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Fisheries Organization

International Council for
the Exploration of the Sea

Conseil International pour
l'Exploration de la Mer

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NAFO/ICES *Pandalus* Assessment Group Meeting, 7–14 September 2016

Institute of Marine Research, Bergen, Norway

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NAFO/ICES *Pandalus* Assessment Group Meeting
7–14 September 2016

Contents

Report of NIPAG Meeting

7–14 September 2016

Co-Chairs: Katherine Sosebee, Guldborg Søvik. Rapporteurs: Various

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met at the Institute of Marine Research, Bergen, Norway during 7-14 September 2016 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 Greenland), European Union (Denmark, Spain and Sweden), 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 2015

Recommendations applicable to individual stocks are given under each stock in the "stock assessments" section of this report. The following recommendations are common to several stocks:

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

  STATUS: *No progress has been made. NIPAG questions the possibility to standardize a means of predicting recruitment for the different stocks assessed at NIPAG. The Skagerrak and Norwegian Deep Pandalus, for example, shows a different size structure and population dynamics compared to the stocks in colder waters.*

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 (*Pandalus borealis*) on the Flemish Cap (NAFO Div. 3M)

(SCR Doc. 16/51)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- Ocean climate composite index in SA3 – Flemish Cap continues to decrease from peak levels in 2010. The large negative anomalies observed in 2014-2015 are comparable with the previous cold period during the early-mid 1990s.
- The composite spring bloom index in 3LM is also in decline in recent years with the lowest value in the time series observed in 2015.
- Despite the reduction in climate and bloom indices, the zooplankton index has remained above normal since 2009 and reached its highest level in 2015.
  - The composite trophic index has tended to remain below normal in recent years.

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 2016. Recent catches were as follows:

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NIPAG	21000	13000	5000	2000	0	0	0	0	0	0[1]
STATLANT 21	17642	13431	5374	1976	0	0	0	0	0	
SC Recommended Catches	48000	17000–32000	18000–27000	ndf	ndf	ndf	ndf	ndf	ndf	ndf
Effort[2] (Agreed Days)	10555	10555	10555	5227	0	0	0	0	0	0

1 To September 2016
2 Effort regulated

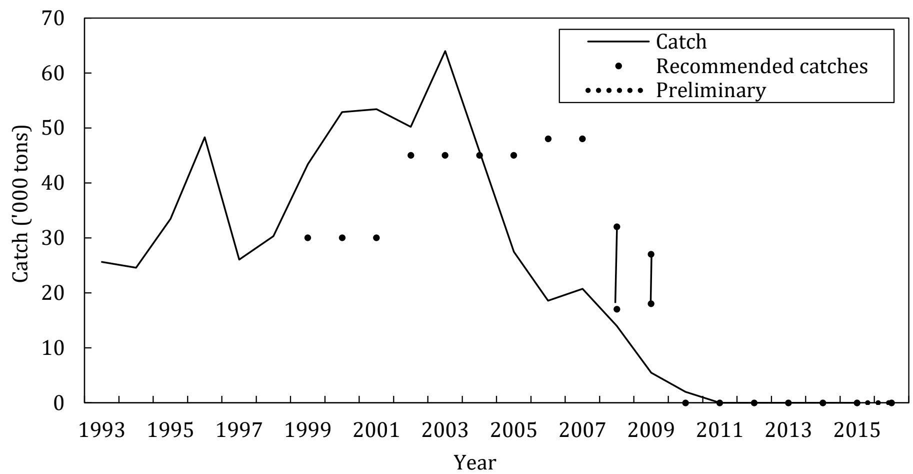

Fig. 1.1. Shrimp in Div. 3M: Catches (t) of shrimp on Flemish Cap and catches recommended in the period 1993-2016. Due to a moratorium, the shrimp catch is expected to be zero in 2016.

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 the Flemish Cap by the EU in July from 1988 to 2016. 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

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

d) 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 t. The index has been below B_{lim} since 2011. A limit reference point for fishing mortality has not been defined.

e) State of the stock

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

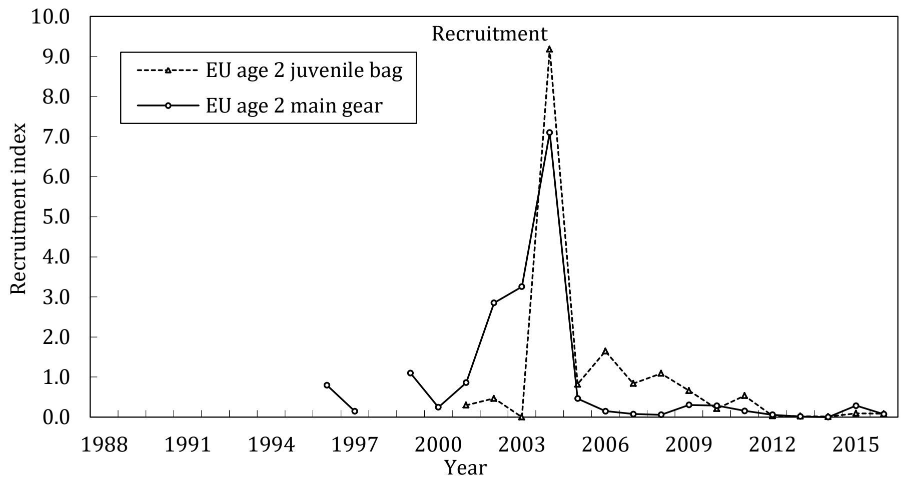

Fig. 1.2. Shrimp in Div. 3M: Abundance indices at age 2 from the EU survey. Each series was standardized to its mean.

SSB: The survey female biomass index was stable at a high level from 1998 to 2007, and has declined since then. In 2016 although the female biomass increased (79%) over 2015, the estimated biomass (1929 t) remained among the lowest recorded in the historical series, well below B_{lim}.

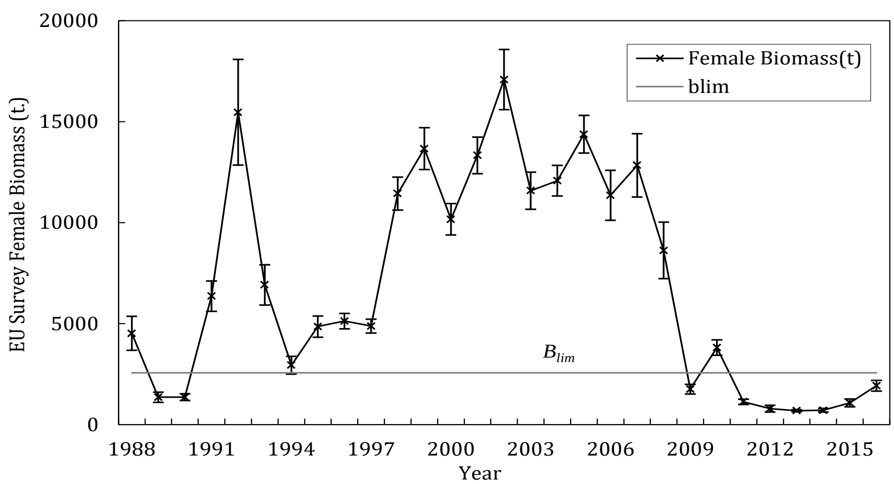

Fig. 1.3. Shrimp in Div. 3M: Female biomass index from EU trawl surveys, 1988-2016. Error bars are 1 std. err.

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.

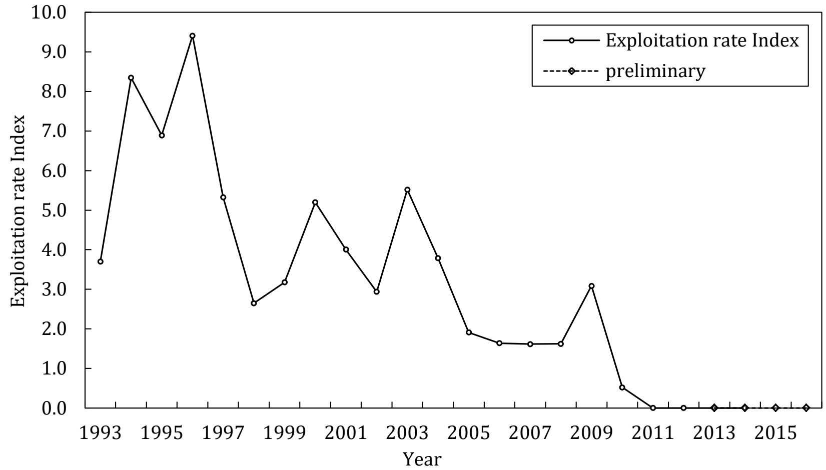

Fig. 1.4. Shrimp in Div. 3M: Exploitation rate index as derived by catch divided by the EU survey biomass index of the same year.

State of the Stock: Following several years of low recruitment, the spawning stock has declined, and has remained below B_{lim} since 2011. The probability that SSB in 2016 is below B_{lim} is >0.95. Due to continued poor recruitment there are concerns that the stock will remain at low levels.

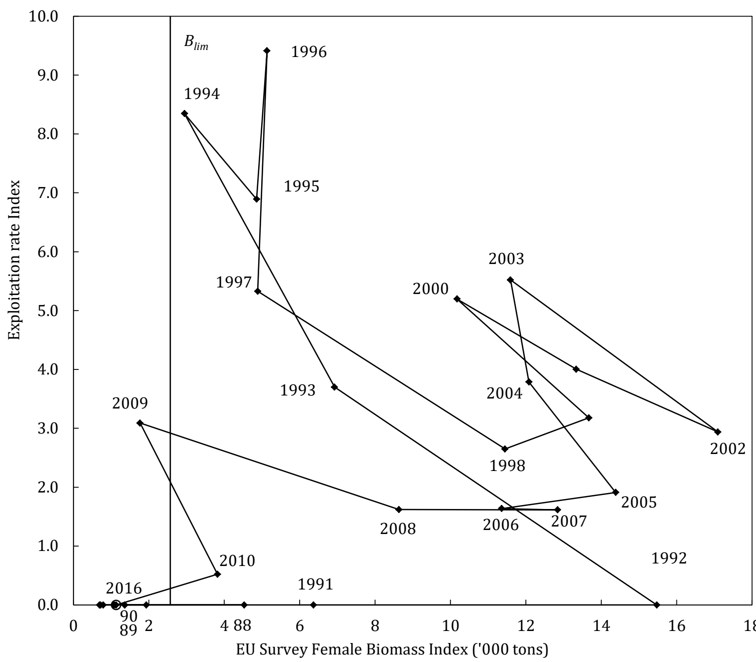

Fig. 1.5. Shrimp in Div. 3M: Exploitation rate index plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 15% of the maximum point in 2002. Due to the moratorium on shrimp fishing the expected catch in 2016 is 0 t.

f) Ecosystem considerations

The environment, trophic interactions, and fisheries are important drivers of fish stock dynamics.

During the meeting a multispecies model developed in Gadget covering the main commercial stocks in Flemish Cap over the period 1988-2012: cod *Gadus morhua*, redfish *Sebastes* sp. and northern shrimp *Pandalus borealis* (Pérez-Rodríguez et al. 2016) was presented by WebEx. The model highlights the interdependent dynamic of these stocks, and reveals strong interactions between recruitment, fishing and predation (including cannibalism). These drivers have shown marked changes in their relative importance by species, age, and length over time, producing a transition from a traditional redfish-cod dominated system in the early 1990s, to an intermediate shrimp-other fish species state by the late 1990s, and in turn back to something close to the initial state by the late 2000s.

Results of modelling suggest that, predation by redfish, together with fishing have been the main factors driving the shrimp stock to collapse. Predation by cod contributed to the decline of shrimp especially after 2007-2008. The increment of large cod in the stock, especially since 2010, has raised the predation mortality on redfish, and it is the main factor inducing the decline of abundance and biomass in the last years.

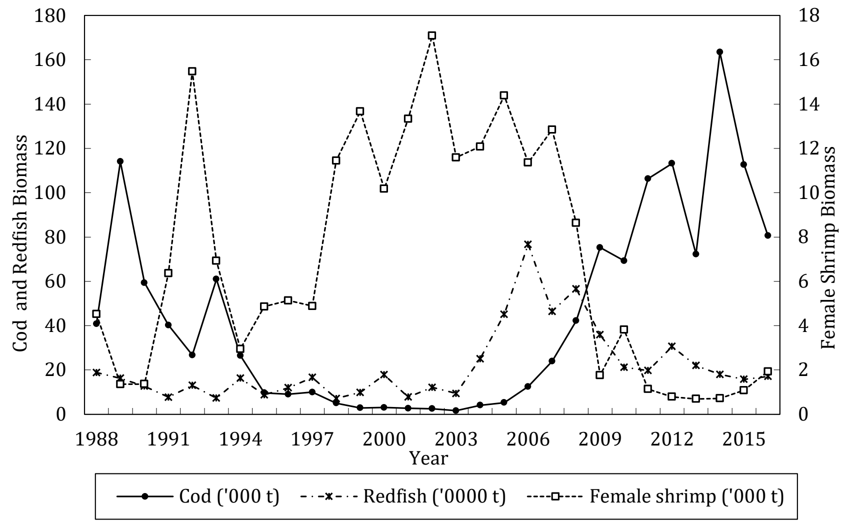

Fig. 1.6. Shrimp in Div. 3M: Cod, Redfish and Female shrimp biomass from EU trawl surveys, 1988-2016.

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.*

Recent progresses have been made, cf. the article presented at the meeting (Pérez-Rodríguez, A. et al. 2016).

References

Pérez-Rodríguez, A.; Howell, D.; Casas, M.; Saborido-Rey, F.; Ávila-de Melo, A. 2016. Dynamic of the Flemish Cap commercial stocks: use of a gadget multispecies model to determine the relevance and synergies between predation, recruitment and fishing**.** *(doi: 10.1139/cjfas-2016-0111).*

2. Northern shrimp (*Pandalus borealis*) on the Grand Bank (NAFO Div. 3LNO)

(SCR Docs. 16/058, 15/XX)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- Ocean climate composite index in SA3 - Grand Bank continues to shift downward from the record-high in 2011 with below normal conditions in 2014-2015.
- The composite spring bloom index shifts between positive and negative phases every 2-3 years and was below normal in 2015.
- The composite zooplankton index has remained consistently above normal since 2009.
- The composite trophic index also shows frequent phase shifts between positive and negative levels and reached the lowest level in the time series in 2015.

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 in 2015 and 2016 (Fig. 2.1). The TAC entries in the table below 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:

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TAC[1]	24029	27306	32767	32767	20971	13108	9393	4697	ndf	ndf
STATLANT 21	22315	26097	27236	19745	13013	10099	7919	2282	0	
NIPAG[2]	23570	25407	25900	20536	12900	10108	8647	2289	0	

[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 (≤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 quota at about 10% of the total NAFO recommended TAC rather than the 1% allocated to them under the NAFO quota key.

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.

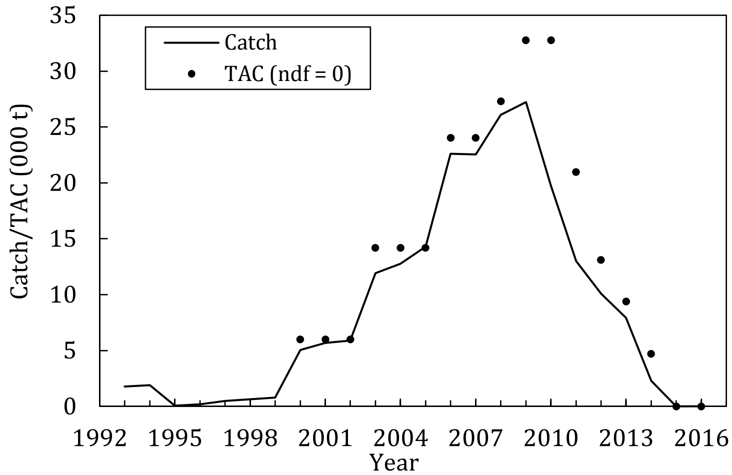

Fig. 2.1. Shrimp in Div. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas, set by Denmark, with respect to Faroes and Greenland. No directed fishing is plotted as zero TAC.

b) Input data

i) Commercial fishery data

Effort and CPUE. Catch and effort data have been available from Canadian vessel logbooks and observer records since 2000; however there was no fishery in 2015 or 2016. The 2010 - 2014 indices for small vessel CPUEs were significantly lower than the long term mean and were similar to the 2001 value 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.

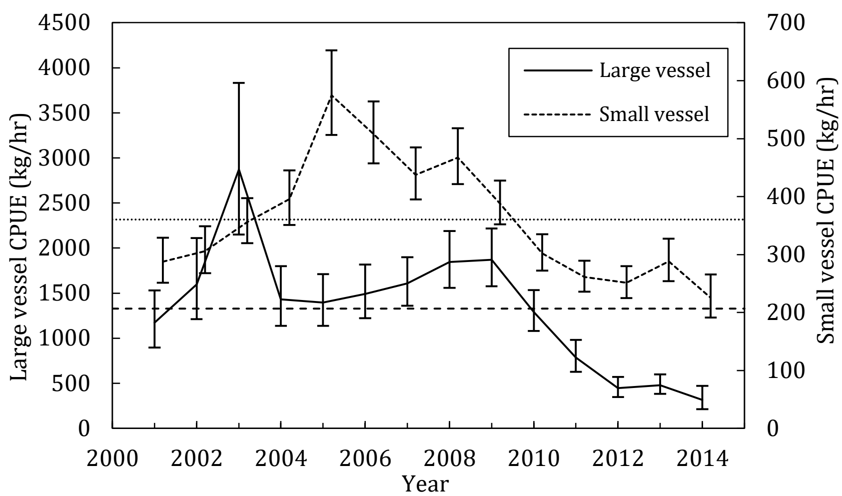

Fig. 2.2. Shrimp in Div. 3LNO: Standardized CPUEs for the Canadian large-vessel (>500 GT) and small-vessel (≤500 GT; LOA<65’) fleets fishing shrimp in Div. 3L within the Canadian EEZ.

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

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 are available for spring (1999–2016) and autumn

(1996–2015). The autumn survey in 2004 and the spring survey in 2015 were incomplete and therefore could not be used to produce a biomass estimate in 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 for 2014.

Results from a revised version of Ogmap were presented in comparison to the version utilized in previous years. Improvements to determination of bootstrap confidence limits over the new version presented in 2015 led to acceptance, and incorporation into this report, of the results based on the new version.

An important consideration in developing a new version of Ogmap was extending the estimation to the entirety of Div. 3L, in particular at the northern border. The old integration procedure omitted areas close to the border, leading to estimates that are biased low. This is particularly concerning when a number of the largest survey catches are near the Div. 3KL border. The revised version of Ogmap also corrects for the following:

1. Formerly Ogmap chose bandwidths to minimize mean prediction error, whereas new Ogmap uses tests of the assertion that the survey observations are independent random samples from their respective probability distributions.
2. The previous version of Ogmap used a kernel smoothing function that peaked at the origin and dropped exponentially with distance. This tended to overweight the nearest observation, possibly reducing the variability generated from resampling. The revised version of Ogmap utilizes a smoothing function with a flatter top and estimates the degree of flatness.
3. The bootstrapping methods for determining confidence limits were changed; although simulation tests favour the new method used here, unlike the other changes which are clear improvements, this is an area of ongoing research.

Spanish multi-species trawl survey. EU-Spain has been conducting a stratified-random survey in the NRA part of Div. 3L since 2003. Data are collected with a Campelen 1800 trawl. There was no EU-Spain survey in 2005.

c) Assessment results

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

Total biomass Indices. In Canadian surveys, about 95% 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 autumn index decreased further in 2014, however there was a slight increase during spring 2014. The autumn 2015 and spring 2016 total biomass indices remained at low levels (Fig. 2.3). Confidence intervals from the spring surveys are usually broader than from the autumn surveys.

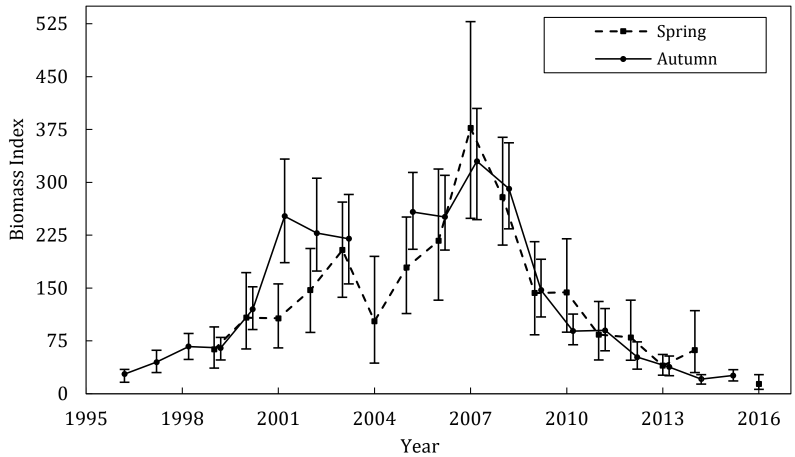

Fig. 2.3. Shrimp in Div. 3LNO: Total biomass index estimates from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only.

EU-Spain 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 2016 (Fig. 2.4).

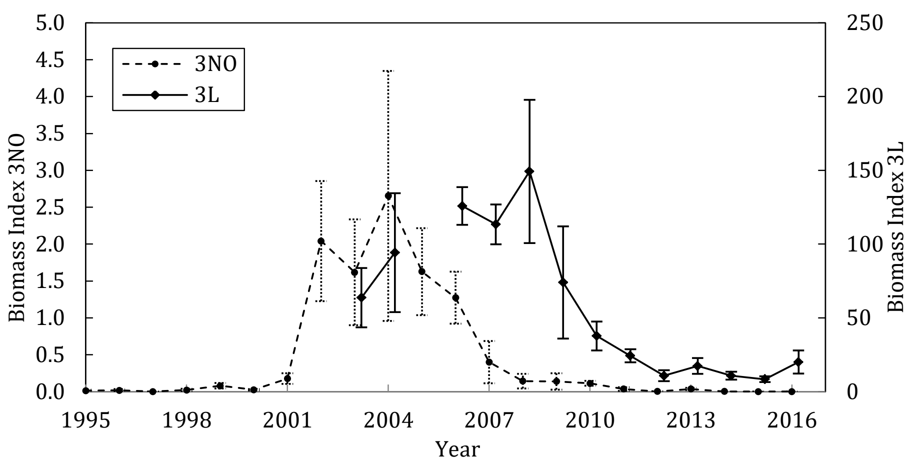

Fig. 2.4. Shrimp in Div. 3LNO: Total biomass index estimates from EU - Spain multi-species surveys (± 1 std.err.) in the NRA of Div. 3LNO.

Female biomass (SSB) indices. The spring Div. 3LNO female SSB index decreased by 97% between 2007 and 2016. The autumn SSB index showed an increasing trend to 2007 but decreased 93% by 2015 (Fig. 2.5).

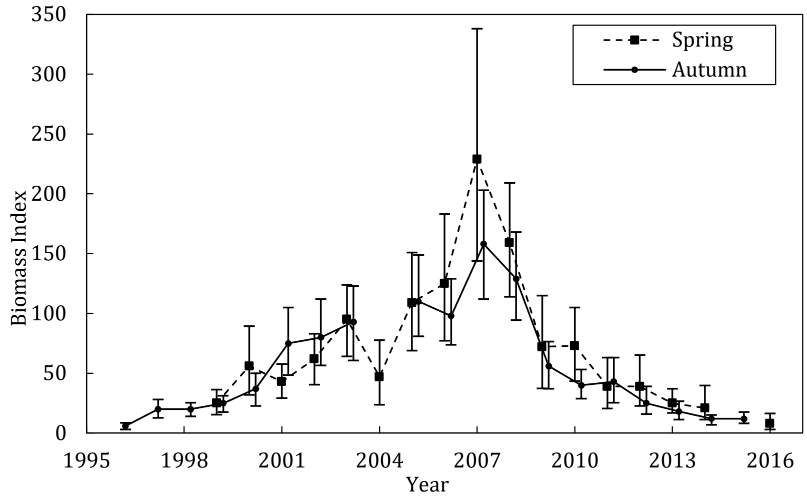

Fig. 2.5. Shrimp in Div. 3LNO: Female SSB indices from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The autumn index for 2014 is for Div. 3L only.

Stock Composition. Both males and females showed a broad distribution of lengths in recent surveys indicating the presence of more than one year class, however low abundance indices are evident (Fig. 2.6).

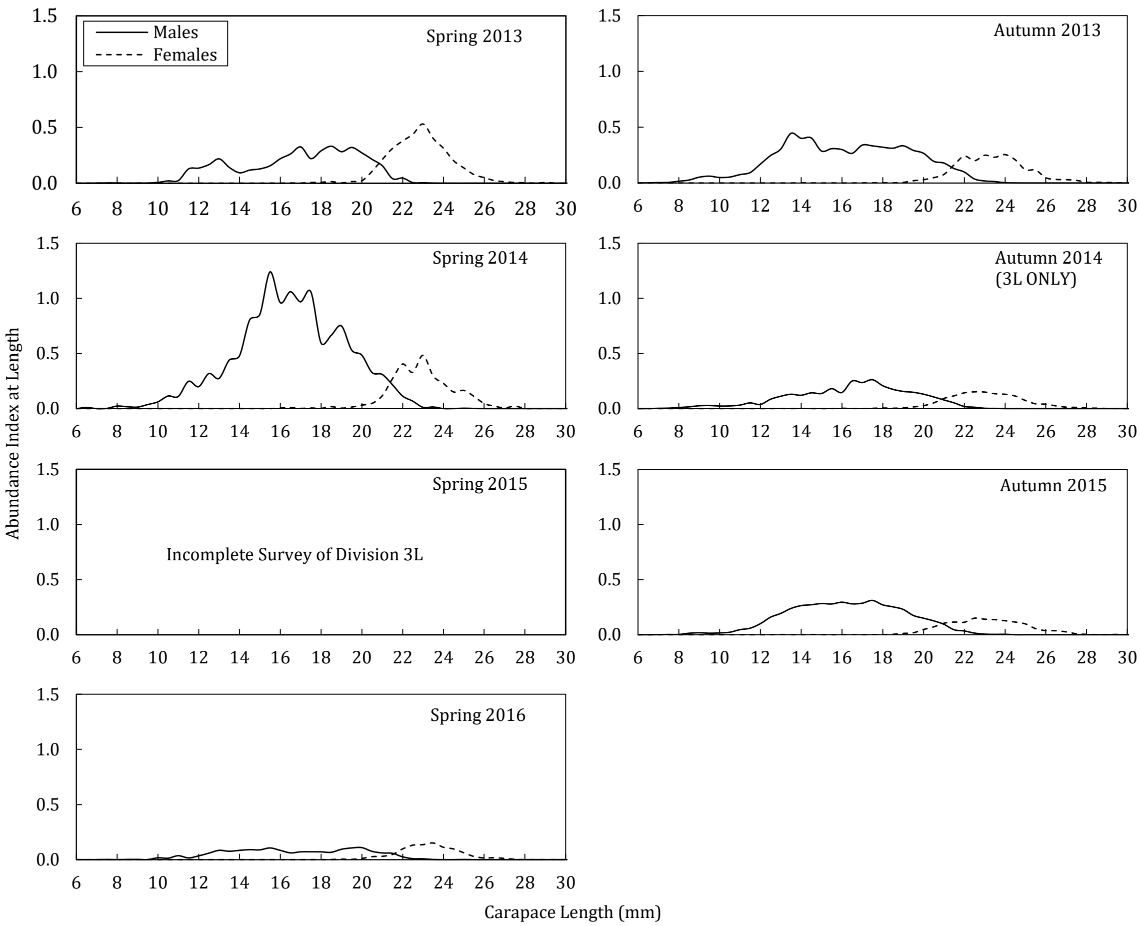

Fig. 2.6. Shrimp in Div. 3LNO: Abundance at length estimated from Canadian spring and autumn multi-species survey data. No data for spring 2015.

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 capture in 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 of large catches of small male shrimp, however there was no evidence that they contributed to the biomass in subsequent surveys. Recruitment indices are some of the lowest in the time series in autumn 2015 and spring 2016.

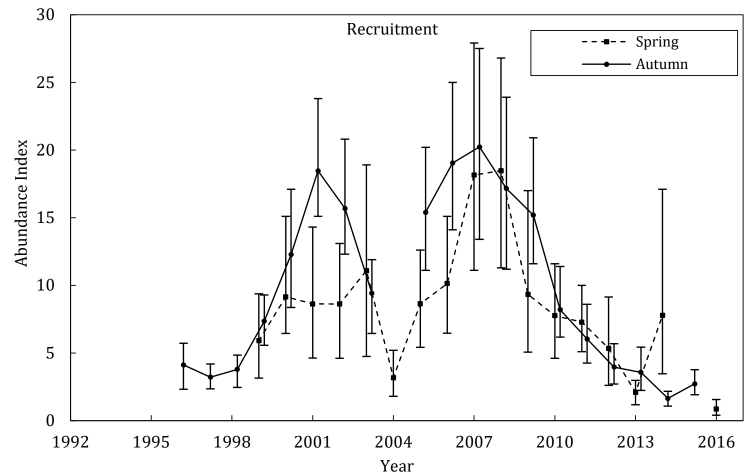

Fig. 2.7. Shrimp in Div. 3LNO: Recruitment indices derived from abundances of all shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn multi-species survey (1996–2016) data. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

Fishable biomass and exploitation index. The spring fishable biomass (shrimp > 17mm CL) index increased to 2007 but has since decreased by 97% to 2016. Similarly, the autumn fishable biomass index showed an increasing trend until 2007 then decreased by 93% through to 2015 (Fig. 2.8).

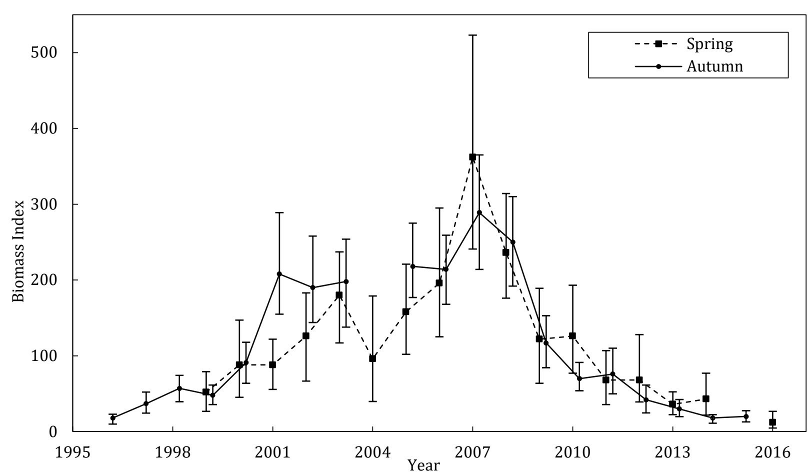

Fig. 2.8. Shrimp in Div. 3LNO: Fishable (shrimp >17mm CL) biomass indices from Canadian spring and autumn multi-species survey data. Bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

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). Since there was no directed fishing in 2015-2016, the exploitation rate is expected to be 0.

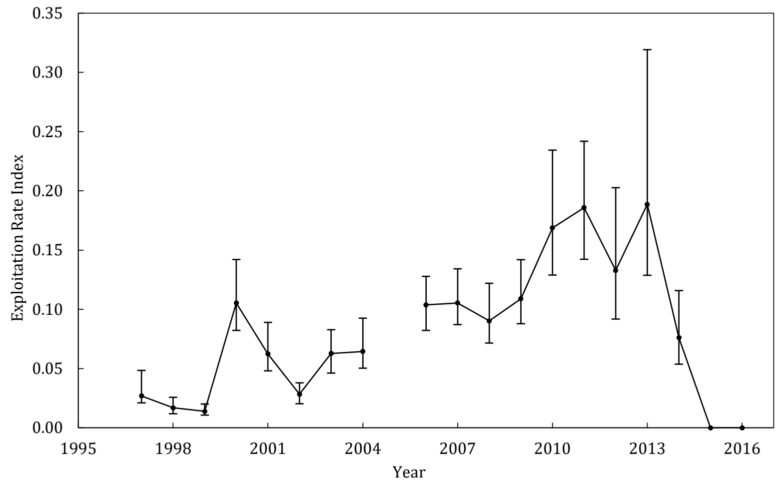

Fig. 2.9. Shrimp in Div. 3LNO: Exploitation rates calculated as a year's catch divided by the previous year's autumn fishable biomass index. Bars indicate 95% confidence intervals.

d) Reference points

The point at which a valid index of female spawning stock size has declined to 15% of its highest observed value is considered to be B_{lim} (SCS Doc. 04/12). B_{lim} was updated from 19 330 to 23 700 as a result of revision of the series with the incorporation of the new version of Ogmap. The 2015 autumn female biomass index was 12 000, and in 2015 the risk of being below B_{lim} was greater than 0.95 (Fig. 2.10 and Fig. 2.11). A limit reference point for fishing mortality has not been defined.

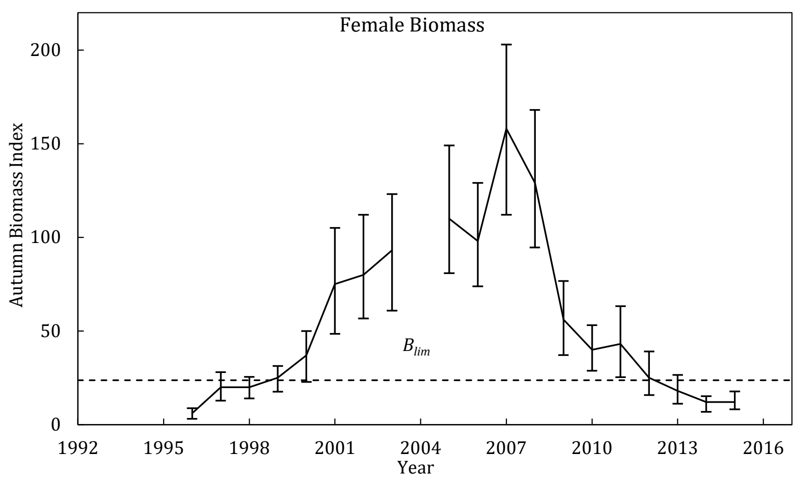

Fig. 2.10. Shrimp in Div. 3LNO: Autumn female spawning stock biomass index (SSB) and precautionary approach B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time series. Bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

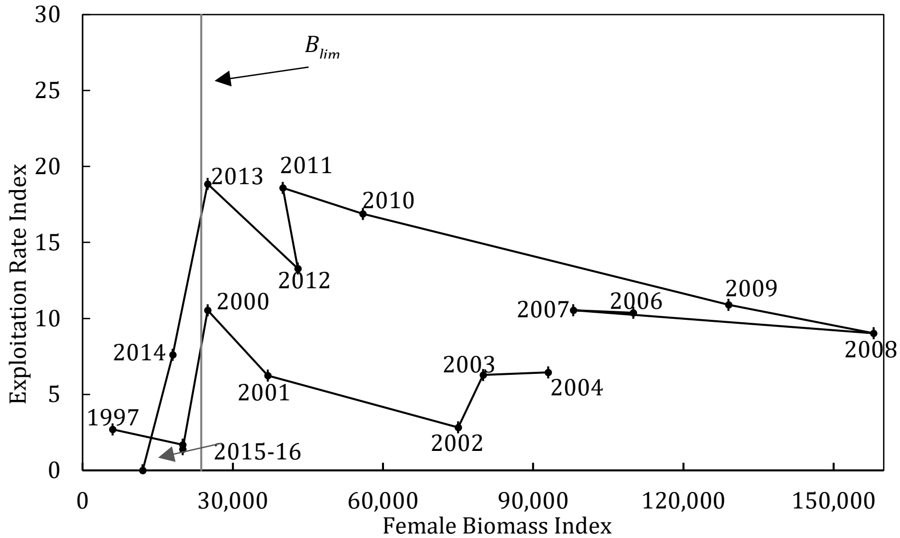

Fig. 2.11. Shrimp in Div. 3LNO: Exploitation rate against female SSB index from Canadian autumn survey. Grey vertical line denotes B_{lim} (23 700 t).

e) State of the stock

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.

Exploitation. The index of exploitation generally increased over the 1997 – 2013 period but declined sharply in 2014, was zero in 2015 and is expected to be zero in 2016.

State of the Stock. The stock has declined since 2007, and in 2015 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.

f) Research recommendations

NIPAG **recommended in 2015** 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*.

STATUS: In progress. There was no information specific to address this request presented at NIPAG in 2016. However, it was noted that during the 2016 June SC meeting that WGESA has included an item (ToR 6) endorsed by SC to develop ecosystem summaries for ecosystem units in the NAFO Convention Area. These summaries are to include provision of information for assessments at the ecosystem, multispecies, and stock level. It is anticipated that this information for 3LNO shrimp will be available considering that shrimp is a key forage species in the ecosystem. NIPAG reiterates this recommendation for 2016.

3. Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO SA 0 And SA1)

(SCR Docs. 04/75, 04/76, 08/6, 11/53, 11/58, 12/44, 13/54, 16/041, 16/042, 16/043, 16/044, 16/047)

Environmental overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The composite climate index in Subarea 0-1 has remained mostly above normal with a peak in 2010 but has been in decline in recent years with a negative anomaly in 2015, indicating colder than normal conditions.
- The composite spring bloom index reached its 2nd highest peak in 2015 after several years of below normal conditions.

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). The Canadian fishery has been limited to Div. 0A.

Four fleets, one from Canada and three from Greenland (KGH fleet fishing from 1976 to 1990, the offshore fleet and coastal fleet) have participated in the fishery since the late 1970s. The Canadian fleet and the Greenland offshore fleets 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 40 mm in both Greenland, and 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 enacted TAC for Greenland Waters in 2016 was set at 82 801 and for Canadian Waters, 10 625 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. 16/43). 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. 16/44). 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 an average over 150 000 t in 2005 to 2008, but have since decreased to 70 650 t in 2015 and a projected catch of 82 000 t in 2016.

Recent catches, projected catches for 2016 and recommended and enacted TACs (t) for Northern Shrimp in Sub-area 1 (south of 73°30'N) and Div. 0A (east of 60°30'W) are as follows:

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
TAC											
Advised	130000	130000	110000	110000	110000	120 000	90000	80000	80000	60000	90000
Enacted[1]	152380	152417	145717	132987	132987	139583	114425	98596	94140	79561	93426
Catches (NIPAG)											
SA 1	153188	142245	153707	134940	128104	122523	115931	95286	87358	70650	*80000*[2]
Div. 0A	4127	1945	0	429	5 882	1330	12	2	0	0	*2000*[2]
TOTAL	157315	144190	153707	135369	133985	123853	115943	95288	87358	70650	*82000*[2]
STATLANT 21											
SA 1	153188	142245	148550	133561	123973	122061	114958	91800	88834	70091	
Div. 0A	3788	1878	0	429	5206	1134	12	2	0	0	

[1]Canada and Greenland set independent autonomous TACs.
[2]Provisional Total catches for the year as predicted by industry observers.

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 1998 catch and effort in southern West Greenland have continually decreased, and since 2008 effort in Div. 1F has been virtually nil (SCR Doc. 16/43).

In 2002–2005 the Canadian catch 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 Div. 0A (SCR Doc. 16/43).

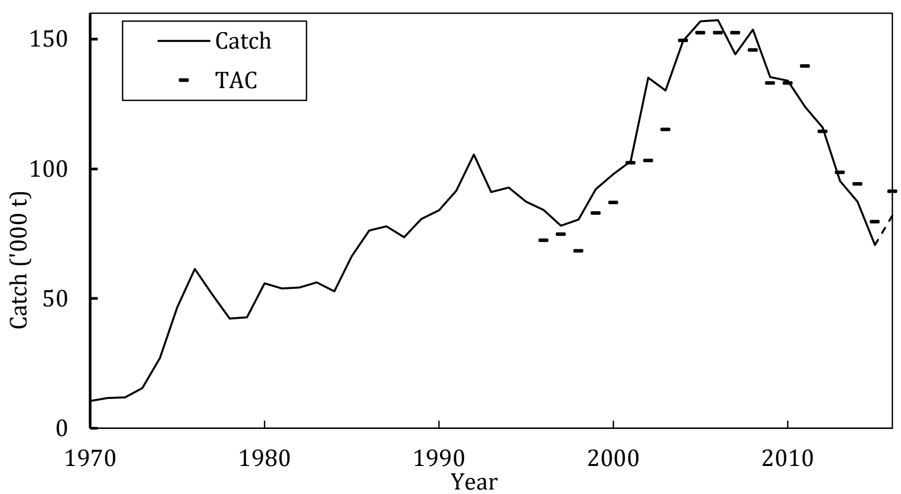

Fig. 3.1. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches (2016 predicted for the year).

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 Div. 0A and from Greenland logbooks for Subarea 1 (SCR Doc. 16/43). 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 Div. 0A (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. 16/43).

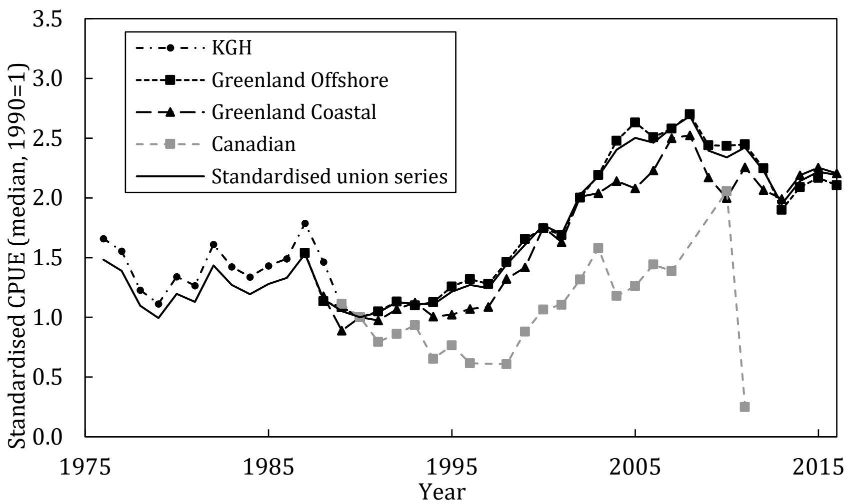

Fig. 3.2. Northern shrimp in Subarea 1 and Div 0A: Standardised CPUE index series 1976–2016.

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.

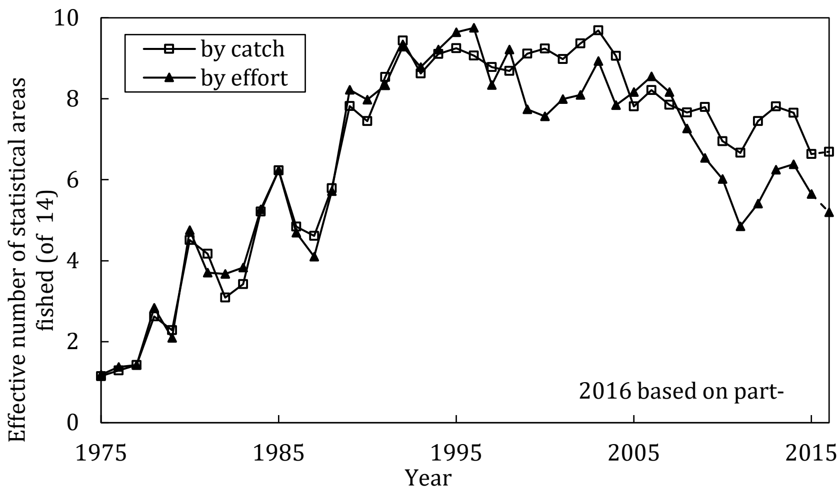

Fig. 3.3. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2016.

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 Subarea 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. 16/41). 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 were adjusted.

The survey average bottom temperature increased from about 1.7°C in 1990–93 to about 3.1°C in 1997–2016 (SCR Doc. 16/41). 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. 16/41). 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. 16/41). In 2015 survey biomass overall increased by 60% over 2014 (Fig. 3.4). The increase was not maintained in 2016 and overall biomass was 25% less than in 2015, above the past 5-year mean, but below the 20-year lower quartile. While offshore biomass was 28% less than previous year, inshore biomass, in Disko Bay and Vaigat was only 17% less than in 2015. For both regions biomass is below their lower 20-year quartile. Offshore regions comprise 69% of the total survey biomass, and 31% is inshore in Disko Bay and Vaigat. Although, the inshore regions had far higher densities than other areas, almost four times as high as offshore (Fig. 3.4) (SCR Doc. 16/41).

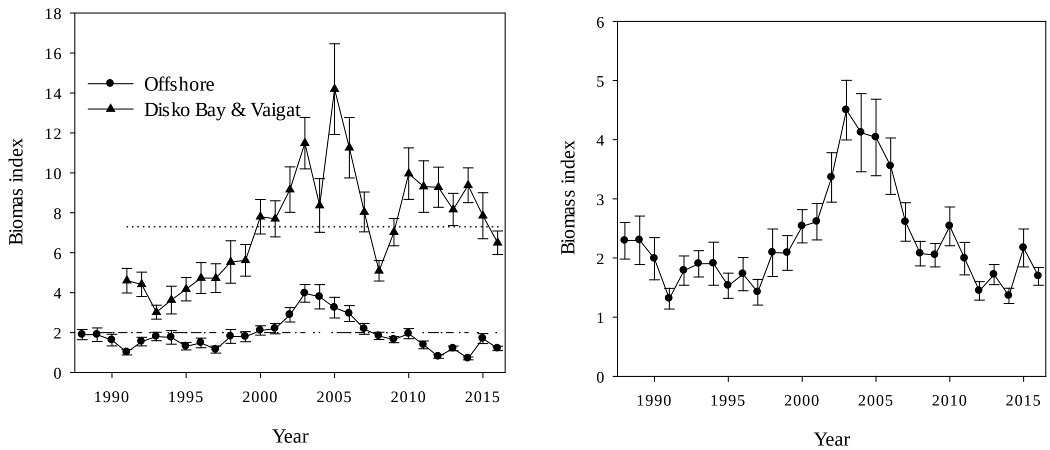

Fig. 3.4. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates inshore and offshore (panel a) and overall (panel b) 1988–2016 (error bars 1 s.e.).

Length and sex composition (SCR 16/041).

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 where 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 composed 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 2016 in both inshore and offshore areas were 'all females' and stock composition was comparable to 2014 (SCR Doc. 16/41).

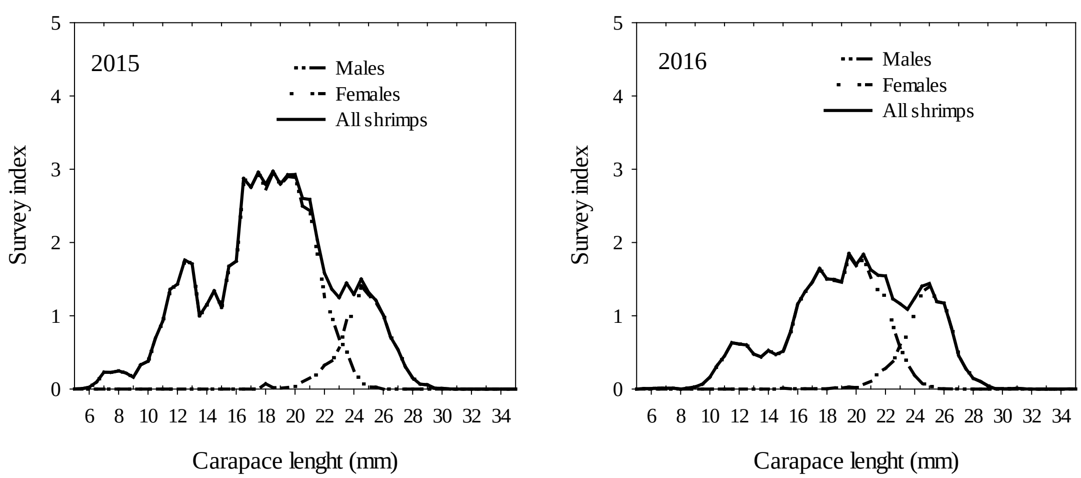

Fig. 3.5. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates at length in the West Greenland trawl survey in 2015 and 2016.

Recruitment Index. In 2016, 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. 16/41).

Components were required to have equal CVs of CPL. This method was used to revise numbers at age 2 back to 2005.

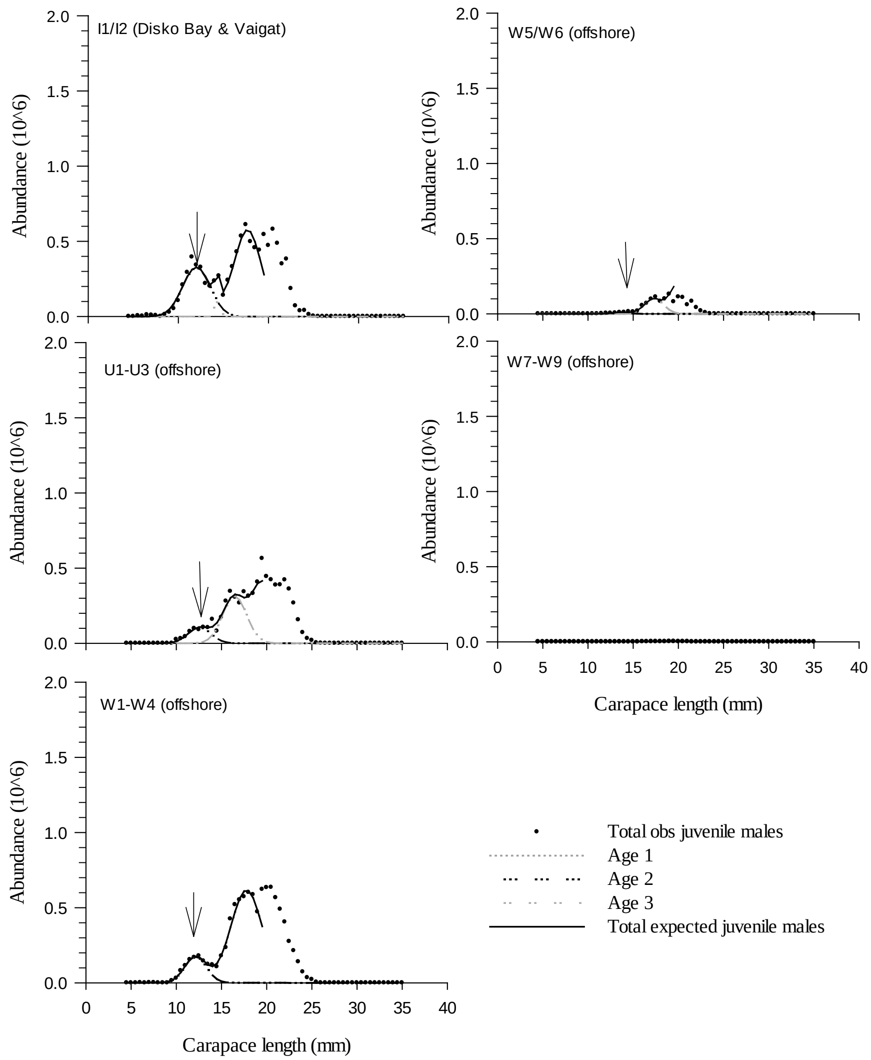

Fig. 3.6. Northern Shrimp in Subarea 1 and Div. 0A: Examples of estimating numbers at age by fitting Normally distributed components, two full and one partial, with equal CVs, to the length distribution of males, arrows indicating age 2. For stratum W7-W9, there were insufficient data to calculate numbers at age.

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 and in total number of age 2 is well above its 20-year upper quartile (SCR Doc. 15/43) (Fig. 3.7). Both inshore and offshore the number of age 2 shrimps, decreased over 2015, was above the 20-year median inshore and above the lower 20-year quartile offshore (SCR Doc. 16/42) (Fig. 3.7).

The stock composition inshore has historically been characterized by a higher proportion of young shrimps than that offshore, in 2016 numbers of age 2-shrimps were 1.4 times the numbers of offshore, but in contrast, large pre-recruits are higher offshore than inshore.

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 minimum inshore and at its 20-year median offshore, so prospects for short-term recruitment are poor; this is true both in Disko Bay & Vaigat and offshore as well.

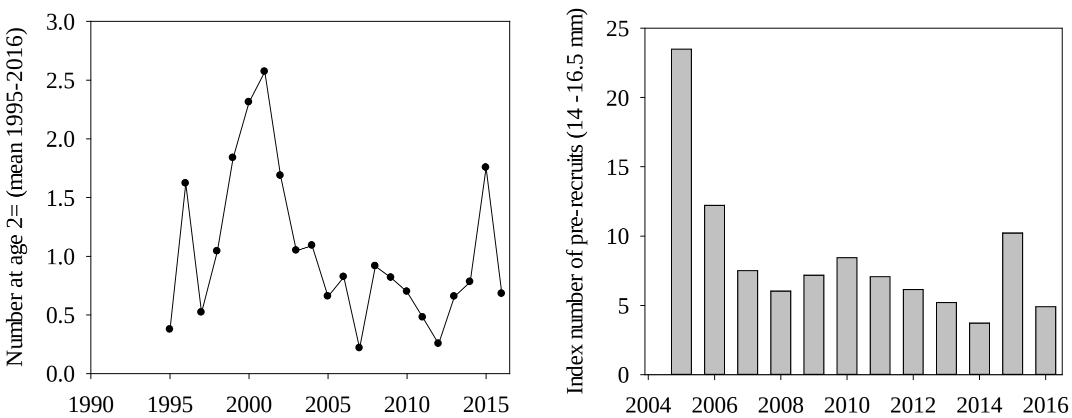

Fig. 3.7. Northern Shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2, 1995–2016 and index of number of pre-recruits (4-16.5mm), 2005-2016.

Predation index

Three or four distinct stocks of Atlantic cod, spawning variously in West Greenland, East Greenland, and Iceland, mix at different life stages on the West Greenland banks. They are subject to different influences, oceanographic and other, including drift of pelagic larval stages. The resulting dynamics are unpredictable both for the individual stocks and for their combination.

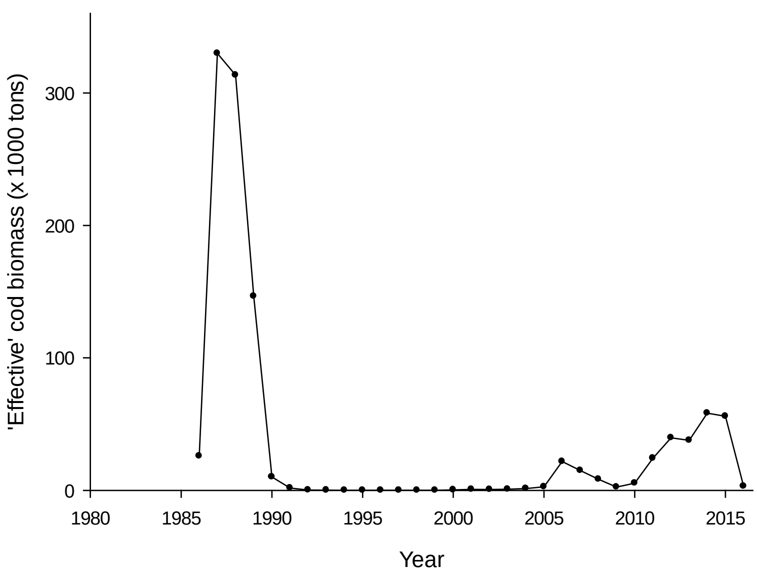

Fig. 3.8. Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A 1987 - 2016 (measure of the overlap between the stocks of cod and shrimps).

Indices of cod biomass are adjusted by a measure of the overlap between the stocks of cod and shrimps in order to obtain an index of 'effective' cod biomass, which is entered in the assessment model. In 2016 the cod biomass density estimated by research trawl survey in West Greenland was about one-seventh of its value in 2015 and the index of its overlap with the shrimp stock also dropped, by a factor of about 3. This resulted in an 'effective cod biomass' index of about 3 Kt, compared with values of 50–60 Kt in 2014–15 (Fig. 3.8) (SCR Doc. 16/42, 16/47).

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. 16/47).

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.

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 2016 were projected at 82 000 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.

The modelled biomass (Fig. 3.9a) 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. Modelled biomass steadily declined from 2004 to 2013 but has since stabilized at a level similar to that of the late 1990s which is close to B_{msy}.

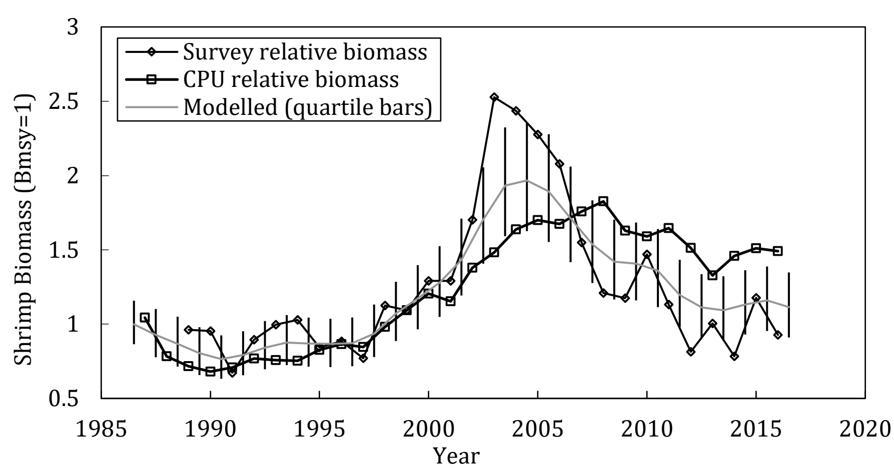

Fig. 3.9a. Northern Shrimp in SA 1 and Div. OA: Trajectory of the median estimate of relative stock biomass at start of year 1987–2016, with median CPUE and survey indices; 30 years' data with constrained CVs.

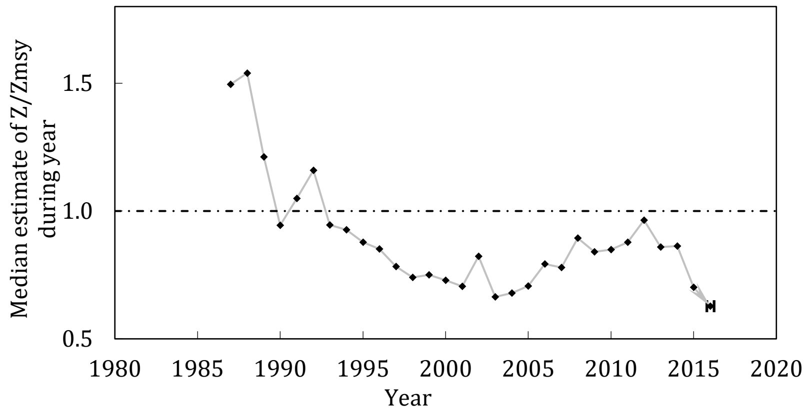

Fig 3.9b. Northern Shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1987–2016.

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. 3.9b). From 1998 to 2005 total mortality was noticeably low: in 1998–2001 this was because catches were still below 100 Kt while the stock had started to increase, and 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 2016 are given in the table below. Median values from the 2015 assessment are provided for comparison. Biomass at the end of 2016 is projected to be below the 2015 value but still 11% above B_{msy}. The projected catches for 2016 (82 000 t) are expected to hold total estimable mortality below 65% of $Z_{msy.}$

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2015)
Max.sustainable yield	134.7	77.7	96.4	126.7	158.1	110.7	140.2
B/Bmsy, end current year (proj.)(%)	114.8	33.3	91.0	111.4	134.8	104.6	123.0
Biomass risk, end current year(%)	35.5	47.9	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	43.3	62.8	88.8	–	58.6
Carrying capacity	3734	3313	1868	2818	4449	986	3365
Max. sustainable yield ratio (%)	10.6	7.0	5.2	9.7	14.6	8.0	9.2
Survey catchability (%)	19.4	14.8	8.8	15.3	25.7	7.1	12.3
CPUE catchability	1.3	1.0	0.6	1.0	1.7	0.5	0.8
Effective cod biomass 2016 (Kt)	4.1	4.1	2.0	3.1	4.6	1.2	55.9
$P_{50\%}$	4.3	7.7	0.2	1.3	4.9	-4.6	1.1
V_{max}	1.7	2.1	0.3	0.8	2.3	-1.2	0.6
CV of process (%)	14.6	3.8	11.8	14.0	16.7	13.0	13.7
CV of survey fit (%)	16.7	1.9	15.5	16.8	18.0	17.0	16.5
CV of CPUE fit (%)	20.2	3.1	18.2	19.7	21.6	18.6	19.0

d) Reference points

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 2016, the stock will be above B_{msy}, and the risk of being below B_{lim} (30% of B_{msy}) is very low (<1%).

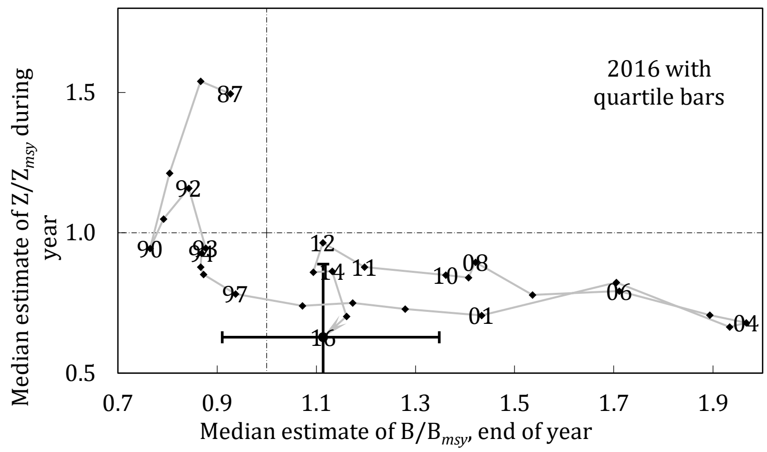

Fig. 3.10. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1987–2016.

e) State of the stock

Biomass. A stock-dynamic model showed a maximum biomass in 2004 with a continuing decline over 2004 to 2013. The decline appears to have ceased. At the end of 2016, the stock is estimated to be 11% above B_{msy}. The risk of being below B_{lim} is very low (<1%).

Mortality. With 2016 catches projected at 82 000 t the risk that total mortality will exceed Z_{msy} is estimated to be 63%.

Recruitment. The number of large pre-recruits (14–16.5mm, expected to recruit to next year's fishable biomass) is close to its 11-year minimum, so prospects for short-term recruitment are poor; this is true both in Disko Bay and offshore as well. The number at age 2 in 2016 (approximately 11.0 to 13.5mm, expected to recruit in subsequent years) is overall close to its 20-year median.

State of the Stock. The stock is estimated to be 11% above B_{msy} and the risk of being below B_{lim} in 2016 is very low (<1%). Recruitment to the fishable biomass in 2017 is expected to be poor.

f) Projections

Predicted probabilities of transgressing precautionary reference points in 2017–2019 under eight catch options and subject to predation by the cod stock were evaluated. In choosing the value for the effective cod stock biomass, it was considered unlikely that the low level of 2016 would be maintained in the prediction period. Therefore an effective cod biomass near the mean of the most recent three years, i.e. 35 Kt, was used as a basis for the forecasting of trajectories. Additional projections assuming effective cod biomasses of 3 Kt, 25 Kt and 55 Kt were conducted but not shown in this report and results indicated small differences in risk probabilities except for the estimate based on 55 Kt (SCR doc 16/047, 16/042).

35 000 t cod	Catch option ('000 tons)							
Risk of:	60	70	75	80	85	90	95	100
falling below Bmsy end 2017 (%)	32.6	33.2	34.2	34.8	35.4	35.0	35.4	36.5
falling below Bmsy end 2018 (%)	30.1	30.9	32.1	33.6	34.7	35.9	36.3	36.5
falling below Bmsy end 2019 (%)	28.0	29.6	31.1	32.4	34.1	35.2	36.5	37.6
falling below Blim end 2017 (%)	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
falling below Blim end 2018 (%)	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.2
falling below Blim end 2019 (%)	0.1	0.1	0.2	0.3	0.3	0.4	0.3	0.4
exceeding Zmsy in 2017 (%)	15.9	20.1	23.0	25.8	28.7	32.0	35.2	38.9
exceeding Zmsy in 2018 (%)	16.3	20.1	22.9	26.1	28.9	31.9	36.1	39.7
exceeding Zmsy in 2019 (%)	16.4	20.1	23.0	26.0	29.6	32.9	36.2	39.4

At the present state the biomass is 11% above its $B_{msy,}$ and in the medium term, model results estimate that catches of up to 100 000 t/yr, based on an effective cod biomass of 35 Kt, would be associated with a stable or slowly increasing stock (Fig. 3.11).

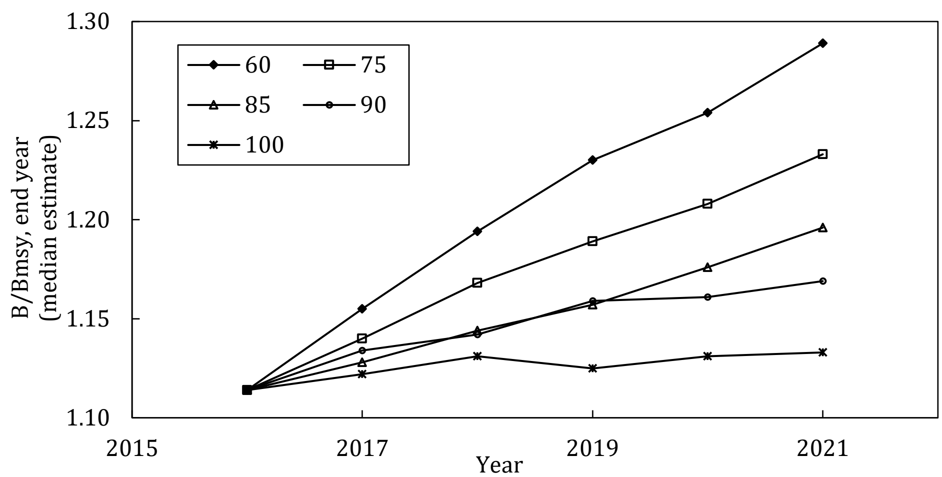

Fig. 3.11. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2016–2021 with annual catches at 60–100 Kt and an 'effective' cod stock assumed at 35 Kt.

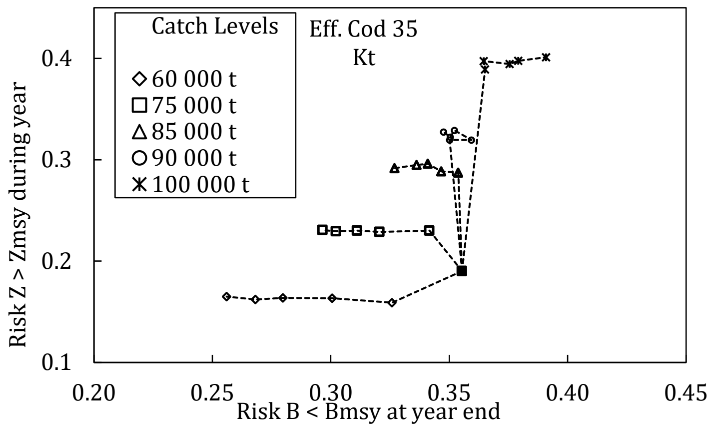

Fig. 3.12. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality and biomass precautionary limits with annual catches at 60–100 Kt projected for 2017–21 with an 'effective' cod stock assumed at 35 Kt.

Medium-term projections were summarized by plotting the risk of exceeding Z_{msy} against the risk of falling below B_{msy} over 5 years for 5 of the 8 catch levels, considering an 'effective' cod stock at 35 000 t (Fig. 3.12). For catches of 90 Kt the mortality risk is less than 35% 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 (up to 90 Kt), 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.

g) 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.

NIPAG **recommended in 2014** 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 **recommended in 2014** that *further refinements to the "partial MIXing" method of estimating numbers at age should be explored*.

STATUS: In progress; this recommendation is reiterated.

Survey trends inshore and offshore are divergent and NIPAG **recommended in 2015** that *the nature and implications of this divergence is explored*.

Status: In progress; this recommendation is reiterated.

In 2016:

NIPAG **recommends** that *methods for prediction of future cod biomass should be explored.*

NIPAG **recommends** that *genetic stock structure in West and East Greenland should be further explored.*

4. Northern shrimp (*Pandalus borealis*) In the Denmark Strait and off East Greenland (Ices Div. XIVb and Va)

(SCR Docs. 03/74, 16/45, 16/46)

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, catches have decreased and in 2014 and 2015, catches of about 650 t have been obtained. Catches in the first half year of 2016 were 49 t.

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

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[1]
Recommended TAC, total area	12400	12400	12400	12400	12400	12400	12400	2000	2000	2000
Actual TAC, Greenland	12400	12400	12835	11835	12400	12400	12400	8300	6100	5300
North of 65°N, Greenland EEZ	3313	2529	3945	3323	1145	1893	1714	622	576	49
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	3313	2529	3945	3323	1145	1893	1714	622	576	49
South of 65°N, Greenland EEZ	1286	266	610	280	53	215	3	0	0	0
TOTAL NIPAG	4599	2794	4555	3602	1199	2109	1717	622	576	49

[1] Catches until July 2016

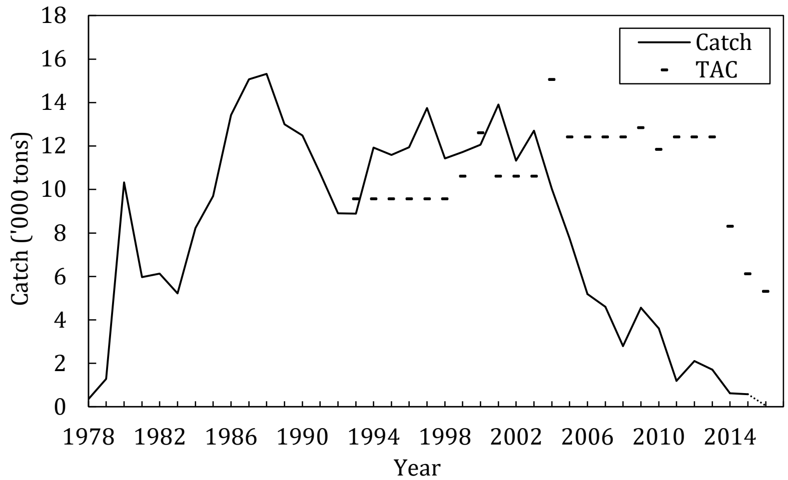

Fig. 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2016 catches until July).

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 to 2008, nearly doubled in 2009, declined until 2014 and was at the same level in 2015 as in 2014 (Fig. 4.2). The estimate for 2016 is based on a low number of hauls (36) and is therefore subject to great uncertainty. 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).

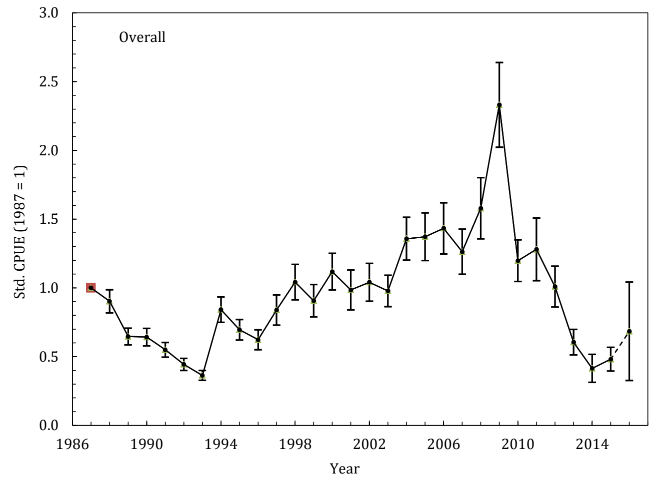

Fig. 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE-indices (1987 = 1) with ± 1 SE combined for the total area (2016 data until July).

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 to 2008. In 2009, the catch rates nearly doubled, declined until 2014 and was at the same level in 2015 as in 2014. The estimate for 2016 is based on a low number of hauls (36) and is therefore subject to great uncertainty. (Fig. 4.3).

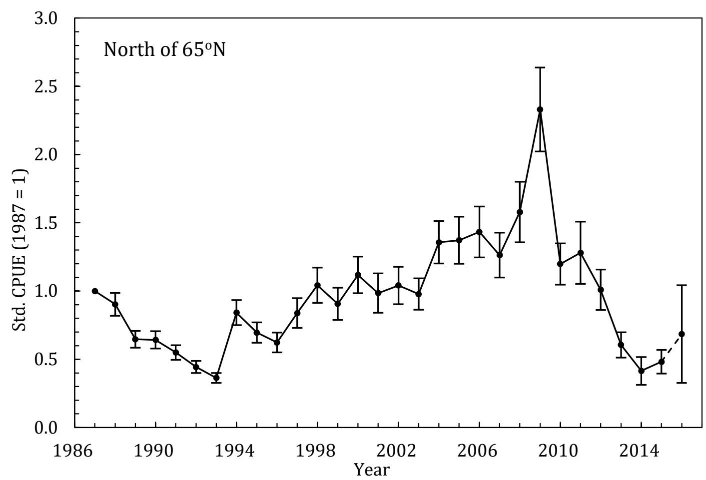

Fig. 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N (2016 data until July).

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 has been calculated since 2010 due to a low number of hauls.

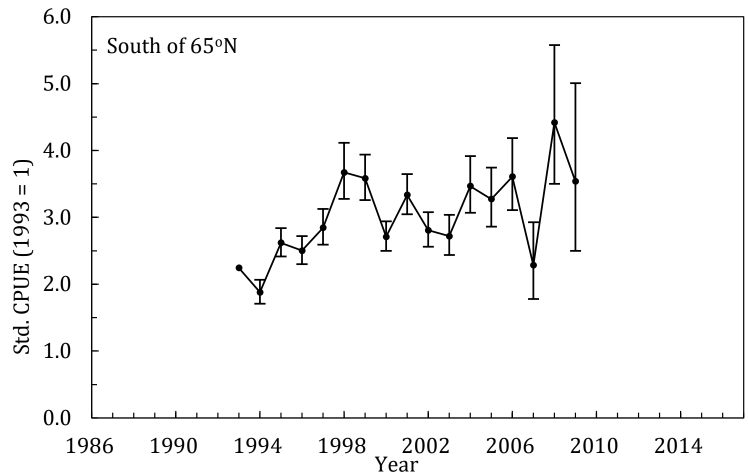

Fig. 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010).

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).

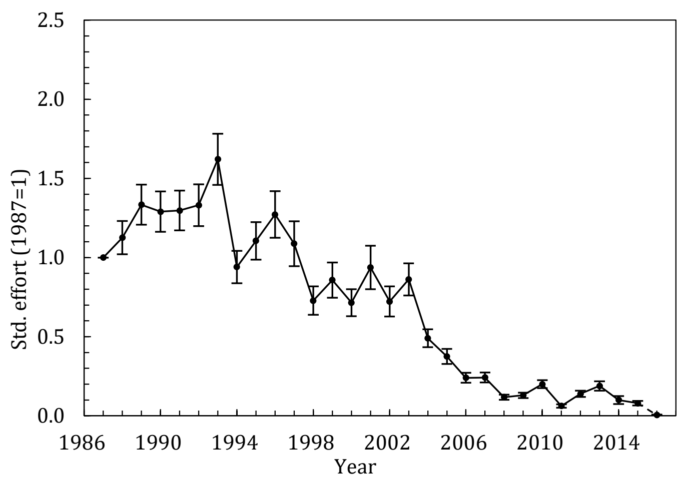

Fig. 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2016 effort until July).

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 surveys are 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).

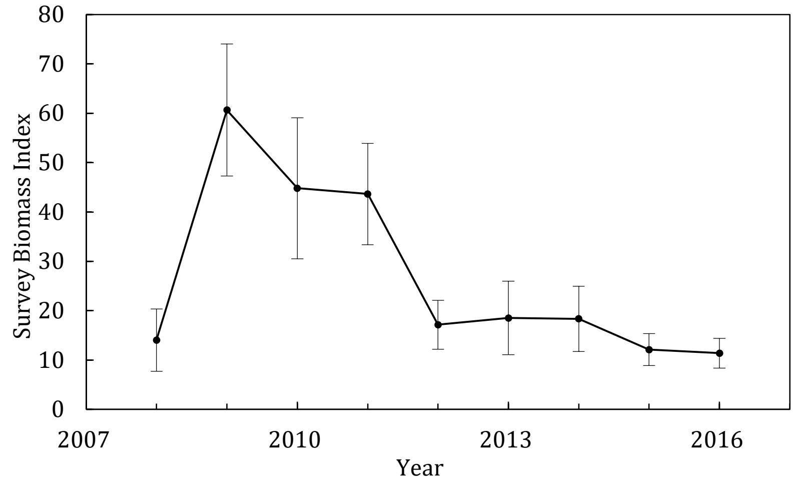

Fig. 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008- 2016 (± 1 SE).

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

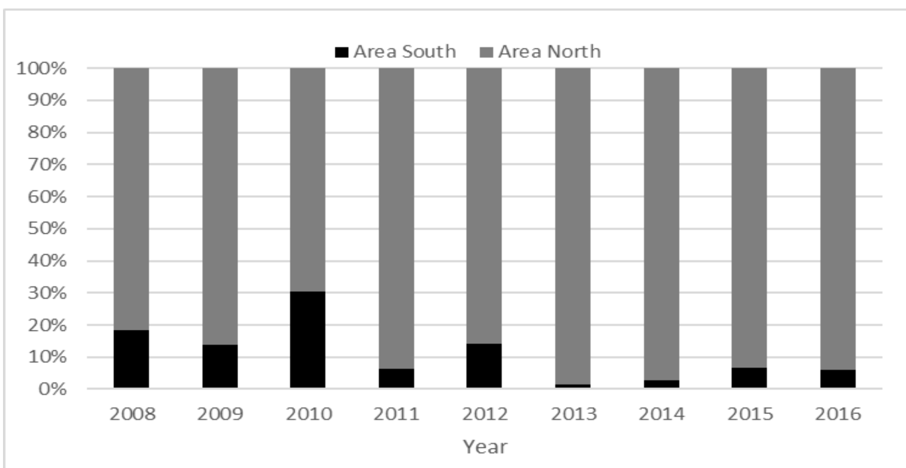

Fig. 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass North and South of 65°N (in %) from 2008-2016.

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. 4.8).

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

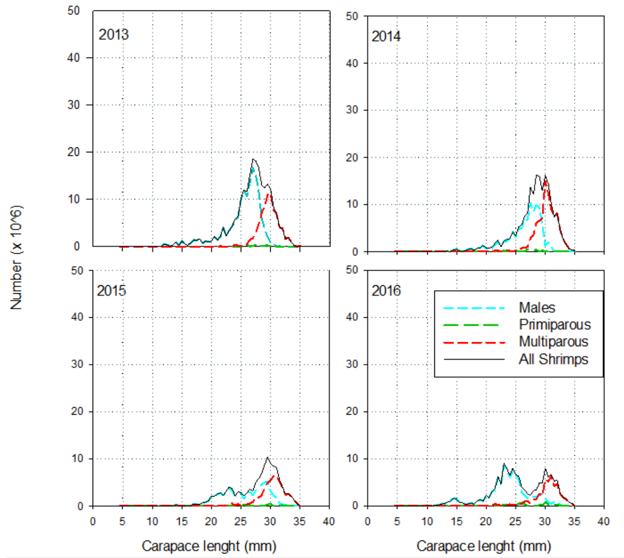

Fig. 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2013–2016.

c) Assessment results

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

d) Reference points

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

e) State of the stock

CPUE: The CPUE index has declined continuously since its highest point in 2009 and is now at similar levels to the 1990s (25% of 2009 level).

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 2016 despite several years of very low exploitation rates.

f) Recommendations

NIPAG **recommends** that *the potential for developing a* B_{LIM} *reference point for the stock be explored.*

NIPAG **recommends** that *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*

5. Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Divs. IIIa and IVa east)

See Annex 6 for update assessment inserted March 2017.

Background documentation is found in SCR Docs. 08/75; 13/68, 74; 14/66; 16/53, 55, 56, 57; and in the ICES Stock Annex.

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 (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 2016. 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. A new length based assessment model was agreed in a benchmark in January 2016 (ICES 2016a).

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 fisheries 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). Since 2009, an EU ban on high grading was implemented and since 2016, the EU landing obligation applies for *Pandalus* in IIIa and IVa East.

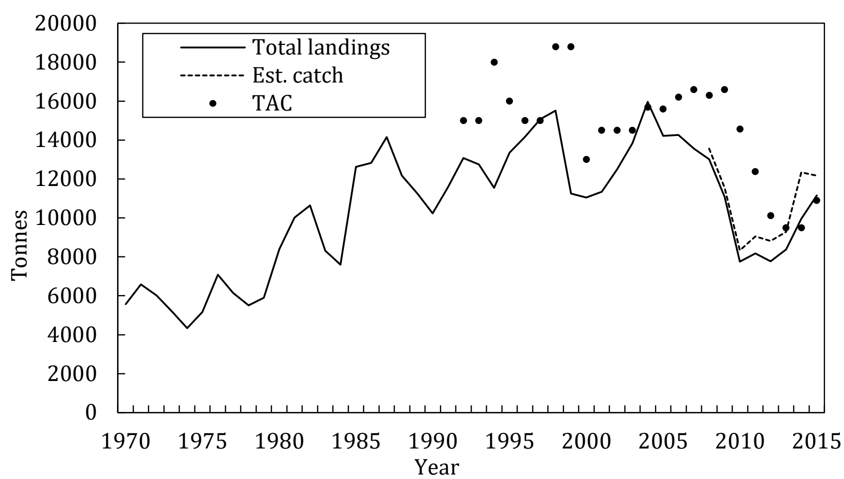

Fig. 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008-2015, and Norwegian and Danish discards for 2009-2015.

Table 5.1. Northern shrimp in Skagerrak and Norwegian deep: TACs, landings, and estimated discards and catches (‘000 t).

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[1]
Recommended TAC	13500	14000	15000	15000	13000	8800	*	5800	5400	9800	11869
Agreed TAC	16200	16600	16300	16600	14558	12380	10115	9500	9500	10900	12380
Denmark landings	3111	2422	2274	2224	1301	1601	1454	2026	2432	2709	
Norway landings	8669	8688	8261	6362	4673	4800	4852	5179	6123	6808	
Sweden landings	2488	2445	2479	2483	1781	1768	1521	1191	1397	1644	
Total landings	14268	13553	13013	11071	7755	8168	7771	8379	9953	11161	
Est. Swedish discards			540	337	386	504	671	265	572	325	
Est. Norw. Discards				94	133	247	292	459	1289	476	
Est. Danish discards				36	53	123	88	185	526	204	
Total catch	14268	13552	13554	11539	8327	9044	8822	9288	12341	12166	

[1]Recommended and agreed TACs from October 2015 were changed following a benchmark assessment in March 2016

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 9 in 2015. The efficiency of the fleet has increased due to the introduction of twin trawls and increased trawl size (SCR Doc. 16/56).

In Norway, the number of vessels participating in the shrimp fishery has decreased from 423 in 1995 to 204 in 2015. Twin trawls were introduced around 2002, and in 2011-2015 were used by more than half of the Norwegian trawlers longer than 15 meters (SCR Doc. 16/57).

The Swedish specialized shrimp fleet (landings of shrimp ≥ 10 t/yr) has decreased from more than 60 vessels in 1995-1997 to below 40 in 2011-2015. There has not been any major change in single trawl size or design, but during the last ten years the twin trawlers have increased their landings from 7 to over 50% (recent 5 years) of total Swedish *Pandalus* landings (SCR Doc. 16/56).

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 more than 12 300 t in 2014 and 2015 (Table 5.1 and Fig. 5.1).

Shrimps may be discarded for one of two reasons: 1) shrimp < 15 mm CL are not marketable and 2) to replace medium-sized, lower-value shrimps with larger and more profitable ones (“high-grading”). High grading has been illegal since 2009 in EU waters and since 2016, *Pandalus borealis* is included in the list of EU landing obligation species. 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 2008-2015, and Danish discards have been estimated to be between 2 and 18% for 2009-2015. 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. 16/57). 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 2015. Combined data from Danish and Swedish logbooks and Norwegian sale slips.

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 demersal fish species 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 and Fig 5.2).

The catches of demersal fish in the Campelen-trawl are also used to calculate an index of potential shrimp predators. The large inter-annual variation in this predator biomass index is mainly due to variations in the indices of saithe and roundnose grenadier, which in some years are important components. The contribution of these species to the biomass index depend on which survey stations are trawled, as the largest densities of saithe are found in shallow water and roundnose grenadier is found in deep water. The peak in 2013 was due to a high abundance of blue whiting. An index of potential shrimp predators without these species varied without a trend from 2007 to 2016 (Fig 5.2). The 2016-value is the second lowest in the time series, which is not in line with increasing trends in stock size observed in recent stock assessments of demersal fish species in the North Sea and Skagerrak (ICES 2016b, ICES 2016c).

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 2006-2016.

Species		biomass index											
English	Latin	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	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	6.26	
Saithe	*Pollachius virens*	7.33	39.75	208.3	53.89	18.53	7.52	5.66	112.80	14.13	8.56	6.93	
Cod	*Gadus morhua*	0.51	1.28	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	2.74	
Roundnose grenadier	*Coryphaenoides rupestris*	3.22	6.85	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	0.30	
Rabbit fish	*Chimaera monstrosa*	2.24	2.15	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	1.70	
Haddock	*Melanogrammus aeglefinus*	0.97	4.21	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	1.66	
Redfish	Scorpaenidae	0.18	0.40	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	0.25	
Velvet belly	*Etmopterus spinax*	1.31	2.58	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	1.20	
Skates, rays	Rajidae	0.41	0.95	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	0.35	
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	0.52	
Hake	*Merluccius merluccius*	0.98	0.78	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	1.07	
Angler	*Lophius piscatorius*	0.15	0.91	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	0.90	
Witch	*Glyptocephalus cynoglossus*	0.24	0.74	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	0.28	
Dogfish	*Squalus acanthias*	0.31	0.19	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	0.24	
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	0.34	
Whiting	*Merlangius merlangus*	0.35	1.01	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	1.87	
Blue ling	*Molva dypterygia*	0	0	0	0	0	0	0	0.01	0.01	0.03	0	
Ling	*Molva molva*	0.04	0.11	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	0.18	
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	0.05	
Cusk	*Brosme brosme*	0.20	0	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	0.01	
Halibut	*Hippoglossus hippoglossus*	0.08	0.07	3.88	0.09	0.20	0.05	0.19	0	0	0.10	0	
Pollack	*Pollachius pollachius*	0.06	0.25	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	0.08	
Greater forkbeard	*Phycis blennoides*	0	0	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	0.07	
Total		18.99	63.19	244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	27.00	72.77
Total (except saithe and roundnose grenadier)		8.44	16.59	17.47	21.34	20.65	20.58	19.95	49.46	24.15	24.46	19.77	20.07

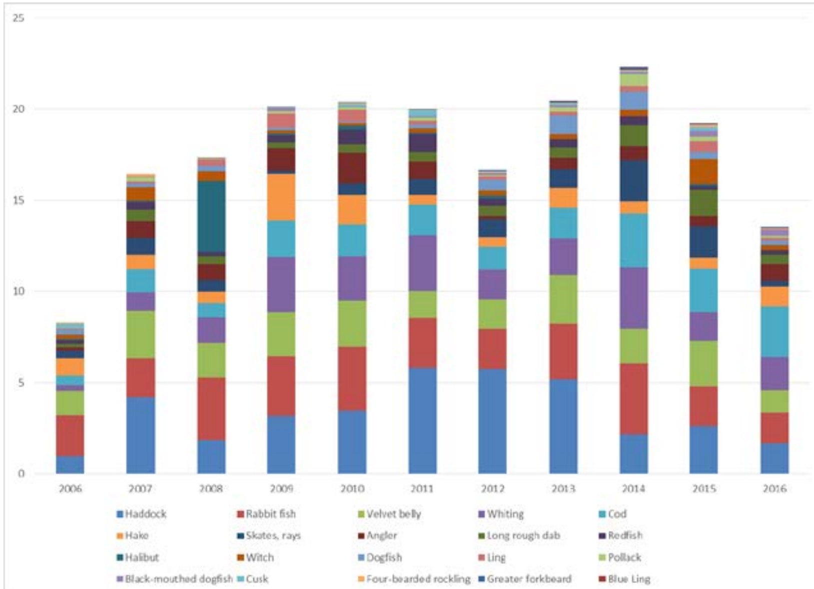

Fig. 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in kg per towed nautical mile) from the Norwegian shrimp survey in 2006-2016 excluding saithe, roundnose grenadier and blue whiting.

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; 16/56, 57).

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. The estimate based on data from the first half of 2016 is at a similar level to 2015 (Fig. 5.3).

Time series of standardized effort indices from Norway and Denmark have been fluctuating without any clear trend since the mid-1990s while the Swedish standardized effort has decreased (Fig. 5.4).

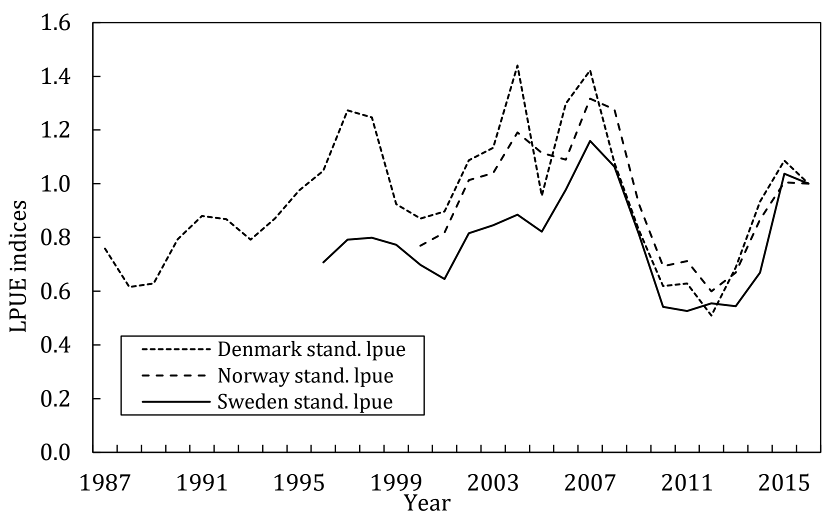

Fig. 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardized LPUE until 2016. 2016 data are preliminary (first 6 months). Each series is standardized to its final year.

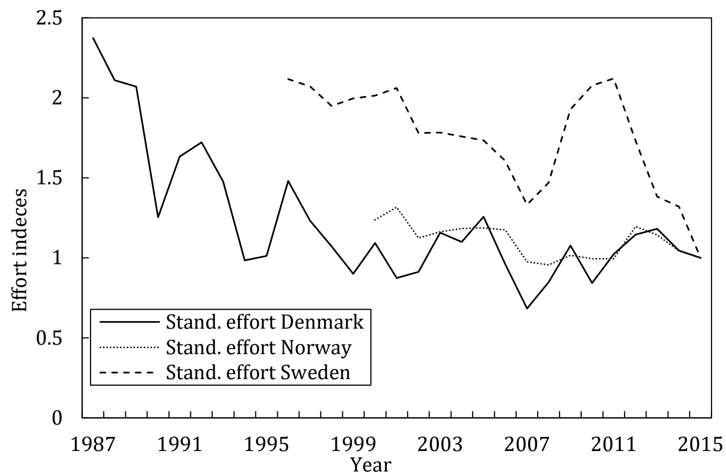

Fig. 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardized effort. Each series is standardized to its final year.

ii) Sampling of catches.

Length frequencies of the catches from 1985 to 2015 (SCR Doc. 16/56, 57,) 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. 16/53): 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. 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.

The biomass peaked in 2007 then declined until 2012. The index thereafter increased until 2015 but showed a sharp decline to the lowest value in the series in 2016 (Fig 5.5). However, the survey time series has not been standardised for variability in factors such as swept volume, spatial coverage and trawling speed, which might add uncertainty to the stock estimates. Moreover, the survey indicated a large decline in biomass in 2016, which is not observed in the LPUE of the Swedish, Norwegian and Danish fleets.

A recruitment index has been calculated for the fourth survey time-series as the abundance of age 1 shrimp. The recruitment index declined from 2007 to 2010, and has since fluctuated at a low level except for a peak in 2014 (Fig. 5.6).

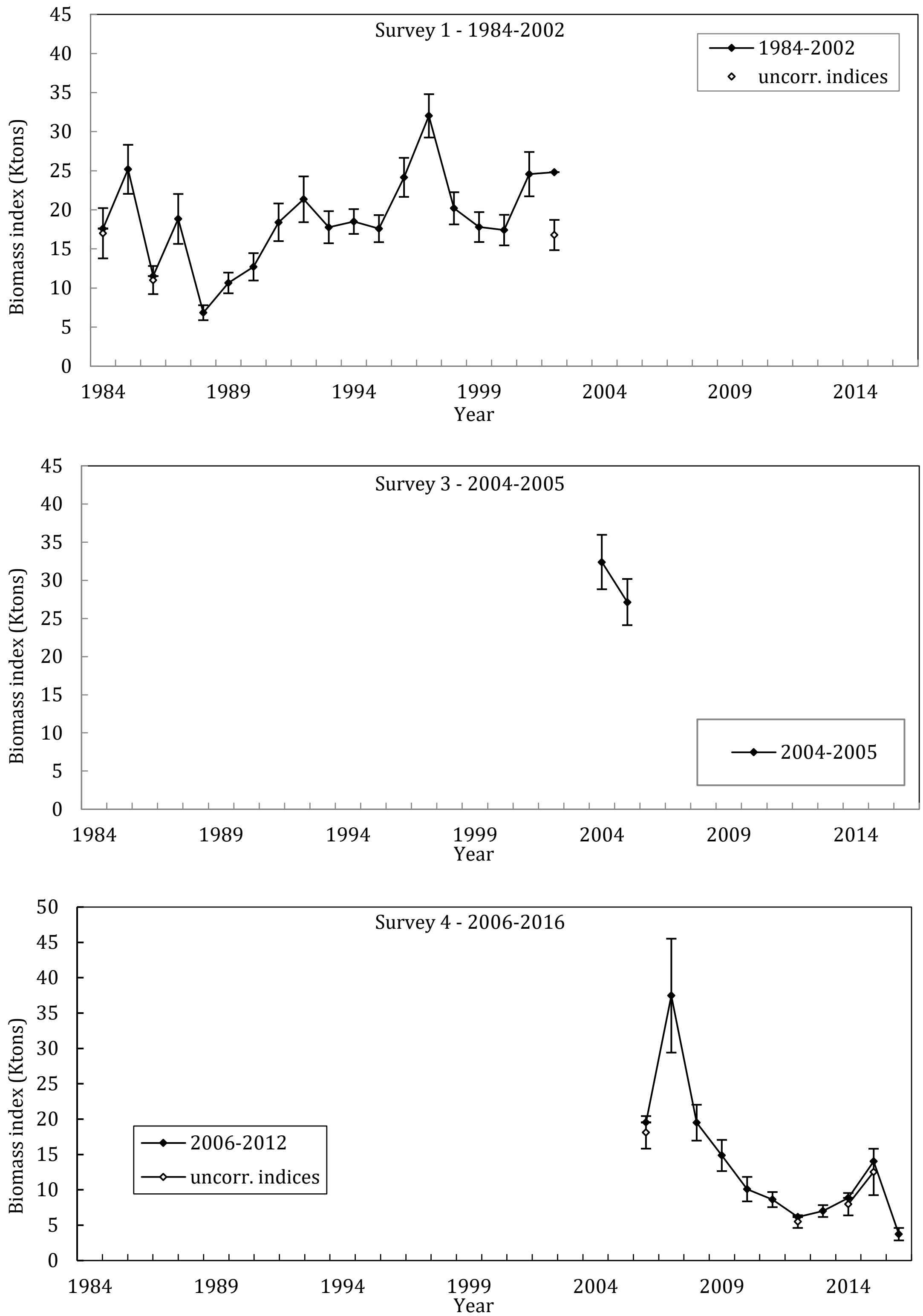

Fig. 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984 to 2016. The point estimate of 2003 is not shown.

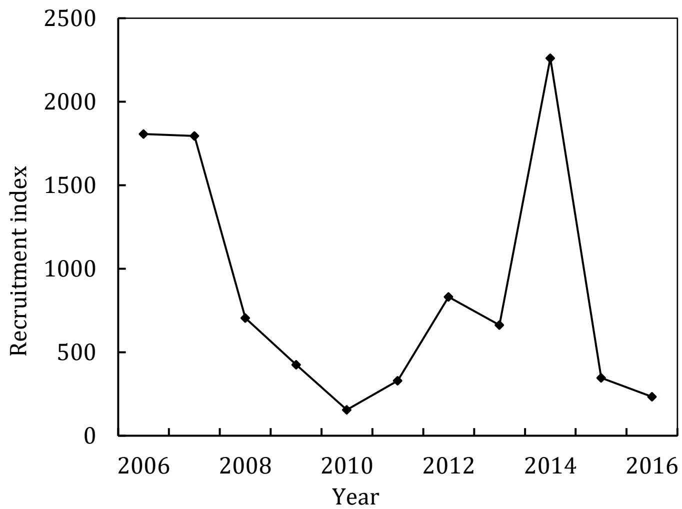

Fig. 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006-2016.

c) Assessment model

The stock assessment was benchmarked January 2016 (ICES 2016a). At the benchmark it was decided that a length based Stock Synthesis (SS3) statistical framework (ICES 2016a, and references therein) should replace the surplus production model (SCR Doc. 15/059) used since 2013, to assess status of the stock and form a basis for advice. New reference points were also defined at the 2016 benchmark (ICES 2016a).

d) Assessment results

Model diagnostics are included in SCR Doc. 16/55 and did not indicate any major issues with the model fit.

Sensitivity analysis

The benchmark in 2016 (ICES 2016a) recognized the uncertainty in the current assumption of M = 0.75 to the assessment, which is based on estimates from the Barents Sea in the 1990s (Barenboim et al. 1991), and recommended that the sensitivity of model outputs and catch advice to the specifications of M should be explored. Preliminary sensitivity analyses of the assessment model regarding different levels of M carried out at the current NIPAG meeting, showed that M = 0.90 does not change the perception of the current level of F and SSB relative to the reference points of F_{msy} and B_{pa} compared with M = 0.75 (base model) (Fig. 5.7). Using M = 0.90, the SSB in 2017 will still be under B_{lim} (the new B_{lim}) at the current level of catches, indicating that the advice is rather robust to the assumption of M within this range. However, shrimp in the North Sea/Skagerrak are considered to have a lifespan of only about half of that of shrimp in the Barents Sea and it is therefore likely that M could be substantially higher and outside the 0.75-0.90 range explored. Previous analyses of different M-assumptions for this stock (SCR 14/66) provide support for this hypothesis. NIPAG was not in a position at this meeting to fully explore the sensitivity to the M assumption used and stresses the importance of further investigations to be conducted no later than during the proposed benchmark in 2018-19.

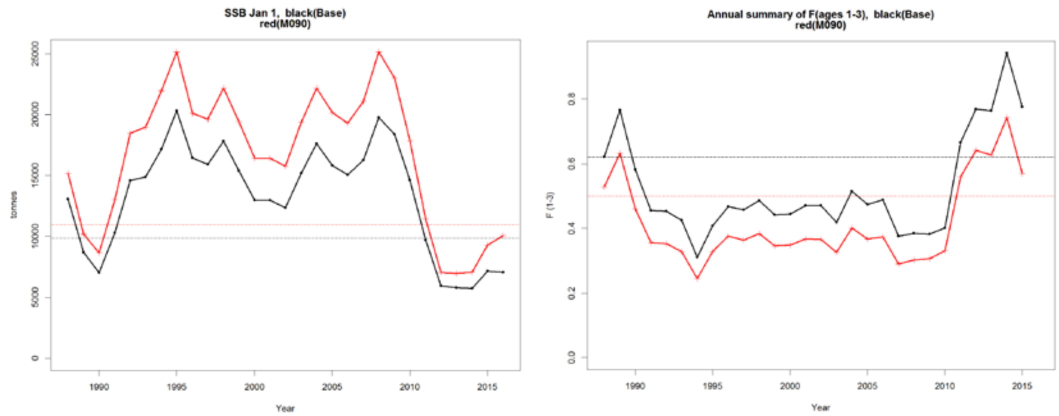

Fig. 5.7. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for natural mortality M = 0.75 (base model, black) and M = 0.90 (red). Straight lines indicate B_{pa} (left figure panel) and F_{msy} (right figure panel).

Historical stock trends and recruitment

Historical stock trends are shown in Fig. 5.8.

Since 2008, when SSB was 19 780 t, which is the second highest SSB estimate of the time series, the SSB decreased to the time series low of 5 800 t in 2014. The SSB then increased slightly in 2015, but decreased again to 7 100 t in 2016.

SS3 models recruitment as the abundance of the 0-group. A series of lower recruitment years between 2008 and 2015, with the exception of year 2013, should be noted. During this period of lower recruitment the estimates of SSB were also for some years historically low and at the level of B_{lim}. The uncertainty around the estimate of recruitment in 2015 is large. The reason for this is that the model has not yet seen the recruits in the fishery data (data until 2015), only in the survey data (January 2016).

Fishing mortality (F) for ages 1 to 3 remained relatively stable since the beginning of the 1990s to about 2010. After 2010, F increased steeply to 0.94 in 2014, which is the highest value of the time series, to the second highest value of 0.78 in 2015. Since 2010, the stock has consequently been exploited at a level greater than the F_{msy} of 0.62.

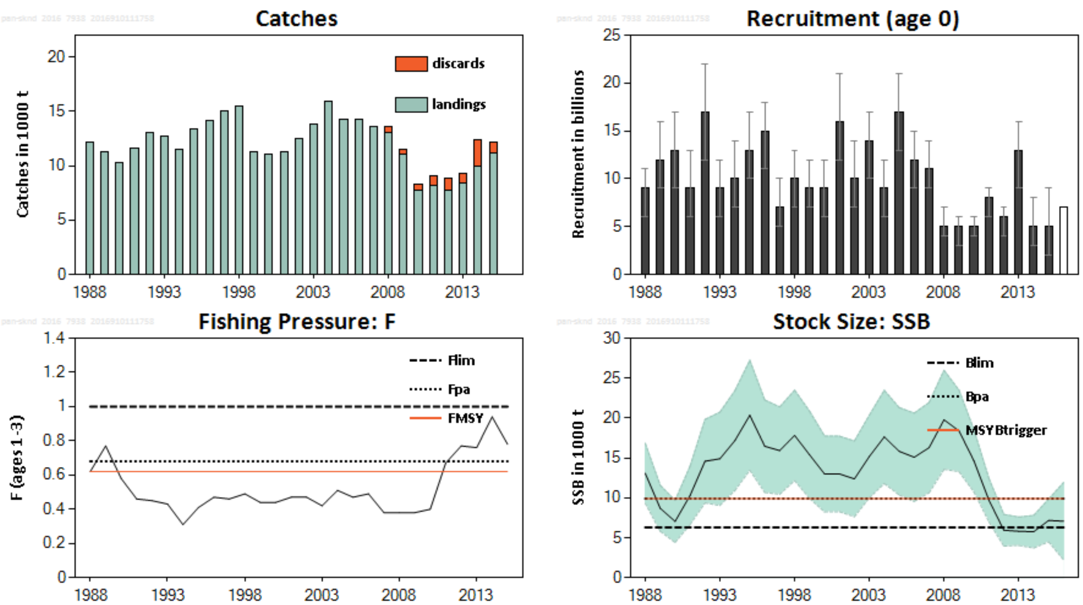

Fig. 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Summary assessment output. Total catch, including estimated discard since 2008 (t) and *F*, *SSB* and *R* assessment results. *SSB* and *R* depicted with 90% confidence intervals. The assumed recruitment value (geometric mean of the last 10 years) for 2016 is unshaded.

e) Reference points

The reference points were computed at the benchmark in January 2016 based on the definition of the *Pandalus* stock as being a medium-lived species (ICES 2016a; Table 5.4).

In 2009, ICES adopted a "Maximum Sustainable Yield (MSY) framework" (ACOM. ICES Advice, 2016. Book 1. Section 1.2) for deriving advice. It considers two reference points: F_{msy} and $B_{trigger}$ (Table 5.4). Under the ICES PA two reference points are also required; B_{lim} and B_{pa} (Table 5.4). B_{lim} was set to B_{loss}, which is the lowest observed value of the time series. The values below B_{lim} in the 2016 assessment (Fig. 5.6) is due to the SSB estimates and curve being shifted slightly downwards compared to the estimates of the benchmark assessment, and the reference points not being updated.

Table 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Reference points computed at the benchmark 2016 (ICES 2016a).

	Type	Value	Technical basis
MSY Approach	MSY $B_{trigger}$	9900 t	5th percentile of equilibrium distribution of SSB when fishing at F_{MSY}, constrained to be no less than B_{pa}
	F_{MSY}	0.62	F that maximises median equilibrium yield (defining yield as the total catch)
Precautionary Approach	B_{lim}	6300 t	B_{loss} (lowest observed SSB)
	B_{pa}	9900 t	B_{lim} * exp(1.645 * σ), where σ = 0.27
	F_{lim}	1.00	F that leads to 50% probability of SSB < B_{lim}
	F_{pa}	0.68	F_{lim} * exp(- 1.645 * σ), where σ = 0.23

f) Catch options

Table 5.5. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the catch options.

Variable	Value	Source	Notes
F_{2016}	1.53	ICES (2016a)	Corresponds to the assumed catch in 2016.
SSB_{2017}	2755 t	ICES (2016a)	
R_{2017}	6.84 billions	ICES (2016a)	GM 2006–2015
Catch (2016)*	12842 t	ICES (2016a)	Equal to projected landings 2016 plus estimated discards.
Landings (2016)**	11085 t	ICES (2016a)	Projected landings 2016
Discards (2016)	1757 t	ICES (2016a)	Average discard rate in 2013–2015 (12.5%)

* Equal to projected landings, corrected for weight loss due to on-board boiling and with estimated discards added.
** Swedish projected landings 2016 are recorded landings corrected by applying a factor of 1.13 to boiled landings to correct for weight loss due to on-board boiling. Danish and Norwegian projected landings 2016 are not corrected for boiling.

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

Rationale	Catch (2017)	Wanted catch* (2017)	Basis	F catch (2017)	SSB (2018)	%SSB change^	%TAC change^^
MSY approach	2840	2485	B_{lim} in 2018	0.30	6310	129	-84
Zero catch	0	0	F = 0	0	8054	192	-100
Other options	5146	4503	F_{MSY}	0.62	4991	81	-71
	1725	1509	$F = F_{MSY} \times (SSB_{2017}/ \text{MSY } B_{trigger})$	0.17	6981	153	-90
	9406	8230	F_{2016}	1.53	2875	4	-48

* "Wanted catch" is used to describe shrimp that would be landed in the absence of the EU landing obligation, and has been calculated based on the average discard rates in 2013–2015 (12.5%).
^ SSB 2018 relative to SSB 2017.
^^ Wanted catch 2017 relative to TAC 2016.

g) Projections

Given an estimated catch of 12 166 t in 2015 and a projected 2016 catch of 12 842 t (based on data from the first half year), catch options were evaluated for 2017 (Table 5.6). The 2016 projected catch will result in SSB at the beginning of 2017 of 2 755 t, which is less than B_{lim} (SCR Doc. 16/55). According to the ICES MSY framework, if SSB at the beginning of the intermediate year (2017) is below B_{lim}, F should be reduced to a level at which SSB will be allowed to increase to B_{lim} in 2018. This corresponds to catches in 2017 of no more than 2 840 t which is equivalent to an F of 0.3 (Table 5.6).

h) State of the stock

Mortality. Fishing mortality has been above F_{msy} since 2011.

Biomass. Stock biomass has been below $B_{trigger}$ since 2011 and just above B_{lim} since 2015.

Recruitment. Recruitment has been relatively low since 2008, except for the 2013 year class.

State of the Stock. The stock is estimated to be below $B_{trigger}$ and just above B_{lim}. Recruitment is low and mortality is above F_{msy}.

Yield. According to the ICES MSY approach, catches in 2017 should be no more than 2 840 t, which is equivalent to an F of 0.3.

i) Management recommendations

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

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

  STATUS: Not implemented

j) Research recommendations

- Improved diagnostics and sensitivity analyses should be developed for the LBM

  STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- Alternative assumptions regarding natural mortality, length-age relationship and selectivity should be explored to see whether the LBM fit to survey length data can be improved.

  STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- Reasons for the large retrospective pattern in F for recent assessments using the LBM should be explored.

  STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- Seasonal patterns of spatial distribution resulting from the migration of different age and sex classes should be investigated, as well as seasonal patterns of LPUE in the three fisheries, particularly the reason why LPUE for a given year increases when we have the full years' data compared to the LPUE from only the first 5-6 months.

  STATUS: Spatial patterns in *Pandalus* distribution of the different age and sex classes has not been addressed and with the current sampling regime it is unlikely this can be addressed in the near future. However, spatial distribution of LPUE will be addressed at the proposed benchmark for 2018.

- Reference points from the LBM were considered provisional and alternative reference points based on stock-recruit data should be investigated using standard ICES methodology.

  STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- Age determination and validation using sections of eye-stalks should continue and results used to refine the life-history knowledge of the stock including age-length relationship and natural mortality assumption.

  STATUS: This work is ongoing.

Recommendations from the 2010-2014 meetings

- *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: This will be assessed in the proposed in-year assessment in February 2017.

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

  STATUS: *This is not applicable as a new assessment model was adopted at the 2016 benchmark.*

- *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.

Research recommendations from the 2016 meeting

- NIPAG **recommends** an interim benchmark in conjunction with an in-year assessment in early 2017 to investigate the sensitivity of the assessment, reference points and the catch options to the setting of M and B_{lim}. Also to investigate possibilities for producing a new standardized survey index.

- NIPAG **recommends** a full benchmark for this stock including a data compilation workshop in the near future and no later than 2019

References

Berenboim, B.I., Korzhev, V.A., Tretjak, V.L. and Sheveleva, G.K. 1991. On methods of stock assessment and evaluation of TAC for shrimp *Pandalus borealis* in the Barents Sea. ICES C.M. 1991/K:15. 22 pp.

ICES. 2017a. Report of the Benchmark Workshop on *Pandalus borealis* in Skagerrak and Norwegian Deep Sea (WKPAND), 20–22 January 2016, Bergen, Norway. ICES CM 2016/ACOM:39. 116 pp.

ICES. 2016b. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) 26 April – 5 May 2016, Hamburg, Germany. ICES CM 2016/ACOM: 14. 1023 pp.

ICES. 2016c. Report of the Working Group for the Bay of Biscay and the Iberian waters Ecoregion (WGBIE) 13 – 19 May 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM: 12. 485 pp.

6. Northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES Sub-Areas I and II)

Background documentation (equivalent to stock annex) is found in SCR Docs. 16/48, 49, 50; 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).

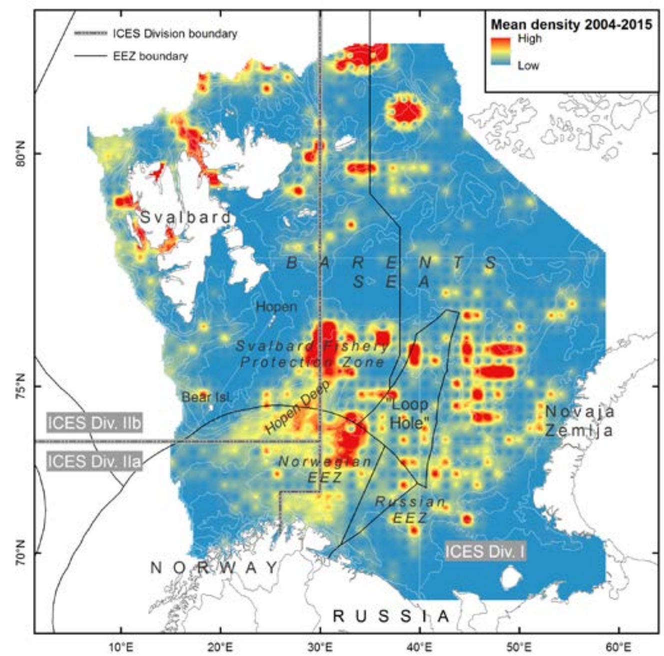

Fig. 6.1. Shrimp in ICES SA I and II: Stock distribution. Survey density index (kg/km2), mean of recent 10 years of data.

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, Faeroes 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 are predicted at 36 000 t in 2016.

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

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[1]
Recommended TAC	40 000	50 000	50 000	50 000	50 000	60 000	60 000	60 000	60 000	70 000	70 000
Norway	27352	25558	20662	19784	16779	19928	14158	8846	10234	16839	18000
Russia	4	192	417	0	0	0	0	1067	741	1151	2000
Others	2271	4181	7109	7488	8419	10298	10598	9336	9989	15634	16000
Total	29627	29931	28188	27272	25198	30226	24756	19249	20964	33624	36000

[1] Catches projected to the end of the year.

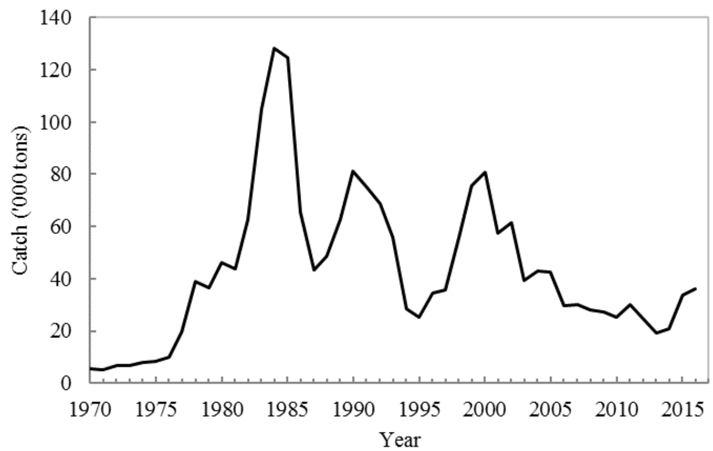

Fig. 6.2. Shrimp in ICES SA I and II: Total catches since 1970 (2016 projected to the end of the year).

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 (AFWG 2016). Area-specific bycatch rates are then multiplied by the corresponding shrimp catches from logbooks to give an overall bycatch estimate. Revised and updated discards estimates (1983–2015) of cod, haddock and redfish juveniles in the commercial shrimp fishery in the Barents Sea were available in 2016 (Fig 6.3). 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.

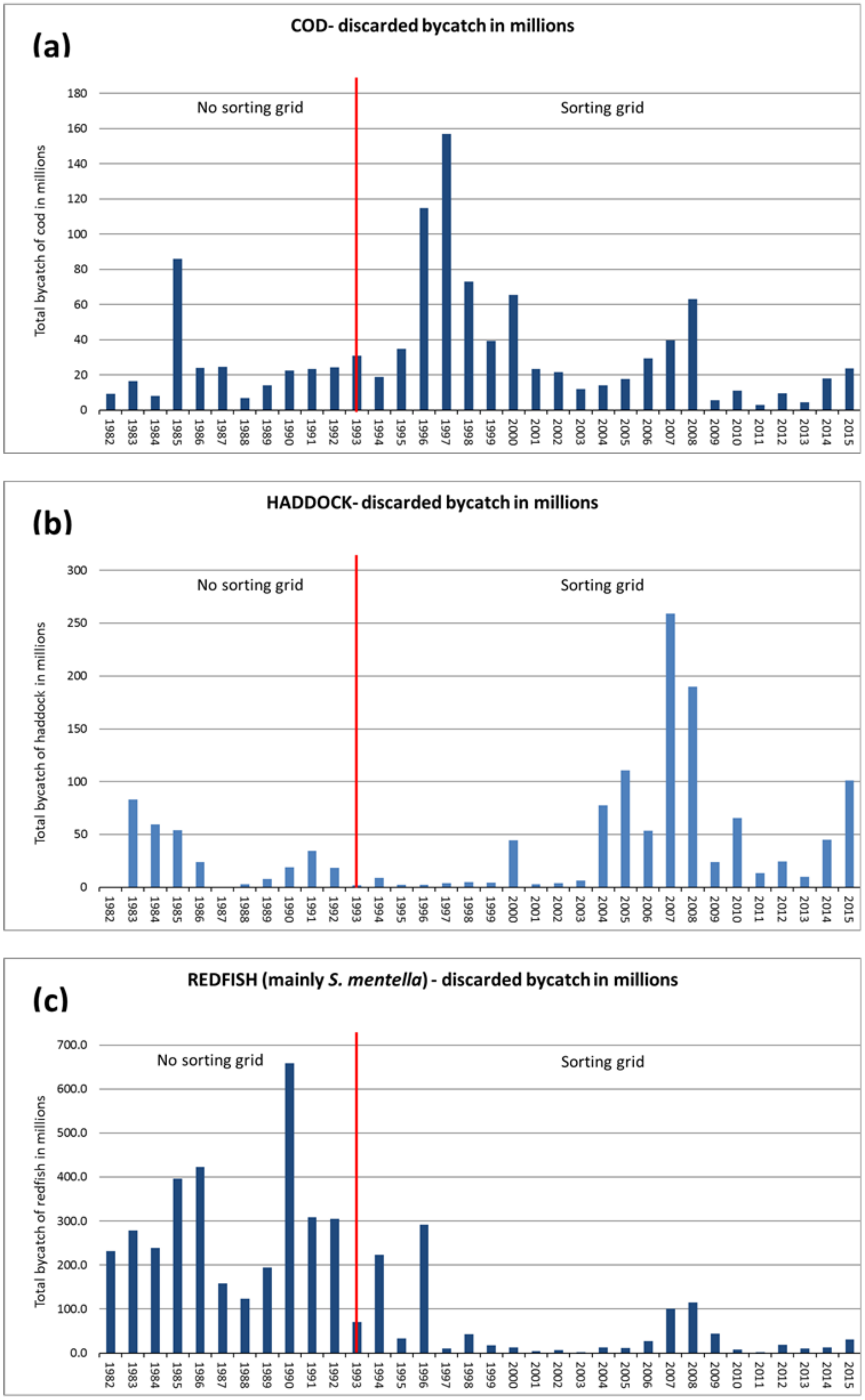

Fig. 6.3. Shrimp in ICES SA I and II: Estimated bycatch of (a) cod, (b) haddock and (c) redfish in the Norwegian shrimp fishery (million individuals). The sorting grid was introduced in 1992 and has been mandatory since. (Figures from AFWG 2016.)

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 late-1990s through the early 2000s (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.

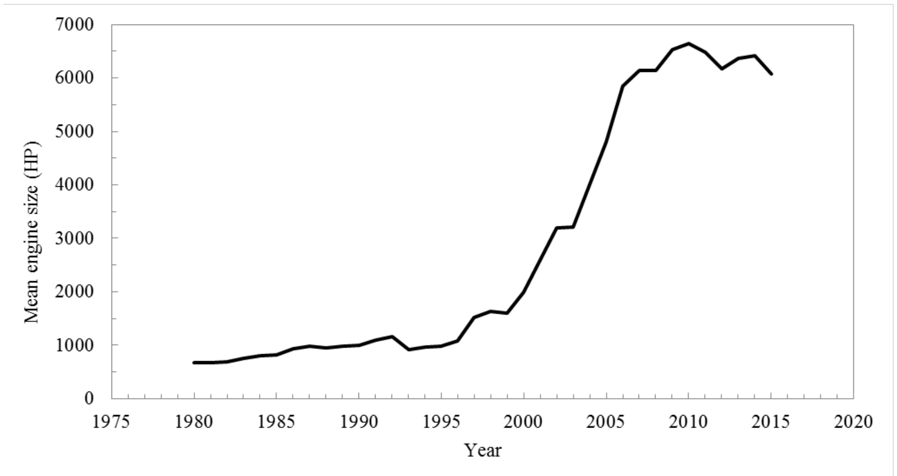

Fig. 6.4. Shrimp in ICES SA I and II: Mean engine power (HP) weighted by trawl-time (Norwegian data).

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 (Fig. 6.5).

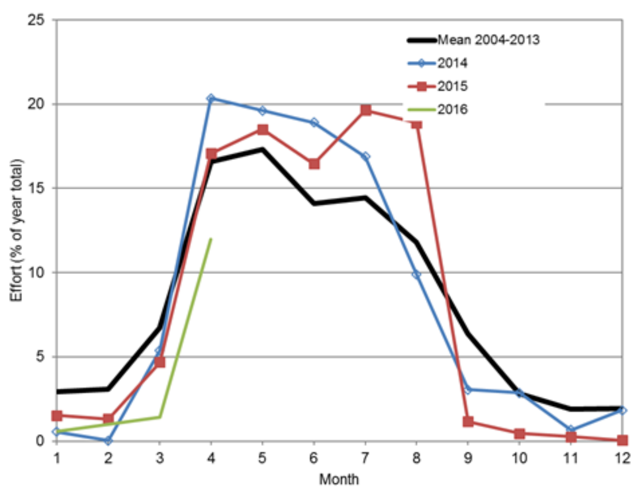

Fig. 6.5. Shrimp in ICES SA I and II: Seasonal distribution of Norwegian fishing effort (hours trawled in a month as a percentage of total effort of the year) 2014-2016 and mean 2004-2013.

The fishery is conducted mainly in the central Barents Sea (Hopen Deep) and on the Svalbard Shelf along with the Goose Bank (southeast Barents Sea) (Fig. 6.6). Norwegian 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 6.6). 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.

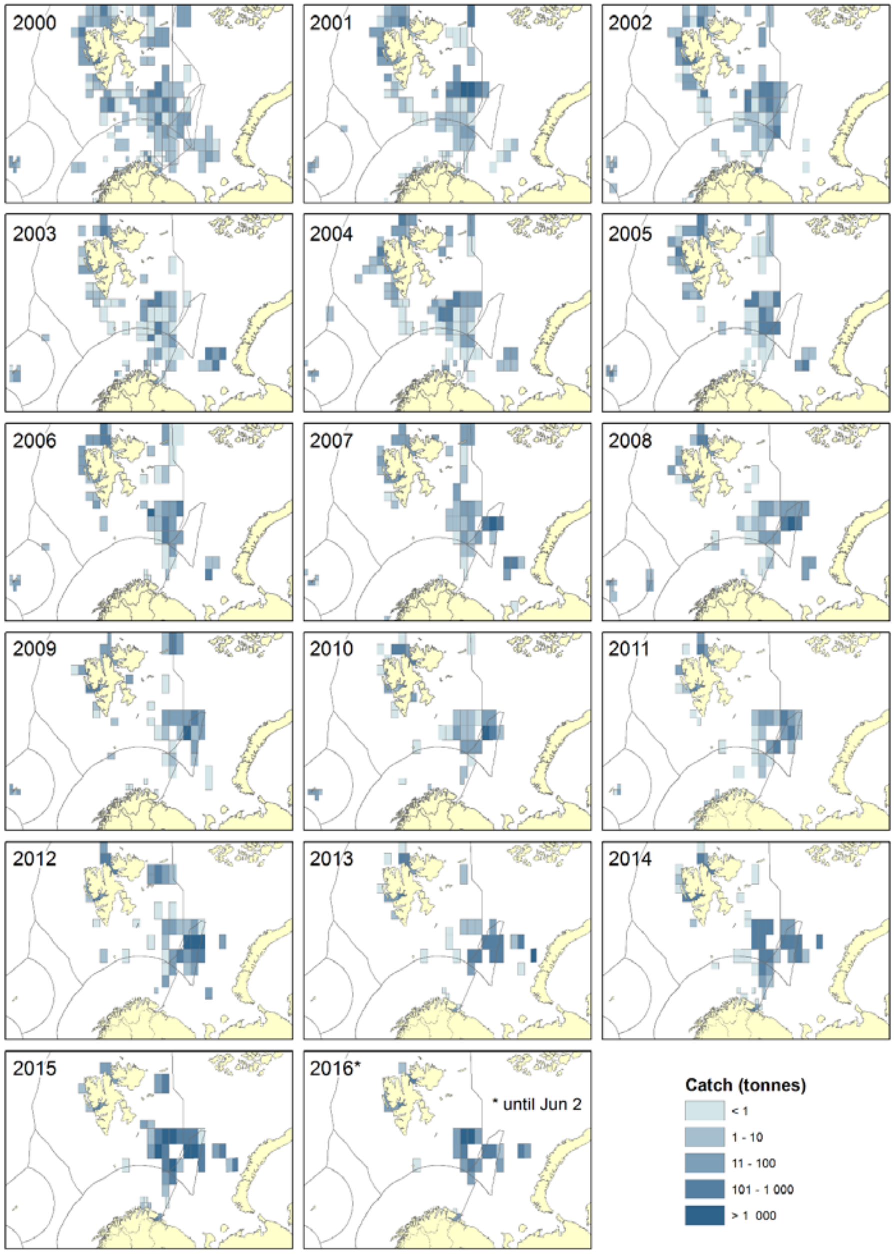

Fig. 6.6. Shrimp in ICES SA I and II: Distribution of catches by Norwegian vessels since 2000 based on logbook information.

Norwegian logbook data were used in a multiplicative model (GLM) to calculate standardized annual catch rate indices (SCR Doc. 16/49). 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 (Fig. 6.7). After 2012 indices have been increasing but are below the average of the time series.

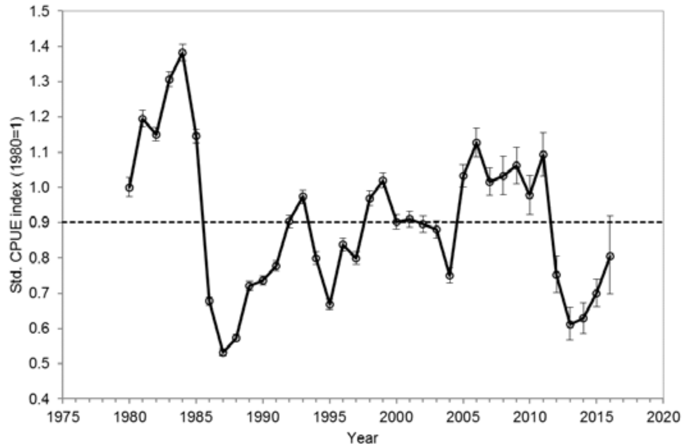

Fig. 6.7. Shrimp in ICES SA I and II: Standardized CPUE based on Norwegian data. Error bars represent one standard error; dotted line is the mean of the series.

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 Docs.14/55, 16/50).

Biomass. The Biomass indices of all surveys have fluctuated without trend over their respective time periods covered (Fig. 6.8).

In general, the entire survey area is covered in all years, however, due to heavy ice conditions in 2014 the northern part of the area (stratum 3, see SCR Doc. 16/50) was not covered. For the 2004-2013 survey period this area accounts for on average 13% of the biomass (range: 8-27%). The 2014 biomass for stratum 3 was estimated by calculating the average ratio of biomass density in stratum 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 stratum 3 was taken as the variance of the 2009-2013 estimates for stratum 3.

The geographical distribution of the stock in 2009-2015 was more easterly compared to that of the previous years (Fig. 6.9).

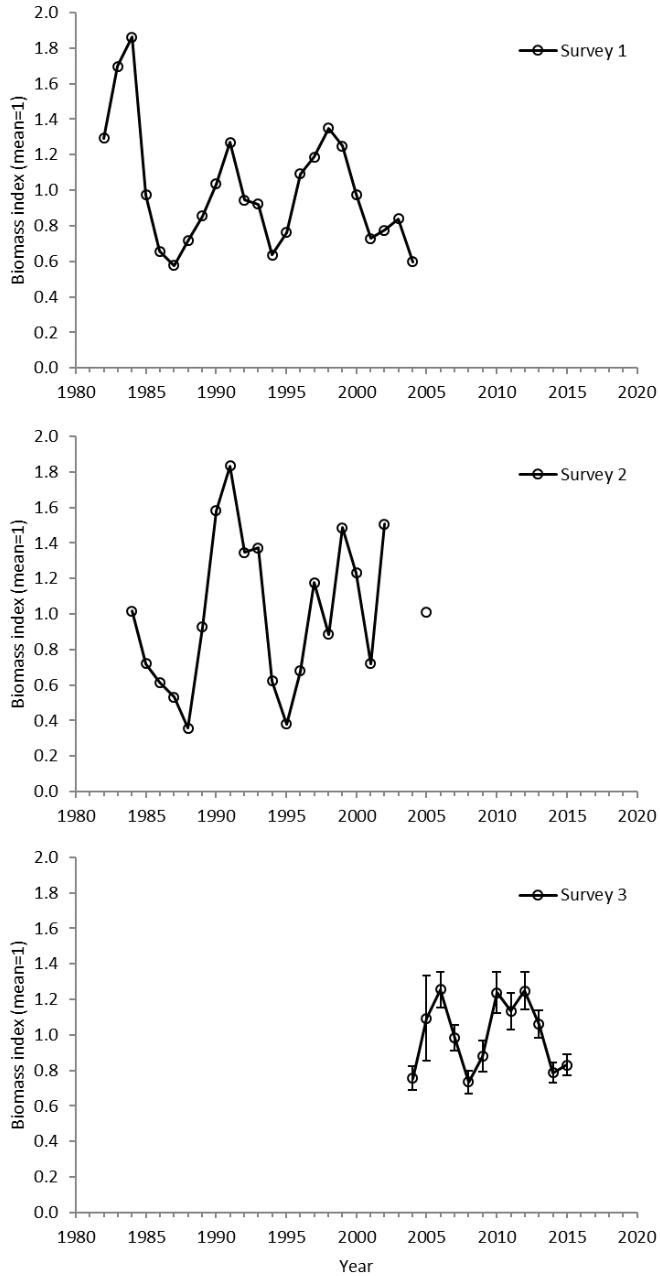

Fig. 6.8. Shrimp in ICES SA I and II: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey since 2004 (the 2016 survey data is not available at the time of the NIPAG meeting). Error bars represent one standard error.

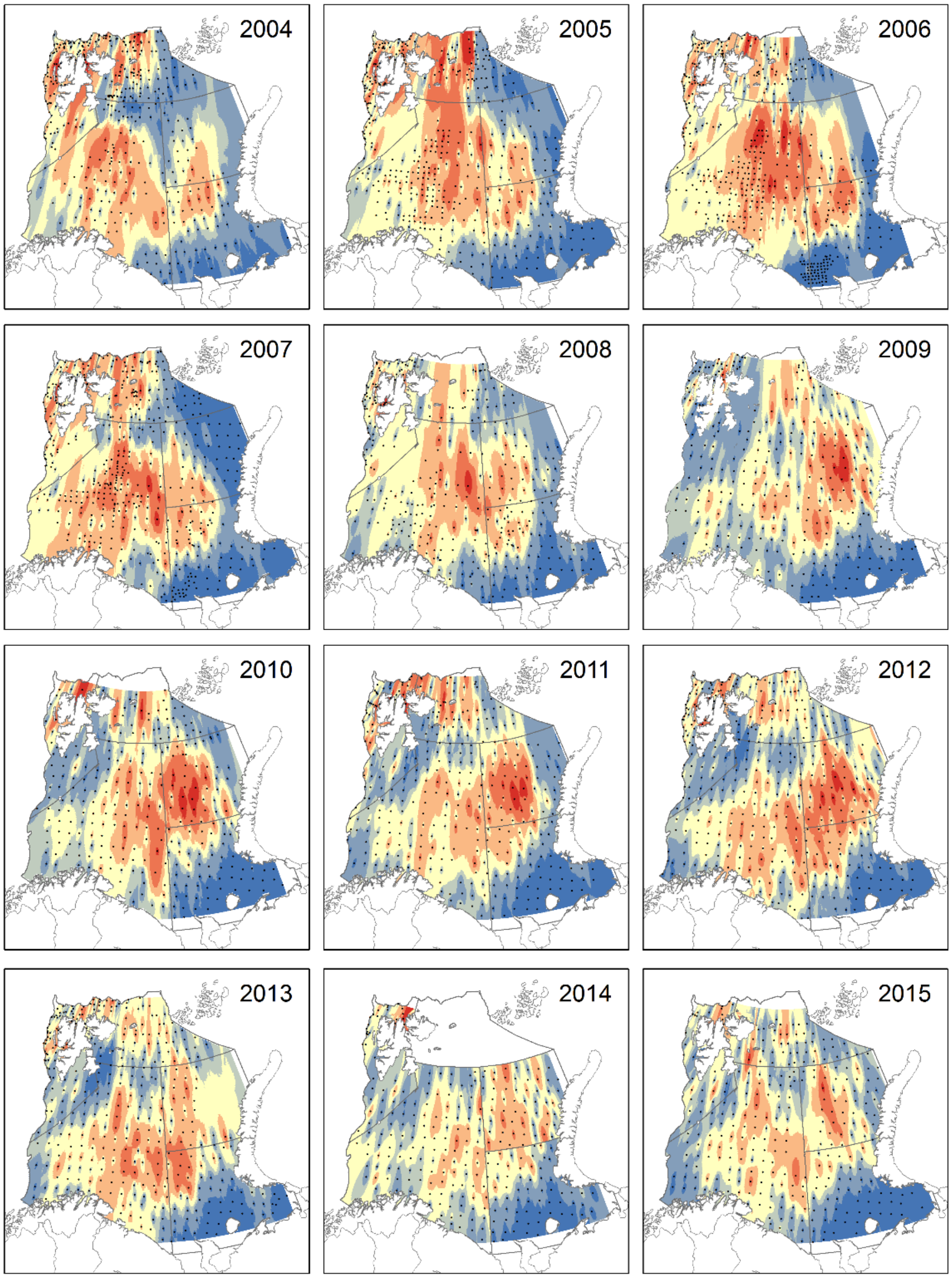

Fig. 6.9. Shrimp in ICES SA I and II: Shrimp density (kg/km2) as calculated from the Ecosystem survey data since 2004 (no data for stratum 3 in 2014 due to ice conditions).

Recruitment indices. Recruitment indices 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. 6.10).

Fig. 6.10. Shrimp in ICES SA I and II: Indices 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) Assessment

The modelling framework introduced in 2006 (SCR Doc. 06/64) was used for the assessment. Model settings were the same as those 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. 16/48).

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 1980–2016 (Fig. 6.7, SCR Doc. 16/49); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2015 (Fig, 6.8, SCR Doc. 16/50). 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. 16/59). 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 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. *K* could not be well estimated from the data alone and its posterior will depend somewhat on the chosen prior. For the estimates of relative stock size relaxing the *K*-prior did not have much effect (SCR Doc. 07/76) except for a slight increase in uncertainty. However, the posterior for *MSY* is sensitive as *K* is correlated with *MSY*: in particular, the right-hand side of the posterior distribution is widened while the left-hand side seem pretty well determined by the data. The mode of the distribution of MSY is around 100 kt and would likely be a best point estimate of this parameter.

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	191	124	216	356
K (ktons), carying capacity	3521	1879	2107	3086	4520
r, intrinsic growth rate	0.31	0.15	0.20	0.30	0.41
q_R, catchability of survey 2	0.11	0.08	0.06	0.09	0.14
q_{Ru}, catchability of survey 1	0.28	0.19	0.15	0.23	0.35
q_E, catchability of survey 3	0.18	0.12	0.09	0.14	0.22
q_C, catchability of CPUE index	4.0E-04	2.7E-04	2.1E-04	3.2E-04	5.0E-04
P_0, initial relative biomass (1969)	1.51	0.26	1.33	1.51	1.68
P_{2016}, relative biomass in 2016	1.69	0.46	1.40	1.67	1.96
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	0.20
σ_C, coefficient of variation for CPUE index	0.13	0.02	0.12	0.13	0.15
σ_P, coefficient of variation for process	0.19	0.03	0.17	0.19	0.21

Reference points. Four reference points are considered (reference points are obsolete due to the available risk analyses):

	Type	Value	Technical basis
MSY approach	$B_{trigger}$	$0.5B_{MSY}$	Approximately corresponding to 10th percentile of the B_{MSY} estimate (NIPAG 2010)
	F_{MSY}		Resulting from the assessment model.
Precautionary approach	B_{lim}	$0.3B_{MSY}$	The B where production is reduced to 50% MSY (NIPAG 2006)
	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 largely 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 almost dropped to the Bmsy-level (Fig. 6.11, upper). Since the late 1980s, however, the stock has varied with a slightly increasing trend. The median 2015-16 values are above B_{msy}. The estimated risk of stock biomass being below $B_{trigger}$ in 2016 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. 6.11 lower). In 2016, there is a less than 5% risk of the F being above F_{msy} (Table 6.3).

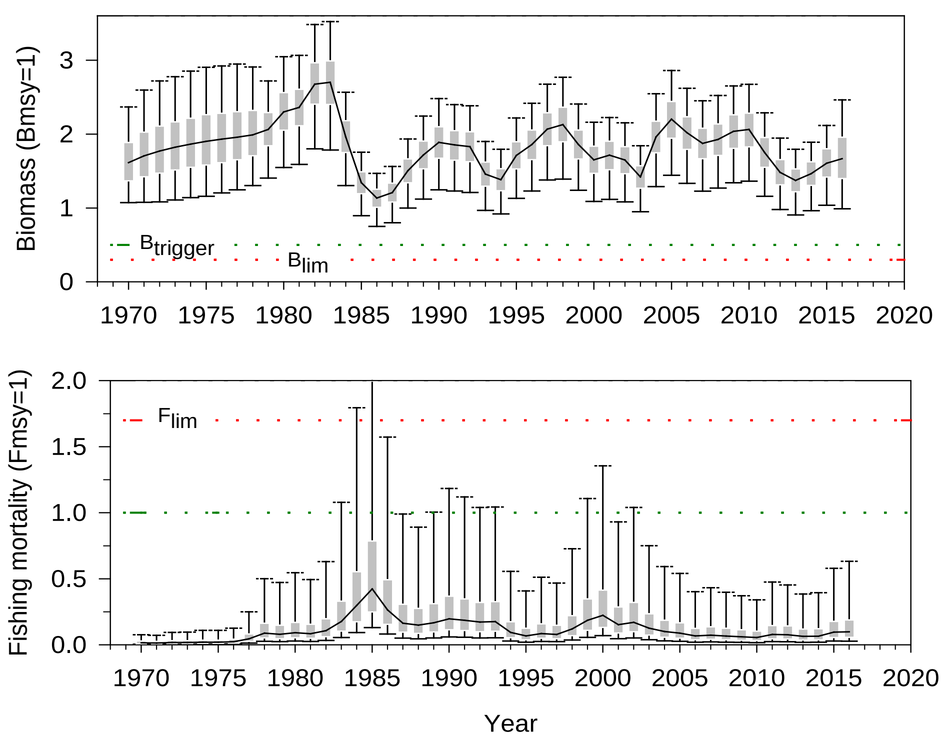

Fig. 6.11. Shrimp in ICES SA I and II: Estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) since 1970. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines indicate MSY and precautionary approach reference points.

Table 6.3. Shrimp in ICES SA I and II: Stock status for 2015 and predicted to the end of 2016.

Status	2015	2016*
Risk of falling below B_{lim}	0.1 %	0.1 %
Risk of falling below $B_{trigger}$	0.3 %	0.4 %
Risk of exceeding F_{MSY}	2.3 %	2.7 %
Risk of exceeding F_{lim}	1.0 %	1.2 %
Stock size (B/Bmsy), median	1.61	1.67
Fishing mortality (F/Fmsy),	0.10	0.10
Productivity (% of MSY)	63 %	55 %

*Projected catch = 35 kt

Predictions. Assuming a catch of 35 kt for 2016, catch options up to 90 kt for 2017 have low risks of exceeding F_{msy} (<10%), F_{lim} (<5%), and of going below $B_{trigger}$ (<1%) by the end of 2017 (Table 6.4) and all these options are likely to maintain the stock at its current high level. Catches at the median of F_{msy} (ICES MSY approach) would imply catches of no more than 315 kt – way outside the catch history of the fishery. Given that the right-hand side of the probability distributions of the yield at the F_{msy} is less well estimated, it is considered more appropriate to apply the mode as a point estimate of yield at F_{msy}. This mode is at 120 kt.

Table 6.4. Shrimp in ICES SA I and II: Predictions of risk and stock status associated with optional catch levels for 2017.

	Catch option 2017 (ktons)						Yield at Fmsy (mode)	Yield at Fmsy (median)
	50	60	70	80	90	100	120	315
Risk of falling below B_{lim}	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.2 %	0.3 %	0.8 %
Risk of falling below $B_{trigger}$	0.5 %	0.6 %	0.6 %	0.5 %	0.6 %	0.7 %	1.0 %	2.7 %
Risk of exceeding F_{MSY}	4.2 %	5.7 %	7.0 %	8.3 %	9.9 %	11.6 %	18.2 %	50 %
Risk of exceeding F_{lim}	2.2 %	2.8 %	3.6 %	4.1 %	4.9 %	5.7 %	6.8 %	30 %
Stock size (B/Bmsy), median	1.70	1.69	1.68	1.69	1.67	1.66	1.63	1.48
Fishing mortality (F/Fmsy),	0.14	0.16	0.19	0.22	0.25	0.27	0.33	1.00
Productivity (% of MSY)	52 %	53 %	54 %	53 %	55 %	56 %	60 %	77 %

The risks associated with ten-year projections of stock development assuming annual catch of 50 000 to 100 000 t were investigated (Fig. 6.12). For all options the probability of the stock falling below $B_{trigger}$ in the short to medium term (1-5 years) is low (<5%). Catch options up to 70 kt have a low risk (<5%) of exceeding F_{lim} in the short to medium term.

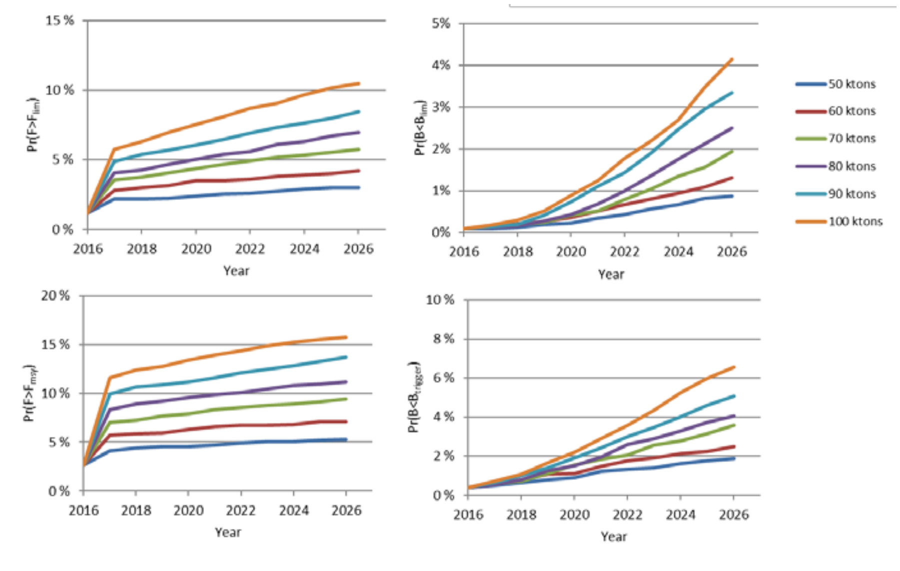

Fig. 6.12. Shrimp in ICES SA I and II: Projections of estimated risk of going below $B_{trigger}$ and B_{lim}, and of exceeding F_{msy} and F_{lim}, given different catch options.

Additional considerations

Model performance. The model was able to produce good simulations of the observed data (Fig. 6.13). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically (SCR Doc 16/48). They were found not to include excessively large deviation.

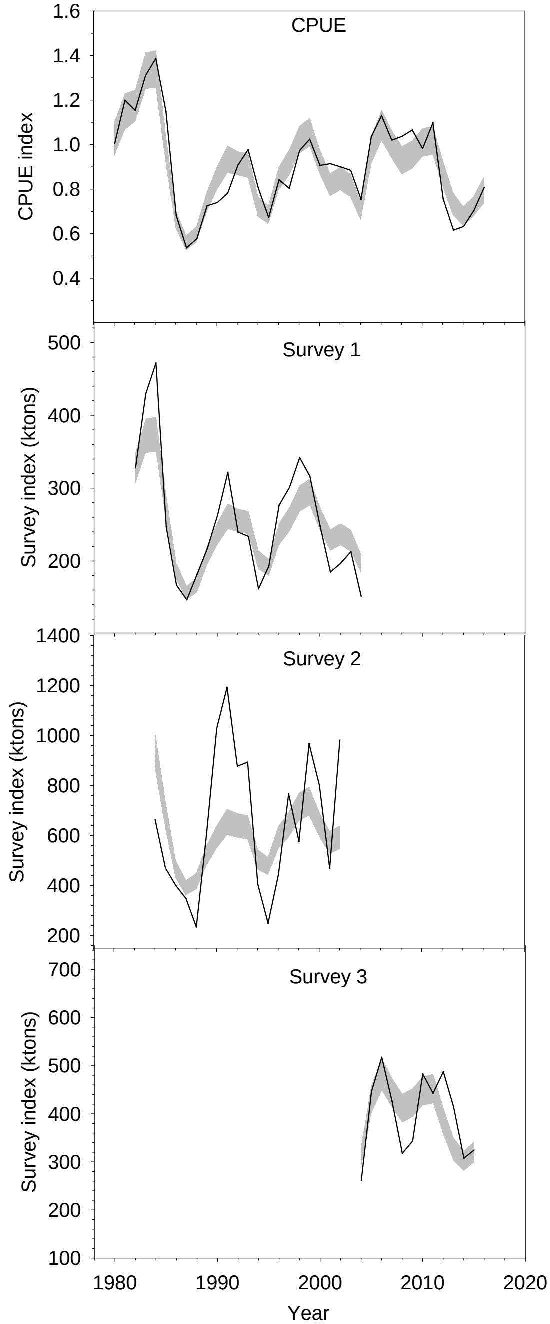

Fig. 6.13. Shrimp in ICES SA I and II: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 shrimp survey (survey 1), a Russian survey index discontinued in 2005 (Survey 2) and the Joint Norwegian-Russian Ecosystem 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 was 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 0.52 per year it would take between 1.5 and 6 years to rebuild the stock from B_{lim} to $B_{trigger}$ and 4-15 years to rebuild the stock to B_{msy} without a fishery.

e) State of the stock

Mortality. Fishing mortality is likely to have remained below F_{msy} throughout the history of the fishery. In 2016, there is a less than 5% risk of fishing mortality exceeding F_{lim}.

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The probability that the biomass at the end of 2016 is below $B_{trigger}$ is less than 1%.

State of the Stock. The Stock is estimated to be in a healthy state and exploited sustainably.

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 2015

There was no recommendation from 2015.

g) Research recommendations

- The assessment procedure used has been in place since 2006 and is recommended to be considered for a benchmark workshop in near future, no later than 2019
- The fishery has expanded since 2014 and catches by countries other than Norway have increased to account for about 50% of the total. NIPAG therefore **recommends** that *available data (logbook data and catch samples) from the participating nations be made available to NIPAG.*

7. Northern shrimp (*Pandalus borealis*) in the 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 (Fig. 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 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.

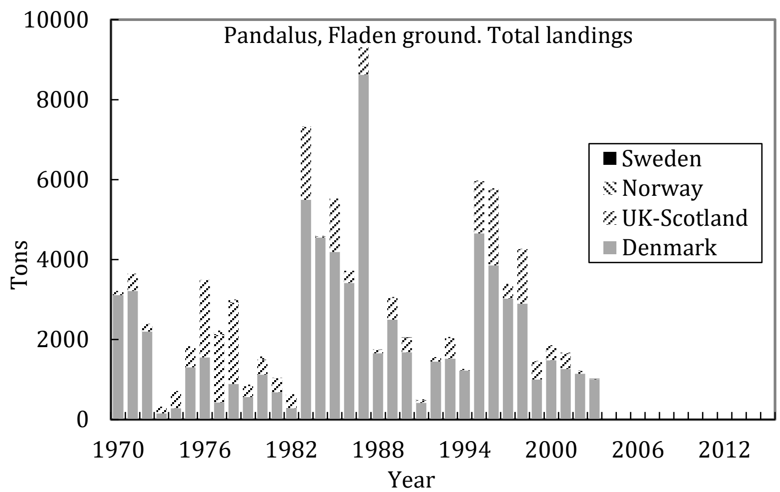

Fig. 7.1. Northern shrimp in Fladen Ground: Landings.

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 3LN Redfish			
Intermediate	3M Redfish[2] 3NO Witch flounder	SA0+1 Northern shrimp DS Northern shrimp 0&1A Offsh. & 1B–1F Greenland halibut	3M Cod	Greenland halibut in Uummannaq[1] Greenland halibut in Upernavik[1] Greenland halibut in Disko Bay[1] 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[2] 3LNO Northern shrimp			SA1 Redfish SA0+1 Roundnose grenadier SA1 Atlantic Wolffish
Unknown	SA2+3 Roughhead grenadier 3NO Capelin 3O Redfish			SA2+3 Roundnose grenadier

[1] Assessed as Greenland halibut in Div. 1A inshore

[2] Fishing mortality may not be the main driver of biomass for Div. 3M Shrimp and Redfish

b) Future meetings

NIPAG discussed the possibility of holding next year's meeting later in the year (after the September Annual Meeting) as was the practice prior to 2013. This would have the advantage of providing more time for the analysis of several surveys which take place in the summer but would mean that full assessment based advice would not be available to FC in September. Update advice based on limited analysis of survey data would be available in September, and this may be sufficient for stocks which are under moratorium. Pending agreement from FC and ICES ACOM, next year's meeting will be held in early October (dates to be decided).

Tentative offers to host next year's meeting were received from Sweden and the USA. The relevant WG members will make further enquiries to confirm availability and a decision on meeting location will subsequently be taken by correspondence.

c) Genetic stock structure of northern shrimp in NAFO Div. 0A, 0B and Subarea 1

Scientific Council were in 2015 informed of preliminary results from a research project focusing on the genetic stock structure of northern shrimp in Div. 0A, 0B and Subarea 1. Sampling was also done in North East Greenland. The data set is not yet finalized, and statistical analyses are still ongoing.

However, the preliminary results indicate that the shrimp population in Div. 0A, Disko Bay and offshore north of Disko Bay is distinct from the shrimp population south of Disko Bay. Results from the southern part of Greenland (Julianehåb Bay) and from East Greenland are hard to interpret due to a low number of samples, but results indicate that the shrimp in this region may differ from the rest of West Greenland.

V. ADJOURNMENT

The NIPAG meeting was adjourned at 1800 hours on 13 September 2016. 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 to the Institute of Marine Research for their hospitality during this meeting.

APPENDIX I. AGENDA NAFO/ICES *PANDALUS* ASSESSMENT GROUP
Institute of Marine Research, Bergen, Norway, 7-14 September 2016

I. Opening (Co-chairs Katherine Sosebee and Guldborg Søvik)

1. Appointment of Rapporteur
2. Adoption of Agenda
3. Plan of Work

II. General Review

1. Review of Recommendations in 2014 and in 2015
2. Review of Catches

III. Stock Assessments

- Northern shrimp (Division 3M)
- Northern Shrimp (Divisions 3LNO)
- Northern shrimp (Subareas 0 and 1)
- Northern shrimp (in Denmark Strait and off East Greenland)
- Northern shrimp in Skagerrak and Norwegian Deep (ICES Divisions IIIa and IVa East)
- Northern Shrimp in Barents Sea and Svalbard area (ICES Sub-areas I & II)
- Northern shrimp in Fladen Ground (ICES Division IVa)

IV. Other Business

1. FIRMS Classification for NAFO Shrimp Stocks

V. Adjournment

ANNEX 1. FISHERIES COMMISSION'S REQUEST FOR SCIENTIFIC ADVICE ON MANAGEMENT IN 2017 AND BEYOND OF CERTAIN STOCKS IN SUBAREAS 2, 3 AND 4 AND OTHER MATTERS

1. Fisheries Commission requests that the Scientific Council provide advice for the management of the fish stocks below according to the assessment frequency presented below. The advice should be provided as a range of management options and a risk analysis for each option (rather than a single TAC recommendation).

Yearly basis	Two year basis	Three year basis
Northern shrimp in Div. 3LNO	American plaice in Div. 3LNO Cod in Div. 3M Redfish in Div. 3M Northern shrimp in Div. 3M Thorny skate in Div. 3LNO White hake in Div. 3NO Witch flounder in Div. 3NO	American plaice in Div. 3M Capelin in Div. 3NO Cod in Div. 3NO Northern shortfin squid in SA 3+4 Redfish in Div. 3O Witch flounder in Div. 2J+3KL Yellowtail flounder in Div. 3LNO

To implement this schedule of assessments, the Scientific Council is requested to conduct the assessment of these stocks as follows:

In 2016, advice should be provided for 2017 for Northern shrimp in NAFO Div. 3LNO

In 2016, advice should be provided for 2017 and 2018 for American plaice in Div. 3LNO and for Thorny skate in Div. 3LNO.

In 2016, advice should be provided for 2017, 2018 and 2019 for Redfish in Div.3O, Witch flounder in Div. 2J+3KL and Northern shortfin squid in SA 3+4.

Advice should be provided using the guidance provided in **Annexes A or B as appropriate**, or using the predetermined Harvest Control Rules in the cases where they exist.

The Fisheries Commission also requests the Scientific Council to continue to monitor the status of all these stocks annually and, should a significant change be observed in stock status (e.g. from surveys) or in bycatch in other fisheries, provide updated advice as appropriate.

2. The Fisheries Commission adopted in 2010 an MSE approach for Greenland halibut stock in Subarea 2 + Division 3KLMNO (FC Doc. 10/12) and agreed to use it until 2017 (FC Doc.13/23). This approach considers a survey based harvest control rule (HCR) to set a TAC for this stock on an annual basis. The Fisheries Commission requests the Scientific Council to:

    a) Monitor and update the survey slope and to compute the TAC according to HCR adopted by the Fisheries Commission according to Annex 1 of FC Doc. 10/12.
    b) Advise on whether or not an exceptional circumstance is occurring.

3. The Fisheries Commission adopted in 2014 an MSE approach for Redfish in Division 3LN (FC Doc. 14/24). This approach uses a Harvest Control Rule (HCR) designed to reach 18 100 t of annual catch by 2019-2020 through a stepwise biannual catch increase, with the same amount of increase every two years The Fisheries Commission request Scientific Council conduct a full assessment in 2016 to evaluate the effect of removals in 2014 and 2015 on stock status.

4. The Fisheries Commission requests the Scientific Council to continue to develop work on Significant Adverse Impacts in support of the reassessment of NAFO bottom fishing activities required in 2016,

specifically an assessment of the risk associated with bottom fishing activities on known and predicted VME species and elements in the NRA.

FC further requests that:

a) that Scientific Council should take into account the protection afforded to VME areas outside the NAFO fisheries footprint in the calculation of the VME area and biomass at risk of bottom fishing impact;
b) that Scientific Council refine VME kernel density analysis polygon boundaries, taking into account current understanding of distribution patterns in relation to environmental variables.

5. FC requests the Scientific Council consider widening the scope of the NAFO coral and sponge identification guides to include other relevant species on seamounts.

6. FC requests that Scientific Council consider options to expedite a risk assessment of scientific trawl surveys impact on VME in closed areas, and the effect of excluding surveys from these areas on stock assessments.

7. FC requests the Scientific Council consider, based on analysis of logbook data and patterns of fishing activity, to be conducted by the Secretariat, to examine relative levels of bycatch and discards of 3M cod/redfish, and stocks under moratoria in the different circumstances (e.g. fisheries, area, season, fleets, depth, timing)

8. It is difficult to match the current F_{lim} proxy with the 3M cod assessment results given by the 2015 Bayesian XSA assessment. These results were presented to SC in June and used for short term (2016-2017) projections under several *F* options (NAFO SCR 15/33 González-Troncoso, 2015); NAFO SC June 2015 Report). Focusing on the last assessment and projections, assuming at the same time a candidate F_{lim}= $F_{30\%}$SPR=0.131, they would imply that:

- During the past five years (2010-2014) 3M cod has been exploited at an average F_{bar} level over two fold F_{lim}.
- While SSB was sustained at a high average level representing 87% of the highest estimated SSB of the 1972-2014 interval (36 7041 on 1972).
- The two highest year classes since 1992 occurred in 2011-2012.

Under these circumstances the Scientific Council is requested to analyze whether the current F_{lim} value for 3M cod is currently underestimated and to revise if required the relevant fishing mortality and biomass reference points appropriately.

9. The stock of redfish 3M covers catches of three Sebastes species and the scientific advice is based on data of only two species (*S. mentella* and *S. fasciatus*). Golden redfish, *Sebastes marinus* (aka norvegicus), represents part of the catch but has not yet been subject to a full assessment in NAFO. The Scientific Council is requested to explore the possibility and options of an individual assessment of the golden redfish (*S. marinus*, aka norvegicus) and of including this species in the scientific advice for 2018-2019. The Scientific Council is also requested to advice on the implications for the three species in terms of catch reporting and stock management.

10. As part of the Greenland halibut's MSE review scheduled for 2016-2017, the SC is asked to specifically monitor and evaluate Contracting Parties surveys with the aim of optimizing resources in order to avoid duplication of data, identify data gaps and streamline survey methodologies, so that all data is used in the assessment.

11. Article 23 NCEM foresees a reassessment of bottom fishing activities in 2016. The NAFO Roadmap for Developing an Ecosystem Approach to Fisheries extends the work of the Scientific Council to include the assessment of potential impacts of activities other than fishing. Also, impacts of human activities in ecosystems should not be analyzed in isolation since cumulative effects might occur representing more than the sum of the individual factors. The Scientific Council is therefore requested to develop a workplan at its meeting in 2016 that will allow to address and analyze the potential impact of activities other than

fishing (eg. oil and gas exploration, marine cables, ocean dumping, marine transportation) on NAFO VMEs, in particular VME closed areas.

12. The Fisheries Commission requests the Scientific Council to conduct a full assessment of Greenland halibut in Subarea 2 + Division 3KLMNO (using both XSA and SCAA[1]) and to consider the weighting of each survey as a first step to inform the 2017 MSE review.

13. The Fisheries Commission requests the Scientific Council to advise on how many SSB points above 30,000t are considered sufficient to conduct a review of Blim of cod in 3NO.

14. The Fisheries Commission requests the Scientific Council to provide survey biomass trend(s) of witch flounder in Div. 3M for as long as data is available.

15. The Fisheries Commission requests the Scientific Council to review the results of the 2015 Canadian in situ photographic surveys for non-coral and sponge VME indicator species on Grand Bank (tail of Grand Bank) in relation to previous analyses presented in 2014 (that modelled their distribution using research vessel survey trawl bycatch data), and to identify areas of significant concentrations of non-coral and sponge VME indicator species using all available information.

16. Recognizing the importance of the 3M cod fishery to NAFO.
    Mindful that even though the current SSB is well above B_{lim}, the recruitment of the two most recent years is low.

    Noting that according to the Scientific Council stock assessment we are currently fishing only on two year-classes – once they are depleted in about two years time prospects for a continued fishery at the current level is not likely to be possible.

    Further noting that recent assessment of the stock has shown some year-to-year instability and that estimation of risk levels associated with given fishing mortalities cannot be calculated at this time, which further adds to our concern for the future of this fishery and its management.

    It is proposed that Scientific Council organize a full benchmark review of the 3M cod assessment in two stages: For 2016 Scientific Council will agree on a standardized approach and prepare a plan for the benchmark process at NAFO including required resources. For 2017 SC will review the benchmark assessment methodology for 3M cod.

[1.] SCAA will not be possible unless a contractor can be hired.

ANNEX A: GUIDANCE FOR PROVIDING ADVICE ON STOCKS ASSESSED WITH AN ANALYTICAL MODEL

The Fisheries Commission request the Scientific Council to consider the following in assessing and projecting future stock levels for those stocks listed above. These evaluations should provide the information necessary for the Fisheries Commission to consider the balance between risks and yield levels, in determining its management of these stocks:

1. For stocks assessed with a production model, the advice should include updated time series of:

- Catch and TAC of recent years
- Catch to relative biomass
- Relative Biomass
- Relative Fishing mortality
- Stock trajectory against reference points
- And any information the Scientific Council deems appropriate.

Stochastic short-term projections (3 years) should be performed with the following constant fishing mortality levels as appropriate:

- For stocks opened to direct fishing: 2/3 F_{msy}, 3/4 F_{msy} 85% F_{msy}, 75% F_{2015}, F_{2015}, 125% F_{2015},
- For stocks under a moratorium to direct fishing: F_{2015}, F = 0.

The first year of the projection should assume a catch equal to the agreed TAC for that year.
Results from stochastic short term projection should include:

- The 10%, 50% and 90% percentiles of the yield, total biomass, spawning stock biomass and exploitable biomass for each year of the projections
- The risks of stock population parameters increasing above or falling below available biomass and fishing mortality reference points. The table indicated below should guide the Scientific Council in presenting the short term projections.

				Limit reference points														
				$P(F>F_{lim})$			$P(B<B_{lim})$				$P(F>F_{msy})$			$P(B<B_{msy})$				P(B2019 > B2016)
F in 2016 and following years*	Yield 2017 (50%)	Yield 2018 (50%)	Yield 2019 (50%)	2016	2017	2018	2016	2017	2018		2016	2017	2018	2016	2017	2018		
2/3 F_{msy}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
3/4 F_{msy}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
85% F_{msy}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
F_{msy}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
0.75 X F_{2015}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
F_{2015}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
1.25 X F_{2015}	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%
F=0	t	t	t	%	%	%	%	%	%		%	%	%	%	%	%		%

2. For stock assessed with an age-structured model, information should be provided on stock size, spawning stock sizes, recruitment prospects, historical fishing mortality. Graphs and/or tables should be provided for all of the following for the longest time-period possible:

- historical yield and fishing mortality;
- spawning stock biomass and recruitment levels;
- Stock trajectory against reference points

And any information the Scientific Council deems appropriate
Stochastic short-term projections (3 years) should be performed with the following constant fishing mortality levels as appropriate:

- For stocks opened to direct fishing: $F_{0.1}$, F_{max}, 2/3 F_{max}, 3/4 F_{max}, 85% F_{max}, 75% F_{2015}, F_{2015}, 125% F_{2015},
- For stocks under a moratorium to direct fishing: F_{2015}, F = 0.
  The first year of the projection should assume a catch equal to the agreed TAC for that year.

Results from stochastic short term projection should include:
- The 10%, 50% and 90% percentiles of the yield, total biomass, spawning stock biomass and exploitable biomass for each year of the projections
- The risks of stock population parameters increasing above or falling below available biomass and fishing mortality reference points. The table indicated below should guide the Scientific Council in presenting the short term projections.

				Limit reference points												
				P(F.>F_{lim})			P(B<B_{lim})			P(F>F0.1)			P(F>F_{max})			P(B2019 > B2016)
F in 2016 and following years*	Yield 2017	Yield 2018	Yield 2019	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	
F0.1	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
66% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
75% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
85% F_{max}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
0.75 X F_{2015}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
F_{2015}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%
1.25 X F_{2015}	t	t	t	%	%	%	%	%	%	%	%	%	%	%	%	%

ANNEX B. GUIDANCE FOR PROVIDING ADVICE ON STOCKS ASSESSED WITHOUT A POPULATION MODEL

For those resources for which only general biological and/or catch data are available, few standard criteria exist on which to base advice. The stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with the precautionary approach.

The following graphs should be presented, for one or several surveys, for the longest time-period possible:

a) time trends of survey abundance estimates
b) an age or size range chosen to represent the spawning population
c) an age or size-range chosen to represent the exploited population
d) recruitment proxy or index for an age or size-range chosen to represent the recruiting population.
e) fishing mortality proxy, such as the ratio of reported commercial catches to a measure of the exploited population.
f) Stock trajectory against reference points

And any information the Scientific Council deems appropriate.

ANNEX 2. DENMARK (ON BEHALF OF GREENLAND) REQUEST FOR SCIENTIFIC ADVICE ON MANAGEMENT IN 2017 OF CERTAIN STOCKS IN SUBAREAS 0 AND 1

1. Roundnose Grenadier: For Roundnose Grenadier in Subarea 0 + 1 advice was in 2014 given for 2015-2017. Denmark (on behalf of Greenland) requests the Scientific Council to continue to monitor the status of Roundnose Grenadier in Subareas 0 and 1 annually, and should significant changes in the stock status be observed (e.g. from surveys) the Scientific Council is requested to provide updated advice as appropriate.

2. Golden Redfish, Demersal Redfish, American Plaice, Atlantic Wolffish and Spotted Wolfish: Advice on Golden Redfish (Sebastes marinus), Demersal Deep-sea Redfish (Sebastes mentella) American Plaice (Hippoglossoides platessoides), Atlantic Wolffish (Anarhichas lupus) and Spotted Wolffish (Anarhichas minor) in Subarea 1 was in 2014 given for 2015-2017. Denmark (on behalf of Greenland) requests the Scientific Council to continue to monitor the status of these species annually, and should significant changes in stock status be observed the Scientific Council is requested to provide updated advice as appropriate.

3. Greenland Halibut, offshore: Subject to the concurrence of Canada as regards Subareas 0 and 1, the Scientific Council is requested to provide advice on appropriate TAC levels for 2017 and as long time ahead as considered appropriate separately for Greenland Halibut in 1) the offshore areas of NAFO Division 0A and Division 1A plus Division 1B and 2) NAFO Division 0B plus Divisions 1C-1F. The Scientific Council is also asked to advice on any other management measures it deems appropriate to ensure the sustainability of these resources.

4. Greenland Halibut, inshore: Advice on Greenland Halibut in Division 1A inshore was in 2014 given for 2015-2016. Denmark (on behalf of Greenland) requests the Scientific Council for advice on Greenland Halibut in Division 1A inshore for 2017-2018.

5. Northern Shrimp, West Greenland: Subject to the concurrence of Canada as regards Subarea 0 and 1, Denmark (on behalf of Greenland) requests the Scientific Council before December 2016 to provide advice on the scientific basis for management of Northern Shrimp (*Pandalus borealis*) in Subarea 0 and 1 in 2017 and for as many years ahead as data allows for.

   The Scientific Council is asked to consider, if the advice for Subarea 0 and 1 could be limited in north to 73 °30’N owing to the fact, that stock assessment is based on data from scientific survey and logbooks within the area 60°N to 73°30’N.

6. Northern Shrimp, East Greenland: Furthermore, the Scientific Council is in cooperation with ICES requested to provide advice on the scientific basis for management of Northern Shrimp (*Pandalus borealis*) in Denmark Strait and adjacent waters east of southern Greenland in 2017 and for as many years ahead as data allows for.

ANNEX 3. REQUESTS FOR ADVICE FROM CANADA

1. Greenland halibut (Subareas 0 and 1)

The Scientific Council is requested, subject to the concurrence of Denmark (on behalf of Greenland) as regards Subarea 1, to provide an overall assessment of status and trends in the total stock area throughout its range and to specifically advise on TAC levels for 2017, separately, for Greenland halibut in Divisions 0A+1A (offshore) and 1B, and Divisions 0B+1C-F.[1] The Scientific Council is also asked to provide advice on any other management measures it deems appropriate to ensure the sustainability of these resources.

a) It is noted that at this time only general biological advice and/or catch data are available, few standard criteria exist on which to base advice. The stock status should be evaluated in the context of management requirements for long-term sustainability and the advice provided should be consistent with the precautionary approach and include likely risk considerations and implications as much as possible, including risks of maintaining current TAC levels and any risks and available details of observations that would support an increase or decrease in the TACs.[2]
   -

The following graphs should be presented, for one or several surveys, for the longest time-period possible:

- historical catches;
- abundance and biomass indices;
- an age or size range chosen to represent the spawning population;
- an age or size range chosen to represent the exploited population;
- recruitment proxy or index for an age or size-range chosen to represent the recruiting population;
- fishing mortality proxy, such as the ratio of reported commercial catches to a measure of the exploited population;
- stock trajectory against reference points

Any other information the Scientific Council feels is relevant should also be provided.

2. Shrimp (Divisions 0A and Subarea 1)

Canada requests the Scientific Council to consider the following options in assessing and projecting future stock levels for Shrimp in Subareas 0 and 1:

a) The status of the stock should be reviewed and management options evaluated in terms of their implications for fishable stock size, spawning stock size, recruitment prospect, catch rate and catch over the next 5 years. The implications of catch options ranging from 30,000 t to the catch corresponding to Z MSY, in 5,000 t increments, should be forecast for 2017 through 2021 if possible, and evaluated in relation to precautionary reference points of both mortality and fishable stock biomass. Results should include a partitioning of the future estimable removals between catches and estimable predation for the various catch options requested. The present stock size and fishable stock size should be described in relation to those observed historically and those to be expected in the next 5 years under the various catch options requested, and any other options Scientific Council feels worthy of consideration.

b) Management options should be provided within the Northwest Atlantic Fisheries Organization Precautionary Approach Framework. Uncertainties in the assessment should be evaluated and presented in the form of risk analyses related to the limit reference points of B_{lim} and Z_{MSY}.

c) Presentation of the results should include the following:

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[1] The Scientific Council has noted previously that there is no biological basis for conducting separate assessments for Greenland halibut throughout Subareas 0-3, but has advised that separate TACs be maintained for different areas of the distribution of Greenland halibut.

[2] Canada encourages the Scientific Council to continue to explore opportunities to develop risk-based advice in the future, including the implications of increases in the TAC (e.g. by 10, 15 or 25%), noting that data conditions do not allow for such advice at this time.

- a graph and table of historical yield and fishing mortality for the longest time period possible;
- a graph of biomass relative to B_{MSY}, and recruitment levels for the longest time period possible.
- a graph of the stock trajectory compared to B_{lim} and/or B_{MSY} and Z_{MSY}.;
- graphs and tables of total mortality (Z) and fishable biomass for a range of projected catch options (as noted in 2 a) for the years 2017 to 2021 if possible. Projections should include both catch options and a range of cod biomass levels considered appropriate by SC. Results should include risk analyses of falling below B_{MSY} and B_{lim}, and of exceeding Z_{MSY}.;
- a graph of the total area fished for the longest time period possible; and

any other graph or table the Scientific Council feels is relevant.

ANNEX 4. ICES TORS FOR NIPAG

2015/2/ACOM15 The **Joint NAFO/ICES *Pandalus* Assessment Working Group** (NIPAG), chaired by Guldborg Søvik*, Norway (ICES) and Katherine Sosebee, United States of America (NAFO), will meet in Bergen, Norway 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.

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

f) 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.

APPENDIX II. LIST OF RESEARCH (SCR) AND SUMMARY (SCS) DOCUMENTS
RESEARCH DOCUMENTS (SCR)

SCR Doc. 16-041	N6590	A.Burmeister and M.C.S. Kingsley	The West Greenland trawl survey for Pandalus borealis, 2016, with reference to earlier results.
SCR Doc. 16-042	N6591	A.Burmeister and M.C.S. Kingsley	A provisional Assessment of the shrimp stock off West Greenland in 2016
SCR Doc. 16-043	N6592	N. Hammeken Arboe	The Fishery for Northern Shrimp (Pandalus borealis) off West Greenland, 1970–2016
SCR Doc. 16-044	N6593	N. Hammeken Arboe	Catch Table Update for the West Greenland Shrimp Fishery
SCR Doc. 16-045	N6594	H. Siegstad	Results of the Greenland Bottom Trawl Survey for Northern shrimp (Pandalus borealis) Off East Greenland (ICES Subarea XIV b), 2008-2016
SCR Doc. 16-046	N6595	N. Hammeken Arboe	The Fishery for Northern Shrimp (Pandalus borealis) in Denmark Strait / off East Greenland 1978 – 2016.
SCR Doc. 15-047	N6596	M. C. S. Kingsley	A Stock-Dynamic Model of the West Greenland Stock of Northern Shrimp
SCR Doc. 16-048	N6598	C. Hvingel	Shrimp (Pandalus borealis) in the Barents Sea – Stock Assessment 2016
SCR Doc. 16-049	N6599	Carsten Hvingel and Trude H. Thangstad	The Norwegian fishery for northern shrimp (Pandalus borealis) in the Barents Sea and round Svalbard 1970-2016
SCR Doc. 16-050	N6600	Carsten Hvingel and Trude H. Thangstad	Research survey results pertaining to northern shrimp (Pandalus borealis) in the Barents Sea and Svalbard area 2004-2015
SCR Doc. 16-051	N6602	J. M. Casas	Northern Shrimp (Pandalus borealis) on Flemish Cap Surveys 2016
SCR Doc. 16-052	N6603	Casas, J.M., E. Román and M. Álvarez	Northern Shrimp (Pandalus borealis, Krøyer) from EU-Spain Bottom Trawl Northern Shrimp (Pandalus borealis, Krøyer) from EU-Spain Bottom Trawl Northern Shrimp (Pandalus borealis, Krøyer) from EU-Spain Bottom Trawl Survey 2016 in NAFO Div. 3LNO
SCR Doc. 16-053	N6604	G. Søvik and T. H. Thangstad	Results of the Norwegian Bottom Trawl Survey for Northern Shrimp (Pandalus borealis)in Skagerrak and the Norwegian Deep (ICESDivisions IIIa and IVa east) in 2015
SCR Doc. 16-054	N6605	G. Søvik and E. Johnsen	Abundance and biomass of northern shrimp (Pandalus borealis) from the annual Norwegian shrimp survey in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa east) estimated using the new open source software StoX
SCR Doc. 16-055	N6606	Mikaela Bergenius, Massimiliano Cardinale, Ole Ritzau Eigaard, Guldborg Soevik and Mats Ulmestrand.	An assessment of the Norwegian Deep/Skagerrak shrimp stock using the Stock Synthesis statistical framework
SCR Doc. 16-056	N6607	Ulmetstrand et al	The Northern shrimp (Pandalus borealis) Stock in Skagerrak and the Norwegian Deep (ICES Divisions IIIa and IVa East)

SCR Doc. 16-057	N6608	G. Sovik	Norweigan Fishery
SCR Doc. 16-058	N6610	K. Skanes	3LNO Shrimp

SUMMARY DOCUMENTS (SCS)

SCS No.	**Ser. No.**	**Author(s)**	**Title**
SCS 16/17	N**6611**	NAFO	NIPAG Report
SCS 16/18	N6616	NAFO	SC Report

APPENDIX III. LIST OF REPRESENTATIVES, ADVISERS AND EXPERTS

CANADA

Don Power	Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, P.O. Box 5667, St John's, NL A1C 5X1	Phone +709 772 4935 Email: don.power@dfo-mpo.gc.ca
Katherine Skanes	Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, P.O. Box 5667, St John's, NL A1C 5X1	Phone +709 772 7343 Email:katherine.skanes@dfo-mpo.gc.ca

EUROPEAN UNION (EU)

Alfonso Perez-Rodriguez (via WebEX)	Institute of Marine Research, P.O. Box 1870, N-5817 Bergen, Norway	E-mail: alfonso.perez.rodriguez@imr.no
Massimiliano Cardinale	Swedish University of Agricultural Sciences (SLU), Department of Aquatic Resources, Institute of Marine Research, 45330 Lysekil, Sweden	Email: Massimiliano.cardinale@slu.se
Mikaela Bergenius	Swedish University of Agricultural Sciences (SLU), Department of Aquatic Resources, Institute of Marine Research, 45330 Lysekil, Sweden	Email: Mikaela.bergenius@slu.se
José Miguel Casas Sanchez	Instituto Espanol de Oceanografia, Centro Oceanografio, De Vigo, Subida a Radiofaro, 50 P.O. Box 1552, E-36200 Vigo (Pontevedra), Spain	Phone +34 986 492 111 Email: mikel.casas@vi.ieo.es
Ole Ritzau Eigaard	DTU-AQUA Technical University of Denmark, Charlottenlund Slot, DK-2920, Charlottenlund	Phone: +45 21154565 Email: ore@aqua.dtu.dk
Mats Ulmestrand	Swedish University of Agricultural Sciences (SLU), Department of Aquatic Resources, Institute of Marine Research, 45330 Lysekil, Sweden	Phone +46 10 478 4048 Email: mats.ulmestrand@slu.se

GREENLAND

AnnDorte Burmeister	Greenland Institute of Natural Resources, P. O. Box 570. GL-3900, Nuuk	Phone: +299 36 1200 Email: anndorte@natur.gl
Nanette Hammeken-Arboe	Greenland Institute of Natural Resources, P. O. Box 570. GL-3900, Nuuk	Phone: +299 36 1200 Email: nanette@natur.gl
Michael C.S. Kingsley	Rue Principal, Cortiça, Apartado No. 3, 3300-357 São Martinho da Cortiça, Portugal	Phone +351 23 945 8224 Email: mcskingsley@gmail.com

NORWAY

Carsten Hvingel	Institute of Marine Research, P.O. Box 1870, N-5817 Bergen	Phone +47 77609750 Email: carsten.hvingel@imr.no
Guldborg Søvik	Institute of Marine Research, P.O. Box 1870, N-5817 Bergen	Phone +47 5523 5348 Email: guldborg.soevik@imr.no

UNITED STATES OF AMERICA

Katherine Sosebee	National Marine Fisheries Service, NEFSC, 166 Water St., Woods Hole, MA 02543	Phone +1 508 495 2372 Email: katherine.sosebee@noaa.gov

NAFO Secretariat

Tom Blasdale	Scientific Council Coordinator, Northwest Atlantic Fisheries Organization, P.O. Box 638 Dartmouth, NS, Canada B2Y 3Y9	Phone +1 902 468 7542 Email: tblasdale@nafo.int
Dayna Bell	Scientific Information Administrator NAFO Secretariat	Phone +1 902 468 5590 Email: dbell@nafo.int

APPENDIX IV. LIST OF RECOMMENDATIONS

1. Northern Shrimp in Div. 3M

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.*

Recent progresses have been made, cf. the article presented at the meeting (Pérez-Rodríguez, A. et al. 2016).

2. Northern Shrimp in SA 0+1

NIPAG **recommended in 2015** 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*.

STATUS: In progress. There was no information specific to address this request presented at NIPAG in 2016. However, it was noted that during the 2016 June SC meeting that WGESA has included an item (ToR 6) endorsed by SC to develop ecosystem summaries for ecosystem units in the NAFO Convention Area. These summaries are to include provision of information for assessments at the ecosystem, multispecies, and stock level. It is anticipated that this information for 3LNO shrimp will be available considering that shrimp is a key forage species in the ecosystem. NIPAG reiterates this recommendation for 2016.

3. Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO SA 0 And SA1)

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.

NIPAG **recommended in 2014** 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 **recommended in 2014** that *further refinements to the "partial MIXing" method of estimating numbers at age should be explored*.

STATUS: In progress; this recommendation is reiterated.

Survey trends inshore and offshore are divergent and NIPAG **recommended in 2015** that *the nature and implications of this divergence is explored*.

Status: In progress; this recommendation is reiterated.

In 2016:

NIPAG **recommends** that *methods for prediction of future cod biomass should be explored.*

NIPAG **recommends** that *genetic stock structure in West and East Greenland should be further explored.*

4. Northern shrimp (*Pandalus borealis*) In the Denmark Strait and off East Greenland (Ices Div. XIVb and Va)

NIPAG **recommends** that *the potential for developing a B_{LIM} reference point for the stock be explored.*

NIPAG **recommends** that *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*

5. Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Divs. IIIa and IVa east)

Management Recommendations

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

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

STATUS: Not implemented

- Improved diagnostics and sensitivity analyses should be developed for the LBM

STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- Alternative assumptions regarding natural mortality, length-age relationship and selectivity should be explored to see whether the LBM fit to survey length data can be improved.
    - STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.
- Reasons for the large retrospective pattern in F for recent assessments using the LBM should be explored.
    - STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.
- Seasonal patterns of spatial distribution resulting from the migration of different age and sex classes should be investigated, as well as seasonal patterns of LPUE in the three fisheries, particularly the reason why LPUE for a given year increases when we have the full years' data compared to the LPUE from only the first 5-6 months.
    - STATUS: Spatial patterns in Pandalus distribution of the different age and sex classes has not been addressed and with the current sampling regime it is unlikely this can be addressed in the near future. However, spatial distribution of LPUE will be addressed at the proposed benchmark for 2018.
- Reference points from the LBM were considered provisional and alternative reference points based on stock-recruit data should be investigated using standard ICES methodology.
    - STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.
- Age determination and validation using sections of eye-stalks should continue and results used to refine the life-history knowledge of the stock including age-length relationship and natural mortality assumption.
    - STATUS: This work is ongoing.

Recommendations from the 2010-2014 meetings

- *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: This will be assessed in the proposed in-year assessment in February 2017.

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

STATUS: *This is not applicable as a new assessment model was adopted at the 2016 benchmark.*

- *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.

Research Recommendations from the 2016 meetings

- NIPAG **recommends** an interim benchmark in conjunction with an in-year assessment in early 2017 to investigate the sensitivity of the assessment, reference points and the catch options to the setting of M and B_{lim}. Also to investigate possibilities for producing a new standardized survey index.
- NIPAG **recommends** a full benchmark for this stock including a data compilation workshop in the near future and no later than 2019.

6. Northern shrimp (*Pandalus borealis*)in the Barents Sea (ICES Sub-Areas I and II)

Research Recommendations

- The assessment procedure used has been in place since 2006 and it is recommended to be considered for a benchmark workshop in near future, no later than 2019.
- The fishery has expanded since 2014 and catches by countries other than Norway have increased to account for about 50% of the total. NIPAG therefore recommends that available data (logbook data and catch samples) from the participating nations be made available to NIPAG.

APPENDIX V. BENCHMARK INFORMATION

Benchmark information per stock

To be filled in by the stock coordinator (send to Scott Large scott.large@ices.dk)

Stock	**Pand-sknd**	
Stock coordinator	Name: Mats Ulmestrand	Email: mats.ulmestrand@slu.se
Stock assessor	Name: Massimiliano Cardinale, Mikaela Bergenius	Email: massimiliano.cardinale@slu.se, mikaela.bergenius@slu.se
Data contact	Name: Mats Ulmestrand, Ole Eigaard, Guldborg Søvik	Email: mats.ulmestrand@slu.se, ore@aqua.dtu.dk, Guldborg.soevik@imr.no

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
(New) data to be Considered and/or quantified[2]				

[2] Include all issues that you think may be relevant, even if you do not have the specific expertise at hand.If need be, the Secretariat will facilitate finding the necessary expertise to fill in the topic. There may be items in this list that result in 'action points for future work' rather than being implemented in the assessment in one benchmark.

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
Tuning series	Standardisation of survey time series	The existing survey time series should be standardised according to depth, trawling speed, bottom temperature, varying coverage, gear, time of day, season	New survey index from StoX	Standardisation method/model developed at DTU Aqua (Anders Nielsen)
Discards				
Biological Parameters	The natural mortality (M) assumptions of the stock assessment model needs to be better justified/explored	Sensitivity analyses of assessment model to different M assumptions: 1. A range of constant Ms 2. Time-varying M based on e.g. predator abundance or temperature change. 3. Age-varying M	Assessment model data are available. 1. Constant M values are theoretical and can be substantiated from literature 2. Predator abundance data are available from shrimp survey. Temperature data can be obtained from ICES 3. Age-varying M assumptions are theoretical but can be substantiated from literature	No
Assessment method				
Biological Reference Points				

Benchmark information per stock

To be filled in by the stock coordinator (send to Scott Large scott.large@ices.dk)

Stock	**Pand-Barn**	
Stock coordinator	Name: Carsten Hvingel	Email: carsten.hvingel@imr.no
Stock assessor	Name: Carsten Hvingel	Email: carsten.hvingel@imr.no
Data contact	Name: Trude Thangstad	Email:trude.thangstad@imr.no

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
(New) data to be Considered and/or quantified[3]	Recruitment index	Collate available data on length composition of survey and commercial catches.	IMR, Norway, Pinro Russia	Trude Thangstad, Denis Zakharov, NIPAG people
	Ecosystem drivers	Explore oceanographic data		

[3] Include all issues that you think may be relevant, even if you do not have the specific expertise at hand.If need be, the Secretariat will facilitate finding the necessary expertise to fill in the topic. There may be items in this list that result in 'action points for future work' rather than being implemented in the assessment in one benchmark.

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
Tuning series	Standardised survey series Technical creep in the fishery affecting the use of the std. CPUE series as a stock indicator + potential inclusion of data from “other” fleets than Norway.	Explore alternative methods for calculation of survey estimates, e.g. handling of incomplete coverage of the survey area Review the method of standardization of catch-per-unit-effort, evaluate new data	IMR, Norway, Pinro Russia IMR, Norway, Pinro Russia, EU countries (Portugal, Spain, UK, Lithuania, Estonia), Iceland, Faroes, and Greenland.	Carsten Hvingel, Denis Zakharov Country representatives
Discards				
Biological Parameters				
Assessment method	Does the fact that the stock has been above Bmsy throughout the history of the fishery have implications for the current model’s suitability? Predation effects be further explored for potential inclusion in the assessment model explore the possible inclusion of an explicit recruitment term in the assessment model Explore alternative assessment models e.g. length/stage-based models			NIPAG representatives and some modelling people
Biological Reference Points				

Benchmark information per stock

To be filled in by the stock coordinator (send to Scott Large scott.large@ices.dk)

Stock	**Pand-sknd**	
Stock coordinator	Name: Mats Ulmestrand	Email: mats.ulmestrand@slu.se
Stock assessor	Name: Massimiliano Cardinale, Mikaela Bergenius	Email: massimiliano.cardinale@slu.se, mikaela.bergenius@slu.se
Data contact	Name: Mats Ulmestrand, Ole Eigaard, Guldborg Søvik	Email: mats.ulmestrand@slu.se, ore@aqua.dtu.dk, Guldborg.soevik@imr.no

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
(New) data to be Considered and/or quantified[4]	Calculation of Norwegian discards based on data from the coastal reference fleet (from 2016)		Data available from 2016	no
	Survey design of the catch sampling programme in the three countries	Evaluate present design and possible design new design, document and standardise		Statistical expertise (Jon Helge Vølstad, IMR)

[4] Include all issues that you think may be relevant, even if you do not have the specific expertise at hand.If need be, the Secretariat will facilitate finding the necessary expertise to fill in the topic. There may be items in this list that result in 'action points for future work' rather than being implemented in the assessment in one benchmark.

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
Tuning series	Evaluate present standardisation of lpue times series – standardise across countries			
Discards				
Biological Parameters	The natural mortality (M) assumptions of the stock assessment model needs to be better justified/explored	Sensitivity analyses of assessment model to different M assumptions: 4. A range of constant Ms 5. Time-varying M based on e.g. predator abundance or temperature change. 6. Age-varying M	Assessment model data are available. 4. Constant M values are theoretical and can be substantiated from literature 5. Predator abundance data are available from shrimp survey. Temperature data can be obtained from ICES 6. Age-varying M assumptions are theoretical but can be substantiated from literature	No

Issue	**Problem/Aim**	**Work needed / possible direction of solution**	**Data needed to be able to do this: are these available / where should these come from?**	**External expertise needed at benchmark type of expertise / proposed names**
Assessment method	Catches included as three fleets in SS3-model (presently included as one) Input data by sex (survey and catches) (presently no data by sex) Inclusion of fourth fleet in the SS3 model with non-selective gear		Data already available Input data available for last years at least, but catches by sex have to be recalculated. Survey data by sex will be available with new Stox-index Data may be available from the Norwegian coastal reference fleet	
Biological Reference Points	Sensitivity of assessment results to the choice of Blim	Sensitivity analysis	Different Blim assumptions will be tested out. 1. Blim smaller than Bloss (at present Blim is set equal to Bloss) 2. Blim defined as a proportion of the greatest observed SSB	No

ANNEX 5. TECHNICAL MINUTES OF THE UNIVERSITY OF MAINE REVIEW GROUP FOR THE JOINT NAFO/ICES *PANDALUS* ASSESSMENT WORKING GROUP ON THE THREE *PANDALUS* STOCKS IN SKAGERRAK AND NORWEGIAN DEEP, BARENTS SEA, AND FLADEN GROUND.

September 27 - October 4, 2016 Chen Lab, University of Maine, USA

University of Maine Review Group:

Dr. Jie Cao (Chair), Jocelyn Runnebaum (PhD candidate, Co-Chair), Kisei Tanaka (PhD candidate, Co-Chair), Robert Boenish (PhD student), Bai Li (PhD student), Mackenzie Mazur (PhD student), Ashley Charleson (Dual Master s' degrees student), Dongyan Han (PhD candidate), Zengguang Li (PhD student), Mattie Rodrigue (Dual Masters' degrees student), Max Ritchie (Master student), Kevin Staples (Dual Master s' degrees student), Katherine Thompson (PhD student), Michael Torre (PhD student), Dr. Jintao Wang, Luoliang Xu (PhD student)

Faculty Advisor:

Dr. Yong Chen (Professor, School of Marine Sciences, University of Maine)

ICES Secretariat:

Dr. Anne Cooper, Dr. Rui Catarino

REVIEW PROCESS

The University of Maine Review Group (RG) received the draft *Pandalus* assessment report on September 27, 2016, and distributed the draft report to each reviewer. The RG met on September 30, 2016 to discuss the assessment report and compile the final review report. Under Dr. Yong Chen's supervision, the RG determined the final decision of accepting or rejecting each *Pandalus* assessment, discussed remaining issues, and finalized the review report on October 3, 2016. The RG would like to thank Dr. Rui Catarino for providing logistical assistance during this review process. Table 1 lists the three *Pandalus* stocks reviewed by the University of Maine RG along with the RG recommendation.

Table 1: List of stocks reviewed by the University of Maine RG

Stock Name	**ICES Divisions**	**Assessment Model**	**RG Decision**	**Page Number**
Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep	IIIa and IVa east	Stock Synthesis (SS3)	Accept with caveats	5
Northern shrimp (*Pandalus borealis*) in the Barents Sea	Sub-Areas I and II	Bayesian Surplus production model	Accept with caveats	8
Northern shrimp *(Pandalus borealis)* in the Fladen Ground	Iva	Trend in landings	N/A	11

1. Overall Comments

The RG followed the ICES guidelines for the review process of three *Pandalus* stocks. The RG focused on whether the assessment, calculation of biological reference points (BRPs) and forecast were carried out in accordance with appropriate stock assessment methods.

Furthermore, the RG examined the data quantity and quality, as well as the uncertainty associated with assessments and calculated BRPs for the three stocks to ensure that management measures are based upon the best available science.

The RG recognized spatiotemporal discrepancies among multiple surveys as they were likely sampling different portions of the stock, given variation in spatial and temporal coverage, and variability in abundance indices might have reflected more seasonal variation than annual variability. In this case, the RG would recommend a model-based approach to develop a composite standardized abundance index by integrating all of the available survey data. The RG believes that the model-based approach would produce abundance indices that are more representative of interannual changes in stock abundance and allow better inferences to be made using limited historical data and expensive ongoing surveys (Thorson et al., 2014).

The RG found that there were different analytical assessments used for the same species in different stocks (e.g. Stock Synthesis and Bayesian Surplus Production Model). Given the fact that these stocks are likely to have similar biological and fishery characteristics, the RG recommends using similar assessment methods where model assumptions are consistent and model results can be compared.

The RG recommends the use of time blocks to consider potential changes in selectivity and catchability over time. In this way, models can more accurately account for changes in vessels and gear or describe the context of commercial landings.

The RG appreciates that basic diagnostic plots (e.g., retrospective analysis) were provided for each stock. The RG believes that model diagnostic plots should be a part of default plots used in assessment. Also, the RG believes that Mohn's rho should be provided with every retrospective analysis for further evaluation of retrospective analyses (i.e., quantify the magnitude of retrospective pattern) and that retrospective analyses should be conducted for F, SSB, and R where applicable.

The RG believes that more attention should be paid to evaluating the degree of uncertainty in assessment results and the management advice derived from a model configuration. The RG suggests structural sensitivity analyses as a standard protocol in a stock assessment with uncertainty in model configuration/parameterization and data quality being evaluated (e.g., alternative assumptions regarding life history parameters, fishery characteristics, reliability of data sources, and model configurations).

Little to no justification was given for the choice of natural mortality. While natural mortality is one of the most difficult parameters to estimate, the RG believes that in each report, adequate biological and ecological context should be given for selection of natural mortality. If natural mortality is impossible to estimate, then rates used for similar species in the same spatial area or for the same species in different areas should be employed and compared. Finally, the RG recommends adding a brief list of assessment model assumptions. Inclusion of such a list would make it easier for both WG and RG to evaluate the appropriateness of the model and to develop scenarios for sensitivity analysis.

It would be helpful if the assessment reports conformed to a standardized format to facilitate review. Different assessment methods will require different figures and tables, but the RG recommends using the general format suggested by ICES for each section.

2. Stock Specific Comments

Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep

The RG suggests the assessment for *Pandalus* stock in the Skagerrak and Norwegian Deep to be accepted as long as the following shortcomings are addressed in future assessments. First, the RG is highly concerned with the quality of biological reference points (BRPs) provided in this report. It was assumed that the BRPs from

2016 benchmark assessment were used in this assessment as the RG did not find any updates on BRPs. While the RG recognizes the large uncertainty with 2016 input data, the RG believes that a comparison between the 2016 benchmark BRPs and updated BRPs should be provided. Second, with regard to the quality of input survey data, the RG finds the methods used to account for missing strata may result in high uncertainty. The RG is also concerned with the quality of size-composition data with no correction for years which have missing strata. Third, time-invariant catchability and selectivity were assumed in the assessment model despite the reported changes in capacity and size specifications of commercial vessels and survey gears. The RG finds these assumptions problematic and would like to see this addressed further. Finally, the RG believes that the diagnostic plot of the assessment suggested a moderate to strong retrospective pattern. However, without the Mohn's Rho criterion, the RG was unable to determine the magnitude of this potential retrospective pattern.

Northern shrimp (Pandalus borealis) in the Barents Sea

The RG suggests the assessment for *Pandalus* stock in the Barents Sea to be accepted as long as a transition towards a better modeling framework is considered in the next benchmark assessment. The RG found that the stock assessments might have underutilized available data. Extensive data were seemingly available but were not incorporated into the assessment model (e.g., recruitment and bycatch estimates). Most notably, size composition data seemed to be available but were not used in this assessment. The RG recommends moving to a length-based assessment to make use of all available data. The WG noted that the spatial distribution of shrimp biomass appears to have shifted, with warming temperature potentially affecting shrimp distribution. The RG recommends moving towards more flexible assessment modeling framework, such as Stock Synthesis (SS3), to incorporate environmental variables (e.g., water temperature) and to consider potential shifts in the spatial distribution of the stock.

Northern shrimp (*Pandalus borealis*) in the Fladen Ground

The report was not provided with enough materials for the RG to review this stock.

Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep

Assessment Type:

- Update

Assessment:

- Accepted with caveats.

Forecast:

- Short term – Landings: 12 842t (2016); SSB: 2 755t (2017); TAC: 2 840t (2017)
- Long term – N/A

Assessment Method:

- Length-based Stock Synthesis (SS3) that uses catches in assessment and forecast. The length-based SS3 replaced surplus production model at the January 2016 benchmark assessment.

Consistency:

- The reference points have been re-calculated since the 2015 assessment, which led to a revised stock status.
- SS3 assessment method replaced a surplus production model that had been used since 2013.
- The same survey indices were used for current and previous assessments.

Stock Status:

- The stock size has been below $B_{trigger}$ since 2011 and above B_{lim} since 2015.
- Fishing mortality has been above F_{MSY} since 2011.
- Recruitment has remained low since 2008.
- There has been an SSB decline of 14 000t from 2008 to 2014, current levels estimated near time series minimum.
- SSB is currently above B_{lim} (6 300t) and below $B_{trigger}$ (9 900t).
- F in this fishery has increased sharply since 2010, following a period of stable effort.
- During this recent period, effort had been near historical highs, exceeding the F_{msy} value of 0.62.
- Recruitment for this fishery has been low since 2008, with the exception of 2013, corresponding with lower SSB estimates.
- 2016 estimates put SSB below Btrigger, enacting ICES MSY framework measures to reduce F to 0.3, allowing for SSB to rebound to B_{lim}.

Management Plan:

There is no management plan for northern shrimp in this area.

General Comments

The stock assessment was benchmarked January, 2016. It was agreed that the Stock Synthesis 3 would replace the former surplus production model. The RG greatly appreciates this transition towards a more flexible and versatile model framework. However, the RG thinks this update assessment suffers from a number of drawbacks regarding survey index, model configuration, model diagnostic and biological reference points (BRPs). Details are listed below:

I. New BRPs were developed at the benchmark, but the RG did not see updates on them in this assessment. Therefore, the RG assumes that the benchmark BRPs were used in this assessment to determine the stock status. This might be problematic because of incomparability. The RG understands the concern about the uncertainty in 2016 data given that only one half-year's data are available, but it would be helpful if at least a comparison between the benchmark and update BRPs were provided.

II. The RG is concerned about the quality of the input survey data. Although the index of total biomass for the years when the survey had missing strata has been corrected, the RG thinks that the method used for correction may lead to large uncertainty. The RG suggests that alternative weights for these data points should be explored. Furthermore, the size composition data have not been corrected for those years, which may lead to biased composition data, particularly since shrimp have size- dependent habitat preferences. The RG suggests that model-based indices could be developed. Spatio-temporal models could be good candidate models for predicting un-sampled locations or strata (Thorson et al., 2014).

III. As the report describes, commercial and survey vessels and gears all experienced significant changes over time. The RG is surprised that time-invariant catchability and selectivity were specified in the model. The RG suggests time blocks be set up for these model parameters.

IV. Discard estimates are available after 2009 and were used in the assessment model. The RG is concerned that discards before 2009 were not accounted for in the model. The RG would like to see an alternative run with the whole time series of discard estimates used. Also, sensitivity runs on the uncertainty of Norwegian fleets discard could be informative.

V. Given that predators may have a large effect on the shrimp population as described in detail in the report, the RG thinks that time-varying natural mortality would be more realistic and that such a model setting should be explored.

VI. Regarding the retrospective pattern, the RG did not see Mohn's rho reported in the document. Based on the visual inspection, the RG thinks this assessment suffers from a moderate to strong retrospective pattern. The RG wonders whether specifying time- varying natural mortality, catchability and selectivity in the model would reduce the retrospective pattern. If not, the RG suggests exploring alternative length-structured assessment models. Recently, a length-structured assessment model dedicated to *Pandalus* stock has been developed (Cao et al., 2016).

Technical Comments:

- Fig. 5.1. Remove the outline.
- Fig. 5.2. Remove the orizontal line in the figure, and add a Y axis
- Fig. 5.7. Axes legibility would be greatly improved with larger axes as well as larger axes labels and numbers.
- Fig. 5.7. Fix the caption statement: "The horizontal lines are xxxxxx derived from yyyyy."
- Table 5.3. The table should be rotated so it can fit in a single page.
- pg 45: Please correct "lengthbased" to "length-based"
- Spelling/grammar error in section (e)

References:

Cao, J., Chen, Y. and Richards, R.A., 2016. Improving assessment of Pandalus stocks using a seasonal, size-structured assessment model with environmental variables: Part I: Model description and application. *Canadian Journal of Fisheries and Aquatic Sciences*, (ja).

Cao, J., Chen, Y. and Richards, R.A., 2016. Improving assessment of Pandalus stocks using a seasonal, size-structured assessment model with environmental variables: Part II: Model evaluation and simulation. *Canadian Journal of Fisheries and Aquatic Sciences*, (ja).

Thorson, J.T., Shelton, A.O., Ward, E.J. and Skaug, H.J., 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. *ICES Journal of Marine Science: Journal du Conseil*, p.fsu243.

Northern shrimp (*Pandalus borealis*) in the Barents Sea

Assessment Type:

- Update
- Benchmarked in 2006

Assessment:

- Accept with caveats

Forecast:

- Short term – Landings: 35 000t (2016); TAC: 70 000t (2017)
- Long term – N/A

Assessment Method:

- Bayesian State-Space Production Model
- Input data - one time series of shrimp catch, a standardized series of annual fishery catch rates, and three scaled trawl survey biomass indices

Consistency:

- Assessment methods and data consistent since benchmarking in 2006.

Stock Status:

- Stock biomass has been estimated to be above B_{msy} for the duration of the fishery.
- F has been declared likely to have been below F_{msy} throughout the history of the fishery.
- Shrimp discards cannot be quantified but are considered to be small.

Management Plan:

- ICES MSY framework adopted in 2009.
- If B_{lim} threshold is crossed, then F must be reduced so that the stock biomass recovers to $B_{trigger}$ in the next fishing year.

General Comments:

The RG encourages a benchmark assessment to be undertaken as soon as possible. The WG noted a potential shift in distribution of the population, changes in temperature, and the current model not predicting year to year changes very well. This leads the RG to believe that a length-based assessment model that can incorporate temperature needs to be explored as soon as possible. The RG is also concerned that there has not been a benchmark assessment in ten years despite these noted changes in distribution of the population.

The RG is concerned about unaccounted uncertainty in the risk assessment that states that there "*is less than a 5% chance that the fishery will be fished beyond F_{lim}*" despite noted changes in temperature, shifts in the population, and the model predicting interannual changes well. The RG recommends sensitivity analyses for varying or constant K (consider different time blocks) to better understand environmental changes and a shifting distribution.

The RG appreciates that a retrospective analysis was provided for this stock. The RG found that the visualized retrospective pattern showed an underestimation in the early years and an overestimation during the later years. The RG suggests calculating Mohn's rho (Deroba, 2014) to help interpret implications. The RG also recommends a retrospective analysis of fishing mortality and recruitment along with biomass.

The WG acknowledged that retrospective patterns led to overestimation in the final years (2010-2016). The RG recommends considering a correction to be made in the determination of stock status.

Stratum 3 was not covered by the survey in 2014. In 2014, the biomass for stratum 3 was estimated by calculating the average ratio of biomass density in stratum 3 to biomass density in the remaining survey areas for the 2009-2013 period and applying this average to the density of the 2014 surveyed area. The RG requests a justification for this approach. The RG also recommends exploring a generalized additive model to standardize the indices. Alternatively, the model sensitivity to the 2014 stratum index could be examined by running the model with and without the 2014 stratum 3 index.

The WG "*scaled the survey indices to absolute biomass by individual catchability parameters*". The RG would like more clarification on how survey indices were scaled. Given the strong variation in survey 2 indices and the mismatch between observed and predicted indices, the RG recommends creating a model-based abundance index using a spatiotemporal model (Thorson et al., 2014).

The equation describing the state transition from time t to t+1 was parameterized in terms of MSY rather than r. The RG recommends further explanation of this approach. For example, listing the advantages and disadvantages of the parameterization. The RG would like to see more justification on methodology and model specification.

The risk associated with different catch levels was explored. Given the posterior distribution of model parameters, the RG suggests a stochastic projection of expected exploitable biomass of shrimp under different levels of fishing mortality.

The report should be explicit if year was included in the standardization of the logbook CPUE. The RG would also like clarification on how an area was defined for CPUE standardization.

The RG would like more information regarding the assumption of *"no discarding problems"* in this stock. Discarding of small, unmarketable shrimp is a problem in the Skagerrak and Norwegian Deep stocks. Does this problem not exist for this fishery? The RG requests validation of this assumption beyond the fishery not being managed by TAC. For example, are observer data that quantify bycatch available?

The RG would like to see more information regarding the assumption of log-normal distribution of observation error. Model specifications should be clarified with relevant citations.

The RG recommends Table 6.2 be changed to a probability density function figure and that prior distributions be considered as well. The mode should also be included if used as a parameter. The RG would also like justification on the choice of the mode as a parameter.

Technical Comments

- The RG recommends that the figures be listed in the same order as the figure captions.
- Fig. 6.1. The mean density plot should be accommodated by changes in density plot.
- Fig. 6.3., 6.5., 6.12. Please make axis & legend text larger.
- Fig. 6.3. A description of the sorting grid would be helpful.
- Fig. 6.6. Environmental factors should be considered if possible.
- Fig. 6.7. What does the horizontal line (h = 0.9) mean? Why not h = 1?
- Fig. 6.8. Please add standard error bars for surveys 1 and 2.
- Fig. 6.8. Add error bars for surveys 1 and 2.
- Fig. 6.9. Add a legend.
- Fig. 6.10. Add labels and a title.
- Fig. 6.11. Need to expand the y-axis range for relative fishing mortality to show 90% of the distribution. The y labels could be explained in the caption. The term "biomass" may need to be changed to "relative biomass" and "fishing mortality" to "relative fishing mortality".
- In the recruitment indices paragraph, Fig. 6.9 is mistakenly cited instead of Fig. 6.10.
- Fig. 6.11. 90% distribution increased with increases in biomass & fishing mortality values. Possible issues with heteroscedasticity?
- Fig. 6.11. The RG recommends changing this figure to a Kobe plot.
- There are two figures labeled "Fig. 6.12."
- The RG would like clarification on TAC in Table 6.1. Is TAC established?
- Given that predation may have a large effect on the shrimp population, the RG recommends considering the multispecies Gadget model.
- Unassociated annex in section (g)
- pg 58: Please reformat Fig. 6.8 so that the figure does not block the text.
- pg 60: Please include the equation for stock dynamics.
- pg 61: Please include the equation for standardized CPUE from the surveys.

References:

Deroba, J. J. (2014). Evaluating the consequences of adjusting fish stock assessment estimates of biomass for retrospective patterns using Mohn's Rho. *North American Journal of Fisheries Management*, 34(2), 380-390.

Northern Shrimp (*Pandalus borealis*) in Fladen Ground

Assessment Type

- N/A

Assessment:

- N/A

Forecast:

- Short term – N/A
- Long term – N/A

Assessment method:

- N/A

Consistency:

- No assessment/no landings since 2006

Stock Status:

- Unknown

Management Plan:

- N/A

General Comments

The report did not provide enough material for the RG to review this stock; however, the RG wonders whether this stock could be incorporated into the Skagerrak and Norwegian Deep assessment.

Technical Comments

- The RG recommends using color in Figure 7.1; it is difficult to read.
- Capitalize words in the header for subsection C.
- Fig. 7.1. The outline should be removed; title of each axis should be added ("ton" is a unit, not an axis title).

ANNEX 6: UPDATE ASSESSMENT OF NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN DIVISION 4.A EAST AND SUBDIVISION 20 (NORTHERN NORTH SEA IN THE NORWEGIAN DEEP AND SKAGERRAK)

This annex was added to the NIPAG 2016 report in March 2017.

Background documentation is found in SCR Doc. 08/75; 13/68, 74; 14/66; 16/53, 55, 56, 57 and in the ICES Stock Annex.

6a. Introduction

The shrimp in the northern part of ICES Subdivision 27.3a.20 (Skagerrak) and the eastern part of Division 27.4a (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 5000 t and in 1981 they exceeded 10 000 t. Since 1992, the shrimp fishery has been regulated by a TAC (Figure 6.1, Table 6.1). 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 59%, Denmark 27%, and Sweden 14% between 2011 and 2016. 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. Thereafter, a new length-based assessment model was agreed on in a benchmark in January 2016 (ICES, 2016a).

The shrimp fishery is also regulated by a minimum 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**)**. In 2009, an EU ban on highgrading was implemented and since 2016, the EU landing obligation applies for *Pandalus* in 27.3a and 27.4a.

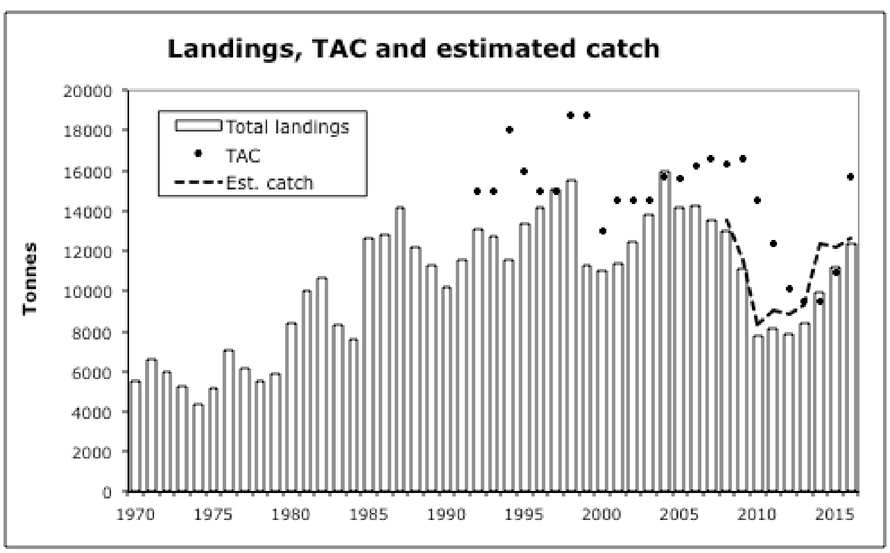


Fig. 6.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008–2016, and Norwegian and Danish discards for 2009–2016.

Table 6.1. Northern shrimp in Skagerrak and Norwegian deep: TACs, landings, and estimated discards and catches ('000 t).

YEAR	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016[1]
Recommended TAC	13500	14000	15000	15000	13000	8800	*	5800	5400	9800	11869
Agreed TAC	16200	16600	16300	16600	14558	12380	10115	9500	9500	10900	15696
Denmark landings	3111	2422	2274	2224	1301	1601	1454	2026	2432	2709	1997
Norway landings	8669	8688	8261	6362	4673	4800	4852	5179	6123	6808	8305
Sweden landings	2488	2445	2479	2483	1781	1768	1521	1191	1397	1644	2095
Total landings	14268	13553	13013	11071	7755	8168	7771	8379	9953	11161	12397
Est. Swedish discards			540	337	386	504	671	265	572	325	87
Est. Norw. Discards				94	133	247	292	459	1289	476	162
Est. Danish discards				36	53	123	88	185	526	204	35
Total catch	14268	13552	13554	11539	8327	9044	8822	9288	12341	12166	12681

[1]Recommended and agreed TACs from October 2015 were changed in March 2016 following the benchmark assessment.

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 seven in 2016. The efficiency of the fleet has increased due to the introduction of twin trawls and increased trawl size (SCR Doc. 16/56).

In Norway the number of vessels participating in the shrimp fishery has decreased from 423 in 1995 to 177 in 2016. Twin trawls were introduced around 2002, and in 2011–2016 were used by more than half of the Norwegian trawlers longer than 15 meters (SCR Doc. 16/57).

The Swedish specialized shrimp fleet (landings of shrimp larger than 10 t per year) has decreased from more than 60 vessels in 1995–1997 to below 40 in 2011–2016. There has not been any major change in single trawl size or design, but during the last ten years the landings of the twin trawlers have increased from 7 to over 50% (recent six years) of the total Swedish *Pandalus* landings (SCR Doc. 16/56).

Landings and discards. Total landings have varied between 7500 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 8800 t, but has since increased to more than 12 600 t in 2016 (Table 6.1 and Figure 6.1).

Shrimps may be discarded for one of two reasons: 1) shrimp <15 mm CL are not marketable and 2) to replace medium-sized, lower-value shrimps with larger and more profitable ones ("highgrading"). However, since 2016, shrimp <15 mm CL are marketable, but fetch a lower price than medium-sized shrimp. Highgrading has been illegal since 2009 in EU waters and since 2016, *Pandalus borealis* is included in the list of EU landing obligation species. The Swedish fishery has often been constrained by the national quota, which may have resulted in highgrading. Based on on-board sampling by observers, discards in the Swedish fisheries were estimated to be between 12 and 31% of total catch for 2008–2015, and Danish discards were estimated to be between 2 and 18% for 2009–2015. In 2016, due to the landing obligation, discarding has decreased to 4 and 2% in Sweden and Denmark respectively. Discarding is illegal in Norwegian waters, but there are no observer data. From 2009 onwards, Norwegian discards in Skagerrak have been estimated 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. 16/57). In the absence of observer data, Norwegian discards from the Norwegian Deep are assumed to be constituted mainly of shrimp <15 mm CL and thus discards from this area are estimated as the weight of catches of shrimp <15 mm CL as estimated 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 6.2). 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 > approximately 20 cm length from the catch. Landings delivered by vessels using grids comprise 95–99% of shrimp (Table 6.2). 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 6.2. Northern shrimp in Skagerrak and Norwegian Deep: Bycatch landings by the *Pandalus* fishery in 2016. Combined data from Danish and Swedish logbooks and Norwegian sale slips (t).

	SD IIIA, GRID		SD IIIA, GRID+FISH TUNNEL		SD IVA EAST, GRID	
SPECIES:	Landings (t)	% of total landings	Landings (t)	% of total landings	Landings (t)	% of total landings
Pandalus	788.0	98.6	8262.9	82.1	2409.8	76.2
Norway lobster	5.6	0.7	25.0	0.2	4.0	0.1
Anglerfish	0.1	0.0	83.1	0.8	55.0	1.7
Whiting	0.0	0.0	6.5	0.1	1.5	0.0
Haddock	0.1	0.0	46.9	0.5	18.9	0.6
Hake	0.1	0.0	26.8	0.3	47.2	1.5
Ling	0.0	0.0	60.9	0.6	31.2	1.0
Saithe	0.5	0.1	588.2	5.8	220.4	7.0
Witch flounder	0.6	0.1	85.3	0.8	2.3	0.1
Norway pout	0.0	0.0	30.6	0.3	13.4	0.4
Cod	1.7	0.2	623.6	6.2	116.3	3.7
Other marketable fish	2.3	0.3	226.4	2.2	240.8	7.6

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 are available and the impact on stocks is difficult to assess.

Catches of demersal fish species 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 6.3 and Figure 6.2).

The catches of demersal fish in the Campelen-trawl are also used to calculate an index of potential shrimp predators. The large interannual variation in this predator biomass index is mainly due to variations in the indices of saithe and roundnose grenadier, which in some years are important components. The contribution of these species to the biomass index depends on which survey stations are trawled, as the largest densities of saithe are found in shallow water and roundnose grenadier is found in deep water. The peak in 2013 was due to a high abundance of blue whiting. An index of potential shrimp predators without these three species varied without a trend from 2007 to 2015, but increased in 2017, indicating higher biomass of potential predators in the last year (Figure 6.2; the 2016 survey data were omitted, see below). This is in agreement with increasing trends in stock size observed in recent stock assessments of demersal fish species in the North Sea and Skagerrak (ICES, 2016b; ICES, 2016c).

Table 6.3. 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 2006–2017. The 2016 survey data have been omitted (see text for details).

SPECIES		BIOMASS INDEX											
English	Latin	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2017	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	31.18	
Saithe	*Pollachius virens*	7.33	39.75	208.32	53.89	18.53	7.52	5.66	112.80	14.13	8.56	9.71	
Cod	*Gadus morhua*	0.51	1.28	0.78	2.01	1.79	1.66	1.26	1.69	2.92	2.37	2.00	
Roundnosed grenadier	*Coryphaenoides rupestris*	3.22	6.85	19.02	19.03	10.05	4.99	4.43	1.97	2.90	1.46	1.41	
Rabbit fish	*Chimaera monstrosa*	2.24	2.15	3.41	3.26	3.51	2.73	2.22	3.05	3.90	2.19	5.99	
Haddock	*Melanogrammus aeglefinus*	0.97	4.21	1.85	3.18	3.46	5.82	5.75	5.18	2.15	2.60	1.86	
Redfish	*Scorpaenidae*	0.18	0.40	0.26	0.43	0.80	1.02	0.37	0.47	0.48	0.20	0.52	
Velvet belly	*Etmopterus spinax*	1.31	2.58	1.95	2.42	2.52	1.47	1.59	2.67	1.91	2.51	4.19	
Skates, rays	Rajidae	0.41	0.95	0.64	0.17	0.60	0.88	0.98	1.00	2.25	1.69	1.64	
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	0.94	
Hake	*Merluccius merluccius*	0.98	0.78	0.64	2.56	1.60	0.56	0.52	1.06	0.69	0.59	1.24	
Angler	*Lophius piscatorius*	0.15	0.91	0.87	1.25	1.70	0.92	0.17	0.65	0.75	0.58	1.13	
Witch	*Glyptocephalus cynoglossus*	0.24	0.74	0.54	0.16	0.13	0.24	0.29	0.27	0.35	1.38	0.47	
Dogfish	*Squalus acanthias*	0.31	0.19	0.28	0.14	0.11	0.21	0.60	1.02	1.00	0.36	0.42	
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	0.26	
Whiting	*Merlangius merlangus*	0.35	1.01	1.35	3.02	2.42	3.07	1.64	2.02	3.38	1.59	2.60	
Blue Ling	*Molva dypterygia*	0	0	0	0	0	0	0	0.01	0.01	0.03	0.01	
Ling	*Molva molva*	0.04	0.11	0.34	0.79	0.64	0.24	0.17	0.22	0.32	0.63	0.90	
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	0.04	
Cusk	*Brosme brosme*	0.20	0	0.02	0.05	0.13	0.29	0.04	0.10	0.05	0.19	0	
Halibut	*Hippoglossus hippoglossus*	0.08	0.07	3.88	0.09	0.20	0.05	0.19	0	0	0.10	0.16	
Pollack	*Pollachius pollachius*	0.06	0.25	0.03	0.13	0.12	0.15	0.07	0.24	0.65	0.23	0.10	
Greater forkbeard	*Phycis blennoides*	0	0	0	0.01	0.04	0.02	0.05	0.06	0.12	0.05	0.18	
Total		18.99	63.19	244.81	94.26	49.23	33.09	30.04	164.23	41.18	34.48	66.95	72.29
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	55.83	24.89

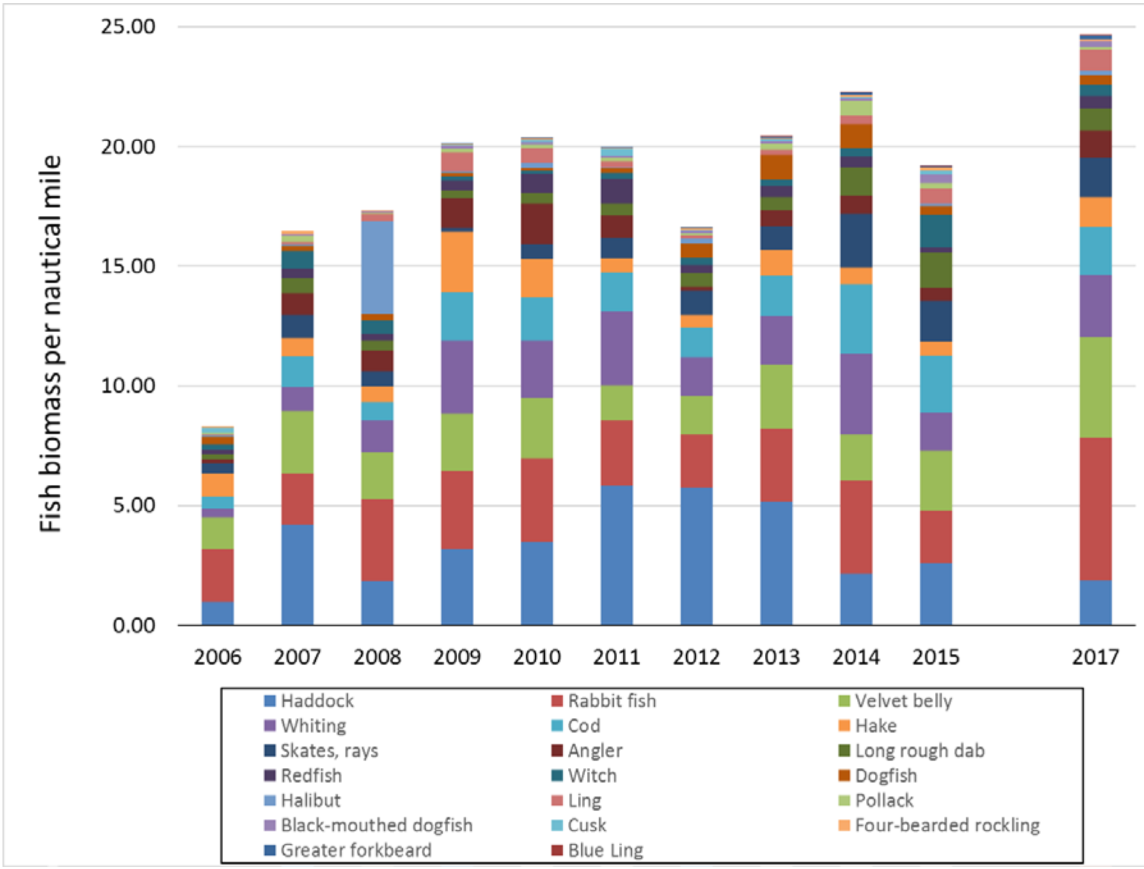


Fig. 6.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in kg per towed nautical mile) from the Norwegian shrimp survey in 2006–2017 excluding saithe, roundnose grenadier and blue whiting. The 2016 survey data have been omitted (see text for details).

6b. Input data

6b.1. Fishery data

Danish, Swedish and Norwegian catch and effort data from logbooks have been analysed and standardized (SCR Doc. 08/75; 16/56, 57).

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. The estimate for 2016 is slightly lower than for 2015 (Fig. 6.3).

Time-series of standardized effort indices from Norway and Denmark have been fluctuating without any clear trend since the mid-1990s while the Swedish standardized effort has decreased (Fig. 6.4).

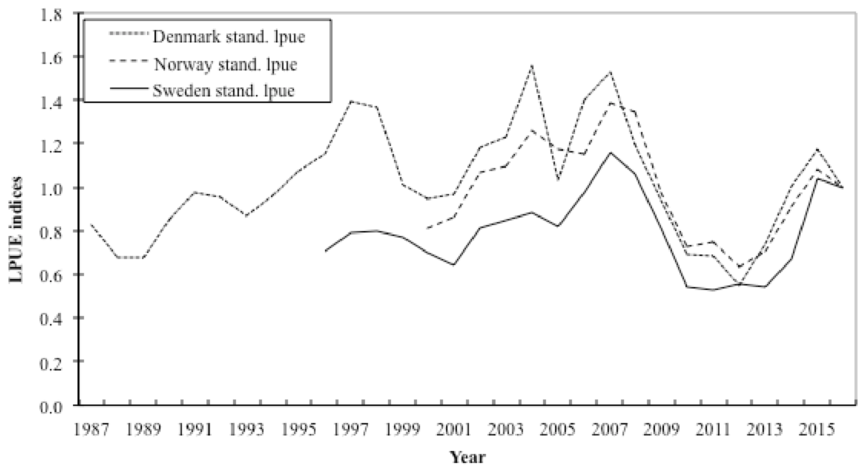


Fig. 6.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardized lpue until 2016. Each series is standardized to its final year.

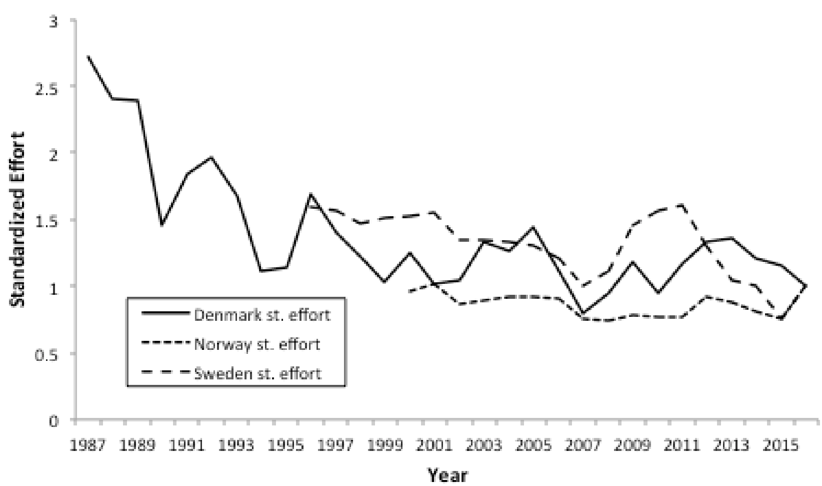


Fig. 6.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardized effort. Each series is standardized to its final year.

6b.2. Sampling of catches

Length frequencies of the catches from 1985 to 2016 (SCR Doc. 16/56, 57) have been obtained by sampling. The samples also provide information on sex distribution and maturity. Numbers-at-length are input data to the newly implemented length-based assessment model for this stock (see below).

6b.3. Survey data

The Norwegian shrimp survey went through large changes in vessel, gear and timing in 2003–2006, resulting in four indices (SCR Doc. 16/53): 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. 6.5). The index of total biomass for these years has been standardized 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 standardized, which means that the length-based model (see below) uses unstandardized survey data.

In 2016, there were technical problems with the survey trawl (unequal wire lengths of the trawl gear) and this year's data have therefore been omitted.

The biomass peaked in 2007, then declined until 2012. The index thereafter increased until 2015 but decreased again in 2017 to the 2014 level (Fig. 6.5). However, the survey time-series has not been standardised for variability of factors such as swept volume, spatial coverage and trawling speed, which might add uncertainty to the stock estimates.

A recruitment index has been calculated for the fourth survey time-series as the abundance of age 1 shrimp. The recruitment index declined from 2007 to 2010, and has since fluctuated at a low level except for a peak in 2014 (Fig. 6.6). The 2016 year class is estimated to be around the average of the last ten years.

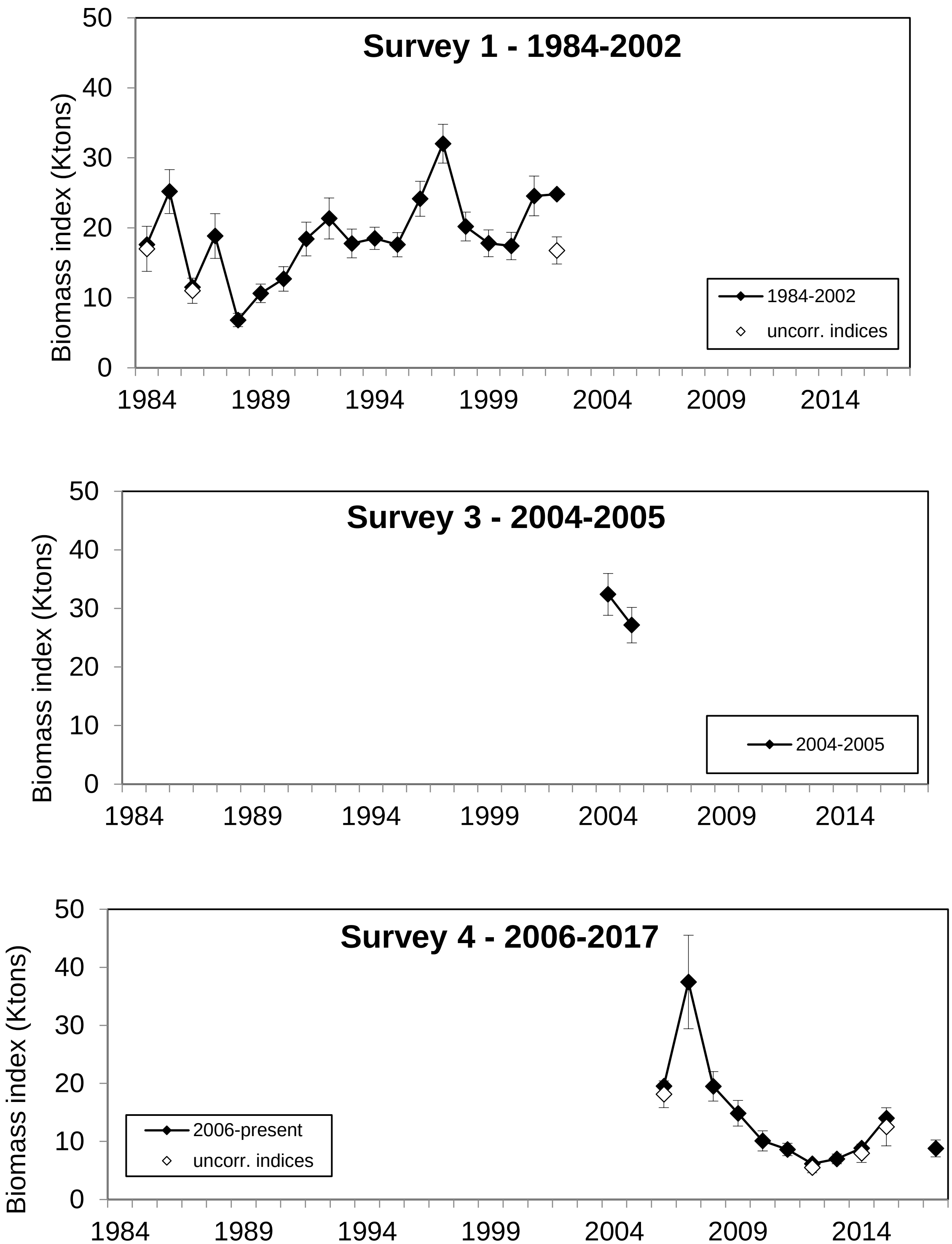


Fig. 6.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984–2017. The point estimate of 2003 is not shown. The 2016-survey data have been omitted (see text for details).

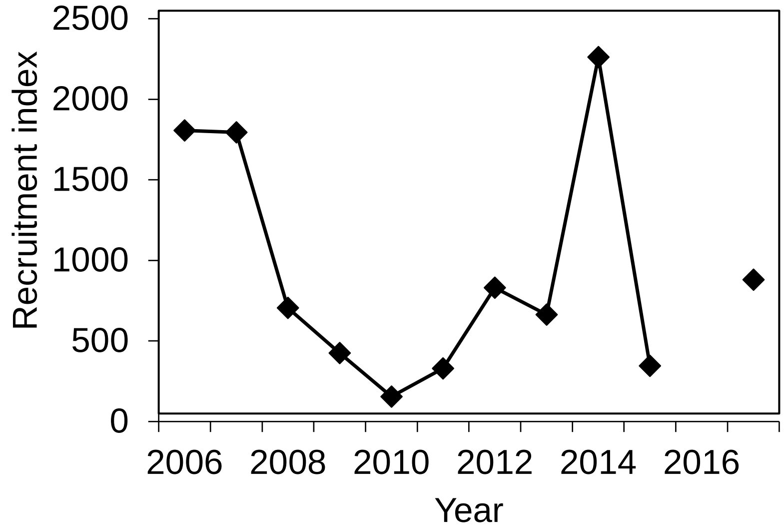


Fig. 6.6. Northern shrimp in Skagerrak and Norwegian Deep: Estimated recruitment index, 2006–2017. The 2016 survey data have been omitted (see text for details).

6c. Assessment model

The stock assessment was benchmarked in January 2016 (ICES, 2016a). At the benchmark it was decided that a length-based Stock Synthesis (SS3) statistical framework (ICES, 2016a, and references therein) should replace the surplus production model (SCR Doc. 15/059) used since 2013, to assess status of the stock and form a basis for advice. New reference points were also defined at the 2016 benchmark (ICES, 2016a).

6d. Assessment results

SS3 model diagnostics of this year's run are very similar to the diagnostics of the run conducted in October 2016 (SCR Doc. 16/55), which did not indicate any issues with the model fit.

Sensitivity analysis

The benchmark in 2016 (ICES, 2016a) recognized the uncertainty in the current assumption of M = 0.75 to the assessment, which is based on estimates from the Barents Sea in the 1990s (Barenboim *et al.*, 1991), and recommended that the sensitivity of model outputs and catch advice to the specifications of *M* should be explored. Preliminary sensitivity analyses of the assessment model regarding different levels of M carried out at the 2016 NIPAG meeting, showed that *M* = 0.90 did not change the perception of the current level of F and SSB relative to the reference points of F_{MSY} and B_{pa} compared with M = 0.75 (base model) (Fig. 6.7). However, shrimp in the Norwegian Deep/Skagerrak are considered to have a lifespan of only about half of that of shrimp in the Barents Sea and it is therefore likely that M could be substantially higher and outside the 0.75–0.90 range explored. Previous analyses of different M assumptions for this stock (SCR 14/66) provide support for this hypothesis. NIPAG was not in a position at the meeting to fully explore the sensitivity to the M assumption used and stresses the importance of further investigations to be conducted well in advance of the next proposed benchmark in 2019–2020.

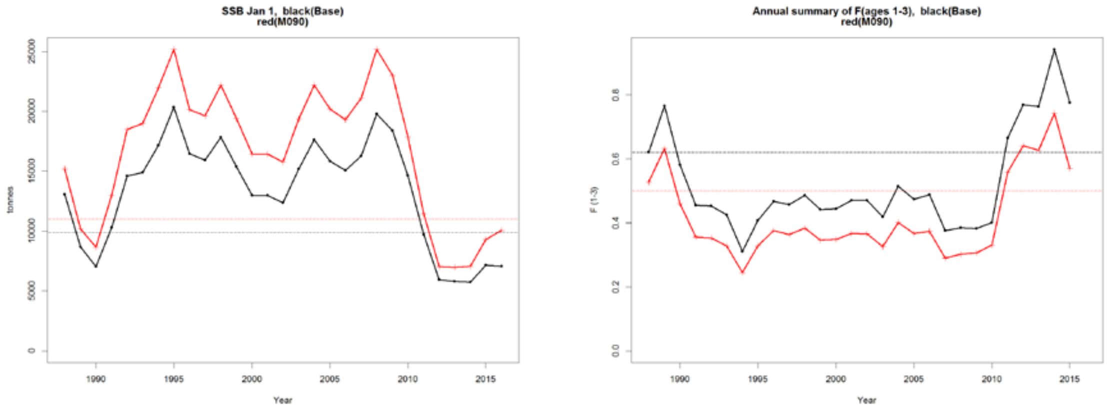


Fig. 6.7. Northern shrimp in Skagerrak and Norwegian Deep: F and SSB assessment results for natural mortality M = 0.75 (base model, black) and M = 0.90 (red). The horizontal lines indicate MSY $B_{trigger}$ (left panel) and F_{MSY} (right panel) values for each of the two M-levels.

Historical stock trends and recruitment

Historical stock trends are shown in Fig. 6.8.

Since 2008, when SSB was 21 648 t, which is the second highest SSB estimate of the time-series, the SSB decreased to the time-series low of 6070 t in 2012. The SSB then increased up to 2016, but decreased again to 9155 t in 2017.

SS3 models recruitment as the abundance of the 0-group. A series of lower recruitment years between 2008 and 2016, with the exception of year 2013, should be noted. During this period of lower recruitment the estimates of SSB were also for some years historically low and below B_{lim}. The uncertainty around the estimate of recruitment in 2016 is large. The reason for this is that the model has not yet seen the recruits in the fishery data (catch data are until 2016) but only in the survey data (collected in January 2017).

Fishing mortality (F) for ages 1 to 3 remained relatively stable from the beginning of the 1990s to about 2010. After 2010, F increased steeply to 0.76 in 2014, which is the highest value of the time-series. Since 2011, the stock has consequently been exploited at a level greater than the F_{MSY} of 0.62, except in 2015.

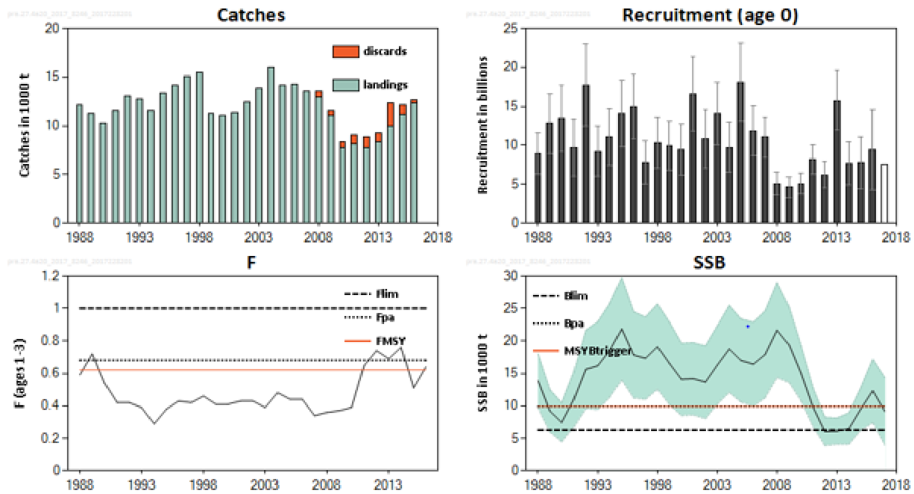
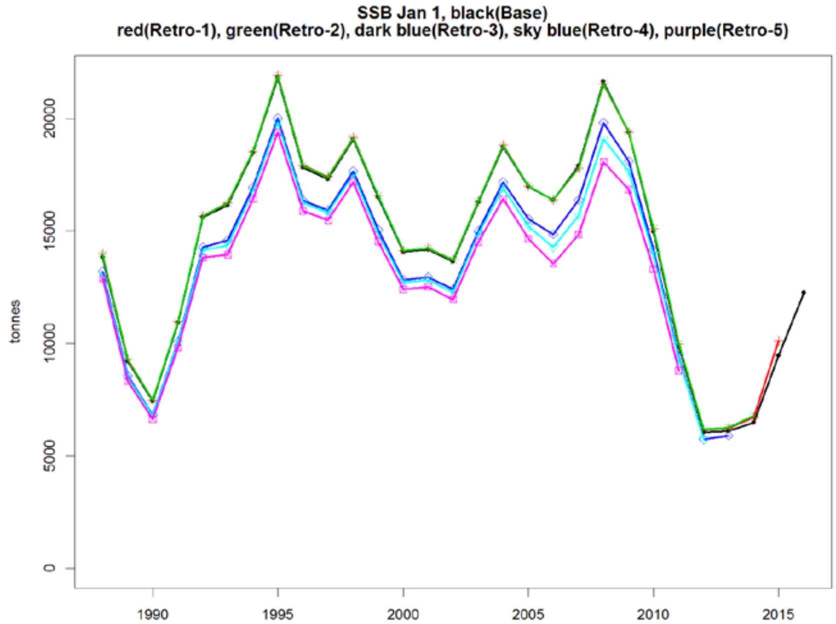
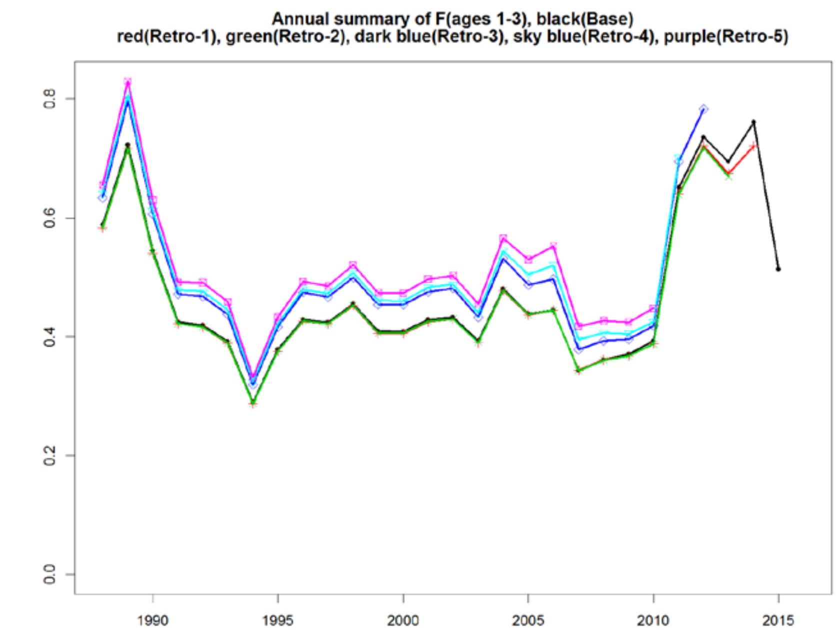


Fig. 6.8. Northern shrimp in Skagerrak and Norwegian Deep: Summary assessment output. Total catch, including estimated discards since 2008 (tonnes) and F, SSB and R assessment results. SSB and R depicted with 90% confidence intervals. The assumed recruitment value (geometric mean of the last ten years) for 2017 is unshaded.

6e. Model retrospective





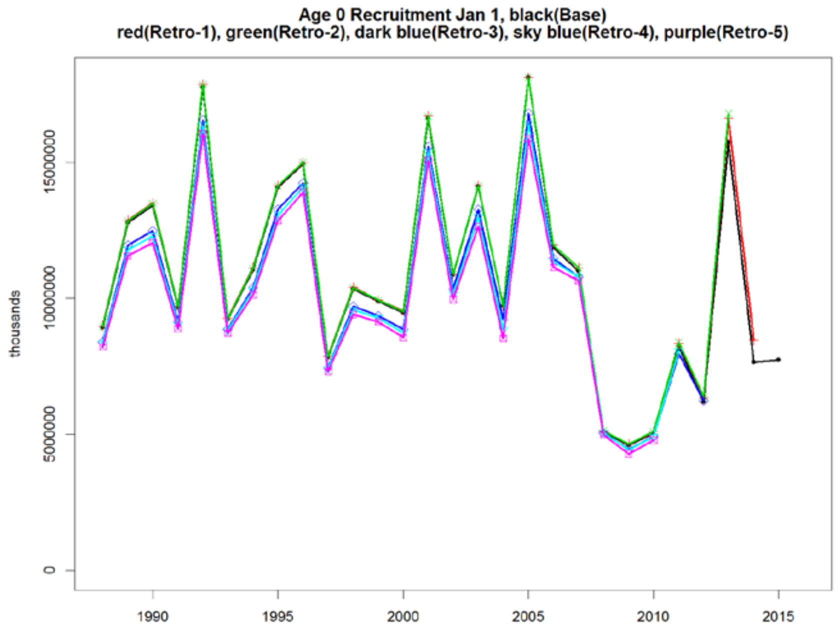


Fig. 6.9. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of SSB, F(ages 1–3) and R.

Model retrospective is shown in Fig. 6.9. There is a moderate retrospective pattern for the historical part of the time-series of SSB and F, but the retrospective pattern is small after 2009 for SSB and after 2010 for F. Recruitment does not show any particular retrospective pattern for any part of the time-series.

6f. Reference points

The reference points were computed at the benchmark in January 2016 based on the definition of the *Pandalus* stock as being a medium-lived species (ICES, 2016a; Table 6.4).

In 2009, ICES adopted a "Maximal Sustainable Yield (MSY) framework" (ACOM. ICES Advice, 2016. Book 1. Section 1.2) for deriving advice. It considers two reference points: F_{MSY} and MSY $B_{trigger.}$ (Table 6.4). Under the ICES PA two reference points are also required; B_{lim} and B_{pa} (Table 6.4). B_{lim} was set to $B_{loss,}$ which is the lowest observed value of the time-series estimated at the benchmark in 2016.

Table 6.4. Northern shrimp in Skagerrak and Norwegian Deep: Reference points computed at the benchmark 2016 (ICES, 2016a).

	Type	Value	Technical basis
MSY Approach	MSY $B_{trigger}$	9900 t	5th percentile of equilibrium distribution of SSB when fishing at F_{MSY}, constrained to be no less than B_{pa}
	F_{MSY}	0.62	F that maximises median equilibrium yield (defining yield as the total catch)
Precautionary Approach	B_{lim}	6300 t	B_{loss} (lowest observed SSB)
	B_{pa}	9900 t	B_{lim} * exp(1.645 * σ), where σ = 0.27
	F_{lim}	1.00	F that leads to 50% probability of SSB < B_{lim}
	F_{pa}	0.68	F_{lim} * exp(- 1.645 * σ), where σ = 0.23

6g. Catch options

Table 6.5. Northern shrimp in Skagerrak and Norwegian Deep: The basis for the catch options.

Variable	Value	Source	Notes
F_{2016}	0.64	ICES (2017)	Corresponds to the estimated catches in 2016.
SSB_{2017}	9155 t	ICES (2017)	
R_{2017}	7523 million	ICES (2017)	GM 2006–2015
Catch (2016)	12 681 t	ICES (2017)	

Table 6.6. Northern shrimp in Skagerrak and Norwegian Deep: The catch options.

Basis	Total catch (2017)	Ftotal (2017)	SSB (2018)	% SSB change *	% TAC change **
ICES advice basis					
MSY approach: F = F_{MSY} x (SSB_{2017}/ MSY $B_{trigger}$)	10 316	0.57	9393	3	-42
Other options					
F = 0	0	0	16 110	76	-100
F_{pa}	11 730	0.68	8543	-7	-35
F_{MSY}	10 979	0.62	8992	-2	-39
F_{2016}	11 231	0.64	8840	-3	-37

*** SSB 2018 relative to SSB 2017.**

**** Catch in 2017 relative to TACs 2016.**

6h. Projections

Given an estimated catch of 12 681 t in 2016, catch options were evaluated for 2017 (Table 6.6). The 2017 estimated catch when applying the MSY approach (10 316 t) will result in an SSB at the beginning of 2018 of 9393 t.

6i. State of the stock

Mortality. Fishing mortality has been above F_{MSY} since 2011 except in 2015.

Biomass. Stock biomass has been below $B_{trigger}$ since 2011 except in 2016, and below B_{lim} between 2012 and 2014.
Recruitment. Recruitment has been below average since 2008, except for the 2013 year class.

State of the Stock. The stock is estimated to be below $B_{trigger}$ and above B_{lim}. Recruitment is low in recent years and fishing mortality is above F_{MSY} in 2016.

Yield. According to the ICES MSY approach, catches in 2017 should be no more than 10 316 t, which is equivalent to an F of 0.57.

6j. Management recommendations

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

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

STATUS: Not implemented

6k. Research recommendations

- *Improved diagnostics and sensitivity analyses should be developed for the LBM*

STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- *Alternative assumptions regarding natural mortality, length–age relationship and selectivity should be explored to see whether the LBM fit to survey length data can be improved.*

STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- *Reasons for the large retrospective pattern in F for recent assessments using the LBM should be explored.*

STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- *Seasonal patterns of spatial distribution resulting from the migration of different age and sex classes should be investigated, as well as seasonal patterns of lpue in the three fisheries, particularly the reason why lpue for a given year increases when we have the full year's data compared to the lpue from only the first 5–6 months.*

STATUS: Spatial patterns in *Pandalus* distribution of the different age and sex classes has not been addressed and with the current sampling regime it is unlikely this can be addressed in the near future. However, spatial distribution of lpue will be addressed at the proposed benchmark for 2018.

- *Reference points from the LBM were considered provisional and alternative reference points based on stock–recruit data should be investigated using standard ICES methodology.*

STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- *Age determination and validation using sections of eye-stalks should continue and results used to refine the life-history knowledge of the stock including age–length relationship and natural mortality assumption.*

STATUS: This work is ongoing.

Recommendations from the 2010-2014 meetings

- *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: This will be assessed in the proposed in-year assessment in February 2017.

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

  STATUS: This is not applicable as a new assessment model was adopted at the 2016 benchmark.

- *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.

Research recommendations from the 2016 meetings

- NIPAG **recommends** *an interim benchmark in conjunction with an in-year assessment in early 2017 to investigate the sensitivity of the assessment, reference points and the catch options to the setting of M and B_{lim}. Also to investigate possibilities for producing a new standardized survey index.*
- NIPAG **recommends** *a full benchmark for this stock including a data compilation workshop in the near future and no later than 2019 (Annex V).*

References

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