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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 2015

by

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Abstract

The Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) has gone through large changes. 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 annual survey biomass estimate fluctuated around a high level from the mid 1990s to 2002 when this 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, but has increased since.

Recruitment (abundance of 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, 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. The good 2014 recruitment indicates that the positive trend in the biomass will continue in the coming years.

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

The mean index-value of shrimp predator biomass was estimated to 34.5 kg/nm in 2015. This is a decrease compared with 2014, mainly due to a decrease in the saithe index. A predator index excluding saithe and roundnosed grenadier shows less interannual variation.

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 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 shrimp.

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 2015 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 far 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 nm² (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, resulting in a new list of 104 fixed stations (Fig. 1). Some new trawl stations in the Swedish EZZ were trawled in 2015 on request from Swedish fishers. The deepest and shallowest stations have depths of respectively 540 and 111 m. A coverage of one haul per 151 nm² is obtained when all 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 in general the former area that 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". The new rigging worked very well. 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. This rigging has been kept. 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. Tow speed is roughly 3 knots (Table 2), but in 2013-2015, the tow speed has been reduced compared with earlier years and the variation in tow speed between stations has increased. The skippers have not provided a satisfactory explanation for this change in towing speed. No compensation for diurnal vertical migration is made.

Stock size index

Biomass estimates are calculated using SAS (version 9.3). In 2012, biomass estimates (with SE) from the years 1984-2002 and 2004-2005 were recalculated using the same SAS-programme as has been used for calculating

the 2006-2015 estimates. 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 a stratum. From these samples the mean and standard error of the density in each stratum is 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 time series 1984-2002, and 2006-2015. 2) The total biomass for year t, B, is calculated as: B = (Σ biomasses 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 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 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 measurements truncated to the nearest mm below. The length frequency distributions are partitioned into age groups by modal analysis using the method of Bhattacharya (1967) (software: FISAT).

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 a good 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 (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-February.

Hydrographical measurements

In all present and past surveys CTD casts have been made 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 2015, CTD was taken on 88 out of 92 trawl stations (Fig. 3).

Results and discussion

Area coverage

In 2015, the survey was carried out from January 13 to February 3. Ninety-two out of the 104 fixed stations were covered (Fig. 4). There were technical problems with the trawl on three of these stations. Calculations were carried out using data from the remaining 89 valid stations. Due to many days with bad weather and strong winds the northernmost part of the Norwegian Deep was not covered by the survey. Two strata (1, 2) were not covered and stratum 4 was only poorly covered (strata 3 and 8 are hardly ever trawled (Table 5)). The northernmost stations of strata 5, 6, and 9 were also not trawled. This adds to the uncertainty of the 2015 biomass estimate.

Temperature and salinity

The bottom temperature in the survey area in January/February during the time span 2006-2015 has ranged between 6 and 8.5 °C (Fig. 5). This is in agreement with winter bottom temperature measurements from the area (December-March) in 1982-2002, which are in the range 5-9 °C (Schlüter and Jerosch 2009). The average survey temperature has lied between 7 and 8 °C, except in 2011 (Table 3). During the unusually cold winter 2009-2010 the area was cooled down which led to cold water sinking into the Norwegian Deep and Skagerrak basin in late winter 2010, replacing the warmer bottom water. The bottom water was still unusually cold in early 2011. The sparse 2012-CTD data indicated that the bottom temperature was back to the average level in January 2012. In 2015, mean bottom temperature was 7.24 and 7.27 in respectively Skagerrak and the Norwegian Deep.

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 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 on this year's survey. In 2013-2015, 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 in these three years (Table 2). In 2015, four tows with door spreads ≥ 61 m contributed to a positive relationship between door spread and depth (Table 4, Fig. 6). On two of these stations, technical problems during trawling operation caused the strepping-rope to be torn off. 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 particular trawl haul. From 2008, the biomass declined steadily to the recent time series' minimum in 2012. Since 2013, the biomass has been increasing (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). There are reasons to believe 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).

Trends in the survey time series follow trends in LPUE-indices closely (Ulmestrand et al. 2015). The Danish LPUE-series which started in 1987, also reached its minimum in 2012.

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 (2006-2015), and the biomass in Skagerrak is presently 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 2006-2015 (Fig. 10). 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 2015) seem to take place from deeper to shallower parts of the trench, not over larger areas. Another plausible explanation is that a shrinking shrimp stock contracts into the southern part of the Norwegian Deep and Skagerrak. This explanation is supported by the decrease in stratum 2.

Size and age

The model analysis of the 2015-data gave three age groups in Skagerrak and three in the Norwegian Deep (Table 6, Fig. 11). Length frequency distributions for the years 2006-2015 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 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 is again low. In the Norwegian Deep in 2006-2009 and in 2011-2014, recruitment was very low compared with Skagerrak (Fig. 13). In 2010 and 2015, 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 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 will likely imply good catches of large shrimp in 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 mature females with external roe. 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 2015 are given for the main shrimp predators (Table 8). Saithe was the most abundant species, with an average catch of 8.6 kg/nm. The mean total index of shrimp predator biomass was estimated to 34.5 kg/nm in 2015, which is below the mean of the series for 2006-2015 (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 predator biomass is 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, and consequently the total predator index, depends largely on the number of shallow and deep stations covered each year. A predator index excluding saithe and roundnose grenadier shows less inter-annual variation (Table 8). The shallow and deep stations have very low densities of shrimp. A more informative predator index should be based on only trawl stations with a certain minimum density of shrimp.

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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 2015. Depth intervals are given in meter, and stratum area in nm². SE is the standard error. The total values do not include estimated numbers for missing strata.

Stratum	Depth (m)	Area (nm^2)	Hauls	Biomass	SE	Abund.	SE
1	100-200	1 245					
2	200-300	2 500					
3	100-200	277					
4	200-300	1 560	3	2.46	0.98	606	247
5	100-200	1 401	7	0.09	0.05	29	19
6	200-300	1 159	5	0.59	0.19	116	34
7	300-500	555	2	0.42	0.14	98	34
8	100-200	136					
9	200-300	590	4	1.20	0.65	303	151
10	300-500	541	6	0.26	0.07	58	18
11	100-200	367	6	0.62	0.11	146	27
12	200-300	254	7	0.53	0.24	159	73
13	300-500	739	6	2.18	0.77	535	190
14	100-200	1 411	13	0.21	0.09	72	41
15	200-300	739	16	0.26	0.05	72	15
16	300-500	1 138	11	0.72	0.49	166	110
17	> 500	1 137	3	2.99	2.90	715	701
Total		15 749	89	12.53	3.28	3076	796

Table 2. Annual mean towing speed with standard deviation (SD), 2006-2015.

	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

Table 3. Average temperature (°C) and salinity (‰) (with standard deviation) over 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 2006-2015. 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

| | 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

Table 4. Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2015: 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

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. Values from the different survey time series are not comparable (see text). SE is the standard error.

Survey Year	Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total area 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

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.

Table 6. Mean carapace length (CL) with standard deviation (SD), abundance (millions) and proportion of age groups from the 2015 survey length frequency distribution in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).

		Skagerrak		
age	CL (mm)	SD	abundance	proportion
1	11.41	1.16	209	0.11
2	17.15	1.77	1551	0.81
3+	22.97	1.13	147	0.08

		Norwegian Deep		
age	CL (mm)	SD	abundance	proportion
1	10.00	1.01	124	0.09
2	15.99	1.10	748	0.56
3+	20.30	2.68	458	0.34

		Total		
age	CL (mm)	SD	abundance	proportion
1	11.07	1.35	346	0.11
2	16.27	1.25	2125	0.66
3	19.83	1.38	491	0.15
4+	23.23	1.47	268	0.08

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), 2006-2015 (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

Table 8. Index of predator biomass (catch in kg per towed nm) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2015.

| Species English	Latin	biomass index										mean
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Blue whiting	*Micromesistius poutassou*	0.13	0.13	0.12	1.21	0.27	0.62	3.30	29.03	1.88	5.25	
Saithe	*Pollachius virens*	7.33	39.75	208.32	53.89	18.53	7.52	5.66	112.80	14.13	8.56	
Cod	*Gadus morhua*	0.51	1.28	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	
Roundnosed Grenadier	*Coryphaenoides rupestris*	3.22	6.85	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	
Rabbit fish	*Chimaera monstrosa*	2.24	2.15	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	
Haddock	*Melanogrammus aeglefinus*	0.97	4.21	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	
Redfish	Scorpaenidae	0.18	0.40	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	
Velvet Belly	*Etmopterus spinax*	1.31	2.58	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	
Skates, Rays	Rajidae	0.41	0.95	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	
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	
Hake	*Merluccius merluccius*	0.98	0.78	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	
Angler	*Lophius piscatorius*	0.15	0.91	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	
Witch	*Glyptocephalus cynoglossus*	0.24	0.74	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	
Dogfish	*Squalus acanthias*	0.31	0.19	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	
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	
Whiting	*Merlangius merlangus*	0.35	1.01	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	
Blue Ling	*Molva dypterygia*	0	0	0	0	0	0	0	0.01	0.01	0.03	
Ling	*Molva molva*	0.04	0.11	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	
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	
Cusk	*Brosme brosme*	0.20	0	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	
Halibut	*Hippoglossus hippoglossus*	0.08	0.07	3.88	0.09	0.20	0.05	0.19	0	0	0.10	
Pollack	*Pollachius pollachius*	0.06	0.25	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	
Greater Forkbeard	*Phycis blennoides*	0	0	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	
Total		18.99	63.19	244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	77.35
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	22.31
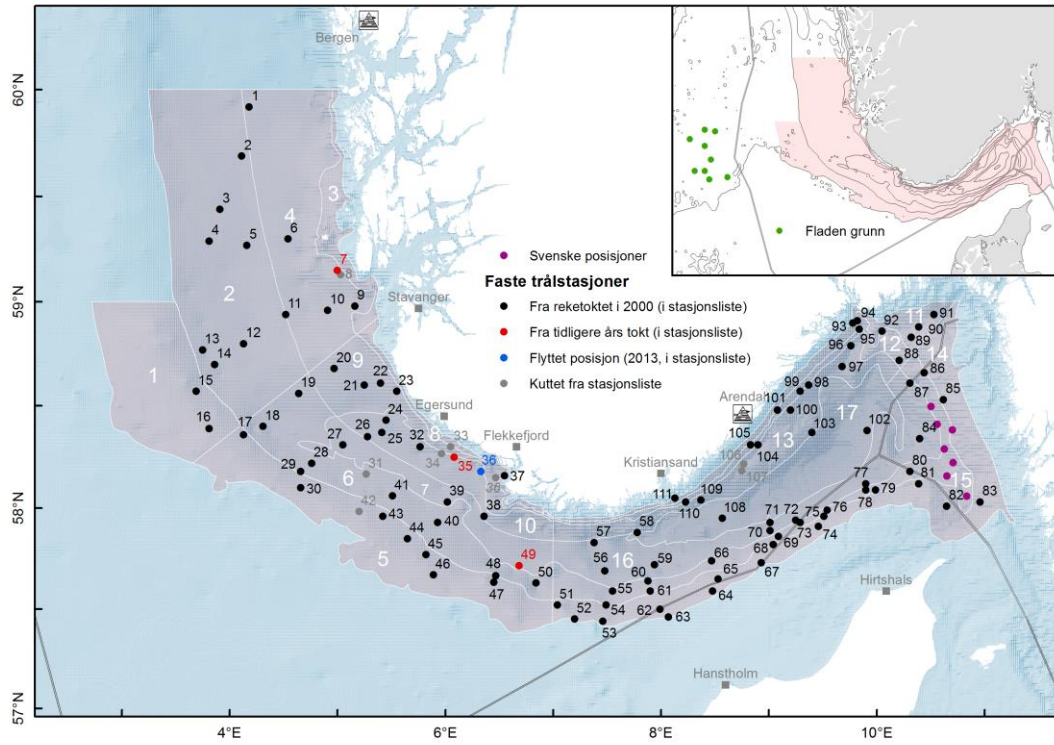
Fig. 1. Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east): the revised strata system (introduced in 2007 and adjusted in 2008) with the 104 fixed trawl stations. Trawl stations marked in red were introduced in 2008, the one marked in blue was introduced in 2013 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 on request from Swedish fishers. Trawl stations on Fladen Ground, visited on previous surveys in 1987-1994, were not trawled in 2015 due to weather constraints. Strata areas are given in Table 1.
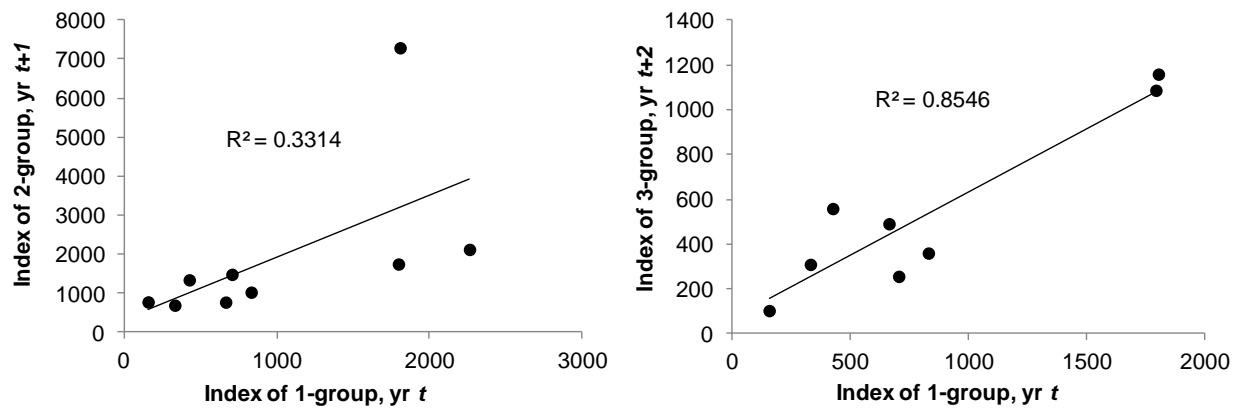
Fig. 2. Correlation between the index of 1-year old shrimp (indices are given in abundance in millions) in year t and the index of 2-year old shrimp in year $t+1$ (left); and correlation between the index of 1-year old shrimp in year t and the index of 3-year old shrimp in year $t+2$ (right), in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from January/February 2006-2015.
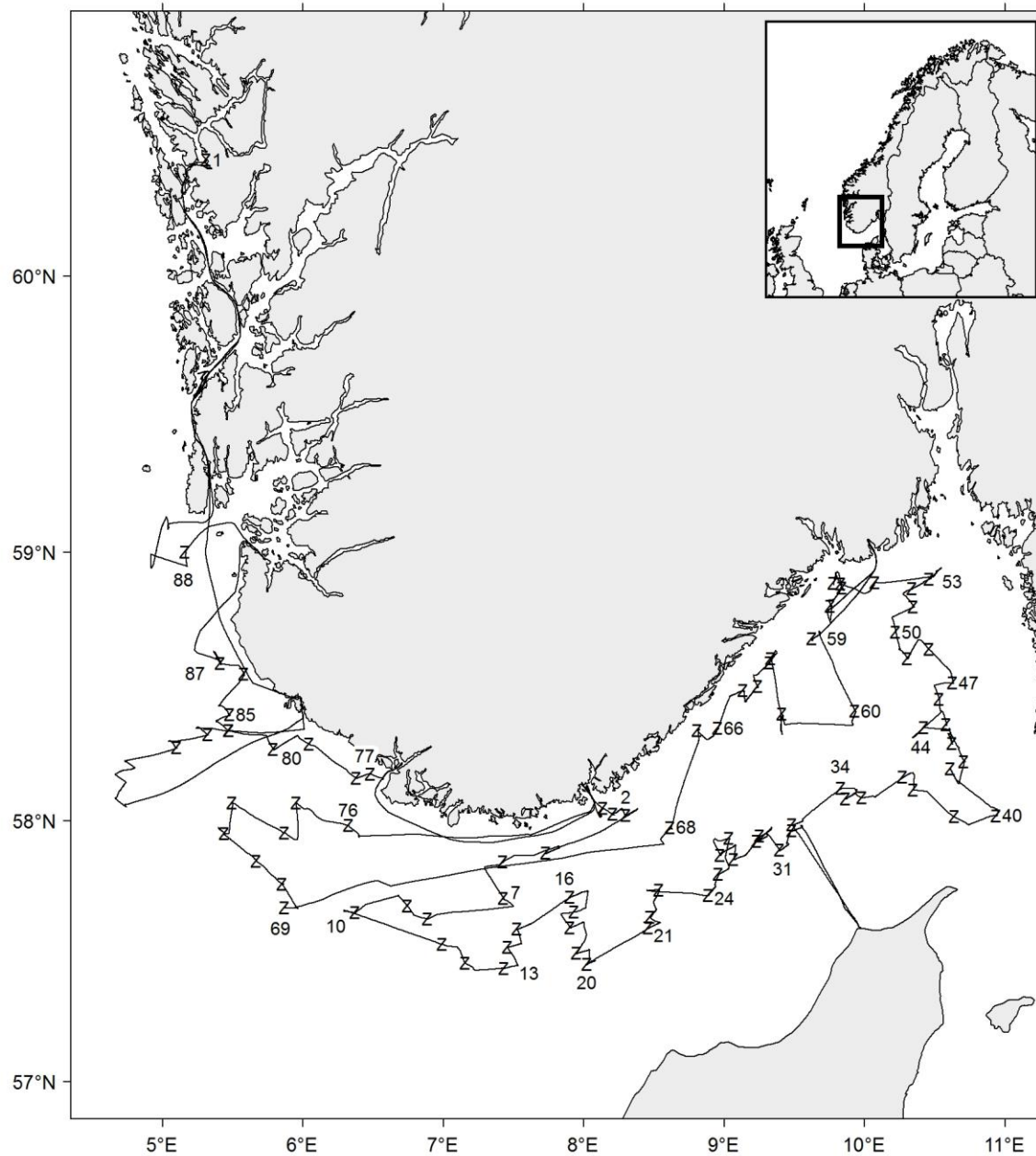
Cruise no 2015601 "Håkon Mosby"
10 January–3 February 2015

z CTD st.no 1–88

Fig. 3. CTD-stations (z) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January/February 2015.
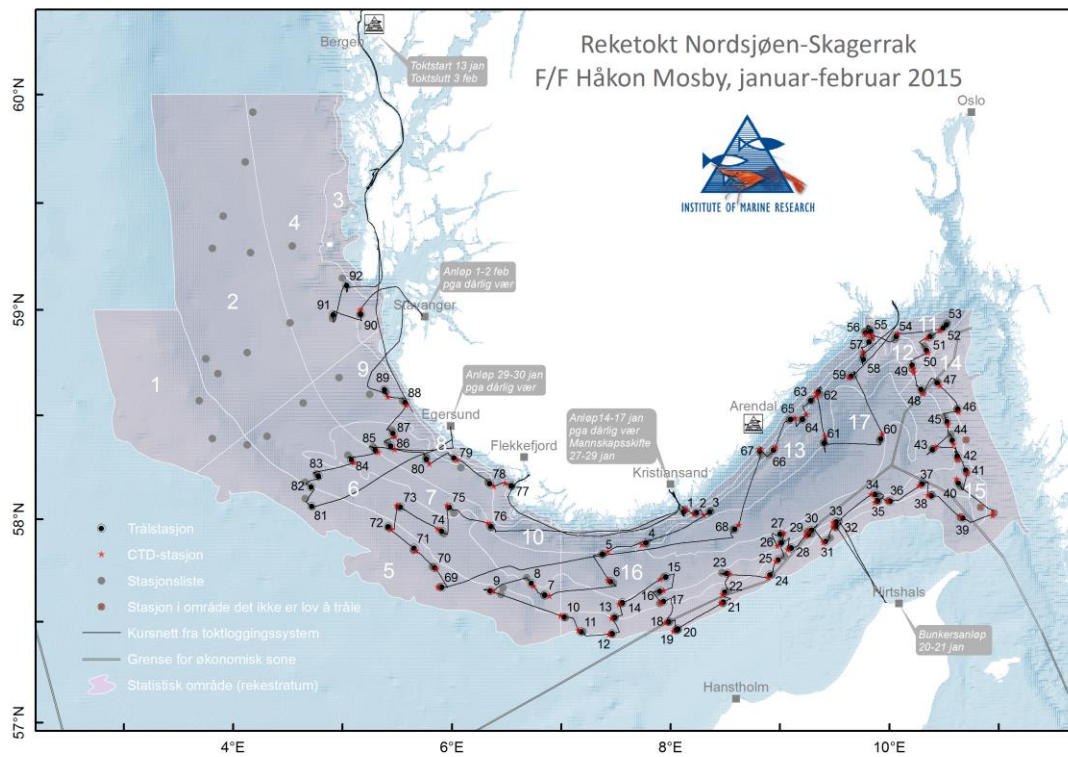
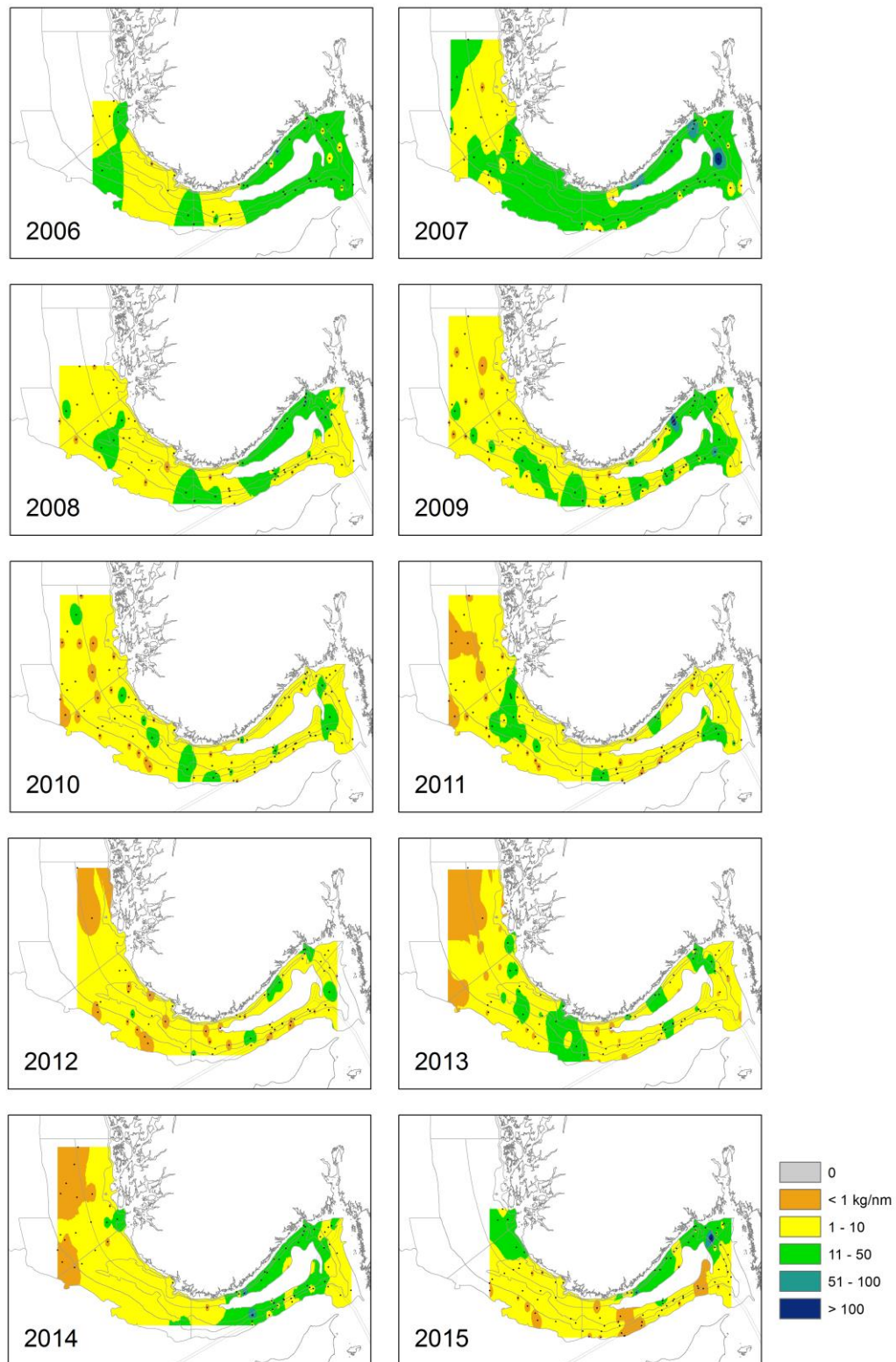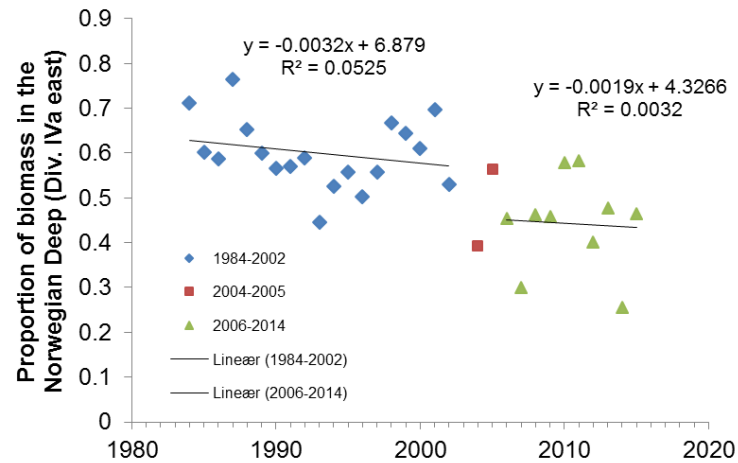**Fig. 4.** The Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January/February 2015 with R/V *Håkon Mosby*: sailing route and trawled stations.
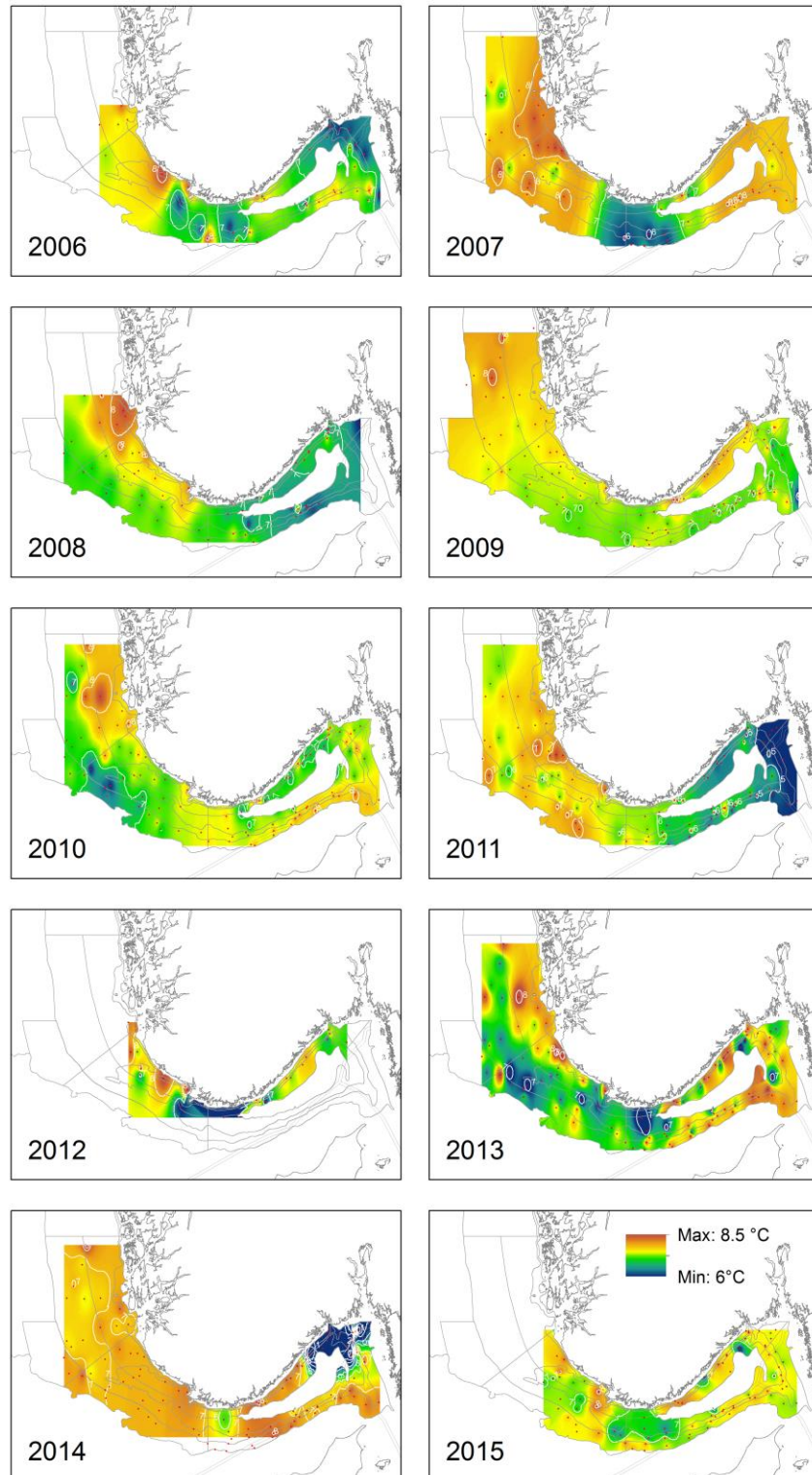
Fig. 5. Bottom temperatures (ºC) measured with CTD on fixed trawl stations from the 2006-2015 Norwegian shrimp surveys in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).
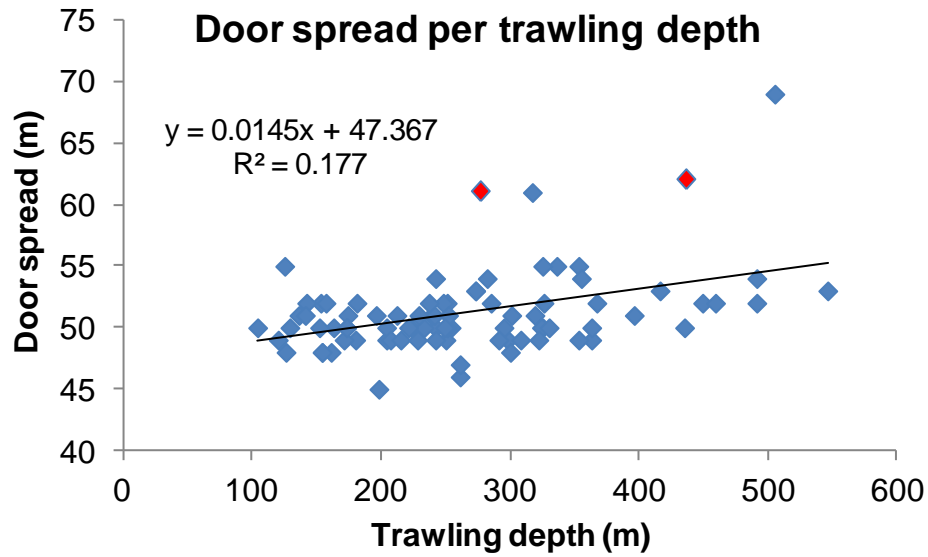
Fig. 6. Door spread (m) by trawling depth (m) for all trawl stations on the 2015 Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Points marked in red are stations where technical problems during trawling operations caused the strepping to be torn off.
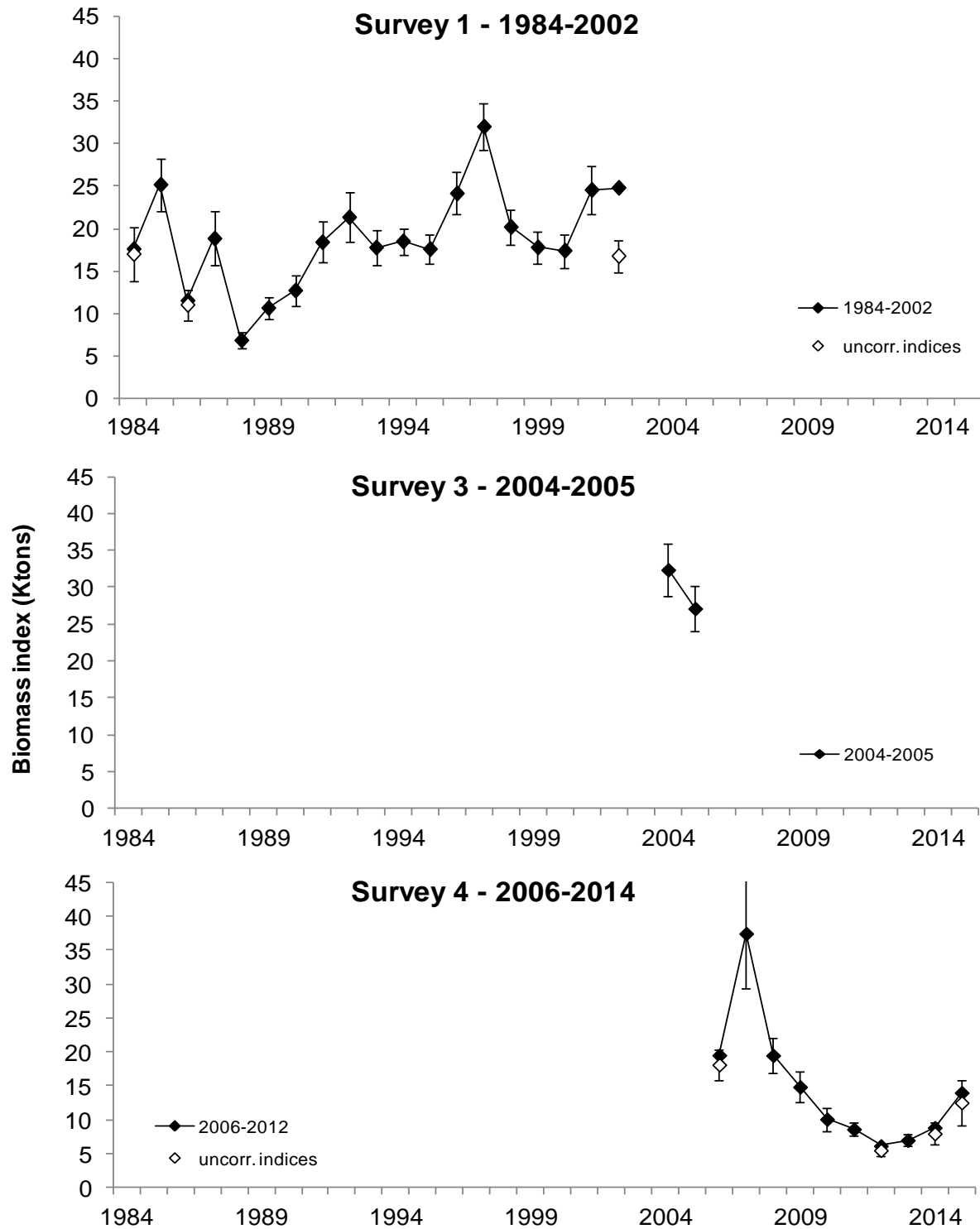
Fig. 7. Estimated total biomass index (with standard error) of shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 1984-2015. The 2003-value is not shown. Uncorrected values (◊) due to missing strata (see Table 5) are plotted.
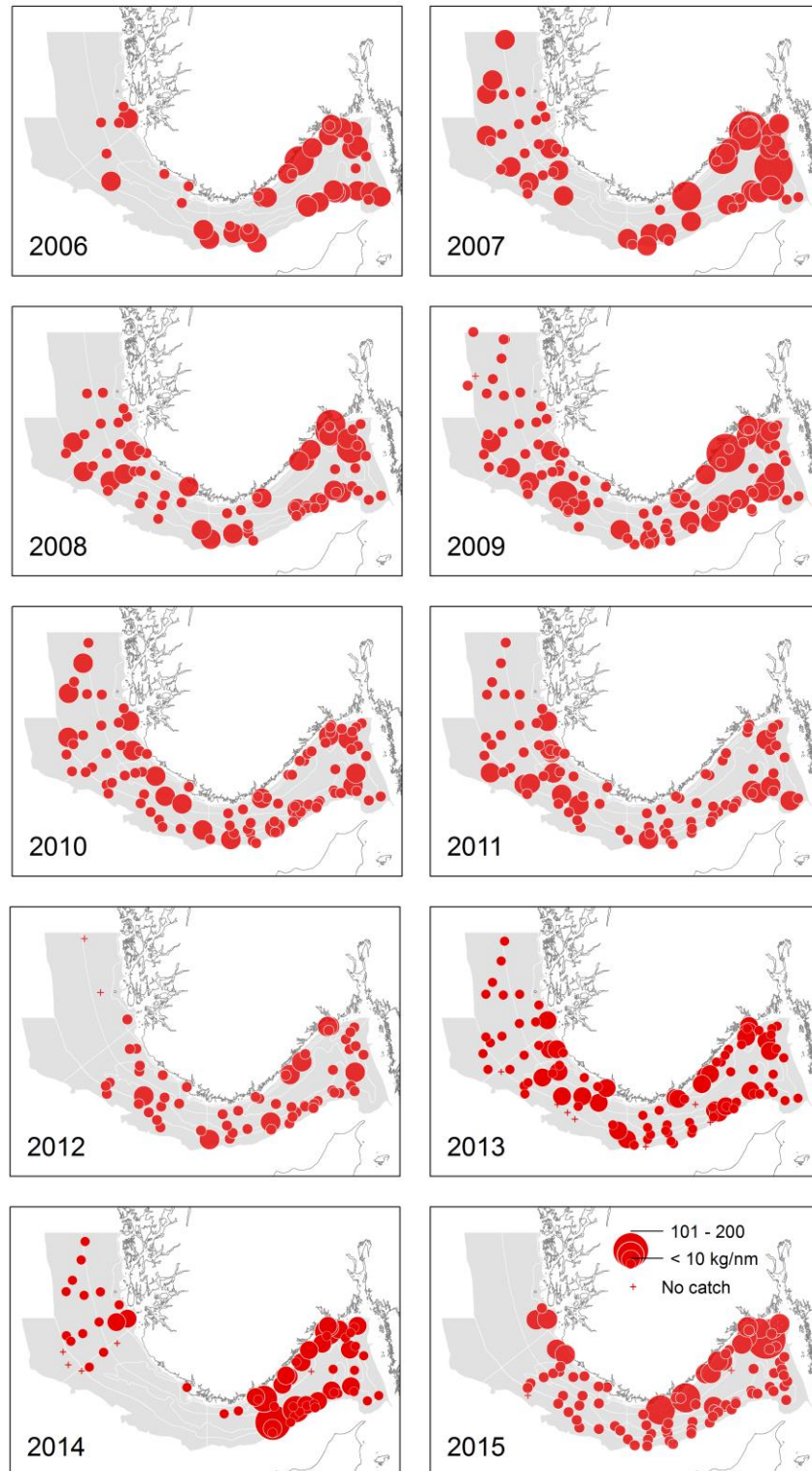
Fig. 8a. Shrimp catches per trawl station (kg/nm) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January/February 2006-2015.

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 2006-2015.

Fig. 9. The proportion of shrimp biomass in the Norwegian Deep from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 1984-2015. The 2003-value is not shown.
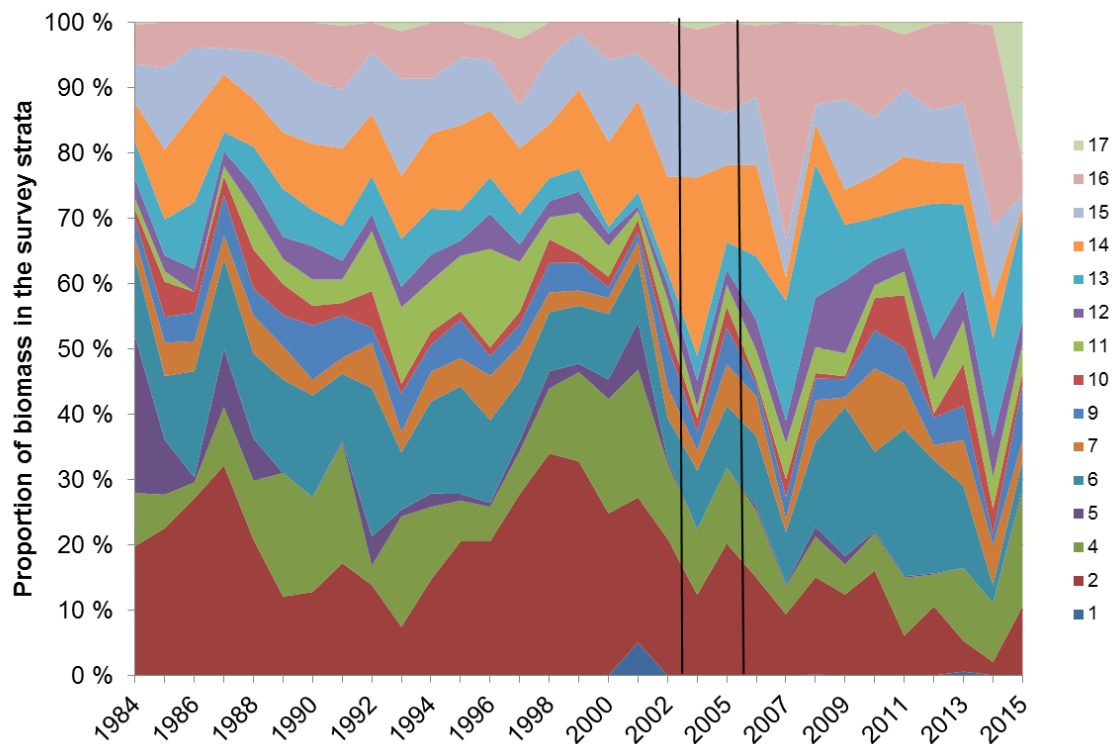
Fig. 10. The proportion of shrimp biomass per stratum from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 1984-2015. The vertical lines mark the different survey time series (1984-2002, 2004-2005, 2006-2015). The 2003-value is not shown.
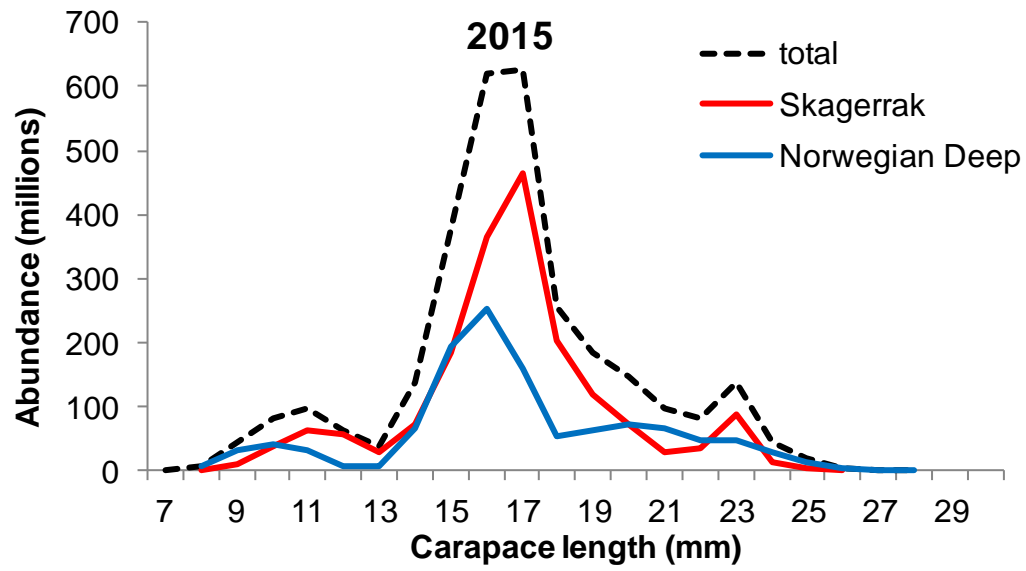
Fig. 11. Length frequency distributions of the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by area and total, in 2015.
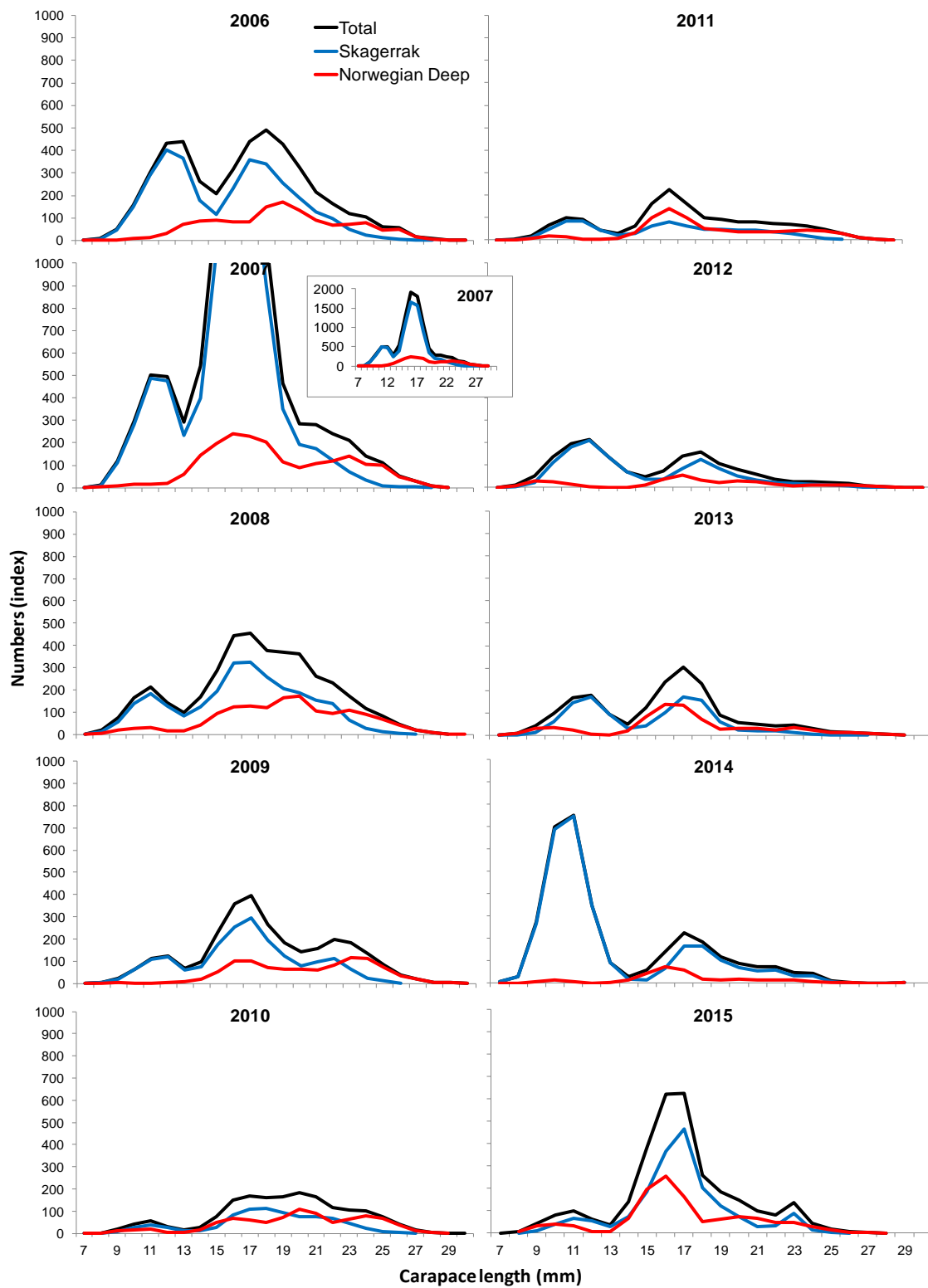
Fig. 12a. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by area and total, in 2006-2015.
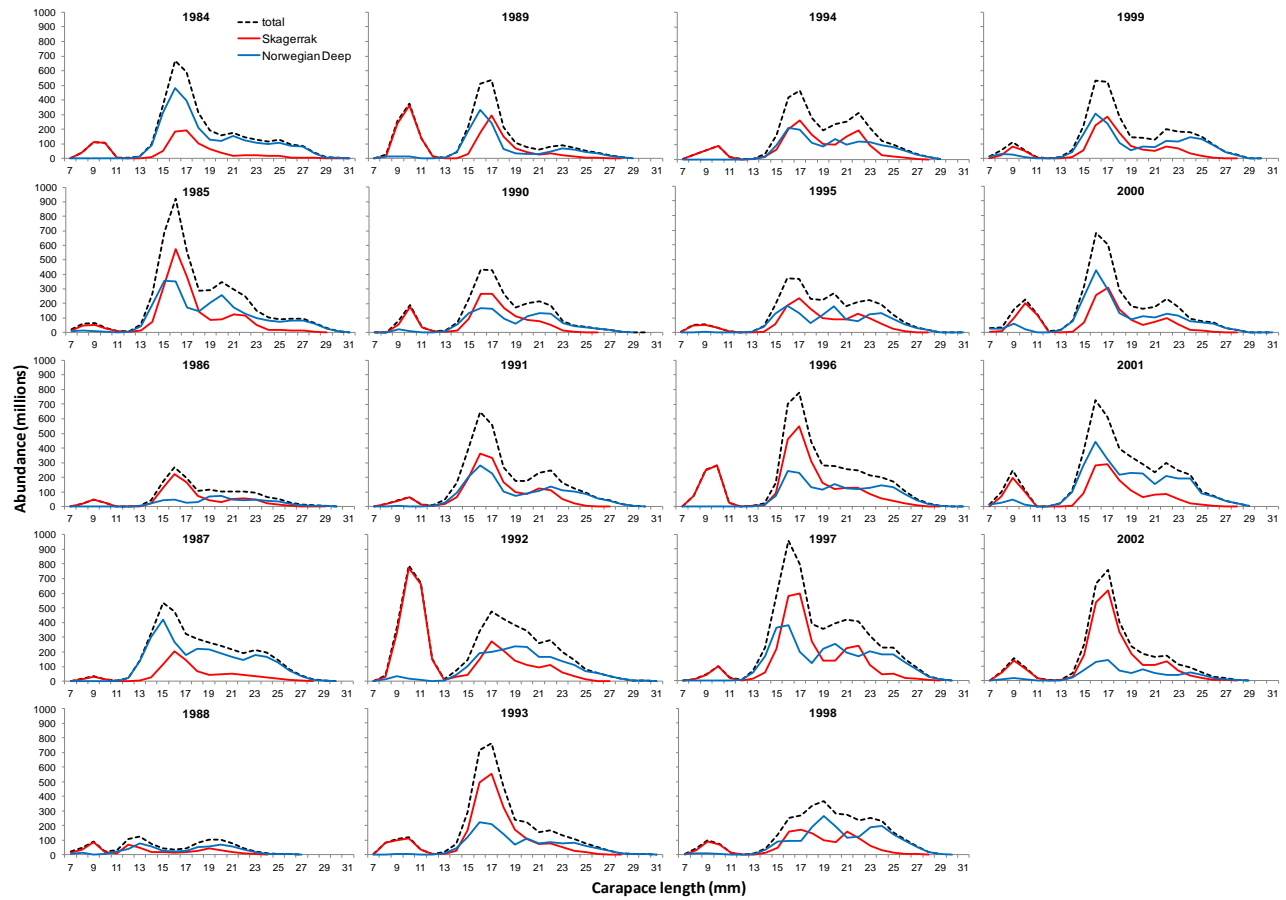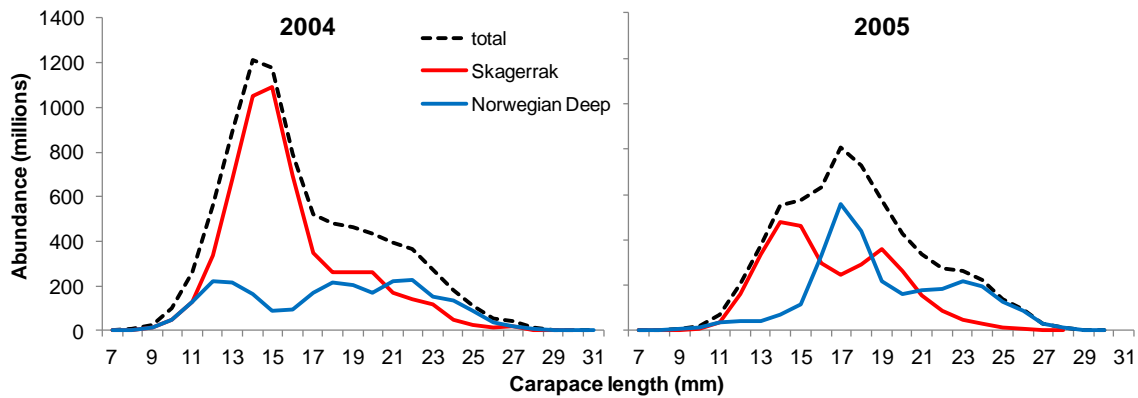
Fig. 12b. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 1984-2002.

Fig. 12c. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2004-2005.
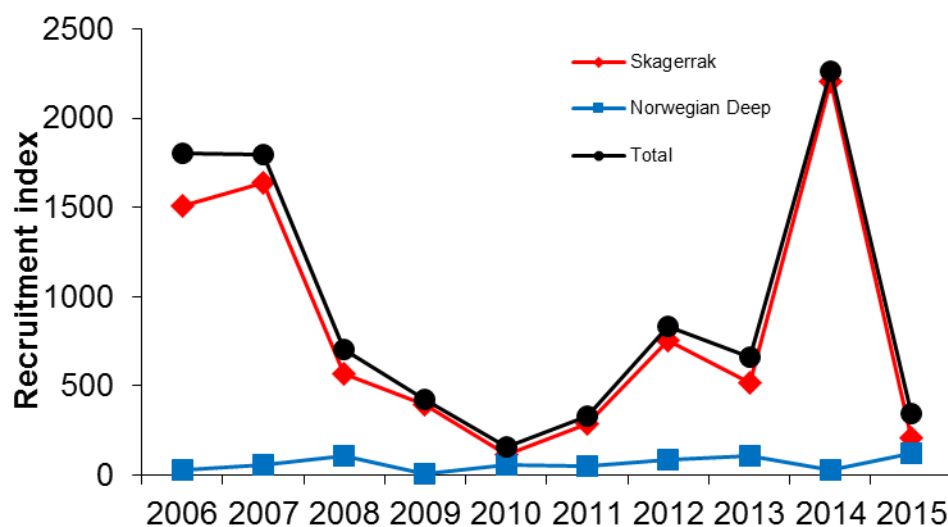
Fig. 13. Recruitment index (abundance in millions) of 1-year old shrimp in ICES Div. IIIa (Skagerrak), Div. IVa east (the Norwegian Deep), and in the overall area for 2006-2015. The higher number of 1-year old shrimp in the whole area in 2006 compared with Skagerrak, despite hardly any 1-year old shrimp in the Norwegian Deep, can be explained by the 1-groups in the two areas having different mean lengths. In the total area, shrimps < 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).
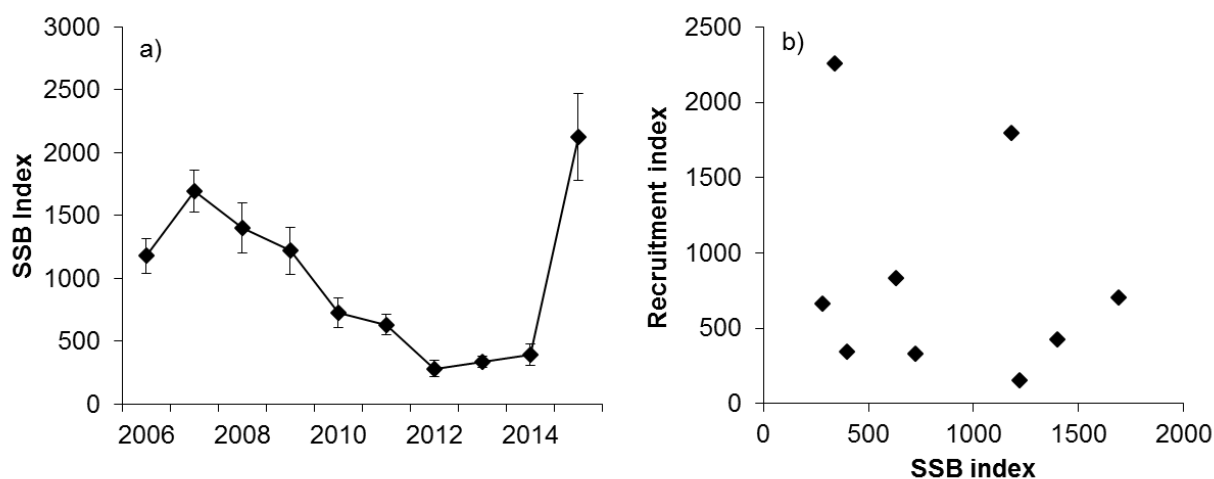

Fig. 14. a) SSB index (abundance in millions) in 2006-2015, and b) SSB-recruitment relationship 2006-2015 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).