Northwest Atlantic Fisheries Organization

Serial No. N6725 **NAFO SCR Doc. 17/056**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP—SEPTEMBER 2017

The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2017

by

Nanette Hammeken Arboe

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 85 527 tons in 2016. The projected catch for 2017 is set at 90 000 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.

Catch and effort data from logbooks was 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. Standardised CPUE was variable, but on average moderately high, from 1976 through 1987, 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. In 2013 the index was 72 % of the 2008 value. Since then the standardized CPUE index has increased and the value obtained in 2017 is close to the 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 is now concentrated in Division 1B and 1A. Since 2005 the catches taken in Division 1B has averaged 50% of the total catch. From 1990 to 2005 the proportion of the catch taken in Division 1A was less than 15%. The proportion af the total catch taken in Division 1A has been rising since 2006 constituting between 35% and 43% of total catch in the years 2009-2016.

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 76°N; densities are highest in water between 150 and 550 m deep (Fig. 4 and Fig. 10). 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 thought to be 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. From 2012 to 2015 virtually no fishing in SFA1 has been conducted. In 2016 and 2017 there has been some fishery conducted. 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 have been available since 1979.

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 spacings of 22 or 28 mm, and 93% with spacings 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 (about 3.1%) to allow for the Canadian interest, the proportion being reckoned on the basis of 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 2017).

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. 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. 4). 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 (Fig. 4) and in statistical area -1. 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 (DFO) (Kingsley 2007, Hammeken Arboe 2017). 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 last provided in August 2013 by T. Siferd (DFO).

CPUE Analyses

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 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 $N(0,\sigma^2/n)$ 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 neighbouring 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 73°30 N and beyond, so an statistical Area 0 has been defined (Fig. 4) and in 2013 was for the first time included in the GLM calculation of year effect on CPUE (for all years).

From 2014 to 2016 an exploratory fishery for northern shrimp has been conducted in Melville Bay north of 73°30N (to 76°N) has been conducted. This area (Statistical Area -1) is now included in the GLM calculation of year effect on CPUE (for all years) (Hammeken Arboe 2017; Burmeister and Christensen 2017).

The 'Offshore' index covers the most recent 31 years of the offshore production fishery in NAFO Div. 1A to 1F. 50 vessels were included providing data since 1987, grouped into 19 groups of 1–4 vessels with similar estimated effects. Statistical Areas -1, 0 and 3–12 were included in the analysis; statistical Areas 7 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 anlaysis. 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 since 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 1976–2017, was derived by combining these four 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

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

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_{yf}^2 whose relative sizes were calculated from the individual error variances estimated by the GLM— $\hat{\sigma}_{yf}^2$ —and weights w_f assigned on the basis of the area fished by fleet f. The weights w_f for the KGH, Greenland offshore, Greenland coastal and Canadian fleets were assigned as 0.355, 0.410, 0.180 and 0.055. The year effects $\overline{A}_y$ were fitted using Bayesian methods on the OpenBUGS platform and were given uninformative uniform prior distributions.

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 2016 for the period 1991–2014, in 6 4-year periods, both overall and separately for the offshore and coastal fleets (Hammeken Arboe 2016).

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; Burmeister and Riget 2017), but the recording of montagui is reported as improved by the offshore fleet in recent years (Pers. communication M. Rossing Lund, GFLK).

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. 1b).

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 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 and Rigét, 2017) 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 followed by a decrease in TACs and catches (Fig. 2). Since 2015 TACs and catches have increased (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. 2017). 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 1991–2010 Canadian catches averaged 1.2% of the estimated survey biomass in the entire stock distribution area (Burmeister et al. 2017). Since 2011, due to ice cover in the Canadian area, SFA1 has only been surveyed in 2013 and 2017. From 2012 to 2015 the Canadian fishery virtually ceased in SFA1.

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 about 85 000 hr as a result of management measures, reduced activity in Div. 0A (Table 1, Table 3) and a generally increased fishing efficiency.

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 40%—to a minimum in 1998–2000. The standardised effort increased by 17% from 2000 to 2002, and then decreased by approximately 2.5% a year from 2002 to 2012. Since then standardized effort has been decreasing and has been about half of the standardized effort in 2002 for the last 3 years (Table 1, Fig. 3).

Spatial and seasonal distribution

Logbook records show that since 1975 the relative importance of the different fishing grounds has varied a lot (Fig. 5). At first, the fishery concentrated on the wide shelf west and southwest of Disko Bay (Div. 1B/statistical Area 6; Fig. 4, Fig. 5b), but the effective number of statistical areas fished increased steadily up to the early 1990s (Fig. 6) as the fishery extended first into southwestern Disko Bay (statistical Areas 3 and 4) and the Holsteinsborg Deep (statistical Area 7), with short-lived excursions in the late 1980s and early '90s into northern areas (statistical Area 0) and the outer margin of the shelf north of Canadian SFA1 (statistical Area 5). From the end of the 1980s there was a significant expansion of the fishery southwards (Fig. 5), and in the mid-1990s the effective number of statistical Areas being fished peaked at about 9.5 (Fig. 6). Since then, the fishery has contracted northwards and the effective number of statistical Areas fished has decreased as effort has become more concentrated (Fig. 6, Table 4b). During the 1980s 80% of the catch was taken in NAFO Divisions 1A and 1B. This pattern changed from the beginning of the 1990s to the mid-2000s, when between 50% and 65% of the catch was taken in NAFO Divisions 1C–1F. However, these southern areas have since become less important and the fishery is now concentrated in Division 1A and 1B (Fig. 5a). Catch has also become more concentrated and the southern areas (NAFO Divs. 1C–1F) has accounted for less than 25% of total catch since 2007 (Table 3, Table 4a). Since 2005 the catches taken in Division 1B has averaged 50% of the total catch. From 1990 to 2006 the proportion of the catch taken in Division 1A was less than 15%. The proportion af the total catch taken in Division 1A has been rising since 2006 constituting between 35% and 43% of total catch in the years 2009-2016 (Fig. 5a). This is especially due to increased fishing in the Disko Bay Area (statistical Areas 2 and 3, Fig. 7) and statistical Areas 0 and -1, which in recent years has yielded between 10 and 17% of total catch (Fig. 8).

The results of analyses for the current year must always be viewed in the light of a somewhat seasonal distribution of the fishery, in that access to the most northerly grounds is restricted by sea-ice in the early part of the year. The concentration of the fishery for the current year, based on a half year's data, is therefore exaggerated. (Fig. 6).

The fishery is active all year, but more so in summer and fall. A strongly seasonal pattern prevalent up to about 15 years ago, with summer monthly catches 2–3 times the winter minimum, appears to have given way to a more uniform seasonal distribution, where 21 % of the catches are taken from December through February, 25 % in March to May, 28 % in June to August and 26 % in September to October (Table 5).

Depth distribution

The depth distribution of catches has shifted significantly over the most recent 27 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 100 m shallower at 246.5 m and catches extended down to 454 m (99th percentile). In 2007–2010 and in 2011-2014 the median catch depth increased with 20 meters to around 267 m (Fig. 10).

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 1975–2014 (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. Since 1999 registered annual discards of fish have been below 1.5% of total shrimp catch, but fish discard reports are based on visual estimates of weight, not on physical weighing, and errors are likely (Table 6). 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).

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 therefore in the past been an underestimate, while logbook records of *borealis* catches have been an overestimate (see also Burmeister and Rigét, 2017a).

From 1995 to 2016 logbook reports included overall annual catches of *P. montagui* in the range of about 100 to 4950 tons (Table 6); From 2001–2010, the reported catch of *P. montagui* averaged under 1% of the catch of *borealis*. In 2011 the catch of *P. montagui* was 2% of the catch of *borealis* which rose to 3% in 2012 and in

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

2013 further increased to 5%. In 2014 the catch of *P. montagui* was 1.5% of the catch of *P. borealis* whereas the catch of *P. montagui* in 2015 and 2016 constituted 3% and 4% respectively. 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 (Siegstad and Hammeken Arboe 2011 and Burmeister and Rigét, 2017b). 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).

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) 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 2003 the CPUE indices from the Greenland coastal and the Greenland offshore fleets have remained closely in step. After 2004 they diverged more than in previous years (Table 2, Fig. 9), but since 2007 they seem to have returned to closer agreement except for 2 years in 2009 and 2010. In 2016 and 2017 the indices again diverged, with CPUE for the inshore fleet decreasing and CPUE for the offshore fleet increasing. From 2004 to 2008 the catch rate for for the offshore fleet reached the highest level seen in the series and has since been decreasing, being down with 25 % in 2013 compared to the catch rate from 2004 to 2008. The catch rate for the offshore fleet in 2017 is the highest catch rate observed in the time series. The catch rate for the inshore fleet reached its highest level in 2007 to 2008 and has on average been 15% less since then. The catch rate for the inshore fleet has been decreasing since 2015.

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 (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, and stayed fairly flat until 1997. Since then, the unified CPUE index increased markedly and sustainedly for 11 years, reaching the highest level in 2008, to turn downward in 2009. The unified CPUE index has been decreasing until 2013, but have been increasing since then and in 2017 are among the highest values observed in the time series.

Acknowledgements

Mads Rossing Lund of Grønlands Fiskeri- og Licenskontrol helped in obtaining logbook data for the Greenland fleets and with many insights into the conduct of the fishery. Tim Siferd of the Canadian Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg, has provided a data series for the Canadian fishery in SFA1 for 1979–2014.

References

BURMEISTER, AD and KINGSLEY, M.C.S. 2014. The West Greenland trawl survey for *Pandalus borealis*, 2014, with reference to earlier results. NAFO SCR Doc. 14/052, Ser. No. N6354.

BURMEISTER, AD and CHRISTENSEN H. TORP. 2017. Experimental and development fishery for shrimp (*Pandalus borealis*) in Melville Bay, Westgreenland waters North of 73°30'N, 2014 - 2016. NAFO SCR Doc. 17/054, Ser. No. N6723.

BURMEISTER, AD and RIGET, F. FARSØ. 2017. The West Greenland trawl survey for *Pandalus borealis*, 2017, with reference to earlier results. NAFO SCR Doc. 17/051, Ser. No. N6720.

BURMEISTER, AD and RIGET, F. FARSØ. 2017a. *Pandalus montagui* in the West Greenland offshore shrimp fishery 2011–2016. NAFO SCR Doc. 17/053, Ser. No. N6722.

BURMEISTER, AD and RIGET, F. FARSØ. 2017b. Applying a stochastic surplus production model (SPiCT) to the Est Greenland Stock of *Pandalus montagui*. NAFO SCR Doc. 17/062, Ser. No. N6731.

G.H. 1996. Hjemmestyrets bekendtgørelse nr. 39 af 30. december 1996 om kontrol med kystnært fiskeri efter rejer.

http://www.nanoq.gl/gh.gl-love/dk/1996/bkg/bkg_nr_39-1996_dk.htm

G.H. 2002. Hjemmestyrets bekendtgørelse nr. 23 af 29. august 2002 om geografisk adgang til rejefiskeri på Grønlands fiskeriterritorium.

http://www.nanoq.gl/gh.gl-love/dk/2002/bkg/bkg_nr_29-2002_dk.htm

G.H. 2003. Hjemmestyrets bekendtgørelse nr. 25 af 29. december 2003 om beregningsmetoder ved rapportering af visse fangster.

http://www.nanoq.gl/gh.gl-love/dk/2003/bkg/bkg_nr_25-2003_dk.htm

G.H. 2010 Selvstyrets bekendtgørelse nr. 20 af 16. december 2010 om kontrol med kystnært fiskeri efter rejer

http://www.lovgivning.gl/gh.gl-love/dk/2010/bkg/bkg_nr_20-2010_dk.htm

G.H. 2010 Selvstyrets bekendtgørelse nr. 18 af 9. december 2010 om kontrol med havgående fiskeri

http://www.lovgivning.gl/gh.gl-love/dk/2010/bkg/bkg_nr_18-2010_dk.htm

G. H. 2011 Selvstyrets bekendtgørelse nr. 14 af 6. december 2011 om fiskeriets bifangster

http://www.lovgivning.gl/gh.gl-love/dk/2011/bkg/bkg_nr_14-2011_dk.htm

G.H 2011 Selvstyrets bekendtgørelse nr. 12 af 17. november 2011 om tekniske bevaringsforanstaltninger i fiskeriet

http://www.lovgivning.gl/gh.gl-love/dk/2011/bkg/bkg_nr_12-2011_dk.htm

G.H. 2011 Inatsisartutlov nr. 8 af 22. november 2011 om ændring af Landstinglov om fiskeri (Ændringer om ejerskab og kvoteloftbegrænsninger).

http://www.lovgivning.gl/gh.gl-love/dk/2011/ltl/L_08-2011_fiskeri/L_08-2011_dk.htm

G.H. 2012 Selvstyrets bekendtgørelse nr. 1 af 2. februar 2012 om licens og kvoter til fiskeri.

http://www.lovgivning.gl/gh.gl-love/dk/2012/bkg/bkg_nr_01-2012_dk.htm

HAMMEKEN ARBOE, N. 2016. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2016. NAFO SCR Doc. 16/046, Ser. No. N6595.

HAMMEKEN ARBOE, N. 2017. Catch Table Update for the West Greenland Shrimp Fishery. NAFO SCR Doc. 17/055, Ser. No. N6724.

HVINGEL, C. 2003. Correction of reported past catches of Northern Shrimp within the Greenland EEZ to conform to a revision of reporting practices. NAFO SCR Doc. 03/74, Ser. No. N4913. 3 pp.

HVINGEL, C. 2004. The fishery for Northern Shrimp *(Pandalus borealis*) off West Greenland, 1970–2004. NAFO SCR Doc. 04/75, Ser. No. 4914. 24 pp.

HVINGEL, C., H. LASSEN and D.G. PARSONS. 2000. A biomass index for northern shrimp (*Pandalus borealis*) in Davis Strait based on multiplicative modelling of commercial catch-per-unit-effort data (1976–1997). J. Northw. Atl. Fish. Sci. 26: 25–31.

KANNEWORFF, P. 2003. Occurrence of *Pandalus montagui* in trawl survey samples from NAFO Subarea 0+1. NAFO SCR Doc. 03/70, Ser. No. N4909.

KINGSLEY, M.C.S. 2007. Catches of Northern Shrimp (*Pandalus borealis*) off West Greenland, 1999–2006. NAFO SCR Doc. 07/66, Ser. No. N5451. 4 pp.

KINGSLEY, M.C.S. 2011. *Pandalus montagui* in the West Greenland shrimp fishery, 2001–2010. NAFO SCR Doc. 11/057, Ser. No. N5982. 5 pp.

SAS Institute. 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1988. 1028 pp.

SIMPSON, E.H. 1949. Measurement of diversity. Nature 163:688.

SIEGSTAD, H. and N. HAMMEKEN ARBOE. 2011. Occurence of *Pandalus montagui* in Trawl Survey Samples from NAFO Subareas 0 & 1. NAFO SCR Doc. 11/070, Ser. No. N5996. 13pp.

SÜNKSEN, K. 2007. Discarded by-catch in shrimp fisheries in Greenlandic offshore waters 2006–2007. NAFO SCR Doc. 07/88, Ser. No. 5474. 12 pp

Table 1a. *P. borealis* in W. Greenland: Catch limits, effort, catch and CPUE, NAFO SA 1 up to 76°00'N, 1970–1989.

Year	TAC (t)			Catch (t)				Catch (t)	Effort				CPUE			
	SA 1*	Div. 0A	Total	SA 1 Up to 76°00'N			Div. 0A	Total	SA 1	Div. 0A	Total	Total	SA 1	Div. 0A	Total	Std. Total
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			Std. (index)	Unstd. (kg/hr)			(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	1.19
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	1.44
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	54889	8250	63139	3069	66208	129.1	23.6	153	0.62	489	130	433	1.28
1986	42120	6120	48240	65623	8250	73873	2995	76868	133.4	-	*133*	0.69	554	-	576	1.33
1987	40120	6120	46240	64223	7613	71836	6095	77931	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	1.16
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 76°00'N, 1990–2017.

Year	TAC (t)			Catch (t)					Effort				CPUE			
	SA 1*	Div. 0A	Total	SA 1			Div. 0A	Total	SA 1	Div. 0A	Total	Total Std.	SA 1	Div. 0A	Total	Total Std.
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			(1990=1)	Unstd. (kg/hr)			(1990=1)
1990	45245	7520	52765	62800	14993	77793	6177	83970	209.6	14.3	224	1.00	371	433	375	1.00
1991	46225	8500	54725	66817	17884	84701	6788	91489	230.8	19.6	250	1.05	367	346	365	1.04
1992	44200	8500	52700	75341	22653	97994	7493	105487	234.2	16.6	251	1.12	418	451	421	1.13
1993	40600	8500	49100	65894	19627	85522	5491	91013	206.1	12.2	218	0.98	415	450	417	1.11
1994	42300	8500	50800	68109	19930	88039	4766	92805	209.8	15.3	225	1.00	420	312	412	1.11
1995	39500	8500	48000	66955	18072	85027	2361	87388	184.7	7.3	192	0.86	460	322	455	1.22
1996	63922	8500	72422	62368	19095	81463	2632	84095	164.6	9	174	0.79	495	293	484	1.27
1997	64600	8500	74800	62743	14868	77611	517	78128	184.9	1.3	186	0.75	420	412	420	1.24
1998	60729	7650	68379	69156	10406	79562	933	80495	152.7	2.6	155	0.67	521	353	518	1.43
1999	73500	9350	82850	71203	18948	90152	2046	92198	164.7	5.1	170	0.69	547	398	543	1.60
2000	77675	9350	87025	73013	23365	96378	1590	97968	156.2	2.6	159	0.66	617	613	617	1.76
2001	92950	9350	102300	79291	20010	99301	3625	102926	158.3	6	164	0.73	627	602	626	1.68
2002	91150	12040	103190	107195	21729	128925	6247	135172	173.3	9	182	0.80	744	695	741	2.01
2003	101000	14167	115167	104237	18799	123036	7137	130173	141.5	8.4	150.0	0.72	869	846	868	2.16
2004	135352	14167	149519	121658	20653	142311	7021	149332	148.6	12.3	160.9	0.75	958	569	928	2.38
2005	134000	18452	152452	128068	21910	149978	6921	156899	150.8	9.3	160.1	0.76	994	744	980	2.47
2006	134000	18380	152380	127747	25441	153188	4127	157315	148.7	4.7	153.4	0.77	1030	884	1026	2.43
2007	134000	18417	152417	116674	25571	142245	1945	144190	138.3	2.2	140.6	0.67	1028	872	1026	2.55
2008	127300	18417	145717	119797	34092	153889	0	153889	144.7	-	144.7	0.69	1064	-	1064	2.65
2009	114570	15583	130153	97051	37978	135029	429	135458	144.1	-	144.1	0.68	937	-	-	2.36
2010	114570	15583	130153	94596	33513	128109	5882	133991	144.5	5.8	150.3	0.69	886	1017	891	2.30
2011	124000	15583	139583	78437	44222	122659	1330	123989	131.6	2.5	134.1	0.62	932	527	924	2.38
2012	101675	12750	114425	76090	39875	115965	12	115977	134.5	-	134.5	0.63	862	-	862	2.19
2013	89263	11333	100596	65797	29582	95379	2	95381	116.8	-	116.8	0.59	817	-	817	1.92
2014	86316	11333	97649	60768	27997	88765	0	88765	105.4	-	105.4	0.50	842	-	842	2.10
2015	74061	8500	82561	49246	23008	72254	2	72256	83.2	-	83.2	0.39	868	-	868	2.20
2016	85801	10625	96426	56593	27763	84356	1171	85527	95.9	-	95.9	0.43	879	-	892	2.34
2017#	88956	12750	101706	64223	24777	89000	1000	90000	86.2	-	86.2	0.42	1032	-	1044	2.55

* 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 76°00'N:
Standardised (1990=1) CPUE series for 4 fleets and a combined standardised CPUE series.

	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							1.481	0.207
1977	1.556	0.082							1.390	0.153
1978	1.230	0.082							1.097	0.154
1979	1.113	0.080							0.994	0.149
1980	1.340	0.082							1.194	0.155
1981	1.266	0.077							1.131	0.147
1982	1.611	0.083							1.435	0.155
1983	1.423	0.081							1.272	0.155
1984	1.338	0.079							1.194	0.152
1985	1.432	0.077							1.278	0.147
1986	1.490	0.077							1.330	0.146
1987	1.787	0.080	1.531	0.030			–	–	1.526	0.062
1988	1.465	0.079	1.141	0.027	1.179	0.054	–	–	1.156	0.056
1989	1.086	0.088	1.083	0.026	0.889	0.040	1.114	0.110	1.050	0.055
1990	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
1991			1.049	0.024	0.975	0.036	0.795	0.095	1.042	0.054
1992			1.132	0.024	1.069	0.036	0.861	0.103	1.126	0.055
1993			1.099	0.025	1.125	0.036	0.935	0.098	1.110	0.056
1994			1.125	0.025	1.007	0.035	0.652	0.095	1.107	0.055
1995			1.257	0.026	1.022	0.036	0.765	0.102	1.215	0.056
1996			1.317	0.027	1.071	0.037	0.616	0.100	1.271	0.057
1997			1.271	0.029	1.088	0.036	–	–	1.238	0.058
1998			1.448	0.031	1.323	0.040	0.609	0.135	1.427	0.060
1999			1.644	0.032	1.419	0.036	0.880	0.129	1.597	0.061
2000			1.736	0.034	1.753	0.036	1.067	0.137	1.762	0.062
2001			1.671	0.035	1.632	0.035	1.106	0.116	1.682	0.064
2002			1.978	0.032	2.012	0.036	1.318	0.107	2.010	0.060
2003			2.162	0.033	2.040	0.036	1.579	0.113	2.156	0.061
2004			2.446	0.033	2.142	0.035	1.180	0.107	2.383	0.060
2005			2.598	0.032	2.081	0.036	1.261	0.117	2.474	0.061
2006			2.466	0.032	2.231	0.037	1.443	0.141	2.427	0.061
2007			2.532	0.033	2.499	0.037	1.388	0.141	2.547	0.062
2008			2.651	0.033	2.526	0.036	–	–	2.647	0.062
2009			2.395	0.036	2.172	0.036	–	–	2.359	0.064
2010			2.380	0.035	2.000	0.037	2.055	0.182	2.297	0.063
2011			2.399	0.037	2.257	0.037	0.250	0.305	2.382	0.063
2012			2.199	0.036	2.068	0.037	–	–	2.191	0.065
2013			1.865	0.037	1.995	0.040	–	–	1.923	0.064
2014			2.028	0.038	2.191	0.041	–	–	2.096	0.065
2015			2.143	0.040	2.255	0.044	–	–	2.202	0.068
2016			2.378	0.040	2.149	0.041	–	–	2.342	0.066
2017			2.752	0.059	2.054	0.056	–	–	2.546	0.087

* relative i.q.r.: the interquartile range divided by the median

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	1029	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	1216	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	1065	1017	1345	1064
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	1391	1449	1850	856
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	1025	1470	1399	1031	565
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	1102	1366	1284	952	519
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	1085	1294	1144	1081	473
2008	0.0	42.3	96.1	6.7	4.4	4.4	0.1	0.0	42.7	88.1	5.7	3.7	4.5	0.1	-	991	1090	1189	1179	977	1170
2009	0.4	48.1	71.9	5.0	6.5	3.6	0.0	0.1	54.8	77.7	4.6	4.6	2.5	0.0	-	877	926	1084	1391	1463	-
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	1017	786	899	1319	1620	1852	-
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	1036	1531	1548	2085	-
2012	0.0	45.7	45.3	6.3	12.0	6.4	0.3	0.0	67.1	51.6	4.6	7.6	3.4	0.2	-	680	878	1377	1576	1886	1539
2013	0.0	33.9	39.2	6.6	10.6	4.6	0.6	0.0	52.5	46.6	5.5	8.5	3.5	0.3	-	646	840	1214	1240	1314	2141
2014	0.0	37.9	38.3	4.0	6.2	1.6	0.7	0.0	55.4	39.3	3.8	5.3	1.3	0.3	-	685	973	1068	1181	1285	1971
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	1269	1078	1372	1692
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	1283	1253	2078	2382
2017*	1.0	13.8	51.3	15.9	6.6	1.3	0.1	0.0	21.2	49.8	10.5	4.3	0.4	0.1	-	651	1030	1517	1536	3022	2583

*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	15-16
1A	9.2	23.4	12.8	8.1	12.1	19.4	39.1	39.1
1B	72.1	56.1	38.3	29.1	33.7	55.4	43.6	42.6
1C	17.4	13.9	21.5	17.2	20.0	10.6	5.6	6.8
1D	1.3	6.4	21.5	26.1	19.0	8.2	8.4	7.1
1E	0.0	0.0	4.0	10.2	6.2	4.3	3.0	2.6
1F	0.0	0.2	2.1	9.3	9.0	2.1	0.3	1.9
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	15-16
1A	9.3	30.5	15.9	16.7	23.8	24.1	48.3	46.9
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	4.6
1D	1.1	6.0	20.0	21.0	15.6	6.4	5.1	5.3
1E	0.0	0.0	2.4	6.5	4.0	4.2	1.6	1.3
1F	0.0	0.9	2.1	6.7	7.4	3.9	0.1	0.9
Diversity	1.8	2.8	3.9	4.6	4.4	2.8	2.5	2.5

[1]unstandardised single-trawl-equivalent time

Table 5. *P. borealis* in W. Greenland: Catch by month 1976–2017, 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	16044	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*	7935	7420	3476	5120	7387	6333	-	-	-	-	-	-

* 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		Fish		P. montagui
	discard (tons)	discard (%)	discard (tons)	discard (%)	landed (tons)
1980	0	0.00	3518	6.4	0
1981	0	0.00	724	1.5	0
1982	0	0.00	776	1.5	0
1983	0	0.00	1026	1.9	0
1984	0	0.00	1326	2.6	0
1985	151	0.24	1514	2.4	0
1986	110	0.15	1639	2.2	0
1987	189	0.25	918	1.2	0
1988	216	0.31	1100	1.6	0
1989	196	0.27	1401	1.9	0
1990	265	0.34	1270	1.6	0
1991	406	0.48	2049	2.4	0
1992	335	0.34	2162	2.2	0
1993	251	0.29	1911	2.2	0
1994	332	0.38	2683	3.0	5
1995	476	0.56	2702	3.2	563
1996	323	0.40	2710	3.3	772
1997	310	0.40	2326	3.0	422
1998	314	0.39	2183	2.7	1253
1999	197	0.22	7	0.0	4
2000	268	0.28	685	0.7	305
2001	382	0.38	1120	1.1	881
2002	648	0.50	1272	1.0	225
2003	639	0.52	1291	1.0	967
2004	762	0.54	1044	0.7	831
2005	753	0.50	982	0.7	512
2006	865	0.56	1178	0.8	1444
2007	741	0.52	2085	1.5	2003
2008	860	0.56	1116	0.7	89
2009	710	0.53	1321	1.0	53
2010	739	0.58	1426	1.1	1168
2011	720	0.59	1109	0.9	2324
2012	587	0.51	1039	0.9	3121
2013	491	0.52	831	0.9	4944
2014	443	0.50	1101	1.2	1357
2015	325	0.45	708	1.0	2027
2016	329	0.39	606	0.7	3176
2017*	358	0.40	573	0.6	1487

[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.

* projected from part-year's data.

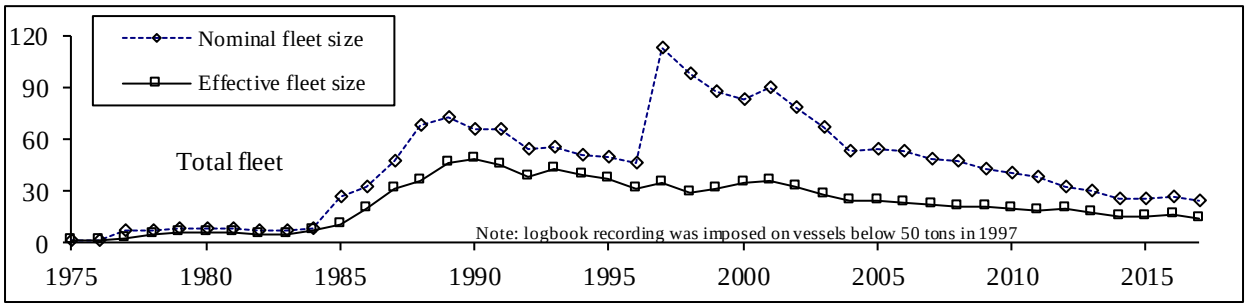

Fig. 1a. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland trawler fleet, 1975–2017, from logbook records.

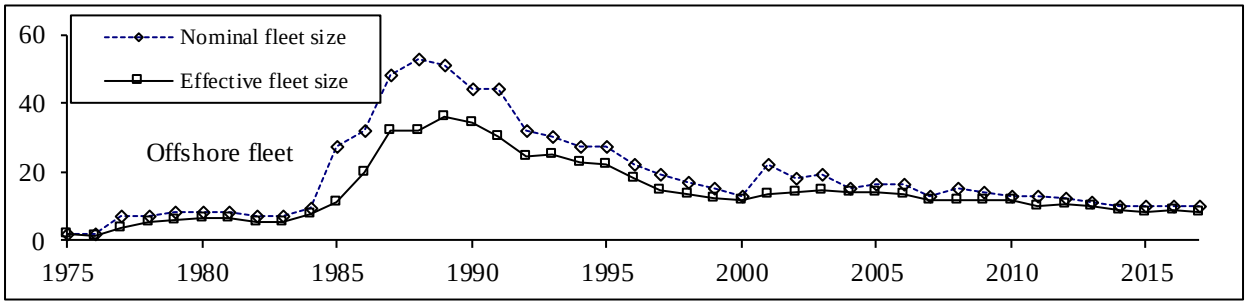

Fig. 1b. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland offshore trawler fleet, 1975–2017, from logbook records.

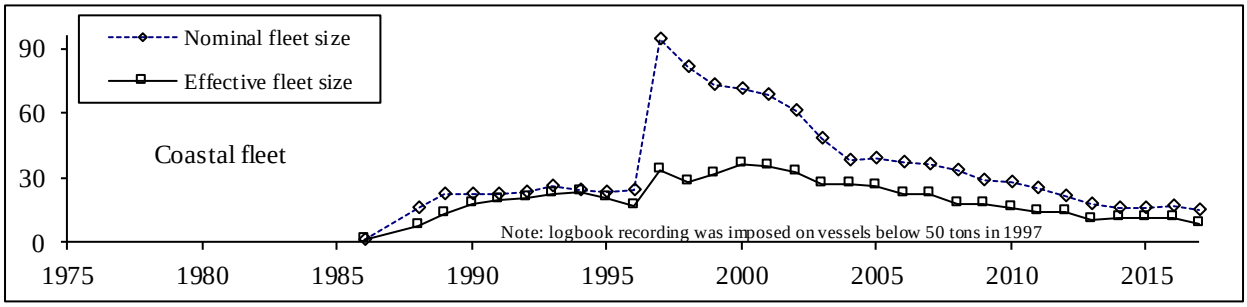

Fig. 1c. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland coastal trawler fleet, 1986–2017, from logbook records.

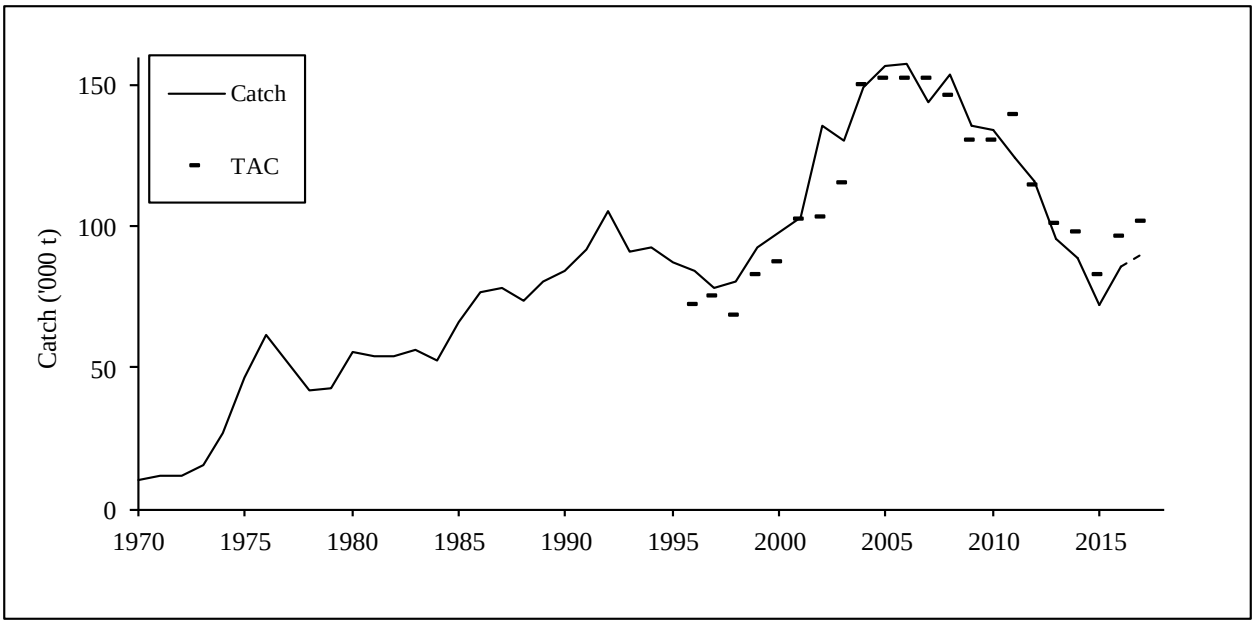

Fig. 2. *P.borealis* in W. Greenland: Catches and TACs in NAFO Subarea 1 and Canadian SFA 1, 1970–2017; 2017 catch estimate is based on forecasts from GFLK and DFO.

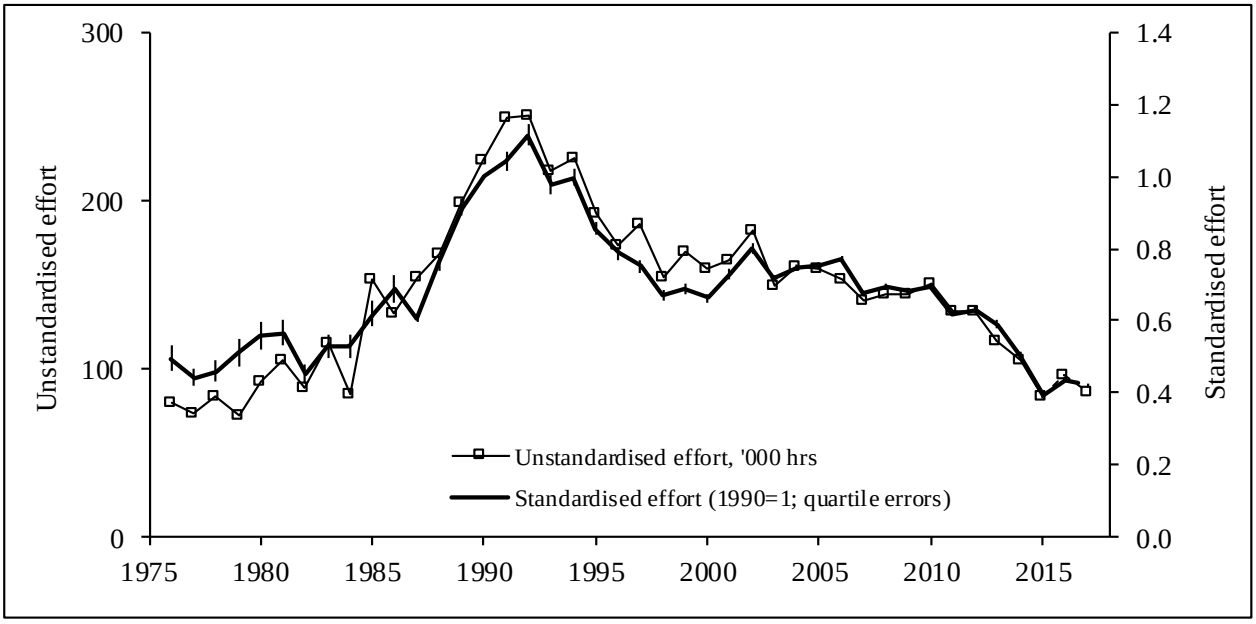

Fig. 3. *P. borealis* in W. Greenland: Fishing effort applied in NAFO Subarea 1 and Canadian SFA 1, 1970–2017. 2017 is projected from part-year's data.

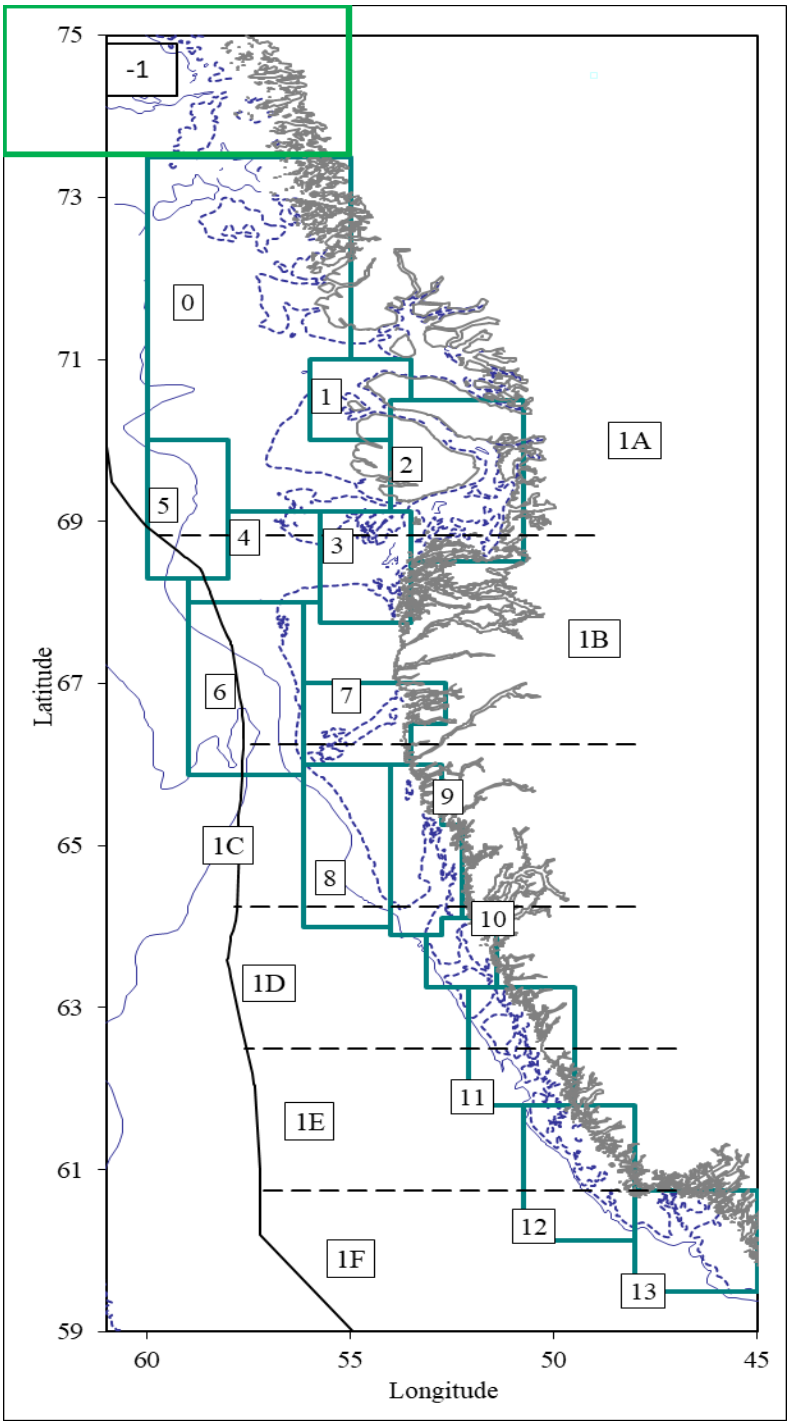

Fig. 4. *P. borealis* in W. Greenland: Map showing Statistical Areas (in green frames). Area -1 goes from 73°30'N to 76°00'N. 200 meter depth contour dotted purple line and 600 meter depth contour solid purple line.

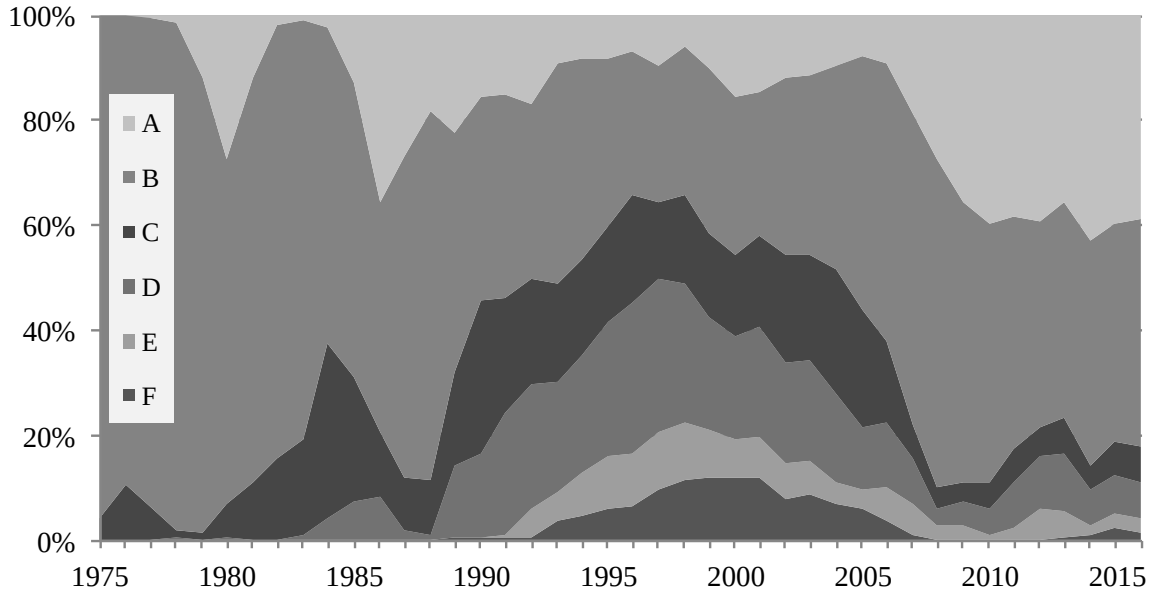

Fig. 5a. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between NAFO Divisions in Subarea 1 up to 76°00'N, 1975-2016.

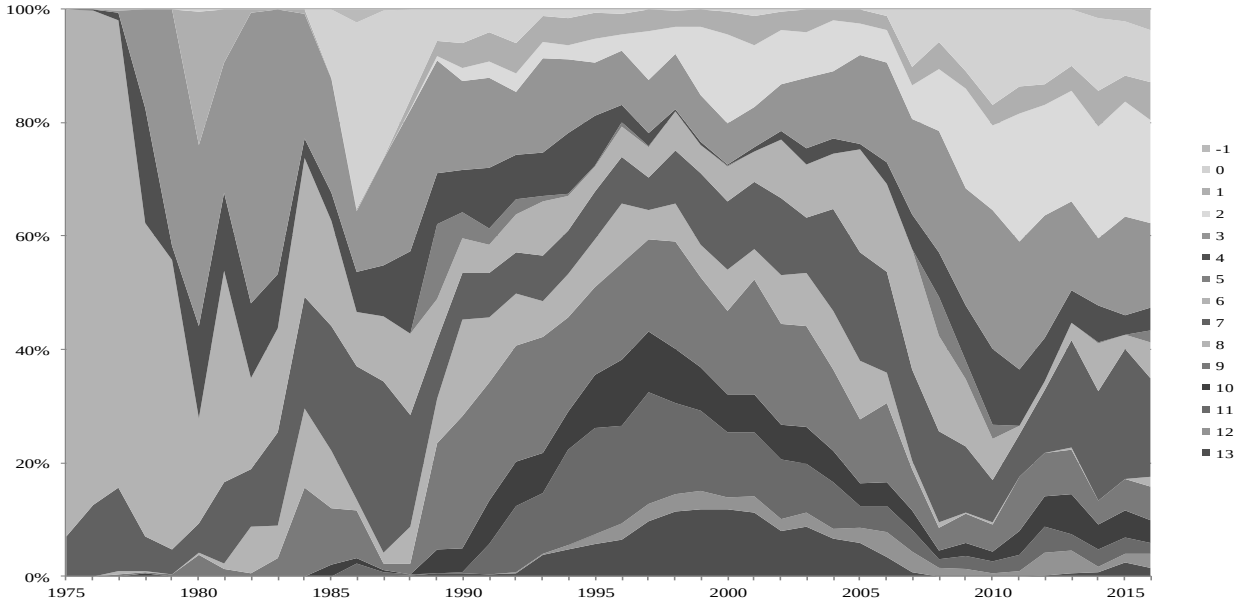

Fig. 5b. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between statistical Areas in Greenland waters, 1975-2016. (The light band that starts broad on the left-hand side is Area 6; the light band at the top is Area 0, the dark wedge at the very bottom from 1992 to 2007 is Area 13.)

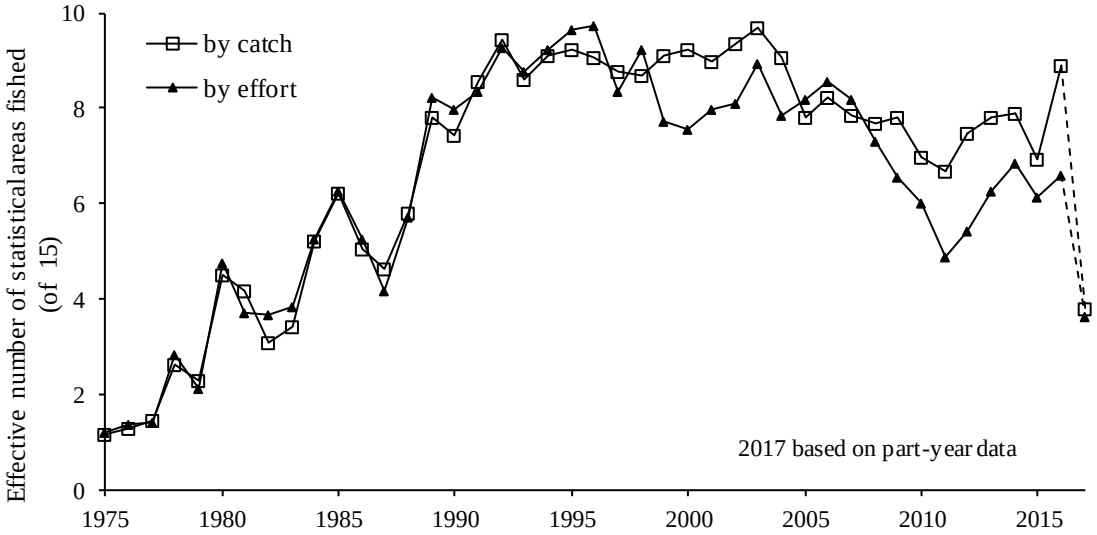

Fig. 6a. *P. borealis* in W. Greenland: Diversity indices for the distribution of logbook-recorded catch between statistical Areas in Greenland waters, 1975–2017. 2017 is on part-year's data.

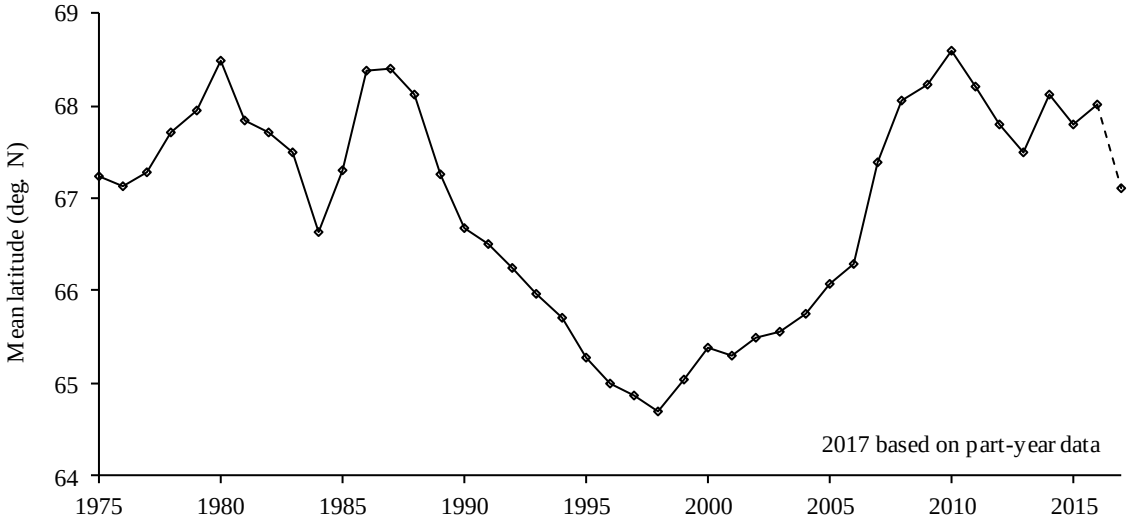

Fig. 6b. *P. borealis* in W. Greenland: Mean latitude by weight of the logbook recorded catch in the Greenland fishery, 1975–2017. 2017 is on part-year's data.

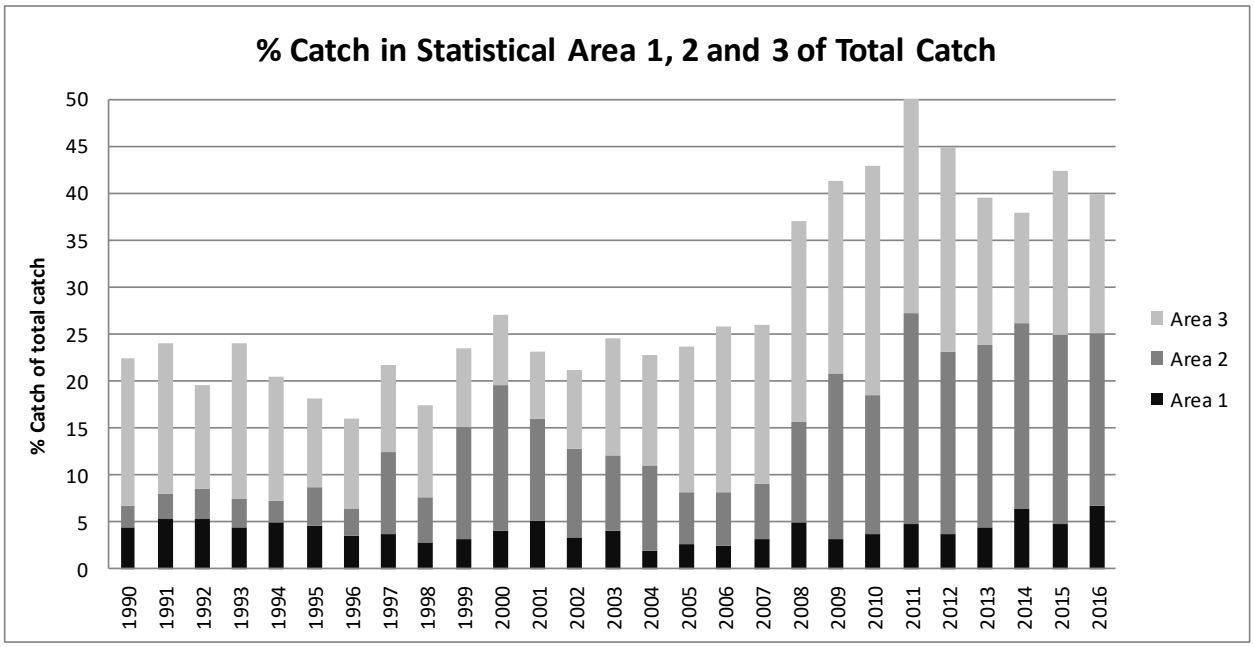

Fig. 7. *P. borealis* in W. Greenland: Distribution of catches in the Disko Bay Area (statistical Areas 1, 2 and 3) 1990–2016.

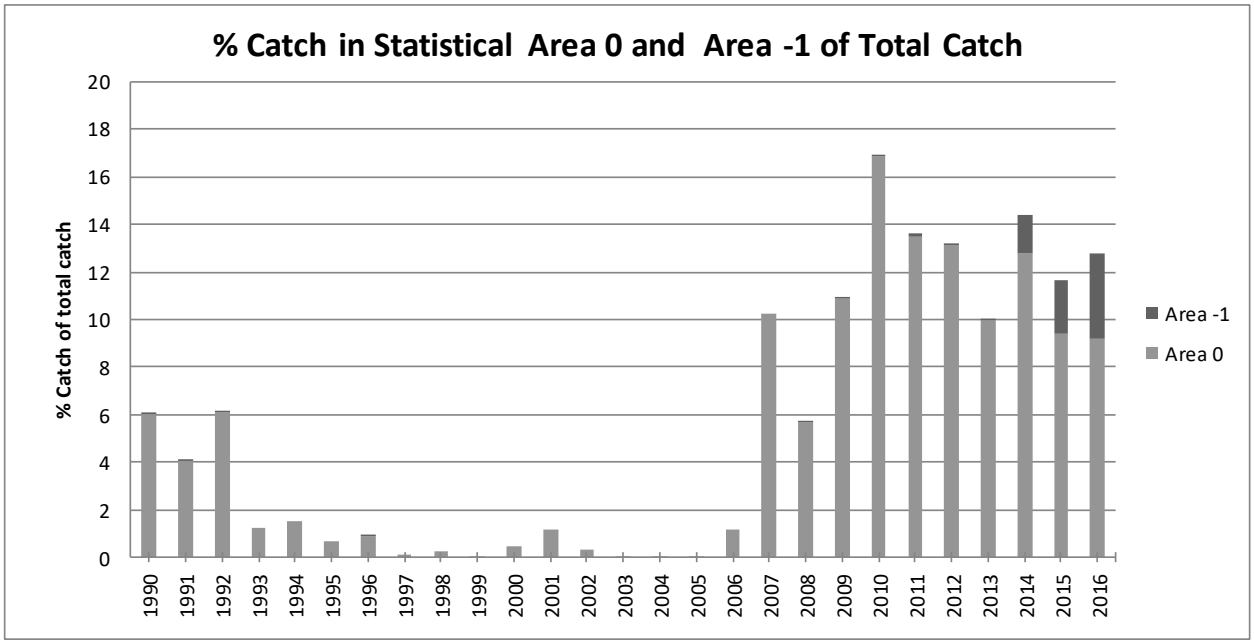

Fig. 8. *P. borealis* in W. Greenland: catches taken in statistical Areas 0 and -1 as a percentage of total catches, 1990–2016.

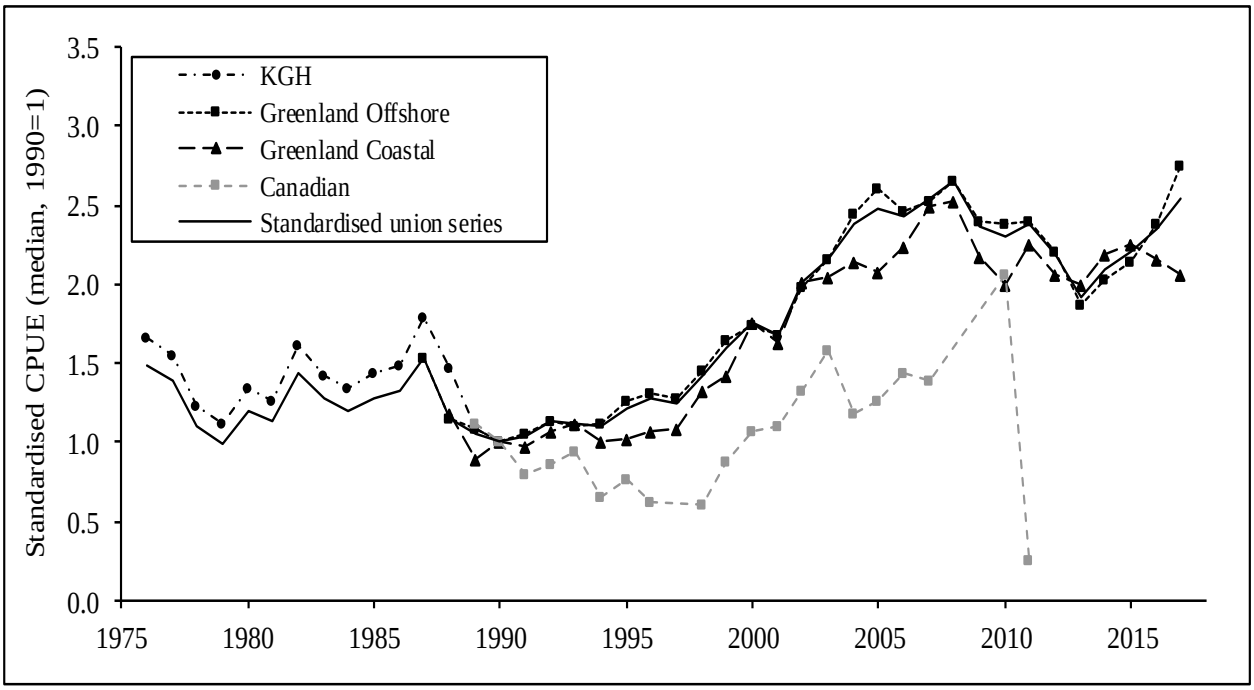

Fig. 9. *P. borealis* in W. Greenland: standardised (1990=1) CPUE series from 4 fleets and a standardised union series 1976–2017. 2017 is on part-year's data.

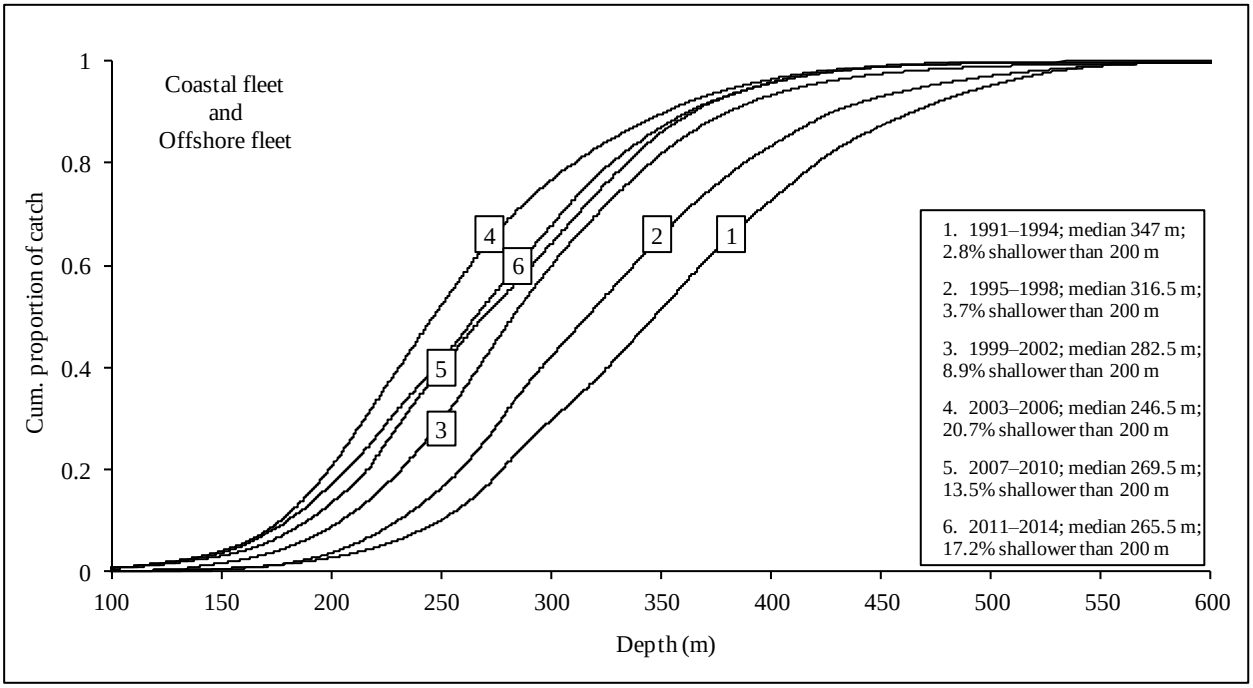

Fig. 10. *P. borealis* in W. Greenland: Depth distribution of catches taken by the Greenland fleet, 1991-2014.

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

Greenland Offshore fleet: Areas -1 and 0 and 3 to 12
Group March w. April, June w. July and September w. October
Group Area 7 w. Area 9

The GLM Procedure
Class Level Information

Class Levels Values
VESSEL 19 hh02 hh03 hh06 hh10 hh13 hh15 hh19 hh22 hh25 hh26 hh28 hh31 hh33 hh37 hh39 hh42 hh44 hh46 hh50
year 31 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 2090
MONTH 9 1 2 4 5 7 8 10 11 12
AREA 11 -1 0 3 4 5 6 8 9 10 11 12
HOLD 2 1 2

Number of Observations Read 10091
Number of Observations Used 10091

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	66	122545.2543	1856.7463	483.32	<.0001
Error	10024	38508.4324	3.8416		
Corrected Total	10090	161053.6868			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.760897	82.89058	1.960006	2.364570

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VESSEL	18	90961.93963	5053.44109	1315.44	<.0001
MONTH	8	2770.20184	346.27523	90.14	<.0001
AREA	10	8290.69519	829.06952	215.81	<.0001
year	30	20522.41768	684.08059	178.07	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VESSEL	18	19947.36169	1108.18676	288.47	<.0001
MONTH	8	1928.42877	241.05360	62.75	<.0001
AREA	10	4160.39939	416.03994	108.30	<.0001
year	30	20522.41768	684.08059	178.07	<.0001

Dependent Variable: LNCPUE
Weight: hauls

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	2.435211549 B	0.03317173	73.41	<.0001
VESSEL hh02	-1.156886411 B	0.02781099	-41.60	<.0001
VESSEL hh03	-1.021472912 B	0.03432850	-29.76	<.0001
VESSEL hh06	-0.928534400 B	0.02212926	-41.96	<.0001
VESSEL hh10	-0.724953088 B	0.01581415	-45.84	<.0001
VESSEL hh13	-0.660345126 B	0.01593961	-41.43	<.0001
VESSEL hh15	-0.630056673 B	0.01799265	-35.02	<.0001
VESSEL hh19	-0.592586794 B	0.01465145	-40.45	<.0001
VESSEL hh22	-0.574306010 B	0.01611986	-35.63	<.0001
VESSEL hh25	-0.520843395 B	0.01798610	-28.96	<.0001
VESSEL hh26	-0.487510736 B	0.02699021	-18.06	<.0001
VESSEL hh28	-0.439217684 B	0.02142920	-20.50	<.0001
VESSEL hh31	-0.396754335 B	0.01348635	-29.42	<.0001
VESSEL hh33	-0.357439244 B	0.01982008	-18.03	<.0001
VESSEL hh37	-0.320998663 B	0.01509862	-21.26	<.0001

VESSEL hh39	-0.269075056 B	0.01868227	-14.40	<.0001
VESSEL hh42	-0.173592947 B	0.01609707	-10.78	<.0001
VESSEL hh44	-0.145686241 B	0.01723858	-8.45	<.0001
VESSEL hh46	-0.116036773 B	0.01692483	-6.86	<.0001
VESSEL hh50	0.000000000 B	. . .		

Dependent Variable: LNCPUE
Weight: hauls

Parameter	Estimate	Standard Error	t Value	Pr > |t|
MONTH 1	-0.033594830 B	0.01757865	-1.91	0.0560
MONTH 2	0.029077312 B	0.01759204	1.65	0.0984
MONTH 4	0.108367716 B	0.01428549	7.59	<.0001
MONTH 5	0.004374824 B	0.01535326	0.28	0.7757
MONTH 7	0.198124943 B	0.01377850	14.38	<.0001
MONTH 8	0.076748024 B	0.01539156	4.99	<.0001
MONTH 10	0.061165199 B	0.01395284	4.38	<.0001
MONTH 11	0.044792598 B	0.01576812	2.84	0.0045
MONTH 12	0.000000000 B	. . .		
AREA -1	-1.130005420 B	0.05381194	-21.00	<.0001
AREA 0	-0.390755596 B	0.03049147	-12.82	<.0001
AREA 3	0.009403369 B	0.03078790	0.31	0.7600
AREA 4	-0.230638448 B	0.02994809	-7.70	<.0001
AREA 5	-0.326588819 B	0.03431110	-9.52	<.0001
AREA 6	-0.128543131 B	0.02940059	-4.37	<.0001
AREA 8	-0.167464374 B	0.02951082	-5.67	<.0001
AREA 9	-0.153132376 B	0.02838081	-5.40	<.0001
AREA 10	-0.129604591 B	0.02971011	-4.36	<.0001
AREA 11	-0.103887652 B	0.02889500	-3.60	0.0003
AREA 12	0.000000000 B	. . .		
year 1987	0.425670836 B	0.02250909	18.91	<.0001
year 1988	0.132057537 B	0.01992644	6.63	<.0001
year 1989	0.079323124 B	0.01921595	4.13	<.0001
year 1991	0.048169789 B	0.01773746	2.72	0.0066
year 1992	0.123982316 B	0.01798669	6.89	<.0001
year 1993	0.094814852 B	0.01846919	5.13	<.0001
year 1994	0.117358949 B	0.01853727	6.33	<.0001
year 1995	0.228835024 B	0.01922444	11.90	<.0001
year 1996	0.275178723 B	0.02022040	13.61	<.0001

Dependent Variable: LNCPUE
Weight: hauls

Parameter	Estimate	Standard Error	t Value	Pr > |t|
year 1997	0.239982551 B	0.02126237	11.29	<.0001
year 1998	0.369962062 B	0.02292738	16.14	<.0001
year 1999	0.497426153 B	0.02400690	20.72	<.0001
year 2000	0.551313040 B	0.02527385	21.81	<.0001
year 2001	0.513318359 B	0.02569802	19.98	<.0001
year 2002	0.682297450 B	0.02338193	29.18	<.0001
year 2003	0.771118140 B	0.02429161	31.74	<.0001
year 2004	0.894630962 B	0.02431128	36.80	<.0001
year 2005	0.954779469 B	0.02382409	40.08	<.0001
year 2006	0.902716499 B	0.02384866	37.85	<.0001
year 2007	0.928869573 B	0.02455452	37.83	<.0001
year 2008	0.974919330 B	0.02461082	39.61	<.0001
year 2009	0.873383724 B	0.02641825	33.06	<.0001
year 2010	0.867329980 B	0.02598120	33.38	<.0001
year 2011	0.875026525 B	0.02715006	32.23	<.0001
year 2012	0.787910586 B	0.02693597	29.25	<.0001
year 2013	0.623292480 B	0.02740516	22.74	<.0001
year 2014	0.706880258 B	0.02808805	25.17	<.0001
year 2015	0.762166777 B	0.02996445	25.44	<.0001
year 2016	0.866719143 B	0.02961208	29.27	<.0001
year 2017	1.012345268 B	0.04356961	23.24	<.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.

Greenland coastal fleet: Areas 1 to 3, 7 and 13
Group January w. February

The SAS System
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	30	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 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 11085
Number of Observations Used 11085

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	59	52137.27893	883.68269	286.47	<.0001
Error	11025	34009.11860	3.08473		
Corrected Total	11084	86146.39753			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.605217	89.03903	1.756339	1.972550

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AREA	4	2936.84265	734.21066	238.01	<.0001
MONTH	10	2975.37876	297.53788	96.46	<.0001
VESSEL	16	21253.96612	1328.37288	430.63	<.0001
year	29	24971.09140	861.07212	279.14	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AREA	4	2897.12341	724.28085	234.80	<.0001
MONTH	10	2175.92745	217.59274	70.54	<.0001
VESSEL	16	9157.52039	572.34502	185.54	<.0001
year	29	24971.09140	861.07212	279.14	<.0001

Dependent Variable: LNCPUE
Weight: Hauls

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	2.368500693 B	0.03449313	68.67	<.0001
AREA 1	-0.286998545 B	0.01464624	-19.60	<.0001
AREA 2	-0.361528790 B	0.01370697	-26.38	<.0001
AREA 3	-0.140227556 B	0.01300953	-10.78	<.0001
AREA 7	-0.287665035 B	0.01408321	-20.43	<.0001
AREA 13	0.000000000 B	. . .		
MONTH 2	-0.027022519 B	0.01727361	-1.56	0.1178
MONTH 3	0.124982454 B	0.01984227	6.30	<.0001
MONTH 4	0.264683392 B	0.01840426	14.38	<.0001
MONTH 5	0.129011115 B	0.01748388	7.38	<.0001
MONTH 6	0.160561226 B	0.01764434	9.10	<.0001
MONTH 7	0.214207644 B	0.01790519	11.96	<.0001
MONTH 8	0.140238419 B	0.01815824	7.72	<.0001
MONTH 9	0.040649764 B	0.01815195	2.24	0.0251

MONTH 10	-0.000165338 B	0.01783766	-0.01	0.9926
MONTH 11	0.031240425 B	0.01808024	1.73	0.0840
MONTH 12	0.000000000 B	. . .		

Parameter	Estimate	Standard Error	t Value	Pr > |t|
VESSEL cc01	-1.280323051 B	0.04201136	-30.48	<.0001
VESSEL cc02	-1.208414686 B	0.06028955	-20.04	<.0001
VESSEL cc05	-1.129663738 B	0.02984258	-37.85	<.0001
VESSEL cc08	-1.011900983 B	0.02621494	-38.60	<.0001
VESSEL cc09	-0.975171718 B	0.03018328	-32.31	<.0001
VESSEL cc12	-0.909357370 B	0.02474780	-36.74	<.0001
VESSEL cc13	-0.856869559 B	0.02914622	-29.40	<.0001
VESSEL cc16	-0.827752569 B	0.02373714	-34.87	<.0001
VESSEL cc17	-0.784529498 B	0.02672874	-29.35	<.0001
VESSEL cc20	-0.725511736 B	0.02323933	-31.22	<.0001
VESSEL cc24	-0.691610438 B	0.02244814	-30.81	<.0001
VESSEL cc27	-0.653902807 B	0.02367371	-27.62	<.0001
VESSEL cc29	-0.598606163 B	0.02454002	-24.39	<.0001
VESSEL cc32	-0.532291435 B	0.02585463	-20.59	<.0001
VESSEL cc33	-0.424525346 B	0.03855090	-11.01	<.0001
VESSEL cc34	-0.344661389 B	0.03306420	-10.42	<.0001
VESSEL cc35	0.000000000 B	. . .		
year 1988	0.164835809 B	0.03972207	4.15	<.0001
year 1989	-0.117657948 B	0.02975787	-3.95	<.0001
year 1991	-0.025312054 B	0.02677157	-0.95	0.3444
year 1992	0.066881911 B	0.02682880	2.49	0.0127
year 1993	0.117386272 B	0.02663086	4.41	<.0001
year 1994	0.007340468 B	0.02597187	0.28	0.7775
year 1995	0.021830691 B	0.02632202	0.83	0.4069
year 1996	0.068407802 B	0.02738732	2.50	0.0125
year 1997	0.084463166 B	0.02683507	3.15	0.0017
year 1998	0.279689408 B	0.02955288	9.46	<.0001
year 1999	0.349881425 B	0.02634382	13.28	<.0001
year 2000	0.561382487 B	0.02655086	21.14	<.0001
year 2001	0.489548412 B	0.02615326	18.72	<.0001
year 2002	0.699007049 B	0.02632967	26.55	<.0001
year 2003	0.712966809 B	0.02698363	26.42	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
year 2004	0.761680698 B	0.02610666	29.18	<.0001
year 2005	0.732856197 B	0.02640067	27.76	<.0001
year 2006	0.802281883 B	0.02720575	29.49	<.0001
year 2007	0.915998791 B	0.02727678	33.58	<.0001
year 2008	0.926475342 B	0.02632168	35.20	<.0001
year 2009	0.775783381 B	0.02690387	28.84	<.0001
year 2010	0.692979456 B	0.02716080	25.51	<.0001
year 2011	0.813965036 B	0.02726070	29.86	<.0001
year 2012	0.726770569 B	0.02734164	26.58	<.0001
year 2013	0.690736981 B	0.02955350	23.37	<.0001
year 2014	0.784523549 B	0.03052221	25.70	<.0001
year 2015	0.813116542 B	0.03232658	25.15	<.0001
year 2016	0.765217185 B	0.03025774	25.29	<.0001
year 2017	0.719698227 B	0.04153300	17.33	<.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 III: A standardised CPUE series for the Canadian fleet fishing for shrimps in SFA1

09:07 Friday, August 23, 2013 121

The GLM Procedure

Class Level Information

Class	Levels	Values
Year	20	1989 1991 1992 1993 1994 1995 1996 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2010 2011 2090
Month	4	7 8 9 11
vess	14	1 2 3 4 5 6 9 12 13 14 17 20 23 27
Gear	2	17 66
tclass	3	5 6 7
Cod_Mesh	24	0 40 41 42 43 44 45 46 47 48 50 51 54 55 56 59 60 61 135 140 145 147 155 160
Body_mesh	42	6 40 42 43 44 45 46 47 48 49 50 51 52 53 55 56 57 58 59 60 61 62 63 64 65 69 70 71 72 73 75 77 78 80 83 90 100 114 123 145 155 160
grate	5	22 28 betw lrge smal

Number of Observations Read	805
Number of Observations Used	803

Dependent Variable: log_catch

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	1816.272093	49.088435	366.37	<.0001
Error	765	102.498499	0.133985		
Corrected Total	802	1918.770592			

R-Square	Coeff Var	Root MSE	log_catch Mean
0.946581	10.24827	0.366040	3.571721

Source	DF	Type I SS	Mean Square	F Value	Pr > F
log_effort	1	1595.960659	1595.960659	11911.5	<.0001
Year	19	167.648816	8.823622	65.86	<.0001
Month	3	3.332558	1.110853	8.29	<.0001
tclass	2	18.943472	9.471736	70.69	<.0001
vess(tclass)	11	15.112787	1.373890	10.25	<.0001
Gear	1	15.273801	15.273801	114.00	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
log_effort	1	1255.164638	1255.164638	9367.95	<.0001
Year	19	55.175442	2.903971	21.67	<.0001
Month	3	2.290432	0.763477	5.70	0.0007
tclass	2	2.123076	1.061538	7.92	0.0004
vess(tclass)	11	10.639522	0.967229	7.22	<.0001
Gear	1	15.273801	15.273801	114.00	<.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
1 vs 2	1	0.18531701	0.18531701	1.38	0.2399
2 vs 3	1	0.47825380	0.47825380	3.57	0.0592
3 vs 4	1	0.20066783	0.20066783	1.50	0.2214
4 vs 5	1	0.16805527	0.16805527	1.25	0.2631
6 vs 9	1	0.69594576	0.69594576	5.19	0.0229
9 vs 12	1	0.56236591	0.56236591	4.20	0.0408
12 vs 13	1	0.26504677	0.26504677	1.98	0.1600
14 vs 17	1	0.72300422	0.72300422	5.40	0.0204
17 vs 20	1	0.82774399	0.82774399	6.18	0.0131
20 vs 23	1	0.34131118	0.34131118	2.55	0.1109
23 vs 27	1	0.32451814	0.32451814	2.42	0.1201
7 vs 8	1	1.09708035	1.09708035	8.19	0.0043
8 vs 9	1	0.21331136	0.21331136	1.59	0.2074
9 vs 11	1	0.73020215	0.73020215	5.45	0.0198

Dependent Variable: log_catch

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		-0.461050445 B	0.10258409	-4.49	<.0001
log_effort		1.079816316	0.01115649	96.79	<.0001
Year	1989	0.107754826 B	0.08136010	1.32	0.1858
Year	1991	-0.229574760 B	0.07076054	-3.24	0.0012
Year	1992	-0.149597127 B	0.07636285	-1.96	0.0505
Year	1993	-0.067428964 B	0.07264446	-0.93	0.3536
Year	1994	-0.427610224 B	0.07011616	-6.10	<.0001
Year	1995	-0.268109745 B	0.07525496	-3.56	0.0004
Year	1996	-0.484719147 B	0.07414550	-6.54	<.0001
Year	1998	-0.496667179 B	0.10008684	-4.96	<.0001
Year	1999	-0.127785119 B	0.09539855	-1.34	0.1808
Year	2000	0.064500338 B	0.10113001	0.64	0.5238
Year	2001	0.100669823 B	0.08564831	1.18	0.2402
Year	2002	0.276032348 B	0.07950804	3.47	0.0005
Year	2003	0.456774328 B	0.08346450	5.47	<.0001
Year	2004	0.165710783 B	0.07958366	2.08	0.0377
Year	2005	0.232277430 B	0.08698554	2.67	0.0077
Year	2006	0.366740237 B	0.10415504	3.52	0.0005
Year	2007	0.327512946 B	0.10419939	3.14	0.0017
Year	2010	0.720400807 B	0.13501038	5.34	<.0001
Year	2011	-1.386205880 B	0.22511556	-6.16	<.0001
Year	2090	0.000000000 B	.	.	.
Month	7	0.154695597 B	0.03965157	3.90	0.0001
Month	8	0.034007991 B	0.03769058	0.90	0.3672
Month	9	0.083817458 B	0.03590385	2.33	0.0198
Month	11	0.000000000 B	.	.	.
tclass	5	-0.169438105 B	0.26656763	-0.64	0.5252
tclass	6	-0.134647781 B	0.11682179	-1.15	0.2494
tclass	7	0.000000000 B	.	.	.
vess(tclass)	1 5	-1.194786246 B	0.49960077	-2.39	0.0170
vess(tclass)	2 5	-0.681800807 B	0.28194747	-2.42	0.0158
vess(tclass)	3 5	-0.446335720 B	0.27537823	-1.62	0.1055
vess(tclass)	4 5	-0.309804110 B	0.27662354	-1.12	0.2631
vess(tclass)	5 5	0.000000000 B	.	.	.
vess(tclass)	6 6	-0.519770362 B	0.14411702	-3.61	0.0003
vess(tclass)	9 6	-0.282500114 B	0.11146206	-2.53	0.0115
vess(tclass)	12 6	-0.165006966 B	0.11731919	-1.41	0.1600
vess(tclass)	13 6	0.000000000 B	.	.	.
vess(tclass)	14 7	-0.752436192 B	0.19228392	-3.91	<.0001
vess(tclass)	17 7	-0.301427780 B	0.05548303	-5.43	<.0001
vess(tclass)	20 7	-0.169269794 B	0.05116241	-3.31	0.0010
vess(tclass)	23 7	-0.087180851 B	0.05601826	-1.56	0.1201
vess(tclass)	27 7	0.000000000 B	.	.	.
Gear	17	-0.473619877 B	0.04435927	-10.68	<.0001
Gear	66	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.

Code for simplifying input data

```
IF 5<MONTH<12;
if grate_mm = . or grate_mm = ' ' then
do ;
                    grate_mm = '99' ;
end ;
if grate_mm lt 22 then grate = 'smal' ;
else if grate_mm = 22 then grate = '22';
else if grate_mm lt 28 then grate = 'betw';
else if grate_mm = 28 then grate = '28' ;
else grate = 'lrge'  ;
if year ge 1987 ;
```

```
IF YEAR=1990 THEN YEAR=2090;  * STANDARDIZE TO 1990;

if vessel =5  and tclass = 5 then vess = 1  ;
if vessel =24 and tclass = 5 then vess = 2  ;
if vessel =40 and tclass = 5 then vess = 3  ;
if vessel =33 and tclass = 5 then vess = 4  ;
if vessel =70 and tclass = 5 then vess = 5  ;
if vessel =39 and tclass = 6 then vess = 6  ;
if vessel =16 and tclass = 6 then vess = 7  ;
if vessel =32 and tclass = 6 then vess = 8  ;
if vessel =33 and tclass = 6 then vess = 9  ;
if vessel =14 and tclass = 6 then vess = 10 ;
if vessel =65 and tclass = 6 then vess = 11 ;
if vessel =5  and tclass = 6 then vess = 12 ;
if vessel =70 and tclass = 6 then vess = 13 ;
if vessel =21 and tclass = 7 then vess = 14 ;
if vessel =1  and tclass = 7 then vess = 15 ;
if vessel =77 and tclass = 7 then vess = 16 ;
if vessel =13 and tclass = 7 then vess = 17 ;
if vessel =30 and tclass = 7 then vess = 18 ;
if vessel =15 and tclass = 7 then vess = 19 ;
if vessel =31 and tclass = 7 then vess = 20 ;
if vessel =25 and tclass = 7 then vess = 21 ;
if vessel =4  and tclass = 7 then vess = 22 ;
if vessel =2  and tclass = 7 then vess = 23 ;
if vessel =5  and tclass = 7 then vess = 24 ;
if vessel =3  and tclass = 7 then vess = 25 ;
if vessel =65 and tclass = 7 then vess = 26 ;
if vessel =6  and tclass = 7 then vess = 27 ;

if vess = 7 then vess = 8 ;
if vess = 10 then vess = 11 ;
if vess = 15 then vess = 16 ;
if vess = 18 then vess = 19 ;
if vess = 21 then vess = 22 ;
if vess = 24 then vess = 25 ;
if vess = 26 then vess = 27 ;

if vess = 8 then vess = 9 ;
if vess = 11 then vess = 12 ;
if vess = 16 then vess = 17 ;
if vess = 22 then vess = 23 ;

if vess = 19 then vess = 20 ;

if vess = 25 then vess = 27 ;



if month = 6 then month = 7 ;
if month = 10 then month = 11 ;
```