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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 2013

by

G. Søvik and T. H. Thangstad
Institute of Marine Research
Box 1870 Nordnes, N-5817 Bergen, 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. Thus, a new time series at the most optimal time of year is established.

The annual survey biomass estimate was fluctuating 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. In 2008 the biomass index decreased back to the 2006 level. The decline continued until 2012. The 2013-value increased slightly compared with the 2012-value.

Recruitment (abundance of 1-group) in Skagerrak was much lower in 2008-2013 than in 2006-2007. Recruitment increased from 2010 to 2012, but decreased again in 2013. For most of the time series, recruitment has been lower in the Norwegian Deep compared with Skagerrak, suggesting that Skagerrak is a nursery area for the stock. The low recruitment in 2008-2013 is probably the main reason behind the low stock size in recent years. The SSB-index has shown a decreasing trend since 2008.

The mean index-value of shrimp predator biomass was estimated to 164.23 kg/nm in 2013. This is an increase compared with 2012, mainly due to an increase in the blue whiting index. A predator index excluding saithe and roundnosed grenadier shows less interannual variation.

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, recruitment, and demographic composition of the shrimp stock and 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). Since 2006 the survey has been conducted in January/February. Thus, a new time series at the most optimal time of year is established.

This paper presents the results of the 2013 survey.

Material and Methods

Survey design

The survey design has not changed much throughout the whole time series. 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 60° 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 59° N as the two southern trawl stations in this stratum cannot be considered representative of the whole area north to 60° 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 (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. Ideally, all stations should be trawled every year, giving a coverage of one haul per 142 nm². However, this rarely happens due to time and weather constraints.

In 2013 the survey was carried out from January 12 to 26. 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 and has been kept since. 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. In 2013 the average tow speed was 2.47 knots (SD = 0.50). No compensation for diurnal vertical migration is made. Strapping was introduced on the survey in 2008 to ensure fixed trawl geometry. Due to poor door spread 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 since.

Stock size index

In 2012, biomass indices (with SE) from the years 1984-2002 and 2004-2005 were recalculated using the same procedure as was used for calculating the 2006-2013 indices.

The swept area was estimated by applying a wingspread of 11.7 m to tow length. Tow length was set to time towed multiplied by an average towing speed of 3 knots. The swept area is thus 0.019 nm²/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 respective stratum to give estimates of strata biomass and abundance. The biomass and abundance for the 17 strata were summed to give the overall value for the survey area. Due to weather constraints some strata were not covered in some years. The biomass in any missing stratum was estimated by applying the portion of total biomass in the stratum,
averaged over all years with data, to the total biomass of the year. Standard errors were corrected in 2009: SE (whole survey area) = √[Σ (SE (stratum)^2)].

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

**Biological samples**

Samples of 250-300 shrimp are taken from each trawl haul, sorted by sexual characteristics, and measured to the nearest mm below (carapace length (CL)). Shrimp are sorted and measured also when the total catch contains less than 250-300 shrimp (sample = the total catch). 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).

A recruitment index was estimated as the number of 1-year old shrimp from the modal analysis. There is a good correlation between the number of 1-year old shrimps in January/February in one year and the number of 2- and 3-year old shrimps the following two years, despite few data points (Fig. 2).

A SSB-index was 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 damages on the equipment, the CTD is not lowered further than 10 m above the bottom. In 2012, CTD casts were made on only 22 stations due to problems with the CTD-winch.

**Results**

**Area coverage**

In 2013, 101 out of the 111 fixed stations were covered (Figs. 3, 4), and none were invalid (“mud hauls” or problems with gear or rigging).

**Temperature and salinity**

The average temperature (10 m above the bottom) in January/February in the survey area has in general lied between 7 and 8 °C in the period 2006-2013. In most years the bottom temperature has been slightly higher in the Norwegian Deep compared with Skagerrak (Table 2, Fig. 5). The area was cooled down during the unusually cold winter 2009-2010, 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 2013 mean bottom temperature was 7.48 °C in both Skagerrak and the Norwegian Deep.

Average salinity has varied between 34.9 and 35.3 ‰ in the same time period.

**Strapping**

The introduction of strapping has caused the average door spread to decrease from more than 50 m in 2006-2007 to 46-47 m in 2008-2012 (Table 3). The former relationship of increased door spread with increased depth is not seen in the 2008, and 2010-2012 tows. In 2009 there was a slight decrease in door spread with depth, probably due to difficulties with the trawl gear at this year’s survey. In 2013, mean door spread was 51.1 m. The difference from former years may be explained by a decreased mean tow speed in 2013 (2.47 knots compared with a tow speed of between 2.85 and 3.05 in 2008-2012). The difference in door spread between the different years is not corrected for.
Biomass indices

The recalculated biomass index resembles the old time series quite well, except for the year 1999. The recalculation of the index enabled the calculation of SE’s.

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 4, Fig. 6). A decrease in 1998-2000 was followed by an increase in 2001. The first time series was discontinued in 2002. The very low 2003 biomass index 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 heavily influenced by the very high mean biomass in stratum 16 (Table 4), which was due to the high biomass in one particular trawl haul. In 2008 the biomass declined to the 2006 level. The decreasing trend continued until 2012, but in 2013 the biomass increased slightly (Figs. 6, 7a, 7b).

As the time series is short (only 8 years), there are few years with which to compare the low values of 2010-2013. The Norwegian LPUE-index has been decreasing since 2008 and was in 2012-2013 at the lowest level since 2000 (Søvik and Thangstad 2013). Thus, the shrimp biomass seems to be at a very low level in 2012 and 2013.

Size, age and sex distribution

The model analysis gave four age groups in Skagerrak and three age groups in the Norwegian Deep (Table 5, Fig. 8). Length frequency distributions for the years 2006-2013 showed that in most years in the Skagerrak/Norwegian Deep area there are two clearly identifiable age groups as well as one 3+-group (Fig. 9).

In Skagerrak, recruitment (1-group) declined from 2007 to 2010, increased in 2011 and 2012, but declined again in 2013 (Fig. 10). The relatively large 1-group in 2012 (the 2011 year class) entered the fishery in autumn 2012, and will likely mean increased catches of large shrimp in 2014. In the Norwegian Deep in 2006-2009 and in 2011-2013, recruitment was very low compared with Skagerrak (Fig. 10). In 2010 recruitment was of equal 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 in 2008-2013 is probably the main reason behind the decreasing stock size since 2008. However, it is not known why recruitment has been so low in recent years.

SSB had decreased since 2008 (Fig 11a). There seems to be no relationship between SSB and recruitment (1-year old shrimp (Fig. 11b).

Predator abundance

Mean catch per trawl haul (kg/nm) in 2013 are given for various shrimp predators (Table 6). Saithe is the most abundant species, with an average catch of 112.80 kg/nm. The mean total index of shrimp predator biomass was estimated to 164.23 kg/nm in 2013, which is above the mean of the series for 2006-2013 (Table 6). Results from the first survey series (1984-2002) range from 28.6 to 63.1 kg/nm (ICES 2004), while in 2004-2005 the indices 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 6). The shallow and deep stations have very low densities of shrimp. A more informative predator index should be based on only the trawl stations with a certain minimum density of shrimp.
Acknowledgement

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References


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 2013. Depth intervals are given in meter, and stratum area in nm\(^2\). SE is the standard error.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth (m)</th>
<th>Area (nm(^2))</th>
<th>Hauls</th>
<th>Biomass</th>
<th>SE</th>
<th>Abund.</th>
<th>SE</th>
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<td>2</td>
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<tr>
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<td>0.84</td>
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Table 2. Average temperature (°C) and salinity (‰) over all trawl hauls from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2013. 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.

<table>
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<th>Salinity (‰)</th>
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<td></td>
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<tr>
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<td>2013</td>
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<td>2013</td>
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Table 3. Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2006-2013: mean door spread with standard deviation, and regression coefficient and $R^2$ from the linear regression line.

<table>
<thead>
<tr>
<th>Year</th>
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<th>SD</th>
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Table 4. Estimated biomass indices (t) from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by survey and stratum 1984-2013. Indices from the different surveys series are not comparable (see text). SE is the standard error.

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<th>Year</th>
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<td>-</td>
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<td>1257</td>
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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 5. Mean carapace length (CL) with standard deviation (SD), abundance (millions) and proportions of age groups from the 2013 survey estimate of stock length frequency distribution in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).

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Table 6. 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 2006-2013.

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<td>Dogfish</td>
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<td>0.28</td>
<td>0.14</td>
<td>0.11</td>
<td>0.21</td>
<td>0.60</td>
<td>1.02</td>
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<td>Black-mouthed dogfish</td>
<td>Galeus melastomus</td>
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<td>0.00</td>
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<td>0.15</td>
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<td>Whiting</td>
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<td>1.35</td>
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<td>0.15</td>
<td>0.07</td>
<td>0.24</td>
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<td>0</td>
<td>0.01</td>
<td>0.04</td>
<td>0.02</td>
<td>0.05</td>
<td>0.06</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>18.99</td>
<td>63.19</td>
<td>244.81</td>
<td>94.26</td>
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<td>33.09</td>
<td>30.04</td>
<td>164.23</td>
<td>87.23</td>
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<td>Total (except saithe and roundnosed grenadier)</td>
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<td>16.59</td>
<td>17.47</td>
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<td>20.65</td>
<td>20.58</td>
<td>19.95</td>
<td>49.46</td>
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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. Correlation between a) the index of 1-year old shrimp (abundance in millions) in January/February, year $t$ and the index of 2-year old shrimp (abundance in millions) in January/February, year $t+1$; and b) the index of 1-year old shrimp in year $t$ and the index of 3-year old shrimp in year $t+1$, in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from 2006-2013.
Fig. 3. CTD-stations (z) in the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January 2013.
Fig. 4. The Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January 2013 with R/V Håkon Mosby: sailing route and trawled stations.
Fig. 5. Bottom temperatures (°C) measured with CTD on fixed trawl stations during the 2006-2013 Norwegian shrimp surveys in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).
Fig. 6. Estimated survey biomass indices (with standard errors) of shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 1984-2013. The 2003-estimate is not shown. The old time series (---) for 1984-2002 and 2004-2005 are plotted together with recalculated indices (♦). Uncorrected indices for some years (◊) (Table 4) are plotted.
Fig. 7a. 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 2006-2013.
Fig. 7b. 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 2006-2013.
Fig. 8. Length frequency distributions for the overall area, Skagerrak, and the Norwegian Deep from the Norwegian shrimp survey in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in January 2013.
Fig. 9. Length frequency distributions for the shrimp stock in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), in 2006-2013.
Fig. 10. 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 2006-2013. 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 modal groups being slightly skewed. 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.
Fig. 11. a) SSB index (abundance in millions) in 2006-2013, and b) SSB-recruitment relationship 2006-2012 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep).