PART E: NAFO/ICES *Pandalus* Assessment Group Meeting (NIPAG)
27 September –03 October 2017
Lysekil, Sweden

Recommended Citation:

NAFO. 2017. Report of the NAFO/ICES *Pandalus* Assessment Group, 27 September – 03 October 2017, Lysekil, Sweden. NAFO SCS Doc. 17/17ADD. ICES CM 2017/ACOM:09.

Report of the NIPAG Meeting

27 September –3 October 2017

Co-Chairs: Karen Dwyer, Guldborg Søvik. Rapporteur: Tom Blasdale

I. OPENING

The NAFO/ICES *Pandalus* Assessment Group (NIPAG) met at the Swedish University of Agricultural Sciences, Lysekil, Sweden during 27 September to 3 October 2017 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 (Estonia, Spain and Sweden), and Norway. The NAFO Scientific Council Coordinator and Scientific Information Administrator were also in attendance.

II. GENERAL REVIEW

1. Review of Research Recommendations in 2016

Recommendations applicable to individual stocks are given under each stock in the “stock assessments” section of this report.

2. Review of Catches

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

III. STOCK ASSESSMENTS

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

(SCR Docs. 17/50, 63, 64, 65)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- Ocean climate composite index in SA3 – Flemish Cap continues to remain below normal since 2014. The large negative anomalies observed in 2014-2016 are comparable with the previous cold period during the early-mid 1990s.
- The magnitude of the spring bloom was at a record low in 2016 with mostly below normal levels since 2013. The timing of the spring bloom changed in 2016 from predominately early onset but shorter duration in 2011-2015 to later onset and longer duration compared to the reference period.
- Despite the decline in ocean climate and bloom indices, the zooplankton index has remained well above normal since 2013.
- The composite trophic index (integrating nutrients, phytoplankton and zooplankton indices) has tended to remain above normal in recent years but near the standard climatology in 2016.

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 (Fig. 1.1).

Fishery and catches: A moratorium was imposed in 2011. Recent catches were as follows:

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NIPAG	21000	13000	5000	2000	0	0	0	0	0	0	0[1]
STATLANT 21	17642	13431	5374	1976	0	0	0	0	0	0	
SC Recommended Catches	48000	17000–32000	18000–27000	ndf[3]	ndf[3]	ndf[3]	ndf[3]	ndf[3]	ndf[3]	ndf[3]	ndf[3]
Effort[2] (Agreed Days)	10555	10555	10555	5227	0	0	0	0	0	0	0

[1] To September 2017
[2] Effort regulated
[3] ndf = no directed fishery

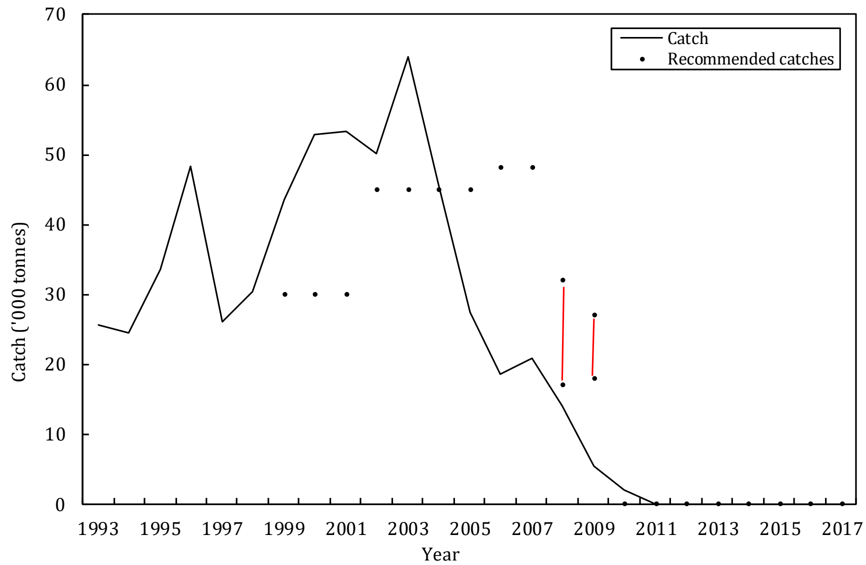

Fig. 1.1. Shrimp in Div. 3M: Catches (t) of shrimp on Flemish Cap and catches recommended in the period 1993-2017. The red bars indicate where catches were recommended to fall within a range.

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 2017. 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 on 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. This 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).

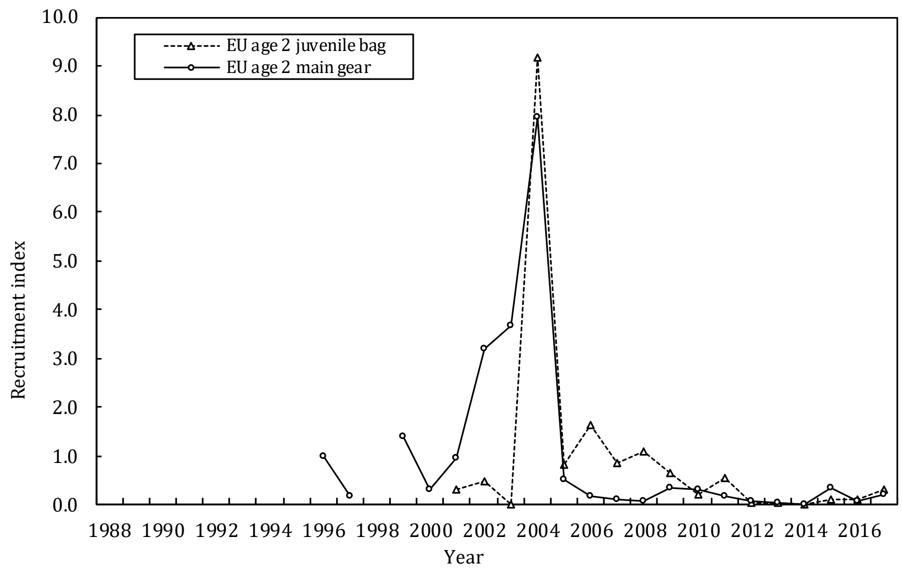

Fig. 1.2. Shrimp in Div. 3M: Abundance indices at age 2 from the EU survey. Each series was standardized to its mean.

SSB: The survey female biomass index (Fig. 1.3) was stable at a high level from 1998 to 2007, and has declined since then. In 2017 although the female biomass increased (14%) over 2016, the estimated biomass (2304 tonnes) remained below B_{lim}.

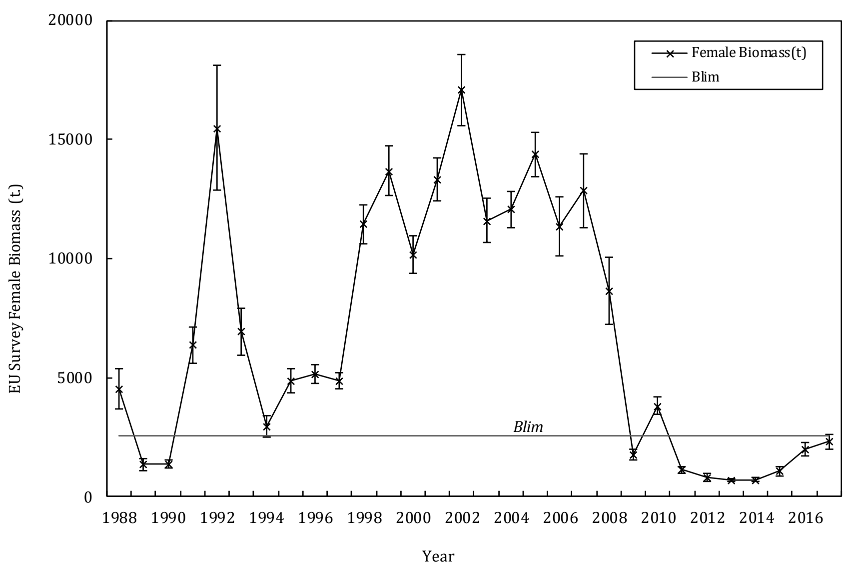

Fig. 1.3. Shrimp in Div. 3M: Female biomass index from EU trawl surveys, 1988-2017. Error bars are 1 SE.

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, Fig. 1.4) declined to zero and has remained at that level since 2011.

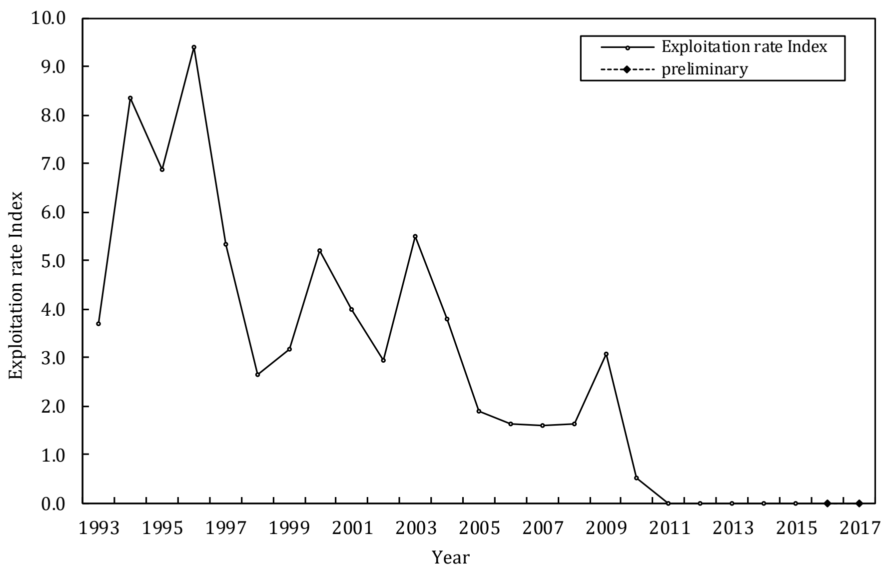

Fig. 1.4. Shrimp in Div. 3M: Exploitation rate index as derived by catch divided by the EU survey biomass index of the same year.

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 2017 is below B_{lim} is >95%. Due to continued poor recruitment there are concerns that the stock will remain at low levels.

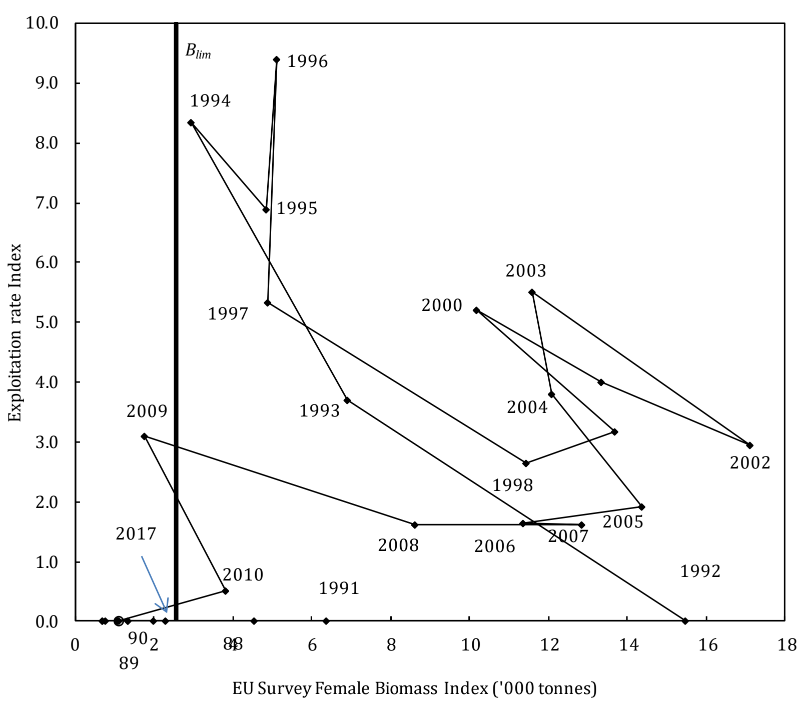

Fig. 1.5. Shrimp in Div. 3M: Exploitation rate index plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 15% of the maximum point in 2002. Due to the moratorium on shrimp fishing the expected catch in 2017 is 0 t.

f) Ecosystem considerations

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

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

Recent models developed in GADGET (Pérez-Rodríguez et al. 2016) suggest that predation by redfish and cod, together with fishing were the main factors driving the shrimp stock to the collapse (Fig. 1.6).

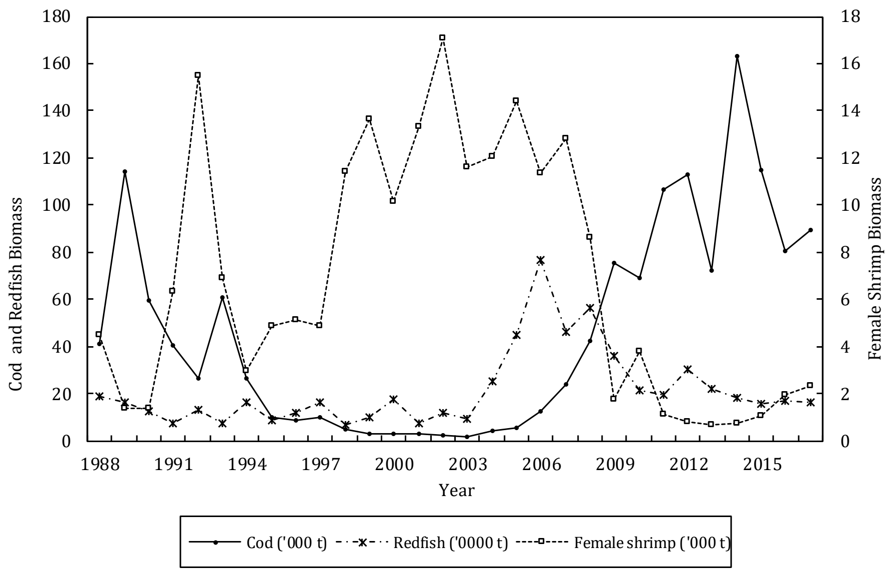

Fig. 1.6. Shrimp in Div. 3M: Cod, Redfish and Female shrimp biomass from EU trawl surveys, 1988-2017.

g) Research recommendations

For northern shrimp in Div. 3M NIPAG **recommended in 2016** 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.*

Status: In progress. Recent progress has been made, based on the work done by Pérez-Rodríguez, A. et al. (2016). Further progress will be reported under WG-ESA.

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. 17/70)

Environmental Overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- After a decade of above average ocean climate conditions in SA3 - Grand Bank, the trend in recent years shows signs of returning to colder conditions similar to the mid-1990s.
- The magnitude of the spring bloom has declined since the record-high observed in 2011 reaching a record-low in 2016. The timing indices indicate delayed onset but longer duration blooms since 2014.
- The composite zooplankton index has remained mostly above normal since 2009. Limited data prevented an updated value for 2016.
- The composite trophic index has declined in recent years from above average levels but reached the lowest level in the time-series in 2016.

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. 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 (ndf) was implemented in 2015 to 2017 (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:

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
TAC[1]	27306	32767	32767	20971	13108	9393	4697	ndf	ndf	ndf
STATLANT 21	26097	27236	19745	13013	10099	7919	2282	0	0	
NIPAG[2]	25407	25900	20536	12900	10108	8647	2289	0	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).

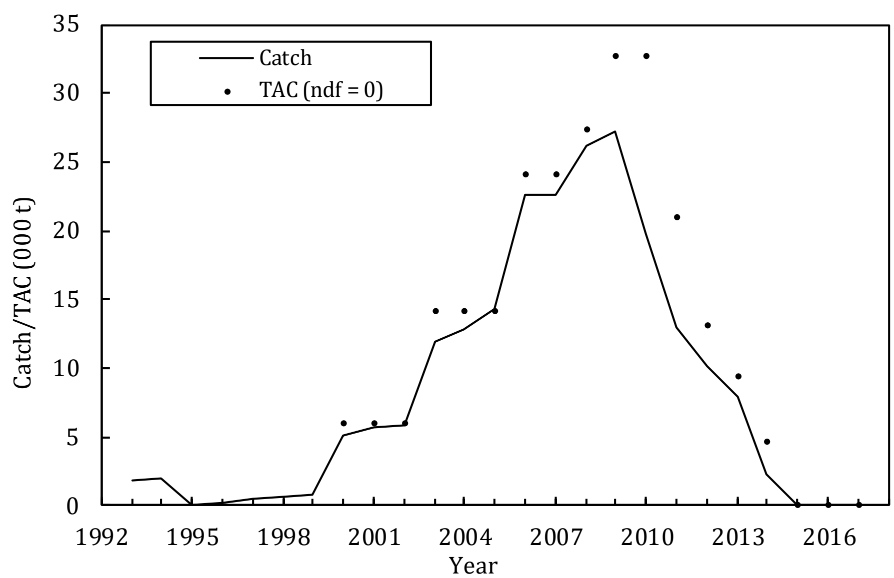

Fig. 2.1. Shrimp in Div. 3LNO: Catches and TAC. The TAC illustrated includes the autonomous quotas, set by Denmark, with respect to Faroes and Greenland. No directed fishing is plotted as zero TAC.

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 from 2015 to present. 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.

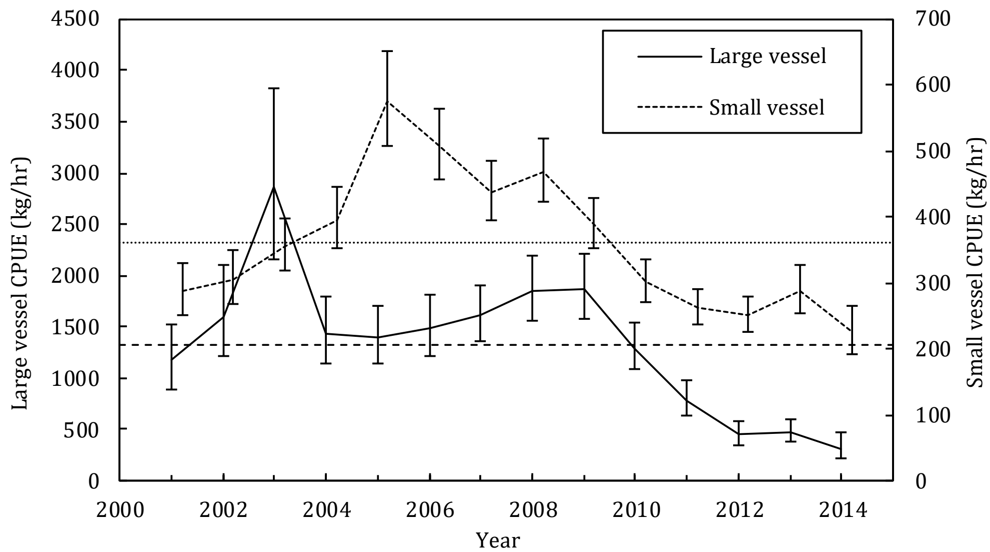

Fig. 2.2. Shrimp in Div. 3LNO: Standardized CPUEs for the Canadian large-vessel (>500 GT) and small-vessel (≤500 GT; LOA<65') fleets fishing shrimp in Div. 3L within the Canadian Exclusive Economic Zone (EEZ). Error bars indicate 95% confidence intervals. The horizontal lines represent long term means of the time-series.

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 (1996–2016). The autumn survey in 2004, and the spring surveys in 2015 and 2017 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.

Spanish multi-species trawl survey. EU-Spain has been conducting a stratified-random survey in the NAFO Regulatory Area (NRA) part of Div. 3L since 2003 and in the NRA part of Division 3NO since 1995. Data are collected with a Campelen 1800 trawl. There was no EU-Spain Div. 3L survey in 2005.

c) Assessment results

No analytical assessment is available. Evaluation of stock status is currently based upon interpretation of 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. There was an overall increase in both the spring and autumn indices to 2007 after which they decreased by over 90% to the lowest levels in the time-series in 2016 (Fig. 2.3).

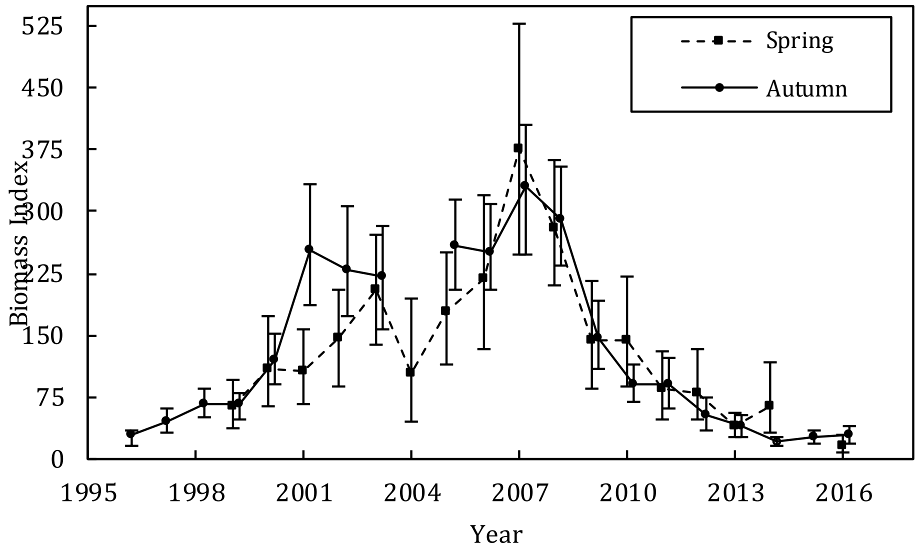

Fig. 2.3. Shrimp in Div. 3LNO: Total biomass index estimates from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The 2014 autumn index is for Div. 3L only.

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 2017 (Fig. 2.4).

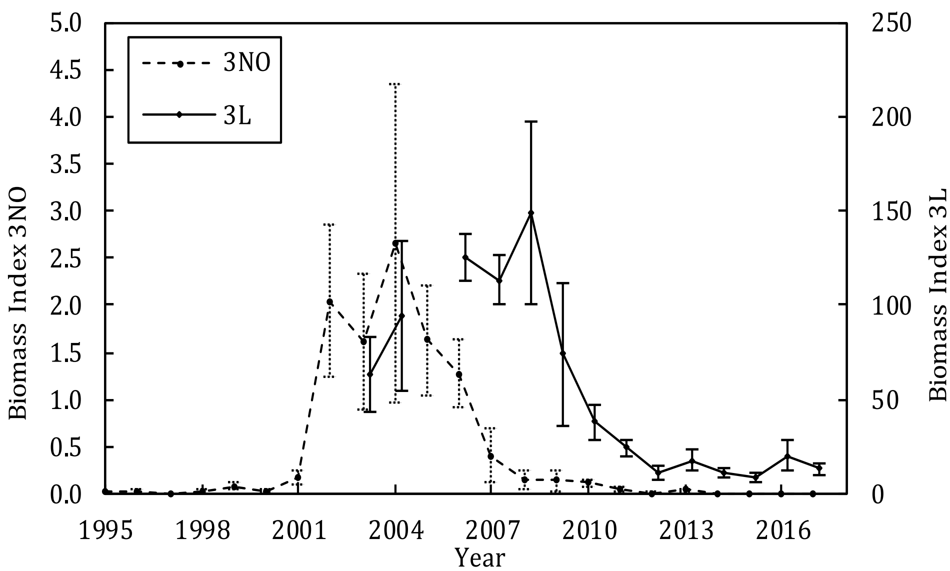

Fig. 2.4. Shrimp in Div. 3LNO: Total biomass index estimates from EU - Spain multi-species surveys (± 1 SE) in the NAFO Regulatory Area (NRA) of Div. 3LNO.

Female biomass (SSB) indices. The Canadian research vessel spring Div. 3LNO SSB index decreased by 97% between 2007 and 2016. The Canadian RV autumn SSB index showed an increasing trend to 2007 but decreased 93% by 2015 and has remained at a low level (Fig. 2.5).

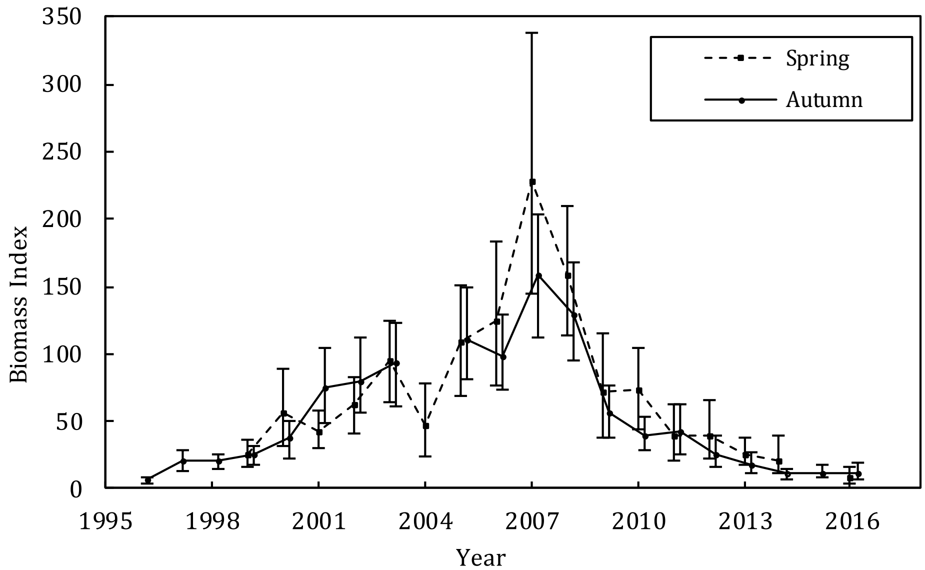

Fig. 2.5. Shrimp in Div. 3LNO: Female SSB indices from Canadian spring and autumn multi-species surveys (with 95% confidence intervals). The autumn index for 2014 is for Div. 3L only.

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).

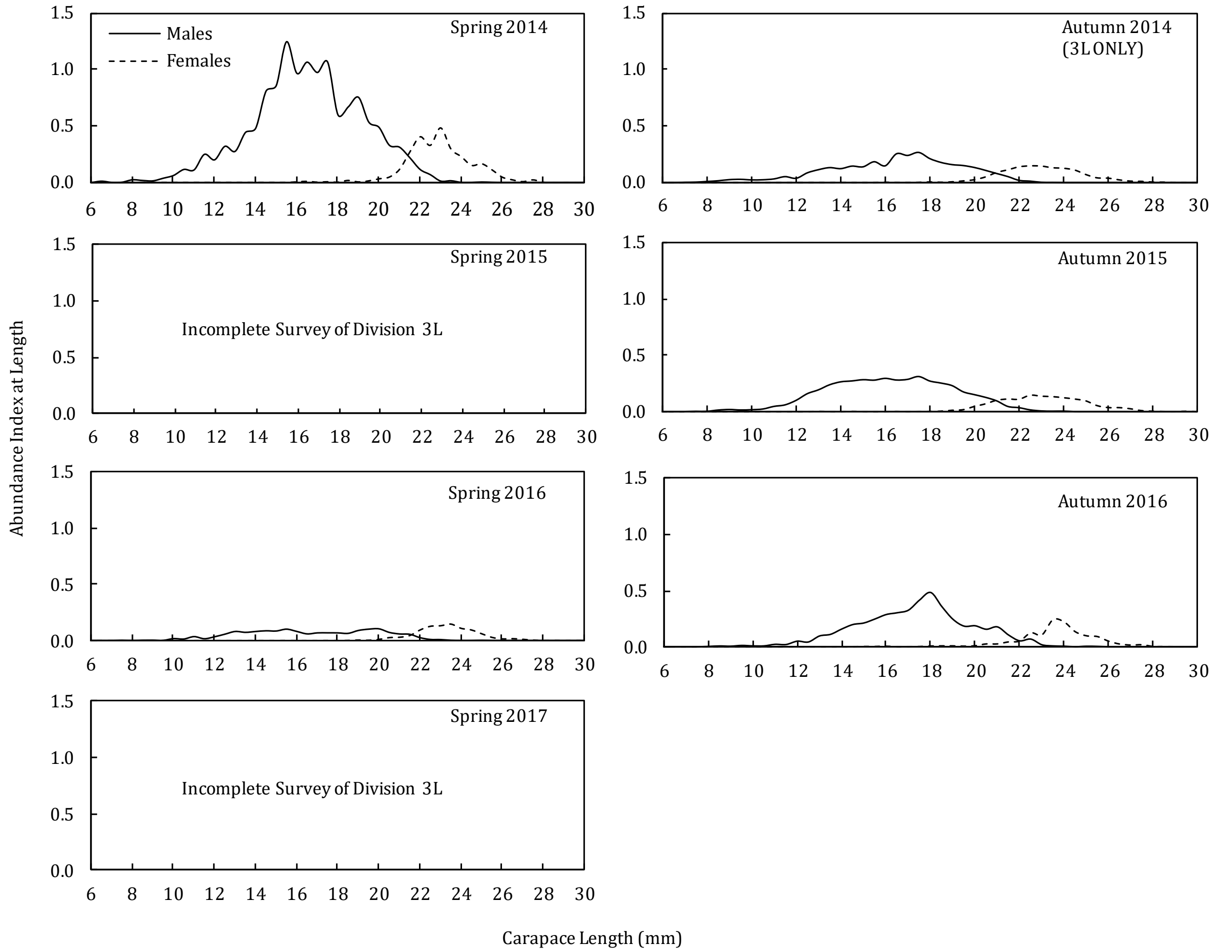

Fig. 2.6. Shrimp in Div. 3LNO: Abundance at length estimated from Canadian spring and autumn multi-species survey data. No data for spring 2015 or 2017.

Recruitment indices. The recruitment indices were based upon abundance indices of 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 and spring 2016.

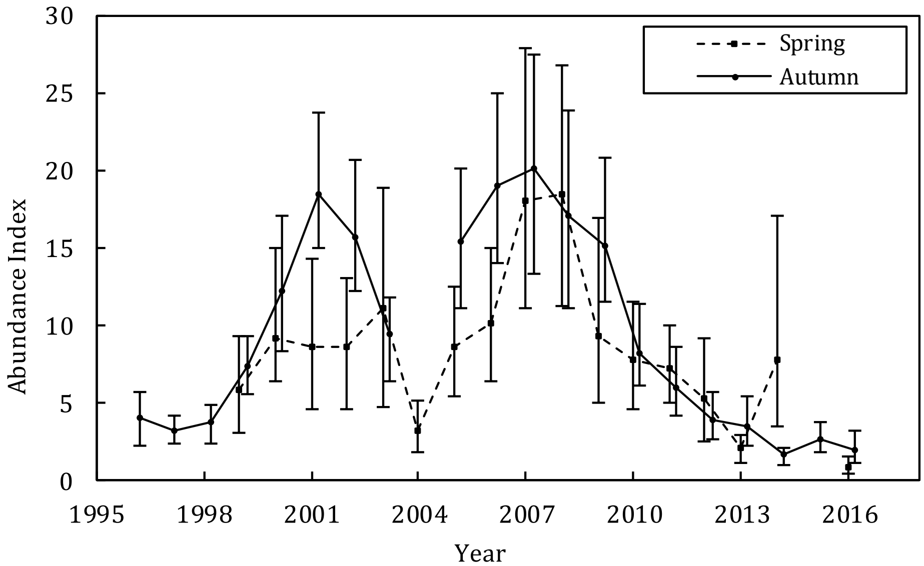

Fig. 2.7. Shrimp in Div. 3LNO: Recruitment indices derived from abundance of shrimp with 11.5 – 17 mm carapace lengths from Canadian spring and autumn multi-species surveys. Error bars represent 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

Fishable biomass and exploitation index. The spring and autumn fishable biomass (shrimp > 17 mm CL) indices increased to 2007 but have since decreased by over 90% to 2016 (Fig. 2.8).

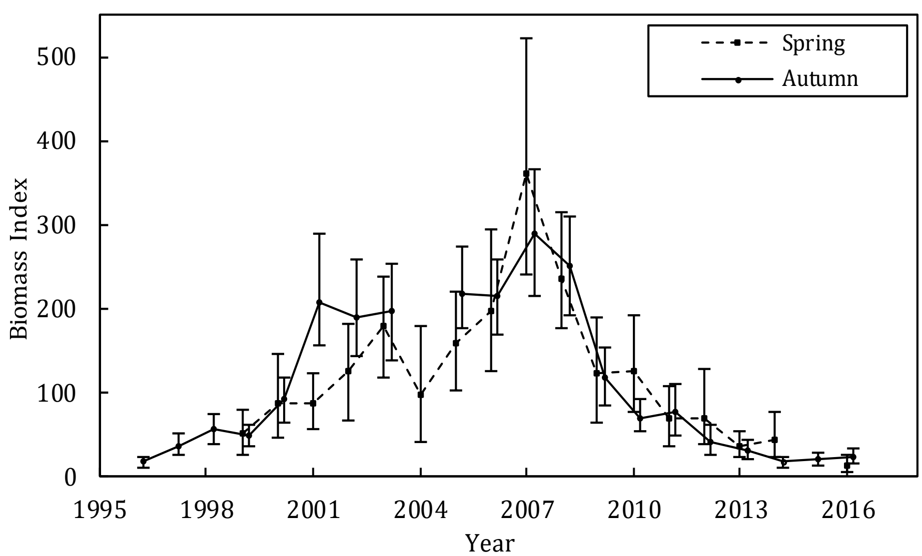

Fig. 2.8. Shrimp in Div. 3LNO: Fishable (shrimp >17 mm CL) biomass indices from Canadian spring and autumn multi-species survey data. Error bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

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 2015-2017, the exploitation index is zero.

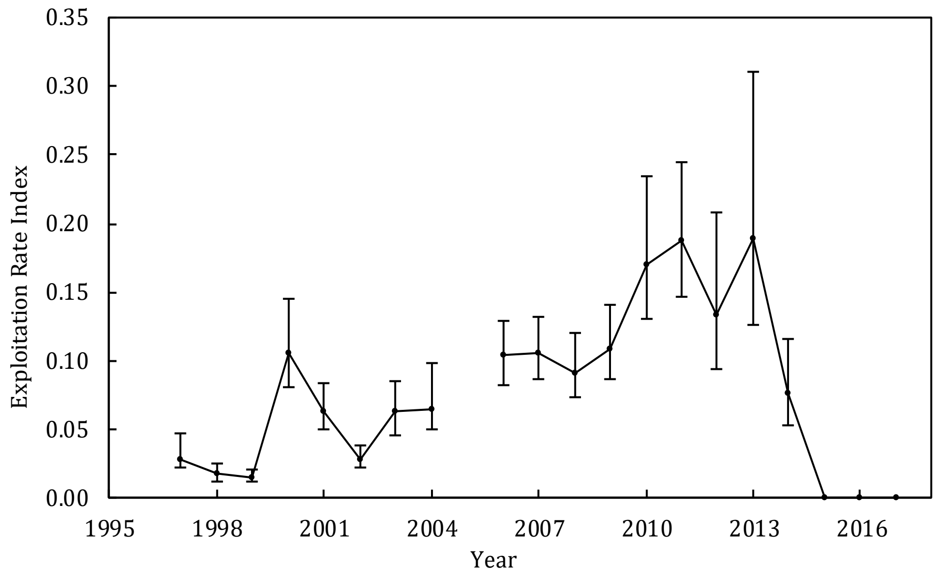

Fig. 2.9. Shrimp in Div. 3LNO: Exploitation indices calculated as a year's catch divided by the previous year's autumn fishable biomass index. Error bars (calculated based on estimates of fishable biomass index) indicate 95% confidence intervals.

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). In 2016 the risk of being below B_{lim} was greater than 95% (Fig. 2.10 and Fig. 2.11). A limit reference point for fishing mortality has not been defined.

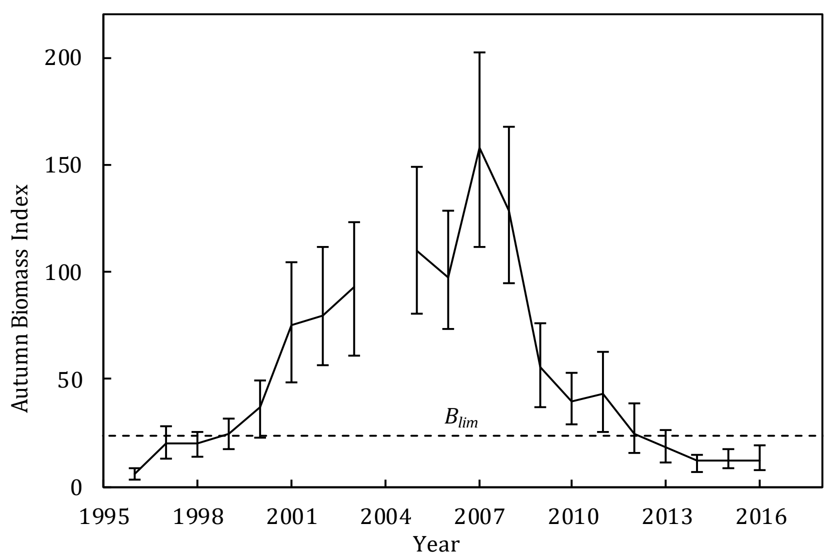

Fig. 2.10. Shrimp in Div. 3LNO: Autumn female spawning stock biomass index (SSB) and B_{lim}. B_{lim} is defined as 15% of the maximum autumn female biomass over the time-series. Error bars indicate 95% confidence intervals. The autumn index for 2014 is for Div. 3L only.

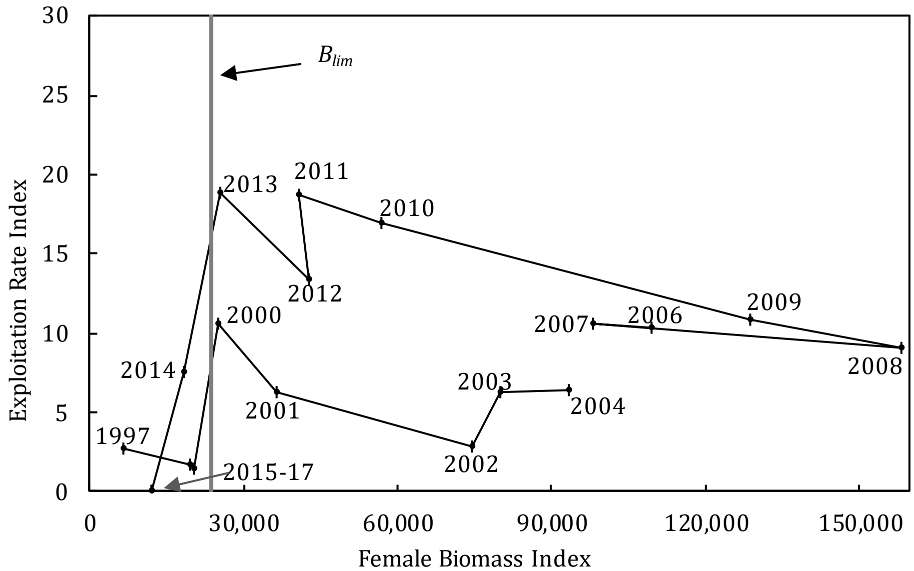

Fig. 2.11. Shrimp in Div. 3LNO: Exploitation rate vs female SSB index from Canadian autumn survey. Vertical line denotes B_{lim} (23 700 t).

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 has been zero since 2015.

State of the Stock. In 2016 the risk of the stock being below B_{lim} is greater than 95%.

Given prospects of poor recruitment in recent years, the stock is not expected to increase in the near future.

f) Ecosystem considerations

Predation on northern shrimp has been high in recent years (DFO, 2017) due to a higher abundance of shrimp predators (cod, Greenland halibut, redfish, etc.) together with a low abundance of higher-energy prey (i.e. capelin). Predation and environmental factors (i.e. phytoplankton bloom, bottom temperature, etc.) appear to be important drivers of the decline of northern shrimp in Division 2J3KL. There is no evidence that predation mortality will decrease or that environmental conditions will become more favorable in the short term. Further work on biological and environmental interactions is continuing.

g) Other Studies

Preliminary results from ongoing research on larval drift/dispersal were presented at the meeting. The research includes a simulated release of 100 larvae from 100 sites in a biophysical model. The larvae are then permitted to drift and disperse for 85 days, approximately the period it takes for larvae to settle, and vertically behave as larval shrimp in the water column. Two subsamples of the results were presented; one demonstrated that most larvae hatched in Div. 3L end up in Div. 3M and the other demonstrated that most larvae that settle in Div. 3L originate in areas north of that division. Results are expected to be published within the next year.

Preliminary results from a study on estimating age from eye stalks of shrimp were presented. More information is to follow once the study is concluded and results become final. There does not appear to be any relationship between number of growth rings and length of shrimp in NAFO Div. 3LNO.

h) 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 information presented to address this request at NIPAG in 2017, however, the work presented was applicable to NAFO Divisions 2J3KL as a whole. 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. This recommendation is reiterated

References

DFO. 2017. Review of Reference Points used in the Precautionary Approach for Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Area 6. DFO Can. Sci. Advis. Sec. Sci. Resp. 2017/009.

3. Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO SA 0 And SA 1)

(SCR Docs. 04/75, 04/76, 08/6, 11/53, 11/58, 12/44, 13/54, 17/052, 17/051, 17/055, 17/056, 17/059, 17/060)

Environmental overview

Recent Conditions in Ocean Climate and Lower Trophic Levels

- The composite climate index in Subarea 0-1 has remained mostly above normal since the early 2000s, it reached a peak in 2010 but has been in decline since then, reaching a below normal state in 2015 before returning to near normal climatological conditions in 2016.
- The magnitude of the spring bloom reached a record-high in 2012 but has since declined and is below normal in 2016.
- The timing of the spring bloom in Subarea 0-1 was later but longer than normal in recent years but closer to normal conditions in 2016.

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 (Kongelige Grønlandske Handel (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 licenses 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 2017 was set at 88 956 and for Canadian Waters, 12 750 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. Since 2012, *Pandalus montagui* has been included among the species protected by a 'moving rule' to limit bycatch and there are no licenses issued for directed fishing on it (SCR Doc. 17/55). Instructions for reporting *P. montagui* in logbooks were changed in 2011, to improve the reporting of these catches.

The table of recent catches was updated (SCR Doc. 17/55). 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 72 256 t in 2015. The catch in 2016 was 85 527 t and the projected catch for 2017 is 90 000 t.

Recent catches, projected catch for 2017 and recommended and enacted TACs (t) for northern shrimp in Sub-area 1 and Div. 0A (east of 60°30'W) are as follows:

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
TAC											
Advised	130000	110000	110000	110000	120 000	90000	80000	80000	60000	90000	90000
Enacted[1]	152417	145717	130153	130153	139583	114425	100596[3]	97649[3]	82561[3]	96426[3]	101706[3]
Catches (NIPAG)											
SA 1	142245[3]	153889[3]	135029[3]	128109[3]	122659[3]	115965[3]	95379[3]	88765[3]	72254[3]	84356[3]	*89000*[2]
Div. 0A	1945	0	429	5 882	1330	12	2	0	2	1171	*1000*[2]
TOTAL	144190[3]	153889[3]	135458[3]	133991[3]	123989[3]	115977[3]	95381[3]	88765[3]	72256[3]	85527[3]	*90000*[2]
STATLANT 21											
SA 1	142245	148550	133561	123973	122061	114958	91800	88834	71777	80008	
Div. 0A	1878	0	429	5206	1134	12	2	0	2	794	

1Canada and Greenland set independent and autonomous TACs

2 Provisional total catches for the year as expected by industry observers.

3 This table has been updated to include the area North of 73°30.

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. 17/56). The fishery has moved north in recent years and since 2009 at least 35% of the total catch was taken in Div. 1A. In earlier years catches taken in Div. 1A were on average 12% of total catch.

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 from 2012 to 2015 no fishing was conducted in Div. 0A (SCR Doc. 17/56). In 2016 Canadian catch was 1171 t.

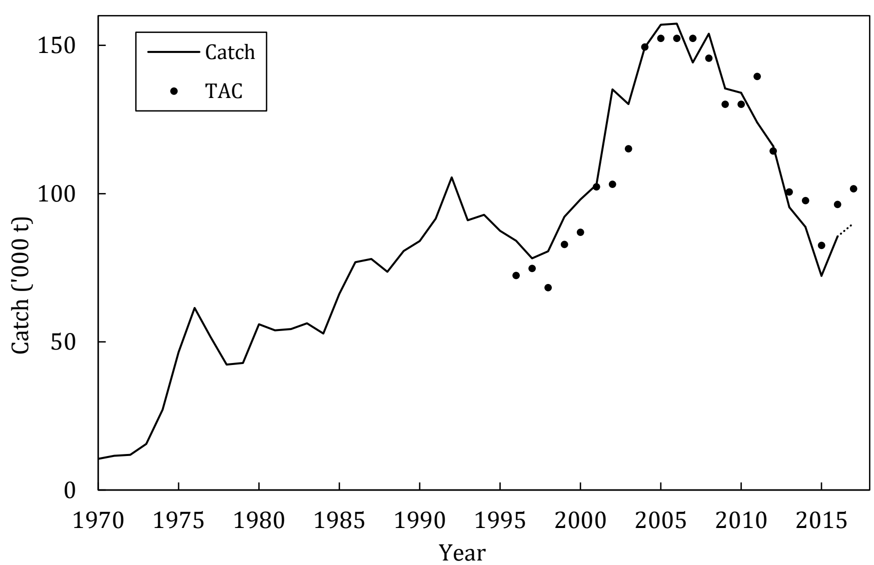

Fig. 3.1. Northern shrimp in Subarea 1 and Div. 0A: Enacted TACs and total catches (2017 expected for the year).

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. 17/56). 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 standardized by linearized 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. From 2014 to 2016 an exploratory fishery has been conducted in Melville Bay (north of 73°30N). Greenland authorities set a separate quota for this area from 2013 to 2016. In 2017 for the first time catch and effort data for statistical area -1, (north of 73°30N), were included in the CPUE analyses. This area comprises about 59 850 sq. km. and in 2014-2016 yielded 3.5% of the offshore catch. A series for 1976–1990 was constructed for the KGH 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 standardized 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 are unified in a separate step to produce a single series that is input to the assessment model. This all-fleet standardized 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 (Fig. 3.2). The index decreased from 2008 to 2013 then increased to its 3rd highest value observed in the series in 2017 (SCR Doc. 17/56). After 2015, the Greenland inshore and offshore indices have shown opposite trends.

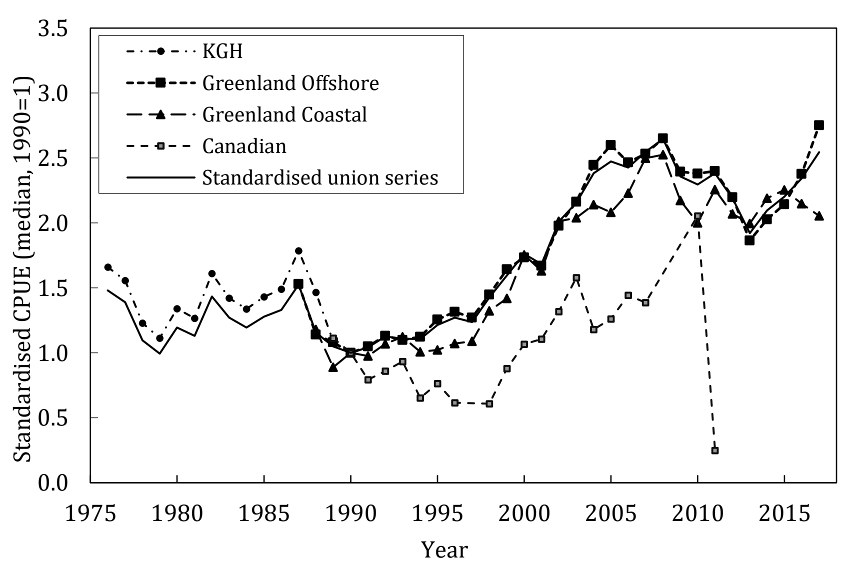

Fig. 3.2. Northern shrimp in Subarea 1 and Div 0A: Standardized CPUE index series 1976–2017.

The distribution of catch and effort among statistical areas was summarized 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). 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. The fishery area contracted in the period 2005 to 2015; NIPAG has for some years been concerned about the 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.

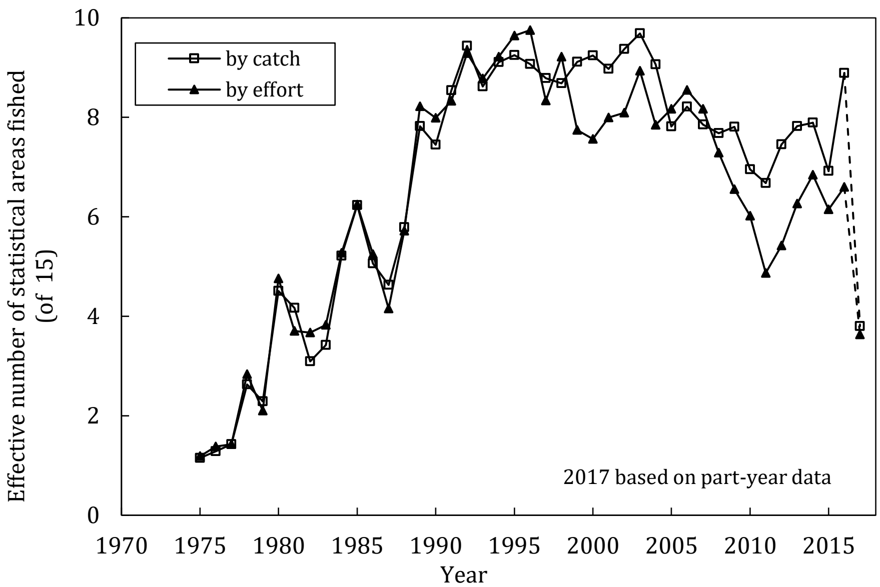

Fig. 3.3. Northern shrimp in Subarea 1 and Div. 0A: Indices for the distribution of the Greenland fishery between statistical areas in 1975–2017.

Catch composition. There is no biological sampling program 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. 17/51). 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 1997–2017 (SCR Doc. 17/51). 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. 17/51). 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, with the second lowest level in the last 20 years occurring in 2014 (Fig. 3.4) (SCR Doc. 17/51). Over the past 2 years biomass has been fluctuating at a slightly higher level. Offshore regions comprise 74% of the total survey biomass, and 26% is inshore in Disko Bay and Vaigat. The inshore regions have far higher densities than other areas, almost four times as high as offshore (Fig. 3.4) (SCR Doc. 17/51).

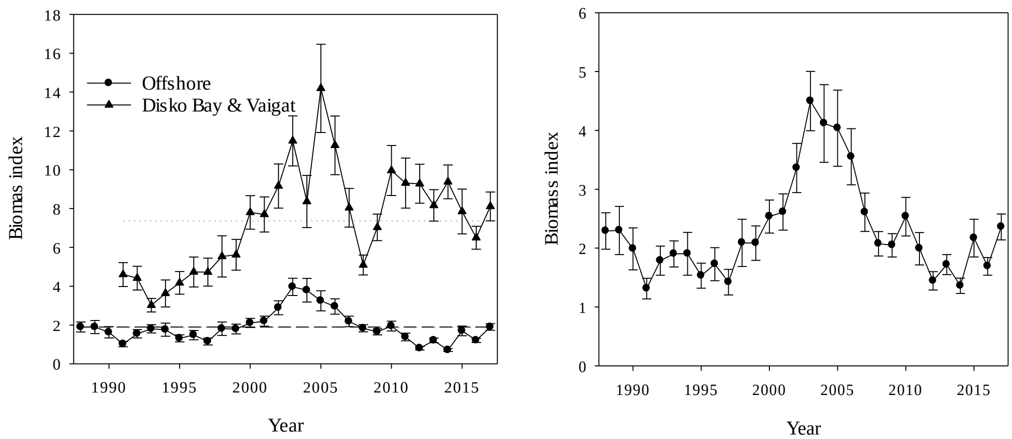

Fig. 3.4. Northern shrimp in Subarea 1 and Div. 0A: Biomass index (survey mean catch rates) inshore and offshore (panel a) and overall (panel b) 1988–2017 (error bars 1 SE).

Length and sex composition (SCR 17/051). In 2017, in both offshore and Disko Bay regions fishable biomass of males increased over 2016, nevertheless proportion of males is below or close to their 12-year lower quartile of the total survey and fishable biomass indices. Like in most recent years, females compose a high proportion of survey and fishable biomass index in both regions, above their 12-year median offshore and above their 12-year upper quartile in Disko Bay (SCR Doc. 17/51).

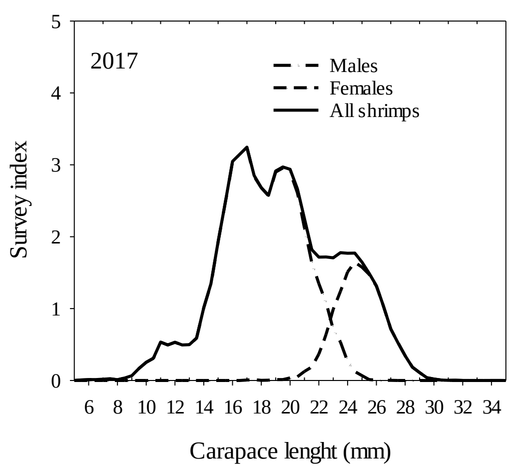

Fig. 3.5. Northern Shrimp in Subarea 1 and Div. 0A: Survey mean catch rates at length in the West Greenland trawl survey in 2016 and 2017.

Recruitment index. The recruitment index (number at age 2, 10.5 to 13.5 mm) reached a high point in 2000 and 2001 and has since declined to a much lower level, with a high value only in 2015. The pre-recruit index (14–16.5 mm, expected to recruit to next year's fishable biomass) had a high value in 2005 and has since fluctuated at a lower level, with relatively high values in 2015 and 2017 (SCR Doc. 17/52) (Fig. 3.6). There is some uncertainty in the relationship between the pre-recruit index and the subsequent year's fishable biomass and this should be investigated further.

Linear regression has shown a significant relationship between the number of age-2 shrimp and the fishable biomass with a lag of 2, 3 or 4 years later. The correlation was strongest ($R^2 = 0.69$) between number of age-2 shrimp and the fishable biomass 4 years later (SCR doc 17/058).

The stock composition in Disko Bay has historically been characterized by a higher proportion of young shrimps than that offshore, but in 2017 numbers of age 2-shrimps were 0.6 times the numbers of offshore, and both in numbers and relative to survey biomass pre-recruits were by far much higher offshore than in Disko Bay (SCR Doc. 17/52).

The relative number of pre-recruits in 2017 increased over 2016, and is way above its 12-year upper quartile offshore, in fact the second highest observation, while in Disko Bay it is close to its 12-year lower quartile.

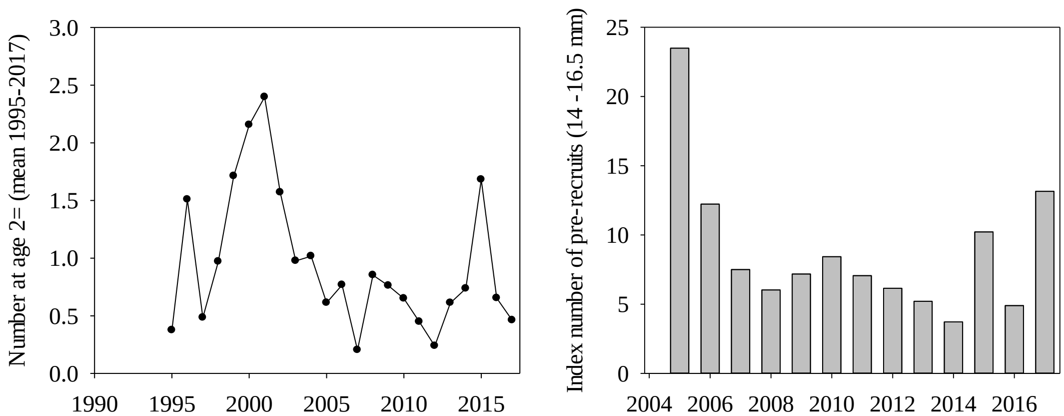

Fig. 3.6. Northern shrimp in Subarea 1 and Div. 0A: Survey index of numbers at age 2 (10.5 - 13.5 mm), 1995–2017 and index of number of pre-recruits (14-16.5 mm), 2005-2017.

Predation index. Four distinct stocks of Atlantic cod, spawning variously in inshore and offshore 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.

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 2017 the cod biomass density estimated by research trawl survey in West Greenland increased over 2016, but was about one-fifth of its value in 2015 and the index of its overlap with the shrimp stock increased, by a factor of about 5. This resulted in an 'effective cod biomass' index of a 21.4 kt, compared with values of 50–60 kt in 2014–15 but only 3.1 kt in 2016 (Fig. 3.7) (SCR Doc. 16/42, 16/47, SCR Doc. 17/52).

A new approach was established for predicting cod biomass in 2018 based on linear regressions of the biomass of a given age group with the biomass one year ahead. The biomass of cod used in the assessment model in 2018 was predicted to be 23 242 t (SCR Doc. 17/59).

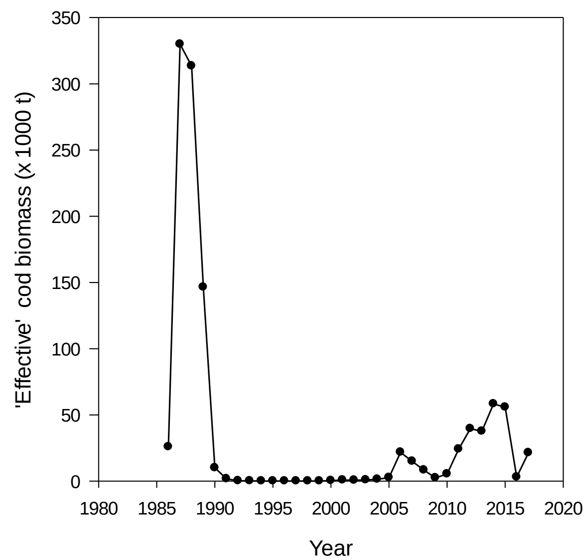

Fig. 3.7. Indices of the 'effective' cod biomass in Subarea 1 and Div. 0A 1987 - 2017 (measure of the overlap between the stocks of cod and shrimps).

c) Assessment results

A Schaefer surplus-production model of population dynamics was fitted to series of CPUE, catch, and survey biomass indices (SCR Doc. 17/52).

The model includes a term for predation by Atlantic cod. 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.

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 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 shrimp catches for 2017 are expected to be 90 000 t. The assessment model was modified in 2012 to include the uncertainty of the current year's expected catches.

Since 2011, the model has been run with data series shortened to 30 years to speed up the running; the effect of shortening the data series was checked in 2011 and found not significant (SCR Doc. 11/58). In 2011 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. 3.8a) was low and stable until the late 1990s, when it started a rapid increase. Biomass doubled by about 2004; the survey index increased much more than the fishery CPUE. Modelled biomass steadily declined from 2004 to 2013 but has since slightly increased. The median biomass has been above B_{msy} since the late 1990s.

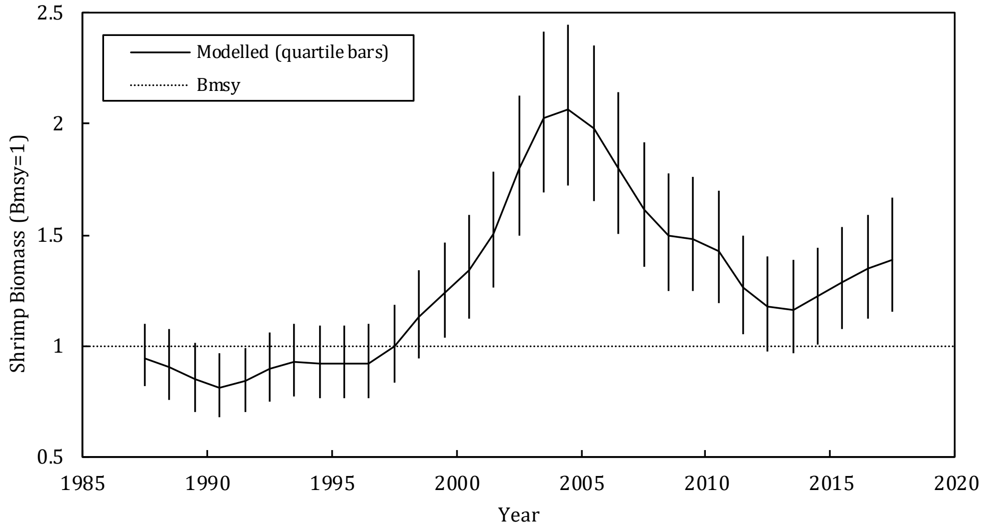

Fig. 3.8a. Northern shrimp in SA 1 and Div. 0A: The modelled biomass Trajectory of the median estimate of relative stock biomass at start of year 1987–2017.

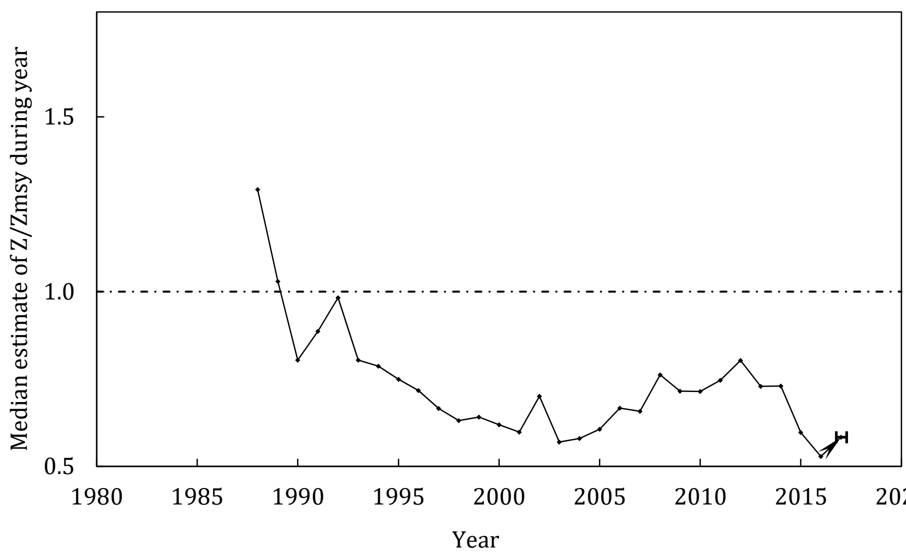

Fig 3.8b. Northern shrimp in SA 1 and Div. 0A: Trajectory of the median modelled estimate of mortality relative to Z_{msy} during the year, 1987–2017.

Mortality has generally been below Z_{msy} during the modelled period, although a short-lived episode of high cod biomass occasioned two years of high values in the late 1980s (Fig. 3.8b). 2016 and 2017 are amongst the lowest values in the time-series. Estimates of stock-dynamic and parameters from fitting a Schaefer stock-production model to 30 years' data on the West Greenland stock of the northern shrimp in 2017 are given in table 3.1. Median values from the 2016 assessment are provided for comparison. Biomass at the end of 2017 is projected to be above the 2016 value and about 39% above B_{msy}. The expected catches for 2017 (90 000 t) are predicted to hold total estimable mortality below 65% of Z_{msy}.

Table 3.1. Estimates of stock-dynamic and parameters from fitting a Schaefer stock-production model to 30 years' data on the West Greenland stock of the northern shrimp in 2017.

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2016)
Max.sustainable yield	153.3	90.5	107.5	137.4	180.2	105.6	126.7
B/Bmsy, end current year (proj.) (%)	143.6	40.3	115.0	138.8	166.5	129.2	111.4
Biomass risk, end current year (%)	12.0	32.5	–	–	–	–	–
Z/Z_{msy}, current year (proj.) (%)	–	–	39.0	58.3	84.0	–	62.8
Carrying capacity	3878	3248	1920	2969	4721	1151	2818
Max. sustainable yield ratio (%)	11.2	7.1	5.9	10.4	15.4	8.8	9.7
Survey catchability (%)	18.1	15.2	7.8	13.6	23.2	4.4	15.3
CPUE catchability	1.2	1.0	0.5	0.9	1.6	0.3	1.0
Effective cod biomass 2017 (kt)	26.2	25.5	15.1	21.4	29.6	11.8	–
$P_{50\%}$	4.0	7.7	0.2	1.1	4.2	-4.8	1.3
V_{max}	1.5	2.0	0.3	0.6	1.8	-1.2	0.8
CV of process (%)	14.4	3.8	11.7	13.8	16.6	12.6	14.0
CV of survey fit (%)	16.9	1.8	15.8	17.0	18.2	17.2	16.8
CV of CPUE fit (%)	20.1	2.9	18.2	19.6	21.4	18.5	19.7

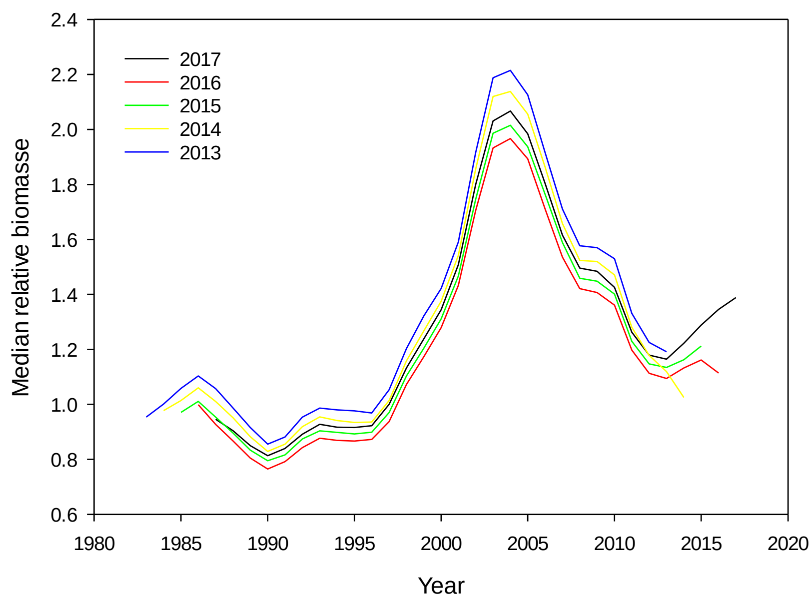

Fig. 3.9. Retrospective plots of the relative biomass B/B_{msy} 2013 to 2017.

NIPAG noted the 2017 parameter estimate of MSY was quite different than that estimated in 2016 (table above) suggesting some degree of instability of the model. This was further demonstrated by changes in perception of stock trajectory in recent years based on a 5-year retrospective analysis (Fig. 3.9). It was also noted that since 2011, the input data is based on the most recent 30-year period which effectively loses a year of historical data in the current year assessment. This was introduced as a practical computational convenience which has the consequence of eliminating an earlier period in which high cod abundance was realized. The resulting instability should be investigated further.

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 (Fig. 3.10). 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. Increases in the cod stock coupled with high catches were associated with higher mortalities and continuing decline in the modelled biomass until 2013. At the end of 2017, the stock will be above B_{msy}, and the risk of being below B_{lim} is very low (<1%).

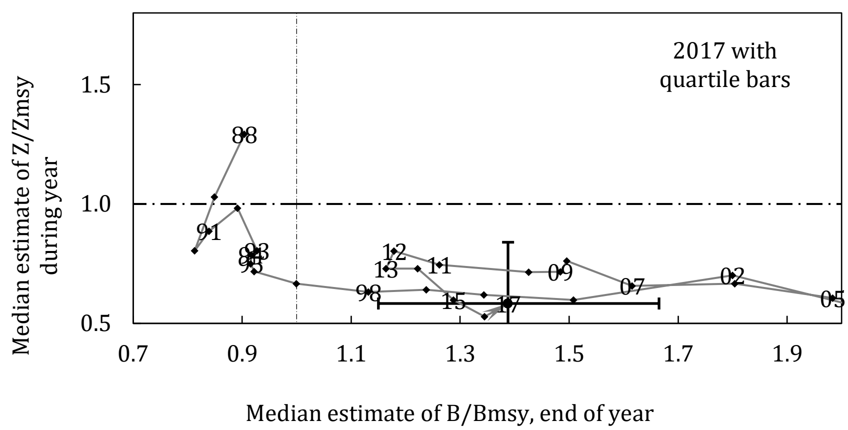

Fig. 3.10. Northern shrimp in Subarea 1 and Div. 0A: Trajectory of relative biomass and relative mortality, 1987–2017.

e) State of the stock

Biomass. A stock-dynamic model showed a maximum biomass in 2004 with a decline over 2004 to 2013. Since then the biomass has increased slightly. At the end of 2017, the biomass is estimated to be 39% above B_{msy}. The risk of being below B_{lim} is very low (<1%).

Mortality. With 2017 expected catches at 90 000 t the probability that total mortality will exceed Z_{msy} is estimated to be 15.5%.

Recruitment. The number of pre-recruits (14 – 16.5 mm) observed in the survey is close to its 12-year maximum. The number at age 2 in 2017, expected to contribute significantly to the fishable biomass within four years, is below its 12-year lower quartile, and has been declining since the last peak in 2015.

State of the Stock. The stock is estimated to be 39% above B_{msy} and the risk of being below B_{lim} in 2017 is very low (<1%).

F) Projections

Predicted probabilities of transgressing precautionary reference points in 2018–2022 under eight catch options and subject to predation by the cod stock with an 'effective' biomass of 25 kt (the value for 2017 being 21.4 kt) were evaluated. Additional projections assuming 'effective' cod biomasses of 40 kt were conducted but not shown in this report and results indicated small differences in risk probabilities (SCR doc 17/052).

At the present state the biomass is 39% above its $B_{msy,}$ and in the medium term, model results estimate that catches of up to 105 t/yr would be associated with a stable stock (Fig. 3.11).

Medium-term projections were summarized by plotting the risk of exceeding Z_{msy} against the risk of falling below B_{msy} over 5 years (Fig. 3.12). For catches of less than 105 kt the mortality risk is less than 21% but increasing over the projection period. The immediate biomass risk is relatively insensitive to catch level but changes with time.

25 000 t cod	Catch option ('000 t)							
Risk of:	100	105	110	115	120	125	130	135
falling below Bmsy end 2018 (%)	13.3	14.7	14.6	15.0	15.0	15.4	16.3	16.5
falling below Bmsy end 2019 (%)	14.6	16.0	16.8	17.3	17.8	18.7	19.5	19.2
falling below Bmsy end 2020 (%)	16.0	17.6	18.5	19.2	20.3	21.6	22.4	22.6
falling below Blim end 2018 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
falling below Blim end 2019 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
falling below Blim end 2020 (%)	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
exceeding Zmsy in 2018 (%)	18.0	20.5	22.7	25.0	27.6	30.5	32.9	34.9
exceeding Zmsy in 2019 (%)	19.0	21.2	23.8	26.8	29.3	31.8	34.5	37.0
exceeding Zmsy in 2020 (%)	19.8	22.9	25.0	27.4	30.3	33.9	36.5	38.5

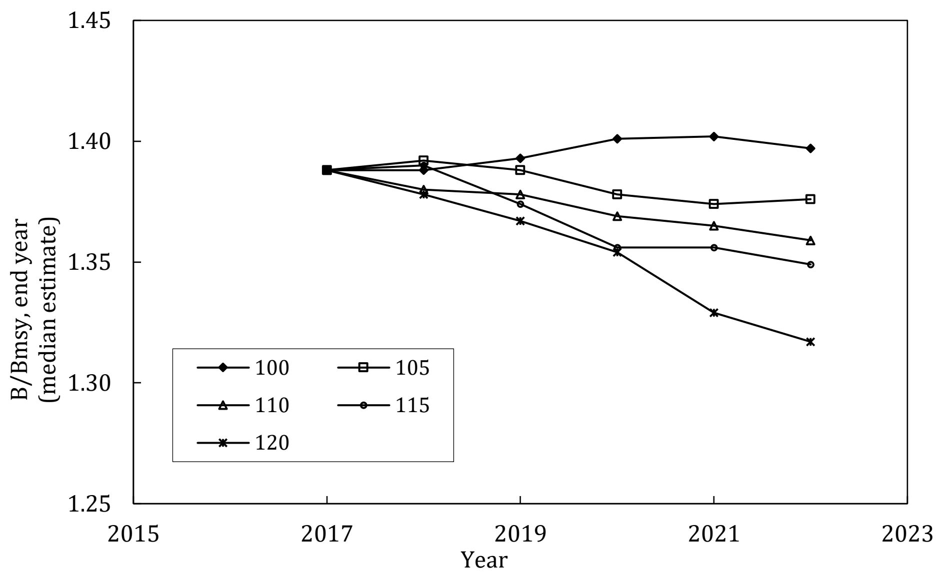

Fig. 3.11. Northern shrimp in Subarea 1 and Div. 0A: Median estimates of year-end biomass trajectory for 2018–2022 with annual catches at 100–120 kt and an 'effective' cod stock assumed at 25 kt.

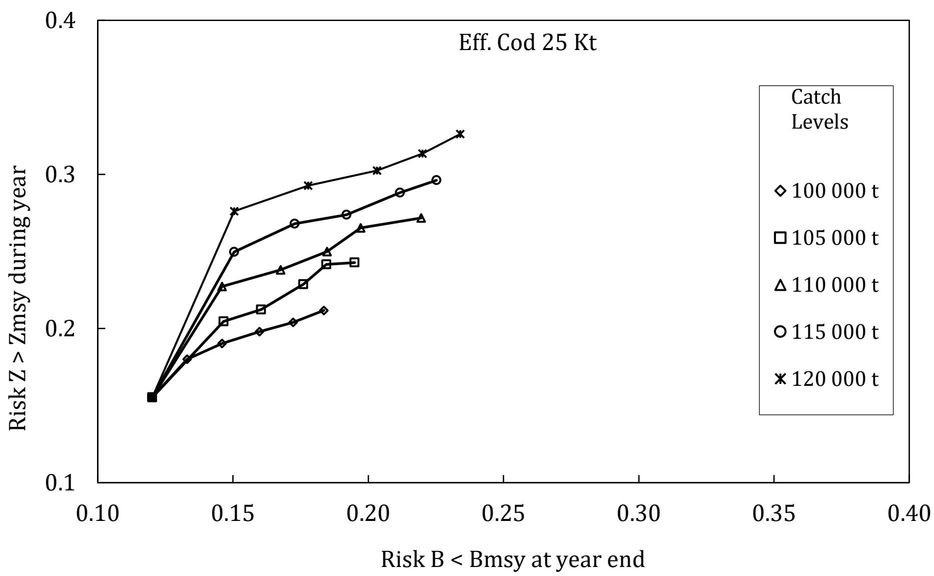

Fig. 3.12. Northern shrimp in Subarea 1 and Div. 0A: Risks of transgressing mortality and biomass precautionary limits with annual catches at 100–120 kt projected for 2018–22 with an 'effective' cod stock assumed at 25 kt.

g) Other studies

A stochastic surplus production model (SPiCT, Pedersen and Berg 2016) was applied using similar indices of fishable biomass, CPUE and catch data as in the current production model. The results of the SPiCT model were comparable to the output based on the current model (SCR Doc. 17/60).

An exploratory fishery has been conducted in Melville Bay in 2014 to 2016. Results indicated that CPUE was less than that south of 73°30'N and shrimps tended to be larger than those south of 73°30'N (SCR Doc. 17/54).

Applying the SPiCT model to *Pandalus montagui* data did not show reliable results. Analysis of logbooks indicated increasing catches of *P. montagui* since 2011. At the current time it is not possible to provide scientific advice for this stock. However, the data need to be further explored (SCR Doc.17/53, 17/62).

h) 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 offshore 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*

Status: Completed.

NIPAG **recommended in 2013 that** *the relationship between estimated numbers of small shrimps and later estimates of fishable biomass should be investigated anew.*

Status: Completed (SCR Doc. 17/052 and SCR Doc.17/058)). The study showed a relatively good correlation between the number of age-2 shrimp and the fishable biomass 3 or 4 years later. Relationships should only be adjusted for autocorrelation, if found significant.

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: Completed. 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 (SCR Docs. 15/050 and 160/47).

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

Status: Completed. In order to move from an 'expert judgment' of next year's cod biomass to be applied in the predictions of shrimp biomass in the following year, a linear regression approach was presented where biomass of an age-group was regressed against the biomass of the year-class in next year's survey. Based on these regression outputs, the prediction of cod biomass in the following year was derived (SCR Doc 17/059).

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

Status: In progress; this recommendation is reiterated.

In 2017:

NIPAG **recommends**: *as information from the fishery indicates that catch sensors have been used for some time, the use of new technology which may influence the CPUE should be investigated and documented.*

NIPAG **recommends that** *the relationship between the pre-recruit index and the subsequent years' fishable biomass should be investigated further.*

NIPAG **recommends that** *the instability of the model should be explored*.

NIPAG **recommends that** *the P. montagui fishery should be explored further.*

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

(SCR Docs. 04/12, 16/45, 17/57)

a) Introduction

Northern shrimp off East Greenland in ICES Div. XIVb and Va is assessed as a single population.

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 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.

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. As the fishery developed, catches increased rapidly to more than 15 000 t in 1987-88, but declined thereafter to about 9 000 t in 1992-93.

Following the extension of the fishery south of 65°N in 1993, catches increased again reaching 11 900 t in 1994. From 1994 to 2003, total catches fluctuated between 11 500 and 14 000 t, with the southern area accounting for 50-60% of the catch (Fig. 4.1). Since 2012, no fishery has taken place in the southern area.

Since 2004, total catches have decreased and in 2016 only 49 t were caught. Catches in the first half year of 2017 were 557 t. Since 2015, this has been an opportunistic fishery with vessels stopping off on route between other fishing grounds.

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

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[1]
Recommended TAC, total area	12400	12400	12400	12400	12400	12400	2000	2000	2000	2000
Actual TAC, Greenland	12400	12835	11835	12400	12400	12400	8300	6100	5300	5300
North of 65°N, Greenland EEZ	2529	3945	3323	1145	1893	1714	622	576	49	557
North of 65°N, Iceland EEZ	0	0	0	0	0	0	0	0	0	0
North of 65°N, total	2529	3945	3323	1145	1893	1714	622	576	49	557
South of 65°N, Greenland EEZ	266	610	280	53	215	3	0	0	0	0
TOTAL NIPAG	2794	4555	3602	1199	2109	1717	622	576	49	557

[1] Catches until July 2017

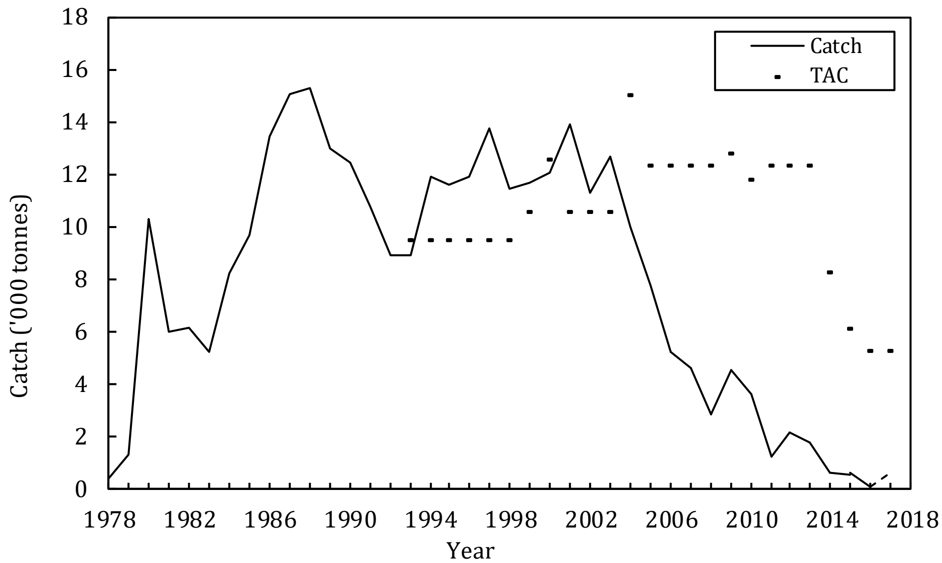

Fig. 4.1. Shrimp in Denmark Strait and off East Greenland: Catch and TAC (2017 catches until July).

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. 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 the two areas, north and south of 65˚N. Standardised Catch-Per-Unit-Effort (CPUE) was calculated and applied to the total catch of the year to estimate the total annual standardised effort.

The overall CPUE index increased from 1993 to 2009, followed by a continuous decline to a low value in 2014 and has been increasing since 2014 (Fig. 4.2). In 2016 and 2017 the overall CPUE index increased, but the estimates for 2016 and 2017 are based on a low number of hauls (36 and 219) and are therefore subject to large uncertainty. Due to changing fishing patterns, it is unclear whether recent values reflect the state of the stock. As most of the fishing has been conducted in the northern area the overall CPUE index is dominated by the CPUE index for this area (Fig. 4.2 and Fig. 4.3). 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.

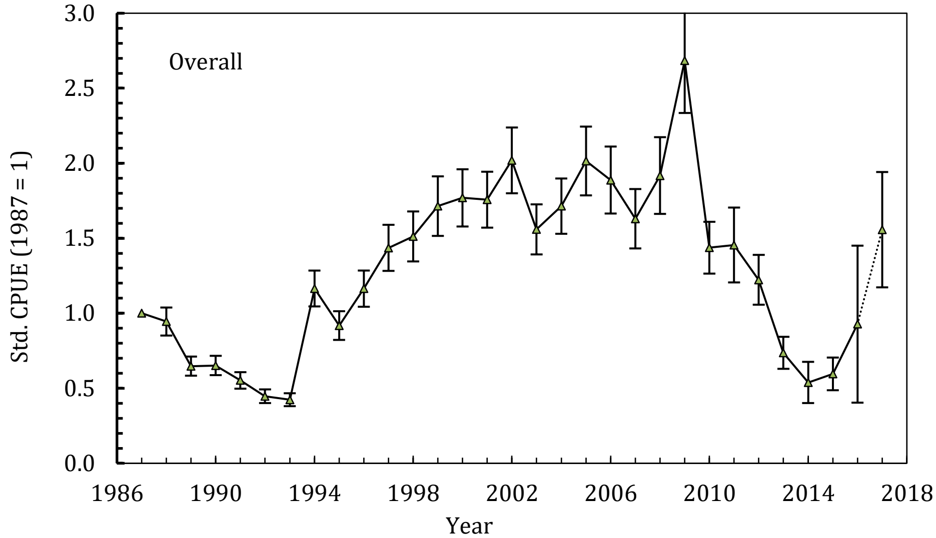

Fig. 4.2. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE index (1987 = 1) with ± 1 SE combined for the total area. 2017 data until July (grey dotted line).

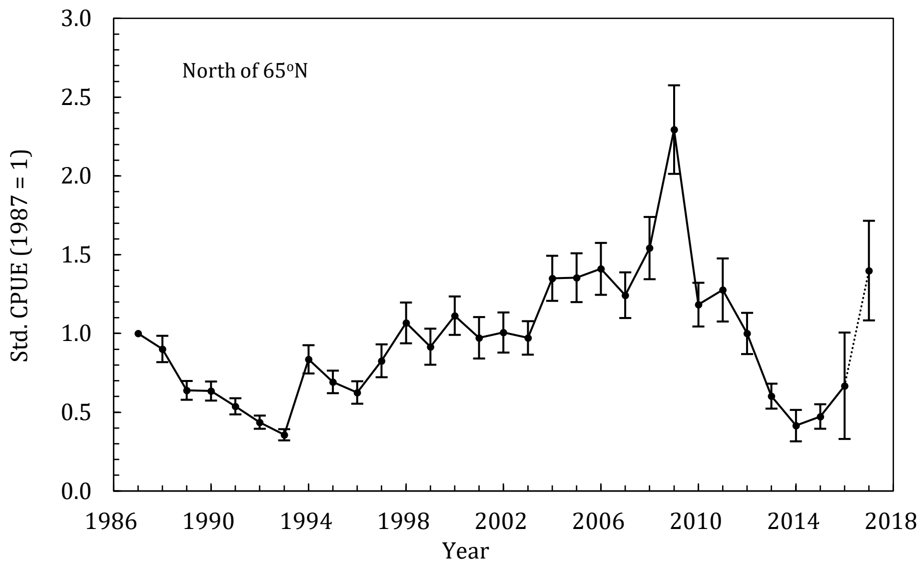

Fig. 4.3. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1987 = 1) with ±1 SE fishing north of 65°N. 2017 data until July (grey dotted line).

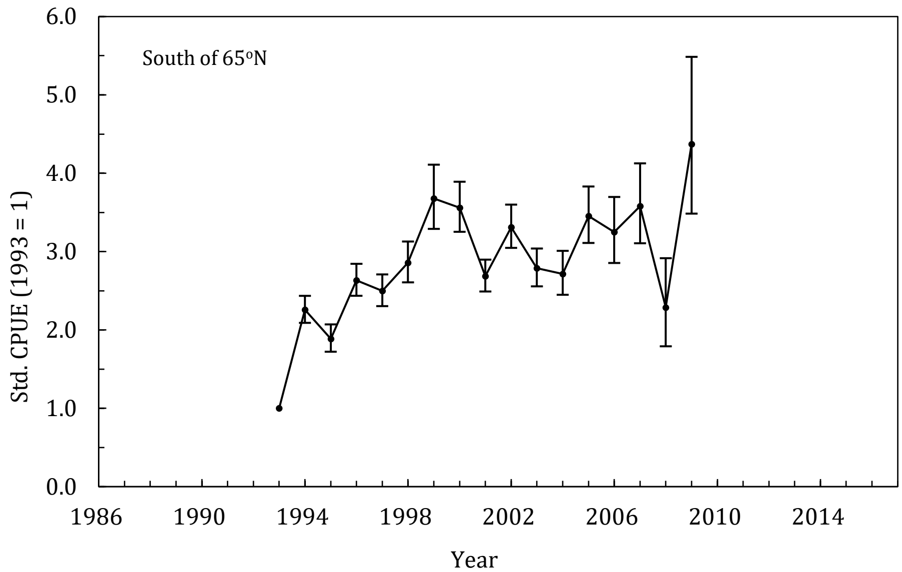

Fig. 4.4. Shrimp in Denmark Strait and off East Greenland: Annual standardized CPUE (1993 = 1) with ±1 SE fishing south of 65°N (no data for the area since 2010).

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).

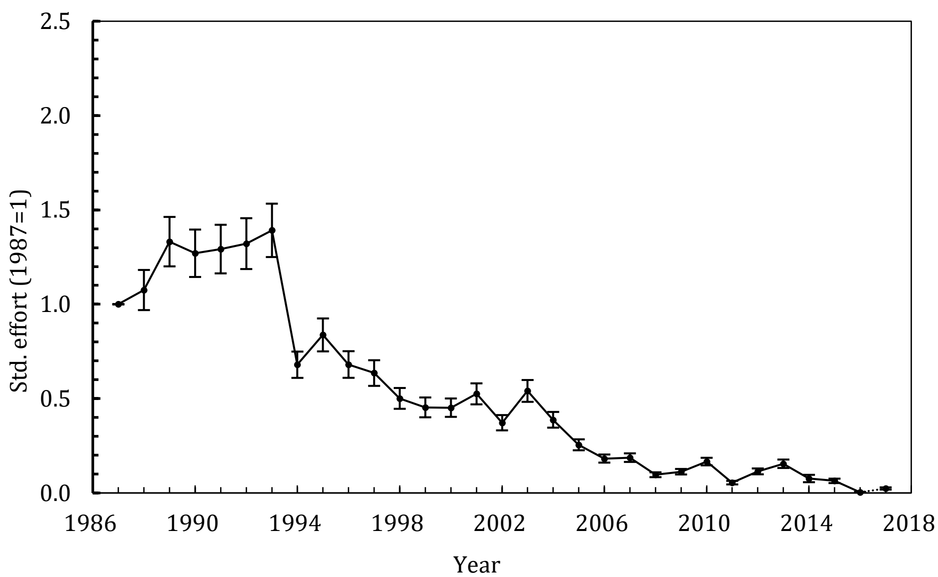

Fig. 4.5. Shrimp in Denmark Strait and off East Greenland: Annual standardized effort indices, as a proxy for exploitation rate (± 1 SE; 1987 = 1), combined for the total area (2017 effort until July).

ii) Research survey data

Trawl surveys have been conducted to assess the stock status of northern shrimp in the East Greenland area since 2008. Due to technical problems, no survey was conducted in 2017. The main objectives of the survey are 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 has since then remained at a low level (Fig. 4.6).

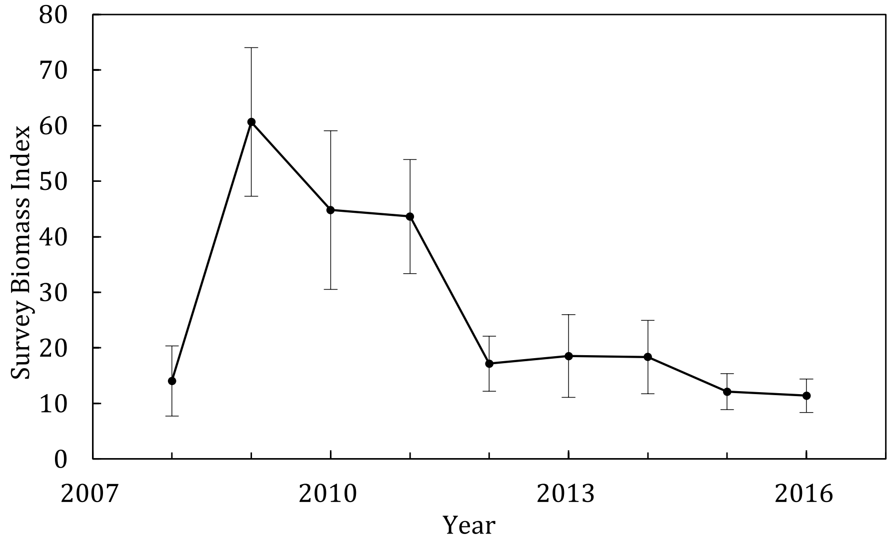

Fig. 4.6. Shrimp in Denmark Strait and off East Greenland: Survey biomass index from 2008- 2016 (± 1 SE). No survey was carried out in 2017.

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

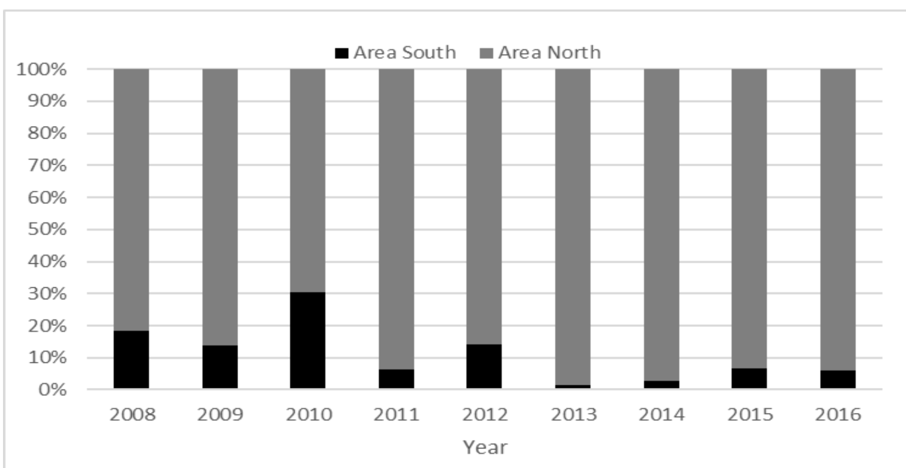

Fig. 4.7. Shrimp in Denmark Strait and off East Greenland: Distribution of survey biomass north and south of 65°N (in %) from 2008-2016. No survey was carried out in 2017.

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.

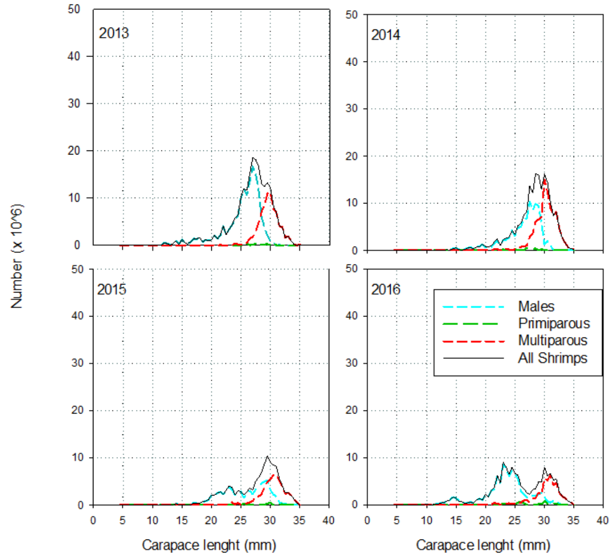

Fig. 4.8. Shrimp in Denmark Strait and off East Greenland: Numbers of shrimp by length group (CL) in the total survey area in 2013–2016. No survey was carried out in 2017.

c) Assessment results

Evaluation of stock status is based upon interpretation of commercial fishery and research survey data. The trends in the survey and the standardized CPUE have been similar since the start of the survey, however they diverged in 2016. Since 2015, this has been an opportunistic fishery with vessels stopping off on route between other fishing grounds. This may indicate that the CPUE may no longer be a reliable indicator of the stock status. No research survey was carried out in 2017.

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} (SCS Doc. 04/12). This corresponds to an index value of 495 t.

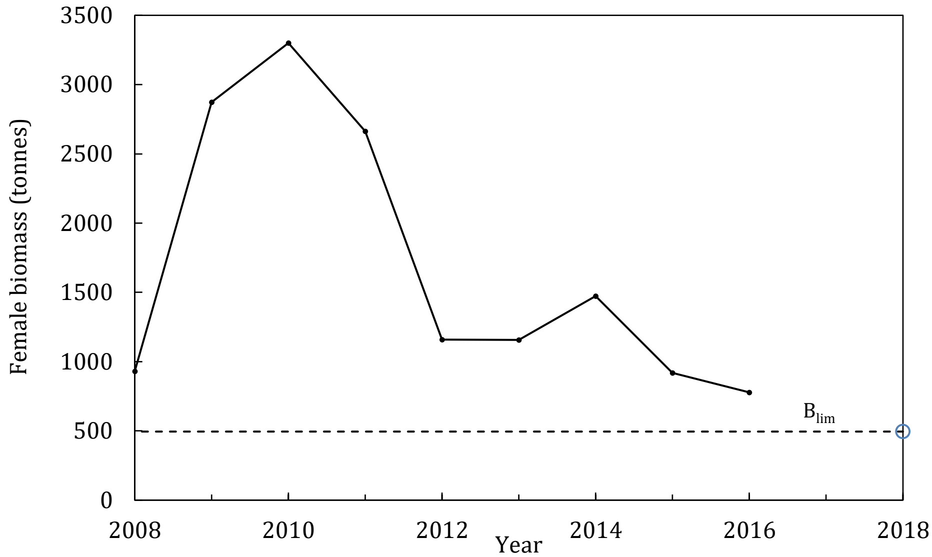

Fig. 4.9. Shrimp in Denmark Strait and off East Greenland : Spawning stock biomass index (SSB) from 2008-2016 and precautionary approach B_{lim}. B_{lim} is defined as 15% of the maximum female biomass over the time-series. No survey was carried out in 2017.

e) State of the stock

CPUE: The CPUE index declined continuously from its highest point in 2009 to a low value in 2014 and has been increasing since then (Fig. 4.2). Estimates for 2016 and 2017 are relatively uncertain. It is unclear whether recent values reflect the state of the stock.

Recruitment. No recruitment estimates were available.

Biomass. The survey biomass index has decreased by around 80% since 2009. No survey was conducted in 2017.

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

State of the stock. The stock size remained at a very low level in 2016 (relatively close to B_{lim}) despite several years of very low exploitation rates. There is no new information to indicate a change in stock status.

f) Research recommendations

NIPAG **recommended in 2016** that *the potential for developing a B_{lim} reference point for the stock be explored.*

Status: completed, A proxy limit reference point has been established based on the NAFO PA framework (SCS 04/12).

NIPAG **recommended in 2016** that *genetic stock structure of Pandalus borealis in West and East Greenland should be further explored.*

Status: in progress. This recommendation is reiterated.

NIPAG **recommends in 2017** that *error bars should be added to the SSB so that risk can be assessed in relation to B_{lim}.*

5. Northern shrimp (*Pandalus borealis*) in the Skagerrak and Norwegian Deep (ICES Subdivision 27.3a.20 and the eastern part of Division 27.4a)

(SCR Docs. 08/75; 13/68, 74; 14/66; 16/53, 55, 56, 57 and ICES Stock Annex.)

a) 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 (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 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 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). In 2009, an EU ban on high-grading was implemented and since 2016, the EU landing obligation applies for *Pandalus* in 27.3a and 27.4a. To protect juvenile shrimp, a real time closure (RTC) regime, triggered when the amount of small shrimp exceeds a certain threshold, was implemented in Norwegian waters in 2016.

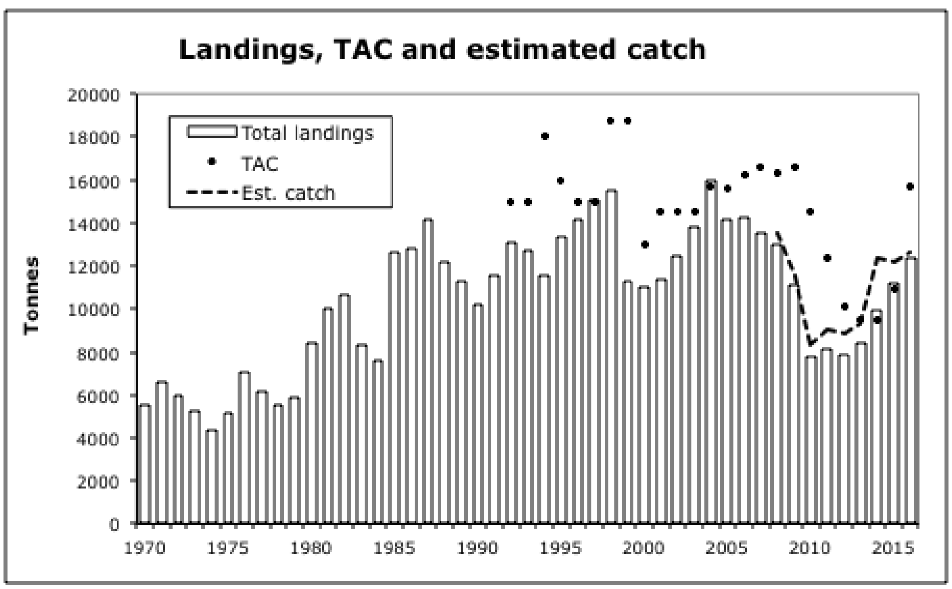

Fig. 5.1. Northern shrimp in Skagerrak and Norwegian Deep: TAC, total landings by all fleets, and total estimated catch including estimated Swedish discards for 2008–2016, and Norwegian and Danish discards for 2009–2016.

Table 5.1. Northern shrimp in Skagerrak and Norwegian deep: TACs, landings, and estimated discards and catches (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 a 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 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"). However, since 2016, shrimp <15 mm CL are marketable, but fetch a lower price than medium-sized shrimp. 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 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 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 > approximately 20 cm length from the catch. Landings delivered by vessels using grids comprise 95–99% of shrimp (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 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 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 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 (Fig. 5.2; 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 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 2006–2017. 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

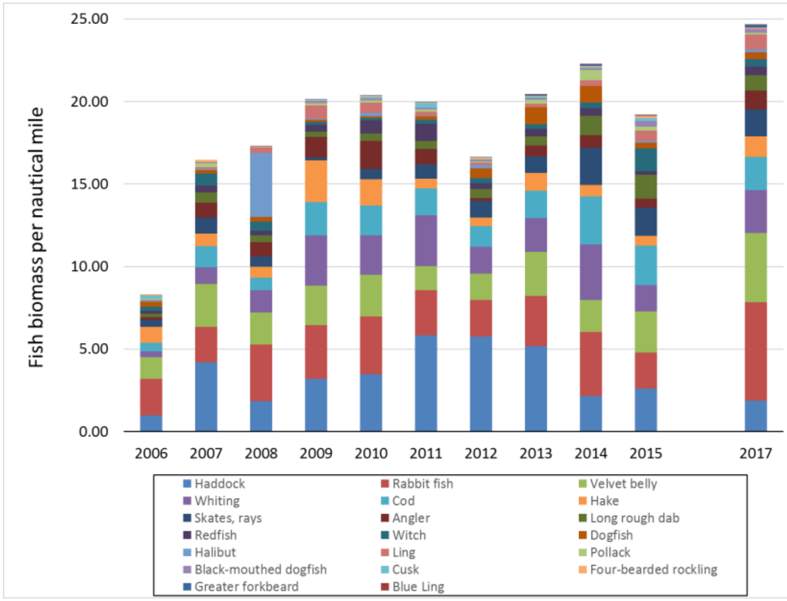

Fig. 5.2. Northern shrimp in Skagerrak and Norwegian Deep: Estimated indices of predator biomass (catch in kg per towed nautical mile) from the Norwegian shrimp survey in 2006–2017 excluding saithe, roundnose grenadier and blue whiting. The 2016 survey data have been omitted (see text for details).

b) Input data

i) Commercial fishery data

Danish, Swedish and Norwegian catch and effort data from logbooks have been analyzed and standardized (SCR Docs. 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. 5.3).

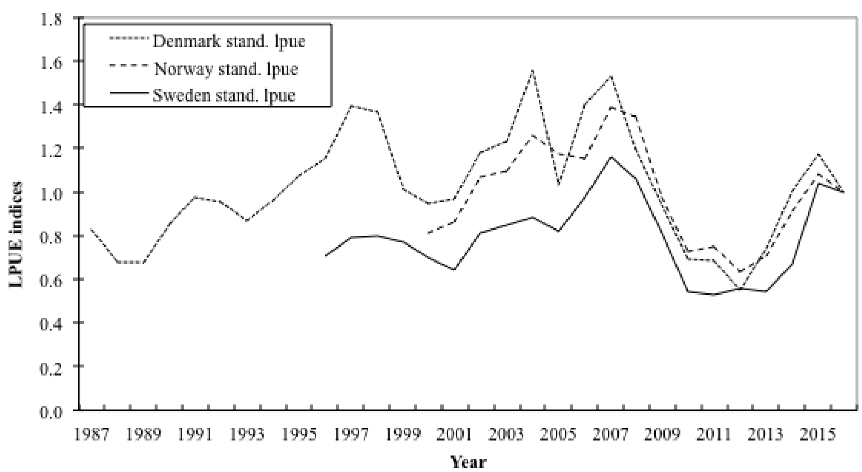

Fig. 5.3. Northern shrimp in Skagerrak and Norwegian Deep: Danish, Norwegian and Swedish standardized LPUE until 2016. Each series is standardized to its final year.

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

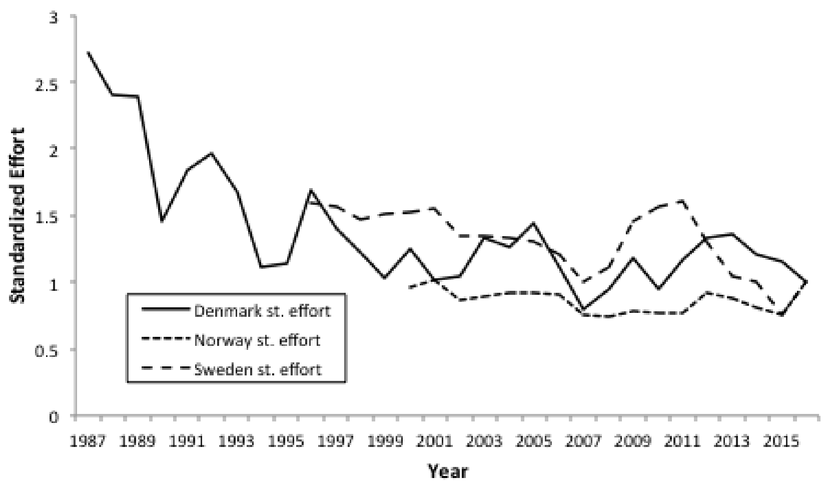

Fig. 5.4. Northern shrimp in Skagerrak and Norwegian Deep: Estimated standardized effort. Each series is standardized to its final year.

ii) Sampling of catches

Length frequencies of the catches from 1985 to 2016 (SCR Docs. 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).

iii) Research 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. 5.5). 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 from the time-series.

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. 5.5). However, the survey time-series has not been standardized 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. 5.6). The 2016 year class is around the average of the last ten years.

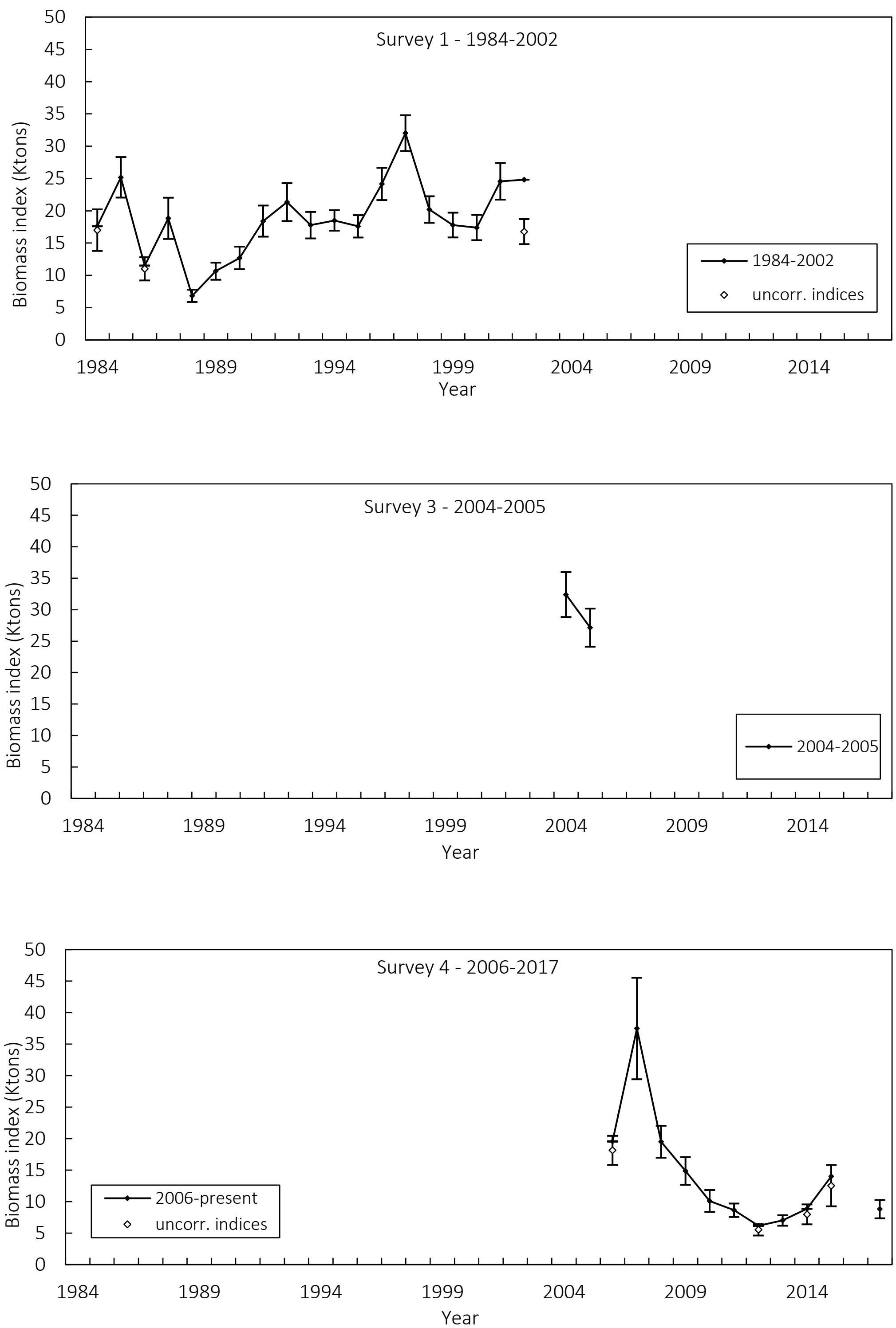

Fig. 5.5. Northern shrimp in Skagerrak and Norwegian Deep: Estimated survey biomass index in 1984–2017. The point estimate of 2003 is not shown. The 2016-survey data have been omitted (see text for details).

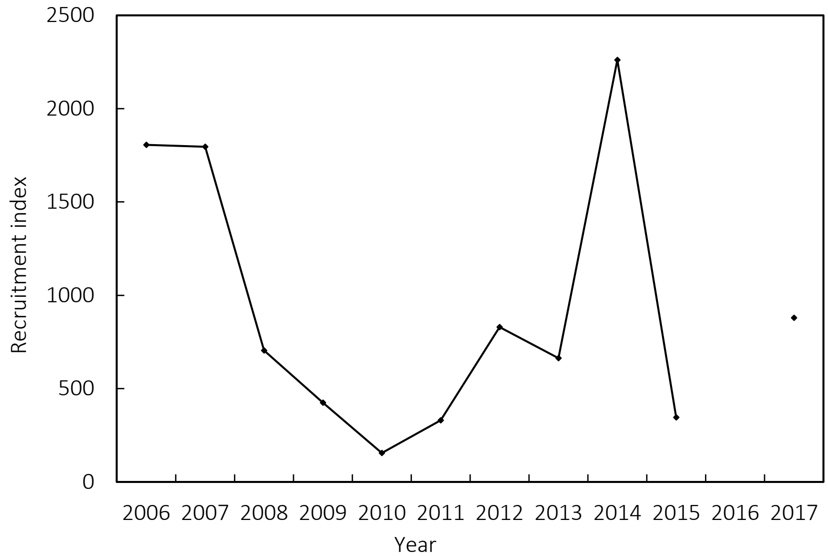

Fig. 5.6. Northern shrimp in Skagerrak and Norwegian Deep: Recruitment index as numbers at age 1, 2006–2017. The 2016 survey data have been omitted (see text for details).

c) Assessment

Assessment model

The stock assessment model 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).

Assessment results

SS3 model diagnostics of this year's run are very similar to the diagnostics of the run conducted in February 2017, 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 (Berenboim *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. 5.7). 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 2016 meeting to fully explore the sensitivity to the M assumption used and stressed the importance of further investigations to be conducted well in advance of the next proposed benchmark in 2019–2020.

Fig. 5.7. Northern shrimp in Skagerrak and Norwegian Deep: *F* and *SSB* assessment results from 2016 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. 5.8.

Since 2008, when *SSB* was 21 643 t, which is the second highest *SSB* estimate of the time-series, the *SSB* decreased to the time-series low of 6069 t in 2012. The *SSB* then increased up to 2016, but decreased again to 9187 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 been exploited at a level higher than the F_{msy} of 0.62, except in 2015 when the stock was fished at 0.52.

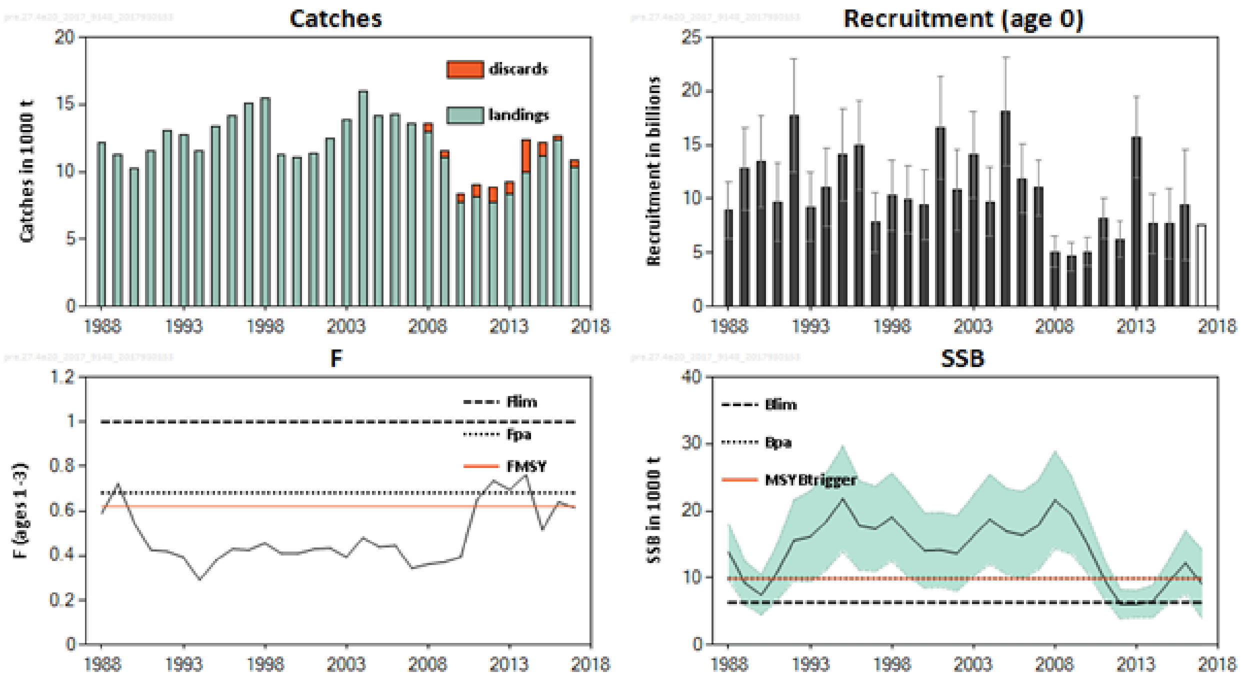

Fig. 5.8. Northern shrimp in Skagerrak and Norwegian Deep: Summary assessment output. Total catch, including estimated discards since 2008 ('000 tonnes) and *F*, *SSB* and *R* assessment results. *SSB* and *R* depicted with 90% confidence intervals. The assumed recruitment value (geometric mean of the last ten years) for 2017 is unshaded.

Model retrospective

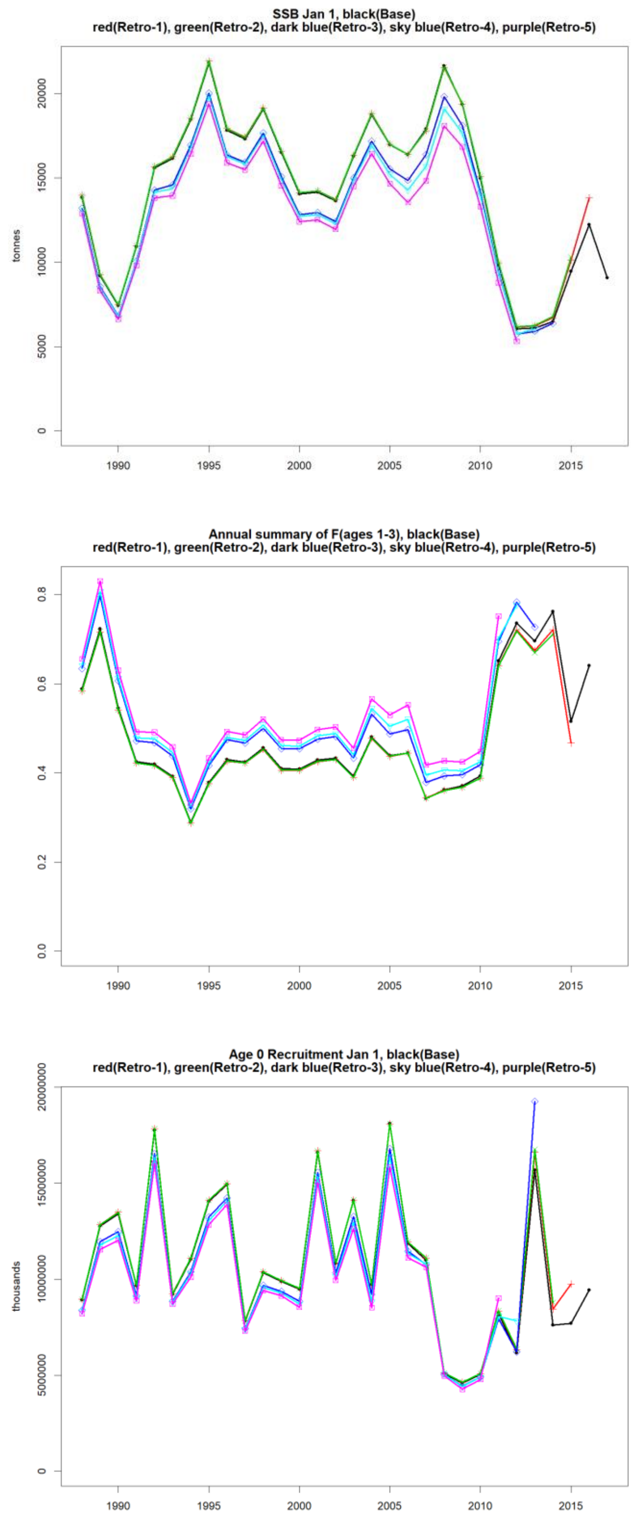

Fig. 5.9. Northern shrimp in Skagerrak and Norwegian Deep: Model retrospective of *SSB*, *F* (ages 1–3) and *R*.

Model retrospective is shown in Fig. 5.9. 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.

d) 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 "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 5.4). Under the ICES Precautionary Approach (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 estimated at the benchmark in 2016.

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

e) Catch options

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

VARIABLE	VALUE	SOURCE	NOTES
F_{2017}	0.62	ICES (2017)	Corresponds to the assumed catches in 2017
SSB_{2018}	8965 t	ICES (2017)	
R_{2017}	7515 million	ICES (2017)	Geometric mean 2007–2016
R_{2018}	7515 million	ICES (2017)	Geometric mean 2007–2016
Catch (2017)	10904 t	ICES (2017)	

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

Basis	Total catch (2018)	Ftotal (2018)	SSB (2019)	% SSB change *	% TAC change **
ICES advice basis					
MSY approach: F = F_{MSY} x (SSB_{2017}/ MSY $B_{trigger}$)	10 475	0.57	9246	3.1	1.5
Other options					
F = 0	0	0	16 361	82	-100
F_{pa}	11 916	0.68	8334	-7	15.5
F_{MSY}	11 153	0.62	8414	-6.1	8.1
F_{2017}	11 153	0.62	8414	-6.1	8.1

* SSB 2019 relative to SSB 2018.

** Catch in 2018 relative to TACs 2017.

f) Projections

Given an estimated catch of 10 904 t in 2017, catch options were evaluated for 2018 (Table 5.6). The 2018 estimated catch when applying the MSY approach (10 475 t) will result in an SSB at the beginning of 2019 of 9246 t.

g) 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 2013.

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 has been below average in recent years and fishing mortality is above F_{msy} in 2016.

Yield. According to the ICES MSY approach, catches in 2018 should be no more than 10 475 t, which is equivalent to an *F* of 0.57.

h) Recommendations

Management recommendations

NIPAG in 2016 **recommended** 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

Research recommendations

- *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 2019 or 2020. This recommendation is reiterated.

- *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. This recommendation is reiterated.

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

Status: No progress has been made. this recommendation is reiterated.

Research recommendations from the 2016 meeting

- *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 recommendation is reiterated.

- NIPAG **recommended** *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.*

***Status**:* not conducted*.*

NIPAG **recommends** *in 2017 a full benchmark for this stock including a data compilation workshop in the near future and no later than 2020 (Annex V).*

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. 2016a. 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. 72 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 Subareas 1 and 2)

Background documentation (equivalent to stock annex) is found in SCR Docs. 17/67, 68, 69; 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 Subareas 1 and 2) 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).

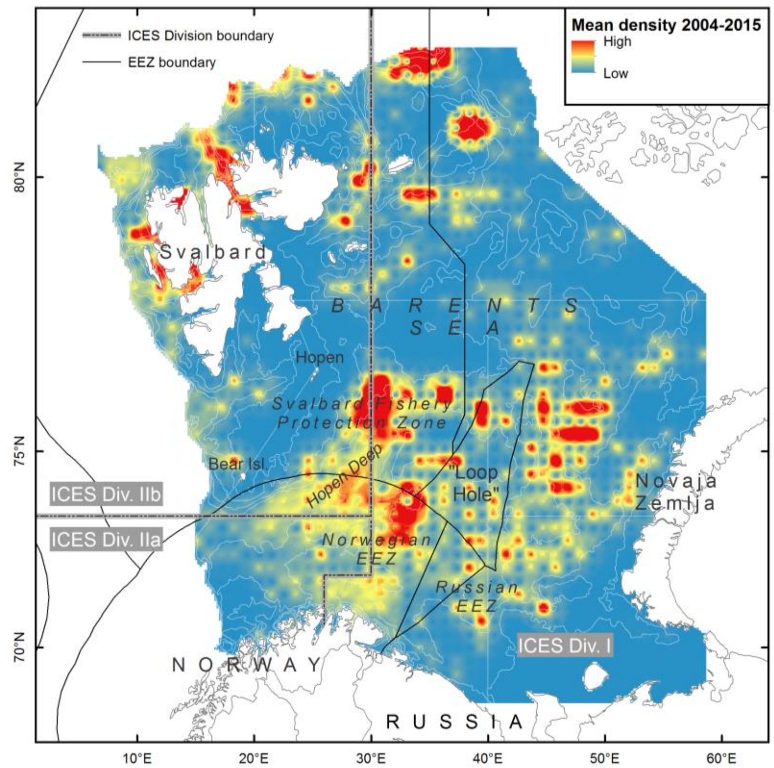

Fig. 6.1. Shrimp in ICES SA 1 and 2: Stock distribution. Survey density index (kg/km2).

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 28 000 t in 2017.

Table 6.1. Shrimp in ICES SA 1 and 2: Recent catches in metric tonnes, as used by NIPAG for the assessment.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017[1]
Recommended TAC	50 000	50 000	50 000	50 000	60 000	60 000	60 000	60 000	70 000	70 000	70 000
Norway	25558	20662	19784	16779	19928	14158	8846	10234	16618	10896	9000
Russia	192	417	0	0	0	0	1067	741	1151	2460	3000
Others	4181	7109	7488	8419	10298	10598	9336	9989	16252	16223	16000
Total	29931	28188	27272	25198	30226	24756	19249	20964	34022	29609	28000

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

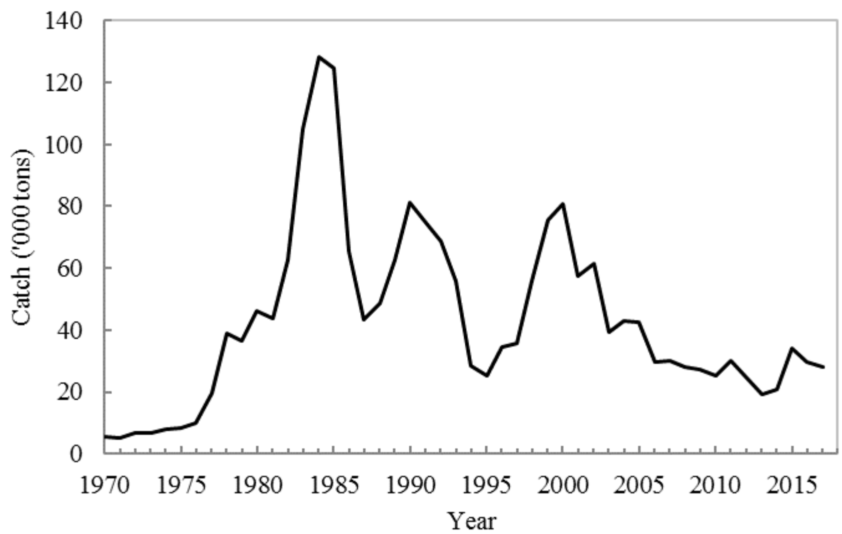

Fig. 6.2. Shrimp in ICES SA 1 and 2: Total catches since 1970 (2017 projected to the end of the year).

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 (ICES 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.

In 2017, specific information on bycatch from EU-Estonia based on onboard scientific observers was presented. They indicated 2.9% by weight of fish discards and 0.6% discards of shrimp. Work will continue to explore these data further.

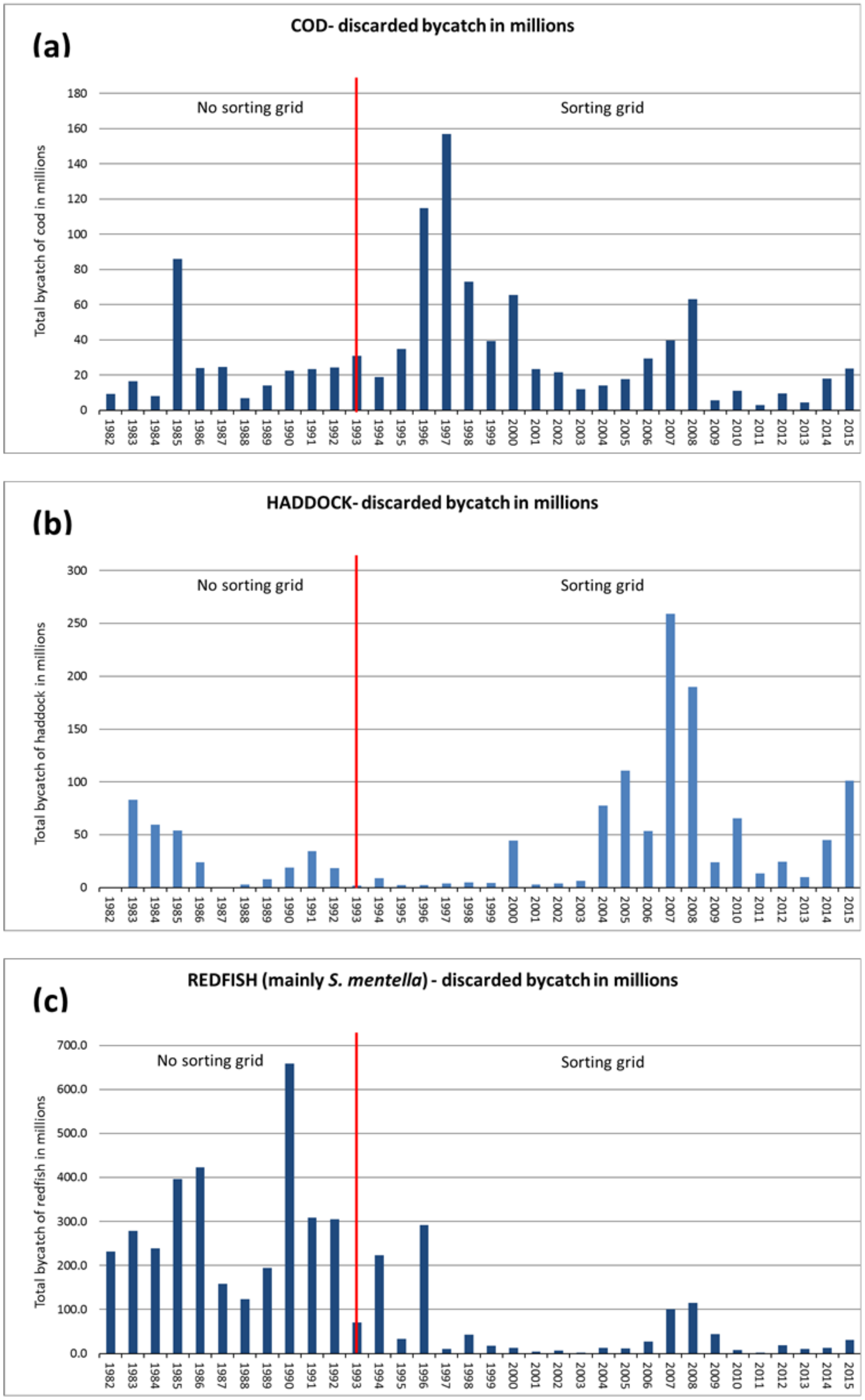

Fig. 6.3. Shrimp in ICES SA 1 and 2: Estimated bycatch of (a) cod, (b) haddock and (c) redfish in the Norwegian shrimp fishery (million individuals). The sorting grid was introduced in 1992 and has been mandatory since. (Figures from AFWG 2016.)

b) Input data

i) Commercial fishery data

A major restructuring of the shrimp fishing fleet towards fewer and larger vessels took place during 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.

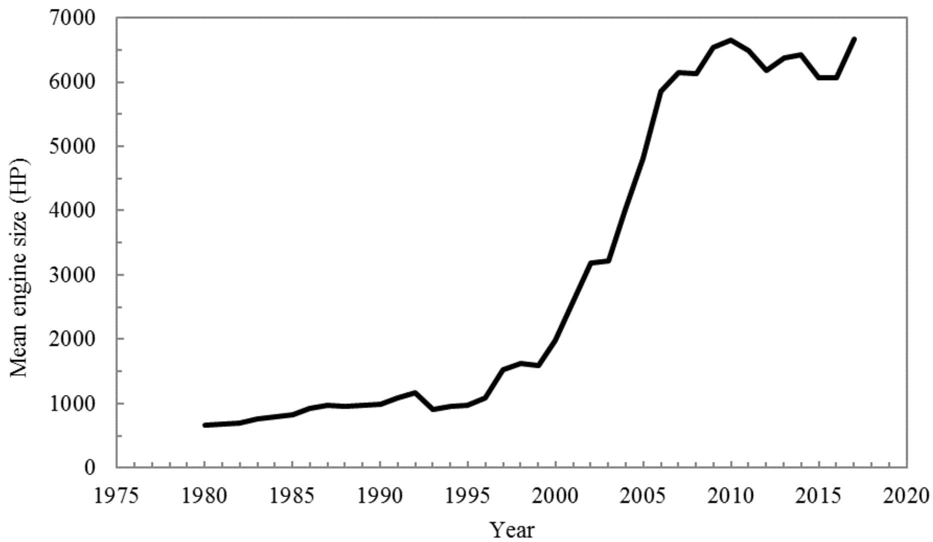

Fig. 6.4. Shrimp in ICES SA 1 and 2: Mean engine power (HP) weighted by trawl-time (Norwegian data).

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.

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). 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. 6.5). Information from the industry points to decreasing catch rates and more frequent area closures due to bycatch of juvenile fish on the traditional shrimp fishing grounds as the main reasons for the observed change in fishing pattern.

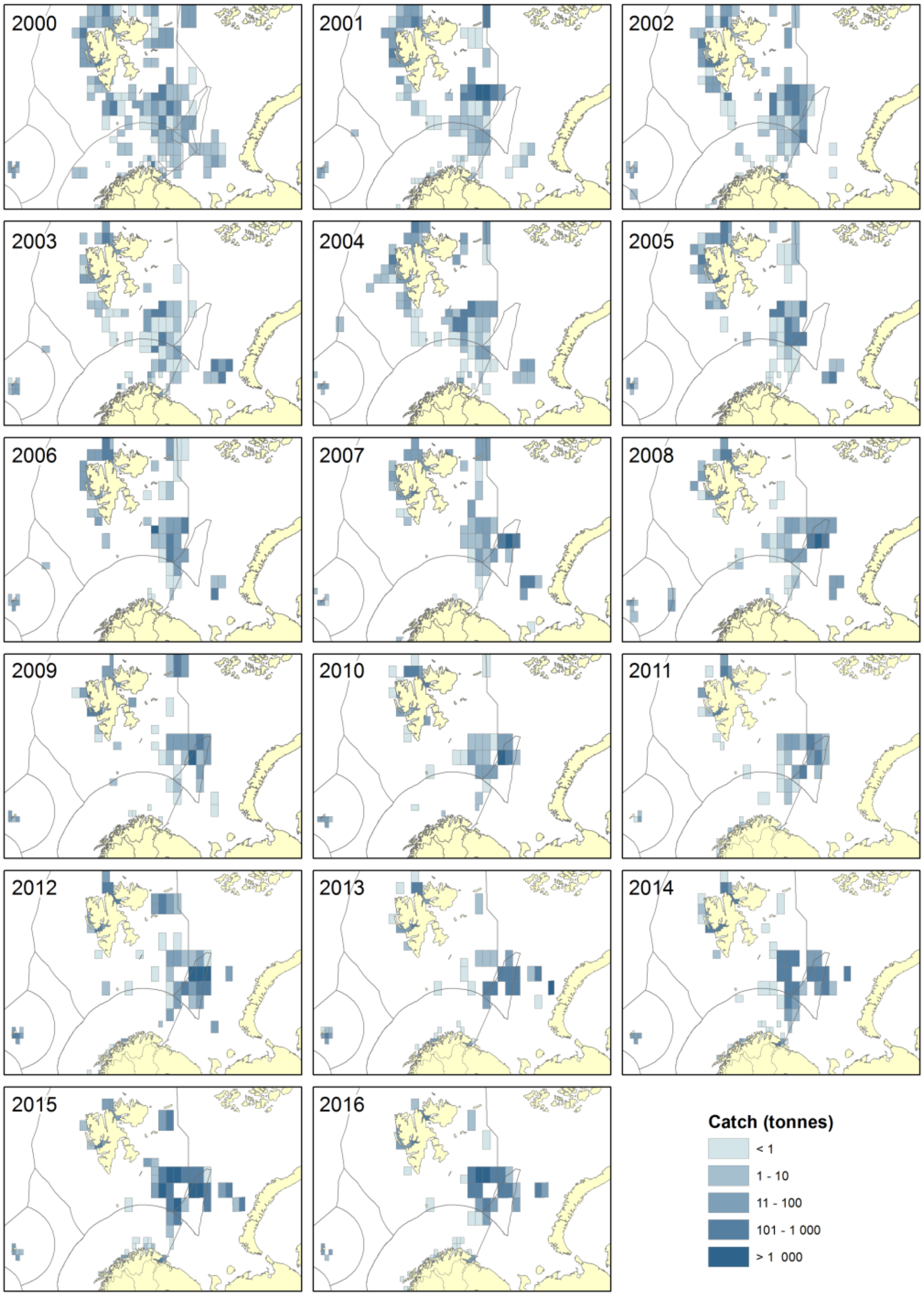

Fig. 6.5. Shrimp in ICES SA 1 and 2: Distribution of catches by Norwegian vessels since 2000 based on logbook information.

Norwegian logbook data were used in a multiplicative model (GLM) to calculate standardized annual catch rate indices (SCR Doc. 17/67). 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. 6.6).

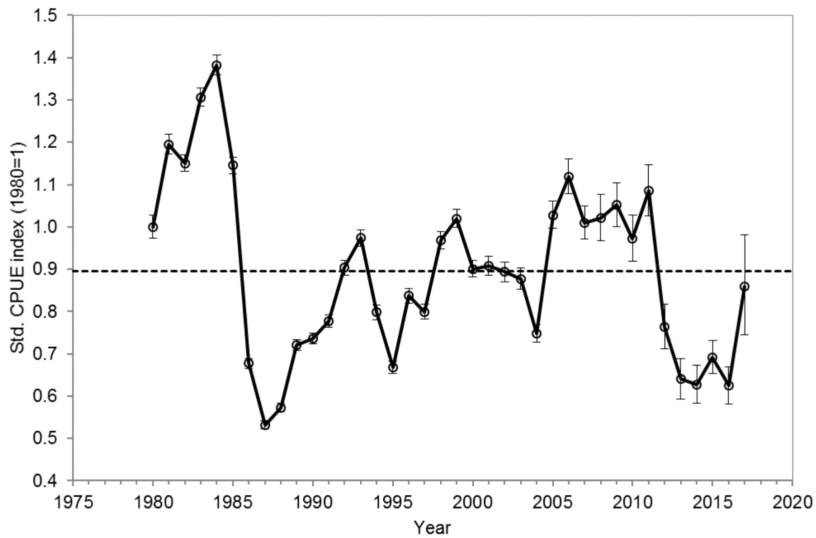

Fig. 6.6. Shrimp in ICES SA 1 and 2: Standardized CPUE based on Norwegian data. Error bars represent 1 SE; dotted line is the mean of the series.

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 Docs. 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" in August/September, which monitors shrimp along with a multitude of other ecosystem variables in the Barents Sea and around Svalbard (SCR Docs.14/55, 7/68).

Biomass. The biomass indices of all surveys have fluctuated without trend over their respective time periods covered (Fig. 6.7). 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. 17/68) 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 2009-2016 was more easterly compared to that of the previous years (Fig. 6.8).

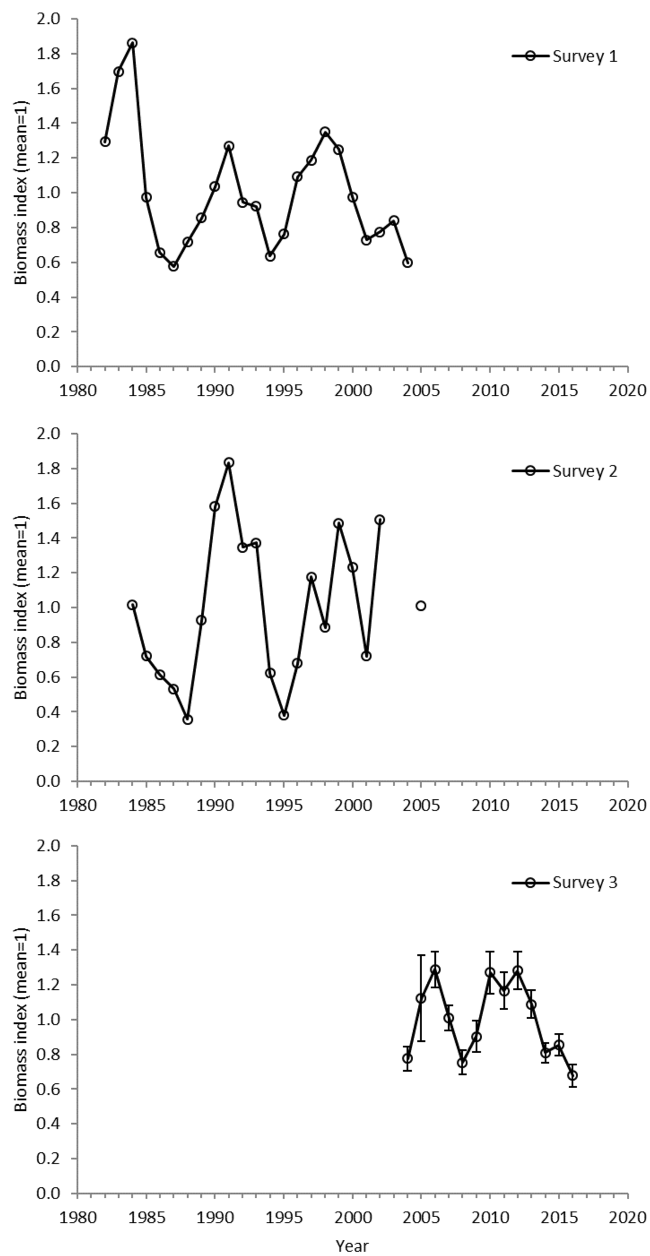

Fig. 6.7. Shrimp in ICES SA 1 and 2: Indices of total stock biomass from the (1) 1982-2004 Norwegian shrimp survey, (2) the 1984-2005 Russian survey, and (3) the joint Russian-Norwegian ecosystem survey since 2004 (the 2017 survey data is not available at the time of the NIPAG meeting). Error bars represent 1 SE.

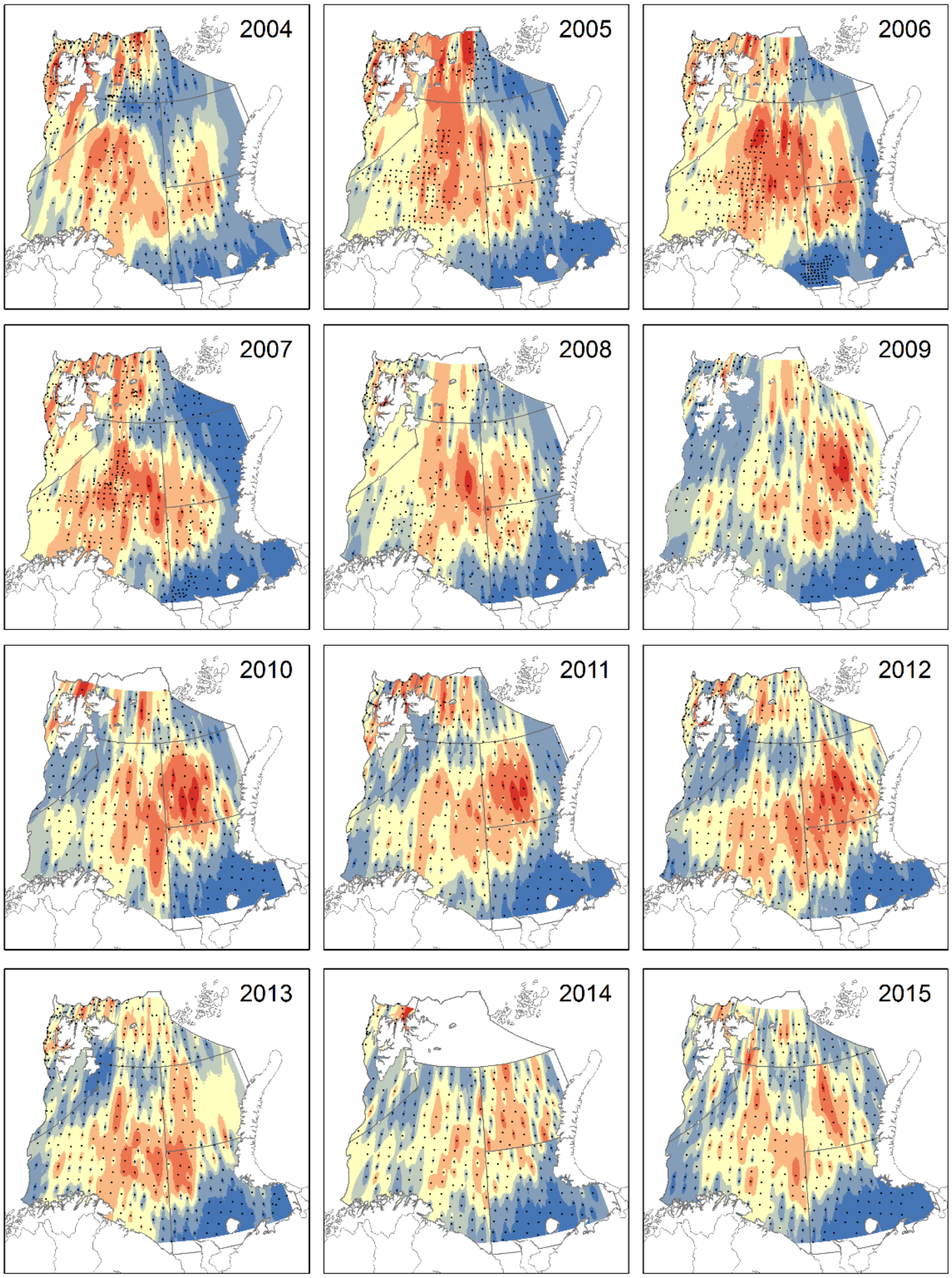

Fig. 6.8. Shrimp in ICES SA 1 and 2: shrimp density (kg/km2) as calculated from the Ecosystem survey data since 2004 (no data for stratum 3 in 2014 due to ice conditions).

Recruitment indices. No explicit information available since 2013.

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. 17/69).

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 1980–2017 (Fig. 6.6, SCR Doc. 17/67); and trawl-survey biomass indices for 1982–2004, 1984–2005 and for 2004–2016 (Fig. 6.7, SCR Doc. 17/68). 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. 1 and 2 since 1970 was used as yield data (Fig. 6.2, SCR Doc. 17/67). 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 1 and 2: 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	254	183	120	205	343
K (ktons), carying capacity	3423	1814	2059	3000	4410
r, intrinsic growth rate	0.30	0.15	0.20	0.30	0.40
q_R, catchability of survey 2	0.12	0.08	0.06	0.09	0.14
q_{Ru}, catchability of survey 1	0.29	0.20	0.15	0.23	0.36
q_E, catchability of survey 3	0.18	0.13	0.10	0.15	0.23
q_C, catchability of CPUE index	4.1E-04	2.8E-04	2.2E-04	3.3E-04	5.1E-04
P_0, initial relative biomass (1969)	1.51	0.26	1.33	1.51	1.68
P_{2017}, relative biomass in 2017	1.71	0.47	1.41	1.68	1.98
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	0.34	0.37
σ_E, coefficient of variation for survey 3	0.18	0.03	0.15	0.17	0.20
σ_C, coefficient of variation for CPUE index	0.13	0.02	0.12	0.13	0.14
σ_P, coefficient of variation for process	0.19	0.03	0.17	0.19	0.21

Reference points. Four reference points are considered (buffer reference points are obsolete as probability of transgressing the PA limit reference points can be calculated directly):

	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 Docs. 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. 6.9, upper). Since the late 1980s, however, the stock has varied with a slightly increasing trend. The median 2016-17 values are above B_{msy}. The estimated risk of stock biomass being below $B_{trigger}$ in 2017 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. 6.9 lower). In 2017, there is a less than 5% risk of the F being above F_{msy} (Table 6.3).

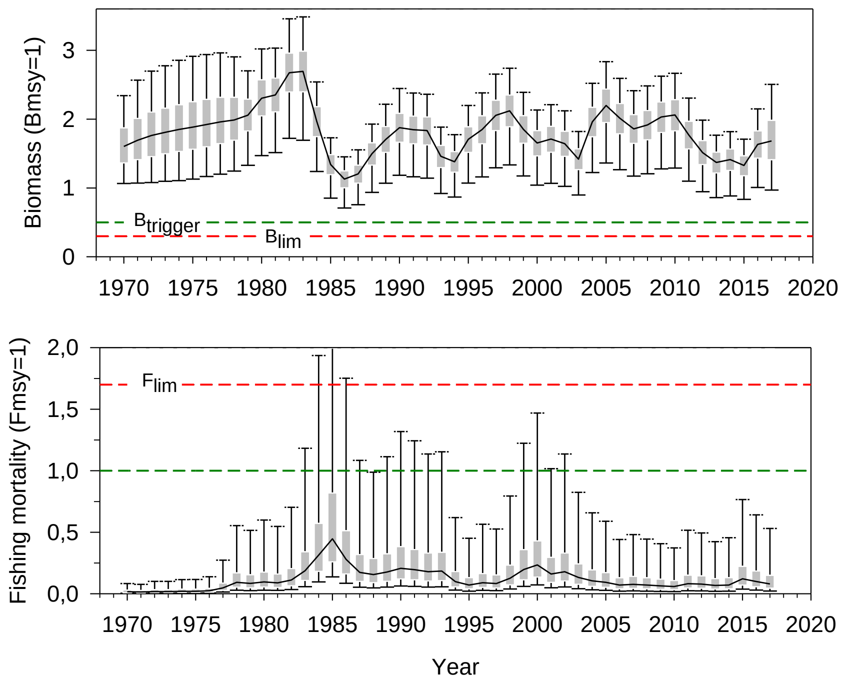

Fig. 6.9. Shrimp in ICES SA 1 and 2: Estimated relative biomass (B/B_{msy}) and fishing mortality (F/F_{msy}) since 1970. Boxes represent inter-quartile ranges and the solid black line in the middle of each box is the median; the arms of each box cover the central 90% of the distribution. The broken lines indicate *MSY* and precautionary approach reference points.

Table 6.3. Shrimp in ICES SA 1 and 2: Stock status for 2016 and predicted to the end of 2017.

Status	2016	2017*
Risk of falling below B_{lim}	0.0 %	0.0 %
Risk of falling below $B_{trigger}$	0.3 %	0.4 %
Risk of exceeding F_{MSY}	2.8 %	2.1 %
Risk of exceeding F_{lim}	1.2 %	0.9 %
Stock size (B/Bmsy), median	1.63	1.68
Fishing mortality (F/Fmsy),	0.10	0.08
Productivity (% of MSY)	60 %	53 %

*Predicted catch = 28 kts

Projections. Assuming a catch of 28 kt for 2017, catch options up to 80 kt for 2018 have low risks of exceeding F_{msy} (<10%), F_{lim} (<5%), and of going below $B_{trigger}$ (<1%) by the end of 2018 (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 1 and 2: Predictions of risk and stock status associated with optional catch levels for 2018.

	Catch option 2018 (kt)						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 %	0.1 %	0.3 %	0.8 %
Risk of falling below $B_{trigger}$	0.6 %	0.7 %	0.7 %	0.7 %	0.8 %	0.8 %	1.0 %	2.7 %
Risk of exceeding F_{MSY}	4.7 %	6.2 %	7.5 %	9.0 %	10.4 %	12.1 %	18.2 %	50 %
Risk of exceeding F_{lim}	2.4 %	3.1 %	3.8 %	4.6 %	5.3 %	6.2 %	6.8 %	30 %
Stock size (B/Bmsy), median	1.70	1.70	1.69	1.68	1.67	1.67	1.63	1.48
Fishing mortality (F/Fmsy),	0.14	0.17	0.20	0.23	0.26	0.29	0.33	1.00
Productivity (% of MSY)	51 %	51 %	53 %	54 %	55 %	55 %	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. 6.10). 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.

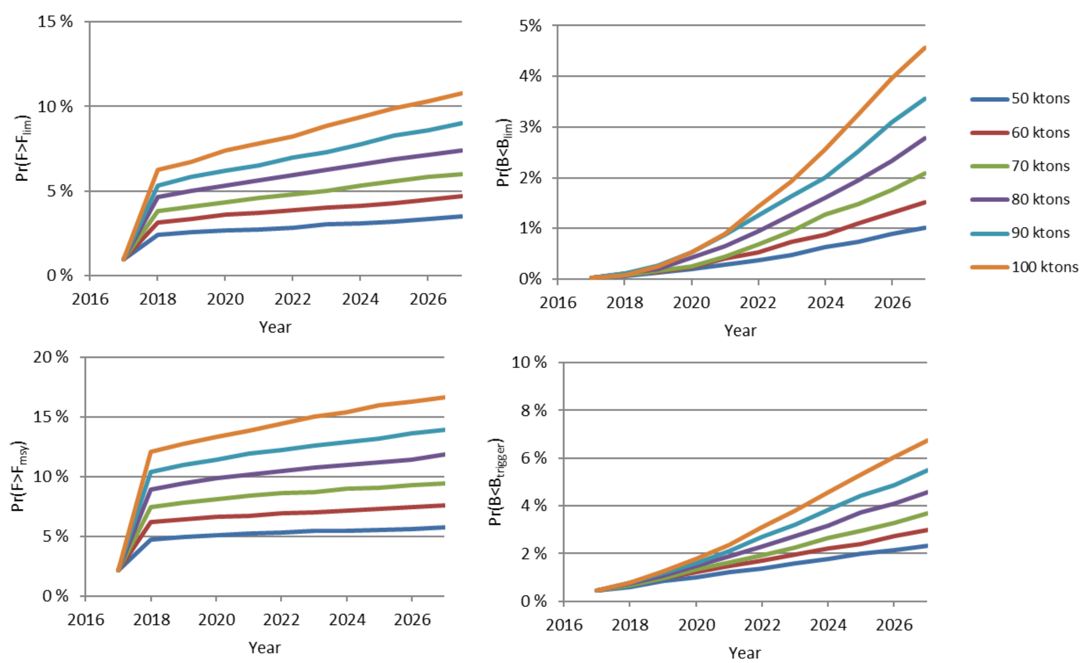

Fig. 6.10. Shrimp in ICES SA 1 and 2: Projections of estimated risk of going below $B_{trigger}$ and B_{lim}, and of exceeding F_{msy} and F_{lim}, given different catch options.

e) Additional considerations

Environmental conditions. Since the 1980s, the Barents Sea has gone from a situation with high fishing pressure, cold conditions and low demersal fish stock levels, to the current situation with high levels of demersal fish stocks, reduced fishing pressure and warm conditions. 2016 was a record warm year with the smallest area of Arctic and cold bottom waters (<0°C) and largest area of Atlantic waters (>3°C). The decrease in ice coverage provides improved conditions for phytoplankton production. Zooplankton biomasses in the Central Bank and Great Bank subareas have shown declining trends since the peak in 1995. The capelin stock biomass is well below the long-term mean while the cod stock is at a high level. As the level of capelin is low, cod and other piscivores must compensate by feeding on other prey and therefore a predation pressure on other prey is potentially large. So far, minor effects of low biomass of pelagic fish on growth of cod have been observed. The levels of environmental and organic pollution in the Barents Sea are generally low and do not exceed threshold limits or global background levels. More detailed information can be found in the annual report "The state and trends of the Barents Sea ecosystem in 2016", which is available on the ICES WGIBAR page as separate document (ICES CM 2017/SSGIEA:04. 186 pp).

Temperature. In the ecosystem survey, shrimps were only caught in areas where bottom temperatures were above 0°C. Highest shrimp densities were observed between zero and 4°C, while the limit of their upper temperature preference appears to lie at about 6-8°C. The warming of the western Barents Sea coincides with the shift in shrimp distribution eastwards (Fig. 6.8), thus temperature is probably a factor in explaining the observed change in spatial distribution.

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 remained at a relatively high level during the recent 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.

Model performance. The model was able to produce good simulations of the observed data (Fig. 6.11). The differences between observed values of biomass indices and the corresponding values predicted by the model were checked numerically (SCR Doc 17/69). They were found not to include excessively large deviation.

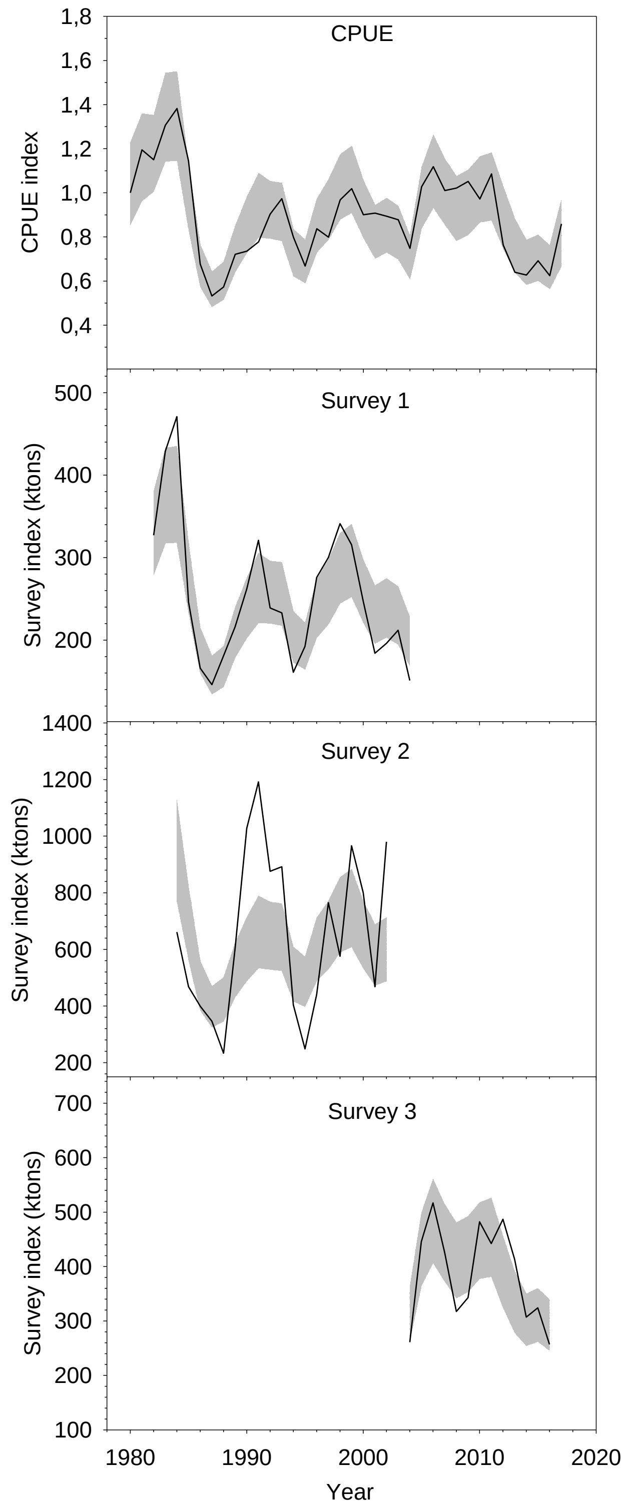

Fig. 6.11. Shrimp in ICES SA 1 and 2: Observed (solid line) and estimated (shaded) series of the included biomass indices: the standardized catch-per-unit-effort (CPUE), the 1982–2004 shrimp survey (survey 1), a Russian survey index discontinued in 2005 (Survey 2) and the Joint Norwegian-Russian Ecosystem Survey (survey 3) since 2004. Grey shaded areas cover the 90% probability interval of their posteriors.

f) State of the stock

Biomass. Stock biomass has been above $B_{trigger}$ throughout the history of the fishery. The probability that the biomass at the end of 2017 is below $B_{trigger}$ is less than 1%.

Mortality. Fishing mortality is likely to have remained below F_{msy} throughout the history of the fishery. In 2017, there is a less than 5% risk of fishing mortality exceeding F_{lim}.

Recruitment. No explicit information has been available since 2013.

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.

g) Review of recommendations from 2016

- *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.*

Status: In progress. Planned to be conducted in conjunction with the benchmark of the Skagerrak stock.

- *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.*

Status: In progress. Information from EU-Estonia was presented at the 2017 NIPAG. An official data call is underway.

h) Research recommendations in 2017

- NIPAG **recommends that** *a recruitment index should be developed for this stock.*
- NIPAG **recommends that** *the information regarding catch effort and bycatch from the Estonian commercial fishery should be further analysed eg. CPUE data explored as a potential index of biomass.*
- NIPAG **recommends that** *information from all fleets fishing on this stock should be made available to NIPAG.*

References

ICES 2016. Report of the Arctic Fisheries Working Group. ICES CM 2016/ACOM:06. ICES HQ, Copenhagen, Denmark. 19-25 April 2016. 630 pp.

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.

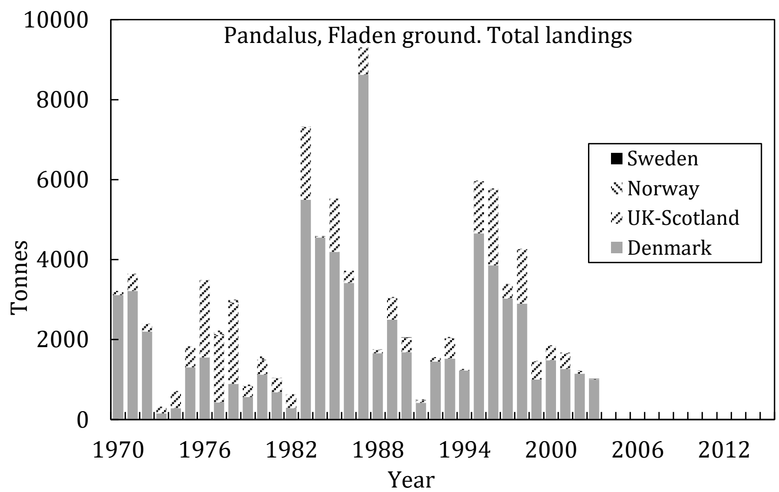

Fig. 7.1. Northern shrimp in Fladen Ground: Landings.

IV. OTHER BUSINESS

a) FIRMS classification for NAFO shrimp stocks

The table as agreed during the September SC meeting 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 Offshore. & 1B–1F Greenland halibut SA2+3KLMNO 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
Depleted	3M American plaice 3LNO American plaice 2J3KL Witch flounder 3NO Cod 3M Northern shrimp[2] 3LNO Northern shrimp[2]			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 noted that there is a divergence of opinion amongst advice recipients regarding when future NIPAG meeting should be scheduled. Members of the NAFO Commission have expressed a preference for the meeting to be held prior to the NAFO annual meeting in September in order that advice that could lead to re-opening of the stocks might be available for consideration at that meeting. On the other hand, ICES advice recipients (Norway and EU) would prefer the meeting to be held in February/March in order that the results of the current year's Norwegian shrimp survey can be included in the assessment of the North Sea/Skagerrak stock. NIPAG recognized that a possible consequence of this divergence could be pressure to dissolve NIPAG as a joint ICES/NAFO working group, and to hold separate assessment meetings for the ICES and NAFO stocks.

Members of NIPAG discussed the history of the group and the relative benefits of its continued existence as a joint WG. There was general agreement that the opportunities presented for internal review and exchange of information are highly valuable. Other possibilities to facilitate review and information sharing were considered, for example, benchmark meetings and/or *Pandalus* biology workshops to be held every few years. The possibility of adding days onto the meeting for discussion of science topics was also discussed. It was noted that this year and last it was possible to finish comfortably within the allocated time and so it would have been possible to use some of the time for a workshop, however this may be because two stocks are under moratorium and there were missing surveys, hence less data than normal.

Alternative arrangements considered by the group that would accommodate the requirement for assessments at different times of year while maintaining the opportunity for review included:

- *conduct the assessments together in autumn, as currently, and then to hold an additional WebEx meeting in spring for the North Sea/Skagerrak stock. There are precedents within ICES for having a separate WebEx assessment for some stocks after the main meeting.*
- *hold separate stock assessment meetings and periodic benchmarks and/or Pandalus biology workshops.*

Regarding the question of whether to have the NIPAG meeting before or after NAFO Annual Meeting, this is constrained by the timing of the Greenland survey: holding the meeting in early September would allow very little time for data processing. The WG preference would therefore be to continue to hold the meeting after the Annual meeting. If the group is going to be continued, then late October/November may be the best option for all but one of the stocks.

It was agreed that next year's NIPAG meeting will be held at IEO, Vigo, Spain during 17th to 23rd October 2018.

V. ADJOURNMENT

The NIPAG meeting was adjourned at 1800 hours on 3 October 2017, 1 day ahead of the scheduled finish. 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 Swedish University of Agricultural Sciences, Institute of Marine Research for hosting the meeting and for supporting a social gathering. The report was adopted at the close of the meeting, subject to a two week period for editorial changes.

The following annex can be found on the NAFO website: https://www.nafo.int

- **Annex 4:** Update assessment of Northern shrimp (Pandalus borealis) in Division 4.a East and Subdivision 20 (northern North Sea in the Norwegian Deep and Skagerrak