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H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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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 2016/2017 derives from two dedicated acoustic surveys in February and March 2017 (Óskarsson 2017). The nursery grounds of the stock were then in a survey in October 2016. 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 2017). The biological sampling in the survey is detailed in Table 11.1.1.2.

11.1.2 The surveys results

The fishable part of the herring stock was observed in two main areas, west of Iceland (Kolluáll) and southeast of Iceland (Lónsdýpi) (Fig. 11.1.2.1; Óskarsson 2017). The majority of the stock was found in the west (Figure 11.1.2.2). The total acoustic estimate of Icelandic summer-spawning herring this winter, according to these three surveys came to 2.07 billions in numbers and total biomass estimate was 389 kt (Table 11.1.1.1). The fishable part of the stock (≥27 cm) accounted for 96% of the biomass, or 373 thousands tons. Apart from the one and two years olds, the three most numerous year classes were those from 2010 and 2008(19% and 18%, respectively, of the total number). Together, the 2008-2010 year classes contributed to ~51% of the total number and the biomass. The total abundance index is in line with the acoustic indices from recent years, which indicate a declining trend (Figure 11.1.2.2).

The juvenile survey, which was conducted for the second time as part of the shrimp survey (for the first time on RV Bjarni Sæmundsson), is specially aimed for assessing the number-at-age 1 because different from number-at-age 2, number-at-age 1 in the juvenile survey can be used to predict the year class strength later at age 3. The results indicate that the 2015 year class is below average. Applying the linear-regression provided by Gudmundsdottir et al. (2007) implied that the 2015 year class will be 496 millions at age 3 in the autumn 2018, or below average year class size of 666 millions at age 3 and geometric mean of 588 millions. This number should be used in the forecast in the 2017 assessment below.

11.1.3 Prevalence of *Ichthyophonus* infection in the stock

In a working document to NWWG 2013, Óskarsson and Pálsson (2013) addressed the development and nature of the massive and long-lasting *Ichthyophonus hoferi* outbreak in Icelandic summer-spawning herring since the autumn 2008 to 2013. Their main conclusions were that the infection was only causing significant additional mortality in the first two years, despite a high prevalence of infection for five years. These data have been revisted recently with updated data and lead to different estimates of the infection mortality (Óskarsson *et al*. 2017). Their results are considered to be more robust than previous estimates and are proposed to be used in the analytical assessment from now and on. The results 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). 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 2016/17 was estimated in a same way as has been done since the initiation of the infection in the autumn 2008 (Óskarsson and Pálsson 2017). The prevalence of infection west of Iceland was yet again highest for the 2005 and 2006 year classes according to the catch samples, or 47% and 42%, respectively (Figure 11.1.3.1). Prevalence in other year classes of herring at age 6+ were in the range of 24-33% this winter. Since 2009, the highest prevalence has been in the 2006, 2005 and 2004 year classes, and bit less in 2003 and 2002 even if it has varied, and that pattern continues. The prevalence of infection for the younger year classes (2008-2012) was low until the autumn 2014 when is it started to increase, which continued in 2015 and to a much larger extend now in 2016 (Figure 11.1.3.1). This indicates a new infection has been taken place in the stock in the last three years, particularly in the last year. 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.

During the winter 2016-17, no apparent trend in the staging of the infection was observed that can be used to tell something about the development of the infection. However, all the data indicate an ongoing new infection, which will most likely result in significant infection mortality in the coming months. It calls for applying additional infection mortality for 2017. It means that the abundance estimates from the final year of the assessment (1st Jan. 2017) and extrapolated to SSB near the beginning of the next fishing season (July 2017) to provide advice should be lowered by this additional M as done in 2009-2011 assessments. The subsequent question is, what should the additional M be? The estimated infection M for the whole stock (from prevalence of infection and survey abundance estimates) indicates age dependent infection. It is argued that applying the results by Óskarsson et al. (2017) is the most reasonable approach, which means that the estimates of $M_{infected}$ estimates should be multiplied by 0.3 and that value used in the prognosis in 2017 (Table 11.3.2.1). Furthermore, this increased M for 2017 should also be used in the analytical assessment in 2018 until better more reliable estimates become available.

11.2 Information from the fishing industry

The total landings of Icelandic summer-spawning herring in 2016/2017 season were about 60.4 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 fishery in June-September 2016 (6.6 kt), even if partly (70%) belonging to the official fishing season 2015/2016. This is a traditional method in assessment of the stock. The quality of the herring landing data regarding discards and misreporting is consider to be adequate as implied in a general summary in section 7 and in the Her-Vasu stock annex. The recommended TAC, provided in the spring 2016, was 63 kt and allowable TAC 63 kt. The difference between the catches in 2016 and TAC is partly due to 3 kt overshoot in the season before that was transferred to the next season.

The direct fishery started in October in offshore areas west of Iceland. Most of the catches were taken over a wide area there in October to December in pelagic trawls, or 89% of the total catch (Fig. 11.2.2). The remaining of the catch was taken as bycatch in the fishery for the Norwegian spring-spawning herring, NSSH, and Atlantic mackerel during June to September.

Like in some of the previous winters, spring-spawning herring (Icelandic spring spawners or NSSH) was mixed with the Icelandic summer-spawning herring stock in the catches in the winter 2016/2017.

This applied to the fishery in the west as maturity stage of the herring in catch samples in September-December indicated that 4.1% of the herring caught there were spring spawners.

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 2016/2017 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 2016/17. 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 2016/2017:

The procedure for the catch at age estimations, as described in the Stock Annex, was followed for the 2016/17 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 five cells confined by season and area as detailed in Óskarsson and Pálsson (2017). In the same way, five 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-Sept.) and the winter (Oct.-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 of the total catches in 2016/2017 was somewhat different from the composition in the bycatch of herring in the mackerel and NSS-herring fishery in the summer 2016 (Figure 11.2.2.1). The summer fishery included to a higher degree younger age groups (age 2-4; 37% of the biomass) than the direct fishery in the west (14%), and consequently vice versa for older age groups. This difference is 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, according to the acoustic surveys (79% vs 14% by biomass; Óskarsson 2017), where the main bycatch takes place. This pattern is in coherence with recent years.

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 2016/17 was 3130 and 2752 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 2016. The main difference was for age 5 (2011 YC) which was more numerous in the catches than predicted, as well as age 6, while other age groups were less numerous (Figure 11.2.2.1). This reflects that the size of the small 2011 year class (age 4), as well as for the 2010 year class, has been revised upwards in every assessments since 2015 (Figure 11.3.2.4).

11.3 Analytical assessment

11.3.1 Analysis of input data

Examination of catch curves for the year classes from 1985 to 2012 (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 1985-2012 (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 can not 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 must mean an increased M during that period.

11.3.2 Exploration of different assessment models

Input data:

In order to explore the data this year, only the assessment tool NFT-ADAPT (VPA/ADPAT version 3.3.0 NOAA Fisheries Toolbox) that has been used as the basis for the assessments since 2005 was run. Applying it 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 1987/88-2015/16 (Table 11.2.2.1) and survey data from 1987/88-2015/16 (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 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. 2017); (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, except for M which has been reduced.

It should be noted that at a MSE work took place prior to the assessment meeting in 2017 (ICES 2017b), where a different model was applied on the same data as in the 2016 assessment (except for applying same M as in the final 2017 run). Applying the same input data resulted in similar stock size for both of the models (ICES 2017b).

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 2017, while the stock numbers at age 3 was derived from survey estimates in 2015 (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 has increased, which is caused by the lower total M applied during 2009-2011 since a comparison on Final 2017 and SPALY 2017 gave corresponding difference.

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 is 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.

Retrospective analysis indicate a more stability for the most recent three years than often before, i.e. adding new data to the model does not change the present perception of the stock size (Figure 11.3.2.4). The same applies correspondingly to the fishing mortality. 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. Furthermore, to sustain the high M in the input data for 2009-2011 because of the infection, SSB of the years prior to 2012 lifts in comparison to the preceding years. It required also an increase in recruitment estimates as apparent on the retrospective plots of number-at-age 3. 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 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.

Comparisons to runs from previous year:

The final NFT-Adapt 2017 run was compared to the final run in 2016 and a SPALY run in 2017, which had the same updated input data as the final run in 2017 except for the using the approach for M as in the final assessment in 2016. As expected, the biomass estimates were lower for the period prior to the years of the *Ichthyophonus* outbreak in 2009-2011 in the final assessment in 2017 since it had lower total

M (Figure 11.3.3.2). For the other runs, the model gives higher biomass to sustain the higher total M applied. For the final year (2017), the runs give biomasses, particularly for age 3+.

The results of the final NFT run in 2017 gives a more pessimistic view on the stock size than the final run in 2016 as seen on biomass estimates (Figure 11.3.3.2) and abundance estimate at 1st Jan. 2016 (Figure 11.3.2.6). The 2008 and 2010 year classes were estimated slightly smaller in 2017 while the 2011 year class bigger. This resulted in 11.8% lower SSB in 2016 from the 2017 run, while the SPALY run gave 4.8% lower SSB than the 2016 run. This indicates that approximately half of the downward revision of the estimates is related to the changes in the approach regarding infection M and half to the addition of the new catch and survey data. The big difference for the 2013 year class is related to that the number-at-age 3 in 2016 was based on prediction from survey estimation of number-at-age 1 in the 2016 assessment while estimated by NFT in the 2017 assessment.

11.3.3 Final assessment

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 fishing mortality (weighed average for age 5-10) was 0.25 in 2016 or above $F_{pa}=F_{MSY}=0.22$, which is the target. The low F during 2009 to 2011 was related to cautious TAC and apparently overestimation of mortality induced by the *Ichthyophonus* outburst. Notice that the estimated number of herring that died in Kolgrafafjörður in the two incidents of the mass mortalities (Óskarsson *et al*. 2013) 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.

11.4 Reference points

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, 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:

The MSY based reference points have not been set for Icelandic summer-spawning herring, but exploratory work was present at the NWWG meeting in 2011 in a form as requested by ICES (ICES 2011b). 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.

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 $F_{MSY}=0.22$. During a Management Strategy Evaluation for the stock in April 2017 (ICES 2017b) these reference points were evaluated and advised to be unchanged.

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 small year classes entering the stock since around 2005, particularly the 2011-2013 year classes. Hence, SSB will be below MSY $B_{trigger}$ in 2017 but above 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, 2017, 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 2017 (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 (ICES 2011b).

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 (Figure 11.6.1.1). The selection pattern used in the prognosis was based on averages over 2014 to 2016 from the final run (Figure 11.6.1.2) (see Stock Annex). 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 2014 year class: An acoustic survey aimed for getting an abundance index for this year class took place in September-October 2015 (Óskarsson 2016), and using a relation obtained by Gudmundsdóttir *et al*. (2007) provides estimate of 391 millions at age 3 in 2017.

The 2015 year class: An acoustic survey aimed for getting an abundance index for this year class took place in September-October 2016 (Óskarsson 2016), and using a relation obtained by Gudmundsdóttir *et al.* (2007) provides estimate of 496 millions at age 3 in 2018.

The 2016 year class: No acoustic estimates are available for the year class yet thus the number-at-age 3 in 2019 was set to the geometrical mean for age-3 over 1987-2013, which give 528 millions.

In summary, the basis for the stock projection is as follows: SSB(2017)=238 kt; Biomass age 4+ (1st Jan. 2017) = 258 kt; Catch (2016/17) = 60 kt; WF_{5-10}(2016)=0.25.

11.6.2 Prognosis results

SSB in the beginning of the fishing season 2017/18 (approximately the same time as at spawning in July 2017) is estimated to be 238 kt, which is below MSY $B_{trigger}$ of 273 kt. Consequently adviced TAC on basis of MSY approach should be in accordance with $F = F_{MSY} \times (SSB_{2017}/B_{trigger}) = 0.22 \times 238/273 = 0.192$ (instead of 0.220).

The results of the short term prediction indicate that fishing at 0.192 would correspond to TAC in 2017/2018 fishing season of 41 kt and SSB at the spawning season in 2018 would be 245 kt, or below MSY $B_{trigger}$ but above B_{lim} (Table 11.6.1.2).

Table 11.6.1.3 provides TAC options for the different harvest control rules tested in the MSE in 2017 (ICES 2017b). A decision on HCR to be adoped by the managers from 2017 and onwards will be taken in the coming months. All of the four HCRs, as well as the currently applied harvest rule, were found to be precautionary and in conformity with the MSY approach.

The proposed composition of the catch in the season 2017/18 consists mainly of the 2009-2012 year classes and the plus group, each contributing to 12-16% 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 year and possibly changes in management of the stock in 2017 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. Different from previous four assessments where additional natural mortality caused by the *Ichthyophonus* infection was set for the first two years on full force, it was set for three years now but at lower level ($M_{infected,\ year}$ multiplied by 0.3 instead of 1; see section 11.1.3). This quantification of the infection mortality is considered to improve the assessment and reduce its uncertainty. The new approach changes the historical perception of the stocks size from last year's assessment but has minor impacts on the assessment of the final year and the resulting advice.

An apparent new infection in the stock in the winter 2014/15 and 2015/16 was not considered to cause induced natural mortality in the stock in the last two assessments. The indication for new infection again this winter (2016/17) are however, much stronger (11.1.3.1) so setting additional infection mortality in 2017 was considered unavoidable. The level of the mortality was based on estimates on prevalence of infection that winter multiplied by 0.3, which corresponds to the 2009-2011 infection mortality. More accurate estimation will be possible in the years to come but in the mean time this approach will add uncertainty to the assessment and the advice.

11.8.2 Forecast

The uncertainty in the assessment mentioned above related to the apparent new infection in the stock in last three years applies also for the forecast.

The number-at-age 3 in the beginning of 2017 used in the prognosis (391 millions) was predicted from a survey estimate of number at age 1 in 2015 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

In previous years there has been concerns regarding the assessment because of retrospective patterns of the models. 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 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, except for the changes in M in 2009-2011 (section 11.1.3). In the current assessment, SSB in 2016 is 11.8% lower (284 kt versus 318 kt), size of the 2011 year class at age 3 is 25% higher, size of the 2012 year class at age 3 is 9% lower, and $WF_{5\text{-}10}$ in 2015 is 17% higher (0.219 versus 0.264), compare to the 2016 assessment. Thus there is a downward revision of stock size in this year's assessment. As pointed out in section 11.3.2 a further comparison with a SPALY run in 2017 indicates that half of the downward revision of the estimates is related to the changes in the approach regarding infection M and half to the addition of the new catch and survey data.

11.10 Management plans and evaluations

The practice has been to manage fisheries on this stock at $F = F_{0.1} = F_{MSY}$ (= 0.22 = F_{pa}) for more than 20 years. Formal management strategy evaluation took place in April 2017 where five different rules were tested (ICES 2017b). Selection of harvest rule for providing advice in the next years will be done by the managers in the coming weeks.

11.11 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 with an increased intensity in 2016/2017. Significant new infection was otherwise last observed in 2010. Correspondingly, induced mortality due to the infection was unavoidably applied for 2017 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.

11.12 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 of such an outbreak are needed and planned to start at MFRI in 2017. It involves how the herring get infected, i.e. through intake of free floating spores or through zooplankton that contain spores etc. With respect to the impacts of the outbreak on the herring stock, recent analyses shows that significant additional mortality took place over the first three years only (Óskarsson *et al.* 2017), despite a high prevalence of infection for now nine years. As pointed out above, the new infection in 2016/17 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).

11.13 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 juveniles 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 2015/2016. 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.

11.14 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 2014/2015 to 2016/2017 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, this bycatches are well sampled and contributes to less than 10% of the total annual catch (except for 13% in 2014/2015) so 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.

11.15 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 a*l. 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 2015). 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).

11.16 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).

11.17 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. A revision and lowering in this year's assessment of the *Ichthyophonus* mortality imposed over 2009–2011 resulted in lower estimations of SSB over the years ~2003–2011. It contributed also, along with adding the 2016/17 data, to slightly lower perception of the present stock size (section 11.9). However, this new approach is considered adequate and lead to improvements of the assessment.

There are compelling evidence for serious new infection by *Ichthyophonus* in the stock in the winter 2016/17, which called for applying additional infection mortality in 2017 until spawning. This decision and on the applied mortality level is rationalized by expert judgement derived from the experience from the previous outbreak. The mortality level for 2017 cannot be estimated at present, but can within several years. When depends on the development of the current outbreak in the coming months and years. This current outbreak adds uncertainty to the asssessment and advice.

Information from informal chats of the stock assessor with skippers of the herring fishing fleet and people from the industry in the winter 2016/17 implied more effort of the fleet this year to get the herring quota and observations of increased *Ichthyophonus* infection by inspection of the catches. These informations can be interpreted as a support to the assessment, advice and present perception on the condition of the stock.

Table 11.1.1.1. Icelandic summer-spawning herring. Acoustic estimates (in millions) in the winters 1973/74-2016/17 (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

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 1987/88-2016/17 (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.

	Number of scales															Number 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

***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

***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

*** 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

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
1986-2016	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

*** 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) and should by applied in the prognosis in the 2017 assessment.**

Table 11.3.2.2. Model settings and results of model parameters from the final NFT-Adapt run in 2017 for Icelandic summer spawning herring.

VPA Version 3.3.0	Input File: D:\NFT\VPA\2017\RUN1NWWG\RUN1NWWG.DAT
Model ID: k=0.3, 2009-2011 Ichtio.	Date of Run: 07-APR-2017 Time of Run: 17:03

Levenburg-Marquardt Algorithm Completed 5 Iterations

Residual Sum of Squares = 51.0119

Number of Residuals = 232
Number of Parameters = 9
Degrees of Freedom = 223
Mean Squared Residual = 0.233237
Standard Deviation = 0.482946

Number of Years = 30
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-2017

Age	Stock Predicted	Std. Error	CV
4	126724.446	6.23E+04	4.92E-01
5	112317.581	4.27E+04	3.80E-01
6	100959.834	3.49E+04	3.45E-01
7	112108.965	3.82E+04	3.41E-01
8	125709.946	3.76E+04	2.99E-01
9	63851.451	2.16E+04	3.39E-01
10	36695.24	1.14E+04	3.11E-01
11	27710.602	8.63E+03	3.11E-01
12	22396.729	9.10E+03	4.06E-01

Catchability Values for Each Survey Used in Estimate

INDEX	Catchability	Std. Error	CV
1	1.08E+00	9.89E-02	9.14E-02
2	1.36E+00	1.19E-01	8.77E-02

3	1.40E+00	9.54E-02	6.81E-02
4	1.44E+00	9.40E-02	6.54E-02
5	1.59E+00	1.28E-01	8.06E-02
6	1.72E+00	1.54E-01	8.97E-02
7	1.82E+00	2.04E-01	1.12E-01
8	1.77E+00	2.07E-01	1.17E-01

-- Non-Linear Least Squares Fit --

Maximum Marquadt Iterations = 100

Scaled Gradient Tolerance = 6.06E-05

Scaled Step Tolerance = 1.00E-18

RelativeFunction Tolerance = 1.00E-18

Absolute Function Tolerance = 4.93E-32

Reported Machine Precision = 2.22E-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 2017 = Geometric Mean of First Age Populations Year Range Applied = 1991 to 2013
- 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 = 0.247

F in Oldest TRUE Age in Terminal Year = 0.2499

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	Calc	Partial	Fishing	Used	In			
Recruitment		Recruitment		Mortality		Full	F	Comments		
3	0.5	0.246	0.0775	NO	Stock	Estimate		in	T+1	
4	0.8	0.621	0.1957	NO	Stock	Estimate		in	T+1	
5	1	0.787	0.2477	YES	Stock	Estimate		in	T+1	
6	1	0.964	0.3037	YES	Stock	Estimate		in	T+1	
7	1	0.566	0.1782	YES	Stock	Estimate		in	T+1	
8	1	1	0.315	YES	Stock	Estimate		in	T+1	
9	1	0.699	0.22	YES	Stock	Estimate		in	T+1	
10	1	0.746	0.235	YES	Stock	Estimate		in	T+1	
	11	1	0.729	0.2295	YES	Stock	Estimate		in	T+1
		12	1	0.793	0.2499	F-Oldest				

Table 11.3.2.3. Icelandic summer spawners stock estimates (from NFT-Adapt in 2017) in numbers (millions) by age (years) at January 1st during 1987-2017.

YEAR\AGE	3	4	5	6	7	8	9	10	11	12	13+	TOTAL
1987	529.83	988.97	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	240.69	391.82	676.97	128.70	29.84	20.62	18.03	10.18	9.48	26.10	2000
1990	300.83	383.26	192.47	280.68	433.68	75.61	19.30	13.07	9.41	4.69	26.46	1739
1991	840.58	258.06	292.67	140.37	178.35	243.51	39.78	9.72	7.68	5.31	24.86	2041
1992	1033.14	676.35	186.92	183.02	94.01	109.04	116.17	26.44	4.86	4.36	24.19	2458
1993	635.48	844.70	495.59	132.71	110.07	58.60	62.27	54.88	12.96	2.77	23.67	2434
1994	691.77	526.40	595.63	360.47	100.34	72.51	40.39	37.75	35.19	7.69	22.92	2491
1995	202.74	498.19	368.82	403.42	243.45	67.16	46.36	21.12	19.31	17.95	23.14	1912
1996	181.42	163.50	320.66	251.32	261.55	147.52	40.53	27.52	11.03	8.38	27.53	1441
1997	772.67	148.98	109.71	208.42	162.05	156.44	95.87	22.71	16.93	4.47	22.16	1720
1998	320.56	661.84	106.20	74.32	153.72	114.65	112.11	65.61	12.47	12.10	10.03	1644
1999	552.81	246.96	432.41	74.56	59.06	100.31	79.13	71.06	45.47	9.27	13.41	1684
2000	391.66	446.71	171.48	257.74	52.20	40.63	60.94	52.77	43.42	29.19	11.68	1558
2001	469.30	300.00	275.03	108.44	160.59	36.28	28.89	39.62	38.38	28.54	25.27	1510
2002	1458.96	384.45	189.52	160.19	69.36	93.69	22.99	17.84	24.25	25.33	32.49	2479
2003	1077.26	1243.27	280.66	128.23	93.60	42.65	44.86	11.45	11.68	15.76	25.72	2975
2004	668.46	774.04	853.63	198.80	89.48	60.42	25.14	30.21	8.24	7.32	28.30	2744
2005	996.80	544.66	567.93	599.28	141.46	67.93	45.80	17.27	20.67	4.49	24.09	3030
2006	739.56	877.14	452.81	402.00	415.66	101.84	50.01	32.71	10.73	13.85	20.53	3117
2007	658.12	556.65	587.21	357.68	317.86	321.75	79.23	39.56	25.52	8.85	26.72	2979
2008	555.46	506.52	425.63	379.65	263.30	202.66	202.55	49.49	24.64	16.12	21.50	2648
2009	455.35	465.70	372.01	309.44	241.47	181.65	124.43	131.75	27.61	14.49	23.00	2347
2010	420.78	346.97	343.37	270.91	232.24	174.06	136.89	91.92	97.51	20.23	27.94	2163
2011	498.74	306.62	239.62	234.76	187.86	168.20	121.04	98.71	65.76	69.43	34.61	2025
2012	421.68	429.18	215.13	167.95	162.75	127.97	120.42	79.65	68.93	46.87	75.23	1916
2013	406.12	364.60	303.48	146.04	111.11	98.72	76.14	76.11	46.28	38.75	80.24	1748
2014	212.97	322.98	306.31	241.29	115.76	82.93	71.26	48.21	53.73	26.91	80.09	1562
2015	173.17	189.34	241.70	229.12	151.93	72.14	54.10	43.50	31.01	31.79	80.65	1298
2016	151.33	150.96	142.94	167.87	166.03	96.69	50.54	38.74	31.14	20.32	88.67	1105
2017*	391.30	126.72	112.32	100.96	112.11	125.71	63.85	36.70	27.71	22.40	84.02	1204

*** Number at age 3 in 2017 is predicted from an survey index of number at age 1 in 2015 (see section 11.6.1)**

Table 11.3.2.4. Estimated fishing mortality at age of Icelandic summer-spawning herring (from NFT-Adapt in 2017) by age (years) during 1987-2016 (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	0.369	0.301	0.392	0.640	0.309	0.592	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	0.301	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	0.421	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	0.417	0.257	0.274	0.398	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	0.277	0.699	0.335
2001	0.099	0.359	0.441	0.347	0.439	0.356	0.382	0.391	0.315	0.361	0.456	0.414
2002	0.060	0.215	0.291	0.437	0.386	0.637	0.597	0.324	0.331	0.472	0.945	0.417
2003	0.231	0.276	0.245	0.260	0.338	0.429	0.295	0.229	0.367	0.330	0.254	0.279
2004	0.105	0.210	0.254	0.240	0.176	0.177	0.275	0.279	0.508	0.310	0.286	0.243
2005	0.028	0.085	0.246	0.266	0.229	0.206	0.237	0.376	0.300	0.280	0.222	0.252
2006	0.184	0.301	0.136	0.135	0.156	0.151	0.135	0.148	0.092	0.132	0.166	0.143
2007	0.162	0.168	0.336	0.206	0.350	0.363	0.371	0.373	0.359	0.367	0.416	0.319
2008	0.076	0.209	0.219	0.353	0.271	0.388	0.330	0.484	0.431	0.408	0.380	0.307
2009	0.055	0.088	0.100	0.070	0.110	0.066	0.086	0.084	0.094	0.083	0.074	0.088
2010	0.025	0.078	0.103	0.107	0.073	0.119	0.086	0.097	0.108	0.103	0.098	0.098
2011	0.020	0.095	0.099	0.116	0.152	0.096	0.172	0.121	0.137	0.131	0.095	0.122
2012*	0.045	0.247	0.287	0.313	0.400	0.419	0.359	0.443	0.476	0.424	0.260	0.357
2013	0.129	0.074	0.129	0.132	0.193	0.226	0.357	0.248	0.442	0.318	0.285	0.183
2014	0.018	0.190	0.190	0.363	0.373	0.327	0.394	0.341	0.425	0.372	0.127	0.301
2015	0.037	0.181	0.265	0.222	0.352	0.256	0.234	0.234	0.323	0.262	0.092	0.264
2016	0.078	0.196	0.248	0.304	0.178	0.315	0.220	0.235	0.230	0.250	0.141	0.251

*** 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 2017 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	$WF_{age\ 5-10}$
1987	530	504	415	384	75	0.20	0.35
1988	271	495	452	423	93	0.22	0.27
1989	447	459	401	386	101	0.26	0.32
1990	301	410	371	350	104	0.30	0.40
1991	841	424	310	310	107	0.34	0.44
1992	1033	502	349	343	107	0.31	0.42
1993	635	546	454	424	103	0.24	0.25
1994	692	553	461	441	134	0.30	0.31
1995	203	462	435	406	125	0.31	0.34
1996	181	348	322	307	96	0.31	0.36
1997	773	368	267	269	65	0.24	0.25
1998	321	366	323	298	86	0.29	0.28
1999	553	373	297	290	93	0.32	0.38
2000	392	387	324	306	100	0.33	0.33
2001	469	348	283	272	94	0.34	0.41
2002	1459	513	278	298	96	0.32	0.42
2003	1077	580	412	390	129	0.33	0.28
2004	668	617	518	488	112	0.23	0.24
2005	997	709	540	528	102	0.19	0.25
2006	740	790	650	616	130	0.21	0.14
2007	658	703	600	572	158	0.28	0.32
2008	555	694	597	570	151	0.26	0.31
2009	455	640	554	497	46	0.09	0.09
2010	421	604	518	459	43	0.09	0.10
2011	499	570	476	430	49	0.11	0.12
2012*	422	536	449	429	73	0.17	0.21
2013	406	471	397	379	71	0.19	0.18
2014	213	458	415	391	95	0.24	0.30
2015	173	375	340	324	70	0.22	0.26
2016	151	329	298	284	60	0.21	0.25
2017	391	337	258	256			
Mean	546	499	412	391	97	0.25	0.29

*** 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 2017 is predicted from an survey index of number at age 1 in 2015 (see section 11.6.1)

Table 11.3.2.6. The residuals from survey observations and NFT-Adapt 2017 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	-0.251	-0.299	0.023	-0.360	-0.760	-0.266	-0.179	-0.462
1989	-0.258	-0.827	-0.912	0.019	-0.020	-0.003	0.000	0.000
1990	0.457	-0.376	-0.344	-0.049	0.403	-0.402	-0.001	-0.002
1991	-0.748	-0.430	-0.735	-0.293	0.286	0.150	0.008	-0.004
1992	0.360	0.334	0.221	-0.408	-0.224	0.253	-0.814	0.001
1993	-0.096	0.081	-0.158	-0.190	-0.541	-0.105	-0.032	0.069
1994	-0.121	0.088	-0.018	-0.767	-0.681	0.425	-0.340	-0.541
1995								
1996	-0.280	0.559	-0.237	0.025	-0.281	0.344	-0.031	-0.183
1997	0.518	-0.108	0.473	0.148	0.271	0.278	0.812	0.618
1998	-0.175	-0.576	-0.597	0.262	-0.154	0.055	-0.121	0.476
1999	-0.044	0.611	-0.011	-0.494	-0.163	-0.656	-0.240	-0.399
2000	0.551	0.026	0.517	0.163	-0.397	0.459	-0.065	0.458
2001	1.091	1.260	0.228	0.738	-0.516	-1.149	-0.641	-1.555
2002	-0.372	-0.169	0.148	0.480	0.844	0.458	0.566	-0.110
2003	0.355	0.373	0.135	0.669	0.815	1.277	1.562	0.836
2004	0.538	0.574	0.171	-0.163	0.049	-0.110	-0.186	-0.007
2005	0.191	0.282	0.220	-0.171	-0.547	-0.574	-1.054	-0.423
2006	-0.761	-0.578	0.374	0.715	0.554	0.352	0.779	1.353
2007	0.009	0.284	-0.201	-0.073	0.306	-0.349	0.543	0.078
2008	-0.183	-0.692	0.017	-0.201	0.225	0.703	0.901	1.726
2009	-0.944	-0.192	-0.409	0.277	-0.077	0.055	-0.349	-0.489
2010	-0.173	0.051	0.379	-0.206	0.169	-0.455	-0.689	-0.094
2011	-0.168	-0.352	-0.076	0.093	-0.655	0.371	-1.079	0.196
2012	0.743	0.398	0.287	0.152	0.164	-0.291	0.190	-0.365
2013	0.682	0.427	-0.206	-0.229	-0.099	-0.172	-0.355	-0.096
2014	-0.105	-0.643	0.020	-0.092	0.008	-0.014	0.301	-0.059
2015	-0.820	0.006	-0.208	0.172	0.495	0.186	0.147	-0.370
2016	0.005	-0.106	0.283	-0.054	0.338	0.077	-0.115	0.314
2017	0.000	-0.004	0.618	-0.163	0.190	-0.583	-0.177	0.249
Max. Residuals	1.091	1.260	-0.912	-0.767	0.844	1.277	1.562	1.726

Table 11.6.1.1. The input data used for prognosis of the Icelandic summer-spawning herring in the 2017 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 2017
3 (2014)	0.191	0.11	0.200	0.169	0.000	0.500	391.3
4 (2013)	0.247	0.12	0.850	0.684	0.000	0.500	126.7
5 (2012)	0.278	0.12	1.000	1.000	0.000	0.500	112.3
6 (2011)	0.309	0.17	1.000	1.000	0.000	0.500	101.0
7 (2010)	0.326	0.17	1.000	1.000	0.000	0.500	112.1
8 (2009)	0.340	0.17	1.000	1.000	0.000	0.500	125.7
9 (2008)	0.351	0.21	1.000	1.000	0.000	0.500	63.9
10 (2007)	0.366	0.19	1.000	1.000	0.000	0.500	36.7
11 (2006)	0.369	0.26	1.000	1.000	0.000	0.500	27.7
12 (2005)	0.376	0.28	1.000	1.000	0.000	0.500	22.4
13+ (2004+)	0.377	0.19	1.000	1.000	0.000	0.500	84.0

Table 11.6.1.2. Icelandic summer-spawning herring. Catch options table for the 2017/2018 season according to MSY approach where the basis is: SSB (1st July 2017) 238 kt; Biomass age 4+ (1st Jan. 2017) 258 kt; Catch (2016/17) 60 kt; WF_{5-10}(2016) 0.251. The fishery has been managed on basis of $F_{0.1}=F_{MSY}=0.22$ for over 20 years. SSB is in the spawning seasons, which is approximately the beginning of the subsequent fishing season. Catches and SSB are in thousands tons.

Rationale	Catches (2017/2018)	Basis	F (2017/2018)	SSB 2017	%SSB change *	% TAC change **
MSY approach§	41	$F_{MSY} \times 0.87$	0.19	246	3	-35
Zero catch	0	F = 0	0	280	18	-100
F_{pa}	47	$F_{pa}=0.22$	0.22	241	1	-25
F_{lim}	109	$F_{lim}=0.61$	0.61	188	-21	73
Other options	41	$0.75 \times F_{2016/17}$	0.19	246	3	-35
	48	$0.9 \times F_{2016/17}$	0.23	240	1	-24
	53	$F_{2016/17}$	0.25	236	-1	-16
	58	$1.1 \times F_{2016/17}$	0.28	231	-3	-8
	63	$1.25 \times F_{2016/17}$	0.31	227	-5	0

*** SSB 2018 relative to SSB 2017.**

**** TAC 2017/18 relative to landings 2016/17.**

§ SSB_{2017} < MSY $B_{trigger}$=273 kt, hence adviced F is: $F_{MSY} \times SSB_{2017}/B_{trigger} = 0.22 \times 238/273 = 0.19$

Table 11.6.1.3. Icelandic summer-spawning herring. Alternative catch options table for the 2017/2018 season for different harvest control rules tested by ICES (2017b) where the basis is: SSB (1st July 2017) 238 kt; Biomass age 4+ (1st Jan. 2017) 258 kt; Catch (2016/17) 60 kt; WF_{5-10}(2016) 0.251. SSB is in the spawning seasons, which is approximately the beginning of the subsequent fishing season. Catches and SSB are in thousands tons.

Rationale	Landings (2017/18)	Basis	F (2017/2018)	SSB (2018)	Biomass of age 4+ (2018)	%SSB change*	% TAC change**
HCR 2 §	31	HR=0.19, $B_{trigger}$=273 kt, reduce HR by 33% when Icht. Outbreaks	0.14	254	260	7	-51
HCR 3 §§	29	HR=0.17, $B_{trigger}$=200 kt, reduce HR by 33% when Icht. outbreaks	0.13	256	262	8	-53
HCR 4	39	HR=0.15, $B_{trigger}$=150 kt	0.18	247	253	4	-39
HCR 5	39	HR=0.15, $B_{trigger}$=200 kt	0.18	247	253	4	-39

*** SSB 2018 relative to SSB 2017.**

**** TAC 2017/18 relative to landings 2016/17.**

§ Because $SSB_{2017} < B_{trigger}$=273 kt and *Ichthyophonus* outbreak is observed in 2017 the adviced HR of 0.19 is lowered: 0.19 × 0.67 × $SSB_{2017}/B_{trigger}$ = 0.19 × 256/273 × 0.67 = 0.119. The SSB_{2017} =256 kt is when no additional infection M is applied in 2017.

§§ Because *Ichthyophonus* outbreak is observed in 2017 the adviced HR of 0.17 is lowered: 0.17 × 0.67 = 0.114.

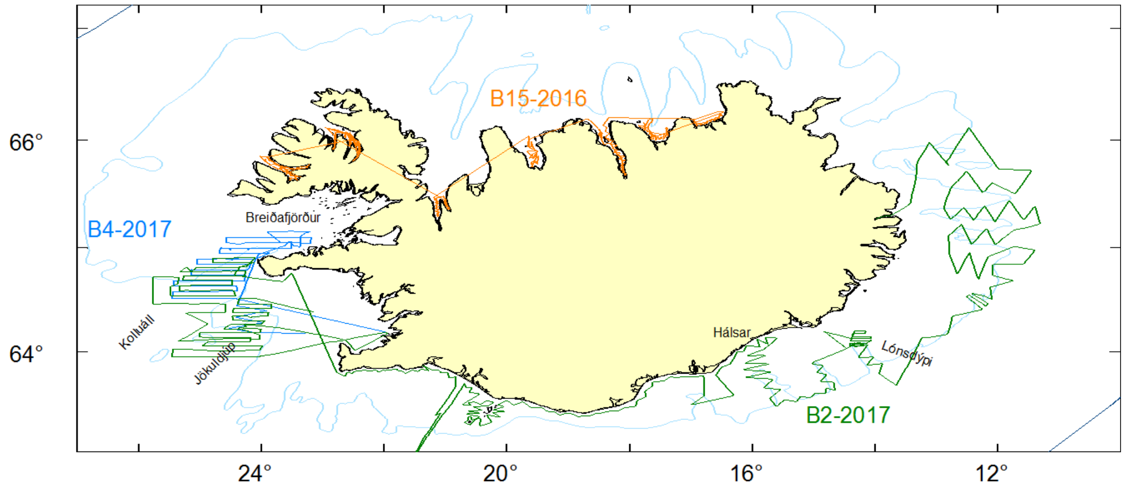

Figure 11.1.2.1. The survey tracks of three acoustic surveys on Icelandic summer-spawning herring in Sept.-Oct. 2016 (B15-2016 on juveniles; orange line), February 2017 (B2-2017 on adults; green line), and March 2017 (B4-2017 on adults; blue line) and locations of the areas that are referred to in the text.

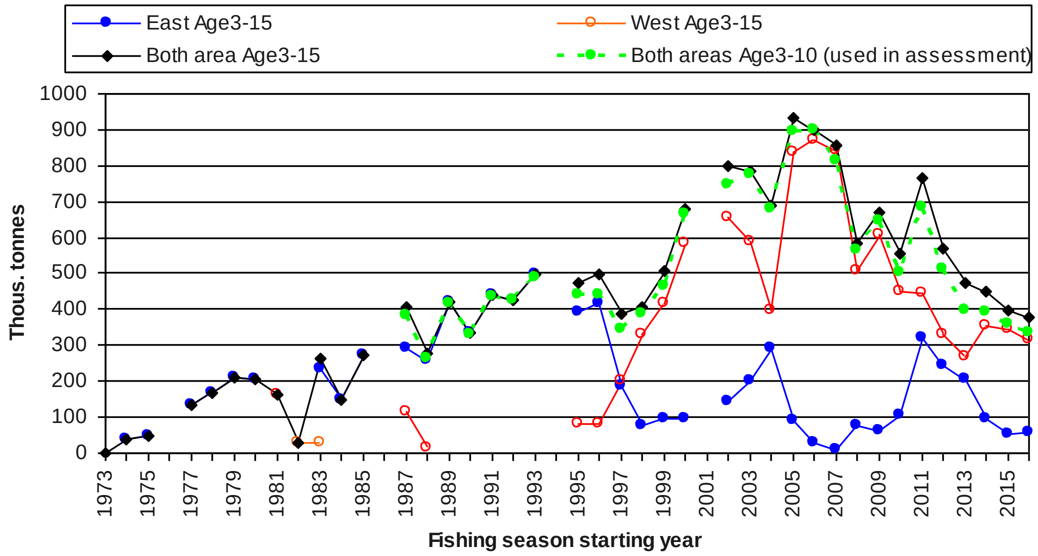

Figure 11.1.2.2 Total biomass index for Icelandic summer-spawning herring from the acoustic surveys for ages 3+ in the areas east and west of 18°W (except in 2011 and 2012 where fish outside of Breiðafjörður was set to the eastern part), combined over all areas and age 3-10 which are used in tuning of the analytical assessment. The years in the plot (1973-2016) refer to the autumn of the fishing seasons.

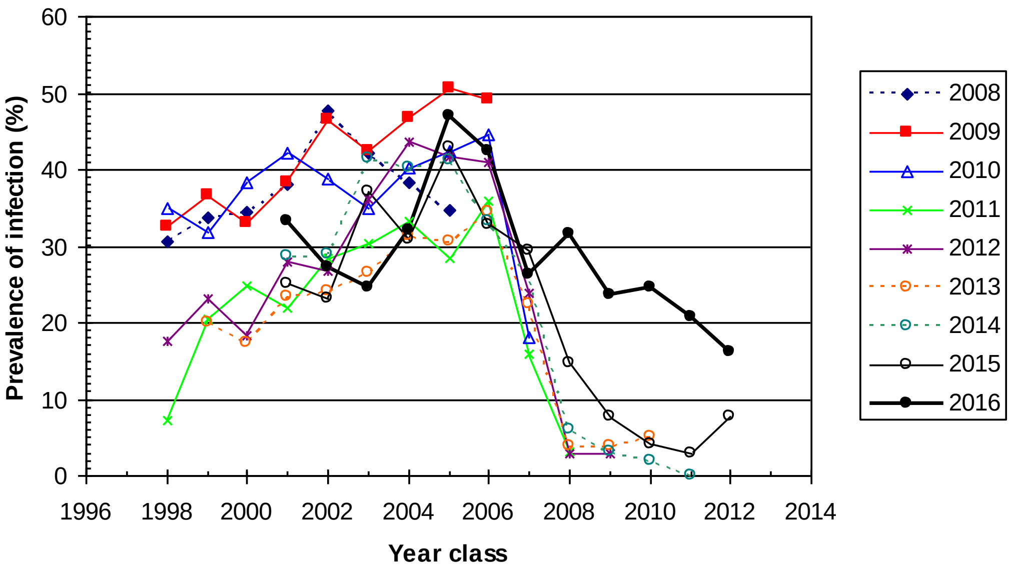

Figure 11.1.3.1. The prevalence of Ichthyophonus infection for the different year classes of Icelandic summer-spawning herring in Breiðafjörður and west of Iceland as estimated in the autumns 2008 to 2016.

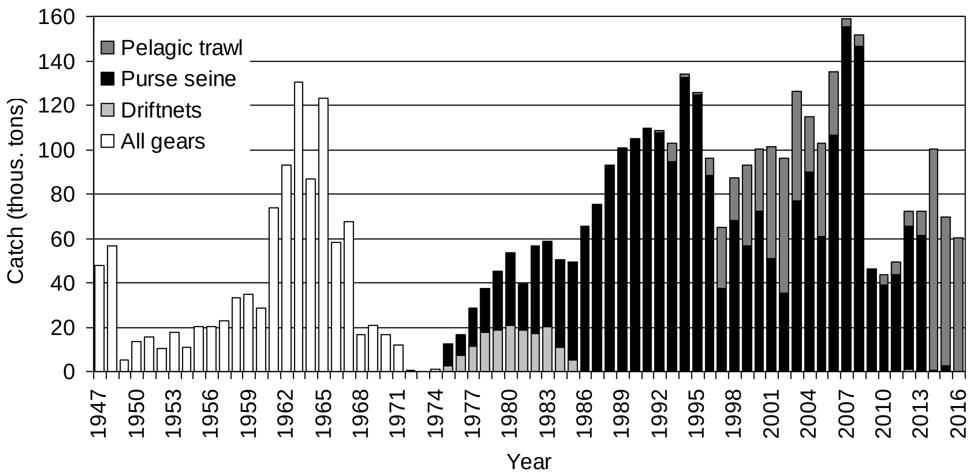

Figure 11.2.1. Icelandic summer spawning herring. Seasonal total landings (in thousand tonnes) during 1947-2016, referring to the autumns, by different fishing gears (from 1975-2016).

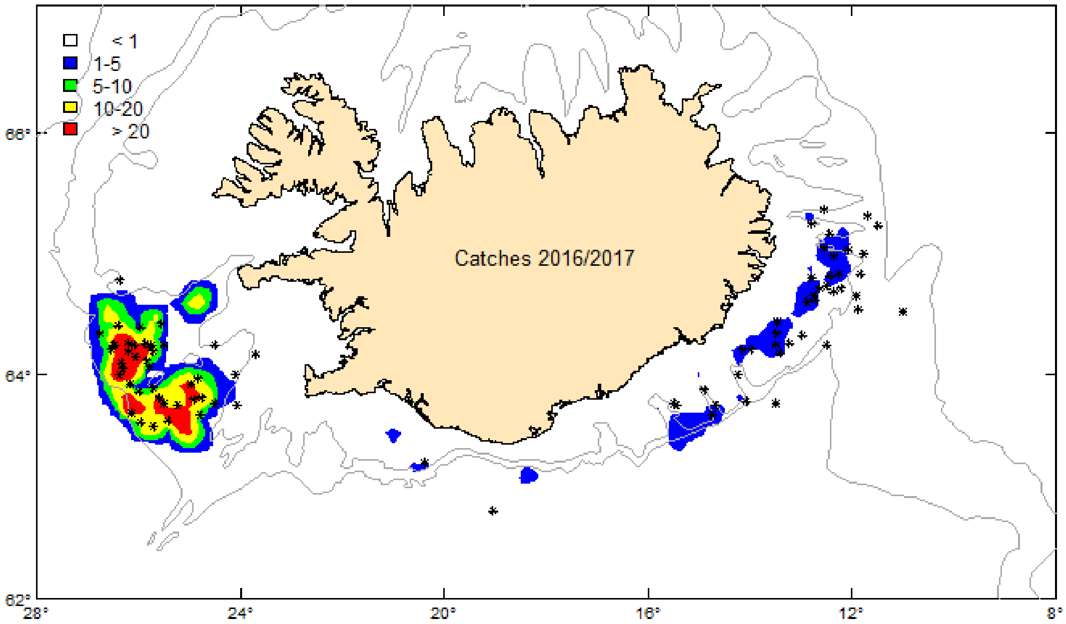

Figure 11.2.2. The distribution of the fishery (in tonnes) of Icelandic summer spawning herring during the fishing season 2016/17, including the bycatch in the mackerel fishery in June-September 2016, where the stars indicate the location of catch samples.

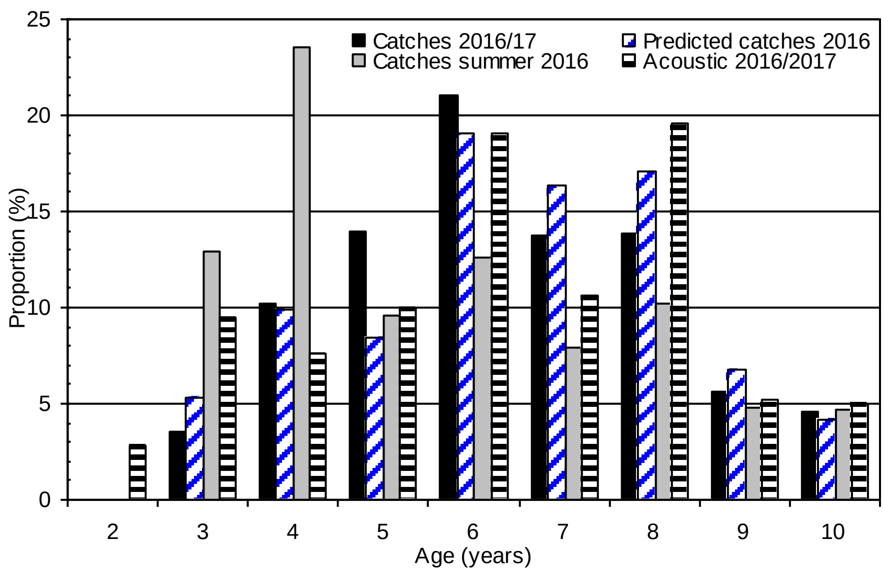

Figure 11.2.2.1. Proportion of the different age groups of Icelandic summer-spawning herring to the total catches (biomass) as observed in 2016/2017 fishing season (June 2016-Februay 2017), predicted in the 2016 assessment (ICES 2016) for the 2016/2017 fishing season, and the summer catches in June-September 2016 in comparison to the age composition in the stock according to the acoustic measurements in the winter 2016/2017.

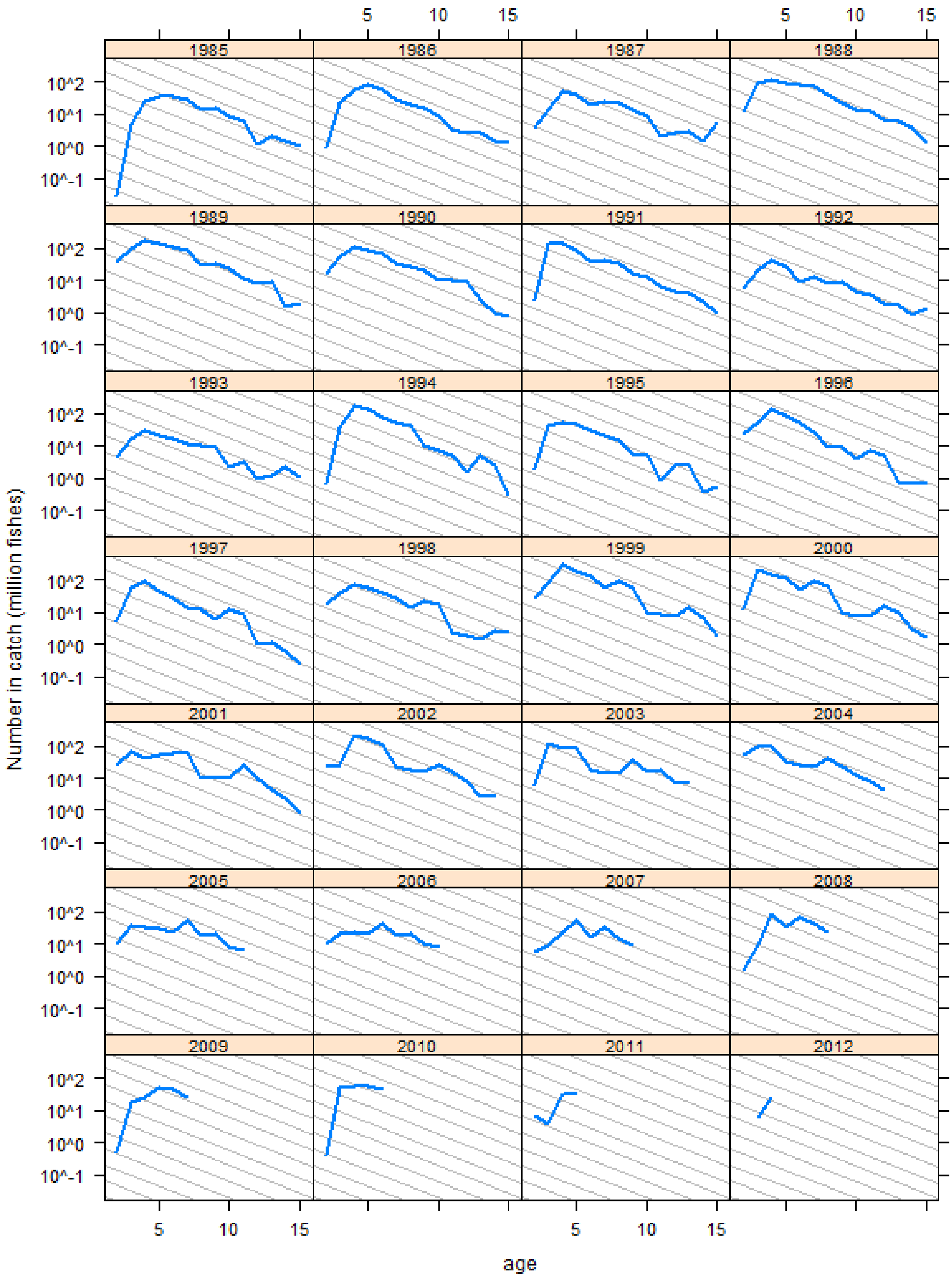

Figure 11.3.1.1. Icelandic summer-spawning herring. Catch curves by year classes 1985-2012. Grey lines correspond to Z=0.4. Note that the mass mortality in Kolgrafafjörður is added to the catches in 2012.

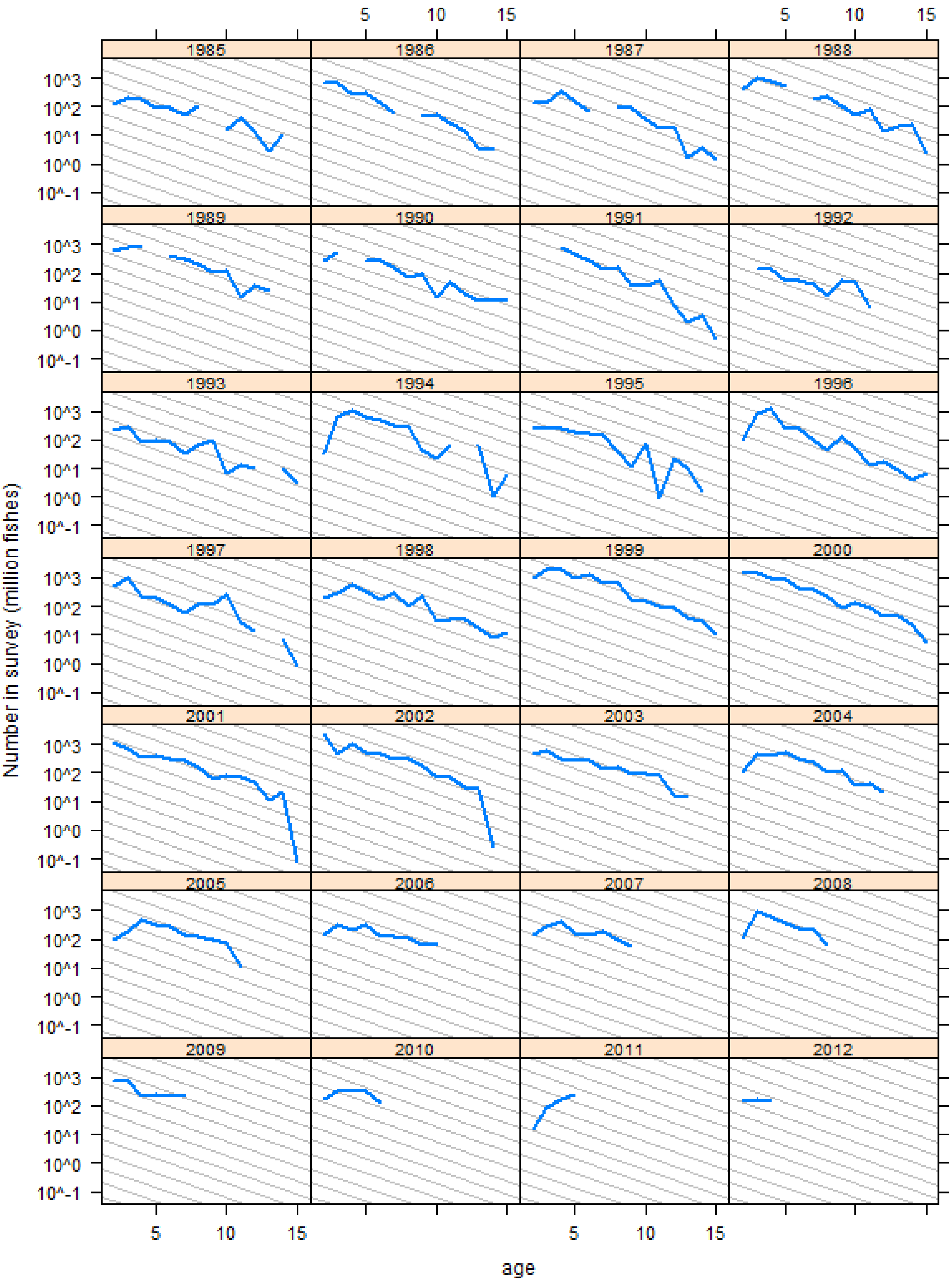

Figure 11.3.1.2. Icelandic summer spawning herring. Catch curves from survey data by year classes 1985-2012. Grey lines correspond to Z=0.4.

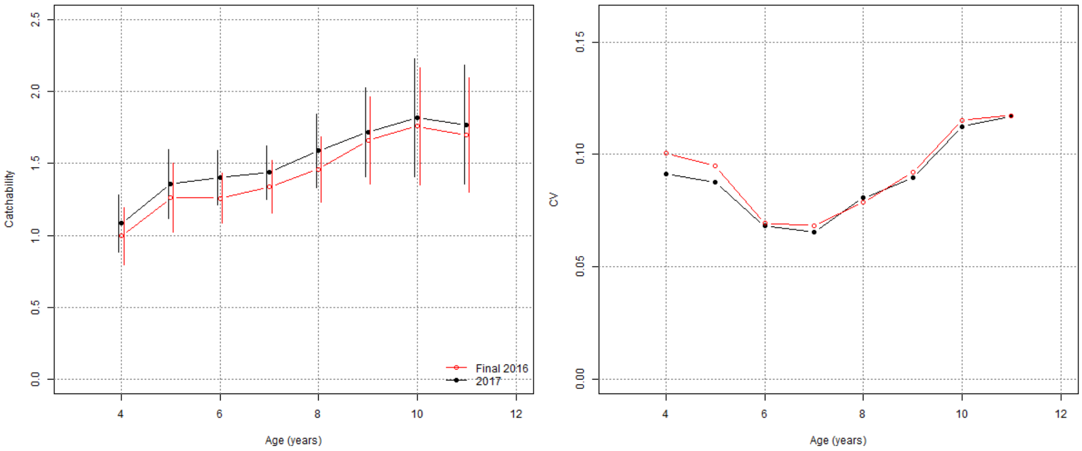

Figure 11.3.2.1. Icelandic summer-spawning herring. The catchability (± 2 SE) and its CV for the acoustic surveys used in the final Adapt run in 2017 (1987-2016) compare to the assessment in 2016.

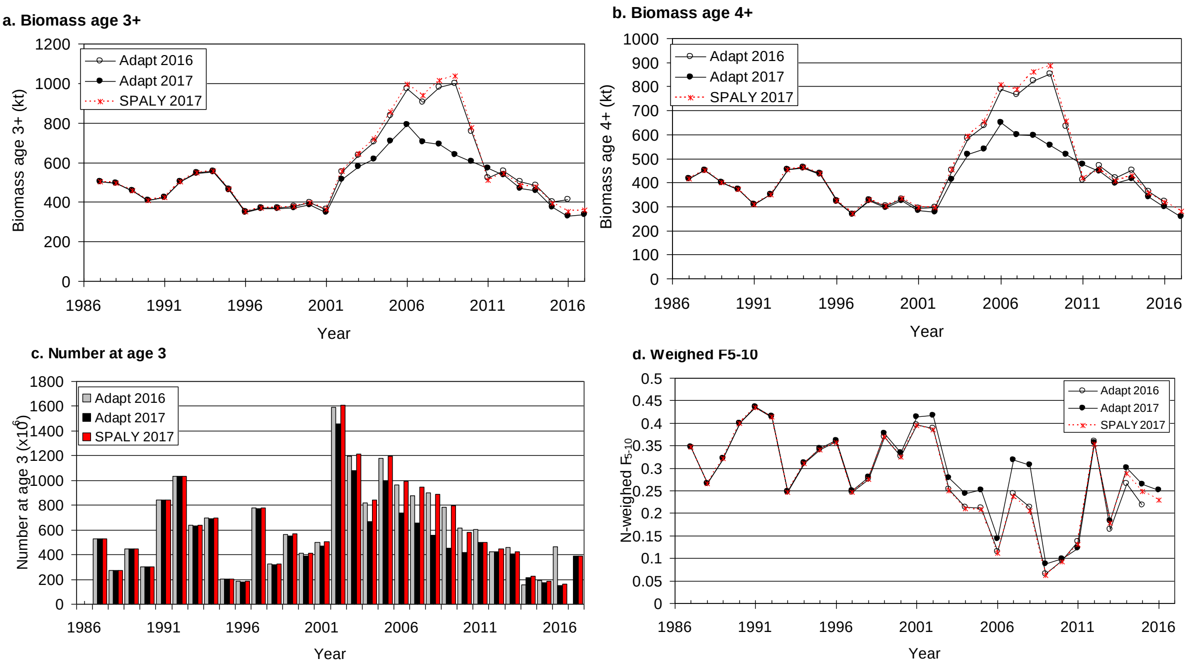

Figure 11.3.2.2. Icelandic summer-spawning herring. Comparisons of the final NFT-Adapt run in 2017, the final run in 2016, and SPALY run in 2017 (i.e. same estimates of M applied as in 2016) concerning (a) biomass of age 3-12, (b) biomass of age 4-12, (c) number at age 3, and N-weighed F for age 5-10. 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) and the difference for the period ~2002-2011 is related to lower *Ichthyophonus* mortality set in the final run in 2017.

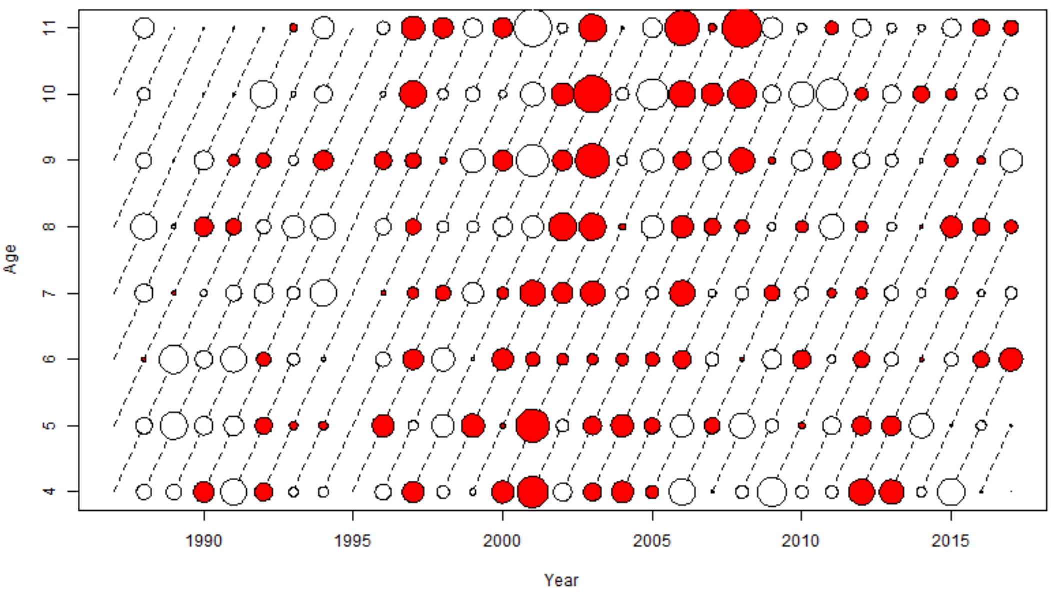

Figure 11.3.2.3. Icelandic summer spawning herring. Residuals of NFT-Adapt run in 2017 from survey observations (moved to 1st January). Filled bubbles are positive and open negative. Max bubble = 1.72.

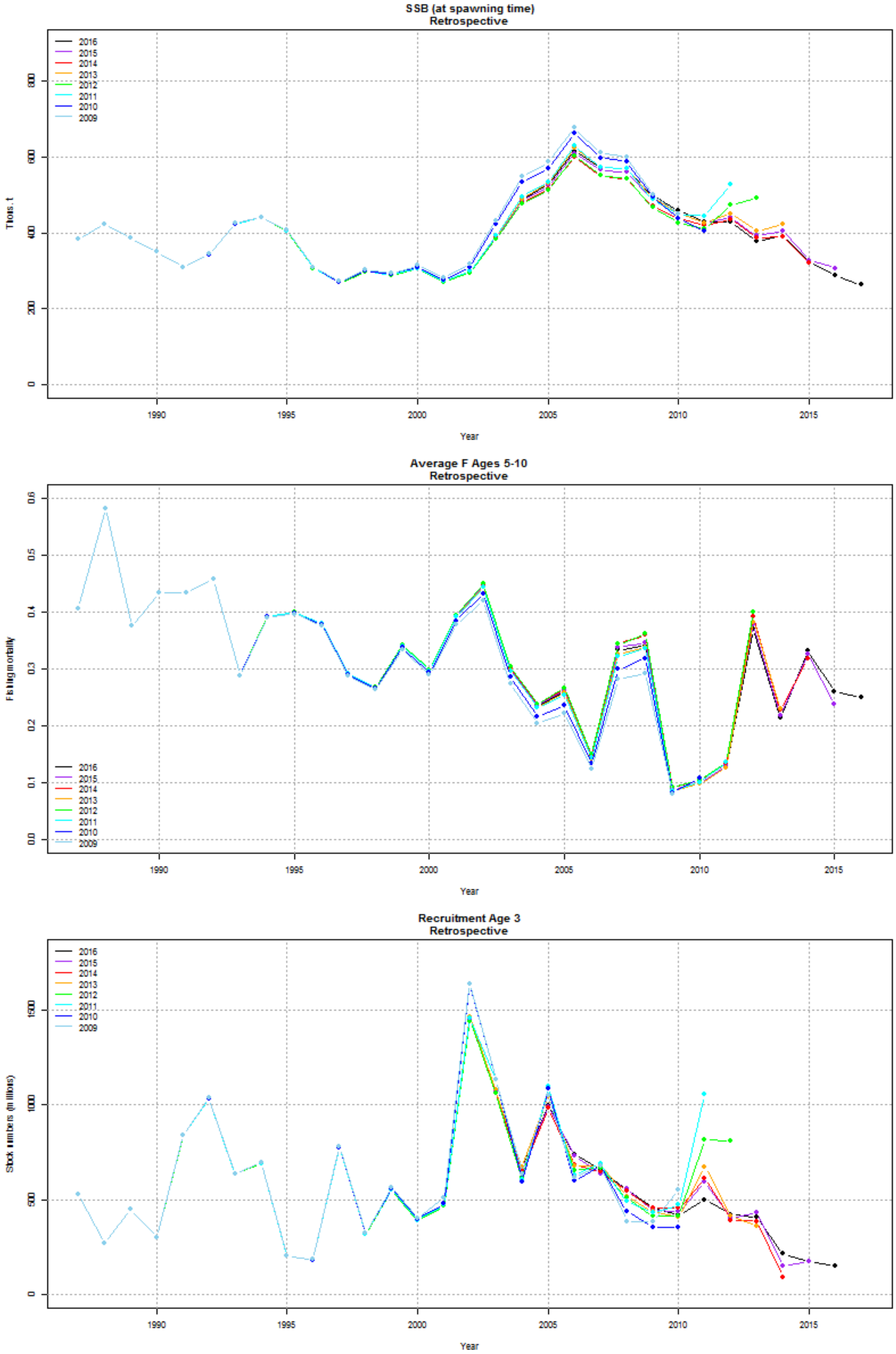

Figure 11.3.2.4. Icelandic summer spawning herring. Retrospective pattern from NFT-Adapt in 2017 in spawning stock biomass (the top panel), N weighted $F_{5\text{-}10}$ (middle panel) and recruitment as number at age 3 (lowest panel).

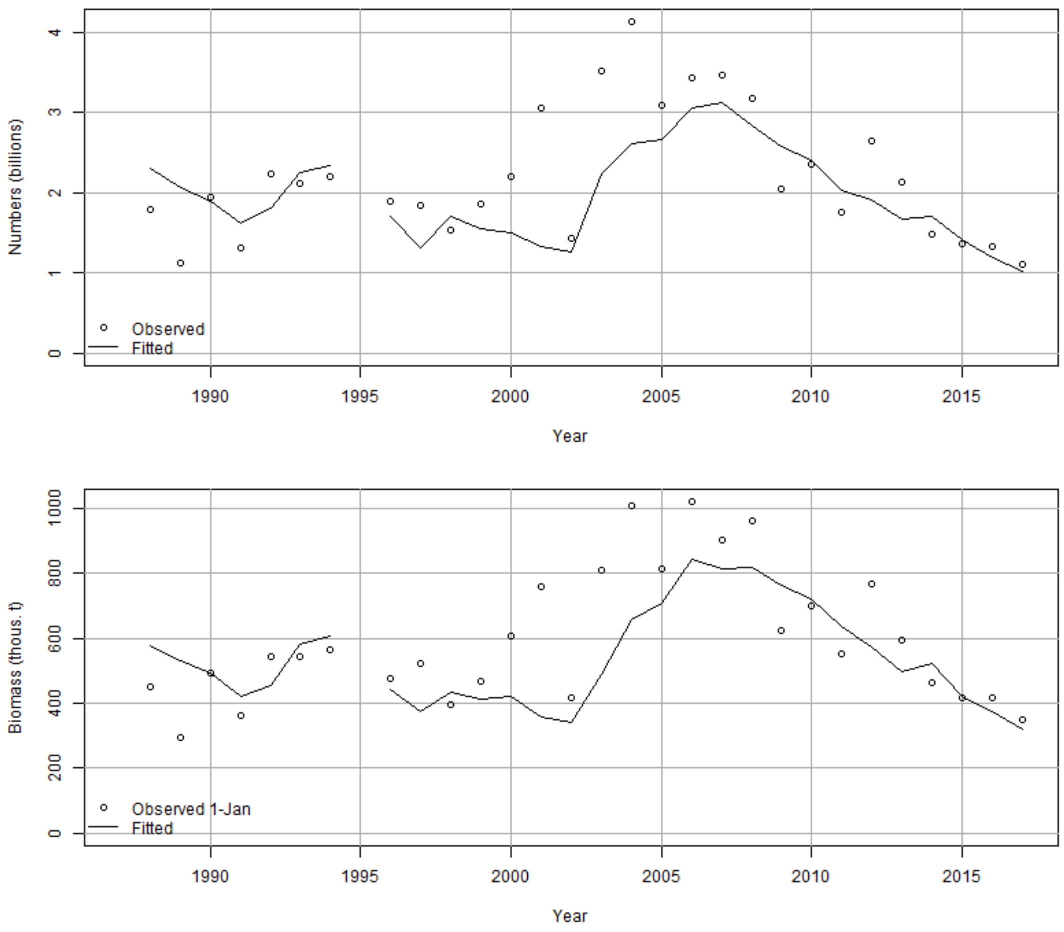

Figure 11.3.2.5. Icelandic summer-spawning herring. Observed versus. predicted survey values from NFT-Adapt run in 2017 for ages 4-11 with respect to numbers (upper) and biomass (lower).

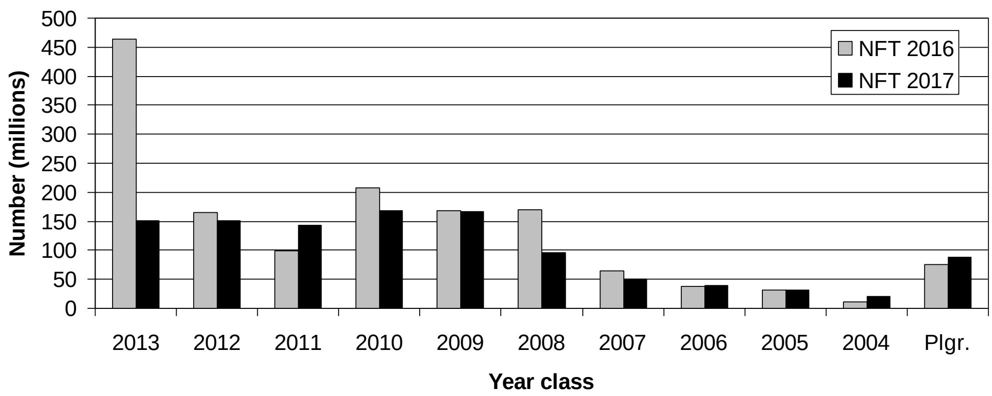

Figure 11.3.2.6. Icelandic summer-spawning herring. Comparison of number-at-age on Jan. 1st. 2016 from the final NFT model runs in 2016 and 2017 assessments.

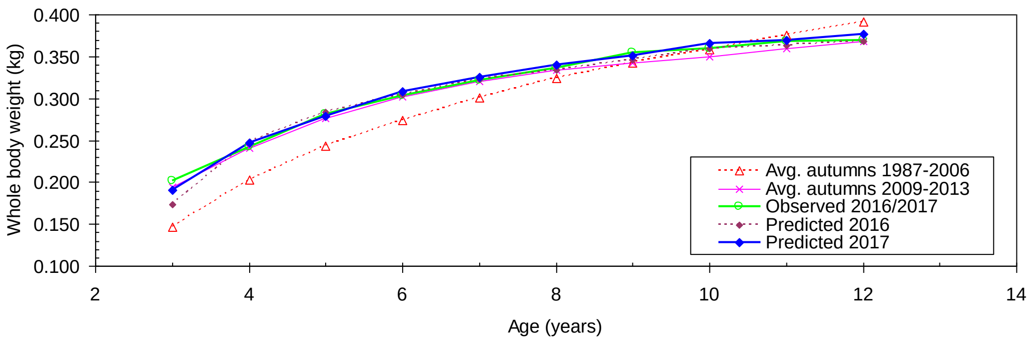

Figure 11.6.1.1. Icelandic summer spawning herring. The mean weight-at-age for age groups 3 to 12 (+ group) in 1987-2006, 2009-2013, in the catches in the winter 2015/2016, predicted weights for the winter 2016/2017 in the 2016 assessment (ICES 2016) and finally predicted weights for the autumn 2017 from the weights in 2016, which was used in the stock prognosis.

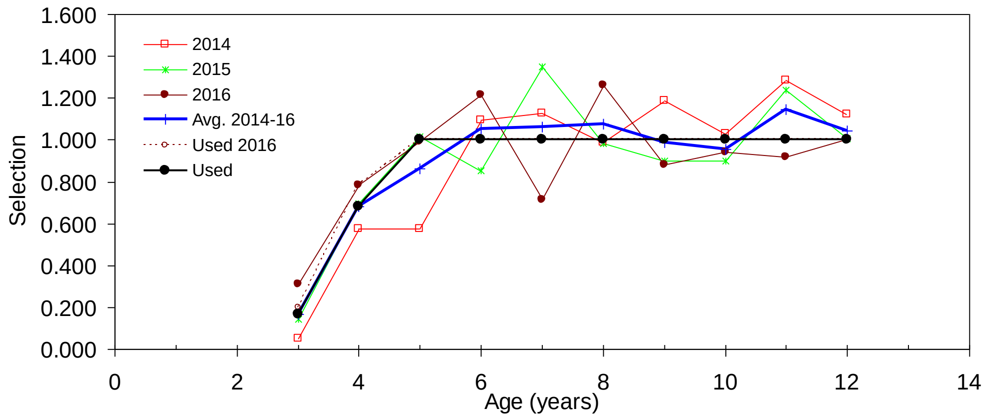

Figure 11.6.1.2. Icelandic summer spawning herring. The selection pattern for age groups 3 to 12 (+ group) for the years 2014 to 2016, the average selection across these three years, the selection used in 2016, and the selection used in the prognosis 2017 (three years average for age 3 and 4, but fixed at 1.0 for age 4+).

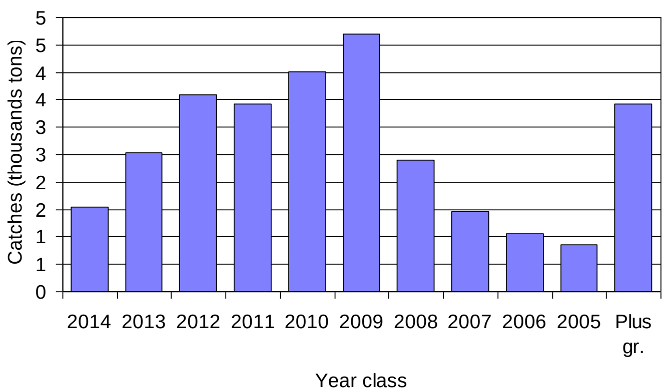

Figure 11.6.2.1. Icelandic summer spawning herring. The predicted biomass contribution of the different year classes to the catches in the fishing season 2017/2018 (total catch of 41 thousands tons).