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The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2013

by

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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; Canadian regulations set a separate shrimp TAC for the part of this Division lying east of 60°30'W (Canadian SFA1). 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.

Catches 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. In 2009 and 2010 the catches were near 135 000 tons decreasing to 124 000 tons in 2011, with a further decrease to 116 000 tons in 2012.

Canadian catches in recent years have decreased from about 7000 tons in 2003–05 to 2000 tons in 2007, with no fishery at all in 2008 and insignificant catches in 2009. In 2010 the Canadian catch was about 6 000 tons and in 2011 about 1 300 tons and in 2012 merely 5 tons.

The 2013 Greenland catch has been projected at 100 000 tons; there appears to be little or no fishing in Canadian SFA1.

The Total Allowable Catch (TAC) for the stock advised for 2008–10 was 110 000 tons live-caught weight, a reduction from 130 000 tons advised for 2004–07. The advised TAC for 2011 was 120 000 tons. Consequent to a change in

assessment method the advised TAC was decreased to 90 000 tons for 2012. The advised TAC for 2013 was 80 000 tons.

Since 2012 a joint TAC for Subarea 1 and Div. 0A has been set by the Greenland Government, where 3.1 % of the joint TAC is reserved for Canada. In 2013 the joint TAC was set at 90 000 tons; of this, 2 737 tons were set aside for Canada resulting in an enacted TAC for Greenland of 87 263 tons. Canada set a TAC of 15 504 tons for its fishery in SFA1 for 2013. The fishery in Greenland is regulated by individual quotas. Quota drawdowns have until recently been based not on live-caught weight, but on traded weight, less than the logbook recorded catch by an allowance for crushed and broken shrimps.

Reported discard and by-catch of other species are low, but investigations have shown that by-catch is probably under-reported, even by on-board observers.

The distribution of fishery catches of *P. borealis* by depth has changed over the most recent 20 years. Between 1991–94 and 2003–06 the median catch depth decreased by 100 m, or 30%.

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. Since 2008 the standardised CPUE index has been decreasing. In 2012 standardised CPUE was 83 % of the 2008 value and in 2013 the index was down with 28 % (based on part-years-data) compared to the 2008 value.

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 again concentrated in Division 1B—more so than at any time since the late 1980s. Since 2005 the catches taken in Division 1B has averaged 50% of the total catch. Since 1990 the proportion of the catch taken in Division 1A has been less than 15%. The proportion af the total catch taken in Division 1A has been rising since 2006 constituting between 35% and 40% of total catch in the years 2009-2012. This is especially due to increased fishing in statistical Area 2 (Disko Bay area), statistical Area 3 (Disko Bay mouth) and statistical Area 0 (Offshore between 69°12’5 N and 74° N). Even though CPUEs remain high, if the area that the stock is spread over is shrinking, then its biomass could also be decreasing.

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 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 SA 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, 1, 7, 10 and 2 ships fishing in 2008–2012. 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 (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 (43%) and the offshore (57%) quotas.

Material and Methods

<u>Fleet Data</u>

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, or 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 (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 Denise Croft, 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.

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); data from statistical Area 0 (for all years) was included in the analysis for the first time in 2013. The multiplicative model was linearised as as:

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

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° 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.

The ‘Offshore’ index covers the most recent 27 years of the offshore production fishery in NAFO Div. 1A to 1F. 50 vessels were included providing data since 1987, grouped into 22 groups of 1–4 vessels with similar estimated effects. Statistical Areas 0 and 3–12 were included in the analysis; statistical Areas 7, 8 and 9 were grouped. The month effect was reduced to 8 levels by grouping adjacent months with similar indices.

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 15 groups of 1-6 vessels. The month effect was reduced to 10 levels by grouping adjacent months with similar indices.

A consolidated file of data on 61 624 hauls from the Canadian fishery in SFA 1 was available for 1979 through 2012. 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 1976–2012, 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

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

the A_{yf}—GLM-estimated year effects for fleet f—being considered to be Normally distributed about a series of overall year effects $\bar{A}_y$ 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, Greenland coastal and Canadian fleets were assigned as 0.36, 0.46, 0.13 and 0.05. The year effects $\bar{A}_y$ 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 2011 for the period 1991–2010, in 5 4-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 is reported as improved in 2013 (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. 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 little less than 2/3 since 1997, but its effective size has decreased by only 1/3, 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. 2013) 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 2006 survey biomass has decreased 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. 2013). 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. 2013).

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 110 000 hr as a result of management measures, reduced activity in Div. 0A (Table 1) and a generally increased fishing efficiency. The increase in the overall unstandardised effort reported, in particular in Div. 1A from 1996 to 1997 (Fig. 3), is due to the imposition in 1997 of logbook recording on vessels below 50 tons, until then exempt.

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, but has been decreasing since then by approximately 2% a year.

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. 5), 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). Catch has also become more concentrated and the southern areas (NAFO Divs. 1C–1F) accounted for less than 25% of total catch in 2005–09, and barely over 15% in 2010–2012 (Table 3, Table 4a). 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 63% of the catch was taken in NAFO Divisions 1C–1F. From 2005 to 2009 75% of the catch, and since 2010 nearly 85%, has been taken in NAFO Divisions 1A–1B.

In recent years up 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 (Disko Bay), which has yielded between 15 and 25% of the total catch in recent years (Fig. 7a, 7b), statistical Area 3 (Disko Bay mouth), which has yielded between 20 and 25% of the total catch in recent years (Fig. 7a and 7c) and statistical Area 0 (Offshore between 69°12'5 N and 74° N), which in recent years has yielded between 6 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 inBurmeister et al. 2013). An increasing concentration of the stock and the fishery would be 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.

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 20 % of the catches are taken from December through February, 25 % in March to May, 30 % in June to August and 25 % in September to October (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 100 m shallower at 246.5 m. The median depth for the offshore and the coastal fleets changed by almost exactly the same 100 m. In 2007–2010 the median catch depth for the offshore fleet increased again, nearly back to where it was in 1999–2002, but the depth profile for catches in the coastal fleet stayed exactly the same as in 2003–2006. In 2011, this movement of the stock into shallower water did not seem to be continuing, but to have reached a plateau (Kingsley 2011).

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 1975–2013 (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 1.5% 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.

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

From 1995 to 2013 logbook reports included overall annual catches of *P. montagui* in the range of about 100 to 7200 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 7% (on part-year's data) (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 (Siegstad and Hammeken Arboe 2011). 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. 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 13 % in 2012 and 27 % in 2013 (based on part years data) compared to the catch rate from 2004 to 2008. The catch rate for the inshore fleet reached its highest level in 2007 to 2008 and has been decreasing since then, being down with 18 % in 2012 and 23 % in 2013 compared to the catch rate in 2007 and 2008.

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. Since then the unified CPUE index has been decreasing. In 2012 the decrease was 17 % and in 2013 (based on part years data) the decrease was 28 % compared to the 2008 value.

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.

CPUE does not truly measure biomass, it only measures density in fished areas; and if the fished areas are contracting it is difficult not to be concerned that the stock biomass might also be on its way down. Between 1995–99 and 2005–2009 the effective number of NAFO Divisions providing catches for the Greenland fleet has decreased to below 60% of its peak value, so that although densities in the fished areas remain high, the extent of the fishery, and therefore the likely biomass, is reduced. The same is true when the distribution by statistical Areas is analysed in the same way. And this contraction of the fishery appears to have continued since 2009 (Fig. 6). This reduction in the 'effective number of areas' does not translate directly into a reduction in the fished area, but it exceeds the increase in the CPUE over the same period. A decreasing area of distribution of the stock is consistent with changes in the research survey estimate of fishable biomass, which since 2003 has decreased, overall by 50% from its then value (Burmeister et al 2013). Catch rates in the fishery in recent years have been high although decreasing since

2009, but we hear from fishermen that high catch rates are coming from concentrations of shrimps that are restricted, sparse and local, so they might well not be a reflection of an abundant stock.

In 2013, therefore, the fishery has continued to contract, and while overall the CPUE index has declined from the levels of 2005–08, there is reason to suspect that the decrease in CPUE does not fully reflect a decrease in the fishable biomass.

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Table 1a. *P. borealis* in W. Greenland: Catch limits, effort, catch, and CPUE, 1970–1989.

Year	**TAC (t)**			**Catch (t)**					**Effort**				**CPUE**			
	SA 1*	**Div. 0A**	**Total**	**SA 1**			**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	0.44	762	-	766	1.66
1977	-	-	36000	42578	8580	51158	457	51615	73.1	-	73	0.39	699	-	706	1.56
1978	-	1000	41000	33835	8360	42195	122	42317	84.2	-	84	0.41	501	-	503	1.23
1979	-	2000	31500	32852	8250	41102	1732	42834	72.4	-	72	0.46	568	-	592	1.11
1980	-	2500	32000	44916	8250	53166	2726	55892	80	11.6	92	0.50	665	235	610	1.34
1981	35000	5000	40000	40295	8250	48545	5284	53829	88.2	16.6	105	0.51	551	318	514	1.27
1982	34800	5000	39800	43979	8250	52229	2064	54293	81.1	8.1	89	0.40	644	256	609	1.61
1983	34625	5000	39625	42553	8250	50803	5413	56216	89	26.1	115	0.47	571	208	488	1.42
1984	34925	5000	39925	42414	8250	50664	2142	52806	85	-	*85*	0.47	596	-	*621*	1.34
1985	42120	6120	48240	54889	8250	63139	3069	66208	129.1	23.6	153	0.55	489	130	433	1.43
1986	42120	6120	48240	65623	8250	73873	2995	76868	133.4	-	*133*	0.61	554	-	*576*	1.49
1987	40120	6120	46240	64222	7613	71836	6095	77931	137.1	17.7	155	0.60	524	344	503	1.56
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, 1990–2013.

Year	TAC (t)			Catch (t)					Effort				CPUE			
	SA 1*	**Div. 0A**	**Total**	**SA 1**			**Div. 0A**	**Total**	**SA 1**	**Div. 0A**	**Total**	**Total**	**SA 1**	**Div. 0A**	**Total**	**Total Std.**
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			Std. (index)	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	66818	17884	84701	6788	91489	230.8	19.6	250	1.06	367	346	365	1.03
1992	44200	8500	52700	75341	22653	97994	7493	105487	234.2	16.6	251	1.12	418	451	421	1.12
1993	40600	8500	49100	65894	19627	85522	5491	91013	206.1	12.2	218	0.99	415	450	417	1.09
1994	42300	8500	50800	68109	19930	88039	4766	92805	209.8	15.3	225	1.01	420	312	412	1.09
1995	39500	8500	48000	66955	18072	85027	2361	87388	184.7	7.3	192	0.87	460	322	455	1.20
1996	63922	8500	72422	62368	19095	81463	2632	84095	164.6	9	174	0.79	495	293	484	1.26
1997	64600	8500	74800	62743	14868	77611	517	78128	184.9	1.3	186	0.76	420	412	420	1.23
1998	60729	7650	68379	69156	10406	79562	933	80495	152.7	2.6	155	0.68	521	353	518	1.41
1999	73500	9350	82850	71203	18948	90152	2046	92198	164.7	5.1	170	0.68	547	398	543	1.61
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	0.72	627	602	626	1.70
2002	91150	12040	103190	107195	21729	128925	6247	135172	173.3	9	182	0.82	744	695	741	1.96
2003	101000	14167	115167	104237	18799	123036	7137	130173	124.4	8.2	133	0.74	989	873	982	2.11
2004	135352	14167	149519	121627	20684	142311	7021	149332	130.0	12.3	142.3	0.76	1095	569	1049	2.33
2005	134000	18452	152452	128051	21927	149978	6921	156899	129.4	9.3	138.8	0.77	1159	744	1131	2.42
2006	134000	18380	152380	127712	25476	153188	4127	157315	126.1	4.7	130.8	0.79	1215	884	1203	2.38
2007	134000	18417	152417	116240	26005	142245	1945	144190	114.0	2.2	116.2	0.69	1248	872	1241	2.48
2008	127300	18417	145717	116649	37240	153889	0	153889	119.1	-	119.1	0.72	1292	-	1292	2.56
2009	114570	18417	132987	95361	39668	135029	429	135458	119.1	-	119.1	0.71	1134	-	-	2.28
2010	114570	18417	132987	92617	35491	128108	5882	133990	118.5	5.8	124.3	0.71	1081	1017	1078	2.24
2011	124000	18417	142417	77217	45438	122655	1330	123985	107.7	2.5	110.2	0.64	1139	527	1125	2.31
2012	101675	16921	118596	74945	41018	115963	12	115975	110.7	-	110.7	0.65	1047	-	1048	2.13
2013[#]	87263	15504	102767	65892	34108	100000	0	100000	100.1	-	100.1	0.64	999	-	999	1.85

* 1981-1995 TAC for offshore only.

[#] Projections based on information received from GFLK and DFO.

Table 2. *P. borealis* in W. Greenland: 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	0.119							1.659	0.200
1977	1.556	0.080							1.558	0.135
1978	1.230	0.079							1.229	0.133
1979	1.113	0.077							1.112	0.130
1980	1.340	0.080							1.340	0.135
1981	1.266	0.075							1.266	0.126
1982	1.611	0.080							1.612	0.134
1983	1.423	0.079							1.422	0.132
1984	1.338	0.077							1.339	0.128
1985	1.432	0.075							1.431	0.126
1986	1.490	0.075							1.491	0.125
1987	1.787	0.078	1.531	0.032			—	—	1.559	0.045
1988	1.465	0.077	1.127	0.028	1.176	0.053	—	—	1.156	0.038
1989	1.086	0.086	1.070	0.027	0.888	0.040	1.114	0.110	1.050	0.036
1990	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
1991			1.039	0.025	0.971	0.037	0.795	0.095	1.028	0.034
1992			1.127	0.026	1.061	0.037	0.861	0.103	1.117	0.036
1993			1.089	0.026	1.118	0.036	0.935	0.098	1.091	0.036
1994			1.113	0.026	1.005	0.036	0.652	0.095	1.093	0.036
1995			1.242	0.027	1.016	0.036	0.765	0.102	1.203	0.037
1996			1.308	0.029	1.064	0.038	0.616	0.100	1.262	0.040
1997			1.258	0.030	1.089	0.037	—	—	1.228	0.042
1998			1.440	0.033	1.327	0.041	0.609	0.135	1.414	0.045
1999			1.639	0.035	1.514	0.038	0.880	0.129	1.607	0.046
2000			1.740	0.038	1.862	0.039	1.067	0.137	1.758	0.049
2001			1.702	0.040	1.746	0.038	1.106	0.116	1.704	0.051
2002			1.947	0.035	2.031	0.036	1.318	0.107	1.957	0.046
2003			2.133	0.036	2.045	0.037	1.579	0.113	2.109	0.047
2004			2.403	0.036	2.167	0.036	1.180	0.107	2.331	0.047
2005			2.551	0.035	2.063	0.036	1.261	0.117	2.422	0.046
2006			2.426	0.035	2.233	0.037	1.443	0.141	2.377	0.047
2007			2.482	0.037	2.500	0.037	1.388	0.141	2.477	0.047
2008			2.568	0.037	2.522	0.036	—	—	2.557	0.048
2009			2.329	0.039	2.153	0.036	—	—	2.284	0.050
2010			2.325	0.038	1.988	0.037	2.055	0.182	2.239	0.050
2011			2.340	0.040	2.239	0.037	0.250	0.305	2.306	0.051
2012			2.151	0.040	2.046	0.037	—	—	2.125	0.051
2013			1.823	0.051	1.929	0.045	—	—	1.851	0.064

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

Table 3. *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
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
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	8.2	32.6	41.6	17.2	17.5	5.3	10.1	873	427	1018	1440	1324	1512	1061
2004	7.0	13.8	55.0	33.6	24.6	5.7	9.6	12.3	33.4	51.2	18.1	13.3	2.8	11.2	569	413	1074	1853	1857	2019	856
2005	6.9	11.3	73.0	33.6	18.0	5.4	8.7	9.3	23.1	58.6	16.5	10.6	5.2	15.5	744	488	1244	2039	1700	1039	565
2006	4.1	13.8	81.0	23.7	19.3	9.8	5.5	4.7	21.5	60.6	12.3	11.2	10.0	10.6	884	642	1336	1932	1730	984	519
2007	1.9	26.5	84.8	9.1	12.0	8.7	1.1	2.2	27.2	63.3	5.6	8.6	7.0	2.3	872	973	1340	1635	1406	1241	473
2008	0.0	42.3	96.1	6.7	4.4	4.4	0.1	-	36.3	71.4	4.3	3.1	3.9	0.1	-	1165	1345	1562	1410	1119	1170
2009	0.4	48.1	71.9	5.0	6.5	3.6	0.0	-	46.5	63.1	3.6	3.8	2.1	0.0	-	1034	1140	1377	1702	1738	-
2010	5.9	50.8	63.4	6.2	6.6	1.1	0.0	5.8	55.2	56.5	3.2	3.1	0.5	0.0	1017	922	1122	1928	2132	2123	-
2011	1.3	46.9	54.2	7.9	10.9	2.7	0.0	2.5	56.4	41.6	3.7	5.0	1.0	0.0	527	832	1303	2127	2176	2852	-
2012	0.0	45.7	45.3	6.3	12.0	6.4	0.3	0.0	56.2	42.7	3.4	5.5	2.7	0.2	-	812	1061	1851	2187	2364	-
2013*	0.0	24.5	45.8	8.8	13.2	6.6	1.1	0.0	37.9	44.2	5.6	8.0	3.9	0.5	-	646	1035	1571	1659	1705	-

*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	10–13
1A	9.2	23.4	12.8	8.1	12.1	19.4	37.4
1B	72.1	56.1	38.3	29.1	33.7	55.4	44.6
1C	17.4	13.9	21.5	17.2	20.0	10.6	5.9
1D	1.3	6.4	21.5	26.1	19.0	8.2	8.7
1E	0.0	0.0	4.0	10.2	6.2	4.3	3.3
1F	0.0	0.2	2.1	9.3	9.0	2.1	0.2
Diversity	1.8	2.5	3.9	4.8	4.6	2.7	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	10–13
1A	9.3	30.5	15.9	16.7	24.9	25.4	48.3
1B	71.4	49.9	37.7	32.9	34.0	52.2	42.1
1C	18.1	12.6	21.9	16.2	14.1	7.0	3.4
1D	1.1	6.0	20.0	21.0	15.1	6.1	4.5
1E	0.0	0.0	2.4	6.5	4.1	4.6	1.6
1F	0.0	0.9	2.1	6.7	7.8	4.7	0.1
Diversity	1.8	2.8	3.9	4.6	4.4	2.9	2.4

[1]unstandardised single-trawl-equivalent time

Table 5. *P. borealis* in W. Greenland: Catch by month 1976–2013, 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	3337	3152	3553	5311	4768	9021	8382	7412	9571	14932	4401	3029
1987	2979	1731	4748	6167	7616	8168	9707	10340	7869	10724	4970	2911
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	15255	14472	12182	12523	10702	10385
2011	10229	9270	11831	10877	10480	10265	12522	9619	8883	10221	11471	8317
2012	9399	8623	5839	10089	10780	10026	11486	11514	9176	9684	10728	8632
2013*	8008	6341	8487	9366	8866	8302	-	-	-	-	-	-

* 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 (t)	discard (%)	discard (t)	discard (%)	landed (t)
1975	0	0	0	0	0
1976	0	0	0	0	0
1977	0	0	23	0	0
1978	0	0	27	0.1	0
1979	0	0	151	0.4	0
1980	0	0	186	0.3	0
1981	0	0	725	1.5	0
1982	0	0	788	1.5	0
1983	0	0	964	1.9	0
1984	0	0	1311	2.6	0
1985	149	0.2	1501	2.4	0
1986	110	0.1	1639	2.2	0
1987	182	0.3	885	1.2	0
1988	209	0.3	1067	1.6	0
1989	197	0.3	1403	1.9	0
1990	263	0.3	1261	1.6	0
1991	407	0.5	2053	2.4	0
1992	335	0.3	2162	2.2	0
1993	250	0.3	1906	2.2	0
1994	331	0.4	2671	3	5
1995	476	0.6	2700	3.2	562
1996	324	0.4	2712	3.3	773
1997	310	0.4	2327	3	422
1998	314	0.4	2183	2.7	1253
1999	197	0.2	7	0	4
2000	268	0.3	685	0.7	305
2001	382	0.4	1122	1.1	882
2002	649	0.5	1274	1	225
2003	638	0.5	1291	1	967
2004	762	0.5	1044	0.7	831
2005	753	0.5	982	0.7	512
2006	865	0.6	1178	0.8	1444
2007	741	0.5	2085	1.5	2003
2008	860	0.6	1116	0.7	89
2009	710	0.5	1321	1.0	53
2010	739	0.6	1426	1.1	1168
2011	720	0.6	1109	0.9	2324
2012	587	0.5	1039	0.9	3121
2013	545*	0.5*	648	0.6	7157

[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.

* 2013: projected from part-year's data.

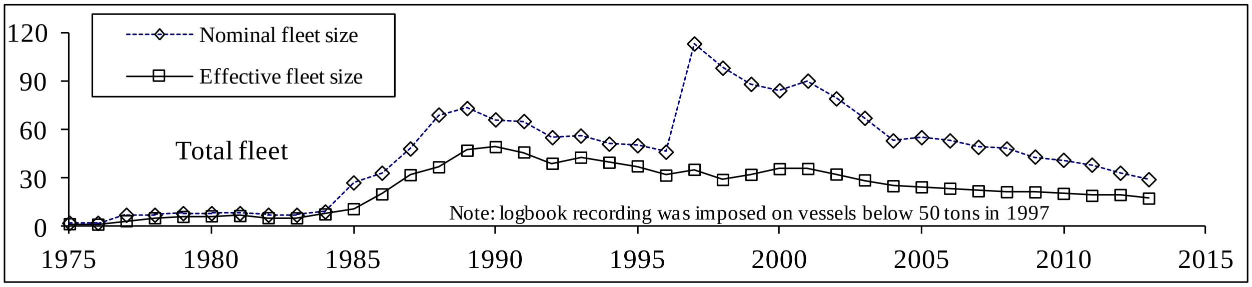

Fig. 1a. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland trawler fleet, 1975–2013, from logbook records.

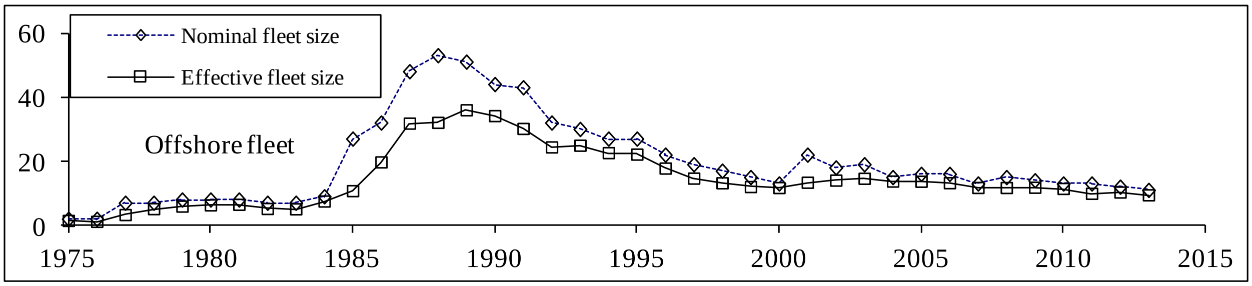

Fig. 1b. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland offshore trawler fleet, 1975–2013, from logbook records.

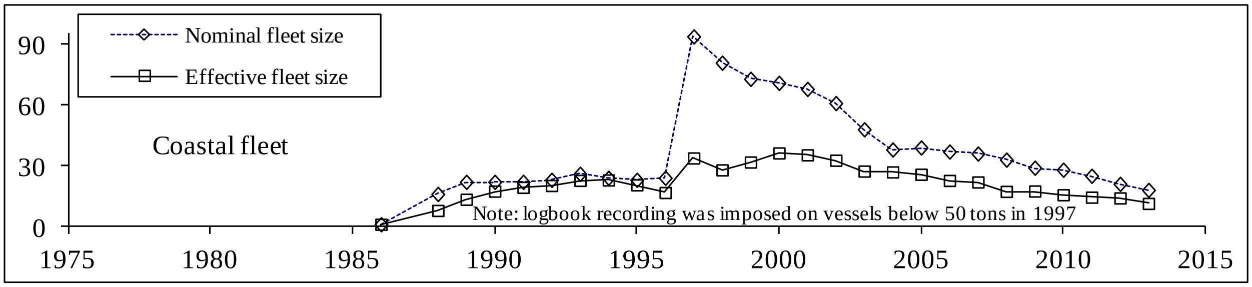

Fig. 1c. *P. borealis* in W. Greenland: Nominal and effective sizes of the Greenland coastal trawler fleet, 1986–2013, from logbook records.

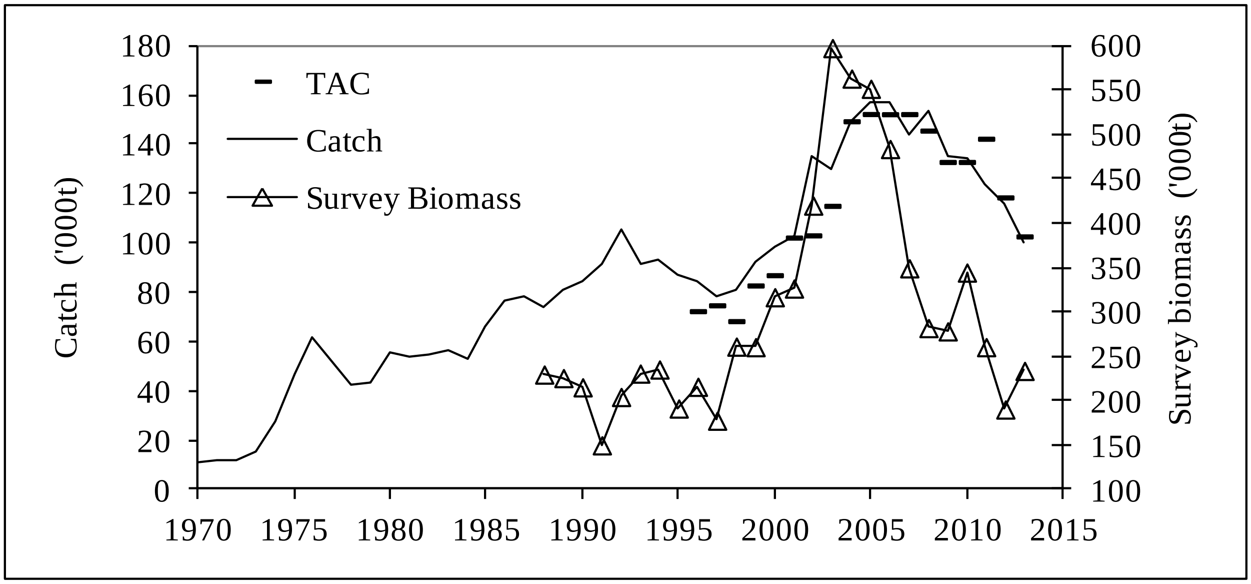

Fig. 2. *P. borealis* in W. Greenland: Catches in NAFO Subarea 1 and Canadian SFA 1, 1970–2013; 2013 catch estimate is based on forecasts from GFLK and DFO.

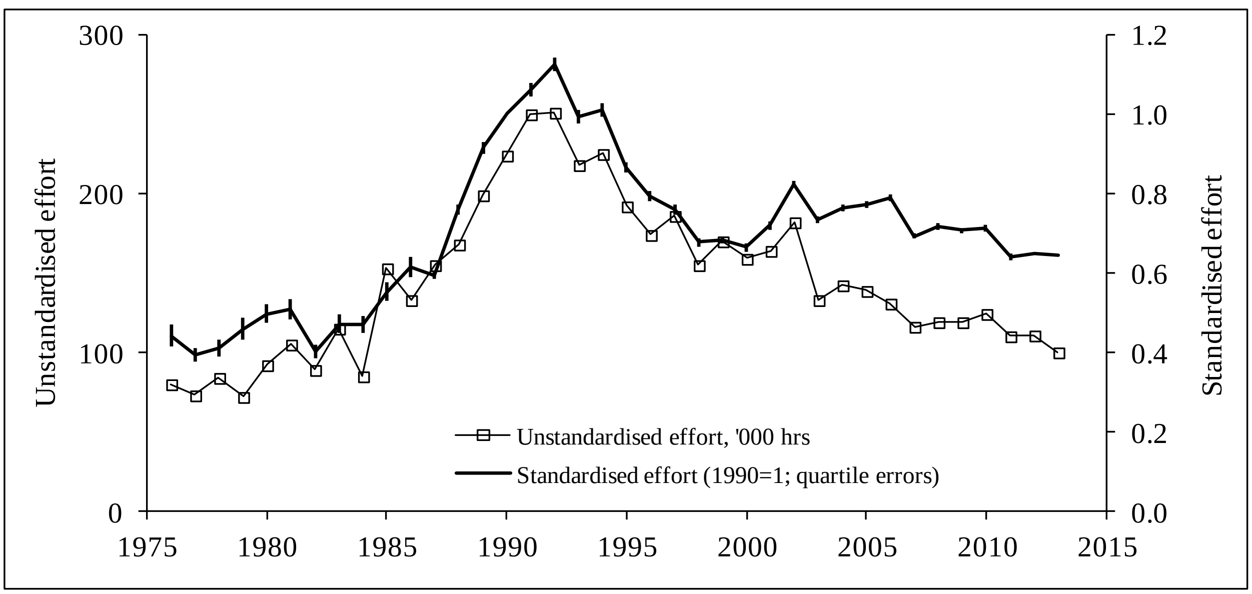

Fig. 3. *P. borealis* in W. Greenland: Fishing effort applied in NAFO Subarea 1 and Canadian SFA 1, 1970–2013.

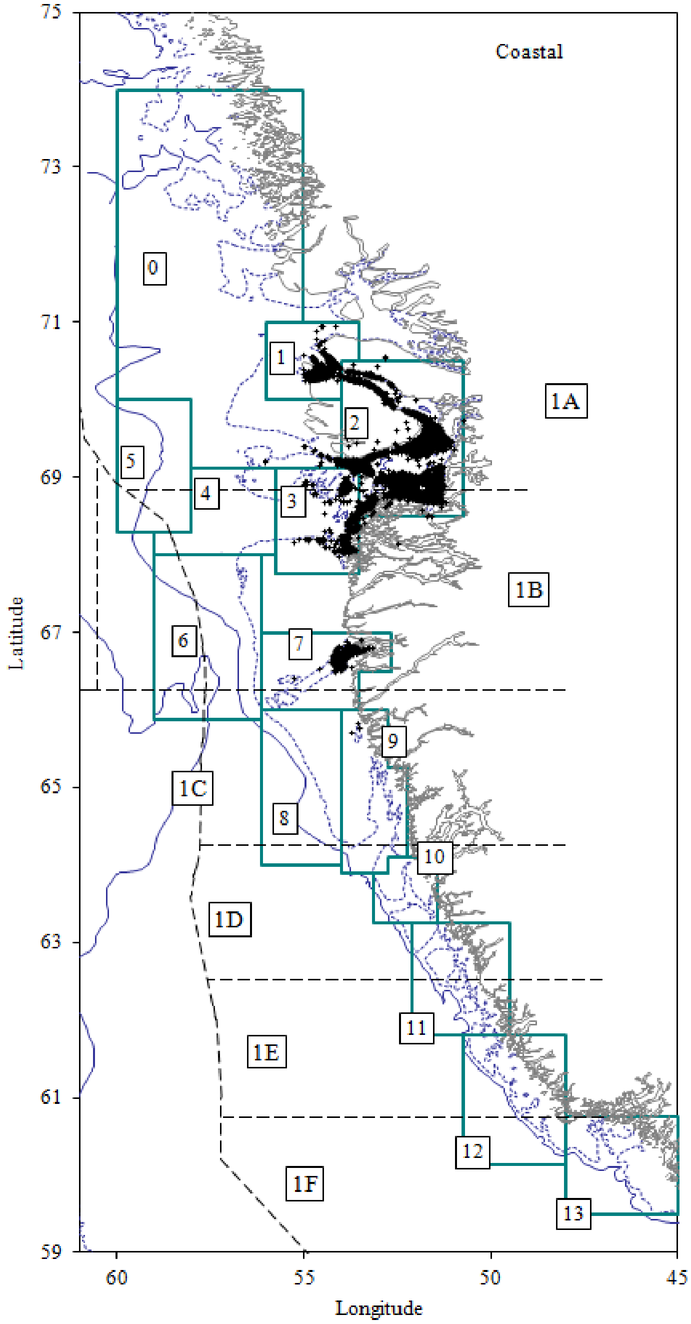

Fig. 4a. *P. borealis* in W. Greenland: positions of 10 758 hauls by the Greenland coastal fleet in NAFO Subarea 1 from July 2012 through June 2013.

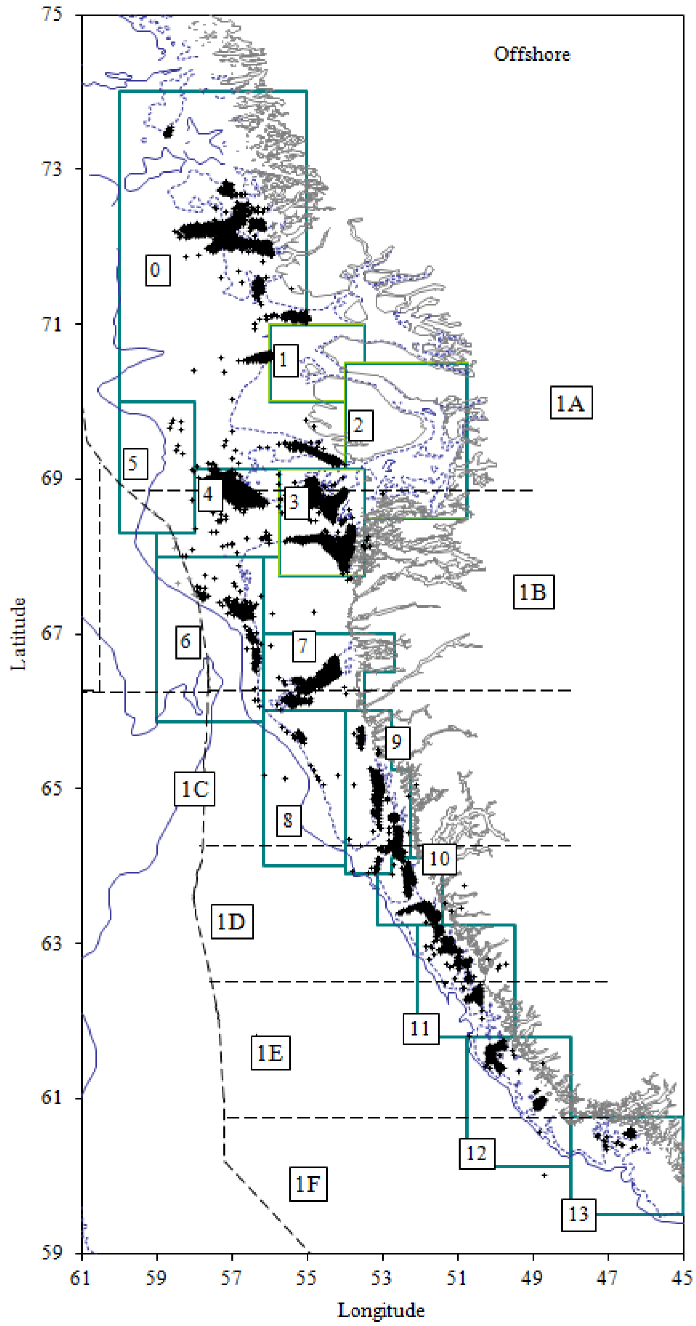

Fig. 4b. *P. borealis* in W. Greenland: positions of 12 874 hauls by the Greenland offshore fleet in NAFO Subarea 1 from July 2012 through June 2013.

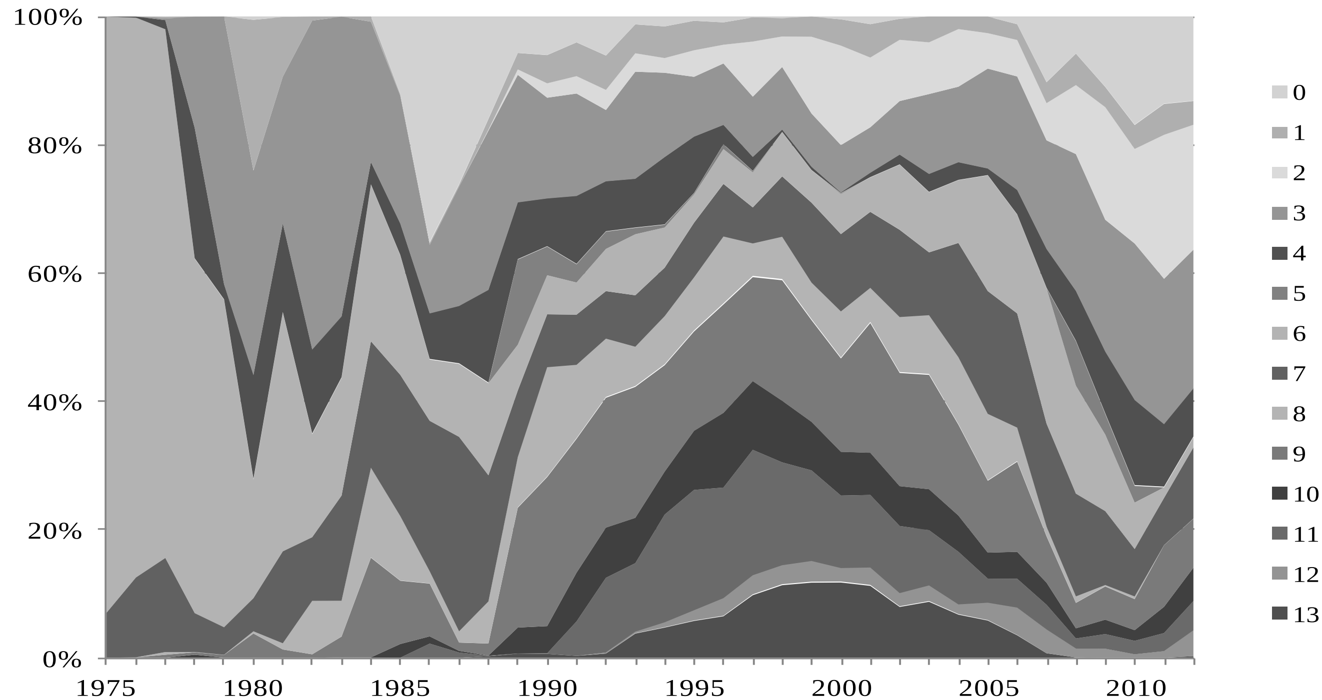

Fig. 5a. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between statistical Areas in Greenland waters, 1975-2012. (The light band that starts broad on the left-hand side is Area 6; the light band at the top is Area 0, the dark wedge at the very bottom from 1992 to 2007 is Area 13.)

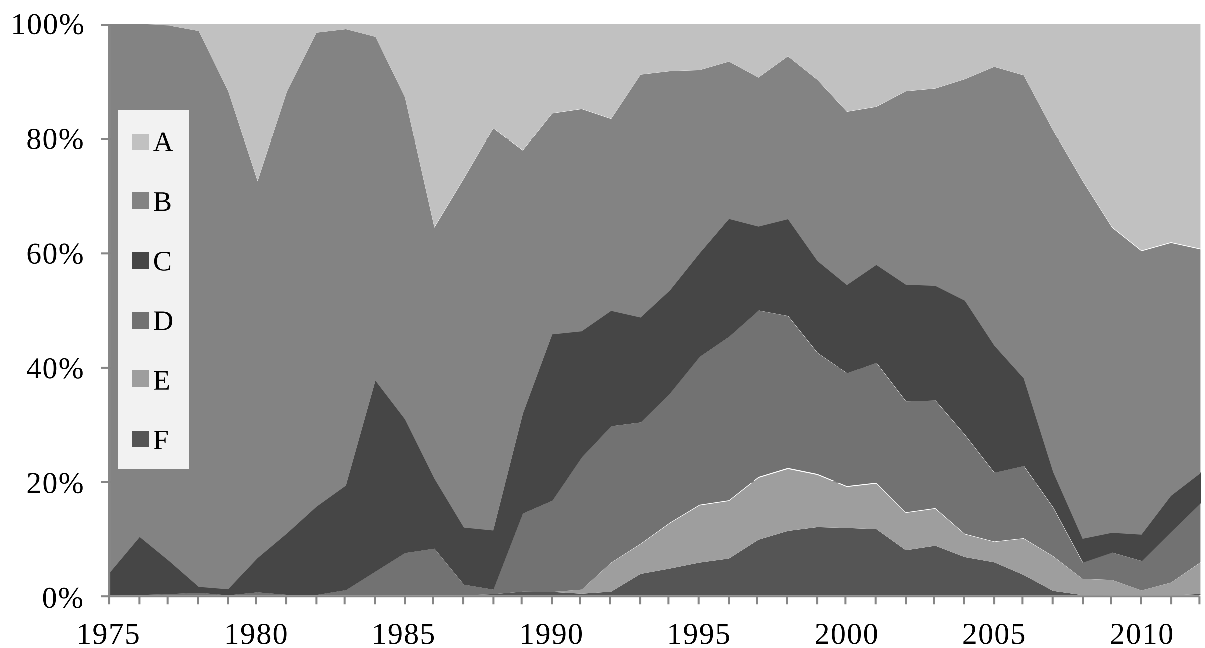

Fig. 5b. *P. borealis* in W. Greenland: Distribution of the logbook-recorded catch between NAFO Divisions in Subarea 1, 1975-2012.

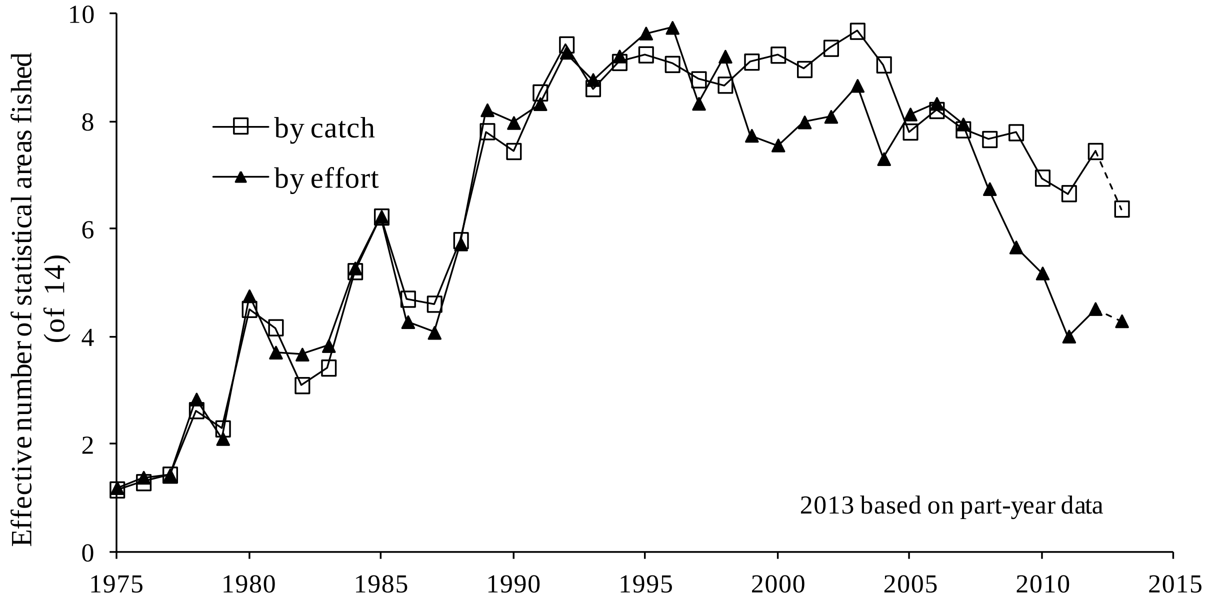

Fig. 6. *P. borealis* in W. Greenland: diversity indices for the distribution of logbook-recorded catch between statistical Areas in Greenland waters, 1975–2013.

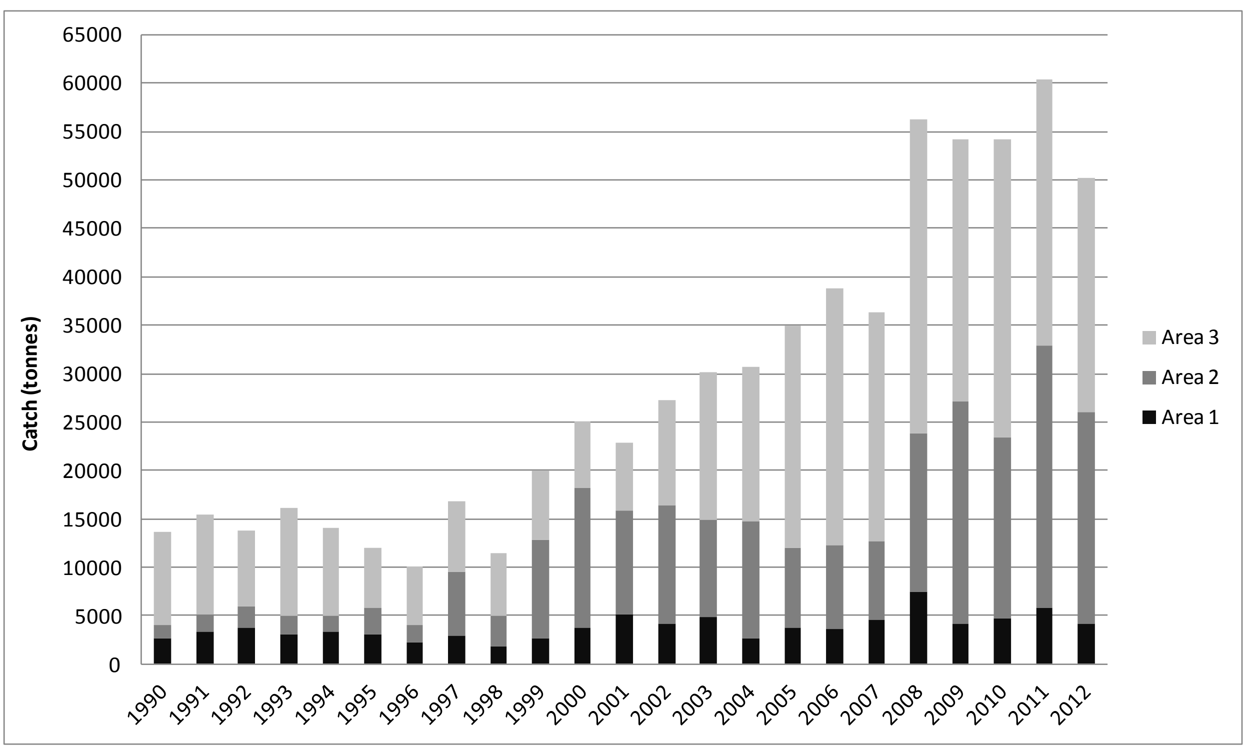

Fig. 7a. *P. borealis* in W. Greenland: distribution of catches in the Disko Bay Area (statistical Areas 1, 2 and 3) 1990–2012.

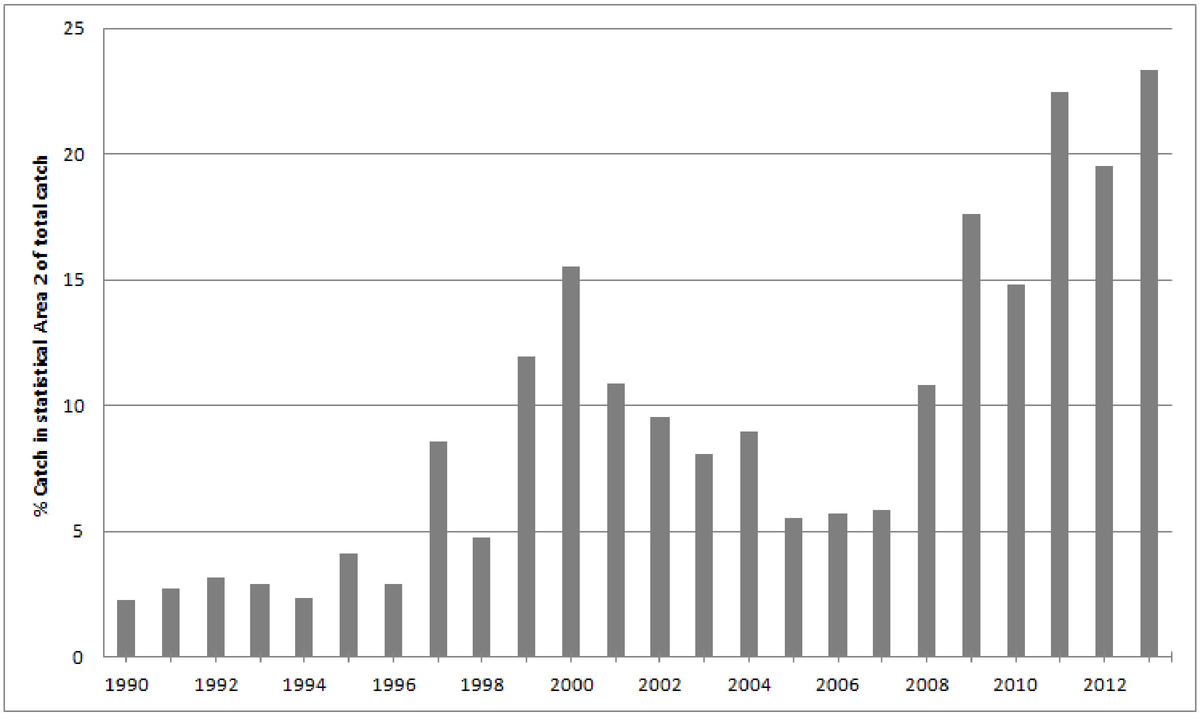

Fig. 7b. *P. borealis* in W. Greenland: catches taken in statistical Area 2 as a percentage of total catches, 1990–2012.

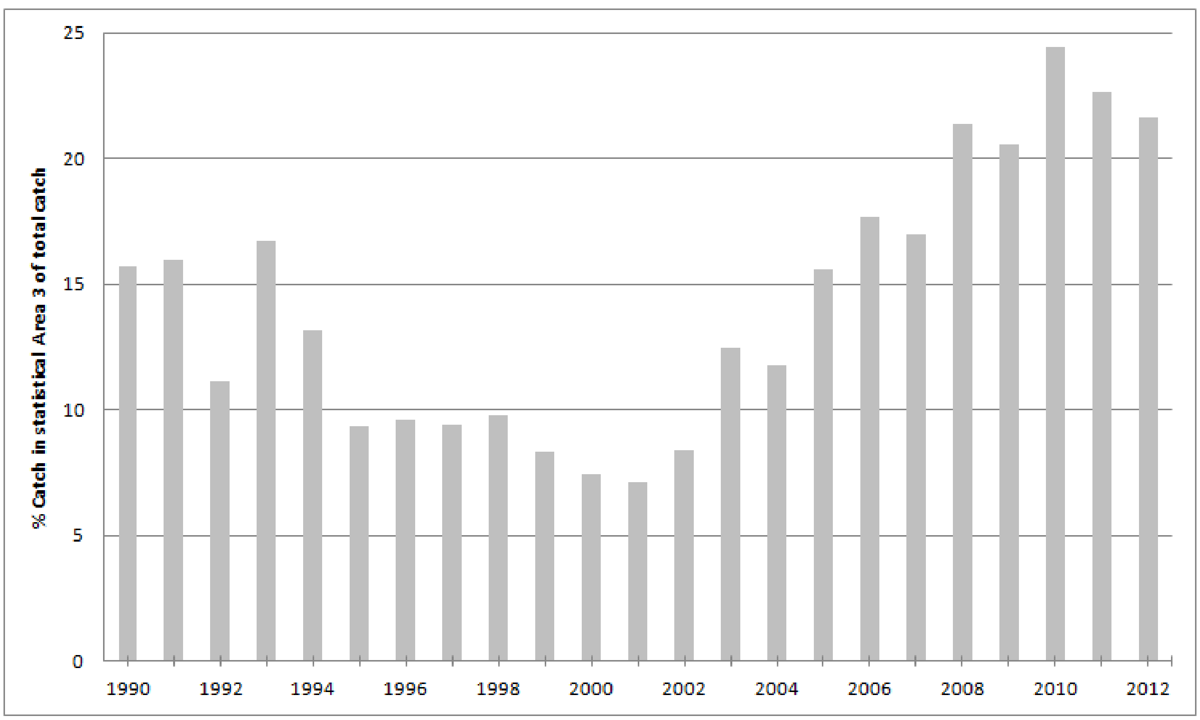

Fig. 7c. *P. borealis* in W. Greenland: catches taken in statistical Area 3 as a percentage of total catches, 1990–2012.

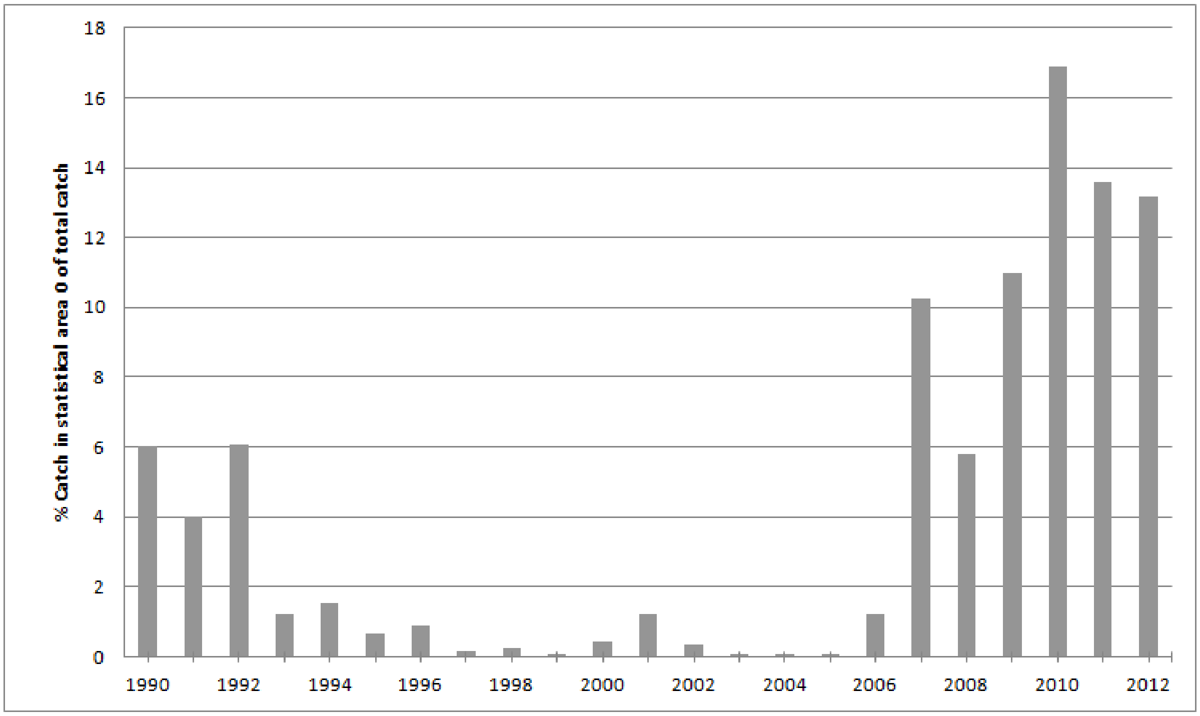

Fig. 8. *P. borealis* in W. Greenland: catches taken in statistical area 0 as a percentage of total catches, 1990–2012.

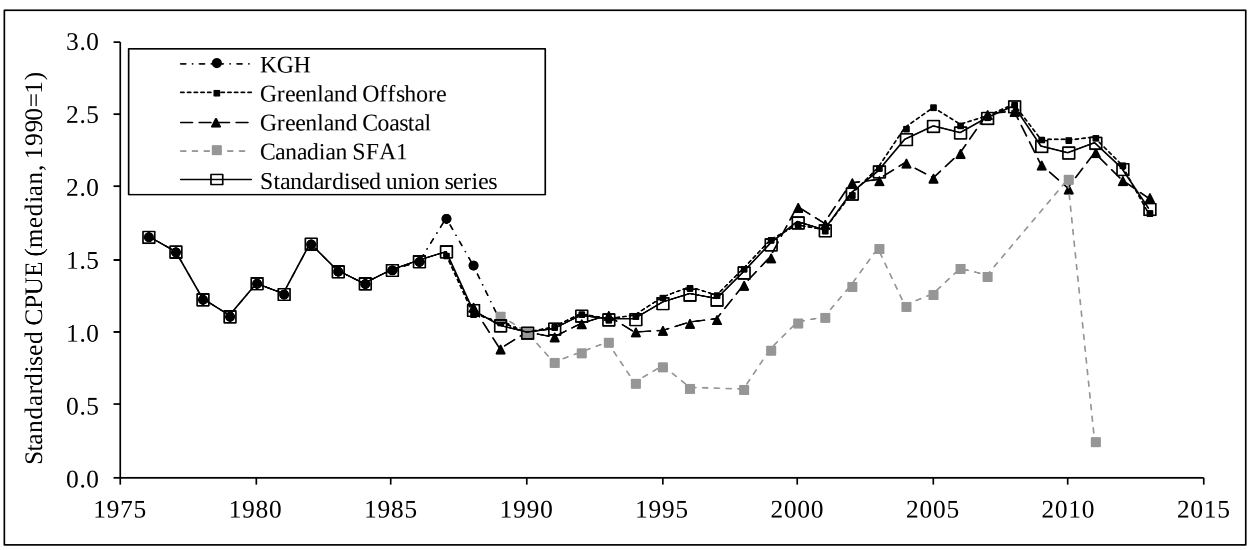

Fig. 9. *P. borealis* in W. Greenland: standardised (1990=1) CPUE series from 4 fleets and a standardised union series 1976–2013.

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

```
                              Greenland Offshore fleet: Areas 0 and 3 - 12                  14:46 Saturday, August 24, 2013

                    Group March w. April, June w. July and September w. October w. November

                                Group Area 7 w. Area 8 w. Area 9

                                        The GLM Procedure

                                     Class Level Information

Class       Levels  Values

vessel          22  hh02 hh03 hh06 hh10 hh13 hh15 hh18 hh21 hh23 hh24 hh25 hh26 hh28 hh31 hh32 hh34 hh38 hh42 hh45 hh46 hh48 hh50

year            27  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 2090

MONTH            8  1 2 4 5 7 8 11 12

AREA             9  0 3 4 5 6 9 10 11 12

hold             2  1 2

                             Number of Observations Read        7200
                             Number of Observations Used        7200
```

Dependent Variable: LNCPUE

Weight: hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	62	179482.0310	2894.8715	709.67	<.0001
Error	7137	29112.9334	4.0792		
Corrected Total	7199	208594.9644			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.860433	81.34269	2.019692	2.482942

Source	DF	Type I SS	Mean Square	F Value	Pr > F
vessel	21	157752.4330	7512.0206	1841.56	<.0001
MONTH	7	2246.8718	320.9817	78.69	<.0001
AREA	8	5572.8222	696.6028	170.77	<.0001
year	26	13909.9039	534.9963	131.15	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
vessel	21	22415.06691	1067.38414	261.67	<.0001
MONTH	7	1723.83502	246.26215	60.37	<.0001
AREA	8	2753.55033	344.19379	84.38	<.0001
year	26	13909.90393	534.99631	131.15	<.0001

Dependent Variable: LNCPUE
Weight: hauls

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
hh02 v hh03	1	41.568159	41.568159	10.19	0.0014
hh03 v hh06	1	20.828218	20.828218	5.11	0.0239
hh06 v hh10	1	305.958170	305.958170	75.01	<.0001
hh10 v hh13	1	61.597245	61.597245	15.10	0.0001
hh13 v hh15	1	7.133700	7.133700	1.75	0.1861
hh15 v hh18	1	6.033565	6.033565	1.48	0.2240
hh18 v hh21	1	5.974743	5.974743	1.46	0.2262
hh21 v hh23	1	38.717925	38.717925	9.49	0.0021
hh23 v hh24	1	16.281608	16.281608	3.99	0.0458
hh24 v hh25	1	4.231134	4.231134	1.04	0.3085
hh25 v hh26	1	11.454219	11.454219	2.81	0.0938
hh26 v hh28	1	27.603459	27.603459	6.77	0.0093
hh28 v hh31	1	72.820137	72.820137	17.85	<.0001
hh31 v hh32	1	20.422938	20.422938	5.01	0.0253
hh32 v hh34	1	22.993552	22.993552	5.64	0.0176
hh34 v hh38	1	7.198310	7.198310	1.76	0.1841
hh38 v hh42	1	109.745303	109.745303	26.90	<.0001
hh42 v hh45	1	67.822249	67.822249	16.63	<.0001
hh45 v hh46	1	41.671786	41.671786	10.22	0.0014
hh46 v hh48	1	35.488522	35.488522	8.70	0.0032
hh48 v hh50	1	25.696151	25.696151	6.30	0.0121
m01 v m02	1	39.847434	39.847434	9.77	0.0018
m02 v m04	1	99.368492	99.368492	24.36	<.0001
m04 v m05	1	238.860588	238.860588	58.56	<.0001
m05 v m07	1	886.954369	886.954369	217.44	<.0001
m07 v m08	1	375.550235	375.550235	92.07	<.0001
m08 v m11	1	5.338772	5.338772	1.31	0.2527
m11 v m12	1	63.046724	63.046724	15.46	<.0001
m12 v m01	1	12.848707	12.848707	3.15	0.0760

Dependent Variable: LNCPUE
Weight: hauls

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
a00 v a03	1	2208.285992	2208.285992	541.36	<.0001
a00 v a04	1	697.498172	697.498172	170.99	<.0001
a00 v a05	1	60.924275	60.924275	14.94	0.0001
a03 v a04	1	622.167047	622.167047	152.52	<.0001
a03 v a05	1	745.347115	745.347115	182.72	<.0001
a04 v a05	1	110.495917	110.495917	27.09	<.0001
a04 v a06	1	129.173159	129.173159	31.67	<.0001
a05 v a06	1	319.738601	319.738601	78.38	<.0001
a06 v a09	1	29.140879	29.140879	7.14	0.0075
a09 v a10	1	9.497565	9.497565	2.33	0.1271
a10 v a11	1	18.900938	18.900938	4.63	0.0314
a11 v a12	1	43.996386	43.996386	10.79	0.0010

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		2.825237832	B	0.04043019	69.88	<.0001
vessel	hh02	-1.526713115	B	0.03383108	-45.13	<.0001
vessel	hh03	-1.389243759	B	0.03998096	-34.75	<.0001
vessel	hh06	-1.300620776	B	0.02869079	-45.33	<.0001
vessel	hh10	-1.096358957	B	0.02369122	-46.28	<.0001
vessel	hh13	-1.027615263	B	0.02363405	-43.48	<.0001
vessel	hh15	-1.001178867	B	0.02581955	-38.78	<.0001
vessel	hh18	-0.975806595	B	0.02256546	-43.24	<.0001
vessel	hh21	-0.952508399	B	0.02333689	-40.82	<.0001
vessel	hh23	-0.888398693	B	0.02580692	-34.42	<.0001
vessel	hh24	-0.815047571	B	0.03768170	-21.63	<.0001
vessel	hh25	-0.777746904	B	0.02433620	-31.96	<.0001
vessel	hh26	-0.731300692	B	0.02946415	-24.82	<.0001

Dependent Variable: LNCPUE
Weight: hauls

Parameter		Estimate		Standard Error	t Value	Pr > |t|
vessel	hh28	-0.656506354	B	0.02704531	-24.27	<.0001
vessel	hh31	-0.556695142	B	0.02346004	-23.73	<.0001

vessel	hh32	-0.483464981 B	0.03327780	-14.53	<.0001
vessel	hh34	-0.401311405 B	0.02623846	-15.29	<.0001
vessel	hh38	-0.373429152 B	0.01878034	-19.88	<.0001
vessel	hh42	-0.291256899 B	0.01903901	-15.30	<.0001
vessel	hh45	-0.209136959 B	0.02162881	-9.67	<.0001
vessel	hh46	-0.125034999 B	0.02509171	-4.98	<.0001
vessel	hh48	-0.050789191 B	0.02023589	-2.51	0.0121
vessel	hh50	0.000000000 B	.	.	.
MONTH	1	-0.034416808 B	0.01939215	-1.77	0.0760
MONTH	2	0.028212219 B	0.01934701	1.46	0.1448
MONTH	4	0.109450916 B	0.01560083	7.02	<.0001
MONTH	5	0.007233334 B	0.01670334	0.43	0.6650
MONTH	7	0.197378941 B	0.01506790	13.10	<.0001
MONTH	8	0.071763438 B	0.01681487	4.27	<.0001
MONTH	11	0.057478422 B	0.01462038	3.93	<.0001
MONTH	12	0.000000000 B	.	.	.
AREA	0	-0.420268142 B	0.03272756	-12.84	<.0001
AREA	3	0.003631044 B	0.03292740	0.11	0.9122
AREA	4	-0.211107334 B	0.03198398	-6.60	<.0001
AREA	5	-0.330351764 B	0.03653491	-9.04	<.0001
AREA	6	-0.125535972 B	0.03135580	-4.00	<.0001
AREA	9	-0.156643713 B	0.03012533	-5.20	<.0001
AREA	10	-0.136325901 B	0.03177022	-4.29	<.0001
AREA	11	-0.101396952 B	0.03087461	-3.28	0.0010
AREA	12	0.000000000 B	.	.	.

Dependent Variable: LNCPUE
Weight: hauls

Parameter		Estimate	Standard Error	t Value	Pr > |t|
year	1987	0.425713759 B	0.02375705	17.92	<.0001
year	1988	0.119267528 B	0.02082924	5.73	<.0001
year	1989	0.067442219 B	0.02024864	3.33	0.0009
year	1991	0.038101172 B	0.01874551	2.03	0.0421
year	1992	0.119703558 B	0.01900010	6.30	<.0001
year	1993	0.085378293 B	0.01941439	4.40	<.0001
year	1994	0.107416312 B	0.01947625	5.52	<.0001
year	1995	0.216662243 B	0.02026656	10.69	<.0001
year	1996	0.268652077 B	0.02135613	12.58	<.0001
year	1997	0.229296828 B	0.02256470	10.16	<.0001
year	1998	0.364483148 B	0.02441457	14.93	<.0001
year	1999	0.493805981 B	0.02589499	19.07	<.0001
year	2000	0.553873019 B	0.02789403	19.86	<.0001
year	2001	0.531555411 B	0.02934536	18.11	<.0001
year	2002	0.666444890 B	0.02580059	25.83	<.0001
year	2003	0.757465666 B	0.02671266	28.36	<.0001
year	2004	0.876813148 B	0.02679970	32.72	<.0001
year	2005	0.936423718 B	0.02623633	35.69	<.0001
year	2006	0.886039582 B	0.02609555	33.95	<.0001
year	2007	0.909147263 B	0.02706914	33.59	<.0001
year	2008	0.943236995 B	0.02728998	34.56	<.0001
year	2009	0.845284515 B	0.02901778	29.13	<.0001
year	2010	0.843771476 B	0.02846728	29.64	<.0001
year	2011	0.850338247 B	0.02968370	28.65	<.0001
year	2012	0.766018180 B	0.02972331	25.77	<.0001
year	2013	0.600522099 B	0.03777998	15.90	<.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--3, 7, 13 12:50 Monday, August 26, 2013 19

Group January w. February and November w. December

The GLM Procedure

Class Level Information

Class	Levels	Values
vessel	15	cc02 cc05 cc08 cc10 cc13 cc16 cc17 cc21 cc22 cc28 cc31 cc32 cc33 cc34 cc35
year	26	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 2090
AREA	5	1 2 3 7 13
MONTH	10	2 3 4 5 6 7 8 9 10 12

Number of Observations Read	10024
Number of Observations Used	10024

Dependent Variable: LNCPUE
Weight: Hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	52	43292.59191	832.54984	279.34	<.0001
Error	9971	29718.17682	2.98046		
Corrected Total	10023	73010.76873			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.592962	88.32162	1.726401	1.954676

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AREA	4	3066.82224	766.70556	257.24	<.0001
MONTH	9	2612.22662	290.24740	97.38	<.0001
vessel	14	14670.92001	1047.92286	351.60	<.0001
year	25	22942.62304	917.70492	307.91	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AREA	4	2418.49827	604.62457	202.86	<.0001
MONTH	9	1964.36897	218.26322	73.23	<.0001
vessel	14	7264.45299	518.88950	174.10	<.0001
year	25	22942.62304	917.70492	307.91	<.0001

Dependent Variable: LNCPUE
Weight: Hauls

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
cc02 v cc05	1	33.609667	33.609667	11.28	0.0008
cc05 v cc08	1	86.663368	86.663368	29.08	<.0001
cc08 v cc10	1	16.938609	16.938609	5.68	0.0171
cc10 v cc13	1	28.490677	28.490677	9.56	0.0020
cc13 v cc16	1	43.530765	43.530765	14.61	0.0001
cc16 v cc17	1	11.923975	11.923975	4.00	0.0455
cc17 v cc21	1	18.742617	18.742617	6.29	0.0122
cc21 v cc22	1	19.576995	19.576995	6.57	0.0104
cc22 v cc28	1	7.934763	7.934763	2.66	0.1028
cc28 v cc31	1	90.585009	90.585009	30.39	<.0001
cc31 v cc32	1	14.181598	14.181598	4.76	0.0292
cc32 v cc33	1	24.237036	24.237036	8.13	0.0044
cc33 v cc34	1	4.254412	4.254412	1.43	0.2322
cc34 v cc35	1	135.188953	135.188953	45.36	<.0001
m02 v m03	1	203.454503	203.454503	68.26	<.0001
m03 v m04	1	192.555887	192.555887	64.61	<.0001
m04 v m05	1	196.488137	196.488137	65.93	<.0001
m05 v m06	1	10.374387	10.374387	3.48	0.0621
m06 v m07	1	21.042595	21.042595	7.06	0.0079
m07 v m08	1	57.035822	57.035822	19.14	<.0001
m08 v m09	1	92.371420	92.371420	30.99	<.0001
m09 v m10	1	26.344880	26.344880	8.84	0.0030
m10 v m12	1	3.449666	3.449666	1.16	0.2820
m02 v m12	1	19.919489	19.919489	6.68	0.0097
a01 v a02	1	61.577864	61.577864	20.66	<.0001
a01 v a03	1	441.899242	441.899242	148.27	<.0001
a02 v a03	1	1073.150533	1073.150533	360.06	<.0001
a03 v a07	1	458.459103	458.459103	153.82	<.0001
a07 v a13	1	1193.754246	1193.754246	400.53	<.0001

Dependent Variable: LNCPUE
Weight: Hauls

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		2.323978309	B	0.03598822	64.58	<.0001
AREA	1	-0.291647567	B	0.01553418	-18.77	<.0001
AREA	2	-0.347907502	B	0.01453175	-23.94	<.0001
AREA	3	-0.140982764	B	0.01351437	-10.43	<.0001
AREA	7	-0.295739552	B	0.01477725	-20.01	<.0001
AREA	13	0.000000000	B	.	.	.
MONTH	2	-0.037449917	B	0.01448617	-2.59	0.0097
MONTH	3	0.109608167	B	0.01782895	6.15	<.0001
MONTH	4	0.265193589	B	0.01598203	16.59	<.0001
MONTH	5	0.130679628	B	0.01454936	8.98	<.0001
MONTH	6	0.159754161	B	0.01483435	10.77	<.0001
MONTH	7	0.202810040	B	0.01516624	13.37	<.0001
MONTH	8	0.129188008	B	0.01543504	8.37	<.0001
MONTH	9	0.033663105	B	0.01539674	2.19	0.0288
MONTH	10	-0.016034256	B	0.01490397	-1.08	0.2820
MONTH	12	0.000000000	B	.	.	.
vessel	cc02	-1.225373508	B	0.04218256	-29.05	<.0001
vessel	cc05	-1.095428510	B	0.03361153	-32.59	<.0001
vessel	cc08	-0.953124557	B	0.03001949	-31.75	<.0001
vessel	cc10	-0.893153205	B	0.03190516	-27.99	<.0001
vessel	cc13	-0.822284597	B	0.02821802	-29.14	<.0001
vessel	cc16	-0.763074512	B	0.02795730	-27.29	<.0001
vessel	cc17	-0.724007819	B	0.03047429	-23.76	<.0001
vessel	cc21	-0.677802014	B	0.02703840	-25.07	<.0001
vessel	cc22	-0.629435996	B	0.03058046	-20.58	<.0001
vessel	cc28	-0.599230815	B	0.02668275	-22.46	<.0001
vessel	cc31	-0.509222386	B	0.02890711	-17.62	<.0001
vessel	cc32	-0.443957775	B	0.03682208	-12.06	<.0001
vessel	cc33	-0.320177087	B	0.04216481	-7.59	<.0001
vessel	cc34	-0.265283589	B	0.03938959	-6.73	<.0001
vessel	cc35	0.000000000	B	.	.	.

Dependent Variable: LNCPUE
Weight: Hauls

Parameter		Estimate	Standard Error	t Value	Pr > |t|
year	1988	0.161732254 B	0.03960130	4.08	<.0001
year	1989	-0.119056289 B	0.02994743	-3.98	<.0001
year	1991	-0.029723926 B	0.02706001	-1.10	0.2720
year	1992	0.059172415 B	0.02723046	2.17	0.0298
year	1993	0.111701081 B	0.02697491	4.14	<.0001
year	1994	0.005398485 B	0.02632558	0.21	0.8375
year	1995	0.015993130 B	0.02676518	0.60	0.5502
year	1996	0.062015842 B	0.02782944	2.23	0.0259
year	1997	0.085663227 B	0.02722136	3.15	0.0017
year	1998	0.282696896 B	0.03008114	9.40	<.0001
year	1999	0.414765238 B	0.02850694	14.55	<.0001
year	2000	0.621658192 B	0.02875206	21.62	<.0001
year	2001	0.557219755 B	0.02820571	19.76	<.0001
year	2002	0.708466432 B	0.02685530	26.38	<.0001
year	2003	0.715482369 B	0.02758380	25.94	<.0001
year	2004	0.773159377 B	0.02675727	28.90	<.0001
year	2005	0.724114165 B	0.02661892	27.20	<.0001
year	2006	0.803254375 B	0.02738341	29.33	<.0001
year	2007	0.916305849 B	0.02745063	33.38	<.0001
year	2008	0.924996088 B	0.02684898	34.45	<.0001
year	2009	0.766849550 B	0.02697644	28.43	<.0001
year	2010	0.687065100 B	0.02725690	25.21	<.0001
year	2011	0.805995481 B	0.02739740	29.42	<.0001
year	2012	0.715717697 B	0.02762039	25.91	<.0001
year	2013	0.656770387 B	0.03361391	19.54	<.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

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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 ;
```