Stock Annex: Haddock (*Melanogrammus aeglefinus*) in divisions 7.b–k (southern Celtic Seas and English Channel)

Stock specific documentation of standard assessment procedures used by ICES.

Stock Haddock

Working Group Working Group for the Celtic Seas Ecoregion (WGCSE)

Created

Authors

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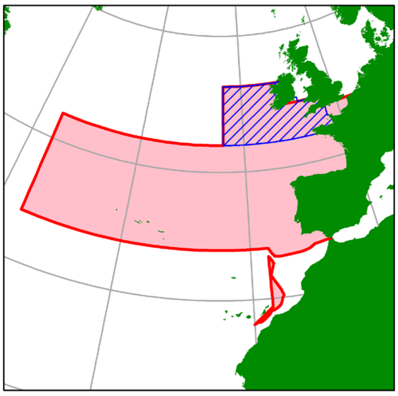
Last updated by Jonathan White, 2020

Last Benchmarch WK CELTIC 2020

A. General

A.1. Stock definition



For assessment purposes, the stock is defined as 7.b–k excluding 7.d and including rectangles 33E2 and 33E3. Landings from 7.d are insignificant and this division is not included in the assessment area. Irish landings from rectangles 33E2 and 33E3 are added to the stock assessment area. Landings from these rectangles were removed from the 7.a stock area following the benchmark of had-7a at WKROUND 2013 and this approach continues following the benchmark of WKCELTIC (2020). WKROUND found that landings from these rectangles had increased substantially in recent years and that geographically this fishery is contiguous with the fishery in 7.g and quite separate from the main haddock fishery in 7.a. These landings have been added to 7.g since 2003 and the landings numbers-at-age have been adjusted. Before 2007 landings from these rectangles were <1% of the total landings in 7.b, 7.c, 7.e–k, between 2007 and 2013 they contributed around 3% of the total landings, this proportion has since increased and represented 9.9% of all other Celtic Seas haddock catch in 2019.

The TAC for haddock is set for 7.b–k, 8, 9 and 10. However, official international landings from outside the assessment area (7.d, 8, 9 and 10) have been less than 2% of all landings in the TAC area in most years since 1973.

Adult haddock appear to be continuously distributed from the north of Biscay along the Irish coasts and the west of Scotland into the North Sea. It is not clear from their distribution if the 7.b, 7.c, 7.e–k stock is distinct from the surrounding areas. Irish Otter trawl lpue in the northernmost rectangles of 7.b is relatively high and similar lpue continues into 6.a, suggesting that the haddock in the north of 7.b might belong to the same stock as those in 6.a (Gerritsen, 2009). The pattern of lpue in the Irish Sea appears to be relatively distinct from 7.b, 7.c, 7.e–k with relatively high otter and beam trawl lpue in 7.g, low lpue in 7.a-South and high lpue in 7.a north (Gerritsen, 2009). Results from the

French EVHOE-WIBTS-Q4 survey suggest that relatively low densities of haddock continue from 7.h into 8.a. Irish Groundfish Survey (IGFS-WIBTS-Q4) data indicates two distinct nursery areas with high catches of 0-group haddock: one area off the southwest coast of Ireland (7.b south and 7.j north) and one area off the southeast coast (7.g north). Catches of older haddock in 7.b are generally low and it is not clear whether the young fish from 7.b move north to 6.a or south to 7.j stock (Gerritsen and Stokes, 2006).

A.2. Fishery

Haddock in Divisions 7.b, 7.c, 7.e–k are taken as a component of catches in mixed trawl fisheries. France usually takes about 60% of the landings. French landings are made mainly by gadoid trawlers, which prior to 1980 were mainly fishing for hake in the Celtic Sea. Ireland has historically taken about 20–30% of the landings. Fleets from Belgium, Norway, the Netherlands, Spain, and the UK take the remainder of the landings. Landings reported between 1984 and 1995 varied between 2600 t and 4900 t, then increased sharply to 10 300 t in 1997. Since then the landings have varied between 5000 t and 19 000 t.

The vast majority of the landings are taken by otter trawls, most of the remainder of the landings are taken by seines and beam trawls.

A.3. Ecosystem aspects

Haddock are widely distributed throughout the stock area across a range of habitats. They have a varied diet but do not appear to be cannibalistic (Needle *et al.*, 2003)

The mixed trawl fisheries impacts on benthic communities through bottom contact. Other ecosystem impacts result from discarding of non-target, undersize, over-quota or low-value fish.

Recruitment of haddock is highly variable. For North Sea haddock, no link could be found between temperature and recruitment (Cook and Heath, 2005). But parental condition has been linked to recruitment success in northwest Atlantic haddock (e.g. Friedland *et al.*, 2003; Marshall and Frank, 1999).

B. Data

B.1 Catch at age data

Member States (MS) fishing the Celtic Sea haddock stock comprise primarily Belgium, France, Ireland and the UK. The ICES meeting WKCELTIC 1 reviewed each MS approach to processing catch and observer data in applying national catch at age raising, and recommended standard approaches be implemented. Following this meeting MS were requested to review their data submissions and resubmit/ upload their data to the ICES InterCatch database.

Following national re-submission of catch at age data, all data were downloaded from InterCatch and processed jointly, through a standardised approach, across the time frame 2002 to 2019.

Almost all catch data submitted were classified by year (Figure 1), with sampling showing similar patterns across countries, years and ages (Figure 2).

The data processing approach applied the observer details of age-length information relative to sample numbers across catch relative to country, area, quarter and fleet hierarchically. Discards were estimated from landings where no direct observation was available through time series of three raising factors, dependent upon the available catch detail and sample, at the resolution of:

i. Year, Country and Gear (Figure 3)
ii. Year and Gear (Figure 4)
iii. Year (Figure 5)

With gears set to: GNS_DEF, OTB_CRU, OTB_DEF, TBB_DEF and MIS_MIS.

This process will be followed in following stock assessments, with appropriate corrective actions where necessary.

As an example, during this processing in 2020, certain catch gears and time frames were removed owing to their discarding approaches not being representative, these included:

- The OTB_DEF Spanish fleet 2002 – 2019
- The UK (England) “MIS-MIS” classification 2002 – 2019
- The UK (England) TBB_DEF fleet in 2002

This process was repeated in July 2020 following data updates.

The R-markdown report of this is available: aggregate_IC_data_had.27.7b-k_July_2020.Rmd.

Note that catch data used in all the assessment runs from 1993, with only data from 2005 onwards updated following the review of the raising of data from 2003, where raising estimates between 2003 and 2004 showed inconsistencies with the empirical understanding of discarding practices over this time (Figures 1 to 4). The proportional discards of the 2020 updated catch data, applied in the final assessment are shown in Figure 7. Data in the ssessment from 1993 to 2004 remain the same as applied in the proceeding benchmark (WKROUND, 2012).

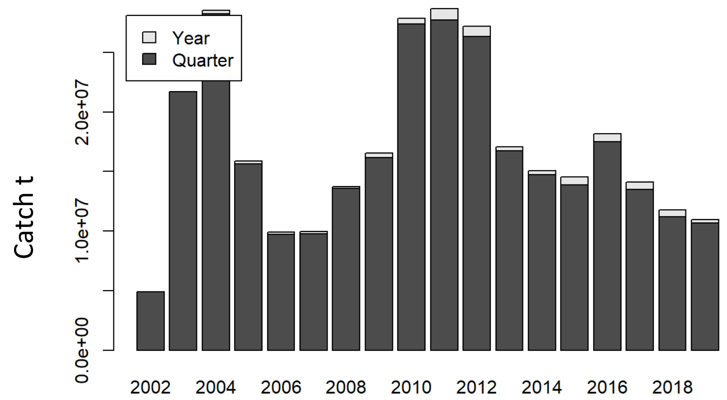


Figure 1. Annual catch time classification 2002 to 2019.

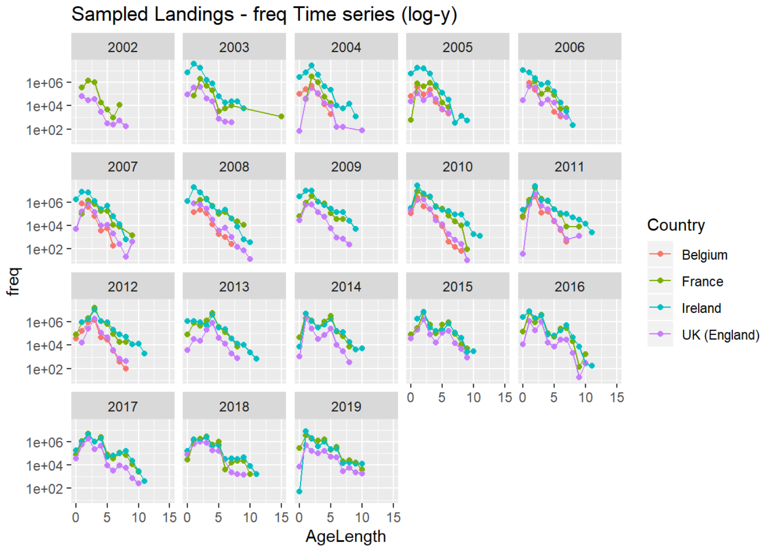


Figure 2. National sampling by age of landings 2003 – 2019 (log y-axis).

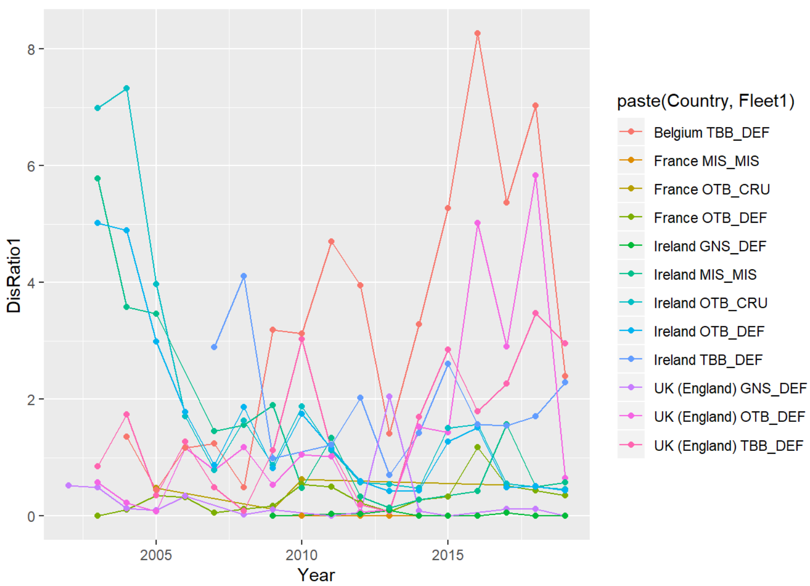


Figure 3. Discard raising ratios by Year, Country and Gear.

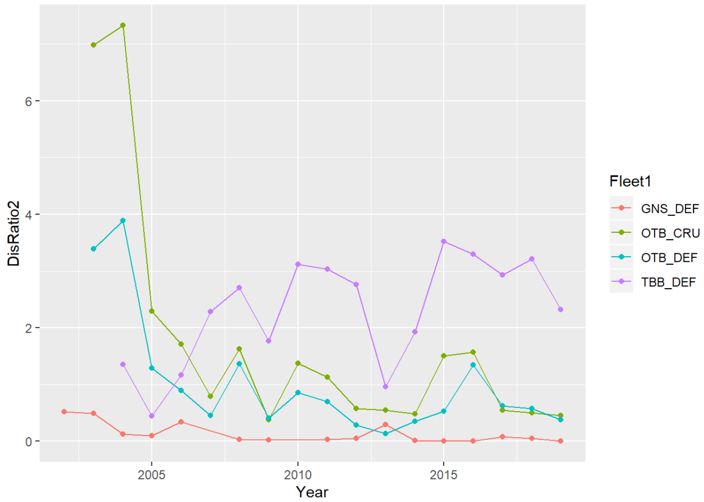


Figure 4. Discard raising ratios by Year and Gear.

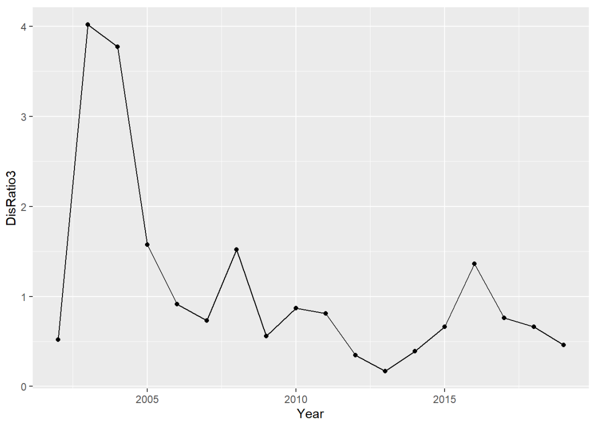


Figure 5. Discard raising ratios by Year.

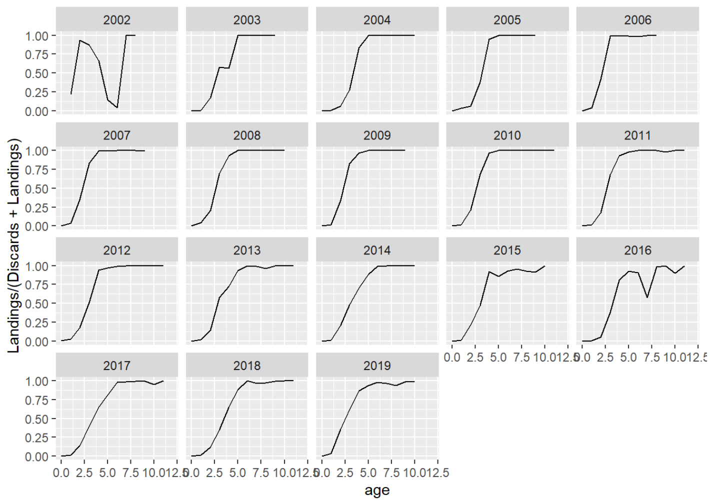


Figure 6. 2019 time series of landings at age relative to catch (discards + landings).

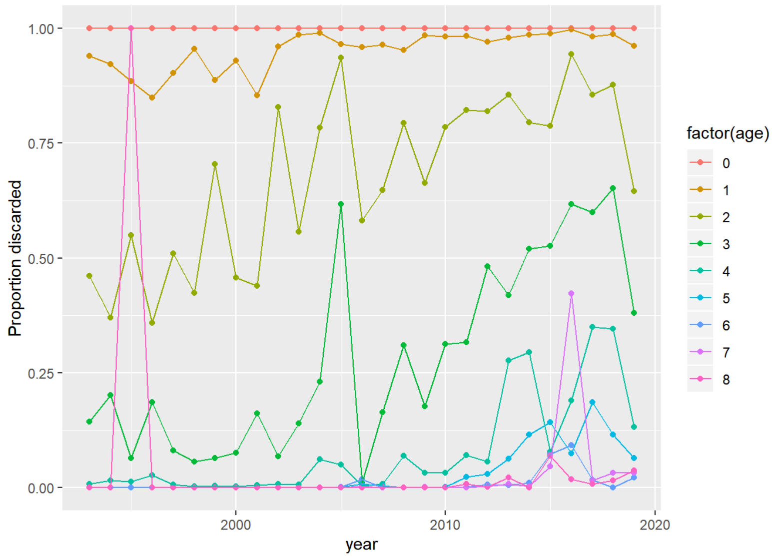


Figure 7. Assessment applied proportional discards by age time series (post 2020 raising processing for years 2005 to 2019).

B.2 Biological

B.2.1 Maturity-at-age estimates

Following review of data collected between 2004 – 2018 new maturity at age estimates were proposed. Maturity at age applied in the previously benchmarked assessment are given in Table 1.

Table 1. Maturity profiles applied in the 2012 assessment.

AGE	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
MATURITY PROPORTION	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

A number of options for applying updated maturity were reviewed, including maintaining the 2012 estimates, and introducing year specific estimates by age. It was decided to adopt a standard set of maturity at age proportions, as this was more likely to be reflective of the general age at maturity, and not depend upon year specific estimates which may lack accuracy owing to sample sizes and origins, and also remove the annual dependence of recalculating maturity for every annual assessment (Table 2).

Table 2. Maturity profiles applied in the 2020 assessment.

AGE	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
MATURITY PROPORTION	0.000	0.039	0.911	0.970	0.980	1.000	1.000	1.000	1000

B.2.2 Natural Mortality

Natural mortality in the 2012 assessment were set for all years in the assessment (Table 3).

Table 3. Mortality profiles applied in the 2012 assessment.

AGE	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
MORTALITY	0.99	0.72	0.60	0.50	0.43	0.40	0.37	0.36	0.34

Revised natural mortality at age options were. Following review of available data from IGFS-WIBTS-Q4 and EVHOE-WIBTS-Q4 surveys, 2003 to 2018, estimates of mortality at age from growth parameters and assumption averages were applied through to Von Bertalanffy parameters 2003 to 2018:

k = 0.256; - Linf = 607mm; t_0 = -1.33.

These were applied through the Lorenzen and Gislason approached to estimate natural mortality (Table 4).

Table 4. Mortality profiles applied in the 2020 assessment.

AGE	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
MORTALITY LORENZEN	1.087	0.721	0.575	0.483	0.440	0.406	0.398	0.385	0.360
MORTALITY GISLASON	1.087	0.544	0.372	0.279	0.239	0.209	0.203	0.190	0.169

Reviewing the Lorenzen and Gislason options it was decided to apply the updated Lorenzen estimated of natural mortality in the proposed 2020 assessment.

B.3. Surveys

The 2020 benchmarked assessment implemented a single tuning indices to the assessment, a joint French-Irish survey indices. These were available for application in the 2020 benchmark.

The joint French-Irish scientific survey (combined IGFS-WIBTS-Q4 and ECHOE-WIBTS-Q4) data were used in a standardised format following the application of a Vector Autoregressive Spatio-Temporal (VAST) modelling approach, following Thornson (2019).

B.4. Commercial CPUE

There are no commercial CPUE indices used in the current assessment.

C. Historical stock development

C.1. Model used

SAM (state-space assessment model) https://www.stockassessment.org/

Software used:

Stockassessment.org https://www.stockassessment.org/

Assessment name: HAD7bk_2020_Assessment

C.2. Model Options chosen

SAM assessment configuration file:

```
# Configuration saved: Mon Feb 10 21:50:00 2020
#
# Where a matrix is specified rows corresponds to fleets and columns to ages.
# Same number indicates same parameter used
# Numbers (integers) starts from zero and must be consecutive
#
$minAge
# The minimium age class in the assessment
 0

$maxAge
# The maximum age class in the assessment
 8

$maxAgePlusGroup
# Is last age group considered a plus group for each fleet (1 yes, or 0 no).
 1 0

$keyLogFsta
# Coupling of the fishing mortality states (nomally only first row is used).
 -1  0  1  2  3  4  5  6  6
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$corFlag
# Correlation of fishing mortality across ages (0 independent, 1 compound symmetry, 2 AR(1), 3 separable AR(1).
 2

$keyLogFpar
# Coupling of the survey catchability parameters (nomally first row is not used, as that is covered by fishing mortality).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
  0  1  2  3  4  5  6  7 -1

$keyQpow
# Density dependent catchability power parameters (if any).
 -1 -1 -1 -1 -1 -1 -1 -1 -1
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarF
# Coupling of process variance parameters for log(F)-process (nomally only first row is used)
  0  0  0  0  0  0  0  0  0
 -1 -1 -1 -1 -1 -1 -1 -1 -1

$keyVarLogN
# Coupling of process variance parameters for log(N)-process
 0 1 1 1 1 1 1 1 1

$keyVarObs
# Coupling of the variance parameters for the observations.
  0  0  0  0  0  0  0  0  0
  1  1  1  1  1  1  2  2 -1

$obsCorStruct
# Covariance structure for each fleet ("ID" independent, "AR" AR(1), or "US" for unstructured). | Possible values are: "ID" "AR" "US"
 "ID" "ID"

$keyCorObs
# Coupling of correlation parameters can only be specified if the AR(1) structure is chosen above.
# NA's indicate where correlation parameters can be specified (-1 where they cannot).
#0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8
 NA  NA  NA  NA  NA  NA  NA  NA
 NA  NA  NA  NA  NA  NA  NA  -1

$stockRecruitmentModelCode
# Stock recruitment code (0 for plain random walk, 1 for Ricker, 2 for Beverton-Holt, and 3 piece-wise constant).
 0
```

```
$noScaledYears
# Number of years where catch scaling is applied.
 0

$keyScaledYears
# A vector of the years where catch scaling is applied.


$keyParScaledYA
# A matrix specifying the couplings of scale parameters (nrow = no scaled years, ncols = no ages).

$fbarRange
# lowest and higest age included in Fbar
 3 5

$keyBiomassTreat
# To be defined only if a biomass survey is used (0 SSB index, 1 catch index, 2 FSB index, 3 total catch, 4 total landings and 5 TSB index).
 -1 -1

$obsLikelihoodFlag
# Option for observational likelihood | Possible values are: "LN" "ALN"
 "LN" "LN"

$fixVarToWeight
# If weight attribute is supplied for observations this option sets the treatment (0 relative weight, 1 fix variance to weight).
 0

$fracMixF
# The fraction of t(3) distribution used in logF increment distribution
 0

$fracMixN
# The fraction of t(3) distribution used in logN increment distribution
 0

$fracMixObs
# A vector with same length as number of fleets, where each element is the fraction of t(3) distribution used in the distribution of that fleet
 0 0

$constRecBreaks
# Vector of break years between which recruitment is at constant level. The break year is included in the left interval. (This option is only used in combination with stock-recruitment code 3)
```

SAM forecast source code:

```
library(stockassessment)
load("run/model.RData")

N.SIM <- 10001  # set the number of iterations the the stochastic forecasts
# Note - the number of iterations 10001, up from 1001. All are stable if seed is set - standard "12345" used.
# set to 101 for quick checking
# set to 1001 for routine checking
# set to 10001 preference

################################
## Reference points
# 24-Aug-2020  Ref points updated following inclusion of 2019 data into model.
F_MSY <- 0.353              # 0.312     # Median point estimates of (F05) EqSim with combined SR
F_MSY_lower <- 0.221        # 0.206     # Median lower point estimates of (F05) EqSim with combined SR
F_MSY_upper <- 0.521        # 0.456     # Median upper point estimates of (F05) EqSim with combined SR
Fpa <- 0.708                # 0.92      # F05.   # was Fpa  1.01 in first 2020  Flim combined with the assessment error
Flim <- 1.40                # 1.28      # F with 50% probability of SSB less than Blim
Blim <- 9227                # 9420      # Lowest SBB with above-average recruitment
Bpa <- 12822                # 13089     # Blim combined with the assessment error
MSY_Btrigger <- 12822       # 13089     # Bpa

################################
## TAC & advice for 2020
prev.advice <- 16671             # Input catch advice from proceeding year   ## 2018 advice <- 8358   ## 2017 advice  <- 12444
```

```
prev.TAC <- 10859                              # Input TAC in intermediate year - in assessment year 2018 from COUNCIL REGULATION (EU)
2018/120 - COUNCIL REGULATION 2020_123 TAC.pdf   HAD/7X7A34

## 2019 catch
cur.cat <- 11259                   # From 2019 catch work up "HAD 7b-k International CNAA 93-19-WORKING_July_2020.xlsx"



################################
## Forecast Assumptions

first.yr <-min(fit$data$years)  # First year in the assessment (intermediate year) for help estimating intermediate year Recruitment
final.yr <-max(fit$data$years)  # Final year in the assessment (intermediate year) for help estimating intermediate year Recruitment
R.range.yrs <-seq(first.yr,final.yr,1)  # Resample R from previous years, start of the time series to end of time series (median is calculated)
av.yrs <- final.yr+(-2:0)  # final.yr   # Use last three years for mean weights & L-D partition  ##  final.yr+(-2:0) # this is last three years, so five
years would be: Ay <- lastyear +(-4:0)

F_last <- tail(fbartable(fit),1)[,"Estimate"]
F_sq <- F_last
# Note - F_sq and F_last are (is) the F used for the faorecast,
# This F is "rescaled" over the average proprtional age structure seen in the number of years defined by "av.yrs" above

################################
## forecast names and structure part 1
## Forecasts

scen <- list(
 "MSY approach: F_MSY" = list(fval = c(F_last, F_sq, F_MSY, F_MSY)),
 "Precautionary approach: Fpa" = list(fval = c(F_last,F_sq, Fpa, Fpa)),
 "FMSY upper" = list(fval = c(F_last, F_sq, F_MSY_upper, F_MSY_upper)),
 "FMSY lower" = list(fval = c(F_last, F_sq, F_MSY_lower, F_MSY_lower)),
 "F = 0" = list(fval = c(F_last, F_sq, 0.000001 ,0.000001)),
 "Fpa" = list(fval = c(F_last,F_sq, Fpa, Fpa)),
 "F = Flim" = list(fval = c(F_last, F_sq, Flim, Flim)),
 "Fsq"  = list(fval = c(F_last, F_sq, F_sq, F_sq)),
 "hit Blim" = list(fval = c(F_last, F_sq, NA,NA), nextssb = c(NA, NA, Blim, Blim)),
 "hit Bpa" = list(fval = c(F_last, F_sq, NA,NA), nextssb = c(NA, NA, Bpa, Bpa)) ,
 "hit MSY Btrigger" = list(fval = c(F_last, F_sq, NA, NA), nextssb = c(NA, NA, MSY_Btrigger, MSY_Btrigger))
)

FC <- ""
FC <- vector("list", length(scen))
names(FC) <- names(scen)

for(i in seq(scen)){
 set.seed(12345)
 ARGS <- scen[[i]]
 ARGS <- c(ARGS,
      list(fit = fit, ave.years=av.yrs, rec.years=R.range.yrs, label=names(scen)[i], splitLD=TRUE, nosim = N.SIM))
 FC[[i]] <- do.call(forecast, ARGS)

 print(paste0("forecast : ", "'", names(scen)[i], "'", " is complete"))
}


################################
## forecast names and structure part 2
## ICES advice rule for MSY

MSYappr <- function(fit, Fmsy=NULL, Btrig=NULL, fscale_init=1, fval_init=NA, catchval_init=NA, label=NA)
{
 fscale <- fscale_init
 fval <- fval_init
 catchval <- catchval_init

 for (i in 2:4){
  fscale[i] <- NA
  fval[i] <- Fmsy
  catchval[i] <- NA

  set.seed(12345)
```

```
  f1 <- forecast(fit, fscale=fscale, fval=fval, catchval=catchval, ave.years=av.yrs, rec.years=R.range.yrs, splitLD=TRUE, nosim=N.SIM)
  SSB <- attr(f1,"shorttab")[3,i]
  a <-  (F_MSY / (Btrig-Blim))
  b <- -a*Blim
  if(SSB < Btrig && SSB > Blim) fval[i] <- a*SSB + b
  if(SSB < Blim) fval[i] <- 0.000001
 }

 set.seed(12345)
 f_final <- forecast(fit, fscale=fscale, fval=fval, catchval=catchval, ave.years=av.yrs, rec.years=R.range.yrs, splitLD=TRUE, label=label,
nosim=N.SIM)
 return(f_final)

}

#FC
save(FC, file="run/forecast.RData")
```

C.1. Input data types and characteristics

A plusgroup of 8+ was used. Age group 0 was included in the assessment data to allow inclusion of 0-group indices. However, catch numbers and selectivity-at-age 0 were set to zero in all years because catches at this age were very low or zero.

Discard estimates are included in the catch numbers and weights, therefore catch is explicitly defined here as landings + discards.

The final updated SAM assessment including forecasts and resulting catch options was prepared in www.stockassessment.org, and may be accessed at: HAD7bk_2020_Assessment. The data inputs to this and variables are detailed in Table 5 (also detailing the 2012 ASAP assessment details for reference) and Table 6. With interim year assumptions in the forecast given in Table 6, and the incorporated reference points detailed in Section C.3 and in Table 9.

The basis for the assessment is summarised in Table 8.

Table 5. Summary of Celtic Sea haddock assessment changes adopted during WKCELTIC benchmark, Feb 2020.

Variable	2012 ASAP Assessment	2020 SAM Benchmarked assessment
Catch data	InterCatch raised catch at age data, with discards from 2003 (and prior) estimated from Irish discard rates.	Catch at age data, raised following standardised raising procedure (external to InterCatch) following WKCELTIC data call. Data from 2005 onwards updated in assessment. Data prior to 2004 maintained as previous assessment.
Maturity	Across all years: Age 0 0.000 Age 1 0.000 Age 2 1.000 Age 3 1.000 Age 4 1.000 Age 5 1.000 Age 6 1.000 Age 7 1.000 Age 8 1.000	Across all years: Age 0 0.000 Age 1 0.039 Age 2 0.911 Age 3 0.970 Age 4 0.980 Age 5 1.000 Age 6 1.000 Age 7 1.000 Age 8 1.000
Natural mortality	Across all years: Age 0 0.990 Age 1 0.720 Age 2 0.600 Age 3 0.500 Age 4 0.430 Age 5 0.400 Age 6 0.370 Age 7 0.360 Age 8 0.340	Across all years: Age 0 1.087 Age 1 0.721 Age 2 0.575 Age 3 0.483 Age 4 0.440 Age 5 0.406 Age 6 0.398 Age 7 0.385 Age 8 0.360
Model	ASAP 3 (September 2012) (Age Structured Assessment Program) NOAA Toolbox Catch data Model Min age 1 Min age 0 Max age 8 Max age 8	SAM (State-space fish Stock Assessment) Stockassessment.org Catch data Model Min age 1 Min age 0 Max age 8 Max age 8
Indices	Two: Survey index (combined IGFS-WIBTS-Q4 and EVHOE-WIBTS-Q4) Irish commercial index (IRL_OTB_HAD) catches (age composition of landings and discards)	One: VAST standardised survey index (combined IGFS-WIBTS-Q4 and EVHOE-WIBTS-Q4) 2003 to 2019 Ages 0 to 7
Reference Points	Basis: Type 1: Type 1 Spasmodic stock with occasional large year classes. B_{lim} based off B_{loss} , the lowest observed SSB showing a recovery – was set to 6700 t	Basis: Type 1: Type 1 Spasmodic stock with occasional large year classes. B_{lim} based off B_{loss} , the lowest observed SSB showing a recovery – now set to 9227 t

Table 6. Haddock in divisions 7.b-k. Summmary of data ranges. Input data types and characteristics

Data	Year range	Age range	Variable from year to year
Catch (tonnes)	1993–current	0–8+	Yes
Catch-at-age in numbers (thousands)	1993–current	0–8+	Yes
Landings-at-age^ in numbers (thousands)	1993–current	0–8+	Yes
Discards-at-age^ in numbers (thousands)	1993–current	0–8+	Yes
Weight-at-age in the commercial catch (kg)	1993–current	0–8+	Yes
Weight-at-age in the commercial landings (kg)	1993–current	0–8+	Yes
Weight-at-age in the commercial discards (kg)	1993–current	0–8+	Yes
Weight-at-age of the stock at spawning time (kg).	1993–current	0–8+	Yes
Weight-at-age of the stock at Jan- 1 (same as stock weights)	1993–current	0–8+	Yes
Landings fraction by age	1993–current	0–8+	Yes
Proportion of natural mortality before spawning (Lorenzen M)	1993–current	0–8+	No
Proportion of fishing mortality before spawning	1993–current	0–8+	No
Proportion mature-at-age	1993–current	0–8+	No
Natural mortality	1993–current	0–8+	No

^ Input to SAM is in the form of total catch-at-age. i.e. does not model landings and discards separately. Landings fraction by age incoprorated as a data input.

Table 7. Haddock in divisions 7.b-k. Assumptions made for the interim year and in the forecast.

Variable	Value	Notes
$F_{\text{ages } 3\text{–}5}$ (2020)	0.41	Average F = (2017–2019) scaled to $F_{\text{ages } 3\text{–}5}$ in 2019.
SSB (2021)	71 323	Short term forecast, in tonnes.
$R_{\text{age } 0}$ (2020 - 2021)	351 066	Median resampled (1993–2019) as estimated by stochastic projection; in thousands.
Total Catch (2020)	20 274	Short term forecast; in tonnes.
Projected landings (2020)	9 190	Short-term forecast assuming average 2017–2019 discard pattern; in tonnes.
Projected discards (2020)	11 084	Short-term forecast assuming average 2017–2019 discard pattern; in tonnes.

Table 8. Haddock in divisions 7.b-k. Basis of the assessment and advice.

ICES stock data category	1 (ICES, 2019).
Assessment type	Age-based stochastic analytical assessment (SAM) (ICES, 2020a).
Input data	Commercial catches (age composition of landings and discards); Vector Autoregressive Spatio-Temporal (VAST) standardised survey index (combined IGFS-WIBTS-Q4 and EVHOE-WIBTS-Q4); maturity data (surveys and observer data; constant for all years); Age dependent natural mortality (Lorenzen, 1996).
Discards and bycatch	Included in the assessment for the full time-series. Full observer based estimates from 2005, partial observer based estimates from 1993 to 2004.
Indicators	None.
Other information	This stock was benchmarked in 2020 (ICES, 2020).
Working groups	Working Group for the Celtic Seas Ecoregion (WGCSE)

C.3. Biological reference points

Reference points were calculated with updated 2020 catch data resulting from the assessment in R using the SAM assessment “HAD7bk_2020_Assessment“, with updated data prior to inclusion of the forecast. Reference points were calculated in the statistics package “R”, employing the function “eqsim_run” in the R library “msy”, which simulates the equilibrium results for a population forward in time given biological parameters, fishery parameters and advice parameters.

The Celtic sea haddock was taken as a Type 1 stock, a “Spasmodic stock with occasional large year classes”. Following ICES guidelines, the base of estimating reference points, B_{lim} was based on the lowest SSB where large recruitment was observed (B_{loss}), where F has not been low throughout the observed history (ICES, 2017).

Following this, B_{lim} of 9,227t was based on the B_{loss} (excluding the terminal year of the assessment) which occurred in 1993 (Figure 8).

The assessment of reference points is available as R-markdown “had.27.7b-k_Ref-points_25-6-2020.html”

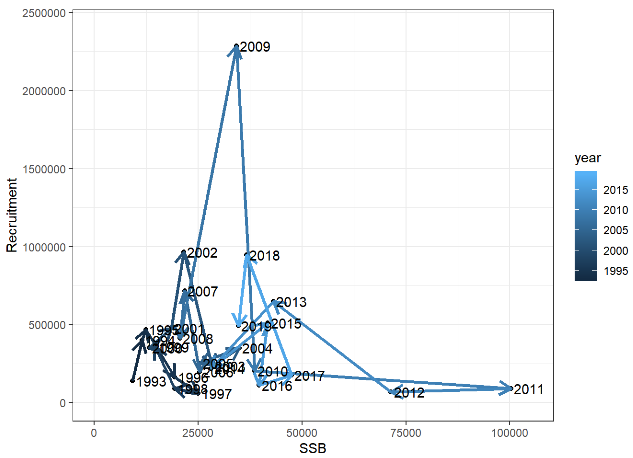


Figure 8. Stock – Recruitment time series 1993 to 2019 of Celtic sea haddock resulting from SAM assessment.

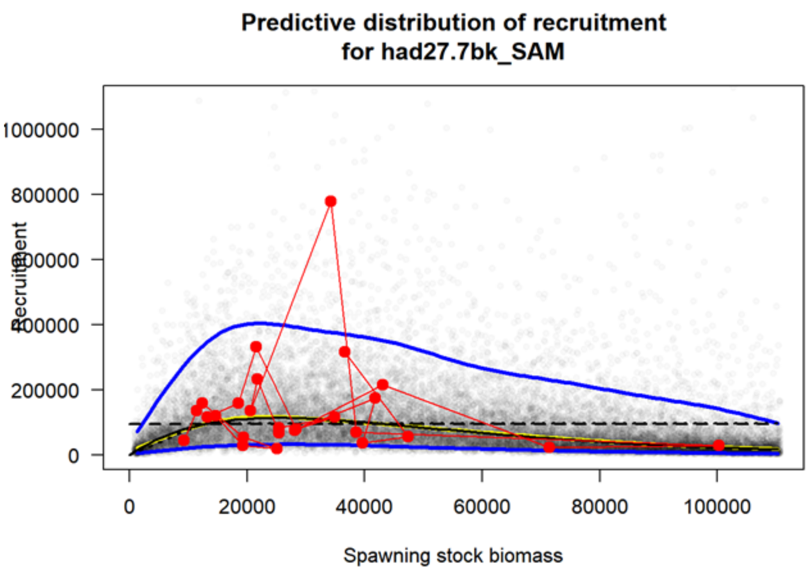


Figure 9. Stock – Recruitment time series 1993 to 2019 of Celtic sea haddock resulting from SAM assessment showing best fit Ricker, Beverton-Holt and Segregated regression fits, and estimate fit points.

Table 9. Reference point estimates.

Framework	Reference Point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	12 822	Tonnes; B_{pa}	ICES (2020)
	F_{MSY}	0.353	Based on simulation using a segmented regression stock–recruitment relationship (EqSim).	ICES (2020)
Precautionary approach	B_{lim}	9227	Tonnes; lowest observed SSB.	ICES (2020)
	B_{pa}	12 822	Tonnes; B_{lim} combined with the assessment error; B_{lim} × exp (1.645 × σ); σ = 0.20 (default setting)	ICES (2020)
	F_{lim}	1.40	F with 50% probability of SSB < B_{lim}.	ICES (2020)
	F_{pa}	0.71	Fp0.5; the F that leads to SSB ≥ B_{lim} with 95% probability.	ICES (2020)
EUMAP	MAP MSY $B_{trigger}$	12 822	Tonnes; MSY B_{pa}.	EU (2019), ICES (2020)
	MAP B_{lim}	9227	Tonnes; lowest observed SSB.	EU (2019), ICES (2020)
	MAP F_{MSY}	0.353	F_{MSY}	EU (2019), ICES (2020)
	MAP range F_{lower}	0.221	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY.	EU (2019), ICES (2020)
	MAP range F_{upper}	0.521	Consistent with ranges resulting in no more than 5% reduction in long-term yield compared with MSY.	EU (2019), ICES (2020)

D. Other Issues

Table 5 detailing the 2012 ASAP and 2020 SAM assessment details.

E. References

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