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The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2011

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, Sweden, and UK exploit this resource. The Norwegian fishery is catch regulated by individual vessel quotas.

Information on the Norwegian shrimp fishery (fleet, gear, and prices) was updated. The recording of twin trawl use is incomplete in the logbooks. In order to correct the logbooks regarding the use of single and twin trawls, interviews have been made with ship owners identified from logbooks each year since 2007. Eighteen said they use twin trawl, either regularly or occasionally.

Norwegian landings increased from 6 000 t in 2000 to 9 000 t in 2004, but have since decreased. In 2009 4 308 t were landed. Correcting for boiling implies that 300-550 t should be added to the nominal landings for the years 2000-2010.

Landings per unit effort (LPUE) increased from 33 to 93 kg/hour from 2000 to2007, but have since dropped to 34 kg/hour in 2010. Standardised LPUE values calculated for 2000-2010 follow the same trend. The LPUE is decreasing in both Skagerrak and the Norwegian Deep, but the decline the last three years has been much steeper in the former area.

The 2010 catch composition was evaluated using samples from local shrimp fishers and the Norwegian Coast Guard.

Introduction

The resource of Northern shrimp (*Pandalus borealis*) (hereafter synonymous with shrimp) in Skagerrak and the North Sea is assessed as three separate stocks (Munch-Petersen *et al.* 2011a): 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, Sweden, and UK exploit this resource. The Norwegian vessels fish the Skagerrak-Norwegian Deep stock, with minor catches from Fladen Ground in former years (Munch-Petersen *et al.* 2011a).

Since 1992 Norway and EU have negotiated quotas on shrimp in the North Sea and Skagerrak. Norway has the largest quota (60% in 2010 and 2011) of the three Scandinavian countries. 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. 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. The vessels have a maximum quota of 40 t (tons) in the first period and 30 t in both of the other two periods, as well as a trip-quota of 6 t for each trip to sea.

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of 60º N. In 2010, a total of 227 vessels participated in the shrimp fishery south of 62º N (Table 1, Fig. 2), which is a reduction from 2009 when 240 vessels participated. The total number of vessels in the fishery has decreased since 2006. In 2010, 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. Small vessels dominate in the eastern Skagerrak, while the fleet in the west is more varied with a predominance of larger vessels. These changes can partly be explained by different condemnation arrangements in 1998-2005 to reduce the capacity of the fleet. However, in several instances fishers have condemned vessels ≥ 11 m followed by a reinvestment in new vessels just <11 m, often with larger capacity. Few new large vessels can be explained by the required fishery permits for vessels ≥11 m. However, vessels with permits can be substituted by larger ones, increasing the capacity of the fleet.

In 2010 about 90% of the shrimp landings were landed by vessels 10-27.99 m (Table 1). The yearly mean landings per vessel increased with length, but there are large variations. Most catches are landed in ports along the Norwegian coast, while some are landed in Sweden and Denmark. Subsequent processing takes place at two factories on the Skagerrak coast and one on the North Sea coast.

Norwegian logbooks from the shrimp fishery in Skagerrak and the Norwegian Deep are incomplete. In 2010 catches recorded in logbooks only made up 7.3 and 8.6 % of the corrected landings (see Materials and Methods) from respectively Divs. IIIa and IVa east. This is 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, logbooks for vessels ≥11 m are not complete either. For 2010 we have logbook data from only 14 vessels, while the landings statistics contain information from 114 vessels ≥11 m. We do not know why fewer and fewer vessels have been sending in logbooks. However, the data situation improved greatly in 2011, with the introduction of electronic logbooks. All vessels larger than 15 m are required to fill in the new logbooks. These data have not been analysed for this year's working group meeting.

Twin shrimp trawls are common on larger vessels and, according to fisheries organizations, have been used the last nine years. At present twin trawls are used by 40-50 vessels. The use of twin trawl is, however, 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 vessels in 2010 have recorded the use of twin trawl on a regular basis. Other vessels have sporadic records of twin trawls (1-8 per year). This situation is due to the logbooks containing data from few vessels, as well as incorrect recordings. Incorrect recordings are probably due to the wording of the logbooks, where fishers are asked to note the gear type used as [... shrimp trawl, twin trawl, triple trawl ...]. It seems likely that many fishers will note "shrimp trawl" for any type of shrimp trawl used, be it single or twin. Errors may also be produced since the

logbook data provided by FiskDir are given per day, not per haul. Thus, catches from all hauls within one day are summed, and gear will be the gear most frequently used that day. Triple shrimp trawls are allowed in Skagerrak. According to the (non-representative) logbooks this gear type is hardly 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 the catch may nevertheless not contain more than 10% (by weight) cod and haddock combined. Furthermore, bycatch of >10% angler fish or >2.5% cod are not allowed. In Skagerrak there is a limitation that up to 50% of the catch by weight may consist of other market species. It is allowed to have up to 10% undersized shrimp (<6 cm total length = 15 mm carapace length (CL)) 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. Inclined grids for sorting out bycatch are not compulsory south of 62º N, but according to a local fisherman most fishers use these grids. The grids are used in combination with a collection bag with mesh size of 120 mm or more in order to separate the shrimp catch and the valuable bycatch. All vessels with a shrimp permit may also trawl for *Nephrops*. Some larger vessels fish mackerel and herring in addition to shrimp and half of these also conduct industrial fishery (sandeel, blue whiting, Norway pout).

Two categories of shrimp dominate the market: in 2010, 69 % of the total landings were delivered as boiled, fresh large shrimp (140-150 individuals per kg) for the Norwegian and Swedish market, and 31 % of the total as raw (smaller) shrimp for factory processing ashore (mostly 180-250 individuals per kg). The corresponding numbers for 2005 through 2009 were respectively 41, 45, 60, 47 and 55 % boiled and 59, 55, 40, 53 and 45 % raw. The high percentage of boiled landings reflects the stock situation with small younger year classes. 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 two years, the kilo prize for boiled shrimp increased to a mean of 63 NOK in 2009, and further to 72 NOK in 2010. Raw shrimp still costs approx. 10-11 NOK/kg.

The present paper 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 2011 landings were given for August inclusive. The logbook data from 2011 were not analysed due to time constraints (new format).

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 provides landings per statistical location (equivalent to standard “ICES squares”: 0.5º lat. by 1º long). These data are not precise and 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, while landings from the southern part do not and are most likely bycatch. In this document, landings from Div. IVb are therefore not included in numbers for Divs. IIIa or IVa east, only in figures for Subarea IV. LPUE and effort are calculated only for 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 has provided us with landing statistics for the years 2000-2010, where these can be separated. To obtain fresh weight, the fraction of the landings consisting of boiled shrimp, must be corrected using a conversion factor of 1.13.

Fleet composition was derived from the landings statistics. Logbook data were analysed to show the spatial and temporal distribution of the fishery. Landings per statistical location (2009-2010) 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. We decided to

use the combined LPUE from both single and twin trawl to estimate total effort as the nominal landings, which are divided by LPUE to estimate effort, derived from the use of both types of trawl. LPUE-indices were corrected (see below).

In order to include gear use in the calculation of standardised LPUE-indices, logbook data were corrected regarding the incorrect recording of single and twin trawl. 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)
2) 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).
3) All recordings from 11 vessels, for which we could not get secure information on gear use, were deleted (7.9 % of all recordings).
4) 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) (9.4 % of all recordings). Two additional vessel owners informed that they used both gears, but recorded twin trawl when using this gear, thus these data were kept.
5) 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).

Data from the corrected logbooks were used in multiplicative models in order to calculate standardised LPUE indices (2000-2010), 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,σ^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 2000-2010 was derived by dividing the nominal landings by the standardised LPUE indices.

Because of the poor coverage of the Norwegian logbooks, especially for smaller vessels, four fishermen fill out simplified log book forms from all their fishing trips and send these to us. The length of the vessels ranges from 10.55 to 12.21 m. Recording started in 2007.

Until 2001 discards were estimated by assuming that all shrimp <15 mm CL were discarded. Length distributions of unprocessed catches from research surveys in March, June and October/November were used, whilst assuming that the amount of the 0-group/1-group was the same in the research trawl and the commercial trawl. For 2002-2006 discards have been 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 2009 discards were 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 yearly 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, sampling improved, and discards were estimated for both Skagerrak and the Norwegian Deep. Danish discards from Skagerrak have been estimated for 2009 and 2010 based on onboard sampling. Norwegian discards from Skagerrak in 2010 were therefore also estimated applying the Danish discards-to-landings proportion to Norwegian landings.

Samples (approx. 1.5 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2010 catches were obtained from five Norwegian shrimp fishers (35 samples) (Fig. 3). An additional six samples were provided by the Coast Guard after inspection of Norwegian, Danish, and Swedish shrimp trawlers. The samples were taken from the trawl, frozen, and later 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. 4a, Table 2). In the following years landings fluctuated around 7 500 t with a maximum in 1998 of 9 611 t. From 2000 to 2004 overall landings increased continuously from about 6 000 t to 9 000 t, but have decreased since. From 2009 to 2010 the total landings decreased by 27 %, to 4 308 t, the lowest figure since 1979. Correcting for boiling implies that 300-550 t should be added to the nominal landings for the years 2000-2010 (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 in the Norwegian Deep.

In Skagerrak, the Norwegian 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. From 2007 to 2010 the Skagerrak landings have decreased by 56 %. The 2010 nominal landings of 2 598 t are the lowest since 1979. In the Norwegian Deep 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. 4a, Table 2). The 2010 nominal landings of 1 688 t remain at the 2009 level. Landings from January-August for 2005-2010 show that the decreasing trend in the landings is discontinued in 2011 (landings January-August for 2005-2010: Skagerrak: 2 914, 3 393, 4 030, 4083, 2 879, 1 791, 1 853 t; Norwegian Deep: 3 416, 2 443, 1 804, 1705, 1 352, 1 290, 1 569 t) (Fig. 5).

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. 5). Lower landings during winter are probably due to weather conditions.

During the ten last years the Norwegian quota has only been overfished twice (1997 and 2004). Because of the arrangement of evenly allocating the quota to three periods in order to supply the market throughout the year, and because of frequent 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: 4 697 t from a quota of 8 767 t (Table 2). The Norwegian quota for 2011 is reduced by 15 % from the 2010 level (3 882 t in IIIa and 3 570 t in Subarea IV).

Use of single and twin trawl

There is a clear difference in catch efficiency between single and twin shrimp trawls (Fig. 6), which shows why it is important to distinguish between the two gear types. In 2007 we started to interview ship owners about their use of single and/or twin trawl. The logbooks for 2004-2010 contain data on 59 vessels. We have managed to get in touch with the owners of 48 of these, and 18 said they use twin trawl, either regularly or occasionally. In the years between 2002 and 2010 six vessels have used or are using twin trawl seasonally or occasionally, while twelve vessels have used or are using twin trawl all the time. The use of twin trawl is not correlated with vessel size (Fig. 7).

Effort

According to the logbooks, fishing effort was in 2010 more or less evenly allocated to the whole Norwegian Skagerrak and North Sea coast north to 59° 30' N (Fig. 8). However, as effort recorded in the logbooks only makes up a minor portion of the actual effort, the logbooks do not provide the whole picture. Landings per statistical location (provided since 2009) seem to confirm the pattern given by the effort data, but show that shrimp fishing also takes place along the western and southern fringes of the Norwegian Deep, in the northern part of Div. IVa east, as well as in the fjords (Fig. 9). There seems to be no shift in the spatial distribution of the fishery from 2009 to 2010 (Fig. 9).

The estimated number of fishing hours in 2010 was more than twice as high in Div. IIIa compared with Div. IVa east (109 vs. 42 Khours) (Table 2). The estimated effort in the Norwegian Deep decreased from 2005 to 2009. In 2010 the effort (42 Khrs) was similar to that in 2009. In Skagerrak the estimated effort has increased since 2007, possibly due to the low catch rate.

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, and then declined to 127-128 Khours in 2008-2009 (all time low). This was due to a reduction of effort in Div. IVa east (Table 2, Fig. 4c). In 2010 total yearly effort has increased due to increased effort in Div. IIIa. Standardised effort indices (Table 3) show the same trend as the unstandardised figures.

The fishery in 2010 took place in all months (Figs. 5, 10). In Div. IIIa effort seems to be increasing towards the end of the year. Logbook data are lacking for Div. IVa east for October and December.

Standardised landings per unit effort (LPUE)

Overall LPUE increased from 34 kg/hour in 2000 to 55 kg/hour in 2004 (Fig. 4b, Table 2), dropped in 2005, increased in 2007, and decreased again in 2009 (50 kg/hour) and further in 2010 (34 kh/hour). The LPUE-values in Skagerrak and the Norwegian Deep followed each other closely for the years 1999-2004. However, in 2005-2007 the development of LPUE in the two areas differed strongly. In 2005 the LPUE dropped in the Norwegian Deep, while it remained at the same level in Skagerrak. In 2006 the decrease continued in the Norwegian Deep, while the LPUE in Skagerrak increased. In 2007 the LPUE remained at the 2006-level in Div. IVa east, while it increased to an all time high in Div. IIIa. The picture was opposite in 2008, with a slight increase in the Norwegian Deep and a decrease in Skagerrak. In 2009 and 2010 the LPUE decreased further in Skagerrak, while it remained at the same level in the Norwegian Deep. In 2010 the Skagerrak LPUE is, for the first time in the time series, lower than the Norwegian Deep LPUE.

Standardised LPUE values have been calculated for 2000-2010 (Table 3, Fig. 11). These indices follow the same trend as the unstandardised figures, except for the last four years in the Norwegian Deep. Here, the standardised values decrease while the unstandardised values remain at the same level. The fleet structure and fishery pattern have probably been stable during this relatively short time period (2000-2010), which explains the little difference between standardised and unstandardised values. The 2010 LPUE-index decreases in both Skagerrak and the Norwegian Deep.

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. However, when comparing with results from the Norwegian shrimp survey (Søvik and Thangstad 2011), it can be seen that the decrease in the survey biomass index in 2008-2010 is reflected in the decrease in the overall standardised LPUE (Fig. 11).

The LPUE-data from the small trawlers in Skagerrak cover mainly the eastern part of Div. IIIa (Fig. 12). The monthly catch rates decreased from 2007 to 2010 (Fig. 13a), and decreased further in 2011 for January to April. However, in May to July the catch rate increased slightly from 2010 to 2011. The annual catch rate similarly levelled out in 2011 after having decreased from 2007 to 2010 (Fig. 13b). The LPUE-index from the small shrimp trawlers supports the pattern in the survey biomass index (Søvik and Thangstad 2011) and the standardised LPUE-index from Skagerrak.

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.* 2011b), 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 2 and 16 % of the catches, i.e., from 200 to 1000 t annually (Table 2).

The estimated discards from the Norwegian fishery in Skagerrak in 2008 of 1 408 t (Table 2) was probably much too high. The assumption of the Norwegian and Danish fleet fishing on the same fishing grounds may possibly not have been valid.

In 2010 discards from Skagerrak was estimated to 95 t based on comparisons of length frequency distributions (Fig. 14). Discards consist of shrimp smaller than 13 mm CL, as well as some larger shrimp, which may be damaged, poor quality shrimps (Munch-Petersen *et al.* 2011b). Using the Danish numbers, annual discards from Skagerrak in 2010 were estimated to 63 t. The estimated 2010 discards from the Norwegian Deep were negative (-39 t), due to the length frequency distribution of samples of sorted landings having a larger peak for 2-year old shrimp compared with the length frequency distribution of samples of unprocessed catches. This could be due to samples coming from different locations.

Although high-grading cannot be ruled out, the Norwegian discards are probably mainly made up of non-marketable shrimp. Assuming that only shrimp < 15 mm CL are discarded yields discards of 9 and 12 t from respectively Skagerrak and the Norwegian Deep. Estimations based on the Danish numbers are considered most reliable and the Norwegian discards from 2010 are therefore set to 63 t. Norwegian discards per quarter and area are given in Munch-Petersen *et al.* 2011b.

Catch composition

The length frequency distributions from Divs. IIIa and IVa east for 2010 show that the catches mostly consisted of shrimps from two age groups, the 2-group and the 3-group (Fig. 16, Table 4), indicating that recruitment of 1-year old shrimps was low in 2010 in both areas. In 2005-2008 there was a clear difference in recruitment between the two divisions (Figs. 17, 18), high in Div. IIIa and low in Div. IVa east. The low recruitment in recent years is also shown by the Norwegian shrimp survey in January-February (Søvik and Thangstad 2011).

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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 2010: Number of vessels and total (uncorrected) landings (t) per length group; and total landings per vessel in each length group (mean, median, and standard deviation).

Length group	Number of vessels	Landings (t)	Landings per vessel (t)		
			Mean	Median	St.dev
< 10 m	22	27	2.5	1.0	4.4
10-11.99 m	89	482	5.9	3.3	6.5
12-14.99 m	64	978	15.8	10.4	14.6
15-20.99 m	24	847	40.3	32.8	38.6
21-27.99 m	20	1 583	83.3	84.4	41.0
> 28 m	6	390	65.1	68.8	45.5
not given	2				
Total	227	4 308			

Table 2. Norwegian nominal shrimp (*Pandalus borealis*) landings from ICES Div. IIIa and Subarea IV; separate landings from Divs. IIIa and IVa east; increase in landings due to correction for boiling; Total Allowable Catch (TAC); estimated discards for IIIa and IV; landings per unit effort (LPUE) and estimated number of trawling hours (effort) of the Norwegian shrimp fishery in Divs. IIIa and IVa east 1970-2010. All landings back to 1977 were checked and corrected against original files in 2011.

	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	82	192
2001	2959	3933	6914	374	8140	565	33	34	34	93	126	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	92	173
2006	5177	3037	8214	455	8961	*599	63	42	50	85	76	173
2007	5928	2307	8235	450	9331	526	93	42	65	68	58	134
2008	5744	2039	7783	478	9731	1408	79	47	65	72	46	127
2009	4268	1668	5940	428	9731	115	52	46	50	87	40	128
2010	2598	1688	4308	389	8767	63	26	45	34	109	42	137
2011					7452							

Data from the Norwegian Directorate of Fisheries.
Estimated effort 2000-2010 is based on landings corrected for boiling.
"Total" refers to the sum of Divs. IIIa and IVa east, except for "total landings" and discards, which refer to Div. IIIa and all of Subarea IV.
*Based on mean discard percentage 1985-2001.
Discards for 2007-2009 are estimated only for Skagerrak.
Discards for 2010 are estimated for both Skagerrak and the Norwegian Deep

Table 3. Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, 2000-2010.

	Stand. LPUE (index)	Stand.effort (index)
2000	1.20	1.14
2001	1.26	1.23
2002	1.56	1.05
2003	1.60	1.09
2004	1.82	1.11
2005	1.70	1.12
2006	1.68	1.10
2007	2.02	0.91
2008	1.94	0.91
2009	1.46	0.93
2010	1.00	1.00

Table 4. Mean carapace length (with SD), and numbers (millions) in each age class in the 2010 catches, per area. Some 1-groups (-) could not be properly identified in the length distributions.

		Total			Skagerrak			Norwegian Deep		
Quarter	Age	Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
1	1	12.67	1.17	37	12.17	1.2	29	-	-	-
	2	18.06	1.49	941	18.34	1.59	815	18.64	1.99	240
	3+	22.78	1.58	1227	21.81	1.78	606	23.32	1.43	643
2	1	13.49	1.62	189	12.91	1.03	72	13.24	1.35	67
	2	18.9	2.09	1989	18.9	2.45	1656	18.43	1.84	409
	3+	23.43	1.54	877	23.42	1.12	358	22.91	2.02	519
3	1	16.46	1.48	608	16.31	1.19	451	15.91	1.79	98
	2	20.28	1.42	619	19.34	1.26	431	19.77	1.7	162
	3+	23.8	1.83	405	22.93	1.91	496	24.15	1.23	39
4	0	10.76	1.28	79	10.58	1.09	74	-	-	-
	1	17.78	1.63	1326	16.94	1.36	576	16.66	1.16	391
	2/2+	22.75	1.92	1083	19.93	0.95	384	21.4	2.66	591
	3+				23.2	1.35	346	25.56	0.91	152

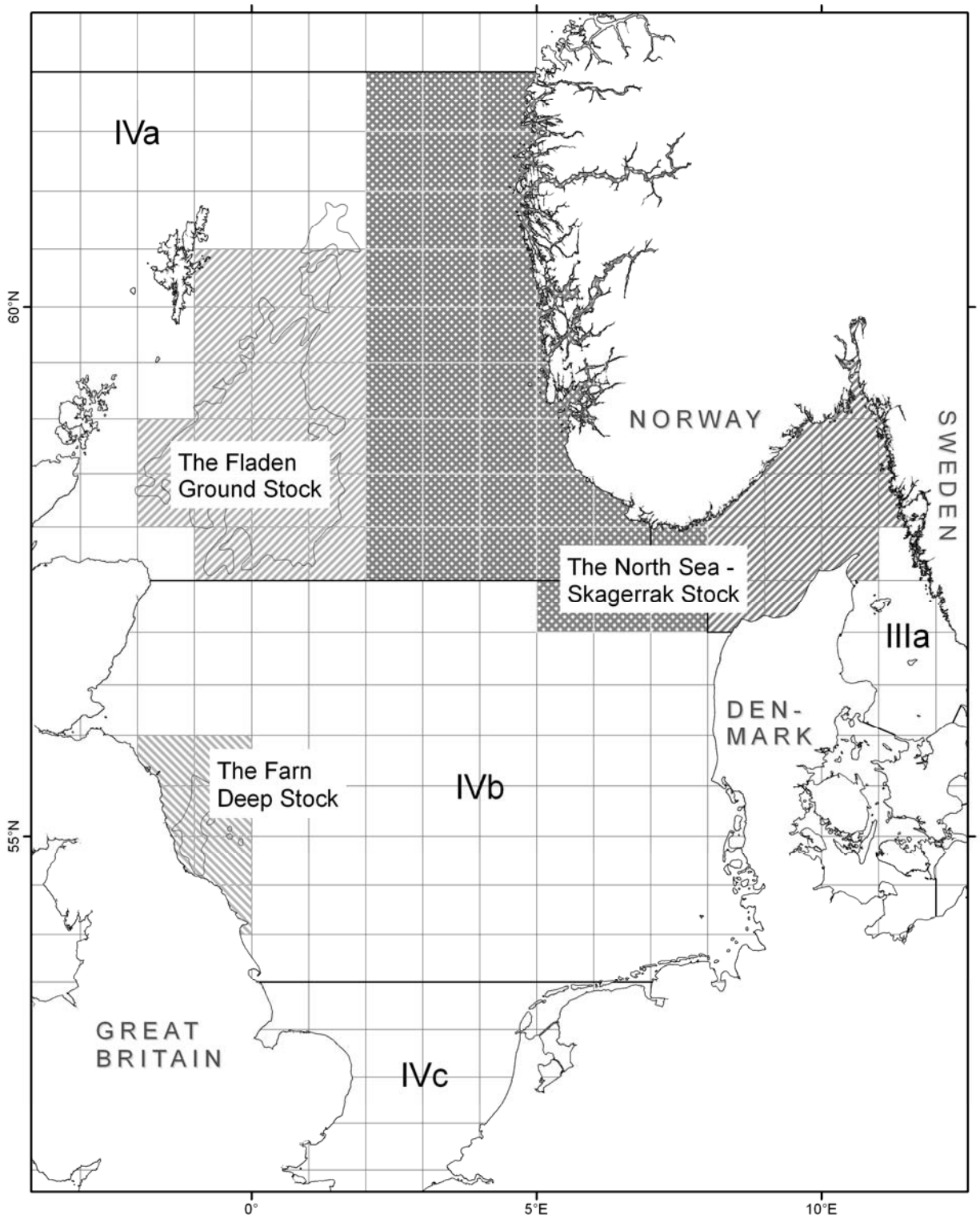

Fig. 1. Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the defined assessment units. Grid is standard "ICES squares": 0.5º lat. by 1º long. (based on Munch-Petersen *et al.* 2011).

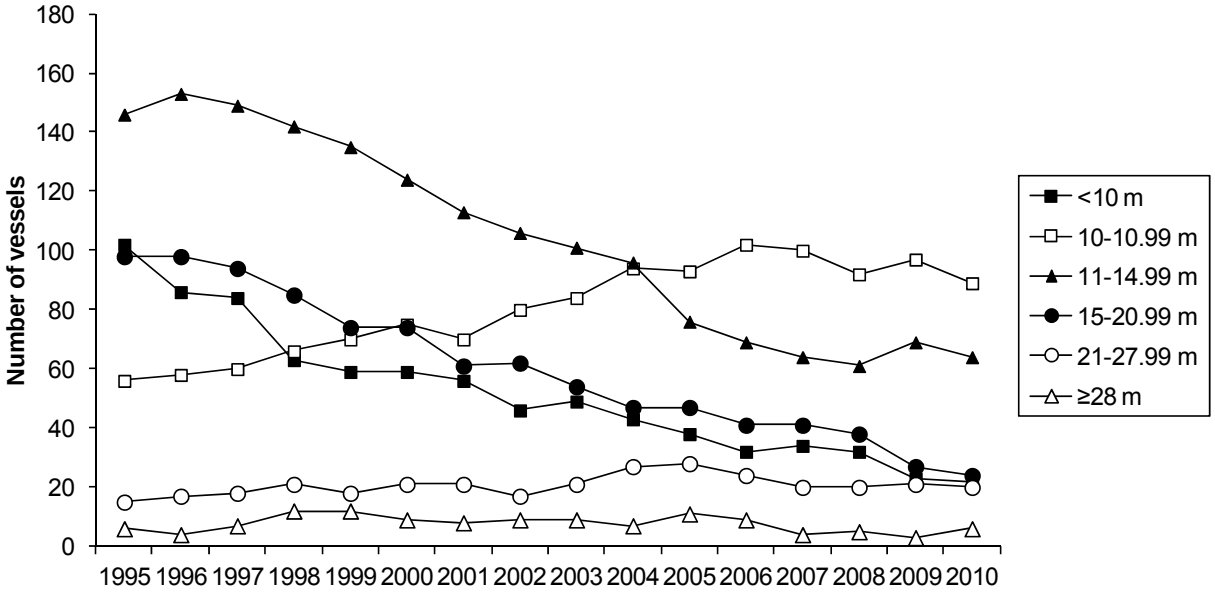

Fig. 2. The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) 1995-2010: number of vessels per length group (m). Data from the Norwegian Directorate of Fisheries.

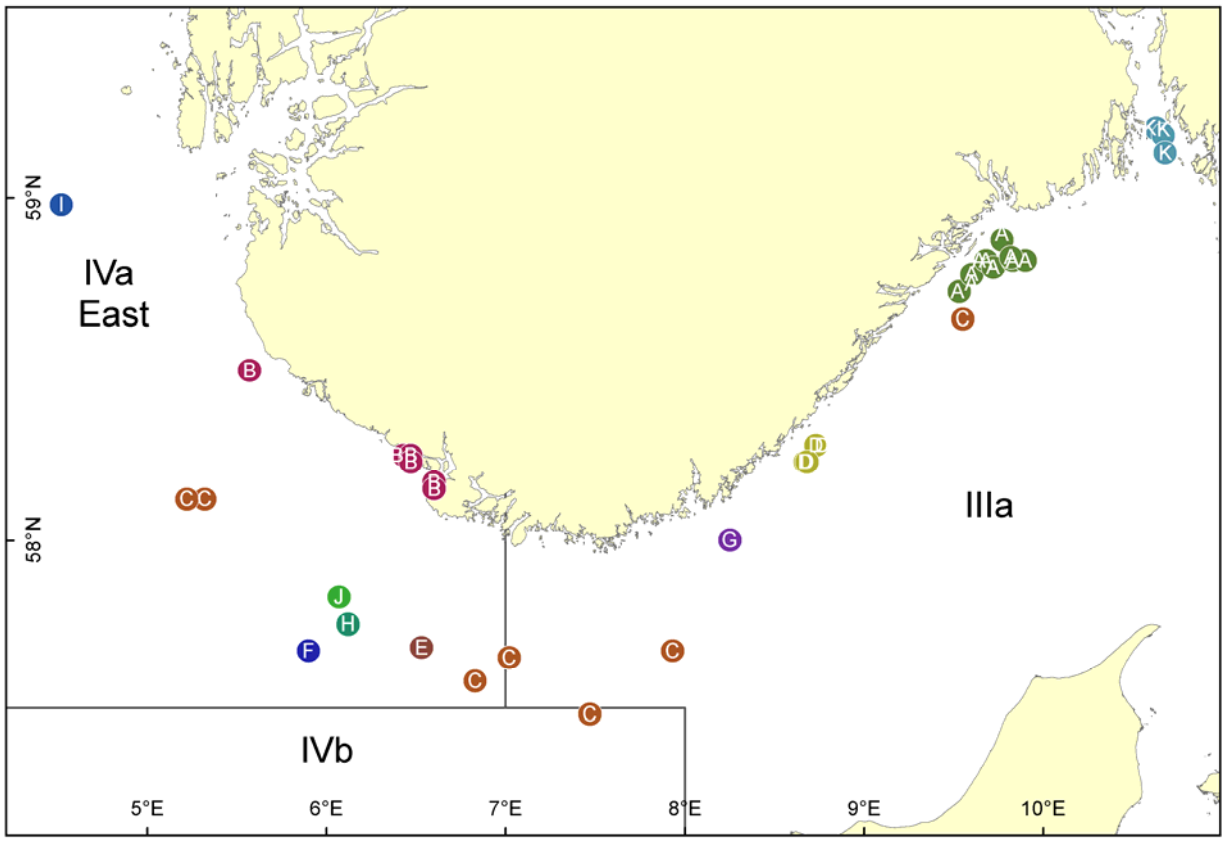

Fig. 3. Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2010 in Skagerrak and the North Sea (ICES Div. IIIa and Subarea IV). Samples were collected by local Norwegian fishermen and the Norwegian Coast Guard. The letters denote different vessels.

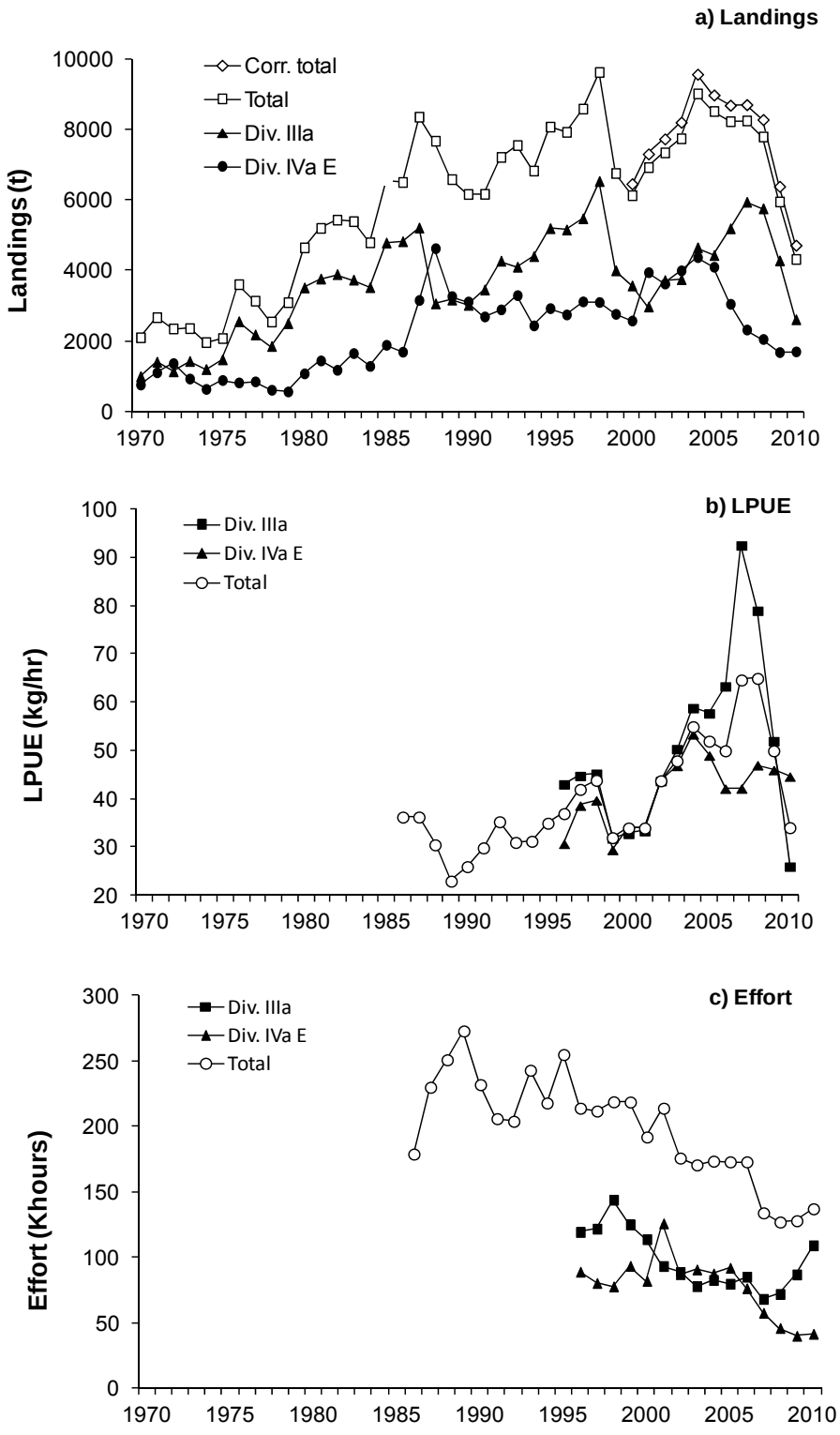

Fig. 4. Landings a) estimated total effort b), and landings per unit effort (LPUE) c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east for all years for which data are available. In a) "total" includes Div. IIIa and all of Subarea IV, and "Corr. total" are total landings corrected due to boiling.

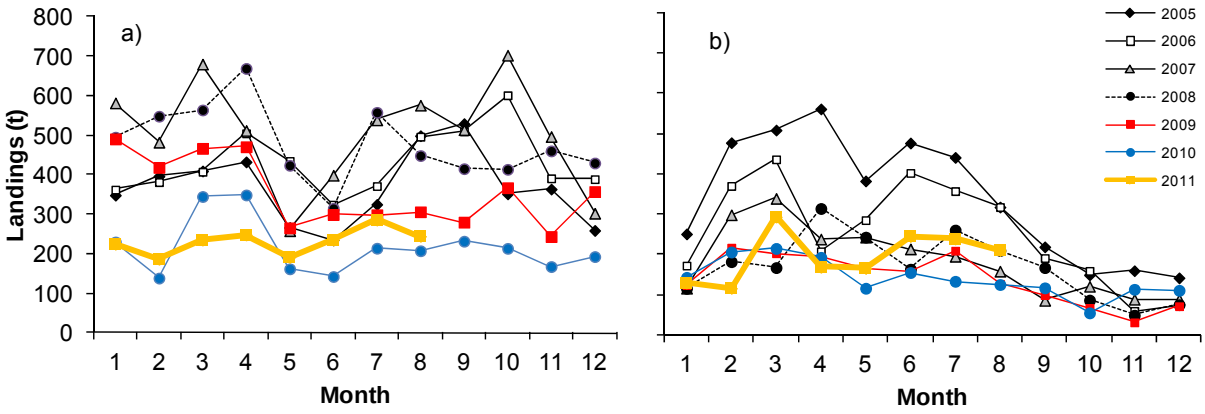

Fig. 5. Monthly (uncorrected) landings of shrimp (*Pandalus borealis*) 2005- 2011 for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries. 2011 data are preliminary.

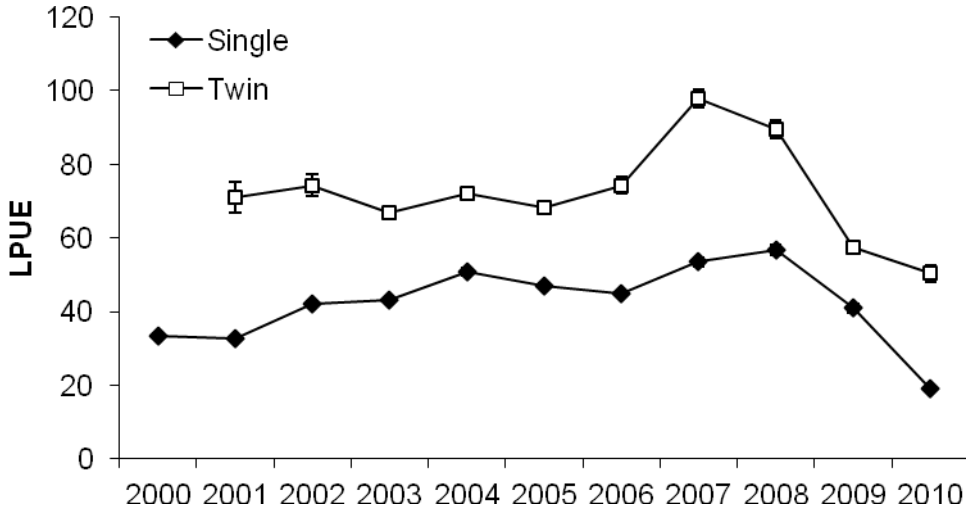

Fig. 6. Unstandardised mean LPUE (with standard error) per gear type and year from Norwegian logbooks (Divs. IIIa and IVa east).

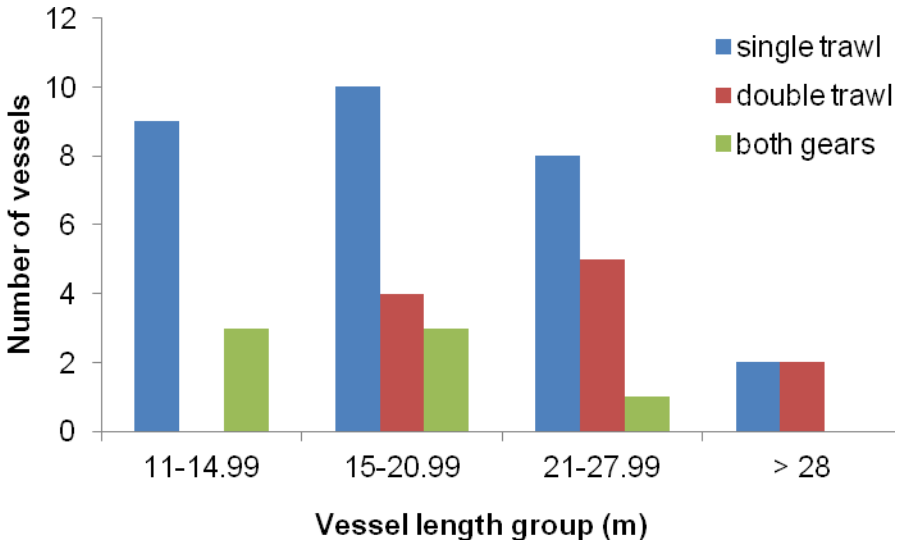

Fig. 7. Gear use by vessel length group. Data from interviews with owners of vessels in log books from the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2010. Vessels <11 m are left out since these are not required to send in log books.

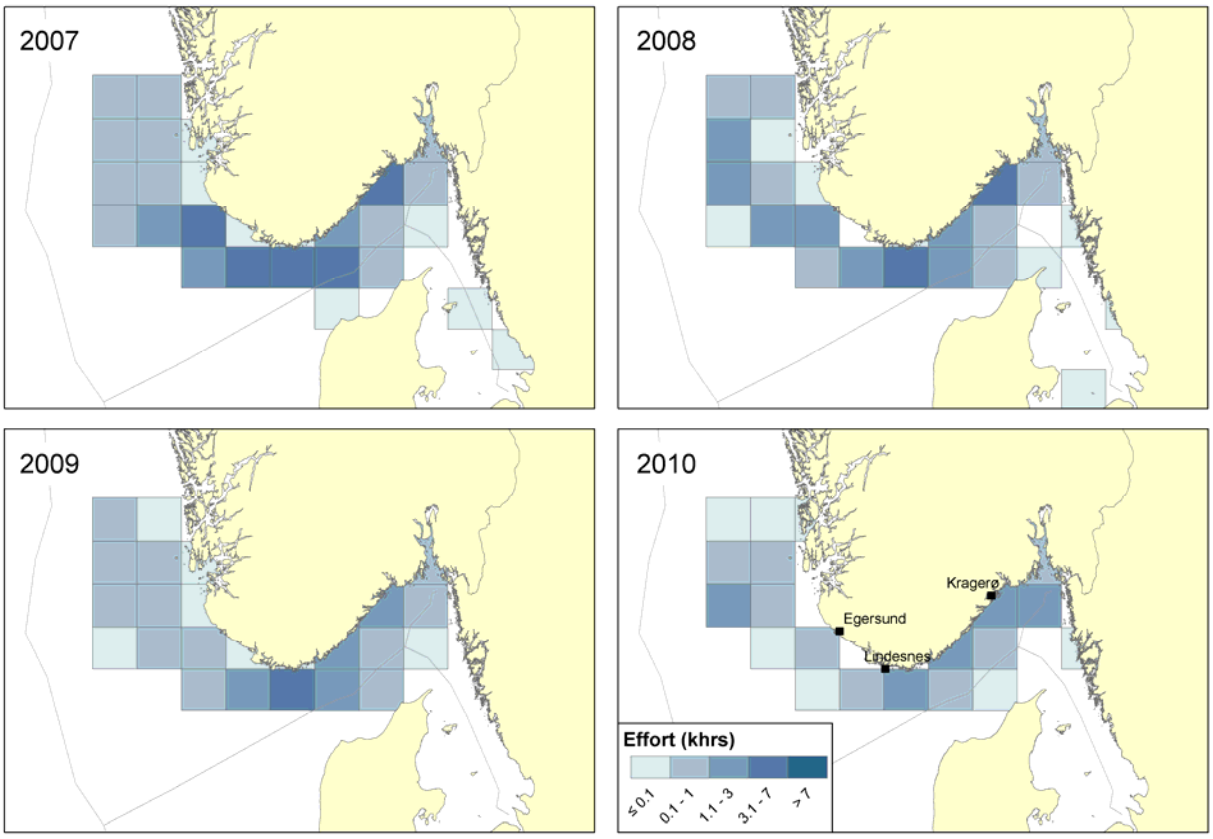

Fig. 8. Geographical distribution of recorded effort (trawling hours) by Norwegian shrimp trawls 2007-2010 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard "ICES squares": 0.5º lat. by 1º long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.

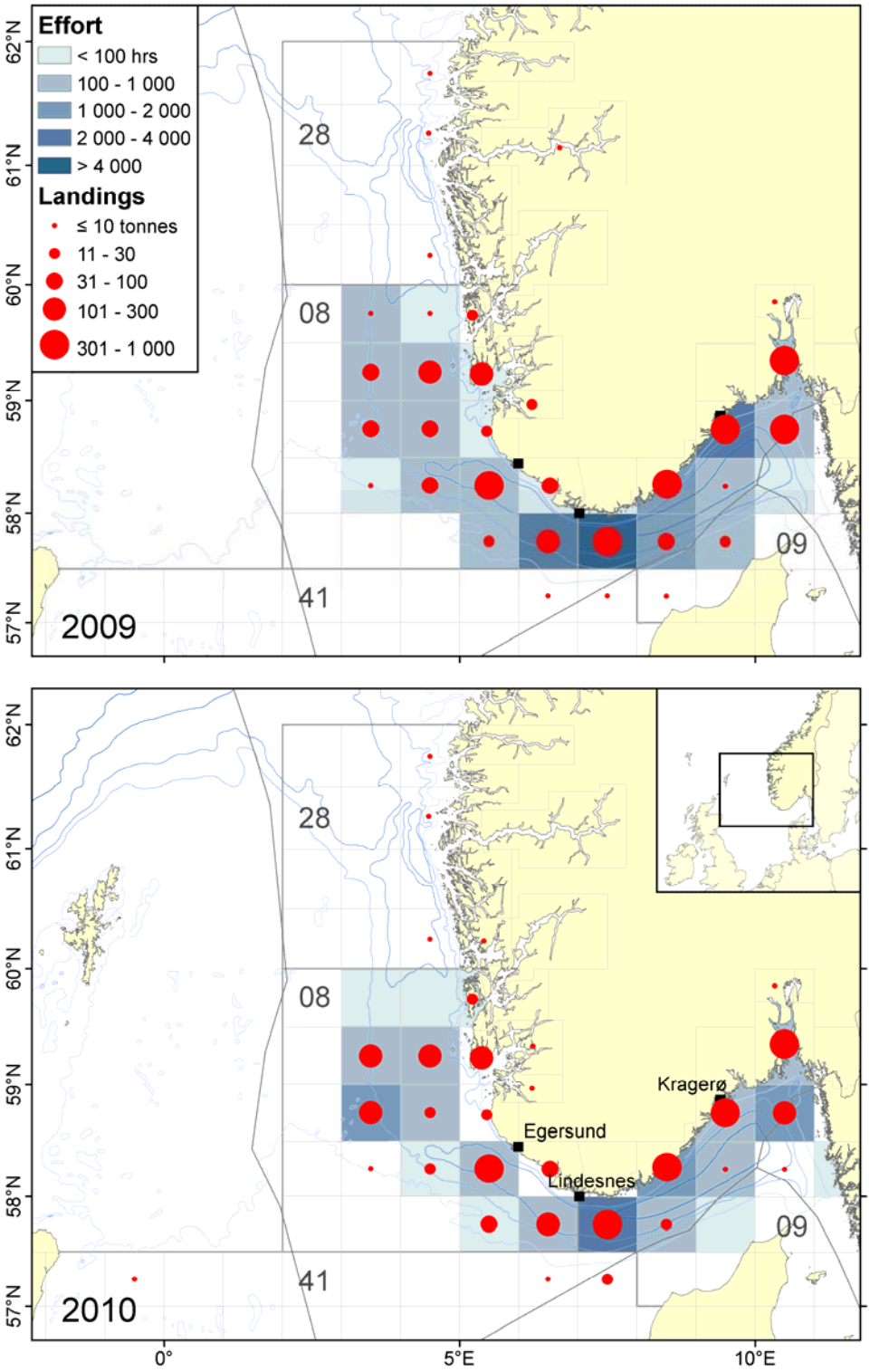

Fig. 9. Geographical distribution of landings (t) and recorded effort (trawling hours) by Norwegian shrimp trawls in 2009 and 2010 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard "ICES squares": 0.5º lat. by 1º long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.

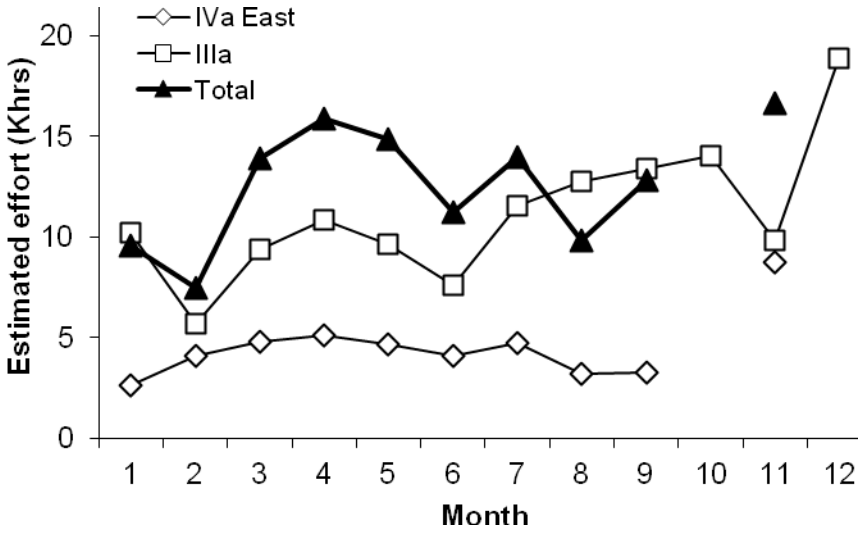

Fig. 10. Estimated total effort (trawling hours) by Norwegian shrimp trawlers in 2010 per month and area, Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east). Effort was estimated as official landings (corrected for boiling) divided by LPUE from logbooks. No logbook data from Div. IVa East from October and December.

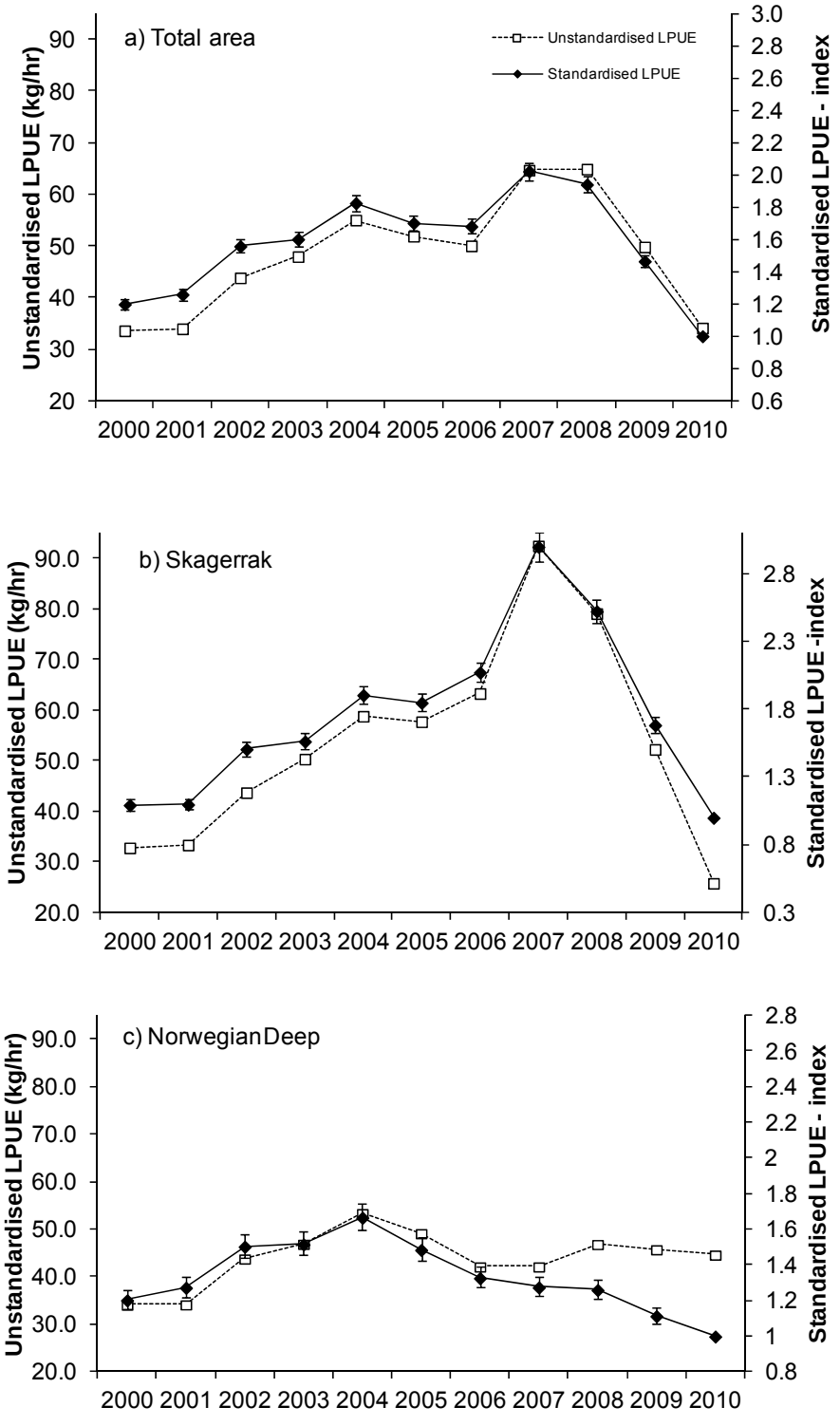

Fig. 11. Standardised LPUE-indices (with standard error), and unstandardised LPUE-values (kg/hour) for 2000-2010 from the Norwegian shrimp (*Pandalus borealis*) fishery in a) both Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), b) Skagerrak, and c) the Norwegian Deep.

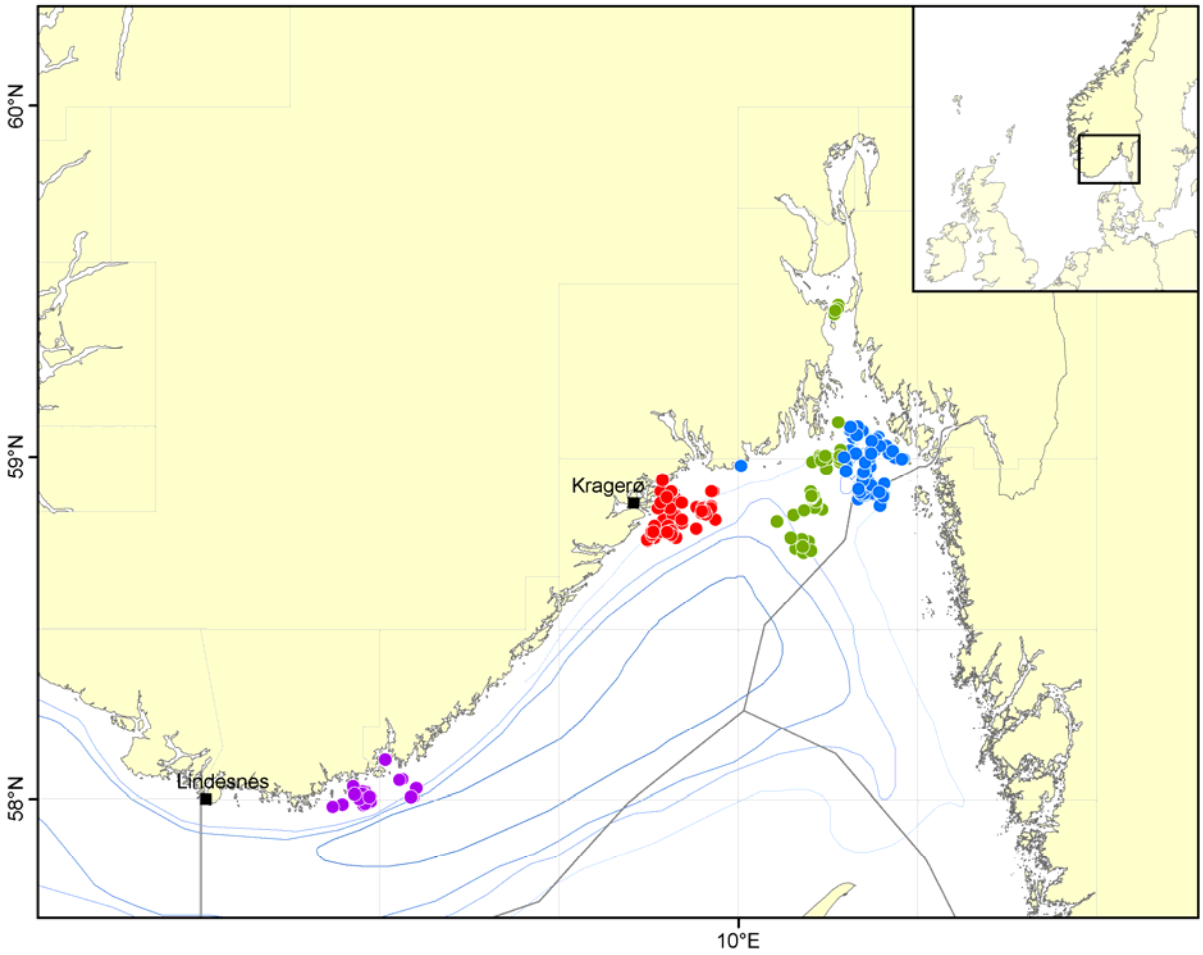

Fig. 12. Positions of all trawl hauls in the logbooks provided by four smaller (10-12 m) shrimp trawlers fishing in Skagerrak (ICES Div. IIIa).

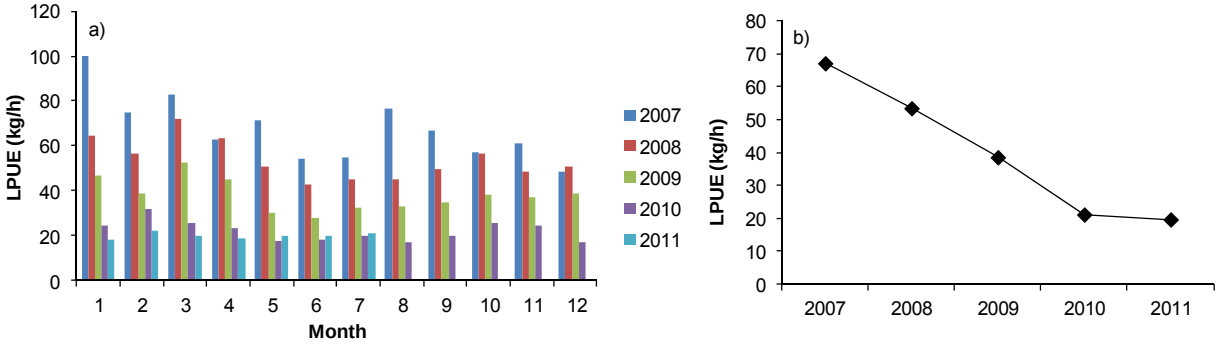

Fig. 13. Landings per unit effort calculated from logbook information from four smaller (10-12 m) shrimp trawlers, per month (a), and for the whole year (b), 2007-2011. Data from 2011 are given for January- July.

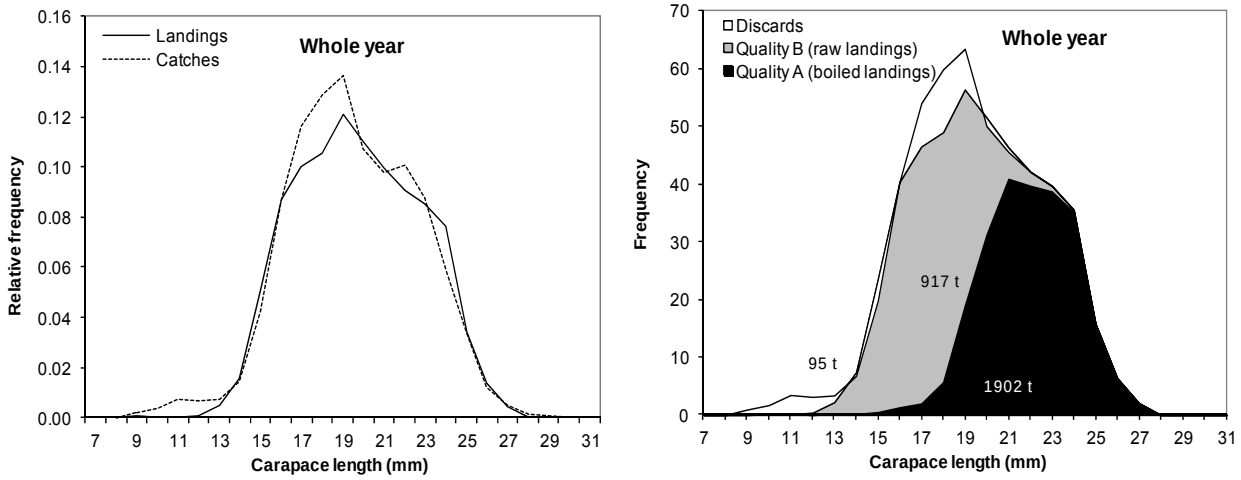

Fig. 14. Length frequency distributions from unsorted commercial catches and sorted landings from Skagerrak in 2010 adjusted to each other for CL > 21 mm (left figure), and size distribution of Skagerrak 2010 landings, separated into boiled and raw shrimps, and estimated discards (right figure).

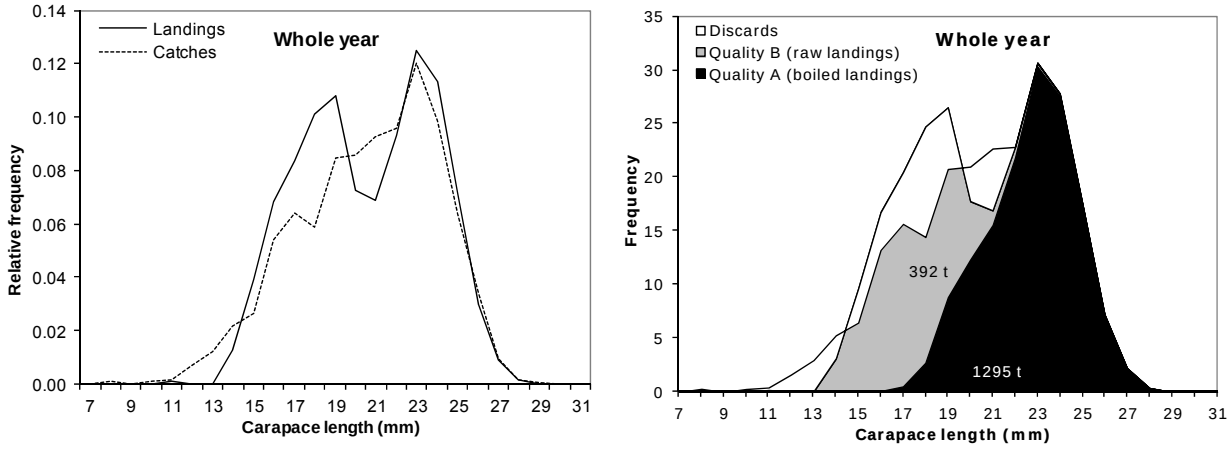

Fig. 15. Length frequency distributions from unsorted commercial catches and sorted landings from the Norwegian Deep in 2010 adjusted to each other for CL > 21 mm (left figure), and size distribution of Norwegian Deep 2010 landings, separated into boiled and raw shrimps, and estimated discards (right figure).

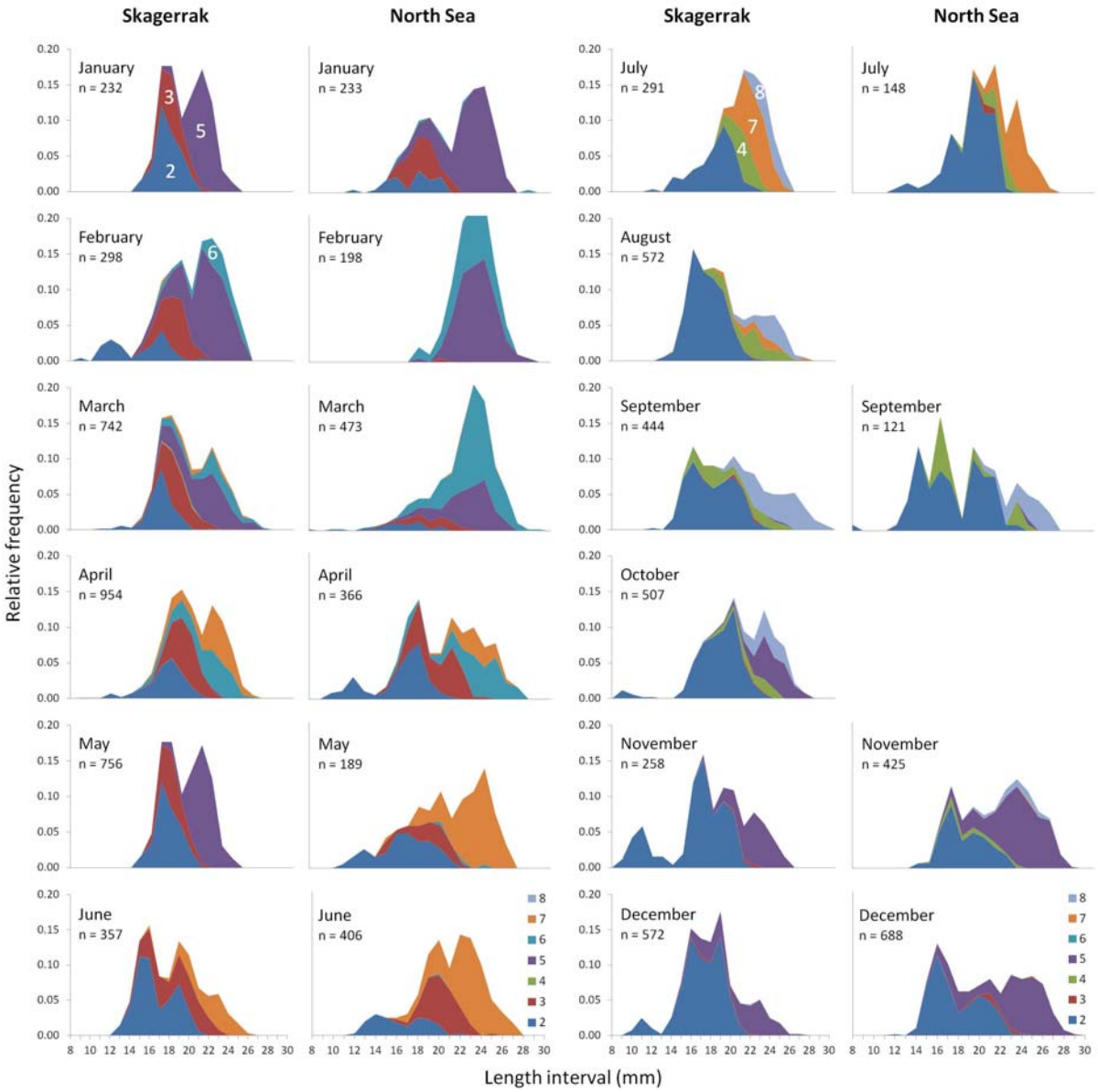

Fig. 16. Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2010 from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local fishermen and the Norwegian Coast Guard. Stages: 2 = males; 3 = transitional; 4 = ripe gonads, first time spawner; 5 = berried; 6 = breeding dress; 7 = resting stage; 8 = ripe gonads, second time spawner. Sample sizes are given in the figure.

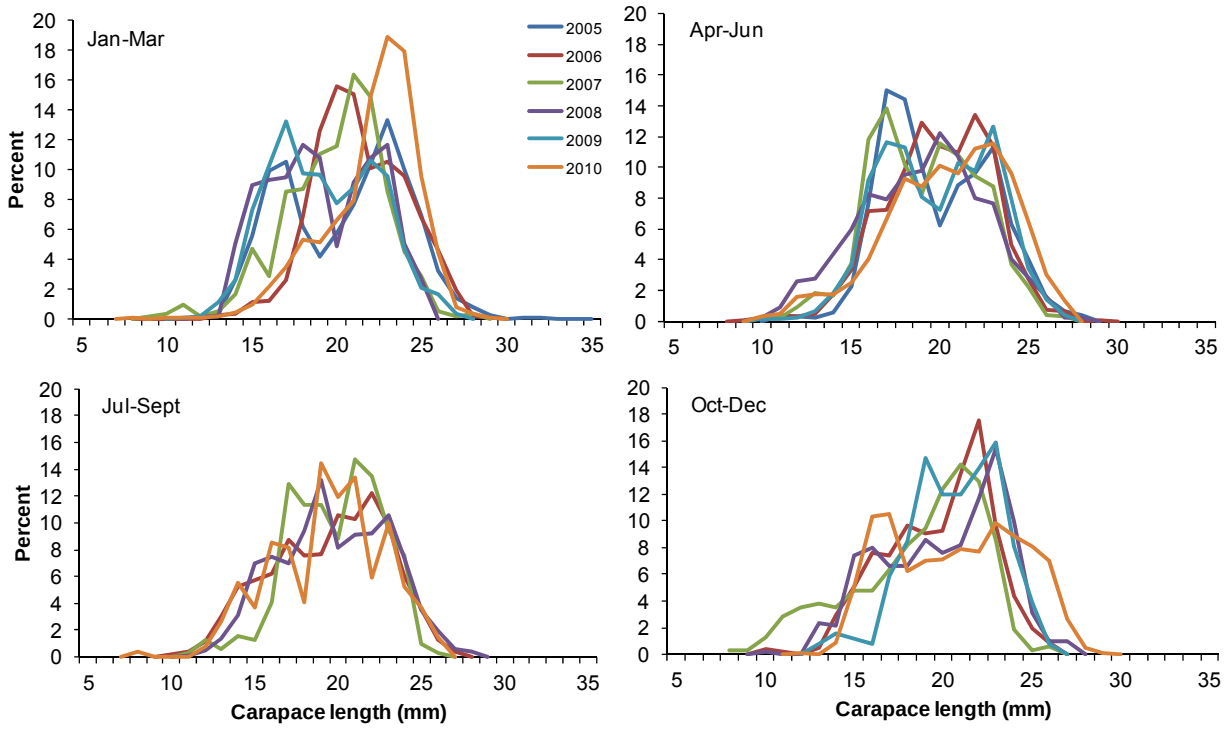

Fig. 17. Length frequency distributions (%) from unsorted commercial catches from Div. IVa east (Norwegian Deep) from 2005 (quarter 1-2, n = 1541, 914), 2006 (quarter 1-4, n = 1503, 1750, 1196, 552), 2007 (quarter 1-4, n = 525, 920, 318, 316), 2008 (quarter 1-4, n = 548, 1507, 1367, 512), 2009 (quarter 1-2, 4, n = 1014, 911, 258), and 2010 (quarter 1-4, n = 904, 961, 269, 1113). Samples were collected by local fishermen.

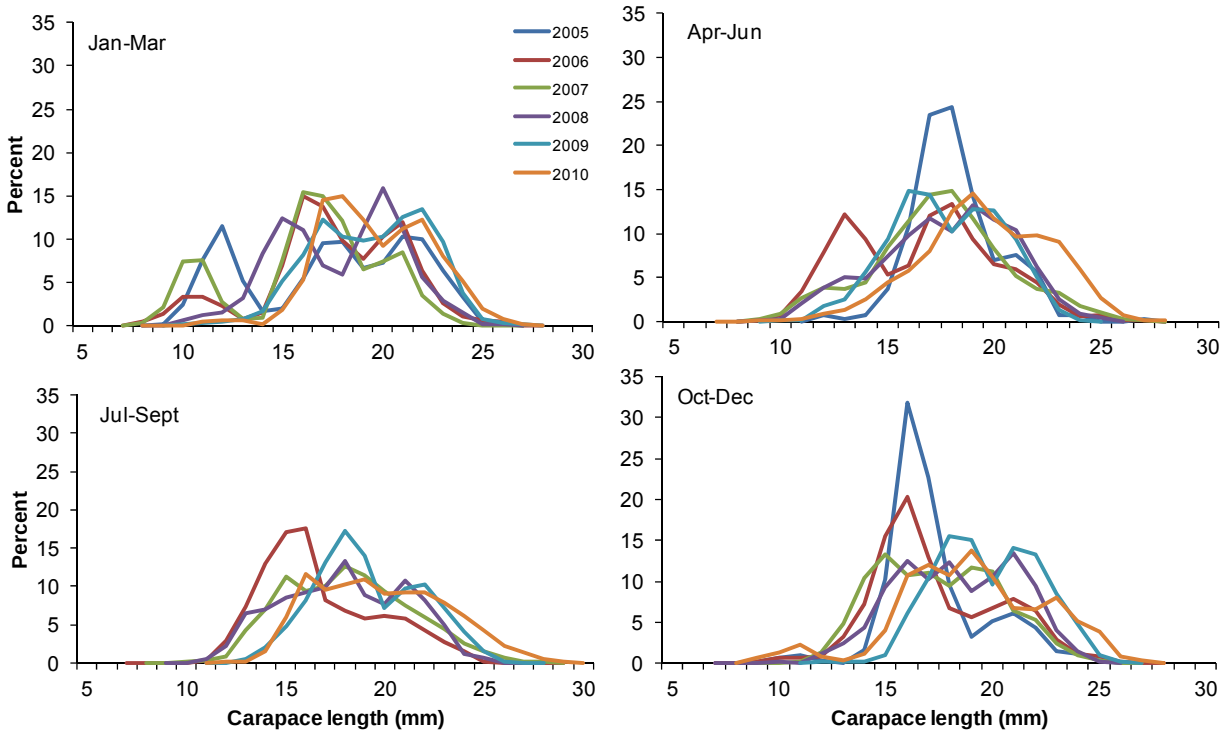

Fig. 18. Length frequency distributions (%) from unsorted commercial catches from Div. IIIa (Skagerrak) from 2005 (quarter 1-2, 4, n = 1249, 303, 1087), 2006 (quarter 1-4, n = 1398, 1833, 1866, 3359), 2007 (quarter 1-4, n = 1388, 1991, 1875, 1837), 2008 (quarter 1-4, n = 1691, 1188, 1186, 1510), 2009 (quarter 1-4, n = 1379, 1107, 1155, 764), and 2010 (quarter 1-4, n = 1272, 2067, 1307, 1337). Samples were collected by local fishermen.