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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 2008

by

G. Søvik[*] and T. Thangstad[#]

[*]Institute of Marine Research
Box 1870 Nordnes, N-5817 Bergen, Norway

[#]Institute of Marine Research
Box 6404, N-9294 Tromsø, Norway

Abstract

The Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) has gone through large changes in recent years. The result is a series of four different surveys, lasting from one 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 recruitment and SSB. Both in 2007 and 2008, the survey was conducted in February, and in 2009 it will be conducted either in February or March. Thus, a new time series at the most optimal time of year is established.

There was no trend in the annual survey biomass estimates 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. In 2008 the biomass index decreased back to the 2006 level.

Recruitment (abundance of 1-group) in Skagerrak was much lower in 2008 than in the two previous years, implying lower catches in 2009. For the last three years recruitment has been much lower in the Norwegian Deep compared with Skagerrak. However, in contrast to Skagerrak, recruitment in the Norwegian Deep in 2008 was larger than in 2006-2007.

An index of shrimp predator biomass was estimated to 244.76 kg/nm in 2008, compared with 63.14 in 2007 and only 18.99 kg/nm in 2006. The increase is mainly due to an increase in the saithe index.

Introduction

A trawl survey for northern shrimp 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 biomass 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 based on a survey conducted in October/November 1984-2002 using R/V *Michael Sars* and the Campelen-trawl; 2) a point estimate for 2003 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 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) a start of yet a new series in February 2006 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 strongly recommended by the *Pandalus* working group in 2004 (ICES 2005). Both in 2007 and 2008 the survey was conducted in February, and in 2009 it will be conducted either in February or March. Thus, a new time series at the most optimal time of year is established.

This paper presents the results of the 2008 survey.

Material and Methods

Survey design

The design of the new time series (2004-2005 and 2006- now) is similar to the old one (1984-2002) (ICES 2005).

The survey area covers depths of approximately 100 to 550 m in ICES Divs. IIIa and IVa east. A couple of stations are 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. The 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 the100 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 (Fig. 1), and two old stations were deleted from the list, resulting in a new total of 111 trawl stations. The deepest and shallowest stations have depths of respectively 540 and 111 m. Ideal, all stations should be trawled every year, giving a coverage of one haul per 142 nm^2. However, this rarely happens due to time and weather constraints.

In 2008 the survey was carried out 4-21 February. 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". This worked out very well, and the new rigging has since been kept. Mesh size in the cod end is 22 mm with a 6 mm lining net. Tow duration was 1 hour until 1989 when it was reduced to 0.5 hour. Tow speed is roughly 3 knots. In 2008 the average tow speed was 3.05 knots (SD = 3.82). No compensation for diurnal vertical migration is made. Strapping was introduced in 2008 in order to ensure a fixed trawl geometry (10 m rope 150 m in front of the doors).

Stock size index

The swept area was estimated by applying a wingspread of 11.7 m to tow length. Tow length was time towed multiplied by an average 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 was calculated and multiplied by the area of the stratum to give an estimate of stratum biomass and abundance. The biomass and abundance for the 17 strata were summed to give the overall values for the survey area. Standard errors were corrected in 2008: SE (whole survey area) = Σ (SE (stratum)^2).

A biomass index of shrimp predators was calculated as average catch/nm over all hauls of 22 fish species.

Biological samples

Samples of 250-300 shrimp specimens are taken from each trawl haul, sorted by sexual characteristics, and measured to the nearest mm below (carapace length (CL)). Overall length frequency distribution, as well as

distributions per area (Skagerrak and the Norwegian Deep), were estimated. The length frequency distributions were partitioned into age groups by modal analysis using the method of Bhattacharya (1967) (software: FISAT).

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 damages on the equipment, the CTD is not lowered further than 10 m above the bottom.

Results

Area coverage

Two and a half days out of the 18 days of the 2008 survey were reserved for hydrographical investigations. 73 out of the 111 fixed stations were covered (Fig. 2). This was an improvement from the 2007 survey, when only 66 stations were covered.

Temperature and salinity

In 2008 the average temperature (10 m above the bottom) on the Norwegian Deep trawl stations was 7.58 ºC (SD: 0.35), and in Skagerrak 7.03 ºC (SD: 0.36) (Fig. 3). The salinity was 35.18 ‰ (SD: 0.06) and 34.88 ‰ (SD: 0.31) in the Norwegian Deep and Skagerrak respectively.

The 2007 temperatures were a bit higher: 7.9 ºC (SD: 0.5) and 7.3 ºC (SD: 0.8) in respectively the Norwegian Deep and Skagerrak. The 2007 salinities were 35.20 ‰ (SD: 0.07) and 35.17 ‰ (SD: 0.07) in the Norwegian Deep and Skagerrak respectively.

Strapping

Strapping caused the average door spread to decrease from 52.9 m (SD: 4.4) and 51.6 m (SD: 1.8) in 2006 and 2007 to 47.0 m (SD: 1.7) in 2008. The former relationship of increased door spread with increased depth was not seen in the 2008 tows (Fig. 4). The difference in door spread between 2008 and the two previous years is considered small and is not corrected for.

Biomass indices

The biomass index increased from the late 1980s to the early 1990s, remained at a stable level until the mid 1990s where after it started fluctuating at a slightly higher level (Table 2, Fig. 5). This series was discontinued in 2002. The very low 2003 biomass index could have resulted from the use of the Shrimp trawl 1420, which has 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 index was 77% higher than the 2006 value, but was heavily influenced by the very high mean biomass in stratum 16 (Table 2), which was due to the high biomass on one particular trawl station. In 2008 the biomass index declined to the 2006 level.

In 2008, as in both 2006 and 2007, mean shrimp catches per nm were higher in Skagerrak (Div. IIIa) compared with the Norwegian Deep (Div. IVa east) (Fig. 6, Søvik and Thangstad 2007). This is also shown by a higher biomass index in Skagerrak (11 350 t) than in the Norwegian Deep (9 020 t). However, the very large inter-area difference seen in 2007, 26 080 vs. 10 650 t in respectively Skagerrak and the Norwegian Deep, has declined. The survey results are supported by trends in the LPUE from the fishery (Søvik and Thangstad 2008): The area specific LPUE has been higher in Skagerrak than in the Norwegian Deep since 2005, but the difference decreased in 2008.

Size, age and sex distribution

In Skagerrak, the size distribution of the 2006 survey showed a large mode of 1-year old shrimp (Table 3, Fig. 7b), which appeared as a very large mode of 2-year old shrimp dominating the catches in the 2007 survey. The 1-group in 2007 was of equal size as the 1-group in 2006, however, the 2-group in 2008 is much smaller than in

2007. The large 2-group in 2007 is seen as a rather large 3-group in 2008. The 1-group (recruitment) in 2008 was much lower than in the two previous years (Figs. 7b, 8) implying lower catches in 2009.

Recruitment is much lower in the Norwegian Deep compared with Skagerrak (Fig. 8). However, in contrast to Skagerrak, recruitment in the Norwegian Deep in 2008 was larger than in 2006-2007 (Fig. 7b).

The total length distribution very much resembles the distribution in Skagerrak due to the much larger catches in this area (Fig. 7c).

Predator abundance

Catch per trawl haul (kg/nm) in 2008 are given for various shrimp predators (Table. 4). Saithe is the most numerous species, with an average catch of 208.32 kg/nm. The total index of shrimp predator biomass was estimated to 244.76 kg/nm in 2008, compared with 63.14 in 2007 and only 18.99 kg/nm in 2006 (Table 4). The increase is mainly due to an increase in the saithe index and likely results from a couple of shallow trawl stations with large amounts of saithe on the 2008 survey Results from the first survey series (1984-2002) range from 28.6 to 63.1kg/nm (ICES 2004), while in 2004-2005 the indices were respectively 58.1 and 115.4 kg/nm (ICES 2006).

References

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Table 1. The estimated biomass available to the trawl (Ktons) and abundance (millions) from the Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) in 2008. Depth intervals are given in meter, and stratum area in nm^2. SE is the standard error.

2008

Stratum	Depth (m)	Area (nm^2)	Hauls	Biomass	SE	Abund.	SE
1	100-200	1,245	1	0.02	-	3	-
2	200-300	2,500	4	2.91	1.32	444	234
3	100-200	277	-	-	-	-	-
4	200-300	1,560	4	1.21	0.44	190	76
5	100-200	1,401	4	0.29	0.28	62	59
6	200-300	1,159	6	2.55	0.82	470	151
7	300-500	555	2	1.23	0.84	214	127
8	100-200	136	-	-	-	-	-
9	200-300	590	5	0.65	0.30	96	42
10	300-500	541	4	0.16	0.05	24	9
11	100-200	367	6	0.78	0.59	209	167
12	200-300	254	4	1.10	0.22	243	47
13	300-500	739	4	5.27	1.22	1387	348
14	100-200	1,411	9	1.14	0.67	190	110
15	200-300	739	10	0.60	0.26	163	79
16	300-500	1,138	8	2.42	1.31	713	387
17	> 500	1,137	2	0.04	0.04	11	11
Total		15,749	73	20.36	7.60	4,421	651

Table 2. Estimated biomass indices (t) from the Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) by survey and stratum 1984-2008. Indices from the different surveys 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	2441	-	2144	4048	3093	1313	-	336	346	316	1)556	605	1253	1305	1535		19291	
1985	1	0	4768	-	1162	3288	2607	2016	0	815	475	1)1900	794	840	4921	2664	4066		30316	
1986	1	0	2183	-	920	1)933	1940	663	-	389	177	1)857	540	618	1521	2073	733		13547	
1987	1	88	3765	-	2482	4103	3294	1237	0	1370	254	1)1470	584	419	2168	1350	964		23548	
1988	1	0	1126	-	720	373	1079	682	0	294	96	472	391	282	814	777	343		7449	
1989	1	-	932	-	2347	1)898	1722	1159	0	560	263	579	556	498	1375	1443	918		13248	
1990	1	0	705	187	3245	1)1067	2373	471	0	647	171	1044	559	564	2088	1895	907		15920	
1991	1	0	1903	1008	2612	189	2851	1053	152	725	189	740	526	716	2163	2683	1312		18821	
1992	1	0	615	717	585	136	5743	2299	0	568	527	2091	951	669	3567	2550	1211		22229	
1993	1	0	1481	401	4063	1)1487	1437	688	-	621	281	2596	758	728	2735	3823	1237		22336	
1994	1	0	1391	626	2321	345	2439	1992	-	461	255	1627	468	844	3004	2284	1320		19377	
1995	1	0	2794	-	1420	202	4042	953	-	818	236	1836	513	665	2950	2076	1714		20220	
1996	1	0	4901	-	1367	133	3576	1108	-	533	441	3590	616	921	4277	2456	1286		25205	
1997	1	0	7882	-	1995	416	3393	2406	-	764	349	1969	1530	1487	3199	3584	3169		32143	
1998	1	-	5069	-	3357	586	2223	1049	-	682	401	1105	451	529	3186	2439	1378		22455	
1999	1	0	5180	-	5360	3158	3254	1051	-	235	243	475	266	311	4560	2228	1596		27917	
2000	1	-	3436	-	2664	1121	2181	695	-	343	158	939	380	286	4159	2495	1497		20354	
2001	1	-	5180	0	5360	3158	3254	1051	-	307	245	512	266	311	4560	2228	1596		28028	
2002	1	-	1)3922	-	1)3104	459	3749	1847	-	1153	364	1403	496	411	5425	4470	3329		30133	
2003	2	-	-	-	1410	750	2770	840	300	1240	430	480	770	960	2210	1950	850		14960	
2004	3	-	3590	-	2830	-	3540	1530	-	690	400	120	1390	1230	11060	4650	2890		33920	11600
2005	3	0	3790	-	5460	0	3160	1900	-	1130	580	1580	570	910	3370	3150	4500		30100	11100
2006	4	-	2920	-	2010	2)180	2110	2)1049	-	380	130	870	900	1910	3340	1600	2490	-	19889	5206
2007	4	-	3500	-	910	120	2980	950	-	1250	980	2130	1250	6860	1480	2230	12470	0	37120	64339
2008	4	20	2910	-	1210	290	2550	1230	-	650	160	780	1100	5270	1140	600	2420	40	20360	7604

1) Estimated as an average of the stratum estimates scaled by overall biomass of the year.

2) Estimated as an average of the stratum estimates in 2007-2008, scaled by yearly overall biomass.

Table 3. Mean carapace length (CL) with standard deviation (SD), abundance (millions) and proportions of age groups from the 2008 survey estimate of stock length frequency distribution in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east).

	Skagerrak			
age	CL (mm)	SD	abundance	proportion
1	10.97	1.21	553	0.20
2	16.49	1.92	1698	0.60
3+	20.65	1.00	573	0.20

	Norwegian Deep			
age	CL (mm)	SD	abundance	proportion
1	10.44	1.34	89	0.06
2	16.84	1.65	507	0.34
3	20.01	0.98	546	0.36
4+	23.39	1.92	362	0.24

	Total			
age	CL (mm)	SD	abundance	proportion
1	10.94	1.28	644	0.15
2	16.55	1.68	2219	0.50
3	20.66	1.71	1224	0.28
4+	24.50	2.11	335	0.08

Table 4. Estimated indices of predator biomass (catch in kg per towed nm) recorded from the Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) in 2006-2008.

	biomass index		
Species	2006	2007	2008
Blue whiting	0.13	0.13	0.12
Saithe	7.33	39.75	208.32
Cod	0.51	1.28	0.78
Roundnosed Grenadier	3.22	6.85	19.02
Rabbit fish	2.24	2.15	3.41
Haddock	0.97	4.21	1.85
Redfishes	0.18	0.40	0.26
Velvet Belly	1.31	2.58	1.95
Skates, Rays	0.41	0.95	0.64
Long Rough Dab	0.22	0.64	0.42
Hake	0.98	0.78	0.64
Angler	0.15	0.91	0.87
Witch	0.24	0.74	0.54
Dogfish	0.31	0.19	0.28
Whiting	0.35	1.01	1.35
Blue Ling	0	0	0
Ling	0.04	0.11	0.34
Fourbearded Rockling	0.06	0.14	0.04
Cusk	0.20	0	0.02
Halibut	0.08	0.07	3.88
Pollack	0.06	0.25	0.03
Greater Fork-beard	0	0	0
Total	18.99	63.14	244.76

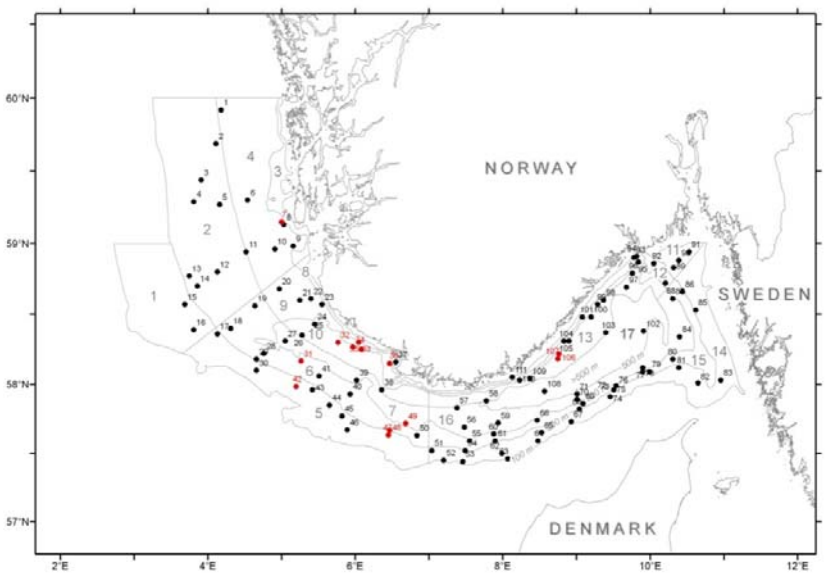

Fig. 1. Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east): the revised strata system (introduced in 2007 and adjusted in 2008) with the 111 fixed trawl stations. Trawl stations marked in red were introduced in 2008 (see text). Strata areas are given in Table 1.

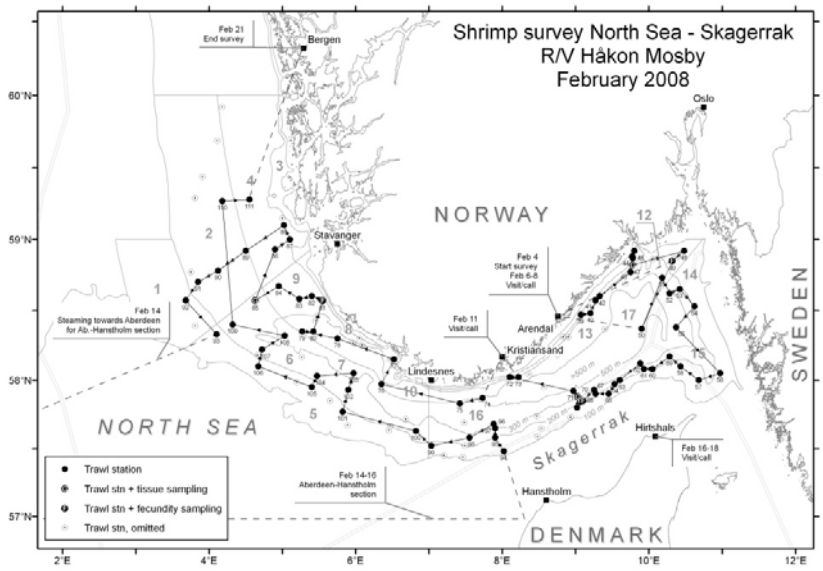

Fig. 2. The Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) in February 2008 with R/V *Håkon Mosby*: sailing route and trawled stations.

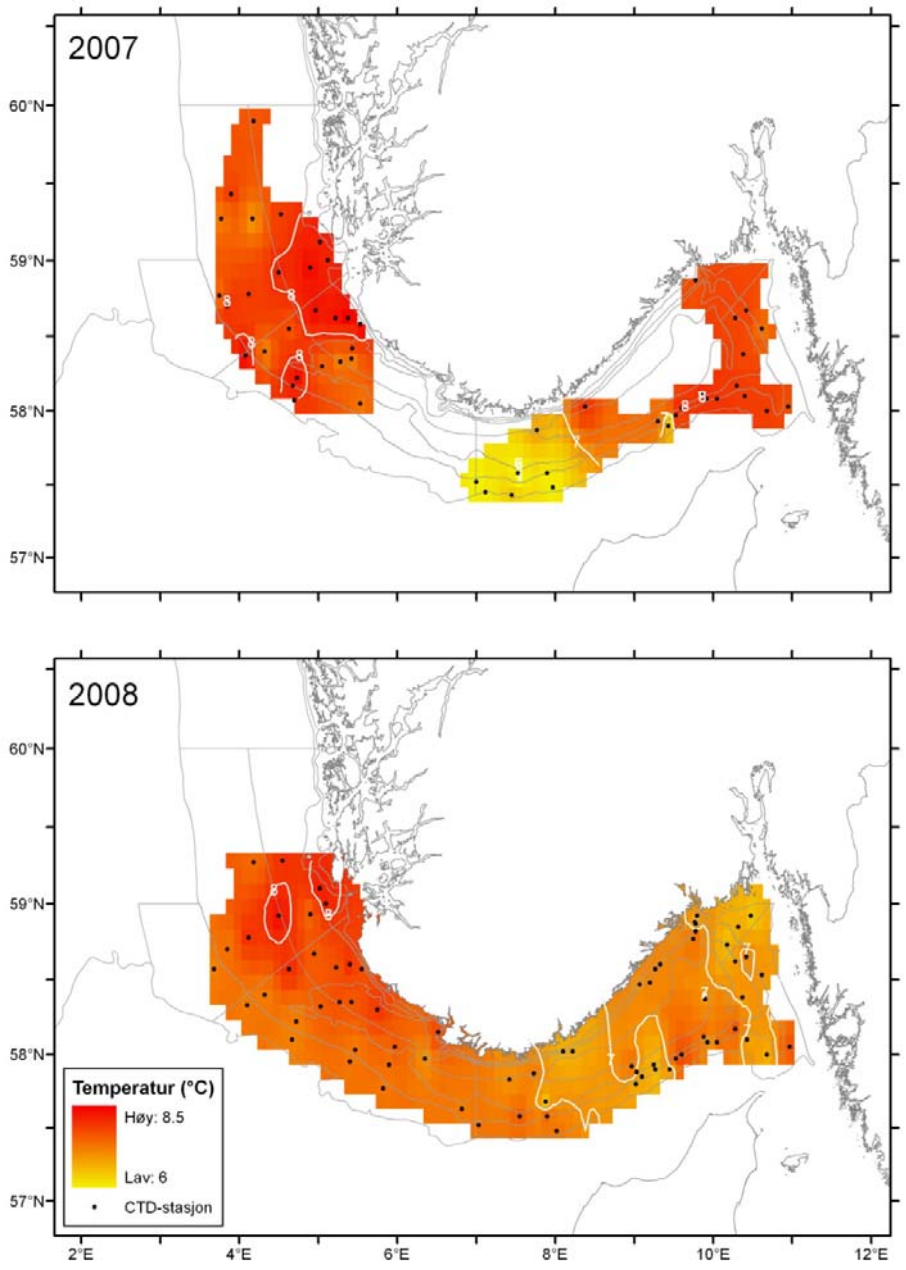

Fig. 3. Temperatures (ºC) measured with CTD on trawl stations during the February 2007 and 2008 shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east).

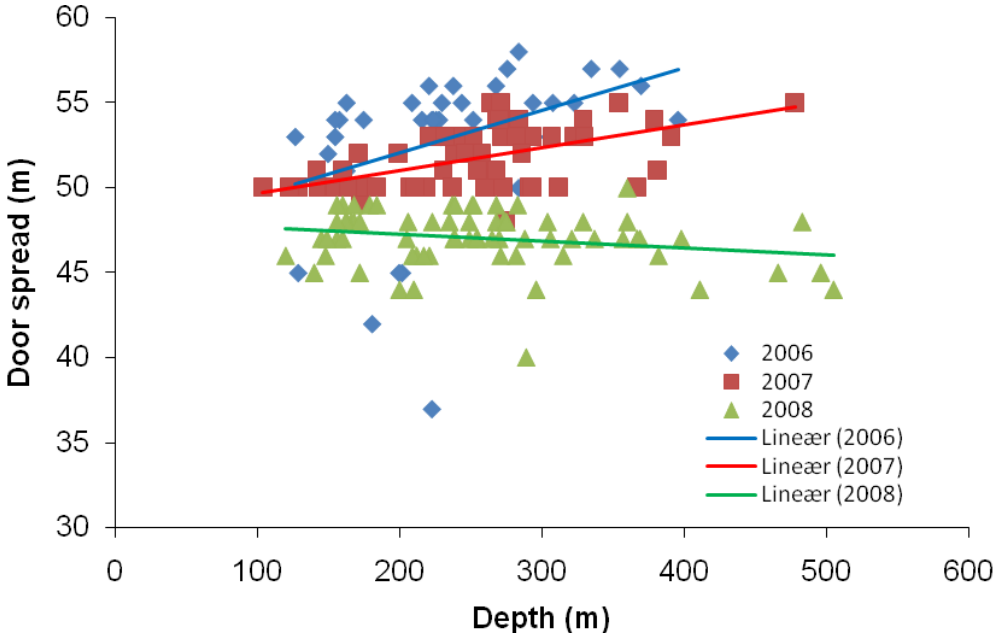

Fig. 4. Door spread vs. depth on the shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) in 2006-2008. Strapping was used in 2008, but not in 2006-2007.

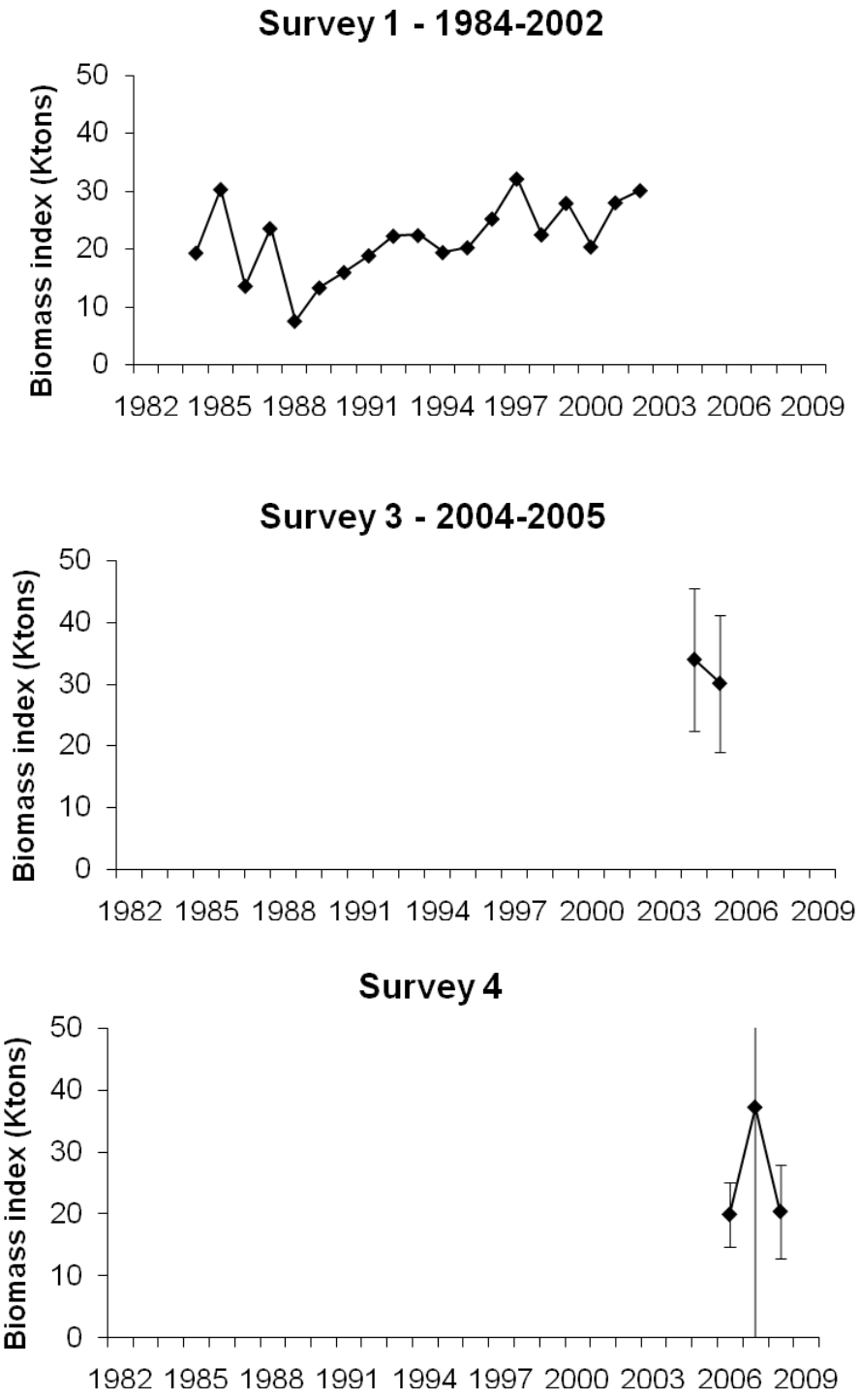

Fig. 5. Estimated survey biomass indices of shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), 1984-2008 (see Table 2). The 2003-estimate is not shown. Standard errors have been calculated for the 2004-2008 surveys.

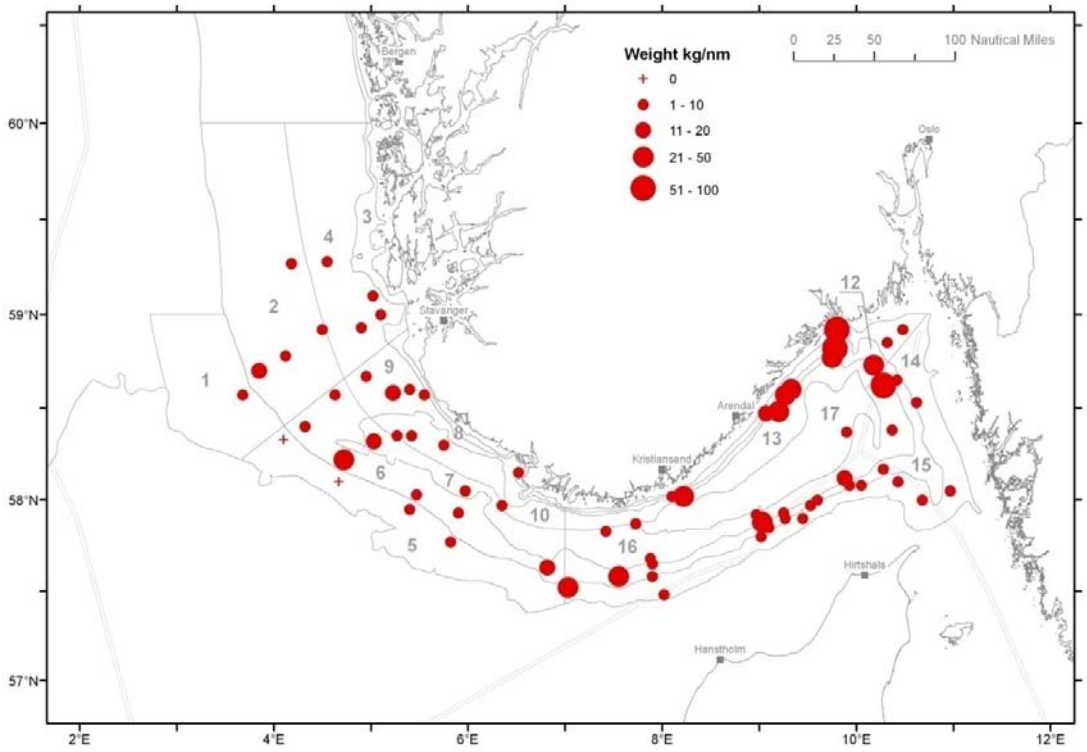

Fig. 6. Shrimp catches per trawl station (kg/nm) from the Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east) in February 2008.

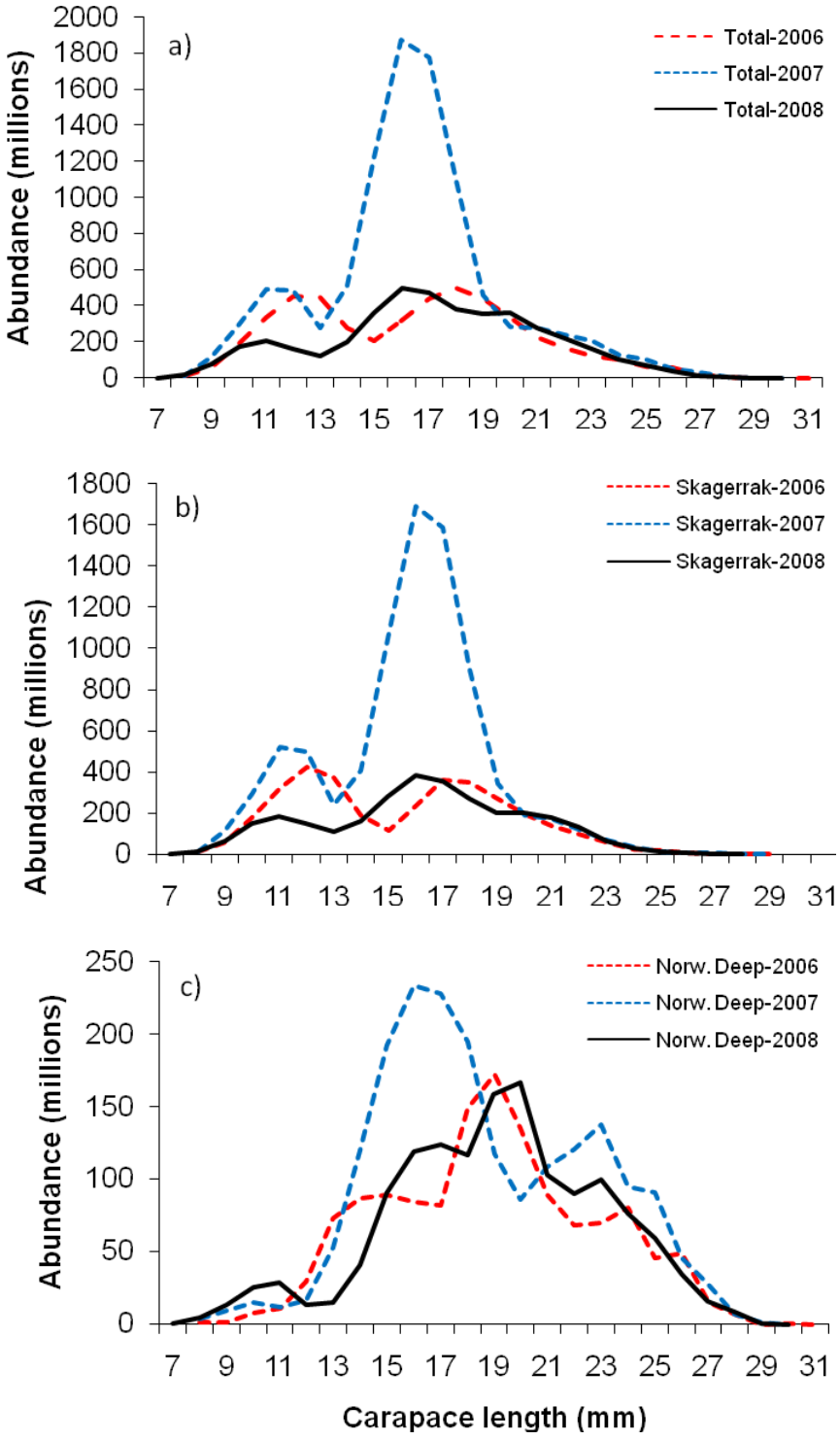

Fig. 7. Length frequency distributions for a) the overall area, b) Skagerrak (ICES Div. IIIa), and c) the Norwegian Deep (ICES Div. IVa east). Data from the Norwegian shrimp survey in February 2008. Note different scales on y-axes.

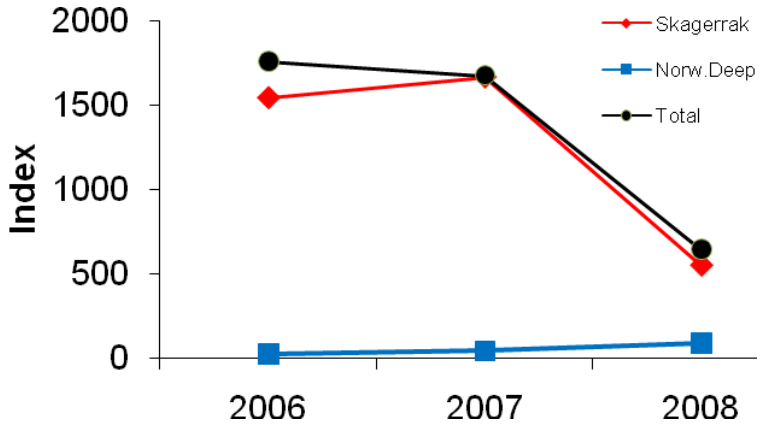

Fig. 8. Recruitment index (abundance in millions) of 1-year old shrimp in Skagerrak (ICES Div. IIIa), the Norwegian Deep (ICES Div. IVa east), and in the overall area for 2006-2008.