Stock Annex 4.3: Haddock in Division 6b

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Haddock in Division 6b
Working Group:	WGCSE
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A. General

A.1. Stock definition

The haddock stock at Rockall is an entirely separate stock from that on the continental shelf of the British Isles (Chuksin and Gerber, 1976; Shestov, 1977; Blacker, 1982; Newton *et al*., 2008; Finina Khlivnoy Vinnichenko 2009,). The TAC for haddock 6b was previously (before 2004) set for subareas 5b, 6, 12 and 14 combined, with a limitation on the amount to be taken in 5b and 6a. In 2004, the TAC for Division 6 was split and the 6b TAC for haddock was included with Divisions 12 and 14. This combined TAC has been in place since then.

A.2. Fishery

The development of the Rockall haddock fishery is documented in the 2001 Working Group Rneport (ICES, WGNSDS 2001) and in the Report of the ICES Group meeting on Rockall haddock convened in January 2001 (ICES, WGNSDS 2002). That meeting was set up to respond to a NEAFC request for information on the Rockall haddock fishery. NEAFC agreed to consider regulation of the international fishery in 2001.

The Rockall haddock fishery changed markedly in 1999 when a revision of the EU EEZ placed the southwestern part of the Rockall plateau in international waters. This has opened opportunities for other nations, notably Russia, to exploit the fishery in this area. The table of official statistics includes Russian catches from the Rockall area.

The Russian fleet started fishing operations in international waters at Rockall in May–October 1999. The Russian haddock fishery uses bottom trawls with codend mesh size of 40–100 mm (mainly 40–70 mm) and retains haddock of all length classes in the catch. This fishery targets concentrations of haddock mainly during the spring and the beginning of summer. Russian catches increased from 458 t in 1999 to 2154 t in 2000. In 2001, they were markedly reduced to 630 t due to the introduction of a closed area and low density of fish concentrations. Russian catches increased again in 2002–2004 from 1630 to 5844 t. In 2005–2007, they decreased from 4708 t to 1282 t, and are estimated to be 1669 t in 2008. Since 2009 Russian catches do not exceed 388 t. Information on the Russian fishery and biological investigations from commercial vessels fishing in Rockall are presented in working documents to WGCSE 2005–2017 (for details see WGCSE reports).

Prior to 1999, the UK and Ireland fisheries had been principally summer fisheries but in more recent years the Scottish and Irish fishery was conducted throughout the year with the peak in April–May. This shift in the fishery appears to have followed the discovery of concentrations of haddock in deeper water to the west of Rockall, at depths between 200 and 400 m. High catch rates attracted effort into the area. However, catch rates in 2000 were reported to be poor in deeper water. Anecdotal evidence suggests that increased discarding has been associated with the deeper water fishery compared to the traditional fishery at northern Rockall. In 2004–2007, a considerable proportion of EU landings were taken in the international waters. Historical fishing patterns of the Scottish fleet at Rockall are presented by Newton *et al*. (2004).

The number of Scottish vessels fishing for haddock and the number of trips made to Rockall declined substantially from 2000 onwards (WD6 to WGNSDS 2004). The declining trend was reversed in 2007. The number of vessels increased from 22 in 2007 to 28 in 2008, and 37 in 2009. Total Scottish demersal landings in 6b in 2009 were estimated to be 4585 t, of which 2951 t were haddock, and that remained stable in 2010 with 2931 t. In 2011, landings declined to 1738 t of haddock and in 2012 to 577 t. In 2013–2017, landings increased from 596 t to 3960 t. Other important target species included anglerfish (*Lophius* spp.), saithe, ling and megrim.

Irish effort in Rockall declined in 2009–2012. Landings totalling 500 t were reported from Irish otter trawlers in 2017 (increased from 31 t in 2012; Table 4.3.1). Irish vessels used single otter trawls with a mesh size ranging from 100 to 120 mm together with a square mesh panel.

In 1991–2018, Norwegian landing 24–152 t were reported. Norwegian demersal fleet fishing on the Rockall Bank consisted mainly of longliners and targeted mainly ling and tusk.

There are some indications that, due to a general decline in catches by the Scottish and Irish fleets in Division 6a, there is an increasing focus in the Rockall fishery in Division 6b (ICES, WGFTFB 2007). Paired gear (both seine and trawl) are to be tested by some Scottish fishermen, which, if it proves successful, can lead to a considerable increase in effective effort in 6b. The fishery at Rockall seems particularly attractive given the lack of effort restrictions in this area.

An analysis of the spatial and depth distributions of Rockall haddock in association with oceanographic variables is presented by Vinnichenko and Sentyabov (2004), a WD to WGNSDS 2004. Changes in distribution have occurred over a period coincidental with changes in oceanographic variables. Information on oceanographic conditions on Rockall bank in spring 2005 was presented by Sentyabov at WGNSDS 2005.

A.3. Ecosystem aspects

In May 2001, the International Waters component of statistical rectangle 42D5, which is mainly at depths less than 200 m, was closed by NEAFC to all fishing activities, except with longlines. That area had the following coordinates:

Latitude	Longitude
57.000°N	15.000°W
57.000°N	14.700°W
56.575°N	14.327°W
56.500°N	14.450°W
56.500°N	15.000°W

In spring 2002, the EU component of this rectangle, again mostly shallow water, was also closed to trawling activities (EC No 2287/2003). The whole Rockall Haddock Box is bounded by the following coordinates:

Latitude	Longitude
57°00'N	15°00'W
57°00'N	14°00'W
56°30'N	14°00'W
56°30'N	15°00'W

At the 25th Annual Meeting of NEAFC (in November 2006), a closure of three areas on the Rockall Bank to bottom fishery was proposed to protect cold-water corals: Northwest Rockall, Logachev Mounds and West Rockall Mounds (NEAFC AM, 2006). This measure will be in force for the period January 2007–December 2009.

In 2007,ICES prepared advice for NEAFC and arrived at the conclusion about the expediency of establishing a new closed area on the so-called Empress of British Banks and adjusting the boundaries of the currently closed area of Northwest Rockall. At the 26th Annual Meeting of NEAFC (in November 2007), a new closed area (Empress of British Banks) was established, and the boundaries of the Northwest Rockall closure were slightly modified (NEAFC AM, 2007). Due to the complex shape of the boundaries of the Northwest Rockall closure proposed by ICES, which potentially could cause problems with enforcement, the introduced changes differed from the ICES recommendation. NEAFC also requested ICES to continue providing all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in and in the vicinity of such habitats.

WGDEC supported the ICES conclusion on the necessity of revising the boundaries of the Northwest Rockall area established to protect cold+water corals and recommended to consider proposals at the WGNSDS meeting. These recent proposals greatly simplify the boundaries, which would create better conditions for enforcement (see WD8 to WGNSDS, 2008).

In 2007–2015, excluding 2012, the abundance of year classess of haddock were estimated to be extremely weak. Poor year classes may be related to environmental factors including rising seawater temperatures in Rockall Bank, a reduction in zooplankton abundance (ephausiids and *Calanus finmarhicus*) and the negative impact of predation on eggs and larvae and food competition from the grey gurnard (Filina, Khlivnoy and Vinnichenko, 2009; Khlivnoy and Sentiabov, 2009). No significant relationship between spawning biomass and the recruitment was found.

B. Data

B.1. Commercial catch

Landings

Nominal landings as reported to ICES are given in Table 4.3.1 of the main Report, along with Working Group estimates of total estimated landings. Reported international landings of Rockall haddock in 1991–2005 were about 4000–6000 t, except for 2001–2002, when they decreased down to about 2300–3000 t. In 2006, they were also low at 2760 t, but increased slightly to 3348 in 2007, and 4221 t in 2008. Revisions to official catch statistics for previous years are also shown in Table 4.3.1.

Anecdotal evidence suggests that misreporting of haddock from Rockall have occurred historically (which may have led to discrepancies in assessment), but an estimation of overall magnitude is not possible.

Age composition and mean weight-by-age of Scottish and Irish landings were obtained from port sampling. Data on the volume, length–age and weight composition of landings for the period from 1988 to 1998 correspond to values used at this WG.

In 2002, there was no sampling of the Russian catch and therefore the length composition has to be estimated for this year.

In 2002 and 2003, the structure of the Russian fishery on the Rockall Bank was the same: the same vessels were operating with the same gear in the same fishing areas. The relationship between the haddock length composition obtained from the trawl survey and that in the Russian catches is assumed to be the same for 2002 and 2003; i.e. it is assumed that the length dependent selectivity pattern in 2002 is the same as that in 2003 as there no changes to the fishery in these years. The relationship is described as:

$$P_L = S_L p_L \qquad (1)$$

where P_L is the proportion of fish with length L in catches, p_L is proportion of fish with length L in the stock (survey), and S_L is the proportion of fish of length L taken aboard. S_L is determined using a theoretical selectivity curve (Stock Annex, Figure 4.3.2) which may be described by the following formula:

$$S_L = \frac{1}{1+\exp(S_1 - S_2 L)}. \qquad (2)$$

where SL is the proportion of fish of size L taken aboard, L is the size group, S1 and S2 are coefficients.

The selectivity curve (Stock Annex, Figure 4.3.2), fitted to the data on catch measurements in different periods of the Russian fishery in 2003 is described well by Equation 2 with coefficients S1 = 12.539 and S2 = 0.4951. The estimated length–frequency distributions for 2003 are compared with the measured length–frequency distributions for this year in Stock Annex, Figure 4.3.2. The size distribution in the Russian catch in 2002 is then estimated by applying the theoretical selectivity curve to the survey length–frequency in 2002.

To determine the age composition in Russian catches in 2002, the combined age–length key for all years of Russian catches was used.

Data on the age composition of Norwegian catches and same years for other fleets are not available for most years. In 2019, a benchmark assessment was conducted on this stock. Landings age compositions were allocated to unsampled fleets using a weighted average of all sampled fleets (excluding the Russian fleet which is likely to be less applicable given they do not discard). The weighting algorithm used is 'Mean weight weighted by numbers-at-age or length.'

Discards

The haddock catch estimated by landings is underestimated as a result of unaccounted discarding of small individuals in the Scottish and Irish fisheries in most years. On Russian vessels, the whole catch of haddock is retained on board and therefore, total catch is equivalent to landings.

Haddock discards onboard Scottish vessels in 1999 and 2001 and Irish vessels in 1995, 1997, 1998, 2000 and 2001 were determined directly. In other years, indirect estimates of discarding were calculated.

The direct estimates from the Scottish trawlers in 1985, 1999 and 2001 showed a higher proportion of discards of small haddock: from 12 to 75% by weight (Table 4.3.1) and up to 80–90% of catch numbers. Discard trips in 1995, 1997, 1998, 2000 and 2001 showed that discarding by Irish fishing vessels also reaches considerable values (Table 4.3.2). Discard trips in 1995, 1997, 1998, 2000 and 2001 showed that discarding by Irish fishing vessels is variable with a mean rate of 30% (Table 4.3.2).

Discard data were also obtained by Irish scientists from discard trips in 2007–2009 and 2011. They showed that 52, 87 and 63% of the catch in numbers, respectively, was discarded. The range of discarded sizes was 19–43 cm (mean 30 cm). In 2011, the discards are significantly reduced as a result of the small number of young haddock in the population. (Table 4.3.2 of main report). It should be noted that these estimates are based on very few trips (one, two and three for 2007, 2008 and 2009 respectively) and should therefore be treated with caution.

Total numbers and weight landed and discarded by age on the Scottish observer trips in 1999 and 2001 are presented in Stock Annex, Tables 4.3.3 and 4.34.

The analysis of the discard data collected by Scottish scientists in 1999 and 2001 indicated that only a relatively small proportion of fish taken aboard is landed (Stock annex Figure 4.2.3). The probability of being retained increases with increasing fish length (Stratoudakis *et al.*, 1999; Palsson *et al.*, 2002; Palsson, 2003; Sokolov, 2003; Khlivnoy, 2004 WD6 to WGNSDS 2004; Khlivnoy, 2006)). The relationship between the number of individuals caught and number discarded may be described by the following relationship:

$$ND_L = PD_L \times NP_L \qquad (3)$$

where ND_L is the number of discarded fish with length L, NP_L is the number of fish caught at length L, PD_L is the portion of discarded fish at length L.

The length composition of fish taken onboard by Scottish and Irish trawlers was calculated by applying the logistic selectivity curve (Stock Annex, Figure 4.3.4) to the haddock stock length composition obtained from the survey. The selectivity parameters were calculated from Scottish and Irish catches taken by trawls with mesh size that are typical for the fleets of those countries operating at Rockall. The parameters were calculated as S_1 = 12.608 and S_2 = 0.4360 for the Scottish fleet. S_1 = 26.248 and S_2 = 0.8524 were used for Irish catches.

The catch-at-length compositions obtained by the theoretical curve of selectivity agree well with available results of catch measurements in 1999 and 2001and the distributions are compared in Stock Annex, Figure 4.3.5.

The proportion of fish discarded from catches at different sizes may be determined and modelled using a logistic curve (Stock Annex, Figure 4.3.6) described by the following equation:

$$PD_L = \frac{1}{1+\exp(-b(L-DL_{50}))} \qquad (4)$$

where L is size group, DL_{50} is the fish length at which 50% of this size fish caught are discarded and b is a constant reflecting the angle of curve slope. The parameters were determined from research on discards by Scottish vessels (Stock Annex, Table 4.3.5). The following values were used in subsequent calculations: DL_{50} = 34.66 cm, b = –0.8764. The logistic curve of discards may be found using Equation 2 and the coefficient values: S_1 = –15.494 and S_2 = –0.4565.

To determine abundance of discards the following procedure was used (Khlivnoy, 2004 WD6 to WGNSDS 2004; Khlivnoy, 2006):

a) A theoretical catch-at-length distribution (%) was calculated by applying the theoretical selectivity curve to the survey length composition.

b) An estimate of total catch-at-length was made by summing the reported landings-by-length to the number of discards-at-length calculated from the assumed discard ogive and the landings-at-length data.

c) An intermediate theoretical catch size distribution in numbers is calculated by dividing the estimate of the total numbers retained (numbers greater than 34 cm) in B by the fraction retained from the theoretical catch length distribution calculated in a).

d) Theoretical discard size frequency is then calculated by applying the theoretical discard ogive to the intermediate theoretical catch size distribution.

The spreadsheet containing these calculations can be found in the stock file.

Calculations where the discard curve was applied agree well with the results of size composition measurements by Scottish vessels in 1999 and 2001 (Stock Annex, Figure 4.3.7).

Aboard Irish vessels, larger fish are retained (Stock Annex, Figure 4.3.8). The portion of discards was calculated using Equation 2 with coefficients $S_1 = –10.093$ and $S_2 = –0.2459$, from the combined 1995–2002 Irish discard trips.

The Russian fleet fish in the areas covered only partially by the bottom+trawl surveys. However, Russian vessels retain all haddock and therefore there is no need to calculate discards. There is no information on large-scale fisheries of other countries outside the surveyed area. In addition, available data on the real length composition of catches indicate a correspondence between length composition obtained by the results from surveys and commercial catches, including the catches obtained in the parts of Russian fishery (Stock Annex, Figures 4.3.2 and 4.3.6).

The amount of discarded haddock by age was determined using an age–length key derived by the data collected during the trawl survey allowing for selectivity of the fishery (Stock Annex, Figure 4.3.3).

A discard ban has been in place in the NEAFC regulatory area since 2009. In 2016 BMS (Below Minimum Size) landings only 0.4 t which are subject EU landings obligation were reported and discards were estimated to be 301 t. In 2016 the level of discards has not changed significantly and was estimate at 11% and 56% by numbers on Scottish and Irish observer trips.

In 1998 and 2000, the trawl survey for haddock in the Rockall Bank area was not carried out. To determine the haddock length composition in these years, the length distribution was calculated from the survey data in the previous and following years.

For this purpose, the age–length matrices characterizing the stock status in the years before and after the missing data year were obtained. The length–age distribution from the year before the missing year was projected forward on the basis of mean growth increment at-age and estimated total mortality. Similarly the distribution from the year after was projected backwards. The length composition in the missing year was then calculated from these two estimates.

The total loss (Z) used in the calculation described above was determined by minimization of values of deviation square sum between survey age group abundance values in previous and following years by the data from surveys and calculated data. At that, the factor of age effect (S_a) was taken into account. The mean growth increment at-age was also estimated from the survey data. The method of calculation is explained further in WD8 to WGNSD 2004 (Khlivnoy, 2004)and a spreadsheet showing the calculations is in the stock file.

The discards for 2010–2017 were estimated from sampling aboard Scottish and Irish vessels collected in 2010–2017 (Table 4.3.5–4.3.8). In 2015, the discard rate was estimate at 38% and 52% by numbers on Scottish and Irish observer trips. In 2016, the level of discards has not changed significantly and was estimate at 11% and 56% by numbers on Scottish and Irish observer trips. In 2017, the discard rate was also high and was estimated at 17% by numbers on Scottish and 39% on Irish observer trips. In 2018 discard rate was estimated at 32% by numbers on Scottish and 32% on Irish fleet.

In 2019, at the benchmark workshop (the WKROCK) discards were recalculated. The data from 2012 onwards were reprocessed in InterCatch to ensure a proper raising of discards and landings. The mean discards proportion-at-age obtained for each year by results of Scottish and Irish discards trips was used for recalculations. Discard age compositions were allocated in a similar manner. For 2012 onwards, the catch-at-age data were estimated in InterCatch. The main fleets (UK(Sco) OTB_DEF_>=120 and Irish OTB_DEF_100-119) are typically sampled for both landings and discards. Discard rate allocation to other unsampled fleets consisted of:

- Manually matching annual discards to available quarterly landings by country/fleet (where necessary).
- Using a weighted average discard rate for all unsampled fleets (weighted by CATON) with the exception of the Norwegian longline fleet and the Russian fleet for which discards are both assumed to be zero.

B.2. Biological

Age composition and mean weight-at-age of Scottish and Irish landings were obtained from port sampling.

Age composition and mean weight-at-age of Russian landings were obtained by observers on board commercial fishing vessels. Observer data from commercial vessels are also available for Norwegian landings for 2006–2008.

Catch data include the landings and discards.

Historically, stock weights-at-age have been assumed to be equal to the raw catch weights. In recent years the number of sampled trips for both landings and discards has been very low. This lead to higher variability in the mean weight-at-age estimates. For this reason, recent years the smoothed catch weights-at-age was applied by the WGCSE To mitigate against variability in the mean weight-at-age since 2019 mean weights in the stock are assumed as five-year means taking into account the recommendations of benchmark 2019.

Natural mortality coefficient and portion of mature individuals by age used for estimation correspond to those adopted by Working Group before.

Previous Working Groups have adopted a maturity ogive with knife-edge maturity-at-age 3 in assessments of this stock (see the Table below).

Age	1	2	3	4	5	6	7+
Proportion mature	0	0	1	1	1	1	1

ACFM in 2001 encouraged the WG to investigate a more realistic maturity ogive for this stock. At the 2002 Working Group combined sex maturity ogives were presented to the WG for Russian sampling in 2000–2001 and Scottish sampling in 2002. In 2003 new sex disaggregated maturity data were supplied to the Working Group for Russian sampling. The results of all these recent studies indicate that a high proportion of both females and males at-age 2 were mature.

The data from new Russian histological examination of haddock gonad samples mass sexual maturation occurs at age of two years with length of 25 cm (WGNSDS WD6 2006, Finina Khlivnoy Vinnichenko 2009,). These data agree well with the results of recent Scottish research in compliance with which the majority of fish become mature at the age of two years (ICES 2003; Newton *et al.*, 2004). Visual estimation of maturity stage of post-spawning haddock on the Rockall Bank in expeditions leads to considerable errors. For more precise estimation of length and age-at-maturity for haddock it is necessary to conduct investigations in pre-spawning and spawning periods as well as to collect gonads for further histological analysis (see WGNSDS WD6 2006 for further details).

Research on determining more precise values for natural mortality and maturity ogive parameters should be continued and new estimates could be used in future stock assessments.

In the absence of any direct estimates of natural mortality, M has been set at 0.2 for all ages and years.

B.3. Surveys

There is only one research survey index available for VPA assessment of this stock from the Scottish survey conducted annually in September (Figure 4.3.1, Table 4.2.3 of main report). However, from 1997 onwards the Scottish survey was only conducted in alternate years. Due to concerns about the haddock stock at Rockall some extra time was allocated to carry out a partial survey in September 2002. Full surveys have been conducted since 2005 to improve the quality of assessment. The Scottish survey is currently conducted on about 40 (the target number for a survey) standard trawl stations. However, the survey area and number of stations varied in different years. The majority of stations are within the 200 m depth contour. In 2002, the survey was expand to northern parts of the bank. In 1999, the survey switched from using an Aberdeen 48′ bottom trawl to a GOV trawl and from 60 min tows to 30 min tows. The indices have been adjusted for tow duration, but no calibration has been made for gear changes. A 20 mm mesh size is used on the survey. In 2011, the gear was changed on the Scottish survey and an analysis showed that there was no detectable difference between the older and new survey on haddock indices in neighbouring areas (IBTSWG 2012).

The area which was covered by the survey was not stable and moreover the survey coverage has been extended in recent years. To mitigate against this, indices were obtained from the standard survey area that was covered by surveys for the whole research period.

In spring 2005, the Russian trawl-acoustic survey (TAS) for haddock on the Rockall Bank was conducted for the first time (Oganin *et al.*, 2005). The survey covered whole area of haddock stock distribution. However, no such survey has been carried out in subsequent years. In the 2005 survey, the trawl survey method estimated the total stock number at 190.63 million individuals and its biomass at 43 400 t (see the Table below). The acoustic survey yielded a haddock biomass estimate of 60 000 t with the abundance of 225.9 million (see the WGNSDS 2006 Report for more details of the trawl-acoustic survey). The estimates of haddock abundance and biomass from the two methods are quite similar. The results of the Russian trawl-acoustic survey are summarised in the Table below:

			Total stock		Spawning stock	
Survey type	Area component	Area (sq. miles)	Abundance (106)	Biomass (103 t)	Abundance (106)	Biomass (103 t)
Trawl survey	Whole	5554	190.6	43.4		
Acoustic survey	International waters	3374	144.2	41.1	133.0	38.5
	EU zone	2180	81.7	18.9	52.4	16.3
	Whole	5554	225.9*	60.0*	185.4	54.8

*** Pelagic component estimated to make up 13.7%.**

The Irish Fisheries Board (BIM) and the Marine Institute recently conducted a collaborative series of surveys to assess the length structure of haddock at various locations on the Rockall Bank and tested the selectivity of a number of codend configurations, which are typically used by both the Irish and Russian fleets.

B.4. Commercial cpue

Commercial cpue series are available for Scottish trawlers, light trawlers, seiners, Irish otter trawlers and Russian trawlers fishing in 6b. The effort data for these five fleets are shown in Figure 4.3.6 and Table 4.3.2 of main report. Commercial cpue series for the different fleets are shown in Figure 4.3.7 of main report.

In 2005–2007, the Russian effort in bottom fishery (in hours and number of vessels/days) decreased due to economic reasons. The effort in 2008 increased slightly compared to 2007. Haddock catches varied accordingly with the changes in fishing effort. In 2006–2007, fishing efficiency in the Russian haddock fishery (mainly with trawlers of tonnage class 10) increased compared to previous years. In 2008, with trawlers of class 8 and 9 only, it was still high (on average, 12.2 t per fishing day for trawlers of class 9), but lower than the efficiency in 2007 (on average, 16.9 t per fishing day for a trawler of class 10). In the period of the targeted fishery (April–May), the mean catch of haddock per hour trawling by a trawler of tonnage class 9 was 0.86 t (in 2007, it was 0.88 t for a trawler of class 10) (Figure 4.3.7 of main report). The dynamics of catch per unit of effort for this type of vessels agrees well with year-to-year variations in total biomass of haddock (Figure 4.3.8 of main report).

The effort data from the Scottish fleets are known to be unreliable due to changes in the practices of effort recording and non-mandatory effort reporting (see the Report of WGNSSK 2000, CM 2001/ACFM:07, for further details). It is unknown what proportion of Scottish and Irish effort was applied directly to the haddock fishery. The apparent effort increase may just be the result of more exact reporting of effort due to VMS, but another suggestion is that it arises from a 'days at sea' measure. Working at Rockall keeps 'days at sea' elsewhere intact (the years in question do correspond to the introduction of the days at sea legislation) and it is possible that vessels are either working extra days in 6b or they are simply reporting extra days from 6b. It is difficult to conclude which of these scenarios is more likely.

The Irish otter trawl effort-series indicated low values between 2002 and 2005 with the lowest value in 2004. In 2006–2008, the effort increased considerably.

The WG decided that the commercial cpue data, which do not include discards and have not been corrected for changes in fishing power despite known changes in vessel size, engine power, fish-finding technology and net design, were unsuitable for catch-at-age tuning.

B.5. Other relevant data

C. Historical stock development

Model used:

The assessment is based on catch-at-age data and one survey index (Scottish Groundfish Survey) and conducted using the XSA method.

Software used:

XSA from Lowestoft suite of VPA programs. Since 2019 FLXSA programs

Model Options chosen:

Settings for the final XSA assessment in the recent years are shown in the Table below.

Assessment year	2005*	2006*	2007*	2008–2018*	2019**
Assessment model	XSA	XSA	XSA	XSA	XSA
Time series weights	none	none	none	none	none
Model	power	power	power	power	power
Catchability dependent for ages <	4	4	4	4	4
Regression type	C	C	C	C	C
Q plateau	5	5	5	5	5
Shk se	1.0	1.0	1.0	1.0	1.0
Shk age-yr	4 yrs 3 ages	4 yrs 3 ages	4 yrs 3 ages	4 yrs 3 ages	4 yrs 3 ages
Min se	0.3	0.3	0.3	0.3	0.3
Plus group	7	7	7	7	7
Fbar	2–5	2–5	2–5	2–5	2–5

*** Lowestoft VPA model**

**** FLXSA model**

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	1991–2018	1–7+	Yes
Canum	Catch-at-age in numbers	1991–2018	1–7+	Yes
Weca	Weight-at-age in the commercial catch	1991–2018	1–7+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1991–2018	1–7+	Yes
Mprop	Proportion of natural mortality before spawning	1991–2018	1–7+	No, set to 0 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1991–2018	1–7+	No, set to 0 for all ages in all years
Matprop	Proportion mature-at-age	1991–2018	1–7+	No, the same ogive for all years
Natmor	Natural mortality	1991–2018	1–7+	No, set to 0.2 for all ages in all years

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	SCOGFS	1991–2018	1–6

D. Short-term projection

Model used: Age-structured

Software used: MFDP prediction with management option table and yield-per-recruit routines. MLA used for probability profiles and sensitivity analysis.

Initial stock size: Taken from XSA for age 1 and older.

Natural mortality: Set to 0.2 for all ages in all years.

Maturity: The same ogive as in the assessment is used for all years.

F and M before spawning: Set to 0 for all ages in all years.

Weight-at-age in the stock: Three-year means.

Weight-at-age in the catch: five-year averages were used in the catch options.

Exploitation pattern: Average of the three last years. Landings F are varied in the management option table.

Intermediate year assumptions: Catch constraint consisting of UK and Ireland quota and expected Russian catch.

Stock–recruitment model used: The RCT3 model estimate is used for the intermediate year estimate of age 1 recruitment.

For forecasting recruitment (age 1) in the subsequent two years, the 25th percentile over the whole time-series is used. The simple rounding of the result to the nearest integer and taking the value that corresponded to that rank of percentile. The rank of percentile was determined by the following equation:

$$n = \frac{P}{100} * N + \frac{1}{2}$$

P being the percentile value (here P=25), and N the length of the time-series

Procedures used for splitting projected catches: F vectors in each of the last three years of the assessment are multiplied by the proportion landed at-age to give partial F for landings. The vectors of partial F are then averaged over the last three years to give the forecast values. The average discard proportion-at-age from the most recent ten years is used to split total catch into wanted and unwanted catch.

E. Medium–term projections

Model used: Age-structured.

Software used: MLA used for Medium-term projections.

Initial stock size: Taken from the XSA for age 1 and older. The recruitment-at-age 1 in year of assessment is estimated using RCT3. For forecasting recruitment for following years a geometric mean was used.

Natural mortality: Set to 0.2 for all ages in all years.

Maturity: The same ogive as in the assessment is used for all years.

F and M before spawning: Set to 0 for all ages in all years.

Weight-at-age in the stock: Three-year means (mean weights in the stock are assumed to be the same as catch weights, see below).

Weight-at-age in the catch: Three-year means.

Exploitation pattern: Average of the three last years.

Intermediate year assumptions:

Stock–recruitment model used: RCT3 model used for intermediate year +1 in 2009.

Uncertainty models used:

1) Initial stock size:
2) Natural mortality:
3) Maturity:
4) F and M before spawning:
5) Weight-at-age in the stock:
6) Weight-at-age in the catch:
7) Exploitation pattern:

8) Intermediate year assumptions:

9) Stock–recruitment model used:

F. Yield and biomass-per-recruit/long-term projections

Model used: Yield and biomass-per-recruit over a range of F values.

Software used: MLA and "st graf".

Maturity: Fixed maturity ogive as used in the assessment.

F and M before spawning: Set to 0 for all ages in all years.

Weight-at-age in the stock: Three-year means (mean weights in the stock are assumed to be the same as catch weights, see below).

Weight-at-age in the catch: Three-year means.

G. Biological reference points

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY Btrigger	3712 tonnes	Bpa	ICES (2019)
	FMSY	0.168	Segmented regression with Bloss, the lowest observed spawning–stock biomass (EqSim).	ICES (2019)
Precautionary approach	Blim	2474 tonnes	Blim = Bloss, the lowest observed spawning–stock estimated in previous assessments.	ICES (2019)
	Bpa	3712 tonnes	Bpa = Blim × 1.4. This is considered to be the minimum SSB required to obtain a high probability (95%) of maintaining SSB above Blim	ICES (2019)
	Flim	1.06	Based on a 50% probability of being above Blim in a stochastic simulation with a segmented regression using breakpoint at Blim.	ICES (2019)
	Fpa	0.710	Fpa = Flim/1.5	ICES (2019)
Management plan	SSBmgt	3712 tonnes	Bpa	ICES (2019)
	Fmgt	0.168	Based on harvest control rule evaluations.	ICES (2019)
Management plan*	MAP MSY Btrigger	3712 tonnes	MSY Btrigger	
	MAP Blim	2474 tonnes	Blim	
	MAP FMSY	0.168	FMSY	
	MAP range Flower	0.105	Consistent with ranges provided by ICES (2016a), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2019)
	MAP range Fupper	0.27	Consistent with ranges provided by ICES (2016a), resulting in no more than 5% reduction in long-term yield compared with MSY.	ICES (2019)

H. Other issues

None.

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Table 4.3.1. Details of Scottish discard trips in the Rockall area (Newton *et al.*, 2003).

Trip no.	Date	Gear	No. of hauls	Hours fished	% (by weight) haddock landed of catch	% (by weight) discarded of haddock
1	May 85	Heavy Trawl	20	89.08	74	17.3
2	Jun 85	Heavy Trawl	28	127.17	74	18.6
3	Jun 99	Heavy Trawl	21	110.83	41	74.9
4	Apr 01	Heavy Trawl	11	47.33	96	12.4
5	Jun 01	Heavy Trawl	35	163.58	58	47.5
6	Aug 01	Heavy Trawl	26	130.08	31	69.7

Table 4.3.2. Landings and Discards haddock estimates at Rockall from discard observer trips conducted aboard Irish vessels between 1995 and 2001, and from an observer trip aboard the MFV (February–March 2000). (ICES CM 2004/ACFM:33).

	FAT/ KBG/ 00/4	FAT/ KBG/ 01/12	FAT/ KBG/ 95/1	FAT/ KBG/ 95/2	FAT/ KBG/ 97/7	FAT/ KBG/ 97/8	FAT/ KBG/ 98/4	February 2000	Discard rate
Landing	3021	942	12727	6893	14258	25866	23805	4400	
Discards	1864	926	1146	1893	6625	17926	3687	6200	
% discarded	38.16	49.57	8.26	21.54	31.72	40.90	13.40	58.49	27%

Table 4.3.3. Scottish landings and raised discards of haddock in 1999 estimates at Rockall from discard observer trips conducted on Scottish vessels.

	Age													
	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Landing, N (*1000)	0	0	436.9	1211.9	1069.5	849.4	1220.6	1432.3	411.9	87.7	0.4	0	1.4	6722
Landing, tonnes	0	0	135.8	432.5	420.7	383.9	646	760.7	245.5	49.6	0.5	0	4.3	3079.5
Discards, N (*1000)[1]	22.4	14420.8	15276.9	6844.7	2534.8	1516	734.3	219.4	39.6	0	0	0	0	41609.1
Discards, tonnes[1]	1.5	2284.1	3658.2	1936.2	799.1	515.4	248.8	86.2	17.6	0	0	0	0	9547.2
Discards, N (*1000)[2]	12.5	13306.1	15895.9	7168.1	2588.9	1555.7	772.5	247.9	48.6	12.2	0.7	0	0	41609.2
Discards, tonnes[2]	0.3	2241.2	3791.3	2035.1	821.7	538.7	268	103.8	22.7	6.3	0.5	0	0	9829.6

[1] raised estimates from discard observer trips at Rockall.

[2] estimates obtained from a logistic discard curve for 1999.

Table 4.3.4. Scottish landings and raised discards of haddock in 2001 estimates at Rockall from discard observer trips conducted aboard Scottish commercial vessels.

	Age													
	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Landing, N (*1000)	0	0	326.5	489.1	132.9	774.3	326	223.9	113.5	22.4	3.8	0	0	2412.3
Landing, tonnes	0	0	128.6	157	82.4	262.4	125.2	90.2	59.3	19.9	3	0	0	928
Discards, N (*1000)[1]	3.1	6309.9	549.7	228.4	66.3	8.1	1	0.1	0.1	0.1	0	0	0	7166.8
Discards, tonnes[1]	0.2	967.4	126.8	58.7	17.8	2.4	0.3	0.1	0	0	0	0	0	1173.8
Discards, N (*1000)[2]	531	5987.3	436.2	162.6	46.9	2.9	0.5	0.1	0	0	0	0	0	7167.6
Discards, tonnes[2]	14.3	936.2	93	38.6	11.6	0.9	0.2	0.1	0	0	0	0	0	1094.9

[1] raised estimates from discard observer trips at Rockall.

[2] estimates from a logistic discard curve for 2001.

Table 4.3.5. Values of DL_{50} by Scottish discard trips in the Rockall area.

Year	DL50	b
1999	36.62	–0.5923
2001	31.20	–0.8238
Theoretical:	34.66	–1.2328

Table 4.3.6 Discards and retained catches of haddock (number per trip) by Irish discard trips in the Rockall area from 2007–2009 and 2011–2012.

Year	2007		2008		2009		2011		2012	
Length (cm)	Discards	Retained Catch	Discards	Retained Catch	Discards	Retained Catch	Discards	Retained Catch	Discards	Retained Catch
10									1	
11									1	
12									1	
13									1	
14										
15										
16										
17										
18										
19	1.3									
20										
21										
22	1.6		14.8							
23	4.6		66.2				13.1			
24	7.3		183.8				98.9	5.7		
25	22.7		576.9		15.6		53.9	5.7		
26	54.2		1424.9		30.4		75.3	11.4		
27	104.6		3024.6		25.2		121.3	34.3	2	
28	256.9		6274.7		228.2		96.4	108.5		
29	386.5	7.9	7193.3		180.6		33.6	62.8		
30	533.4	17.6	7813.5	13.9	573.2	9.9	73.9	5.7	3	2
31	462.6	47.2	7573.7	40.6	1338.1	9.9	28.6	17.1	6	3
32	298.8	88.3	4639.0	77.8	1762.8	57.8	46.9	125.3	7	4
33	227.3	99.4	3664.7	126.8	2256.5	235.9	20.7	92.4	9	5
34	120.8	139.2	2391.8	277.4	1496.5	397.3	16.0	196.8	7	7
35	78.3	118.8	1590.1	503.6	656.6	614.8	4.8	118.6	6	8
36	27.4	187.0	871.7	580.5	423.5	567.1	0.3	340.4	2	6
37	26.1	139.8	280.3	640.9	66.9	526.8	0.0	235.8	1	11
38	24.3	142.7	78.3	581.9	57.4	421.4	0.0	632.2		8
39	3.4	162.5	206.6	443.0	23.1	346.9	4.8	312.7		11
40	8.7	119.4	37.5	535.6		281.4		158.9		9
41	1.3	133.8	5.2	310.7		197.9		203.4		12
42	4.6	133.1	5.2	334.7		155.7		348.1		13
43	3.2	109.3		333.5		195.1		225.4		11
44		118.6		291.1		201.7		305.4		13
45		97.9		253.6		149.9		226.0		10
>45 cm		574.5	0.0	1791.2	0.0	1001.7		2490.8	1	144
Total	2659.9	2436.9	47916.8	7136.8	9134.4	5371.3	688.6	6263.7	48.0	277.0
Discard rate, %	52.2		87.0		63.0		10.0		14.8	

Table 4.3.7. Length composition of Irish discards and landings of haddock (number) by results of Irish discard trips in the Rockall area in 2014-2015.

YEAR	2014		2015	
Length (cm)	Discards	Landings	Discards	Landings
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20	508.86			
21	1249.21		68.03	
22	3757.56		136.45	
23	9882.93		548.57	
24	17742.15		2466.15	
25	26690.88		5489.88	
26	29456.22	206.22	8664.85	
27	27737.04	1787.22	17011.27	
28	28506.24	4605.52	23581.32	
29	23556.01	5224.18	28730.09	
30	22791.88	4261.83	33689.11	274.85
31	25734.19	4330.57	32838.74	742.11
32	25404.86	3436.96	33210.44	1044.45
33	17211.02	4880.48	25934.47	2308.78
34	8877.72	6392.74	17534.75	2666.09
35	4733.26	7217.61	7589.53	8300.60
36	2034.38	6324.00	4142.17	9702.36
37	918.99	5774.09	854.19	16628.69
38	77.02	4674.26	110.53	10636.86
39	153.20	3780.65	88.60	13495.35
40	0.00	4949.22		14787.16
41	39.00	4949.22		12808.21
42	51.67	7011.39		17425.77
43	12.67	4743.00		14732.19
44	12.67	4055.61		11488.91
45	25.34	2680.83		11186.57
>45 cm	290.53	30520.19		77254.68
Total	277455.52	121805.80	242689.10	225483.63
Discard rate, %	69.5		51.8	

Table 4.3.8. Discards and retained catches of haddock (number per trip) by Scottish discard trips in the Rockall area in 2009 and 2011–2015.

Length (cm)	2009		2011		2012		2013*		2014*		2015*	
	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings
9					1.0							
10					3.0							
11					5.2							
12					66.5							
13					233.3							
14					313.0							
15					842.8							
16					516.7		226		1493			
17					247.3		0		7817		138	
18					341.7		0		22709		957	
19					81.5		135		39126		4591	
20					4.7		39		37513		9278	
21							357		25979		15194	
22							1322		8774		16591	
23					4.0		2201		14104		19529	
24					23.0		3665		28818		42079	
25					18.9		6643		64709		122065	
26			3.8		36.4		6714		118616		206928	
27			3.8		15.9		6424		164637		254254	
28	24.2		17.4		22.6		5018		142534		305155	
29	14.7		78.6		53.4		3599		121740	1422	342216	
30			53.0		77.9	37.3	2326		78972	7965	330023	10543
31	5.3	26.4	17.4		126.6	76.1	1286	894	58592	25316	178402	31628
32	12.0		35.2	317.1	119.9	161.9	1181	2682	31670	30389	94018	84630
33	20.1	47.1	28.0	463.7	160.4	464.8	643	6454	13957	33340	23867	195299
34		201.7		637.4	71.0	1093.8	208	18902	10246	52890	9191	271402
35		220.2	139.8	1171.2	25.6	1366.4	101	23579	3404	47790		328955
36		269.0	139.8	1709.7	42.0	1872.7	39	34036		60976		241848
37		296.5		1668.7	10.1	2164.3		35748		57701		277221
38		353.1	139.8	2032.6	17.5	1917.5		33986		57472		197661
39		193.2		1927.7		2393.7	39	27892		61971		256136
40		237.9	139.8	1233.5		2091.6		36058		45808		188271
41		131.7		1020.3	1.5	1876.3		23821		42575		189250
42		107.9		959.1		1247.9		18935		50824		123229
43		181.9		641.2	118.0	1416.8		23001		48330		150363
44		96.8	139.8	406.0	118.0	1288.2		20654		48019		108077
45		72.1		233.1		1326.8		22804		40359		75009
46		82.4	139.8	138.1	2.1	1252.9		22272		34162		78581
47		46.8		122.2	193.5	1023.0		22565		36909		39233
48		47.0	139.8	55.9		833.8		17565		33530		43136
49		33.3	1.0	49.9	194.5	711.7		18802		29220		48753
50		19.3		36.2	1.0	651.6		17499		28263		42833
51		8.9		37.5		410.3		12020		22682		50870
52		4.8		14.7		315.2		14866		23089		72142
53		5.1		20.5		206.1		12313		27292		40558
54		3.2		8.4		210.4		18722		34873		9895
55		2.3		5.4		98.8	26	11861		23816		34552
56		4.6		3.4		203.3		19573		18753		12660
57		2.7		1.6		408.4		14254		17896		9895
58		1.9		3.1		404.8		8962		16511		9506
59		1.7		9.1		87.8		6702		21930		7518
60		1.2				189.9		9813		20822		2765

Length (cm)	2009		2011		2012		2013*		2014*		2015*	
	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings	Discards	Landings
61		1.7		2.7		190.7		5851		12248		
62		1.1		1.3		213.7		6436		20519		5531
63		0.5		2.4		210.2		4016		9150		
64		1.3				97.7		6675		7792		1166
65				1.1		45.1		5212		9321		
66				1.1		105.2		2314		13225		
67						45.0		3830		14393		
68				1.0		24.3		1649		9712		3154
69						63.1		1649		3359		
70				0.9		58.0		1915		4556		
71						47.9		665		2406		
72						42.2		1782		190		
73						20.1		1117		1102		2765
74						20.6		133		2181		
76						5.7						
77						8.6				71		
78				0.7		4.1				759		
82				0.6								
Total	76.3	2705.3	1216.8	14939.0	4110.5	29006.3	42218	600479	995410	1214092	1974476	3245035
Discard rate, %	2.7		7.5		12.4		6.6		45.0		37.8	

***Retained discards and landings**

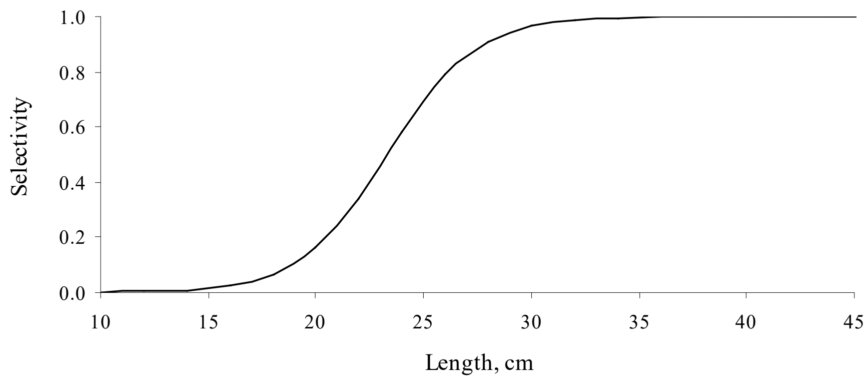

Figure 4.3.1. Theoretical haddock selectivity curve used to estimate the proportion of haddock lifted onboard Russian trawlers.

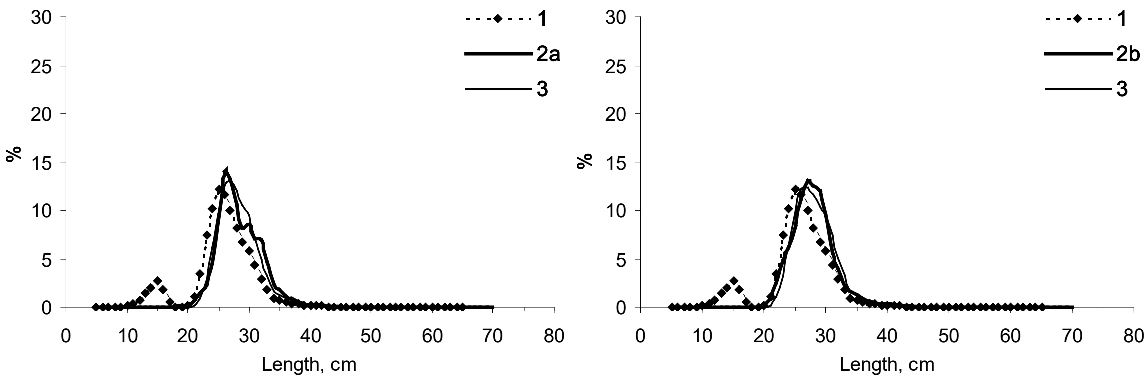

Figure 4.3.2. Length distribution of haddock in 2003: 1 – by Scottish groundfish survey, 2a – by commercial Russian trawlers in June, 2b – by commercial Russian trawlers in July, 3 – theoretically-derived.

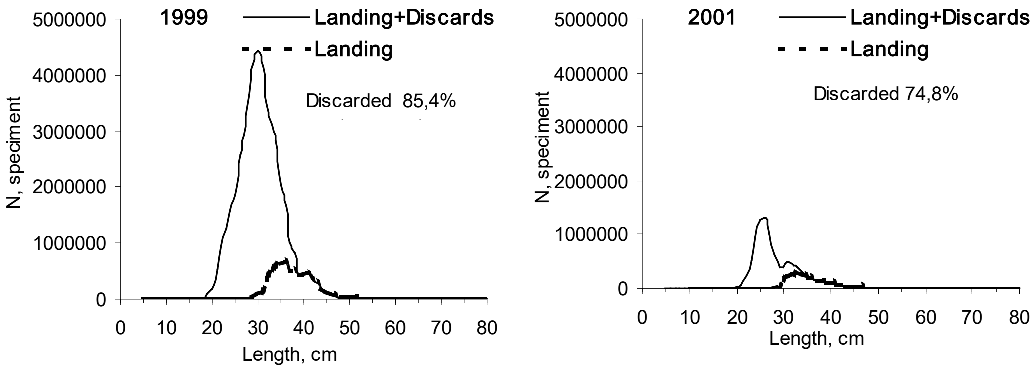

Figure 4.3.3. Length distribution and quantity of haddock lifted onboard and landings by Scottish trawlers in 1999 and 2001 (unpublished data, Newton, 2004).

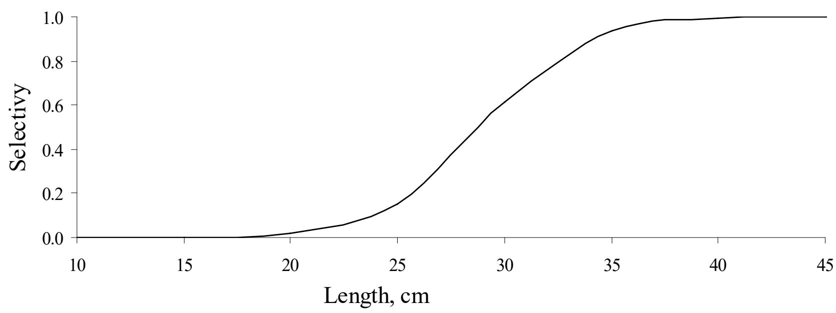

Figure 4.3.4. Theoretical haddock selectivity curve used to estimate the proportion of haddock lifted onboard Scottish trawlers.

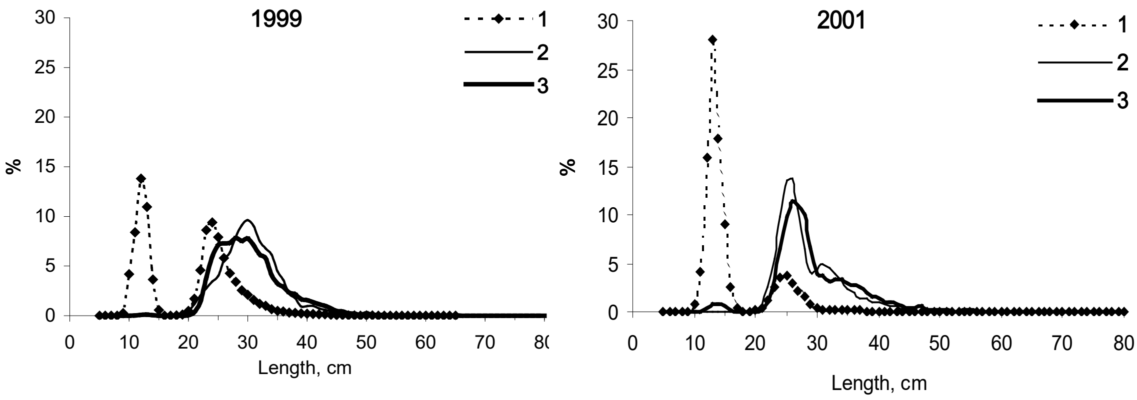

Figure 4.3.5. Length distribution of haddock in 1999 and 2001: 1 – by Scottish groundfish survey, 2 – by commercial Scottish trawlers, 3 – theoretically-derived.

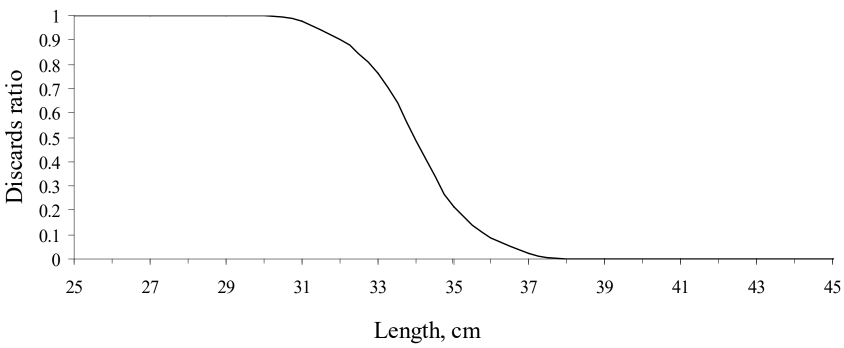

Figure 4.3.6. Selectivity curve used to estimate the proportion of discarded haddock in catches Scottish trawlers.

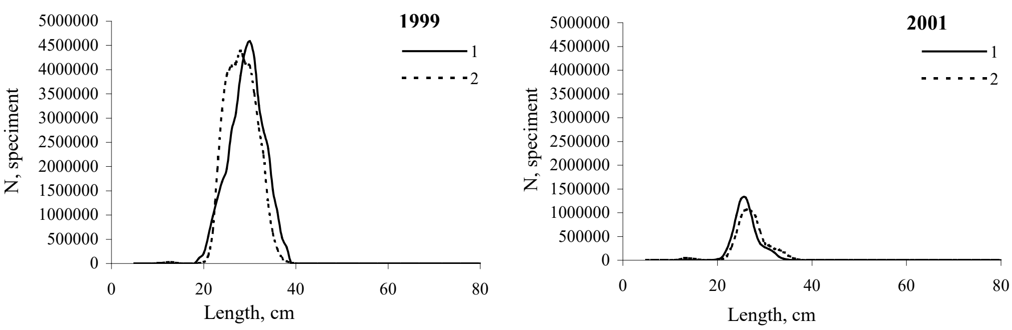

Figure 4.3.7. Length distribution of discarded haddock in catches Scottish trawlers in 1999 and 2001: 1 – research data; 2 – theoretically-derived.

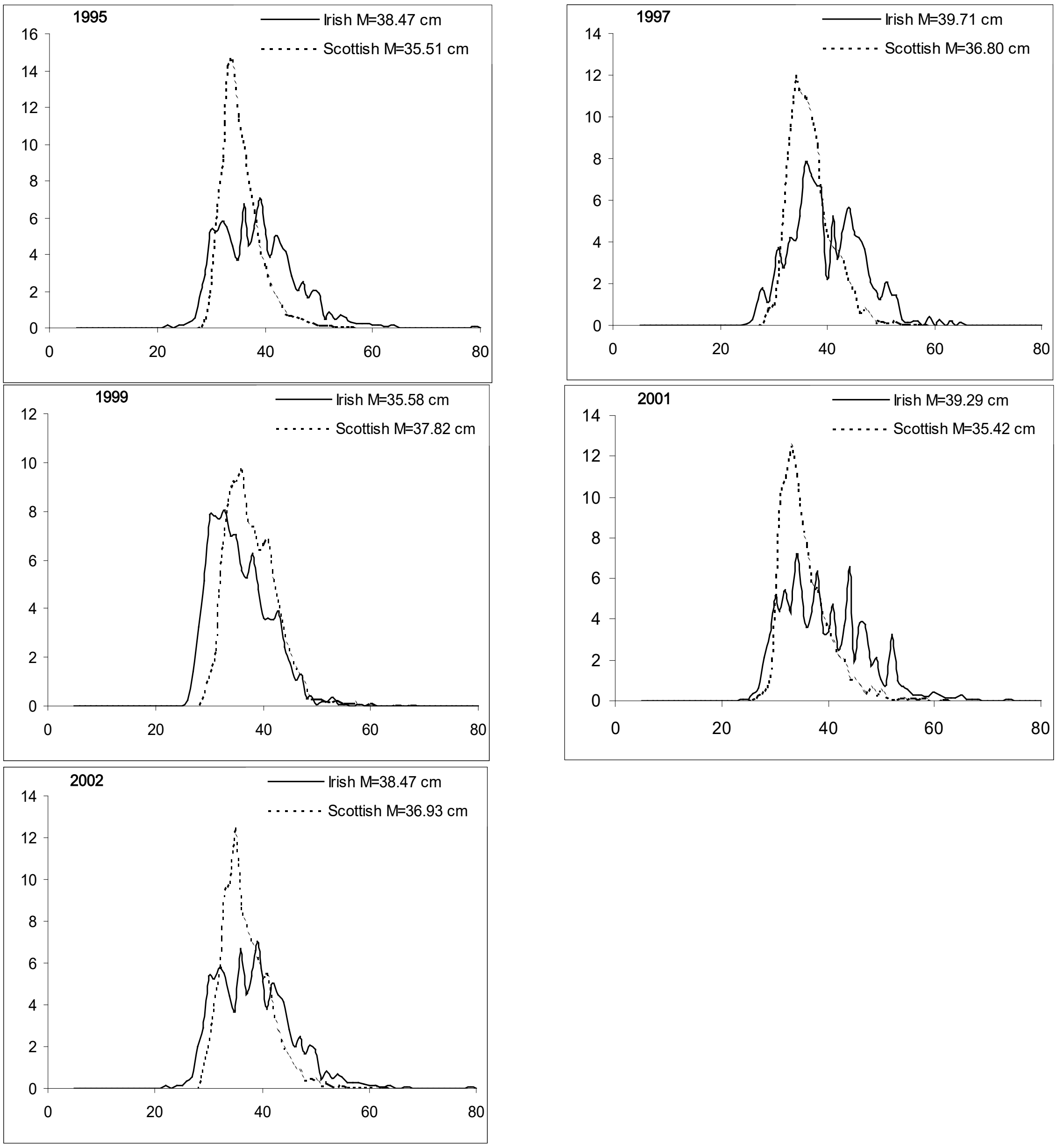

Figure 4.3.8. Length distribution of haddock landings in 6b (Scottish and Irish data).