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The West Greenland trawl survey for *Pandalus borealis*, 2018, with reference to earlier results.

by

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Abstract

A trawl survey is carried in NAFO Subarea 1 and NAFO Division 0A east of 60°30'W, as a contribution to the assessment of the stock of the Northern Shrimp (*Pandalus borealis*). In 2018, 235 stations were fished in 38 fishing days; 184 provided data to the shrimp survey in all strata.

In 2018, the annual trawl survey was conducted with a chartered vessel, the Faroese trawler Sjurdarberg. All the standard gear from the research vessel Paamiut (such as cosmos trawl, doors, all equipment such as bridles ect, Marport sensors on doors and headlines) were used, in attempt to make the 2018 survey identical as possible with the previous years survey.

The 2003 peak in total survey and fishable biomasses has been followed by continuous decline, reaching in 2014 the lowest levels since 1997. In aggregate, the stock has shown no clear trends since 2007. In fact, at short term (10 year), there has been fluctuations in the stock with ups and downs in biomass. The overall survey biomass increased by 49% over 2016 to 316.2 Kt, remained almost stable in 2018 at 292 Kt. The total survey biomass is 113% of its past 10-yr mean, 119% of its past five year mean, and almost at its serial mean (293.3 Kt). Offshore regions comprise 76% of the total survey biomass, and 24% is inshore in Disko Bay and Vaigat.

In all surveyed regions north of 66°N survey biomass shown a minor drop of less than 10%, except the region of Store Hellefiskebanke where survey biomass was 31% less than in 2017. Biomass in the southern part area, W8-W9, amounted less than 1% of the total estimated survey biomass in 2018.

The Fishable proportion (93%) of the survey biomass is at the serial mean (92%). While female biomass is above its serial mean, the biomass of fishable males are little below.

In total, the index of age-2 shrimps is at its past 5-yr mean, but little below the serial mean. While Offshore numbers of age 2 shrimp more than doubled over 2017, almost at its serial and above past 5-yr mean, numbers of age-2 shrimps inshore was bisected over 2016, remain stable in 2018 and is now below its serial mean and only 47% of its paste 5-yr mean.

Since the late 1990s the stock is found in more shallower water than before. This trend have continued since 2011, except for and increase over 2013, and in 2018 the survey biomass depth index at 289 m is at a comparable level to the past 17 years.

Area-weighted mean bottom temperature in the survey area increased at the beginning of the 1990s, by about 1.6°C, to 3.3°C in 1999. In the successive year's bottom temperature remain stable, but starts a continuous decrease from 2015 to 2.1°C in 2018. Despite the decreasing trend in temperature, the relatively warm period continued in 2018.

Introduction

Since 1988, the Greenland Institute of Natural Resources has carried out annual trawl surveys on the West Greenland shelf between June and August to assess the biomass and recruitment of the stock of *Pandalus borealis* and to obtain information on the size and sex composition of the stock as well as on the environmental conditions. This document presents the results of the 2018 survey, and compares them with revised series from previous surveys.

Material and Methods

Survey design and area coverage

The offshore survey area for the Northern shrimp, *Pandalus borealis*, covers waters on the West Greenland continental shelf from Kap Farvel in the south to latitude 72°30'N, comprising NAFO Subarea 1 and, where the shelf bulges into the Canadian EEZ, a small area in the eastern part of NAFO Div. 0A. In the late 1980s when the survey was initiated, *P. borealis* was fished in waters between about 150 m and 550 m deep, and the shrimp survey has always been restricted to depths between 150 m and 600 m. Since 1991 the survey has included the inshore areas of Disko Bay and Vaigat in NAFO Div. 1A but, along most of the coast, the survey does not cover areas closer to shore than 3 miles offshore of the fishery baseline. In some coastal areas fishable concentrations of *P. borealis* exist closer to shore than this, including areas that extend into some fjords (see e.g. Fig. 4a of Hammeken and Kingsley 2010).

The survey area is divided into primary and secondary strata. The survey primary strata correspond to geographical areas identified on the basis of logbook information on the distribution of the fishery (Carlsson *et al*. 2000). They are subdivided into four secondary (depth) strata at 150–200 m, 200-300 m, 300-400 m, and 400-600 m. When the survey was initiated, bathymetric information in Disko Bay, as well as offshore north of 69°30'N, did not support this depth stratification, and these regions were therefore originally subdivided into geographical substrata not based on depth. Depth data logged by the survey and other investigations eventually allowed these waters to be stratified on depth and a new geographical stratification with depth sub-strata was introduced in 2004 (Wieland and Kanneworff, 2004). At the same time, the geographical strata in the Canadian zone, formerly two, were merged into one.

From 1988 through 1999, trawl stations were allocated to strata in proportion to stratum area, but since 2000 more stations have been allocated to strata where biomass variances have been high in previous years in order to improve the precision of the overall biomass estimate (Kingsley *et al*., 1999). An exponential smoothing of previous years' stratum variances was applied in the allocation procedure, giving higher influence to the more recent years. Past variance data for Atlantic cod and Greenland halibut is also made available to the allocation procedure, which is now set to minimize a weighted combination of the expected survey precision for the three species.

Generally the station layout is based on a division of the survey area into elements about 2 nautical miles square. Since 1999 survey stations have been positioned using 'buffered random' sampling, in which stations are placed randomly with the constraint that a minimum distance between them, which depends on station density within the stratum, must be observed (Kingsley *et al*., 2004).

From 1988 through 1998, survey designs were independent from year to year, stations being placed anew in the strata. Since 1999 about 50% of the stations included in the preceding year's design have been repeated as fixed stations in the following year, the others being placed, as before, using the buffered sampling rules. Catches are correlated from year to year by position, and fixing stations improves the ability of the survey to indicate year-to-year changes in stock size by inducing serial correlation in survey error (Kingsley, 2001a).

In 2018, 267 stations were planned at depths between 150 and 600 m in the survey area, with 50 'extra' stations mapped and available to be included if time permitted. 235 of the planned stations incl. 7 'extra' stations were fished. 4 stations were reported as having been moved more than 2 n.mi. from the planned position, with a mean of 9.1 n.mi.; 10 stations were discarded, either due to untrawlable bottom or owing to general trawl difficulties.

Of the 235 stations fished, 184 provided usable data to the shrimp survey. In the course of the shrimp survey, no CTD casts were made along standard transects offshore and in Disko Bay and Vaigat (while the survey was conducted with a charter ship); and in 2018 and no extra station were fished with a beam trawl for benthos monitoring.

Survey period and daily sampling period

The trawl survey has been carried out every year between mid-June and the end of August to minimize the effect of seasonal cycles in the biology of the species. Trawling is carried out between 0800 and 2000 UTC; it appears that the daily vertical migration of the Northern shrimp is quite abrupt at sunrise and sunset.

Tow duration

From 1988 to 1997 all tows in the shrimp survey lasted 60 min. However, shorter tows give just as accurate results (Carlsson *et al*., 2000; Kingsley, 2001b; Kingsley *et al.*, 2002; Wieland and Storr-Paulsen, 2006; Ziemer and Siegstad, 2009) and since 2005 the survey has been operated with 15-minute tows alone.

Fishing practices

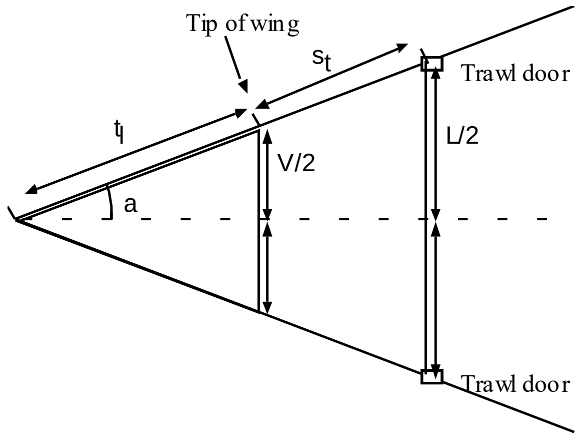
The surveys have been conducted with the research trawler *Paamiut* (722 GRT) since 1991, similar vessels were used in 1988–1990. However, in the beginning of 2018 it was decided that the old research vessel *Paamiut* has to be scraped owing to increasing expenses to maintenance. Instead, the survey was conducted with a chartered fishing vessel *Sjudarberg.* All fishing gear were removed from *Paamiut* and installed on Sjudarberg and fishing practice and handling of catch were exactly as used on the research ship *Paamiut* (See appendix 1).

Initially, a 3000/20-mesh *Skjervøy* bottom trawl with a twin cod-end, and equipped with a heavy steel-bobbin footrope, was used. A 20-mm (stretched-mesh) liner was added to the 44-mm-mesh cod-end in 1993. From 1988 to 1991 estimates of trawl geometry—door spread and height of head-rope—were based on results from tank experiments at the Danish Institute for Fisheries Technology and Aquaculture. Since 1991 *Scanmar* acoustic sensors have been mounted on the trawl doors, and a *Furuno* trawl-eye on the head rope. Door-spread readings are recorded during the tow, and the reading from the trawl-eye is used to judge when the trawl has settled and the tow can be deemed started.

From 1988 through 2003 *Greenland Perfect* trawl doors were used, measuring 9.25 m^2 and weighing 2420 kg. They were replaced in 2004 by *Injector International* 7.5 m^2 trawl doors weighing 2800 kg to facilitate a change of survey trawl in 2005. In 2005 the *Skjervøy* 3000 trawl was replaced by a *Cosmos* 2000 trawl with 'rock-hopper' ground gear comprising steel bobbins and rubber disks. Towing speeds have been about 2.5 knots in all surveys.

Swept area calculation

Nominal swept area for each tow was calculated as the straight-line distance between its GPS start and end positions multiplied by the wingspread. The distance between the trawl doors should be recorded 3 or 5 times during each tow; provided it was recorded at least once, wingspread for a tow was calculated from the mean door spread and the geometry of the trawl. For both trawls the wingspread (i.e. the width of the swept area) V has been calculated as follows. The trawl and the trawl plus bridles are assumed to form two similar triangles, bridles and wings making a straight line:



and the lengths of the bridles (s) and the trawl wings (t) are known. The wingspread V is then calculated as:

$$V= (t_l * L) / (t_l + s_t)$$

where L is the distance between the doors (doorspread).

The length of the *Skjervøy* trawl is 67.15 m and the length of the *Cosmos* trawl is 71.8 m, both measures excluding the cod-ends. Since 2004 the bridle length, i.e. the total length of lines, chains and shackles between the trawl doors and the tip of the trawl wing, has been 54 m for either trawl; other bridle lengths were used in earlier years (Table 1). In the case of the *Skjervøy* trawl, 0.7 m has been added to the calculated wingspread because the *Skjervøy* trawl is a three-winged trawl and the lower wings (directly attached to the ground-rope) were estimated to spread 0.35 meters wider than the middle wings on each side in tank experiments at the Danish Institute for Fisheries Technology and Aquaculture (Per Kanneworff, pers. com.).

If doorspread was not recorded in the course of a tow, the unweighted mean of the calculated wingspreads for the year was used, without regard to fishing depth or wire length. If the speed of the tow calculated from its duration and its start and end positions lay outside a range of 3.0 to 6.5 km/hr, its length was recalculated from the survey average towing speed and the tow duration.

Biomass estimation

Each haul's catch was divided by its estimated swept area calculated from wingspread and track length to estimate a biomass density. Unweighted mean stratum densities were multiplied by the stratum area to compute stratum biomass, and a corresponding error variance for the stratum biomass estimate was also calculated for strata with two or more accepted hauls. For strata with only one accepted haul, an error coefficient of variation of 0.95 was assigned. Stratum biomasses and their error variances were summed to get regional and overall estimates.

Indices of distribution and location of shrimp biomass

Indices to summarize how widely the survey biomass is distributed and a measure of its central latitude were calculated (Kingsley 2008). Data from surveys executed in 1994–2018 was used: there was no survey before 1994 in the southernmost areas and before 1991 in Disko Bay or Vaigat, but since 1994 the series has been consistent. Biomass estimates from the annual survey are customarily presented (e.g Ziemer 2008) for 7 divisions of the survey area:

- a northern division, formerly stratified as N1–N9, and re-stratified according to depth information (Wieland and Kanneworff 2004) as U1–U3 with depth strata;
- Disko Bay and Vaigat, formerly stratified as D1–D9, restratified as I1 and I2 with depth strata;
- Canadian Exclusive Economic Zone, once 2 divisions, now 1;
- subdivisions of the west coast, from the mouth of Disko Bay and adjacent shelf waters to Paamiut;
- an extreme southerly division, comprising Julianehåb Bay and adjacent waters.

These divisions were given southerly ranks: Julianehåb Bay and the adjacent shelf waters were 1; the subdivisions up the coast were given ranks 2, 3 and 4. The small Canadian sub-division was split, half being included with the subdivisions W1 and W2, and the other half included with survey subdivisions W3 and W4. Disko Bay and Vaigat were given rank 5, and the northernmost subdivision of the survey area was ranked 6.

Then a 'lat. index' was calculated as a mean rank for the survey, weighting by estimated total survey biomass. This index summarises how far north a (weighted) centre of gravity of the stock biomass lies.

A 'spread index' was calculated as a Simpson diversity index (Simpson 1949) of the distribution of the biomass:

$$SpreadIndex = \left(\sum_{Subdivisions} Biomass_{Subdiv.} \right)^2 \Bigg/ \sum_{Subdivisions} \left(Biomass_{Subdiv.} \right)^2$$

This index summarizes how widely the survey stock biomass is distributed among survey subdivisions.

Depth distribution of biomass.

The overall depth distribution of the estimated survey biomass was calculated according to available depth information. Up to 2003, such information was only available for the west-coast area and the Canadian EEZ, and the depth distribution of the biomass was analyzed only for those areas. Since 2004, the northern area and the inshore areas in Disko Bay and Vaigat have been sub-stratified depth and the depth analysis extended to those areas.

A single depth index, in meters, was calculated by assuming that the entire survey biomass in any depth stratum was concentrated at the stratum's midpoint depth, except for the deepest stratum: the fishery takes little from water deeper than 520 m, so the central depth for the 400–600 m stratum was set at 460 m.

Sampling, weighting and "area expansion"

The composition of the stock by size and sex is based on a two-stage analysis of lengths and weights. From catch samples, 1000–2000 individual shrimps are both weighed and measured, and these measurement pairs are used to estimate a weight-length relationship. From each catch a sample of about 0.5 to 3 kg was taken and sorted to species. All specimens of Northern shrimp were classified: juveniles and males composed one class, primiparous and multiparous females two others (Allen 1959, McCrary 1971). The oblique carapace length (CL) of each shrimp in the sample was measured to the nearest 0.1 mm. These length measurements are then supplemented with weight estimates based on the fitted weight-length curve. Aggregated, and then averaged over the stations in a stratum, these observations of sex and measurements of length and their associated estimates of weight are used to estimate the distribution of the stratum biomass between sex and length classes as well as the numbers of shrimps in the stratum in the various sex and length classes.

The descriptions of calculation methods that follow consider only one stratum. Survey totals are got by summing stratum results. 'Length class' can be generalized to include sex or sex-length class. From the catch and swept area at a station, the single-station estimate of stratum biomass is

$$\hat{B}_{ts} = \frac{Strat.Area_t \cdot Catch_{ts}}{Sw.Area_{ts}}$$

These single-station estimates are averaged. An unweighted analysis gives

$$\hat{B}_t = \frac{Strat.Area_t}{K_t} \sum_s \frac{Catch_{ts}}{Sw.Area_{ts}}$$

where t is the stratum and s is the station, of which there are K_t in stratum t. Shrimp density does not vary much within a haul's distance (Kingsley et al. 2002) and so it is statistically preferable to use the unweighted mean estimate of stratum biomass. This is what is done in the West Greenland survey.

If the number of shrimps in class l in the Length Sample, of weight $Samp.Wt_s$, from station s in stratum t is n_{lts}, the corresponding single-station estimate of the number of shrimps in the class in the stratum is

$$\hat{N}_{lts} = Strat.Area_t \frac{n_{lts}}{Samp.Wt_{ts}} \cdot \frac{Catch_{ts}}{Sw.Area_{ts}}$$

The stratum estimate from many stations is:

$$\hat{N}_{lt} = \frac{Strat.Area_t}{K_t} \sum_s \left(\frac{n_{lts}}{Samp.Wt_{ts}} \cdot \frac{Catch_{ts}}{Sw.Area_{ts}} \right)$$

where the divisor K_t, the number of stations, includes those with no catch. The coefficient

$$\frac{Catch_{ts}}{Samp.Wt_{ts} \cdot Sw.Area_{ts}}$$

common to all length (and sex) classes counted in the Length Sample for a station can be called its 'raising factor'. Given these estimates of numbers, and if estimates $w(l)$ of individual weight at length are available, length-class biomass is given by

$$\hat{W}_{lt} = w(l) \frac{Strat.Area_t}{K_t} \sum_s \left(\frac{n_{lts}}{Samp.Wt_{ts}} \cdot \frac{Catch_{ts}}{Sw.Area_{ts}} \right)$$

Provided that for all Length Samples $\sum_l n_{lts} w(l) = Samp.Wt_{ts}$, i.e. the weight of every Length Sample answers exactly to the number and size of the shrimps that compose it, the sum of length-class biomasses equals the stratum total biomass calculated from catches and swept areas. This is ensured by using, as the weight of the Length Sample, the total weight of the shrimps it comprises, calculated from the weight-length function, instead of using its weighed weight. In effect, the length-measurement data is used only to partition the stock biomass between sex and length classes.

Where catches were, for one reason or another, not sampled for lengths, the mean of the length frequency distributions from the available samples in that stratum, each raised by its catch and swept area, was applied to the entire stratum biomass. If it occurred that there were no length samples from the catches in an entire stratum, the length distribution estimated for the entire survey from data for the strata that did have length samples would be applied to its estimated biomass.

Results from these calculations were subsequently used to construct area-specific length frequency distributions (LFD). LFD results were used to calculate indices of numbers by sex and length, biomass by sex, an index of fishable biomass (comprising shrimps at least 17 mm CPL), and numbers of small pre-recruits ('age 2 shrimps'), which are expected to enter the fishery in coming years.

For data since 2007 the following weight-length relationship has been fitted:

$$w(l) = w_0 + a \cdot (l - l_0)^z$$

with the parameter l_0 constrained to be less than 4.5 mm. A weighted fit was used with constant coefficient of variation about the fitted line.

As there is no reliable method of aging even young shrimps, indices of numbers at age are obtained by modal analysis of length frequencies for juveniles and males, attempting to fit overlapping age-specific normal distributions to the aggregated length distributions.

Modal analysis is carried out using Partiel Mix (Kingsley, 2014, MCSKMIX 2014 © Greenland Institute of Natural Resources), implemented in an Excel spread sheet. Partiel MIX fits numbers of shrimps at age 2 years and is estimated by decomposing the length distributions, fitting Normally distributed components.. To prevent a skewness to the plus age 3 group, analysis was only done on shrimps below or equal to 19 mm CPL. While using this new method in 2014, all age-2 results from 2005 to 2014 was re-calculated. A more comprehensive description of the method is found in Kingsley (2014).

As growth is probably affected by temperature, the survey area is divided into 6 regions, defined from gradients in bottom temperature (Wieland, 2004), and estimated numbers in strata are pooled over regions. Length-frequency histograms are not smoothed before being analyzed. The analyses of sex and length distribution in the stock, and the modal analyses, were re-done in 2014 for data from 2005–2014. To simplify the modal analysis, and because the main objective is to estimate the numbers at age 2, only the numbers for the 'Juveniles and Males' sex class were put through it. For this re-analysis, strata were grouped: U1 to U3, I1 and I2, W1 to W4, W5 and W6, and W7 to W9. Within each group, the estimated stock numbers in each stratum were aggregated over depth substrata, and the stratum aggregate numbers presented to Partial MIX as a haul.

Bottom temperature

Bottom temperature was measured with a *Starmon* sensor mounted on one of the trawl doors. It records at intervals of 30 s with a resolution of 0.01°C. The average temperature for each haul was calculated after retrieval of the sensor. All measurements taken at greater depths than 150 m were used to calculate a mean bottom temperature weighted for the areas of the survey strata between 150 and 600 m depth.

Results and Discussion

Survey conduct and progress.

The survey in 2018 started from Nuuk on June the 5. The first cruise occupied stations from Nuuk north to Disko Bay having occupied 87 shrimp and fish stations and no CTD cast in 13 days. The second cruise occupied 91 shrimp and fish stations and no CTD cast in 17 days in Vaigat, north to the survey limit, and west of Disko on its way back south, the northern area being less densely sampled. The third cruise started from Nuuk on 14

July to occupy 57 stations south to the southern limit of the survey at 10 days until July the 14. No CTD cast were sampled at the third trip.

In most previous years, a crew engaged in taking photographs of the sea bottom, who used the ship at night when the survey was suspended, has accompanied cruises. However, this part was not conducted on the survey in 2018. From all planned shrimp and fish stations, at the three cruises, by-catch of benthic faunal invertebrates were sorted from each stations, identified to the lowest possible taxonomic level, and some species were preserved in 10% buffered formalin solution for later identification, and both projects aims to investigate the long-term effects of trawling on bottom ecosystems. Same procedure were done for benthic species sampled with a beam-trawl. No beam trawl stations were carried out in 2018.

Of the 58 planned survey strata, 1 (W1-4) had no stations trawled caused by the ice cover; and no stations were fished in C0, also due to ice cover. 24 stations had no catch of *P. borealis*; 2 strata (W7-1,and W7-4), with 5 occupied stations between them had no catches and stratum U1, U2, U3, I1, I2, W1, W2, and W3, had catches *of P. borealis* at all stations. Length samples were measured from 165 stations with catches even very small ones, and length & weight samples were measured at 43 stations.

There were no exceptionally large catches only at one station in W6-2 had a catch which was closed to 1 ton (1122 kg). There were 27 catches over 200 kg, of which 10 were made in Disko Bay or Vaigat, 2 stations north from 69°30 N, 9 in strata W1-W4, 4 in stratum W5, 2 in stratum W6 and no in W7- W9. In southerly areas, strata W7-W9 yielded an average catch of 0.11 kg at the 39 stations, in the southern regions.

Overall Biomass and Area Distribution.

For all strata biomass estimates have been calculated (Table 2) on the basis of the nominal swept area. The biomass estimates (in tons) for the five main regions and the entire survey area in 2016 were:

Region–2016	Biomass estimate (t)	Number of stations	ECV (%)
North (U1-U3)	60 548	26	12.0
Canadian zone (C0)*	-	0	-
West (W1–W9)	86 689	112	15.1
Disko Bay & Vaigat (I1, I2)	67 795	18	18.4
Total	212 031	156	9.0

- Area C0 was not surveyed in 2016, owing to ice cover

and in 2017:

Region–2017	Biomass estimate (t)	Number of stations	ECV (%)
North (U1-U3)	69 843	47	12.4
Canadian zone (C0)	3 057	3	74.6
West (W1–W9)*	162 414	128	15.7
Disko Bay & Vaigat (I1, I2)	80 847	37	13.2
Total	316 152	215	9.2

- Area C0 was not surveyed in 2017, owing to ice cover and W1-4 due to bottom trouble.

and in 2018:

Region–2018	Biomass estimate (t)	Number of stations	ECV (%)
North (U1-U3)	65 798	36	16.1
Canadian zone (C0)	-	-	-
West (W1–W9)*	154 027	124	17.3
Disko Bay & Vaigat (I1, I2)	72 231	24	10.8
Total	292 057	184	10.2

- * Strata W1-4 was not surveyed in 2018, owing to bottom trouble.

Survey biomass decreased over 2010 and the declining trend in survey biomass continued until 2014, where biomass estimate for Disko Bay and Vaigat was little changed from 2011, but with further large decline in all offshore regions. In 2015, perhaps caused by an over optimistic survey (Burmeister and Kingsley, 2015a; Burmeister and Kingsley, 2015; NIPAG, 2015), the total survey biomass increased over 2014 and was 57.6% higher in 2015 (Table 3, Figure 2a and 2b). The increase was not maintained in 2016, where total survey biomass was followed by a 25% drop in offshore regions and in Disko Bay and Vaigat.

The decline in survey biomass was not continued and biomass was in 2017 (316.2 Kt) 49% higher than in 2016. Total survey biomass remain on a comparable level in 2018 at 292 Kt, however 7.6% less than the year before, (Table 3, Figure 2a and 2b) almost at its serial mean (1988 – 2017; 293 Kt) and 119% of its past 5 year value. Offshore survey biomass (219.8 Kt) remain unchanged, over its past 5 yr. mean and close to serial mean at 224.8 Kt. Whereas survey biomass in inshore regions Disko Bay & Vaigat (72.2 Kt) declined by 9% over 2017. Despite the minor decline, inshore survey biomass is 91% of its past 5-yr. mean and above the serial mean (1988 – 2017; 68.5 Kt). Offshore biomass constitute 75% and Disko Bay & Vaigat 25% of the total survey biomass. The Canadian area was not surveyed in 2018 due to ice cover, but was surveyed in 2017, and contributes less than 1% of total offshore survey biomass (Table 3).

In all offshore survey regions survey biomass increased in 2017 over 2016, except for the southernmost area (W8-W9). This increase were not maintained in 2018, but in all regions the 2018 biomass were at or above the past 5-yr mean. The northern offshore regions (U1-U3) and (W1-W2) showed a minor decrease (less than 10%), whereas the survey biomass in the area north and south of Store Hellefiske Banke (W3-W4) declined by 31% (Table 3 Figure 2b). Biomass doubled in the regions (W5-W7) mainly caused by an increase in substrata (W5-2) and one large haul in substrata (W6-2) and way above its past 5-yr mean. Nevertheless, biomass estimates for areas W5-W7 amounted only 15% of the total offshore survey and the southernmost area W8-W9 comprise less than 1% of the total biomass.

Densities of *P. borealis* in Disko Bay were almost stable from 2010 to 2014, followed by a continuous decline in the two succeeding years, increased in 2017, followed by an additional drop in 2018. Nevertheless, the density is almost at its serial mean (1988 – 2018), and close to its past 5 year mean. The inshore region, had far higher densities (7.37 t/km^2) than other areas (Figure 3a), almost four times as high as the second highest strata, W1 and W2 combined (2.89 t/km^2). Lowest densities were found in the Southern areas W8-W9 (0.01 t/km^2) (Table 5). Over all mean density decrease by 19% over 2017, and was estimated to 2.23 t/km^2 in 2018, almost at its serial mean (1988–2018; 2.30 t/km^2), and almost at its past 5 year mean (1.80 t/km^2) (Fig. 3b).

The spread index, of how widely the survey thinks the stock biomass is distributed, has shown an increase since 2016, indicating that the stock is more widely distributed than compared to the period from 2010 to 2014. The north index have shown declining trend over the past 3 years (Figure. 4).

Depth distribution of the shrimp biomass.

During the early and mid-1990s, the depth distribution of the survey biomass was stable, with a significant contribution from the 400–600 m stratum, but most of the biomass found in 300–400 m of water (Fig. 5a, Fig. 5b). The 200–300 m stratum started showing biomass increases as early as the late-1990s, and at that time, the deepest stratum also started its decline—hence the start of the change in the mean-depth index (Fig. 5c).

In the subsequent years biomass at 200 – 300 m increased significantly until 2004, so do the 150–200 and 300–400 m strata, however increased later, and less. In the following years, biomass declined to a low in value in 2012 in strata 300-400, and to a low value two years later in stratum 200–300 m. Since 2015, the biomass has continuously increased in those two depth strata (Fig. 5a). The biomass in the deeper stratum, 400 -600 m, has remained stable since 2010, whereas the biomass in the shallow water has been fluctuated throughout the entire time series.

The proportion of the biomass in the shallow water constitute in general less than 20% of the total shrimp biomass. Some years less than 5% and some years more than 15%, but with no clear trends between years. In the late 80'ties most biomass were found in 300 to 400 m, but as the proportion of biomass declined in that depth strata, biomass moved into more shallow water from 200 to 300 meter. The latter depth strata have since 2000 and until 2018 had far higher proportion of biomass compared to the other depth strata. In general, since the late 90'ties the majority (80%) of the biomass has been found in depths from 200 to 300 m and 300 to 400 m, while little biomass is found to be at deeper waters > 400 m (Fig 5a and Fig 5b).

In 2001–2018 the survey biomass depth index has ranged between 265 and 300 m, with an average near 281.5 m compared to an average of 329 m in the period from 1988 to 2000 (Fig 5.c). In 2018, the depth index was estimated to approx. 289 m, a little deeper than compared with the past 5 year (281 m).

Demography and recruitment

Length-weight relationships

In 2018, 9732 shrimps were individually weighed and measured (Table below). A single weight-length relationship was fitted to all sex classes. The same relationship was retrospectively fitted to data from 2005–2010 to provide a consistent basis for estimating numbers of pre-recruits for those years; we have compared estimated weight at length from the weight-length relationships used in different years. Parameter values estimated in 2018 were little changed from the past years.

Table: *Pandas borealis* in West Greenland: parameters of a relationship $w(l) = w_0 + a \cdot (l - l_0)^z$ fitted to weight-length data for individual shrimps.

Year	w_0 (g)	coefficient a (mg)	l_0 (mm)	exponent z	sample	Scatter c.v. (%)
1988–2000	0	0.669	0	2.96		
2001–02	0	0.483	0	3.0576		
2003	0	0.752	0	2.9177		
2004	0	0.765	0	2.9092		
2005	0.03103	1.726	1.91	2.7188	1616	6.79
2006	0.05771	1.426	1.591	2.761204	1907	7.89
2007	0.7700	1.789	4.5*	2.78216	487	6.42
2008	-0.03285	1.4162	0.797398	2.7501	2147	6.67
2007–08	-0.121034	0.4031	-1.66043	3.052731	2634	6.88
2009	0.01823	2.774	2.19026	2.58902	1768	6.86
2010	0.1533	8.155	4.5*	2.32036	1096	6.66

Year	w_0 (g)	coefficient *a* (mg)	l_0 (mm)	exponent *z*	sample	Scatter c.v. (%)
2011	0.12993	9.753	4.5*	2.25051	2569	6.64
2012	0.08185	8.928	4.229	2.27317	2300	7.31
2013	0.12644	9.541	4.5*	2.26021	2353	6.66
2014	0.10582	9.554	4.5*	2.27123	2371	6.75
2015	0.07269	4.165	3.1	2.49521	1088	6.79
2016	0.18877	8.655	4.5*	2.30198	1125	5.68
2017	0.04806	2.775	2.7	2.61194	3520	7.52
2018	0.13308	7.392	4.5*	2.34835	9732	7.48

* L0 must be no greater than 4.5 mm.

The scatter about the fitted weight-length relationship is consistent from year to year. Whereas the scatter in 2016 was lower than most other years, the scatter in 2018 was relatively high compared to other years, in fact the third highest. Possible because the sample was relatively large and more uncertainty in length and weight measures.

Table: *Pandalus borealis* in West Greenland: weights at length predicted from fitted weight-length relationships.

Year	Weight (g) at length (mm):			
	10	15	20	25
1988–2000	0.61	2.03	4.75	9.19
2001–2002	0.55	1.91	4.59	9.08
2003	0.62	2.03	4.70	9.02
2004	0.62	2.02	4.66	8.92
2005	0.54	1.91	4.56	8.82
2006	0.57	1.91	4.50	8.67
2007	0.98	2.01	4.44	8.75
2008	0.60	2.06	4.76	9.02
2007–2008	0.61	2.04	4.70	8.96
2009	0.59	2.06	4.82	9.12
2010	0.58	2.06	4.87	9.17
2011	0.58	2.07	4.79	8.86
2012	0.56	2.06	4.80	8.90
2013	0.58	2.07	4.80	8.92
2014	0.56	2.10	4.93	9.21
2015	0.59	2.08	4.90	9.28
2016	0.63	2.13	4.95	9.24
2017	0.55	2.00	4.80	9.27
2018	0.54	1.98	4.75	9.03
Mean	0.61	2.03	4.74	9.02

Estimated weights at length have been consistent over years, and there is very little change from 2010–2018. Though 2016 has rather heavy shrimps at the small medium size, 10, 15 and 20 mm, but in 2017 and 2018 the weight of small shrimps at 10 mm decreased and are less than the most previous years. The weight at the other size groups were close to their serial mean

The mean weight of both sexes has decreased steadily over the 30-year history of the survey (Fig. 8), by, on average, 41 mg/yr. for females and 21 mg/yr. for males. We do not know the reason for this; it might be due to a progressive reduction in the size at sex change, which would affect the mean size of both sexes. There is significant serial correlation in the residuals about the trend lines, 0.55 for males and 0.86 for females, indicating that there is some underlying mechanism.

Recruitment and mean length at age 2

Length-frequency plots—e.g. regions I1 – I2 (Disko Bay & Vaigat) in 2014 and W1–W4 in (offshore) in 2014 and 2015 (Fig. 10)—show a first insignificant component with mean CPL at 7–8 mm. These shrimps had probably hatched in the spring of the year before. Age-1 shrimp haven't been observed in the most recent years nor in 2018, neither in inshore as well as offshore regions. Catches of this first component are small owing to the mesh size used in the survey; even the second component is not fully retained by the survey gear (Wieland, 2002b).

Regional differences in length at age 2 are obvious: they tend to be larger in areas that are more southerly and in deeper water. This general pattern was reverse in 2017 and 2018, while mean length at age 2 were a bit larger in the northern regions U1-U3 and in Disko Bay & vaigat (I1-I2) (Table 9), exceptions was in 2018, where mean length at age 2 was greater in region (W5-W6) than compared to the other regions. Year-to-year changes in the mean length at age 2 have been related to shifts in bottom temperature and changes in stock density of shrimp (Wieland, 2005). For the most recent six years, however, estimates of the mean size at age 2 were consistent (Table 9).

In 1993–1995, estimates of numbers at age-2 were low, particularly in Disko Bay and Vaigat (Table 10, Fig. 11); in 1996, they were high, especially offshore, but dropped again in 1997. After 1997, age-2 numbers increased steadily to peak in 2001, followed by a steady decline to 2005. A series minimum observed in 1995 was reached again in 2007 and 2012.

Since 2013 numbers of age-2 shrimps increased and more than double to 10.85 bn in 2015, considerably above the series 1988-2015 mean of 6.27 bn (Fig. 11 and Table 10). The high level of age-2 shrimps was not maintained and numbers of age-2 shrimp was about 72% less in 2017 (3.03 bn). However, numbers of age-2 shrimp increased by 76% (5.33 bn) in 2018, is 99% of its past 5 years mean (2012-2017) at 5.41 bn and close to its serial mean (6.03 bn). The increase in numbers of 2-age shrimp is caused by a significant rise of age-2 shrimps in North (U1-U3) and in the central regions (W5-W6). The number of age-2 remain unchanged in Disko Bay & Vaigat, only 47% of its past 5-yr mean. Age-2 shrimps have always been few in the southernmost region W7 to W9.

Disko Bay and Vaigat, which include only about 7% of the survey area, contributed 28–72% of the numbers at age 2 in 1997–2005, and more than 40% in the period from 2006 -2010 (Table 10). Whereas the contribution of age-2 shrimp from Disko Bay and Vaigat ranged from 33% to 68% in the years from 2013 to 2017, it was only 22% in 2018 (Table 10, Fig 11a). The contribution from offshore regions has historically been lower, but as observed in 2015-2018, except 2016, the abundance of age-2 shrimps were higher in those areas than in Disko Bay & Vaigat (Table 10).

The age-2 index is correlated with the fishable biomass two, three and four years later (Fig. 13); lags of two to four years in such a correlation might be reasonable considering that the main contribution to the fishable biomass comes from sizes corresponding to ages 4 to 6 years. These relationships are corrected for serial correlation (autocorrelation) if it is found significant which only was the case for the correlation of age 2 shrimps and the fishable biomass with 2 years lag. The regressions of age-2 numbers and of fishable biomass with three and four year lag have strong correlation, which indicate that shrimp enter the fishable biomass as 5 to 6 year old shrimps.

Numbers, spawning stock biomass and fishable biomass

Given that the survey biomass is down to a low level compared to 2002-2006, survey biomass and fishable biomass increased considerable over 2014 to a 2015 level comparable with 2009 and 2010 (Table 3 and Table

8). The progress in fishable biomass were not maintained in 2016, rise again in 2017 (208 Kt) and remain unchanged in 2018 (204 Kt) well above the past 5-year mean (150 Kt) and 98% of its serial mean. Spawning stock biomass—i.e. of females—accounted for more than 40% of the total survey biomass from 2010 to 2014, reached its highest level at 47.8% in 2014, but dropped over the past year to 35% in 2015 (Table 7). In 2018 female's biomass constitute approximately 40% of the total biomass, above the level for its past 5-year mean as well as its serial mean (107.6 Kt). Female biomass is in 2018 estimated at 116.3 Kt, and male biomass 175.8 Kt (Table 6).

Compared with the length distributions in past years, there were a greater proportion of the very smallest shrimps, those below about 15 mm CPL caught by 2015 survey in Disko Bay and Vaigat as well as in the offshore regions (Fig. 10). The proportion of those small shrimps was in 2016 comparable with observations from 2013 and 2014, but dropped in 2017, but increased again in 2018 to its past 5-yr mean. The proportion of the largest females above 23 mm CPL were comparable with the 2013 - 2017 level in Disko Bay and Vaigat as well as in the offshore regions (Fig. 7 and Fig. 10). Female biomass in offshore regions were low in 2014, increased significantly in 2015 remain on a comparable level in 2016, followed by an increase in 2017, decline in 2018, but is still at a level above its past 5-yr mean. Female biomass in Disko Bay declined from 2014 to 2018, except for an increase in 2017, to a level just below its past 5-yr mean.

Number of pre-recruits (14-16.5 mm CL) were in 2016 considerably lower 57.9% offshore than in 2015, but close to the 2014 value, while a 37% decrease was observed in Disko Bay. A fraction of the high proportion of pre-recruits observed in 2015 were expected to enter the fishery in 2016, but both inshore and offshore regions reveal no increase in male biomass (shrimps from 17- 23 mm). Nor the high proportions of fishable males observed in 2015, resulted in increased female biomass in 2016 and in both regions, length distribution is relatively deficient in the intermediate lengths. Is was expected that the relatively high number of age 2 shrimp observed in 2015 would have enter the pre-recruit size fraction the year after – they didn't showed up the 2016 catches, but numbers of pre-recruits increased significantly over 2016, to the second highest estimate in 2017. This increase in numbers of was not maintained in 2018, caused by a significant drop of pre-recruits inshore in Disko Bugt & Vaigat as well as in offshore regions. However, the number of pre-recruits is at its past 5-year mean.

Bottom temperature

Area weighted bottom temperatures is given in Fig. 6. Bottom temperature have been stable at somewhat 3.1°C from 2008 to 2012, but starting a decrease in 2015 (2.98°C) which continuing in 2018 to 2.1 °C.

Regionally the bottom temperature in the Northern regions (U1-U3 and I1-I2) have been continuous declining over the past 3 years and is in 2018 on average 1.2C° colder than observed in 2014. In W1-W4 temperature increased about to 3.9 °C in 2014, followed by a continuous decline to 2.25°C and remained in 2018. In the more southern areas (W5-W6) temperature has decrease little since 2014, bottom temperature remain "warm" but in the southernmost regions W7-W9, the temperature dropped from 4.68°C in 2014 to 3.39 °C in 2018. In shallow water in depth between 150-200 m the area weighted average bottom temperature is continuously rising from 2007 to 2014, but a continuous decrease have been observed since 2015. In conclusion the overall bottom temperature has decreased by 1.5°C since 2014.

The depth distribution of the shrimp survey biomass appears to have shifted after, and not concurrently with, the temperature shift (Figure 6 and Figure 14). Thus, bottom temperature has been declining since 2015 the depth index of survey biomass remained comparable to observations for the past 15 years.

Conclusions

Stock size

In aggregate, the stock has, despite for the decline from its high biomass levels in 2003 – 2006, shown no clear trends since 2007. In fact, at short term (10 year), there has been fluctuations in the stock with ups and downs in biomass. The overall survey biomass increased by 49% over 2016 to 316.2 Kt, drop little to 292 Kt in 2018, mainly caused by minor changes in biomass in regions north of 66°N. The total survey biomass is 119% of its past 5-yr mean, and very close to its serial mean (293.2 Kt). The offshore regions are now constitute 75% of the total surveyed biomass, and Disko Bay & Vaigat constitute 25%, comparable with values for the serial mean.

The offshore and inshore components have had very different trajectories since 2008. Inshore, in Disko Bay and Vaigat, the biomass almost doubled from 2008 to 2010 and has then gradually decrease. In the same period the offshore biomass has fluctuated with ups and downs. Recruitment pattern have to some extend shown minor different trajectories, however not so conspicuously as for the survey biomass.

Fishable biomass increased over 2016, caused by a significantly increase in offshore regions, as well as an increase of fishable biomass in Disko Bay and remained almost stable in 2018 at 270.5 Kt. In 2018 fishable biomass, constitute 93% of the total surveyed biomass. In both regions, fishable biomass is at 98% of its serial mean offshore and 109% of its serial mean inshore (Disko Bay & Vaigat).

Stock distribution

The area over which the stock is distributed has increased a little since 2013, and it remains concentrated in Disko Bay, Vaigat and the Northern part of its range (north of 66°N). Densities are almost four times higher in Disko Bay and Vaigat compared to offshore regions, but in both regions, densities are close to their serial means. In almost all strata in the Offshore regions, densities shown some minor decreases over 2017; but was about 1.5 times higher in the central regions (W5-W7) than in 2017, and a value mush higher than observed for the past 10 years. Densities are practically zero on the continental slope west of the banks all the way from Store Hellefiskebanke to Kap Farvel.

The latitude index of the survey has declined from 2010 – 2013, followed by a continuous increase to 2018. The North index remain stable from 2009 to 2015 owing to high proportion of biomass in the Northern regions and in Disko Bay & Vaigat, and lower proportion of biomass in the W– regions. However, for the past 3 years, three have been a declining trend in the North index. Survey biomass from the northern (above 66°N) and inshore regions constitute almost 85% of the total offshore survey biomass, whereas biomass in those regions has account for more than 90% for the past five years.

Since the late 1990s, the stock appears to be found in shallower water than before. Nevertheless, the proportion of the biomass in the shallow water (100-200 m) constitute in general less than 20% of the total shrimp biomass. Since the late 90'ties the majority (80%) of the biomass has been found in depths from 200 to 300 m and 300 to 400 m, while little biomass is found to be at deeper waters > 400 m.

Survey biomass depth index has ranged between 265 and 300 m since 2001, with an average near 281.5 m compared to an average of 329 m in the period from 1988 to 2000 (Fig 5.c). In 2018, the depth index was estimated to approx. 289 m, a little deeper than compared with the past 5 year (281 m).

Stock composition

By numbers and biomass, the stock is heavily weighted toward males, but the females still composed a high proportion of the total fishable (43%) and surveyed biomass (40%). Fishable biomass is at the average for the serial mean and as a proportion of the total survey biomass, but compose to a relatively high degree of males.

Numbers at age-2 are overall, below the serial mean but above the past 5-yr mean. The number of pre-recruits (14-16,5 mm CL) in total are at an average level both in numbers and relative to the survey biomass; average in absolute numbers and relative to their biomass in offshore regions, but below mean in Disko Bay & Vaigat.

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Table 1. *Pandalus borealis* in West Greenland: vessels, trawl types and rigging parameters used in the West Greenland Bottom Trawl Survey for shrimp and fish, 1988–2015

	Vessel	Trawl	Bridle length (m)	Wing-spread (m)	
1988	Elias Kleist	Skjervøy	59.9	23.1	*
1989	Sisimiut	"	81.1	17.9	*
1990	Maniitsoq	"	59.9	23.1	*
1991	Paamiut	"	75.1	28.3	**
1992–2003	"	"	60.1	20.1–25.2	**
2004	"	"	54.0	25.7	**
2005–2017	"	Cosmos	54.0	27.4–29.3	**
2018	Sjurdarberg	Cosmos	54.0	30.2	**

(*: from tank experiments (Per Kanneworff, pers.com.), **: average for all valid tows calculated from measures of door spread and approximate geometry of the trawl).

Table 2. *Pandalus borealis* in West Greenland: survey estimates of total biomass 2018.

Stratum	Area (km²)	Stations	Biomass density (t/km²)	Biomass (Kt)	Biomass error variance	Error coefft of variation (%)
C0-2	903	0	0.000	0.000	0.0000	0.0
C0-3	2179	0	0.000	0.000	0.0000	0.0
C0-4	1154	0				
Overall C0	4236	0	0.000	0.000	0.0000	0.0
I1-1	407	2	7.012	2.851	2.0045	49.7
I1-2	1963	5	16.654	32.692	37.9929	18.9
I1-3	2441	5	6.431	15.700	6.0189	15.6
I1-4	1499	3	2.439	3.655	0.5962	21.1
I2-1	419	2	2.440	1.023	0.0087	9.1
I2-2	815	2	11.941	9.732	11.8929	35.4
I2-3	1085	3	2.697	2.926	1.3556	39.8
I2-4	1338	2	2.729	3.652	1.4425	32.9
Overall I	9967	24	7.247	72.231	61.3123	10.8
U1-1	2486	2	0.303	0.754	0.1441	50.3
U1-2	4633	9	2.409	11.160	7.3240	24.3
U1-3	4785	2	1.539	7.366	0.1904	5.9
U1-4	5129	4	0.051	0.262	0.0160	48.3
U2-2	6710	3	0.532	3.568	1.6460	36.0
U2-3	8481	4	3.527	29.916	62.4870	26.4
U2-4	7994	3	0.097	0.774	0.5086	92.2
U3-1	2012	2	0.093	0.187	0.0308	94.0
U3-2	3017	3	1.539	4.643	4.8587	47.5
U3-3	1675	2	3.744	6.269	34.5198	93.7
U3-4	2710	2	0.332	0.899	0.0446	23.5
Overall U	49631	36	1.326	65.798	111.7698	16.1

W1-1	2873	2	1.440	4.138	13.1606	87.7
W1-2	6099	8	2.832	17.272	67.3145	47.5
W1-3	7520	4	2.104	15.823	14.2584	23.9
W1-4*	816	0	0.000	0.000	0.0000	0.0
W2-1	1674	3	0.629	1.052	0.4907	66.6
W2-2	2612	5	8.067	21.068	24.8195	23.6
W2-3	1741	3	3.965	6.903	7.9382	40.8
W2-4	915	2	1.639	1.499	0.0549	15.6
W3-1	2122	2	1.461	3.100	0.3208	18.3
W3-2	4725	10	3.777	17.848	30.2550	30.8
W3-3	2085	1	2.989	6.231	35.0425	95.0
W3-4	2994	2	0.193	0.577	0.1322	63.0
W4-1	4119	4	0.212	0.875	0.6520	92.3
W4-2	1818	3	5.571	10.129	69.2922	82.2
W4-3	821	2	0.023	0.019	0.0003	87.2
W4-4	1961	2	1.585	3.108	9.4277	98.8
W5-1	3001	3	0.086	0.258	0.0113	41.4
W5-2	3648	13	4.076	14.869	44.5864	44.9
W5-3	1950	2	0.962	1.876	3.5209	100.0
W5-4	3021	4	0.385	1.164	1.3374	99.3
W6-1	1206	3	2.816	3.396	9.8079	92.2
W6-2	2006	4	10.778	21.619	379.5649	90.1
W6-3	1585	3	0.337	0.535	0.0404	37.6
W6-4	1234	2	0.514	0.634	0.4018	100.0
W7-1	2442	4	0.000	0.000	0.0000	0.0
W7-2	891	6	0.000	0.000	0.0000	100.0
W7-3	265	2	0.000	0.000	0.0000	6.5
W7-4	317	1	0.000	0.000	0.0000	0.0
W8-1	424	2	0.000	0.000	0.0000	100.0
W8-2	567	3	0.004	0.002	0.0000	93.0
W8-3	405	2	0.019	0.008	0.0000	80.1
W8-4	718	2	0.032	0.023	0.0004	87.7
W9-1	1711	6	0.000	0.000	0.0000	100.0
W9-2	938	4	0.000	0.000	0.0000	100.0
W9-3	516	3	0.000	0.000	0.0000	51.3
W9-4	430	2	0.000	0.000	0.0000	100.0
Overall W	72169	124	2.134	154.027	712.4309	17.3
Survey totals	136003	184	2.147	292.057	885.5131	10.2

† strata with 1 trawled station have been assigned an error coefficient of variation of 95%
* Substrata W1-4 owing to Ice cover.

Table 3. *Pandalus borealis* in West Greenland: biomass estimates (Kt) for survey subdivisions and standard errors for the entire survey in 1988–2018.

Year	N1-9/ U1-3 [1.5]	C1-3/C0 [1,6]	W1-2	W3-4	W5-7 [2]	S/W8-9 [1]	D1-9/I1-2 [3,1]	Total	SE[4]
1988	22.6	9.5	55.1	85.5	17.7		39.2	229.7	24.7
1989	11.1	3.7	50.0	82.7	39.0		39.2	225.7	32.3
1990	11.0	9.1	78.6	53.9	23.5		39.2	215.3	32.6
1991	5.1	4.2	26.8	47.4	23.3		43.1	149.9	23.0
1992	18.1	22.2	46.2	30.6	45.8		41.4	204.4	32.5
1993	6.9	2.9	93.8	36.7	62.2		28.3	230.8	30.9
1994	6.6	6.0	95.0	44.5	32.6	16.7	34.0	235.4	51.7
1995	6.8	3.9	39.0	52.4	48.7	1.6	39.1	191.4	30.6
1996	8.8	1.5	46.4	31.5	80.0	3.3	44.3	215.9	40.4
1997	5.7	0.2	34.7	13.1	57.9	21.8	44.3	177.7	31.1
1998	7.0	0.4	37.8	100.6	45.1	18.6	51.8	261.2	57.6
1999	17.6	10.5	50.1	23.2	50.5	56.0	52.6	260.6	42.1
2000	8.4	10.7	62.1	69.8	71.0	21.8	73.0	316.9	40.3
2001	34.1	3.7	74.3	47.6	58.5	36.3	72.1	326.7	44.2
2002	17.4	5.4	114.0	62.1	94.9	40.5	85.8	420.2	60.0
2003	109.3	5.9	148.6	93.3	98.0	35.0	107.7	597.8	77.0
2004	111.2	3.5	152.8	96.5	102.6	15.4	81.4	563.4	103.7
2005	100.5	9.3	159.9	87.2	53.4	1.9	139.6	551.9	88.4
2006	54.7	45.8	108.9	60.6	92.2	12.5	110.7	484.0	65.1
2007	61.2	1.7	128.1	64.0	21.3	1.2	79.1	356.6	44.3
2008	91.7	16.7	61.3	40.0	20.9	0.7	50.8	282.1	28.3
2009	91.7	4.3	62.9	30.1	18.4	1.0	70.1	278.4	27.1
2010	73.1	3.0	89.6	65.3	13.5	0.9	99.3	344.7	44.6
2011	55.5	-[1]	69.2	6.1	34.3	2.6	92.9	260.6	36.1
2012	33.5	-[1]	33.8	7.0	23.1	0.4	92.5	190.3	20.6
2013	54.1	0.4	51.6	37.4	8.6	0.2	81.4	233.8	23.2
2014	29.4	-[1]	34.5	12.1	10.4	0.0	93.5	179.9	16.6
2015	75.4	-[1]	51.5	59.9	18.0	0.6	78.2	283.6	41.7
2016	60.5	-[1]	48.0	25.5	10.3	2.8	64.8	212.0	19.1
2017	69.8	3.1	72.7	60.0	29.6	0.0	80.8	316.2	29.1
2018	65.8	-[1]	67.8	41.9	44.4	0.0	72.2	292.1	29.5

[1]: New stratification introduced in 2003 (regions N and S) and in 2004 (regions U, C and D)

[2]: Areas W6 and W7 were sampled from 1990 and 1993, respectively

[3]: D1-D9 1988-90 not sampled, but set to mean of 1991-1997.

[4]: Standard error calculated excluding D1-D9 in 1988-1990

[5]: Probably underestimated due to poor coverage of the northern part of the area N

[6]: Canada(C) in 2011, 2012 and 2014, 2015, 2016 and 2018 was not sampled due to ice condition

Table 4. *Pandalus borealis* in West Greenland: error coefficients of variation (%) for the biomass estimates of five main survey regions and the entire survey area in 1988–2018.

Year	N1-9/ U1-3	C1-3/C0	W1-2	W3-4	W5-7	S/W8-9	D1-9/I1-2	Total suvey	Number of hauls
1988	31.4	40.0	17.9	26.4	42.5	-	-	14.41	131
1989	22.2	42.8	23.9	33.2	35.0	-	-	18.60	130
1990	43.5	39.9	22.7	39.5	42.0	-	-	18.30	109
1991	40.2	27.1	21.2	30.4	30.6	-	22.9	13.37	194
1992	16.9	68.9	15.5	17.9	42.0	-	15.7	13.84	167
1993	51.6	53.3	14.6	28.0	28.5	-	19.4	11.66	157
1994	48.7	18.3	27.2	16.8	45.9	99.2	26.0	19.11	157
1995	47.1	44.7	20.0	22.6	36.3	74.0	17.7	13.93	163
1996	52.6	91.0	23.9	19.8	36.2	95.0	10.6	16.31	148
1997	37.9	61.9	15.8	20.2	43.1	14.6	14.5	15.26	167
1998	40.4	44.0	33.2	44.5	30.6	58.8	18.4	19.19	209
1999	51.1	80.0	13.1	14.8	27.7	52.1	14.2	14.08	227
2000	36.1	7.8	21.5	32.7	18.5	56.8	12.9	11.08	198
2001	26.5	44.5	24.9	45.0	25.6	22.8	18.6	11.77	224
2002	56.0	45.4	16.0	28.9	36.5	55.0	18.7	12.44	216
2003	26.8	44.4	17.5	16.0	34.9	49.9	17.5	11.21	172
2004	24.9	22.6	22.8	27.1	24.1	71.4	11.6	16.03	187
2005	17.4	97.3	22.8	38.0	50.4	48.7	34.6	16.02	194
2006	20.5	79.0	19.2	20.5	41.3	79.4	12.9	13.41	223
2007	21.9	45.1	19.8	32.6	8.8	56.8	20.8	12.43	223
2008	17.3	80.7	15.6	33.1	43.5	44.8	11.5	10.02	204
2009	22.1	59.6	12.8	18.7	39.0	53.0	15.9	9.72	247
2010	11.1	29.7	27.0	61.0	66.9	98.7	10.0	12.94	270
2011	9.8	-(1)	19.1	26.2	89.0	80.5	12.4	13.85	192
2012	16.0	-(1)	12.4	23.9	45.8	84.6	17.4	10.83	193
2013	16.1	76.8	21.1	41.8	55.6	78.6	11.6	9.93	181
2014	26.8	-(1)	19.6	43.2	34.7	65.0	11.6	9.23	189
2015	20.3	-(1)	33.2	58.3	45.5	51.8	10.7	14.69	186
2016	12.0	-(1)	15.7	31.6	54.2	99.9	18.4	9.03	156
2017	12.4	74.2	16.2	31.0	46.3	53.8	13.2	9.20	215
2018	16.1	-(1)	14.7	27.4	47.3	63.3	10.8	10.11	184
Mean 1994-2018	27.5	55.1	20.2	31.0	41.1	64.3	15.7	12.9	197.0

1: C (Canada) in 2011, 2012, 2014-2016 and 2018 was not sampled owing to ice cover

Table 5. *Pandalus borealis* in West Greenland: estimated mean densities (t/km²) for survey subdivisions in 1988–2018.

Year	N1-9/ U1-3	C1-3/C0	W1-2	W3-4	W5-7	S/W8-9	D1-9/I1-2
1988	0.54	2.77	2.34	3.94	1.76	-	-
1989	0.25	1.08	2.76	3.81	3.88	-	-
1990	0.25	2.65	3.33	2.48	1.59	-	-
1991	0.12	1.23	1.14	2.18	1.57	-	4.60
1992	0.44	6.46	1.96	1.41	3.09	-	4.42
1993	0.17	0.85	3.55	1.68	3.32	-	3.02
1994	0.17	1.76	3.59	2.03	1.74	3.22	3.63
1995	0.18	1.15	1.47	2.39	2.60	0.24	4.17
1996	0.23	0.44	1.75	1.44	4.27	0.51	4.73
1997	0.15	0.06	1.31	0.60	3.09	3.35	4.73
1998	0.18	0.11	1.43	4.59	2.41	2.85	5.54
1999	0.46	3.06	1.89	1.10	2.70	8.59	5.62
2000	0.22	3.10	2.35	3.18	3.79	3.35	7.80
2001	0.89	1.08	2.81	2.17	3.12	5.57	7.70
2002	0.45	1.57	4.31	4.46	5.07	6.21	9.16
2003	2.22	1.39	6.11	6.25	5.23	5.80	11.49
2004	2.20	0.82	6.25	4.71	4.76	2.65	8.37
2005	1.99	2.20	6.54	4.25	2.48	0.34	14.19
2006	1.08	10.81	4.46	2.96	4.28	2.20	11.26
2007	1.21	0.40	5.24	3.12	0.99	0.21	8.04
2008	1.85	3.94	2.53	1.94	0.97	0.13	5.09
2009	1.85	1.01	2.59	1.46	0.85	0.17	7.03
2010	1.47	0.70	3.70	3.16	0.63	0.16	9.96
2011	1.12	-	2.95	0.30	1.59	0.46	9.32
2012	0.67		1.40	0.34	1.07	0.07	9.28
2013	1.09	0.13	2.13	1.81	0.40	0.05	8.16
2014	0.59	0.00	1.42	0.59	0.48	0.00	9.38
2015	1.52	-	2.12	2.90	0.84	0.10	7.85
2016	1.22	-	1.98	1.24	0.48	0.49	6.50
2017	1.41	0.99	3.10	2.91	1.37	0.01	8.11
2018	1.33	-	2.89	2.03	2.06	0.01	7.25

Table 6. *Pandalus borealis* in West Greenland: estimated numbers (billions) by sex in 1988–2018.

Year	Males	Females	Total	Males %	Females %
1988 [1]	26.8	9.3	36.1	74.3	25.7
1989 [1]	39.0	6.9	45.9	85.0	15.0
1990 [1]	29.3	8.9	38.1	76.8	23.2
1991	19.6	5.1	24.7	79.3	20.7
1992	29.4	6.5	35.9	81.9	18.1
1993	34.8	8.3	43.1	80.7	19.3
1994	32.0	8.9	40.9	78.3	21.7
1995	27.7	6.5	34.2	80.9	19.1
1996	38.2	6.6	44.8	85.2	14.8
1997	27.2	6.3	33.5	81.2	18.8
1998	41.0	9.9	50.9	80.5	19.5
1999	42.5	9.9	52.3	81.1	18.9
2000	62.4	11.1	73.4	84.9	15.1
2001	56.6	11.8	68.4	82.7	17.3
2002	85.3	14.9	100.1	85.1	14.9
2003	99.4	24.9	124.4	80.0	20.0
2004	89.4	26.3	115.8	77.3	22.7
2005	94.5	25.1	119.6	79.0	21.0
2006	78.3	24.6	102.9	76.1	23.9
2007	55.1	16.0	71.1	77.4	22.6
2008	42.4	11.8	54.2	78.2	21.8
2009	41.3	12.0	53.3	77.4	22.6
2010	52.9	13.5	66.3	79.7	20.3
2011 [2]	36.8	13.0	49.8	74.0	26.0
2012 [2]	28.8	8.7	37.4	77.0	23.2
2013	31.1	12.0	43.1	72.2	27.8
2014	22.8	9.2	32	71.3	28.8
2015	51.3	10.6	61.9	82.9	17.1
2016	27.6	10.5	38.1	72.4	27.6
2017	47.7	14.2	61.9	77.1	22.9
2018	44.3	12.6	56.9	77.9	22.1
Average	46.3	12.1	58.4	79.0	21.1

[1] mean values for Disko Bay and Vaigat in 1991–1997 have been inserted for 1988–1990, and included in the calculation of the average.
[2] area C0 was not surveyed in 2011, 2012, 2014 – 2016 and 2018 owing to sea ice; and in 2014 due to time trouble; no correction has been made.
[3] Substrata W1-4 in 2011, 2015, 2017 and 2018, W9-4 in 2015 and W9-4 were not surveyed due to trawl difficulties and poor bottom conditions.

Table 7. *Pandalus borealis* in West Greenland: biomass estimates ('000 t) by sex based on length-weight distributions from the West Greenland shrimp survey in 1988–2018.

Year	Males	Females	Total	Males %	Females %
1988	134.7	94.8	229.5	58.7	41.3
1989	157.1	68.6	225.7	69.6	30.4
1990	129.4	85.4	214.9	60.2	39.8
1991	100.5	49.4	149.9	67.0	33.0
1992	141.3	63.1	204.4	69.1	30.9
1993	149.2	81.9	231.1	64.6	35.4
1994	146.5	88.9	235.4	62.2	37.8
1995	124.5	66.9	191.4	65.0	35.0
1996	147.9	68.0	215.9	68.5	31.5
1997	114.7	62.9	177.7	64.6	35.4
1998	170.4	90.9	261.3	65.2	34.8
1999	166.7	93.9	260.6	64.0	36.0
2000	213.8	100.2	314.0	68.1	31.9
2001	199.1	108.3	307.4	64.8	35.2
2002	293.6	126.6	420.2	69.9	30.1
2003	389.2	208.6	597.8	65.1	34.9
2004	353.1	210.3	563.4	62.7	37.3
2005	355.2	196.7	551.9	64.4	35.6
2006	297.4	188.0	485.4	61.3	38.7
2007	227.8	128.7	356.6	63.9	36.1
2008	182.6	99.5	282.1	64.7	35.3
2009	173.5	105.0	278.4	62.3	37.7
2010	222.3	122.4	344.7	64.5	35.5
2011	148.5	112.0	260.6	57.0	43.0
2012	115.4	74.9	190.3	60.7	39.3
2013	129.9	103.9	233.8	55.6	44.4
2014	93.8	86.0	179.8	52.2	47.8
2015	184.6	99.0	283.6	65.1	34.9
2016	113.6	98.4	212.0	53.6	46.4
2017	181.1	135.1	316.2	57.3	42.7
2018	175.8	116.3	292.1	60.2	39.8
Average	184.9	107.6	292.5	63.1	36.9

1991–1997 mean values for Disko Bay and Vaigat have been used for 1988–1990, and included in the calculation of the average.data for 2005–2010 was re-analyzed in 2011.

Table 8. *Pandalus borealis* in West Greenland: estimates of fishable biomass (≥17mm CL; '000 t) from the West Greenland shrimp survey in 1988–2018

FB	>= 17mm CL		10^3 tons			
Year	Offshore fishable		Disko fishable		Overall fishable	
	biomass	%	biomass	%	biomass	%
1988	186.2		37.0		223.2	
1989	171.9		37.0		209.0	
1990	170.0		37.0		207.0	
1991	104.7	98%	41.3	96%	146.0	97%
1992	154.8	95%	39.4	95%	194.2	95%
1993	189.4	94%	27.1	96%	216.5	94%
1994	191.0	95%	32.1	94%	223.1	95%
1995	144.9	95%	38.3	98%	183.2	96%
1996	150.6	88%	41.5	94%	192.1	89%
1997	127.7	96%	39.4	89%	167.1	94%
1998	197.2	94%	47.1	91%	244.3	94%
1999	195.0	94%	42.3	80%	237.3	91%
2000	219.8	90%	60.6	83%	280.3	88%
2001	216.8	85%	63.7	88%	280.5	86%
2002	302.2	90%	67.2	78%	369.5	88%
2003	454.0	93%	94.3	88%	548.3	92%
2004	457.5	95%	70.8	87%	528.3	94%
2005	381.8	93%	112.3	80%	494.2	90%
2006	358.6	96%	92.4	83%	451.0	93%
2007	264.7	95%	71.3	90%	336.1	94%
2008	216.8	94%	45.8	90%	262.6	93%
2009	192.2	92%	62.8	90%	255.1	92%
2010	229.8	94%	88.9	90%	318.7	92%
2011	155.9	93%	83.1	89%	239.0	92%
2012	89.5	91%	83.9	91%	173.3	91%
2013	143.6	94%	74.6	92%	218.1	93%
2014	81.7	95%	85.5	91%	167.2	93%
2015	178.8	87%	69.3	89%	248.1	87%
2016	137.3	70%	58.3	90%	195.6	92%
2017	207.5	88%	73.8	91%	281.3	89%
2018	204.1	93%	66.4	92%	270.5	93%
Average	208.9	92%	60.8	89%	269.7	92%

[1] 1991–1997 mean values for Disko Bay and Vaigat have been used for 1988–1990, and included in the calculation of the average.
[2] data for 2005–2010 was re-analysed in 2011.
[3] area C0 was not surveyed in 2011-2016 and 2018, except 2013 nor substratum W1-4 in 2011 and 2015, owing to sea ice; and W9-4 in 2015 and W2-4 due to trawl difficulties.

Table 9. *Pandalus borealis* in West Greenland: mean carapace length (mm) at age 2 in 2005–2018, with standard deviations and coefficients of variation (- : not present, ( ): fixed in the final MIX run, na: no data).

Mean:

Year	U1-U3 150-600 m	I1+I2 150-600 m	Region / Strata C0 200-600 m	W1-W4 150-600 m	W5+W6 150-600 m	W7-W9 150-600 m
2005	11.1	11.5	-	12.5	-	-
2006	11.5	11.4	-	12.3	12.5	-
2007	-	11.5	-	-	12.5	-
2008	13.4	12.6	-	12.4	11.5	-
2009	12.2	11.8	-	12.3	12.2	-
2010	10.8	11.9	-	13.1	-	-
2011	-	11.2	na	11.3	-	-
2012	11.7	11.0	na	-	11.7	-
2013	11.2	13.1	-	13.5	13.0	-
2014	12.3	13.5	na	13.1	-	-
2015	11.5	13.4	na	*12.1*	12.0	-
2016	12.6	12.0	na	12.1	13.7	-
2017	11.5	11.8	na	11.0	11.2	-
2018	11.5	11.5	na	10.9	13.6	-

Standard deviation:

Year	U1-U3 150-600 m	I1+I2 150-600 m	Region / Strata C0 200-600 m	W1-W4 150-600 m	W5+W6 150-600 m	W7-W9 150-600 m
2005	0.9	1.5	-	1.3	-	-
2006	1.0	1.1	-	1.4	1.3	-
2007	-	1.4	-	-	1.3	-
2008	1.7	1.9	-	1.3	0.8	-
2009	1.4	1.4	-	1.1	1.26	-
2010	1.3	1.2	-	1.3	-	-
2011	-	1.0	na	1.2	-	-
2012	1.5	1.1	na	-	0.4	-
2013	1.0	1.3	-	1.1	1.4	-
2014	1.0	1.4	na	1.4	-	-
2015	0.9	1.5	na	1.1	1.0	-
2016	1.3	1.5	na	1.9	0.9	-
2017	1.3	1.2	na	1.2	0.9	-
2018	1.1	0.9	na	1.2	1.3	-

Coefficent of variation:			Region / Strata			
	U1-U3	I1+I2	C0	W1-W4	W5+W6	W7-W9
Year	150-600 m	150-600 m	200-600 m	150-600 m	150-600 m	150-600 m
2005	0.08	0.13	-	0.10	-	-
2006	0.09	0.09	-	0.11	0.10	-
2007	-	0.12	-	-	0.11	-
2008	0.12	0.15	-	0.10	0.07	-
2009	0.11	0.12	-	0.09	0.11	-
2010	0.12	0.10	-	0.10	-	-
2011	-	0.09	na	0.10	-	-
2012	0.13	0.10	na	-	0.03	-
2013	0.09	0.10	-	0.08	0.11	-
2014	0.08	0.10	na	0.11	-	-
2015	0.08	0.11	na	0.09	0.08	-
2016	0.08	0.10	na	0.10	0.07	-
2017	0.10	0.09	na	0.11	0.08	-
2018	0.08	0.16	na	0.11	0.04	-

Table 10. *Pandalus borealis* in West Greenland: survey estimate of numbers (billions) at age 2 years, 1993–2018.

Year	U1 to U3	I1 and I2	C0 and W1 to W4		W5 and W6	W7 to W9	Total
1993	0.06	0.08	2.60		1.54	0.00	4.28
1994	0.01	0.21	1.51		1.20	0.00	2.92
1995	0.02	0.11	0.82		1.37	0.00	2.32
1996	0.11	1.25	2.45		6.20	0.00	10.01
1997	0.05	1.37	0.52		1.27	0.00	3.22
1998	0.04	1.79	2.01		2.60	0.00	6.44
1999	0.42	5.06	2.66		3.22	0.00	11.36
2000	0.33	5.54	4.92		3.50	0.01	14.29
2001	1.66	5.44	7.79		1.01	0.01	15.90
2002	0.02	3.98	3.41		2.97	0.04	10.42
2003	0.76	1.11	1.70		2.88	0.03	6.48
2004	0.64	3.39	2.24		0.47	0.01	6.75
2005	0.32	3.47	0.23		0.05	0.00	4.07
2006	0.33	1.86	2.12		0.78	0.00	5.09
2007	0.00	0.96	0.00	0.00	0.38	0.00	1.34
2008	2.96	1.48	0.00	0.86	0.36	0.00	5.66
2009	1.95	2.05	0.00	0.91	0.14	0.00	5.05
2010	0.95	2.23	0.00	1.13	0.00	0.00	4.31
2011	0.00	2.52	-	0.44	0.00	0.00	2.96
2012	0.30	1.20	-	0.00	0.07	0.00	1.57
2013	0.40	2.03	0.00	1.63	0.00	0.00	4.06
2014	0.17	3.30	-	1.36	-	0.00	4.83
2015	1.38	3.62	-	5.35	0.50	0.00	10.85
2016	0.66	2.51	-	1.04	0.05	0.00	4.26
2017	0.24	1.18	-	1.43	0.18	0.00	3.03
2018	1.20	1.18	-	1.72	1.23	0.00	5.33
Average:	0.58	2.27	1.96		1.28	0.00	6.03

[1] data for 1993 to 2004 has been converted from Skervøy to Cosmos trawl;
[2] for area C0 – numbers of age 2 shrimps is in general very low. Estimating the components in the mixture distribution to the data using maximum-likelihood estimation for the grouped data, resulting is very poor fits.
[*] Numbers of age-2 shrimps from 2005 – 2014 have been recalculated in 2014.

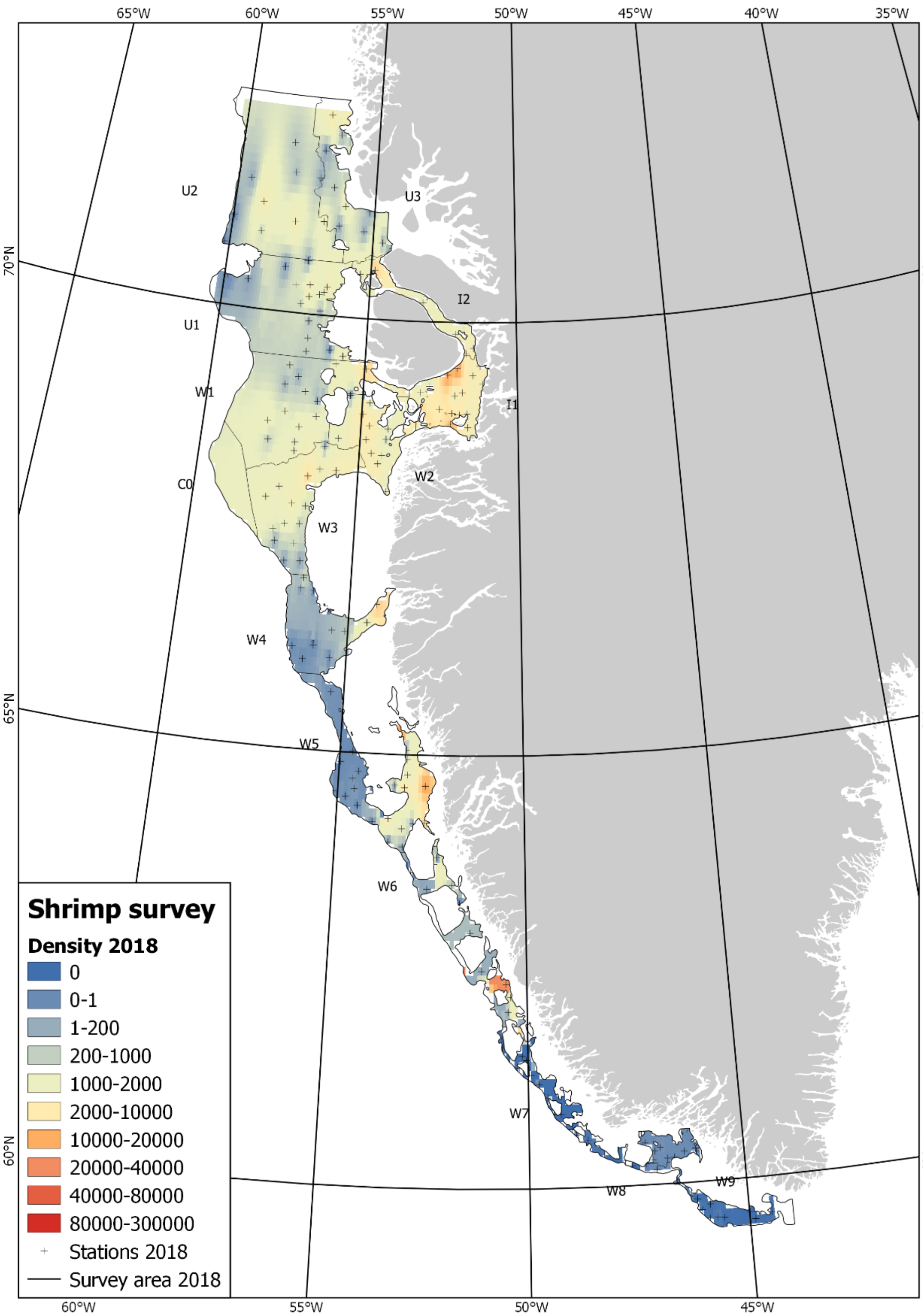

Fig.1. *Pandalus borealis* in West Greenland: density distribution from 215 trawl-survey stations in 2018.

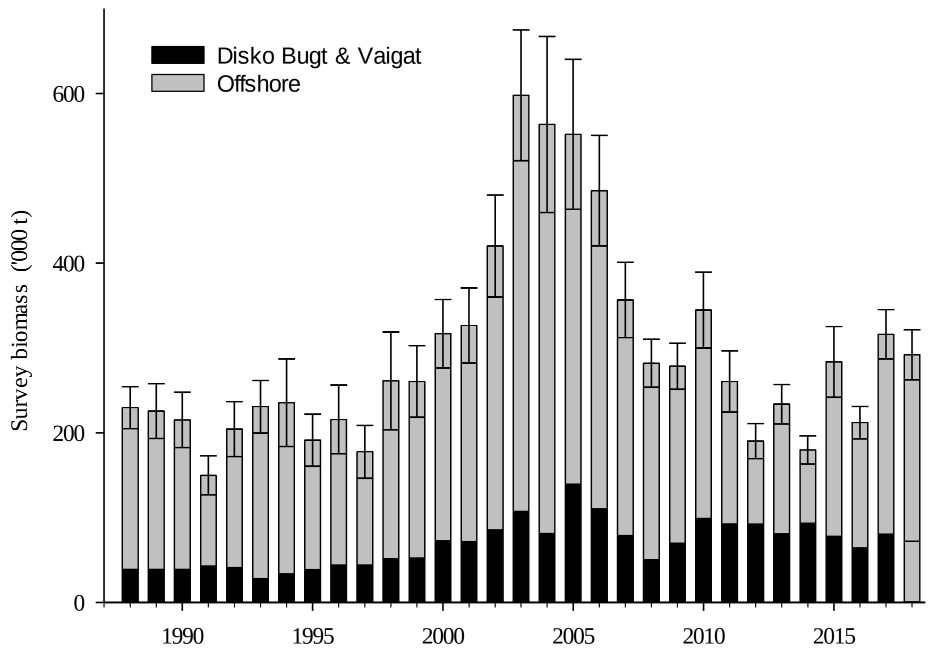

Fig.2a. *Pandalus borealis* in West Greenland: estimated survey biomass, 1988–2018. Area C0-4 was not surveyed in 2011 – 2016, except 2013 because of ice cover, in 2014 W9-4 due to poor bottom conditions, area C0 in 2011, 2012, 2014-2016 and 2018 owing to time trouble and W2-4 due to trawl difficulties and poor bottom conditions.

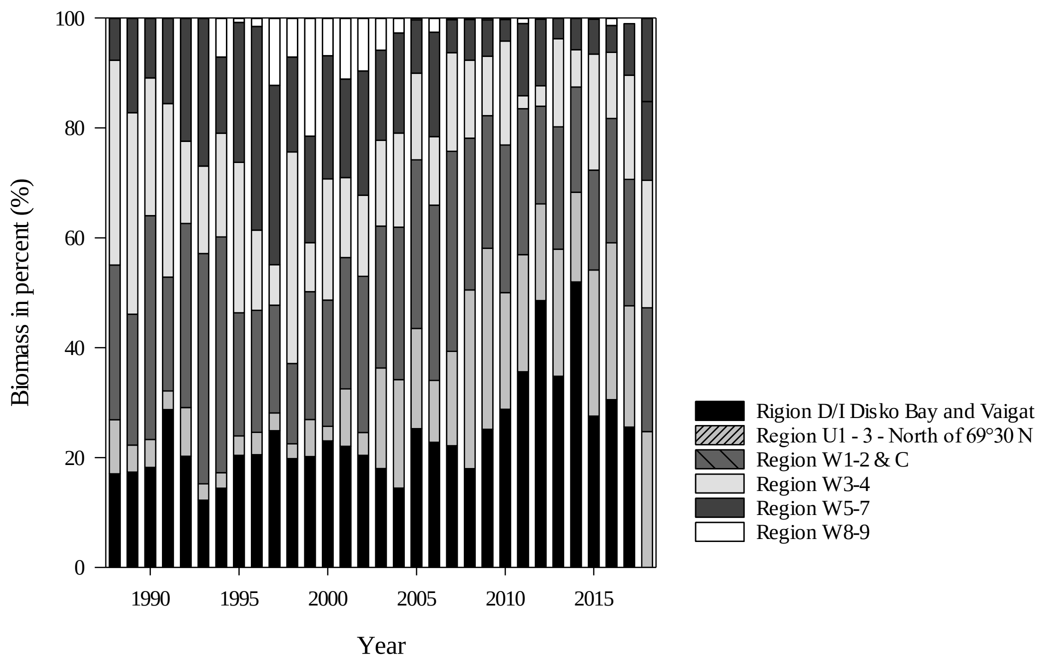

Fig. 2 b. *Pandalus borealis* in West Greenland: distribution of survey biomass between major survey regions, 1991 – 2018. Area C0-4 was not surveyed in 2011 – 2016, except 2013 and in 2018 because of ice cover, in 2014 W9-4 due to poor bottom conditions, area C0 in 2014 owing to time trouble and W2-4 due to trawl difficulties and poor bottom conditions.

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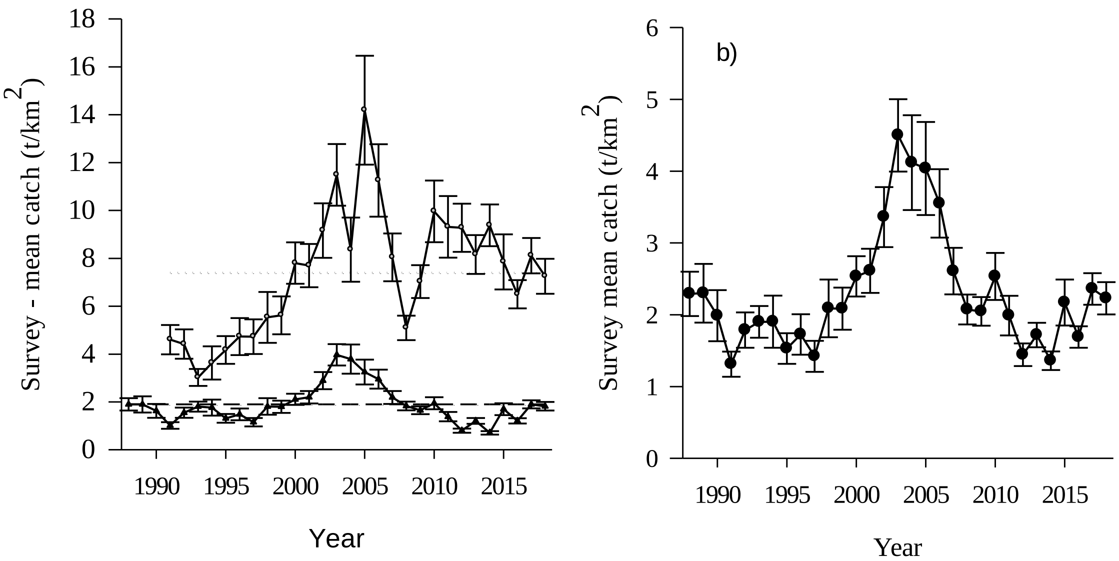

Fig.3. *Pandalus borealis* in West Greenland 1988 - 2018: mean survey density of Northern shrimp in a) -○- Disko Bay and Vaigat (since 1991 cover 7–8% of the survey area), -▲-offshore (92–93%) and b) total surveyed regions.

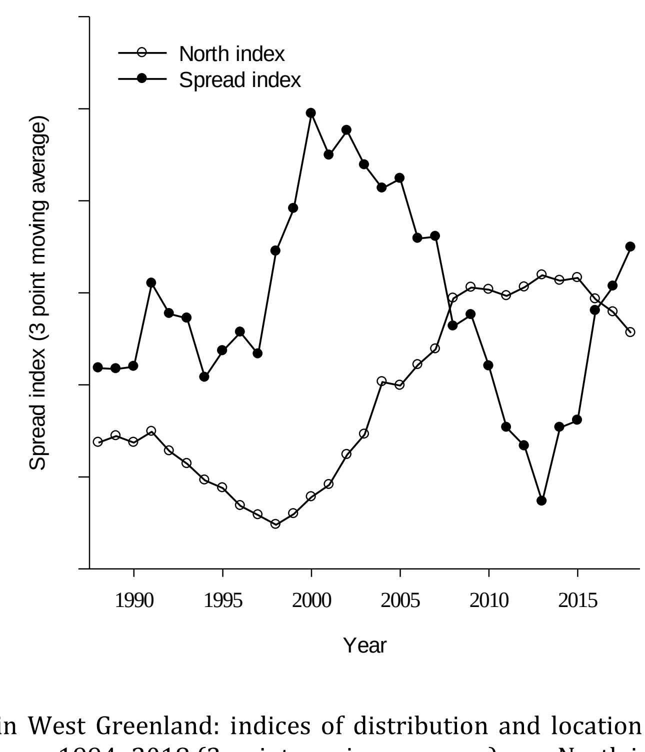

Fig.4. *Pandalus borealis* in West Greenland: indices of distribution and location of shrimp biomass in the West Greenland trawl survey 1994–2018 (3-point moving averages). -□-: North index (3-pt moving average) and -■-; Spread index (3-pt moving average).

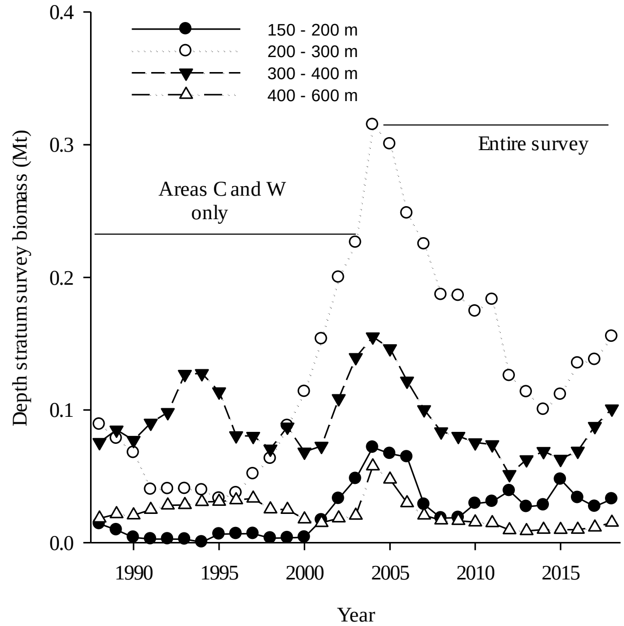

Fig. 5a. *Pandalus borealis* in West Greenland: survey biomass estimates by depth stratum, 1988–2018. 3-point moving averages.; Until 2003, only areas C and W were substratified by depth. -●-: 150 – 200m, -○-: 200-300m, -▼-: 300-400 and –Δ- : 400-600m.

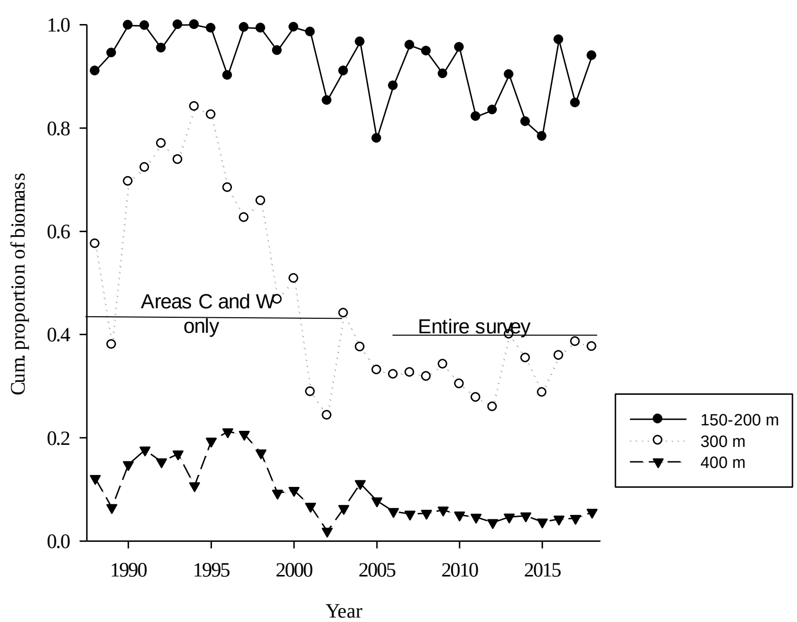

Fig. 5b. *Pandalus borealis* in West Greenland: distribution of survey biomass between 150 and 600 m by depth, 1988–2018. Until 2003, only areas C and W were substratified by depth. -●-: 150 – 200 m, -○-: 300 m and -▼-400m

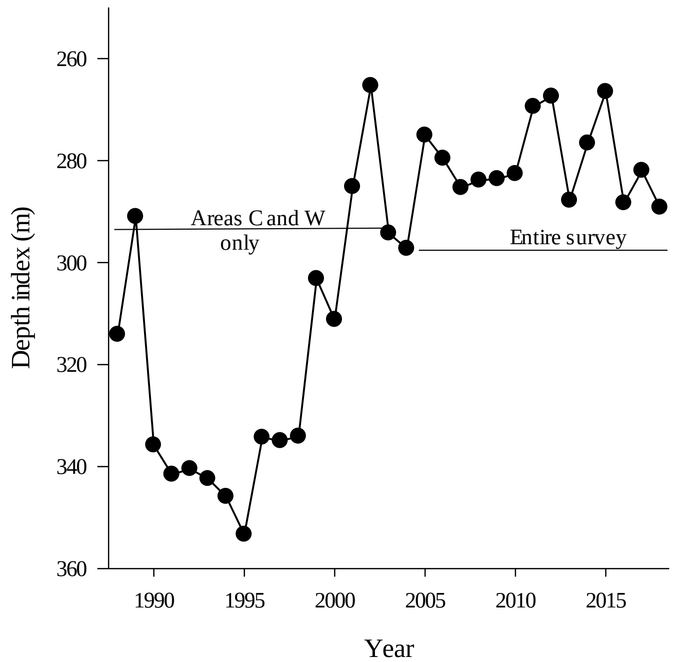

Fig. 5c. *Pandalus borealis* in West Greenland: depth index for survey biomass, 1988–2018. Until 2003, only areas C and W were substratified by depth.

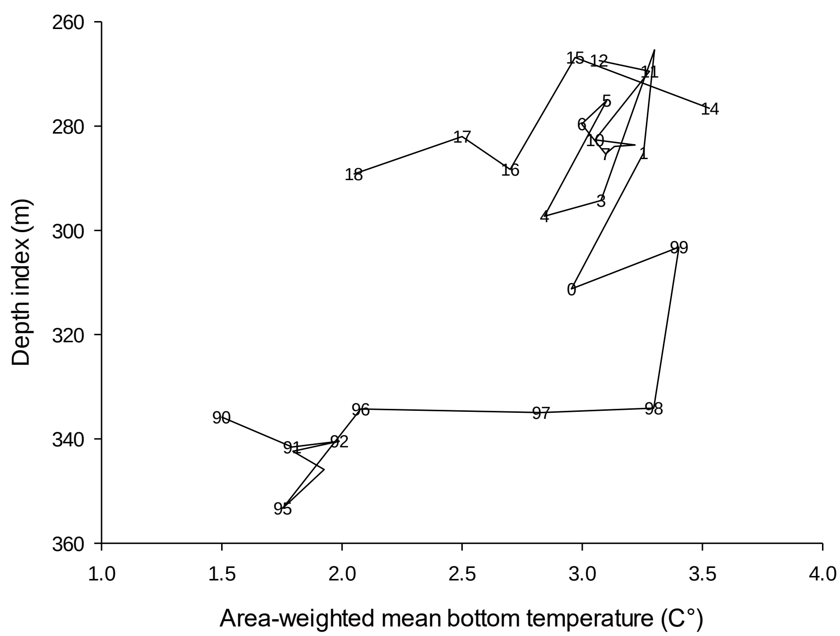

Fig. 6. *Pandalus borealis* in West Greenland: depth index of survey biomass vs. area-weighted mean bottom temperature from survey trawl-door measurements, 1990–2018.

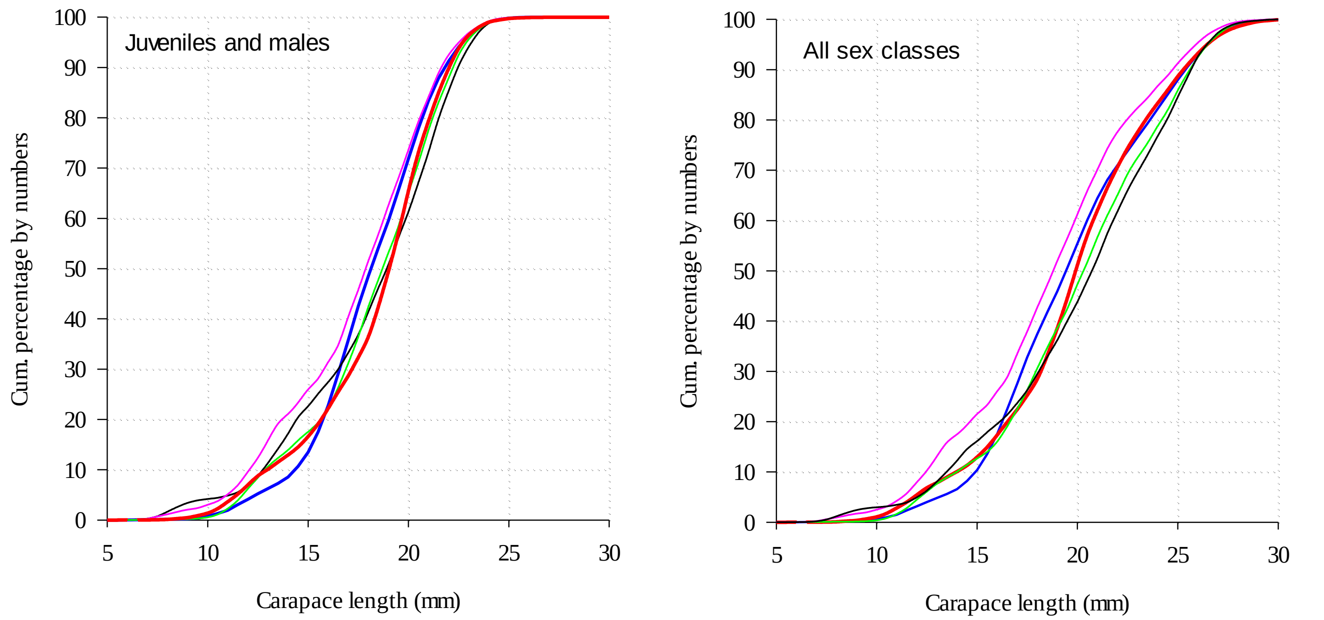

Fig.7. *Pandalus borealis* in W est Greenland: distribution of lengths from survey length analyses in 2014 (black line), 2015 (pink line), 2016 (grøn line), 2017 (blue line) and 2018 (rød lined).

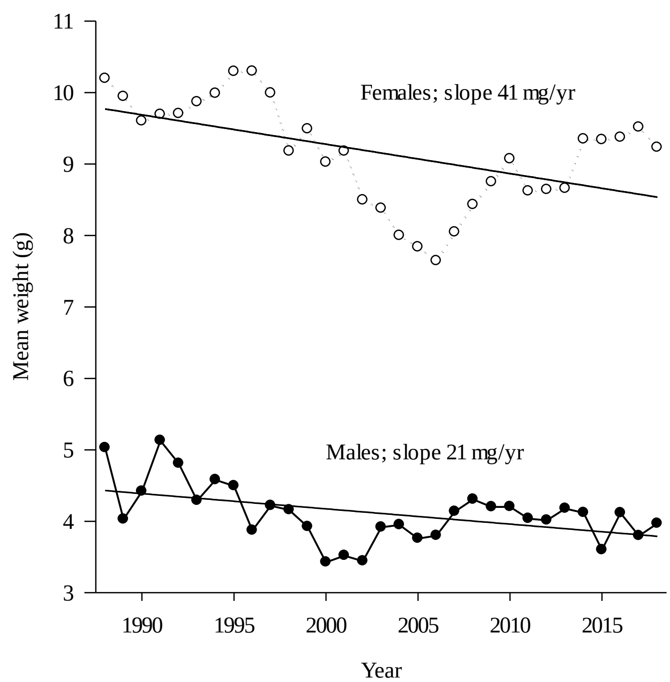

Fig. 8. *Pandalus borealis* in West Greenland: mean weight by sex, from survey data, 1988–2018.

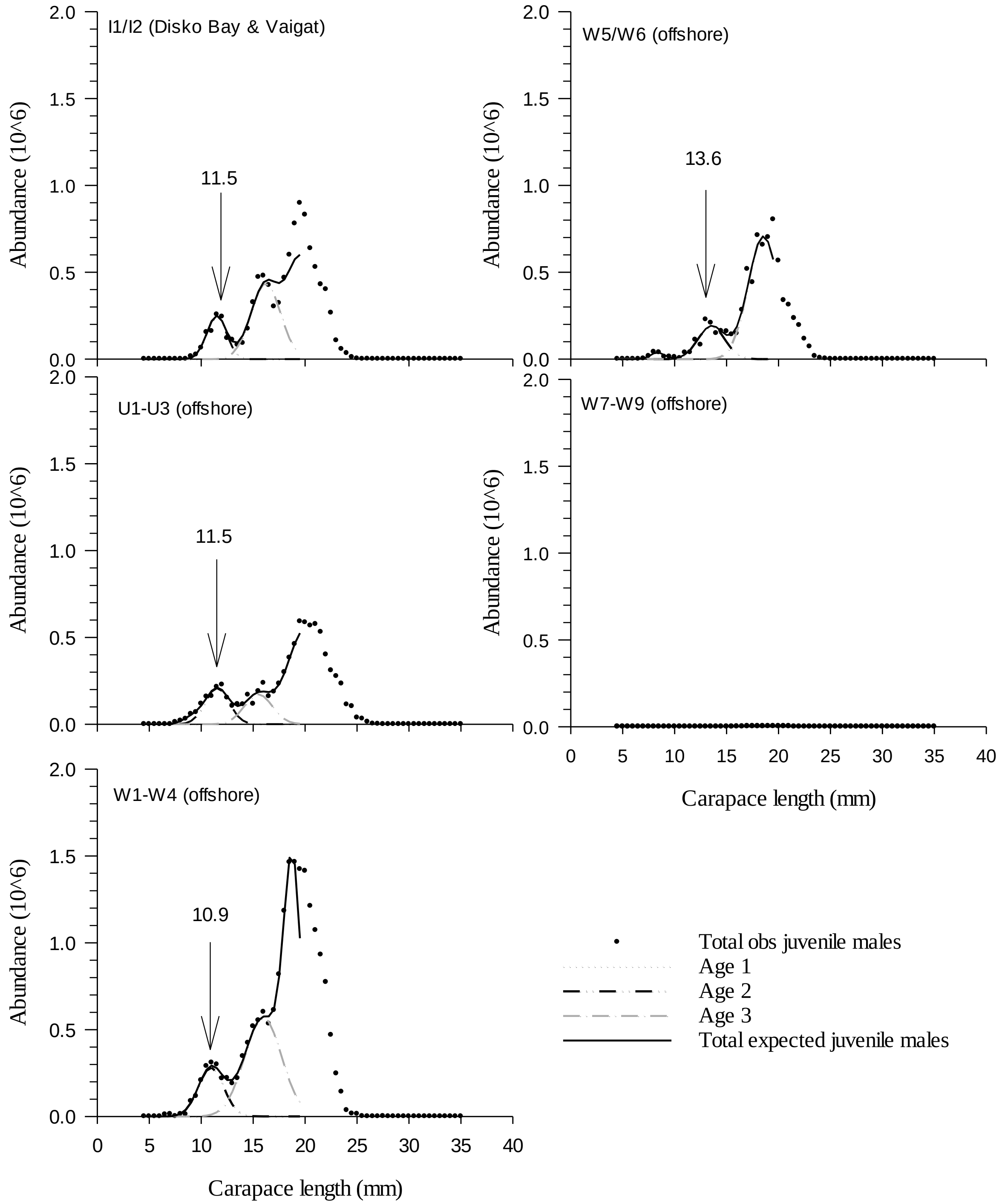

Fig. 9. *Pandalus borealis* in West Greenland: regional length frequencies in 2018.

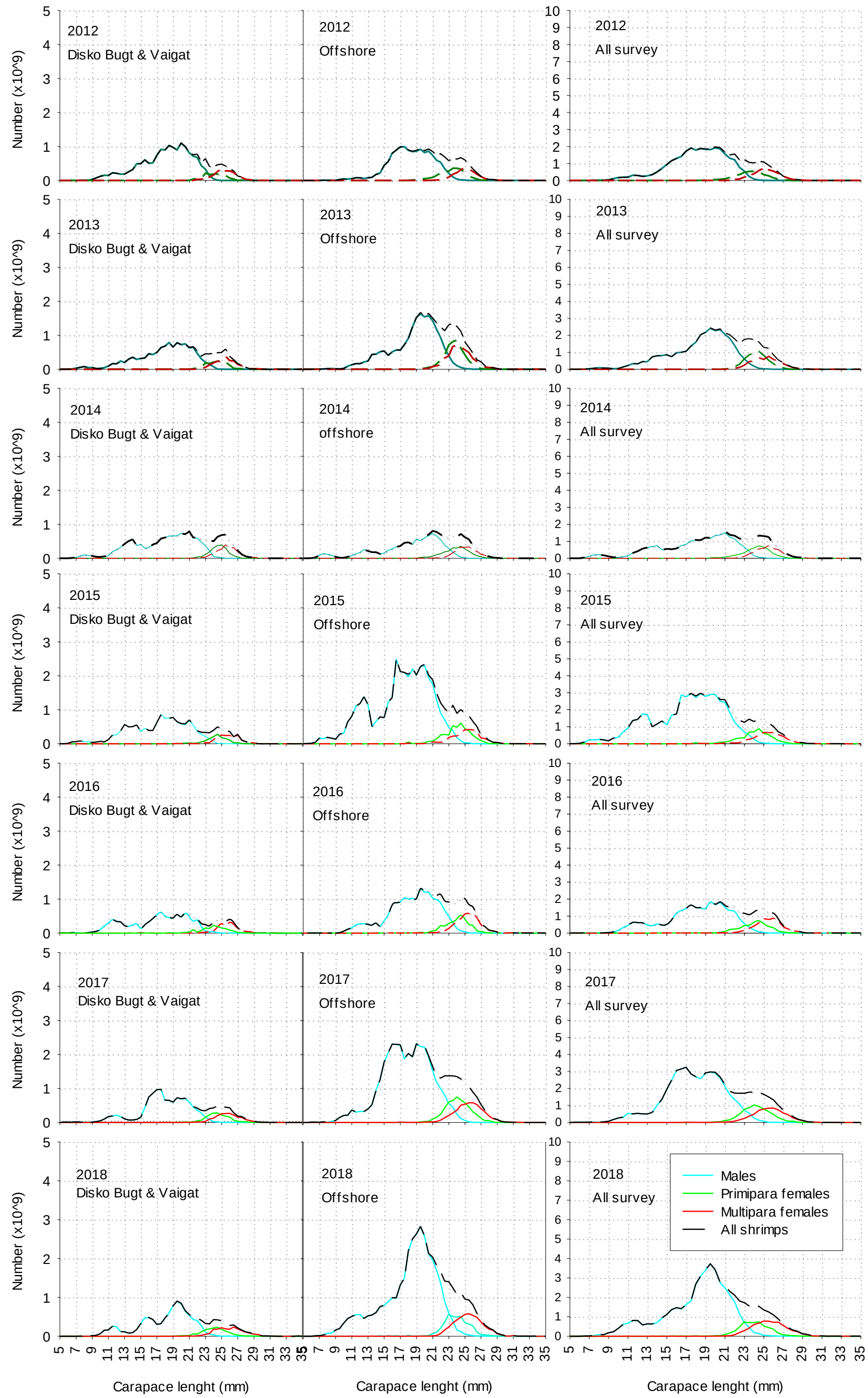

Fig.10. *Pandalus borealis* in West Greenland: length frequencies offshore, in Disko Bay and Vaigat, and overall, 2007–2018.

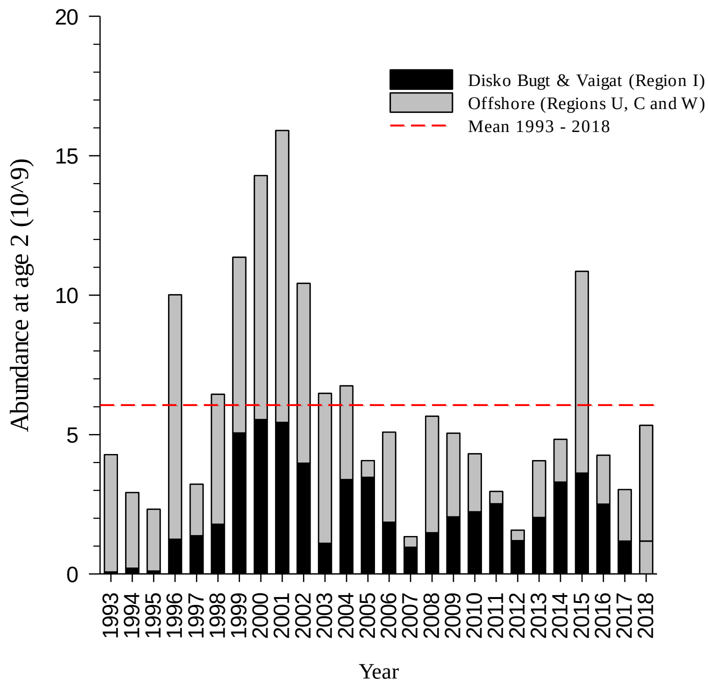

Fig. 11a. *Pandalus borealis* in West Greenland: index of numbers at age 2, 1993–2018.

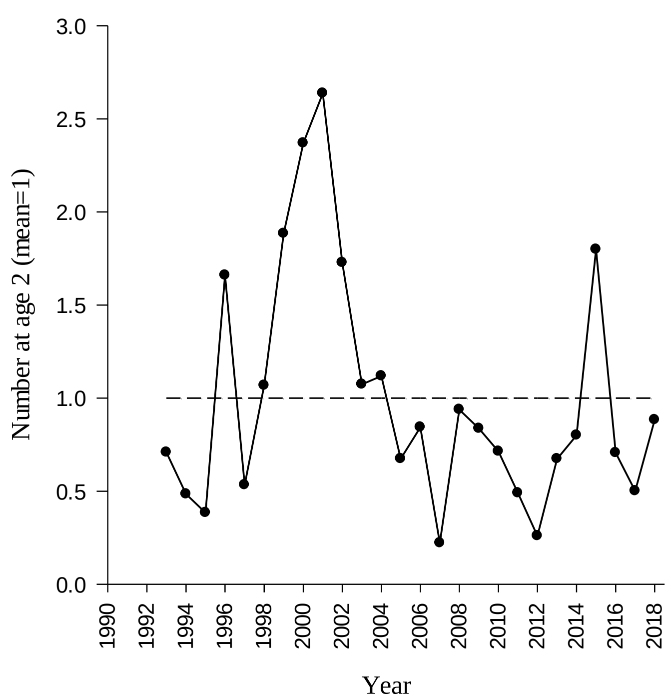

Fig. 11b. *Pandalus borealis* in West Greenland: index of numbers at age 2, 1993–2018.

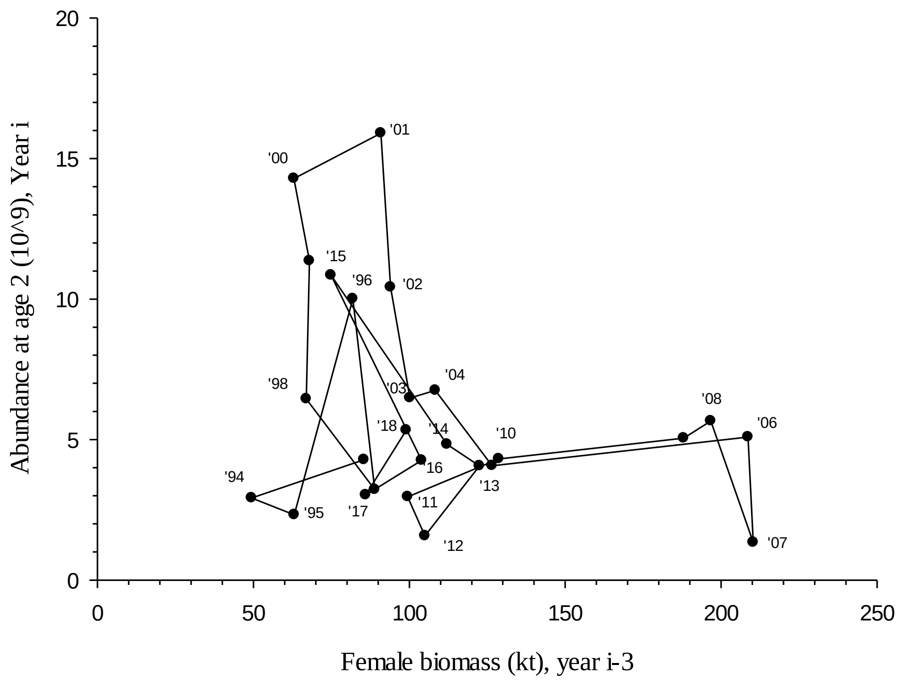

Fig. 12. *Pandalus borealis* in West Greenland: survey estimates of numbers at age 2 in 1993–2018 against female biomass 3 years earlier (labels denote years in which age-2 numbers were estimated).

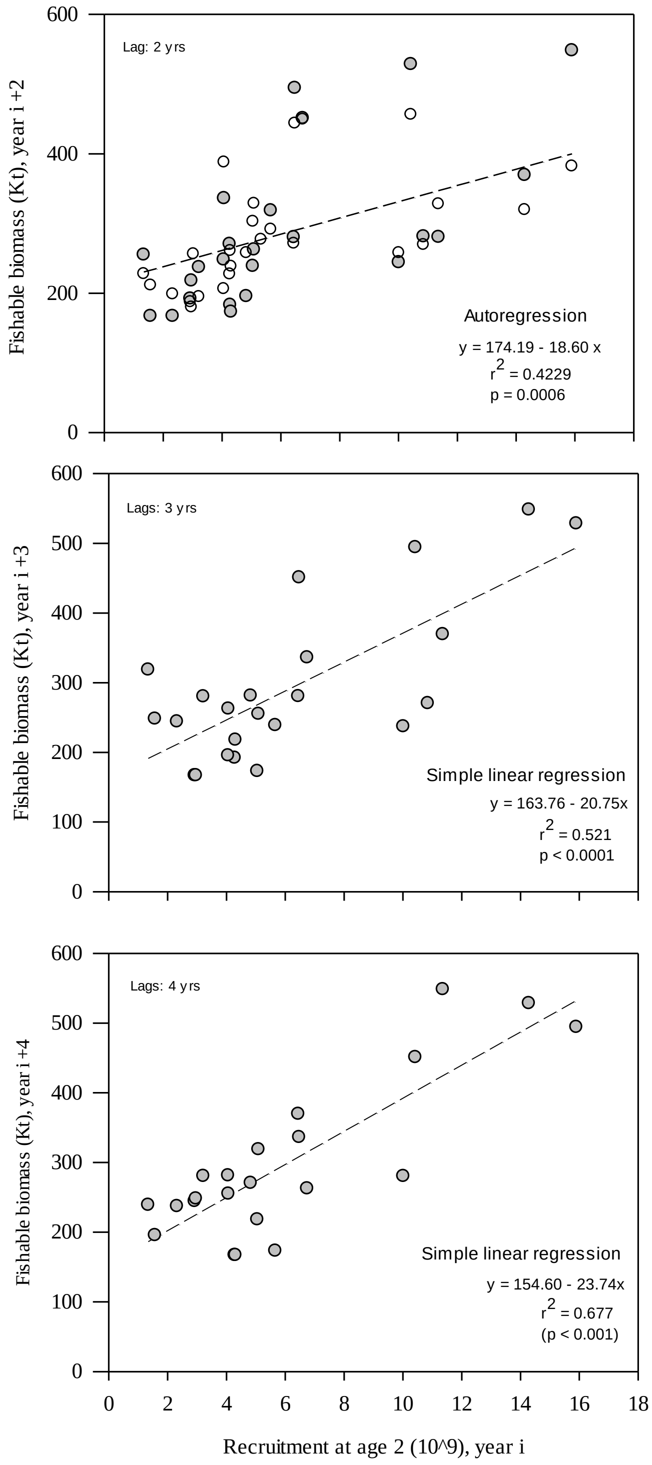

Fig. 13. *Pandalus borealis* in West Greenland: lagged fishable biomass vs. survey estimates of numbers at age 2 from 1993 to 2018 (autocorrelated regressions lags: 2 yrs; open circels predicted values from autoregression).

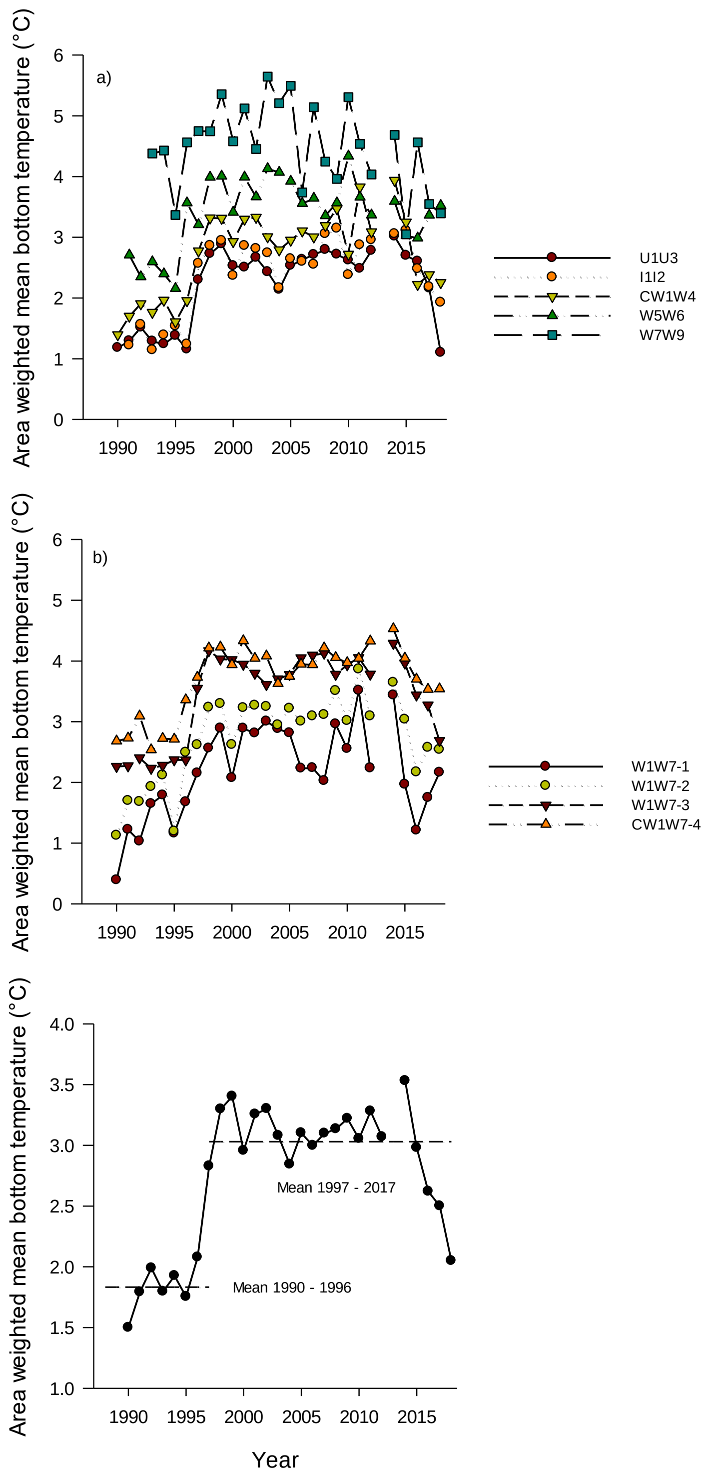

Fig. 14. *Pandalus borealis* in West Greenland: area-weighted mean bottom temperature for survey regions (see Fig. 1 for locations), depth strata in offshore areas C and W1–W7, and the entire survey area in 1990–2018.

Appendix 1:

Grønlands Naturinstitut
Greenland Institute of Natural Resources
R/V Paamiut
OYZC – GR6-251
MMSI 331 102 00
engine.paamiut@gmail.com

Statement regarding using M/Tr Sjúrðarberg to carry out the same surveys as R/V Paamiut

In November 2017 R/V Paamiut failed to comply with DNVGL standards for working in Artic waters. The management of Greenland Institute of Natural Resources (GN) decided not to spend more money on the vessel, but to go for building a new ship.

For the 2018-season, GN decided to charter Sjúrðarberg, a Faroese trawler of almost same dimensions as Paamiut, doing the normal surveys on the Greenland west coast.

To make the surveys as identical as possible this equipment was used from R/V Paamiut:

- Cosmos trawls
- All other equipment, such as bridles etc.
- Doors
- Marport sensors on doors and headline

Other steps taken ensuring the validity of received data:

- The wires/warps on Sjúrðarberg were same dimension (26mm) as used on Paamiut
- The distance between the hanging blocks was the same
- The Marport equipment on the bridge was set up and calibrated as on Paamiut
- All data from the tows were logged as normal procedure on Paamiut
- Skipper on Paamiut (Birgir Sivertsen) was on the bridge as supervisor, taking care of that all of the trawling was carried out as on Paamiut
- Chief Engineer from Paamiut was on board ensuring that all technical equipment performed as normal
- Crew from Paamiut worked together with the rest of the crew, ensuring that all maintenance of trawls etc. were carried out exactly as normal

To my best conviction regarding comparism, the surveys were executed in the best possible way, and I have absolutely no thoughts that this could be done otherwise or better.

Best regards

Kári Hansen, Chief Engineer

KÁRI HANSEN, MASKINCHEF 1