Northwest Atlantic Fisheries Organization

Serial No. N6228 **NAFO SCR Doc. 13/066**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – SEPTEMBER 2013

The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2013

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.

Information on the Norwegian shrimp fishery (fleet, gear, and prices) was updated. Norwegian logbooks are incomplete. The data situation improved in 2011 with the implementation of compulsory electronic logbooks for all vessels ≥15 m. However, a large part of the fleet (especially in Skagerrak) consists of small vessels, which are not in the logbooks. The recording of twin trawl use has been incomplete. 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. In 2012, 4 572 t were landed, a slight increase from 2011. Correcting for boiling implies that 230-550 t should be added to the nominal landings for the years 2000-2012.

Landings per unit effort (LPUE) increased from 32 to 65 kg/hour from 1999 to2007-2008, but then dropped to 34 kg/hour in 2010. From 2010 to 2013 the LPUE has fluctuated without trend around approximately 37 kg/hr. Standardised LPUE values calculated for 2000-2013 follow the same trend, but decrease slightly in 2013, instead of increasing as the unstandardised value. The LPUE index from the Norwegian Deep has shown a steady decline since 2004, while the index in Skagerrak has been increasing the last three years (2011-2013).

The 2012 catch composition was evaluated using samples from unprocessed catches obtained from local shrimp fishers and the Norwegian Coast Guard. The 2012 catches in Skagerrak were dominated by the relative large 2011-year class.

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.* 2013): 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 (Fig. 1). Vessels from Norway, Denmark, and Sweden exploit this resource. The Norwegian vessels fish the Skagerrak-Norwegian Deep stock, with minor catches from Fladen Ground in former years (Ulmestrand *et al.* 2013).

Since 1992 Norway and EU have negotiated quotas on shrimp in the North Sea and Skagerrak. For the Norwegian Deep/Skagerrak 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 and 2013 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 four-month periods with respectively 40 %, 30 % and 30 % of the quota. The Norwegian Directorate of Fisheries (FiskDir) can stop the shrimp fishery when the period or total quotas are estimated to be taken. In 2013 the vessels have a maximum quota of 37 t (tons) in the first period and 28 t in both of the other two periods.

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of 60º N. In 2012, a total of 195 vessels participated in the shrimp fishery south of 62º N (Table 1, Fig. 2), which is a reduction from 2011 when 217 vessels participated. The total number of vessels in the fishery has decreased since 2006 (296 vessels). In 2012, 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 (Fig. 2). 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 Skagerrak, while the fleet in the west is more varied (Fig. 3). The yearly mean landings per vessel increase with length, but there are large variations. In 2012 almost all catches were landed in ports along the Norwegian coast, with a minor portion landed in Denmark.

Norwegian logbooks from the shrimp fishery in Skagerrak and the Norwegian Deep are incomplete (Fig. 4). In 2010 catches recorded in logbooks only made up 7.3 and 8.6 % of the corrected landings (see Materials and Methods) from respectively IIIa and IVa east. This was a poorer coverage compared with 2009 when catches made up 13.3 and 15.7 % of the (corrected) landings in IIIa and IVa east. In 2005-2008, catches made up 25- 35 % of the landings in IVa east, and 13-25 % of the landings in IIIa. The poor coverage is partly due to vessels <11 m not being required to fill out logbooks. However, the data situation improved greatly in 2011, with the introduction of compulsory, electronic logbooks for all vessels ≥15 m. In 2012 in IVa east, catches made up 88 % of the landings (corrected) as roughly half the vessels in this area are ≥ 15 m (Fig. 3), fishing on average much more than smaller vessels (Table 1). Skagerrak is dominated by vessels <15 m, and catches therefore made up only 35 % of the landings. In 2013, electronic logbooks became compulsory for all vessels ≥12 m fishing outside the 4 nm border in Skagerrak.

Twin shrimp trawls are common on larger vessels and, according to the Norwegian Fisheries Organization, have been in use since the beginning of the 2000s. According to the electronic logbooks, respectively 25 and 21 vessels ≥15 m used twin trawl in 2011 and 2012. Prior to 2011 the use of twin trawl was not visible in the logbooks, where 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. Other vessels had sporadic records of twin trawls (1-8 per year). This situation was due to the logbooks containing data from few vessels, as well as incorrect recordings. Incorrect recordings were probably due to the wording of the logbooks, where fishers were asked to note the gear type used as [... shrimp trawl, twin trawl, triple trawl ...]. It seems likely that many fishers noted “shrimp trawl” for any type of shrimp trawl used, be it single or twin. Errors may also have resulted from the old logbook data being given per day, not per haul. Thus, catches from all hauls within one day were summed, and gear was the gear most frequently used that day. In the electronic logbooks, data are given per haul, and both gear type as well as the number of gears are recorded. Triple shrimp trawls are prohibited in the North Sea south of 62 °N, but are allowed in Skagerrak. They are, however, not used.

In the Norwegian fishery for shrimp the minimum mesh size is 35 mm. 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 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. In Skagerrak it is allowed to have up to 10 % undersized shrimp (<6 cm total length = 15 mm carapace length (CL) = minimum legal size (MLS)) (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. In 2013 inclined grids for sorting out bycatch became compulsory in shrimp trawls in Skagerrak outside the 4 nm border. In the North Sea south of 62º N, sorting grids in shrimp trawls have not yet become compulsory, but most fishers seem to use them anyway. The grids are used in combination with a collection bag with mesh size ≥120 mm in order to separate the shrimp catch and the valuable bycatch.

Two categories of shrimp dominate the market: in 2012, 41 % of the total landings were delivered as boiled, fresh large shrimp for the Norwegian market, and 59 % of the total as raw (smaller) shrimp for factory processing ashore. The corresponding numbers for 2005 through 2011 were 44, 46, 45, 50, 58, 72, and 61 % boiled shrimp. In 2006-2008 the fishermen obtained approx. 60 NOK/kg for boiled shrimp, and approx. 10-11 NOK/kg for raw shrimp. The price for boiled shrimp had increased compared with 2005 (52 NOK/kg). Due to low shrimp landings the last years, the kilo prize for boiled shrimp increased to a mean of 63 NOK in 2009, 72 NOK in 2010, 79 NOK in 2011, and 88 NOK in 2012. In 2013 prices are 10-11 NOK/kg for raw shrimp and between 97 and 109 NOK/kg for boiled shrimp.

The present document updates available information derived 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 FiskDir. For 2013, landings data were given for May inclusive and logbook data for June inclusive.

Landings were earlier given only per Norwegian statistical areas, 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 are not precise. 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 calculated using only numbers from Divs. IIIa and IVa east.

Landings consist of a fraction of larger shrimp that are 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 upon request 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 corrected using a conversion factor of 1.13. In the statistics from FiskDir, landings are registered as "boiled", "fresh" and "on ice". We have always assumed shrimp "on ice" to be raw shrimp. However, this year we became aware that the category "on ice" is ambiguous, as both boiled and raw landings may be kept on ice when landed. Sales organizations have not been able to clarify the use of this category. Thus, boiled landings which have been registered as "on ice" when landed, will not have been corrected and total weight may have been underestimated. As it seems to be difficult to distinguish between raw and boiled landings "on ice", we will continue to assume that these shrimp are raw, resulting in total weight being underestimated to some extent. This pertains only to Div. IVa east, as the category "on ice" is not used in Skagerrak for some reason.

Fleet structure was derived from the landings statistics. Logbook data give the spatial and temporal distribution of the fishery, with the electronic logbooks providing information on positions of single trawl hauls by vessels ≥15 m

from 2011 onwards. Landings per statistical location (2009-2012) similarly illustrate the spatial distribution of the fishery. 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, which are divided by LPUE to estimate effort, derived from the use of both types of gear.

In order to include gear use (single and twin trawl) in the calculation of standardised LPUE-indices, 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. The following questions were asked:

1) Do you use twin trawl?
2) If yes, when did you start using twin trawl?
3) If yes, how often do you use twin trawl when fishing for shrimp?

Using the results from these interviews, the logbook data for 2000-2010 were corrected in the following way:

1) All recordings of shrimp catches from gear other than single and twin shrimp trawls were deleted (possible bycatch). Twin shrimp trawls were distinguished from fish twin trawls by mesh size (mesh size <42 mm implies shrimp trawl). (<1 % of all recordings in 2000-2010)
2) "Bottom trawl" with mesh size <42 mm was changed to "shrimp trawl"
3) For all vessels for which owners informed twin trawl was not in use, any twin trawl recordings were corrected to single trawl (rare recordings of twin trawl were assumed to be incorrect).
4) All recordings from 11 vessels, for which we could not get secure information on gear use, were deleted (8 % of all recordings in 2000-2010).
5) All recordings from 6 vessels, for which owners informed of use of both single and twin trawls, were deleted (since it was impossible to know when which gear was used) (9 % of all recordings in 2000-2010). Two additional vessel owners informed that they used both gears, but recorded twin trawl when using this gear, thus these data were kept.
6) For all vessels, for which owners informed of 100 % use of twin trawl, any single trawl recordings were corrected to twin trawl from the starting year inclusive. The starting year of twin trawl use was not always precisely given by ship owners, and then owners' information was compared with the logbook data (vessel specific annual mean LPUE).

The electronic logbooks from 2011-2013 provide information on both gear type and number of trawls (single, twin). However, mesh size is lacking in the 2011-2012 log books (reintroduced in 2013), which makes distinguishing between fish bottom trawl and shrimp bottom trawl impossible (both may be recorded as just "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 (2000-2013), 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 h^{th} vessel; A_i is the effect of the i^{th} area; M_j is the effect of the j^{th} month; Y_k is the effect of the k^{th} year; G_l is the effect of the l^{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 indices are the antilog of the year coefficients.

A standardised effort series for 2000-2013 was derived by dividing landings (corrected for boiling) by the standardised LPUE indices.

Since owners of vessels <15 m are not required to fill in logbooks, 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 complete simplified logbooks from all their fishing trips.

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, whilst 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 and onwards discards have been estimated by comparing length distributions from sorted landings (sampling initiated in 2007) with length distributions from unprocessed commercial catches (sampling initiated in 2005). In 2008 this comparison gave negative discards, so instead the length distributions from sorted landings were compared with Danish landings, assuming that the fishing takes place on the same fishing grounds and that the level of discarding in the Danish fishery is low. The annual length distribution from unprocessed catches is scaled to fit the annual length distribution from the landings for the larger sizes, based on the assumption that there is 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 are then multiplied with the mean weight of each size group, and the sum is considered the weight of the discard. In 2007-2009 discards were only estimated from Skagerrak due to too few data from the Norwegian Deep. In 2010-2012, sampling improved, and discards were estimated for both Skagerrak and the Norwegian Deep.

The "*comparison-of-length-distributions-method*" has now been used for several years, and the results are often unreliable (e.g., negative estimates). Part of the explanation could be that the sampling of catches covers the whole fishery, while the sampling of landings covers only a small part of the fishery (samples from one fisher in IVa east, and from one landings location in IIIa). The above mentioned ambiguous registration of raw and boiled landings (category "on ice") in Div. IVa east may also be part of the problem (calculations of sorted landings by length group rely on estimated total weights of respectively boiled and raw landings).

As discarding is illegal in Norway, onboard sampling is difficult to organize, and it is highly unlikely that we will find shrimp fishers willing to record their discards. Denmark initiated onboard sampling of their shrimp fishery in Skagerrak in 2009, yielding estimates of Danish discards. These data are considered the best available for estimating Norwegian discards in Skagerrak. Thus, from 2009 onwards Norwegian discards are estimated using the Danish discards-to-landings ratio to Norwegian landings. The underlying assumptions are that the size structure of the shrimp stock is the same on the Danish and Norwegian fishing grounds, and that the level of discarding is the same in the two fisheries. The Danish at-sea-sampling-program has not covered the rather few fishing trips by Danish shrimp vessels in the Norwegian Deep. Norwegian discards from the Norwegian Deep is therefore estimated as the weight of all shrimp < 15 mm CL (MLS) in the catches, assuming that all shrimp < MLS are discarded. The numbers pr length group in the Norwegian landings are multiplied by the mean weight pr length group (Danish data), where the length frequency distribution is obtained from catch sampling.

Samples (approx. 1.5 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2012 catches were obtained from five Norwegian shrimp fishers (35 samples) (Fig. 5). The Norwegian Coast Guard provided 24 samples after inspection 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

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. 6a, Table 2). In the following years landings fluctuated around 7 500 t with a maximum in 1998 of 9 707 t. From 2000 to 2004 total nominal landings increased continuously from about 6 000 t 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 nominal landings increased slightly in 2011 (4 466 t) and

further in 2012 (4 572 t). Correcting for boiling implies that between 230 and 550 t are added to the nominal landings for the years 2000-2012 (Table 2). As noted above, corrections may be underestimated for the Norwegian Deep.

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, the difference between the two areas again increased due to an increase in IIIa and a decrease in IVa east.

In Skagerrak, the nominal landings peaked in 1998 at about 6 500 t, decreased to 3 000 t in 2001, and until 2007 increased to nearly the same level as in 1998 (Fig. 6a, Table 2). From 2007 to 2010 the Skagerrak landings decreased by 56 % to the lowest level since 1979. The 2011 landings were of the same size as the 2010 ones, while in 2012 the nominal landings increased by about 1 000 t compared with 2011, to 3 565 t. In the Norwegian Deep nominal landings fluctuated around 3 000 t in the 1990s, increased to around 4 300 t in 2004, and thereafter steadily decreased to about 1 700 t in 2009 (Fig. 6a, Table 2). Both the 2010 and the 2011 nominal landings remained at the 2009 level, but in 2012 landings decreased further to 1 004 t, the lowest value since 1979. Monthly landings for 2005-2013 (Fig. 7) indicate that the increasing trend in landings in Skagerrak continues in 2013. In the Norwegian Deep, on the other hand, preliminary landings from January-May 2013 indicate that the fishery is not improving. 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. 7). Lower landings during winter are probably due to weather conditions.

In 2012, 2 075 t were landed by small vessels (< 15 m), while a slightly larger quantity (2 495 t) was landed by large vessels (> 15 m) (Table 1). This is in contrast to 2011, when landings from large vessels (3 007 t) were more than 50 % higher than landings from small vessels (1 444 t), and is explained by the respectively increasing and decreasing fisheries in Skagerrak and the Norwegian Deep, and the different fleet structure within the two areas (Fig. 3).

In 2008 and 2009 the Norwegian TAC was 9 731 t. From 2010 the quota has steadily declined to almost half this level, being set to only 5 469 t in 2013 (3 099 t in IIIa and 2 370 t in Subarea IV). The decline from 2012 to 2013 was 7 %. During the last ten years the Norwegian quota has only been overfished twice (1997 and 2004). In 2003 and 2005 estimated total landings corrected for boiling also exceeded the total Norwegian TAC. Because of the arrangement of evenly allocating the quota to three periods in order to supply the market throughout the year, and because of frequently bad weather in late autumn and winter rendering fishing difficult, the whole Norwegian quota is rarely fished. In 2006-2009 respectively 97, 93, 85 and 65 % of the quota was landed (corrected landings as percentage of Norwegian TAC), while in 2010 only 54 % of the quota was landed (Table 2). In 2011, 64 % was taken. In 2012, 4 800 t (landings corrected for boiling) were taken from a quota of 5 855 t (82 %).

Use of single and twin trawl

There is a clear difference in catch efficiency between single and twin shrimp trawls (Fig. 8). In 2007 we started interviewing ship owners about their use of single and/or twin trawl. The logbooks for 2004-2010 contain data from 59 vessels. We have managed to get in touch with the owners of 48 of these. In the years 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. The use of twin trawl was to some extent correlated with vessel size, but is in use by all length categories (Fig. 9). We do not have any information on the use of twin trawls by vessels <15 m.

Spatial distribution of the fishery

According to the electronic logbooks from 2011 and 2012, the fleet of large vessels (≥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 of the west coast of Norway (Fig. 10). Effort in terms of trawling hours shows that the main fishing areas for the large vessel fleet are off Egersund and Lindesnes (Fig. 11). The small vessels are not in the logbooks, but landings per statistical location (provided since 2009) indicate that the Norwegian Skagerrak coast and the northeastern part of Skagerrak constitute the main fishing grounds for this fleet component. Landings per statistical location also illustrate that some fishing takes place in the northern part of Div. IVa east, as well as in the fjords (Fig. 11). In 2011

the fishing pattern changed with the time of year, with fishing taking place on the southwestern edges of the Norwegian Deep in spring, and spreading over a larger area in summer and early autumn (Fig. 12). In 2012, however, the vessels covered a much larger area of Div. IVa east throughout the whole year.

Effort

The estimated number of fishing hours in 2012 was more than twice as high in Div. IIIa compared with Div. IVa east (86 vs. 38 Khours) (Table 2). The inter area difference was less pronounced in 2011 with respectively 77 and 48 Khours. The estimated effort in the Norwegian Deep decreased from 2005 to 2009, increased in 2011, and then decreased again in 2012. In Skagerrak the pattern is opposite with an increase from 2007 to 2010, a decrease in 2011, and an increase again in 2012.

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. 6c).In 2012, the total estimated effort increased to 140 Khours. Standardised effort indices (2000-2013) (Table 3, Fig. 13) show almost the same trend as the unstandardised figures, but with no decrease in 2011. The index increased in 2012 and further in 2013. However, the 2013 index is estimated from preliminary logbook data from January to June, and preliminary landings from January to May, projected to the end of the year. Therefore, one should probably not put too much emphasis on the 2013-index.

The fishery in 2011 took place in all months (Figs. 7, 14). In Div. IIIa effort was more or less equally distributed over the year, while in Div. IVa east the main fishing season was from March to August. The fishing pattern was similar in 2012, however, in Div. IIIa the effort increased in August and October, likely reflecting fishing on the incoming relatively large 2011-year class (Søvik and Thangstad 2013).

Standardised landings per unit effort (LPUE)

Overall LPUE increased from 1999 to 2007-2008 (Fig. 6b, Table 2), decreased in 2009 and further in 2010. Since 2010 the LPUE has fluctuated without trend around approximately 37 kg/hr. The 2013 index is higher than the one in 2012, however, it is based on preliminary logbook data from January-June, and as such could change with more data coming in. 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 from 2005 to 2011, to the lowest level observed in the time series. The 2012 index has remained at the same low level. In Skagerrak, on the other hand, the LPUE index increased from 2005 to a record high level in 2007. Thereafter the index decreased sharply to the lowest level observed in the time series in 2010. The last three years have seen an increase in the LPUE in Skagerrak.

Standardised LPUE values have been calculated for 2000-2013 (Table 3, Fig. 15). These indices follow the same trend as the unstandardised figures. Fleet structure and fishery pattern have probably remained stable during this relatively short time period, but gear use has changed (see above). Due to the incomplete logbooks, it can be questioned whether the LPUE data are representative of the Norwegian fishery, and whether they can be used as an index of stock biomass. At least from 2011 onwards we know that the data are representative of the large vessel fishery. Furthermore, when comparing with results from the Norwegian shrimp survey (Søvik and Thangstad 2013), it is seen that the decrease in the survey biomass index from 2008 to 2012 is reflected in the decrease in the standardised overall LPUE (Fig. 15). In Skagerrak the standardised index increased from 2010 to 2013, while in Div. IVa east and in the whole area the standardised index decreased slightly from 2012 to 2013. In comparison, the survey biomass index shows a slight increase in 2013 compared with 2012. However, both time series show that the shrimp stock in the Skagerrak/Norwegian Deep area still is at a low level. Signs of improvement are seen in Div. IIIa though.

The LPUE-data from the small vessel fleet in Skagerrak cover mainly the eastern part of Div. IIIa (Fig. 16). The monthly catch rates decreased from 2007 to 2010, levelled out in 2011, and then increased again in 2012, especially from August to December, reflecting the incoming of the relatively large 2011-year class in the fishery in autumn 2012 (Fig. 17a). Preliminary monthly catch rates from January to April 2013 have increased substantially compared with the corresponding catch rates in 2012, indicating an improved status of the stock along the Norwegian Skagerrak coast in 2013. The annual catch rates from the small vessel fleet and the unstandardised LPUE indices

from the logbooks from Div. IIIa show the same trend in the time period 2007-2013 (Fig. 18). The much larger increase in LPUE from 2012 to 2013 in the small vessel fleet compared with the large vessel fleet (≥ 15 m) (official log book data) suggests that the shrimp stock biomass has increased more in the eastern than in the southern Skagerrak (Figs. 10, 16).

Discards
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.

Estimates of discards due to high-grading was estimated for 1996 and 1997 based on separate quarterly length distributions for the categories large and medium sized and the selection ogive for the sieved ones (ICES 1999). However, already next year the working group considered these estimates too inaccurate to be included in assessments (ICES 2000). Later Norwegian estimates of high grading are not available.

Estimates of "quality discard" have varied between 1 and 17 % of the catches, i.e., from 93 to 1400 t annually (Table 2). However, the estimated discards from the Norwegian fishery in Skagerrak in 2008 of 1 408 t was probably much too high. The assumption of the Norwegian and Danish fleet fishing on the same fishing grounds may not have been valid, and the assumption of no Danish discards is not correct (see below).

Estimated Norwegian annual discards from Skagerrak in 2009-2012 range from 78 to 248 t, and in the Norwegian Deep from 15 to 40 t (Tables 2, 4, 5). The discards from 2009 to 2011 were recalculated using updated information on Danish discards and landings. The Norwegian and Danish fisheries are partly overlapping (Figs. 10, 19). Comparison of length frequency distributions in Danish and Norwegian catches from Skagerrak in 2009-2012 show that the size structure of the shrimp stock on the Danish and Norwegian fishing grounds is more or less similar (Fig. 20). Some quarterly distributions differ in some years, but the annual distributions are similar, supporting the use of the Danish data to estimate Norwegian discards from Skagerrak. Length frequency distributions in Norwegian catches from the Norwegian Deep show that the shrimp caught in this area are larger than shrimp caught in Skagerrak.

Catch composition
Length frequency distributions show that the catches in the 1st quarter (January-March) of 2012 consisted of all three year classes (Table 6, Fig. 21). The 1-group (the relatively large 2011 year class) is smaller than the MLS of 15 mm CL and was probably mainly discarded. In the second quarter the 1-group dominated the catches in Skagerrak, while the much smaller catches in the Norwegian Deep were dominated by older shrimp. Being still below the MLS, most of the 1-group shrimp were probably discarded. In autumn 2012 the Skagerrak catches were still dominated by the 1-group, and as most of these shrimp now had grown larger than the MLS, they were landed as raw shrimp. The 0-group (the 2012-year class) entered the catches in October-December (Figs. 21, 22).

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 1999. Report of the *Pandalus* assessment working group, 1-4 September 1998. ICES CM 1999/ACFM:5. 33 pp.

ICES 2000. Report of the *Pandalus* assessment working group, 23-26 August 1999. ICES CM 2000/ACFM:2. 30 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. 2013. Results of the Norwegian Bottom Trawl Survey for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east) in 2013. – NAFO SCR Doc. 13/071.

Ulmestrand, M., Munch-Petersen, S., Søvik, G., and Eigaard, O. 2013. The Northern shrimp (*Pandalus borealis)* Stock in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa East). - NAFO SCR Doc. 13/072.

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 2012: Number of vessels and total (uncorrected) landings (t) per length group; and landings per vessel per length group (mean, median, and standard deviation).

Length group	Number of vessels	Landings (t)	Landings per vessel (t)		
			Mean	Median	St.dev
< 10 m	14	54	3.9	1.0	7.9
10-11.99 m	77	781	10.1	4.6	11.7
12-14.99 m	58	1 240	21.4	13.3	21.9
15-20.99 m	21	618	29.4	11.9	34.3
21-27.99 m	18	1 261	70.1	57.9	50.1
> 28 m	6	616	102.6	109.9	49.3
unknown	1				
Total	195	4 571			

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); and estimated number of trawling hours (effort) of the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east 1970-2013. 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 updated information on Danish discards.

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	2339									
1973	1415	918	2346									
1974	1186	623	1953									
1975	1463	876	2067									
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	450	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	93	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	246	37	40	39	77	47	122
2012	3565	1004	4572	228	5855	288	44	27	34	86	38	140
2013	1674	531	2205		5469		46	28	38			

Data from the Norwegian Directorate of Fisheries.
The 2013 landings are from January-May.
The 2013 LPUE data are from January-June.
Estimated effort 2000-2012 is 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. Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, 2000-2013. The 2013 LPUE-index is based on logbook data January-June. The 2013 effort index is based on logbook data from January-June and corrected landings from January-May projected to the end of 2013.

	Stand. LPUE (index)	Stand.effort (index)
2000	1.28	0.85
2001	1.35	0.91
2002	1.67	0.77
2003	1.71	0.80
2004	1.96	0.82
2005	1.83	0.82
2006	1.79	0.82
2007	2.15	0.68
2008	2.08	0.67
2009	1.55	0.69
2010	1.14	0.69
2011	1.19	0.68
2012	1.02	0.79
2013	1.00	1.00

Table 4. Estimated discards (t), landings (t) and catches (t) in the Norwegian shrimp fishery in Div. IIIa (Skagerrak) in 2009-2012, per quarter and annually.

	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	25	709	735	11	709	720	5	624	629	110	2817	2926
2011	33	695	729	87	725	812	54	822	877	53	647	700	227	2890	3117
2012	58	1002	1060	20	536	556	47	1159	1207	122	1072	1194	248	3768	4016

Table 5. Estimated discards (t), landings (t) and catches (t) in the Norwegian shrimp fishery in Div. IVa east (the Norwegian Deep) in 2009-2012, per quarter and annually. There were no catch sampling in the third quarter in 2009.

	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		474	474	1	186	187	15	1812	1827
2010	1	621	622	8	512	520	13	415	428	1	309	310	23	1857	1880
2011	7	582	589	5	625	630	4	580	584	3	124	127	19	1911	1930
2012	14	349	363	13	262	275	7	249	256	5	168	173	40	1028	1068

Table 6. Mean carapace length (with SD), and numbers (millions) per age class in the 2012 catches from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, per area and total.

		Total			Skagerrak			Norwegian Deep		
Quarter	Age	Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
1	1	12.06	1.27	81	11.96	1.26	72	12.89	1.61	10
	2	18.06	1.37	148	18.37	1.43	122	17.22	1.02	25
	3/3+	22.63	1.79	66	22.72	1.66	41	20.04	1.64	19
	4+							24.8	1.39	11
2	1	14.31	1.34	125	14.59	1.34	118	14.14	1.61	13
	2	19.74	1.82	81	19.74	1.48	47	18.85	1.23	19
	3/3+	24.6	1.64	11	23.62	1.19	5	21.76	1.27	13
	4+							25.55	1.32	6
3	1	16.23	1.21	240	16.26	1.16	222	15.42	1.20	15
	2	20.85	1.83	99	21.24	1.35	64	19.93	1.20	12
	3/3+	26.68	1.46	5	24.5	0.65	2	23.08	1.45	13
	4+							26,92	1.40	4
4	0	11.25	0.95	13	11.13	1.11	11	10.24	0.89	2
	1	17.01	1.27	252	17.07	1.23	223	16.47	0.99	25
	2/2+	21.48	1.07	53	21.63	1.54	53	21.68	1.42	9
	3+	24.36	1.26	7				26.27	1.65	1

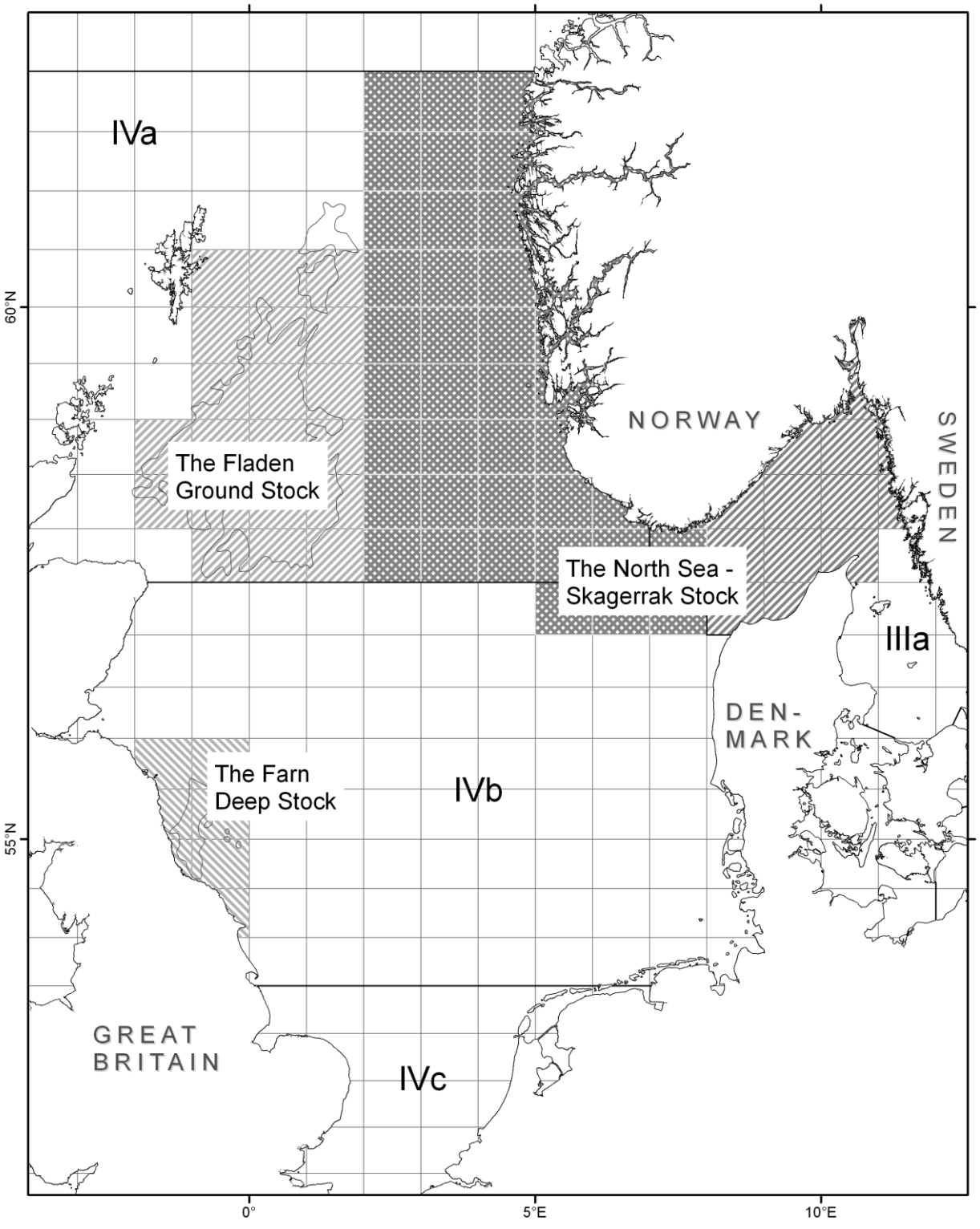

Fig. 1. Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the ices defined management units. Grid is standard "ICES squares" (0.5º lat. by 1º long.).

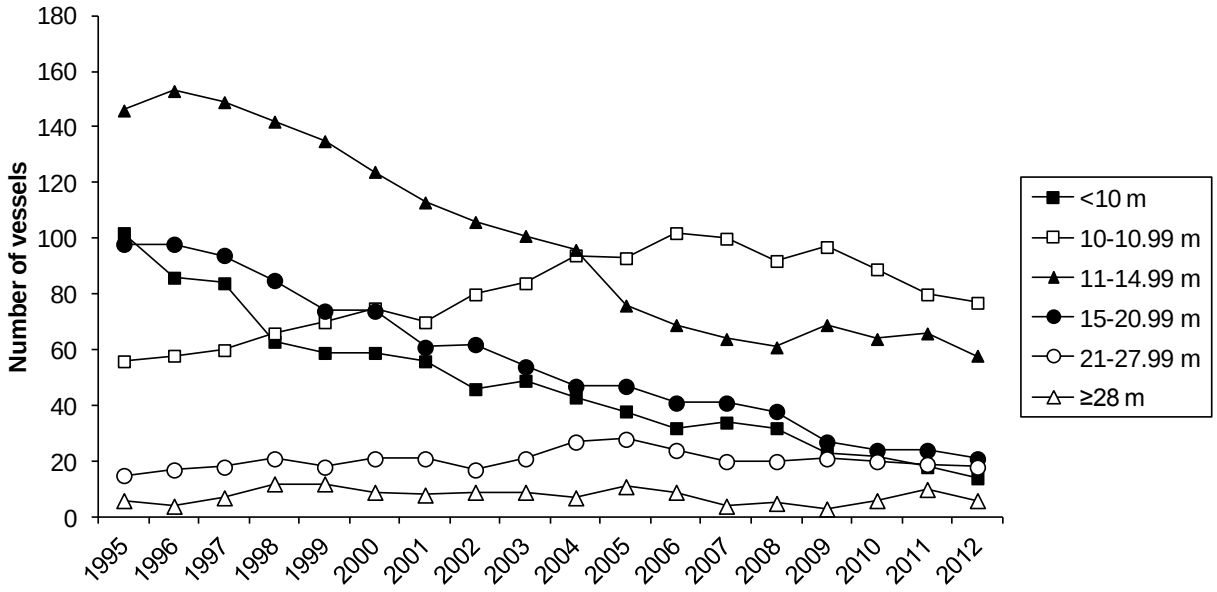

Fig. 2. The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) 1995-2012: number of vessels per length group (m). Data from the Norwegian Directorate of Fisheries.

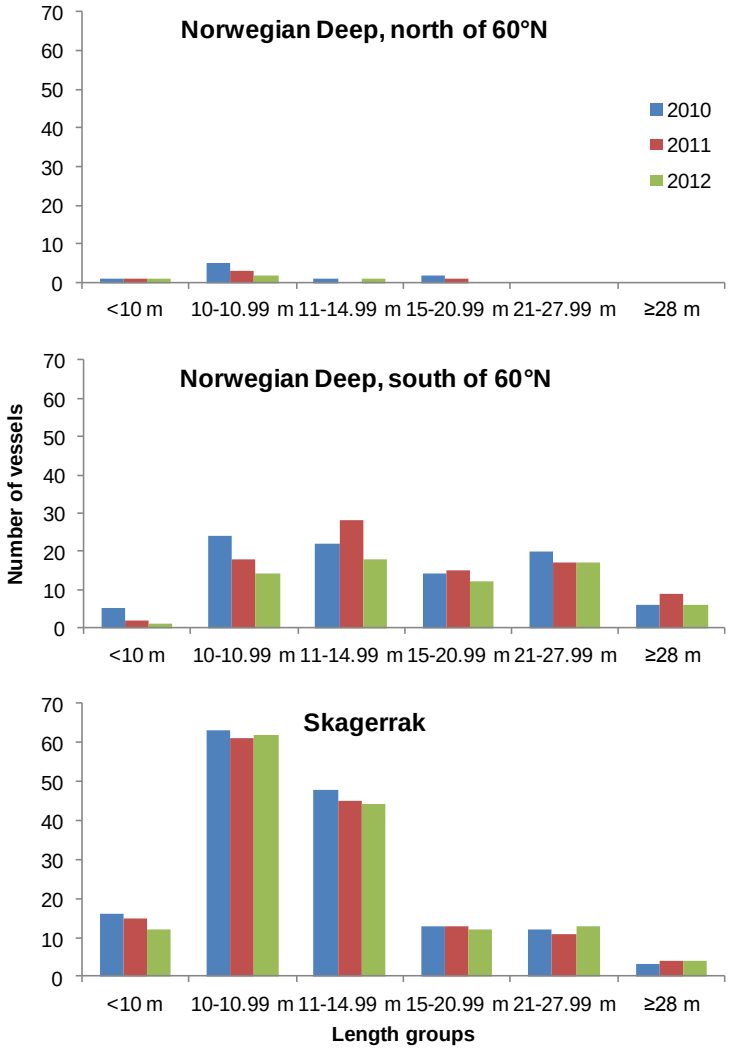

Fig. 3. Number of vessels per length group in the Norwegian fleet fishing for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2010-2012. Some vessels are represented in more than one area. Data from the Norwegian Directorate of Fisheries.

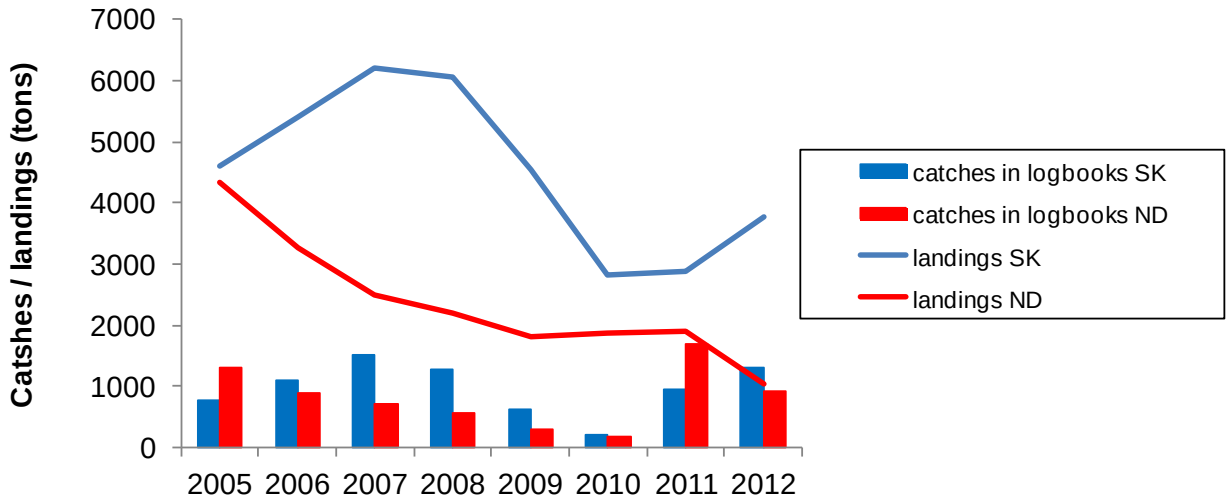

Fig. 4. Incomplete logbooks from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) illustrated by landings (corrected for boiling) and catches in logbooks, per area for 2005-2012. Data from the Norwegian Directorate of Fisheries.

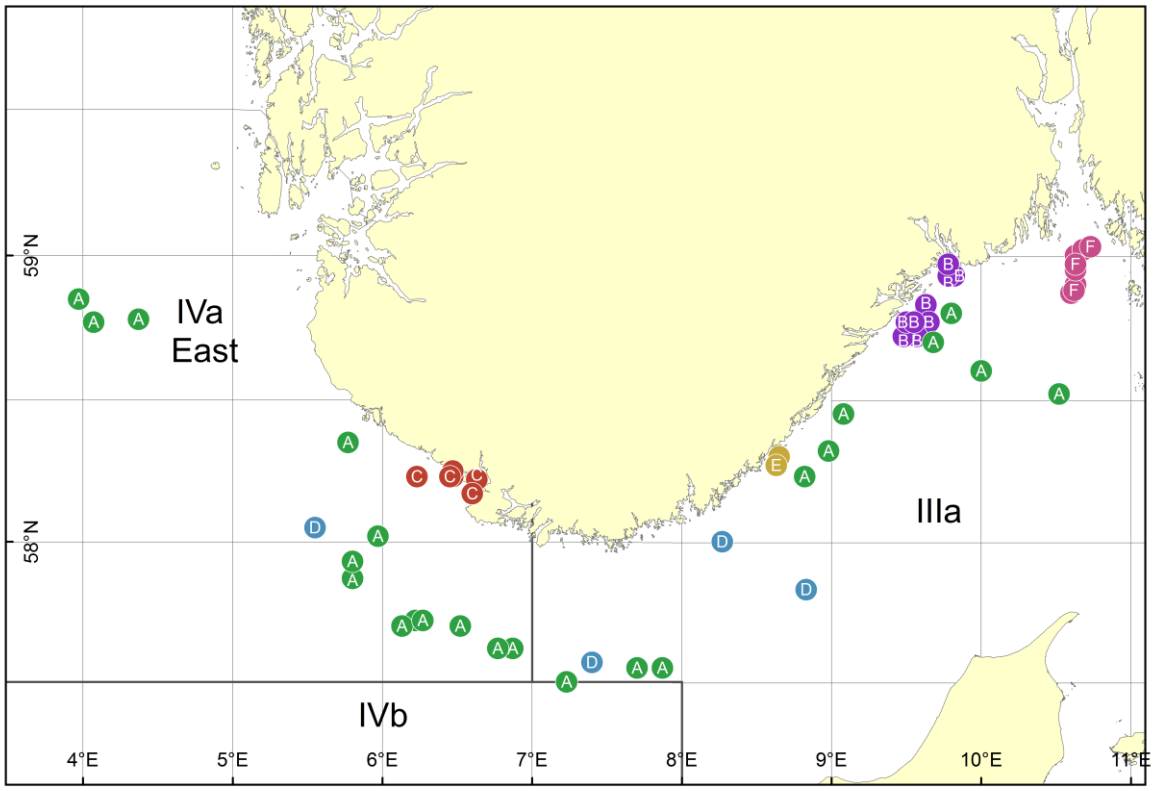

Fig. 5. Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2012 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local Norwegian fishermen (B-F, representing different vessels) and the Norwegian Coast Guard (A).

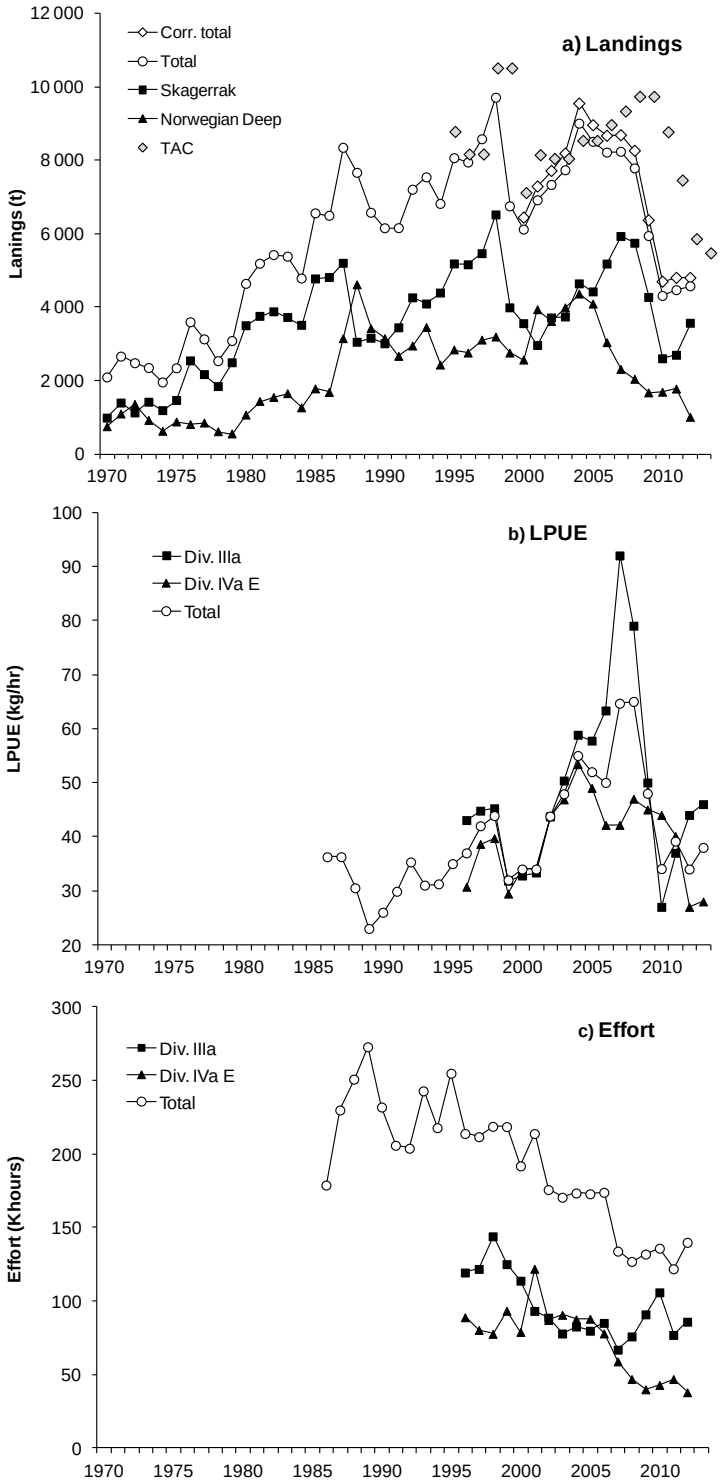

Fig. 6. Landings (nominal and corrected) and TAC a); unstandardised landings per unit effort (LPUE) b); and estimated total effort c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) for all years for which data are available. LPUE data from 2013 are based on preliminary data from January-June. In a) "total" includes Div. IIIa and all of Subarea IV, and "Corr. total" are total landings corrected due to boiling. Data from the Norwegian Directorate of Fisheries.

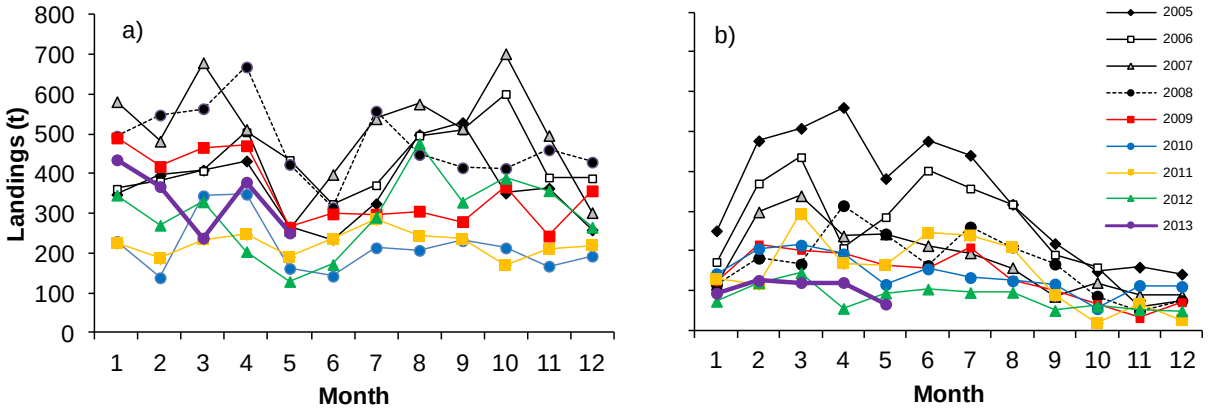

Fig. 7. Monthly (uncorrected) Norwegian landings of shrimp (*Pandalus borealis*) 2005- 2013 for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries. Data from 2013 are preliminary.

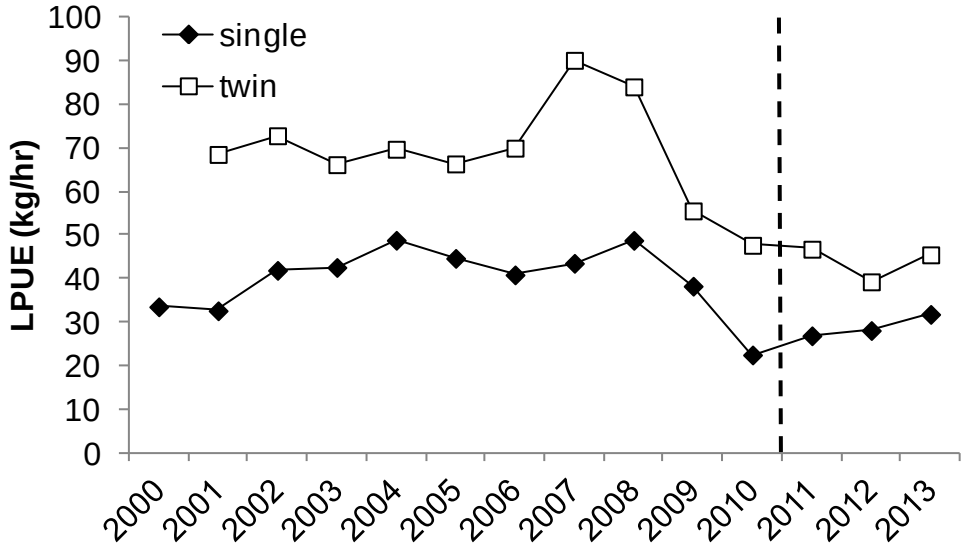

Fig. 8. Annually unstandardised LPUE indices per gear type from logbooks from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). The 2000-2010 indices are based on data corrected regarding use of gear type (shrimp trawl, twin trawl). The 2011-2013 indices are based on information on the number of trawls used per haul (single, twin). The dashed line shows the year of the implementation of the electronic logbooks. Data from the Norwegian Directorate of Fisheries.

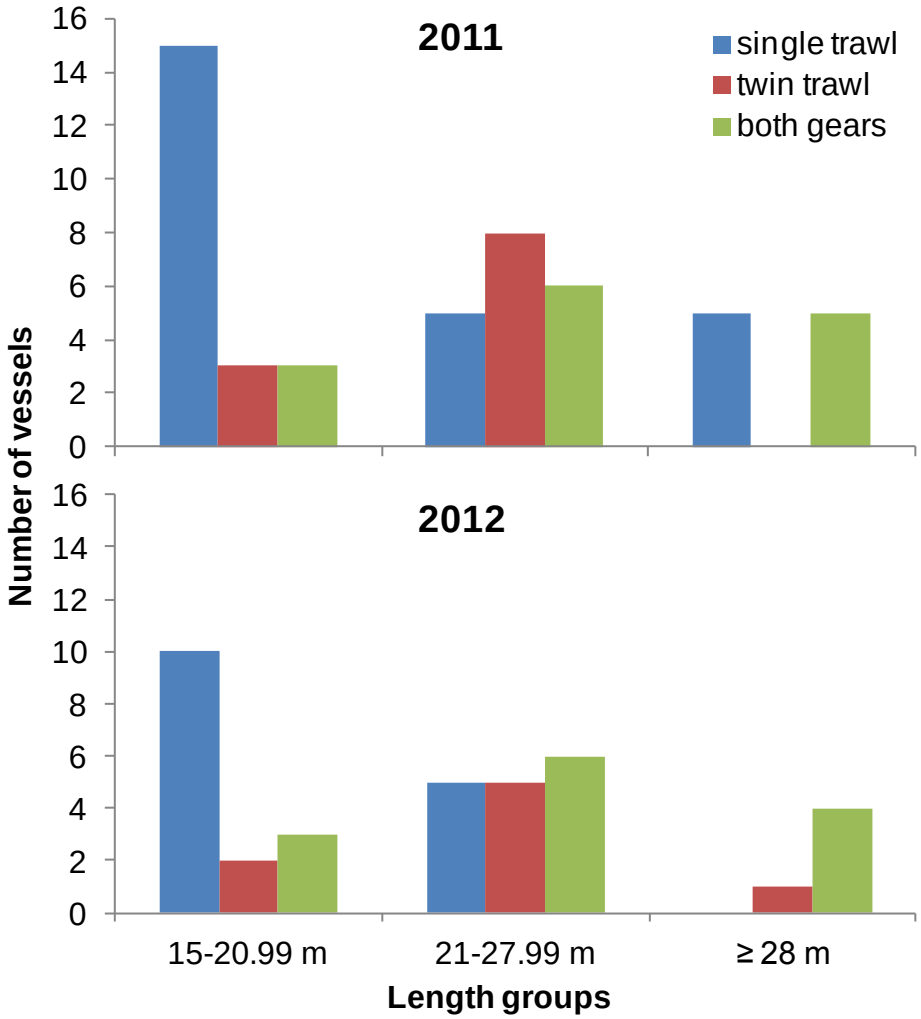

Fig. 9. Gear use by vessel length group. Data from electronic logbooks from the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011-2012. There is no information on vessels <15 m, as these were not required to send in logbooks in 2011-2012.

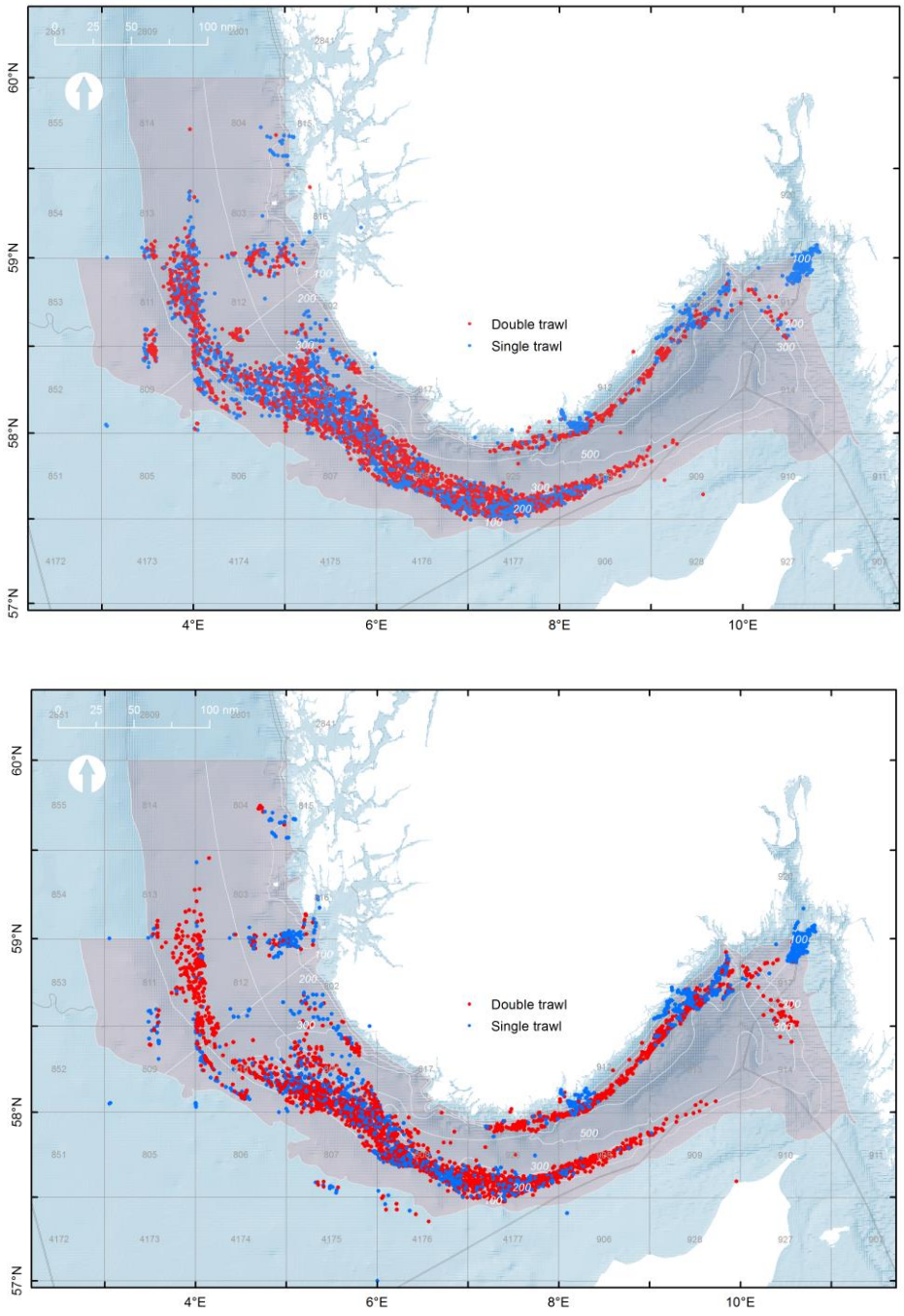

Fig. 10. Spatial distribution of the Norwegian large vessel (≥ 15 m) fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011 (above) and 2012: positions of trawl hauls with single (blue) and twin (red) trawl in electronic logbooks. Depth contours are given for areas deeper than 100 m (shaded area). Grid is standard "ICES squares" (0.5º lat. by 1º long.) = Norwegian statistical locations (numbering). Data from the Norwegian Directorate of Fisheries.

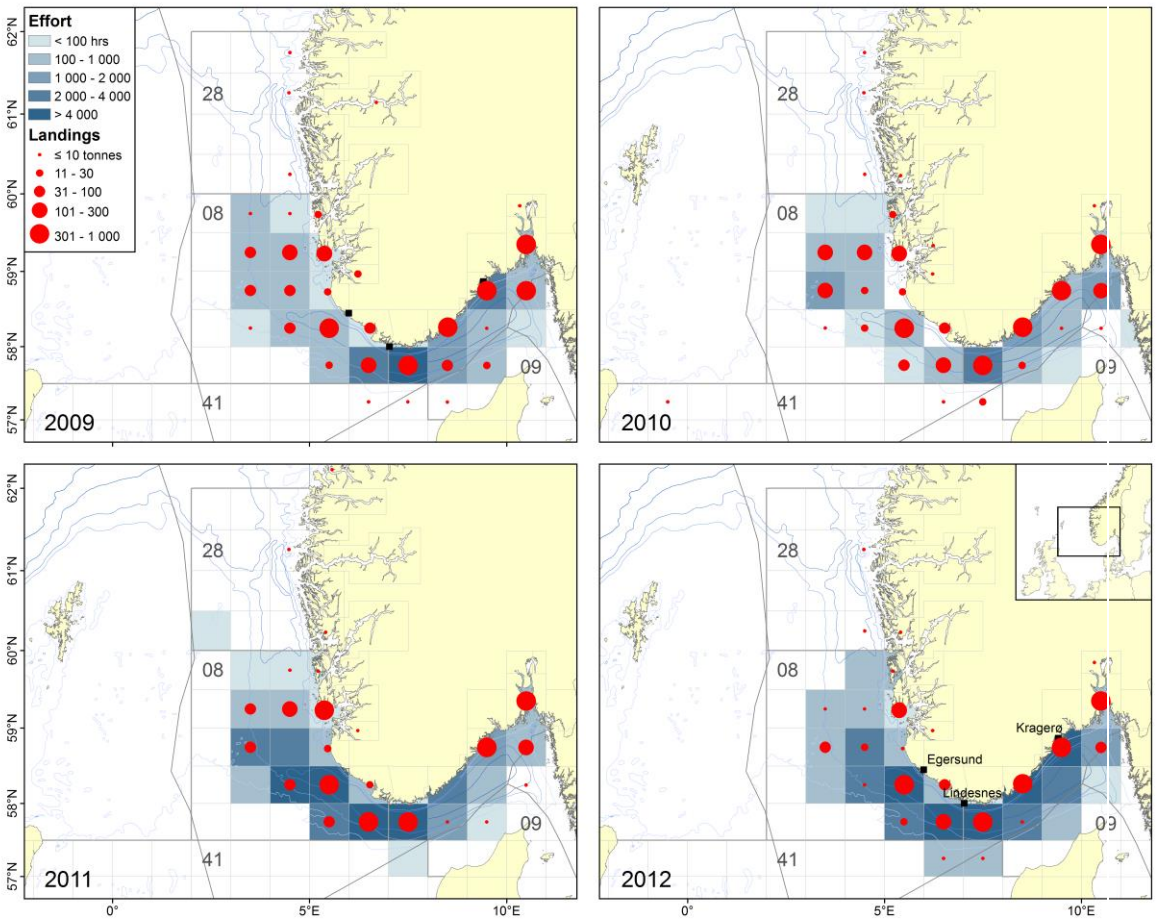

Fig. 11. Distribution of landings (t) and recorded effort (trawling hours) in the Norwegian fishery for shrimp (*Pandalus borealis*) in 2009-2012 in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) by standard "ICES squares" (0.5º lat. by 1º long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.

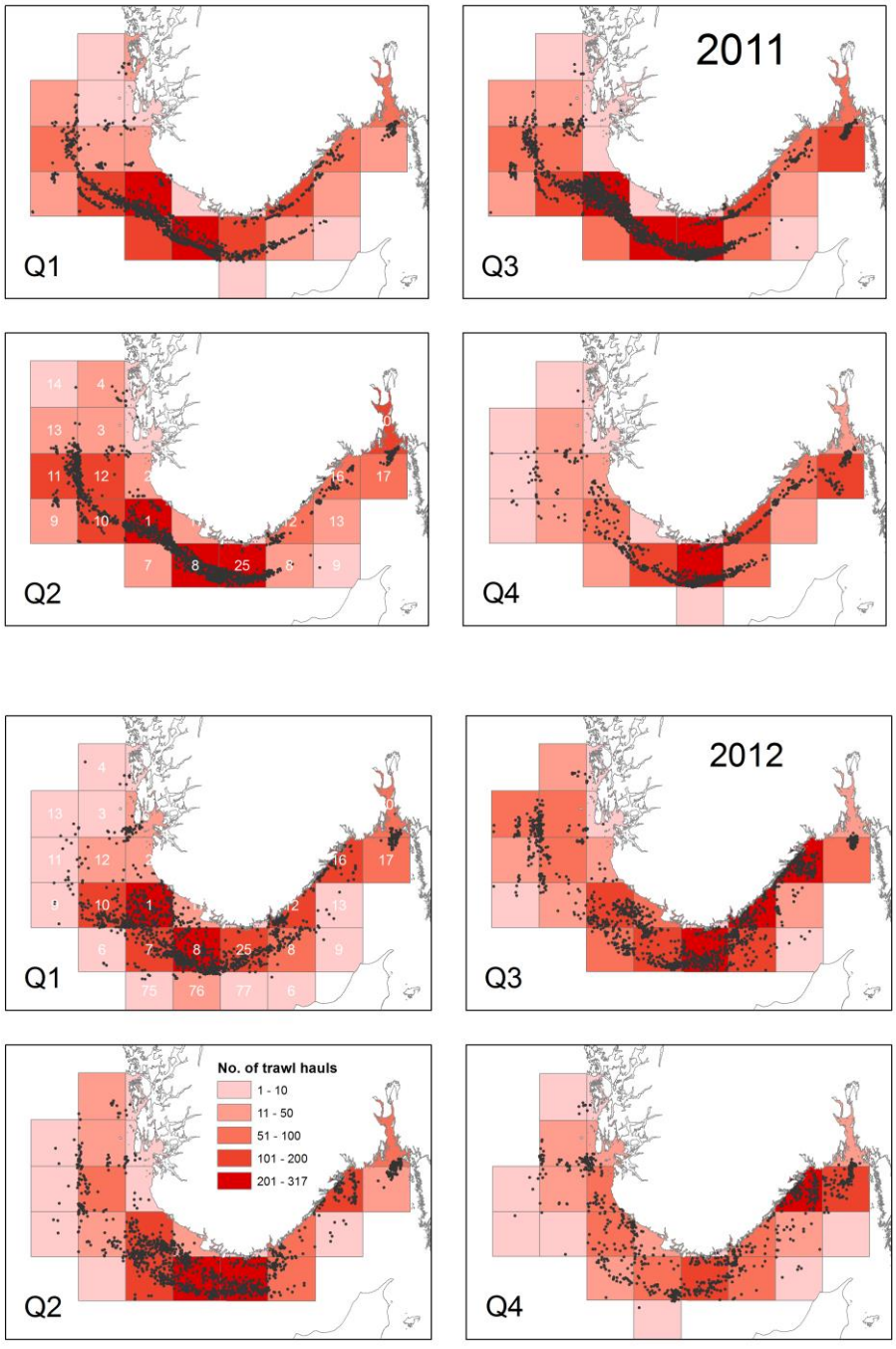

Fig. 12. Quarterly distribution of the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011 and 2012 based on electronic logbooks from vessels ≥ 15 m: positions of single trawl hauls. Grid is standard "ICES squares" (0.5º lat. by 1º long.) = Norwegian statistical locations (numbering). Colour shading shows number of trawl hauls per "ICES square". Data from the Norwegian Directorate of Fisheries.

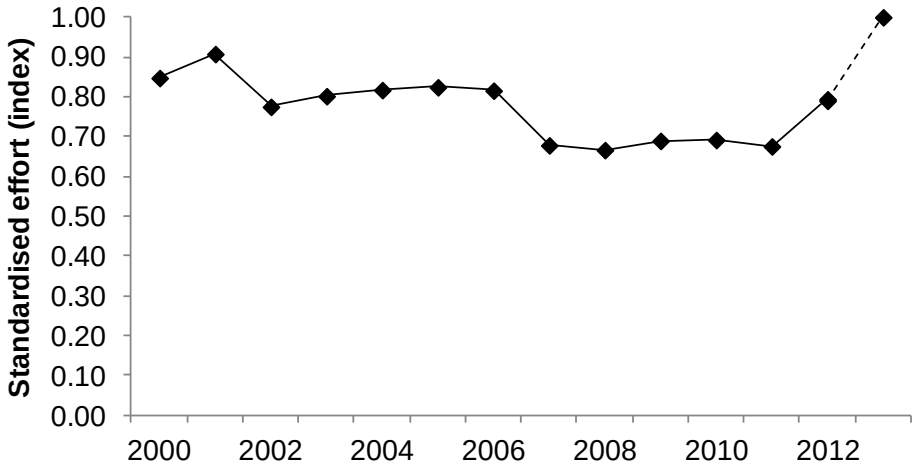

Fig. 13. Standardised total effort in the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2013. The 2013 effort index is estimated from preliminary logbook data from January to June and preliminary landings (corrected for boiling) from January to May, projected to the end of the year. Data from the Norwegian Directorate of Fisheries.

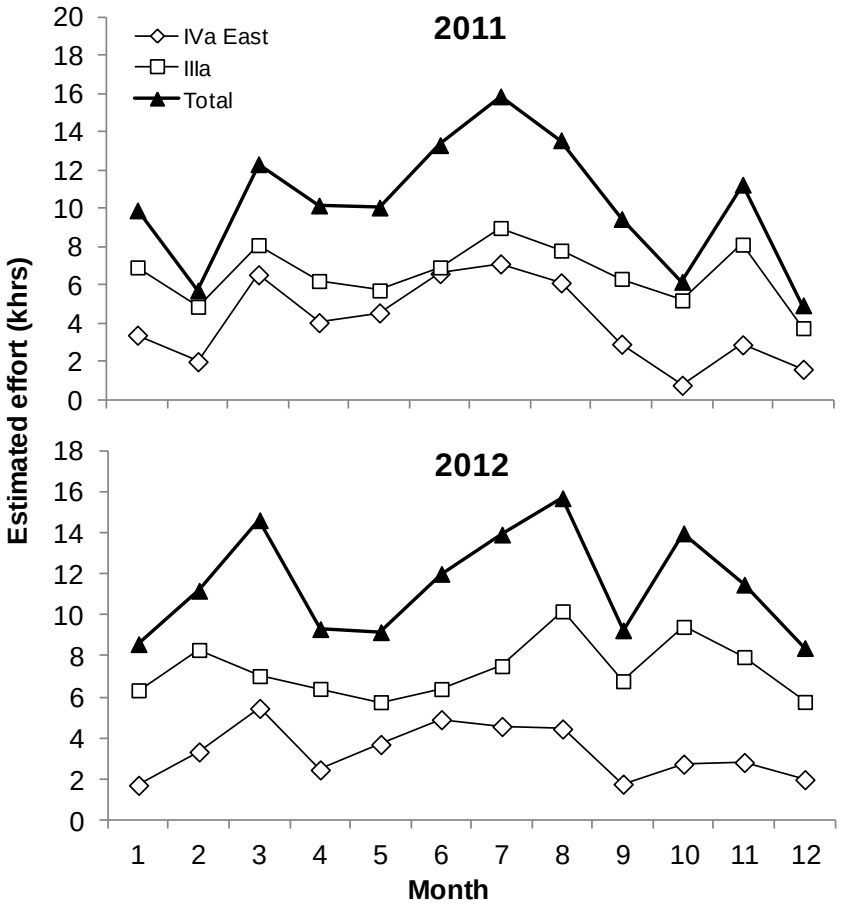

Fig. 14. Estimated monthly effort (trawling hours) in the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011 and 2012. Effort was estimated as official monthly landings (corrected for boiling) divided by monthly LPUE from logbooks (vessels ≥ 15 m). Data from the Norwegian Directorate of Fisheries.

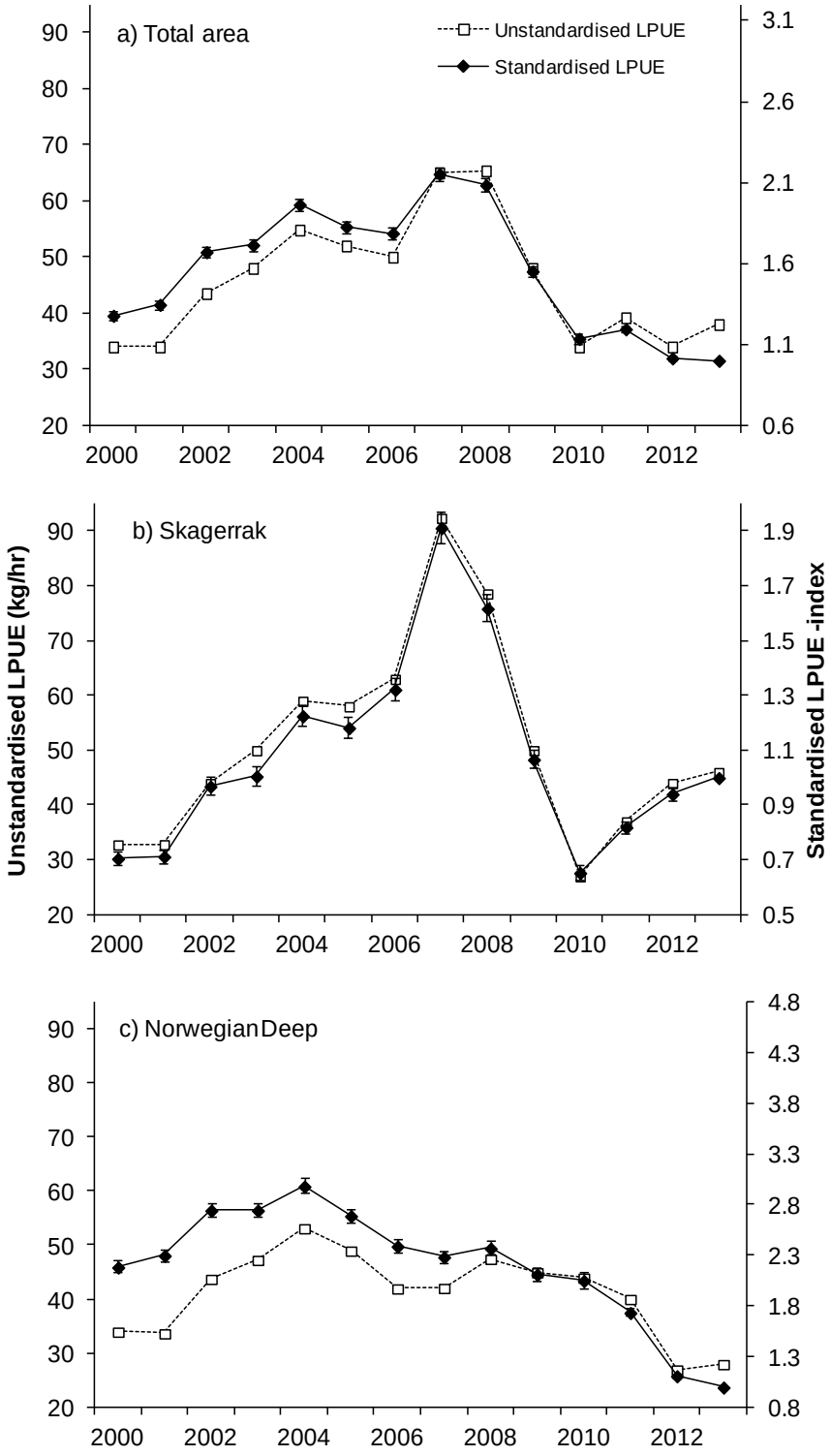

Fig. 15. Standardised LPUE-indices (with standard error), and unstandardised LPUE-indices (kg/hour) for 2000-2013 from the Norwegian shrimp (*Pandalus borealis*) fishery in a) both ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), b) Skagerrak, and c) the Norwegian Deep. Data from the Norwegian Directorate of Fisheries.

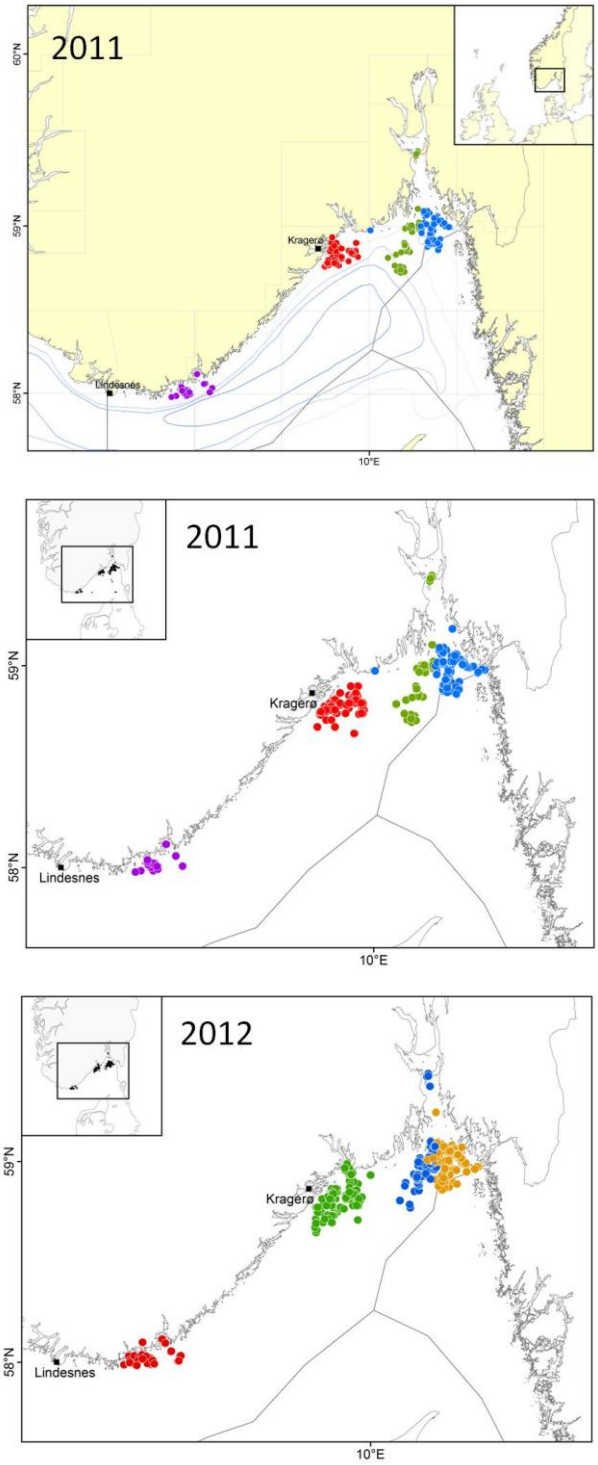

Fig. 16. Positions of all trawl hauls in the 2010-2012 logbooks from four small (10-12 m) shrimp trawlers fishing in ICES Div. IIIa (Skagerrak).

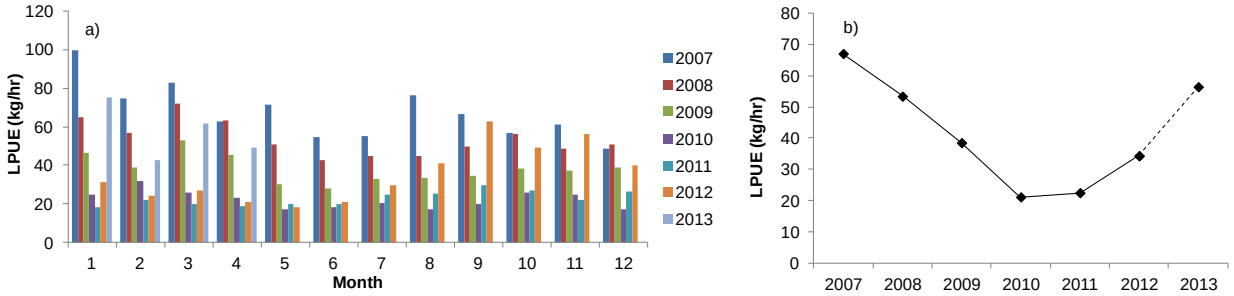

Fig. 17. Monthly a) and annual b) unstandardised LPUE indices from logbooks from four smaller (10-12 m) shrimp trawlers fishing in ICES Div. IIIa (Skagerrak), 2007-2013. The 2013 data are preliminary data from January-July.

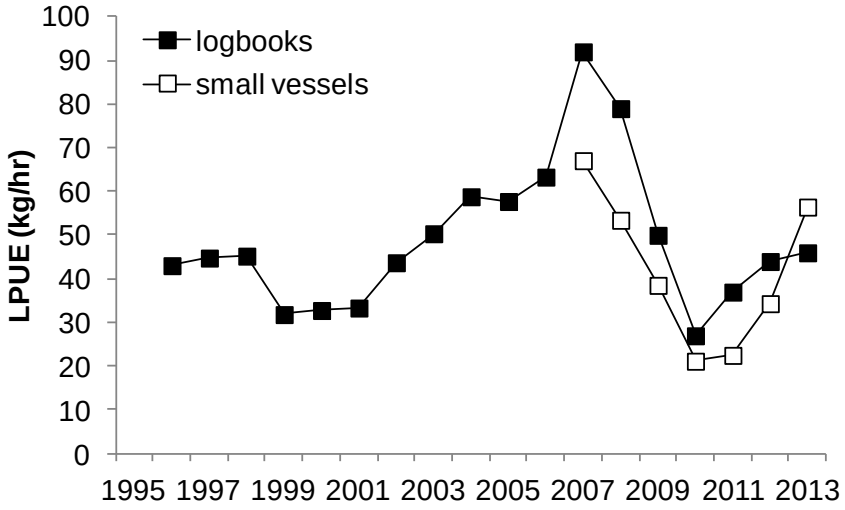

Fig. 18. Unstandardised LPUE indices (kg/hour) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Div. IIIa (Skagerrak) (1996-2013), and from four smaller (10-12 m) shrimp trawlers fishing along the Norwegian Skagerrak coast (2007-2013).

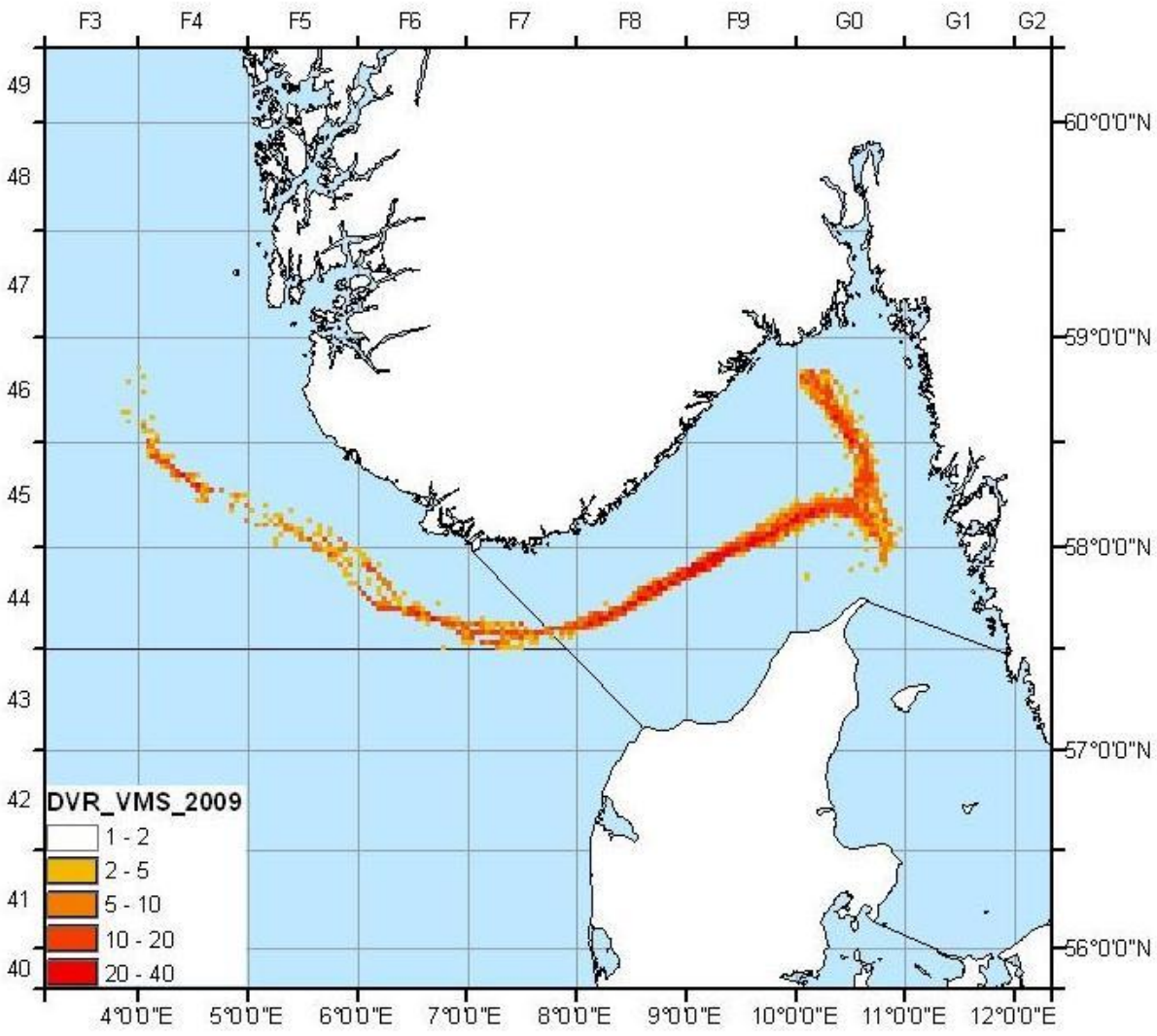

Fig. 19. Spatial distribution of the Danish fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2009, based on VMS data. Data from DTU-Aqua.

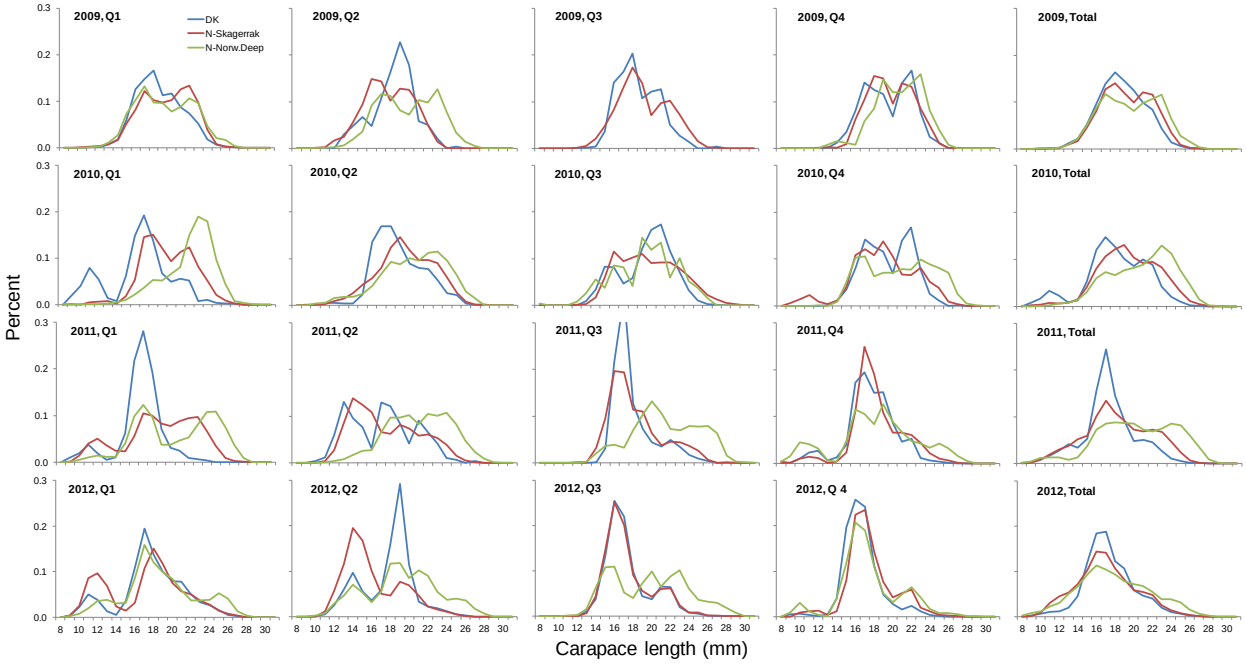

Fig. 20. Comparison of relative length frequency distributions in Danish shrimp (*Pandalus borealis*) catches (DK – blue line) from ICES Div. IIIa (Skagerrak) and Norwegian shrimp catches from Skagerrak (N-Skagerrak – red line) and the Norwegian Deep (ICES Div. IVa east) (N-Norw.Deep – green line) in 2009-2012, per quarter (Q1-Q4) and annually.

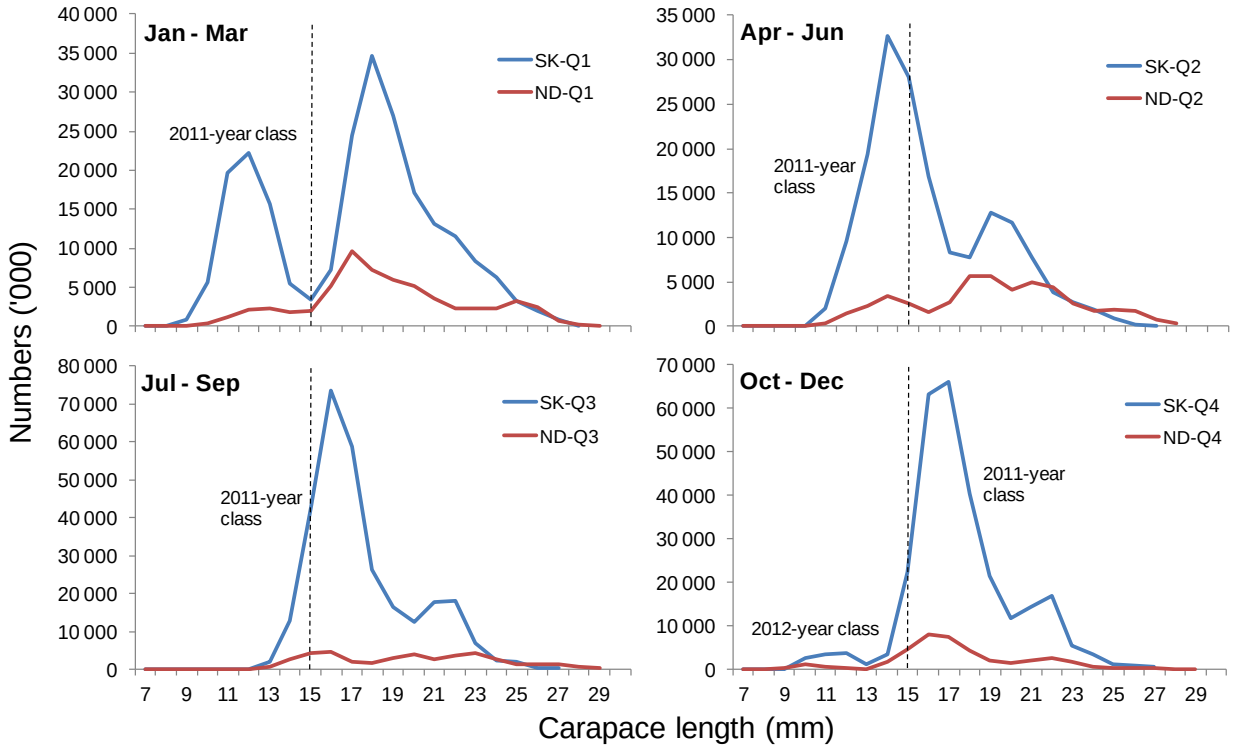

Fig. 21. Numbers per length in the 2012 catches from the Norwegian fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), per quarter and area. Note different scales on the y-axes. Samples sizes (Skagerrak and the Norwegian Deep): Q1: 3136, 1899; Q2: 2838, 1736; Q3: 2946, 956; Q4: 1977, 918. Dashed lines mark MLS of 15 mm CL.

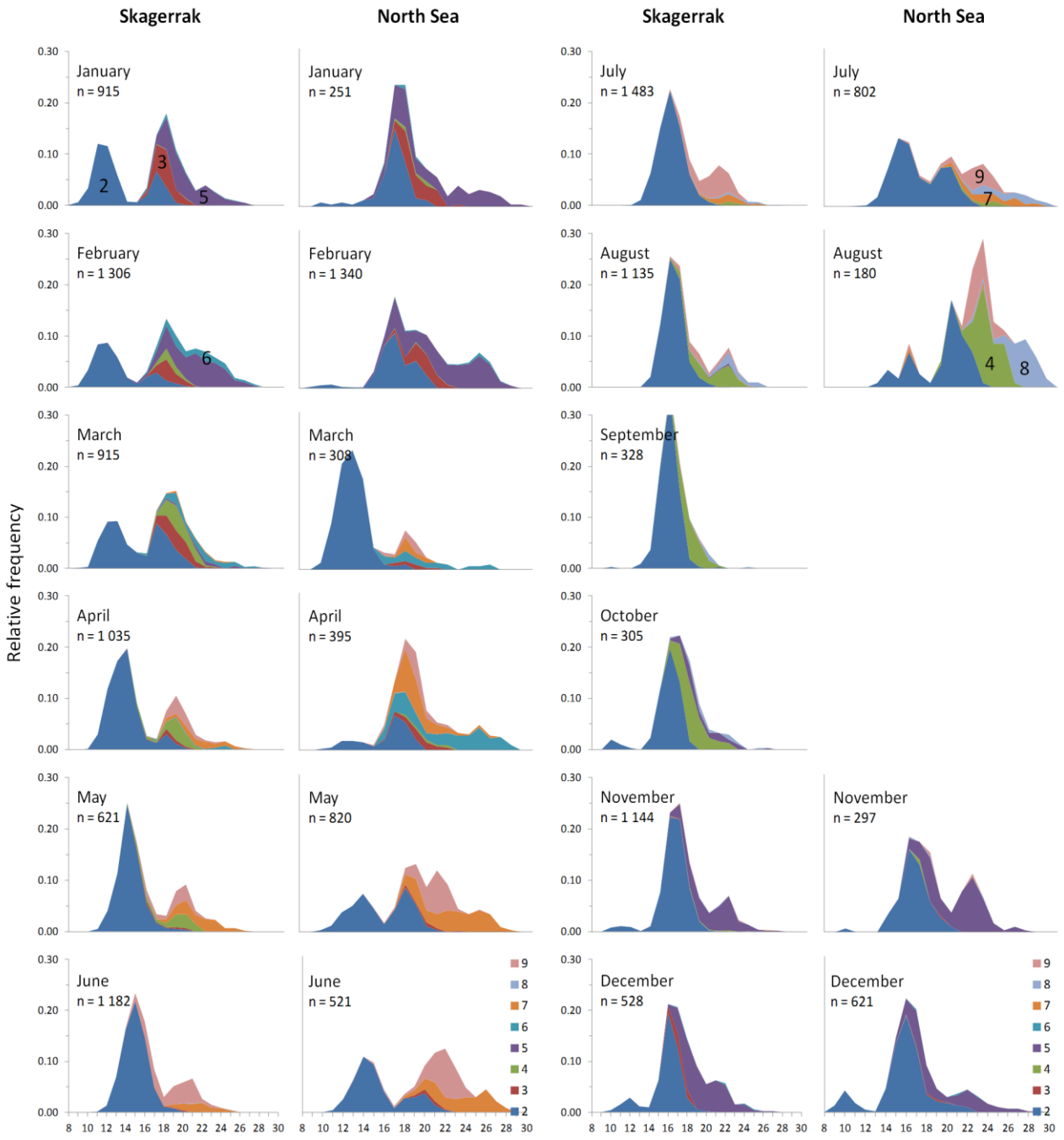

Fig. 22. Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2012 from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local fishermen and the Norwegian Coast Guard. Stages: 2 = males; 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.