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Estimating abundance and biomass of North Sea cod based on surveys with commercial fishing vessels

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Abstract

A collaborative fishermen-biologists project on cod in the north-eastern central North Sea was started by the National Institute of Aquatic Resources at the Technical University of Denmark and the Danish Fishermen Association in summer 2006. Three commercial vessels representing different fishing methods participated in the study. The surveys with these vessels, which allowed fishing also on rough bottom and at ship wrecks, provided information on the distribution, abundance and size composition of North Sea cod in respect to bottom type, and for comparison with results from the International Bottom Trawl Survey (IBTS). In general, catch rates were higher on rough bottom than on smooth bottom, and considerable catches were made in areas where the IBTS reported low densities or no cod at all. This was in particular pronounced for cod of older ages. Scaling the commercial catch rates based on the ratio of IBTS indices for the study area to the entire North Sea suggests that spawning stock biomass and abundance of older cod may have increased faster in the past years than the present assessment indicates.

Keywords: cod; North Sea; fishery-science collaboration; effect of bottom type on CPUE; catchability at age

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Introduction

Commercial CPUE series are not included in the tuning procedure of the assessment for North Sea cod and the tuning solely depends on indices from the International Bottom Trawl Survey (IBTS) conducted in the 1st and the 3rd quarter of the year. Fishermen, however, do not consider the IBTS as representative for the stock status as the commercial fishery maintained viable catch rates also in areas where the IBTS reported no or low densities of cod above minimum landings size. The fishermen complained that the IBTS does not cover rough bottom where highest commercial CPUE of cod is usually obtained and have thus a less pessimistic perception of the status of the stock than reflected in the current ICES advice. Against this background, a collaborative biologist-fishermen project on spatially-explicit management methods for North Sea cod (REX) was initiated by DTU-Aqua (National Institute of Aquatic Resources at the Technical University of Denmark) and the Danish Fishermen Association in summer 2006 (Pedersen et al. 2009). Three commercial vessels representing different fishing methods participated in the study. These were a trawler, a flyshooter and a gillnetter, and the initial survey area consisted of 7 ICES statistical rectangles in the north-eastern central North Sea (Fig. 1). The main objective of the surveys has been to provide new information on distribution, density and size composition of North Sea cod in particular in respect to bottom type and for comparison with the IBTS.

Material and Methods

Survey strategy

During the first two surveys in June and August 2006 the fishermen were almost free to select the fishing positions. This resulted in a few clusters of stations accumulating in the favourite areas of the fishermen with most of the stations mainly located on rough bottom which is usually not covered by scientific bottom trawl surveys. In order to allow an unbiased investigation of a potential effect of bottom type, the fishermen were requested to select paired stations within 10 * 10 nmi squares with one station on sand bottom and the other on other bottom types (gravel and stone bottom as well as ship wrecks in the case of the gillnetter) during the next two surveys in January/February and June 2007. In order to obtain an even better impression on the spatial distribution in a wider area, a higher degree of randomisation in the survey design was used in surveys conducted in August 2007 and thereafter. Here, the survey area was divided into 5 * 5 nmi squares of which a certain number was randomly selected, with fishing position within each square

chosen by the fishermen but requiring at least 25 % of the stations on sand bottom, and where the number of squares to be covered in an ICES rectangle differed between the vessels to account for differences their fishing method (Tab. 1).

Vessel and fishing gear specifications

The flyshooter L-426 used ropes of 3100 m length and a diameter of 50 mm. Duration of the operation from setting the buoy to the recovery of the net was approximately 2 hours of which fishing time amounted usually to 1 hour. According to the length of the ropes each set covered an area of about 1 nmi² at each set. Hence, catch per tow can directly be considered as a measure of catch per unit effort (CPUE). All fishing operations were conducted during daylight because catch rates depend critically on visibility for this fishing method. Three different nets were used during survey 1 to 3. These were a flatfish net, a roundfish net with medium-sized rubberdisks (diameter: 10" (25.4 cm) in the middle section and 8" (20.3 cm) in the wings) in the groundrope and a roundfish net with 2" larger rubberdisks. The flatfish net was used on sand bottom, the roundfish net equipped with the large rubberdisks on rough ground and the roundfish net with medium-sized rubberdisk on all bottom types. In the later surveys, all fishing was conducted with the medium-sized rubberdisk roundfish net. This net has an overall length of 91 m. The length of the ground rope is 36.2 m, which gives a wingspread of 8 to 10 m during normal fishing operation, and the maximum vertical opening is about 7 to 8 m. The mesh size in the codend has been 100 mm in all of the three nets.

The trawler L-757 fished with two trawls of the same type simultaneously with a roller clump between them (double trawl fishing). If valid, the catches of the two trawls were added or the catch of the one trawl was multiplied by two if one trawl was damaged. Stations with damages of both trawls were rejected as invalid. Towing time varied from 0.5 to 3.75 hours but was between 1 and 2 hours in most cases, and total catch by station was transformed to CPUE (in kg/hr) accordingly. Towing speed was usually about 3 knots, and trawling was conducted from early morning to late evening but not during the night. Trawl doors were Thyborøn type 4 96" (4.84 m², 900 kg) on the first three surveys and Thyborøn type 11 92" (4.33 m², 900 kg) on the two later surveys. The weight of the roller clump between the two trawls was 1000 kg in both cases. Total doorspread was monitored with a Simrad ITI system. Two combitrawls for flat- and roundfish were used during survey 1 to 3 and a part of survey 4. These trawls had a total length of 63.8 m and were equipped with small rubberdisks (6 and 8" at wing section, 10" in the middle section; total groundrope length:

57.7 m, with 3 chains of subsequent shorter length in front). Vertical opening was about 3 – 3.5 m at normal operation. The combitrawls performed well on sand and on gravel while problems occurred on stone bottom. Hence, the combitrawls were replaced by rockhopper roundfish trawls in the later part of survey 4 and during survey 5 in order to allow fishing also on rougher bottom. The rockhopper trawls had an overall length of 65.0 m and the groundrope consisted of 10" and 12" rubberdisks in the wing and the central section, respectively. The total groundrope length amounted to 34.9 m, and vertical opening was usually about 6 – 6.5 m. Depending on water depth, door spread ranged from 195 to 240 m for the combitrawl stations and from 170 to 200 m at the rockhopper trawl stations. The meshsize in the codend of the combitrawl was 100 mm and has been 105 mm in the codend of the rockhopper trawl.

The gillnetter L-353 used set of nets with a combination of three different meshsizes. In general, 18 nets were used on each station (6 * 65 mm + 6 * 75 mm + 6 * 85 mm half-mesh), but in some cases when fishing at isolated structures such as ship wrecks or on top of small stone reefs a lower number of nets of each mesh size were used. Soaking time of the nets varied between 6 and 27 hours and was about 14 hours on average with no systematic difference in respect of bottom type. CPUE at a station was calculated as catch per net and hour of fishing.

Age length keys

Age length keys for single years and quarters from the IBTS were very erratic for larger sizes of cod. Hence, age length data from the IBTS were combined with age readings from the Danish commercial fishery in the central and north-eastern North Sea including the Skagerrak. The resulting age length data had still some gaps and continuation-ratio logits following the approach described by Rindorf and Lewy (2001) and Rindorf et al. (2008) were used to obtain smoothed age length keys (Figs. 2a-c). These age length keys were then applied to length frequencies from the REX study area for both the commercial vessels and the IBTS.

Estimation of abundance at age for the REX study area

To increase the number of rectangles sampled in order to compare with results from the IBTS, trawler catch rates were converted to flyshooter values. Average catch rates by ICES rectangle from three surveys conducted with the 'restricted-random' design were available for this purpose, which yielded significant correlations for all age groups considered in this study (Fig. 3). The following age dependent conversion equations were applied:

Age 2: $CPUE_{Trawler\ converted} = 15.608 + 3.597 * CPUE_{Trawler\ original}$

Age 3: $CPUE_{Trawler\ converted} = 49.333 + 4.130 * CPUE_{Trawler\ original}$

Age 4: $CPUE_{Trawler\ converted} = -7.185 + 8.224 * CPUE_{Trawler\ original}$

Age 5: $CPUE_{Trawler\ converted} = -2.853 + 9.484 * CPUE_{Trawler\ original}$

Age 6+: $CPUE_{Trawler\ converted} = -1.145 + 8.081 * CPUE_{Trawler\ original}$.

A corresponding conversion of gillnetter catches was not attempted because it would not have resulted in an increase of number of rectangles covered by the REX surveys.

Average CPUE in numbers at age for the surveyed area were calculated using the number of stations per rectangle as weighting factors to account for differences in sampling effort. The mean densities at age were then multiplied with a catchability coefficient, which was determined from a series of depletion experiments with the flyshooter (Olesen et al. 2009), and with the surveyed area for the trawler and the flyshooter combined (3rd quarters 2006 and 2007: 2700 nmi^2, 3 quarter 2008: 5400 nmi^2) to obtain abundance estimates for the different survey dates.

The catchability coefficient was estimated for the flyshooter from a series of experiments in which the same spot was fished repeatedly in short time intervals (appr. 2 hrs). So far, 5 experiments of this type have been carried out each comprising 2 to 6 tows. In 3 of the experiments the original fishing spot was visited again after 1 or two days. All the experiments were done during summer at fine weather conditions. The experiments were done on different bottom types (coarse sand, gravel and stone bottom). Initial cod density varied considerably between the experiments but in general the catch rates declined exponentially in all cases (Fig. 4 upper panel). Standardisation by setting the CPUE in the first tow equal to 1 allows fitting an asymptotic regression to the pooled data set of cumulative catch rates (Fig. 4 lower panel):

$$cumulative\ CPUE_{standardized} = y_o - a \times b^x$$

where x is the time since the first tow and the catchability coefficient q is:

$$q = \frac{1}{y_0}.$$

In doing so, a catchability coefficient of 0.3415 ($r^2 = 0.88$, $P < 0.001$) was obtained.

Estimation of abundance at age and spawning stock biomass for the entire North Sea

Abundance estimates by age (N_i) obtained for the REX study area from the flyshooter and the trawler were raised to the IBTS cod standard area in the North Sea and the western Skagerrak according to:

$$N_{i,\,IBTS\ cod\ area} = \frac{N_{i,REX\ area}}{Area_{\,REX\ survey}} \times f_i \times Area_{\,IBTS\ cod\ area}$$

where the scaling factor *f* is the ratio of the IBTS indices for cod standard area and the area covered during the REX project in a particular survey. Spawning stock biomass was calculated from the abundance estimates by age using mean weight at age and maturity ogives from the most recent assessment for North Sea cod (ICES 2009).

The area surveyed in the REX project by the trawler and the flyshooter as well as coverage of the IBTS in the REX area differed between sampling dates, which restricted the number of rectangles with overlapping sampling between the commercial vessels and the IBTS to 3 rectangles in the 3rd quarter 2006 and 2007 and to 6 rectangles in the 3rd quarter 2008 (Tab. 2) while the IBTS cod standard area consists of 139 rectangles which corresponds to an area of 125100 nmi^2.

Results and Discussion

Spatial distribution and effect of bottom type

The 3rd quarter survey in 2006 resulted in sampling of a few clusters of stations accumulating in favourite spots of the fishermen and yielded considerable catch rates of cod (Fig. 5). In the later surveys a much wider extension of areas with high densities of cod was recorded (Figs. 6 and 7). Catch rates obtained with the flyshooter of more than 1 ton of cod per square nautical mile were found in 25 % of the stations in the August 2007 survey and in more than 30 % of the stations in the August/September 2008 survey, and maximum cod catch per station increased from 3.0 t/nmi^2 in 2006 to 7.1 t/nmi^2 in 2008. CPUE's for the trawler and the gillnetter revealed in general a similar trend than those for the flyshooter. Hence, low quota for cod together with the broad extension of areas with high cod densities and co-occurrence of cod with other commercial roundfish species made it increasingly difficult for the fishermen to avoid unintended by-catch and discard of cod when fishing in this area.

The IBTS, however, reported only a few cod at age 2 and older throughout the three years in this area (Figs. 5d, 6d, and 7d), and found no cod in the REX study area in 2 out of 3 rectangles in the 3rd quarter 2007 (Fig. 6d) and likewise no cod were recorded in 2 out of 6 rectangles in the 3rd

quarter 2008 (Fig. 7d). The catch rates of the commercial vessel were considerable in these rectangles (Tab. 3a-c) and it appears that the IBTS is inadequate to monitor the distribution and abundance of cod on small spatial scales.

Average catch rates were consistently higher on rough bottom than on sand in the all of the 3rd quarter surveys for all of the three commercial fishing methods (Fig. 8; see also Wieland et al. 2009). The survey means indicates a continuous increase in cod density on the rough bottom from 2006 to 2008 for the three commercial vessels. This was not entirely the case for the mean CPUE on sand bottom, and as the IBTS is more or less restricted to the latter, the IBTS indices may not have detected properly the overall change in cod density in this area.

Size and age distributions

The IBTS catches of cod in the REX study area were dominated by the 1-group in the 3rd quarter 2006 and 2008 and by 2 year olds in the 3rd quarter 2007 (Fig. 9a-c). 1-group cod and also 2 year olds in the case of the gillnetter were not well represented in the commercial catches due to mesh size selection despite the use of smaller sizes than applied by the vessels during their routine fishing activities of e.g. 125 mm instead of the 105 mm codend used by the trawler and the flyshooter in our study. Cod larger than 80 cm were rare in the IBTS catches but occurred regularly in the commercial catches, especially in the 2008 survey (Figs. 9c). For both, the 3rd quarter 2006 and 2008, the decline in catch rates beyond age 2 was less steep in the catches obtained with the trawler and the flyshooter than in the IBTS (Figs. 9a and 9c) which may indicate a lower efficiency of the IBTS for catching larger and older cod in the REX study area. This was less pronounced in the 3rd quarter 2007 (Fig. 9b), and it appears that clustered aggregations of larger cod were not covered representatively by the IBTS due to its relative coarse station grid.

Abundance and spawning stock biomass

Abundance at age from the assessment followed closely the IBTS 3rd quarter indices for age 2 and 3 and revealed similar trends for age 5 and 6+ but showed some discrepancy for age 4 in 2008 (Fig. 10). This may indicate a strong dependence of the assessment results from the tuning solely with 1st and 3rd quarter IBTS indices. Abundance estimates obtained in this study based on catch rates from commercial vessels scaled to the cod standard area using 3rd quarter IBTS indices were below the assessment results for age 2 in all years, for age 3 to 5 in 2006 and 2007 and for age 6+ in 2008. The abundance estimates for age 3 and older from this study increased at a much higher rate for the

past two years than indicated by the assessment (Fig. 10). Estimated spawning stock biomass were below the assessment values for 2006 and 2007 but exceeded the assessment result for 2008 by a factor of more than 2 (Fig. 11).

Conclusions

The internanual changes in abundance and spawning stock biomass and their differences to the assessment results need further investigation because they were based on three ICES rectangles only for which spatial overlap between the sampling with the commercial vessels and the IBTS was encountered in 2006 and 2007 in contrast to six rectangles which were available for 2008. The relative high spawning stock biomass obtained for 2008 in this study, however, may suggest that it would be worthwhile to re-introduce representative CPUE series from the commercial fishery or to establish and consider time series from surveys with commercial fishing vessels in order to supplement or to replace IBTS indices for older cod in the tuning procedure of the assessment model.

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Tab. 1: REX survey dates, area coverage and station allocation strategies.

Survey period	Days at sea	ICES Rectangles *	Survey strategy
June '06	4	42F6, 42F7	A) no restrictions concerning station selection
Aug '06	9	43F6, 43F7, 42F6, 42F7	
Jan/Febr '07	9	44F5, 43F7, 42F7	B) pairs of different bottom types within 10 nmi distance
June '07	6	43F6, 43F7, 42F6, 42F7	
Aug '07	9	44F5, 43F6, 43F7, 42F6, 42F7	C) 'restricted-random': ICES rectangles divided in 5 * 5 nmi squares;
Febr '08	9	45F4, 44F5, 42F6, 42F7	75 % of squares randomly selected,
June '08	5, 6 *	43F7, 42F6, 42F7	25 % of squares selected by fishermen**;
Aug/Sept '08	12, 13, 14 *	44F5, 43F5, 43F6, 43F7, 43F8, 42F6, 42F7	at least 25 % of the stations on sand bottom;
Jan/Febr '09	12, 14 *	45F4, 44F5, 44F6, 43F5, 43F6, 43F7, 42F6, 42F7	fishing positions within 5 * 5 nmi squares choosen by fishermen

*: differed between vessels; no gillnetter in June '08, no flyshooter in Jan/Febr '09

**: appr. 10 to 12 random selected squares (out of 36 if all suitable in respect to depth (< 200 m) and bottom condition) per rectangle for trawler and flyshooter, higher number of pre-selected 'micro-squares' for gillnetter (results in a lower number of rectangles covered in the same survey period)

Tab. 2: ICES rectangles and number of stations available for the comparison of the commercial vessel CPUE and the IBTS indices in the REX study area in the 3rd quarter 2006, 2007 and 2008 (IBTS data according to DATRAS download in June 2009, *: no rockhopper trawl stations in 2006).

Year	Rectangel	Flyshooter	Trawler	IBTS
2006	43F6	1	*	1
	43F7	16	*	0
	42F6	18	*	2
	42F7	10	*	1
2007	44F5	0	17	2
	43F6	1	0	0
	43F7	15	19	0
	42F6	15	0	2
	42F7	17	20	1
2008	44F5	0	10	2
	43F5	0	11	2
	43F6	11	10	2
	43F7	10	10	1
	42F6	11	11	4
	42F7	13	11	3

Tab. 3a: Cod density and abundance by age for the REX study area and the IBTS standard area in the 3rd quarter 2006 (*: weighted by number of stations per rectangle).

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2006	43F6	2	1.640	502.562	-			
	42F6		35.370	406.317	-			
	42F7		11.710	415.711	-			
	Mean for survey area*:		21.023	412.875	-	-	-	1209.005
	Mean for cod standard area:		1.890					
		f:	0.090				Abundance survey area:	3264312
							Abundance cod standard area:	13597614

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2006	43F6	3	0.970	77.445	-			
	42F6		4.750	90.021	-			
	42F7		27.080	201.576	-			
	Mean for survey area*:		9.388	128.055	-	-	-	374.977
	Mean for cod standard area:		1.252					
		f:	0.133				Abundance survey area:	1012437
							Abundance cod standard area:	6256279

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2006	43F6	4	0.040	2.646	-			
	42F6		0.240	6.141	-			
	42F7		4.610	15.002	-			
	Mean for survey area*:		1.283	9.076	-	-	-	26.576
	Mean for cod standard area:		0.219					
		f:	0.171				Abundance survey area:	71756
							Abundance cod standard area:	567729

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2006	43F6	5	0.000	0.353	-			
	42F6		0.030	1.853	-			
	42F7		2.090	3.856	-			
	Mean for survey area*:		0.538	2.492	-	-	-	7.297
	Mean for cod standard area:		0.044					
		f:	0.082				Abundance survey area:	19703
							Abundance cod standard area:	74729

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2006	43F6	6+	0.000	0.410	-			
	42F6		0.030	0.937	-			
	42F7		0.280	1.229	-			
	Mean for survey area*:		0.085	1.020	-	-	-	2.986
	Mean for cod standard area:		0.059					
		f:	0.694				Abundance survey area:	8061
							Abundance cod standard area:	259244

Tab. 3b: Cod density and abundance by age for the REX study area and the IBTS standard area in the 3rd quarter 2007 (*: weighted by number of stations per rectangle).

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2007	44F5	2	43.370	-	66.759	255.741		
	42F6		0.000	557.106	-	-		
	42F7		0.000	488.118	131.546	488.779		
	Mean for survey area*:		17.348	520.456		381.707	446.055	1306.163
	Mean for cod standard area:		6.154					
		f:	0.355				Abundance survey area:	3526639
							Abundance cod standard area:	57964571

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2007	44F5	3	9.170	-	9.161	87.170		
	42F6		0.000	70.032	-	-		
	42F7		0.000	130.140	27.029	160.962		
	Mean for survey area*:		3.668	101.964		127.058	115.420	337.980
	Mean for cod standard area:		0.975					
		f:	0.266				Abundance survey area:	912545
							Abundance cod standard area:	11238886

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2007	44F5	4	4.490	-	4.289	28.091		
	42F6		0.000	17.929	-	-		
	42F7		0.000	44.560	9.260	68.966		
	Mean for survey area*:		1.796	32.077		50.186	41.787	122.364
	Mean for cod standard area:		0.344					
		f:	0.192				Abundance survey area:	330382
							Abundance cod standard area:	2931990

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2007	44F5	5	0.820	-	1.045	7.055		
	42F6		0.000	3.632	-	-		
	42F7		0.000	8.097	1.592	12.250		
	Mean for survey area*:		0.328	6.004		9.863	8.073	23.641
	Mean for cod standard area:		0.137					
		f:	0.418				Abundance survey area:	63830
							Abundance cod standard area:	1235283

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler $_{converted}$	Both vessels combined	Adjusted for q
2007	44F5	6+	0.540	-	0.808	5.383		
	42F6		0.000	3.148	-	-		
	42F7		0.000	3.844	1.068	7.485		
	Mean for survey area*:		0.216	3.518		6.519	5.127	15.013
	Mean for cod standard area:		0.122					
		f:	0.565				Abundance survey area:	40535
							Abundance cod standard area:	1060793

Tab. 3c: Cod density and abundance by age for the REX study area and the IBTS standard area in the 3rd quarter 2008 (*: weighted by number of stations per rectangle).

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler converted	Both vessels combined	Adjusted for q
2008	44F5	2	9.165	-	25.885	108.715		
	43F5		1.530	-	34.531	139.817		
	43F6		10.291	220.846	42.177	167.318		
	43F7		0.000	82.516	24.808	104.841		
	42F6		14.895	363.366	62.354	239.894		
	42F7		0.000	396.645	107.752	403.190		
	Mean for survey area*:		7.254	275.730		197.153	229.894	673.188
	Mean for cod standard area:		2.518					
		f:	0.347				Abundance survey area:	3635215
							Abundance cod standard area:	29234589

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler converted	Both vessels combined	Adjusted for q
2008	44F5	3	8.203	-	21.127	136.588		
	43F5		1.400	-	22.716	143.151		
	43F6		7.480	234.522	33.146	186.228		
	43F7		0.000	141.251	30.030	173.355		
	42F6		7.052	307.089	42.400	224.444		
	42F7		0.000	273.122	65.636	320.410		
	Mean for survey area*:		4.455	242.685		198.885	217.135	635.827
	Mean for cod standard area:		3.000					
		f:	0.673				Abundance survey area:	3433468
							Abundance cod standard area:	53560412

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler converted	Both vessels combined	Adjusted for q
2008	44F5	4	2.164	-	4.737	31.771		
	43F5		0.120	-	4.092	26.466		
	43F6		2.716	91.608	10.366	78.063		
	43F7		0.000	72.461	6.652	47.521		
	42F6		0.958	46.980	5.830	40.763		
	42F7		0.000	30.106	6.109	43.059		
	Mean for survey area*:		0.988	58.677		44.234	50.252	147.149
	Mean for cod standard area:		0.516					
		f:	0.522				Abundance survey area:	794607
							Abundance cod standard area:	9613832

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler converted	Both vessels combined	Adjusted for q
2008	44F5	5	0.604	-	1.350	9.955		
	43F5		0.000	-	1.770	13.933		
	43F6		1.199	58.999	5.826	52.404		
	43F7		0.000	38.347	1.611	12.426		
	42F6		0.096	8.527	0.937	6.032		
	42F7		0.000	3.418	0.358	0.542		
	Mean for survey area*:		0.285	26.015		15.451	19.853	58.134
	Mean for cod standard area:		0.249					
		f:	0.873				Abundance survey area:	313926
							Abundance cod standard area:	6352214

Year	Rectangle	Age	CPUE IBTS	REX Flyshooter	Trawler	Trawler converted	Both vessels combined	Adjusted for q
2008	44F5	6+	0.132	-	0.487	2.789		
	43F5		0.000	-	1.151	8.159		
	43F6		0.275	25.602	2.540	19.382		
	43F7		0.000	11.261	0.633	3.972		
	42F6		0.033	2.934	0.393	2.034		
	42F7		0.000	1.612	0.214	0.584		
	Mean for survey area*:		0.068	9.944		6.031	7.662	22.435
	Mean for cod standard area:		0.116					
		f:	1.716				Abundance survey area:	121149
							Abundance cod standard area:	4814814

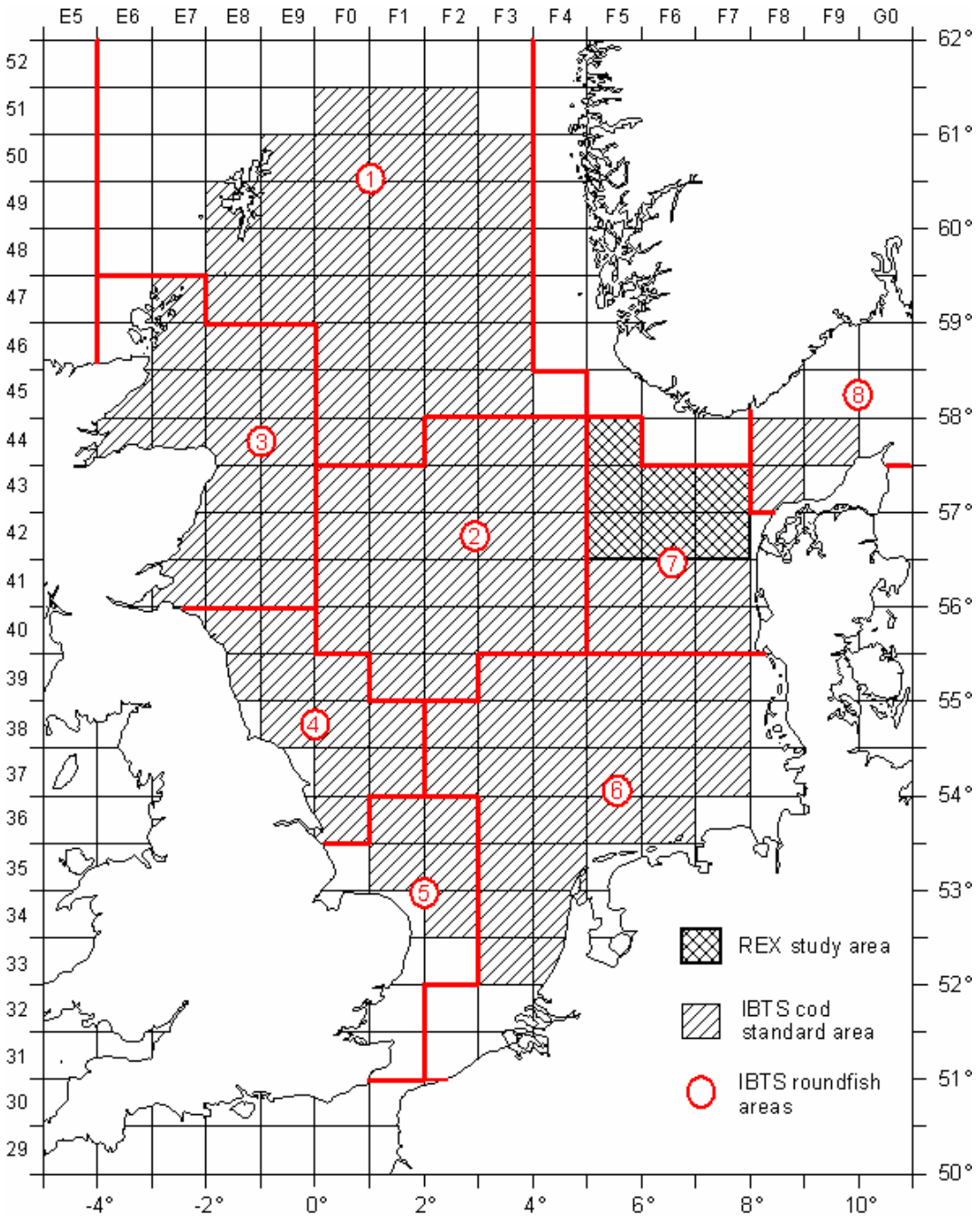

Fig 1: REX main study area and IBTS cod standard area in the North Sea and the western Skagerrak.

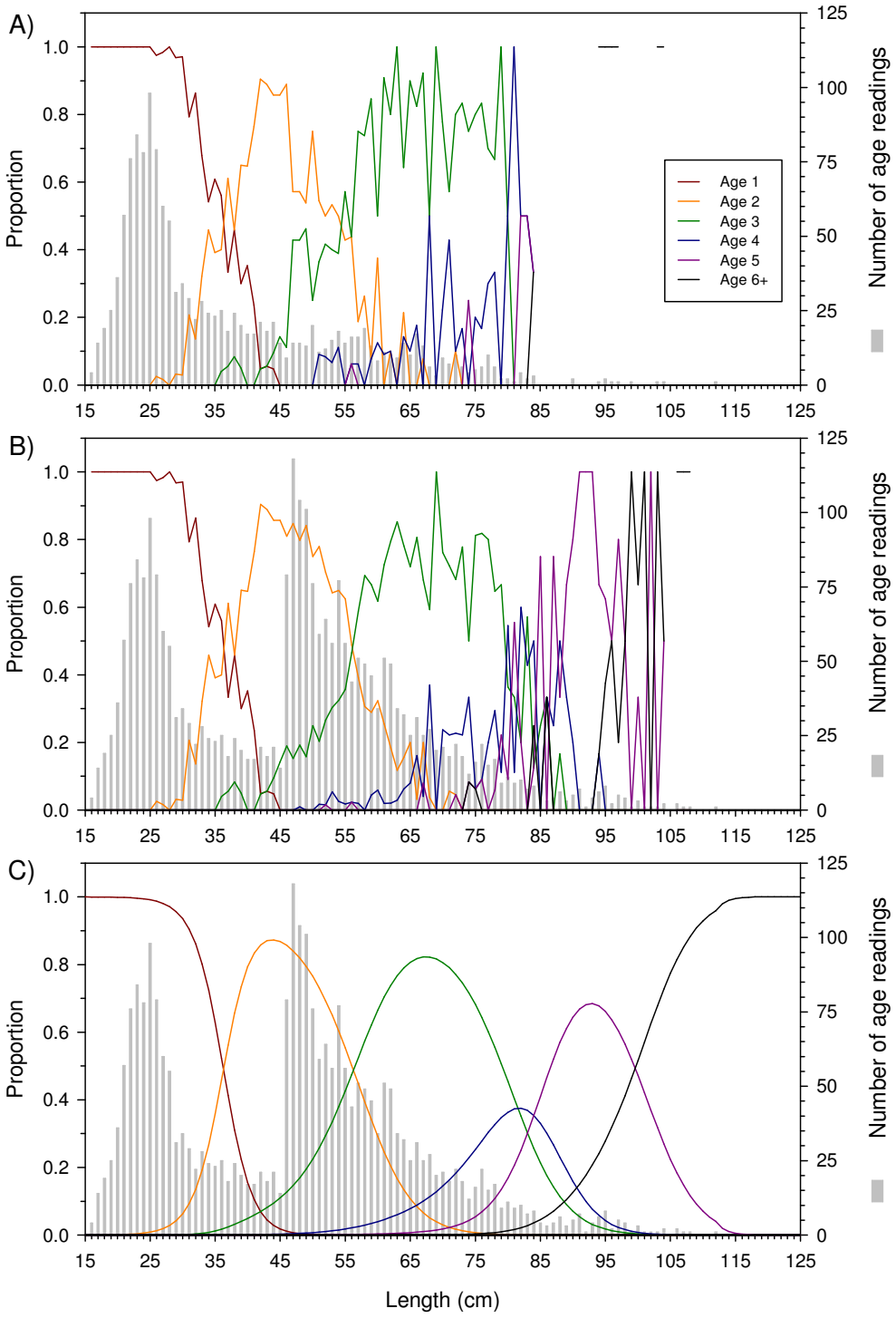

Fig. 2a: Age length keys for the 3rd quarter 2006. A) IBTS*, B) IBTS* and Danish commercial fishery**, C) Based on continuation-ratio logits with IBTS and Danish commercial fishery data (*: IBTS roundfish areas 1, 2, 7 and 8; **: North Sea and Skagerrak).

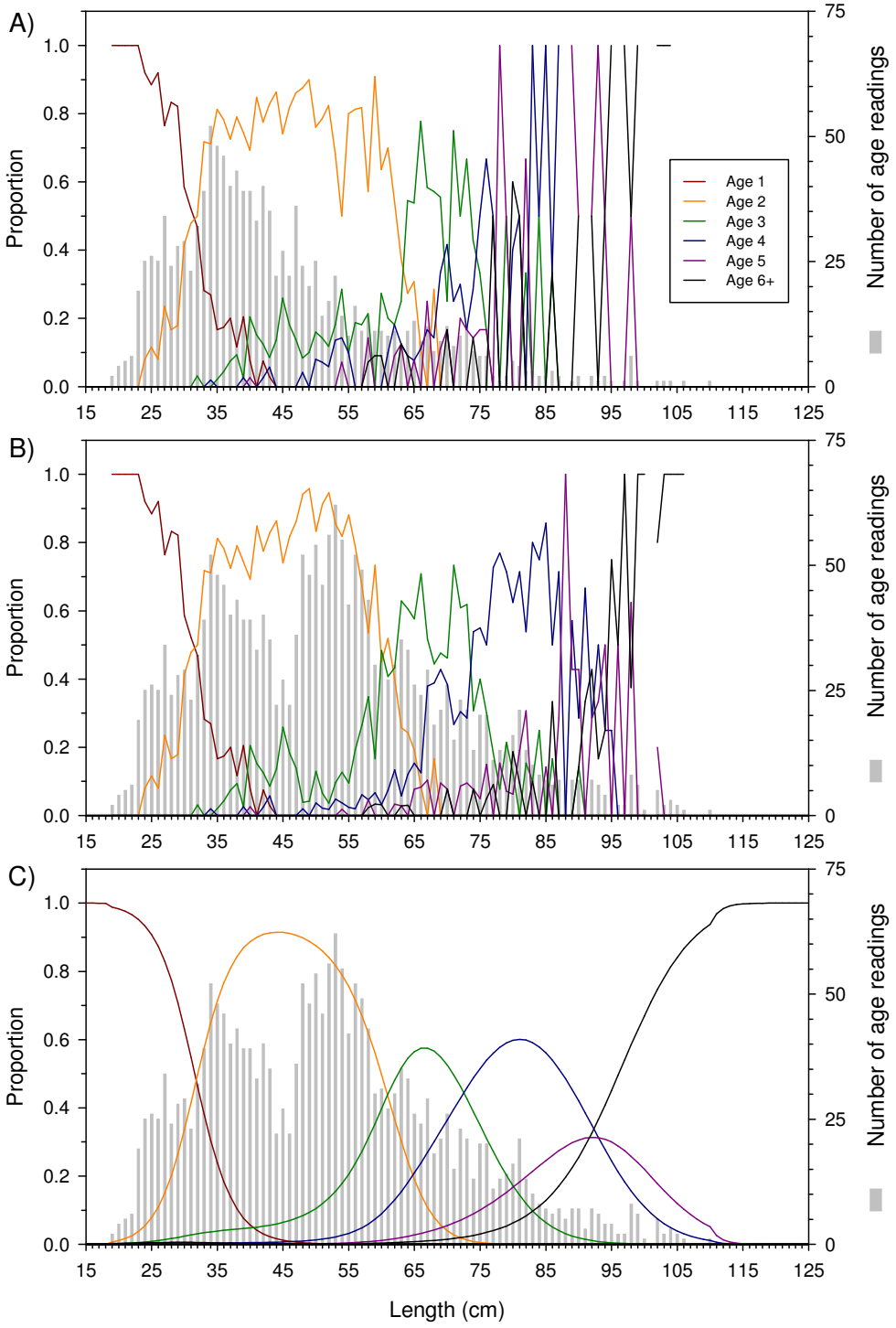

Fig. 2b: Age length keys for the 3rd quarter 2007. A) IBTS*, B) IBTS* and Danish commercial fishery**, C) Based on continuation-ratio logits with IBTS and Danish commercial fishery data (*: IBTS roundfish areas 1, 2, 7 and 8; **: North Sea and Skagerrak).

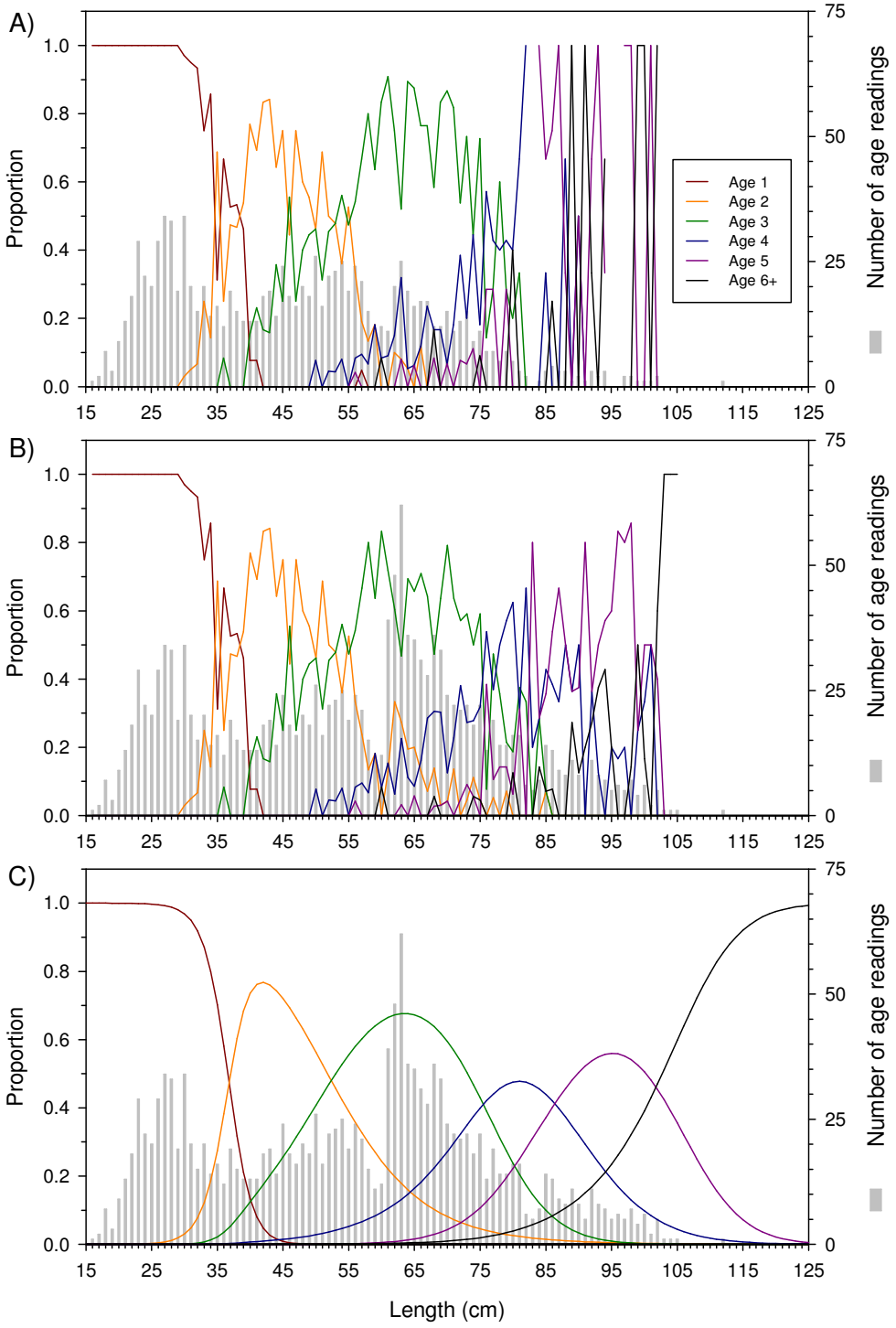

Fig. 2c: Age length keys for the 3rd quarter 2008. A) IBTS*, B) IBTS* and Danish commercial fishery**, C) Based on continuation-ratio logits with IBTS and Danish commercial fishery data (*: IBTS roundfish areas 1, 2, 7 and 8; **: North Sea and Skagerrak).

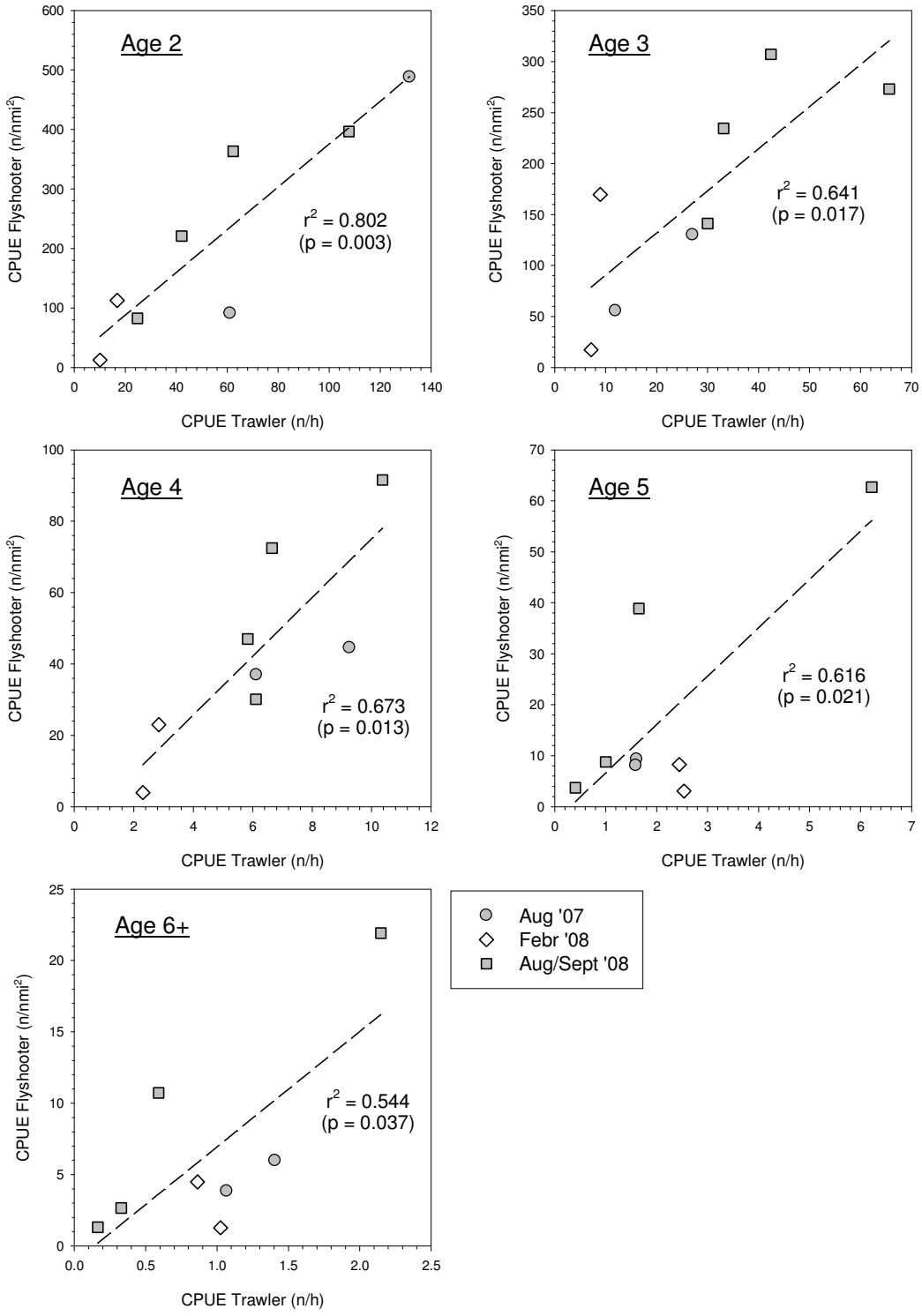

Fig. 3: Comparison of flyshooter and trawler CPUE for rectangles sampled with 'restricted random' station allocation and with ≥ 5 stations per rectangle for each vessel.

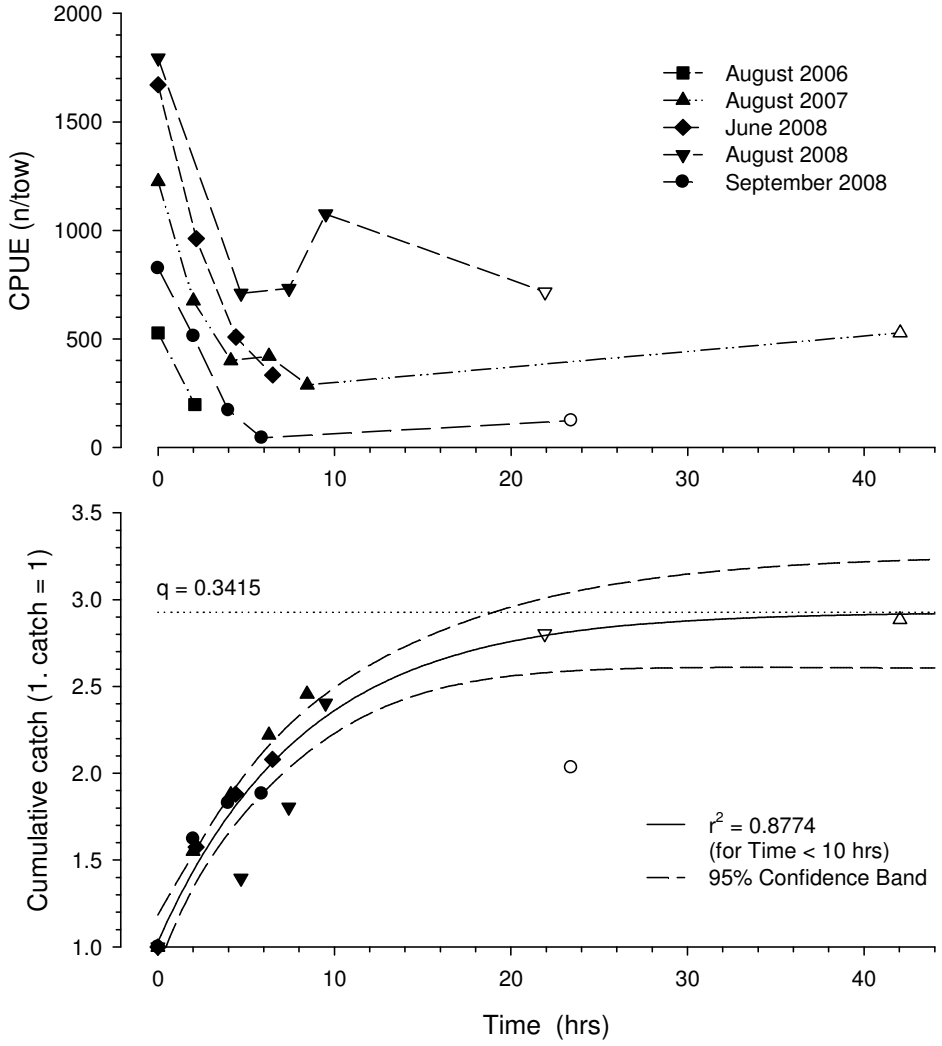

Fig. 4: Estimation of the catchability (q) for the flyshooter.

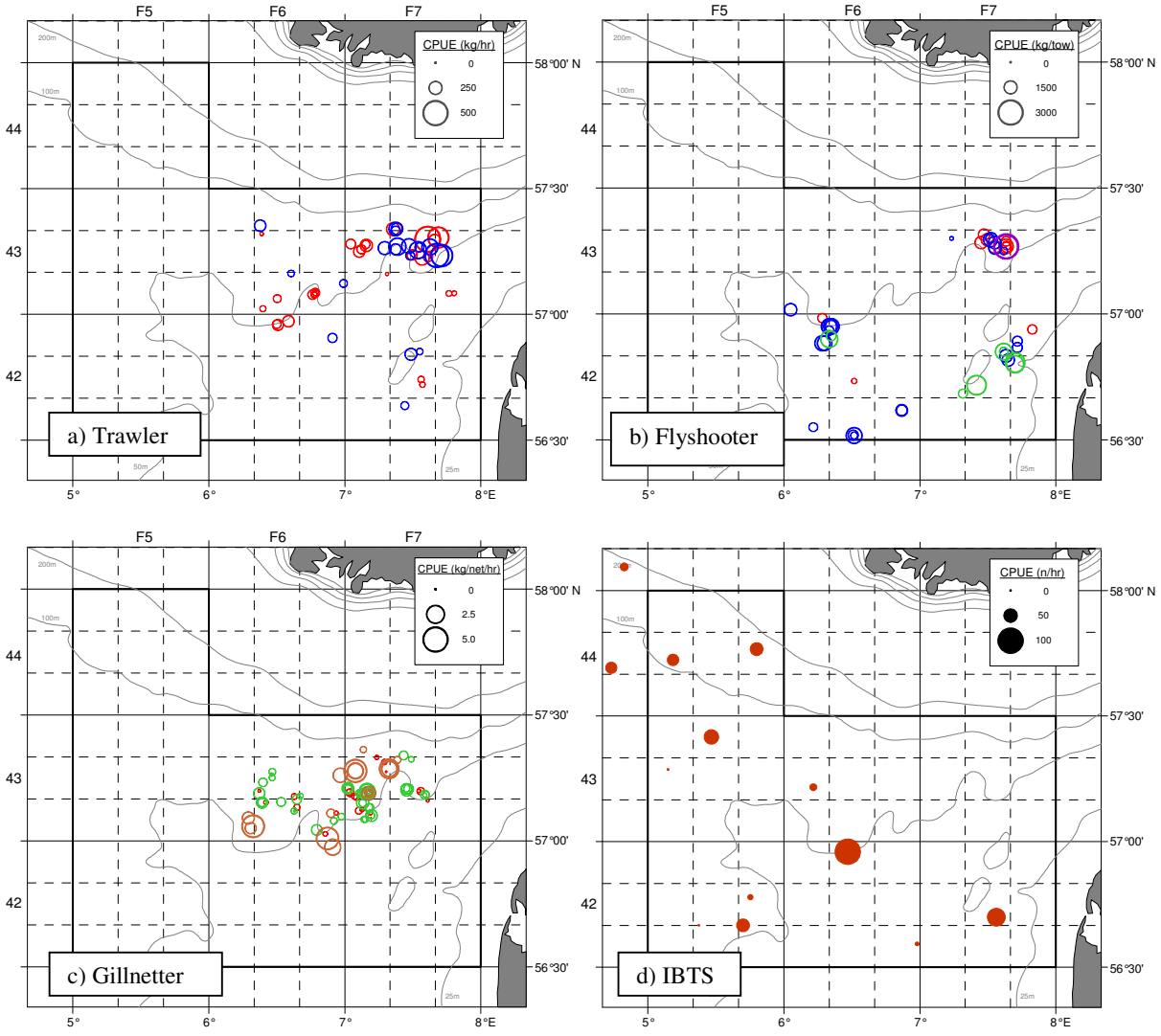

Fig. 5: Distribution of cod in the north-eastern central North Sea in August 2006. a) Trawler, b) Flyshooter (each 'tow' covered 1 square nautical mile), c) Gillnetter. (red: sand, blue: gravel, green: stone and stone reefs, brown: ship wrecks), d) IBTS age 2+.

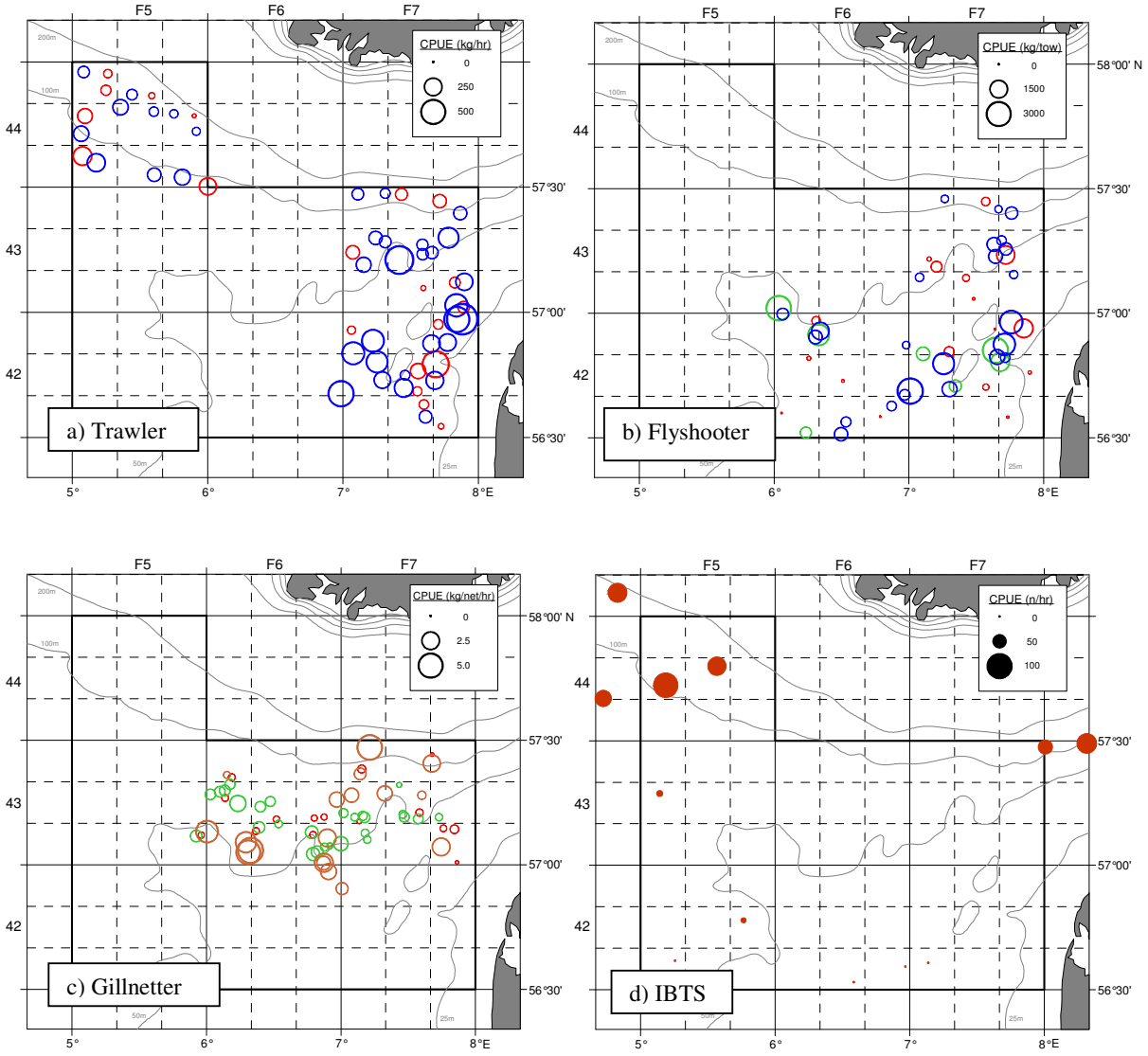

Fig. 6: Distribution of cod in the north-eastern central North Sea in August 2007. a) Trawler, b) Flyshooter (each 'tow' covered 1 square nautical mile), c) Gillnetter. (red: sand, blue: gravel, green: stone and stone reefs, brown: ship wrecks), d) IBTS age 2+.

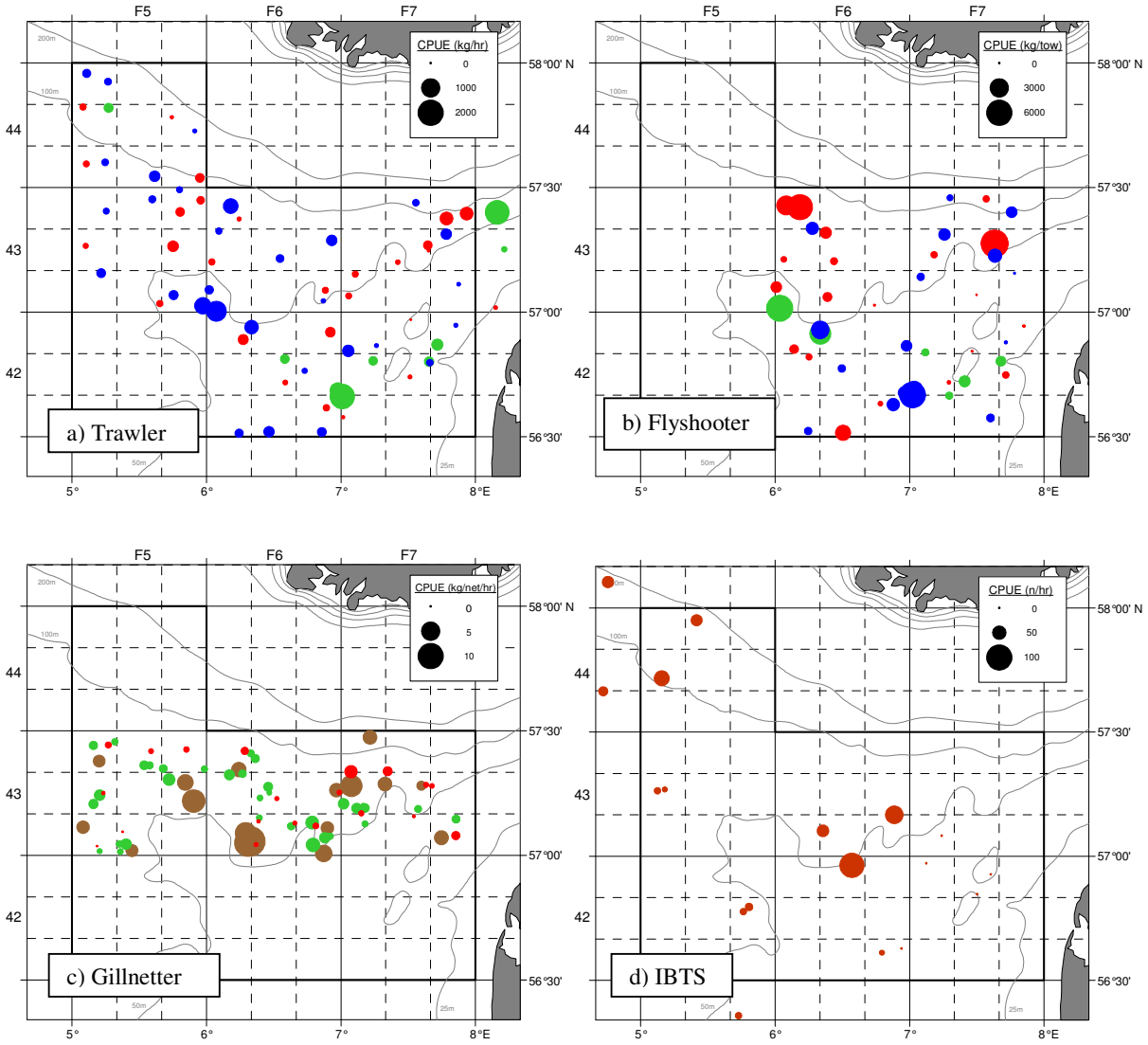

Fig. 7: Distribution of cod in the north-eastern central North Sea in August/September 2008. a) Trawler, b) Flyshooter (each 'tow' covered 1 square nautical mile), c) Gillnetter. (red: sand, blue: gravel, green: stone and stone reefs, brown: ship wrecks), d) IBTS age 2+.

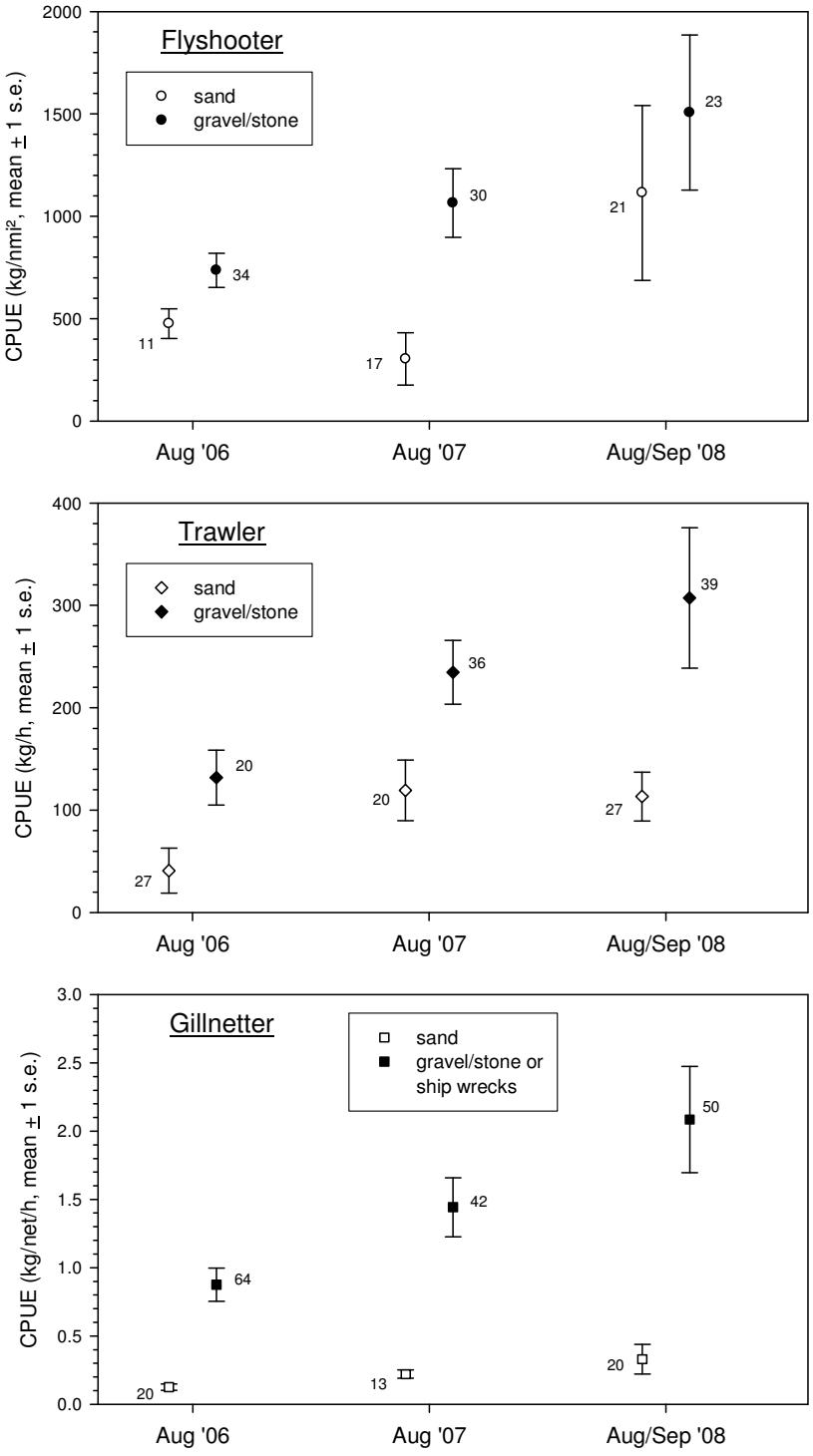

Fig. 8: Comparison of mean survey CPUE on sand and on gravel or stone bottom and at ships wrecks (number of stations denoted at symbols).

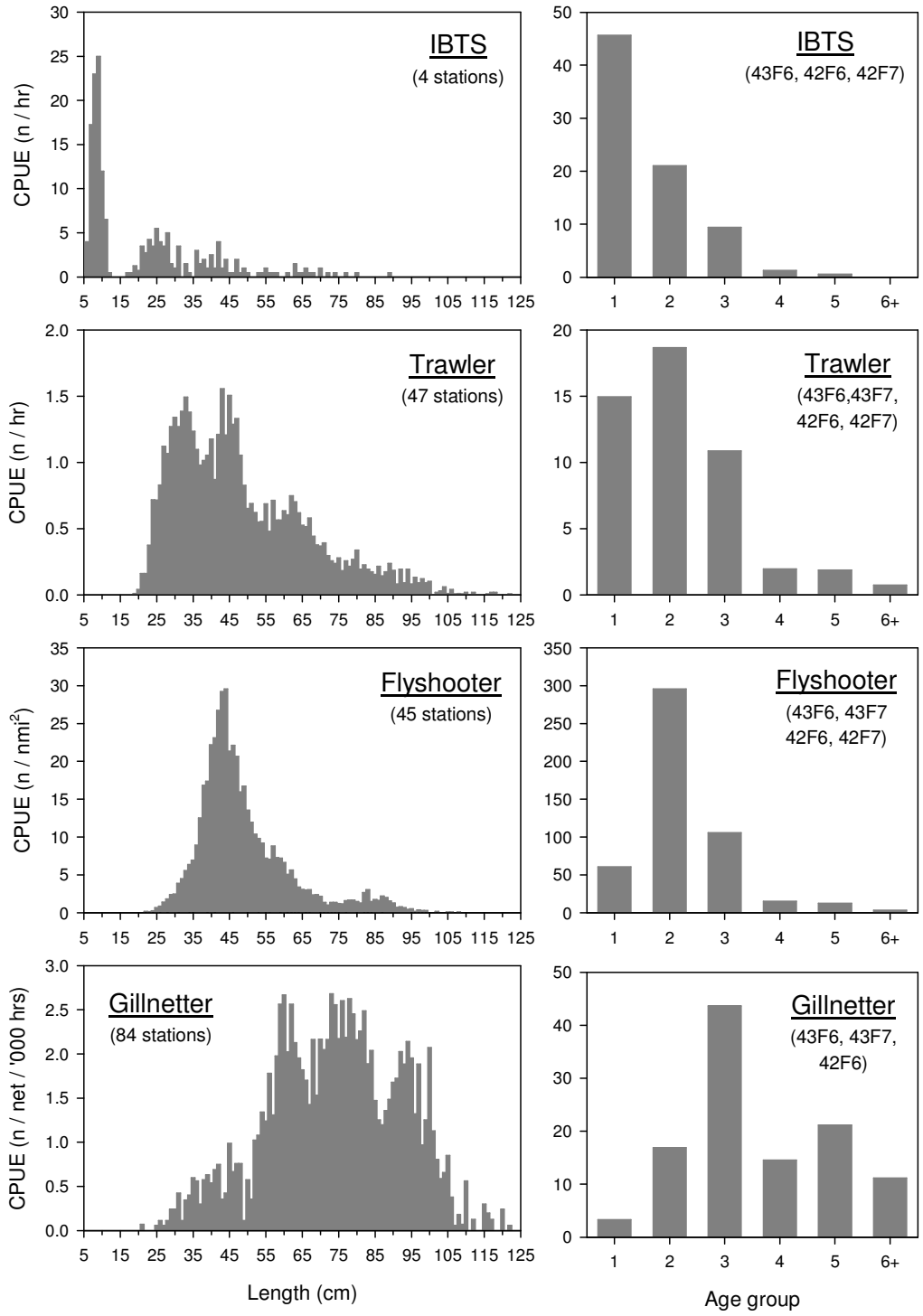

Fig. 9a: Average length and age distributions for the IBTS and the commercial vessels from the REX study area in the 3rd quarter 2006.

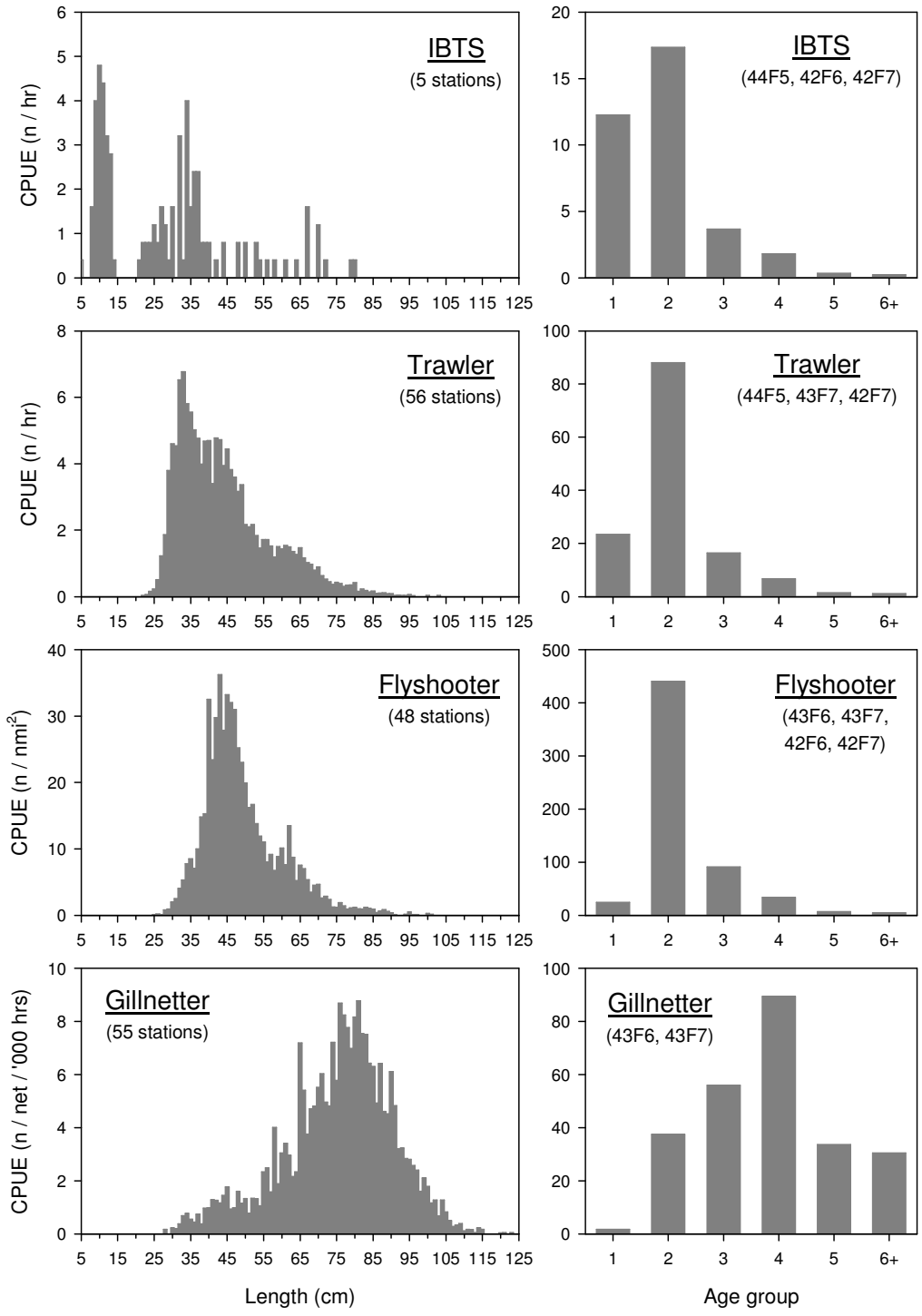

Fig. 9b: Average length and age distributions for the IBTS and the commercial vessels from the REX study area in the 3rd quarter 2007.

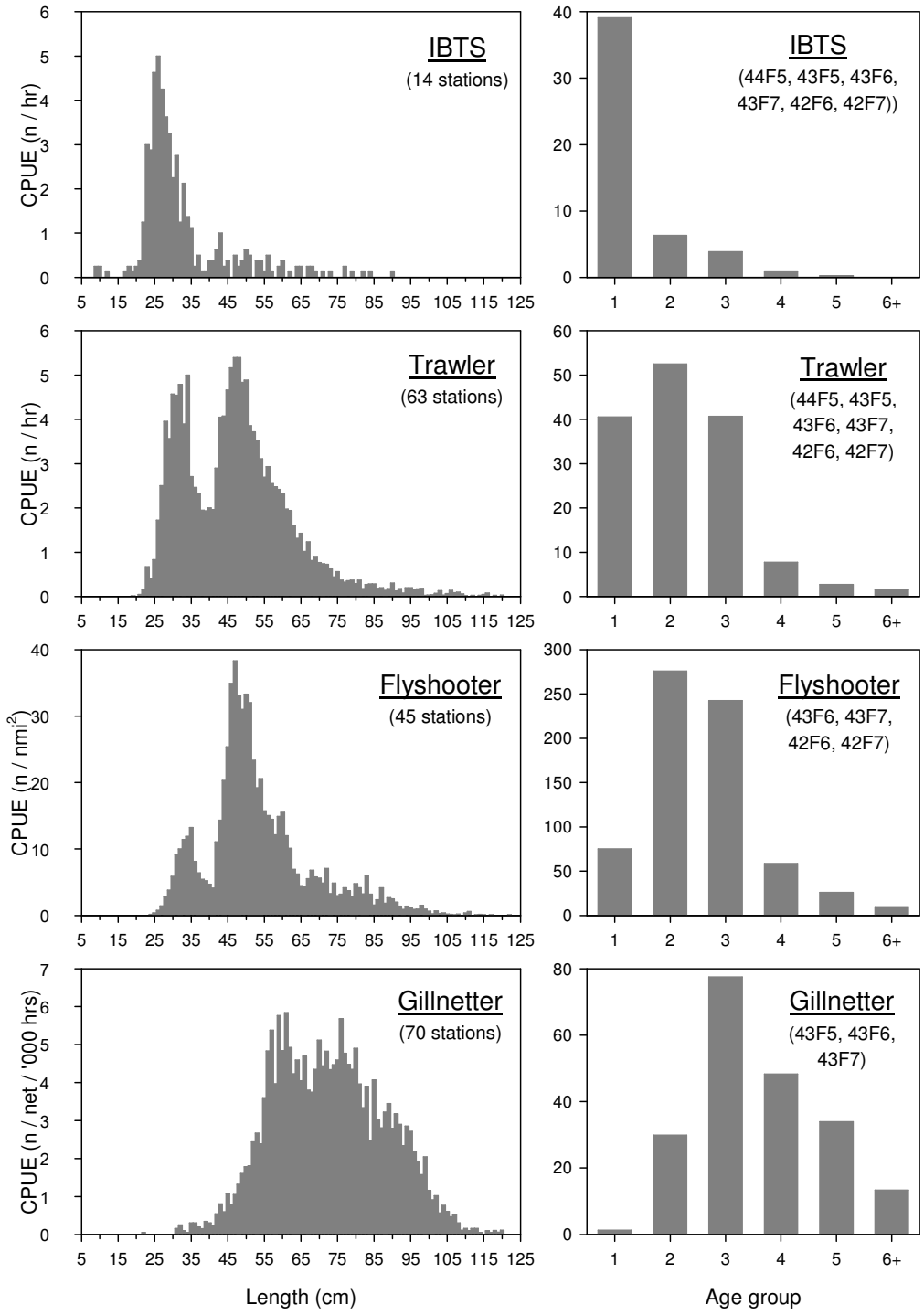

Fig. 9c: Average length and age distributions for the IBTS and the commercial vessels from the REX study area in the 3rd quarter 2008.

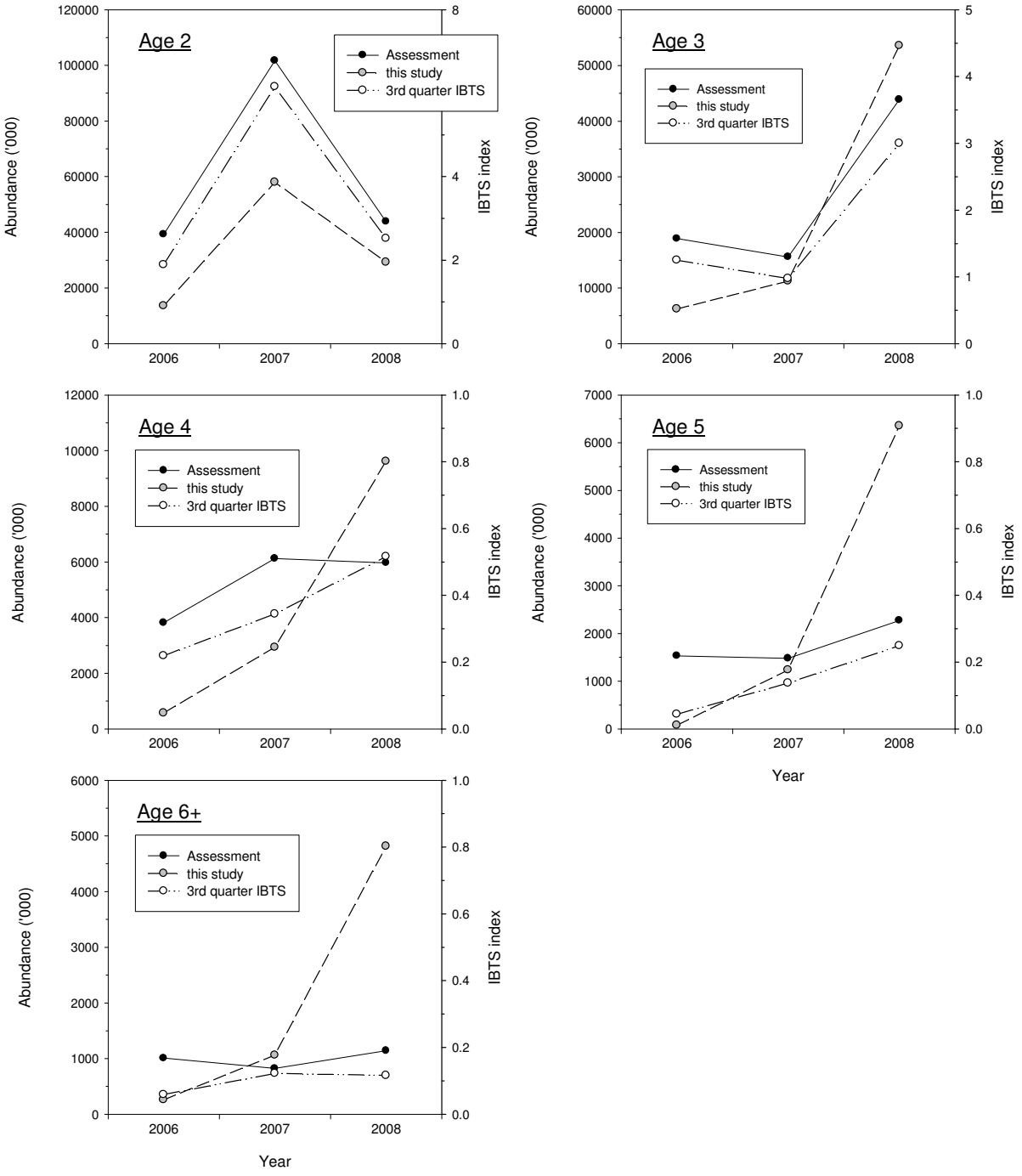

Fig. 10: North Sea cod abundance at age from the most recent assessment (ICES 2009) and as estimated in the present study. 3rd quarter IBTS indices for the cod standard area (ICES 2009) are given for comparison.

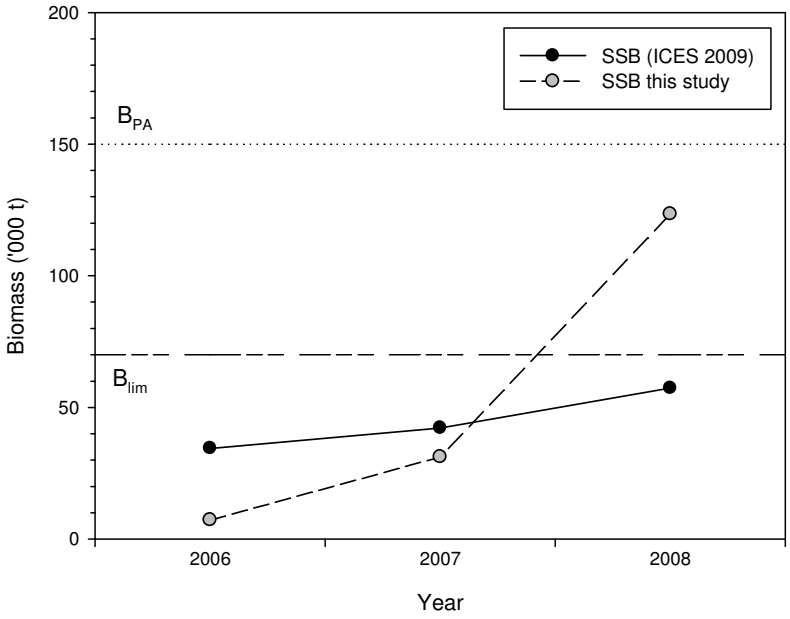

Fig. 11: North Sea cod spawning stock biomass from the most recent assessment (ICES 2009) and as estimated in the present study.