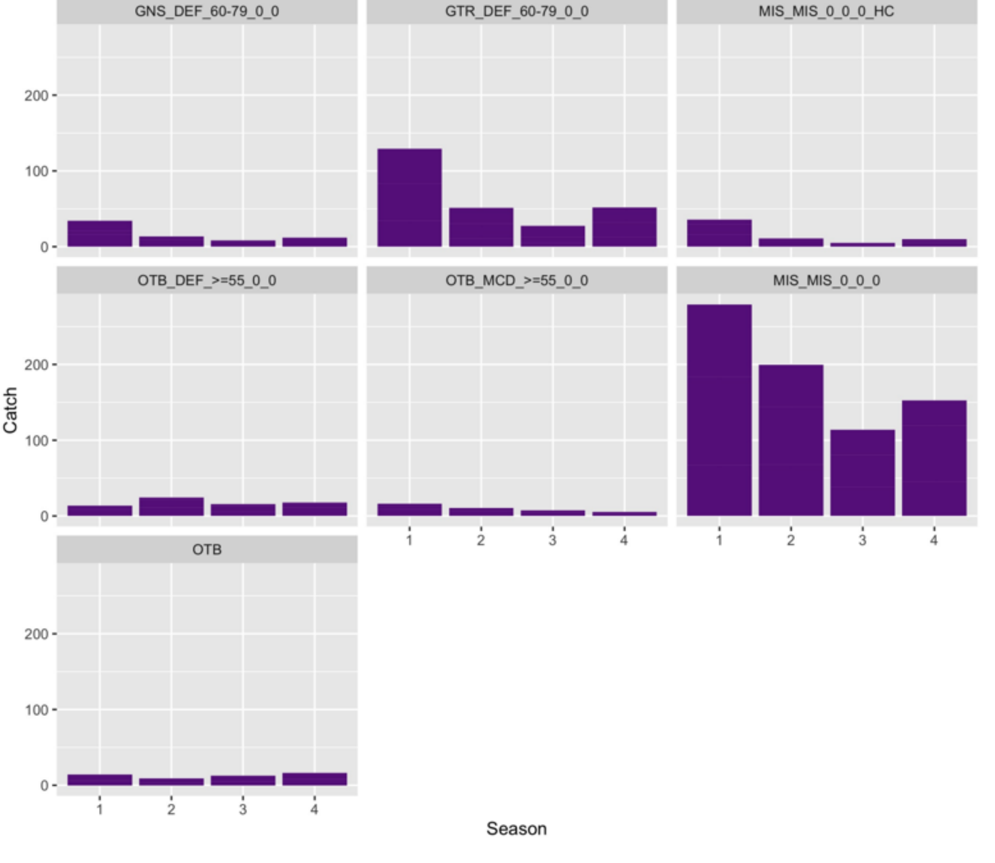

Figure 9: Catches for *Solea solea* by quarter and the main fleet in the ICES divisions 8c9a for Portugal, Spain and France from 2009 to 2019. Source data: InterCatch.

Length distribution

In InterCatch data of length distribution are available for the years 2011-2019 (Figure 10). The majority of the data are of the polyvalent fleet (i.e. metier “MIS_MIS_0_0_0”) from Portugal (Table 2). The sampling level of this fleet is showed in Table 3.

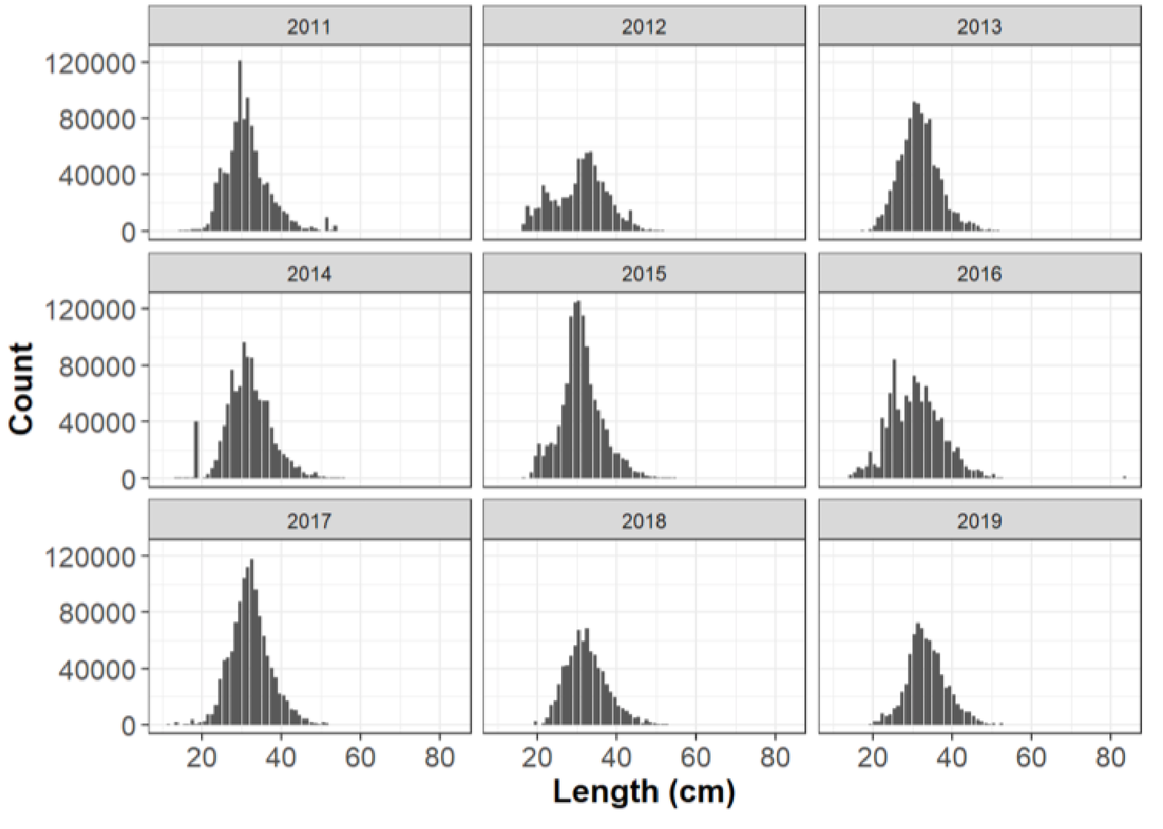

Figure 10: Length distribution of catches for *Solea solea* by year in the ICES divisions 8c9a for Portugal, Spain and France from 2011 to 2019. Source data: InterCatch.

Table 2: Proportion of catches of which length distribution data are available by fleets and year.

Year	OTB_MCD_>=55_0_0	GNS_DEF_60_79_0_0	OTB	OTB_DEF_>=55_0_0	GTR_DEF_60_79_0_0	MIS_MIS_0_0_0
2011	0.02	0.03	0.08	0.12		0.75
2012	0.11		0.08	0.22		0.59
2013	0.06		0.05	0.12		0.77
2014			0.07	0.13	0.20	0.60
2015	0.04		0.04	0.08		0.84
2016	0.03		0.06	0.05		0.86
2017	0.01	0.02	0.05	0.08	0.10	0.74
2018			0.11	0.14		0.75
2019		0.13	0.05	0.03	0.07	0.72

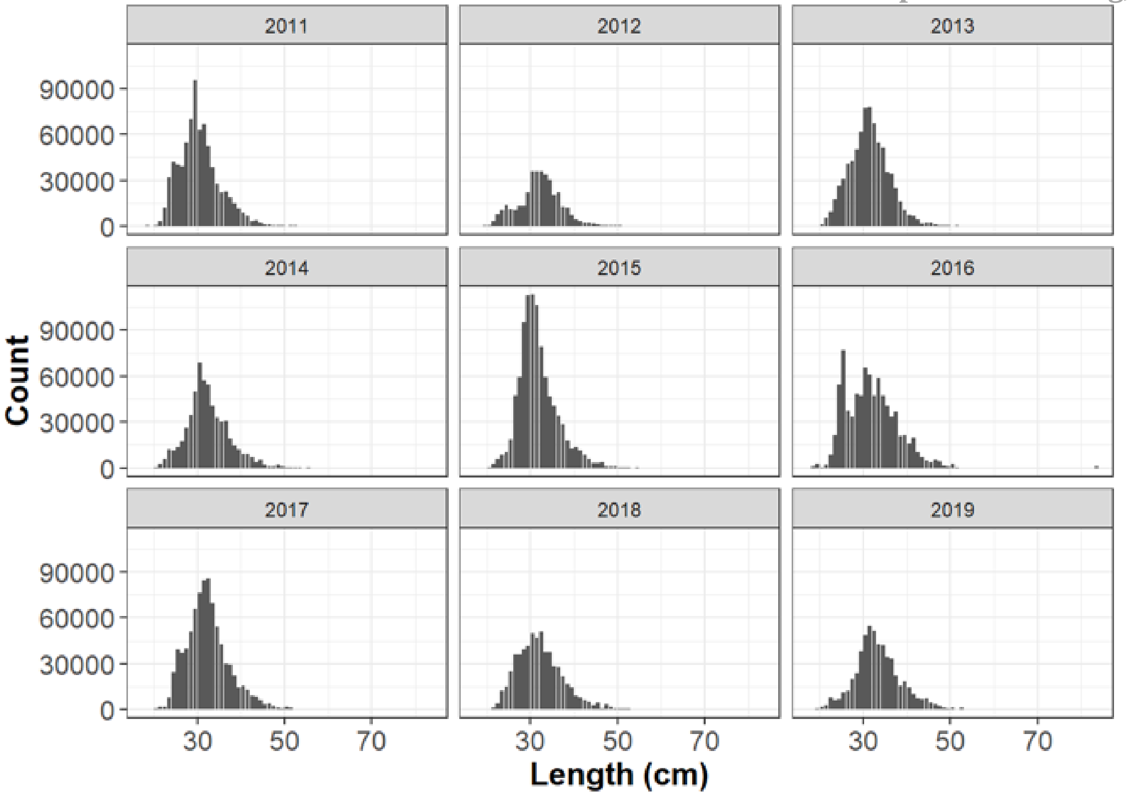

Figure 11: Length distribution of catches for *Solea solea* for the polyvalent fleet (i.e. metier "MIS_MIS_0_0_0") from Portugal from 2011 to 2019. Source data: InterCatch.

Table 3: Sampling level of the polyvalent fleet (i.e. metier "MIS_MIS_0_0_0") from Portugal from 2011 to 2019 for *Solea solea* catches.

Year	quarter	Weight sampled	N_trips_sampled	N_ind_sampled	N_ind_sampled_rounded
2011	1	434.15	32	1255.792957	1256
2011	2	264.21	53	1129.736434	1130
2011	3	197.18	46	898	898
2011	4	328.76	53	1099.621128	1100
2012	1	426.75	38	1262.444966	1262
2012	2	158.25	39	579.3333333	579
2012	3	253.58	45	1020.217914	1020
2012	4	319.89	52	969.914165	970
2013	1	1054.18	59	2661.538692	2662
2013	2	445.74	71	1738.379368	1738
2013	3	204.1	39	798.9576068	799
2013	4	468.68	40	1525.620143	1526
2014	1	1050.01	69	2584.5385	2585
2014	2	148.51	54	523.7630662	524
2014	3	114.98	35	407	407
2014	4	207.22	37	619.8571429	620
2015	1	1251.66	60	3557.671448	3558
2015	2	186.22	48	609.9268551	610
2015	3	310.02	39	836.1594119	836
2015	4	409.2	40	1227.930597	1228
2016	1	832.74	47	1622.107357	1622
2016	2	370.32	42	1478.164061	1478
2016	3	236.3	34	909.194498	909
2016	4	686.54	44	1488.60686	1489
2017	1	573.8566861	55	1144	1144
2017	2	202.1950331	43	664.5412844	665
2017	3	120.2943545	33	398	398
2017	4	275.4673121	28	803.1052632	803
2018	1	411.6433341	38	854.9257642	855
2018	2	373.8434497	55	961.720556	962
2018	3	109.3227089	31	361	361
2018	4	212.3981377	33	436	436
2019	1	672.067038	55	1156	1156
2019	2	136.2011109	37	369	369
2019	3	100.4059854	27	381	381
2019	4	141.3537688	29	321	321

Spanish abundance index from scientific survey

Common sole data was collected during the scientific survey series SP-NSGFS Q4 performed by the Instituto Español de Oceanografía (IEO) in autumn (September and October) between 2000 and 2019. Surveys were conducted on the northern continental shelf of the Iberian Peninsula (ICES divisions 8c and the northern part of 9a) which has a total surface area of almost 18,000 km^2 (Figure 12). The sea bottom composition of this area is mainly rock or sand sediments until 100 m of depth. Below 100 m depth, muddy bottoms characterize the Galician waters (ICES division 9a) whereas rocky ground and deep canyons are typical in the Cantabrian Sea (ICES division 8c) (Abad et al., 2019).
Surveys were performed using a stratified sampling design based on depth with three bathymetric strata: 70–120 m, 121–200 m and 201–500 m. Sampling stations consisted of 30 min trawling hauls located randomly within each stratum at the beginning of the design. The gear used is the baka 44/60 and the survey follow the protocol of the International Bottom Trawl Survey Working Group (IBTSWG) of ICES (ICES, 2017).

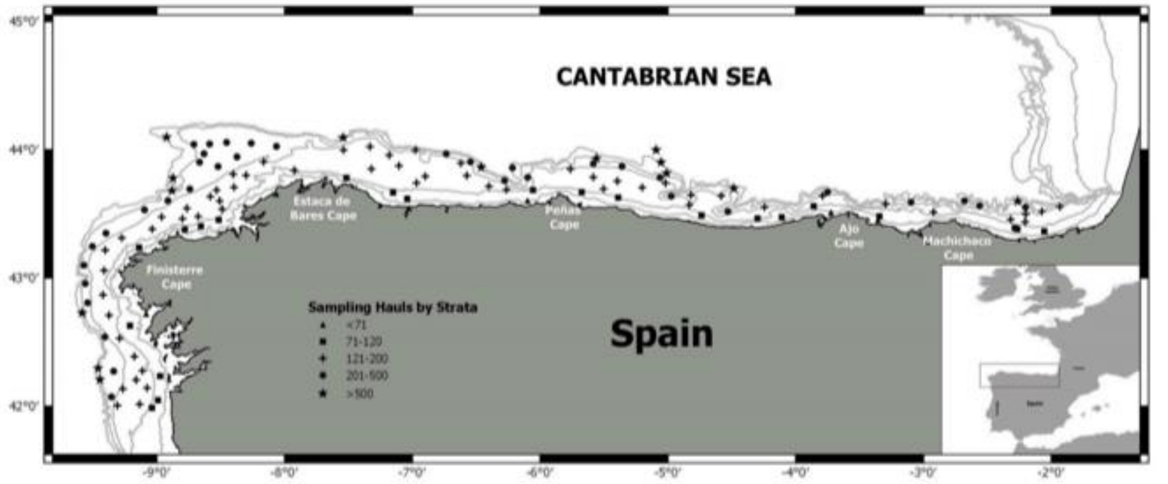

Figure 12: Map of the study area. Black dots represent annual sampling locations.

In Figure 13 are showed the hauls where common sole was found by year.

The common sole (*Solea solea*) is a species with a biological bathymetric range between 0 and 200 meters in the Iberian Atlantic waters. The SP-NSGFS Q4 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, we applied to this dataset a hurdle Bayesian spatiotemporal.
Two variables were analysed in order to characterize the spatiotemporal behaviour of common sole individuals. Firstly, a presence/absence variable was considered to measure the occurrence probability of the species. Secondly, the weight by haul (kg) was used as an indicator of the conditional-to-presence abundance of the species.
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).

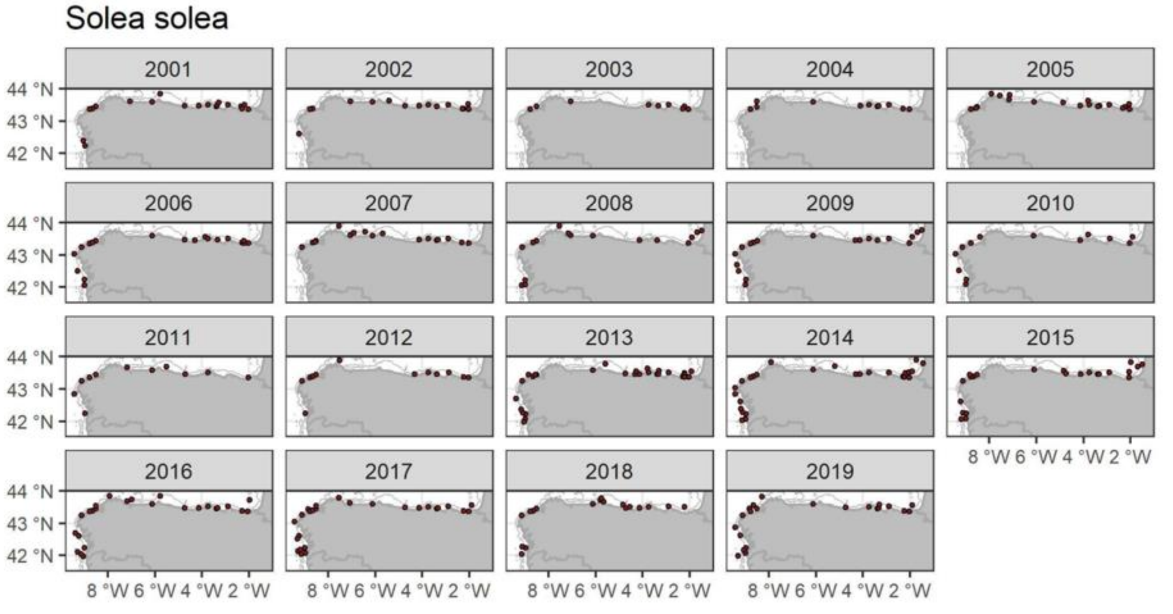

Figure 13: Dots indicates hauls where the species *S.Solea* was present by year.

Spatiotemporal modelling

An exploratory analysis highlighted that common sole abundance data have two main features, namely strong spatial and temporal dependence and a large proportion of observed zeros (i.e., zero inflated data). These data are commonly analysed using two-part models, also known as delta models (Quiroz et al., 2015) and in general, occurrence and abundance are modelled independently. However, the abundance and occurrence processes are often related, which consequently violates the independence assumption of common delta models (Pennino et al., 2019).

In this study we applied hurdle Bayesian spatiotemporal models that simultaneously fitted common sole occurrence and conditional-to-presence abundance processes while sharing bathymetry effects. These effects were incorporated as described in Paradinas et al., (2017, 2020) in order to integrate information on both the occurrence and the conditional-to-presence abundance to better fit informed environmental effects and avoid the violation of the aforementioned independence assumption.

Models were fitted using the integrated nested Laplace approximation approach INLA (Rue et al., 2009) in the R software (R Core Team, 2019). 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. This matrix depends on the distance between locations and two hyperparameters, r_w and σ_w representing the range and the variance of the spatial effect respectively (Muñoz et al., 2013).

As spatiotemporal 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) prior to allow 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.

Y_{st} and Z_{st} were considered the spatiotemporally distributed occurrence and conditional-to-presence abundance, respectively, s = 1, ..., n_t refers to the spatial location and t = 1, ..., m to the temporal index. 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 spatiotemporal effects as:

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

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 parametrised as unknown values f = $(f_0, \ldots\ f_{i-1})_t$ 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 spatiotemporal structures of common sole occurrence and conditional-to-presence abundance respectively.

Moreover, a median length model was fitted to assess whether different common sole life stages occupy different areas. Median length was modelled using a Gaussian distribution with the usual identity link. The distributed median length V_{st} was modelled as:

$$V_{st} \sim Gaussian(\mu_{st}, \sigma) \quad (2)$$
$$\mu_{st} = \alpha(V) + f(ds) + U_{st}(V)$$

where μ_{st} represents the mean while σ the variance of the distribution and the remaining model parameters follow the same structures as in Eq. (1). In addition, bathymetry f(ds) and the year effect g(t) were included in the model as explicative variables and fitted with RW2 functions.

The Bayesian approach requires prior distributions for all the parameters of the model and vague prior distributions for the dispersion and precision of the conditional-to-presence-abundance and median size models respectively. Following this approach, the fixed effects and the scaling parameter of the shared effects were assigned. 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, the most important results that we obtained are the predicted distribution of the species (Figure 14), the median length distribution (Figure 15) and a new spatiotemporal abundance index (Figure 16).

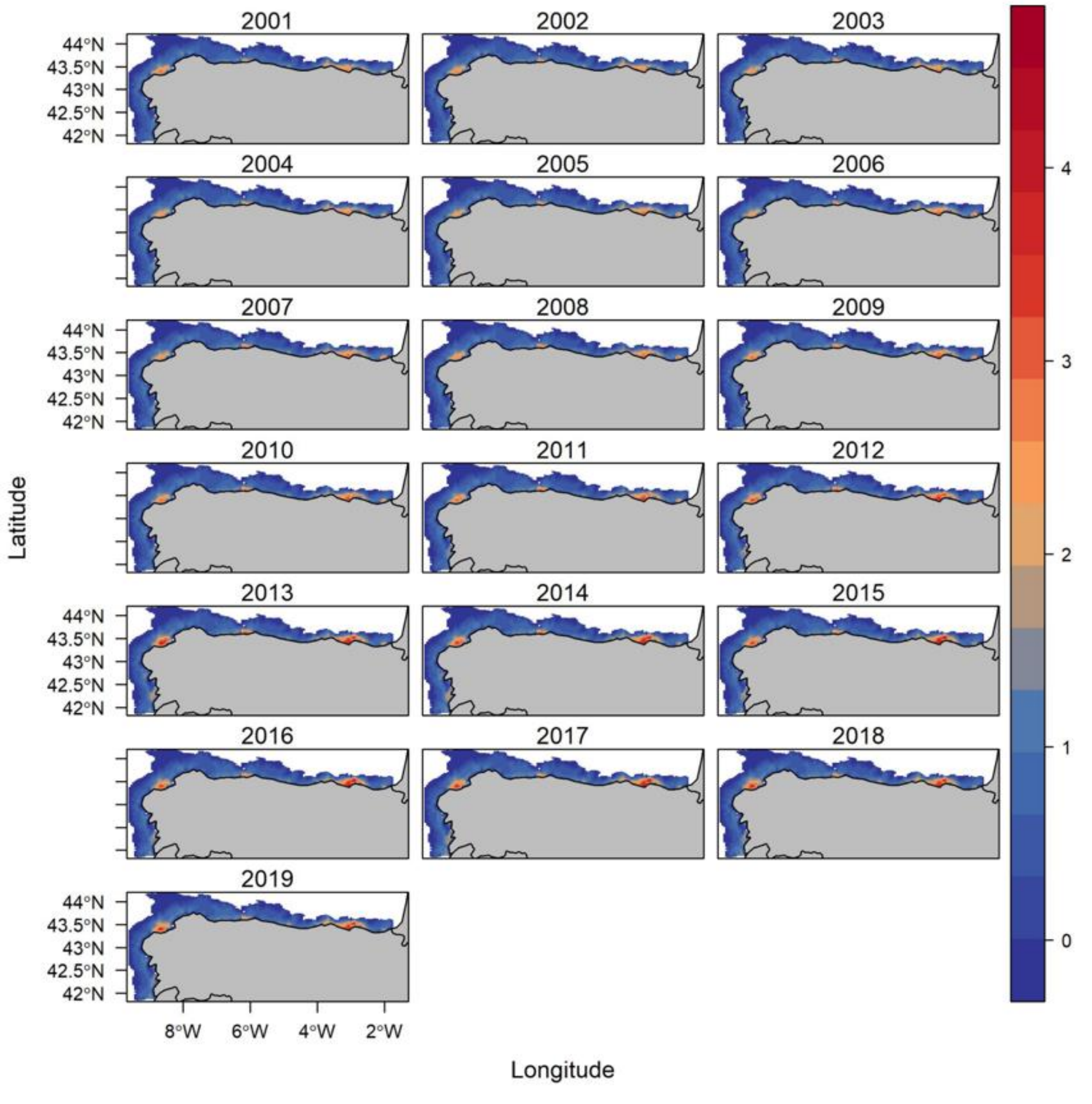

Figure 14: Prediction maps (2001-2019) of the common sole conditional-to presence median abundance estimated by the hurdle Bayesian spatiotemporal model.

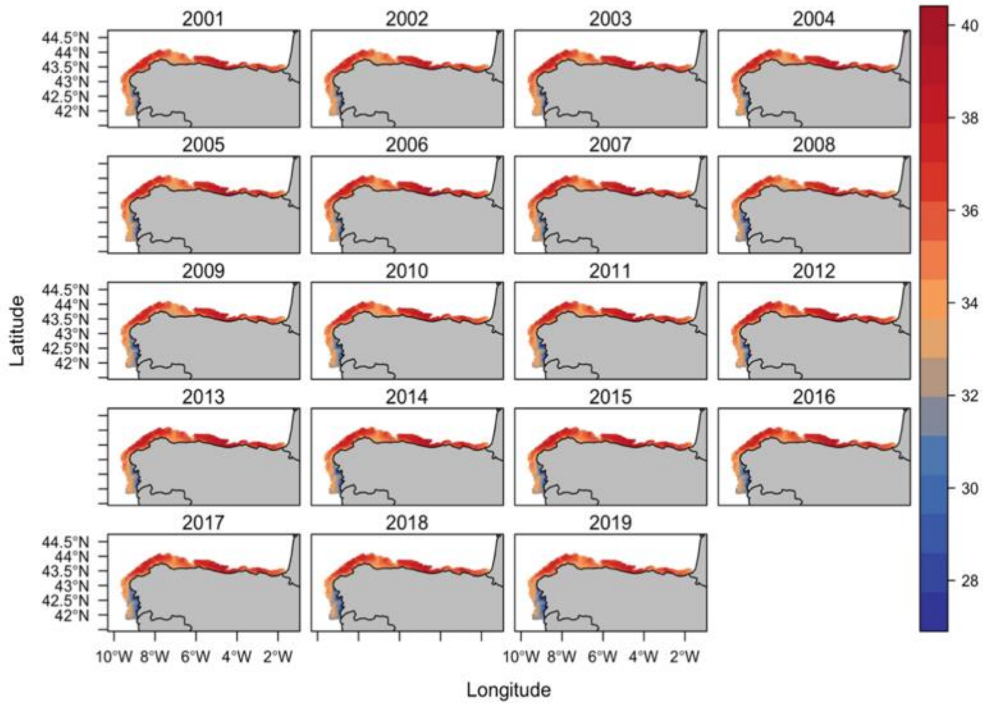

Figure 15: Prediction maps (2001-2019) of the common sole median length distribution estimated by the Bayesian spatiotemporal model.

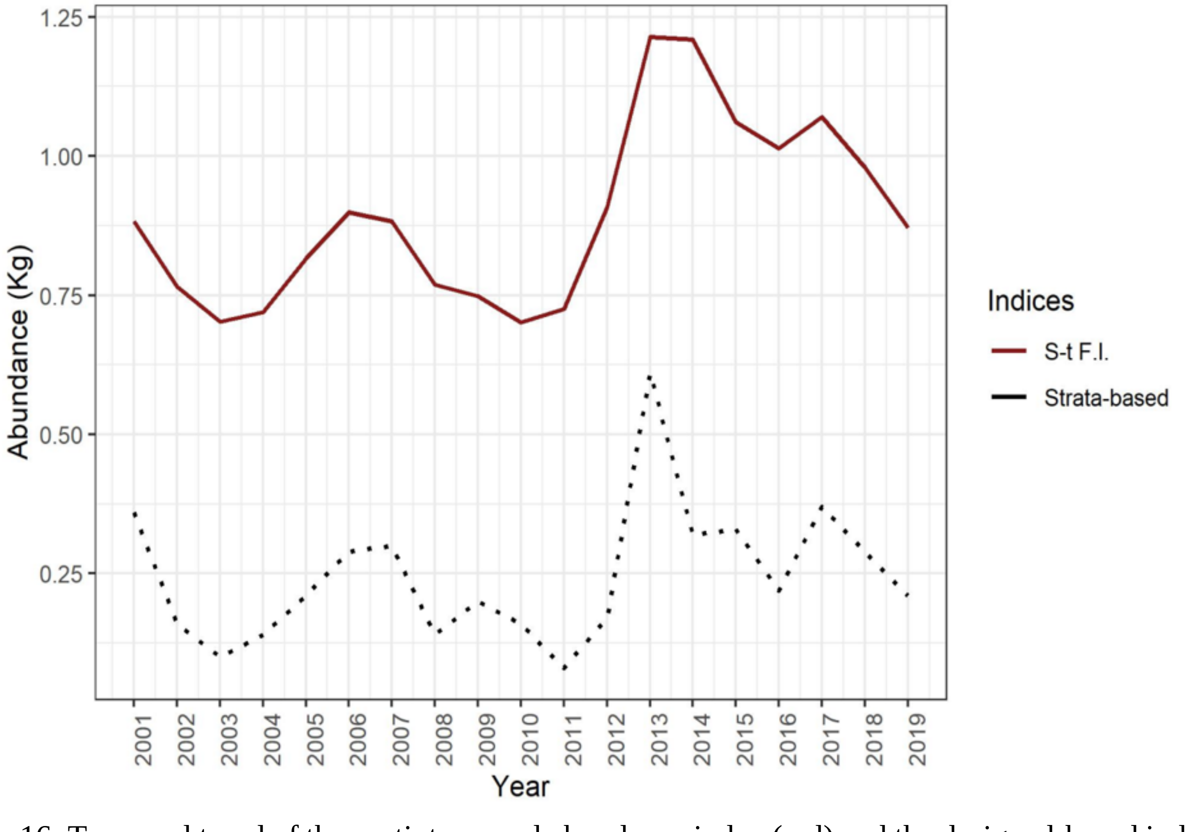

Figure 16: Temporal trend of the spatiotemporal abundance index (red) and the designed-based index for the SP-NSGFS Q4.

A sensitive analysis was performed to check if the area used to standardize the survey index and the area used by the Bayesian model for the prediction are similar (see Annex 1).

Catch Per Unit Effort (CPUE) from Spain

Fishery-dependent data were collected by the Galician government Technical Unit of Artisanal Fisheries (Unidade Técnica de Pesca de Baixura, UTPB, in Galician). Usually an on-board observer is assigned to fishing vessels randomly selected from this sector and covers the full set of multiple gears used in Galician waters and all along the geographical range (Figures 17 and 18). In a single trip each vessel usually performs several hauls. At each haul, observers record all basic operational data (i.e., date, geographical position, gear, etc.) and the number and weight of all retained and discarded taxa. The analysed database in this study counts 4350 hauls for which common sole was caught from January 2000 until December 2018.

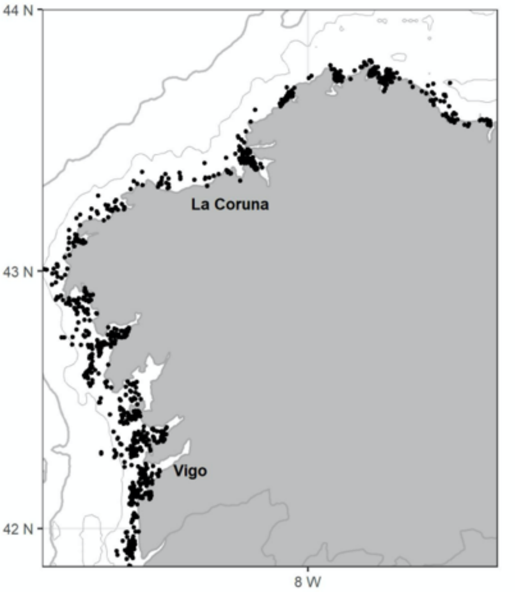

Figure 17: Data collected by observer on board on trammel net fleet in Galicia (Spain) from 2000-2018 for common sole (*S. Solea*).

Before fitting any model, we selected the data for the trammel net which is the most representative gear for the common sole in order to reduce sources of variation. This selection was based on three criteria: i) proportion of hauls with zero catch, ii) total number of individuals sampled and iii) the spatiotemporal coverage. The first and second criterion were used as proxies of gear catchability and thus constant catchability was assumed along the time series.

An exploratory analysis highlighted that common sole data have two main features, namely strong spatial and temporal dependence and a large proportion of observed zeros (i.e., zero inflated data). For this reason, we applied the same hurdle Bayesian spatiotemporal models that we performed for the SP-NSGFS Q4 data. As environmental variables we included bathymetry and type of substratum, both present in the dataset. Bathymetry was fitted using a non-linear RW2 effect. Gear saturation can exert a significant nonlinear effect on catchability, thus preliminary models included it but was left out of the final model due to its negligible contribution to the model. In addition to the spatiotemporal correlation structure (ie. Same of model above) we fitted a cyclic non-linear month effect to capture the intra-annual variability of the abundance. The remaining potential source of abundance variability could be driven by the differences between vessels, caused by a skipper effect or unobserved gear characteristics. To remove bias caused by vessel-specific differences in fishing operation, we included a vessel random effect.
The final CPUE index is showed in Figure 19.

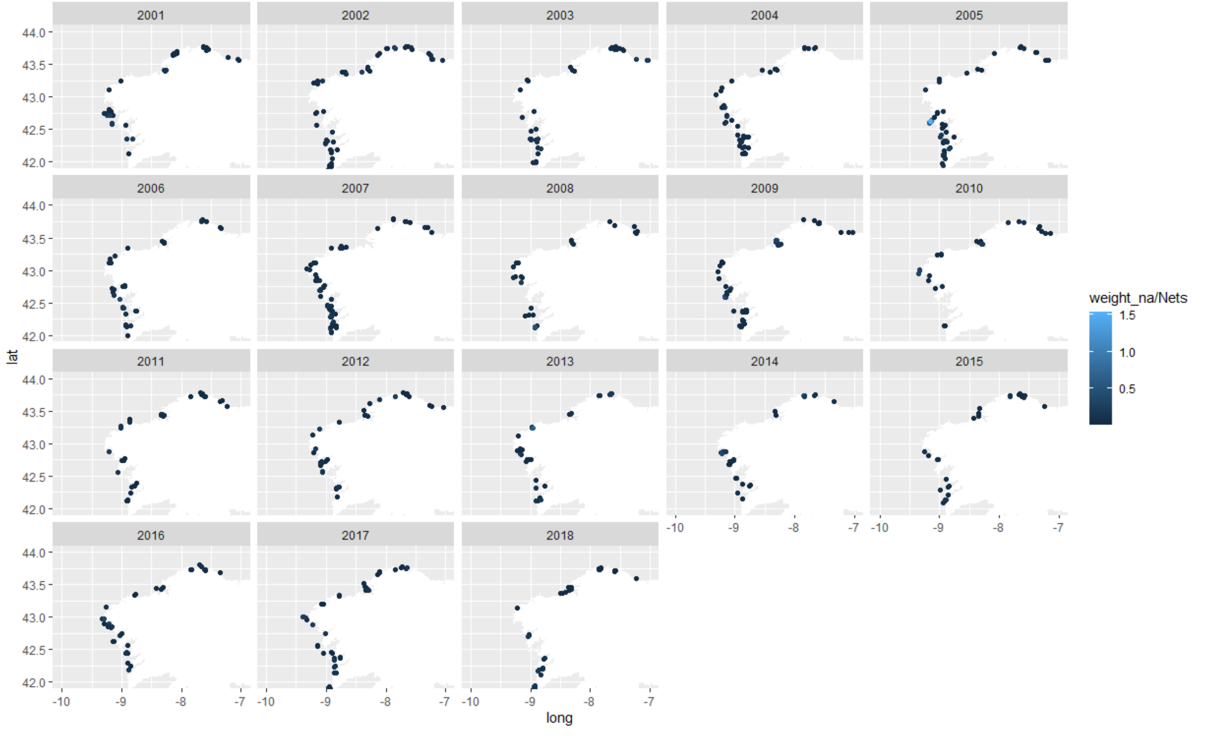

Figure 18: Data collected by observer on board on trammel net fleet in Galicia (Spain) from 2000-2018 for common sole (*S. Solea*) by year.

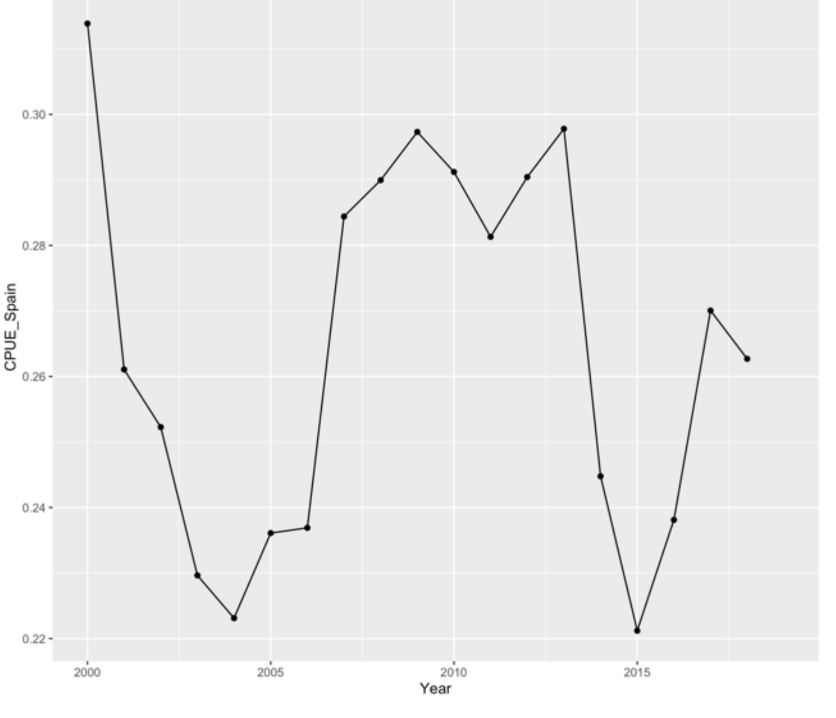

Figure 19: CPUE index derived from the hurdle Bayesian spatiotemporal model for 2000-2018 for common sole (*S. Solea*).

Portuguese survey data

The Portuguese Groundfish Survey (PtGFS-WIBTS-Q4) has been conducted by the Portuguese Institute for the Sea and Atmosphere (IPMA) and covers Division 9a in Portuguese continental waters (from latitude 41°20'N to 36°30'N). The survey is mainly conducted at the beginning of the 4th quarter, in October, and aims to monitor the abundance and distribution of *Merluccius merluccius* (hake) and *Trachurus trachurus* (horse mackerel) recruitment (Cardador et al., 1997). Data on all Soleidae species caught is collected in this survey, including species identification, number of specimens caught and weight. The surveys have been carried with the Portuguese RV "Noruega", which is a stern trawler of 47.5 m LOA, 1500 HP and 495 GRT and using a Norwegian Campelen Trawl (1800/96 NCT) gear with a 20 mm codend mesh size and groundrope with bobbins. PT-GFS fishing operations are performed during daylight and the duration of each tow changed in 2002, from 60 to 30 min. The sampling scheme (Figure 20) is based on a systematic and stratified random sampling covering depths from 20 to 500 m, following the standard IBTS methodology for the western and southern areas (ICES, 2017). The mixed systematic and stratified sampling scheme comprises 66 fixed and 30 random trawl positions. The surveyed area is stratified into 12 sectors (from north to south: CAM: Caminha, MAT: Matosinhos, AVE: Aveiro, FIG: Figueira, BER: Berlenga, LIS: Lisboa, SIN: Sines, MIL: Vila Nova de Mil Fontes, SAG: Sagres, POR: Portimão, VSA: Vila Real de Santo António), each further divided into four depth strata: 1) 20-100 m, 2) 101-200 m, 3) 201-500 m, and 4) 501-750 m. The deeper stratum (4) was only sampled in the period before the yearly 2000's. In 1996, 1999, 2003 and 2004 the surveys were conducted using a different vessel, the RV "Capricórnio" and a different bottom trawl net, CAR type FGAV019, without rollers in the groundrope (ICES, 2007). In 2018, due to technical problems in the RV "Noruega" part of the survey was conducted on the commercial trawler "Calypso" (24.8 m LOA, 7215 GRT), using a CAR bottom trawl net type FGAV019, without rollers in the groundrope, and covering the centre and southwest coasts (sectors: LIS, SIN, MIL and ARR). In 2012 and 2019 no survey was conducted. In December 2020, the survey is planned to be conducted in a new vessel, RV "Mário Ruivo" (72.6 m LOA, and 2290 GRT) using a similar NCT net but with differences in the groundrope and bobbins.

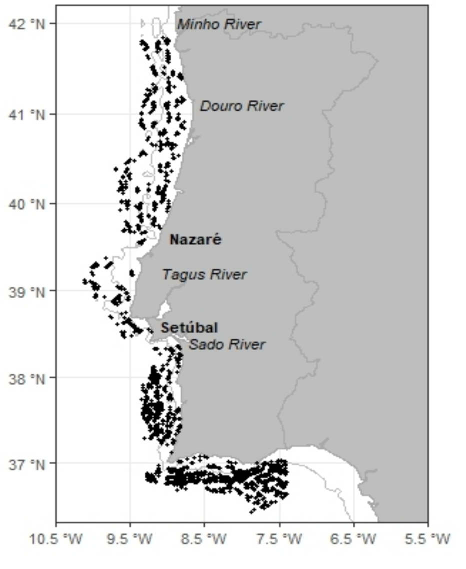

Figure 20: Map of the sampling scheme of the Portuguese survey.

Data from the annual Portuguese Groundfish Survey were provided by the Instituto Português do Mar e da Atmosfera (IPMA) from 2000 to 2018. Despite of the partially overlay between the survey and *Solea solea* distribution in Portuguese waters (Cabral et al. (2012) references preferential empirical bathymetrical range, as assumed by fishermen, to be between 50 and 150 m), the species is rarely caught and numbers per hour are very low (Figure 21 and 22). Both the number of hauls and the proportion of hauls with catches of the species are very low (Figure 23). The fishing gear used in this survey has low catchability for the species and it is considered inadequate for monitoring its populations. The catchability of this survey for the common sole species is worst with respect the Spanish in both spatial and temporal coverage (Figure 24).

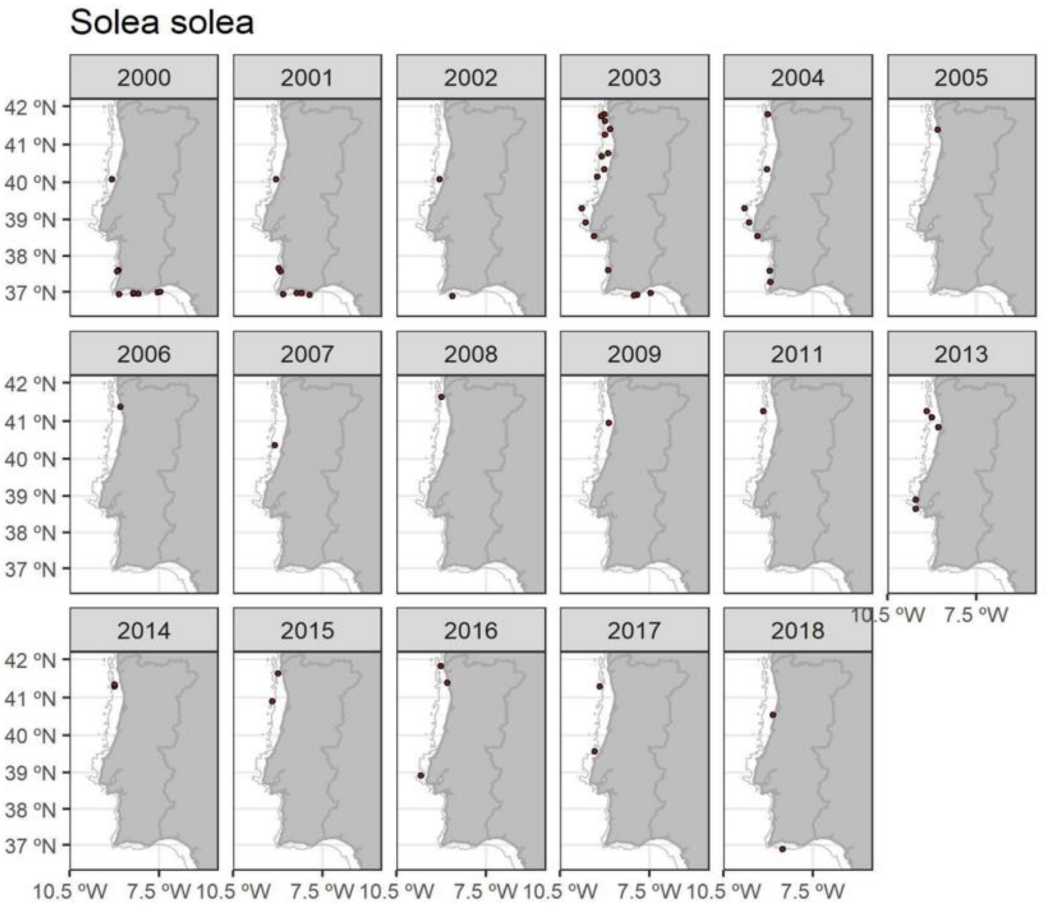

Figure 21: Dots indicates hauls where the species *S.Solea* was present by year.

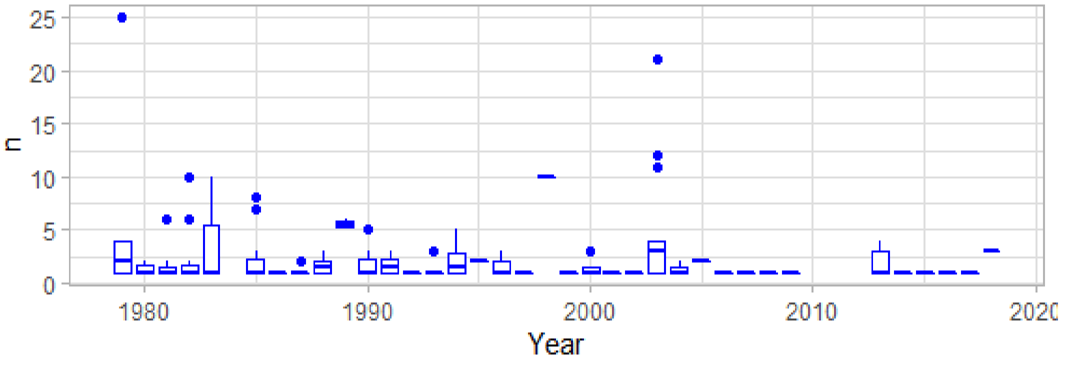

Figure 22: Boxplots of the number of *Solea solea* individuals caught per hour in the Portuguese Groundfish Survey.

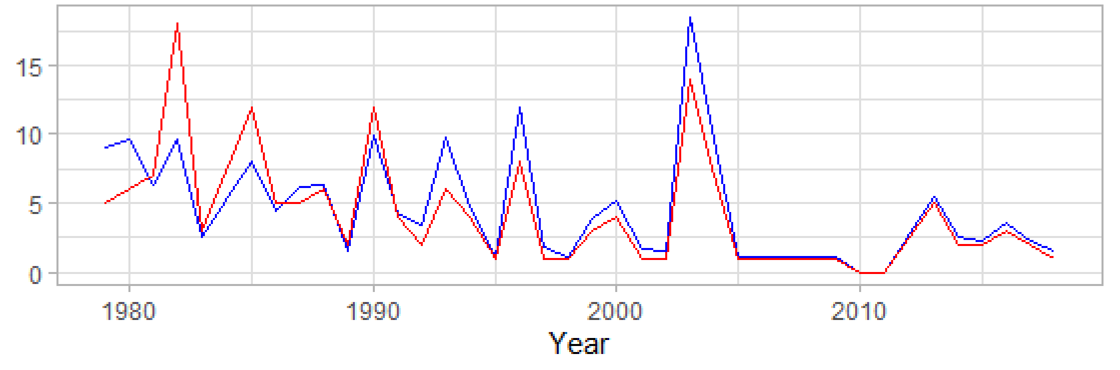

Figure 23: Number of hauls (red) and percentage of total hauls (blue) with *Solea solea* in the Portuguese Groundfish Survey.

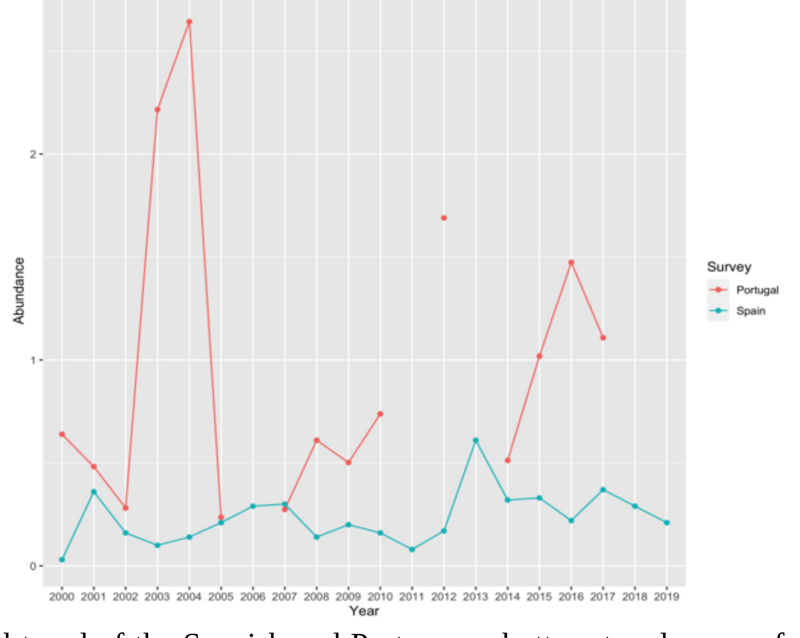

Figure 24: Temporal trend of the Spanish and Portuguese bottom trawl survey from 2000 to 2019 for common sole.

LPUE standardization of common sole *Solea solea* caught in the polyvalent fleet in Portuguese waters (Division 9a)

Input data

The LPUE estimates relied on fishery dependent data derived from the Portuguese polyvalent fleet and are based on the estimated *S. solea* landed weight by fishing trip (see Annex 2 to more information on data). The analysis was restricted to the most important landing ports in term of *S. solea* landed weight: Viana do Castelo, Matosinhos, Aveiro, Peniche and Setúbal.

The Portuguese polyvalent fleet segment comprises multi-gear/multi-species fisheries, usually licensed to operate with more than one fishing gear (most commonly gill and trammel nets, longlines and traps), that can be deployed in the same trip, targeting different species. The time period considered in the present study extends from 2011 to 2019.

Methods

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

All the explanatory variables were considered as categorical variables. The function "bestglm" implemented in R software was used to select the best subset of explanatory variables (McLeod and Xu, 2010). The selection of the set explanatory variables to enter into the model is done following McLeod and Xu (2010) procedure, which 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, are used to assess model fitting. Changes in deviance explained by the selected model and the proportions of deviance explained to the total explained deviance was determined and used as indicative of r2. Annual estimates of LPUE and the corresponding standard error are determined for a reference condition where one level of each explanatory variable other the Year is fixed.

All the statistical analysis was performed using R programming language, version 3.6.2 (R Development Core Team, 2019).

Data overview

Most *S. solea* landings were derived from the polyvalent fleet (between 87 and 95% for the period 2011-2019, Table 4). The data set used to estimate LPUE was constrained to landing ports of Viana do Castelo, Matosinhos, Aveiro, Peniche and Setúbal. For the period 2011-2019, these five landings ports were the ones more frequently included in the top 5 ports with the highest *S. solea* annual total landed weight.

Table 4. *Solea solea* in Portuguese waters (Division 9a). *Solea solea* estimated landed weight per fleet, polyvalent and trawl, for the period 2011-2019. Percentages of the total national landed weight are present in brackets.

Year	Polyvalent (in Ton)	Trawl (in Ton)
2011	219.2 (90.6%)	22.7 (9.4%)
2012	126.5 (87.8%)	17.5 (12.2%)
2013	239.6 (94.2%)	14.7 (5.8%)
2014	201.8 (90.1%)	22.1 (9.9%)
2015	308.9 (95.2%)	15.5 (4.8%)
2016	296 (93.4%)	21 (6.6%)
2017	296.9 (93.4%)	21 (6.6%)
2018	205.6 (87.3%)	30 (12.7%)
2019	217.2 (93.3%)	15.7 (6.7%)

For each year, landing port and vessel size (<9m or >9m), the 1st, 2nd, 3rd and 4th quantiles of the number of trips, of the annual landed weight and of the average landed weight per trip were estimated. For each landing port, year and vessel size group, the vessels with occasional landings and reduced activity on the species capture were excluded if the annual number of trips, total annual landed weight and average landed weight per fishing trip were smaller than the correspondent 1^{st} quantile. For the selected landing port, the total landed weigh of the excluded vessels represented between 3-7% of the total.

The density distribution and the boxplot of the nominal LPUE (kg/trip) of *S. solea* per year are presented in Figure 24. There is a high density of fishing trips with landed weight close to zero, as well as, the presence of some fishing trips with very high values. The LPUE analysis proceed with the exclusion of very high values of landed weight per fishing trip, i.e., fishing trips with landed weight above 95% quantile corresponding to 35 kg.trip$_{-1}$).

For vessels >9m the landed weight per fishing trip was highly variable. This group was also the one for which landed weight per trip attained the higher values (Figure 25).

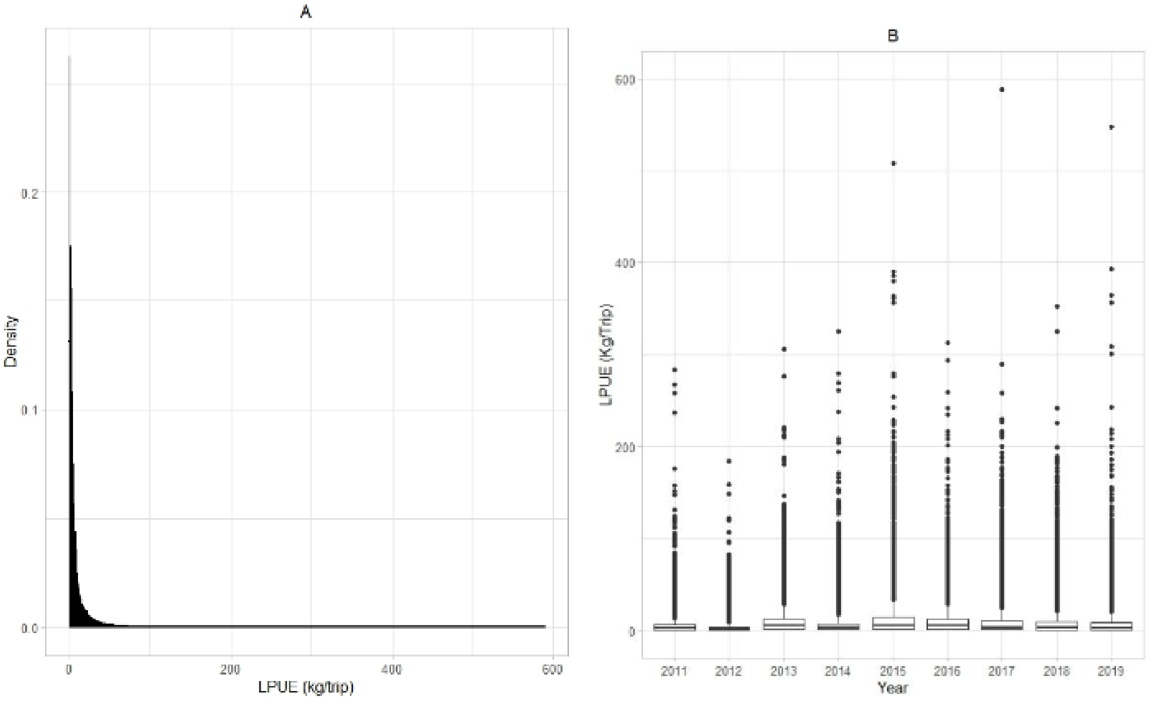

Figure 24. *Solea solea* in Portuguese waters (Division 9a). Nominal LPUE of *Solea solea* in the reference ports (all data excluding occasional vessels). A) density distribution and B) distribution by year.

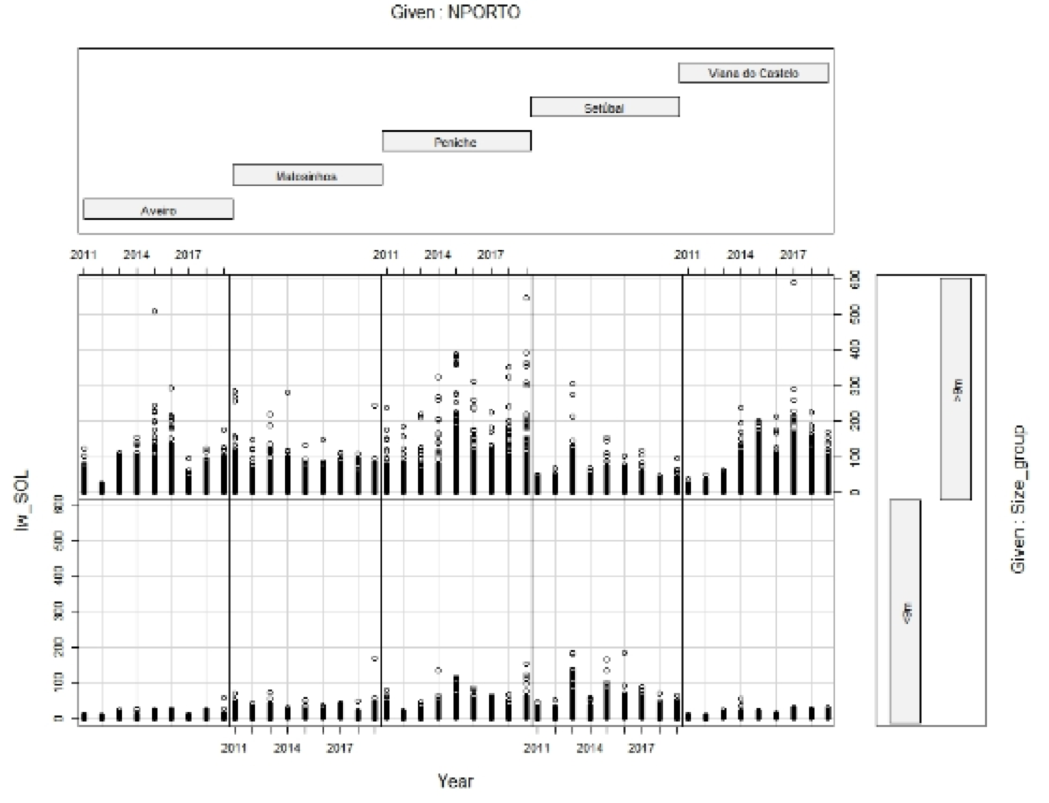

Figure 25. *Solea solea* in Portuguese waters (Division 9a). Coplot between estimated landed weight (lw_SOL, all data excluding occasional vessels) and year by trip of the polyvalent fleet given the vessel size (Size_group, <9m or >9m) and and the landing port (nport).

For the period 2011-2019, the mean nominal CPUE by year varied between 3.6-12.9 kg/trip, with a minimum registered in 2012 and a peak in 2015, slightly decreasing afterwards (Figure 26).

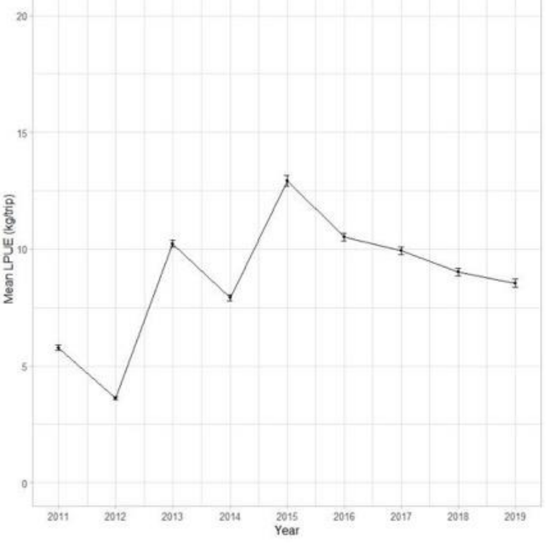

Figure 26: *Solea solea* in Portuguese waters (Division 9a). Mean nominal CPUE and associated standard error by year of *Solea solea* in the selected ports (all data excluding occasional vessels).

CPUE standardization model

To build the dataset, the following settings were considered: landing ports of Viana do Castelo, Matosinhos, Aveiro, Peniche and Setúbal; occasional vessels were removed; trips with landed weight of *S. solea* below the quantile 95% (<35 kg.trip-1).

The GLM model with the best adjustment included the explanatory variables year, month, landing port and vessel size and can be expressed as:

glm(LPUE ~ Year + Month + Port+ Vessel size, family=Gamma)

Estimated effects of each explanatory variable, as well as, the residual graphical analysis for the best model selected are presented in Figures 27 and 28.

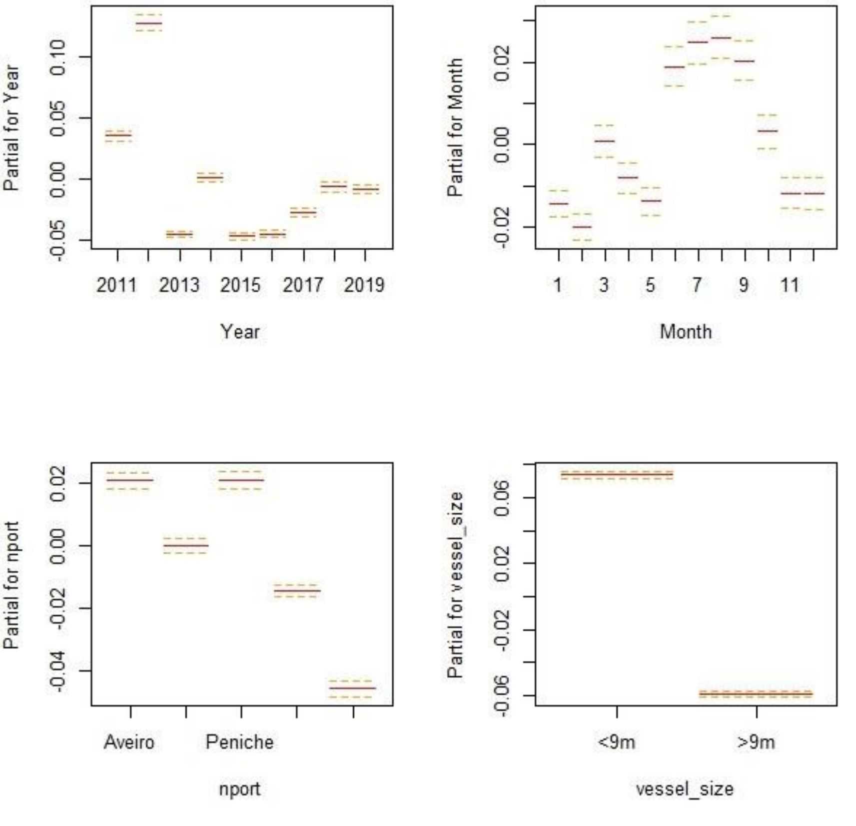

Figure 27. *Solea solea* in Portuguese waters (Division 9a). Effect of each explanatory variable included in the standardization of the LPUE for *S. solea* caught by the polyvalent segment in mainland Portugal (Division 9a): year, month, landing port (nport) and vessel size (vessel_size).

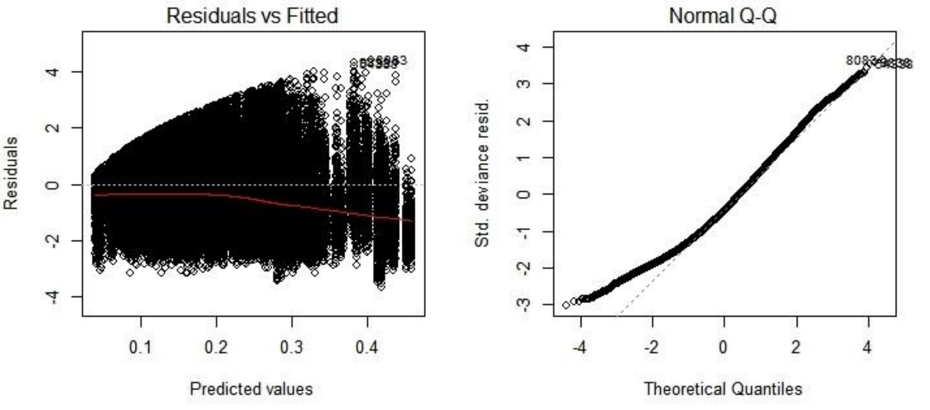

Figure 28. *Solea solea* in Portuguese waters (Division 9a). Residuals of the best GLM model fitted to the LPUE data for the Portuguese polyvalent fleet: (left) fitted vs. residuals (right) quantile-quantile (Q-Q) plot.

The value of r^2 was about 87% and the annual standardized mean LPUE (by fixing the landing port at Peniche, the month at February and for ≤9m vessel size group) is presented in Figure 4 and Table 5.

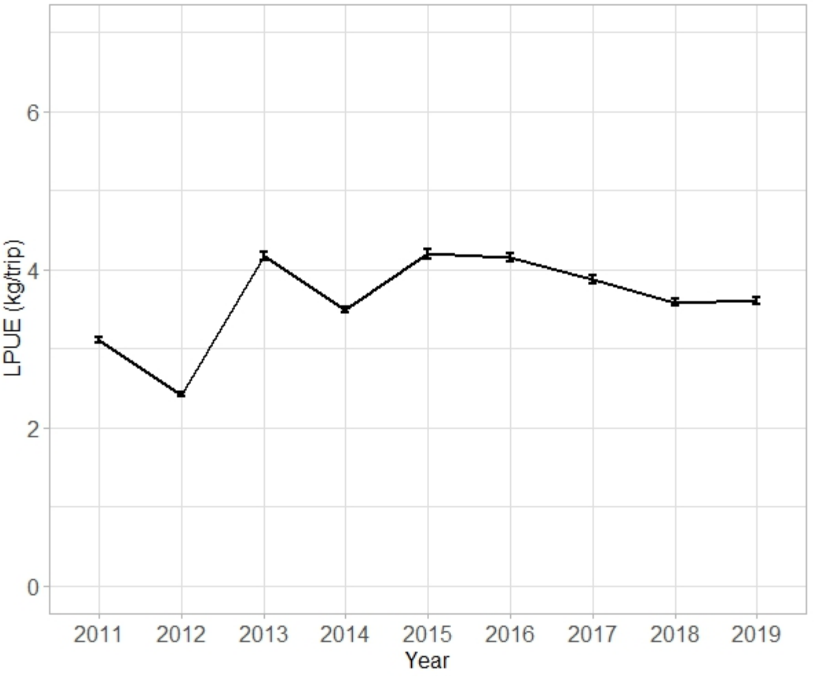

Figure 29. *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019 (Explained variance = 0.87).

Table 5. *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019.

Year	LPUE	Lower s.e.	Upper s.e.
2011	3.11	3.08	3.15
2012	2.42	2.39	2.44
2013	4.16	4.11	4.21
2014	3.49	3.45	3.53
2015	4.19	4.14	4.25
2016	4.16	4.10	4.21
2017	3.87	3.83	3.92
2018	3.58	3.54	3.62
2019	3.60	3.56	3.64

Test of model sensitivity

Test 1 - reduce weight per trip by 25% for data from 2019

Data from 2019 was reduced by 25% in order to test the sensitivity of the model to an decrease.

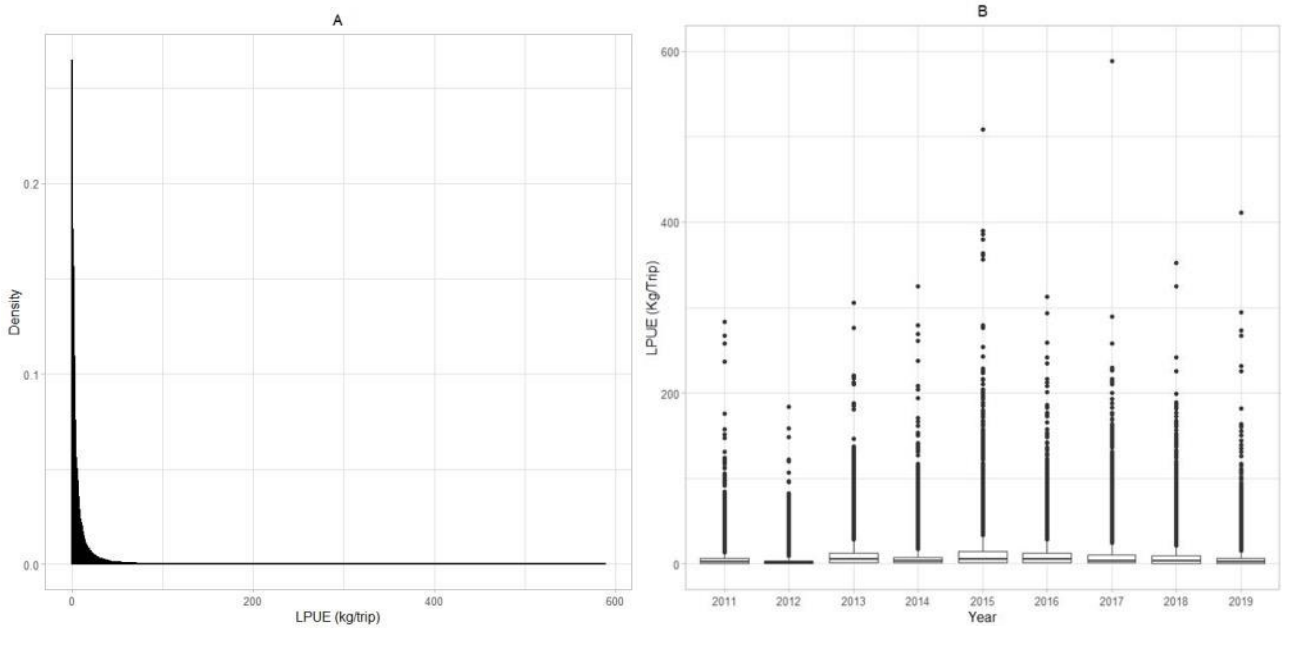

Figure 30. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Nominal LPUE of *Solea solea* in the reference ports (all data excluding occasional vessels). A) density distribution and B) distribution by year.

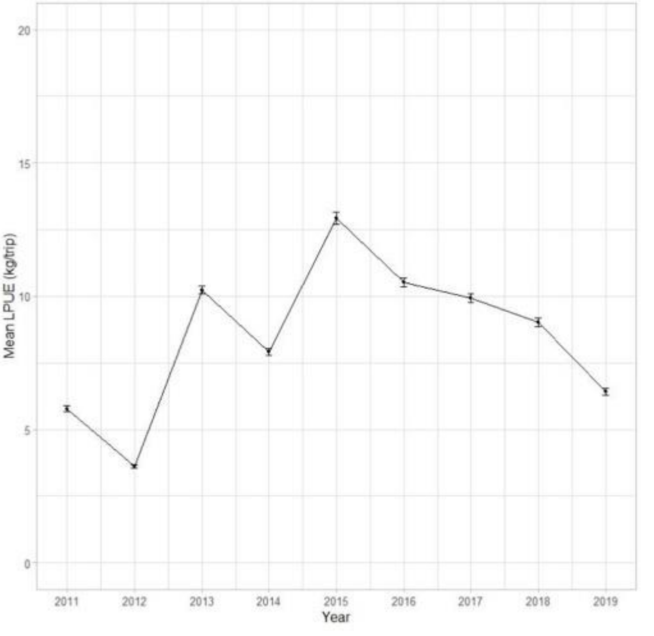

Figure 31. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Mean nominal CPUE and associated standard error by year of *Solea solea* in the selected ports (all data excluding occasional vessels).

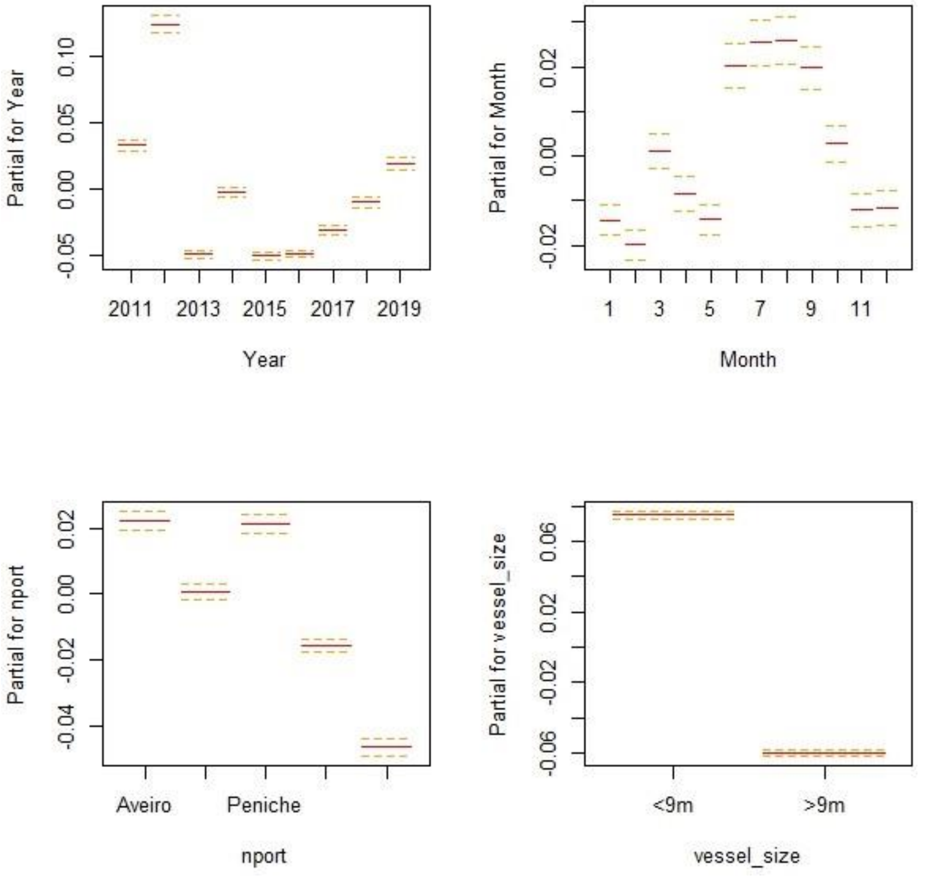

Figure 32. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Effect of each explanatory variable included in the standardization of the LPUE for *S. solea* caught by the polyvalent segment in mainland Portugal (Division 9a): year, month, landing port (nport) and vessel size (vessel_size).

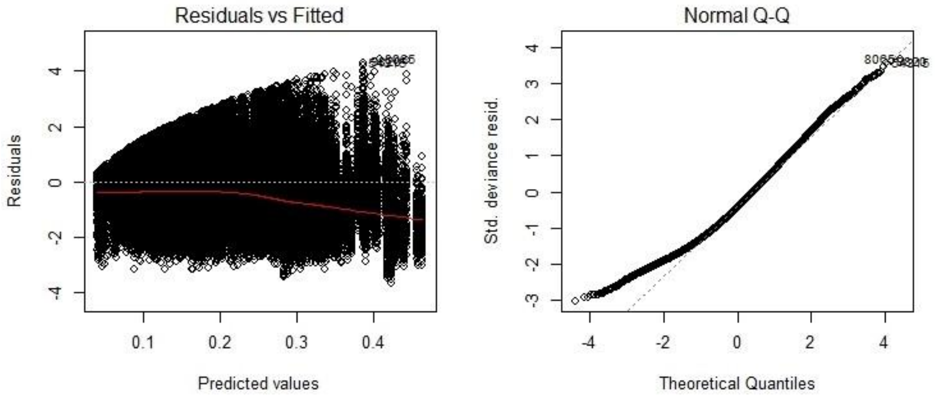

Figure 33. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Residuals of the best GLM model fitted to the LPUE data for the Portuguese polyvalent fleet: (left) fitted vs. residuals (right) quantile-quantile (Q-Q) plot.

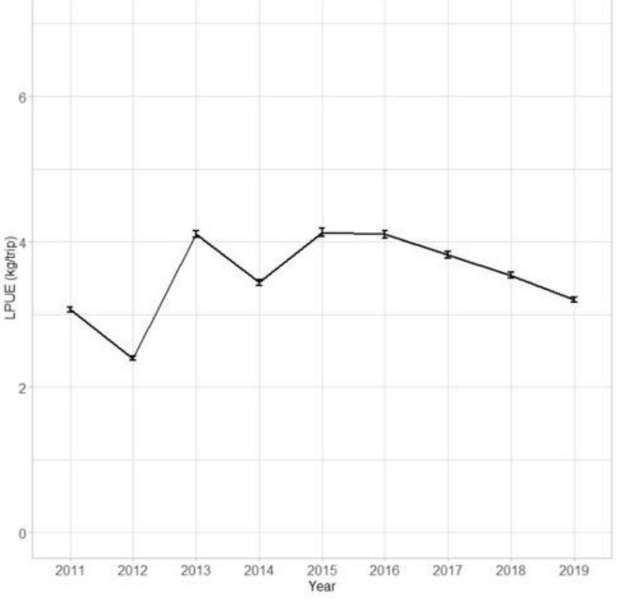

Figure 34. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019 (Explained variance = 0.87).

Table 6. Test 1 - *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019.

Year	LPUE	Lower_SE	Upper_SE
2011	3,07	3,04	3,10
2012	2,40	2,37	2,42
2013	4,10	4,05	4,15
2014	3,44	3,40	3,48
2015	4,13	4,08	4,18
2016	4,10	4,05	4,15
2017	3,82	3,77	3,86
2018	3,54	3,49	3,58
2019	3,20	3,17	3,24

Test 2 - increase by weight per trip by 25% for data from 2019

Data from 2019 was increased by 25% in order to test the sensitivity of the model to an increase.

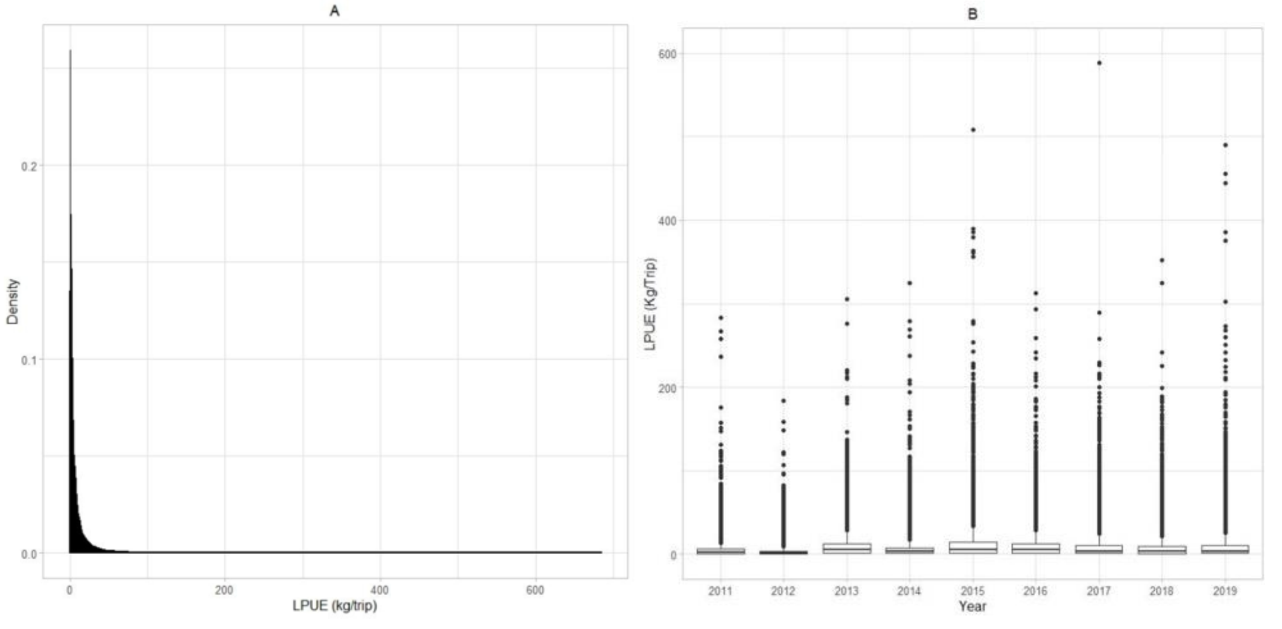

Figure 35. Test 2 - *Solea solea* in Portuguese waters (Division 9a). Nominal LPUE of *Solea solea* in the reference ports (all data excluding occasional vessels). A) density distribution and B) distribution by year.

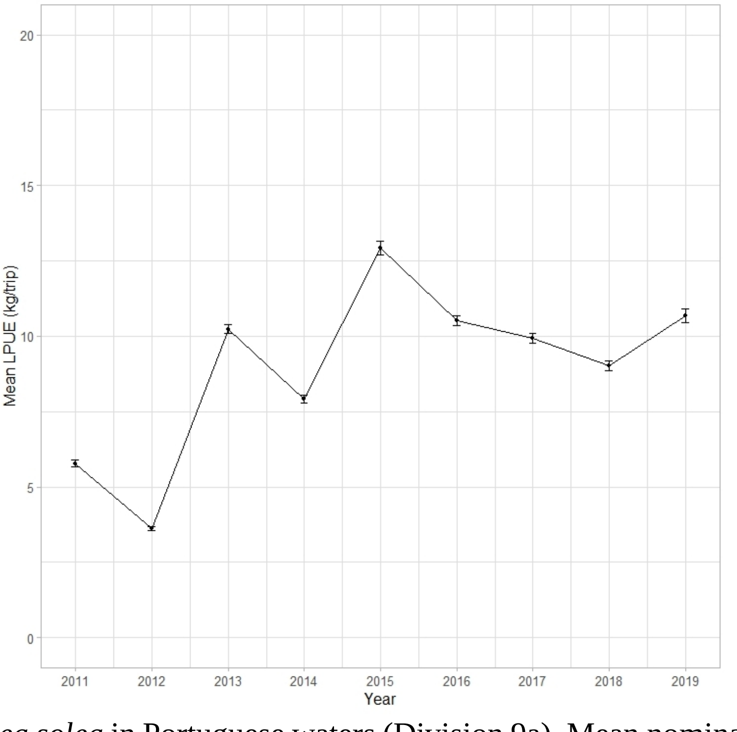

Figure 36. Test 2 - *Solea solea* in Portuguese waters (Division 9a). Mean nominal CPUE and associated standard error by year of *Solea solea* in the selected ports (all data excluding occasional vessels).

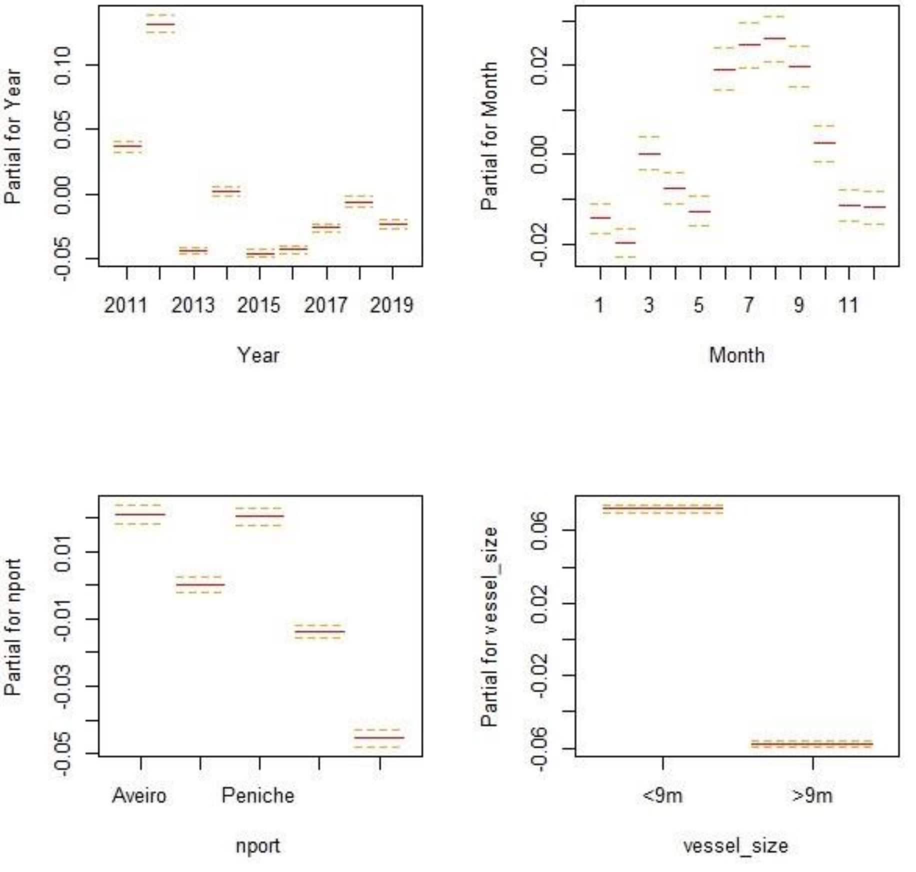

Figure 37. Test 2 - *Solea solea* in Portuguese waters (Division 9a). Effect of each explanatory variable included in the standardization of the LPUE for *S. solea* caught by the polyvalent segment in mainland Portugal (Division 9a): year, month, landing port (nport) and vessel size (vessel_size).

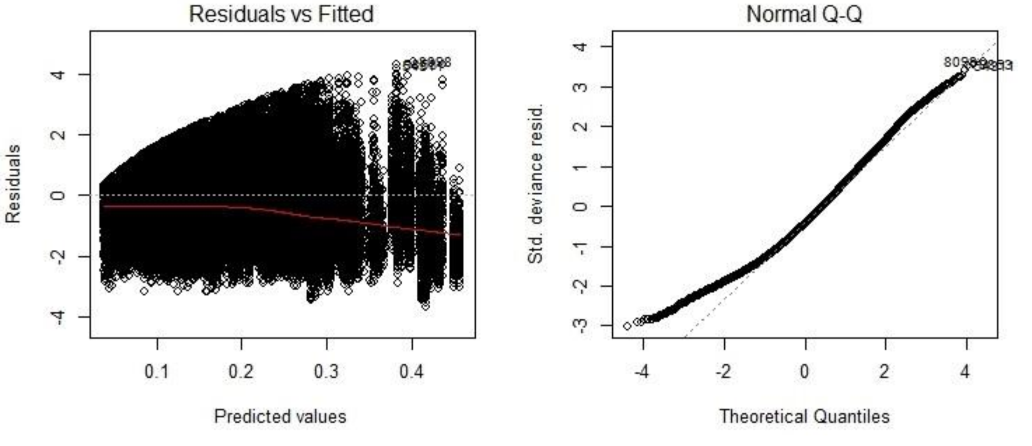

Figure 38. Test 2 - *Solea solea* in Portuguese waters (Division 9a). Residuals of the best GLM model fitted to the LPUE data for the Portuguese polyvalent fleet: (left) fitted vs. residuals (right) quantile-quantile (Q-Q) plot.

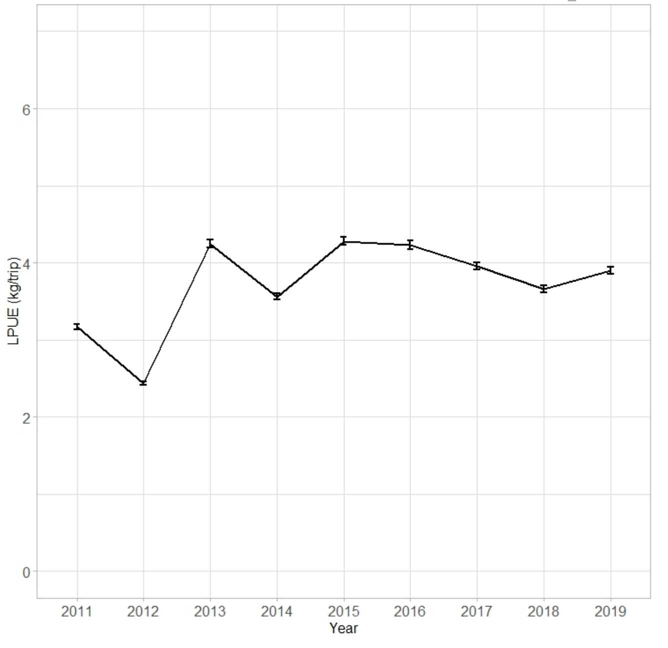

Figure 39. Test 2 - Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019 (Explained variance = 0.86).

Table 7. Test 2 - *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019.

Year	LPUE	Lower_SE	Upper_SE
2011	3,17	3,13	3,20
2012	2,44	2,41	2,46
2013	4,24	4,19	4,30
2014	3,56	3,52	3,60
2015	4,28	4,23	4,33
2016	4,23	4,18	4,28
2017	3,95	3,91	4,00
2018	3,66	3,62	3,70
2019	3,90	3,86	3,95

Plot Model, test 1 and test 3 outputs together

The model seems to be sensitive to small increases or decreases.

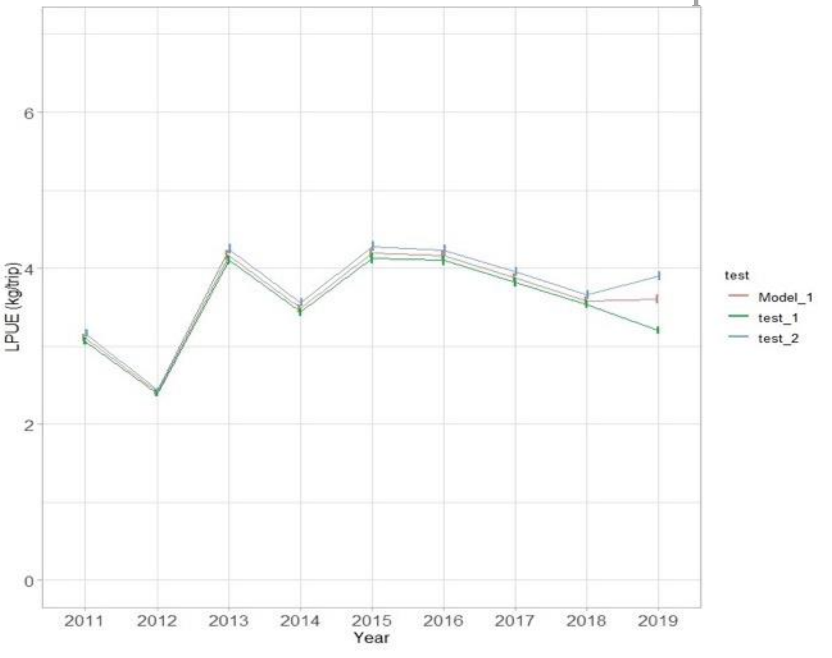

Figure 40. Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019 for: red - model; green - test 1 (2019 data reduced by 25%) and; blue - Test 2 (2019 data increased by 25%).

Comparison with reference situation

The reference situation selected for prediction was the landing port of Peniche, month 2 and vessels <9m. Are the prediction trends different if we select a different reference situation? Following is the comparison between LPUE for the different levels of the variable “Port” and for the different levels of the variable “Vessel size”. Apart from the absolute values, trends are similar.

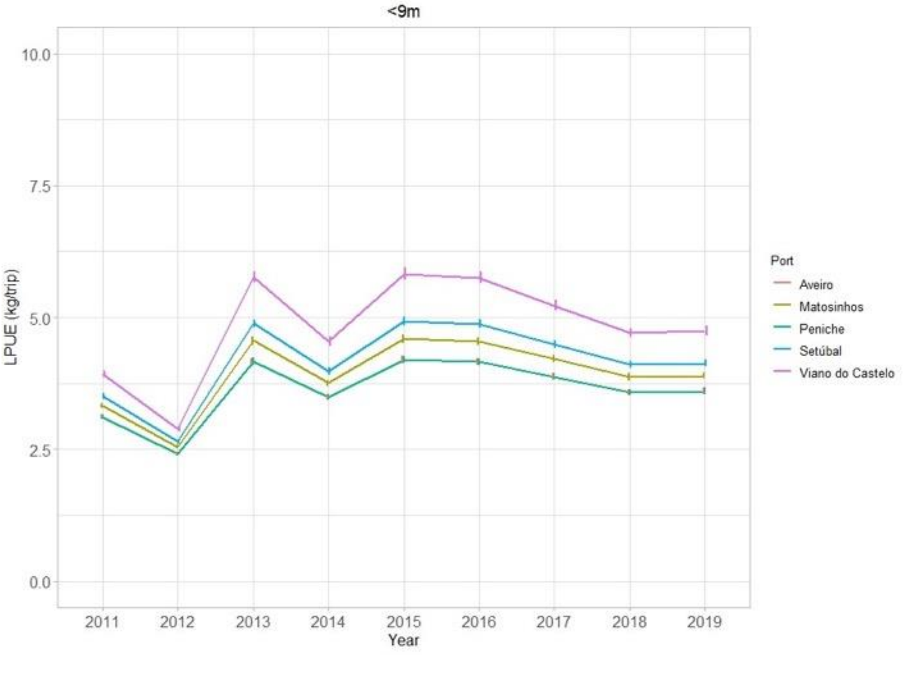

Figure 41. Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery with LOA <9m from 2011 to 2019 considering different reference situations (i.e. the different levels of the explanatory variable “Port”).

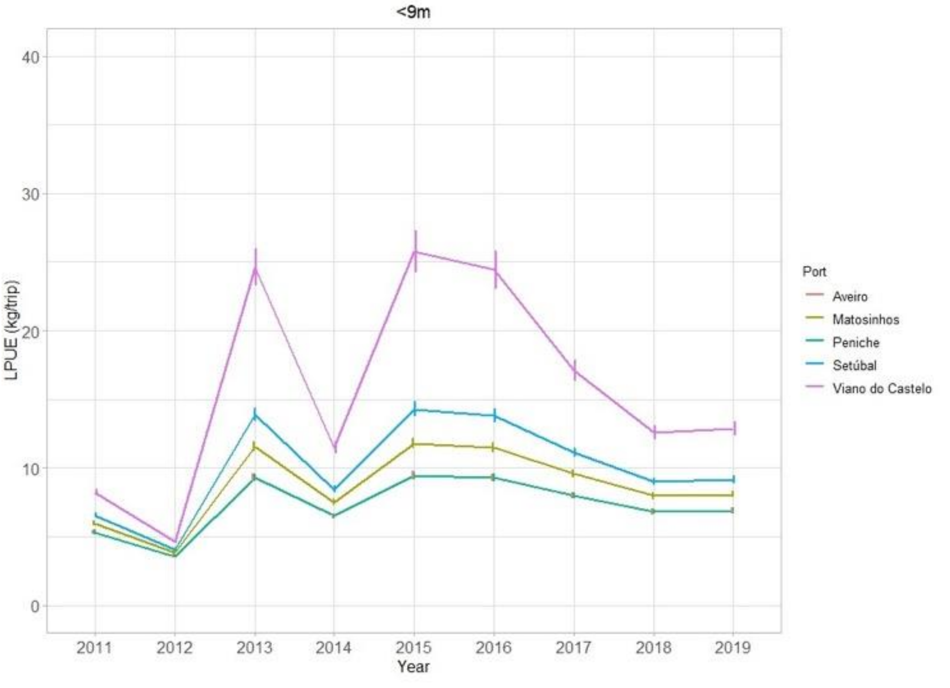

Figure 42. Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery with LOA >9m from 2011 to 2019 considering different reference situations (i.e. the different levels of the explanatory variable "Port").

Least-square means (lsmeans)

Instead of set a reference situation, the standardized LPUE can be fitted using estimated marginal means (R package: emmeans). The least-squares mean (lsmeans() method) catch per unit effort with 95% confidence intervals and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019 is presented in Table 8.

Table 8. *Solea solea* in Portuguese waters (Division 9a). lsmeans method - Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019.

Year	LS mean (kg/trip)	Standard error	Lower bound (95%)	Upper bound (95%)
2011	3,98	0,04	4,06	3,91
2012	2,91	0,03	2,97	2,85
2013	5,87	0,05	5,98	5,77
2014	4,61	0,04	4,70	4,53
2015	5,94	0,06	6,05	5,83
2016	5,86	0,05	5,97	5,76
2017	5,31	0,05	5,41	5,22
2018	4,78	0,05	4,88	4,68
2019	4,82	0,05	4,91	4,72

The comparison between the previous method (the reference situation Peniche, month 2 and vessels with LOA <9m) and the results obtained with the estimated marginal means are present in Figure 21. Trends in the LPUE are similar.

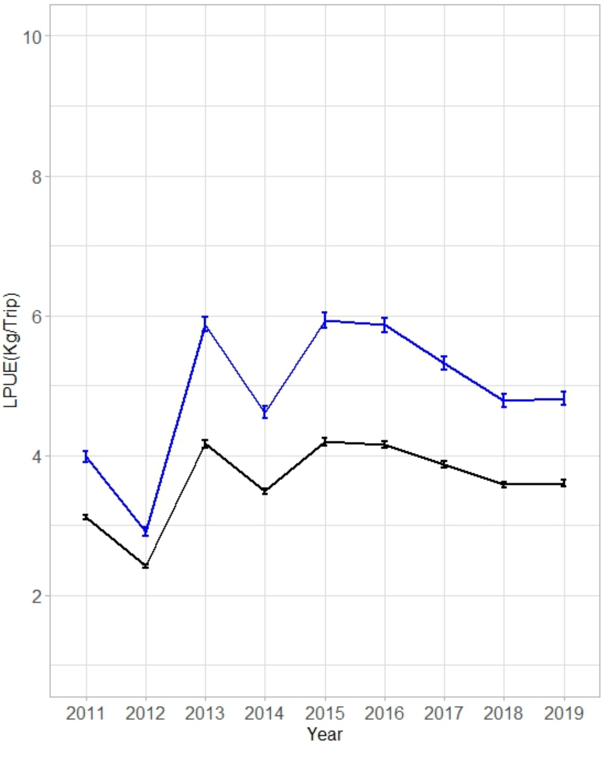

Figure 43. *Solea solea* in Portuguese waters (Division 9a). Standardized LPUE index (kg.trip-1) and respective standard error for the Portuguese polyvalent fishery from 2011 to 2019; black line - reference situation Peniche, month 2 and >9m and; blue line - least-squares mean catch per unit effort with 95% confidence intervals.

General biology

In Portuguese waters, sole length of first maturity was estimated as 25 cm for males and 27 cm for females (Jardim, et al., 2011).
Growth studies based on *S. solea* otolith readings in the Portuguese coast indicate Linf of 52.1cm for females and 45.7 cm for males. The growth coefficient estimate of females (K=0.23) was slightly higher than for males (K=0.21) and t_0 estimate, -0.11 and 1.57 for females and males, respectively (Teixeira and Cabral, 2010).
The natural mortality parameter M is not known for this stock but for the stock of common sole ICES division 8a, b is used a M of 0.2. A recent study of Cerim et al. (2020) defined the M of the common sole M= 0.31 yr-1.
L_{95} is not known for this stock but for the common sole ICES division 8a, b is 27.5 (see stock annex sol-bisc division 8a,b).
Bayesian length-weight: a=0.00759 (0.00629 - 0.00915), b=3.06 (3.00 - 3.12), in cm Total Length, based on LWR estimates for this species (Frose et al., 2014).

Stock identity and possible assessment areas

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

Others sole species

For the WKWEST21 an official data call was requested for this stock to get all the possible data, not only for the common sole (*S. Solea*) but also for the other sole species *Solea senegalensis*, *Pegusa lascaris* and sole spp.

For Portugal, the *S. Senegalensis* and *P. lascaris* landings and length distribution are available for 2011-2019. For Solea spp. landings are also available for 2011-2019.
For Spain, the *S. Senegalensis*, *P. lascaris* and Solea spp. landings are available for 2009-2019.
For France no data were available for these other species.

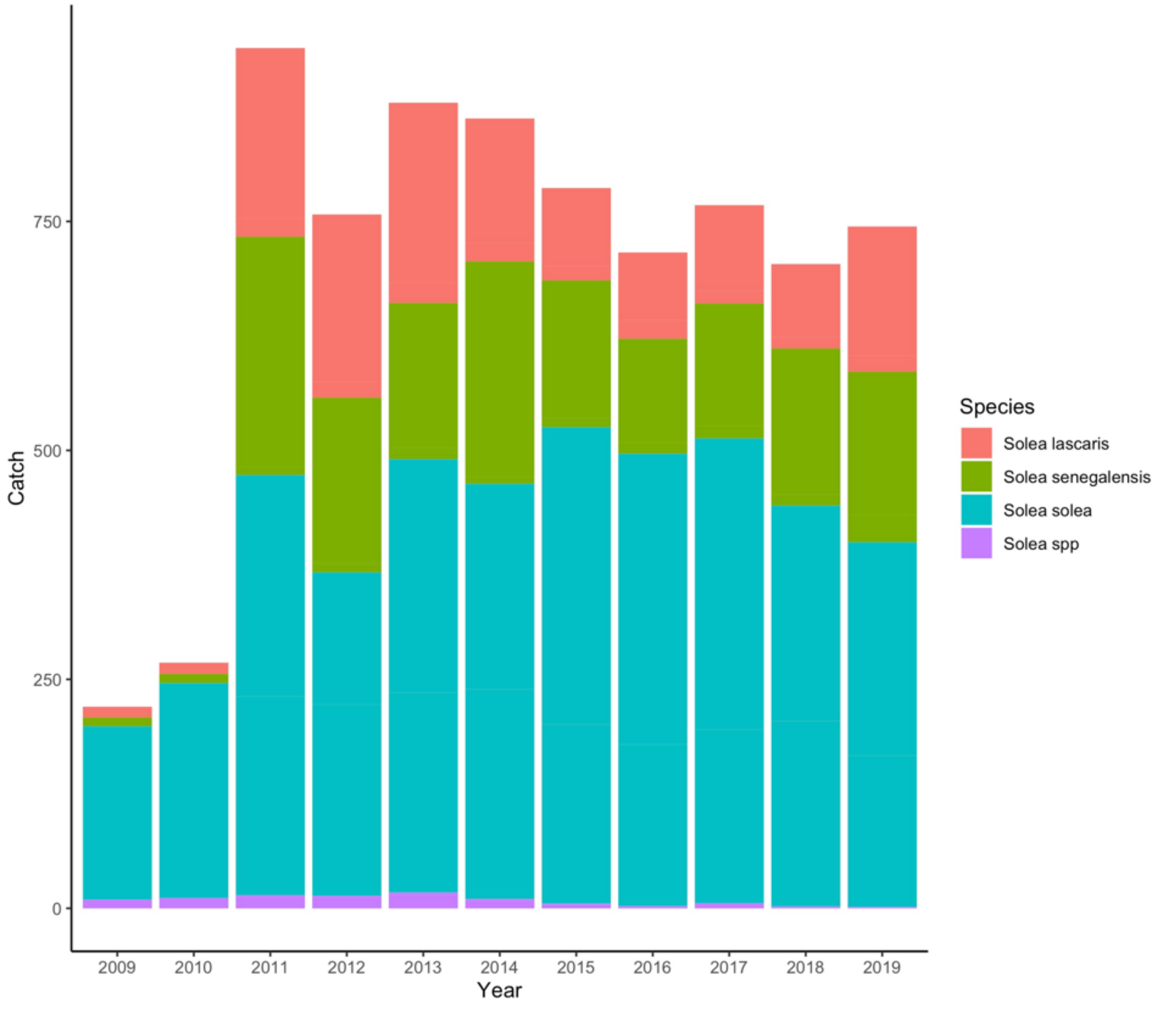

Figure 44: All sole species landings for the Division 8c9a. Data are from Spain and Portugal together.

S. senegalensis

The majority of this species is caught my Portugal (Figure 45), by the polyvalent fleet (Figure 46), homogenously along all the year (Figure 47) and in the ICES division 9a.

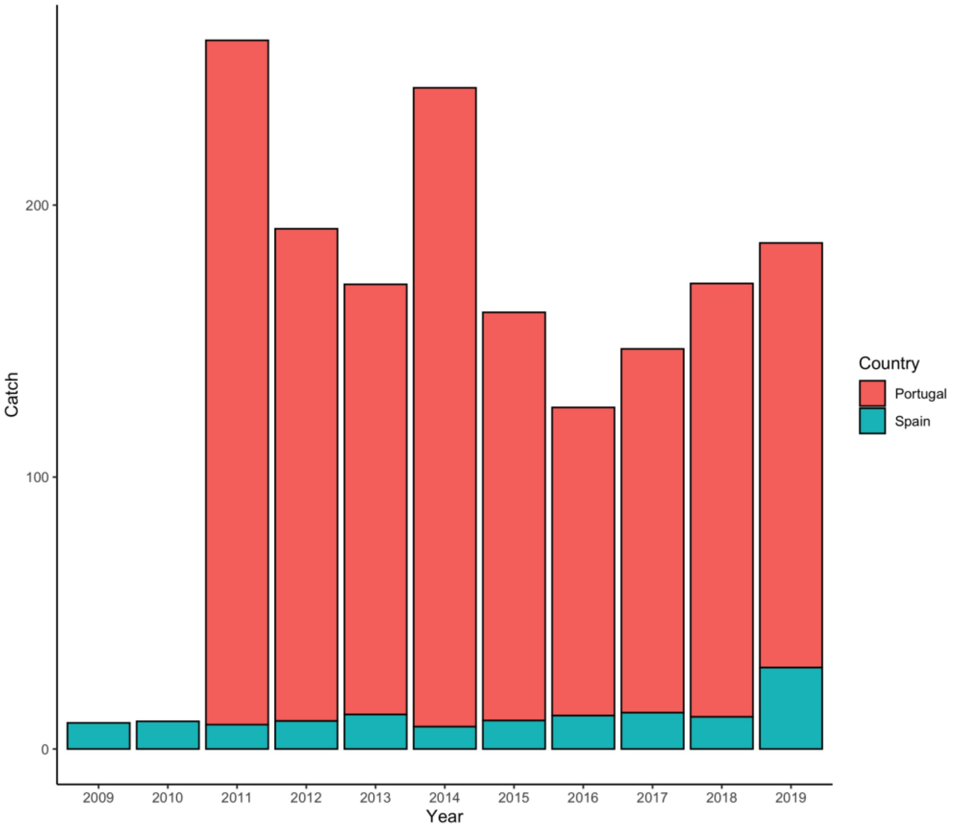

Figure 45: *S. Senegalensis* catches by country from 2009 to 2019.

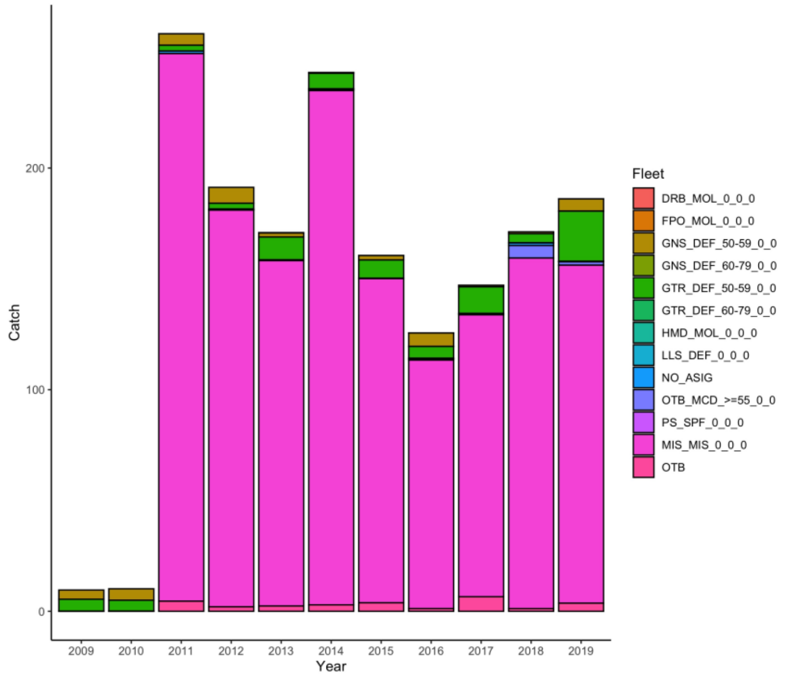

Figure 46: *S. Senegalensis* catches by fleet from 2009 to 2019.

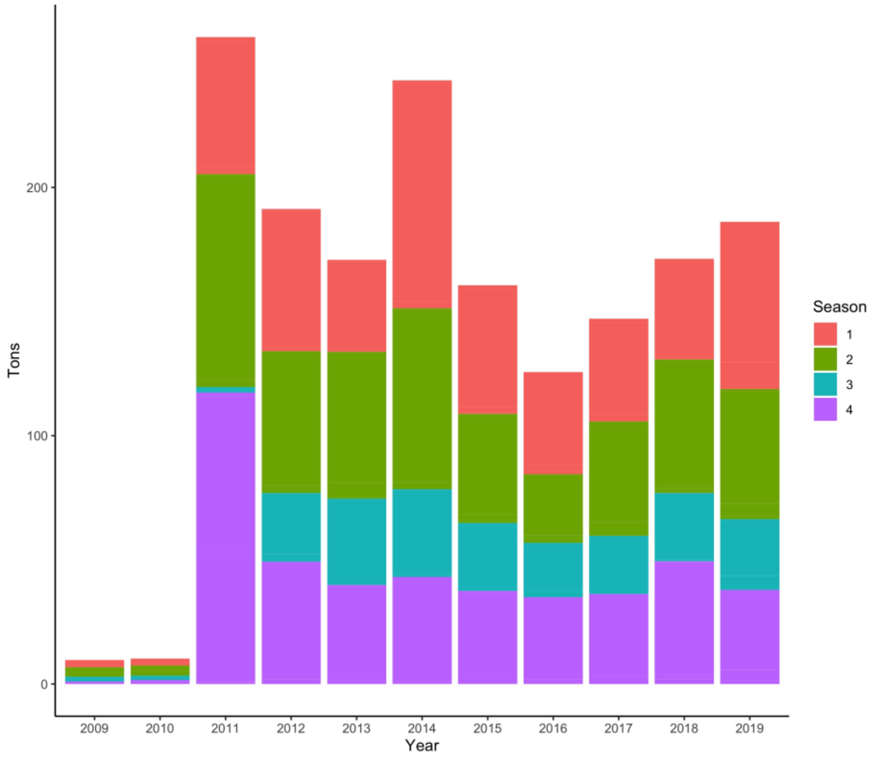

Figure 47: *S. Senegalensis* catches by quarter from 2009 to 2019.

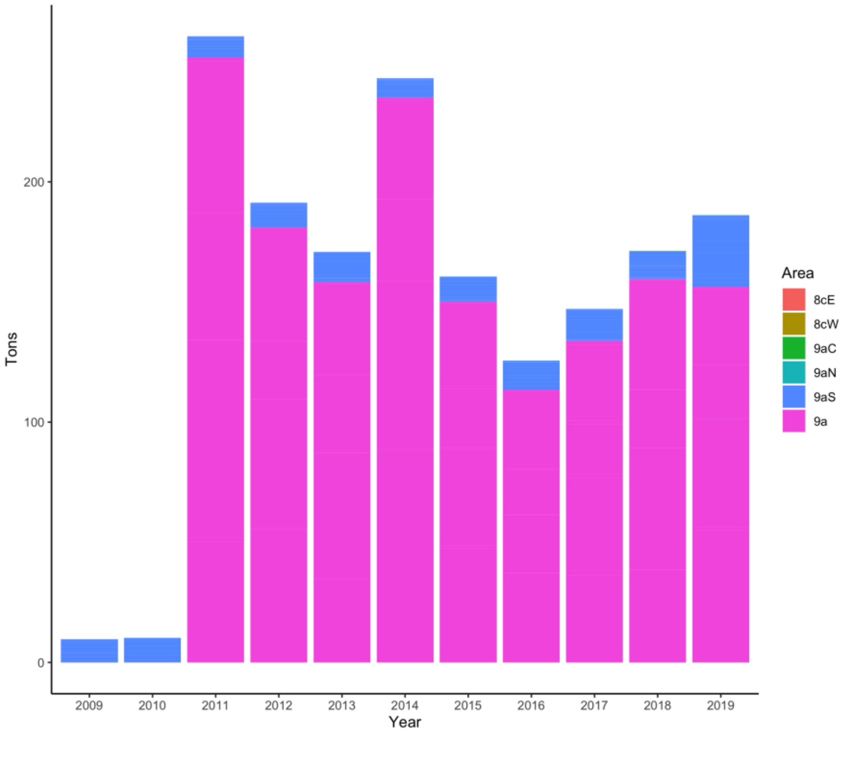

Figure 48: *S. Senegalensis* catches by area from 2009 to 2019.

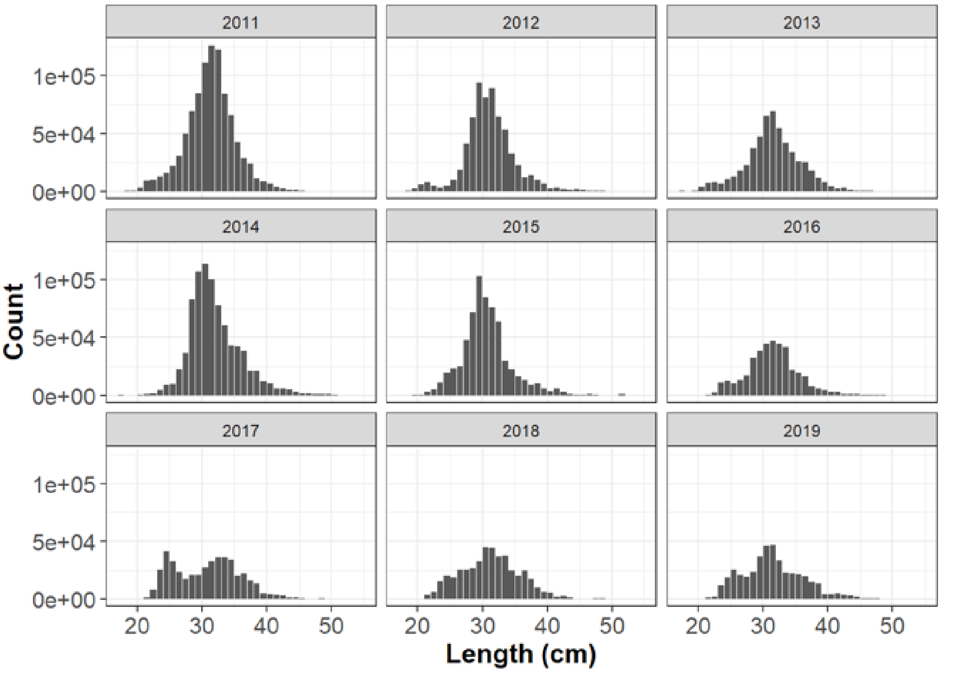

Figure 49. *S. Senegalensis* length distribution from 2011 to 2019 for Portugal.

There is no abundance information for this species for Spain. The bottom trawl demersal surveys performed by Spain don't catch this species and in the Portuguese survey (PtGFS-WIBTS-Q4) the catch of this species is very sporadic (Figure 50).

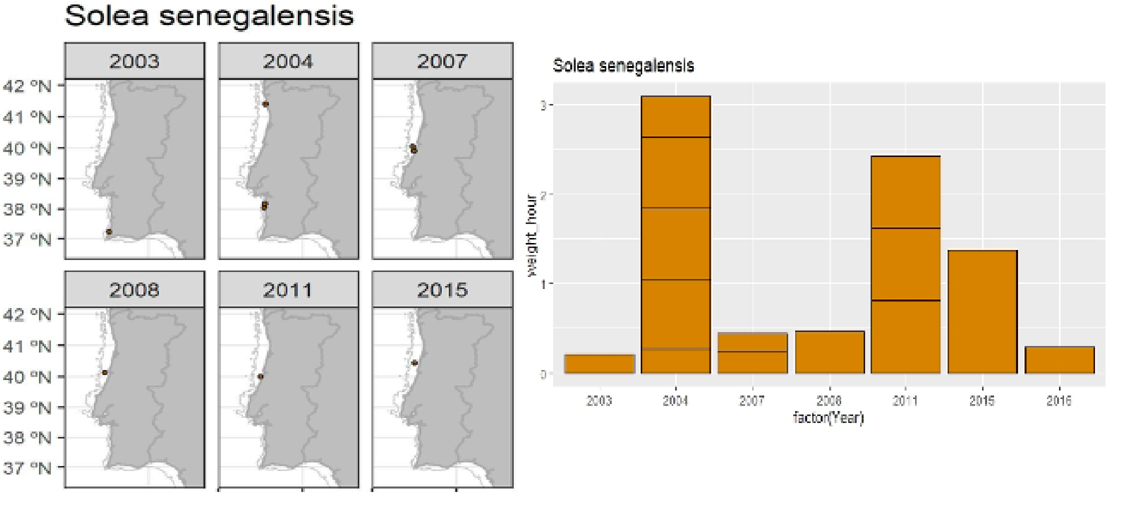

Figure 50. Hauls where the *S. Senegalensis* was present in the in Portuguese bottom trawl survey **(**PtGFS-WIBTS-Q4) (left) and temporal trend of the abundance caught (right).

P. lascaris

Similar to the *S. senegalensis* this species is for the majority caught my Portugal (Figure 51), by the polyvalent fleet (Figure 52), homogenously along all the year (Figure 52) and in the ICES division 9a (Figure 54).

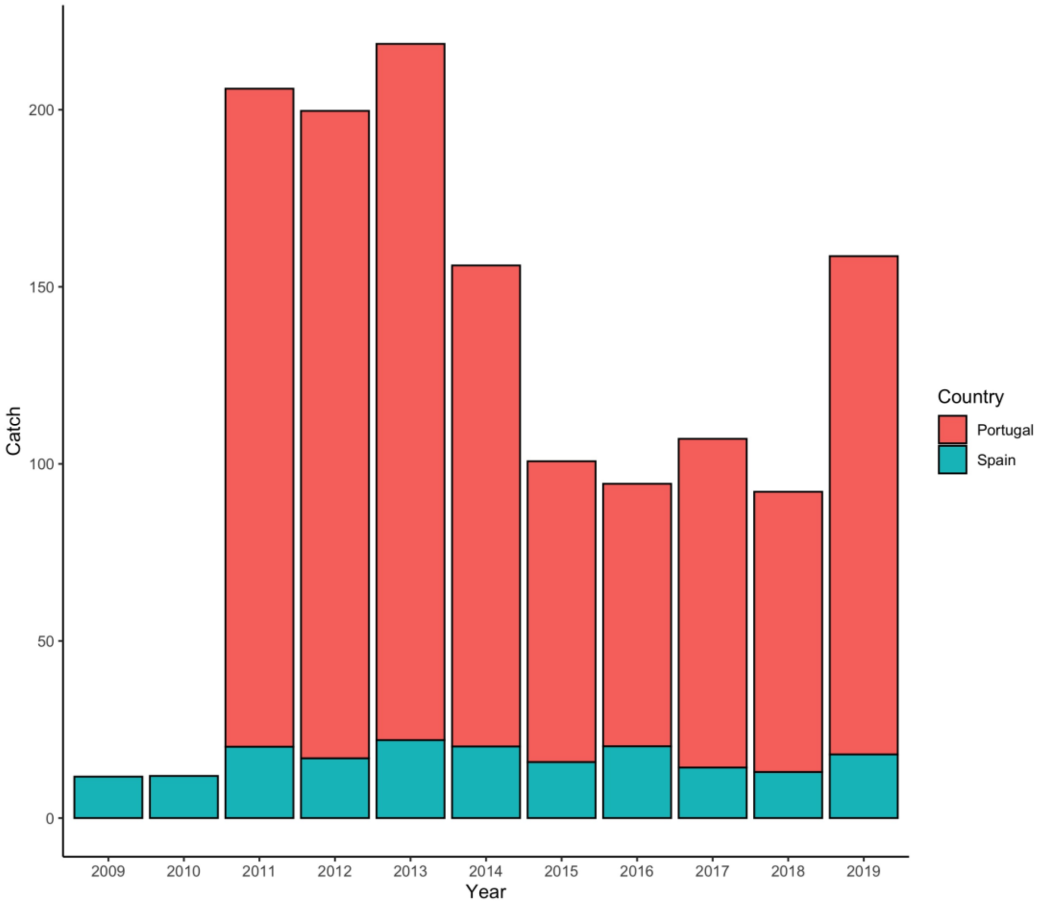

Figure 51: *P.lascaris* catches by country from 2009 to 2019.

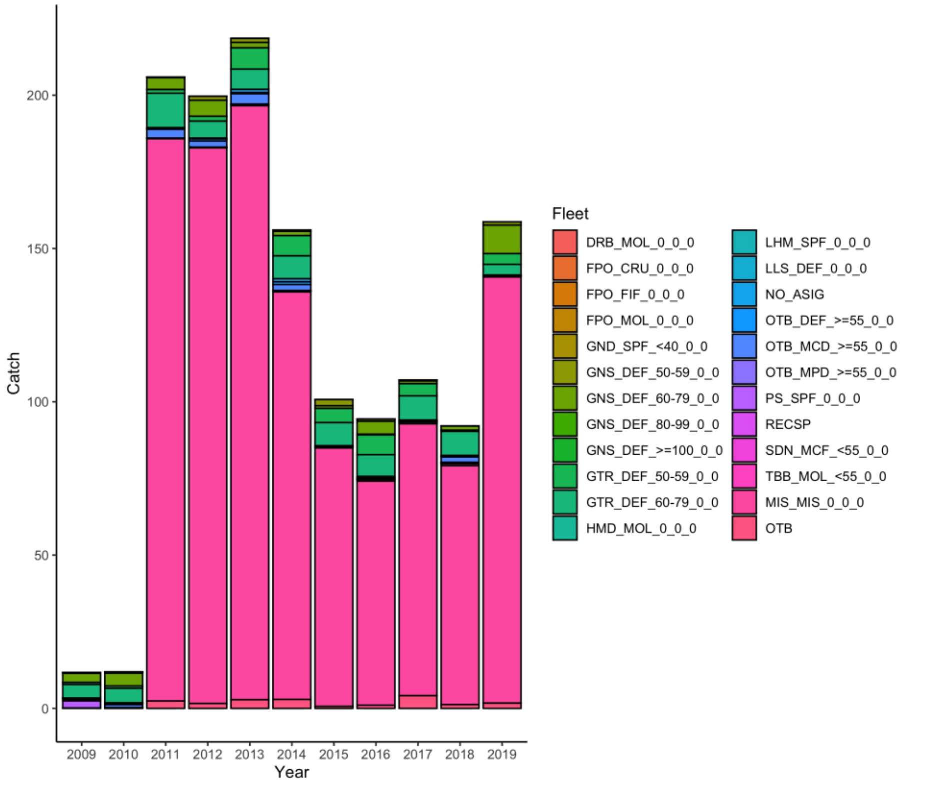

Figure 52: *P.lascaris* catches by fleet from 2009 to 2019.

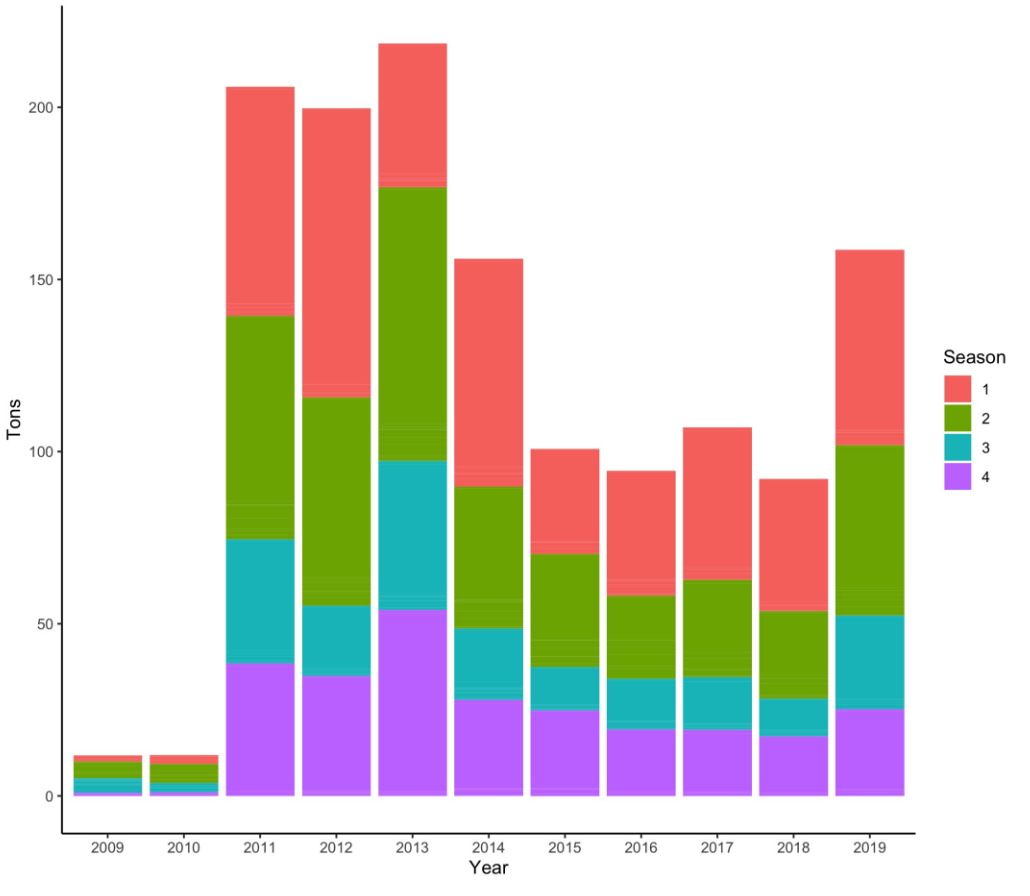

Figure 53: *P.lascaris* catches by quarter from 2009 to 2019.

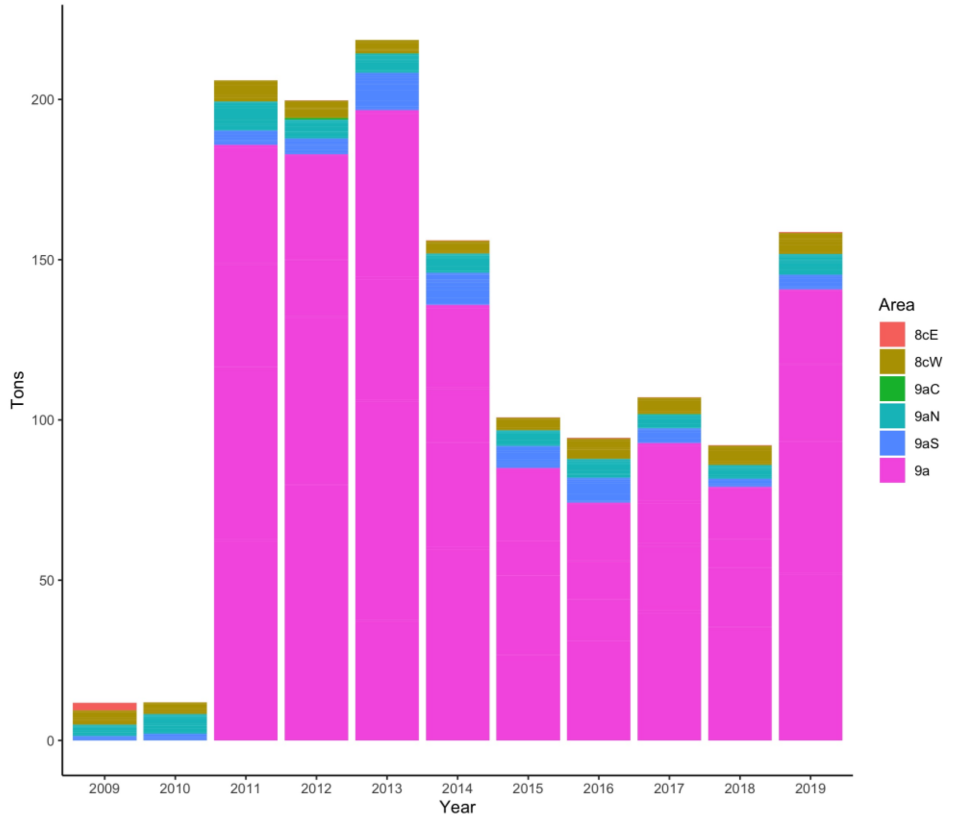

Figure 54: *P.lascaris* catches by area from 2009 to 2019.

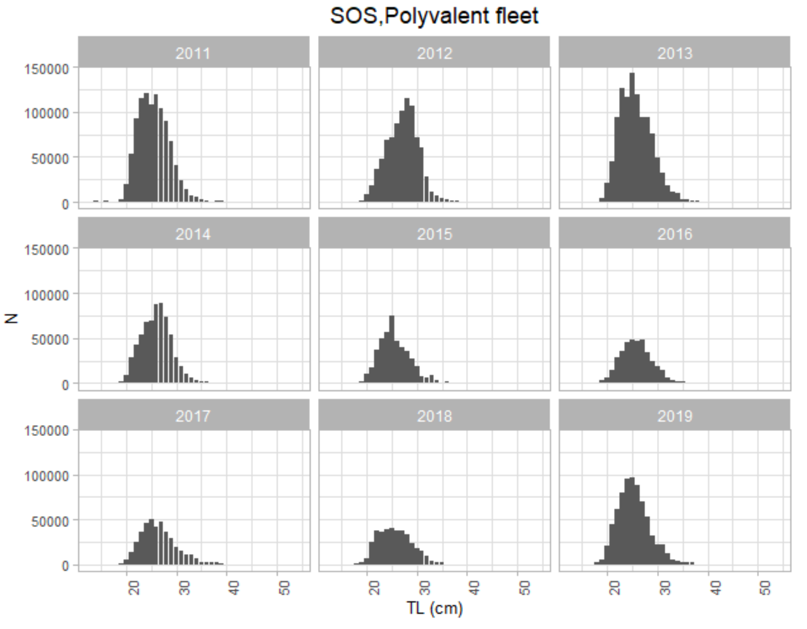

Figure 55. *P.lascaris* length distribution in Portuguese waters (Division 9a) for the main fleet.

This species is very sporadically caught by the Spanish (SP-NSGFS Q4) and Portuguese (PtGFS-WIBTS-Q4) bottom trawl demersal surveys (Figures 38 and 39).

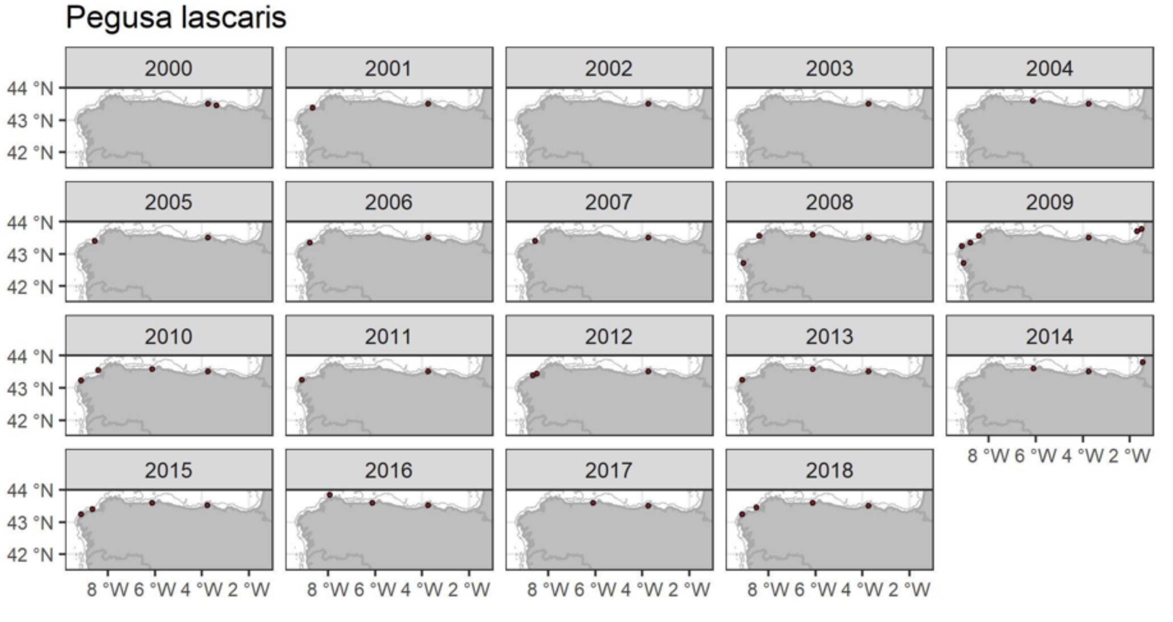

Figure 56: Hauls where the *P.lascaris* was caught during the Spanish survey (SP-NSGFS Q4).

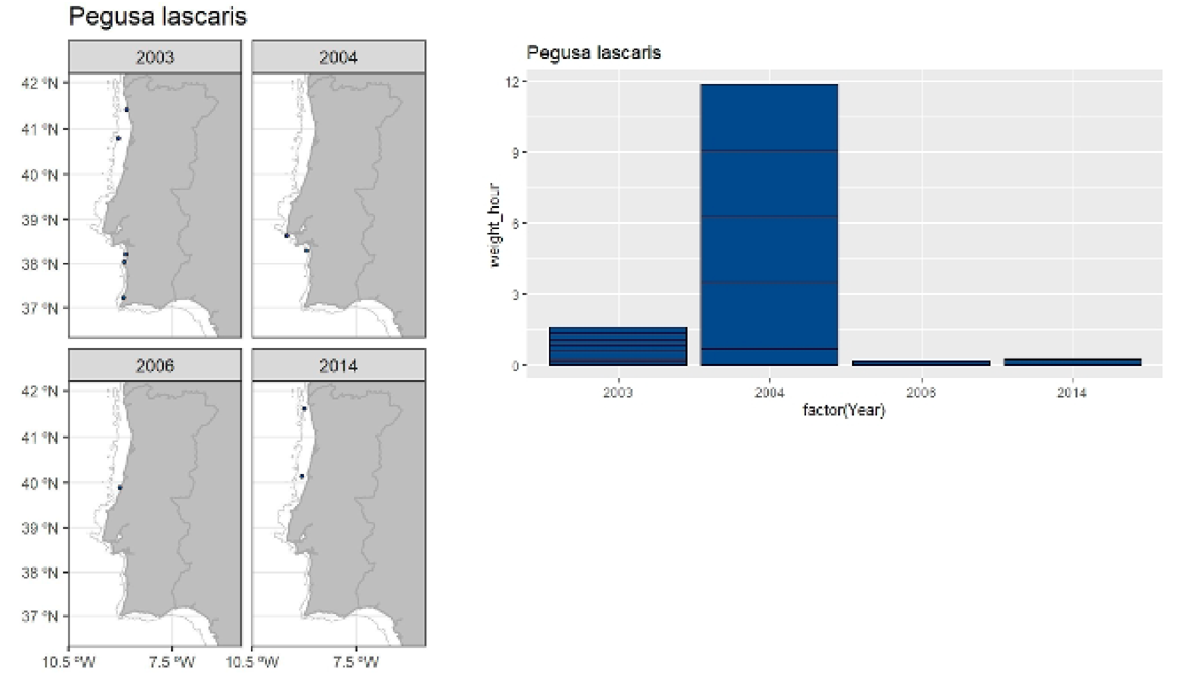

Figure 57: Hauls where the *P.lascaris* was caught during the Portuguese survey (PtGFS-WIBTS-Q4) (left) and temporal trend of the abundance caught (right).

Solea spp

The majority of the catches Solea spp. are in Spain (Figure 58), by the bottom trawlers (Figure 59), Along all the year (Figure 60) in the area 9aS (gulf of Cadiz, Spain) (Figure 61).

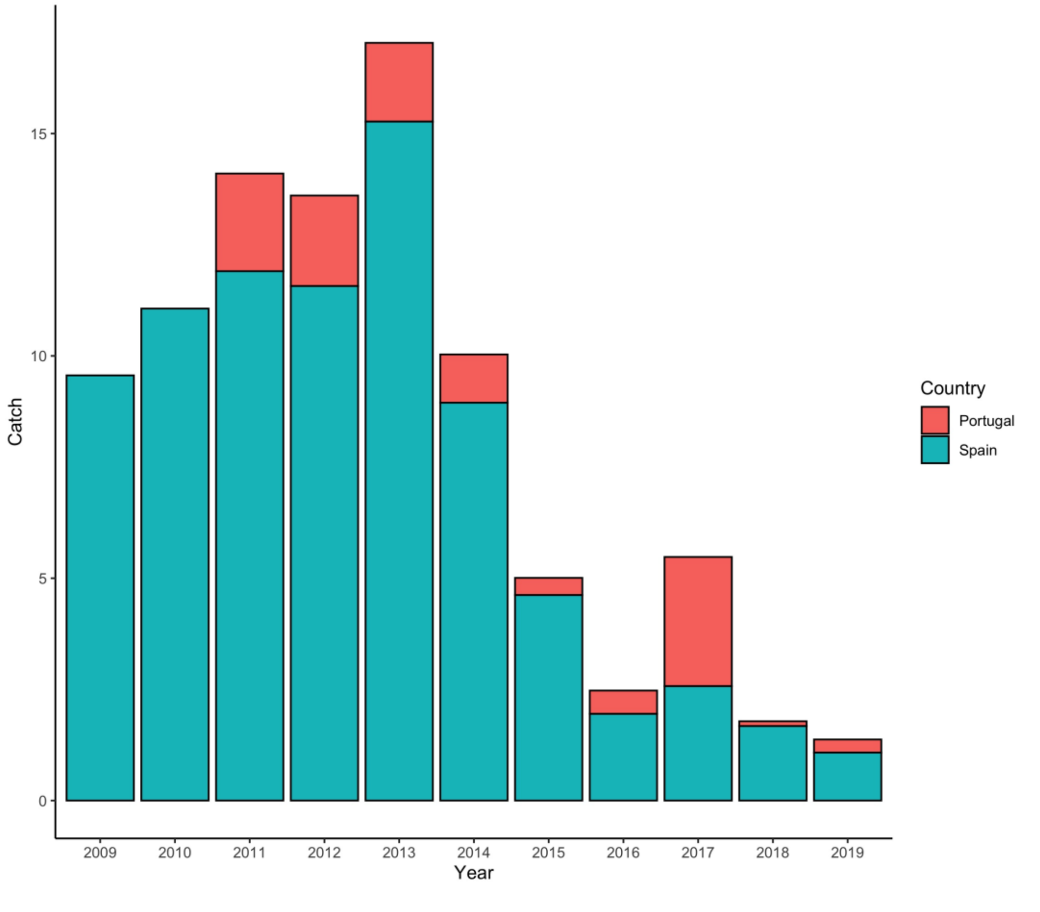

Figure 58: Solea spp. catches by country from 2009 to 2019.

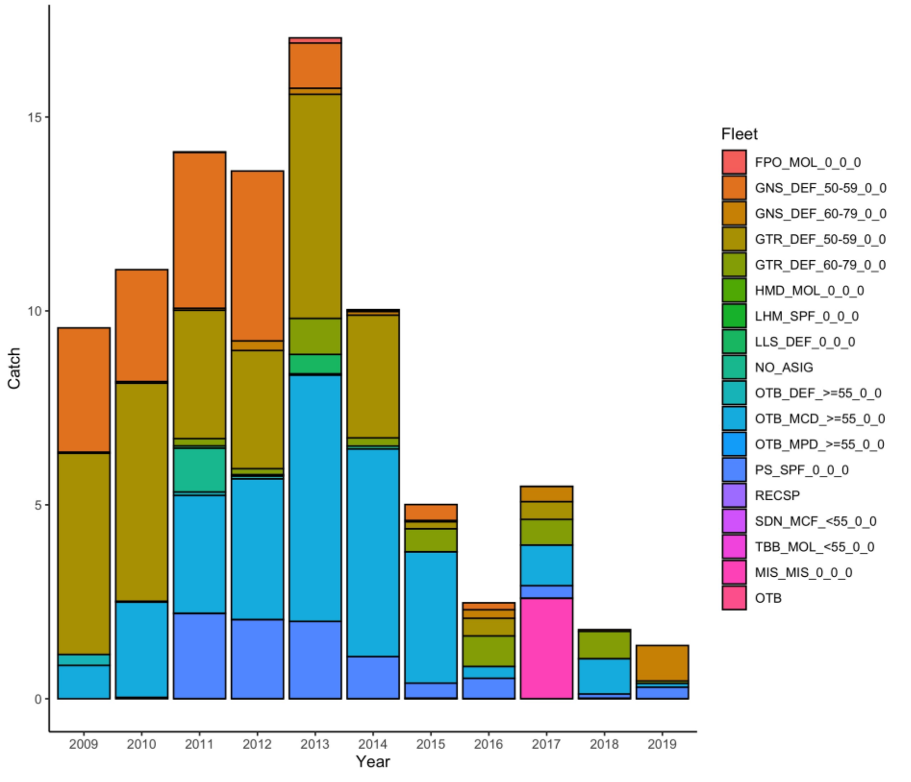

Figure 59: Solea spp. catches by fleet from 2009 to 2019.

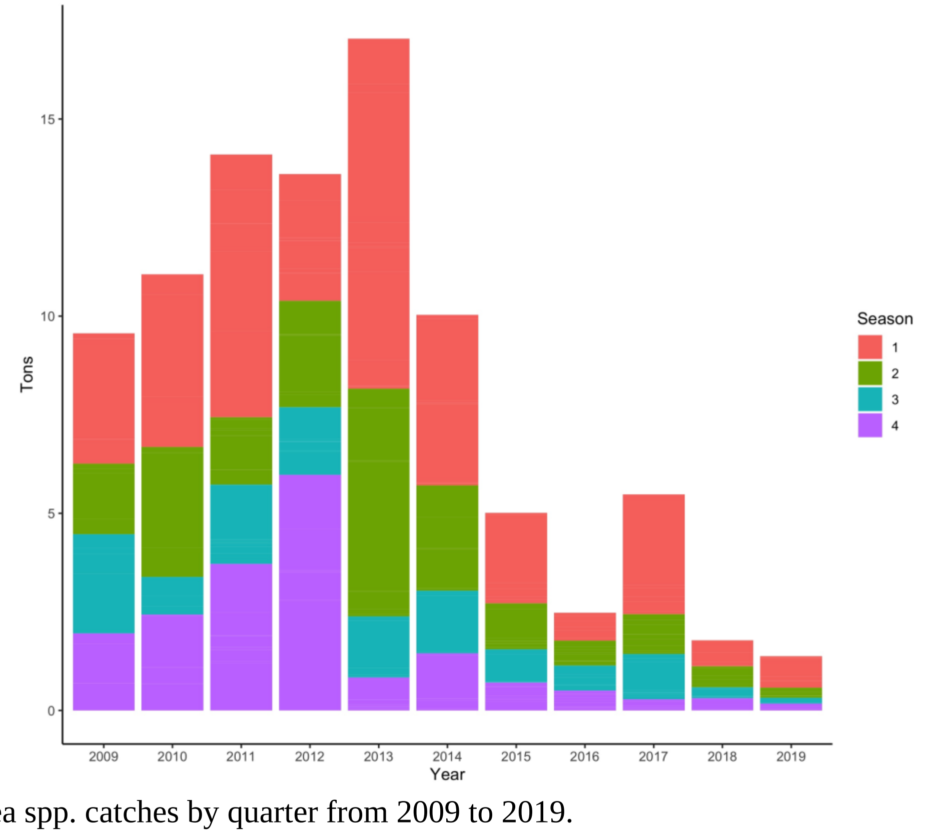

Figure 60: Solea spp. catches by quarter from 2009 to 2019.

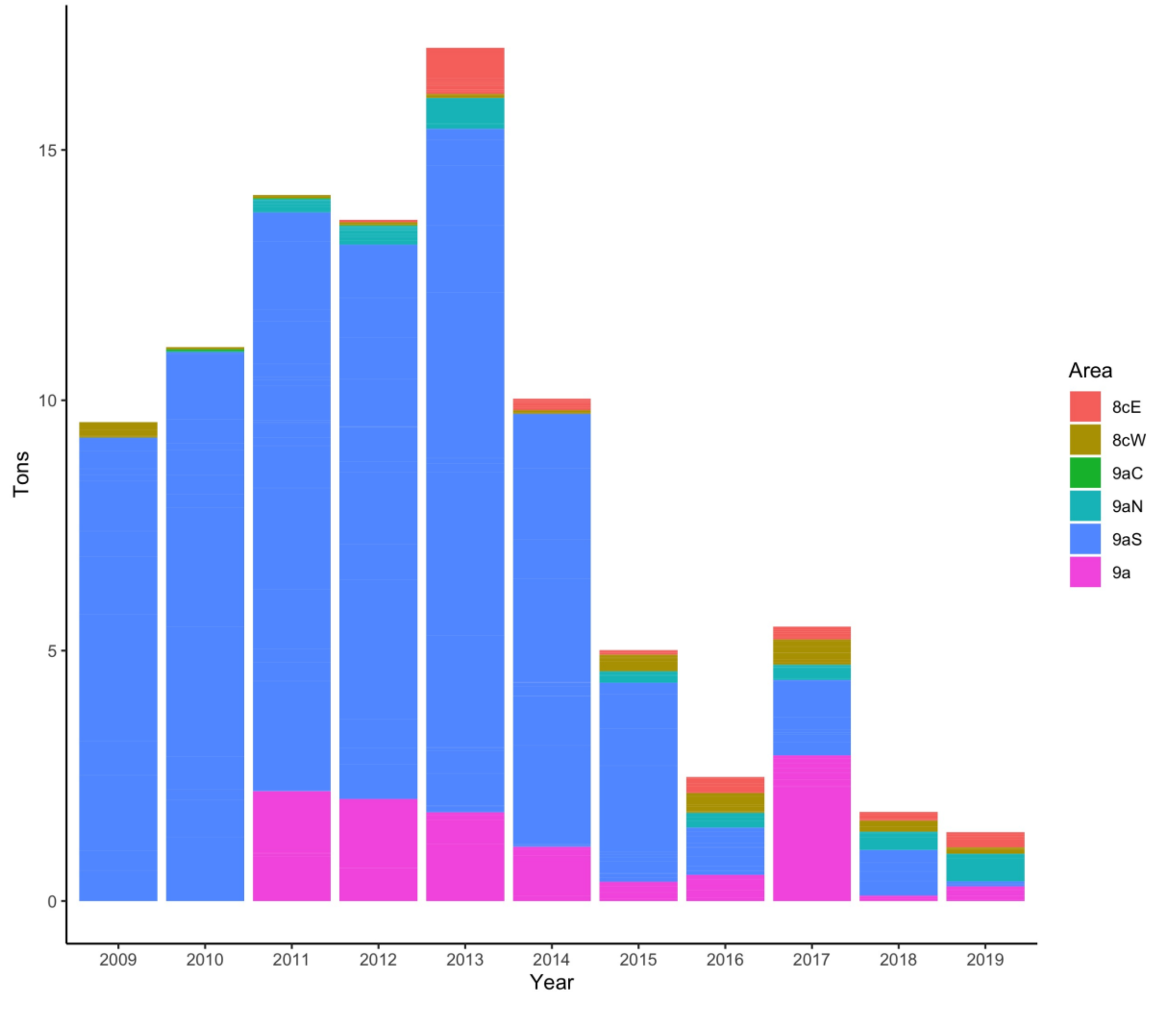

Figure 61: Solea spp. catches by area from 2009 to 2019.

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ANNEX 2

S. solea spatiotemporal model prediction and strata areas issue

In order to check if there was any issue with the spatial prediction of the abundance index generated with the Bayesian model, we compared the areas used for prediction for both the Bayesian model and the usual survey index.

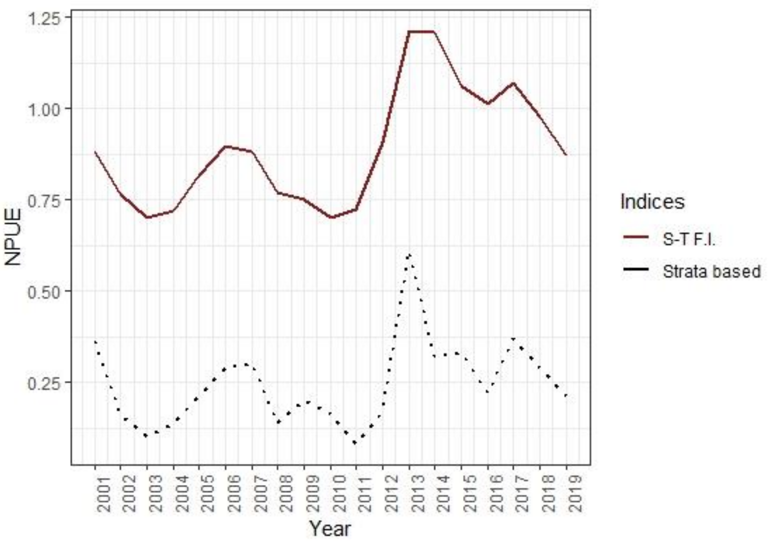

Figure 1. In red the spatio-temporal abundance index obtained for fishery-independent data (2001-2019) versus the survey abundance index standardized for the three bathymetric strata (i.e.,70–120 m and 121–200 m).

We mapped firstly the bathymetry map used for the model and we cropped for the bathymetric strata 70-200 as was the one used for the predictions.

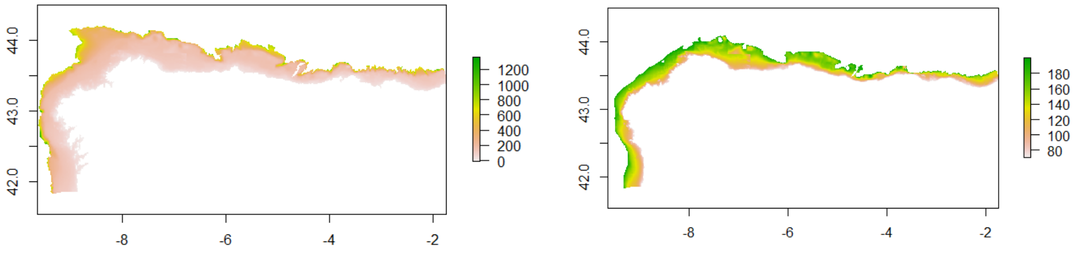

Figure 2. Bathymetry map for the entire study area (left panel), and the cropped one between 70 and 200 m (right panel).

We then computed the superficies of each bathymetric strata used for standardize the survey index.

Figure 3. Spatio-temporal averaged (2001-2019) predicted abundance performed between 70 and 200 m.

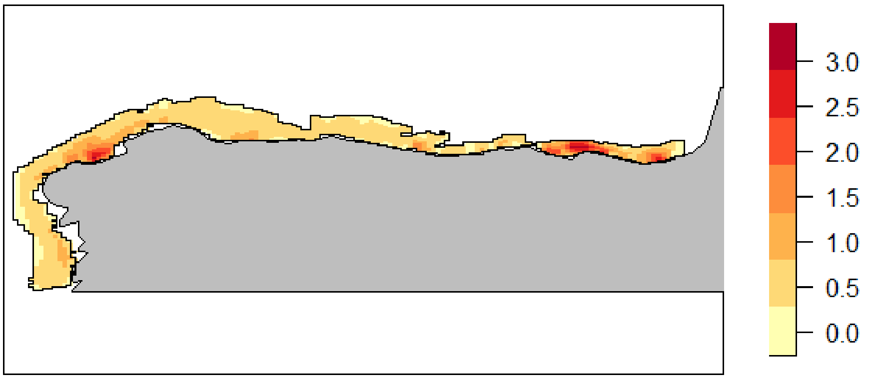

Figure 4. Spatio-temporal averaged (2001-2019) predicted abundance area performed between 70 and 200 m. This area is 21566 km^2.

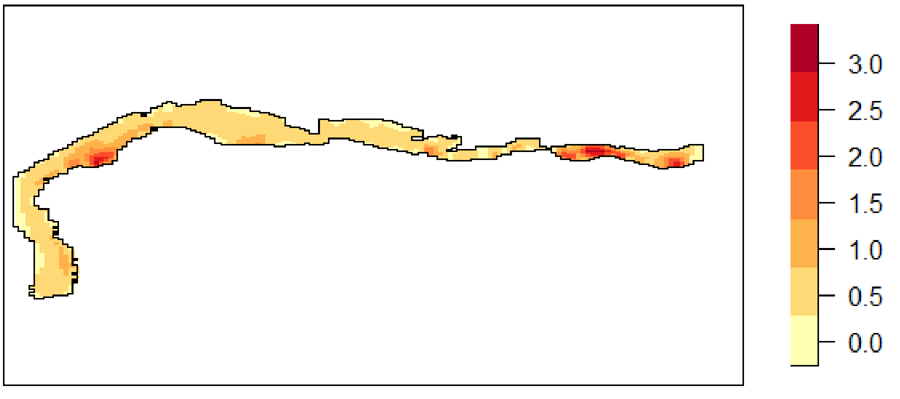

Figure 5. Spatio-temporal averaged (2001-2019) predicted abundance area performed between 70 and 200 m. This area is 21566 km^2.

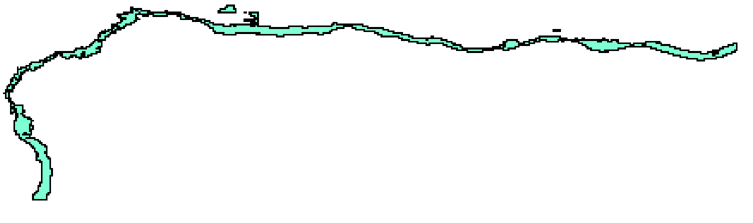

Figure 6. Bathymetric strata corresponding to the 70-120 m isobaths. This area is 5740 km^2.

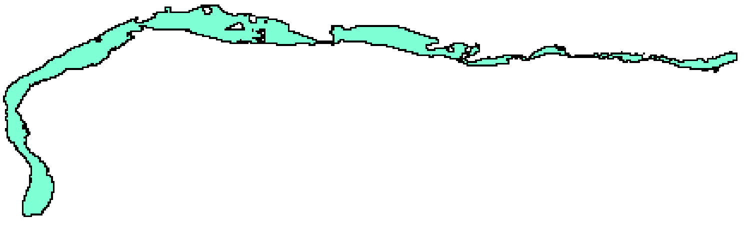

Figure 7. Bathymetric strata corresponding to the 121-200 m isobaths. This area is 11951 km^2.

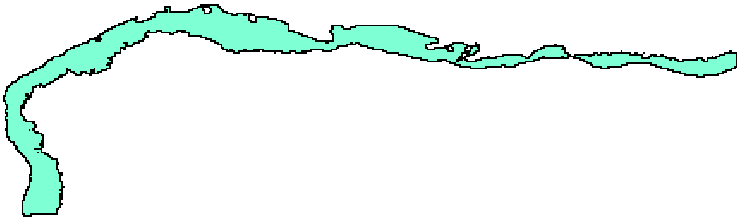

Figure 8. Bathymetric strata corresponding to the 70-200 m isobaths. This is the total bathymetric strata where sampling point and prediction take place. This area is 17591 km^2.

Finally, we computed the intersection area between the prediction area and the strata used for standardize the survey index.

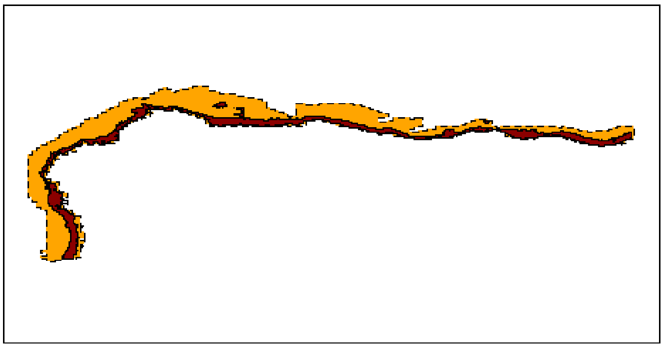

Figure 9. Intersection between predicted abundance area (orange) and 70-121 m strata. This area is 5740 km^2, what means the total strata area.

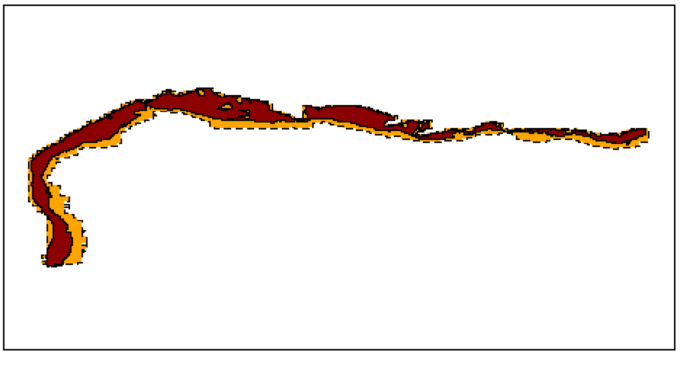

Figure 10. Intersection between predicted abundance area (orange) and 121-200 m strata. This area is 11944 km^2, what means almost the total strata area.

Figure 11. Intersection between predicted abundance area (orange) and 70-121 m strata. This area is 17573 km^2, what means the total strata area.

Figure 13. Sp-GNF survey strata areas.

Table 1. SP GNF strata areas.

	Id	AREA	Primary	Secondary	ID3	ID4	ZLEVEL	Area_KM2
0	0	1181159977	MF	a	<NA>	<NA>	0	1181.1600
1	0	2190284192	MF	b	<NA>	<NA>	0	2190.2842
2	0	956077943	MF	c	<NA>	<NA>	0	956.0779
3	0	908414198	AB	a	<NA>	<NA>	0	908.4142
4	0	921466432	AB	b	<NA>	<NA>	0	921.4664
5	0	538619575	AB	c	<NA>	<NA>	0	538.6196
6	0	1024129435	PA	a	<NA>	<NA>	0	1024.1294
7	0	2623404925	PA	b	<NA>	<NA>	0	2623.4049
8	0	1273646608	EP	a	<NA>	<NA>	0	1273.6466
9	0	1137910064	FE	a	<NA>	<NA>	0	1137.9101
10	0	955632958	PA	c	<NA>	<NA>	0	955.6330
11	0	3253610715	FE	b	<NA>	<NA>	0	3253.6107
12	0	3010442407	EP	b	<NA>	<NA>	0	3010.4424
13	0	665875091	EP	c	<NA>	<NA>	0	665.8751
14	0	3400494018	FE	c	<NA>	<NA>	0	3400.4940

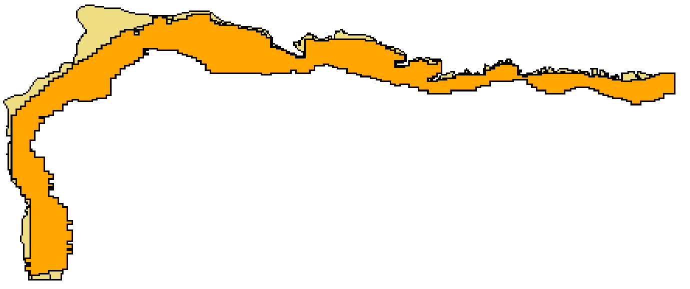

Figure 14. Prediction abundance area over SP-GNF strata areas.

Figure 15. Part of SP-GNF strata areas (green) that are overlapped by the abundance predicted area.

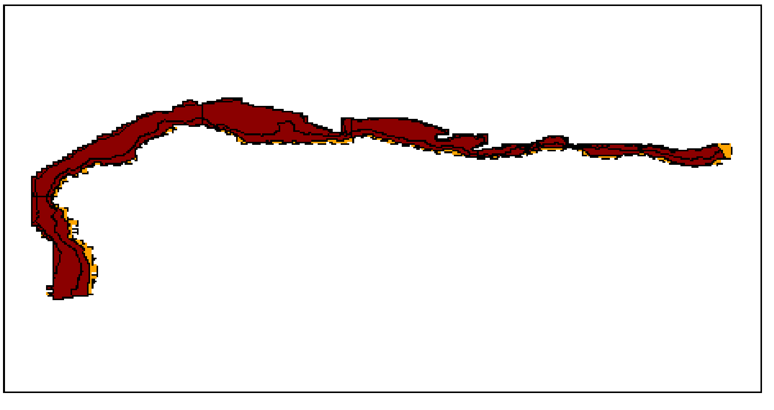

Figure 16. Intersection (dark red) between SP-GNF strata areas and the abundance predicted area.

Table 2. Intersected area between prediction abundance area (21566 km^2) and each SP-GNF strata area.

```
> inti#intersected area with prediction
 [1] 1085.8616 2073.4222  474.8008  909.0725  915.4009  134.6158
 [7] 1024.2816 2597.0128 1270.5984 1124.9613  350.3088 3183.4571
[13] 2965.8259  212.7180  584.5996
```

Table 3. Overlapping proportion (SP-GNF areas/intersection areas).

```
> por# proportion between total and inti
 [1] 0.9243313 0.9520981 0.4996263 0.9999888 0.9926920 0.2497405
 [7] 1.0000000 0.9898615 0.9991208 0.9927144 0.3665065 0.9826559
[13] 0.9869415 0.3199327 0.1726801
```

ANNEX 2

Soleidae Portuguese landings estimation

1. Data available

Table 1. Summary of the data sources used in Soleidae landings estimation.

Type	Period	Description	Source
Official daily landings	2011-2019	Weight (Kg) and value (€) of all landed species (or commercial name) by trip	Portuguese Directorate General for Natural Resources (DGRM)
Landings sampling by species	2011-2019	Commercial common name and total weight (Kg) of each auction box landing soleidae species by trip. Species, weight (kg), total length (cm) by each soleidae specimen in each auction box landed by trip.	DCF-PNAB sampling programme. Data was extracted by Cristina Silva in August 2020

1.1. Polyvalent Fleet

Table 2. Number of trips landing Soleidae species sampled under the DCF sampling program for the Polyvalent fleet per region, landing port, year and semester. * for analysis purposes, data will be pooled together.

Region	Landing Port	Semester	2011	2012	2013	2014	2015	2016	2017	2018	2019
North	**Aveiro**	**1**	14	2	15	16	15	16	21	2	9
		2	18	17	11	14	22	24	28	23	2
	Figueira da Foz	**1**		5	11	15	9	5	8	4	13
		2	1	8	5	8	9	7	6	7	12
	Matosinhos*	**1**	26	18	29	3	22	16	13	15	18
		2	19	2	27	17	18	11	15	16	18
	Póvoa de Varzim*	**1**	12	13	11	14	19	7	7	12	14
		2	6	5	15	1	2	5	4	4	6
	Viana do Castelo	**1**				3	4	4	8	7	4
		2				4	5	2	4	3	1
Southwest	**Costa da Caparica**	**1**				6	8	11	17	7	9
		2				6	4	8	9	6	
	Nazaré	**1**					3	1	4	1	
		2				1	2	1	2	1	1
	Peniche	**1**	3	41	4	57	35	39	43	34	33
		2	28	28	38	33	31	32	2	14	13
	Sesimbra*	**1**	5	5	7	5	7	11	1	12	13

		2	1	4	4	3	7	5	3	12	12
	Setúbal*	**1**	3	4	2	5	11	3	4	6	1
		2	5	2	2	6	7	5	4	9	1
	Sines	**1**	22	17	19	19	3	3	1		3
		2	19	17	15	1	4	1	2	3	4
South	**Lagos**	**1**	1			2	1			1	
		2				1	1				
	Olhão	**1**	21	27	72	34	6	8	3	5	3
		2	49	55	57	12	2	5	2	7	3
	Portimão	**1**	1				1			1	1
		2					1	1	1		1
	Quarteira	**1**					3	2	2	2	3
		2				7		4	3	2	1
	Sagres	**1**				2	3	2	1	2	3
		2				3	3	1			1
	Vila Real de Santo António	**1**				1	1			2	3

1.2. Trawl Fleet

Table 3. Number of trips landing Soleidae species sampled under the DCF sampling program for the Trawl fleet per Region and year.

Region	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
North	44	30	35	51	49	54	43	36	22
Southwest	24	26	24	31	26	33	22	47	41
South	1	1	3	1	3	4	3		

2. Estimation method

2.1. Polyvalent Fleet

Due to the proximity of the landing ports of Póvoa de Varzim to Matosinhos and Setúbal to Sesimbra (far apart around 11 nautical miles, i.e. around 21 km), data available for each pair was pooled together. Vessels landing in these areas often select one of the landing ports either because of the distance between it and the fishing ground or because commercial reasons.

The species weight proportion to the total weight of Soleidae in each year, landing port, and semester ($p\hat{a}_{(s,y,p,g)}$) was calculated using a simple random sampling estimator, following equation (Figueiredo et al. 2020):

$$P\hat{a}_{(s,y,p,g)} = \sum_{i=1} w_{(s,y,p,g)i} \,/\, wt_{(y,p,g)}$$

where $\boldsymbol{w}_{(s,p,y,g)i}$ is the landed weight of of s^{th} Soleidae species in the i^{th} fishing trip and $\boldsymbol{wt}_{(y,p,g)}$ is the total landed weight of Soleidae in the sampled trips at the y^{th} year, p^{th} port and g^{th} semester.
The estimate of the total landed weight of one species $\hat{W}_{(s,y,p,g)}$ in year y port p and semester g is given by:

$$\hat{W}_{(s,y,p,g)} = \sum_{g} p\hat{a}_{(s,y,p)g} \; x \; Wt_{(y,p)g}$$

Where $\boldsymbol{Wt}_{(y,p)g}$ is the total landed weight of Soleidae species at the y^{th} year, p^{th} port and g^{th} semester.

When a group (port and semester) was not sampled in one of the semesters (considered less than 3 sampled trips), the proportion applied was the one obtained for the all region (North, southwest or South),($p\hat{a}_{(s,y,r)}$), following equation:

$$P\hat{a}_{(s,y,r)} = \sum_{i=1} w_{(s,y,r,g)i} \, / \, wt_{(y,r,g)}$$

where $\boldsymbol{w}_{(s,y,r,g)i}$ is the landed weight of of s^{th} Soleidae species in the i^{th} fishing trip and $\boldsymbol{wt}_{(y,r,g)}$ is the total landed weight of Soleidae in the sampled trips at the y^{th} year, region r^{th} and g^{th} semester.
The estimate of the total landed weight of one species $\hat{W}_{(s,y,r,g)}$ in year y region r and semester g is given by:

$$\hat{W}_{(s,y,r,g)} = \sum_{g} p\hat{a}_{(s,y,r)g} \; x \; Wt_{(y,r)g}$$

Where $\boldsymbol{Wt}_{(y,r)g}$ is the total landed weight of Soleidae species at the y^{th} year, r^{th} region and g^{th} semester.

2.2. Trawl Fleet

Due to due to the general low number of samples, soleidae species weight proportions will be estimated considering only the year and region ($p\hat{a}_{(s,y,r)}$), using a simple random sampling estimator, following equation:

$$P\hat{a}_{(s,y,r)} = \sum_{i=1} w_{(s,y,r)i} \, / \, wt_{(y,r)}$$

where $\boldsymbol{w}_{(s,y)i}$ is the landed weight of of s^{th} Soleidae species in the i^{th} fishing trip and $\boldsymbol{wt}_{(y)}$ is the total landed weight of Soleidae in the sampled trips at the region r^{th} and year y^{th} .

The estimate of the total landed weight of one species $\hat{W}_{(s,y,r)}$ in year y and region r is given by:

$$\hat{W}_{(s,y,r)} = \sum_{g} p\hat{a}_{(s,y)r} \; x \; Wt_{(y)r}$$

Where $\boldsymbol{Wt}_{(y)r}$ is the total landed weight of Soleidae species at the y^{th} year and r^{th} region.

Data is lacking for the South region in years 2011, 2012, 2014, 2018 and 2019. Assuming a certain stability in the trawl fleet:

- 2011-2012 apply proportions estimated for 2013
- 2014 apply proportions estimated for 2015
- 2018-2019 apply proportions estimated for 2017

2.3. Purseine Fleet

Given the lack of data from the purseine fleet, Soleidae landings from this fleet segment were considered to be *Solea* spp.