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The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2016

by

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**Abstract**

The resource of northern shrimp (*Pandalus borealis*) in the North Sea and Skagerrak is assessed as three separate stocks. The Skagerrak-Norwegian Deep stock (ICES Divs. IIIa and IVa east) is the largest one and the only one which is fished at present. Vessels from Norway, Denmark, and Sweden exploit this resource.

Information on the Norwegian shrimp fishery (fleet, gear, and prices) was updated for the 2015 fishery. Norwegian logbooks are incomplete. The data situation improved in 2011 with the implementation of compulsory electronic logbooks for all vessels  $\geq 15$  m, and further in 2013 with the implementation of compulsory logbooks for all vessels  $\geq 12$  m in Skagerrak. However, a large part of the fleet consists of small vessels down to 10 m. The recording of twin trawl use was incomplete until 2011, and logbook recordings were corrected by interviews with ship owners. The electronic logbooks provide information both on gear type as well as the number of trawls.

Norwegian landings increased from 6 000 t in 2000 to 9 000 t in 2004, and then decreased to less than 4 500 t in 2010-2011. Since 2012, landings have increased. In 2015, 6 369 t were landed. Correcting for boiling implies that between 230 and 550 t were added to the nominal landings for the years 2000-2015. The Danish discard-to-landings-ratio is used for estimating Norwegian discards, as there has not been any Norwegian discard data available. Estimated Norwegian annual discards from Skagerrak in 2009-2015 range from 78 to 1 191 t (discard rates between 2 and 20% of total catches), and in the Norwegian Deep from 16 to 98 t (1-7%). Higher proportions of boiled, large shrimp in the Norwegian landings compared with the Danish ones indicate that Norwegian vessels discard more than Danish vessels, and that the Norwegian discards are likely underestimates.

The Norwegian LPUE-index decreased from 2008 to 2012, and increased from 2013 to 2015. The 2016-value is at the same level as the 2015-value. The LPUE-index follows the same trend as the LPUE-indices from the Swedish and Danish fisheries, as well as the Norwegian annual shrimp survey, except in 2016, when the survey index drops to a very low level. The standardised Norwegian effort index (2000-2016) shows a fluctuating, but stable trend.

The 2015 catch composition was evaluated using samples from unprocessed catches obtained from local shrimp fishers and the Norwegian Coast Guard. Length frequency distributions show that the catches in 2015 were dominated by three year classes. The 4+ group is very small. The biomass of the 2-group (the large 2013-year class) dominated the 2015-catches in both Skagerrak and the Norwegian Deep.

## Introduction

The resource of northern shrimp (*Pandalus borealis*) (hereafter synonymous with shrimp) in Skagerrak and the North Sea is assessed as three separate stocks (Ulmestrand *et al.* 2016): 1) the Norwegian Deep/Skagerrak (NDSK) stock, which is largely confined to ICES Divs. IIIa and IVa east, 2) the Fladen Ground stock in ICES Div. IVa west, and 3) the Farn Deep stock in ICES Div. IVb west (Fig. 1). Presently, a commercial fishery exists only in Skagerrak and the Norwegian Deep. Vessels from Norway, Denmark, and Sweden exploit the shrimp in this area.

### Fleet

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of 60° N. In 2015, a total of 204 vessels participated in the shrimp fishery south of 62° N (Table 1, Fig. 2), which is an increase from 2014 when 184 vessels participated. The total number of vessels in the fishery has decreased from more than 400 vessels in 1995 to around 200 vessels in recent years (Fig. 2). In 2015, as in preceding years, the length group 10-10.99 m dominated in numbers, with the length group 11-14.99 m as the second largest. The fleet has changed considerably since the mid-1990s. The number of trawlers <10 m has decreased, as has the number of vessels 11-20.99 m, while there has been an increase in the number of vessels 10-10.99 m. A high number of small vessels <15 m characterises the Skagerrak fleet, while in the west the number of vessels is more evenly distributed across length categories (Fig. 3). Annual mean landings per vessel increase with vessel length (Table 1).

### Gear use

Twin shrimp trawls are common on larger vessels and have been in use since the beginning of the 2000s. Prior to 2011, the use of twin trawl was only sporadically registered in logbooks. Only 1-2 vessels in 2002-2003, three in 2004-2006, seven in 2007, nine in 2008, six in 2009, and four in 2010 recorded the use of twin trawl on a regular basis. This was due to the logbooks containing data from few vessels, and probably also incorrect recordings.

In electronic logbooks introduced in 2011 (see below), data are given per haul, and both type and number of gears are recorded. According to these logbooks, respectively 50, 58, 70, 71 and 63% of vessels  $\geq 15$  m used twin trawl in 2011-2015, either exclusively or in combination with single trawl. Corresponding percentages for smaller vessels 12-14.99 m in Skagerrak were respectively 13, 13 and 19% in 2013-2015 (data available from 2013). Triple shrimp trawls are prohibited in the North Sea south of 62° N but allowed in Skagerrak. They are, however, not used.

In the Norwegian fishery for shrimp the minimum mesh size is 35 mm. In both Skagerrak and the Norwegian Deep, mesh sizes between 35 and 40 mm have been in use since 2000. In the Norwegian Deep, mesh size of 35 mm is more frequently in use than in Skagerrak. Mesh sizes >40 mm are used to some extent, especially in Skagerrak (Fig. 4).

### Quotas, management and regulations

Since 1992, Norway and EU have negotiated quotas on shrimp in the North Sea and Skagerrak. For the NDSK stock, Norway, due to historical rights, has the largest quota. In 2010-2011, the Norwegian quota constituted 60% of the total TAC; in 2012-2015, it constituted 58% of the total. In 2008-2009, the Norwegian TAC was 9 731 tons (t) (Table 2). Thereafter, the quota gradually declined, to 5 469 t in 2013-2014. For 2016, a total quota of 17 440 t was agreed between the EU and Norway based on ICES advice from October 2015 (ICES 2015), out of which Norway could land 10 392 t. The ICES advice, was however, updated in March 2016 (ICES 2016a) following a benchmark where a new length-based assessment model (SS3) was agreed for shrimp in NDSK (ICES 2016b). The updated advice implied total landings of only 11 869 t, which resulted in Norway and the EU adjusting the total 2016 TAC down to 15 696 t (10% reduction). Of this, Norway could land 9 317 t (59%).

In 1998, a general quota regulation system was initiated in the Norwegian shrimp fishery in NDSK, resulting in admittance regulation for vessels  $\geq 11$  m. Vessels <11 m have free admission to the fishery, but are subject to the same quota regulations as larger ones. In order to supply the market throughout the whole year, the total Norwegian quota is evenly allocated to three periods (January 1 – April 30, May 1 – August 31, September 1 – December 31 in 2016). The Norwegian Directorate of Fisheries (NDF) can stop the shrimp fishery when the period or total quotas are estimated to be taken. In 2016, the vessels have a maximum quota of 34 t in the first period, 32 t in the second and 36 t in the third period.

The whole Norwegian quota is rarely fished. Possible explanations are the resource situation and/or the arrangement of evenly allocating the quota to three periods with frequently bad weather in the third period. The Norwegian quota was overfished in 1997, 2004 and 2014. In 2006-2015, respectively 92, 88, 80, 61, 49, 60, 78, 89, 105 and 100% of the quota was landed (uncorrected landings as percentage of Norwegian TAC as NDF does not consider corrected numbers). Quota was transferred from 2015 to 2014 (279 t).

The following restrictions apply: no trawling in waters shallower than 60 m, no fishing on Sundays and holy days, and, in the inner part of Skagerrak, no trawling within the 4 nm border between 20:00 and 05:00. In the North Sea, bycatch of market fish is allowed, but single catches may nevertheless not contain >15% (by weight) cod and haddock combined. Furthermore, bycatch of >10% angler fish or >10% cod are not allowed. In Skagerrak, there is a limitation that up to 50% of the catch by weight in shrimp trawls may consist of other market species. The minimum legal catch size (MLS) for shrimp in the NDSK area was raised from 6 to 7 cm in 2016, measured from the front of the eye to the back of the tail. New measurements show that the relationship between total length (TL) and carapace length (CL) is slightly different from what has been used earlier. A TL of 6 cm equals a CL of 13.4 mm, while a TL of 7 cm equals a CL of 16.0 mm (Fig. 5). In Skagerrak, it is allowed to have up to 10% undersized shrimp by weight in the catch. Per 10 kg of shrimp it is not allowed to have more than eight undersized specimens of cod, twenty of haddock and three of redfish. Discarding of shrimp is prohibited in Norwegian waters. Since 1<sup>st</sup> of February 2013, inclined grids for sorting out bycatch has been compulsory in shrimp trawls in Skagerrak outside the 4 nm border. If fish quotas allow, a fish retention device (120 mm square mesh tunnel) may be used in order to retain large fish. From 1<sup>st</sup> of January 2015, sorting grids were made compulsory also in the North Sea south of 62° N, outside the 4 nm border. Work is currently on-going to develop selective gear for sorting out undersized shrimp. Presently, 1-2 Norwegian vessels are using sorting grids for undersized shrimp, and 1-2 Norwegian vessels are using a shortened trawl. The use of sorting grids and selective gears is not recorded in logbooks.

An RTC regime was introduced for shrimp in the Norwegian Exclusive Economic Zone south of 62° N in 2016. The shrimp fishery may be prohibited in areas where catches contain more than 15% shrimp <MLS (in numbers). Areas are closed for 14 days and then automatically reopened. Shrimp fishery is allowed within closed areas if a sorting grid for undersized shrimp is used.

### **Value of landings**

Two categories of shrimp dominate the market: large shrimp boiled at sea and sold fresh, fetching high prizes, and smaller shrimp landed raw for factory processing ashore. In 2006-2008, fishermen obtained approx. 60 NOK/kg for boiled shrimp, and 10-11 NOK/kg for raw shrimp. The mean kilo prize for boiled shrimp has since increased: 63 NOK in 2009, 72 NOK in 2010, 79 NOK in 2011, 88 NOK in 2012, and 90 NOK in 2013. In 2014 in Skagerrak, fishers got on average 82 NOK per kilo boiled shrimp and 8 NOK per kilo raw shrimp. Corresponding prizes in the Norwegian Deep were 94 and 9 NOK. In 2015 in Skagerrak, the mean kilo prizes were respectively 81 and 11 NOK for boiled and raw shrimp; corresponding prizes from the Norwegian Deep were 93 and 12 NOK.

The present document compiles updated information from landings statistics, logbooks and catch sampling from the Norwegian trawl fishery for shrimp in Skagerrak and the Norwegian Deep (Divs. IIIa and IVa east).

## **Materials and Methods**

Landings statistics and logbook data were provided by NDF. For 2016, landings and logbook data were given for August inclusive.

### **Landings**

Landings were earlier given only per Norwegian statistical area, where area 9 corresponds to ICES Div. IIIa, areas 8 and 28 correspond to Div. IVa east, area 42 to Div. IVa west, and area 41 to Div. IVb. From 2009, NDF has provided landings per statistical location (equivalent to standard "ICES squares": 0.5° lat. by 1° long). Prior to 2009, landings from the Fladen Ground can be identified (area 42), while landings from area 41 cannot be divided into northern (belonging to the Norwegian Deep/Skagerrak stock) and southern components (Farn Deep) (Fig. 1). In this document, landings from Div. IVb are therefore not included in numbers for the Norwegian Deep/Skagerrak stock, only in figures for Subarea IV. LPUE and effort are calculated using only numbers from Divs. IIIa and IVa east.

Official landings give landed weight as a mixture of raw and boiled shrimp, but conservation category when landed is reported in the landing statistics (data back to 2000). Boiled shrimp lose weight and to obtain fresh weight, the fraction of the landings consisting of boiled shrimp is multiplied by a conversion factor of 1.13. In the landings statistics, conservation is recorded as “sea boiled”, “salt boiled”, and “fresh” (Fig. 6). In 2011, a new category, “on ice”, was introduced, which was interpreted as raw shrimp until 2013, when we became aware that both boiled and raw shrimp may be stored on ice upon landing. The sales organization in Skagerrak, Skagerakfisk SA, has confirmed that since 2011, they have used “on ice” only for raw shrimp (Fig. 6), thus conservation information from NDF is still used to separate boiled and raw landings from this area. The sales organization in Rogaland, Rogaland Fiskesalgslag SA, on the other hand, uses “on ice” both for boiled and raw shrimp (Fig. 7). The proportion of boiled landings from the Norwegian Deep is therefore obtained from landings data provided by this sales organization, where landings are given as sea boiled, salt boiled or raw shrimp. In 2015, shrimp sold through Rogaland Fiskesalgslag constituted 83% of the total landed volume from Div. IVa east.

### **Effort**

Norwegian logbooks from the shrimp fishery in NDSK are incomplete (Fig. 8). In 2005-2010, logbook catches made up between 9 and 35% of the landings in IVa east, and between 7 and 25% of the landings in IIIa. The data situation improved greatly in 2011, with the introduction of compulsory, electronic logbooks for all vessels  $\geq 15$  m. In 2013, electronic logbooks became compulsory also for vessels  $\geq 12$  m fishing outside the 4 nm border in Skagerrak. In 2015, in IVa east, catches made up 76% of the landings (corrected) as roughly half the vessels in this area are  $\geq 15$  m (Fig. 3), landing on average much more than smaller vessels (Table 1). Skagerrak is dominated by vessels  $< 15$  m and logbook catches made up 54% of the landings in 2015. Due to the incomplete logbooks, we estimated total fishing effort by dividing nominal landings (corrected for boiling) by LPUE (landings per unit effort) calculated from the logbooks. The combined LPUE from both single and twin trawl was used to estimate total effort as the nominal landings derive from both types of gear.

Gear use (single/twin trawl) is accounted for in the estimation of a standardised LPUE-index as there is a clear difference in catch efficiency between these trawl types (Fig. 9). Few recordings of twin trawl in logbooks prior to 2011 called for a quality check of gear recordings, by interviewing ship owners about their use of single and twin trawl. Ship owners were identified from the international ship base [www.ship-info.com/login.htm](http://www.ship-info.com/login.htm) and logbooks for 2004-2010, which contained data from 59 vessels (Søvik and Thangstad 2014). We managed to get in touch with the owners of 48 of these. Gear recordings were corrected according to information obtained in the interviews. The electronic logbooks provide information on both gear type and number of trawls. Mesh size is lacking in the 2011-2012 logbooks (reintroduced in 2013), which makes distinguishing between fish bottom trawl and shrimp trawl difficult (both may be recorded as “bottom trawl”). All logbook recordings of shrimp from bottom trawl (2011-2012) have been kept in the analyses.

Corrected logbook data were used in multiplicative models in order to calculate a standardised LPUE index (2000-2016), removing effects of monthly variations in fishing pattern, geographical variation (area), gear use (single or twin trawl), and changes in the composition of the fleet (e.g., Hvingel *et al.* 2000, Hvingel and Aschan 2006). The SAS statistical software was used in the calculations. The multiplicative model was represented in logarithmic form:

$$\ln(LPUE_{hijkl}) = \ln(LPUE) + \ln(V_h) + \ln(A_i) + \ln(M_j) + \ln(Y_k) + \ln(G_l) + e_{hijkl}$$

where  $LPUE_{hijkl}$  is the mean LPUE for vessel  $h$ , fishing in area  $i$  in month  $j$  and year  $k$ , using gear  $l$ ;  $\ln(LPUE)$  is the overall mean;  $V_h$  is the effect of the  $h^{\text{th}}$  vessel;  $A_i$  is the effect of the  $i^{\text{th}}$  area;  $M_j$  is the effect of the  $j^{\text{th}}$  month;  $Y_k$  is the effect of the  $k^{\text{th}}$  year;  $G_l$  is the effect of the  $l^{\text{th}}$  gear; and  $e_{hijkl}$  is the error term assumed to be normally distributed  $N(0, \sigma^2/n)$ , where  $n$  is the number of observations in the cell. The standardised LPUE estimates are the antilog of the year coefficients.

A standardised effort index for 2000-2016 was derived by dividing landings (corrected for boiling) by the standardised LPUE index.

### **Fleet structure and spatial distribution of fishery**

Fleet structure (length) is available through the vessel registry and was provided by NDF. Logbook data give the spatial and temporal distribution of the fishery, with the electronic logbooks providing information on positions of

single trawl hauls. Landings per statistical location (from 2009) similarly illustrate the spatial distribution of the fishery.

### **Discards**

Discarding of small, less valuable shrimp has been an issue in the shrimp fishery in the NDSK area for years. Discarding of shrimp may take place in two ways: 1) “high-grading” (discarding of medium, less valuable shrimp to improve the economic return of quotas) (Munch-Petersen *et al.* 2013), and 2) “quality discard” (processing plants do not accept shrimp smaller than approx. 15 mm CL). A summary of how Norwegian discards were estimated in earlier years is given in Søvik and Thangstad (2014).

As discarding is illegal in Norway, onboard sampling is difficult to organize. Denmark initiated onboard sampling of their shrimp fishery in Skagerrak in 2009. Since 2009, Norwegian discards in Skagerrak have been estimated using the Danish discards-to-landings ratio to Norwegian landings.

The Danish at-sea-sampling-program does not cover the Norwegian Deep. Norwegian discards from this area are therefore estimated as the weight of all shrimp <15 mm CL (old MLS) in the catches, assuming that all undersized shrimp are discarded. The reported discard estimates since 2009 in the current document and in the NIPAG report are based on the Danish data.

### **Sampling of catches**

Samples (approx. 2 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2015-catches were obtained from eight Norwegian shrimp fishers (59 samples) and the Norwegian Coast Guard, which provided 50 samples from inspections of Norwegian, Danish, and Swedish shrimp trawlers (Fig. 10). Samples were sorted to stage by sexual characteristics and measured to the nearest mm below. The length distributions were split into age groups by modal analysis by the method of Bhattacharya (1967) (software: FISAT).

## **Results and discussion**

### **Spatial distribution of fishery**

According to the electronic logbooks from 2011-2015, the large vessel fleet ( $\geq 15$  m) fished mainly in the southern and western parts of the Norwegian Deep, with some effort allocated to the Skagerrak coast and the west coast of Norway (Fig. 11a). In 2013-2015, the distribution of the fishery in the Norwegian Deep has shifted south compared with 2011-2012. According to the 2013-2015 logbooks, which include vessels between 12 and 15 m in Skagerrak, the small vessels fished along the Skagerrak coast, with the smallest ones (12-13 m length) concentrated in the northeast part of Skagerrak (Fig. 11b). The fishery seems to be more concentrated along the coast in recent years compared with 2009-2010, illustrated by distribution of effort (trawling hours) in logbooks and landings per statistical location (Fig. 12).

### **Landings**

The percentage of boiled shrimp in the Norwegian landings has, since 2000, always been higher in the Norwegian Deep compared with Skagerrak (Fig. 13, Table 3). During the last four years (2012-2015), the percentage of boiled landings has been around 50% in Skagerrak, while it has laid between 60 and 70% in the Norwegian Deep, except in 2013.

Total Norwegian landings from Skagerrak and the North Sea (Div. IIIa and Subarea IV) increased from 2 000 t in 1970 to around 8 300 t in 1987 (Fig. 14a, Table 2). Since 1987, nominal landings have fluctuated, with two peaks in 1998 and 2004. From 2004 to 2010, the landings steadily declined to 4 308 t, the lowest figure since 1979. Since 2011, landings have increased again. In 2015, 6 369 t were landed. Correcting for boiling implies that between 230 and 550 t are added to the nominal landings for the years 2000-2015 (Table 2).

In 2002 to 2005, landings from Skagerrak and the Norwegian Deep were of equal size, but this pattern changed in 2006 with landings from Skagerrak being 70% higher than landings from the Norwegian Deep. The difference increased even more in 2007 and 2008, with Skagerrak landings nearly three times larger than landings from the Norwegian Deep. This changed in 2009-2010 with a large decrease in landings from Skagerrak, bringing the IIIa

landings down to the level of the IVa east landings. Since 2012, more than 70% of the total landings have come from Skagerrak.

In Skagerrak, the nominal landings peaked in 1998 at about 6 500 t, decreased to 3 000 t in 2001, and then increased again until 2007 to nearly the same level as in 1998 (Fig. 14a, Table 2). From 2007 to 2010 the Skagerrak landings decreased by 56% to the lowest level since 1979. Since 2011, the Skagerrak landings have steadily increased, and 4 741 t were landed in 2015. This can be explained by the good 2013 year-class becoming 2 year old in 2015 (Søvik and Thangstad 2016). In the Norwegian Deep nominal landings fluctuated around 3 000 t in the 1990s, increased to around 4 300 t in 2004, and thereafter decreased until 2012 to 1 000 t, the lowest value since 1979 (Fig. 14a, Table 2). Landings increased slightly from 2013 to 2015, when 1 628 t were landed. Monthly landings from January to August 2016 are of the same size as the 2015 January-August landings in Skagerrak, but slightly higher in the Norwegian Deep (Fig. 15).

The fishery takes place throughout the whole year. In Skagerrak, most shrimp are landed in spring and late summer/autumn, while landings are highest in late winter to late summer in the Norwegian Deep (Fig. 15). This pattern is persistent over years. Lower landings during winter are probably due to weather conditions.

In 2015, 3 208 t were landed by small vessels (<15 m), while 3 160 t were landed by large vessels ( $\geq 15$  m) (Table 1). More or less equal landings from small and large vessels was seen also in 2012-2014, while in 2011, landings from large vessels were more than 50% higher than landings from small vessels. The development in recent years can be explained by the respectively increasing and decreasing fisheries in Skagerrak and the Norwegian Deep, and the different fleet structure in the two areas (Fig. 3).

### **Effort**

The estimated number of fishing hours in 2015 was more than twice as high in Div. IIIa compared with Div. IVa east (76 vs. 37 Khours) (Table 2, Fig. 14c), similar to what was estimated for 2012-2014. The estimated effort in the Norwegian Deep decreased from 2001 to 2014, but showed an increase in 2015. In Skagerrak, estimated effort has fluctuated without trend since 2000. Total estimated effort has shown a decreasing trend since the late 1980s. In 2015, total effort was estimated to 116 Khours, the lowest number in the time series. The standardised effort index (2000-2016) shows a fluctuating, but stable trend (Table 4, Fig. 16).

### **Standardised landings per unit effort (LPUE)**

The unstandardised LPUE-index increased from 1999 to 2007-2008 (Fig. 14b, Table 2), and then decreased in 2009 and further in 2010. Since 2012, the LPUE has increased again, to 63 kg/h in 2016 (preliminary logbook data January-August). The LPUE-indices in Skagerrak and the Norwegian Deep followed each other closely for the years 1999-2004, but since 2005 the development of LPUE in the two areas has differed. In the Norwegian Deep, the index decreased until 2013, to the lowest level observed in the time series, but has been increasing since. In Skagerrak, the LPUE-index increased to a record high level in 2007, and thereafter it decreased sharply until 2010, to the lowest level observed in the time series. The index has been increasing since 2011.

A standardised LPUE-index has been calculated for 2000-2016 (Table 4, Fig. 17). This index follows the same trend as the unstandardised one, except that an increase in 2016 is not seen in the standardised time series. Despite the incomplete logbooks until 2010, the Norwegian LPUE seems to represent a valid index of shrimp stock biomass as trends in the survey biomass index and the Norwegian LPUE index are similar. Both indices show a decrease from 2008 to 2012, followed by an increasing trend from 2013 to 2015 (Søvik and Thangstad 2016). However, the decrease in shrimp biomass in 2016 indicated by the survey is not reflected in the LPUE-index. The Swedish and Danish LPUE-indices show the same trend as the Norwegian one (Ulmestrand *et al.* 2016), i.e. a slight decrease from 2015 to 2016. As the good 2013-year class are 3 years old in 2016, a sharp decrease in biomass in 2016 was not expected. Inspection of the logbook data show that monthly catch rates in the first half of 2016 were on the same level as in 2015 (Fig. 18). Fig. 18 also shows that catch rates generally are higher in the winter months compared with the summer season.

### **Discards**

Results on estimation of Norwegian discards in earlier years is summarized in Søvik and Thangstad (2014).

Estimated Norwegian annual discards from Skagerrak in 2009-2015 range from 78 to 1 191 t (discard rates between 2 and 20% of total catches), and in the Norwegian Deep from 16 to 98 t (1-7% discard rates) (Tables 5, 6). Discards in Skagerrak increased from 405 t in 2013 to 1191 t in 2014, almost four-fold. This was probably due to the large 2013-year class, indicating that a large part of the 2014-discards was 1-year olds.

The justification for using Danish data to estimate the Norwegian discards have been that the two fisheries are partly overlapping in eastern Skagerrak and that the size structure of the stock is the same on these fishing grounds (Søvik and Thangstad 2014). However, this does not say anything about the behaviour of fishers, or how they handle the catch. The underlying assumption that the level of discarding is the same in the two fisheries may not be valid as the Danish fishery, unlike the Norwegian and Swedish fisheries, is not constrained by quotas. Comparison of the boiled proportion in landings from the three fisheries indicate that the Norwegian discard practice may be more similar to the Swedish than the Danish one (Ulmestrand *et al.* 2016). High proportions of boiled shrimp in landings indicate large discards. The Norwegian discards, as they are presently estimated, are therefore likely underestimates.

### Catch composition

Length frequency distributions show that the catches in the 1<sup>st</sup> quarter (January-March) of 2015 were dominated by three year classes both in Skagerrak and the Norwegian Deep (Table 7, Fig. 19). The catches in the second and third quarters were similarly made up of three year classes. The 4+ group is very small. In the 4<sup>th</sup> quarter, the 0-group is seen in catches in Skagerrak. The biomass of the 2-group (the large 2013-year class) dominated the 2015-catches in both Skagerrak and the Norwegian Deep. (Fig. 20). With the new MLS of 7 cm, the whole 1-group as well as part of the 2-group constitute undersized shrimp in quarters 1 and 2. In quarters 3 and 4, part of the 1-group is undersized. With the earlier MLS of 6 cm, most of the 1-group was larger than the MLS in quarters 3 and 4. Comparison of length distributions by quarter (quarters 1-3), show that the number of 3-year old shrimp relative to the number of 2-year old shrimp is higher in the 2016 catches compared with the three previous years (Figs. 21, 22). This is expected as the large 2013-year class constitute the 3-group in 2016. This is, however, not so clearly seen in the catches of the 2016 shrimp survey (Søvik and Thangstad 2016). The mean size of the 3-group is smaller in 2016 compared with previous years (clearest seen in length distributions in the first quarter) (Figs. 21, 22).

The shrimp life cycle in the NDSK area is illustrated by the distribution of stages per length (age groups) (Fig. 23).

### References

- Bhattacharya, C.G. 1967. A simple method of resolution of a distribution into Gaussian components. *Biometrics*, 23: 115-135.
- Hvingel, C., Lassen, H. and Parsons, D.G. 2000. A Biomass Index for Northern Shrimp (*Pandalus borealis*) in Davis Strait Based on Multiplicative Modelling of Commercial Catch-per-unit-effort Data (1976-97). *J. Northw. Atl. Fish. Sci.*, 26: 25-36.
- Hvingel, C. and Aschan, M. 2006. The Fishery for Northern Shrimp (*Pandalus borealis*) in the Barents Sea. NAFO SCR Doc. 06/65. 12 pp.
- ICES. 2015. Advice October 2015. Book 6 (6.3.17).
- ICES. 2016a. Advice March 2016. Book 6 (6.3.17a (update)).
- ICES. 2016b. Report of the Benchmark Workshop on *Pandalus borealis* in Skagerrak and Norwegian Deep Sea (WKPAND), 20–22 January 2016, Bergen, Norway. ICES CM 2016/ACOM:39. 72 pp.
- Munch-Petersen, S., Ulmestrand, M., Søvik, G., and Eigaard, O. 2013. Discarding in the shrimp fisheries in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east). NAFO SCR Doc. 13/068.
- Søvik, G. and Thangstad, T. 2014. The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2014. NAFO SCR Doc. 14/063.
- Søvik, G. and Thangstad, T. 2016. 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. – NAFO SCR Doc. 16/053.
- Ulmestrand, M., Bergenius, M., Eigaard, O., Søvik, G. and Munch-Petersen, S. 2016. The Northern shrimp (*Pandalus borealis*) Stock in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa East). - NAFO SCR Doc. 16/056.

**Table 1.** The Norwegian fleet participating in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) in 2015: Number of vessels and total (uncorrected) landings (t) per vessel length group; and landings per vessel per length group (mean, median, and standard deviation).

Vessel length group	Number of vessels	Landings (t)	Landings per vessel (t)		
			Mean	Median	St.dev
< 10 m	16	103	6.4	1.4	9.9
10-11.99 m	88	1337	15.2	9.2	15.4
12-14.99 m	57	1768	31.0	28.7	28.3
15-20.99 m	13	632	48.6	35.8	37.3
21-27.99 m	21	1840	87.6	69.7	63.8
> 28 m	6	688	114.6	109.4	66.1
unknown	3	1	0.3	0.2	0.2
<b>Total</b>	<b>204</b>	<b>6 368</b>			

**Table 2.** Nominal landings from ICES Div. IIIa, Div. IVa east, and total in Div. IIIa and Subarea IV; increase in total landings due to correction for boiling; Total Allowable Catch (TAC); estimated discards; landings per unit effort (LPUE) (kg/hour); and estimated effort (Khours) of the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east 1970-2016. Discard data 2009-2012 were recalculated in 2013 using information on Danish discards.

Year	Landings (t)				TAC (t)	Disc. (t)	LPUE (kg/hour)			Effort (Khours)		
	IIIa	IVaE	Total	Corr.	Total	Total	IIIa	IVaE	Total	IIIa	IVaE	Total
1970	982	747	2089									
1971	1392	1094	2657									
1972	1123	1354	2447									
1973	1415	918	2346									
1974	1186	623	1953									
1975	1463	876	2339									
1976	2541	807	3592									
1977	2167	847	3126									
1978	1841	611	2533									
1979	2489	550	3082									
1980	3498	1064	4638									
1981	3753	1434	5187									
1982	3877	1545	5422									
1983	3722	1648	5379									
1984	3509	1261	4783									
1985	4772	1778	6557			460						
1986	4811	1681	6492			338			36			179
1987	5198	3145	8343			634			36			230
1988	3047	4612	7662			645			31			251
1989	3156	3418	6574			920			23			273
1990	3006	3146	6152			990			26			232
1991	3441	2663	6155			376			30			206
1992	4257	2945	7202			414			35			204
1993	4089	3449	7538			695			31			243
1994	4388	2426	6815			157			31			218
1995	5181	2838	8060		8775	212			35			255
1996	5157	2753	7942		8160	253	43	31	37	119	89	214
1997	5461	3107	8576		8160	821	45	39	42	122	80	212
1998	6515	3189	9707		10505	279	45	40	44	144	78	219



1999	3985	2752	6748		10505	486	32	29	32	125	93	219
2000	3554	2562	6116	326	7110	521	33	34	34	114	79	192
2001	2959	3933	6914	374	8140	565	33	34	34	93	122	214
2002	3709	3612	7331	382	8040	534	44	44	44	89	87	173
2003	3736	3986	7731	455	8040	563	50	47	48	78	91	171
2004	4638	4360	9002	546	8530	656	59	53	55	83	88	174
2005	4419	4087	8507	452	8530	620	58	49	52	80	88	173
2006	5177	3037	8214	455	8961	599	63	42	50	85	78	174
2007	5928	2307	8235	453	9331	526	92	42	65	67	59	134
2008	5744	2039	7783	478	9731	1408	79	47	65	76	47	127
2009	4268	1668	5940	428	9731	94	50	45	48	91	40	132
2010	2598	1687	4308	389	8767	133	27	44	34	106	43	136
2011	2693	1773	4466	335	7452	247	37	40	39	77	47	122
2012	3564	1000	4573	228	5855	292	44	27	34	86	40	141
2013	3739	1132	4871	308	5469	459	43	28	37	92	43	138
2014	4500	1249	5749	375	5469	1289	53	43	50	88	31	122
2015	4741	1628	6369	440	6346	476	66	47	58	76	37	116
2016	3754	1764			9317		66	58	63			

Data from the Norwegian Directorate of Fisheries.

The 2016 landings are from January-August.

The 2016 LPUE data are from January-August.

Estimated effort 2000-2015 are based on landings corrected for boiling.

"Total" refers to the sum of Divs. IIIa and IVa east, except for "total landings" and correction for boiling, which refer to Div. IIIa and Subarea IV.

**Table 3.** Percentage of boiled landings (numbers corrected for boiling) of total Norwegian shrimp (*Pandalus borealis*) landings from ICES Div. IIIa and Subarea IV (Skagerrak and the Norwegian Deep), in 2000-2015. Data from the Norwegian Directorate of Fisheries (first two rows of table). The shaded numbers from IVa east for 2012-2015 are not correct (see text), and numbers from Rogaland Fiskesalgslag SA (sales organization) are used.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
IIIa	0.42	0.43	0.39	0.42	0.41	0.36	0.35	0.38	0.45	0.54	0.67	0.59	0.47	0.50	0.51	0.53
IVa east	0.47	0.46	0.48	0.54	0.59	0.52	0.63	0.63	0.65	0.69	0.79	0.63	0.20	0.15	0.11	0.11
Rogaland county												0.68	0.68	0.56	0.61	0.67

**Table 4.** Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, 2000-2016. The 2016 LPUE-index is based on logbook data January-August. The 2016 effort index is based on logbook effort from January-August and corrected landings from January-August projected to the end of 2016.

	Stand. LPUE (index)	Stand.effort (index)
2000	0.77	1.03
2001	0.82	1.09
2002	1.01	0.93
2003	1.04	0.96
2004	1.19	0.98
2005	1.11	0.98

2006	1.09	0.97
2007	1.32	0.81
2008	1.28	0.79
2009	0.93	0.84
2010	0.69	0.83
2011	0.71	0.83
2012	0.60	0.99
2013	0.67	0.95
2014	0.87	0.87
2015	1.01	0.83
2016	1.00	1.00

**Table 5.** Estimated discards (t), corrected landings (t) and catches (t) in the Norwegian shrimp (*Pandalus borealis*) fishery in Div. IIIa (Skagerrak) in 2009-2015, per quarter and annually. The Norwegian discards are estimated by applying the Danish discards-to-landings ratio on the Norwegian landings.

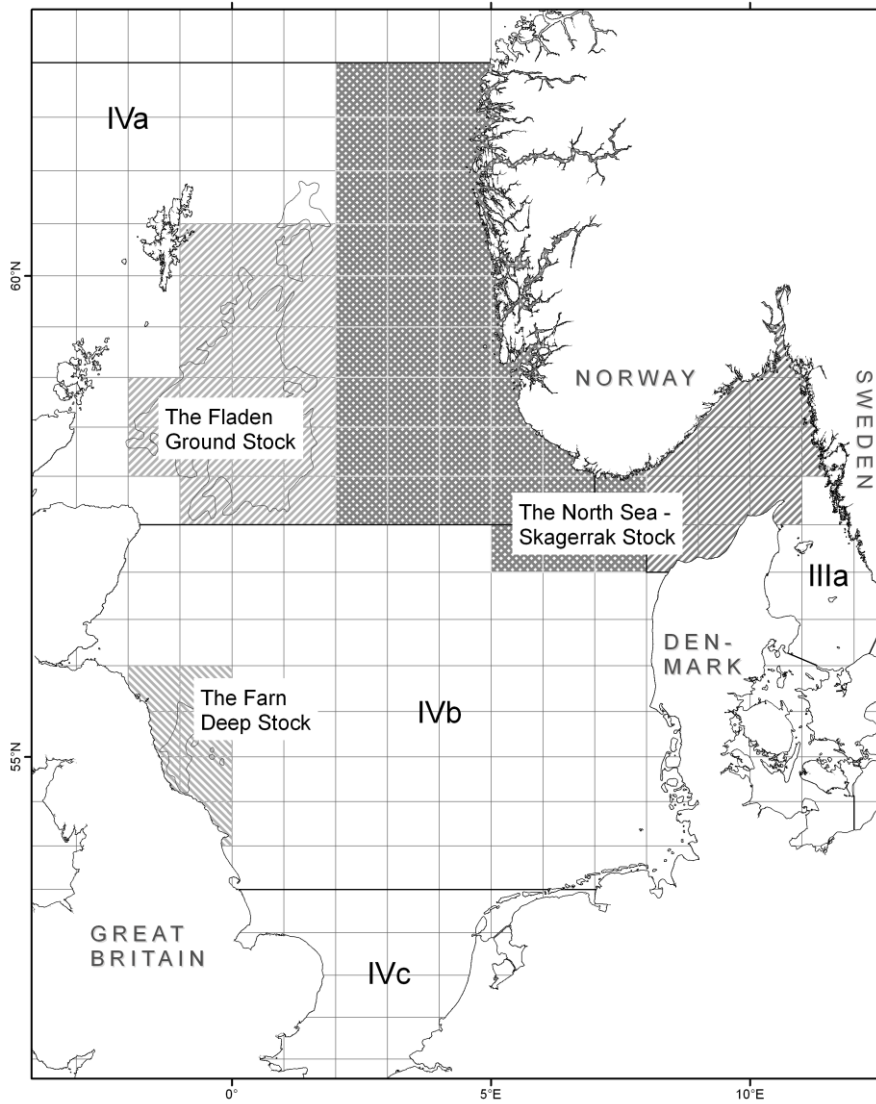
year	Q 1			Q 2			Q 3			Q 4			Annual		
	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.
2009	26	1468	1494	21	1105	1127	21	944	965	10	1033	1043	78	4551	4629
2010	68	775	843	26	709	735	11	709	720	5	624	629	110	2817	2927
2011	33	695	729	87	725	812	55	822	877	53	647	700	228	2890	3118
2012	59	1002	1061	20	536	556	47	1159	1207	122	1072	1194	249	3768	4017
2013	218	1057	1275	69	1001	1070	56	1042	1098	62	869	931	405	3969	4374
2014	506	1083	1590	205	986	1191	97	1568	1665	383	1141	1524	1191	4779	5970
2015	215	1786	2001	74	1071	1145	72	1157	1229	57	1032	1088	418	5045	5463

**Table 6.** Estimated discards (t), corrected landings (t) and catches (t) in the Norwegian shrimp (*Pandalus borealis*) fishery in Div. IVa east (the Norwegian Deep) in 2009-2015, per quarter and annually. The 2009 numbers from Q3 are based on Danish length frequency data as there was no Norwegian catch sampling in this quarter. The Norwegian discards are estimated from length frequency distributions of commercial catches, assuming that only shrimp <15 mm CL are discarded in the Norwegian Deep (there are little or no Danish catch sampling in this area).

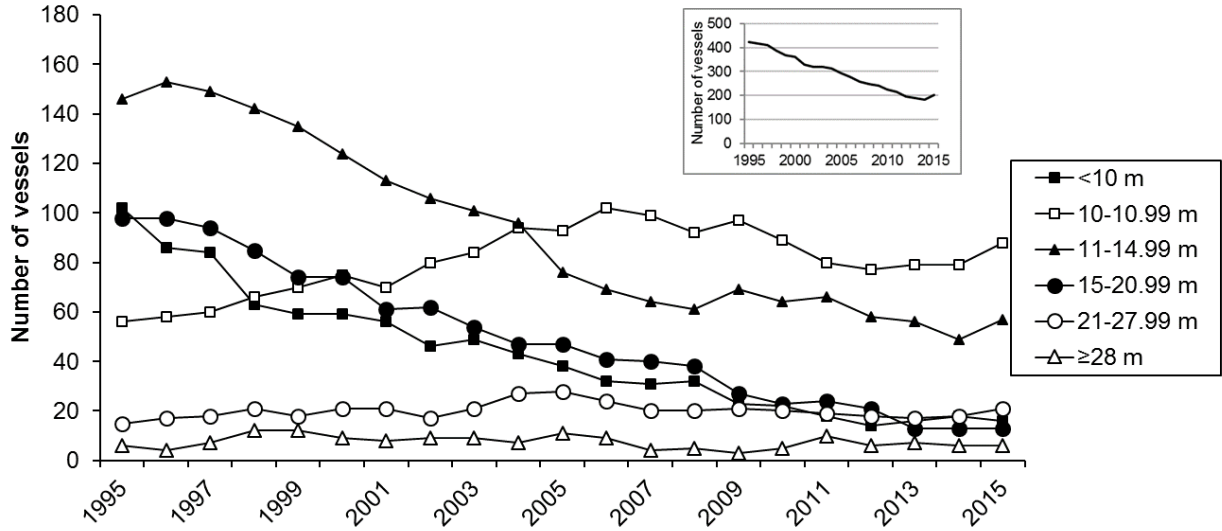
year	Q 1			Q 2			Q 3			Q 4			Annual		
	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.	disc.	land.	catch.
2009	9	592	601	5	560	565	1	474	475	1	186	187	16	1812	1828
2010	1	621	622	8	512	520	14	415	429	1	309	310	24	1857	1881
2011	7	582	589	5	625	630	4	580	584	3	124	127	19	1911	1930
2012	16	364	380	15	278	293	8	264	272	5	178	183	44	1084	1128
2013	11	365	376	25	305	330	18	381	399	1	159	160	55	1210	1265
2014	26	455	481	39	339	378	23	329	352	11	221	232	98	1345	1443
2015	6	669	675	12	404	416	18	404	422	22	287	309	58	1763	1821

**Table 7.** Mean carapace length (with SD), and numbers (millions) per age group in the 2015 catches from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, per area and total.

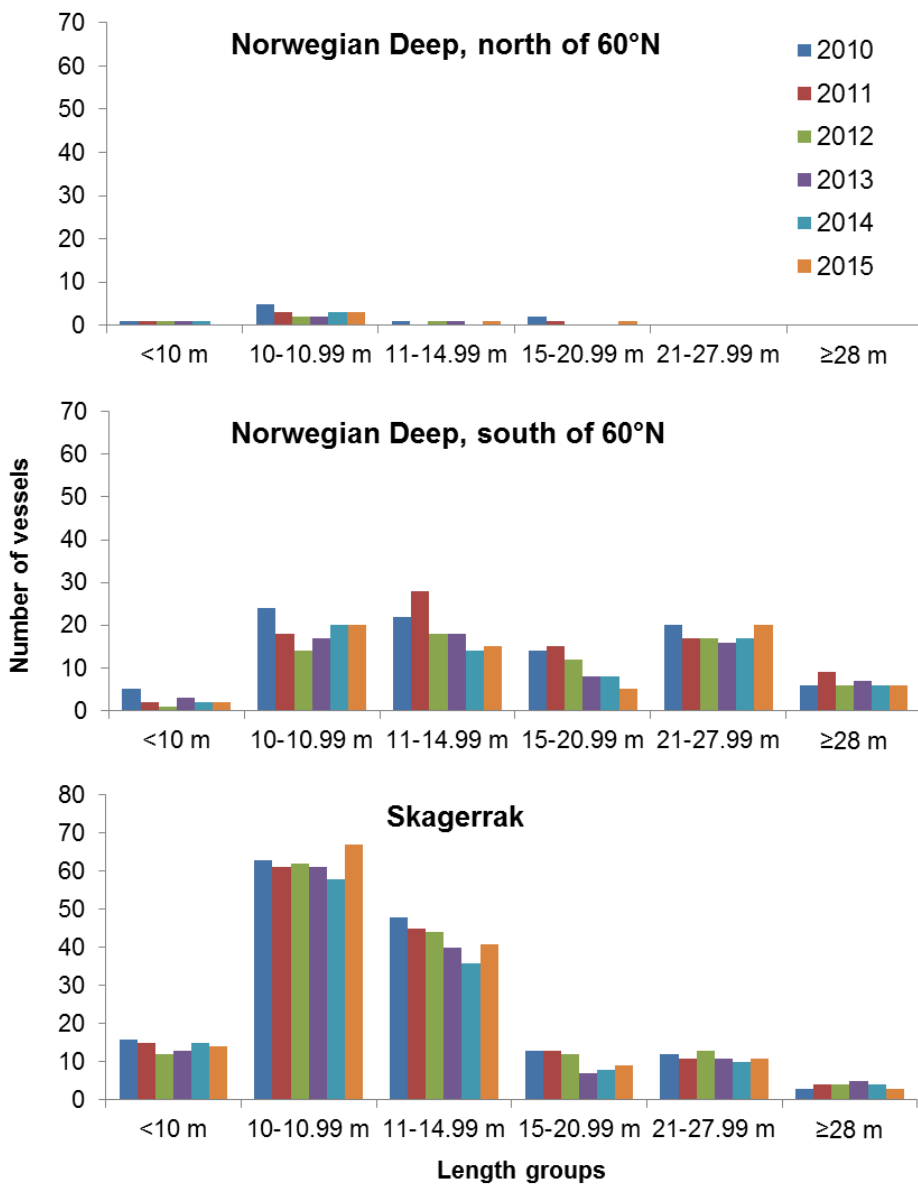
	Age	Total			Skagerrak			Norwegian Deep		
		Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
Q1	1	11.58	1.15	74	11.57	1.14	73	11	1.22	1
	2	17.09	1.33	399	17.14	1.31	334	16.49	1.22	60
	3/3+	22.15	1.77	140	22.02	1.85	88	21.88	1.73	56
	4+							26.5	0.61	0
Q2	1	13.7	1.48	140	13.75	1.52	131	14	1.89	15
	2	17.74	1.69	230	17.75	1.57	172	17.46	1.35	40
	3+	22.56	1.41	43	22.54	1.55	24	21.81	1.66	30
Q3	1	15.81	1.65	185	15.78	1.48	146	15	1.89	29
	2	19.84	1.8	167	19.71	1.81	131	19.18	1.23	34
	3+	24.29	1.27	13	24.47	1.22	6	22.64	1.75	20
Q4	0	10.72	1.46	9	10.28	1.31	7			
	1	15.97	1.31	160	16.06	1.06	114	15.35	1.48	40
	2/2+	20.02	1.89	141	19.67	1.84	123	20.44	2.08	30
	3+	24.63	0.85	6	24.62	0.82	4			



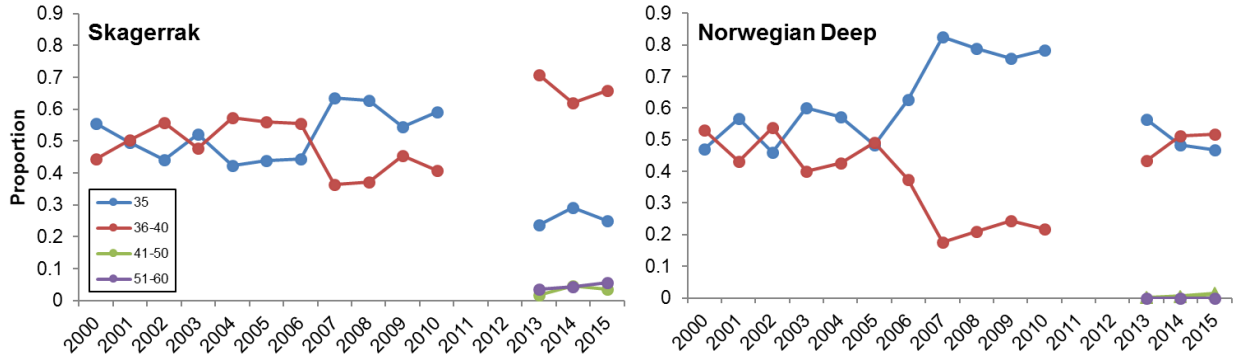
**Fig. 1.** Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the ICES defined management units. Grid is standard “ICES squares” (0.5° lat. by 1° long.).



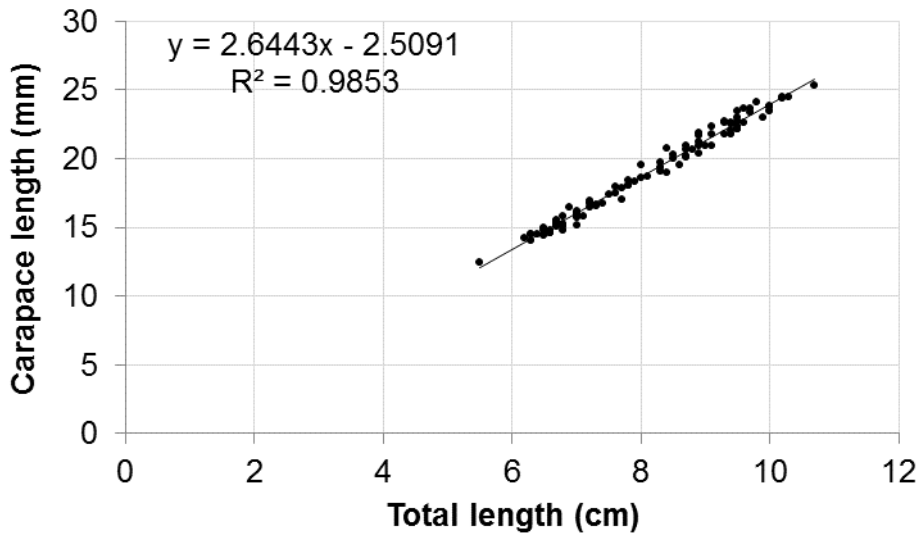
**Fig. 2.** The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) in 1995-2015: number of vessels per length group. Total numbers of vessels per year is given in the inserted figure. Data from the Norwegian Directorate of Fisheries.



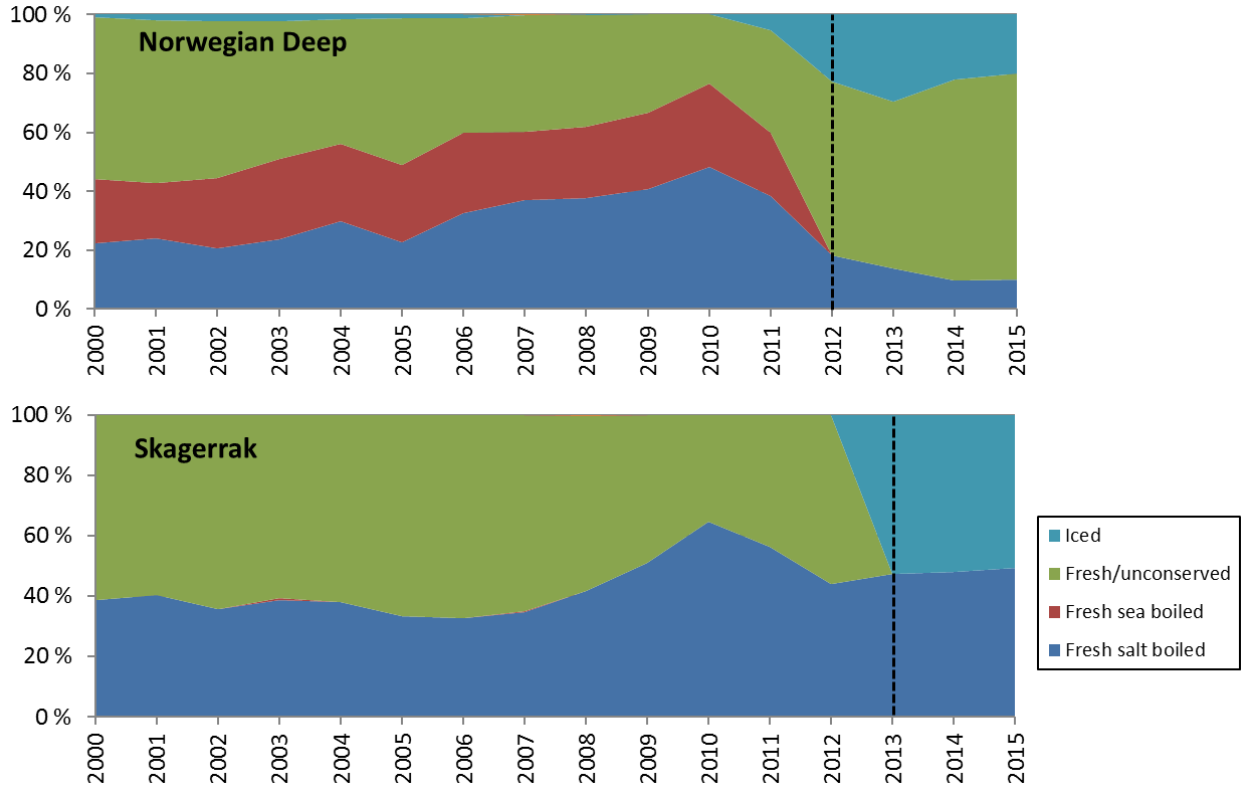
**Fig. 3.** Number of vessels per length group in the Norwegian fleet fishing for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2010-2015. Some vessels fish in more than one area. Data from the Norwegian Directorate of Fisheries.



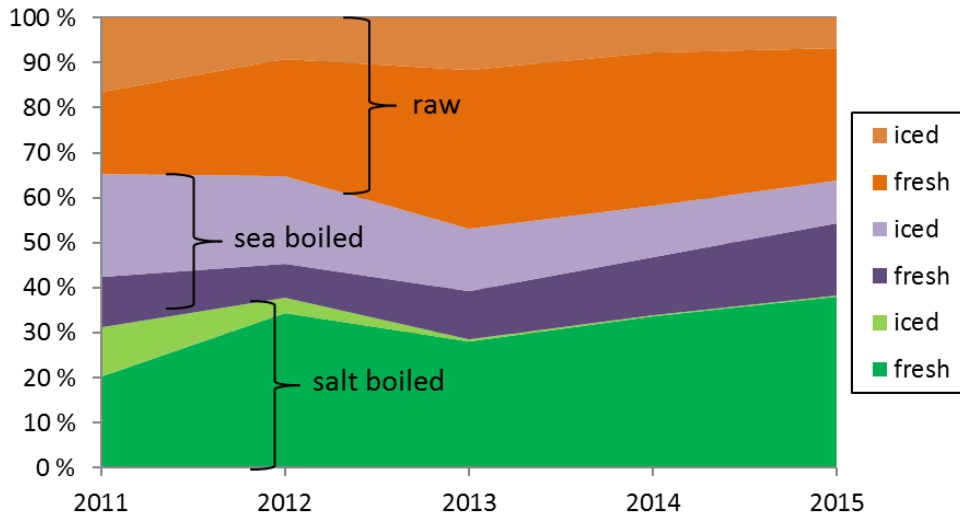
**Fig. 4.** Use of different mesh size (mm) by the Norwegian fleet fishing for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2000-2015. Mesh size per day in 2000-2010, and per haul in 2013-2015. There were no data on mesh size in 2011-2012. Data from the Norwegian Directorate of Fisheries.



**Fig. 5.** Carapace length as a function of total length (measured from the front of the eye to the back of the tail) from measurements of 100 shrimp (*Pandalus borealis*) from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), collected in summer 2016.

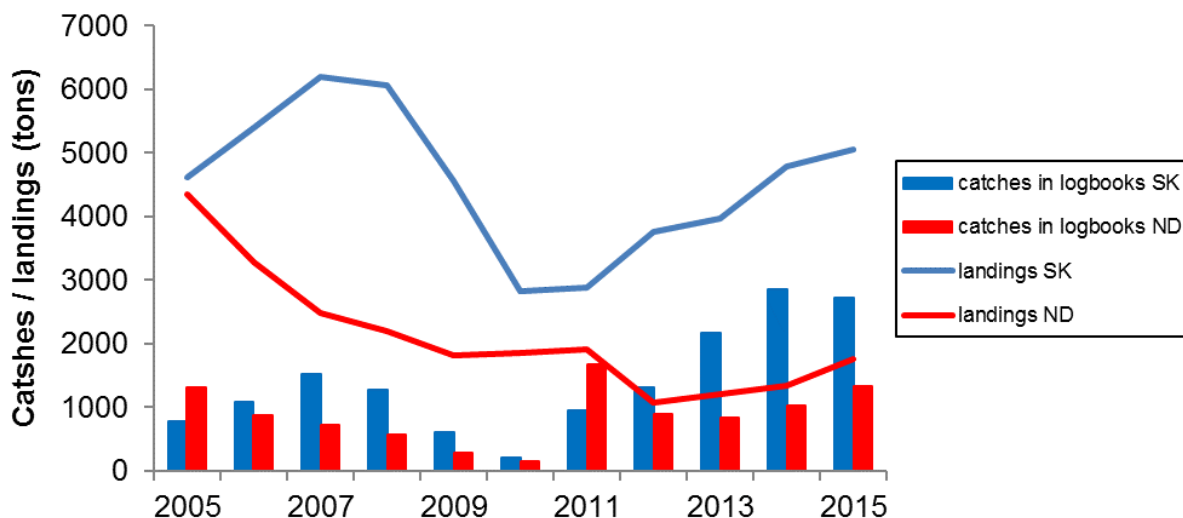


**Fig. 6.** Proportions of respectively iced, fresh/unconserved, sea boiled, and salt boiled shrimp landings from ICES Divs. IIIa and IVa East (Skagerrak and the Norwegian Deep) in the 2000-2015 landings data from the Norwegian Directorate of Fisheries. Dotted lines indicate years when there was a change in the use of conservation categories.

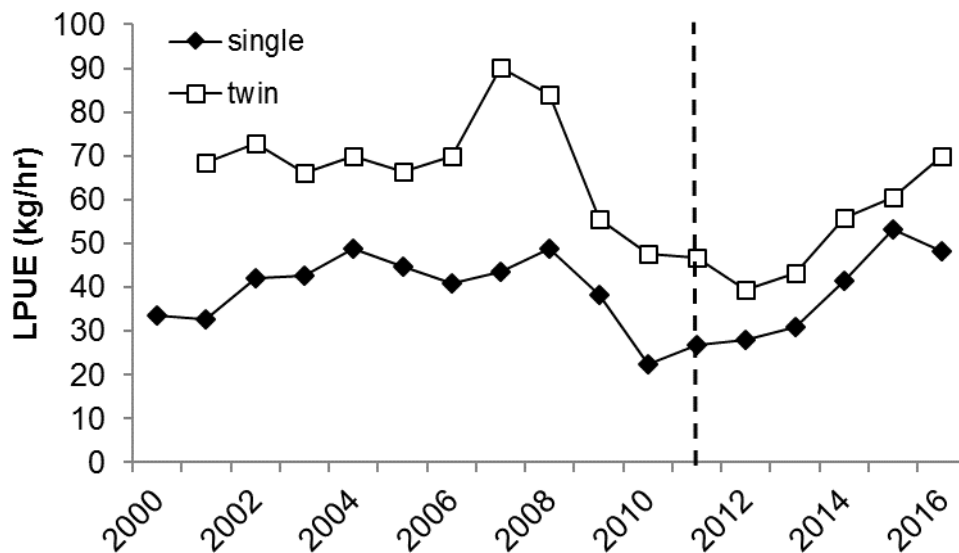


**Fig. 7.** Proportions of respectively raw, sea boiled, and salt boiled landings from the Rogaland county in 2011-2015, landed as either fresh or on ice. Data from Rogaland Fiskesalgs lag SA.

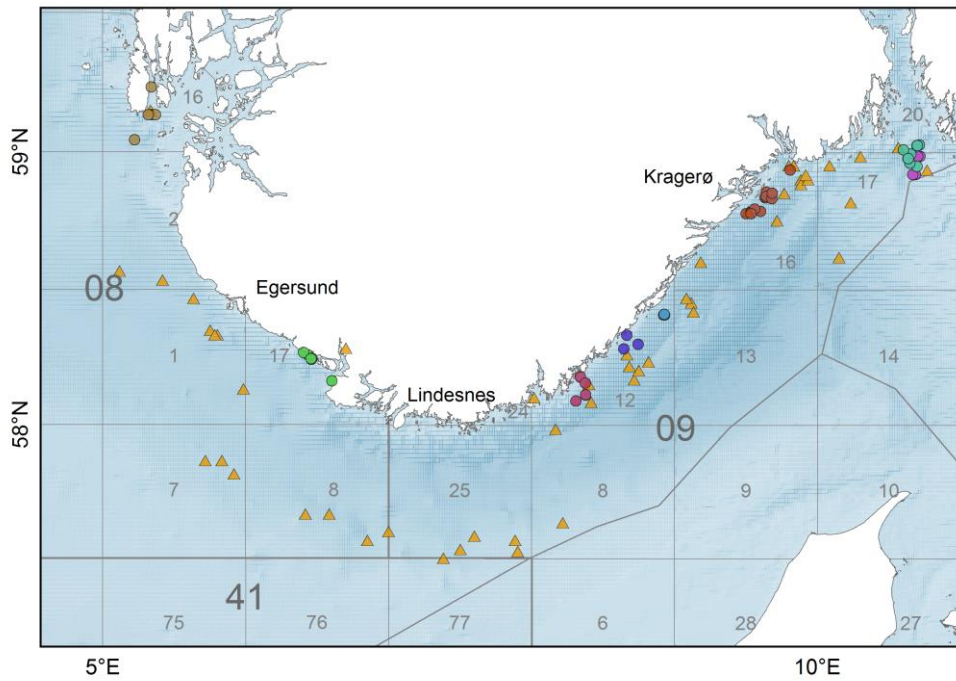




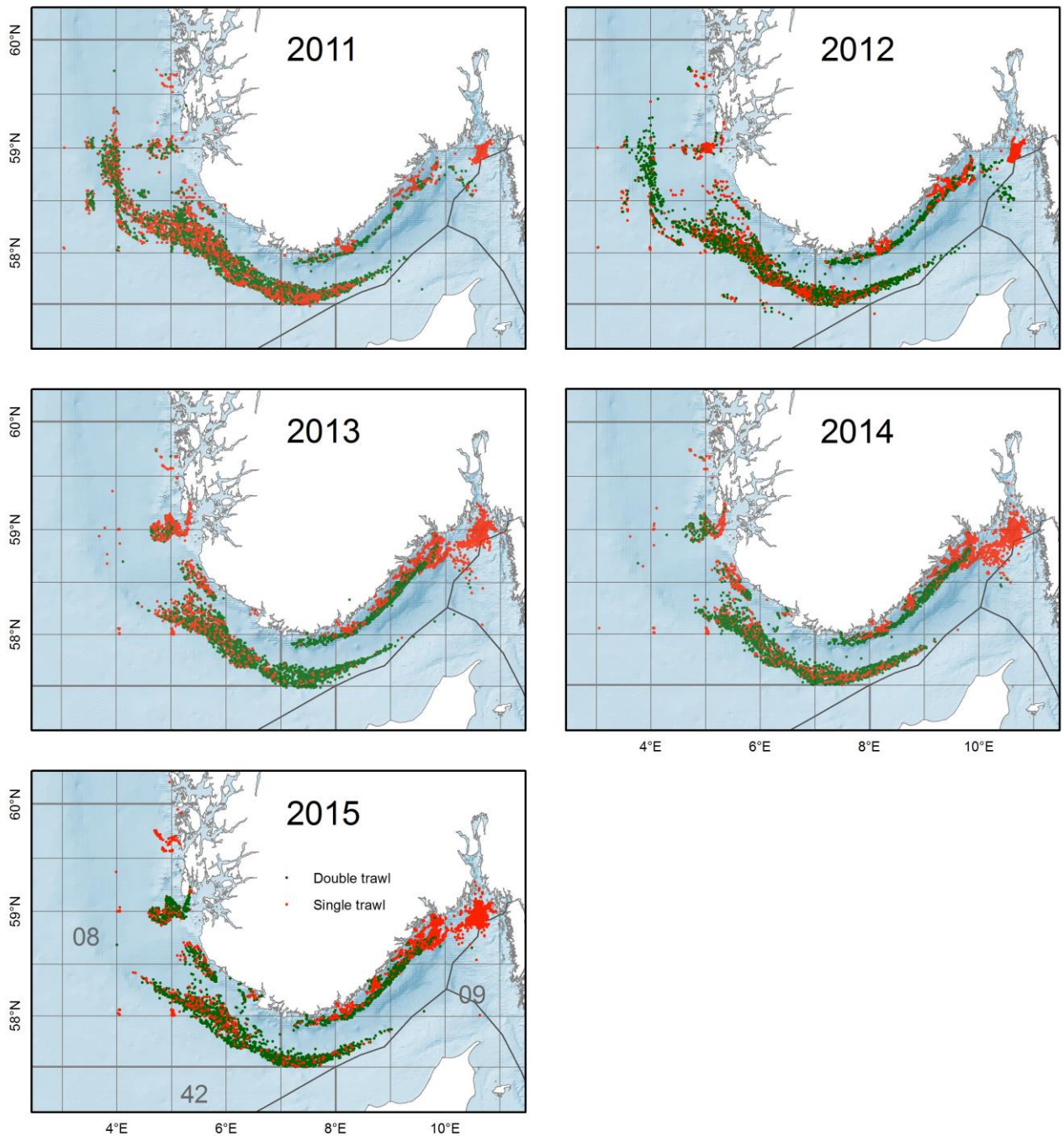
**Fig. 8.** Incomplete logbooks from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) illustrated by landings (corrected for boiling) and catches registered in logbooks, per area for 2005-2015. Data from the Norwegian Directorate of Fisheries.



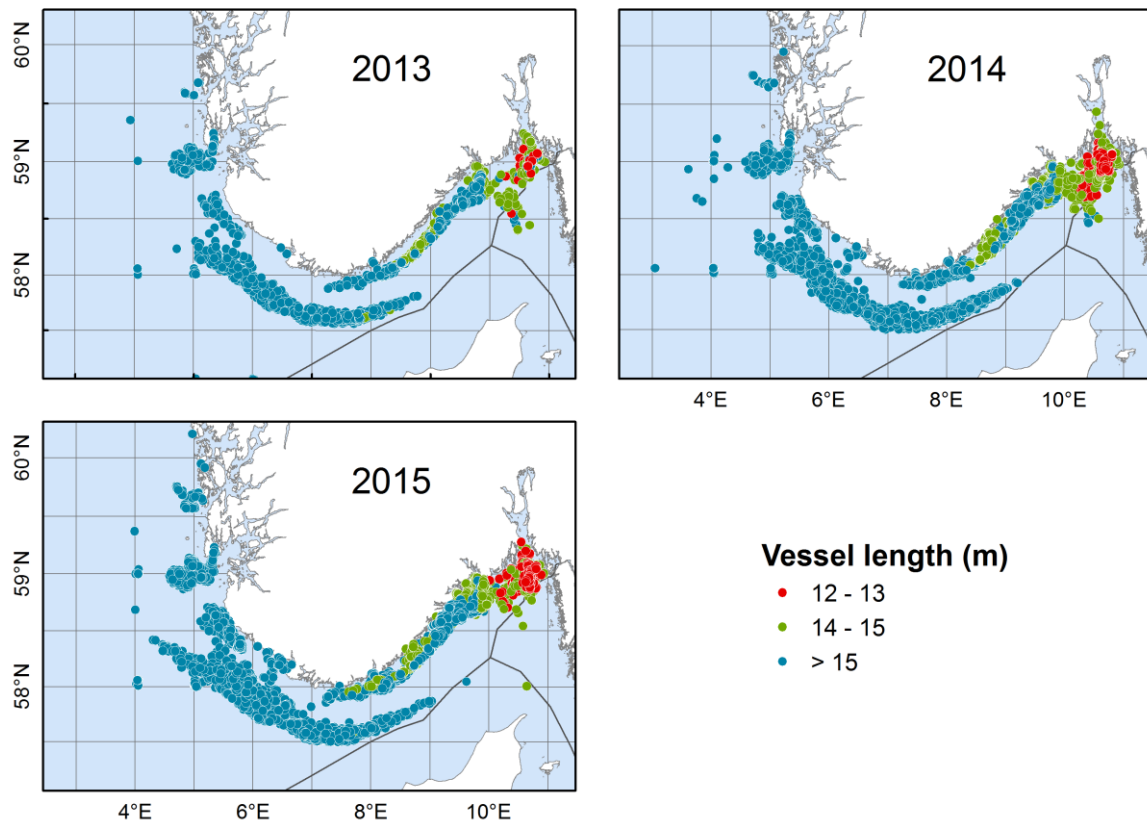
**Fig. 9.** Annually unstandardised LPUE indices per gear type from logbooks from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). The 2000-2010 indices are based on data corrected regarding use of gear type (shrimp trawl, twin trawl). The 2011-2016 indices are based on information on the number of trawls used per haul (single, twin) (2016 data until August). The dashed line shows the year of the implementation of the electronic logbooks. Data from the Norwegian Directorate of Fisheries.



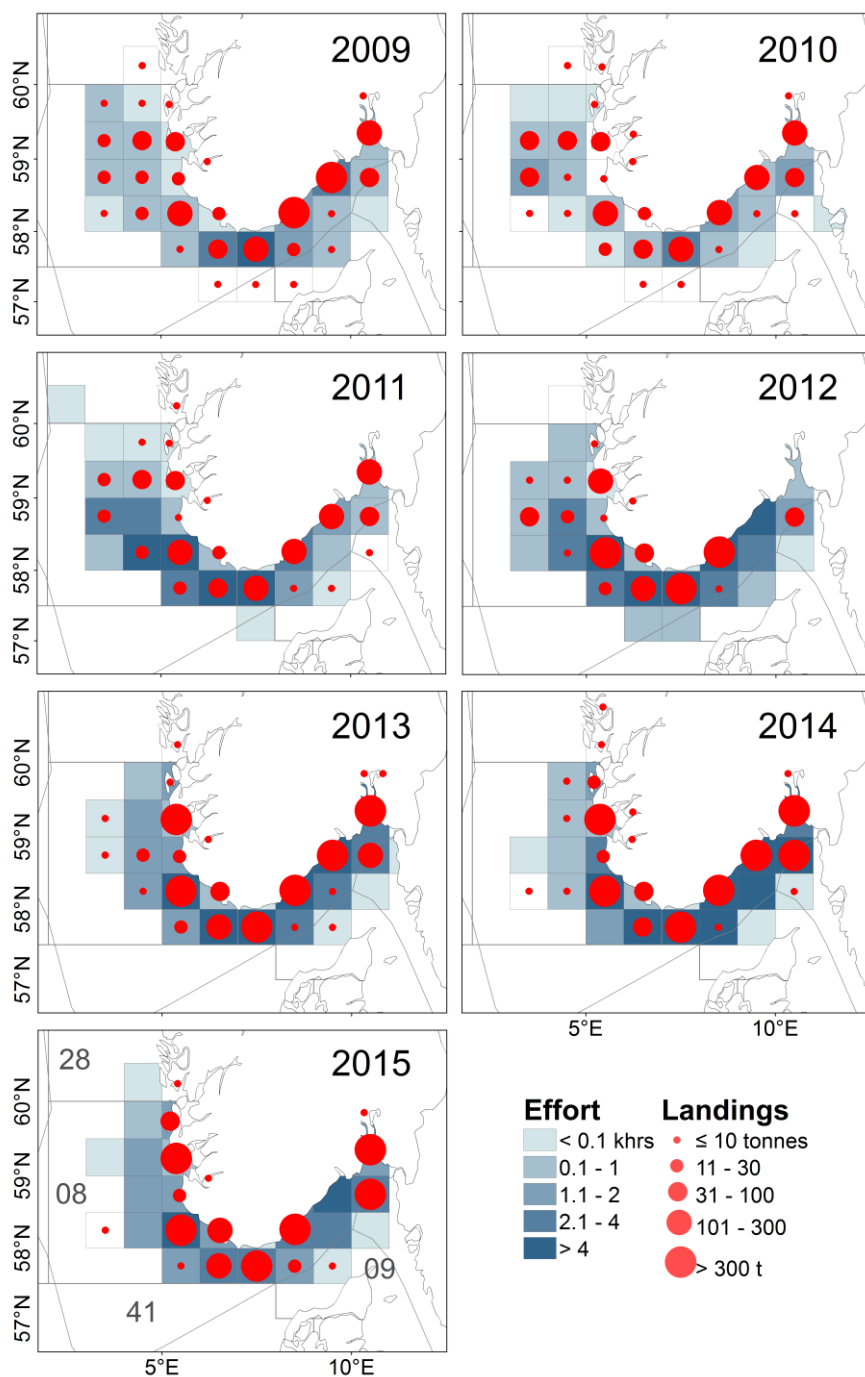
**Fig. 10.** Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2015 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by Norwegian fishermen (circles) and the Norwegian Coast Guard (triangles). Colours represent individual fishing vessels.



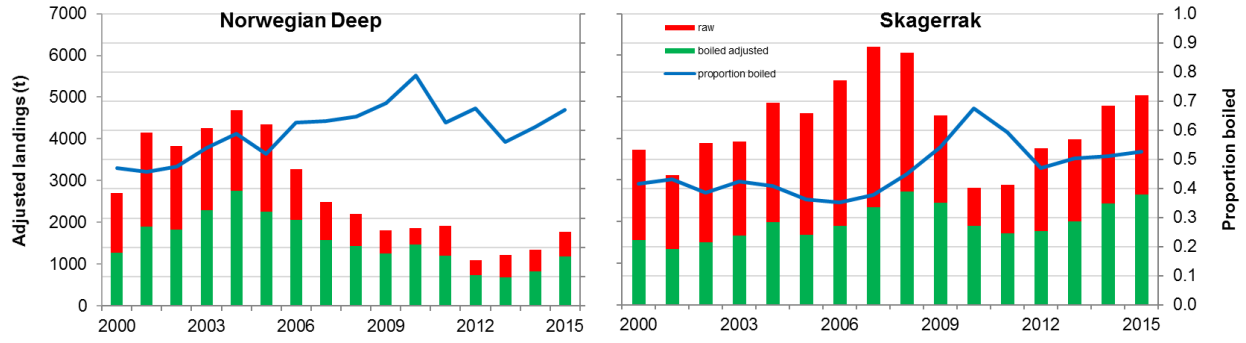
**Fig. 11a.** Spatial distribution by gear of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011-2015: positions of single trawl hauls with single and twin trawl in electronic logbooks. Grid is standard “ICES squares” (0.5° lat. by 1° long.). Norwegian statistical areas are marked by numbers. National economic zones are included on the maps. Data from vessels  $\geq 15$  m (from vessels  $\geq 12$  m in Skagerrak in 2013-2015). Data from the Norwegian Directorate of Fisheries.



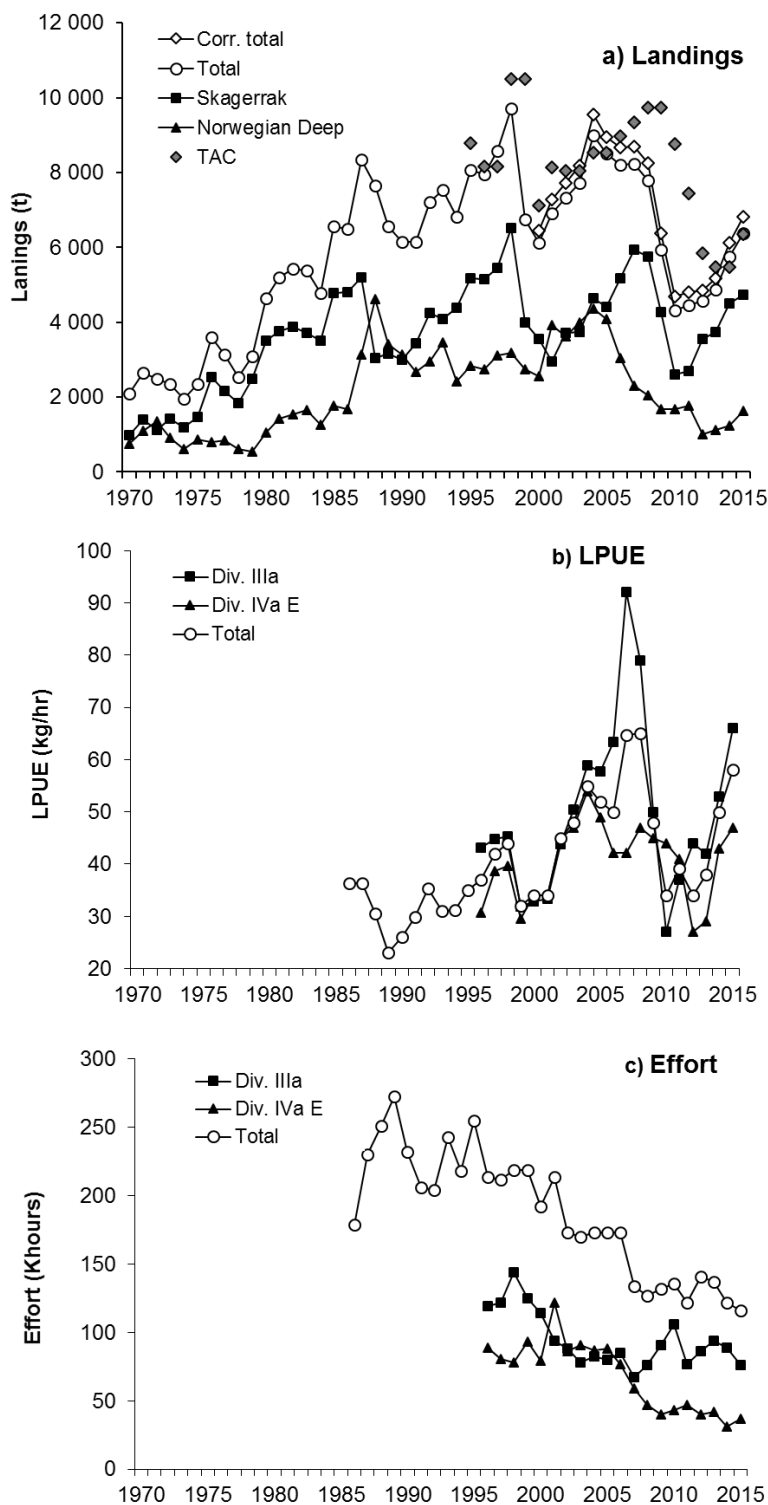
**Fig. 11b.** Spatial distribution by vessel length group of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2013-2015: positions of single trawl hauls in electronic logbooks. Data from vessels  $\geq 15$  m in the Norwegian Deep, and from vessels  $\geq 12$  m in Skagerrak. Data from the Norwegian Directorate of Fisheries.



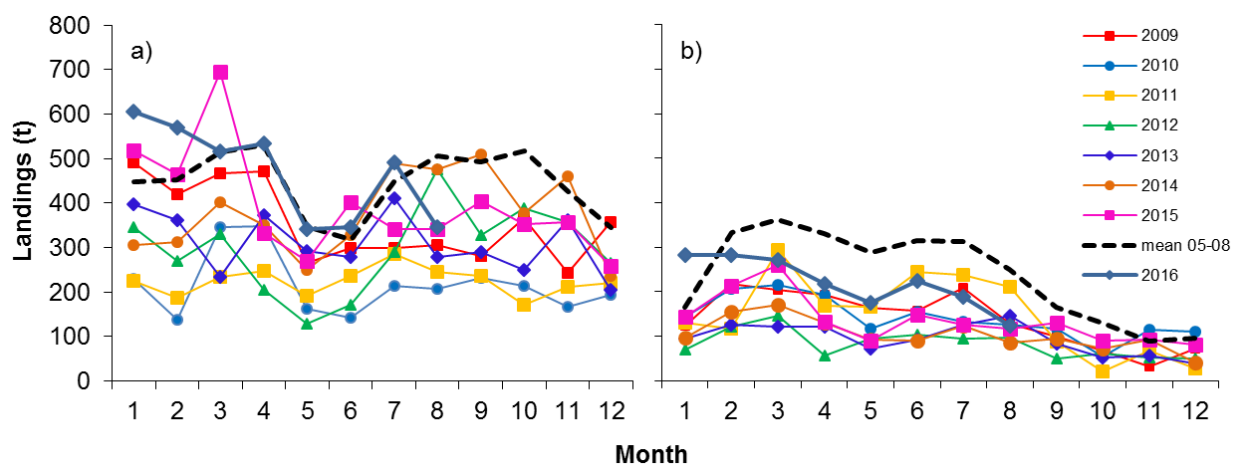
**Fig. 12.** Spatial distribution of landings (t) (uncorrected) and recorded effort (1000 trawling hours) in the Norwegian fishery for shrimp (*Pandalus borealis*) in 2009-2015 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by standard “ICES squares” (0.5° lat. by 1° long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.



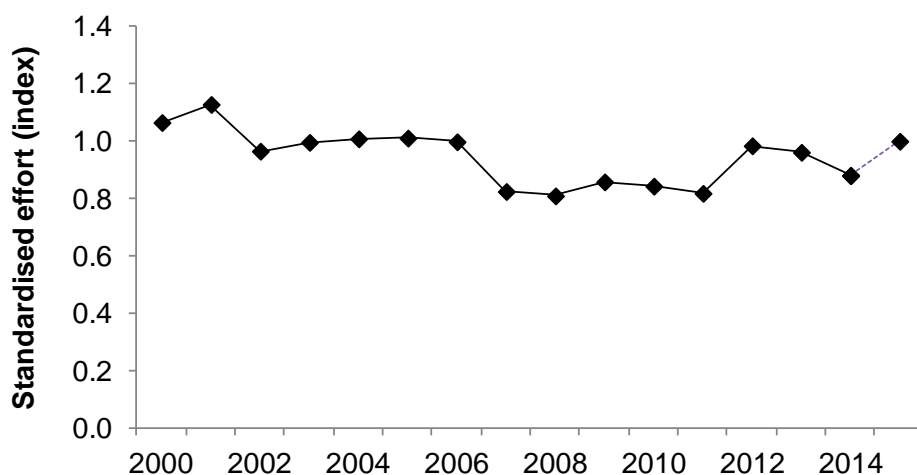
**Fig. 13.** Norwegians landings of raw and boiled shrimp (boiled weight adjusted for boiling) from ICES Divs. IIIa and IVa East (Skagerrak and the Norwegian Deep) in 2000-2015, and proportion of boiled shrimp. Data from the Norwegian Directorate of Fisheries and Rogaland Fiskesalgslag SA.



**Fig. 14.** Landings (nominal and corrected for boiling at sea) and TAC a); unstandardised landings per unit effort (LPUE) b); and estimated total effort c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) for all years for which data are available. In a) “total” includes Div. IIIa and all of Subarea IV, and “Corr. total” are total landings corrected for boiling at sea. Data from the Norwegian Directorate of Fisheries.

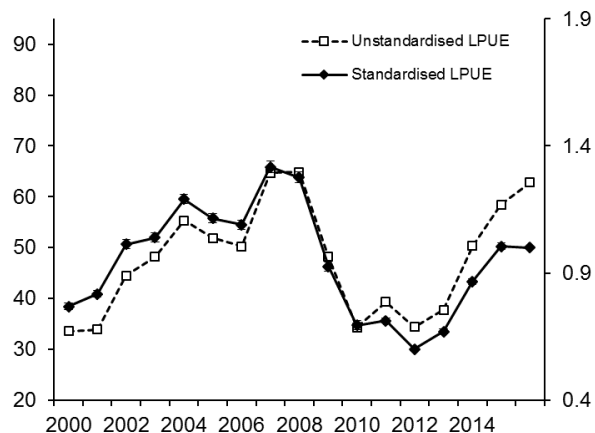


**Fig. 15.** Monthly (uncorrected) Norwegian landings of shrimp (*Pandalus borealis*) 2009-2016 and the 2005-2008 mean for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries. Data from 2016 are preliminary.

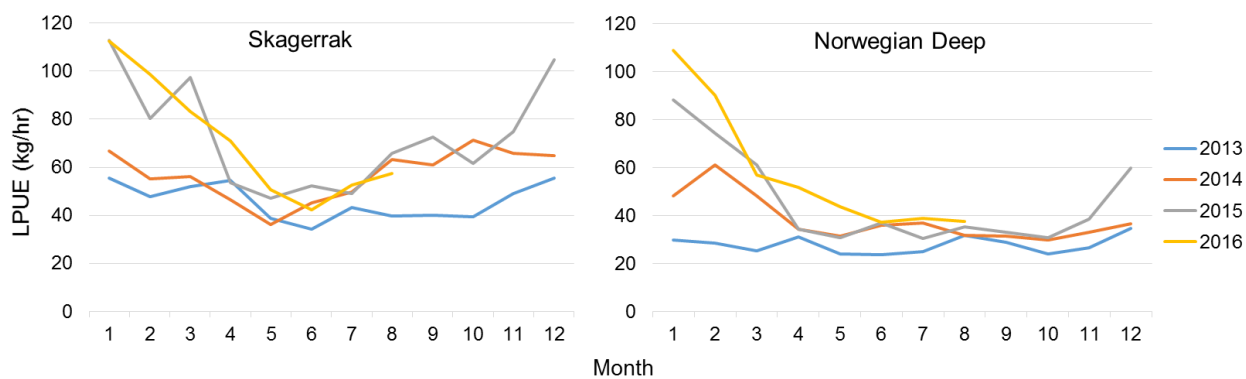


**Fig. 16.** Standardised total effort in the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2016. The 2016 effort index is estimated from preliminary logbook data (January-August) and preliminary landings corrected for boiling (January to August) projected to the end of the year. Data from the Norwegian Directorate of Fisheries.

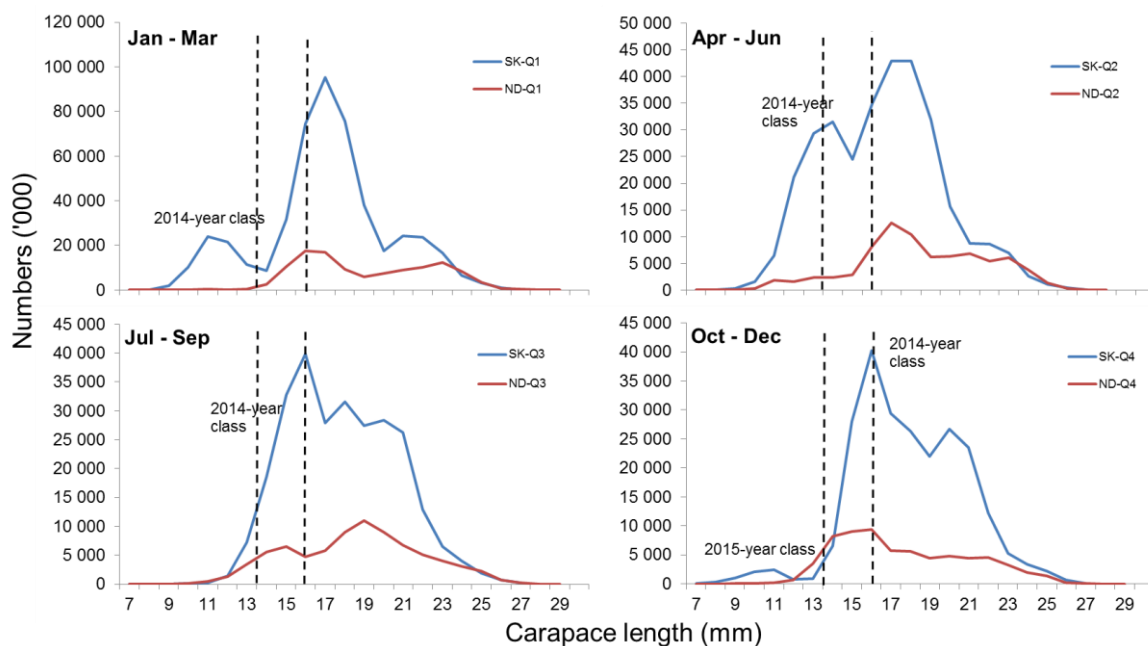




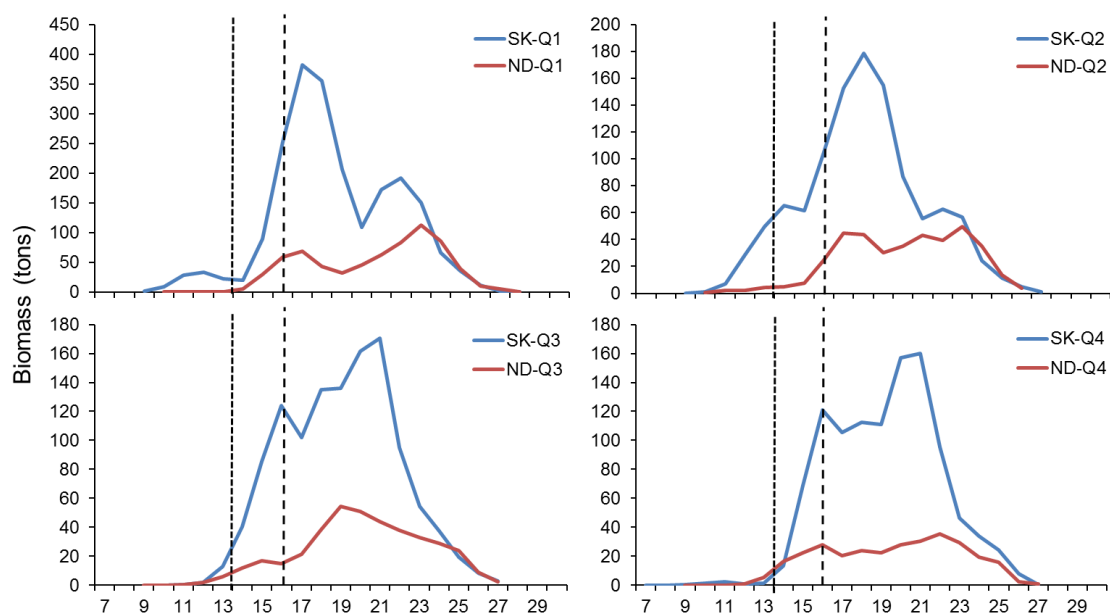
**Fig. 17.** Standardised LPUE-index (with standard error), and unstandardised LPUE-index (kg/hr) for 2000-2016 from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from the Norwegian Directorate of Fisheries. The 2016-data are preliminary.



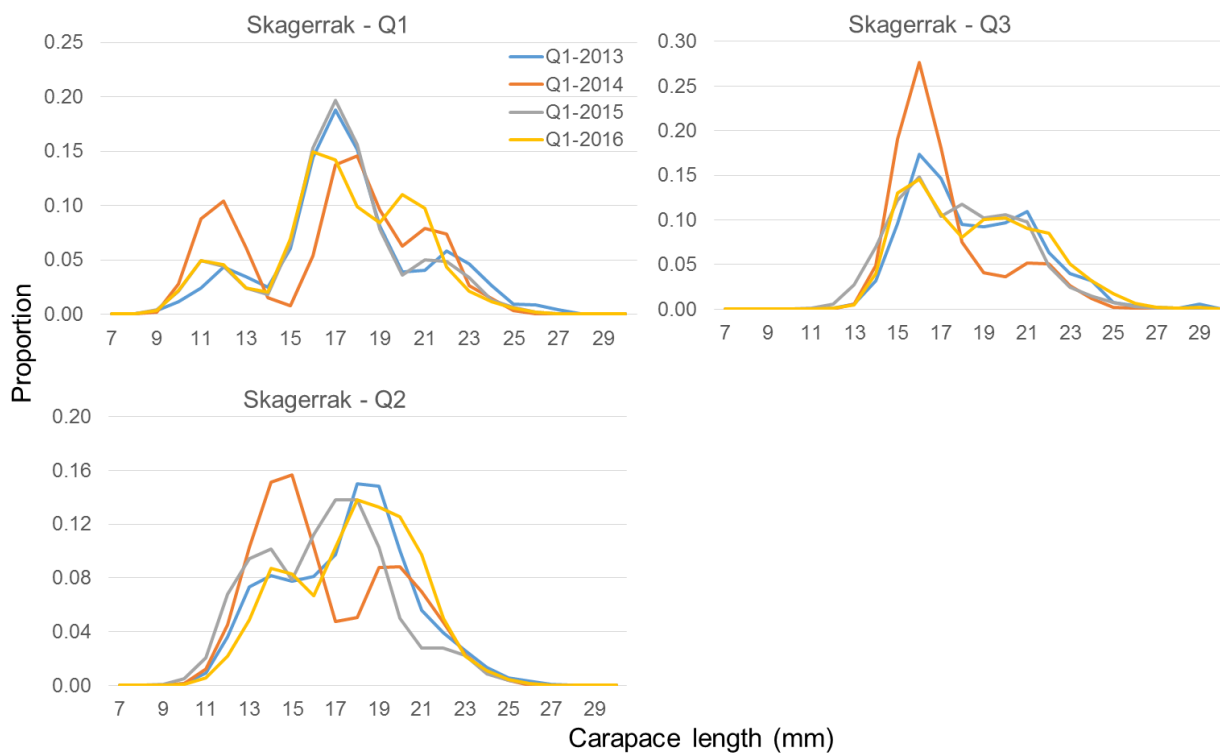
**Fig. 18.** Monthly unstandardised LPUE-indices for 2013-2016 from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from the Norwegian Directorate of Fisheries. The 2016-data are preliminary.



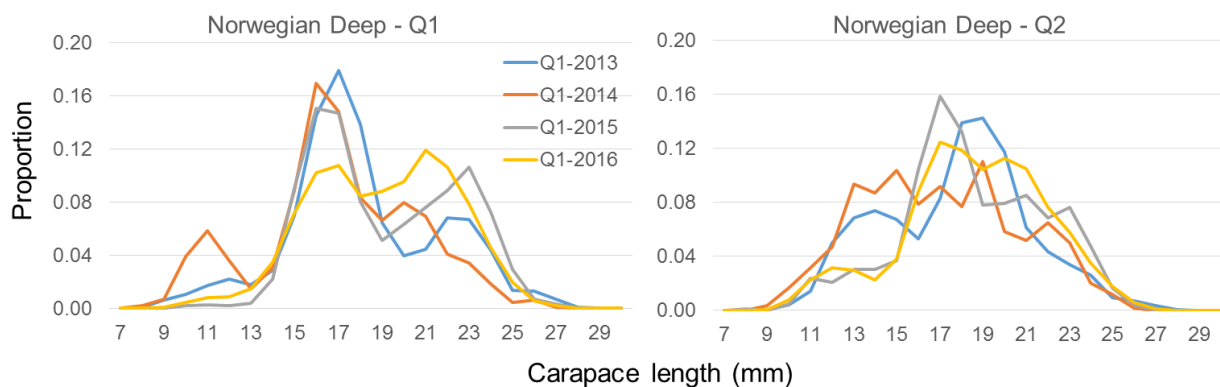
**Fig. 19.** Numbers per length in the 2015 catches from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), per quarter and area. Note different scales on the y-axes. Samples sizes (Skagerrak and the Norwegian Deep): Q1: 6629, 2740; Q2: 3695, 1544; Q3: 6246, 2287; Q4: 5583, 1464. Dashed lines mark old and new MLS of 13.4 and 16.0 mm CL (equivalent to 6 and 7 cm TL).



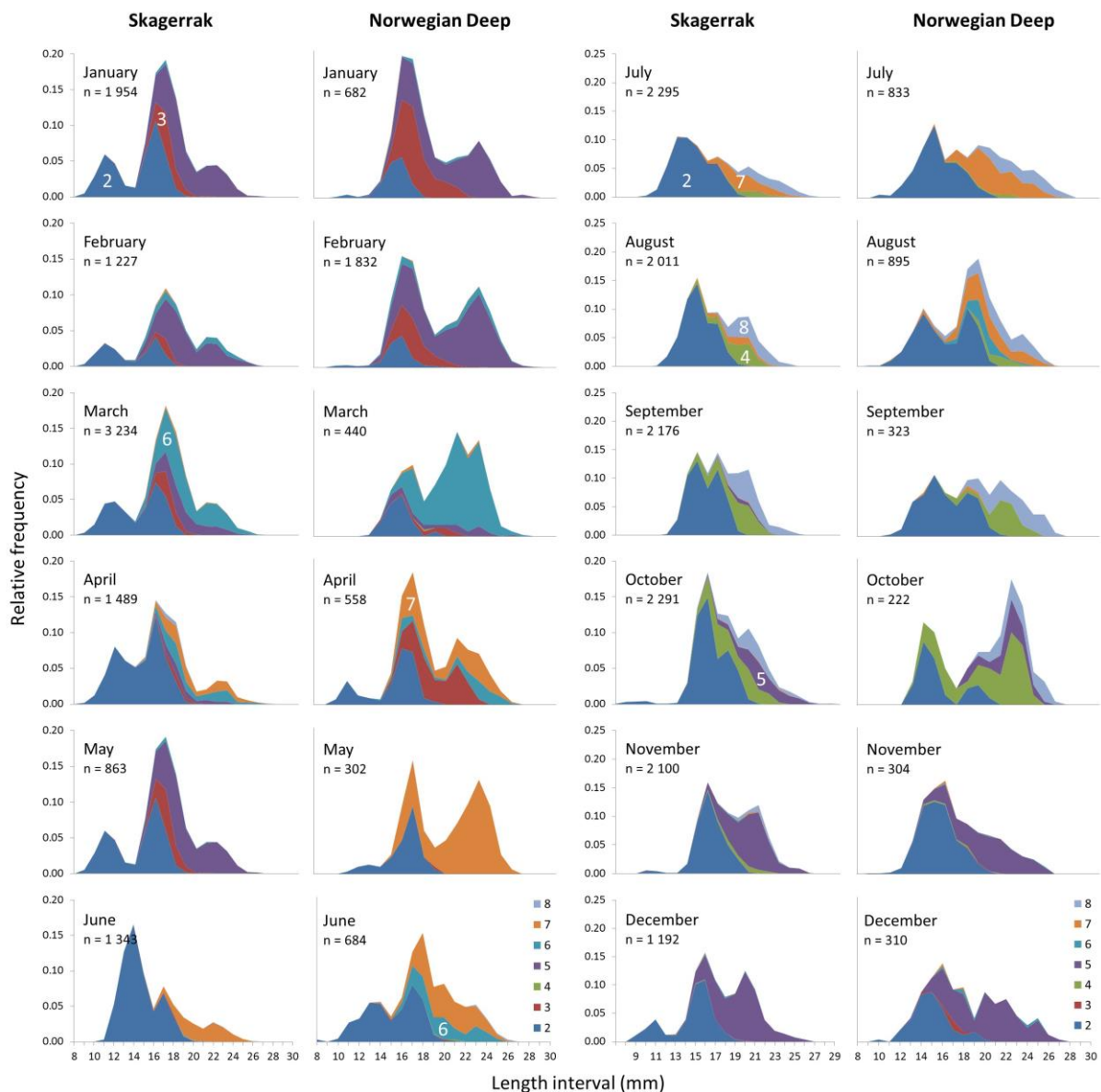
**Fig. 20.** Biomass per length in the 2015 catches from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), per quarter and area. Note different scales on the y-axes. Samples sizes (Skagerrak and the Norwegian Deep): Q1: 6629, 2740; Q2: 3695, 1544; Q3: 6246, 2287; Q4: 5583, 1464. Dashed lines mark old and new MLS of 13.4 and 16.0 mm CL (equivalent to 6 and 7 cm TL).



**Fig. 21.** Relative length frequency distributions in unsorted Norwegian shrimp (*Pandalus borealis*) catches from ICES Div. IIIa (Skagerrak) by quarter, 2013-2016.



**Fig. 22.** Relative length frequency distributions in unsorted Norwegian shrimp (*Pandalus borealis*) catches from ICES Div. IVa east (the Norwegian Deep) by quarter, 2013-2016.



**Fig. 23.** Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2015 from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by fishermen and the Norwegian Coast Guard. Stages: 2 = males; 3 = transitional; 4 = ripe gonads, first time spawner; 5 = berried; 6 = breeding dress; 7 = second time spawner with no roe; 8 = ripe gonads, second time spawner; 9 = first time spawner with no roe. Sample sizes (number of shrimp measured) are given in the figure.