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Results of the Norwegian Bottom Trawl Survey for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east) in 2016

by

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Abstract

The timing of the Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) has changed from 1984 to present. The result is a series of three different biomass index time series, lasting from two to nineteen years. New series were initiated in both 2004 (May) and 2006 (February). Conducting the survey in the 1st quarter gives good estimates of both recruitment and SSB. Thus, the newest time series has been established at the most optimal time of year.

The biomass index fluctuated around a high level from the mid 1990s to 2002 when the first time series was discontinued. The 2004 and 2005 mean values of a new biomass index series were not statistically different. The 2007 index was 77% higher than the 2006 value. The biomass index decreased from 2008 to 2012, increased from 2013 to 2015, and the decreased to the time series' lowest level in 2016.

Recruitment (abundance of the 1-group) in Skagerrak has been much lower in recent years compared with 2006-2007, with the exception of 2014 when the recruitment was very good and at a higher level than in 2006-2007. For most of the time series (2006-2016), recruitment has been much lower in the Norwegian Deep compared with Skagerrak, suggesting that Skagerrak is a nursery area for the stock. The low recruitment is probably the main reason behind the low stock size in recent years. Recruitment was again low in 2016.

The SSB-index decreased from 2008 to 2012, but increased sharply in 2015.

The mean index-value of shrimp predator biomass was estimated to 42.5 kg/nm in 2016. This is an increase compared with 2015, mainly due to an increase in the indices of cod, haddock, whiting and long rough dab.

Introduction

A trawl survey for northern shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east, and the far north-east corner of Div. IVb) has since 1984 been conducted annually by the Norwegian Institute of Marine Research (IMR) with the objective of assessing the distribution, biomass, amount, recruitment, length distribution, and demographic composition of the shrimp stock, the size of the stocks of shrimp predators, as well as measuring hydrographical conditions in the distributional area of this shrimp stock.

The survey data consist of: 1) one time series from 1984-2002 (October/November) using R/V *Michael Sars* and the Campelen-trawl; 2) a point estimate for 2003 (October) as R/V *Michael Sars* was taken out of service and substituted with R/V *Håkon Mosby*, whose winches at that time were not powerful enough for the Campelen-trawl, resulting in the survey being conducted with the Shrimp trawl 1420; 3) a start of a potential new time series as the survey in both 2004 and 2005 was conducted in May/June with R/V *Håkon Mosby* using the standard Campelen trawl; and 4) one time series from 2006 until present (January/February), still using R/V *Håkon Mosby* and the Campelen trawl. Conducting the survey in the 1st quarter gives good estimates of the 1-group (recruitment) and SSB (berried females) and was recommended by the *Pandalus* working group in 2004 (ICES 2005).

This paper presents the results of the 2016 survey.

Material and Methods

Survey design

The survey area covers depths of approximately 100 to 550 m in ICES Divs. IIIa and IVa east. A couple of stations are also located in the north-east corner of Div. IVb. The survey is stratified by four depth zones (100-200 m, 200-300 m, 300-500 m, and >500 m), and area (Table 1, Fig. 1). In 2007, the strata division was revised. The depth contours were updated using GIS and the bathymetric database GEBCO, and the strata areas were recalculated accordingly. Strata 1-4 were extended north to 60º N in order to incorporate the two northernmost stations in the strata system, and the deep water area in the middle of Skagerrak (>500 m) was included as a 17th stratum as four trawl stations are located in this area. A second revision of the strata system in 2008 moved the northern border of stratum 1 to 59º N as the two southern trawl stations in this stratum cannot be considered representative of the whole area north to 60º N (Fig. 1). Furthermore, the strata areas were recalculated using an "equal area" projection, which gives more correct area estimates than the earlier used projection. The survey area is now estimated to cover 15 749 nm^2 (Table 1).

The survey has a fixed station design, assuming that the temporal variation in the shrimp stock generates the necessary randomness. In 2006, it was decided that the 100 stations trawled during the 2000 survey should be considered fixed stations for future surveys. In 2008, thirteen stations (positions found in old survey reports from 1984-1996) were added in order to obtain a better coverage of the area. In 2013, all stations were trawled and/or inspected on the OLEX system, resulting in a new revision of the station list. Eight trawl stations were removed due to rough bottom conditions and one new station was included (Fig. 1). In 2016, three stations were removed from the list due to new cables on the sea floor preventing trawling, resulting in a new list of 101 fixed stations.
A complete station list is given in the 2016-survey report (Thangstad et al. 2016). Seven new trawl stations in the Swedish EZZ were trawled in 2015 and 2016 on request from Swedish fishers to better survey their fishing grounds. The deepest and shallowest stations have depths of respectively 540 and 111 m. A coverage of one haul per 156 nm^2 is obtained when all 101 stations are trawled. However, this rarely happens due to time and weather constraints. As weather conditions are rougher in IVa east than in IIIa, it is generally the former area which in some years has been poorly covered.

The trawl used is a Campelen 1800/35 bottom trawl with rockhopper gear. In 2006, the rigging was changed with more float added in order to reduce the number of "mud hauls". Strapping was introduced on the survey in 2008 to ensure fixed trawl geometry independent of depth. On the 2009 survey, various rope lengths and distances between the rope and the doors were tried out. A 10 m rope 200 m in front of the doors gave an optimal door spread of 47-48 m. Mesh size in the cod end is 20 mm with a 6 mm inner lining net. Tow duration was 1 hour until 1989 when it was reduced to 0.5 hour. When towing on shallow fish banks tow duration is reduced to 5-10 minutes to prevent the trawl filling up with fish. Mean tow speed until 2012 was roughly 3 knots (Table 2), but in 2013-2016, mean tow speed has been lower (2.2-2.5 knots) compared with earlier years and the variation in tow speed between stations has increased. The skippers have not provided a satisfactory explanation for the change in tow speed. No compensation for diurnal vertical migration is made.

Stock size index

Biomass estimates are calculated using SAS (version 9.3). Swept area is estimated by applying a wingspread of 11.7 m to tow length. Tow length is set to time towed multiplied by a towing speed of 3 knots. The swept area is thus 0.019 nm^2/hour.

The catch in each tow divided by the swept area represents a sample of shrimp density (in kg and numbers) in a stratum. From these samples the mean and standard error of the density in each stratum are calculated and multiplied by the area of the respective stratum to give estimates of strata biomass and abundance. The biomass and abundance for the 17 strata are summed to give the overall value for the survey area.

Due to weather constraints some strata have not been covered in some years. For any missing stratum in year *t*, the stratum biomass is estimated as follows. 1) The proportion of biomass (*p*) (out of the total biomass) in the specific stratum is taken as the mean of all *p'*s from years where data exist for all strata. Mean *p*'s are calculated separately for the first and last time series. 2) The total biomass for year *t*, *B*, is calculated as: B = (Σ biomass in all strata with data in year *t*) / (1- *p*). The biomass in the missing stratum, $B_{stratum}$, is then given as: $B_{stratum} = B * p$. These calculations implicitly assume that the distribution of shrimp is constant from year to year.

Standard errors are calculated as: SE (whole survey area) = $\sqrt{[\Sigma (SE\ (stratum)^2)]}$.

A biomass index of potential shrimp predators is calculated as average catch/nm towed over all hauls of 23 fish species/fish families.

Biological samples

Samples of approximately 300 shrimp are taken from each trawl haul, sorted by sexual characteristics (stage) and measured with a precision of 0.1 mm (carapace length (CL)). Shrimp are sorted and measured also when the total catch contains less than 300 shrimp (sample = the total catch). An overall CL length frequency distribution, as well as distributions per area (Skagerrak and the Norwegian Deep), are estimated using CL truncated to the nearest mm below. The length frequency distributions are partitioned into age groups by modal analysis using the method of Bhattacharya (1967) (FISAT (version 1.2.2), http://www.fao.org/fi/oldsite/STATIST/fisoft/fisat/index.htm).

In January/February, the youngest age group is almost 1 year old (hatching of the eggs takes place from February to April). A recruitment index is estimated as the abundance of these (almost) 1-year old shrimp from the modal analysis. There is some correlation between the abundance of 1-year old shrimp in January/February in one year and the number of 2- and 3-year old shrimp the following two years, mainly due to the years with high recruitment (Fig. 2).

A SSB-index is estimated as the total number of berried females and females with newly hatched eggs. Berried females are dominating the catches in January and February. This year, the SSB-index has not been estimated by the formerly used SAS-routine, as a new time series will be calculated using StoX (Søvik and Johnsen 2016).

Hydrographical measurements

In all present and past surveys a CTD has normally been taken at each station, but previously the data were not analysed. To avoid damage on the equipment, the CTD is not lowered further than 10 m above the bottom. In 2012 and 2014, CTD was taken on respectively 22 (out of 65) and 58 (out of 69) trawl stations due to problems with the winch. In 2016, CTD was taken on all regular trawl stations (Fig. 3).

Results and discussion

Area coverage

In 2016, the survey was carried out from January 8 to 28. According to new standards of the year, the trawl gear was tested in the sea before the ordinary survey started (towing with open cod end on sandy bottom). Hundred and six trawl stations were covered, including six Swedish ones, and all strata were covered (Fig. 4). There were technical problems with the trawl on only one of the stations. Calculations were carried out using data from the other 105 valid stations.

Temperature and salinity

The bottom temperature in the survey area in January/February during the time span 2006-2015 ranged between 6 and 8.5 °C (Søvik and Thangstad 2015). The year 2016 is the warmest observed in the time series back to 2006 (Fig. 5), with 4 and 9 trawl stations in respectively Skagerrak and the Norwegian Deep with bottom temperatures above 8.5 °C. This is still within the range of winter bottom temperatures from the area (December-March) in 1982-2002 (range 5-9 °C) (Schlüter and Jerosch 2009). The average survey temperature has been between 7 and 8 °C, except in 2011 and 2016 (Table 3). In 2016, mean bottom temperature was 8.24 and 7.75 in the Norwegian Deep and Skagerrak respectively, the highest mean temperature observed in both areas. The mean temperature in the Norwegian Deep in 2016 is almost a degree higher than the mean temperature in 2015.

Average salinity has varied between 34.9 and 35.3 ‰ in the same time period (Table 3). This is in agreement with winter salinity data from the area, which in the period 1982-2002 was between 35 and 36 ‰ (Schlüter and Jerosch 2009).

Strapping

The introduction of strapping in 2008 caused the average door spread to decrease from more than 50 m in 2006-2007 to 45-48 m in 2008-2012 (Table 4). The former relationship of increased door spread with increased depth disappeared with the introduction of strapping. In 2009, there was a slight decrease in door spread with depth, probably due to difficulties with the trawl gear. In 2013-2016, however, mean door spread has varied between 48 and 51 m. The increase compared with the previous years may be explained by the decreased mean tow speed these four years (Table 2). In 2016, there is also a positive relationship between door spread and depth (Table 4, Fig. 6). It is unclear why the use of strapping did not prevent this. The inter-annual difference in door spread is not corrected for in the calculations.

Biomass index

The biomass index increased from the late 1980s to the early 1990s, remained at a stable level until the mid 1990s when it increased further to this time series' maximum in 1997 (Table 5, Fig. 7). A decrease in 1998-2000 was followed by an increase in 2001 and 2002. The very low 2003 biomass estimate (Table 5) could have resulted from the use of the Shrimp trawl 1420, which had mesh size in the cod end of 36 mm, and no lining. However, the trawl opening is taller compared with the Campelen trawl. The 2005 mean value is lower than that of 2004, but not statistically different. The 2007 value was 77% higher than the 2006 value, but was influenced by the very high mean biomass in stratum 16 (Table 5) which was due to a very large catch in one single trawl haul. From 2008, the biomass declined steadily to the recent time series' minimum in 2012. From 2013 to 2015, the biomass increased (Figs. 7, 8ab). The 2015-biomass estimate includes an estimated value for stratum 2, based on the mean of all *p*'s from years back to 2006 (see above). It seems likely that the estimated value of 1481 t (Table 5) in stratum 2 in 2015 is too high, as the stock seems to have contracted into the southern part of the Norwegian Deep in recent years (see below). The estimated biomass of stratum 17 in 2015 (2990 t) is probably also too high (Table 5). Mean density was highly influenced by one good trawl haul (out of three).

The 2016 biomass estimate of 3730 t is the lowest in the time series back to 2006. Only a handful of the fixed trawl stations had shrimp catches of > 10 kg/nm trawled (Fig. 8a). The 2016 survey result has been discussed with local shrimp fishers, who claim that they, contrary to the survey, have good catch rates this year.

Trends in the survey time series have followed trends in LPUE-indices closely for many years (Ulmestrand et al. 2016). The Danish LPUE-series, which goes back to 1987, also has its minimum in 2012. Both the Danish and the Swedish LPUEs showed a slight decline from 2015 to 2016. The Norwegian LPUE from 2016 is at the same level as the 2015-estimate (Søvik and Thangstad 2016).The decrease seen in the survey index in 2016 is not reflected in the LPUE time series.

Distribution

During the 1980s and 1990s, the shrimp biomass in the Norwegian Deep was larger than the biomass in Skagerrak (Fig. 9). This has changed from the first to the last time series (2006-2016), and the biomass in Skagerrak is presently estimated to be larger than in the Norwegian Deep. It is in particular the proportion of the survey biomass in stratum 2 in the northern part of the Norwegian Deep, which has decreased. In 1987 and 1998-1999, more than 30% of the total survey biomass was found in this stratum, compared with 3-6% in 2006-2016 (Fig. 9). As the distribution of shrimp changes with the time of year, it cannot be ruled out that the decrease is due to the shift in the timing of the survey, from October/November to January/February. Seasonal shifts in shrimp distribution documented in recent years by positions of trawl hauls of commercial fishing vessels in logbooks (Søvik and Thangstad 2016), seem to take place from deeper to shallower parts of the trench, not over larger areas. Another plausible explanation is that the declining shrimp stock has contracted into the southern part of the Norwegian Deep and Skagerrak. This explanation is supported by the decrease in biomass in stratum 2, and to some extent in stratum 4.

The depth distribution of shrimp differs between the Norwegian Deep and Skagerrak (Fig. 10). In the former area, the largest proportion of the biomass is found in strata covering depths between 200 and 300 m and very little shrimp biomass is found in the shallowest strata 1 and 5 (100-200 m). The exception was one trawl station with a large catch in 2016 in stratum 5. In Skagerrak, on the other hand, the biomass is more or less equally distributed between the depth strata of 100-200 m, 200-300 m, and 300-500 m. The pattern is the same for both the October/November time series and the recent time series in January/February.

Size and age

The model analysis of the 2016-data gave three age groups in Skagerrak and three in the Norwegian Deep (Table 6, Fig. 11). The bulk of the shrimp biomass in 2016 consist of shrimp larger than 16 mm CL (Fig. 11). Length frequency distributions for the years 2006-2016 show that in most years in the whole Skagerrak/Norwegian Deep area there are two clearly identifiable age groups (the 1-group and 2-group) as well as a 3+-group (Fig. 12a). In the length frequency distributions from earlier years (1984-2002) often four age groups are identifiable (0-, 1-, and 2-groups as well as a 3+ group) (Fig. 12b). Numbers per age group back to 1984 are given in Table 7a and b.

In Skagerrak, recruitment (1-group) declined from 2007 to 2010, increased in 2011 and 2012, but declined again in 2013 (Fig. 13). In 2014, the recruitment increased to the highest level observed in this recent time series. The 2015-value was again low, and the 2016-value is the second lowest in the time series. In the Norwegian Deep in 2006-2009 and in 2011-2014, recruitment was very low compared with Skagerrak (Fig. 13). In 2010, 2015 and 2016, recruitment was of equally low size in the two areas. Recruitment in the Norwegian Deep seems to be constantly very low. The much larger abundance of 1-year old shrimp in Skagerrak compared with the Norwegian Deep indicates that these waters constitute a nursery area for the stock. The generally low recruitment since 2008 has probably been the main reason behind the low stock size in recent years. It is not known why recruitment has been so low. The large 1-group in 2014 (the 2013 year class) entered the fishery in autumn 2014 and was thought to give good catches of 3-year olds in 2016. Whether we for some reason did not catch them in the survey, or whether a large proportion of this year class was discarded as 1- and 2-year olds is hard to know. Good catches of large, old shrimp three years after recruitment peaks were observed in the surveys in 2007-2009 (Table 7b). The 2013-year class is, however,

seen in the length frequency distribution of catches from the first two quarters of 2016 (Søvik and Thangstad 2016).

SSB decreased from 2008 to 2012 and then stabilized at a low level until 2013 (Fig. 14a). In 2015, the SSB-value increased sharply due to the high abundance of 2-year old shrimp (Table 7b), many of which are berried females. In 2016, the SSB decreased (Søvik and Johnsen 2016). There seems to be no relationship between SSB and recruitment (1-year old shrimp) (Fig. 14b).

Predator abundance

Mean catch per trawl haul (kg/nm) in 2016 is given for potential shrimp predators (Table 8). Saithe was the most abundant species, with an average catch of 6.9 kg/nm, but the average saithe catch has decreased compared with previous years. Blue whiting was the second most abundant species with an average catch of 6.3 kg/nm. Cod and whiting were the third and fourth most abundant species. The mean total index of shrimp predator biomass was estimated to 27.0 kg/nm in 2016, which is a large decrease from 2015 and the second lowest value in the time series back to 2006 (Table 8). Results from the first survey series (1984-2002) range from 28.6 to 63.1 kg/nm (ICES 2004), while in 2004-2005 the abundances were respectively 58.1 and 115.4 kg/nm (ICES 2006).

The index of total predator biomass was earlier heavily influenced by the indices for saithe and roundnose grenadier, and in 2013, also by the blue whiting index, which increased tenfold from 2012 to 2013. Some shallow trawl stations yield large catches of saithe, while roundnose grenadier is caught mainly in the deep parts of Skagerrak. Thus, the value of these two indices depends largely on the number of shallow and deep stations covered each year. The deep stations were trawled in 2016, but the catches of roundnose grenadier were very small (index of 0.3 kg/nm). Recruitment to this stock has been low for many years. A predator index excluding saithe and roundnose grenadier shows less inter-annual variation (Table 8).

The index without these species varied without a trend from 2007 to 2015. There is however, a decrease from 2014 to 2016 (Fig. 15). This is not in line with increasing trends in stock size observed in recent stock assessments of demersal fish species in the North Sea and Skagerrak (ICES 2016ab).

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Table 1. The estimated biomass available to the trawl (Ktons) and abundance (millions) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2016. Depth intervals are given in meter, and stratum area in nm^2. SE is the standard error.

Stratum	Depth (m)	Area (nm^2)	Hauls	Biomass	SE	Abund.	SE
1	100-200	1 245					
2	200-300	2 500	8	0.17	0.13	38	29
3	100-200	277					
4	200-300	1 560	6	0.39	0.19	57	39
5	100-200	1 401	8	0.84	0.75	202	180
6	200-300	1 159	7	0.18	0.06	43	16
7	300-500	555	3	0.07	0.03	12	6
8	100-200	136					
9	200-300	590	7	0.24	0.09	39	14
10	300-500	541	4	0.05	0.01	8	2
11	100-200	367	4	0.34	0.24	92	73
12	200-300	254	9	0.09	0.02	24	7
13	300-500	739	5	0.20	0.08	53	25
14	100-200	1 411	14	0.49	0.25	98	50
15	200-300	739	18	0.45	0.12	119	42
16	300-500	1 138	10	0.21	0.08	55	22
17	> 500	1 137	2	0.01	0.01	3	2
Total		15 749	105	3.73	0.88	843	214

Table 2. Annual mean towing speed with standard deviation (SD), 2006-2016.

	mean	SD
2006	2.52	0.24
2007	3.01	0.19
2008	3.05	0.38
2009	2.87	0.30
2010	2.85	0.20
2011	2.90	0.22
2012	2.93	0.23
2013	2.47	0.50
2014	2.18	0.52
2015	2.34	0.48
2016	2.49	0.49

Table 3. Average temperature (°C) and salinity (‰) (with standard deviation) for all trawl hauls (with available CTD data) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2016. The 2012 data result from only 22 CTD casts (8 in the Norwegian Deep and 14 in Skagerrak) due to difficulties with the CTD-winch.

Norwegian Deep				
	Temperature (°C)		Salinity (‰)	
	mean	SD	mean	SD
2006	7.40	0.58	35.25	0.02
2007	7.90	0.50	35.20	0.07
2008	7.58	0.35	35.18	0.06
2009	7.43	0.32	35.26	0.04
2010	7.30	0.55	35.16	0.05
2011	6.61	0.47	35.15	0.04
2012	7.84	0.75	35.18	0.03
2013	7.48	0.35	35.21	0.06
2014	7.05	0.54	35.17	0.04
2015	7.27	0.49	35.10	0.09
2016	8.24	0.37	35.22	0.06

Skagerrak				
	Temperature (°C)		Salinity (‰)	
	mean	SD	mean	SD
2006	7.01	0.65	35.13	0.10
2007	7.30	0.80	35.17	0.07
2008	7.03	0.36	34.88	0.31
2009	7.13	0.57	35.11	0.22
2010	7.47	0.46	35.16	0.28
2011	5.44	0.68	34.86	0.21
2012	7.28	0.64	35.01	0.22
2013	7.48	0.47	35.19	0.08
2014	7.29	0.71	35.07	0.14
2015	7.24	0.41	34.97	0.19
2016	7.75	0.57	35.11	0.17

Table 4. Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2016: average door spread with standard deviation (SD), regression coefficient from the linear regression line, and R^2.

	mean	SD	regression coefficient	R^2
2006	52.9	4.4	0.025	0.14
2007	51.6	1.8	0.014	0.31
2008	47.0	1.7	-0.004	0.05
2009	45.3	3.2	-0.012	0.10
2010	46.9	2.2	0.001	0.00
2011	47.7	2.2	-0.005	0.04
2012	47.5	3.0	-0.001	0.00
2013	51.1	1.5	-0.001	0.00
2014	48.7	1.3	-0.002	0.01
2015	51.1	3.5	0.015	0.18
2016	49.7	2.4	0.015	0.29

Table 5. Estimated biomass (t) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by year and stratum 1984-2015. Strata 1-10 are in the Norwegian Deep, while strata 11-17 are in Skagerrak (see Fig. 1). Values from the different survey time series are not comparable (see text). SE is the standard error.

Survey		Stratum																	Total area	
Year	Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Index	SE
1984	1	0	3480	-	1430	4210	2090	570	-	510	250	290	[1]530	1010	1050	1060	1060	[1]57	17597	3217
1985	1	0	5630	-	1280	2100	2440	1270	180	990	1340	410	600	1370	2690	3110	1750	0	25180	3137
1986	1	0	3120	-	280	90	1870	530	-	[1]503	370	0	400	1180	1590	1140	440	0	11513	1799
1987	1	0	6050	-	1690	1680	2590	670	0	1160	550	290	430	550	1670	750	750	0	18830	3193
1988	1	0	1420	-	620	440	890	400	0	280	410	410	260	410	500	500	300	0	6830	956
1989	1	-	1280	-	2010	0	1520	540	-	510	500	410	360	780	920	1220	570	0	10640	1324
1990	1	0	1620	-	1840	0	1980	300	0	1060	380	510	650	700	1290	1240	1120	0	12700	1750
1991	1	0	3160	-	3390	60	1890	450	-	1200	350	660	530	980	2180	1650	1820	90	18400	2409
1992	1	0	2910	-	620	940	4790	1440	290	490	1190	1920	550	1220	2010	1980	970	0	21340	2928
1993	1	0	1320	-	3010	180	1570	550	-	1050	270	2080	560	1310	1710	2650	1300	240	17770	2054
1994	1	0	2710	-	2060	380	2610	840	-	770	360	1450	740	1300	2130	1550	1590	10	18500	1586
1995	1	0	3530	-	1070	180	2840	740	360	1010	230	1460	400	800	2240	1780	930	0	17590	1732
1996	1	0	4950	-	1280	140	3060	1640	-	730	330	3630	1300	1350	2470	1880	1180	200	24150	2498
1997	1	0	8820	-	2080	520	2900	1720	280	1020	630	2420	840	1470	3220	2090	3230	800	32020	2771
1998	1	0	6860	-	2010	530	1830	610	-	910	730	680	500	720	1660	2090	1060	0	20190	2057
1999	1	0	5830	-	2430	230	1580	410	-	760	230	1130	580	620	2160	1540	290	0	17790	1915
2000	1	0	4250	-	3000	510	1720	420	290	270	290	800	330	180	2220	2160	980	0	17400	1957
2001	1	1230	5460	-	4810	1790	2330	700	-	350	470	350	170	520	3440	1770	1180	0	24560	2837
2002	1	0	[1]5187	-	[1]2857	160	1590	1160	-	1560	660	1110	580	490	3600	3670	2190	0	24815	1937
2003	2	-	-	-	1410	750	2770	840	300	1240	430	480	770	960	2210	1950	850	-	14960	
2004	3	-	4000	-	3230	0	2940	990	-	940	650	570	1300	1250	8840	3780	3570	350	32400	3570
2005	3	0	5480	-	3150	0	2570	1730	-	1540	870	900	640	1140	3200	2180	3760	0	27150	3028
2006	4	-	2920	-	2010	[2]118	2110	[2]1188	-	380	130	870	900	1910	2730	2050	2130	[2]92	19538	2303
2007	4	-	3500	-	1620	120	2980	740	-	1250	1050	2040	1320	6860	1380	2140	12470	0	37470	8055

2008	4	20	2910	-	1210	290	2550	1230	-	650	160	780	1480	3980	1200	570	2420	40	19500	2539
2009	4	0	1840	-	680	190	3400	220	-	410	70	520	1660	1270	800	2060	1680	70	14860	2208
2010	4	0	1620	-	580	30	1230	1290	-	590	500	200	400	640	660	890	1450	30	10100	1733
2011	4	0	520	-	760	20	1930	600	40	470	690	310	320	500	690	880	720	160	8620	1069
2012	4	-	[2)]651	-	300	10	1070	140	-	260	40	310	390	1280	390	490	820	10	6161	897
2013	4	40	330	-	780	0	880	490	-	370	450	460	340	910	440	650	860	0	7000	838
2014	4	0	180	-	800	0	240	[2)]539	-	150	[2)]346	430	530	1350	540	990	2720	40	8855	1582
2015	4	-	[2)]1481	-	2460	90	590	420	-	1200	260	620	530	2180	210	260	720	2990	14010	3280
2016	4	-	170	-	390	840	180	70	-	240	50	340	90	200	490	450	210	10	3730	881

1) estimated as the stratum's mean portion of total biomass (averaged over 1985, 1987-2001) applied to the total biomass of the year.
2) estimated as the stratum's mean portion of total biomass (averaged over 2007-2011, and 2013) applied to the total biomass of the year. Not updated with 2016-data.

Table 6. Mean carapace length (CL) with standard deviation (SD), abundance (millions) and proportion of age groups from the 2016 survey length frequency distribution in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).

Skagerrak				
age	CL (mm)	SD	abundance	proportion
1	11.19	1.13	147	0.32
2	16.92	1.19	193	0.42
3	20.42	1.34	103	0.23
4+	23.44	1.72	13	0.03

Norwegian Deep				
age	CL (mm)	SD	abundance	proportion
1	10.12	1.26	78	0.18
2	16.45	1.53	186	0.42
3+	20.44	2.53	176	0.40

Total				
age	CL (mm)	SD	abundance	proportion
1	10.95	1.38	233	0.26
2	16.76	1.43	384	0.43
3+	20.74	2.24	275	0.31

Table 7a. Numbers per age group in the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 1984-2002 (October/November).

	0-group	1-group	2-group	3-group
1984	273	2324	576	599
1985	197	2869	1536	402
1986	100	849	767	9
1987	75	1955	1435	571
1988	196	401	530	12
1989	816	1613	616	
1990	320	1882	602	139
1991	150	2210	1049	250
1992	2038	2133	1127	122
1993	356	2681	945	7
1994	212	1518	1347	209
1995	164	1322	673	985
1996	642	2270	973	918
1997	187	3228	2337	366
1998	249	1912	1205	
1999	254	1769	370	992
2000	561	2152	1007	181
2001	483	2463	1879	
2002	338	2349	839	172

Table 7b. Numbers per age group in the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2006-2016 (January/February).

	1-group	2-group	3-group	4-group
2006	1806	2297	592	
2007	1795	7293	1361	
2008	705	1750	1160	629
2009	425	1485	1087	
2010	155	1345	256	
2011	330	779	559	
2012	830	696	103	
2013	663	1029	309	
2014	2261	774	360	
2015	346	2125	491	268
2016	233	384	275	

Table 8. Index of predator biomass (mean catch in kg per towed nm) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2016.

Species		biomass index											
English	Latin	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	mean
Blue whiting	*Micromesistius poutassou*	0.13	0.13	0.12	1.21	0.27	0.62	3.30	29.03	1.88	5.25	6.26	
Saithe	*Pollachius virens*	7.33	39.75	208.32	53.89	18.53	7.52	5.66	112.80	14.13	8.56	6.93	
Cod	*Gadus morhua*	0.51	1.28	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	2.74	
Roundnosed grenadier	*Coryphaenoides rupestris*	3.22	6.85	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	0.3	
Rabbitfish	*Chimaera monstrosa*	2.24	2.15	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	1.7	
Haddock	*Melanogrammus aeglefinus*	0.97	4.21	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	1.66	
Redfish	Scorpaenidae	0.18	0.40	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	0.25	
Velvet belly	*Etmopterus spinax*	1.31	2.58	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	1.2	
Skates, rays	Rajidae	0.41	0.95	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	0.35	
Long rough dab	*Hippoglossoides platessoides*	0.22	0.64	0.42	0.28	0.47	0.51	0.56	0.56	1.17	1.45	0.52	
Hake	*Merluccius merluccius*	0.98	0.78	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	1.07	
Angler	*Lophius piscatorius*	0.15	0.91	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	0.9	
Witch	*Glyptocephalus cynoglossus*	0.24	0.74	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	0.28	
Dogfish	*Squalus acanthias*	0.31	0.19	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	0.24	
Black-mouthed dogfish	*Galeus melastomus*	0.00	0.05	0.05	0.15	0.09	0.09	0.09	0.12	0.11	0.35	0.34	
Whiting	*Merlangius merlangus*	0.35	1.01	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	1.87	
Blue ling	*Molva dypterygia*	0	0	0	0	0	0	0	0.01	0.01	0.03	0	
Ling	*Molva molva*	0.04	0.11	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	0.18	
Four-bearded rockling	*Rhinonemus cimbrius*	0.06	0.14	0.04	0.03	0.05	0.03	0.09	0.04	0.06	0.12	0.05	
Cusk	*Brosme brosme*	0.20	0	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	0.01	
Halibut	*Hippoglossus hippoglossus*	0.08	0.07	3.88	0.09	0.20	0.05	0.19	0	0	0.10	0	
Pollack	*Pollachius pollachius*	0.06	0.25	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	0.08	
Greater forkbeard	*Phycis blennoides*	0	0	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	0.07	
Total		18.99	63.19	244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	27.00	72.77
Total (except saithe and roundnosed grenadier)		8.44	16.59	17.47	21.34	20.65	20.58	19.95	49.46	24.15	24.46	19.77	22.08

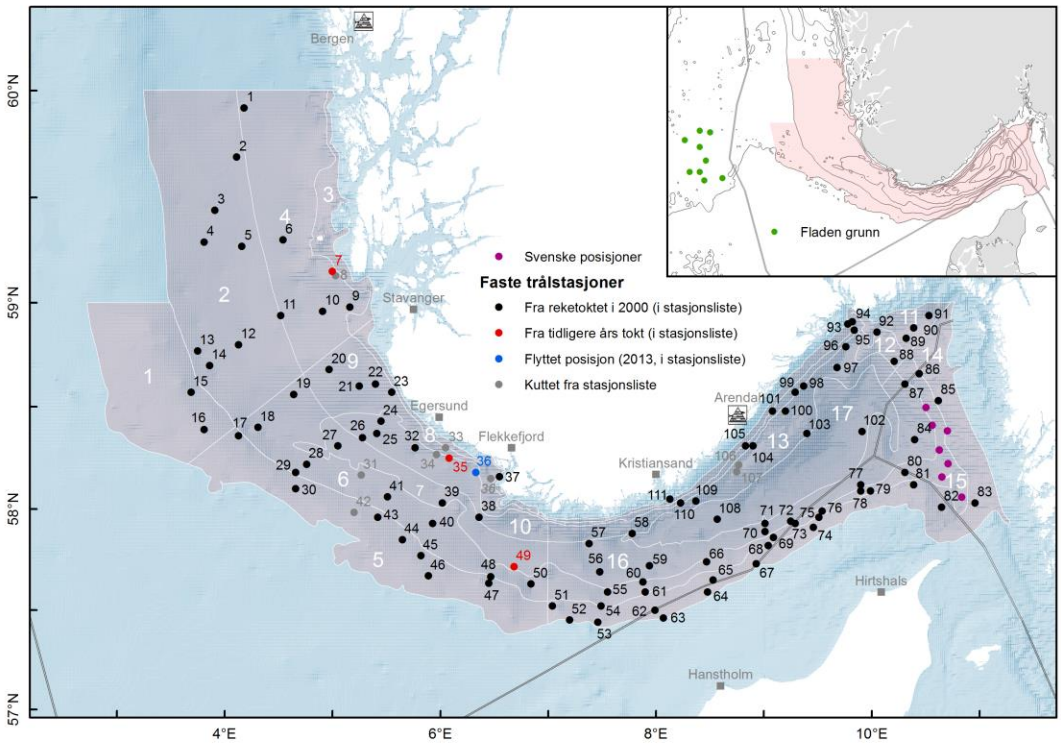

Fig. 1. Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east): the revised strata system (introduced in 2007 and adjusted in 2008) with the 104 fixed trawl stations. Trawl stations marked in red were introduced in 2008, the one marked in blue was introduced in 2013 while the ones marked in grey were deleted from the station list in 2013 (see text). Some new trawl stations in the Swedish EZZ (purple) were trawled in 2015 and 2016 on request from Swedish fishers. Trawl stations on Fladen Ground (from previous surveys in 1987-1994), although planned visited in 2016, were not trawled due to weather constraints. Strata areas are given in Table 1.

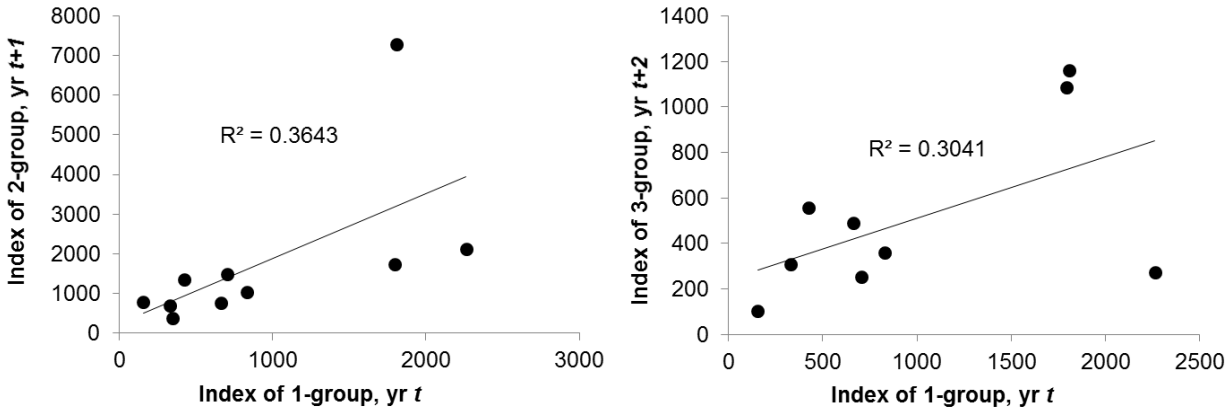

Fig. 2. Correlation between the index of 1-year old shrimp (indices are given in abundance in millions) in year *t* and the index of 2-year old shrimp in year *t*+1 (left); and correlation between the index of 1-year old shrimp in year *t* and the index of 3-year old shrimp in year *t*+2 (right), in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from January/February 2006-2016.

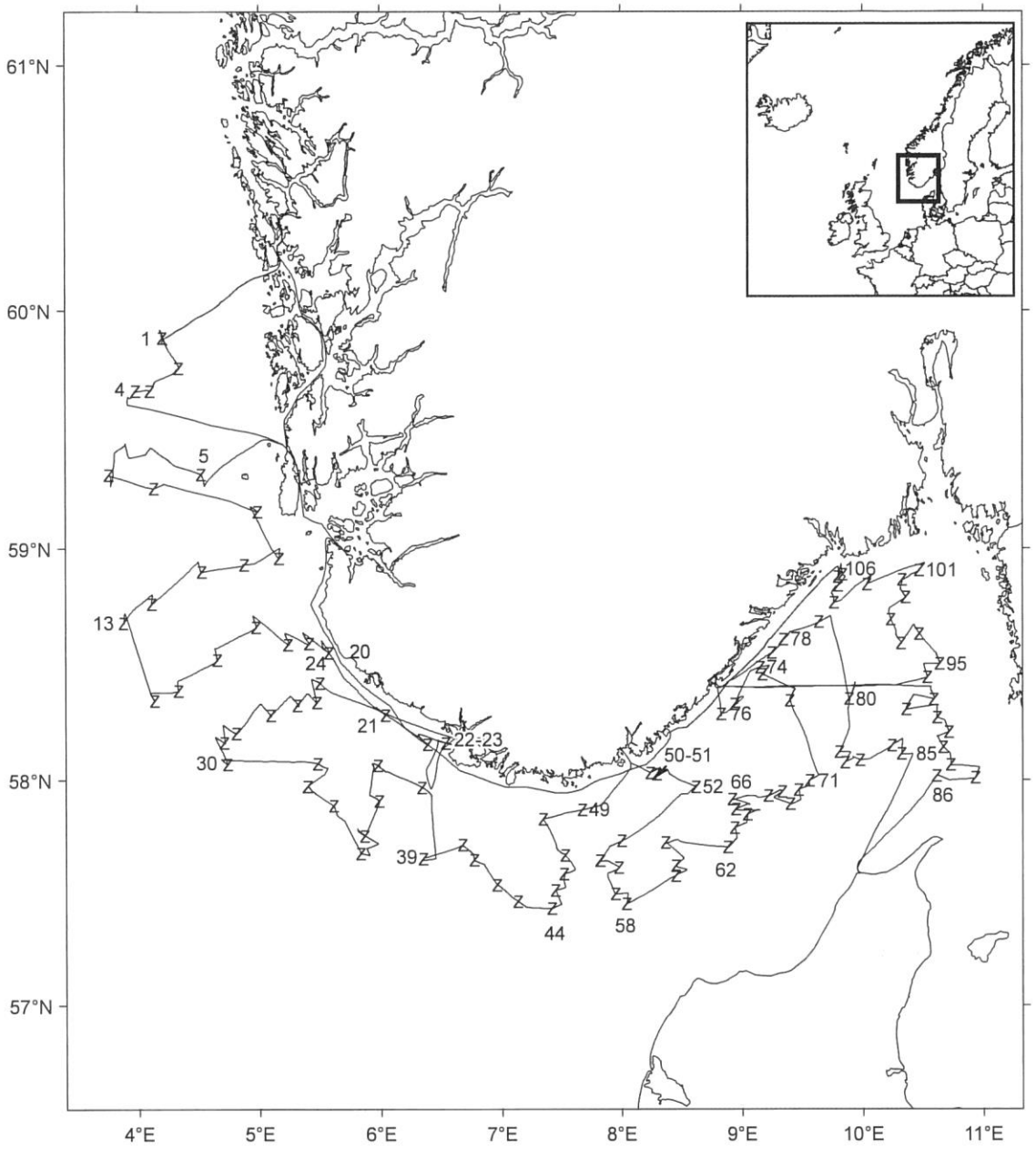

Fig. 3. CTD-stations (z) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January 2016.

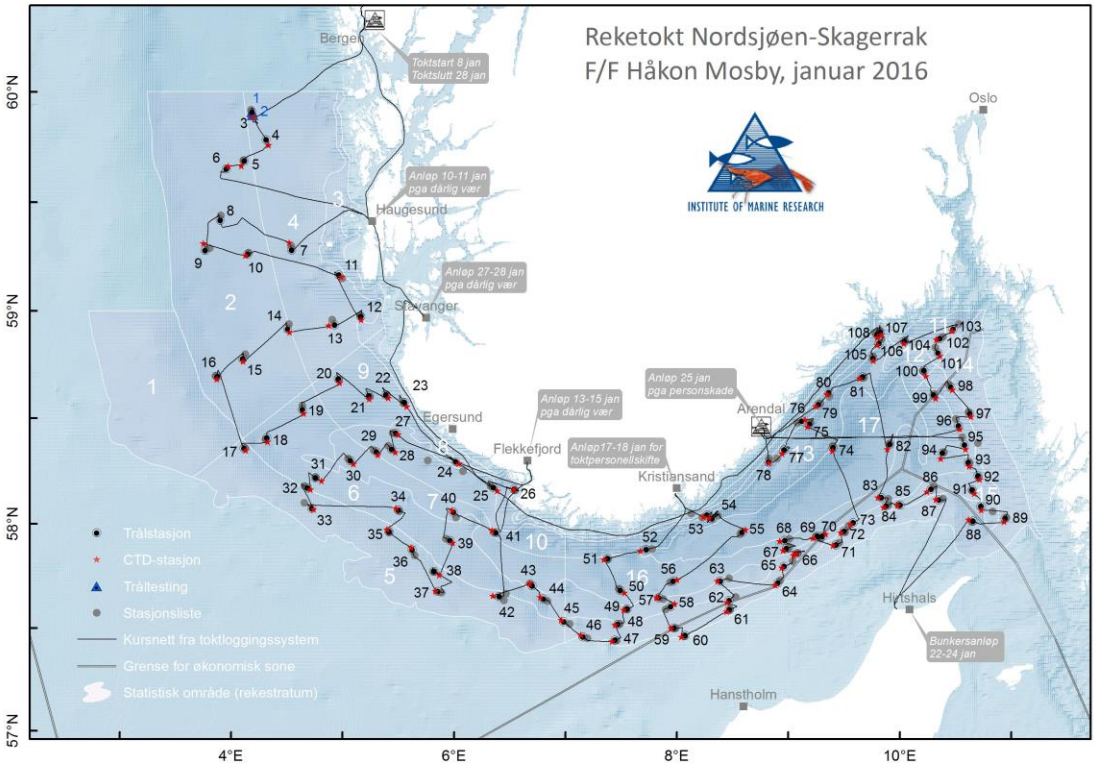

Fig. 4. The Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January 2016 with R/V *Håkon Mosby*: sailing route and trawled stations (●), CTD-stations (red star), and stations for testing of the trawl gear (numbers in blue). National EEZs are indicated on the map.

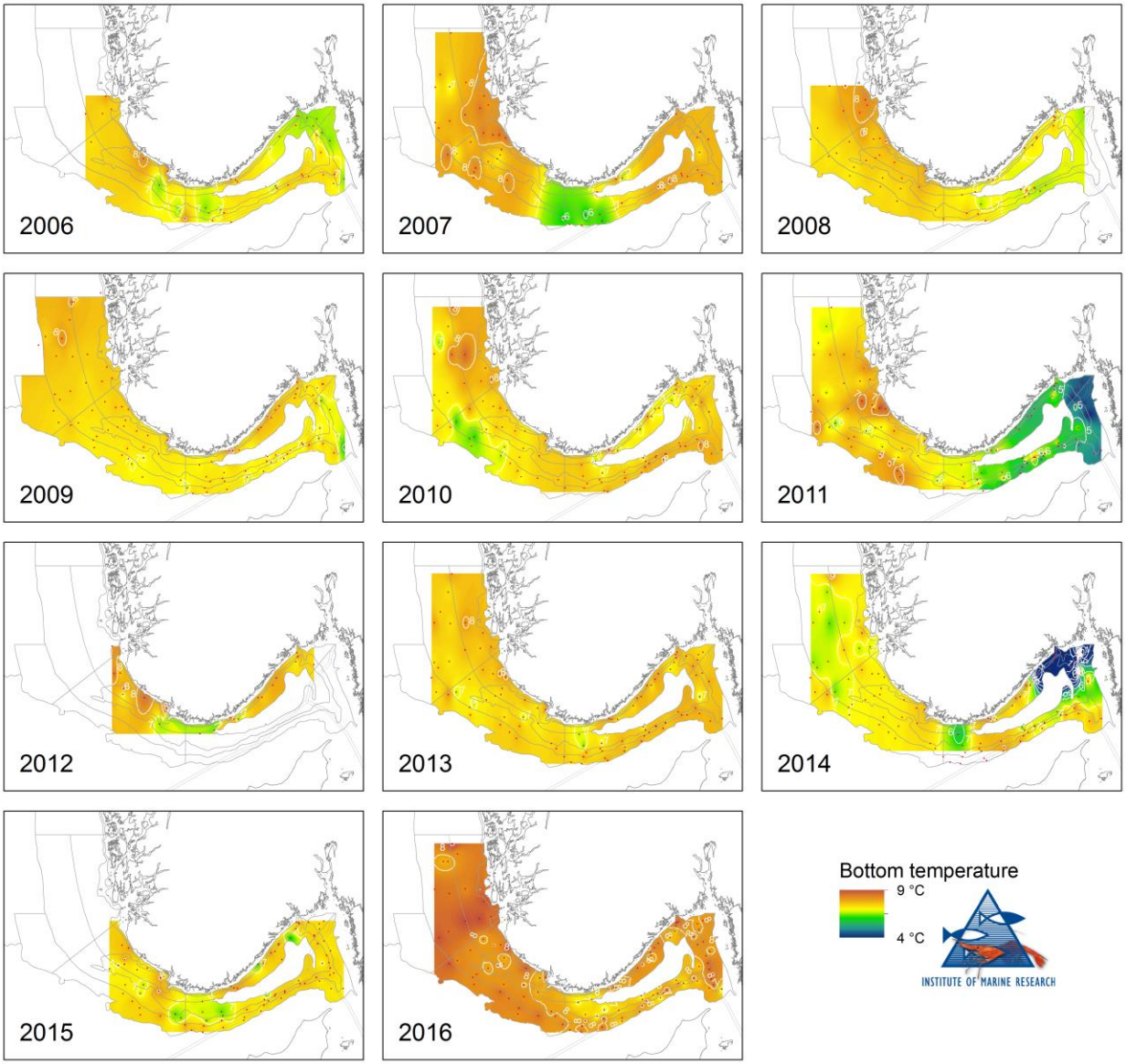

Fig. 5. Bottom temperatures (ºC) measured with CTD on fixed trawl stations from the Norwegian shrimp survey in 2006-2016 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).

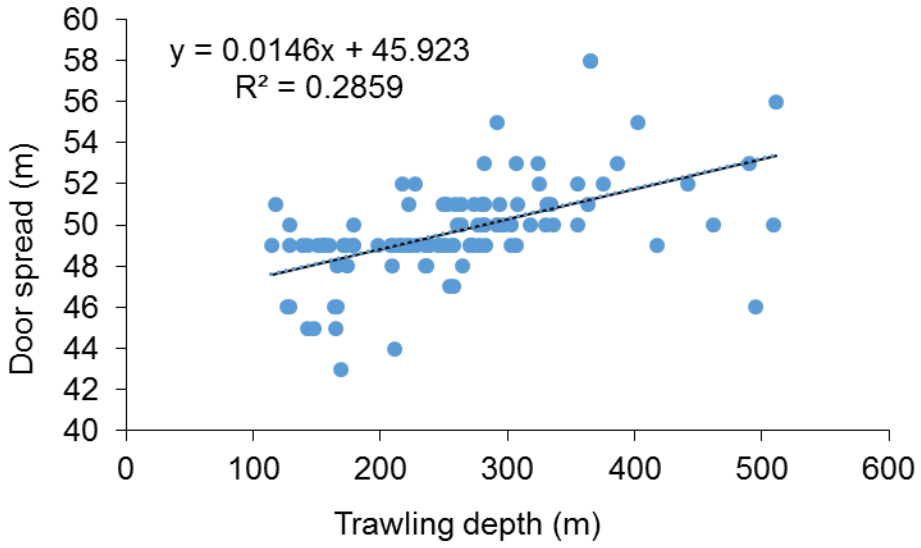

Fig. 6. Door spread (m) by trawling depth (m) for all valid trawl stations on the 2016 Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).

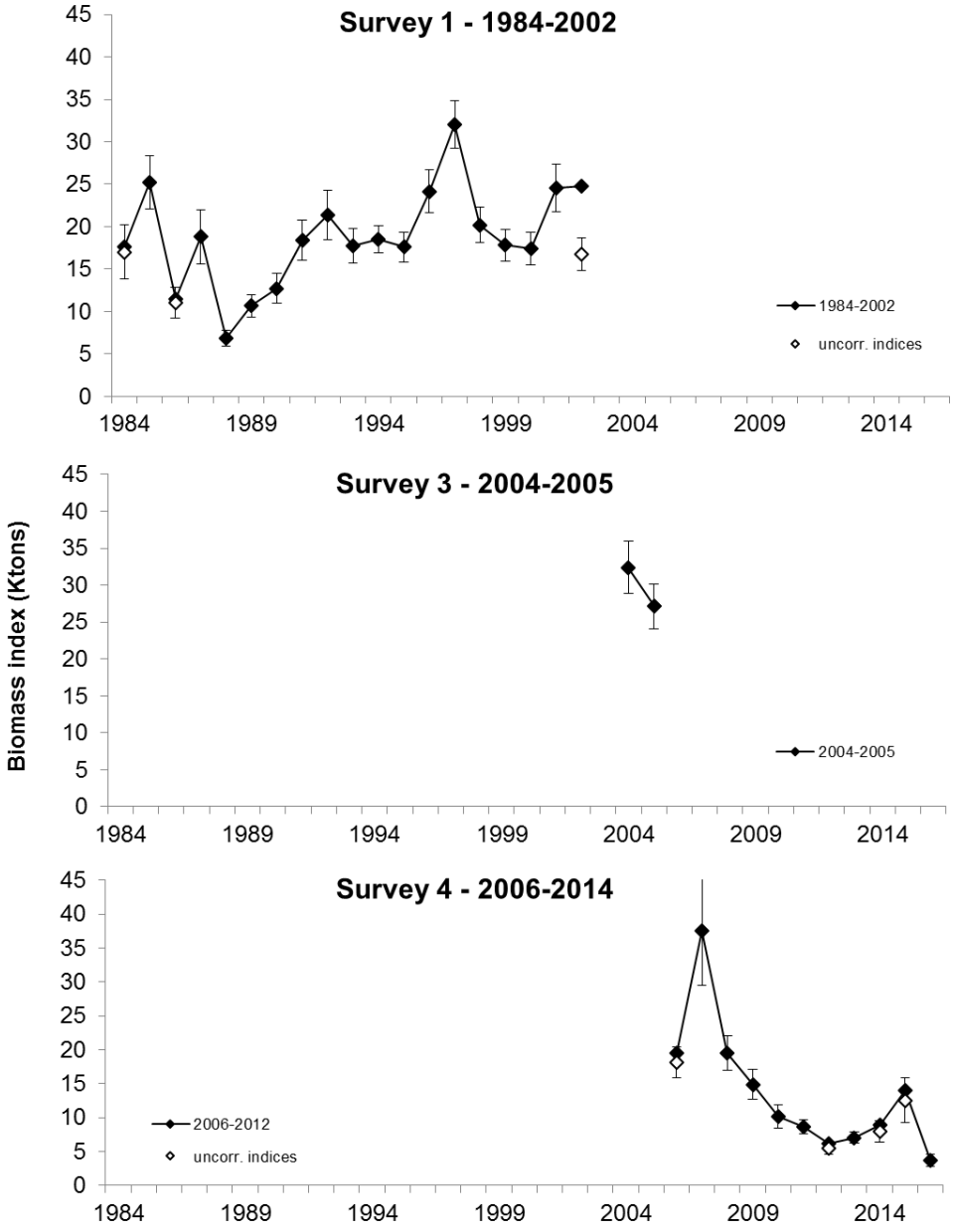

Fig. 7. Estimated total biomass index (with standard error) of shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 1984-2016. The 2003-value is not shown. Uncorrected values (◊) due to missing strata (see Table 5) are plotted.

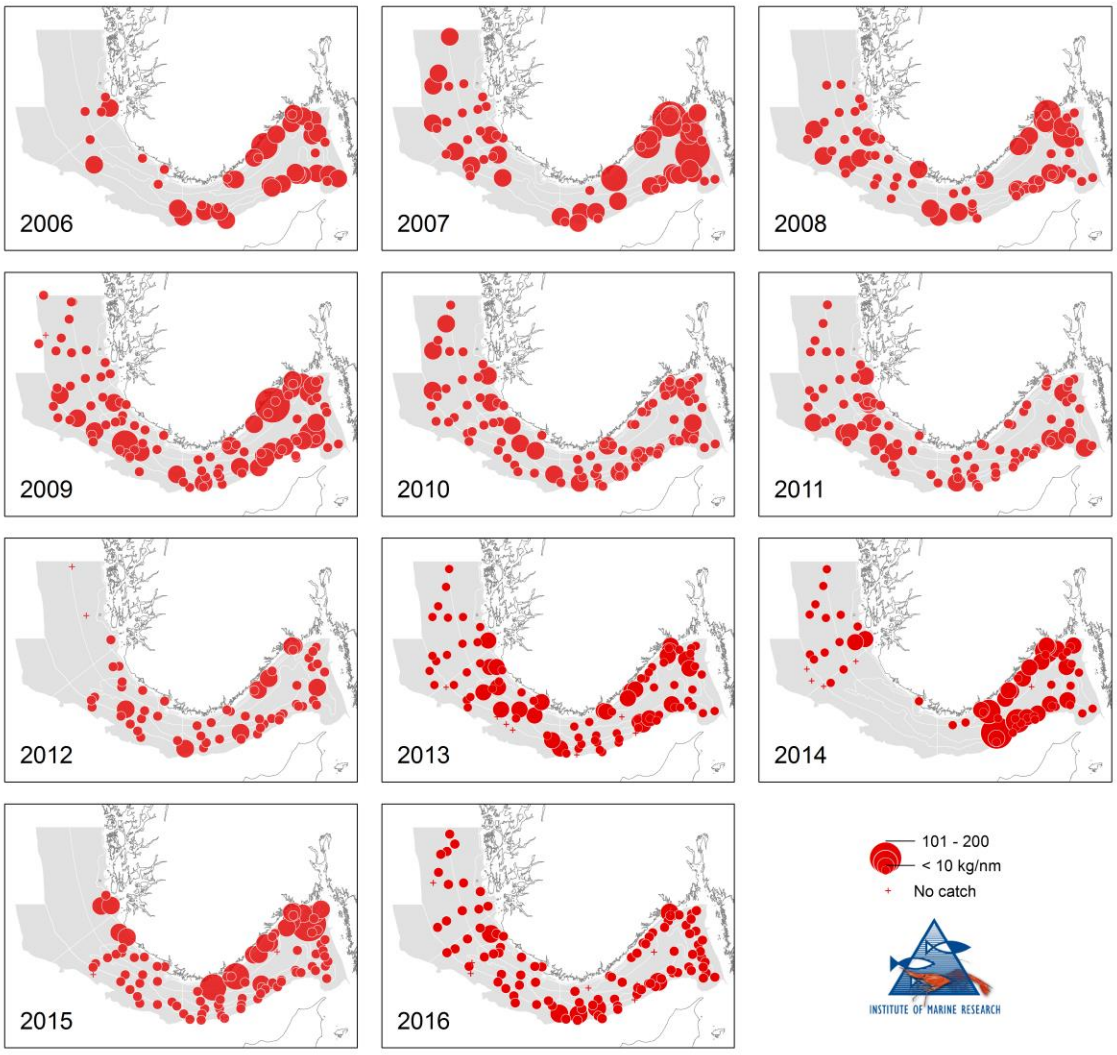

Fig. 8a. Shrimp catches per trawl station (kg/nm) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January/February 2006-2016.

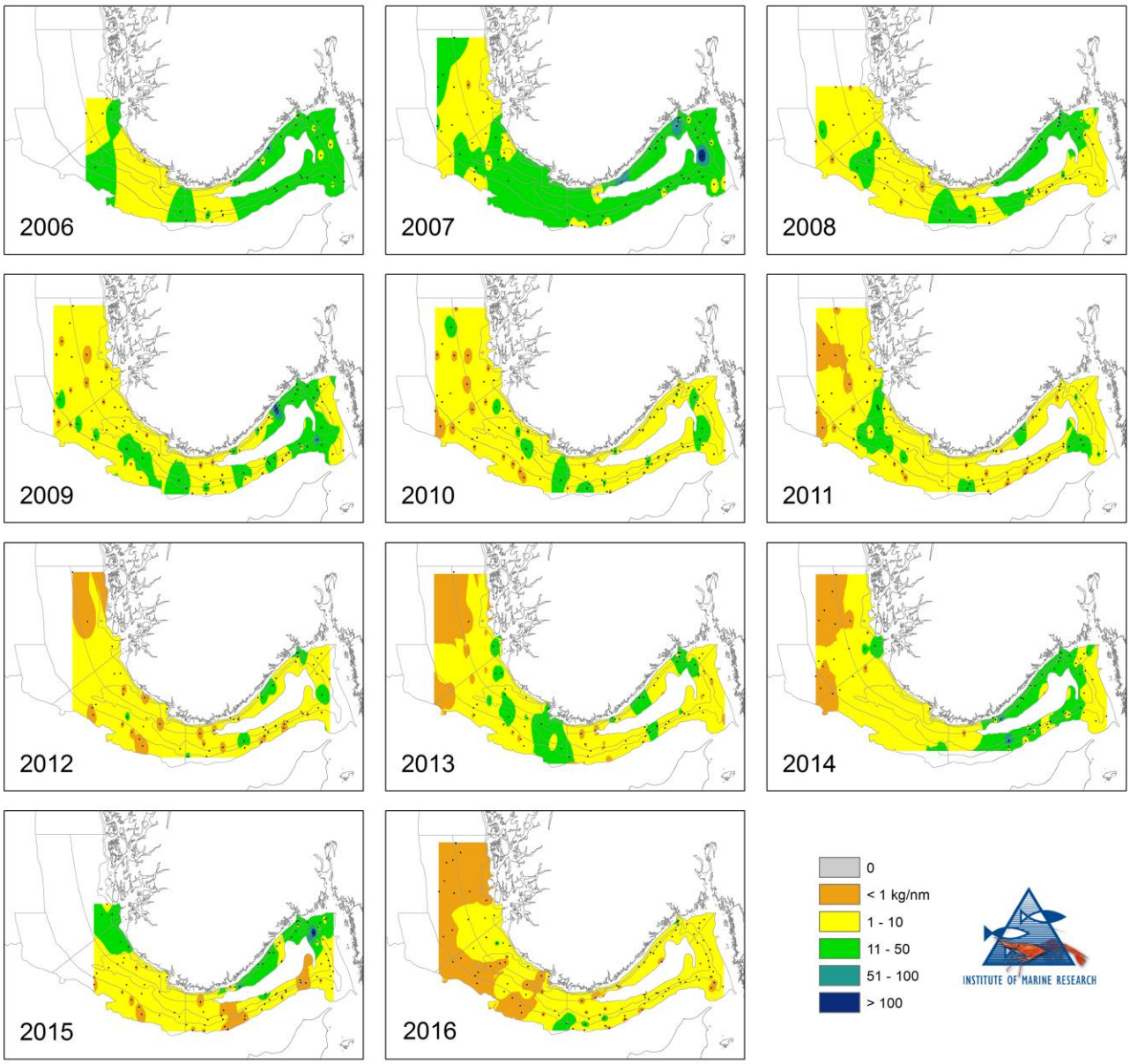

Fig. 8b. The distribution of shrimp biomass (kg/nm) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east Skagerrak and the Norwegian Deep) in January/February 2006-2016.

Fig. 9. The proportion of shrimp biomass per stratum from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in years when all survey strata have been covered, in the time period 1984-2016. Strata 1-10 are in the Norwegian Deep, and strata 11-17 are in Skagerrak (see Fig. 1).The vertical lines mark the different survey time series (1984-2002, 2004-2005, 2006-2016). The 2003-value is not shown.

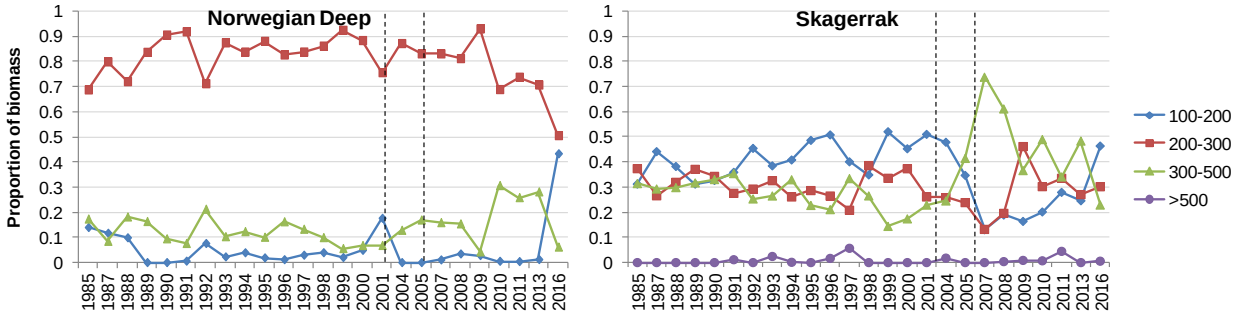

Fig. 10. The proportion of shrimp biomass per depth interval from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in years when all survey strata have been covered, in the time period 1984-2016. The vertical lines mark the different survey time series (1984-2002, 2004-2005, 2006-2016).

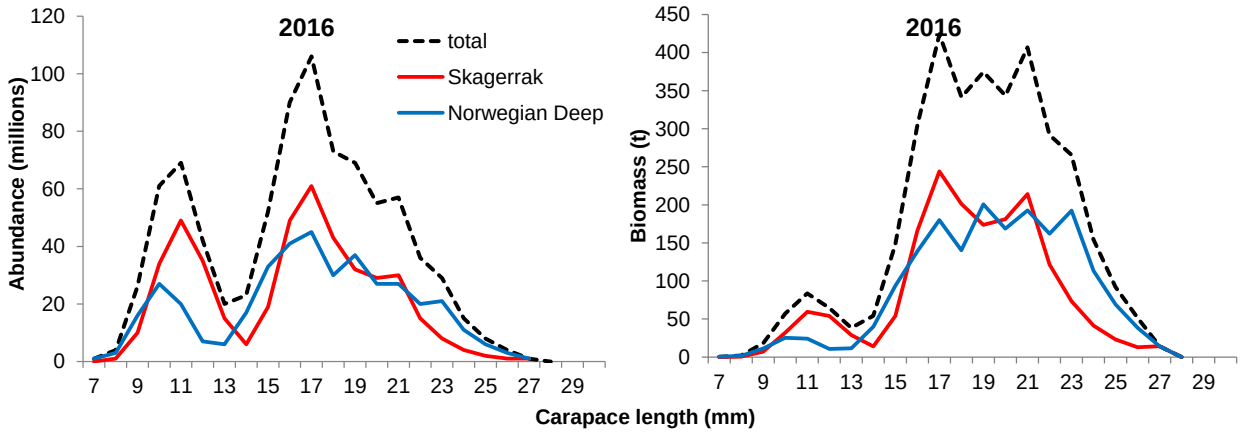

Fig. 11. Length frequency distributions (left) and biomass per length class (right) of the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by area and total, in 2016.

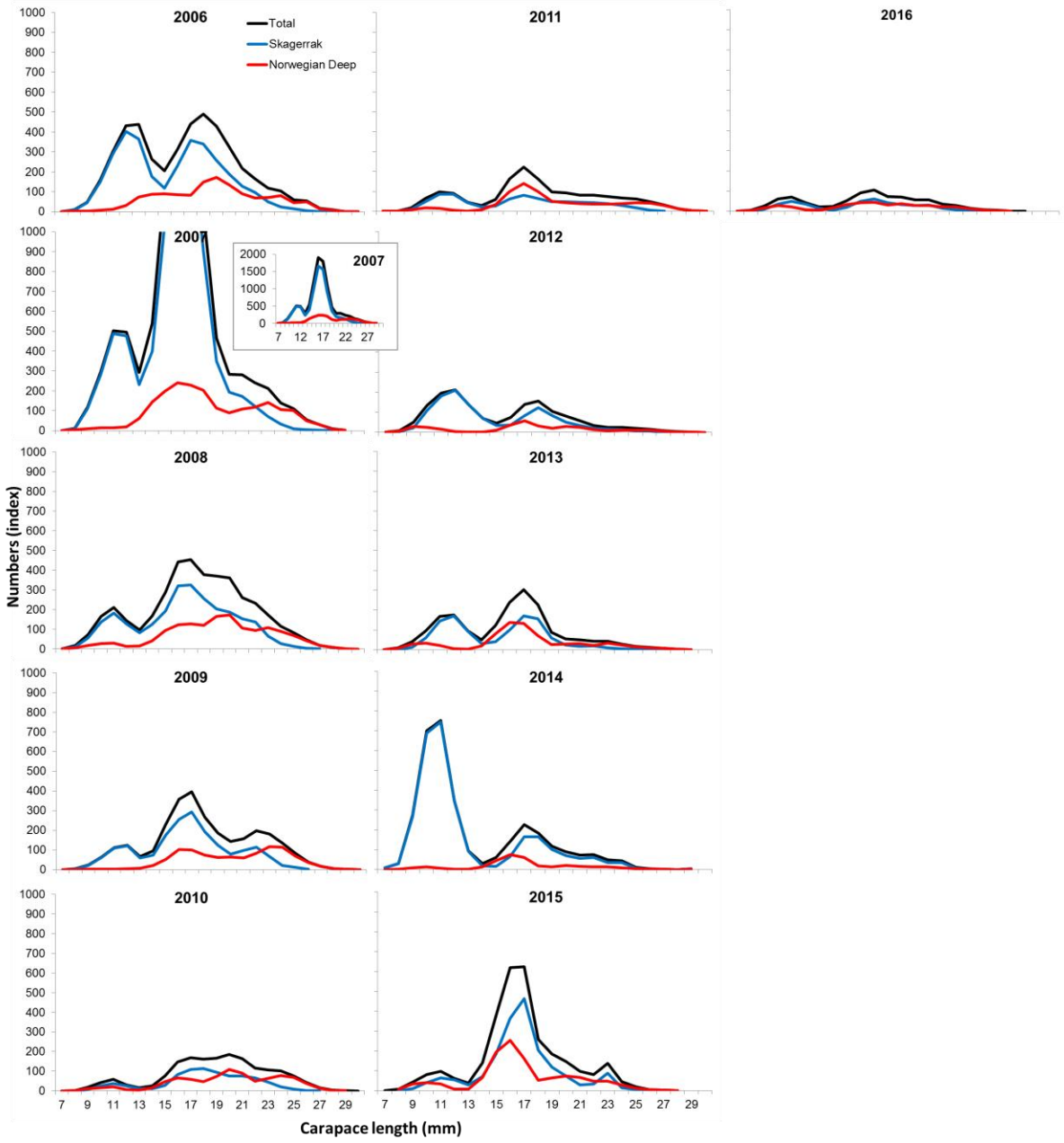

Fig. 12a. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by area and total, in 2006-2016.

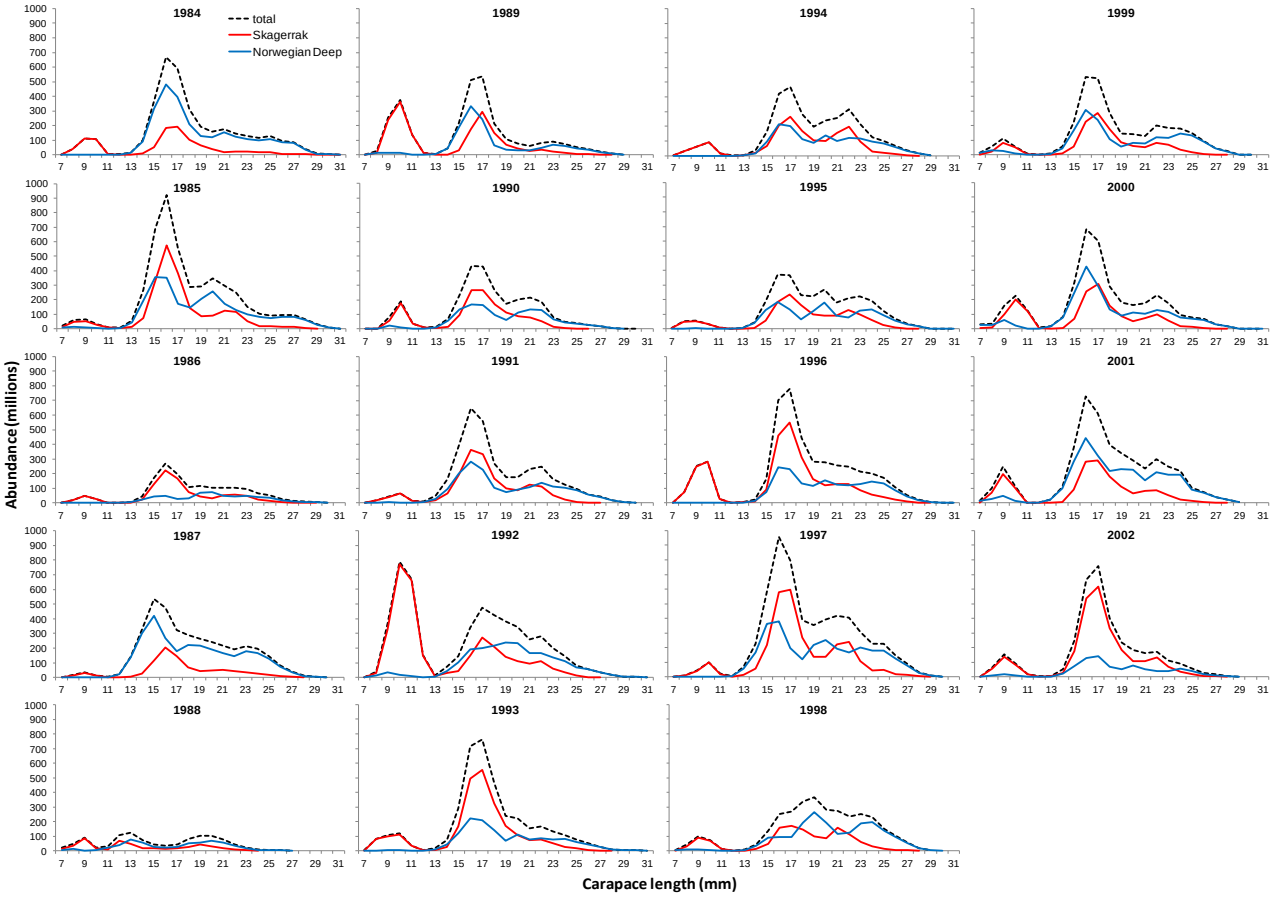

Fig. 12b. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 1984-2002.

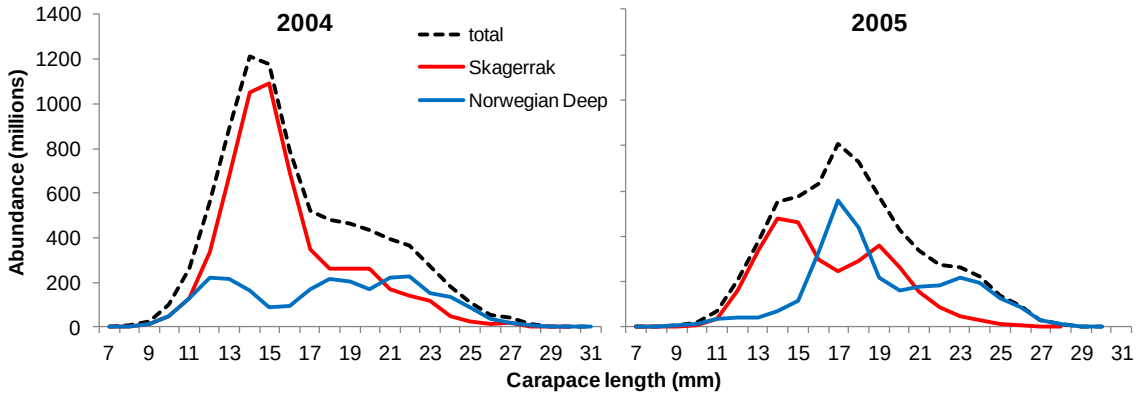

Fig. 12c. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2004-2005.

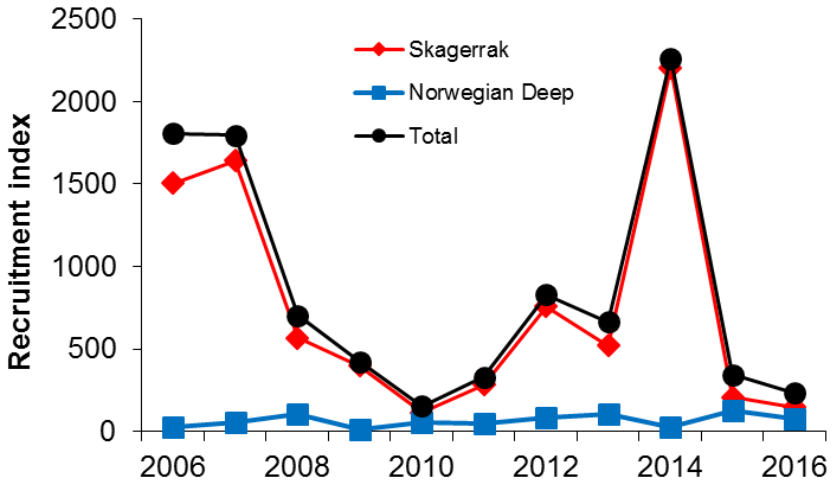

Fig. 13. Recruitment index (abundance in millions) of 1-year old shrimp in ICES Div. IIIa (Skagerrak), Div. IVa east (the Norwegian Deep), and in the overall area for 2006-2016. The higher number of 1-year old shrimp in the whole area in 2006 compared with Skagerrak, despite hardly any 1-year old shrimp in the Norwegian Deep, can be explained by the 1-groups in the two areas having different mean lengths. In the total area, shrimp < 15.5 mm are defined as 1-year old by the modal analysis, while the analysis put shrimp > 12 mm in the 2-group in the Norwegian Deep (see Fig. 12a).

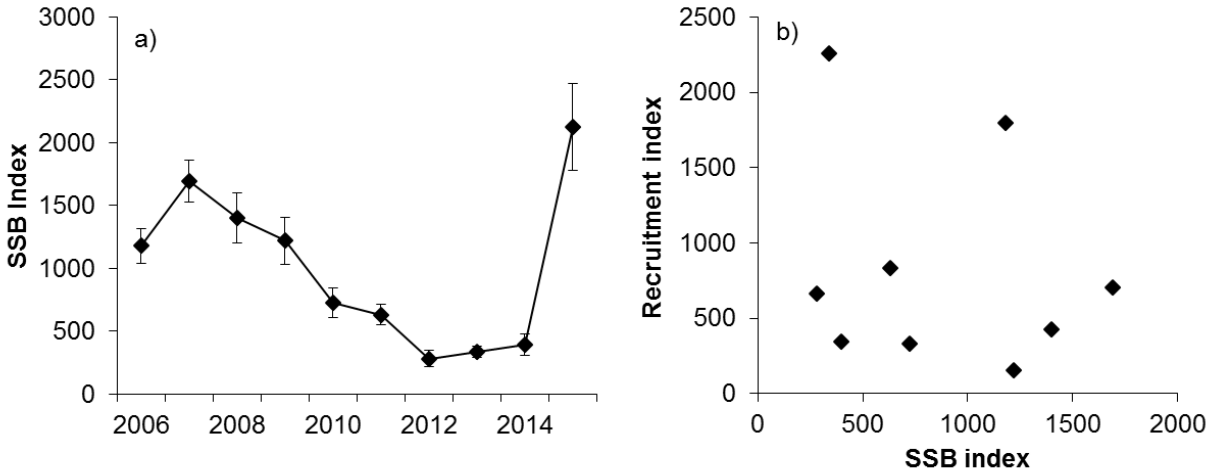

Fig. 14. a) SSB index (abundance in millions) in 2006-2015, and b) SSB-recruitment relationship 2006-2015 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). The figures were not updated in 2016 (see text).

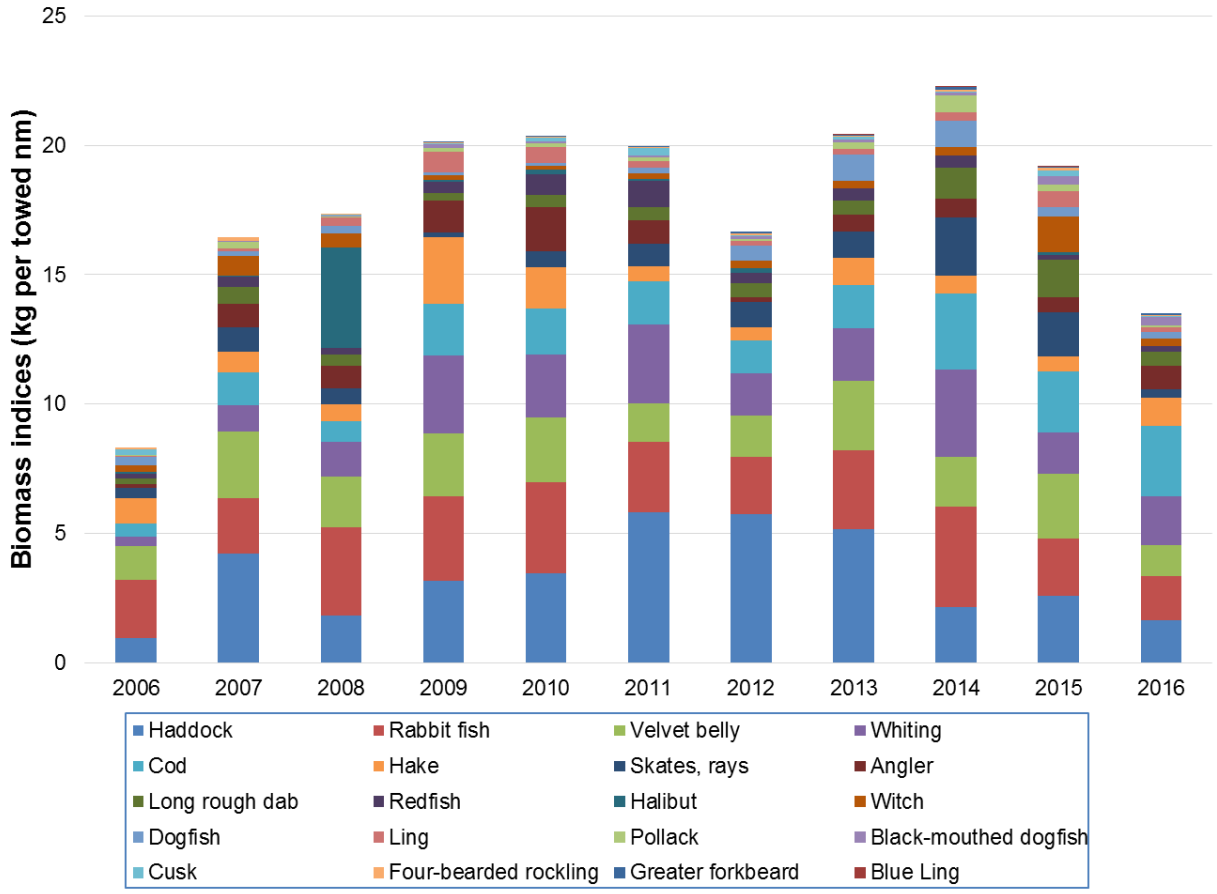

Fig. 15. Indices of demersal fish species (potential shrimp predators) (kg per towed nm) in 2006-2016 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), not including indices of saithe, roundnose grenadier and blue whiting (see text).