

6 Herring in the Celtic Sea (divisions 7.a South of 52°30'N and 7.g, 7.h and 7.j)

The assessment year for this stock runs from 1 April until 31 March. Unless otherwise stated, year and year class are referred to by the first year in the season i.e. 2019 refers to the 2019–2020 season.

The WG notes that the use of “age”, “winter rings”, “rings” and “ringers” still causes confusion outside the group (and sometimes even among WG members). The WG tries to avoid this by consequently using “rings”, “ringers”, “winter ringers” or “wr” instead of “age” throughout the report. However, if the word “age” is used it is qualified in brackets with one of the ring designations. It should be observed that, for autumn and winter spawning stocks such as this one, there is a difference of one year between “age” and “rings”. Further elaboration on the rationale behind this, specific to each stock, can be found in the individual Stock Annexes. It is the responsibility of any user of age based data for any of these herring stocks to consult the relevant annex and if in doubt consult a relevant member of the Working Group.

6.1 The Fishery

6.1.1 Advice and management applicable to 2019–2020

The TAC is set by calendar year and in 2019 was 4 742 t (agreed by the Council of the European Union, based on the long-term management plan). In 2019, the EC requested ICES to advise on the minimum level of catches (tonnages) required in a sentinel TAC, which would provide sufficient data for ICES in order to continue providing scientific advice on the state of the stock (ICES, 2019). ICES advised that at least 17 samples from the main and the sentinel fleet would be required to provide advice on similar bases as with a commercial fishery. Those samples could be obtained through a monitoring catch of 869 t. As a result, the TAC agreed by the Council of the European Union was 869 t.

Long-Term Management Plan

A long-term management plan has been proposed by the Pelagic RAC in 2011. The most recent evaluation of this plan took place in 2018 (ICES, 2018).

ICES advises that the harvest control rule in the long-term management plan for Celtic Sea herring is no longer consistent with the precautionary approach. The management plan results in a greater than 5% probability of the stock falling below B_{lim} in several years throughout the 20 year simulated period. The simulations indicate the management plan cannot ensure that the stock is fished and maintained at levels which can produce maximum sustainable yield as soon as or by 2020.

6.1.2 The fishery in 2019–2020

In 2019, the Irish fishery took place in 7.g in Q3 and in 7.g and 7.a.S in Q4 as in previous years.

The Irish fishery is divided in two fleets, the main fleet and the sentinel fleet. The Celtic Sea Herring Management Advisory Committee (CSHMAC) provide inputs in the management of the Celtic Sea Herring. According to 2019 herring fishery arrangements, the main fleet was scheduled to fish from 15th September to 04th October 2019 and from 13th October 22nd November. The Sentinel fleet was scheduled to fish from the 16th November to 20th December.

The main fleet started to fish as planned on 15th September. The first catches of this fleet were reported with a majority of fish < 20cm (MCRS). As a result, the CSHMAC advised the Irish Department of Agriculture Food and the Marine (DAFM) to close the fishery which was enacted on 19th September. Over that week of fishing, 976 t of fish were landed. Two pairs of vessels were allowed to fish from 06th to 11th October and tested various fishing grounds (the smalls, off Cork harbour and off Ballycotton). Although, some hauls exhibited a higher prevalence of fish >MCRS, there was no evidence that the size composition of the Celtic Sea Herring stock was meeting the regulation criteria. The catch taken by those vessels was 314 t. Following that trial, the main fleet was not allowed to fish until the end the year 2019.

The sentinel fleet fished from 16th November to 20th December as planned in the fishery arrangements. An enhanced sampling programme was arranged by the Marine Institute. The primary fishing grounds were the estuary off Dunmore East and off Power Head. The fleet fished on aggregations of fish meeting the management criteria in regards to the size composition. The total landings of this fleet was 512 t.

The Netherlands reported a total catch of 38 t from 7.g in Q4. Germany, France and the UK did not utilize their quota. The area 7.h is part of the management area, but it is unclear if it is part of the stock area.

The spatial distribution of the 2019 landings is presented in Figure 6.1.2.1. There was not full quota uptake in 2019.

The estimated catches from 1988–2019 for the combined areas (7.aS, 7.g, 7.h, 7.j) by quota year and by assessment year (1st April–31st March) are given in tables 6.1.2.1 and 6.1.2.2 respectively. The catch taken during the 2019–2020 season decreased to 1841 t (Figure 6.1.2.2).

The catch data include discards in the directed fishery until 1997. An independent observer study of the Celtic Sea herring fishery was conducted annually from 2012 to 2017. This observer programme was discontinued in 2018 and 2019. Discards from these trips were raised to the total international catch using a weighted average for each year from 2012 to 2017.

Regulations and their effects

Under the previous rebuilding plan, the closure of Subdivision 7.aS from the 2007-present, except for a sentinel fishery, meant that only small dry hold vessels, no more than 50 feet total length, could fish in that area. In 2012, local quota management arrangements were adopted to restrict fishing in 7.aS to vessels under 50 feet, but the total quota allocation increased from 8% to 11%. Therefore, from 2012 there was a slight increase in landings from this area. There is evidence that closure of Subdivision 7.aS under the rebuilding plan, helped to reduce fishing mortality (Clarke and Egan, 2017). The exact mechanisms for this are unclear.

6.1.3 Changes in fishing patterns and Information from the Industry

The fishery in the past number of years has changed compared to previous years. In recent years, herring have been found very close to the bottom in the main fishery, in the acoustic dead-zone of the echosounder, particularly offshore in Division 7.g. The fishery reports that herring are

often not visible on echosounders. Tow duration has increased markedly because it takes longer to catch the desired quantity of herring. In 2017, the fishery was concentrated offshore initially, but effort shifted to more inshore areas in Division 7.g when herring became difficult to locate offshore. It was difficult for the Irish fleet to catch its quota in 2017. The fishery in 2018 was mainly concentrated inshore in 7.g with no significant offshore fishery. Irish vessels had difficulty catching the quota in 2018. In 2019, the high prevalence of fish <MCRS prevented the main fleet to fish more than 5 days and catch their quota.

Vessels greater than 50 feet total length are excluded from 7.aS under local Irish legislation. This has shifted effort onto The Smalls/Celtic Deep ground, south of the 52°N line, in an area which straddles the boundary between the Irish and UK exclusive economic zones (EEZs).

Information provided by the Irish industry reported that in late 2019 fish were considered to be good quality inshore but offshore they were plentiful but small. A decision was made not to open the fishery at the time. A monitoring TAC of 869 t has been agreed for 2020 and the Celtic Sea Advisory Committee is actively engaged with the Marine Institute on how to implement this in autumn 2020. Irish fishers are very concerned about the future of this fishery given the lack of marketable herring on the traditional fishing grounds. Fishers are also of the view that there is considerable mixing with Irish Sea herring which needs to be addressed from scientific viewpoint. It is known that mixing occurs but the level of mixing is unquantified

6.1.4 Discarding

As in all pelagic fisheries, estimation of discarding is very difficult. Individual instances of discarding may be quite infrequent in occurrence. However individual slippages could result in considerable quantities of herring being discarded. The estimates produced by the HAWG in 2012 provided a sensitivity analysis of the assessment to maximum possible discarding. The risk of discarding (slippage induced by restrictive vessel quotas) is now reduced, due to the flexibility mechanism introduced in quota allocation since 2012. Available evidence is that the discard rate is negligible in directed fisheries. The Marine Institute carried out seven herring directed discard trips in 2019 with no discarding observed.

Estimates of discarding from observer trips for the purposes of marine mammal bycatch studies, reported 1% discarding in 2012, 0.8% in 2013 (McKeogh and Berrow, 2013), 3.4% in 2014 (McKeogh and Berrow, 2014), 1.4% in 2015 in the main fishery and 1.5% in the 7.aS small boat fishery (Pinfield and Berrow, 2015), 1.13% in 2016 (O'Dwyer *et al.*, 2016) and 1.19% in 2017 (O'Dwyer and Berrow, 2017). This observer programme was discontinued in 2018 and 2019 and no discard estimates were available for those two years.

Since 2015, this stock is covered by the landings obligation.

6.2 Biological composition of the catch

6.2.1 Catches in numbers-at-age

Catch numbers-at-age are available for the period 1958 to 2019. One winter ringers were the dominant age class in 2019, followed by 2–, 4– and 3–wr, respectively (Table 6.2.1.1.). The 1 ringers were mainly taken by the main fleet in quarter 3. The yearly mean standardized catch numbers-at-age are shown in Figure 6.2.1.1. Year classes 6, 7, 8 and 9 wr were barely observed in the catch. Truncation of ages is again evident in this stock.

The overall proportions-at-age in the catch and the survey are presented in Figure 6.2.1.2. There is generally good agreement between the data sources. The Q4 acoustic survey picks up 1-wr fish in larger proportions than the catch data in some years including 2018. The catch and survey data both show a peak in three winter ring fish in 2018. These samples were taken inshore and are comprised mainly of younger fish. In 2019, a larger proportion of 4-wr was observed in the commercial fishery that might be related to the 3 wr observed in 2018. These fish were caught by the sentinel fleet in Dunmore East's estuary where a significant part of the catch was taken. An enhanced sampling programme was arranged in 2019 to monitor this fleet's catch.

Length–frequency data by division and quarter are presented in Table 6.2.1.2. The 3 length frequencies show 3 different patterns. In Q3 7.g, the catches show the largest size range with a significant amount of fish <20 cm (MCRS). The size composition of this catch led to the closure of the fishery. The trial fishery from 06th–11th October still had a proportion of the catch <20 cm meaning, the main fleet was not allowed to fish again in 2019. The sentinel fleet, which fished in 7.aS in Q4 primarily inshore (estuary at Dunmore East and off power head) and also caught a proportion of fish >MCRS.

6.2.2 Quality of catch and biological data

Biological sampling of the catches was carried out in the area exploited by the Irish fishery (Table 6.2.2.1) in 2019. Under the Data Collection Framework, the sampling of this stock is well above that required by the Minimum Programme (Section 1.5). In the context of high prevalence of fish <MCRS in the catch, an enhanced port sampling programme was arranged by the MI. As a result, 35 samples were collected, 10 from the main fleet and 25 for the sentinel fleet.

6.3 Fishery-Independent Information

6.3.1 Acoustic Surveys

The Celtic Sea herring acoustic survey (CSHAS) time-series currently used in the assessment runs from 2002 to 2019, excluding 2004 (no survey) and 2017 (insufficient biological data). The full survey time-series is presented in Table 6.3.1.1. The internal consistency between ages 1–9 from the acoustic survey is good and presented in Figure 6.3.1.4.

The acoustic survey of the 2019–2020 season was carried out from 09th to 29th October 2019, on the Celtic Explorer <https://oar.marine.ie/handle/10793/1494> (O'Donnell *et al.*, 2019). Survey effort (acoustic sampling) for the core area consisted of 3 011 nautical miles (nm), an increase of 25% from 2018. The geographical coverage was 16 360 square nautical miles. Five adaptive surveys were carried out, accounting for 700 nm of transects covering an area of 1 508 nm². The acoustic survey track is shown in Figure 6.3.1.1.

The 2019 survey consisted of ladder replicate surveys (two broad-scale Pass 1 and Pass 2, and five adaptive mini-surveys) covering the same area. Pass 1 and adaptive survey “Smalls 2” were used in combination to estimate the biomass and numbers–at–age that were used as input data to tune ASAP. NASC distribution plots from the broad-scale survey are presented in Figure 6.3.1.2 and from the adaptive mini survey in Figure 6.3.1.3. Herring TSB (total-stock biomass) and abundance (TSN) estimates from the 2019 survey were 3 070 t and 129 327·10³ individuals respectively.

A total of 21 trawl hauls were carried out during the survey in 2019, with one haul containing >50% herring by weight of catch. Of the 21 hauls, 9 contained herring of less than 50% contribution by weight. A total of 263 herring were aged from survey samples in addition to 338 length measurements and 356 length–weights recorded. Herring age samples ranged from 0–5 winter-rings.

A large proportion of 0 group herring was observed during the 2019 survey. Small herring are often found to mix with sprat. A number of tows were carried out on these echotracers to estimate the prevalence of fish from each species.

Herring were found in two areas. The first area was located inshore from Cork Harbour to Helvick, within 6 nm of the coast. The second area was located offshore and to the east of the first one, on the “Smalls grounds”. Those two areas were also identified by the main fleet that operated in September and early October.

During the 2018 CSHAS, an increased number of 0 group herring were observed above baseline levels. This year class was also observed during the WESPAS survey in June 2019. Although the survey effort increased in the CSHAS 2019, this year class was not observed in the numbers expected.

The SSB estimate in 2019 is the lowest SSB point in the current time-series. The absence of the offshore migratory component of the stock within the wider survey area cannot be attributed to containment as good area coverage was attained.

WGIPS have highlighted in recent years that herring are frequently distributed close to the bottom, within the acoustic dead-zone of the echosounder making the estimation of the biomass in the survey area difficult. However, this was not the case in 2019, and was supported by observations from the commercial fleet.

In 2019 the Western European Shelf Pelagic Acoustic Survey (WESPAS) directed at boarfish, horse mackerel and herring on the Malin Shelf, also had some coverage in the Celtic Sea. An abundance estimate for Celtic Sea herring was calculated for this survey in 2019 (<https://oar.marine.ie/handle/10793/1462>) but is not used for stock assessment purposes. This survey is scheduled in 2020 and methods will be further refined to increase the precision of future estimates. This survey has the potential to be used as an index for the Celtic Sea herring stock when a sufficient time-series of data becomes available. However, given the current low standing stock biomass, the ability of this, or any acoustic survey to report reliable year-on-year estimates of abundance are limited.

6.4 Mean weights-at-age and maturity-at-age and Natural Mortality

The mean weights in the catch and mean weights in the stock at spawning time are presented in Figure 6.4.1.1 and Figure 6.4.1.2 respectively. There has been an overall downward trend in mean weights-at-age in the catch since the early 1980s. After a slight increase around 2008, they have declined again. In 2018 slight increases in mean weights at some ages were observed but 2019 exhibited again a decrease for most of the year classes. None of the increasing 2019 year classes exhibited a high increase in body weight. Mean weights in the stock at spawning time were calculated from biological samples from Q4 (Figure 6.4.1.2). The overall trends in stock weights are the same as the catch weights.

In the assessment, 50% of 1-wr fish are considered mature. Sampling data from the Celtic Sea catches suggest that greater than 50% of 1-wr fish are mature (Lynch, 2011). However, the 2014 benchmark (ICES, 2014) concluded that there was insufficient information to change the maturity ogive.

Following the final procedure of ICES, HAWG 2015, natural mortality values used in the final assessment incorporated the SMS run as obtained in 2011.

The time-invariant natural mortalities and maturities-at-age are presented in the text table below.

	1	2	3	4	5	6	7	8	9+
Maturity	0.5	1	1	1	1	1	1	1	1
Natural mortality	0.767	0.385	0.356	0.339	0.319	0.314	0.307	0.307	0.307

6.5 Recruitment

At present there are no independent recruitment estimates for this stock.

6.6 Assessment

This stock was benchmarked in 2015 by WKWEST (ICES, 2015) and inter-benchmarked by WKPELA 2018.

6.6.1 Stock Assessment

This update assessment was carried out using ASAP. The assessment was tuned using the Celtic Sea herring acoustic survey (CSHAS) ages 2–7 winter rings and excluding the 2004 and 2017 surveys. The input data are presented in tables 6.6.1.1 and 6.6.1.2. The ASAP settings are as per the 2018 inter-benchmark (Table 6.6.1.3). The stock summary is presented in Table 6.6.1.4.

Figure 6.6.1.1 shows the catch proportions-at-age residuals. The residuals are large for the young ages, which is to be expected because these are estimated with low precision. Larger residuals can be seen in recent years. Overall there is no pattern in the residuals. Figure 6.6.1.2 shows the observed and predicted catches. The model followed closely the observed catches. The observed and predicted catch proportions-at-age are shown in Figure 6.6.1.3. There is some divergence in the most recent years, most notable at 2 and 9 wr with a larger proportion predicted than observed catches. Overall the fits are good throughout the full time-series.

The selection pattern in the fishery for the final assessment run is shown in Figure 6.6.1.4. Selection is fixed at 1 for 3-wr which is the age that Celtic Sea herring are considered to be fully selected. Selection at all other ages is estimated by the model. This gives a dome-shaped selection pattern which is considered appropriate to this fishery. The model predicts a drop in selection at-age 9-wr. This may be the case given the lesser abundance of 9-wr in the catch data.

Figure 6.6.1.5 shows the residuals of the index proportions-at-age. The largest residuals can be seen at the younger ages. The index fit shows generally good agreement with the exception of the very large survey index in 2012 (Figure 6.6.1.6). The selectivity parameters were adjusted at

the inter-benchmark. Selection is now fixed for ages 3–5. This gives a more dome-shaped selection pattern with selection declining at older ages (Figure 6.6.1.7).

The analytical retrospective for SSB, Fishing pressure and recruitment is shown in Figure 6.6.1.8. The Mohn's Rho on SSB calculated by ASAP is 1.1 over a five-year peel. This is a significant increase compared to the previous update assessment (–0.17) and it is significantly higher than the 0.2 threshold. Following WKFORBIAS suggestion (ICES, 2020), the 95% confidence interval of the update assessment was added to figures. Regarding SSB (top panel of Figure 6.6.1.8), 3 out of 5 peels were out of the 95% CI bounds. This is most likely due to the current low level of the stock, the low level of the survey index (associated with high CV) and the absence of index for the year 2017. Following the decision tree provided by WKFORBIAS, advice was given because $SSB < B_{lim}$.

Figure 6.6.1.9 shows uncertainties over time in the assessment estimates. Overall, the uncertainty is higher at the start and at the end of the time-series. Recruitment exhibits the highest uncertainty from 2013 to 2019. This may be related to the lack of a fisheries-independent estimate of recruitment.

State of the stock

The stock summary plots from the final assessment in 2019 and the update assessment in 2020 are presented in Figure 6.6.1.10 and the stock summary in Table 6.6.1.4. The assessment shows SSB is declining and is estimated to be 11 751 t in 2019, well below B_{lim} (34 000 t). There is a strong historical retrospective with a downward revision in SSB. HAWG 2019 estimated that SSB was below B_{lim} in 2017–2018. The update assessment indicates that the stock was below B_{lim} in 2016–2019.

The update assessment estimated mean F (2–5 ring) in 2019 to be 0.49, decreasing from 1.16 and 1.11 for 2017 and 2018 respectively. F was estimated to be above F_{pa} (0.27) and F_{MSY} (0.26) since 2014 and above F_{lim} (0.45) since 2015. There is again a strong historical retrospective with F being revised upwards.

Recruitment was good for several years with strong cohorts in 2005, 2007, 2009, 2010, 2011, and 2012 having entered the stock. However, since 2013, recruitment has been below average and no strong cohort has entered the fishery. The 2019 recruitment predicted by the model is higher than the 2018 recruitment and if confirmed in the years ahead might help to rebuild the stock.

6.7 Short-term projections

6.7.1 Deterministic Short-Term Projections

An updated procedure for STF was performed, using the procedure agreed at the 2014 benchmark (ICES 2014/ACOM 43). The 2020 short-term forecast follows the benchmark procedures.

Recruitment (final year, interim year and advice year) in the short-term forecast is to be set to the same value based on the segmented stock–recruit relationship, based on the SSB in the forecast year - 2 (2018). As this SSB value (6 493 t) is below the change-point (54 453 t), the following adjustment is applied.

$$Recruitment_{forecast\ year} = plateau\ recruitment \times \frac{SSB_{forecast\ year-2}}{SSB_{changepoint}}$$

$$Recruitment_{2020} = 441545.4 \times \frac{6462.79}{54452.73} = 52405$$

Interim year catch was taken to be the monitoring TAC. No carryover on the national quotas was used as it is a monitoring TAC. Non-Irish intermediate year catches were not adjusted based on recent quota uptake as done in recent years. The intermediate year catch was 869 t.

The deterministic short-term forecast was performed in FLR. The input data are presented in Table 6.7.1.1.

The results of the short-term projection are presented in Table 6.7.1.2. Fishing in accordance with the MSY approach implies a zero catch in 2021.

6.7.2 Multiannual short-term forecasts

No multiannual simulations were conducted in 2019.

6.7.3 Yield-per-recruit

No yield-per-recruit analyses were conducted in 2019.

6.8 Long-term simulations

Long-term simulations were carried out as part of the ICES evaluation of the long-term management plan for Celtic Sea herring. ICES advised that the harvest control rule was no longer consistent with the precautionary approach. The management plan resulted in >5% probability of the stock falling below B_{lim} in several years throughout the 20 year simulated period. The simulations indicated the management plan could not ensure that the stock is fished and maintained at levels which can produce maximum sustainable yield as soon as or by 2020. The long-term management plan is no longer used to give advice for this stock.

In the framework of the development of a monitoring TAC for the CSH, long-term simulations were carried out to study the recovery of the stock under 2 scenarios, no catch and monitoring TAC (869 t). A shortcut approach implemented in SimpSim was used (ICES, 2016). The operating model was the update assessment agreed by the HAWG in 2019 (ICES, 2019). The simulations showed that in the no catch scenario, the stock would recover in 2023 (risk to B_{lim} <5%). The recovery would be delayed by one year if the monitoring TAC would be taken. (ICES, 2019, special request monitoring TAC).

6.9 Precautionary and yield-based reference points

Reference points were re-estimated by WKPELA 2018.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	54 000 t	B_{pa}	ICES (2018a)
	F_{MSY}	0.26	Stochastic simulations using segmented regression stock–recruitment relationship from 1970–2014	ICES (2018a)

Precautionary approach	B_{lim}	34 000 t	B_{loss} = the lowest observed SSB (1980)	ICES (2018a)
	B_{pa}	54 000 t	$B_{pa} = B_{lim} \times \exp(1.645 \times \sigma B)$, with $\sigma B = 0.29$.	ICES (2018a)
	F_{lim}	0.45	Equilibrium F maintaining SSB > B_{lim} with 50% probability	ICES (2018a)
	F_{pa}	0.27	$F_{pa} = F_{lim} \times \exp(-1.645 \times \sigma F)$, where $\sigma F = 0.30$ from assessment uncertainty (capped) in the terminal year	ICES (2018a)

6.10 Quality of the Assessment

Figure 6.6.1.9 shows uncertainties over time in the assessment estimates for the three key parameters (SSB, recruitment and F). The CVs for each of the parameters are between 0.1 and 0.3 for the majority of the time-series; uncertainties have increased in the final years. Recruitment estimates in the final year show the highest uncertainty.

The SSB and F values based on the assessment and forecast in 2019 are compared with the assessment outputs in 2020 and are shown in the table below. The assessment in 2020 shows a significantly more pessimistic outlook for this stock with SSB revised downwards and F revised upwards. This can also be seen in the historical retrospective plot in Figure 6.10.1

2019 Assessment				2020 Assessment				% change in the estimates	
Year	SSB	Catch	F 2-5	Year	SSB	Catch	F 2-5	SSB	F 2-5
2017	21999	10767	0.64	2017	12034	10767	1.16	–45%	81%
2018	22977	4418	0.33	2018	6463	4418	1.11	–72%	236%
2019*	22787	5320	0.34	2019	11751	1841	0.49	–48%	44%

* from intermediate year in STF.

The 2019 acoustic survey estimate is by far the lowest in the time-series. The survey time-series used in the assessment includes data from 2002 to 2019 (no survey in 2004 and the 2017 survey excluded). Since 2014, herring have been observed close to the bottom in the acoustic dead-zone of the echosounder. The stock is therefore less reliably estimated by the survey.

Estimates of recruitment are uncertain and this may be related to the lack of a fisheries-independent recruitment estimator. In the Irish Sea, mixing occurs between juvenile winter spawned Celtic Sea fish and autumn spawned Irish Sea fish but the level of mixing is unquantified.

6.11 Management Considerations

The stock has declined substantially from a high in 2012, as older cohorts have moved through the fishery. Recruitment has been below average since 2013. The stock is currently forecast to be below B_{lim} in 2021. Fishing is currently above F_{MSY} (0.26) and F_{lim} (0.45).

The advice provided for this stock for 2021 is based on the ICES MSY approach. The basis for the advice is the same as previous years. The Council of the European Union set the 2020 TAC based on the response to a special request where ICES advised that monitoring catches of 869 t would be required to collect sufficient information to provide advice on similar bases as with a commercial fishery. The management plan that was used to set the TAC from 2011 to 2018 was evaluated in 2018. ICES advised that the long-term management plan was no longer precautionary (ICES, 2018).

A change in fish behaviour has been observed by the acoustic survey since 2014. The fish have been observed close to the bottom and have been difficult to detect acoustically.

The closure of the Subdivision 7.aS as a measure to protect first time spawners has been in place since 2007–2008, with limited fishing allowed. Currently only vessels of no more than 50 feet in registered length are permitted to fish in this area. A maximum catch limitation of 11% of the Irish quota is allocated to this fishery.

6.12 Ecosystem considerations

Herring are an important prey species in the ecosystem and also one of the dominant planktivorous fish.

The spawning grounds for herring in the Celtic Sea are well known and are located close to the coast (O'Sullivan *et al.*, 2013). These spawning grounds may contain one or more spawning beds on which herring deposit their eggs. Individual spawning beds within the spawning grounds have been mapped and consist of either gravel or flat stone (Breslin, 1998). Spawning grounds tend to be vulnerable to anthropogenic influences such as dredging, sand and gravel extraction, dumping of dredge spoil and waste from fish cages. There have been several proposals for extraction of gravel and to dump dredge spoil in recent years. Many of these proposals relate to known herring spawning grounds. ICES have consistently advised that activities that perturb herring spawning grounds should be avoided.

Herring fisheries are considered to be clean with little bycatch of other fish. Mega-fauna bycatch is unquantified, though anecdotal reports suggest that seals, blue sharks, tunas, and whitefish are caught from time to time. In the 2017 observer study of the Celtic Sea herring fishery, whiting was the most frequently recorded bycatch species followed by haddock and mackerel. No marine mammals or seabirds were recorded as bycatch in the fishery, with only one elasmobranch (an unidentified dogfish species) recorded. A total of 26 marine mammal sightings were recorded during observer trips (O'Dwyer and Berrow, 2017).

6.13 Changes in the environment

Weights in the catch and in the stock at spawning time have shown fluctuations over time (Figures 6.4.4.1 and 6.4.1.2), but with a decline to lowest observations in the series at the end. The declines in mean weights are a cause for concern, because of their impact on yield and yield-per-recruit. Harma (unpublished) and Lyashevskaya *et al.* (in prep) found that global environmental factors, reflecting recent temperature increases (AMO and ice extent) were linked to changes in the size characteristics during the 1970s–1980s. Outside this period, size-at-age patterns were correlated with more local factors (SST, salinity, trophic and fishery-related indicators). Generally, length-at-age was mostly correlated with global temperature-related indices (AMO and Ice), and weight was linked to local temperature variables (SST). There was no evidence of density-

dependent growth in the Celtic Sea herring population, which is in accordance with previous studies (Molloy, 1984; Brunel and Dickey-Collas, 2010; Lynch, 2011). Rather, stock size exhibited a positive relationship with long-term size-at-age of Celtic Sea herring (Harma, unpublished).

In the Celtic Sea, a change towards spawning taking place later in the season has been documented by Harma *et al.* (2013). The causes of this are likely to be environmental, though to date they have not been elucidated (Harma *et al.*, 2013). It should be noted that declines in mean weights, examined by Harma *et al.* (2013) are not explained by the relative contribution of heavier at-age autumn spawners. Rather, both autumn and winter spawners experienced concurrent declines in mean weights in recent years.

A shift towards later spawning has also been reported by local fishers in this area. WKWEST received a submission from the Celtic Sea Herring Management Advisory Committee of substantial spawning aggregations in Division 7.j in January 2015. This area is mainly an autumn spawning area (O'Sullivan *et al.*, 2012).

Analyses of productivity changes over time in European herring stocks was examined by ICES (HAWG, 2006). It was found that this stock was the only one not to experience a change in productivity or so-called regime shift. This is also seen in the Surplus production per unit stock biomass using information from the 2013 assessment. Evidence from the new ASAP assessment, in terms of recruits per spawner, does not alter this perception (ICES, WKWEST 2015).

Table 6.1.2.1. Herring in the Celtic Sea. Landings by quota year (t), 1988–2019. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	France	Germany	Ireland	Netherlands	UK	Unallocated	Discards	Total
1988	-	-	16 800	-	-	-	2400	19 200
1989	+	-	16 000	1900	-	1300	3500	22 700
1990	+	-	15 800	1000	200	700	2500	20 200
1991	+	100	19 400	1600	-	600	1900	23 600
1992	500	-	18 000	100	+	2300	2100	23 000
1993	-	-	19 000	1300	+	-1100	1900	21 100
1994	+	200	17 400	1300	+	-1500	1700	19 100
1995	200	200	18 000	100	+	-200	700	19 000
1996	1000	0	18 600	1000	-	-1800	3000	21 800
1997	1300	0	18 000	1400	-	-2600	700	18 800
1998	+	-	19 300	1200	-	-200	-	20 300
1999		200	17 900	1300	+	-1300	-	18 100
2000	573	228	18 038	44	1	-617	-	18 267
2001	1359	219	17 729	-	-	-1578	-	17 729
2002	734	-	10 550	257	-	-991	-	10 550
2003	800	-	10 875	692	14	-1506	-	10 875
2004	801	41	11 024	-	-	-801	-	11 065
2005	821	150	8452	799	-	-1770	-	8452
2006	-	-	8530	518	5	-523	-	8530
2007	581	248	8268	463	63	-1355	-	8268
2008	503	191	6853	291	-	-985	-	6853
2009	364	135	5760	-	-	-499	-	5760
2010	636	278	8406	325	-	-1239	na	8406
2011	241	-	11 503	7	-	-248	na	11 503
2012	3	230	16 132	3135	-	2104	161*	21 765
2013	-	450	14 785	832	-	-	118	16 185
2014	244	578	17 287	821	-		644	19 574
2015	-	477	15 798	1304	+	-	247	17 825
2016	-	419	15 107	1025	559	-451	182	16 847
2017	-	298	10 184	648	64		130	11 324
2018			4398	436		-245		4589
2019	-	-	1803	38	-	-	-	1841

* Added in 2014 after report of 1% discarding.

Table 6.1.2.2. Herring in the Celtic Sea. Landings (t) by assessment year (1 April–31 March) 1988/1989–2019/2020. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	France	Germany	Ireland	Netherlands	UK	Unallocated	Discards	Total
1988/1989	-	-	17 000	-	-	-	3400	20 400
1989/1990	+	-	15 000	1900	-	2600	3600	23 100
1990/1991	+	-	15 000	1000	200	700	1700	18 600
1991/1992	500	100	21 400	1600	-	-100	2100	25 600
1992/1993	-	-	18 000	1300	-	-100	2000	21 200
1993/1994	-	-	16 600	1300	+	-1100	1800	18 600
1994/1995	+	200	17 400	1300	+	-1500	1900	19 300
1995/1996	200	200	20 000	100	+	-200	3000	23 300
1996/1997	1000	-	17 900	1000	-	-1800	750	18 800
1997/1998	1300	-	19 900	1400	-	-2100	-	20 500
1998/1999	+	-	17 700	1200	-	-700	-	18 200
1999/2000		200	18 300	1300	+	-1300	-	18 500
2000/2001	573	228	16 962	44	1	-617	-	17 191
2001/2002	-	-	15 236	-	-	-	-	15 236
2002/2003	734	-	7465	257	-	-991	-	7465
2003/2004	800	-	11 536	610	14	-1424	-	11 536
2004/2005	801	41	12 702	-	-	-801	-	12 743
2005/2006	821	150	9494	799	-	-1770	-	9494
2006/2007	-	-	6944	518	5	-523	-	6944
2007/2008	379	248	7636	327	-	-954	-	7636
2008/2009	503	191	5872	150	-	-844	-	5872
2009/2010	364	135	5745	-	-	-499	-	5745
2010/2011	636	278	8370	325	-	-1239	na	8370
2011/2012	241	-	11 470	7	-	-248	na	11 470
2012/2013	3	230	16 132	3135	-	2104	161*	21 765
2013/2014	-	450	14 785	832	-	-	118	16 185
2014/2015	244	578	17 287	821	-	-	644	19 574
2015/2016	-	477	16 320	1304	+	-	254	18 355
2016/2017	-	419	14 585	1025	559	-451	182	16 319
2017/2018	-	298	9627	648	64	-	130	10 767
2018/2019	-	-	4227	436	-	-245	-	4418

2019/2020	-	-	1803	38	-	-	-	1841
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* Added in 2014 after report of 1% discarding.

Table 6.2.1.1. Herring in the Celtic Sea. Comparison of age distributions (percentages) in the catches of Celtic Sea and 7.j herring from 1970–2019/2020. Age is in winter rings.

Year	1	2	3	4	5	6	7	8	9
1970	1%	24%	33%	17%	12%	5%	4%	1%	2%
1971	8%	15%	24%	27%	12%	7%	3%	3%	1%
1972	4%	67%	9%	8%	7%	2%	1%	1%	0%
1973	16%	26%	38%	5%	7%	4%	2%	2%	1%
1974	5%	43%	17%	22%	4%	4%	3%	1%	1%
1975	18%	22%	25%	11%	13%	5%	2%	2%	2%
1976	26%	22%	14%	14%	6%	9%	4%	2%	3%
1977	20%	31%	22%	13%	4%	5%	3%	1%	1%
1978	7%	35%	31%	14%	4%	4%	1%	2%	1%
1979	21%	26%	23%	16%	5%	2%	2%	1%	1%
1980	11%	47%	18%	10%	4%	3%	2%	2%	1%
1981	40%	22%	22%	6%	5%	4%	1%	0%	1%
1982	20%	55%	11%	6%	2%	2%	2%	0%	1%
1983	9%	68%	18%	2%	1%	0%	0%	1%	0%
1984	11%	53%	24%	9%	1%	1%	0%	0%	0%
1985	14%	44%	28%	12%	2%	0%	0%	0%	0%
1986	3%	39%	29%	22%	6%	1%	0%	0%	0%
1987	4%	42%	27%	15%	9%	2%	1%	0%	0%
1988	2%	61%	23%	7%	4%	2%	1%	0%	0%
1989	5%	27%	44%	13%	5%	2%	2%	0%	0%
1990	2%	35%	21%	30%	7%	3%	1%	1%	0%
1991	1%	40%	24%	11%	18%	3%	2%	1%	0%
1992	8%	19%	25%	20%	7%	13%	2%	5%	0%
1993	1%	72%	7%	8%	3%	2%	5%	1%	0%

Year	1	2	3	4	5	6	7	8	9
1994	10%	29%	50%	3%	2%	4%	1%	1%	0%
1995	6%	49%	14%	23%	2%	2%	2%	1%	1%
1996	3%	46%	29%	6%	12%	2%	1%	1%	1%
1997	3%	26%	37%	22%	6%	4%	1%	1%	0%
1998	5%	34%	22%	23%	11%	3%	2%	0%	0%
1999	11%	27%	28%	11%	12%	7%	1%	2%	0%
2000	7%	58%	14%	9%	4%	5%	2%	0%	0%
2001	12%	49%	28%	5%	3%	1%	1%	0%	0%
2002	6%	46%	32%	9%	2%	2%	1%	0%	0%
2003	3%	41%	27%	16%	6%	4%	3%	0%	1%
2004	5%	10%	50%	24%	9%	2%	1%	0%	0%
2005	12%	38%	30%	10%	4%	3%	2%	1%	1%
2006	3%	58%	19%	4%	11%	4%	1%	0%	0%
2007	12%	17%	56%	9%	2%	3%	1%	0%	0%
2008	3%	31%	20%	38%	6%	1%	1%	0%	0%
2009	24%	11%	30%	12%	20%	2%	1%	1%	0%
2010	4%	33%	13%	25%	8%	16%	1%	0%	1%
2011	7%	19%	38%	8%	15%	6%	6%	1%	0%
2012	6%	34%	24%	20%	3%	6%	3%	2%	0%
2013	5%	24%	33%	18%	13%	3%	4%	1%	0%
2014	11%	16%	25%	22%	15%	7%	2%	2%	1%
2015	0%	9%	18%	24%	21%	15%	7%	3%	2%
2016	2%	8%	20%	18%	20%	18%	8%	4%	1%
2017	1%	15%	34%	17%	12%	10%	7%	3%	2%
2018	4%	19%	51%	15%	6%	3%	1%	1%	0%
2019	60%	18%	8%	10%	3%	1%	0%	0%	0%

Table 6.2.1.2. Herring in the Celtic Sea. Length frequency distributions of the Irish catches (raised numbers in '000s) in the 2019/2020 season.

Length cm	7G Q3	7G Q4	7aS Q4
6.5	15		
13.5	15		
16	45		
16.5	76		3
17	121		10
17.5	423	10	35
18	1 149	30	84
18.5	1 663	18	125
19	2 541	25	200
19.5	2 571	35	168
20	2 465	45	246
20.5	1 558	75	183
21	741	70	320
21.5	423	80	281
22	242	178	448
22.5	151	178	419
23	151	258	488
23.5	60	223	383
24	106	334	434
24.5	136	386	435
25	91	366	504
25.5	45	308	385
26		203	211
26.5	15	53	88
27	30	23	56
27.5	15	5	30

28	5	25
28.5	5	8

Table 6.2.2.1. Herring in the Celtic Sea. Sampling intensity of commercial catches (2019–2020). Only Ireland provides samples of this stock.

Division	Year	Quarter	Catch (t)	No. Samples	No. Measured	No. aged	Aged/1000 t
7.g	2019	3	976	4	982	150	154
7.g	2019	4	314	6	1162	300	955
7.aS	2019	4	512	25	4452	830	1621
Total	2019		1803	35	6596	1280	710

Table 6.3.1.1. Herring in the Celtic Sea. Revised acoustic index of abundance used in the assessment. Total stock numbers-at-age (10⁶) estimated using combined acoustic surveys (age refers in winter rings, biomass and SSB in 000's tonnes). 2–7 ring abundances are used in tuning. There was no survey in 2004. The survey in 2017 (shaded) was excluded; it was not recommended for tuning by HAWG in 2018; the single biological sample of herring obtained on the survey in 2017 was considered not adequate.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0	24	-	2	-	1	99	239	5	0	31	4
1	42	13	-	65	21	106	64	381	346	342	270	698
2	185	62	-	137	211	70	295	112	549	479	856	291
3	151	60	-	28	48	220	111	210	156	299	615	197
4	30	17	-	54	14	31	162	57	193	47	330	43
5	7	5	-	22	11	9	27	125	65	71	49	38
6	7	1	-	5	1	13	6	12	91	24	121	10
7	3	0	-	1	-	4	5	4	7	33	25	5
8	0	0	-	0	-	1		6	3	4	23	0
9	0	0	-	0	-	0		1		2	3	1
Nos.	423	183	-	312	305	454	769	1147	1414	1300	2322	1286
SSB	41	20	-	33	36	46	90	91	122	122	246	71
CV	.49	.34	-	.48	.35	.25	.20	.24	.20	.28	.25	.28

	2014	2015	2016	2017	2018	2019
	2015	2016	2017	2018	2019	2020
0	0	0	0	0	109	98
1	41	0	125	0	55	22
2	117	40	21	6	16	8
3	112	48	43	3	27	0.5
4	69	41	40	7	6	0.3
5	20	38	36	5	0	0.1
6	24	7	25	4	0	0
7	7	6	5	1	-	0
8	17	5	6	1	-	0
9	1	0	0	0		0
Nos.	408	184	301	27	213	129
SSB	48	25	30	4	8	362.6
CV	0.59	0.18	0.33	-	49.6	55

Table 6.6.1.1. Herring in the Celtic Sea: Natural mortality inputs to the ASAP model. Age is in winter rings.

Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
0.767	0.385	0.356	0.339	0.319	0.314	0.307	0.307	0.307

Table 6.6.1.1. Continued. Herring in the Celtic Sea: Maturity inputs to the ASAP model. Age is in winter rings.

Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
0.5	1	1	1	1	1	1	1	1

Table 6.6.1.1. Continued. Herring in the Celtic Sea: Weight-at-age in the catch inputs to the ASAP model. Age is in winter rings.

	1	2	3	4	5	6	7	8	9
1958	0.096	0.115	0.162	0.185	0.205	0.217	0.227	0.232	0.23
1959	0.087	0.119	0.166	0.185	0.2	0.21	0.217	0.23	0.231
1960	0.093	0.122	0.156	0.191	0.205	0.207	0.22	0.225	0.239
1961	0.098	0.127	0.156	0.185	0.207	0.212	0.22	0.235	0.235
1962	0.109	0.146	0.17	0.187	0.21	0.227	0.232	0.237	0.24
1963	0.103	0.139	0.194	0.205	0.217	0.23	0.237	0.245	0.251
1964	0.105	0.139	0.182	0.215	0.225	0.23	0.237	0.245	0.253
1965	0.103	0.143	0.18	0.212	0.232	0.243	0.243	0.256	0.26
1966	0.122	0.154	0.191	0.212	0.237	0.248	0.24	0.253	0.257
1967	0.119	0.158	0.185	0.217	0.243	0.251	0.256	0.259	0.264
1968	0.119	0.166	0.196	0.215	0.235	0.248	0.256	0.262	0.266
1969	0.122	0.164	0.2	0.217	0.237	0.245	0.264	0.264	0.262
1970	0.128	0.162	0.2	0.225	0.24	0.253	0.264	0.276	0.272
1971	0.117	0.166	0.2	0.225	0.245	0.253	0.262	0.267	0.283
1972	0.132	0.17	0.194	0.22	0.245	0.259	0.264	0.27	0.285
1973	0.125	0.174	0.205	0.215	0.245	0.262	0.262	0.285	0.285
1974	0.141	0.18	0.21	0.225	0.237	0.259	0.262	0.288	0.27
1975	0.137	0.187	0.215	0.24	0.251	0.26	0.27	0.279	0.284
1976	0.137	0.174	0.205	0.235	0.259	0.27	0.279	0.288	0.293
1977	0.134	0.185	0.212	0.222	0.243	0.267	0.259	0.292	0.298
1978	0.127	0.189	0.217	0.24	0.279	0.276	0.291	0.297	0.302
1979	0.127	0.174	0.212	0.23	0.253	0.273	0.291	0.279	0.284
1980	0.117	0.174	0.207	0.237	0.259	0.276	0.27	0.27	0.275
1981	0.115	0.172	0.21	0.245	0.267	0.276	0.297	0.309	0.315
1982	0.115	0.154	0.194	0.237	0.262	0.273	0.279	0.288	0.293
1983	0.109	0.148	0.198	0.22	0.276	0.282	0.276	0.319	0.325

	1	2	3	4	5	6	7	8	9
1984	0.093	0.142	0.185	0.213	0.213	0.245	0.246	0.263	0.262
1985	0.104	0.14	0.17	0.201	0.234	0.248	0.256	0.26	0.263
1986	0.112	0.155	0.172	0.187	0.215	0.248	0.276	0.284	0.332
1987	0.096	0.138	0.186	0.192	0.204	0.231	0.255	0.267	0.284
1988	0.097	0.132	0.168	0.203	0.209	0.215	0.237	0.257	0.283
1989	0.106	0.129	0.151	0.169	0.194	0.199	0.21	0.221	0.24
1990	0.099	0.137	0.153	0.167	0.188	0.208	0.209	0.229	0.251
1991	0.092	0.128	0.168	0.182	0.19	0.206	0.229	0.236	0.251
1992	0.096	0.123	0.15	0.177	0.191	0.194	0.212	0.228	0.248
1993	0.092	0.129	0.155	0.18	0.201	0.204	0.21	0.225	0.24
1994	0.097	0.135	0.168	0.179	0.19	0.21	0.218	0.217	0.227
1995	0.088	0.126	0.151	0.178	0.188	0.198	0.207	0.227	0.227
1996	0.088	0.118	0.147	0.159	0.185	0.196	0.207	0.219	0.231
1997	0.093	0.124	0.141	0.157	0.172	0.192	0.206	0.216	0.22
1998	0.099	0.121	0.153	0.163	0.173	0.185	0.199	0.204	0.225
1999	0.09	0.12	0.149	0.167	0.18	0.183	0.202	0.209	0.208
2000	0.092	0.111	0.148	0.168	0.185	0.187	0.197	0.21	0.224
2001	0.082	0.107	0.139	0.162	0.177	0.19	0.185	0.204	0.229
2002	0.096	0.115	0.139	0.156	0.185	0.196	0.203	0.211	0.226
2003	0.089	0.102	0.128	0.146	0.165	0.184	0.195	0.202	0.214
2004	0.08	0.13	0.134	0.151	0.159	0.174	0.203	0.215	0.225
2005	0.077	0.102	0.142	0.147	0.158	0.168	0.181	0.208	0.252
2006	0.093	0.105	0.127	0.151	0.155	0.165	0.174	0.186	0.198
2007	0.074	0.106	0.123	0.141	0.166	0.162	0.17	0.171	0.229
2008	0.091	0.12	0.144	0.156	0.172	0.191	0.194	0.199	0.224
2009	0.078	0.122	0.146	0.16	0.169	0.185	0.187	0.197	0.211
2010	0.076	0.111	0.131	0.145	0.158	0.159	0.163	0.178	0.19
2011	0.07	0.104	0.127	0.141	0.154	0.161	0.167	0.18	0.179

	1	2	3	4	5	6	7	8	9
2012	0.072	0.094	0.124	0.138	0.152	0.157	0.164	0.164	0.171
2013	0.062	0.101	0.122	0.142	0.153	0.164	0.17	0.166	0.18
2014	0.067	0.1	0.127	0.14	0.153	0.161	0.163	0.179	0.176
2015	0.071	0.102	0.122	0.137	0.143	0.151	0.158	0.167	0.182
2016	0.061	0.095	0.119	0.131	0.140	0.144	0.151	0.157	0.162
2017	0.06	0.080	0.090	0.123	0.143	0.160	0.163	0.171	0.178
2018	0.067	0.092	0.11	0.124	0.136	0.146	0.162	0.143	0.15
2019	0.06	0.085	0.109	0.123	0.131	0.155	0.153	0.156	0.163

Table 6.6.1.1. Continued. Herring in the Celtic Sea: Weight-at-age in the stock inputs to the ASAP model. Age is in winter rings.

	1	2	3	4	5	6	7	8	9
1958	0.096	0.115	0.162	0.185	0.205	0.217	0.227	0.232	0.23
1959	0.087	0.119	0.166	0.185	0.2	0.21	0.217	0.23	0.231
1960	0.093	0.122	0.156	0.191	0.205	0.207	0.22	0.225	0.239
1961	0.098	0.127	0.156	0.185	0.207	0.212	0.22	0.235	0.235
1962	0.109	0.146	0.17	0.187	0.21	0.227	0.232	0.237	0.24
1963	0.103	0.139	0.194	0.205	0.217	0.23	0.237	0.245	0.251
1964	0.105	0.139	0.182	0.215	0.225	0.23	0.237	0.245	0.253
1965	0.103	0.143	0.18	0.212	0.232	0.243	0.243	0.256	0.26
1966	0.122	0.154	0.191	0.212	0.237	0.248	0.24	0.253	0.257
1967	0.119	0.158	0.185	0.217	0.243	0.251	0.256	0.259	0.264
1968	0.119	0.166	0.196	0.215	0.235	0.248	0.256	0.262	0.266
1969	0.122	0.164	0.2	0.217	0.237	0.245	0.264	0.264	0.262
1970	0.128	0.162	0.2	0.225	0.24	0.253	0.264	0.276	0.272
1971	0.117	0.166	0.2	0.225	0.245	0.253	0.262	0.267	0.283
1972	0.132	0.17	0.194	0.22	0.245	0.259	0.264	0.27	0.285
1973	0.125	0.174	0.205	0.215	0.245	0.262	0.262	0.285	0.285
1974	0.141	0.18	0.21	0.225	0.237	0.259	0.262	0.288	0.27

	1	2	3	4	5	6	7	8	9
1975	0.137	0.187	0.215	0.24	0.251	0.26	0.27	0.279	0.284
1976	0.137	0.174	0.205	0.235	0.259	0.27	0.279	0.288	0.293
1977	0.134	0.185	0.212	0.222	0.243	0.267	0.259	0.292	0.298
1978	0.127	0.189	0.217	0.24	0.279	0.276	0.291	0.297	0.302
1979	0.127	0.174	0.212	0.23	0.253	0.273	0.291	0.279	0.284
1980	0.117	0.174	0.207	0.237	0.259	0.276	0.27	0.27	0.275
1981	0.115	0.172	0.21	0.245	0.267	0.276	0.297	0.309	0.315
1982	0.115	0.154	0.194	0.237	0.262	0.273	0.279	0.288	0.293
1983	0.109	0.148	0.198	0.22	0.276	0.282	0.276	0.319	0.325
1984	0.093	0.142	0.185	0.213	0.213	0.245	0.246	0.263	0.262
1985	0.104	0.14	0.17	0.201	0.234	0.248	0.256	0.26	0.263
1986	0.112	0.155	0.172	0.187	0.215	0.248	0.276	0.284	0.332
1987	0.096	0.138	0.186	0.192	0.204	0.231	0.255	0.267	0.284
1988	0.097	0.132	0.168	0.203	0.209	0.215	0.237	0.257	0.283
1989	0.106	0.129	0.151	0.169	0.194	0.199	0.21	0.221	0.24
1990	0.099	0.137	0.153	0.167	0.188	0.208	0.209	0.229	0.251
1991	0.092	0.128	0.168	0.182	0.19	0.206	0.229	0.236	0.251
1992	0.096	0.123	0.15	0.177	0.191	0.194	0.212	0.228	0.248
1993	0.092	0.129	0.155	0.18	0.201	0.204	0.21	0.225	0.24
1994	0.097	0.135	0.168	0.179	0.19	0.21	0.218	0.217	0.227
1995	0.088	0.126	0.151	0.178	0.188	0.198	0.207	0.227	0.227
1996	0.088	0.118	0.147	0.159	0.185	0.196	0.207	0.219	0.231
1997	0.093	0.124	0.141	0.157	0.172	0.192	0.206	0.216	0.22
1998	0.099	0.121	0.153	0.163	0.173	0.185	0.199	0.204	0.225
1999	0.09	0.12	0.149	0.167	0.18	0.183	0.202	0.209	0.208
2000	0.092	0.111	0.148	0.168	0.185	0.187	0.197	0.21	0.224
2001	0.082	0.107	0.139	0.162	0.177	0.19	0.185	0.204	0.229
2002	0.096	0.115	0.139	0.156	0.184	0.196	0.203	0.211	0.223

	1	2	3	4	5	6	7	8	9
2003	0.078	0.1	0.13	0.141	0.156	0.158	0.168	0.2	0.213
2004	0.077	0.127	0.133	0.151	0.156	0.168	0.216	0.228	0.257
2005	0.074	0.103	0.145	0.143	0.155	0.161	0.175	0.221	0.233
2006	0.085	0.104	0.123	0.153	0.15	0.157	0.164	0.177	0.188
2007	0.068	0.101	0.122	0.138	0.156	0.159	0.163	0.167	0.251
2008	0.083	0.117	0.14	0.156	0.17	0.18	0.177	0.189	0.232
2009	0.076	0.117	0.142	0.158	0.168	0.176	0.17	0.186	0.226
2010	0.076	0.106	0.127	0.139	0.152	0.157	0.164	0.188	0.18
2011	0.067	0.108	0.127	0.138	0.148	0.16	0.17	0.194	0.197
2012	0.061	0.094	0.125	0.138	0.149	0.159	0.161	0.165	0.167
2013	0.06	0.101	0.126	0.144	0.153	0.159	0.168	0.17	0.186
2014	0.065	0.1	0.128	0.142	0.153	0.158	0.163	0.177	0.169
2015	0.065	0.098	0.119	0.133	0.14	0.146	0.153	0.16	0.162
2016	0.059	0.096	0.117	0.131	0.139	0.143	0.150	0.160	0.165
2017	0.055	0.079	0.088	0.116	0.139	0.158	0.164	0.170	0.177
2018	0.065	0.095	0.121	0.142	0.154	0.166	0.171	0.166	0.170
2019	0.055	0.087	0.106	0.122	0.127	0.141	0.15	0.161	0.16

Table 6.6.1.1. Continued. Herring in the Celtic Sea: Fishery Selectivity block inputs (1–9) to the ASAP model. Age is in winter rings.

Age	Selectivity	Block	#1	Data
1	0.3	1	0	1
2	0.5	1	0	1
3	1	–1	0	1
4	1	1	0	1
5	1	1	0	1
6	1	1	0	1
7	1	1	0	1
8	1	1	0	1

9	1	1	0	1
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Table 6.6.1.1. Continued. Herring in the Celtic Sea: Catch numbers-at-age and total catch inputs to the ASAP model. Age is in winter rings.

Year	1	2	3	4	5	6	7	8	9	Total catch
1958	1642	3742	33094	25746	12551	23949	16093	9384	5584	22978
1959	1203	25717	2274	19262	11015	5830	17821	3745	7352	15086
1960	2840	72246	24658	3779	13698	4431	6096	4379	4151	18283
1961	2129	16058	32044	5631	2034	5067	2825	1524	4947	15372
1962	772	18567	19909	48061	8075	3584	8593	3805	5322	21552
1963	297	51935	13033	4179	20694	2686	1392	2488	2787	17349
1964	7529	15058	17250	6658	1719	8716	1304	577	2193	10599
1965	57	70248	9365	15757	3399	4539	12127	1377	7493	19126
1966	7093	19559	59893	9924	13211	5602	3586	8746	3842	27030
1967	7599	39991	20062	49113	9218	9444	3939	6510	6757	27658
1968	12197	54790	39604	11544	22599	4929	4170	1310	4936	30236
1969	9472	93279	55039	33145	12217	17837	4762	2174	3469	44389
1970	1319	37260	50087	26481	18763	7853	6351	2175	3367	31727
1971	12658	23313	37563	41904	18759	10443	4276	4942	2239	31396
1972	8422	137690	17855	15842	14531	4645	3012	2374	1020	38203
1973	23547	38133	55805	7012	9651	5323	3352	2332	1209	26936
1974	5507	42808	17184	22530	4225	3737	2978	903	827	19940
1975	12768	15429	17783	7333	9006	3520	1644	1136	1194	15588
1976	13317	11113	7286	7011	2872	4785	1980	1243	1769	9771
1977	8159	12516	8610	5280	1585	1898	1043	383	470	7833
1978	2800	13385	11948	5583	1580	1476	540	858	482	7559
1979	11335	13913	12399	8636	2889	1316	1283	551	635	10321
1980	7162	30093	11726	6585	2812	2204	1184	1262	565	13130
1981	39361	21285	21861	5505	4438	3436	795	313	866	17103
1982	15339	42725	8728	4817	1497	1891	1670	335	596	13000
1983	13540	102871	26993	3225	1862	327	372	932	308	24981

Year	1	2	3	4	5	6	7	8	9	Total catch
1984	19517	92892	41121	16043	2450	1085	376	231	180	26779
1985	17916	57054	36258	16032	2306	228	85	173	132	20426
1986	4159	56747	42881	32930	8790	1127	98	29	12	25024
1987	5976	67000	43075	23014	14323	2716	1175	296	464	26200
1988	2307	82027	30962	9398	5963	3047	869	297	86	20447
1989	8260	42413	68399	19601	8205	3837	2589	767	682	23254
1990	2702	41756	24634	35258	8116	3808	1671	695	462	18404
1991	1912	63854	38342	16916	28405	4869	2588	954	593	25562
1992	10410	26752	35019	27591	10139	18061	3021	6285	689	21127
1993	1608	94061	9372	10221	4491	2790	5932	855	508	18618
1994	12130	35768	61737	3289	3025	4773	1713	1705	474	19300
1995	9450	79159	22591	36541	3686	3420	2651	1859	842	23305
1996	3476	61923	38244	7943	16114	2077	1586	1507	1025	18816
1997	3849	37440	53040	31442	8318	6142	1148	827	603	20496
1998	5818	41510	27102	28274	13178	3746	2675	597	387	18041
1999	14274	34072	36086	14642	15515	8877	1865	2012	551	18485
2000	9953	77378	18952	12060	5230	6227	2320	662	578	17191
2001	15724	62153	35816	5953	4249	1774	1145	466	386	15269
2002	3495	26472	18532	5309	1416	1269	437	154	201	7465
2003	2711	37006	24444	14763	5719	3363	2335	388	542	11536
2004	4276	9470	46243	21863	8638	1412	473	191	75	12743
2005	15419	30710	5766	18666	7349	1923	435	77	60	9494
2006	1460	33894	10914	2469	6261	2331	561	57	48	6944
2007	8043	11028	36223	5509	1365	2040	410	56	4	7636
2008	1288	12468	8144	15565	2328	518	321	58	11	5872
2009	10171	4465	12859	4887	8458	971	279	247	80	5745
2010	2468	20929	8183	15917	4846	10080	919	273	321	8370
2011	6384	17151	33453	7301	13087	5347	5165	1089	141	11470

Year	1	2	3	4	5	6	7	8	9	Total catch
2012	11712	62528	44819	37500	6303	11811	5549	3540	347	21820
2013	6191	30471	42133	22649	16687	3305	5463	1778	535	16247
2014	16664	24120	39102	33320	22450	11165	3047	2774	1022	19574
2015	286	12247	23835	32140	27382	19861	9820	4207	3279	18355
2016	2023	9822	25030	22800	25310	22447	10484	4684	1464	16318
2017	707	14144	31912	16004	10718	8963	6722	2401	1473	10767
2018	1654	7646	20545	5974	2296	1011	264	380	188	4418
2019	14146	4371	1857	2265	612	212	88	73	33	1841

Table 6.6.1.1. Continued. Herring in the Celtic Sea: Index selectivity inputs (2–7) to the ASAP model. Age is in winter rings.

Age (wr)	Index-1	Selectivity
2	0.8	4
3	1	-1
4	1	-1
5	1	-1
6	1	4
7	1	4

Table 6.6.1.2. Herring in the Celtic Sea. Survey data input to ASAP. Age is in winter rings.

year	value	CV	2	3	4	5	6	7	Sample Size
2002	381900	0.5	185200	150600	29700	6600	7100	2700	15
2003	146400	0.5	61700	60400	17200	5400	1400	300	15
2004	-1	-1	-1	-1	-1	-1	-1	-1	0
2005	246700	0.5	137100	28200	54200	21600	4900	700	18
2006	284999	0.5	211000	48000	14000	11000	1000	-1	17
2007	346120	0.5	69800	220000	30600	8970	13100	3650	21
2008	606000	0.5	295000	111000	162000	27000	6000	5000	21
2009	519370	0.5	112040	209850	57490	124630	11710	3650	23
2010	1060760	0.5	548940	155860	193030	65240	91040	6650	18
2011	953000	0.5	479000	299000	47000	71000	24000	33000	16
2012	1995300	0.5	856000	615000	330000	48500	121000	24800	13

2013	584900	0.5	291400	197400	43700	37900	9800	4700	9
2014	349000	0.5	117300	112100	69400	19800	23600	6800	5
2015	179400	0.5	40100	48100	41200	37700	6800	5500	6
2016	169376	0.5	20629	42736	39835	36124	24590	5462	10
2017	-1	-1	-1	-1	-1	-1	-1	-1	0
2018	49130	0.5	16104	26831	5984	110	101	0	9
2019	8873	0.5	98229	7934	524	284	131	0	3

Table 6.6.1.3. Herring in the Celtic Sea. ASAP final Run settings.

Discards Included	No
Use likelihood constant	No
Mean F (Fbar) age (wr)range	2–5
Number of selectivity blocks	1
Fleet selectivity	By Age: 1–9-wr: 0.3,0.5,1,1,1,1,1,1,1 Fixed at-age 3-wr
Index units	2 (numbers)
Index month	October (10)
Index selectivity linked to fleet	-1 (not linked)
Index Years	2002–2019 (no survey in 2004 and 2017 not included)
Index age (wr)range	2–7
Index Selectivity	0.8,1,1,1,1,1 Fixed from ages 3–5-wr
Index CV	0.5 all years
Sample size	No of herring samples collected per survey
Phase for F-Mult in 1st year	1
Phase for F-Mult deviations	2
Phase for recruitment deviations	3
Phase for N in 1st Year	1
Phase for catchability in 1st Year	1
Phase for catchability deviations	-5
Phase for Stock recruit relationship	1
Phase for steepness -	-5 (Do not fit stock–recruitment curve)

Recruitment CV by year	1
Lambdas by index	1
Lambda for total catch in weight by fleet	1
Catch total CV	0.2 for all years
Catch effective sample size	No of samples from Irish sampling programme. Downweighted to 5 in 2015, 2016, 2017, 2018 and 2019
Lambda for F-Mult in 1st year	0 (freely estimated)
CV for F mult in the first year	0.5
Lambda for F-Mult deviations	0 (freely estimated)
CV for f mult deviations by fleet	0.5
Lambda for N in 1st year deviations	0 (freely estimated)
CV for N in the 1st year deviations	1
Lambda for recruitment deviations	1
Lambda for catchability in 1st year index	0
CV for catchability in 1st year by index	1
Lambda for catchability deviations	0
CV for catchability deviations	1
Lambda for deviation from initial steepness	0
CV for deviation from initial steepness	1
Lambda for deviation from unexplained stock size	0
CV for deviation from unexplained stock size	1

Table 6.6.1.4. Herring in the Celtic Sea. Update assessment stock summary table. Recruitment is at 1-winter ring.

Year	Catch	SSB	TSB	Fbar 2-5	Recruitment
1958	22978	212881	288401	0.127	416389
1959	15086	203797	331840	0.11	1594650
1960	18283	194358	262201	0.123	368441
1961	15372	164157	226821	0.118	399134

Year	Catch	SSB	TSB	Fbar 2-5	Recruitment
1962	21552	160451	258184	0.19	853511
1963	17349	148618	211785	0.151	407405
1964	10599	168268	292743	0.095	1392530
1965	19126	172804	243341	0.138	419978
1966	27030	167733	269110	0.197	739764
1967	27658	161269	263025	0.223	772745
1968	30236	164268	277325	0.241	903981
1969	44389	143568	231462	0.36	464186
1970	31727	108429	167458	0.329	250351
1971	31396	99043	194233	0.451	823299
1972	38203	86732	149747	0.557	280943
1973	26936	65242	119014	0.516	326911
1974	19940	50604	86801	0.492	161218
1975	15588	40093	74381	0.514	203101
1976	9771	37219	69100	0.385	227445
1977	7833	37807	64937	0.288	185840
1978	7559	36540	59521	0.266	146362
1979	10321	36355	71083	0.423	279745
1980	13130	33306	60395	0.541	167492
1981	17103	36829	87249	0.832	467127
1982	13000	57842	127196	0.454	728109
1983	24981	76920	159816	0.552	788475
1984	26779	79578	149508	0.468	669958
1985	20426	85739	154963	0.317	646179
1986	25024	93825	171769	0.363	658128
1987	26200	106334	212706	0.386	1207080
1988	20447	109884	171881	0.23	478279
1989	23254	96523	165556	0.284	579069

Year	Catch	SSB	TSB	Fbar 2-5	Recruitment
1990	18404	90006	148262	0.246	506130
1991	25562	71730	112583	0.379	208702
1992	21127	71592	153847	0.482	967209
1993	18618	74274	120320	0.323	361611
1994	19300	81042	152741	0.32	772174
1995	23305	82505	150819	0.385	725049
1996	18816	72951	117277	0.307	353773
1997	20496	60327	105456	0.406	374420
1998	18041	48357	83668	0.444	249788
1999	18485	42320	88372	0.622	488919
2000	17191	42348	87825	0.63	478526
2001	15269	41902	83659	0.531	493225
2002	7465	53935	99872	0.209	539997
2003	11536	42922	65223	0.306	142293
2004	12743	39128	70945	0.392	360298
2005	9494	54395	116761	0.308	1054640
2006	6944	66923	102403	0.133	354347
2007	7636	69590	116543	0.132	720272
2008	5872	82391	116310	0.08	292507
2009	5745	93745	160167	0.077	1006110
2010	8370	101575	159799	0.101	746881
2011	11470	109720	175603	0.13	952159
2012	21820	99597	154951	0.253	628844
2013	16247	87806	127867	0.214	365501
2014	19574	67969	104862	0.322	303675
2015	18355	43886	70248	0.46	172583
2016	16318	26045	49388	0.765	209482
2017	10767	12034	24404	1.156	61806

Year	Catch	SSB	TSB	Fbar 2-5	Recruitment
2018	4418	6463	13587	1.107	56038.5
2019	1841	11751	29809	0.492	451705

Table 6.7.1.1. Herring in the Celtic Sea. Input data for short-term forecast.

2020								
Age	N	M	Mat	PF	PM	SWt	Sel	CWt
1	52405	0.77	0.5	0.5	0.5	0.058	0.06	0.062
2	202760	0.38	1	0.5	0.5	0.087	0.72	0.086
3	11158	0.36	1	0.5	0.5	0.105	0.98	0.103
4	3136	0.34	1	0.5	0.5	0.127	0.98	0.123
5	2284	0.32	1	0.5	0.5	0.14	0.98	0.137
6	549	0.31	1	0.5	0.5	0.155	0.98	0.154
7	398	0.31	1	0.5	0.5	0.162	0.92	0.159
8	250	0.31	1	0.5	0.5	0.166	0.92	0.157
9	3993	0.31	1	0.5	0.5	0.169	0.26	0.164
2021								
Age	N	M	Mat	PF	PM	SWt	Sel	CWt
1	52405	0.77	0.5	0.5	0.5	0.058	0.06	0.062
2	-	0.38	1	0.5	0.5	0.087	0.72	0.086
3	-	0.36	1	0.5	0.5	0.105	0.98	0.103
4	-	0.34	1	0.5	0.5	0.127	0.98	0.123
5	-	0.32	1	0.5	0.5	0.14	0.98	0.137
6	-	0.31	1	0.5	0.5	0.155	0.98	0.154
7	-	0.31	1	0.5	0.5	0.162	0.92	0.159
8	-	0.31	1	0.5	0.5	0.166	0.92	0.157
9	-	0.31	1	0.5	0.5	0.169	0.26	0.164

2022								
Age	N	M	Mat	PF	PM	SWt	Sel	CWt
1	52405	0.77	0.5	0.5	0.5	0.058	0.06	0.062
2	-	0.38	1	0.5	0.5	0.087	0.72	0.086
3	-	0.36	1	0.5	0.5	0.105	0.98	0.103
4	-	0.34	1	0.5	0.5	0.127	0.98	0.123
5	-	0.32	1	0.5	0.5	0.14	0.98	0.137
6	-	0.31	1	0.5	0.5	0.155	0.98	0.154
7	-	0.31	1	0.5	0.5	0.162	0.92	0.159
8	-	0.31	1	0.5	0.5	0.166	0.92	0.157
9	-	0.31	1	0.5	0.5	0.169	0.26	0.164

Table 6.7.1.2. Herring in the Celtic Sea. Results of short-term deterministic forecast.

Rationale	F _{bar} (2020)	Catch (2020)	SSB (2020)	F _{bar} (2021)	Catch (2021)	SSB (2021)	SSB (2022)
Catch(2021) = Zero	0.066	869	17485	0	0	16063	15426
F _{bar(2020)} = F _{MSY}	0.066	869	17485	0.26	3504	14199	11055
F _{bar(2020)} = F _{pa}	0.066	869	17485	0.27	3622	14132	10919
F _{bar(2020)} = F _{lim}	0.066	869	17485	0.45	5566	12987	8786
F _{bar(2020)} = F ₂₀₂₀	0.066	869	17485	0.34	978	15564	14144
Catch(2021) = 2020 TAC	0.066	869	17485	0.294	869	15620	14240

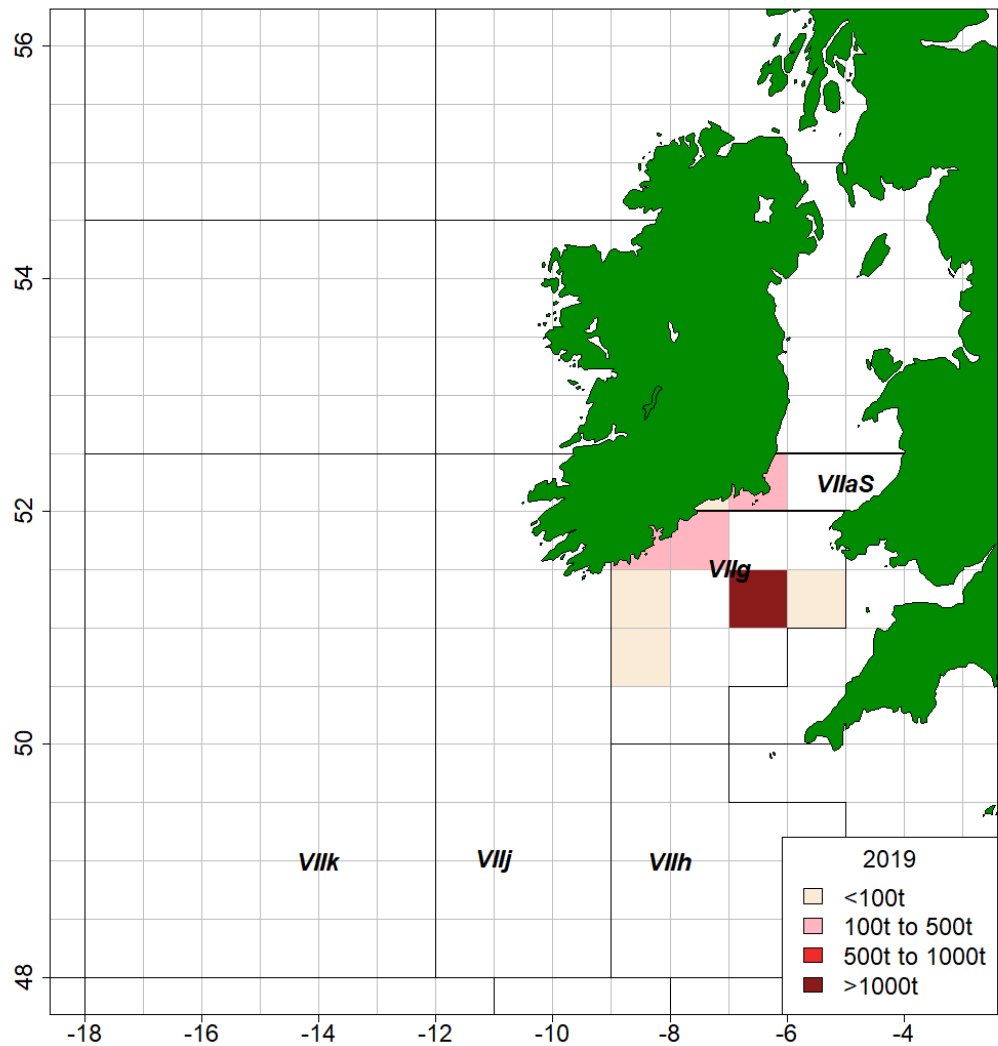


Figure 6.1.2.1. Herring in the Celtic Sea. Total official herring catches by statistical rectangle in 2019/2020.

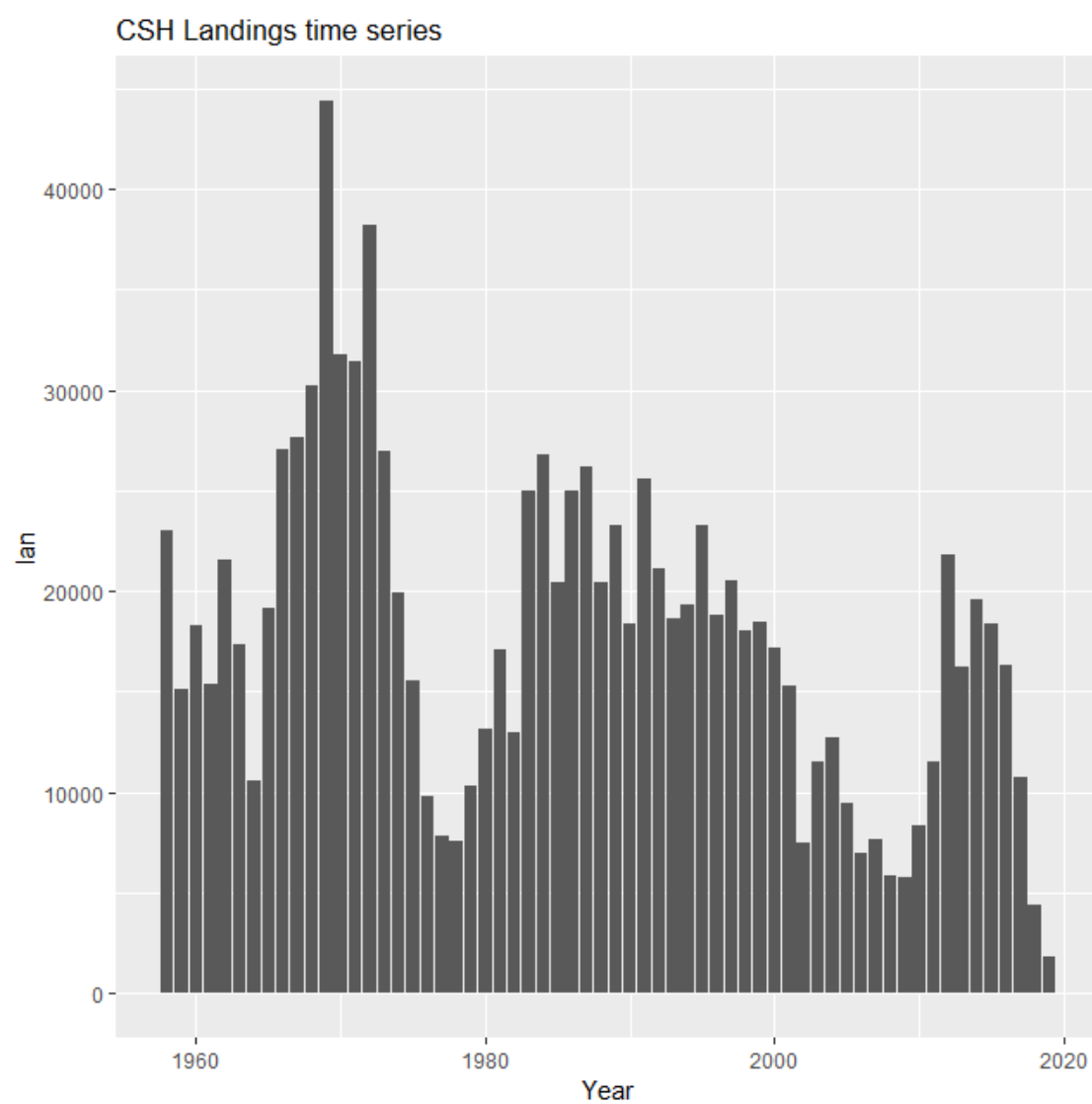


Figure 6.1.2.2. Herring in the Celtic Sea. Working Group estimates of herring catches per season.

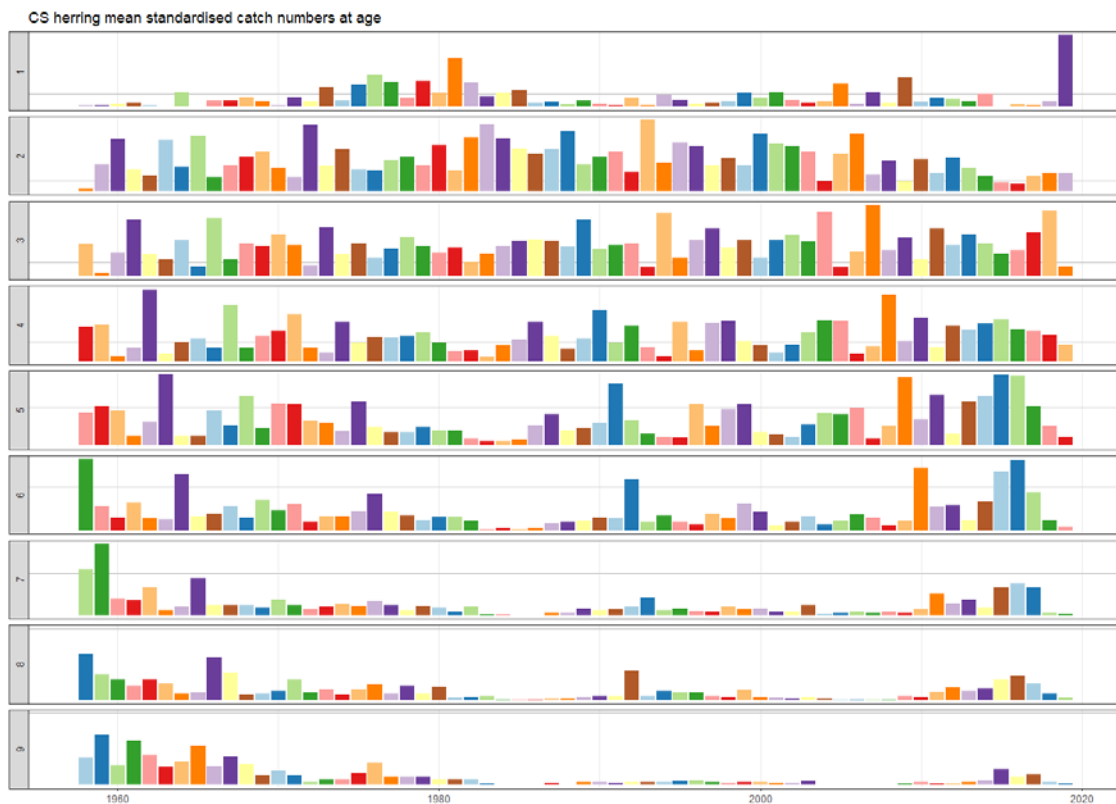


Figure 6.2.1.1. Herring in the Celtic Sea. Catch numbers-at-age standardized by yearly mean. 9-wr is the plus group. Age in winter rings.

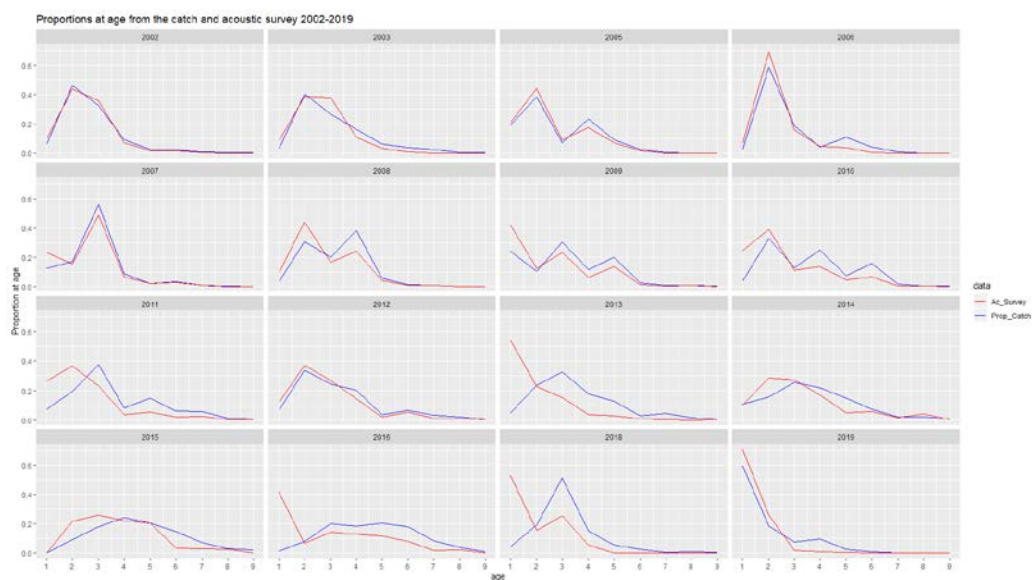


Figure 6.2.1.2. Herring in the Celtic Sea. Proportions at age in the survey (1–9 wr) and the commercial fishery (1–9 wr) by year. Age in winter rings.

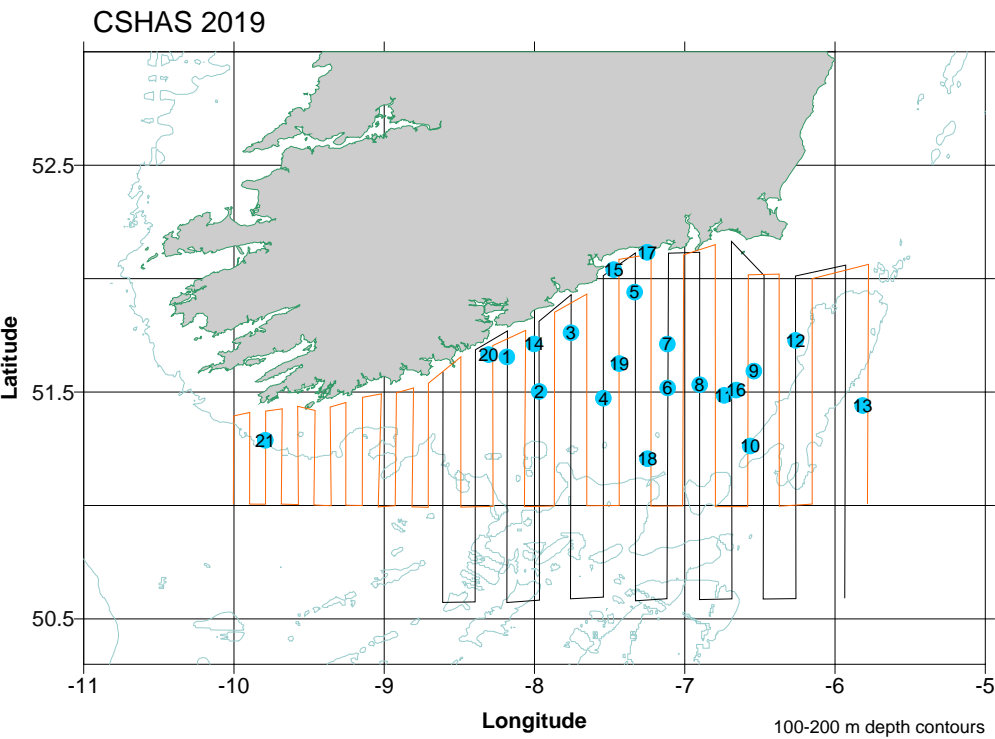


Figure 6.3.1.1. Herring in the Celtic Sea. Acoustic survey tracks for the core and adaptive surveys in 2019, haul positions are numbered.

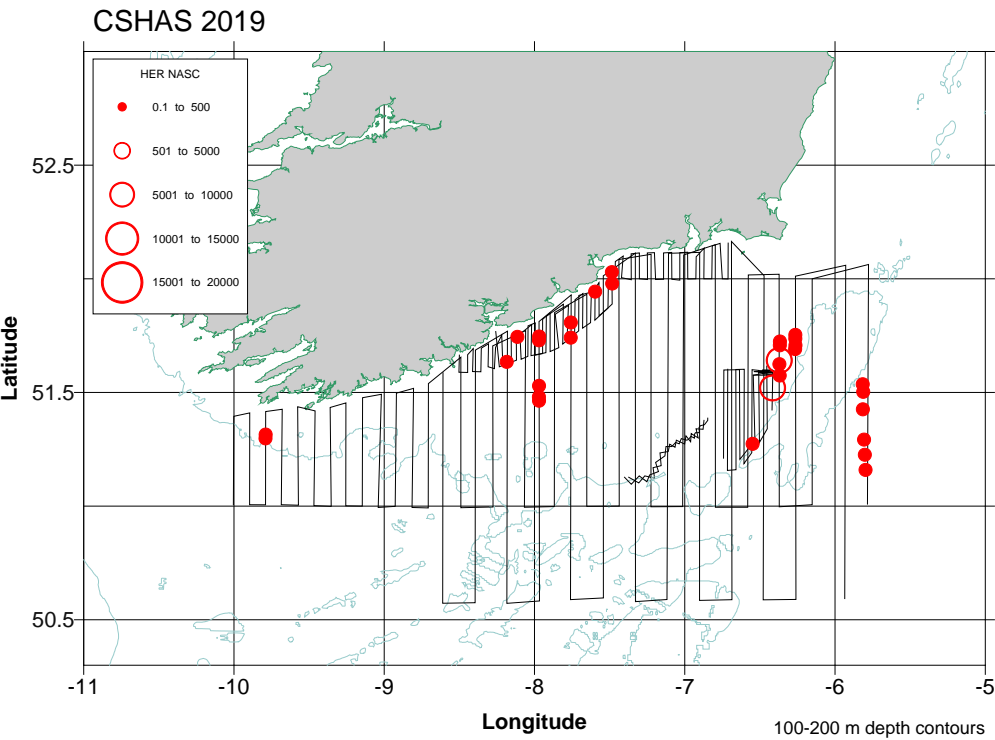


Figure 6.3.1.2. Herring in the Celtic Sea. NASC (Nautical area scattering coefficient) distribution plot of the distribution of herring in 2019 in the broad-scale surveys (1st pass = black lines; 2nd pass = orange lines).

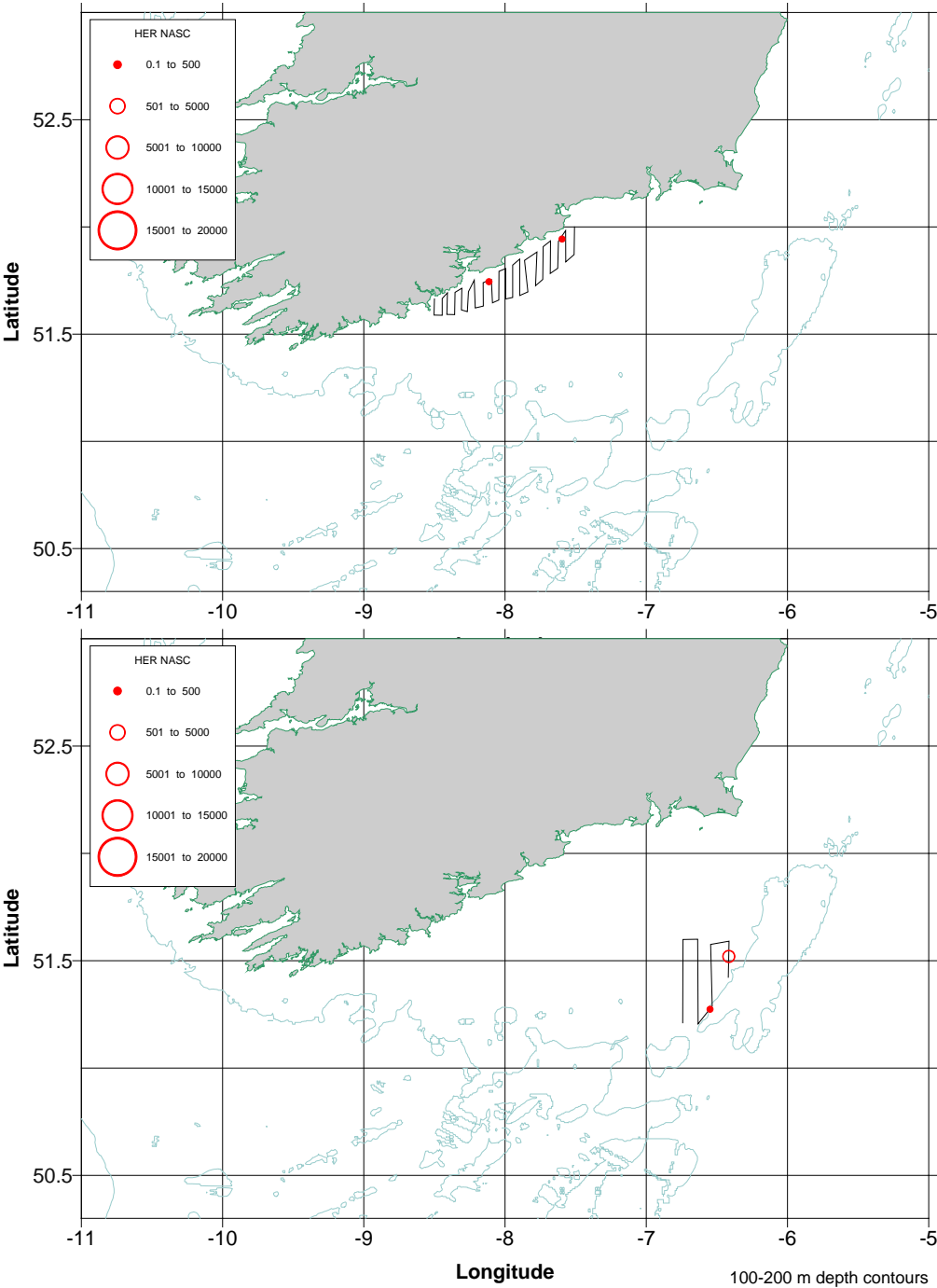


Figure 6.3.1.3. Herring in the Celtic Sea. NASC (nautical area scattering coefficient) plot of the distribution of herring in 2019 in the adaptive mini-survey 2 strata. Top Panel: coastal area; bottom panel: offshore area.

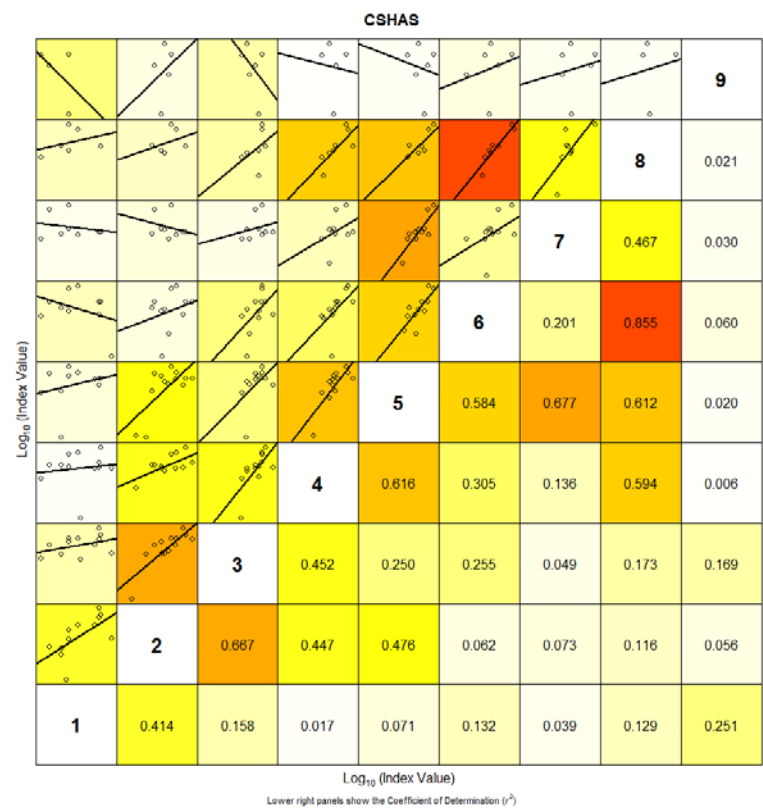


Figure 6.3.1.4. Herring in the Celtic Sea. Internal consistency between ages in the Celtic Sea Herring acoustic survey time-series. Age in winter rings.

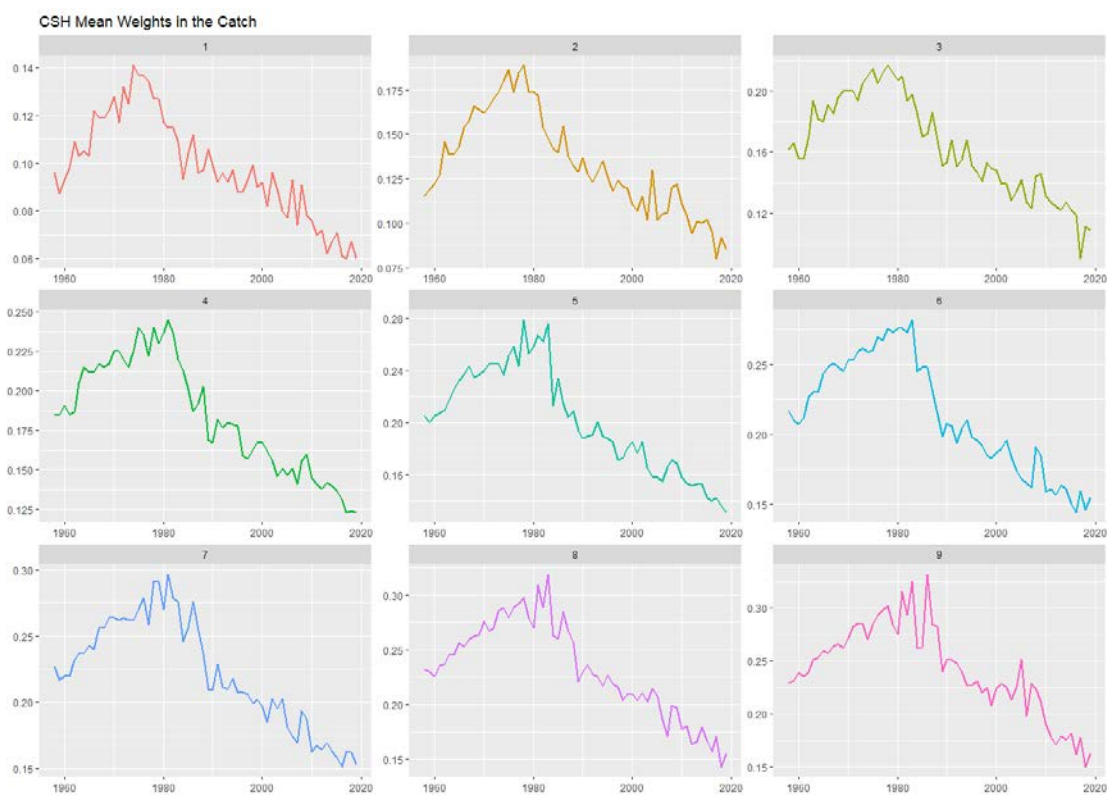


Figure 6.4.1.1. Herring in the Celtic Sea. Trends over time in mean weight-at-age in the catch from 1958–2019 for 1–9+.

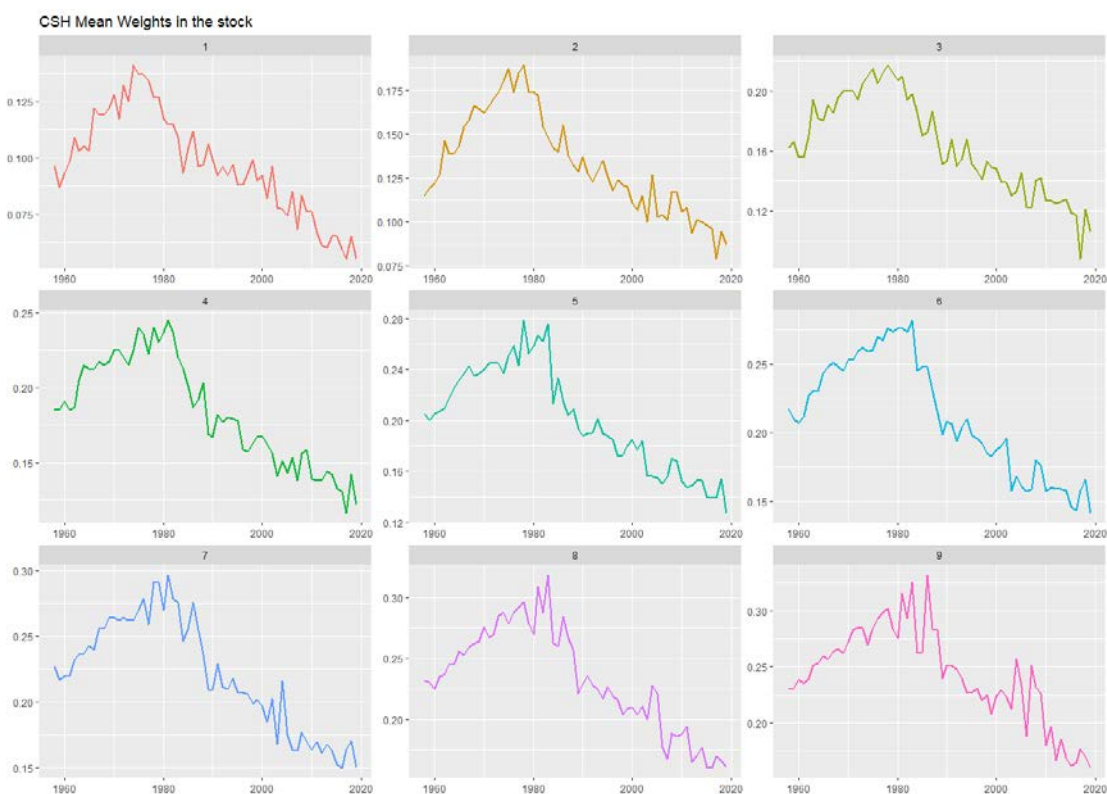


Figure 6.4.1.2. Herring in the Celtic Sea. Trends over time in mean weight-at-age in the stock at spawning time from 1958–2019 for 1–9+. Age in winter rings.

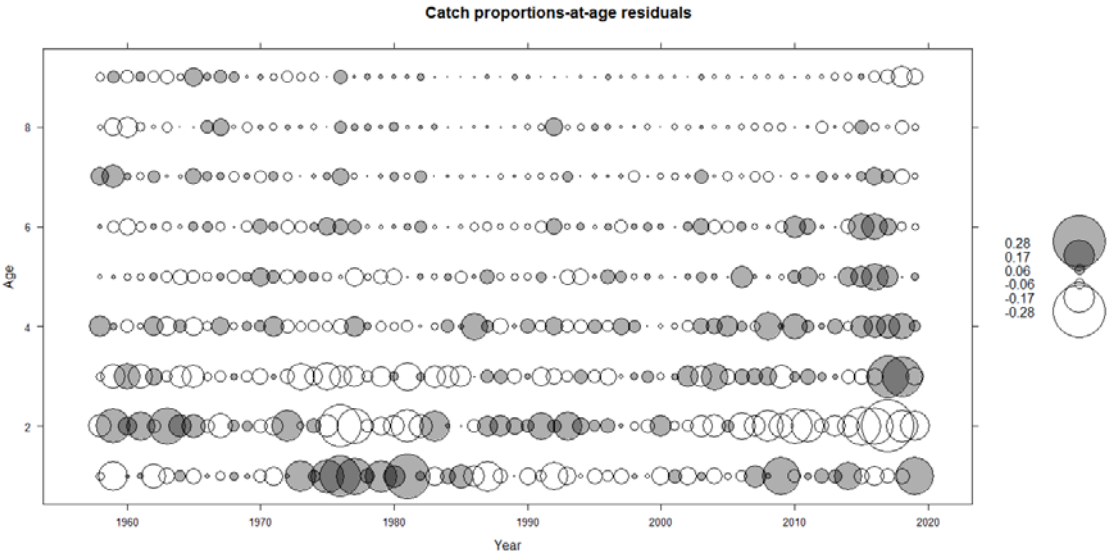


Figure 6.6.1.1. Herring in the Celtic Sea. Catch proportion-at-age residuals. Age in winter rings.

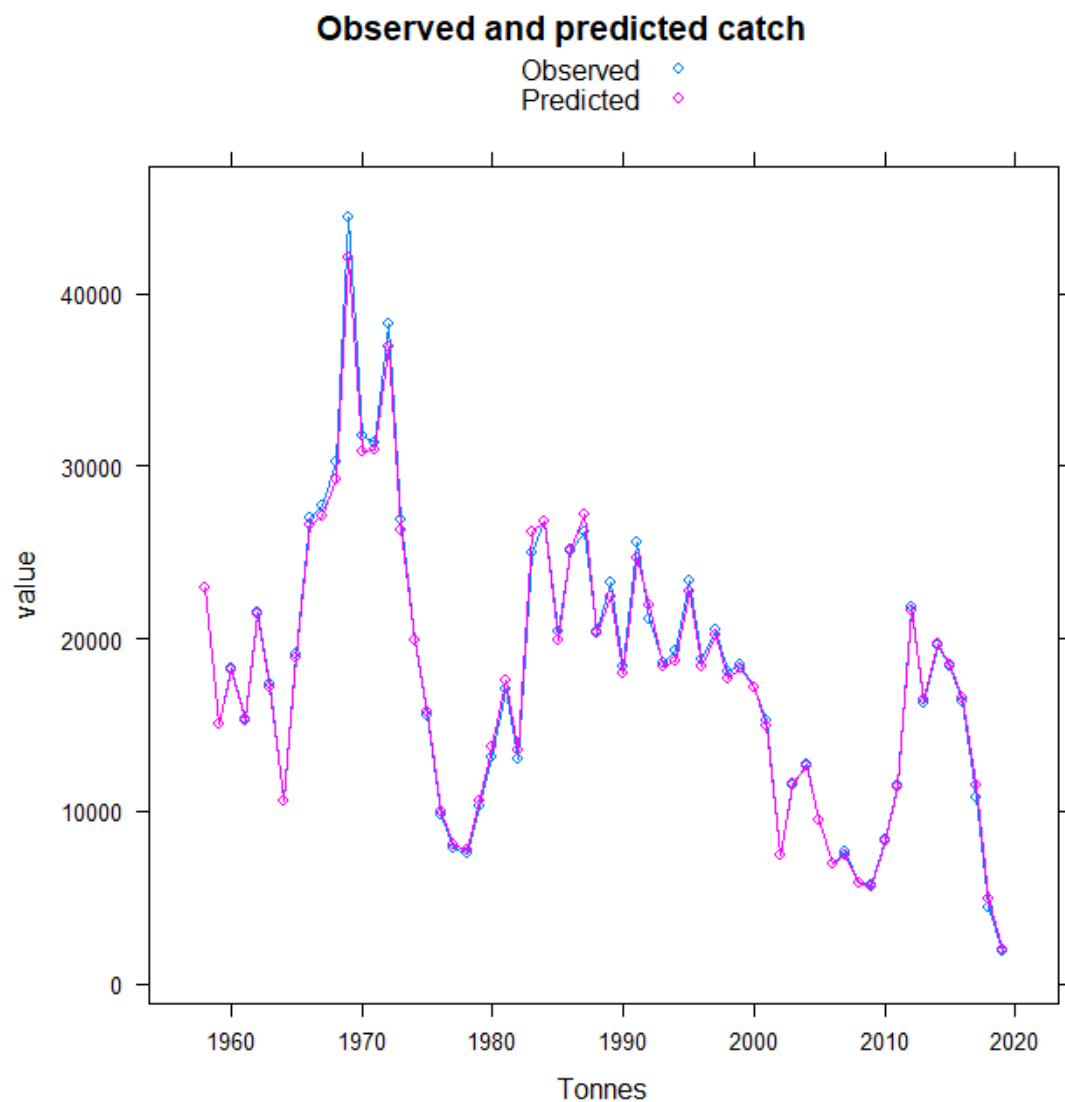


Figure 6.6.1.2. Herring in the Celtic Sea. Observed catch and predicted catch for the final ASAP assessment.

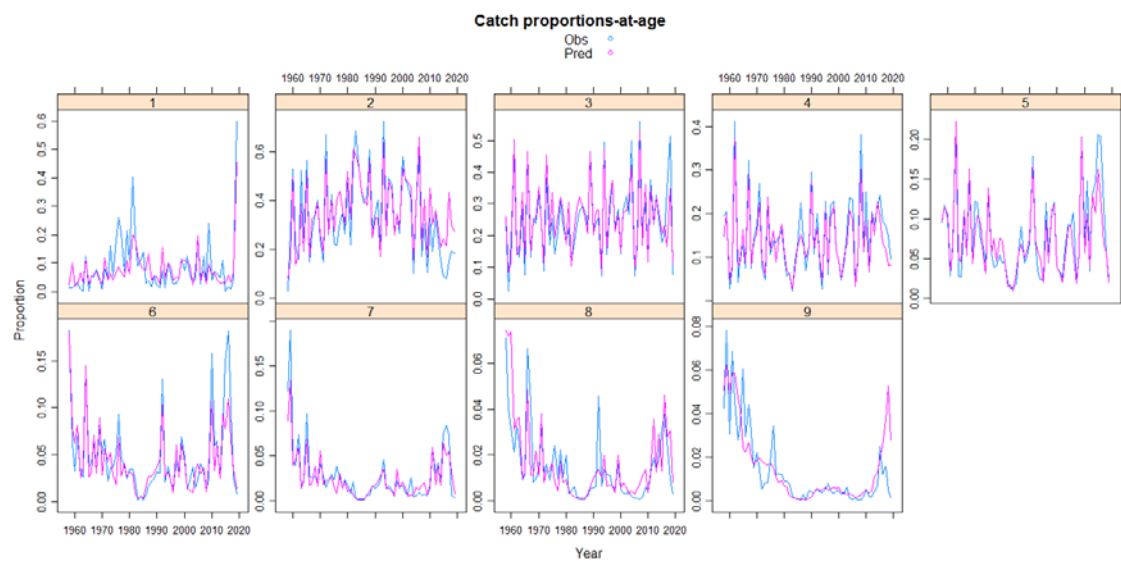


Figure 6.6.1.3. Herring in the Celtic Sea. Observed and predicted catch proportions-at-age for the final ASAP assessment.

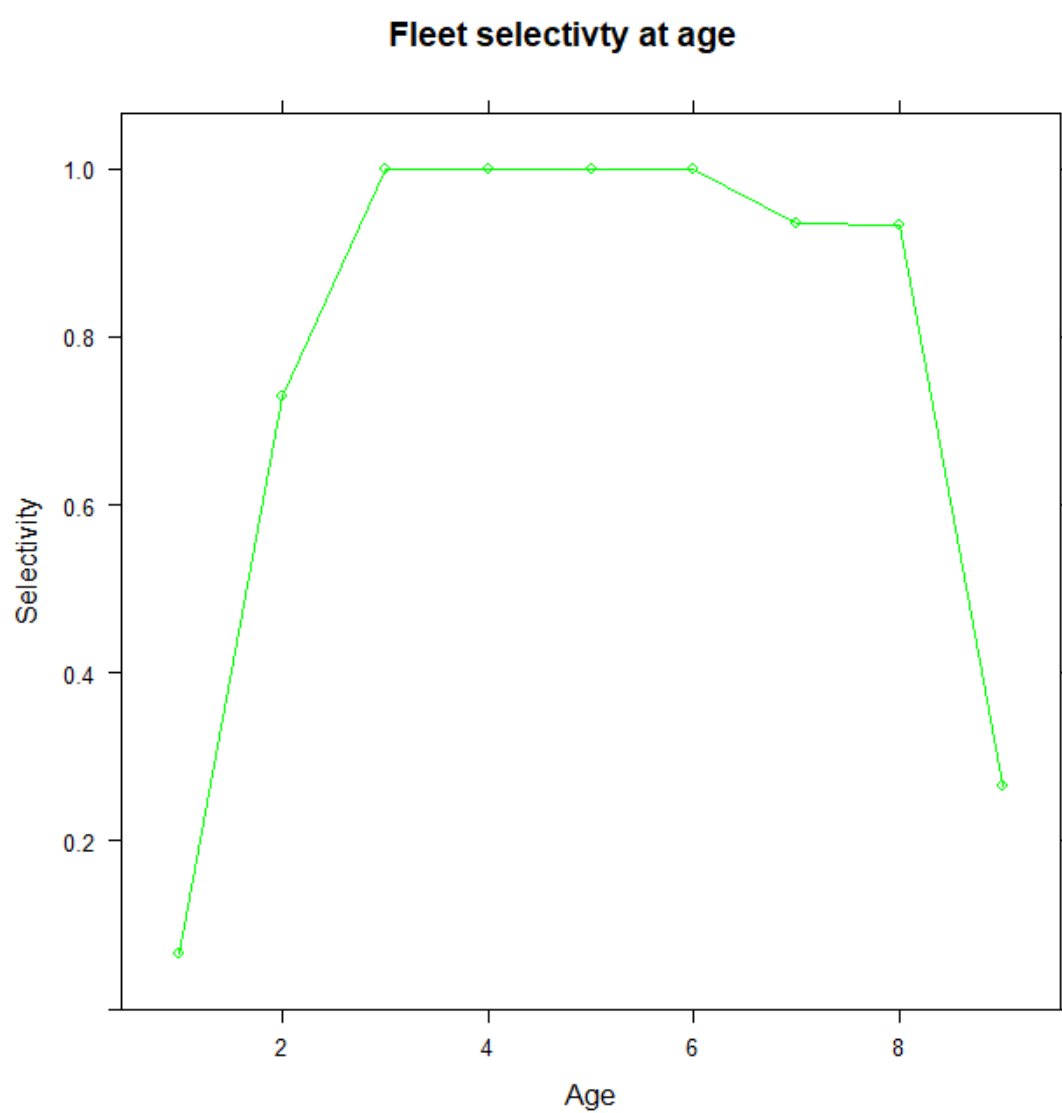


Figure 6.6.1.4. Herring in the Celtic Sea. Selection pattern in the fishery from the final ASAP assessment.

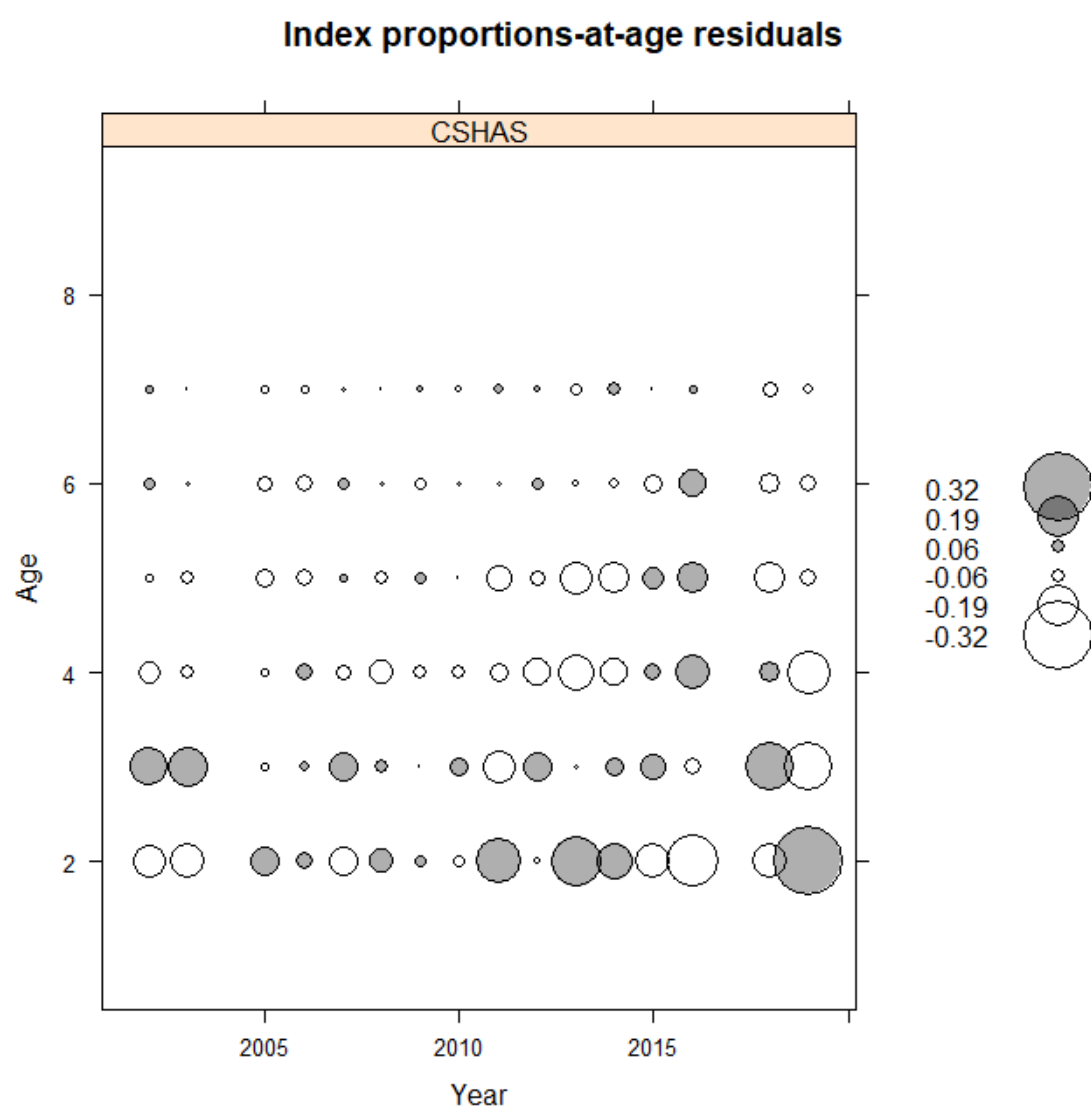


Figure 6.6.1.5. Herring in the Celtic Sea. Index proportions-at-age residuals (observed–predicted). Age in winter rings.

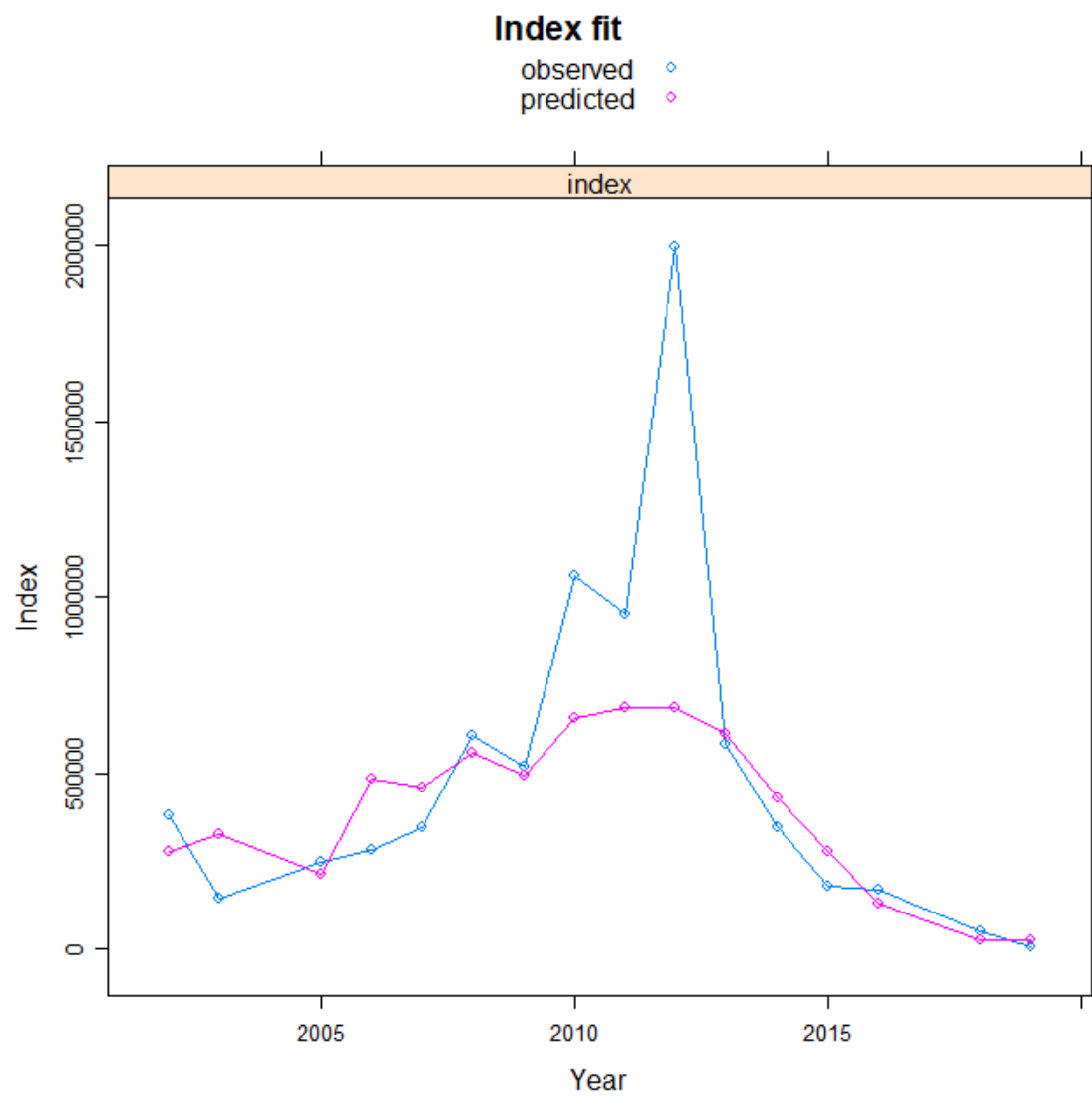


Figure 6.6.1.6. Herring in the Celtic Sea. Index fits.

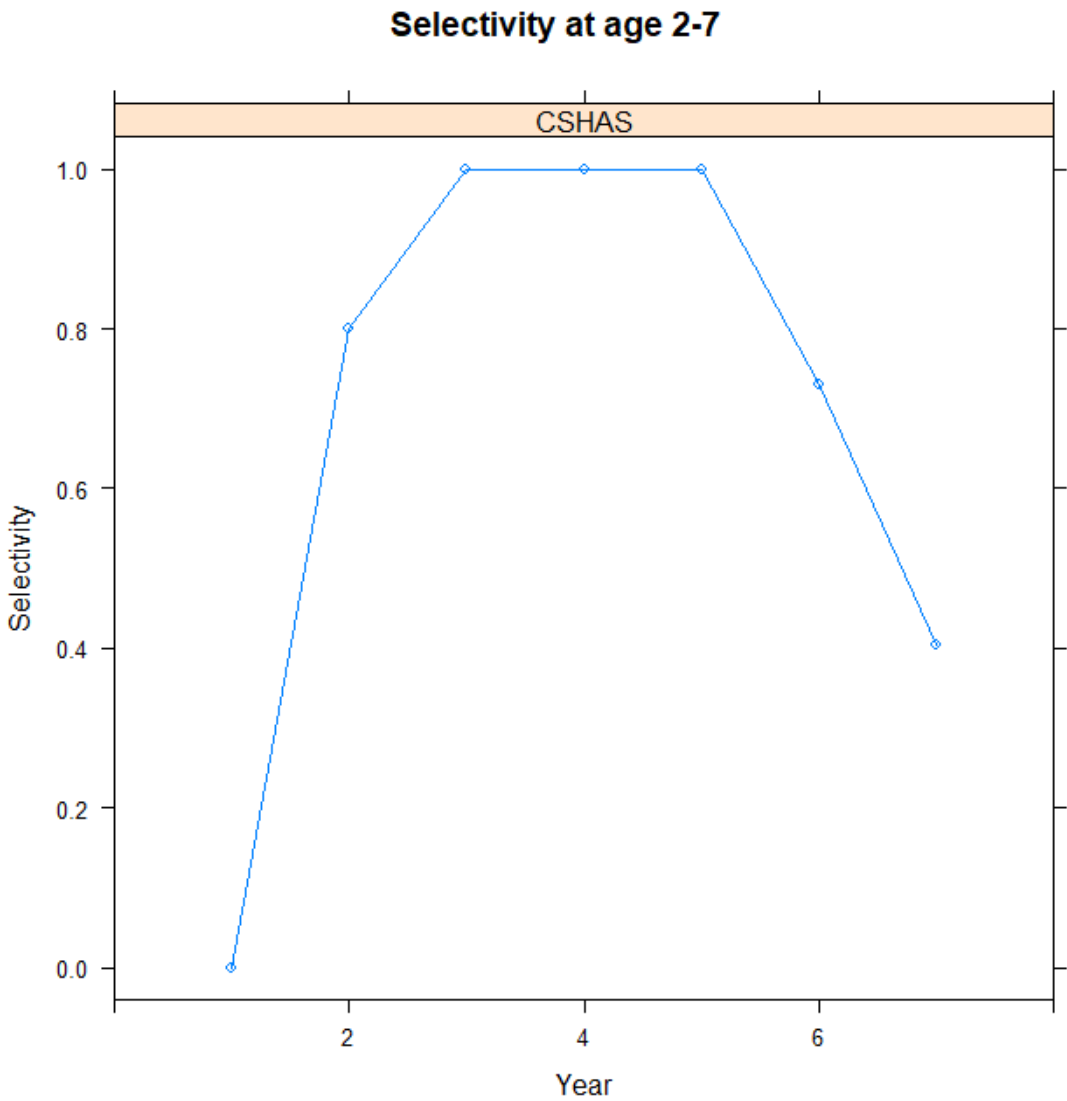


Figure 6.6.1.7. Herring in the Celtic Sea. Survey Selectivity pattern from the final assessment run.

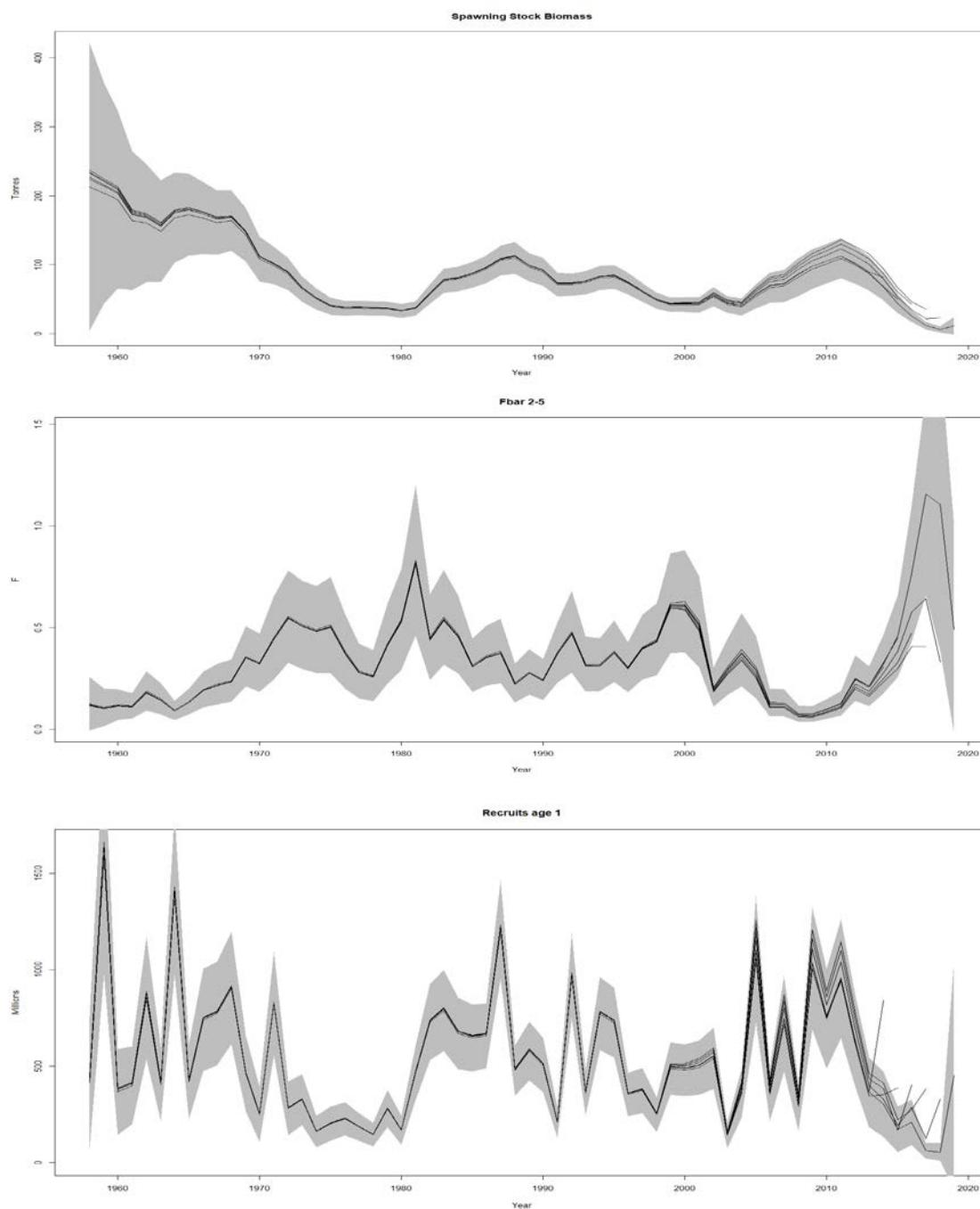


Figure 6.6.1.8. Herring in the Celtic Sea. Retrospective plots for SSB (top), Mean F (bottom left), Recruitment (bottom). The shaded area is the 95% confidence interval.

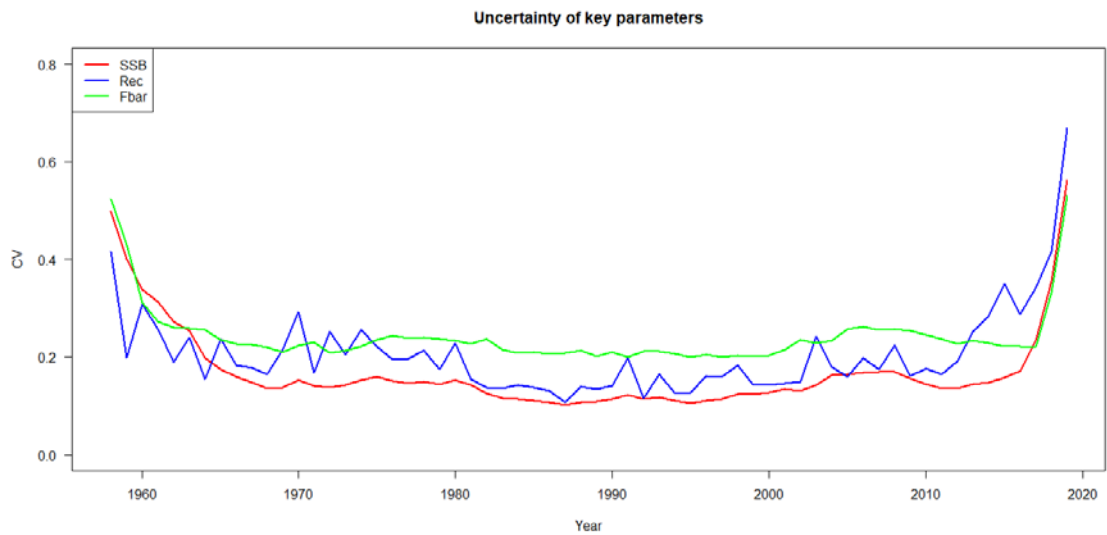


Figure 6.6.1.9. Herring in the Celtic Sea. Uncertainty of key parameters in the final assessment.

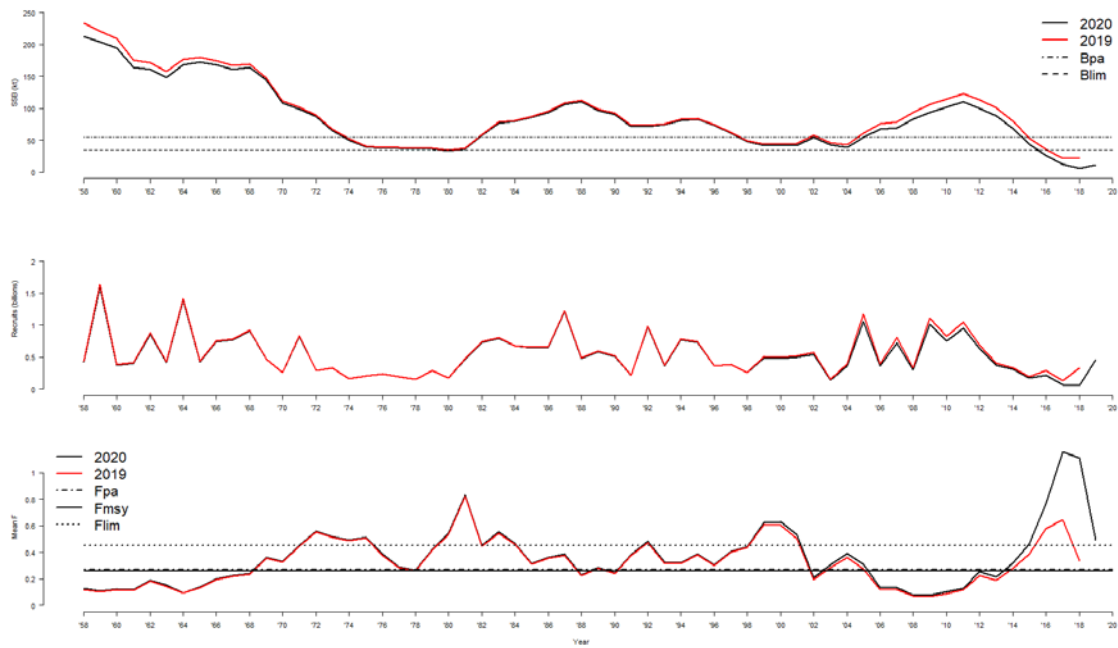


Figure 6.6.1.10. Herring in the Celtic Sea. Stock Summary from the final assessment run showing SSB (top), Recruitment (middle) and Mean F₂₋₅ (bottom)

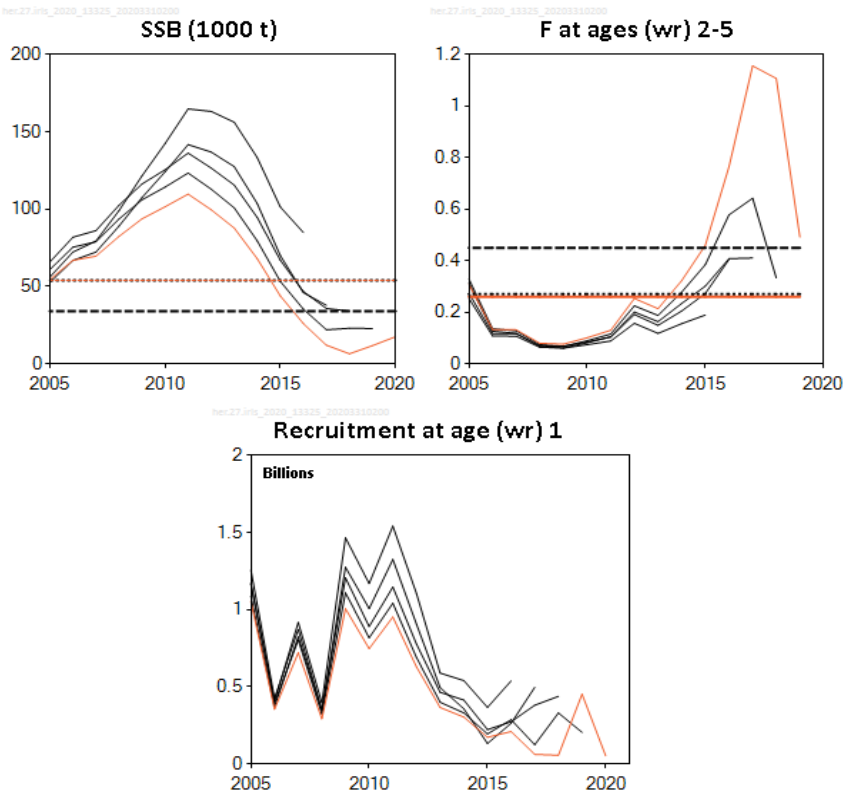


Figure 6.10.1. Herring in the Celtic Sea. Historical retrospective from the final assessments 2015–2020