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The West Greenland trawl survey for *Pandalus borealis*, 2019, with reference to earlier results.

by

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Abstract

A trawl survey is carried out 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 2019, 207 stations were fished in 43 fishing days; 166 stations provided data to the shrimp survey in all strata.

In 2019, the annual trawl survey was conducted with a chartered vessel, the Islandic trawler Helga Maria. 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 2019 survey as identical as possible with the previous years survey.

The 2003 peak in total survey and fishable biomasses was followed by a 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 years), there has been fluctuations in the stock with ups and downs in biomass. The overall survey biomass increased by 14% to 334 Kt in 2019 almost comparable with the 2018 value at 292 Kt. The total survey biomass is 129% of its past 10-yr mean, 130% of its past five year mean, and almost at its serial mean (295 Kt). Offshore regions comprise 87% of the total survey biomass, and 13% is inshore in Disko Bay and Vaigat.

In offshore regions survey biomass increased by 31% over 2018, mainly caused by an increase in the regions west of Disko Bay (W1-W3) and in the central part (Toqqusaq banke (W5) and Frederikhåb Isblink (W6). Biomass in the southern part area, W7-W9, amounted less than 1% of the total estimated survey biomass in 2019. Inshore, Disko Bay and Vaigat, survey biomass have been fluctuated over the 12 years, but declined by 38% over 2018 and is in 2019 at a low level, last observed in the mid 90'ties.

The Fishable proportion (90%) of the survey biomass is almost at the serial mean (92%). Both female and males biomass are above their serial means.

In total, the age-2 shrimp index is well above its past 5-yr mean and the serial mean. While Offshore numbers of age-2 shrimp more than doubled over 2018, way above its serial mean and above past 5-yr mean, numbers of age-2 shrimp inshore has dropped over 2018, and is far below its serial mean and only 15% of its past 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 r 2013, and in 2019 where the survey biomass depth index was 279 m, which is at a comparable level to the past 18 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, followed by a minor increase to 2.5°C in 2019.

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 2019 survey, and compares it 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 2019, 231 stations were planned at depths between 150 and 600 m in the survey area, with 52 'extra' stations mapped and available to be included if time permitted. 207 of the planned stations incl. 39 'extra' stations were fished. 27 stations were reported as having been moved more than 2 n.mi. from the planned position, with a mean of 10.9 n.mi.; 6 stations were discarded, either due to untrawlable bottom or owing to general trawl difficulties.

Of the 207 stations fished, 166 provided usable data to the shrimp survey. In the course of the shrimp survey, CTD casts were made along standard transects offshore and in Disko Bay and Vaigat; and in 2019, 34 extra station were fished with a beam trawl for benthos monitoring, at 116 station a video beam-sledge were used for benthos recording and at 5 station a drop camera was used.

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

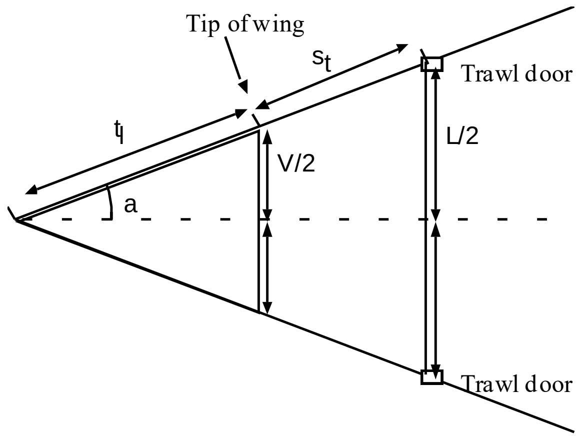
The surveys have been conducted with the research trawler *Paamiut* (722 GRT) since 1991, similar vessels were used in 1988–1990. However, in the beginning of 2018 it was decided that the old research vessel *Paamiut* has to be scraped owing to increasing expenses to maintenance. Instead, the survey was conducted with a chartered fishing vessel *Sjudarberg* in 2018 and *Helga Maria* in 2019*.* All fishing gear were removed from *Paamiut* and installed at the chartered vessels, both in 2018 and 2019. 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 1994–2019 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) center 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 2019 started from Nuuk on June the 15. The first cruise occupied stations from Nuuk north to Disko Bay having occupied 70 shrimp and fish stations and 18 CTD cast in 13 days. The second cruise occupied 85 shrimp and fish stations and 8 CTD cast in 19 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 19 July to occupy 54 stations south to the southern limit of the survey at 11 days until July the 29. 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 but again in 2019. 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.

Of the 58 planned survey strata, 1 (C0) had no stations trawled caused by lack of ship time. 29 stations had no catch of *P. borealis*; 6 strata (W7-3, W7-4, W8-1, W9-1, W9-3 and W9-4), with 11 occupied stations between them had no catches and stratum U1, U3, I1, I2 and W3, had catches *of P. borealis* at all stations. Length samples were measured from 124 stations with catches even very small ones, and length & weight samples were measured at 59 stations.

There were one exceptionally large catches only at one station in W6-1 with a catch which was closed to 2 ton (2044.5 kg) and one station in W3-2 had a catch close to 1 ton (1134.5 kg). There were 21 catches over 200 kg, of which 9 were made in Disko Bay or Vaigat, no stations north from 69°30 N, 9 in strata W1-W4, 2 in stratum W5, 2 in stratum W6 and none in W7- W9. In southerly areas, strata W7-W9 yielded an average catch of 0.19 kg at the 25 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 2017 were:

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 W1-4 was not surveyed in 2017, owing 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

- Area C0 was not surveyed in 2018, owing to ice cover and W1-4 due to bottom trouble.

and in 2019:

Region–2019	Biomass estimate (t)	Number of stations	ECV (%)
North (U1-U3)	65 080	41	15.2
Canadian zone (C0)	-	-	-
West (W1–W9)*	224 002	104	20.1
Disko Bay & Vaigat (I1, I2)	44 907	21	7.9
Total	333 989	166	13.9

- Strata C0 was not surveyed in 2019, owing to lack of ship time.

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 and in 2019 (334 Kt), however in 2019, 10% higher than the year before, (Table 3, Figure 2a and 2b) and above its serial mean (1988 – 2019; 295 Kt). The 2019 biomass value is about 130% of its past 5 yr. and its past 10 yr value. While offshore survey biomass (289.1 Kt) increased by 36%, is considerably above both its past 5 yr and past 10 yr mean as well as the serial mean (226.8 Kt), survey biomass in inshore regions Disko Bay & Vaigat (44.9 Kt) declined by 38% over 2018. Inshore survey biomass is 84% of its past 5-yr. mean and far above the serial mean (1988 – 2019; 67.7 Kt). Offshore biomass constitute 87% and Disko Bay & Vaigat 13% of the total survey biomass. The Canadian area was not surveyed in 2019 due to lack of ship time, but was surveyed in 2017, and contributes less than 1% of total offshore survey biomass (Table 3).

In offshore survey regions, survey biomass increased with 45% in W1-W2, 28% in W6 and more than doubled in W5 (141%). Biomass in W4 (Holstsinsborg Dyb) declined to low but not an exceptional low value. The survey biomass in the other strata remain comparable with the most recent years (Table 3 Figure 2b). Nevertheless, biomass estimates for areas W5-W6 amounted 28% of the total offshore survey (based on one haul with large catch in W5 and two hauls in W6) and the southernmost area W7-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, but declined in 2019 to a value below its most recent values and now considerably below the serial mean. Nevertheless, the inshore region had higher densities

(4.51t/km^2) than the average offshore regions (2.37 t/km^2) (Figure 3a). Highest densities in offshore regions were found in W1-W2 (West of Disko Bay) and lowest densities were found in the Southern areas W8-W9 (0.01 t/km^2) (Table 5). Over all mean density (1.83 km^2) declined in 2019 to a value a little less than its serial mean (1988–2019; 2.28 t/km^2), but almost at its past 5 year mean (1.90 t/km^2) (Fig. 3b).

The spread index, of how widely the survey thinks the stock biomass is distributed, has shown an increase from 2016 to 2018, remain stable in 2019, 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 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 2019, 24% of the biomass were found in the shallow water and this increase was mainly caused by one large catch in one haul in the strata W6-1. 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 and biomass moved into more shallow water from 200 to 300 meter. The latter depth strata have since 2000 and until 2019 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 2001–2019 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 2019, the depth index was estimated to approx. 279 m and is compared with the past 5 year (281 m).

Demography and recruitment

Length-weight relationships

In 2019, 3256 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 2019 were little changed from the past years.

Table: *Pandalus 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
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
2019	0.09774	4.820	3.5	2.45119	3256	6.92

* 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 2019 was almost average compared to other years.

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

Year	Weight (g) at length (mm):			
	10	15	20	25
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
2019	0.57	2.00	4.72	8.96
Mean	0.60	2.03	4.74	9.02

Estimated weights at length have been consistent over years, and there is very little change from 2010–2019. 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 were little less than the most previous years. The weight at the four size groups were in 2019 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, 38 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, 0.54 for males and 0.87 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 2019, 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. In 2019, mean length at age 2, varied from 10.2 mm to 12.2 mm carapace length. The smallest age 2 shrimps were found in the most northern regions whereas the largest were found in the more southern 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 in 2018, and almost doubled its value in 2019 (10.55 bn), comparable to the high 2015 value, is 186% of its past 5 years mean (2014-2018) at 5.66 bn and above to its serial mean (6.20 bn). The increase in numbers of 2-age shrimp is caused by a significant rise of age-2 shrimps in the central regions (W5), which account for 89% of the age 2 shrimp. The number of age-2 declined to a value far below the serial mean in Disko Bay & Vaigat, and is only 15% of its past 5-yr mean. In the southernmost region W7 to W9 age-2 shrimps have always been very few.

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 3% in 2019 (Table 10, Fig 11a). The contribution from offshore regions has historically been lower, but as observed in 2015-2019, except 2016, the abundance of age-2 shrimps are higher 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.

Number of pre-recruits (14-16.5 mm CL) were high from 1999 to 2005, then followed by a declining to a low value in 2014. This turned to a significant increase of pre-recruits in 2015, which was not remained in 2016. However, the abundance of pre-recruits reach a relatively high value in 2017, has since varied in numbers and is in 2019 above the average from the past five and ten years. Numbers of pre-recruits has historically been higher in offshore regions compared to inshore Disko Bay & Vaigat, and 2019 is no exception, while 86% of the pre-recruits are found in offshore regions.

Numbers, spawning stock biomass and fishable biomass

Survey and fishable biomass peaked in 2002 to 2006 and since decreased to a very low level in 2014 (Table 3 and Table 8). In the subsequent years, survey as well as fishable biomass, have increased to 2019 values above their past 5-year and 10-year mean and of their serial means. 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 and 2019 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 (108 Kt). Female biomass is in 2019 estimated at 130 Kt, and male biomass 204 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. An additional increase has been found again in 2018 and 2019. The proportion of the largest females above 23 mm CPL are comparable with observations from the past years, however in numbers considerably higher in offshore regions compared to Disko Bay and Vaigat (Fig. 10, table 6 and table 7). 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 and 2019, and above its serial mean. Female biomass in Disko Bay declined from 2014 to a low level in 2019, except for an increase in 2017, to a level well below both its most recent values and serial mean.

Numbers of males is in 2019 nine times higher in offshore regions compared to Disko Bay and Vaigat, and in total, both in numbers and biomass, above the serial mean (Fig. 10, table 6 and table 7). It is not unusual that males are more abundant offshore, but in 2019, the occurrence of males inshore is at a record low value since 2005.

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. Nevertheless, bottom temperature increased to 2.5 °C in 2019.
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 at a comparable value in 2018. However, this cooling trend stopped in 2019, and bottom temperature increased in those regions to values comparable to observations from 2017. In the more southern areas (W5-W6) temperature has decrease little since 2014, but in general bottom temperature remained "warm". While temperature in the southernmost regions W7-W9, dropped from 4.68°C in 2014 to 3.39 °C in 2018, bottom temperature increased considerably to above 5 °C in 2019 (Fig. 6) In conclusion the overall bottom temperature has decreased by 1.5°C since 2014 and until 2018, but a minor increase has been observed in 2019.
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 16 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 in 2017, drop little to 292 Kt in 2018, but rise again in 2019 to 334 Kt, caused by a changes in biomass in offshore regions West of Disko Bay and in the central regions along the West coast. The total survey biomass is in 2016, 131% of its past 5-yr mean, and above its serial mean (295 Kt). The offshore regions are now constitute 87% of the total surveyed biomass, and in 2019, only 13% of the biomass in situated in Disko Bay & Vaigat, which is a situation not observed since 2004.

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 to a low level in 2019. 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 2018, caused by a significantly increase in offshore regions, and despite a significant drop of fishable biomass in Disko Bay, and with the value of 302 Kt in 2019 above its serial mean (271Kt). In 2019 fishable biomass, constitute 90% of the total surveyed biomass. In offshore regions fishable biomass is above of its serial mean, but below 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 two times higher in Disko Bay and Vaigat compared to offshore regions. While densities in offshore regions are close to its serial means, it is considerably below in Disko Bay and Vaigat. In almost all strata in the offshore regions, densities shown some minor increases over 2018 and at value much higher than observed for the past 12 years. Densities are practically zero on in the southern most regions.

The latitude index of the survey has declined from 2010 – 2013, followed by a continuous increase to 2018 and remaind almost unchanged in 2019. 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, there have been a declining trend in the North index. Survey biomass from the northern (above 66°N) and inshore regions constitute almost 76% of the total offshore survey biomass, whereas biomass in those regions has account for more than almost 90% for the past 10 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 2019, the depth index was estimated to approx. 279 m, comparable 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 (approx. 40%). Fishable biomass is above 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 shrimp are overall, well above the serial mean but considerably below inshore in Disko Bay and Vaigat. The number of pre-recruits (14-16,5 mm CL) in total are close to 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 far 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, 1988–2019

	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	**
2019	Helga Maria	Cosmos	54.0	31.3	**

(*: 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 2019.

Stratum	Area (km^2)	Stations	Biomass density (t/km^2)	Biomass (Kt)	Biomass error variance	Error coefft of variation (%)
C0-2	903	0	0.000	0.000	0.000	0.0
C0-3	2179	0	0.000	0.000	0.000	0.0
C0-4	1154	0				
Overall C0	4236	0	0.000	0.000	0.000	0.0
I1-1	407	2	6.589	2.679	0.409	23.9
I1-2	1963	4	7.695	15.105	3.006	11.5
I1-3	2441	5	3.932	9.599	5.385	24.2
I1-4	1499	1	0.976	1.462	1.930	95.0
I2-1	419	2	7.315	3.067	0.953	31.8
I2-2	815	3	4.011	3.269	0.223	14.4
I2-3	1085	2	7.014	7.610	0.453	8.8
I2-4	1338	2	1.581	2.116	0.181	20.1
Overall I	9967	21	4.506	44.907	12.540	7.9
U1-1	2486	2	1.499	3.726	6.641	69.2
U1-2	4633	6	2.052	9.506	7.635	29.1
U1-3	4785	3	1.080	5.169	4.163	39.5
U1-4	5129	4	0.227	1.165	0.511	61.4
U2-2	6710	5	2.596	17.417	54.043	42.2
U2-3	8481	6	1.658	14.064	13.659	26.3
U2-4	7994	3	0.231	1.844	3.329	98.9
U3-1	2012	2	0.254	0.511	0.000	0.1
U3-2	3017	4	2.190	6.606	7.834	42.4
U3-3	1675	2	2.129	3.565	0.085	8.2
U3-4	2710	4	0.556	1.508	0.085	19.3
Overall U	49631	41	1.311	65.080	97.984	15.2
W1-1	2873	2	0.037	0.106	0.010	94.0
W1-2	6099	11	1.749	10.665	5.348	21.7
W1-3	7520	4	5.073	38.146	396.494	52.2
W1-4*	816	2	0.043	0.035	0.001	98.7
W2-1	1674	2	5.547	9.283	86.170	100.0
W2-2	2612	4	11.926	31.145	55.255	23.9
W2-3	1741	3	4.361	7.593	6.689	34.1
W2-4	915	2	1.221	1.117	0.134	32.8
W3-1	2122	2	0.219	0.465	0.070	56.7
W3-2	4725	9	6.259	29.575	360.289	64.2
W3-3	2085	2	4.671	9.739	3.216	18.4
W3-4	2994	2	1.156	3.461	11.897	99.7
W4-1	4119	3	0.119	0.488	0.209	93.6
W4-2	1818	3	0.041	0.075	0.004	87.8

W4-3	821	2	0.001	0.001	0.000	100.0
W4-4	1961	2	0.923	1.809	2.032	78.8
W5-1	3001	3	3.329	9.991	98.404	99.3
W5-2	3648	4	7.058	25.743	471.130	84.3
W5-3	1950	2	0.020	0.038	0.001	100.0
W5-4	3021	2	2.652	8.012	25.430	62.9
W6-1	1206	3	28.002	33.770	507.422	66.7
W6-2	2006	6	0.698	1.401	1.078	74.1
W6-3	1585	2	0.012	0.018	0.000	88.5
W6-4	1234	2	1.033	1.276	1.627	100.0
W7-1	2442	2	0.000	0.000	0.000	100.0
W7-2	891	3	0.000	0.000	0.000	100.0
W7-3	265	2	0.000	0.000	0.000	0.0
W7-4	317	2	0.000	0.000	0.000	0.0
W8-1	424	2	0.000	0.000	0.000	0.0
W8-2	567	2	0.001	0.001	0.000	100.0
W8-3	405	3	0.016	0.006	0.000	87.0
W8-4	718	2	0.058	0.042	0.002	100.0
W9-1	1711	3	0.000	0.000	0.000	0.0
W9-2	938	2	0.000	0.000	0.000	100.0
W9-3	516	1	0.000	0.000	0.000	0.0
W9-4	430	1	0.000	0.000	0.000	0.0
Overall W	72169	104	3.104	224.002	2032.912	20.1
Survey totals	136003	166	2.456	333.989	2143.437	13.9

† strata with 1 trawled station have been assigned an error coefficient of variation of 95%
* Substrata C0 were not covered due to lack of ship time.

Table 3. *Pandalus borealis* in West Greenland: biomass estimates (Kt) for survey subdivisions and standard errors for the entire survey in 1988–2019.

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
2019	65.1	-[(1)]	98.1	45.6	80.2	0.0	44.9	334.0	46.3
Mean 1988-2019	43.4	7.5	73.2	50.4	44.7	11.2	67.7	294.5	41.1

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 1988–2019.

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
2019	15.2	-(1)	21.2	42.6	41.4	86.1	7.7	13.86	166
Mean 1994-2019	27.0	55.1	20.2	31.5	41.1	65.2	15.4	12.9	195.8

Table 5. *Pandalus borealis* in West Greenland: estimated mean densities (t/km^2) for survey subdivisions in 1988–2019.

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
2019	1.31	-	4.05	2.21	3.72	0.01	4.51
Serial mean	0.90	1.91	2.98	2.49	2.38	1.80	7.27

Table 6. *Pandalus borealis* in West Greenland: estimated numbers (billions) by sex in 1988–2019.

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
2019	53.2	14.2	67.4	78.9	21.1
Average	46.5	12.2	58.7	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 1988–2019.

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
2019	204.3	129.7	334	61.2	38.8
Average	185.6	108.3	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 1988–2019

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%
2019	260.8	90%	41.2	92%	302.0	90%
Average	210.5	92%	60.2	90%	270.7	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 2005–2019, with standard deviations and coefficients of variation (- : not present, ( ): fixed in the final MIX run, na: no data).

Mean:

			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	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	-
2019	10.2	12.1	na	10.9	12.2	-

Standard deviation:

			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	0.9	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	-
2019	0.9	1.6	na	1.3	1.4	-

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	-
2019	0.07	0.16	na	0.12	0.03	-

Table 10. *Pandalus borealis* in West Greenland: survey estimate of numbers (billions) at age 2 years, 1993–2019.

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
2019	0.43	0.35	-	0.35	9.42	0.00	10.55
Average:	0.57	2.19	1.96		1.59	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.

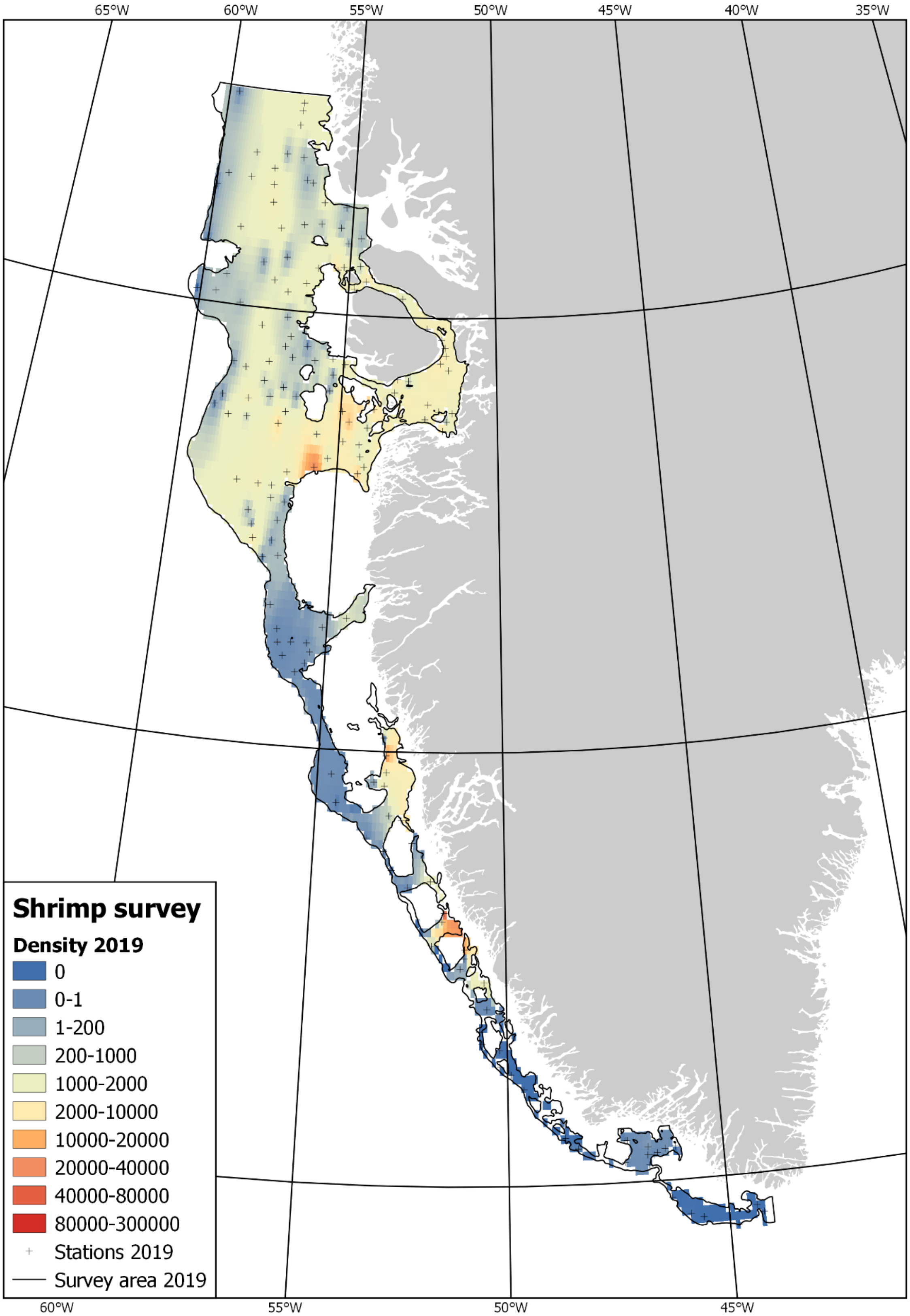

Figure 1. *Pandalus borealis* in West Greenland: density distribution from 166 trawl-survey stations in 2019.

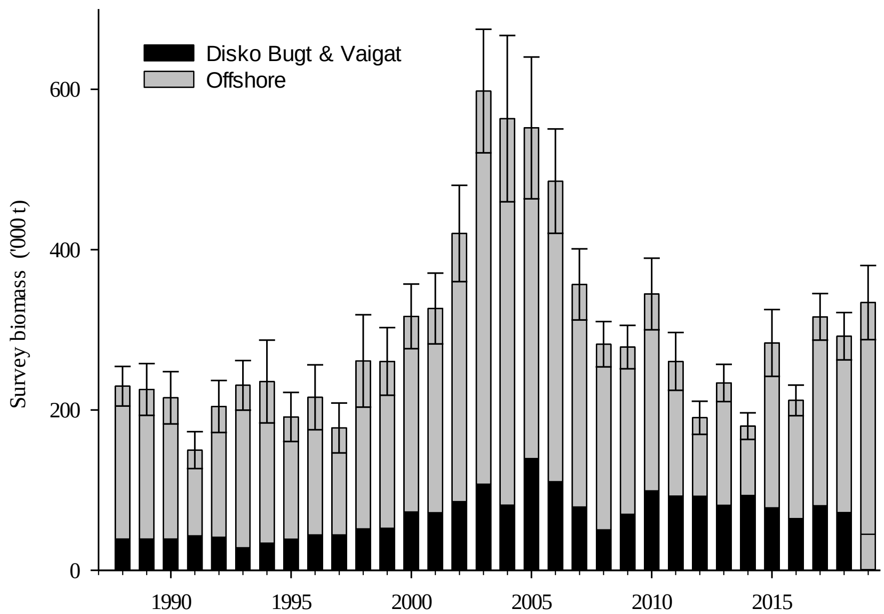

Figure 2a. *Pandalus borealis* in West Greenland: estimated survey biomass, 1988–2019. Area C0-4 was not surveyed in 2011 – 2016, except 2013 because of ice cover, in 2014 W9-4 due to poor bottom conditions, area C0 in 2011, 2012, 2014-2016, 2018 and 2019 owing to lack of ship time.

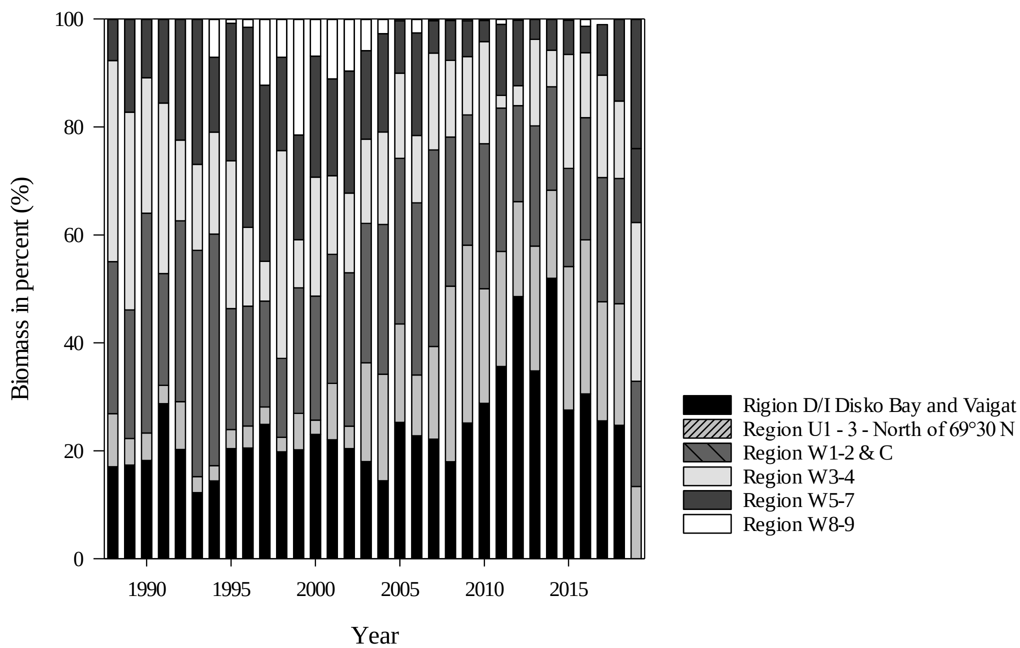

Figure 2 b. *Pandalus borealis* in West Greenland: distribution of survey biomass between major survey regions, 1991 – 2019. Area C0-4 was not surveyed in 2011 – 2016, except 2013 and in 2018 - 2019 because of lack of ship time, in 2014 W9-4 due to poor bottom conditions, area C0 in 2014 owing to time trouble and W2-4 due to trawl difficulties and poor bottom conditions.

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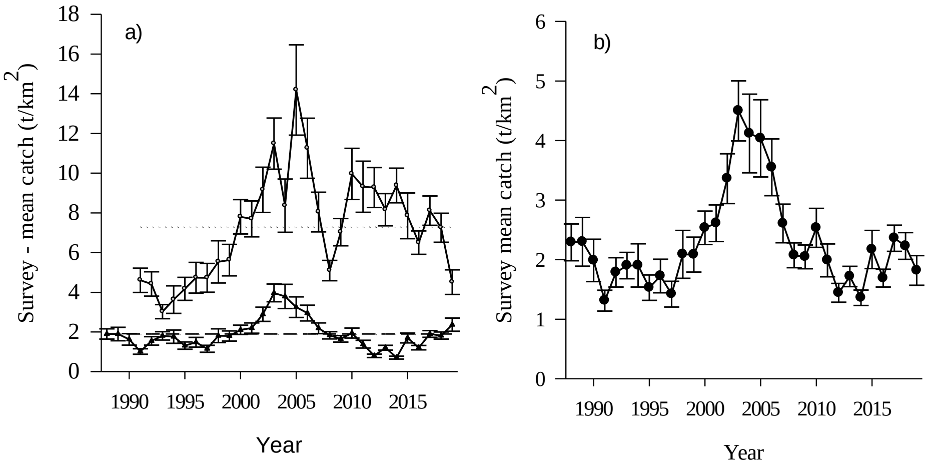

Figure 3. *Pandalus borealis* in West Greenland 1988 - 2019: mean survey density of Northern shrimp in a) -○- Disko Bay and Vaigat (since 1991 cover 7–8% of the survey area), -▲-offshore (92–93%) and b) total surveyed regions.

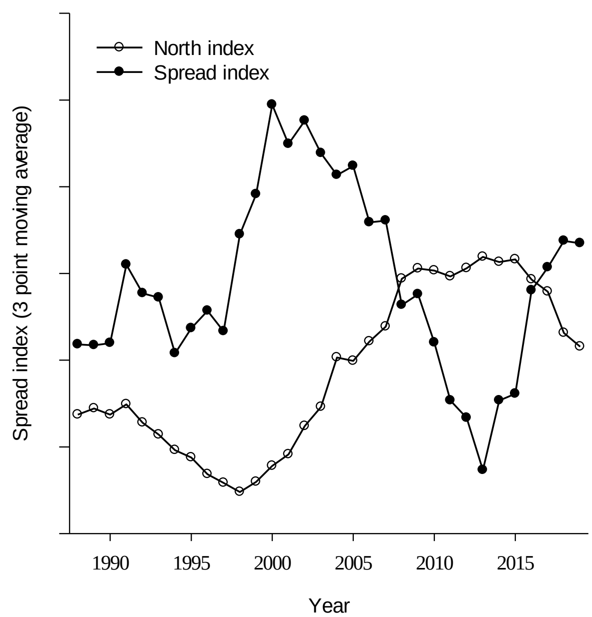

Figure 4. *Pandalus borealis* in West Greenland: indices of distribution and location of shrimp biomass in the West Greenland trawl survey 1994–2019 (3-point moving averages). -□-: North index (3-pt moving average) and -■-; Spread index (3-pt moving average).

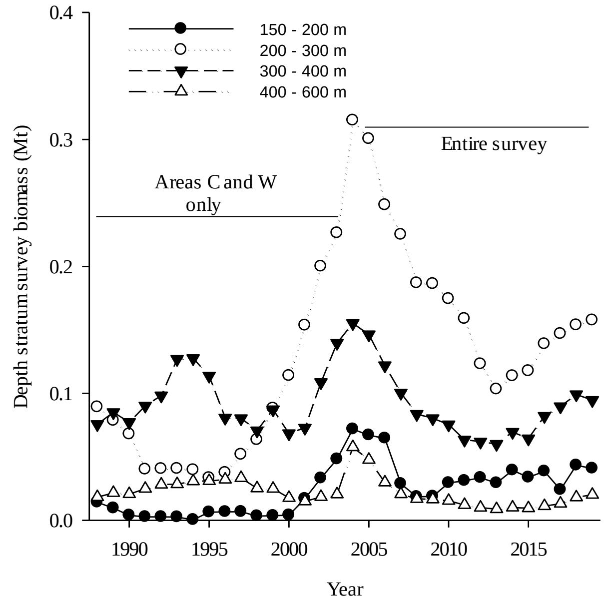

Figure 5a. *Pandalus borealis* in West Greenland: survey biomass estimates by depth stratum, 1988–2019. 3-point moving averages.; Until 2003, only areas C and W were substratified by depth. -● -: 150 – 200m, -ᴑ-: 200-300m, -▼-: 300-400 and –Δ- : 400-600m.

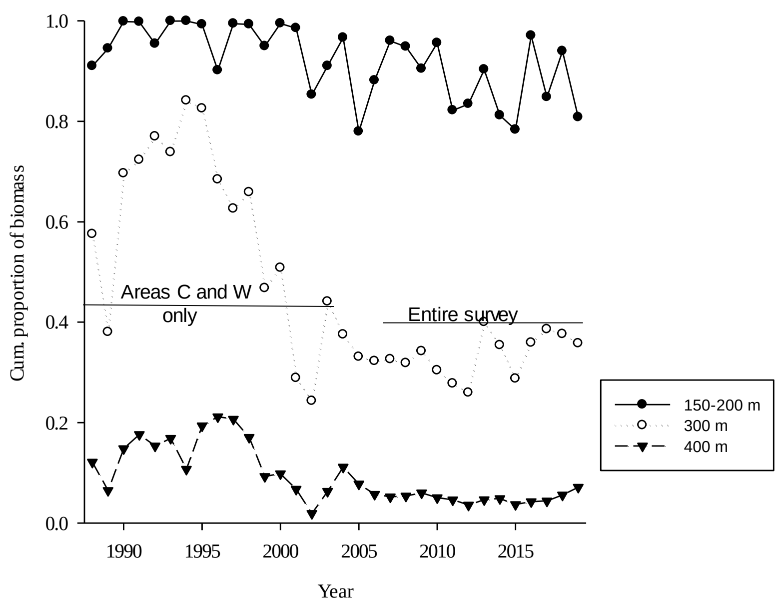

Figure 5b. *Pandalus borealis* in West Greenland: distribution of survey biomass between 150 and 600 m by depth, 1988–2019. Until 2003, only areas C and W were substratified by depth. -● -: 150 – 200 m, - ᴑ-: 300 m and - ▼-400 m

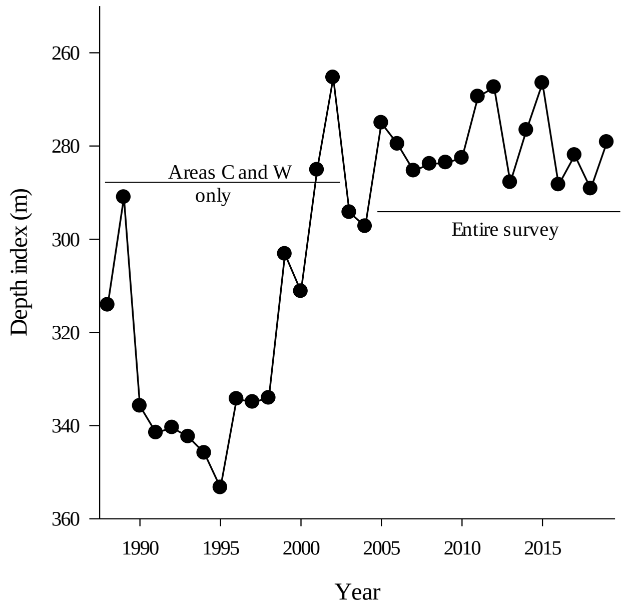

Figure 5c. *Pandalus borealis* in West Greenland: depth index for survey biomass, 1988–2019. Until 2003, only areas C and W were substratified by depth.

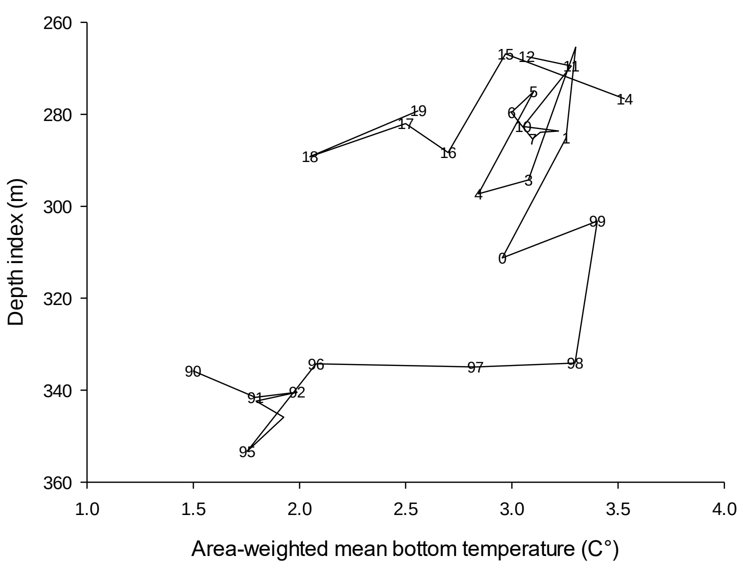

Figure 6. *Pandalus borealis* in West Greenland: depth index of survey biomass vs. area-weighted mean bottom temperature from survey trawl-door measurements, 1990–2019.

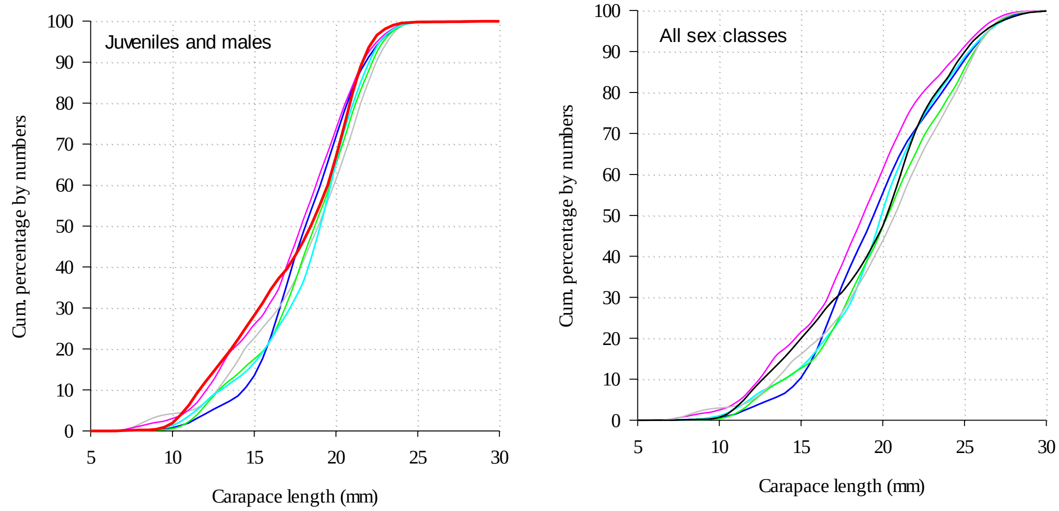

Figure 7. *Pandalus borealis* in West Greenland: distribution of lengths from survey length analyses in 2015 (gray line), 2016 (pink line), 2017 (grøn line), 2018 (blue line) and 2019 (rød line juleniles and males black females).

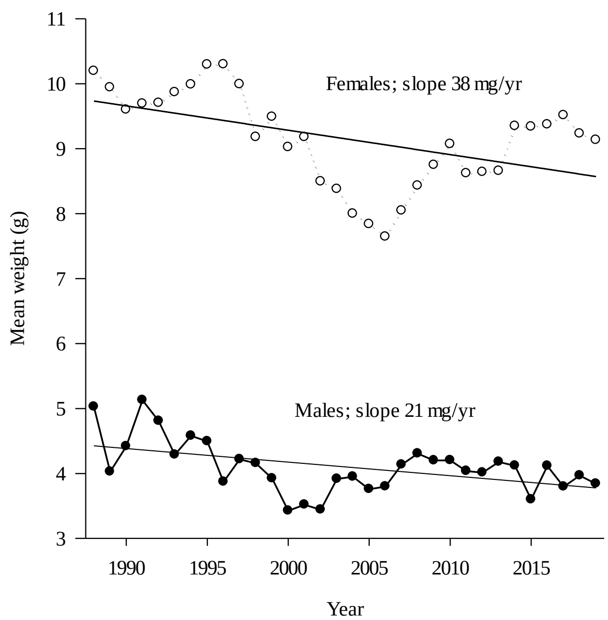

Figure 8. *Pandalus borealis* in West Greenland: mean weight by sex, from survey data, 1988–2019.

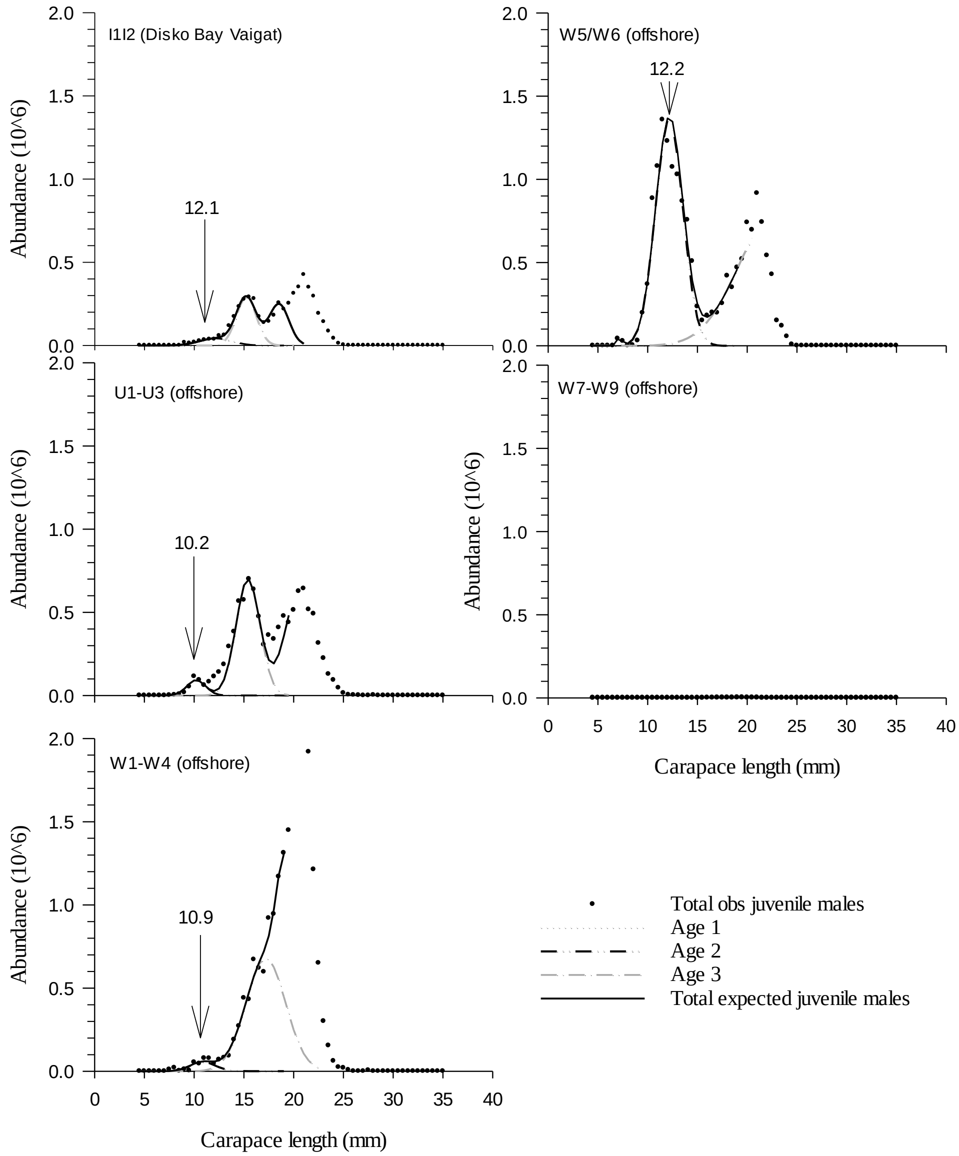

Figure 9. *Pandalus borealis* in West Greenland: regional length frequencies in 2019.

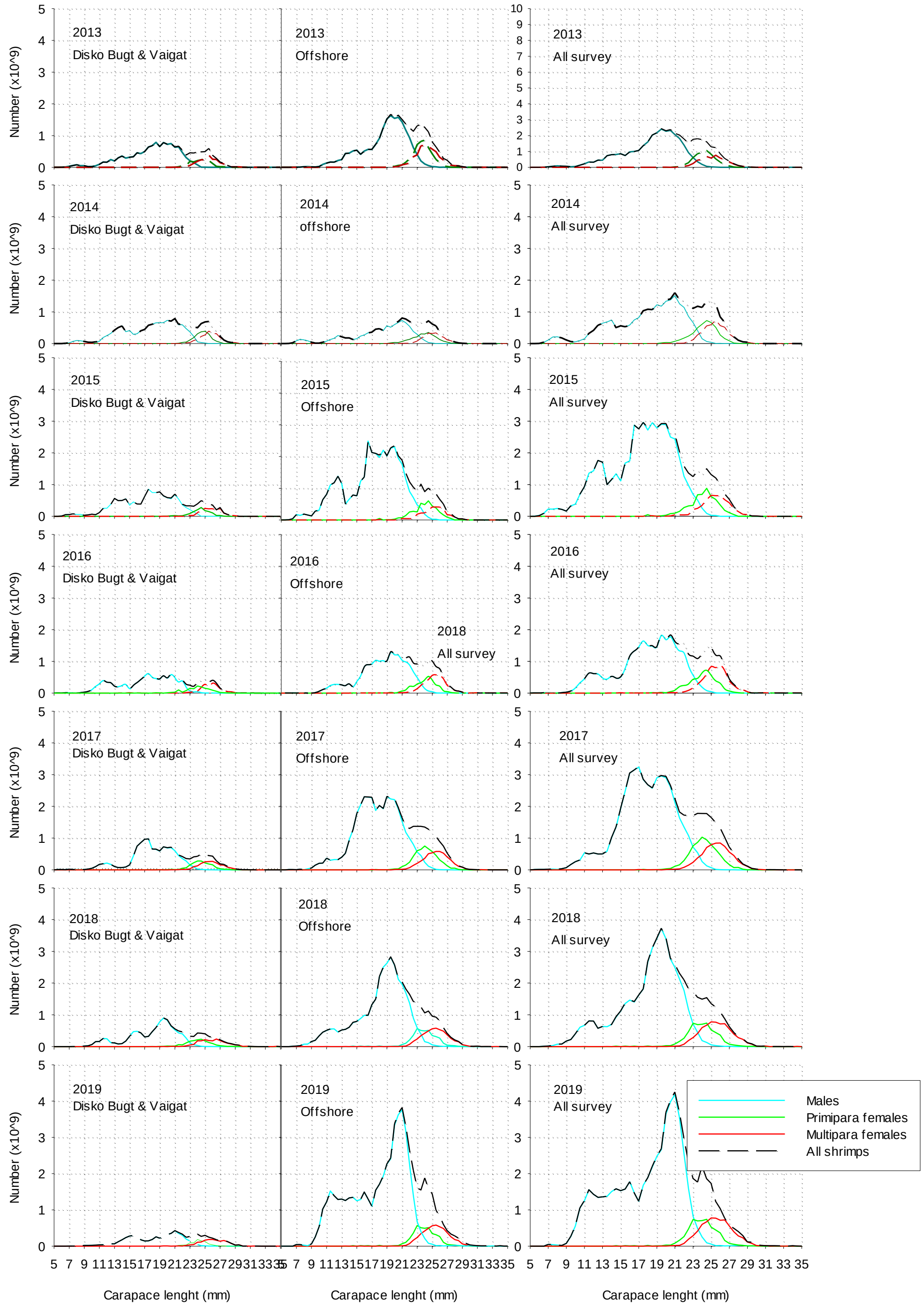

Figure 10. *Pandalus borealis* in West Greenland: length frequencies offshore, in Disko Bay and Vaigat, and overall, 2007–2019.

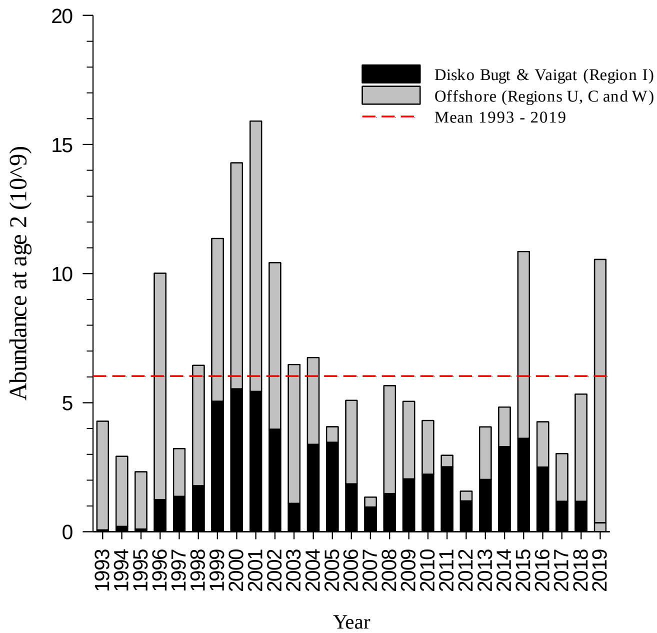

Figure 11a. *Pandalus borealis* in West Greenland: index of numbers at age 2, 1993–2019.

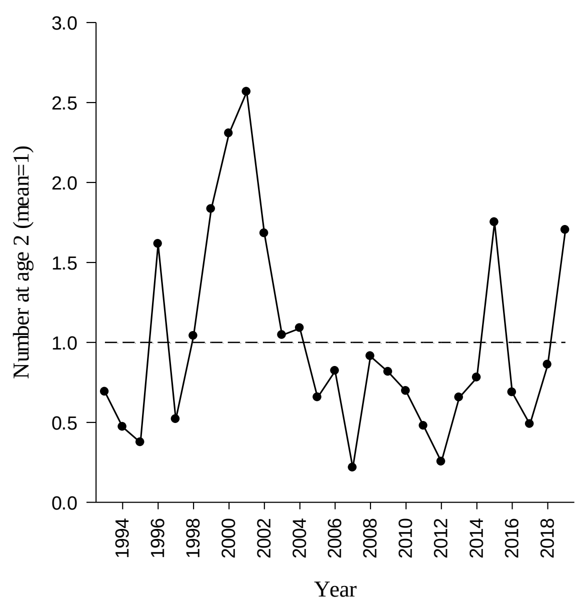

Figure 11b. *Pandalus borealis* in West Greenland: index of numbers at age 2, 1993–2019.

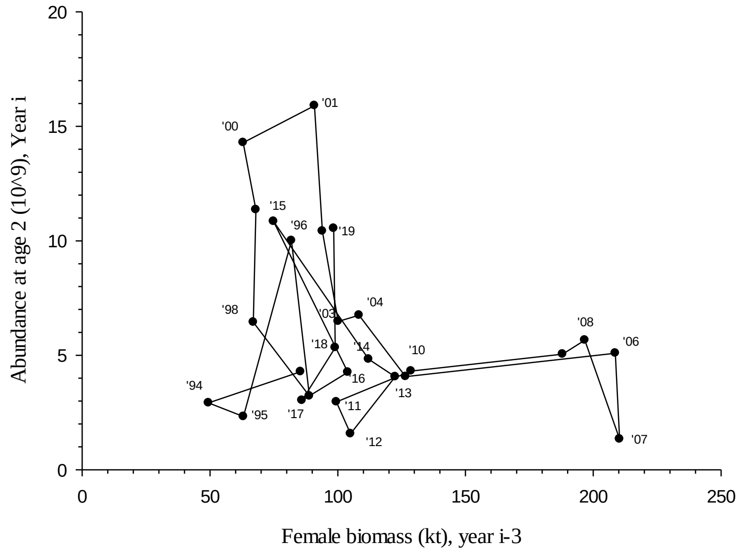

Figure 12. *Pandalus borealis* in West Greenland: survey estimates of numbers at age 2 in 1993–2019 against female biomass 3 years earlier (labels denote years in which age-2 numbers were estimated).

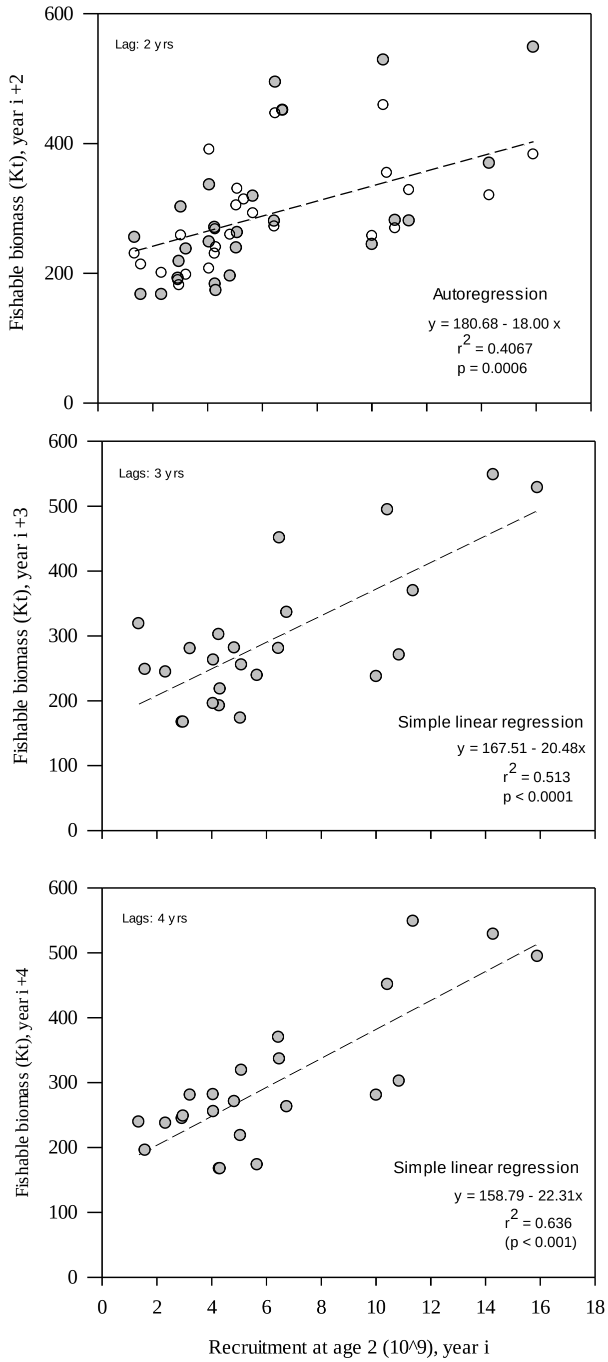

Figure 13. *Pandalus borealis* in West Greenland: lagged fishable biomass vs. survey estimates of numbers at age 2 from 1993 to 2019 (autocorrelated regressions lags: 2 yrs; open circles predicted values from autoregression).

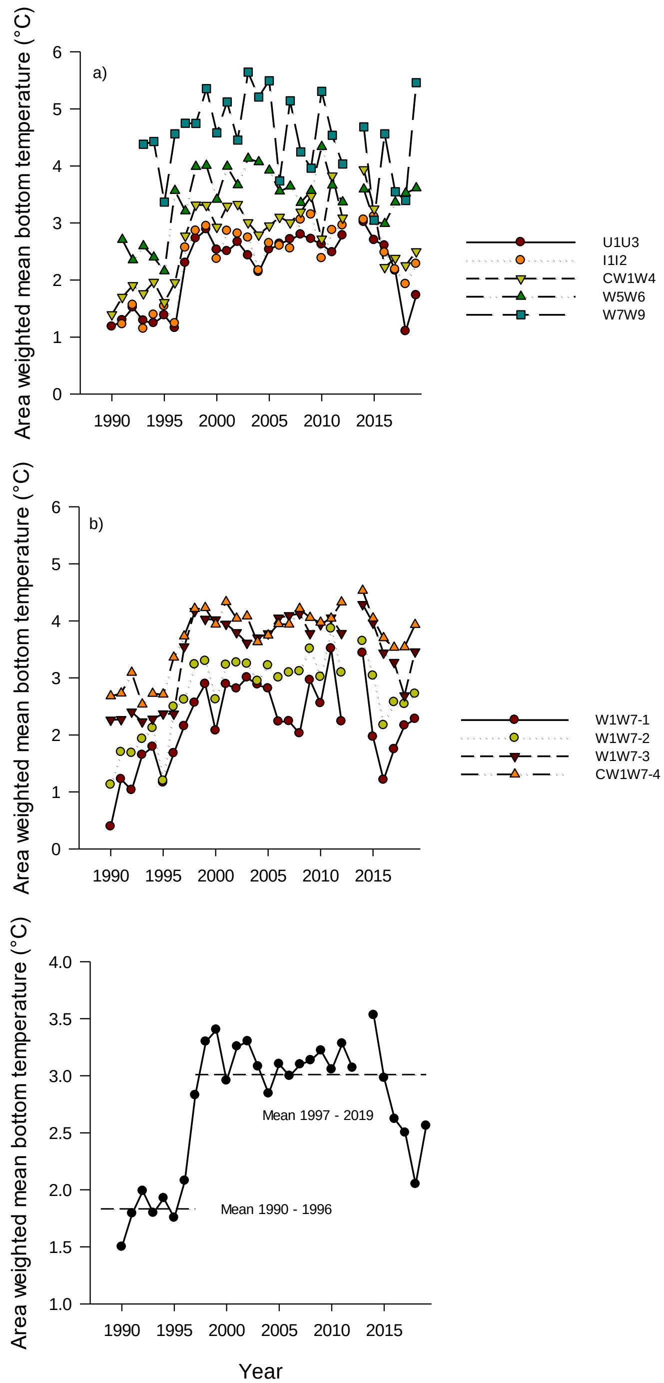

Figure 14. *Pandalus borealis* in West Greenland: area-weighted mean bottom temperature for survey regions (see Figure 1 for locations), depth strata in offshore areas C and W1–W7, and the entire survey area in 1990–2019.

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

Grønlands Naturinstitut
Greenland Institute of Natural Resources
R/V Paamiut
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Statement regarding using M/Tr Helga Maria to carry out the same surveys as R/V Paamiut for 2019
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 2019-season, GN decided to charter Helga Maria, a Islandic trawler of almost same dimensions as Paamiut, doing the normal surveys on the Greenland west coast and Canada east coast.

To make the surveys as identical as possible this equipment was used from R/V Paamiut:
Alfredo trawls with 96 mtr bridles, as with R/V Paamiut
Cosmos trawls with 48 mtr bridles, as with R/V Paamiut
• All other equipment, such as bridles ,gear etc.
• Doors
• Marport sensors on doors and headline

Other steps taken ensuring the validity of received data:
• The wires/warps on Helga Maria 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 (Jakup G.Mikkelsen) and Chief Engineer Kari Hansen was on Island ,used 14 days onboard Helga Maria, before departure to Greenland, to prepare and make the right arrangement on deck and factory for trawl equipment, and what else the Scientifics need, to make the surveys as simular as possible compare with R/V Paamiut. Skipper Jakup G.Mikkelsen also was onboard for one month, working on the bridge and deck as supervisor, taking care of that all of the trawling and equipment was carried out as on Paamiut
• 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 our best conviction regarding comparison, the surveys were executed in the best possible way, and we have absolutely no thoughts that this could be done otherwise or better.

Best regards

Jakup G Mikkelsen Kàri Hansen
Captajn Chief Engineer 1