

Northwest Atlantic



Fisheries Organization

Serial No. N6126

NAFO SCR Doc. 12/064

## NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – OCTOBER 2012

The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2012

by

G. Søvik\* and T. Thangstad#

\*Institute of Marine Research  
Box 1870 Nordnes, N-5817 Bergen, Norway

#Institute of Marine Research  
Box 6404, N-9294 Tromsø, Norway

### 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 introduction of compulsory electronic logbooks for all vessels >15 m. However, a large part of the fleet 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, but have since decreased. In 2011 4 466 t were landed, a slight increase from 2010. Correcting for boiling implies that 300-550 t should be added to the nominal landings for the years 2000-2011.

Landings per unit effort (LPUE) increased from 32 to 65 kg/hour from 1999 to 2007-2008, thereafter dropped to 34 kg/hour in 2010, and increased again in 2011 to 39 kg/hour. Standardised LPUE values calculated for 2000-2012 follow the same trend, but show a decrease again in 2012. The LPUE index from the Norwegian Deep has shown a steady decline since 2004, while the index in Skagerrak has been increasing the last two years (2011-2012).

The 2011 catch composition was evaluated using samples from unprocessed catches obtained 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 (Ulmestrand *et al.* 2012): 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.* 2012).

Since 1992 Norway and EU have negotiated quotas on shrimp in the North Sea and Skagerrak. For the Norwegian Deep/Skagerrak stock, Norway has the largest quota of the three Scandinavian countries. In 2010 and 2011 the Norwegian quota constituted 60 % of the total TAC; in 2012 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  $\geq 11$  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. The vessels have a maximum quota of 40 t (tons) in the first period and 30 t in both of the other two periods.

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of 60° N. In 2011, a total of 217 vessels participated in the shrimp fishery south of 62° N (Table 1, Fig. 2), which is a reduction from 2010 when 227 vessels participated. The total number of vessels in the fishery has decreased since 2006 (296 vessels). In 2011, 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 2011 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 IVa east catches made up 88 % of the landings (corrected) as roughly half the vessels in this area are larger than 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 33 % of the landings.

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, 25 vessels  $> 15$  m used twin trawl in 2011. 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. Triple shrimp trawls are allowed in Skagerrak, but are 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 the catch may nevertheless not contain  $> 10$  % (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. Bycatch of >10 % angler fish (by weight) in each haul is nonetheless not allowed. In Skagerrak it is allowed to have up to 10 % undersized shrimp (<6 cm total length = 15 mm carapace length (CL)) (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. Inclined grids for sorting out bycatch are not compulsory south of 62° N, but most fishers seem to use these grids. The grids are used in combination with a collection bag with mesh size  $\geq 120$  mm in order to separate the shrimp catch and the valuable bycatch.

Two categories of shrimp dominate the market: in 2011, 58 % of the total landings were delivered as boiled, fresh large shrimp (140-150 individuals per kg) for the Norwegian market, and 42 % of the total as raw (smaller) shrimp for factory processing ashore (mostly 180-250 individuals per kg). The corresponding numbers for 2005 through 2010 were 41, 45, 60, 47, 55, and 69 % 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 three years, the kilo prize for boiled shrimp increased to a mean of 63 NOK in 2009, 72 NOK in 2010, and further to 79 NOK in 2011. Raw shrimp still yielded approx. 10-11 NOK/kg in 2011.

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 2012 landings and logbook data were given for August 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": 0.5° lat. by 1° 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, 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 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.

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 from 2011 onwards (for vessels > 15 m). Landings per statistical location (2009-2011) 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 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](http://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) “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).
- 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). 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 2011-2012 provide information on both gear type and number of trawls (single, twin). These data are trusted.

Data from the corrected logbooks were used in multiplicative models in order to calculate standardised LPUE indices (2000-2012), 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 2000-2012 was derived by dividing the nominal landings by the standardised LPUE indices.

Since owners of vessels <15 m are not required to fill in logbooks, four fishermen on vessels ranging from 10.55 to 12.21 m length complete simplified logbooks from all their fishing trips. Recording started in 2007.

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 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 annual length distribution from the landings for the larger sizes, based on the assumption that there is no discarding of the largest size groups ( $\geq 21$  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 2010-2011, sampling improved, and discards were estimated for both Skagerrak and the Norwegian Deep. Danish discards from Skagerrak have been estimated based on onboard sampling since 2009. Norwegian discards from Skagerrak in 2010-2011 were therefore also estimated applying the Danish discards-to-landings ratio to Norwegian landings from Skagerrak.

Samples (approx. 1.5 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2011 catches were obtained from five Norwegian shrimp fishers (26 samples) (Fig. 5). The Norwegian Coast Guard provided 29 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 9 611 t. From 2000 to 2004 overall landings increased continuously from about 6 000 t to 9 000 t. The trend then reversed with a steady decline until 2010, with total landings of 4 308 t, the lowest figure since 1979. 2011 saw a slight increase to 4466 t. Correcting for boiling implies that 300-550 t are added to the nominal landings for the years 2000-2011 (Table 2).

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

In 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 decreased by 56 % to the lowest level since 1979. The 2011 landings were of the same size as the 2010 ones. 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. 6a, Table 2). Both the 2010 and the 2011 landings have remained at the 2009 level. Monthly landings for 2005-2012 (Fig. 7) indicate that the decreasing trend in landings was discontinued in Skagerrak in 2012. The good 2011 year class observed on the survey in January 2012 entered the fishery in autumn 2012 (Søvik and Thangstad 2012), which is confirmed by shrimp fishers. In the Norwegian Deep, on the other hand, 2012 could turn into one of the worst shrimp fishing years in many years. 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 2011, 1 444 t were landed by small vessels (< 15 m), while almost the double (3007 t) were landed by large vessels (> 15 m) (Table 1).

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 quota), while in 2010 only 54 % of the quota was landed (Table 2). In 2011, 4 801 t were landed out of a quota of 7 452 t (64 %). The Norwegian quota for 2012 was reduced by 21 % from the 2011 one (3 300 t in IIIa and 2 555 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. 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 > 5 m used twin trawl regularly or occasionally in 2011. 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 available in 2011, 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 (Fig. 10). The main fishing areas seem to be off Egersund and Lindesnes (Fig. 11). The incomplete logbooks from earlier years indicate that the fleet has been fishing the whole Norwegian Deep/Skagerrak area at least back to 2007 (Fig. 11). The small vessels are not represented 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. 12).

### *Effort*

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 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, but increased again in 2011. In Skagerrak the pattern is opposite with an increase from 2007 to 2010, and a decrease in 2011.

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 (Table 2, Fig. 6c). In 2010 total effort increased, but decreased again in 2011 to an all time low of 123 Khours. Standardised effort indices (Table 3) show the same trend as the unstandardised figures.

The fishery in 2011 took place in all months (Figs. 7, 13). 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.

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

Overall LPUE increased from 1999 to 2008 (Fig. 6b, Table 2), decreased in 2009 and 2010, but showed a slight increase again in 2011 (39 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 was, for the first time in the time series, lower than the Norwegian Deep LPUE. In 2011 the LPUE in both areas were of equal size.

Standardised LPUE values have been calculated for 2000-2012 (Table 3, Fig. 14). 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 (2000-2012), which explains the little difference between standardised and unstandardised values. The 2011-2012 LPUE-indices increased and decreased in respectively 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 2012), it can be seen that the decrease in the survey biomass index in 2008-2012 is reflected in the decrease in the overall standardised LPUE (Fig. 14).

The LPUE-data from the small trawlers in Skagerrak cover mainly the eastern part of Div. IIIa (Fig. 15). The monthly catch rates decreased from 2007 to 2010 (Fig. 16a), and decreased further in 2011 for January to April. However, in May to December 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. 16b). The LPUE-index from the small shrimp trawlers supports the pattern in the survey biomass index (Søvik and Thangstad 2012) 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.* 2011), 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 15 % of the catches, i.e., from 80 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.

In 2011 discards from Skagerrak was estimated to 426 t based on comparisons of length frequency distributions (Fig. 17). Discards consist of shrimp smaller than 15 mm CL, as well as some larger shrimp, which may be damaged, poor quality shrimp (Munch-Petersen *et al.* 2011). Using the Danish numbers, discards from Skagerrak in 2011 were estimated to 229 t. The estimated 2011 discards from the Norwegian Deep were negative (-398 t) (Fig. 18), 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 154 and 6 t from respectively Skagerrak and the Norwegian Deep. Estimations based on the Danish numbers are considered most reliable and the Norwegian discards from Skagerrak in 2011 are therefore set to 229 t, while discards from the Norwegian Deep are set to 6 t.

### *Catch composition*

The length frequency distributions from 2011 show that the catches in spring consist of all three year classes, especially in Div. IIIa, less so in Div. IVa east (Table 4, Fig. 19). In autumn the 1-group dominated the catches in Skagerrak, while the catches in the Norwegian Deep consisted of shrimp of both the 1-, 2-, and 3-groups. The 0-group entered the catches in November-December. Catch composition vary both between the areas as well as between years (Figs. 20, 21).

## 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. 2011. Discarding in the shrimp fisheries in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east). NAFO SCR Doc. 11/67, 11 pp.
- Søvik, G. and Thangstad, T. 2012. 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 2012. – NAFO SCR Doc. 12/059, 23 pp.
- Ulmestrand, M., Eigaard, O., Søvik, G. and Munch-Petersen, S. 2012. The Northern shrimp (*Pandalus borealis*) Stock in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa East). - NAFO SCR Doc. 12/065, 27 pp.



**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 2011: 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). Note that total uncorrected landings are not equal to total uncorrected landings in Table 2 due to minor mismatch between the vessel information in the landings statistics and the vessel register.

Length group	Number of vessels	Landings (t)	Landings per vessel (t)		
			Mean	Median	St.dev
< 10 m	18	29	1.6	0.6	3.7
10-11.99 m	80	464	5.8	2.9	6.5
12-14.99 m	66	951	14.4	10.2	15.1
15-20.99 m	24	739	30.8	26.8	32.3
21-27.99 m	19	1 638	86.2	93.4	49.3
> 28 m	10	630	63.0	21.5	64.1
Total	217	4 451			

**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 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 fishery in Divs. IIIa and IVa east 1970-2011. All landings back to 1977 were checked and corrected against original files in 2011.

Year	Landings (t)				TAC (t)	Disc. (t)	LPUE (kg/hour)			Effort (Khours)		
	IIIa	IVaE	Total	Corr.	Total	Total	IIIa	IVaE	Total	IIIa	IVaE	Total
1970	982	747	2089									
1971	1392	1094	2657									
1972	1123	1354	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	92	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	1687	4308	389	8767	75	27	44	34	109	42	136
2011	2693	1773	4466	335	7452	235	38	40	39	77	48	123
2012					5855							

Data from the Norwegian Directorate of Fisheries.

Estimated effort 2000-2011 is based on landings corrected for boiling.

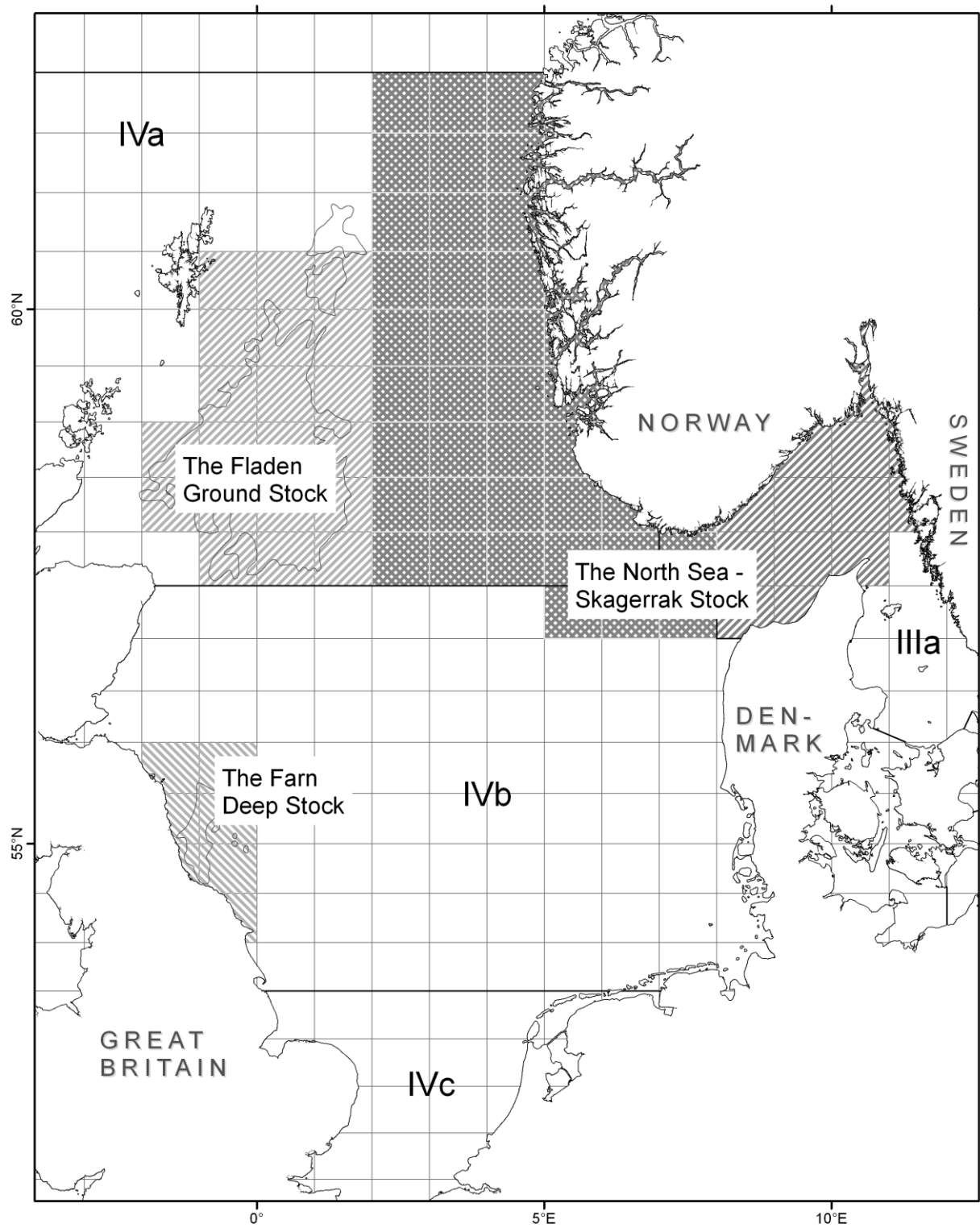
"Total" refers to the sum of Divs. IIIa and IVa east, except for "total landings" and correction for boiling, which refer to Div. IIIa and Subarea IV.

**Table 3.** Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, 2000-2012.

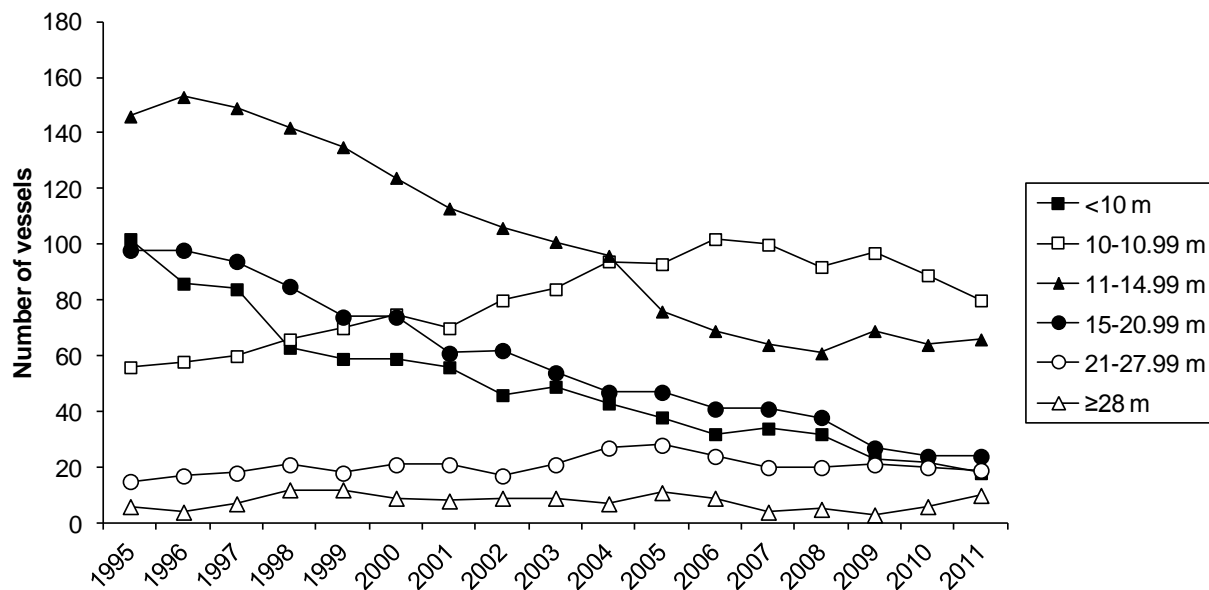
	Stand. LPUE (index)	Stand.effort (index)
2000	1.30	1.17
2001	1.37	1.26
2002	1.70	1.07
2003	1.74	1.11
2004	1.98	1.14
2005	1.84	1.15
2006	1.80	1.14
2007	2.17	0.95
2008	2.11	0.93
2009	1.58	0.95
2010	1.14	0.97
2011	1.20	0.94
2012	1.00	1.00

**Table 4.** Mean carapace length (with SD), and numbers (millions) in each age class in the 2011 catches from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, per area and total.

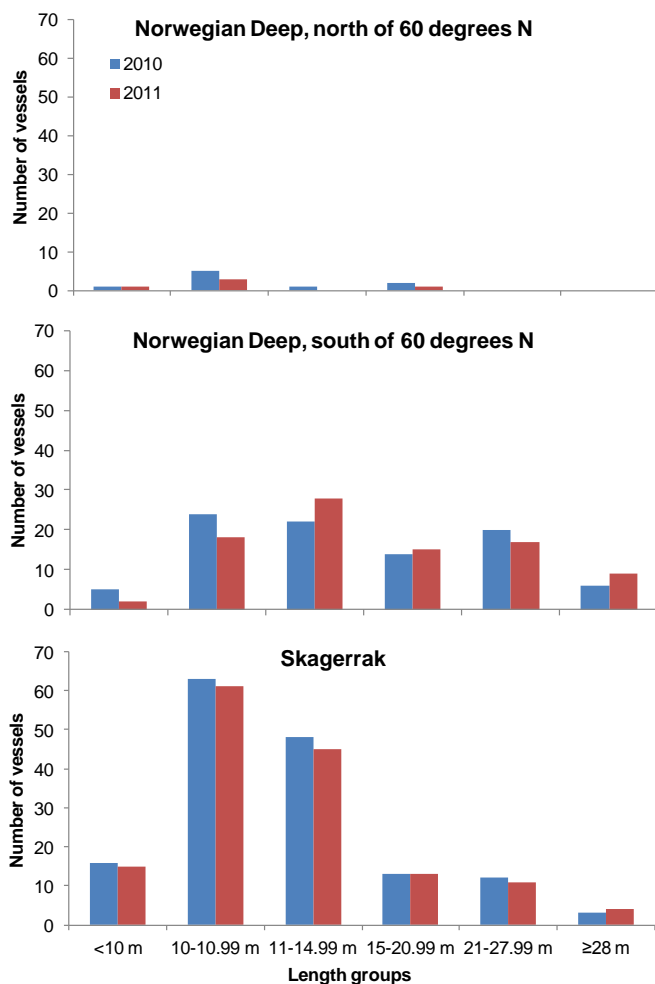
Quarter	Age	Total			Skagerrak			Norwegian Deep		
		Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
1	1	12.01	1.20	24	12.09	1.26	21	12.04	1.36	4
	2	17.45	1.56	87	17.94	1.72	57	17.04	1.21	32
	3+	22.96	1.96	98	22.55	1.53	49	23.34	2.05	45
2	1	14.75	1.35	110	14.73	1.36	102	15.75	1.78	11
	2	19.54	1.90	120	19.39	1.60	62	19.63	1.99	48
	3+	23.68	1.60	64	23.34	1.37	30	24.01	1.58	37
3	1	16.89	1.45	162	17.04	1.54	158	15.87	1.19	11
	2	20.11	1.41	64	22.22	1.87	44	20.15	1.77	45
	3+	24.14	1.66	59				25.11	1.45	28
4	0	10.73	1.13	9	10.78	1.12	6	10.69	1.16	3
	1	17.54	1.23	118	17.52	1.23	106	16.34	0.85	7
	2/2+	21.71	1.65	43	21.96	1.63	37	19.81	1.78	11
	3+	25.43	1.20	4				24.79	1.60	4



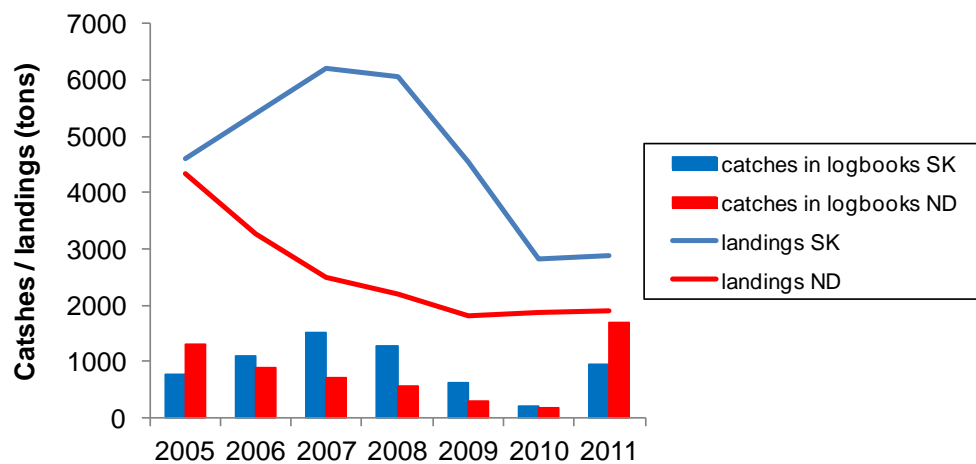
**Fig. 1.** Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the defined management units. Grid is standard “ICES squares”: 0.5° lat. by 1° long. (based on Ulmestrand *et al.* (2012)).



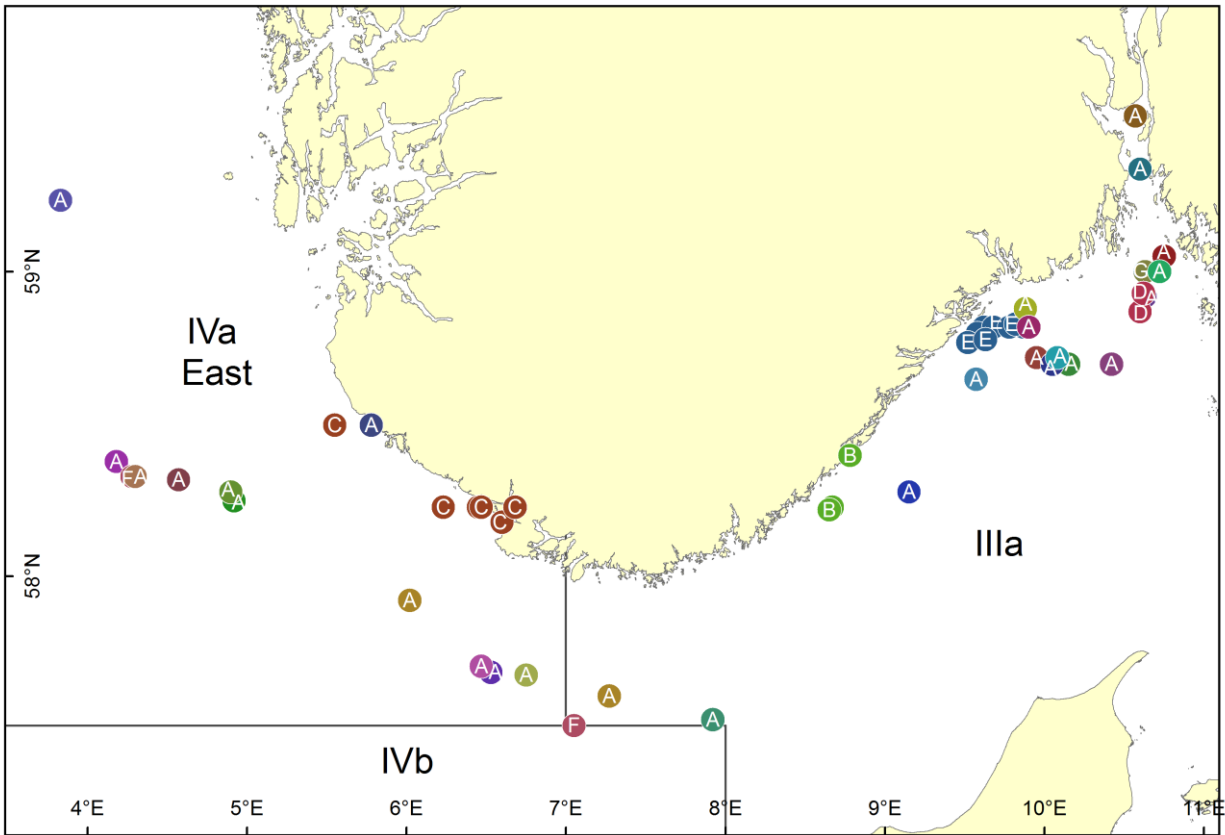
**Fig. 2.** The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) 1995-2011: number of vessels per length group (m). Data from the Norwegian Directorate of Fisheries.



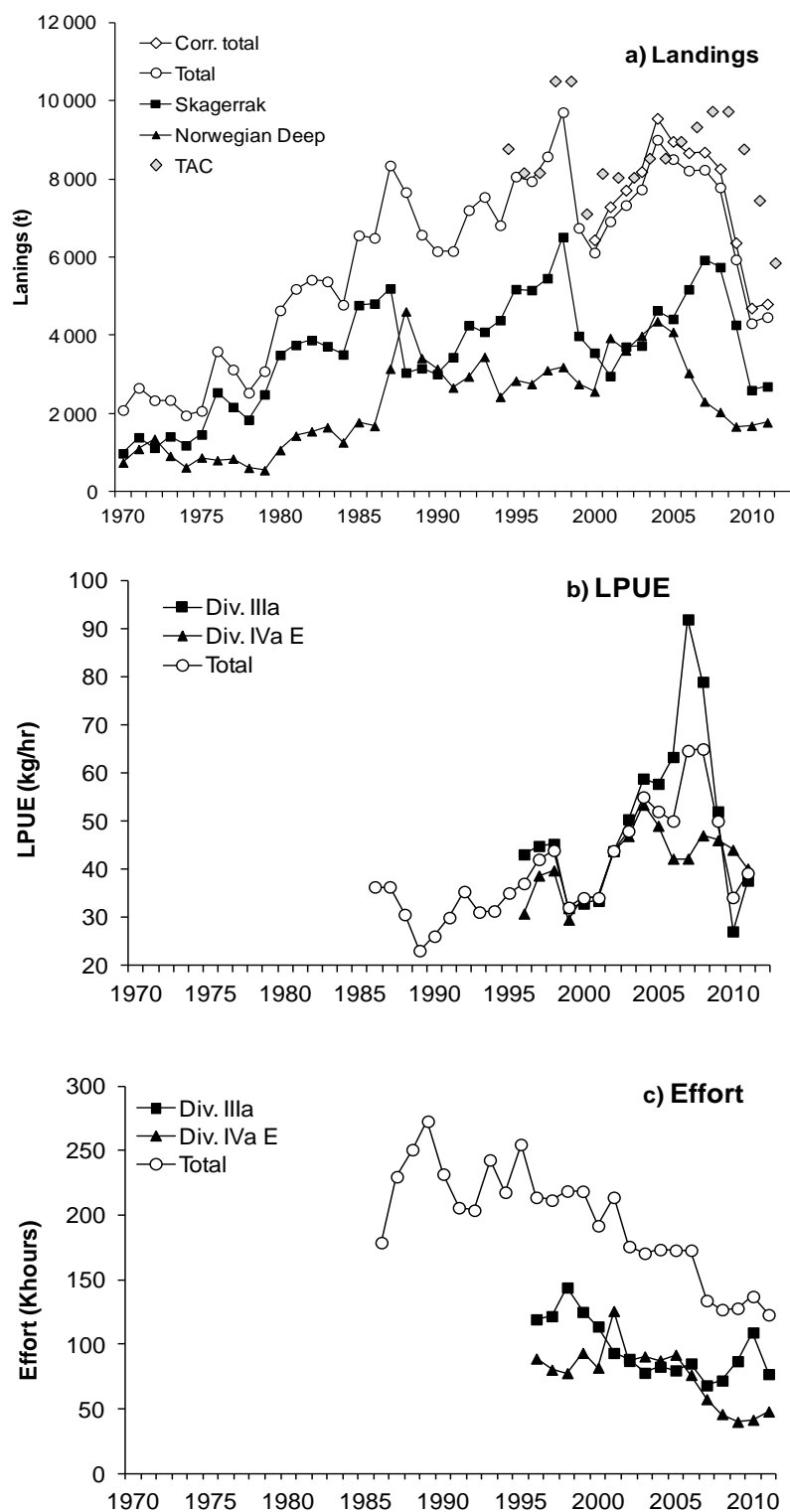
**Fig. 3.** Structure of the fleet (number of vessels per length group) involved in the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2010 and 2011.



**Fig. 4.** Incomplete logbooks from the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep): landings (corrected for boiling) and catches from logbooks, per area for 2005-2011.

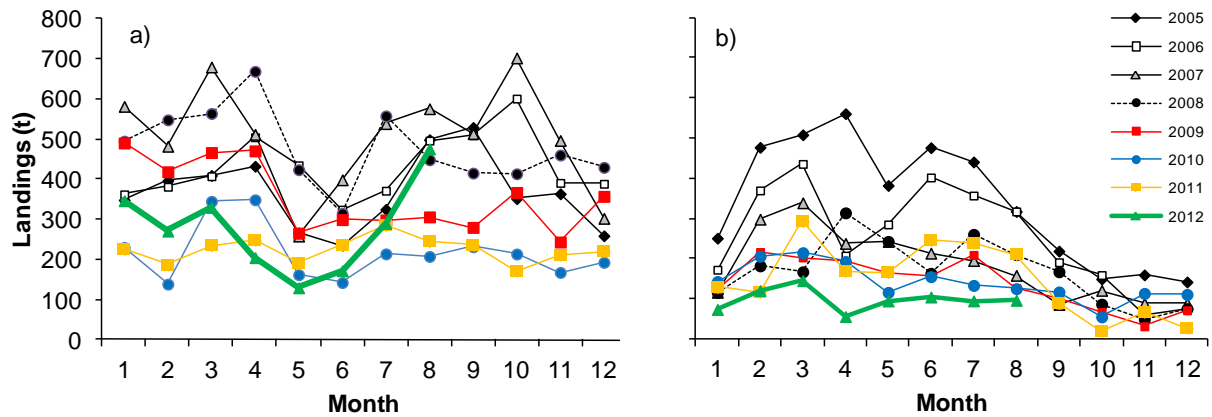


**Fig. 5.** Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2011 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east). Samples were collected by local Norwegian fishermen and the Norwegian Coast Guard, where “A” denotes vessels inspected by the Coast Guard (different colours represent different vessels), while “B-E” denote vessels sampling catches.

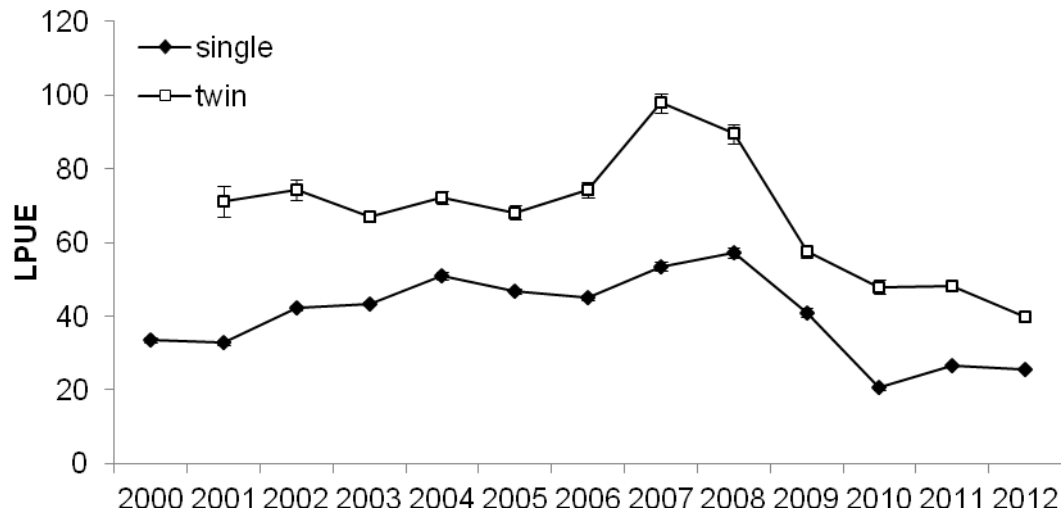


**Fig. 6.** Landings (nominal and corrected) and TAC a); landings per unit effort (LPUE) b); and estimated total effort c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east for all years for which data are available. In a) “total” includes Div. IIIa and all of Subarea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

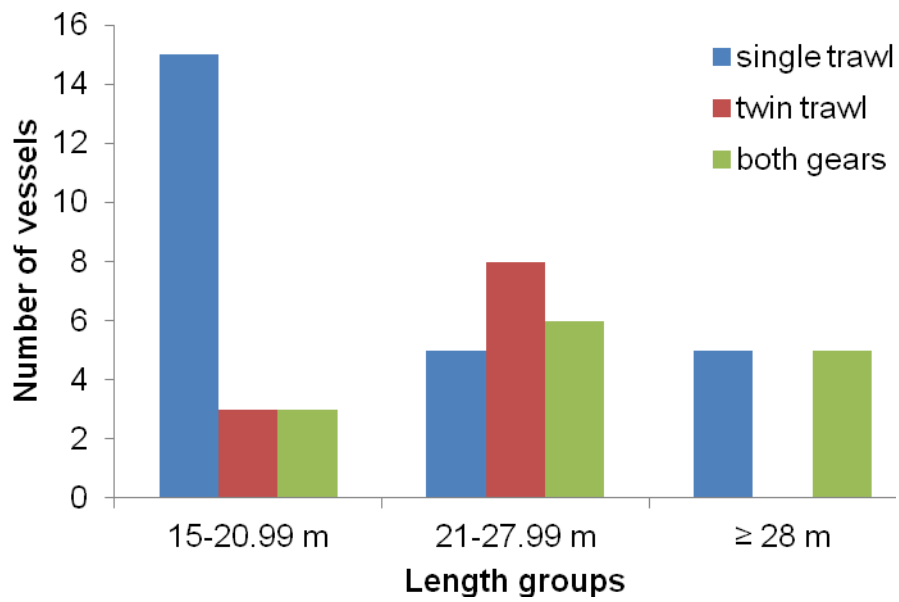




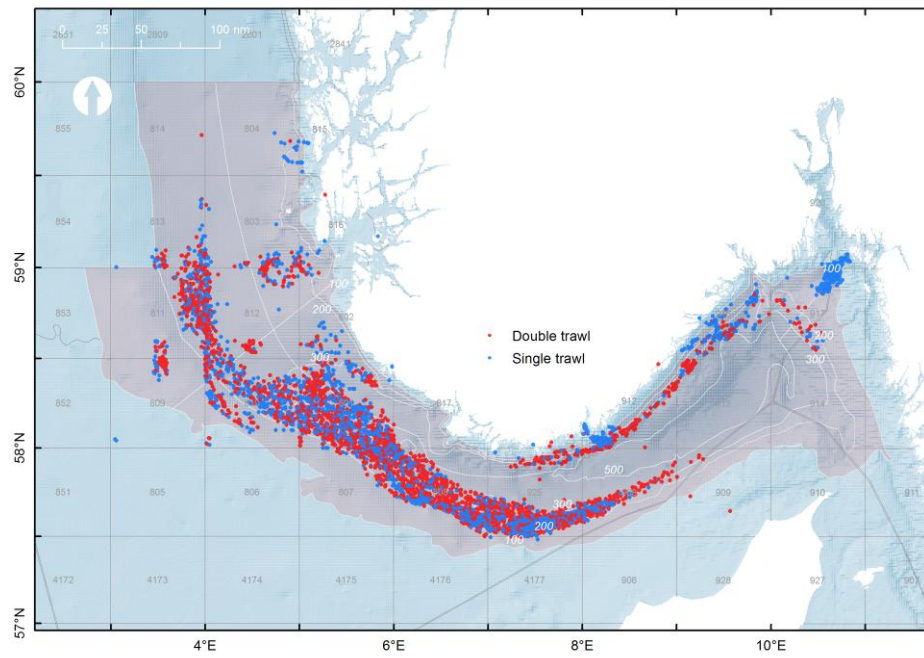
**Fig. 7.** Monthly (uncorrected) landings of shrimp (*Pandalus borealis*) 2005- 2012 for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries. Data from 2012 are preliminary.



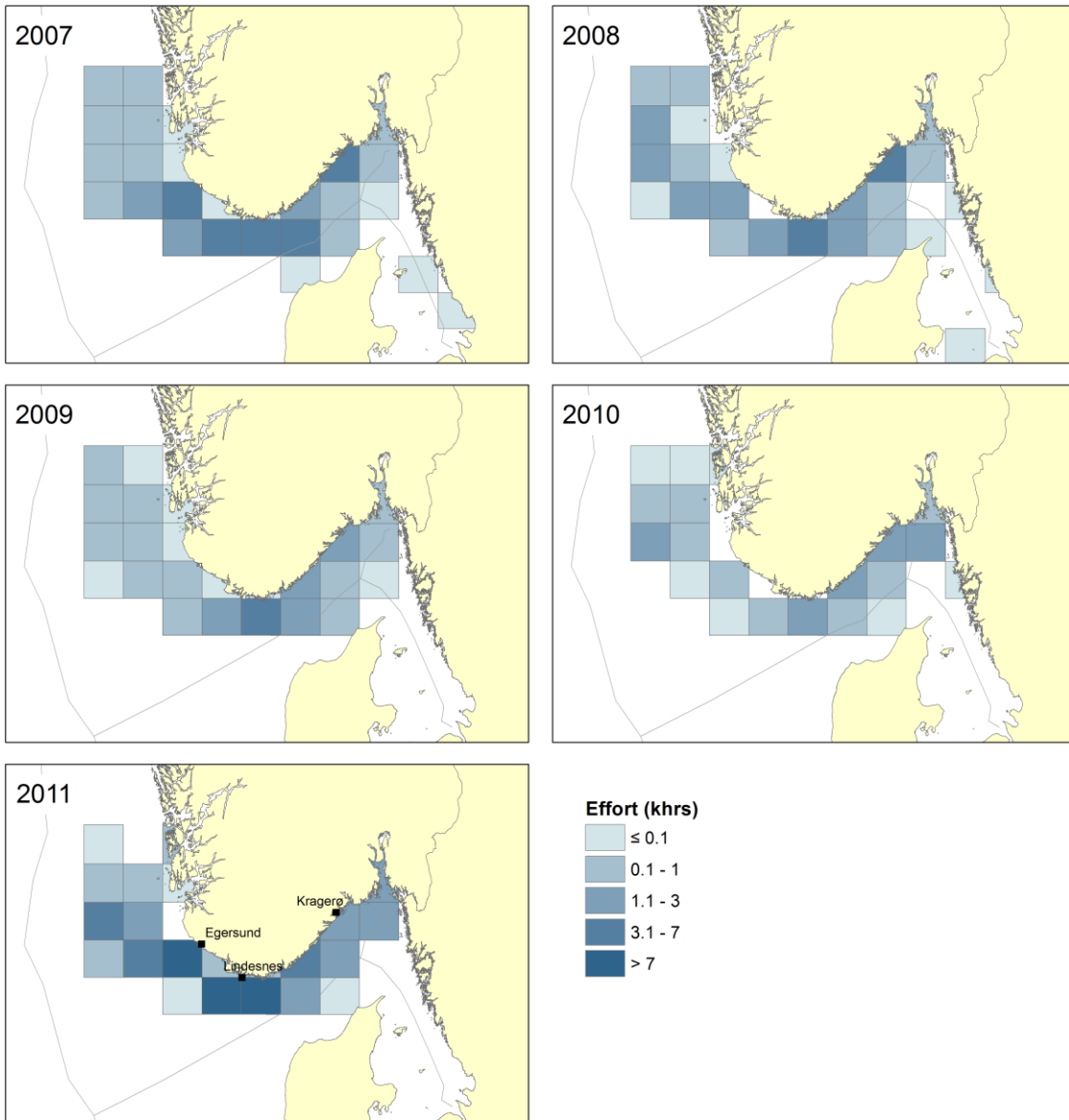
**Fig. 8.** Unstandardised mean LPUE (with standard error) per gear type and year from Norwegian logbooks (ICES Divs. IIIa and IVa east). Data from the Norwegian Directorate of Fisheries.



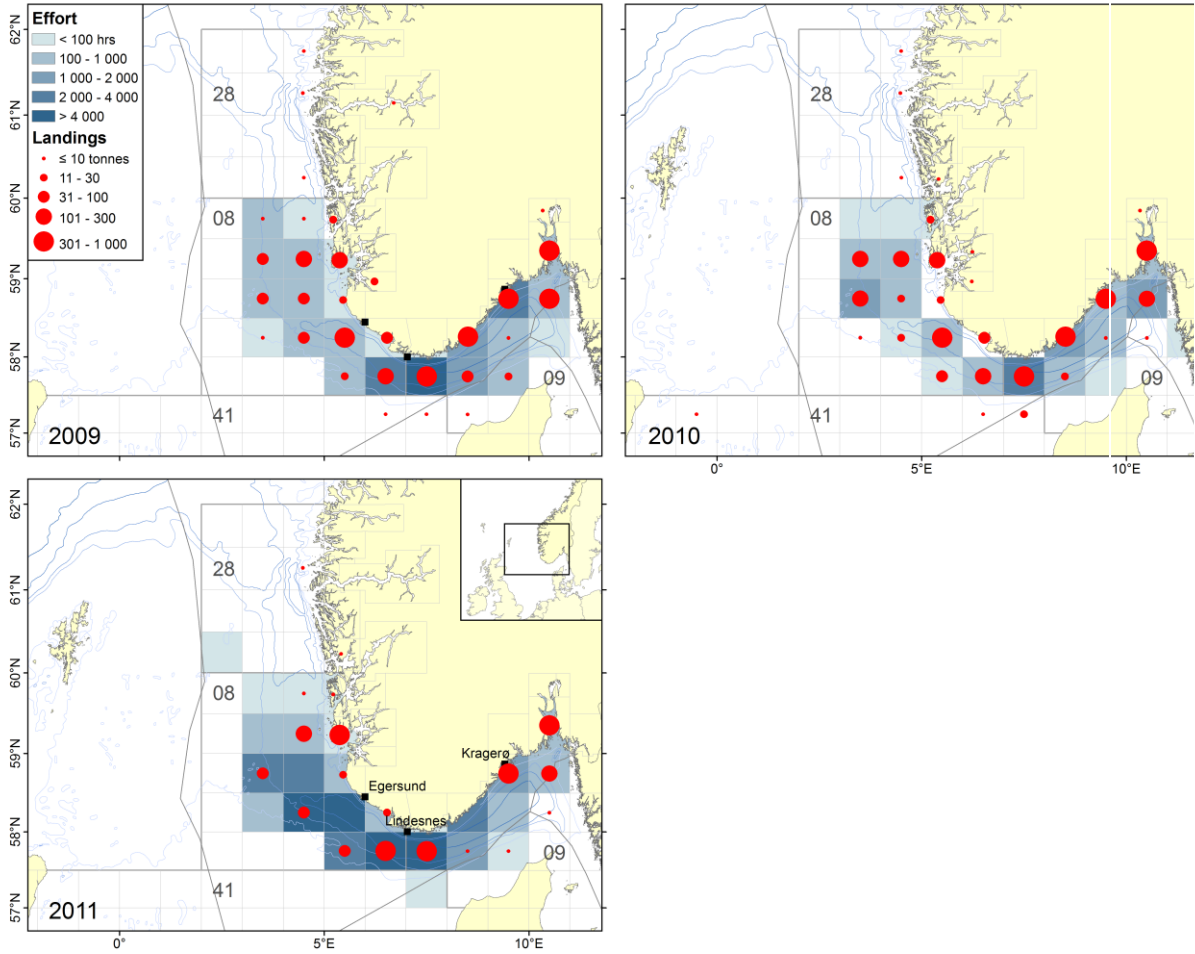
**Fig. 9.** Gear use by vessel length group. Data from electronic logbooks from the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011. There is no information on vessels <15 m, as these are not required to send in logbooks.



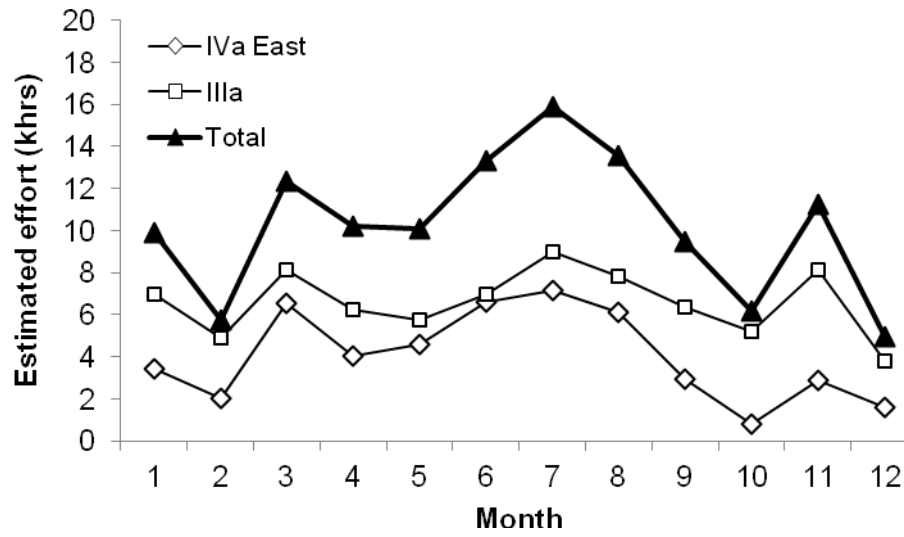
**Fig. 10.** Spatial distribution of the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep) in 2011 based on electronic logbooks from vessels > 15 m: positions of single trawl hauls with single and twin trawl. Data from the Norwegian Directorate of Fisheries.



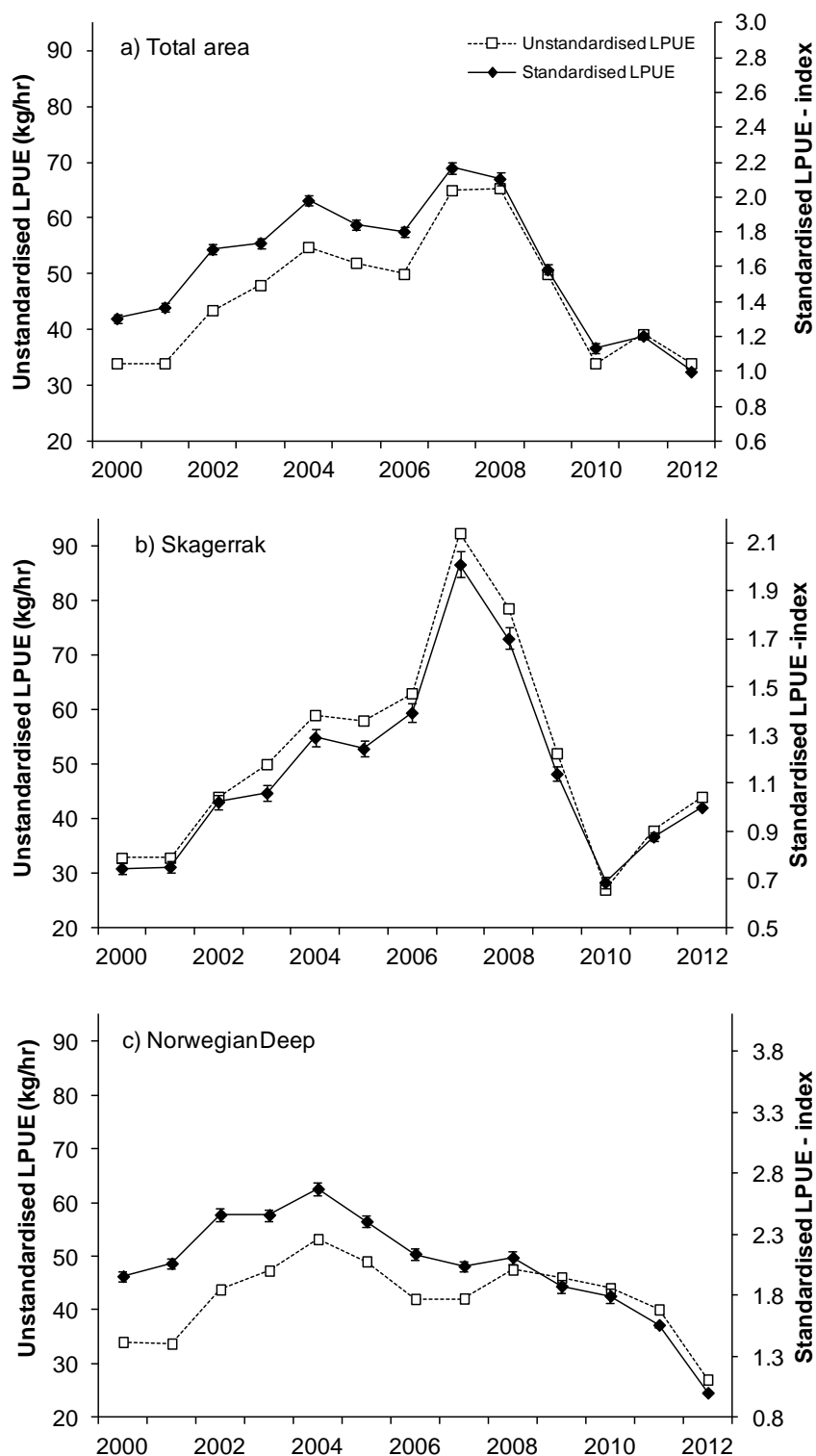
**Fig. 11.** Spatial distribution of recorded effort (trawling hours) by Norwegian shrimp trawls 2007-2011 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard “ICES squares”: 0.5° lat. by 1° long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.



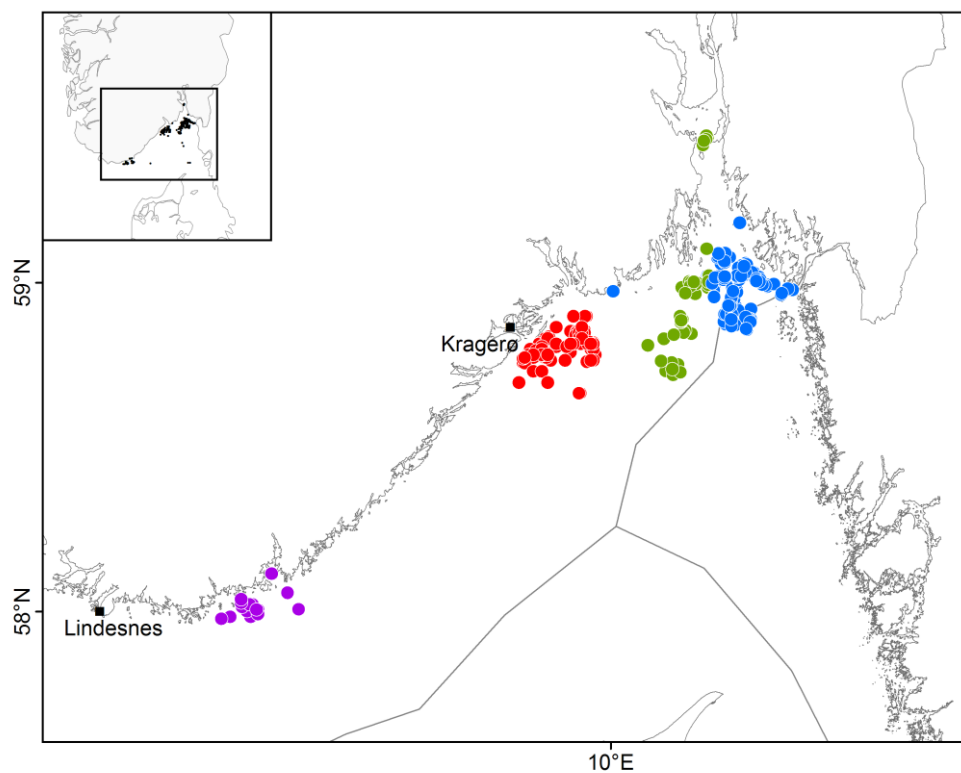
**Fig. 12.** Spatial distribution of landings (t) and recorded effort (trawling hours) by Norwegian shrimp trawls in 2009-2011 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard “ICES squares”: 0.5° lat. by 1° long.). Fishing by both single and twin trawl is included. Data from the Norwegian Directorate of Fisheries.



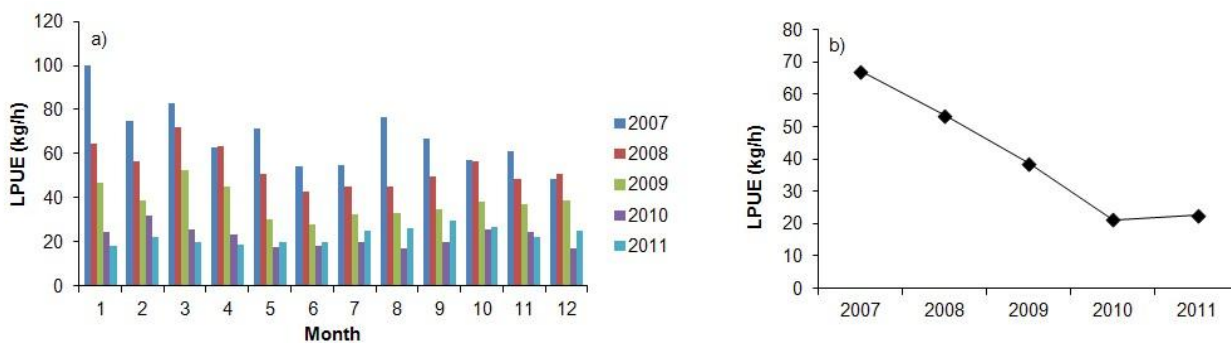
**Fig. 13.** Estimated total effort (trawling hours) by Norwegian shrimp (*Pandalus borealis*) trawlers in 2011 per month and area (Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east)). Effort was estimated as official monthly landings (corrected for boiling) divided by monthly LPUE from the 2011 logbooks (only for vessels > 15 m).



**Fig. 14.** Standardised LPUE-indices (with standard error), and unstandardised LPUE-values (kg/hour) for 2000-2012 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. Data from the Norwegian Directorate of Fisheries.

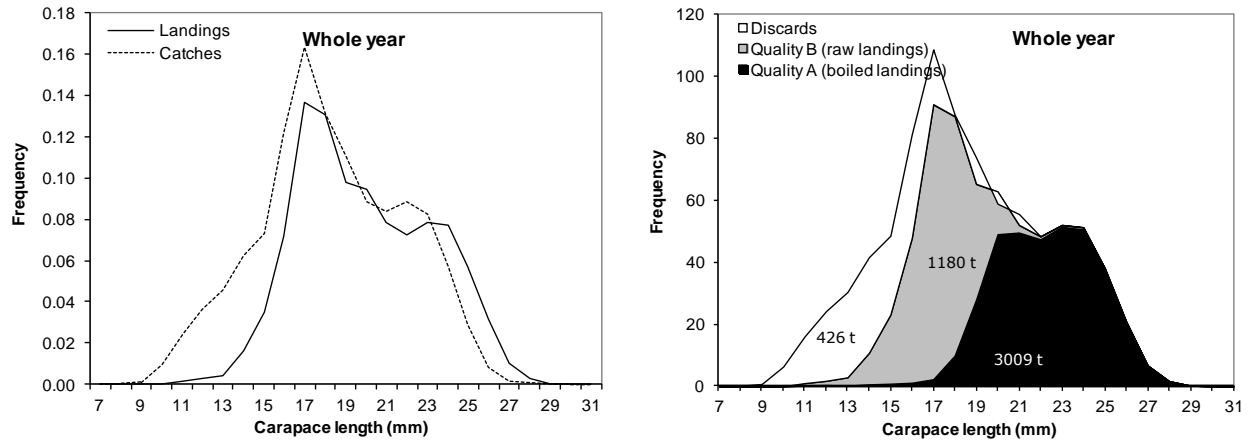


**Fig. 15.** Positions of all trawl hauls in the logbooks provided by four smaller (10-12 m) shrimp trawlers fishing in Skagerrak (ICES Div. IIIa).

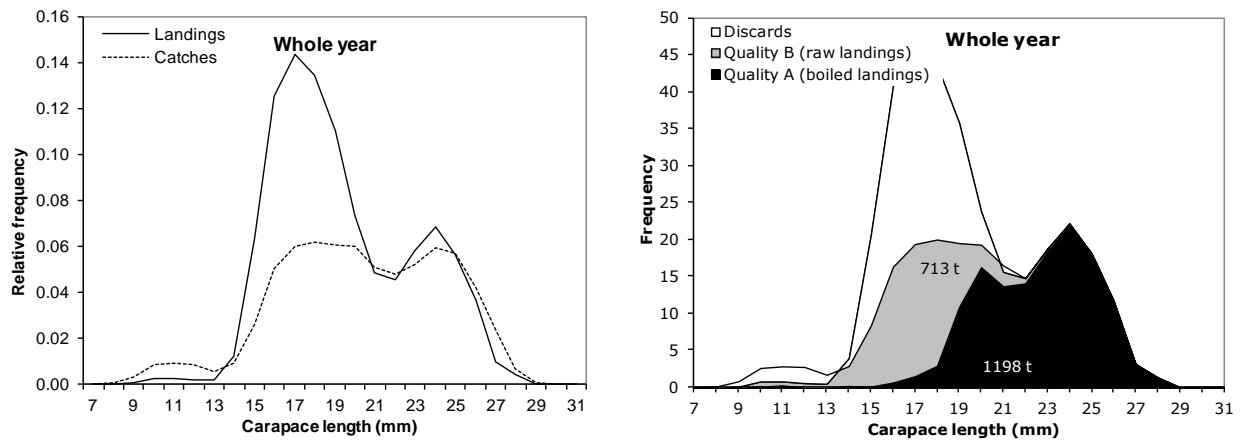


**Fig. 16.** Monthly a) and annual b) LPUE (unstandardised) indices from logbooks from four smaller (10-12 m) shrimp trawlers, 2007-2011.

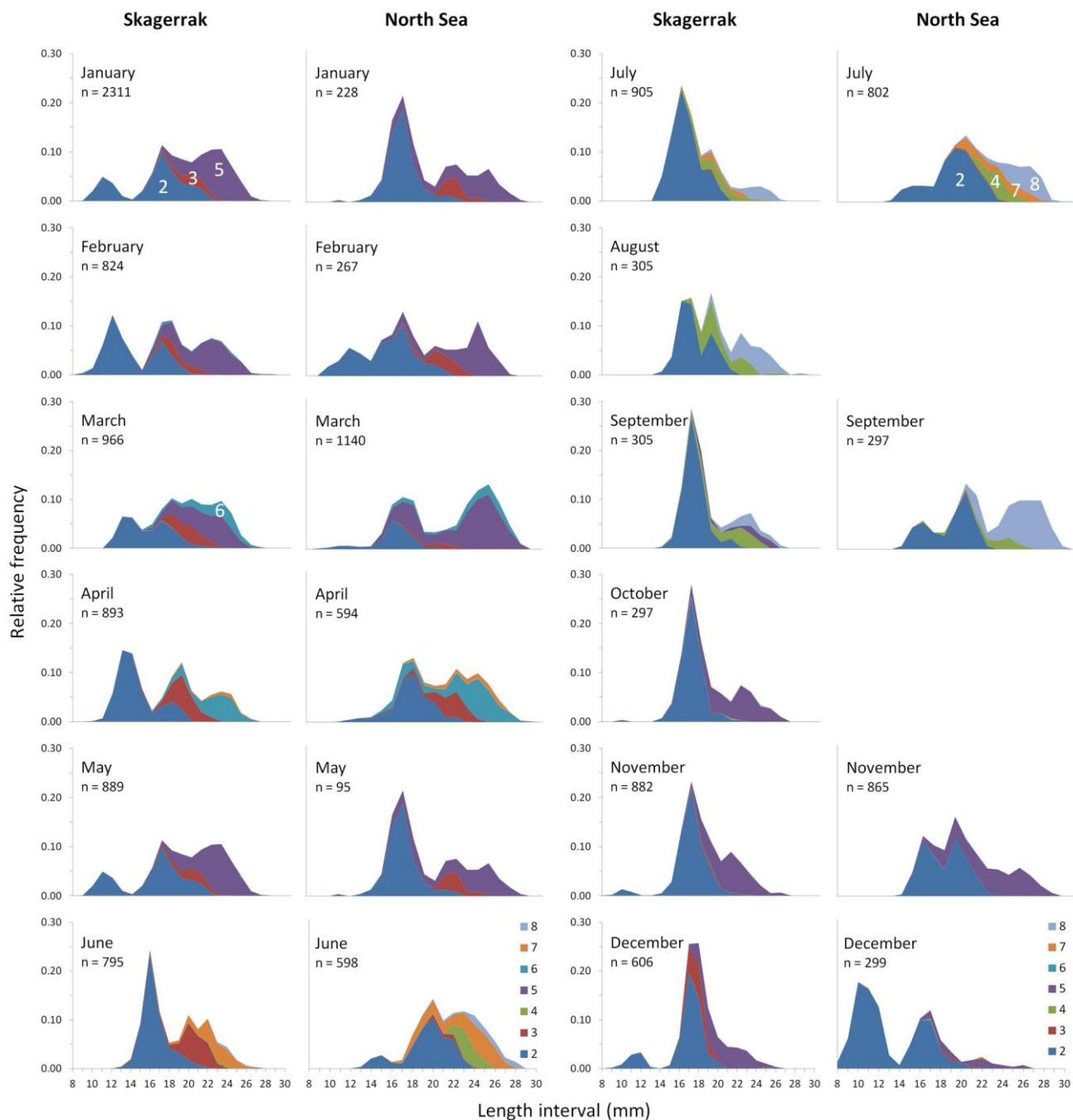




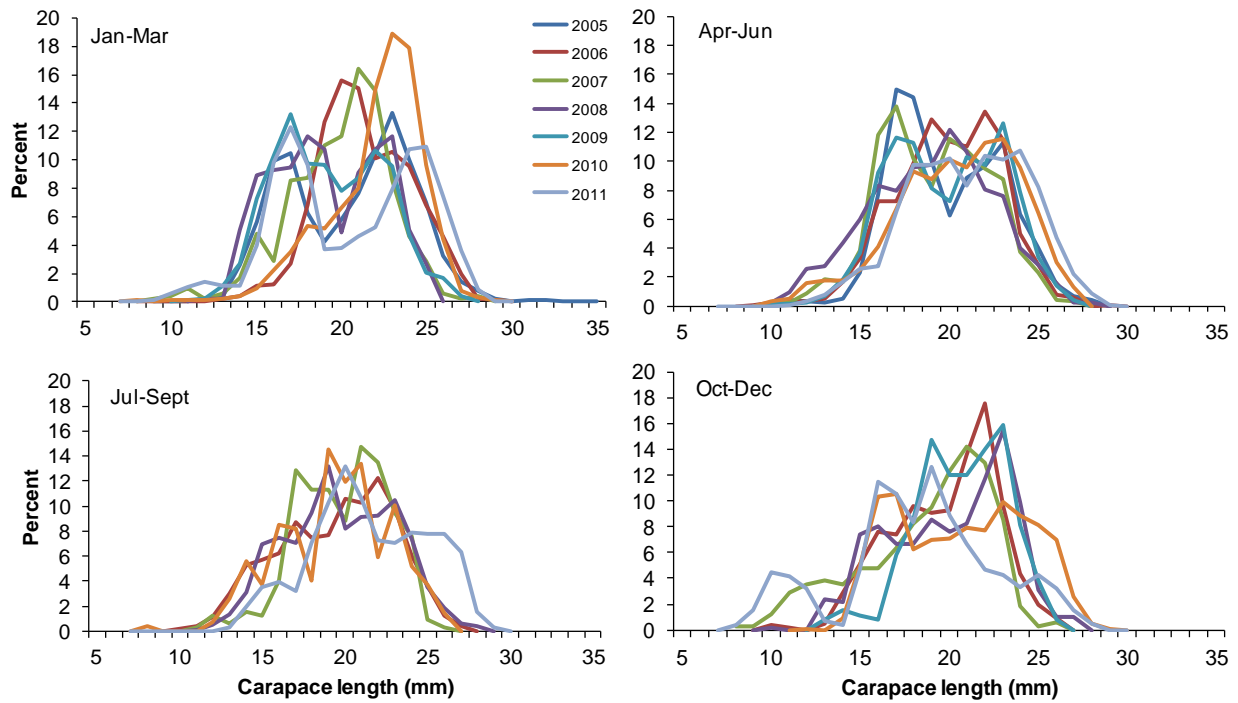
**Fig. 17.** Length frequency distributions from unsorted commercial catches and sorted landings from Skagerrak in 2011 adjusted to each other for CL > 21 mm (left figure), and size distribution of Skagerrak 2011 landings, separated into boiled and raw shrimp, and estimated discards (right figure).



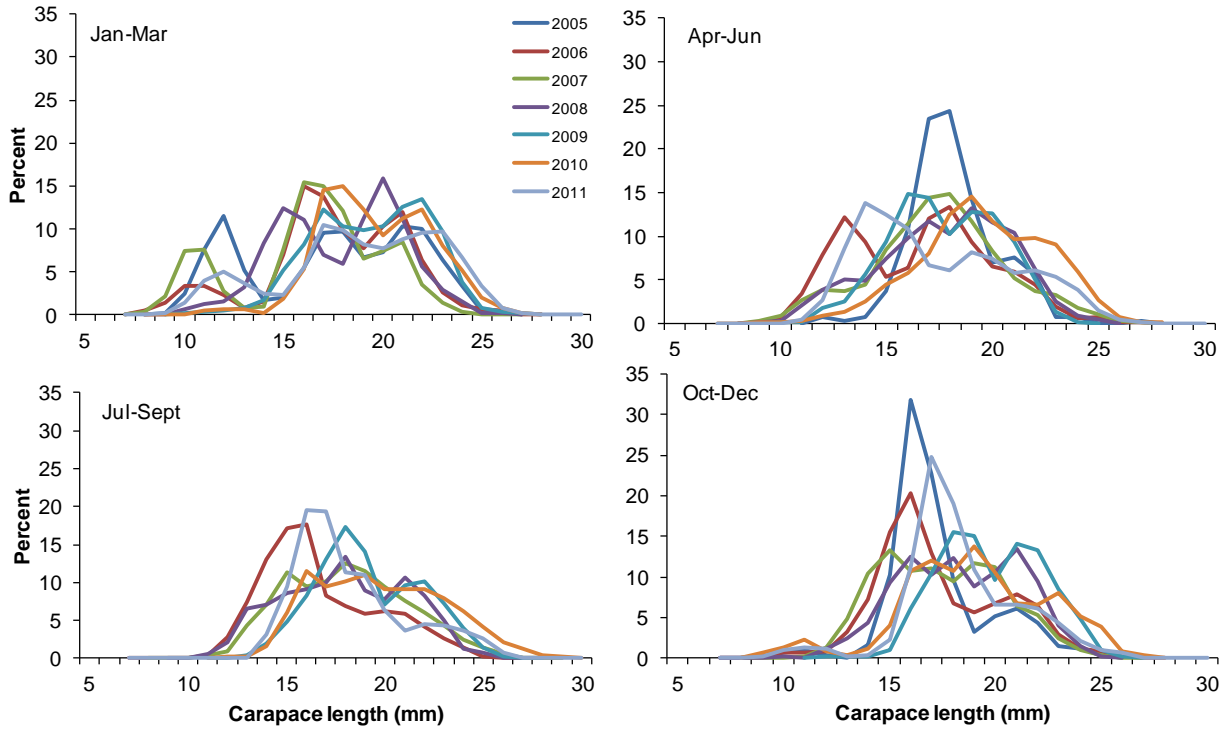
**Fig. 18.** Length frequency distributions from unsorted commercial catches and sorted landings from the Norwegian Deep in 2011 adjusted to each other for CL > 21 mm (left figure), and size distribution of Norwegian Deep 2011 landings, separated into boiled and raw shrimp, and estimated discards (right figure).



**Fig. 19.** Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2011 from Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east). 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 (number of shrimp measured) are given in the figure.



**Fig. 20.** Length frequency distributions (%) from unsorted commercial catches from the Norwegian Deep (ICES Div. IVa east) 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,  $n = 1014, 911, 258$ ), 2010 (quarter 1-4,  $n = 904, 961, 269, 1113$ ), and 2011 (quarter 1-4,  $n = 1635, 1287, 1099, 1164$ ). Samples were collected by local fishermen and the Norwegian Coast Guard.



**Fig. 21.** Length frequency distributions (%) from unsorted commercial catches from Skagerrak (ICES Div. IIIa) 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,  $n = 1379, 1107, 1155, 764$ ), 2010 (quarter 1-4,  $n = 1272, 2067, 1307, 1337$ ), and 2011 (quarter 1-4,  $n = 4101, 2577, 1515, 1785$ ). Samples were collected by local fishermen and the Norwegian Coast Guard.