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The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2015

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: 1) the Skagerrak-Norwegian Deep 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. Vessels from Norway, Denmark, and Sweden exploit this resource.

Norwegian logbooks are incomplete. The data situation improved in 2011 with the implementation of compulsory electronic logbooks for all vessels ≥ 15 m, and further in 2013 with the implementation of compulsory logbooks for all vessels ≥ 12 m in Skagerrak. However, a large part of the fleet (especially in Skagerrak) consists of small vessels down to 10 m, which are not in the logbooks. The recording of twin trawl use was incomplete until 2011. Earlier, logbook recordings were corrected by interviews with ship owners identified from logbooks. 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. Total landings have increased since 2011, to 5 749 t in 2014. Correcting for boiling implies that between 290 and 550 t are added to the nominal landings for the years 2000-2014.

In 2012-2013, total effort increased, but declined again in 2014. Standardised effort indices (2000-2015) show the same trend as the unstandardised figures. Landings per unit effort (LPUE) increased from 1999 to 2007-2008, decreased in 2009 and further in 2010. After some years with little change, the LPUE increased in 2014, and further in 2015. The standardised LPUE index for 2000-2015 follows the same trend as the unstandardised one.

The 2014 catch composition was evaluated by sampling unprocessed catches obtained from local shrimp fishers and the Norwegian Coast Guard. In the second to fourth quarter the 1-group (the large 2013-year class) dominated the catches in both Skagerrak and the Norwegian Deep. High discard estimates for 2014 indicate that many of these were discarded.

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.* 2015): 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). Vessels from Norway, Denmark, and Sweden exploit this resource. The Norwegian vessels fish the NDSK stock, with minor catches from Fladen Ground in former years (Ulmestrand *et al.* 2015).

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).

Fleet

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of 60º N. In 2014, a total of 184 vessels participated in the shrimp fishery south of 62º N (Table 1, Fig. 2), which is a decrease from 2013 when 188 vessels participated. The total number of vessels in the fishery has decreased from more than 400 vessels in 1995 to less than 200 vessels in recent years (Fig. 2). In 2014, 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 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). Yearly mean landings per vessel increase with vessel length, but there are large variations (Table 1). In 2014, almost all catches were landed in ports along the Norwegian coast, with a minor portion landed in Denmark and Sweden.

Gear use

Twin shrimp trawls are common on larger vessels and, according to the Norwegian Fisheries Organization (Fiskarlaget), have been in use since the beginning of the 2000s. Prior to 2011, the use of twin trawl was only sporadically registered in the 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, as well as incorrect recordings (Søvik and Thangstad 2014a). In electronic logbooks introduced in 2011 (see below), data are given per haul, and both gear type and the number of gears are recorded. According to these logbooks, respectively 50, 58, 55 and 67% of vessels ≥ 15 m used twin trawl in 2011-2014, either exclusively or in combination with single trawl. Corresponding percentages for smaller vessels 12-14.99 m in Skagerrak were 17 and 16% in respectively 2013 and 2014 (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 size between 35 and 40 mm has been in use since 2000. In the last two years, mean mesh size has increased in both areas, 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 of the three Scandinavian countries. In 2010 and 2011, the Norwegian quota constituted 60% of the total TAC; in 2012-2015, it constituted 58% of the total. In 1998, a general quota regulation system was initiated in the Norwegian shrimp fishery in this area, resulting in admittance regulation for vessels ≥ 11 m (pers. comm., Norwegian Fisheries Organization). Vessels < 11 m have free admission to the shrimp 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 5, April 6 – August 16, August 17 – December 31, with 33.3% of the total quota in each period). In 2015, the vessels, independent of vessel size, have a maximum quota of 28 t (tons) in the first period and 20 t in both of the other two periods. The Norwegian Directorate of Fisheries (FiskDir) can stop the shrimp fishery when the period or total quotas are estimated to be taken. However, vessels < 20 m can continue the fishery within a guaranteed quantum of 7 t, even if the total period quota is taken.

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 > 10% (by weight) cod and haddock combined. Furthermore, bycatch of > 10% angler fish or > 5% cod in single catches 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, but catches of angler fish may nonetheless only constitute up to 10% in weight in individual trawl hauls. The minimum legal catch size (MLS) is 6 cm total length (15 mm carapace length (CL)). 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 1st 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, it is legal to use a fish retention device (a 120 mm square mesh tunnel) in order to retain large fish. From 1st of January 2015, corresponding grids were made compulsory in the North Sea south of 62º N, outside the 4 nm border. The use of grid is not recorded in logbooks.

Value of landings

Two categories of shrimp dominate the market: large shrimp boiled at sea and sold fresh, which fetch high prizes, and smaller shrimp landed raw for factory processing ashore. In 2006-2008, fishermen obtained approx. 60 NOK/kg for boiled shrimp, and approx. 10-11 NOK/kg for raw shrimp. Due to low shrimp landings the last years, the mean kilo prize for boiled shrimp has 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 82 NOK per kilo boiled shrimp and 8 NOK per kilo raw shrimp. Corresponding prizes in the Norwegian Deep were 94 and 9 NOK.

Materials and Methods

Landings statistics and logbook data were provided by FiskDir. For 2015, landings and logbook data were given for May inclusive.

Landings

Landings were earlier given 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, FiskDir has provided landings per statistical location (equivalent to standard "ICES squares": 0.5º lat. by 1º long), however, these data should be used with caution. In data prior to 2009, landings from the Fladen Ground can be identified (area 42), while landings from area 41 are more ambiguous. Landings from the northern part belong to the Norwegian Deep/Skagerrak stock (Fig. 1), while landings from the southern part do not and are most likely bycatch and/or misreportings. 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 estimated using only numbers from Divs. IIIa and IVa east.

Landings consist of a fraction of larger shrimp boiled on board and a remaining portion of smaller shrimp landed fresh (see above). Official landings give landed weight as a mixture of raw and boiled shrimp, but FiskDir provides landing statistics where these can be separated (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 statistics from FiskDir, conservation has been recorded as "sea boiled", "salt boiled", and "fresh" (Fig. 5). In 2011, a new category was introduced: "on ice". The category "on ice" was interpreted as raw shrimp until 2013, when we became aware that both boiled and raw landings may be stored on ice upon landing. The sales organization in Skagerrak, Skagerakfisk SA, has confirmed that since 2013, they have used "on ice" only for raw shrimp (Fig. 5), thus conservation information from Fiskdir can continued to be used to distinguish boiled 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. 6). 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 2014, shrimp sold through Rogaland Fiskesalgslag constituted 85% of the total landed in Div. IVa east.

Effort

Norwegian logbooks from the shrimp fishery in NDSK are incomplete (Fig. 7). In 2005-2010, logbook catches made up 9-35% of the landings in IVa east, and 7-25% of the landings in IIIa. The poor coverage was partly due to vessels < 11 m not being required to fill out logbooks. The data situation improved greatly in 2011, with the introduction of compulsory, electronic logbooks for all vessels ≥ 15 m. In 2013, electronic logbooks became compulsory for all vessels ≥ 12 m fishing outside the 4 nm border in Skagerrak. In 2014 in IVa east, catches made up 77% of the

landings (corrected for boiling) as roughly half the vessels in this area are ≥ 15 m (Fig. 3), landing on average much more than smaller vessels (Table 1). Skagerrak is dominated by vessels < 15 m and registered catches made up 60 % of the landings in 2014. Due to the incomplete logbooks, total fishing effort was estimated 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 derived from the use of both types of gear.

In order to include gear use (single and twin trawl) in the calculation of a standardised LPUE-index, the incorrect recordings of gear in the logbook data were corrected. Every year since 2007 interviews have been made with ship owners identified from the logbooks for the years 2004-2010, and the international ship base www.ship-info.com (Søvik and Thangstad 2014a). The electronic logbooks from 2011-2015 provide information on both gear type and number of trawls (single, twin). However, mesh size is lacking in the 2011-2012 logbooks (reintroduced in 2013), which makes distinguishing between fish bottom trawl and shrimp bottom trawl difficult (both may be recorded as "bottom trawl"). All recordings from bottom trawl (2011-2012) have been kept, as large catches of shrimp presumably are not often caught with large mesh trawls.

Data from the corrected logbooks were used in multiplicative models in order to calculate standardised LPUE indices (2000-2015), thereby removing effects of monthly variations in fishing pattern, geographical variation (Divs. IIIa or IVa east), 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 hth vessel; A_i is the effect of the ith area; M_j is the effect of the jth month; Y_k is the effect of the kth year; G_l is the effect of the lth 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 indices are the antilog of the year coefficients.

A standardised effort series for 2000-2015 was derived by dividing landings (corrected for boiling) by the standardised LPUE indices.

Since owners of vessels < 15 m have not been required to fill in logbooks until last year, data from the small vessel fleet in Skagerrak have since 2007 been obtained from four fishermen (vessel size ranging from 10.55 to 12.21 m length) who have completed simplified logbooks from all their fishing trips. However, since the Skagerrak logbooks from 2013 onwards include vessels in the size range 12-15 m, this data collection programme was terminated in 2015.

Fleet structure

Fleet structure (length classes) is available through the vessel registry and was provided by FiskDir. 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. Discard of shrimp may take place in two ways: 1) as a result of "high-grading" (discard of medium, less valuable shrimp to improve the economic return of quotas) (Munch-Petersen *et al.* 2013), and 2) as a "quality discard", since the processing plants do not accept shrimp smaller than approx. 15 mm CL.

Until 2001, discards were estimated by assuming that all shrimp < 15 mm CL were discarded. Length distributions from research surveys in March, June and October/November were used, assuming that the proportion of small shrimp was the same in the research trawl as in commercial trawls. For 2002-2006, discards were estimated by applying the mean discard percentage (discard as percentage of total landings) for the years 1985-2001 to the nominal landings.

In 2007 to 2012, Norwegian discards were estimated by comparing length distributions from sorted landings with length distributions from unprocessed commercial catches. The annual length distribution from unprocessed catches was scaled to fit the annual length distribution from the landings for the larger sizes, based on the assumption that there was no discarding of the largest size groups (≥ 21 mm CL). The higher numbers in the smaller size groups in the catches compared to the landings were then multiplied with the mean weight of each size group, and the sum was considered the weight of the discard. Results from this "*comparison-of-length-distributions-method*" were often unreliable (e.g., negative estimates). Part of the explanation could be that the sampling of catches covered the whole fishery, while the sampling of landings covered only a small part of the fishery.

As discarding is illegal in Norway, onboard sampling is difficult to organize. Denmark initiated onboard sampling of their shrimp fishery in Skagerrak in 2009, yielding estimates of Danish discards. Since 2009, Norwegian discards in Skagerrak have been estimated using the Danish discards-to-landings ratio to Norwegian landings. The underlying assumptions are that 1) the size structure of the shrimp stock is the same on the Danish and Norwegian fishing grounds, and 2) the level of discarding is the same in the two fisheries. In 2013, it was decided that the Danish discards data are the best available for estimating Norwegian discards in Skagerrak, and the use of the "*comparison-of-length-distributions-method*" was terminated. 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 (MLS) in the catches, assuming that all shrimp < MLS are discarded. The reported discard estimates back to 2009 in the current document and in the NIPAG report are the ones based on the Danish data.

Sampling of catches

Samples (approx. 1.5 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2014-catches were obtained from eight Norwegian shrimp fishers (42 samples) (Fig. 8). The Norwegian Coast Guard provided 23 samples from inspections of Norwegian, Danish, and Swedish shrimp trawlers. 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

Landings

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. 9a, Table 2). In the following years landings fluctuated around 7 500 t with a maximum in 1998 of 9 707 t. After a sharp decline in 1999-2000, the total nominal landings increased continuously until 2004, from about 6 000 to 9 000 t. The trend then reversed with a steady decline until 2010, with total nominal landings of 4 308 t, the lowest figure since 1979. The total landings have increased since 2011, to 5 749 t in 2014. Correcting for boiling implies that between 290 and 550 t are added to the nominal landings for the years 2000-2014 (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 the ones from the Norwegian Deep. This changed in 2009 with a large decrease in landings from Skagerrak, followed by a further decline in 2010, bringing the IIIa landings down to the level of the IVa east landings. In 2012-2014, the difference between the two areas again increased due to an increase in IIIa, but only a slight increase in IVa east (Fig. 9a).

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. 9a, Table 2). From 2007 to 2010 the Skagerrak landings decreased to the lowest level since 1979. Since 2011 they have increased, to 4 500 t in 2014. 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. 9a, Table 2). Since then they have increased slightly, to 1 249 t in 2014. Monthly landings from January to March 2015 have increased compared with the 2014 January-March landings, both in IIIa and IVa east (Fig. 10). The good 2013-year class observed as 1-year old shrimp

in Skagerrak in the 2014 shrimp survey (Søvik and Thangstad 2014b) recruited to the fishery in Skagerrak in autumn 2014, explaining the increase in landings in the second half of 2014 and early 2015. Fishers claim that a large shrimp stock in Skagerrak will drift/migrate west. The 2013-year class probably contributed to the increased landings in the first three months of 2015 in the Norwegian Deep.

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. 10). Lower landings during winter are probably due to rough weather.

In 2014, 2 650 t were landed by small vessels (< 15 m), while a slightly larger quantity (3 105 t) was landed by large vessels (≥ 15 m) (Table 1). This is similar to the pattern in 2012-2013, but different from 2011, when landings from large vessels were more than 50% higher than landings from small ones, and is 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).

In 2008 and 2009 the Norwegian TAC was 9 731 t (Table 2). From 2010 the quota steadily declined to almost half of this level, being set to only 5 469 t in 2013 and 2014 (3 099 t in IIIa and 2 370 t in IVa east). The 2015 quota has increased to 6 346 t. Since 1995, the Norwegian quota has been overfished three times (1997, 2004, and 2014). In 2003-2005, estimated total landings corrected for boiling also exceeded the total Norwegian TAC. Because of the allocation of the quota to three periods, and because of frequently bad weather in late autumn and winter rendering fishing difficult, the whole Norwegian quota is rarely fished. In 2006-2013, respectively 97, 93, 85, 65, 54, 64, 83, and 95% of the quota was landed (corrected landings as percentage of Norwegian TAC). In 2014, 6 124 t (landings corrected for boiling) were taken, while the quota was 5 469 t, but some of the 2015-quota was transferred to 2014 (borrowing).

In 2014, 51% of the total Skagerrak landings and 61% of the Norwegian Deep landings were delivered as boiled, fresh large shrimp for the Norwegian market (Table 3, Fig. 11). The proportion boiled in landings from the Norwegian Deep has always been higher than in Skagerrak. Corresponding numbers for the Swedish and Danish landings in 2014 were approximately 25% and > 60% (Ulmestrand *et al.* 2015), which indicates that the Norwegian fishery and discarding practices are somewhere in between the Danish and Swedish ones (see below).

Spatial distribution of the fishery

According to the electronic logbooks from 2011-2014, the large vessel fleet (≥ 15 m) fished mainly in the southern and western parts of the Norwegian Deep, with some effort allocated to the Skagerrak coast and some parts along the west coast of Norway (Fig. 12a). In 2013-2014, the distribution of the fishery in the Norwegian Deep has shifted south compared with 2011-2012. According to the 2013 and 2014 logbooks, which include vessels between 12 and 15 m for 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. 12b). The fishery seems to be more concentrated in recent years compared with 2009-2010, illustrated by distribution of effort (trawling hours) in logbooks and landings per statistical location (Fig. 13).

In 2011, the fishing pattern (and presumably also the distribution of the shrimp stock) changed with season, with fishing taking place on the southwestern edge of the Norwegian Deep in spring, while spreading over a larger area in summer and early autumn (Fig. 14). In 2012, however, the vessels covered a much larger area of Div. IVa east throughout the whole year. The fishing pattern in 2013 and 2014 resembled the pattern in 2011.

Use of single and twin trawl

There is a clear difference in catch efficiency between single and twin shrimp trawls (Fig. 15). In 2007, we started interviewing ship owners about their use of single and twin trawl. The logbooks for 2004-2010 contain data from 59 vessels. We managed to get in touch with the owners of 48 of these. Between 2002 and 2010, six vessels used twin trawl seasonally or occasionally, while twelve vessels used only twin trawl. According to the electronic logbooks, 25 out of a total of 50 vessels ≥ 15 m used twin trawl regularly or in combination with single trawl in 2011. In 2012, 21 out of 36 vessels used twin trawl. In 2013, the corresponding figures were 22 out of 40, and in 2014, 24 out of 36. Thus, the use of twin trawl seems to be stable the last 3-4 years. In Skagerrak in 2013 and 2014, respectively 3 out of 18, and 3 out of 19 vessels (12-15 m length) used twin trawl, and only one vessel (the same vessel both years) used twin trawl exclusively.

Effort
The estimated number of fishing hours has since 2009 been more than twice as high in Div. IIIa compared with Div. IVa east (Table 2). The estimated effort in the Norwegian Deep decreased from 2011 to 2014. In Skagerrak the pattern is opposite with an increase until 2013, followed by a slight decrease in 2014.

After a relatively stable period from 1996 to 2001, with total fishing efforts of around 200 Khours/year, effort declined to 176 Khours in 2002, stabilized, declined to about 130 Khours in 2007, stabilized, and then declined again to an all time low of 122 Khours in 2011 (Table 2, Fig. 9c). In 2012-2013, total effort increased, but declined again in 2014 to 122 Khours. Standardised effort indices (2000-2015) (Table 4, Fig. 16) show the same trend as the unstandardised figures.

Landings per unit effort (LPUE)
Overall LPUE increased from 1999 to 2007-2008 (Fig. 9b, Table 2), decreased in 2009 and further in 2010. After some years with little change, the LPUE increased in 2014, and further in 2015 (preliminary data). The LPUE-values in Skagerrak and the Norwegian Deep followed each other closely for the years 1999-2004. However, since 2005 the development of LPUE in the two areas has differed strongly. In the Norwegian Deep, the LPUE decreased until 2012-2013, to the lowest level observed in the time series, and then increased again in 2013, and further in 2014. In Skagerrak, on the other hand, the LPUE index increased to a record high level in 2007. Thereafter the index decreased sharply until 2010, to the lowest level observed in the time series. The last five years have seen an increase in the LPUE in Skagerrak.

A standardised LPUE time series has been calculated for 2000-2015 for the total area (Table 4, Fig. 17). This index follows the same trend as the unstandardised one. Fleet structure and fishery pattern have probably remained stable during this relatively short time period, but gear use has changed (see above). Despite the incomplete logbooks until 2010, the Norwegian LPUE seems to represent a valid index of shrimp stock biomass: 1) from 2011 onwards, we know that the data are representative of the large vessel fishery; and 2) trends in the survey biomass index and the Norwegian LPUE index are similar, with a decrease from 2008 to 2012, followed by an increasing trend since 2013 (Fig. 17) (Søvik and Thangstad 2015). Both time series indicate that the shrimp stock in the Skagerrak/Norwegian Deep area has recovered. The contracted distribution of the fishery (Figs. 12a, 13) should, however, be noted.

Discards
Estimated Norwegian annual discards from Skagerrak in 2009-2014 range from 78 to 1191 t, and in the Norwegian Deep from 16 to 98 t (Tables 5, 6). Estimated discards in Skagerrak increased from 405 t in 2013 to 1191 t in 2014, almost four-fold. This was due to the large 2013-year class, and thus a large part of the 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 2014a). However, this does not say anything about the behaviour of fishers, or how they handle the catch. Comparison of the boiled proportion in landings from the three fisheries indicate that the Norwegian practice is more similar to the Swedish than the Danish one. 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 first quarter (January-March) of 2014 consisted of three year classes in Skagerrak and three to four in the Norwegian Deep (Table 7, Fig. 18). The 1-group (the large 2013-year class) was smaller than the MLS of 15 mm CL and was probably mainly discarded. In the second to fourth quarter the 1-group dominated the catches in both Skagerrak and the Norwegian Deep. The high discard estimates for 2014 (Table 5) and the high proportion of boiled landings (Fig. 11) despite the catches being dominated by 1-year olds indicate that many of these were discarded. The 0-group (the 2014-year class) entered the catches in October-December (Figs. 18, 19).

The shrimp life cycle in the area is illustrated by the distribution of stages per length (age groups) (Fig. 19).

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Table 1. The Norwegian fleet participating in the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2014: 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	18	64	3.5	1.0	6.6
10-11.99 m	79	1 017	12.9	6.2	14.4
12-14.99 m	49	1 569	32.0	24.6	32.1
15-20.99 m	13	654	50.3	43.8	40.4
21-27.99 m	18	1 720	90.5	95.3	54.4
> 28 m	6	731	121.9	107.3	67.0
unknown	1		0.4	0.4	
Total	184	5 755			

Table 2. Nominal landings from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), and total in Div. IIIa and Subarea IV; increase in total landings due to correction for boiling (see text); Total Allowable Catch (TAC); estimated discards; landings per unit effort (LPUE); and estimated number of trawling hours (effort) of the Norwegian shrimp (*Pandalus borealis*) fishery, 1970-2015. All landings back to 1977 were checked and corrected against original files in 2011. LPUE and effort values were checked and corrected against original files in 2013. Discard data 2009-2012 were recalculated in 2013 using information on Danish discards. Data from the Norwegian Directorate of Fisheries.

Landings (t)					TAC (t)	Disc. (t)	LPUE (kg/hour)			Effort (Khours)		
Year	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	176
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	134	27	44	34	106	43	136
2011	2693	1773	4466	335	7452	247	37	41	39	77	47	122
2012	3564	1000	4573	288	5855	293	44	27	34	86	40	141
2013	3739	1132	4871	308	5469	460	43	28	37	92	43	138
2014	4500	1249	5749	375	5469	1289	54	41	50	88	33	122
2015					6346		64	49	57			

The 2015 LPUE data are from January-May.
Estimated effort 2000-2014 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. Boiled shrimp (*Pandalus borealis*) landings (weight corrected for boiling) as proportion of Norwegian landings from Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), in 2000-2014. Data from the Norwegian Directorate of Fisheries. The shaded values from Div. IVa east (2012-2014) result from the interpretation of the conservation category "on ice" as raw shrimp. Values from Rogaland county are from the sales organization Rogaland Fiskesalgslag SA and are used in the analyses (see text).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Skagerrak	0.39	0.40	0.36	0.39	0.38	0.33	0.33	0.35	0.42	0.51	0.65	0.56	0.44	0.47	0.48
Norwegian Deep	0.44	0.43	0.45	0.51	0.56	0.49	0.60	0.60	0.62	0.67	0.77	0.60	0.18	0.14	0.10
Rogaland county												0.65	0.65	0.53	0.58

Table 4. Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2015. The 2015 LPUE-index is based on logbook data January-May. The 2015 effort index is based on logbook data (January-May) and corrected landings from January-May projected to the end of 2015.

	Stand. LPUE (index)	Stand.effort (index)
2000	0.72	1.07
2001	0.77	1.13
2002	0.95	0.97
2003	0.98	1.00
2004	1.13	1.01
2005	1.06	1.01
2006	1.04	1.00
2007	1.26	0.82
2008	1.22	0.81
2009	0.88	0.86
2010	0.66	0.84
2011	0.70	0.82
2012	0.59	0.98
2013	0.64	0.96
2014	0.83	0.88
2015	1.00	1.00

Table 5. Estimated discards (t), landings (t) and catches (t) in the Norwegian shrimp (*Pandalus borealis*) fishery in Div. IIIa (Skagerrak) in 2009-2014, per quarter and annually. The Norwegian discards are estimated by applying the Danish discards to landings ratio on the Norwegian landings.

	Q 1			Q 2			Q 3			Q 4			Annual		
year	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	1275	1493	69	1070	1139	56	1097	1153	62	931	993	405	4374	4779
2014	506	1083	1590	205	986	1191	96.8	1568	1665	383	1141	1524	1191	4779	5970

Table 6. Estimated discards (t), landings (t) and catches (t) in the Norwegian shrimp (*Pandalus borealis*) fishery in Div. IVa east (the Norwegian Deep) in 2009-2014, 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).

	Q 1			Q 2			Q 3			Q 4			Annual		
year	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

Table 7. Mean carapace length (with standard deviation), and numbers (thousands) per age class in the 2014 catches from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), per area and total.

		Total			Skagerrak			Norwegian Deep		
Quarter	Age	Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
1	1	11.90	1.21	143691	11.93	1.00	118391	11.12	1.24	19615
	2	17.61	1.34	260878	17.80	1.09	182790	16.47	1.27	65784
	3/3+	21.57	1.45	121313	21.54	1.34	98138	20.87	2.14	39835
	4+	25.50	1.02	768						
2	1	14.62	1.77	262501	14.59	1.54	204128	13.46	1.74	34926
	2+	20.47	1.80	155846	20.35	1.90	123769	18.59	2.53	59832
3	1	16.13	1.17	416783	16.17	1.14	339270	16.09	1.26	77924
	2	20.77	2.08	119741	20.98	1.59	92389	21.62	1.71	13627
4	0	10.71	1.12	5480	10.64	1.11	4971	10.50	1.21	629
	1	16.47	1.21	332928	16.55	1.22	292416	15.79	1.21	43011
	2+	21.31	1.69	88602	20.78	2.16	88828	21.20	1.89	16548

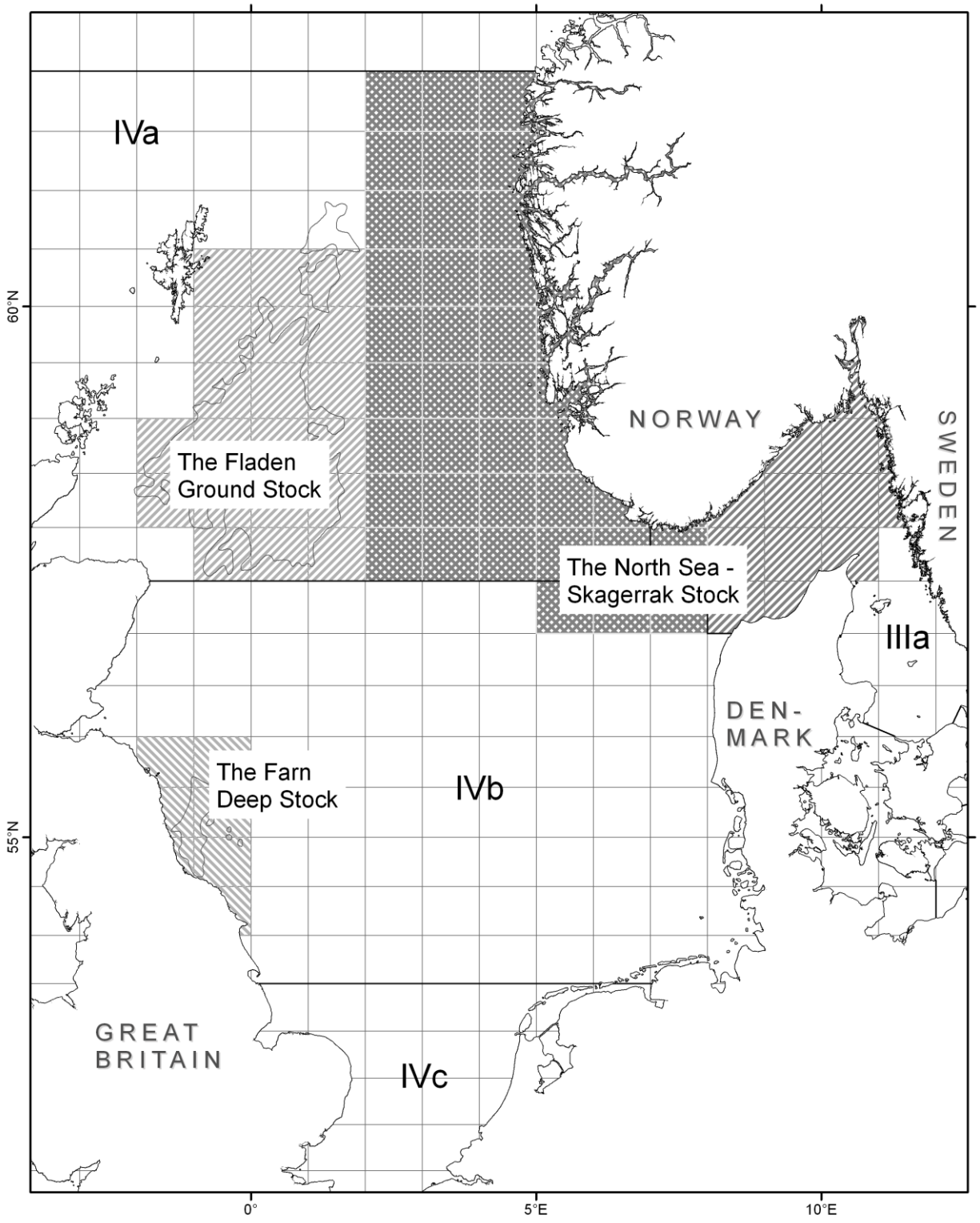

Fig. 1. Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the ICES defined management units. Grid is standard "ICES squares" (0.5º lat. by 1º long.).

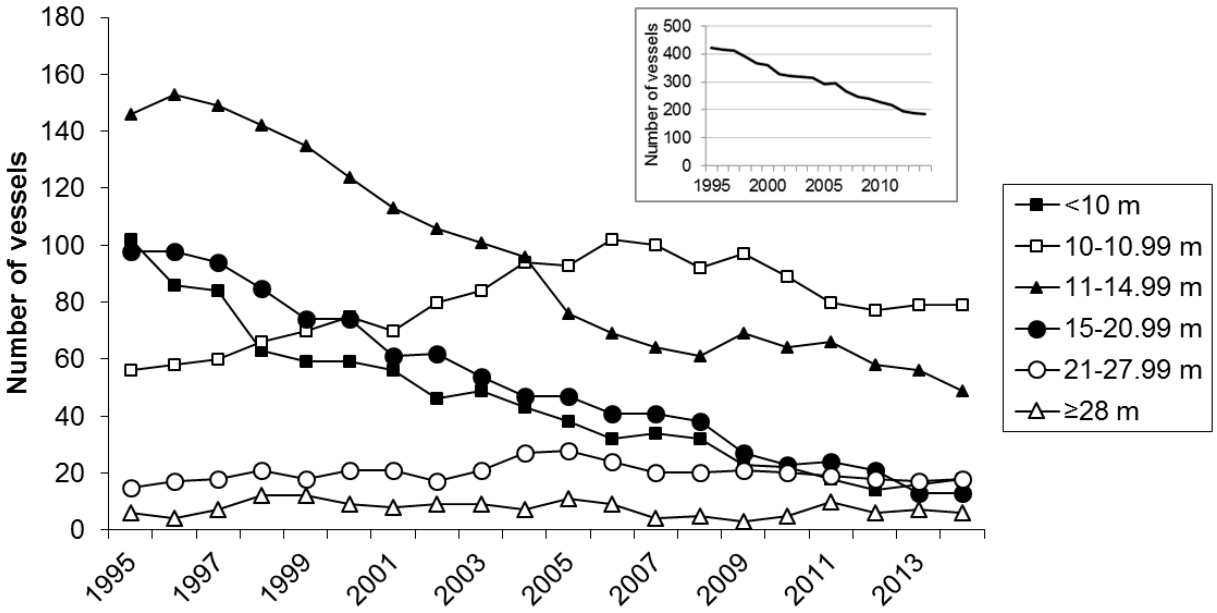

Fig. 2. The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) 1995-2014: number of vessels per length group. Total numbers of vessels per year is given in the inserted figure. Data from the Norwegian Directorate of Fisheries.

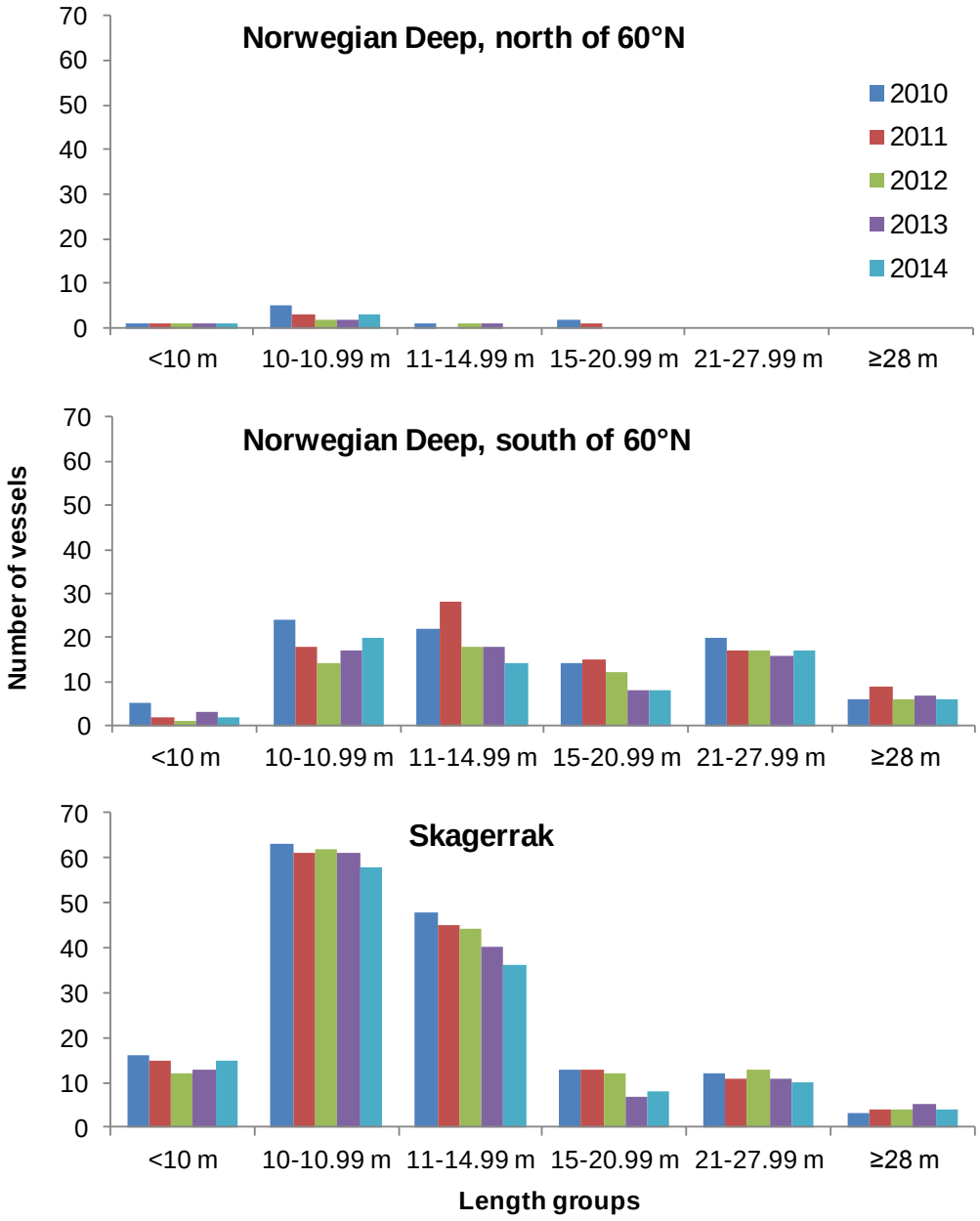

Fig. 3. Number of vessels per length group in the Norwegian fleet fishing for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2010-2014. Some vessels fish in more than one area. Data from the Norwegian Directorate of Fisheries.

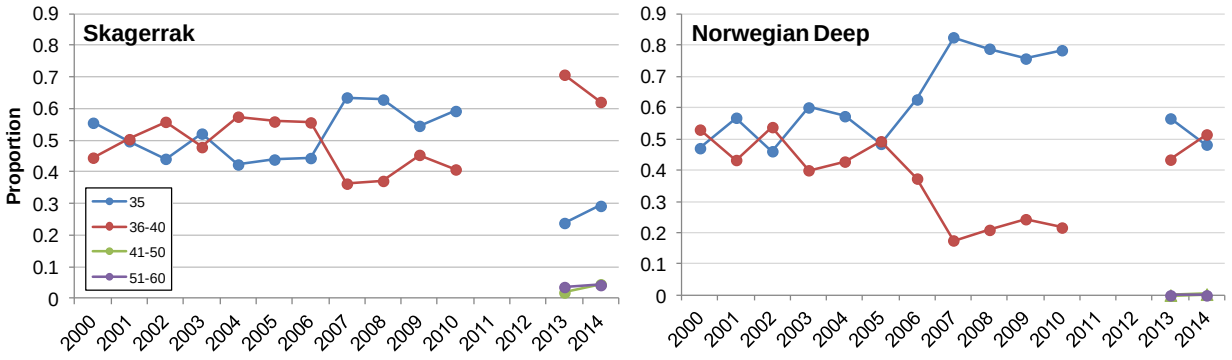

Fig. 4. Use of different mesh size (mm) by the Norwegian fleet fishing for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2000-2014. Mesh size given per day in 2000-2010, and per haul in 2013-2014. No data on mesh size in 2011-2012. Data from the Norwegian Directorate of Fisheries.

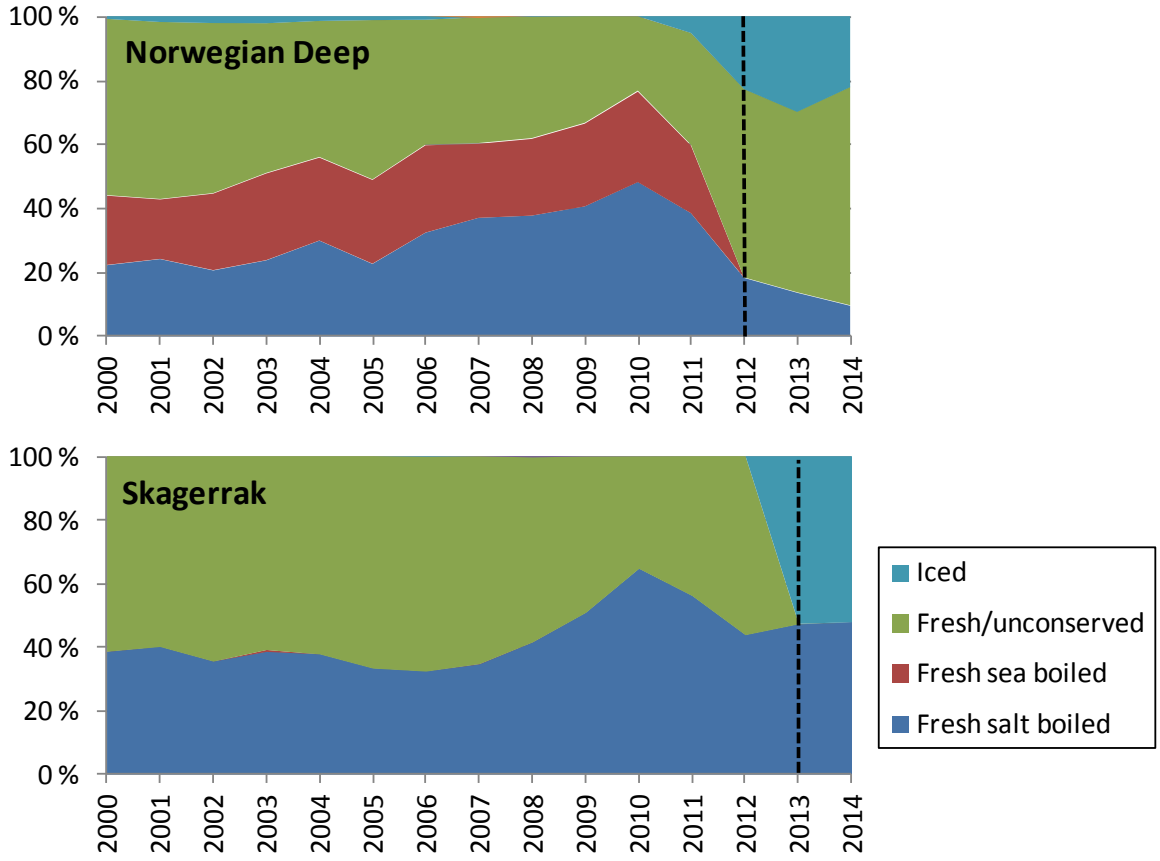

Fig. 5. Proportions of respectively iced, fresh, sea boiled, and salt boiled landings from ICES Divs. IIIa and IVa East (Skagerrak and the Norwegian Deep) in 2000-2014. Dotted lines indicate years when there was a change in the use of conservation categories. Data from the Norwegian Directorate of Fisheries.

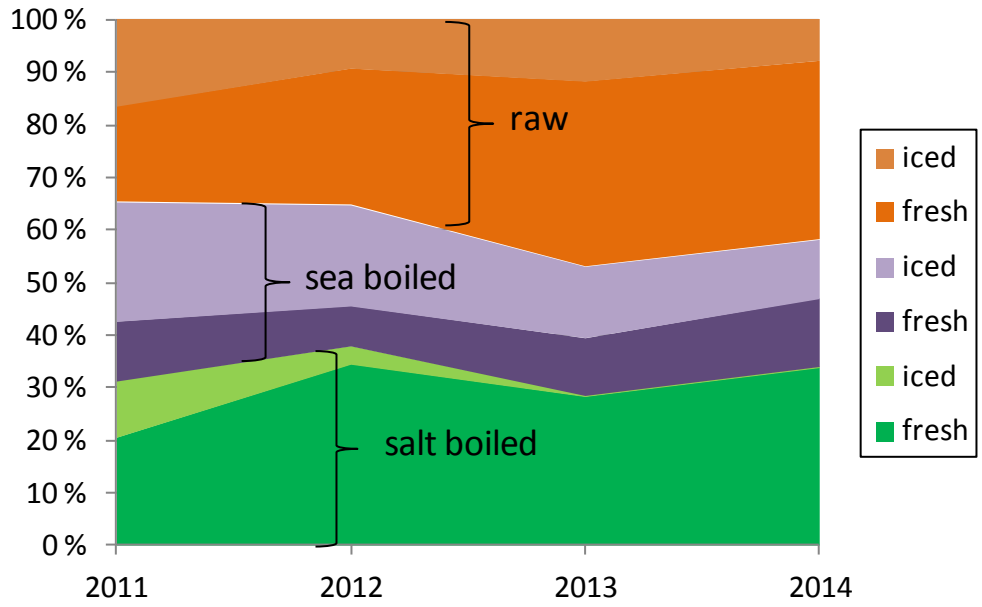

Fig. 6. Proportions of respectively raw, sea boiled, and salt boiled landings from Rogaland county in 2011-2014, landed as fresh or on ice. Data from Rogaland Fiskesalgslag SA.

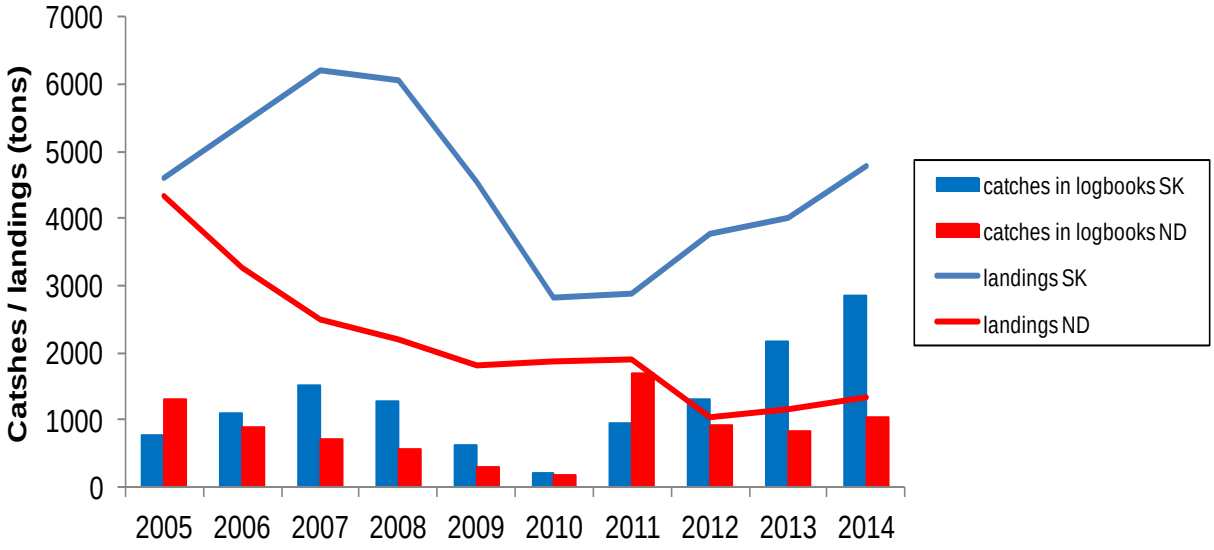

Fig. 7. Incomplete logbooks from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) illustrated by landings (corrected for boiling) and catches in logbooks, per area for 2005-2014. Data from the Norwegian Directorate of Fisheries.

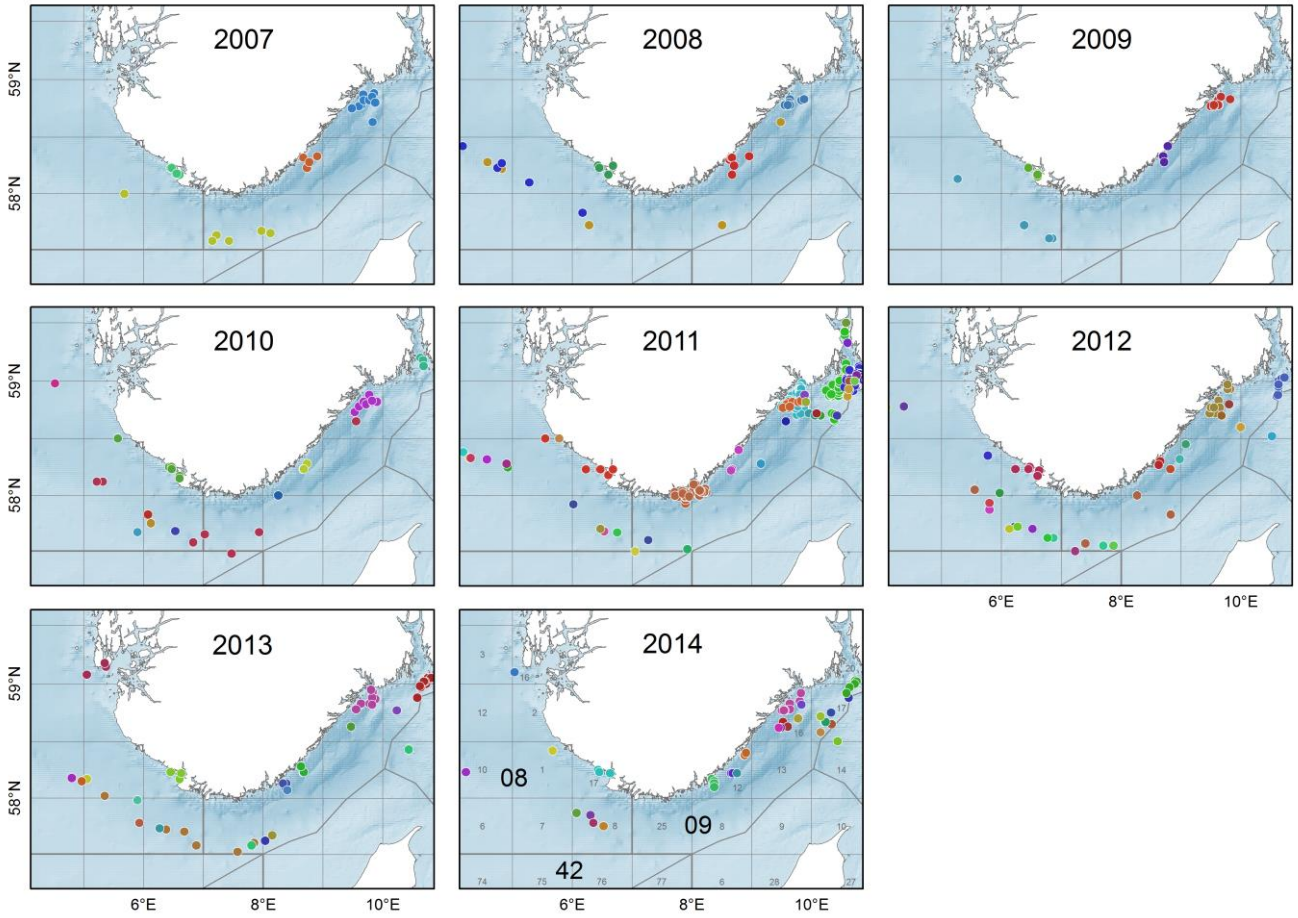

Fig. 8. Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2007-2014 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local Norwegian fishermen and the Norwegian Coast Guard. Colours represent individual fishing vessels. National EEZ and the Norwegian statistical areas are plotted.

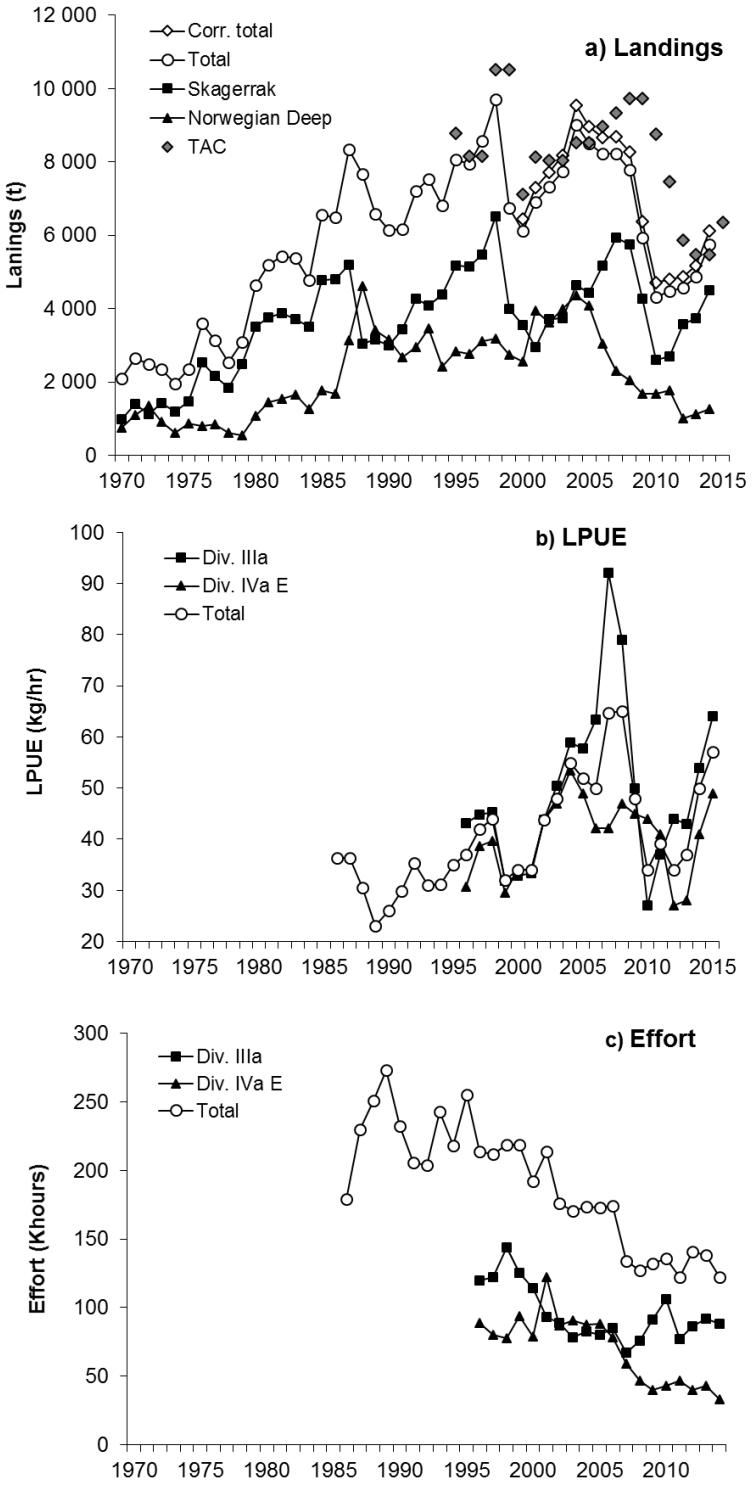

Fig. 9. Landings (nominal and corrected for boiling at sea) and TAC a); unstandardised landings per unit effort (LPUE) b); and estimated total effort c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) for all years for which data are available. LPUE data from 2015 are based on preliminary data from January-May. 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.

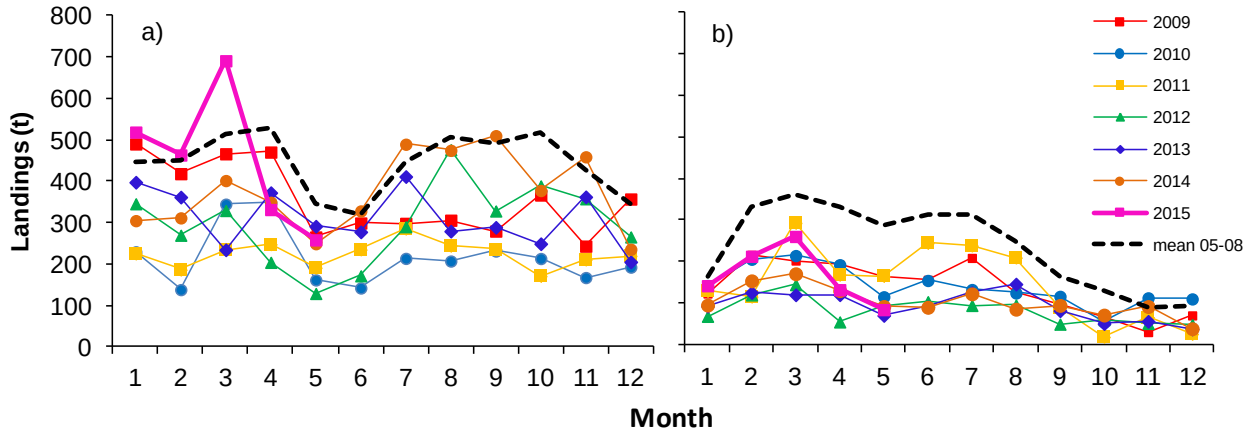

Fig. 10. Monthly (uncorrected) Norwegian landings of shrimp (*Pandalus borealis*) 2009-2015 and means for 2005-2008 for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries.

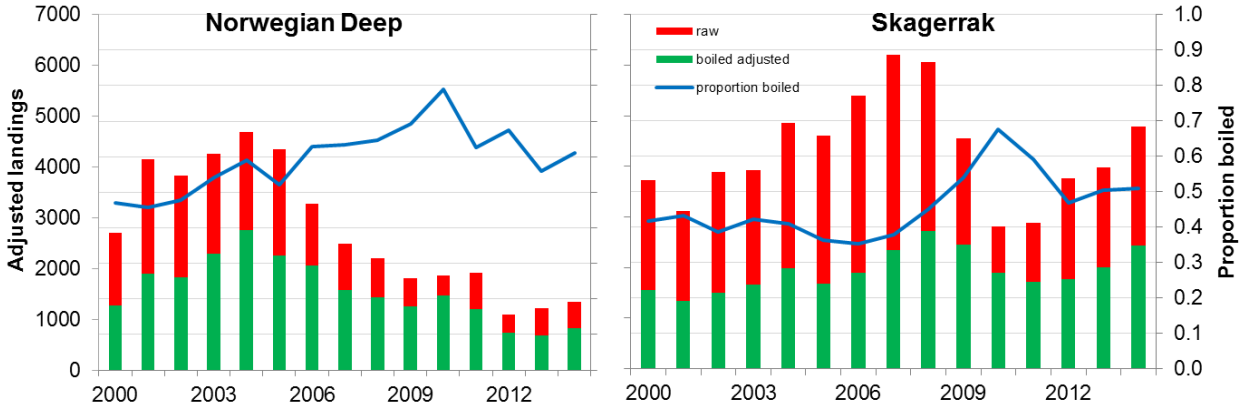

Fig. 11. Landings of boiled and raw shrimp, and proportion of boiled shrimp in Norwegian landings (corrected for boiling) from ICES Divs. IIIa and IVa East (Skagerrak and the Norwegian Deep) in 2000-2014. Data from the Norwegian Directorate of Fisheries, and Rogaland Fiskesalgslag SA (2012-2014 in the Norwegian Deep, see Table 3).

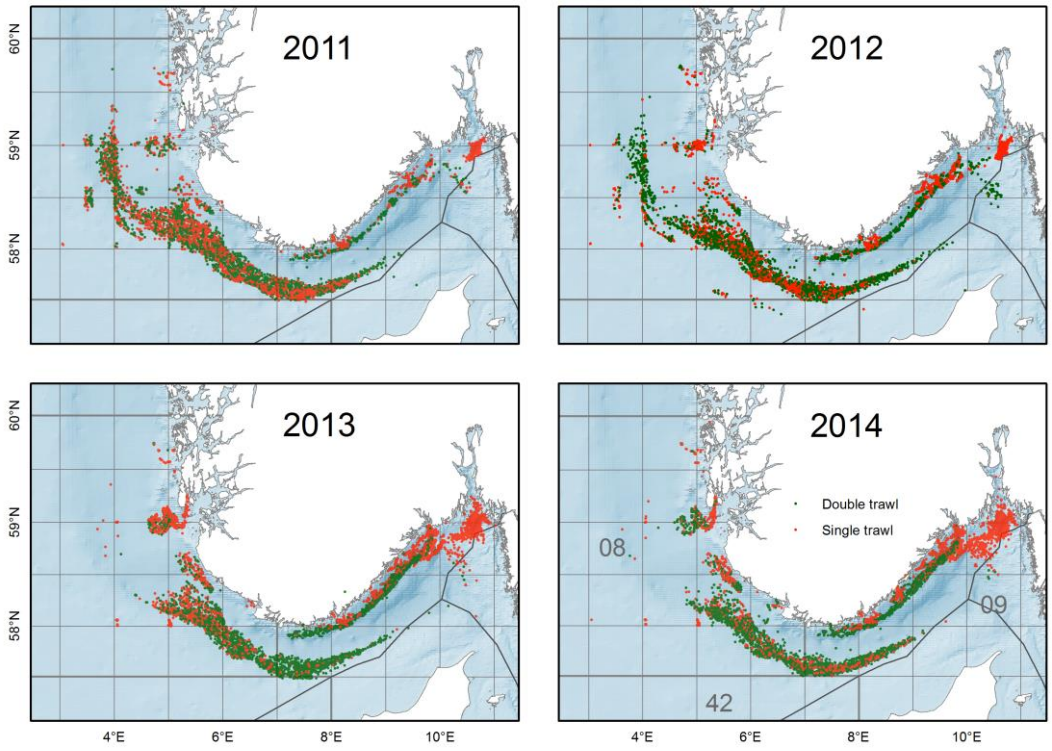

Fig. 12a. Spatial distribution per gear of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011-2014: positions of single hauls with single and twin trawl in electronic logbooks. Grid is standard "ICES squares" (0.5º lat. by 1º long.). Norwegian statistical areas (numbered) and national EEZ are plotted. Data from vessels ≥ 15 m (from vessels ≥ 12 m in Skagerrak in 2013-2014). Data from the Norwegian Directorate of Fisheries.

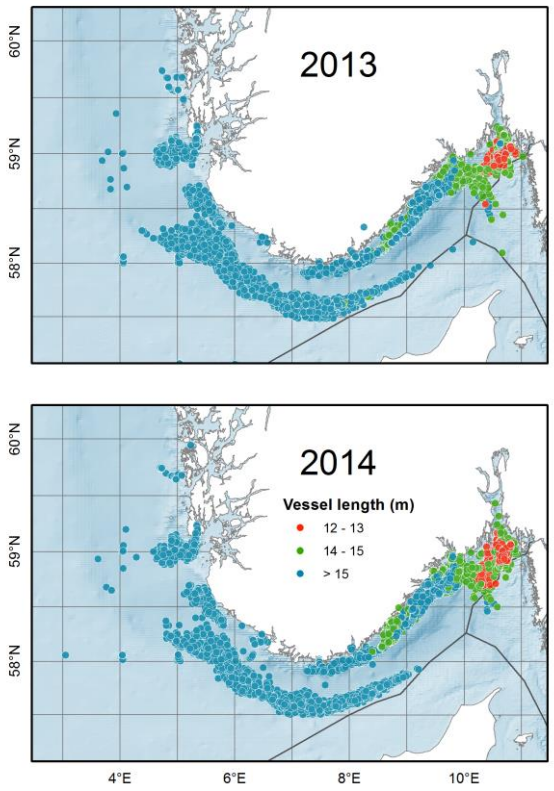

Fig. 12b. Spatial distribution by vessel length groups of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2013 and 2014: positions of single trawl hauls in electronic logbooks. Data from vessels ≥ 15 m in the Norwegian Deep, and from vessels ≥ 12 m in Skagerrak. Data from the Norwegian Directorate of Fisheries.

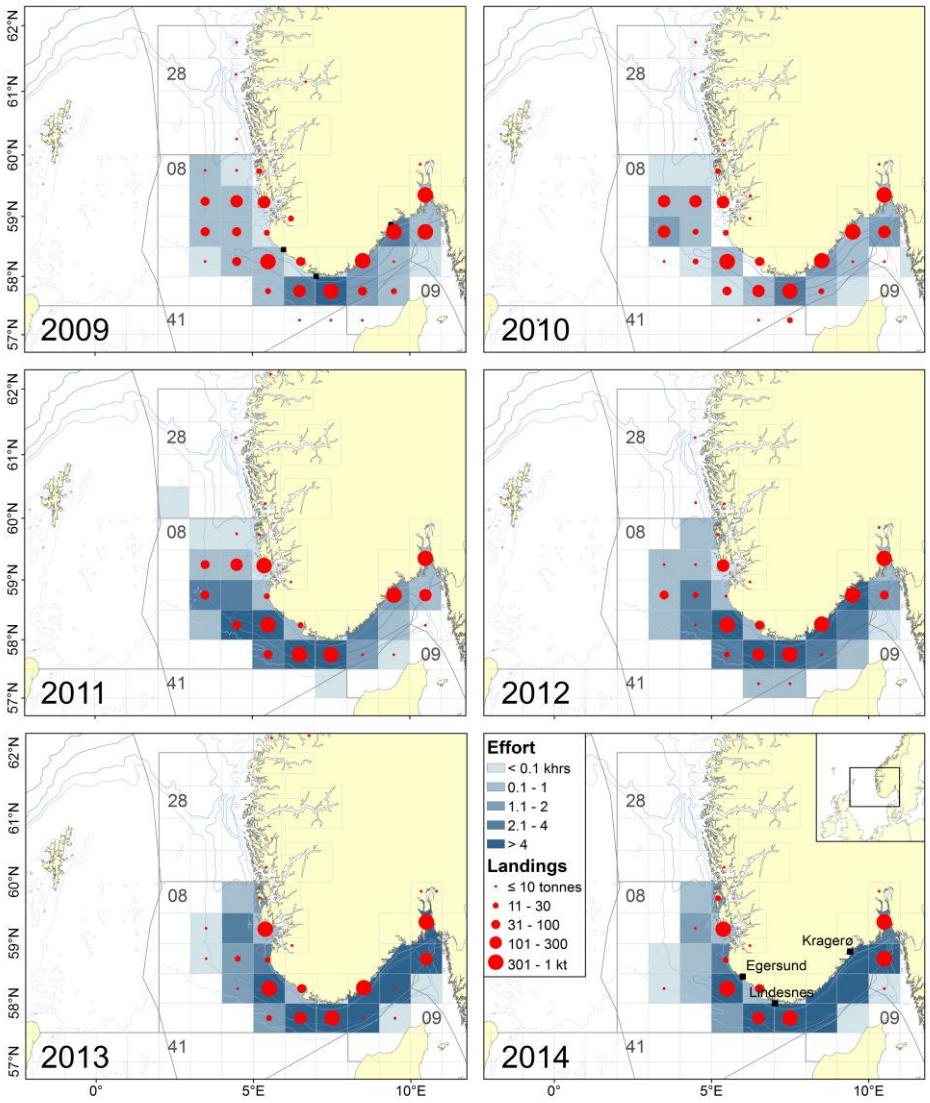

Fig. 13. Spatial distribution of landings (t) (uncorrected) and recorded effort in logbooks (trawling hours) in the Norwegian fishery for shrimp (*Pandalus borealis*) in 2009-2014 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by standard "ICES squares" (0.5º lat. by 1º long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.

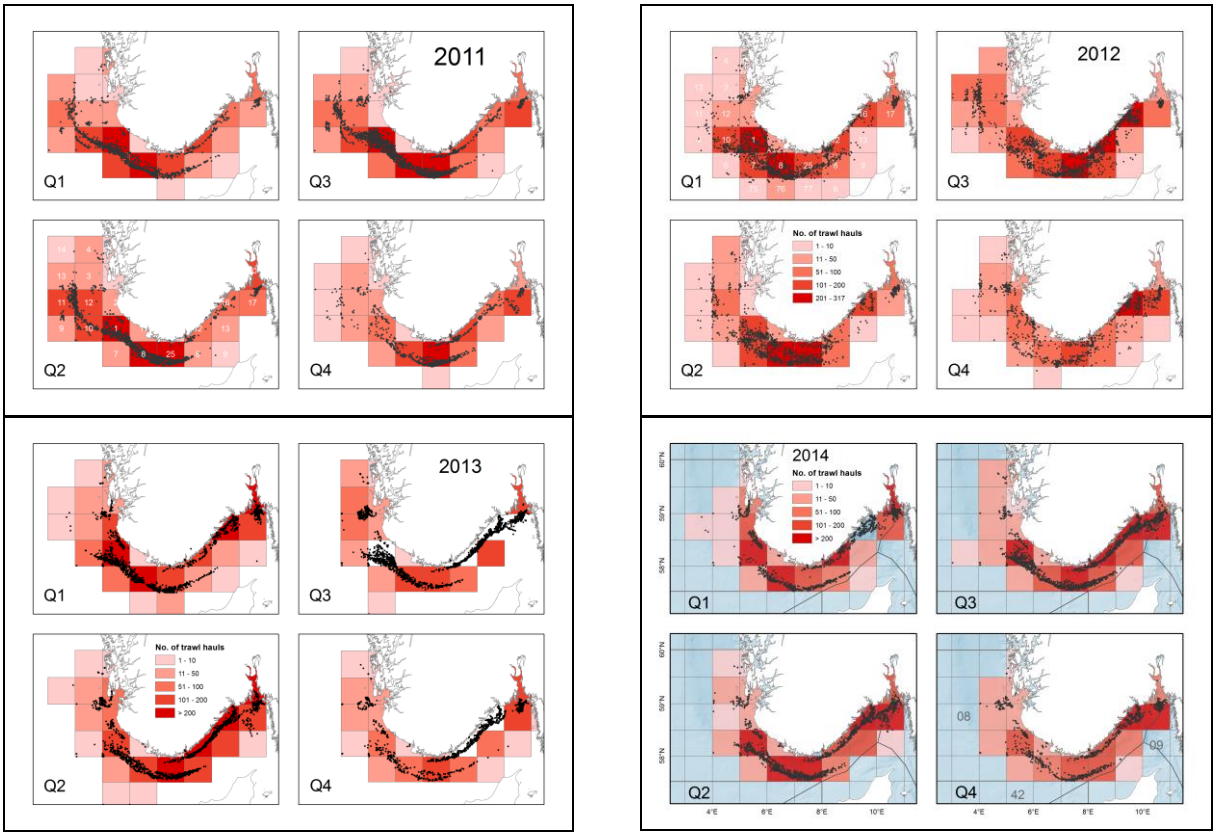

Fig. 14. Quarterly spatial distribution of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011-2014: positions of single trawl hauls from electronic logbooks from vessels ≥ 15 m (≥ 12 m from 2013 onwards in Skagerrak). Grid is standard "ICES squares" (0.5º lat. by 1º long.) = Norwegian statistical locations (numbering). Colour shading shows number of trawl hauls per "ICES square". Data from the Norwegian Directorate of Fisheries.

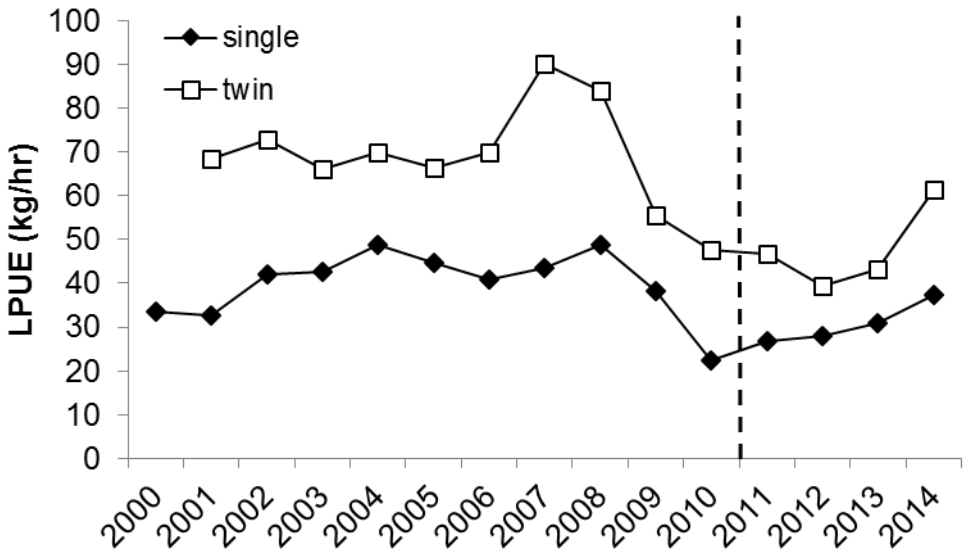

Fig. 15. Annually unstandardised LPUE indices per gear type from logbooks from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). The 2000-2010 indices are based on data corrected regarding use of gear type (shrimp trawl, twin trawl). The 2011-2014 indices are based on information on gear use per haul (single, twin) in the electronic logbooks. The dashed line indicates the year of implementation of electronic logbooks. Data from the Norwegian Directorate of Fisheries.

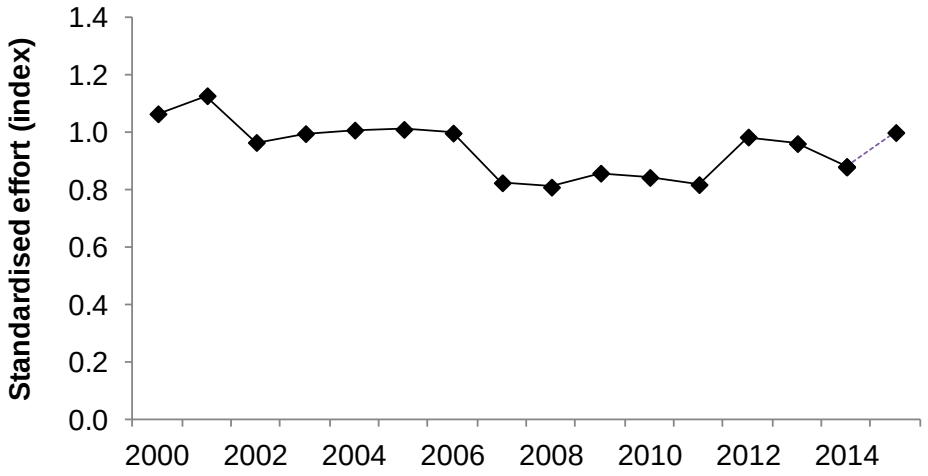

Fig. 16. Standardised total effort in the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2015. The 2015 effort index is estimated from preliminary logbook data (January-May) and preliminary landings corrected for boiling (January to May) projected to the end of the year. Data from the Norwegian Directorate of Fisheries.

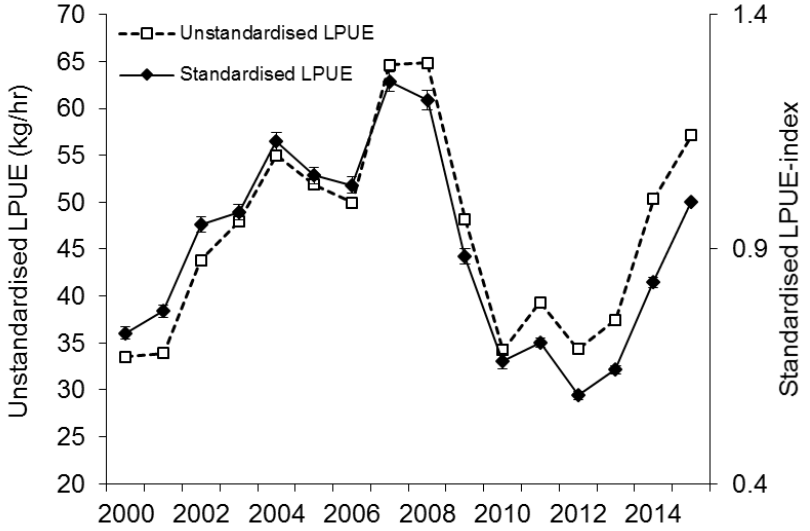

Fig. 17. Standardised LPUE-index (with standard error), and unstandardised LPUE-index (kg/hour) for 2000-2015 from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Data from the Norwegian Directorate of Fisheries. The 2015-data are preliminary.

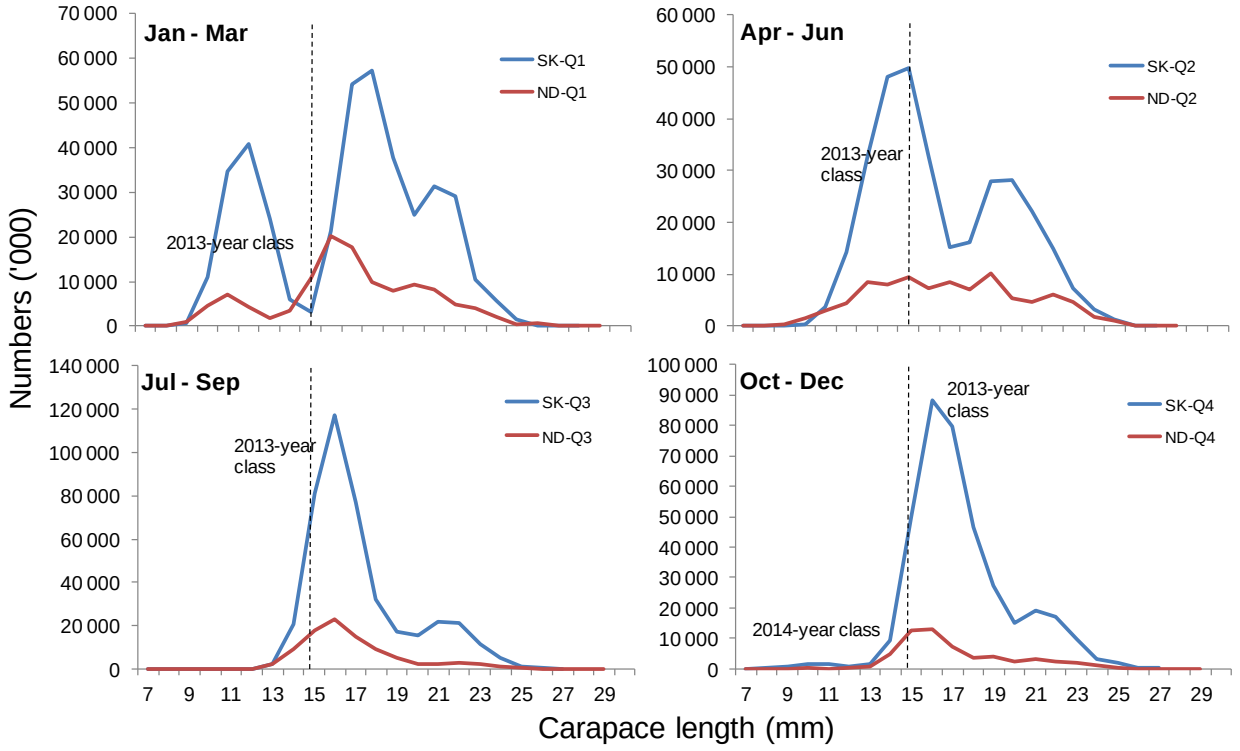

Fig. 18. Numbers per length in the 2014 catches from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), per quarter and area. Note different scales on the y-axes. Samples sizes (Skagerrak and the Norwegian Deep): Q1: 3383, 2008; Q2: 4505, 598; Q3: 3019, 616; Q4: 3388, 614. Dashed lines mark MLS of 15 mm CL.

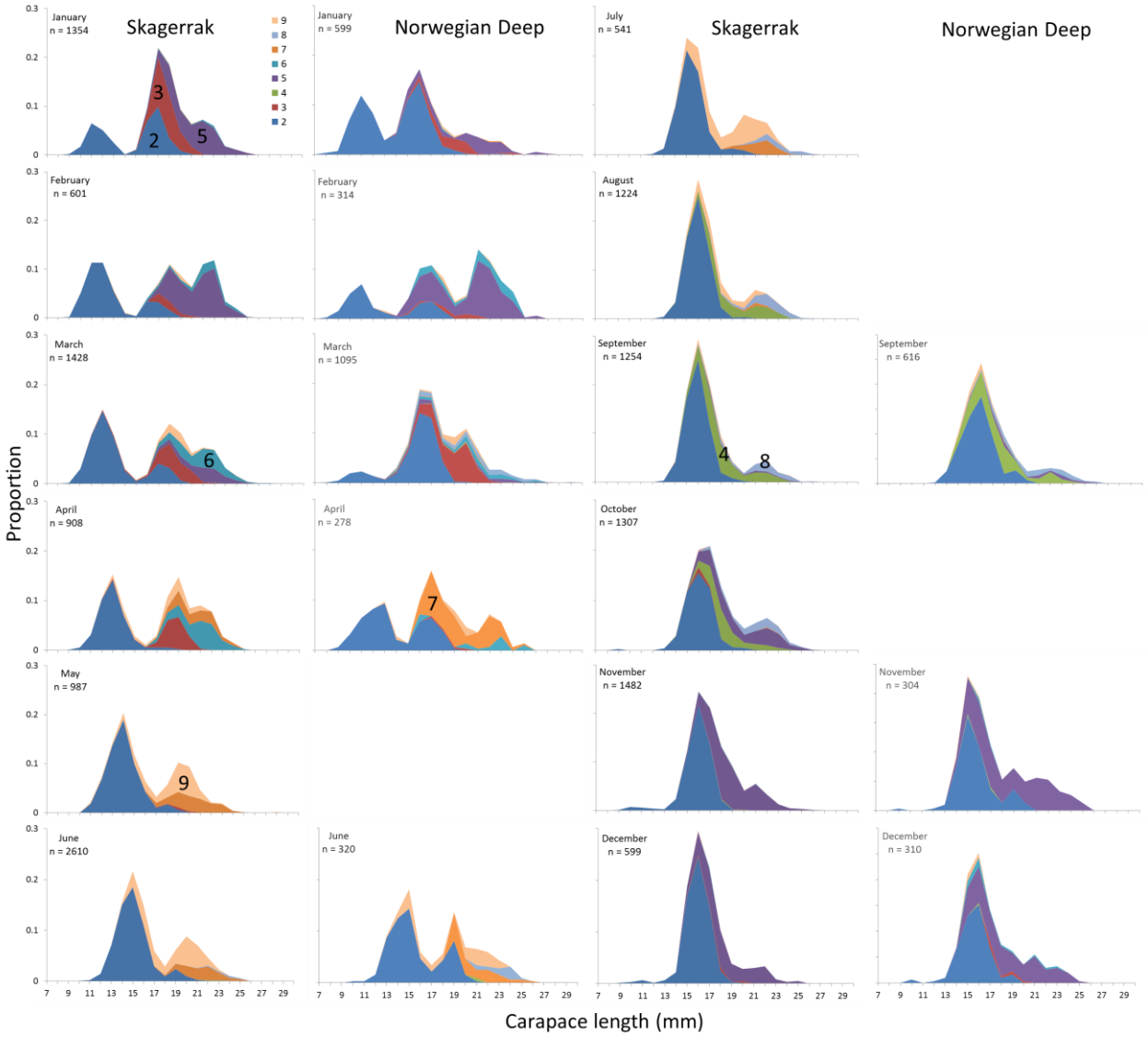

Fig. 19. Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2014 from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local fishermen and the Norwegian Coast Guard. Stages: 2 = males; 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.