

Stock Annex: Greater silver smelt (*Argentina silus*) in Subarea 14 and Division 5.a (East Greenland and Iceland grounds)

Stock:	Greater Silver Smelt
Working Group:	Working Group on Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP)
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A. General

A.1. Stock definition

Greater Silver Smelt (*Argentina silus*) stock in Division 5.a (Icelandic waters) is treated as a separate assessment unit is from greater silver smelt in Subareas 1, 2, 4, 6, 7, 8, 9, 12, 14 and Divisions 3.a and 5.b.

A.2. Fishery

Greater silver smelt is mostly fished along the south, southwest, and west coast of Iceland, at depths between 500 and 800 m.

Greater silver smelt was caught in bottom trawls for years as bycatch in the redfish fishery. Only small amounts were reported prior to 1996 as most of the greater silver smelt was discarded. Since 1997, direct fishery for greater silver smelt has been ongoing and the landings have increased significantly. In the beginning, the fishery was mainly located along the slopes of the south and southwest coast, but in recent years the fishery has expanded and significant catches are taken along the slopes west of Iceland.

The greater silver smelt fishery is at present not managed by quotas but rather as an exploratory fishery subject to licensing (see A.2.1) since 1997. Greater silver smelt is now mainly taken both in a directed fishery with, but also as a bycatch in the redfish fishery.

A.2.1. Fleet

Greater silver smelt in 5.a is caught only in bottom trawls, often as a bycatch or in conjunction with redfish and Greenland halibut fishing. Between 20 and 30 trawlers have participated in the fishery since 1996. In recent years, the majority of the greater silver smelt landings have been taken in hauls where the species was 50% or more of the catch in the haul. The trawlers that target greater are mainly freezer trawlers that are between 1000 and 2000 GRT. The fleet uses a bottom trawl with small mesh size belly (80 mm) and codend (40 mm).

A.2.2. Regulations

The greater silver smelt fishery is subject to regulation nr 717, 6th of October 2000 with amendments 1138/2005 from the Ministry of Fisheries. In short the regulation states among others that:

- 1) All fishing of greater silver smelt is subject to licensing by the Directorate of Fisheries that has to be renewed each year.
- 2) Fishing for Greater silver smelt is only allowed south and west of Iceland. That is west of W19°30 and south of N66°00 at depths greater than 220 fathoms (approximately 430 m). Between W19°30 and W14°30 taking of greater silver smelt is allowed south of given line (Figure 1 and Table 1).
- 3) It is mandatory to keep logbooks where the date, exact position of haul, catch and depth are recorded.
- 4) Samples shall be collected, at least one from each fishing trip. The sample shall consist of randomly selected 100–200 specimens of greater silver smelt. The sample is frozen on board and sent to the Marine Research Institute in Reykjavik for further investigation.
- 5) Minimum mesh size in the trawl is 80 mm but 40 mm in the codend.

On the 7th of June 2010 the Ministry of Fisheries and Agriculture redrew licences for the remaining time of that fishing year (2009/2010). Licences were similarly redrawn on the 7th of March 2011 (for 2010/2011), 2nd of December 2011 (for 2011/2012) and on the 18th of March 2013 (for (2012/2013).

As of the 2013/2014 fishing year, greater silver smelt is regulated by the ITQ system (regulation 662/2013) used for many other Icelandic stocks such as cod, haddock, tusk and ling. Fishing for greater silver smelt is still subjected to the conditions listed in bullet points 1 to 6 above.

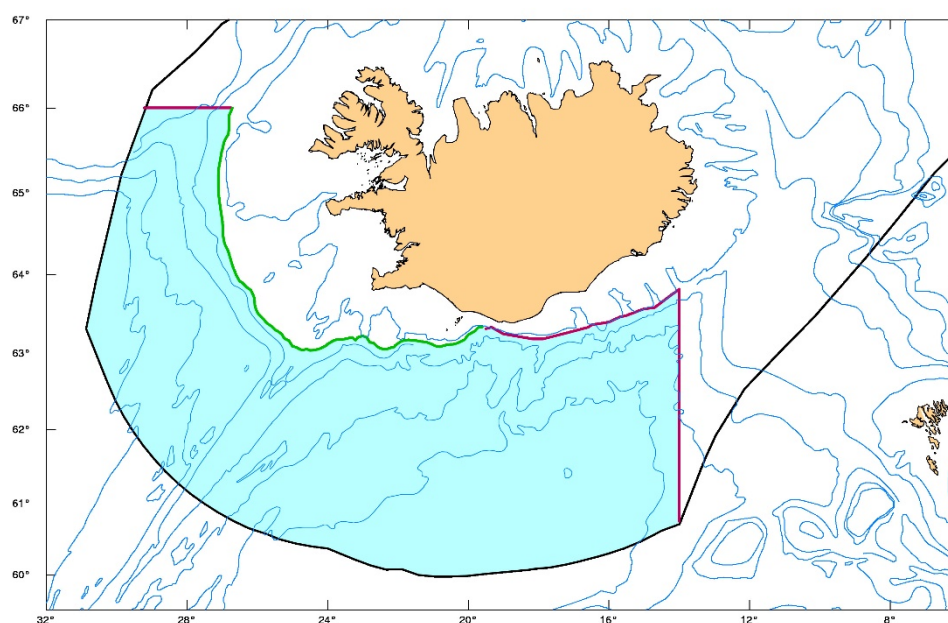


Figure 1. Area open to commercial fishing of Greater Silver Smelt in 5.a according to regulation nr 717, 6th of October 2000 with amendments 1138/2005 from the Ministry of Fisheries (the shaded blue area). The red-line off the south coast drawn according to Table 1 and the green line is an approximation of the 400 m depth contour.

A.3. Ecosystem aspects

Warming of sea temperature, have been documented in 5.a and an expansion of distributional area of warm water species such as anglerfish. The significance and reliability of such metrics is considered at the moment insufficient for their consideration in the provision of management advice of greater silver smelt in 5.a.

B. Data

B.1. Commercial catches

Icelandic commercial catches in tonnes by month and gear are provided by Statistical Iceland and the Directorate of Fisheries. Data on catch in tonnes from other countries are taken from ICES official statistics (STATLAN) and/or from the Icelandic Coast Guard. Annual landings are available from 1985 or from the commencing of the targeted fishery. The fishing statistics are considered accurate. Discards are not considered to be of relevance and therefore not included in the assessment. There are limited measurements of discard from 2002 to 2009. The distribution of catches is obtained from logbook statistics where location of each haul, effort, depth of trawling and total catch of greater silver smelt is given. From the logbook catch per unit of effort and effort is estimated.

B.2. Biological

Biological data from the greater silver smelt catch are collected onboard of the fishing vessel, as it is mandatory to send at least one sample from each fishing trip. The sample is sent to the Marine Research Institute and analysed by scientists and technicians. Each sample consists of randomly selected 100–200 specimens of greater silver smelt. In each

sample, otoliths are extracted from 50 specimens. The biological data collected are length (to the nearest cm), sex and maturity stage, and ungutted weight (to the nearest gram). The rest of the sample is only length measured.

From 1987–1996, biological sampling from the catches were sporadic. Biological sampling of the catches has been generally considered sufficient since 1997. Age reading is considered accurate.

Greater silver smelt in 5.a reaches 50% maturity at around 36 cm or at around 6–8 years of age. The species enters the fishery at around 30 cm or 3–4 years of age. Only very few greater silver smelt have been measured 60 cm or larger.

B.3. Surveys

The annual Icelandic groundfish surveys give trends on fishable biomass of many exploited stocks on Icelandic fishing grounds. The main objective in the design of the surveys was to monitor the most important commercial stocks such as cod, haddock, saithe, and redfish. However the surveys are considered representative for many other exploited stocks of lesser economic importance.

B.3.1. The Icelandic groundfish survey in March

The Icelandic groundfish survey which has been conducted annually in March since 1985 gives trends on fishable biomass of many exploited stocks on Icelandic fishing grounds. Total of more than 500 stations are taken annually in the survey at depths down to 500 meters. Therefore the survey area does not cover the most important distribution area of greater silver smelt and is not considered fully representative for greater silver smelt in 5.a.

B.3.2. The Icelandic groundfish survey in October (Autumn Survey)

The Icelandic Autumn Groundfish Survey (AGS) has been conducted annually since 1996 by the Marine Research Institute (MRI). The objective is to gather fishery independent information on biology, distribution and biomass of demersal fish species in Icelandic waters, with particular emphasis on Greenland halibut (*Reinhardtius hippoglossoides*) and deep-water redfish (*Sebastes mentella*). This is because the Icelandic Groundfish Survey (IGS) conducted annually in March does not cover the distribution of these deep-water species. Secondary aim of the survey is to have another fisheries independent estimate on abundance, biomass and biology of demersal species, such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and golden redfish (*Sebastes marinus*), in order to improve the precision of stock assessment.

AGS is conducted in October as it is considered the most suitable month in relation to diurnal vertical migration, distribution and availability of Greenland halibut and deep-sea redfish. The research area is the Icelandic continental shelf and slopes within the Icelandic Exclusive Economic Zone to depths down to 1500 m. The research area is divided into a shallow-water area (0–400 m) and a deep-water area (400–1500 m). The shallow-water area is the same area as covered by IGS. The deep-water area is directed at the distribution of Greenland halibut, mainly found at depths from 800–1400 m west, north and east of Iceland, and deep-water redfish, mainly found at 500–1200 m depths southeast, south and southwest of Iceland and on the Reykjanes Ridge.

Initially, a total of 430 stations were divided between the two areas. Of them, 150 stations were allocated to the shallow-water area and randomly selected from the IGS station list. In the deep-water area, half of the 280 stations were randomly positioned in the area. The other half were randomly chosen from logbooks of the commercial

bottom-trawl fleet fishing for Greenland halibut and deep-water redfish in 1991–1995. The locations of those stations were, therefore, based on distribution and pre-estimated density of the species.

Because MRI was not able to finance a project in order of this magnitude, it was decided to focus the deep-water part of the survey on the Greenland halibut main distributional area. For this reason, important deep-water redfish areas south and west of Iceland were omitted. The number and location of stations in the shallow-water area were unchanged.

The number of stations in the deep-water area was therefore reduced to 150. A total of 100 stations were randomly positioned in the area. The remaining stations were located on important Greenland halibut fishing grounds west, north and east of Iceland and randomly selected from a logbook database of the bottom-trawl fleet fishing for Greenland halibut 1991–1995. The number of stations in each area was partly based on total commercial catch.

In 2000, with the arrival of a new research vessel, MRI was able finance the project according to the original plan. Stations were added to cover the distribution of deep-water redfish and the location of the stations selected in a similar manner as for Greenland halibut. A total of 30 stations were randomly assigned to the distribution area of deep-water redfish and 30 stations were randomly assigned to the main deep-water redfish fishing grounds based on logbooks of the bottom-trawl fleet 1996–1999. The years 1996–1999 cannot be used for abundance and biomass estimates of greater silver smelt since the AGS in those years did not cover adequately the distribution of the species.

In addition, 14 stations were randomly added in the deep-water area in areas where great variation had been observed in 1996–1999. However, because of rough bottom which made it impossible to tow, five stations have been omitted. Finally, 12 stations were added in 1999 in the shallow-water area, making total stations in the shallow-water area 162. Total number of stations taken since 2000 has been around 381 (Figure 2).

The R/V “Bjarni Sæmundsson” has been used in the shallow-water area from the beginning of the survey. For the deep-water area MRI rented one commercial trawler 1996–1999, but in 2000 the commercial trawler was replaced by the R/V “Árni Friðriks-son”.

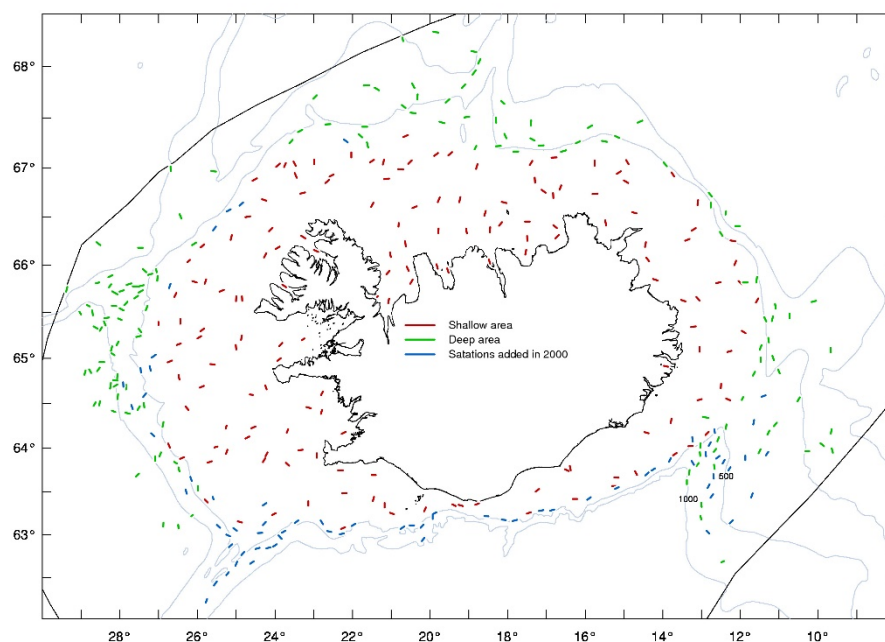


Figure 2. Stations in the Autumn Groundfish Survey (AGS). R/V “Bjarni Sæmundsson” takes stations in the shallow-water area (red lines) and R/V “Árni Friðriksson” takes stations in the deep-water areas (green lines), the blue lines are stations added in 2000.

B.3.2.1. Data collection (biological sampling)

B.3.2.1.1. Length measurement, counting (sub-sampling)

All fish species are measured for length. For the majority of species including greater silver smelt, total length is measured to the nearest cm from the tip of the snout to the tip of the longer lobe of the caudal fin. At each station, the general rule, which also applies to greater silver smelt is to measure at least four times the length interval of a given species. Example: If the continuous length distribution of greater silver smelt at a given station is between 15 and 45 cm, the length interval is 30 cm and the number of measurements needed is 120. If the catch of greater silver smelt at this station exceeds 320 individuals, the rest is counted.

Care is taken to ensure that the length measurement sampling is random so that the fish measured reflect the length distribution of the haul in question.

B.3.2.1.2. Recording of weight, sex and maturity stages

Sex and maturity data have not been collected from greater silver smelt sampled in the autumn survey, nor has silver smelt been weighted. Collection of these data is supposed to commence in 2010.

B.3.2.1.3. Otolith sampling and weighing

For greater silver smelt a minimum of one and a maximum of 25 otoliths are collected from each haul. Otoliths are sampled at a 30 fish interval so that if in total 300 greater silver smelt are caught in a single haul, ten otoliths are sampled.

B.3.2.2. Station information

At each station relevant information on the haul and environmental factors, are filled out by the captain and the first officer in co-operation with the cruise leader.

Tow information

- **General:** Year, Station, Vessel registry no., Cruise ID, Day./month, Statist. Square, Sub-square, Tow number, Gear type no., Mesh size, Briddles length (m).
- **Start of haul:** Pos. N, Pos. W, Time (hour:min), Tow direction in degrees, Bottom depth (m), Towing depth (m), Vert. opening (m), Horizontal opening (m).
- **End of haul:** Pos. N, Pos. W, Time (hour:min), Warp length (fm), Bottom depth (m), Tow length (naut. miles), Tow time (min) , Tow speed (knots).
- **Environmental factors:** Wind direction, Air temperature °C, Wind speed, Bottom temperature °C, Sea surface, Surface temperature °C, Towing depth temperature °C, Cloud cover, Air pressure, Drift ice.

B.3.2.3. Fishing gear

Two types of the bottom survey trawl “Gulltoppur” are used for sampling: “Gulltoppur” is used in the shallow water and “Gulltoppur 66.6 m” is used in deep waters. The trawls were common among the Icelandic bottom trawl fleet in the mid-1990s and are well suited for fisheries on cod, Greenland halibut and redfish.

The bottom trawl used in the shallow water is called “Gulltoppur”. The headline is 31.0 m, and the fishing line is 19.6 m. The trawl used in the deep-water area is “Gulltoppur 66.6 m” (Figures 6–9). The headline is 35.6 m and the fishing line is 22.6 m.

Towing speed and distance: The towing speed is 3.8 knots over the bottom. The trawling distance is 3.0 nautical miles calculated with GPS when the trawl touches the bottom until the hauling begins (i.e. excluding setting and hauling of the trawl).

B.3.2.4. Data processing

B.3.2.4.1. Abundance and biomass estimates at a given station

As described above the normal procedure is to measure at least four times the length interval of a given species. The number of fish caught of the length interval L_1 to L_2 is given by:

$$P = \frac{n_{measured}}{n_{counted} + n_{measured}}$$

$$n_{L_1-L_2} = \sum_{i=L_1}^{i=L_2} \frac{n_i}{P}$$

Where $n_{measured}$ is the number of fished measured and $n_{counted}$ is the number of fish counted.

Biomass of a given species at a given station is calculated as:

$$B_{L_1-L_2} = \sum_{i=L_1}^{i=L_2} \frac{n_i \alpha L_i^\beta}{P}$$

Where L_i is length and alpha and beta are coefficients of the length–weight relationship.

B.3.2.4.2. Index calculation

For calculation of indices the Cochran method is used (Cochran, 1977). The survey area is split into subareas or strata and an index for each subarea is calculated as the mean number in a standardized tow, divided by the area covered multiplied with the size of the subarea. The total index is then a summed up estimates from the subareas.

A ‘tow-mile’ is assumed to be 0.00918 square nautical mile. That is the width of the area covered is assumed to be 17 m ($17/1852=0.00918$). The following equations are a mathematical representation of the procedure used to calculate the indices:

$$I_{strata} = \frac{\sum_{strata} Z_i}{N_{strata}}$$

$$\sigma_{strata}^2 = \frac{\sum_{strata} (Z_i - I_{strata})^2}{N_{strata} - 1}$$

$$I_{region} = \sum_{region} I_{strata}$$

$$\sigma_{strata}^2 = \sum_{region} \sigma_{strata}^2$$

$$CV_{region} = \frac{\sigma_{region}}{I_{region}}$$

Where *strata* refers to the subareas used for calculation of indices which are the smallest components used in the estimation, *I* refers to the stations in each subarea and region is an area composed of two or more subareas. Z_i is the quantity of the index (abundance or biomass) in a given subarea. *I* is the index and sigma is the standard deviation of the index. CV refers to the coefficient of variation.

The subareas or strata used in the Icelandic groundfish surveys (same strata division in both surveys) are shown in Figure 3. The division into strata is based on the so-called BORMICON areas and the 100, 200, 400, 500, 600, 800 and 1000 m depth contours.

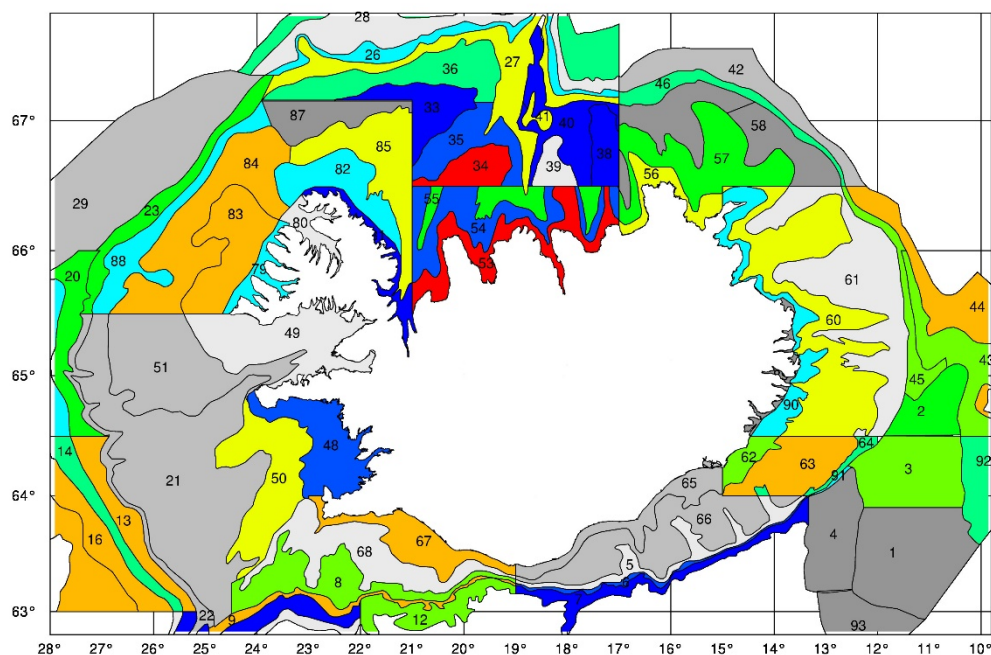


Figure 3. Subareas or strata used for calculation of survey indices in Icelandic waters.

B.3.2.4.3. Stratification for Greater Silver Smelt

The standard calculations of regional survey indices are not particularly applicable to greater silver smelt (originally designed for cod). Therefore, the processing of the autumn survey data is done at a slightly different regional scale. In short, the main distributional area of greater silver smelt off the southeast, south and west coast of Iceland, and in recent years also off the northwest coast. Also, fishing of greater silver smelt is banned at depths less than 220 fathoms (~400 m). To get a proxy for 'fishable' survey indices a few regions are defined for depths greater than 400 m (Table 1 and Figure 4).

Table 1. Survey regions used for calculation of various Autumn Groundfish Survey indices for greater silver smelt in 5.a.

REGION	NO. STRATA	AREA (KM2)	NO. STATIONS
Total	74	339 691	378
GSS fishing grounds	13	46 993	80
Depth >400 m	32	152 626	186
Depth <400 m	41	186 870	192
NW >400 m	2	20 081	16
W >400 m	9	31 613	60
S >400 m	6	26 715	24
SE >400 m	7	30 358	36

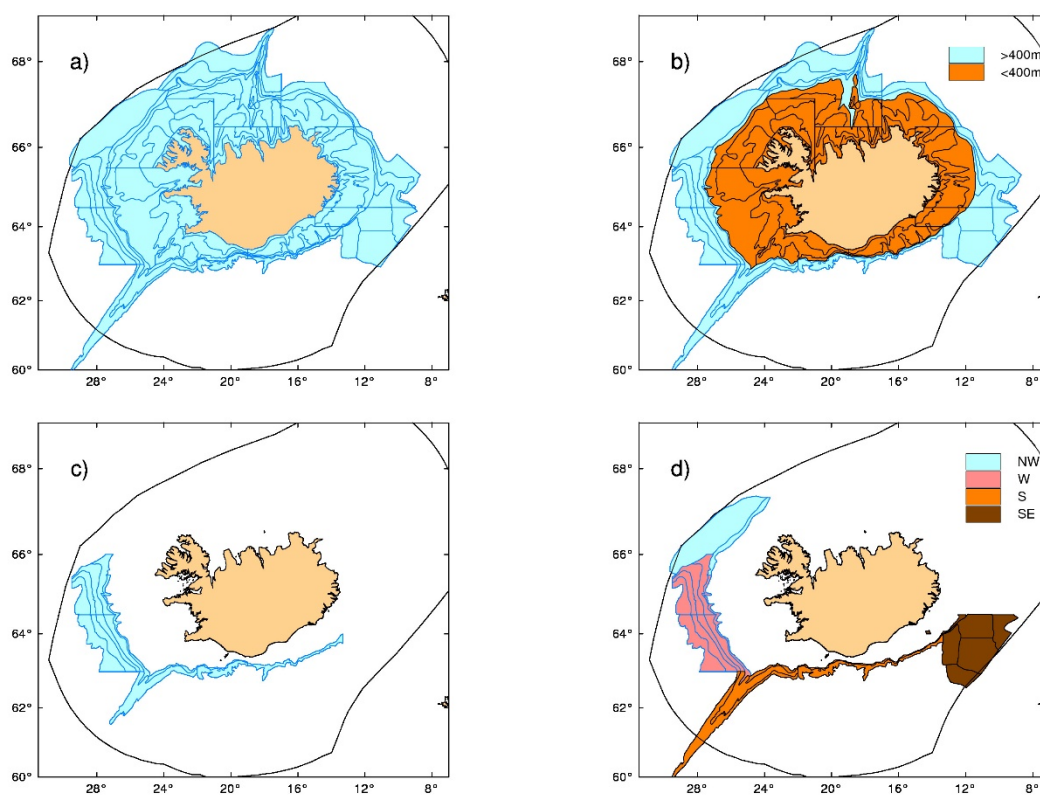


Figure 4. Divisions used in calculation of indices for greater silver smelt in 5.a. a) Total area. b) Division at 400 m depth contour. c) Greater silver smelt fishing area. d) Subdivisions of the main distributional area of greater silver smelt.

B.3.2.4.4. Winsorization of survey data

One of the main problems when calculating indices from tow surveys is how to treat few large hauls. In some cases, one or two hauls, that happens to be inside a large stratum, can result in very marked increase in survey estimates. This is a problem for greater silver smelt as for many other species. Not only can exceptionally large hauls increase survey estimates but also greatly affect estimated CV of the index in question.

Winsorization is one way to deal with outliers (Sokal and Rolf, 1995). A typical way to go when applying Winsorization is to set all outliers to a specified percentile of the data; for example, a 90% Winsorisation would set all data below the 5th percentile to

the 5th percentile, and data above the 95th percentile set to the 95th percentile. Winsorised estimators are usually more robust to outliers than their un-winsorised counterparts.

This strategy is applied to the greater silver smelt data from Autumn Groundfish Survey. The number of greater silver smelt in a tow that are greater than the 95th percentile are set at the quantile. The same is done for the 5th percentile quantile, that is, numbers of greater silver smelt in a tow that are lower than 5th percentile quantile are set at the quantile. It should be noted that tow-stations that have no greater silver smelt are excluded from the Winsorization.

B.4. Commercial cpue

Catch per unit of effort (cpue) has been calculated using all data where catches of the greater silver smelt were more than 30%, 50% and 70% of the total reiterated catch in each haul. Estimates of raw cpue is simply the sum of all catch divided by the sum of the hours trawled. As the trawlers do not set out the trawl except when the captain is certain there is an aggregation of greater silver smelt and as the fishery is largely driven by markets and quota shares in other species (deep-water redfish and Greenland halibut) it is not certain how representative the cpue series is of stock trends.

C. Historical stock development

Greater silver smelt in 5.a is assessed based on trends in survey biomass indices (standard un-winsorized and winsorized) from the Icelandic Autumn survey and changes in age distributions from commercial catches and surveys. Supplementary data used include relevant information from the fishery and surveys such as changes in spatial (geographical and depth range) and temporal distribution, length distributions and maturity ogives.

At present analytical assessments cannot be conducted because of contrasting signals in the available data and the relative shortness of the time-series available.

D. Assessment and advice

There is a clear gradient in mean length of greater silver smelt with depth, larger fish being in deeper water. Also fishing for greater silver smelt in 5.a is banned at depths less than 400 meters. The autumn survey index for depth greater than 400 meters is therefore considered the best indicator of available biomass to the fishery.

At the Benchmark for greater silver smelt in 5.a (WKDEEP-2010), it was concluded that the assessment of the unit should be based on trends in the Icelandic autumn survey, both standard calculated index and a Winsorized version of the index of GSS, at depths greater than 400 meters.

At WGDEEP 2010 three versions of indices from the autumn survey were presented:

- 1) Index using the original stratification scheme for the spring and autumn survey (See stock annex for details).
- 2) A Winsorized index using the same stratification scheme as in 1 (See stock annex for details).
- 3) Index using a revised stratification scheme, specially designed for the autumn survey.

The group considered the revised indices (3) a step forward and that the data from the Icelandic autumn survey should in the future be processed using the revised stratification scheme. The index for greater silver smelt at depths greater than 400 meters, based on the revised stratification scheme was then used by ACOM in the advisory process in 2014. The index for depth greater than 400 meters was assumed to be the best available indicator of the available biomass to the fishery (Figure 5). However at WGDEEP 2015 this biomass index is seen to be highly variable, with the estimate for 2014 being roughly five times higher than of the previous year whilst not being significantly different. Therefore at WGDEEP 2015 presented the fourth alternative:

- 1) A Winsorized index using the revised stratification scheme from 3).

A comparison of indices derived using approaches (3) and (4) are shown in Figure 7.3.7. The group considered the revised indices (4) to be an improvement when compared to the previous approach (3) and thus recommended it for further use.

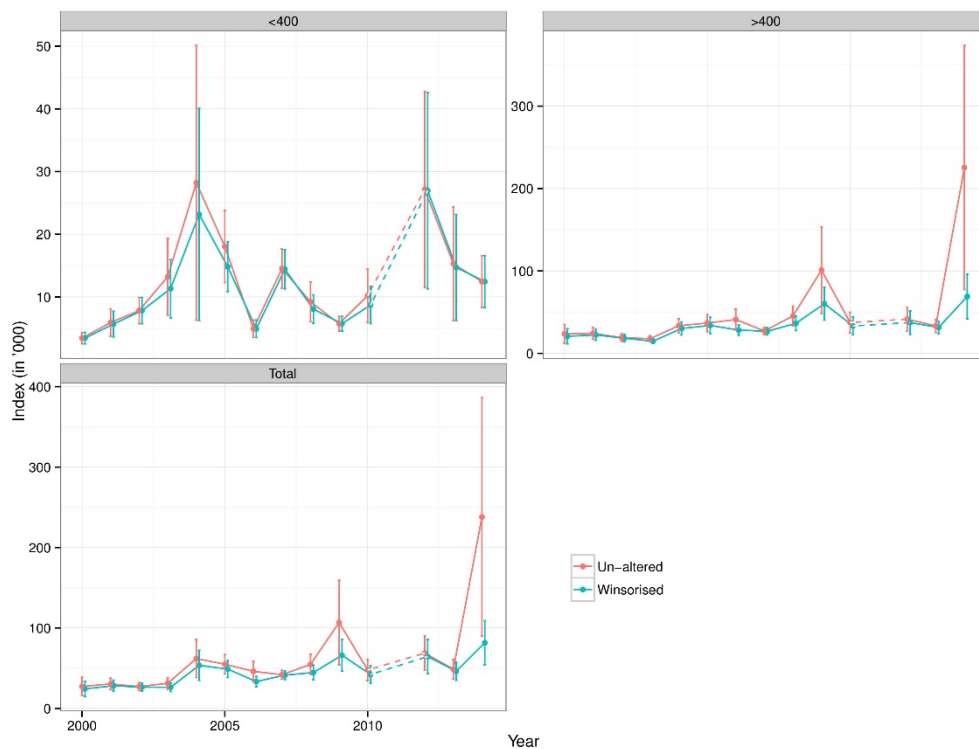


Figure 5. Greater silver smelt in 5.a. Index from the Icelandic autumn survey, divided by depth. The line colour indicates the biomass index used, either unaltered or Winsorized (see text for further details).

The assessment for greater silver smelt in 5.a is based on the ICES DLS approach for category 3 stocks and was proposed by the ADG in 2012. The advice is found by multiplying the terminal index value with a target F_{proxy} (Catch/Survey biomass). For setting the target F_{proxy} a reference period is chosen when the index increased which can then be inferred that the F (or F_{proxy}) was at sustainable levels (ICES DLS Category 3.3). The main points in the evolution of the advisory procedure are listed below.

- In the 2012 advice the target F_{proxy} calculated using the total biomass index as the average F_{proxy} in 2002 to 2007.

- In 2013 WGDEEP reiterated the conclusions of WKDEEP-2010 that the biomass index from the autumn survey at depths greater than 400 m was a more appropriate measure of the biomass available to the fishery.
- In 2014 the basis for the advice was the index from depths greater than 400 meters using a revised stratification, the same reference period was chosen for the target F_{proxy} (2002 to 2007). Additionally a 20% uncertainty buffer was applied to the target F_{proxy} . The basis for the advice for GSS in 5.a in 2014 was the following: For data-limited stocks with reliable abundance information from fisheries-independent data and a target F_{proxy} , where abundance is considered above $\text{MSY } B_{\text{trigger}}$, ICES uses a harvest control rule that calculates catches based on the F_{proxy} target multiplied by the most recent survey biomass estimates.
- In 2015 the index was recalculated using the same winsorization procedure as recommended by WKDEEP-2010 and the revised stratification presented in 2010. In 2015 the same advisory procedure was used but additionally the index increase in 2014 was capped at 20% increase/decrease. Exact wording was: *The Icelandic autumn trawl survey was applied as harvest rate index. The advice is based on a comparison of the latest index value (index A) with the preceding value (index B), combined with the F_{proxy} target (catch/survey biomass) defined from years 2002 to 2007. The index is estimated to have increased by more than 20%, which means that the uncertainty cap was applied to calculate the catch advice. The stock status relative to candidate reference points is unknown.*

E. Medium-term predictions

F. Long-term predictions

G. Biological reference points

H. Other issues

Stock identity of greater silver smelt in the Northeast Atlantic is unclear and further research is needed. Strong recommendations are given in the 2010 WKDEEP Report on this issue (Section 7.1, WKDEEP 2010 Report).

I. References

- Cochran, W.G. 1977. Sampling techniques, 3rd edition. New York: Wiley & Sons.
- Sokal, R. R. and Rohlf, F. J. 1995. Biometry. W. H. Freeman and Company, 3rd edition.