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the Exploration of the Sea

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NAFO/ICES *Pandalus* Assessment Group Meeting, 9–16 September 2015

Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, Canada

NAFO/ICES *Pandalus* Assessment Group Meeting
9–16 September 2015

Contents

Report of NIPAG Meeting

9–16 September 2015

Co-Chairs: Brian Healey, Peter Shelton. Rapporteurs: Various

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met at the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland during 9-16 September 2015 to review stock assessments referred to it by the Scientific Council of NAFO and by the ICES Advisory Committee. Representatives attended from Canada, Denmark (in respect of Faroe Islands and Greenland), European Union (Denmark, Estonia, Spain and Sweden), Iceland, Norway, and the United States of America. The NAFO Scientific Council Coordinator and Scientific Information Officer were also in attendance.

II. GENERAL REVIEW

1. REVIEW OF RESEARCH RECOMMENDATIONS IN 2014

These are given under each stock in the "stock assessments" section of this report.

2. REVIEW OF CATCHES

Catches and catch histories were reviewed on a stock-by-stock basis in connection with each stock.

III. STOCK ASSESSMENTS

1. NORTHERN SHRIMP ON FLEMISH CAP (NAFO DIV. 3M)

(SCR Doc. 15/047)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- Ocean climate composite index for the Flemish Cap has trended downward since 2010 to a negative level in 2014 after 16 years of consecutive above average conditions.

- The composite spring bloom index in 3LM has shifted to negative levels in 2013-2014 after relatively high positive anomalies observed in previous 5 years.

- The composite zooplankton index has remained above normal since 2009 and reached its highest level in 2014.

- The composite trophic index increased to its highest level in 2014.

a) Introduction

The shrimp fishery in Div. 3M is now under moratorium. This fishery began in 1993. Initial catch rates were favorable and, shortly thereafter, vessels from several nations joined. Catches peaked at over 60 000 t in 2003 and declined thereafter.

Fishery and catches: A moratorium was imposed in 2011. Catches are expected to be close to zero in 2015. Recent catches were as follows:

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
NIPAG	18000	21000	13000	5000	2000	0	0	0	0	0[1]
STATLANT 21	15191	17642	13431	5374	1976	0	0	0	0	
SC Recommended Catches	48000	48000	17000–32000	18000–27000	ndf	ndf	ndf	ndf	ndf	ndf
Effort[2] (Agreed Days)	10555	10555	10555	10555	5227	0	0	0	0	0

1 To September 2015
2 Effort regulated

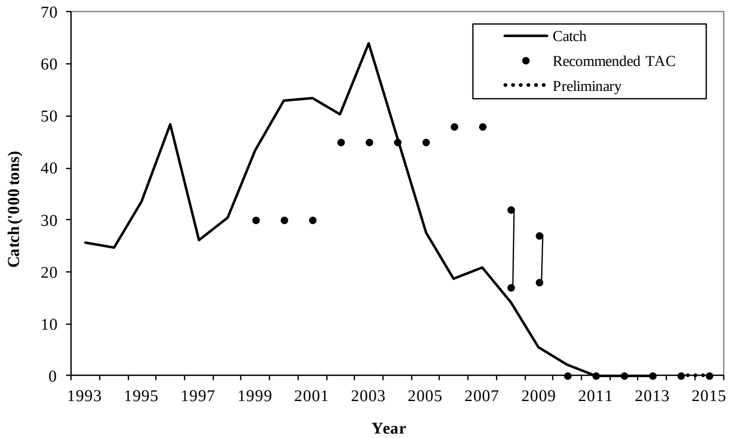

Fig. 1.1. Shrimp in Div. 3M: Catches (t) of shrimp on Flemish Cap and TACs recommended in the period 1993-2015. Due to a moratorium, the shrimp catch is expected to be zero in 2015.

b) Input Data

i) Commercial fishery data

Time series of size and sex composition data were available mainly from Iceland and Faroes between 1993 and 2005. Because of the moratorium catch and effort data have not been available since 2010, and therefore the standardized CPUE series has not been extended.

ii) Research Survey Data

Stratified-random trawl surveys have been conducted on Flemish Cap by the EU in July from 1988 to 2015. A new vessel was introduced in 2003 which continued to use the same trawl employed since 1988. In addition, there were differences in cod-end 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 using the methods accepted by STACFIS in 2004 (NAFO 2004 SC Rep., SCR Doc. 04/77).

c) Assessment Results

No analytical assessment is available. Evaluation of stock status is based upon interpretation of commercial fishery up to 2010, and research survey data.

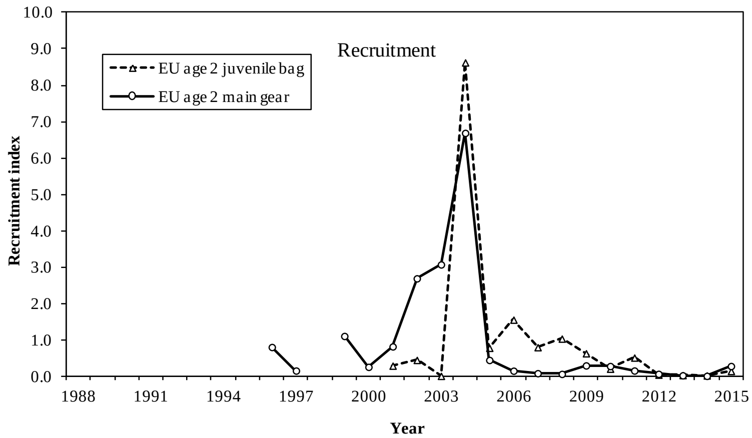

Fig. 1.2. Shrimp in Div. 3M: Abundance indices at age 2 from the EU survey. Each series was standardized to its mean.

Recruitment: All year-classes after the 2002 cohort (i.e. age 2 in 2004) have been weak

SSB: The survey female biomass index was stable at a high level from 1998 to 2007, and has declined since then. In 2015 although the female biomass increased (48%) over 2014, the estimated biomass (1057 t.) remained among the lowest recorded in the historical series, well below B_{lim}.

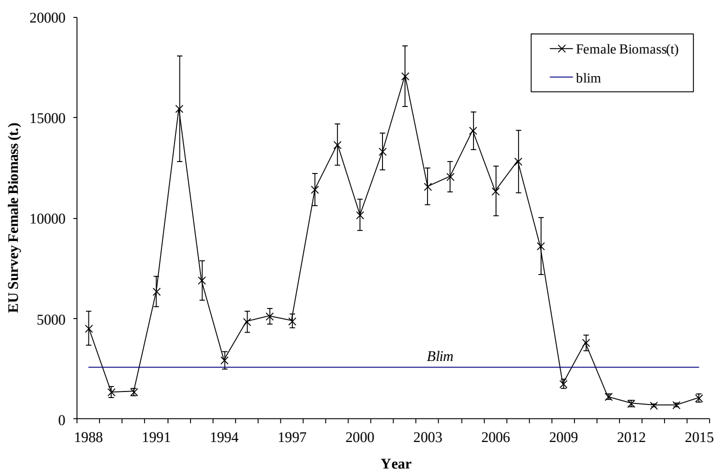

Fig. 1.3. Shrimp in Div. 3M: Female biomass index from EU trawl surveys, 1988-2015. Error bars are 1 std. err.

Exploitation rate: Because of low catches, followed by the moratorium, the exploitation rate index (nominal catch divided by the EU survey biomass index of the same year) has declined to near zero.

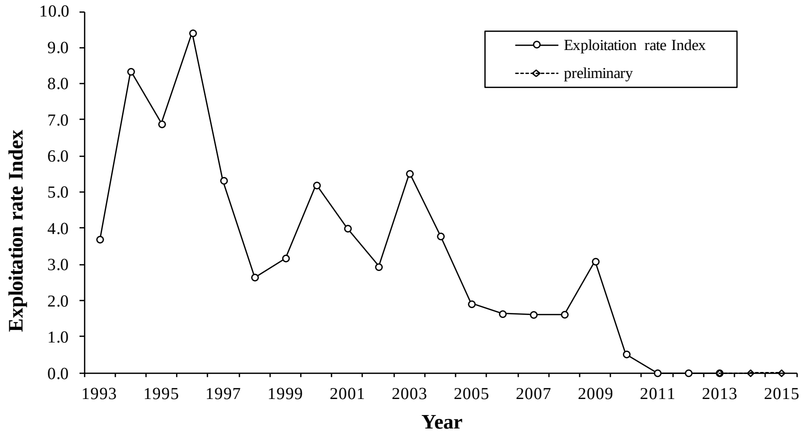

Fig. 1.4. Shrimp in Div. 3M: exploitation rate index as derived by catch divided by the EU survey biomass index of the same year.

d) State of the Stock

Following several years of low recruitment, the spawning stock has declined, and has remained below B_{lim} since 2011. Due to continued poor recruitment there are concerns that the stock will remain at low levels.

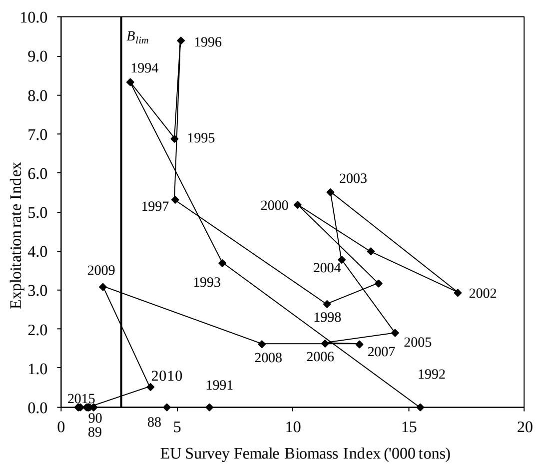

Fig. 1.5. Shrimp in Div. 3M: Exploitation rate index plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 15% of the maximum point in 2002. Due to the moratorium on shrimp fishing the expected catch in 2015 is 0 t.

e) Reference Points

Scientific Council considers that a female survey biomass index of 15% of its maximum observed level provides a proxy for B_{lim}. This corresponds to an index value of 2 564. The index has been below B_{lim} since 2010. A limit reference point for fishing mortality has not been defined.

f) Ecosystem considerations

The drastic decline of shrimp biomass since 2007 correlates with the increase of the cod stock in Div. 3M. It is uncertain whether this represents a causal relationship and/or covariance as the result of an environmental factor.

The environment, trophic interactions, and fisheries are important drivers of fish stock dynamics. Analyses of fish stomachs over 1990 to 2012 show an increasing proportion of shrimp in the diets of most fish species. Since the early 2000s, there has been an increase of redfish in the diet of large individuals of predatory species. These trends are observed throughout the Flemish Cap fish community.

Results of modelling suggest that, in unexploited conditions, cod would be expected to be a highly dominant component of the system, and high shrimp stock sizes, like the ones observed in the 1998 – 2007 period, would not be a stable feature in the Flemish Cap.

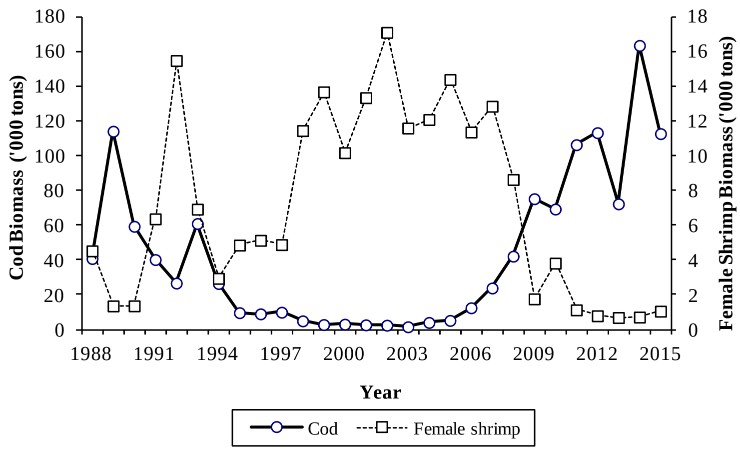

Fig. 1.6. Shrimp in Div. 3M: Cod and total shrimp biomass from EU trawl surveys, 1988-2015.

g) Research Recommendations

For Northern Shrimp in Div. 3M NIPAG **recommends** that *further exploration of the relationship between shrimp, cod and the environment be continued in WGESA and NIPAG encourages the shrimp experts to be involved in this work.*

No progress.

2. NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN NAFO DIV. 3LNO

(SCR Doc. 14/048, 15/048, /055)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

● Ocean climate composite index on the Grand Bank transitioned to a weak negative value in 2014 after 16 consecutive years of above normal conditions, similar to the pattern observed on the Flemish Cap.

●The composite spring bloom index has returned to near normal in 2014 after negative anomalies observed in 2012-2013.

●The composite zooplankton index has remained above normal since 2009.

●The composite trophic index has remained near normal in recent years.

a) Introduction

This shrimp stock is distributed around the edge of the Grand Bank, mainly in Div. 3L. The fishery began in 1993 and came under TAC control in 2000 with a 6 000 t TAC and fishing restricted to Div. 3L. Annual TACs were raised several times between 2000 and 2009 reaching a level of 30 000 t for 2009 and 2010. The TAC was then reduced annually until no directed fishing was implemented for 2015 (Fig. 2.1). The TAC entries in the table have been updated with corrected autonomous TACs from Denmark and the STATLANT 21 entries updated from the NAFO website.

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

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TAC[1]	24029	24029	27306	32767	32767	20971	13108	9393	4697	ndf
STATLANT 21	22377	22315	26097	27236	19745	13013	10204	8524	2289	
NIPAG[2]	25689	23570	25407	25900	20536	12900	10108	8647	2289	

[1] Includes autonomous TAC as set by Denmark.
[2] NIPAG catch estimates have been updated using various data sources (see p. 13, SCR. 14/048).

Since this stock came under TAC regulation, Canada has been allocated 83% of the TAC. This allocation is split between a small-vessel (less than 500 GT and less than 65 ft) and a large-vessel fleet. The annual quota within the NAFO Regulatory Area (NRA) is 17% of the total TAC. Denmark (Faroes and Greenland) did not agree to the quotas during the years 2003-2014 and set their own TACs at about 10% of the total NAFO recommended TAC rather than the 1% recommended for them by NAFO.

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

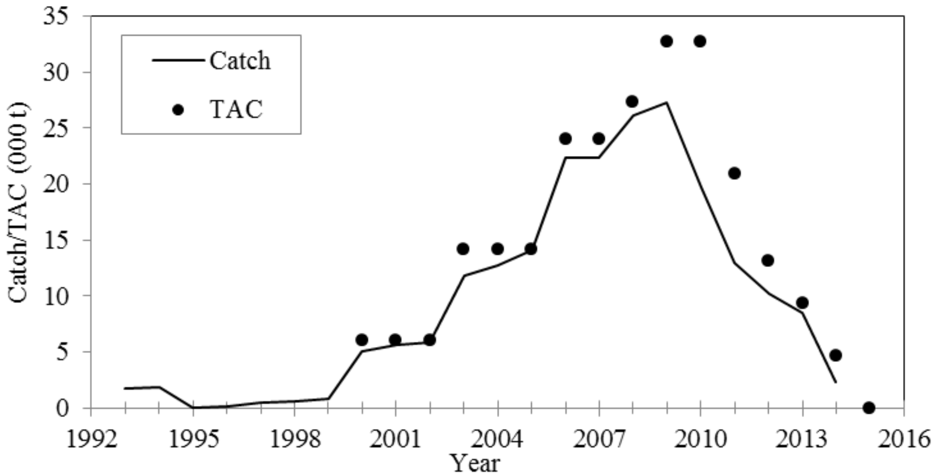

Fig. 2.1. Shrimp in Div. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas, set by Denmark, with respect to Faroes and Greenland.

b) Input Data

i) Commercial fishery data

Effort and CPUE.

Catch and effort data have been available from vessel logbooks and observer records since 2000, however there was no fishery in 2015 and observer records utilized for large vessel CPUE are not yet available for 2014. The 2010 - 2014 indices for small vessel CPUEs were significantly lower than the long term mean and were similar to the 2001 values while the large vessel CPUEs were the lowest in the time series (Fig. 2.2). CPUE, while reflecting fishery performance, is not effectively indicating the status of the resource. The trends of these CPUE indices show conflicting patterns with the survey biomass indices and were therefore not used as indicators of stock biomass.

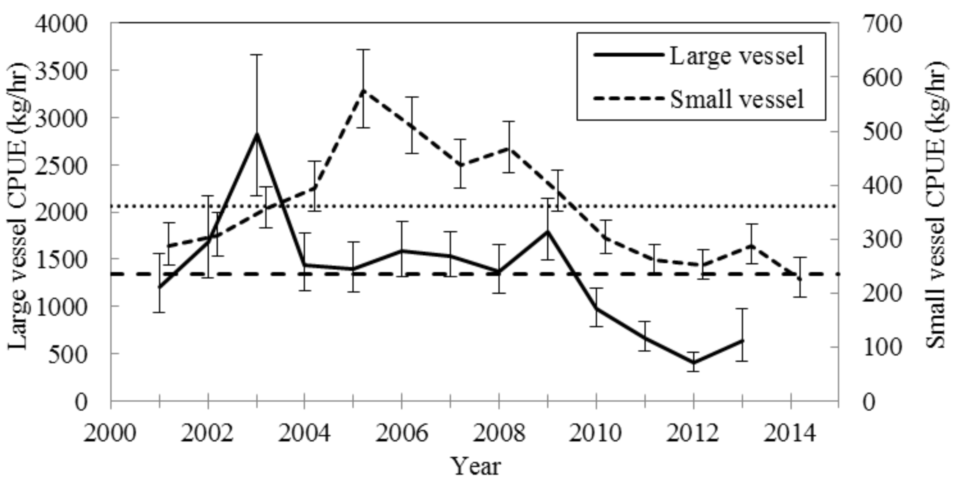

Fig. 2.2. Shrimp in Div. 3LNO: Standardized CPUE for the Canadian large-vessel (>500 t) and small-vessel (≤500 t; LOA<65') fleets fishing shrimp in Div. 3L within the Canadian EEZ.

Logbook data from Spain and Estonia, were available for the shrimp fishery within the NRA in 2014. The data was insufficient to produce a standardized CPUE model.

Catch composition. Length compositions were derived from Canadian (2003 – 2012) and Estonian (2010 – 2014) observer datasets. Catches appeared to be represented by a broad range of size groups of both males and females.

ii) Research survey data

Canadian multi-species trawl survey. Canada has conducted stratified-random surveys in Div. 3LNO, using a Campelen 1800 shrimp trawl, from which shrimp data is available for spring (1999–2015) and autumn (1996–2014). The autumn survey in 2004 and the spring survey in 2015, were incomplete and therefore of limited use for the assessment. The autumn 2014 survey only surveyed Div. 3L, however since about 95% of the biomass in Div. 3LNO comes from 3L, it was considered useful as a proxy for Div. 3LNO in 2014.

Results from a revised version of Ogmap were presented in comparison to the version utilized in previous years. The meeting decided to continue with the previous version for use and incorporation into this report. Work will continue on the new version for future assessments. **Spanish multi-species trawl survey**. EU-Spain has been conducting a stratified-random survey in the NRA part of Div. 3L since 2003. Data is collected with a Campelen 1800 trawl. There was no Spanish survey in 2005.

Biomass. In Canadian surveys, over 90% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185 to 550 m. Since Div. 3NO was not sampled during autumn 2014, the biomass index displayed for that season and year is based solely on Div. 3L. There was an overall increase in both the spring and autumn indices to 2007 after which they decreased by over 90% to 2013. The spring 2014 survey index increased compared to 2013, however the autumn index decreased further (Fig. 2.3). Confidence intervals from the spring surveys are usually broader than from the autumn surveys.

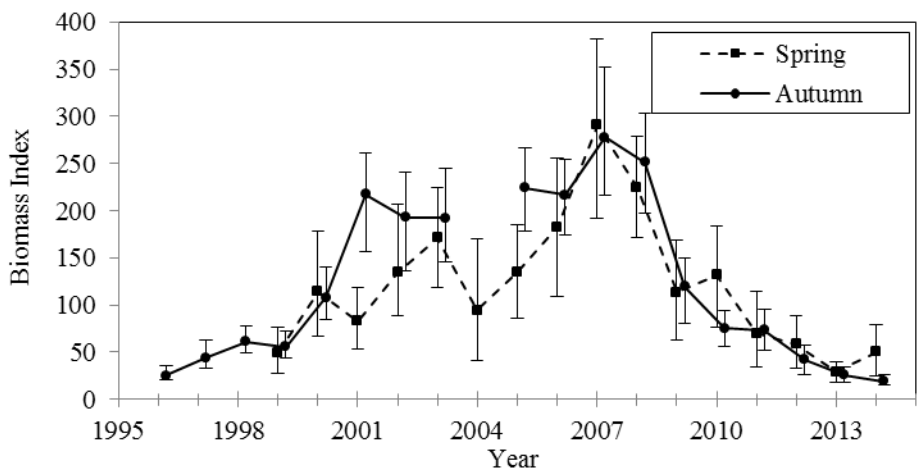

Fig. 2.3. Shrimp in Div. 3LNO: Total biomass index estimates from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only.

Spanish survey biomass indices for Div. 3LNO, within the NRA only, increased from 2003 to 2008 followed by a 93% decrease by 2012 remaining near that level through 2015 (Fig. 2.4).

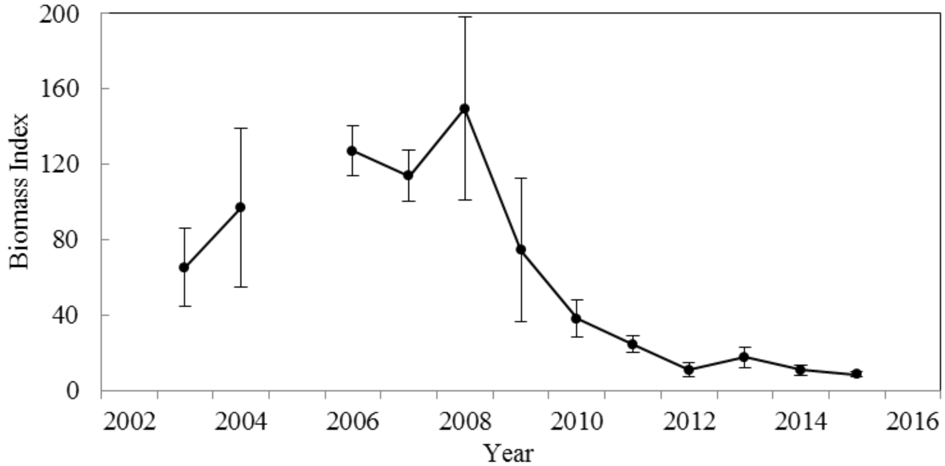

Fig. 2.4. Shrimp in Div. 3LNO: Biomass index estimates from EU - Spanish multi-species surveys (± 1 s.e.) in the NRA of Div. 3LNO.

Female Biomass (SSB) indices. The spring Div. 3LNO female SSB index decreased by 91% between 2007 and 2013, however it increased slightly in 2014. The autumn SSB index showed an increasing trend to 2007 but decreased 92% by 2014 (Fig. 2.5).

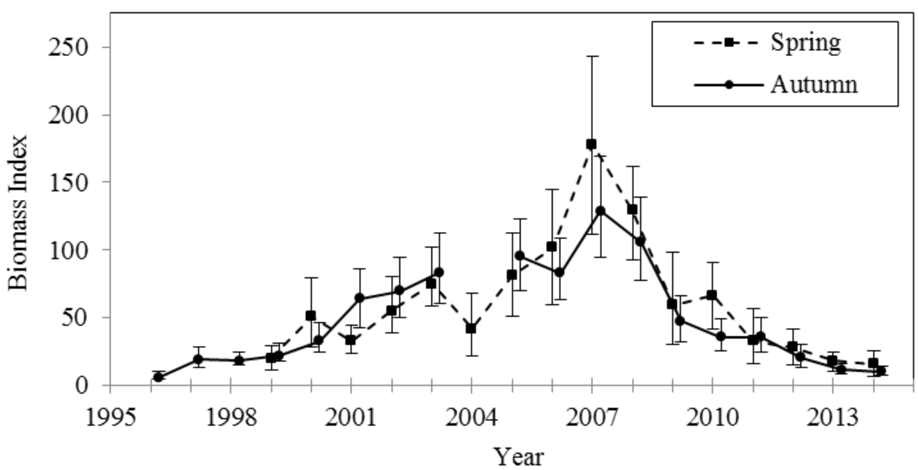

Fig. 2.5. Shrimp in Div. 3LNO: Female SSB indices from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The autumn index for 2014 is for Div. 3L only.

Stock Composition.

Both males and females showed a broad distribution of lengths in recent surveys indicating the presence of more than one year class (Fig. 2.6).

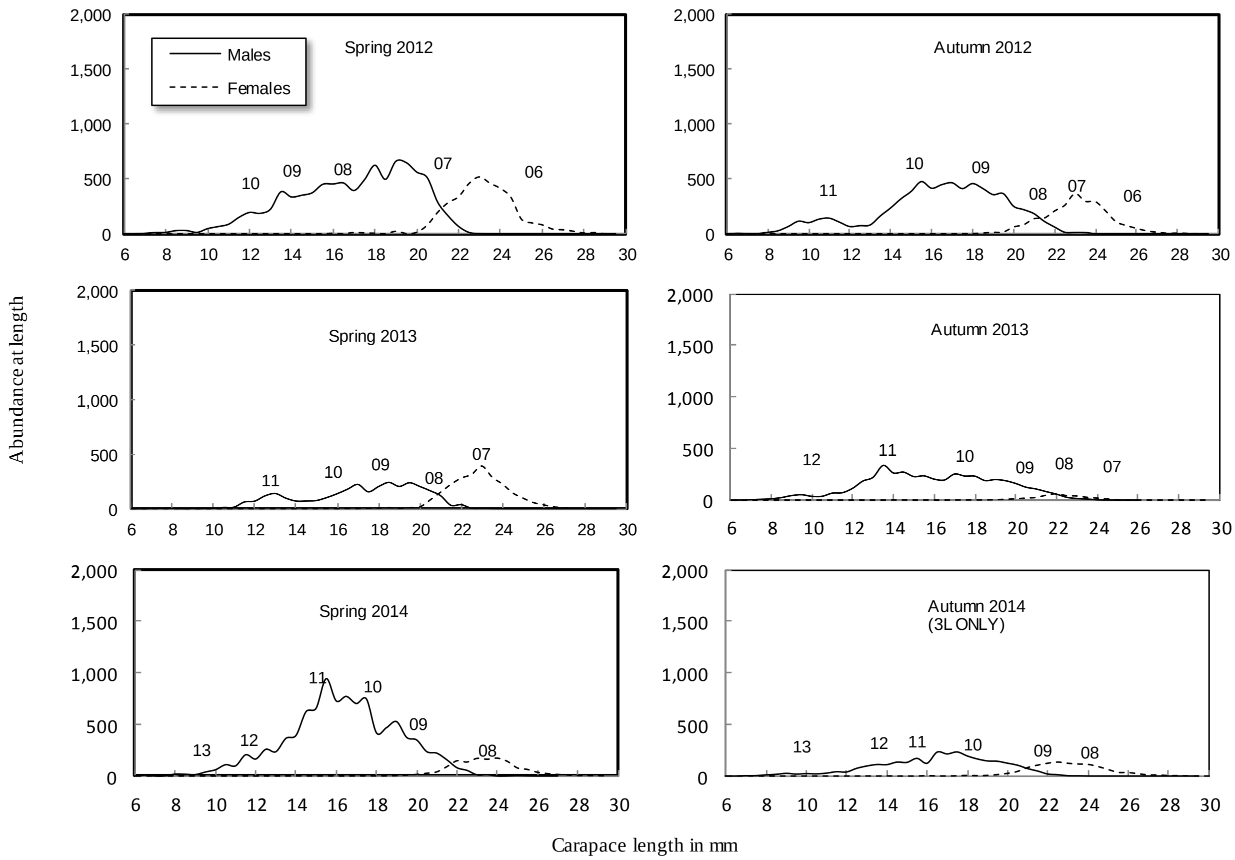

Fig. 2.6. Shrimp in Div. 3LNO: Abundance at length estimates, from Canadian multi-species survey data, as calculated using Ogmap. The numbers within each plot indicate likely year classes.

Recruitment indices. The recruitment indices were based upon abundance indices of all shrimp with carapace lengths of 11.5 – 17 mm from Canadian multi-species survey data. These animals are thought to be one year away from the fishery. The 2006 – 2008 recruitment indices were among the highest in both spring and autumn time series. Both indices decreased through to autumn 2013. The spring index increased in 2014, with a high degree of uncertainty (Fig. 2.7). The increase in the spring 2014 index was highly influenced by a couple large catches of small male shrimp, however there were no evidence that they contributed to the biomass in autumn 2014 and recruitment still appears to be low.

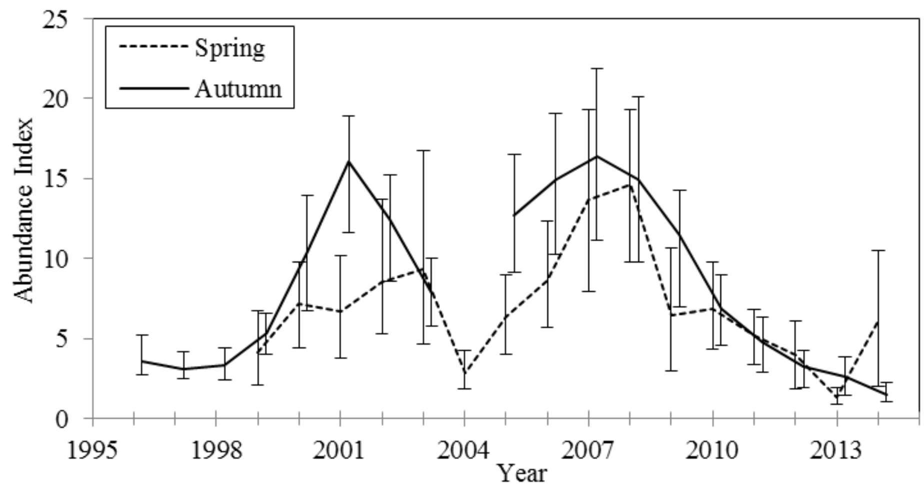

Fig. 2.7. Shrimp in Div. 3LNO: Recruitment indices derived from abundances of all shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn bottom trawl survey (1996–2014) data. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

Fishable biomass and exploitation index. The spring fishable biomass (shrimp > 17mm CL) index increased to 2007 but has since decreased by 89% through to 2013 followed by a slight increase during 2014. Similarly, the autumn fishable biomass showed an increasing trend until 2007 then decreased by 93% through to 2014 (Fig. 2.8).

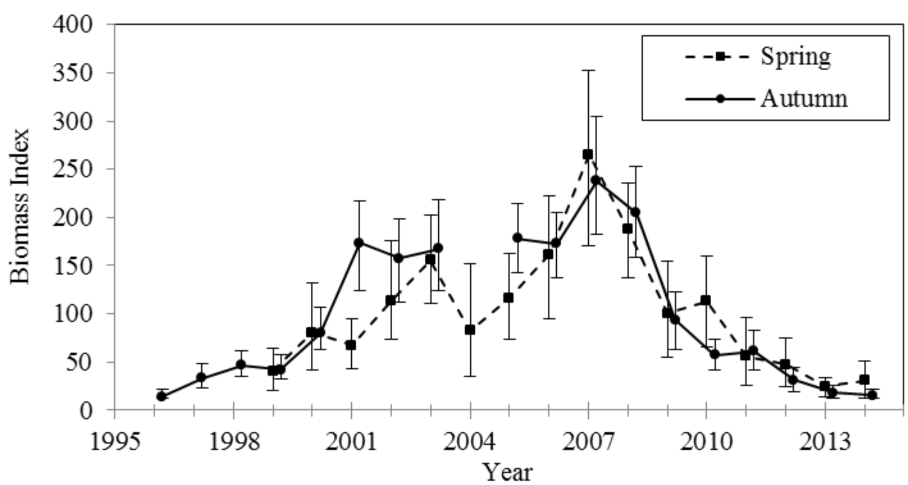

Fig. 2.8. Shrimp in Div. 3LNO: fishable (shrimp >17mm CL) biomass index. Bars indicate 95% confidence limits. The autumn index for 2014 is for Div. 3L only.

An index of exploitation was derived by dividing the catch in a given year by the fishable biomass index from the previous autumn survey. The exploitation index generally increased throughout the course of the fishery until dropping sharply in 2014. (Fig. 2.9). The exploitation rate for 2015 is not illustrated but is expected to be 0.

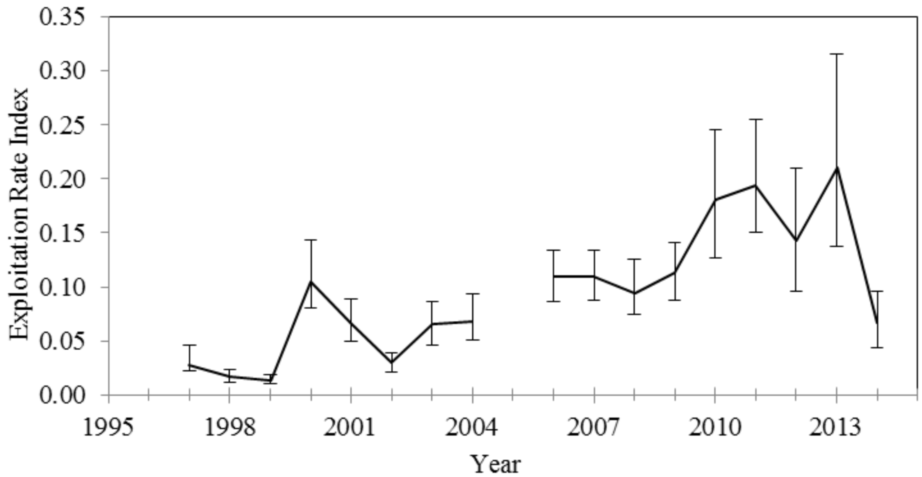

Fig. 2.9. Shrimp in Div. 3LNO: exploitation rates calculated as a year's catch divided by the previous year's autumn fishable biomass index. Bars indicate 95% confidence limits.

c) Assessment Results

Recruitment. Recruitment indices have decreased since 2008 and are now among the lowest observed values.

Biomass. Spring and autumn biomass indices have decreased considerably since 2007 and are now among the lowest observed values.

Exploitation. The index of exploitation generally increased over the 1997 – 2013 period but declined sharply in 2014 and is expected to be zero in 2015.

State of the Stock. The stock has declined since 2007, and in 2014 the risk of being below B_{lim} is greater than 95%.

Given expectations of poor recruitment, the stock is not predicted to increase in the near future.

d) Reference Points

The point at which a valid index of stock size has declined to 15% of its highest observed value is considered to be B_{lim} (SCS Doc. 04/12). The 2014 autumn female biomass index, for Div. 3L, was 10 000 t, and in 2014 the risk of being below B_{lim} was greater than 95% (Fig 2.10). A limit reference point for fishing mortality has not been defined.

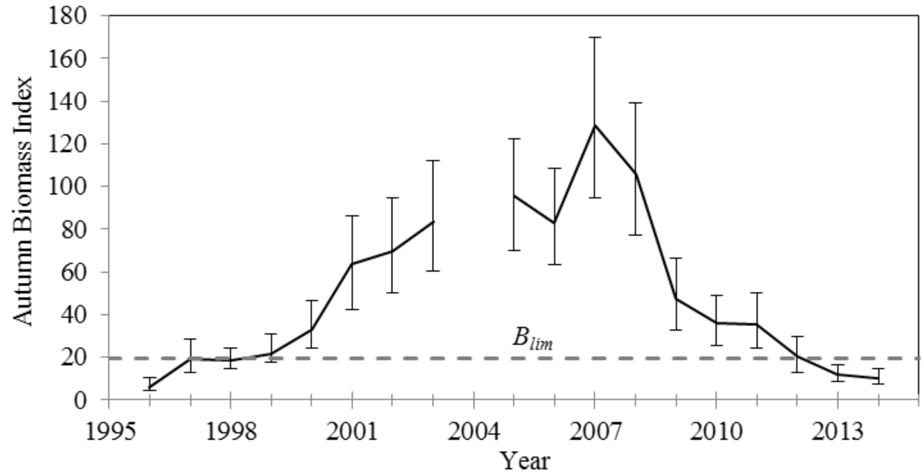

Fig. 2.10. Shrimp in Div. 3LNO: autumn female spawning stock biomass (SSB) and precautionary approach B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time series. Bars indicate 95% confidence limits. The autumn index for 2014 is for Div. 3L only.

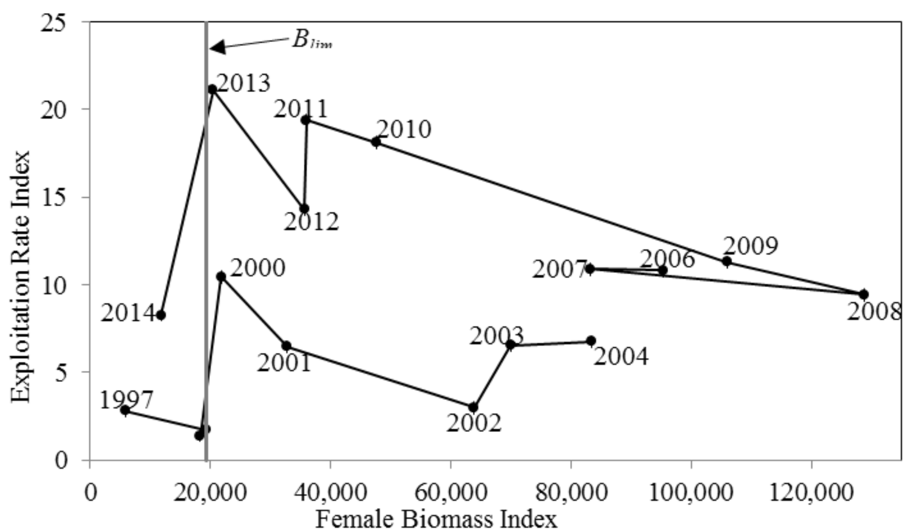

Fig. 2.11. Shrimp in Div. 3LNO: Exploitation rate against female SSB index from Canadian autumn survey. Line denoting B_{lim} (19 330 t) is drawn where female biomass index is 15% of the maximum estimate throughout the time series.

e) Research Recommendations

It is **recommended** that *ecosystem information related to the role of shrimp as prey in the Grand Bank (i.e. 3LNO) Ecosystem be presented to the 2016 NIPAG meeting.*

3. NORTHERN SHRIMP (NAFO SUBAREAS 0 AND 1)

(SCR Docs 04/75, 04/76, 08/6, 11/53, 11/58, 12/44, 13/54, 15/042, 15/043, 15/044, 15/048, 15/049; SCS Doc. 04/12)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

● *The composite climate index in Subarea 1 has remained above or near normal in recent years but has trended downward from the record-high in 2010.*

● *The composite spring bloom index remains well below normal since 2012.*

a) Introduction

The shrimp stock off West Greenland is distributed mainly in NAFO Subarea 1 (Greenland EEZ), but a small part of the habitat, and of the stock, intrudes into the eastern edge of Div. 0A (Canadian EEZ). Canada has defined 'Shrimp Fishing Area 1' (Canadian SFA1), to be the part of Div. 0A lying east of 60°30'W, i.e. east of the deepest water in this part of Davis Strait.

The stock is assessed as a single population. The Greenland fishery exploits the stock in Subarea 1 (Div. 1A–1F). Since 1981 the Canadian fishery has been limited to Div. 0A.

Three fleets, one from Canada and two from Greenland (offshore and coastal) have participated in the fishery since the late 1970s. The Canadian fleet and the Greenland offshore fleet have been restricted by areas and quotas since 1977. The Greenland coastal fleet has privileged access to inshore areas (primarily Disko Bay and Vaigat in the north, and Julianehåb Bay in the south). Coastal licences were originally given only to vessels under 80 tons, but in recent years larger vessels have entered the coastal fishery. Greenland allocates a quota to EU vessels in Subarea 1; this quota is usually fished by a single vessel which, for analyses, is treated as part of the Greenland offshore fleet. Mesh size is at least 44 mm in Greenland, 40 mm in Canada. Sorting grids to reduce bycatch of fish are required in both of the Greenland fleets and in the Canadian fleet. Discarding of shrimps is prohibited.

The TAC advised for the entire stock for 2004–2007 was 130 000 t, reduced for 2008–2010 to 110 000 t and increased again for 2011 to 120 000 t. The TAC advised for 2012 was 90 000t. For 2012, Greenland enacted a TAC of 101 675 t for Subarea 1; Canada enacted a TAC of 16 921 t for SFA 1. Further deterioration of the assessed status of the stock in 2012 induced yet lower advised TACs of 80 000 t for 2013 and 2014 and 60 000 t for 2015. In 2015 Greenland enacted a TAC of 71 061 t with quotas of 2 000, 39 365 and 29 696 t, and Canada a TAC of 8 500 t.

Greenland requires that logbooks should record catch live weight. For shrimps sold to on-shore processing plants, a former allowance for crushed and broken shrimps in reckoning quota draw-downs was abolished in 2011 to bring the total catch live weight into closer agreement with the enacted TAC. However, in previous years, the coastal fleet catching bulk shrimps did not log catch weights of *P. montagui* separately from *borealis;* weights were estimated by catch sampling at the point of sale and the price adjusted accordingly, but the weight of *montagui* was not deducted from the quota (SCR Doc. 11/53). Logbook-recorded catches could therefore still legally exceed quotas. Since 2012 *P. montagui* has been included among the species protected by a 'moving rule' to limit bycatch and there are no licences issued for directed fishing on it (SCR Doc. 15/42). Instructions for reporting *montagui* in logbooks were changed in 2012, to improve the reporting of these catches.

The table of recent catches was updated (SCR Doc. 15/48). Total catch increased from about 10 000 t in the early 1970s to more than 105 000 t in 1992 (Fig. 3.1). Moves by the Greenlandic authorities to reduce effort, as well as fishing opportunities elsewhere for the Canadian fleet, caused catches to decrease to about 80 000 t by 1998. Total catches increased to average over 150 000 t in 2005–08, but have since decreased, to 88 765 t in 2014 and 65 000 t (projected) in 2015.

Recent catches, projected catches for 2015 and recommended and enacted TACs (t) for Northern Shrimp in Div. 0A south of 73°30N and east of 60°30'W and in Subarea 1 are as follows:

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TAC										
Advised	130 000	130 000	110 000	110 000	110 000	120 000	90 000	80 000	80 000	60 000
Enacted[3]	152 380	152 417	145 717	132 987	132 987	142 597	118 596	102 767	94 140	79 561
Catches (NIPAG)										
SA 1	153 188	142 245	153 889	135 029	128 108	122 655	115 963	95 379	88 765	*65 000*[1]
Div. 0A (SFA 1)	4127	1945	0	429	5882	1 330	12	2	0	0
TOTAL SA 1–Div. 0A	157 315	144 190	153 889	135 458	133 990	123 985	115 975	95 380	88 765	*65 000*[1]
STATLANT 21										
SA 1	153 188	142 245	148 550	133 561	123 973	122 061	114 958	91 800	88 834[2]	
Div. 0A	3788	1878	0	429	5206	1134	12	2	0	

[1] Total catches for the year as predicted by industry observers.
[2] Provisional
[3] Canada and Greenland set independent autonomous 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. However, since about 1996 catch and effort in southern West Greenland have continually decreased, and since 2008 effort in Div. 1F has been virtually nil (SCR Doc. 15/42).

In 2002–2005 the Canadian catch in SFA1 was stable at 6000 to 7000 t - about 4–5% of the total - but since 2007 fishing effort has been sporadic and catches variable, averaging about 1750 t in 2007–11 and since 2012 no fishing has been conducted in SFA1 (SCR Doc. 15/48).

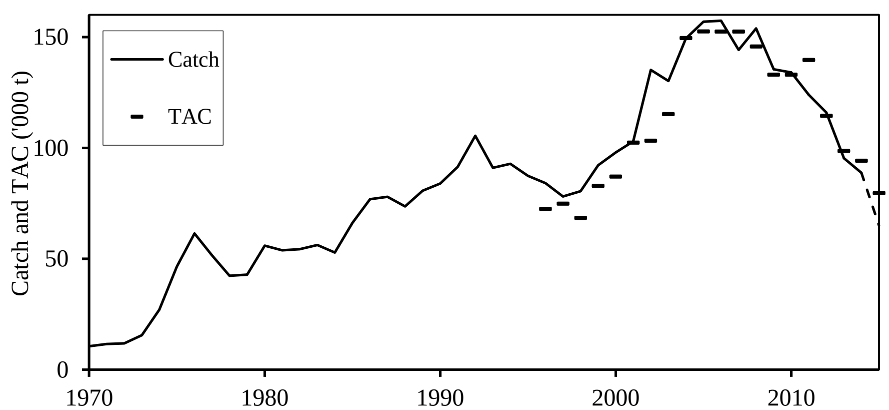

Fig. 3.1. Northern shrimp in Subarea 1 and Canadian SFA1: enacted TACs and total catches (2015 predicted for the year).

b) Input Data

i) Fishery data

Fishing effort and CPUE. Catch and effort data from the fishery were available from logbooks from Canadian vessels fishing in Canadian SFA 1 and from Greenland logbooks for Subarea 1 (SCR Doc. 15/42). In recent years both the distribution of the Greenland fishery and fishing power have changed significantly: for example, larger vessels have been allowed in coastal areas; the coastal fleet has fished outside Disko Bay; the offshore fleet now commonly uses double trawls; and the previously rigid division between the offshore and coastal quotas has been relaxed and quota transfers between the two fleets are now allowed. A change in legislation effective since 2004 requiring logbooks to record catch live weight in place of a previous practice of under-reporting would, by increasing the recorded catch weights, have increased apparent CPUEs since 2004; this discontinuity in the CPUE data was corrected in 2008.

CPUEs were standardised by linearised multiplicative models including terms for vessel, month, year, and statistical area; the fitted year effects were considered to be series of annual indices of total stock biomass. Series for the Greenland fishery after the end of the 1980s were divided into 2 fleets, a coastal and an offshore; for those ships of the present offshore fleet that use double trawls, only double-trawl data was used. In 2013 for the first time catch and effort data for statistical area 0, which extends north to 73°30N, comprises about 82 000 sq. km. and in 2007–14 yielded 17% of the offshore catch, was included in the CPUE analyses. A series for 1976–1990 was constructed for the KGH (Kongelige Grønlandske Handel) fleet of sister trawlers and a series for 1989–96, 1998–2007 and 2010–11 for the Canadian fleet fishing in SFA1 (Fig. 3.2). The standardised CPUE estimate for the Canadian fleet in 2011 was anomalously low; close examination of the data confirmed that there had been low catch rates and little fishing. This value has little influence on the unified series.

The four CPUE series were unified in a separate step to produce a single series that was input to the assessment model. This all-fleet standardised CPUE was variable, but on average moderately high, from 1976 through 1987, but then fell to lower levels until about 1997, after which it increased markedly to peak in 2008 at over twice its 1997 value (Fig. 3.2). Values for 2009 to 2015 have been lower but remain relatively high (SCR Doc. 15/42).

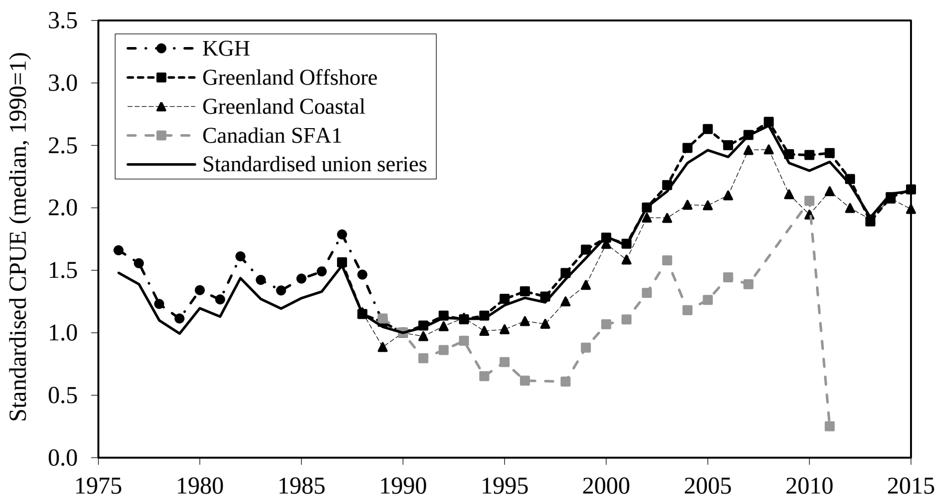

Fig. 3.2. Northern shrimp in Subarea 1 and Canadian SFA1: standardised CPUE index series 1976–2015.

The distribution of catch and effort among statistical areas was summarised using Simpson's diversity index to calculate an 'effective' number of statistical areas being fished as an index of how widely the fishery is distributed (Fig 3.3). The fishery area has contracted; NIPAG has for some years been concerned for effects of this contraction on the relationship between CPUE and stock biomass, and in particular that relative to earlier years biomass might be overestimated by recent CPUE values.

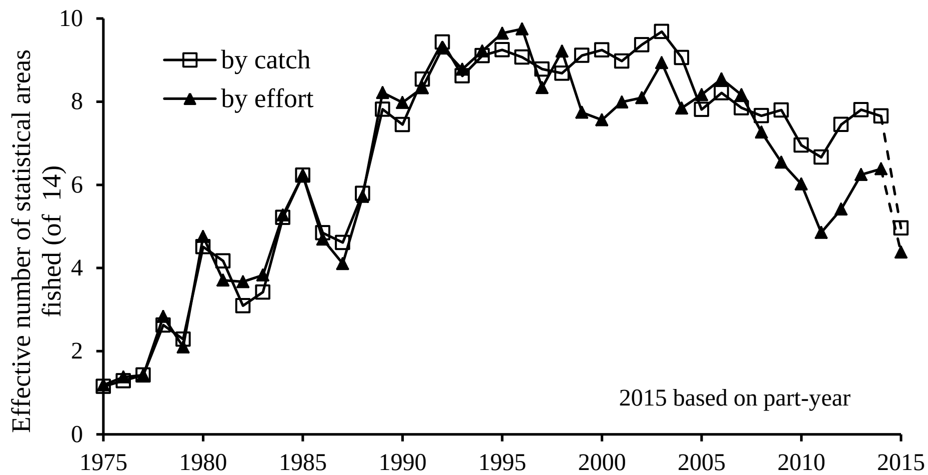

Fig. 3.3. Northern shrimp in Subarea 1 and Canadian SFA1: indices for the distribution of the Greenland fishery between statistical areas in 1975–2015.

From the end of the 1980s there was a significant expansion of the fishery southwards and in 1996–98 areas south of Holsteinsborg Deep (66°00'N) accounted for 65% of the Greenland catch. The effective number of statistical areas being fished in SA 1 reached a plateau in 1992–2003. The range of the fishery has since contracted northwards and the effective number of statistical areas being fished has decreased.

Catch composition. There is no biological sampling programme from the fishery that is adequate to provide catch composition data to the assessment.

ii) Research survey data

Greenland trawl survey. Stratified semi-systematic trawl surveys designed primarily to estimate shrimp stock biomass have been conducted since 1988 in offshore areas and since 1991 also inshore in Subarea 1 (SCR Doc. 15/43). From 1993, the survey was extended southwards into Div. 1E and 1F. A cod-end liner of 22 mm stretched mesh has been used since 1993. From its inception until 1998 the survey only used 60-min. tows, but since 2005 all tows have lasted 15 min. In 2005 the *Skjervøy 3000* survey trawl used since 1988 was replaced by a *Cosmos 2000* with rock-hopper ground gear, calibration trials were conducted, and the earlier data was adjusted.

The survey average bottom temperature increased from about 1.7°C in 1990–93 to about 3.1°C in 1997–2015 (SCR Doc. 15/43). About 80% of the survey biomass estimate is in water 200–400 m deep. In the early 1990s, about ¾ of this 80% was deeper than 300 m, but after about 1995 this proportion decreased and since about 2001 has been about ¼, and most of the biomass has been in water 200–300 m deep (SCR Doc. 15/43). The proportion of survey biomass in Div. 1E–F has been low in recent years and the distribution of survey biomass, like that of the fishery, has become more northerly.

Biomass. The survey index of total biomass remained fairly stable from 1988 to 1997 (c.v. 18%, downward trend 4%/yr). It then increased by, on average, 19%/yr until 2003, when it reached 316% of the 1997 value. Subsequent values were consecutively lower, by 2008–2009 less than half the 2003 maximum (Fig. 3.4); this decline continued in the subsequent years, reaching in 2014 the second lowest level in the last 20 years (SCR Doc. 15/43). In 2015 survey biomass overall increased by 60% over 2015, while offshore survey biomass was 137% higher in 2015 than in 2014, about 85% of its previous maximum in 2010, in Disko Bay and Vaigat the survey biomass is 16% less than in 2014 (Fig. 3.4). Offshore regions comprise 73% of the total biomass, and 27% is inshore in Disko Bay and Vaigat. Although, the inshore regions, had far higher densities than other areas, almost three times as high as offshore (Fig. 3.4) (SCR Doc. 15/43).

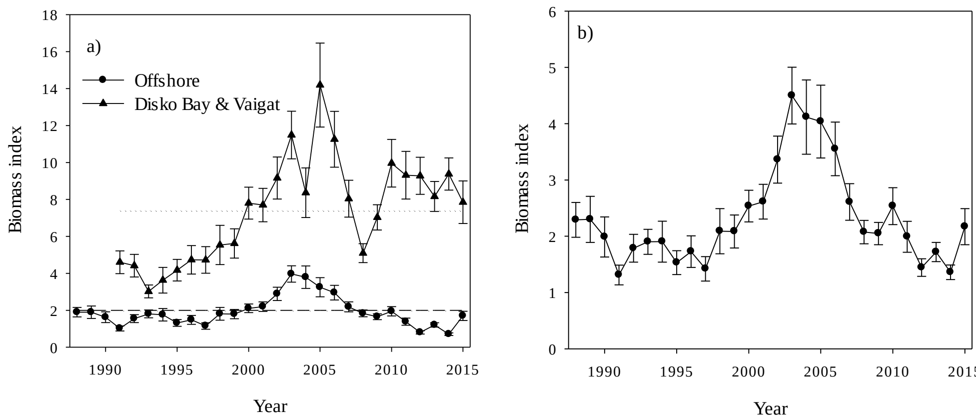

Fig. 3.4. Northern Shrimp in Subarea 1 and Canadian SFA 1: survey mean catch rates inshore and offshore (panel a) and overall (panel b) 1988–2015 (error bars 1 s.e.).

Length and sex composition (SCR 15/043).

In 2012 overall the fishable biomass at 91.1% of total was a little below its 20-year median, but included an exceptionally high proportion of females. Pre-recruits (14 – 16.5mm, expected to recruit to next year's fishable biomass) have been few since 2008 in absolute numbers. In 2013 the fishable biomass was estimated to have increased by one-third, but this seemed entirely due to increases in number and biomass of females, which composed an exceptionally high proportion of the stock (SCR Doc. 14/52). This size distribution continued in 2014 were females composed a high proportion of both the fishable and total biomass, while both fishable males and unrecruited males at 14–16.5 mm remain low in absolute numbers and as a proportion of the stock.

In 2015, in both regions males compose a higher proportion close to their 10-year median of the survey biomass, of both the total and fishable biomass indices, but females comprised a record low proportion of the offshore index, well below the lower quartile. In contrast, the index in 2014 in both inshore and offshore areas were 'all females'.

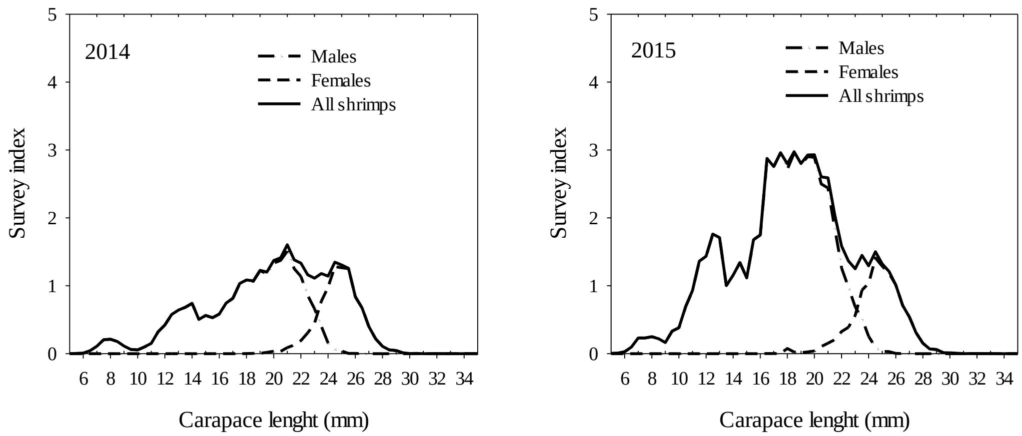

Fig. 3.5. Northern Shrimp in Subarea 1 and Canadian SFA 1: survey mean catch rates at length in the West Greenland trawl survey in 2014 and 2015.

Recruitment Index. In 2015 numbers at age 2 were estimated by fitting Normally distributed components to the length distribution, but only as far as 19 mm CPL. In other words, two components, considered age-1 and age-2, were fully fitted, and a third component was fitted only on its left-hand limb (SCR Doc. 15/43). Components were required to have equal CVs of CPL. This method was used to revise numbers at age 2 back to 2005.

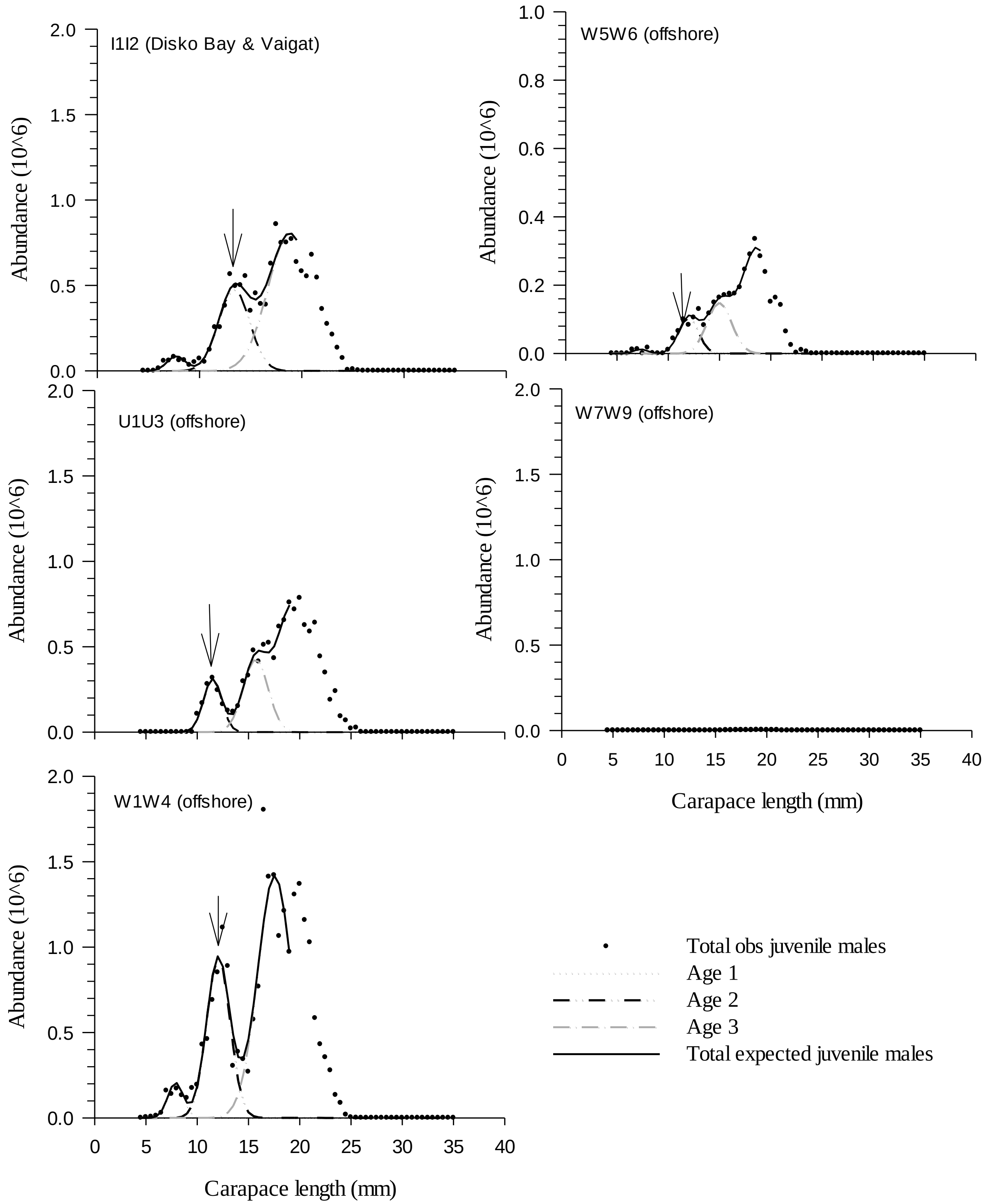

Fig.3.6: Northern Shrimp in Subarea 1 and Canadian SFA 1: Examples of estimating numbers at age by fitting Normally distributed components, two full and one partial, with equal CVs, to the length distribution of males, arrows indicating age 2.

From 2014 to 2015, numbers at age 2 increased by more than four times offshore, but remain at a comparable 2014 level in Disko bay & Vaigat. In total number of age 2 is well above its 20-year upper quartile (SCR Doc, 15/43) (Fig. 3.7). The stock composition inshore has historically been characterized by higher proportion of young shrimps than that offshore.

The relative number of large pre-recruits (14 – 16.5mm, expected to recruit to next year's fishable biomass) is close to its ten-year maximum, so prospects for short-term recruitment are good; this is true both in Disko bay & Vaigat and offshore as well.

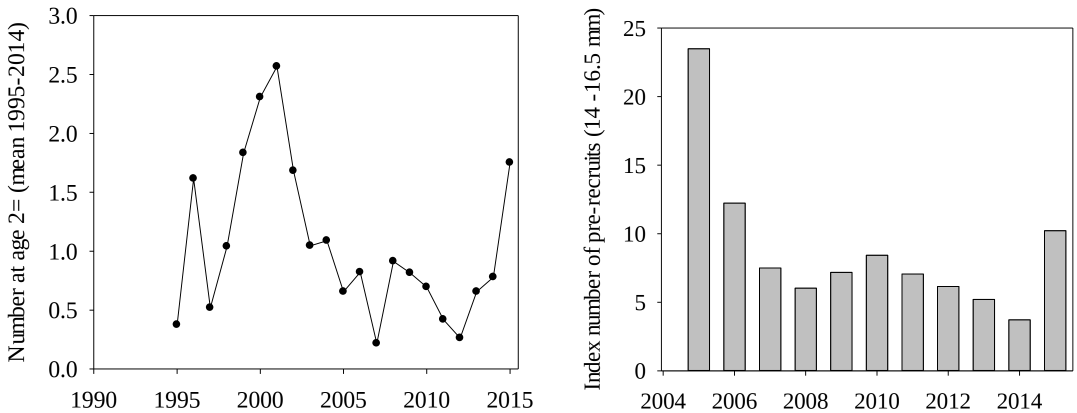

Fig. 3.7. Northern Shrimp in Subarea 1 and Canadian SFA 1: survey index of numbers at age 2, 1995–2015 and index of number of pre-recruits (4-16.5mm), 2005-2015.

c) Assessment Results

i) Estimation of Parameters

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 15/44).

Series of estimates of cod biomass in West Greenland waters are available for different periods from VPA, from the German groundfish survey at West Greenland and from the Greenland trawl survey for shrimps. The results from the German survey for the current year are not available in time for the assessment. Heretofore the estimate from the German survey has been used as the main estimate, the Greenland trawl survey value, adjusted, being used only for the current year.

The model includes a term for predation by Atlantic cod. In 2014 the full Greenland trawl survey was combined with the German survey within the assessment model, the two always having been well correlated, to produce an overall cod-stock biomass estimate series. The estimate for the current year depends only on the (scaled) Greenland survey value, the German survey being late in the year. The methods used in the German survey have recently been reviewed and revised; past estimates were little changed. The index of cod biomass is adjusted by a measure of the overlap between the stocks of cod and shrimps in order to arrive at an index of 'effective' cod biomass, which is used in the assessment model to estimate predation.

Total catches for 2015 were projected at 65 000 t. The assessment model had been modified in 2012 to include the uncertainty of projecting the current year's catches. The model was run with data series shortened to 30 years to speed up the running; the effect of shortening the data series was checked and found not significant (SCR Doc. 11/58). Stability of the assessment was checked by looking at changes, due to the addition of subsequent years' data, in year-end stock status estimates. Though slight changes occurred, they were commensurate with fluctuations in biomass indices and did not trend either up or down.

Corrections to coding of the quantitative assessment model for 2015 were reviewed by NIPAG. They included wider (less informative) prior distributions for parameters of the function relating predation to biomasses of predator and prey, and revised calculation of future mortalities. Both would tend to result in calculated mortalities lower than before under the conditions now expected in 2016, viz. high biomass of shrimps and moderately high biomass of cod.

These changes to coding appear to be responsible for about half of the improvement in apparent stock status at the end of 2015 compared with the corresponding values for the end of 2014. The other half is due to the increases in biomass observed in survey and CPUE indices for 2015. The modelled biomass (Fig. 3.8a) was low and stable until the late 1990s, when it started a rapid increase. Biomass doubled by about 2004; the survey index increased much more than the fishery CPUE. Over 2004 - 2013 modelled biomass steadily declined but has since stabilized at a level similar to that of the late 1990s, close to B_{msy}.

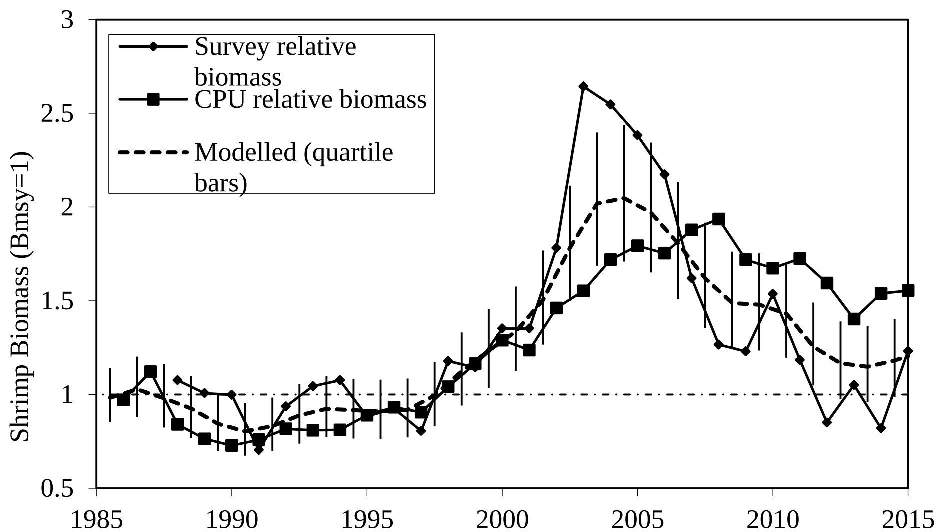

Fig. 3.8.a: Northern Shrimp in SA 1 and Canadian SFA1: trajectory of the median estimate of relative stock biomass at start of year 1986–2015, with median CPUE and survey indices; 30 years' data with constrained CVs.

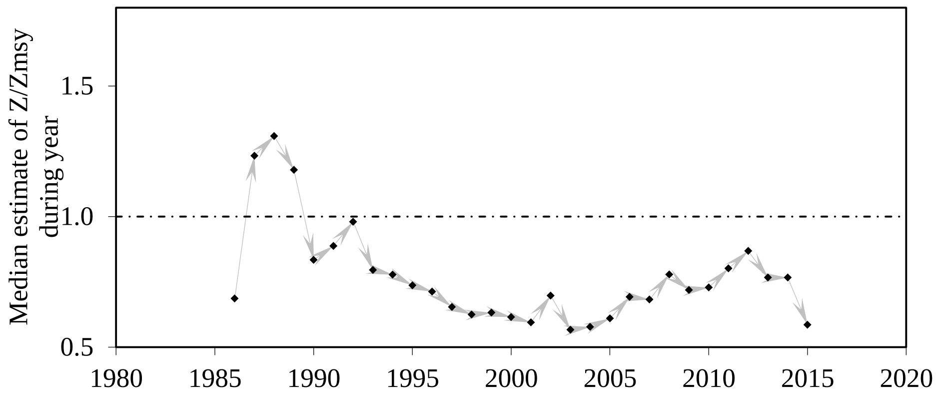

Fig 3.8.b: Northern Shrimp in SA 1 and Canadian SFA1: trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1986–2015.

Mortality has generally been below Z_{msy} during the modelled period, although a short-lived episode of high cod biomass occasioned three years of high values in the late 1980s (Fig. 3.8b). From 1998 to 2005 total mortality was noticeably low—in 1998–2001 because catches were still below 100 Kt while the stock had started to increase, in 2002–05 because the stock biomass increased, to high levels, much faster than catches.

Estimates of stock-dynamic and fit parameters from fitting a Schaefer stock-production model, to 30 years' data on the West Greenland stock of the Northern shrimp in 2015 is given in the table below. Median values from the 2014 assessment are provided for comparison. Biomass at the end of 2015 is projected to be above the 2014 value and is 23% above B_{msy}. The assumed catches for 2015 (65 000 t) are expected to hold total mortality below 58.6 % of Z_{msy}

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2014)
Max. sustainable yield (Kt)	155.3	94.7	104.7	140.2	186.2	110.0	131.3
B/B_{msy}, end current yr (proj.)	126.9	35.7	102.0	123.0	147.3	115.2	97.3
Biom. risk, end current yr (%)	23.0	42.1	–	–	–	–	–
Z/Z_{msy}, current yr (proj.)	–	–	37.4	58.6	94.1	–	103.1
Carrying capacity	4255	3166	2226	3365	5257	1585	3126
M.S.Y. ratio (%)	10.1	6.6	5.2	9.2	13.8	7.5	9.0
Survey catchability (%)	15.8	12.6	7.3	12.3	20.2	5.1	14.1
CPUE catchability	1.0	0.8	0.5	0.8	1.3	0.3	0.9
Effective cod biomass 2015 (Kt)	75.2	88.4	36.1	55.9	84.5	17.2	44.3
$P_{50\%}$	4.5	10.6	0.2	1.1	4.7	-5.9	7.2
V_{max}	1.5	2.0	0.3	0.6	1.8	-1.2	3.0
CV of process (%)	14.2	3.7	11.5	13.7	16.4	12.7	12.1
CV of survey fit (%)	16.4	1.8	15.2	16.5	17.8	16.6	15.9
CV of CPUE fit (%)	19.3	2.7	17.5	19.0	20.6	18.3	19.0
CV of predation fit (%)	139.9	90.5	66.1	124.7	198.2	94.3	115.4

d) State of the stock

Recruitment. The number of large pre-recruits (14 – 16.5mm, expected to recruit to next year's fishable biomass) is close to its ten-year maximum, so prospects for short-term recruitment are good; this is true both in Disko and offshore as well. The number at age 2 in 2015 is well above its 20-year upper quartile.

Biomass. A stock-dynamic model showed a maximum biomass in 2004 with a continuing decline over 2004 – 2013. The decline appears to have paused At the end of 2015, the stock is estimated to be 23% above B_{msy}. The risk of being below B_{lim} (30% of B_{msy}) is very low (<1%).

Mortality. With 2015 catches projected at 65 000 t the risk that total mortality will exceed Z_{msy} is estimated to be 58.6%. Atlantic cod is, in 2015, still concentrated in southerly areas where shrimps are now scarce, but its biomass is high and predation pressure is expected to be at least as high as the previous 3 years.

State of the Stock. Biomass is estimated to have been declining since 2004, but at the end of 2015 is projected to be above B_{msy} The risk of being below B_{lim} (30% of B_{msy}) is very low (<1%).d)

Precautionary Approach

B_{lim} has been established as 30% B_{msy}, and Z_{msy} (fishery and cod predation) has been set as the mortality reference point.

The fitted trajectory of stock biomass showed that the stock had been below its MSY level until the late 1990s, with mortalities mostly near the MSY mortality level except for an episode of high mortality associated with a short-lived resurgence of cod in the late 1980s. In the mid-1990s, with cod stocks at low levels, biomass started to increase at low mortalities to reach high proportions of B_{msy} in 2003–05. Recent increases in the cod stock coupled with high catches have been associated with higher mortalities and continuing decline in the modelled biomass. At the end of 2015, the stock will be above B_{msy}, and the risk of being below B_{lim} (30% of B_{msy}) is very low (<1%).

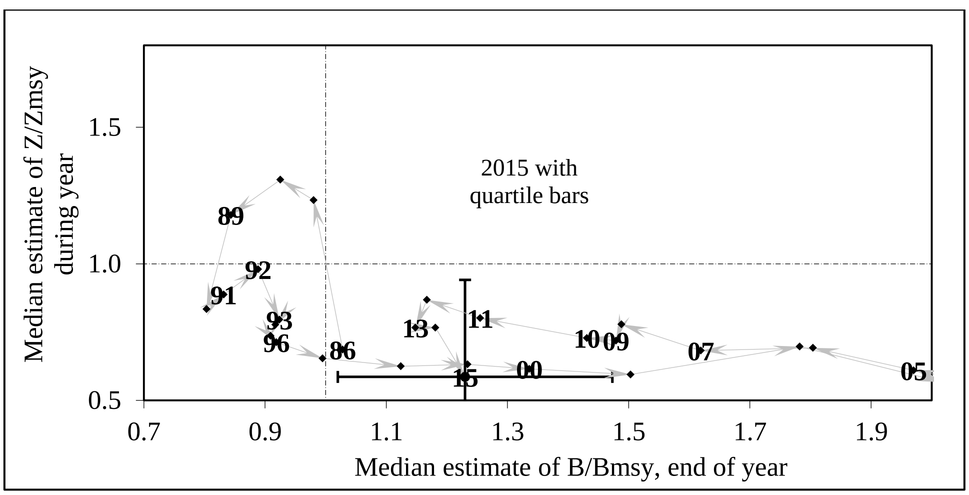

Fig. 3.9: Northern shrimp in Subarea 1 and Canadian SFA1: trajectory of relative biomass and relative mortality, 1986–2015.

e) Projections

Predicted probabilities of transgressing precautionary reference points in 2016 – 2018 under seven catch options and subject to predation by a cod stock with an effective biomass of 55 Kt (the value for 2015 being 56Kt.). Additional projections assuming an effective cod biomass of 65Kt were conducted (not shown) and results indicated small differences in risk probabilities.

55 000 t cod	Catch option ('000 tons)							
Risk of:	60	70	75	80	85	90	95	100
falling below B_{msy} end 2016 (%)	25.0	25.0	25.4	26.2	26.6	26.6	27.0	27.2
falling below B_{msy} end 2017 (%)	25.3	26.0	26.5	27.4	27.7	28.4	29.2	30.3
falling below B_{msy} end 2018 (%)	26.4	27.8	28.9	29.7	30.5	31.0	32.1	33.0
falling below B_{lim} end 2016 (%)	1.2	1.3	1.1	1.3	1.4	1.1	1.2	1.2
falling below B_{lim} end 2017 (%)	2.1	2.1	2.1	2.2	2.5	2.0	2.2	2.2
falling below B_{lim} end 2018 (%)	3.3	3.4	3.5	3.3	3.7	3.3	3.5	3.4
exceeding Z_{msy} in 2016 (%)	21.7	24.5	26.6	28.2	30.7	32.3	34.7	36.9
exceeding Z_{msy} in 2017 (%)	23.0	26.3	27.6	29.4	31.9	33.4	36.8	38.8
exceeding Z_{msy} in 2018 (%)	23.8	27.3	28.8	31.0	33.2	35.3	37.8	40.0

In the medium term, model results estimate that catches up to 90 000 t/yr could be associated with a slowly decreasing stock (Fig. 3.10). At the present state the biomass is 23% above its B_{msy}, and therefore less productive. Catches up to 90 000 t/yr will reduce the biomass in medium term, but the biomass might become more productive.

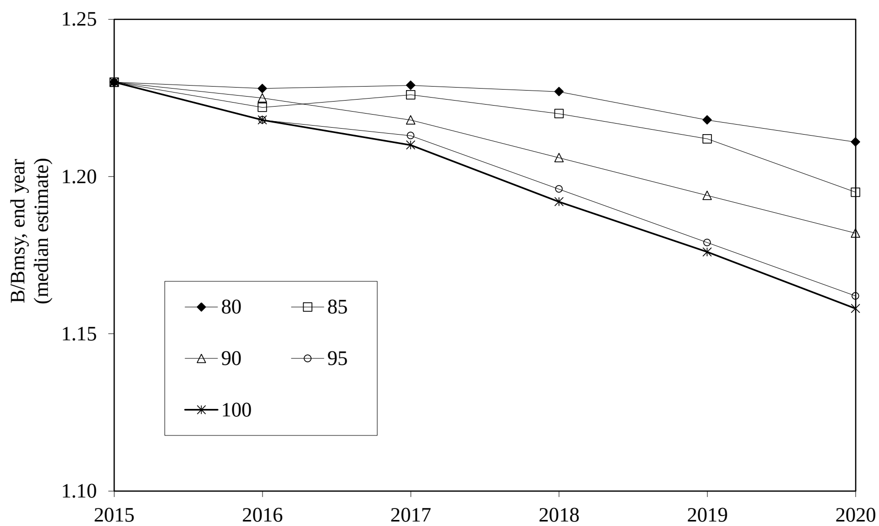

Fig. 3.10. Northern shrimp in Subarea 1 and Canadian SFA1: median estimates of biomass trajectory for 5 years with annual catches at 80–100 Kt and an ‘effective’ cod stock assumed at 55 Kt .

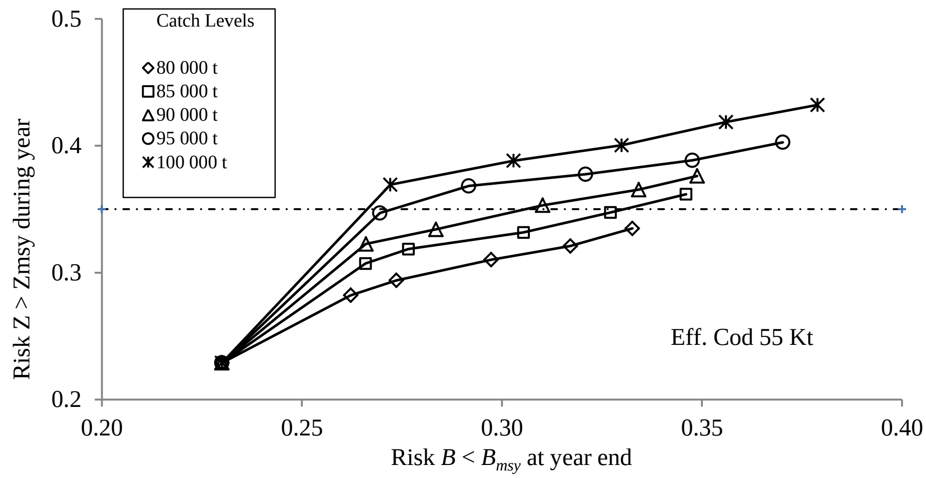

Fig. 3.11. Northern shrimp in Subarea 1 and Canadian SFA1: Risks of transgressing mortality and biomass precautionary limits with annual catches at 80–100 Kt projected for 2016–20 with an 'effective' cod stock assumed at 55 Kt.

Medium-term projections were summarised by plotting the risk of exceeding Z_{msy} against the risk of falling below B_{msy} over 5 years for 5 catch levels, considering an 'effective' cod stock close to the 2015 estimate (Fig. 3.11). The mortality risk depends immediately upon the assumed future catch and cod-stock levels, but changes little with time. For catches of 90 Kt to 95 Kt the mortality risk is 32–38% and nearly constant over the projection period. The immediate biomass risk is relatively insensitive to catch level but changes with time. At catch levels that permit rapid growth in biomass (90Kt), biomass risk decreases with time, but at catch levels that allow only slow growth, the compounding of uncertainties eventually causes estimated biomass risk to increase. This is aggravated by the high cod-stock biomass for which predictions are being made, the uncertainty associated with predation by cod being large in the present assessment.

f) Research Recommendations

NIPAG **recommended** in 2012 that, for Northern shrimp off West Greenland (NAFO Subareas 0 and 1):

- given that the CPUE series for the Greenland sea-going and coastal fleets continue to agree while neither agrees with changes in the survey estimates of biomass since 2002, possible causes for change in the relationship between fishing efficiency and biomass should be investigated;

STATUS: In progress; this recommendation is reiterated.

- the relationship between estimated numbers of small shrimps and later estimates of fishable biomass should be investigated anew.

STATUS: In progress; this recommendation is reiterated.

In 2014:

NIPAG **recommends** that *the structure and coding in the assessment model of the relationship between cod biomass, shrimp biomass and estimated predation should be reviewed, including an analysis of the error variation*.

STATUS: Ongoing. A correction to the coding of the model was implemented in the 2015 assessment, but further investigations of the treatment of the error variance is indicated.

NIPAG **recommends** that *further refinements to the "partial MIXing" method of estimating numbers at age should be explored*.

STATUS: In progress; this recommendation is reiterated.

In 2015:

Survey trends inshore and offshore are divergent and NIPAG **recommends** *exploration of the nature and implications of this divergence*.

4. NORTHERN SHRIMP OFF EAST GREENLAND IN ICES DIV. XIVB AND VA

Background documentation (equivalent to stock annex) is found in SCR Docs. 03/74, 15/45, 15/50.

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, until 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.

A multinational fleet exploits the stock. During the recent ten years, vessels from Greenland, EU, the Faroe Islands and Norway have fished in the Greenland EEZ. Only Icelandic vessels are allowed to fish in the Icelandic EEZ. At any time access to these fishing grounds depends strongly on ice conditions.

In 1993 a new fishery began in areas south of 65°N down to Cape Farewell. From 1996 to 2005 catches in this area accounted for 50 - 60% of the total catch. In 2006 and 2007 catches in the southern area only accounted for 25% of the total catch, decreasing to about 10% from 2008 - 2012. No fishery has taken place in the Southern area since then.

In the Greenland EEZ, the minimum permitted mesh size in the cod-end 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, however there have been no catches by Iceland after 2005. 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.

As the fishery developed, catches increased rapidly to more than 15 000 tons in 1987-88, but declined thereafter to about 9 000 t in 1992-93. Following the extension of the fishery south of 65°N catches increased again reaching 11 900 t in 1994. From 1994 to 2003 catches fluctuated between 11 500 and 14 000 t (Fig. 4.1). Since 2004 the catches decreased continually from 10 000 tons. Catches have been between 1200 and 2100 t from 2011 to 2013. In 2014 and the first half of 2015 catches of about 600 t has been obtained.

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

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015[1]
Recommended TAC, total area	12400	12400	12400	12400	12400	12400	12400	12400	2000	2000
Actual TAC, Greenland	12400	12400	12400	12835	11835	12400	12400	12400	8300	6100
North of 65°N, Greenland EEZ	3887	3313	2529	3945	3323	1145	1893	1714	622	572
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	3887	3313	2529	3945	3323	1145	1893	1714	622	572
South of 65°N, Greenland EEZ	1302	1286	266	610	279	53	215	3	0	0
TOTAL NIPAG	5189	4599	2794	4555	3602	1199	2109	1717	622	572

[1] Catches until June 2015

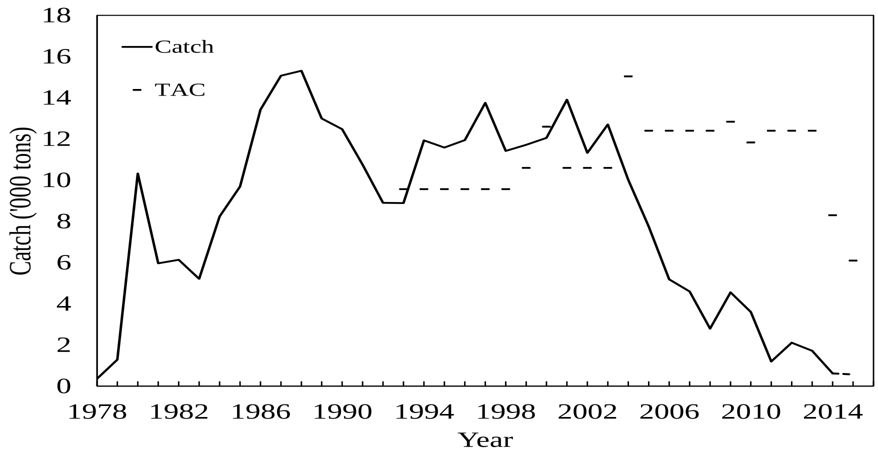

Fig. 4.1. Shrimp in Denmark Strait and off East Greenland. Catch and TAC (2015 catches until June).

b) Input Data

i) Commercial fishery data

Fishing effort and CPUE. Data on catch and effort (hours fished) on a haul by haul basis from logbooks from Greenland, Iceland, Faroe Islands and EU since 1980 and from Norway since 2000 are used. Until 2005, the Norwegian fishery data was not reported in a compatible format and were not included in the standardized catch rates calculations. In 2006 an evaluation of the Norwegian logbook data from the period 2000 to 2006 was made and since then these data have been included in the standardized catch rate calculations. Since 2004 more than 60% of all hauls were performed with double trawl, and both single and double trawl are included in the standardized catch rate calculations.

Catches and corresponding effort are compiled by year for two areas, one area north of 65°N and one south thereof. Standardised Catch-Per-Unit-Effort (CPUE) was calculated and applied to the total catch of the year to estimate the total annual standardised effort. Catches in the Greenland EEZ are corrected for “overpacking” up to 2004 (SCR Doc. 03/74).

The overall CPUE index declined continuously from 1987 to 1993. From 1993 to 1999 the overall CPUE index increased. The overall CPUE index remained relatively high from 2000-2008, nearly doubled in 2009, declined until 2014 and is at the same level in 2015 as in 2014 (Fig. 4.2). As most of the fishing has been conducted in the northern area the overall CPUE index is dominated by the CPUE index for the area north of 65°N (Fig. 4.2 and Fig. 4.3).

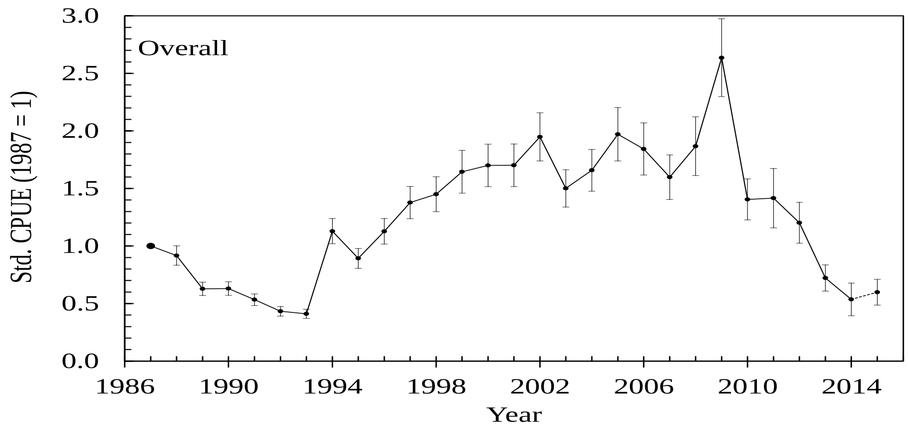

Fig. 4.2. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE-indices (1987 = 1) with ± 1 SE combined for the total area (2015 catches until June).

North of 65°N standardized catch rates declined continuously from 1987 to 1993. From 1993 to 1999 catch rates increased and remained relatively high from 2000-2008. In 2009 the catch rates nearly doubled but have since decreased and have since 2013 been close to the lowest level seen in the time series (Fig. 4.3).

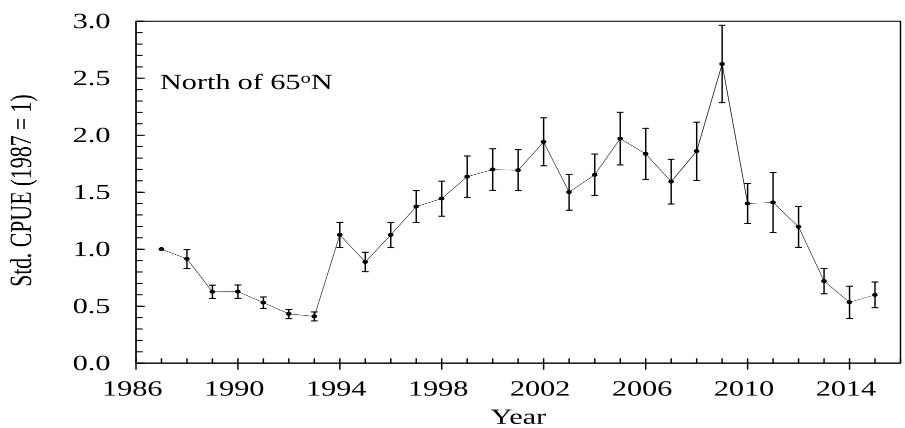

Fig. 4.3. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N (2015 catches until June).

In the southern area a standardized catch rate series increased until 1998, and has since then fluctuated without a trend (Fig. 4.4). No index for the southern area was calculated since 2010 due to a low number of hauls.

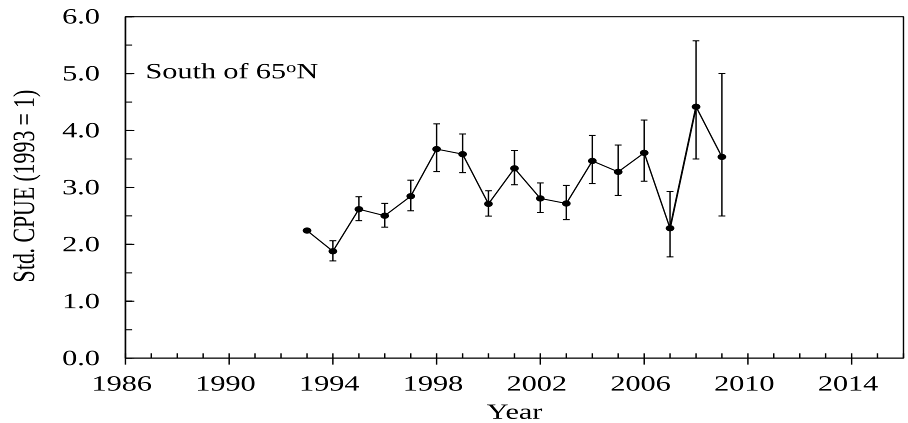

Fig. 4.4. Shrimp in Denmark Strait and off East Greenland: annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010).

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

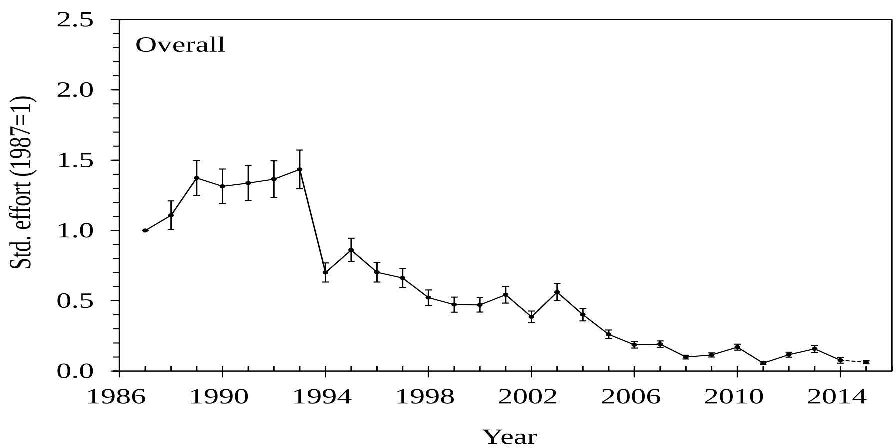

Fig. 4.5. Shrimp in Denmark Strait and off East Greenland: annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2015 effort until June).

ii) Research survey data

Stratified-random trawl surveys have been conducted to assess the stock status of northern shrimp in the East Greenland area since 2008. The main objectives were to obtain indices for stock biomass, abundance, recruitment and demographic composition. The area was also surveyed in 1985-1988 (Norwegian survey) and in 1989-1996 (Greenlandic survey). The historical survey is not directly comparable with the recent survey due to different areas covered, survey technique and trawling gear.

Biomass. The survey biomass index decreased from 2009 to 2012 and have since then remained at a low level (Fig. 4.6).

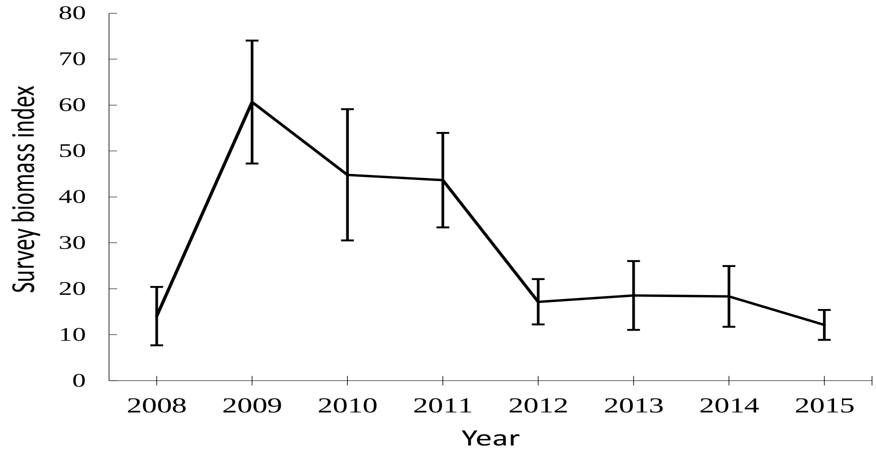

Fig. 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008-2015 (± 1 SE).

The surveys conducted since 2008 indicate that the shrimp stock is concentrated in the area north of 65°N (Fig. 4.7).

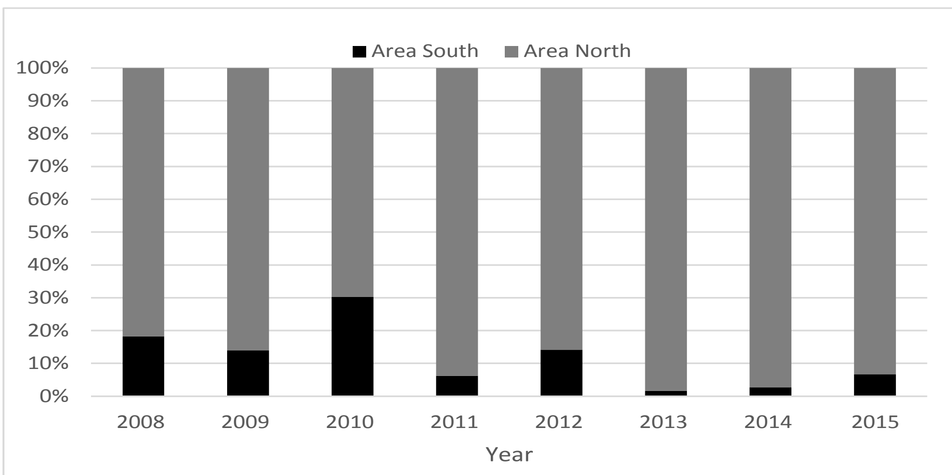

Fig. 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of Survey biomass North and South of 65°N (%) from 2008 - 2015.

Stock composition.

The demography in East Greenland is dominated by a large proportion of females and shows a paucity of males smaller than 20 mm CL (Fig. 4.7).

Scarcity of smaller shrimp in the survey area stresses that the total area of distribution and recruitment patterns of the stock are still unknown.

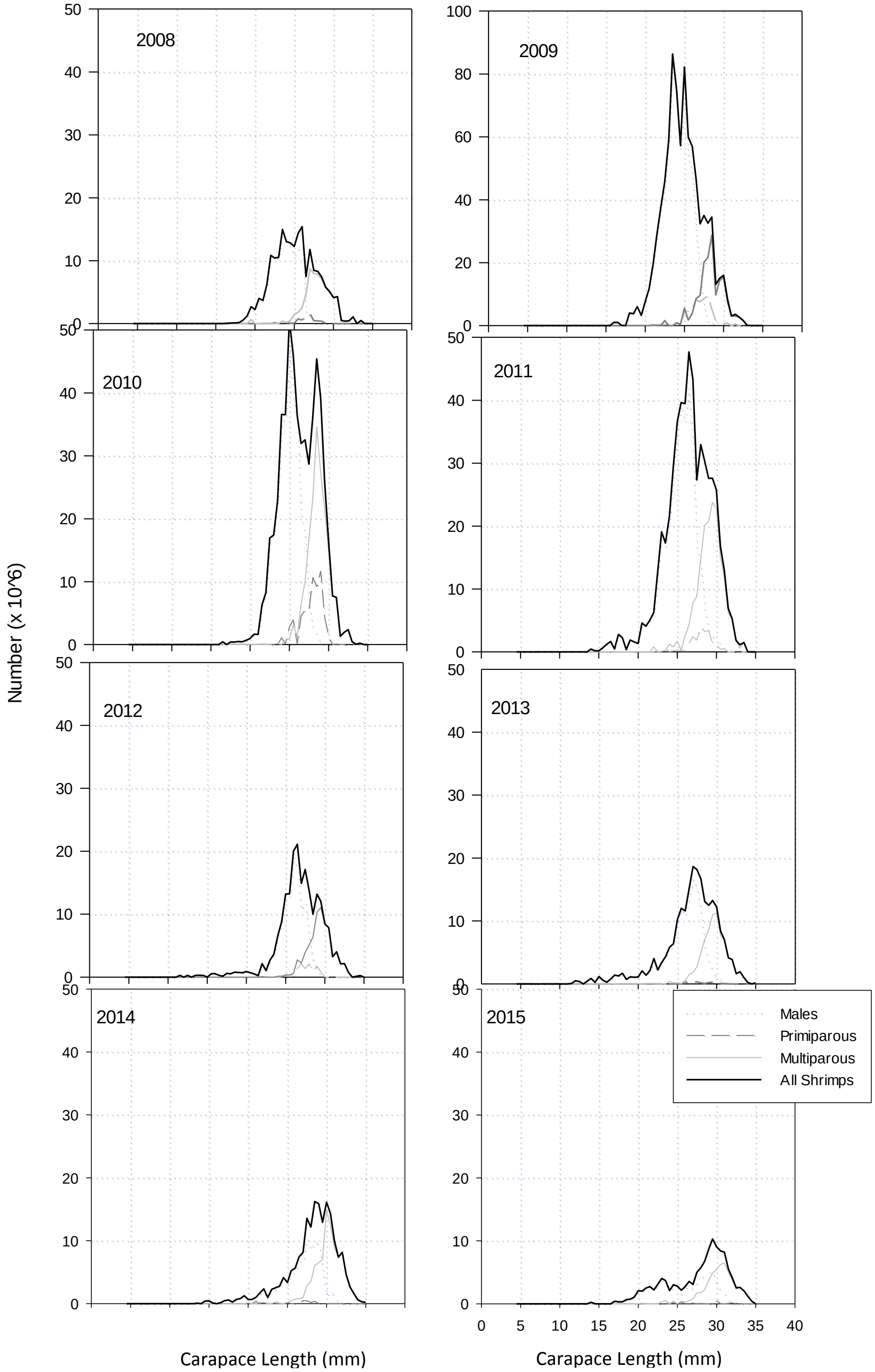

Fig.4.7. Shrimp in Denmark Strait and off East Greenland. Numbers of shrimp by length group (CL) in the total survey area in 2008 - 2015 (Please note that the scale in the figure for 2009 differs from other years).

c) Assessment Results

CPUE: The overall CPUE index remained at a high level from 2000-2008, nearly doubled in 2009, but has been declining since, and have since 2013 been close to the lowest level seen in the time series.

Recruitment. No recruitment estimates were available.

Biomass. The survey biomass index has decreased by around 80% since 2009.

Exploitation rate. Since the mid-1990s the exploitation rate index has decreased, reaching the lowest levels seen in the time series.

State of the stock. The stock size remained at a very low level in 2015 despite several years of very low exploitation rates.

d) Reference points

NIPAG is unable to determine precautionary reference points at this time.

5. NORTHERN SHRIMP IN SKAGERRAK AND NORWEGIAN DEEP (ICES DIV. IIIA AND IVA EAST) – ICES STOCK

Background documentation (equivalent to stock annex) is found in SCR Doc. 08/75; 13/68, 74; 15/56, 57, 58, 59, 60

a) Introduction

The shrimp in the northern part of ICES Div. IIIa (Skagerrak) and the eastern part of Div. IVa (Norwegian Deep) is assessed as one stock and is exploited by Norway, Denmark and Sweden. The Norwegian and Swedish fisheries began at the end of the 19th century, while the Danish fishery started in the 1930s. All fisheries expanded significantly in the early 1960s. By 1970 the landings had reached 5 000 t and in 1981 they exceeded 10 000 t. Since 1992 the shrimp fishery has been regulated by a TAC, which was around 16 500 t in 2006-2009, thereafter declined steadily to only 9 500 t in 2013 and 2014, but increased to 10 900 t in 2015 (Fig. 5.1, Table 5.1). In the Swedish and Norwegian fisheries approximately 50% of catches (large shrimp) are boiled at sea, and almost all catches are landed in home ports. Since 2002, an increasing number of the Danish vessels are boiling the shrimp on board and landing the product in Sweden to obtain a better price. The rest is landed fresh in home ports. The overall TAC is shared according to historical landings, giving Norway 58-60%, Denmark 26-28%, and Sweden 14% in 2011 to 2015. The recommended TACs were until 2002 based on catch predictions. In 2003, the cohort-based assessment was abandoned and no catch predictions were available. The recommended TACs were therefore based on perceived stock development in relation to recent landings until 2013, when an assessment based on a stock production model was introduced for this stock. In 2015, a length based model was run in parallel. The shrimp fishery is also regulated by mesh size (35 mm stretched), and by restrictions in the amount of landed bycatch. Since February 1st 2013, it has been mandatory to use grids in all *Pandalus* trawl fishery in Skagerrak, and since January 1st 2015, the same regulation applies to the North Sea south of 62 °N (see section on Bycatch and ecosystem effects below).

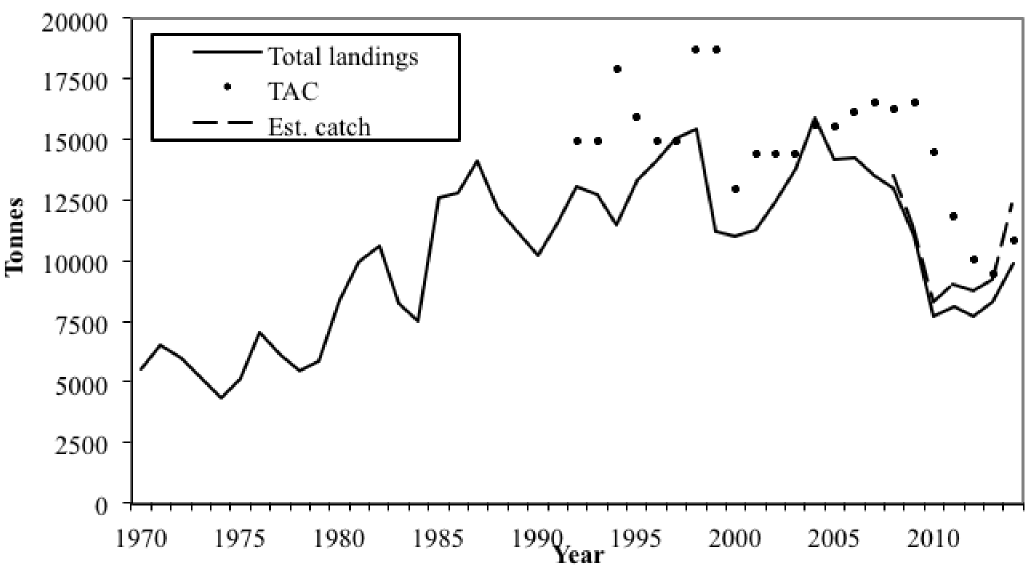

Fig. 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008-2014, and Norwegian and Danish discards for 2009-2014.

Table 5.1. Northern shrimp in Skagerrak and Norwegian deep: TACs, landings, and estimated discards and catches (t).

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Recommended TAC	13.000	14.000	14.000	15.000	15.000	13.000	8.800	*	6.500	10.900
Agreed TAC	15.600	16.200	16.600	16.300	16.600	14.558	11.928	10.115	9.500	10.900
Denmark	2.992	3.111	2.422	2.274	2.224	1.301	1.601	1.454	2.026	2.432
Norway	8.959	8.669	8.686	8.260	6.364	4.673	4.800	4.796	5.179	6.124
Sweden	2.257	2.488	2.445	2.479	2.483	1.781	1.768	1.521	1.191	1.397
Total landings	14.208	14.268	13.553	13.013	11.071	7.755	8.168	7.771	8.379	9.953
Est. Swedish discards				540	337	386	504	671	265	572
Est. Norw. Discards					115	75	235	288	450	1.289
Est. Danish discards					36	53	123	92	185	526
Total catch	14.208	14.268	13.553	13.553	11.560	8.269	9.030	8.834	9.279	12.340

The Danish and Norwegian fleets have undergone major restructuring during the last 25 years. In Denmark, the number of vessels targeting shrimp has decreased from 138 in 1987 to only 10 in 2014. The efficiency of the fleet has increased due to the introduction of twin trawls and increased trawl size (SCR Doc. 15/60).

In Norway the number of vessels participating in the shrimp fishery has decreased from 423 in 1995 to 203 in 2014. Twin trawls were introduced around 2002, and the use is increasing. In 2011-2014 twin trawls were used by more than half of the Norwegian trawlers larger than 15 meters (SCR Doc. 15/57).

The Swedish specialized shrimp fleet (landings of shrimp ≥ 10 t/yr) has decreased from more than 60 vessels in 1995-1997 to 33 in 2014. There has not been any major change in single trawl size or design, but during the last nine years the twin trawlers have increased their landings from 7 to over 50% (recent 4 years) of total Swedish *Pandalus* landings (SCR Doc. 15/60).

Landings and discards. Total landings have varied between 7 500 and 16 000 t during the last 30 years. In the total catch estimates the boiled fraction of the landings has been raised by a factor of 1.13 to correct for weight loss caused by boiling. Total catches, estimated as the sum of landings and discards, decreased from 2008 to 2012, to 8 800 t, but increased to 9 300 t in 2013 and to 12 300 t in 2014 (Table 5.1 and Fig. 5.1).

Shrimps can be discarded for one of two reasons: 1) shrimp < 15 mm CL are not marketable (and in Norway, not legal to land), and 2) to replace medium-sized, lower-value shrimps with larger and more profitable ones ("high-grading"). The Swedish fishery has often been constrained by the national quota, which may have resulted in high-grading. Based on on-board sampling by observers, discards in the Swedish fisheries have been estimated to be between 12 and 31% of total catch for 2008 -2014, and Danish discards have been estimated to be between 2 and 18% for 2009-2014. Discarding is illegal in Norwegian waters, but there are no observer data. From 2009 onwards Norwegian discards in Skagerrak have been estimated by applying the Danish discards-to-landings ratio to the Norwegian landings. Norwegian discards are probably underestimated as the proportion of boiled large shrimp in the Norwegian landings is larger than in the Danish landings (SCR Doc. 15/57). Assuming, in the absence of observer data, that Norwegian discards from the Norwegian Deep are mainly made up of shrimp < 15 mm CL, discards from this area are estimated as the weight of catches of shrimp < 15 mm CL, obtained from length distributions of catches and mean weight at length.

Bycatch and ecosystem effects. Shrimp fisheries in the Norwegian Deep and Skagerrak have bycatches of 10-22% (by weight) of commercially valuable species, which are legal to land if quotas allow (Table 5.2).

Since 1997, trawls used in Swedish national waters must be equipped with a Nordmøre grid, with a bar spacing of 19 mm, which excludes fish > approx. 20 cm length from the catch. Landings delivered by vessels using grids comprise 95-99% shrimp compared to only 60-84% in landings from trawls without grids (Table 5.2). Following an agreement between EU and Norway, the Nordmøre grid has been mandatory since 1st February 2013 in all shrimp fisheries in Skagerrak (except Norwegian national waters within the 4 nm limit). From 1st of January 2015, the grid has also been mandatory in shrimp fisheries in the North Sea south of 62 °N. If the fish quotas allow, it is legal to use a fish retention device of 120 mm square mesh tunnel at the grid's fish outlet.

Table 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Bycatch landings by the *Pandalus* fishery in 2014. Combined data from Danish and Swedish logbooks and Norwegian sale slips (t).

Species:	SD IIIa, grid		SD IIIa, grid+fish tunnel		SD IVa East, no grid	
	Landings (t)	% of total landings	Landings (t)	% of total landings	Landings (t)	% of total landings
Pandalus	527.1	98.3	7390.4	82.1	1294.5	79.6
Norway lobster	4.2	0.8	22.5	0.2	5.2	0.3
Angler fish	0.1	0.0	66.3	0.7	35.1	2.2
Whiting	0.0	0.0	4.1	0.0	1.3	0.1
Haddock	0.0	0.0	64.4	0.7	15.9	1.0
Hake	0.0	0.0	16.6	0.2	6.0	0.4
Ling	0.0	0.0	45.3	0.5	22.3	1.4
Saithe	0.5	0.1	566.2	6.3	148.7	9.1
Witch flounder	0.2	0.0	102.9	1.1	1.0	0.1
Norway pout	0.9	0.2	1.1	0.0	0.0	0.0
Cod	1.4	0.3	555.9	6.2	59.0	3.6
Other marketable fish	1.6	0.3	161.3	1.8	36.4	2.2

The use of a fish retention device also prevents the escape of non-commercial species. Deep-sea species such as argentines, roundnose grenadier, rabbitfish, and sharks are frequently caught in shrimp trawls in the deeper parts of Skagerrak and the Norwegian Deep. No quantitative data on this mainly discarded catch is available and the impact on stocks is difficult to assess.

Catches of fish in the Campelen-trawl of the Norwegian annual shrimp survey covering Skagerrak and the Norwegian Deep (see below) give an indication of the level of bycatch of non-commercial species in shrimp trawls (Table 5.3). The large inter-annual variation in the predator biomass index is mainly due to variations in the indices for saithe and roundnose grenadier, which in some years are important components. These contributions depend upon which survey stations are trawled as the largest densities of saithe are found in shallow water and roundnose grenadier is found in deep water. An index without hese species (given at the bottom of Table 5.3) has been at the same level for the last 10 years. The peak in 2013 was due to a high abundance of blue whiting.

Table 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in kg per towed nautical mile) from the Norwegian shrimp survey in 2006-2015.

Species English	Latin	biomass index 2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	mean
Blue whiting	*Micromesistius poutassou*	0.13	0.13	0.12	1.21	0.27	0.62	3.30	29.03	1.88	5.25	
Saithe	*Pollachius virens*	7.33	39.75	208.32	53.89	18.53	7.52	5.66	112.80	14.13	8.56	
Cod	*Gadus morhua*	0.51	1.28	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	
Roundnosed Grenadier	*Coryphaenoides rupestris*	3.22	6.85	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	
Rabbit fish	*Chimaera monstrosa*	2.24	2.15	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	
Haddock	*Melanogrammus aeglefinus*	0.97	4.21	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	
Redfish	Scorpaenidae	0.18	0.40	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	
Velvet Belly	*Etmopterus spinax*	1.31	2.58	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	
Skates, Rays	Rajidae	0.41	0.95	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	
Long Rough Dab	*Hippoglossoides platessoides*	0.22	0.64	0.42	0.28	0.47	0.51	0.56	0.56	1.17	1.45	
Hake	*Merluccius merluccius*	0.98	0.78	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	
Angler	*Lophius piscatorius*	0.15	0.91	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	
Witch	*Glyptocephalus cynoglossus*	0.24	0.74	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	
Dogfish	*Squalus acanthias*	0.31	0.19	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	
Black-mouthed dogfish	*Galeus melastomus*	0.00	0.05	0.05	0.15	0.09	0.09	0.09	0.12	0.11	0.35	
Whiting	*Merlangius merlangus*	0.35	1.01	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	
Blue Ling	*Molva dypterygia*	0	0	0	0	0	0	0	0.01	0.01	0.03	
Ling	*Molva molva*	0.04	0.11	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	
Four-bearded Rockling	*Rhinonemus cimbrius*	0.06	0.14	0.04	0.03	0.05	0.03	0.09	0.04	0.06	0.12	
Cusk	*Brosme brosme*	0.20	0	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	
Halibut	*Hippoglossus hippoglossus*	0.08	0.07	3.88	0.09	0.20	0.05	0.19	0	0	0.10	
Pollack	*Pollachius pollachius*	0.06	0.25	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	
Greater Forkbeard	*Phycis blennoides*	0	0	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	
Total		18.99	63.19	244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	77.35
Total (except saithe and roundnosed grenadier)		8.44	16.59	17.47	21.34	20.65	20.58	19.95	49.46	24.15	24.46	22.31

b) Input Data

i) Fishery data

Danish, Swedish and Norwegian catch and effort data from logbooks have been analyzed and standardized (SCR Doc. 08/75; 15/57, 60).

There was an increasing trend in the standardized LPUE for all three series from 2000 to 2007 followed by a decreasing trend until 2012. All three series have increased since 2013 (Fig. 5.2).

Time series of standardized effort indices have been fluctuating without any clear trend since the mid-1990s (Fig. 5.3).

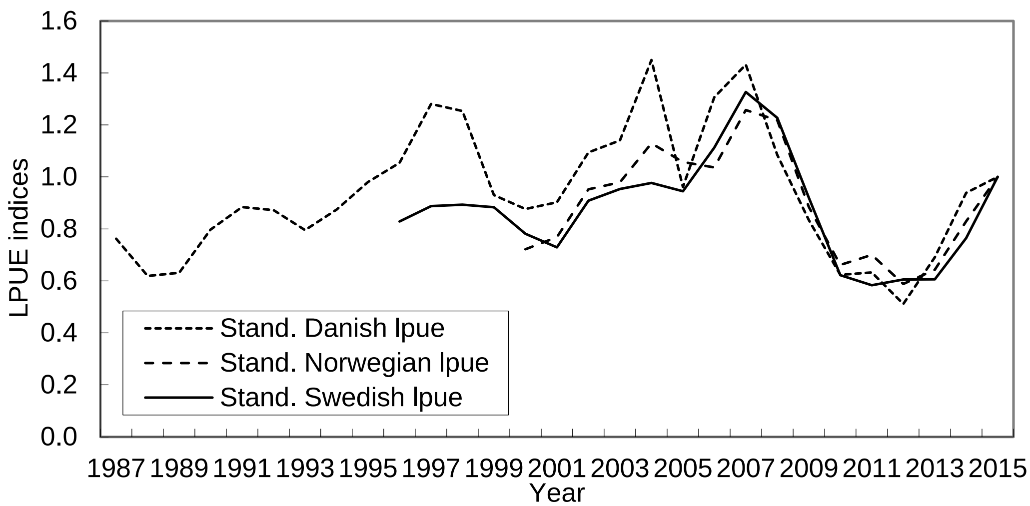

Fig. 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardized LPUE until 2015. 2015 data are preliminary. Each series is standardized to its last year.

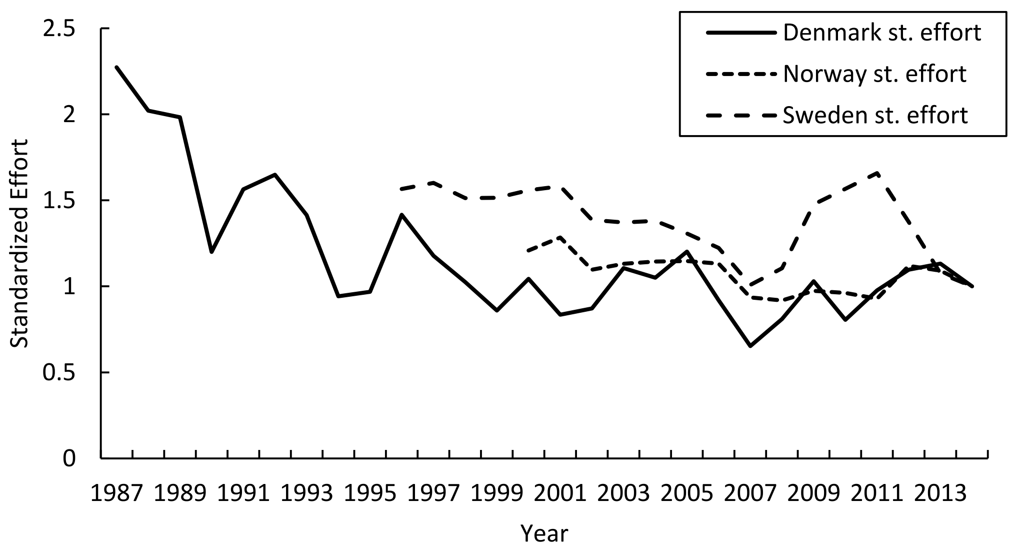

Fig. 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardized effort. Each series is standardized to its final year.

ii) Sampling of catches.

Length frequencies of the catches from 1985 to 2014 (SCR Doc. 15/57, 60) have been obtained by sampling. The samples also provide information on sex distribution and maturity. Numbers at length are input data to the newly developed length-based assessment model for this stock (see below).

iii) Survey data

The Norwegian shrimp survey went through large changes in vessel, gear and timing in 2003-06, resulting in four indices (SCR Doc. 15/58): Survey 1: October/November 1984-2002 with Campelen trawl; Survey 2: October/November 2003 with shrimp trawl 1420; Survey 3: May/June 2004-2005 with Campelen trawl; and Survey 4: January/February 2006-present with Campelen trawl.

Due to time and weather restrictions not all survey strata were covered in all years. The following years have missing strata: 1984, 1986, 2002, 2006, 2012, 2014, and 2015 (Fig. 5.4). The index of total biomass for these years has been corrected by applying the missing strata's mean portion of the total biomass (averaged over all years with complete coverage) to the total biomass of the year. However, total numbers at length have not yet been corrected, which means that the length-based model (see below) uses uncorrected survey data while the surplus production model (see below) uses corrected data.

The biomass index increased from 1988 to the first series's maximum in 1997 (Fig. 5.4). A decrease in 1998-2000 was followed by an increase in 2001-2002, when this series was discontinued. "Series 2" comprises a single point in 2003. The 2004 and 2005 values from the third series were similar. The fourth series peaked in 2007 and after that showed a steady decline to a minimum in 2012. Thereafter the index has increased.

A recruitment index has been calculated for the fourth series as the abundance of age 1 shrimp. The recruitment index value declined from 2007 to 2010, fluctuated at a low level until 2013 and thereafter increased to the time series' highest value in 2014 (Fig. 5.5). In 2015, the abundance of age 1 shrimp was again low.

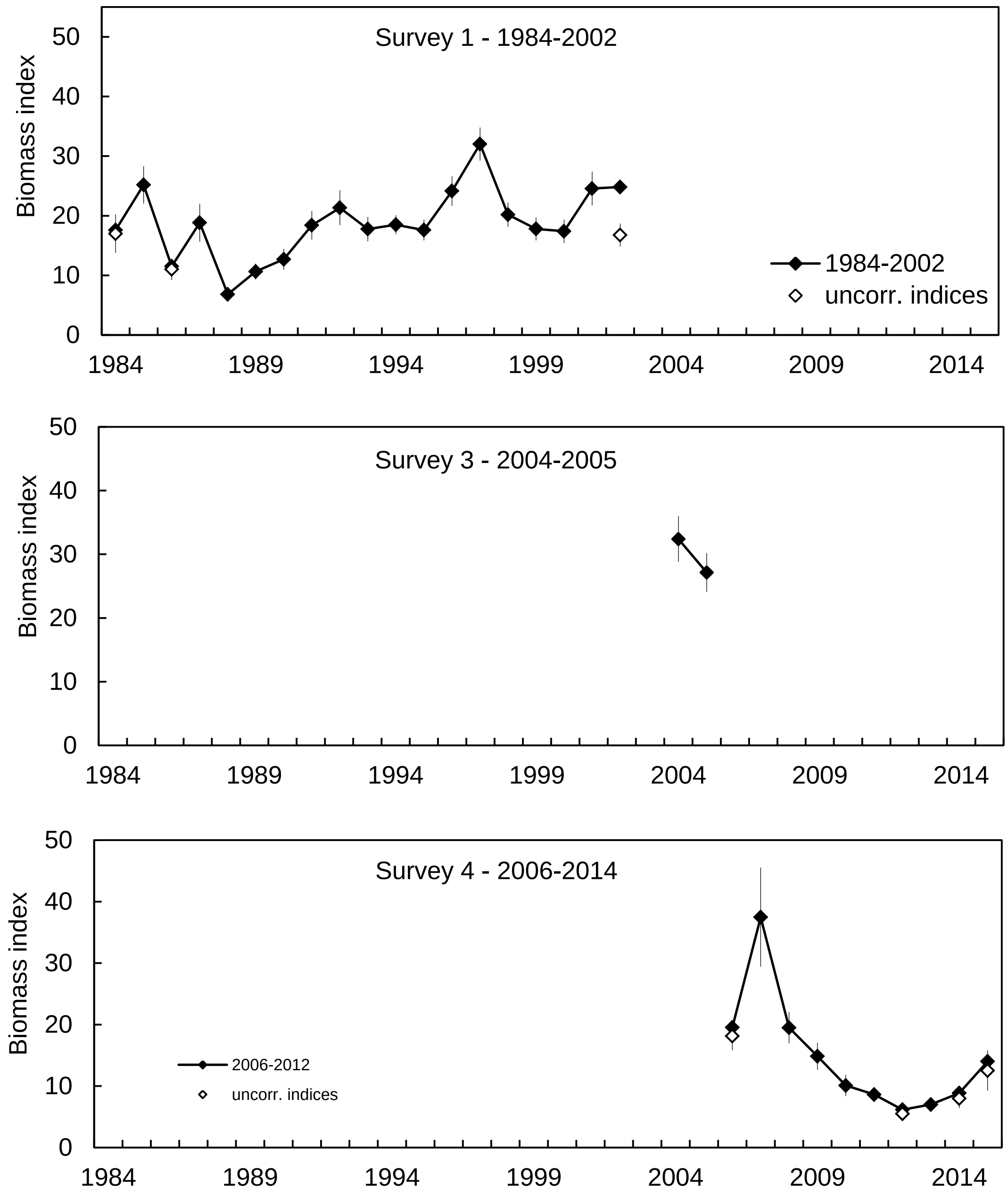

Fig. 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984 to 2015. The point estimate of 2003 is not shown.

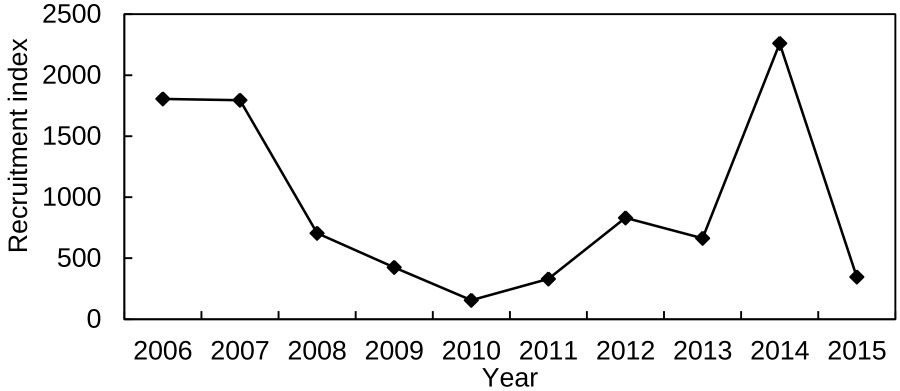

Fig. 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006-2015.

c) Assessment models

In the benchmark of this stock (ICES, 2013a), a length-based model (LBM) and a surplus production model (SPM) were considered: "While both the LBM and the SPM models gave similar results and were considered capable of forming the basis for the stock assessment, the Benchmark preferred the length-based model because it made more use of the available data from the surveys and the catches and because it was relatively easy to update and run. However it was decided that the SPM should be run alongside the LBM, at least initially, to provide reassurance that the assessments from the two models continued to remain consistent". The LBM was not fully operational in 2013 and 2014, but for this year's assessment, both models produced full assessment outputs and were considered in parallel. Both models gave similar results in terms of biomass dynamics but diverged in estimation of recent F values and in estimation of stock status relative to reference points and hence in derived advice.

The WG noted significant progress in the completion of the LBM as an assessment tool, so that it now produces all the output needed to provide ICES standard advice, but never the less decided to use the SPM as the primary basis for this year's advice and use the LBM for supportive information.

Rationale:

A very high LBM-estimate of $F_{1\text{-}3}$ in 2014 was of some concern to the WG. Although a substantially increasing F for the larger shrimp up to 2014 is to be expected from five preceding years of historically low recruitment to the fishable biomass, the 2014 estimate of $F_{1\text{-}3}$ of 1.45 is considered a possible over-estimation. The retrospective plots show no serious problems with regards to the SSB and the R, whereas for F there has been some retrospective pattern (Fig. 5.6). Particularly the high estimate for 2012 was considerably revised down. It is unknown whether this situation will apply also to the high 2014 estimate.

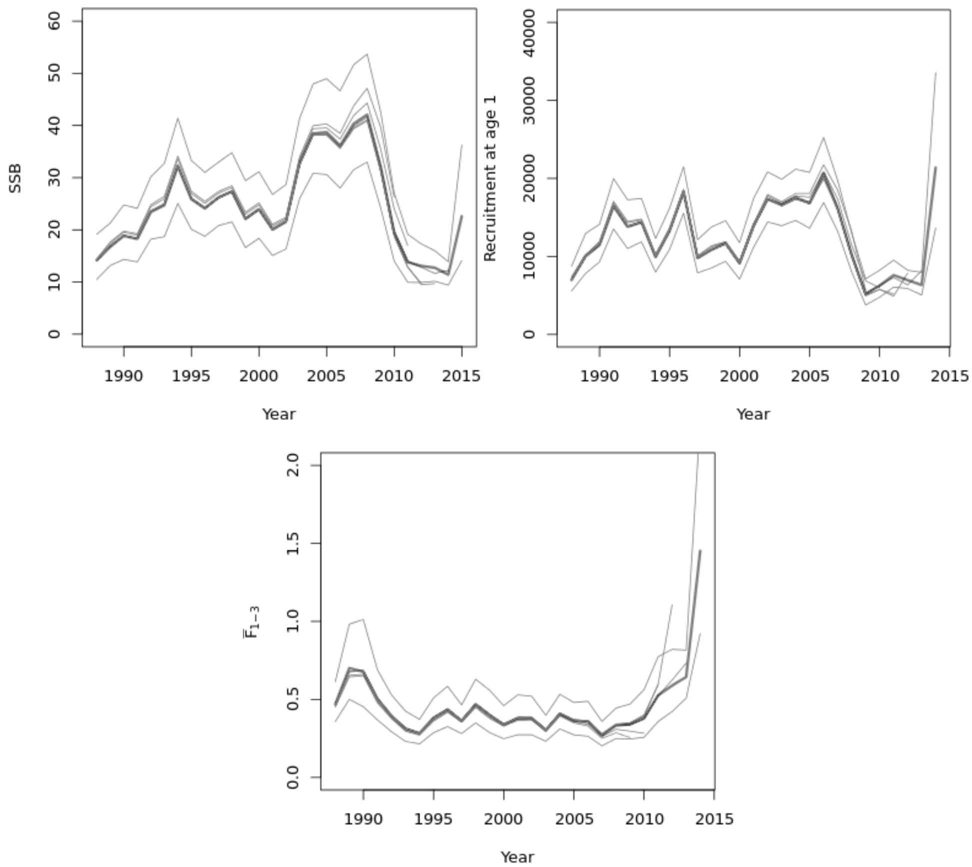

Fig. 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimates of SSB (t), recruits (thousands) and $F_{1\text{-}3}$ from the length-based model. Light grey lines represent 95% confidence limits.

The WG also noticed that LBM-estimates of commercial catches by length fit the actual observations better than the model-estimates of survey catch. More specifically the model frequently under-estimates peaks in the survey observations of the youngest age-classes and also often estimates a double peak in the 15-20mm range, while the data show a single peak. Possible explanations of this are that the growth rates of the model are incorrectly defined (von Bertalanffy growth relationship), selectivity is modelled incorrectly, and/or natural mortality is poorly defined. These improvement potentials of the LBM were also highlighted in an ad hoc external review of the model (Annex II).

Based on the above considerations it was decided to use the SPM as primary basis for this year's advice and use the LBM for supportive information, until the potential of alternative growth rate and selectivity assumptions have been explored.

It is noted that the SPM depends on ecosystem state to remain within the range of the modelled historical period. If e.g. predation or recruitment were to increase rapidly outside the range previously experienced by the shrimp stock within the modelled period, the shrimp stock might decrease or increase in size more than the model results have indicated as likely. The LBM would in theory be more precise in making short-term predictions as it explicitly keeps account of the incoming recruitment to the fishery. The LBM will however, also be sensitive to regime shifts through its assumptions about M. While the SPM might not be the perfect model for this stock the diagnostics and conclusions made at the recent benchmark (ICES, 2013a) still hold.

d) Assessment Results

i) Length-based model (SCR Doc. 15/056)

Historical stock trends and recruitment

The spawning stock biomass (SSB) has been variable over the assessment period 1988 to 2015 (Fig. 5.7). From 2001, SSB increased to over 42 000 t in 2008, after which it decreased to about 11 000 t in 2014. This is the lowest observed SSB in the times series. SSB has increased to about 23 000 t in 2015, but the large uncertainties around the most recent estimates should be taken into account when deciding on the MSY.

Recruitment (R) has similar to the SSB been variable over the assessment period 1988 to 2015 (Fig. 5.7). A series of low recruitment years between 2009 and 2015, with the exception of year 2014, should be noted. During this period of low recruitment the estimates of SSB were also historically low and below B_{lim}. The uncertainties around the estimate of recruitment in 2015 were exceptionally large. The reason for this is that the model has not yet seen the recruits in the fishery data (data until 2014), only in the survey data (January 2015).

Fishing mortality (F) for ages 1 to 3 has remained relatively stable since the beginning of the 1990s to about 2010, after which F has increased steeply to 1.45 in 2014 (Fig. 5.7). The uncertainties around the most recent estimates, in particular in 2014, should be noted.

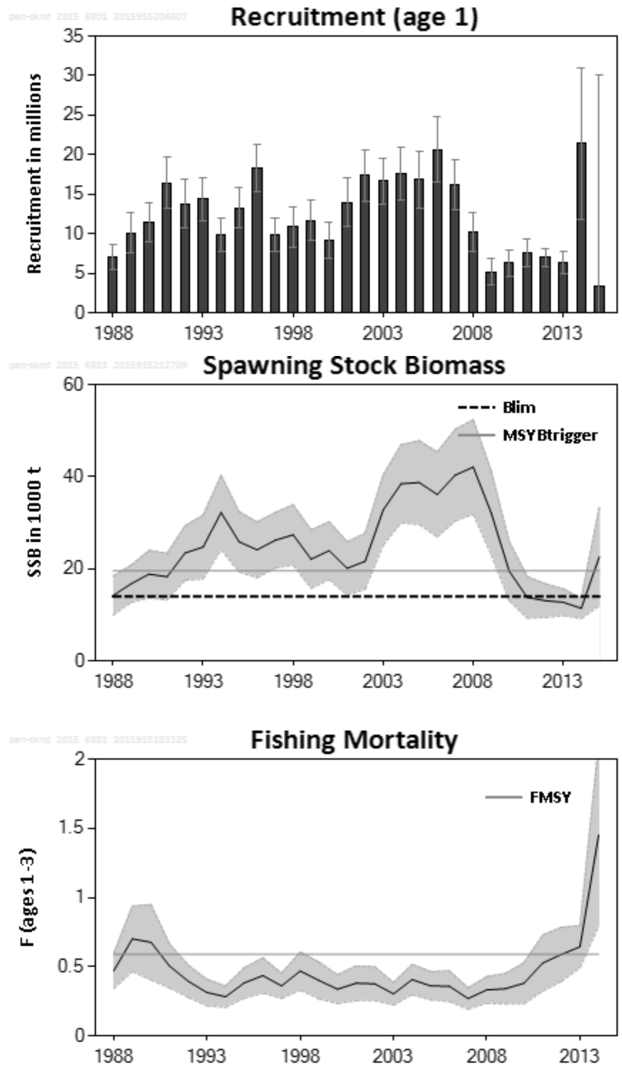

Fig. 5.7. Northern shrimp in Skagerrak and Norwegian Deep: Summary of the stock assessment of LBM. The 2.5% and 97.5% quantiles are included in all three figures.

Reference points

The reference points are defined based on a WG-definition of the *Pandalus* stock as being medium-lived (Table 5.4). F_{MSY} was defined as $F_{0.1}$, estimated from a yield per recruit curve as no stock-recruitment relationship was identified (Fig. 5.8). B_{lim} was defined as the lowest SSB (nearest thousand tonnes) of the time series, above which recruitment did not seem to be negatively influenced by SSB (14 000 t). B_{pa} was set at B_{lim} * 1.4 (= 19 600 t). MSY $B_{trigger}$ is set equal to B_{pa}. These reference points were to some extent considered provisional and possibilities for establishing new reference points based on stock-recruitment relationship (using standard ICES methodology) will be explored next year.

Table 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Definition of reference points.

Framework	Reference point	Value	Technical basis	Source
MSY approach	MSY $B_{trigger}$	19600	$B_{trigger} = B_{pa}$	NIPAG report, ICES
	$Fmsy$	0.59	$F_{0.1}$ from the yeild per recruit curve	NIPAG report
Precautionary approach	B_{lim}	14000	Defined as the lowest SSB of the time series, above which recruitment does not seem to be negatively impaired by the level of SSB (14 000t).	NIPAG report
	B_{pa}	19600	B_{lim}*1.4	NIPAG report; ICES
	F_{lim}	Not defined		
	F_{pa}	Not defined.		
Management plan	SSB_{MGT}		There is no management plan for this stock	
	F_{MGT}		There is no management plan for this stock	

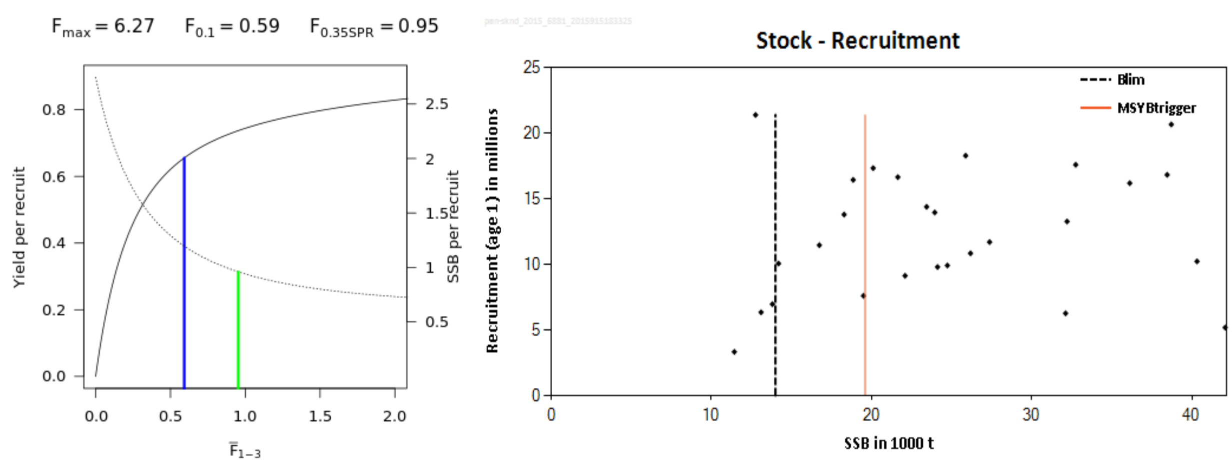

Fig. 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Yield per recruit and stock - recruitment plot. $F_{0.1}$ is indicated by the blue line and $F_{0.35SPR}$ by the green line. In the stock-recruitment plot, B_{lim} is indicated with a dashed line and $MSYB_{trigger}$ with a pink line.

Catch options

Table 5.5. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the catch options. Weights in thousand tonnes. Recruitment in thousands.

Variable	Value	Source	Notes
F ages 1-3 (2015)	0.33	ICES (2015)	F equivalent to TAC in 2015
SSB (2016)	21954	ICES (2015)	
R_{age0} (2016)	12484	ICES (2015)	Median of full time series minus two most recent years with large uncertainties in the estimates
R_{age1} (2016)		ICES (2015)	
R_{age0} (2017)	12484	ICES (2015)	Median of full time series minus two most recent years with large uncertainties in the estimates
Total catch (2015)	10614	ICES (2015)	Catch assumed equal to landings in 2015
Commercial landings (2015)	10614	ICES (2015)	TAC in 2015 (10 900t) minus 286t caught in advance by Norway in 2014
Discards (2015)	*	ICES (2015)	
Recreational catch (2015)		ICES (2015)	

*Not estimated/assumed

Table 5.6. Northern shrimp in Skagerrak and Norwegian Deep: The catch options.

Rationale	Catch (2016)	Basis	F (2016)	SSB (2016)	SSB (2017)	%SSB change*	% TAC change**
MSY approach	11920	$F_{MSY} = 0.59$	0.59	21594	19544	-9.5	9.4
Zero catch	0	$F_{2015} \times 0$	0	21594	29813	38.1	-100.0
	11920	F_{2016}	0.59	21594	19544	-9.5	9.4
Other options	7825	F_{2015} ***	0.33	21594	22926	6.2	-28.2
	8436	$F_{2015} \times 1.10$	0.37	21594	22409	3.8	-22.6
	9519	$F_{2015} \times 1.30$	0.43	21594	21504	-0.4	-12.7
	10638	$F_{2015} \times 1.50$	0.5	21594	20581	-4.7	-2.4

*SSB in 2017 relative to SSB in 2016.
**Catch in 2016 relative to TAC 2015.
*** F equivalent to TAC in 2015.

ii) Stock production model fitted by Bayesian methods using fishery catch and effort data and data from the Norwegian shrimp survey (SCR Doc. 15/059).

The input series of biomass indices span 1984-2015. Since the late 1980s the stock has varied with a slightly increasing trend until 2006 when it started to decline (Fig. 5.9). This is similar to the development of SSB according to the LBM (Fig. 5.7). The median 2015 estimate is above B_{msy} (Table 5.7). The estimated risk of stock biomass being below $B_{trigger}$ in 2015 was 0% and of being below B_{lim}, 0% (Table 5.7).

Median estimate of fishing mortality has remained below F_{msy} since 1989 (Fig. 5.10). There is a 2% risk of F_{2015} being above F_{msy} (Table 5.7).

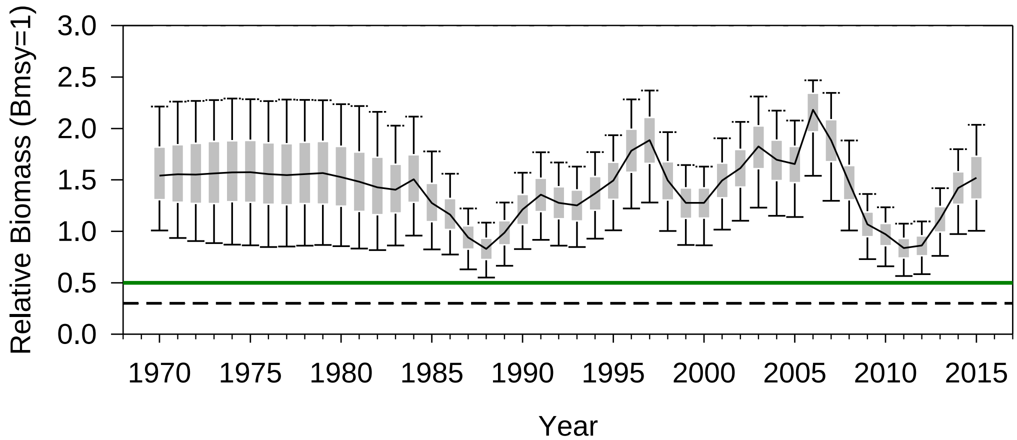

Fig. 5.9. Northern shrimp in Skagerrak and Norwegian Deep: Estimated time series of relative biomass (B_t/B_{msy}) 1970-2015. The solid black line is the median; boxes represent quartiles; the whiskers cover the central 90% of the distribution. Dashed black line represents B_{lim}. Green line represents $B_{trigger}$.

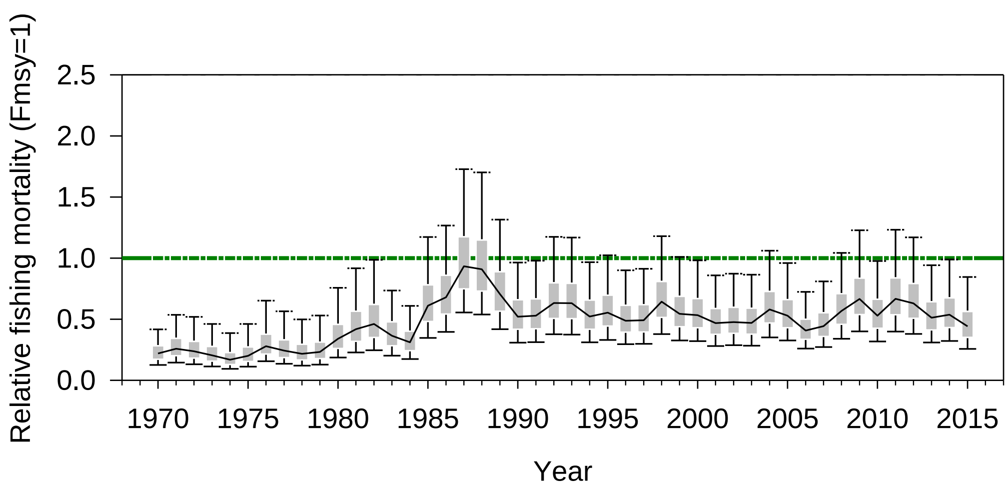

Fig. 5.10. Northern shrimp in Skagerrak and Norwegian Deep: Estimate of relative fishing mortality (F_t/F_{msy}) 1970-2015. The solid black line is the median; boxes represent quartiles; the whiskers cover the central 90% of the distribution. Green line marks F_{msy}.

Table 5.7. Northern shrimp in Skagerrak and Norwegian Deep: Risk analysis 2014-2015.

Status	2014	2015*
Risk of falling below B_{lim} ($0.3B_{MSY}$)	0%	0%
Risk of falling below *Btrig* ($0.5B_{MSY}$)	0%	0%
Risk of exceeding F_{MSY}	5%	2%
Stock size (B/Bmsy), median	1.41	1.50
Fishing mortality (F/Fmsy), median	0.54	0.44
Surplus production (% of MSY)	84%	75%

*Predicted catch = TAC

d) Stock development and biological reference points

Reference points. In 2009, ICES adopted a "Maximal Sustainable Yield (MSY) framework" (ACOM. ICES Advice, 2013. Book 1. Section 1.2) for deriving advice. It considers two reference points: F_{msy} and $B_{trigger}$. In keeping with the reference points developed in 2006 and 2010 for the Barents Sea shrimp stock, 50% B_{msy} was adopted as $B_{trigger}$ (NIPAG, 2006). Under the ICES PA two reference points are required; B_{lim} and B_{pa}. Again in line with the Barents Sea shrimp stock, B_{lim} was set at 30% B_{msy} (NIPAG, 2006). B_{pa} is not considered relevant in the presence of a risk analysis. F_{lim} is equal to $1.7F_{msy}$ – the fishing mortality that drives the biomass to B_{lim}.

Projections. Given a catch of 12 340 t in 2014 and assuming a 2015 catch of 10 900 t (TAC), catch options from 14 000 t to 24 000 t were evaluated for 2016. Under all these catch options the risk of going below B_{lim} is <1%. Catches of up to 20 000 t have a <50% risk of exceeding F_{msy} and a <1% risk of falling below $B_{trigger}$ (Table 5.8).

Table 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Catch options for 2016.

	Catch option 2016 (ktons)					
	14	16	18.5	20	21.5	24
Risk of falling below B_{lim} ($0.3B_{msy}$)	0%	0%	0%	0%	0%	0%
Risk of falling below B_{trig} ($0.5B_{msy}$)	0%	0%	0%	0%	0%	0%
Risk of exceeding F_{msy}	12%	19%	28%	41%	50%	63%
Risk of exceeding F_{lim}	1%	2%	5%	7%	12%	17%
Stock size (B/B_{msy}), median	1.42	1.40	1.38	1.33	1.31	1.28
Fishing mortality (F/F_{msy}),	0.60	0.69	0.79	0.91	1.00	1.14
Productivity (% of MSY)	82%	84%	85%	89%	90%	92%

Comparison of Assessment Models

Two models are used in the assessment of this stock. One is length/age based, uses data on numbers at length from catches and survey, and tracks the age cohorts into which those numbers are converted. The other is a surplus-production model which considers only the dynamics of the stock biomass using series of indicators of biomass.

1. The models agree that SSB decreased fairly drastically since about 2006, but with an increasing trend the most recent years.

2. The length-based model measures a rapid recent increase in fishing mortality, not evident in the results of the surplus-production model.
3. The length-based model takes into account, in its predictions, the recent (2015) low observation of age-1 shrimps in the stock, which the surplus-production model is not constructed to be able to do.
4. The length-based model estimates current SSB to be above B_{lim} for the first time since 2009 while the surplus production model estimates SSB above $B_{trigger}$ throughout the series.
5. The length-based method estimates short-term yield of 11 920 t at F_{msy}, while the surplus production model would yield 18 500 t.

Summary of Assessment (SPM)

Mortality. Fishing mortality has remained below F_{msy} since 1990. There is a 2% risk of F_{2015} being above F_{msy}.

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The risk that the biomass at the end of 2015 is below $B_{trigger}$ is less than 1%.

Recruitment. The abundance of age-1 shrimp in the survey catches was low in 2009 and 2011, just below the mean in 2012-13 and record high in 2014. The 2015 value is low.

State of the Stock. The stock declined from 2006 to 2011, followed by an increase from 2011 to 2015. It is estimated to be well above $B_{trigger}$.

Yield. Catch options up to 18 500 t/yr for 2016 have a risk less than 30% of exceeding F_{msy} and less than 5% of exceeding F_{lim}.

e) Management Recommendations

NIPAG **recommends** that, for shrimp in Skagerrak and Norwegian Deep:

- *Sorting grids should be implemented in the Norwegian Deep in addition to the Skagerrak.*

STATUS: Sorting grids are implemented since 1st January 2015.

- *Norwegian vessels between 12 and 15 m in the Norwegian Deep should be required to complete and provide log books.*

f) Research Recommendations

There were no research recommendations for shrimp in Skagerrak and the Norwegian Deep.

g) Research Recommendations from the 2010-2014 meetings

- *In the length-based model, explore the replacement of 'weight at age' with 'weight at length' data from the fishery*

STATUS: 'weight at age' data from the fishery have been replaced with 'weight at length' data to improve model fit.

- *the Norwegian shrimp survey should be extended east to cover important shrimp grounds in Swedish waters.*

STATUS: Five trawl stations in Swedish national waters were covered by the survey in January 2015.

- *the results of the current assessment should be compared with those of an updated run including survey data collected early in the following year.*

STATUS: No progress has been made. NIPAG reiterates this recommendation.

- *the Stochastic assessment model as described in SCR Doc.10/70 should be implemented and MSY reference points should be established.*

STATUS: The benchmark assessment which was finalized during the NIPAG meeting in September 2013 chose the length based model as a basis for advice for the shrimp stock in Skagerrak and the Norwegian Deep. However, it was also decided that the Bayesian surplus production model would be run alongside the coming years, as a quality check of the forecast produced by the length based model.

- *collaborative efforts should be made to standardize a means of predicting recruitment to the fishable stock.*

STATUS: No progress has been made. NIPAG reiterates this recommendation.

- *Differences in recruitment and stock abundance between Skagerrak and the Norwegian Deep should be explored.*

STATUS: No progress has been made. NIPAG reiterates this recommendation.

- *the ongoing genetic investigations to explore the relation/connection/mixing between the shrimp (stock units) in Skagerrak and the Norwegian Deep on the one hand and the Fladen Ground shrimp on the other hand should be continued until these relationships have been clarified.*

STATUS: Results from the project "*Sustainable shrimp fishing in Skagerrak*" has detected weak genetic structure in the Skagerrak/North Sea region, primarily associated with fjords in the Skagerrak region (Knutsen *et al.* 2015). The shrimp in Skagerrak and the Norwegian Deep most likely comprise one single stock, which is in agreement with the oceanic current pattern in the area. The benchmark assessment in September 2013 concluded that we have one single shrimp stock in the Skagerrak and Norwegian Deep area. Genetic and time-series data (survey and LPUE) together with information on ocean currents in the North Sea suggest that the Fladen Ground shrimp constitute a separate population from the Skagerrak and Norwegian Deep stock (Knutsen *et al.* 2015).

References

Knutsen, H., Jorde, P.E., Gonzalez, E.B., Eigaard, O.R., Pereyra, R.T., Sannæs, H., Dahl, M., André, C., Søvik, G. 2015. Does population genetic structure support present management regulations of the northern shrimp (*Pandalus borealis*) in Skagerrak and the North Sea? ICES Journal of Marine Science 72(3): 863-871.

6. NORTHERN SHRIMP IN THE BARENTS SEA (ICES SUB-AREAS I AND II)

Background documentation (equivalent to stock annex) is found in SCR Doc 15/52, 53, 54; 06/64, 08/56, 07/86, 07/75, 06/70.

a) Introduction

Northern shrimp (*Pandalus borealis*) in the Barents Sea and in the Svalbard fishery protection zone (ICES Sub-areas I and II) is considered as one stock (Fig. 6.1). Norwegian and Russian vessels exploit the stock in the entire area, while vessels from other nations are restricted to the Svalbard fishery zone and the "Loop Hole" (Fig. 6.1).

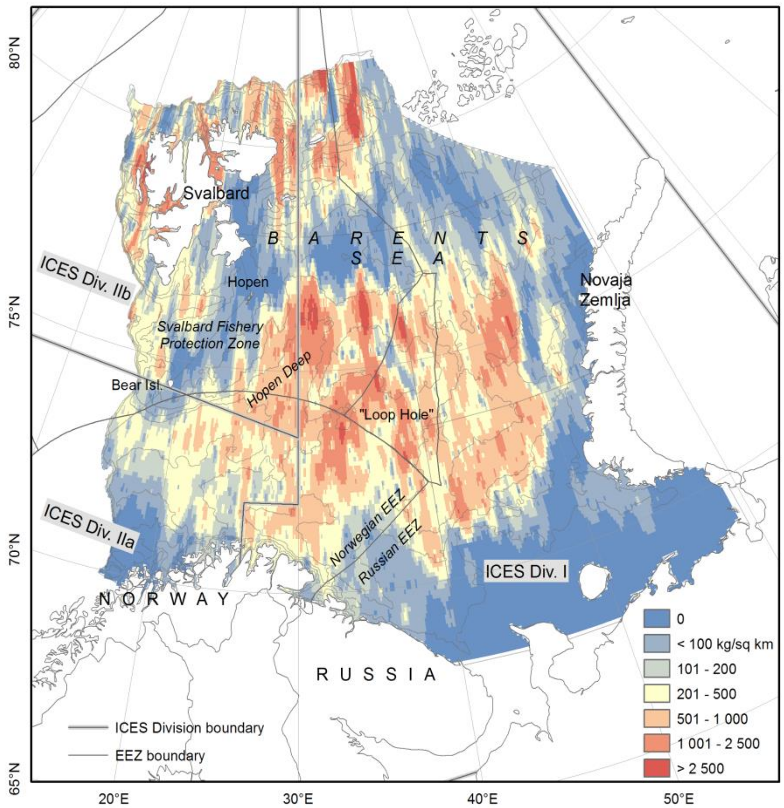

Fig. 6.1. Shrimp in the Barents Sea: stock distribution, mean density index (kg/km^2), based on survey data.

Norwegian vessels initiated the fishery in 1970. As the fishery developed, vessels from several nations joined and the annual catch reached 128 000 t in 1984 (Fig. 6.2). In the recent 10-year period catches have varied between 20 000 and 40 000 t/yr, 50–90% taken by Norwegian vessels and the rest by vessels from Russia, Iceland, Greenland and the EU (Table 6.1).

There is no TAC established for this stock. The fishery is partly regulated by effort control, and a partial TAC (Russian zone only). Licenses are required for the Russian and Norwegian vessels. The fishing activity of these license holders is constrained only by bycatch regulations whereas the activity of third country fleets operating in the Svalbard zone is also restricted by the number of effective fishing days and the number of vessels by country. The minimum stretched mesh size is 35 mm. Bycatch is limited by mandatory sorting grids and by the temporary closing of areas where excessive bycatch of juvenile cod, haddock, Greenland halibut, redfish or shrimp <15 mm CL is registered.

Catch. Catches have ranged from 5 000 to 128 000 t/yr. (Fig. 6.2) since 1970. The most recent peak was seen in 2000 at approximately 83 000 t. Catches thereafter declined to about 20 000 t in 2013 and are predicted to remain at about that level in 2014 and 2015.

Table 6.1. Shrimp in ICES SA I and II: Recent catches in metric tons, as used by NIPAG for the assessment.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015[1]
Recommended TAC	41 299[2]	40 000	50 000	50 000	50 000	50 000	60 000	60 000	60 000	60 000	70 000
Norway	37253	27352	25558	20662	19784	16779	19928	14158	8846	7701	10000
Russia	435	4	192	417	0	0	0	0	1067	741	1000
Others	4930	2271	4181	7109	7488	8419	10298	10598	9336	8229	9000
Total	42618	29627	29931	28188	27272	25198	30226	24756	19249	16671	20000

[1] Catches projected to the end of the year;
[2] Should not exceed the 2004 catch level (ACFM, 2004).

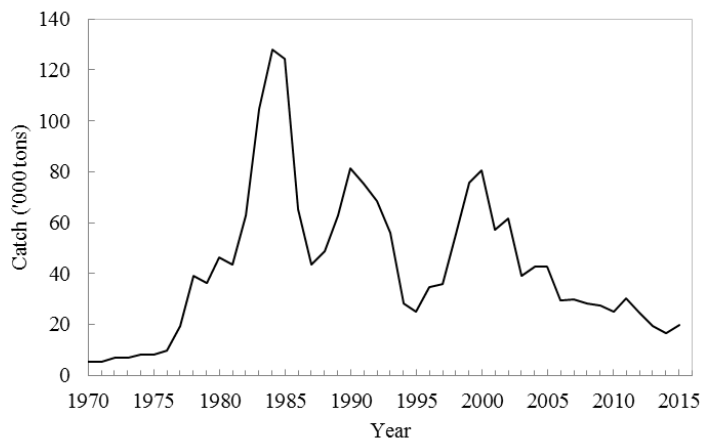

Fig. 6.2. Shrimp in ICES SA I and II: total catches 1970–2015 (2015 projected to the end of the year).

Discards and bycatch. Discard of shrimp cannot be quantified but is believed to be small as the fishery is not limited by quotas. Bycatch rates of other species are estimated from at-sea inspections and research surveys and are corrected for differences in gear selection pattern (SCR Doc. 07/86). Area-specific bycatch rates are then multiplied by the corresponding shrimp catches from logbooks to give an overall bycatch estimate.

Since the introduction of the Nordmøre sorting grid in 1992, only small individuals of cod, haddock, Greenland halibut, and redfish, in the 5–25 cm size range, are caught as bycatch. The bycatch of small cod ranged between 2 and 67 million individuals/yr and redfish between 2 and 25 million individuals/yr from about 1992 to 2010 while 1–9 million haddock/yr and 0.5–14 million Greenland halibut/yr were registered in 2000–2004 (Fig. 6.3). In recent years there has been a decline in bycatch owing to reduced effort in the shrimp fishery. Details of bycatch are no longer reported by the ICES Arctic Fisheries Working Group. NIPAG will update this bycatch information at its 2016 meeting.

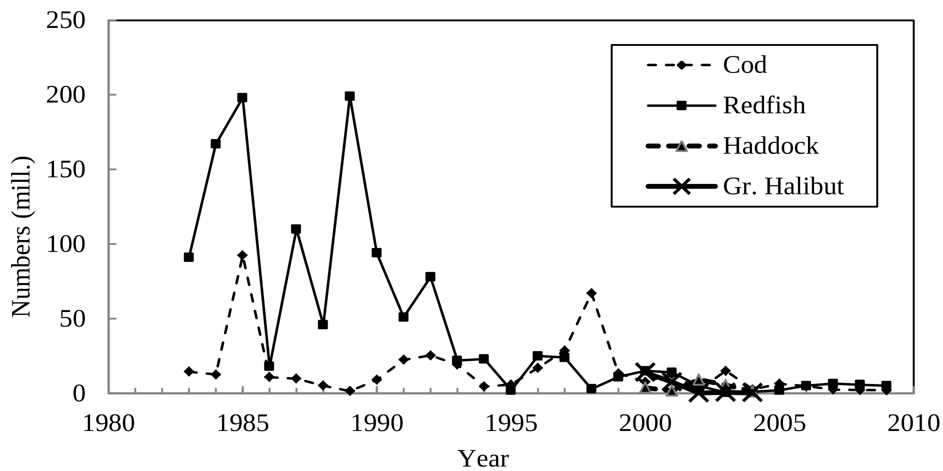

Fig. 6.3. Shrimp in ICES SA I and II: Estimated bycatch of cod, haddock, Greenland halibut and redfish in the Norwegian shrimp fishery (million individuals). No data available for 2010-15.

b) Input Data

i) Commercial fishery data

A major restructuring of the shrimp fishing fleet towards fewer and larger vessels has taken place since the mid-1990s. At that time an average vessel had around 1 000 HP; 10 years later this value had increased to more than 6 000 HP (Fig. 6.4). Until 1996 the fishery was conducted using single trawls only. Double and triple trawls were then introduced. An individual vessel may alternate between single and multiple trawling depending on what is appropriate on given fishing grounds.

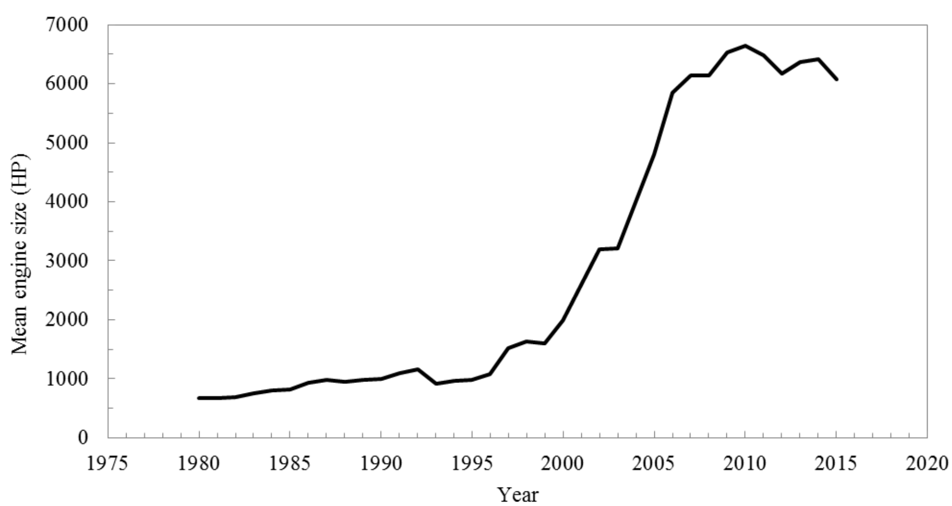

Fig. 6.4. Shrimp in ICES SA I and II: Mean engine power (HP) weighted by trawl-time, 1980–2015 (Norwegian data).

The fishery is conducted mainly in the central Barents Sea (Hopen Deep) and on the Svalbard Shelf along with the Goose Bank (south east Barents Sea) (Fig. 6.5). The fishery takes place throughout the year but may in some years be seasonally restricted by ice conditions. The lowest effort is generally in October through March, the highest in May to August.

Logbook data since 2009 show decreased activity in the Hopen Deep and around Svalbard, coupled with increased effort further east in international waters in the “Loop Hole” (Fig 6.5). Information from the industry points to decreasing catch rates and more frequent area closures due to bycatch of juvenile fish on the traditional shrimp fishing grounds as the main reasons for the observed change in fishing pattern.

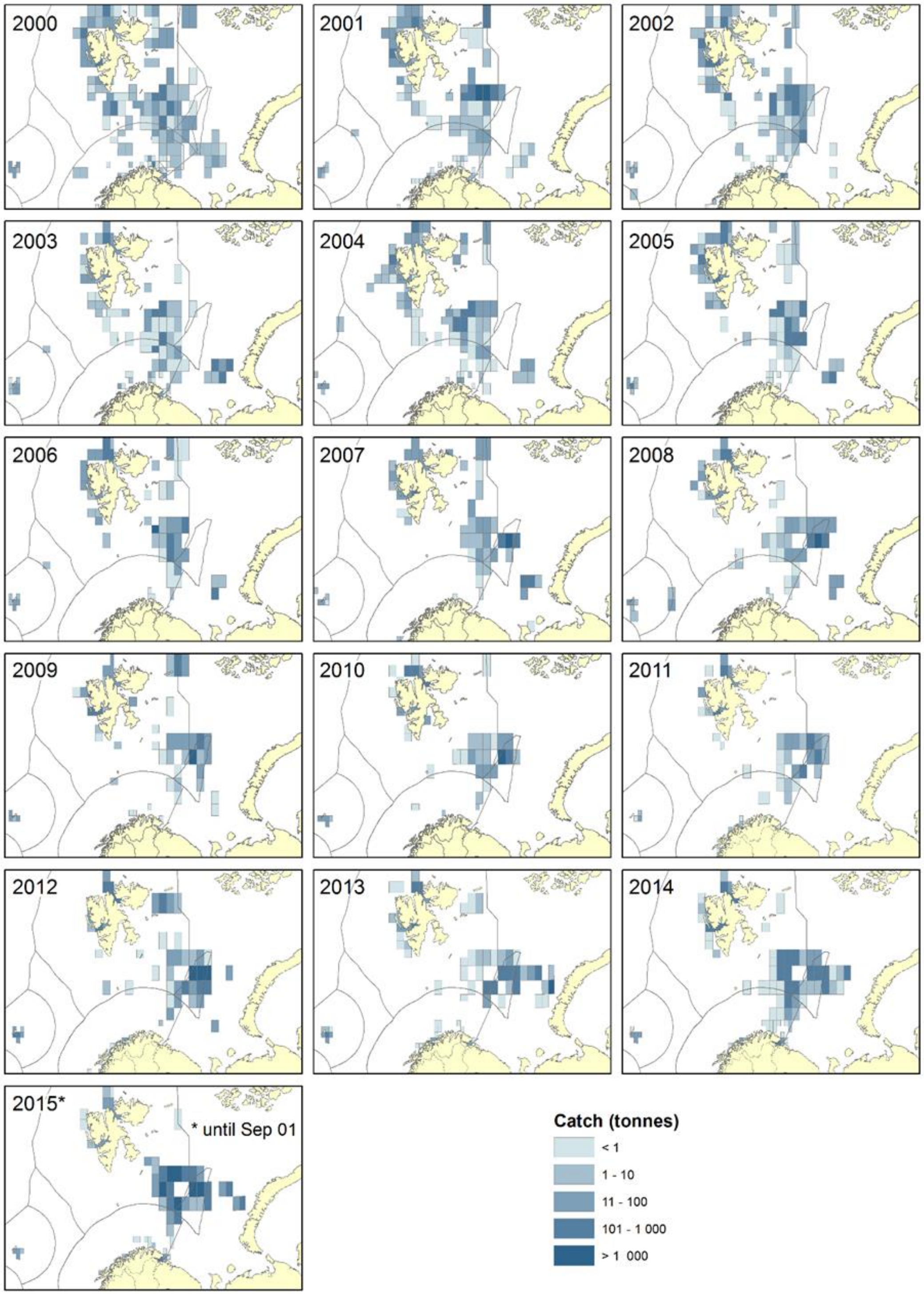

Fig. 6.5. Distribution of catches by Norwegian vessels since 2000 based on logbook information.

Norwegian logbook data were used in a multiplicative model (GLM) to calculate standardized annual catch rate indices (SCR Doc. 15/53). A new index series based on individual vessels rather than vessel groups was introduced in 2008 (SCR Doc. 08/56) in order to take into account the changes observed in the fleet. The GLM model used to derive the CPUE indices included the following variables: (1) vessel, (2) season (month), (3) area, and (4) gear type (single, double or triple trawl). The resulting series provides an index of the fishable biomass of shrimp ≥17 mm CL, *i.e*. females and older males.

The standardized CPUE declined by 60% from a maximum in 1984 to the lowest value of the series in 1987 (Fig. 6.6). From then until 2011 it showed an overall increasing trend until 2005. Between 2005 and 2011 it fluctuated above the average of the time series, however after 2012 indices are below-average.

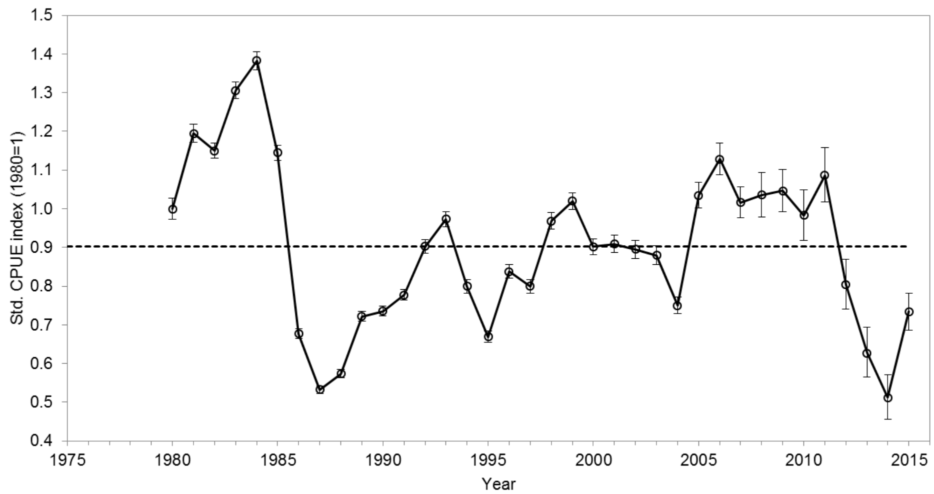

Fig. 6.6. Shrimp in ICES SA I and II: standardized CPUE based on Norwegian data. Error bars represent one standard error; dotted line is the mean of the series.

ii) Research survey data

Russian and Norwegian surveys have been conducted in their respective EEZs of the Barents Sea since 1982 to assess the status of the northern shrimp stock (SCR Doc. 06/70, 07/75, 14/51, 15/52). The main objectives have been to obtain indices for stock biomass, numbers, recruitment and demographic composition. In 2004, these surveys were replaced by a joint Norwegian-Russian "Ecosystem survey" which monitors shrimp along with a multitude of other ecosystem variables in the Barents Sea and around Svalbard (SCR Doc.14/55, 15/52).

Biomass. The Biomass indices of the Norwegian and Russian shrimp surveys (survey 1 and 2) varied without trend between 1982 and 2005 (Fig. 6.7). The Joint Russian-Norwegian Ecosystem Survey (survey 3) increased by about 66% from 2004 to 2006 and then decreased back to the 2004-value in 2008 (Fig. 6.7). The 2011 to 2013 values are back up close to that of 2006 while the 2014 value is down again from this level by about 25%

Due to heavy ice conditions the north-eastern part of the area was poorly covered and there were no hauls taken in stratum 3. For the 2004-2013 survey period this area accounts for on average 13% of the biomass (range: 8-27%). The 2014 biomass for area 3 was estimated by calculating the average ratio of biomass density in area 3 to biomass density in the remaining survey area for the 2009-2013 period and applying this average to the density of the 2014 surveyed area. Estimates of variance for area 3 was taken as the variance of the 2009-2013 estimates for area 3 (Table 4, SCR Doc. 15/052).

The geographical distribution of the stock in 2009-2014 was more easterly compared to that of the previous years (Fig. 6.8).

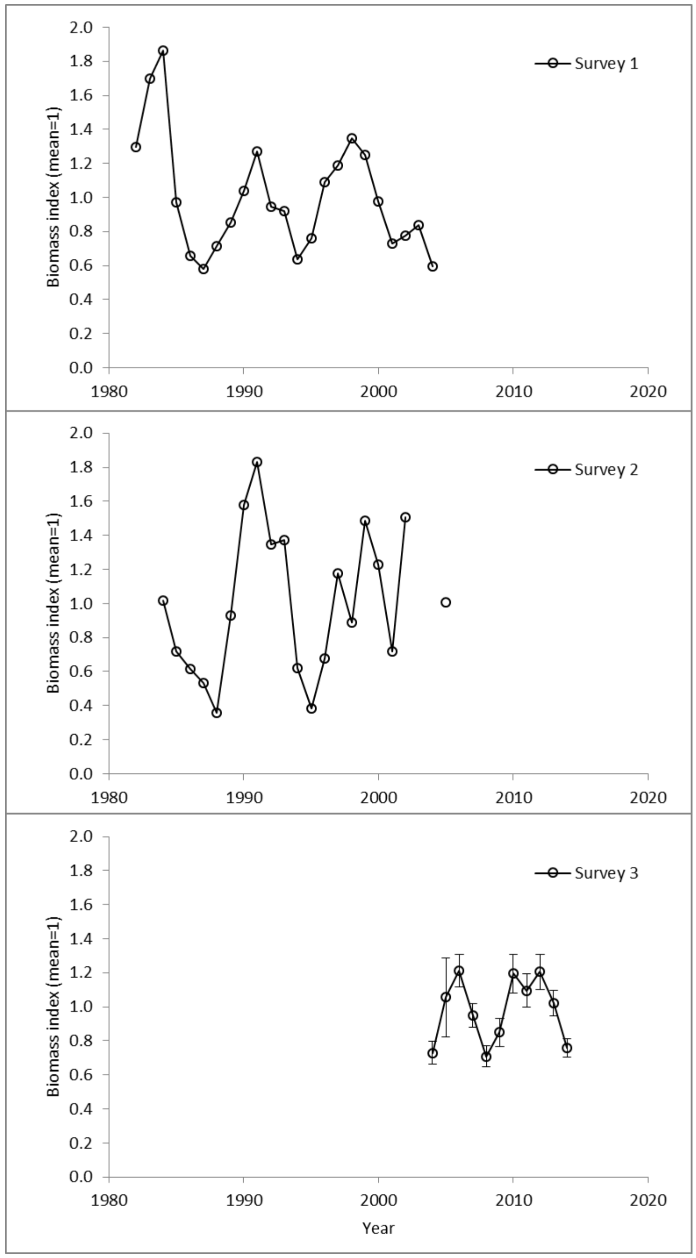

Fig. 6.7. Shrimp in ICES SA I and II: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey 2004-2014 (the 2015 survey data is not available at the time of the NIPAG meeting). Error bars represent one standard error.

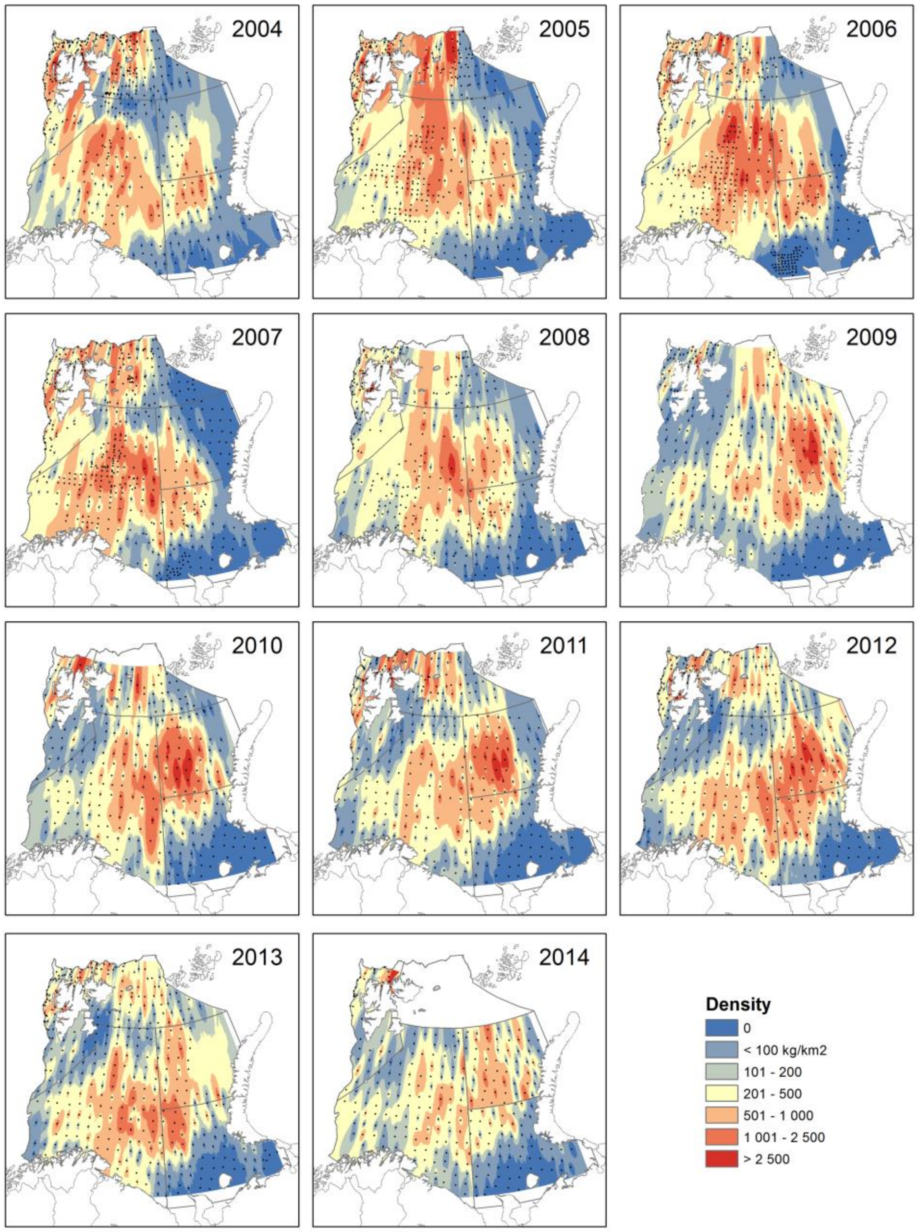

Fig. 6.8. Shrimp in ICES SA I and II: Shrimp density (kg/km2) as calculated from the Ecosystem survey data 2004–2014 (no data for strata 3 due to ice conditions).

Recruitment indices. A recruitment index were derived from the overall size distributions based on Russian and Norwegian survey samples (SCR Doc. 14/55 and 15/52 respectively) as estimated abundances of shrimp at 13 to 16 mm CL. Shrimp at this size will probably enter the fishery in the following one to two years. This index has varied without trend (Fig. 6.9).

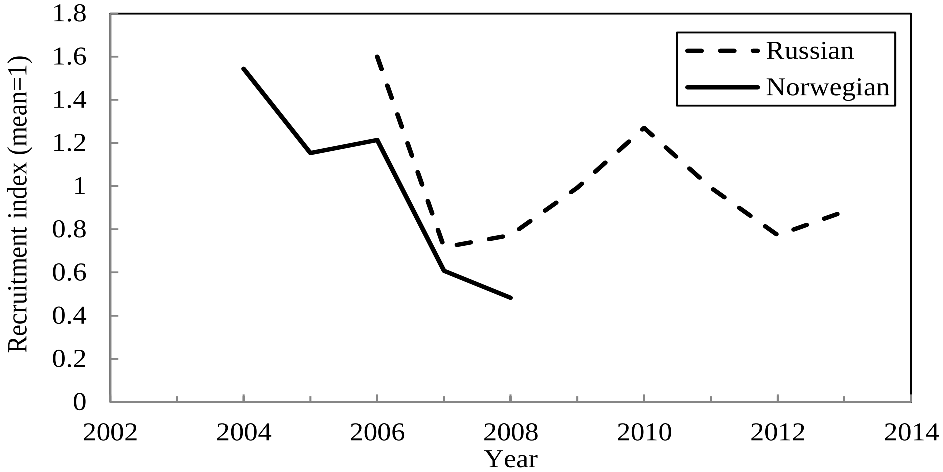

Fig. 6.9. Shrimp in ICES SA I and II: Index of recruitment: abundance of shrimp at size 13–16 mm CL based on Norwegian survey samples 2004-2008 and Russian survey samples 2006-2013.

Environmental considerations. Temperatures in the Barents Sea have been high since 2004, largely due to increased inflow of warm water masses from the Norwegian Sea. Shrimps are mainly caught in areas where bottom temperatures are above 0°C. Highest densities are observed between zero and 4°C, while the upper limit of their preferred temperature range appears to lie at about 6-8°C. The eastward shift in shrimp distribution in recent years may be associated with changes in temperature.

c) Estimation of Parameters

The modelling framework introduced in 2006 (SCR Doc. 06/64) was used for the assessment. Model settings were the same as ones used in previous years.

Within this model, parameters relevant for the assessment and management of the stock are estimated, based on a stochastic version of a surplus-production model. The model is formulated in a state-space framework and Bayesian methods are used to derive "posterior" probability density distributions of the parameters (SCR Doc. 15/54).

The model synthesized information from input priors, four independent series of shrimp biomass indices and one series of shrimp catch. The biomass indices were: a standardized series of annual fishery catch rates for 1980–2015 (Fig. 6.6, SCR Doc. 15/53); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2014 (Fig, 6.7, SCR Doc. 15/52). These indices were scaled to true biomass by individual catchability parameters, q_j, and lognormal observation errors were applied. Total reported catch in ICES Div. I and II since 1970 was used as yield data (Fig. 6.2, SCR Doc. 15/52). The fishery being without major discarding problems or variable misreporting, reported catches were entered into the model as error-free.

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 fishing mortality, *F*, refers to the removal of biomass by fishing and is scaled to the fishing mortality at MSY, F_{msy}. The state equation describing stock dynamics took the form:

$$P_{t+1} = \left(P_t - \frac{C_t}{B_{MSY}} + \frac{2\,MSY\,P_t}{B_{MSY}} \left(1 - \frac{P_t}{2} \right) \right) \cdot \exp(\nu_t)$$

where P_t is the stock biomass relative to biomass at MSY ($P_t = B_t/B_{MSY}$) in year t. This frames the range of stock biomass on a relative scale where $B_{MSY} = 1$ and the carrying capacity (K) equals 2. The 'process errors', v, are normally, independently and identically distributed with mean 0 and variance σ_P^2.

The observation equations had lognormal errors, ω, κ, η and ε, for the series of standardised CPUE ($CPUE_t$), Norwegian shrimp survey ($survR_t$), The Russian shrimp survey ($survRu_t$) and joint ecosystem survey ($survE_t$) respectively giving:

$$CPUE_t = q_C B_{MSY} P_t \exp(\omega_t)\,,\ survR_t = q_R B_{MSY} P_t \exp(\kappa_t)\,,\ survRu_t = q_{Ru} B_{MSY} P_t \exp(\eta_t)\,,\ survE_t = q_E B_{MSY} P_t \exp(\varepsilon_t)$$

The observation error terms, ω, κ, η and ε are treated as normally, independently and identically distributed with mean 0 and variances (observation error) σ_C^2, σ_R^2, σ_{Ru}^2 and σ_E^2 respectively. Summaries of the estimated posterior probability distributions of selected parameters are shown in Table 6.2. Values are similar to the ones estimated in previous assessments.

Table 6.2. Shrimp in ICES SA I and II: Summary of parameter estimates: mean, standard deviation (sd) and quartiles of the posterior distributions of selected parameters (symbols are as in the text; r = intrinsic growth rate, P_0 = the 'initial" stock biomass in 1969).

	Mean	sd	25 %	Median	75 %
MSY (ktons), maximum sustainable yield	265	197	120	213	357
K (ktons), carying capacity	3522	1869	2093	3115	4549
r, intrinsic growth rate	0.31	0.16	0.19	0.30	0.42
q_R, catchability of survey 2	0.12	0.08	0.06	0.09	0.14
q_{Ru}, catchability of survey 1	0.29	0.21	0.15	0.23	0.36
q_E, catchability of survey 3	0.19	0.13	0.10	0.15	0.23
q_C, catchability of CPUE index	4.1E-04	2.9E-04	2.1E-04	3.3E-04	5.1E-04
P_0, initial relative biomass (1969)	1.51	0.26	1.34	1.51	1.68
P_{2015}, relative biomass in 2015	1.56	0.46	1.28	1.54	1.83
σ_R, coefficient of variation for survey 2	0.17	0.03	0.15	0.17	0.19
σ_{Ru}, coefficient of variation for survey 1	0.34	0.05	0.30	0.33	0.37
σ_E, coefficient of variation for survey 3	0.18	0.04	0.16	0.18	0.21
σ_C, coefficient of variation for CPUE index	0.14	0.02	0.12	0.14	0.15
σ_P, coefficient of variation for process	0.20	0.03	0.18	0.19	0.22

Reference points. Four reference points are considered: F_{msy}, $B_{trigger}$, F_{lim} and B_{lim}. In the present assessment, F_{msy} is estimated directly as is the probability of exceeding reference points. "Buffer" reference points are obsolete due to the available risk analyses. B_{lim} is set at 30% B_{msy} (NIPAG, 2006), $B_{trigger}$ at 50% B_{msy} and F_{lim} at $1.7F_{msy}$ (NIPAG, 2010).

	Type	Value	Technical basis
MSY approach	$B_{trigger}$	$0.5B_{MSY}$	Approximately corresponding to10th percentile of the B_{MSY} estimate
	F_{MSY}		Resulting from the production model.
Precautionary approach	B_{lim}	$0.3B_{MSY}$	The B where production is reduced to 50% MSY
	F_{lim}	$1.7F_{MSY}$	the F that drives the stock to B_{lim}

d) Assessment Results

The results of this year's model run are similar to those of the previous years (model introduced in 2006). The conclusions drawn from the model have been found on investigation to be insensitive to the setting of the priors for initial stock biomass and carrying capacity (SCR Doc. 06/64 and 07/76).

Stock size and fishing mortality. A steep decline in stock biomass in the mid-1980s was noted following some years with high catches and the median relative biomass dropped nearly to 1 (Fig. 6.10, upper). Since the late 1980s, however, the stock has varied with a slightly increasing trend. The median 2014-15 values are above B_{msy}. The estimated risk of stock biomass being below $B_{trigger}$ in 2015 is less than 5% (Table 6.3). The median estimate of fishing mortality has remained below F_{msy} throughout the history of the fishery (Fig. 6.10 lower). In 2015, there is a less than 5% risk of the F being above F_{msy} (Table 6.3).

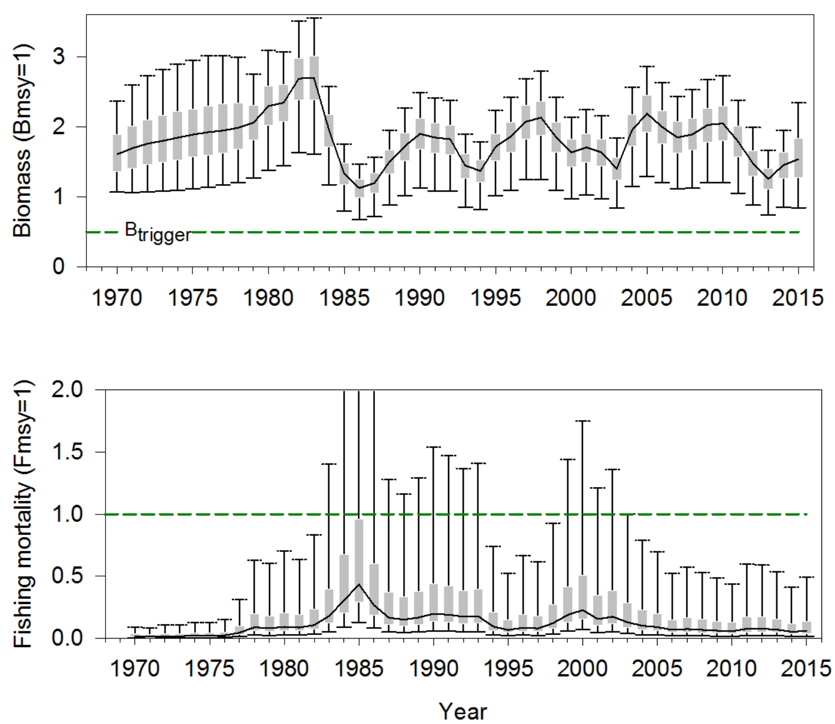

Fig. 6.10. Shrimp in ICES SA I and II: estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) for 1970–2015. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines are the $B_{trigger}$ and F_{msy} references respectively.

Table 6.3. Shrimp in ICES SA I and II: stock status for 2014 and predicted to the end of 2015.

Status	2014	2015*
Risk of falling below B_{lim}	0.1 %	0.1 %
Risk of falling below $B_{trigger}$	0.9 %	1.1 %
Risk of exceeding F_{MSY}	1.5 %	2.1 %
Risk of exceeding F_{lim}	0.7 %	0.9 %
Stock size (B/Bmsy), median	1.45	1.54
Fishing mortality (F/Fmsy),	0.05	0.06
Productivity (% of MSY)	79 %	71 %

*Predicted catch = 20 ktons

Predictions. Assuming a catch of 20 kt for 2015, catch options up to 70 kt for 2016 have low risks of exceeding F_{msy} (<10%), F_{lim} (<4.9%), and of going below $B_{trigger}$ (<5%) in 2016 (Table 6.4) and all are likely to result in stock increase.

Table 6.4. Shrimp in ICES SA I and II: Predictions of risk and stock status in 2016 associated with six optional catch levels for 2016.

	Catch option 2016 (ktons)					
	50	60	70	80	90	100
Risk of falling below B_{lim}	0.2 %	0.2 %	0.2 %	0.3 %	0.2 %	0.3 %
Risk of falling below $B_{trigger}$	1.4 %	1.4 %	1.5 %	1.6 %	1.5 %	1.7 %
Risk of exceeding F_{MSY}	6.4 %	7.8 %	9.3 %	11.3 %	12.7 %	14.1 %
Risk of exceeding F_{lim}	3.5 %	4.4 %	4.9 %	6.1 %	7.0 %	8.1 %
Stock size (B/Bmsy), median	1.59	1.59	1.57	1.57	1.57	1.55
Fishing mortality (F/Fmsy),	0.15	0.18	0.21	0.23	0.27	0.30
Productivity (% of MSY)	65 %	66 %	67 %	68 %	68 %	69 %

The risks associated with ten-year projections of stock development assuming annual catch of 50 000 to 100 000 t were investigated (Fig. 6.11). For all options the risk of the stock falling below $B_{trigger}$ in the longer term (10 years) is less than 10%. Catch options up to 60 000 t, have a low risk (<10%) of exceeding F_{MSY} after 10 years. Taking up to 90 000 t/yr will increase the risk of going above F_{msy} by the end of the ten-year projection to around 15%.

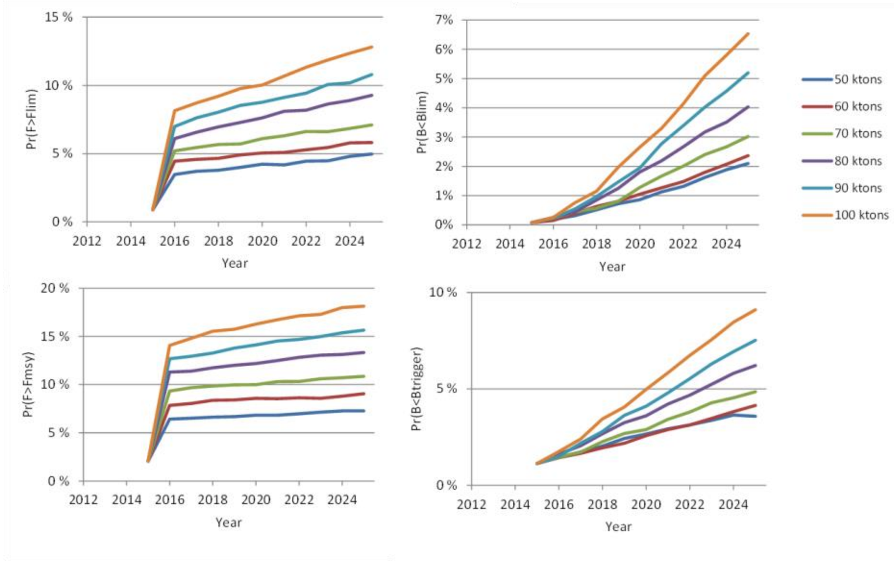

Fig. 6.11. Shrimp in ICES SA I and II: Projections of estimated risk of going below $B_{trigger}$ and B_{lim}, and of exceeding F_{msy} and F_{lim}, given different catch options.

Additional considerations

Model performance. The model was able to produce good simulations of the observed data (Fig. 6.12). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically. They were found not to include excessively large deviation.

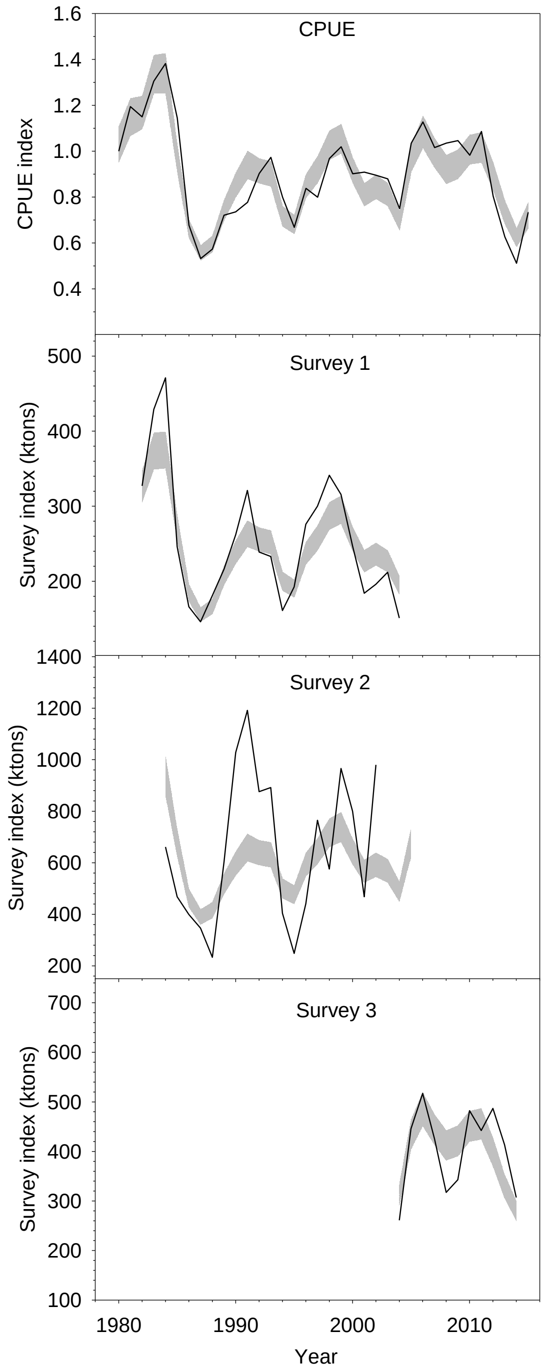

Fig. 6.12. Shrimp in ICES SA I and II: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 shrimp survey (survey 1), a Russian survey index discontinued in 2005 (Survey 2) and the Joint Norwegian-Russian Ecosystem Survey (survey 3) since 2004. Grey shaded areas are the inter-quartile ranges of their posteriors.

Predation. Both stock development and the rate at which changes might take place can be affected by changes in predation, in particular by cod, which has been documented as capable of consuming large amounts of shrimp. Continuing investigations to include cod predation as an explicit effect in the assessment model have so far not been successful; it has not been possible to establish a relationship between the density of cod and the stock dynamics of shrimp. The cod stock in the Barents Sea has increased considerably within the last ten years. If predation on shrimp were to increase rapidly beyond the range previously experienced, the shrimp stock might decrease in size more than the model results have indicated as likely.

Recruitment, and reaction time of the assessment model. The model used is best at projecting trends in stock development but estimates, and uses, long-term averages of stock dynamic parameters. Large and/or sudden changes in recruitment or mortality may therefore be underestimated in model predictions. However such changes have not been observed in the recent period.

Rebuilding potential. At 30% B_{msy} (B_{lim}) production is reduced to 50% of its maximum. With an 80% confidence interval on *r* (the intrinsic rate of increase) ranging from 0.11 to 0.53 per year, it would take 4-14 years to rebuild the stock from B_{lim} to B_{msy} without a fishery.

e) Summary

Mortality. Fishing mortality is likely to remained below F_{msy} throughout the history of the fishery. In 2015 there is a less than 5% risk of the *F* being above F_{msy} with a projected catch at 20 000 t.

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The risk that the biomass at the end of 2015 is below $B_{trigger}$ is less than 5%

Recruitment. Recruitment indices have varied without trend in 2004 – 2013; no data from 2014.

State of the Stock. The stock has remained around 1.4B_{msy} since 2012, with a low risk of being below $B_{trigger}$. The risks of fishing mortality being above F_{msy} at the end of 2015 is less than 5%.

Yield. Catch options up to 70 000 t/yr, have a risk below 10% of exceeding F_{msy} and below 4.9% of exceeding F_{lim} in 2016. At a higher risk larger yields may be achieved. E.g. catches of more than 200 kt can be taken without exceeding the median estimate of F_{msy}.

Special Comment. In recent years the distribution of the stock has changed, and some of the traditional fishing grounds are now less attractive to the fishery. Access to certain other fishing grounds is restricted by closures to prevent bycatch, and by regulations requiring vessels to sail long distances to specified entry and exit points of the Russian EEZ.

f) Review of Recommendations from 2014

For the shrimp stock in Barents Sea and Svalbard (ICES Div. I and II), NIPAG **recommended** that *the technical basis for the assessment in various SCR Docs be collated into a single technical stock annex*.

STATUS: There has been no progress on this recommendation

NIPAG reiterated its **recommendations** from 2010 that, *for the shrimp stock in Barents Sea and Svalbard (ICES Div. I and II):*

- *Demographic information (length, sex and stage etc.) be collected also from the Norwegian part of* ***the Joint Norwegian – Russian Ecosystem Survey.***

STATUS: There has been no progress on this recommendation

- *Collaborative efforts should be made to standardize a means of predicting recruitment to the fishable stock.*

STATUS: There has been no progress on this recommendation

- *Work to include explicit information on recruitment in the assessment model should be continued.*

STATUS: There has been no progress on this recommendation.

g) Research Recommendations

There were no research recommendations.

7. NORTHERN SHRIMP IN FLADEN GROUND (ICES DIVISION IVA)

From the 1960s up to around 2000 a significant shrimp fishery exploited the shrimp stock on the Fladen Ground in the northern North Sea. A short description of the fishery is given, as a shrimp fishery could be resumed in this area in the future. The landings from the Fladen Ground have been recorded since 1970 (SCR Doc. 09/69). Total reported landings have fluctuated between zero since 2006 to above 8 000 t (Figure 7.1). The Danish fleet accounts for the majority of these landings, with the Scottish fleet landing a minor portion. The fishery took place mainly during the first half of the year, with the highest activity in the second quarter. Since 2006 no landings have been recorded from this stock.

Since 1998 landings have decreased steadily and since 2004 the Fladen Ground fishery has been virtually non-existent with total recorded landings being less than 25 t. Interview information from the fishing industry obtained in 2004 gives the explanation that this decline is caused by low shrimp abundance, low prices on the small shrimp which are characteristic of the Fladen Ground, and high fuel prices. This stock has not been surveyed for several years, and the decline in this fishery may reflect a decline in the stock.

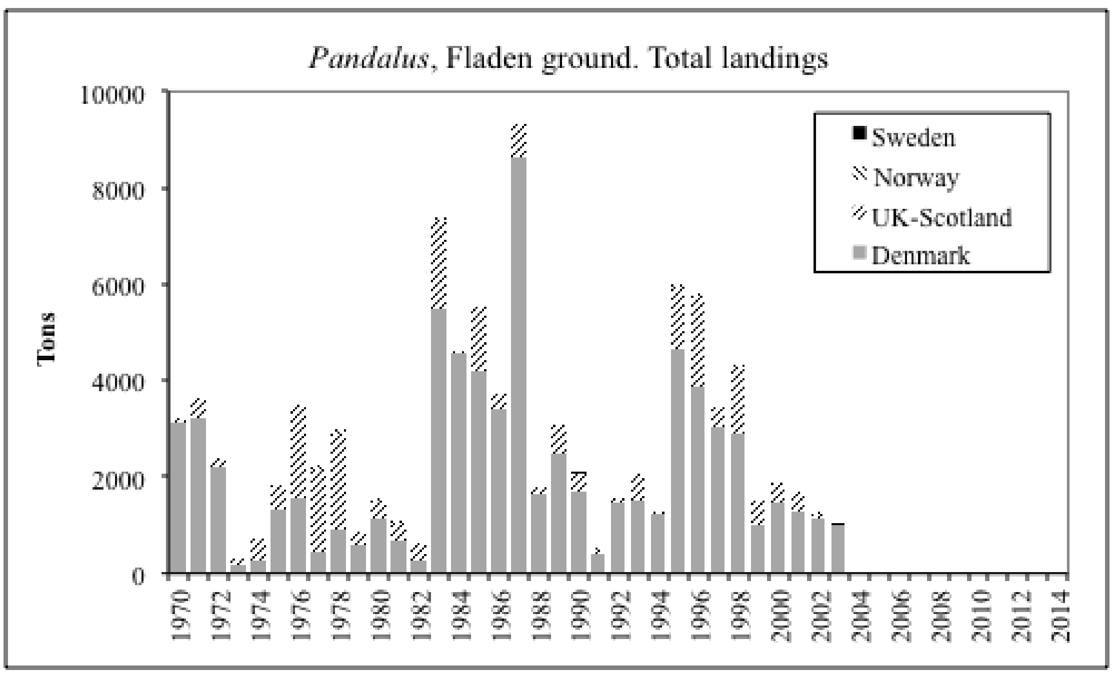

Fig. 7.1. Northern shrimp in Fladen Ground: Landings

IV. OTHER BUSINESS

a) FIRMS Classification for NAFO Shrimp Stocks

The table as agreed in June was updated with the agreed classifications for the Northern shrimp stocks assessed this year.

Stock Size (incl. structure)	Fishing Mortality			
	None–Low	Moderate	High	Unknown
Virgin–Large	3LNO Yellowtail flounder			
Intermediate	3M Redfish[3] 3LN Redfish 3NO Witch flounder	SA0+1 Northern shrimp[1] DS Northern shrimp[1] 0&1A Offsh. & 1B–1F Greenland halibut	3M Cod	Greenland halibut in Uummannaq[2] Greenland halibut in Upernavik[2] Greenland halibut in Disko Bay[2] SA1 American Plaice SA1 Spotted Wolffish
Small	SA3+4 Northern shortfin squid 3NOPs White hake			3LNOPs Thorny skate SA2+3KLMNO Greenland halibut
Depleted	3M American plaice 3LNO American plaice 2J3KL Witch flounder 3NO Cod 3M Northern shrimp[1,3] 3LNO Northern shrimp[1]			SA1 Redfish SA0+1 Roundnose grenadier SA1 Atlantic Wolffish
Unknown	SA2+3 Roughhead grenadier 3NO Capelin 3O Redfish			SA2+3 Roundnose grenadier

[1] Shrimp will be re-assessed in September 2015
[2] Assessed as Greenland halibut in Div. 1A inshore
[3] Fishing mortality may not be the main driver of biomass for Div. 3M Shrimp and Redfish

b) Future Meetings

The next meeting of NIPAG will be held at ICES Headquarters, Copenhagen, during 7 – 14 September, 2016. The chairs stressed the importance of the administrative support provided by the NAFO Secretariat staff in helping this meeting achieve its objectives, and requested the SC Coordinator and SIA attend future meetings.

c) Long-term management strategy for Northern shrimp (*Pandalus borealis*) in Skagerrak and the Norwegian Deep.

In addressing the request from Norway to ICES on development of a long-term management plan for Northern shrimp in the Skagerrak and Norwegian Deep (Annex III), the group responded:

The accepted approach for evaluating management plans is to evaluate one or more management strategies consistent with the plan using the approach of Management Strategy Evaluation (MSE; Punt et al. 2014).

A full MSE to evaluate the proposed long-term management strategy is a large undertaking that will likely take up to two years to complete. It requires the availability of one or more quantitative fisheries scientists for all or part of that time.

MSE is characterized by applying the management strategy to the perceived population as seen through the lens of the stock assessment in a computer simulation. The stock assessment is based on data generated with error from the simulated true population and fishery.

It is essential that model for the simulated population and fishery (called the operating model) captures the main sources of uncertainty, such as in stock-recruitment, natural mortality, body growth, discarding etc.

Typically more than one operating model is considered, based on alternative assumptions regarding the population and fishery that are equally plausible given the available data.

In the simulation, the assessment is typically applied at each time step to generate the perceived state of the stock. The management strategy is then applied to this perceived state in the form of a feedback harvest control rule. This can be complicated to program and take time to run on the computer. ICES has developed a "short-cut" approach to MSE (ICES 2013a) in which, rather than applying the stock assessment in each time step of the simulation, the assessment is approximated by generating observations directly, with error, from the true simulated population. This short-cut method may be appropriate in some cases but is less desirable than a full MSE and conclusions may not be robust to the assessment errors. A full MSE is therefore recommended.

There are two models currently under consideration by ICES for providing advice on the SKND Pandalus stock, as identified by the 2013 ICES Inter-benchmark process (ICES 2013b). The model applied in the 2013-15 assessments had been a surplus production model (SPM; Hvingel 2012, 2014). The other model is a length-based model (LBM) described in Nielsen et al. 2012, 2015). The LBM was preferred by the Inter-benchmark (ICES 2013b) as the assessment model but there have been some problems in getting the LBM fully functional. This was achieved in 2015, however there are still some concerns based on the diagnostics and model estimates that require further consideration. Consequently scientific advice in 2015 was again based on the SPM.

Neither assessment model had previously been used as a basis for MSE and considerable work may be required before an MSE can be carried out based on either assessment model. If the more complex model, LBM, is considered as a basis for the operating model, it could be used to generate data within an MSE to which the SPM, as an assessment model, could be applied. The reverse is not the case because SPM cannot generate length frequency data.

Workplan

1. Complete remaining work on the LBM to answer issues raised in the most recent NIPAG meeting.

2. Determine what work would be required to use both/either the LBM and/or SPM as the basis for MSE.

3. Hire early to mid-career quantitative scientist to carry out the work required for MSE using one or both models – to be undertaken under supervision of one or more senior researchers proficient in the biology, fishery and assessment models for the SKND *Pandalus* stocks, as well as a good understanding of MSE.

4. Conduct an initial meeting between scientists and managers/decision makers to clarify the approach to be undertaken, clarify the management objectives, quantify these objectives into performance statistics and agree on acceptable outcomes with regard to imperative and trade-off performance statistics that meet the objectives (see for example Miller and Shelton 2010).

5. Consult *Pandalus* experts and modelers to agree on major sources of uncertainty to include and the number and characteristics of the operating models required.

6. Carry out programming required to set up the MSE. Do deterministic runs to ensure that the software is working correctly.

7. Carry out preliminary stochastic runs and compute performance statistics.

8. Consult with mangers/decision makers with regard to preliminary results. Minor modification of the management objectives/performance statistics may be required. Alternative harvest control rules may be suggested, or tuning of existing rules by changing coefficients may be considered to improve performance.

9. Carry out final runs of the MSE, prepare results and write a full report.

10. Constitute an expert independent peer review of methods and results.

11. Carry out any final revisions to MSE based on the peer review.

12. ICES presents report and results to Norway, along with peer review report.

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d) Chairs of Future Meetings

NIPAG considered the succession of the chairmanship and elected Guldborg Soevik as its chair from the ICES community. Joel Vigneau was elected as chair of NAFO's Standing Committee on Fisheries Science in June, and as such, will become the other NIPAG co-chair. The proposed ICES terms of reference for the group are presented in Annex IV.

VI. ADJOURNMENT

The NIPAG meeting was adjourned at 1500 hours on 16 September 2015. The Co-Chairs thanked all participants, especially the designated experts and stock coordinators, for their hard work. The Co-Chairs thanked the NAFO and ICES Secretariats for all of their logistical support. Special thanks were given the to Department of Fisheries and Oceans for their hospitality during this meeting.

ANNEX I. REPORT OF THE MINI-WORKSHOP ON *PANDALUS* RECRUITMENT TO FISHABLE BIOMASS AND AGEING (WKPRA)

Chair: Don Stansbury, Friday, September 11, 2015

Objectives

Age and size distributions and the prediction/projection of recruitment are potentially important considerations in assessments of *Pandalus* stocks worldwide.

WKPRA will provide an opportunity to discuss ongoing work on ageing methods (see Kilada et al, 2012) including age validation and production techniques, interpretation of ages from length frequency data, use of length and age information in stock assessment models, determination of recruitment and relationship with fishable biomass.

It is anticipated that the workshop will lead to increased collaboration among Pandalus researchers worldwide, a possible proposal to ACOM and STACFIS for a full joint workshop in the future, and joint research and publications on topics, including age determination validation studies, interpretation of age at length data, determination of age distributions for stock assessment, and the possibility of projecting future fishable biomass from estimates of recruitment.

Agenda

1) AnnDorte Burmeister: Recruitment to fishable biomass in shrimp stocks in the North-Atlantic.
2) Anne Richards: Use of satellite data to identify critical periods for early life survival in the Gulf of Maine.

Discussion on progress in current work on recruitment to fishable biomass of stocks of northern shrimp (*Pandalus borealis*); can new ageing techniques of crustaceans bring this work forward?

3) Raouf Kilada: Age determination methods for crustaceans.
4) Ingibjörg G. Jónsdóttir: Age determination of crustaceans – state of the art after Reykjavik workshop, February 2015.
5) Guldborg Søvik: Ongoing work on age determination at IMR – validating the technique using shrimp from Skagerrak with a known age distribution.
6) Don Stansbury and Darrell Mullowney: Age determination of Newfoundland/Labrador shrimp stocks.
7) Ole Ritzau Eigaard, Mikaela Bergenius, and Mats Ulmestrand: How length frequency data are used in the new length-based, age-structured stock assessment model for SKND shrimp.

Discussion on ageing techniques - strengths, weaknesses, validation methods, comparison with information from length frequency data, incorporation of lengths and ages into stock assessments and associated analytical models. Consideration will be given to the differences in growth rates and age compositions between stocks and the implications for developing length and age based stock assessment models for Pandalus.

8) Anne Richards: identifying causes for the decline of the Gulf of Maine shrimp stock.

Discussion of recent declines in some shrimp stocks and implications for providing scientific advice for sustainable fisheries management and rebuilding plans given periodic shifts in abundance that may be only partially related to fishing.

Documentation

The report of the Mini-workshop, consisting of extended abstracts of presentations as well as a short summary of discussion, conclusions and research recommendations is included as an annex to the 2015 NIPAG Report. Consideration will be given to a proposal to ACOM and SC for a follow up full WKPRA in fall 2016 or 2017.

Summary of presentations

1. Recruitment to fishable biomass in shrimp stocks in the North-Atlantic. (withdrawn)

2. Anne Richards, Jay O'Reilly and Kimberly Hyde: Use of Satellite Data to Identify Critical Periods for Early Life Survival of Northern Shrimp

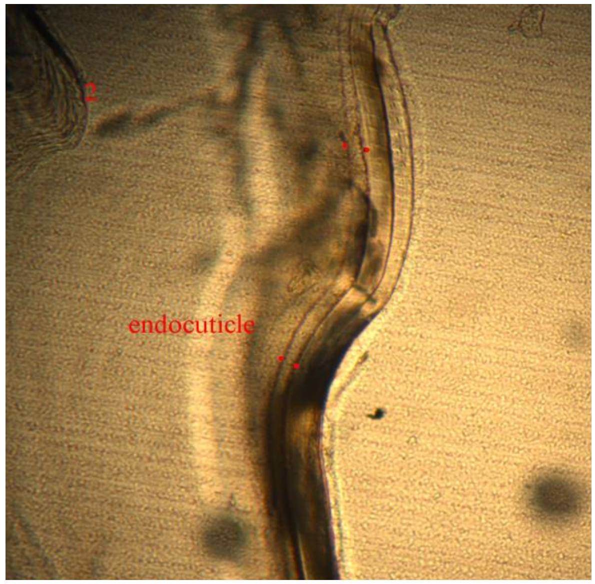
Recruitment success of northern shrimp in the Gulf of Maine (GOM) is higher in cooler years. A long-standing hypothesis is that temperature effects on hatch timing may cause a mismatch in timing of larval emergence and production of planktonic food. We used rolling window analysis of daily satellite data to test this hypothesis and identify critical periods for early life survival of the 1998-2012 northern shrimp year-classes. Survival was negatively correlated with sea surface temperature (SST) during a six-week period around the time of larval emergence (late winter) and during a four-week period in late summer when SST and stratification reached annual maxima. Survival was negatively correlated with chl-*a* concentration (chl-*a*) during two 5-week periods centered (1) about a month before the hatch midpoint and (2) around the time of settlement to the benthos. The results did not reveal a link between survival and bloom-hatch phenology. Warmer SST may be detrimental primarily because of poorer physiological performance outside thermal optima. Possible explanations for the chl-*a* effects include succession in the plankton community to unfavorable species or stages, allelopathic effects, or unobserved processes correlated with temporal changes in chl-*a*. Summer SST increased significantly during the study period but the other environmental variables did not show a trend.

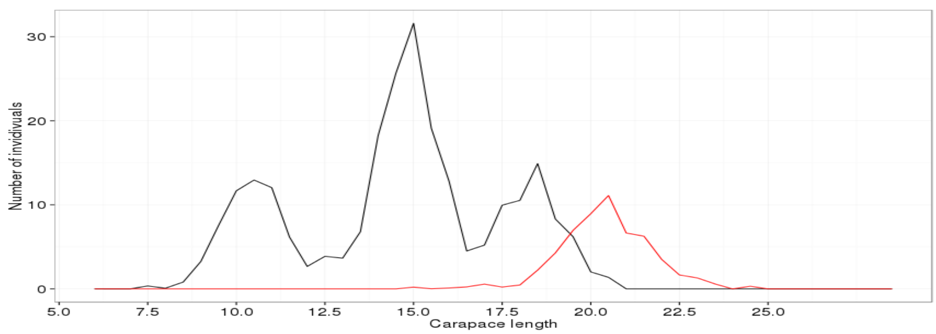
3. Raouf Kilada: Age determination methods for crustaceans

Experience around the world in determining age from sectioning of eye stalks and gastric hard parts (teeth) were presented. An approach for preparing material has been developed and is being applied by various institutes. Workshops, including the recent one in Iceland have been beneficial in this regard. Consistency in determining age requires considerable experience and while two readers in the same lab obtained good consistency, there were considerable differences among independent readers, particularly those with little prior experience. Consideration could be given to have all age material prepared and read by a single lab.

4. Ingibjörg G. Jónsdóttir: Age determination of crustaceans – state of the art after workshop in Reykjavík February 2015

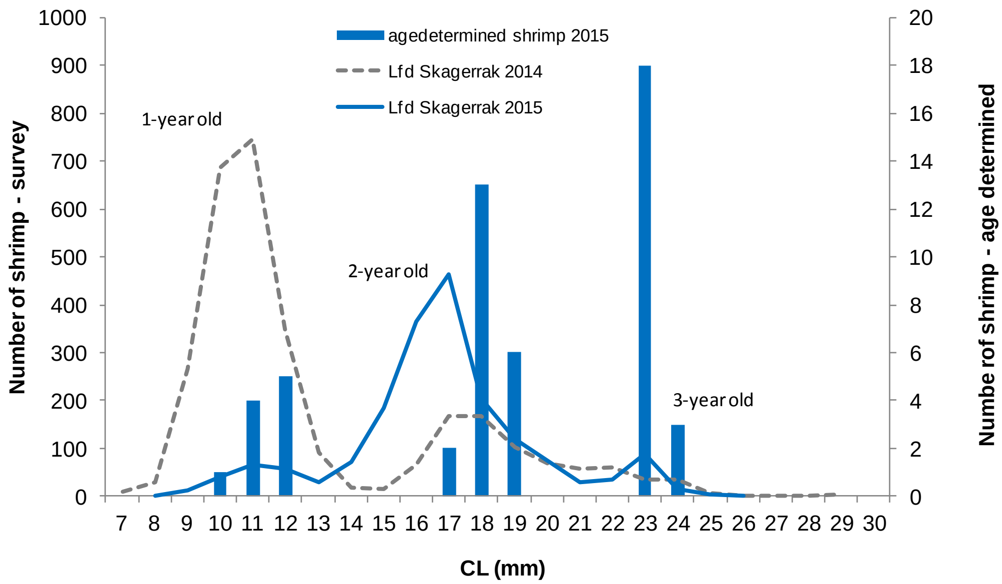
A workshop was held in February 2015 in Iceland, where Dr. Raouf Kilada introduced a feasible technique to estimate the age of crustaceans. Sixteen persons from five countries attended this workshop and worked with northern shrimp, crabs, lobsters and krill. After the workshop the Icelanders started working with a sample of northern shrimp from a fjord in north-west Iceland. Several problems occurred, including; removing samples from the trays, adjusting the eye stalks in the epoxin before it got too hard and making the slices as the saw could was not working well at all times. Growth bands could not be counted for at about 20% of the pictures. The biggest challenge was to find out what were real growth bands and where to start counting. Futhermore, the samples were from the autumn. As the formation of the growth bands are unknown, it was uncertain whether the last growth band was formed during the summer, therefore only representing half a year. The individual at the picture is 12.5 mm and could therefore, according to the length distribution, be either 1.5 or 2.5 years old. It is necessary to look at individuals from various times of the year in order to try to estimate this.





5. Guldborg Søvik: Ongoing work on age determination at IMR – validating the technique using shrimp from Skagerrak with a known age distribution.

The purpose of the on-going work on age determination of shrimp (*Pandalus borealis*) at IMR is to use shrimp from the Norwegian Deep/ Skagerrak (NDSK) stock to validate the ageing method for crustaceans currently being explored. The NDSK shrimp are fast growing, and age groups are clearly visible as modes in the stock length frequency distribution (lfd), especially the 1- and 2-year old animals (Fig. 1). These two age groups are hardly overlapping in size. Thus, they will allow correlation between bands and age, and identification of the starting point of age reading (in the 1-group). Shrimp were sampled at the annual Norwegian shrimp survey in January 2015. In order to obtain shrimp of known age (i.e., animals from length intervals with no overlap between age groups) shrimp were collected from the maxima of the modes (based on the length frequency distribution from 2014) (Fig. 1). Thirty shrimp from each of the age groups 1, 2 and 3 years (respectively 10-12 mm, 17-19 mm, and 23-24 mm) were collected and preserved in a solution of 4% glycerol, 26% water, and 70% alcohol. The shrimp were length measured in the laboratory and imbedded in epoxy. At IMR there is no cutting machine similar to the one used at the Marine Research Institute of Iceland (MRI). Thus, most of the time spent on this project in spring 2015 was used for testing if the equipment available at IMR would suit our purposes. The conclusion was that we need a cutting machine similar to the one used at MRI, and such a machine will be borrowed from the University of Bergen in autumn 2015 to continue the work.



Length frequency distributions of the shrimp stock in Norwegian Deep/ Skagerrak in 2014 and 2015 (January), and lengths of shrimp sampled in January 2015 for age determination.

6. Don Stansbury and Darrell Mullowney: Age determination of Newfoundland/Labrador shrimp stocks.

A sampling program is being developed for determining the age composition of Newfoundland/Labrador shrimp stocks, supported by the offshore fishing industry. Shrimp individuals will be collected from different fishing areas to compare the growth pattern from different geographic regions and depths. The efficacy of a future age-based assessment model may depend on the extent to which such variations occur. Individual shrimp from the samples will be shipped to the lab at the University of New Brunswick for processing. The carapace length of each individual will be measured to the nearest 0.1 mm using a vernier caliper. Then, the eyestalks will be removed intact and left in a vial with a mixture of ethanol:glycerol:water (70:4:26) until processing starts. Each eyestalk will be cleaned and embedded in resin-epoxy. Thin sections (~160 µm) will be prepared by Isomet saw. The sections will be checked under compound microscope and digital images will be saved and enhanced before checking the growth bands. Age-at-size relationship will be produced for each region. A training workshop was organized at NAFC in August 2015. In addition to the workshop, there will be follow-up with the training of DFO staff. A progress report will be submitted at the end of six months from the beginning date and a final report at the end of this project. This latter will include an electronic format along with the photos indicating the age rings. The photos will cover all readable sections that are processed from the individuals collected during the course of the project. A manuscript will be prepared for publication at the end of this work.

7. Ole Ritzau Eigaard, Mikaela Bergenius, and Mats Ulmestrand: How length frequency data are used in the new length-based, age-structured stock assessment model for SKND shrimp.

The model uses an age based stock equation but is fit to length frequency data. A von Bertalanffy growth equation (length and age) is estimated to link length to age. Input data are yearly catches at length from survey and commercial fishery. The model produces estimates of N and F at age. Details of the model can be found in Nielsen et al. (2013). There could be benefits to the length-based modeling of the shrimp stock if age determinations are available. It is possible that shrimp growth can be better described/assumed than by a standard von Bertalanffy equation because deviations due to sex-change or molding could have an impact.

External information (not estimated within model) of the age ~ length relationship might improve model performance. If age-determination methods are improved, standard age-based models might become preferable, given modelling challenges experienced with the length-based approach (convergence and over-parameterization issues).

8. Anne Richards: Causes for the Decline of Northern Shrimp in the Gulf of Maine.

This presentation described the recent decline of northern shrimp (shrimp) in the Gulf of Maine (GOM) and explored potential causes. In 2012, shrimp survey length compositions revealed the sudden disappearance of all size/age classes in the stock, including two age groups that are not susceptible to the fishery. The primary hypotheses examined were a shift in distribution and an increase in predation. The possibility that shrimp had moved out of the survey area was explored by examining shrimp distribution in the NEFSC autumn bottom trawl survey which covers the entire GOM in addition to the shrimp habitat area. There was no evidence from the autumn survey that shrimp distribution had shifted. The year 2012 was the warmest on record in the GOM; however, comparison of mean bottom temperature and abundance-weighted mean temperature at stations in the summer shrimp survey showed no evidence of compression of the population into smaller areas of suitable thermal habitat in 2012. It was concluded that shifts in distribution did not explain the decline in survey indices.

The hypothesis of increased predation pressure was examined using food habits data coupled with survey data to devise an annual predation pressure index (PPI). The PPI was the weighted sum of annual biomass indices of the 21 predator species, where the weights were the average (during 1977-2012) of the percent frequency of occurrence of Pandalids in predator diets. The PPI thus accounted for the relative importance of each predator and changes in their biomass over time. The PPI showed an increasing trend starting in the early 2000s, and a shift from a diversity of predators prior to the mid 1990s to dominance by dogfish sharks (*Squalus acanthias*) and Acadian redfish (*Sebastes fasciatus*) subsequently. Predation pressure was high in 2012, but had been high for several years. An index of predation intensity (frequency of occurrence of shrimp in predator stomachs relative to shrimp abundance) spiked in 2012, suggesting that a greater proportion of the population had been subject to predation. Future studies will examine potential shifts in predator abundance relative to shrimp distribution during the warm year of 2012.

The PPI time series was used to scale an assumed average natural mortality rate (M) to derive an annual M that replaced a constant M assumption in the stock assessment model. Use of the PPI-scaled M improved a retrospective pattern that had developed with the constant M model.

Summary of discussion and conclusions

The discussion took both a “bottom up” and a “top down” approach under the philosophy that, just because you can measure something, this does not necessarily imply that it is required in the assessment in order to provide reliable advice. The question was therefore posed “Why do we need age composition information for *Pandalus* shrimp?” Several of the shrimp stocks are adequately assessed using age- aggregated production models.

The Skagerak-Norwegian Deep shrimp stock provides the opportunity to compare an age-aggregated production model with a length-based age structured model since both models have been developed for this stock and judged by the ICES 2012 Inter-benchmark as being able to provide management advice.

Traditional age determination in *Pandalus* stocks is based on Mix analysis (see web link under references). This method works best on fast growing stocks in warmer water areas. In slow growing stocks the length groups become smeared together after the first year or two. Being able to determine ages-at-length for fish that cannot be separated using Mix would be a big advantage. In fast growing stocks, recruitment determined either from Mix and/or age determination would be a considerable advantage in predicting fishable biomass and deciding on management options. Age at length gives us growth rates. Having true ages separates out the structure of the population and an is particularly useful for the older ages where Mix may be ineffective.

The recent workshop in Iceland (Kilada *et al.*, 2015) examined age determination in shrimp and other crustacean from sections of eye stalks and gastric mill. The technique shows promise but is considered presently to be at the validation stage. In addition to validation (which relates to accuracy), it is also important to ensure consistency between institutes through an exchange program (which relates to precision).

It was noted that better information on size at age would improve general understanding of the life history strategies among shrimp stocks with implications for determining natural mortality through life-history invariants approaches (Charnov *et al.*, 2015). Age determinations may lead to better understanding of life history and can feed into the assessment.

It was noted that in some cases samples only come from a specific season each year. Having samples from different seasons, and being able to observe the progression of age lines in the eye-stalk and gastric mill sections would be of considerable use in validation on a stock by stock basis.

In summary, it was considered that the application of the age determination approach has the potential to improve our understanding of the life history of the various shrimp stocks. This could lead to better estimates of growth and natural mortality. Age determination in slow growing stocks could be important for older ages for which the length modes are smeared together preventing Mix from being an effective method. For both fast and slow growing stocks, determining year class strength based on age determination could provide valuable information in model fitting and in providing forecasts.

Research on validating the method and gaining confidence in the age readings by the various institutes should continue to improve consistency in results between institutes. When this is achieved, the method will be directly useful in improving stock assessments for *Pandalus* shrimp. A full joint NAFO-ICES workshop on age determination and the incorporation of age information into stock assessments may be proposed in the future, depending on progress at the validation stage.

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ANNEX II. REVIEW OF THE LENGTH-TUNED AGE BASED *PANDALUS* MODEL FOR IIIA AND IVA, AS OF 16.09.2015

Reviewer: Daniel Howell

In principle using length-based data to model tuning is a reasonable approach for a stock of this kind, and I see no reason why the proposed LBM model should not be able to do this. However the model description and diagnostics presented to date do not allow for an assessment of whether the model is behaving adequately to form the basis of an assessment, and there are several issues which need further investigation.

The main points of concern in tuning a model of this kind relate to recruitment and growth, and the way in which these are confounded. Using age data it is clear in what year a fish (shrimp) was recruited, and growth rates can be directly computed from cohort development. Using only length data, growth rates, year of recruitment and size of recruitment must all be back calculated from length data, and there is a clear risk of confounding. An absence of good recruitment survey data can compound this. It is therefore important that both the recruitment pattern and the growth estimates be investigated carefully.

The key issues to be investigated are around growth and recruitment in the hindcast, and the impact of recruitment assumptions in the forecast part. In the hindcast there are several anomalies in the length distributions, one where the model is having double peaks where the survey has just one, and one where the modeled recruitment peak seems absent in some years (indicating possible growth issues). In the forecast there has been a rather uncritical adoption of a historical average recruitment without an analysis of the degree to which forecasts are sensitive to the choice made. In the reference point section, there is no suggested limit reference point. Finally the model diagnostic section could use some more diagnostics (for instance fit to trends in survey, retrospective plots). All of these points need to be addressed before the model could be considered in a state to use for advice. In addition the model description needs to be improved before the review panel can fully understand what the model is doing. Specific detail comments are provided below.

The next step in the process is to address the issues described in this document, and analyse which, if any, of the potential problems actually impact on the model's ability to give advice. A useful, but longer term, possibility is to do a model comparison. A *Pandalus* "Gadget" model exists for the Flemish Cap – this is an age-length structured model and can compare directly on length data. It should be possible to take this model structure and tune it to the length data used here, and then compare the model outputs.

The specific comments below partly relate to the model description provided, and partly to some of the results which seem lacking in diagnostics.

Model description

In general the model description is lacking in detail, and one must often infer the structure that has been chosen. This needs to be fixed. Specific points include (but are not limited to):

- State early on that growth is modeled by fixing L_{inf} and estimating K. This is the same approach as used for Southern Hake (WKSOUTH, ICES Advisory Committee
- ICES CM 2014/ACOM:40) , so it is not in itself a problem, it just needs to be made clear – together with a rationale for the choice of L_{inf}, and an analysis of the estimated growth.
- More generally, a table showing the parameters and showing which are estimated and which are fixed (and which are annually variable) would be helpful
- How are the maturity stages/sexes handled within the model? How does growth depend on this structure?
- How is the catch in tonnes (as opposed to length distributions) modeled? As exact values or as a data set with errors to tune F to? If the latter, then you should check how close the modeled catches are to the data, and discuss any misfits.

- The text talks about "observation error which is assumed to be independent normally distributed for the catches with a separate variance parameter", but it is not stated if these are length distributions or catch in tonnes data
- Plus group. The model description seems correct, but given that forward simulation models (such as this) are much less reliant on the choice of plus groups than a VPA-style analysis. This should be made clear in the text.
- The first mention on proportion mature is in the reference points section. The method for calculating this should be in the model description section. It is not clear if this is inherent in the model structure, or if it is a post-hoc value computed from model outputs.

Model assumptions

There are several model assumptions which may, or may not, have an important impact on model performance.

- There is an assumption of uniform fishing throughout the year. This needs to be investigated and described. How good an approximation is this to actual fishing? If it is significantly different, to what extent does this impact on the model outcomes? In general for a high *F*, short(ish) lived fishery one could expect that the fishing pattern through the year could have an impact
- Errors in catch and survey data assumed to be normally distributed. We need to see a justification for this.

Model fits

The model fit section is lacking in both the diagnostics presented, and the description of the diagnostics that are there. More seriously there is a potential problem with the survey selectivity and/or growth rates, resulting in the model having multiple peaks in the 15.20cm range where the data has one. This may indicate a problem with growth rates. There is also an issue in 2014 and 2015 where the initial recruitment peak seems missing in the model in 2014, despite the larger individuals showing up in 2015.

- The length fits are not bad. In general there is considerable year-to-year variation in the real world fishery and survey which is not captured by the survey. One would therefore expect a certain noise in the fit. In particular spiky peaks and troughs will (and should) not be followed by the model if the swings are faster than the species biology allows. However where there are trends in the misfist, then one should more concerned
- In the survey fits there are a number of years where the survey gives a single large peak and the model gives two smaller peaks in the c.15-20cm range (eg. 2004, 2013). This suggests a more systematic problem. This may indicate incorrect growth rates (although mistiming of recruitment or problematic survey data are also possibilities)
- In the 2014 and 2015 fits there is a problem. In 2015 there are peaks at c. 11cm and c. 17 cm, presumably new recruits and last year's recruits. However there is no 11cm peak in 2014. Where are these coming from in the model? Possibly this is because what is presented is using a modeled survey selectivity (although this is not made clear), but then why are they present in 2014? This could simply be a result of insufficient description of the model, or could indicate a serious problem in growth estimates.
- I would print catch and survey fits separately – the current format is a bit too crowded to easily see the trends.

- There are no fits presented between model and survey (and catch in tonnes if this is modeled), these should be presented.
- Retrospective plots should be presented
- Minor issue with figures 6-8, the green line mentioned does not appear

Reference points

The reference point section seems overly focused on F_{msy}. The priority is to first produce a "good" assessment of the current stock level, then a limit biomass reference point, and only as a third step to work on target *F*. There is an assumption that F_{msy} is desirable for this stock. In general the "smoother" a stock development the better a F_{msy} works. Conversely for a stock marked by rapid biomass fluctuations driven by erratic recruitment (and possibly a short life span), a F_{msy} approach may not be the best way to manage the stock.

- The reference points section only talks about F_{msy}. In general a stock would need both an *F* reference and a biomass limit (or trigger) reference points. Of the two, the B_{lim} type reference point is the more fundamental, as this is basis for precautionary fishing. MSY fishing should only ever be an extension of the precautionary approach. If B_{lim} can be calculated from the model then do so, if not then explain this and provide a suggestion of a B_{lim}.
- $F_{0.1}$ seems to be a suitable "F_{msy}-ish proxy", choosing a conservative *F* value delivering high yield.
- However I would question whether the model is currently capable of estimating F_{msy}. See the section on forecasts for details, however I would be more concerned to set in place a solid B_{lim} before worrying about possible MSY fishing.

Forecasts

- The worry here is that by running 3 year projections for a short(ish) lived species, you may be reaching a point where assumptions about future recruitment may significantly impact on the forecasts. This needs to be checked. Try using different lengths of averaging period for the recruitment (3, 5, 7, 10 years) and see if these impact the forecasts results. A sensitivity analysis (+/- 50% of recruitment) may also be useful. Since future recruitment success is neither known nor readily predictable, having assumptions about this recruitment significantly impacting on the forecasts is undesirable.
- Why is there a three year forecast rather than a two year forecast? Reducing the length by one year, if possible, may help mitigate the issues described above.
- If the recruitment is found to have a significant impact on the forecasts, then I would say that any results need to be treated with extreme caution. This is especially true given that there is no SSB-recruit relationship here. Neither the trend nor the noise are modeled.

ANNEX III. REQUEST FROM NORWAY TO ICES REGARDING ELEMENTS IN A NEW LONG-TERM MANAGEMENT STRATEGY FOR NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN DIVISIONS IIIA WEST AND IVA EAST (SKAGERRAK AND THE NORWEGIAN DEEP).

The assessment of this stock is carried out in September each year, using survey results from January of the same year and catch statistics from the previous year. This means that the information used in the assessment was collected at least 9 months previously. In a short-lived species like Northern shrimp, this can be a significant source of uncertainty. The Parties would therefore like to explore the possibility of developing a management strategy for Northern shrimp that incorporates an in-year revision of the TAC including the results of the survey carried out January in the TAC year and catch statistics from the year previous to the TAC year.

The management strategy would have the following elements:

1. The Parties shall set a TAC for Northern shrimp within the range of fishing mortalities that is consistent with fishing at maximum sustainable yield provided that this is forecast to result in a biomass equal to or greater than Bpa at the end of the TAC year.

2. Where fishing at F_{msy} would result in a biomass that is forecasted to be less than B_{pa}, the Parties agree that the lower and upper bounds of the fishing mortality range referred to in paragraph 1 are reduced linearly to zero.

ICES is requested to evaluate whether or not this strategy would be precautionary with and without an inter-annual quota flexibility (banking and borrowing) of +/- 10%. When evaluating the impact of the inter-annual flexibility, ICES is asked to take into account assessment uncertainty as well as the inter-annual variability of stock size and recruitment.

ICES is further requested to assess the sensitivity of their analyses to presumed levels of discarding in numbers of [5%], [10%], [15%], [20%] and [30%], considering small, non-marketable shrimp and medium sized shrimp (high-grading) separately.

Finally, an in-year adjustment of the TAC based on the results of the survey carried out in January of the TAC year would largely depend on an estimate of the size of the incoming year class. Noting that the discarding of these 1 year old shrimps is prevalent in this fishery, ICES is requested to assess the possible consequences of in-year TAC increases on discard levels of respectively small and medium-sized shrimp, and whether the net effect would be positive or negative with regard to average yields and to the precautionary approach (B should remain above B_{pa}).

ANNEX IV. PROPOSED ICES TERMS OF REFERENCE FOR NIPAG IN 2016

The **Joint NAFO/ICES *Pandalus* Assessment Working Group** (NIPAG), co-chaired by Guldborg Søvik*, Norway (ICES) and Joel Vigneau, EU-France (NAFO), will meet in ICES HQ, Denmark 7-14 September, 2016, to:

a) Address generic ToRs for Regional and Species Working Groups.

b) Test the sensitivity of the length based model to assumptions though sensitivity analysis, investigate the retrospective problem in *F* and develop further diagnostic plots to aid in achieving confidence in the estimates.

c) Apply the new ICES method Eqsim to the stock-recruit data to obtain reference points.

d) Investigate the suitability of both the length based model and the surplus production model for providing advice on the long-term management plan outlined in the request from Norway, including in-season TAC adjustment (This work should commence before the next NIPAG meeting and may best be addressed by a separate meeting?).

e) Initiate a stock annex for Barents Sea shrimp and Fladen Ground shrimp, and revise the stock annex for Skagerrak-Norwegian Deep shrimp.

f) Explore all available data on the Fladen Ground shrimp stock when updating the advice.

g) Consider shrimp stocks as decided by the NAFO Scientific Council

h) Compile, update, analyse and document time-series of by-catches in the shrimp fishery

The assessments will be carried out on the basis of the stock annex. The assessments must be available for audit on the first day of the meeting.

Material and data relevant for the meeting must be available to the group no later than XX 2016 according to the Data Call 2016.

NIPAG will report by 21 September 2016 on the ICES shrimp stocks for the attention of ACOM.