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Pandalus Assessment Working Group Report (WGPAND)

26 October– 3 November

Halifax, Canada

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Executive Summary

ToR

The ICES *Pandalus* Assessment Working Group [WGPAND] met in Halifax, 26 October–3 November 2005. The WG participants represented Denmark, Norway, Sweden and Russia (Section 2). The terms of reference for the Working group were: To carry out assessments of the stock of *Pandalus* in Skagerrak and the Norwegian Deeps (IIIa and Iva East) and the stock in the Barents Sea and Svalbard area (I and II) and to provide advice (catch options) for these stocks in 2006, see Section 1.

This year's meeting was organised as a joint meeting between WGPAND and NAFO STACFIS annual shrimp meeting with common participation in all sessions by both WGPAND and STACFIS members.

The *Pandalus* stocks included in WGPAND

The WG deals with the *Pandalus* stock in the Barents Sea and two *Pandalus* stocks in the North Sea area: The stock in the Skagerrak and Norwegian Deep and the stock in the Fladen Ground, see Section 3.

Assessments and state of stocks

Pandalus in the Skagerrak and Norwegian Deep (IIIa & IVa East)

This year's assessment is based on a (new) stock production assessment model (described in WP, Annex 3) together with observed trends in LPUEs. The model does not provide a basis for forecasts but gives some relative information on the state of the stock relative to a MSY based reference point.

The state of this *Pandalus* stock in 2005 and 2006 is presented in Sect. 4.5. It is based on the stock production assessment model and the recent trends in LPUE. The stock seems to be on the same, rather high, level as in recent years. Stock level seems to be well above the suggested reference point (30% B_{msy}).

Pandalus in the Fladen Ground (IVa)

The most recent analytical assessment of this stock was presented in the 1992 ACFM Report (ICES, 1993). Landings have declined gradually from 1999 to 2003, but in 2004 nearly no catches were recorded (23 t). No monitoring of this stock has taken place, but it cannot be ruled out that the dramatic drop in 2004 also reflects a serious decline in the stock, see Section 5.3.

Pandalus in the Barents Sea and Svalbard area (Subareas I & II)

Several models have been applied for assessment of this stock. However in recent years, the views on the state of the stock have been based on survey indices combined with trends in CPUE. SSB appears to have been declining in recent years, see Section 6.4.

By-catch in the *Pandalus* fisheries

Sections 7 and 8 give overviews of the by-catch based on mainly available logbook information.

Working procedures joint ICES-NAFO meetings

Comparing with the 2004 joint meeting, the 2005 ICES-NAFO meeting saw considerable improvements. The advantages and disadvantages of these joint meetings have become clearer. Disregarding the problems of adapting the ICES and NAFO meeting procedures it is obvious that (Section 2.1):

A major advantage is the improved opportunities and obligations to discuss scientific and other topics of common interest concerning assessment of *Pandalus* stocks along with the increased number of scientists at the joint meetings.

However, integrated management advice including ecosystem considerations in relation to management, is better discussed on a regional basis.

1 Terms of Reference

2ACFM15 The ***Pandalus* Assessment Working Group** [WGPAND] (Chair: S. Munch-Petersen, Denmark) will meet 26 October to 4 November 2005 in Halifax, Canada to:

a) assess the status of and provide management options for 2006 for the stocks of Pandalus borealis in the Barents Sea, the North Sea, Skagerrak, and Kattegat and, taking predation mortality on Pandalus stocks into account;

b) for the stocks mentioned in a) perform the tasks described in C.Res. 2ACFM01*).

*) *WGNSSK, WGSSDS, WGHMM, WGMHSA, WGBFAS, WGNSDS, WGNPBW, AFWG, HAWG, NWWG,* ***and WGPAND*** *will, in addition to the tasks listed by individual group, in 2005:*

1) *for stocks where it is considered relevant, review limit reference points (and come forward with new ones where none exist) and develop proposals for management strategies including target reference points if management has not already agreed strategies or target reference points (or HCRs) – following the guidelines from SGMAS (2005) and AMAWGC (2004 and 2005);*

2) *comment on the outcome of existing management measures including technical measures, TACs, effort control and management plans;*

3) *based on input from WGRED incorporate (where appropriate) existing knowledge on important environmental drivers for stock productivity and management into assessment and prediction, and important impacts of fisheries on the ecosystem;*

4) *update the description of fisheries exploiting the stocks, including major regulatory changes and their potential effects. The description of the fisheries should include an enumeration of the number, capacity and effort of vessels prosecuting the fishery by country;*

5) *where misreporting is considered significant provide information on its distribution on fisheries and the methods used to obtain the information;*

6) *provide for each stock information on discards (its distribution in time and space) and the method used to obtain it. Describe how it has been considered in the assessment;*

7) *provide on a national basis an overview of the sampling of the basic assessment data for the stocks considered;*

8) *provide specific information on possible deficiencies in the 2005 assessments including, at least, any major inadequacies in the data on landings, effort or discards; any major inadequacies in research vessel surveys data, and any major difficulties in model formulation; including inadequacies in available software. The consequences of these deficiencies for both the assessment of the status of the stocks and the projection should be clarified.*

WGPAND will report by 21 November 2005 for the attention of ACFM.

2 Participants

Aschan, Michaela	Norway
Bakanov, Sergei	Russia
Hvingel, Carsten	Norway
Munch-Petersen, Sten (Chair)	Denmark
Sunnanå, Knut	Norway
Søvik, Guldborg	Norway
Ulmestrand, Mats	Sweden

2.1 Working procedures in joint ICES-NAFO meetings

Comparing with the 2004 joint meeting, the 2005 ICES-NAFO meeting saw considerable improvements. The advantages and disadvantages of these joint meetings have become clearer. The purpose of such joint meeting is to exchange views and experience in data and methodologies in assessments *Pandalus* stocks.

Advantages of NAFO-ICES joint assessment meetings

Before 2004 the WGPAND was a very small group focusing on the stocks in the North Sea only. The assessment of the *Pandalus* stock in the Barents Sea was carried out in the ICES Arctic Working Group. However, the few *Pandalus* scientists considered them selves very isolated here and not integrated in the fish stock assessments.

The obvious and major advantage is the opportunities and obligations to discuss scientific and other topics of common interest concerning assessment of *Pandalus* stocks. This holds for both the NAFO and the ICES scientists.

Meeting Procedures.

The disadvantages of the routines of the joint meetings (as experienced in 2005) are relating to the (at least formal) obligations of all participants to take part in the management advice for all stocks. It is the opinion of the WGPAND members, that some of the meeting time could be better spent dealing with regional management aspects relating to the particular stocks, e.g. advice taking into account the fisheries in the particular areas.

The WGPAND has followed the NAFO meeting procedures, resulting in extra workload for the WGPAND, because of the required separate ICES WG Report to be delivered to ICES.

The current time of the meeting (following the NAFO STACFIS meeting schedule) in relation to the requested ICES advice further increases the work pressure.

In order to optimise meeting time some of current NAFO procedures should be changed (adapted) to such joint ICES-NAFO meetings.

Integrated management advice

WGPAND notes that ecosystem considerations in relation to management are better discussed on a regional basis.

Presently there is a general aim of the ICES management advice to focus on regional integrated advice, e.g. to consider all the stocks within an area together as well as the environment, e.g. the Baltic, North Sea, Northern Shelf, Arctic etc. Therefore, keeping the *Pandalus* stocks outside this process seems somewhat inconsistent with the current aim of ICES advice.

3 Definition of Stock / Assessment units

3.1 The North Sea and Skagerrak

The distribution of *Pandalus* in the Entire North Sea area is shown in Figure 3.1. The WG has, so far, maintained the view that shrimp caught on the Fladen constitute a stock separated from the *Pandalus* in the Norwegian Deeps and Skagerrak. The main arguments for this separation were presented in ICES (1990):

- Geographical separation combined with hydrographical considerations.
- The Fladen shrimp are normally characterized by fewer age groups. This difference was quantified by multivariate analyses of length frequency distributions (LFD) from the three areas, these suggested that especially the Fladen LFDs deviate from the other two (ICES, 1990).

A close connection between the shrimp in the two areas has, however, been postulated by earlier investigations (e.g. Poulsen, 1970). It was done based on trends in size distribution of the shrimp in various parts of the entire North Sea–Skagerrak area and on probable larval drift with surface currents in the northern North Sea. The WG has, furthermore, observed that:

- Norwegian Survey data on recruitment for IIIa and IVa East and LPUE in the Danish Fladen fishery is correlated.
- Pattern in LPUE fluctuations in the fisheries exploiting the two stocks have frequently been similar

This could indicate a close connection between the two stock units.

Improvements in genetic separation technologies in recent years could elucidate this particular stock separation problem. Norwegian samples for such genetic analyses have been collected in 2005 from the Skagerrak and Norwegian deeps, but have not been analysed yet. Samples from the Fladen stock will be collected in 2006.

3.2 The Barents Sea and Svalbard area

The *Pandalus* stock in the Barents Sea and Svalbard area is distributed as shown in Figure 3.2. Genetic investigations, allozyme electrophoresis and DNA-fingerprinting have been conducted in attempts to identify potential sub populations of shrimp in the Northeast-Atlantic including the Jan Mayen area, the Norwegian coast, the Barents Sea and the Svalbard area (Kartavtsev *et al.*, 1991, Rasmussen *et al.*, 1993, Drengstig *et al.*, 2000 and Martinez *et al.*, 1997). The latter analyses showed that there are no distinct sub-populations in the open sea, and that there is a high degree of genetic variance between individuals within each location. However, genetic gradients related to geographic distance and sea currents have been identified. The transport pattern produced by the currents, varies between years, and results in annually different dispersion patterns of settled shrimp larvae. This may have a strong influence on the year class strength in sub-areas as well as in the entire Barents Sea.

The shrimp in the Barents Sea should be considered as one population, where female shrimp produce settling larvae in the whole distribution area. The transport of larvae secures genetic Flow within the population. The abundance of reproducing females in each sub area is of great importance for the annual recruitment and therefore management has to secure the spawning females throughout the Barents Sea (Pedersen *et al.*, 2003).

4 The *Pandalus* Stock in Divisions IVa East and IIIa

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

4.1.1 The Danish *Pandalus* fishery

Historically, the Danish *Pandalus* fishery has targeted both the shrimp stock in the Sub-area IVa East and division 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 landings from IVa East and IIIa have gradually become more important. In 2005 the Fladen Ground fishery was practically non existing with total recorded landings of only 23 tonnes. Interview information from the fishing industry obtained in 2004 gives the explanation that this decline in recent years is caused partly by low abundance of shrimp on the Fladen Ground combined with low prices on especially the small Fladen shrimp and high prices on fuel. The latter condition has further favoured fishing in waters close to landing harbours (Skagerrak) in order to minimize fuel costs.

During recent years an increasing number of vessels have started processing (boiling) the shrimp aboard and landing them in Sweden thus obtaining a better price. The majority of the catches are however still landed in Danish fishing ports. Most of these shrimp are landed directly to a few large factories processing almost all sizes of shrimp.

The fishing vessels

In a study performed by Ulrich and Andersen (2004) all Danish fishing vessel were grouped in categories based on similarities in catch composition, gear used and area fished. According to their analyses of logbook data on catch, effort as well as landings from all the Danish fishing trips in 1999, a total of 14 vessels could be identified as being trawlers targeting *Pandalus* in the North Sea and/or Skagerrak in 1999. They accounted for the majority of the total landings and had an average of 68 yearly trips targeting *Pandalus*. A larger poorly defined vessel group occasionally took part in the *Pandalus* fishery, but only accounted for small catches of *Pandalus*.

According to the above mentioned study the smaller trawlers (<24 meters) formerly made up a substantial part of the fleet (app. 50% in numbers) but during the 5 most recent years almost all of the smaller vessels have disappeared from the *Pandalus* fishery leaving only the large vessels (>24 meters) located in Skagen, Hirtshals and Hanstholm.

This development in fleet structure agrees well with the 2004 interview information (from the industry) where Skagen, Hirtshals and Hanstholm were pointed out as being the major harbours of *Pandalus* trawlers in 2004, Skagen being the home harbour of 6–7 vessels of approximately 100–200 GRT and Hirtshals and Hanstholm each having 2–3 somewhat larger *Pandalus* trawlers of between 200 and 300 GRT. The major landing harbours were the same.

Fishing Gear

The largest net manufacturer in Denmark (Cosmos Trawls) provides shrimp trawls to many of the Danish vessels. At present the two most common trawls are the ”Sputnik” (or ”Skagerrak”) trawl and the ”Fladen shrimp” trawl differing mostly with respect to the height of their trawl opening. The Sputnik trawl has almost twice the height as that of the Fladen shrimp trawl but only a slightly larger width. The two trawls are chosen by turn depending on fishing area and time. The mesh size in the cod ends used is almost exclusively 40 mm whole-mesh with a 70 mm square mesh window in the top panel.

Of particular interest is the information from this net manufactory, that within the last 5–10 years almost all trawlers had been equipped with twin trawls. This change had allowed the individual vessels to increase the swept area (wing end to wing end) with approximately 50% without increased demands to the vessels engine capacity or in any noticeably increase in fuel consumption.

The influence of twin trawls on fishing effort

The official Danish logbook record do not provide any information on single/trawl riggings, but based on the information described in the section above a preliminary simple model for the development of true effort is suggested based on the following assumptions for the introduction of twin trawls in the Danish *Pandalus* fleet:

- a simple linear introduction pattern over a 10 year period starting in 1994
- a final (2003) introduction among the *Pandalus* trawlers of app. 72 % (10/14)
- a 100% application to *Pandalus* fishing operations after purchase
- a resulting 50% increase in swept area and catch rates

Standardisation of effort (and subsequently of LPUE) is carried out by the following conversion:

$$\text{Effort}_{\text{hypothetical}}(t) \quad = \quad \text{Effort}_{\text{nominal}}(t) \; + \; (\, 0.5 * \text{Effort}_{\text{nominal}}(t) * I_{\text{factor}}(t)\,)$$

Where the introduction factor (I_{factor}) = 1/14, 2/14, …..10/14, for t = 1994 to 2003

The resulting values for the standardised LPUE’s are shown in Figure 4.1 (Section 4.2.3) together with the trends for the nominal Danish-LPUE’s and the nominal Swedish LPUE’s. In Sweden the use of twin trawls in the *Pandalus* Fishery is not yet common. In 2004 only 3 vessels applied this gear in the fishery. For assessment purposes the estimated total international LPUE and effort have been adjusted accordingly, see Section 4.5.

4.1.2 The Norwegian *Pandalus* fishery (SCR Doc. 05/80)

The Norwegian fishery is conducted by multi-purpose fishing vessels (20–100 GRT) largely trawling south of 62^{o}N. In 2002, a total of 143 trawlers were registered in three categories of shrimp trawlers. There were 45 vessels being less that 50 GRT and smaller than 13m in length delivering 980 t of shrimp from this area, there were 69 trawlers less than 50 GRT and longer than 13 m, delivering 2770 t of shrimp and finally, there were 29 trawlers being larger than 50 GRT delivering 2330 t of shrimp. Vessels belonging to other categories also land some shrimp. According to the Norwegian logbook records for 2003, 38 vessels have reported shrimp catches and these vessels are all longer than 13 m. Of the 18 vessels less than 50 GRT, 4 vessels deliver less than 10 t, 10 vessels between 10 t and 50 t, and 4 vessels more than 50 t. Of the 20 vessels larger than 50 GRT, 2 delivered less than 10 t, 3 between 10 t and 50 t, 5 between 50 t and 100 t and 10 more than 100 t.

In the Norwegian fishery for shrimp in this area the minimum mesh is 35 mm. It is not allowed to fish in waters shallower than 60 m. It is allowed to have 50% by-catch of other market species. For cod and haddock combined there is a limitation that the number of undersized specimens may not exceed 8 per 10 kg of shrimp. It is allowed to have up to 10% undersized shrimp (< 6 cm – 15 mm carapace length) in the catch. Discarding is prohibited in the Norwegian waters. Due to these regulations, the trawlers fish a considerable by-catch of market fish. They also conduct other fisheries during the year, e.g. mackerel trolling. The larger vessels (>50 GRT) also conduct trawl fishery for sandeel and herring.

In 1999 a general quota regulation system was initiated in the Norwegian fishery. The total Norwegian quota is divided into periods of four months each with app. 1/3 of the quota each period. The vessels have a maximum quota each for each period, a trip-quota for each trip to sea and a mandatory number of days of no fishing between each trip. There is some variation depending on whether they are fishing for boiled landings or for shrimp to be landed fresh.

Two categories of shrimp dominate the market: Approximately 35% of the total landings is delivered as boiled or fresh large shrimp (140–150 individuals per kg) for the Norwegian inland market (app. 60%) and the Swedish market (app. 40%) and app 65% of the total as raw (smaller) shrimp for factory processing (mostly 180–250 individuals per kg). A price and quota regulation is in work to regulate the available shrimp for the Swedish market, for which there is an export quota free of toll. The fisher gets app. 55 NOK/Kg for boiled shrimp and app. 10 NOK for the raw shrimp. Some high grading and discarding is assumed to take place. Especially shrimp sized below 15 mm carapace length are probably all discarded and may account for 5–10% of the catches.

4.1.3 The Swedish *Pandalus* fishery

In 2004, a total of 74 trawlers reported landings of *Pandalus* in the Swedish logbooks. Of these 50 landed more than 10 tonnes *Pandalus* and can be considered active in this fishery.

The size of the vessels ranges between 11–34 m (length) with an average of 21 m. GRT varies from 18 to 235, with an average of 103 GRT. The average engine effect is around 355 kW (92 kW–720 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 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 boarder 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 boarder as an alternative to the EU legislated 70 mm square mesh panel in shrimp trawls.

This particular *Pandalus* trawl with grid can be distinguished from other shrimp trawls in the log books since 1997 and the effort of this gear has had an increasing trend and was 16% (10 khrs) of total Swedish *Pandalus* trawl effort in 2004 (63 khrs).

There are two different Swedish markets for *Pandalus:* a) higher value boiled larger sized shrimps, sorted by a 10.5 mm sieve and constituting around 50 % of the landings, b) lower value smaller sized shrimps, sorted by 8.5 mm sieve, landed fresh and sold to the industry for further processing. The boiled *Pandalus* landings are cooked onboard before landed. Since the shrimp loses weight when boiled, these landings must be raised by a factor of 1.13 to obtain fresh weight for the landings statistics.

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, increasing the discarding of less valuable smaller *Pandalus* to increase the proportion of the more valuable boiled shrimp in the individual landings ration. The discard of small *Pandalus* was this year estimated to around 800 tonnes based on comparison of the size compositions in the Swedish and Danish catches.

4.2 Landings, catch and effort data

4.2.1 Landings

Landings are given in Table 4.1 by area (Division IIIa and Subarea IV) as officially reported to ICES. In Skagerrak the landings for 2004 increased approximately 15% compared to 2003. Landings increased in all 3 countries. In Subarea IV total landings have decreased due to a drastic decrease in the Danish Fladen Ground fishery in 2004. The combined total landings from IIIa and IV were 7% higher in 2004 than in 2003.

Table 4.2 presents the landings and estimated discards for the assessment unit ‘Skagerrak and the Norwegian Deeps’ i.e. Division IIIa and the eastern part of Division IVa. The landings in 2004 were around 15 000 t, an increase of almost 2000 t compared to landings in 2003.

Landings from Norway and Sweden (and to a very small extent from Denmark) consist of a fraction of larger shrimp that are boiled on board and a remaining portion of smaller shrimp landed fresh. The boiling causes the shrimp to loose weight. The conversion factor to obtain live weight is 1.13. Official reported figures from Norway are given as landed weight. Sweden has adopted the same procedure for the last few years. In the amounts used by Working Group, the Swedish landings of large shrimp have, however, always been converted to live weight. The amount added for 2003 was 164 t. The Working Group has applied no conversion on the Norwegian landings. The underestimate of total landings by this omission was for 2000 roughly estimated to about 300 t. The Working Group felt that this estimate was too inaccurate to include in the assessment figures. When more reliable data for estimations become available, the landings for all years should be updated.

4.2.2 Discards

In the Norwegian and Swedish fisheries one may distinguish two categories of discarded shrimp, 1) all small or low quality shrimp are discarded either at sea (Sweden) or at shore (Norway) and 2) discards because of high grading:

The smallest size fractions (from the grading procedure are not accepted by the canning industry and are discarded. This practice is traditional in the Norwegian and Swedish fisheries. This is probably also the case for the Danish catches. The proportions below 15 mm carapace length are considered to be discarded.

Estimates of the Norwegian high grading discards for 1996 and 1997 were 400 and 1000 tons respectively or approximately 5 and 12% of the catches. Estimates for other years are not available. Instead Norwegian discards were estimated by the difference in length distribution in commercial landings and in the unprocessed catches of a research survey vessel using commercial-type trawling gear, see Table 4.2.

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. In recent years several Danish shrimp vessels landing boiled shrimp in Sweden have probably been following this practice. The amounts of discards in this category in the Swedish fisheries were estimated to around 800 t in 2004 based on comparison of size distributions in Swedish and Danish landings. However, the total annual amount of this type of discards could be more than 1000 tons. However, at present such estimates are considered too inaccurate to be included in assessments, but the working group expects that better data on discards will available through the current EU funded discard sampling programmes. According to qualitative information from the Danish fishing industry, the amounts of discarded shrimp in the Danish *Pandalus* fishery are rather small.

4.2.3 Effort data

Annual national figures for landings per unit of effort (LPUE) and estimated effort are shown in Table 4.3 and Figure 4.2. Total national effort values have been estimated from LPUE data based on logbook records. The Danish and Norwegian LPUE increased in 2004, while the Swedish LPUE remained at the same level, possibly due to the discarding practices described above. The technological creeping in the Danish *Pandalus* fishery described in Section 4.1.1

has been taking into account in the figures for Danish LPUE. The Swedish shrimp trawls are still mainly single trawls. No quantitative information on the development in the Norwegian shrimp gear for Skagerrak and the Norwegian Deeps was available.

In order to obtain the same effort unit for all 3 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). The missing Norwegian data from 1984–85 were estimated by functional regression Norway-Sweden and the factor 1.12 applied. The estimated time series of total international effort (Khrs) and LPUE (Kg/hr) are shown in Table 4.4 and Figure 4.3.

4.3 Biological sampling of landings

4.3.1 Sampling frequency, intensity

Information of the size and subsequently age distribution distributions in 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 4.5. The overall sampling level 2004 was around 14 kg per 1000 t landed or 2400 specimen. Variations in the intensities between countries and between seasons indicate that improvements could be made.

4.3.2 Catch in numbers at age

The length data are pooled by quarter, and these national quarterly length distributions have then been partitioned into age compositions by the method of Bhattacharya (1967) (software: FISAT). As in previous years the mean lengths by age group are used as a check of the consistency of the estimates, see Figure 4.4. Due to lack of Norwegian length data for 2003 and 2004 the Norwegian total landings were age distributed according to the combined Danish and Swedish age data.

Table 4.6 gives the "catch-at-age" data. While previous years' tables also tabulated landings at age, this year's tables have included discarded 0 and I-Group shrimp. Catches are dominated by shrimp of ages 1 and 2. The numbers of age 3 and older are likely to be underestimates, due to the way the Bhattacharya method operates. In general, the WG doubts the reliability of estimates of the older age groups, i.e. those > age 3. This doubt is also reflected in the pooling of ages >3 in to a 'plus-group' in the XSAs performed in previous years.

4.3.3 Mean weights at age

Weights-at-age for the Danish 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. The corresponding Norwegian and Swedish weights-at-age figures are based on quarterly length-weight relationships obtained from the Swedish length samples in which all shrimp are weighted individually. The mean weights-at-age in the catch is given in Table 4.7. In some years there were no records 0-group shrimp in the catches, then averages for the other years were used. The same procedure was applied for the +group (+gp) in 2004.

4.3.4 Estimation of SSB, maturity ogives

For estimation of SSB for the *Pandalus* stocks in the North Sea area the 0- and 1-groups are assumed to be immature, and age group 3 (all females) and older groups are fully mature. In the cohort based assessments (XSA) the mature part of the 2-group or potential spawners was taken as the sum of intersexes and females in the first quarter of the year. These proportions are available from 1985. The text table below gives the figures for the 10 recent years:

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
0.51	0.58	0.51	0.60	0.65	0.76	0.51	0.52	0.74	0.89

This method was not appropriate in connection with the SPP model used for 2001–03, where stock size estimates were based on survey data from October-November. At the time of the survey it is assumed, that the spawning stock consists of the females in the stock, and estimates of SSB were based on the proportion of females (by weight) in the survey catch. They were then applied on the estimates of average biomass, $(B_y + B_{y+1})/2$.

The WG recommends, that in future assessments the procedures for estimating SSB be standardised for all *Pandalus* stocks in the North Atlantic.

4.4 Trawl survey data

4.4.1 The Norwegian trawl surveys (SCR Doc. 05/82)

Norwegian Trawl surveys for northern shrimp in Skagerrak and the Norwegian Deeps (ICES Divisions IIIa and IVa East) have been conducted annually since 1984 with the objective of assessing the size and demographic composition of the stock and hydrographical conditions in its distributional area. From 1984–2002 the R/V *Michael Sars* was used. However in 2003 and 2004 significant changes took place, and from 2004 a 'new' survey, taking place in the spring, has been conducted. Further description of gear and design for the 'old' survey is found in ICES (2005a).

At present the Norwegian survey data consist of: 1.) One series based on a survey conducted in October-November 1984 to 2002 using R/V *Michael Sars*; 2.) A point estimate for 2003, as the survey vessel and trawl previously used was changed; 3.) A start of a potential new series as the survey in both 2004 and 2005 was conducted in May-June with R/V *Håkon Mosby* using the same shrimp trawl as in the 'old' survey (Campelen 1800/35 bottom trawl). Mesh size in the cod-end is 22 mm with a 6 mm lining. A fixed trawl geometry is assumed.

The design of the 'new' survey is similar to that of the 'old' one (Hvingel, 2005). The survey area covers depths of 100 to 500 m in ICES Divisions IIIa and IVa East. It is stratified by depth zones of 100–200 m, 200–300 m and 300–500 m, and area (Figure 4.5). The total survey area is hereby divided in 16 strata covering 13 128 nm².

The survey is a fixed station design with 100 stations evenly distributed over the survey area (Figure 4.6). The hauls are repeated annually on the 100 stations, giving a coverage of 1 haul per 1312 nm². Haul duration is 30 min. No compensation for diurnal vertical migrations is made.

Due to weather and time constraints and a number of invalid tows only 58 tows from the 2004 survey and 83 tows from the 2005 survey were available for analyses.

4.4.2 Analysis of Survey Data

4.4.2.1 Shrimp: Swept area estimates of numbers-at-age

The width of the trawl opening, used for calculating swept area estimates, is 11.7 m. (Teigsmark and Øynes, 1983). The average speed is 3 nm/hour and thus the trawl covers 0.019 nm^2 in 1 hour. The catch in each tow divided by the swept area represents a sample of shrimp density in a stratum. From these samples the mean and standard error of the density in each stratum was calculated and multiplied by the area of the stratum to give an estimate of stratum biomass and abundance. Standard error was calculated as $B * 0.985$ (Cochran, 1977) for strata with only one tow. The means and their standard errors for the 16 strata were summed to give the overall values for the survey area.

Samples of 250–300 specimens are taken from each trawl haul, sorted by sexual characteristics, and measured to the nearest mm below (carapace length, CL). The length and sex frequency distribution in the samples was weighted by total catch and stratum area to obtain estimates of the overall distribution. The length distribution was then split into age groups by modal analysis using the NormSep software MIX (Macdonald and Pitcher, 1979) to produce indices of abundance by age group. Note, that the method of partitioning of the length distributions in the Norwegian survey catches into assumed age groups differs from the method used for the Danish and Swedish length data.

The mean length at sex change was estimated by fitting a logistic function to the percentage of females in 1mm length intervals.

4.4.2.2 Shrimp: Swept area estimates of total biomass

Figure 4.7 and Table 4.8 show the estimated biomass (indices) from both the 'old' and 'new' survey. The biomass indices increased in the late 1980s to early 1990s, was stable until the mid-1990s after which it began fluctuating at a slightly higher level (Figure 4.7). The indices from the 'new' survey are of the same magnitude as those from the 'old' one. The 2005 index value is lower than that for 2004, but not statistically different.

Size, age and sex distribution

The estimated size distribution of 2004 showed a large mode of mainly males at 15 mm CL (Figure 4.8) in 2005 which was assigned to age-group 1 in the modal analyses. These shrimp may be recognised as a large mixed male and female mode at around 18–19 mm CL in 2005. This might indicate a high abundance of large female shrimp in 2006 as these shrimp grow into age-group 3.

However the abundance of the lengths around 15 mm (age 1) is considerably lower in 2005 than in 2004 (Figure 4.8) and the estimated mean abundance of age 1 shrimp in the survey in 2005 is only half of the 2004 mean indicating a possible reduced recruitment of mid-sized shrimp to the fishery in 2006.

4.4.2.3 Fish biomass.

The index of shrimp predator biomass increased from 58 in 2004 to 115 in 2005 (Table 4.9).

4.5 Assessment of the *Pandalus* stock in Divisons IIIa and IVa East.

4.5.1 Previous Assessment Models

The *Pandalus* stock in Divisions IIIa and IVa East was assessed by cohort analyses (VPA/XSA) from 1987 to 2000.

However, several features characteristic to the shrimp stocks reduce the applicability of the XSA:

- Few age groups in the stock.
- Uncertainties in the ageing of especially the older age groups.
- A variable natural mortality much higher than the fishing mortality.

From 2001 to 2003 a Stock production model taking predation into account was applied. The main input to this was recruitment and total biomass indices of shrimp and predators available from the 'old' Norwegian trawl survey.

However, because of the break in the time series of this survey in Skagerrak and the Norwegian Deeps in 2003, as well as severe limitations of the model, this approach was abandoned in 2004 (ICES, 2005a). An analysis (see Annex 3) in 2005 showed that the previously used model was inappropriate and that the available data was uninformative with respect to the parameters of this model. Thus the model cannot be used to make predictions. An alternative approach using a stochastic version of the logistic production model and Bayesian inference to estimate the status of the stock and risks of transgressing the suggested reference point was introduced to the WG this year.

4.5.2 State of Stock in 2005 and 2006

This year's assessment of the current state of stock is based on 1) evaluation of LPUE from the fishery 1984–2005 and the 2004–2005 survey indices of biomass and 2) model based estimates using the 1985–2002 survey and catch data (1984–2005):

1. *The trend in commercial LPUEs presented in Tables 4.3 and 4.4 and Figures 4.2 and 4.3 as indicator of the development of the stock up to 2005: The combined LPUEs (Figure 4.3) show an increasing long term trend from 1989 to a peak in 1997-98, declined again in 1999 to 2001 and increased in the recent 3 years and LPUE in 2004 is the highest observed during the period of available data. The combined effort shows a decreasing long term trend, even after the Danish effort figures have been adjusted. The similar pattern in LPUE between Denmark and Norway indicate that the exploitable stock biomass has followed the same pattern, i.e. increased until 1998, decreased in 1999 to 2001 and increased again in recent 3 years. The trend in Swedish LPUEs is slightly different, probably due to not including discards due to high-grading in the LPUEs. It is recognized however that raw CPUE data is affected by changes in fishing practices and does not always accurately reflect changes in stock.*

   The biomass index provided by the Norwegian survey in May 2005 is 10% lower than the index for 2004. Compared with previous variations this change is small (Table 4.8, Figure 4.7), thus the survey indices contribute to the overall impression of a stable stock.

   Both these sets of stock indicators point to the perception of a stable stock at a high level with no signs of over-exploitation.

The model indicated a high probability of the stock having been above both B_{msy} and B_{lim} between 1984 and 2005 (B_{lim} = 30% B_{msy} as currently used by NAFO: SCS Doc. 04/12). For those years the risk of the stock being below B_{msy} range from 1.5 to 8.2% and from 0.1 to 2.2% for being below B_{lim} (Table 4.10). The risk of the fishing mortality being above F_{lim} ($=F_{msy}$)(SCR Doc. 04/12) was not estimated due to the inability to estimate the full probability distribution of MSY, however, an index of harvest rate (landings/estimated survey biomass) showed a slightly declining trend since the late 1980s (Figure 4.9). A series of estimated median stock sizes relative to Precautionary Approach reference points are shown in Figure 4.10.

> *This model indicates a stable stock at a level well above Bmsy. The model also shows that there is a high probability that catches have been below MSY throughout the period 1984–2005 and that the stock could likely sustain larger catches than the current TAC.*

The WG concludes that catches at the recent TAC level of around 15 000 t are not likely to have an impact on stock status provided that the abundance of predators remains within the recent ranges. The stock might be able to sustain higher catches, but the WG was not able to estimate MSY.

4.5.3 Biological Reference Points

The view of the WG 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, 2002b). In 1998 ICES (ICES, 1999) pointed out that there was not 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, predation accounts for at least twice as much removal from the *Pandalus* stock compared to fishery removals from 1985–2002. 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.

Following the current NAFO definition (SCS Doc. 04/12), 30% B_{msy} could be used as a limit reference point (B_{lim}).

5 The *Pandalus* Stock on Fladen Ground (Division IVa)

5.1 Catch and Effort

Table 5.1 shows the landings from the Fladen Ground since 1972. Since 1991 total landings have fluctuated between a low of around 23 t (2004) to a high of more than 5000 t. Denmark accounts for the majority of landings while the Scottish fleet takes only a minor part of the catches. Since 1999 total Fladen landings have declined, in 2004 there was a drop to almost no catches. No monitoring of this stock has taken place, and it cannot be ruled out that this drop could reflect a decline in the stock. However, the most likely explanation for this dramatic drop, which is confirmed by the fishing industry, is the low price for Fladen shrimp combined with the rather high fuel costs.

In general, the shrimp fisheries on Fladen take place mainly during the first half of the year, mainly in the second quarter.

Total effort for the Danish and Scottish Fladen fisheries is estimated from logbook based LPUE data from these fisheries (Table 5.2). In 2004 the Danish LPUE was at half the level as in 2003. Estimated total Danish effort in 2004 was insignificant. No effort data for 2001, 2002 and 2003 have been reported from U.K.

5.2 Previous Assessments

The shrimp stock on Fladen has not been assessed since 1992, due to scarcity of assessment data (ICES, 1992).

The existing data on age composition for later years have been compiled at the national laboratories (Denmark and Scotland) and are available to the Working Group. However, due to the frequent large fluctuations in the Fladen fishery, the data do not always cover the entire year. Furthermore, they are lacking for the most recent years.

Catches from Fladen consist mainly of two age groups. During the first two quarters of the year age groups 2 and 3 normally dominate the catches. During the 4th quarter age group 3 usually disappears from the catches, while age group 1 adds to the catches.

5.3 State of the stock.

Since no assessment is available, the WG cannot give any advice on the current status of the stock. However, it must be pointed out that the development in the 2004 fishery, as described above, could indicate a low stock level. For the Fladen stock such events have occurred previously, notably in 1987–88. However, a recovery of the stock after that decline was observed already in 1989–90 without any management actions.

6 The *Pandalus* Stock in the Barents Sea and Svalbard area

6.1 Description of the fishery

Norwegian vessels began to exploit the shrimp fisheries in the Barents Sea and Svalbard area in 1970. Russian vessels entered the shrimp fishery in 1974. The yield increased continuously until 1984 when the total yield reached a maximum of 128 000 t. By that time vessels from other countries had entered the fishery. Since then, biomass and yield levels have fluctuated because there were different recruitments, cod consumption and effort in the fisheries due to price of shrimp. The yield peaked above 80 000 t in 1990 and in 2000 but has decreased since to approximately 40 000 t 2003 and 2004. The most important fishing ground is the Hopen area in the central Barents Sea.

The first vessels using double trawls entered the fishery in 1996. Since then the efficient effort has increased continuously and in 2002 approximately 35 Norwegian vessels had the technology to use double trawl or even triple trawl. Since 2002 the majority of the yield is taken by double trawl.

In the Svalbard area the shrimp fisheries are regulated by number of effective fishing days and number of vessels by country. In the Barents Sea and Svalbard area, Norwegian rules are that the fisheries be regulated by fishing licences and since 1985 by smallest allowable shrimp size (maximum 10% of catch weight may be < 15 mm carapace length, CL). However, the regulation by smallest allowable shrimp size is not considered to be an efficient management tool in the Russian Economic Zone (REZ) due to the high predation of shrimp. In the REZ, a TAC is established each year by Russian authorities. Fishing grounds are closed if by-catch limits given as number of individuals of fish by species group or shrimp in 10 kg of shrimp are exceeded. In 2004 the values of allowed by-catch are set at eight for the sum of cod and haddock, ten for redfish and three for Greenland halibut per catch of 10 kg shrimp.

Sorting grids in the shrimp trawls first became mandatory operating within the Norwegian 12 miles zone in February 1990. In October 1991 this rule was extended to apply to shrimp trawls used in all of the Norwegian EZ. Finally, in 1993 the Joint Norwegian Russian Fisheries Commission agreed that the sorting grid was to be mandatory for all vessels conducting shrimp fishery in the Barents Sea and the Svalbard area.

6.2 Catch and effort data

6.2.1 Landings

Preliminary reported landings for all countries show a substantial decrease of landings from 82 816 t in 2000 to approximately 60 000 t in 2002 and 2001 and a further decrease to approximately 40 000t in 2003 and 2004 (Table 6.1, Figure 6.1). Thereby the total landings have decreased to 50% in three years. The 2005 landings are believed to stay at the level of the last two years on approximately 42 000 t.

6.2.2 Discards

Since there is no TAC in the Barents Sea it is believed that all catches are landed and that there are no discards of shrimp in the area.

6.2.3 Effort and CPUE

The Norwegian CPUE has been standardised to vessels 1000–1500 hp with single trawls by using a GLM model including year, region, vessel and gear. The Russian CPUE represents only vessels of 1300 hp using one type of single trawl. Catch, effort, and annual CPUE series for Norway (un-standardised and standardised) and Russia are presented in Table 6.2. The CPUE series for Russia and standardised CPUE for Norway are given in Figure 6.2. The Norwegian shrimp fleet has since late 1990s been upgraded both concerning vessels and the use of double and triple trawls. The Norwegian data show a peak in the effort in 2000 at the same level as the earlier peaks in 1985 and 1990. Both the Russian and Norwegian effort decreased in 2001 with a slight increase in 2002 followed by a further decrease in 2003 and 2004. The CPUE of the Russian fleet has fluctuated in accordance with the shrimp biomass and the standardised Norwegian CPUE series show the same pattern. It should, however, be noted that the Russian fleet is also under development.

6.2.4 Sampling of landings

In 2002, 2003 and 2004 observers collected samples on board commercial Spanish vessels in the Svalbard EZ (Casas, 2005). Length and sex distribution data and data on by-catch of young fish were obtained. These data show a reduction of females from 33% in 2002 to 18% in 2003 and increased to 38% in 2004.

Monitoring of the shrimp catches is required due to the regulation protecting juvenile fish and shrimp through area closures. The Directorate of Fisheries in Norway has, during surveillance cruises conducted by hired commercial shrimp trawlers, collected data on length distributions in the shrimp catch since 1995. The Norwegian Coast Guard also samples some length data during inspections of shrimp catches. In 2002 the Institute of Marine Research established a reference fleet where fishermen take samples of the catch. One of the vessels included in the reference fleet is a part time shrimp trawler. The carapace length is measured on 300 individuals of shrimp in each sample. The sampling frequency will be further increased by more inspections conducted by the Coast Guard.

The catch in 2000 was dominated by shrimp aged four and five years (Figure 6.3). The catch pattern moved towards three year olds in 2001. The catches in 2003 were again dominated by four-year-old shrimp of the 1999 year class. The 1999 year class entered the spawning stock in 2004.

6.3 Research Vessel Data

6.3.1 Trawl Surveys

In the Barents Sea and the Svalbard area, surveys were conducted by Norway in the period 1982–2004 and by Russia from 1984 to 2002 and in 2005 (Figure 6.4.). The Russian survey is a stratified random swept area survey. So was the Norwegian survey until 1989. Since 1990 the Norwegian survey has been using fixed grid stations. The CV of the Norwegian survey index has been less than 10% since 1990. During the 90’s, both surveys have suffered from reductions in survey time and in 2003 and 2004 no Russian shrimp survey was conducted while no Norwegian shrimp survey was conducted in 2005. However, a joint Norwegian-Russian ecosystem survey, also recording shrimp, was conducted in August-September covering the whole Barents Sea. This survey will be conducted annually, but it will take three to four years before a new time-series reliable for the shrimp stock assessment is established. Resources for calibrating the spring shrimp survey to the autumn ecosystem survey are not available. Evaluations of previous surveys, sampling strategies etc are reported in the ICES reports from AFWG 2002, AFWG 2003 and WGPAND 2004 (ICES, 2002a, 2003b, 2005a Tilfoejet af Michala).

6.3.2 Analysis of Survey Data

6.3.2.1 Swept area estimates of biomass

There is a strong correlation between the Norwegian and the Russian survey results (Figure 6.5). Biomass indices were highest during 1984, and have since fluctuated between 30% and 60% of this level with peaks in 1991 and 1998 and low values below the long term mean in 1987–1988, 1994–1995 and 2001–2004. Norwegian bottom trawl surveys indicate a decrease in shrimp biomass in the Barents Sea and Svalbard of 29% from 2003 to 2004. The Russian surveys indicate a reduction of 36 % from 2002 to 2005 (Bakanev *et al.*, 2005). Especially the important Hopen Deep and the Thor Iversen Bank area show a strong reduction in biomass.

The recruitment index from the Norwegian surveys for one-year-old shrimp was low in 2004 and the number of two and three year old shrimp reduced dramatically since 2003 (Figure 6.6, Table 6.5).

6.3.2.2 Natural mortality and predation

Predation by cod is a large source of natural mortality. However, it should be noted that other fish species such as Greenland halibut (*Reinhardtius hippoglossoides*), long rough dab (*Hippoglossoides platessoides*), thorny skate (*Raja radiata*) and blue whiting (*Micromesistius poutassou*) also prey on shrimp (Dolgov, 1997; Dolgova and Dolgov, 1997). The methods used in estimating cod consumption are described by Bogstad and Mehl (1997), and dos Santos and Jobling (1995). In the Barents Sea, the recorded annual consumption of shrimp was estimated to be above 280 000 t throughout the period 1994–2001 (Figure 6.7, Table 6.6). Shrimp consumption may, however, have been overestimated by as much as 50% (Johannesen and Aschan 2005). Future shrimp assessments have to include cod as predator, although it is still important to identify and further study the reasons for the overestimated cod consumption. It is advised that new estimates for shrimp consumed by cod are presented in 2006.

6.4 Assessment of the Pandalus Stock in the Barents Sea

6.4.1 Background

The great plasticity in growth of shrimp and age at sex change, as well as a lack of biological data and length distributions from the catches, make it difficult to apply traditional analytical fishery assessment methods to the data.

Several models have been attempted unsuccessfully in assessing shrimp in the Barents Sea and some of these are listed below:

Production models: Shaefer and Fox stock models and stock production model including predation (Stefánsson *et al.*, 1994, Berenboim and Korzhev, 1997). Catch at age analysis (cohort models): Single species virtual population analysis (VPA) and multi species virtual population analysis (Sparre, 1984, Bulgakova *et al.*, 1995)). A length based biomass model for shrimp in the North-east Atlantic has been developed in 2005 (Sunnanå, 2005). The assessment is still based on an evaluation on the available CPUE time series and incomplete survey series.

6.4.2 Status of the Stock

- Standardised Norwegian CPUE and Russian CPUE show a decrease from 2002 to 2004 of 22% and 40% respectively (Table 6.2, Figure 6.2).
- The Russian survey in 2005 shows a 36% decrease in the biomass index from the previous survey conducted in 2002 (Table 6.4). From 2003 to 2004 the Norwegian survey index decreased by 29%, to the lowest level observed since 1987 (Table 6.3).

- The spawning stock number has decreased 32% from 2002 to 2004 (Table 6.5). The strong 1999 and 2000 year classes seem to have been reduced by predators and the fishery, and did not contribute to an increase in fishable biomass in 2004 and 2005.
- The abundance of one-year-old shrimp is low and two- and three-year-old shrimp show a reduction from 2003 to 2004 (Table 6.5 and Figure 6.6).

As the time series of surveys has ceased it is not possible to give a prediction for the stock. As the recruitment indices were low in 2004, the stock is expected to remain at a low level in 2006. It is recommended that a TAC should be implemented for 2006 and set no higher than the current catch level of 40 000 t.

6.4.3 Recommendations on further work

- It is strongly recommended that the Russian and Norwegian shrimp surveys should be re-instituted;
- If the shrimp surveys can not be re-instituted, the existing ecosystem survey should be calibrated by conducting a directed survey for shrimp in spring in a limited area in two consecutive years.
- Scientists should further investigate procedures for estimating the shrimp consumed by cod and give reliable estimates of biomass consumed;
- Licensing of vessels participating in the shrimp fishery must include an obligation for all nations active in the fishery to report length and sex distributions from commercial catches;
- Authorities should enforce the submission of accurately completed logbooks; it is especially important that the use of single, double or triple trawls should be recorded;
- Work on developing and evaluating assessment methods should be continued;
- Catch and effort statistics should be submitted to ICES by all countries active in the shrimp fishery in the Barents Sea and the Svalbard area by 1 September.

7 The by-catch in the *Pandalus* fisheries in the Subarea IV and Division IIIa

7.1 Available data

In recent years there has been increasing focus on mixed fisheries or fisheries, where species from stocks 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, but nevertheless are several valuable fish species, e.g. cod, anglerfish, taken and landed as by-catch. Since the *Pandalus* fisheries are classified as ‘small mesh fisheries’ for ‘human consumption (h.c.) species’ there has for a long time been concern on the by-catches in these fisheries, and the WGPAND has since the 1980s regularly compiled and presented relevant information on by-catch in the WG reports.

Tables 7.1 A–G give for the recent 10 years period the available Danish, Norwegian and Swedish data on by-catch of the main species in the *Pandalus* fisheries landed for h.c. In the some years quantities of Norway pout and Blue whiting have been specified. For all 3 countries the data are from log book records and are only recording landings, i.e. not the discarded by-catch. Both the Danish and Swedish log book records cover nearly all the recorded *Pandalus* landings. No Norwegian by-catch data for 2004 was available records for 2004

These tables also give cod as well as total h.c. by-catch as the percentage of *Pandalus* landings. It is believed that these are better estimators than % of total catch, since log-book recordings probably not always are consistent in recordings of e.g. Norway pout and/or Blue whiting. In Skagerrak the percentages of landed total h.c. by-catch are similar for all 3 countries (excluding trawls with selective grids). Considering cod only, it is noted that the percentage is highest in the Danish fisheries. However, for the Norwegian log-book records it is likely that the rather low percentages of recorded cod is because some of the cod by-catch has not been specified as cod, but merely as unspecified h.c. by-catch. Note that for the Norwegian data the category ‘other market fish’ is very high compared to this category in the Danish and Swedish data. Note that the Danish by-catches from the Norwegian Deep are higher than the Norwegian. A minor fraction of the Swedish *Pandalus* fishery is conducted with trawls equipped with a selective grid, and judging from the logbook records of landings by this gear type, it seems to be very efficient in reducing by-catch, see Table 7.1 C and Section 7.3.

It cannot be ruled out, that some times in some areas by-catch of valuable species, for instance angler fish, cod and witch flounder is considered a positive contribution to the total landings from a fishing trip for *Pandalus*.

The current ‘at-sea-sampling’ programme has provided sporadic samples of discarded by-catch in the Danish and Swedish *Pandalus* fisheries. However, these data are presently considered to scanty to base any assessments of the amount of e.g. discarded cod on.

7.2 The magnitude of cod landings from the *Pandalus* fisheries.

The historic data given in Tables 7.1 A–G indicate minor fluctuations without any trends in the amount of cod as by-catch. They do not seem to follow the trend in the development of the cod stock in the North Sea and Skagerrak. However, the relative high by-catch figures of Saithe in recent years in contrast to low values for the first half of the 1990s (Denmark and Sweden) could reflect the increase in size of this stock.

These historic cod by-catch figures indicate for instance that in recent years the total of amount of cod landed by the *Pandalus* fisheries in the North Sea and IIIa by Denmark, Norway and Sweden has fluctuated around 300 t. Since the U.K. shrimp fishery on Fladen Ground has been small in recent years, the overall picture would not change by adding this component. The overall conclusion on the total annual landed by-catch of cod in the *Pandalus* fisheries in these areas is that it contributes less than 1 % of total annual landings of cod in the North Sea and Skagerrak. This amount could probably be reduced further, if the shrimp-trawls were equipped with selective grids, as described below.

7.3 Improved species selection in shrimp trawls equipped with selective grids.

The current legal minimum mesh size of 35 mm (stretched mesh) in shrimp (*Pandalus* sp.) trawls implies the catch of also other unwanted undersized fish species and a resulting increase in mortality due to discards. Experiments with species selective grids installed in the trawl started in Norway 1988, and the Nordmøre grid with 20 mm bar space is now mandatory in Norwegian *Pandalus* trawls in the Norwegian zone. Recent experiments on shrimp fishing grounds in the Norwegian Deeps have shown that the by-catch of cod, haddock, saithe and whiting is low when targeting shrimp at depths deeper than 240–250 meters, which are the common fishing depths in this area. Particularly juveniles of such species are absent in shrimp trawl catches in this fishing area. (Valdemarsen and Misund, 2003). Similar species selective shrimp trawls have been tested in the North Sea and the Skagerrak in an EU Study project by Denmark and Sweden (Madsen *et al.*, 1998). The Swedish experimental fishing was performed both inshore and offshore with identical rigging as in the Norwegian legislation. The results shows that the total proportion of fish in the inshore catch was reduced by 85% when the Nordmøre grid was used and the remaining fish by-catch consisted almost solely of

Norway pout. No significant loss of shrimp could be seen, but average catch of shrimp per trawling hour decreased by about 7% when using the grid. Even in the offshore fishery the by far largest by-catch was Norway pout, which also is the most difficult species to sort out because of its small size. All other fish species were sorted to 97%, and commercial fish species to 99% efficacy.

The conclusions from these studies are that an introduction of the equivalent grids in the shrimp trawl fishery will drastically reduce the by-catch of fish in general, and commercial fish species in particular and according to published results, a comparable selection efficacy is unlikely to be achieved using techniques that depend solely on mesh selection.

Detailed description of Nordic experiments with grids in shrimp trawls is found in (Anon., 1996) and an extensive reference list is presented in (ICES, 1998).

8 The by-catch in the *Pandalus* fisheries in the Barents Sea

Young cod, haddock, redfish and Greenland halibut of the Northeast Arctic stocks are caught as by-catch in Norwegian shrimp fisheries. The cod and red-fish by-catch is estimated based on commercial shrimp catch statistic, logbook data, surveys and surveillance data from 1983–2005 will be available in December 2005. Data on haddock by-catch will be available in April 2006 and reported to the AFWG.

Especially one and two year old cod are subject to the shrimp fishery due to overlapping in the distribution of shrimp and cod in the central area of the Barents Sea and around Svalbard. Cod by-catch in shrimp fishery is regulated by area closures since 1983 (Aschan, 1999, 2000); In 1983, 3 juvenile cod and haddock were allowed as by-catch pr 10 kg of shrimp. As a result of the introduction of the sorting grid in 1995 the number of cod and haddock allowed as by-catch increased to 10. The weight and number of individuals of other by-catch species are not believed to exceed the estimates for cod. However, strong year classes of haddock may reach the same values as cod.

9 Environmental considerations

9.1 The North Sea

Relevant information on the ecosystem of ecosystem/environment in the North Sea area related to the *Pandalus* stocks and fisheries are found in ICES ACFM and ACE reports.

The WG notes that many of the by-catch species in the *Pandalus* fisheries are considered deep sea species found in fragile environments. The amount of by-catch may be effectively reduced by the use of selective grids.

9.2 The Barents Sea and Svalbard area

A general description of the ecosystem of ICES areas I and II is found in the report of the ICES Arctic Fisheries Working Group (ICES, 2005b). Some highlights of importance to the North-east Arctic (ICES I and IIb) stock of Northern Shrimp (*Pandalus borealis)* are given here.

The Barents Sea (also containing the Svalbard Waters) is a shelf area of approx. 1.4 million km^2, which borders to the Norwegian Sea in the west and the Arctic Ocean in the north, and is part of the continental shelf area surrounding the Arctic Ocean. The extent of the Barents Sea is limited by the continental slope between Norway and Spitsbergen in west, the top of the continental slope against the Arctic Ocean in north, Novaja Zemlya in east and the coast of

Norway and Russia in the south. The average depth is 230 m, with a maximum depth of about 500 m at the western entrance. There are several bank areas, with depths around 50–200 m.

Temperatures in the Barents Sea were relatively high during most of the 1990s. There was a continuous warm period from 1989–1995, followed by a short period with below average conditions. Since 1998 the temperature has, with few exceptions, stayed well above average. In 2004 the temperature in the Barents Sea was well above the long-term average throughout the whole year, and this transferred into the beginning of 2005.

The Barents Sea is a relatively simple ecosystem with few fish species of potentially high abundance. These are the Northeast Arctic stocks of cod, haddock and northern shrimp, the Barents Sea capelin, polar cod, and the immature part of the Norwegian Spring-Spawning stock of herring. The last few years there has been an increase of blue whiting migrating into the Barents Sea. The composition and distribution of species in the Barents Sea depends considerably on the position of the polar front. Variation in the recruitment of some species, including cod and herring, has been associated with changes in the influx of Atlantic waters into the Barents Sea. Cod, capelin and herring are key species in this system. Cod is the most important predator and prey on capelin, herring, shrimp and cod, while herring prey on capelin larvae. As an indication of possible impact on the shrimp stock development the consumption from cod and the status of the pelagic system illustrated by the time series of capelin and zooplankton biomasses may be used (Figure 3.2)

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Table 4.1 Nominal landings (tonnes) of Pandalus borealis in ICES Division IIIa and subarea IV as officially reported to ICES.

	Division IIIa				Sub-area IV					
Year	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	3952	154	0	465	6601
2002	1967	3709	2044	7720	1647	3612	143	0	70	5472
2003	2612	3736	2098	8446	1631	3979	144	0	0	5754
2004	3044	4638	2152	9834	884	4360	147	0	0	5391

* Includes small amounts of other Pandalid shrimp
† 1970 to 1974 includes subarea IV.
Total 1988 - 1990 includes19, 21 and 51 t. by the Netherlands
Note: 2004 figures are preliminary.

Tabel 4.2 Pandalus borealis landings from divisions IIIa (Skagerrak) and IVa (eastern part). as estimated by the Working Group

Year	Denmark	Norway	Sweden	Total	Estimated discards*)	TAC	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	*200*		7805
1985	4498	6646	1571	12715	558		13273
1986	4866	6490	1463	12819	414		13233
1987	4488	8343	1322	14153	723		14876
1988	3240	7661	1278	12179	750		12929
1989	3242	6411	1433	11086	1107		12193
1990	2479	6108	1608	10195	1226		11421
1991	3583	6119	1908	11610	497		12107
1992	3725	7136	2154	13015	541	15000	13556
1993	2915	7371	2300	12586	889	15000	13475
1994	2134	6813	2601	11548	214	18000	11761
1995	2460	8095	2882	13437	275	16000	13713
1996	3868	7878	2371	14117	318	15000	14436
1997	3909	8565	2597	15071	1039	15000	16110
1998	3330	9606	2469	15406	348	18800	15753
1999	2072	6739	2445	11256	639	18800	11895
2000	2371	6118	2225	10714	687	13000	11401
2001	1953	6895	2108	10956	701	14500	11657
2002	2466	7321	2301	12088	254	14500	12342
2003	3244	7715	2389	13348	1253		14601
2004	3905	8998	2464	15203	1248		16451

*) see Sect. 4.2.2

Table 4.3 National LPUE and total effort as estimated by the Working Group, Pandalus division IIIa and IVa east

Year	Denmark LPUE kg/day	Denmark ted LPUE	Total effort days	Norway LPUE kg/hr	Total effort Khrs	Sweden LPUE kg/hr	Total effort Khrs
1984	452	452	3869			25	40
1985	743	743	6053			32	49
1986	556	556	8700	36	179	30	49
1987	499	499	9212	36	230	23	57
1988	432	432	7104	31	251	22	57
1989	441	441	7143	23	273	23	63
1990	591	591	4195	26	232	26	58
1991	645	645	5555	30	206	31	61
1992	641	641	5811	35	204	27	80
1993	571	571	5068	31	243	25	91
1994	677	655	3146	31	218	33	82
1995	801	747	3072	35	255	39	76
1996	860	782	4466	37	214	32	74
1997	1034	907	3770	42	212	33	78
1998	1023	868	3256	44	219	34	73
1999	833	682	2501	32	219	34	72
2000	870	699	2713	31	195	30	75
2001	840	656	2314	32	217	29	74
2002	1069	809	2306	39	186	35	65
2003	1073	793	3013	47	166	33	72
2004	1393	1032	2788	57	159	33	74

Table 4.4 Total international LPUE and effort as estimated by the Working Group ,

Year	LPUE kg/hr	effort Khrs
1984	No Norwegian data	
1985	No Norwegian data	
1986	32.8	403
1987	31.5	473
1988	28.7	451
1989	25.4	480
1990	30.5	375
1991	31.9	379
1992	33.8	401
1993	30.9	436
1994	32.2	366
1995	34.5	397
1996	37.2	388
1997	42.8	377
1998	42.7	369
1999	33.8	352
2000	33.7	338
2001	33.2	351
2002	39.5	312
2003	45.6	320
2004	53.2	309

Table 4.5 Sampling of Pandalus in IVaE and IIIa, 2004

Denmark		N:o		Numbers		
Quarter	Landing (ton)	samples	Weight (kg)	measured-sexed		
1	1204	6	7.6	1350		
2	1020	5	5.7	1197		
3	863	2	2.3	488		
4	818	3	3.6	813		
Total	3905	16	19.3	3848		
Norway		N:o		Numbers		
Quarter	Landing (ton)	samples	Weight (kg)	measured-sexed		
1		0		0		
2		0		0		
3		0		0		
4		0		0		
Total	0	0	0.0	0		
Sweden		N:o		Numbers		
Quarter	Landing (ton)	samples	Weight (kg)	measured-sexed		
1	623	6	19	2856		
2	698	5	17	3024		
3	618	6	20	3409		
4	523	4	13	1964		
Total	2462	21	69.8	11253		
Total		N:o		Numbers	Sampling per 1000 ton landed	
Quarter	Landing (ton)	samples	Weight (kg)	measured-sexed	Weight	Numbers
1	1827	12	27.1	4206	14.9	2301.9
2	1718	10	22.5	4221	13.1	2457.6
3	1481	8	22.5	3897	15.2	2630.8
4	1341	7	17.1	2777	12.8	2071.3
Total	6366.66612	37.0	89.2	15101	14.0	2371.9

Table 4.6 Catch in numbers at age. Pandalus division IIIa and IVa east.

Numbers*10**-6											
YEAR		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
AGE											
	0	17.7	7.4	2.7	14.1	31.3	0.0	3.9	25.5	27.2	0.7
	1	1200.8	1146.4	1260.5	1086.6	2083.6	2250.1	1231.8	1071.4	1889.6	671.9
	2	1305.4	1029.7	1205.6	923.9	385.5	910.8	1035.8	1289.2	803.8	1380.4
	3	187.9	482.7	390.2	300.2	173.8	121.1	326.7	569.1	262.7	143.0
+gp		52.3	25.1	203.2	146.7	13.6	31.3	25.6	57.5	15.5	30.5
TOTALNUM		**2764.1**	**2691.3**	**3062.1**	**2471.5**	**2687.9**	**3313.3**	**2623.8**	**3012.7**	**2998.7**	**2226.4**
TONSLAND		13273	13233	14876	12929	12193	11421	12107	13556	13475	11761
SOPCOF%		89	97	105	102	106	88	97	88	93	0
YEAR		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
AGE											
	0	2.7	61.1	19.7	12.7	4.6	88.1	0.0	3.9	2.4	5.7
	1	646.0	1211.6	2175.6	903.4	1436.1	1270.7	1308.0	922.3	668.7	1062.9
	2	970.5	991.4	1181.9	1597.9	720.1	836.3	826.2	858.4	1466.5	1251.4
	3	851.5	454.6	295.6	468.1	318.3	199.3	382.5	581.8	283.8	477.6
+gp		42.0	69.5	29.8	48.2	43.3	39.2	80.8	101.8	0.0	50.4
TOTALNUM		**2512.5**	**2788.2**	**3702.6**	**3030.2**	**2522.4**	**2433.5**	**2597.5**	**2468.3**	**2421.4**	**2847.9**
TONSLAND		13713	14436	16110	15753	11895	11401	11657	12339	13338	15815
SOPCOF%		87	88	94	96	95	95	90	88	99	104

Table 4.7 Mean weight at age in catches. Pandalus division IIIa and IVa east.

Catch weights at age (kg)

YEAR	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
AGE										
0	0.0009	0.0012	0.0009	0.0009	0.0011	0.0009	0.0015	0.0010	0.0009	0.0009
1	0.0032	0.0032	0.0024	0.0030	0.0034	0.0030	0.0033	0.0035	0.0035	0.0034
2	0.0064	0.0054	0.0048	0.0054	0.0065	0.0053	0.0053	0.0052	0.0067	0.0060
3	0.0104	0.0083	0.0077	0.0090	0.0099	0.0083	0.0079	0.0078	0.0088	0.0093
+gp	0.0134	0.0140	0.0114	0.0117	0.0133	0.0106	0.0122	0.0095	0.0109	0.0117

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
AGE										
0	0.0009	0.0007	0.0009	0.0007	0.0007	0.0007	0.0006	0.0008	0.0014	0.0017
1	0.0033	0.0037	0.0031	0.0033	0.0033	0.0032	0.0031	0.0036	0.0035	0.0037
2	0.0057	0.0067	0.0061	0.0055	0.0063	0.0063	0.0056	0.0054	0.0060	0.0061
3	0.0089	0.0094	0.0094	0.0087	0.0088	0.0103	0.0086	0.0083	0.0082	0.0077
+gp	0.0116	0.0138	0.0119	0.0133	0.0112	0.0139	0.0117	0.0113	0.0121	0.0107

Table 4.8 Estimated biomass (tonnes) of shrimp by area (stratum), assuming catch efficiency = 1.0

Survey		Stratum																Total area	
Year	Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Index	CV
1984	1	0	2441	-	2144	4048	3093	1313	-	336	346	316	[1)]556	605	1253	1305	1535	19291	
1985	1	0	4768	-	1162	3288	2607	2016	0	815	475	[1)]1900	794	840	4921	2664	4066	30316	
1986	1	0	2183	-	920	[1)]933	1940	663	-	389	177	[1)]857	540	618	1521	2073	733	13547	
1987	1	88	3765	-	2482	4103	3294	1237	0	1370	254	[1)]1470	584	419	2168	1350	964	23548	
1988	1	0	1126	-	720	373	1079	682	0	294	96	472	391	282	814	777	343	7449	
1989	1	-	932	-	2347	[1)]898	1722	1159	0	560	263	579	556	498	1375	1443	918	13248	
1990	1	0	705	187	3245	[1)]1067	2373	471	0	647	171	1044	559	564	2088	1895	907	15920	
1991	1	0	1903	1008	2612	189	2851	1053	152	725	189	740	526	716	2163	2683	1312	18821	
1992	1	0	615	717	585	136	5743	2299	0	568	527	2091	951	669	3567	2550	1211	22229	
1993	1	0	1481	401	4063	[1)]1487	1437	688	-	621	281	2596	758	728	2735	3823	1237	22336	
1994	1	0	1391	626	2321	345	2439	1992	-	461	255	1627	468	844	3004	2284	1320	19377	
1995	1	0	2794	-	1420	202	4042	953	-	818	236	1836	513	665	2950	2076	1714	20220	
1996	1	0	4901	-	1367	133	3576	1108	-	533	441	3590	616	921	4277	2456	1286	25205	
1997	1	0	7882	-	1995	416	3393	2406	-	764	349	1969	1530	1487	3199	3584	3169	32143	
1998	1	-	5069	-	3357	586	2223	1049	-	682	401	1105	451	529	3186	2439	1378	22455	
1999	1	0	5180	-	5360	3158	3254	1051	-	235	243	475	266	311	4560	2228	1596	27917	
2000	1	-	3436	-	2664	1121	2181	695	-	343	158	939	380	286	4159	2495	1497	20354	
2001	1	-	5180	0	5360	3158	3254	1051	-	307	245	512	266	311	4560	2228	1596	28028	
2002	1	-	[1)]3922	-	[1)]3104	459	3749	1847	-	1153	364	1403	496	411	5425	4470	3329	30133	
2003	2	-	-	-	1410	750	2770	840	300	1240	430	480	770	960	2210	1950	850	14960	
2004	3	-	3590	-	2830	-	3540	1530	-	690	400	120	1390	1230	11060	4650	2890	33920	34%
2005	3	0	3790	-	5460	0	3160	1900	-	1130	580	1580	570	910	3370	3150	4500	30100	37%

[1)]Estimated as an average of the stratum estimates scaled by overall biomass of the year.

Table 4.9 Indices of predators of *Pandalus.*

Species	2004	2005
Blue Whiti	5.4	12.7
Saithe	20.4	68.4
Cod	1.9	3.3
Roundnose	11.0	6.7
Rabbit fish	9.5	4.5
Haddock	0.8	3.3
Redfishes	0.2	0.4
Velvet Bel	1.5	7.5
Skates,Ray	1.9	0.2
Long Roug	0.3	0.6
Hake	1.5	4.1
Angler	2.0	0.6
Witch	1.1	0.2
Dogfish	0.2	0.1
Whiting	0.0	1.0
Blue Ling	0.0	0.0
Ling	0.1	0.6
Fourbearde	0.0	0.1
Cusk	0.3	0.4
Halibut	0.0	0.6
Pollack	0.0	0.2
Greater Fork-beard	0.0	0.0
Total	58.1	115.38

Table 4.10 Shrimp in Skagerrak and Norwegian Deep: risk that the following reference points have been transgressed during 1990-2005: Bmsy (biomass giving maximum production), Blim (30% Bmsy (Shelton, 2004), the biomass limit) Flim (=Fmsy, the limit fishing mortality) and that the catches were above the MSY.

Year	p(B<Bmsy)	p(B<Blim)	p(F>Flim)	p(C>MSY)
1990	8.2%	0.2%		1.6%
1991	5.4%	0.1%		2.4%
1992	4.1%	0.1%		2.5%
1993	3.7%	0.1%		1.7%
1994	3.4%	0.1%		2.4%
1995	3.0%	0.1%		3.2%
1996	2.4%	0.1%		4.6%
1997	2.0%	0.1%		4.8%
1998	2.2%	0.1%		2.0%
1999	2.1%	0.1%		1.3%
2000	2.2%	0.1%		1.4%
2001	1.7%	0.1%		1.7%
2002	1.5%	0.1%		2.3%
2003	6.4%	1.0%		2.2%
2004	5.1%	1.2%		2.2%
2005	7.7%	2.2%		1.6%

Table 5.1 Landings in tonnes of Pandalus borealis from the Fladen Ground (Division IVa) 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	23

Note: 2004 figures are preliminary.

Table 5.2 Pandalus borealis, Fladen Ground. Reported LPUE (shrimp trawlers), and estimated total effort.

Year	Recorded Denmark LPUE (ton./day)	Total effort (Days)	effort Index	UK (Scotland) 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

*) average weighted by total landings

**) No directed shrimp fishery

Table 6.1 Nominal shrimp catches (t) by country (Sub-areas I and II combined). Data were provided by ICES and Working Group members.

YEAR	NORWAY	RUSSIA	OTHERS	TOTAL
1970	5508	0	0	5508
1971	5116	0	0	5116
1972	6772	0	0	6772
1973	6921	0	0	6921
1974	8008	0992	0	9000
1975	8197	0	2	8199
1976	9752	0548	0	10300
1977	6780	12774	4854	24408
1978	20484	15859	0	36343
1979	25435	10864	390	36689
1980	35061	11219	0	46280
1981	32713	10897	1011	44621
1982	43451	15552	3835	62838
1983	70798	29105	4903	104806
1984	76636	43180	8246	128062
1985	82123	32104	10262	124489
1986	48569	10216	6538	65323
1987	31353	6690	5324	43367
1988	32021	12320	4348	48689
1989	47064	12252	3432	62748
1990	54182	20295	6687	81164
1991	39663	29434	6156	75253
1992	39657	20944	8021	68622
1993	32663	22397	806	55866
1994	20116	7108	1063	28287
1995	19337	3564	2319	25220
1996	25445	5747	3320	34512
1997	29079	1493	5164	35736
1998	44792	4895	6103	55790
1999	52612	10765	12292[2]	75669
2000	55333	19596	8241[3]	83170
2001	43021	5875	8136[4]	57032
2002	48799	3802	8105[5]	60706
2003	34652	2776	2340[5]	39768
2004[1]	36188	2400	5002[6]	43590

[1] Preliminary data

[2] Catches reported by Estonia, Faroe Islands, Germany, Greenland, Iceland, Lithuania, Portugal Spain and UK(Eng.Wal.NI)

[3] Catches reported by Estonia, Faroe Islands, Iceland, Lithuania, Portugal, Spain and UK.

[4] Catches reported by Estonia, Faroe Islands, Lithuania, Portugal, Spain and UK

[5] Catches reported by Estonia, Faroe Islands, Lithuania, Spain and UK

[6] Catches reported by Estonia, Faroe Islands, Lithuania, Spain and Portugal

Table 6.2 Catch (t), effort (h) and CPUE (kg/h) data in ICES sub-areas I, IIa and IIb. Norwegian data based on log books from all vessels and scaled to the level of vessels fishing with single trawl at the size of between 1000hp and 1500hp. Russian data based on daily reports from vessels smaller than 1300 hp.

			NORWAY				RUSSIA	
Year	Catch	Effort	New effort	New CPUE	CPUE	Catch	Effort	CPUE
1980	20386	110931	97521	209	177			
1981	21408	99546	87840	244	195	2341	8100	289
1982	30051	151531	134066	224	210	4966	20400	243
1983	50403	219820	198459	254	264	13223	48000	276
1984	54555	222259	202629	269	230	33403	118900	281
1985	56589	249235	230428	246	204	27974	110900	252
1986	32212	208964	200133	161	139	7912	33500	236
1987	17192	155672	150964	114	101	3818	23900	160
1988	20803	188194	181581	115	118	9010	61600	146
1989	33775	242843	236601	143	131	7928	53500	148
1990	39722	267423	263021	151	160	17126	94500	181
1991	32922	193227	194172	170	152	15532	74100	210
1992	36449	173105	179101	204	187	13025	57000	229
1993	27376	131157	124522	220	178	11390	60000	190
1994	11655	70782	68551	170	136	4521	27500	164
1995	10448	71846	70901	147	145	3347	26100	128
1996	15221	83940	84941	179	169	5680	35300	161
1997	22460	105850	124851	180	154	1507	7600	198
1998	36642	126807	153809	238	256	4900	21212	231
1999	45137	155683	197202	229	257	6238	30900	202
2000	48462	173265	237431	204	238	12204	71784	170
2001	41175	117239	182490	226	256	2484	16609	150
2002	48321	118029	223616	216	265	3745	21773	172
2003	30200	79528	151352	200	270	2775	16390	127
2004	31661	77843	165394	191	296	2400	23301	103

Table 6.3 Indices of shrimp biomass from Norwegian surveys in the years 1982–2002 by main areas.

MAIN	A	B	C - THOR	D - BEAR	E	F	G	H	TOTAL	SUM.
Area	East	Tiddly	Iversen	Island	Hopen	Bear	Storfjord	Spits-		A,B,C, E
	Finnmark	Bank	Bank	Trench		Island	Trench	bergen		
Strata	38078	6 - 7	10 - 12	5, 8, 9,	14 - 18,	19 - 22/	41 - 50	51 - 70		
				13	24	31 - 40				
1982	35	34	44	53	66	56	17	22	327	179
1983	40	57	61	53	112	52	21	33	429	270
1984	40	51	64	60	141	66	20	29	471	296
1985	23	17	27	18	96	31	17	17	246	163
1986	10	7	13	25	57	34	10	10	166	87
1987	29	13	18	23	31	10	9	13	146	91
1988	26	18	18	36	32	24	13	14	181	94
1989	41	17	13	17	33	53	22	20	216	104
1990	31	13	25	42	58	43	27	23	262	127
1991	22	28	22	54	120	44	21	10	321	192
1992	18	22	33	37	62	38	14	15	239	135
1993	17	19	32	29	85	20	12	19	233	153
1994	19	8	13	15	52	33	9	12	161	92
1995	10	10	11	17	83	33	16	13	193	114
1996	21	8	26	26	110	42	21	22	276	165
1997	24	34	20	34	116	44	12	16	300	194
1998	18	24	41	26	120	72	12	28	341	203
1999	17	19	23	21	169	31	21	16	316	227
2000	14	29	25	26	102	29	10	12	247	170
2001	18	10	30	15	61	25	10	17	184	118
2002	11	18	28	16	86	18	9	10	196	143
2003	15	17	36	12	94	15	8	16	213	162
2004	14	24	22	13	46	14	7	11	151	106
% 03/02	34	-3	30	-22	9	-19	-12	60	9	14
% 04/03	-4	38	-39	6	-51	-3	-8	-33	-29	-35

Table 6.4 Indices of shrimp biomass (1000 t) from Russian survey in the 1984–2002 and 2005 by main areas. Catchability of 0.182 is used in the estimate.

MAIN	A	B	C-THOR	E	F	G	H	I	K	TOTAL	SUM.
Area	East	Tiddly	Iversen	Hopen	Bear	Storfiord	Spits-	Kola	Goose		A,B,C,E
	Finmark	Bank	Bank		Island	Trench	bergen	coast	Bank		
Strata	1-4	6,7,1s	10-12,25	14-18	38-40,	48-50	53-55,58-60,	2s-6s	7s-8s		
					43-45		63-65,58-70				
1984	38	137	99	254				133		661	528
1985	14	45	74	255		6	46	19	9	468	388
1986	9	19	44	140		42	127	9	9	399	212
1987	16	17	59	107	45	36	27	25	14	346	199
1988	14	31	39	49		22	29	36	13	233	133
1989	70	128	57	132	6	60	25	105	20	603	387
1990	90	195	119	259	14	110	30	196	15	1028	663
1991	90	153	104	541	9	70	27	155	43	1192	888
1992	80	153	92	409				65	77	876	734
1993	45	91	159	382	9		58	37	111	892	677
1994	4	35	48	255	21			14	27	404	342
1995	5	28	15	80	33	53		16	18	248	128
1996	20	98	127		21			67	108	441	245
1997	26	108	130	341				108	52	765	605
1998	14	106	136	172				108	41	576	427
1999	43	139	107	523				93	61	966	812
2000	29	73	109	328	9	39		72	141	800	539
2001	11	52	105	185	19	14	13	14	55	468	353
2002	30	129	198	353	15	39	51	70	105	980	710
2005	23	103	126	203	31	54	30	29	58	656	455
% 02/01	173	148	89	91	-21	179	292	400	91	109	101
% 05/02	-23	-20	-36	-42	107	38	-41	-59	-45	-33	-36

Table 6.5 Shrimp in the Barents Sea defined as index of numbers in size groups according to carapace length at age and number of egg bearing females contributing to the recruitment (SSN) in the Norwegian Barents sea survey (whole mm).

CL (MM)	<9	9<CL<13	13<CL<17	17<CL<19	>19MM	
year	1	2	3	4	5+	SSN
1990		8	192	357	567	131
1991		59	213	391	756	123
1992		84	308	291	567	109
1993		44	355	316	405	101
1994		23	186	221	250	30
1995	0,4	20	238	233	307	9
1996	0,2	27	335	374	367	25
1997	0,5	22	372	511	440	47
1998	0,8	9	374	517	567	51
1999	1,3	12	192	357	510	111
2000	2,6	33	147	278	559	66
2001	2,1	20	138	138	410	61
2002	1,1	22	218	295	390	165
2003	0,5	19	254	249	362	110
2004	0,7	5	106	198	295	75

Table 6.6 Biomass indices for shrimp from the Norwegian surveys, biomass estimate for cod (age 3 years and older) and the shrimp consumed by the cod in the Barents Sea.

YEAR	COD (3+)	SHRIMP INDEX	SHRIMP CONSUMED
1984	818	471	436
1985	957	246	155
1986	1292	166	142
1987	1120	146	191
1988	913	181	129
1989	891	216	132
1990	963	262	194
1991	1560	321	188
1992	1910	239	373
1993	2355	233	315
1994	2149	161	516
1995	1815	193	362
1996	1700	276	341
1997	1526	300	311
1998	1221	341	326
1999	1097	316	256
2000	1108	247	461
2001	1393	184	284
2002	1593	196	230
2003	1815	212	230
2004	1749	151	250

Tables 7.1 A - G 1995 - 2004

A: Skagerrak, Sub-div. IIIA. Danish log book records

	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
Species:	Tons	% of total catch	Tons	% of total catch	Total	% of total catch	Total	% of total catch	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	151.6	4.8	88.5	2.0	97.5	2.3	53.4	1.5	8.1	0.5	1.4	0.1	0.1	0.0	128.4	5.2	0.0	0.0	0.0	0.0
Norway lobster	28.3	0.9	65.5	1.5	38.8	0.9	31.0	0.9	22.1	1.3	18.6	0.8	14.4	1.0	13.9	0.6	31.8	1.0	13.9	0.4
Pandalus	2421.0	76.1	3664.2	82.1	3617.0	84.4	2933.0	83.0	1398.5	81.8	1897.6	83.9	1185.9	84.3	1966.6	79.2	2612.1	83.0	3044.3	84.7
Angler fish	12.3	0.4	28.5	0.6	18.7	0.4	12.5	0.4	8.0	0.5	12.4	0.5	10.0	0.7	13.2	0.5	6.7	0.2	7.3	0.2
Whiting	0.1	0.0	0.9	0.0	0.9	0.0	0.2	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.3	0.0	1.1	0.0	0.2	0.0
Haddock	10.8	0.3	19.8	0.4	9.3	0.2	17.8	0.5	9.7	0.6	11.3	0.5	13.1	0.9	72.1	2.9	81.0	2.6	36.7	1.0
Hake	3.9	0.1	7.3	0.2	6.2	0.1	2.9	0.1	2.8	0.2	3.8	0.2	7.5	0.5	4.7	0.2	5.0	0.2	4.0	0.1
Ling	0.7	0.0	1.1	0.0	0.4	0.0	0.7	0.0	0.6	0.0	0.5	0.0	0.4	0.0	0.5	0.0	1.0	0.0	1.2	0.0
Saithe	6.0	0.2	82.6	1.9	80.8	1.9	85.6	2.4	41.0	2.4	53.9	2.4	52.6	3.7	129.1	5.2	214.3	6.8	263.2	7.3
Witch flounder	39.8	1.3	32.5	0.7	33.8	0.8	66.6	1.9	56.1	3.3	104.5	4.6	32.6	2.3	37.6	1.5	43.6	1.4	50.1	1.4
Norway pout	144.3	4.5	114.6	2.6	83.9	2.0	29.9	0.8	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cod	159.0	5.0	179.5	4.0	187.8	4.4	188.4	5.3	100.9	5.9	84.7	3.7	51.6	3.7	72.6	2.9	89.1	2.8	113.2	3.1
Other market fish	203.0	6.4	179.2	4.0	111.7	2.6	111.7	3.2	61.4	3.6	71.7	3.2	37.9	2.7	45.2	1.8	62.2	2.0	61.3	1.7
Cod as % of shrimp:		6.6		4.9		5.2		6.4		7.2		4.5		4.4		3.7		3.4		3.7
Total H.C. as % of shrimp:		31.4		21.8		18.5		20.5		22.3		19.1		18.6		26.3		20.5		18.1

B: Skagerrak, Sub-div. IIIA. Swedish log book records

	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
Species:	Total	% of total catch	Total	% of total catch	Total	% of total catch	Total	% of total catch	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		0.0		0.0	16.0	0.8	14.6	0.7
Norway lobster	23.0	0.9	24.0	1.1	19.0	0.8	30.0	1.3	27.0	1.2	23.0	1.1	13.0	0.6	10.0	0.5	10.1	0.5	5.9	0.3
Pandalus	2453.0	93.6	1978.0	89.2	2092.0	89.2	2044.0	86.1	2107.0	89.9	1885.0	88.6	1815.0	89.3	1836.0	85.0	1769.8	85.9	1754.4	80.0
Angler fish	3.0	0.1	2.0	0.1	4.0	0.2	3.0	0.1	3.0	0.1	3.0	0.1	5.0	0.2	4.0	0.2	2.6	0.1	2.6	0.1
Whiting	1.0	0.0	2.0	0.1	3.0	0.1	1.0	0.0	2.0	0.1	3.0	0.1	3.0	0.1	6.0	0.3	3.5	0.2	2.8	0.1
Haddock	17.0	0.6	11.0	0.5	15.0	0.6	40.0	1.7	11.0	0.5	18.0	0.8	29.0	1.4	55.0	2.5	18.4	0.9	13.8	0.6
Hake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	0.1	2.0	0.1	2.0	0.1	1.6	0.1	4.8	0.2
Ling	2.0	0.1	3.0	0.1	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	2.0	0.1	1.2	0.1	1.9	0.1
Saithe	3.0	0.1	57.0	2.6	84.0	3.6	91.0	3.8	31.0	1.3	31.0	1.5	26.0	1.3	119.0	5.5	144.5	7.0	270.5	12.3
Witch flounder	16.0	0.6	11.0	0.5	23.0	1.0	38.0	1.6	58.0	2.5	71.0	3.3	46.0	2.3	51.0	2.4	39.8	1.9	51.1	2.3
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cod	69.0	2.6	95.0	4.3	70.0	3.0	89.0	3.8	74.0	3.2	65.0	3.1	51.0	2.5	59.0	2.7	34.5	1.7	44.7	2.0
Other market fish	33.0	1.3	34.0	1.5	35.0	1.5	36.0	1.5	28.0	1.2	25.0	1.2	41.0	2.0	15.0	0.7	17.4	0.9	25.4	1.2
Cod as % of shrimp:		2.8		4.8		3.3		4.4		3.5		3.4		2.8		3.2		1.9		2.5
Total H.C. as % of shrimp:		5.7		10.8		10.9		14.7		10.1		11.8		9.9		16.8		15.5		23.3

C:																				
Skagerrak, Sub-div. IIIA.				**Swedish log book records**				**Trawls with selective grids**												
	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
Species:	Tons	% of total catch	Tons	% of total catch	Total	% of total catch	Total	% of total catch	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	0.0	0.0	0.0
Norway lobster					0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	1.0	0.6	0.4	0.2	0.9	0.3
Pandalus					1.0	100.0	35.0	100.0	1.0	100.0	0.0		21.0	100.0	177.0	99.4	232.7	98.5	274.3	98.3
Angler fish					0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Whiting						0.0		0.0		0.0				0.0		0.0	0.1	0.0	0.0	0.0
Haddock						0.0		0.0		0.0				0.0		0.0	0.4	0.2	0.2	0.1
Hake						0.0		0.0		0.0				0.0		0.0	0.0	0.0	0.0	0.0
Ling						0.0		0.0		0.0				0.0		0.0	0.0	0.0	0.0	0.0
Saithe					0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	2.0	0.8	2.5	0.9
Witch flounder						0.0		0.0		0.0				0.0		0.0	0.2	0.1	0.3	0.1
Norway pout						0.0		0.0		0.0				0.0		0.0	0.0	0.0	0.0	0.0
Cod						0.0		0.0		0.0				0.0		0.0	0.2	0.1	0.8	0.3
Other market fish						0.0		0.0		0.0				0.0		0.0	0.2	0.1	0.0	0.0
Cod as % of shrimp:								0.0								0.0		0.1		0.3
Total H.C. as % of shrimp:						0.0		0.0		0.0				0.0		0.6		1.5		1.7

D:																				
Skagerrak, Sub-div. IIIA.						**Norwegian logbook records (* new log book format)**														
	1995		1996		1997		1998		1999		2000		2001		2002*		2003*		2004	
Species:	Tons	% of total catch	Tons	% of total catch	Total	% of total catch	Total	% of total catch	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							12.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Norway lobster							3.0	0.2	7.0	0.5	9.0	0.8	20.0	1.2	37.0	0.9	28.0	0.7		
Pandalus							1689.0	87.5	1328.0	87.9	1031.0	86.2	1461.0	88.3	3663.0	87.3	3700.0	86.3		
Angler fish							9.0	0.5	11.0	0.7	13.0	1.1	13.0	0.8	32.0	0.8	26.0	0.6		
Whiting							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.3	14.0	0.3		
Haddock							1.0	0.1	4.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Hake							1.0	0.1	1.0	0.1	2.0	0.2	2.0	0.1	6.0	0.1	6.0	0.1		
Ling							4.0	0.2	5.0	0.3	6.0	0.5	4.0	0.2	26.0	0.6	28.0	0.7		
Saithe							15.0	0.8	27.0	1.8	26.0	2.2	34.0	2.1	43.0	1.0	58.0	1.4		
Witch flounder							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0	0.9	34.0	0.8		
Norway pout							41.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Cod							30.0	1.6	25.0	1.7	24.0	2.0	20.0	1.2	153.0	3.6	184.0	4.3		
Other market fish							126.0	6.5	103.0	6.8	85.0	7.1	101.0	6.1	187.0	4.5	208.0	4.9		
Cod as % of shrimp:								1.8		1.9		2.3		1.4		4.2		5.0		
Total H.C. as % of shrimp:								13.6		13.8		16.0		13.3		14.6		15.8		

E:

Norwegian Deeps, Sub-div. IVA East **Danish log book records**

	1995		1996		1997		1998		1999		2000		2001		2002		2003		2004	
Species:	Tons	% of total catch	Tons	% of total catch	Total	% of total catch	Total	% of total catch	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	0.6	0.1	2.4	0.2	7.2	1.1	2.7	0.3	0.6	0.1	0.4	0.0	0.1	0.0
Norway lobster	3.7	6.9	22.4	8.1	15.6	4.2	50.8	9.0	57.0	5.7	23.8	3.8	20.3	2.1	20.8	3.2	9.5	1.2	28.7	2.5
Pandalus	39.5	74.1	203.7	73.4	291.8	78.6	397.2	70.2	673.5	67.4	473.7	75.5	767.2	77.6	500.2	76.3	631.7	81.5	860.4	75.1
Angler fish	1.7	3.3	14.8	5.3	10.4	2.8	27.4	4.8	56.8	5.7	22.6	3.6	27.2	2.8	16.9	2.6	14.6	1.9	42.2	3.7
Whiting	0.0	0.0	0.1	0.0	0.6	0.2	1.0	0.2	0.9	0.1	0.2	0.0	0.8	0.1	0.4	0.1	1.8	0.2	2.2	0.2
Haddock	0.1	0.2	1.9	0.7	1.1	0.3	1.9	0.3	13.8	1.4	2.5	0.4	5.6	0.6	4.5	0.7	7.1	0.9	6.4	0.6
Hake	0.6	1.2	2.4	0.8	3.2	0.9	2.3	0.4	3.0	0.3	8.9	1.4	7.3	0.7	6.9	1.1	2.6	0.3	2.6	0.2
Ling	0.5	1.0	1.1	0.4	2.4	0.6	5.8	1.0	19.4	1.9	6.2	1.0	11.6	1.2	5.9	0.9	4.4	0.6	7.7	0.7
Saithe	0.9	1.7	8.1	2.9	18.1	4.9	28.5	5.0	81.1	8.1	36.8	5.9	81.7	8.3	52.8	8.1	59.6	7.7	137.7	12.0
Witch flounder	0.7	1.2	1.5	0.5	2.0	0.5	7.0	1.2	6.8	0.7	2.4	0.4	7.0	0.7	2.0	0.3	2.8	0.4	5.3	0.5
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	4.5	0.5	1.0	0.1	1.7	0.2	0.2	0.0
Cod	2.5	4.7	13.9	5.0	17.8	4.8	28.2	5.0	56.2	5.6	29.2	4.7	34.5	3.5	30.1	4.6	29.1	3.8	42.3	3.7
Other market fish	3.1	5.7	7.9	2.8	8.0	2.2	15.1	2.7	28.8	2.9	13.7	2.2	18.6	1.9	13.3	2.0	9.5	1.2	10.1	0.9
Cod as % of shrimp:		6.4		6.8		6.1		7.1		8.3		6.2		4.5		6.0		4.6		4.9
Total H.C. as % of shrimp:		34.9		36.3		27.1		42.5		48.4		32.5		28.9		31.0		22.6		33.2

F:

Norwegian Deeps, Sub-div. IVA East **Norwegian logbook records**

	1995		1996		1997		1998		1999		2000		2001		2002*		2003*		2004	
Species:	Total	% of total catch	Total	% of total catch	Total	% of total catch	Total	% of total catch	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							12.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Norway lobster							3.0	0.2	7.0	0.5	9.0	0.8	20.0	1.2	14.0	0.5	15.0	0.3		
Pandalus							1689.0	87.5	1328.0	87.9	1031.0	86.2	1461.0	88.3	3599.0	89.6	3927.0	85.6		
Angler fish							9.0	0.5	11.0	0.7	13.0	1.1	13.0	0.8	158.0	0.9	135.0	2.9		
Whiting							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	11.0	0.2		
Haddock							1.0	0.1	4.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Hake							1.0	0.1	1.0	0.1	2.0	0.2	2.0	0.1	12.0	0.3	13.0	0.3		
Ling							4.0	0.2	5.0	0.3	6.0	0.5	4.0	0.2	44.0	0.3	34.0	0.7		
Saithe							15.0	0.8	27.0	1.8	26.0	2.2	34.0	2.1	137.0	1.3	164.0	3.6		
Witch flounder							0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	5.0	0.1		
Norway pout							41.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Cod							30.0	1.6	25.0	1.7	24.0	2.0	20.0	1.2	127.0	0.9	125.0	2.7		
Other market fish							126.0	6.5	103.0	6.8	85.0	7.1	101.0	6.1	127.0	6.4	158.0	3.4		
Cod as % of shrimp:								1.8		1.9		2.3		1.4		3.5		3.2		#DIV/0!
Total H.C. as % of shrimp:								13.6		13.8		16.0		13.3		17.7		16.8		#DIV/0!

G:

Fladen Ground, Sub_div. IVA. **Danish log book records**

Species:	1995 Tons	1995 % of total catch	1996 Tons	1996 % of total catch	1997 Total	1997 % of total catch	1998 Total	1998 % of total catch	1999 Total	1999 % of total catch	2000 Total	2000 % of total catch	2001 Total	2001 % of total catch	2002 Total	2002 % of total catch	2003 Total	2003 % of total catch	2004 Total	2004 % of total catch
Blue Whiting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway lobster	119.2	2.2	104.2	2.2	44.0	1.3	134.6	3.9	40.2	3.2	42.5	2.5	17.6	1.3	37.8	2.7	21.7	1.9	0.9	3.1
Pandalus	4658.5	85.5	3858.4	82.6	3022.2	89.0	2899.8	84.1	1004.6	80.5	1482.4	86.6	1263.3	92.5	1147.1	81.9	999.1	85.6	**23.3**	**77.0**
Angler fish	145.3	2.7	192.5	4.1	60.1	1.8	57.9	1.7	28.2	2.3	30.5	1.8	19.0	1.4	28.1	2.0	19.8	1.7	1.5	5.0
Whiting	9.3	0.2	6.0	0.1	0.6	0.0	2.1	0.1	0.5	0.0	2.5	0.1	0.2	0.0	2.7	0.2	0.6	0.0	0.0	0.0
Haddock	54.0	1.0	59.3	1.3	16.2	0.5	34.8	1.0	49.7	4.0	33.4	2.0	4.1	0.3	20.0	1.4	28.4	2.4	0.4	1.2
Hake	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Ling	6.2	0.1	3.2	0.1	1.1	0.0	1.0	0.0	0.4	0.0	0.8	0.0	0.1	0.0	0.5	0.0	0.2	0.0	0.0	0.0
Saithe	31.9	0.6	31.9	0.7	9.7	0.3	50.2	1.5	27.4	2.2	21.0	1.2	19.3	1.4	62.2	4.4	42.9	3.7	4.3	14.2
Witch flounder	1.2	0.0	4.1	0.1	0.4	0.0	1.0	0.0	0.2	0.0	0.8	0.0	0.0	0.0	0.1	0.0	1.7	0.1	0.0	0.0
Norway pout	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cod	378.5	6.9	371.9	8.0	223.5	6.6	235.3	6.8	85.6	6.9	84.8	5.0	34.3	2.5	93.9	6.7	47.4	4.1	2.5	8.2
Other market fish	43.1	0.8	41.1	0.9	17.9	0.5	31.2	0.9	10.8	0.9	12.2	0.7	7.2	0.5	8.1	0.6	5.7	0.5	0.5	1.6
Cod as % of shrimp:		8.1		9.6		7.4		8.1		8.5		5.7		2.7		8.2		4.7		10.6
Total H.C. as % of shrimp:		16.1		20.2		11.8		17.8		23.1		14.6		7.5		21.5		16.9		43.1

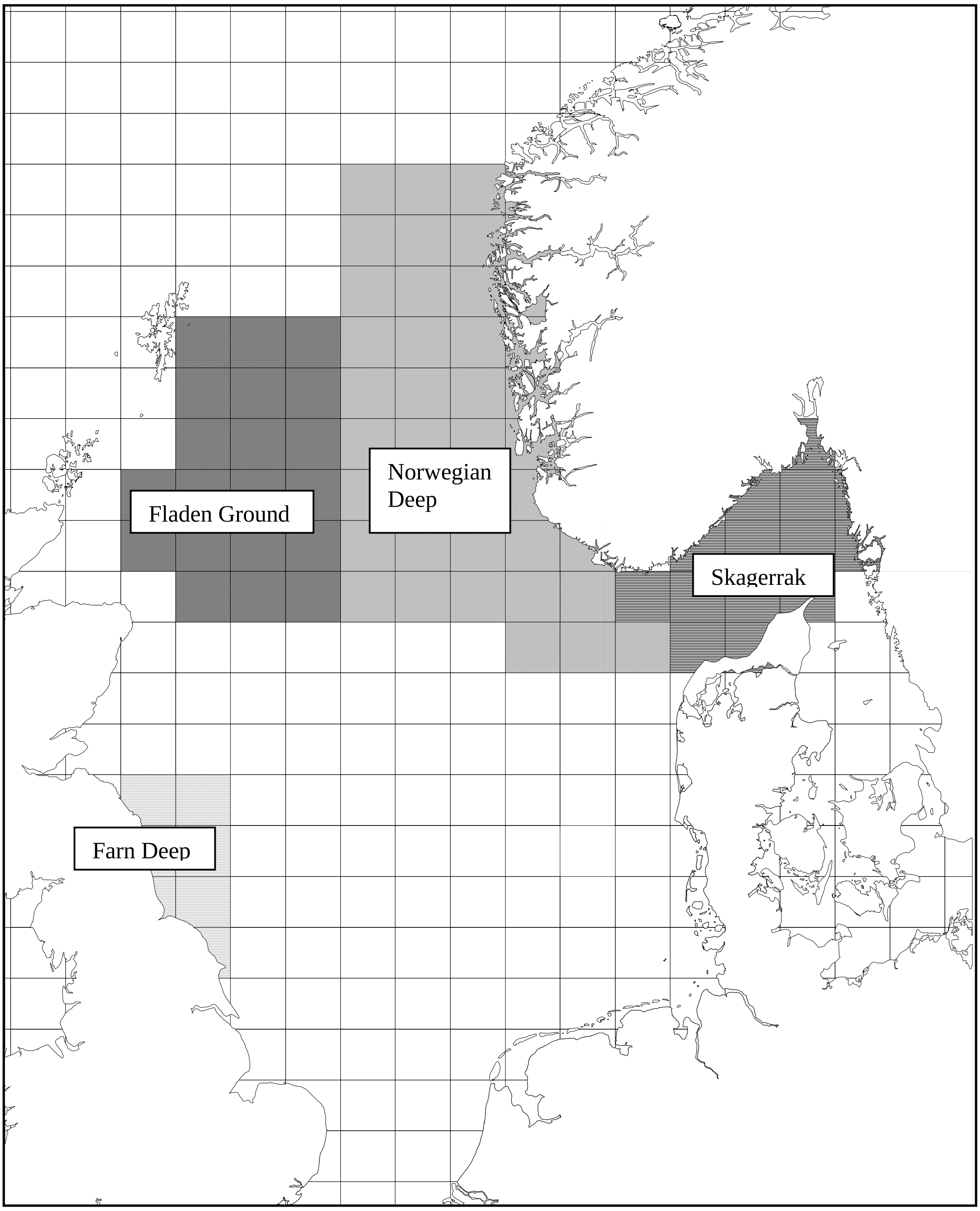

Figure 3.1. The distribution of the *Pandalus* stocks in the North Sea area as defined by the ICES squares.

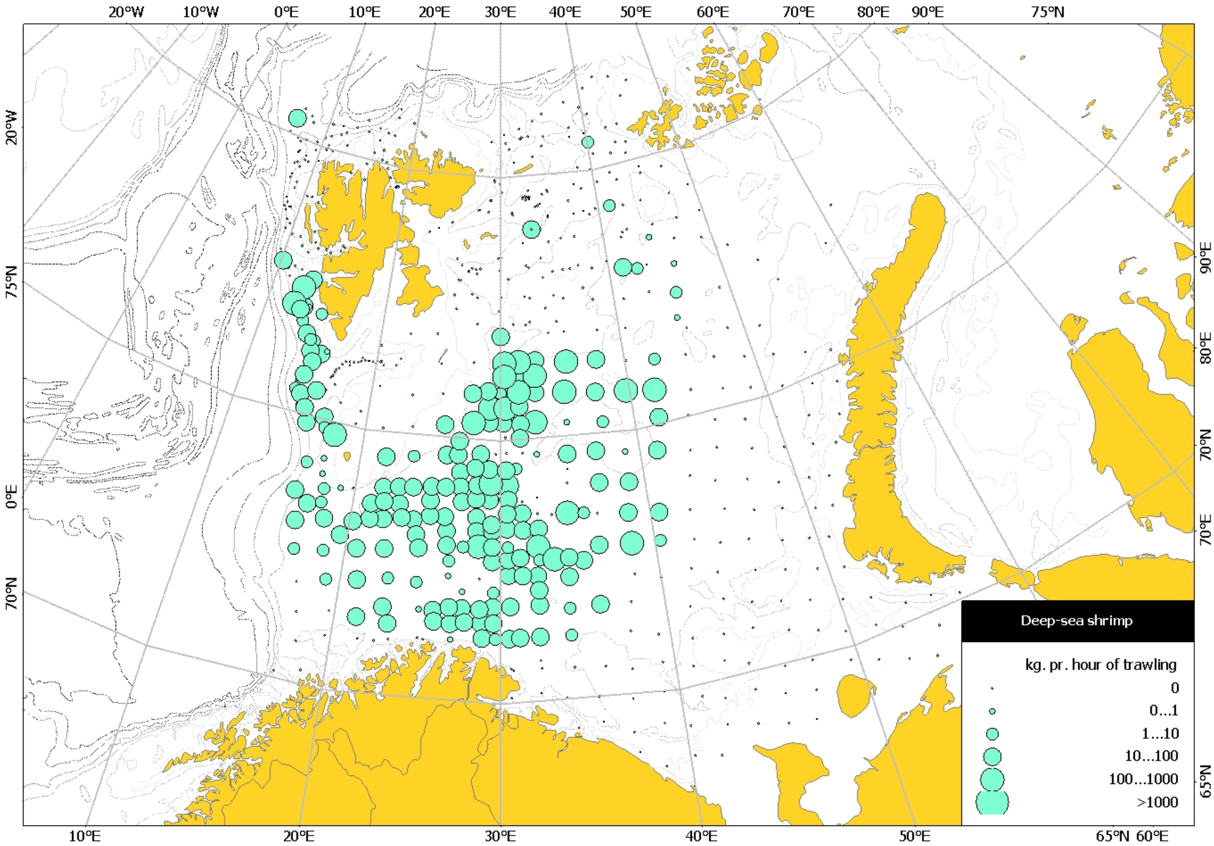

Figure 3.2 Shrimp distribution in the Barents Sea according to Surveys conducted in the period August-October 2005.

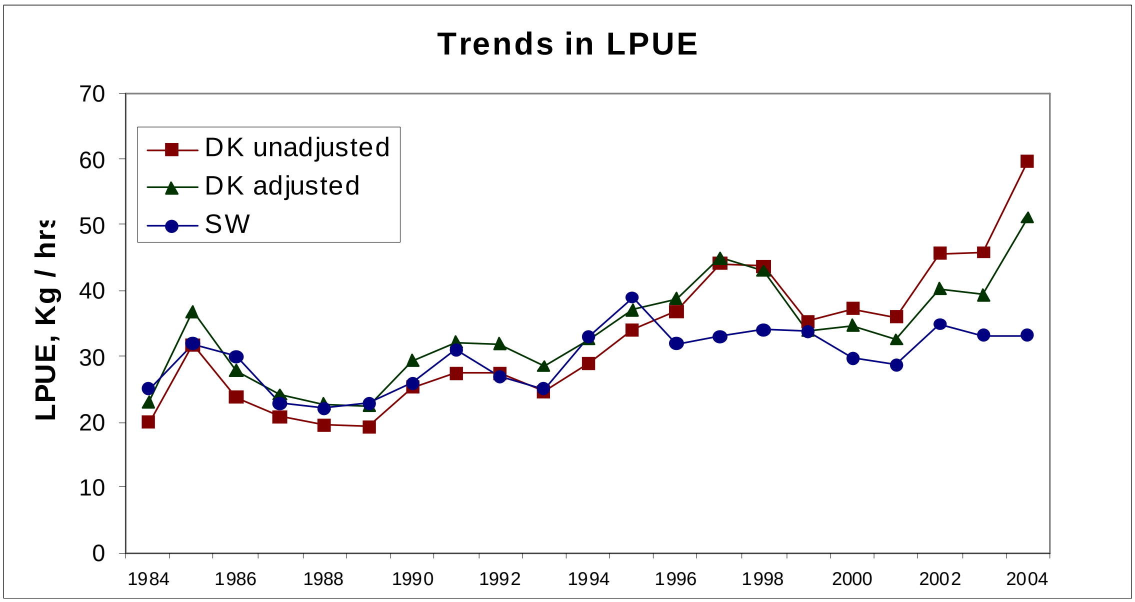

Figure 4.1 Comparison of Danish LPUE, unandjusted and adjusted, with Swedish LPUE.

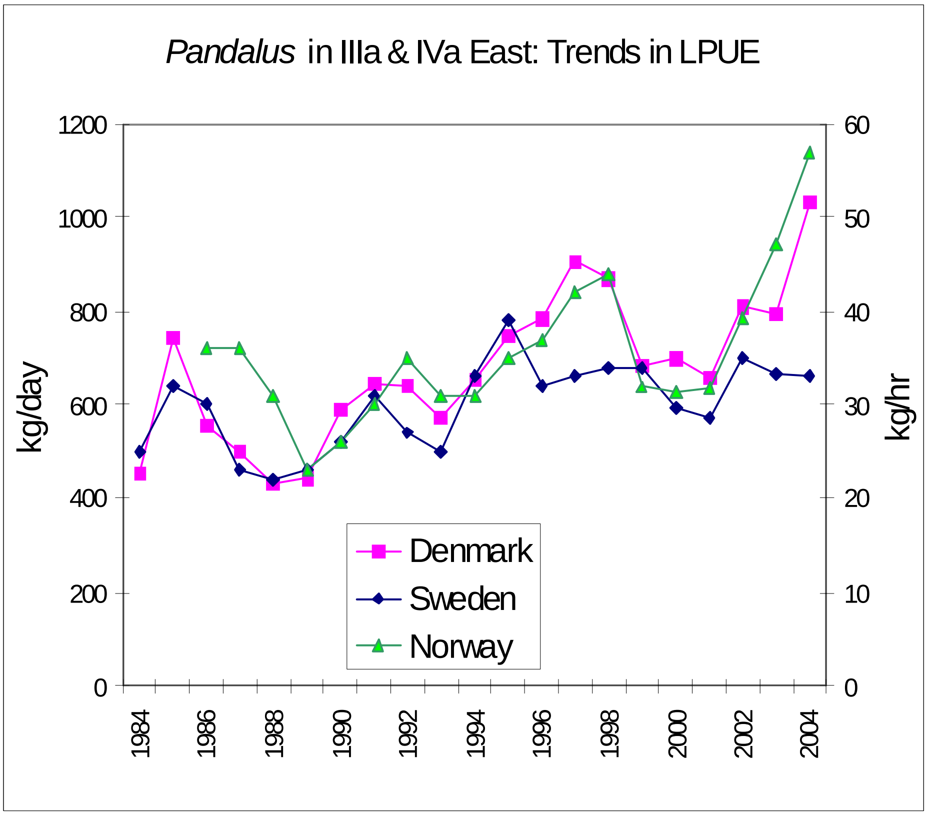

Figure 4.2

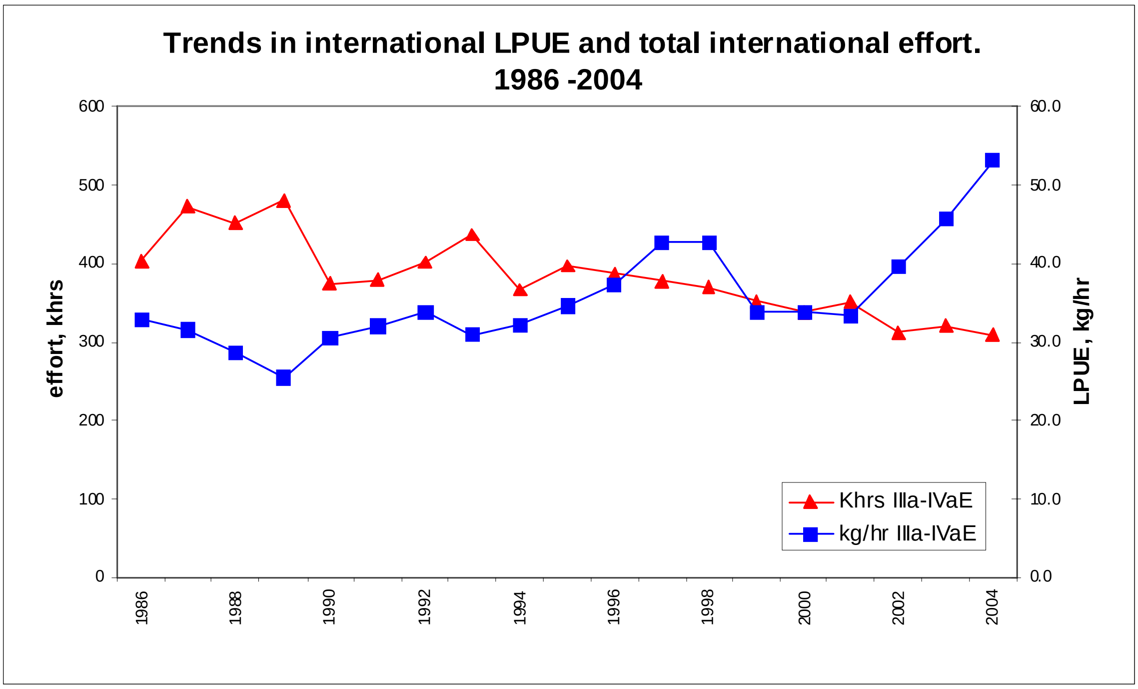

Figure 4.3

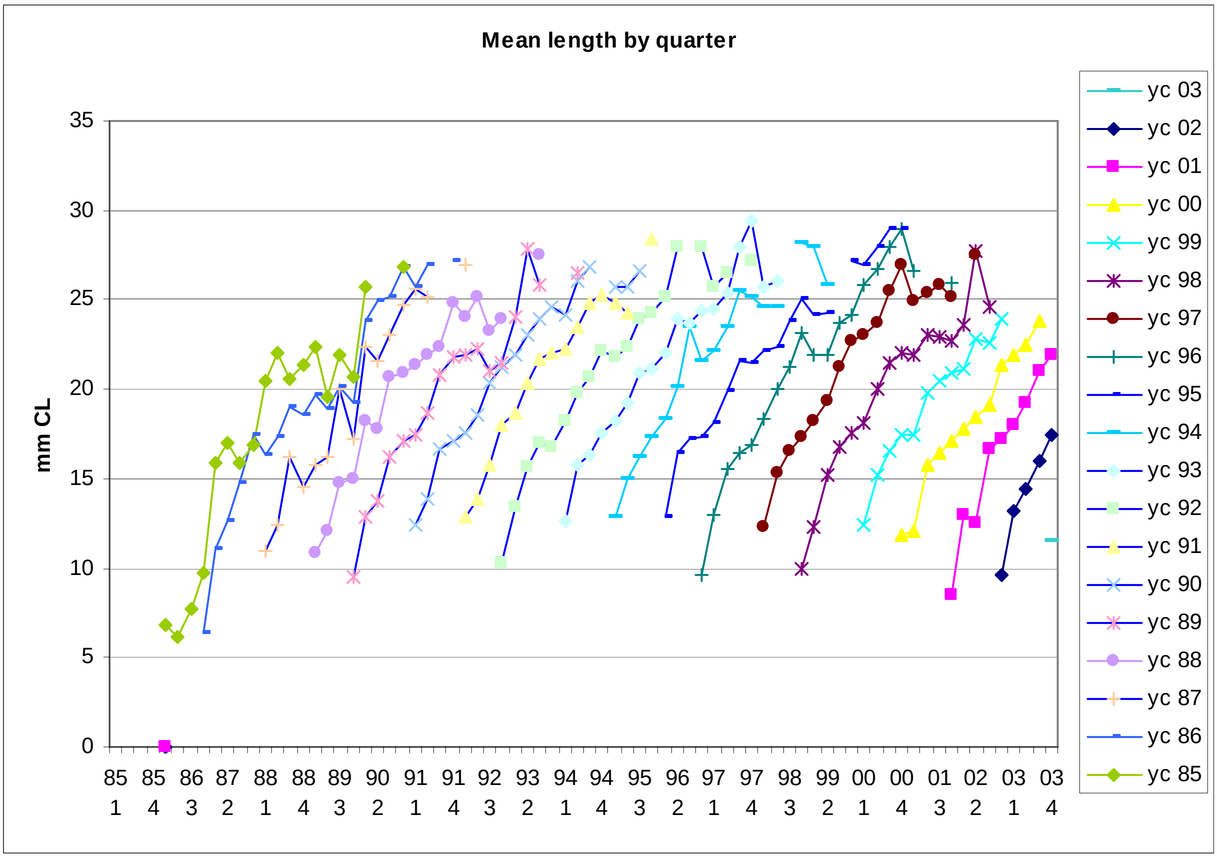

Figure 4.4 Mean quarterly carapace length (mm) for Pandalus in Div. IIIa and IVaEast

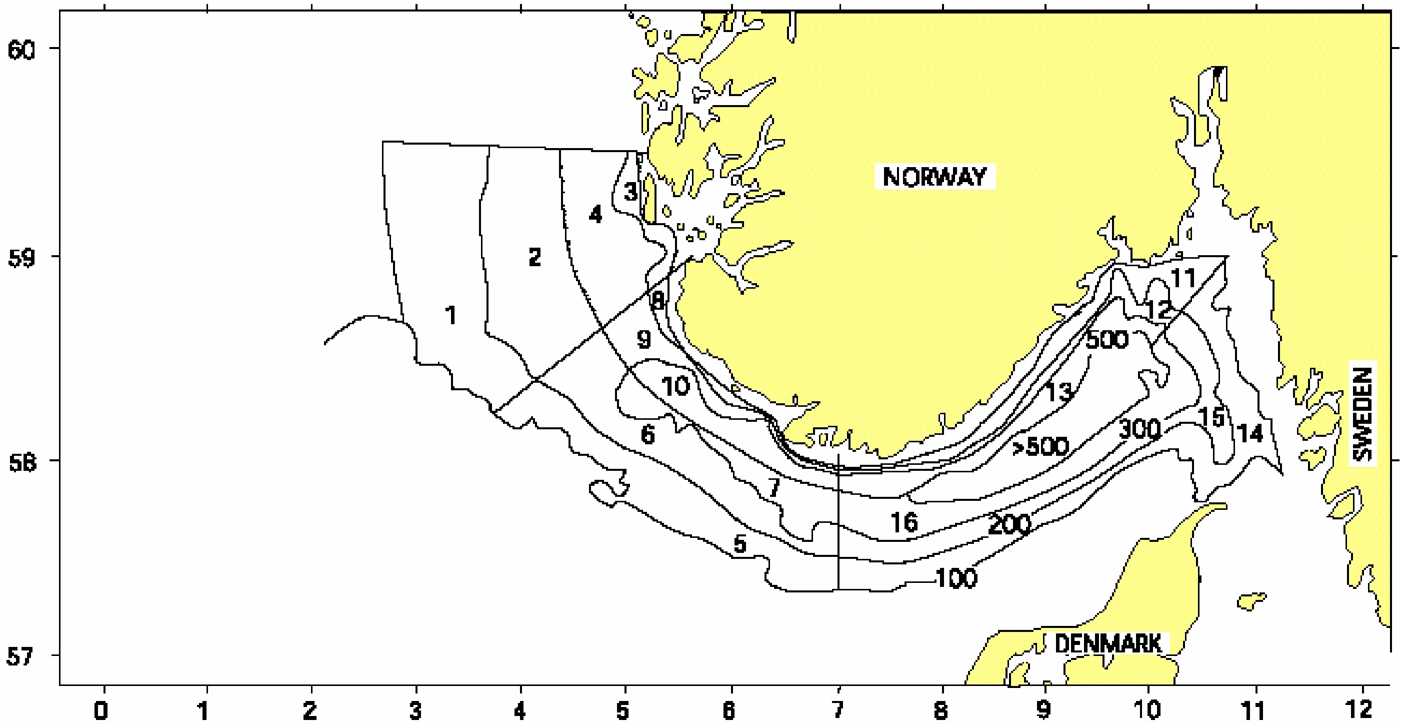

Figure 4.5 Norwegian Trawl Survey Area. Strata 1-16 and depth contour lines.

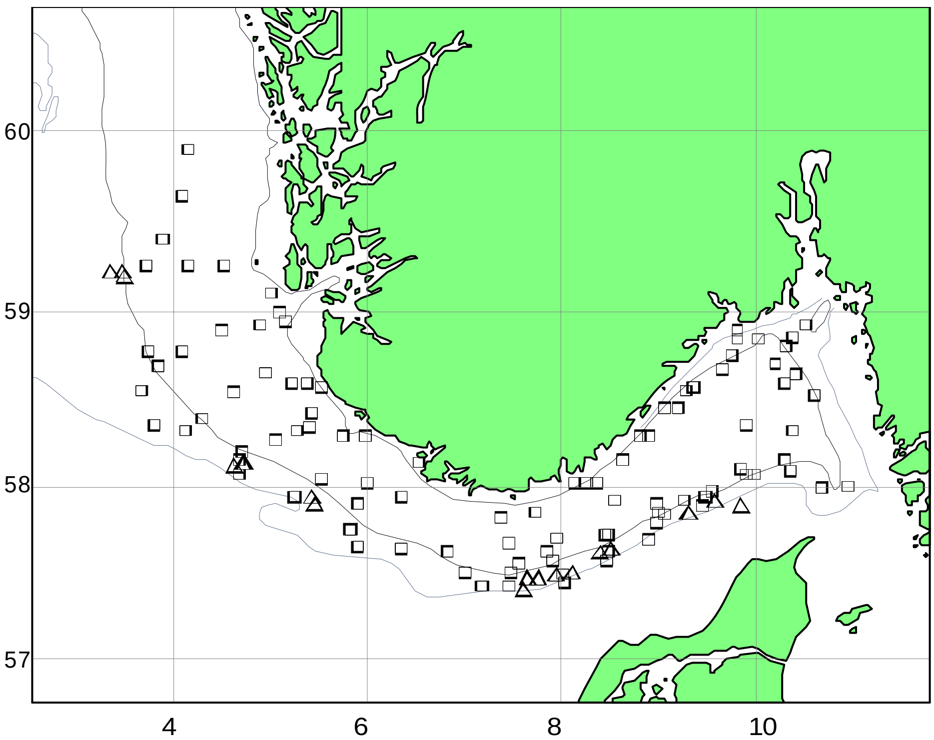

Figure 4.6 Trawl stations of the Norwegian survey (squares are shrimp stations; triangles are Norway lobster stations).

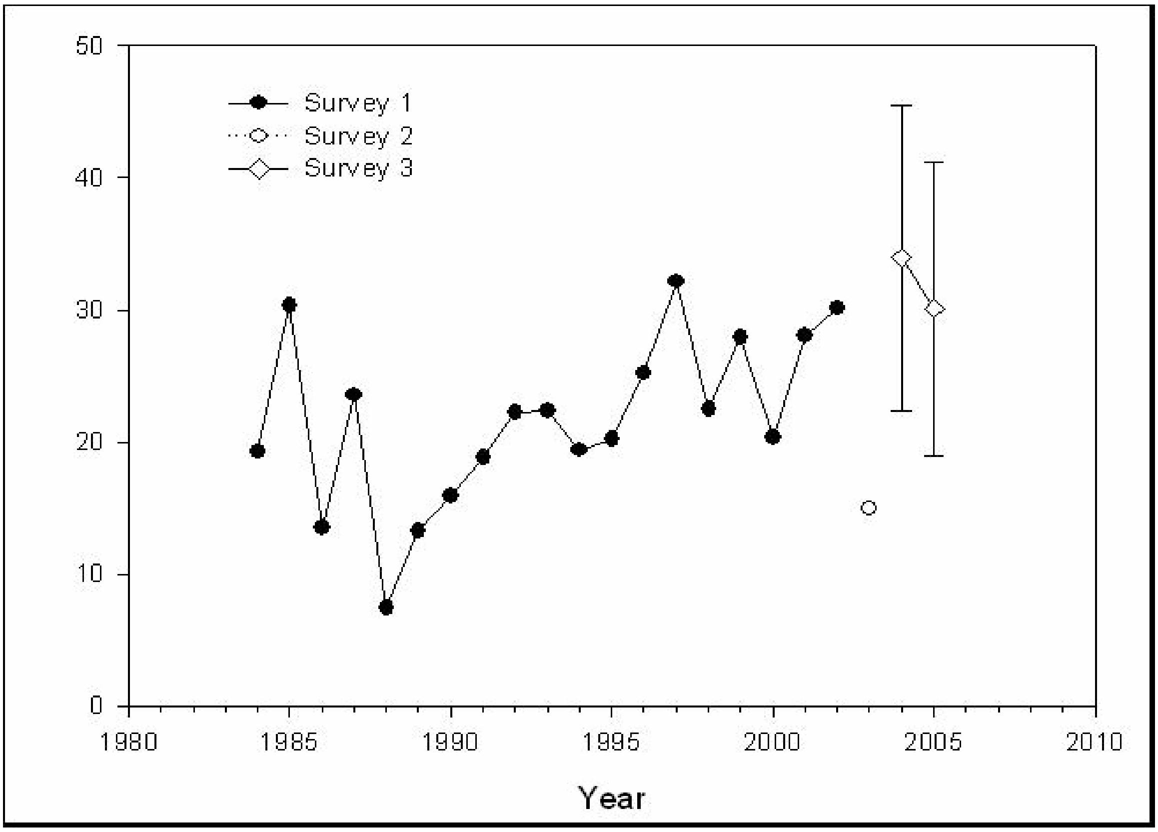

Figure 4.7 Estimated survey biomass indices (1000 t) for Pandalus in IIIa and IVa East, see also Table 4.8. The three surveys are not calibrated to a common scale. Standard errors (error bars) were calculated for the 2004 and 2005 surveys

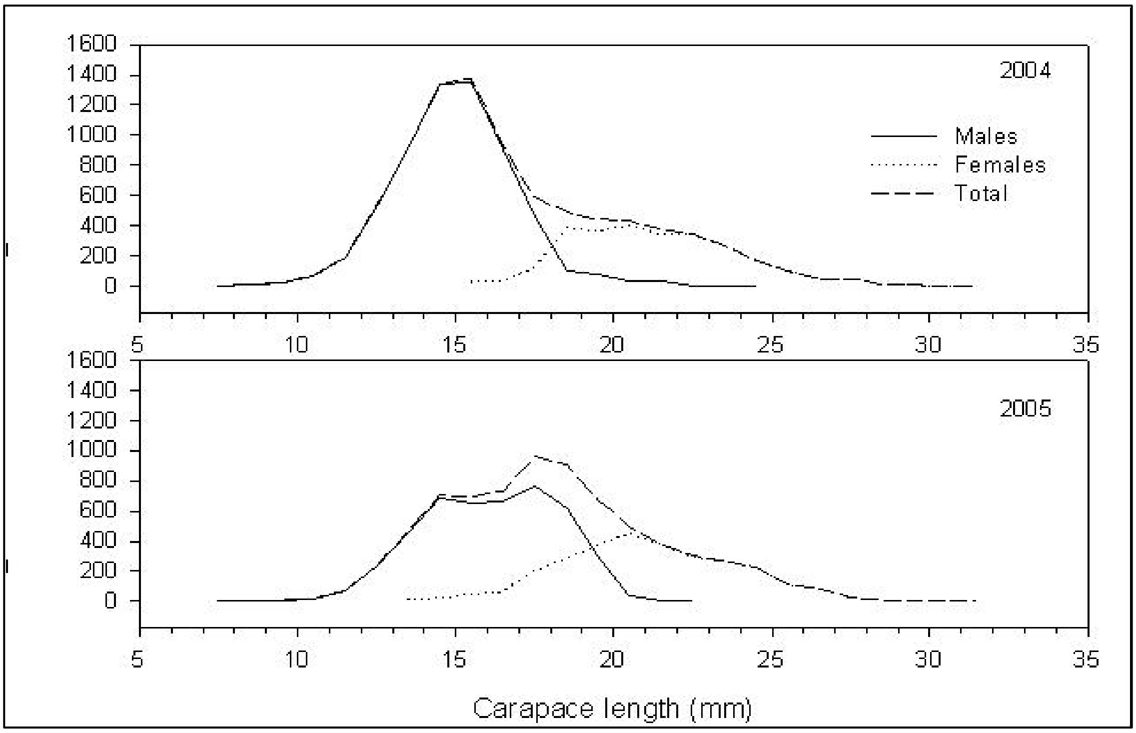

Figure 4.8 Estimated length frequency distribution of shrimp in Skagerrak and the Norwegian deeps 2004 and 2005.

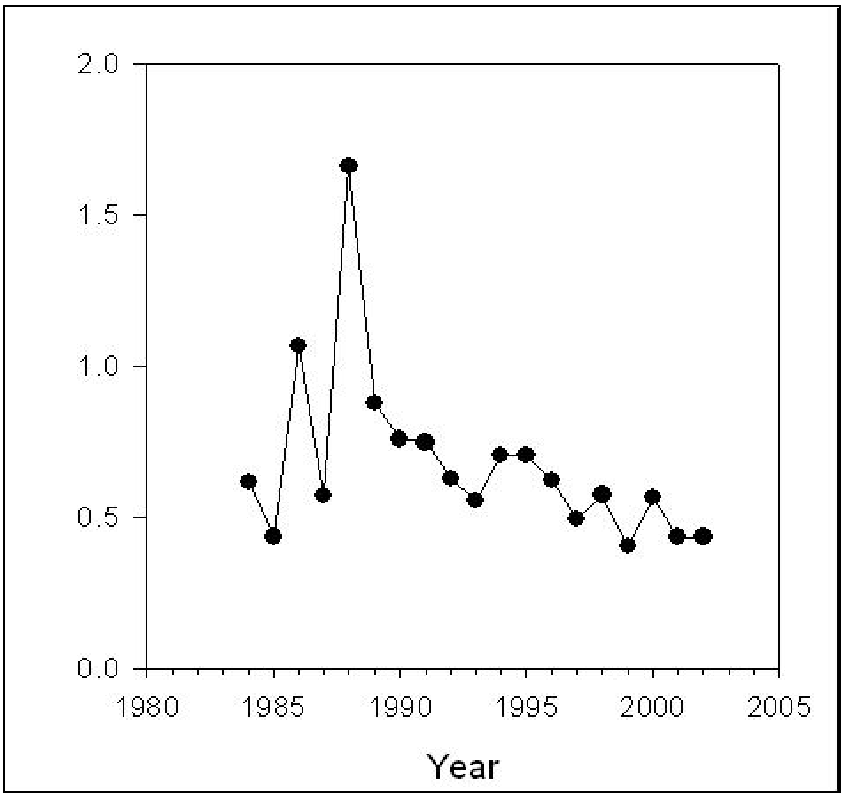

Figure 4.9 Indices of harvest rate (survey biomasst/0.25*landingt+0.75*landingt+1t indices year).

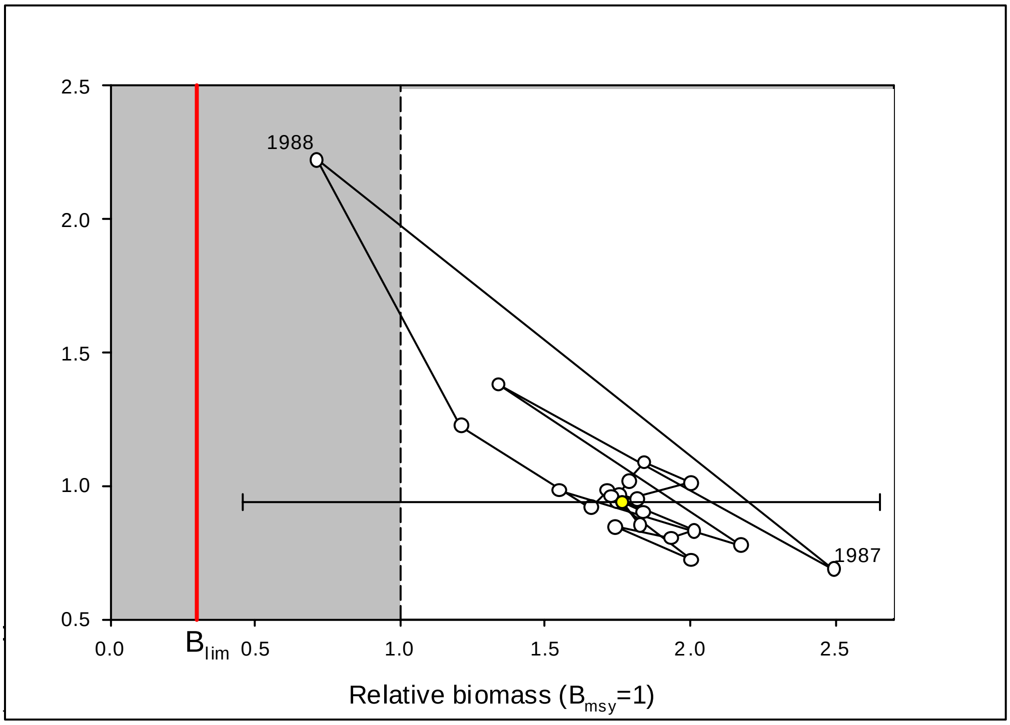

Figure 4.10 Shrimp in Skagerrak and Norwegian Deep: Stock dynamics 1984 to 2005 in a fishing mortality/biomass continuum. Points are the median values of estimated biomass and harvest rate. Red line is limit reference point. Error bars for the 2005-value (yellow point) are 95% conf. interval.

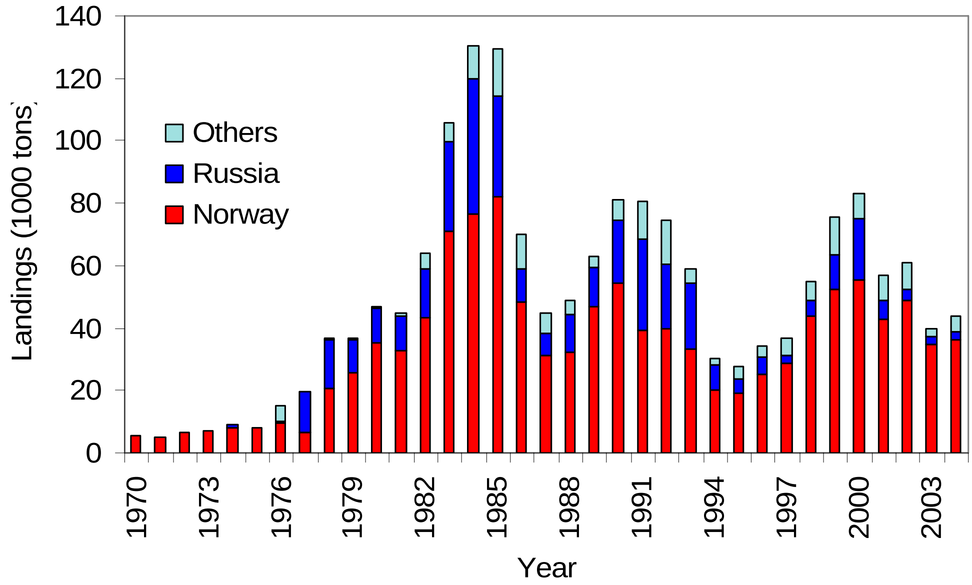

Figure 6.1 Shrimp landings from ICES areas I, IIa and IIb by Norway, Russia and other countries in the period 1970–2004

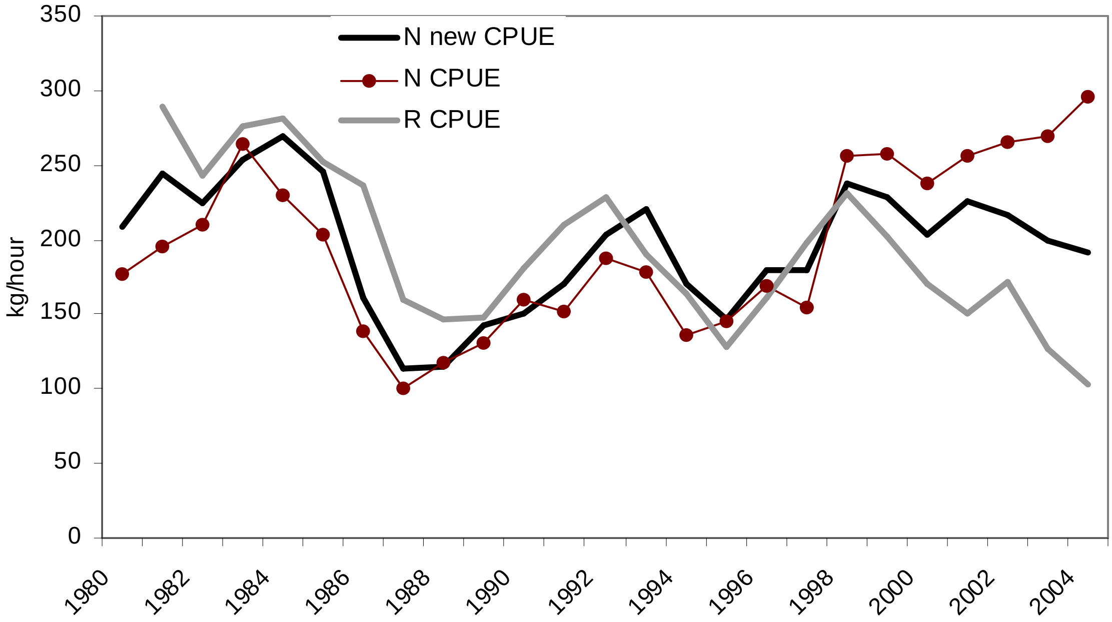

Figure 6.2 Un standardised Norwegian CPUE (N- CPUE), standardised CPUE to vessels with 1000-1550hp and single trawl (N-new CPUE) and Russian CPUE (R-CPUE) for ICES areas I, IIa and IIb.

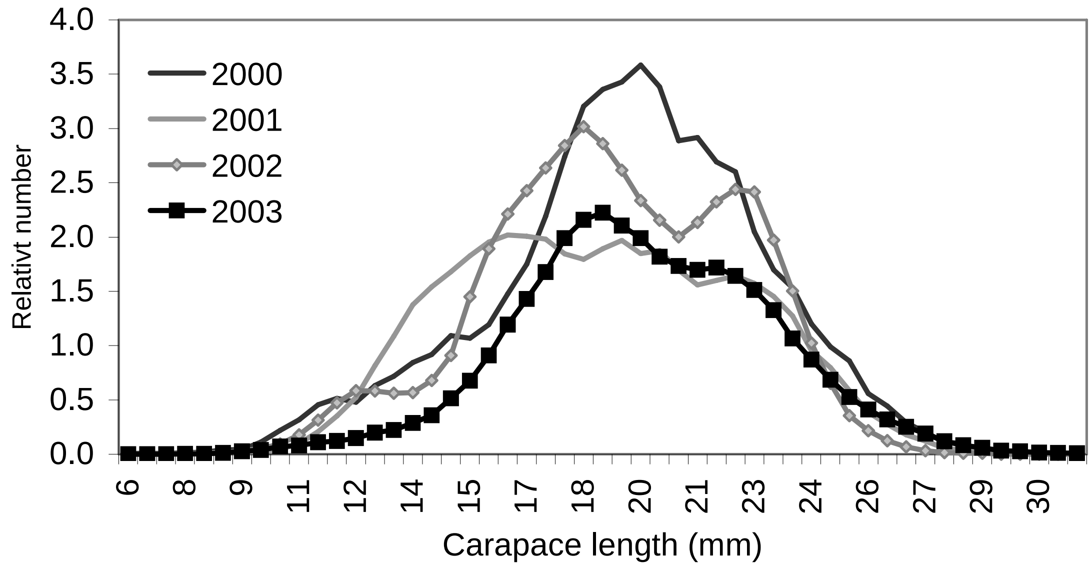

Figure 6.3 Length distribution in Norwegian shrimp catches in 2000 to 2003.

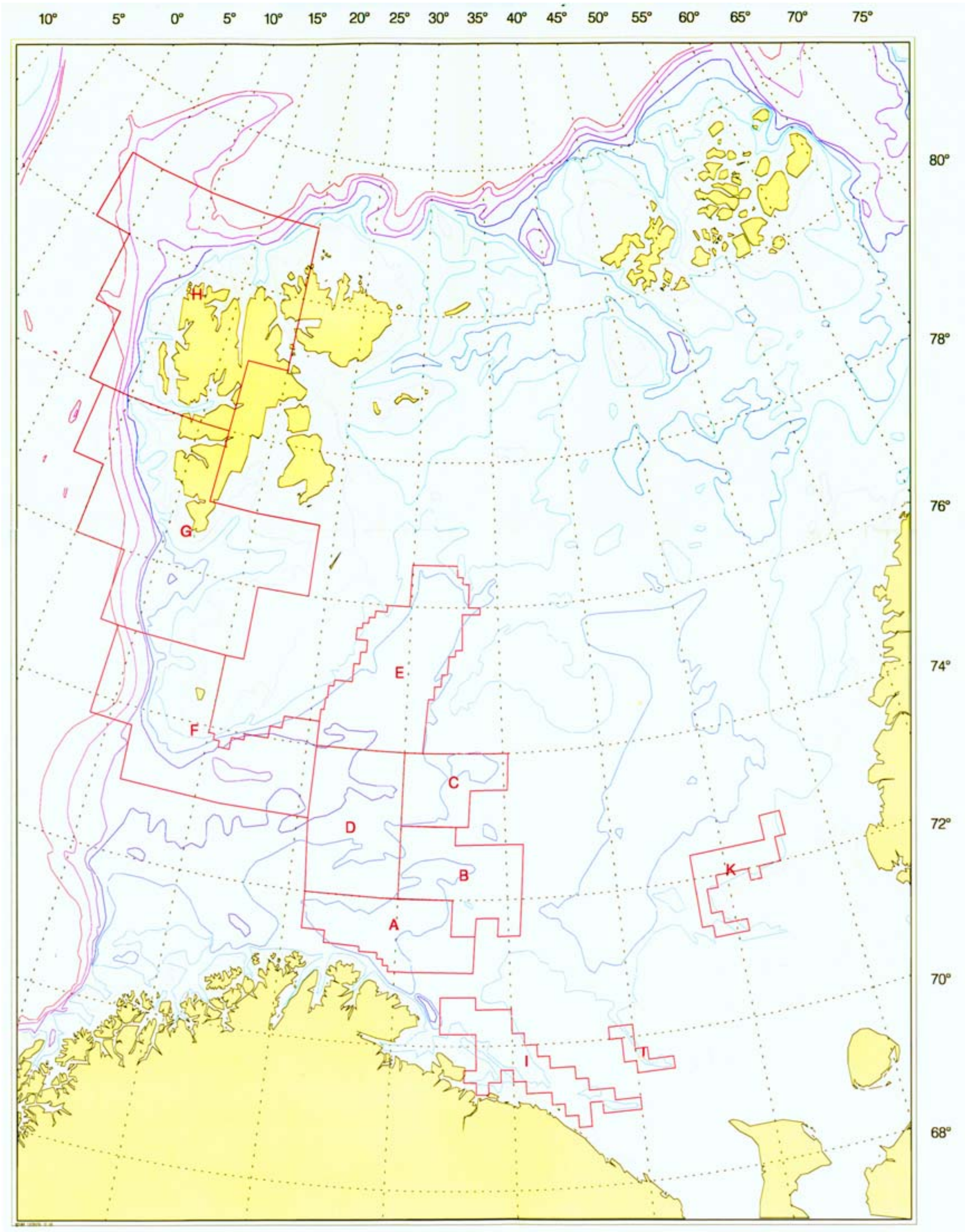

Figure 6.4 Survey strata are combined to 9 larger areas marked with letters A to K. East Finnmark (A), Tiddly Bank (B), Thor Iversen Bank (C), Hopen (E), Bear Island (F), Storfjord Trench (G), Spitsbergen (H), Kola coast (I) and the Goose Bank (K) (ICES, 2003b).

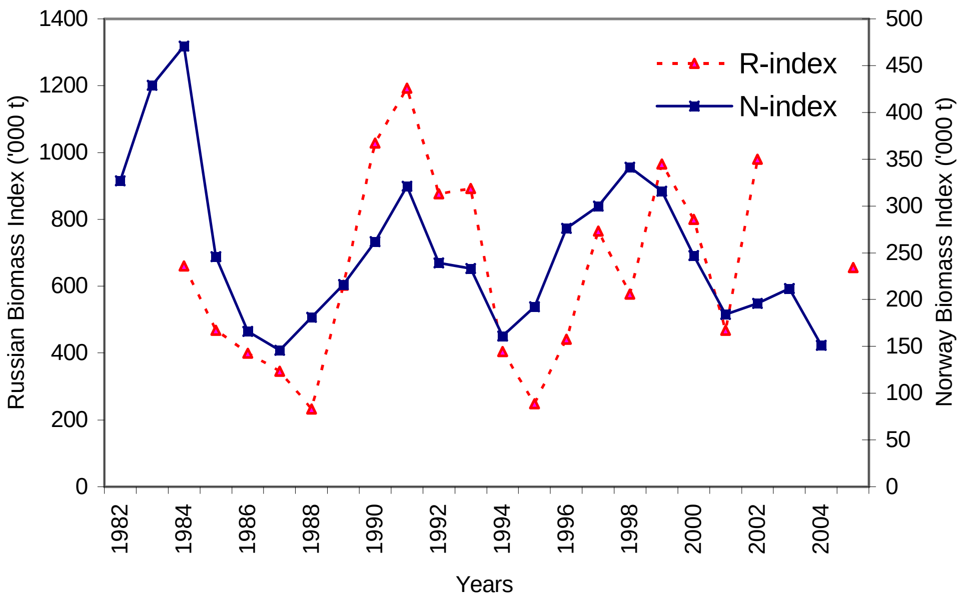

Figure 6.5 Shrimp biomass indices from Norwegian and Russian surveys in the Barents Sea and Spitsbergen area in 1982–2005.

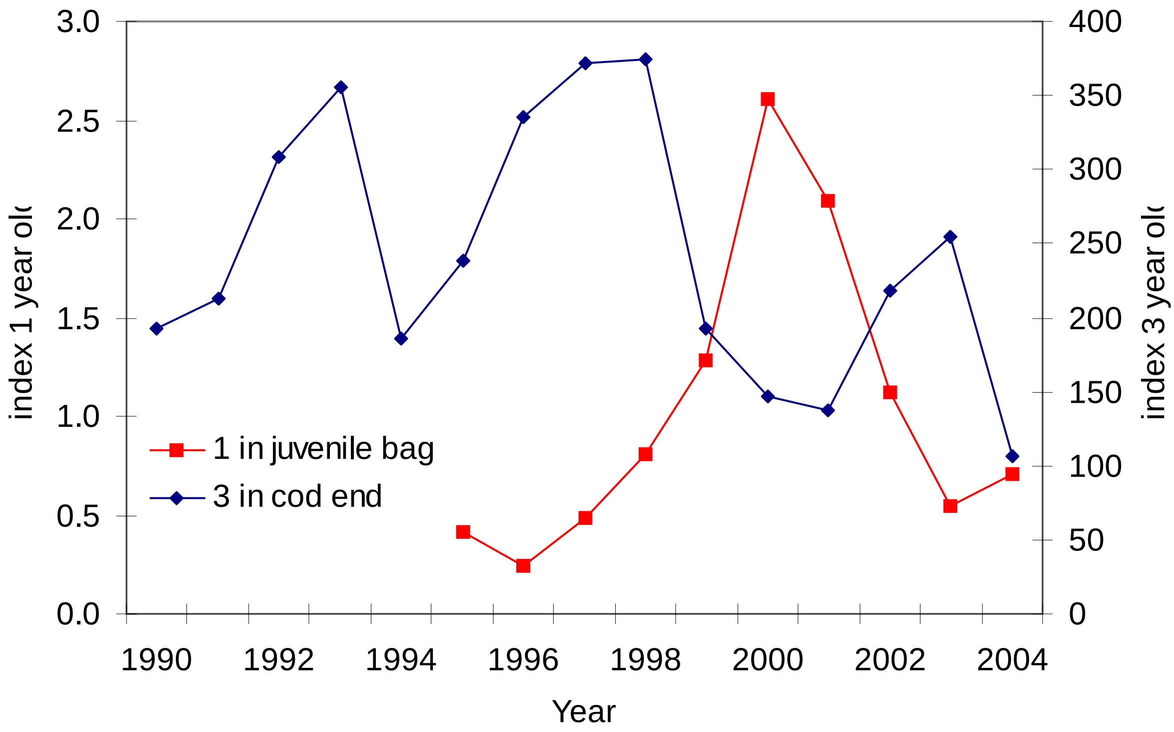

Figure 6.6 Index for one and three year old shrimp in the Norwegian Survey 2003.

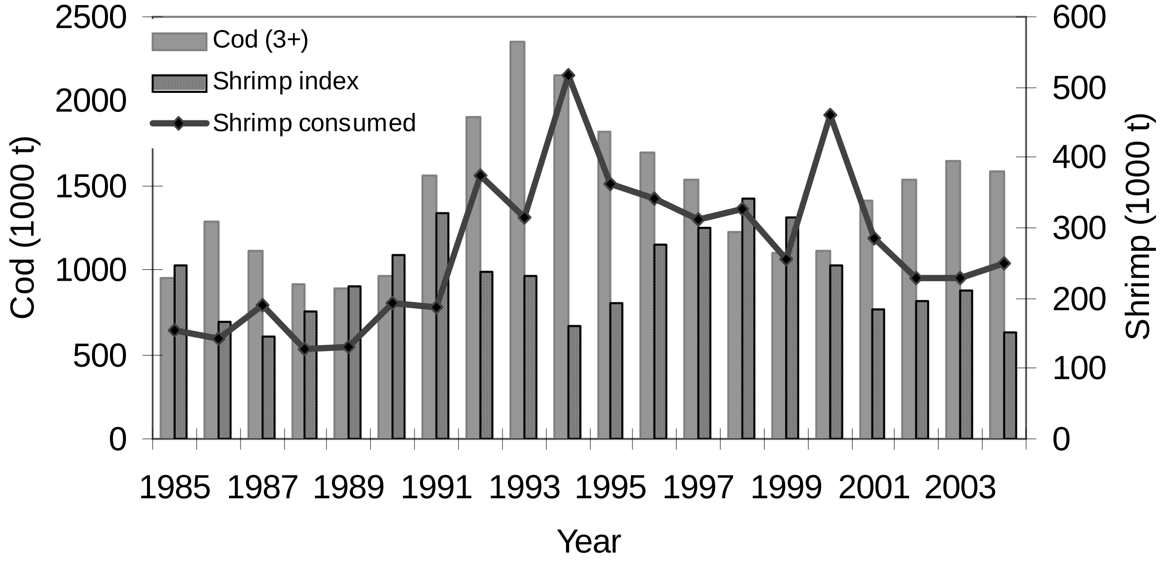

Figure 6.7 Biomass indices for shrimp from the Norwegian surveys, biomass estimate for cod (age 3 years and older) and the shrimp consumed by the cod in the Barents Sea.

Annex 1: Participants

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Annex 2: Technical Minutes for WGPAND 2005

Methods: The report does not always describe the methods used in sufficient detail to enable an evaluation. This applies especially to the model used to assess the stocks in Iva east and IIIa.

Stock identity issues: Last year the stock Figure (3.1) included a stock called Farn deep but there is no onformation on this this year. The WG should comment on why it is not included in the report this year. The WG reports data for genetic analysis being collected. The WG need to set up a process for coordination of this data collection and analysis which also should guide the design of the sampling programme. Is the proper expertise available for this? Other wg's (redfish) have had problems here which required inputs from stock identity experts.

Stock in IVa east and IIIa

The main problem with the assessment is the discontinuity of the Norwegian survey data due to a change in vessel/gear in 2003 and change in timing in 2004. Different methods are used to partition lengths to age groups in diff countries. Are the results comparable?

The WG discusses earlier approaches and provides some rather startling comments that 'an analysis in 2005 showed that the previously used model was inappropriate and that the available data was uninformative with respect to the parameters of this model'. It would have been very appropriate if the WG had explained what the consequences of using this model were for the perception of the stock and the advice given at the time.

A new model is introduced and is described in a working document. The details of the analysis in terms of input data and diagnostics are not presented but the exploration demonstrates that this approach may be worthwhile extending in the future. Presently the model does not provide a basis for forecasts but gives some relative information on the state of the stock relative to MSY based reference points. This confirms the impression from the analysis of LPUE trends and gives a good basis for the advice.

The WG should continue the work with this approach in order to develop reference points and an extended basis for the advice in relation to those. When the WG decides that this method should be the main basis for the advice it must be fully documented including data and diagnostics.

Specific issues

Section 4.1.3: Why is it possible to convert Swedish landings of boiled shrimps but not Norwegian/Danish? Problems with statistics? There seem still to be problems in getting reliable discard data. The conversion of Danish fishing days to Norw/Sweed hours could be better explained.

Section 4.3.1: The report states that sampling could be improved – it would be usefull when such comments are made to also discuss how improvements could be made. No length data are available in 2003 and 2004 for the major fishing nation. The estimation of the SSB seems to be problematic and it is difficult to evaluate the method used but it seems sensible to standardise this for all stocks in the NA.

Section 4.4.2.3: Shrimp predator biomass doubled from 2004 to 2005 – there is a need to discuss the implications of this in relation to management implications

Stock on Fladen Ground and Farn deep

No comments

Barents Sea stock

The WG investigates possible approaches given the poor recent data and concludes that predictions cannot be given because survey time series have been discontinued. The assessment is then based on various CPUE trends.

Specific comments:

Section 6.1: This sentence is not easy to understand: *However, the regulation by smallest allowable shrimp size is not considered to be an efficient management tool in the Russian Economic Zone (REZ) due to the high predation of shrimp*.

Section 6.2.3: Discards: In the REZ a TAC regulation is in place. Does the GLM used for standardization of CPUE take into account double/triple gears? There does not seem to be an overview of actual sampling intensity in the report.

Annex 3:

Annex 3: WGPAND Report 2005: WG paper

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SCIENTIFIC COUNCIL MEETING – NOV. 2005

Deriving quantitative biological advice for the shrimp fishery in Skagerrak and Norwegian Deep (ICES Div IVa east and IIIa)

by

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Abstract

A previously used method for assessing the shrimp resource in Skagerrak and Norwegian Deep was investigated. The biomass dynamic model used to describe stock variability lack feedback mechanisms and may in some instances be unstable. Available data series of stock size, recruitment, predation and catch used for fitting the model were found not to be informative.

A model based on these data cannot estimate management parameters such as Maximum Sustainable Yield and fishing mortality and thus its predictive capability is low.

The data did, however, indicate a long period of stable stock size in a stable environment of catch and predation. This information is used to estimate the relative location of the stock on a logistic stock-production curve. The risk that the stock had been overexploited (catches above MSY and stock below the optimal biomass level, B_{MSY},) or below the stock biomass limit reference point, B_{lim}, was by use of Bayesian inference quantified to be low, less than 9% for the period 1990-2005.

The stock may likely sustain larger catches than the current level of around 13000 t given that the environmental settings remain stable. However, increases in the exploitation level should be carefully planned and designed to provide more information to help estimate the productive capability of the stock. Management should be ready to respond to new information e.g. by reducing catches. This approach could be founded in a multi-annual adaptive management plan.

Introduction

The stock has previously been assessed by Virtual Population Analysis (VPA) (Megrey 1989) by applying standard ICES software packets to the age distributions of the catches. Ageing was done by modal analyses of their estimated length distributions. Commercial catch rates or abundance indices from the Norwegian survey (Hvingel 2005a) was used for tuning. However, this method performed poorly and was therefore replaced by a biomass dynamic model in 2001 (Anon 2004a).

This model relied on data from the survey. The survey series was, however, discontinued after 2002 (Hvingel 2005a) and the model was therefore not updated in 2003 and 2004 and stock projections were not made. Furthermore, the assessment working group did not seem satisfied with the model (Anon. 2004): “the Working Group has taken notice of the problems and criticism of the simple SPP model used” and provides in the report a 4-bulletpiont list of disadvantages. However, the criticism is imprecise and leaves some confusion in where exactly the shoe pinches.

The purpose of this paper is to investigate the suitability of the biomass dynamic model hitherto used in this assessment and to derive quantitative statements of stock status in the context of the Precautionary Approach.

Investigating the assessment model currently used

The model currently used is a process equation describing the hypotheses of how the stock varies, and a data link function giving the hypotheses of how the data relate to the process equation:

$$\begin{aligned} &\text{Process:} \quad B_{t+1} = \alpha B_t - C_t + \beta R_t - \delta D_t \\ &\text{Data link:} \quad U_t = qB_t + \varepsilon_t \end{aligned} \qquad \text{(eq. 1)}$$

where the subscript t indexes year, B is shrimp biomass, C is catch, R is observed recruitment, D is observed biomass of predators, and U is an observed index of shrimp biomass from the Norwegian survey (Hvingel 2005a). α, β, δ and q are model parameters to be estimated along with initial biomass B_0, and ϵ_t, an error term Normally, independently and identically distributed with mean 0 and variance σ_ε^2. A similar model has been used for assessing shrimp in offshore Icelandic waters (Stefánsson et al. 1994)

Model behaviour and its predictive properties may not be optimal for the assessment for several reasons. In the model predation rate, δ, is independent of prey biomass, while stock biomass, B, has no limits. With no feedback based on biomass, the model risks being unstable: for example, if the biomass went below some critical threshold, unremitting predation could quickly drive it to extinction, or if it went above a critical upper limit, predation and catch could become insignificant and the stock run off to infinity. Stochastic behaviour is not included, but if it was, it would likely make the model even more unstable (Hvingel 2005b).

However, a bigger problem for the assessment might be the level of information regarding stock dynamics contained in the data series. The variability of the two explicit components of mortality, catch and predation, have been low in the time series (Fig. 1A and 1C) – and without trend. The CVs (standard error/mean) of the annual values are 10% for the catches and 20% for the index of predator biomass, which is at or even lower than the within-year variation typically estimated for such data.

The recruitment series (Fig. 1D) supposedly being a main determinant of future stock size do have periods with trend as do the survey biomass indices (Fig. 1B), and some correlation between these two variables is noticeable. Part of this is likely a year-effect of the survey, but neither this correlation (Fig. 2A) nor the one between recruitment and the stock in the following year (Fig. 2.B) is significant ($p>0.17$). However, a correlation between the recruitment and survey biomass two years later (Fig. 2C) was ($p<0.01$).

As expected the catches could not be found to correlate with either the biomass of recruits or the 2+ group (Fig. 3A and 3B). The Biomass of predators did not correlate with recruitment (Fig. 4A and 4B), but showed a positive correlation with the biomass of the 2+ group in the same year ($p<0.05$) (Fig. 4C). Again some year effect of the survey might be to blame. With a one year lag (Fig.4D) the correlation is still positive but not significant ($p=0.12$).

Finally the variables were analysed together using a General Linear Model (GLM) of the form:

$$B_t = u + B_{t-1} + C_{t-1} + R_{t-1} + D_{t-1} + e \qquad \text{(eq. 2)}$$

where B is the index of biomass of age group 2+, u is the intercept, C is the landings (C_{t-1} is 0.25*landings in year t-1 + 0.75*landings in year t because the survey is conducted in the autumn), R is recruitment (biomass index of age 0 and 1), D is the index of predator biomass taken as a sum of the estimated survey biomass of 20 different fish species, *e* is an error term and t indexes year. Input data series were based on Anon 2004. Neither the individual main effects or their interactions nor the model were significant:

The GLM Procedure. Dependent variable: B_t

Source	DF	SS	MS	F Value	Pr > F
Model	4	0.61293030	0.15323257	1.17	0.3698
Error	13	1.70678162	0.13129089		
Corrected Total	17	2.31971192			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
B_{t-1}	1	0.00066142	0.00066142	0.01	0.9445
C_{t-1}	1	0.18905529	0.18905529	1.44	0.2516
D_{t-1}	1	0.10855779	0.10855779	0.83	0.3797
R_{t-1}	1	0.03947770	0.03947770	0.30	0.5927

Parameter	Estimate	SE	t Value	Pr > |t|
Intercept	-.7528493398	0.91479585	-0.82	0.4254
B_{t-1}	0.0226627544	0.31929325	0.07	0.9445
C_{t-1}	0.0000828340	0.00006903	1.20	0.2516
D_{t-1}	0.5387551394	0.59248620	0.91	0.3797
R_{t-1}	0.1286604984	0.23463166	0.55	0.5927

In conclusion: the hypothesis of how the stock varies as represented by the assessment model (eq. 1) lacks biological realism and might in some instances be unstable. The perturbation history of the stock is badly suited for extracting information on how the fishery and predation affect the stock. Neither of the explanatory variables used in the model correlate with the stock biomass in the following year. Thus the model cannot be used to make predictions.

For extracting information on exploitation level (fishing mortality) the model relies on the ability to estimate absolute biomass. As there is no information on absolute consumption by predators the stock size can be scaled only by the catch series. As this series has low variability and no correlation with stock size absolute stock biomass cannot be estimated.

An alternative model

The stock has since the mid 1980s experienced a relatively stable environment of predation and exploitation (Fig. 1A and 1C) and have itself remained relatively stable (Fig. 1B). This indicates that the stock can sustain the current level of exploitation. With such information in the data it is with a few assumptions still possible to quantify the risks of the stock being overexploited (catches above MSY and stock below B_{MSY} (biomass that gives MSY)) or outside safe limits (=below B_{lim}, a limit reference point for stock biomass).

Assume that the production curve of the stock is dome shaped, e.g. population growth follows a logistic curve and the biomass series therefore can be described by:

$$\text{Process:} \quad B_{t+1} = B_t + rB_t(1 - \frac{B_t}{K}) - C_t \qquad \text{(eq. 3)}$$

$$\text{Data links:} \quad U_t = qB_t$$

where r is intrinsic rate of growth (per year), K is carrying capacity; otherwise notation as before. The logistic model deviates from model used previously (eq. 1) in also including a function of density-dependent population growth – and thus adds some biological realism and stability to the model. Predation, although an important source of mortality for shrimp (Hvingel 2005b and references therein), was not included as an explicit variable because the predation indices do not vary much (see previous section).

As the uncertainty of absolute stock size is huge biomass is dealt with on a relative scale to cancel out the uncertainty in q (Hvingel and Kingsley 2005). Relative biomass $P_t=B_t/B_{MSY}$, this implies that K=2 and $P_{MSY}=1$. Observation and process error was implemented simultaneously using a state space framework:

$$\text{Process:} \quad P_{t+1} = \left(P_t - \frac{C_t}{B_{MSY}} + rP_t \left(1 - \frac{P_t}{2} \right) \right) \cdot \exp(\nu_t) \qquad \text{(eq. 4)}$$

$$\text{Data links:} \quad U_t = qB_t \exp(\beta_t)$$

The 'process errors', v, and observation errors, β, are normally, independently and identically distributed with mean 0 and variance σ_ν^2 and σ_β^2. Bayesian inference was used to estimate probability distributions of model parameters following the approach of Hvingel and Kingsley (2005). Similar models have been applied to the shrimp fisheries off West Greenland (Hvingel and Kingsley 2005, Hvingel 2004, Anon. 2004b).

Low-information or reference priors were given to *MSY*, *q*, *K*, P_1 and σ_ν as there was little or no information on what their probability distributions might look like. *MSY* was given a generously wide uniform prior between 0 and 150 000 tons. The catchability *q* were given a distribution uniform on a log scale as a reference prior (Hvingel and Kingsley 2005). A similar distribution was used for *K* between 1 and 665 000 tons (The upper limit corresponds to about 11g or about 5-10 shrimp per m^2 over the survey area of 57 300 km^2 which by shrimp experts is considered to be high). The prior for the stock size in the first year, P_1, was uniform 0 to 2. The prior distributions for the error terms associated with the biomass indices were assigned inverse gamma distributions (the gamma distribution, $G(r,\mu)$, is defined by: $\mu^r x^{r-1} e^{-\mu x}/\Gamma(r)$; $x>0$). Estimates of the variance of survey biomass estimates 1984—2002 was not available. CVs of the 2004-2005 survey values were 30% (Hvingel 2005a) but are probably over-estimated due to the fixed station design. Observation error was therefore given an inverse gamma distribution with a mode at 0.2, comparable to the CVs found in the Greenlandic shrimp survey (Wieland et al 2004).

Results

As expected absolute scale of stock biomass and production (Fig. 5) could not be determined with any precision. However, the model is quite certain that the stock has been larger than B_{msy} (P=1) and indeed above the limit reference of P=0.3 (The limit reference point for stock size, B_{lim}, for a logistic production curve is 30% B_{msy} (Shelton, P. A. 2004)) (Fig. 6). The uncertainty of the relative stock size are big for all years but increases after 2002 as these values are model predictions due to missing survey data (Fig. 6).

The risk of the stock being below B_{msy} is between 1.5 and 8.2% and and even smaller, 0.1–2.2% for being below B_{lim} for the period 1990–2005. The risk of the fishing mortality being above F_{lim} was not estimated due to the inability to estimate the full distribution of MSY, however, an index of harvest rate (landings/estimated median biomass) (Fig. 7) has shown a declining trend since the late 1980s. The risk table are as follows:

Year	p(B<Bmsy)	p(B<Blim)	p(F>Flim)	p(C>MSY)
1990	8.2%	0.2%		1.6%
1991	5.4%	0.1%		2.4%
1992	4.1%	0.1%		2.5%
1993	3.7%	0.1%	Declining trend	1.7%
1994	3.4%	0.1%		2.4%
1995	3.0%	0.1%		3.2%
1996	2.4%	0.1%		4.6%
1997	2.0%	0.1%		4.8%
1998	2.2%	0.1%		2.0%
1999	2.1%	0.1%		1.3%
2000	2.2%	0.1%		1.4%
2001	1.7%	0.1%		1.7%
2002	1.5%	0.1%		2.3%
2003	6.4%	1.0%		2.2%
2004	5.1%	1.2%		2.2%
2005	7.7%	2.2%		1.6%

Estimated series of median stock size relative to the reference points are shown in Fig. 9.

As the productive potential of the stock remains unknown an evaluation of different future catch options could not be made.

Discussion

The choice of upper limits of the priors for K and MSY has a small influence on the calculated risk values. If they are increased the risk values tend to increase slightly, and decline if they are reduced. However, the truncation was chosen so that higher values would be unlikely and the calculated risks may in this respect therefore be considered to be conservative.

Berenboim et al. (1980) estimated a catchability of 0.173 by calibrating trawl catches to the results of a photo survey. If this is chosen as basis for an informative prior by giving q a lognormal distribution with a median of 0.173 and a variance of 0.3 (Fig. 8) the estimated posterior distribution of K would be tighter; however MSY can still not be determined as the data have not “explored” that region of the production curved yet. With this prior the risks calculated in the first model run (see text table above) remain largely unchanged.

The stock may likely sustain larger catches than the current level of around 13000 t given that the environmental settings remain stable. However, increases in the exploitation level should be carefully planned and designed to provide more information on stock dynamics and to help estimate the productive capability of the stock. It should be kept in mind that an increased exploitation could affect catch rates negatively and might also lead to lower mean size of shrimp in the catch. Management should be ready to respond to new information e.g. by reducing catches. This approach could be founded in a multi-annual adaptive management plan.

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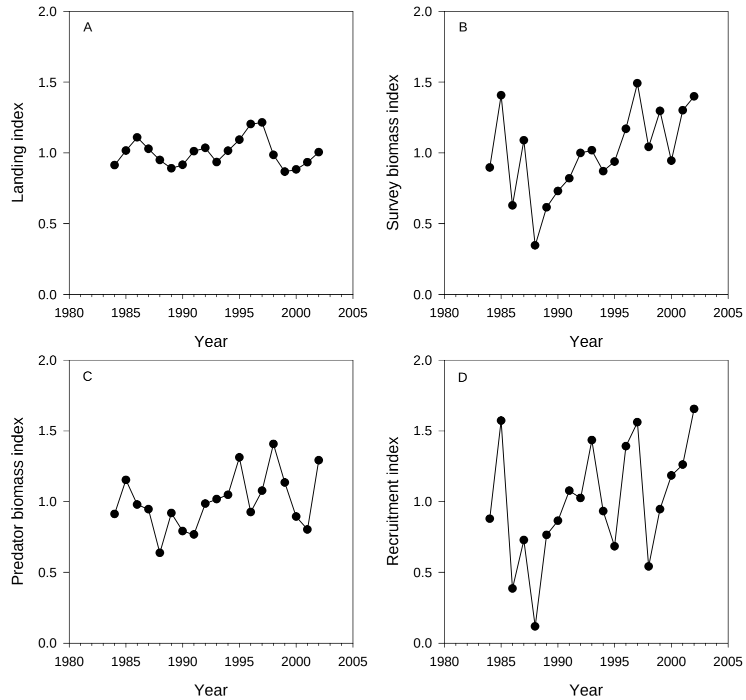

Fig. 1. Time series of landings (A), biomass index of age 2+ (B), biomass index of predators (C) and recruitment biomass index (age 0 and 1) (D) available for the biomass dynamic model used in the assessment of the shrimp stock in Skagerrak and Norwegian Deep. All scaled to their mean (mean=1)

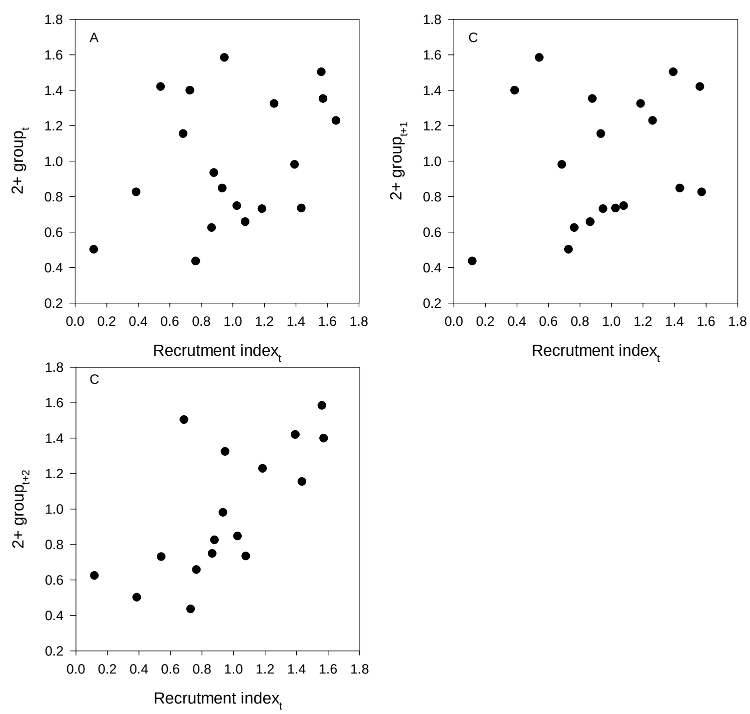

Fig. 2. Index of recruitment (biomass of age 0 and 1 from the survey) *vs.* the 2+ group survey index 0, 1 and 2 years later. The variables were scaled to their means (mean=1).

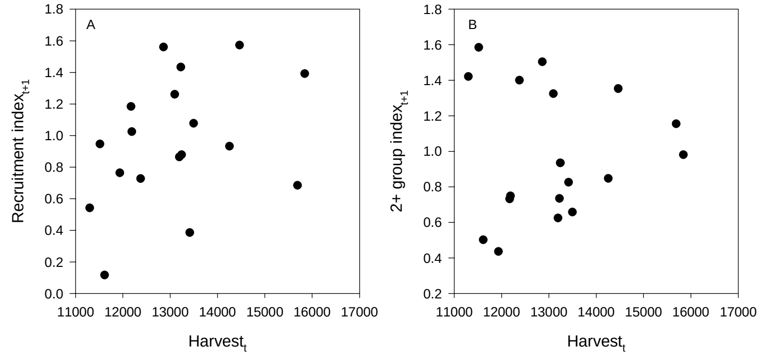

Fig. 3. Harvest (0.25*landing in year t+0.75*landings in t+1) *vs.* survey biomass of recruits (age 0 and 1s) and 2+ group scaled to their means (mean=1).

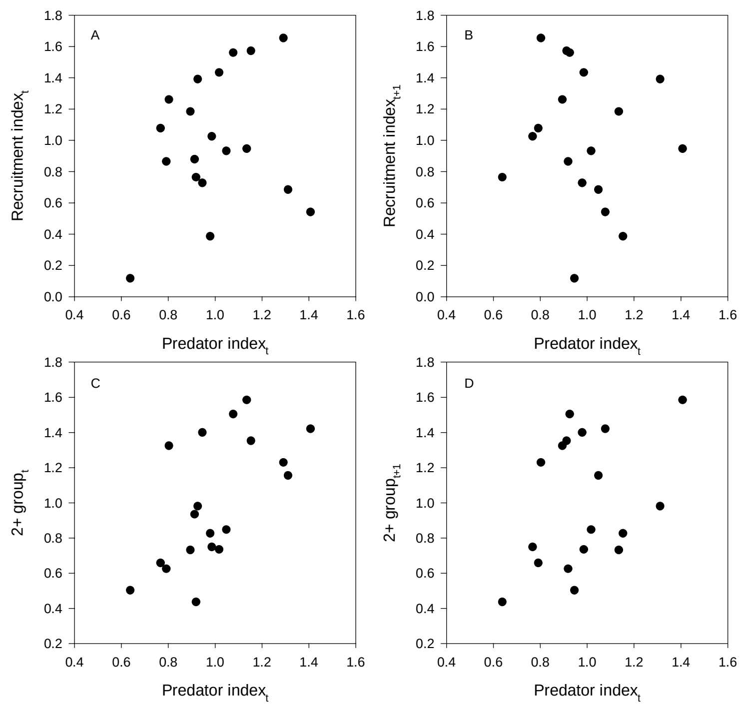

Fig. 4. Predator biomass indices from the Norwegian survey (mean=1) *vs.* the survey recruitment and 2+ group indices in the same and following year (mean=1).

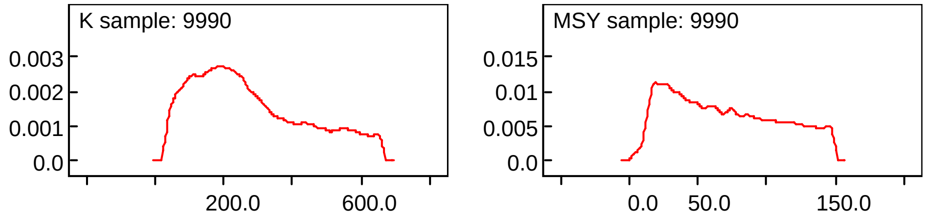

Fig. 5. Posterior probability density distributions of the carrying capacity, K, and maximum sustainable yield, MSY, derived by Monte-Carlo-Markov-Chain (MCMC) sampling methods using the model (eq. 4). The scale of the X-axis is Ktons.

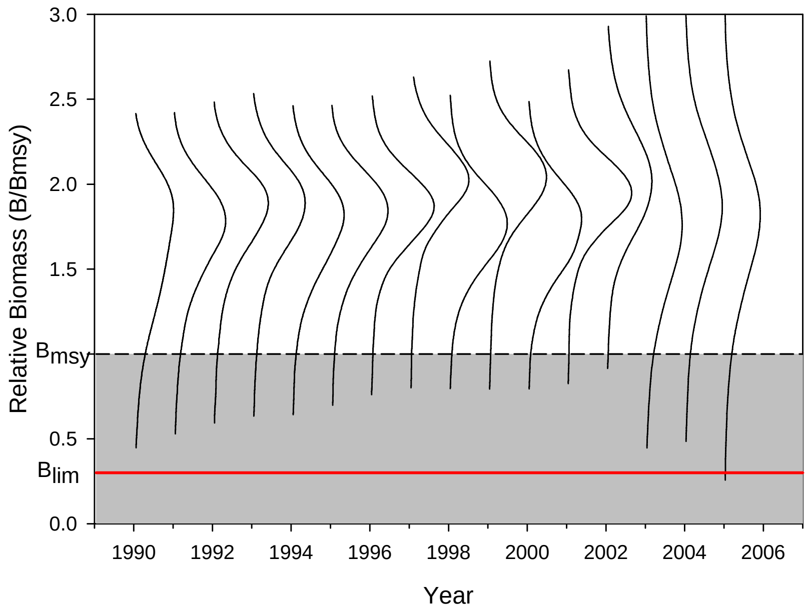

Fig. 6. Posterior probability density distributions of stock biomass (relative to Bmsy) 1990-2006 derived by applying Bayesian inference and MCMC sampling techniques to a logistic model of shrimp stock dynamics. The 2003-2006 values are predicted due to the lack of standardised survey data after 2002. Red line is a limit reference point.

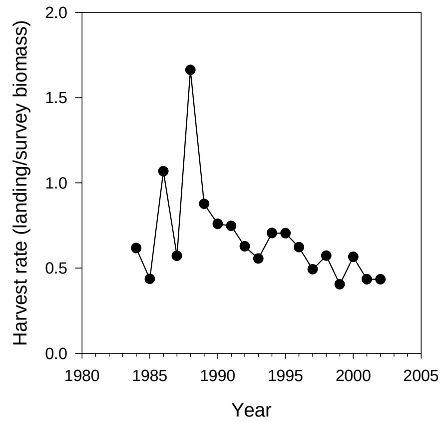

Fig. 7. An index of harvest rate (survey biomass$_t$/0.25*landing$_t$+0.75*landing$_{t+1}$t indxes year).

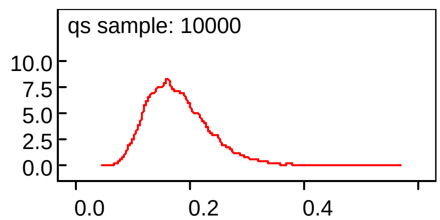

Fig. 8. Alternative informative prior for the catchability, q (scaling survey biomass to real biomass), based on Berenboim et al. (1980).

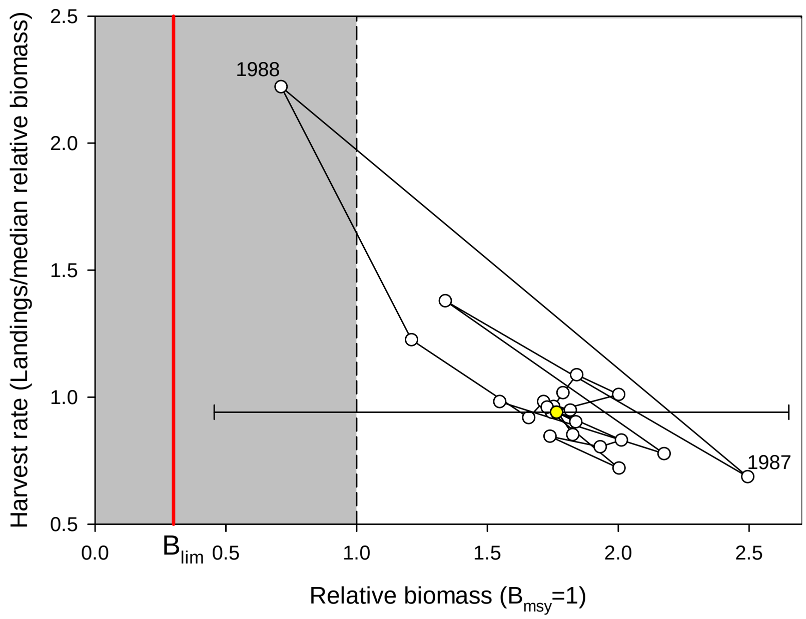

Fig. 9. Shrimp in Skagerrak and Norwegian Deep: Stock dynamics 1984 to 2005 in a fishing mortality/biomass continuum. Points are the median values of estimated biomass and harvest rate. Red line is limit reference point. Error bars for the 2005-value (yellow point) are 95% conf. interval.