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The Norwegian Fishery for Northern Shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east), 1970-2010

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. Twentyfive vessels reported the use of twin trawls in this period.

Norwegian landings increased from 6 000 t in 2000 to 9 000 t in 2004, but have since decreased. In 2009 5 936 t were landed. Since 2006 there has been a large difference between Skagerrak and the Norwegian Deep, with landings respectively increasing and decreasing in the two areas. Correcting for boiling implies that 300-550 t should be added to the nominal landings for the years 2000-2009.

Landings per unit effort (LPUE) increased from 33 to 93 kg/hour from 2000 to 2007, but have since dropped to 52 kg/hour in 2009. Standardised LPUE values calculated for 2000-2008 follow the same trend. Again, there was a large difference between Skagerrak and the Norwegian Deep since 2006, with LPUE respectively increasing and decreasing in the two areas.

The 2009 catch composition was evaluated using samples from local shrimp fishers.

**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.* 2010): 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.* 2010).

Since 1992 Norway and EU have negotiated quotas on shrimp in the North Sea and Skagerrak. Norway has the largest quota (55%) 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  $\geq 11$  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 vessels have a maximum quota of 45 t in the first period and 35 t in both of the other two periods, as well as a trip-quota of 6 t (tons) for each trip to sea.

The Norwegian fishery is conducted by multi-purpose fishing vessels mainly trawling south of  $60^{\circ}$  N. In 2009, a total of 240 vessels participated in the shrimp fishery south of  $62^{\circ}$  N (Table 1, Fig. 2), a slight reduction from 2008 (253 vessels), but higher than in 2007 when 227 vessels participated. 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, resulting in 69 fewer shrimp permits. However, in several instances fishers have condemned vessels  $\geq 11$  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  $\geq 11$  m. However, vessels with permits can be substituted by larger ones, increasing the capacity of the fleet.

In 2009 about 94% 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 2009 catches recorded in logbooks only made up 14.2 and 17.1 % of the respective landings in Divs. IIIa and IVa east. This is a poorer coverage compared with 2008 when catches made up 20.5 and 26.4 % in respectively IIIa and IVa east. The poor coverage is partly due to vessels  $< 11$  m not being required to fill out logbooks. However, logbooks for vessels  $\geq 11$  m are not complete either. For 2009 we have logbook data from 24 vessels, while the landings statistics contain information from at least 120 vessels  $\geq 11$  m.

Two-, three- and four-bridle shrimp trawls are in use by Norwegian shrimp fishers in the Skagerrak and North Sea, the two-bridle one being used most frequently, also in twin trawls. Twin shrimp trawls are common on larger vessels and, according to fisheries organizations, have been used the last eight years. At present twin trawls are used by 40-50 vessels. The extent of this change in gear is, however, not visible in the logbooks, where only 1-2 vessels in 2002-2003, three vessels in 2004-2006, seven vessels in 2007, nine vessels in 2008, and six vessels in 2009 have recorded the use of twin trawl on a regular basis. Other vessels have sporadic records of twin trawls, from 1-8 per year. 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. Furthermore, data on large vessels are lacking in the logbooks as mentioned above. Finally, errors may be produced by the fact that the logbook data provided by the Norwegian Directorate of Fisheries (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 in use.

In the Norwegian fishery for shrimp in this area the minimum mesh is 35 mm. The following restrictions apply: no fishing 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  $62^{\circ}$  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 2009 about 55 % of the total landings were delivered as boiled, fresh large shrimp (140-150 individuals per kg) for the Norwegian and Swedish market, and 45 % of the total as raw (smaller) shrimp for factory processing ashore (mostly 180-250 individuals per kg). The corresponding numbers for 2005 through 2008 were respectively 41, 45, 60, and 47 % boiled and 59, 55, 40, and 53 % raw. In 2006 and 2007 the fishermen obtained approx. 60 NOK/kg for boiled shrimp, and approx. 10 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 prizes have increased to 65 and 75 NOK/kg for boiled shrimp in respectively 2009 and 2010, and 11-12 NOK/kg for raw shrimp.

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 2010 landings were given for August inclusive, while log books were given for July inclusive (incomplete data).

The landings are given per Norwegian statistical area, where area 9 corresponds to ICES Div. IIIa, areas 8 and 28 correspond to Div. IVa east, area 42 to Div. IVa west, and area 41 to Div. IVb. Thus, landings from the Fladen Ground can be identified in the data, while landings from area 41 (Div. IVb) 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 the FiskDir has provided us with landing statistics for the years 2000-2009, 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. From 2009 FiskDir provides landings per statistical location (equivalent to standard "ICES squares": 0.5° lat. by 1° long). These data are not precise and should be used with caution, but they illustrate the spatial distribution of the fishery. Due to the incomplete nature of the Norwegian 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 2004-2009, 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 2000-2009 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).
- 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 9 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) (9.0 % of all recordings). One vessel owner informed that they did record 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  $h^{th}$  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 2000-2010 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 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 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 ( $\geq 20$  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.

Samples (approx. 1.5 kg, 250-400 specimens) for resolving the size, age and stage distribution of the 2009 catches were obtained from four Norwegian shrimp fishers (25 samples) (Fig. 3). The samples were taken from the trawl, frozen, and later sorted to stage by sexual characteristics and measured to the nearest mm below. Earlier, specimen samples or shrimp length measurement data have also been obtained from Coast Guard inspection of Norwegian, Danish, and Swedish shrimp trawlers, but in 2008 and 2009 no Coast Guard personnel had been trained for these duties.

The length distributions were split into age groups by modal analysis by the method of Bhattacharya (1967) (software: FISAT).

In 2007 we started receiving bycatch data from a shrimp vessel trawling in Div. IVa east. The trawl used is a single two-bridle shrimp trawl 2800 with sorting grid and a collection bag. All bycatch is determined to species and weighed. Due to poor fishing, this vessel has not been fishing for shrimp in 2009 or 2010.

## 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 since gradually decreased back to the year 2000 level in 2009. Correcting for boiling implies that 300-550 t should be added to the nominal landings for the years 2000-2009 (Table 2).

Since 2002 landings have been equally divided between Skagerrak (Div. IIIa) and the Norwegian Deep (Div. IVa east), but this pattern changed in 2006 with landings from Skagerrak being 70% higher than the ones from the Norwegian Deep. The difference increased even more in 2007 and since, with Skagerrak landings nearly three times larger than the ones from 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. In 2008 the landings from this area were slightly lower than in 2007, at a total of 5 744 t, and in 2009 even lower at 4 268 t. In the Norwegian Deep landings fluctuated around 3 000 t in the 1990s, increased to around 4 300 t in 2004, and have thereafter steadily decreased to about 1 700 t in 2009 (Fig. 4a, Table 2). Comparisons between the years 2005-2010 show that the decreasing trend in the landings in both Skagerrak and the Norwegian Deep continues in 2010 (accumulated landings January-August for 2005 through 2010: Skagerrak: 2 914, 3 393, 4 030, 4083, 2 879, 1 523 t; Norwegian Deep: 3 416, 2 443, 1 804, 1705, 1 352, 1 189 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, 2007, and 2008 respectively 92, 88, and 80 % of the quota was landed, while in 2009 only 61% of the quota was landed: 5 936 t from a quota of 9 731 t (1 668 t in the Norwegian Deep, and 4 268 t in Skagerrak) (Table 2). The Norwegian quota for 2010 is reduced by 10% from the 2008/2009 quota level.

### *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 2004-2009 contain data on 58 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 2009 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*

As in 2008, most of the recorded effort in 2009 was allocated to waters off Lindesnes and Kragerø (Fig. 8). The waters off Egersund are fished less compared with 2007 and 2008. However, as effort recorded in the logbooks, only makes up a minor portion of the actual effort, the true fishing pattern is different. The estimated number of

fishing hours in 2009 was more than twice as high in Div. IIIa compared with Div. IVa east (87 vs. 40 Khours) (Table 2). Since 2009 FiskDir in addition to logged catch also provides data on landed catch allocated to statistical locations (equivalent to standard “ICES squares”: 0.5° lat. by 1° long). These detailed landing figures also illustrate the spatial extent of the shrimp fishery in IIIa and IVa east (Fig. 9). The estimated effort in the Norwegian Deep decreased from 2005 to 2009 (92 to 40 Khours). In Skagerrak the effort has increased the last two years.

The fishery in 2009 took place in all months (Fig. 10), but was most intense from April to August. Fishing effort thereafter declined throughout autumn and winter. Maximum and minimum effort was recorded in respectively July and November.

After a relatively stable period from 1996 to 2001, with total fishing efforts of around 200 Khours/year, effort declined to 176 Khours in 2003, stabilized, and then declined to 134 Khours in 2007. The decline continued in 2008, to an all time low of 127 Khours/year. This was due to a reduction of effort spent in Div. IVa east (Table 2, Fig. 4c). In 2009 total effort remained at the 2008-level (128 Khours). Standardised effort indices (Table 3) show the same trend as the unstandardised figures.

From 2002-2006 about 75-90 Khours were spent in each of the two areas, this number declined to 72 and 46 Khours in 2008 in respectively IIIa and IVa east. In 2009 effort increased again in IIIa (87 Khours), while the decline continued in IVa east (40 Khours).

#### *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 to 50 kg/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 IVa east, while it increased to a historic maximum in IIIa. The picture was opposite in 2008, with a slight increase in Norwegian Deep and a slight decrease in Skagerrak. In 2009 the LPUE decreased further in Skagerrak, while it remained at the same level in Norwegian Deep.

Standardised LPUE values have been calculated for 2000-2010 (Table 3, Fig. 11), and are seen to follow the same trend as the unstandardised data, except for the last four years in the Norwegian Deep. Here, the standardised value decreases while the unstandardised value increases. The fleet structure and fishery pattern have probably been stable during this relatively short time period, which explains the little difference between standardised and unstandardised values. The 2010 LPUE-index remains at the same level in the Norwegian Deep, while it decreases further in Skagerrak. However, the 2010 data are preliminary.

Due to the incomplete logbooks, it can be questioned whether the LPUE data are representative of the 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 2010), it can be seen that the decrease in the biomass index in 2008-2010 is reflected in the decrease in the overall standardised LPUE (Fig. 11).

The LPUE-data from the smaller trawlers in Skagerrak do not yet provide very much information after only three and a half year of collection. All monthly catch rates have decreased from 2007 to 2010 (Fig. 12), supporting the pattern in the survey biomass index and the standardised LPUE from the Skagerrak logbooks.

#### *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.* 2010), 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 2009, the length frequency distribution of samples of sorted landings had a larger peak for 2-year old shrimp compared with the length frequency distribution of samples of unprocessed catches, which does not make sense. This could be due to samples coming from different locations. The area between the two curves for all shrimp with CL < 15 mm were considered discarded, giving discards of 115 t for Skagerrak in 2009 (Fig. 13). The Norwegian discards are probably mainly made up of non-marketable shrimp, but high-grading cannot be ruled out.

The number of samples from the Norwegian Deep was too low to estimate discards from this area. However, as the catches from IVa east comprise very few 1-year old shrimp, it is probable that discards from this area are very low.

#### *Catch composition*

The length frequency distributions from Divs. IIIa and IVa east for 2009 showed only faint or no discernible peaks for 1-group (stage 2) shrimp in all months (Fig. 14), indicating that recruitment is low in both areas. For the years 2005-2008 a difference in recruitment between the two areas could still be seen (Figs. 15 and 16). This recruitment drop is supported by data from the Norwegian shrimp survey in January-February (Søvik and Thangstad 2010). For all quarters numbers in all age groups were lower in the Norwegian Deep (IVa) than in Skagerrak (IIIa), but in both areas age 2 and 3+ shrimp dominated the catches (Table 4).

#### *Bycatch*

In 2007 about 70% of the catches by weight by the shrimp trawl 2800 with sorting grid consisted of shrimp, in 2008 the figure was 85% (Table 5, Fig. 17). Norway pout was the dominating bycatch species in both years. For 2009 and 2010 no bycatch data were available, since the fisherman normally providing these data has considered catch rates of shrimp to be too low to be profitable.

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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 2009: Number of vessels and total 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	23	50	2.2	1.5	3.6
10-11.99 m	97	980	10.1	5.1	11.3
12-14.99 m	69	1 488	21.6	11.4	23.0
15-20.99 m	27	1 171	43.4	39.0	39.7
21-27.99 m	21	1 920	91.4	95.5	58.2
> 28 m	3	327	109.1	109.7	24.2
Total	240	5 936			



**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 1970-2009.

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	837	3127									
1978	1841	599	2533									
1979	2489	551	3083									
1980	3498	1064	4638									
1981	3753	1430	5188									
1982	3877	1165	5422									
1983	3722	1639	5379									
1984	3509	1274	4783									
1985	4772	1874	6557			460						
1986	4811	1679	6492			338			36			179
1987	5198	3145	8343			634			36			230
1988	3047	4614	7661			645			31			251
1989	3156	3255	6574			920			23			273
1990	3006	3102	6152			990			26			232
1991	3441	2678	6156			376			30			206
1992	4257	2879	7202			414			35			204
1993	4089	3282	7538			695			31			243
1994	4388	2425	6814			157			31			218
1995	5181	2914	8060		8775	212			35			255
1996	5143	2735	7915		8160	253	43	31	37	119	89	214
1997	5460	3105	8572		8160	821	45	39	42	122	80	212
1998	6519	3087	9611		10505	279	45	40	44	144	78	219
1999	3987	2752	6748		10505	486	32	29	32	125	93	219
2000	3556	2562	6116	326	7110	521	33	34	34	114	82	192
2001	2959	3933	6914	374	8140	565	33	34	33	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	5936	428	9731	115	52	46	50	87	40	128
2010	1523	1189	2712		8767							

Data from the Norwegian Directorate of Fisheries.

Data from 2010 are preliminary.

Estimated effort 2000-2009 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.

**Table 3** Standardised LPUE and effort indices from the Norwegian shrimp (*Pandalus borealis*) fishery in Divs. IIIa and IVa east, 2000-2010. The 2010 effort index is calculated using estimated 2010 total landings (based on data until July).

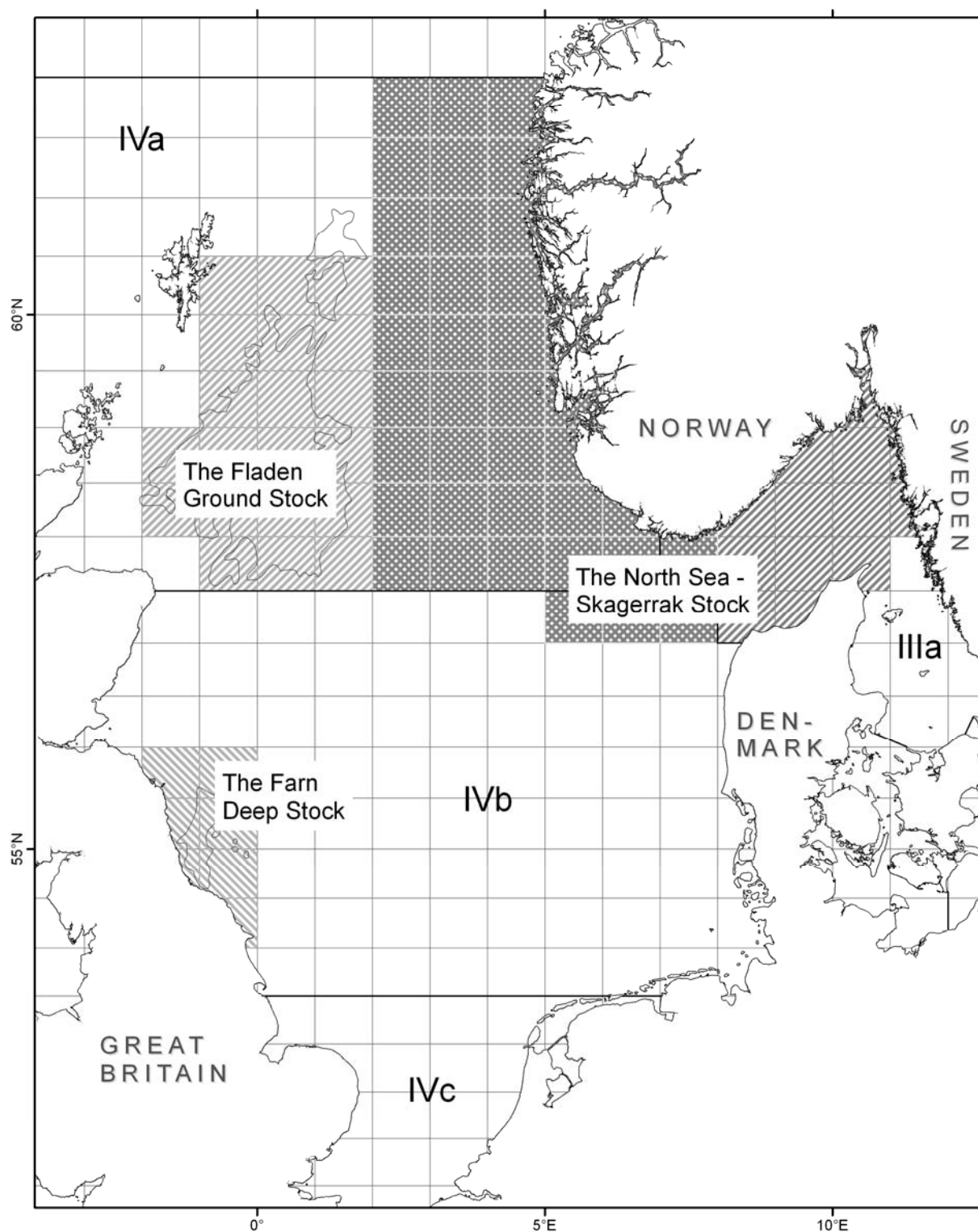
	Stand. LPUE (index)	Stand.effort (index)
2000	1.12	1.34
2001	1.18	1.44
2002	1.46	1.23
2003	1.51	1.27
2004	1.72	1.30
2005	1.60	1.30
2006	1.58	1.28
2007	1.91	1.06
2008	1.84	1.05
2009	1.40	1.06
2010	1.00	1.00

**Table 4** Mean carapace length (with SD), and numbers (millions) in each age class 1, 2, 3/3+, and 4+ in the 2009 catches, per area. Some 1-groups (-) could not be properly identified in the length distributions.

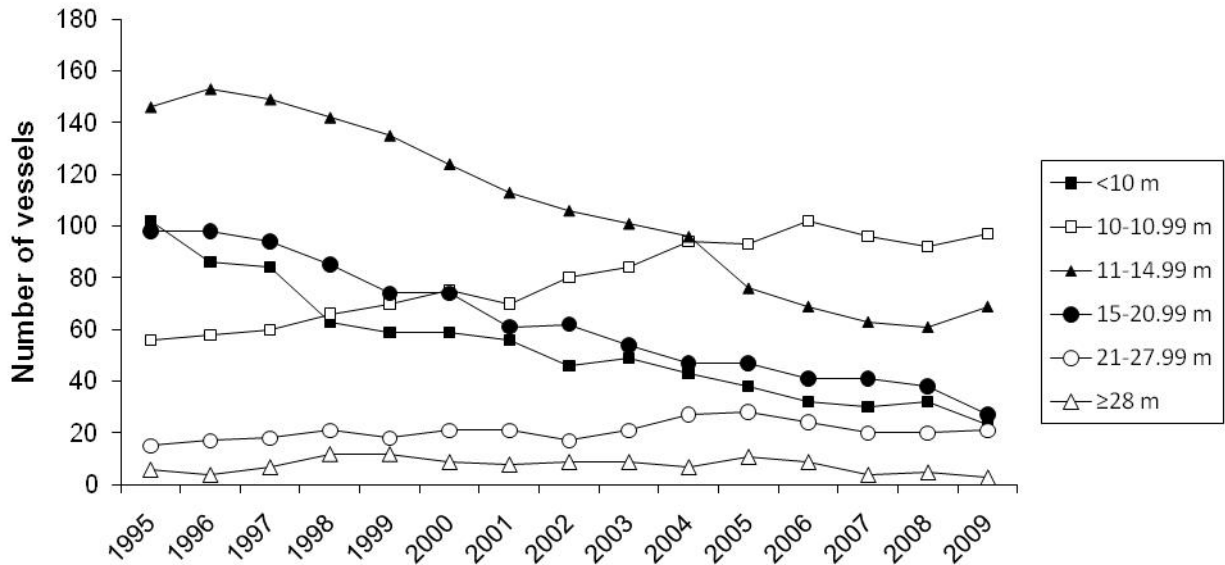
Quarter	Age	Total			Skagerrak			Norwegian Deep		
		Mean	SD	Numbers	Mean	SD	Numbers	Mean	SD	Numbers
1	1	-	-	-	12.91	1.86	6	-	-	-
	2	16.99	1.6	171	17.11	1.47	109	17.36	1.83	61
	3/3+	21.47	1.68	179	21.34	1.51	135	22.22	1.42	38
	4+							25.96	0.64	2
2	1	12.8	0.82	11	12.68	0.73	11			
	2	16.89	1.75	188	16.52	1.71	152	17.5	1.57	46
	3+	21.38	2.06	140	20.28	1.17	84	22.6	1.73	45
3	1	15.83	1.24	29	15.83	1.24	29			
	2	18.37	1.25	85	18.37	1.25	85		no data	
	3+	22.05	1.46	59	22.05	1.46	59			
4	1	13.69	0.93	2	13	0.85	1	14.5	1.35	1
	2	18.53	1.42	106	18.39	1.37	95	19.23	1.15	12
	3+	22.11	1.41	84	21.91	1.34	70	22.57	1.26	14

**Table 5** Bycatch data from a single shrimp vessel fishing in Div. IVa east in 2007 and 2008. No data for 2009 or 2010.

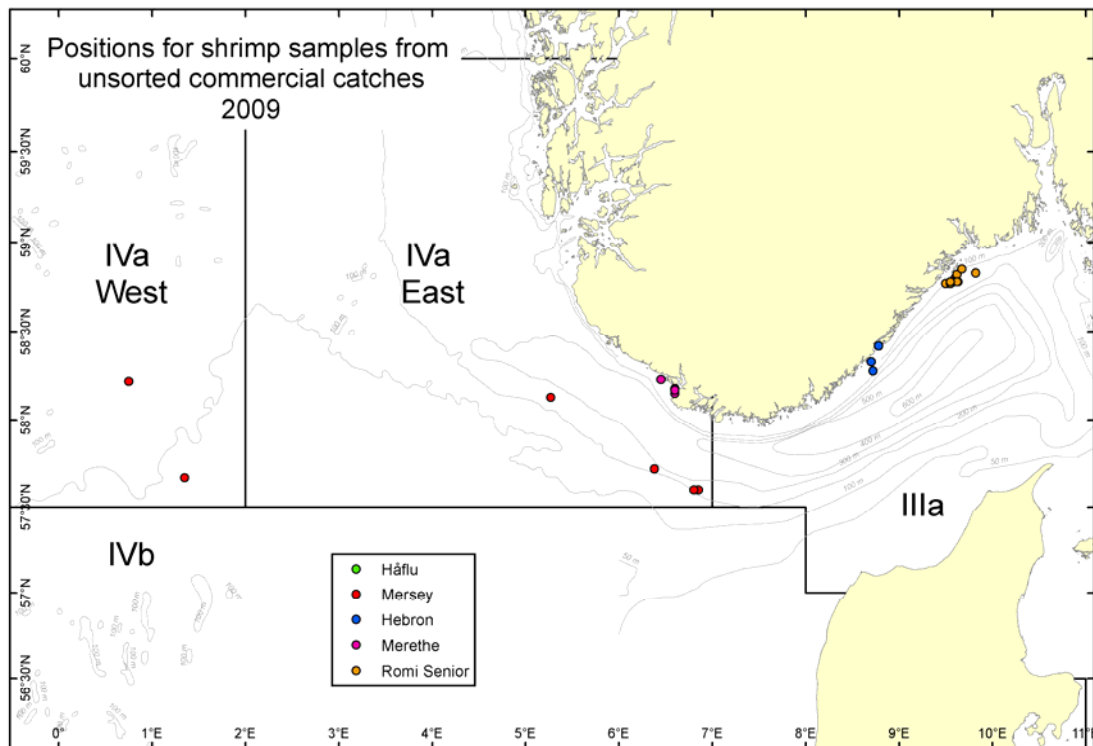
Species	Catches in kg	
	2007	2008
Northern shrimp	4 958	4 449
Blue whiting	470	173
Saithe	350	65
Norway pout	340	-
Cod	213	122
Angler fish	153	-
Velvet belly	135	11
Sculpins	-	140
Lumpsucker	90	26
Ling	50	40
Silvery pout	50	17
Hake	35	16
<i>Pasiphaea</i> shrimps	-	50
Cusk	5	31
Rabbitfish	-	34
Flounders	25	-
Greater argentine	20	-
Atlantic halibut	-	12
Skates	-	9
Roundnose grenadier	-	5
Witch flounder	-	2
Plaice	-	2
Total	6 994	5 204



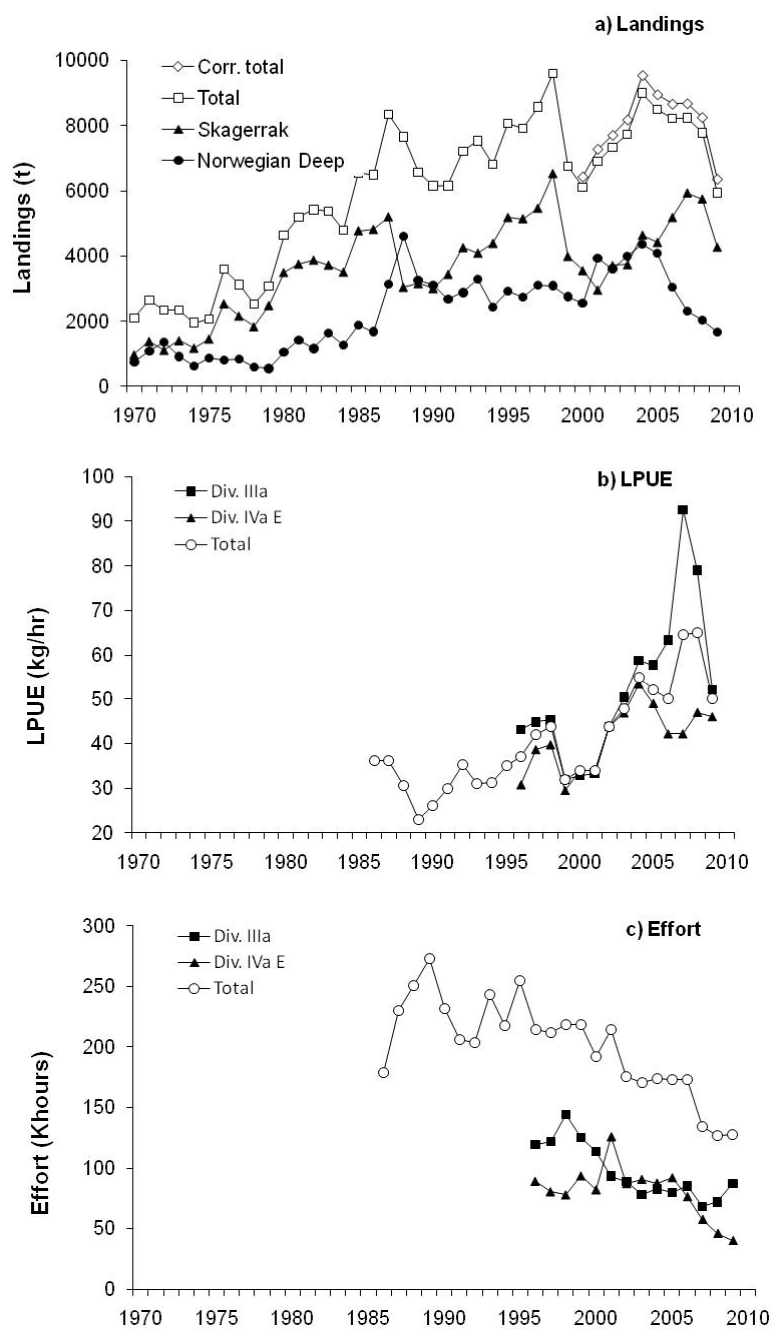
**Figure 1** Distribution of shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea), and the defined assessment units. Grid is standard “ICES squares”: 0.5° lat. by 1° long. (based on Munch-Petersen *et al.* 2010).



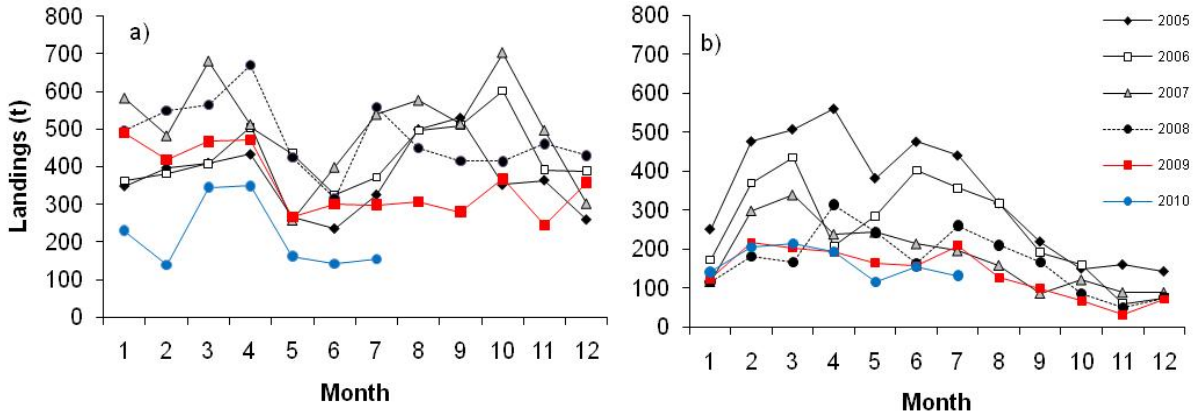
**Figure 2** The Norwegian fleet involved in the fishery for shrimp (*Pandalus borealis*) in ICES Div. IIIa and Subarea IV (Skagerrak and the North Sea) 1995-2009: number of vessels per length group (m). Data from the Norwegian Directorate of Fisheries.



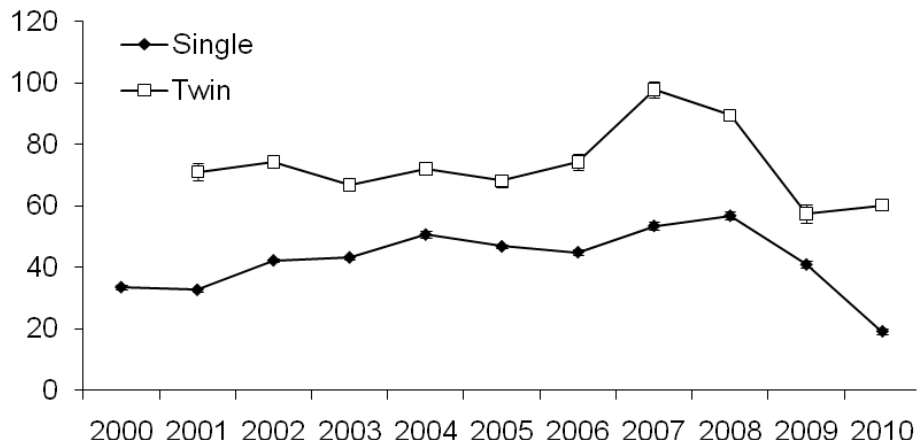
**Figure 3** Positions of shrimp (*Pandalus borealis*) samples from unsorted commercial catches in 2009 in Skagerrak and the North Sea (ICES Div. IIIa and Subarea IV). Samples were collected by local Norwegian fishermen.



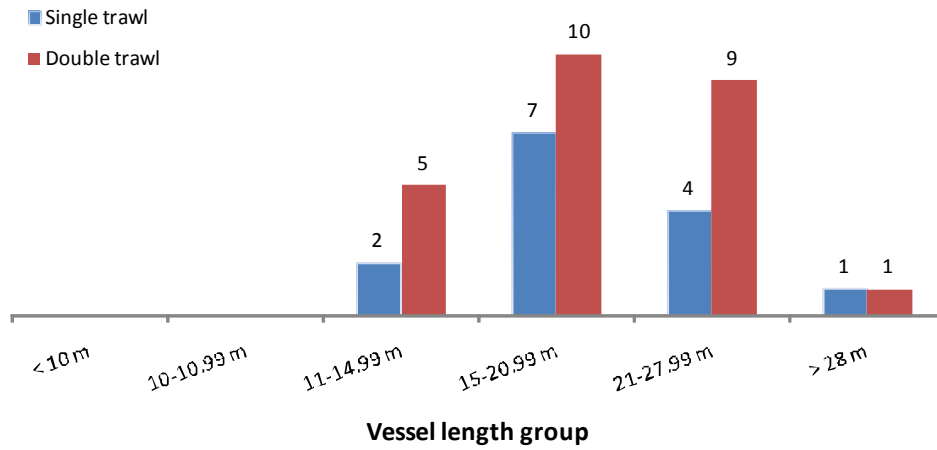
**Figure 4** Landings a) estimated total effort b), and landings per unit effort (LPUE) c) from the Norwegian shrimp (*Pandalus borealis*) fishery in ICES Divs. IIIa and IVa east for all years for which data are available. In a) “total” includes Div. IIIa and all of Subarea IV, and “Corr. total” are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



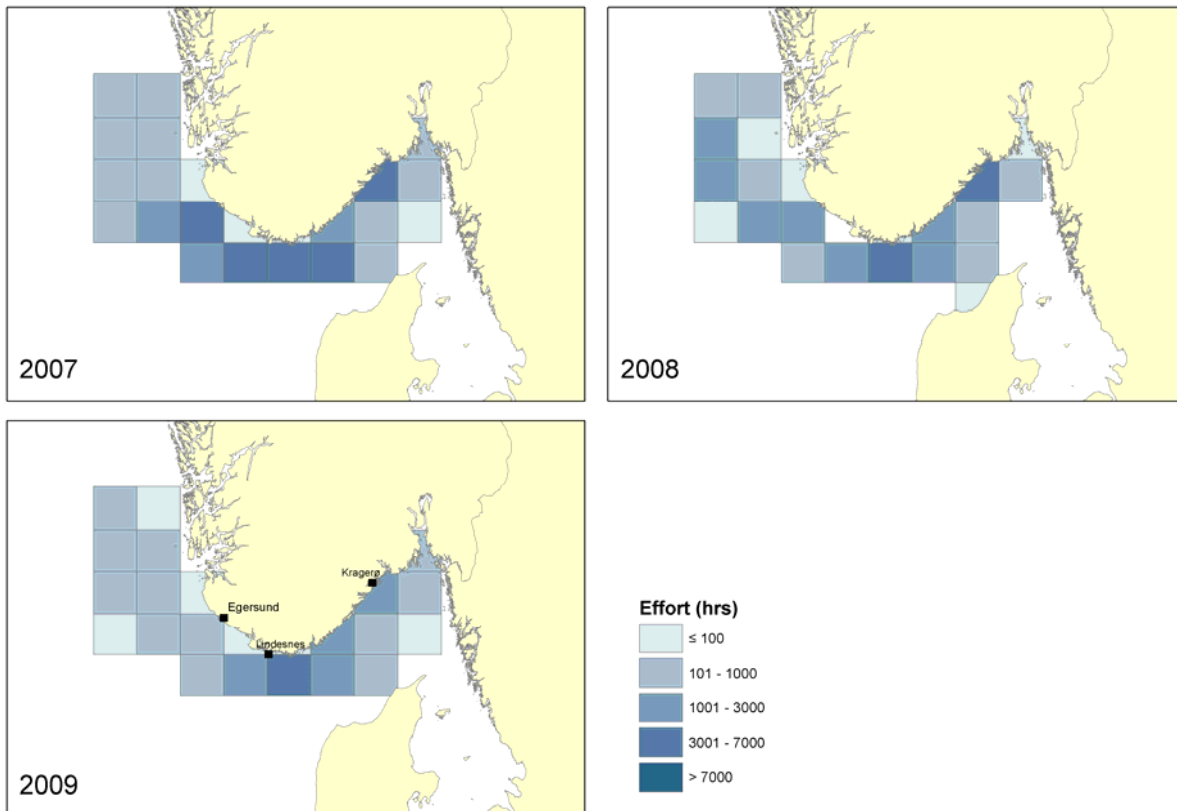
**Figure 5** Monthly landings of shrimp (*Pandalus borealis*) 2005- 2010 (January-August) for a) ICES Div. IIIa (Skagerrak), and b) ICES Div. IVa east (Norwegian Deep). Data from the Norwegian Directorate of Fisheries. 2010 data are preliminary.



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

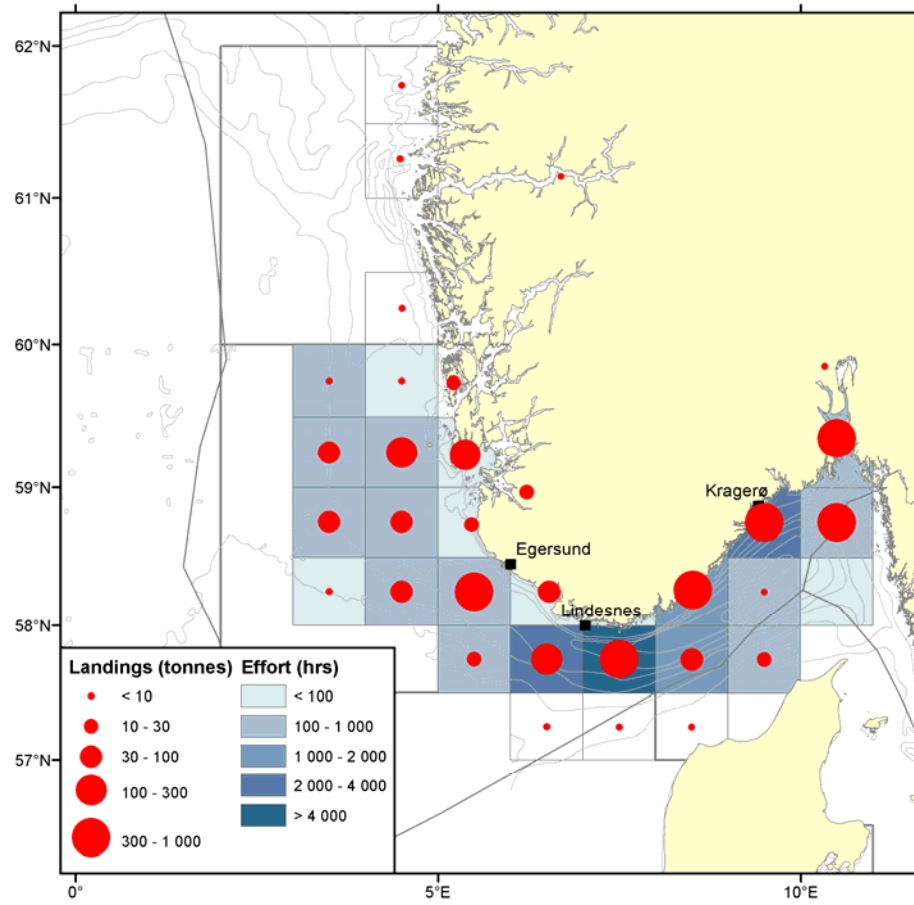


**Figure 7** Gear use by vessel length group. Data from interviews with vessel owners involved in the fishery for shrimp (*Pandalus borealis*) in ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep), 2000-2010. Vessels <11 m are left out since these are not required to report on gear use.

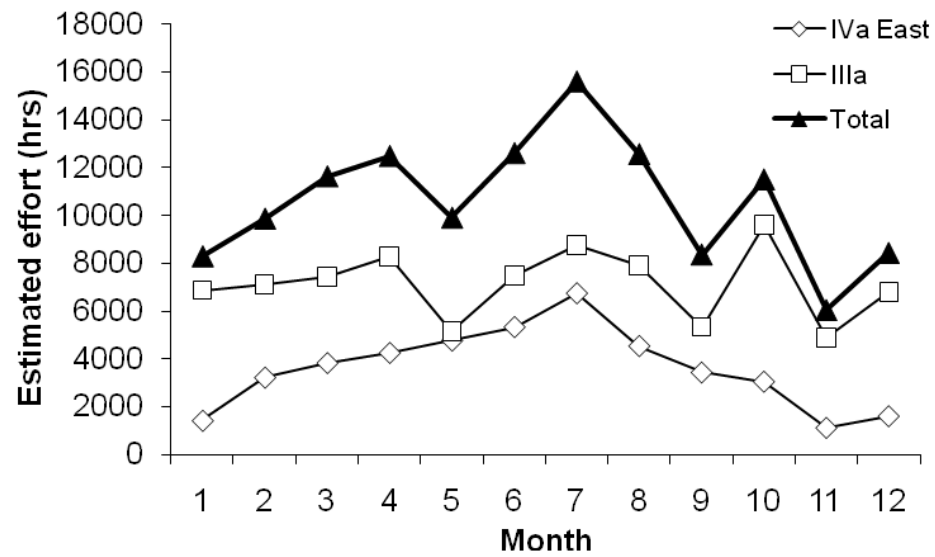


**Figure 8** Geographical distribution of recorded effort (trawling hours) by Norwegian shrimp trawls 2007-2009 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard “ICES squares”: 0.5° lat. by 1° long.). Fishing by both single and twin trawl is included.

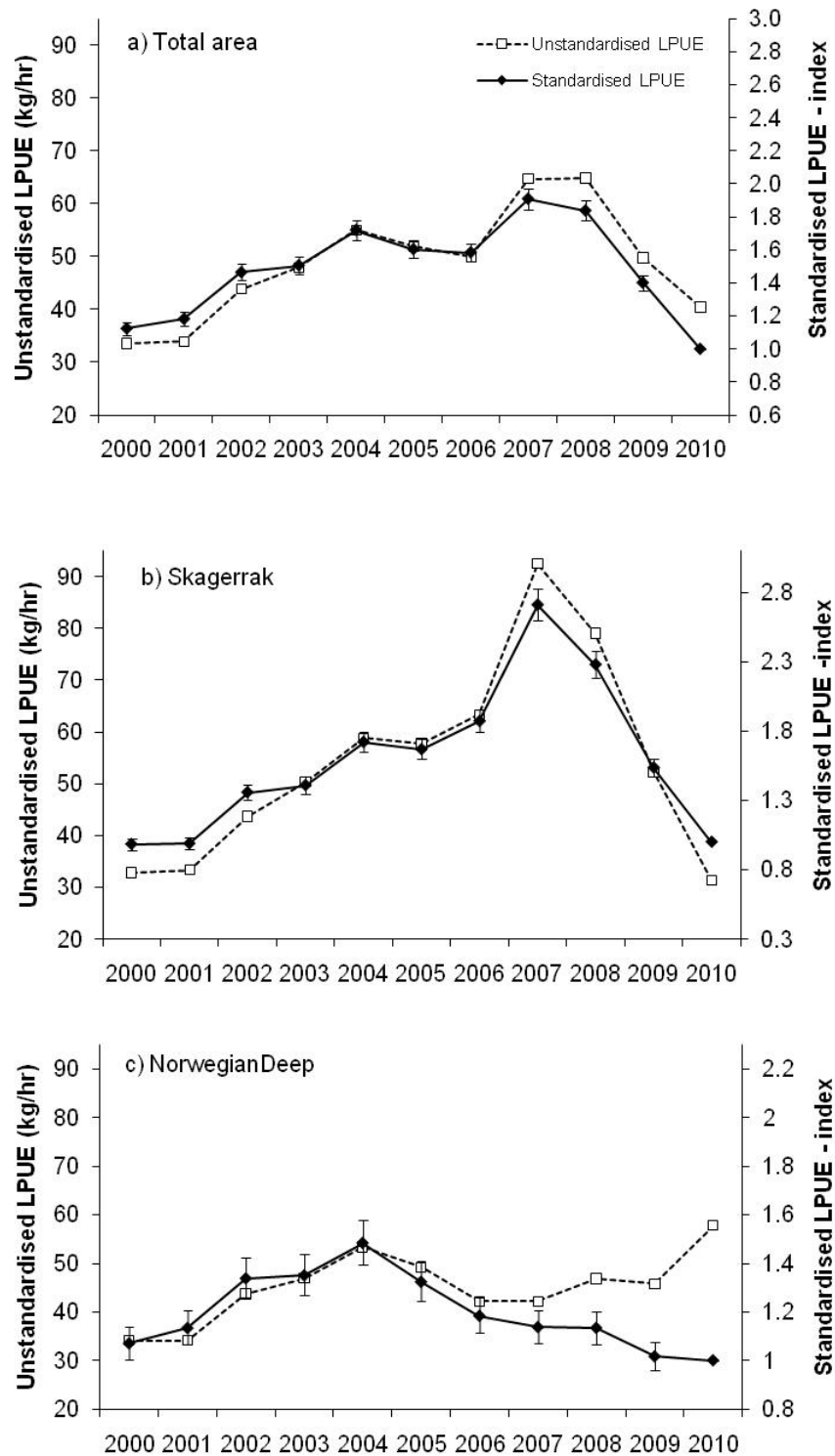




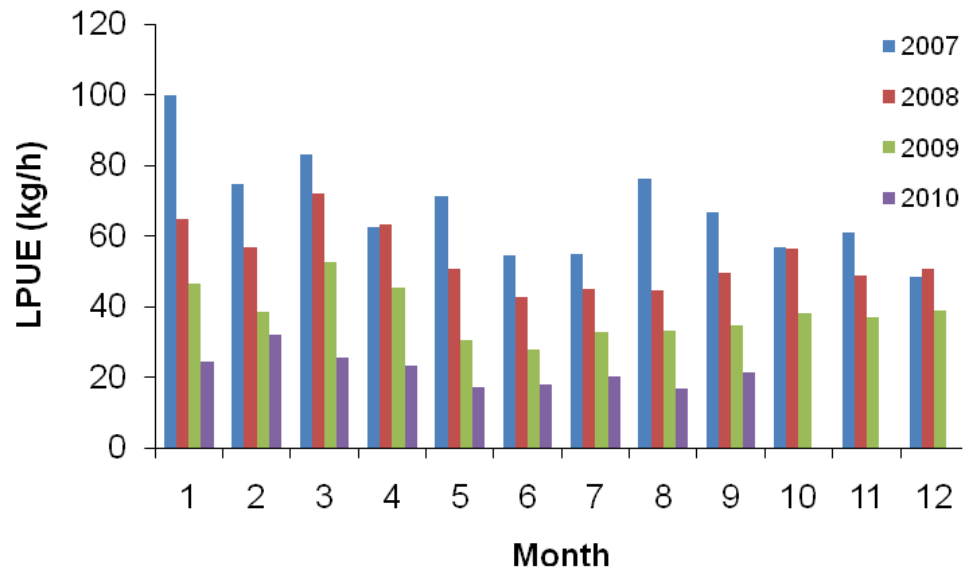
**Figure 9** Geographical distribution of landings (t) and recorded effort (trawling hours) by Norwegian shrimp trawls in 2009 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), by statistical squares (standard “ICES squares”: 0.5° lat. by 1° long.). Fishing by both single and twin trawl is included.



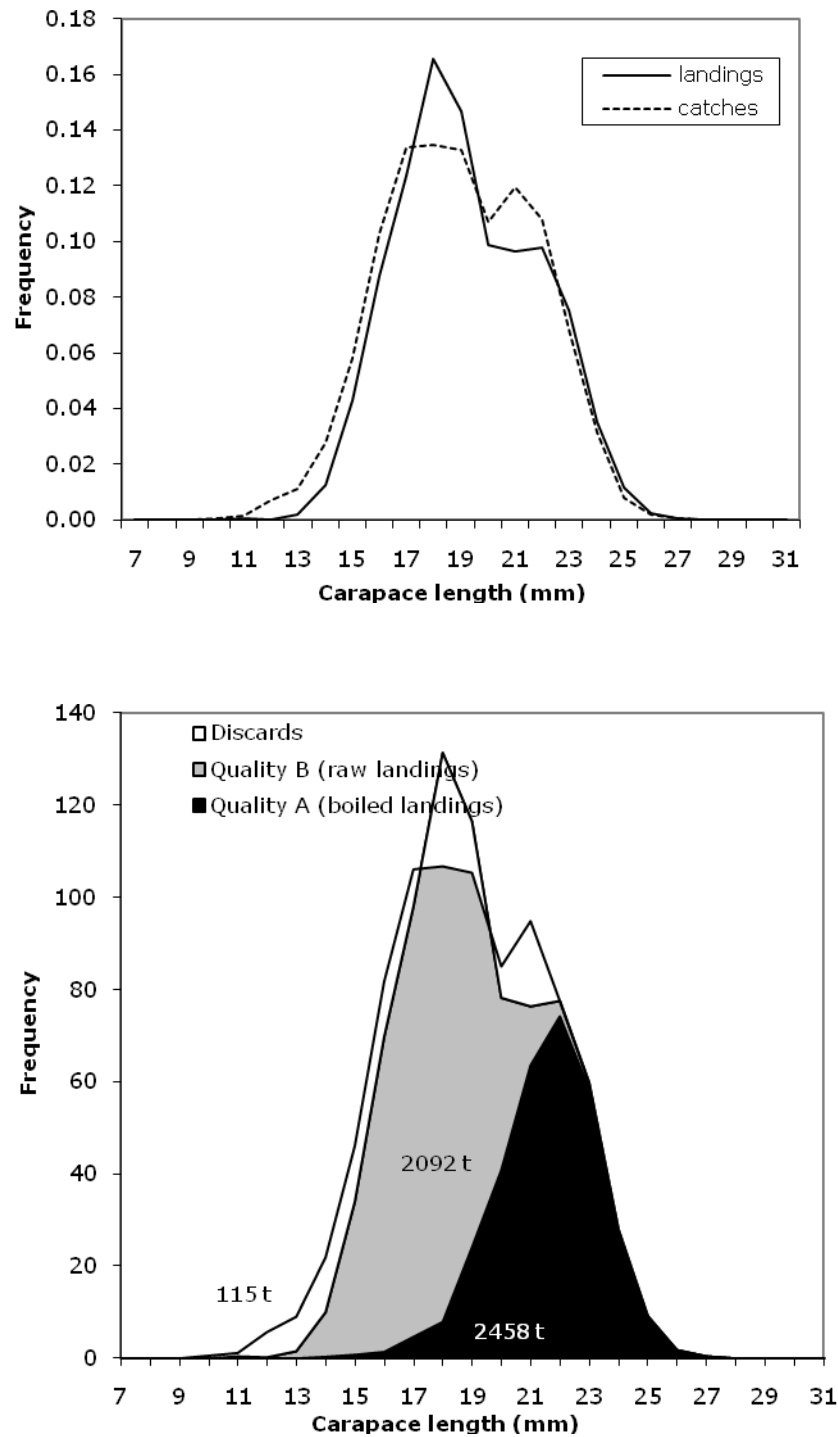
**Figure10** Monthly distribution of estimated total effort (trawling hours) by Norwegian shrimp trawlers in 2009 in Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east).



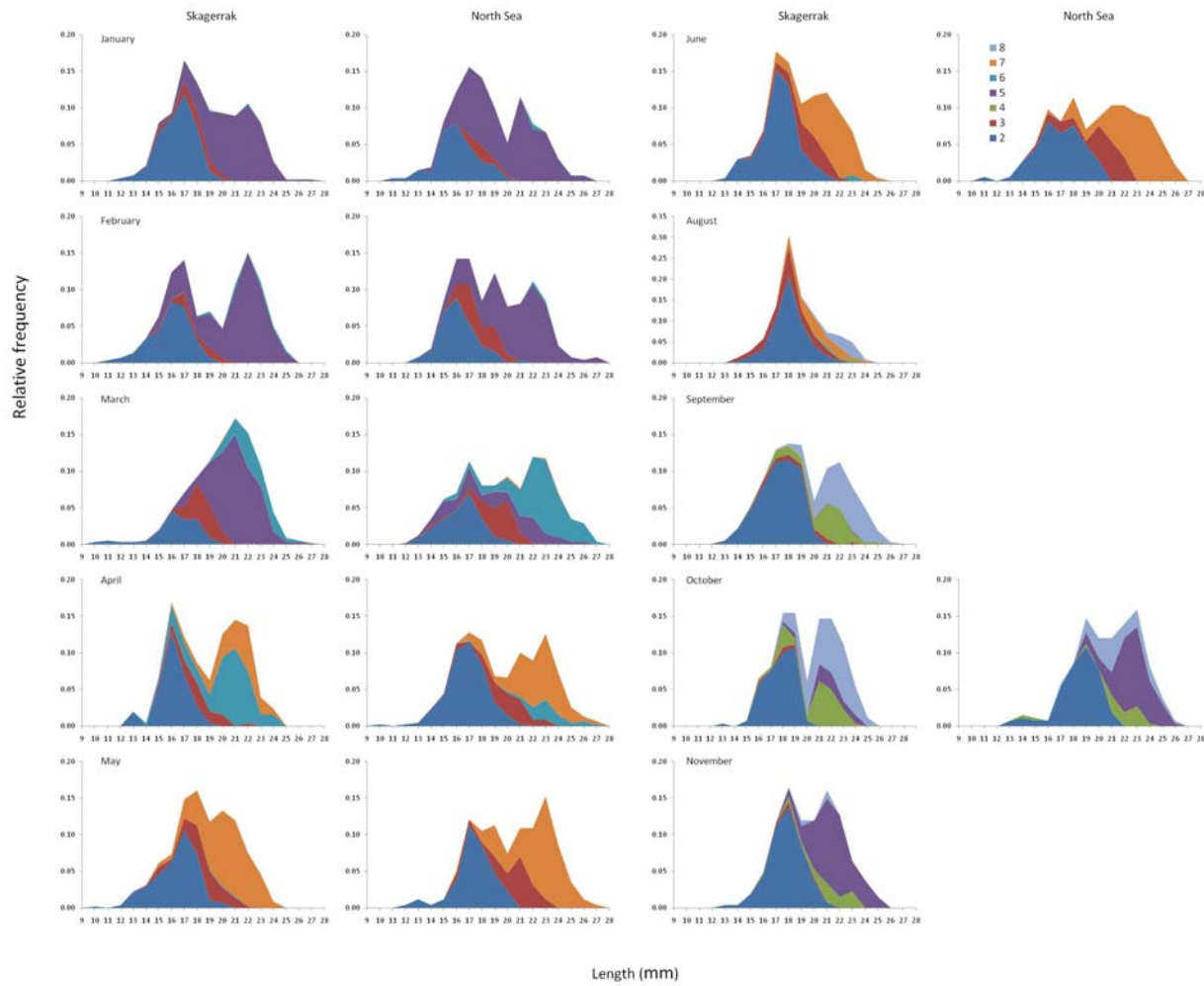
**Figure 11** Standardised LPUE-indices (with standard error), and unstandardised LPUE-values (kg/hour) for 2000-2010 from the Norwegian shrimp (*Pandalus borealis*) fishery in a) both Skagerrak and the Norwegian Deep (ICES Divs. IIIa and IVa east), b) Skagerrak, and c) the Norwegian Deep. Data from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



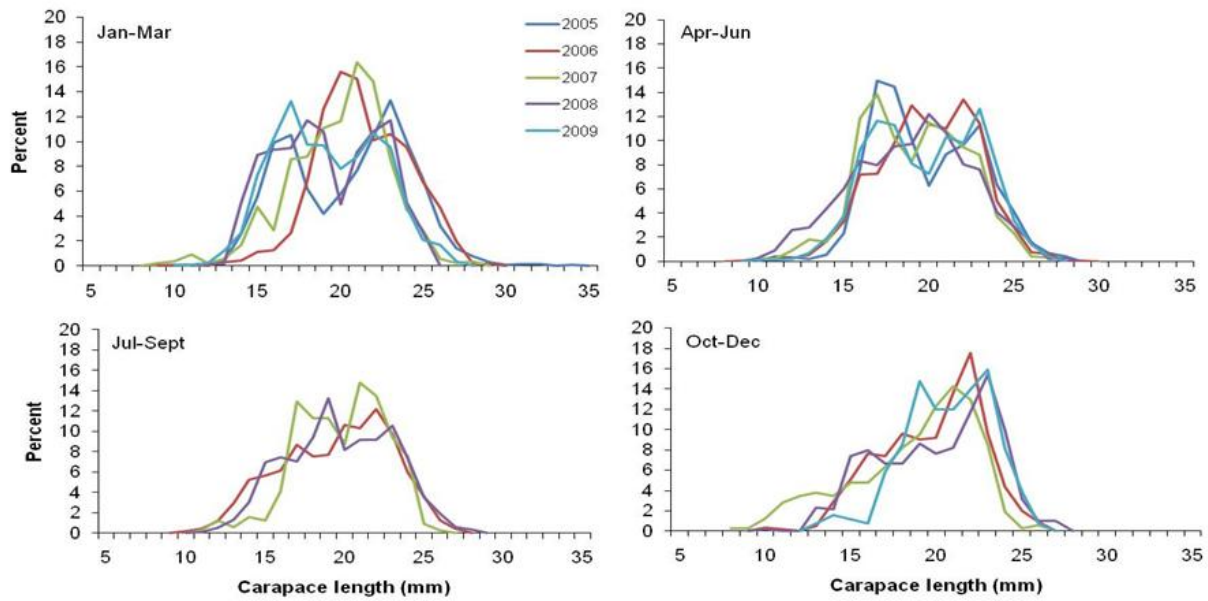
**Figure 12** Landings per unit effort calculated from logbook information from four smaller (10-12 m) shrimp trawlers, 2007-2010 (until August).



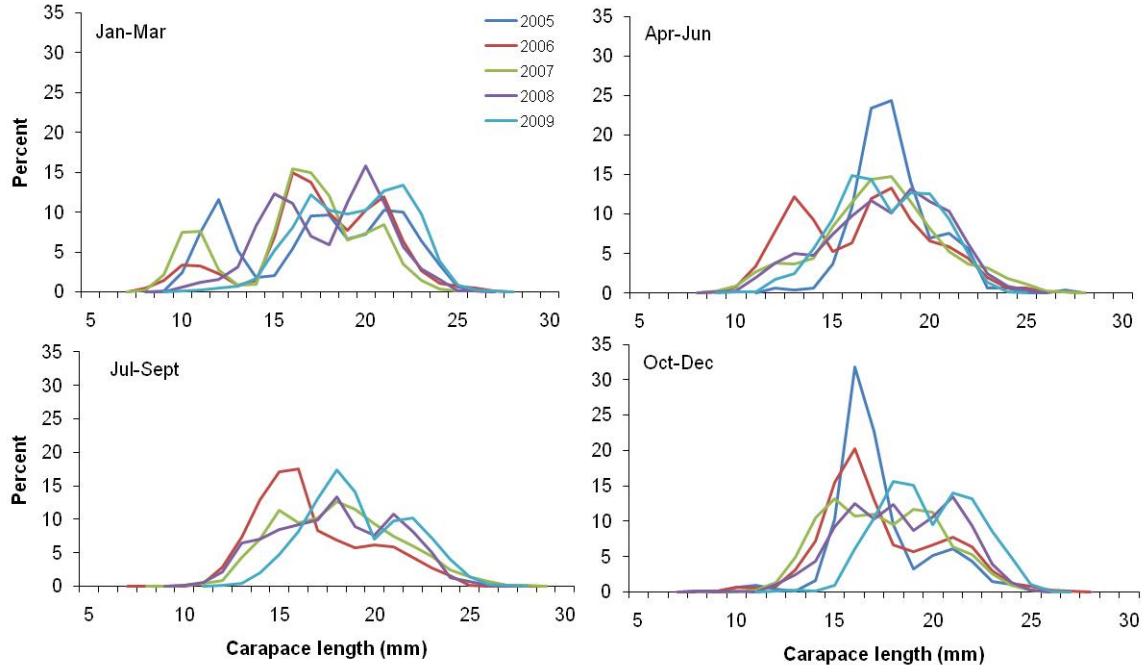
**Figure 13** a) Norwegian 2009 length frequency distributions from unsorted commercial catches and sorted landings from Skagerrak adjusted to each other for CL > 21 mm, and b) size distribution of Norwegian Skagerrak landings, separated into boiled and raw shrimps, and estimated discards.



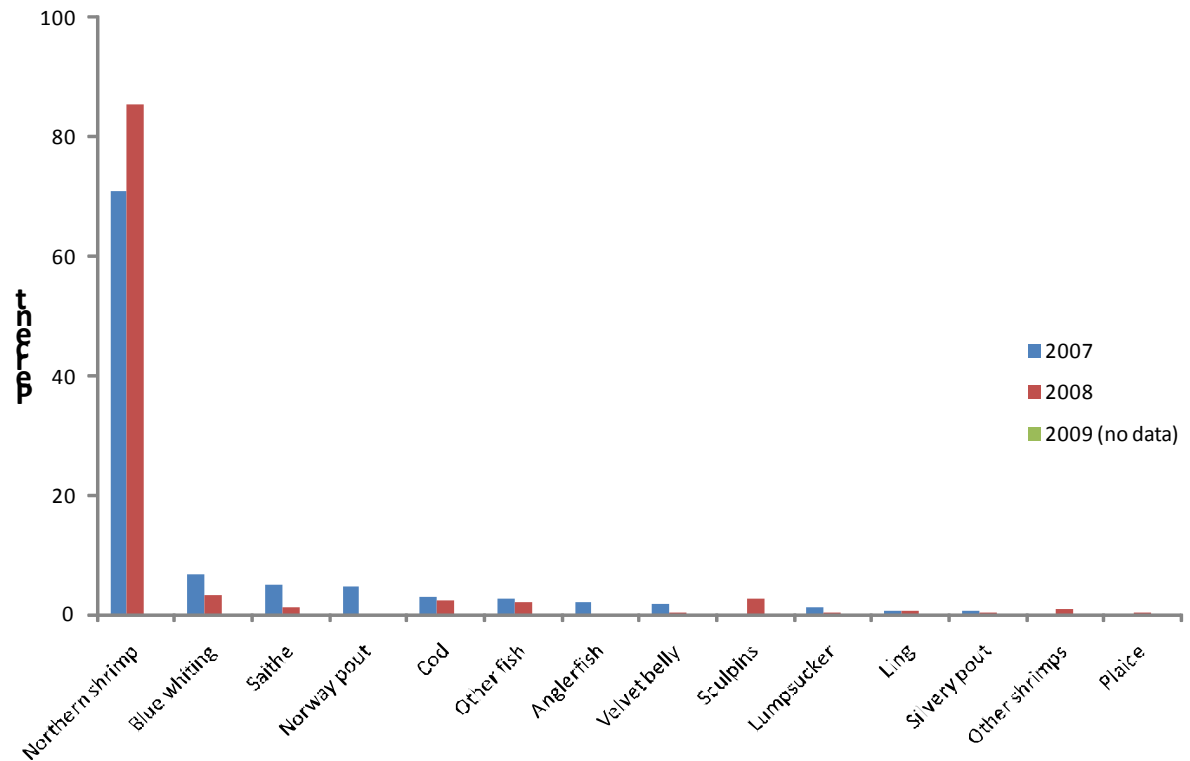
**Figure 14** Monthly stage based relative length frequency distributions of shrimp (*Pandalus borealis*) from unsorted commercial catches in 2009 from ICES Divs. IIIa and IVa east (Skagerrak and the Norwegian Deep). Samples were collected by local fishermen. Stages: 2 = males; 3 = transitional; 4 = ripe gonads, first time spawner; 5 = berried; 6 = breeding dress; 7 = resting stage; 8 = ripe gonads, second time spawner. Sample sizes per month for Skagerrak (Jan-Jun, Aug-Dec): 528, 299, 552, 255, 587, 265, 247, 908, 259, 268, 237; and Norwegian Deep (Jan-Jun, Oct): 269, 260, 485, 470, 257, 184, 258.



**Figure 15** 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,  $n = 548, 1507, 1367, 512$ ), and 2009 (quarter 1-2, 4,  $n = 1014, 911, 258$ ). Samples were collected by local fishermen.



**Figure 16** 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,  $n = 1691, 1188, 1186, 1510$ ), and 2009 (quarter 1-4,  $n = 1379, 1107, 1155, 764$ ). Samples were collected by local fishermen.



**Figure 17** Percentage bycatch by species from a single shrimp vessel fishing in Div. IVa east in 2007 and 2008. The vessel has not fished for shrimp in 2009 or 2010.