Stock Annex: Sole (*Solea solea*) in Division 7.d (eastern English Channel)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Sole (*Solea solea*) in Division 7.d (eastern English Channel)
Working Group:	Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK)
Last date when the stock was updated:	February 2021
Revised by:	Lies Vansteenbrugge
Timeline of revisions:	May 2011, February 2017, October 2019
Main modifications:	New stock annex as a result of the WKNSEA 2021 benchmark
Last Benchmarked:	February 2021 (WKNSEA 2021)
Last update:	May 2021

A. General

A.1 Stock definition

Sole in the eastern English Channel (27.7.d) is considered to be a stock separated from the larger North Sea stock (27.4) to the east and the smaller geographically-separated stock to the west in 27.7.e (western English Channel).

Genetic analyses using outlier Single Nucleotide Polymorphisms (SNP) revealed that sole in area 27.7.d is genetically distinct from sole in 27.7.e, while it shows a pattern of isolation by distance (gradual change in genetic diversity) with the North Sea sole (Diopere *et al.*, 2018).

The intensive CEFAS tagging programme (Burt and Millner, 2008) showed that overall 91% of sole in the North Sea and 72% in 27.7.d remained resident. The remaining 9% of the North Sea were found in 27.7.d (7%) and in 27.7.e (2%). 20% of the sole released in 27.7.d had moved west into the neighbouring area 27.7.e (and 1% beyond 27.7.e), but more noticeably so in autumn and winter (31% in Q4–Q1 vs 15% in Q2–Q3). 7% moved into the North Sea. The extent of movement between 27.7.d and 27.7.e increases closer to the boundary between the two areas. However, the abundance of sole in the western part of 27.7.d is much lower than in the eastern area and this movement across the management boundary, although significant, might represent a relatively small number of fish. The assessment does not take account of these movements.

Three regions are distinguished <u>*within*</u> area 27.7.d that are associated with low connectivity **for larvae and juveniles**: a) along the English coast, b) in the Seine Bay, and c) along the coast of northern France (Rochette *et al.*, 2013; Archambault *et al.*, 2016) (Figure 1). Limited exchange of larvae or juveniles occurs between these three areas (Eastwood *et al.*, 2001; Grioche *et al.*, 2000), with the exception of the northern side of the region 'coast of northern France', where exchange with the North Sea was observed due to the strong hydrodynamics (Savina *et al.*, 2010; Savina *et al.*, 2016).

A tagging study showed minimal large-scale **adult** movements between the three subunits (Lecomte *et al.*, 2020). Growth and density-at-age were analysed using data from the UK BTS survey and showed significant differences between subpopulations (Randon *et al.,* 2018). Finally, genetic and otolith shape analyses suggest a metapopulation structure at fine spatial scale, with one subunit (Seine Bay) being more isolated (Randon *et al.,* 2020).

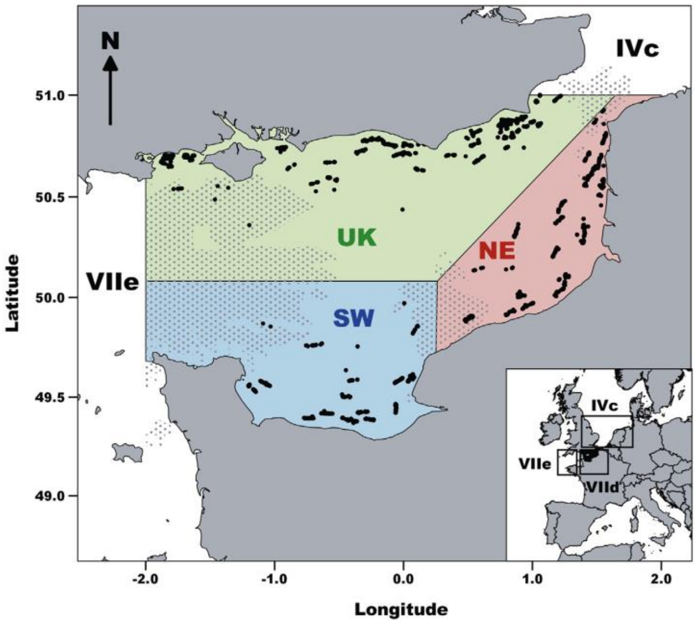


Figure 1: Map indicatin the three subpopulations present in the 27.7.d sole stock. Black dots represent sampling locations of the UK BTS survey as used in Randon *et al.,* 2018.

A.2 Fishery

A.2.1 General description

Countries involved in this fishery are France (contributing ~60%), Belgium (~25%) and the UK (England and Wales) (~15%). Some years, also Ireland, UK (Scotland), UK (Northern Ireland), Germany and the Netherlands have a minor contribution to this fishery.

There is a directed fishery for sole by small inshore (mostly French and English) vessels using trammelnets, which fish mainly along the English and French coasts and possibly exploit different coastal populations. Sole represents the most important species for these vessels in terms of the annual value to the fishery. The fishery for sole by these boats occurs throughout the year with peaks in landings in autumn and late winter. In 2020, French trammel net fishers applied for subsidies to decommission their vessels or switched to pot fisheries for certain periods of the year.

The French otter trawl fleet is also an important fleet fishing on sole in the eastern English Channel, with generally most of their landings in the thrid and fourth quarter. A selection of the French otter trawl fleet is used to calculate the French commercial otter trawl tuning fleet for the assessment. Their spatial distribution is shown in Figure 2.

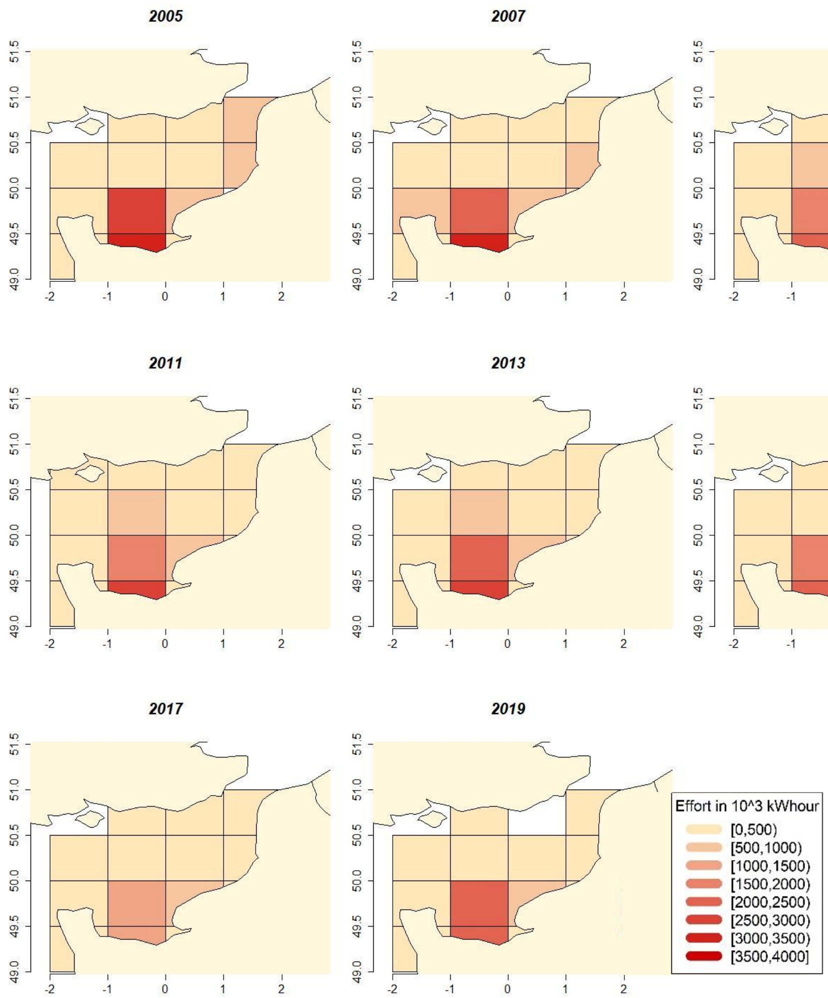


Figure 2: Spatial distribution of fishing effort per year (2005-2019) and ICES rectangles of the selected French otter trawl fleet as used for the tuning index.

There is also a directed fishery by English and Belgian beam trawlers. These vessels are able to fish for sole in winter before the fish move inshore and become accessible to the local fleets. In cold winters, sole are particularly vulnerable to the offshore beamers when they aggregate in localized areas of deeper water. The Belgian beam trawl fleet covers a large part of Division 7.d, including the UK coastal areas and the central part of the division (Figure 3).

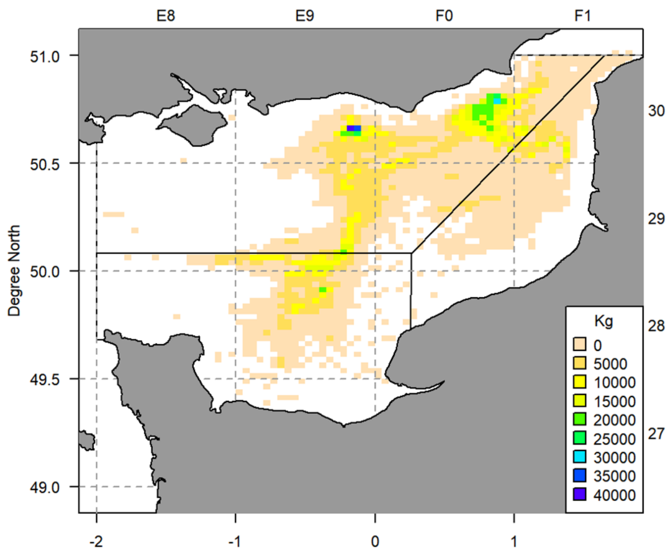


Figure 3: Spatial distribution of sole landings from the Belgian beam trawl fleet for the period 2006–2019.

The UK fleet targeting sole has decreased significantly since the 1980s. This corresponds to an overall decrease in landings and a concentration of the remaining effort (and landings) to the UK coastal areas (Figure 4).

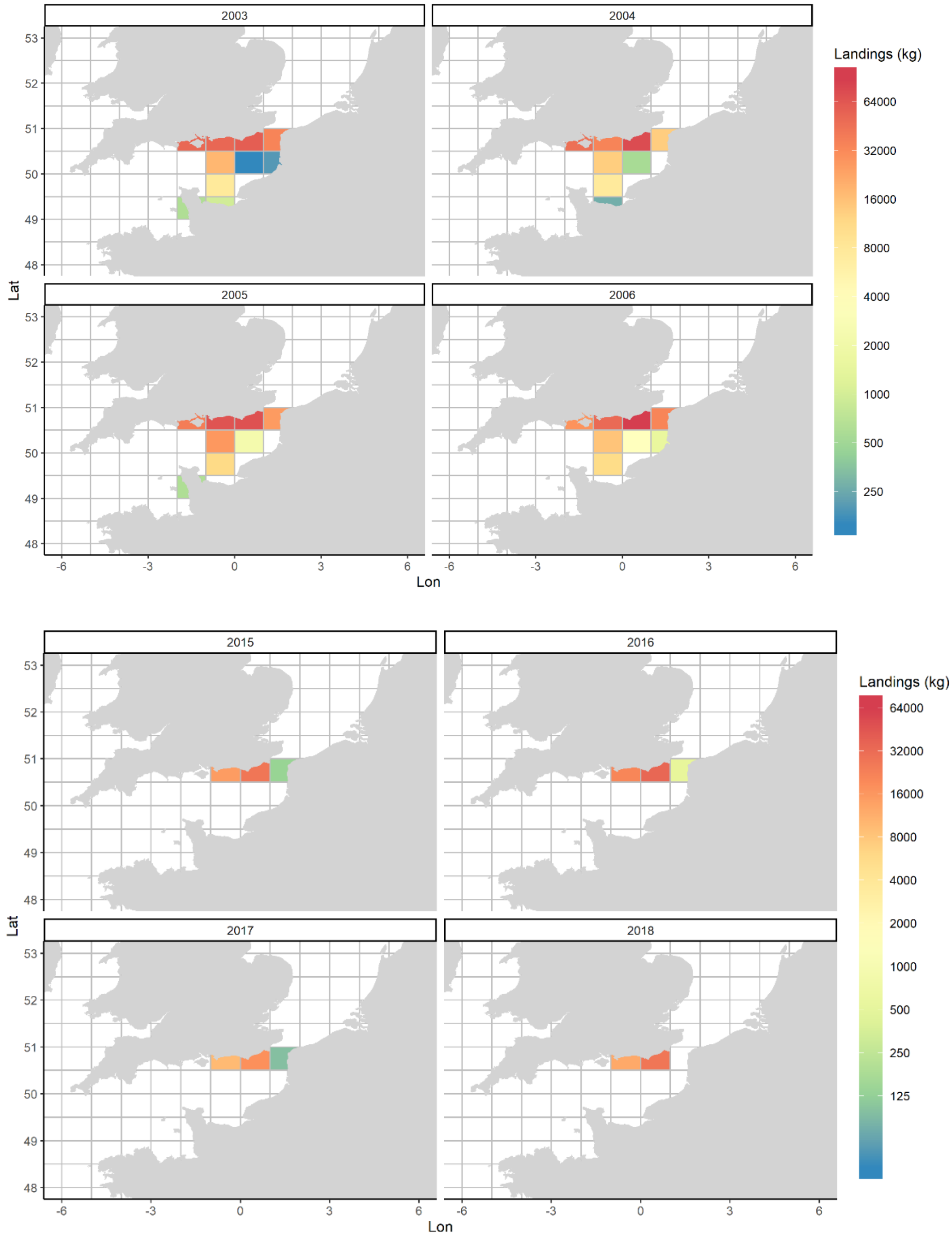


Figure 4: Spatial landings by ICES rectangle of sole by the UK beam trawl fleet in Division 27.7.d for the period 2003–2006 and 2015–2018.

A.2.2 Fishery management regulations

Management of sole in 27.7.d is by TAC and technical measures.

A historical overview of the TAC for sole 27.7.d since 2000 is presented in the table below.

Historical overview of the TACs for sole in Division 27.7.d (2000-2020); Note: *TAC represents catch from 2016 onwards (landing obligation)

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
TAC	4100	4600	5200	5400	5900	5700	5720	6220	6590	5274	4219
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016***	**2017***	**2018***	**2019***	**2020***	
TAC	4852	5580	5900	4838	3483	3258	2724	3405	2515	2797	

Except for 2009 and 2010, the TAC has not been restrictive since 2003. In 2014, it became restrictive for Belgium, and in 2015 this was the case for Belgium and France.

The minimum landing size for sole is 24 cm. Sole in the eastern English Channel is fully under the landing obligation since 2018 (partially since 2016). BMS landings reported for this stock are small, mainly because there are two exemptions in place which allow discarding of undersized sole in division 7.d (Delegated Regulation (EU) 2018/2034):

1) a survival exemption for small coastal otter trawlers (<10 m and <221 kW) fishing less than 90 minutes in areas with a depth less than 30 m (outside nursery areas) and with cod-end mesh size of 80–99 mm.

2) a *de minimis* exemption for vessels using trammel and gill nets (max. 3% of annual catches) and using TBB gear with a mesh size of 80–119 mm equipped with the Flemish panel (max. 3% of annual catches).

In response to the drop in SSB and the poorer recruitment in 2012–2016 (exception 2015), the main countries participating in the fishery implemented additional conservation measures. For Belgian beam trawlers in 27.7.d (and 27.7.fg, 27.7.a) it is mandatory since 1 April 2015 to incorporate a 3 m long section (tunnel) with a 120 mm mesh size before the cod-end (Flemish panel), in order to reduce the catches of small sole (reduction of undersized sole with 40% and marketable sole with 16%). France engaged in 2016 to i) strengthen the protection of the nursery areas, ii) increase the area closed to fishing within the nursery areas, and iii) increase the minimum conservation reference size to 25 cm for French vessels in accordance with EU legislation, where appropriate. From 11 March 2017, the minimum conservation reference size for Belgian vessels has also increased to 25 cm. Finally, also UK beam trawlers usually fish using mesh sizes greater than statutory in order to avoid discarding and to avoid wasting quota.

Technical measures applicable to the mixed demersal beam trawl fishery affect both sole and plaice. The minimum mesh size of 80 mm for the sole fishery generates high discards of plaice, which have a larger minimum landing size than sole. The use of larger mesh sizes would reduce the catch of undersized plaice and sole, but would also result in a loss of marketable sole in the short term.

A.3 Ecosystem aspects

Biology: Adult sole feed on worms, small molluscs and crustaceans. Sole are active, especially at night, and bury themselves more or less completely during the day. In the English Channel, reproduction occurs between February and April, mainly in the coastal areas of the Dover Strait and in large bays (Somme, Seine, Solent, Mont-Saint-Michel, Start and Lyme Bay). Pelagic eggs hatch after 5 to 11 days leading to larvae that are also pelagic and that metamorphose into benthic fry after 1 or 2 weeks. Juveniles spend the first 2 or 3 years in coastal nurseries (bays and estuaries), where fast growth occurs (11 cm at 1 year old) before moving to deeper waters (Carpentier *et al.*, 2009).

Environment: Sole is a benthic species that lives on fine sand and muddy seabeds between 0 and 150 meters depth. The species is found from marine to brackish waters in temperatures between 8 and 24°C (Carpentier *et al.*, 2009). An overview of physical and hydrological features of the eastern English Channel is shown in Figure 5.

Geographical distribution: Sole is found in the Eastern Atlantic, from southern Norway to Senegal, Mediterranean Sea including Sea of Marmara and Black Sea.

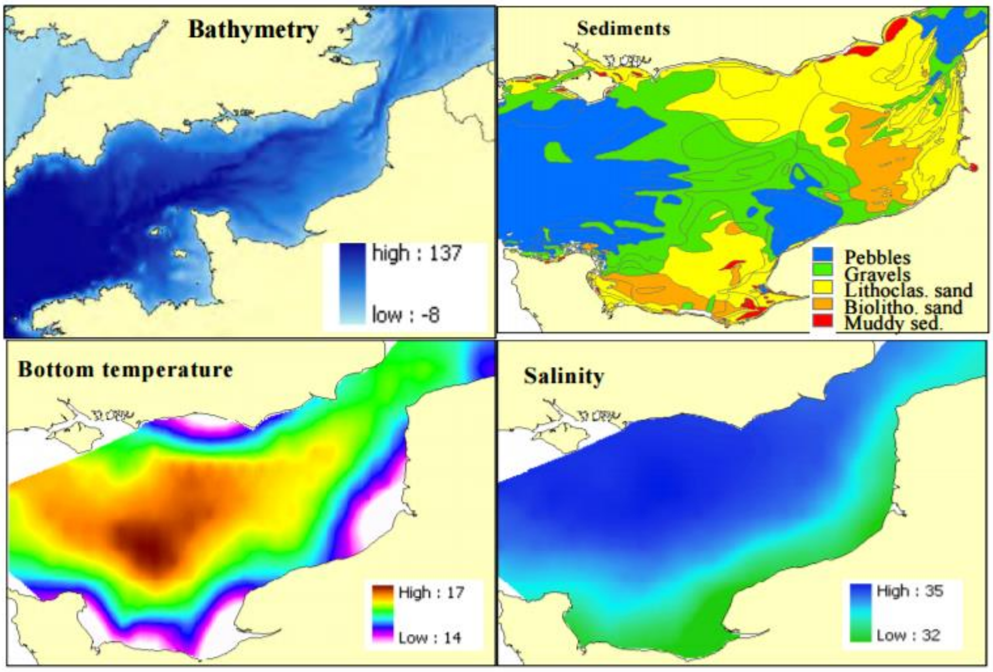


Figure 5: Eastern English Channel physical and hydrological features: Bathymetric depth and simplified sediment types representation. Survey bottom temperature and bottom salinity (averaged for 1997 to 2003) obtained by Kriging (in Vaz *et al.*, 2005).

Species assemblage: Vaz *et al.*, 2007 used multivariate and spatial analyses to identify and locate fish, cephalopod, and macrocrustacean species assemblages in the eastern English Channel from 1988 to 2004. Four sub-communities with varying diversity levels were identified in relation to depth, salinity, temperature, seabed shear stress, sediment type, and benthic community nature. One Group (class 4 in Figure 6 below) was a coastal heterogeneous community represented by pouting, poor cod, and sole and was classified as preferential for many flatfish. It displayed the greatest diversity and was characterized by heterogeneous sediment type (from muds to coarse sands) and various associated benthic community types, as well as by coastal hydrology and bathymetry. It was mostly near the coast, close to large river estuaries, and in areas subject to larger salinity and temperature variations. Possibly resulting from this potentially heterogeneous environment (both in space and in time), this sub-community type was the most diverse.

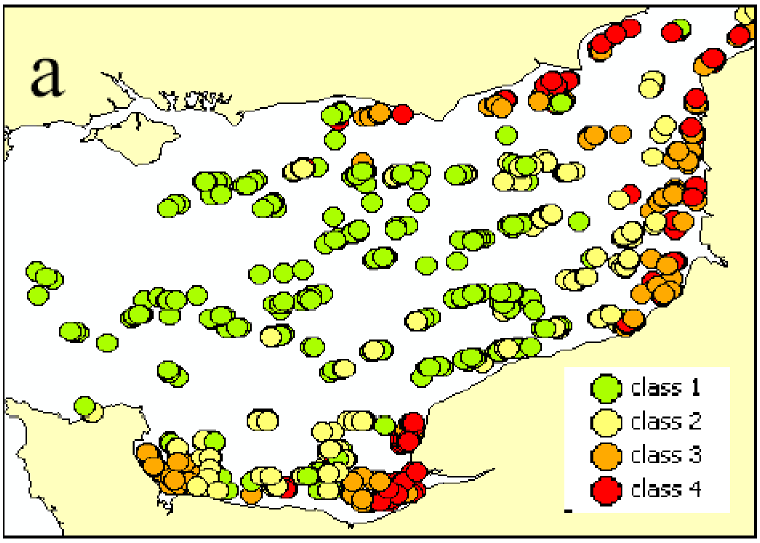


Figure 6: Spatial distribution of fish sub-communities in the eastern Englisch Channel from 1988–2004. The graduation from open sea community to coastal and estuarine communities is shown (from Vaz *et al.*, 2007).

Vaz *et al.* (2007) investigated the community evolution over time and concluded that the community relationship with its environment was remarkably stable over the 17 years of observation. However, the community structure changed significantly over time without any detectable trend, as did temperature and salinity. The community is so strongly structured by its environment that it may reflect interannual climate variations, although no patterns could be distinguished over the study period. The absence of any trend in the structure of the eastern English Channel fish community suggests that fishing pressure and selectivity have not altered greatly over the study period at least. However, the period considered here (1988–2004) may be insufficient to detect such a trend.

More details on the biology, habitat and distribution of sole in division 27.7.d may be found in section H1 (from the Interreg 3a project CHARM II, Carpentier *et al.*, 2009).

B. Data

B.1 Commercial catch

B.1.1 Catch data

Three main countries are involved in taking up the landings of this stock: France (60% ± 4%), Belgium (25% ± 4%) and UK (England and Wales) (16 ± 2%). This uptake is more or less constant over the years. Some years, also Ireland, UK (Scotland), UK (Northern Ireland), Germany and the Netherlands have a minor contribution to this fishery (<1%).

Landings data are available from 1982 onwards and processed in InterCatch from 2004 onwards as a result of the benchmark data call (WKNSEA 2017 and WKNSEA 2021). Age sampling for the period before 1980 was poor, but between 1981 and 1984 quarterly samples were provided by both Belgium and the UK. Since 1985, quarterly catch and weight-at-age compositions were available from Belgium, France, and the UK. The proportion of landings with discards has gradually increased over the years (2004-2012; yellow line in Figure 7). From 2012 onwards, this increasing trend leveled off and showed a slight decrease in 2020 most likely due to the Covid-19 pandemic. The age coverage for landings also increase from 2004–2011 and remained stable around 80%

(orange line in Figure 7). The age coverage for discards fluctuated around 60% over the whole time series (grey line in Figure 7).

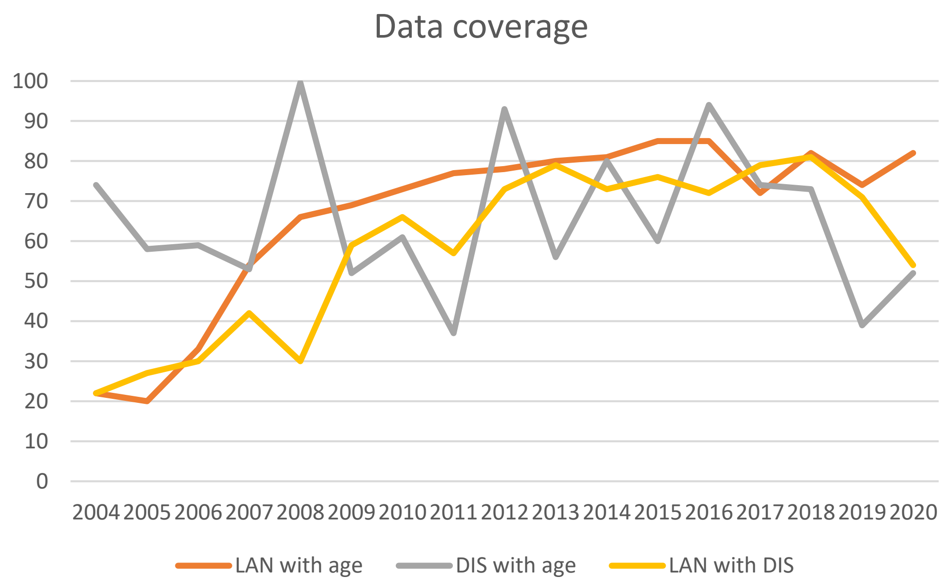


Figure 7: Overview of data coverage for data uploaded to InterCatch (from 2004 onwards).

Discards are included in the assessment from working year 2017 onwards. Prior to the 2017 benchmark, discard rates were estimated.

If discards were not included for a particular year-quarter-country-métier combination, they were assumed to be unknown (non-zero) and therefore raised (InterCatch). Discards on a year-quarter-country-métier basis were automatically matched by InterCatch to the corresponding landings. The matched discards-landings provided a landing-discard ratio estimate, which was then used for further raising (creating discard amounts) of the unmatched discards. The weighting factor for raising the discards was *'Landings CATON'* (landings catch).

Discard raising was performed on a **gear level** regardless of season or country. This approach was favoured over a more detailed one (e.g. using 1 or 2 quarters from 1 country to complete all other quarters of that country). The following groups were distinguished based on gear:

- TBB
- OTB including OTB, OTT, SSC, SDN
- GTR including GTR and GNS

The remaining gears were combined in a REST group (including MIS, FPO, DRB, LHM, LLS).

Raising within a gear group was performed when the proportion of landings for which discard weights are available was **equal or larger than 50%** compared to the total landings of that group. When the threshold was not reached for a gear group, it was pooled with the REST group to raise discards based on all available information. Modifications to this method should be mentioned in the report.

To **allocate age** compositions, landings and discards were handled separately; samples from landings were used only for landings and *vice versa*. When age distributions (both landings and discards) had to be borrowed from other strata, allocations were performed on a **gear level**. The same gear groups (TBB, OTB, GTR and REST) as used for discard raising were applied. When the **threshold of 50%** was reached for the proportion of landings or discards covered by age, allocation of age occurred with all available information within that gear group. When the threshold was not reached, unsampled data were pooled in the REST group and ages were allocated using all sampled data. The weighting factor was '*Mean Weight weighted by numbers at age*'. Modifications to this method should be mentioned in the report.

Belgium was the only country providing both landings and discard age distributions for the entire time period (2004–2019), which resulted in the use of the Belgian strata to fill an important part of the gaps.

From 2018 onwards, BMS landings and logbook registered discards were available in InterCatch. Logbook registered discards were not considered for the age allocations. Age allocation of BMS landings was done together with discards.

B.1.2 Data collection and quality by country

Data are uploaded to InterCatch by the countries involved (mainly France, Belgium and UK (England)) and include quarterly or yearly numbers at age/length, mean weight at age/length, raised discards and total landings. The files are processed in InterCatch by the stock coordinator. SOP (Sum of Products) corrections are applied to the data prior to making the data object for the assessment.

B.1.2.1 French data

French commercial landings in tonnes by quarter, area and gear are derived from logbooks for boats over 10 m and from sales declaration forms for vessels under 10 m. These self-declared catches are then linked to the auction sales in order to have a complete and precise trip description.

The collection of discard data began in 2003 within the EU Regulation 1639/2001. The first years of collection were incomplete in terms of time and métier coverage. An increase of sampling effort as required by ICES/ACOM from 2009 onwards, has positively affected the data quality.

The length measurements are done by market commercial categories and by quarter into the principal auctions of Grandcamp, Port-en-Bessin, Dieppe and Boulogne. Samplings from Grandcamp and Port-en-Bessin are used for raising catches from Cherbourg to Fecamp and samplings from Dieppe and Boulogne are used to raise the catches from Dieppe to Dunkerque.

Otoliths samples are taken by quarter throughout the length range of the catch for quarters 1 to 4. These are aged and combined to the quarterly level. The age-length key (ALK) thus obtained is used to transform the quarterly length compositions. For landings, gaps in the ALK are filled using a multinomial model per quarter whereas for discards von Bertallanfy growth curves are fit to quarterly age-length samples and gaps in the ALK are extrapolated from von Bertallanffy model estimates (ICES, 2020).

Weight, sex and maturity-at-length and -at-age are obtained from the fish sampled for the age–length keys.

B.1.2.2 Belgian data

Belgian commercial landings and effort information by quarter, area and gear are derived from logbooks and sales notes. Every period of 24 hours during a fishing trip, except while steaming, the skipper has to report his fishing activity in the electronic logbook. The logbooks contain the estimated live weight (kg) for all commercial species landed, grouped by ICES statistical rectangle (if fishing activity occurred in more than one ICES statistical rectangle, the ICES statistical rectangle with the highest proportion of fishing effort must be reported) and by day. They also provide information on the hours spent fishing per day. As the retained landings from the logbooks are estimated weights (with an upper and lower tolerance of 10%), the landed weights are derived from the quantities recorded in the sales notes. The sales notes contain information on the quantities auctioned by market category for all species landed, but no area information. Therefore, the percentage share of a species in an ICES statistical rectangle from the logbooks, is the basis for the distribution of the quantities auctioned on the ICES statistical rectangles.

Sampling for age and length occurs on board by seagoing observers for both landings and discards. Only the beam trawl fleet is sampled (TBB_DEF), as it is the most important Belgian fleet operating in the area, which is in accordance to the Belgian national data gathering programme (DCF). During every observer trip, length is measured in mm and later on rounded to the cm below. Soles are collected throughout the length range of the catch, to sample for age, sex, maturity, individual weight and weight of the gonads (5 fish per cm class for discards; 3 for landings). Length-weight keys and age-length keys are constructed and used to provide numbers at age/length, mean weight at age/length, raised discards and total landings for this stock.

B.1.2.3 UK (England) data

English commercial landings in tonnes by quarter, area and gear are derived from the sales notes statistics for vessels under 12 m which do not complete logbooks. For those over 12 m (or >10 m fishing away for more than 24 h), data are taken from the EC logbooks. Since 2002, discarding from vessels >7 m has been included under the EU Data Collection Framework.

For the length and age estimation from the on-market sampling scheme the numbers-at-length were raised to the vessel level, based on an estimated proportion of the total landings and volume sampled. The length-based data is converted to biomass, using length-weight relationships for each species collected during various scientific trawl surveys (Cefas, unpubl. data). Trip-raised estimates are summed for sampled vessels in a port and raised to landings of the port (within a year, quarter and ICES area). The ports estimations are then summed across the same stratum (year x quarter x métier x ICES area x species) and raised to the total fleet using a ratio between the reported total fleet landings of the stock and the reported landings of the stock by the sampled vessels.

For discards estimates from the off-shore sampling scheme, numbers-at-length were raised to the haul level based on an estimated proportion of the total catch volume sampled. Then, they were raised to the trip level based on the proportion of sampled hauls and fished hauls. The length-based data is converted to biomass, using length-weight relationships for each species collected during various scientific trawl surveys (Cefas, unpubl. data). Trip-raised estimates are summed for sampled vessels in the same stratum (year x quarter x métier x ICES area x species) and raised to the total fleet using a ratio between the reported total fleet landings of the stock and the reported landings of the stock by the sampled vessels. When no landings are reported, effort is used (number of trips in stratum) to raise the discard data.

For both landings and discards, the raised numbers-at-length are converted to age using commercial age length keys (ALKs). Different levels of aggregated ALKs are used to fill the gaps. No further imputations are applied for this stock.

B.1.3 Recreational catches

Information from recreational fisheries is currently not included in the assessment. No official estimation of the amount of sole caught by recreational fishermen in division 27.7.d is available. Only recently, countries have initiated the official data collection for recreational fisheries or are still finalising the pilot study involving a nationwide survey (questionnaires and telephone calls).

B.2 Biological sampling

B.2.1 Maturity

During the WKNSEA 2017 benchmark, the knife-edged maturity ogive with full maturation from age 3 onwards was investigated. Using data from the French IBTS survey and commercial data from Belgium, France and the UK (15191 records), a new maturity ogive was constructed (see table below). More information on how this was achieved is provided in the WKNSEA 2017 report and the associated working document (ICES, 2017).

Age	0	1	2	3	4	5	6	7	8	9	10	11(+)
Maturity	0.00	0.00	0.53	0.92	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00

B.2.2 Natural mortality

Natural mortality is assumed constant over ages and years at 0.1. English and French tagging data were investigated, but two problems were encountered. First, most of the tagging data dated back to before the beginning of the sole 7.d time series. Second, in the most recent years, there were too little recaptures which inhibited the calculation of a new estimate for natural mortality (Lecomte *et al*., 2019).

B.2.3 Age composition of landed and discarded fish in commercial fisheries

Available age composition data is described in paragraph B.1.1 for both landings and discards. Age allocations are performed using Intercatch. The method is also described in paragraph B.1.1.

B.3 Surveys

Three survey indices are used as tuning series for the calibration of the assessment of sole in division 27.7.d:

- The UK Beam Trawl Survey (BTS) in quarter 3 from 1989 onwards
- The French Young Fish Survey (YFS) from 1987 onwards
- The UK Young Fish Survey (YFS) from 1987–2006

B.3.1 Survey design and analysis

The **UK BTS** is a dedicated 4 m beam trawl survey for plaice and sole and has been carried out by the UK using the RV Corystes since 1988. From 2008 onwards the RV Endeavour was used to carry out this survey. The survey is depth stratified with most samples allocated to the shallower inshore stations where the abundance of sole is highest (Figure 8). Each station is trawled for 30 minutes at 4 knots with a 40 mm cod end.

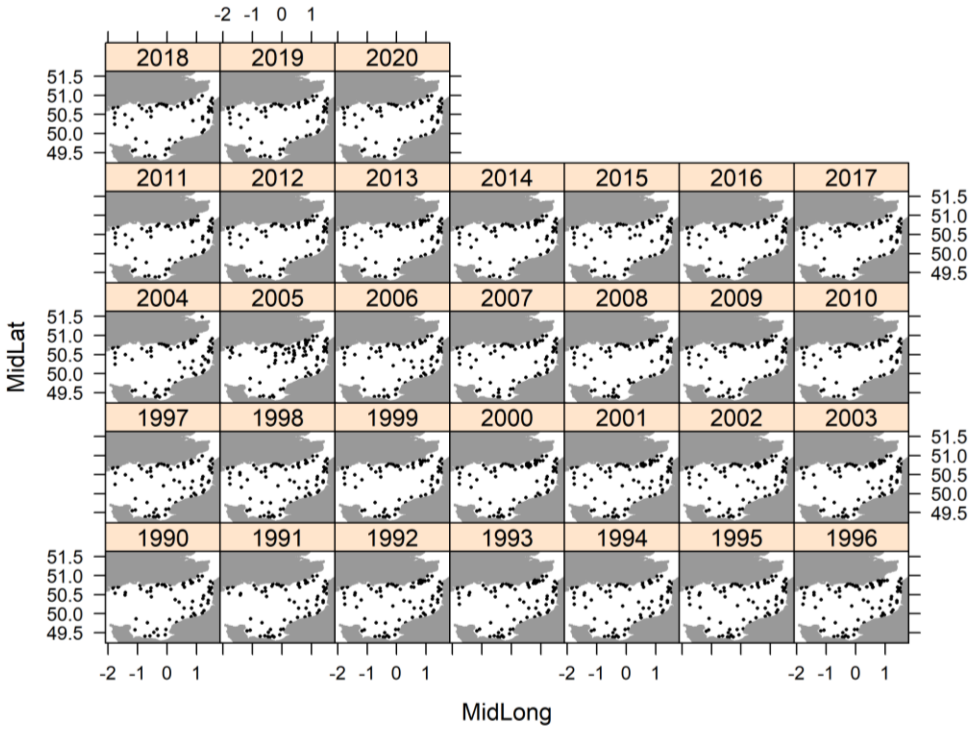


Figure 8: Sampled UK BTS stations in Division 27.7d over the period 1990–2020 as available in Datras.

In addition, 2 inshore small boat **Young Fish Surveys** using beam trawls are undertaken along the English coast and in a restricted area of the Somme Bay on the French coast (Figure 9). The two surveys operate with the same gear (beam trawl) during the same period of the year (September) in two different nursery areas. The UK YFS used a 2 m beam trawl towed for 35 minutes at a speed of one knot at depths ranging from 1 to 20 m and was last conducted in 2006. The UK index is used in the assessment (1987-2006). The French component of the YFS uses a 3 m beam trawl outside the Somme Bay and a 2 m beam trawl within the bay (Figure 10). The French YFS index is also used in the assessment from 1987 up to the most recent data year. The lack of information from the UK YFS may impede the recruitment estimates, especially in light of the suspected presence of three subpopulations in the stock.

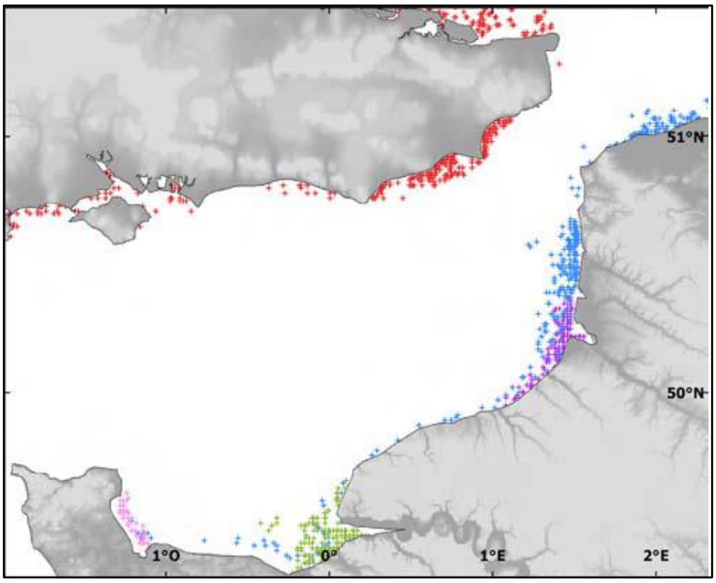


Figure 9: Location of stations sampled during the French and UK YFS (1977–2006). Red: UK YFS; Blue: Demersal YFS; purple: Somme Bay; green: Seine Bay; pink: Veys Bay. Note only indices from the UK YFS (red) and the Somme Bay (purple) are included in the sole 27.7d assessment (From: Carpentier *et al.*, 2009).

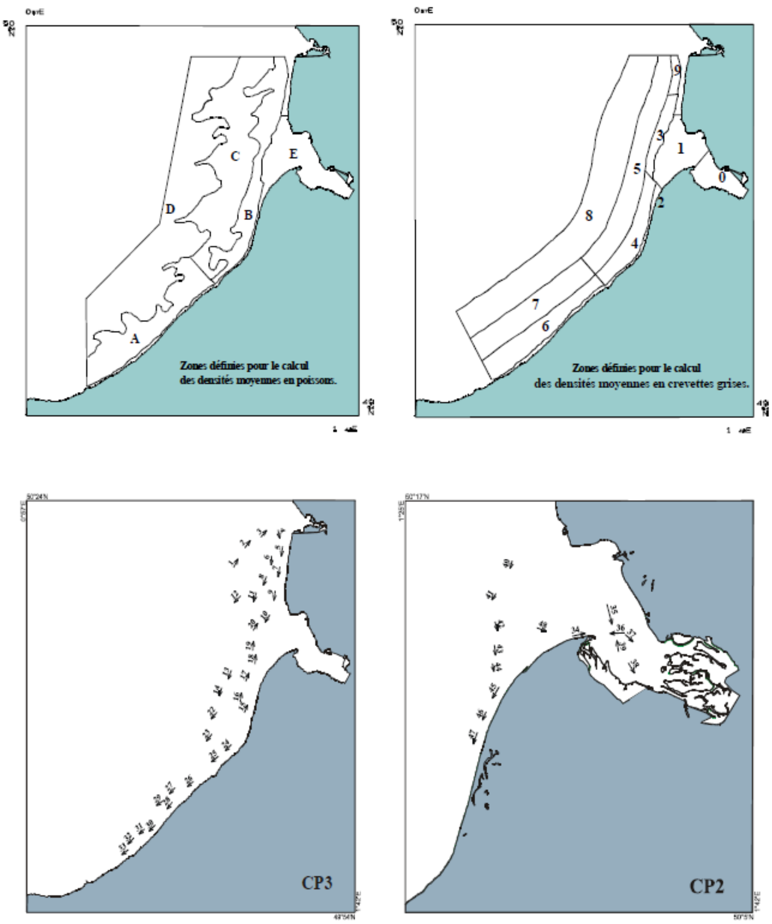


Figure 10: Sampled French YFS stations along the Somme Bay (lower panel) and the bathymetric zones in which sampling locations are situated (upper panel).

B.3.2 Survey data used

The survey data used in the assessment are summarised in the following tables (Table 1-3).

Table 1: Sol 27.7.d - Tuning series: UK (E&W) beam trawl survey (Q3) (1989–2020)

	Effort	Age1	Age2	Age3	Age4	Age5	Age6
1989	1	3.01	22.09	4.62	2.45	0.56	0.35
1990	1	17.96	5.55	5.55	1.24	1.01	0.33
1991	1	12.14	31.17	3.19	2.82	0.48	0.67
1992	1	1.33	15.29	13.47	1.07	1.61	0.34
1993	1	0.82	22.96	11.42	9.97	1.14	1.52
1994	1	8.33	4.26	11.07	4.65	4.3	0.28
1995	1	5.89	16.09	2.22	3.51	1.67	2.12
1996	1	5.3	10.79	5.97	1.07	1.86	1.15
1997	1	24.75	10.85	4.42	1.94	0.26	0.82
1998	1	3.27	24.11	3.67	1.47	0.83	0.19
1999	1	35.99	8.22	11.33	1.59	0.73	1.02
2000	1	14.98	27.45	5.52	4.85	1.48	0.68
2001	1	10.19	27.88	11.55	1.67	2.33	0.75
2002	1	53.56	16.11	8.6	5.11	0.45	1.04
2003	1	11.03	45.65	5.87	3.2	2.05	0.42
2004	1	12.67	11.81	10.97	2.08	2.02	1.34
2005	1	43.27	6.91	3.5	5.18	1.9	1.15
2006	1	10.84	42.62	4.51	2.68	2.59	0.55
2007	1	2.57	28.97	15.45	1.47	1.04	1.56
2008	1	3.77	7.35	9.14	5.82	0.4	0.68
2009	1	51.25	19.16	7.1	5.81	5.02	0.44
2010	1	16.59	30.76	5.14	1.66	2.7	2.73
2011	1	13.66	28.6	14.7	1.66	0.54	2.62
2012	1	1.75	9.72	7.51	3.53	0.92	0.39
2013	1	0.72	8.91	15.09	9.72	3.23	1.12
2014	1	25.39	16.35	12.38	11.92	5.09	2.73
2015	1	25.24	21.36	6.04	2.29	4.51	2.08
2016	1	10.17	33.14	11.17	3.16	3.17	3.02
2017	1	27.85	15.18	16.26	2.67	2.13	1.52
2018	1	14.86	36.49	6.66	10.32	1.74	2.13
2019	1	56.54	31.08	19.53	1.18	4.01	2.53
2020	1	1.87	42.73	8.01	4.62	1.15	1.84

Table 2: Sol 27.7.d - Tuning series: UK (E&W) young fish survey (1987–2006).

	Effort	Age1
1987	1	1.38
1988	1	1.87
1989	1	0.62
1990	1	1.9
1991	1	3.69
1992	1	1.5
1993	1	1.33
1994	1	2.68
1995	1	2.91
1996	1	0.57
1997	1	1.12
1998	1	1.12
1999	1	1.47
2000	1	2.47
2001	1	0.38
2002	1	4.15
2003	1	1.44
2004	1	2.72
2005	1	4.07
2006	1	2.21

Table 3: Sol 27.7.d - Tuning series: French young fish survey (1987–2020) funded by EDF (noursom).

	Effort	Age1
1987	1	0.07
1988	1	0.17
1989	1	0.14
1990	1	0.54
1991	1	0.38
1992	1	0.22
1993	1	0.03
1994	1	0.7
1995	1	0.28
1996	1	0.15
1997	1	0.03
1998	1	0.1
1999	1	0.35
2000	1	0.31
2001	1	1.21
2002	1	0.11
2003	1	0.32
2004	1	0.15
2005	1	0.82
2006	1	0.83
2007	1	0.08
2008	1	0.06
2009	1	2.78
2010	1	0.1
2011	1	0.32
2012	1	0.35
2013	1	0.052
2014	1	0.04
2015	1	0.09
2016	1	0.04
2017	1	0.05
2018	1	0.03
2019	1	0.45
2020	1	0.38

B.4 Commercial indices

The commercial tuning series have been revised during the last benchmark (WKNSEA 2021) and the inter-benchmark (ICES, 2019). From working year 2017 (2016 assessment) onwards, three commercial tuning fleets were used: the Belgian commercial beam trawl fleet (BE-CBT), the UK commercial beam trawl fleet (UK-CBT) and the French commercial otter trawl fleet (FR-COTB).

The **UK-CBT** tuning series was revised during the inter-benchmark in August 2019 (ICES, 2019). Due to database issues, it was no longer possible to provide an LPUE index based on kW. fishing hours. The new index is a modelled landings per activity days index from 1986-2018 disaggregated by age. During the WKNSEA 2021 benchmark, this tuning series was used as a fishable biomass index (aggregated over all ages).

The **BE-CBT** tuning series was revised during the WKNSEA 2021 benchmark in February 2021 (ICES, 2021). In consistence with the correction of the Belgian catch data, the index was calculated using data from fishing trips in which fishing activity, as registered in the electronic logbooks, was restricted to the eastern English Channel (division 27.7d). To reduce the noise generated by the unbalanced sampling design of the logbook data, only observations from (i) fishing vessels that fished at least 5 years in the eastern English Channel, and (ii) ICES statistical rectangles that where fished at least twice per year on average during the study period (2004-2019), were included in the analysis. The statistical model used to standardize the landings and effort data was also modified. This tuning series was also used as a fishable biomass index (aggregated over all ages).

Prior to the WKNSEA 2017 benchmark, no French commercial tuning series was included in the assessment. A new raw LPUE index was calculated based on the OTB_DEF_70-99 fleet (**FR-COTB**), which targets sole seasonally and mainly along the French coast (WKNSEA 2017 report and associated working document, ICES, 2017). During the WKNSEA 2021 benchmark, this index was also recalculated according to the revision of the French catch data and a model was applied (ICES, 2021). To account for dependencies in the landings and effort data, a new FRA commercial otter trawl index was developed (2005-present) based on a selected number of vessels practicing the OTB_DEF_70_99_0 métier. Only vessels accounting for the top 95% sole landings of OTB_DEF_70-99_0 were kept in the analysis and they had to be active in the fishery at least two thirds of the time series (i.e. 10 years as of 2019). To standardized the LPUE, a hurdle lognormal mixed model is used to correct for vessels, seasonality and spatial effects.

B.5 Other relevant data

No other relevant data are used.

C. Assessment methods and settings

C.1 Choice of stock assessment model

During the WKNSEA 2017 benchmark, three different assessment models were tested: XSA, AAP and SAM. Especially the XSA model, which was also the model used for the assessment in working year 2016, was extensively investigated. For the SAM and AAP model, only exploratory runs were conducted as the baserun could not be fully reproduced. The different runs are described in the report and associated working document on assessment (ICES, 2017). When comparing similar scenarios of the SAM, AAP and XSA model, the trends generally concurred, but absolute values differed, with XSA estimating SSB higher and Fbar lower.

Investigations after the inter-benchmark in August 2019 highlighted an issue with the older ages in the data and more specifically the plusgroup. The XSA model showed to have trouble with a very large plusgroup, which resulted in even larger estimates for the plusgroup. This issue was found to be the primary cause of large fluctuations in TAC advice over the past few years. It was also found that French catch data was aggregated incorrectly for older ages for 2016 and 2017, which meant that the catch data was not reliable for these years. For this reason, the XSA 2019 assessment was not considered reliable in absolute terms, and therefore downgraded to Category 3 (indicative of trends only). This issue will be investigated in depth during the next benchmark in 2020 (WKFLATNSCS 2020).

During the WKFLATNSCS 2020, data issues could not be resolved and this stock was therefore added to the WKNSEA 2021 benchmark. The shorcomings of the XSA framework over the past few years led to the further exploration of a state-space stock assessment model (SAM). The main feature of SAM is that it includes both process models on survival, recruitment and fishing mortality (describing the internal states of the system), and observation models for catch and tuning data. Additionally, tuning data can be introduced in different ways, e.g. as SSB (spawning–stock biomass), FSB (fishable stock biomass) or TSB (total stock biomass). The random effects formulation of the process models resulting from the hierarchical nature of the state–space modelling framework can easily be used to handle missing observations. Finally, SAM allows to specify different model configurations, and parametrization of both process and observation models. These advantages led to a switch from XSA to SAM during the WKNSEA 2021 benchmark.

C.2 Model used for basis for advice

From WGNSSK 2021 onwards, the SAM model was used for the advice.

C.3 Assessment model configuration

Settings	
Model	SAM
First data year	1982
Last data year	2020
Ages	1–11+
Plus group	Yes
Stock weights-at-age	Q1 catch weight-at-age; reconstructed for 1982-2003
Discards Numbers- and weight-at-age	Reconstructed for 1982-2003
Abundance indices	Commercial: BEL CBT LPUE (2004-present); FRA COTB LPUE (2005-present); UK CBT LPUE (1986-present)
	Survey: UK (E&W) BTS (1989-present); UK YFS (1987-2006); FRA YFS (1987-present)
Natural mortality	0.1
Maturity ogive	Age1 = 0.00; Age2 = 0.53; Age3 = 0.92; Age4 = 0.96; Age5 = 0.97; Age6-11+ = 1.00
Number of parameters describing F-at-age in catch (keyLogFsta) (columns represent ages)	0 1 2 3 4 5 5 6 6 7 7 (catch)
Correlation of F across ages (corFlag)	0 (independent)
Number of parameters describing F-at-age in surveys (keyLogFpar) (columns represent ages)	0 (BEL CBT LPUE; FSB) 1 (UK CBT LPUE; FSB) 2 (FRA COTB LPUE; FSB) 3 4 5 6 7 7 (UK BTS; age 1 -6) 8 (UK YFS; age 1) 9 (FRA YFS; age 1)
Density dependent catchability power parameters (keyQpow)	None
Coupling of process variance parameters for F (keyVarF)	0 0 0 0 0 0 0 0 0 0 0
Coupling of process variance parameters for log(N) (keyVarLogN)	0 1 1 1 1 1 1 1 1 1 1
Coupling of variance parameters on the observations (keyVarObs) (columns represent ages)	0 1 2 2 2 2 2 2 2 2 2 (catch; age 1 – 11+) 3 (BEL CBT LPUE; FSB) 4 (UK CBT LPUE; FSB) 5 (FRA COTB LPUE; FSB) 6 7 8 8 8 8 (UK BTS; age 1 - 6) 9 (UK YFS; age 1) 10 (FRA YFS; age 1)
Covariance structure per fleet (obsCorStruct) (columns represent fleets: catch, BEL CBT LPUE, UK CBT LPUE, FRA COTB LPUE, UK BTS, UK YFS, FRA YFS)	AR ID ID ID AR ID ID

ID = independent AR = autocorrelated	
Coupling of correlation parameters (keyCorObs) (columns represent ages)	0 1 1 1 1 1 1 1 1 1 (catch; age 1/2 – 10/11+) 2 3 3 3 3 (UK BTS; age 1/2 – age 5/6)
Stock recruitment code (stockRecruitmentModelCode)	0 (random walk)
Number of years where catch scaling is applied (noScaledYears)	None
Vector of years where catch scaling is applied (keyScaledYears)	None
Matrix specifying coupling of scale parameters (keyParScaledYA)	None
Fbar ranges	3-7
Type of biomass index (keyBiomassTreat)	2 (fishable stock biomass, FSB)
Option for observational likelihood (obsLikelihoodFlag)	LN LN LN LN LN LN LN
Treatment for weight attribute (fixVarToWeight)	/
Fraction of t(3) distribution used in log(F) increment distribution	/
Fraction of t(3) distribution used in log(N) increment distribution	/
Vector describing fraction for fleets (fracMixObs)	/
Vector describing break year between recruitment (constRecBreaks)	/
Coupling of parameters used in prediction-variance link for observations (predVarObsLink)	None

D. Short-term prediction

The short term forecast is performed using the *stockassessment* package. Stock weights-at-age for the next three years is assumed to be the mean stock weight-at-age of the last five years. Selectivity of the fishery for the next three years is assumed to be the mean selectivity of the last five years.

Recruitment in the future years is resampled from the entire past recruitment estimates except for the last year (1982–2018). A stochastic forecast is conducted implying that the projections of the numbers and fishing mortality-at-age are characterized by process noise. The number of simulations was set at 5001.

During the assessment working group, the fishing mortality in the intermediate year is chosen. There are two possible scenarios: 1) status quo fishing mortality (Fsq) or 2) TAC constraint. For the status quo fishing mortality, there are again two options: 1a) if the Fbar shows no trend over the last three years, the mean Fbar of the last three years is taken as intermediate year assumption, 1b) if the Fbar shows a decreasing or increasing trend over the last three years, we scale to the last data year, which means that the Fbar in the intermediate years is the same as the last data year. For the TAC constraint option, the Fbar is calculated in the intermediate year as if the TAC would be fully fished in that year.

Following the ICES advice rules, the target F in the advice year (2021) is set at F_{MSY} in case the SSB in the advice year (2021) is above $B_{trigger}$, else, the target F is set as F_{MSY} x ($SSB_{advice\_year}/B_{trigger}$). In case the SSB is insufficient to bring the stock above B_{lim} in the advice year + 1 (2022), a zero TAC can be advised.

E. Medium-term prediction

No medium-term prediction was performed for this stock. In the past an age structured model was used (WGMTERMc software), but since 2005 no more medium-term predictions were done.

F. Long-term prediction

No long-term prediction was performed for this stock.

G. Biological reference points

	Type	Value	Technical basis
MSY Approach	MSY $B_{trigger}$	15135 t	B_{pa}
	F_{MSY}	0.193	EQsim analysis based on recruitment period 1982-2018
Precautionary Approach	B_{lim}	10811 t	B_{loss}
	B_{pa}	15135 t	1.4 × B_{lim}
	F_{lim}	0.422	EQsim analysis based on recruitment period 1982–2018
	F_{pa}	0.379	$F_{p0.5}$
Management plan	MAP MSY $B_{trigger}$	15135 t	MSY $B_{trigger}$
	MAP B_{lim}	10811 t	B_{lim}
	MAP F_{MSY}	0.193	F_{MSY}
	MAP range F_{lower}	0.113–0.193	Consistent with ranges provided by ICES (2021), resulting in no more than 5% reduction in long-term yield compared with MSY
	MAP range F_{upper}	0.193–0.331	Consistent with ranges provided by ICES (2021), resulting in no more than 5% reduction in long-term yield compared with MSY

H. Other issues

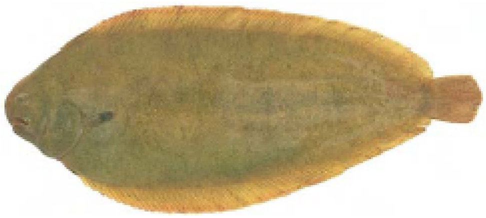
H.1 Biology of species (from Carpentier *et al.*, 2009)

Solea solea

(Linnaeus, 1758)

Sole commune
Common sole, Dover sole

Embranchement-Phylum : Chordata
Classe-Class : Actinopterygii
Ordre-Order : Pleuronectiformes
Famille-Family : Soleidae



© IFREMER

Biologie **-** La sole adulte se nourrit d'annélides, petits mollusques et crustacés. Elle est active surtout la nuit, et s'enfouit plus ou moins totalement dans la journée. En Manche, la période de reproduction s'étale de février à juin avec une période d'intensité maximale en avril-mai, essentiellement dans les zones côtières du Pas-de-Calais et les grandes baies (Somme, Seine, Solent, Mont Saint-Michel, Start et Lyme). Les œufs pélagiques éclosent après 5 à 11 jours pour donner des larves, elles aussi pélagiques, qui se métamorphoseront en alevins benthiques après 1 à 2 semaines. Les juvéniles passent leurs 2 à 3 premières années dans les nourriceries côtières (baies et estuaires) où la croissance est rapide (11 cm à un an) avant de gagner les eaux plus profondes. A partir de cet âge, certains individus peuvent entamer une migration.

Caractères démographiques **-** Taille maximale 70 cm ; taille commune 24-35 cm ; taille minimale de capture 24 cm (UE) ; longévité maximale 27 ans ; âge et taille à maturité 3-5 ans et 23-35 cm ; paramètres de von Bertalanffy : taille asymptotique L_{inf} = 37.7 cm, taux de croissance k = 0.3 an^{-1}, âge théorique t_0 = -0.84 ; paramètres de fécondité *alpha* = 0.0031 ovules.cm^{-beta} et *beta* = 4.97 (130 000 à 1 300 000 ovules par femelle).

Environnement **-** Poisson benthique vivant sur les fonds de sables fins ou vaseux, entre 0 et 150 mètres de profondeur. Il peut se trouver dans les eaux marines à saumâtres ayant des températures comprises entre 8 et 24°C.

Répartition géographique **-** Atlantique est, du sud de la Norvège au Sénégal, mer Méditerranée dont la mer de Marmara et la mer Noire.

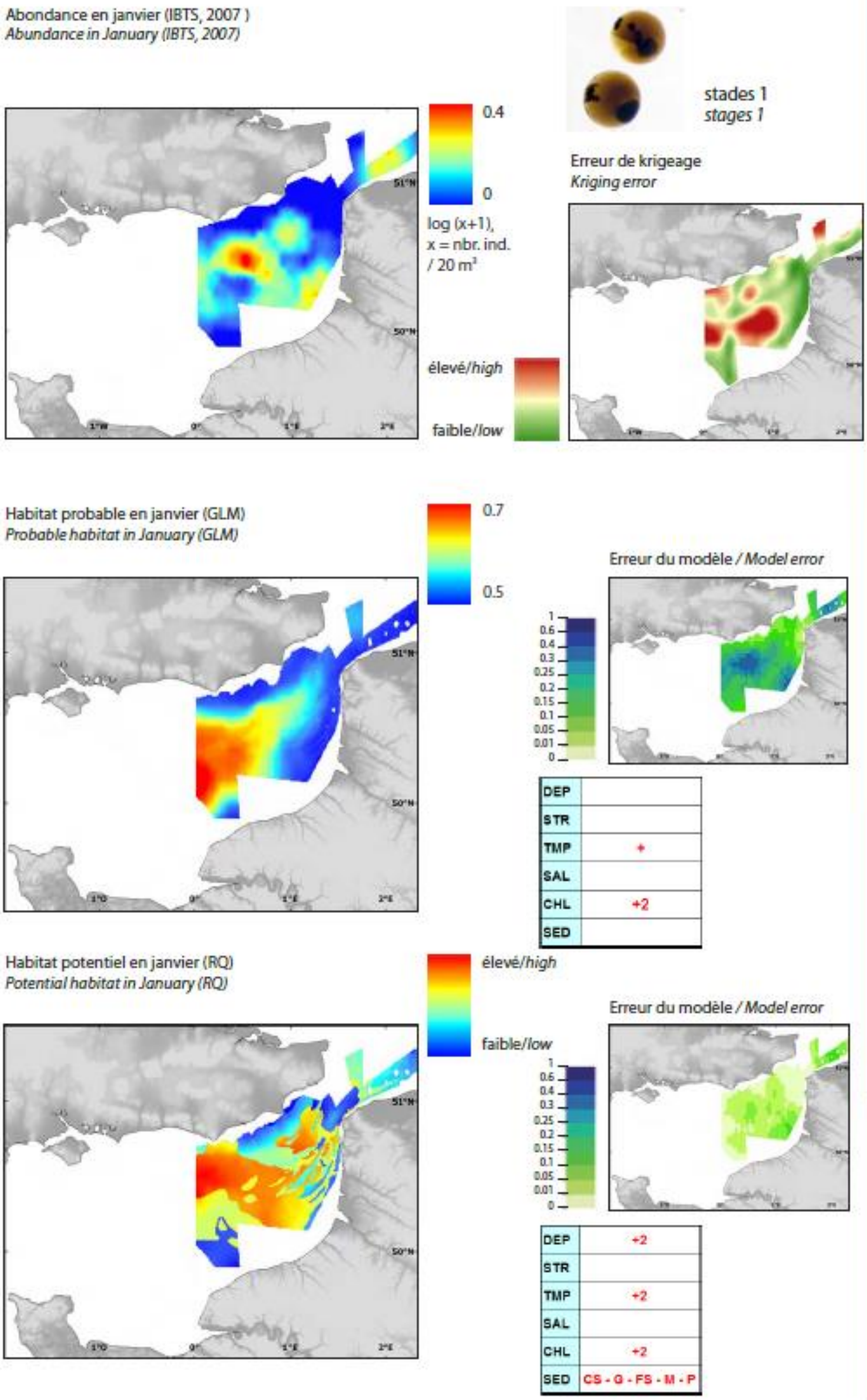
Biology **-** Adult sole feed on annelid worms, small molluscs and crustaceans. Sole are active, especially at night, and bury themselves more or less completely during the day. In the English Channel, breeding takes place between February and June, with a peak from April to May, mainly in the coastal areas of the Dover Strait and in larger bays (e.g. Somme, Seine, Solent, Mont-Saint-Michel, Start and Lyme Bays). Pelagic eggs hatch after 5 to 11 days leading to larvae that are also pelagic and that will metamorphose into benthic fry after 1 or 2 weeks. Juveniles spend the first 2 or 3 years in coastal nurseries (bays and estuaries), where fast growth occurs (11 cm at 1 year old), before later moving to deeper waters. From this age, some individuals start migrating to join the adult stock.

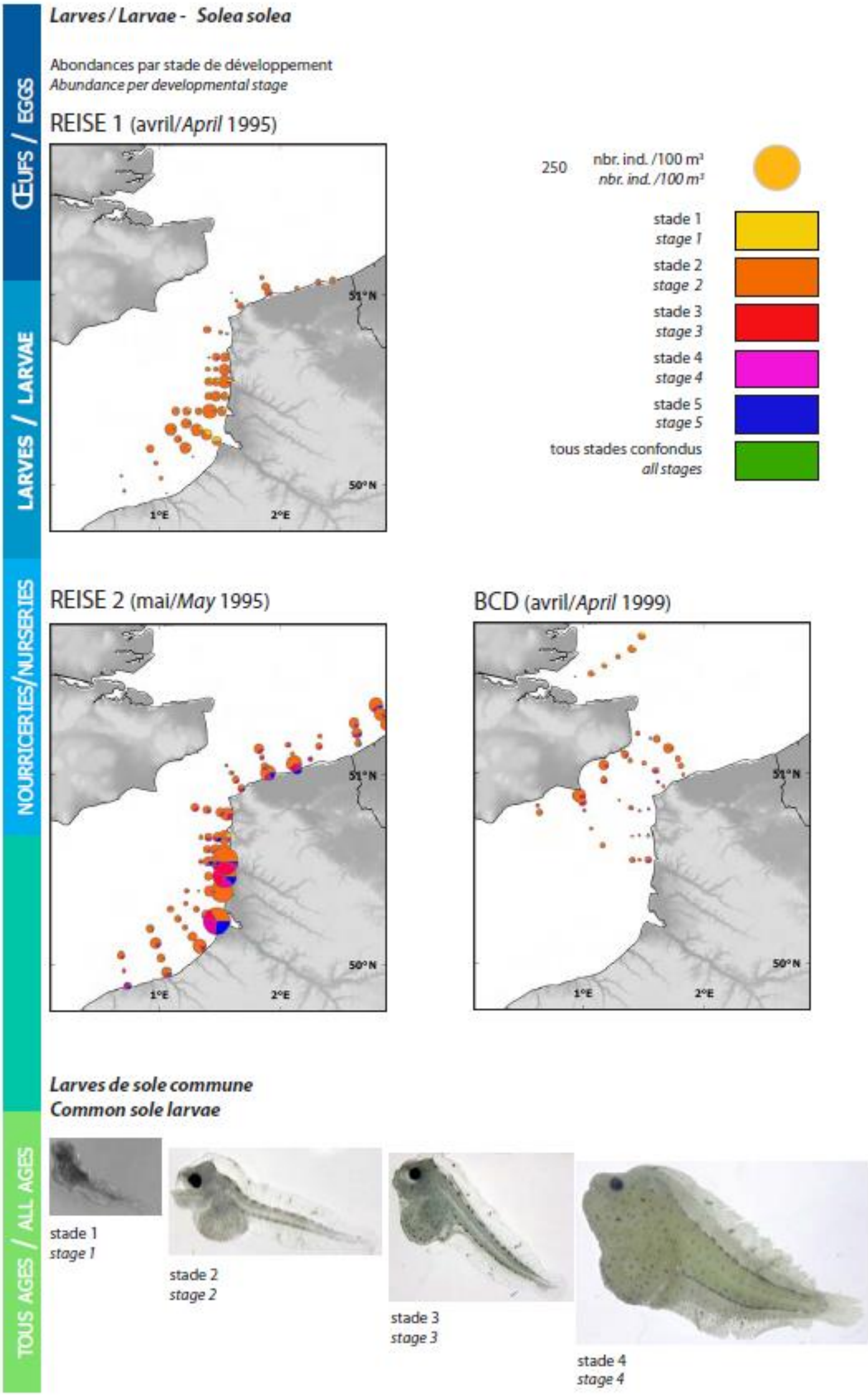
Life history parameters - Maximum length 70 cm; common length 24-35 cm; minimum landing size 24 cm (EU); maximum lifespan 27 years; age and length at maturity 3-5 years and 23-35 cm; von Bertalanffy parameters: asymptotic length L_{inf} = 37.7 cm, growth rate k = 0.3 $year^{-1}$, theoretical age t_0 = -0.84; fecundity parameters *alpha* = 0.0031 oocytes.cm^{-beta} and *beta* = 4.97 (130,000 to 1,300,000 oocytes per female).

Environment **-** A benthic species that lives on fine sand and muddy substrates between 0 and 150 metres in depth. They can be found from marine to brackish waters where temperatures are between 8 and 24°C.

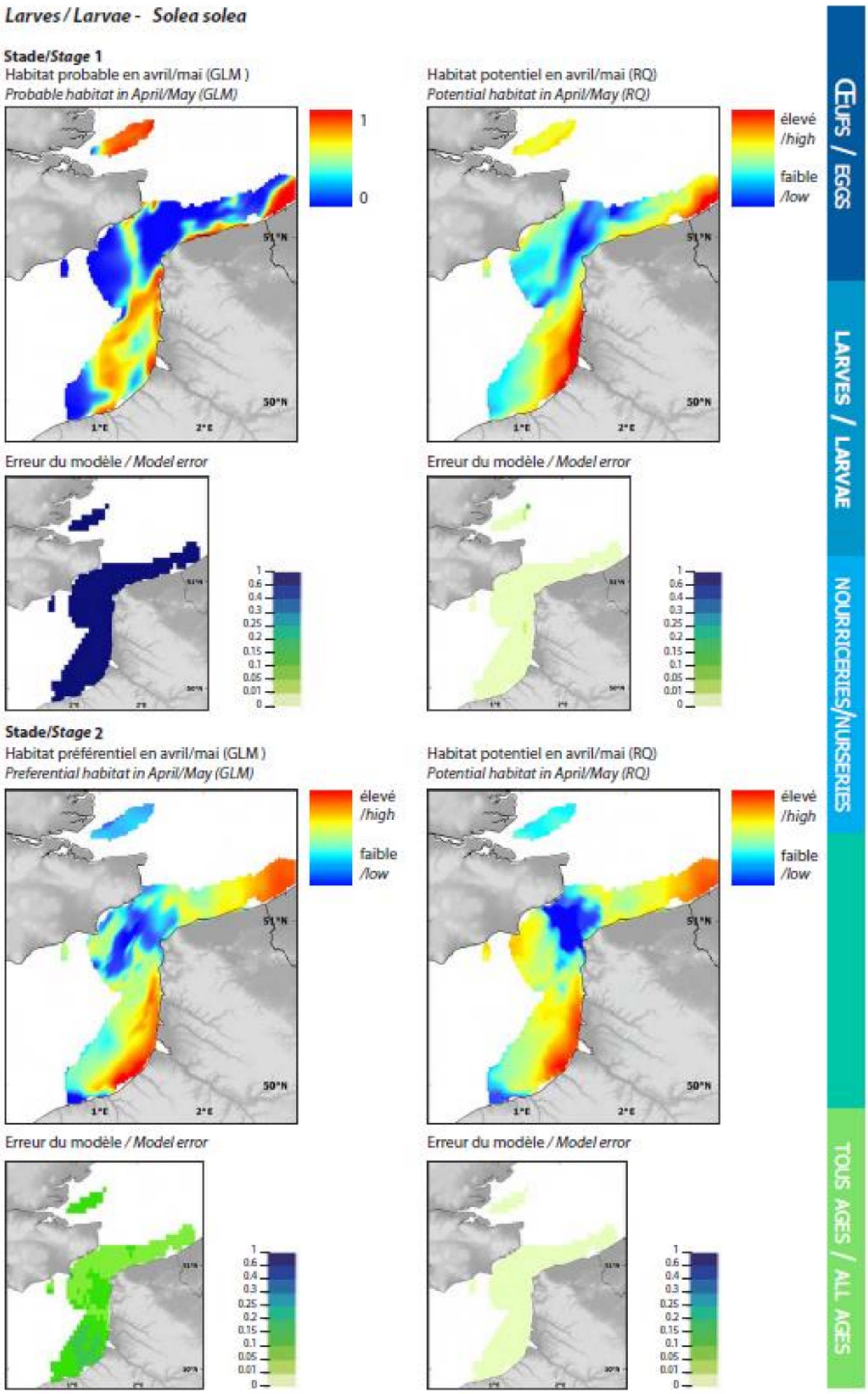
Geographical distribution **-** Eastern Atlantic, from southern Norway down to Senegal, and the Mediterranean Sea including the Marmara and Black Seas.

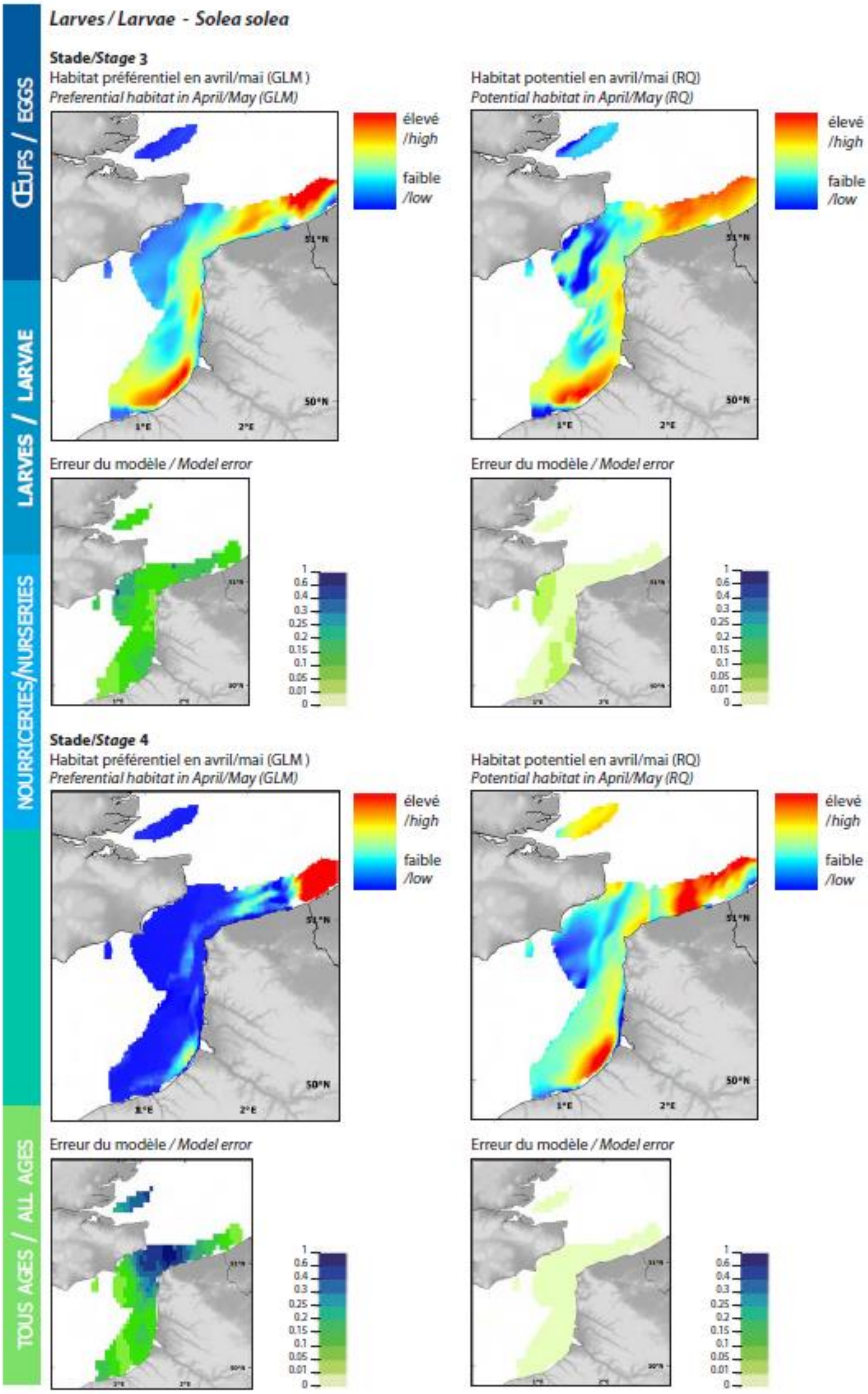
Œufs / Eggs - Solea solea





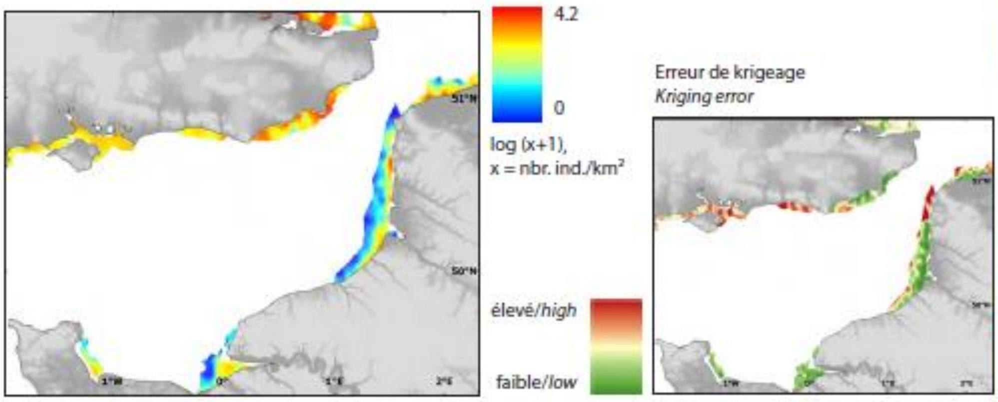
ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES
Larves / Larvae - Solea solea
Abondances par stade de développement
Abundance per developmental stage
REISE 1 (avril/April 1995)
250 nbr. ind. /100 m³
nbr. ind. /100 m³
stade 1
stage 1
stade 2
stage 2
stade 3
stage 3
stade 4
stage 4
stade 5
stage 5
tous stades confondus
all stages
REISE 2 (mai/May 1995)
BCD (avril/April 1999)
51°N
50°N
1°E
2°E
Larves de sole commune
Common sole larvae
stade 1
stage 1
stade 2
stage 2
stade 3
stage 3
stade 4
stage 4


Larves / Larvae - Solea solea
Stade/Stage 1
Habitat probable en avril/mai (GLM)
Probable habitat in April/May (GLM)
1
0
51°N
50°N
1°E
2°E
Habitat potentiel en avril/mai (RQ)
Potential habitat in April/May (RQ)
élevé
/high
faible
/low
51°N
50°N
1°E
2°E
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
Stade/Stage 2
Habitat préférentiel en avril/mai (GLM)
Preferential habitat in April/May (GLM)
élevé
/high
faible
/low
51°N
50°N
1°E
2°E
Habitat potentiel en avril/mai (RQ)
Potential habitat in April/May (RQ)
élevé
/high
faible
/low
51°N
50°N
1°E
2°E
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES

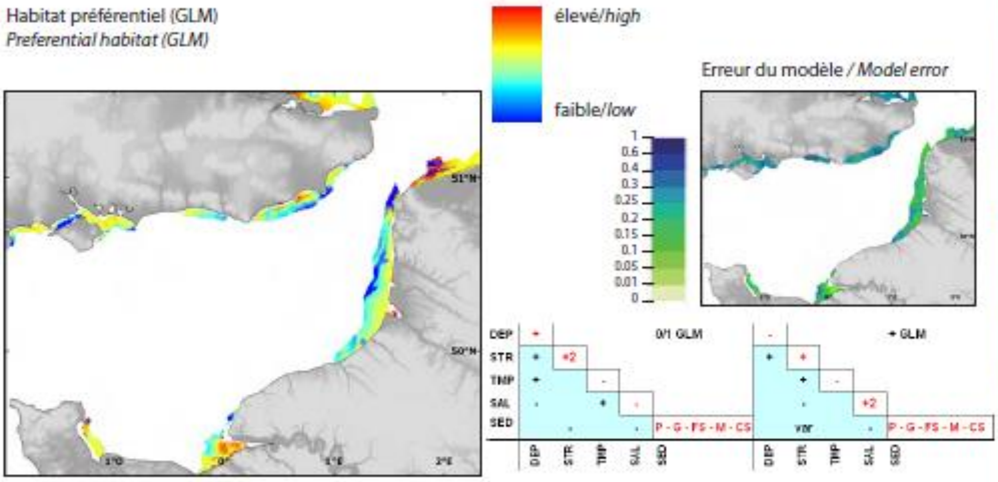

ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES
Larves / Larvae - Solea solea
Stade/Stage 3
Habitat préférentiel en avril/mai (GLM)
Preferential habitat in April/May (GLM)
Habitat potentiel en avril/mai (RQ)
Potential habitat in April/May (RQ)
élevé /high
faible /low
51°N
50°N
1°E
2°E
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
Stade/Stage 4
Habitat préférentiel en avril/mai (GLM)
Preferential habitat in April/May (GLM)
Habitat potentiel en avril/mai (RQ)
Potential habitat in April/May (RQ)
Erreur du modèle / Model error

Nourriceries côtières / Coastal nurseries - Solea solea

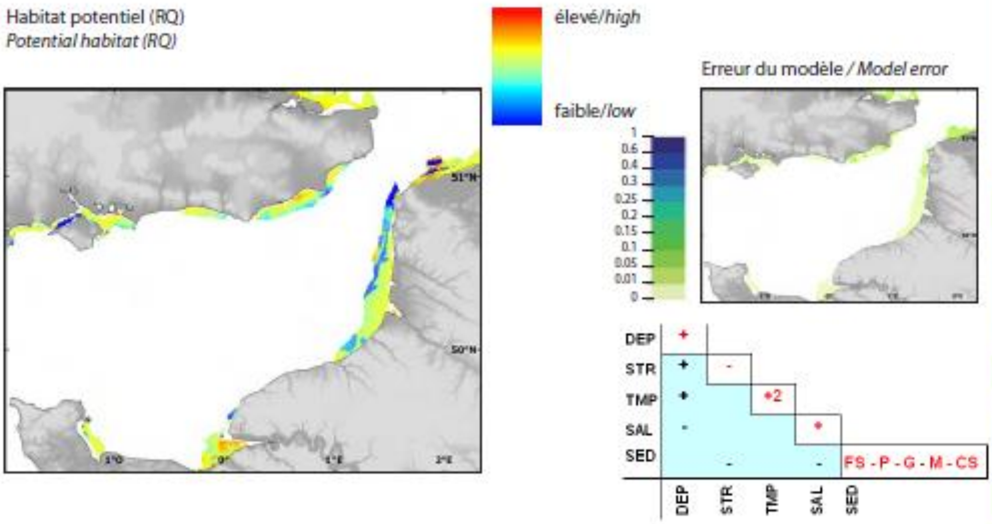
Abondance pluriannuelle en septembre
(YFS, 1977-2006)
Multi-annual abundance in September (YFS, 1977-2006)

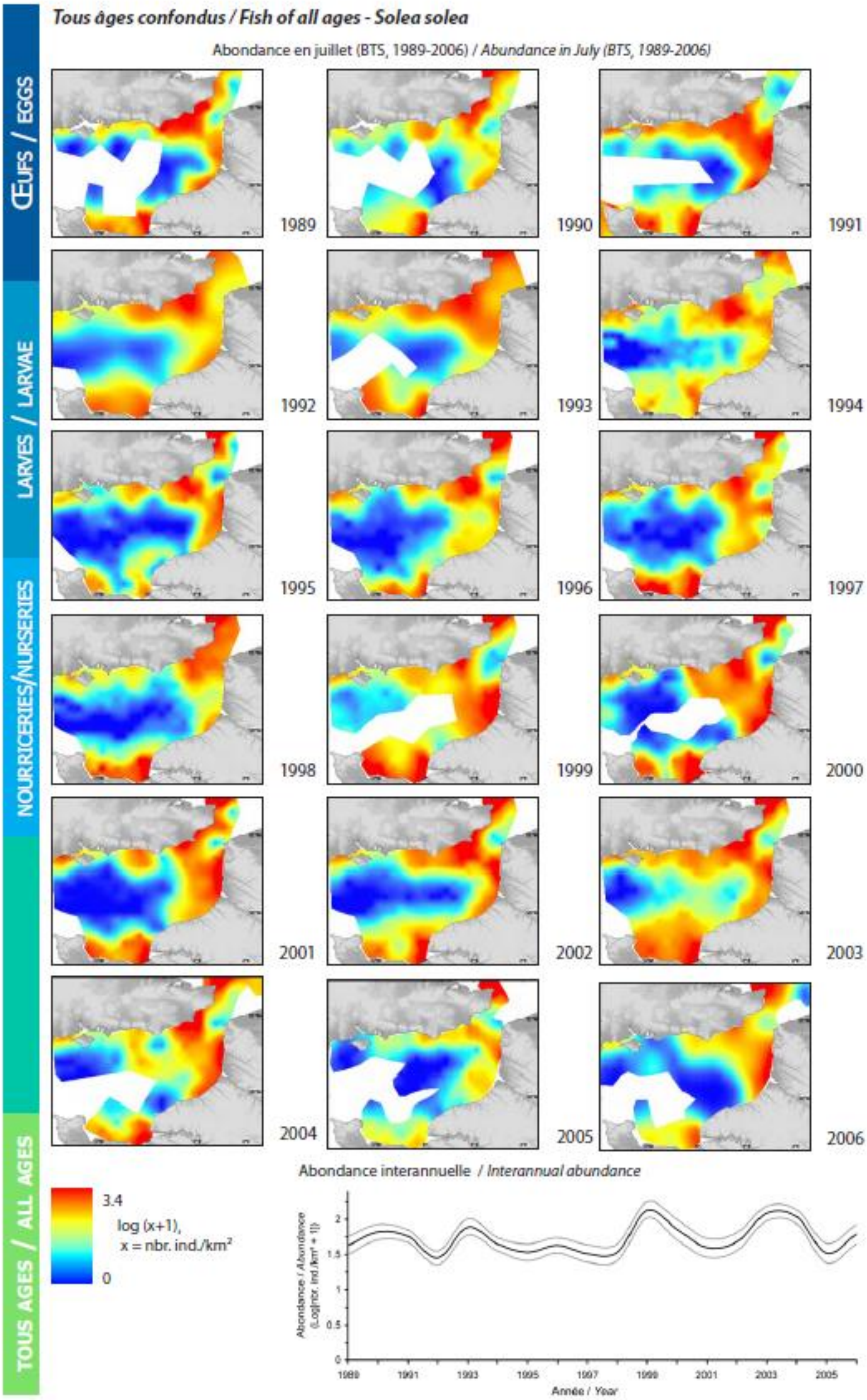


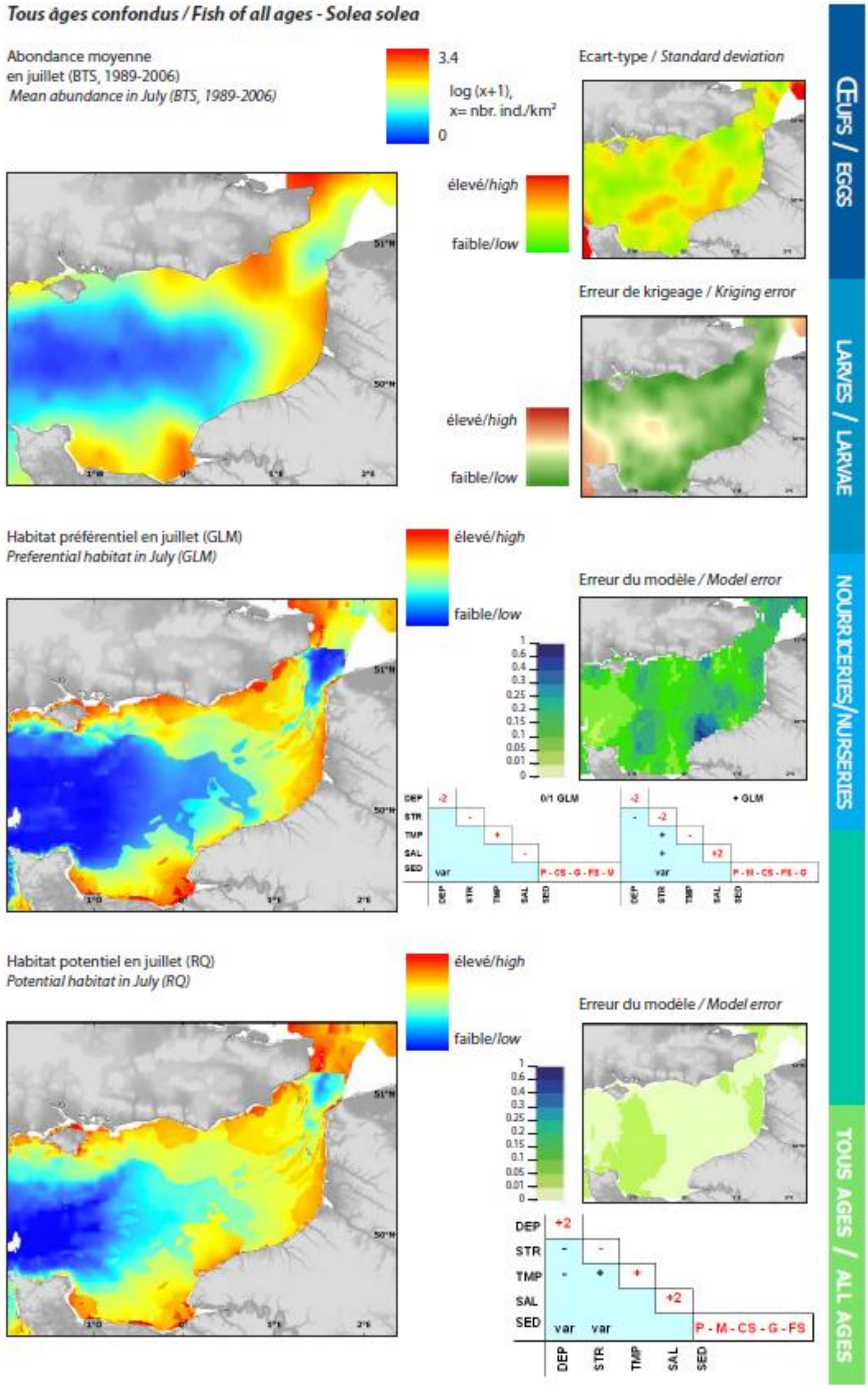
Habitat préférentiel (GLM)
Preferential habitat (GLM)

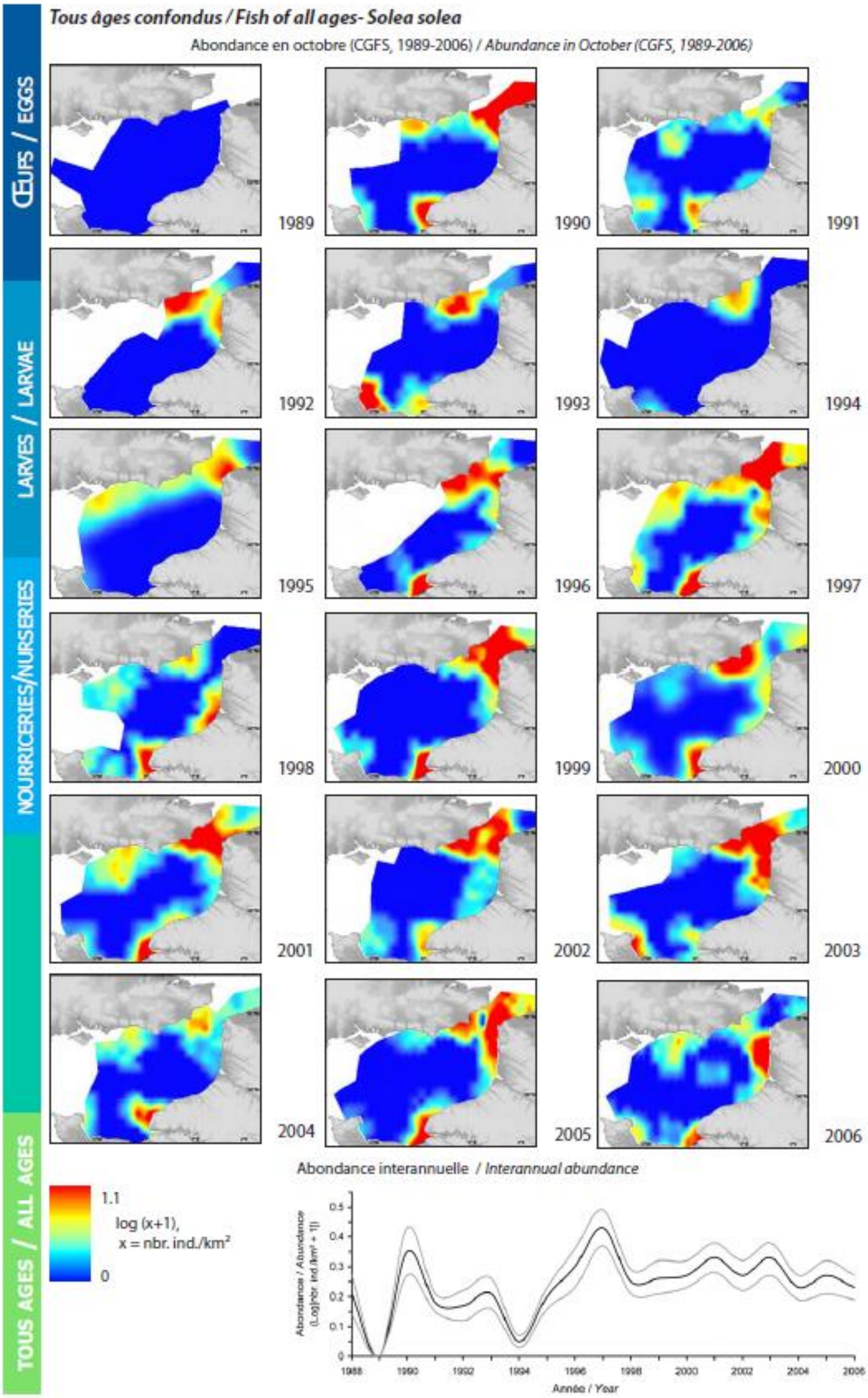


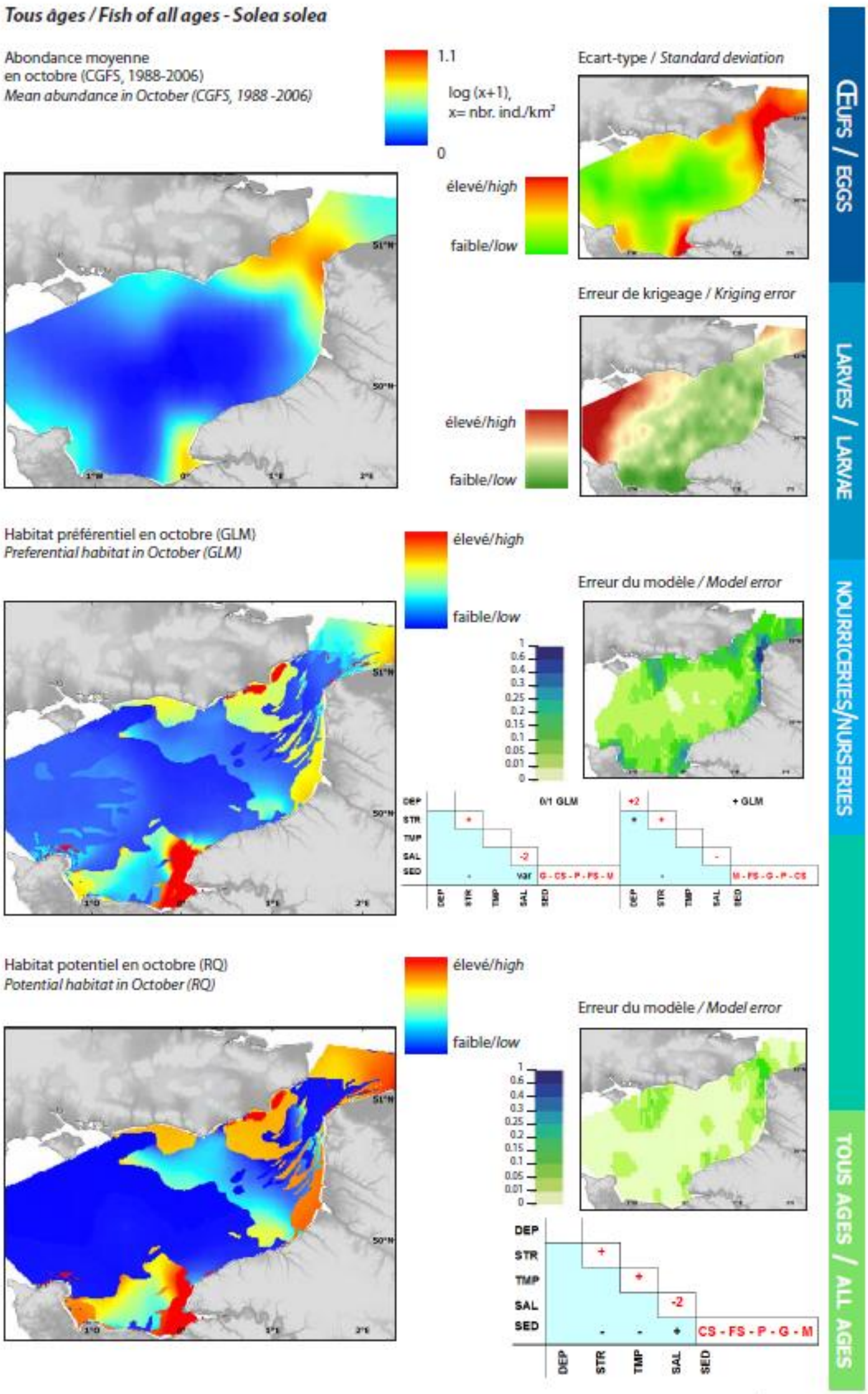
Habitat potentiel (RQ)
Potential habitat (RQ)




ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES
Tous âges confondus / Fish of all ages - Solea solea
Abondance en juillet (BTS, 1989-2006) / Abundance in July (BTS, 1989-2006)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
3.4
log (x+1),
x = nbr. ind./km²
0
Abondance interannuelle / Interannual abundance
Abondance / Abundance (Log(nbr. ind./km² + 1))
Année / Year


Tous âges confondus / Fish of all ages - Solea solea
Abondance moyenne en juillet (BTS, 1989-2006)
Mean abundance in July (BTS, 1989-2006)
3.4
log (x+1), x= nbr. ind./km²
0
Ecart-type / Standard deviation
élevé/high
faible/low
Erreur de krigeage / Kriging error
élevé/high
faible/low
Habitat préférentiel en juillet (GLM)
Preferential habitat in July (GLM)
élevé/high
faible/low
Erreur du modèle / Model error
0/1 GLM
+ GLM
Habitat potentiel en juillet (RQ)
Potential habitat in July (RQ)
élevé/high
faible/low
Erreur du modèle / Model error
DEP
STR
TMP
SAL
SED
var
P - M - CS - G - FS
ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES


Tous âges confondus / Fish of all ages- Solea solea
Abondance en octobre (CGFS, 1989-2006) / Abundance in October (CGFS, 1989-2006)
ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
1.1
log (x+1),
x = nbr. ind./km²
0
Abondance interannuelle / Interannual abundance
Année / Year


Tous âges / Fish of all ages - Solea solea
Abondance moyenne
en octobre (CGFS, 1988-2006)
Mean abundance in October (CGFS, 1988 -2006)
1.1
log (x+1),
x= nbr. ind./km²
0
Ecart-type / Standard deviation
élevé/high
faible/low
Erreur de krigeage / Kriging error
élevé/high
faible/low
Habitat préférentiel en octobre (GLM)
Preferential habitat in October (GLM)
élevé/high
faible/low
Erreur du modèle / Model error
0/1 GLM
+ GLM
DEP
STR
TMP
SAL
SED
G - CS - P - FS - M
M - FS - G - P - CS
Habitat potentiel en octobre (RQ)
Potential habitat in October (RQ)
élevé/high
faible/low
Erreur du modèle / Model error
1
0.6
0.4
0.3
0.25
0.2
0.15
0.1
0.05
0.01
0
CS - FS - P - G - M
ŒUFS / EGGS
LARVES / LARVAE
NOURRICERIES/NURSERIES
TOUS AGES / ALL AGES

Œufs

Les soles pondent de février à juin en Manche, la ponte démarrant lorsque la température de l'eau dépasse 7°C. La carte d'abondance correspondant à janvier 2007 montre un pic d'abondance au centre de la zone échantillonnée, et des abondances un peu moins importantes au large de la baie de Somme. La zone de forte abondance est en accord avec le modèle d'habitat probable mais celui-ci prévoit une occurrence plus forte à l'ouest de la zone échantillonnée et ne considère pas le large de la baie de Somme comme une zone d'habitat probable. La température et la concentration en chlorophylle *a* sont les seuls paramètres significatifs prédictifs de ce modèle. L'habitat potentiel est plus étalé, défini dans des zones profondes avec des températures assez élevées et des sédiments grossiers. Les données étant récoltées en janvier, les densités d'œufs sont encore très faibles car la période de reproduction commence à peine. Le schéma de distribution n'est peut-être alors pas représentatif de son étendue en pleine période de reproduction.

Larves

Les larves de soles ont été capturées à chacune des campagnes. Si les larves sont largement distribuées lors du printemps, l'habitat préférentiel des stades 2 se trouve le long des côtes de Flandres et le long du pays de Caux, s'étendant au centre de la Manche. Ces habitats sont localisés à proximité des frayères connues pour cette espèce et en accord avec la distribution spatiale des œufs décrite dans la littérature (Grioche *et al.*, 2001). Il s'agit probablement d'une stratégie qui permet aux jeunes larves de se développer dans des zones de rétention associées à de faibles courants, les frayères étant dans des eaux de faible profondeur avec de fortes températures et fluorescences (Grioche *et al.*, 2001). Les larves plus âgées ont un habitat plus côtier. Cette distribution côtière semble s'expliquer par la présence de phénomènes de rétention face aux estuaires. Ces larves montrent, en Manche orientale, même pour les jeunes stades, des migrations verticales (Grioche *et al.*, 2000). Ce comportement aide au transport lors des marées descendantes et limite l'advection de cette espèce vers la mer du Nord. Pour le moment, on ne peut estimer les mélanges des larves issues des frayères du centre Manche par rapport à celles issues des frayères de la mer du Nord. Pour cela, il faudrait utiliser des techniques de génétique des populations.

Nourriceries côtières

La carte d'abondance pluriannuelle pour les nourriceries côtières montre que plus d'individus ont été trouvés le long des côtes britanniques. Pourtant le modèle d'habitat préférentiel ne favorise pas vraiment ces zones, sauf quelques petites zones près de Dungeness. Du coté français, on retrouve plus d'individus en face de la baie de Somme qu'en baie de Seine même si les deux modèles considèrent la zone comme moins favorable. Ces résultats montrent que les nourriceries se trouvent dans un secteur très côtier et, comme il a été dit précédemment, dans des zones de rétentions.

Tous âges confondus

Les abondances de soles recueillies en juillet sont relativement importantes. De plus, l'aire de répartition

Eggs

Sole spawn from February to June in the English Channel, and laying starts when the temperature reaches at least 7°C. In January 2007, there was a high abundance area in the centre of the sampled zone, with lower abundance levels found off the Bay of Somme. The higher abundance area agrees with the probable habitat model even though it predicts a higher occurrence in the western part of the study area and does not consider the Bay of Somme as probable habitat. Temperature and chlorophyll *a* concentrations were the only significant predictive parameters of the model. The potential habitat is more dispersed, covering deep waters with warmer temperatures and coarse sediments. With data being collected in January, eggs densities were low because it was the beginning of the breeding period, and therefore the spatial extent of the distribution pattern may not be representative of that of the main reproductive period.

Larvae

Sole larvae were caught during each survey. Though larvae were ubiquitous during the spring, the potential habitat for stage 2 larvae was along the Flanders coast, near the Pays de Caux, spreading up to the central parts of the English Channel. These habitats were located close to known spawning grounds for this species, i.e. in agreement with the egg distribution described by Grioche *et al.* (2001). This may be linked to the strategy of the youngest larvae being in areas with weaker currents (which allows their retention), with spawning occurring in shallow waters with high temperatures and fluorescence (Grioche *et al.*, 2001). Older larvae preferred more inshore coastal habitats, which can be explained by retention phenomenons linked to estuarial characteristics. In the eastern English Channel, these larvae exhibit, even at the youngest stages, vertical migrations (Grioche *et al.*, 2000). This behaviour enables transport during ebb tides and limits advection of the species to the North Sea. At the present time, it is not possible to estimate the mixing of larvae from the English Channel with those from the North Sea spawning grounds. Population genetics studies may help in assessing the extent of this mixing.

Coastal nurseries

Multi-annual abundance maps of the coastal nurseries showed that common sole were found along the British coast even though the preferential habitat model does not indicate these areas as being favourable, except for some areas around Dungeness. On the French side, more sole were found off the Bay of Somme than off the Bay of Seine, even though both models consider this area as less favourable. Results show that nurseries were mainly found in areas very close to the coast, where young fish are readily retained.

Fish of all ages

Abundance levels in July were relatively high. Moreover, the spatial extent of the distribution pattern was wide across the study area, with a preference for coastal areas. No sole were found in the western central part of the study area. High abundance patches were found in the Dover Strait and in the Bay of Seine, with this pattern recurring every year. In the summer, the preferential habitat was based on semble assez large dans la zone échantillonnée avec toutefois une préférence pour les zones côtières. Aucun individu n'est trouvé dans la partie centrale de la Manche orientale. Les zones de fortes abondances sont situées au niveau du détroit du Pas-de-Calais et de la baie de Seine. Ce schéma est retrouvé tous les ans. L' habitat préférentiel pour cette période s'appuie sur une faible tension de cisaillement, de faibles profondeurs et un type de sédiment de fond plutôt meuble. Le modèle favorise les zones côtières et est en accord avec la distribution moyenne observée en Manche orientale. Seule la côte britannique, de l'île de Wight jusque Beachy Head, révèle de faibles abondances malgré le fait que ce soit un habitat préférentiel. Les habitats potentiels sont similaires aux habitats préférentiels et s'appuient sur les même paramètres, plus un certain nombre d'interactions illustrant la complexité des relations entre paramètres prédictifs.

Les cartes d'abondances montrent en octobre une abondance moindre et une répartition plus restreinte. Cela est probablement dû aux différences d'efficacité des engins de prélèvement, le chalut à perche utilisé lors des campagnes de juillet étant plus approprié pour les poissons plats enfouis, comme la sole, que le chalut de fond GOV utilisé lors des campagnes d'octobre. Cependant, comme en été, les zones de forte abondance sont situées dans des secteurs côtiers comme le détroit du Pas-de-Calais et la baie de Seine. L'erreur de krigeage est plus élevée là où l'échantillonnage est plus clairsemé. Le modèle d'habitat préférentiel privilégie la baie de Seine et la côte près de Dungeness et propose ainsi des habitats toujours très côtiers. La carte d'habitat potentiel est très semblable à celle de l'habitat préférentiel. Ces poissons benthiques préfèrent les zones côtières peu profondes où prédominent les sédiments sableux et la vase.

Les aires de distribution de la sole en été et en automne sont similaires et sont en accord avec les données sur les nourriceries côtières. La sole est un poisson benthique vivant dans des secteurs très côtiers. La superposition des frayères, des zones de distribution des larves et des nourriceries rend la distribution spatiale de la sole commune particulière.

weak bed shear stress and shallow depths, in areas having soft sediment type. The model favours coastal areas which agrees with the mean survey distribution in the English Channel. From the Isle of Wight up to Beachy Head however, low abundance levels were found in spite of the fact that this is preferential habitat. The potential habitat model is similar to the preferential habitat model, depending on the same predictive parameters, with additional interactions that illustrate the complexity of the relationships between environmental parameters.

Maps from the October survey show lower abundance levels and a less dispersed distribution pattern. This is probably caused by differences in the survey gear efficiency. The beam trawl used during the July surveys is more suitable than the VHVO (or GOV) bottom trawl used during the October surveys for catching flatfish like sole that are buried in the sand. Still, as in the summer, areas of high abundance were also located in coastal areas, as well as the Dover Strait and the Bay of Seine. The kriging error was higher where observations were more sparse. The preferential habitat model shows the Bay of Seine and the coast close to Dungeness as favourable areas. The potential habitat map resembles the preferential habitat map. This benthic fish prefers shallow coastal areas with sandy or muddy sediment types.

Distribution patterns in the summer and autumn are very similar and they agree with the nursery data. Sole is a benthic fish living in very coastal areas. The spatial distribution of the various life stages is very particular as there is overlapping of spawning, larval and nursery areas.

H.2 Overview of the previous assessment method

The settings (XSA diagnostics) used for the assessment from WKFLAT 2009 until WGNSSK 2016 are listed in the table below.

	WKFLAT 2009 - WGNSSK 2016		
Fleets	Years	Ages	α-β
BE_CBT commercial	86– ass. year-1	2–10	0–1
UK(E&W)_CBT commercial	86– ass. year-1	2–10	0–1
UK(E&W)_BTS survey	89– ass. year-1	1–6	0.5–0.75
YFS – survey (combined index UK-FR)			
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–ass. year-1	1–1	0.5–0.75
-First data year	1982		
-Last data year	Assessment year -1		
-First age -Last age	1 11+		
Time series weights	None		
-Model	No Power model		
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F	5 years / 5 ages		
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

During the WKNSEA 2017 benchmark, discards were included in the assessment. Additionally, thorough modifications to the tuning series occurred and a new maturity ogive was included (detailed information on the modifications are described in the benchmark report and the associated working documents; ICES, 2017).

The XSA diagnostics as used during the benchmark are listed in the table below.

	WKNSEA 2017		
Fleets	Years	Ages	α-β
BE_CBT_2004-2015 commercial	04–ass. year -1	3–8	0–1
FR_COT commercial	02–ass. year -1	3–8	0–1
UK(E&W)_CBT commercial	86–ass. year -1	3–8	0–1
UK(E&W)_BTS survey	89–ass. year -1	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–ass. year -1	1–1	0.5–0.75
-First data year	1982		
-Last data year	Assessment year - 1		
-First age -Last age	1 11+		
Time series weights	None		
-Model	No Power model		
-Q plateau set at age	7		
-Survivors estimates shrunk towards mean F	5 years / 5 ages		
-s.e. of the means	2.0		
-Min s.e. for pop. Estimates	0.3		
-Prior weighting	None		

During the inter-benchmark in August 2019, the UK-CBT series and the BE-CBT were revised (ICES, 2019). This assessment was used to provide category 3 advice using the relative SSB estimated by the assessment model as an index of stock development. The advice is based on the ratio between the average of the two latest index values (index A: 2017–2018) and the average of the three preceding values (index B: 2014–2016), multiplied by the recent average catch (2016–2018). This methodology was used during the WGNSSK 2020 as the WKFLATNSCS in February 2020 could not solve severe issues with the data.

	2020 ASSESSMENT		
Fleets	Years	Ages	α-β
new BE_CBT_2004–2018 commercial	**04–19**	**3–8**	**0–1**
FR_COT commercial	02–19	3–8	0–1
new UK(E&W)_CBT commercial	**86–19**	**3–8**	**0–1**
UK(E&W)_BTS survey	89–19	1–6	0.5–0.75
UK_YFS survey	87–06	1–1	0.5–0.75
FR_YFS survey	87–19	1–1	0.5–0.75

-First data year	1982
-Last data year	2019
-First age -Last age	1 11+
Time series weights	None
-Model	No Power model
-Q plateau set at age	7
-Survivors estimates shrunk towards mean F	5 years / 5 ages
-s.e. of the means	2.0
-Min s.e. for pop. Estimates	0.3
-Prior weighting	None

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