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The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2018

by

AnnDorte Burmeister

and

Frank Rigét

Greenland Institute of Natural Resources

Box 570, 3900 Nuuk, Greenland

Abstract

The Northern shrimp (*Pandalus borealis*) occurs on the continental shelf off West Greenland in NAFO Divisions 0A and 1A–1F in depths between approximately 150 and 600 m. Greenland fishes this stock in Subarea 1, Canada in Div. 0A. The species is assessed in these waters as a single stock and managed by catch control. The fishery has been prosecuted over time by four fleets: Greenland small-vessel inshore; Greenland KGH offshore; Greenland recent offshore, and Canadian offshore.

Catch peaked in 1992 at 105 000 tons but then decreased to around 80 000 tons by 1998 owing to management measures. Increases in allowed takes were subsequently accompanied by increased catches. The logbook recorded catches in 2005 and 2006, around 157 000 tons, were the highest recorded. Since then catches has decreased and the catch was 88 952 tons in 2017. The projected catch for 2018 is set at 101 250 tons.

The advised Total Allowable Catch (TAC) for 2017 was 90 000 tons. The enacted TAC for Greenland in 2017 is set at 88 956 tons and the enacted TAC for Canada in 2017 is 12 750 tons. The enacted TAC for Greenland in 2018 is set at 99 998 tons and a TAC of 1 252 tons were set for Canada, by the Greenland Self-government.

The overall combined index fluctuated without trend by a factor of 1½ between 1976 and 1987. It then dropped precipitously to the lowest levels in the series in 1989–91, then fell to uniform lower levels until the mid 1990s. It has since increased markedly, reaching a plateau in 2004–08 of about twice its 1997 value. From 2009 to 2013, the standardised CPUE index decreased and was in 2013, 72% of the 2008 value. In the following year's catch rate continuously increased to a high level in 2017 and 2018, which was comparable to the high value observed in 2008.

According to logbook records, the early fishery was concentrated in NAFO Division 1B, but from the late 1980s the fishery spread southwards, and by 1996–98 Divisions 1C–1F were producing nearly 70% of the catches. However, these southern areas have since become less important and the fishery, which moved northwards, is now concentrated in Division 1B and 1A where more than 80% of the catches have been conducted since 2007.

Introduction—the Fishery

The West Greenland stock of Northern shrimp (*Pandalus borealis*) is distributed on the continental shelf off West Greenland between about 60°N and about 74°N; densities are highest in water between 150 and 550 m deep (Fig. 4). On the West Greenland shelf, the Greenland EEZ comprises NAFO Subarea 1 (Divs 1A–1F), and the Canadian EEZ is a westward bulge of the shelf across the mid-line at the eastern edge of Div. 0A, between about 67°24'N and 68°40'N. 'Shrimp Fishing Area 1' (SFA1), consisting of Div. 0A east of 60°30'W, has been defined by Canada since 1994. Its least depth is 270 m; its greatest E-W extent of waters shallower than 600 m is about 24 n.mi.

A bottom-trawl fishery began in Greenland inshore areas in 1935. In 1970 a multinational offshore fishery started to develop and landings increased, to approximately 153 000 tons in 2006 (Table 1, Fig. 2). Catches were first restricted in 1977 and the fishery has since been managed by Total Allowable Catch (TAC). TACs have at some times been allocated to subdivisions of the stock area in Greenland waters, especially with a view to limiting catches in northern areas (north variously of 72°52'N, 71°00'N, or 68°00'N) but since 1993 the species has been assessed as a single stock, and since 2002 a single TAC has been enacted for NAFO Subarea 1. In NAFO Subarea 1 the fishery was limited to Greenlandic vessels from 1981 through 2002, but quotas have since been allocated to EU vessels under fisheries agreements with Greenland.

Three types of licence are issued to Greenland vessels in Subarea 1 (Fig. 1). A fleet of about 10 deep-sea trawlers with on-board production licences must stay 3 n.mi. outside the baseline (but can fish to the baseline between 61°N and 65°N from 1 Nov. to 31 March) and are further excluded from 5 'shrimp boxes' extending up to 47 n.mi. west from the baseline; they fish from an offshore quota. (The EU quota is also fished offshore and for the assessment is treated as part of the Greenland offshore fishery.) A few smaller sea-going trawlers also holding on-board production licenses but fishing from a coastal quota may fish to the baseline (but must stay 3 n.mi. offshore of it between 61°N and 65°N in summer) and are excluded from 3 of the boxes (G.H. 2002). Also fishing from the coastal quota are vessels without production licences, which may fish anywhere, thus having privileged access to the 'shrimp boxes' and to good grounds inside the baseline in Julianehåb Bay, Disko Bay, Vaigat, and fjords. Coastal quotas are mostly restricted to vessels under 75 GRT/120 GT, but there are trawlers of several hundred tons that fish on coastal quotas. The coastal fleet generally ices its catch and lands it at shore stations for processing, and Greenland vessels with on-board production licences are also required to land 25% of their catches. The total coastal quota is fixed by law at 43% of the Greenland TAC. Individual Transferable Quotas (ITQs) were introduced in the Greenlandic fishery in 1991. Transfer of quotas between the coastal and the offshore fleet has been allowed since 2009. Vessels above 50 GRT have been required to keep fishery logbooks since 1986, and all vessels since 1997.

In earlier years, the true weight of packages produced on board was often greater than the nominal weight, which was the weight both invoiced and recorded in the logbook. This practice of 'overpacking' led to systematic underreporting. Since 2004 logbook entries have been required to correspond to live catch weight (G.H. 2003), and earlier catch data was corrected (Hvingel 2004) by 21–25%. TAC advice is based on the perceived ability of the stock to withstand reported catches, so upward adjustment of historical catch reports has led to an increase in advised TACs.

The tactical management of the Greenland fishery has been partly based on weights caught, and partly on weights traded. Even after elimination of overpacking the quota drawdown for shrimps sold to shore stations in Greenland by any fleet component remained less than the live weight by an allowance for crushed or broken

shrimps, included in the landing but not in the sale (G.H. 1996). The stock assessment, the advice, and the enacted TACs and quotas were based on analysis of live-caught weights, but quota drawdowns and tactical fishery management were partly based on such, smaller, traded weights, so annual catches, recorded in log-books as live-caught weight, were apt to exceed TACs. From 1 January 2011 quotas are required to be drawn down by the amount caught, without allowances for shrimps landed in poor condition (G.H. 2010). However, many catches, especially those taken in shallower waters, contain some admixture of *Pandalus montagui*. Hitherto, catches of *P. montagui* have often not been distinguished in logbooks from *borealis*, especially by vessels fishing bulk shrimps for landing in Greenland, the proportion of *montagui* being estimated by sampling the catch at the point of sale. Quota drawdowns were then restricted to the estimated weight of *borealis* and logbook records could in this way still come to exceed quotas. However, *P. montagui* is now among the species protected by by-catch regulations (G.H. 2011) and logbooks should record at least estimated catches of this species (G.H. 2010).

A licence holder who fishes out his quota may apply to start fishing the following year's quota from 15 November, and licence holders with quotas unfished at the end of the year may apply to fish them until 30 April in the following year. These concessions can lead to accumulation of unfished quotas (G.H. 2012).

Gear restrictions in Greenland include a cod-end mesh size of at least 40 mm stretched and sorting grids with 22-mm bar spacing to reduce fin-fish bycatch (G.H. 2011). Owing to improvements in sorting grids it is no longer necessary to exempt small vessels, for safety reasons, from being required to use them. Other measures to limit bycatch include a requirement to move at least 5 n.mi. if bycatch exceeds 5% of the catch (G.H. 2011).

Regulations now in force in Greenland to protect bottom habitats (G.H. 2011) include the use of rolling rockhopper ground gear, and toggle chains of 72 mm or longer to keep trawl netting off the bottom. Waters between 64°10'N and 65°15'N from the shore to 3 n.mi. outside the baseline (comprising about 650 n.mi.^{2}), an area in which there are high concentrations of sponge and coral beds, have been closed to shrimp trawling. Vessels are required to report live coral catches of 60 kg or more and live sponge catches of 800 kg or more to the Licensing Authority and to move a minimum of 2 n.mi. from any place at which such catches are taken before continuing to fish. In addition the authorities have powers to close areas which can be considered 'vulnerable marine areas'. 'New fishing areas' in West Greenland have been defined as lying North of 74°N and special regulations are in force for protecting vulnerable habitats there.

The fishery in SFA 1 is restricted to Canadian vessels. From 1996 to 2007 on average about 8 vessels (range 5–12) participated. Since then, the number of ships has varied, with 0 to 2 ships fishing in 2008-2009 and 2012-2013, 7 ships fishing in 2010 and 10 ships fishing in 2011. Catches are nominally subject to individual quotas; a quota can be retroactively adjusted to cover an overrun, with a corresponding correction in a later year. Logbooks from the Canadian fishery in SFA1 have been available have been available from 1979 to 2011 and in 2016.

For the Canadian fishery in SFA 1 observer log-books record all catches, including non-target species, in detail, as well as technical details of each set. Minimum mesh sizes ranging from 24 to 52 mm have been used, but 89% of catches have been taken with 40–46 mm mesh; 63% with 42, 43 or 45 mm. Since 1993, grates with bar spacing from 19 to 55 mm have been used, but 83% of catches (with bar spacing recorded) have been taken with bar spacing's of 22 or 28 mm, and 93% with spacing's in that range.

There is no procedure or formula agreed between the two range states, Greenland and Canada, for setting or sharing a TAC on the stock. Instead they set TACs independently. The Greenland Government has instituted a practice of deciding on a TAC for the entire stock and setting aside a part of that TAC (3.1%) to allow for the Canadian interest, the proportion being reckoned based on habitat area, recent catches, and recent survey estimates of stock biomass in the respective EEZs. The EU quota is also deducted from the Greenland TAC before dividing the remainder between the coastal fleet (43%) and the offshore fleet (57%) quotas (Hammeken Arboe 2014).

Material and Methods

Fleet Data

Logbook records were analysed to follow the recent development of the fleet and the fishery. Two Greenland fleets were defined. Vessels were classified as 'offshore' or 'coastal' from information including licence type and tonnage, but mostly relying on the mapping of fishing positions (Fig. 4). Coastal vessels fish mostly in statistical Areas 1 (Disko Bay), 2 (Vaigat), 3 (Disko Bay mouth) and 13 (Julianehåb Bay), and in statistical Area 7 (the Holsteinsborg Deep), they fish east of about 54°W in to the coast and fjords (Fig. 4a). Offshore vessels do not have permission to fish in statistical Areas 1, 2 and part of statistical Area 13, but fish in statistical Areas 4 and 6 north and west of Store Hellefiske Banke. In statistical Area 7 they fish west of about 54°W. Only the offshore fleet fishes in statistical Area 0 and -1 (Fig. 4b). Both fleets fish in statistical Areas 8–12, but the offshore fleet more than the coastal fleet.

The number of vessels providing logbook data for the West Greenland fishery was used to track fleet size, and the distribution of catches between vessels was assessed by an 'effective' fleet size calculated using Simpson's (1949) diversity index $D = 1 \Big/ \sum_i p_i^2$ where p_i is the proportion of the total catch taken by the i^{th} vessel. If this index is much lower than the nominal fleet size, it indicates large differences in annual catch between different vessels, while if it is close to the nominal fleet size, all ships are catching about the same amount. Nominal and effective fleet sizes were calculated for the offshore and coastal fleets separately and for the total fleet (Fig. 1).

Catch Data

Sources for catch data comprised: STATLANT 21A (sum of 'N Prawn' and 'Shrimps (NS)'); weekly and annual summaries of quota drawdowns ('kvotetræk') from the Greenlandic Fishery and Licence Control (GFLK); logbooks from vessels fishing in Greenlandic waters; and the Canadian Atlantic 'Quota Reports' from the website of the Canadian Department of Fisheries and Oceans (Kingsley 2007, Hammeken Arboe 2013) as well as the private version distributed by Wojciech Walkusz, DFO. These sources are all (on-line) electronic databases, not printed documents, and are therefore labile; audit trails, if they exist, are not easily accessible. For years up to 1998, the catch series for the Greenland fishery was taken from existing SCR Documents, incorporating a correction for earlier overpacking (Kingsley 2007). For 1999 to 2001, STATLANT 21A data fetched in July 2007 was corrected for overpacking using the correction factors of SCR 03/74 (Hvingel 2003). For 2002 and 2003, Greenland logbooks were used as the source of catch data, again using correction factors for overpacking. This catch series for 1999 to 2003 was close to the values used in SCR 04/75 (Hvingel 2004). For years from 2004 on, Greenland logbooks were used without correction.

For analysing CPUE data and standardising CPUE series, the following catch correction measures were used:

- the coastal fleet of small vessels, which land iced raw shrimps for processing by shore stations, was assumed not to have changed its practices as a result of the 2004 change in the laws, and no correction was applied;
- for the sea-going fleet, for which summary statistics were available as 'large' 'small' and 'unsorted', a correction of 15% was applied to reported catches of 'large' shrimp before 2004 and of 42% to catches of 'small' and 'unsorted'.

Up to 2006, no catch corrections had been used in standardising CPUE series, and in 2007 an overall average catch correction had been applied to all catches from both fleets.

The Canadian fishery in SFA1 has 100% observer coverage, and a comprehensive data record based on observer logbooks was provided in August 2013 by T. Siferd. However, from 2011 no data from the Canadian fishery in SFA1 have been available.

CPUE Analyses

Catch and effort data from logbooks are analysed with standard linear models to create fleet-specific series of annual catch-per-unit-effort (CPUE) indices, standardised for changes in fleet composition and fishing power and for variation in the distribution of the fishery. These were combined to give a single standard CPUE series as an index of the biomass densities available to the fishery.

CPU was analysed separately for four different fleets (Hvingel *et al*., 2000). The 'KGH index' was derived from catches in the early offshore fishery, executed by 7 sister trawlers (722 GRT) operated by Den Kongelige Grønlandske Handel (KGH—the Royal Greenland Trading Company). This fishery only covered Div 1A and part of Div. 1B and data from statistical Areas 3, 4, 6 and 7 (Fig. 4) for the years 1976–1990 was incorporated in the index. During this period this small fleet had a near monopoly of the fishery and enjoyed fishing conditions somewhat different from those in subsequent years when the fishery became more populous. 6 of the 7 vessels were grouped;. months were reduced to 10 levels and statistical Areas 4, 6 and 7 were combined. This analysis was not repeated and results from Hvingel (2004) were incorporated into the present analysis.

Catch and effort data from Greenlandic vessels above 50 GRT fishing in Subarea 1 was used in calculating CPUE indices for the more recent fishery. Corrected unstandardised effort was calculated by adding 60% to trawl times with twin trawls and a series of unstandardised CPUE was obtained by dividing corrected logbook catch by total corrected unstandardised effort. Standardised series of annual CPUE indices were obtained by analysing catch and effort data with multiplicative models that included the following effects: (1) a vessel effect (its fishing power, and the skill of its men), (2) a month effect (seasonal fishability of the shrimp and the fishing grounds) , (3) an area effect and (4) a year effect (overall year-to-year changes in CPUE). The main criterion for including a vessel was three years of participation in the fishery. Statistical Areas were defined *ad hoc* based on distinct fishing grounds (Fig. 4). The multiplicative model was linearised as:

$$\ln\left(CPUE_{mjki}\right) = \ln\left(u\right) + \ln\left(A_m\right) + \ln\left(S_j\right) + \ln\left(V_k\right) + \ln\left(Y_i\right) + \varepsilon_{mjki}$$

where $CPUE_{mjki}$ is the observed (logbook) mean CPUE for vessel (or vessel class) k, fishing in area m in month j in year i; ln(u) is overall mean ln(CPUE); A_m is the area effect; S_j is the month effect; V_k is the vessel effect; Y_i is the year effect; the residuals ε_{mjki} are assumed to be distributed N(0,σ^2/n) where n is the number of observations in the cell and σ^2 is the residual variance. The model was fitted with SAS Proc GLM (SAS Institute 1988). Vessel effects were sorted by value, month and area effects were kept in their natural order, and then to reduce the number of empty cells in the model neighboring classes of effect variables were combined if a pairwise contrast of their effects had an F statistic less than one; however, we note that such posterior grouping of class variables on the basis of similar effect values causes uncertainty to be underestimated. The year effects were then used as standardised annual CPUE indices in assessment models. They are assumed (on the basis of the central limit theorem) to be (approximately) normally distributed.

The offshore fleet has recently been active north of 69°12'5 to 76° N and beyond, so two statistical Area 0 and Area -1 has been defined (Fig. 4) and in 2013 and 2016 respectively, was for the first time included in the GLM calculation of year effect on CPUE (for all years).

The 'Offshore' index covers the most recent 28 years of the offshore production fishery in NAFO Div. 1A to 1F. 50 vessels were included providing data since 1987, grouped into 17 groups of 1–5 vessels with similar estimated effects. Statistical Areas – 1, 0 and 3–12 were included in the analysis;statistical Areas 7, 8 and 9 were grouped. The month effect was reduced to 9 levels by grouping adjacent months with similar indices (App.I).

Checks of keyed data files against logbooks for 2007–08 showed that double-trawl hauls were often keyed as single trawl, but the reverse error was less frequent. Double-trawling vessels in the present offshore fleet use

double trawls in over 80% of hauls. Therefore, for ships with much double-trawling activity, only double-trawl data was used. This reverses earlier practice up to 2009, according to which only single-trawl data was used. Since 2007 double- and single-trawl data has been completely checked and corrected. There is no information on double trawling before 1995, so if a ship was using double trawls in 1995 and after, its data for 1994 and before, if any, was not used in the CPUE analyses.

A 'Coastal' index was based on vessels below 80 GRT or 210 GT, which have privileged access to the inshore grounds. Some larger vessels holding coastal quotas and, according to their logbook records, fishing only in coastal areas were included in this analysis. This part of the fishery is prosecuted largely in areas around Disko Island in Div. 1A and 1B shown as statistical Areas 1, 2 and 3 in Fig. 4, but is also active in some inshore areas further south, especially in statistical Area 7 and in previous years in statistical Areas 11–13. Statistical Areas 1–3, 7 and 13 were included in the analysis. Comprehensive data were available since 1988; 35 vessels were included, in 17 groups of 1-4 vessels. The month effect was reduced to 11 levels by grouping adjacent months with similar indices (App.II).

A consolidated file of data on 61 624 hauls from the Canadian fishery in SFA 1 was available for 1979 through 2012. No data were available for 2013. It included data from 79 vessels, using 56 types of gear with 189 combinations of mesh sizes. Data was selected to include hauls between half an hour and six hours long, using gear types 17 or 66 (standard single or double shrimp trawls), and with no or insignificant gear damage. Ships were deleted that had less than two effective years in the fishery, and years were deleted with less than two effective ships. The resulting data file comprised 34 124 hauls by 27 vessels in years 1980–82, 89–96, 1998–2007 and 2010–11. Years before 1987 and months before May were then also removed. Catch and trawl-time were summed over year, month, vessel and gear characteristics. Vessels were grouped by combining pairs with contrast F-statistics less than one; the same was done for pairs of consecutive months (Appendix III). Grate bar spacing and mesh sizes were omitted from the final GLM model, which included year, month, tonnage class, vessel group within tonnage class, and gear (Appendix III). The GLM model fitted was:

$$\ln\left(C_{ymtvg}\right) = \ln\left(E_{ymtvg}\right) + A_{yC} + B_m + C_t + D_{vt} + G_g + \varepsilon_{ymtvg}$$

where C_{ymtvg} was tons caught in year y and month m by vessel group v in tonnage class t using gear g trawling for a total of E_{ymtvg} hours. Year effects A_{yC} were then considered annual indices provided by the Canadian fleet of stock size difference from the reference year 1990 in log. space; the B_m, C_t, D_{vt} and G_g were assumed to be nuisance variables by which year-to-year variation in the composition and behaviour of the fishing fleet alter the relationship between effort and catch. The residuals ε_{ymtvg} were assumed independently distributed with equal variances.

One unified series of standardised CPUE, covering 1976–2018, was derived by combining these three index series, considered for each year to be a set of independent estimates of how much the biomass differed from its size in the reference year, set to be 1990. For each year, the values from the several series were combined with weighting. Their reported uncertainties could be considered to comprise three factors: for each series, the overall size of the uncertainties reflects how much data there was, how well the model fitted, and generally how well the data was arranged to estimate differences from the reference year, while within the series, each several value reflected how suitably the data was arranged to estimate it, in particular, relative to the values for the other years. However, neither severally nor collectively did they betoken the importance of the fleet in the fishery nor how well, relative to other fleets, its catch rates should consequently be supposed to follow changes in *total* stock size. An additional weighting was therefore applied in combining the year-effects series, so

$$A_{yf} \sim N\left(\overline{A}_y, \sigma^2_{yf}\right) \text{ where } \sigma^2_{yf} = \hat{\sigma}^2_{yf} \Big/ w_f$$

the A_{yf}—GLM-estimated year effects for fleet f—being considered to be Normally distributed about a series of overall year effects $\overline{A}_y$ with individual error variances σ^2_{yf} whose relative sizes were calculated from the

individual error variances estimated by the GLM— $\hat{\sigma}^2_{yf}$ —and weights w_f assigned on the basis of the area fished by fleet *f*. The weights w_f for the KGH, Greenland offshore and Greenland coastal fleets were assigned as 0.376, 0.434, and 0.191. The year effects were fitted using Bayesian methods on the OpenBUGS platform and were given uninformative uniform prior distributions.

Until 2017, A Canadian CPUE index was included in the combine CPUE index. In 2018 is was decided to the remove index from the combine index, while it since 2012 have been difficult to obtain logbook data and catch/effort and CPUE information from then Canadian fishery in SFA1. Because Canadian catches in SFA1 is very low, removing this index from the combine CPUE index, have no influence in the perception of the trajectory of CPUE over time.

The standardisation method used accounts for the increase in efficiency from renewal of the fleet but does not account for technological improvements to existing vessels. Examination of records of motor power changes in the GFLK fleet database showed very few real changes in motor power. Hvingel *et al*. (2000) considered the possible effects that upgrading ships, crews, or electronics might have on CPUE series, which are always liable to be over-optimistic in respect of the historical trend of stock biomass.

Distribution of the Fishery

To aid in interpreting the time trajectory of CPUE estimates, the distribution of the fishery and its change with time were also examined. Catch and effort were allocated to the same statistical Areas as those used for the GLM standardisation of CPUE and summed up by year and statistical Area, and also by year and NAFO Division. The distribution of catch and effort between areas or Divisions was plotted, and was also summarised by Simpson's diversity index to calculate an 'effective' number of statistical Areas or Divisions being fished.

Distribution by depth

The distribution by depth of catches of *P. borealis* recorded in Greenland logbooks was analysed in 2011 for the period 1991–2010, in 5-year periods, both overall and separately for the offshore and coastal fleets (Kingsley 2011).

Biological Sampling

There is at the moment no programme for sampling from the fishery for obtaining data on length, sex or weight of individual shrimps.

Pandalus montagui in the West Greenland fishery

Aesop shrimp *P. montagui* occurs off West Greenland. Most *montagui* is caught in mixed catches, but mixed catches have in the past often—even usually—not been identified in logbooks, especially by the fleet fishing iced bulk shrimps. Logbook records have therefore presumably underestimated catches of *montagui* (Kingsley 2011), but the recording of montagui reported has improved in recent years (Nedergaard pers. comm.).

Results and Discussion

Evolution of the fishery: TACs, effort and catches

Logbook data available since 1975 gives a picture of the evolution of the fishery. The first logbook data shows a small fishery comprising 1 or 2 vessels taking small catches in a restricted area, increasing to a fleet of the 7 sister trawlers of the KGH fleet. Nominal and effective sizes of this homogeneous fleet were nearly the same (Fig. 1a). After 1984 more vessels entered the fishery and the offshore fleet became larger and more heterogeneous, reaching a peak in the late 1980s (Fig. 1b). Since then a progressive rationalisation has forced a reduction in nominal fleet numbers, and the fleet has also returned close to its initial level of homogeneity (Fig. 1).

The early logbook records from the coastal fleet, in the early 1990s, also show a small, homogeneous fleet, but this is artificial: vessels had to be under 80 tons to be in the coastal fishery, but below 50 tons didn't have to complete logbooks, so coastal vessels submitting logbooks were all much the same size (Fig. 1c). After 1997 all trawlers had to report, so the nominal size of the coastal fleet, as shown by logbooks, quadrupled from 24 to 94. However, the small ships were catching so few shrimps that the effective size of the coastal fleet only doubled, from 16 to 33, and the effective size of the total shrimp fleet changed little (Fig. 1c). Rationalisation and modernisation have driven the nominal size of the coastal fleet down by 85 % since 1997, but its effective size has decreased by only 2/3, as many of the smallest vessels have left the fishery and the fleet has become less diverse (Fig. 1c).

In conjunction with the development of the offshore shrimp fishery total annual catch increased from about 10 000 tons in the early 1970s to more than 105 000 tons in 1992 (Fig. 2, Table 1). Measures by the Greenland Home Rule Government to reduce effort, as well as improved fishing opportunities elsewhere for the Canadian shrimp fleet and the disappearance of a strong 1985 year-class (Garcia 2007), then introduced a period of lower catches lasting to the early 2000s. Canadian catches, in particular, were low in the mid- to late 90s. After 2000 survey estimates of stock size (Burmeister et al. 2014) and catches increased very rapidly, by about 50% by 2005, and high TACs were enacted, and large catches taken, in 2004–2008 (Fig. 2). Since the peak from 2003 to 2005 survey biomass has decreased (Burmeister and Rigét 2017, 2018) followed by a decrease in TACs and catches (Fig. 2).

Canada sets autonomous TACs for SFA1 that in 1991–2010 averaged 154% of the estimated survey biomass in that area (Burmeister et al. 2014). In those 20 years, catches in SFA1 did not exceed 90% of the TAC and averaged 31% of it (Table 1). The catches therefore appear, overall, to be *de facto* unregulated; they average near to 50% of the estimated survey biomass. However, SFA1 is such a small proportion of the total distribution area that an unregulated fishery there seems unlikely to threaten the continued existence of the stock, given that this is not a highly migratory species. In 1991–2017 Canadian catches averaged approx. 1.2% of the estimated survey biomass in the entire stock distribution area (Burmeister et al. 2014).

From 1975, when the offshore fishery was well established, through 1984 annual unstandardised effort increased slightly from about 75 000 hr to about 100 000 hr (Table 1, Fig. 3). In the subsequent years the offshore fleet was considerably enlarged and effort went up by almost a factor of three, reaching 250 000 hr in 1991–92. Unstandardised effort has since decreased to low about 80 000 hr in 2015 because of management measures, reduced activity in Div. 0A (Table 1) and a generally increased fishing efficiency. For the past two years, 2016 and 2017, unstandardized effort increased to about 90 000 hr.

The trajectory of the standardised effort time series agrees with that of the unstandardised (Fig. 3). After 1992, when it reached its highest value, standardised effort decreased steadily—overall by about 35%—to a minimum in 1998–2000. The standardised effort increased by 20% from 2000 to 2002, followed by continuous decline by approximately 3% a year, were somewhat stable until 2015 and have since declined to a 2017 value 29% less than observed in 2015.

Spatial and seasonal distribution

According to logbook records, the early fishery was concentrated in NAFO Division 1B, but from the late 1980s the fishery spread southwards, and by 1996–98 Divisions 1C–1F were producing nearly 70% of the catches (Table 3, Table 4a, Fig. 5a). However, these southern areas have since become less important and the fishery, which moved northwards, is now concentrated in Division 1B and 1A where more than 80% of the catches have been conducted since 2007. Number of statistical Areas fished increased steadily up to the early 1990s (Fig. 6), remained quite stable until 2003, dropped to fewer fished statistical areas in 2004 and 2005, remained stable again until 2015, then followed by an increase in number of fished areas (Fig. 6). Effort has since 2005 become more concentrated (Fig. 6, table 4b).

Since 2007 35 to 40% of the catch has been taken in Division 1A alone (Fig. 5b). This is especially due to increased fishing in statistical Area 2 and Area 3 (Disko Bay and Disko Bay mouth), which has yielded between

30% to 40% since 2009 (Fig. 7a, 5b). Where the majority of catches were based on fishery in statistical Area 0, Area 2 and Area 3, in the years 2009 to 2012, statistical Area 7 has since become more important and over the past five years produced 20% of the fishery (Fig. 5a). Area 0 (Offshore between 69°12'5 N and 74° N), which in recent years has yielded between 10 and 17% of the catch (Fig. 8). This is consistent with results from the survey, in which the proportion of survey biomass in Disko Bay has been high since 2005 and the proportion of survey biomass in the northern Areas has been high since 2003 (Fig. 2b in Burmeister and Rigét 2017). An increasing concentration of the stock and the fishery has been consistent with a decreasing biomass index from the research trawl survey while catch rates in the commercial fishery remain high, and this agrees with data since 2003.

Fishing activity happen during all months a year. A strongly seasonal pattern were prevalent up to about 15 years ago, with summer monthly catches 2–3 times the winter minimum. The most recent 8 years, appears to have a more uniform seasonal distribution, where catches are somewhat divide equally between annual quarters (Table 5).

Depth distribution

The depth distribution of catches has shifted significantly over the most recent 20 years. In 1991–1994 the median depth by weight for all catches was 347 m, and catches extended down to 547 m (99th percentile). 12 years later, in 2003–2006, the median catch was taken 80 m shallower at 254 m. The median depth for the offshore and the coastal fleets changed by almost exactly the same 100 m. In 2007–2010 the median depth distribution for the offshore fleet increased again, nearly back to where it was in 1999–2002, but the depth distributions for catches in the coastal fleet stayed exactly the same as in 2003–2006 (Fig. 10a, Fig. 10b and Fig. 10c). In the following years depth distributions of catches was continuous increasing and has in the most previous years (2015-2018) been 312 m, almost comparable to observations from the late 90'ties.

By-catch and discard

The logbook-reported at-sea discard of shrimps, mostly for quality reasons by production trawlers, has remained less than 1% by weight of total catch throughout 1975–2018 (Table 6). However, these statistics do not include shrimps discarded for quality reasons from land processing stations ('vragrejer'). Placing observers on offshore vessels in 1991 may have improved the reporting of discard—hence an apparent increase—while an improved market for smaller shrimps may have offset a corresponding effect of observers on the reported discard of shrimps.

Bycatch of fish—especially pre-recruits—in small-mesh shrimp trawls has long been a serious problem, partly solved by the development of sorting grids that deflect fish, but not shrimps, out of the trawl through escape openings. In the most recent years registered annual discards of fish have been below 1% of total shrimp catch, but fish discard reports are based on visual estimates of weight, not on physical weighing, and errors are likely. An EU project[1] to verify the quantity of bycatch and the accuracy with which it is reported—by both captain and observer—found from observations, including the weighing of bycatch, by a scientific assistant of 166 hauls on 7 vessels in NAFO Divs 1B–1E in 2006–07, that reports by captain and observer tended to agree on the bycatch weight, but not necessarily at the correct value, that the presence of the scientific assistant probably affected the estimates made by the captain and the observer, and that the weighed bycatches were on average larger—at 1.2–3.2% of the shrimp catch—than logbook reports on average indicate (Sünksen 2007).

Catch per unit of effort

Logbook data for selected ships from four fleets were analysed using SAS PROC GLM (see Appendices 1–3) to give standardised series and unified by fitting a separate model. All fleets included in the analysis exploit(ed)

[1] 'CEDER: Catch, Effort and Discard Monitoring in Real Time'

mainly shrimp greater than 16 mm cpl. The CPUE indices are therefore indicative of the stock of females and older males combined. From 1988 to 2008 the CPUE indices from the Greenland coastal and the Greenland offshore fleets have remained closely in step except for a few years. (Table 2, Fig. 9). Since 2007 they seem to have returned to closer agreement except for 2 years in 2009 and 2010. From 2004 to 2008 the catch rate of the offshore fleet reached the highest level seen in the series and has since been decreasing, to a low in 2013 only 73% of the 2008 value. The catch rate for the inshore fleet reached its highest level in 2007 to 2008, and decreased correspondingly to the offshore fleet. In the successive year's offshore fleet catch rate increased to a record high value in 2017 but close to what was obtained in 2008. The catch rate trend of the coastal fleet shown a different trajectory, increased until 2015 but have since steadily declined to a 2013 value in 2017 (Fig. 9).

CPUE in the Canadian fishery in SFA1 has always varied more from year to year and has never stayed closely in step with the Greenland fleets, but no CPUE data has been available since 2011 (Table 2, Fig. 9).

The overall combined index (Table 2, Fig. 9) fluctuated without trend by a factor of 1½ between 1976 and 1987. It then dropped precipitously to the lowest levels in the series in 1989–91, then fell to uniform lower levels until the mid 1990s. It has since increased markedly, reaching a plateau in 2004–08 of about twice its 1997 value. From 2009 to 2013, the standardised CPUE index decreased and was in 2013, 72 % of the 2008 value. In the following year's catch rate continuously increased to a peak value in 2017, which was comparable to the high value observed in 2008.

Pandalus montagui

The Aesop, or striped pink, shrimp *Pandalus montagui* is in general not highly sought after by the Greenland fishery, and few vessels catch much of it. Its presence lowers the price paid for bulk shrimps and can exclude catches from markets for the highest-quality products. Nonetheless, some vessels, sometimes, have made protracted series of catches, some large, with unusually high proportions of *montagui*. The offshore fleet records catches of *montagui*, estimated by sampling from the on-board holding tank, in logbooks. The coastal fleet fishing bulk shrimps for processing on shore has not recorded *P. montagui* in its logbooks; weights of *borealis* and *montagui* have been reckoned from catch samples taken at the point of sale. Logbook records of *montagui* catches have in the past been an underestimate, while logbook records of *borealis* catches have been an overestimate.

From 1995 logbook reports included overall annual catches of *P. montagui* in the range of about 100 tons to a 2014 peak of 4944 tons (Table 6); for 27 vessels recording catches of *P. montagui* in 2001–2010, the (under-) reported catch of *montagui* averaged under 1% of the catch of *borealis* (Kingsley 2011). In 2011 the catch of *montagui* was 2% of the catch of *borealis* which rose to 3% in 2012 and in 2013 further increased to 5%, but by-catch of *montagui* have since dropped to less than 1% in 2017 (Table 6). There were indications of increased biomass of *P. montagui* in the mid- and late 1990s (Kanneworff, 2003), but survey estimates of biomass have been low since the turn of the century (Rigét and Burmeister 2017, Rigét and Burmeister 2018). The effect of the fishery for *borealis* on the stock of *montagui* has not been evaluated and is of some concern. Since 2012 *P. montagui* has been included among the species for which a moving rule is in force for reducing bycatch, and efforts are being made to have fleets fishing in Greenland waters record catches of these shrimps better (G.H. 2011).

Based on the logbooks from five offshore fleets a standardized CPUE index series (2001-2018) was derived using GLM including the factors year, area, month and fleet weighted with the number of hauls (Fig. 11A). Throughout the period, the CPUE index has fluctuated with an increasing tendency in the period after 2010 compared to previous years.

In order to construct a time series comprising the coastal fleet, a standardized LPUE index series (2008-2018) based on sale notes was initiated. A GLM model including the factors year, month and fleet was performed (Fig.

11B). In the period 2008 to 2010 LPUE were considerably lower than in the period 2013 to 2018). During the recent 4 years LPUE has been stable.

Correspondingly, to last year, a stochastic surplus production model (SPiCT) was applied to the West Greenland stock of *Pandalus montagui* (Rigét and Burmeister, 2017). Input data composed of catch and commercial CPUE index derived from five offshore vessels and survey biomass excluding hauls below 150 m during the period 2001 to 2018. The SPiCT model was only able to converge when fixing key parameters such as n = 2 (symmetric Schaefer production curve) and the ratios of error terms to a known value of 1. However, the model did not lead to reliable results as the uncertainties were extreme large, likely because of the large fluctuations in catch and index values and that the time series is relative short.

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Table 1a. *P. borealis* in W. Greenland: Catch limits, effort, catch and CPUE, SA 1 up to 73°30'N, 1970–1989.

Year	TAC (t)			Catch (t)				Catch (t)	Effort				CPUE			
	SA 1*	Div. 0A	Total	SA 1 Offshore	SA 1 Inshore	SA 1 Total	Div. 0A Offshore	Total	SA 1 Unstd. ('000 hr)	Div. 0A Unstd. ('000 hr)	Total Unstd. ('000 hr)	Total Std. (index)	SA 1 Unstd. (kg/hr)	Div. 0A Unstd. (kg/hr)	Total Unstd. (kg/hr)	Std. Total (1990=1)
1970	no	no	no	1243	9272	10515	0	10515	-	-	-	-	-	-	-	-
1971	no	no	no	1978	9615	11593	0	11593	-	-	-	-	-	-	-	-
1972	no	no	no	3786	8076	11862	0	11862	-	-	-	-	-	-	-	-
1973	no	no	no	6785	8745	15530	0	15530	-	-	-	-	-	-	-	-
1974	no	no	no	15967	11070	27038	0	27038	-	-	-	-	-	-	-	-
1975	no	no	no	36977	9570	46547	0	46547	74.2	-	74	-	628	-	628	-
1976	no	no	no	52993	8030	61023	392	61415	80.1	-	80	0.49	762	-	766	1.48
1977	-	-	36000	42578	8580	51158	457	51615	73.1	-	73	0.44	699	-	706	1.39
1978	-	1000	41000	33835	8360	42195	122	42317	84.2	-	84	0.46	501	-	503	1.10
1979	-	2000	31500	32852	8250	41102	1732	42834	72.4	-	72	0.51	568	-	592	0.99
1980	-	2500	32000	44916	8250	53166	2726	55892	80	11.6	92	0.56	665	235	610	1.20
1981	35000	5000	40000	40295	8250	48545	5284	53829	88.2	16.6	105	0.57	551	318	514	1.13
1982	34800	5000	39800	43979	8250	52229	2064	54293	81.1	8.1	89	0.45	644	256	609	1.43
1983	34625	5000	39625	42553	8250	50803	5413	56216	89	26.1	115	0.53	571	208	488	1.27
1984	34925	5000	39925	42414	8250	50664	2142	52806	85	-	*85*	0.53	596	-	*621*	1.19
1985	42120	6120	48240	54888	8250	63138	3069	66207	129.1	23.6	153	0.62	489	130	433	1.28
1986	42120	6120	48240	65019	8250	73269	2995	76264	133.4	-	*133*	0.68	554	-	*576*	1.33
1987	40120	6120	46240	64161	7613	71774	6095	77869	137.1	17.7	155	0.61	524	344	503	1.53
1988	40120	6120	46240	56479	11256	67735	5881	73616	152.9	14.9	168	0.76	443	395	439	1.15
1989	45245	7520	52765	58890	14546	73436	7235	80671	179.6	19.7	199	0.91	409	367	405	1.05

* in 1981–1995 quotas applied to the offshore area only

Table 1b. *P. borealis* in W. Greenland: Catch limits, effort, catch, and CPUE, SA 1 up to 73°30'N, 1990–2018. (2018 is only preliminary data from January the 1. to June the 30).

Year	TAC (t)			Catch (t)					Effort				
	SA 1*	Div. 0A	Total	SA 1			Div. 0A	Total	SA 1	Div. 0A	Total	Total Std.	SA 1
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			(1990=1)	Uns
1990	45245	7520	52765	62800	14993	77793	6177	83970	209.6	14.3	224	1.00	371
1991	46225	8500	54725	66817	17884	84701	6788	91489	230.8	19.6	250	1.04	367
1992	44200	8500	52700	75341	22653	97994	7493	105487	234.2	16.6	251	1.12	418
1993	40600	8500	49100	65894	19627	85522	5491	91013	206.1	12.2	218	0.98	415
1994	42300	8500	50800	68109	19930	88039	4766	92805	209.8	15.3	225	1.00	420
1995	39500	8500	48000	66955	18072	85027	2361	87388	184.7	7.3	192	0.85	460
1996	63922	8500	72422	62368	19095	81463	2632	84095	164.6	9	174	0.79	495
1997	64600	8500	74800	62743	14868	77611	517	78128	184.9	1.3	186	0.75	420
1998	60729	7650	68379	69156	10406	79562	933	80495	152.7	2.6	155	0.67	521
1999	73500	9350	82850	71203	18948	90152	2046	92198	164.7	5.1	170	0.68	547
2000	77675	9350	87025	73013	23365	96378	1590	97968	156.2	2.6	159	0.66	617
2001	92950	9350	102300	79291	20010	99301	3625	102926	158.3	6	164	0.72	627
2002	91150	12040	103190	107195	21729	128925	6247	135172	173.3	9	182	0.79	744
2003	101000	14167	115167	104237	18799	123036	7137	130173	141.5	8.4	150.0	0.71	869
2004	135352	14167	149519	121658	20653	142311	7021	149332	148.6	12.3	160.9	0.74	958
2005	134000	18452	152452	128068	21910	149978	6921	156899	150.8	9.3	160.1	0.75	994
2006	134000	18380	152380	127747	25441	153188	4127	157315	148.7	4.7	153.4	0.76	1030
2007	134000	18417	152417	116674	25571	142245	1945	144190	138.3	2.2	140.6	0.66	1028
2008	127300	18417	145717	119797	34092	153889	0	153889	144.7	-	144.7	0.68	1064
2009	114570	15583	130153	97051	37978	135029	429	135458	144.1	-	144.1	0.67	937
2010	114570	15583	130153	94596	33513	128109	5882	133991	144.5	5.8	150.3	0.68	886
2011	124000	15583	139583	78437	44222	122659	1330	123989	131.6	2.5	134.1	0.61	932
2012	101675	12750	114425	76090	39875	115965	12	115977	134.5	-	134.5	0.62	862
2013	89263	11333	100596	65797	29582	95379	2	95381	116.8	-	116.8	0.58	817
2014	86316	11333	97649	60768	27997	88765	0	88765	105.4	-	105.4	0.51	842
2015	74061	8500	82561	49246	23008	72254	3	72257	83.2	-	83.2	0.40	868
2016	85801	10625	96426	56593	27763	84356	1171	85527	95.9	-	95.9	0.45	879
2017	88957	12750	101707	63037	26332	89369	3215	92584	90.2	-	90.2	0.41	991
2018#	99998	14875	114873	78108	21890	99998	737	100735	44.9	-	44.9	0.48	2227

* 1981-1995 TAC for offshore only.

Projections based on information received from GFLK and DFO.

Table 2. *P. borealis* in W. Greenland, SA 1 up to 73°30: Standardised (1990=1) CPUE series for 4 fleets and a combined standardized CPUE series. * relative i.q.r.: the interquartile range divided by the median. ***2018 is only preliminary data***

	KGH		**Offshore**		**Coastal**		**Canada SFA1**		**Combined**	
Year	median	rel. iqr	median	rel. iqr	median	rel. iqr	median	rel. iqr	median	rel. iqr
1976	1.660	0.124							1.495	0.219
1977	1.556	0.082							1.389	0.158
1978	1.230	0.082							1.101	0.145
1979	1.113	0.080							1.000	0.154
1980	1.340	0.082							1.206	0.145
1981	1.266	0.077							1.132	0.143
1982	1.611	0.083							1.434	0.149
1983	1.423	0.081							1.275	0.151
1984	1.338	0.079							1.197	0.144
1985	1.432	0.077							1.288	0.136
1986	1.490	0.077							1.340	0.144
1987	1.787	0.080	1.528	0.031			—	—	1.519	0.063
1988	1.465	0.079	1.148	0.027	1.179	0.053	—	—	1.163	0.054
1989	1.086	0.088	1.083	0.026	0.889	0.040	1.114	0.110	1.052	0.048
1990	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
1991			1.048	0.024	0.975	0.036	0.795	0.095	1.044	0.052
1992			1.127	0.025	1.069	0.036	0.861	0.103	1.125	0.049
1993			1.096	0.025	1.125	0.036	0.935	0.098	1.109	0.051
1994			1.123	0.025	1.007	0.035	0.652	0.095	1.110	0.049
1995			1.257	0.026	1.022	0.035	0.765	0.102	1.220	0.053
1996			1.316	0.028	1.071	0.037	0.616	0.100	1.271	0.053
1997			1.272	0.029	1.088	0.036	—	—	1.240	0.053
1998			1.452	0.031	1.323	0.040	0.609	0.135	1.431	0.057
1999			1.647	0.033	1.419	0.035	0.880	0.129	1.604	0.058
2000			1.737	0.034	1.753	0.036	1.067	0.137	1.767	0.059
2001			1.680	0.035	1.631	0.035	1.106	0.116	1.693	0.057
2002			2.001	0.031	2.012	0.035	1.318	0.107	2.027	0.055
2003			2.191	0.033	2.039	0.036	1.579	0.113	2.180	0.057
2004			2.477	0.033	2.139	0.035	1.180	0.107	2.406	0.055
2005			2.635	0.032	2.082	0.036	1.261	0.117	2.502	0.058
2006			2.508	0.031	2.229	0.037	1.443	0.141	2.465	0.060
2007			2.583	0.032	2.498	0.037	1.388	0.141	2.598	0.059
2008			2.696	0.033	2.529	0.035	—	—	2.693	0.056
2009			2.443	0.035	2.175	0.036	—	—	2.398	0.059
2010			2.440	0.034	2.002	0.037	2.055	0.182	2.351	0.058
2011			2.455	0.036	2.259	0.037	0.250	0.305	2.434	0.060
2012			2.252	0.035	2.071	0.037	—	—	2.236	0.060
2013			1.906	0.036	2.001	0.040	—	—	1.956	0.061
2014			1.990	0.037	2.198	0.041	—	—	2.075	0.063
2015			2.087	0.040	2.263	0.043	—	—	2.164	0.061
2016			2.248	0.039	2.155	0.041	—	—	2.264	0.061
2017			2.930	0.039	2.020	0.042	—	—	2.684	0.066
2018			2.720	0.050	1.990	0.053	—	—	2.523	0.076

Table 3a. *P. borealis* in W. Greenland: Annual catch, effort and CPUE of the shrimp fishery on the West Greenland shelf by NAFO Divisions. Data from logbooks, weighted up to annual 'agreed' catch.

Year	Agreed Catch ('000 tons)							Corrected, Unstandardised Effort ('000 hr)							Unstandardised CPUE (agreed kg/hr)						
	0A	1A	1B	1C	1D	1E	1F	0A	1A	1B	1C	1D	1E	1F	0A	1A	1B	1C	1D	1E	1F
1975	0	0	44.6	2	0	0	0	-	0	70.5	3.6	0	0	0	-	-	632	551	-	-	-
1976	0.4	0	54.7	6.3	0	0	0	-	0.1	70.1	8	0.1	0.8	1.1	-	-	780	785	-	-	40
1977	0.5	0.2	47.8	3.1	0.1	0	0	-	0.5	67.8	4.4	0.5	0	0	-	357	705	691	253	-	-
1978	0.1	0.5	40.9	0.5	0.2	0	0	-	1.4	80.7	1.3	0.8	0	0	-	382	507	416	259	-	-
1979	1.7	4.8	35.7	0.5	0	0	0	-	6.7	64.1	1.5	0.1	0	0	-	719	557	348	112	-	-
1980	2.7	14.6	35	3.3	0.3	0	0	11.6	21.2	53.3	4.9	0.5	0	0	235	690	655	668	596	-	-
1981	5.3	5.7	37.5	5.3	0	0	0	16.6	11.2	66.4	10.4	0.1	0	0	318	511	564	510	409	-	-
1982	2.1	0.8	43.2	8.2	0	0	0	8.1	1.7	65.7	13.5	0.1	0	0	256	472	657	604	388	-	-
1983	5.4	0.5	40.5	9.4	0.5	0	0	26.1	0.9	69.5	17.8	0.9	0	0	208	559	582	528	531	-	614
1984	2.1	1.2	30.4	17	2.1	0	0	-	2.7	51.1	28.4	2.7	0	0.1	-	431	595	598	785	-	47
1985	3.1	8.1	35.5	14.9	4.7	0	0	23.6	28.7	66.2	25.6	8.7	0	0	130	282	536	580	540	-	-
1986	3	26.3	32.4	9.2	6	0	0	-	54.2	55.2	14.1	9.6	0.1	0.1	-	485	586	649	624	273	-
1987	6.1	19.4	43.7	7.3	1.3	0	0	17.7	54.4	67.9	10.7	4.2	0	0	344	357	644	685	324	-	-
1988	5.9	12.4	47.5	7.1	0.5	0	0.1	14.9	40.9	94.3	14.7	2	0	1	395	302	504	486	268	-	153
1989	7.2	16.3	33.8	12.9	10	0	0.5	19.7	47.3	77.7	30.5	19.8	0	4.2	367	343	435	422	507	-	111
1990	6.2	12.2	30	22.7	12.4	0	0.5	14.3	42.3	77.5	56.1	30.8	0	2.8	433	288	387	405	403	-	165
1991	6.8	12.6	32.9	18.8	19.6	0.6	0.2	19.6	37	90	52.6	49.2	0.7	1.3	346	341	365	357	398	824	191
1992	7.5	16.3	32.8	19.9	23.4	5	0.6	16.6	49.3	76.2	48	51.7	7.8	1.3	451	330	431	415	452	642	497
1993	5.5	7.6	36.3	15.8	18.1	4.5	3.2	12.2	22.9	82	41.3	44.3	8	7.6	450	331	442	383	410	559	425
1994	4.8	7.3	33.7	15.9	19.9	7	4.2	15.3	23.3	84.1	40.9	42.7	9.6	9.3	312	313	401	390	467	736	450
1995	2.4	6.9	27.2	15.5	22	8.6	4.9	7.3	20.9	69.2	33.8	40.8	12.3	7.9	322	330	393	458	539	696	624
1996	2.6	5.4	22.4	16.8	23.3	8.3	5.3	9	18.4	51	35	39.3	11.8	9.1	293	293	439	481	594	700	579
1997	0.5	7.3	20.2	11.5	22.6	8.5	7.6	1.3	43.7	53.7	24	39.2	11.6	12.6	412	167	376	477	576	730	605
1998	0.9	4.5	22.6	13.5	21.1	8.7	9	2.6	20	48.9	25.4	34.2	10.6	13.5	353	226	463	532	618	817	671
1999	2	8.8	28.5	14.6	19.1	8.3	10.9	5.1	34.2	58.9	22.5	27.1	9.2	12.9	398	259	484	650	704	902	839

Table 3b. *P. borealis* in W. Greenland: Annual catch, effort and CPUE of the shrimp fishery on the West Greenland shelf by NAFO Divisions. Data from logbooks, weighted up to annual 'agreed' catch.

Year	Agreed Catch ('000 tons)							Corrected, Unstandardised Effort ('000 hr)							Unstandardised CPUE (agreed kg/hr)						
	0A	1A	1B	1C	1D	1E	1F	0A	1A	1B	1C	1D	1E	1F	0A	1A	1B	1C	1D	1E	1F
2000	1.6	14.8	29.2	15	19	7	11.5	2.6	36.2	51.7	20.3	26.2	7.7	14.1	613	409	564	737	727	909	810
2001	3.6	14.4	27.4	17.1	20.8	8	11.6	6	41	49.2	21.1	27.4	7.7	11.8	602	351	557	810	760	102.9	980
2002	6.2	15.2	43.5	26.5	25	8.5	10.3	9	41.6	58.7	27.5	28.2	7	10.4	695	365	741	963	888	121.6	989
2003	7.1	13.9	42.4	24.8	23.1	8	10.8	8.4	32.6	46.8	23.3	22.7	5.9	10.2	842	427	905	106.5	101.7	134.5	106.4
2004	7.0	13.8	55.0	33.6	24.6	5.7	9.6	12.3	33.4	59.7	24.2	17.0	3.1	11.2	569	413	921	139.1	144.9	185.0	856.6
2005	6.9	11.3	73.0	33.6	18.0	5.4	8.7	9.3	23.2	71.2	22.8	12.9	5.2	15.5	744	486	5	102.1	147.1	139.1	565.4
2006	4.1	13.8	81.0	23.7	19.3	9.8	5.5	4.7	21.9	73.5	17.4	15.1	10.3	10.6	884	631	2	110.6	136.6	128.4	519.8
2007	1.9	26.5	84.8	9.1	12.0	8.7	1.1	2.2	32.3	78.1	7.1	10.5	8.0	2.3	872	821	5	108.5	129.4	114.4	473.1
2008	0.0	42.3	96.1	6.7	4.4	4.2	0.1	0.0	42.7	88.1	5.7	3.7	4.5	0.1	-	991	0	109.9	118.9	117.7	977.1	117.0
2009	0.4	48.1	71.9	5.0	6.5	3.6	0.0	0.1	54.8	77.8	4.6	4.6	2.5	0.0	-	877	926	108.4	139.1	146.3	3 -
2010	5.9	50.9	63.4	6.2	6.6	1.1	0.0	5.8	64.7	70.5	4.7	4.1	0.6	0.0	101.7	786	899	131.9	162.0	185.2	-
2011	1.3	46.9	54.2	7.9	10.9	2.7	0.0	2.5	65.8	52.3	5.2	7.0	1.3	0.0	527	713	6	103.1	153.1	154.8	208.5 -
2012	0.0	45.7	45.3	6.3	12.0	4.6	0.3	0.0	67.1	51.6	4.6	7.6	3.4	0.2	-	680	878	137.7	157.6	188.6	153.9
2013	0.0	33.9	39.2	6.6	10.6	4.6	0.6	0.0	52.1	46.6	5.5	8.5	3.5	0.3	-	646	840	121.4	124.0	131.4	214.1
2014	0.0	37.9	38.3	4.0	6.2	1.6	0.7	0.0	55.1	39.3	3.8	5.3	1.3	0.3	-	685	973	106.8	118.1	128.5	197.1
2015	0.0	28.6	30.0	4.7	5.4	1.8	1.8	0.0	40.0	32.2	3.7	5.0	1.3	1.0	-	715	933	126.9	107.8	137.2	169.2
2016	1.2	32.6	36.6	5.9	5.7	2.2	1.2	0.0	44.0	41.1	4.6	4.5	1.1	0.5	-	741	891	128.3	125.3	207.8	238.2

2017	1.0	36.1	35.2	10.8	5.1	1.4	0.3	0.0	44.6	35.1	6.6	3.2	0.5	0.1	-	809	1002	1633	1574	2832	2820
2018*	1.3	18.8	44.4	24.1	10.0	2.7	0.0	0.0	12.0	20.1	7.9	4.3	0.6	0.0	-	1565	2214	3044	2347	4253	6640

*Projected

Table 4a. *P. borealis* in W. Greenland; Distribution (%; columns sum to 100) of catches between Divisions in NAFO Subarea 1 by 5-year period.

	5-year-period							
	80–84	85–89	90–94	95–99	00–04	05–09	10–14	15-17
1A	9.2	23.4	12.8	8.1	12.1	19.4	39.1	39.6
1B	72.1	56.1	38.3	29.1	33.7	55.4	43.6	41.5
1C	17.4	13.9	21.5	17.2	20.0	10.6	5.6	8.7
1D	1.3	6.4	21.5	26.1	19.0	8.2	8.4	6.6
1E	0.0	0.0	4.0	10.2	6.2	4.3	3.0	2.2
1F	0.0	0.2	2.1	9.3	9.0	2.1	0.3	1.3
Diversity	1.8	2.5	3.9	4.8	4.6	2.7	2.8	2.9

Table 4b. *P. borealis* in W. Greenland; Distribution (%; columns sum to 100) of fishing effort[1] between Divisions in NAFO Subarea 1 by 5-year period.

	5-year-period							
	80–84	85–89	90–94	95–99	00–04	05–09	10–14	15-17
1A	9.3	30.5	15.9	16.7	23.8	24.1	48.3	44.8
1B	71.4	49.9	37.7	32.9	34.2	53.5	41.1	40.9
1C	18.1	12.6	21.9	16.2	15.0	7.9	3.7	7.3
1D	1.1	6.0	20.0	21.0	15.6	6.4	5.1	5.4
1E	0.0	0.0	2.4	6.5	4.0	4.2	1.6	1.1
1F	0.0	0.9	2.1	6.7	7.4	3.9	0.1	0.5
Diversity	1.8	2.8	3.9	4.6	4.4	2.8	2.5	2.7

[1]unstandardised single-trawl-equivalent time

Table 5. *P. borealis* in W. Greenland: Catch by month 1976–2018, summed from vessel logs and weighted up to total catch.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	5778	736	0	0	154	10861	10457	11588	11398	8369	1985	89
1977	3062	3145	2229	2780	3736	5565	5972	5052	4321	6459	5682	3612
1978	971	366	152	777	5829	6620	6134	6348	4506	3601	3529	3483
1979	2428	540	5245	6444	6184	5252	4298	3904	2352	1563	3007	1617
1980	4651	5383	4976	5892	7072	7453	6656	5226	5499	2508	0	576
1981	3564	3555	2964	4279	7157	4890	7118	7121	4476	3171	3431	2103
1982	3422	709	1	2441	8342	7738	6784	7803	4738	6907	4239	1168
1983	37	247	577	2029	7655	7838	9260	6855	5952	6785	5625	3357
1984	45	494	4426	7258	7881	8490	7800	3765	2408	4429	4310	1498
1985	2109	3513	5362	3419	5318	7221	6889	9117	6051	8733	6047	2429
1986	3388	3200	3607	5392	4757	9422	8665	6898	8119	14642	5217	2958
1987	3094	1798	4931	6404	7907	8627	10797	8590	8170	9368	5161	3023
1988	2318	2913	3589	7443	7636	7663	8835	8384	9110	7529	5412	2785
1989	2513	3029	4344	7873	6499	10254	13429	9699	6996	7883	4749	3403
1990	4097	4286	4952	8453	9011	8972	8997	8225	7393	7087	7957	4540
1991	4103	3653	4056	3834	6416	9439	11591	9941	8654	10243	11233	8326
1992	4695	3591	6037	6724	8463	11196	11442	10880	11384	13591	10274	7210
1993	2639	3164	4357	5950	7670	7991	8703	9659	10350	12584	11009	6937
1994	4321	3905	6566	8553	7342	7165	9656	9408	10678	11705	7942	5565
1995	3851	5268	7792	10378	8138	7761	8575	8931	8398	8010	6283	4004
1996	4028	6409	7885	9144	8873	8793	8842	9446	8570	6118	3302	2684
1997	3634	5995	6273	6562	7664	8185	9514	8061	7882	7277	5035	2047
1998	8625	6420	5896	9980	10438	10505	10308	5015	5366	3549	2634	1758
1999	5035	5648	7382	8133	9390	8547	11074	8738	8348	8203	6625	5075
2000	4440	6528	7491	9121	9738	11435	11580	8573	7934	6922	8377	5830
2001	4287	5471	6248	5763	8624	11195	12545	12011	9930	10981	8163	7708
2002	8815	5971	7985	11485	12324	12234	15668	14696	12415	11495	12711	9373
2003	8561	7984	10616	11832	12708	11228	10886	11542	14117	11901	10915	7881
2004	8439	9047	9341	12989	14820	14539	13469	10477	16048	15194	13265	11707
2005	10695	8782	12726	14837	15193	15076	15775	16301	13581	12903	10449	10579
2006	12785	11920	14185	11116	14430	11138	15719	15802	15251	13153	12505	9312

2007	5517	8820	10584	13624	13544	13726	17126	14775	14224	11436	10121	10693
2008	8989	7386	9007	12488	13827	15429	18407	15311	14414	12982	13608	12039
2009	10993	8126	4321	9183	12422	12698	14606	16683	12642	12892	12352	8540
2010	8277	7237	8289	9462	11250	13956	15256	14473	12182	12523	10702	10385
2011	10230	9270	11831	10877	10480	10265	12523	9619	8884	10222	11472	8317
2012	9399	8623	5839	10089	10780	10026	11487	11514	9176	9684	10728	8632
2013	8008	6725	8487	9366	8866	8539	7115	8764	7064	8112	7711	6621
2014	7224	7900	7734	10055	6767	7169	7623	7580	6893	6839	7435	5545
2015	6855	4863	3536	5629	6411	5804	5641	6516	6678	6759	7214	6347
2016	7758	7534	6950	7162	5631	5978	7431	7427	7371	7425	8418	6440
2017	7985	7473	3547	5183	7440	6421	7958	7640	8531	7758	10332	9733
2018 *	9588	6765	4789	6816	8035	9186	-	-	-	-	-	-

* Greenland and EU only, uncorrected logbook-reported catches.

Table 6. *P. borealis* in W. Greenland: Discards, and landed catch reported[1] as *P. montagui,* in NAFO Subarea 1.

Year	P. borealis		P. montagui		P. borealis
	discard (tons)	discard (%)	landed (tons)	%-by catch	Catch
1975	0	0.00	0		
1976	0	0.00	0		
1977	0	0.00	0		
1978	0	0.00	0		
1979	0	0.00	0		
1980	0	0.00	0		
1981	0	0.00	0		
1982	0	0.00	0		
1983	0	0.00	0		
1984	0	0.00	0		
1985	151	0.24	0		
1986	110	0.15	0		
1987	189	0.25	0		
1988	216	0.31	0		
1989	196	0.27	0		
1990	265	0.34	0		49729
1991	406	0.48	0		52392
1992	335	0.34	0		56748
1993	251	0.29	0		54822
1994	332	0.38	5		56538
1995	476	0.56	563	1.0%	53633
1996	323	0.40	772	1.5%	51407
1997	310	0.40	422	0.7%	63913
1998	314	0.39	1253	2.3%	54356
1999	197	0.22	4	0.0%	70099
2000	268	0.28	305	0.4%	76350
2001	382	0.38	881	1.1%	81060
2002	648	0.50	225	0.2%	105473
2003	639	0.52	967	0.9%	100963
2004	762	0.54	831	0.6%	135213
2005	753	0.50	512	0.3%	147687
2006	865	0.56	1444	1.0%	150533
2007	741	0.52	2003	1.4%	139657
2008	860	0.56	89	0.1%	153889
2009	710	0.53	53	0.0%	135029
2010	739	0.58	1168	0.9%	128109
2011	720	0.59	2324	1.9%	122659
2012	587	0.51	3121	2.6%	115965
2013	491	0.52	4944	4.9%	95379
2014	443	0.50	1357	1.5%	88765
2015	325	0.45	2027	2.7%	72254
2016	329	0.39	3176	3.6%	84356
2017	403	0.45	661	0.7%	89369
2018*	455	0.45	288	0.6%	45179

[1]the coastal fleet does not report *P. montagui* separately in logbooks. Information on how much *montagui* that fleet catches is captured at the point of sale, and is recorded on sales slips.

* 2018: projected from part-year's data.

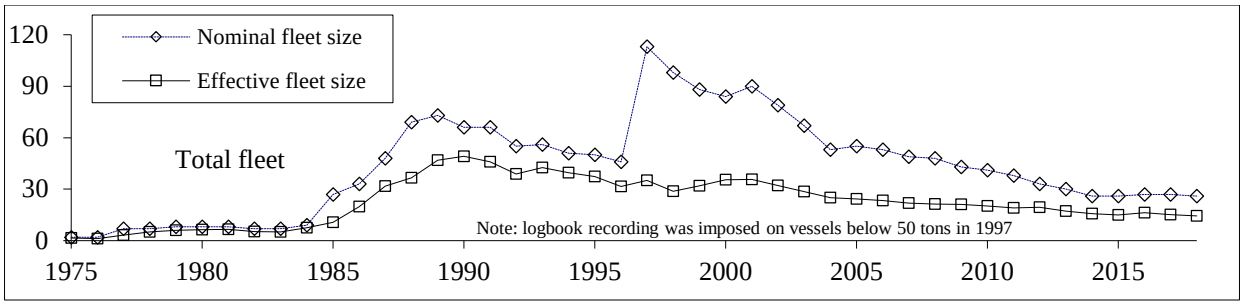

Fig. 1a. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland trawler fleet, 1975–2018, from logbook records.

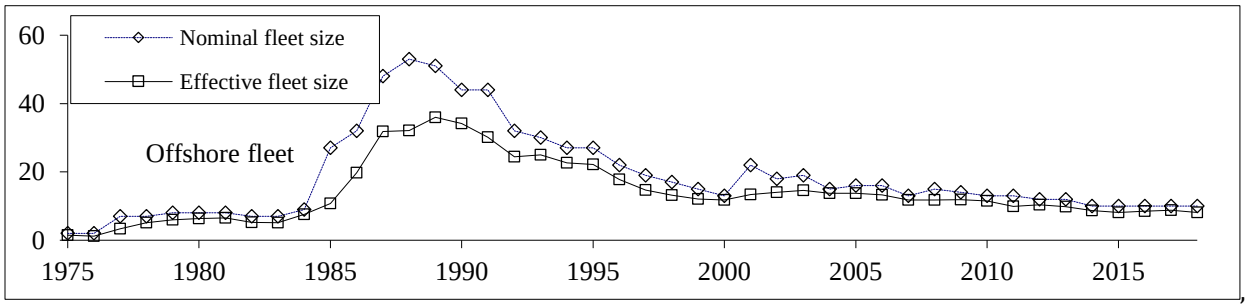

Fig. 1b. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland offshore trawler fleet, 1975–2018, from logbook records.

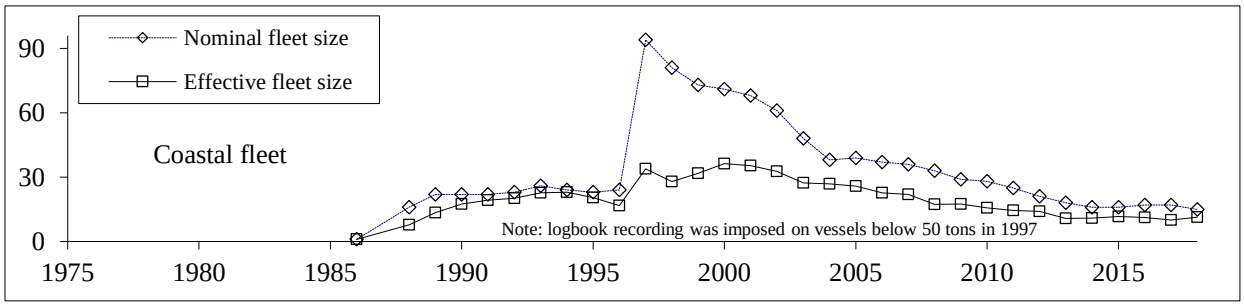

Fig. 1c. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland coastal trawler fleet, 1986–2018, from logbook records.

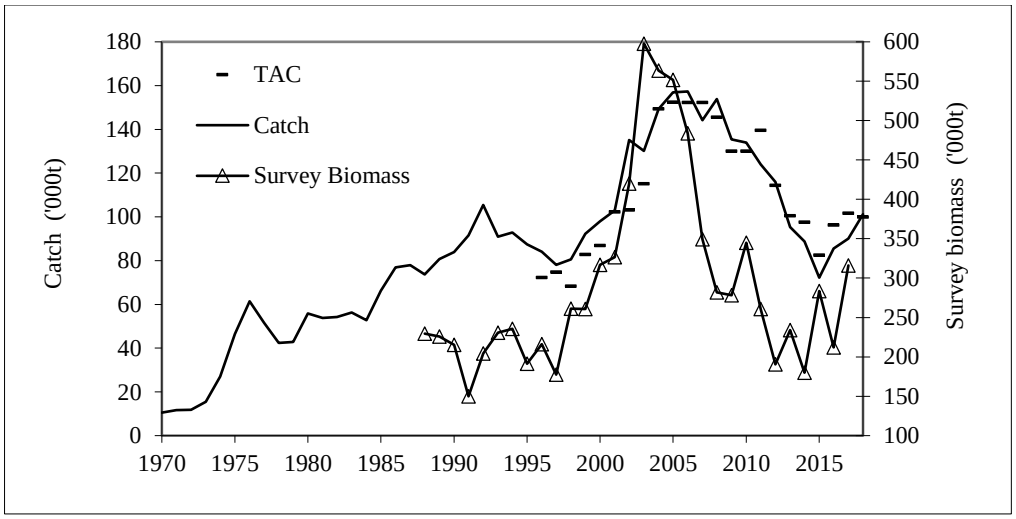

Fig. 2. *P. borealis* in W. Greenland: Catches in NAFO Subarea 1 and Canadian SFA 1, 1970–2018; 2018 is projected catch.

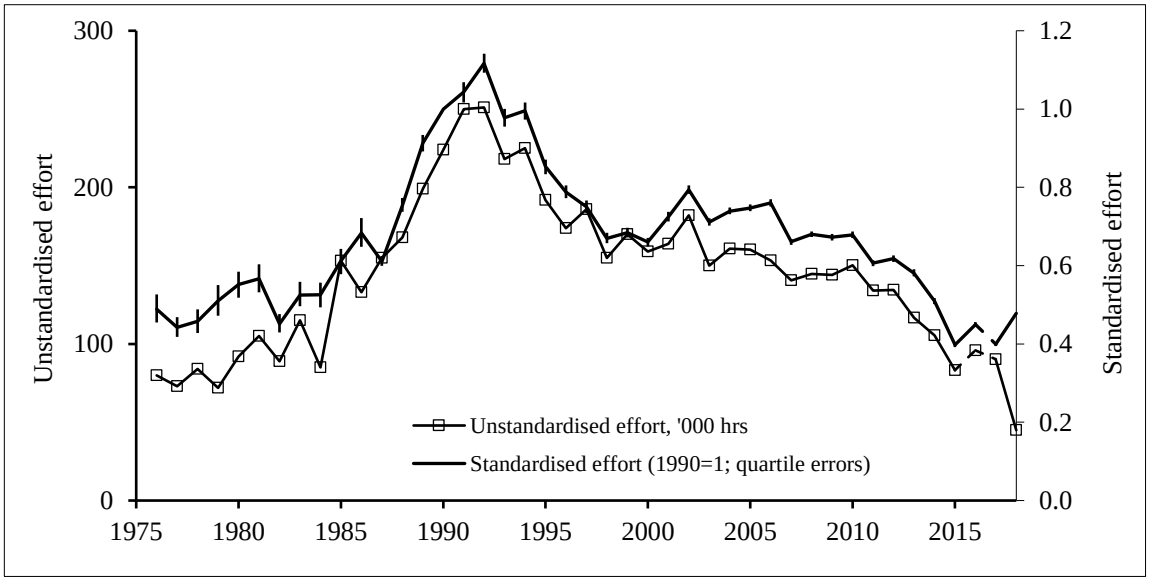

Fig. 3. *P. borealis* in W. Greenland: Fishing effort applied in NAFO Subarea 1 and Canadian SFA 1, 1970–2018. 2018 is on part-year's data.

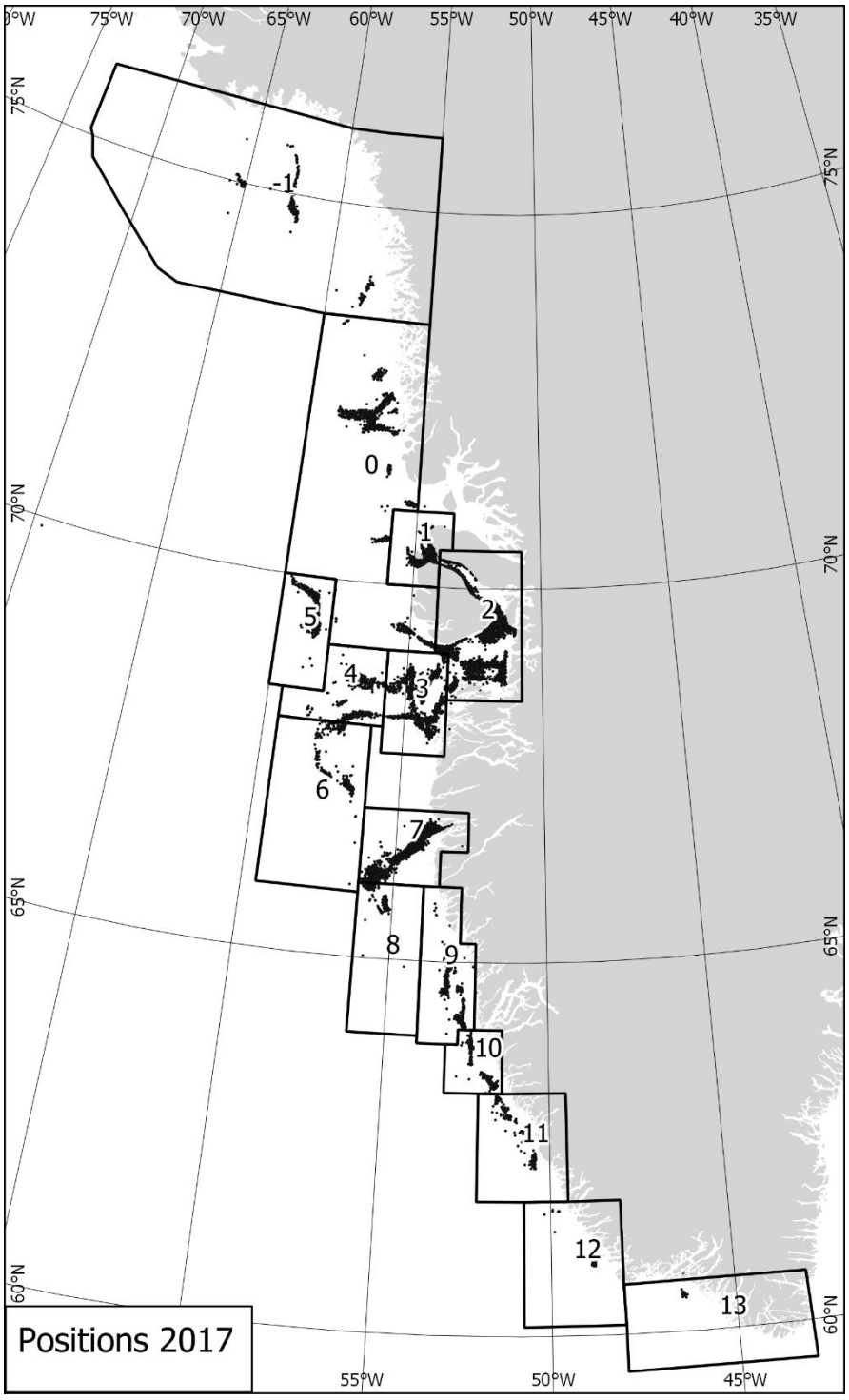

Fig. 4a. *P. borealis* in W. Greenland: positions of 7 183 hauls by the Greenland coastal fleet in NAFO Subarea 1 up to 73°30'N from January the 1 to December the 31, 2017. Statistical Areas in green frames. 200 meter depth contour dotted purple line and 600 meter depth contour solid purple line.

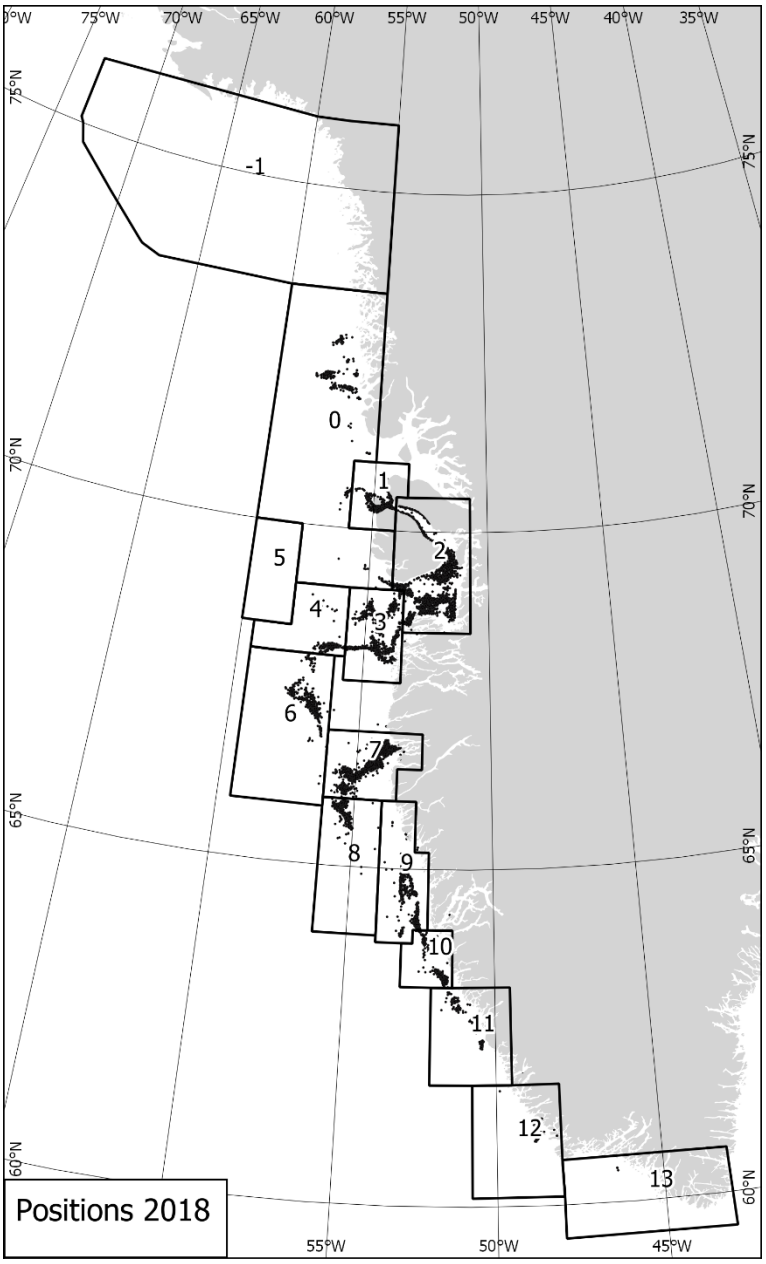

Fig. 4b. *P. borealis* in W. Greenland: positions of 7 831 hauls by the Greenland offshore fleet in NAFO Subarea 1 up to 73°30'N from January the 1 through June 2018. Statistical Areas in green frames. 200 meter depth contour dotted purple line and 600 meter depth contour solid purple line.

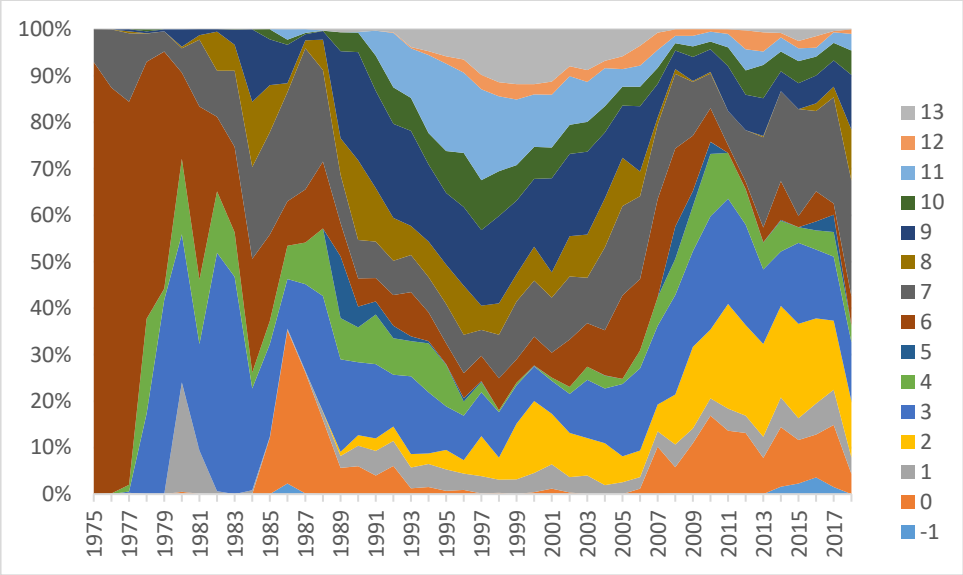

Fig. 5a. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between statistical Areas in Greenland waters, 1975-2018. (The light band that starts broad on the left-hand side is Area 6; the light band at the top is Area 0, the dark wedge at the very bottom from 1992 to 2007 is Area 13.)

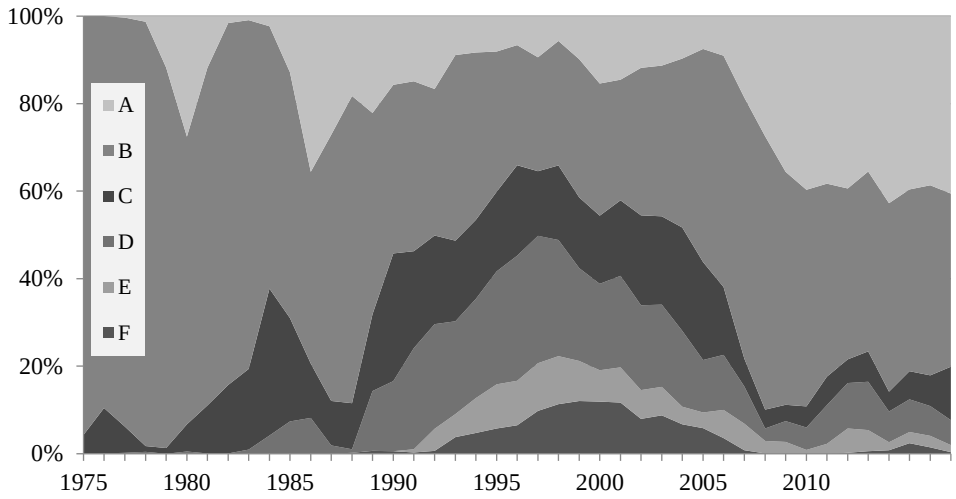

Fig. 5b. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between NAFO Divisions in Subarea 1 up to 73°30'N, 1975-2018.

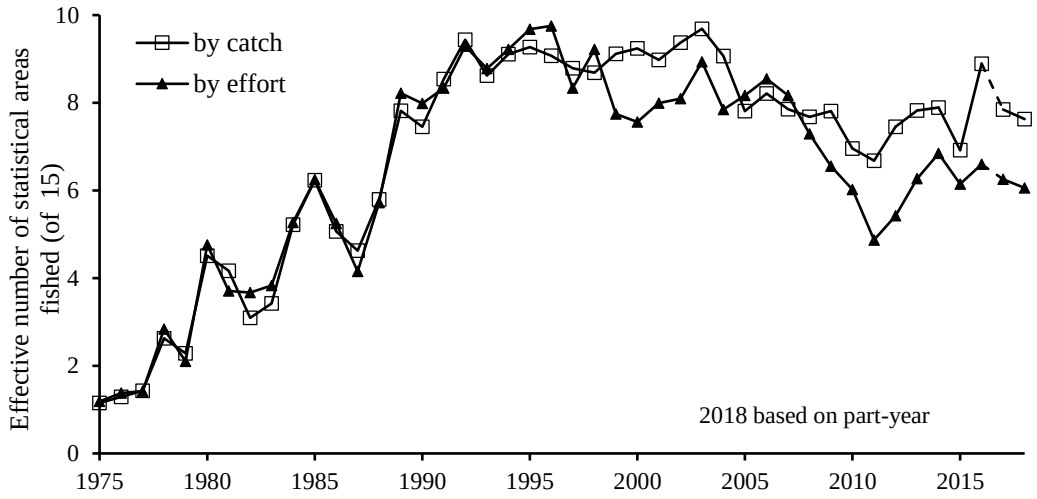

Fig. 6a. *P. borealis* in W. Greenland: diversity indices for the distribution of logbook-recorded catch between statistical Areas in Greenland waters, 1975–2018. 2018 is on part-year's data.

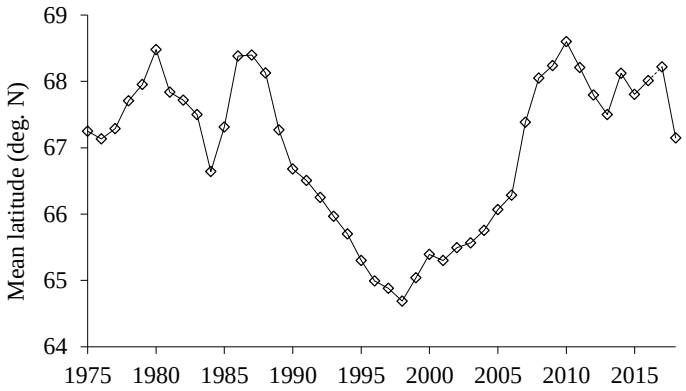

Fig. 6b. *P. borealis* in W. Greenland: diversity indices for the distribution of logbook-recorded catch between statistical Areas in Greenland waters, 1975–2018. 2018 is on part-year's data.

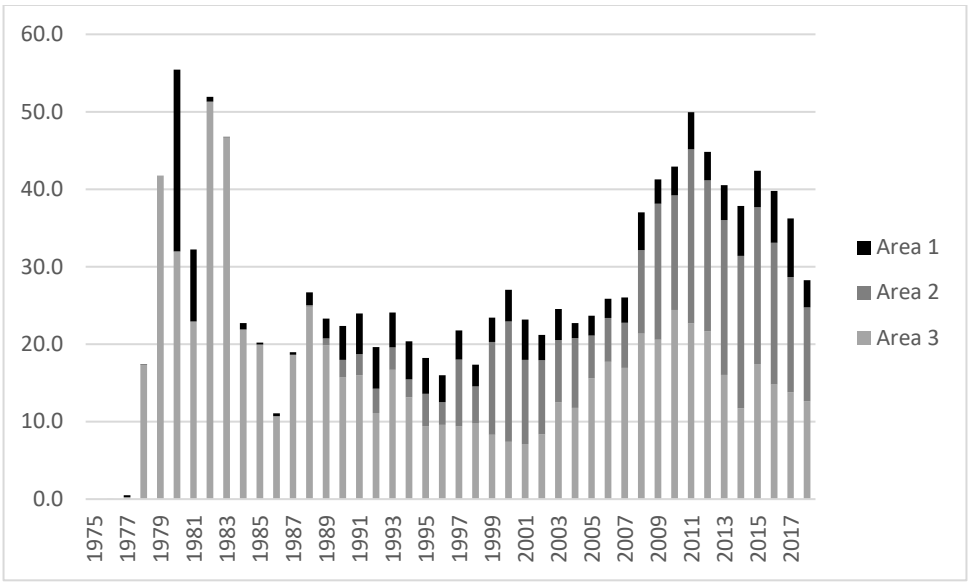

Fig. 7a. *P. borealis* in W. Greenland: distribution of catches in the Disko Bay Area (statistical Areas 1, 2 and 3) 1990–2018. 2018 is on part-year's data.

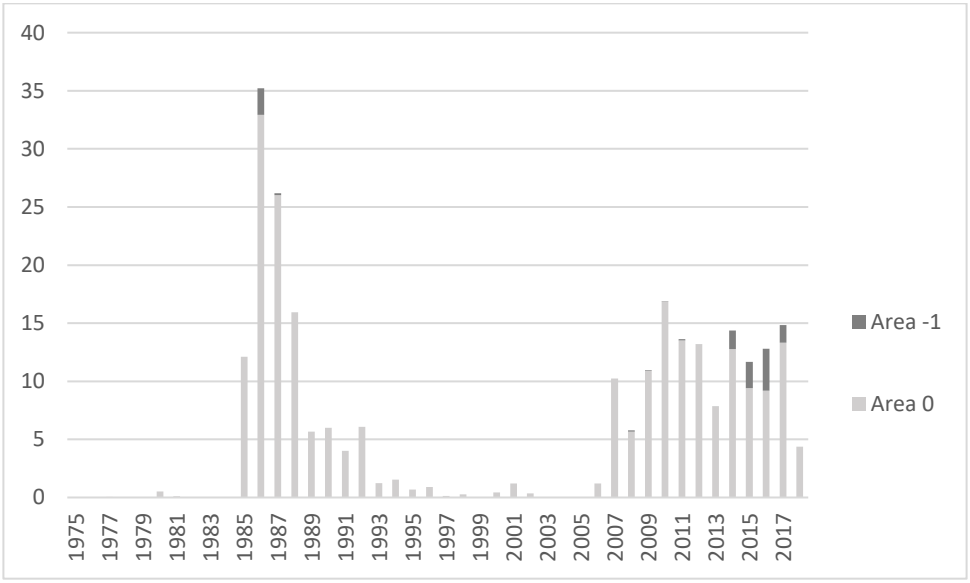

Fig. 8. *P. borealis* in W. Greenland: catches taken in statistical area 0 and -1 as a percentage of total catches, 1990–2018. 2018 is on part-year's data.

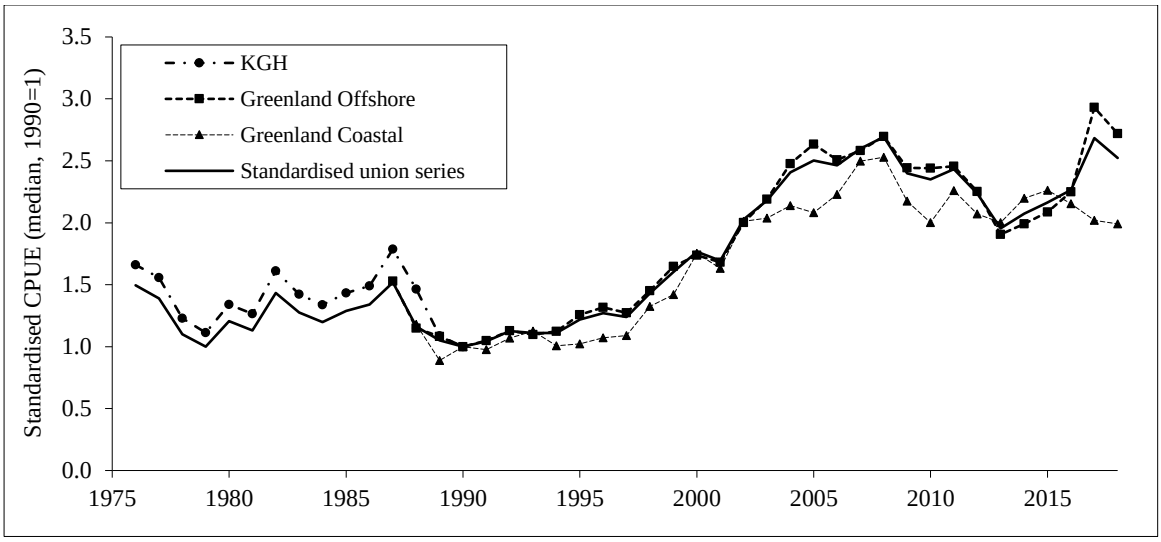

Fig. 9. *P. borealis* in W. Greenland: standardized (1990=1) CPUE series from three fleets and a standardized union series 1976–2018. 2018 is on part-year's data.

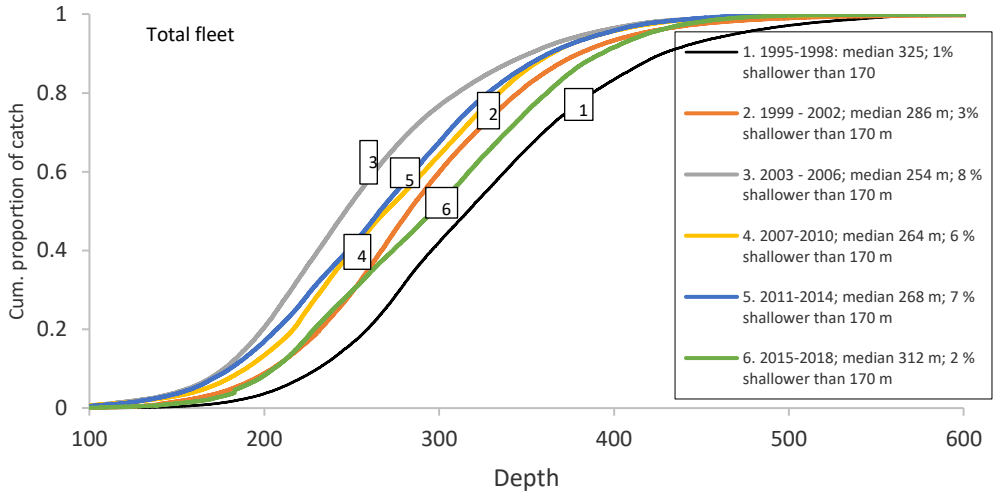

Fig. 10a. *P. borealis* in W. Greenland: standardised (1990=1) CPUE series from all fleets and a standardised union series 1976–2018. 2018 is on part-year's data.

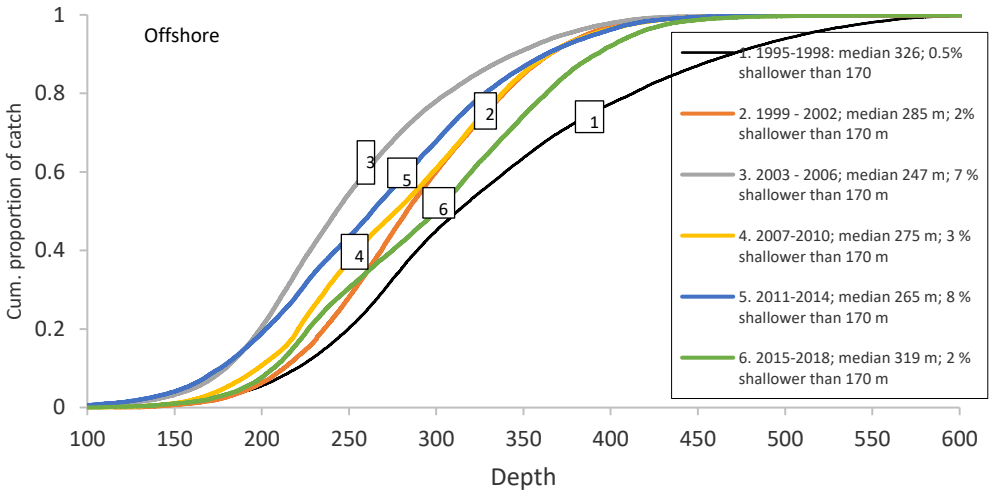

Fig. 10b. *P. borealis* in W. Greenland: standardised (1990=1) CPUE series from offshore fleets and a standardised union series 1976–2018. 2018 is on part-year's data.

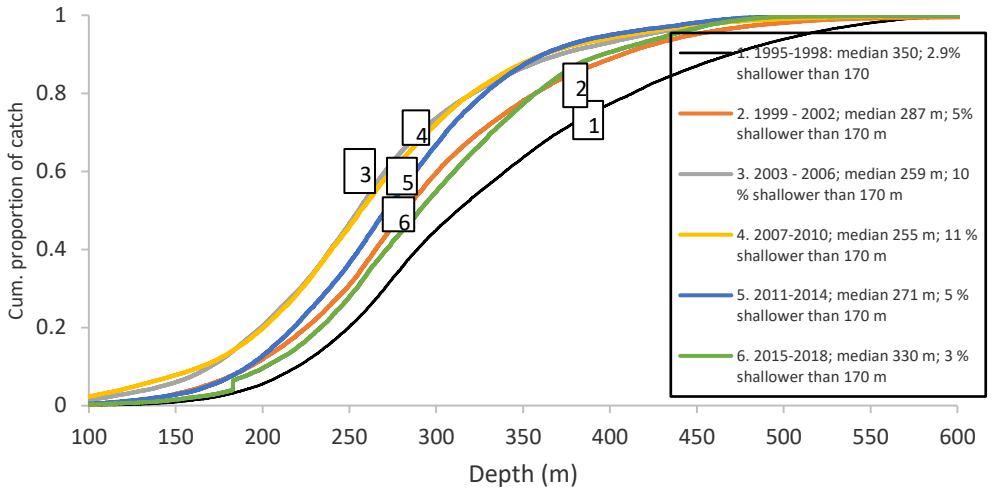

Fig. 10c. *P. borealis* in W. Greenland: standardised (1990=1) CPUE series from coastal fleets and a standardised union series 1976–2018. 2018 is on part-year's data.

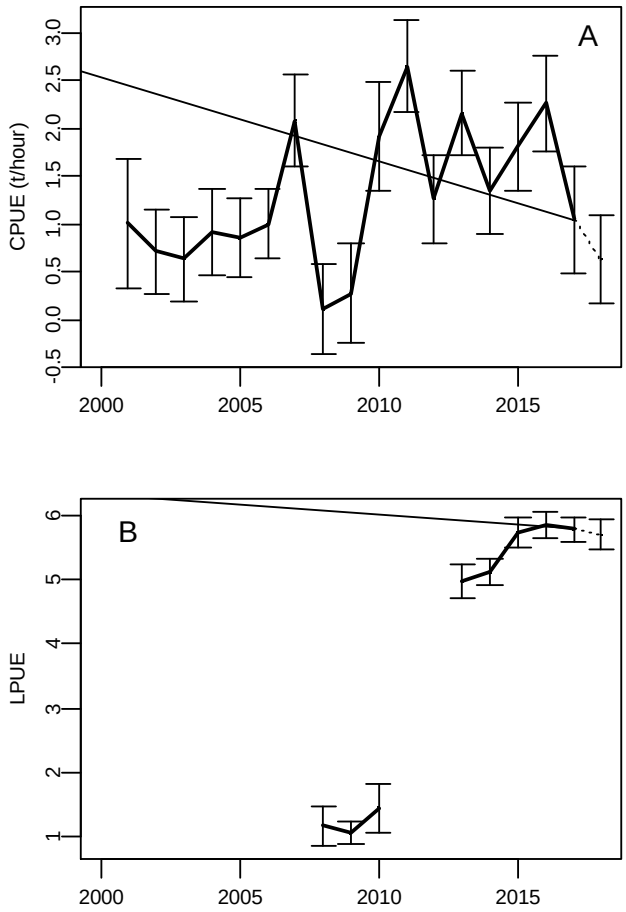

Fig. 11. *P. montagui* in W. Greenland. A: standardized CPUE series from 5 offshore fleets. B: standardized LPUE series from sale notes 2008–2018. 2018 is on part-year's data. Error bars show 95% confidence limits

Appendix I: A standardised CPUE series for the Greenland Offshore fleet.

The SAS System

year HOLD

1987 1988 1989 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2090 1 2

N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N N

199 303 336 497 490 417 455 447 444 420 339 315 305 289 352 334 343 307 327 286 271 238 254 221 249 252 235 214 212 210 115 444 5984 4136

The SAS System

AREA

0 3 4 5 6 8 9 10 11 12

N N N N N N N N N N

598 557 978 300 1420 1283 2213 1396 1075 300

The SAS System

AREA

0 3 4 5 6 8 9 10 11 12

N N N N N N N N N N

VESSEL 16 . 22 5 21 24 38 14 3 .

hh02

hh03 14 6 12 4 12 15 30 6 3 .

hh06 19 1 23 10 22 26 42 13 4 .

hh10 30 25 52 17 57 58 82 46 24 3

hh11 27 4 38 14 61 69 87 38 21 4

hh13 22 15 38 16 38 41 56 34 19 1

hh17 23 88 47 14 54 68 111 52 34 4

hh22 56 137 76 25 92 118 246 172 107 15

hh26 56 5 74 34 106 86 135 76 61 6

hh28 10 83 25 2 24 24 52 23 27 7

hh31 59 60 99 28 180 150 261 175 137 12

hh36 57 17 105 22 171 132 224 130 103 6

hh39 55 14 98 32 137 122 210 147 120 31

hh44 84 47 131 39 207 156 324 222 189 83

hh46 53 15 77 22 114 63 142 90 77 20

hh50 17 40 61 16 124 131 173 158 146 108

The SAS System

The GLM Procedure

Class Level Information

Class Levels Values

VESSEL 16 hh02 hh03 hh06 hh10 hh11 hh13 hh17 hh22 hh26 hh28 hh31 hh36 hh39 hh44 hh46 hh50

year 32 1987 1988 1989 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2090

MONTH 9 1 2 4 5 7 8 10 11 12

AREA 10 0 3 4 5 6 8 9 10 11 12

HOLD 2 1 2

Number of Observations Read 10120

Number of Observations Used 10120

The SAS System

The GLM Procedure

Dependent Variable: LNCPUE

Weight: hauls

Source DF Sum of Squares Mean Square F Value Pr > F

Model 63 125045.7642 1984.8534 500.88 <.0001

Error 10056 39849.2907 3.9627

Corrected Total 10119 164895.0549

R-Square Coeff Var Root MSE LNCPUE Mean

0.758335 83.74349 1.990663 2.377095

Source DF Type I SS Mean Square F Value Pr > F

VESSEL 15 83834.27020 5588.95135 1410.38 <.0001

MONTH 8 2468.33364 308.54170 77.86 <.0001

AREA 9 7869.42776 874.38086 220.65 <.0001

year 31 30873.73259 995.92686 251.32 <.0001

Source DF Type III SS Mean Square F Value Pr > F

VESSEL 15 20167.27483 1344.48499 339.28 <.0001

MONTH 8 1876.16806 234.52101 59.18 <.0001

AREA 9 3101.99530 344.66614 86.98 <.0001

year 31 30873.73259 995.92686 251.32 <.0001

Parameter Estimate Standard

Error t Value Pr > |t|

Intercept 2.441472431 B 0.03349201 72.90 <.0001

VESSEL hh02 -1.157288643 B 0.02814490 -41.12 <.0001

VESSEL hh03 -1.012055993 B 0.03477558 -29.10 <.0001

VESSEL hh06 -0.920330416 B 0.02235746 -41.16 <.0001

VESSEL hh10 -0.716523311 B 0.01588895 -45.10 <.0001

VESSEL hh11 -0.678784425 B 0.02039316 -33.28 <.0001

VESSEL hh13 -0.646725418 B 0.02021823 -31.99 <.0001

VESSEL hh17 -0.605431690 B 0.01508119 -40.14 <.0001

VESSEL hh22 -0.576319974 B 0.01341383 -42.96 <.0001

VESSEL hh26 -0.511198133 B 0.01605165 -31.85 <.0001

VESSEL hh28 -0.440117896 B 0.02162468 -20.35 <.0001

VESSEL hh31 -0.395203868 B 0.01353464 -29.20 <.0001

VESSEL hh36 -0.346029637 B 0.01444814 -23.95 <.0001

VESSEL hh39 -0.282852698 B 0.01564957 -18.07 <.0001

VESSEL hh44 -0.154933806 B 0.01321814 -11.72 <.0001

VESSEL hh46 -0.143035611 B 0.01625170 -8.80 <.0001

VESSEL hh50 0.000000000 B . . .

MONTH 1 -0.038951727 B 0.01758624 -2.21 0.0268

MONTH 2 0.022924702 B 0.01761803 1.30 0.1932

MONTH 4 0.093618929 B 0.01434445 6.53 <.0001

MONTH 5 -0.005963395 B 0.01543602 -0.39 0.6993

MONTH 7 0.187774181 B 0.01382653 13.58 <.0001

MONTH 8 0.066827542 B 0.01544352 4.33 <.0001

MONTH 10 0.047162576 B 0.01396484 3.38 0.0007

MONTH 11 0.037561526 B 0.01580361 2.38 0.0175

MONTH 12 0.000000000 B . . .

AREA 0 -0.409664859 B 0.03070138 -13.34 <.0001

AREA 3 -0.000855037 B 0.03093082 -0.03 0.9779

AREA 4 -0.236401139 B 0.03031379 -7.80 <.0001

AREA 5 -0.321056251 B 0.03455506 -9.29 <.0001

AREA 6 -0.129338961 B 0.02978814 -4.34 <.0001

AREA 8 -0.162151998 B 0.02987400 -5.43 <.0001

AREA 9 -0.154739190 B 0.02874426 -5.38 <.0001

AREA 10 -0.130310031 B 0.03007175 -4.33 <.0001

AREA 11 -0.101975957 B 0.02927607 -3.48 0.0005

AREA 12 0.000000000 B . . .

year 1987 0.424018186 B 0.02284782 18.56 <.0001

year 1988 0.138224829 B 0.02023920 6.83 <.0001

year 1989 0.079326583 B 0.01950549 4.07 <.0001

year 1991 0.047036359 B 0.01800899 2.61 0.0090

year 1992 0.119896367 B 0.01825534 6.57 <.0001

year 1993 0.092004068 B 0.01874256 4.91 <.0001

year 1994 0.115778306 B 0.01881018 6.16 <.0001

year 1995 0.228624031 B 0.01950985 11.72 <.0001

year 1996 0.274683072 B 0.02054620 13.37 <.0001

year 1997 0.240792470 B 0.02159395 11.15 <.0001

year 1998 0.372797191 B 0.02325864 16.03 <.0001

year 1999 0.498791152 B 0.02431704 20.51 <.0001

year 2000 0.552279853 B 0.02544290 21.71 <.0001

year 2001 0.518787065 B 0.02589857 20.03 <.0001

year 2002 0.693530297 B 0.02333572 29.72 <.0001

year 2003 0.784425727 B 0.02418518 32.43 <.0001

year 2004 0.907014510 B 0.02418142 37.51 <.0001

year 2005 0.968794971 B 0.02351078 41.21 <.0001

year 2006 0.919511482 B 0.02334549 39.39 <.0001

year 2007 0.948932564 B 0.02408078 39.41 <.0001

year 2008 0.991585010 B 0.02411008 41.13 <.0001

year 2009 0.893141280 B 0.02588566 34.50 <.0001

year 2010 0.891987357 B 0.02535102 35.19 <.0001

year 2011 0.898256988 B 0.02642169 34.00 <.0001

year 2012 0.811719850 B 0.02626691 30.90 <.0001

year 2013 0.644807953 B 0.02688649 23.98 <.0001

year 2014 0.688159561 B 0.02750152 25.02 <.0001

year 2015 0.735502684 B 0.02951396 24.92 <.0001

year 2016 0.810247657 B 0.02874201 28.19 <.0001

year 2017 1.075101510 B 0.02893327 37.16 <.0001

year 2018 1.000599688 B 0.03731218 26.82 <.0001

year 2090 0.000000000 B . . .

Note: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Appendix II: A standardised CPUE series for the Greenland Coastal fleet.

he SAS System

VESSEL
cc01 cc02 cc05 cc08 cc09 cc12 cc13 cc16 cc17 cc20 cc24 cc27 cc29 cc32 cc33 cc34 cc35
N N N N N N N N N N N N N N N N N
AREA 5 13 142 26 13 191 87 122 142 204 454 117 119 83 34 17 39
1
2 38 51 311 137 101 191 199 306 232 309 783 270 312 191 62 32 81
3 46 5 38 210 90 227 72 351 114 346 580 326 291 190 39 96 78
7 41 . 12 236 100 94 17 288 36 183 315 214 108 88 11 8 94
13 19 . . 142 . 148 2 99 6 200 163 100 9 119 . . .

The SAS System

AREA
1 2 3 7 13
N N N N N
1808 3606 3099 1845 1007
The SAS System

MONTH
2 3 4 5 6 7 8 9 10 11 12
N N N N N N N N N N N
1608 721 1071 1246 1062 883 918 948 1022 1040 846

The SAS System

MONTH
2 3 4 5 6 7 8 9 10 11 12
N N N N N N N N N N N
AREA 112 19 118 304 197 128 152 196 243 238 101
1
2 423 157 292 358 357 321 335 348 362 351 302
3 366 175 380 388 327 275 275 242 228 238 205
7 496 234 183 122 117 84 82 90 117 145 175
13 211 136 98 74 64 75 74 72 72 68 63

The GLM Procedure

Class Level Information
Class Levels Values
VESSEL 17 cc01 cc02 cc05 cc08 cc09 cc12 cc13 cc16 cc17 cc20 cc24 cc27 cc29 cc32 cc33 cc34 cc35
year 31 1988 1989 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2090
AREA 5 1 2 3 7 13
MONTH 11 2 3 4 5 6 7 8 9 10 11 12

Number of Observations Read 11365
Number of Observations Used 11365

The SAS System

The GLM Procedure

Dependent Variable: LNCPUE

Weight: Hauls

Source DF Sum of Squares Mean Square F Value Pr > F
Model 60 52794.16123 879.90269 286.28 <.0001
Error 11304 34743.91990 3.07360
Corrected Total 11364 87538.08113

R-Square Coeff Var Root MSE LNCPUE Mean
0.603099 88.59773 1.753167 1.978795

Source DF Type I SS Mean Square F Value Pr > F
AREA 4 2821.31796 705.32949 229.48 <.0001
MONTH 10 2950.69996 295.07000 96.00 <.0001
VESSEL 16 21855.90040 1365.99378 444.43 <.0001
year 30 25166.24291 838.87476 272.93 <.0001

Source DF Type III SS Mean Square F Value Pr > F
AREA 4 2935.73332 733.93333 238.79 <.0001
MONTH 10 2161.41432 216.14143 70.32 <.0001
VESSEL 16 9246.80131 577.92508 188.03 <.0001
year 30 25166.24291 838.87476 272.93 <.0001

Contrast DF Contrast SS Mean Square F Value Pr > F
cc01 v cc02 1 3.7651083 3.7651083 1.22 0.2684
cc02 v cc05 1 5.3829258 5.3829258 1.75 0.1857
cc05 v cc08 1 67.2810225 67.2810225 21.89 <.0001
cc08 v cc09 1 20.3093244 20.3093244 6.61 0.0102
cc09 v cc12 1 5.4228013 5.4228013 1.76 0.1841

cc12 v cc13 1 17.4127764 17.4127764 5.67 0.0173
cc13 v cc16 1 5.7615664 5.7615664 1.87 0.1710
cc16 v cc17 1 15.8391204 15.8391204 5.15 0.0232
cc17 v cc20 1 35.4593241 35.4593241 11.54 0.0007
cc20 v cc24 1 20.0099436 20.0099436 6.51 0.0107
cc24 v cc27 1 30.5123800 30.5123800 9.93 0.0016
cc27 v cc29 1 17.5786098 17.5786098 5.72 0.0168
cc29 v cc32 1 54.6541841 54.6541841 17.78 <.0001
cc32 v cc33 1 18.8409069 18.8409069 6.13 0.0133
cc33 v cc34 1 13.7592756 13.7592756 4.48 0.0344
cc34 v cc35 1 384.6488266 384.6488266 125.15 <.0001

Parameter Estimate Standard
Error t Value Pr > |t|
Intercept 2.371245429 B 0.03386513 70.02 <.0001
AREA 1 -0.284144129 B 0.01456782 -19.50 <.0001
AREA 2 -0.360770050 B 0.01362509 -26.48 <.0001
AREA 3 -0.138695319 B 0.01296164 -10.70 <.0001
AREA 7 -0.289043838 B 0.01399927 -20.65 <.0001
AREA 13 0.000000000 B . . .
MONTH 2 -0.034834108 B 0.01703338 -2.05 0.0409
MONTH 3 0.116635373 B 0.01961134 5.95 <.0001
MONTH 4 0.255716058 B 0.01814664 14.09 <.0001
MONTH 5 0.118710273 B 0.01721146 6.90 <.0001
MONTH 6 0.147303798 B 0.01736227 8.48 <.0001
MONTH 7 0.198897358 B 0.01763124 11.28 <.0001
MONTH 8 0.127240864 B 0.01787119 7.12 <.0001
MONTH 9 0.027619081 B 0.01788951 1.54 0.1226
MONTH 10 -0.013338759 B 0.01755846 -0.76 0.4475
MONTH 11 0.025513132 B 0.01779395 1.43 0.1517
MONTH 12 0.000000000 B . . .
VESSEL cc01 -1.273029464 B 0.04154439 -30.64 <.0001
VESSEL cc02 -1.200173507 B 0.05989418 -20.04 <.0001
VESSEL cc05 -1.122685445 B 0.02923182 -38.41 <.0001
VESSEL cc08 -1.004672099 B 0.02554688 -39.33 <.0001

VESSEL cc09 -0.936293779 B 0.02897393 -32.32 <.0001
VESSEL cc12 -0.902937357 B 0.02402389 -37.58 <.0001
VESSEL cc13 -0.850192507 B 0.02853098 -29.80 <.0001
VESSEL cc16 -0.820551005 B 0.02294374 -35.76 <.0001
VESSEL cc17 -0.778344467 B 0.02607322 -29.85 <.0001
VESSEL cc20 -0.716506132 B 0.02243172 -31.94 <.0001
VESSEL cc24 -0.686312983 B 0.02160664 -31.76 <.0001
VESSEL cc27 -0.646575511 B 0.02289546 -28.24 <.0001
VESSEL cc29 -0.606244252 B 0.02363978 -25.65 <.0001
VESSEL cc32 -0.522941327 B 0.02503315 -20.89 <.0001
VESSEL cc33 -0.434651865 B 0.03787205 -11.48 <.0001
VESSEL cc34 -0.348728345 B 0.03117298 -11.19 <.0001
VESSEL cc35 0.000000000 B . . .
year 1988 0.164442164 B 0.03964840 4.15 <.0001
year 1989 -0.117980109 B 0.02970293 -3.97 <.0001
year 1991 -0.025502875 B 0.02672287 -0.95 0.3399
year 1992 0.066932235 B 0.02677984 2.50 0.0125
year 1993 0.117796199 B 0.02658216 4.43 <.0001
year 1994 0.007420802 B 0.02592438 0.29 0.7747
year 1995 0.021841934 B 0.02627350 0.83 0.4058
year 1996 0.068990836 B 0.02733716 2.52 0.0116
year 1997 0.084712791 B 0.02678488 3.16 0.0016
year 1998 0.280211679 B 0.02949514 9.50 <.0001
year 1999 0.350082838 B 0.02629412 13.31 <.0001
year 2000 0.561231622 B 0.02650023 21.18 <.0001
year 2001 0.489493204 B 0.02610460 18.75 <.0001
year 2002 0.699154687 B 0.02628016 26.60 <.0001
year 2003 0.712318408 B 0.02693194 26.45 <.0001
year 2004 0.760387488 B 0.02605393 29.19 <.0001
year 2005 0.733508368 B 0.02634745 27.84 <.0001
year 2006 0.801383057 B 0.02714979 29.52 <.0001
year 2007 0.915454205 B 0.02721642 33.64 <.0001
year 2008 0.927954497 B 0.02625967 35.34 <.0001
year 2009 0.777046779 B 0.02682785 28.96 <.0001
year 2010 0.694081790 B 0.02708667 25.62 <.0001
year 2011 0.815088658 B 0.02717392 30.00 <.0001
year 2012 0.728098143 B 0.02726028 26.71 <.0001

year 2013 0.693782160 B 0.02945853 23.55 <.0001
year 2014 0.787720048 B 0.03043320 25.88 <.0001
year 2015 0.816619886 B 0.03223696 25.33 <.0001
year 2016 0.767762220 B 0.03016770 25.45 <.0001
year 2017 0.703222560 B 0.03102709 22.66 <.0001
year 2018 0.688063013 B 0.03934157 17.49 <.0001
year 2090 0.000000000 B . . .

Note: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.