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**The Northern shrimp (*Pandalus borealis*) Stock in Skagerrak and the Norwegian Deep
(ICES Divisions IIIa and IVa East)**

by

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Abstract

This paper presents the Danish, Swedish, and Norwegian fisheries data used in the annual assessment of the shrimp stock in Skagerrak and the Norwegian Deep. Long term fluctuations/trends in landings and trends in national LPUE's are presented and described. Increasing gear efficiency has been taken into account in analyses of the Danish and Norwegian LPUE. Estimation of Swedish discards due to high grading indicates that a significant amount of the catches are discarded. Estimates of Danish and Norwegian discards are also presented. Age compositions of the annual landings since 1985 are presented. A short overview of the Fladen Ground shrimp fishery is presented.

1 The *Pandalus borealis* stock in Skagerrak and the Norwegian Deep

1.1 The *Pandalus* fisheries in the North Sea and Skagerrak

In the North Sea and Skagerrak three geographically separated aggregations of the northern shrimp (*Pandalus borealis*) are recognised and assessed as three separate stocks (ICES, 1990): 1) the Norwegian Deep-Skagerrak stock which is confined to ICES Divs. IVa east and IIIa, 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 Denmark, Sweden, Norway and UK exploit these resources. The Fladen ground stock has been exploited by Danish and UK (Scottish) vessels. In recent years only the stock in the Norwegian Deep and Skagerrak has been exploited.

1.1.1 The Danish *Pandalus* fishery.

Historically, the Danish *Pandalus* fishery has targeted both the shrimp stock in Divs. IVa east and IIIa and the stock on Fladen Ground. In the period 1994 to 1999 the fisheries in the two areas were of about the same size, but since 2000 the Fladen fishery has declined and came to a stop during 2004. Virtually no shrimp landings have been recorded from Fladen since 2004 (Sect. 4). At present, all Danish shrimp landings come from IVa east and IIIa. During recent years an increasing amount of Danish shrimp catches have been landed in Swedish west coast fishing ports. Minor amounts have also been landed in Norwegian ports. In 2005–2007, 19–27% of total Danish shrimp landings were landed in Swedish ports. In 2008 and 2009 the amount decreased to around 10%. Since 'at sea' boiled shrimps fetch better prices and the demand in Sweden for this product traditionally has been high, an increasing number of Danish vessels land boiled shrimp in Sweden. The majority of the Danish catches are, however, still landed in Danish fishing ports unprocessed. Most of these shrimp are landed directly to a few large factories processing almost all sizes of shrimp.

New analyses for the period 1987 to 2009 of the Danish log book data on catch and corresponding effort, vessel size from the vessel register, and economical data of landings on single trip basis have been made. Results show that the number of vessels participating in the *Pandalus* fishery has decreased from 191 vessels in 1987 to only 11 vessels in 2009. Fig. 2 shows the development from 1987 to 2009. It is the smaller vessels which have left the *Pandalus* fishery, and the average vessel size has increased from 20 to 26 m in the period and average horse power from 415 to around 700 (Fig. 2).

Gear development in the Danish shrimp fishery and its influence on effort.

The technological improvements of the fishing fleet and its implication for the effective effort has been described in SCR Doc. 08/75. The effective effort by vessels has increased considerably. Following this development the nominal LPUE is standardised accordingly. The difference between standardised LPUE and the logbook recorded LPUE for the period 1987-2009 is shown in Fig. 7.

1.1.2 The Norwegian *Pandalus* fishery (SCR Doc. 10/62)

1.1.3 The Swedish *Pandalus* fishery

In 2009, a total of about 75 trawlers reported landings of *Pandalus* in the Swedish log books. Of these, 45 landed more than 10 t *Pandalus* and can be considered specialised in this fishery.

The size of the vessels ranges between 11-34 m with an average of 21 m. GRT varies from 17 to 260, with an average of 100 GRT. The average engine effect is around 378 kW (92-736 kW). The larger trawlers are normally fishing in the eastern and central part of Skagerrak. The smaller trawlers are mostly fishing in the Swedish coastal zone inside a 'trawling border' where special regulations apply for the use of trawls: Trawling is in these areas restricted to waters deeper than 60 m and there are special limits in the length of ground rope and in the size of the trawl and trawl doors. Furthermore, the trawls to be used inside this border must be equipped with a species selective Nordmøre grid of 19 mm bar space and an unblocked fish opening in the trawl roof. This has resulted in very clean landings from these trawls (99% *Pandalus*). The Nordmøre grid may also be used outside the trawling border as an alternative to the EU legislated 70 mm square mesh panel in shrimp trawls. There is a suggestion that grid should be legislated in EU council regulation in all shrimp fisheries in Skagerrak and the North Sea from 2010.

This particular *Pandalus* trawl with grid can be distinguished from other shrimp trawls in the log books back to 1997. The effort of this gear has shown an increasing trend, and in 2008 constituted 52% (36 khrs) of total Swedish *Pandalus* effort (71 khrs).

The Swedish specialized shrimp fleet (≥ 10 t/yr) has consisted of around 40-50 vessels for a long time according to log books and there has not been any major change in trawl size or trawl design according to the Swedish net manufacturer. In Sweden the use of twin trawls in the *Pandalus* fishery is not yet common. During the last four years the number of twin trawlers has increased from 5 to 13. These vessels have 50- 80% higher catch rate compared with vessels using single trawls (Fig. 3). In 2009, the 11 shrimp trawlers using twin trawls caught 26% of the Swedish *Pandalus* landings. Swedish *Pandalus* landings (1990-2009) by trawl gear are given in Fig. 4.

The TACs are limiting the Swedish *Pandalus* fishery and in order to distribute landings over the year the fishers have voluntarily introduced rations per fisher per week. This has resulted in high-grading of the catch, i.e. discarding less valuable smaller *Pandalus* (16% of the price of boiled shrimp) to increase the proportion of the more valuable boiled shrimp in the individual landings ration. The discard due to high grading of small *Pandalus* was in 2009 estimated to around 671 t based on comparison of the length distributions in the Swedish and Danish landings. According to the Swedish fishers, last year's estimate of 2000t is unrealistic and it is probably an overestimation as the Swedish fishery tries to avoid areas with known smaller shrimp size compositions, which is not the case in the Danish fishery where the quota is not restricting the landings. There is also an increasing number of Swedish vessels voluntarily using 45 mm mesh size (instead of the legislated minimum of 35 mm) to avoid catching small shrimp.

During the years 1963 to 1983 the Swedish National Board of Fisheries conducted an inquire investigation to on average 190 shrimp trawling trips per year. The inquire gives information of kg landed and discarded shrimps, trawling duration, location, trawl size, etc. The information on yearly lpue has then been used to estimate the total Swedish un-standardized effort given the total landings. Corresponding information on effort and lpue for 1984 to 2009 comes from the logbooks (Figs. 5 and 6).

There are two different Swedish markets for *Pandalus*, resulting in two different kinds of landings: high valuable large shrimps boiled onboard and smaller low value shrimps landed raw to the industry for further processing. The shrimps are sorted twice, firstly by a sieve of 10 mm bar space meaning an L50 of approximately 20 mm carapace length and secondly by a 7.5-8 mm sieve to get the low quality part. Shrimps going through the 7.5 mm sieve are discarded. The high quality sizes are thus 3+ age group (females) and the low quality sizes < 20 mm CL are mainly males less than 3 years old. The long term trends with un-standardised effort for these categories are shown in Figs. 7a and 7 b.

1.2 Landings, catch and effort data (IVa East and IIIa)

1.2.1 Landings

Landings, as officially reported to ICES, are shown in Table 1 by area (Division IIIa and Sub-area IV). In Skagerrak the landings for 2009 decreased by almost 2000 t compared to 2008, mainly due to a decrease in Norwegian landings. In Sub-area IV landings have decreased since 1995 and 2009 landings are the lowest in 35 years. , Table 2 presents the landings and estimated catch for the assessment unit ‘Skagerrak and the Norwegian Deep’ (ICES Div. IIIa and Div. IVa East). Total landings in 2009 were around 11000 t, which is 2000 tons less than in 2008.

Landings from Norway and Sweden (and to a lesser extent from Denmark, see Sect. 1.1.1) consist of a fraction of larger shrimp that are boiled on board and a remaining portion of smaller shrimp landed fresh. Official landings and log book data from Norway and Sweden give landed weight as a mixture of raw and boiled shrimp, but these can be separated in Swedish and Norwegian sale slip data. The Swedish and Norwegian landings figures (Table 2) have been corrected with the conversion factor of 1.13 to obtain fresh weight for the years where sufficient information is available. The amount added to the Swedish landings (all years) has ranged between 100 and 200 t, while the amount added to the Norwegian landings for the last ten years has ranged between 320 and 550 t. The Danish landings figures corresponding to boiled shrimps landed in Swedish ports have not yet been corrected. Norwegian and Swedish landings in 2009 consisted of approximately 55% boiled shrimps.

1.2.2 Discards

Discard of shrimp may take place in two ways: 1) as discard of small (<15 mm CL), not marketable shrimp since the processing plants do not accept them, and 2) as a result of high-grading, i.e. discard of medium sized, less valuable shrimp to improve the economic return of quotas.

In Sweden, quota restrictions and the substantial price difference between large, boiled shrimp and medium sized fresh ones together with a voluntary system of weekly rations (different for medium and large shrimp) have resulted in high grading at sea by discarding the medium sized ones (only 14% of kg price for boiled shrimp).

The amount of discards in this category in the Swedish fisheries was estimated to 671 t in 2009 based on comparison of length distributions of Swedish and Danish landings (Figs. 8a and b). The annual Danish length distribution is scaled to fit the yearly Swedish length distribution (Fig. 8a) for the larger *Pandalus* sizes based on the assumption that there is no discarding of the most valuable larger size groups (right hand side of the curve, ≥ 21 mm CL), and that the Swedish and Danish fisheries are conducted on the same *Pandalus* grounds. The higher numbers in the Danish smaller size groups, compared to the Swedish numbers, are then multiplied with the mean weight of each size group, and the sum is considered as the weight of the Swedish discarding due to high grading (Fig. 8b). Estimations based on such Swedish high grading are shown for the last eight years in Table 2.

In 2007 sampling of Norwegian sorted landings were initiated. The length frequency distribution from these samples are compared with the length frequency distribution from the Norwegian catches in the same manner as described

above for the Swedish and Danish distributions. For the 2009 samples the length frequency distribution in the landings had a larger mode for the two year old shrimp than in the catches. This could be due to sampling in different areas. The estimated discard from the Norwegian fishery in Skagerrak in 2009 is 115 t (Fig. 9a and b). Most of the shrimp with $CL \leq 15\text{mm}$ are discarded. There were too few samples from the Norwegian Deep to estimate discards from this area. However, as the catches from the Norwegian Deep comprise very few 1-group shrimp it is likely that discards from this area is low.

Based on discard samples from the Danish at sea sampling programme in 2009 (mainly in Skagerrak) an estimate of around 30 t discard for 2009 has been obtained.

1.2.3 Effort and LPUE

Annual national figures for effort and landings per unit of effort (LPUE) based on logbook records are shown in Table 3 and Fig. 10. Notice that the figures for un-standardised (Danish, Norwegian and Swedish) as well as the standardised LPUEs (Danish and Norwegian) show the same trend since 2005: Increasing LPUEs up to 2007, followed by a decrease until 2009 and for the Norwegian fleet also in 2010. The standardisation of the Danish effort data has taken development both in vessel size and gear into account (SCR Doc. 08/75). From Fig. 10 it is seen that the Swedish un-standardised LPUEs are similar to the Danish standardised. This is explained by the fact that there have been no significant changes in the Swedish shrimp fleet for many years and the vessels are still mainly using single trawls. The information in Norwegian log books from Divs. IIIa and IVa east on the use of trawl gear is not correct. In order to include gear type (single and twin trawl) as a variable in the standardisation of the Norwegian LPUE, the incorrect recordings of gear type in the log books were corrected based on interviews with ship owners (SCR Doc. 10/62). The Norwegian LPUE indices have thus been standardised according to area, month, gear, and vessel for the years 2000-2010. Further information on the Norwegian logbook data is given in SCR Doc. 10/62.

In order to obtain the same effort unit for all three countries, i.e. ‘fishing hours’, the Danish unit ‘fishing days’ was converted to ‘hours’ on basis of functional regressions between Danish-Norwegian and Danish-Swedish LPUE. These two regression coefficients were averaged to get Danish kg/hr as well as the total Danish effort in hours (unit=1000 hours, Table 3). The Norwegian, Swedish and Danish effort and LPUE data were combined to give a time series of total international effort and LPUE (kg per hour) (Fig. 11).

1.3 Biological sampling of landings and catches

1.3.1 Sampling frequency and intensity

Information on the size and subsequently age distribution of the landings are obtained by sampling the landings. The biological samples also provide information on sex distribution and maturity.

National sampling effort is presented in Table 4. The overall sampling level in 2009 was around 12 kg per 1000 t landed or 2700 specimens. An increasing amount of the Danish samples are taken as at-sea samples during fishing trips. In this way samples of discards and information on discarding are also provided. Notice, that in 2009, according to mutual agreement between Denmark and Sweden, some samples from Danish shrimp landings in Sweden have been included in the Swedish samples.

1.3.2 Catches in numbers at age

The length data have been pooled by quarter, and the national quarterly length distributions have then been partitioned into age compositions by the Bhattacharya and Norm Sep methodology (software: FISAT).

Table 5 gives the “catch-at-age” data on an annual basis. Catches are dominated by shrimp of ages 1 and 2. Separation of age group 3 from older groups is often uncertain due to lack of distinct modes in the length distributions. For this *Pandalus* stock the number of distinguishable size groups rarely exceeds 4, and the WG doubts the reliability of separation of the age groups older than age 3.

1.3.3 Mean weights at age

Weights-at-age for the Danish and Norwegian catches were derived from the length samples of the catches, where the weights of the measured shrimp in each sample are recorded by length group (mm CL). The Swedish weight at length figures are derived from individually measured shrimps. The mean weights-at-age in the catches are given in Table 6.

1.4 Trawl survey data (SCR Doc. 10/67)

1.5 Assessment of the *Pandalus* stock in Divisions IIIa and IVa East.

1.5.1 State of Stock in 2009 and 2010

This year's assessment of the current state of stock is based on evaluation of Danish and Norwegian standardised LPUE from the fishery 1987-2009 and survey indices from 2006-2010 and can be found in the 2010 NIPAG report.

1.5.2 Biological Reference Points. MSY evaluation

The view of NIPAG is that the data on the stock-recruitment relationship from previous assessments, did not support establishment of a SSB reference value for this *Pandalus* stock based on this relationship (ICES, 2003). In 1998 ICES (ACFM, 1998) pointed out that there was no basis for establishment of a B_{lim} on basis of the available S-R data. Considering the major impact from predation, such a poor relationship is likely.

According to previous assessments (1985-2002), predation accounts for at least twice as much removal from the *Pandalus* stock compared to fishery removals. Such dynamics also render it problematic to establish a reference value for F (or Y/B), at least if the relative magnitudes of F and M (predation) are independent of stock size.

This year's assessment does not provide basis for MSY evaluation of the stock.

1.5.3 Implementation of a new assessment model.

In order to improve the assessment of this stock a 'state-space' fish stock assessment model (SAM) was presented to the group with focus on the rationale behind using random effects to describe the underlying random variables that are not observed (fishing mortalities and stock sizes). A brief summary of the model, which already has been applied in other ICES WGs, is given below.

SAM is an age structured time series model designed to be an alternative to the (semi-) deterministic procedures (e.g. VPA, Adapt, and XSA) and the fully parametric statistical catch at age models (e.g. SCAA, and SMS). Compared to the deterministic procedures it solves the problem of falsely assuming catches at age are known without errors, and in addition the problem of selecting appropriate so-called 'shrinkage', and in certain cases convergence problems in the final years. Compared to fully parametric statistical catch- at- age models SAM avoids the problem of fishing mortality being restricted to a parametric structure (e.g. multiplicative), and many problems related to having too many model parameters compared to the number of observations (e.g. borderline identification problems, convergence issues, and asymptotic results). In addition, the model has a number of appealing properties. It allows selectivity to gradually evolve during the data period, it allows missing data, and finally it estimates the underlying process noise, which is useful for forward predictions.

Previous implementations of state-space assessment models (Gudmundsson 1987,1994, and Fryer 2001) have been based on the extended Kalman filter, which uses a first order Taylor approximation of the non-linear parts of the model. The current implementation is based on the Laplace approximation which is better suited to handle non-linearities, and further validated by importance sampling. The state-space model has previously been validated at the ICES Methods Working Group by comparing to existing assessments and via simulated data.

SAM is currently used for the following ICES stocks: Kattegat Cod, Western Baltic Cod, Sole in 3A, Eastern Baltic Cod, North Sea Sole, Plaice in 3A, and North Sea Cod. Of these the state-space assessment model is primary for the first three stocks, and included as exploratory for the remaining. In addition to the stocks mentioned above it has been applied to other stocks (Western Baltic spring spawning herring, North Sea Haddock, 3PS Cod, and Georges Bank Yellowtail Flounder) for testing purposes, and has performed well.

A simple web interface (<http://www.stockassessment.org>) to the state-space assessment model was presented. Collaboration at assessment working groups are often reduced to one or two members doing the actual assessment modelling, and remaining working group members reviewing and commenting on the results only. Part of the reason most working group members don't even try to reproduce the assessment, is that it takes a lot of work to get everything set up correctly. Typically several programs (specific versions) need to interact and the data need to be on a specific format. The web interface presented completely removes this obstacle. Once the stock coordinator has set up an assessment, all members can reproduce the assessment and all the resulting graphs and tables simply by logging in and pressing 'run'. The working group members can also experiment with the model configuration and input data and easily compare the results. It would clearly be beneficial to have more hands and eyes on the details of each assessment.

Preliminary implementation of SAM for *Pandalus* was presented, using data from 1987 to 2008. Total catch data is separated into age classes 0, 1, 2, 3, and 4+. Further two tuning fleets (Swedish and Danish) for ages 1, 2, and 3 are used, and a Norwegian TSB survey. The results and model diagnostics showed that catch-at-age data are uncertain, and that the tuning fleets are not corresponding well, which leads to fairly wide confidence intervals on key model outputs (SSB and F). Work leading up to the next benchmark for *Pandalus* will focus on improving these data issues.

2 Genetic investigations of northern shrimp

The working group has recommended genetic investigations to determine if the Norwegian Deep/Skagerrak stock and the Fladen Ground stock comprise one common or two separate stocks.

In 2008 a pilot study was carried out based on one sample from the Norwegian Deep, two samples from fjords on the Swedish west coast, and one sample from the Barents Sea (Bear Island). In 2009 two additional samples have been analyzed, one from the northeast Barents Sea and one from northeast Skagerrak. Seven microsatellite DNA loci were analyzed. During the quality control of the data, two of these seven markers were discarded due to abnormal behavior. Thus, five markers were included in the statistical analysis of the data.

There is a substantial genetic difference between the Barents Sea samples and the samples from the North Sea and Skagerrak (Fig. 12). In addition to the north-south component, there seems to be a less pronounced east-west component.

Two 3-year projects aiming at studying the genetic population structure in all of the North Atlantic with a special emphasis on the North Sea and Skagerrak are now financed by the Norwegian Research Council and EU/Interreg.

3 By-catch in the *Pandalus* fisheries in Subarea IV and Division IIIa

In recent years there has been increasing focus on (mixed) fisheries with by-catches of species subject to recovery plans or under special surveillance. The fisheries for *Pandalus* in the North Sea area cannot be classified as mixed fisheries as for instance some of the fisheries for *Nephrops*. The current by-catch regulations in force for the gears used in the fisheries for *Pandalus* restrict the amounts of by-catch. Nevertheless several valuable fish species, e.g. cod, witch flounder and anglerfish, are landed as by-catch. WGPAND has since the 1980s regularly compiled and presented relevant information on by-catch in the WG reports.

Tables 7 A - F give for the three most recent years the available Danish, Norwegian and Swedish data on by-catch of the main species in the *Pandalus* fisheries landed for human consumption (h.c.) In some years significant quantities of Norway pout and Blue whiting have also been recorded. For Denmark and Sweden the data are from log book records, and are only recorded landings, i.e. not the discarded by-catch. Both the Danish and Swedish log book records cover nearly all the recorded *Pandalus* landings. The Norwegian data come from the landings statistics.

Tables 7 A - F also give cod percentage of *Pandalus* landings. It is believed that this is a better estimator than % of total catch, since log-book recordings probably not always are consistent in recordings of e.g. Norway pout and/or blue whiting. Notice that for Skagerrak the percentages of landed total h.c. by-catch are similar for all 3 countries (excluding trawls with selective grids). Rough estimates give magnitudes of around 500 t of cod landed annually from the *Pandalus* fisheries in this area. Notice that trawls equipped with a selective grid, judging from the logbook records of landings from this gear type, seem to be very efficient in reducing by-catch (Table 7 C).

4 A short note on the *Pandalus* Stocks on Fladen Ground (Division IVa) and Farn Deep (Division IVb)

4.1 The development in the fishery for *Pandalus* on Fladen Ground.

A short description of the fishery is given, as a shrimp fishery may be conducted in this area in the future. Table 8 and Fig. 13 show the shrimp landings from Fladen Ground since 1972. Since 1991 total landings have fluctuated between none in 2006-2009 to nearly 6000 t. The Danish fleet has accounted for the majority of landings while the Scottish fleet stands for a minor part. The fishery has taken place mainly during the first half of the year, with the highest activity in the second quarter. Table 9 shows the effort and LPUE.

Since 1999 total Fladen landings have declined continuously, and since 2004 the Fladen Ground fishery has been practically non-existing with total recorded landings of less than 25 t. Interview information from the fishing industry obtained in 2004 gives the explanation that this decline is caused by low shrimp abundance, low prices on small shrimp characteristic for the Fladen Ground, and high fuel prices. This stock has not been surveyed for several years, and the decline in this fishery could also reflect a decline in the stock.

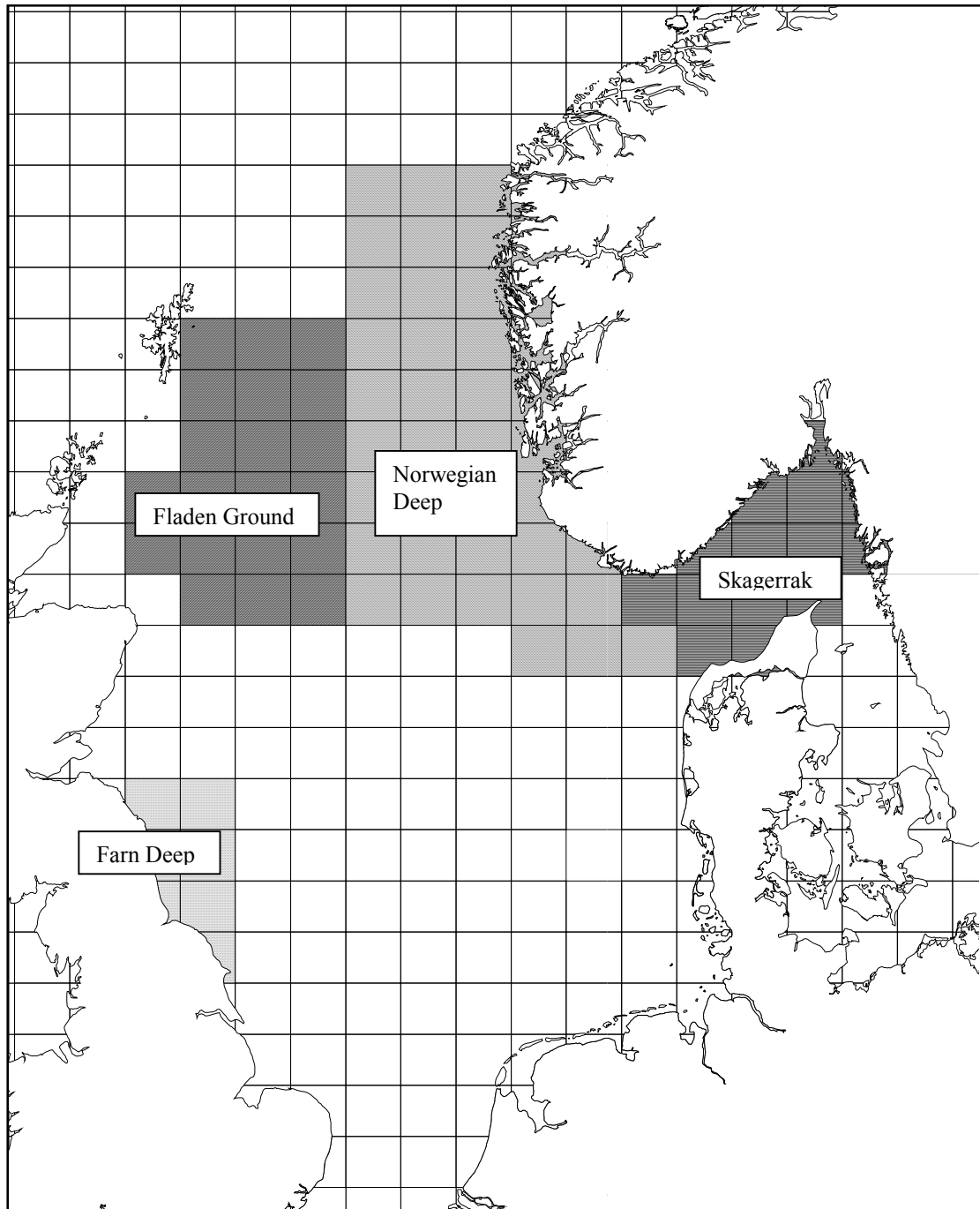
4.2 The *Pandalus* Stock in the Farn Deep (Division IVb)

The WG has not provided advice on this small stock because no catches have been recorded since 1998. Since 1991, only UK vessels have fished *Pandalus* in the Farn Deeps. Total landings fell from 500 t in 1988 to none in 1993. In 1995 and 1996 again about 100 t were reported. In the past 10 years the *Pandalus* fishery in Farn Deeps has been negligible.

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Fig.1. The distribution of the *Pandalus* stocks in the North Sea area as defined by the ICES squares.



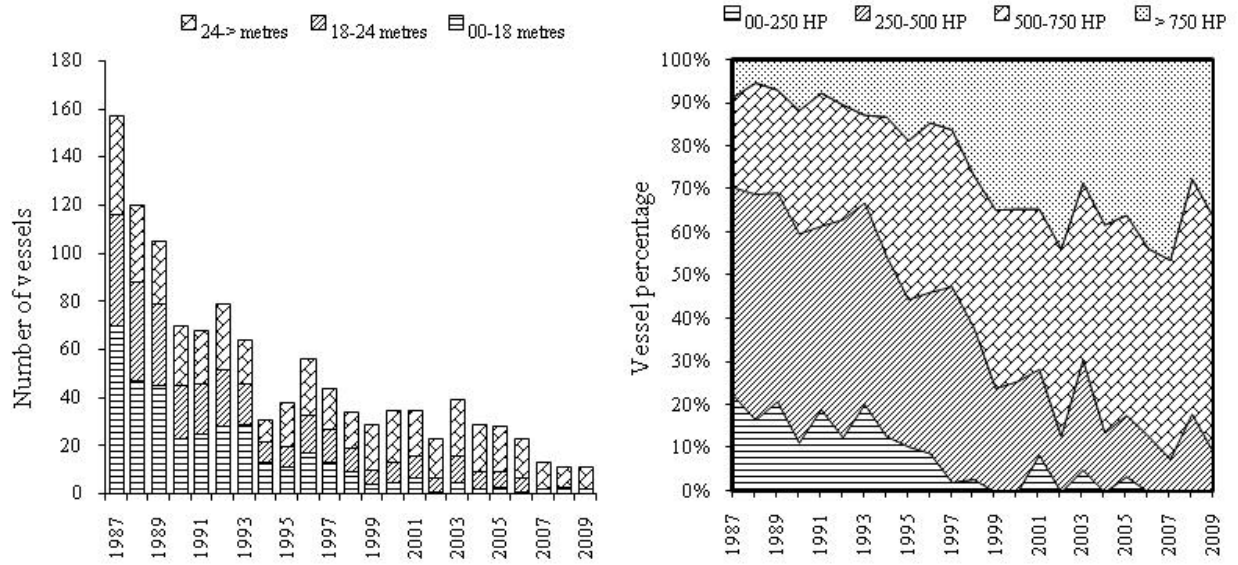


Fig. 2. Trend in numbers (left) and engine power (right) by size groups of Danish *Pandalus* trawlers from 1987 to 2009.

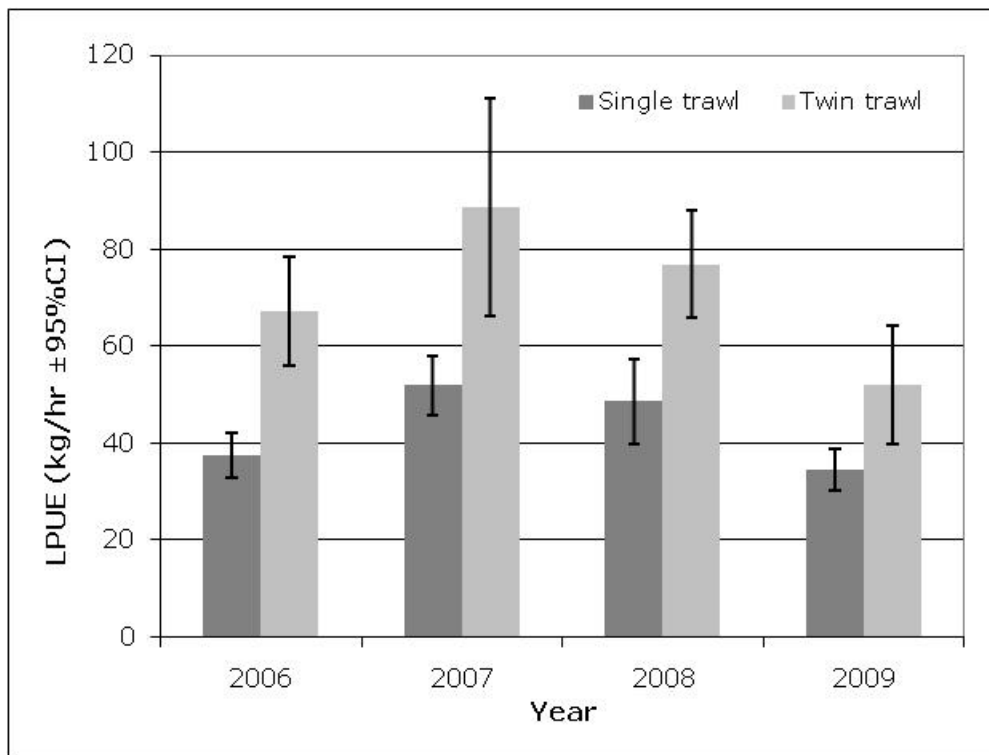


Fig. 3. LPUE for Swedish single and twin trawlers during 2006 - 2009.

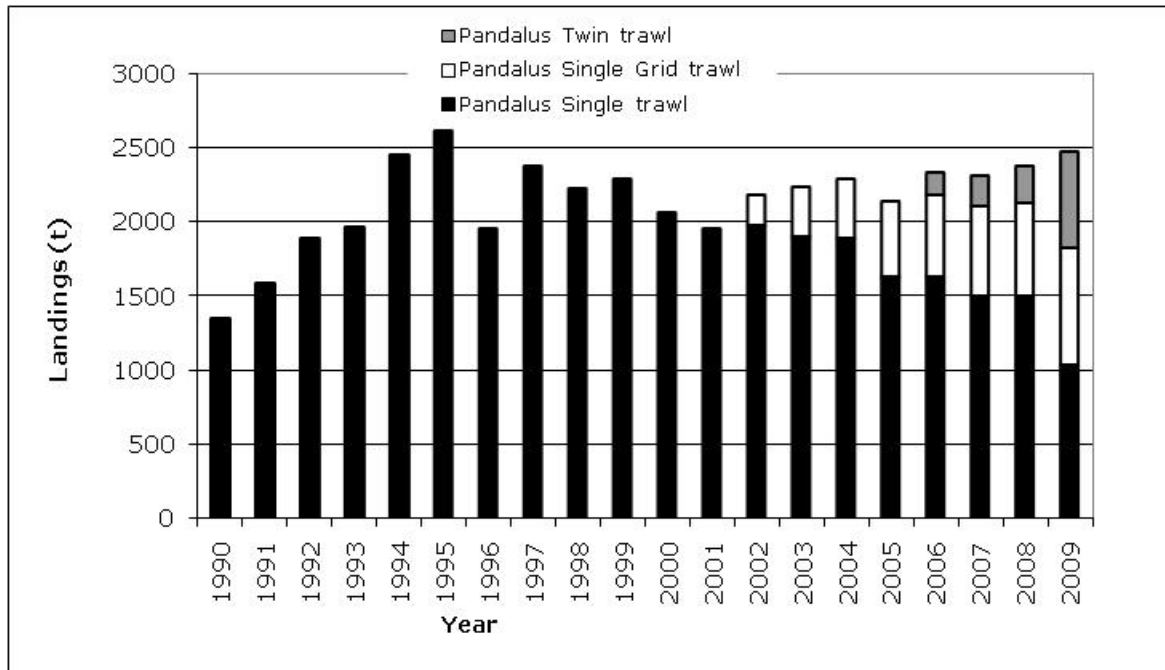


Fig. 4. Swedish *Pandalus* logbook landings per trawl type 1990-2009.

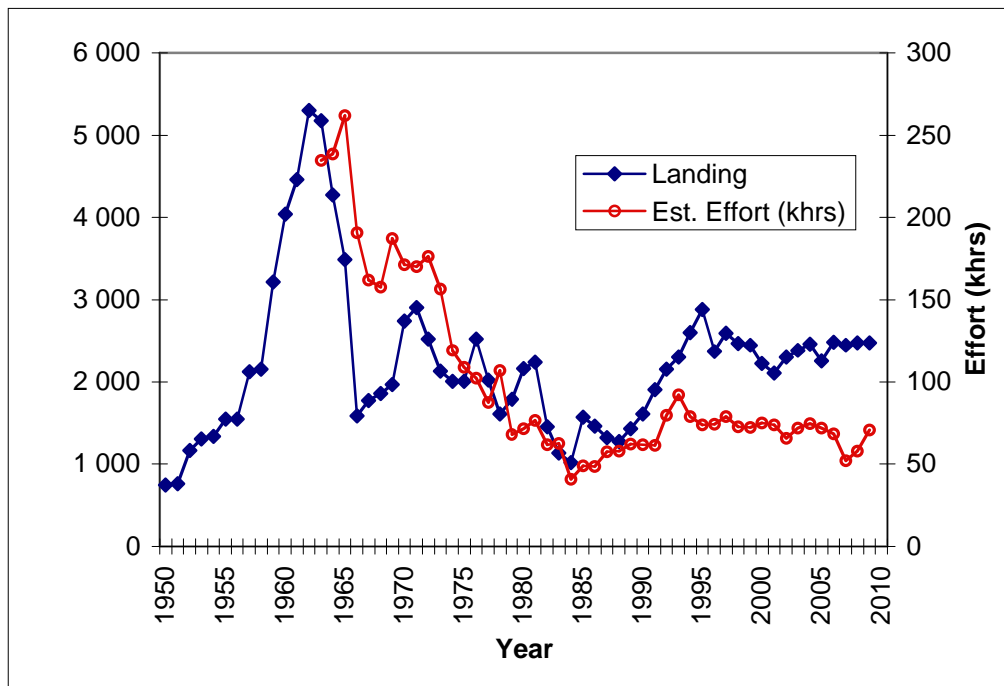


Figure 5. Swedish yearly landings from IIIa and IVa east during 1950 to 2009 and estimated unstandardised effort d

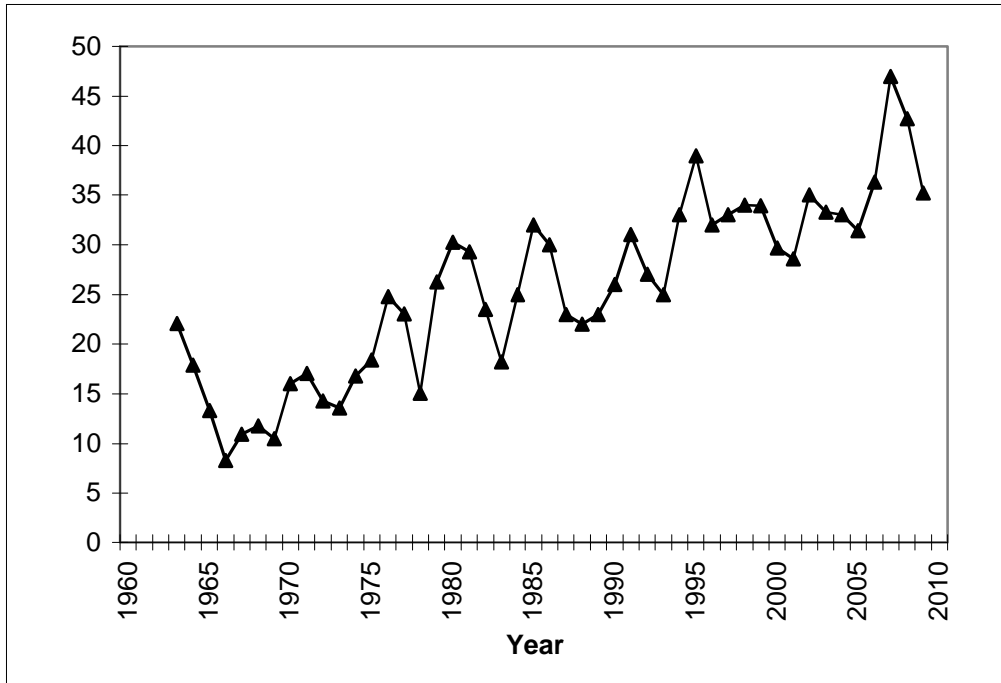


Figure 6. Swedish unstandardised lpue (kg/hour) for areas IIIa and IVa east during 1963 to 2009.

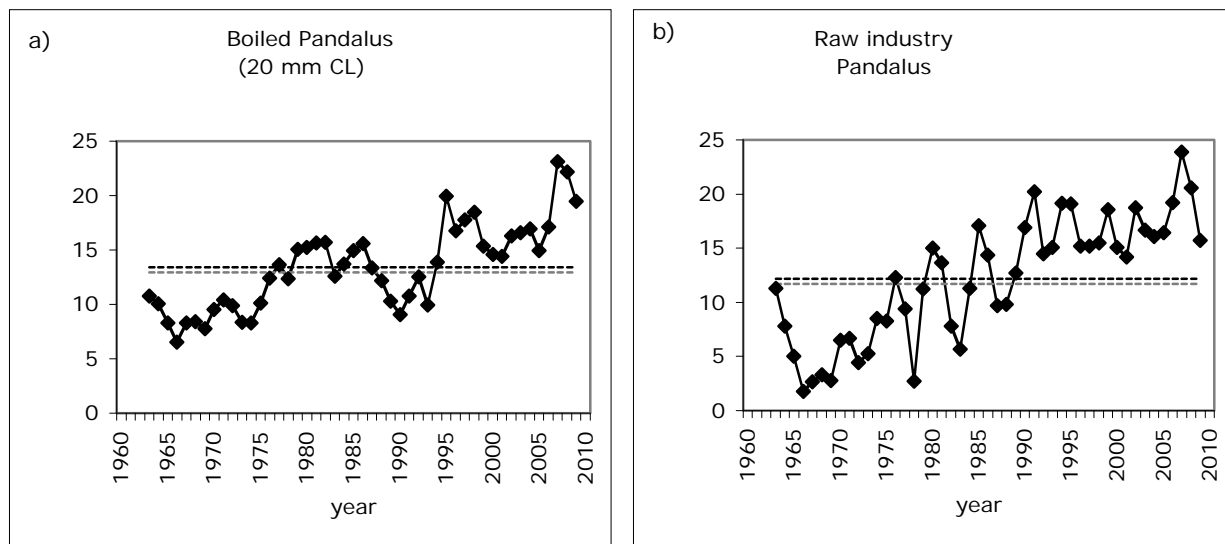


Fig. 7. Unstandardised lpue for areas IIIa and IVa east during 1963 to 2009 partitioned into A: large shrimps (>20 mm) and B: small shrimps. Dotted lines show averages.

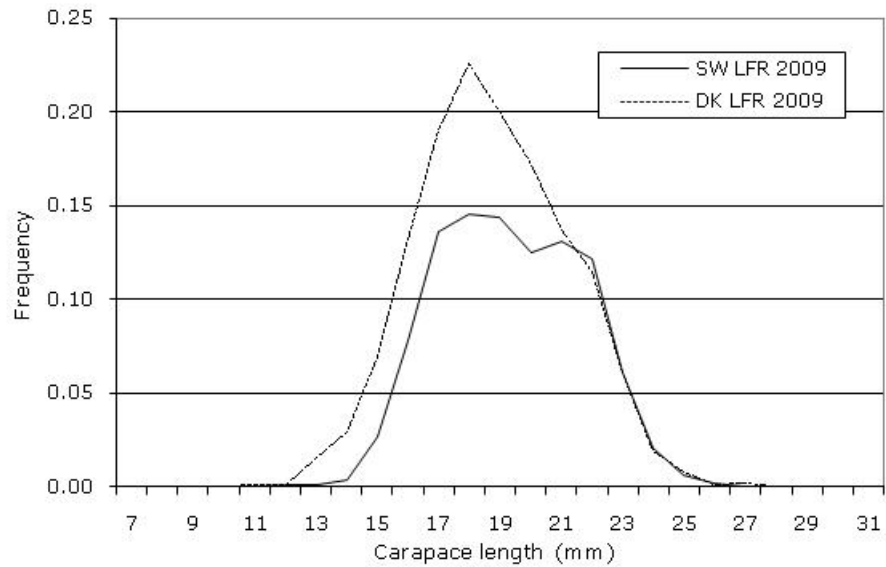


Fig. 8a. Swedish length frequency distribution in landings for 2009 and corresponding Danish length frequency distribution in landings adjusted to Swedish CL \geq 21 mm.

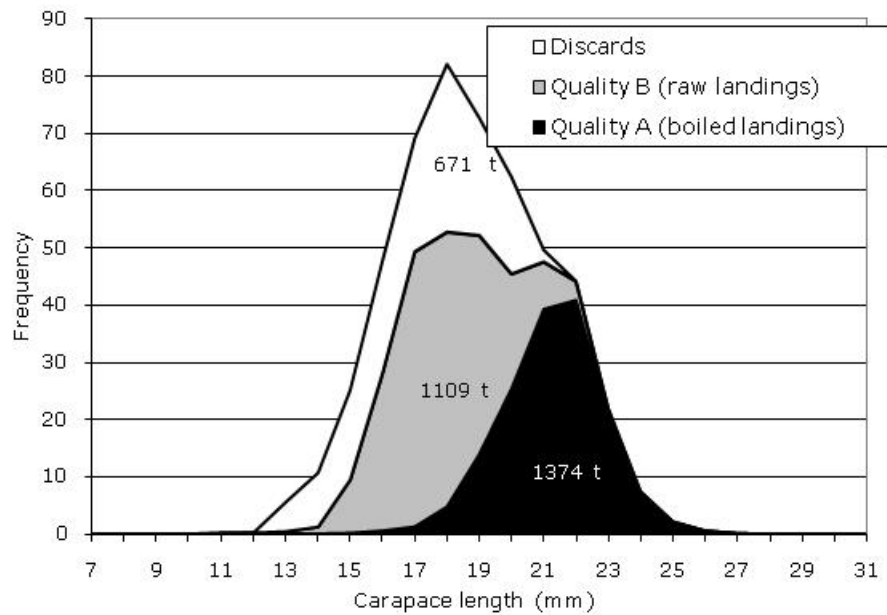


Fig. 8b. Length distribution of Swedish landings, separated into boiled and raw shrimps, and estimated discards due to high-grading.

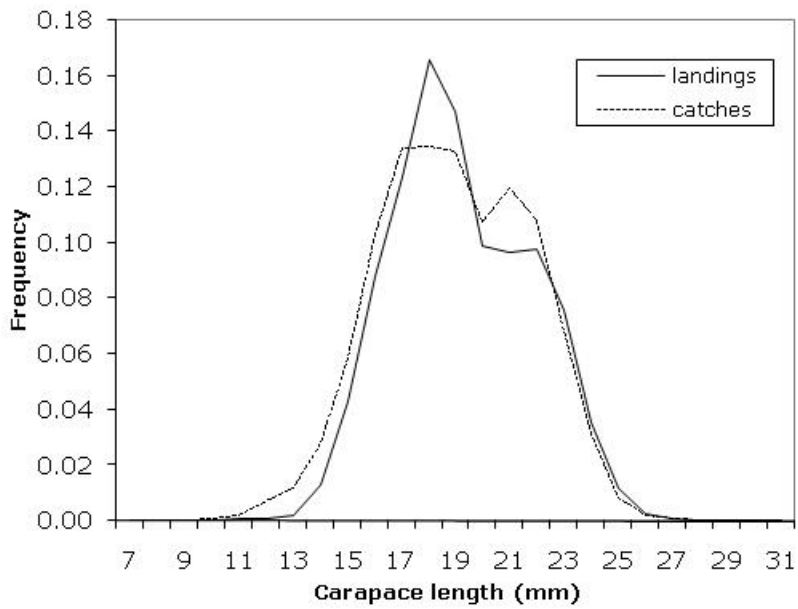


Fig. 9a. Norwegian 2009 length frequency distributions from sorted landings and from unsorted catches adjusted to the sorted landings for $CL \geq 21$ mm.

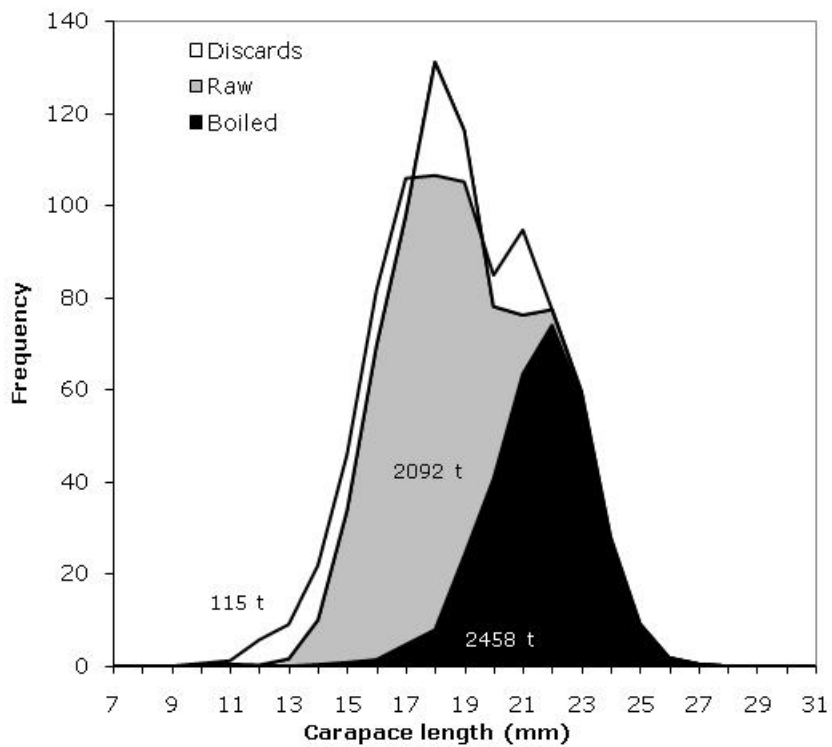


Fig. 9b. Length distribution in Norwegian landings in 2009, separated into boiled and raw shrimps, and estimated discards.

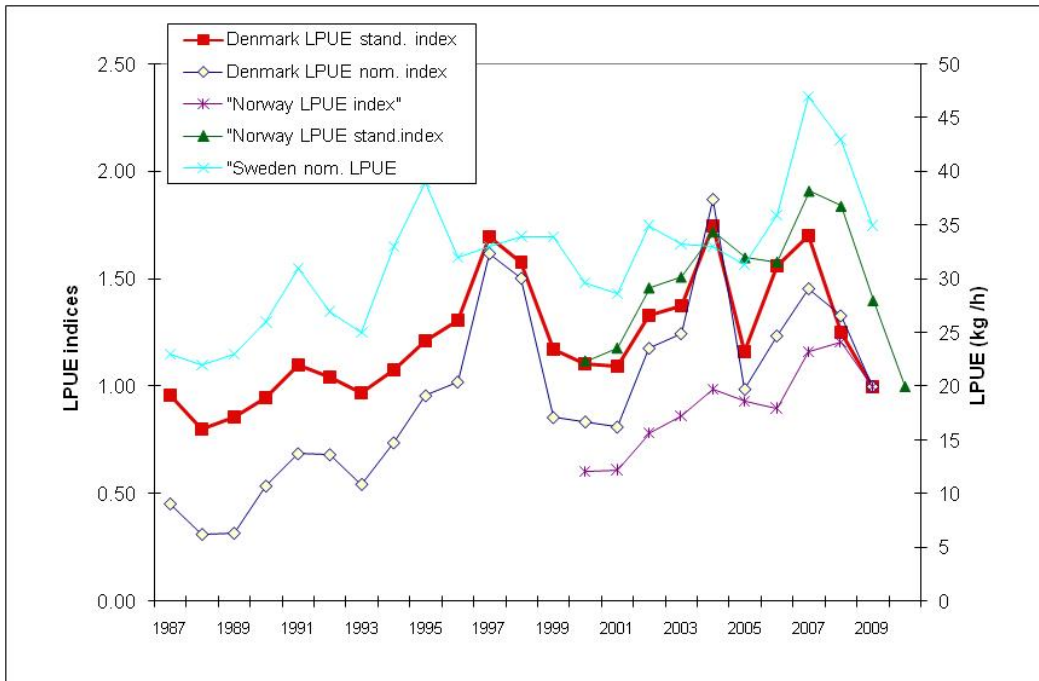


Fig.10. Comparison of Danish, Norwegian and Swedish trends in LPUE, standardised and unstandardised time series.

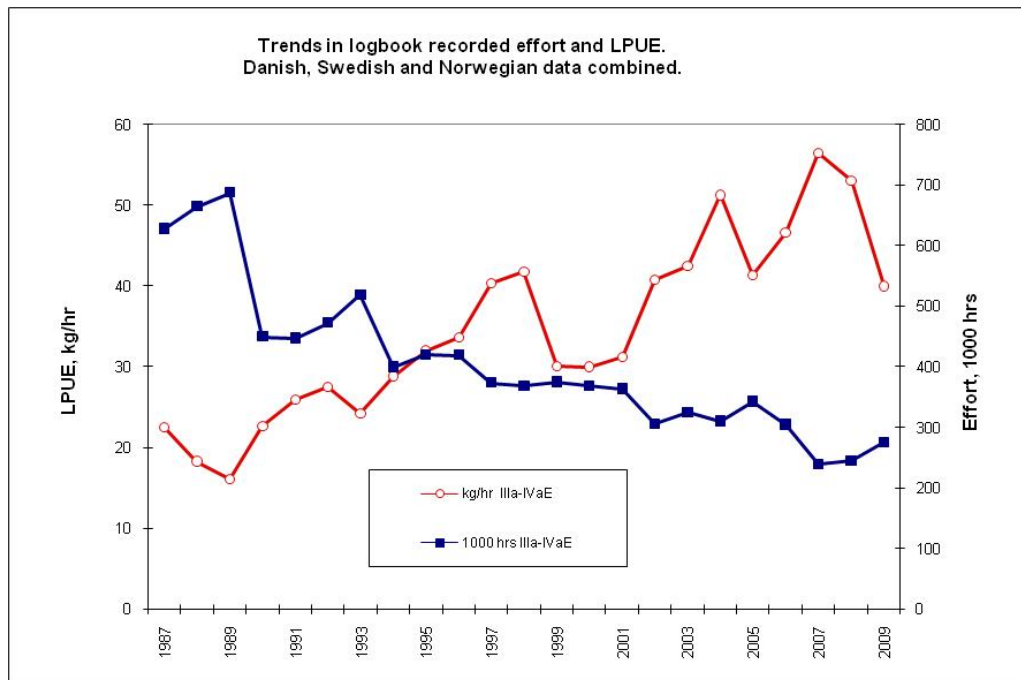


Fig. 11. Combined Norwegian, Swedish and Danish LPUE (kg/hr) and estimated total effort for 1987- 2009.

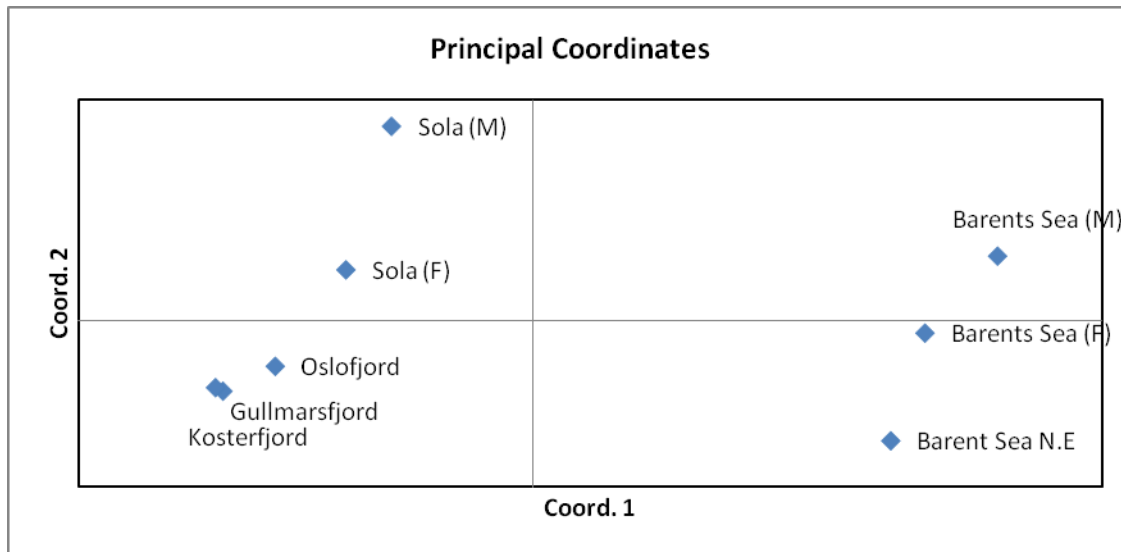


Fig. 12. PCA plot showing the 6 samples of *Pandalus borealis*: Oslofjord (Skagerrak), Sola (Norwegian Deep), Gullmarsfjord (Sweden), Kosterfjord (Sweden), Barents Sea (by Bear Island), and Northeast Barents Sea. The plot is based on 5 microsatellite loci. Coordinate 1 explains 66.7% of the total variation in the data, while coordinate 2 explains 24.4%.

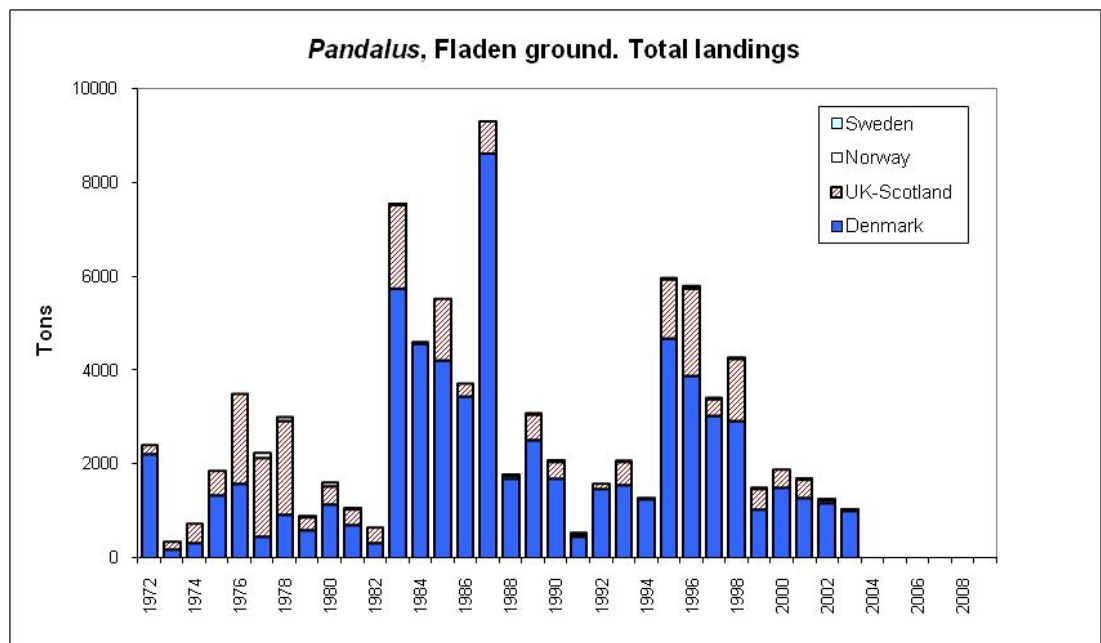


Fig. 13. Total shrimp landings from the Fladen Ground, 1972 – 2009.

Table 1. Nominal landings (tonnes) of *Pandalus borealis* in ICES Division IIIa and Subarea IV as officially reported to ICES.

Year	Division IIIa				Sub-area IV					
	Denmark	Norway	Sweden †	Total	Denmark	Norway	Sweden	UK (Engl.)*	UK (Scotl.)*	Total
1970	757	982	2740	4479	3460	1107		14	100	4681
1971	834	1392	2906	5132	3572	1265			438	5275
1972	773	1123	2524	4420	2448	1216		692	187	4543
1973	716	1415	2130	4261	196	931		1021	163	2311
1974	475	1186	2003	3664	337	767		50	432	1586
1975	743	1463	1740	3946	1392	604	261		525	2782
1976	865	2541	2212	5618	1861	1051	136	186	2006	5240
1977	763	2167	1895	4825	782	960	124	265	1723	3854
1978	757	1841	1529	4127	1592	692	78	98	2044	4504
1979	973	2489	1752	5214	962	594	34	238	309	2137
1980	1679	3498	2121	7298	1273	1140	38	203	406	3060
1981	2593	3753	2210	8556	719	1435	31	1	341	2527
1982	2985	3877	1421	8283	1069	1545	92		354	3060
1983	1571	3722	988	6281	5724	1657	112	65	1836	9394
1984	1717	3509	933	6159	4638	1274	120	277	25	6334
1985	4105	4772	1474	10351	4582	1785	128	415	1347	8257
1986	4102	4811	1357	10270	4288	1681	157	458	358	6942
1987	3466	5198	1085	9749	9642	3145	252	526	774	14339
1988	2246	3047	1075	6368	2656	4614	220	489	109	8107
1989	2527	3156	1304	6987	3298	3418	122	364	579	7802
1990	2277	3006	1471	6754	2080	3146	137	305	365	6084
1991	3258	3441	1747	8446	747	2715	161	130	54	3807
1992	3293	4257	2057	9607	1880	2945	147	69	116	5157
1993	2451	4089	2133	8673	1985	3449	167	29	516	6146
1994	2001	4388	2553	8942	1362	2426	176	41	35	4040
1995	2421	5181	2512	10114	4698	2879	166	217	1324	9284
1996	3664	5143	1985	10792	4063	2772	82	97	1899	8913
1997	3617	5460	2281	11358	3314	3112	316	52	365	7159
1998	2933	6519	2086	11538	3297	3092	187	55	1364	7995
1999	1398	3987	2114	7499	1679	2761	182	46	479	5147
2000	1898	3556	1890	7344	1956	2562	184	0	378	5080
2001	1186	2959	1958	6103	2030	3955	154	0	465	6604
2002	1967	3709	2044	7720	1647	3622	143	0	70	5482
2003	2612	3736	2098	8446	1631	3994	144	0	0	5769
2004	3044	4638	2152	9834	884	4364	147	0	0	5391
2005	2485	4419	1996	8900	477	4087	148	0	0	4712
2006	2837	5177	2235	10249	224	3037	141	0	0	3402
2007	2285	5928	2164	10377	95	2307	160	0	0	2562
2008	2155	5744	2246	10145	104	2039	114	0	0	2257
2009	1931	4268	2157	8356	224	1672	169	0	0	2065

* Includes small amounts of other Pandalid shrimp
† 1970 to 1974 includes subarea IV.
Total 1988 - 1990 includes 19, 21 and 51 t. by the Netherlands
2009 figures are preliminary

Table 2. *Pandalus borealis* landings and catches in ICES Divs. IIIa (Skagerrak) and IVa east (Norwegian Deep) as estimated by the Working Group.

Year	Denmark	Norway *)	Sweden *)	Total landings	Est. Sw. high grading	Est. Norw. discards	Est. Danish discards	TAC	Est. catch
1970	1102	1729	2742	5573					
1971	1190	2486	2906	6582					
1972	1017	2477	2524	6018					
1973	755	2333	2130	5218					
1974	530	1809	2003	4342					
1975	817	2339	2003	5159					
1976	1204	3348	2529	7081					
1977	1120	3004	2019	6143					
1978	1459	2440	1609	5508					
1979	1062	3040	1787	5889					
1980	1678	4562	2159	8399					
1981	2593	5183	2241	10017					
1982	3766	5042	1450	10258					
1983	1567	5361	1136	8064					
1984	1800	4783	1022	7605					
1985	4498	6646	1571	12715					
1986	4866	6490	1463	12819					
1987	4488	8343	1322	14153					
1988	3240	7661	1278	12179					
1989	3242	6411	1433	11086					
1990	2479	6108	1608	10195					
1991	3583	6119	1908	11610					
1992	3725	7136	2154	13015				15000	
1993	2915	7371	2300	12586				15000	
1994	2134	6813	2601	11548				18000	
1995	2460	8095	2882	13437				16000	
1996	3868	7878	2371	14117				15000	
1997	3909	8565	2597	15071				15000	
1998	3330	9606	2469	15406				18800	
1999	2072	6739	2445	11256				18800	
2000	2371	6444	2225	11040				13000	
2001	1953	7266	2108	11327	375			14500	11702
2002	2466	7703	2301	12470	908			14500	13378
2003	3244	8178	2389	13811	868			14500	14679
2004	3905	9544	2464	15913	1797			15690	17710
2005	2952	8959	2257	14168	1483			15600	15651
2006	3061	8669	2488	14218	1186			16200	15404
2007	2380	8686	2445	13511	1124	526		16600	15161
2008	2259	8260	2479	12998	2003	1408		16300	16409
2009	2155	6364	2483	11002	671	115	29	16600	11817

*) Swedish (all years) and Norwegian (2000-2009) landings have been corrected for loss in weight due to boiling.

Table 3. National LPUE and total effort. *Pandalus* in ICES Divs. IIIa and IVa east.

Year	Denmark		Norway		Sweden	
	LPUE kg/hr	effort Khrs	LPUE kg/hr	effort Khrs	LPUE kg/hr	effort Khrs
1987	13	347	36	179	30	49
1988	9	364	36	230	23	57
1989	9	358	31	251	22	57
1990	15	162	23	273	23	63
1991	20	183	26	232	26	58
1992	19	192	30	206	31	61
1993	16	188	35	204	27	80
1994	21	102	31	243	25	91
1995	27	90	31	218	33	82
1996	29	133	35	255	39	76
1997	46	85	37	214	32	74
1998	43	78	42	212	33	78
1999	24	85	44	219	34	73
2000	24	100	32	219	34	72
2001	23	85	33	195	30	75
2002	33	74	33	206	29	74
2003	35	92	44	168	35	65
2004	53	74	47	163	33	72
2005	28	105	55	164	33	74
2006	36	86	50	173	36	65
2007	41	58	65	134	47	52
2008	38	60	65	127	43	58
2009	28	76	50	128	35	71

Table 4. National sampling effort of commercial catches in 2009. *Pandalus* in ICES Divs. IIIa and IVa east.

Denmark		Landings			Numbers			
Quarter	(tons)	samples	Weight (kg)	measured-sexed				
1	600	7	7.5	1490				
2	557	1	1.1	237	*)			
3	437	2	3.4	744				
4	560	6	8.9	1732				
Total	2155	16	20.9	4203				
Norway								
Norway		Landings			Numbers			
Quarter	(tons)	samples	Weight (kg)	measured-sexed				
1	2060	9	15.1	2393				
2	1665	8	11.3	2018				
3	1419	5	8.2	1412				
4	1219	3	5.0	764				
Total	6363	25	39.6	6587				
Sweden								
Sweden		Landings			Numbers			
Quarter	(tons)	samples	Weight (kg)	measured-sexed				
1	582	7	29.7	6440				
2	656	7	18.3	4147				
3	564	1	3.2	3914				
4	681	7	20.7	4190				
Total	2483	22	71.9	18691				
Total								
Total		Landings			Numbers		Sampling per 1000 ton landed	
Quarter	(tons)	samples	Weight (kg)	measured-sexed	Weight	Numbers		
1	3242	23	52.3	10323	16.1	3184.0		
2	2878	16	30.7	6402	10.7	2224.2		
3	2420	8	14.8	6070	6.1	2507.7		
4	2460	16	34.6	6686	14.1	2717.6		
Total	11001	63.0	132.4	29481	12.0	2679.8		

Table 5. Catch in numbers at age. *Pandalus* in Divs. IIIa and IVa east.

Numbers*10**6													
YEAR	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AGE													
0	17.7	7.4	2.7	14.1	31.3	0.0	3.9	25.5	27.2	0.7	2.7	61.1	19.7
1	1200.8	1146.4	1260.5	1086.6	2083.6	2250.1	1231.8	1071.4	1889.6	671.9	646.0	1211.6	2175.6
2	1305.4	1029.7	1205.6	923.9	385.5	910.8	1035.8	1289.2	803.8	1380.4	970.5	991.4	1181.9
3	187.9	482.7	390.2	300.2	173.8	121.1	326.7	569.1	262.7	143.0	851.5	454.6	295.6
+gp	52.3	25.1	203.2	146.7	13.6	31.3	25.6	57.5	15.5	30.5	42.0	69.5	29.8
TOTALNUM	2764.1	2691.3	3062.1	2471.5	2687.9	3313.3	2623.8	3012.7	2998.7	2226.4	2512.5	2788.2	3702.6
CATON	13273	13233	14876	12929	12193	11421	12107	13556	13475	11761	13713	14436	16110

YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AGE												
0	12.7	4.6	88.1	0.1	3.9	2.4	5.7	13.7	4.8	0.1	1.2	0.1
1	903.4	1436.1	1270.7	904.7	922.3	668.7	1062.9	749.4	1021.4	433.1	701.9	555.1
2	1597.9	720.1	836.3	824.5	858.4	1466.5	1251.4	1172.7	1149.2	1349.9	915.0	853.2
3	468.1	318.3	199.3	390.0	581.8	283.8	477.6	410.1	379.0	220.1	673.7	592.9
+gp	48.2	43.3	39.2	68.3	101.8	0.0	50.4	0.0	28.5	0.0	0.0	16.5
TOTALNUM	3030.2	2522.4	2433.5	2187.6	2468.3	2421.4	2847.9	2345.9	2582.8	2003.1	2291.9	2017.8
CATON	15753	11895	11401	11657	12339	13338	15815.3	13715	13763	10750	12541	11816

Table 6. Mean weight at age in catches. *Pandalus* in Divs. IIIa and IVa east.

Catch weights at age (kg)													
YEAR	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AGE													
0	0.0009	0.0012	0.0009	0.0009	0.0011	0.0009	0.0015	0.0010	0.0009	0.0009	0.0009	0.0007	0.0009
1	0.0032	0.0032	0.0024	0.0030	0.0034	0.0030	0.0033	0.0035	0.0035	0.0034	0.0033	0.0037	0.0031
2	0.0064	0.0054	0.0048	0.0054	0.0065	0.0053	0.0053	0.0052	0.0067	0.0060	0.0057	0.0067	0.0061
3	0.0104	0.0083	0.0077	0.0090	0.0099	0.0083	0.0079	0.0078	0.0088	0.0093	0.0089	0.0094	0.0094
+gp	0.0134	0.0140	0.0114	0.0117	0.0133	0.0106	0.0122	0.0095	0.0109	0.0117	0.0116	0.0138	0.0119

YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AGE												
0	0.0007	0.0007	0.0007	0.0006	0.0008	0.0014	0.0017	0.0014	0.0014	0.0014	0.0010	0.0015
1	0.0033	0.0033	0.0032	0.0031	0.0036	0.0035	0.0037	0.0038	0.0035	0.0032	0.0036	0.0049
2	0.0055	0.0063	0.0063	0.0056	0.0054	0.0060	0.0061	0.0059	0.0061	0.0057	0.0059	0.0057
3	0.0087	0.0088	0.0103	0.0085	0.0083	0.0082	0.0077	0.0092	0.0075	0.0075	0.0070	0.0069
+gp	0.0133	0.0112	0.0139	0.0118	0.0113	0.0121	0.0107	0.0113	0.0123	0.0123	0.0123	0.0091

Table 7. By-catch, 2007-2009 in the *Pandalus* fisheries in the Norwegian Deep & Skagerrak

A: Skagerrak, Sub-div. IIIA. Danish log book records						D: Norwegian Deeps, Sub-div. IVA East Danish log book records							
Species:	2007		2008		2009		Species:	2007		2008		2009	
	Total	% of total catch	Total	% of total catch	Total	% of total catch		Total	% of total catch	Total	% of total catch	Total	% of total catch
Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0	Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0
Norway lobster	15.8	0.6	8.9	0.4	3.6	0.1	Norway lobster	0.3	0.2	0.9	0.7	1.1	0.5
Pandalus	2287.1	89.5	2120.4	84.5	2151.1	82.3	Pandalus	81.4	72.6	87.6	68.9	197.1	80.0
Angler fish	8.5	0.3	13.2	0.5	16.2	0.6	Angler fish	1.9	1.7	7.0	5.5	6.9	2.8
Whiting	0.0	0.0	0.0	0.0	0.0	0.0	Whiting	0.0	0.0	0.0	0.0	0.0	0.0
Haddock	7.2	0.3	13.0	0.5	16.5	0.6	Haddock	0.4	0.4	0.1	0.1	0.2	0.1
Hake	0.8	0.0	5.3	0.2	7.3	0.3	Hake	1.1	1.0	4.5	3.5	3.1	1.3
Ling	0.9	0.0	1.4	0.1	2.9	0.1	Ling	0.4	0.3	3.3	2.6	2.4	1.0
Saithe	113.8	4.5	213.5	8.5	286.2	11.0	Saithe	21.0	18.7	14.6	11.5	20.9	8.5
Witch flounder	47.1	1.8	39.9	1.6	37.1	1.4	Witch flounder	0.7	0.6	0.3	0.2	0.1	0.0
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	Norway pout	0.0	0.0	0.0	0.0	0.0	0.0
Cod	48.8	1.9	63.2	2.5	62.9	2.4	Cod	2.7	2.4	4.9	3.9	8.2	3.3
Other market fish	24.6	1.0	29.5	1.2	28.9	1.1	Other market fish	2.3	2.1	3.9	3.1	6.2	2.5
Cod as % of shrimp:		2.1		3.0		0.0	Cod as % of shrimp:		3.3		5.6		4.2

B: Skagerrak, Sub-div. IIIA. Swedish log book records						F: Norwegian Deeps, Sub-div. IVA East Norwegian sales slips data							
Species:	2007		2008		2009		Species:	2007		2008		2009	
	Total	% of total catch	Total	% of total catch	Total	% of total catch		Total	% of total catch	Total	% of total catch	Total	% of total catch
Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0	Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0
Norway lobster	4.6	0.2	6.5	0.3	8.1	0.5	Norway lobster	38.4	1.4	75.3	2.9	65.6	3.2
Pandalus	1710.4	80.7	1743.1	84.3	1235.4	77.3	Pandalus	2190.3	81.2	2038.9	77.4	1667.6	82.5
Angler fish	4.2	0.2	6.0	0.3	6.1	0.4	Angler fish	75.2	2.8	67.4	2.6	68.9	3.4
Whiting	2.5	0.1	3.4	0.2	3.9	0.2	Whiting	3.3	0.1	4.6	0.2	2.2	0.1
Haddock	14.0	0.7	21.8	1.1	12.9	0.8	Haddock	27.3	1.0	24.1	0.9	10.2	0.5
Hake	8.8	0.4	15.9	0.8	9.4	0.6	Hake	17.7	0.7	36.3	1.4	30.3	1.5
Ling	3.3	0.2	5.2	0.3	6.4	0.4	Ling	29.8	1.1	27.5	1.0	34.4	1.7
Saithe	195.9	9.2	137.0	6.6	156.5	9.8	Saithe	163.6	6.1	218.7	8.3	17.9	0.9
Witch flounder	23.0	1.1	25.7	1.2	27.7	1.7	Witch flounder	2.7	0.1	3.4	0.1	1.9	0.1
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	Norway pout	0.0	0.0	0.0	0.0	0.0	0.0
Cod	55.4	2.6	77.0	3.7	111.9	7.0	Cod	96.0	3.6	96.1	3.6	62.7	3.1
Other market fish	96.5	4.6	27.2	1.3	19.2	1.2	Other market fish	52.8	2.0	41.9	1.6	59.5	2.9
Cod as % of shrimp:		3.2		4.4		9.1	Cod as % of shrimp:		4.4		4.7		3.8

C: Skagerrak, Sub-div. IIIA. Swedish log book records (sorting grid)						F: Skagerrak, Sub-div. IIIA. Norwegian sales slips data							
Species:	2007		2008		2009		Species:	2007		2008		2009	
	Total	% of total catch	Total	% of total catch	Total	% of total catch		Total	% of total catch	Total	% of total catch	Total	% of total catch
Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0	Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0
Norway lobster	2.9	0.5	3.4	0.5	2.6	0.3	Norway lobster	35.4	0.5	36.7	0.6	39.1	0.8
Pandalus	610.9	99.1	633.6	99.3	923.4	96.9	Pandalus	6046.2	91.0	5742.5	88.6	4267.0	86.5
Angler fish	0.1	0.0	0.0	0.0	0.4	0.0	Angler fish	34.9	0.5	33.0	0.5	35.4	0.7
Whiting	0.0	0.0	0.0	0.0	0.0	0.0	Whiting	7.4	0.1	5.9	0.1	5.0	0.1
Haddock	0.0	0.0	0.0	0.0	0.3	0.0	Haddock	39.2	0.6	43.6	0.7	51.0	1.0
Hake	0.0	0.0	0.0	0.0	0.9	0.1	Hake	11.8	0.2	24.0	0.4	23.7	0.5
Ling	0.0	0.0	0.0	0.0	0.6	0.1	Ling	29.6	0.4	38.2	0.6	33.1	0.7
Saithe	0.1	0.0	0.0	0.0	15.3	1.6	Saithe	95.0	1.4	159.5	2.5	137.8	2.8
Witch flounder	0.2	0.0	0.1	0.0	0.8	0.1	Witch flounder	31.4	0.5	29.4	0.5	21.4	0.4
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	Norway pout	35.4	0.5	0.0	0.0	0.0	0.0
Cod	1.9	0.3	0.3	0.0	8.5	0.9	Cod	208.7	3.1	258.8	4.0	198.1	4.0
Other market fish	0.3	0.0	0.3	0.0	0.6	0.1	Other market fish	106.8	1.6	107.1	1.7	122.0	2.5
Cod as % of shrimp:		0.3		0.0		0.9	Cod as % of shrimp:		3.5		4.5		4.6

Table 8. Landings in tonnes of *Pandalus borealis* from the Fladen Ground (Division IVa west) as estimated by the Working Group

Year	Denmark	Norway	Sweden	UK (Scotland)	Total
1972	2204			187	2391
1973	157			163	320
1974	282			434	716
1975	1308			525	1833
1976	1552			1937	3489
1977	425	112		1692	2229
1978	890	81		2027	2998
1979	565	44		268	877
1980	1122	76		377	1575
1981	685	1		347	1033
1982	283			352	635
1983	5729	8		1827	7564
1984	4553	13		25	4591
1985	4188			1341	5529
1986	3416			301	3717
1987	8620			686	9306
1988	1662	2		84	1748
1989	2495	25		547	3067
1990	1681	3	4	365	2053
1991	422	31		53	506
1992	1448			116	1564
1993	1521	38		509	2068
1994	1229	0		35	1264
1995	4659	15		1298	5972
1996	3858	32		1893	5783
1997	3022	9		365	3396
1998	2900	3		1365	4268
1999	1005	9		456	1470
2000	1482			378	1860
2001	1263	18		397	1678
2002	1147	9		70	1226
2003	999	8	1	0	1008
2004	23	0	0	0	23
2005	10	0	0	0	10
2006	0	0	0	0	0
2007	0	0	0	0	0
2008	0	0	0	0	0
2009	0	0	0	0	0

Table 9. *Pandalus borealis*, Fladen Ground. Reported LPUE (shrimp trawlers) and estimated total effort.

Year	Recorded Denmark			UK (Scotland)		
	LPUE (ton./day)	Total effort (Days)	effort Index	LPUE (kg/hour)	Total effort (hours)	effort Index
1982	0.96	295	0.10	74	4757	0.31
1983	1.18	4855	1.61	89	20528	1.32
1984	0.97	4694	1.56	37	676	0.04
1985	1.21	3016	1.00	86	15593	1.00
1986	0.96	3558	1.18	71	4239	0.27
1987	1.24	5908	1.96	81	8469	0.54
1988	0.83	1298	0.43	44	1909	0.12
1989	0.99	2463	0.82	65	8415	0.54
1990	1.28	1313	0.44	106	3493	0.22
1991	1.50	281	0.09	124	429	0.03
1992	1.44	1006	0.33	69	1685	0.11
1993	1.83	831	0.28	90	5656	0.36
1994	1.93	637	0.21	91	386	0.02
1995	2.00	2331	0.77	130	9949	0.64
1996	1.79	2155	0.71	62	30532	1.96
1997	2.86	1078	0.36	202	1807	0.12
1998	2.20	1405	0.47	97	14145	0.91
1999	1.62	606	0.20	107	4263	0.27
2000	1.79	830	0.28	121	3128	0.20
2001	2.20	577	0.19	*)	-	-
2002	1.62	711	0.24	*)	-	-
2003	1.70	598	0.20	*)	-	-
2004	0.92	27	0.01	*)	-	0.01
2005	*)	-	-	*)	-	-
2006	*)	-	-	*)	-	-
2007	*)	-	-	*)	-	-
2008	*)	-	-	*)	-	-
2009	*)	-	-	*)	-	-

*) No directed shrimp fishery