# 11 Icelandic summer spawning herring

## 11.1 Scientific data

### 11.1.1 Survey description

The scientific data used for assessment of the Icelandic summer-spawning (ISS) herring stock derives from annual acoustic surveys (IS-Her-Aco-4Q/1Q), which have been ongoing since 1973 (Table 11.1.1.1). Normally these surveys are conducted in the period of October–January, but also as late as end of March. The surveyed area each year is decided based on available information on the distribution of the stock in the previous and the current year, which include information from the fishery. Thus, the survey area varies spatially as the survey is focused on the adult and incoming year classes but is considered to cover the whole stock each year.

The acoustic abundance index for the adult stock in the winter 2020/2021 derives from two dedicated acoustic surveys on RV Bjarni Sæmundsson: (1) A survey aiming at herring juveniles in the east and southeast of Iceland in November; (2) A survey in the end of March aiming at the fishable stock at the main overwintering area of the stock west of Iceland.

In addition to getting an acoustic estimate on the adult part and on juveniles at age 1, the objective was also to get an estimate of the prevalence of *Ichthyophonus* infection in the stock. The instrument and methods in the surveys were the same as in previous years. The biological sampling in the survey is detailed in Table 11.1.1.2.

### 11.1.2 The survey results

The fishable part of the Icelandic summer-spawning herring stock was observed mainly in two areas, west of Iceland in Kolluáll in the end of March, and east and southeast of Iceland (Figure 11.1.2.1). The total acoustic estimate, according to these two surveys, came to 3.8 billion in numbers and the total biomass index was 623 kt (Table 11.1.1.1). The fishable part of the stock (≥ 27 cm) accounted for 50% in number and 75% of the biomass, or 465 kt. When considering age, the 2017-year class was the most numerous and accounted for 25% of the total biomass (177 kt), with the 2018 year class next in line with 17% (106 kt).

The annual survey aiming for the abundance of herring juveniles east and southeast of Iceland took place in November 2020. Areas covered (Figure 11.1.2.1) were different from previous years, with the distribution more to the south. The juvenile survey is specially aimed for assessing the number-at-age 1. This is different from number-at-age 2, because number-at-age 1 has been shown to give a signal of year class strength later at age 3 (Gudmundsdottir *et al.,* 2007). The herring juvenile survey has been conducted in a comparable way since 1980, with gaps in the time series.

A widespread ichthyophoniasis epizootic infection has been occurring in ISS-herring since 2008. This is caused by the parasite *Ichthyophonus* sp. Results of comprehensive analyses for the period 2008–2014 imply that significant infection mortality took place in the first three years after the outbreak started (2009–2011) but not the years after (2012–2016; Óskarsson *et al.*, 2018b). The level of the mortality was estimated with series of runs of the NFT-adapt assessment model, which gave the best fit to the data when applying infection mortality equivalent to 30% of the infected herring (heart inspection and survey abundance estimates provided $M_{infected}$) died annually in the first three years of the outbreak ($M_{year,\ age} = M_{fixed} + M_{infected,\ year,\ age} \times 0.3$; Table 11.3.2.1). The prevalence of the *Ichthyophonus* infection in the stock in 2020/21 was estimated in a same way as has been done since the initiation of the infection in the autumn 2008 (Óskarsson and Pálsson, 2018). The prevalence of infection shows a declining trend for all age classes for the past decade. The infection rate for the large 2017-year class seems to be low, or 5.4% in the west and 15% in the southeast (Figure 11.1.3.1.) There are still new infections taking place as seen with the younger ages, so infection mortality is assumed to take place in 2021, like in previous years. Thus, in the stock prognosis (Section 11.6), the abundance estimates from the final year of the assessment (1 January 2021) is lowered by this additional M as done in assessments for the past years. The level of M should then follow the results by Óskarsson *et al.* (2018b), where age specific $M_{infected}$ (estimated from the catch samples; Figure 11.1.3.1) is multiplied by 0.3 and the fixed M (0.1) added to it. These M for 2020 (Table 11.3.2.1) should be used in the prognosis in 2021 and in the analytical assessment from 2021 and onwards, until better more reliable estimates become available.

## 11.2 Information from the commercial fishery

The total landings of ISS herring in 2020/2021 season was 36 100 t with no discards reported (Table 11.2.1 and in Figure 11.2.1). This includes also bycatches of ISSH in the mackerel and Norwegian spring-spawning herring (NSSH) fisheries in June–November 2020, where the part caught in June–August belongs to the official fishing season September 2019/August 2020. Including the summer catches in the subsequent fishing season, as done here, is a traditional handling of the catch data when assessing this stock. The quality of the herring landing data regarding discards and misreporting are consider adequate as implied in the Her-Vasu stock annex.

The recommended TAC for 2020/2021 fishing season (September–August; ICES, 2018) and TAC (Regulation No. 672, 2 July 2020) was 35.5 kt (Table 11.2.1). Officially, according to the Directorate of Fisheries (http://www.fiskistofa.is/veidar/aflaupplysingar/heildaraflamarksstada/), 36.1 kt had been caught in April 2021, slightly above the TAC.

The direct fishery in offshore areas west of Iceland in November-February contributed 44% (15.8 kt) of the total catches (Figure 11.2.2). The remaining 56% (20.3 kt) of the catch was taken as bycatch in the fishery for mackerel in the southwest in June-July (3.4 kt), and in the fishery for mackerel and NSS-herring in the east in June-July (4.4 kt) and September-November (12.5 kt) (Figure 11.2.2).

### 11.2.1 Fleets and fishing grounds

The herring fishing season has taken minor changes in the last three decades as detailed in the stock annex. All seasonal restricted landings, catches and recommended TACs since 1985 are given in thousands of tonnes (kt) in Table 11.2.1.

All the catch in 2020/2021 was taken in pelagic trawls (Figure 11.2.1), which reflects that both the targeting and bycatch fisheries takes mainly place in offshore areas. During all fishing seasons from 2007/2008 to 2012/2013, most of the catches (~90%) were taken in inshore areas west off Iceland in Breiðafjörður, while prior to that they were mainly taken off the south-, southeast-, and the east coast. In 2013/2014 there was an indication for changes in this pattern, with less proportion in Breiðafjörður, and then in 2014/2015 almost all the overwintering west of Iceland took place offshore, which continued this winter. These changes in the stock distribution explain the dominance of pelagic trawl in the fishery, which is preferred by the fleet over purse seine in offshore areas.

To protect juvenile herring (27 cm and smaller) in the fishery, area closures are enforced based on a regulation of the herring fishery set by the Icelandic Ministry of Fisheries (no. 376, 8 October

1992). No closure was enforced in this herring fishery in 2020/21. Normally, the age of first recruitment to the fishery is age-3, which is fish at length around 26–29 cm.

### 11.2.2 Catch in numbers, weight at age and maturity

#### Catch at age in 2020/2021:

The procedure for the catch at age estimations, as described in the Stock Annex, was followed for the 2020/21 fishing season. It involves calculations from catch data collected at the harbours by the research personnel (0%) or at sea by fishermen (100%). This year, the calculations were accomplished by dividing the total catch into four cells confined by season and area. In the same way, weight-at-length relationships derived from the length and weight measurements of the catch samples were used. On basis of difference in length-at-age between the summer months and the winter, four length-age keys were applied. The catches of the Icelandic summer spawners in number-at-age for this fishing season as well as back to 1975 are given in Table 11.2.2.1. The geographical location of the sampling in 2020/2021 is shown on Figure 11.2.2.

#### Weight at age:

As stated in the stock annex, the mean weight-at-age of the stock is derived from the catch samples (Table 11.2.2.2).

#### Proportion mature:

The fixed maturity ogives were used in this year's assessment, as described in detail in the stock annex, where proportion mature-at-age 3 is set 20% and 85% for fish at age 4, while all older fish is considered mature.

## 11.3 Analytical assessment

### 11.3.1 Analysis of input data

Examination of catch curves for the year classes from 1987 to 2016 (Figure 11.3.1.1) indicates, in general, that the total mortality signal (Z) in the fully recruited age groups is around 0.4. It is under the assumption that the effort has been the same the whole time. In recent years the effort has changed a lot because of the infection and spatial distribution of the stock, and the mass mortality in 2012/2013, which makes any strong deductions from the catch curves for those recent less meaningful.

Catch curves were also plotted using the age disaggregated survey indices for each year class from 1987–2016 (Figure 11.3.1.2). Even if the total mortalities look at bit noisy for some year classes, they seem to be fairly close to 0.4. There is an indication that the fish is fully assessable to the survey at age 3–5.

Increased mortality in the stock because of the *Ichthyophonus* outbreak cannot be detected clearly from the catch curves of the surveys. However, considering that F was reduced drastically in the beginning of the outbreak, similar Z means an increased M during that period, representing infection mortality.

### 11.3.2 Exploration of different assessment models

#### Input data:

In order to explore the data this year, two models were run, NFT-ADAPT (VPA/ADAPT version 3.3.0 NOAA Fisheries Toolbox) that has been used as the basis for the assessments since 2005 and a separable model (Muppet) also used in the MSE in 2017 for the stock (ICES 2017b; Björnsson 2018) as well as analytical assessment of Icelandic saithe. Applying NFT-ADAPT was evaluated at benchmark assessment in January 2011 (ICES, 2011a) and it found to be appropriate as the principal assessment tool for the stock. The catch data used were from 1987/88–2020/21 (Table 11.2.2.1) and survey data from 1987/88–2020/21 (Table 11.1.1.1). Other input data consisted of: (i) mean weight at age (Table 11.2.2.2); (ii) maturity ogive (Table 11.2.2.3); (iii) natural mortality, M, that was set to 0.1 for all age groups in all years, except for 2009–2011 and 2017–2020 where additional age dependent mortality was applied because of the *Ichthyophonus* infection (see Section 11.1.3; Table 11.3.2.1; Óskarsson *et al.*, 2018b); (iv) proportion of M before spawning was set to 0.5; and (v) proportion of F before spawning was set to 0. Thus, in comparison to last year's assessment, all the input data are the same with an additional year of data.

## Results:

The estimated parameters in NFT Adapt are the stock in numbers at age. The parameters are output by the Levenburg-Marquardt Non-Linear Least Squares minimization algorithm (see VPA/ADAPT Version 3.3.0, Reference Manual). The estimated parameters were stock numbers for ages 4 to 12 in the beginning of year 2021, while the stock numbers at age 3 was derived from survey estimates in 2020 (i.e. projection from age-1 survey index to age-3 according to Gudmundsdóttir *et al.,* 2007 and recommended by ICES (2011a)) instead of geometric mean as default in the model. Like in last years' assessments, the *input partial recruitment* was set to 1 for ages 4 and older and the *classic* method was used to calculate the value of fully-recruited fishing mortality in the terminal year.

The catchability at age in the survey, as estimated by the NFT Adapt, and the CV is shown in Figure 11.3.2.1. The age groups 3–10 were used for tuning (Table 11.1.1.1 as decided at the benchmark in ICES (2011a). In comparison to last year, the catchability of the survey is relatively the same with similar uncertainty.

The output and model settings of the NFT-Adapt run (the adopted final assessment model) are shown in Table 11.3.2.2. Stock numbers and fishing mortalities derived from the run are shown in Table 11.3.2.3 and Table 11.3.2.4, respectively, and summarized in Table 11.3.2.5 and Figure 11.3.2.2.

Residuals of the model fit are shown in Figure 11.3.2.3 and Table 11.3.2.6, and shows both cohort and year affects. The main pattern is the same as presented in recent assessments. Positive residuals, where the model estimates are smaller than seen in the survey, can be seen for 1994- and 1999-year classes for almost all age groups and negative residuals for the 2001 and 2003 year classes. Year blocks of positive residuals are apparent for the years ~2000 to 2006 (i.e. referring to 1 January). During these years, the stock was overwintering in offshore areas off the east and west coast, compare to mainly easterly distribution before and overwintering in inshore areas there after (from ~2006–2012). These positive blocks could therefore reflect changes in catchability of the survey for these years. After 2008 the residuals are generally behaving well.

Retrospective analyses indicate a consistency over the most recent six years, i.e. adding new data to the model does not change the present perception of the stock size much (Figure 11.3.2.4). The small upward revision for the last years is likely caused by the increased M in 2017 and 2018 (due to infection mortality), and for compensating for it, the model increased the stock size back in time. This is a pattern seen before (ICES, 2017c). The retros for the fishing mortality and recruits behave, in a same way, well for the last four years.

Like demonstrated and analysed earlier (ICES, 2014), the main difference between observed and predicted survey values from the NFT-Adapt model was for the period 1999–2004, where the observed values were well above the predicted (Figure 11.3.2.5), otherwise they fitted relatively well. Like seen in the residual plot (Figure 11.3.2.3), the observed value for the 2009 survey was lower than predicted and the vice versa for the 2012 survey (referring to the beginning of the year; Figure 11.3.2.5). The low survey value in 2009 is likely underestimate due to distribution of the stock that year in the fjord west of Iceland (Breiðafjörður; Óskarsson *et al.*, 2010), while the positive block during 2000–2004 was previously found to be mainly caused by the large 1999-year class (ICES, 2014) and possibly changes in the catchability of the survey as suggested above. However, an exploratory run in NFT-Adapt done in the 2011 assessment (ICES, 2011b) where these years were excluded in the tuning, did not change the point estimate of the stock size in the latest year (1 January 2011), implying that the terminal point estimates in the final run was not driven by this residual block.

Comparisons of different models:

The two models explored, NFT-Adapt and the separable model (Muppet), gave very similar results, and especially for the latest years of the assessments (Figure 11.3.2.2). This indicates that the results are driven by the input data and not by the model used.

### 11.3.3 Final assessment and TAC advice on basis of Management Plan

In this update assessment, where the 2020/21 catch and survey data have been added to the input data, additional natural mortality was applied for 2020 because of the *Ichthyophonus* infection in the stock. The same approach was used as for 2009–2011 and 2017-2020 where the applied mortality corresponds to that 30% of infected herring died.

The results from the analytical assessment model, NFT-Adapt, indicate that the stock size has increased because of an upward revision in the stock size, due to a large 2017 year-class entering the fishery at age 4 this autumn. Spawning stock biomass for 2021 is estimated 377.1 kt and the reference biomass of age 4+ ($B_{Ref}$) is 481.6 kt in the beginning of the year 2021. As the SSB will be above MGT $B_{trigger}$ = 200 kt, the advised TAC according to the Iceland Management Plan is $HR_{MGT} \times B_{Ref} = 0.15 \times 481\,594 = 72\,239$ tonnes.

## 11.4 Reference points and the Management plan

Precautionary approach reference points:

The working group points out that managing this stock at an exploitation rate at or above $F_{0.1} = F_{MSY} = 0.22$ has been successful in the past for almost 30 years, despite biased assessments. At the 2016 NWWG meeting, the PA reference points for the stock were verified and revised (ICES, 2016). On basis of the stock-recruitment relationship deriving from time-series ranging from 1947–2015, keeping $B_{lim}$ = 200 kt was considered reasonable as the Study Group on Precautionary Reference Points for Advice on Fishery Management concluded also in February 2003. Other PA reference points were derived from $B_{lim}$ and these data in accordance to the ICES Advice Technical Guidelines and became these: $B_{pa}$ = 273 kt ($B_{pa} = B_{lim} \times e^{1.645\sigma}$ , where $\sigma = 0.19$); $F_{lim}$ = 0.61 (F that leads to SSB = $B_{lim}$, given mean recruitment); $F_{pa}$= 0.43 ($F_{pa} = F_{lim} \times \exp(-1.645 \times \sigma)$ , where $\sigma = 0.18$).

MSY based reference points:

At a NWWG meeting in 2011 an exploratory work, using the HCS program Version 10.3 (Skagen, 2012), was used to evaluate possible points based on the MSY framework that could be a basis for a management plan and Harvest Control Rule later (ICES, 2011b). Number of different runs was made with varying settings. The results implied that the MSY framework was confirmative with the currently used precautionary reference points. It means that the currently used $F_{0.1} = 0.22$ could be a valid candidate for $F_{MSY}$. During a Management Strategy Evaluation (MSE) for the stock in April 2017 (ICES, 2017b), $F_{MSY} = 0.22$ was not considered to be significantly different from results of simulation giving 0.24. Thus, it was concluded adequate to keep $F_{MSY} = 0.22$.

### Management plan

A Management Strategy Evaluation (MSE) for the stock took place in 2017 (ICES, 2017b). Five different HCRs were tested and all of them, except for the advisory rule applied at that time ($F_{MGT} = 0.22$), were considered precautionary and in accordance with the ICES MSY approach. One of these HCR was later adopted by Icelandic Government as a Management plan for the stock. This HCR is based on reference biomass of age 4+ in the beginning of the assessment years ($B_{ref,\ Y}$), a spawning stock biomass trigger (MGT $B_{trigger}$) is defined as 200 kt, and the harvest rate ($HR_{MGT}$) is set as 15% of the reference biomass age4+ in the beginning of the assessment year. In the assessment year (Y) the TAC in the next fishing year (1 September of year Y to 31 August of year Y+1) is calculated as follows:

When $SSB_Y$ is equal or above MGT $B_{trigger}$:

$TAC_{Y/y+1} = HR_{MGT} * B_{Ref,y}$

When $SSB_Y$ is below MGT $B_{trigger}$:

$TAC_{Y/y+1} = HR_{MGT} * (SSB_y/\text{MGT } B_{trigger}) * B_{ref,y}$

In the MSE simulation, the ongoing *Ichthyophonus* epidemic was considered to continue and was accounted for. Consequently, this HCR is independent of estimated level of *Ichthyophonus* mortality and requires no further action during such epidemics.

The distribution of the realized harvest rate when the HCR is followed showed that the 90% expected range are within a harvest rate of 0.099–0.22 with no bias and 0.122–0.247 if bias is applied. The recent realized harvest rates are within the above range.

## 11.5 State of the stock

The stock was at high levels around 2002 but showed a steady decline to 2017 despite a low fishing mortality. The reduction is a consequence of mortality induced by the *Ichthyophonus* outbreak in the stock in 2009–2011 and 2016–2018 in addition to small year classes entering the stock since around 2005, particularly the 2011–2014-year classes. Survey indices from autumn 2020 and spring 2021 indicate that the 2017-year class is well above average and will enter the fishable stock in autumn 2021, causing an upward revision of the stock size.

## 11.6 Short term forecast

### 11.6.1 The input data

The final adopted model, NFT-Adapt, which gave the number-at-age on 1 January, 2021, was used for the prognosis. All input values for the prognosis are given in Table 11.6.1.1. Because of the expected *Ichthyophonus* mortality in the stock in the spring 2021 (see Section 11.1.3), the NFT-Adapt model output were reduced according to the infection ratios times 0.3 (Table 11.3.2.1), or the same approach as used in the assessments in 2009–2011 and 2018–2020 (ICES, 2011b; 2018a; Óskarsson *et al.*, 2018b).

The weights were estimated from the last year catch weights (see Stock Annex) and as in the recent years, the weights are expected to continue to be high, except for the youngest age groups, which is though still well within observed range (Figure 11.6.1.1). The weight for age 3 was set equal to the value used in 2020 (ICES; 2020) because the weight deriving from the formula provided in the Stock Annex gave much lower and unrealistic value.

In summary, the basis for the stock projection is as follows: SSB(2021) = 377 kt; Biomass age 4+ (1 January 2021) = 481.6 kt; Catch (2020/21) = 36.1 kt; $WF_{5-10}$(2020) = 0.228; HCR (2020) = 0.15.

### 11.6.2 Prognosis results

SSB in the beginning of the fishing season 2021/22 (approximately the same time as spawning in July 2021) is estimated to be 377 kt, which is above MGT $B_{trigger}$ of 200 kt. Consequently, advised TAC on basis of the Management rule is 0.15 × Biomass 4+ (481 594 kt) = 72 239 kt. This results in $F_{W5-10}$ = 0.217 in 2021/22 and SSB = 421 132 kt in 2022 (Table 11.6.2.1). The results of different options are given in Table 11.6.2.1.

## 11.7 Medium term predictions

Because of the increased uncertainty of the assessment in relation to the development of the *Ichthyophonus* outbreak in the coming months and years, the uncertainty in size of the recruiting year classes, and the new management rule, no medium-term prediction is provided.

## 11.8 Uncertainties in assessment and forecast

### 11.8.1 Uncertainty in assessment

There are number of factors that could lead to uncertainty in the assessment. Two of them are addressed here. Additional natural mortality caused by the *Ichthyophonus* infection was set for the first three years of the outbreak (2009–2011) and in 2017-2020 ($M_{infected, age, year}$ multiplied by 0.3 (see Section 11.1.3). This quantification of the infection mortality based on Óskarsson *et al*. (2018b), was considered to improve the assessment and reduce its uncertainty. For the most recent years, where new infection reappeared (2017–2020), more accurate estimation of the infection mortality will be possible in the years to come but until then, this approach will add uncertainty to the assessment. Worth noticing, increasing M has been shown to increase the historical perception of the stocks size but has minor impacts on the assessment of the final year and the resulting advice.

The signals from the last catches and the surveys give somewhat contradicting results about the size of the 2013–2015-year classes (Figure 11.2.2.1), even if all of them appears to be small, particularly the 2014-year class. The size of these year classes is therefore not very well determined yet, which adds uncertainty to the assessment. Considering that the direct winter fishery west of Iceland is not targeting these year classes, which are mainly found southeast and east of Iceland, their size is more likely to be underestimated in the analytical assessment.

### 11.8.2 Uncertainty in forecast

It is important to notice that the advice for 2019/2020 fishing season deriving from the Management plan is independent of the forecast and its uncertainty as it is only based on the reference biomass in the beginning of the assessment year. The uncertainty in the assessment mentioned above related to the apparent new infection in the stock in 2017–2019 and size of the recruiting year classes, apply also for the forecast.

Moreover, the number-at-age 3 in the beginning of the year 2019 used in the prognosis (360 millions) was predicted from a survey estimate of number at age 1 in 2017 in accordance with the approach described in the Stock Annex. This index derives from an incomplete survey but is used here as it is in accordance with the Stock Annex, the survey covered the single most important nursery grounds of the stock (Eyjafjörður), it was considered to be more appropriate than applying geometric mean, and this decision has no impact on the fishing advice. Thus, the resulting stock size in 2020 is likely to be too pessimistic.

### 11.8.3 Assessment quality

For a period, there was concerns regarding the assessment because of retrospective patterns of the results. No assessment was provided in the 2005 due to data and model problems and in the two next consecutive years, ACFM rejected the assessment due to the retrospective pattern. In the assessments in 2007–2009 there was observed an improvement in the pattern from NFT-Adapt, while in 2010–2011, a retrospective pattern appeared again which was both related to the high M because of the *Ichthyophonus* infection but also due to new and more optimistic information about incoming year classes to the fishable stock (particularly the 2008-year class) and fishing pattern in recent year. The retrospective pattern in the last five and this year's assessment are less than seen for many years for SSB and F (Figure 11.3.2.4). Simultaneously the residuals from the survey are behaving better than before (Figure 11.3.2.3). This together could be interpreted as indications for improvements in the assessment quality in recent years in comparison to the years before. The small retros in the SSB for this year's assessment is considered to be related to the additional infection mortality set for 2017–2018, where the model increase the stock size back in time to compensate for the increase M.

As stated in the 2017 NWWG report (ICES, 2017c), the revision of the infection mortality applied in the analytical assessment for the years 2009–2011 in accordance to the estimated mortality levels (Section 11.1.3), is also considered as an improvement of the assessment. Thus, the downward revision of the stock size over the period ~2003–2011 compared to the last year's assessment (Figure 11.3.2.2) is considered to provide more robust figure of development in the historical stock's size.

## 11.9 Comparison with previous assessment and forecast

This year's assessment was conducted in the same way as in last year, apart from the correction on the survey indices from 2017 (see Section 11.2.3). Additional natural mortality was applied to 2017–2018 because of the infection (see Section 11.1.3), which caused an upward revision of the stock size for the most recent years (Figure 11.3.2.4). When the estimates for 1 January 2018 are compared with last year's assessment, the results of the final NFT run in 2019 gives a more optimistic view on the size of the small 2013- and 2014-year classes (Figure 11.3.2.6). Apart from that there is not a big difference. Note that the estimate of the 2015-year class in 2018 was based on a survey estimation while in the assessment model in 2019.

## 11.10 Management consideration

Inspections indicate still a high prevalence of heart lesions related to *Ichthyophonus hoferi* in the herring stock. More importantly, new infection has been taken place in the stock last three winters but possibly with a decreased intensity in 2018/2019. Significant new infection was otherwise last observed in 2010 (Óskarsson *et al.*, 2018b). Correspondingly, induced mortality due to the infection was unavoidably applied for 2017–2019, and this second outbreak might continue in the coming year. Considering the presently low stock size, the ongoing second outbreak, and continuing poor year classes entering the fishable stock, the stock size will most likely remain at low level in the next two years and be between $B_{lim}$ and MSY $B_{trigger}$. The survey results implying large 2017-year class might change this situation from 2021 onwards when it starts to enter the fishable stock.

## 11.11 Ecosystem considerations

The reason for the outbreak of *Ichthyophonus* infection in the herring stock that was first observed in the autumn 2008 is not known but is probably the effect of interaction between environmental factors and distribution of the stock (Óskarsson *et al.* 2009). It includes that outbreak of *Ichthyophonus* spores in the environment, which infect the herring via oral intake (Jones and Dawe, 2002), could be linked to the observed increased temperature off the southwest coast. Further researches on the causes and origins of such an outbreak are ongoing at MFRI. It involves scanning for *Ichthyophonus* DNA in zooplankton species that the herring feeds on with PCR (Polymerase chain reaction) technique. Results from that work (MS thesis) can be expected in the summer 2019, while preliminary results indicate that the source of the infection is widespread and is in various zooplankton groups and species. With respect to the impacts of the outbreak on the herring stock, recent analyses show that significant additional mortality took place over the first three years only (Óskarsson *et al.*, 2018b), despite a high prevalence of infection for now nine years. As pointed out above, a new infection since the summer 2016 is however, expected to cause significant mortality again. For how long time this outbreak will last is unknown as this is basically an unprecedented outbreak. The signs of the infection that is found in the stock will most likely remain for some years, even if no new infection will occur, and then decrease and disappear over some years as new year classes replace the older ones. The observed new infection will however delay this process.

All general ecosystem consideration with respect to the stock can be found in the Ecosystem Overview for the Icelandic Ecoregion (ICES, 2017a).

## 11.12 Regulations and their effects

The fishery of the Icelandic summer-spawning herring is limited to the period 1 September to 1 May each season, according to regulations set by the Icelandic Fishery Ministry (**no. 770, 8 September 2006**). Several other regulations are enforced by the Ministry that effect the herring fishery. They involve protections of juvenile herring (27 cm and smaller) in the fishery where area closures are enforced if the proportion of juveniles exceeds 25% in number (no. 376, 8 October 1992). No such closures took place in 2020/2021. Another regulation deals with the quantity of bycatch allowed. Then there is a regulation that prohibits use of pelagic trawls within the 12 nautical miles fishing zone (**no. 770, 8 September 2006**), which is enforced to limit bycatch of juveniles of other fish species.

## 11.13 Changes in fishing technology and fishing patterns

There are no recent changes in fishing technology which may lead to different catch compositions. The fishing pattern in the seasons 2014/2015 to 2020/2021 was different from the previous nine seasons. Instead of fishing near only in a small inshore area off the west coast in purse seine, the directed fishery took place in offshore areas west and east of Iceland by pelagic trawls. These changes are not considered to affect the selectivity of the fishery because the fishery is still targeting dense schools of overwintering herring in large fishing gears, getting huge catches in each haul and is by none means size selective.

Bycatch of Icelandic summer-spawning herring in summer fishery for NE-Atlantic mackerel and Norwegian spring-spawning herring has been taken place since around mid-2000s. Until that time, no summer fishery on this stock had taken place for decades. Part of this bycatch is on the stock components (e.g. juveniles and herring east of Iceland) that are not fished in the direct fishery on the overwintering grounds in the west. However, these bycatches are well sampled and contributes normally to less than 10% of the total annual catch, but were as high as 37% in the season 2017/2018. It can be explained by the low TAC, so the fleet did not have much quota left for direct autumn fishery. Still, the impacts of these changes on the assessment are considered to be insignificant.

The fishing pattern varies annually as noted in Section 11.2 and it is related to variation in winter distribution of the different age classes of the stock. This variation can have consequences for the catch composition but it is impossible to provide a forecast about this variation.

## 11.14 Species interaction effects and ecosystem drivers

The WG have not dealt with this issue in a thoroughly and dedicated manner. However, some work has been done in this field in recent years in one way or another.

Regarding relevant researches on species interaction, the main work relates to the increasing amount of North East Atlantic mackerel (NEAM) feeding in Icelandic waters after 2006 (Astthorsson *et al.*, 2012; Nøttestad *et al.*, 2016). Surveys in the summers since 2010 indicate a high overlap in spatial and temporal distribution of NEAM and Icelandic summer-spawning herring (Óskarsson *et al.*, 2016). Moreover, the diet composition of NEAM in Icelandic waters showed a clear overlap with those of the two herring stocks, i.e. Icelandic summer-spawning herring and Norwegian spring-spawning herring (Óskarsson *et al.*, 2016). Even if copepoda was important diet group for all the three stocks its relative contribution to the total diet was apparently higher for NEAM than the two herring stocks. Considering former studies of herring diet, this finding was unexpected, and particularly how little the copepoda contributed to the herring diet. This difference in the stomach content of NEAM and the two herring stocks indicated that there could be some difference in feeding ecology between them in Icelandic waters, where NEAM preferred copepoda, or feed in the water column where they dominate over other prey groups, while the opposite would be for the herring and the prey Euphausiacea. Recent studies in the Nordic Seas have shown similar results (Langøy *et al.*, 2012; Debes *et al.*, 2012). The indication for difference in feeding ecology of the species is further supported by the fact that the body condition of the two herring stocks showed no clear decreasing trend since the invasion of NEAM started into Icelandic waters. On the contrary the mean weights-at-age (and at-length) of the summer spawners have been high after 2010 (Óskarsson, 2019b) and for example record high in the autumn 2014 (Figure 11.6.1.1). It should though be noted that comparison of the diet composition of herring in recent years to earlier studies, mainly on NSS herring, indicate that the herring might have shifted their feeding preference towards Euphausiacea instead of Copepoda. That is possibly a consequence of increased competition for food with NEAM, where the herring is overwhelmed and shifts towards other preys.

The WG is not aware of documentations of strong signals from ecosystem or environmental variables that impact the herring stock and could possibly be a basis for implementing ecosystem drivers in the analytical basis for its advice. For example, recruitment in the stock has been positively, but weakly, linked to NAO winter index (North Atlantic Oscillation) and sea temperature (Óskarsson and Taggart, 2010), while indices representing zooplankton abundance in the spring have not been found to impact the recruitment (Óskarsson and Taggart, 2010) or body condition and growth rate of the adult part of the stock (Óskarsson, 2008). Considering these relations derived from the historical data, relatively warm waters around Icelandic (MRI 2016), and high positive NAO in recent years (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml), it was concluded in last year's report (ICES, 2018) that we could expect a good recruitment in the stock. It seems to be coming about with an encouraging first measurement of the 2017-year class.

## 11.15 Comments on the PA reference points

The WG dealt with the reference points in 2016 and revised them in accordance to the ICES Technical Guidelines (ICES, 2016).

## 11.16 Comments on the assessment

The assessment shows that the stock size was declining 2000–2018 due to a combination of *Ichthyophonus* mortality and series of below average and poor year classes entering the stock. The 2017-year class entering the reference biomass and SSB in 2021 is estimated large and will cause an upward revision from last year's assessment.

There is compelling evidence for new infection by *Ichthyophonus* in the stock in the winter 2021/22, even if less intensive than in the years before. This called for applying additional infection mortality. This current outbreak adds uncertainty to the assessment and advice.

## 11.17 References


Astthorsson, O. S., Valdimarsson H., Gudmundsdottir, A., Óskarsson, G. J. 2012. Climate-related variations in the occurrence and distribution of mackerel (*Scomber scombrus*) in Icelandic waters. ICES Journal of Marine Science. 69: 1289–1297.

Björnsson, H. 2018. Icelandic herring. ICES North Western Working Group, 27 April - 4 May 2018, Working Document No. 20. 2 pp.

Debes, H., Homrum, E., Jacobsen, J. A., Hátún, H., and Danielsen, J. 2012. The feeding ecology of pelagic fish in the southwestern Norwegian Sea – Inter species food competition between herring (*Clupea harengus*) and mackerel (*Scomber scombrus*). ICES CM 2012/M:07. 19 pp.

Guðmundsdóttir, Á., G.J. Óskarsson, and S. Sveinbjörnsson 2007. Estimating year-class strength of Icelandic summer-spawning herring on the basis of two survey methods. ICES Journal of Marine Science, **64**: 1182–1190.

ICES. 2011a. Report of the Benchmark Workshop on Roundfish and Pelagic Stocks (WKBENCH 2011), 24–31 January 2011, Lisbon, Portugal. ICES CM 2011/ACOM:38. 418 pp.

ICES. 2011b. Report of the North Western Working Group (NWWG), 26 April - 3 May 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:7. 975 pp

ICES. 2014. Report of the North Western Working Group (NWWG), 24 April-1 May 2014, ICES HQ, Copenhagen, Denmark. ICES CM 2014/ACOM:07. 902 pp.

ICES. 2016. Report of the North-Western Working Group (NWWG), 27 April–4 May, 2016, ICES Headquarters, Copenhagen. ICES CM 2016/ACOM:08.

ICES. 2017a. Icelandic Waters ecoregion – Ecosystem overview. http://ices.dk/sites/pub/Publication%20Reports/Advice/2017/2017/Ecosystem_overview-Icelandic_Waters_ecoregion.pdf

ICES. 2017b. Report of the Workshop on Evaluation of the Adopted Harvest Control Rules for Icelandic Summer Spawning Herring, Ling and Tusk (WKICEMSE), 21–25 April 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:45. 49 pp.

ICES. 2017c. Report of the North Western Working Group (NWWG), 27 April – 4 May 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:08. 642 pp.

ICES. 2018. Report of the North-Western Working Group (NWWG), 26 April–3 May, 2018, ICES HQ, Copenhagen, Denmark. ICES CM 2018/ACOM:09. 733 pp.

Jones, S.R.M. and Dawe, S.C., 2002. *Ichthyophonus hoferi* Plehn & Mulsow in British Columbia stocks of Pacific herring, *Clupea pallasi Valenciennes*, and its infectivity to chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Diseases 25, 415-421.

Langøy, H., Nøttestad, L., Skaret, G., Broms, C. and Fernö, A. 2012. Overlap in distribution and diets of Atlantic mackerel (*Scomber scombrus*), Norwegian spring- spawning herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) in the Norwegian Sea during late summer. Marine biology research, 8: 442–460.

MRI 2016. Environmental conditions in Icelandic waters 2015. Marine and Freshwater Research Institute. HV 2016-001, ISSN 2298-9137 (https://www.hafogvatn.is/is/midlun/utgafa/haf-og-vatnarannsoknir/thaettir-ur-vistfraedi-sjavar-2015)

Nøttestad, L., Utne, K.R., Guðmundur J. Óskarsson, Sigurður Þ. Jónsson, Jacobsen, J.A., Tangen, Ø., Anthonypillai, V., Aanes, S., Vølstad, J.H., Bernasconi, M., Debes, H., Smith, L., Sveinn Sveinbjörnsson, Holst, J.C., Jansen, T. og Slotte, A. 2016. Quantifying changes in abundance, biomass and spatial distribution of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic seas from 2007 to 2014. ICES Journal of Marine Science, 73: 359-373.

Óskarsson, G.J. 2008. Variation in body condition, fat content and growth rate of Icelandic summer-spawning herring (*Clupea harengus* L.). Journal of Fish Biology 72: 2655–2676.

Óskarsson, G.J. 2019. Estimation on number-at-age of the catch of Icelandic summer-spawning herring in 2018/2019 fishing season and the development of *Ichthyophonus* sp. infection in the stock. ICES North Western Working Group, 25 April - 1 May 2019, Working Document No. 5. 15 pp.

Óskarsson, G.J. and C.T. Taggart 2010. Variation in reproductive potential and influence on Icelandic herring recruitment. Fisheries Oceanography. 19: 412–426.

Óskarsson, G.J. and Pálsson, J. 2017. Estimation on number-at-age of the catch of Icelandic summer-spawning herring in 2016/2017 fishing season and the development of *Ichthyophonus hoferi* infection in the stock. ICES North Western Working Group, 27 April - 4 May 2017, Working Document No. 10. 15 pp.

Óskarsson, G.J. and Pálsson, J. 2018. Estimation on number-at-age of the catch of Icelandic summer-spawning herring in 2017/2018 fishing season and the development of *Ichthyophonus* sp. infection in the stock. ICES North Western Working Group, 27 April - 4 May 2018, Working Document No. 2. 15 pp.

Óskarsson, G.J., J. Pálsson, and Á. Guðmundsdóttir 2009. Estimation of infection by *Ichthyophonus hoferi* in the Icelandic summer-spawning herring during the winter 2008/09. ICES North Western Working Group, 29 April - 5 May 2009, Working Document 1. 10 p.

Óskarsson, G.J., P. Reynisson, and Á. Guðmundsdóttir 2010. Comparison of acoustic measurements of Icelandic summer-spawning herring the winter 2009/10 and selection of measurement for stock assessment. Marine Research Institute, Reykjavik, Iceland. An Internal Report. 14 pp.

Óskarsson, G.J., A. Gudmundsdottir, S. Sveinbjörnsson & Þ. Sigurðsson 2016. Feeding ecology of mackerel and dietary overlap with herring in Icelandic waters. Marine Biology Research, 12: 16-29.

Óskarsson, G.J., Ólafsdóttir, S.R., Sigurðsson, Þ., and Valdimarsson, H. 2018a. Observation and quantification of two incidents of mass fish kill of Icelandic summer spawning herring (*Clupea harengus*) in the winter 2012/2013. Fisheries Oceanography. DOI: 10.1111/fog.12253.

Óskarsson, G.J., Pálsson, J., and Gudmundsdottir, A. 2018b. An ichthyophoniasis epizootic in Atlantic herring in marine waters around Iceland. Can. J. Fish. Aquat. Sci. dx.doi.org/10.1139/cjfas-2017-0219.

Skagen, D. 2012. HCS program for simulating harvest control rules. Program description and instructions for users. Version HCS12_2. Available from the author.

# 11.18 Tables

**Table 11.1.1.1. Icelandic summer-spawning herring. Acoustic estimates (in millions) in the winters 1973/74–2020/21 (age refers to the autumns). No surveys (and gaps in the time-series) were in 1976/77, 1982/83, 1986/87, 1994/95.**

| Year\age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1973/74 | 154.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 154 |
| 1974/75 | 5.000 | 137.000 | 19.000 | 21.000 | 2.000 | 2.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 186 |
| 1975/76 | 136.000 | 20.000 | 133.000 | 17.000 | 10.000 | 3.000 | 3.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 322 |
| 1977/78 | 212.000 | 424.000 | 46.000 | 19.000 | 139.000 | 18.000 | 18.000 | 10.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 886 |
| 1978/79 | 158.000 | 334.000 | 215.000 | 49.000 | 20.000 | 111.000 | 30.000 | 30.000 | 20.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 967 |
| 1979/80 | 19.000 | 177.000 | 360.000 | 253.000 | 51.000 | 41.000 | 93.000 | 10.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1004 |
| 1980/81 | 361.000 | 462.000 | 85.000 | 170.000 | 182.000 | 33.000 | 29.000 | 58.000 | 10.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1390 |
| 1981/82 | 17.000 | 75.000 | 159.000 | 42.000 | 123.000 | 162.000 | 24.000 | 8.000 | 46.000 | 10.000 | 0.000 | 0.000 | 0.000 | 0.000 | 666 |
| 1983/84 | 171.000 | 310.000 | 724.000 | 80.000 | 39.000 | 15.000 | 27.000 | 26.000 | 10.000 | 5.000 | 12.000 | 0.000 | 0.000 | 0.000 | 1419 |
| 1984/85 | 28.000 | 67.000 | 56.000 | 360.000 | 65.000 | 32.000 | 16.000 | 17.000 | 18.000 | 9.000 | 7.000 | 4.000 | 5.000 | 5.000 | 689 |
| 1985/86 | 652.000 | 208.000 | 110.000 | 86.000 | 425.000 | 67.000 | 41.000 | 17.000 | 27.000 | 26.000 | 16.000 | 6.000 | 6.000 | 1.000 | 1688 |
| 1987/88 | 115.544 | 401.246 | 858.012 | 308.065 | 57.103 | 32.532 | 70.426 | 36.713 | 23.586 | 18.401 | 24.278 | 10.127 | 3.926 | 4.858 | 1965 |
| 1988/89 | 635.675 | 201.284 | 232.808 | 381.417 | 188.456 | 46.448 | 25.798 | 32.819 | 17.439 | 10.373 | 9.081 | 5.419 | 3.128 | 5.007 | 1795 |
| 1989/90 | 138.780 | 655.361 | 179.364 | 278.836 | 592.982 | 179.665 | 22.182 | 21.768 | 13.080 | 9.941 | 1.989 | 0.000 | 0.000 | 0.000 | 2094 |
| 1990/91 | 403.661 | 132.235 | 258.591 | 94.373 | 191.054 | 514.403 | 79.353 | 37.618 | 9.394 | 12.636 | 0.000 | 0.000 | 0.000 | 0.000 | 1733 |
| 1991/92 | 598.157 | 1049.990 | 354.521 | 319.866 | 89.825 | 138.333 | 256.921 | 21.290 | 9.866 | 0.000 | 9.327 | 0.000 | 0.000 | 1.494 | 2850 |
| 1992/93 | 267.862 | 830.608 | 729.556 | 158.778 | 130.781 | 54.156 | 96.330 | 96.649 | 24.542 | 1.130 | 1.130 | 3.390 | 0.000 | 0.000 | 2395 |
| 1993/94 | 302.075 | 505.279 | 882.868 | 496.297 | 66.963 | 58.295 | 106.172 | 48.874 | 36.201 | 0.000 | 4.224 | 18.080 | 0.000 | 0.000 | 2525 |
| 1995/96 | 216.991 | 133.810 | 761.581 | 277.893 | 385.027 | 176.906 | 98.150 | 48.503 | 16.226 | 29.390 | 47.945 | 4.476 | 0.000 | 0.000 | 2197 |
| 1996/97 | 33.363 | 270.706 | 133.667 | 468.678 | 269.888 | 325.664 | 217.421 | 92.979 | 55.494 | 39.048 | 30.028 | 53.216 | 18.838 | 12.612 | 2022 |
| 1997/98 | 291.884 | 601.783 | 81.055 | 57.366 | 287.046 | 155.998 | 203.382 | 105.730 | 35.469 | 27.373 | 14.234 | 36.500 | 14.235 | 11.570 | 1924 |
| 1998/99 | 100.426 | 255.937 | 1081.504 | 103.344 | 51.786 | 135.246 | 70.514 | 101.626 | 53.935 | 17.414 | 13.636 | 2.642 | 4.209 | 8.775 | 2001 |
| 1999/00 | 516.153 | 839.491 | 239.064 | 605.858 | 88.214 | 43.353 | 165.716 | 89.916 | 121.345 | 77.600 | 21.542 | 3.740 | 11.149 | 0.000 | 2823 |
| 2000/01 | 190.281 | 966.960 | 1316.413 | 191.001 | 482.418 | 34.377 | 15.727 | 37.940 | 14.320 | 15.413 | 14.668 | 1.705 | 3.259 | 0.000 | 3284 |
| 2001/02 | 1047.643 | 287.004 | 217.441 | 260.497 | 161.049 | 345.852 | 62.451 | 57.105 | 38.405 | 46.044 | 38.114 | 21.062 | 3.663 | 0.000 | 2586 |

| Year\age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002/03 | 1731.809 | 1919.368 | 553.149 | 205.656 | 262.362 | 153.037 | 276.199 | 99.206 | 47.621 | 55.126 | 18.798 | 24.419 | 24.112 | 1.377 | 5372 |
| 2003/04 | 1115.255 | 1434.976 | 2058.222 | 330.800 | 109.146 | 100.785 | 38.693 | 45.582 | 7.039 | 6.362 | 7.509 | 10.894 | 0.000 | 2.289 | 5268 |
| 2004/05 | 2417.128 | 713.730 | 1022.326 | 1046.657 | 171.326 | 62.429 | 44.313 | 10.947 | 23.942 | 12.669 | 0.000 | 1.948 | 11.088 | 0.000 | 5539 |
| 2005/06 | 469.532 | 443.877 | 344.983 | 818.738 | 1220.902 | 281.448 | 122.183 | 129.588 | 73.339 | 65.287 | 10.115 | 9.205 | 3.548 | 12.417 | 4005 |
| 2006/07 | 109.959 | 608.205 | 1059.597 | 410.145 | 424.525 | 693.423 | 95.997 | 123.748 | 48.773 | 0.955 | 0.000 | 0.000 | 0.000 | 0.480 | 3576 |
| 2007/08 | 90.231 | 456.773 | 289.260 | 541.585 | 309.443 | 402.889 | 702.708 | 221.626 | 244.772 | 13.997 | 22.113 | 68.105 | 10.136 | 2.800 | 3376 |
| 2008/09 | 149.466 | 196.127 | 416.862 | 288.156 | 457.659 | 266.975 | 225.747 | 168.960 | 29.922 | 26.281 | 17.790 | 9.881 | 0.974 | 3.195 | 2258 |
| 2009/10 | 151.066 | 315.941 | 490.653 | 554.818 | 271.445 | 327.275 | 149.143 | 83.875 | 156.920 | 36.666 | 13.649 | 8.507 | 1.458 | 5.590 | 2567 |
| 2010/11 | 106.178 | 280.582 | 228.857 | 304.885 | 296.254 | 138.686 | 301.285 | 60.997 | 141.323 | 97.412 | 37.006 | 0.000 | 4.019 | 0.000 | 1997 |
| 2011/12 | 704.863 | 977.323 | 434.876 | 313.742 | 272.140 | 239.320 | 154.581 | 175.088 | 84.582 | 92.435 | 89.376 | 17.638 | 6.808 | 4,989 | 3676 |
| 2012/13 | 178.500 | 781.083 | 631.421 | 166.627 | 126.961 | 142.044 | 110.084 | 97.000 | 74.340 | 69.473 | 43.376 | 38.450 | 7.458 | 0.773 | 2468 |
| 2013/14 | 15.919 | 314.865 | 218.715 | 344.981 | 151.631 | 132.767 | 120.756 | 118.377 | 89.555 | 74.602 | 48.695 | 44.637 | 31.096 | 11.598 | 1718 |
| 2014/15 | 152.422 | 90,269 | 330.084 | 260.919 | 259.079 | 187.905 | 111.955 | 91.629 | 37.855 | 76.680 | 30.366 | 10.619 | 22.799 | 10.108 | 1667 |
| 2015/16 | 381.900 | 164.221 | 174.507 | 312.350 | 225.836 | 215.207 | 93.743 | 62.753 | 75.339 | 41.961 | 15.696 | 26.756 | 20.159 | 5.401 | 1816 |
| 2016/17 | 97.036 | 220.642 | 137.217 | 151.937 | 262.488 | 136.801 | 241.382 | 61.220 | 55.869 | 62.805 | 11.435 | 20.135 | 13.733 | 0.313 | 1473 |
| 2017/18 | 32.749 | 22.947 | 95.097 | 171.664 | 201.944 | 319.933 | 209.174 | 255.348 | 75.813 | 34.505 | 83.460 | 54.903 | 25.370 | 28.115 | 1611 |
| 2018/19 | 306.295 | 137.402 | 67.933 | 201.362 | 101.946 | 110.810 | 167.397 | 163.804 | 73.346 | 30.040 | 29.950 | 38.499 | 9.138 | 7.271 | 1445 |
| 2019/20 | 1525 | 229.841 | 158.605 | 103.631 | 211.106 | 98.785 | 53.723 | 59.527 | 42.221 | 37.186 | 21.341 | 15.089 | 10.393 | 0.986 | 2568 |
| 2020/21 | 1399.761 | 1114.743 | 424.292 | 138.193 | 81.983 | 127.703 | 66.488 | 102.847 | 82.755 | 63.522 | 56.970 | 22.767 | 11.122 | 21.563 | 3802 |

**Table 11.1.1.2. Icelandic summers-spawning herring. Number of fish aged (number of scales) and number of samples taken in the annual acoustic surveys in the seasons 1987/88–2020/21 (age refers to the former year, i.e. autumns). In 2000 seven samples were used from the fishery.**

| | Number of scales | | | | | | | | | | | | | | | N of samples | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year/age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Total | Total | West | East |
| 1987/88 | 11 | 59 | 246 | 156 | 37 | 28 | 58 | 33 | 22 | 16 | 23 | 10 | 5 | 8 | 712 | 8 | 1 | 7 |
| 1988/89 | 229 | 78 | 181 | 424 | 178 | 69 | 50 | 77 | 42 | 29 | 23 | 13 | 7 | 12 | 1412 | 18 | 5 | 10 |
| 1989/90 | 38 | 245 | 96 | 132 | 225 | 35 | 2 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 783 | 8 | | 8 |
| 1990/91 | 418 | 229 | 303 | 90 | 131 | 257 | 28 | 6 | 3 | 8 | 0 | 0 | 0 | 0 | 1473 | 15 | | 15 |
| 1991/92 | 414 | 439 | 127 | 127 | 33 | 48 | 84 | 5 | 3 | 0 | 2 | 0 | 0 | 1 | 1283 | 15 | | 15 |
| 1992/93 | 122 | 513 | 289 | 68 | 73 | 28 | 38 | 34 | 6 | 2 | 2 | 6 | 0 | 0 | 1181 | 12 | | 12 |
| 1993/94 | 63 | 285 | 343 | 129 | 13 | 15 | 7 | 14 | 11 | 0 | 1 | 3 | 0 | 0 | 884 | 9 | | 9 |
| 1994/95* | | | | | | | | | | | | | | | | | | |
| 1995/96 | 183 | 90 | 471 | 162 | 209 | 107 | 38 | 18 | 8 | 14 | 18 | 2 | 0 | 0 | 1320 | 14 | 9 | 5 |
| 1996/97 | 24 | 150 | 88 | 351 | 141 | 137 | 87 | 32 | 15 | 10 | 7 | 14 | 4 | 2 | 1062 | 11 | 4 | 7 |
| 1997/98 | 101 | 249 | 50 | 36 | 159 | 95 | 122 | 62 | 21 | 13 | 8 | 15 | 8 | 5 | 944 | 14 | 7 | 7 |
| 1998/99 | 130 | 216 | 777 | 72 | 31 | 65 | 59 | 86 | 37 | 22 | 17 | 5 | 6 | 11 | 1534 | 17 | 10 | 7 |
| 1999/00 | 116 | 227 | 72 | 144 | 17 | 13 | 26 | 26 | 27 | 10 | 8 | 2 | 1 | 0 | 689 | 7 | 3 | 4 |
| 2000/01 | 116 | 249 | 332 | 87 | 166 | 10 | 7 | 21 | 8 | 14 | 11 | 3 | 1 | 0 | 1025 | 14 | 10 | 4 |
| 2001/02 | 61 | 56 | 130 | 114 | 62 | 136 | 25 | 24 | 17 | 21 | 17 | 10 | 3 | 0 | 676 | 9 | 4 | 5 |
| 2002/03 | 520 | 705 | 258 | 104 | 130 | 74 | 128 | 46 | 26 | 25 | 13 | 15 | 10 | 1 | 2055 | 22 | 12 | 10 |
| 2003/04 | 126 | 301 | 415 | 88 | 35 | 32 | 15 | 17 | 3 | 4 | 4 | 6 | 1 | 1 | 1048 | 13 | 8 | 5 |
| 2004/05 | 304 | 159 | 284 | 326 | 70 | 29 | 17 | 5 | 8 | 4 | 0 | 3 | 3 | 0 | 1212 | 13 | 4 | 9 |
| 2005/06 | 217 | 312 | 190 | 420 | 501 | 110 | 40 | 38 | 26 | 18 | 5 | 5 | 5 | 7 | 1894 | 22 | 14 | 8 |
| 2006/07 | 19 | 77 | 134 | 64 | 71 | 88 | 22 | 4 | 2 | 2 | 0 | 0 | 0 | 1 | 484 | 6 | 4 | 2 |
| 2007/08 | 58 | 288 | 180 | 264 | 85 | 80 | 104 | 19 | 15 | 2 | 2 | 6 | 1 | 3 | 1107 | 17 | 13 | 4 |
| 2008/09 | 274 | 208 | 213 | 136 | 204 | 123 | 125 | 97 | 18 | 13 | 9 | 7 | 4 | 17 | 1448 | 29 | 19 | 10 |
| 2009/10 | 104 | 100 | 105 | 116 | 60 | 74 | 34 | 19 | 36 | 8 | 3 | 4 | 2 | 2 | 667 | 17 | 10 | 7 |
| 2010/11 | 35 | 74 | 102 | 157 | 139 | 61 | 119 | 22 | 52 | 36 | 13 | 0 | 1 | 0 | 811 | 11 | 8 | 3 |
| 2011/12 | 229 | 330 | 134 | 115 | 100 | 106 | 74 | 87 | 45 | 48 | 51 | 10 | 3 | 3 | 1335 | 15 | 9 | 6 |
| 2012/13‡ | 42 | 266 | 554 | 273 | 220 | 252 | 198 | 165 | 126 | 114 | 69 | 61 | 12 | 2 | 2370 | 60 | 55‡ | 5 |
| 2013/14 | 26 | 472 | 275 | 414 | 199 | 200 | 199 | 208 | 163 | 138 | 90 | 85 | 60 | 23 | 2552 | 45 | 37‡ | 8 |
| 2014/15 | 83 | 50 | 96 | 71 | 72 | 53 | 32 | 26 | 11 | 22 | 8 | 3 | 6 | 4 | 534 | 10 | 8 | 2 |
| 2015/16 | 229 | 112 | 131 | 208 | 148 | 123 | 47 | 32 | 32 | 22 | 13 | 7 | 12 | 4 | 1120 | 14 | 7 | 7§ |
| 2016/17 | 66 | 164 | 122 | 137 | 202 | 117 | 169 | 43 | 50 | 44 | 14 | 15 | 9 | 4 | 1162 | 14 | 12 | 2 |
| 2017/18 | 35 | 58 | 82 | 77 | 75 | 101 | 65 | 77 | 29 | 11 | 27 | 18 | 8 | 9 | 672 | 10 | 5 | 5 |
| 2018/19 | 28 | 39 | 31 | 98 | 50 | 53 | 77 | 75 | 36 | 15 | 15 | 21 | 5 | 4 | 547 | 7 | 5 | 2 |
| 2019/20 | 265 | 143 | 94 | 48 | 101 | 60 | 43 | 54 | 45 | 43 | 27 | 26 | 20 | 6 | 975 | 10 | 5 | 5 |
| 2020/21 | 248 | 215 | 116 | 68 | 59 | 104 | 52 | 79 | 55 | 44 | 35 | 13 | 6 | 8 | 1102 | 13 | 5 | 8 |

*** No survey ‡ Samples in the western part were mainly from the commercial catch as there was impossible to secure a usable research survey samples from Kolgrafafjörður where most of the herring was observed. § Three samples were taken in the east and south in this survey (B1-2016), while four were taken in the west and used also in the age-length key.**

**Table 11.2.1. Icelandic summer spawners. Landings, catches, recommended TACs, and set National TACs in thousand tonnes.**

| Year | Landings | Catches | Recom. TACs | Nat. TACs | Year | Landings | Catches | Recom. TACs | Nat. TACs |
|---|---|---|---|---|---|---|---|---|---|
| 1972 | 0.31 | 0.31 | | | 2007/2008 | 158.9 | 158.9 | 130 | 150 |
| 1973 | 0.254 | 0.254 | | | 2008/2009 | 151.8 | 151.8 | 130 | 150 |
| 1974 | 1.275 | 1.275 | | | 2009/2010 | 46.3 | 46.3 | 40 | 47 |
| 1975 | 13.28 | 13.28 | | | 2010/2011 | 43.5 | 43.5 | 40 | 40 |
| 1976 | 17.168 | 17.168 | | | 2011/2012[‡] | 49.4 | 49.4 | 40 | 45 |
| 1977 | 28.925 | 28.925 | | | 2012/2013[‡] | 72.0 | 72.0 | 67 | 68.5 |
| 1978 | 37.333 | 37.333 | | | 2013/2014[‡] | 72.0 | 72.0 | 87 | 87 |
| 1979 | 45.072 | 45.072 | | | 2014/2015[‡§] | 95.0 | 95.0 | 83 | 83 |
| 1980 | 53.268 | 53.268 | | | 2015/2016[‡] | 69.7 | 69.7 | 71 | 71 |
| 1981 | 39.544 | 39.544 | | | 2016/2017[‡] | 60.4 | 60.4 | 63 | 63 |
| 1982 | 56.528 | 56.528 | | | 2017/2018[‡] | 35.0 | 35.0 | 39 | 39 |
| 1983 | 58.867 | 58.867 | | | 2018/2019[‡] | 40.7 | 40.7 | 35.1 | 35.1 |
| 1984 | 50.304 | 50.304 | | | 2019/2020 | 30.0 | 30.0 | 34.6 | 34.6 |
| 1985 | 49.368 | 49.368 | 50 | 50 | 2020/2021 | 36.1 | 36.1 | 35.5 | 35.5 |
| 1986 | 65.5 | 65.5 | 65 | 65 | 2021/2022 | | | 72.2 | 72.2 |
| 1987 | 75 | 75 | 70 | 73 | | | | | |
| 1988 | 92.8 | 92.8 | 90 | 90 | | | | | |
| 1989 | 97.3 | 101 | 90 | 90 | | | | | |
| 1990/1991 | 101.6 | 105.1 | 80 | 110 | | | | | |
| 1991/1992 | 98.5 | 109.5 | 80 | 110 | | | | | |
| 1992/1993 | 106.7 | 108.5 | 90 | 110 | | | | | |
| 1993/1994 | 101.5 | 102.7 | 90 | 100 | | | | | |
| 1994/1995 | 132 | 134 | 120 | 120 | | | | | |
| 1995/1996 | 125 | 125.9 | 110 | 110 | | | | | |
| 1996/1997 | 95.9 | 95.9 | 100 | 100 | | | | | |
| 1997/1998 | 64.7 | 64.7 | 100 | 100 | | | | | |
| 1998/1999** | 87 | 87 | 90 | 70 | | | | | |
| 1999/2000 | 92.9 | 92.9 | 100 | 100 | | | | | |
| 2000/2001 | 100.3 | 100.3 | 110 | 110 | | | | | |
| 2001/2002 | 95.7 | 95.7 | 125 | 125 | | | | | |
| 2002/2003* | 96.1 | 96.1 | 105 | 105 | | | | | |
| 2003/2004* | 130.7 | 130.7 | 110 | 110 | | | | | |
| 2004/2005 | 114.2 | 114.2 | 110 | 110 | | | | | |
| 2005/2006 | 103 | 103 | 110 | 110 | | | | | |
| 2006/2007 | 135 | 135 | 130 | 130 | | | | | |

***Summer fishery in 2002 and 2003 included**

**** TAC was decided 70 thousand tonnes but because of transfers from the previous quota year the national TAC became 90 thousand tonnes.**

**‡ Landings and catches include bycatch of Icelandic summer-spawning herring in the mackerel and NSS herring fishery during the preceding summer (i.e. from the fishing season before in June–August).**

**§ The landings and catches in 2014/2015 consist of transfer of 7 kt from the year before and 5 kt from the year to come, which explains the discrepancy to the TACs.**

**Table 11.2.2.1. Icelandic summer-spawning herring. Catch in numbers (millions) and total catch in weight (thousand tonnes) (1981 refers to season 1981/1982 etc).**

| Year\ age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ | Catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 1.518 | 2.049 | 31.975 | 6.493 | 7.905 | 0.863 | 0.442 | 0.345 | 0.114 | 0.004 | 0.001 | 0.001 | 0.001 | 0.001 | 13.280 |
| 1976 | 0.614 | 9.848 | 3.908 | 34.144 | 7.009 | 5.481 | 1.045 | 0.438 | 0.296 | 0.134 | 0.092 | 0.001 | 0.001 | 0.001 | 17.168 |
| 1977 | 0.705 | 18.853 | 24.152 | 10.404 | 46.357 | 6.735 | 5.421 | 1.395 | 0.524 | 0.362 | 0.027 | 0.128 | 0.001 | 0.001 | 28.925 |
| 1978 | 2.634 | 22.551 | 50.995 | 13.846 | 8.738 | 39.492 | 7.253 | 6.354 | 1.616 | 0.926 | 0.4 | 0.017 | 0.025 | 0.051 | 37.333 |
| 1979 | 0.929 | 15.098 | 47.561 | 69.735 | 16.451 | 8.003 | 26.04 | 3.05 | 1.869 | 0.494 | 0.439 | 0.032 | 0.054 | 0.006 | 45.072 |
| 1980 | 3.147 | 14.347 | 20.761 | 60.727 | 65.328 | 11.541 | 9.285 | 19.442 | 1.796 | 1.464 | 0.698 | 0.001 | 0.11 | 0.079 | 53.268 |
| 1981 | 2.283 | 4.629 | 16.771 | 12.126 | 36.871 | 41.917 | 7.299 | 4.863 | 13.416 | 1.032 | 0.884 | 0.760 | 0.101 | 0.062 | 39.544 |
| 1982 | 0.454 | 19.187 | 28.109 | 38.280 | 16.623 | 38.308 | 43.770 | 6.813 | 6.633 | 10.457 | 2.354 | 0.594 | 0.075 | 0.211 | 56.528 |
| 1983 | 1.475 | 22.499 | 151.718 | 30.285 | 21.599 | 8.667 | 14.065 | 13.713 | 3.728 | 2.381 | 3.436 | 0.554 | 0.100 | 0.003 | 58.867 |
| 1984 | 0.421 | 18.015 | 32.244 | 141.354 | 17.043 | 7.113 | 3.916 | 4.113 | 4.517 | 1.828 | 0.202 | 0.255 | 0.260 | 0.003 | 50.304 |
| 1985 | 0.112 | 12.872 | 24.659 | 21.656 | 85.210 | 11.903 | 5.740 | 2.336 | 4.363 | 4.053 | 2.773 | 0.975 | 0.480 | 0.581 | 49.368 |
| 1986 | 0.100 | 8.172 | 33.938 | 23.452 | 20.681 | 77.629 | 18.252 | 10.986 | 8.594 | 9.675 | 7.183 | 3.682 | 2.918 | 1.788 | 65.500 |
| 1987 | 0.029 | 3.144 | 44.590 | 60.285 | 20.622 | 19.751 | 46.240 | 15.232 | 13.963 | 10.179 | 13.216 | 6.224 | 4.723 | 2.280 | 75.439 |
| 1988 | 0.879 | 4.757 | 41.331 | 99.366 | 69.331 | 22.955 | 20.131 | 32.201 | 12.349 | 10.250 | 7.378 | 7.284 | 4.807 | 1.957 | 92.828 |
| 1989 | 3.974 | 22.628 | 26.649 | 77.824 | 188.654 | 43.114 | 8.116 | 5.897 | 7.292 | 4.780 | 3.449 | 1.410 | 0.844 | 0.348 | 101.000 |
| 1990 | 12.567 | 14.884 | 56.995 | 35.593 | 79.757 | 157.225 | 30.248 | 8.187 | 4.372 | 3.379 | 1.786 | 0.715 | 0.446 | 0.565 | 105.097 |
| 1991 | 37.085 | 88.683 | 49.081 | 86.292 | 34.793 | 55.228 | 110.132 | 10.079 | 4.155 | 2.735 | 2.003 | 0.519 | 0.339 | 0.416 | 109.489 |
| 1992 | 16.144 | 94.86 | 122.626 | 38.381 | 58.605 | 27.921 | 38.42 | 53.114 | 11.592 | 1.727 | 1.757 | 0.153 | 0.376 | 0.001 | 108.504 |
| 1993 | 2.467 | 51.153 | 177.78 | 92.68 | 20.791 | 28.56 | 13.313 | 19.617 | 15.266 | 4.254 | 0.797 | 0.254 | 0.001 | 0.001 | 102.741 |
| 1994 | 5.738 | 134.616 | 113.29 | 142.876 | 87.207 | 24.913 | 20.303 | 16.301 | 15.695 | 14.68 | 2.936 | 1.435 | 0.244 | 0.195 | 134.003 |
| 1995 | 4.555 | 20.991 | 137.232 | 86.864 | 109.14 | 76.78 | 21.361 | 15.225 | 8.541 | 9.617 | 7.034 | 2.291 | 0.621 | 0.235 | 125.851 |
| 1996 | 0.717 | 15.969 | 40.311 | 86.187 | 68.927 | 84.66 | 39.664 | 14.746 | 8.419 | 5.836 | 3.152 | 5.18 | 1.996 | 0.574 | 95.882 |
| 1997 | 2.008 | 39.24 | 30.141 | 26.307 | 36.738 | 33.705 | 31.022 | 22.277 | 8.531 | 3.383 | 1.141 | 10.296 | 0.947 | 2.524 | 64.682 |
| 1998 | 23.655 | 45.39 | 175.529 | 22.691 | 8.613 | 40.898 | 25.944 | 32.046 | 14.647 | 2.122 | 2.754 | 2.15 | 1.07 | 1.011 | 86.998 |
| 1999 | 5.306 | 56.315 | 54.779 | 140.913 | 16.093 | 13.506 | 31.467 | 19.845 | 22.031 | 12.609 | 2.673 | 2.746 | 1.416 | 2.514 | 92.896 |
| 2000 | 17.286 | 57.282 | 136.278 | 49.289 | 76.614 | 11.546 | 8.294 | 16.367 | 9.874 | 11.332 | 6.744 | 2.975 | 1.539 | 1.104 | 100.332 |
| 2001 | 27.486 | 42.304 | 86.422 | 93.597 | 30.336 | 54.491 | 10.375 | 8.762 | 12.244 | 9.907 | 8.259 | 6.088 | 1.491 | 1.259 | 95.675 |
| 2002 | 11.698 | 80.863 | 70.801 | 45.607 | 54.202 | 21.211 | 42.199 | 9.888 | 4.707 | 6.52 | 9.108 | 9.355 | 3.994 | 5.697 | 96.128 |
| 2003 | 24.477 | 211.495 | 286.017 | 58.120 | 27.979 | 25.592 | 14.203 | 10.944 | 2.230 | 3.424 | 4.225 | 2.562 | 1.575 | 1.370 | 130.741 |
| 2004 | 23.144 | 63.355 | 139.543 | 182.45 | 40.489 | 13.727 | 9.342 | 5.769 | 7.021 | 3.136 | 1.861 | 3.871 | 0.994 | 1.855 | 114.237 |
| 2005 | 6.088 | 26.091 | 42.116 | 117.91 | 133.437 | 27.565 | 12.074 | 9.203 | 5.172 | 5.116 | 1.045 | 1.706 | 2.11 | 0.757 | 103.043 |
| 2006 | 52.567 | 118.526 | 217.672 | 54.800 | 48.312 | 57.241 | 13.603 | 5.994 | 4.299 | 0.898 | 1.626 | 1.213 | 0.849 | 0.933 | 135.303 |
| 2007 | 10.817 | 94.250 | 83.631 | 163.294 | 61.207 | 87.541 | 92.126 | 23.238 | 11.728 | 7.319 | 2.593 | 4.961 | 2.302 | 1.420 | 158.917 |
| 2008 | 10.427 | 38.830 | 90.932 | 79.745 | 107.644 | 59.656 | 62.194 | 54.345 | 18.130 | 8.240 | 5.157 | 2.680 | 2.630 | 1.178 | 151.780 |
| 2009 | 5.431 | 21.856 | 35.221 | 31.914 | 18.826 | 22.725 | 10.425 | 9.213 | 9.549 | 2.238 | 1.033 | 0.768 | 0.406 | 0.298 | 46.332 |
| 2010 | 1.476 | 8.843 | 22.674 | 29.492 | 24.293 | 14.419 | 17.407 | 10.045 | 7.576 | 8.896 | 1.764 | 1.105 | 0.672 | 0.555 | 43.533 |
| 2011 | 0.521 | 9.357 | 24.621 | 20.046 | 22.869 | 23.706 | 13.749 | 16.967 | 10.039 | 7.623 | 7.745 | 1.441 | 0.618 | 0.785 | 49.446 |
| 2012* | 0.403 | 17.827 | 89.432 | 51.257 | 43.079 | 51.224 | 41.846 | 34.653 | 27.215 | 24.946 | 15.473 | 13.575 | 2.595 | 0.253 | 125.369 |
| 2013 | 6.888 | 46.848 | 24.833 | 35.070 | 17.250 | 18.550 | 19.032 | 21.821 | 15.952 | 15.804 | 10.081 | 9.775 | 6.722 | 2.486 | 72.058 |
| 2014 | 0.000 | 3.537 | 53.241 | 50.609 | 70.044 | 34.393 | 22.084 | 22.138 | 13.298 | 17.761 | 7.974 | 4.461 | 2.862 | 1.746 | 94.975 |
| 2015 | 0.089 | 6.024 | 29.89 | 53.573 | 43.501 | 43.015 | 15.533 | 10.76 | 8.664 | 8.161 | 6.981 | 2.726 | 2.467 | 1.587 | 69.729 |
| 2016 | 0.072 | 10.740 | 25.575 | 29.908 | 41.952 | 25.823 | 24.925 | 9.516 | 7.734 | 6.088 | 4.284 | 7.154 | 3.108 | 0.827 | 60.403 |
| 2017 | 1.262 | 5.236 | 31.855 | 18.113 | 10.239 | 15.506 | 10.223 | 8.830 | 5.676 | 3.399 | 1.616 | 2.220 | 1.533 | 1.596 | 35.034 |
| 2018 | 0.000 | 8.911 | 19.642 | 34.284 | 16.847 | 12.376 | 17.161 | 6.978 | 7.379 | 3.482 | 1.713 | 1.153 | 2.159 | 0.489 | 40.683 |
| 2019 | 0.461 | 4.601 | 15.845 | 12.970 | 16.084 | 12.244 | 6.944 | 9.531 | 6.167 | 4.732 | 2.983 | 2.808 | 2.200 | 1.866 | 30.038 |
| 2020 | 0.384 | 23.603 | 15.956 | 22.572 | 16.333 | 19.385 | 11.071 | 7.098 | 6.241 | 3.035 | 3.359 | 1.809 | 1.567 | 1.129 | 36.100 |

*** Includes both the landings (73.4 kt) and the herring that died in the mass mortality (52.0 kt) in the winter 2012/13 in Kolgrafafjörður.**

**Table 11.2.2.2. Icelandic summer-spawning herring. The mean weight (g) at age from the commercial catch (1981 refers to season 1981/1982 etc.).**

| Year\age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 110 | 179 | 241 | 291 | 319 | 339 | 365 | 364 | 407 | 389 | 430 | 416 | 416 | 416 |
| 1976 | 103 | 189 | 243 | 281 | 305 | 335 | 351 | 355 | 395 | 363 | 396 | 396 | 396 | 396 |
| 1977 | 84 | 157 | 217 | 261 | 285 | 313 | 326 | 347 | 364 | 362 | 358 | 355 | 400 | 420 |
| 1978 | 73 | 128 | 196 | 247 | 295 | 314 | 339 | 359 | 360 | 376 | 380 | 425 | 425 | 425 |
| 1979 | 75 | 145 | 182 | 231 | 285 | 316 | 334 | 350 | 367 | 368 | 371 | 350 | 350 | 450 |
| 1980 | 69 | 115 | 202 | 232 | 269 | 317 | 352 | 360 | 380 | 383 | 393 | 390 | 390 | 390 |
| 1981 | 61 | 141 | 190 | 246 | 269 | 298 | 330 | 356 | 368 | 405 | 382 | 400 | 400 | 400 |
| 1982 | 65 | 141 | 186 | 217 | 274 | 293 | 323 | 354 | 385 | 389 | 400 | 394 | 390 | 420 |
| 1983 | 59 | 132 | 180 | 218 | 260 | 309 | 329 | 356 | 370 | 407 | 437 | 459 | 430 | 472 |
| 1984 | 49 | 131 | 189 | 217 | 245 | 277 | 315 | 322 | 351 | 334 | 362 | 446 | 417 | 392 |
| 1985 | 53 | 146 | 219 | 266 | 285 | 315 | 335 | 365 | 388 | 400 | 453 | 469 | 433 | 447 |
| 1986 | 60 | 140 | 200 | 252 | 282 | 298 | 320 | 334 | 373 | 380 | 394 | 408 | 405 | 439 |
| 1987 | 60 | 168 | 200 | 240 | 278 | 304 | 325 | 339 | 356 | 378 | 400 | 404 | 424 | 430 |
| 1988 | 75 | 157 | 221 | 239 | 271 | 298 | 319 | 334 | 354 | 352 | 371 | 390 | 408 | 437 |
| 1989 | 63 | 130 | 206 | 246 | 261 | 290 | 331 | 338 | 352 | 369 | 389 | 380 | 434 | 409 |
| 1990 | 80 | 127 | 197 | 245 | 272 | 285 | 305 | 324 | 336 | 362 | 370 | 382 | 375 | 378 |
| 1991 | 74 | 135 | 188 | 232 | 267 | 289 | 304 | 323 | 340 | 352 | 369 | 402 | 406 | 388 |
| 1992 | 68 | 148 | 190 | 235 | 273 | 312 | 329 | 339 | 355 | 382 | 405 | 377 | 398 | 398 |
| 1993 | 66 | 145 | 211 | 246 | 292 | 324 | 350 | 362 | 376 | 386 | 419 | 389 | 389 | 389 |
| 1994 | 66 | 134 | 201 | 247 | 272 | 303 | 333 | 366 | 378 | 389 | 390 | 412 | 418 | 383 |
| 1995 | 68 | 130 | 183 | 240 | 277 | 298 | 325 | 358 | 378 | 397 | 409 | 431 | 430 | 467 |
| 1996 | 75 | 139 | 168 | 212 | 258 | 289 | 308 | 325 | 353 | 353 | 377 | 404 | 395 | 410 |
| 1997 | 63 | 131 | 191 | 233 | 269 | 300 | 324 | 341 | 355 | 362 | 367 | 393 | 398 | 411 |
| 1998 | 52 | 134 | 185 | 238 | 264 | 288 | 324 | 340 | 348 | 375 | 406 | 391 | 426 | 456 |
| 1999 | 74 | 137 | 204 | 233 | 268 | 294 | 311 | 339 | 353 | 362 | 378 | 385 | 411 | 422 |
| 2000 | 62 | 159 | 217 | 268 | 289 | 325 | 342 | 363 | 378 | 393 | 407 | 425 | 436 | 430 |
| 2001 | 74 | 139 | 214 | 244 | 286 | 296 | 324 | 347 | 354 | 385 | 403 | 421 | 421 | 433 |
| 2002 | 85 | 161 | 211 | 258 | 280 | 319 | 332 | 354 | 405 | 396 | 416 | 433 | 463 | 460 |
| 2003 | 72 | 156 | 189 | 229 | 260 | 283 | 309 | 336 | 336 | 369 | 394 | 378 | 412 | 423 |
| 2004 | 84 | 149 | 213 | 248 | 280 | 315 | 331 | 349 | 355 | 379 | 388 | 412 | 419 | 425 |
| 2005 | 106 | 170 | 224 | 262 | 275 | 298 | 324 | 335 | 335 | 356 | 372 | 394 | 405 | 413 |
| 2006 | 107 | 189 | 234 | 263 | 290 | 304 | 339 | 349 | 369 | 416 | 402 | 413 | 413 | 467 |
| 2007 | 93 | 158 | 221 | 245 | 261 | 277 | 287 | 311 | 339 | 334 | 346 | 356 | 384 | 390 |
| 2008 | 105 | 174 | 232 | 275 | 292 | 307 | 315 | 327 | 345 | 366 | 377 | 372 | 403 | 434 |
| 2009 | 113 | 190 | 237 | 274 | 304 | 318 | 326 | 335 | 342 | 360 | 372 | 394 | 409 | 421 |
| 2010 | 87 | 204 | 243 | 271 | 297 | 315 | 329 | 335 | 341 | 351 | 367 | 366 | 405 | 416 |
| 2011 | 97 | 187 | 245 | 283 | 309 | 328 | 343 | 352 | 356 | 364 | 375 | 386 | 378 | 432 |
| 2012 | 65 | 206 | 244 | 282 | 301 | 320 | 333 | 344 | 350 | 359 | 364 | 367 | 373 | 391 |
| 2013 | 95 | 182 | 238 | 271 | 300 | 322 | 337 | 349 | 360 | 365 | 362 | 375 | 377 | 394 |
| 2014 | | 202 | 259 | 288 | 306 | 328 | 346 | 354 | 362 | 366 | 367 | 380 | 383 | 403 |
| 2015 | 107 | 203 | 249 | 275 | 299 | 313 | 329 | 347 | 352 | 358 | 361 | 368 | 380 | 378 |
| 2016 | 129 | 202 | 242 | 281 | 303 | 322 | 336 | 355 | 359 | 368 | 369 | 379 | 386 | 402 |
| 2017 | 95 | 192 | 252 | 281 | 303 | 324 | 341 | 350 | 367 | 376 | 384 | 389 | 395 | 402 |
| 2018 | | 191 | 252 | 293 | 317 | 333 | 347 | 350 | 366 | 375 | 389 | 388 | 392 | 383 |
| 2019 | 103 | 175 | 244 | 282 | 305 | 308 | 328 | 340 | 349 | 357 | 360 | 366 | 374 | 374 |
| 2020 | 81 | 140 | 229 | 267 | 288 | 311 | 329 | 345 | 351 | 367 | 372 | 370 | 382 | 398 |

**Table 11.2.2.3. Icelandic summer-spawning herring. Proportion mature at age (1981 refers to season 1981/1982 etc.).**

| Year\age | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 0 | 0.27 | 0.97 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1976 | 0 | 0.13 | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1977 | 0 | 0.02 | 0.87 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1978 | 0 | 0.04 | 0.78 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1979 | 0 | 0.07 | 0.65 | 0.98 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1980 | 0 | 0.05 | 0.92 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1981 | 0 | 0.03 | 0.65 | 0.99 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1982 | 0.02 | 0.05 | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1983 | 0 | 0 | 0.64 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1984 | 0 | 0.01 | 0.82 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1985 | 0 | 0 | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1986–2020 | 0 | 0.2 | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 11.3.2.1. Icelandic summer-spawning herring. Natural mortality at age for the different years (refers to the autumn) where the deviation from the fixed M = 0.1 is due to the *Ichthyophonus* infection (1981 refers to season 1981/1982 etc.). The estimate of, for example, M for age 4 in 2020 represents estimated infection rate of age 3 in 2019.**

| Year\age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 13+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987–2008 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2009* | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| 2010* | 0.29 | 0.29 | 0.28 | 0.26 | 0.25 | 0.24 | 0.24 | 0.24 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| 2011* | 0.13 | 0.26 | 0.26 | 0.25 | 0.23 | 0.24 | 0.25 | 0.24 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| 2012-2016 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2017 | 0.111 | 0.118 | 0.124 | 0.173 | 0.175 | 0.175 | 0.207 | 0.187 | 0.256 | 0.279 | 0.210 | 0.180 | 0.191 | 0.183 |
| 2018 | 0.116 | 0.112 | 0.172 | 0.162 | 0.175 | 0.228 | 0.226 | 0.247 | 0.275 | 0.338 | 0.307 | 0.184 | 0.186 | 0.250 |
| 2019** | 0.111 | 0.135 | 0.144 | 0.168 | 0.216 | 0.169 | 0.171 | 0.183 | 0.245 | 0.189 | 0.243 | 0.182 | 0.140 | 0.189 |
| 2020*** | 0.119 | 0.146 | 0.122 | 0.155 | 0.191 | 0.164 | 0.193 | 0.159 | 0.230 | 0.100 | 0.146 | 0.151 | 0.100 | 0.275 |

*** Based on prevalence of infection estimates and acoustic measurements ($M_{infected}$ multiplied by 0.3 and added to 0.1; Óskarsson *et al.* 2018b).**

**** Based on prevalence of infection estimates in the winter 2019/20 and 2020/21 (multiplied by 0.3 and added to 0.1; Óskarsson and Pálsson, 2017; 2018).**

***** Based on prevalence of infection estimates in the winter 2020/21 (multiplied by 0.3 and added to 0.1) and should be applied in the prognosis in the 2021 assessment.**

**Table 11.3.2.2. Model settings and results of model parameters from the final NFT-Adapt run in 2021 for Icelandic summer spawning herring.**

VPA Version 3.3.0

Model ID: RUN1 2021

Input File: C:\HAFRONET_GOGN\NWWG OG UTTEKTIR\NWWG2021\VPA\RUN1_2021_R_00.DAT

Date of Run: 26-APR-2021 Time of Run: 13:27

Levenburg-Marquardt Algorithm Completed 7 Iterations

Residual Sum of Squares = 59.4232

Number of Residuals = 264

Number of Parameters = 9

Degrees of Freedom = 255

Mean Squared Residual = 0.233032

Standard Deviation = 0.482734

Number of Years = 34

Number of Ages = 11

First Year = 1987

Youngest Age = 3

Oldest True Age = 12

Number of Survey Indices Available = 10

Number of Survey Indices Used in Estimate = 8

VPA Classic Method - Auto Estimated Q's

Stock Numbers Predicted in Terminal Year Plus One (2021)

| Age | Stock Predicted | Std. Error | CV |
|---|---|---|---|
| 4 | 1130123.745 | 0.554399E+06 | 0.490565E+00 |
| 5 | 257398.668 | 0.918374E+05 | 0.356791E+00 |
| 6 | 88145.395 | 0.293167E+05 | 0.332595E+00 |
| 7 | 29378.669 | 0.103832E+05 | 0.353427E+00 |
| 8 | 64413.772 | 0.196232E+05 | 0.304643E+00 |
| 9 | 39228.065 | 0.111259E+05 | 0.283621E+00 |
| 10 | 34522.515 | 0.900332E+04 | 0.260795E+00 |
| 11 | 43267.578 | 0.109880E+05 | 0.253954E+00 |
| 12 | 31864.455 | 0.865457E+04 | 0.271606E+00 |

Catchability Values for Each Survey Used in Estimate

| INDEX | Catchability | Std. Error | CV |
|---|---|---|---|
| 1 | 0.986382E+00 | 0.940359E-01 | 0.953342E-01 |
| 2 | 0.127444E+01 | 0.106471E+00 | 0.835434E-01 |
| 3 | 0.138258E+01 | 0.797671E-01 | 0.576942E-01 |
| 4 | 0.150767E+01 | 0.959402E-01 | 0.636346E-01 |

5 0.159940E+01 0.113761E+00 0.711275E-01

6 0.178267E+01 0.144659E+00 0.811474E-01

7 0.189357E+01 0.201581E+00 0.106456E+00

8 0.177107E+01 0.187207E+00 0.105703E+00

-- Non-Linear Least Squares Fit --

Maximum Marquadt Iterations = 100

Scaled Gradient Tolerance = 6.055454E-05

Scaled Step Tolerance = 1.000000E-18

Relative Function Tolerance = 1.000000E-18

Absolute Function Tolerance = 4.930381E-32

Reported Machine Precision = 2.220446E-16

VPA Method Options

- Catchability Values Estimated as an Analytic Function of N
- Catch Equation Used in Cohort Solution
- Plus Group Forward Calculation Method Used
- Arithmetic Average Used in F-Oldest Calculation
- F-Oldest Calculation in Years Prior to Terminal Year

  Uses Fishing Mortality in Ages 8 to 11

- Calculation of Population of Age 3 In Year 2021

  = Geometric Mean of First Age Populations

  Year Range Applied = 1991 to 2014

- Survey Weight Factors Were Used

Stock Estimates

Age 4

Age 5

Age 6

Age 7

Age 8

Age 9

Age 10

Age 11

Age 12

Full F in Terminal Year = 0.2098

F in Oldest True Age in Terminal Year = 0.1512

Full F Calculated Using Classic Method

F in Oldest True Age in Terminal Year has been

Calculated in Same Manner as in All Other Years

| Age | Input Partial Recruitment | Calc Partial Recruitment | Fishing Mortality | Used In Full F | Comments |
|---|---|---|---|---|---|
| 3 | 0.500 | 0.048 | 0.0196 | NO | Stock Estimate in T+1 |
| 4 | 0.800 | 0.139 | 0.0568 | NO | Stock Estimate in T+1 |
| 5 | 1.000 | 0.521 | 0.2123 | YES | Stock Estimate in T+1 |
| 6 | 1.000 | 1.000 | 0.4073 | YES | Stock Estimate in T+1 |
| 7 | 1.000 | 0.600 | 0.2444 | YES | Stock Estimate in T+1 |
| 8 | 1.000 | 0.568 | 0.2313 | YES | Stock Estimate in T+1 |
| 9 | 1.000 | 0.418 | 0.1702 | YES | Stock Estimate in T+1 |
| 10 | 1.000 | 0.301 | 0.1225 | YES | Stock Estimate in T+1 |
| 11 | 1.000 | 0.199 | 0.0809 | YES | Stock Estimate in T+1 |
| 12 | 1.000 | 0.371 | 0.1512 | | F-Oldest |

**Table 11.3.2.3. Icelandic summer spawners stock estimates (from NFT-Adapt in 2021) in numbers (millions) by age (years) at 1 January during 1987–2021.**

| Year\Age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 529.83 | 988.96 | 300.67 | 84.6 | 69.14 | 107.46 | 42.63 | 38.03 | 26.41 | 34.26 | 34.29 | 2256.28 |
| 1988 | 270.99 | 476.42 | 852.47 | 214.85 | 56.99 | 43.83 | 53.49 | 24.15 | 21.19 | 14.26 | 36.99 | 2065.62 |
| 1989 | 447.32 | 240.68 | 391.81 | 676.97 | 128.7 | 29.84 | 20.62 | 18.03 | 10.18 | 9.48 | 26.1 | 1999.74 |
| 1990 | 300.82 | 383.25 | 192.47 | 280.67 | 433.68 | 75.61 | 19.3 | 13.07 | 9.41 | 4.69 | 26.46 | 1739.43 |
| 1991 | 840.53 | 258.05 | 292.66 | 140.37 | 178.35 | 243.51 | 39.78 | 9.72 | 7.68 | 5.31 | 24.86 | 2040.81 |
| 1992 | 1033.07 | 676.3 | 186.91 | 183.01 | 94.01 | 109.04 | 116.17 | 26.44 | 4.86 | 4.36 | 24.19 | 2458.36 |
| 1993 | 635.4 | 844.64 | 495.55 | 132.7 | 110.06 | 58.6 | 62.27 | 54.88 | 12.95 | 2.76 | 23.67 | 2433.49 |
| 1994 | 691.69 | 526.33 | 595.58 | 360.43 | 100.33 | 72.5 | 40.39 | 37.75 | 35.19 | 7.69 | 22.92 | 2490.81 |
| 1995 | 202.69 | 498.11 | 368.75 | 403.38 | 243.41 | 67.16 | 46.36 | 21.12 | 19.31 | 17.95 | 23.14 | 1911.36 |
| 1996 | 181.37 | 163.46 | 320.6 | 251.26 | 261.5 | 147.48 | 40.52 | 27.52 | 11.03 | 8.38 | 27.53 | 1440.65 |
| 1997 | 772.48 | 148.94 | 109.67 | 208.36 | 162 | 156.4 | 95.84 | 22.7 | 16.92 | 4.46 | 22.16 | 1719.93 |
| 1998 | 320.43 | 661.68 | 106.16 | 74.28 | 153.66 | 114.6 | 112.07 | 65.59 | 12.46 | 12.1 | 10.03 | 1643.06 |
| 1999 | 552.47 | 246.83 | 432.26 | 74.53 | 59.03 | 100.26 | 79.08 | 71.03 | 45.45 | 9.26 | 13.4 | 1683.61 |
| 2000 | 391.18 | 446.4 | 171.37 | 257.61 | 52.17 | 40.6 | 60.9 | 52.74 | 43.39 | 29.17 | 11.67 | 1557.18 |
| 2001 | 468.43 | 299.56 | 274.75 | 108.34 | 160.47 | 36.25 | 28.87 | 39.58 | 38.35 | 28.51 | 25.24 | 1508.35 |
| 2002 | 1455.46 | 383.66 | 189.13 | 159.94 | 69.27 | 93.58 | 22.97 | 17.81 | 24.21 | 25.3 | 32.44 | 2473.75 |
| 2003 | 1074.87 | 1240.11 | 279.95 | 127.87 | 93.37 | 42.57 | 44.76 | 11.42 | 11.66 | 15.72 | 25.65 | 2967.95 |
| 2004 | 663.28 | 771.87 | 850.77 | 198.16 | 89.15 | 60.22 | 25.07 | 30.12 | 8.22 | 7.3 | 28.2 | 2732.36 |
| 2005 | 991.08 | 539.98 | 565.97 | 596.69 | 140.88 | 67.64 | 45.62 | 17.21 | 20.59 | 4.47 | 23.99 | 3014.11 |
| 2006 | 736.81 | 871.97 | 448.57 | 400.23 | 413.31 | 101.32 | 49.74 | 32.54 | 10.67 | 13.78 | 20.42 | 3099.35 |
| 2007 | 658.32 | 554.17 | 582.54 | 353.84 | 316.26 | 319.63 | 78.76 | 39.31 | 25.36 | 8.8 | 26.55 | 2963.54 |
| 2008 | 526.78 | 506.71 | 423.38 | 375.43 | 259.83 | 201.22 | 200.64 | 49.06 | 24.43 | 15.98 | 21.3 | 2604.75 |
| 2009 | 444.7 | 439.76 | 372.18 | 307.4 | 237.65 | 178.51 | 123.12 | 130.02 | 27.22 | 14.3 | 22.7 | 2297.55 |
| 2010 | 468.5 | 338.4 | 322.49 | 271.05 | 230.6 | 170.99 | 134.37 | 90.87 | 96.12 | 19.91 | 27.54 | 2170.83 |
| 2011 | 532.88 | 342.25 | 233.22 | 218.93 | 187.97 | 166.92 | 118.63 | 96.72 | 64.93 | 68.33 | 34.04 | 2064.82 |
| 2012 | 394.18 | 459.16 | 242.63 | 162.99 | 150.43 | 128.05 | 119.41 | 77.77 | 67.37 | 46.19 | 73.87 | 1922.04 |
| 2013 | 478.67 | 339.72 | 330.59 | 170.9 | 106.63 | 87.59 | 76.21 | 75.2 | 44.59 | 37.33 | 78.39 | 1825.83 |
| 2014 | 240.45 | 388.62 | 283.8 | 265.82 | 138.25 | 78.88 | 61.19 | 48.27 | 52.91 | 25.37 | 77.15 | 1660.71 |
| 2015 | 223.09 | 214.21 | 301.08 | 208.75 | 174.1 | 92.48 | 50.43 | 34.4 | 31.07 | 31.05 | 76.59 | 1437.25 |
| 2016 | 288.88 | 196.13 | 165.44 | 221.58 | 147.61 | 116.73 | 68.93 | 35.42 | 22.91 | 20.38 | 84.33 | 1368.34 |
| 2017 | 122.79 | 251.18 | 153.18 | 121.31 | 160.67 | 109.05 | 81.98 | 53.33 | 24.72 | 14.96 | 80.15 | 1173.31 |
| 2018 | 191.51 | 104.94 | 193.25 | 118.33 | 92.67 | 120.71 | 82.2 | 58.72 | 39.09 | 16.16 | 71.16 | 1088.74 |
| 2019 | 346.73 | 162.14 | 75.3 | 131.39 | 85.15 | 66.49 | 80.87 | 59.37 | 39.38 | 26.67 | 62.17 | 1135.65 |
| 2020 | 1286.45 | 305.95 | 126.88 | 53.17 | 96.33 | 57.67 | 49.79 | 59.44 | 43.83 | 26.66 | 64.56 | 2170.73 |
| 2021 | 572 | 1130.12 | 257.4 | 88.15 | 29.38 | 64.41 | 39.23 | 34.52 | 43.27 | 31.86 | 65.33 | 2328.37 |

**Table 11.3.2.4. Estimated fishing mortality at age of Icelandic summer-spawning herring (from NFT-Adapt in 2021) by age (years) during 1987–2020 (referring to the autumn of the fishing season) and weighed average F by numbers for age 5–10.**

| Year\Age | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13+ | WF5-10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 0.006 | 0.049 | 0.236 | 0.295 | 0.356 | 0.598 | 0.468 | 0.485 | 0.516 | 0.517 | 0.517 | 0.347 |
| 1988 | 0.019 | 0.096 | 0.131 | 0.412 | 0.547 | 0.654 | 0.988 | 0.764 | 0.704 | 0.777 | 0.506 | 0.266 |
| 1989 | 0.055 | 0.124 | 0.234 | 0.345 | 0.432 | 0.336 | 0.356 | 0.550 | 0.674 | 0.479 | 0.111 | 0.322 |
| 1990 | 0.053 | 0.170 | 0.216 | 0.353 | 0.477 | 0.542 | 0.586 | 0.431 | 0.472 | 0.508 | 0.071 | 0.400 |
| 1991 | 0.117 | 0.223 | 0.370 | 0.301 | 0.392 | 0.640 | 0.309 | 0.593 | 0.466 | 0.502 | 0.055 | 0.436 |
| 1992 | 0.101 | 0.211 | 0.243 | 0.409 | 0.373 | 0.460 | 0.650 | 0.613 | 0.465 | 0.547 | 0.023 | 0.415 |
| 1993 | 0.088 | 0.249 | 0.218 | 0.180 | 0.317 | 0.272 | 0.400 | 0.345 | 0.421 | 0.360 | 0.011 | 0.248 |
| 1994 | 0.228 | 0.256 | 0.290 | 0.293 | 0.302 | 0.347 | 0.549 | 0.571 | 0.573 | 0.510 | 0.090 | 0.312 |
| 1995 | 0.115 | 0.341 | 0.284 | 0.333 | 0.401 | 0.405 | 0.422 | 0.550 | 0.735 | 0.528 | 0.154 | 0.343 |
| 1996 | 0.097 | 0.299 | 0.331 | 0.339 | 0.414 | 0.331 | 0.479 | 0.386 | 0.804 | 0.500 | 0.350 | 0.361 |
| 1997 | 0.055 | 0.239 | 0.290 | 0.205 | 0.246 | 0.233 | 0.279 | 0.500 | 0.235 | 0.312 | 1.042 | 0.250 |
| 1998 | 0.161 | 0.326 | 0.254 | 0.130 | 0.327 | 0.271 | 0.356 | 0.267 | 0.197 | 0.273 | 0.582 | 0.280 |
| 1999 | 0.113 | 0.265 | 0.418 | 0.257 | 0.274 | 0.399 | 0.305 | 0.393 | 0.344 | 0.360 | 0.735 | 0.377 |
| 2000 | 0.167 | 0.385 | 0.359 | 0.373 | 0.264 | 0.241 | 0.331 | 0.219 | 0.320 | 0.278 | 0.700 | 0.335 |
| 2001 | 0.100 | 0.360 | 0.441 | 0.347 | 0.439 | 0.357 | 0.383 | 0.392 | 0.316 | 0.362 | 0.457 | 0.415 |
| 2002 | 0.060 | 0.215 | 0.291 | 0.438 | 0.387 | 0.638 | 0.598 | 0.324 | 0.332 | 0.473 | 0.947 | 0.418 |
| 2003 | 0.231 | 0.277 | 0.246 | 0.261 | 0.339 | 0.430 | 0.296 | 0.229 | 0.368 | 0.331 | 0.255 | 0.280 |
| 2004 | 0.106 | 0.210 | 0.255 | 0.241 | 0.176 | 0.178 | 0.276 | 0.280 | 0.510 | 0.311 | 0.287 | 0.244 |
| 2005 | 0.028 | 0.086 | 0.247 | 0.267 | 0.230 | 0.207 | 0.238 | 0.378 | 0.302 | 0.281 | 0.223 | 0.253 |
| 2006 | 0.185 | 0.303 | 0.137 | 0.136 | 0.157 | 0.152 | 0.135 | 0.149 | 0.093 | 0.132 | 0.167 | 0.144 |
| 2007 | 0.162 | 0.169 | 0.339 | 0.209 | 0.352 | 0.366 | 0.373 | 0.376 | 0.362 | 0.369 | 0.419 | 0.322 |
| 2008 | 0.081 | 0.209 | 0.220 | 0.357 | 0.275 | 0.391 | 0.334 | 0.489 | 0.436 | 0.412 | 0.384 | 0.310 |
| 2009 | 0.056 | 0.093 | 0.100 | 0.071 | 0.112 | 0.067 | 0.087 | 0.085 | 0.096 | 0.084 | 0.075 | 0.088 |
| 2010 | 0.022 | 0.080 | 0.110 | 0.107 | 0.073 | 0.122 | 0.088 | 0.098 | 0.109 | 0.104 | 0.100 | 0.101 |
| 2011 | 0.019 | 0.085 | 0.102 | 0.125 | 0.152 | 0.097 | 0.175 | 0.124 | 0.139 | 0.134 | 0.097 | 0.126 |
| 2012* | 0.049 | 0.229 | 0.250 | 0.324 | 0.441 | 0.419 | 0.362 | 0.456 | 0.490 | 0.432 | 0.265 | 0.354 |
| 2013 | 0.108 | 0.080 | 0.118 | 0.112 | 0.202 | 0.259 | 0.357 | 0.252 | 0.464 | 0.333 | 0.293 | 0.175 |
| 2014 | 0.016 | 0.155 | 0.207 | 0.323 | 0.302 | 0.347 | 0.476 | 0.341 | 0.433 | 0.399 | 0.132 | 0.296 |
| 2015 | 0.029 | 0.158 | 0.207 | 0.247 | 0.300 | 0.194 | 0.253 | 0.307 | 0.322 | 0.269 | 0.098 | 0.240 |
| 2016 | 0.040 | 0.147 | 0.210 | 0.221 | 0.203 | 0.254 | 0.157 | 0.260 | 0.326 | 0.249 | 0.149 | 0.216 |
| 2017 | 0.046 | 0.144 | 0.134 | 0.096 | 0.111 | 0.108 | 0.127 | 0.124 | 0.169 | 0.132 | 0.076 | 0.116 |
| 2018 | 0.051 | 0.220 | 0.214 | 0.167 | 0.157 | 0.173 | 0.099 | 0.152 | 0.107 | 0.133 | 0.062 | 0.171 |
| 2019 | 0.014 | 0.110 | 0.204 | 0.142 | 0.174 | 0.120 | 0.137 | 0.120 | 0.145 | 0.131 | 0.129 | 0.151 |
| 2020 | 0.020 | 0.057 | 0.212 | 0.407 | 0.244 | 0.231 | 0.170 | 0.123 | 0.081 | 0.151 | 0.081 | 0.228 |

*** Derived from both the landings ($WF_{5–10}$ ~0.209) and the herring that died in the mass mortality (0.148) in the winter 2012/13 in Kolgrafafjörður (Óskarsson *et al.*, 2018a). WF5–10 without the mass mortality was 0.214.**

**Table 11.3.2.5. Summary table from NFT-Adapt run in 2021 for Icelandic summer spawning herring.**

| Year | Recruits age 3 (millions) | Biomass age 3+ (kt) | Biomass age 4+ (kt) | SSB (kt) | Landings age 3+ (kt) | Yield/SSB | $WF_{age\ 5\text{-}10}$ | HR 4+ |
|---|---|---|---|---|---|---|---|---|
| 1987 | 530 | 504 | 415 | 384 | 75 | 0.20 | 0.35 | 0.182 |
| 1988 | 271 | 495 | 452 | 423 | 93 | 0.22 | 0.27 | 0.205 |
| 1989 | 447 | 459 | 401 | 386 | 101 | 0.26 | 0.32 | 0.251 |
| 1990 | 301 | 410 | 371 | 350 | 104 | 0.30 | 0.40 | 0.281 |
| 1991 | 841 | 424 | 310 | 310 | 107 | 0.34 | 0.44 | 0.344 |
| 1992 | 1033 | 502 | 349 | 343 | 107 | 0.31 | 0.42 | 0.307 |
| 1993 | 635 | 546 | 454 | 424 | 103 | 0.24 | 0.25 | 0.226 |
| 1994 | 692 | 553 | 461 | 441 | 134 | 0.30 | 0.31 | 0.290 |
| 1995 | 203 | 462 | 435 | 406 | 125 | 0.31 | 0.34 | 0.288 |
| 1996 | 181 | 347 | 322 | 307 | 96 | 0.31 | 0.36 | 0.297 |
| 1997 | 772 | 368 | 267 | 269 | 65 | 0.24 | 0.25 | 0.243 |
| 1998 | 320 | 366 | 323 | 298 | 86 | 0.29 | 0.28 | 0.266 |
| 1999 | 552 | 373 | 297 | 290 | 93 | 0.32 | 0.38 | 0.312 |
| 2000 | 391 | 386 | 324 | 306 | 100 | 0.33 | 0.34 | 0.308 |
| 2001 | 468 | 347 | 282 | 272 | 94 | 0.34 | 0.41 | 0.332 |
| 2002 | 1455 | 512 | 278 | 297 | 96 | 0.32 | 0.42 | 0.346 |
| 2003 | 1075 | 579 | 411 | 389 | 129 | 0.33 | 0.28 | 0.313 |
| 2004 | 663 | 615 | 516 | 486 | 112 | 0.23 | 0.24 | 0.218 |
| 2005 | 991 | 705 | 537 | 526 | 102 | 0.19 | 0.25 | 0.191 |
| 2006 | 737 | 785 | 646 | 612 | 130 | 0.21 | 0.14 | 0.201 |
| 2007 | 658 | 699 | 595 | 569 | 158 | 0.28 | 0.32 | 0.265 |
| 2008 | 527 | 684 | 593 | 564 | 151 | 0.27 | 0.31 | 0.254 |
| 2009 | 445 | 628 | 543 | 489 | 46 | 0.09 | 0.09 | 0.084 |
| 2010 | 469 | 602 | 507 | 451 | 43 | 0.10 | 0.10 | 0.086 |
| 2011 | 533 | 575 | 476 | 429 | 49 | 0.12 | 0.13 | 0.104 |
| 2012 | 394 | 538 | 457 | 434 | 72 | 0.16 | 0.21 | 0.158 |
| 2013 | 479 | 486 | 399 | 384 | 71 | 0.19 | 0.18 | 0.179 |
| 2014 | 240 | 482 | 434 | 408 | 95 | 0.23 | 0.30 | 0.219 |
| 2015 | 223 | 409 | 364 | 347 | 70 | 0.20 | 0.24 | 0.192 |
| 2016 | 289 | 392 | 333 | 321 | 60 | 0.19 | 0.22 | 0.181 |
| 2017 | 123 | 350 | 326 | 296 | 35 | 0.12 | 0.12 | 0.107 |
| 2018 | 192 | 329 | 292 | 268 | 41 | 0.15 | 0.17 | 0.139 |
| 2019 | 347 | 305 | 244 | 229 | 30 | 0.13 | 0.15 | 0.123 |
| 2020 | 1286 | 437 | 257 | 260 | 36 | 0.14 | 0.23 | 0.140 |
| 2021 | 572 | 578 | 482 | 377 | | | | |

*** The mass mortality of 52 thousand tonnes in Kolgrafafjörður in the winter 2012/13 is not included in the landings, yield/SSB, or WF, even if included as landings in the analytical assessment.**

**Table 11.3.2.6. The residuals from survey observations and NFT-Adapt 2021 results for Icelandic summer spawning herring (no surveys in 1987 and 1995) on 1 January.**

| Year\Age | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | |
| 1988 | -0.158 | -0.236 | 0.036 | -0.409 | -0.768 | -0.303 | -0.220 | -0.464 |
| 1989 | -0.165 | -0.763 | -0.898 | -0.029 | -0.027 | -0.354 | -0.039 | -0.034 |
| 1990 | 0.550 | -0.313 | -0.331 | -0.098 | 0.396 | -0.439 | -0.128 | -0.242 |
| 1991 | -0.655 | -0.366 | -0.721 | -0.342 | 0.278 | 0.112 | 0.715 | -0.371 |
| 1992 | 0.454 | 0.398 | 0.234 | -0.456 | -0.232 | 0.216 | -0.855 | 0.136 |
| 1993 | -0.003 | 0.144 | -0.145 | -0.238 | -0.548 | -0.142 | -0.073 | 0.067 |
| 1994 | -0.027 | 0.151 | -0.004 | -0.815 | -0.688 | 0.388 | -0.380 | -0.543 |
| 1995 | | | | | | | | |
| 1996 | -0.186 | 0.623 | -0.223 | -0.024 | -0.288 | 0.307 | -0.072 | -0.185 |
| 1997 | 0.611 | -0.045 | 0.487 | 0.100 | 0.264 | 0.241 | 0.771 | 0.616 |
| 1998 | -0.081 | -0.512 | -0.582 | 0.214 | -0.161 | 0.018 | -0.161 | 0.474 |
| 1999 | 0.050 | 0.675 | 0.003 | -0.541 | -0.170 | -0.693 | -0.280 | -0.400 |
| 2000 | 0.645 | 0.090 | 0.531 | 0.115 | -0.404 | 0.423 | -0.105 | 0.457 |
| 2001 | 1.186 | 1.324 | 0.243 | 0.690 | -0.523 | -1.185 | -0.681 | -1.557 |
| 2002 | -0.277 | -0.103 | 0.164 | 0.433 | 0.838 | 0.422 | 0.526 | -0.110 |
| 2003 | 0.451 | 0.439 | 0.151 | 0.623 | 0.810 | 1.242 | 1.523 | 0.836 |
| 2004 | 0.634 | 0.641 | 0.188 | -0.208 | 0.045 | -0.144 | -0.224 | -0.727 |
| 2005 | 0.293 | 0.349 | 0.238 | -0.215 | -0.550 | -0.607 | -1.091 | -0.421 |
| 2006 | -0.661 | -0.505 | 0.392 | 0.673 | 0.552 | 0.321 | 0.743 | 1.356 |
| 2007 | 0.107 | 0.356 | -0.176 | -0.116 | 0.305 | -0.380 | 0.508 | 0.082 |
| 2008 | -0.090 | -0.623 | 0.042 | -0.236 | 0.225 | 0.675 | 0.869 | 1.733 |
| 2009 | -0.794 | -0.129 | -0.389 | 0.245 | -0.067 | 0.028 | -0.376 | -0.477 |
| 2010 | -0.055 | 0.177 | 0.392 | -0.248 | 0.180 | -0.474 | -0.719 | -0.081 |
| 2011 | -0.185 | -0.261 | 0.007 | 0.044 | -0.655 | 0.354 | -1.099 | 0.206 |
| 2012 | 0.769 | 0.341 | 0.331 | 0.182 | 0.156 | -0.320 | 0.173 | -0.344 |
| 2013 | 0.846 | 0.405 | -0.349 | -0.236 | 0.014 | -0.210 | -0.384 | -0.061 |
| 2014 | -0.197 | -0.503 | -0.063 | -0.318 | 0.051 | 0.102 | 0.259 | -0.045 |
| 2015 | -0.850 | -0.151 | -0.101 | -0.013 | 0.239 | 0.219 | 0.341 | -0.374 |
| 2016 | -0.164 | -0.189 | 0.019 | 0.015 | 0.142 | -0.271 | -0.067 | 0.619 |
| 2017 | -0.116 | -0.353 | -0.099 | 0.080 | -0.243 | 0.502 | -0.501 | 0.244 |
| 2018 | -1.507 | -0.952 | 0.048 | 0.368 | 0.505 | 0.356 | 0.831 | 0.091 |
| 2019 | -0.152 | -0.345 | 0.103 | -0.230 | 0.041 | 0.149 | 0.376 | 0.050 |
| 2020 | -0.272 | -0.019 | 0.343 | 0.374 | 0.069 | -0.502 | -0.637 | -0.609 |
| 2021 | 0.000 | 0.257 | 0.126 | 0.616 | 0.215 | -0.050 | 0.453 | 0.077 |
| Max. Residuals | 1.186 | 1.324 | 0.531 | 0.690 | 0.838 | 1.242 | 1.523 | 1.733 |

**Table 11.6.1.1. The input data used for prognosis of the Icelandic summer-spawning herring in the 2021 assessment: the predicted weights, the selection pattern, M, proportion of M before spawning, and the number-at-age derived from NFT-Adapt run.**

| Age (year class) | Mean weights (kg) | M | Maturity ogive | Selection pattern | Mortality prop. before spawning | | Number at age |
|---|---|---|---|---|---|---|---|
| | | | | | F | M | 1 January 2021 |
| 3 (2018) | 0.153 | 0.11 | 0.200 | 0.207 | 0.000 | 0.500 | 572.0 |
| 4 (2017) | 0.199 | 0.12 | 0.850 | 0.784 | 0.000 | 0.500 | 1130.1 |
| 5 (2016) | 0.268 | 0.15 | 1.000 | 1.000 | 0.000 | 0.500 | 257.4 |
| 6 (2015) | 0.297 | 0.12 | 1.000 | 1.000 | 0.000 | 0.500 | 88.1 |
| 7 (2014) | 0.314 | 0.15 | 1.000 | 1.000 | 0.000 | 0.500 | 29.4 |
| 8 (2013) | 0.332 | 0.19 | 1.000 | 1.000 | 0.000 | 0.500 | 64.4 |
| 9 (2012) | 0.346 | 0.16 | 1.000 | 1.000 | 0.000 | 0.500 | 39.2 |
| 10 (2011) | 0.358 | 0.19 | 1.000 | 1.000 | 0.000 | 0.500 | 34.5 |
| 11 (2010) | 0.363 | 0.16 | 1.000 | 1.000 | 0.000 | 0.500 | 43.3 |
| 12 (2009) | 0.375 | 0.23 | 1.000 | 1.000 | 0.000 | 0.500 | 31.9 |
| 13+ (2008+) | 0.379 | 0.28 | 1.000 | 1.000 | 0.000 | 0.500 | 65.3 |

**Table 11.6.2.1. Icelandic summer-spawning herring. Catch options table for the 2021/2022 season according to the Management plan where the basis is: SSB (1 July 2021) 377 kt (accounted for $M_{infection}$ in 2020); Biomass age 4+ (1 January 2021) is 481.6 kt; Catch (2020/21) 36.1 kt; HR (2020) 0.15, and $WF_{5–10}$(2020) 0.228. Other options are also shown, including MSY approach, where $SSB_{2021}$ < MSY $B_{trigger}$ = 273 kt, hence resulting F = 0.217.**

| Rationale | Catches (2021/2022) | Basis | F (2021/2022) | Biomass of age 4+ (2022) | SSB 2022 | %SSB change * | % TAC change ** |
|---|---|---|---|---|---|---|---|
| **Management plan** | **72.2** | **HR = 0.15** | **0.217** | **441** | **421** | **12** | **100** |
| MSY approach | 73.0 | $F_{MSY}$=0.22 | 0.220 | 440 | 420 | 11 | 2 |
| Zero catch | 0 | F = 0 | 0 | 515 | 492 | 30 | -100 |
| $F_{pa}$ | 45.4 | $F_{pa}$ = 0.43 | 0.430 | 379 | 363 | -4 | 29 |
| $F_{lim}$ | 106.9 | $F_{lim}$ = 0.61 | 0.612 | 334 | 321 | -15 | 204 |

***SSB 2022 relative to SSB 2021**

****TAC 2021/22 relative to landings 2020/21**

# 11.19 Figures

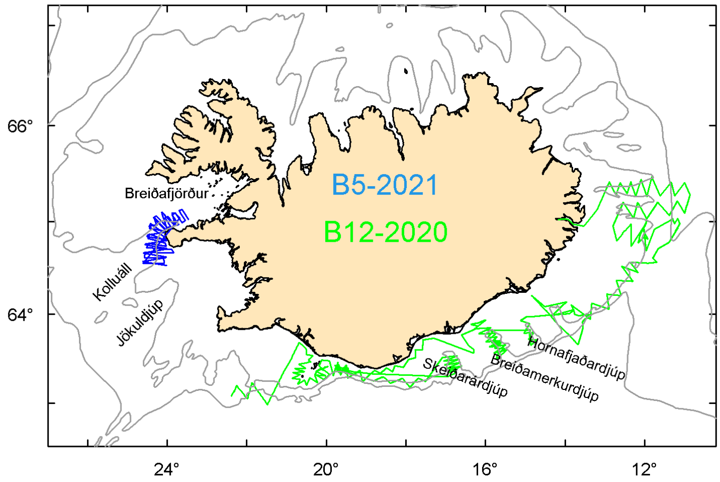


**Figure 11.1.2.1. The survey tracks of two acoustic surveys on Icelandic summer-spawning herring in the south and south-east (B12-2020; juveniles; green) and in the west (B5-2021; adult; blue) in 2020/21 and locations of the areas that are referred to in the text.**

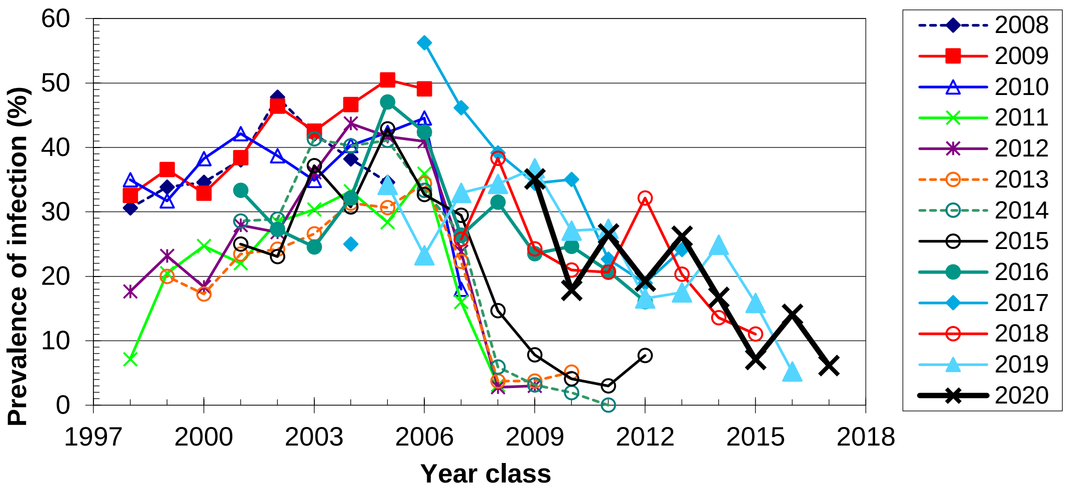


**Figure 11.1.3.1. The prevalence of the *Ichthyophonus* infection for each age of Icelandic summer-spawning herring as estimated from catch samples southwest of Iceland in the autumn (Oct.–Dec.) and samples southeast of Iceland from the acoustic survey (Nov).**

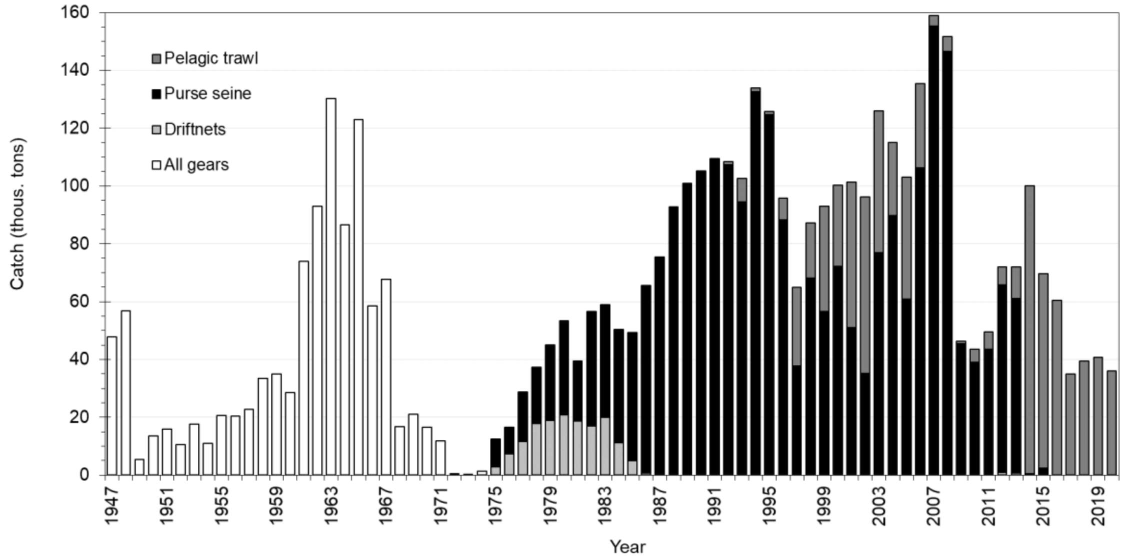


**Figure 11.2.1. Icelandic summer spawning herring. Seasonal total landings (in thousand tonnes) during 1947–2020, referring to the autumns, by different fishing gears from 1975 onwards).**

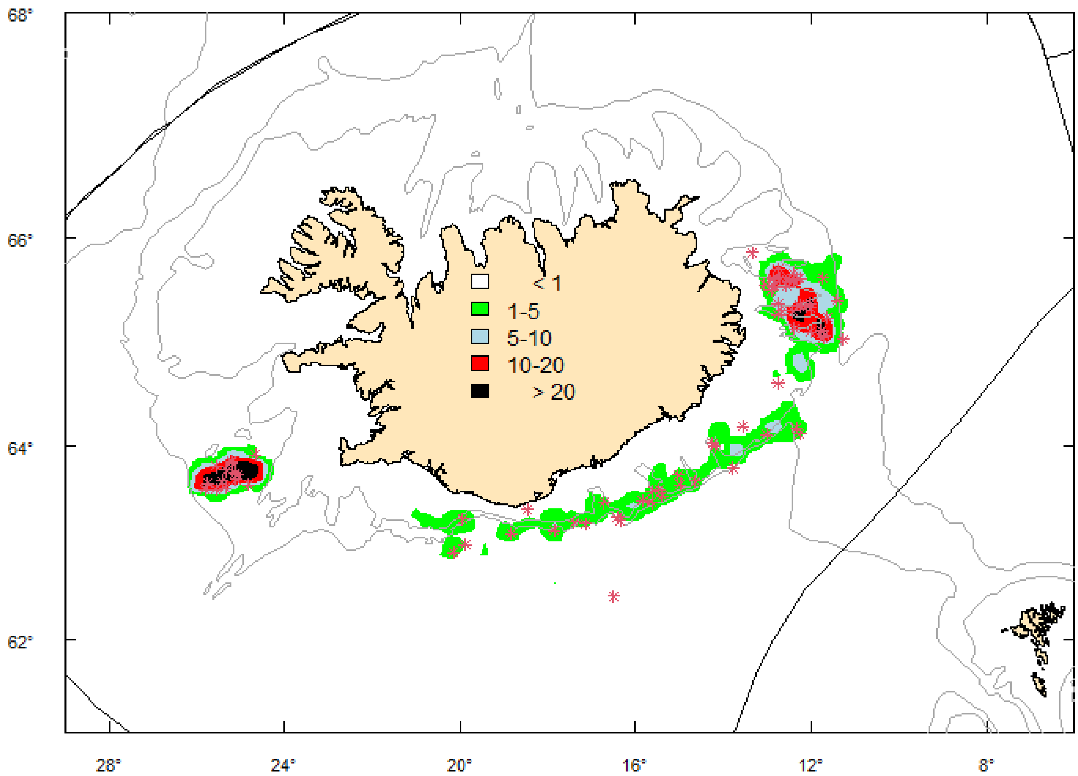


**Figure 11.2.2. The distribution of the fishery (in tonnes) of Icelandic summer spawning herring during the fishing season 2020/21, including the bycatch in the mackerel fishery in July–September 2020. The stars indicate the location of catch samples.**

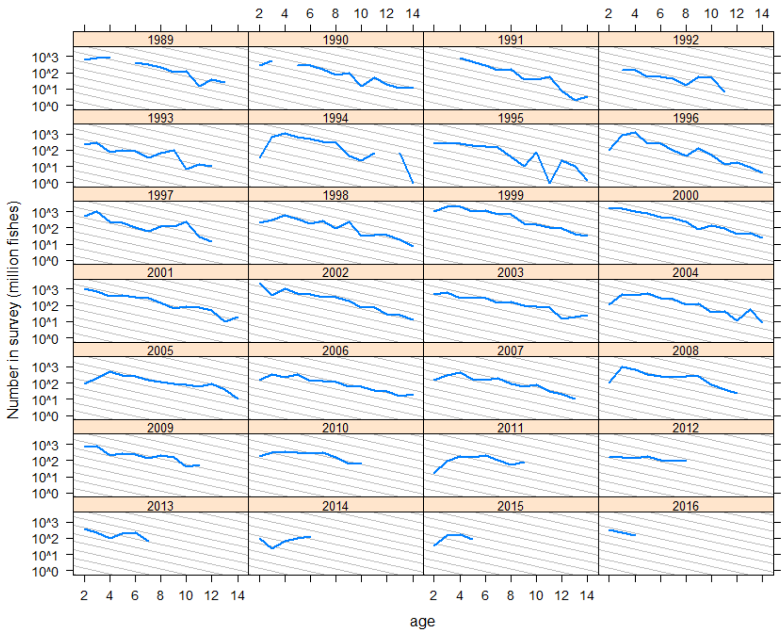

**Figure 11.3.1.1. Icelandic summer-spawning herring. Catch curves ($log_2$ of catches) by year classes 1987–2016. Grey lines correspond to Z = 0.4. Note that the mass mortality in Kolgrafafjörður is added to the catches in 2012.**

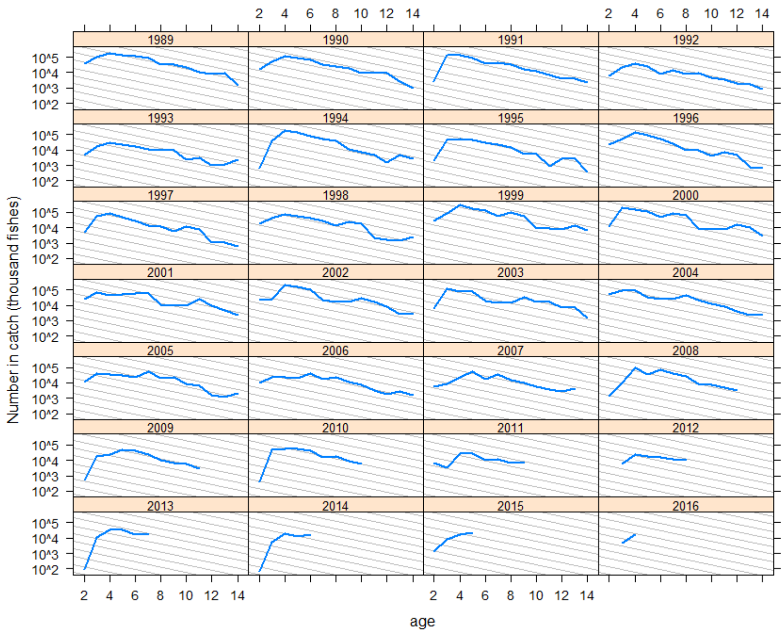

**Figure 11.3.1.2. Icelandic summer spawning herring. Catch curves ($log_2$ of indices) from survey data by year classes 1987–2016. Grey lines correspond to Z = 0.4.**

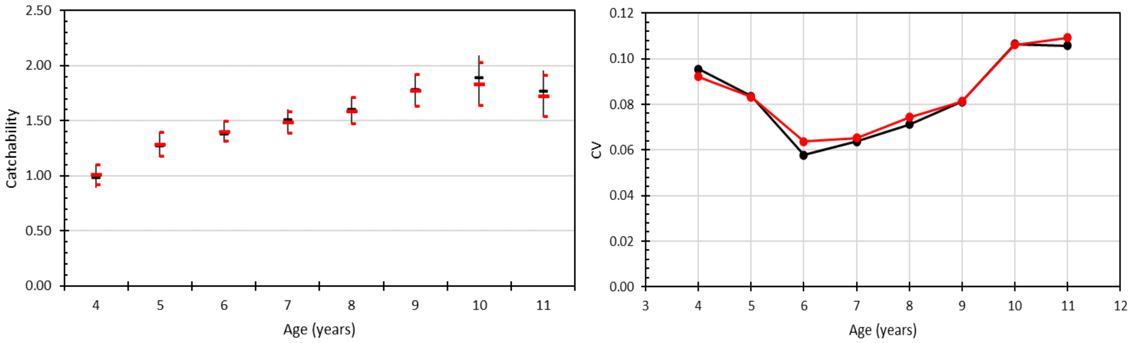


**Figure 11.3.2.1. Icelandic summer-spawning herring. The catchability (± 2 SE; left graph) and its CV (right graph) for the acoustic surveys used in the final Adapt run in 2021 (1987–2020) compared to the assessment in 2020 (red lines).**

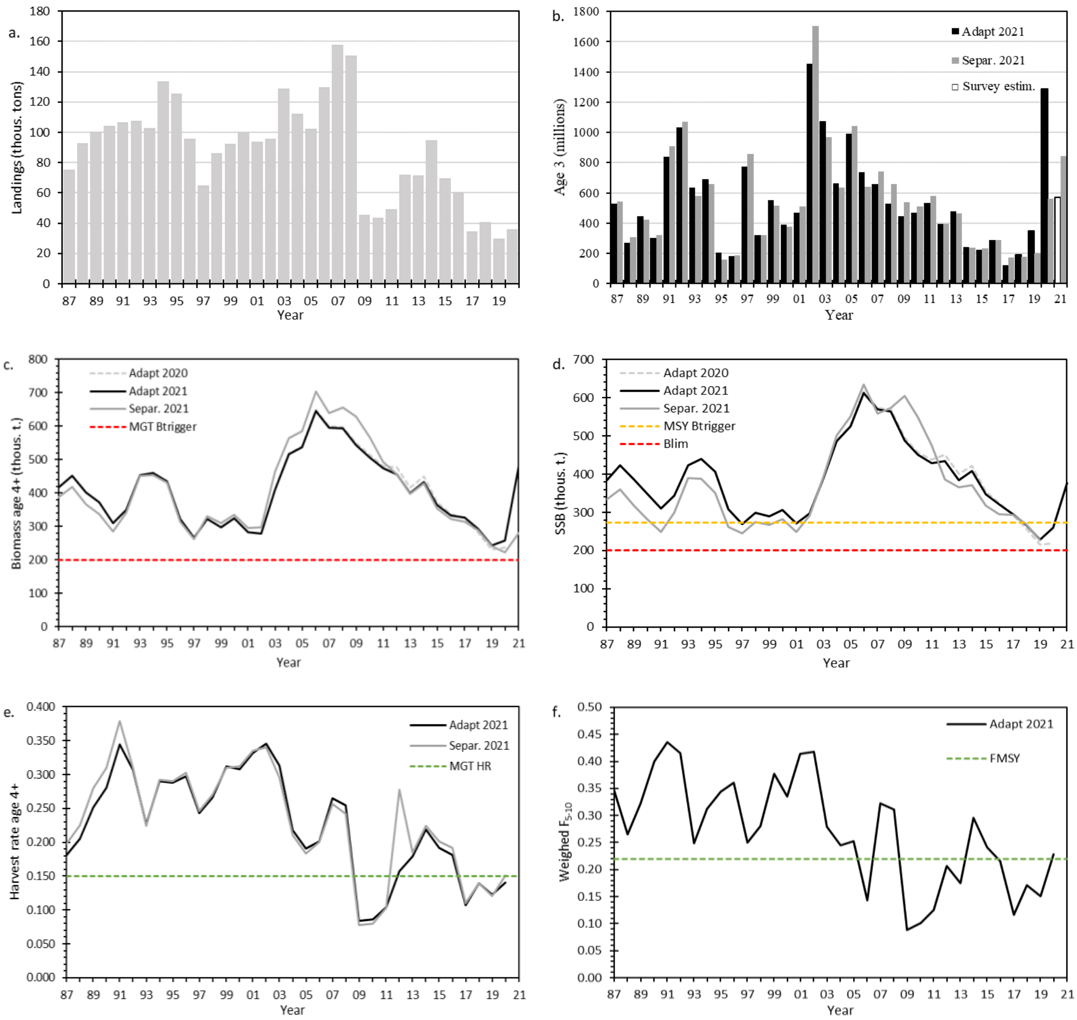


**Figure 11.3.2.2. Icelandic summer-spawning herring. Comparisons of the final NFT-Adapt run in 2021, NFT-Adapt run in 2020 and a run from a separable model (Muppet) in 2021 concerning (a) landings, (b) number at age-3 (recruitment), (c) biomass of age 4+ (reference biomass) and (d) SSB. Harvest rate (e) of the reference biomass ($HR_{MGT}$ shown) and (f) N-weighed F for age 5–10. Some reference points are also shown. Note that the mass mortality in Kolgrafafjörður in the winter 2012/13 is included in harvest rate (e) for Muppet but not in Adapt run 2021.**

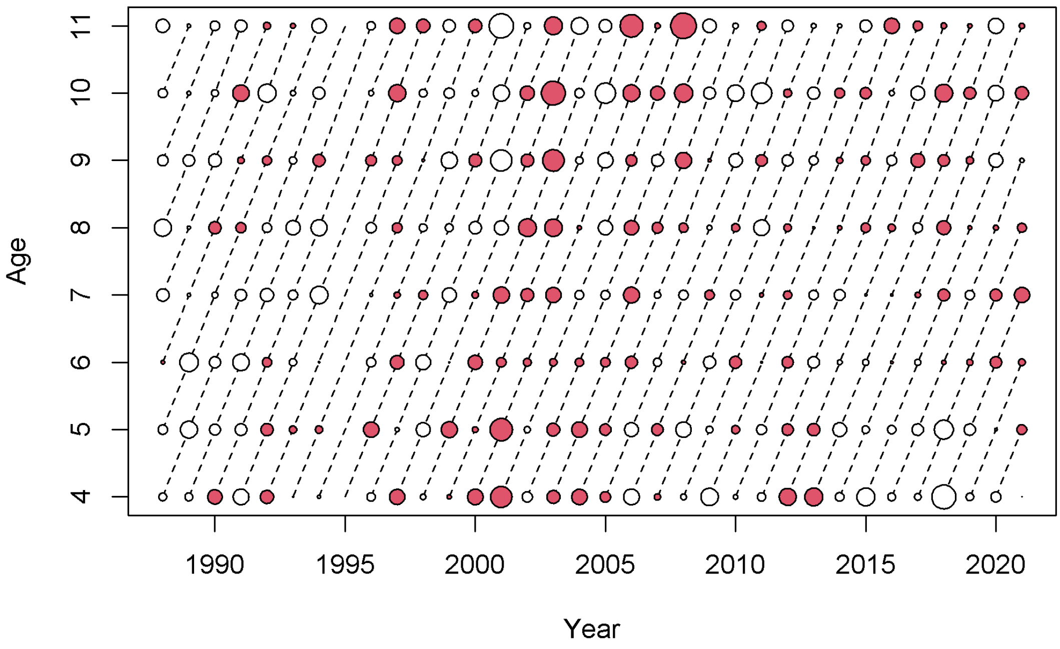


**Figure 11.3.2.3. Icelandic summer spawning herring. Residuals of NFT-Adapt run in 2021 from survey observations (moved to 1 January). Filled bubbles are positive (i.e. survey estimates higher than the assessment) and open negative. Max bubble = 1.73.**

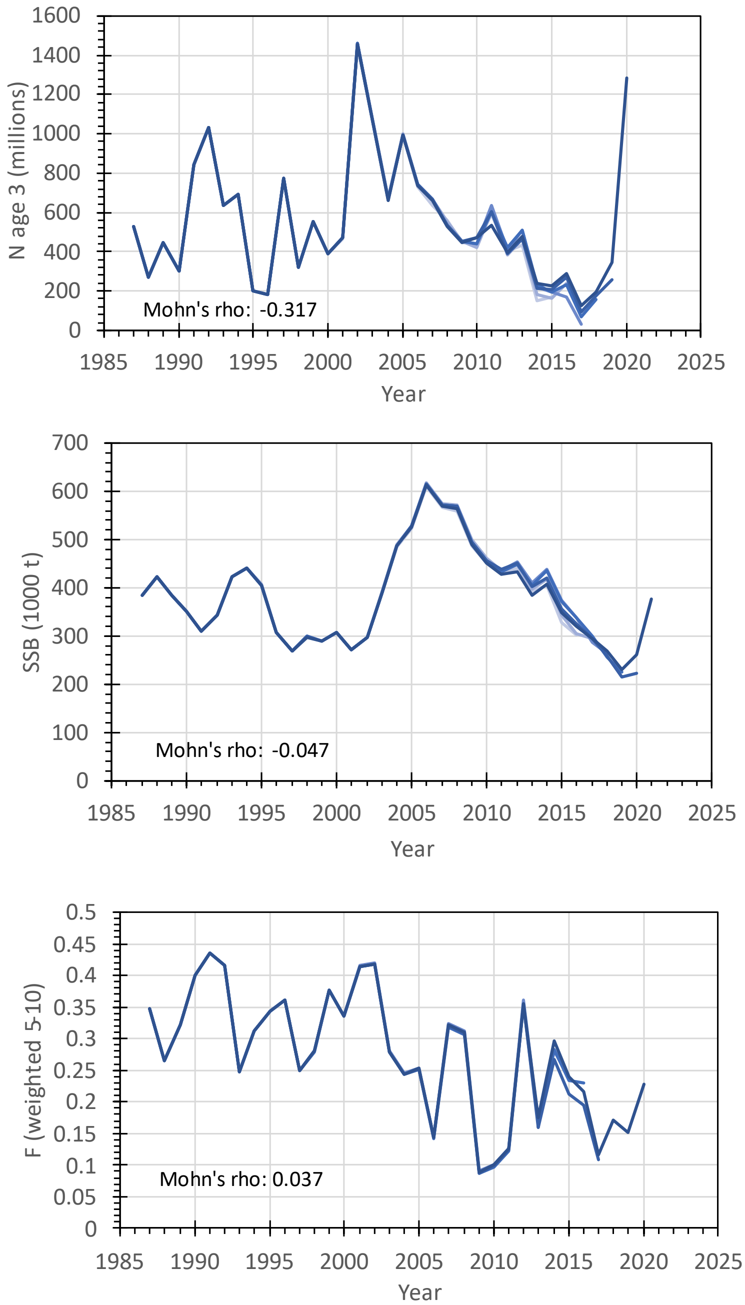


**Figure 11.3.2.4. Icelandic summer spawning herring. Six years (2014–2021) retrospective pattern from NFT-Adapt in 2021 in recruitment as number at age 3 (the top panel), spawning stock biomass (middle panel) and N weighted $F_{5-10}$ (lowest panel).**

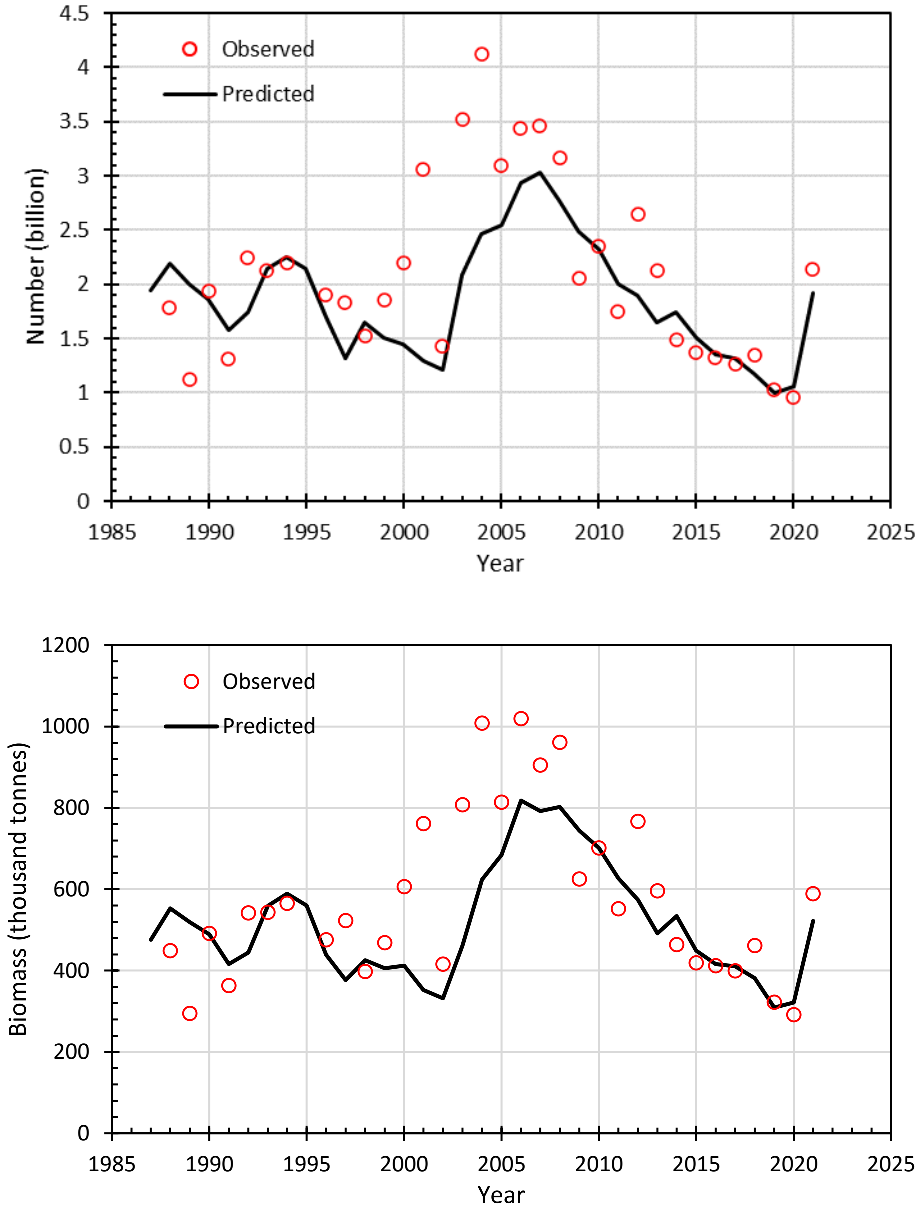


**Figure 11.3.2.5. Icelandic summer-spawning herring. Observed versus predicted survey values from NFT-Adapt run in 2021 for ages 4–11 with respect to numbers (upper) and biomass (lower). Note that there was no survey in 1995.**

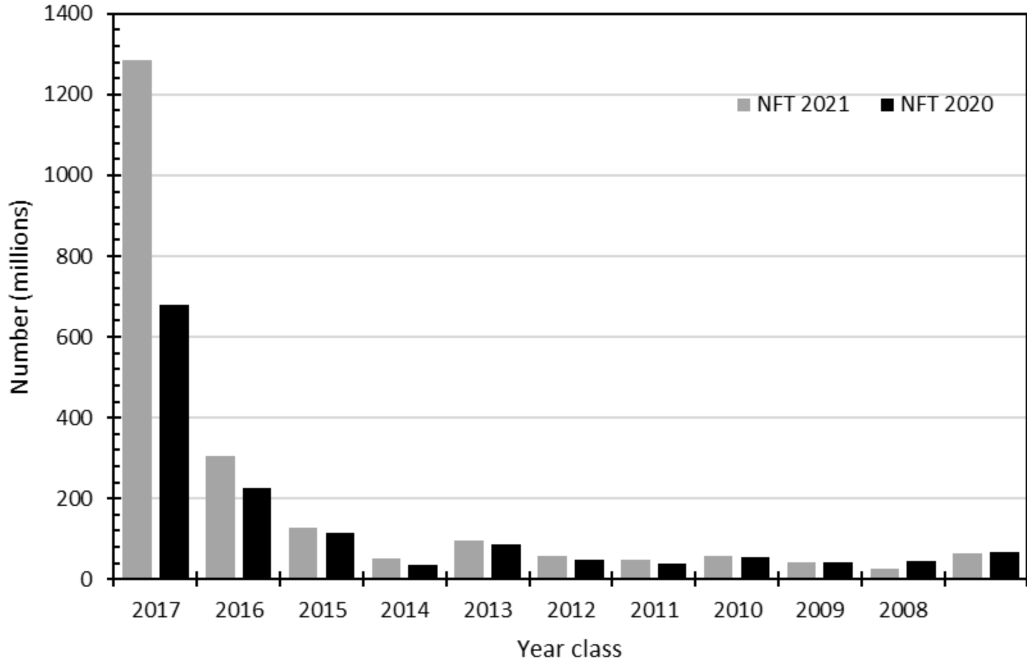


**Figure 11.3.2.6. Icelandic summer-spawning herring. Comparison of number-at-age on 1 January from the final NFT model runs in 2020 and 2021 assessments.**

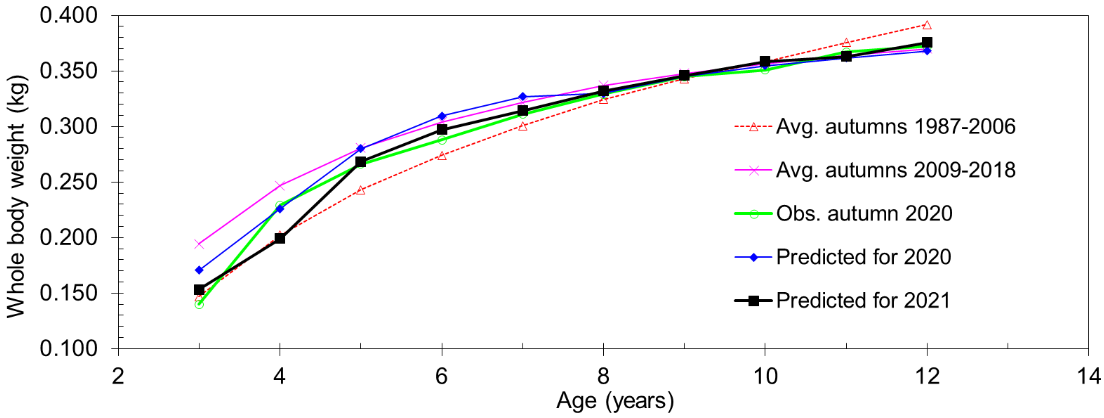


**Figure 11.6.1.1. Icelandic summer spawning herring. The mean weight-at-age for age groups 3 to 12 (+ group) in 1987–2006, 2009–2018, in the catches in the autumn 2019, predicted weights for autumn 2020 in the 2020 assessment (ICES, 2020) and finally predicted weights for the autumn 2021 from the weights in 2020, which was used in the stock prognosis.**

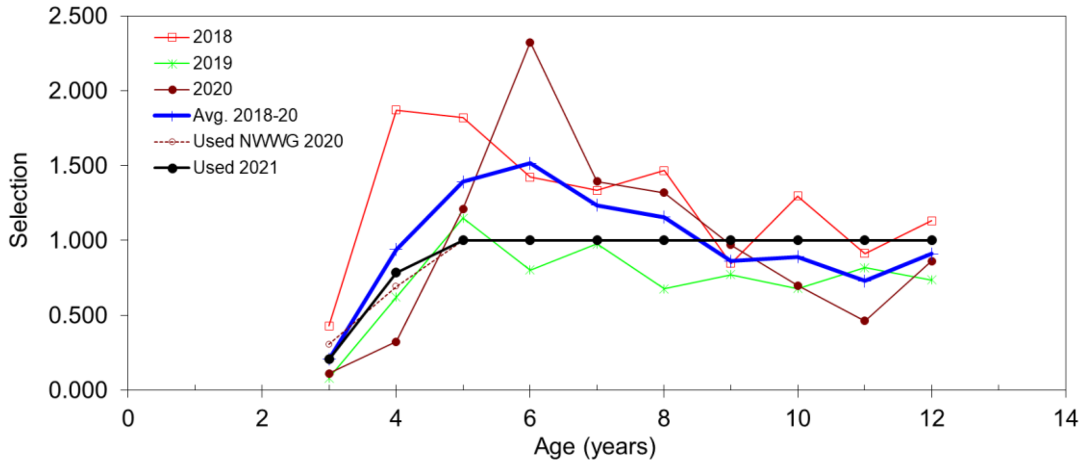


**Figure 11.6.1.2. Icelandic summer spawning herring. Estimate of selection pattern ($F_{age}/F_{weighted\ mean\ 5\text{–}10}$) in the fishery in the stock prognosis for age groups 3 to 12 (+ group) on basis of the Fs in 2018 to 2020, the average over these three years (used for the prognosis according to the Stock Annex), the selection used in 2020 (ICES, 2020), and the selection used in the prognosis 2021.**

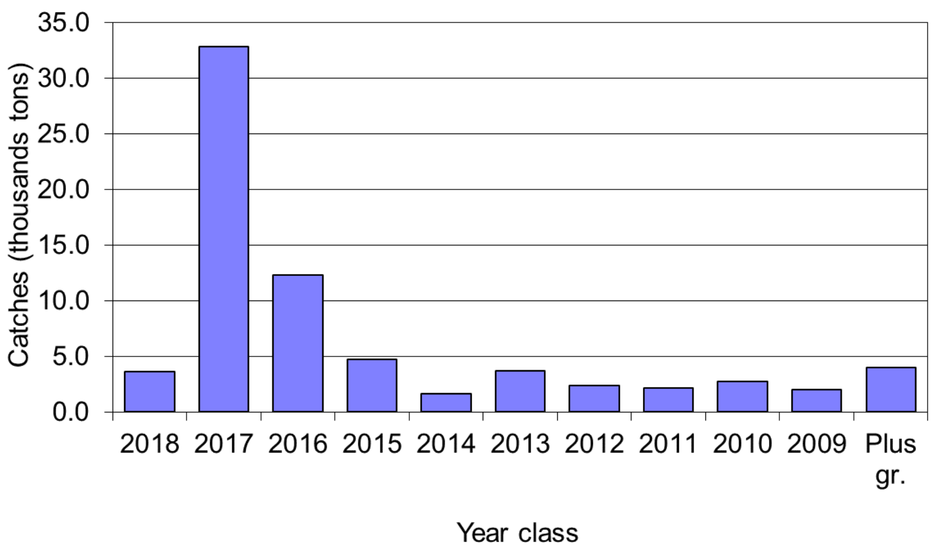


**Figure 11.6.2.1. Icelandic summer spawning herring. The predicted biomass contribution of the different year classes to the catches in the fishing season 2021/2022 (total catch of 72 239 tonnes).**