Stock Annex: Herring (*Clupea harengus*) in Divisions 7.a South of 52°30'N, 7.g, 7.h, 7.j and 7.k (Irish Sea, Celtic Sea, and southwest of Ireland)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Celtic Sea Herring
Working Group (HAWG)	Herring Assessment Working Group for the Area South of 62ºN
Created	March 2018
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A. General

The Celtic Sea Herring stock area includes ICES divisions 7.a (South of 52°30'N) and 7.g, 7.h, 7.j, and 7.k (Celtic Sea and South of Ireland) (Figure 1).

A.1. Stock definition

Herring (*Clupea harengus*) to the south of Ireland in the Celtic Sea and in Division 7.j comprise both autumn and winter spawning components. For the purpose of stock assessment and management, these areas have been combined since 1982. The inclusion of 7.j was to deal with misreporting of catches from 7.g. The same fleet exploited these stocks and it was considered more realistic to assess and manage the two areas together. This decision was backed up by the work of the ICES Herring Assessment Working Group (HAWG) in 1982 that showed similarities in age profiles between the two areas. In addition, larvae from the spawning grounds in the western part of the Celtic Sea were considered to be transported into 7.j (ICES, 1982). Also it was concluded that Bantry Bay (in 7.j) was a nursery ground for fish of south coast (7.g) origin (Molloy, 1968).

A study group examined stock boundaries in 1994 and recommended that the boundary line separating this stock from the herring stock of 6.a.S, 7.b and 7.c should be moved southwards from latitude 52°30'N to 52°00'N (ICES, 1994). A further study (Hatfield *et al.*, 2007) examined the stock identity of this and other stocks around Ireland and concluded that the Celtic Sea stock area should remain unchanged.

Some juveniles of this stock are present in the Irish Sea for the first year or two of their life. Juveniles, which are believed to have originated in the Celtic Sea move to nursery areas in the Irish Sea before returning to spawn in the Celtic Sea. This has been verified through herring tagging studies, conducted in the early 1990s, (Molloy *et al.*, 1993) and studies examining otolith microstructure (Brophy and Danilowicz, 2002). Recent work carried out also used microstructure techniques and found that mixing at 1 winter ring is extensive but also suggests mixing at older ages such as 2 and 3 ring fish. The majority of winter spawning fish found in adult aggregations in the Irish Sea are considered to be fish that were spawned in the Celtic sea (Beggs *et al.*, 2008).

Age distribution of the stock suggests that recruitment in the Celtic Sea occurs first in the eastern area and follows a westward movement. After spawning herring move to the feeding grounds offshore (ICES, 1994). In 7.j herring congregate for spawning in autumn but little is known about where they reside in winter (ICES, 1994). A schematic representation of the movements and migrations is presented in Figure 2.

The management area for this stock comprises 7.a.S, 7.g, 7.j, 7.k and 7.h (Figure 1). Catches in 7.k and 7.h have been negligible in recent years. The linkages between this stock and herring populations in 7.e and 7.f are unknown. The latter are managed by a separate precautionary TAC. A small herring spawning component exists in 8.a, though its linkage with the Celtic Sea herring stock area is also unknown.
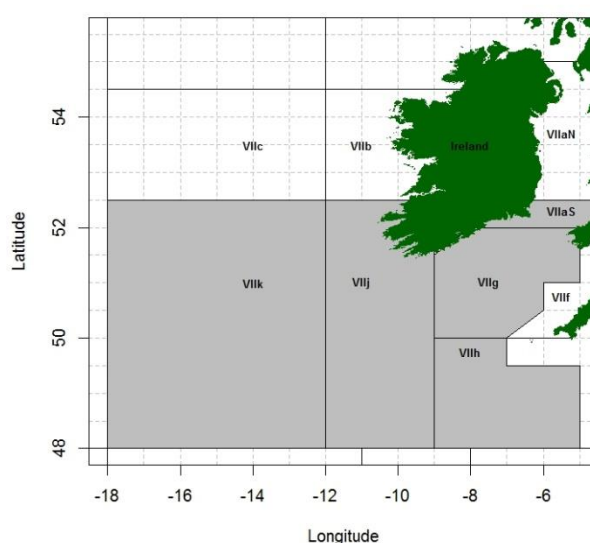

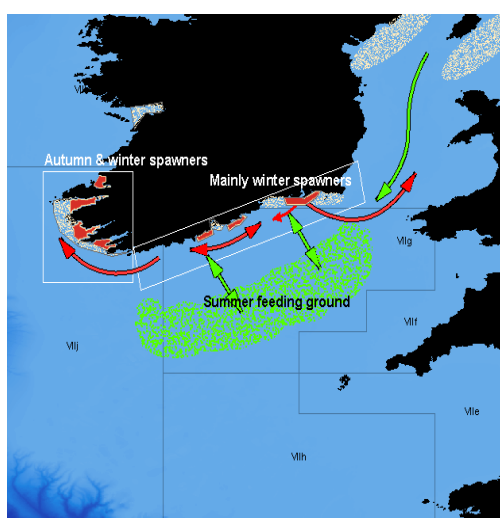**Figure 1. Celtic Sea Herring Stock Area.**

Figure 2. Schematic presentation of the life cycle of Celtic Sea and 7.j Herring.

A. 2. Fishery

Historical fishery development

Coastal herring fisheries off the south coast of Ireland have been in existence since at least the seventeenth century (Burd and Bracken, 1965). These fisheries have been an important source of income for many coastal communities in Ireland. There have been considerable fluctuations in herring landings since the early 1900s.

Fishery in recent years

The stock is exploited by two types of vessels, larger boats with RSW (refrigerated seawater) storage tanks and smaller dry hold vessels. The smaller vessels are confined to the spawning grounds (7.a.S and 7.g) during the winter period. The RSW tank vessels target the stock inshore in winter and offshore during the summer and autumn feeding phase (7.g). There has been less fishing in 7.j in recent seasons.

Since 2009, 7.a.S has been closed to larger vessels, and only vessels of less than 50 feet length are allowed up to 8% of the Irish quota (lower percentage during rebuilding plan). The effect of this may have been to shift exploitation to slightly older fish, and also to reduce the efficiency of the fleet, thus reducing fishing mortality on spawning shoals.

Since 2011 there has been no quarter 1 fishery in the Celtic Sea area. Fishing has taken place mainly in quarter 4 and to a lesser extent in quarter 3. A significant proportion of the fishery has been concentrated in a specific area in the Celtic Deep/Smalls area.

A.2.1. General Description

In the past, fleets from the UK, Belgium, The Netherlands, Germany and France as well as Ireland exploited Celtic Sea herring. In recent years Ireland is the main participant in this fishery with other countries reporting small catches annually. This fishery is managed by the Irish "Celtic Sea Herring Management Advisory Committee", established in 2000 and constituted in law in 2005. Much of the freezer trawler catch comes from 7.h. This division is part of the management unit, but fish in this area may belong to another stock.

A.2.2. Fishery management regulations

The Irish quota is managed by allocating individual quotas to vessels on a weekly basis. Participation in the fishery is restricted to licensed vessels and these licensing requirements have been changed. Previously, vessels had to participate in the fishery each year to maintain their licence. Since 2004 this requirement has been lifted. This has been one of the contributing factors to the reduction in number of vessels participating in the fishery in recent seasons (ICES, 2005b). Fishing is restricted to the period Monday to Friday each week, and vessels must apply a week in advance before they are allowed to fish in the following week. Triennial spawning box closures are enshrined in EU legislation.

A.3. Ecosystem aspects

The ecosystem of the Celtic Sea is described in ICES WGRED (2007b). Temperatures in this area have been increasing over the last number of decades. There are indications that salinity is also increasing (ICES, 2006a). Herring are found to be more abundant when the water is cooler while pilchards favour warmer water and tend to extend further east under these conditions (Pinnegar *et al.*, 2002). However, studies have been unable to demonstrate that

changes in the environmental regime in the Celtic Sea have had any effect on productivity of this stock.

Herring larval drift occurs between the Celtic Sea and the Irish Sea. The larvae remain in the Irish Sea for a period as juveniles before returning to the Celtic Sea. Catches of herring in the Irish Sea may therefore impact on recruitment into the Celtic Sea stock (Molloy, 1989). Distinct patterns were evident in the microstructure and it is thought that this is caused by environmental variations. Variations in growth rates between the two areas were found with Celtic Sea fish displaying fastest growth in the first year of life. These variations in growth rates between nursery areas are likely to impact recruitment (Brophy and Danilowicz, 2002). Larval dispersal can further influence maturity-at-age. In the Celtic Sea faster growing individuals mature in their second year (1-wr) while slower growing individuals spawn for the first time in their third year (2-wr). The dispersal into the Irish Sea which occurs before recruitment and subsequent decrease in growth rates could thus determine whether juveniles are recruited to the adult population in the second or third year (Brophy and Danilowicz, 2003).

The spawning grounds for herring in the Celtic Sea are well known and are located inshore 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 and sand and gravel extraction. The main spawning grounds are displayed in Figure 3, whilst the distributions of spawning and non-spawning fish are presented in Figure 4. Nursery grounds are also thought to be quite discrete and several areas of importance are known, including the western coast of the Irish Sea, Dungarvan Bay, and the bays of SW Ireland (Clarke *et al.*, 2010).

Figure 3. Herring in the Celtic Sea. Spawning grounds (some are named in red text) and general spawning areas (blue text) of herring along the south coast of Ireland, inferred from information on the Irish herring fishery (O'Sullivan *et al.*, 2013).
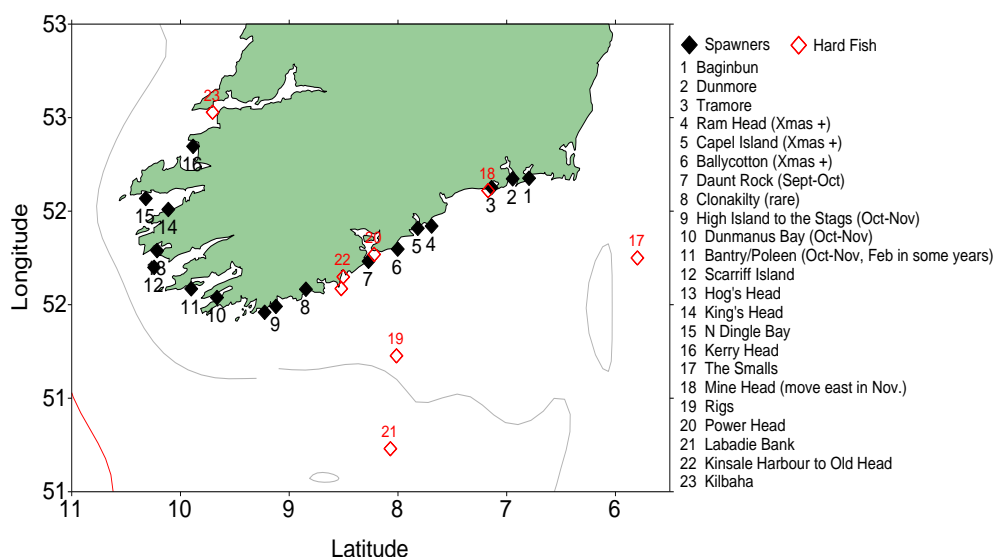
Figure 4. Herring in the Celtic Sea. Location of spawning (closed symbol) and non-spawning (open symbol) herring in the Celtic Sea and SW of Ireland, based on expert fishermen's knowledge.

Herring are an important component of the Celtic Sea ecosystem. There is little in-formation on the specific diet of this stock. Farran (1927) highlighted the importance of *Calanus* spp. copepods and noted that they peaked in abundance in April/May. Fat reserves peak in June to August (Molloy and Cullen, 1981). Herring form part of the food source for larger gadoids such as hake. A study was carried out which looked at the diet of hake in the Celtic Sea. This study found that the main species consumed by hake are blue whiting, poor cod and Norway Pout. Quantities of herring and sprat were also found in fish caught in the northern part of the Celtic Sea close to the Irish coast. Large hake, >50 cm tended to have more herring in their stomachs than smaller hake (Du Buit, 1996).

Cetaceans are important predators of herring in this area. A preliminary estimate of annual consumption of herring by cetaceans is 3300 t (Berrow, pers. comm.). This estimate is based on the estimated abundance of the species, their annual consumption of herring, the time spent eating herring and the estimated percentage of herring in their diets (Ryan *et al.*, 2013).

Recent work by Whooley *et al.* (2011) shows that fin whales *Balaenoptera physalus* are an important component of the Celtic Sea ecosystem, with a high re-sighting rate indicating fidelity to the area. There is a strong peak in sightings in November, and fin whales were observed actively feeding on many occasions, seeming to associate with sprat and herring shoals. These authors go on to suggest that the peak in fin whale sightings in November may coincide with the inshore spawning migration of herring. Fin whales tend to be distributed off the south coast in 7.g in November, but further east, in 7.a.S by February (Berrow, pers. comm.). This suggests that their occurrence coincides with peak spawning time in these areas.

Bycatch

Bycatch is defined as the incidental catch of non-target species. There are few documented reports of bycatch in the Celtic Sea herring fishery. A European study was undertaken to quantify incidental catches of marine mammals from a number of fisheries including the Celtic Sea herring fishery. Small quantities of non-target whitefish species were caught in the nets. Of the non-target species caught whiting was most frequent (84% of tows) followed by

mackerel (32%) and cod (30%). The only marine mammals recorded were grey seals (*Halichoerus grypus*). The seals were observed on a number of occasions feeding on herring when the net was being hauled and during towing. They appear to be able to avoid becoming entangled in the nets. It was considered unlikely by Berrow *et al*., 1998, that this rate of incidental catch in the Celtic Sea would cause any decline in the Irish grey seal population. Results from this project also suggested that there was little interaction between the fishing vessels and the cetaceans in this area. Occasional entanglement may occur but overall incidental catches of cetaceans are thought to be minimal (Berrow *et al*., 1998). The absence of any other by caught mammals does not imply that bycatch is not a problem only that it did not occur during this study period (Morizur *et al*., 1999).

Recent work by the Irish Whale and Dolphin Group (e.g. McKeogh and Berrow, 2013; 2014) suggest that bycatch of non-target species in this fishery is very low, consisting of blue shark, whiting, haddock and gurnard.

B. Data

B.1. Commercial catch

The commercial catch data are provided by national laboratories belonging to the nations that have quota/fisheries for this stock. For many years, Ireland has been the only participant in this fishery, and the data are derived entirely from Irish logbook data. In recent years foreign catches have been reported also. Figure 5 shows the trends in catches over the time-series. Ireland acts as stock coordinator for this stock. Commercial catch at age data are submitted in Exchange sheet v 1.6.4. These data are submitted to ICES accessions annually.
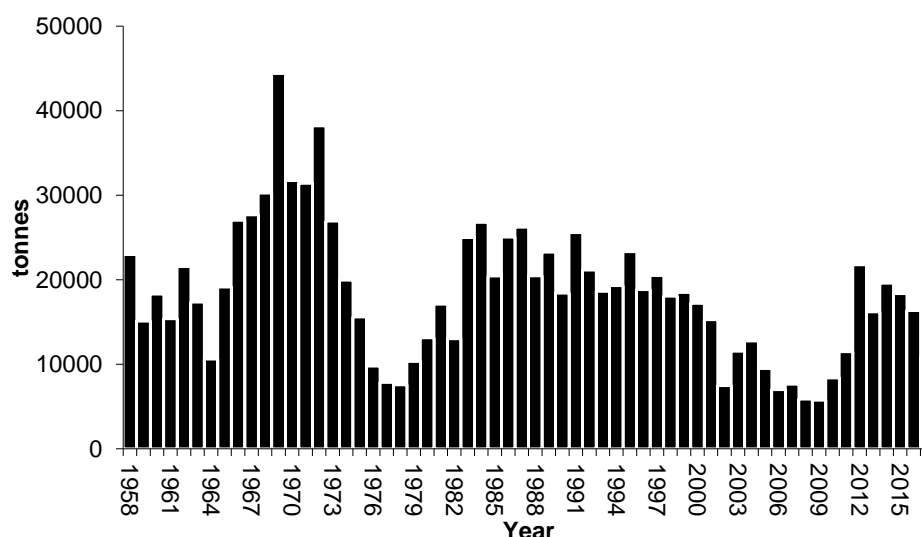

Figure 5. Herring in the Celtic Sea: Trends in catches from 1958–2017.

InterCatch

Since 2007, InterCatch, which is a web-based system for handling fish stock assessment data, was also used. National fish stock catches are imported into InterCatch. Stock coordinators then allocate sampled catches to un-sampled catches, aggregate them to stock level and

download the output. The InterCatch stock output can then be used as input for the assessment models. The comparisons to date have been very good. InterCatch cannot deal with catches from two calendar years therefore for example data from the 2008/2009 season are uploaded to InterCatch as 2008 figures. Catches from quarter 1 in 2009 are entered as being from quarter 1 in 2008.

B.1.1. Landings data

Mainly Irish vessels participate in the fishery on herring in the Celtic Sea. Germany, France and The Netherlands report catches in some years.

B.1.1.1 Irish landings

Sampling is performed as part of commitments under the EU Council Regulation 1639/2001.

- Collect a sample from each pair of boats that lands. Depending on the size range, a half to a full fish box is sufficient. If collecting from a processor make sure sample is ungraded and random.
- Record the boat name, ICES area, fishing ground, date landed for each sample.
- Randomly take 50 fish for ageing. Record length in 0.5 cm, weight, sex, maturity (use maturity scale for guideline). Extract the otolith taking care not to break the tip and store it in an otolith tray. Make sure the tray is clean and dry.
- Record a tally for the 50 aged fish under "Aged Tally" on the datasheet.
- Measure the remaining fish and record a tally on the measured component of the datasheet.

B.1.1.1.1 Data coverage and quality

The Celtic Sea herring stock is well sampled at all of the main landings ports in Ireland.

B.1.2. Discards estimates

Catch is divided into landings (retained catch) and discards (rejected catch). Discards are the portion of the catch returned to the sea as a result of economic, legal, or personal considerations (Alverson *et al.*, 1994). In the 1980s a roe (ovary) market developed in Japan and the Irish fishery became dependent on this market. This market required a specific type of herring whose ovaries were just at the point of spawning. A process developed whereby large quantities of herring were slipped at sea. This type of discarding usually took place in the early stages of spawning and was reduced by the introduction of experimental fishing. This market for roe herring continued to diminish during the late 1990s and it became clear that other markets would have to be found (Molloy, 1995).

Discarding was high during 1980s until late 1990s, though available estimates may be too low. Since then the main reason to discard has been unwanted catch. Like all pelagic fisheries, discarding is known to occur but estimates are unavailable at present. Measures taken in 2012 have reduced the risk of discarding through more flexible individual boat quota regulations.

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 a new flexibility mechanism being introduced in quota allocation, since 2012. Available evidence is that the discard rate is negligible in directed fisheries.

It is thought that discarding has declined since 2012 due to the flexibility incorporated into the weekly quota system. Estimates of discarding from observed trips for the purposes of marine mammal by-catch 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.a.S small boat fishery (Pinfield and Berrow, 2015,) 1.13% (O'Dwyer et al. 2016) and 1.19% in 2017 (O'Dwyer and Berrow, 2017).

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

B.1.3. Recreational catches

No recreational catch data are available for this stock.

B.2. Biological sampling

B.2.1. Maturity

Clupea harengus is a determinate one-batch spawner. In this stock, the assessment considers that 50% of 1-wr are mature and 100% of 2-wr mature. The percentage of males and females at 1-wr are presented in Figure 6. It shows wide fluctuations in percentage maturity from year to year (Lynch, 2011).

It is to be noted that the fish that recruit to the fishery as 1-wr are probably precocious early maturing fish. Late maturing 1-wr may not be recruited. Thus maturity at 1-wr in the population as a whole may be different to that observed in the fishery. Late maturing 1-, 2- and even 3-wr may recruit from the Irish Sea. Brophy and Danilowicz (2002) showed that late maturing 1-wr leave the Irish Sea and appear as 2-wr in the Celtic Sea catches. Beggs (2008) Working Document to HAWG indicated that some older fish also stay in the Irish Sea and return as 3- or even 4-wr to the Celtic Sea. It is possible that when stock size was low, the relative proportion of late maturing fish from the Irish Sea was greater. This may explain why observed maturity in the catches was later in those years.

Maturity at 1-wr is considered to be 50% with 100% at subsequent ages. Lynch (2011) investigated trends over time in maturity at age, in commercial sampling. Earlier maturity at 1-wr began to increase in the early 1970s and has remained high ever since.
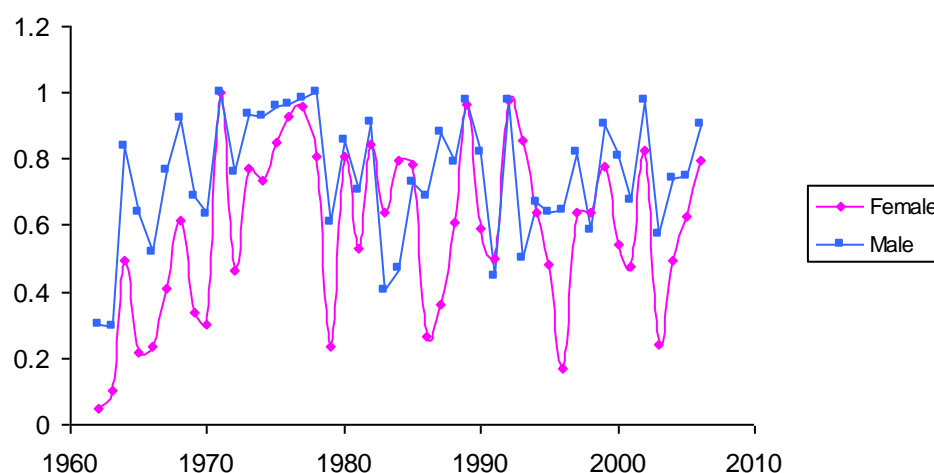
Figure 6. Herring in the Celtic Sea. Percentage maturity in males and females at 1 winter ring (Lynch, 2011).

B.2.2. Natural mortality

A considerable amount of work was carried out in 2014 to look at the natural mortality estimates used in this assessment. Full details of this work are presented in the WKPELA report (ICES, 2014).

At WKWEST an updated run of the North Sea SMS was available using data from 1974–2013. It was decided to calculate an average of these values and use this most recent data to create the natural mortality vector for use in the assessment.

At HAWG 2015 further updated figures became available based on average values from the North Sea Multispecies SMS run from 1974–2010. These values were adopted at HAWG 2015.

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

The new estimates of natural mortality are considered to be an improvement, being mostly higher. However it is noted that in the case of 1-wr, the new estimate is lower than the old estimate, which may seem counter-intuitive. The effect of this lower natural mortality in 1-wr was tested in the assessment models and found not to have an impact on model diagnostics.

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

Age composition in the catch

In the mid to late 2000s there is a decreasing proportion of older fish present in the catch. Figure 7 shows the age composition of the catches over the time-series. In recent years increasing amounts of older fish are present in the catch due to the strong year classes in the fishery.
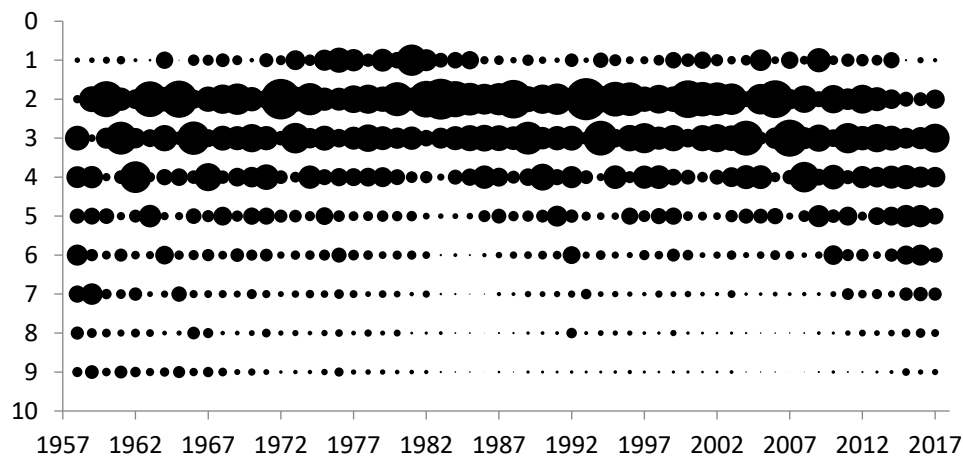
Figure 7. Herring in the Celtic Sea. Mean Standardised Catch Numbers-at-Age.

Precision in ageing

Precision estimates from the ageing data were carried out in the HAWG in 2007, for the 2006/2007 season (ICES, 2007). Results found that CVs are highest on youngest and oldest ages that are poorly represented in the fishery. The main ages present in the fishery had low CVs; between 5% and 13%, which is considered a very good level of precision. In the third and the fourth quarter, estimates of 1-wr on Celtic Sea herring were also remarkably precise. An overall precision level of 5% was reached in Q1 and Q4 in the 2007/2008 season.

Mean weights and mean lengths

An extensive data set on landings is available from 1958. Mean weights-at-age in the catch in Q4 and Q1 are used as stock weights. Trends in mean weights-at-age in the catches and mean weights in the spawning stock are presented in Figure 8. Clearly there has been a decline in mean weights since the early 1980s, to the lowest values observed. The same trends in mean length are apparent in Figure 9.

Similar trends in mean length-at-age have been documented by Harma (2014) and Lynch (2011). Both authors showed that single species density-dependence is not a factor in these cycles. Lynch (2011) reported that increased SST and was associated with reduced size/weight-at-age and condition factor. Also, abundance of *Calanus* copepods is positively correlated with size and weight-at-age (Lynch, 2011). Strong non-linear correlations between herring growth and environmental parameters; particularly with zooplankton abundance (positive) and AMO and phytoplankton indices (negative). These factors explained more than 80% in variability of size of 3-year old fish (Harma, 2014). The declines in mean weights are a cause for concern, because of their impact on yield and yield per recruit. Harma (un-published) 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 of this time 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 (Brunel and

Dickey-Collas, 2010; Harma, unpublished; Lynch, 2011; Molloy, 1984). Rather, stock size exhibited a positive relationship with long-term size-at-age of Celtic Sea herring (Harma, unpublished).

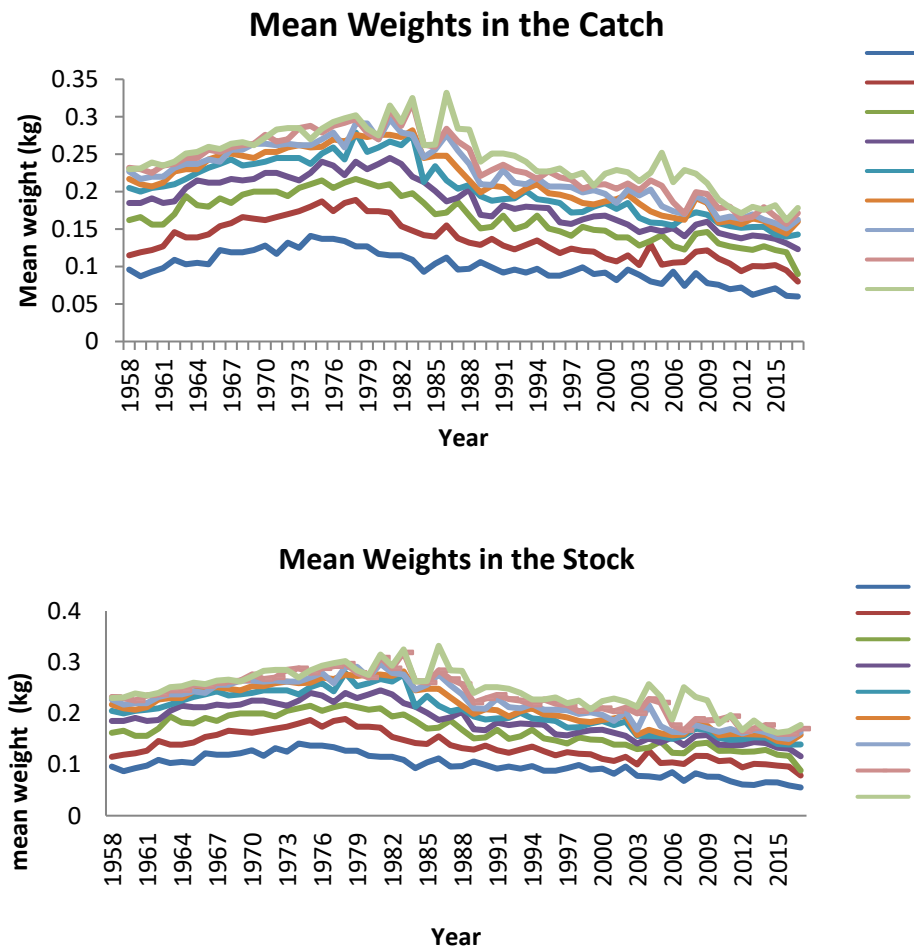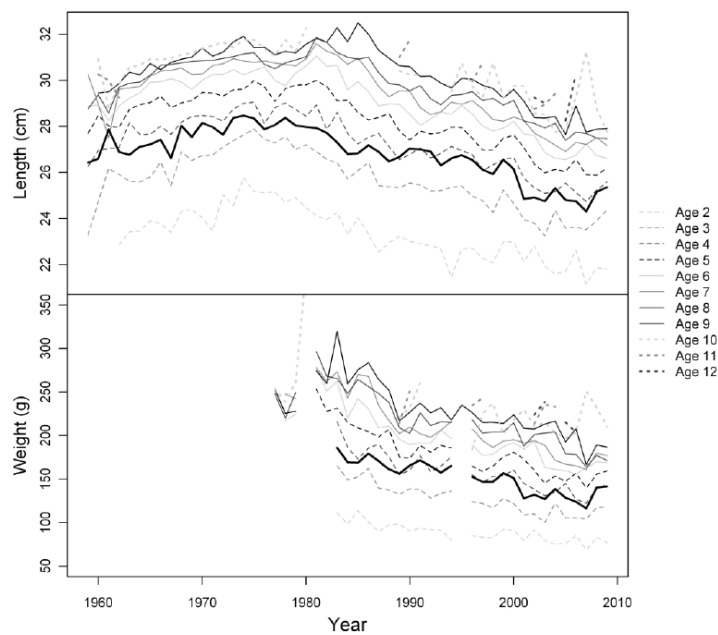## Mean Weights in the Catch

Mean Weights in the Stock

Figure 8. Herring in the Celtic Sea. Catch weights (top) and Stock weights (bottom) from 1958–2017.

Figure 9. Herring in the Celtic Sea. Mean length and weight-at-age from 1958 to 2010 from Irish commercial sampling (Harma, 2014).

B.3. Celtic Sea Herring Acoustic Survey (CSHAS)

Acoustic surveys have been carried out on this stock since 1990. The survey area covers a part of ICES areas 7.j, 7.g and 7.a.S (Figure 10). The most recent survey is reviewed by WGIPS every year in January of the following year. The time-series currently used in the assessment runs from 2002 – present (with no survey in 2004) using ages 2–7 only (WKPELA 2018). The 2017 survey was not used in the assessment; only one biological sample of herring was obtained on the survey and this sample was not considered representative of the stock.

B.3.1 Acoustic survey methods

The acoustic data are collected using a Simrad ER60 scientific echosounder. The Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel. The data collected are scrutinised using Echoview® post processing software. The echo integration (sA) values from aggregations of herring are used to estimate numbers according to the method of Dalen and Nakken (1983). The following target strength to fish length relationships is used for herring.

TS = 20logL – 71.2 dB per individual (L = length in cm)

In 2016 a change was introduced to the survey design to cover a larger area (Figure 10). This was in response to a perceived change in the distribution of herring to more offshore areas as described above, and concerns of bias in the survey. The survey design used since 2016 has 2 spatial components;

1. Broad-scale, with typical 8nmi parallel transect spacing. The broad-scale area is completed in replicate when possible, giving an effective 4nmi transect spacing. If replicates of the broad-scale survey occurs, the higher estimates is used for that area and other broad-scale estimate is not used.

2. Adaptive mini-surveys; high intensity parallel transect spacing, typically 1nmi spacing, in areas where there is information from the survey or the fishery that herring are present

in the area. The mini-survey areas are rectangular, designed to encompass the extent of the area where herring are reported to be present. If replicate mini-survey areas are conducted, the higher estimate is used for that area.

The estimates from the two components (broad-scale and adaptive mini-surveys) are essentially estimates from different strata, with corresponding CVs. The estimates of abundance at age are a combined overall estimate for the entire survey area. The two areas (broad-scale and mini-survey) are exclusive of each other and there is no overlap spatially in terms of the worked up estimate.
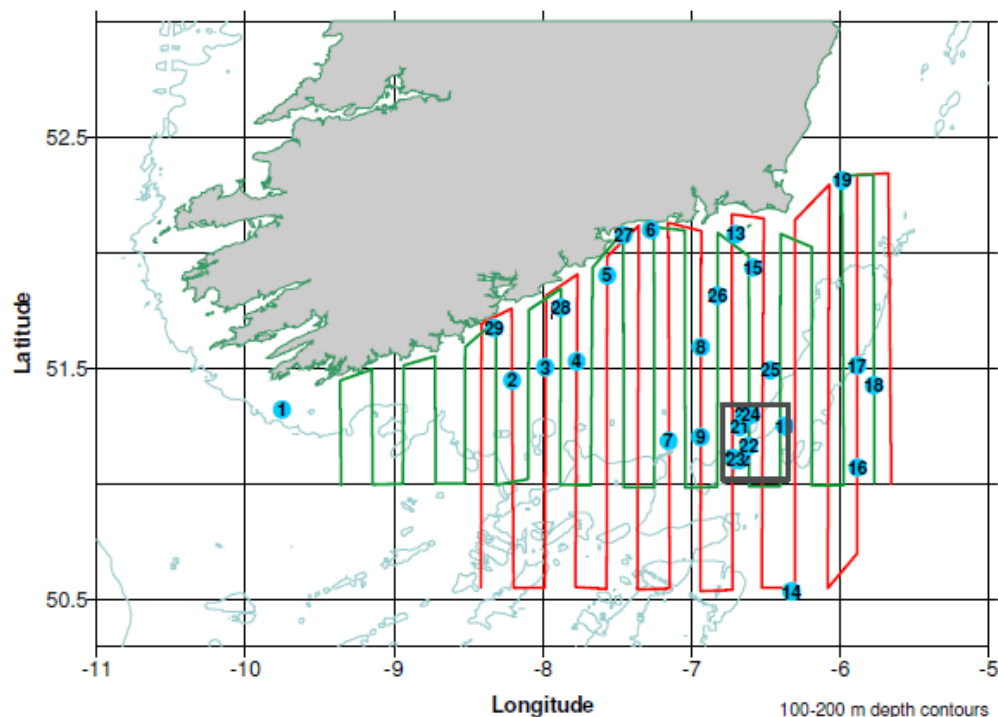

Figure 10. Example survey cruise tracks in 2016 (Pass 1: green track, Pass 2: red track) and adaptive mini-survey area (grey box). Pelagic trawl positions appear as numbered stations.

B.3.1.1. Biomass estimation using StoX

Acoustic data are analysed using the StoX software package recently adopted for WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990). StoX estimates the number of individuals by length group which can be further grouped into population characteristics such as numbers at age and sex. Trawl stations are assigned to the individual acoustic transects. A total length distribution of herring is calculated by transect using all the trawl stations assigned to the individual transects. The conversion from NASC (by transect) to mean density by length group by stratum uses the calculated length distribution and a standard target strength equation within defined parameter values. The mean density by stratum is estimated by using a standard weighted mean function where each transect density is weighted by transect distance. The number of individuals by stratum is given as the product of stratum area and area density.

B.3.1.2 Acoustic survey coefficient of variation (CV) estimation

The bootstrap procedure to estimate the CV follows the same principle as in the baseline StoX run. However, for each run transects within a stratum are selected randomly with replacement, and for each selected transect, the trawl stations which are assigned for the selected transect are randomly sampled with replacement. Each run follows the same estimation procedure as described above. The output of all the runs is stored in an RData-file, which is used to calculate the relative sampling error. The CVs for all strata and the combined overall area are generated.

B.3.1.3 Other sources of uncertainty

The current CSHAS survey is designed to contain herring spatially and temporally in areas where Celtic Sea herring have been distributed historically. A proportion of the Celtic Sea herring stock is known to spend part of its life cycle in the Irish Sea, particularly at younger ages (Molloy et al 1993). The current survey design does not include areas in the Irish Sea and therefore any distributions of fish that display this behaviour as part of their life history is not considered in the Celtic Sea estimate. The proportion of the current stock that is behaving in this way is currently unknown and may have changed in recent years. The CSHAS survey does not contain the stock for the herring that are outside the Celtic Sea area during the survey in October. On-going genetic studies are investigating the mixing of all herring around Ireland, but currently the levels of mixing in each individual stock around Ireland is unknown.

Since 2014, herring have been found in hyper-aggregated distributions offshore in the Celtic Deeps/Smalls area in particular, with very little distribution found inshore closer to the spawning areas. Previous to 2014, there has always been a significant proportion of the stock located inshore. The distribution of herring in close proximity to the seabed (< 1m off bottom) has also been evident in this area for a number of years, and WGIPS have recommended in the past treating the data from CSHAS with caution because of the difficulty in surveying herring distributed close to the bottom, within the dead zone of the echosounder (e.g. ICES 2017). The error in estimating the biomass of fish that are located near the seabed has as yet been unquantified for this survey and is likely to remain an issue as long as fish are observed in aggregations close to the seabed during the survey. It is also unclear whether this is a recent phenomenon associated with lower stock size, increased predators, environment, etc., or a bias that has always existed in this survey, constant or otherwise.

B.3.3 Acoustic survey data in the assessment

The Celtic Sea Herring Assessment is tuned using a single acoustic survey. The survey time-series is presented in Table 1 below. Considerable fluctuations in the biomass estimate from the survey can be seen and the estimate has been particularly low in the last three years. There is a scarcity of data for ages 8 and 9-wr. Age 1-wr and to a lesser extent age 2-wr are variable due to the migration into the Irish Sea. Figure 11 shows the internal consistency of the survey. Agreement between years is generally good, though it is noted that agreement is better at a time lag of one year. The best agreement is between 4 and 7 years, though in recent years there are few fish greater than 6 in the data series. The assessment is tuned using data from 2–7.

In 1998 the HAWG decided to use the age-disaggregated acoustic survey data for 2 to 5-wr fish only as a relative index in the ICA assessment, and this was continued until 2014. In 2004,

an examination of the log ratio of abundances in the survey index was carried out. This showed that there was both high frequency and low frequency noise in the acoustic survey abundances by age. The high frequency noise was associated with 0- and 1-wr and fish older than 5-wr. In addition, the analysis confirmed the strong year effects in the survey also (ICES, 1998; ICES, 2004). At WKPELA 2014 it was decided to increase the number of ages used in tuning to 1–9 as this improved assessment diagnostics. At WKWEST 2015 age 1-wr were removed from the survey data and the final assessment was tuned with ages 2–9. The rationale for this decision is based on the fact that 1-wr fish are often present in the Irish Sea and would not be fully available to the survey. At WKPELA 2018 the age range was further reduced to 2-7-wr due to the consistent low numbers of fish at age 8 and 9-wr. The HAWG in 2018 rejected the CSHAS in 2017; there was only one biological sample obtained and the resultant proportions at age obtained were not considered to be representative of the stock.

Table 1. Herring in the Celtic Sea. Abundance-at-age, biomass and SSB, along with estimation CV, for the acoustic tuning series. R = random start point design, AR = adaptive random start-point design, ARM = adaptive random start-point with mini-surveys design. The survey in 2017 (grey shaded) was not used in the HAWG 2018 assessment.

	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	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	1,147	1,414	1,300	2,322	1,286
SSB	41	20	-	33	36	46	90	91	122	122	246	71
CV	0.49	0.34	-	0.48	0.35	0.25	0.2	0.24	0.2	0.28	0.25	0.28
Design*	AR	AR		R	R	R	R	R	R	AR	AR	AR

2014   2015   2016   2017

	2015	2016	2017	2018
0	0	0	0	0
1	41	0	125	0
2	117	40	21	6
3	112	48	43	3
4	69	41	40	7
5	20	38	36	5
6	24	7	25	4
7	7	6	5	1
8	17	5	6	1
9	1	0	0	0
N os.	408	184	301	27
SS B	48	25	30	4
C V	0.59	0.18	0.33	-
D esi gn *	AR M	AR M	AR M	AR M
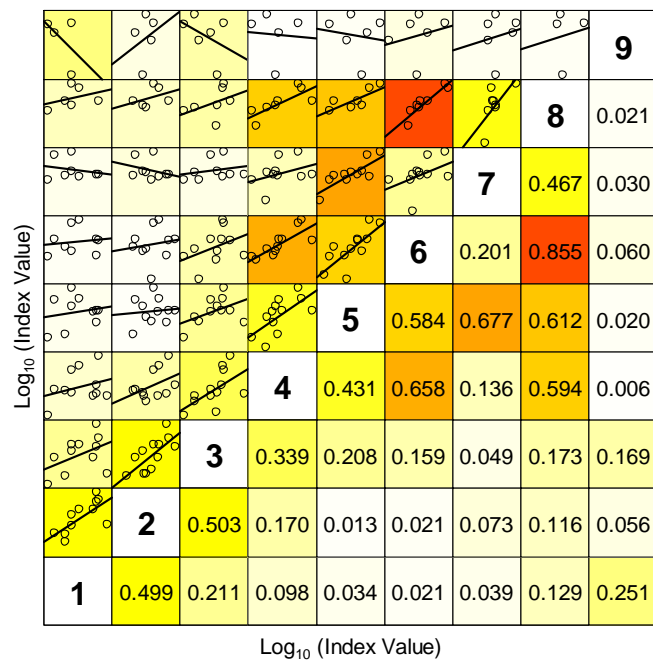
Figure 11. Herring in the Celtic Sea. Internal consistency between ages in the Celtic Sea Herring Acoustic survey time-series.

B.4 Groundfish Surveys

A number of groundfish surveys are carried out in this area including the Irish groundfish survey, French EVHOE and the Northern Ireland groundfish survey. Initial examination of

these surveys found that the estimates produced were noisy and uncertain. Further work in this area is required to examine if these surveys can be used as indices for Celtic Sea Herring.

C. Assessment methods and settings

Assessments 2007–2017

In 2007, a benchmark assessment used a variety of models including ICA (Patterson, 1998), separable VPA, XSA, CSA and Bayesian catch-at-age methods. In addition an analysis of long-term dynamics of recruitment was conducted. Simulations of various fishing mortalities were conducted based on stock productivity. Though no final model formulation was settled upon, the assessment provided information on trends.

In 2008 and 2009, the working group continued to explore different assessment settings in ICA. The working group treated these explorations as extensions of the benchmark of 2007. In 2008 ICA was replaced by FLICA and the same stock trajectories were found in each.

In 2009 a final analytical assessment was proposed and was conducted using FLICA (flr-project.org). This assessment was based on exploratory work done in 2008 and 2009. The refinements to the benchmark assessment of 2007 were as follows:

- Further reduction of plus group from 7+ to 6+
- Exclusion of acoustic surveys before 2002, because a sufficient series of comparable surveys was now available.

The assessment showed improved precision and coherence between the catch-at-age and the survey data. The survey residuals were lower since 2002 which is reflected in better tuning diagnostics.

Benchmark assessment 2014

Due to the issues with the ICA model the exploration of an alternative assessment model was carried out at the 2014 benchmark meeting. This is described in; ICES WKPELA (2014), using the SAM model (Nielsen and Berg, 2014).

WKPELA recommended that further work was required to find a more suitable model that is robust to noisy survey data and delivers improved retrospective patterns.

A new benchmark was proposed for 2015 based on deliberations at ACOM.

- Consider retrospectives
- Check robustness of F_{MSY} estimation
- Check underlying robustness of input data especially survey data.
- Considering other possible models
- Investigate drivers for reduced mean weights, which are impacting on yields

Benchmark assessment 2015

At the 2015 Benchmark working group (WKWEST) a number of assessment models were tested for use on this stock namely SAM, XSA and ASAP. ASAP was chosen as the final assessment model. This change was based on statistical criteria which showed this was the

most appropriate model and due to the SAM model tending to 'smooth out' variability in recruitment which was clearly occurring in the catch data (ICES, 2015).

Inter Benchmark 2018 (WKPELA 2018)

An inter benchmark was held in 2018 to examine the existing assessment in the ASAP framework and how it can be adjusted to deal with the change in apparent behaviour of herring as they are available to the acoustic survey. A number of assessment configurations were tested and the following updates made.

- Inclusion of the 2014 and 2015 survey estimates. Previously, these were excluded due to concern over containment. Subsequent surveys indicate that lateral containment was likely achieved in 2014 and 2015 also.
- The age range for the survey proportions at age were updated from 2-9 to 2–7. This was based on the relative scarcity of age 8 and 9 ring fish in the survey and the internal consistency of the survey.
- Survey selection was fixed at 1 for ages 3-5 (previously 5–9).

The following updates were also implemented during investigations into the retrospective in the assessment.

- Weighting (CV) of the acoustic survey abundance (sum of the numbers at age) data was arbitrarily set to 50%. The basis for the calculation of the CV has changed such that the time series in inconsistent. The assessment was found to be particularly sensitive to the original values, some of which seemed unusually low.
- Weighting of the catch proportion-at-age data in 2015 and 2016 was reduced by lowering the effective sample size. There appears to have been a change in selection since 2015 with increased selection at older ages. While the ASAP model has the capability to use selection blocks for predetermined time periods, this apparent change in selectivity is relatively recent and there is insufficient data to implement a separate selection block within ASAP. By effectively down-weighting the data on the catch at age proportions in 2015 and 2016, the assessment retrospective is reduced.

C.1. Choice of stock assess model

The Celtic Sea Herring stock was assessed using ASAP 3 (http://nft.nefsc.noaa.gov). ASAP (A Stock Assessment Program) is an age-structured stock assessment modelling program (Legault and Restrepo, 1998). ASAP is a variant of statistical catch-at-age model that can integrate annual catches and associated age compositions (by fleet), abundance indices and associated age compositions, annual maturity, fecundity, weight, and natural mortality-at-age.

C.2. Model used as basis for advice

The final ASAP assessment run is used as the basis for the advice. The assessment input data are presented in Table 2 and the settings agreed at WKPELA 2018 are presented in Table 3 below.

C.3. Assessment model configuration

Table 2: Input Data Available

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1958–2017	1–9	Yes
Canum	Catch-at-age in numbers	1958–2017	1–9	Yes
Weca	Weight-at-age in the commercial catch	1958–2017	1–9	Yes
West	Weight-at-age of the spawning stock at spawning time.	1958–2017	1–9	Yes
Fleet	Index numbers at age	2002-2016	2-7	Yes
Mprop	Proportion of natural mortality before spawning	1958–2017	1–9	No
Fprop	Proportion of fishing mortality before spawning	1958–2017	1–9	No
Matprop	Proportion mature at age	1958–2017	1–9	No
Natmor	Natural mortality	1958–2017	1–9	No

Table 3. Herring in the Celtic Sea. ASAP model Settings 2018.

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 1 for age 3-wr
Index units	2 (numbers)
Index month	October (10)
Index selectivity linked to fleet	-1 (not linked)
Index Years	2002–2016 (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	Set at 0.5 for 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 with 2015, 2016 and 2017 downweighted to 5
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

D. Short-term prediction

Model used: FLSTF

STF Input data

Recruitment: A segmented regression is fit to the stock recruit data using Julio's algorithm. 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 years. If the SSB is above the changepoint calculated in the stock recruit relationship. If the SSB in the forecast year – 2 years is less than the changepoint then the calculation below applies.

Recruitment (forecast year) = plateau recruitment *(SSB forecast year -2) / SSB Changepoint)

Maturity: From the final year

F and M before spawning: From the final year

Weight-at-age in the stock: 3 year average

Weight-at-age in the catch: 3 year average

Exploitation pattern: 3 year average

Intermediate year assumptions: Interim year catch was taken to be the estimated uptake of the TAC, plus carryover or undershoot on the Irish quota if relevant, plus discard estimates

Stock–recruitment model used: Segmented Regression fitted to data from 1970 – 2015 (Final year in the assessment – 2) using Julio's algorithm (ICES, 2018b). Estimates prior to 1970 are considered uncertain, as are those from the most recent years.

E. Medium-term prediction

No medium term predictions have been carried out in recent years.

F. Long-term prediction

As part of the development of the long term management plan for Celtic Sea Herring long term simulations were carried out using HCS10 (Skagen, 2010). The stock was projected forward twenty years and a range of possible trigger points, F values and % constraints on TAC change were investigated.

G. Biological reference points

During the WKPELA 2018 meeting a number of updates to the ASAP assessment for Celtic Sea Herring were discussed and agreed. Following on from this work the reference points were examined using EQ-SIM with suggested updated values in the table below. Full details of the EQ-SIM runs are presented in the working document to WKPELA estimation of PA and MSY Reference Points for Celtic Sea Herring (Campbell, 2018).

REFERENCE POINT	WKPELA 2018 (WITH R AUTOCORRELATION)	PREVIOUS VALUES
B_{lim}	34kt	33kt
B_{pa}	54kt	54kt
F_{lim}	0.45	0.61
F_{pa}	0.27	0.37
$MSYB_{trigger}$	54kt	54kt
F_{MSY}	0.26	0.26

H. Other issues

H.1. Biology of species

Herring shoals migrate to inshore waters to spawn. Their spawning grounds are located in shallow waters close to the coast and are well known and well defined. This stock can be divided into autumn and winter spawning components. Spawning begins in October and can continue until February. A number of spawning grounds are located along the South coast, extending from the Saltee Islands to the Old Head of Kinsale. These grounds include Baginbun Bay, Dunmore East Co Waterford, around Capel and Ballycotton Islands and around the entrance to Cork Harbour (Molloy, 2006). The areas surrounding the Daunt Rock and old Head of Kinsale have also been recognised as spawning grounds (Breslin, 1998; O'Sullivan *et al*., 2013). These spawning grounds are shown in Figures 4–5.

When referring to spawning locations the following terminology is used (Molloy, 2006).

A <u>spawning bed</u> is the area over which the eggs are deposited.

A <u>spawning ground</u> consists of one or more spawning beds located in a small area.

A <u>spawning area</u> is comprised of a number of spawning grounds in a larger area.

Spawning grounds are typically located in high energy environments such as the mouth of large rivers and areas where the tidal currents are strong. Herring shoals return to the same spawning grounds each year (Molloy, 2006).

Herring produce benthic eggs that are adhered to the bottom substrate where they remain until hatching. Fertilized eggs hatch into larvae in 7–10 days depending on the water temperature[1]. The size of the egg determines the size of the larvae. Larger eggs have a greater chance of survival but this must be balanced against environmental conditions and the inverse relationship between fecundity and egg size (Blaxter and Hunter, 1982).

A study on fecundity of Celtic Sea herring, conducted in the 1920s found that the eggs produced by spring spawners were 25% bigger than those autumn spawners but were less numerous (Farran, 1938). The relationship between fecundity and length has been calculated for both spawning components of Celtic Sea herring. The regression equations are as shown in Molloy (1979), are as follows:

Autumn spawning component: Fecundity = 5.1173 L–56.69 (n=53)

Winter spawning component: Fecundity = 3.485 L–35.90 (n=37)

The larval phase is an important period in the herring life cycle. Larvae use their oil globule for food and to provide buoyancy. Currents transport the newly hatched larvae to areas in the Celtic Sea or to the Irish Sea (Molloy, 2006). The conditions experienced during the larval phase as well as during juvenile phase are likely to have some influence on the maturation of Celtic Sea herring. Fast growing juveniles can recruit to the population a year earlier than slow growing juveniles. Faster growth may also lead to increased fecundity (Brophy and Danilowich, 2003). Fluctuating environmental conditions play an important role in the growth and survival of herring in this area.

Celtic Sea herring consist of a mixture of autumn- and winter-spawners, with spawning occurring between late September and February (Breslin, 1998; Molloy, 1980; 2006; O'Sullivan, 2013). The occurrence of spawning in spring has occasionally been reported by fishermen, but appears restricted to very exceptional events. The fishery at Dunmore East targets winter-spawners (Molloy, 2006). There are no reports of autumn-spawning in the Celtic Sea prior to 1974 (Molloy, 1980; Molloy and Cullen, 1981). Subsequently, peak spawning period in the Celtic Sea occurred in January off the southeast and in October-November off the southwest Irish coast (Molloy, 1989; Breslin, 1998). More recently although some spawning occurs in autumn, winter spawning appears to dominate (Brophy and Danilowicz, 2002). Spawning grounds are well defined along the south and southwest of the Irish coast. At a smaller spatial-scale, a few individual spawning beds within the spawning grounds have also been mapped (Breslin, 1998).

Herring larvae are found between October and March in close proximity to spawning grounds. Larvae are transported by currents, mainly wind-driven, either into the Irish Sea (Brophy and Danilowicz, 2002; 2003) or westwards (Molloy and Corten, 1975; ICES, 1994) along the south coast. Nursery areas are located in the bays and estuaries of the south and southwest coast and in the western and eastern Irish Sea (Clarke *et al.*, 2010). A recent survey found large concentrations of juvenile herring in the bays southwest of Ireland: Kinsale and Cork harbours, and Roaringwater Bay; and to the east of Ireland: NE of Dublin (Clarke *et al.*, 2010). Juveniles off the west and southwest spend time close to the south coast but have also been found to migrate northwards to the west coast, following the main residual currents

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[1] http://www.gma.org/herring/biology/life_cycle/default.asp

(Molloy, 2006). Evidence shows that winter spawned herring from the Celtic Sea disperse to nursery grounds in the Irish Sea during the first year of life (Brophy and Danilowicz, 2002). The abundance of these juveniles relative to the resident autumn spawned population varies considerably from year to year (Brophy and Danilowicz, 2002; 2003; Burke *et al.*, 2009). This probably reflects both biological parameters such as the yearly spawning potential, and physical conditions such as the current strength and residual direction. Tagging experiments (Molloy *et al.*, 1993) and otolith studies (Brophy *et al.*, 2006) suggest that juveniles migrate from the Irish Sea to the Celtic Sea at the time of first spawning. In one year class examined, otoliths shape analyses revealed that 42% of adults spawning in the Celtic Sea had spent their juvenile period in the Irish Sea (Burke, 2008).

After they congregate for spawning in inshore waters, adult herring shoals quickly disperse (Molloy, 2006). It is then assumed that small shoals move back offshore to deeper waters where they over-winter. Feeding occurs predominantly in offshore grounds over summertime (ICES, 1994; Parrish and Saville, 1965). Such areas include the Smalls, the area around the Kinsale Gas Field and off SW Ireland. Herring fat reserves reach a maximum during June to August, (Molloy and Cullen, 1981). Pre-recruit herring are absent from offshore feeding grounds (Burd and Bracken, 1965), assuming they use nursery areas for optimal growth at this stage.

Celtic Sea herring have undergone changes in growth patterns and a declining trend in mean weights and lengths can be seen over time (Figures 8–10). The declines in mean weight reversed around 2008, but since then have declined to the lowest in the series. A scoping exercise by Lynch (2011) suggested that positive NAO and increased SST was associated with declining weight-at-age. Harma (2014) also found temperature (SST or expressed as AMO) to negatively influence weight-at-age. A positive relationship was found between abundance of *Calanus finmarchicus* and weight-at-age (Lynch, 2011). Work by Harma (2013) found that changes in localised environmental parameters such as wind speed rather than global climatic indices like NAO explained cycles in growth over time.

Researchers have agreed that intra-specific density-dependence does not explain declining size, weight or growth (Brunel and Dickey-Collas, 2010; Harma, 2013; Lynch *et al.*, 2011; Molloy, 1984).

The stock seems to have entered a new phase of much higher recruits per SSB than previously.

H.2. Stock dynamics, regulations in 20th century – historic overview

See Section A.2.

H.3. Current fisheries

See Section A.2.

H.4. Management and advice

The assessment year is from 1st April to 31st March. However for management purposes, the TAC year is from 1st January to 31st December.

The first time that management measures were applied to this fishery was during the late 1960s. This was in response to the increasing catches particularly off Dunmore East. The industry became concerned and certain restrictions were put in place in order to prevent a glut

of herring in the market and a reduction in prices. Boat quotas were introduced restricting the nightly catches and the number of boats fishing. Fishing times were specified with no weekend fishing and herring could not be landed for the production of fishmeal. A minimum landing size was also introduced (Molloy, 1995).

The TAC (total allowable catch) system was introduced in 1972, which meant that yearly quotas were allocated. This continued until 1977 when the fishery was closed. During the closure a precautionary TAC was set for Division 7.j. This division was not assessed analytically (ICES, 1994). After the closure of this fishery a new management structure was implemented with catches controlled on a seasonal basis and individual boat quotas were put in place (Molloy, 1995).

Table 16 shows the history of the ICES advice, implemented TACs and ICES estimates of removals from the stock. It can be seen that the implemented TAC has been set higher than the advice in about 50% of years since the re-opening of the fishery in 1983. The tendency for the TAC to be set higher than the advice has also increased in recent years. It can also be seen that ICES catch estimates have been lower than the agreed TAC in most years.

This fishery is still managed by a TAC system with quotas allocated to boats on a weekly basis. Participation in the fishery is restricted to licensed vessels. A series of closed areas have been implemented to protect the spawning grounds, when herring are particularly vulnerable. These spawning box closures were implemented under EU legislation.

The committee set up to manage the Irish fishery for the stock has the following objectives.

- To build the stock to a level whereby it can sustain annual catches of around 20 000 t.
- In the event of the stock falling below the level at which these catches can be sustained the Committee will take appropriate rebuilding measures.
- To introduce measures to prevent landings of small and juvenile herring, including closed areas and/or appropriate time closures.
- To ensure that all landings of herring should contain at least 50% of individual fish above 23 cm.
- To maintain, and if necessary expand the spawning box closures in time and area.
- To ensure that adequate scientific resources are available to assess the state of the stock.
- To participate in the collection of data and to play an active part in the stock assessment procedure.

The Irish Celtic Sea Herring Management Advisory Committee developed a rebuilding plan for this stock, that was used as the *de facto* management plan from 2009-2011 inclusive. The plan incorporated scientific advice with the main elements of the EU "policy statement "on fishing opportunities for 2009, local stakeholder initiatives and Irish legislation. The proposed rebuilding plan for Celtic Sea and Division 7.j herring was deemed to be in accordance with the precautionary approach by ICES in 2009.

Rebuilding plan

1) For 2009, the TAC shall be reduced by 25% relative to the current year (2008).
2) In 2010 and subsequent years, the TAC shall be set equal to a fishing mortality of $F_{0.1}$.

3) If, in the opinion of ICES and STECF, the catch should be reduced to the lowest possible level, the TAC for the following year will be reduced by 25%.

4) Division 7.a.S will be closed to herring fishing for 2009, 2010 and 2011.

5) A small-scale sentinel fishery will be permitted in the closed area, Division 7.a.S. This fishery shall be confined to vessels, of no more than 65 feet in length. A maximum catch limitation of 8% of the Irish quota shall be exclusively allocated to this sentinel fishery.

6) Every three years from the date of entry into force of this Regulation, the Commission shall request ICES and STECF to evaluate the progress of this rebuilding plan.

7) When the SSB is deemed to have recovered to a size equal to or greater than B_{pa} in three consecutive years, the rebuilding plan will be superseded by a long-term management plan.

Long–term Management Plan

The rebuilding plan ended in 2011 and was replaced by a long-term management plan. In early 2011 the Irish industry agreed a long-term management plan. The plan was evaluated by ICES in 2012 and judged to be in accordance with the PAFM (ICES, ADGCSHER 2012). It was evaluated again in 2015 following the benchmark assessment and was revised in light of the new reference points (B_{lim} 33,000 t.)

Revision of the proposed Long term management plan Herring in the Celtic Sea and Division 7.j. by the Pelagic AC, (2015)

1) Every effort shall be made to maintain a minimum level of Spawning–Stock Biomass (SSB) greater than 33 000 t, the level below which recruitment becomes impaired.

2) Where the SSB, in the year for which the TAC is to be fixed, is estimated to be above 61 000 t ($B_{trigger}$) the TAC will be set consistent with a fishing morality, for appropriate age groups, of 0.23 (F_{target}).

3) Where the SSB is estimated to be below 61 000 tonnes, the TAC will be set consistent with a fishing mortality of:

SSB * 0.23 / 61 000

4) Where the rules in paragraphs 2 and 3 would lead to a TAC which deviates by more than 30% from the TAC of the preceding year, the TAC will be fixed such that it is not more than 30% greater or 30% less than the TAC of the preceding year.

5) Where the SSB is estimated to be below 33 000 tonnes, subdivision 7.aS will be closed until the SSB has recovered to above 33 000 tonnes.

6) Where the SSB is estimated to be below 33 000 tonnes, and subdivision 7.aS is closed, a small-scale sentinel fishery will be permitted in the closed area. This fishery will be confined to vessels, of no more than 50 feet in registered length. A maximum catch limitation of 8% of the Irish quota will be exclusively allocated to this sentinel fishery.

7) Notwithstanding paragraphs 2, 3 and 4, if the SSB is estimated to be at or below the level consistent with recruitment impairment (33 000 t), then the TAC will be set at a lower level than that provided for in those paragraphs.

8) No vessels participating in the fishery, if requested, will refuse to take on-board any observer for the purposes of improving the knowledge on the state of the

stock. All vessels will, upon request, provide samples of catches for scientific analyses.

9) Every three years from the date of entry into force of this Regulation, the Commission will request ICES and STECF to review and evaluate the plan.

10) This arrangement enters into force on 1st January, 2016.

This plan has been the *de-facto* management plan for the stock for 2012 and subsequent years. It is not enshrined in law because it has yet to be considered for approval by the European Parliament.

2018 Management Plan Review

ICES evaluated the long term management plan following the inter-benchmark in 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. However, simulations indicate that median SSB reaches

MSY $B_{trigger}$ in 2020.

ICES considers that the stability clause in the management plan that constrains TAC changes from year to year to ±30% can imply fishing mortalities greater than F_{MSY}, which in turn may result in a greater than 5% probability of the stock falling below B_{lim}. This may also prevent the stock being fished and maintained at levels which can produce maximum sustainable yield, in any given year.

H.5. Others (e.g. age terminology)

The WG uses "rings" rather than "age" or "winter rings" throughout the report to denominate the age of herring, with the intention to avoid confusion. It should be observed that, for autumn spawning stocks, there is a difference of one year between "age" and "rings". HAWG in 1992 (ICES, 1992/Assess: 11) stated that:

"The convention of defining herring age rings instead of years was introduced in various ICES working groups around 1970. The main argument to do so was the uncertainty about the racial identity of the herring in some areas. A herring with one winter ring is classified as 2-years-old if it is an autumn spawner, and one-year-old if it is a spring spawner. Recording the age of the herring in rings instead of in years allowed scientists to postpone the decision on year of birth until a later date when they might have obtained more information on the racial identity of the herring.

The use of winter rings in ICES working groups has introduced a certain amount of confusion and errors. In specifying the age of the herring, people always have to state explicitly whether they are talking about rings or years, and whether the herring are autumn- or spring spawners. These details tend to get lost in working group reports, which can make these reports confusion for outsiders, and even for herring experts themselves. As the age of all other fish species (and of herring in other parts of the world) is expressed in years, one could question

the justification of treating West-European herring in a special way. Especially with the present trend towards multispecies assessment and integration of ICES working groups, there might be a case for a uniform system of age definition throughout all ICES working groups.

However, the change from rings to years would create a number of practical problems. Data files in national laboratories and at ICES would have to be adapted, which would involve extra costs and manpower. People that had not been aware of the change might be confused when comparing new data with data from old working group reports. Finally, in some areas (notably Division 3.a), the distinction between spring- and autumn spawners is still hard to make, and scientists preferred to continue using rings instead of years.

The Working Group discussed at length the various consequences of a change from rings to years. The majority of the Group felt that the advantages of such a change did not outweigh the disadvantages, and it was decided to stick to the present system for the time being."

The text table below gives an example for the correlation between age, rings and year class for the different spawning types in late 2002:

YEAR CLASS (AUTUMN SPAWNERS)	2001/2002	2000/2001	1999/2000	1998/1999
Rings	0	1	2	3
Age (autumn spawners)	1	2	3	4
Year class (spring spawners)	2002	2001	2000	1999
Rings	0	1	2	3
Age (spring spawners)	0	1	2	

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