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11 Icelandic summer spawning herring

11.1 Scientific data

11.1.1 Surveys description

The scientific data used for assessment of the Icelandic summer-spawning herring stock are based on annual acoustic surveys (IS-Her-Aco-4Q/1Q)., which have been ongoing since 1974 (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 on basis of available information on the distribution of the stock in 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 2017/2018 derives from two dedicated acoustic surveys in February and March 2017 (Óskarsson 2018a). The annual survey aiming for the abundance of herring juveniles in the fjords northwest and north of Iceland was cancelled this winter because of failures of RV Bjarni Sæmundsson. Only one fjord, Eyjafjordur, was covered so the index for age 1 is incomplete and not comparable to other years. Consequently, it cannot be used in the assessment or prognosis of the stock (i.e. to predict the year class strength later at age 3).

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 prevalence of *Ichthyophonus* infection in the stock. The instrument and methods in the surveys were the same as in previous years and described in the stock annex and all the results are detailed in a WD to NWWG (Óskarsson 2018a). 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 herring stock was nearly only observed in one area, west of Iceland in Kolluáll, while small part was found southeast of Iceland in three different areas (Fig. 11.1.2.1; Óskarsson 2018a). The total abundance index was higher than those from the most recent four years and this increase took only place west of Iceland as the index east and south of Iceland was lower than seen for years (Figure 11.1.2.2).

The total acoustic estimate of Icelandic summer-spawning herring this winter, according to these two surveys came to 1.84 billion in numbers and the total biomass index was 513 kt (Table 11.1.1.1). The fishable part of the stock (≥27 cm) accounted for 99% of the biomass, or 506 kt. The biomass index for age 4+ came to 489 kt, compare to 339 kt in the winter 2016/17, which is an 44% increase. Apart from the one and two years olds, the three most numerous year classes were those from 2010 and 2008 (20% and 16%, respectively, of the total number). Together, the 2008-2012 year classes contributed to ~73% of the total number and the biomass. The 2014 and 2013 year classes were in low number (1.5% and 6%, respectively).

11.1.3 Prevalence of *Ichthyophonus* infection in the stock

The results of comprehensive analyses of the *Ichthyophonus* outbreak 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. 2018a). 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). M used in the stock assessment in 2018 for the year 2017 reflected these findings (ICES 2017c).

The prevalence of the *Ichthyophonus* infection in the stock in 2017/18 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 west of Iceland was highest for the 2006-2007 year classes according to the catch samples (39-56%; Figure 11.1.3.1). For other age groups at age 4 and older, the prevalence was 19-35%.

The prevalence of infection for the younger year classes (2008-2012) was low until the autumn 2014 when is it started to increase slightly, which continued in 2015 and to a much larger extend in 2016 and again now in 2017 (Figure 11.1.3.1). This indicates a new infection has been taken place in the stock in the last four years, particularly in the last two years. This differs from the results obtained for the period 2010-2014, where analyses of younger age groups showed no indication of new infection, or at insignificant level.

Like in last two years, no apparent trend in the stageing of the infection was observed that can be used to tell something about the development of the infection over the year (Óskarsson and Pálsson 2018). However, all the data indicate an ongoing new infection, which will most likely result in significant infection mortality in the coming months. Moreover, around 10% of the herring sampled in March 2018 had heavy infection (stage 3-4), which are considered to die because of the infection in the coming weeks/months. At the same time, around 23% of the herring had light infection (stage 1-2). This supports the approach to assume infection mortality in 2018, where the abundance estimates from the final year of the assessment (1st Jan. 2018) and extrapolated to SSB near the beginning of the next fishing season (July 2018) to provide advice should be lowered by this additional M as done in 2009-2011 assessments. The level of M should then follow the results by Óskarsson et al. (2018a), where age specific $M_{infected}$ (estimated from the catch samples; Fig. 11.1.3.1) is multiplied by 0.3 and the fixed M (0.1) added to it. These M for 2018 (Table 11.3.2.1) should be used in the prognosis in 2018 and in the analytical assessment from 2019 and onwards, until better more reliable estimates become available.

11.2 Information from the fishing industry

The total landings of Icelandic summer-spawning herring in 2017/2018 season were about 35.0 kt with no discards reported (Table 11.2.1 and in Figure 11.2.1). Note that the total landings include also bycatches in the mackerel and Norwegian spring-spawning herring (NSSH) fisheries in June-October 2017 (12.8 kt), even if partly (5.1 kt) belonging to the official fishing season Sept. 2016/August 2017. This is a traditional method in assessment of the stock. The quality of the herring landing data regarding discards and misreporting are consider adequate as implied in a general summary in section 7 and in the Her-Vasu stock annex. The recommended TAC, provided in the spring 2017, was 39 kt (ICES 2017c) and allowable TAC 39 kt (Table 11.2.1). The difference between the catches in 2017 and TAC of ~4 kt was transferred to the next “assessment season” (June 2018-April 2019). Officially, according to the Directorate of Fisheries (http://www.fiskistofa.is/veidar/aflastada/ aflastodulisti), 9.5 kt remained unfished in March 2018, which needs to compensate for the bycatch in the summer 2018.

The direct fishery started in November and lasted to January in offshore areas west of Iceland and contributed to 63% of the total catches (Fig. 11.2.2). The remaining 37% (12.8 kt) of the catch was taken as bycatch in the fishery for NSSH and mackerel during June to October and mainly southeast and east of Iceland (Fig. 11.2.2).

Spring-spawning herring (assumed to be Icelandic spring spawners and not NSSH) was mixed with the Icelandic summer-spawning herring stock in the catches in the winter 2017 as normally observed (Óskarsson 2018b). The proportion became to 2.3% for the areas west of Iceland during October-December. This proportion is similar to what was observed for the autumns 2013-2016 (2-5%; Óskarsson 2018b).

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 1984 are given in thousands tonnes (kt) in Table 11.2.1.

All the catch in 2017/2018 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 since 2007/2008 to 2012/2013, most of the catches (~90%) were been taken 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 of the overwintering west of Iceland took place offshore which continued this winter. These changes in distribution explain the dominance of pelagic trawl in the fishery, which is preferred by the fleet over purse seine in offshore areas.

To protect juveniles 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. Oktober 1992). No closure was enforced in this herring fishery in 2017/18. 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

<u>Catch at age in 2017/2018</u>:

The procedure for the catch at age estimations, as described in the Stock Annex, was followed for the 2017/18 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 three cells confined by season and area as detailed in Óskarsson and Pálsson (2018). In the same way, three 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 (June-Oct.) and the winter (Nov.-Jan.), two 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 1982 are given in Table 11.2.2.1. The geographical location of the sampling is shown on Figure 11.2.2.

The age composition in the direct winter fishery 2017/2018 was different from the composition in the bycatch of herring in the mackerel and NSS-herring fishery in the summer 2017 (Figure 11.2.2.1). The summer fishery included to a higher degree younger age groups (e.g. age 4-5 contributed to ~58% of the biomass) than the direct fishery in the west (25%), and consequently vice versa for older age groups. This difference is probably reflecting the geographical distribution of the different age groups, with higher proportion of younger age groups in the east and south than in the west. However, it must be noted that these two cohorts (age 4 and 5) were in much lower quantity in the acoustic surveys than in the catches (Fig. 11.2.2.1; Óskarsson 2017). Worth noticing also is the low number of age 3 in the catches, and particularly in the acoustic survey, which have impacts on the assessment (see section 11.3).

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). The total number of fish weighed from the catch in 2017/18 was 1323 and 1271 of them were aged from their fish scales.

Proportion mature:

The fixed maturity ogives were used in this year's assessment, as introduced 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.

Observed versus predictions of catch composition:

The relative contribution of the different year (age) classes was similar to what was predicted in the analytical assessment in 2017 (Fig. 11.2.2.1). The main difference was for age 3 and 4, which were less numerous in the catches than predicted, while most other age groups were more numerous than predicted.

11.3 Analytical assessment

11.3.1 Analysis of input data

Examination of catch curves for the year classes from 1986 to 2013 (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 1986-2013 (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, for example for 1996-2008 year classes. 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.

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/ADPAT version 3.3.0 NOAA Fisheries Toolbox) that has been used as the basis for the assessments since 2005 and a separable model also used in the MSE in 2017 for the stock (ICES 2017b; Björnsson 2018). 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 1987/88-2017/18 (Table 11.2.2.1) and survey data from 1987/88-2017/18 (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 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. 2018a); (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 2018, while the stock numbers at age 3 was derived from survey estimates in 2016 (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 a 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 January 1st). 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. Positive residuals were seen for all age groups above age 5 in this year's survey.

Retrospective analyses indicate a consistency over the most recent four 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 year is likely caused by the increased M in 2017 (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. The retros observed for SSB in 2011 and 2012 are related to high survey indices in the preceding autumns as also seen as difference between observed and predicted survey values (Figure 11.3.2.5). The mass mortality, which was added to the catches in 2012 in the assessment as presented earlier (ICES 2014), are probably also partly explaining this pattern at that time. A revision of the number at age 3 of the 2008 and 2009 year classes (in 2011 and 2012) is also apparent retrospectively, which is related to their high survey indices at age 3.

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 previoulsy 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 (January 1st 2011), implying that the terminal point estimates in the final run was not driven by this residual block.

F in 2017 for age 4 (0.33) and age 3 (0.21) is much higher than the $F_{Avg.5-10}$ and F_{W5-10} (0.12 in both cases) despite their low catches (Table 11.3.2.4). This is related to that these year classes were mainly caught during the summer fishery 2017, hardly observed in the 2017/18 surveys (Óskarsson 2018a) and were, consequently, assessed small by the NFT-Adapt model. In other words, this is a consequence of the discrepancy on estimates for these year classes between the catches and surveys in 2017/2018. This adds uncertainty to the assessment.

Comparisons of different models:

The two models explored, NFT-Adapt and the separable model, gave almost identical stock size estimates for final year of the assessments (2018; Figure 11.3.2.2). The historical estimates of stock size were also similar (see more in Björnsson 2018).

11.3.3 Final assessment and TAC advice on basis of Management Plan

This is an update assessment so the results of the NFT-Adapt were adopted as point estimator for the prediction and thus the basis for the advice as in recent years. The model settings and outputs are shown in Table 11.3.2.2 to Table 11.3.2.4 and Figure 11.3.2.2.

The assessment (Table 11.3.2.5 and Figure 11.3.2.2) indicates that the harvest rate in 2017 (0.117) was below HR_{MGT}=0.15, and the fishing mortality (weighed average for age 5-10; 0.115) was below F_{pa}=F_{MSY}=0.22. The low F during 2009 to 2011 was related to cautious TAC and apparently overestimation of mortality induced by the *Ichthyophonus* outburst. The estimated number of herring that died in Kolgrafafjörður in the two incidents of the mass mortalities (Óskarsson et al. 2018b) were added to the catches in 2012 and is also included in the high F that year (Table 11.3.2.5 and Figure 11.3.2.2). The F related only to landings in 2012 came to 0.20.

SSB in 2018 will be 222 kt and above MGT $B_{trigger}$ = B_{lim} =200 kt so the $TAC_{2018/19}$ according to the Management Plan (section 11.4) is 0.15 × Biomass 4+ (234.7 kt) = 35.186 kt .

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 to 0.15. In the assessment year (Y) the TAC in the next fishing year (September 1 of year Y to August 31 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* $B_{trigger}$:

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

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.

11.5 State of the stock

The stock was at high levels until around late 2000s but since then a substantial reduction has taken place despite a low fishing mortality. The reduction is consequence of mortality induced by *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. Hence, SSB will be below MSY $B_{trigger}$ in 2018 but above the MSG $B_{trigger}$ and B_{lim}.

11.6 Short term forecast

11.6.1 The input data

The final adopted model, NFT-Adapt, which gave the number-at-age on January 1st, 2018, 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 2018 (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 approch as used in the assessments in 2009-2011 (ICES 2011b; Óskarsson et al. 2018a).

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). According to the Stock Annex, the selection pattern in the prognosis should be based averages over 2015 to 2017 from the final run. Because of the high F for age 3 and 4 in 2017 (section 11.3.2), the expected selection pattern for them in 2018 became unrealistically high (Figure 11.6.1.2), and thereby much higher than in recent years. Consequently, it was decided to deviate from the Stock Annex and base the selection only on the average for 2015-2016. This was justified by the fact that the advice deriving from the assessment is not based on the outcome of this forecast.

As traditionally, M was set 0.1, proportion M before spawning was set 0.5 and proportion F before spawning was set 0. The numbers of recruits in the prognosis were determined as follows:

The 2015 year class: An acoustic survey aimed for getting an abundance index for this year class took place in September-October 2016 (Óskarsson 2017), and using a relation obtained by Gudmundsdóttir et al. (2007) provides estimate of 496 million at age 3 in 2018. Accounting for the *Icthtyophonus* infection observed in the autumn 2017 for this age groups (5.2% × 0.3) resulted in 488 million that was used in the prognosis.

The 2016 year class: The planned acoustic survey in the autumn 2017 aimed for getting an abundance index for this year class was cancelled due to vessel problems. An incomplete abundance index for this year class derives from a survey in February 2018 where a single fjord was covered (Eyjafjörður) and the assumed adult areas east and south of Iceland (Óskarsson 2018a). Using a relation obtained by Gudmundsdóttir et al. (2007) provides estimate of 360 million at age 3 in 2019, and it was decided to use it instead of geometric mean of 502 million.

The 2017 year class: No acoustic estimates are available for the year class yet thus the number-at-age 3 in 2020 was set to the geometrical mean for age-3 over 1987-2015, which give 502 million.

In summary, the basis for the stock projection is as follows: SSB(2018)=222 kt; Biomass age 4+ (1st Jan. 2018) = 235 kt; Catch (2017/18) = 35 kt; $WF_{5\text{-}10}$(2017)=0.115.

11.6.2 Prognosis results

SSB in the beginning of the fishing season 2018/19 (approximately the same time as spawning in July 2018) is estimated to be 222 kt, which is above MGT $B_{trigger}$ of 200 kt. Consequently, adviced TAC on basis of the Management rule is 0.15 × Biomass 4+ (234.7 kt) = 35.186 kt. This results in $F_{W5\text{-}10}$ = 0.168 in 2018/19 and SSB = 231 kt in 2019 (Table 11.6.2.1).

The results of different options are given in Table 11.6.2.1. The proposed composition of the catch in the season 2018/19 consists mainly of the 2009-2012 year classes and the plus group, each contributing to 11-15% in total biomass of the catch (Figure 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 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 and in 2017 ($M_{infected,\ age,\ year}$

multiplied by 0.3 (see section 11.1.3). This quantification of the infection mortality based on Óskarsson et al. (2018a), is considered to improve the assessment and reduce its uncertainty. For the most recent years where new infection reappeared (2017 and 2018), 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 year's catches and the survey give somewhat contradicting results about the size of the 2013 year class, while both indicate a record small 2014 year class. The size of these year classes is probably not very well determined yet, which adds uncertainty to the assessment. Like for the 2014 year class, the 2011 year class was seen very small at age 3 in both catches and survey, which however, turned out to be too pessimistic estimate. The same could possibly also apply for the 2014 year class, meaning that the catches and the survey did possibly not cover its spatial distribution adequately.

11.8.2 Forecast

It is important to notice that the advice for 2018/2019 fishing season deriving from the Management plan is independent of the forecast and its uncertainty. The uncertainty in the assessment mentioned above related to the apparent new infection in the stock in 2017 and 2018 and size of the recruiting year classes, apply also for the forecast.

Moreover, the number-at-age 3 in the beginning of the year 2018 used in the prognosis (496 millions) was predicted from a survey estimate of number at age 1 in 2016 in accordance with the approach described in the Stock Annex. The size of the year class is therefore poorly determined and creates some uncertainty in the forecast, even if it considered more appropriate than applying geometric mean.

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 four 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, where the model increase the stock size back in time to compensate for the increase M.

As stated in last year's 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. Additional natural mortality was applied to 2017 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^{st} Jan. 2017 are compared with last year's assessment, the results of the final NFT run in 2018 gives a slightly more optimistic view on number-at-age for the year classes 2012-2007, while similar for others (Figure 11.3.2.6) Note there is a big difference for the 2014 year class where the number-at-age 3 in 2017 assessment was based on prediction from survey estimation of number-at-age 1 in the 2015 survey while estimated by NFT in the 2018 assessment. This low estimate of the 2014 year class in this year's assessment is the main reason for continuation of declining stock size estimates in 2018.

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 four winters with an increased intensity since 2016/2017. Significant new infection was otherwise last observed in 2010 (Óskarsson *et al.* 2018a). Correspondingly, induced mortality due to the infection was unavoidably applied for 2017 and 2018, and this second outbreak might continue in the coming year. Considering the presently low stock size, the ongoing second outbreak, and seemingly continuation of poor year classes entering the fishable stock, the stock size will most likely remain at low level in the next years and be between B_{lim} and MSY $B_{trigger}$ which implies reduced fishing mortality.

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 2019. 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. 2018a), despite a high prevalence of infection for now nine years. As pointed out above, the new infection in 2016/2017 and in 2017/18 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 2017/2018. 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 2017/2018 was different from the previous seven seasons. Instead of fishing near only in a small inshore area off the west coast in purse seine, the whole directed fishery took place in offshore areas west 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. This bycatch of summer spawners is partly 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% this 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 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 since 2007 (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 of the summer spawners have been high, for example record high in the autumn 2014 (Figure 11.6.1.1), and the mean weight-at-length have also been relatively high in recent years (Óskarsson and Pálsson 2018). 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 (IMR 2016), and high positive NAO in recent years (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml), we could expect good recruitment in the stock but it has not come through yet.

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 Advice Technical Guidelines (ICES 2016).

11.16 Comments on the assessment

The assessment implies that the stock size has been declining since end of 2000s due to a combination of *Ichthyophonus* mortality and series of below average and poor year classes entering the stock. The 2014 year class entering the reference biomass and SSB in 2018 is estimated record small. However, it size is yet poorly determined, and the assessment might therefore be rather pessimistic.

There is compelling evidence for serious new infection by *Ichthyophonus* in the stock in the winter 2017/18, like in the year before, which called for applying additional infection mortality in 2018 until spawning. This decision has no impacts on the advice based on the management plan, but lowered the SSB in 2018. The mortality level for 2017 and 2018 cannot be estimated adequately with data at hand but can within several years. This current outbreak adds uncertainty to the assessment and advice.

11.17 References

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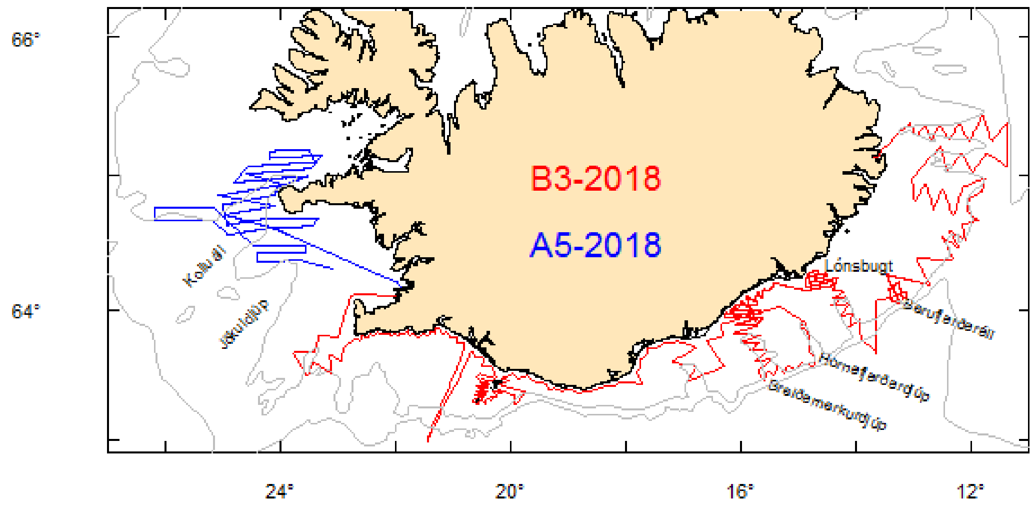

Figure 11.1.2.1. The survey tracks of two acoustic surveys on Icelandic summer-spawning herring in the east and south (B3-2018; adults; red) and in the west (A5-2018; adult; blue) in 217/18 and locations of the areas that are referred to in the text.

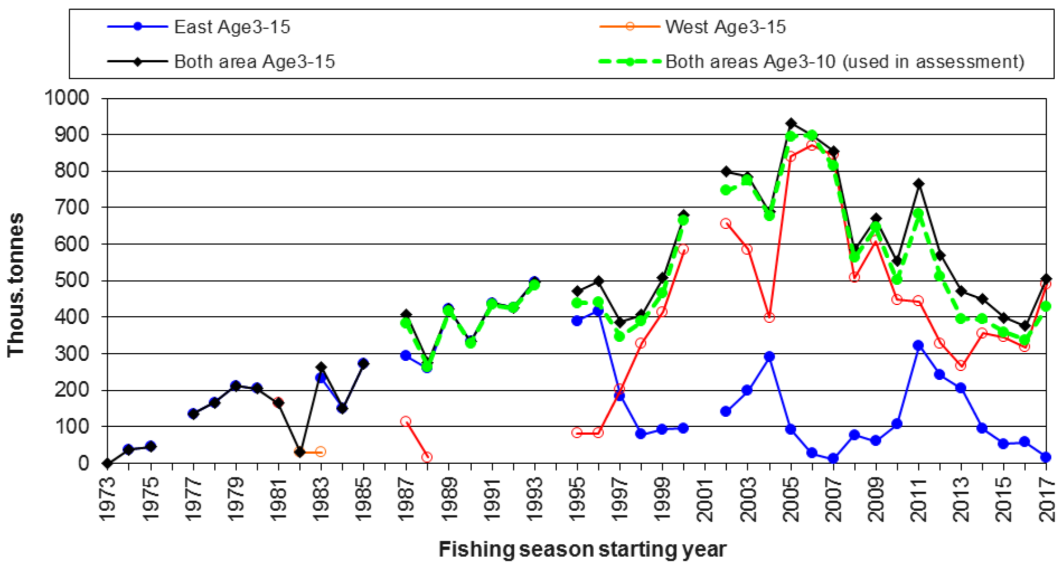

Figure 11.1.2.2 Total biomass index for Icelandic summer-spawning herring from the acoustic surveys for ages 3+ in the areas east and west of 18°W (except in 2011 and 2012 where fish outside of Breiðafjörður was set to the eastern part), combined over all areas and age 3-10 which are used in tuning of the analytical assessment. The years in the plot (1973-2017) refer to the autumn of the fishing seasons.

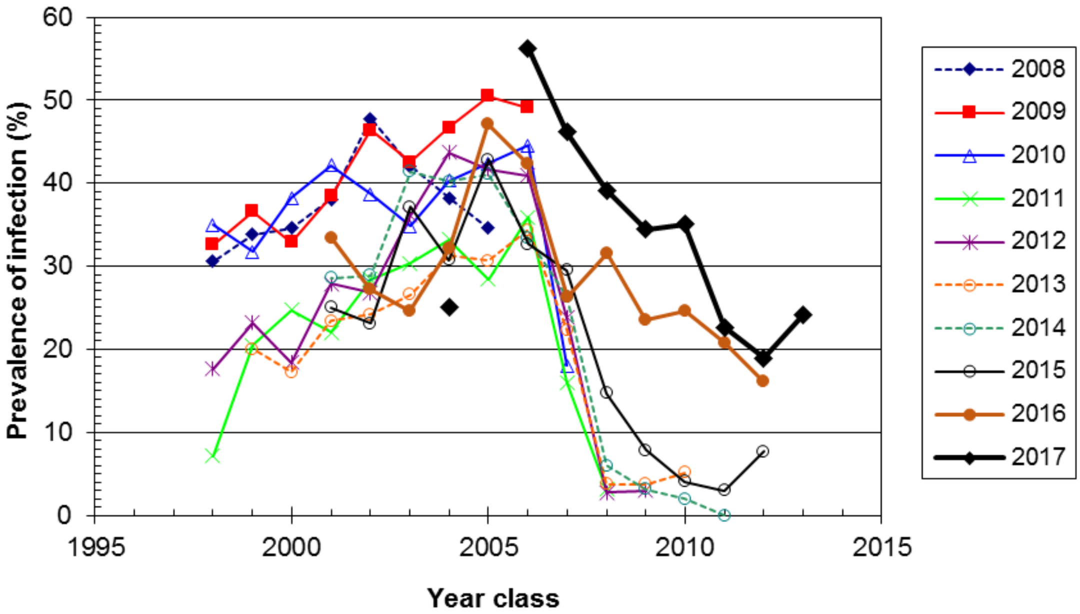

Figure 11.1.3.1. The prevalence of *Ichthyophonus* infection for the different year classes of Icelandic summer-spawning herring in Breiðafjörður and west of Iceland as estimated from catch samples in the autumns 2008 to 2017.

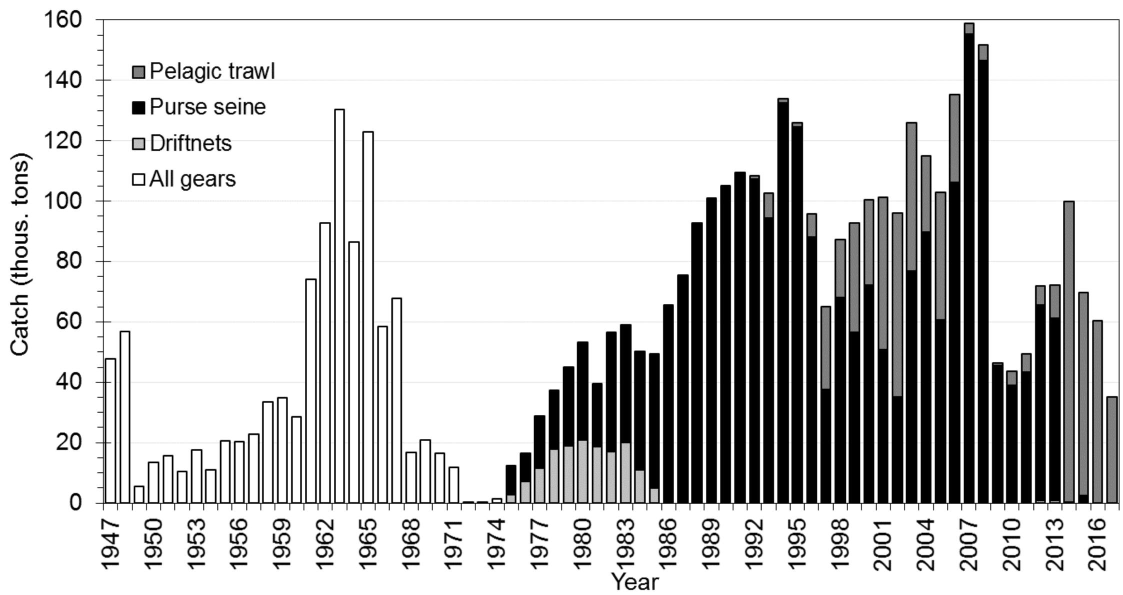

Figure 11.2.1. Icelandic summer spawning herring. Seasonal total landings (in thousand tonnes) during 1947-2017, referring to the autumns, by different fishing gears (from 1975-2017).

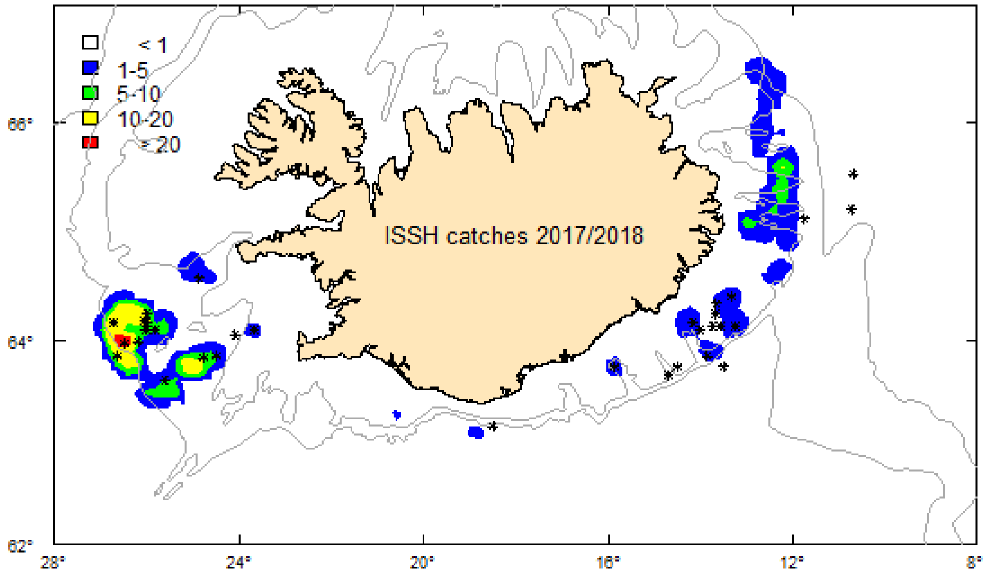

Figure 11.2.2. The distribution of the fishery (in tonnes) of Icelandic summer spawning herring during the fishing season 2017/18, including the bycatch in the mackerel fishery in June-September 2017. The stars indicate the location of catch samples.

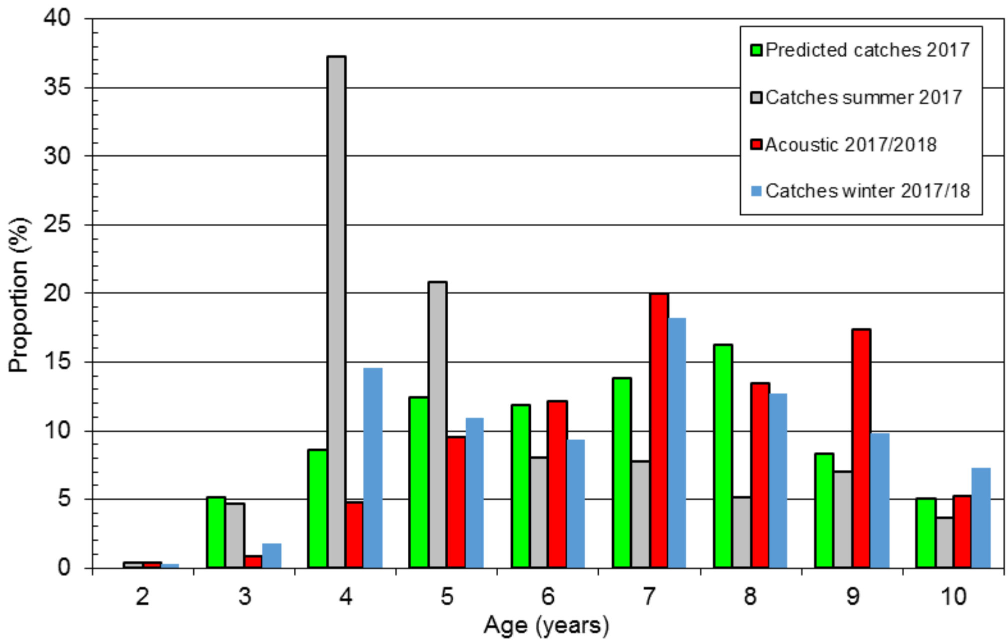

Figure 11.2.2.1. Proportion of the different age groups of Icelandic summer-spawning herring to the total catches (biomass) as observed in 2017/2018 fishing season (June 2017-Februay 2018), predicted in the 2017 assessment (ICES 2017) for the 2017/2018 fishing season, and the summer catches in June-October 2017 in comparison to the age composition in the stock according to the acoustic measurements in the winter 2017/2018.

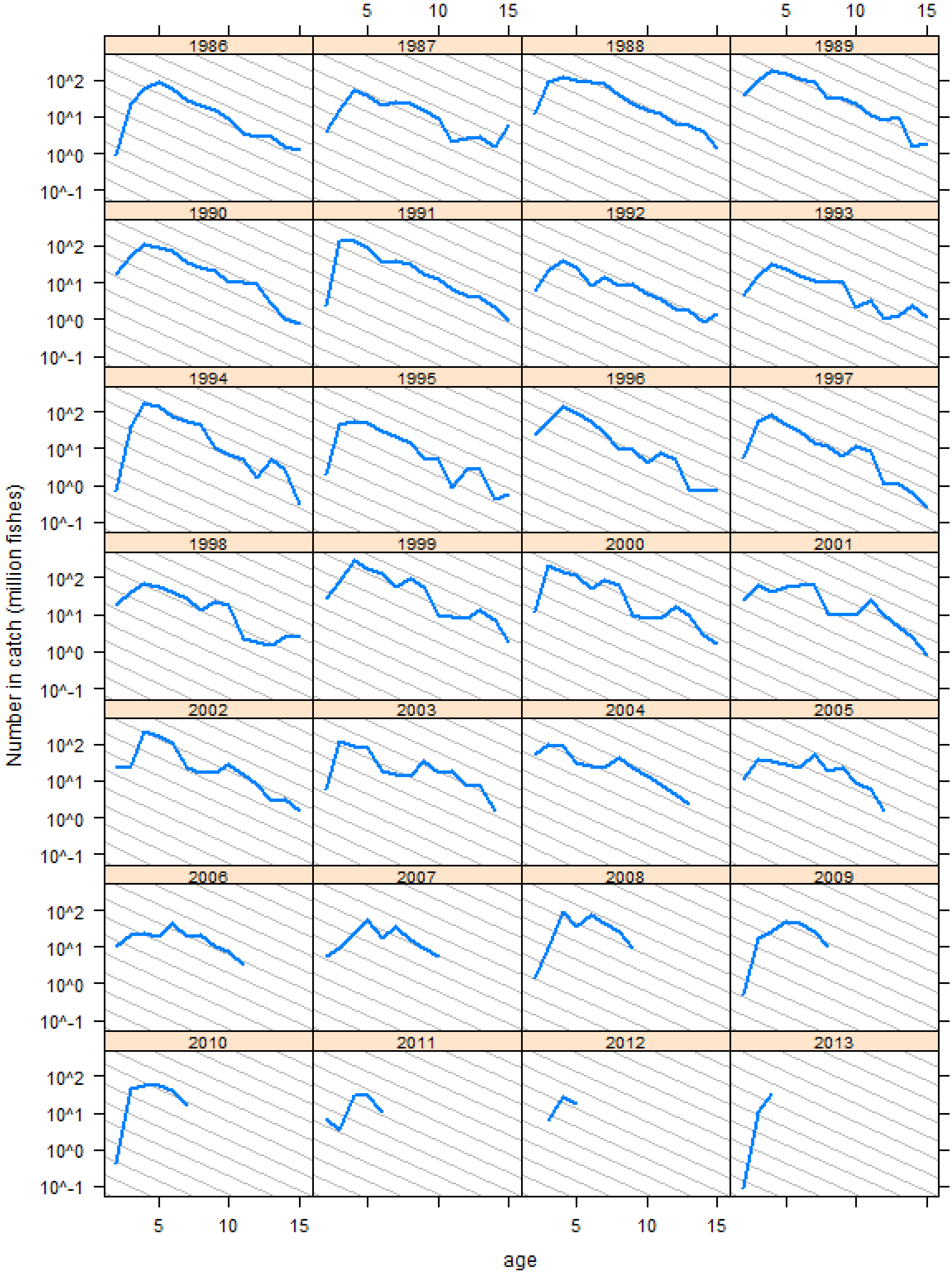

Figure 11.3.1.1. Icelandic summer-spawning herring. Catch curves by year classes 1986-2013. Grey lines correspond to Z=0.4. Note that the mass mortality in Kolgrafafjörður is added to the catches in 2012.

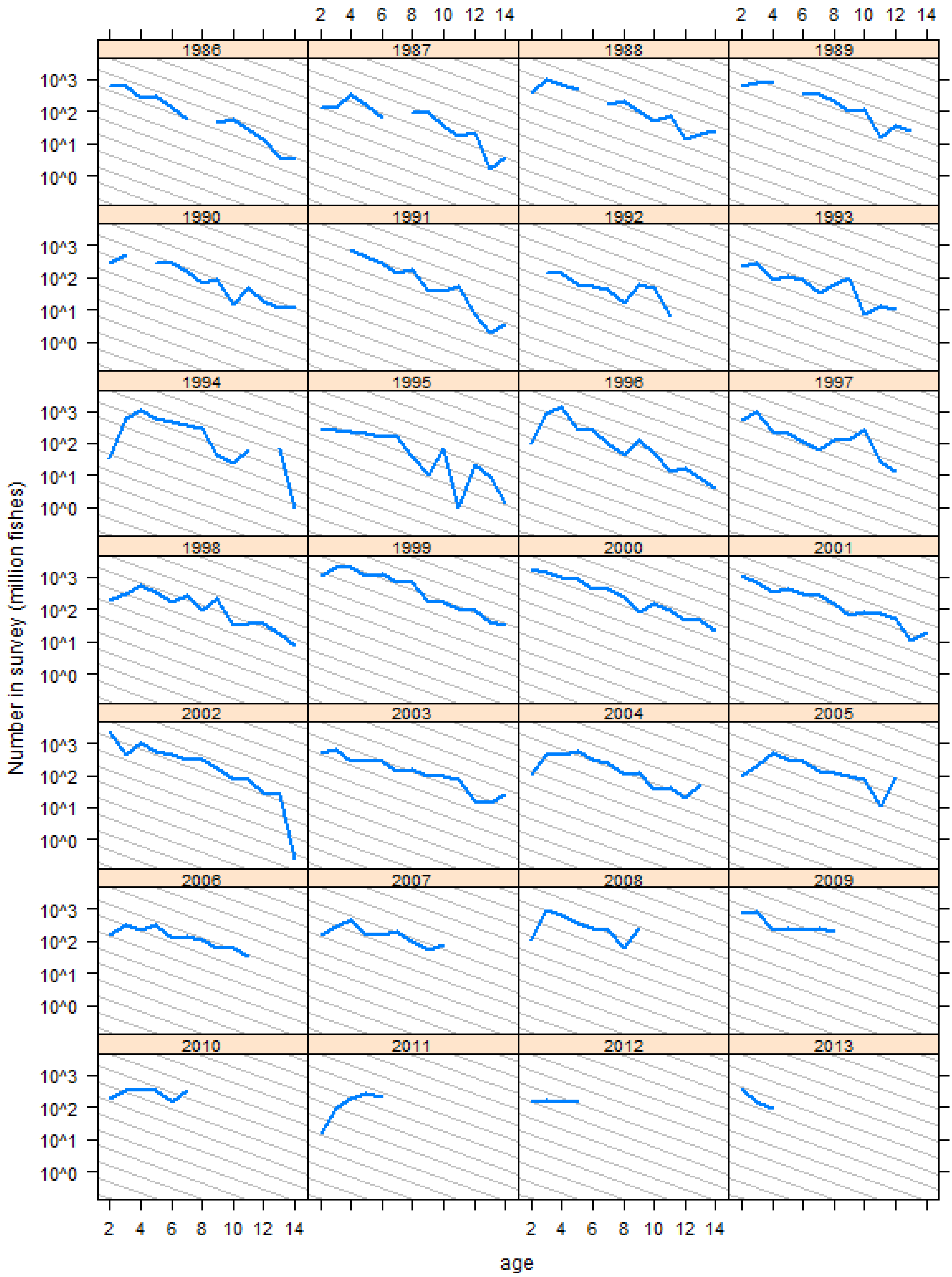

Figure 11.3.1.2. Icelandic summer spawning herring. Catch curves from survey data by year classes 1986-2013. Grey lines correspond to Z=0.4.

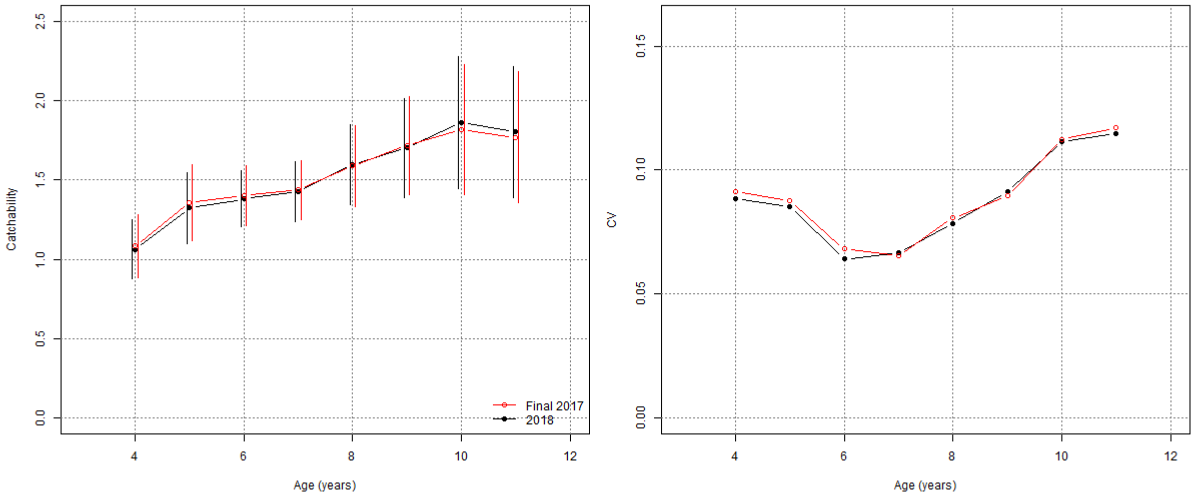

Figure 11.3.2.1. Icelandic summer-spawning herring. The catchability (± 2 SE) and its CV for the acoustic surveys used in the final Adapt run in 2018 (1987-2017) compare to the assessment in 2017 (red lines).

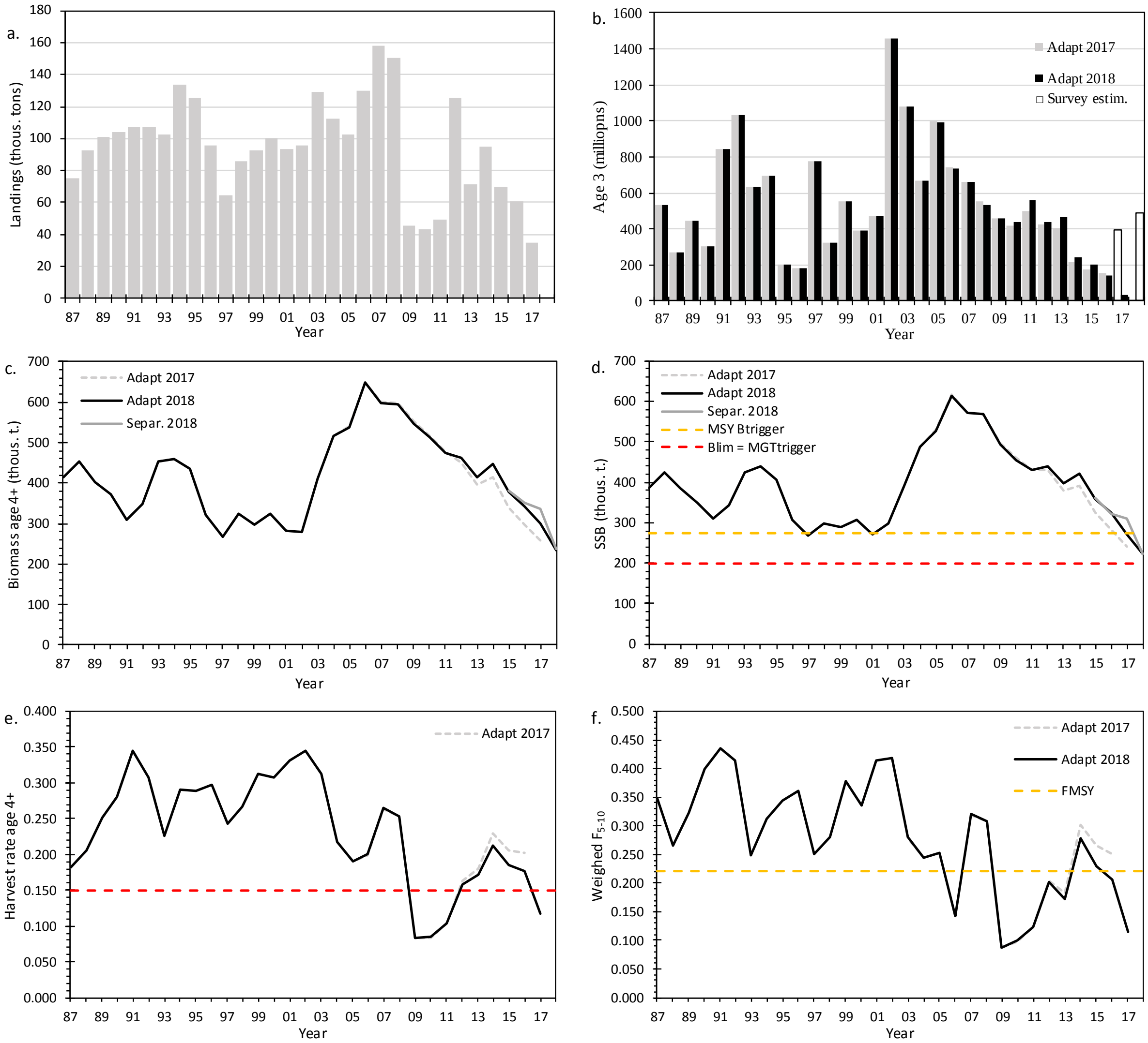

Figure 11.3.2.2. Icelandic summer-spawning herring. Comparisons of the final NFT-Adapt run in 2018, the final run in 2017, and a run from Separable model in 2018 (Björnsson 2018; only last four years shown) concerning (a) landings, (b) number at age-3 (recruitment), (c) biomass of age 4+ (reference biomass), (d) SSB, (e) harvest rate 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 weighed F for that year ($WF_{5\text{-}10}$ without the mass mortality was ~0.22). Note that the estimates of number at age 3 in 2017 from Adapt 2017 and age 3 in 2018 from Adapt 2018 are not model estimates but derive from survey estimates (i.e. projection from age-1 survey indices in 2015 and 2016, respectively, to age-3 according to Gudmundsdóttir et al. 2007).

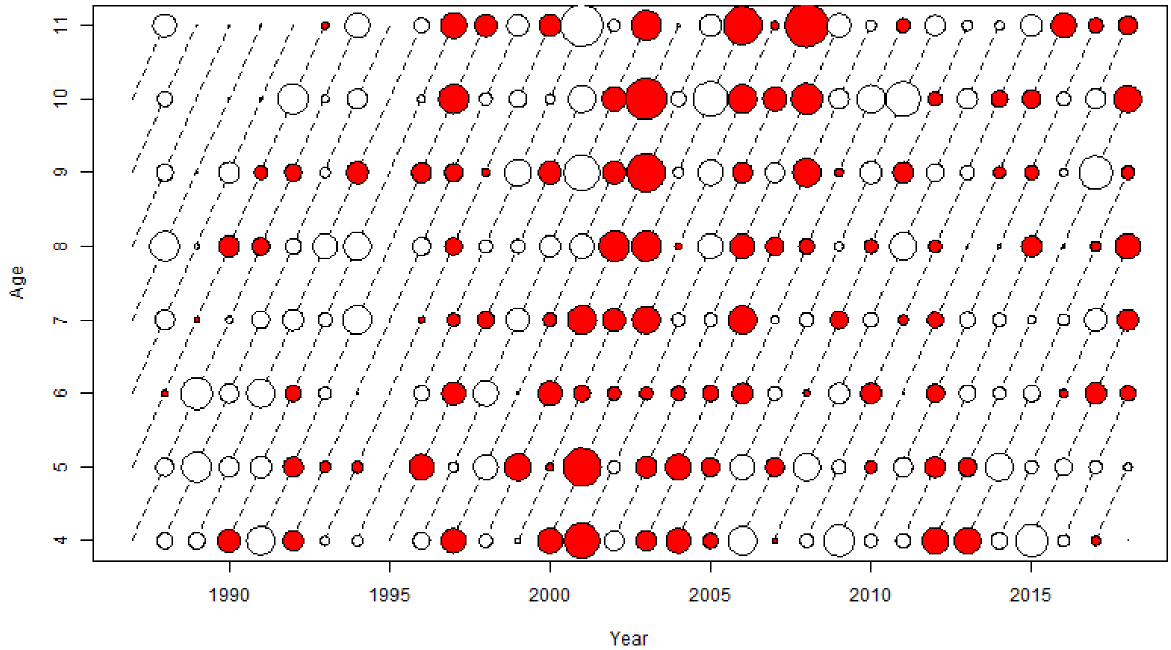

Figure 11.3.2.3. Icelandic summer spawning herring. Residuals of NFT-Adapt run in 2018 from survey observations (moved to 1st January). Filled bubbles are positive (i.e. survey estimates higher than the assessment) and open negative. Max bubble = 1.71.

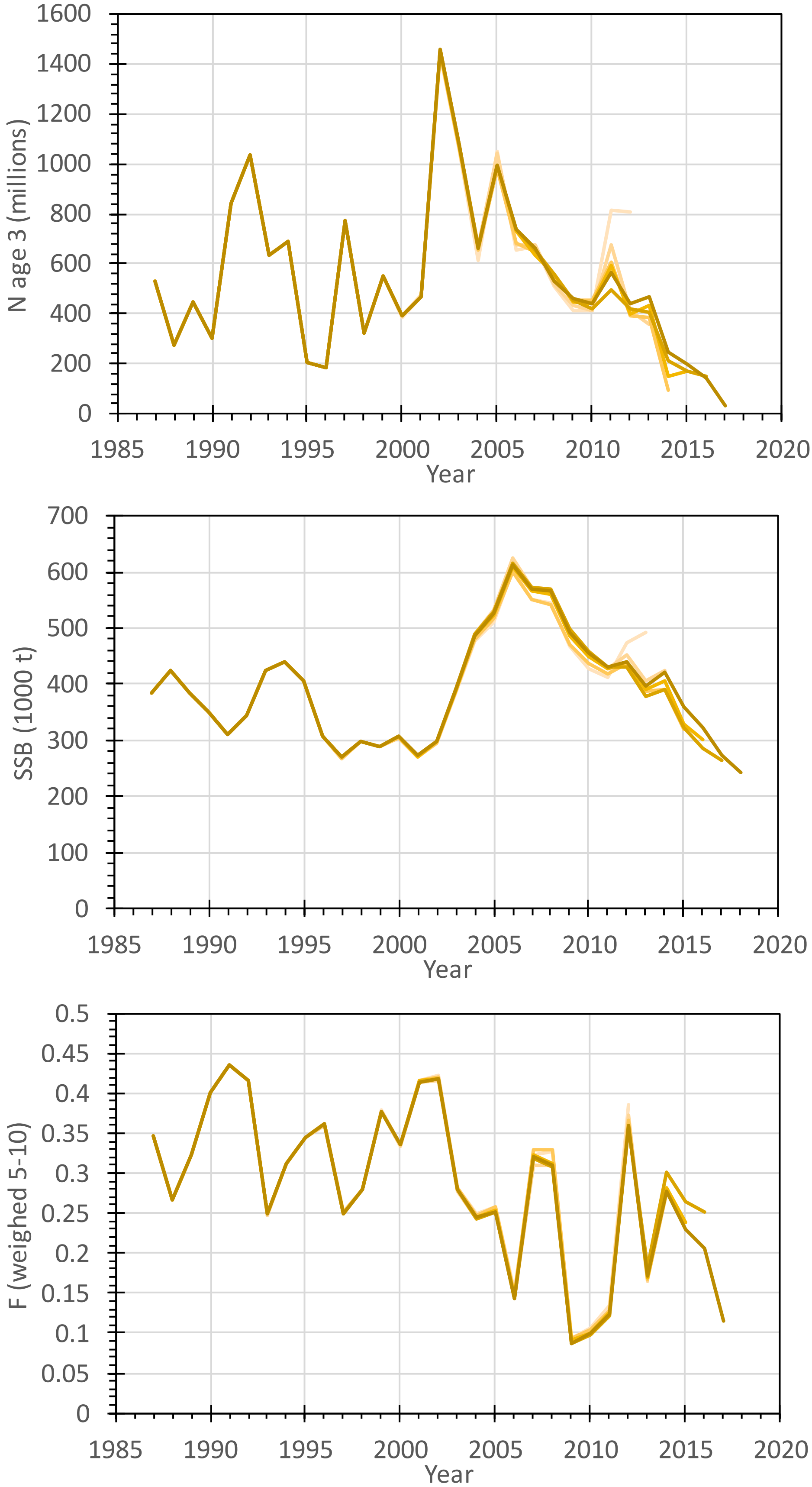

Figure 11.3.2.4. Icelandic summer spawning herring. Retrospective pattern from NFT-Adapt in 2018 in recruitment as number at age 3 (the top panel), spawning stock biomass (middle panel) and N weighted F_{5-10} (lowest panel).

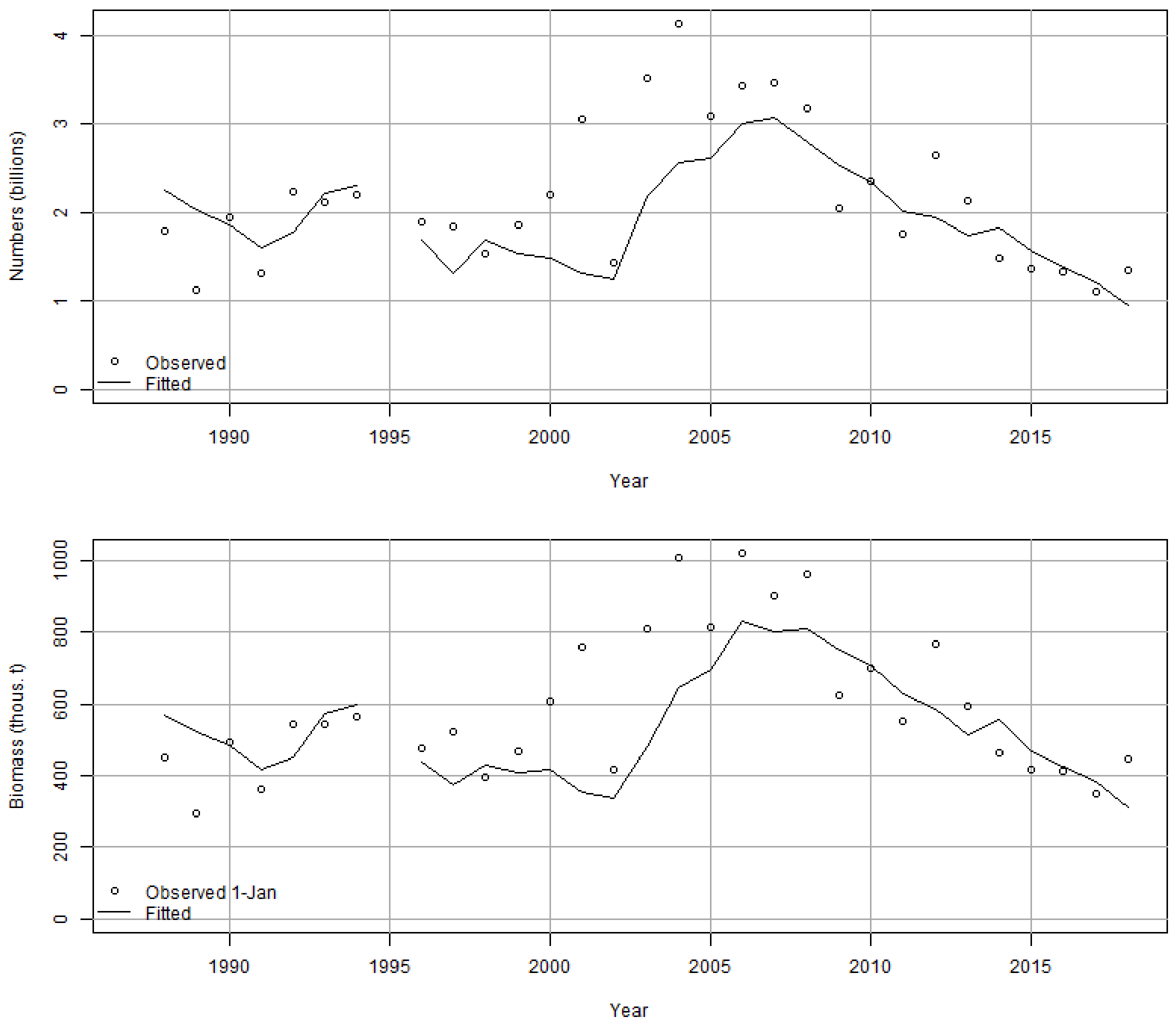

Figure 11.3.2.5. Icelandic summer-spawning herring. Observed versus. predicted survey values from NFT-Adapt run in 2018 for ages 4-11 with respect to numbers (upper) and biomass (lower).

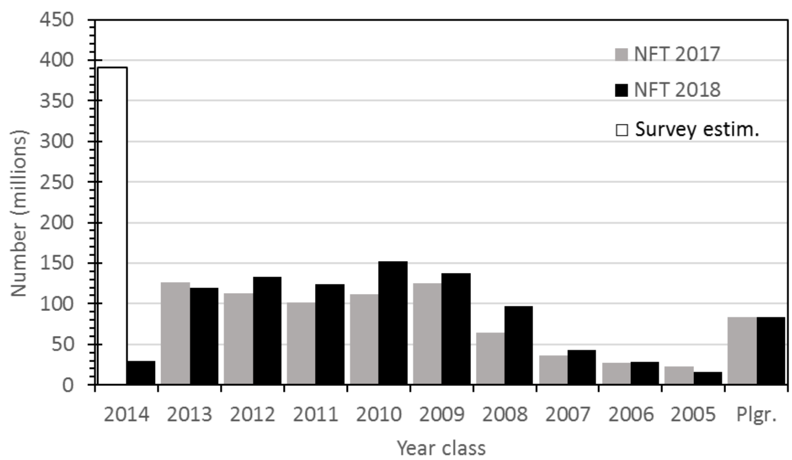

Figure 11.3.2.6. Icelandic summer-spawning herring. Comparison of number-at-age on Jan. 1st. 2017 from the final NFT model runs in 2017 and 2018 assessments. Note that the number of the 2014 year from the NFT-2018 is estimated by the model while not from 2017, but based on survey estimate-at- age 1 in 2015.

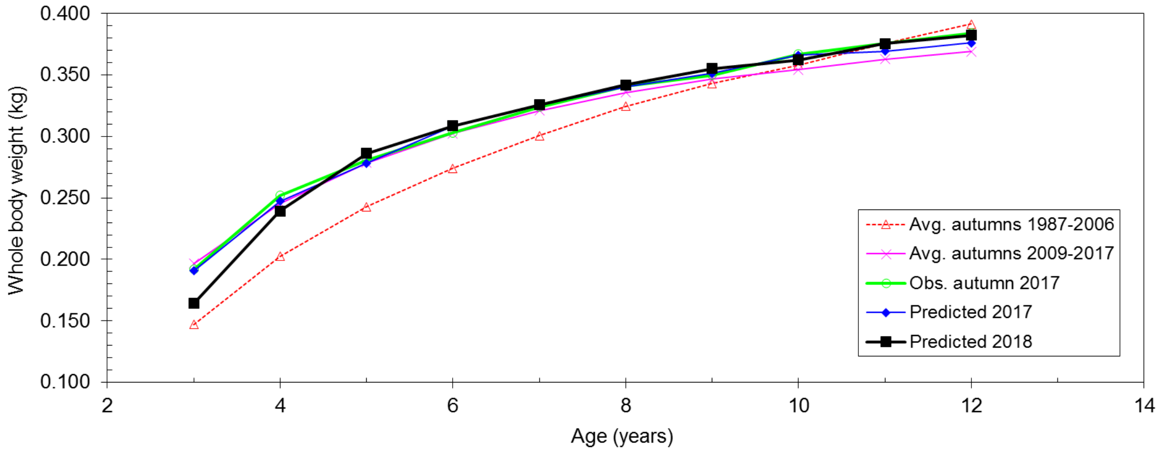

Figure 11.6.1.1. Icelandic summer spawning herring. The mean weight-at-age for age groups 3 to 12 (+ group) in 1987-2006, 2009-2017, in the catches in the autumn 2017, predicted weights for autumn 2017 in the 2017 assessment (ICES 2017) and finally predicted weights for the autumn 2018 from the weights in 2017, which was used in the stock prognosis.

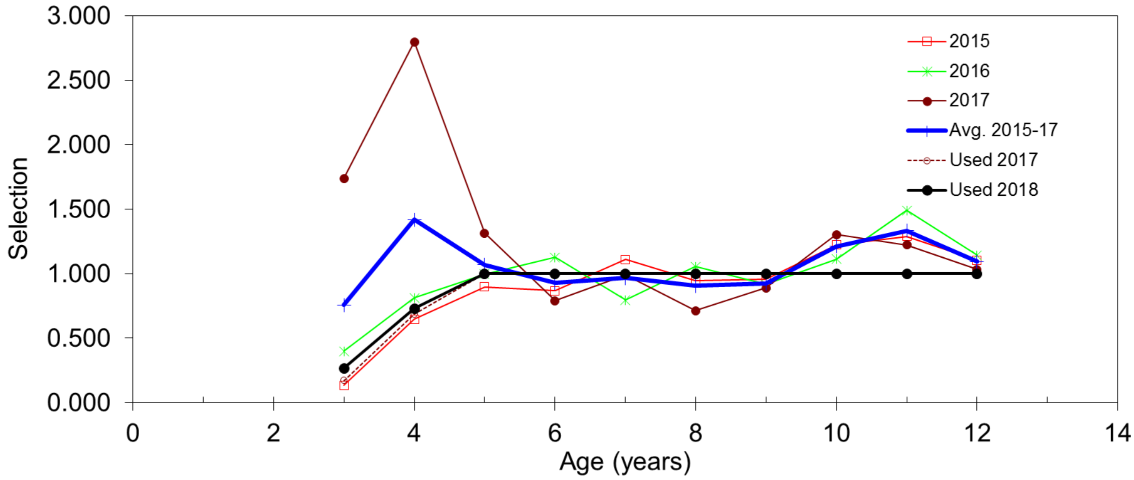

Figure 11.6.1.2. Icelandic summer spawning herring. The selection pattern for age groups 3 to 12 (+ group) for the years 2015 to 2017, the average selection across these three years (used for the prognosis according to the Stock Annex), the selection used in 2017, and the selection used in the prognosis 2017 (deviated from the Stock Annex and represents average over 2015-2016 for age 3 and 4, but fixed at 1.0 for age 5+).

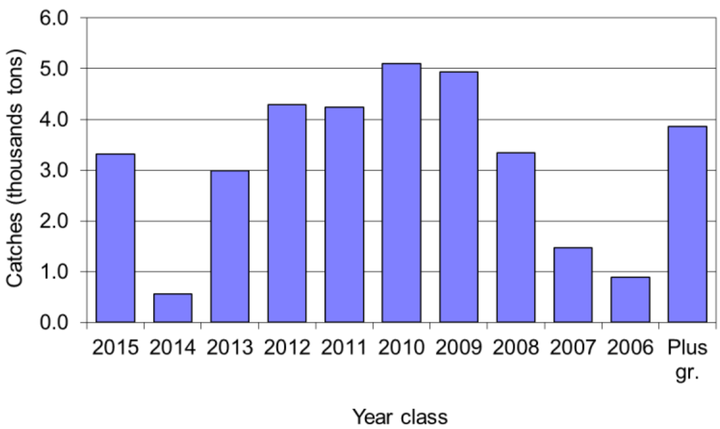

Figure 11.6.2.1. Icelandic summer spawning herring. The predicted biomass contribution of the different year classes to the catches in the fishing season 2018/2019 (total catch of 35 thousand tons).

Table 11.1.1.1. Icelandic summer-spawning herring. Acoustic estimates (in millions) in the winters 1973/74-2017/18 (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
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	175.989	221.052	137.217	151.937	262.488	136.801	241.382	61.220	55.869	62.805	11.435	20.135	13.733	0.313	1552
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

Table 11.1.1.2. Icelandic summers-spawning herring. Number of scales by ages and number of samples taken in the annual acoustic surveys in the seasons 1987/88-2017/18 (age refers to the former year, i.e. autumns). In 2000 seven samples were used from the fishery. No survey was conducted in 1994/95.

Year	Number of scales															Number of samples		
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

***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.

§3 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
1972	0.31	0.31		
1973	0.254	0.254		
1974	1.275	1.275		
1975	13.28	13.28		
1976	17.168	17.168		
1977	28.925	28.925		
1978	37.333	37.333		
1979	45.072	45.072		
1980	53.268	53.268		
1981	39.544	39.544		
1982	56.528	56.528		
1983	58.867	58.867		
1984	50.304	50.304		
1985	49.368	49.368	50	50
1986	65.5	65.5	65	65
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
2007/2008	158.9	158.9	130	150
2008/2009	151.8	151.8	130	150
2009/2010	46.3	46.3	40	47
2010/2011	43.5	43.5	40	40
2011/2012‡	49.4	49.4	40	45
2012/2013‡	72.0	72.0	67	68.5
2013/2014‡	72.0	72.0	87	87
2014/2015‡§	95.0	95.0	83	83
2015/2016‡	69.7	69.7	71	71
2016/2017‡	60.4	60.4	63	63
2017/2018‡	35.0	35.0	39	39

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

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

*** 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

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
1986-2017	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).

Year\age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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**	0.11	0.12	0.13	0.17	0.18	0.21	0.19	0.26	0.29	0.21	0.18	0.19	0.10	0.10
2018***	0.12	0.11	0.17	0.16	0.18	0.23	0.23	0.25	0.27	0.34	0.31	0.18	0.19	0.25

* Based on prevalence of infection estimates and acoustic measurements ($M_{infected}$multiplied by 0.3 and added to 0.1; Óskarsson et al. 2017).

** Based on prevalence of infection estimates in the winter 2016/17 (multiplied by 0.3 and added to 0.1; Óskarsson and Pálsson 2017).

*** Based on prevalence of infection estimates in the winter 2017/18 (multiplied by 0.3 and added to 0.1) and should by applied in the prognosis in the 2018 assessment.

Table 11.3.2.2. Model settings and results of model parameters from the final NFT-Adapt run in 2018 for Icelandic summer spawning herring.

VPA Version 3.3.0, Model ID: First run 2018	Input File: Z:\NFT\VPA\2018\RUN1\RUN1.DAT
Date of Run: 11-APR-2018	Time of Run: 15:09

Levenburg-Marquardt Algorithm Completed 6 Iterations
Residual Sum of Squares = 53.9823

Number of Residuals = 240
Number of Parameters = 9
Degrees of Freedom = 231
Mean Squared Residual = 0.233689
Standard Deviation = 0.483414

Number of Years = 31
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 (2018)

Age	Stock Predicted	Std. Error	CV
4	21591.084	0.106238E+05	0.492043E+00
5	76089.764	0.304273E+05	0.399887E+00
6	100649.167	0.330091E+05	0.327962E+00
7	95336.205	0.281701E+05	0.295482E+00
8	113574.470	0.331954E+05	0.292278E+00
9	105875.278	0.283956E+05	0.268198E+00
10	71246.180	0.201076E+05	0.282227E+00
11	30846.207	0.880202E+04	0.285352E+00
12	19066.126	0.671115E+04	0.351993E+00

Catchability Values for Each Survey Used in Estimate

INDEX	Catchability	Std. Error	CV
1	0.106279E+01	0.939973E-01	0.884439E-01
2	0.132213E+01	0.112400E+00	0.850143E-01
3	0.137960E+01	0.883428E-01	0.640350E-01
4	0.142550E+01	0.949454E-01	0.666050E-01
5	0.159663E+01	0.125365E+00	0.785181E-01
6	0.170162E+01	0.155210E+00	0.912130E-01
7	0.186203E+01	0.207798E+00	0.111597E+00
8	0.180270E+01	0.206889E+00	0.114766E+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 2018
  = Geometric Mean of First Age Populations
  Year Range Applied = 1991 to 2013
- Survey Weight Factors Were Used

Stock Estimates for age 4-12

Full F in Terminal Year = 0.1224

F in Oldest True Age in Terminal Year = 0.1224

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	0.622	0.2061	NO	Stock Estimate in T+1
4	0.800	1.000	0.3316	NO	Stock Estimate in T+1
5	1.000	0.470	0.1559	YES	Stock Estimate in T+1
6	1.000	0.283	0.0937	YES	Stock Estimate in T+1
7	1.000	0.354	0.1175	YES	Stock Estimate in T+1
8	1.000	0.255	0.0846	YES	Stock Estimate in T+1
9	1.000	0.318	0.1056	YES	Stock Estimate in T+1
10	1.000	0.466	0.1544	YES	Stock Estimate in T+1
11	1.000	0.437	0.1449	YES	Stock Estimate in T+1
12	1.000	0.369	0.1224		F-Oldest

Table 11.3.2.3. Icelandic summer spawners stock estimates (from NFT-Adapt in 2018) in numbers (millions) by age (years) at January 1st during 1987-2018.

Year\Age	3	4	5	6	7	8	9	10	11	12	13+	Total
1987	529.83	988.96	300.67	84.60	69.14	107.46	42.63	38.03	26.41	34.26	34.29	2256
1988	271.00	476.42	852.47	214.85	56.99	43.83	53.49	24.15	21.19	14.26	36.99	2066
1989	447.33	240.68	391.81	676.97	128.70	29.84	20.62	18.03	10.18	9.48	26.10	2000
1990	300.82	383.25	192.47	280.67	433.68	75.61	19.30	13.07	9.41	4.69	26.46	1739
1991	840.55	258.05	292.67	140.37	178.35	243.51	39.78	9.72	7.68	5.31	24.86	2041
1992	1033.11	676.32	186.91	183.02	94.01	109.04	116.17	26.44	4.86	4.36	24.19	2458
1993	635.44	844.68	495.57	132.71	110.07	58.60	62.27	54.88	12.96	2.77	23.67	2434
1994	691.73	526.37	595.61	360.45	100.34	72.51	40.39	37.75	35.19	7.69	22.92	2491
1995	202.71	498.15	368.79	403.40	243.43	67.16	46.36	21.12	19.31	17.95	23.14	1912
1996	181.39	163.48	320.63	251.30	261.53	147.50	40.53	27.52	11.03	8.38	27.53	1441
1997	772.58	148.96	109.69	208.39	162.03	156.42	95.85	22.70	16.92	4.46	22.16	1720
1998	320.50	661.76	106.18	74.30	153.69	114.63	112.09	65.60	12.47	12.10	10.03	1643
1999	552.65	246.90	432.34	74.55	59.05	100.28	79.11	71.05	45.46	9.27	13.41	1684
2000	391.43	446.57	171.43	257.68	52.19	40.62	60.92	52.76	43.40	29.18	11.67	1558
2001	468.87	299.79	274.91	108.39	160.53	36.27	28.88	39.60	38.36	28.53	25.26	1509
2002	1457.24	384.06	189.33	160.07	69.32	93.63	22.98	17.83	24.23	25.32	32.46	2477
2003	1076.47	1241.72	280.31	128.06	93.49	42.62	44.81	11.44	11.67	15.74	25.69	2972
2004	665.51	773.32	852.22	198.48	89.32	60.33	25.10	30.17	8.23	7.31	28.25	2738
2005	993.77	541.99	567.28	598.01	141.18	67.79	45.72	17.24	20.63	4.48	24.04	3022
2006	738.42	874.39	450.39	401.41	414.51	101.58	49.88	32.63	10.70	13.82	20.47	3108
2007	662.07	555.63	584.73	355.49	317.32	320.71	79.00	39.44	25.45	8.83	26.64	2975
2008	530.93	510.10	424.70	377.41	261.32	202.18	201.61	49.28	24.54	16.05	21.41	2620
2009	458.05	443.51	375.24	308.60	239.45	179.86	124.00	130.90	27.42	14.40	22.86	2324
2010	440.01	349.14	325.51	273.52	231.56	172.43	135.45	91.57	96.83	20.07	27.75	2164
2011	561.89	320.98	241.24	221.22	189.87	167.67	119.76	97.58	65.48	68.89	34.33	2089
2012	440.73	484.63	226.21	169.20	152.21	129.56	120.00	78.65	68.04	46.64	74.57	1990
2013	465.97	381.84	353.63	156.06	112.25	89.20	77.58	75.73	45.38	37.94	79.43	1875
2014	244.73	377.13	321.91	286.66	124.82	83.95	62.65	49.51	53.39	26.09	78.63	1709
2015	198.64	218.08	290.68	243.22	192.95	80.33	55.02	35.72	32.19	31.48	78.59	1457
2016	143.11	174.01	168.94	212.17	178.79	133.78	57.95	39.58	24.10	21.38	86.53	1240
2017	29.65	119.28	133.17	124.48	152.17	137.25	97.39	43.40	28.47	16.03	83.05	964
2018*	496.00	21.59	76.09	100.65	95.34	113.57	105.88	71.25	30.85	19.07	74.36	1205

* Number at age 3 in 2018 is predicted from an survey index of number at age 1 in 2016 (see section 11.6.1)

Table 11.3.2.4. Estimated fishing mortality at age of Icelandic summer-spawning herring (from NFT-Adapt in 2018) by age (years) during 1987-2017 (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	0.548	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	0.343	0.360	0.734	0.377
2000	0.167	0.385	0.358	0.373	0.264	0.241	0.331	0.219	0.320	0.278	0.699	0.335
2001	0.100	0.360	0.441	0.347	0.439	0.356	0.382	0.391	0.316	0.361	0.456	0.414
2002	0.060	0.215	0.291	0.438	0.386	0.637	0.598	0.324	0.331	0.473	0.946	0.418
2003	0.231	0.276	0.245	0.260	0.338	0.429	0.296	0.229	0.367	0.330	0.255	0.279
2004	0.105	0.210	0.254	0.241	0.176	0.177	0.276	0.280	0.509	0.310	0.287	0.244
2005	0.028	0.085	0.246	0.267	0.229	0.207	0.237	0.377	0.301	0.281	0.223	0.252
2006	0.184	0.302	0.137	0.135	0.157	0.152	0.135	0.149	0.092	0.132	0.167	0.143
2007	0.161	0.169	0.338	0.208	0.351	0.364	0.372	0.375	0.361	0.368	0.418	0.320
2008	0.080	0.207	0.219	0.355	0.274	0.389	0.332	0.486	0.433	0.410	0.382	0.309
2009	0.055	0.092	0.099	0.070	0.111	0.067	0.086	0.085	0.095	0.083	0.074	0.088
2010	0.023	0.078	0.109	0.106	0.073	0.121	0.087	0.097	0.108	0.103	0.099	0.100
2011	0.018	0.091	0.099	0.124	0.150	0.097	0.174	0.123	0.137	0.133	0.096	0.124
2012*	0.043	0.215	0.271	0.310	0.434	0.413	0.360	0.450	0.484	0.427	0.263	0.356
2013	0.112	0.071	0.110	0.123	0.190	0.253	0.349	0.250	0.453	0.326	0.288	0.171
2014	0.015	0.160	0.180	0.296	0.341	0.323	0.462	0.331	0.428	0.386	0.129	0.277
2015	0.032	0.155	0.215	0.208	0.266	0.227	0.230	0.293	0.309	0.265	0.095	0.229
2016	0.082	0.168	0.205	0.232	0.164	0.218	0.189	0.229	0.308	0.236	0.144	0.205
2017	0.206	0.332	0.156	0.094	0.118	0.085	0.106	0.154	0.145	0.122	0.073	0.115

*** Derived from both the landings ($WF_{5\text{-}10}$ ~0.209) and the herring that died in the mass mortality (0.148) in the winter 2012/13 in Kolgrafafjörður**

Table 11.3.2.5. Summary table from NFT-Adapt run in 2018 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	348	322	307	96	0.31	0.36	0.297
1997	773	368	267	269	65	0.24	0.25	0.243
1998	320	366	323	298	86	0.29	0.28	0.266
1999	553	373	297	290	93	0.32	0.38	0.312
2000	391	386	324	306	100	0.33	0.33	0.308
2001	469	348	282	272	94	0.34	0.41	0.331
2002	1457	513	278	297	96	0.32	0.42	0.345
2003	1076	579	411	390	129	0.33	0.28	0.313
2004	666	616	517	487	112	0.23	0.24	0.217
2005	994	707	538	527	102	0.19	0.25	0.190
2006	738	788	648	614	130	0.21	0.14	0.200
2007	662	701	598	571	158	0.28	0.32	0.264
2008	531	688	596	567	151	0.27	0.31	0.253
2009	458	634	547	492	46	0.09	0.09	0.084
2010	440	602	513	455	43	0.10	0.10	0.085
2011	562	581	475	431	49	0.11	0.12	0.104
2012*	441	553	462	440	73	0.17	0.21	0.159
2013	466	499	414	397	71	0.18	0.17	0.172
2014	245	497	448	421	95	0.23	0.28	0.212
2015	199	418	378	359	70	0.19	0.23	0.185
2016	143	370	341	324	60	0.19	0.21	0.177
2017	30	306	300	272	35	0.13	0.11	0.117
2018	496[§]	333	235	222				
Mean	540	503	417	395	95	0.25	0.28	0.23

*** The mass mortality of 52 thousands tons 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.**

[§] Number at age 3 in 2018 is predicted from an survey index of number at age 1 in 2016 (see section 11.6.1)

Table 11.3.2.6. The residuals from survey observations and NFT-Adapt 2018 results for Icelandic summer spawning herring (no surveys in 1987 and 1995) on 1st January.

Year\Age	4	5	6	7	8	9	10	11
1987								
1988	-0.233	-0.273	0.039	-0.353	-0.766	-0.256	-0.203	-0.482
1989	-0.240	-0.800	-0.896	0.027	-0.025	-0.003	0.000	-0.001
1990	0.476	-0.350	-0.328	-0.042	0.398	-0.393	-0.001	-0.003
1991	-0.729	-0.403	-0.719	-0.286	0.280	0.159	0.007	-0.004
1992	0.379	0.361	0.237	-0.400	-0.230	0.262	-0.838	0.001
1993	-0.078	0.107	-0.142	-0.182	-0.547	-0.095	-0.056	0.050
1994	-0.102	0.114	-0.002	-0.759	-0.686	0.435	-0.363	-0.561
1995								
1996	-0.261	0.586	-0.221	0.032	-0.286	0.353	-0.055	-0.203
1997	0.536	-0.082	0.489	0.156	0.265	0.287	0.788	0.598
1998	-0.156	-0.549	-0.580	0.270	-0.160	0.064	-0.144	0.456
1999	-0.025	0.638	0.005	-0.486	-0.169	-0.647	-0.264	-0.418
2000	0.570	0.053	0.533	0.170	-0.403	0.469	-0.088	0.439
2001	1.110	1.287	0.245	0.746	-0.521	-1.139	-0.665	-1.575
2002	-0.352	-0.141	0.165	0.489	0.839	0.468	0.543	-0.129
2003	0.375	0.400	0.152	0.677	0.811	1.287	1.539	0.817
2004	0.557	0.603	0.189	-0.154	0.045	-0.099	-0.209	-0.007
2005	0.214	0.310	0.238	-0.161	-0.550	-0.563	-1.076	-0.441
2006	-0.739	-0.546	0.391	0.726	0.551	0.364	0.757	1.336
2007	0.030	0.315	-0.179	-0.063	0.303	-0.337	0.522	0.061
2008	-0.171	-0.663	0.039	-0.186	0.222	0.717	0.882	1.711
2009	-0.877	-0.174	-0.390	0.293	-0.073	0.068	-0.366	-0.502
2010	-0.161	0.131	0.385	-0.196	0.173	-0.435	-0.709	-0.106
2011	-0.195	-0.332	-0.001	0.090	-0.658	0.391	-1.091	0.180
2012	0.641	0.374	0.296	0.227	0.146	-0.278	0.179	-0.372
2013	0.655	0.300	-0.256	-0.231	-0.003	-0.181	-0.374	-0.096
2014	-0.241	-0.666	-0.137	-0.160	-0.010	0.125	0.250	-0.072
2015	-0.943	-0.152	-0.252	-0.060	0.382	0.179	0.320	-0.427
2016	-0.119	-0.247	0.065	-0.121	0.008	-0.051	-0.161	0.550
2017	0.079	-0.147	0.424	-0.461	0.097	-0.996	-0.369	0.202
2018	0.000	-0.056	0.212	0.396	0.568	0.149	0.655	0.310
Max. Residuals	1.110	1.287	-0.896	-0.759	0.839	1.287	1.539	1.711

Table 11.6.1.1. The input data used for prognosis of the Icelandic summer-spawning herring in the 2018 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	Jan. 1st 2018
3 (2015)	0.164	0.12	0.200	0.266	0.000	0.500	496.0
4 (2014)	0.239	0.11	0.850	0.730	0.000	0.500	21.6
5 (2013)	0.286	0.17	1.000	1.000	0.000	0.500	76.1
6 (2012)	0.309	0.16	1.000	1.000	0.000	0.500	100.6
7 (2011)	0.326	0.18	1.000	1.000	0.000	0.500	95.3
8 (2010)	0.342	0.23	1.000	1.000	0.000	0.500	113.6
9 (2009)	0.355	0.23	1.000	1.000	0.000	0.500	105.9
10 (2008)	0.362	0.25	1.000	1.000	0.000	0.500	71.2
11 (2007)	0.375	0.27	1.000	1.000	0.000	0.500	30.8
12 (2006)	0.382	0.34	1.000	1.000	0.000	0.500	19.1
13+ (2005+)	0.389	0.21	1.000	1.000	0.000	0.500	74.4

Table 11.6.2.1. Icelandic summer-spawning herring. Catch options table for the 2018/2019 season according to the Management plan where the basis is: SSB (1st July 2018) 222 kt; Biomass age 4+ (1st Jan. 2018) is 235 kt; Catch (2017/18) 35 kt; HR (2017) 0.112, and WF_{5-10}(2017) 0.115. Other options are also shown, including MSY approach, where $^{S}SB_{2018}$ < MSY $B_{trigger}$=273 kt, hence resulting F is $F_{MSY} \times SSB_{2018}/B_{trigger} = 0.22 \times 222/273 = 0.179$.

Rationale	Catches (2018/2019)	Basis	F (2018/2019)	SSB 2019	%SSB change *	% TAC change **
Management plan	**35.186**	**HR =0.15**	**0.168**	**231**	**4**	**-10**
MSY approach	37.300	F_{MSY}	0.179	227	2	-4
Zero catch	0.000	F=0	0.000	261	18	-100
Fpa	45.000	Fpa=0.22	0.220	223	1	15
Flim	106.000	Flim=0.61	0.610	171	-23	172

*SSB 2019 relative to SSB 2018
**TAC 2018/19 relative to landings 2017/18