PART C

Scientific Council Meeting, 26 October-3 November 2005

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Scientific Council Meeting, 26 October-3 November 2005 at NAFO Headquarters, Dartmouth, N.S., Canada

Back (left to right): Korzun Yuriy, Sergey Bakanev, Eugene Colbourne, Carsten Hvingel, Bo Bergstrøm, Peter Koeller, Sten Munch-Petersen, Mats Ulmestrand, Bill Brodie, Miguel Casas, Ricardo Federizon

Middle (left to right): Barbara Marshall, Knut Sunnanå, Katherine Skanes, Michaela Aschan, Michael Kingsley, Helle Siegstad, Dorothy Auby, Antonio Vazquez, Don Power

Front (left to right): Dave Orr, Unnur Skuladottir, Guldborg Søvik, Kai Wieland, Don Stansbury

STACFIS, 26 October-3 November 2005: In Session.

Participants enjoying a Traditional Holiday Dinner at the Cole Harbour Heritage Farm in Cole Harbour, Nova Scotia, Canada

REPORT OF SCIENTIFIC COUNCIL MEETING

26 October-3 November 2005

Chair: Antonio Vazquez Rapporteur: Barbara Marshall

I. PLENARY SESSIONS

The Scientific Council met at NAFO Headquarters, Dartmouth, Nova Scotia, Canada, during 26 October-3 November 2005, in conjunction with the Pandalus Working Group of ICES (WGPAND) in accordance with decisions of November 2004. Representatives attended from Canada, Denmark (in respect of Greenland), European Union (Spain and Sweden), Iceland, Norway, Russian Federation, and Ukraine.

The Executive Committee and Chair of WGPAND met briefly before the opening to discuss the plan of work.

The opening session was called to order at 1000 hours on 26 October 2005. The Chair welcomed participants to this second Joint Meeting with ICES WGPAND. He noted that the purpose of the joint meeting was to better coordinate and foster interrelationships and share experiences. He hoped the meeting would be productive and offer participants a good time.

The Executive Secretary welcomed delegates to the NAFO Secretariat and Dartmouth and reiterated hopes that the meeting would be fruitful and promote cooperation between ICES and NAFO.

As was laid out in the Rules of Procedure the Executive Secretary was designated as the official rapporteur. To this end the task was delegated to Barbara Marshall of the NAFO Secretariat.

The Council noted that STACFIS would undertake the assessments of the stocks (see Appendix I), while the prognoses and advice would be undertaken by the Council.

The Provisional Agenda was considered and **adopted** (see Agenda III, Part D, this volume).

The session was adjourned at 1100 hours.

The Council welcomed STACFIS to conduct its business throughout the meeting, noting most of the Council's work would be addressed during 2-3 November 2005.

The concluding session was convened at 1500 hours on 3 November 2005. The Council addressed the requests of the Fisheries Commission and the Coastal States and considering the results of the assessments, provided advice and recommendations.

The Council then considered and **adopted** the STACFIS Report, and considered its own report and **adopted** the report of this meeting of 26 October-3 November 2005.

The meeting was adjourned at 1630 hours on 3 November 2005.

The Report of Standing Committee on Fisheries Science (STACFIS) as **adopted** by the Council is given at Appendix I.

The Report of ICES Working Group on Pandalus (WGPAND) is given at Appendix II.

The Agenda, List of Research (SCR) and Summary (SCS) Documents, and List of Representatives and Advisers/Experts of this meeting (see Part D, this volume).

The Council's considerations on the Standing Committee Report, and other matters addressed by the Council follow in Sections II-IV.

II. FISHERIES SCIENCE

The Council **adopted** the Report of Standing Committee on Fisheries Science (STACFIS) as presented by the Chair, Don Power. The full report is given at Appendix I and it includes detailed analysis of the shrimp stocks considered by both NAFO.

The Council's summary sheets and conclusions on Northern shrimp in Div. 3M, Northern shrimp in Div. 3LNO, Northern shrimp in Subareas 0 and 1 and Northern shrimp in Denmark Strait and off East Greenland are presented in Section III of this report. The recommendations with respect to stock advice appear therein.

The research **recommendations** from this meeting as **endorsed** by the Council are as follows:

1. **For Northern Shrimp in Division 3M**

- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to Designated Experts by 1 September 2006.*
- *indices of female stock size be presented with error bars where possible.*
- *the relationship between the recruitment index and fishable biomass be investigated further.*

2. **For Northern Shrimp in Divisions 3LNO**

- *Ogmap should be reviewed further to determine whether it is an appropriate method to determine Div. 3LNO shrimp biomass/abundance indices from stratified random surveys.*
- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to the Designated Expert, in the standardized format, by 1 September 2006.*

3. **For Northern Shrimp in Subareas 0 and 1**

- *sampling of catches by observers - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - should be re-established in Subarea 1.*
- *ways to include the exploration of the effects of future trajectories of the cod stock on assessment predictions should be investigated and presented in 2006.*
- *the impact of other predators on the stock should also be considered for inclusion in the assessment model.*
- *the age-2 abundance index and its link to subsequent fishable biomass should be considered for inclusion in the shrimp assessment model.*

4. **For Northern Shrimp in Denmark Strait and off East Greenland**

- *a survey be conducted, to provide fishery independent data of the stock throughout its range*
- *as a minimum requirement: sampling of catches by observers is required - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - and be re-established in the Greenland EEZ and improved in the Icelandic EEZ.*

III. FORMULATION OF ADVICE

1. Advice for Northern Shrimp

a) Request from Fisheries Commission

The Scientific Council reviewed the STACFIS assessments of Northern shrimp in Div. 3M and Div. 3LNO, and the agreed summaries are as follows:

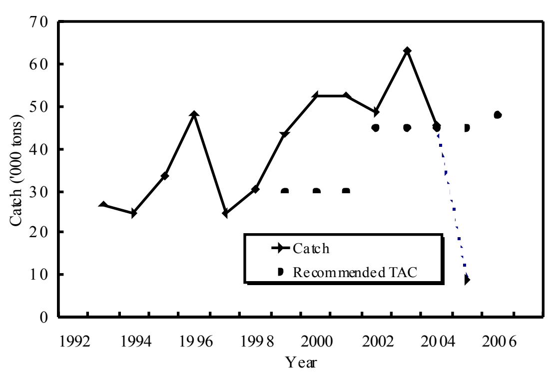
Northern Shrimp (Pandalus borealis) in Division 3M

Background: The shrimp fishery in Div. 3M began in 1993. Initial catch rates were favourable and, shortly thereafter, vessels from several nations joined. Between 1993 and 2004 the number of vessels ranged from 40-110. To date in 2005 there were approximately 26 vessels fishing shrimp in Div. 3M compared to 50 last year.

Fishery and catches: This stock is under effort regulation. Recent catches were as follows.

	Catch ('000 tons)		TAC ('000 tons)	
Year	STACFIS	21A	Recommended	Agreed
2002	49	47[1]	45	er
2003	63	63[1]	45	er
2004	45	44[1]	45	er
2005	9[2]		45	er
2006			48	er

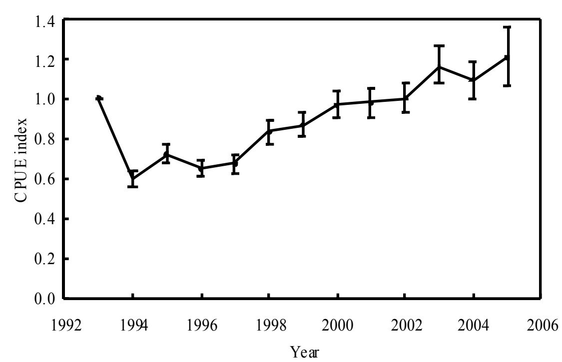
[1] Provisional.
[2] Preliminary to 1 September.
er Effort regulations.



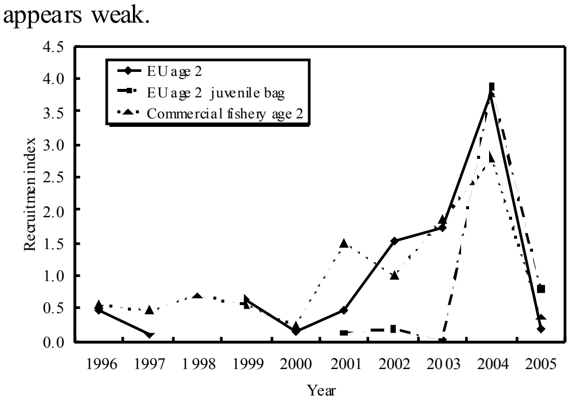
Data: Catch, effort and biological data were available from some, but not all Contracting Parties. A standardized CPUE index was developed. Time series of size and sex composition data were available mainly from two countries and survey indices were available from EU research surveys (1988-2005). A new research vessel was introduced in the EU survey in 2003. The biomass indices have now been converted for the whole series.

Assessment: No analytical assessment is available. Evaluation of stock status is based upon interpretation of commercial fishery and research survey data.

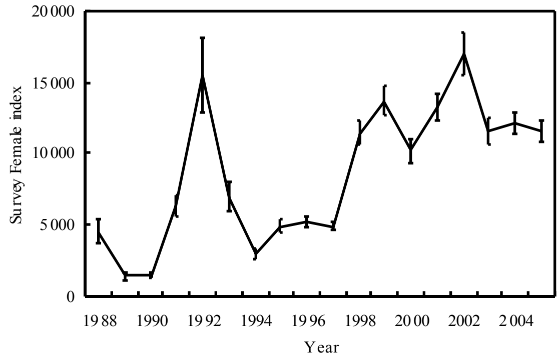
CPUE: Standardized CPUE declined between 1993 and 1994, varied without a trend to 1997 and increased to 2005.



Recruitment: Both the 2001 and 2002 year-classes appear to be above average, but 2003 year-class appears weak.



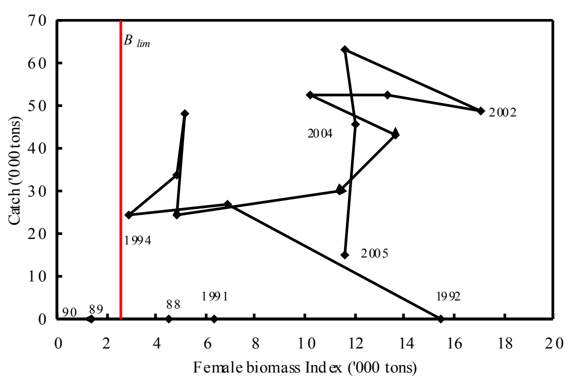
SSB: All indices of female biomass increased from 1997 and have fluctuated without a trend since then.



State of the Stock: The indices of CPUE and biomass are at relatively high levels but there are indications of a decline in recruitment, which may affect the 2007 fishery.

Recommendations: The stock appears to have sustained an average annual catch of about 48 000 tons since 1998 with no detectable effect on stock biomass. The Scientific Council advises a catch of 48 000 tons for 2007.

Reference Points: Scientific Council considers that 15% of the maximum survey female biomass index is a limit reference point for biomass (B_{lim}) for northern shrimp in Div. 3M. It is not possible to calculate a limit reference point for fishing mortality. Currently, the biomass is estimated to be well above B_{lim}.



Special comments: This advice will be reviewed based on updated information in September 2006.

Sources of Information: SCR Doc. 05/78, 79, 89, 94.

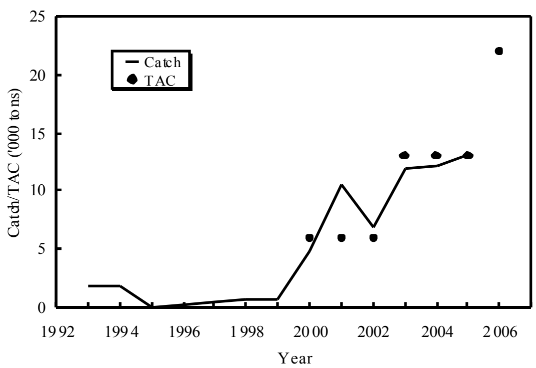
Northern Shrimp (Pandalus borealis) in Divisions 3L, 3N and 3O

Background: Most of this stock is located in Div. 3L and exploratory fishing began there in 1993. The stock came under TAC regulation in 2000, and fishing has been restricted to Div. 3L.

Fishery and catches: Several countries participated in the fishery in 2005. The use of a sorting grid to reduce by-catches of fish is mandatory for all fleets in the fishery. Recent catches from the stock are as follows:

	Catch ('000 tons)		TAC ('000 tons)	
Year	STACFIS	21A	Recommended	Agreed
2002	7	6[1]	6	6
2003	12	11[1]	13	13[3]
2004	13	12[1]	13	13[3]
2005	13[2]		13	13[3]
2006			22	22

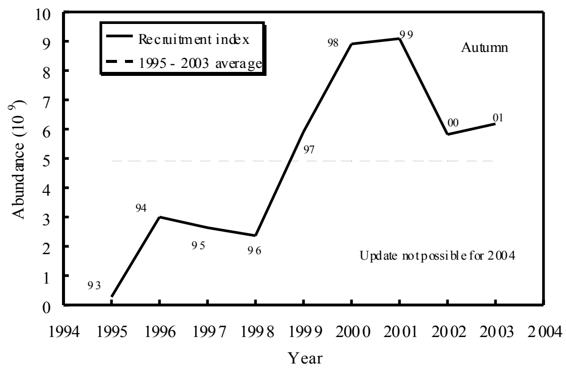
[1] Provisional.
[2] Preliminary to 19 October 2005.
[3] Denmark in respect of Greenland and Faroe Islands set an autonomous TAC of 1 344 tons for 2003 to 2005.

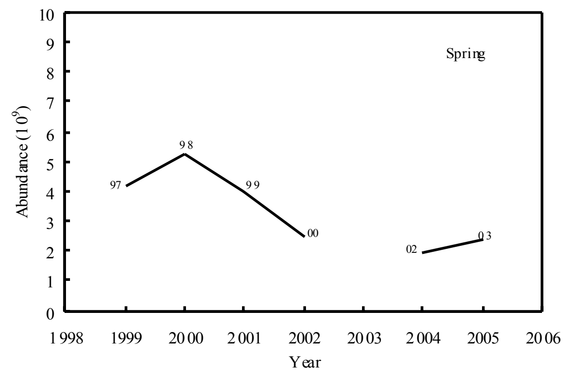


Data: Catch, effort and biological data were available from the commercial fishery. Biomass and recruitment indices and size and sex composition data were available from research surveys conducted in Div. 3LNO during spring (1999 to 2005) and autumn (1995 to 2003). The Canadian survey in autumn 2004 was incomplete.

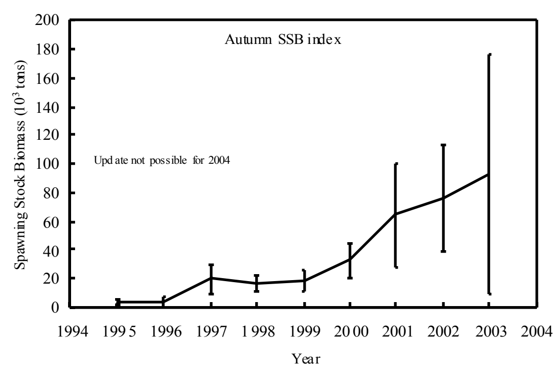
Assessment: No analytical assessment is available. Evaluation of the status of the stock is based upon interpretation of commercial fishery and research survey data.

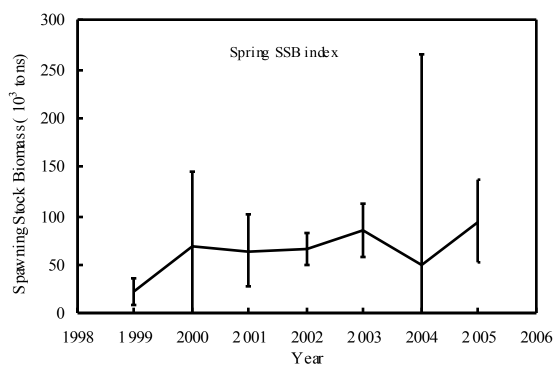
Recruitment: The 1997-2001 year-classes are above average, while the 2002 and 2003 year-classes are lower.



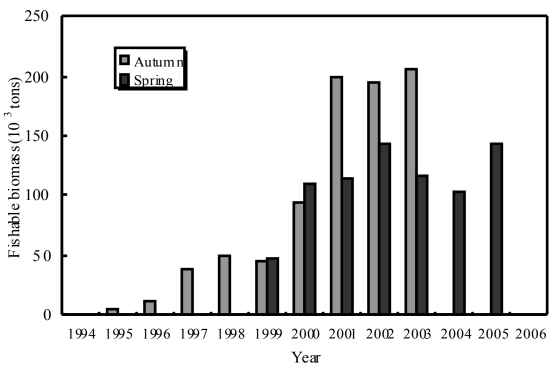


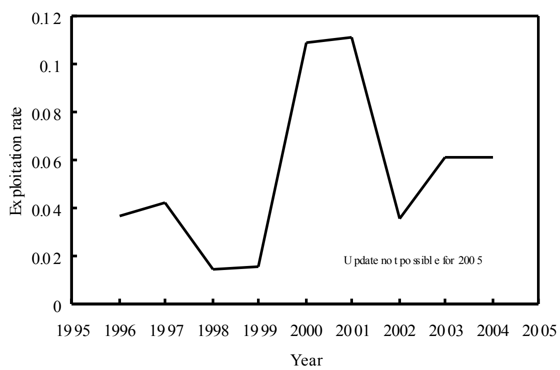
Biomass: There was a significant increase in SSB and total biomass between 1995 and 1997 followed by a period of stability between 1997 and 1999. SSB and total biomass have been at a higher level since 1999.





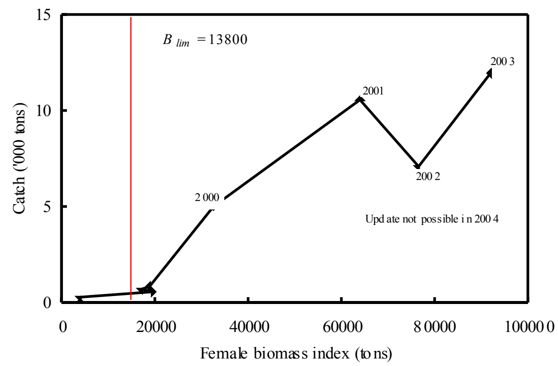
Fishable biomass and exploitation: Fishable biomass has increased from 1995-2001 and remained stable since then. The exploitation index (catch/autumn fishable biomass from previous year) increased during 2000-2001, at the beginning of the fishery, and has decreased since then.





State of the Stock: SSB and total biomass have increased since 1999. The stock appears to be well represented by a broad range of size groups, and the exploitation index is low. Recruitment is anticipated to decline.

Precautionary Approach Reference Points: Scientific Council considers that 15% of the maximum female biomass index is a limit reference point for biomass (B_{lim}) for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the biomass is estimated to be well above B_{lim}.



Recommendation: The Scientific Council advises a TAC of 22 000 tons for 2007. Scientific Council could not update its recent estimate of stock size due to an incomplete survey in 2004. Scientific Council repeats its previous recommendation that the TAC should not be raised for a number of years to allow time to monitor the impact of the fishery upon the Div. 3LNO shrimp stock.

Scientific Council reiterated its recommendations that the fishery be restricted to Div. 3L and that the use of a sorting grate with a maximum bar spacing of 22 mm be mandatory for all vessels in the fishery.

Special Comments: Advice for the 2007 fishery will be reviewed at the September 2006 Scientific Council meeting, when results from the 2005 autumn and 2006 spring surveys will be available.

Sources of Information: SCR Doc. 05/76, 77, 79, 88, 91, 95; SCS Doc. 04/12.

b) **Responses to the Coastal States**

The Scientific Council reviewed the STACFIS assessments for Northern shrimp in Subareas 0 and 1 and in Denmark Strait and off East Greenland, and the agreed summaries are as follows:

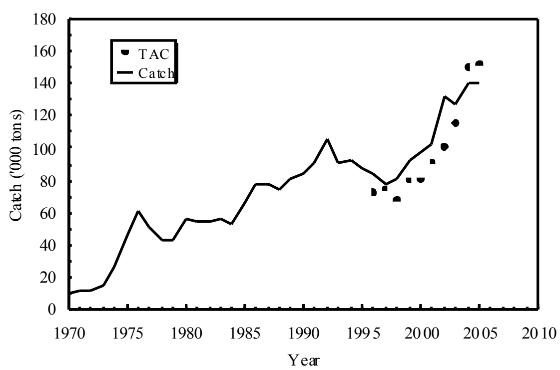
Northern Shrimp (Pandalus borealis) in Subareas 0 and 1

Background: A small-scale inshore fishery began in SA 1 during the 1930s. Since 1969 an offshore fishery has developed. The shrimp stock off West Greenland is distributed in Subarea 1 and Div. 0A east of 60°30'W.

Fishery and Catches: The fishery is prosecuted mostly by Greenland and Canada; since 2004 the EU has had a 4 000 ton quota in SA 1. Recent catches from the stock are as follows:

	Catch ('000 tons)		TAC ('000 tons)	
Year	STACFIS	21A[2]	Recommended	Actual[4]
2002	132.2[1]	105.9	85	101.0
2003	126.5[1]	138.1	100	115.7
2004	141.8	141.8	130	150.0
2005	140.5[3]		130	152.4

[1] Corrected for overpacking.
[2] Provisional.
[3] Estimated to the end of 2005.
[4] Total of TACs set by Greenland and Canada.



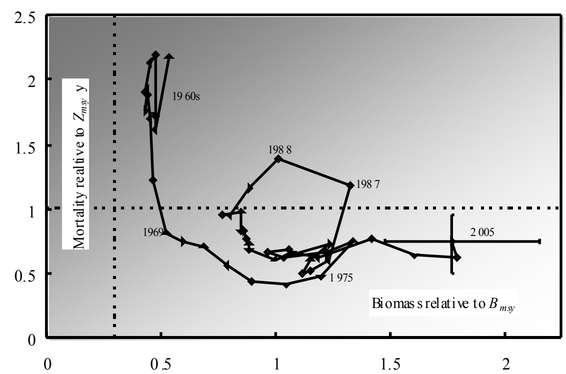
Data: Catch and effort data were available from all vessels. Series of biomass and recruitment indices and size- and sex-composition data were available from research surveys. Series of cod biomass and cod consumption were also available.

Assessment: An analytical assessment framework was used to describe stock dynamics in terms of biomass (B) and mortality (Z) relative to biological reference points.

The model used was a stochastic version of a surplus-production model including an explicit term for predation by Atlantic cod, stated in a state-space framework and fitted by Bayesian methods.

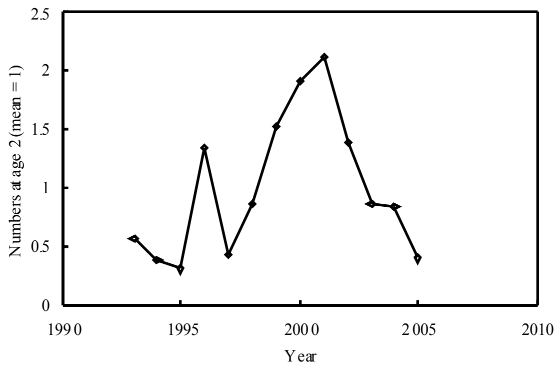
MSY (Maximum Sustainable Yield) defines maximum production, and B_{MSY} is the biomass level giving *MSY*. A precautionary limit reference point for stock biomass (B_{lim}) is 30% of B_{MSY} and the limit reference point for mortality (Z_{lim}) is $Z_{MSY.}$

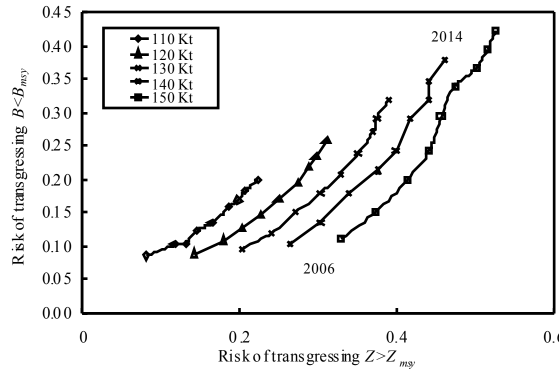
Mortality: The mortality caused by fishing and cod predation (Z) has been stable below the upper limit reference (Z_{msy}) since 1997. With catches in 2005 projected at 140 500 tons the risk that total mortality exceeded Z_{msy} was estimated at about 20%.



Biomass: Since the late 1990s the stock has increased and the survey index reached high levels in 2003 and 2004. This index then decreased in 2005, but CPUE continued to increase. The modelled stock biomass reached its hitherto highest value in 2005; the estimated risk of stock biomass being below B_{msy} at end 2005 was 8%, but less than 1% of being below B_{lim}.

Recruitment: Prospects for recruitment to the fishable biomass in 2006 are still highly favourable. However, the estimated number of age-2 shrimp decreased in 2002, was below average in 2003 and 2004 and decreased again in 2005 to near a 10-year low value. Recruitment to the fishable stock is likely to decrease after 2006.





State of the Stock: The stock biomass has increased substantially since the late 1990s to historically high levels. Biomass at the end of 2005 is estimated to be well above B_{msy} and mortality by fishery and cod predation well below Z_{msy}.

The abundance of recruited males (between 17 and 22 mm CL) in 2005 is estimated to be high and should sustain good catch rates of larger shrimp in 2006. However, both model simulations of stock development and indices of future recruitment indicate that fishable biomass can be expected to follow a decreasing trend.

Recommendations: If catches exceed 130 000 tons in 2006 the risk of exceeding a mortality that is considered to be a limit reference point is greater than 20%. However, given that stock biomass is now estimated considerably above B_{MSY}, risk of its falling below this level within a one-year horizon is low. Scientific Council concludes that a total catch of around 130 000 tons in Div. 0A and SA 1 in 2006 will have a high probability of maintaining the stock within the safe zone.

Risk associated with five optional catch levels for 2006 are as follows:

Catch option ('000 tons)	110	120	130	140	150
Risk of falling below B_{MSY}	9%	9%	10%	11%	11%
Risk of falling below B_{lim}	<1%	<1%	<1%	<1%	<1%
Risk of exceeding Z_{MSY}	8%	14%	20%	27%	38%

Medium-term Considerations: Ten-year projections of stock development were made using the assumption that the cod stock will remain at its 2005 level. Five levels of annual catch: 110, 120, 130, 140 and 150 thousand tons were investigated.

With a catch of 130 000 tons/yr there is a 15% risk of stock biomass falling below B_{MSY} and less than 1% of falling below B_{lim} in the first three years. However, this level of exploitation will not be sustainable in the longer term, as the estimated risk of falling below optimum biomass continues to increase through time.

Special Comments: The Scientific Council advice is for catch weight, correctly reported, without overpacking.

Both stock development and the rate at which changes might take place depend heavily on the abundance of predators (in particular cod) present within the shrimp habitat. In the most recent years increases in cod abundance have been registered, and present levels of cod biomass could consume significant quantities of shrimp. However, these estimates are still well below those of the late 1980s and certainly those of the 1950s and 1960s.

If the cod stock were to increase rapidly above the current level, as it did in the late 1980s, predation could reach the same level as the current catches within a 3-4 year period. Such an event should, however, be detected by routine survey programs and management options can, in that case, be evaluated.

Sources of Information: SCR Doc. 02/158, 04/73, 75, 76, 05/73, 74, 75, 83, 85; SCS Doc. 04/12.

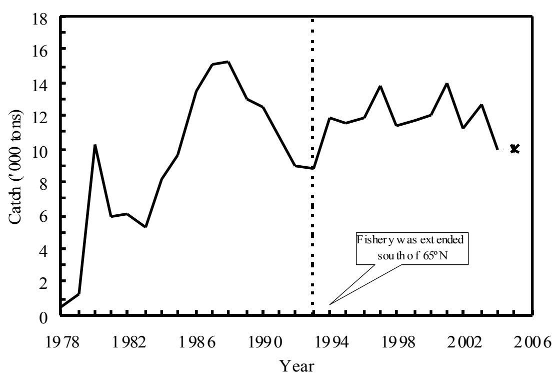
Northern shrimp (Pandalus borealis) in Denmark Strait and off East Greenland

Background: The fishery began in 1978 in areas north of 65°N in Denmark Strait, where it occurs on both sides of the midline between Greenland and Iceland. Areas south of 65°N in Greenlandic waters have been exploited since 1993.

Fishery and Catches: Five nations participated in the fishery in 2005. Recent catches and recommended TACs are as follows:

	Catch ('000 tons)		TAC ('000 tons)		
Year	STACFIS	21A[1]	Recom.	GR EEZ	ICE EEZ[2]
2002	11.2[1]	9.2	9.6	10.6	-
2003	12.6[1]	9.8	9.6	10.6	-
2004	10.0	10.0	12.4	15.6	-
2005	10.0[3]		12.4	12.4	-

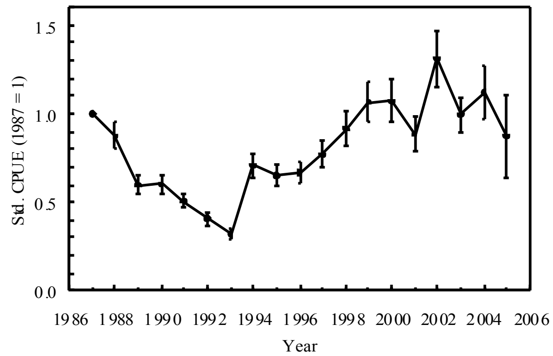
[1] Provisional catches.
[2] Fishery unregulated in Icelandic EEZ
[3] Projected to the end of 2005.

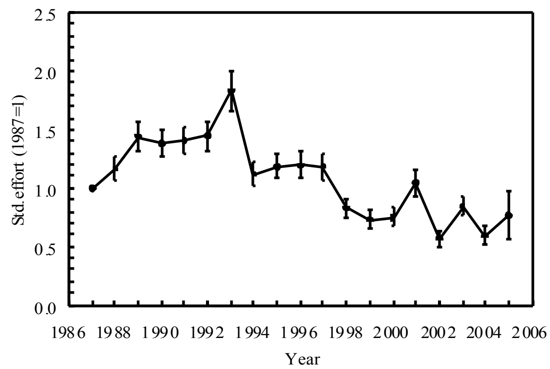


Data: Catch and effort data were available from trawlers of several nations. Surveys have not been conducted since 1996.

Assessment: No analytical assessment is available. Evaluation of the status of the stock is based on interpretation of commercial fishery data.

CPUE: Combined standardized catch-rate index for the total area decreased steadily from 1987 to 1993, showed an increasing trend until the late 1990s, and fluctuated at this level thereafter.





Recruitment: No recruitment estimates were available.

Biomass: No direct biomass estimates were available.

Exploitation rate: From 1998 through 2005 the exploitation rate index (catch/CPUE) has been at its lowest levels in the 19-year series.

State of the Stock: Standardized CPUE data for all the areas combined indicate an increasing trend from 1993 to 2000 in the fishable biomass and has fluctuated at this level thereafter. However, changes in the fishing pattern in 2004 and 2005 leaves some uncertainty as to whether the 2005 value is a true reflection of the stock biomass.

Recommendation: There were no indications that catches in the range of 12 400 tons adversely affect the stock. Scientific Council therefore advises that catches of shrimp in Denmark Strait and off East Greenland should remain at this level in 2006.

Special Comments: The apparent increase in the advised TACs after 2003 is based on a revision of catch estimates to account for overpack and not on a comparable increase in stock production. The advice after 2003 may therefore not be interpreted as if actual removals by the fishery should be increased comparatively. The Scientific Council advice is based on catches in 2005 being reported correctly, accounting for overpack.

Sources of Information: SCR Doc. 03/74, 05/93.

IV. OTHER MATTERS

1. Scientific Council Meeting, October/November 2006

The Scientific Council agreed to the dates 25 October to 2 November 2006 for this meeting to be held jointly with the ICES *Pandalus* Assessment Working Group (WGPAND) at the ICES Headquarters, Copenhagen, Denmark.

It was noted that the nature of the joint NAFO/ICES meeting made the duration of the meeting acceptable. The meeting had been extended to allow time for the ICES stocks to be assessed.

2. Scientific Council Meeting, October/November 2007

The Scientific Council agreed to the dates 24 October to 1 November 2007 for this meeting to be held jointly with the ICES *Pandalus* Assessment Working Group (WGPAND) at the NAFO Headquarters, Dartmouth, Nova Scotia, Canada.

3. Coordination with ICES Working Groups on Shrimp Stock Assessments

Participants all agreed that having the joint meeting was fruitful.

Therefore participants agreed to the dates 25 October to 2 November 2006 for this meeting to be held jointly with NAFO Scientific Council and ICES *Pandalus* Assessment Working Group (WGPAND) at the ICES Headquarters, Copenhagen, Denmark.

In order to facilitate the 2006 meeting the following proposal was agreed:

The schedule and agenda will be developed by the Chairs of Scientific Council, STACFIS, ACFM and WGPAND. The STACFIS agenda will explicitly incorporate the assessments generally addressed by WGPAND. The advice will be provided as requested by NAFO Fisheries Commission and ICES ACFM.

The Scientific Council portion of the meeting will be held as usual, chaired by Chair of Scientific Council. The assessments of the various shrimp stocks will be the joint responsibility of all meeting participants and will involve the participation of all members of STACFIS and WGPAND.

Intersessionally the Chairs will communicate to work out the details regarding the arrangements of the meeting, in consultation with the NAFO and ICES Secretariats. The goal is to have a joint report prepared.

4. Other Business

a) New Possibilities to Improve Catch Information Available

The Fisheries Commission Request for Scientific Advice (FC Doc. 05/14) enables the Scientific Council to obtain information from VMS data from the Secretariat. The VMS data may be a possible source of information regarding position, particularly in the shrimp fishery.

The Scientific Council **recommends** that *approval be sought from the Fisheries Commission to obtain catch information from VMS to be used in assessments.*

Any information available on "overpack" and how to quantify it should also be made available to Scientific Council.

b) By-catch Information

At the September Annual Meeting the Scientific Council was requested by the Fisheries Commission to provide information on by-catch in the Div. 3M shrimp fishery.

Having observed that there is much relevant information contained in documentation presented to it, and in order to determine the impact of the shrimp fishery upon commercially important groundfish species, Scientific Council recommended that information on groundfish by-catch in the shrimp fishery for the NAFO Subarea 2 and Divisions 3KLMNO should be summarized and updated by the authors. This summary should be presented to Scientific Council at the June Meeting.

c) **Assessment Database**

Scientists at this meeting were shown the web-page for the stock assessment database. Designated Experts were encouraged to submit their information to the Secretariat.

d) **Time Needed for the Meeting**

The Council noted that the meeting utilized the full eight days scheduled. The joint group for the meeting considered that this was an appropriate amount of time to complete the proposed agenda. However, to maintain the eight days it will be necessary to improve the efficiency, by making all relevant documentation available well in advance of the meeting.

e) **Proposal for Shrimp Working Group**

A proposal was made to establish a Northern Shrimp Working Group within NAFO Scientific Council. The working group will be used to stimulate concerted studies on the description of life history characteristics of shrimp and the comprehension of life cycle key processes. The main objectives of the working group would be to:

- Review availability of information and existing data on life history characteristics of northern shrimp by areas;
- Develop standard coordinated research protocols to monitor life history characteristics;
- Analyze and document demographic parameter variations in line with the investigation of hypotheses on life cycle key processes including the effect of variable environmental conditions.

Scientific Council agreed that it would be a good idea to establish such a working group, and suggested that a Convenor should be identified and that clear Terms of Reference be established and reviewed by the Council.

Scientific Council expressed their best wishes for the group and **recommends** that *the Working Group submits their progress report to the Council regularly.*

f) **Shrimp and Remotely-sensed Indicators of Marine Production**

A presentation was made by Cesar Fuentes-Yaco, Peter Koeller and Trevor Platt.

Information on a project proposal was presented. The project aims to link changes in shrimp biology, such as growth and recruitment, to remotely-sensed indicators of phytoplankton, specifically chlorophyll a. Results illustrating the potential usefulness (Koeller *et al.*, in press) were presented. The presentation ended with an open invitation to the shrimp research community to expand the above project to a larger geographical area in co-operation with remote-sensing expertise housed at the Bedford Institute of Oceanography.

Scientific Council encouraged the authors to bring their proposal to fruition.

Further reading:

Koeller, P., C. Fuentes-Yaco and T. Platt. (in press). Decreasing shrimp (*Pandalus borealis*) sizes off Newfoundland and Labrador – environment or fishing? *Fisheries Oceanography.*

Fuentes-Yaco, C., P. Koeller, T. Platt and S. Sathyendranath (in press). Shrimp (*Pandalus borealis*) growth and timing of the spring phytoplankton bloom. *Fisheries Oceanography.*

g) **Workshop on Bayesian Methods of Assessments**

Scientific Council was informed by the Greenland Institute of Natural Resources that a workshop on Bayesian methods of assessments is to be held in Nuuk in March-April of 2006. The Council welcomed the information and draws it to the attention of interested scientists.

V. ADOPTION OF REPORTS

The Council at its session on 3 November 2005 considered and adopted the Report of STACFIS (see Appendix I). The recommendations made by STACFIS and endorsed by the Scientific Council are given therein in Sections II and III above. The Council then considered and adopted its own Report of this 26 October-3 November 2005 Meeting.

VI. ADJOURNMENT

It was noted that Ron Myers has already retired and Forbes Keating was due to retire this year. Recognition for their hard work and best regards for their future were extended. Thanks were extended to the Secretariat for their usual efficient work, particularly to Barbara Marshall for her work in the meeting. Best wishes and safe traveling were given to all participants.

APPENDIX I. REPORT OF THE STANDING COMMITTEE ON FISHERIES SCIENCE (STACFIS)

Chair: Don Power Rapporteur: Various

I. OPENING

The Committee met at NAFO Headquarters, Dartmouth, Nova Scotia, Canada, during 26 October-3 November 2005, in conjunction with the WGPAND of ICES in accordance with decisions of November 2004, to consider and report on matters referred to it by the Scientific Council and ICES, particularly those pertaining to the provision of scientific advice on certain Northern shrimp stocks. Representatives attended from Canada, Denmark (in respect of Greenland), European Union (Spain), Iceland, Norway, Russian Federation and Ukraine.

The Chair, Don Power (Canada), opened the meeting on 26 October 2005 welcoming the participants. The Agenda was reviewed and a plan of work developed for the meeting.

II. GENERAL REVIEW

1. Review of Recommendations in 2004 and in 2005

The recommendations from last year were reviewed on a stock-by-stock basis.

Recommendations in November 2004

STACFIS **recommended** that, for shrimp in Div. 3M:

- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to Designated Experts by 1 September 2005.*

STATUS: Some progress has been made.

- *indices of female stock size be presented with error bars where possible.*

STATUS: Error bars were presented for the surveys. No progress on error bars for CPUE indices of females.

STACFIS **recommended** that, for shrimp in Div. 3LNO:

- *sensitivity analyses be conducted to determine whether OGMAP is an appropriate method to determine Div. 3LNO shrimp biomass/abundance indices and population adjusted length frequencies from stratified random surveys.*

STATUS: This was completed and presented at this meeting (see Section III.2.iii). Work is ongoing.

- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to the designated expert, in the standardized format, by 1 September 2005.*

STATUS: Some progress has been made.

For the shrimp stock in Subarea 1 and Div. 0A east of 60°W, STACFIS **recommended** that:

- *sampling of catches by observers - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - be re-established in Subarea 1.*

STATUS: There has been no sampling and no biological data recently collected from the commercial fishery.

- *the time series of cod biomass used as input in the shrimp assessment model be re-evaluated.*

STATUS: Implemented. Information is included in this year's assessment.

- *time series of recruitment (index of age 2 abundance) and its link to the fishable biomass in a later year be considered for inclusion in the shrimp assessment model*

STATUS: No progress has yet been made on modifying the assessment model.

STACFIS **recommended** that, for shrimp in Denmark Strait and off East Greenland:

- *sampling of catches by observers - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - be re-established in the Greenland EEZ and improved in the Icelandic EEZ.*

STATUS: There has been no sampling and no biological data recently collected from the commercial fishery.

Recommendations in June 2005

STACFIS **recommended** that *all available information on by-catch and discards of Greenland halibut in Subarea 2 and Divisions 3KLMNO be presented for consideration in future assessments.*

STATUS: This was addressed in Scientific Council. (see section SC Report IV.4.b)

Summary Discussion

STACFIS noted the general recommendation for each stock of submitting data to the Designated Experts by 1 September 2005 for use in assessments was not completely fulfilled for all data. The committee agreed that such recommendations should continue to be stated as a procedural item, but in practical terms, it was suggested that the Designated Experts should send a detailed communication to representatives of Contracting Parties requesting the various information with sufficient notice to enable compliance by 1 September.

2. Review of Catches

STACFIS reviewed and agreed on the catch figures available for all stocks being assessed at this meeting during consideration of each relevant stock.

3. General Environmental Review

Subarea 3

Stocks on the Flemish Cap, Division 3M: (SCR Doc. 05/87). The water mass characteristics of the Flemish Cap area are a mixture of Labrador Current Slope Water and North Atlantic Current Water, this water mass is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3° to 4°C and salinities in the range of 34 to 34.75. The general circulation in the vicinity of the Flemish Cap consists of the offshore branch of the Labrador Current which flows through the Flemish Pass on the Grand Bank side and a jet that flows to the east, north of the Flemish Cap, which then flows southward. To the south, the Gulf Stream flows to the northeast merging with the Labrador Current to form the North Atlantic Current which influences waters around the southern areas of the Flemish Cap. In the absence of strong wind forcing the circulation over the central Flemish Cap is dominated by a topographically induced anticyclonic gyre. The stability of this circulation pattern may influence the retention of ichthyoplankton on the bank and is probably a factor in determining the year-class strength of shrimp on the Flemish Cap. During the summer of 2005, it appears that the circulation pattern around the Flemish Cap was again dominated by the southward flowing Labrador Current, however there appeared to be a slight increase in the northward component compared to the previous year, indicating a possible strengthening of the gyre circulation. In general, the colder-than-normal temperatures experienced over the continental shelf and on the Flemish Cap from the late 1980s up to the mid-1990s moderated by the summer of 1996 and continued to warm until 1999 after which they decreased slightly until 2002. From 2003 to 2005 most areas of the water column again experienced an increase in both temperature and salinity with near bottom temperatures over and around the Flemish Cap exceeding 4°C, which were above normal by 1°C in some areas.

Stocks on the Grand Bank: Divisions 3LNO: (SCR Doc. 05/91, 23). The water mass characteristics on the Grand Banks are typical cold-intermediate-layer (CIL) sub-polar waters which extend to the bottom in northern areas with average bottom temperatures generally <0°C during most of the year. Bottom temperatures generally increase to 2° to 4°C in southern regions of Div. 3NO due to atmospheric forcing in shallow regions and along the slopes of the banks below 200-m depth due to the presence of warmer Labrador Slope Water. On the southern slopes of the Grand Banks in Div. 3O bottom temperatures may reach 4°C-8°C due to the influence of warm slope water from the south. The general circulation in this region consists of the relatively strong offshore Labrador Current at the shelf break and a considerably weaker branch near the coast in the Avalon Channel. Currents over the banks are very weak and the variability often exceeds the mean flow. The winter formed CIL water mass which is a robust index of ocean climate conditions, was below-normal (implying warm conditions) across the Grand Bank for the 7th consecutive year in 2005. Time series of the spatially average bottom temperatures for Div. 3LNO region shows large inter-annual variations and a downward trend that started in 1984 which continued until the early 1990s. Recently, temperatures have increased over the sub-zero values of the early 1990s with the average bottom temperature during the spring of 2004 reaching near 2.5°C, the highest since 1983. The 2005 value decreased slightly to just under 2°C.

Subarea 1

Stocks off West Greenland: Divisions 1A-1F: (SCR Doc. 05/2, 19, 74) The recent northward extension of pure Irminger Water as far north as Fylla Bank indicates high inflow of warm water of Atlantic origin to the West Greenland area. The average temperature west of Fylla Bank, which is where the core of the Irminger Water is normally found, shows temperatures near 1°C higher than normal during 2004 and was the highest observed in the 54 year time series. The time series of mid-June temperatures on top of Fylla Bank was about 1.5°C above average conditions, while the salinity was slightly higher than normal. Oceanographic data collected during autumn survey to the standard sections along the west coast of Greenland show temperatures in the West Greenland Current and on the Western Greenland Shelf about 2°C warmer than normal during 2004. Bottom temperatures measured on the summer 2005 bottom trawl survey ranged from 1°C in the shallow (<200 m) parts of Disko Bay to about 6°C in the southern offshore areas. Values >4°C were found in large parts of offshore area south of 63°45'N whereas bottom temperatures between 2° to 3°C prevailed in the remaining parts of the survey area. It is further noteworthy that the change from a cold to a warm period has affected all different depth layers of the survey area. The overall area-weighted mean bottom temperature amounted to 3.11°C, which corresponds to the average observed since 1997 and indicates that the recent relatively warm period has continued into 2005.

III. STOCK ASSESSMENTS (from NAFO Area)

1. Northern Shrimp (*Pandalus borealis*) in Division 3M (SCR Doc. 05/78, 79, 89, 94)

a) Introduction

The shrimp fishery in Div. 3M began in late April 1993. Initial catch rates were favourable and, shortly thereafter, vessels from several nations joined. Since 1993 the number of vessels ranged from 40-110, and in 2005 there were approximately 26 vessels fishing shrimp in Div. 3M compared to 50 in 2004.

Catches increased from about 27 000 tons in 1993 to 48 000 tons in 1996, declined to 25 000 tons in 1997 then increased gradually to a peak of 63 000 tons in 2003 (Fig. 1.1). In 2004 the catch declined to 44 000 tons and provisional information to 1 September 2005 indicate removals of about 9 000 tons. Supplementary information from the fishery suggests that economic considerations (price of fuel and market prices for shrimp) may be affecting participation in the fishery.

Recent catches and TACs (tons) are as follows:

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Recommended TAC	-	-	30 000	30 000	30 000	45 000	45 000	45 000	45 000	48 000
STATLANT 21A	23 916	30 035	42 041	50 471[1]	53 793[1]	47 299[1]	63 198[1]	43 953[1]		
STACFIS	25 211	30 308	43 438	52 664	52 671	48 704	63 206	45 486	9 000[2]	

[1] Provisional.
[2] Preliminary to 1 September 2005.

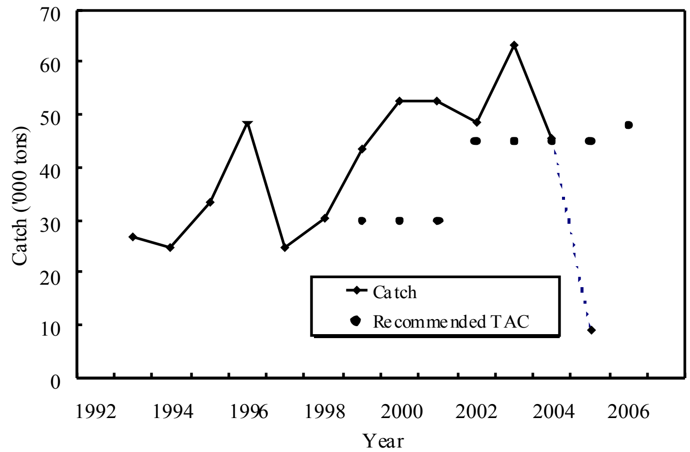


Fig. 1.1. Shrimp in Div. 3M: catches (2005 preliminary).

b) **Input Data**

i) **Commercial fishery data** (SCR Doc. 05/79, 94)

Effort and CPUE. Data from logbooks of Canadian, Greenlandic, Icelandic, Faroese, Norwegian and Russian vessels were available. A standardized CPUE series was produced to address differences due to seasonality, fishing power and gear (single, double and triple trawl). CPUE decreased from 1993 to 1994, varied without a trend to 1997 and increased until 2005 (Fig. 1.2). Due to few observations there is considerable uncertainty regarding the 2005 point.

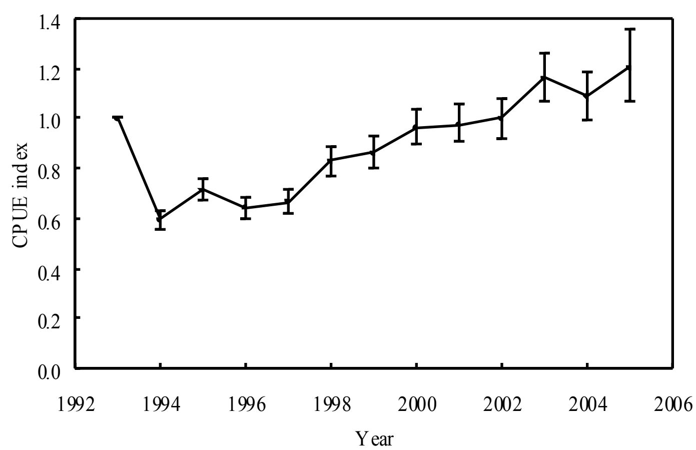


Fig. 1.2. Shrimp Div. 3M: the standardized CPUE of shrimp on Flemish Cap, 1993-2005.

Standardized CPUE female SSB. It has been shown for this stock that transitionals will be functional females at spawning time in the same year (SCR Doc. 04/64). Accordingly a spawning stock index was calculated from the standardized CPUE as kg/hr of all females (transitionals and females). The spawning stock declined from 1993 to 1997, and had shown an increasing trend to 1998. It was stable between 1998 and 2004, then increased in 2005 (Fig. 1.3). The increase in 2005 may however be questionable, as noted for the standardized CPUE above.

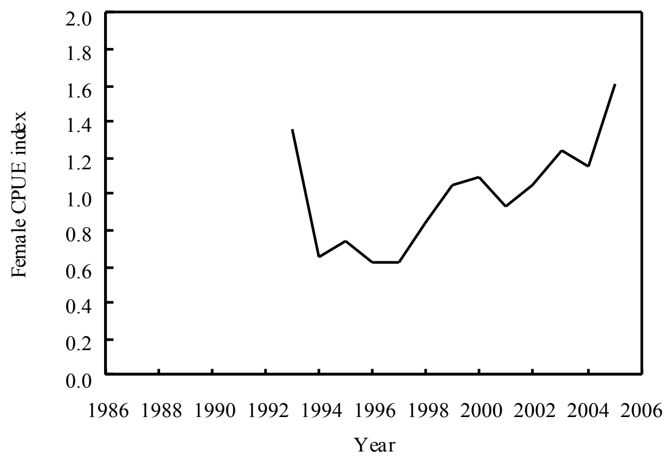


Fig. 1.3. Shrimp Div. 3M: standardized female CPUE index, 1993-2005. The series was standardized to the mean of the series.

Biological data. Age composition was assessed from commercial samples obtained from Iceland from 2003 to 2005 and from Canada, Greenland, Russia and Estonia in previous years. Number/hour was calculated for each year-class by applying a weight/age relationship and the total number as calculated from the nominal catch and the standardized CPUE data.

The results in the Table below indicate that ages 3, 4 and 5 generally dominate the commercial catch in numbers. The 2000 year-class appeared weak as 3 and 4 year olds in the 2003 and 2004 fisheries. Both the 2001 and 2002 year-classes seem to be well above average as 3 and 4 year olds in 2005 and shall be important in the fishery in 2006 as well as in the fishery in 2007 in case of the 2002 year-class.

Numbers per hours at age in the commercial fishery.

Age	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
1				5			23	660			71
2	2 524	2 125	3 195	2 561	1 069	6 922	4 598	8 556	12 784	1 717	4 251
3	26 427	16 338	18 689	15 243	22 366	9 271	38 786	9 444	30 033	26 591	19 127
4	8 051	16 953	21 863	17 631	26 012	29 673	13 200	34 446	10 749	37 500	19 003
5	2 329	3 330	6 974	14 184	15 381	15 028	15 996	14 723	22 725	15 198	11 082
6	1 216	675	2 594	5 107	3 227	4 433	3 268	5 796	4 425	2 773	3 240
7		58	279	59	157	599	129	86	24		312
Total	40 547	40 692	53 594	54 790	68 212	65 926	76 000	73 711	80 740	83 779	63 799

ii) **Research survey data** (SCR Doc. 05/78)

EU bottom trawl surveys. Stratified-random surveys have been conducted on Flemish Cap in July from 1988 to 2005. A new vessel was introduced in 2003 which continued to use the same trawl employed since 1988. In addition, there were differences in codend mesh sizes utilized in the 1994 and 1998 surveys that have likely resulted in biased estimates of total survey biomass. Nevertheless, for this assessment, the series prior to 2003 were converted into comparable units with the new vessel based on the methodology accepted by STACFIS in 2004 (*NAFO Sci. Coun. Rep.*, 2004, SCR Doc. 04/77). The revised index of female shrimp biomass reveals a rapid increase from the lowest observed level in 1990 to a 10 fold increase in 1992 followed by an equally dramatic decline to 1994. The index was stable at a relatively low level between 1994 and 1997; then increased to a higher level with fluctuation between 1998-2005 (Fig.1.4).

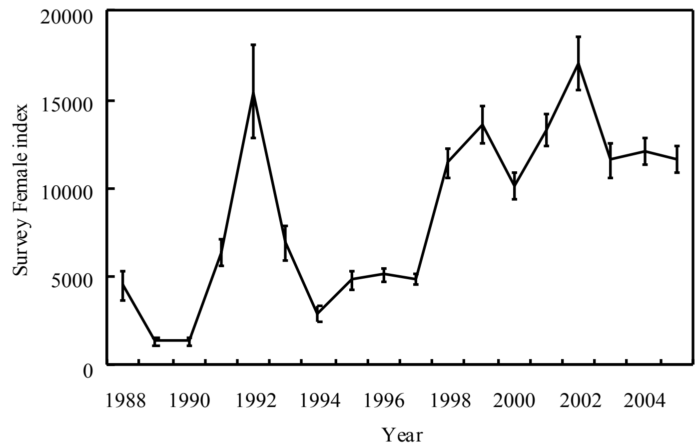


Fig. 1.4. Shrimp in Div. 3M: female biomass index from EU trawl surveys, 1988-2005.

iii) **Recruitment indices**

EU bottom trawl surveys. From 1988 to 1995 shrimp age 2 and younger were not captured by the survey. Beginning in 1996 the presence of this component increased in the surveys and it is believed that the introduction of the new vessel in 2003 greatly improved the catchability of age 2 shrimp due to technological advances in maintaining consistent performance of the fishing gear. In addition, since 2001, a small mesh juvenile bag was also attached to the net which was designed to provide an index of juvenile shrimp smaller than that typically retained by the survey codend. Both indices do not show a good relationship with the 3+ survey index either 2 or 3 years later. This may be because there are only limited data points for a valid comparison.

Commercial fishery. Although the commercial fishery is conducted with larger mesh size than the survey indices, two year olds are frequently detected in the fishery. An index of two year old shrimp from 1996 to 2005, based on standardized number per hour, correlated well (R^2= .74, Fig. 1.5) with a similar index derived for 3+ year olds (a proxy for the fishable biomass) from the fishery two years later.

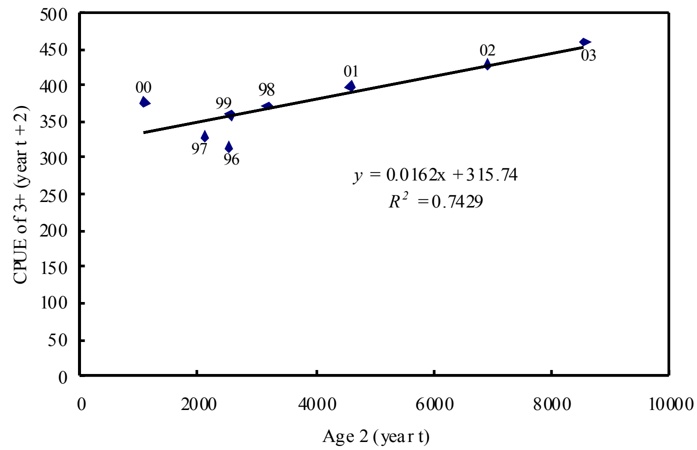


Fig. 1.5. Shrimp in Div. 3M: regression between CPUE of age 2 (year t) shrimp from samples from the commercial fisheries and CPUE of age 3+ (year t+2), 2 years later.

In the future it is perhaps possible to predict the fishable biomass to some extent 2 years ahead using the number of age 2.

The index from the commercial fishery suggests that the 2001 and 2002 year-classes are above average and the 2003 year-class was amongst the lowest since 1994 (Fig.1.6). These results correspond well with estimates from the Faroese surveys and the EU surveys.

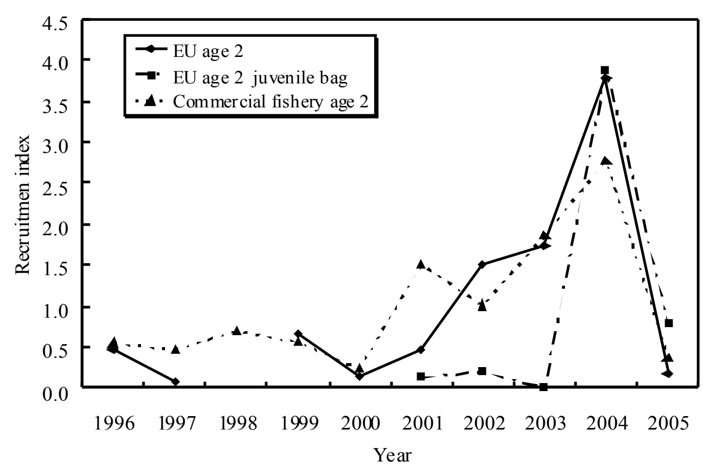


Fig. 1.6. Shrimp in Div. 3M: abundance indices at age 2 from the EU survey and from the commercial fishery. Each series was standardized to its mean.

STACFIS agreed that this was the only possible source of prediction currently available.

c) **Assessment Results**

Commercial CPUE. Standardized catch rates declined between 1993 and 1994, varied without a trend to 1997 and increased to 2005.

Recruitment. Both the 2001 and 2002 year-classes appear to be above average, but 2003 year-class appears weak.

Spawning Stock Biomass. All indices of female biomass increased from 1997 and have fluctuated without a trend since then.

State of the Stock. The indices of CPUE and biomass are at relatively high levels but there are indications of a decline in recruitment, which may affect the 2007 fishery.

STACFIS considers it important to recognize that its ability to assess the resource will improve with the continuation of a series of research surveys directed for shrimp, especially if appropriate measures to sample juvenile shrimp are applied.

d) **Precautionary Approach**

STACFIS noted that the Scientific Council Study Group on Limit Reference Points, recommended that survey biomass indices could be used to indicate a limit reference point for biomass, in situations where other methods were not available (SCS Doc. 04/12). In such cases, "the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim}". B_{lim} is defined as a biomass level, below which stock productivity is likely to be seriously impaired, that should have a very low probability of being violated.

Last year the limit reference point for the Flemish Cap shrimp stock was taken from the EU survey where the biomass index of female shrimp was used. The EU survey of Div. 3M provides an index of female shrimp biomass from 1988 to 2005 which has now been converted to the new vessel, with a maximum value of 17.1 in 2002, (and a similar value of 15.5 in 1992). An 85% decline in this value would give a B_{lim} = 2.6. Due to the conversion the reference level was revised from 1.7 to 2.6. The female biomass index was below this value in only 1989 and 1990, before the fishery, and in 2004-05 was about 30-32% below the maximum. If this method is accepted to define B_{lim}, then it appears unlikely that the stock is below B_{lim} at the present time (Fig. 1.7).

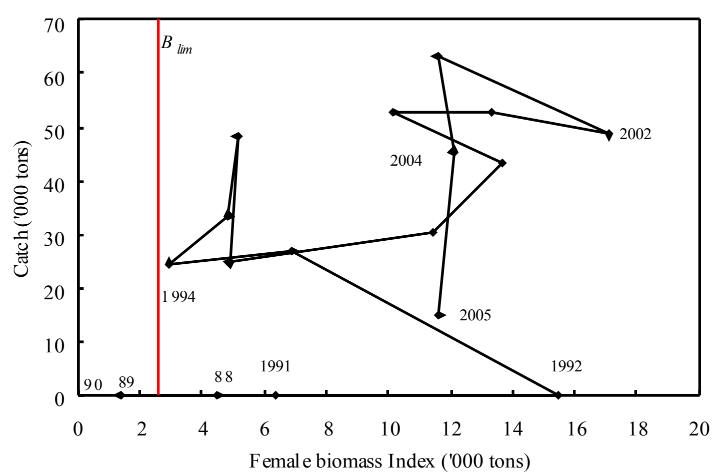


Fig. 1.7. Shrimp in Div. 3M. Catch plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 85% lower than the maximum point in 2002.

e) **Research Recommendations**

STACFIS **recommends** that, for shrimp in Div. 3M:

- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to Designated Experts by 1 September 2006.*

- *indices of female stock size be presented with error bars where possible.*

- *the relationship between the recruitment index and fishable biomass be investigated further.*

2. **Northern Shrimp (*Pandalus borealis*) in Divisions 3L, 3N and 3O** (SCR Doc. 05/76, 77, 79, 88, 91)

a) **Introduction**

This shrimp stock is distributed around the edge of the Grand Banks mainly in Div. 3L. The fishery began in 1993 with catches around 1 800 tons. Exploratory fishing from 1996-99 resulted in catches ranging from 179-795 tons. In 2000, the fishery came under TAC control and fishing was restricted to Div. 3L. In 2000, 4 896 tons of shrimp were taken from an annual TAC of 6 000 tons. Catches of 10 566 tons and 6 977 tons were taken in 2001 and 2002, respectively. Annual TACs were raised to 13 000 tons over the next 3 years resulting in annual catches of 11 947, 12 620 and 13 219 tons, respectively (Fig. 2.1).

Since this stock came under TAC regulation Canada has been allocated 83% of the TAC. The Canadian allocation is split between a small vessel (less than 500 tons and less than 63 ft) and large vessel fleet. By October 2005, the small and large vessel fleets had taken 7 113 and 4 037 tons of shrimp respectively in Div. 3L. In all years, most of the Canadian catch occurred along the northeast slope in Div. 3L.

Fifteen contracting parties have fished in the NRA since 2000. The annual quota within the NRA is 17% of the total TAC and is meant to be split evenly among these nations; however, since 2003, Denmark (in respect of the Faroe Island and Greenland) set autonomous annual TAC of 1 344 tons.

The use of a sorting grid to reduce by-catches of fish is mandatory for all fleets in the fishery. The sorting grid cannot have a bar spacing greater than 22 mm.

Recent catches and TACs (tons) for shrimp in Div. 3LNO (total) are as follows:

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TAC	-	-	-	6 000	6 000	6 000	13 000	13 000[1]	13 000[1]	22 000[1]
STATLANT 21A	485	567	795	4 930	5 323[2]	5 697[2]	11 016[2]	11 660[2]		
STACFIS	485	567	795	4 896	10 566[3]	6 977[3]	11 947	12 620	13 219[4]	

[1] Denmark (in respect of Faroe Islands and Greenland) set an autonomous TAC of 1 344 tons for 2003-2005.

[2] Provisional catches.

[3] Reliable catch reports were not available for all countries therefore estimates were made using other sources (Canadian surveillance, observer datasets, STACFIS estimation, etc.)

[4] Total catch estimated from NAFO provisional data and Canadian Atlantic Quota Reports up to October.

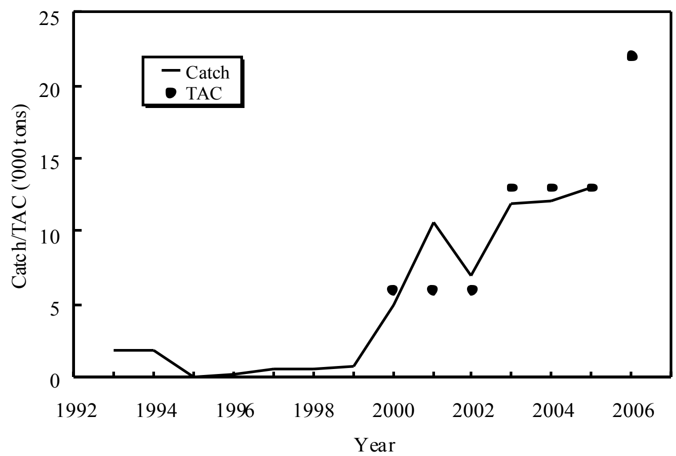


Fig. 2.1. Shrimp in Div. 3LNO: catches and TAC (to October 2005).

b) **Input Data**

i) **Commercial fishery data** (SCR Doc. 05/76, 79, 88)

Effort and CPUE. Catch and effort data have been available from Canadian fishing vessel logbooks and observer records since 2000. Standardized catch rates for large vessels decreased significantly by 34% from 2003 to 2005 (Fig. 2.2). Information provided by the large vessel fleet indicates that this drop in CPUE may have been due to targeting female shrimp, which are less abundant than male shrimp. However, Canadian small vessel standardized CPUE increased 86% between 2003 and 2005.

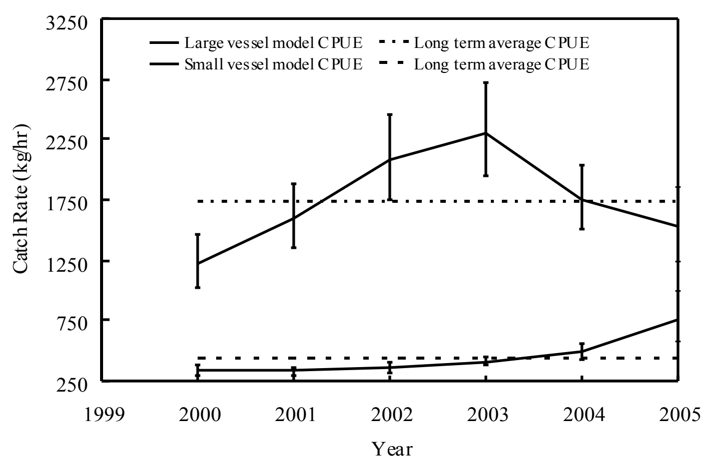


Fig. 2.2. Shrimp in Div. 3LNO: standardized CPUE for Canadian vessels fishing shrimp within the Div. 3L EEZ.

Data were available from other nations fishing in the NRA (Iceland, Greenland, Norway and Spain), although the data were insufficient to produce a standardized CPUE model.

Catch composition. Sampling was available from the Canadian, Icelandic and Norwegian fleets. Catch composition was derived from sampling of Canadian catches in Div. 3L. In 2005, the 1999-2001 year-classes dominated the catch and the female portion was still well represented (year-classes from before 2000).

ii) **Research survey data** (SCR Doc. 05/77, 88, 91)

Canadian multi-species trawl survey. Canada has conducted stratified-random surveys in Div. 3LNO, using a Campelen 1800 shrimp trawl, during spring (1999-2005) and autumn (1995-2004). The autumn survey in 2004 was incomplete and therefore had limited use in the assessment.

Spanish multi-species trawl survey. Spain has been conducting a spring stratified-random survey within the Div. 3NO NRA since 1995. From 2001 onwards data were collected with a Campelen 1800 trawl.

Biomass and abundance. Based on Canadian surveys, over 90% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185-550 m. There was a significant increase in autumn shrimp biomass indices between 1995 and 2001 and this index has since remained stable at a high level (Fig. 2.3).

Analyses, from past surveys, indicated that 25-61% of the biomass/abundance was accounted for in strata that were not surveyed in autumn 2004. An index from strata consistently surveyed, showed that the 2004 survey biomass index (97 000 tons) was the second highest in this series.

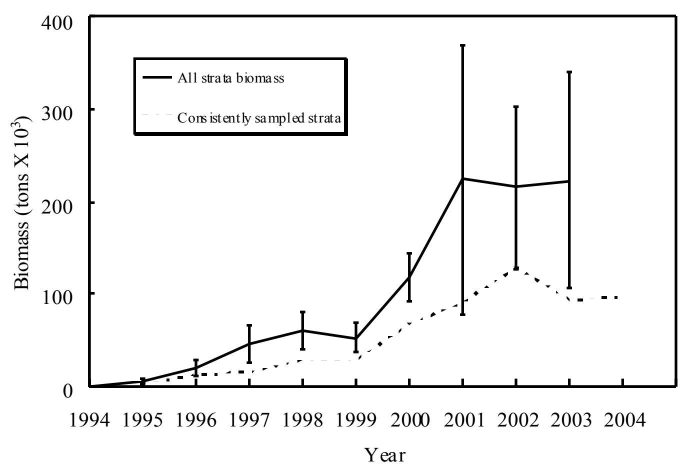


Fig. 2.3. Shrimp in Div. 3LNO: biomass estimates from Canadian autumn multi-species surveys (±95% confidence intervals).

The Canadian spring 2005 survey estimate at 156 000 tons, was the third highest in that time series (Fig. 2.4).

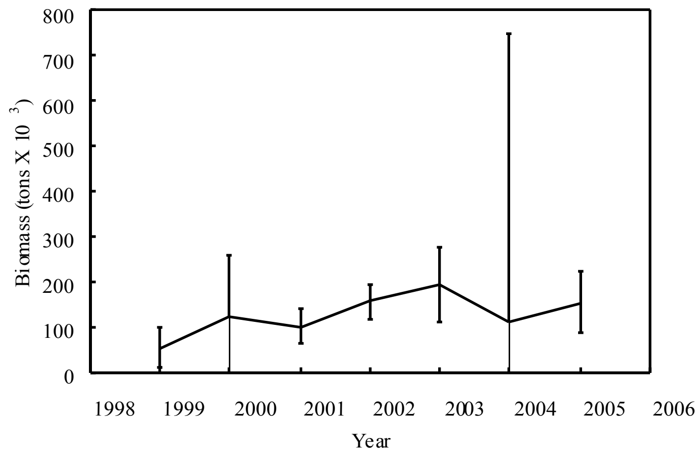


Fig. 2.4. Shrimp in Div. 3LNO: biomass estimates from Canadian spring multi-species surveys (±95% confidence intervals).

The biomass index of the Spanish survey within Div. 3NO in the NRA fluctuated between 1 600 and 2 600 tons over the period 2002-2005.

Sex and age composition

The Canadian spring and autumn surveys showed an increase in the abundance of female (transitionals + females) shrimp over the full-time series. There was a decline in the abundance of male shrimp from 2001 to 2003 in the autumn index, and from 2002 to 2003 then stability to 2005 in the spring index (Fig. 2.5).

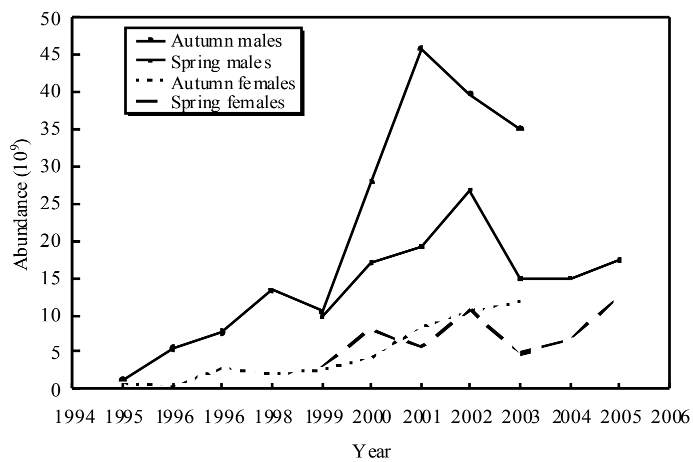


Fig. 2.5. Shrimp in Div. 3LNO: abundances of male and female shrimp within Div. 3LNO as estimated from Canadian multi-species survey data, using areal expansion calculations.

Abundance estimates from the autumn 2003 Canadian survey were dominated by males with a modal length of 19.8 mm CL (1999 year-class). This was corrected from last year's report. Shrimp aged 3 and 4 dominated the male component of the length frequencies in spring 2004 and 2005 surveys (Fig. 2.6).

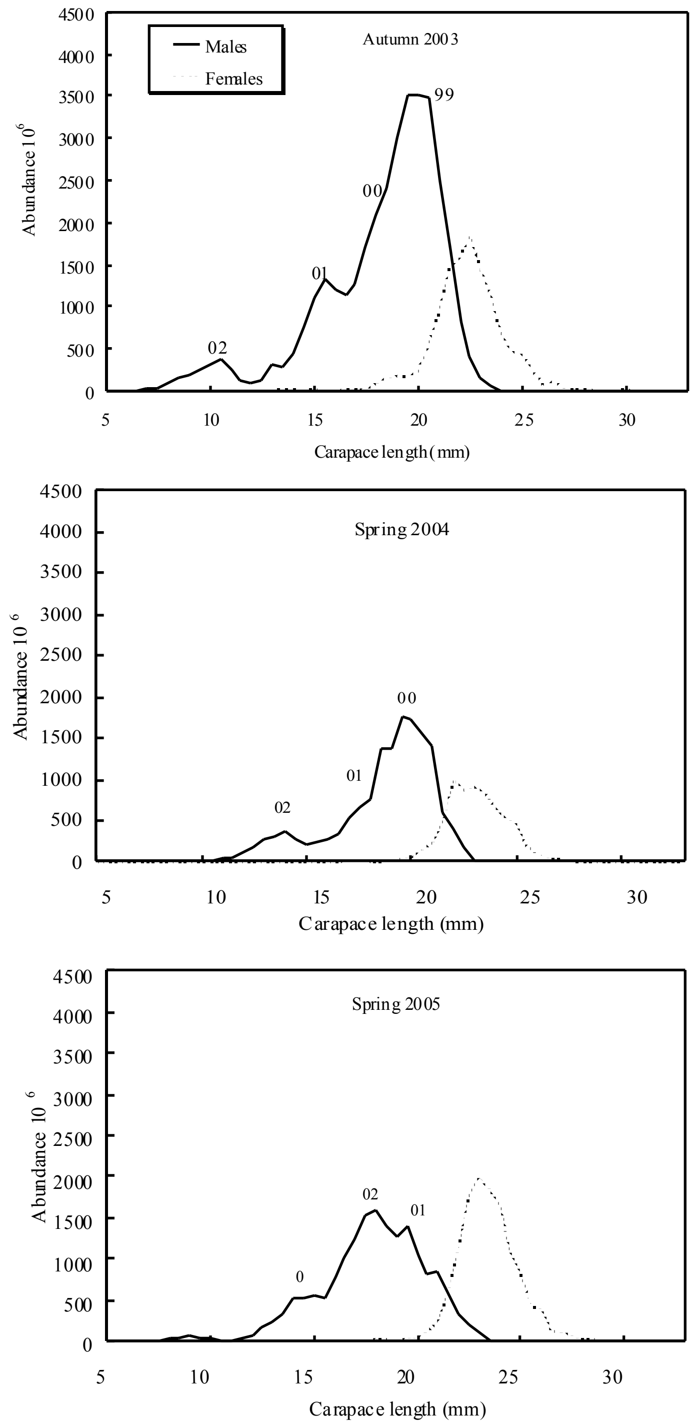


Fig. 2.6. Shrimp in Div. 3LNO: abundance at length for northern shrimp estimated from Canadian multi-species survey data using stratified areal expansion calculations.

Spawning Stock Biomass (SSB). In general, the SSB (transitionals and all females) index from both Canadian surveys increased from 1999-2003 (Fig. 2.7 and 2.8). The spring survey index varied without trend thereafter.

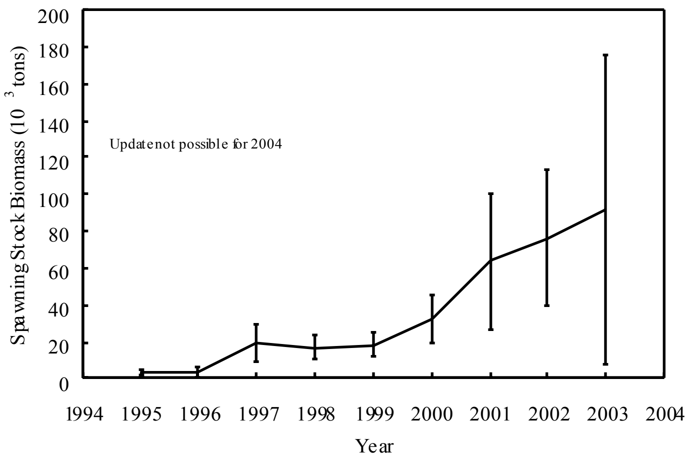


Fig. 2.7. Shrimp in Div. 3LNO: spawning stock biomass (SSB) estimates from Canadian autumn multi-species surveys (±95% confidence intervals).

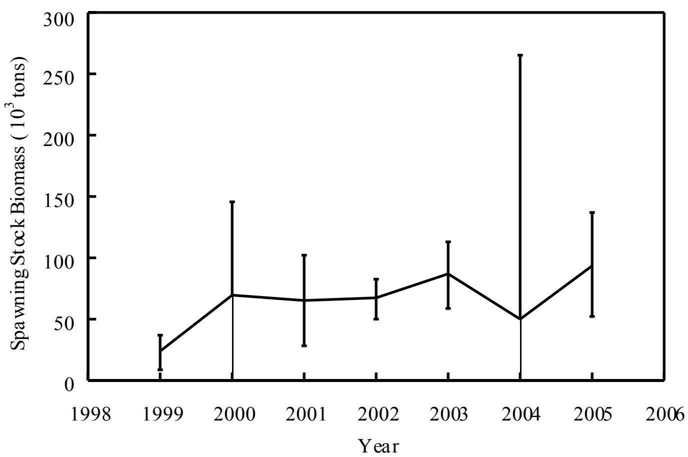
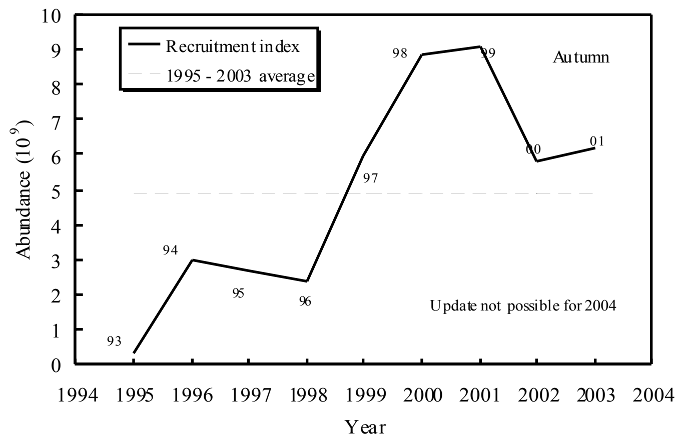


Fig. 2.8. Shrimp in Div. 3LNO: spawning stock biomass (SSB) estimates from Canadian spring multi-species surveys (±95% confidence intervals).

Recruitment index. A recruitment index (shrimp considered to be age 2) was constructed from the Canadian autumn surveys of 1995-2003. Due to the incomplete survey in autumn 2004, a recruitment index from Canadian spring surveys of 1999-2005 was examined. Recruitment indices were based upon modal analysis of length frequencies. The autumn index increased from 1997 to 2001, decreased in 2002, and increased in 2003. The last five points (1997-2001 year-classes) in this index have been above average (Fig. 2.9). The spring index also showed that the 1997-1999 year-classes were the most abundant, but the 2002 and 2003 year-classes are lower.



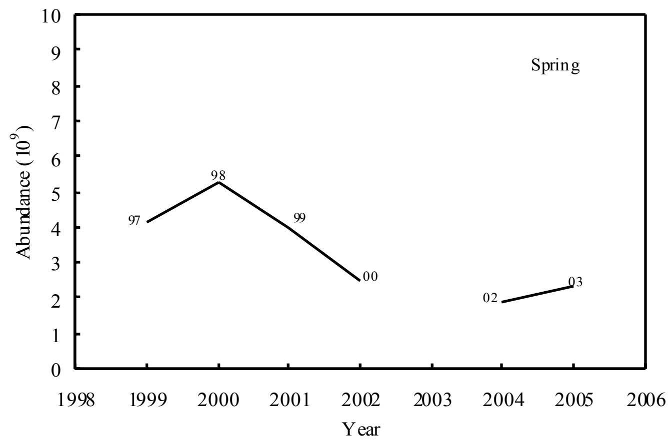


Fig 2.9. Shrimp in Div. 3LNO: age 2 recruitment indexes as determined from Canadian autumn and spring multi-species surveys (numbers indicate year-classes).

Fishable biomass and exploitation. In general, a fishable biomass index (all shrimp ≥17 mm carapace length) from the Canadian autumn survey (1995-2003) and Canadian spring survey (1999-2005) increased from 1995-2001 and remained stable since then (Fig. 2.10). An index of exploitation was derived by dividing the catch in a given year by the fishable biomass index from the previous year's autumn survey. The exploitation index was less than 4% during 1996-99, but increased to 11-12% in 2000-2001; the first two years of TAC regulation. Even though catches increased to 12 620 tons in 2004, the exploitation index is estimated to be less than 7% due to the increase in fishable biomass (Fig. 2.11). Due to an incomplete survey in autumn 2004 it was not possible to update the autumn index of fishable biomass and exploitation in this assessment.

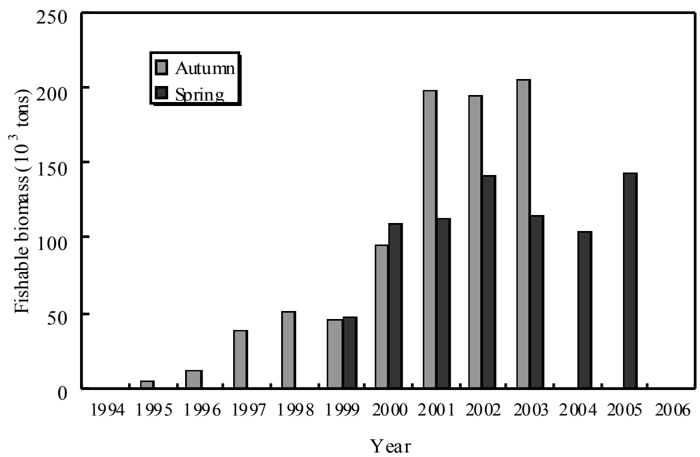


Fig. 2.10. Shrimp in Div. 3LNO: fishable biomass index from Canadian spring and autumn surveys. Values were estimated using strap calculations.

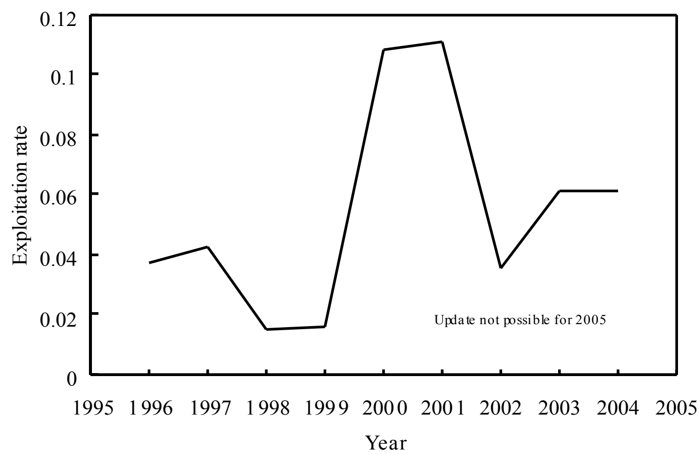


Fig 2.11. Shrimp in Div. 3LNO: exploitation rates as derived by catch divided by the previous year's Canadian autumn fishable biomass index.

iii) **Other biological studies** (SCR Doc. 05/77, 88, 91)

As requested during the 2004 NAFO Scientific Council meeting on shrimp assessment, sensitivity testing was conducted on OGive MAPping (OGMAP) to determine whether it is an appropriate method to estimate shrimp biomass/abundance indices. To address this question, OGMAP analyses from autumn surveys were used as reference populations. Survey points from other autumn surveys were used to take random samples from the reference populations. Results of sensitivity testing were acceptable with many of the simulated confidence intervals containing the biomass estimate. Those that did not; came within 1-2 standard deviations of doing so. The biomass estimates of OGMAP are very similar to those of stratified aerial expansion calculations with much tighter confidence intervals. STACFIS noted that more research is required on bandwidths, which determine the characteristic distance of influence by nearby survey points, and OGMAP's sensitivity to different bandwidths. In addition, questions were raised as to which survey design may be optimal for the OGMAP method. Scientific Council considered the results of sensitivity testing, noted that the method had advantages over areal expansion techniques but because there was insufficient expertise at this meeting to address methodological questions, requested that OGMAP should be thoroughly reviewed in a scientific forum such as a methodology working group (i.e. ICES WKSAD) to determine whether it is an appropriate method to determine Div. 3LNO shrimp biomass/ abundance indices from stratified random surveys.

Length weight relationships for live animals are provided in both SCR Doc. 05/77 and 05/88.

The spatial distributions and abundance of northern shrimp were examined in relation to their thermal habitat for NAFO Div. 3LNO during spring surveys from 1998-05 and for autumn surveys from 1995-2004. The data indicate that the highest numbers of shrimp are generally found in the 2°-4°C temperature range during the spring with lower numbers in water with temperatures <2°C and >4°C. During the autumn most shrimp are found in a colder temperature range of 1°-3°C. Cumulative frequency distribution of the number of shrimp caught and temperature indicates that <5% of the catches are associated with temperatures <1°C in the spring and up to 30% are associated with temperatures <1°C in the autumn. About 90% of the shrimp were caught in the 2°-4°C temperature range during the spring, while only about 50% appeared in this temperature range during the autumn. In terms of available thermal habitat, about 30% of the surveyed region was covered with water in the 2°-4°C temperature range during the spring, while about 40% was covered by water in this temperature range in the autumn. In 2004 the average spring bottom temperature increased significantly over 2003 to >2°C, the highest since the early 1980s but decreased to slightly <2°C in the spring of 2005. An apparent shift in the shrimp distribution towards colder temperatures further upon the Grand Bank and towards the inshore regions occurred during the autumn and as a result, a greater proportion (30%) of the catch shifted into the 0°-1°C temperature range. Very low numbers of shrimp were found in temperatures <0°C and >4°C during both spring and autumn. Shrimp catches were mostly zero in all surveys in the shallow waters (<100 m) of the southeast Grand Bank, where temperatures generally range from 2°-7°C. In general, during the spring most of the large catches were found in the warmer water along the slopes of Div. 3LN, while in the autumn, larger catches were found in most areas of Div. 3L including the inshore areas of the bays along the east coast of Newfoundland. During the spring of 2005 most of the shrimp catches (>70%) were found in temperatures >3°C with an apparent increase in the overall catches over the previous year. Preliminary results indicate that the larger shrimp are associated with temperatures >3°C while smaller shrimp on average are found in temperatures <2°C. The total number of shrimp in sets dominated with small shrimp show a general association with bottom temperature with the higher numbers occuring in years with low bottom temperatures while the opposite seems to be the case for larger size shrimp. Finally, it is not known if the observed changes in the distribution from spring to autumn are environmentally driven, feeding behaviour or due to other factors, such as changes in trawl catchability (SCR Doc. 05/91).

c) **Assessment Results**

Recruitment. The 1997-2001 year-classes are above average, while the 2002 and 2003 year-classes are lower.

Biomass. There was a significant increase in SSB and total biomass between 1995 and 1997 followed by a period of stability between 1997 and 1999. SSB and total biomass have been at a higher level since 1999.

Fishable Biomass and Exploitation. Fishable biomass has increased from 1995-2001 and remained stable since then. The exploitation index (catch/autumn fishable biomass from previous year) increased during 2000-2001, at the beginning of the fishery, and has decreased since then.

State of the Stock. SSB and total biomass have increased since 1999. The stock appears to be well represented by a broad range of size groups, and the exploitation index is low. Recruitment is anticipated to decline.

d) **Precautionary Approach Reference Points** (SCS Doc. 04/12):

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the biomass is estimated to be well above B_{lim} (Fig. 2.12).

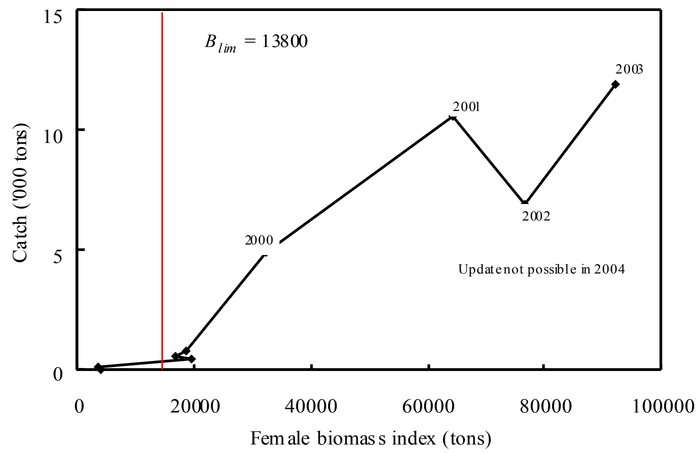


Fig 2.12. Shrimp in Div. 3LNO: Catch plotted against female biomass index from Canadian autumn survey. Line denoting B_{lim} is drawn where biomass is 85% lower than the maximum point in 2003.

e) **Research Recommendations**

STACFIS **recommended** that, for shrimp in Div. 3LNO:

- *OGMAP should be reviewed further to determine whether it is an appropriate method to determine Div. 3LNO shrimp biomass/abundance indices from stratified random surveys.*

- *biological and CPUE data from all fleets fishing for shrimp in the area, be submitted to the Designated Expert, in the standardized format, by 1 September 2006.*

3. **Northern Shrimp (*Pandalus borealis*) in Subareas 0 and 1** (SCR Doc. 02/158, 04/73, 75, 76, 05/73, 74, 75, 83, 85; SCS Doc. 04/12)

a) **Introduction**

The shrimp stock off West Greenland is distributed in Subarea 1 and Div. 0A east of 60°30'W (Canadian SFA1) and within this area is assessed as a single population. The Greenland fishery exploits the stock in Subarea 1 (Div. 1A-F). Since 1981 the Canadian fishery has been limited to Div. 0A.

Three fleets, one from Canada and two from Greenland (vessels above and below 80 GRT) have participated in the fishery since the late 1970s. The Canadian fleet and the Greenland large-vessel fleet have been restricted by areas and quotas since 1977. The Greenland small-vessel fleet has privileged access to inshore areas (primarily Disko Bay); its fishing was unrestricted until January 1997, when quota regulation was imposed. Pursuant to a revised fishery agreement, Greenland now allocates a quota to EU vessels in Subarea 1. Mesh size is at least 44 mm. Sorting grids to reduce by-catch of fish are required in the Greenland large-vessel fleet (max. bar spacing 22 mm) and the Canadian fleet (28 mm). Discarding of shrimp is prohibited.

Until 2003 catches of shrimp taken in SA 1 were reported without accounting for either a prevalent practice of overpacking or the difference between product weight and live weight. On 1 January 2004 new legislation came into force requiring removals by fishing to be reported as live (catch) weight. To maintain consistency of management advice the annual catches from 1978 through 2003 were corrected upwards, by 22.8-25.7%; this was fully reported in the 2004 advisory document.

The advised TAC for the entire stock for 2005 was 130 000 tons; the Greenland authorities set a TAC for Subarea 1 of 134 000 tons, of which 74 100 tons was allocated to the offshore fleet, 55 900 tons to the inshore and 4 000 tons to EU vessels; Canada set a TAC for SFA1 for 2005 of 18 417 tons.

Overall annual catch increased from about 10 000 tons in the early 1970s to more than 105 000 tons in 1992 (Fig. 3.1). Moves by the Greenlandic authorities to reduce effort and fishing opportunities elsewhere for the Canadian fleet caused catches to decrease to about 80 000 tons by 1998. Since then total catches have increased. Logbook-reported catches in Greenland in the early part of 2005 were unusually high and the total for 2005 is expected to be near 140 500 tons assuming that the Greenland catch equals the TAC and the Canadian catch is near the level of the last three years at about 6 500 tons (Fig. 3.1).

Recent nominal catches, projected figures for 2005 and recommended TACs (tons) for shrimp in Div. 0A east of 60°W and Subarea 1 are as follows:

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Recommended TAC[1]	60 000	60 000	55 000	65 000	65 000	85 000	85 000	100 000	130 000	130 000
Enacted TAC	72 422	74 800	68 379	80 350	80 350	91 350	101 000	115 667	150 019	152 417
STATLANT SA 1	66 736	60 325	65 080	73 961	79 738	82 126	102 572	135 465	135 000	134 000[5]
STATLANT Div. 0A	2 617	517	914	2 093	841	2 958	3 300	2 617	6 000	6 500[5]
Total STATLANT	69 353[2]	60 842[2]	65 994[2]	76 054[2]	80 579[3]	85 084[3]	105 872[3]	138 082[3]	141 754[3]	
Total STACFIS[4]	84 095	78 128	80 495	92 191	97 206	102 781	132 206	126 462	141 000	140 500[5]

[1] Until 2003 recommended TACs were given in the units of the STATLANT reporting.
[2] Data updated to be consistent with STATLANT 21A
[3] Provisional catches.
[4] Estimates 1995-2003 corrected for overpack.
[5] Catches projected to end of 2005.

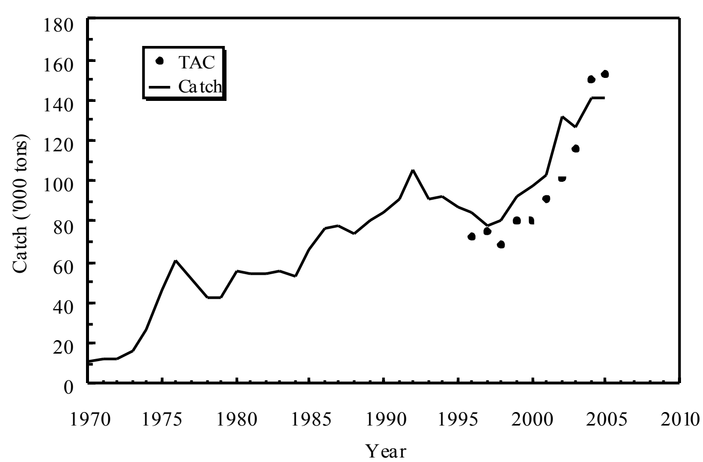


Fig. 3.1. Shrimp in Subareas 0 and 1: total catches (2005 projected to the end of the year; 1996-2003 values have been corrected to live (catch) weight and enacted TACs.

Until 1988 the fishing grounds in Div. 1B were the most important. The offshore fishery subsequently expanded southward, and after 1990 catches in Div. 1C-D, taken together, began to exceed those in Div.

1B. At the end of the 1980s Div. 1E-F began to attract fishing effort, and catches from these areas accounted for 15% of the total catch by 1997 and 20% by the turn of the century. Catch and effort in Div. 1E-F now appears to be decreasing. From low levels in the late 1990s and at the turn of the century, the Canadian catch in SFA1 has stabilised at 6 000 to 6 500 tons in 2002-2004, about 5% of the total.

b) **Input Data**

i) **Commercial fishery data**

Fishing effort and CPUE. Catch and effort data from the shrimp fishery were available from fishing records from Canadian vessels in Div. 0A east of 60°30'W and from Greenland logbooks for Subarea 1 (SCR Doc. 05/83).

Multiplicative models were used to calculate fleet-specific annual catch-rate indices. From these individual indices one unified series was derived for 1976-2005. All the fleets included in the analysis mainly exploit shrimp ≥17 mm carapace length (CL). The CPUE indices are therefore indicative of the combined biomass of older males and females.

The standardized CPUE series showed an increasing trend since 1990 (Fig. 3.2). The 2005 value is the highest in the series.

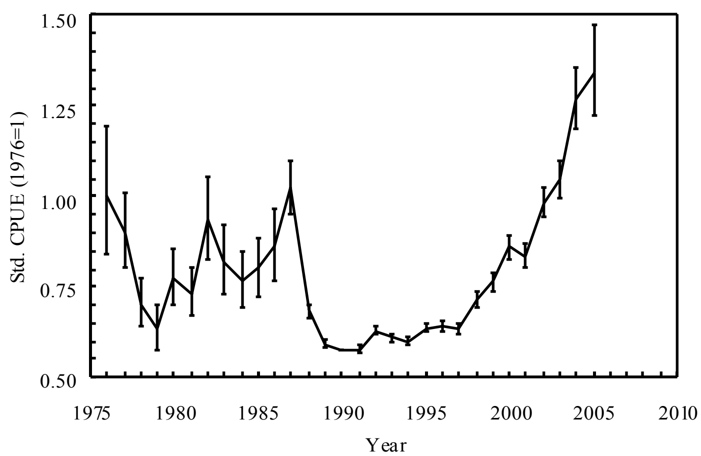


Fig. 3.2 Shrimp in Subareas 0 and 1: standardized CPUE index. Error bars are upper and lower quartiles.

Catch composition. Catch composition was assessed from samples obtained by observers in the commercial fishery in Div. 0A from 1981 to 2001, and in Subarea 1 from 1991 to 2001 (SCR Doc. 04/75). The mean size of shrimp caught declined since 1991. In spite of these changes, the proportions of female to male shrimp in the catches seemed relatively stable until the late 1990s. In 2002 and 2003 STACFIS recommended that "sampling of catches by observers - essential for assessing stock age, size and sex composition - be re-established". However, the sampling program has remained inadequate and sparse sampling prevented an analysis of catch composition for the years 2002-2005 (SCR Doc. 05/83).

ii) **Research survey data**

Greenland trawl survey. Stratified random trawl surveys have been conducted since 1988 in offshore areas (Subarea 1 and Div. 0A east of 60°30'W) and since 1991 also inshore in Subarea 1 (SCR Doc. 05/74). From 1993, the survey was extended southwards into Div. 1E and 1F. From its inception until 1998 the survey only used 60-min. tows, but experiments in the late 1990s and early 2000s showed that shorter tows gave as accurate results, and tows in the survey have since been progressively shortened until in 2005 all were 15 min. No adjustment to previous data has been considered necessary.

The *Skjervøy* trawl with steel-sphere bobbin ground gear used from 1988 through 2004 has been replaced in 2005 by a *Cosmos* trawl with rubber-disk rock-hopper ground gear so that the survey can fish a wider range of bottoms. Calibration trawling was carried out in 2004 and 2005, and length-specific corrections have been applied to the earlier survey data. (SCR Doc. 05/75)

Biomass. The survey biomass indices indicated a fairly stable stock size from 1988 to 1997. Since then an increasing trend has been observed. The 2003-2004 values were the hitherto highest of the series. The estimate for 2005 was 21-24% lower than these two, but larger than that for 2002 (by 13%) and all earlier years (Fig. 3.3).

Within the survey area, large year-to-year variations in the distribution of biomass have been observed geographically as well as over depth zones. Some areas account for a large proportion of the variances of the estimated biomasses. During the recent period of increasing biomass indices, an increased proportion of the biomass has been seen both in depths between 200 and 300 m and in more northerly areas, and the proportion of biomass in Div. 1E-F appears to be decreasing.

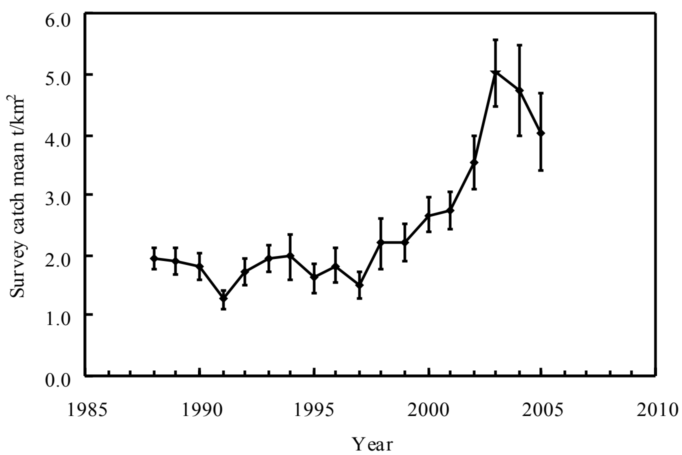


Fig. 3.3. Shrimp in Subareas 0 and 1: survey indices of stock biomass density; error bars are 1 s.e. (SCR Doc. 05/74)

Abundance. Indices of total abundance ($\times 10^9$) of shrimp in Subarea 1 and Div. 0A east of 60°30'W from 1988 to 2005 are as follows (SCR Doc. 05/74):

Year	Males	Females	Total	Males (%)	Females (%)
1988[1]	30.8	10.7	41.5	74.2	25.8
1989[1]	44.8	7.9	52.7	85.0	15.0
1990[1]	33.6	10.2	43.8	76.7	23.3
1991	22.5	5.9	28.4	79.2	20.8
1992	33.7	7.3	41	82.2	17.8
1993	39.9	9.6	49.5	80.6	19.4
1994	36.8	10.2	47	78.3	21.7
1995	31.8	7.5	39.3	80.9	19.1
1996	43.8	7.6	51.4	85.2	14.8
1997	31.3	7.3	38.6	81.1	18.9
1998	47.1	11.4	58.5	80.5	19.5
1999	48.8	11.3	60.1	81.2	18.8
2000	71.6	12.7	84.3	84.9	15.1
2001	65.0	13.6	78.6	82.7	17.3
2002	97.9	17.1	115	85.1	14.9
2003	114.2	28.6	142.8	80.0	20.0
2004	102.7	30.2	132.9	77.3	22.7
2005	91.3	24.2	115.5	79.0	21.0

[1] No inshore survey in 1988–90. The numbers in 1988 to 1990 represent an average of the estimated numbers of shrimp inshore from 1991-97 added to the actual estimates from the offshore area.

The index of total abundance of shrimp in 2005 is 13% lower than in 2004 and 19% lower than the peak reached in 2003, but similar to that of 2002. The proportion of females in 2005 was above average.

Length composition. A strong 1999 year-class that was clearly visible in the length frequency distributions at 17.5 mm CL in 2002 and at about 19 mm CL in 2003 is apparently followed by weaker year-classes that are not so easy to trace (Fig. 3.4). (SCR Doc. 05/75).

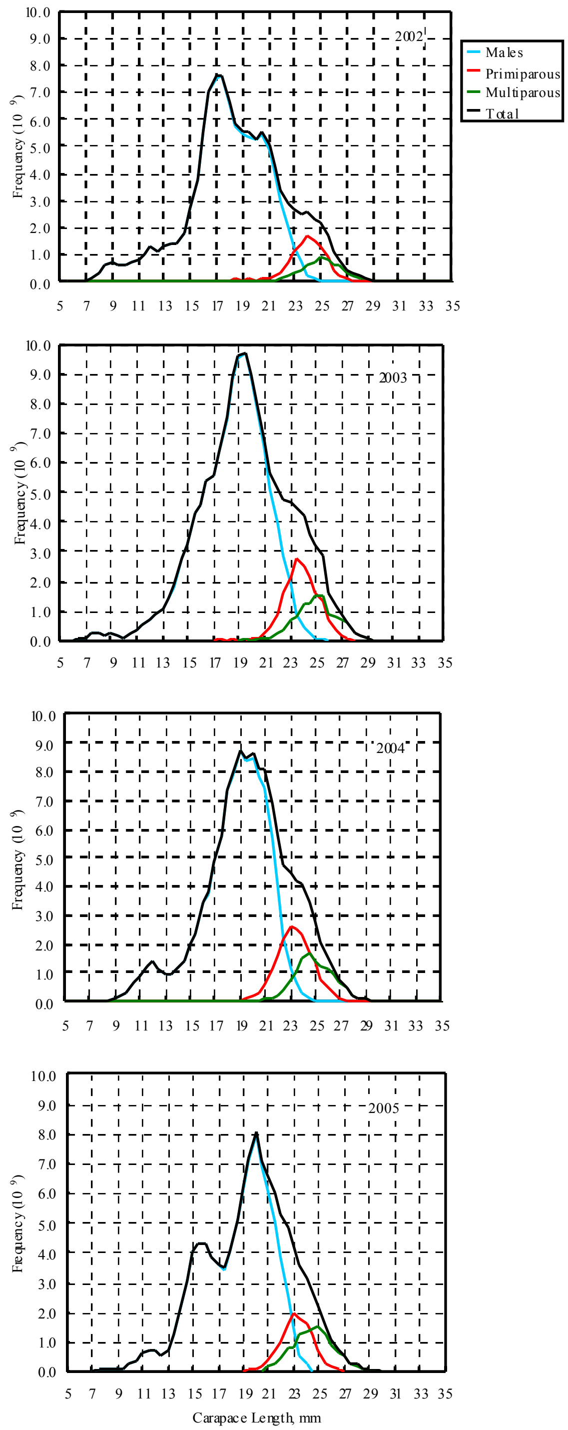


Fig. 3.4. Shrimp in Subareas 0 and 1: length frequencies of northern shrimp in the total survey area (offshore and Disko Bay/Vaigat combined), 2002 to 2005 (Data from 2002 to 2004 converted from *Skjervøy* to *Cosmos* trawl).

Index of recruitment. Numbers at age 2 correlate with indices of fishable biomass two and three years later and may therefore be regarded as a short-term predictor of recruitment to the fishery (SCR Doc. 05/74). This index was high in 2001, but decreased in 2002, was below average in 2003 and 2004, and decreased again in 2005 to a value near the lowest of the 13-year series (Fig. 3.5).

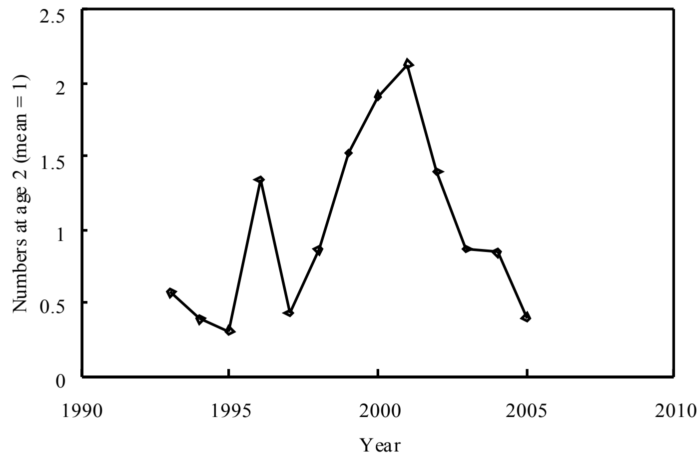


Fig. 3.5. Shrimp in Subareas 0 and 1: index of numbers at age 2 from survey scaled to the mean of the series).

Index of spawning stock biomass. The survey index of female biomass (SCR Doc. 05/74), stationary from 1988 to about 1997, has doubled since 1997. While the estimate for 2005 is high in historic terms, the high estimates of 2003 and 2004 have not been repeated (Fig. 3.6).

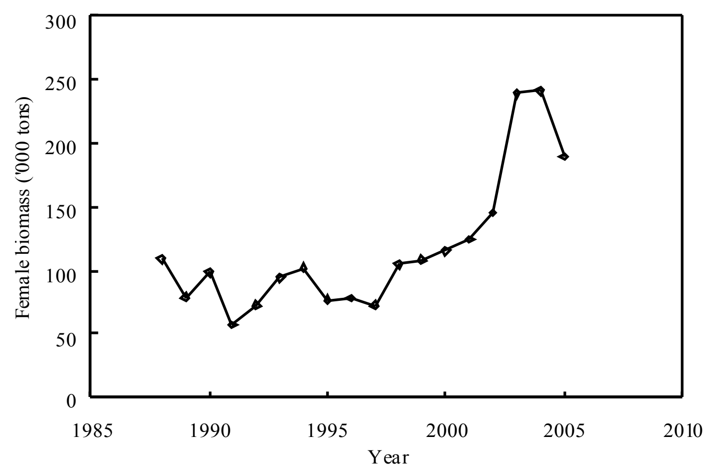


Fig. 3.6. Shrimp in Subareas 0 and 1: female spawning stock biomass index.

iii) **Other studies**

The West Greenland trawl survey, carried out annually to provide a fishery-independent index of stock biomass, has used a *Skjervøy* 3000/20 trawl with bobbin ground gear. In 2005 this was replaced by a *Cosmos* 2000/20 with rubber disk ground gear. Calibration studies were carried out in 2004 and 2005, by fishing twice consecutively over the same track. Sets were of four types, either repeating the same trawl or using the two different trawls in one order or the other. A 'disturbance effect' could be calculated from the results of repeating a set with the same gear and used to correct the differences in catch when two different gears were used consecutively. Correction factors between the two trawls, with appropriate measures of uncertainty, were calculated for each length-class of shrimp. The historic trawl series was adjusted to the *Cosmos* trawl by disaggregating the data by length and correcting each length-class (SCR Doc. 05/75, 05/92)

Estimates of cod biomass from the German groundfish survey at West Greenland are used in the assessment of the shrimp stock in SA 1 and Div 0A east of 60°30'W to estimate consumption of shrimp. The comparative study of cod catches at West Greenland from the German groundfish survey and the Greenland survey for fish and shrimp carried out in 2004 was updated (SCR Doc. 05/73). The correlation between the cod biomass estimates obtained in the two surveys was found to be maintained ($r^2 = 0.85$, $P < 0.001$) and used to generate an updated estimate of cod (predator) biomass for use in the stock assessment. The 2005 biomass estimate at 39.6 Kt was several times higher than those of recent years, but was associated with a wide confidence interval.

c) **Estimation of Parameters**

Parameters relevant for the assessment and management of the stock were estimated, based on a stochastic version of a surplus-production model that included an explicit term for predation by cod. The model was formulated in a state-space framework and Bayesian methods were used to construct "posterior" likelihood distributions of the parameters (SCR Doc. 02/158).

The model synthesized information from input priors and the following data: an 18-year series of survey biomass indices of shrimp ≥17 mm CL; a 30-year series of combined CPUE indices; a 51-year series of catches by the fishery; a 51-year series of cod biomass estimates; and a short series (4 years) of estimates of the shrimp biomass consumed by cod (SCR Doc. 04/76, 05/85).

Absolute biomass estimates had relatively high variances. For management purposes it was therefore desirable to work with biomass on a relative scale in order to cancel out the uncertainty of the "catchability" parameters (the parameters that scale absolute stock size). Biomass, B, was thus measured relative to the biomass that would yield Maximum Sustainable Yield, B_{msy}. The estimated mortality, Z, refers to the removal of biomass by fishing and cod predation and is scaled to Z_{msy} - the mortality at *MSY*.

d) **Assessment Results**

The model estimated the median annual consumption by cod 1956-2005 in the range of 200 tons to about 120 000 tons. The estimated consumption declined since 1960 as a result of a decline in cod abundance at West Greenland (Fig. 3.7). A short-lived resurgence of the cod stock in the late 1980s caused consumption to increase. The cod disappeared in the beginning of the 1990s and estimates of consumption went to zero. Recent estimates of cod have shown increases and the estimate for 2005 - 39 550 tons - is about 5 times that for 2004. The parameters of the predation function estimated by the model showed that cod predation could be a significant burden on the stock and further increases in the cod stock could have significant impacts on the amount of surplus production that would be available to the fishery. The question is, however, complicated by uncertainty as to the overlap between high-shrimp-density areas and the areas where cod are showing their most significant increase.

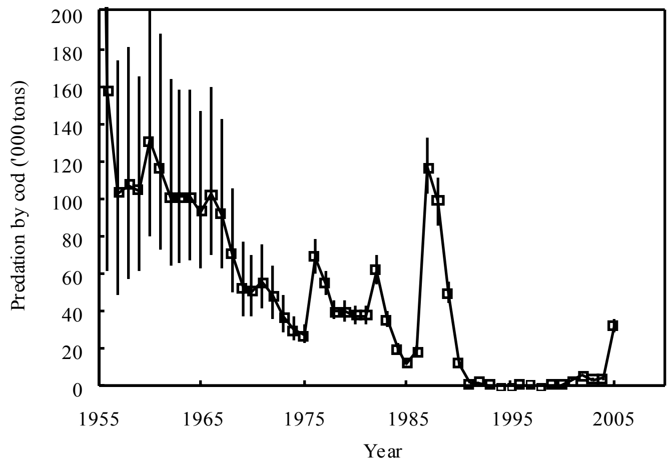


Fig. 3.7. Shrimp in Subareas 0 and 1: estimated consumption of shrimp by cod (error bars are upper and lower quartiles).

The trajectory of the median estimate of 'biomass-ratio' (B_t/B_{msy}) plotted against 'mortality-ratio (Z_t/Z_{msy}) (Fig. 3.8) started in 1956 at about half the optimum biomass ratio and at a mortality ratio well above 1. The stock maintained itself in this region during the years when cod were abundant. When the cod stock declined in the late 1960s (Fig. 3.7) and predation pressure was lifted, shrimp stock biomass increased and eventually began cycling in the left upper corner of the graph (Fig. 3.8) during the current regime of low cod abundance (SCR. Doc. 05/85).

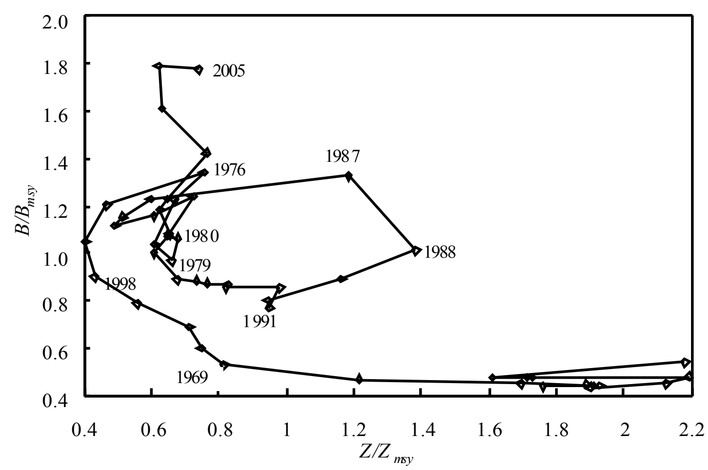


Fig. 3.8. Shrimp in Subareas 0 and 1: estimated annual median biomass-ratio (B/B_{msy}) and mortality-ratio (Z/Z_{msy}) 1956–2005.

Since the early 1970s when the fishery started expanding to offshore areas, the estimated median biomass ratio ranged between about 0.7 and about 1.4 (Fig. 3.8). The probability that it had been below the optimum level was small for most years (Fig. 3.9). However, stock biomass was probably driven below B_{msy} in the late 1980s to mid-1990s associated with a short-lived resurgence of the cod stock. The shrimp stock has increased since then, and reached its highest level in 2004 with a median estimate of biomass ratio of 1.81, corresponding to about 79% of estimated median carrying capacity. The estimated risk of stock biomass being below B_{msy} at the end of 2005 was 8% (Fig. 3.9).

The mortality ratio (Z-ratio, which includes mortality by fishing and predation by cod) has been below 1 for most of the time since 1974, except for the period of high cod predation in the late 1980s to early 1990s (Fig. 3.8). Since 1997, annual median Z-ratio has been stable in the neighbourhood of 0.7, i.e. well below the value that maximizes yield. The median estimate for 2005 (with catches assumed 140 500 tons) is 0.74 with a 20% risk of being above 1 (Fig. 3.9).

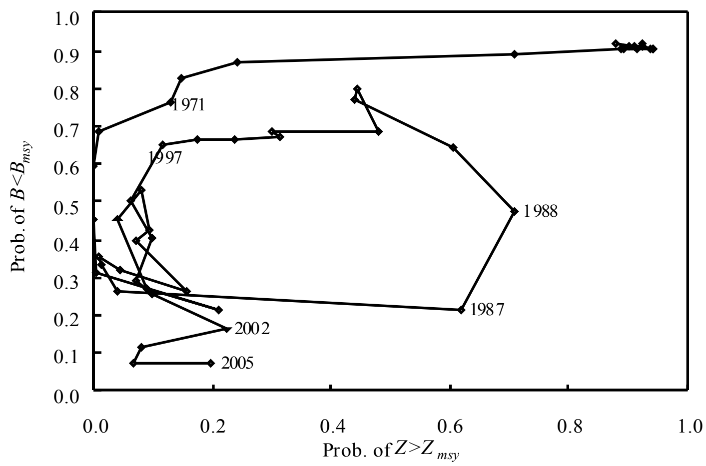


Fig 3.9. Shrimp in Subareas 0 and 1: risk of annual biomass being below B_{msy} and of mortality caused by fishing and cod predation being above Z_{msy} 1956-2005.

The median estimate of the maximum annual production surplus, available to the fishery and the cod (*MSY*) was estimated at 150 000 tons (Fig. 3.10). The risk function relating the probability of exceeding *MSY* to the combined removal by fishery and cod predation is given in Fig. 3.10.

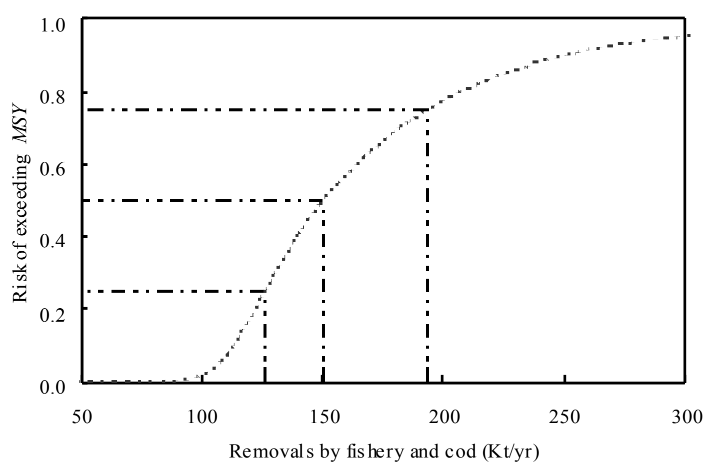


Fig. 3.10. Shrimp in Subareas 0 and 1: cumulative probability distribution of the maximum annual production surplus, available to the fishery and to cod (*MSY*). The median estimate (150 Kt/yr) and quartiles (126 and 193 Kt/yr) are shown.

Given the high probabilities that the stock is considerably above B_{msy}, risk of stock biomass falling below this optimum level within a one-year perspective is low. Risks associated with five optional catch levels for 2006 are as follows:

Catch option ('000 tons) in 2006	110	120	130	140	150
Risk of exceeding Z_{msy} in 2006	8.2%	14.3%	20.4%	26.6%	37.5%
Risk of falling below B_{msy} by end 2006	8.6%	8.9%	9.5%	10.5%	11.1%

Predation by cod can be significant (Fig. 3.7) and have a major impact on shrimp stock size. In spite of recent increases, the cod stock at West Greenland is now still at a low level. A large cod stock that would significantly increase shrimp mortality could be established in two ways: either by a slow rebuilding process or by immigration of one or two large year-classes from areas around Iceland as seen in the late 1980s.

An increase in cod abundance through growth of the existing stock would, however, be noted in an early phase during routine monitoring programs and fisheries management would have at least two years to respond before the shrimp stock is driven below optimal levels, given the current good condition of the stock.

Although there are indications of an increasing cod stock, absolute estimates are still well below those of the late 1980s and certainly those of the 1950s and 1960s.

Given the apparent importance of predation in determining the trajectory of shrimp stocks, STACFIS **recommends** that *ways to include the exploration of the effects of future trajectories of the cod stock on assessment predictions should be investigated and presented in 2006*. STACFIS also **recommends** that *the impact of other predators on the stock should also be considered for inclusion in the assessment model.*

Ten-year projections of stock development were made under the assumption that the cod stock will remain at its present level. Annual catches of 110 000, 120 000, 130 000, 140 000 and 150 000 tons were investigated (Fig. 3.11).

At the investigated catch option of 110 000 t/yr the stock is likely to remain above B_{msy} during the ten years of projection (Fig. 3.11). The combined relative fishing and cod predation mortality, Z_t, has a 77% probability of remaining below Z_{msy} within this period (Fig. 3.12).

Annual catches of 120 000 tons/yr are not likely to drive the stock below B_{msy} in the short to medium term (Fig. 3.11); by the end of 2008 the risk is 12½% and after 10 years, 26% (Fig. 3.12). However, this level of exploitation might not be sustainable in the longer term (>10 years), as uncertainties compound over time and the risk of exceeding B_{msy} continues to increase. The risk of exceeding to Z_{msy} is about 32% after 10 years.

A catch option of 130 000 tons/yr is below the estimated median *MSY* but when combined with predation is likely to drive the stock down, although not below B_{msy} in the short term (Fig. 3.11). By end 2008 the risk is estimated at 15% and is over 30% after 10 years (Fig. 3.12). The risk of exceeding Z_{msy} increases from about 20% to 40% over a 10-year projection.

Fishing at 140 000 tons/yr bears a 27%, and 150 000 tons a 33% risk, of being immediately above *MSY* (Fig. 3.11), so these catch levels are unlikely to be sustainable. Owing to the current high stock level and the high *MSY* the risk of transgressing B_{msy} is no more than 20% by end 2008 at 150 000 tons/yr, although after 10 years it is over 40% with a concomitant 53% risk of exceeding Z_{msy} (Fig. 3.12).

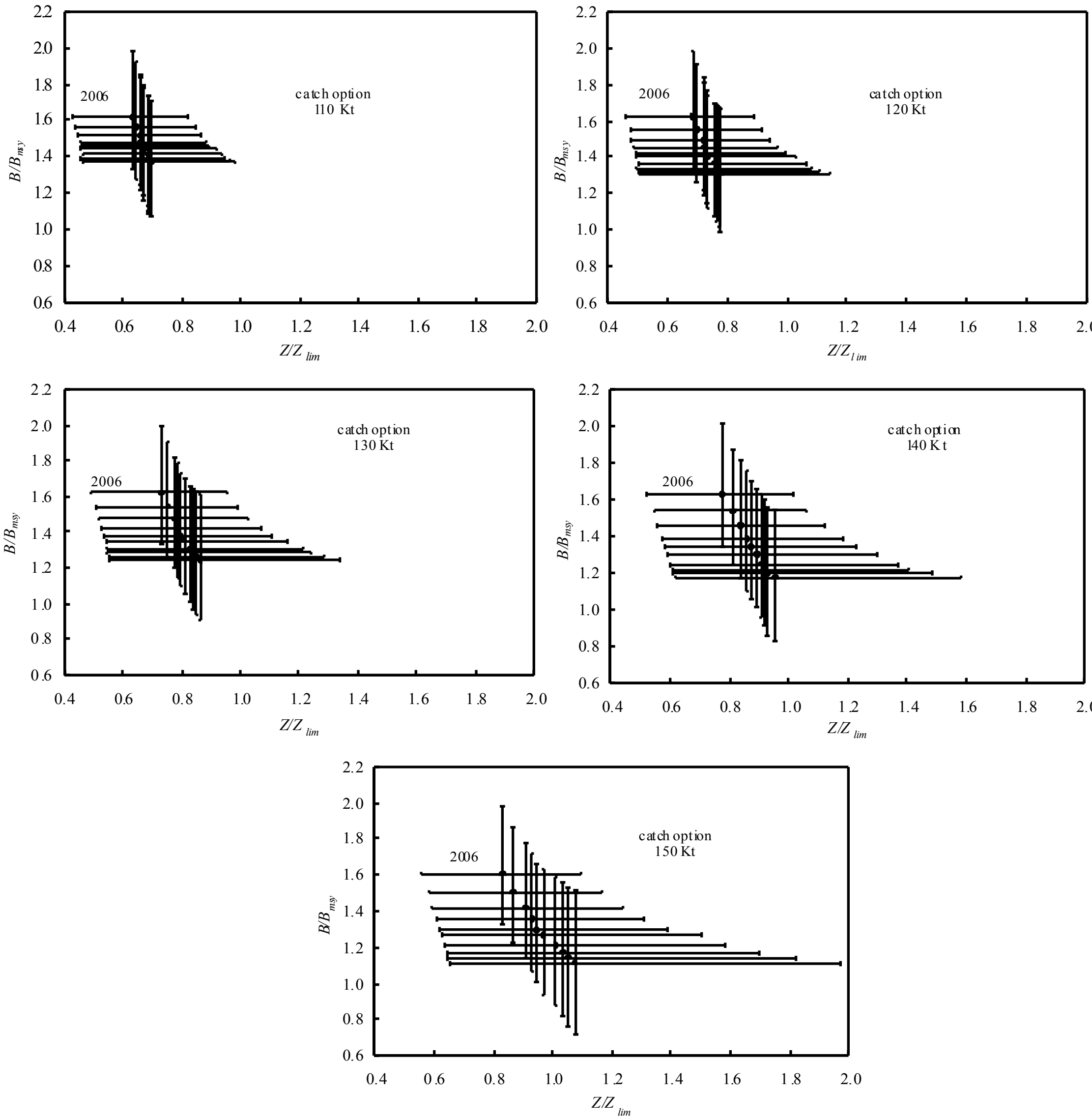


Fig. 3.11. Shrimp in Subareas 0 and 1: estimates of stock development for the period 2005-2015 quantified in a biomass (B/B_{msy})-mortality (Z/Z_{msy}) continuum. Dynamics at 110, 120, 130, 140 and 150 thousand tons of fixed annual catch levels are shown as medians with error-bars at the 25^{th} and 75^{th} percentiles.

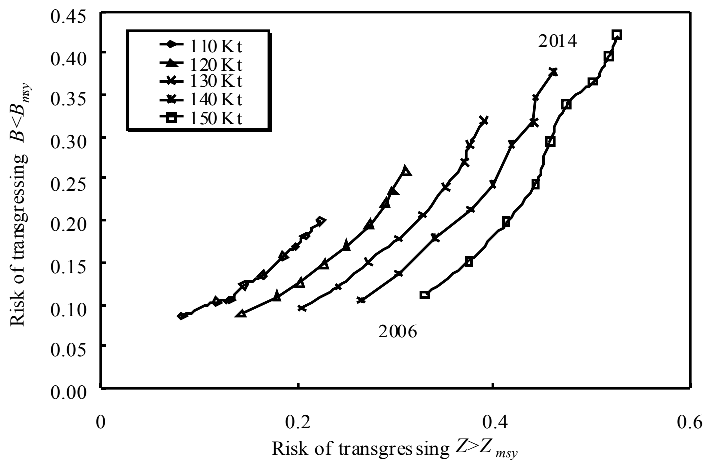


Fig.3.12. Shrimp in Subareas 0 and 1: risk of exceeding Z_{msy} and of driving the stock below B_{msy} by maintaining optional annual catch levels of 110-150 000 tons/yr during the period 2006-2014.

If on the other hand there is an abrupt increase in cod biomass resulting from immigration from other areas changes of shrimp stock condition may be much more rapid. The effect of an immigration of two large year-classes of cod was investigated in 2004 (SCR Doc. 04/76) and it was shown that predation could within a 3-4 year period go from negligible to between 88 000 and 163 000 tons.

Mortality. The mortality caused by fishing and cod predation (*Z*) has been stable below the upper limit reference (Z_{msy}) since 1997. With catches in 2005 projected at 140 500 tons the risk that total mortality exceeded Z_{msy} was estimated at about 20%.

Biomass. Since the late 1990s the stock has increased and the survey index reached high levels in 2003 and 2004. This index then decreased in 2005, but CPUE continued to increase. The modelled stock biomass reached its hitherto highest value in 2005; the estimated risk of stock biomass being below B_{msy} at end 2005 was 8%, but less than 1% of being below B_{lim}.

Recruitment. Prospects for recruitment to the fishable biomass in 2006 are still highly favourable. However, the estimated number of age-2 shrimp decreased in 2002, was below average in 2003 and 2004 and decreased again in 2005 to near a 10-year low value. Recruitment to the fishable stock is likely to decrease after 2006.

State of the Stock. The stock biomass has increased substantially since the late 1990s to historically high levels. Biomass at the end of 2005 is estimated to be well above B_{msy} and mortality by fishery and cod predation well below Z_{msy}.

The abundance of recruited males (between 17 and 22 mm CL) in 2005 is estimated to be high and should sustain good catch rates of larger shrimp in 2006. However, both model simulations of stock development and indices of future recruitment indicate that fishable biomass can be expected to follow a decreasing trend.

Both stock development and the rate at which changes might take place depend heavily on the abundance of predators (in particular cod) present within the shrimp habitat. In the most recent years increases in cod abundance have been registered, and present levels of cod biomass could consume significant quantities of shrimp. However, these estimates are still well below those of the late 1980s and certainly those of the 1950s and 1960s.

e) **Precautionary Approach**

Scientific Council has developed limit reference points for stock size (B_{lim}) at 30% of B_{msy} and for mortality (Z_{lim}) at 100% of Z_{msy} (SCS Doc. 04/12).

	Catch option for 2006 ('000 t)				
	110	120	130	140	150
Risk of falling below B_{lim} by end 2006	<<1%	<<1%	<<1%	<<1%	<<1%

Estimated median biomass has been above B_{lim} throughout the time series (Fig. 3.13). The mortality ratio (relative Z, which is the total mortality caused by fishing and predation by cod) has been below 1 for most of the time since the early 1970s when the modern fishery developed, except for the period of high cod predation from the late 1980s to the early 1990s. At the end of 2005 there is less than 1% risk that the stock would be below B_{lim}, while the risk that Z_{lim} was exceeded is 20%. Therefore there is only a small risk of the stock being outside the safe zone.

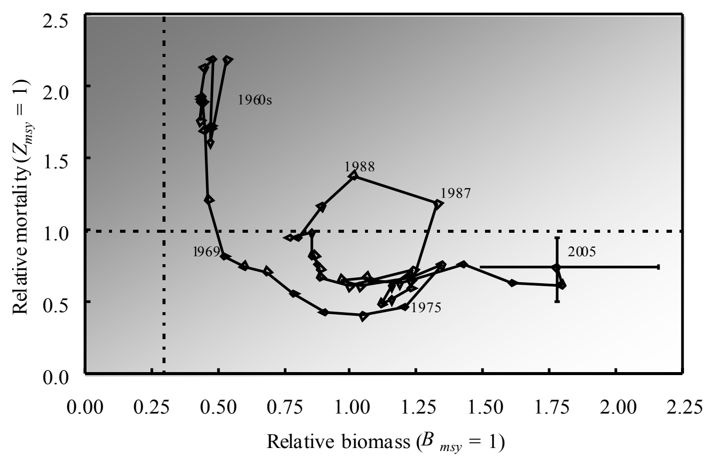


Fig.3.13. Shrimp in Subareas 0 and 1: estimated stock-dynamic trajectory 1957 to 2005 in a mortality–biomass continuum. Points are the median values of estimated biomass and mortality ratio. Limit reference points are shown. Error bars for 2005 are upper and lower quartiles.

f) **Research Recommendations**

For the shrimp stock in Subarea 1 and Div. 0A east of 60°W, STACFIS **recommends** that:

- *sampling of catches by observers - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - should be re-established in Subarea 1.*

- *ways to include the exploration of the effects of future trajectories of the cod stock on assessment predictions should be investigated and presented in 2006.*

- *the impact of other predators on the stock should also be considered for inclusion in the assessment model.*

- *the age-2 abundance index and its link to subsequent fishable biomass should be considered for inclusion in the shrimp assessment model.*

4. Northern Shrimp (*Pandalus borealis*) in Denmark Strait and off East Greenland (SCR Doc. 03/74, 05/93)

a) Introduction

Northern shrimp off East Greenland in ICES Div. XIVb and Va is assessed as a single population. The fishery started in 1978 and, up to 1993, occurred primarily in the area of Stredebank and Dohrnbank as well as on the slopes of Storfjord Deep, from approximately 65°N to 68°N and between 26°W and 34°W.

In 1993 a new fishery began in areas south of 65°N down to Cape Farewell. Access to all these fishing grounds depends heavily on ice conditions. From 1996 to 2003 catches in the area south of 65°N accounted for more than 60% of the total catch. Catches and effort in the area south of 65°N now appears to be decreasing, as the 2004 catches only account for 29% of the total catch.

A multinational fleet exploits the stock. During the recent ten years, vessels from Greenland, Denmark, the Faroe Islands and Norway have fished in the Greenland EEZ. Only Icelandic vessels fish in the Icelandic EEZ.

In the Greenland EEZ, the minimum permitted mesh size in the codend is 44 mm, and the fishery is managed by catch quotas allocated to national fleets. In the Icelandic EEZ, the mesh size is 40 mm and there are no catch limits. In both EEZs, sorting grids with 22-mm bar spacing to reduce by-catch of fish are mandatory. Discarding of shrimp is prohibited in both areas.

Catches of shrimp taken in the Greenland EEZ until 2003 have been reported without accounting for "overpacking" - the amount of surplus weight in packaging - or the difference between the product weight and live weight, all catches in the Greenland EEZ have therefore been adjusted for overpacking (SCR Doc. 03/74).

Total catches increased rapidly to about 15 500 tons in 1987 and 1988, but declined thereafter to about 9 000 tons in 1992 and 1993. Following the extension of the fishery south of 65°N catches increased again to about 13 800 tons in 1997. Catches from 1998 to 2004 have been between 10-14 000 tons (Fig. 4.1) and the 2005 catches are projected to be at the same level (projected from October)

Recent nominal catches and recommended TACs (tons) are as follows:

	1996[3]	1997[3]	1998[3]	1999[3]	2000[3]	2001[3]	2002[3]	2003[3]	2004	2005[1]
Recommended TAC	5 000	5 000	5 000	9 600	9 600	9 600	9 600	9 600	12 400	12 400
North of 65°N, Greenland EEZ	2 924	1 622	3 943	4 058	4 288	2 227	1 344	4 143	6 736	5 808
North of 65°N, Iceland EEZ	566	2 856	1 421	769	132	10	1 144	635	380	21
North of 65°N, total	3 490	4 478	5 364	4 827	4 420	2 237	2 488	4 778	7 116	5 829
South of 65°N, Greenland EEZ	8 453	9 276	6 057	6 893	7 632	11 674	8 753	7 858	2 869	4 171
Total STATLANT 21A	9 713	11 589	9 321	9 467	9 594	11 052	9 196	9 763	9 985[2]	
Total STACFIS[3]	11 944	13 754	11 442	11 719	12 053	13 911	11 242	12 637	9 985	10 000

[1] Provisional.
[2] Estimates 1995-2003 corrected for overpack.
[3] Catches projected to end of 2004.

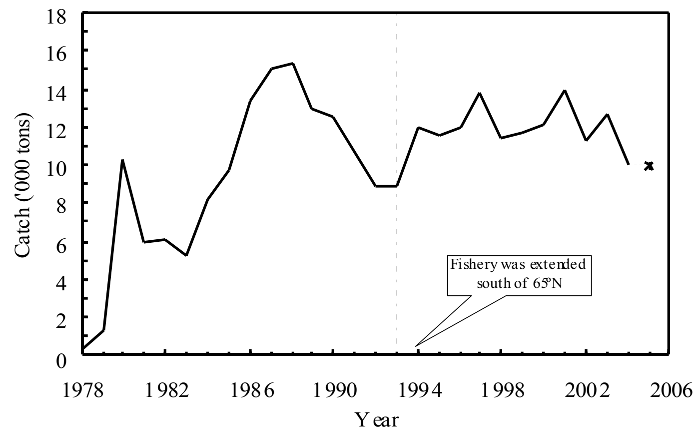


Fig. 4.1. Shrimp in Denmark Strait and off East Greenland: total catches (2005 projected to the end of the year based on January to 1 October data).

b) **Input Data**

i) **Commercial fishery data**

Fishing effort and CPUE. Catch and effort (hours fished) from logbooks were available from Greenland, Norway, Iceland, Faeroe Islands and EU-Denmark since 1980 and from EU-France for 1980 to 1991. Norwegian fishery data from 2000-2005 did not include information on different area fished and therefore data was not included in the standardized catch rates calculations.

Standardized catch rates based on logbook data from Danish, Faroese, Greenlandic and Icelandic vessels in the northern area declined continuously from 1987 to 1993 - showed a significant increase between 1993 and 1994 and fluctuated with a slightly increasing trend thereafter (Fig. 4.2). For 2005 available data for the northern area was too sparse to be included in the model. In the southern area a standardized catch-rate series for the same fleets (Iceland excluded) increased until 1999, and fluctuated with a slightly decreasing trend thereafter (Fig. 4.3).

A combined standardized catch-rate index for the total area decreased steadily from 1987 to 1993, showed an increasing trend until the late 1990s, and fluctuated at this level thereafter (Fig. 4.4).

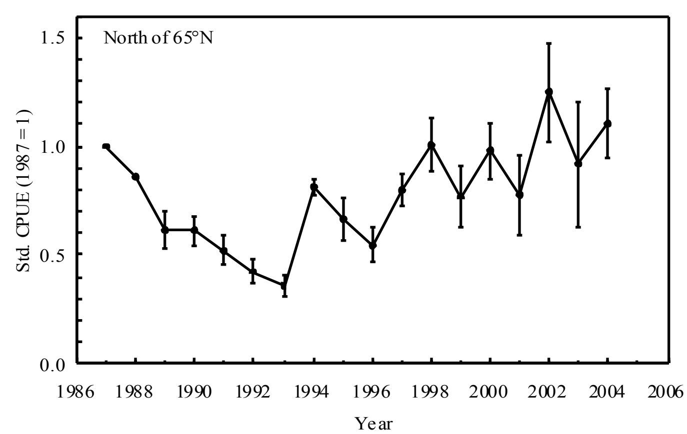


Fig. 4.2. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE (1987 = 1) with ±1 SE calculated from logbook data from Danish, Faroese, Greenlandic and Icelandic vessels fishing north of 65°N (insufficient data for 2005).

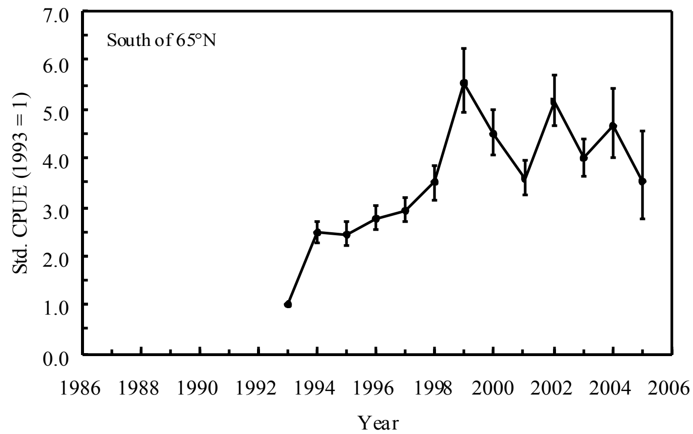


Fig. 4.3. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE (1993 = 1) with ±1 SE calculated from logbook data from Danish, Faroese and Greenlandic vessels fishing south of 65°N.

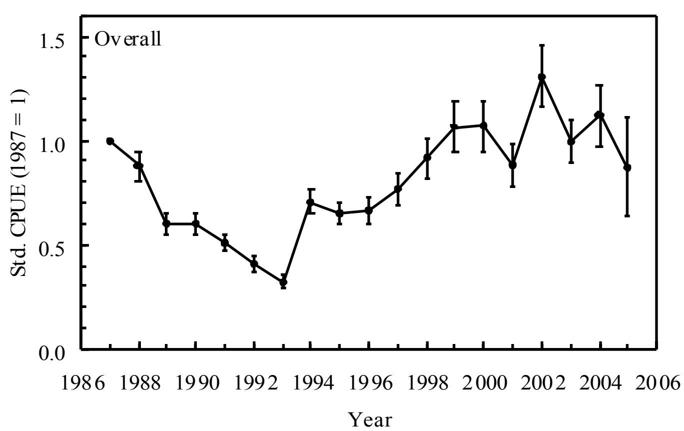


Fig. 4.4. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE-indices (1987 = 1) with ±1 SE combined for the total area.

Standardized effort indices (catch divided by standardized CPUE) as a proxy for exploitation rate for the total area showed a decreasing trend since 1993. Recent levels are the lowest of the time series (Fig. 4.5).

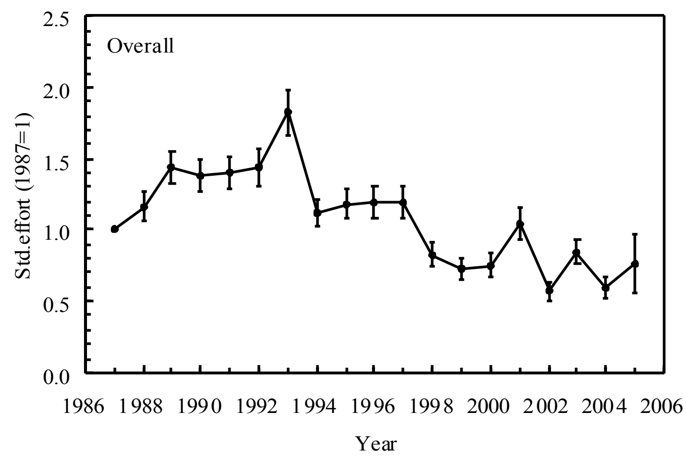


Fig. 4.5. Shrimp in Denmark Strait and off East Greenland: annual standardized effort indices, as a proxy for exploitation rate (±1 SE; 1987 = 1), combined for the total area.

Biological data. Since 2002 STACFIS has recommended that, "sampling of catches by observers - essential for assessing stock age, size and sex composition - should be re-established". However, sampling of the commercial fishery in recent years has been insufficient to obtain annual estimates of catch composition.

ii) **Research survey data**

No surveys have been conducted since 1996.

c) **Assessment Results**

CPUE. Combined standardized catch-rate index for the total area decreased steadily from 1987 to 1993, showed an increasing trend until the late 1990s, and fluctuated at this level thereafter.

Recruitment. No recruitment estimates were available.

Biomass. No direct biomass estimates were available.

Exploitation rate. From 1998 through 2005 the exploitation rate index (catch/CPUE) has been at its lowest level in the 19-year series.

State of the stock. Standardized CPUE data for all the areas combined indicate an increasing trend from 1993 to 2000 in the fishable biomass and has fluctuated at this level thereafter. However, changes in the fishing pattern in 2004 and 2005 leaves some uncertainty to whether the 2005 value is a true reflection of the stock biomass.

d) **Research Recommendations**

STACFIS **recommends** that, for shrimp in Denmark Strait and off East Greenland:

- *a survey be conducted, to provide fishery independent data of the stock throughout its range.*

- *as a minimum requirement: sampling of catches by observers is required - essential for assessing age, size, sex composition, fecundity and frequency of spawning of the stock - and be re-established in the Greenland EEZ and improved in the Icelandic EEZ.*

IV. STOCK ASSESSMENTS (ICES Area)

The assessments of the shrimp stocks in the ICES areas for:

- Northern shrimp in Skagerrak and Norwegian Deep (ICES Divisions IIIa & IVa East)
- Northern shrimp in Fladen Ground (ICES Division IVa)
- Northern Shrimp in Barents Sea and Svalbard area (ICES Sub-areas I & II)

were presented in plenary to the joint STACFIS/WGPAND group. Due to time constraints and differences in the format of reports between NAFO and WGPAND, it was not possible to review the entire WGPAND report in plenary. It was decided that for each of the stocks reviewed, drafts would be prepared and discussed in plenary for only those sections of the report that would be used to support the conclusions about stock status and the development of subsequent advice. The group acknowledged that it would be useful to make every effort to develop a joint report in the future and cited the report of the ICES/NAFO Working Group on Harp and Hooded Seals as a good example. Accordingly, the entire WGPAND report is found in Appendix II.

V. OTHER BUSINESS

1. Adjournment

There being no other business, the Chair expressed his gratitude to the members of the Committee for their valuable contributions. The Chair especially noted the particular effort of the NAFO Designated Experts and the ICES stock coordinators for their roles in providing timely assessments and excellent peer-review during plenary discussions. The Chair considered this joint meeting with ICES WGPAND a successful venture which should be continued in future. The Chair acknowledged and was grateful for the great support he received from the Chair of WGPAND (Sten Munch-Petersen). The Chair thanked the NAFO Secretariat for their exemplary support during the meeting, in particular to Barb Marshall for providing in-situ report editing.

The Chair of WGPAND also thanked the Committee for the good experience of the joint meeting and agreed this was well worth supporting in the future. He noted his chairmanship is ending this year. The Chair of WGPAND thanked the NAFO Secretariat for very good support preparing documents and drafts and providing real time support.

The report was adopted and the meeting was adjourned.

APPENDIX II. ICES WGPAND 2005 REPORT

(*ICES C.M. Doc*., No. 2006/ACFM:10 Ref. G)

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 (Divisions 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 organized 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** (Divisions IIIa and IVa East)

This year' 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 Section 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** (Division 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 tons). 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 and 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 optimize 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 Fig. 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 Div. 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 analyzed 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 Fig. 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 Div. 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 Div. 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 tons. 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

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

$$Effort_{hypothetical}(t) = Effort_{nominal}(t) + (0.5 * Effort_{nominal}(t) * I_{factor}(t))$$

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

The resulting values for the standardized LPUE's are shown in Fig. 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°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 13 m in length delivering 980 t of shrimp from this area, there were 69 trawlers less than 50 GRT and longer than 13 m, delivering 2 770 tons of shrimp and finally, there were 29 trawlers being larger than 50 GRT delivering 2 330 tons 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 tons, 10 vessels between 10 tons and 50 tons, and 4 vessels more than 50 tons. Of the 20 vessels larger than 50 GRT, 2 delivered less than 10 tons, 3 between 10 tons and 50 tons, 5 between 50 tons and 100 tons and 10 more than 100 tons.

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 tons *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 tons 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 (Div. 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 Div. IIIa and Subarea 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. Div. IIIa and the eastern part of Div. IVa. The landings in 2004 were around 15 000 tons, an increase of almost 2 000 tons 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 tons. 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 tons. 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 1 000 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 tons 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 1 000 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 Fig. 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 = 1 000 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 Fig. 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 1 000 tons landed or 2 400 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 Fig. 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 2001-2003, 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 Div. 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 Div. IIIa and IVa East. It is stratified by depth zones of 100-200 m, 200-300 m and 300-500 m, and area (Fig. 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 (Fig. 4.6). The hauls are repeated annually on the 100 stations, giving a coverage of 1 haul per 1 312 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 (Fig. 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 (Fig. 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 (Fig. 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 Divisions IIIa and IVa East

4.5.1. Previous Assessment Models

The *Pandalus* stock in Div. 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 Fig. 4.2 and 4.3 as indicator of the development of the stock up to 2005: The combined LPUEs (Fig. 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 4.9, Fig. 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 (Fig. 4.9). A series of estimated median stock sizes relative to Precautionary Approach reference points are shown in Fig. 4.10.

This model indicates a stable stock at a level well above B_{msy}. 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 tons 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 tons (2004) to a high of more than 5 000 tons. 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 4^{th} 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 tons. 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 tons in 1990 and in 2000 but has decreased since to approximately 40 000 tons 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 licenses 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 tons in 2000 to approximately 60 000 tons in 2002 and 2001 and a further decrease to approximately 40 000 tons in 2003 and 2004 (Table 6.1, Fig. 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 tons.

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 standardized to vessels 1 000-1 500 hp with single trawls by using a GLM model including year, region, vessel and gear. The Russian CPUE represents only vessels of 1 300 hp using one type of single trawl. Catch, effort, and annual CPUE series for Norway (un-standardized and standardized) and Russia are presented in Table 6.2. The CPUE series for Russia and standardized CPUE for Norway are given in Fig. 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 standardized 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 (Fig. 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 (Fig. 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 1990s, 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 (Fig. 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 (Fig. 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 tons throughout the period 1994-2001 (Fig. 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

- Standardized Norwegian CPUE and Russian CPUE show a decrease from 2002 to 2004 of 22% and 40%, respectively (Table 6.2, Fig. 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 Fig. 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 tons.

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 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 7.1A-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 7.1C 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 7.1A-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 Div. IIIa by Denmark, Norway and Sweden has fluctuated around 300 tons. 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 1989-95, 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 (Fig. 3.2).

10. References

ANON. 1996. Seleksjon i reketrål. Red. J. W. Valdemarsen. TemaNord, 1996: 520.

ASCHAN, M. 1999. Bioeconomic analyses of by-catch of juvenile fish in the shrimp fisheries. *Fiskeriforskning Report*, 24/1999.

ASCHAN, M. 2000. Working document on by-catch in the shrimp fishery in the Barents Sea. Fiskeriforskning Preliminary Report, Tromsø, March 2000.

BAKANEV, S., and P. LUBIN. 2005. Results of the Russian stratified-random trawl survey for northern shrimp (*Pandalus borealis*) in the Barents Sea and Spitsbergen area 1984-2005. *NAFO SCR Doc.*, No. 86, Serial No. N5191, 13 p.

BERENBOIM, B., and V. KORZHEV. 1997. On possibility of using Stefansson's production model to assess the northern shrimp (*Pandalus borealis*) stock in the Barents Sea. *ICES C.M. Doc.*, No. 1997/Y.

BHATTACHARYA, C. G. 1967. A simple method of resolution of a distribution into Gaussian components. *Biometrics*, **23**: 115-135

BOGSTAD, B., and S. MEHL. MS 1997. Interactions between cod (*Gadus morhua*) and its prey species in the Barents Sea. *Forage Fishes in Marine Ecosystems*. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. *Alaska Sea Grant College Program Rep.*, No. 97-01: 591-615. University of Alaska Fairbanks.

BULGAKOVA, T., D. VASILYEV, V. KORZHEV, and V. TRETYAK. 1995. The results of multispecies analysis for the Barents Sea fishery community (cod, capelin, shrimp and herring). *ICES C.M. Doc.*, No. 1995/D:14.

CASAS, J. 2005. The Spanish NE Arctic shrimp fishery in 2004. *NAFO SCR Doc.*, No. 96, Serial No. N5202, 28 p.

COCHRAN, W. G. 1977. Sampling techniques, 3rd edition. John Wiley & Sons, New York,

DOLGOV, A. V. 1997. Distribution, abundance, biomass and feeding of thorny skate, *Raja radiata*, in the Barents Sea. *ICES C.M. Doc.*, No. 1997/GG: 04.

DOLGOVA, N. V., and A.V. DOLGOV. 1997. Stock status and predation of long rough dab (*Hippoglossoides platessoides*) in the Barents and Norwegian Seas. (*In*: International Symposium on the Role of Forage Fishes in Marine Ecosystems, Anchorage, Alaska 13-16 November 1996.

DRENGSTIG, A., S. E. FEVOLDEN, P. E. GALAND, and M. M. ASCHAN. 2000. Population structuring of the deep sea shrimp (*Pandalus borealis*) in the NE Atlantic based on allozymic differentiation. *Aquat. Living Resour.*, **13**: 1-9.

HVINGEL C. 2005. Results of the Norwegian bottom trawl survey for northern shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deeps (ICES Divisions IIIa and IVa) in 2004-2005. *NAFO SCR Doc.*, No. 82, Serial No. N5187, 8 p.

ICES. 1990. Report on the Working Group on the Assessment of *Pandalus* Stocks. *ICES C.M. Doc.*, No. 1990/Assess:9.

ICES. 1992. Report on the Working Group on *Nephrops* and *Pandalus* Stocks. *ICES C.M. Doc.*, No. 1992/Assess:8.

ICES. 1993. Report of the Advisory Committee on Fishery Management, 1992. *ICES Coop. Res. Rep.*, **193**.

ICES. 1998. Report of the Study Group on Grid (grate) Sorting Systems in trawls, beam trawls and seine nets. *ICES C.M. Doc.*, No. 1998/B:2.

ICES. 1999. Report of the ICES Advisory Committee on Fishery Management, 1998. *ICES Coop. Res. Rep.*, **229**.

ICES. 2000. Report on the *Pandalus* Assessment Working Group. *ICES C.M. Doc.*, No. 2000/ACFM:2.

ICES. 2001. Report on the *Pandalus* Assessment Working Group, 2001. *ICES C.M. Doc.*, No. 2002/ACFM:4.

ICES. 2002a. Report of the Arctic Fisheries Assessment Working Group. *ICES C.M. Doc.*, No. 2002/ACFM:18.

ICES. 2002b. Report of the Study Group on the Further Development of the Precautionary Approach to Fishery Management. *ICES C.M. Doc.*, No. 2002/ACFM:10.

ICES. 2003a. Report on the *Pandalus* Assessment Working Group, 2003. *ICES C.M. Doc.*, No. 2004/ACFM:5

ICES. 2003b. Report of the Arctic Fisheries Working Group. *ICES C.M. Doc.*, No. 2003/ACFM:22.

ICES. 2005a. Report of the *Pandalus* Assessment Working Group, 27 October-5 November 2004. *ICES C.M. Doc.*, No. 2005/ACFM:05.

ICES. 2005b. Report of the Arctic Fisheries Working Group, 19-28 April 2005. *ICES C.M. Doc.*, No. 2005/ACFM:20.

JOHANNESEN, E., and M. ASCHAN. 2005. How much does the cod really eat? - five years later. *NAFO SCR Doc.*, No. 97, Serial No. N5203, 12 p.

KARTAVTSEV, V.P., BERENBOIM, B. and ZUGUROVSKY, K.I. 1991. Population genetic differentiation on the pink shrimp *Pandalus borealis* Krøyer 1838, from the Barents and Bering Seas. *J. Shellfish Res.*, **10**(2): 333–339.

MACDONALD, P. D. M., and T. J. PITCHER. 1979. Age groups from size-frequency data: a versatile and efficient method of analysing distribution mixtures. *J. Fish. Res. Board Can.*, **36**: 987-1001.

MADSEN, N., P.-0. LARSSON, and M. ULMESTRAND. 1998. Development end testing of grids for the Skagerrak and North Sea shrimp fishery. Interim Report. *EU Study Contract*, No. 96/004

MARTINEZ, I., T. O. SKJELDAL, B. DREYER, and S. M. ALJANABI. 1997. Genetic structuring of *Pandalus borealis* in the NE-Atlantic. II. RAPD analysis. *ICES C.M. Doc.*, No. 1997/T:24.

PEDERSEN, O. P., M. ASCHAN, K. TE, D. SLAGSTAD, and T. RASMUSSEN. 2003. The advection and population dynamics of *Pandalus borealis* investigated by Lagrangian particle tracking model. *Fish. Res.*, **65**: 173-190.

POULSEN, E. M. 1970. On deep-sea prawn in the North Sea-Skagerrak. *Medd. Dan. Fisk-Havunders.*, **7**(1): 22

RASMUSSEN, T., M. THOLLESSON, and E. M. NILSSEN. 1993. Preliminary investigations on the population genetic differentiation of the deep water prawn, *Pandalus borealis* Krøyer 1838, from Northern Norway and the Barents Sea. *ICES C.M. Doc.*, No. 1993/K:11.

DOS SANTOS, J., and M. JOBLING. 1995. Test of a food consumption model for the Atlantic cod. I*CES J. Mar. Sci.*, **52**: 209-219.

SHELTON, P. A. 2004. Report of the NAFO study group on limit reference points, Lorient, France, 15-20 April 2004, 72 pp.

SPARRE P. 1984. A computer program for estimation of food suitability coefficients from stomach content data and multispecies VPA. *ICES C.M. Doc.*, No. 1984/G:25.

STEFÁNSSON, G., U. SKÚLADÓTTIR, and G. PÉTURSSON. 1994. The use of a stock production type model in evaluating the offshore *Pandalus borealis* stock of North Icelandic waters, including the predation of northern shrimp by cod. *ICES C.M. Doc.*, 1994/K:25, 13 p.

SUNNANÅ, K. 2005. A note on a possible concept for a length based biomass model for assessment of North-east Arctic shrimp (*Pandalus borealis*). *NAFO SCR Doc.*, No. 81, Serial No. N5186, 15 p.

TEIGSMARK, G., and P. ØYNES. 1983. Results of a stratified bottom trawl survey for shrimp (*Pandalus borealis*) in the Spitsbergen area in July 1982. *ICES C.M. Doc.*, No. 1983/K:17.

VALDEMARSEN, J. W., and R. MISUND. 2003. Forsøk med 19 og 22 mm spileavstand i sorteringsrist i fisket etter rognreke i Nordsjøen våren 2002. Report. Institute of Marine Research/Directorate of Fisheries, Bergen, Norway.

ULRICH, C., and B. S. ANDERSEN. 2004. Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. *ICES J. Mar. Sci.*, **61**: 308-322.

TABLE 4.1. Nominal landings (tons) of *Pandalus borealis* in ICES Div. 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.

TABLE 4.2. *Pandalus borealis* landings from Div. 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 43. National LPUE and total effort as estimated by the Working Group, *Pandalus* Div. IIIa and IVa east.

Year	Denmark LPUE kg/day	Denmark Adjusted 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 44. 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 Div. IVaE and IIIa, 2004.

Denmark Quarter	Landing (ton)	N:o samples	Weight (kg)	Numbers 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 Quarter	Landing (ton)	N:o samples	Weight (kg)	Numbers Measured-sexed
1		0		0
2		0		0
3		0		0
4		0		0
Total	0	0	0.0	0

Sweden Quarter	Landing (ton)	N:o samples	Weight (kg)	Numbers 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 Quarter	Landing (ton)	N:o samples	Weight (kg)	Numbers Measured-sexed	Sampling per 1000 ton landed 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	6366.666118	37.0	89.2	15101	14.0	2371.9

TABLE 4.6. Catch in numbers at age. *Pandalus* Div. 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* Div. 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 (tons) 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 Whiting ≥30cm	5.4	12.7
Saithe	20.4	68.4
Cod	1.9	3.3
Roundnosed Grenadier	11.0	6.7
Rabbit fish	9.5	4.5
Haddock	0.8	3.3
Redfishes	0.2	0.4
Velvet Belly	1.5	7.5
Skates,Rays	1.9	0.2
Long Rough Dab	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
Fourbearded Rockling	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: B_{msy} (biomass giving maximum production), B_{lim} (30% B_{msy} (Shelton, 2004), the biomass limit) F_{lim} (=F_{msy}, the limit fishing mortality) and that the catches were above the *MSY*.

Year	$P(B<B_{msy})$	$P(B<B_{lim})$	$P(F>F_{lim})$	$P(C>MSY)$
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 tons of *Pandalus borealis* from the Fladen Ground (Div. 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 52. *Pandalus borealis*, Fladen Ground. Reported LPUE (shrimp trawlers), and estimated total effort.

	Recorded	Denmark			UK (Scotland)	
	LPUE	Total effort	effort	LPUE	Total effort	effort
Year	(ton./day)	(Days)	Index	(kg/hour)	(hours)	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	992	0	9000
1975	8197	0	2	8199
1976	9752	548	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 62. 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 1 000 hp and 1 500 hp. Russian data based on daily reports from vessels smaller than 1 300 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 Area	A East Finmark	B Tiddly Bank	C - Thor Iversen Bank	D - Bear Island Trench	E Hopen	F Bear Island	G Storfjord Trench	H Spits-bergen	Total	Sum. A,B,C, E
Strata	38078	6 - 7	10 - 12	5, 8, 9, 13	14 - 18, 24	19 - 22/ 31-40	41 - 50	51 - 70		
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 (1 000 tons) from Russian survey in the 1984-2002 and 2005 by main areas. Catchability of 0.182 is used in the estimate.

Main Area	A East Finmark	B Tiddly Bank	C-Thor Iversen Bank	E Hopen	F Bear Island	G Storfiord Trench	H Spits-bergen	I Kola coast	K Goose Bank	Total	Sum. A,B,C,E
Strata	4-Jan	6,7,1s	10-12,25	14-18	38-40, 43-45	48-50	53-55,58-60, 63-65,58-70	2s-6s	7s-8s		
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

TABLE 7.1A-G.

Tables 7.1 A-B.

1995 - 2004

A:

Skagerrak, Sub-div. IIIA. **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	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**

Species:	1995 Total	1995 % of total catch	1996 Total	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	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

Table 7.1. C-D.

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		

Table 7.1. E-F

E:

Norwegian Deeps, Sub-div. IVA East — **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	0.6	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**

Species:	1995 Total	1995 % of total catch	1996 Total	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							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		
Total H.C. as % of shrimp:								13.6		13.8		16.0		13.3		17.7		16.8		

Table 7.1. G.

G:

Fladen Ground, Sub_div. IVA. **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	0.0	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

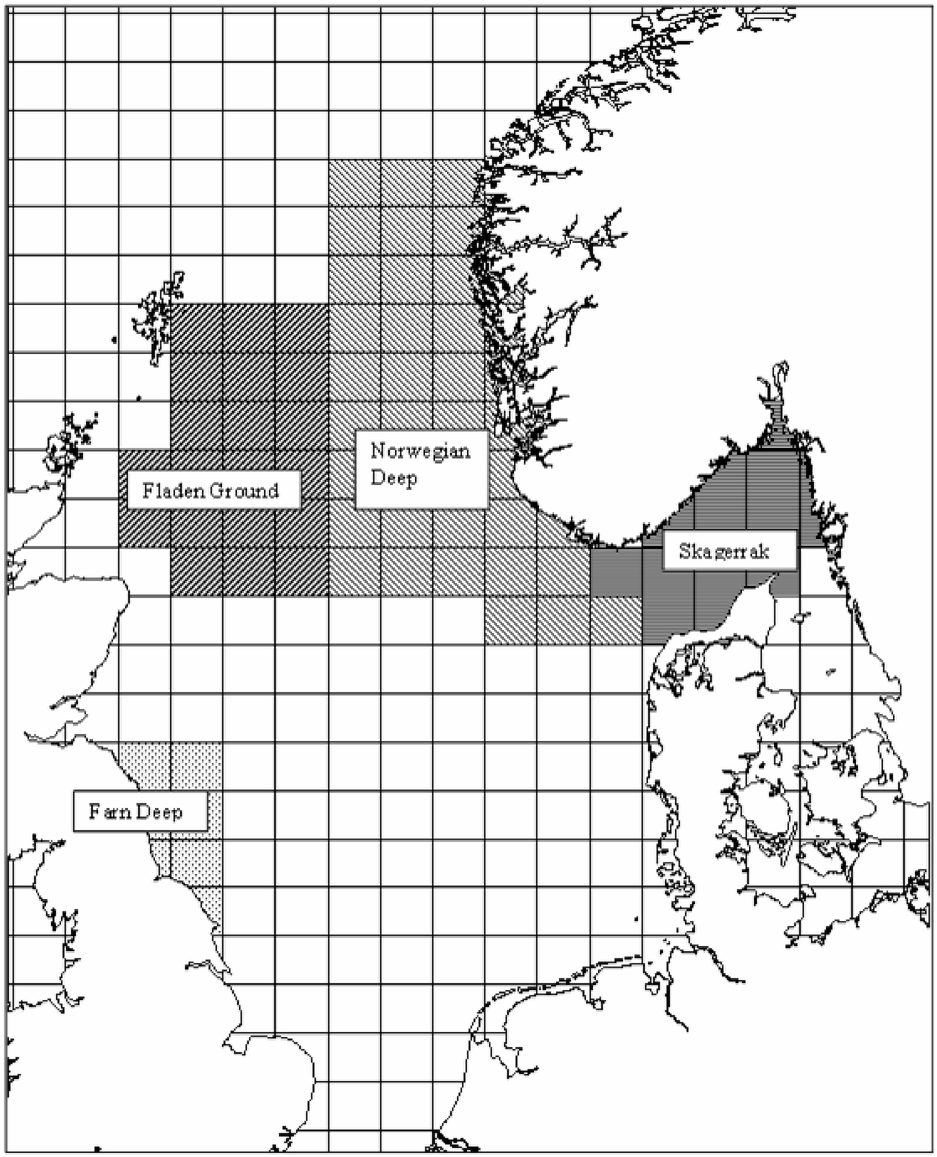


Fig. 3.1. The distribution of the *Pandalus* stocks in the North Sea area as defined by the ICES squares.

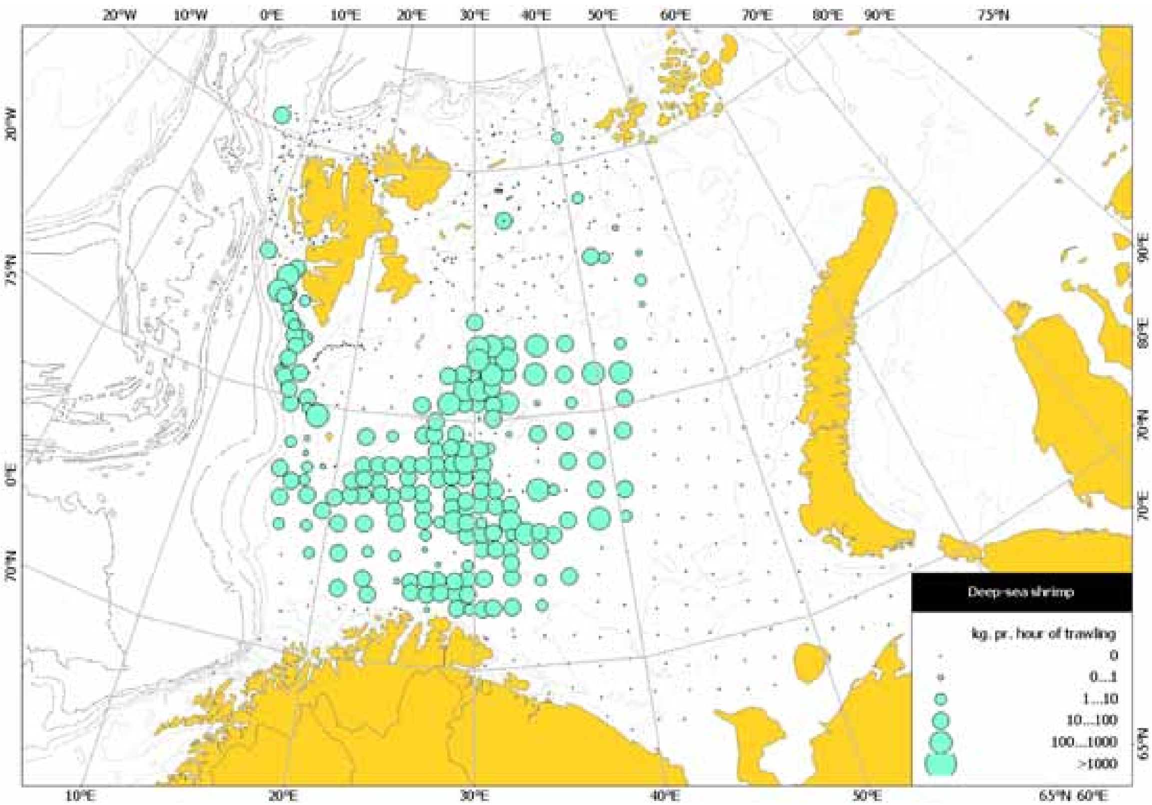


Fig. 3.2. Shrimp distribution in the Barents Sea according to Surveys conducted in the period August-October 2005.

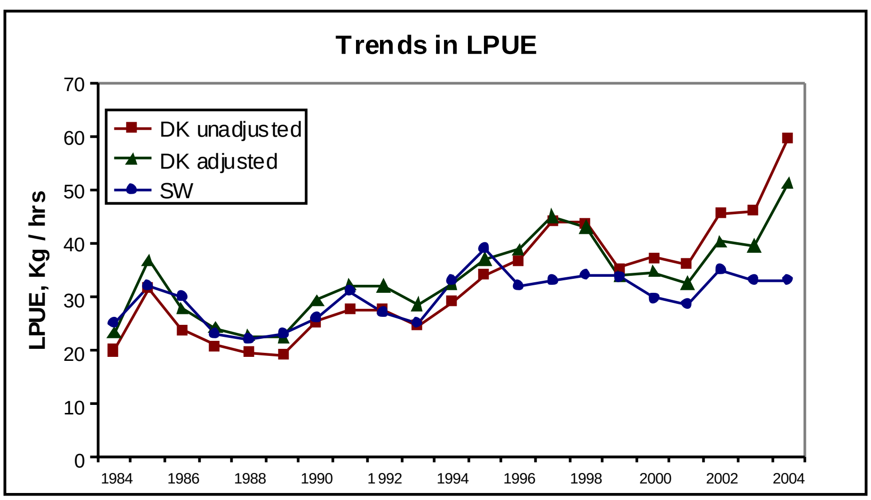


Fig. 4.1 Comparison of Danish LPUE, unadjusted and adjusted, with Swedish LPUE.

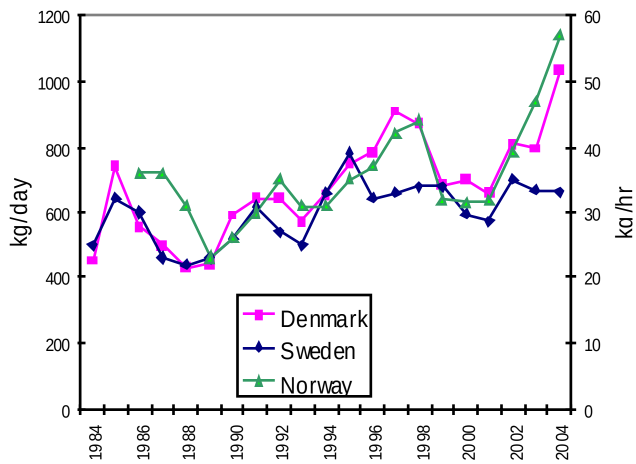


Fig. 4.2. *Pandalus* in Div. IIIa and Iva East trends in LPUE.

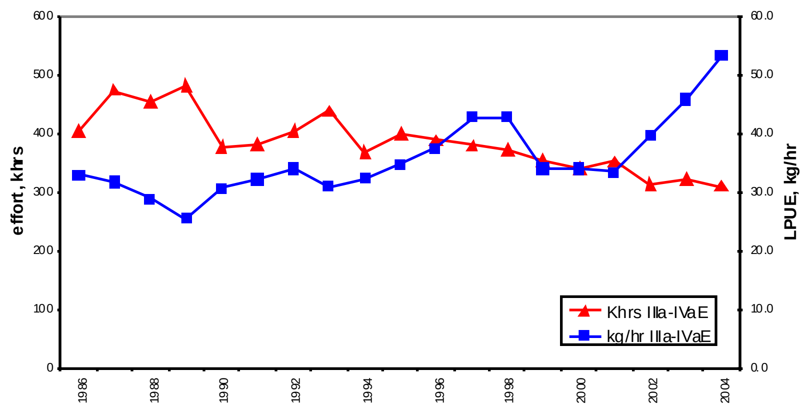


Fig. 4.3. Trends in international LPUE and total international effort, 1986-2004.

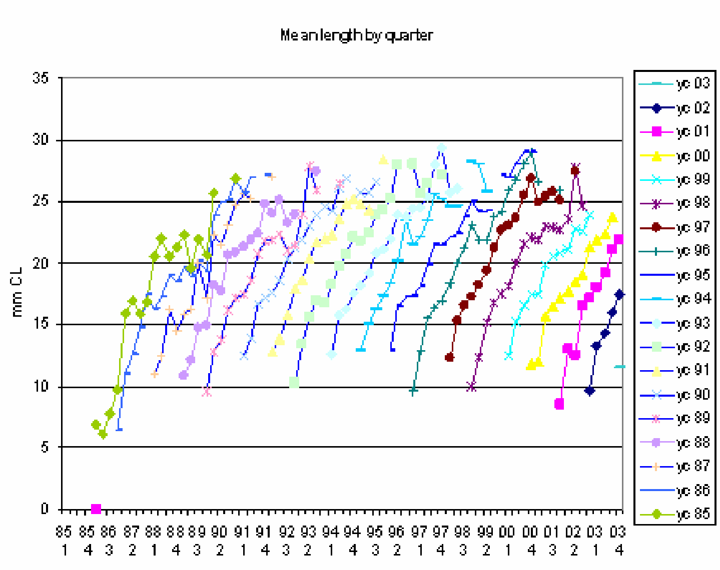


Fig. 4.4. Mean quarterly carapace length (mm) for *Pandalus* in Div. IIIa and Iva East.

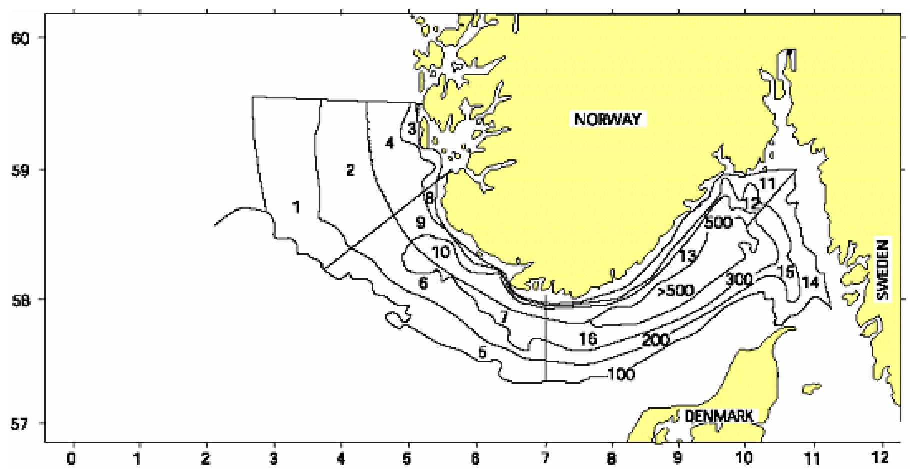


Fig. 4.5. Norwegian Trawl Survey Area. Strata 1-16 and depth contour lines.

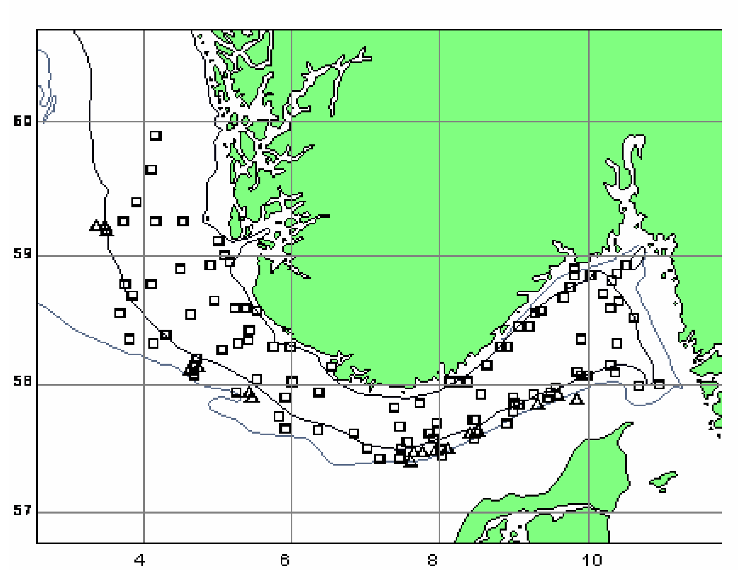


Fig. 4.6. Trawl stations of the Norwegian survey (squares are shrimp stations; triangles are Norway lobster stations).

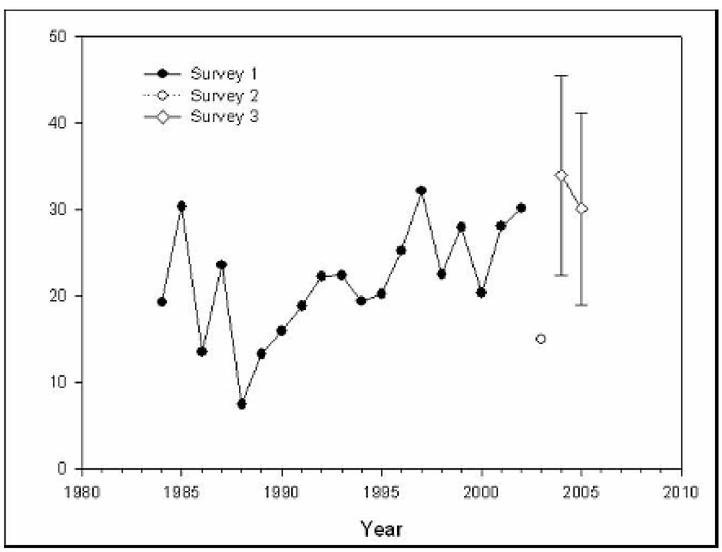


Fig. 4.7. Estimated survey biomass indices (1 000 tons) for *Pandalus* in IIIa and IVa East, see also Table 4.8. The three surveys are not calibrated to a common scale. Standard errors (error bars) were calculated for the 2004 and 2005 surveys

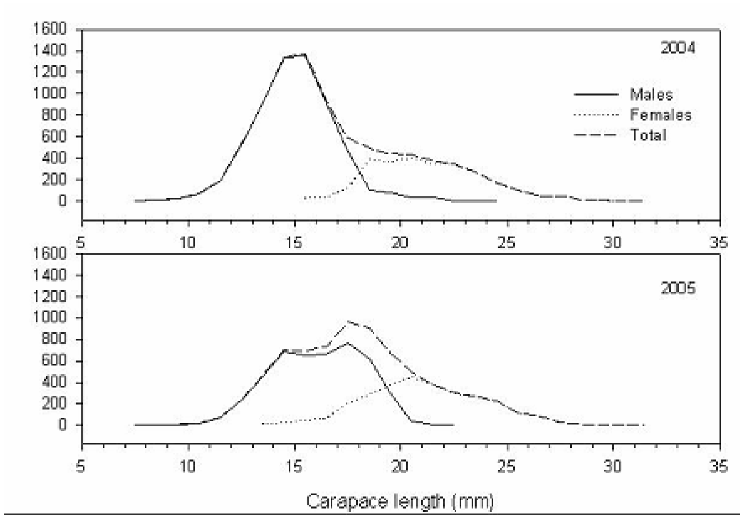


Fig. 4.8. Estimated length frequency distribution of shrimp in Skagerrak and the Norwegian deeps 2004 and 2005.

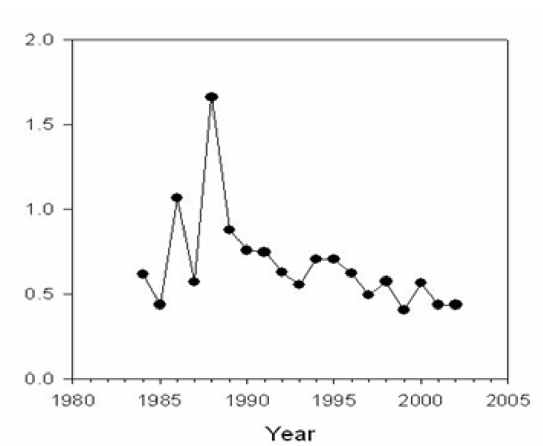


Fig. 4.9. Indices of harvest rate (survey biomasst/0.25*landingt+0.75*landingt+1t indices year).

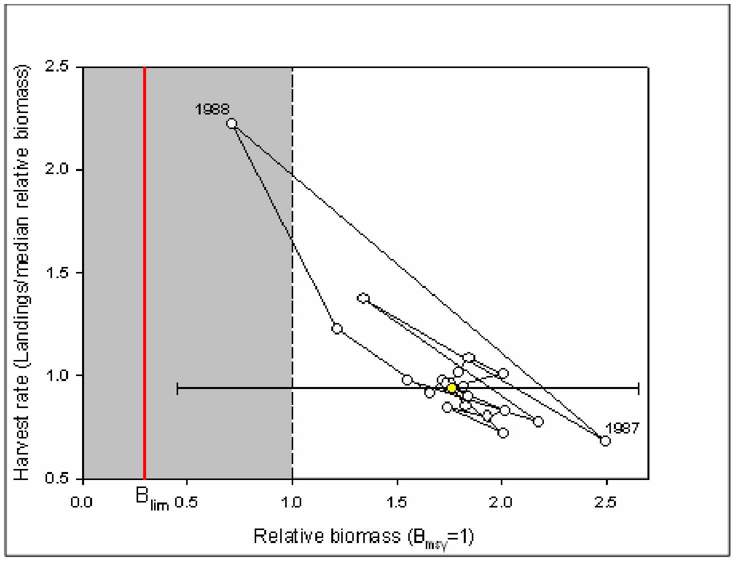


Fig. 4.10. Shrimp in Skagerrak and Norwegian Deep: Stock dynamics 1984 to 2005 in a fishing mortality/biomass continuum. Points are the median values of estimated biomass and harvest rate. Red line is limit reference point. Error bars for the 2005-value (yellow point) are 95% conf. interval.

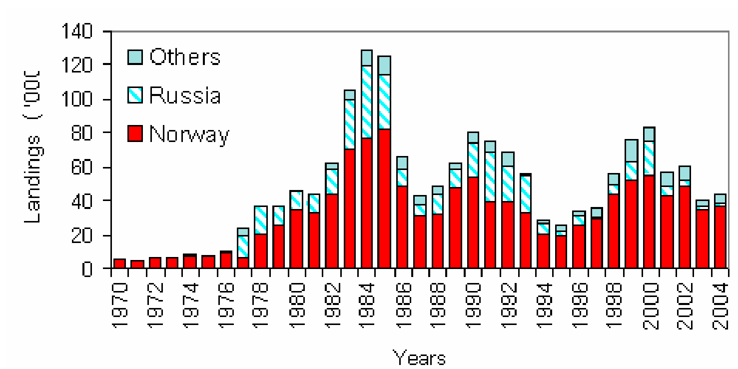


Fig. 6.1. Shrimp landings from ICES Areas I, IIa and IIb by Norway, Russia and other countries in the period 1970-2003.

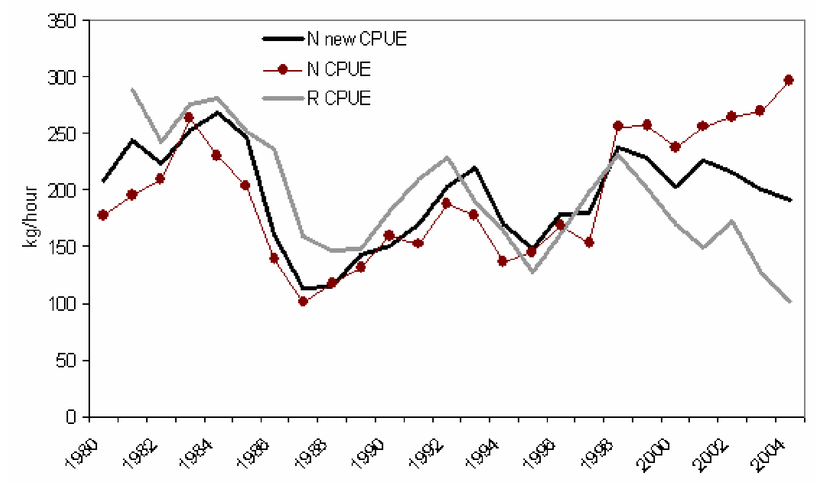


Fig. 6.2. Un-standardized Norwegian CPUE (N-CPUE), standardized CPUE to vessels with 1 000-1 550 hp and single trawl (N-new CPUE) and Russian CPUE (R-CPUE) for ICES Areas I, IIa and IIb.

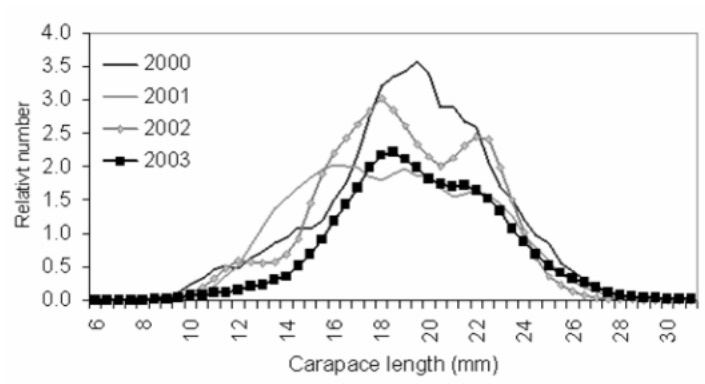


Fig. 6.3. Length distribution in Norwegian shrimp catches in 2000 to 2003.

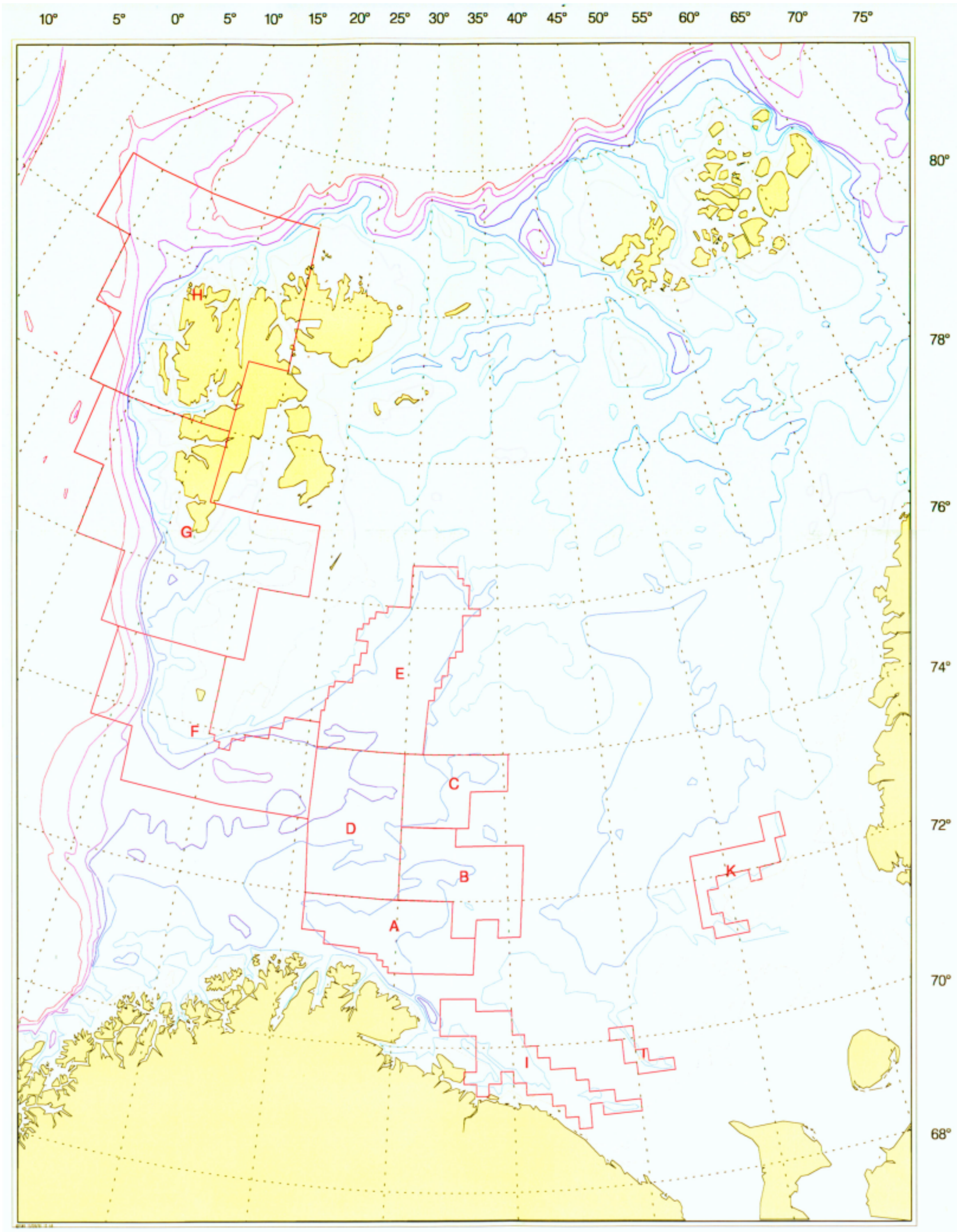


Fig. 6.4. Survey strata are combined to 9 larger areas marked with letters A to K. East Finnmark (**A**), Tiddly Bank (**B**), Thor Iversen Bank (**C**), Hopen (**E**), Bear Island (**F**), Storfjord Trench (**G**), Spitsbergen (**H**), Kola coast (**I**) and the Goose Bank (**K**) (Anon., 2003a).

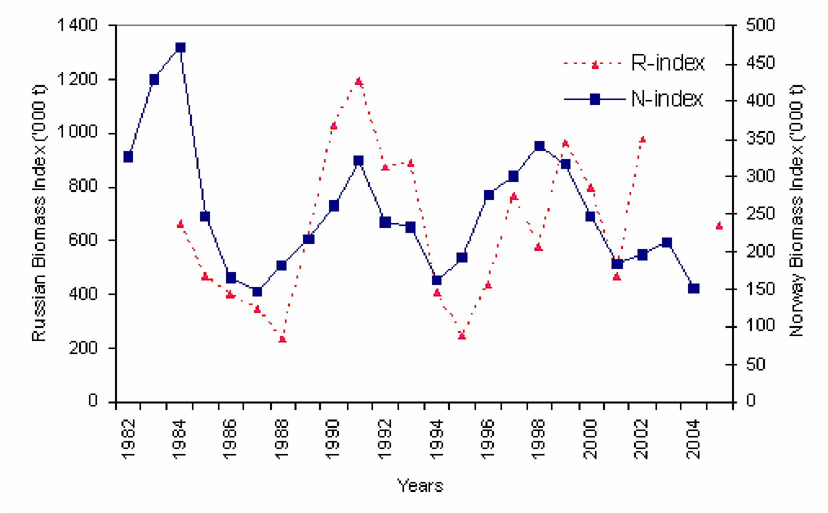


Fig. 6.5. Shrimp biomass indices from Norwegian and Russian surveys in the Barents Sea and Spitsbergen area in 1982-2005.

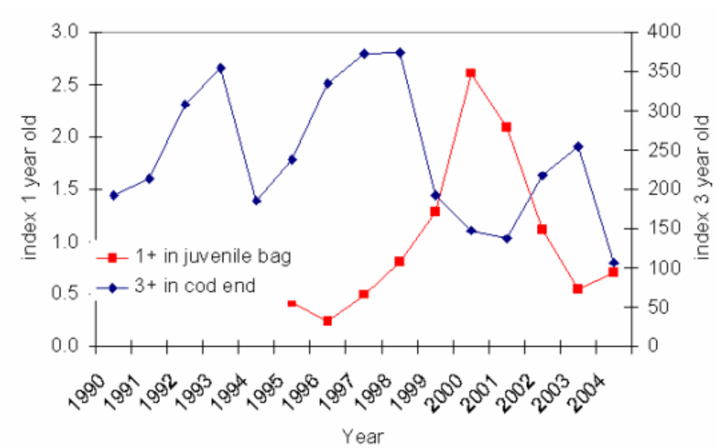


Fig. 6.6. Index for one and three year old shrimp in the Norwegian Survey 2003.

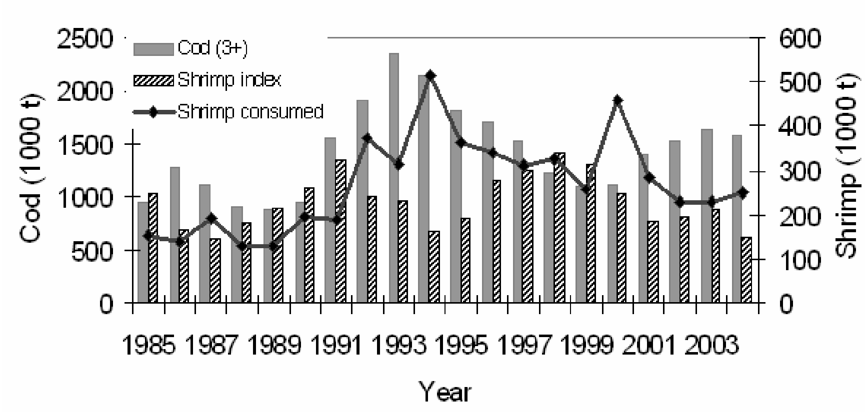


Fig. 6.7. Biomass indices for shrimp from the Norwegian surveys, biomass estimate for cod (age 3 years and older) and the shrimp consumed by the cod in the Barents Sea.

ANNEX 1: Participants

NAME	ADDRESS	PHONE	FAX	EMAIL
Michaela Aschan	Institute of Marine Research, P. O. Box 6404, 9294 Tromsø, Norway	+47 99 26 1458	+47 77 60 9701	michaela.aschan@imr.no
Sergei Bakanov	Knipovich Polar Research Institute of Marine Fisheries & Oceanography (PINRO), 6 Knipovich Street, Murmansk 183763 Russia	+81 52 47 2464	+47 789 10 518	bakanev@pinro.ru
Carsten Hvingel	Institute of Marine Research, Sykehusveien 23, PB 6404, N-9294 Tromsø Norway	+47 77 55 23 8500	+47 77 60 9701	carstenh@imr.no
Sten Munch-Petersen (Chair)	Danish Institute for Fishery Research (DIFRES) Charlottenlund Slot DK-2920 Charlottenlund Denmark	+45 33 96 3390	+45 33 96 3333	smp@dfu.min.dk
Knut Sunnanå	Institute of Marine Research, Sykehusveien 23, PB 6404, N-92494 Tromsø, Norway	+47 77 60 9735	+47 77 60 9701	knut.sunnanaa@imr.no
Guldborg Søvik	Institute of Marine Research, Sykehusveien 23, PB 6404, N-92494 Tromsø, Norway	+47 77 60 9753	+47 77 60 9701	guldborg.soevik@imr.no
Mats Ulmestrand	National Board of Fisheries Institute of Marine Research, P. O. Box 4, SE-45321 Lyseki, Sweden	+46 523 18727	+46 52313977	mats.ulmestrand@fiskeriverket.se

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 Fig. (3.1) included a stock called Farn Deep but there is no information on 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 useful 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: WGPAND Report 2005: WG Paper

SERIAL NO. N5189 **NAFO SCR DOC. 05/84**

SCIENTIFIC COUNCIL MEETING - OCTOBER/NOVEMBER 2005

Deriving Quantitative Biological Advice for the Shrimp Fishery in Skagerrak
and Norwegian Deep (ICES Divisions IVa east and IIIa)

by

C. Hvingel

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

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 13 000 tons 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:

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

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_v^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_v 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,μ), 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, 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 is 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%		1.7%
1994	3.4%	0.1%		2.4%
1995	3.0%	0.1%	Declining trend	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 13 000 tons 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.

1 REFERENCES

ANON. 2004a. Report of the Pandalus assessment working group. *ICES C.M. Doc.*, No. 2005/ACFM:05, 74 p.

ANON. 2004b. Scientific Council Reports 2004. *NAFO,* 203 p.

BERENBOIM, I. B., A. YU. LYSY, and L. I. SEREBROV. 1980. On distribution, stock state and regulation measures of shrimp (*Pandalus borealis* Krøeyer) fishery in the Barents Sea. *ICES C.M. Doc.*, No. 1980/K:**15**. 18 p.

HVINGEL, C. 2005a. Results of the Norwegian bottom trawl survey for northern shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deeps (ICES Div. IIIa and IVa) in 2004-2005. *NAFO SCR Doc.*, No. 82, Serial No. N5187, 8 p.

HVINGEL, C. 2004b. An assessment of the shrimp stock off West Greenland, 1970-2004. *NAFO SCR Doc.*, No. 76, Serial No. N5046, 15 p.

HVINGEL, C. 2005b. Construction of biological advice for the management of a northern shrimp fishery – the West Greenland example. Doctorial Thesis, Doctorial thesis. Greenland Institute of Natural Resources, Nuuk, Greenland /Norwegian College of Fishery Science, University of Tromsø, Norway, 82 p.

HVINGEL, C., and M. C. S. KINGSLEY. 2005. A framework to model shrimp (*Pandalus borealis*) stock dynamics and quantify risk associated with alternative management actions, using Bayesian methods. *ICES J. Mar. Sci.*, **62**: 00-00.

MEGREY, B. A. 1989. Review and comparison of age-structured stock assessment models from theoretical and applied points of view. *Am. Fish. Soc. Symp.*, **6**: 8-48.

SHELTON, P. A. 2004. Report of the NAFO study group on limit reference points, Lorient, France, 15-20 April 2004, 72 p.

STEFANSSON, G., U. SKULADOTTIR, and G. PETURSSON. 1994. The use of a stock production type model in evaluating the offshore *Pandalus borealis* stock of north Icelandic waters, including the predation of northern shrimp by cod. *ICES C.M. Doc.*, No. 1994/K:25, 13 p.

WIELAND, K., P. KANNEWORFF, and B. I. BERGSTRÖM. 2004. Results of the Greenland bottom trawl survey for northern shrimp (*Pandalus borealis*) off West Greenland (NAFO Subarea 1 and Division 0A), 1988-2004. *NAFO SCR Doc.*, No. 72, Serial No. N5042, 31 p.

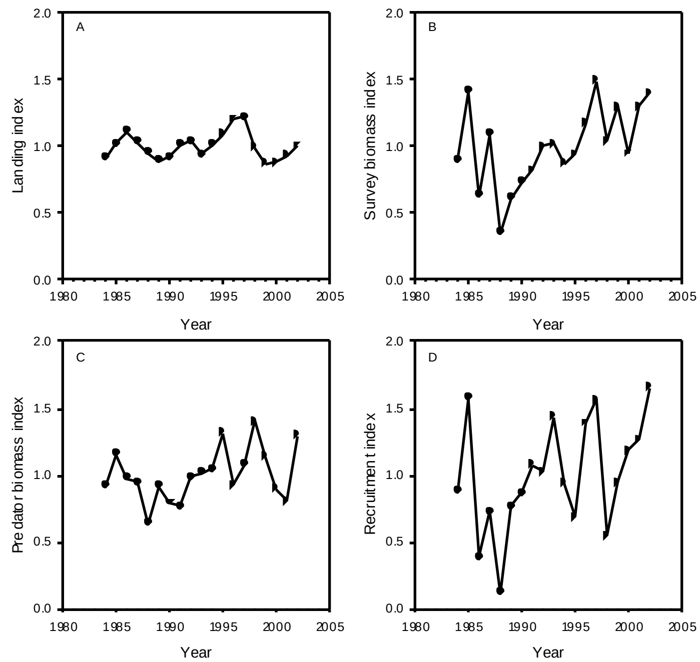


Fig. 1. Time series of landings (**A**), biomass index of age 2+ (**B**), biomass index of predators (**C**) and recruitment biomass index (age 0 and 1) (**D**) available for the biomass dynamic model used in the assessment of the shrimp stock in Skagerrak and Norwegian Deep. All scaled to their mean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

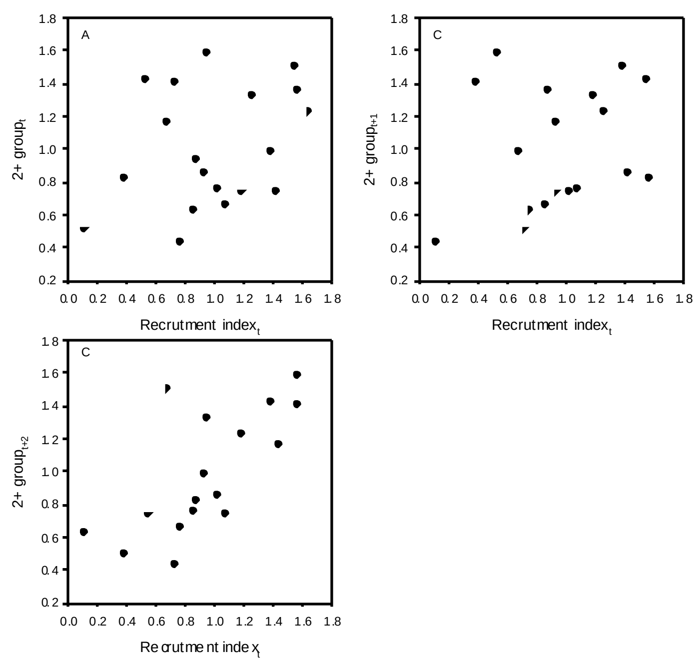


Fig. 2. Index of recruitment (biomass of age 0 and 1 from the survey) *vs.* the 2+ group survey index 0, 1 and 2 years later. The variables were scaled to their means (mean =1).

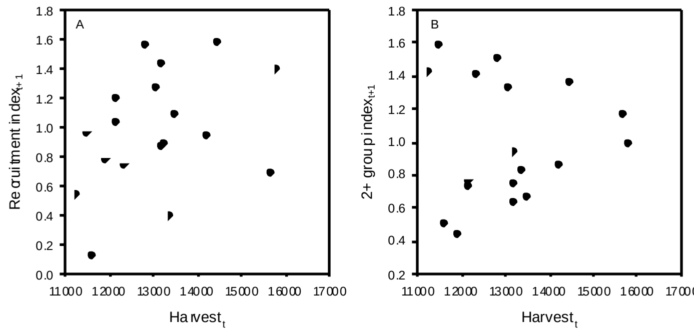


Fig. 3. Harvest (0.25*landing in year t+0.75*landings in t+1) *vs.* survey biomass of recruits (age 0 and 1s) and 2+ group scaled to their means (mean = 1).

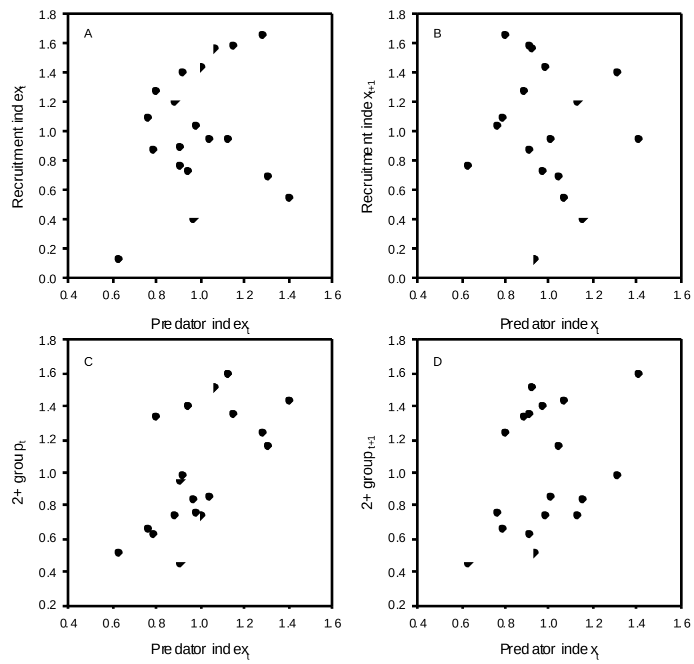


Fig. 4. Predator biomass indices from the Norwegian survey (mean = 1) *vs.* the survey recruitment and 2+ group indices in the same and following year (mean = 1).

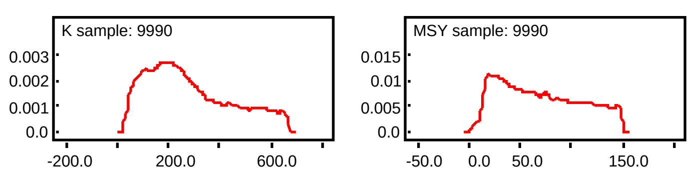


Fig. 5. Posterior probability density distributions of the carrying capacity, *K*, and maximum sustainable yield, *MSY*, derived by Monte-Carlo-Markov-Chain (MCMC) sampling methods using the model (eq. 4). The scale of the X-axis is Ktons.

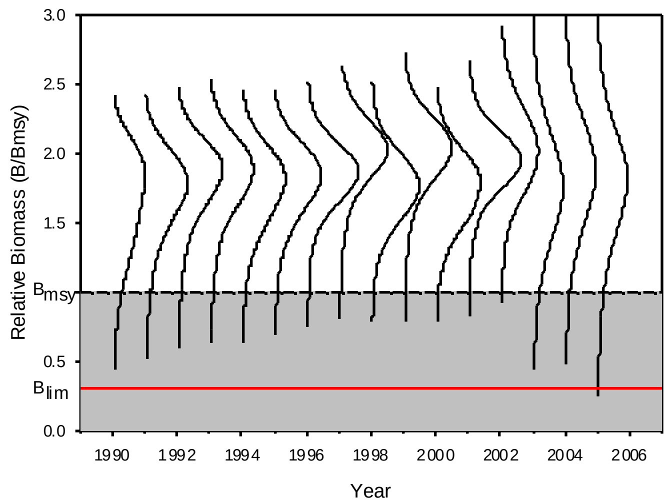


Fig. 6. Posterior probability density distributions of stock biomass (relative to B_{msy}) 1990-2006 derived by applying Bayesian inference and MCMC sampling techniques to a logistic model of shrimp stock dynamics. The 2003-2006 values are predicted due to the lack of standardized survey data after 2002.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

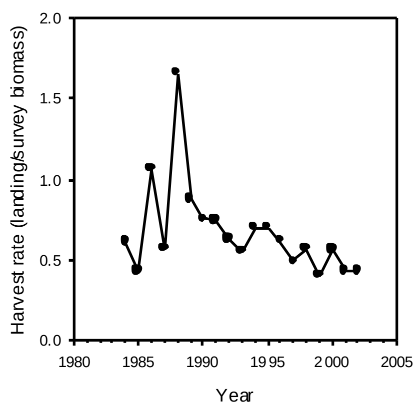


Fig. 7. An index of harvest rate (survey $biomass_t$/0.25*$landing_t$+0.75*$landing_{t+1}$ t indexes year).

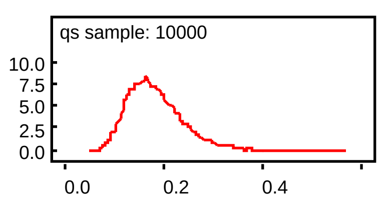


Fig. 8. Alternative informative prior for the catchability, *q* (scaling survey biomass to real biomass), based on Berenboim *et al.* (1980).

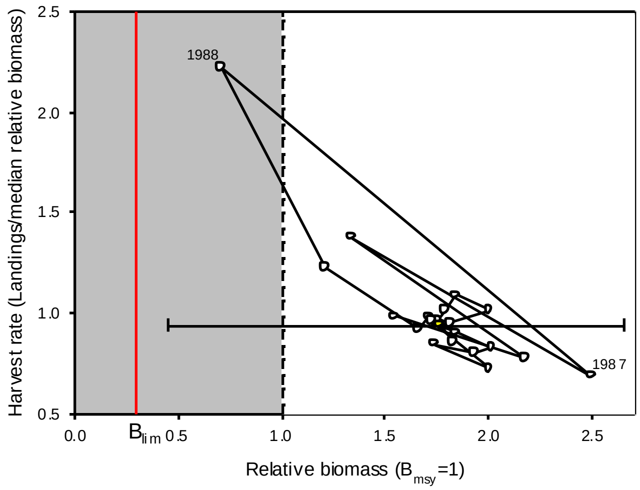


Fig. 9. Shrimp in Skagerrak and Norwegian Deep: Stock dynamics 1984 to 2005 in a fishing mortality/biomass continuum. Points are the median values of estimated biomass and harvest rate. Red line is limit reference point. Error bars for the 2005-value (yellow point) are 95% conf. interval.