Northwest Atlantic Fisheries Organization

SERIAL NO. N5455 **NAFO SCR DOC. 07/69**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – OCTOBER/NOVEMBER 2007

The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970-2007

by

Michael C.S. Kingsley

Greenland Institute of Natural Resources
Box 570, 3900 Nuuk, Greenland

Abstract

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 SFA 1). 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 distinct 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. Since then increases in allowed takes have been accompanied by increased catches. The log-book recorded catches in 2005 and 2006, 154 600 tons, were the highest recorded. The Total Allowable Catch for the stock advised in 2006 for 2007 was 130 000 tons live-caught weight. A TAC for Greenland waters for 2007 was set at 134 000 tons. For the Canadian fishery in the eastern part of Div. 0A a TAC was set at 18 417 tons for 2007, but Canadian catches in recent years have stayed at little over 6 000 tons in spite of much higher TACs. Greenland catches in the first half of 2007 were low, and on that basis, with Canadian catches at the mean of the last 5 years, the 2007 total catch has been projected at about 135 000 tons. The fishery in Greenland is regulated by individual quotas, but quota drawdowns are partly 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 alike low, but recent investigations showed that by-catch is probably under-reported, even by on-board observers.

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 about 1997. It has since increased markedly to reach a maximum in 2007 of about twice its 1997 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. Even though CPUEs remain high, if the area that the stock is spread over is shrinking, then its biomass could also be decreasing.

Introduction

Northern shrimp (*Pandalus borealis*) occurs on the continental shelf off West Greenland in NAFO Div. 0A and in Div. 1A-1F. The species is more or less continuously distributed from Cape Farewell (60°N) to about 74°N, with the highest densities in depths between 150 and 600 m (Fig. 1). Within this habitat area, there is little evidence of sub-structure. TACs have at some times in the past been allocated to subdivisions of the stock area, 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.

A bottom-trawl fishery began in inshore areas in 1935. In 1970 a multinational offshore fishery started to develop and over the following 30 or more years landings increased, to approximately 135 000 tons in 2004 (Fig. 2). Catch restrictions were first imposed in 1977 and the fishery has since been managed by Total Allowable Catch (TAC); a system of Individual Transferable Quotas (ITQs) was introduced in the Greenlandic fishery in 1991. From 1981 until recent years the West Greenland fishery was limited to Greenlandic vessels in NAFO Subarea 1 and to Canadian vessels in NAFO Div. 0A, but pursuant to agreements on fisheries between the European Union (EU) and Greenland, an initial quota of 1000 tons allocated to EU vessels in NAFO Subarea 1 in 2003 has been increased to 4000 tons in subsequent years. The EU quota is an offshore quota and in this document is treated as part of the Greenland offshore fishery.

Three types of licence are issued to Greenland vessels in Subarea 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. 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—generally, those under 75 GRT/120 GT—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. No TAC was set for the small-vessel fleet until 1997; the coastal quota is now fixed by law at 43% of the Greenland TAC, and while (parts of) individual quotas may be sold or transferred between licence holders within fleet components, the coastal and offshore quotas are kept separate. Since 1986 logbook recording of fishing activity has been required for all vessels above 50 GRT, and since 1997 for all vessels, but logbook records before 1986 must be recognised as incomplete.

The inshore fleet of smaller trawlers generally ices its catch and lands it at shore stations for processing, and Greenland vessels with on-board production licences are required to land 25% of their catches. In earlier years, the true weight of packages produced on board was often greater than the nominal weight—which was also the invoiced weight and the weight recorded for the product in the logbook—and this practice of 'overpacking' led to systematic underreporting. Legislation has been modified and since 2004 logbook entries are required to correspond to live catch weight (G.H. 2003). Catch data from 2003 and earlier was corrected (Hvingel 2004) by 21–25% for overpacking. 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.

However, the quota drawdown for shrimps landed at shore stations in Greenland by any fleet component is still less than the live weight by an allowance for crushed or broken shrimps, which are included in the landing, but not in the sale (G.H. 1996). If TACs and quotas are based on analysis of live-caught weights, but quota drawdown and tactical fishery management are partly based on such traded weights—even if honestly reported—annual catches measured as live-caught weight are apt to exceed TACs and the stock is liable to be over-fished.

A licence holder who fishes out his quota for a year 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 the year's quota until 30 April in the following year. This provision can lead to accumulation of unfished quotas.

Canada fishes this stock where the edge of the West Greenland shelf bulges westward into the Canadian EEZ at the eastern edge of NAFO Div. 0A, between about 67°24'N and 68°40'N; 'Shrimp Fishing Area 1' (SFA1), consisting of NAFO 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. It is included in the annual Greenland

research trawl survey. From 1996 to 2005 on average only about 9 vessels (2000–4000 GRT) have participated in the fishery in this area, slightly more in the most recent years. Catches are restricted by quota; a quota may be retroactively adjusted to cover an overrun, with a corresponding correction in a later year. Logbooks have been available since 1979.

Gear restrictions in place in Greenland are a cod-end mesh size of at least 40 mm stretched, and, for the Greenlandic fleet since 2000, sorting grids with 22-mm spaces between the bars to reduce finfish bycatch (G.H. 2001)[1]. The Canadian fishery in SFA 1 uses a 45- or 50-mm cod-end mesh and Nordmore grates with 28-mm spacing. Other measures to limit bycatch include an executive order of the Greenland Home Rule Government that a ship must move its fishing at least 5 n.mi. if bycatch exceeds a given proportion of the catch (G.H. 1995).

Material and Methods

Fleet Data

Logbook records were analysed to follow the development of the fleet and the fishery. Vessels were classified as offshore or coastal from available information, including current information on the type of licence held or the tonnage, but also including mapping of fishing locations. Catch locations were classified into statistical areas (Fig. 4). 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.

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). 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 2004 and 2005 these catch levels were 8–10% higher than the quota drawdown values used for the assessment in 2006.

Logbook records were analysed to follow the development of the fleet and the fishery.

The Canadian fishery in SFA1 has 100% observer coverage (Siferd, pers. comm.), and catch data for this fishery was fetched in September 2007 from the DFO Commercial Quota Reports web-pages. Observer logbook data on catch and effort was provided by DFO staff.

Effort Data

Unstandardised logbook effort in trawl hours was corrected using 1.6 as a multiplier for records of trawl times with twin trawls to give corrected logbook effort. Unstandardised logbook CPUE was obtained by dividing corrected logbook catch by total corrected unstandardised logbook effort, and an unstandardised statistical effort by dividing total statistical catch by mean unstandardised logbook CPUE. Standardised statistical effort was calculated by dividing total statistical catch by standardised CPUE (see below).

[1] dispensation from the requirement for sorting grids on trawls may be granted for vessels under 150 GRT for safety reasons; has been granted for all vessels under 75 GRT/120 GT in 2005 and 2006.

CPUE Analyses

Catch and effort data from Greenlandic vessels above 50 GRT fishing in Subarea 1 and Canadian vessels fishing in SFA1 were used in multiplicative models to calculate indices of standardised CPUE. Four separate index series covering four fleets were derived (Hvingel *et al*., 2000).

All four models 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 covered by the index. Statistical areas were defined *ad hoc* based on distinct fishing grounds (Fig. 1), but area 0 was not included in the analyses. The multiplicative model was represented in logarithmic form either as:

Model 1 $$\ln(CPUE_{mjki}) = \ln(u) + \ln(A_m) + \ln(S_j) + \ln(V_k) + \ln(Y_i) + \varepsilon_{mjki}$$

or with a MONTH*AREA interaction implying a change in distribution repeated regularly every year:

Model 2 $$\ln(CPUE_{mjki}) = \ln(u) + \ln(A_m) + \ln(S_j) + \ln(AS_{mj}) + \ln(V_k) + \ln(Y_i) + \varepsilon_{mjki}$$

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 effect of the mth area; S_j is the effect of the j^{th} month; V_k is the effect of the k^{th} vessel; Y_i is the effect of the i^{th} year; ε_{mjki} is a variance assumed to be normally distributed as $N(0,\sigma^2/n)$ where n is the number of observations in the cell. The year effects have been used as standardised annual CPUE indices in assessment models. These linear models in log. space were fitted using SAS Proc GLM (SAS Institute 1988). Estimates of the vessel, month and area effects from a first run of the main effects model (Model 1) were compared. To reduce the number of empty cells in the models, classes of effect variables were combined if a pairwise contrast had an F statistic less than one. However, posterior grouping on the basis of similar effects causes uncertainty to be underestimated. For further details on model construction and analysis see Hvingel *et al.* (2000).

Compared with model 1, model 2 (month-year interaction term included) produced small changes in year effects, on average about one-half of the estimated standard error, and reduced the estimated standard error of year effects by less than 0.1%. The more parsimonious model without the month-area interaction was therefore preferred and was used for all fleets.

The 'KGH index' was derived from catches in the early offshore fishery, executed by 7 sister trawlers (722 GRT) operated by the Kongelige Grønlandske Handel (KGH). This fishery only covered Div 1A and part of Div. 1B and data from Areas 3, 4, 6 and 7 (Fig. 1) 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. The analyses for reducing variable levels showed that 6 of the seven vessels could be treated as a group in the subsequent analyses. The month variable could be reduced to 10 levels and areas 4, 6 and 7 combined. This analysis was not repeated and results from Hvingel (2004) were incorporated into the present analysis.

The 'Offshore' index covers the most recent 21 years of the offshore production fishery in NAFO Div. 1A to 1F. 47 vessels were included providing data since 1987. The data was grouped into 13 areas (Fig. 1). In previous years, statsistical areas 1–3 have been omitted from this index on the grounds of suspected misreporting of positions. The effect of omitting these areas for years before 2002, when a separate quota for Div. 1A and the northern part of 1B was abolished, was looked at. If they were omitted, the year effects for 1988–91 were reduced, relative to those for 1992–2007, by about 0.6 times the year-effect SE, but within those two periods relative changes were small. It was concluded that there was little reason to omit them; but areas 1 and 2 were in the end omitted simply because the offshore fleet does not fish there, and area 8 and 9 were combined. Vessels were grouped into 18 groups of 1–5 vessels with similar estimated effects. The month effect was reduced to 8 levels by grouping adjacent months with similar indices of fishing success. Double-trawl data was included, a double-trawl effect being added to the model.

A 'Coastal' index was based on vessels below 80 GRT or 210 GT, which have privileged access to the fishery in 'inshore' areas of West Greenland. However, some larger vessels holding coastal quotas and, from mapping of their

logbook records, fishing 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 areas 1, 2 and 3 in Fig. 1, but is also active in some inshore areas further south, especially areas 7 and 11–13. For lack of data, the offshore areas 4, 5, 6 and 8 were omitted from this analysis, and 2 pairs of areas were grouped. Comprehensive data were available since 1988; 30 vessels were included, in 15 groups. January and February were grouped together as were October, November and December.

Data from the Canadian fishery in SF1 was available for 1981 through 2006. However, there was no data from 1986, and before then the fishery was prosecuted by few vessels, most having only one or two years in the fishery, and none continuing in the fishery after 1986. So a standardised CPU index series for SFA1 as a whole was only calculated for 1987–2006. Double- and single-trawl data was used in the analysis, the double-trawl effect being fitted by the GLM model and the data standardised to single trawl. Vessels with reports from fewer than 3 years in the fishery were rejected, and the 22 retained were nested within tonnage class. They were grouped, by examining pairwise contrasts, into 17 small groups.

The four index series were considered independent indices of stock density and were entered into an assessment model of the stock dynamics; the model fitted a catchability (scaling) and an estimate of variance to each series. To generate a unified CPUE series for the present document, the model estimates of catchability and precision were used to scale and weight the four series:

$$\ln(CPU) = \sum_i p_i \ln\left(I_i / c_i \right) \Big/ \sum_i p_i$$

where I_i is the median estimate of the i^{th} individual index with median estimate of catchability c_i and median estimate of lognormal precision[2] p_i; CPU is then the unified value. The input series were arbitrarily standardised to 1990; when corrected by their catchabilities they were standardised to B_{msy} , so the unified index, a weighted mean, was also standardised to B_{msy}. An index of the of the precision of the unified CPUE series was derived from

$$\overline{p} = 1 / \sum p_i$$

giving a precision in log. space for the unified series of logged values. Uncertainty intervals of +/- twice the standard error were calculated in log space before exponentiation.

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 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.

Biological Sampling

There is at the moment no programme for systematic sampling from the fishery for obtaining length, sex or weight distribution or for examining the relationships between these biological variables.

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 fleet sizes were nearly the same as the fleet was homogeneous (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. 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.

The early logbook records from the coastal fleet, in the early 1990s, also show a small, homogeneous fleet, but this is an artefact of the small interval between the 80-ton upper limit for entry into the coastal fishery and the 50-ton

[2] 'precision': i.e. reciprocal of the variance.

lower limit for logbooks (Fig. 1b). When the latter was removed in 1997 and all trawlers had to report, the nominal size of the coastal fleet, as shown by logbooks, quadrupled from 24 to 94. However, the small ships were catching so little shrimp that the effective size of the coastal fleet only doubled, from 16 to 33, and the effective size of the total shrimp fleet hardly changed at all (Fig. 1c). Rationalisation and modernisation has 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.

Since the inception of the fishery, it has seen continued increases in catches and TACs (Fig. 2). 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. Catches have increased very rapidly since 2000, by about 50% by 2006. However, the logbook-recorded catches for the first 6 months of 2007, fetched in August, were about 15% less than those for the same period in the foregoing year. Total enacted TACs have also increased, and in recent years have approximately equalled catches. Management of the fishery in Greenland is bedevilled by mixed regulation, partly based on weights caught, and partly on weights traded; in Canada, TACs have regularly been set that have exceeded catches by 100 or 200%.

From 1975, when the offshore fishery was well established, through 1984 annual unstandardised effort increased slightly from about 75 000 hr to about 93 000 hr (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 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 (Table 2, Fig. 3). After 1992, when it reached its highest value, standardised effort decreased steadily—overall by about 35%—to a minimum in 1998–2000. Since then it has been increasing again.

Spatial and seasonal distribution

Northern shrimp are fished on the continental shelf of Greenland between 59°N and 74°N, mainly between 150 and 600 m depth, i.e. on the gullies between the offshore banks, in parts of Disko Bay, and on the upper shelf break (Fig. 4). However, during the period of logbook recordings (since 1975) a substantial change in the relative importance of the different areas is indicated. At first, the fishery concentrated on the wide shelf west and southwest of Disko Bay (Div. 1B/Area 6; Fig. 5a), but the effective number of areas fished increased steadily up to the early 1990s as the fishery extended first into southwestern Disko Bay (Areas 3 and 4) and the Holsteinsborg Deep (Area 7), with short-lived excursions in the late 1980s and early ‘90s into northern areas (Area 0) and the outer margin of the shelf north of Canadian SFA1 (Area 5). From the end of the 1980s there was a significant expansion of the fishery southwards and by 1996–97 the southern areas 9–13 accounted for almost 60% of the catch (Fig. 5b). At that time the effective number of areas being fished peaked at about 9.5. Since then, the fishery has seen a contraction and the effective number of areas fished has decreased as effort has become more concentrated (Fig. 6). Catches have also become more concentrated and the contribution from the southern part of the distribution has declined (Table 3, Table 4). An increasing concentration of the stock and the fishery would be consistent with a decreasing biomass index from research trawl survey while catch rates in the commercial fishery remain high, and this agrees with data since 2003.

The changing distribution of the fishery is summarised by the trajectory of the effective number of areas being fished and providing the catch. In the 1970s, 1 or 2 areas were fished, but the number increased steadily through the 1980s to reach 9 by the early to mid-1990s (Fig. 6). The distribution of catch stayed steady through the late 1990s to the early 2000s—although effort became more concentrated—but since 2003 the fishery appears quickly to have become more concentrated. The distribution indices calculated for both catch and effort, whether based on NAFO Divisions or statsistical areas, have decreased to levels not seen since the late 1980s (Fig. 6). A contracting distribution of the stock would be consistent with a research survey index that has declined every year since its 2003 peak while CPU values, over the same period, appear to have increased.

It has been suggested that the southward shift of the fishery in the early and mid-1990s could have been promoted by the development of gear that could fish effectively on difficult bottoms, but this would not explain the recent decline of the southern areas. Besides, a similar southward shift of the stock distribution in the early 1990s was also recorded by research trawl surveys (Carlsson and Kanneworff 1997; Rätz 1997).

The fishery is active all year, but more so in summer and fall. A strongly seasonal pattern prevalent as recently as 10 years ago, with summer monthly catches 2–3 times the winter minimum, appears to have given way to a more uniform seasonal distribution, with summer maxima only 25–50% higher than the winter minima (Table 5).

By-catch and discard

The logbook-reported at-sea discard of shrimp, mostly for quality reasons by production trawlers, has remained less than 1% by weight of total catch throughout the period 1975–2007 (Table 6, Table 7). However, these statistics do not include shrimp 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 shrimp may have offset a corresponding effect of observers on the reported discard of shrimp.

Bycatch of fish—including, and 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 shrimp, out of the trawl. In the most recent years registered annual discards of fish have been below 1% of total shrimp catch, but fish discard reports are based on visual estimates of weight, not on physical weighing, and errors are likely. An EU project[3] 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).

From 1995 to 2007 reports have included overall annual catches of *P. montagui* in the range of about 100 to 2 000 tons (Table 6), which can be landed outside the quota on *P. borealis*. However, landings can be classified as *montagui* while including up to 70% *borealis*, so it has been possible to land substantial unrecorded catches of *borealis*, and it is difficult to use the reporting of *montagui* to infer changes either in the targeting strategy of the fishery or in the availability of this species. However there were indications of increased biomass of *P. montagui* in the mid-1990s (Kanneworff, 2003), and catches since 2000 appear to have stayed high, reaching a (projected) maximum in 2007. Catches of fish in the Canadian offshore fishery ranged up to well over 30% of the shrimp catch from the mid-1980s to the mid-1990s, but have since decreased to stable levels below 5%.

Catch per unit of effort

Log-book data for selected ships from four fleets were analysed using SAS PROC GLM. The unified standardised CPUE index is an aggregate of four individual indices (Table 5) derived by GLM methods for the four fleets (Appendices 1–3). 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. However, since 2004 they have diverged more than in previous years, the offshore fleet managing a continued increase in catch rates while the coastal fleet, although its catch rates have remained high in historical terms, has seen greater fluctuation in CPUE from year to year. 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, although over time its overall trend has been similar and it also has increased between the 1990s and the present.

The overall combined index (Fig. 7) fluctuated without trend by a factor of 2 between 1976 and 1987. It then dropped precipitously to the lowest levels in the series in 1990–91, and stayed fairly flat until 1996. Since then, the unified CPUE index has increased markedly and sustainedly for 10 years, continuing to increase to its highest-ever value in 2007. 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

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

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.

A louder alarm signal is sounded by the apparently contracting distribution area of the stock. CPUE does not 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 2005–2007 the effective number of NAFO Divisions providing catches for the Greenland fleet has decreased to two-thirds 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. 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 stock biomass, which since 2003 has continually decreased, overall by 40% from its then value.

Acknowledgements

Mads Rossing Lund of Greenland Fiskeri- og Licenskontrol helped in obtaining logbook data for the Greenland fleets. Tim Siferd of the Canadian Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg, found the data for the Canadian fishery in SFA1 for 2006; I thank David Orr and Pat. J. Veitch, of the Science Branch, Canadian Department of Fisheries and Oceans, Atlantic Region, for help in obtaining and interpreting data on the Canadian fishery for earlier years. I thank Janet Conlin of DFO Statistics Branch for help in interpreting the national statistical web pages.

References

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

CARLSSON, D. M., and P. KANNEWORFF. 1997. Offshore stratified-random trawl survey for shrimp (*Pandalus borealis*) in NAFO Subarea 0+1, in 1997. NAFO SCR Doc., No. 97/101, Ser. No. N2958.

Garcia, E.G. 2007. The Northern Shrimp (*Pandalus borealis*) offshore fishery in the northeast Atlantic. Adv. Mar. Biol. 52:147–266.

G.H. 1995. Hjemmestyrets bekendtgørelse nr. 32 af 14. december 1995 om fiskeriets bifangster. http://-www.nanoq.gl/gh.gl-love/dk/1995/bkg/bkg_nr_32-1995_dk.htm

G.H. 1996. Hjemmestyrets bekendtgørelse nr. 39 af 30. december 1996 om control med kystnært fiskeri efter rejer. http://www.nanoq.gl/gh.gl-love/dk/1996/bkg/bkg_nr_39-1996_dk.htm

G.H. 2001. Hjemmestyrets bekendtgørelse nr. 39 af 6. december 2001 om regulering af fiskeri ved tekniske bevaringsforanstaltninger. http://www.nanoq.gl/gh.gl-love/dk/2001/bkg/bkg_nr_39-2001_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

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

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., No. 03/74 Ser. No. N4913. 3 pp.

HVINGEL, C. 2003. The Fishery for Northern Shrimp *(Pandalus borealis*) off West Greenland, 1970–2003. NAFO SCR Doc., No. 03/75 Ser. No. N4914.

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.

RÄTZ, H.-J. 1997. Biomass Indices and Geographical Distribution Patterns of Survey Catches for Shrimp (*Pandalus borealis*) off West and East Greenland, 1982–96. NAFO SCR Doc., No. 97/96, Serial No. N2953.

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

Table 1a. Catch limits, catch, effort and CPUE statistics for the shrimp fishery on the West Greenland shelf, 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	Total
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			Std. (index)	Unstd. (kg/hr)			Std. (B_{msy}=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	1.00	762	-	766	0.96
1977	-	-	36000	42578	8580	51158	457	51615	73.1	-	73	0.93	699	-	706	0.90
1978	-	1000	41000	33835	8360	42195	122	42317	84.2	-	84	0.98	501	-	503	0.71
1979	-	2000	31500	32852	8250	41102	1732	42834	72.4	-	72	1.09	568	-	592	0.64
1980	-	2500	32000	44916	8250	53166	2726	55892	80.0	11.6	92	1.18	665	235	610	0.77
1981	35000	5000	40000	40295	8250	48545	5284	53829	88.2	16.6	105	1.20	551	318	514	0.73
1982	34800	5000	39800	43979	8250	52229	2064	54293	81.1	8.1	89	0.94	644	256	609	0.93
1983	34625	5000	39625	42553	8250	50803	5413	56216	89.0	26.1	115	1.11	571	208	488	0.82
1984	34925	5000	39925	42414	8250	50664	2142	52806	85.0	-	*85*	1.12	596	-	*621*	0.77
1985	42120	6120	48240	54889	8250	63139	3069	66208	129.1	23.6	153	1.31	489	130	433	0.82
1986	42120	6120	48240	65623	8250	73873	2995	76868	133.4	-	*133*	1.46	554	-	*576*	0.86
1987	40120	6120	46240	64222	7613	71836	6095	77931	137.1	17.7	155	1.25	524	344	503	0.97
1988	40120	6120	46240	56479	11256	67735	5881	73616	152.9	14.9	168	1.76	443	395	439	0.78
1989	45245	7520	52765	58890	14546	73436	7235	80671	179.6	19.7	199	2.18	409	367	405	0.65

Notes: in 1981–1995 quotas applied to the offshore area only;

Table 1b. Catch, effort and CPUE statistics for the shrimp fishery on the West Greenland shelf, 1990-2007.

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
				Offshore	Inshore	Total	Offshore		Unstd. ('000 hr)			Std. (index)	Unstd. (kg/hr)			Std. (B_{msy}=1)
1990	45245	7520	52765	62800	14993	77793	6177	83970	209.6	14.3	224	2.42	371	433	375	0.65
1991	46225	8500	54725	66818	17884	84701	6788	91489	230.8	19.6	250	2.61	367	346	365	0.63
1992	44200	8500	52700	75341	22653	97994	7493	105487	234.2	16.6	251	2.70	418	451	421	0.70
1993	40600	8500	49100	65894	19627	85522	5491	91013	206.1	12.2	218	2.46	415	450	417	0.69
1994	42300	8500	50800	68109	19930	88039	4766	92805	209.8	15.3	225	2.52	420	312	412	0.64
1995	39500	8500	48000	66955	18072	85027	2361	87388	184.7	7.3	192	2.16	460	322	455	0.69
1996	63922	8500	72422	62368	19095	81463	2632	84095	164.6	9.0	174	2.06	495	293	484	0.71
1997	64600	8500	74800	62743	14868	77611	517	78128	184.9	1.3	186	1.95	420	412	420	0.72
1998	60729	7650	68379	69156	10406	79562	933	80495	152.7	2.6	155	1.77	521	353	518	0.79
1999	73500	9350	82850	71203	18948	90152	2046	92198	164.7	5.1	170	1.77	547	398	543	0.91
2000	77675	9350	87025	73013	23365	96378	1590	97968	156.2	2.6	159	1.71	617	613	617	1.04
2001	92950	9350	102300	79291	20010	99301	3625	102926	158.3	6.0	164	1.87	627	602	626	1.01
2002	91150	12040	103190	107195	21729	128925	6247	135172	173.3	9.0	182	2.07	744	695	741	1.21
2003	101000	14167	115167	104237	18799	123036	7137	130173	124.4	8.2	133	1.87	989	873	982	1.28
2004	135352	14167	149519	115560	19652	135212	7021	142233	130.0	12.0	142	1.89	1040	585	1002	1.26
2005	134000	18452	152452	127012	20683	147695	6921	154616	129.5	10.6	140	2.00	1141	652	1104	1.28
2006	134000	18380	152380	133095	17441	150536	4127	154663	126.1	5.0	131	1.95	1193	826	1179	1.35
2007**	134000	18417	152417	101842	27037	128879	6291	135169	107.2	–	–	–	1202	–	–	1.40

*1981-1995 TAC for offshore only; **projected; for SA1 from Jan–June, for Can. SFA1 from average of previous 5 years.

Table 2. Standardised (1990=1) CPUE series for 4 fleets fishing northern shrimp in West Greenland waters and a combined standardised (B_{msy}=1) CPUE series for the fishery.

	KGH		Offshore		Coastal		Canada SFA1		Combined	
Year	mean	se	mean	se	mean	se	mean	se	mean	se
1976	1.660	0.153							0.956	0.100
1977	1.556	0.095							0.896	0.094
1978	1.230	0.074							0.708	0.074
1979	1.113	0.066							0.641	0.067
1980	1.340	0.082							0.772	0.081
1981	1.265	0.072							0.729	0.077
1982	1.610	0.099							0.928	0.097
1983	1.423	0.085							0.820	0.086
1984	1.338	0.078							0.771	0.081
1985	1.432	0.082							0.825	0.087
1986	1.490	0.085							0.858	0.090
1987	1.787	0.106	1.568	0.064			0.948	0.144	0.967	0.057
1988	1.465	0.086	1.157	0.027	1.133	0.047	0.959	0.085	0.777	0.037
1989	1.086	0.071	1.055	0.021	0.893	0.026	0.899	0.050	0.646	0.031
1990	1.000		1.000		1.000		1.000		0.653	0.031
1991			0.980	0.017	0.906	0.024	0.836	0.042	0.629	0.034
1992			1.109	0.020	0.977	0.026	0.956	0.050	0.698	0.038
1993			1.036	0.019	1.005	0.026	0.961	0.050	0.686	0.037
1994			1.045	0.019	0.932	0.024	0.692	0.035	0.643	0.035
1995			1.164	0.022	0.965	0.025	0.774	0.045	0.693	0.037
1996			1.175	0.023	1.029	0.028	0.664	0.037	0.705	0.038
1997			1.134	0.023	1.032	0.028	0.899	0.117	0.717	0.039
1998			1.287	0.028	1.183	0.036	0.727	0.072	0.789	0.043
1999			1.478	0.033	1.333	0.036	0.897	0.062	0.905	0.049
2000			1.591	0.038	1.602	0.044	1.137	0.103	1.041	0.056
2001			1.522	0.037	1.510	0.040	1.258	0.089	1.005	0.054
2002			1.790	0.041	1.883	0.050	1.468	0.089	1.213	0.066
2003			1.939	0.045	1.893	0.053	1.659	0.106	1.276	0.069
2004			2.312	0.054	1.640	0.044	1.230	0.071	1.255	0.068
2005			2.420	0.058	1.628	0.043	1.279	0.083	1.282	0.069
2006			2.382	0.058	1.737	0.047	1.710	0.147	1.351	0.073
2007			2.437	0.076	1.863	0.057			1.402	0.080

Table 3. Annual catch, effort and CPUE of the shrimp fishery on the West Greenland shelf by NAFO Divisions. Data from logbooks, weighted up to annual total catch.

Year	Catch ('000 tons)							Corrected, Unstandardised Effort ('000 hr)							CPUE (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	0.0	44.6	2.0	0.0	0.0	0.0	-	0.0	70.5	3.6	0.0	0.0	0.0	-	-	632	551	-	-	-
1976	0.4	0.0	54.7	6.3	0.0	0.0	0.0	-	0.1	70.1	8.0	0.1	0.8	1.1	-	-	780	785	-	-	40
1977	0.5	0.2	47.8	3.1	0.1	0.0	0.0	-	0.5	67.8	4.4	0.5	0.0	0.0	-	357	705	691	253	-	-
1978	0.1	0.5	40.9	0.5	0.2	0.0	0.0	-	1.4	80.7	1.3	0.8	0.0	0.0	-	382	507	416	259	-	-
1979	1.7	4.8	35.7	0.5	0.0	0.0	0.0	-	6.7	64.1	1.5	0.1	0.0	0.0	-	719	557	348	112	-	-
1980	2.7	14.6	35.0	3.3	0.3	0.0	0.0	11.6	21.2	53.3	4.9	0.5	0.0	0.0	235	690	655	668	596	-	-
1981	5.3	5.7	37.5	5.3	0.0	0.0	0.0	16.6	11.2	66.4	10.4	0.1	0.0	0.0	318	511	564	510	409	-	-
1982	2.1	0.8	43.2	8.2	0.0	0.0	0.0	8.1	1.7	65.7	13.5	0.1	0.0	0.0	256	472	657	604	388	-	-
1983	5.4	0.5	40.5	9.4	0.5	0.0	0.0	26.1	0.9	69.5	17.8	0.9	0.0	0.0	208	559	582	528	531	-	614
1984	2.1	1.2	30.4	17.0	2.1	0.0	0.0	-	2.7	51.1	28.4	2.7	0.0	0.1	-	431	595	598	785	-	47
1985	3.1	8.1	35.5	14.9	4.7	0.0	0.0	23.6	28.7	66.2	25.6	8.7	0.0	0.0	130	282	536	580	540	-	-
1986	3.0	26.3	32.4	9.2	6.0	0.0	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	0.0	17.7	54.4	67.9	10.7	4.2	0.0	0.0	344	357	644	685	324	-	-
1988	5.9	12.4	47.5	7.1	0.5	0.0	0.1	14.9	40.9	94.3	14.7	2.0	0.0	1.0	395	302	504	486	268	-	153
1989	7.2	16.3	33.8	12.9	10.0	0.0	0.5	19.7	47.3	77.7	30.5	19.8	0.0	4.2	367	343	435	422	507	-	111
1990	6.2	12.2	30.0	22.7	12.4	0.0	0.5	14.3	42.3	77.5	56.1	30.8	0.0	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	37.0	90.0	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	0.6	16.6	49.3	76.2	48.0	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	82.0	41.3	44.3	8.0	7.6	450	331	442	383	410	559	425
1994	4.8	7.3	33.7	15.9	19.9	7.0	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	22.0	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	9.0	18.4	51.0	35.0	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	24.0	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	9.0	2.6	20.0	48.9	25.4	34.2	10.6	13.5	353	226	463	532	618	817	671
1999	2.0	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	15.0	19.0	7.0	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	8.0	11.6	6.0	41.0	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	25.0	8.5	10.3	9.0	41.6	58.7	27.5	28.2	7.0	10.4	695	365	741	963	888	1216	989
2003	7.1	13.9	42.4	24.8	23.1	8.0	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	13.1	52.3	31.9	23.4	5.4	9.1	12.0	33.4	51.2	18.1	13.3	2.8	11.2	585	392	1021	1761	1764	1918	813
2005	6.9	11.1	71.9	33.1	17.8	5.3	8.6	10.6	23.1	58.6	16.5	10.6	5.2	15.5	652	481	1225	2007	1675	1022	557
2006	4.1	13.5	79.6	23.3	19.0	9.6	5.4	5.0	21.5	60.6	12.3	11.2	10.0	10.6	826	631	1313	1899	1700	967	510
2007	6.3	9.6	81.1	12.1	15.5	8.8	1.9	–	14.7	63.6	7.2	10.1	7.5	4.0	–	655	1274	1668	1531	1160	464

Table 4a. Distribution (%; columns sum to 100) of catches of northern shrimp between Divisions in NAFO Subarea 1 by 5-year period.

	5-year period						
	75–79	80–84	85–89	90–94	95–99	00–04	05–07
1A	4.7	9.2	23.4	12.8	8.1	12.1	8.1
1B	91.8	72.1	56.1	38.3	29.1	33.7	52.7
1C	3.3	17.4	13.9	21.5	17.2	20.0	17.3
1D	0.2	1.3	6.4	21.5	26.1	19.0	12.3
1E	0.0	0.0	0.0	4.0	10.2	6.2	5.4
1F	0.0	0.0	0.2	2.1	9.3	9.0	4.2
Diversity	1.2	1.8	2.5	3.9	4.8	4.6	3.0

Table 4b. Distribution (%; columns sum to 100) of fishing effort[1] for northern shrimp between Divisions in NAFO Subarea 1 by 5-year period.

	5-year period						
	75–79	80–84	85–89	90–94	95–99	00–04	05–07
1A	4.2	9.3	30.5	15.9	16.7	24.9	16.7
1B	91.9	71.4	49.9	37.7	32.9	34.0	48.8
1C	3.4	18.1	12.6	21.9	16.2	14.1	10.5
1D	0.5	1.1	6.0	20.0	21.0	15.1	8.7
1E	0.1	0.0	0.0	2.4	6.5	4.1	6.2
1F	0.1	0.0	0.9	2.1	6.7	7.8	9.1
Diversity	1.2	1.8	2.8	3.9	4.6	4.4	3.4

[1] unstandardised trawl time

Table 5. Shrimp catch on the West Greenland shelf by month 1976-2006, summed from vessel logs, corrected for overpacking 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	8018	8596	8875	12341	14081	13973	12736	10106	15341	14217	12758	11191
2005	10532	8648	12532	14610	14961	14960	15129	16245	13787	12536	10271	10405
2006	12639	11733	14028	11340	15218	11797	15454	15228	16233	11833	11663	8941.1
2007*	*5417*	*8286*	*10391*	*13367*	*13298*	*13423*	–	–	–	–	–	–

* 2007: Greenland and EU fleets only, uncorrected logbook data, not weighted up.

Table 6. Discards of shrimp and fish, and landed catch reported as *P. montagui,* in the shrimp fishery in NAFO Subarea 1.

Year	P. borealis		Fish		P. montagui
	discard (tons)	discard (%)	discard (tons)	discard (%)	landed (tons)
1975	0	0.0	0	0.0	0
1976	0	0.0	0	0.0	0
1977	0	0.0	23	0.0	0
1978	0	0.0	27	0.1	0
1979	0	0.0	151	0.4	0
1980	0	0.0	186	0.3	0
1981	0	0.0	725	1.5	0
1982	0	0.0	788	1.5	0
1983	0	0.0	964	1.9	0
1984	0	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	3.0	5
1995	476	0.6	2700	3.2	562
1996	324	0.4	2712	3.3	773
1997	310	0.4	2327	3.0	422
1998	314	0.4	2183	2.7	1253
1999	197	0.2	7	0.0	4
2000	268	0.3	685	0.7	305
2001	382	0.4	1122	1.1	882
2002	649	0.5	1274	1.0	225
2003	638	0.5	1291	1.0	967
2004	724	0.5	992	0.7	789
2005	742	0.5	967	0.7	504
2006	850	0.6	1157	0.8	1419
2007	618	0.5	708	0.5	2598

2007, projections from part-year's data;

Table 7. Catches* (tons) of fish in Canadian offshore fisheries in eastern Davis Strait.

	Fish Catch	Shrimp	Percent
1979	186	1732	10.7
1980	104	415	25.1
1981	789	4419	17.9
1982	230	2818	8.1
1983	137	2096	6.5
1984	231	1569	14.7
1985	377	2449	15.4
1986	867	2972	29.2
1987	696	3406	20.4
1988	707	3479	20.3
1989	1848	7360	25.1
1990	1354	5663	23.9
1991	2496	6849	36.4
1992	2457	7480	32.8
1993	1426	5275	27.0
1994	1498	4355	34.4
1995	740	2275	32.5
1996	612	2673	22.9
1997	67	520	12.9
1998	115	819	14.1
1999	131	2081	6.3
2000	35	1676	2.1
2001	84	3443	2.5
2002	176	5966	3.0
2003	196	5439	3.6
2004	352	7155	4.9
2005	228	6077	3.8
2006	91	2909	3.1

* not clear whether this is by-catch in the shrimp fishery, or whether directed catches in other fisheries are included.

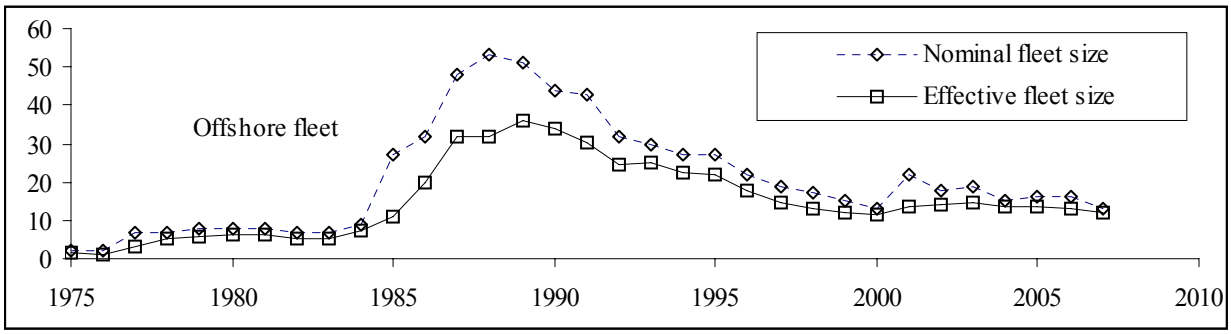

Fig. 1a. Nominal and effective sizes of the offshore trawler fleet in the West Greenland shrimp fishery, 1975–2007, from logbook records.

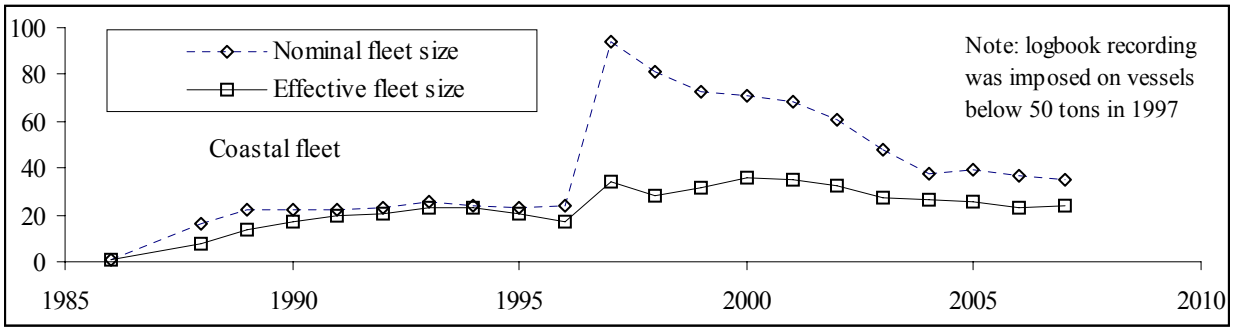

Fig. 1b. Nominal and effective sizes of the coastal trawler fleet in the West Greenland shrimp fishery, 1975–2007, from logbook records.

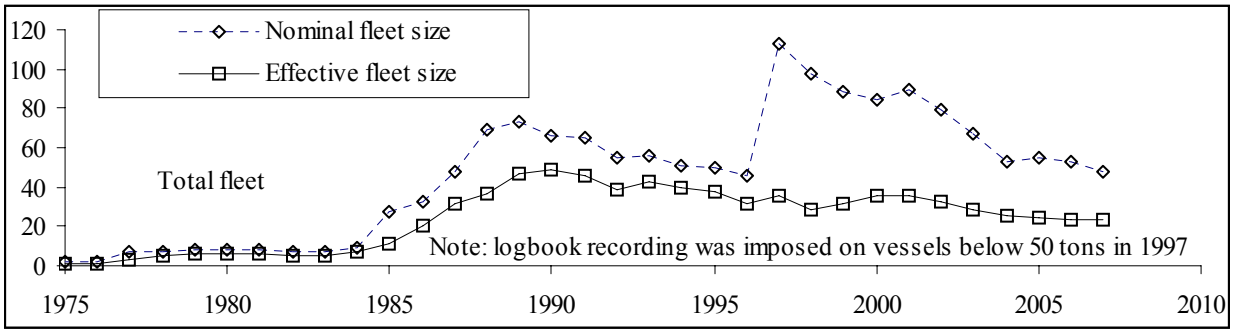

Fig. 1c. Nominal and effective sizes of the trawler fleet in the West Greenland shrimp fishery, 1975–2007, from logbook records.

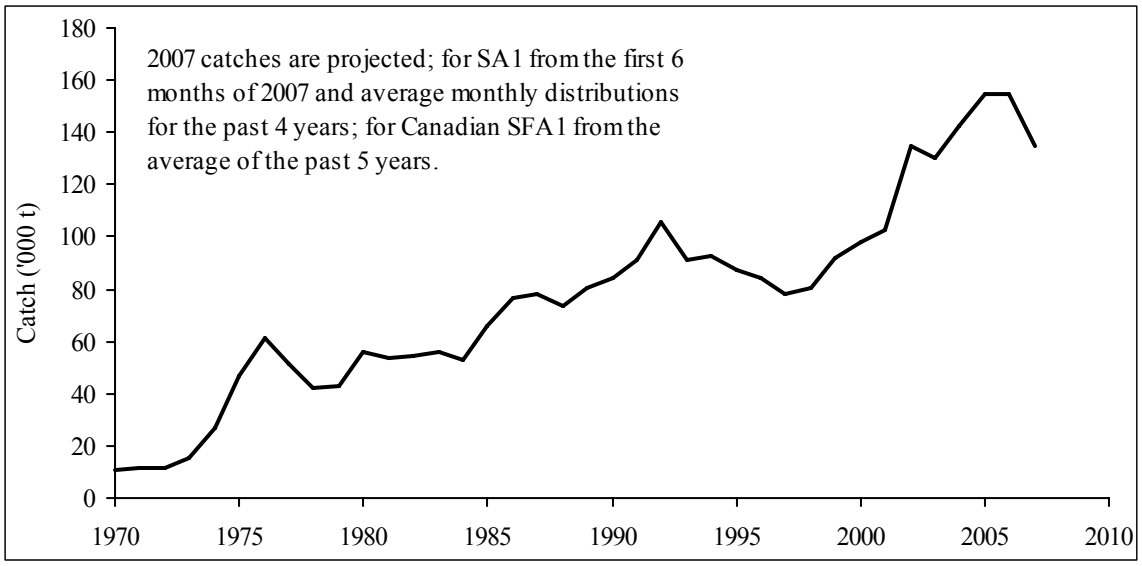

Fig. 2. Catches in the shrimp fishery in NAFO Subarea 1 and Canadian SFA 1, 1970-2006; 2007 value projected.

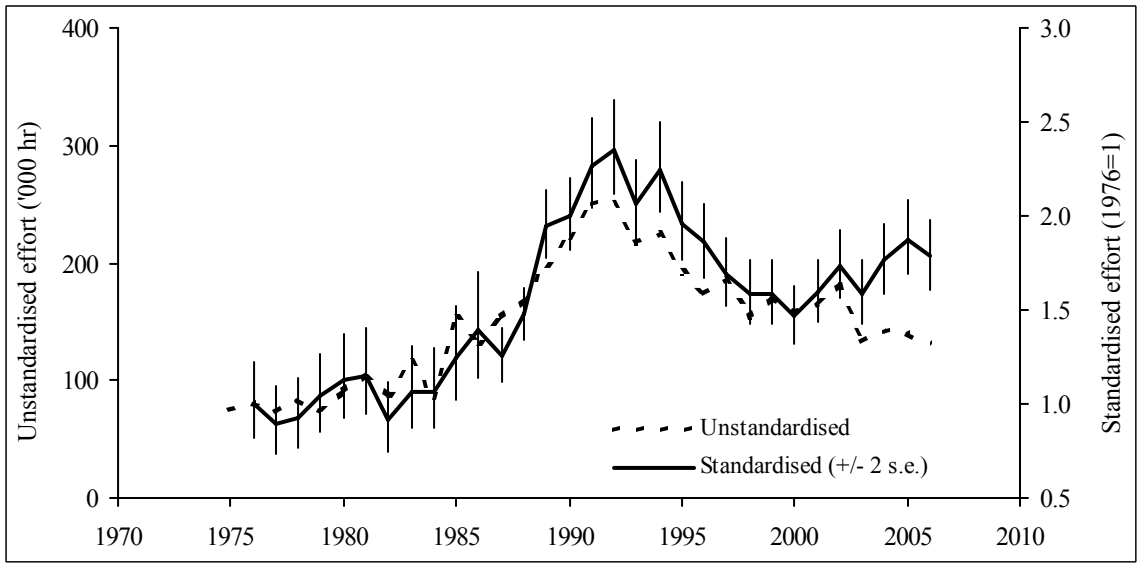

Fig. 3. Fishing effort applied in the shrimp fishery in NAFO Subarea 1 and Canadian SFA 1, 1970–2006.

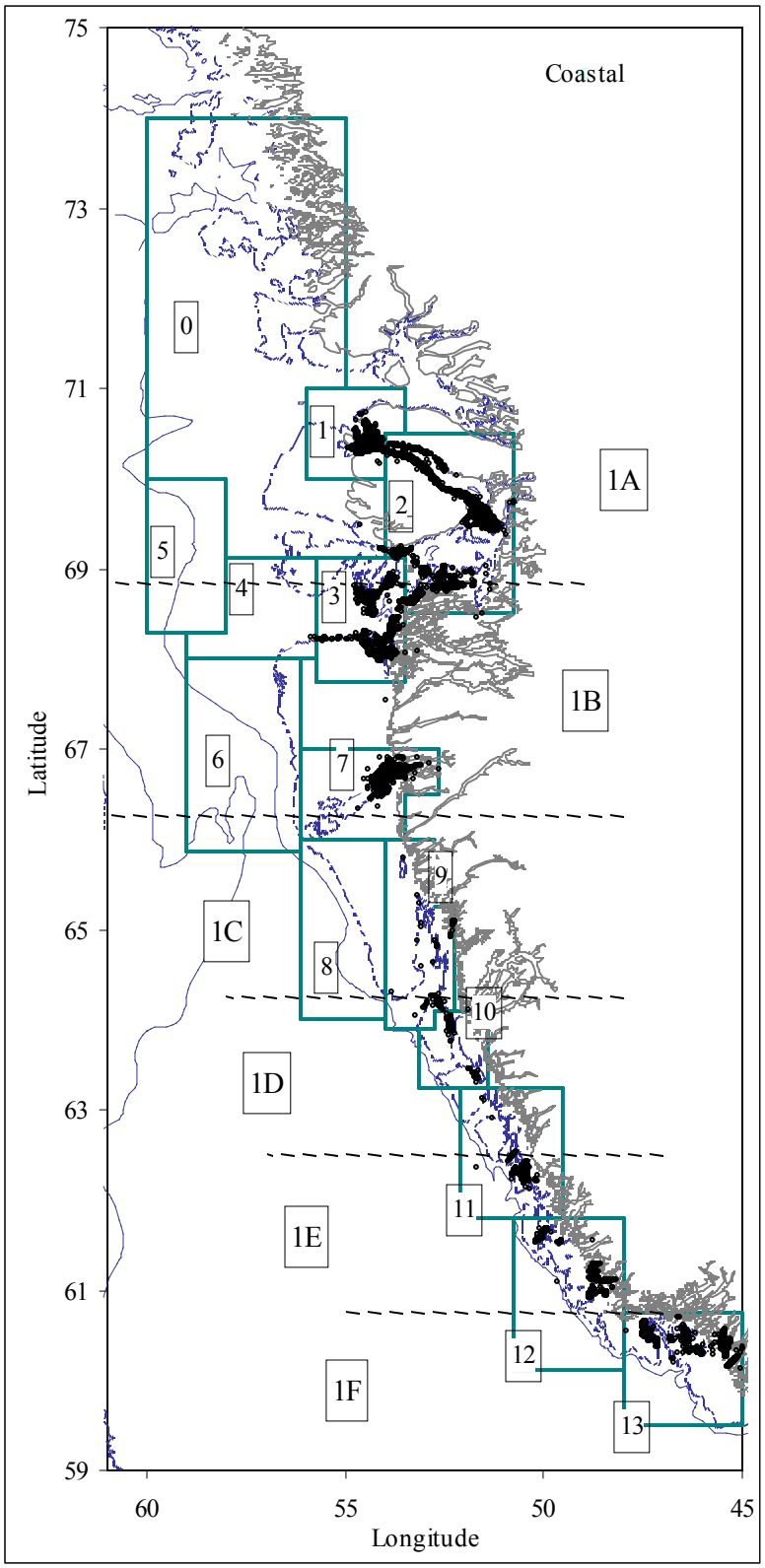

Fig. 4a. Distribution of fishing for Northern Shrimp by the Greenland coastal fleet in NAFO Subarea 1 from July 2006 through June 2007, with NAFO Divisions and statistical areas.

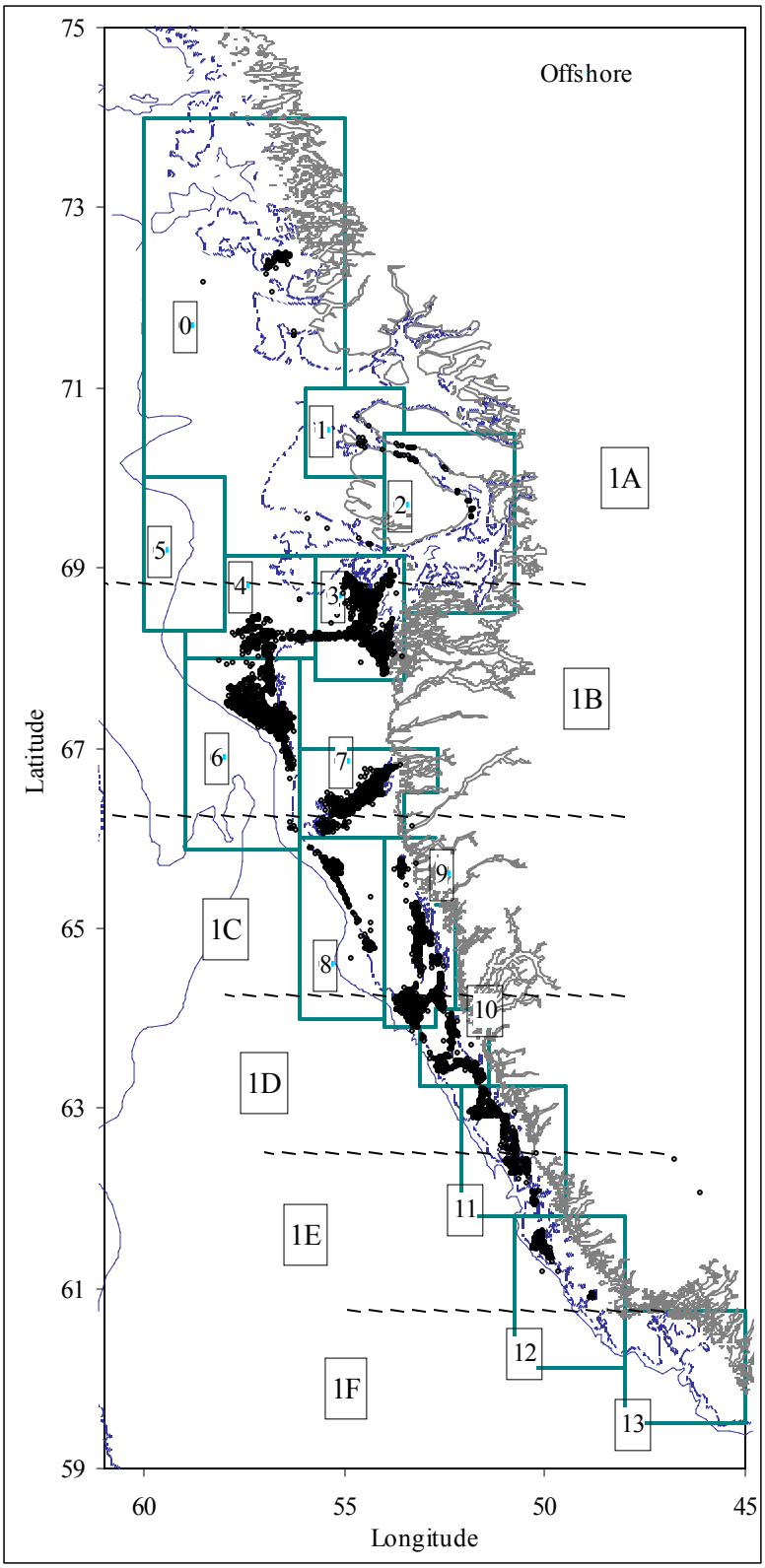

Fig. 4b. Distribution of fishing for Northern Shrimp by the offshore fleet in NAFO Subarea 1 from July 2006 through June 2007, with NAFO Divisions and statistical areas.

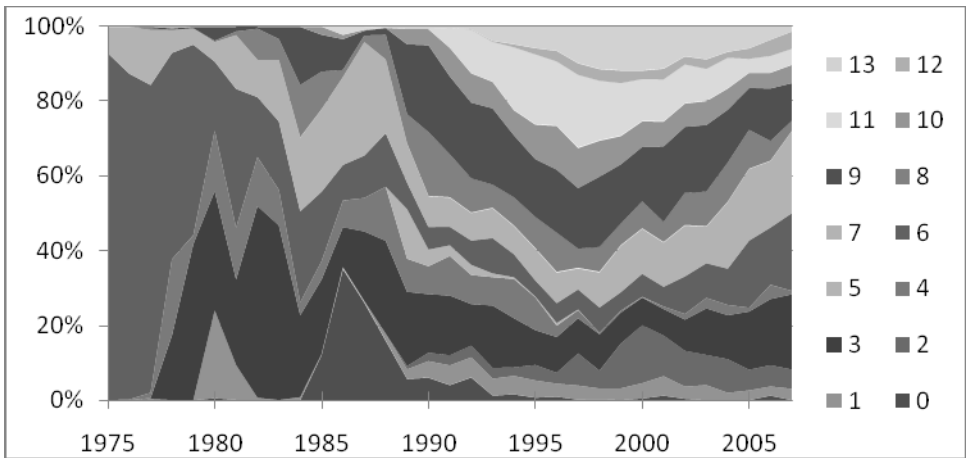

Fig. 5a. Distribution of the logbook-recorded catch of northern shrimp in the West Greenland fishery between statistical areas. (The light band that starts in the top left-hand corner is Area 7; the black band near the bottom is Area 3, that near the top is Area 9.)

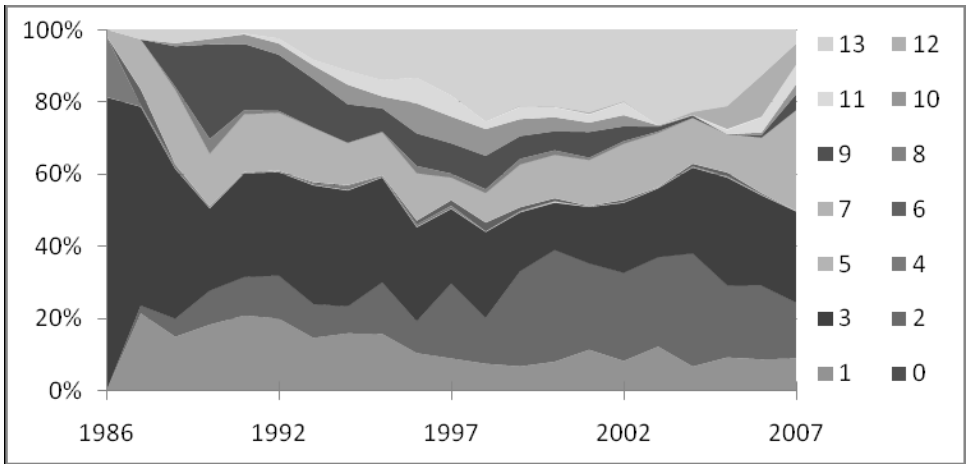

Fig. 5b. Distribution of the logbook-recorded catch of northern shrimp by the coastal fleet in the West Greenland fishery between statistical areas. (The wide dark band across the middle is Area 3; the prominent light band above it is Area 7.)

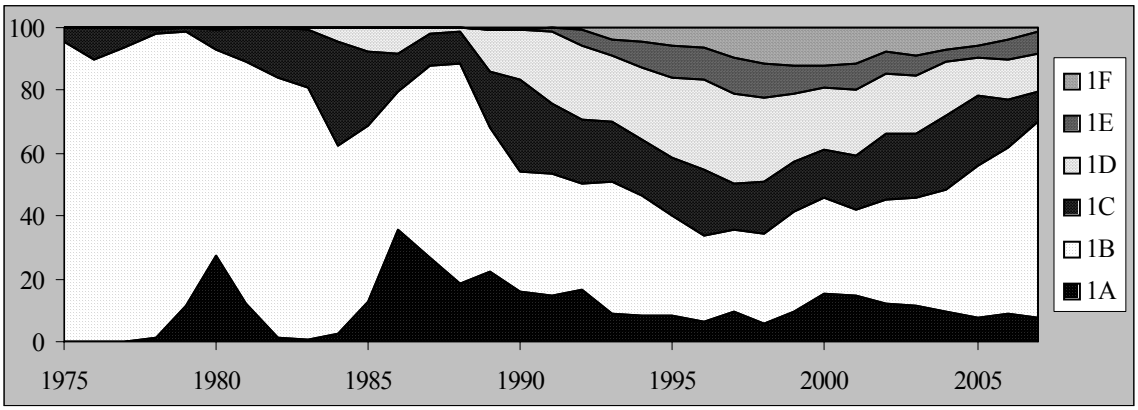

Fig. 5c. Distribution of the logbook-recorded catch of northern shrimp in the West Greenland fishery between NAFO Divisions.

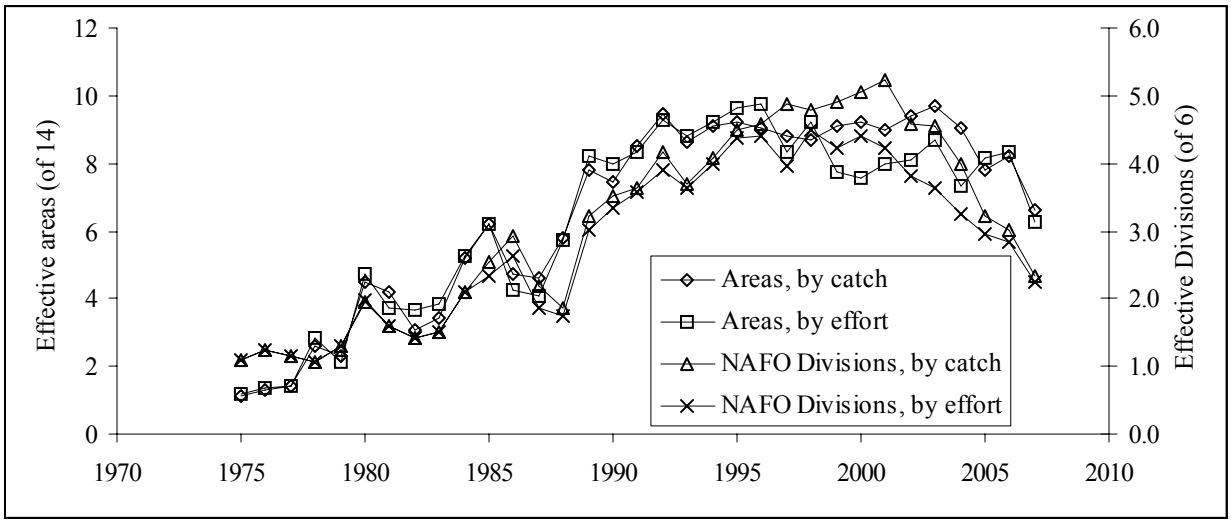

Fig. 6. Diversity indices for the distribution of logbook records of the West Greenland fishery between statistical areas and between NAFO Divisions, 1975–2007.

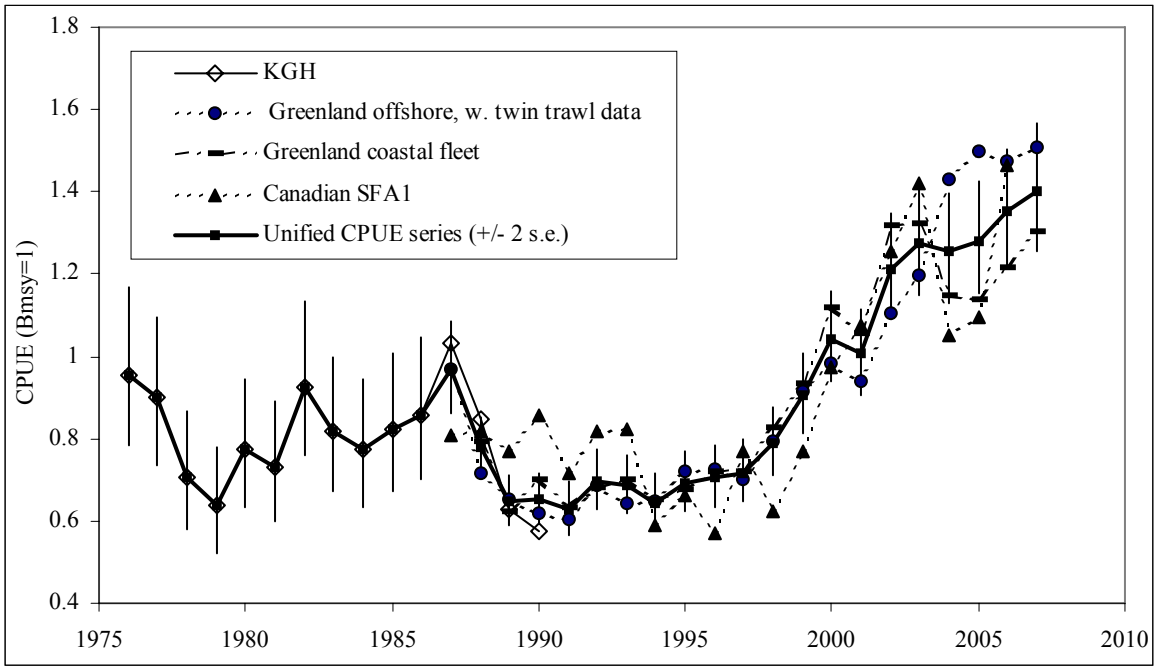

Fig. 7. Standardised CPUE in the West Greenland shrimp fishery, 1976–2007; series from 4 fleets standardised separately, and a weighted mean.

Appendix I: Output from a run of SAS PROC GLM to estimate a series of standardised annual CPUE values for the Greenland offshore fleet

```
                                Include all years and areas;          17:05 Sunday, September 30, 2007  77
                              Areas 1 and 2 deleted; 8 and 9 combined
                           March combined with April; Oct. and Nov. with Sept;
                                          Dec. with Jan.
                           Double-trawl data included w. gear effect in model;
                                  No month-area interaction included

                                          The GLM Procedure

                                       Class Level Information

Class         Levels    Values

VESSEL            18    a01 a03 a06 a07 a09 a13 a17 a19 a24 a27 a28 a31 a34 a35 a37 a40 a44 a46

dateYEAR          21    87 88 89 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 190

MONTH              8    2 3 5 6 7 8 9 12

AREA              10    3 4 5 6 7 8 10 11 12 13

holdn              2    1 2


                                    Number of Observations Read        8118
                                    Number of Observations Used        8118
```

Include all years and areas; 17:05 Sunday, September 30, 2007 78
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Weight: hauls

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	54	128309.8641	2376.1086	700.77	<.0001
Error	8063	27339.2945	3.3907		
Corrected Total	8117	155649.1586			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.824353	76.43650	1.841388	2.409043

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VESSEL	17	105743.9882	6220.2346	1834.49	<.0001
MONTH	7	2047.2808	292.4687	86.26	<.0001
AREA	9	2893.7627	321.5292	94.83	<.0001
dateYEAR	20	16514.8597	825.7430	243.53	<.0001
holdn	1	1109.9726	1109.9726	327.36	<.0001

Include all years and areas; 17:05 Sunday, September 30, 2007 79
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VESSEL	17	17984.55599	1057.91506	312.00	<.0001
MONTH	7	2029.30597	289.90085	85.50	<.0001
AREA	9	1105.05531	122.78392	36.21	<.0001
dateYEAR	20	12930.73213	646.53661	190.68	<.0001
holdn	1	1109.97259	1109.97259	327.36	<.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
03 vs 04	1	205.0974617	205.0974617	60.49	<.0001
04 vs 05	1	158.7182367	158.7182367	46.81	<.0001
04 vs 06	1	42.7463304	42.7463304	12.61	0.0004
06 vs 07	1	22.4383765	22.4383765	6.62	0.0101
07 vs 08	1	5.9443125	5.9443125	1.75	0.1855
08 vs 10	1	4.6635427	4.6635427	1.38	0.2409
10 vs 11	1	43.7225579	43.7225579	12.89	0.0003
11 vs 12	1	158.1479763	158.1479763	46.64	<.0001
12 vs 13	1	5.3136662	5.3136662	1.57	0.2107
mon. 02 vs 03	1	83.2657534	83.2657534	24.56	<.0001
mon. 03 vs 05	1	299.8071846	299.8071846	88.42	<.0001
mon. 05 vs 06	1	593.5175045	593.5175045	175.04	<.0001
mon. 06 vs 07	1	17.2238571	17.2238571	5.08	0.0242

Include all years and areas; 17:05 Sunday, September 30, 2007 80
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
mon. 07 vs 08	1	295.8587238	295.8587238	87.26	<.0001
mon. 08 vs 09	1	54.4816536	54.4816536	16.07	<.0001
mon. 09 vs 12	1	137.5361607	137.5361607	40.56	<.0001
mon. 12 vs 02	1	87.7099227	87.7099227	25.87	<.0001
a02 vs a03	1	121.0931749	121.0931749	35.71	<.0001
a03 vs a06	1	13.6227666	13.6227666	4.02	0.0451
a06 vs a07	1	30.7307188	30.7307188	9.06	0.0026
a07 vs a09	1	22.9298436	22.9298436	6.76	0.0093
a09 vs a13	1	82.2776736	82.2776736	24.27	<.0001
a13 vs a17	1	7.3396070	7.3396070	2.16	0.1413
a17 vs a19	1	62.8571028	62.8571028	18.54	<.0001
a19 vs a24	1	229.1363855	229.1363855	67.58	<.0001
a24 vs a27	1	27.8949469	27.8949469	8.23	0.0041
a27 vs a28	1	9.7410558	9.7410558	2.87	0.0901
a28 vs a31	1	64.6228998	64.6228998	19.06	<.0001
a31 vs a34	1	6.8580697	6.8580697	2.02	0.1550
a34 vs a35	1	5.5075984	5.5075984	1.62	0.2025
a35 vs a37	1	59.0295647	59.0295647	17.41	<.0001
a37 vs a40	1	18.0300325	18.0300325	5.32	0.0211
a40 vs a44	1	46.8276410	46.8276410	13.81	0.0002
a44 vs a46	1	56.0948978	56.0948978	16.54	<.0001

Include all years and areas; 17:05 Sunday, September 30, 2007 81
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		2.937249251	B	0.04015096	73.16	<.0001
VESSEL	a01	-1.375396469	B	0.03431382	-40.08	<.0001
VESSEL	a03	-1.171780314	B	0.02953191	-39.68	<.0001
VESSEL	a06	-1.085393947	B	0.04306928	-25.20	<.0001
VESSEL	a07	-0.960184295	B	0.02643332	-36.32	<.0001
VESSEL	a09	-0.906671361	B	0.02358683	-38.44	<.0001
VESSEL	a13	-0.829786891	B	0.02259143	-36.73	<.0001
VESSEL	a17	-0.803463429	B	0.02452356	-32.76	<.0001
VESSEL	a19	-0.726521424	B	0.02246652	-32.34	<.0001
VESSEL	a24	-0.580082677	B	0.02449092	-23.69	<.0001
VESSEL	a27	-0.506472007	B	0.02579165	-19.64	<.0001
VESSEL	a28	-0.465142371	B	0.02299759	-20.23	<.0001
VESSEL	a31	-0.383828307	B	0.02117952	-18.12	<.0001
VESSEL	a34	-0.326650278	B	0.04077098	-8.01	<.0001
VESSEL	a35	-0.275021818	B	0.02152357	-12.78	<.0001
VESSEL	a37	-0.202585271	B	0.02025509	-10.00	<.0001
VESSEL	a40	-0.171330714	B	0.01929266	-8.88	<.0001
VESSEL	a44	-0.094826046	B	0.02331370	-4.07	<.0001
VESSEL	a46	0.000000000	B	.	.	.
MONTH	2	0.079929248	B	0.01571544	5.09	<.0001
MONTH	3	0.154196283	B	0.01181677	13.05	<.0001

Include all years and areas; 17:05 Sunday, September 30, 2007 82
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
MONTH	5	0.036921488	B	0.01339184	2.76	0.0058
MONTH	6	0.226547156	B	0.01394625	16.24	<.0001
MONTH	7	0.259624615	B	0.01381621	18.79	<.0001
MONTH	8	0.122343177	B	0.01403472	8.72	<.0001
MONTH	9	0.072513149	B	0.01138554	6.37	<.0001
MONTH	12	0.000000000	B	.	.	.
AREA	3	-0.132851854	B	0.03384389	-3.93	<.0001
AREA	4	-0.273076498	B	0.03292858	-8.29	<.0001
AREA	5	-0.432975270	B	0.03745558	-11.56	<.0001
AREA	6	-0.218820089	B	0.03209290	-6.82	<.0001
AREA	7	-0.255152687	B	0.03239070	-7.88	<.0001
AREA	8	-0.270746369	B	0.03099771	-8.73	<.0001
AREA	10	-0.256547186	B	0.03211718	-7.99	<.0001
AREA	11	-0.206779431	B	0.03130956	-6.60	<.0001
AREA	12	-0.046593888	B	0.03722007	-1.25	0.2107
AREA	13	0.000000000	B	.	.	.
dateYEAR	87	0.449912215	B	0.04026899	11.17	<.0001
dateYEAR	88	0.145569577	B	0.02270434	6.41	<.0001
dateYEAR	89	0.053353692	B	0.01953928	2.73	0.0063
dateYEAR	91	-0.020692666	B	0.01767627	-1.17	0.2418
dateYEAR	92	0.103547972	B	0.01826094	5.67	<.0001

Include all years and areas; 17:05 Sunday, September 30, 2007 83
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
dateYEAR	93	0.035271651	B	0.01822369	1.94	0.0530
dateYEAR	94	0.043558002	B	0.01824892	2.39	0.0170
dateYEAR	95	0.151459472	B	0.01870230	8.10	<.0001
dateYEAR	96	0.161512248	B	0.01962624	8.23	<.0001
dateYEAR	97	0.125442859	B	0.02018842	6.21	<.0001
dateYEAR	98	0.251980924	B	0.02140014	11.77	<.0001
dateYEAR	99	0.390624746	B	0.02193048	17.81	<.0001
dateYEAR	100	0.464167618	B	0.02336494	19.87	<.0001
dateYEAR	101	0.420236508	B	0.02371400	17.72	<.0001
dateYEAR	102	0.582208451	B	0.02270740	25.64	<.0001
dateYEAR	103	0.661981802	B	0.02271287	29.15	<.0001
dateYEAR	104	0.838049063	B	0.02301255	36.42	<.0001
dateYEAR	105	0.883904699	B	0.02358680	37.47	<.0001
dateYEAR	106	0.867874095	B	0.02421573	35.84	<.0001
dateYEAR	107	0.890819702	B	0.03063377	29.08	<.0001
dateYEAR	190	0.000000000	B	.	.	.
holdn	1	-0.203098261	B	0.01122523	-18.09	<.0001
holdn	2	0.000000000	B	.	.	.

Include all years and areas; 17:05 Sunday, September 30, 2007 84
Areas 1 and 2 deleted; 8 and 9 combined
March combined with April; Oct. and Nov. with Sept;
Dec. with Jan.
Double-trawl data included w. gear effect in model;
No month-area interaction included

The GLM Procedure

Dependent Variable: LNCPUE

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: Output from a run of SAS PROC GLM to estimate a series of standardised annual CPUE values for the Greenland inshore fleet

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 115
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Class Level Information

Class	Levels	Values
VESSEL	15	a01 a02 a05 a06 a08 a11 a14 a19 a20 a22 a24 a27 a28 a29 a30
year	20	88 89 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 190
AREA	7	1 2 3 7 9 11 12
MONTH	9	1 3 4 5 6 7 8 9 10

Number of Observations Read 8423
Number of Observations Used 8423

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 116
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Dependent Variable: LNCPUE

Weight: HAULS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	29921.74108	636.63279	189.94	<.0001
Error	8375	28070.82056	3.35174		
Corrected Total	8422	57992.56163			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.515958	91.77586	1.830776	1.994834

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AREA	6	5553.31897	925.55316	276.14	<.0001
MONTH	8	2266.33924	283.29241	84.52	<.0001
VESSEL	14	9751.50100	696.53579	207.81	<.0001
year	19	12350.58186	650.03062	193.94	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AREA	6	3160.68997	526.78166	157.17	<.0001
MONTH	8	2127.34967	265.91871	79.34	<.0001
VESSEL	14	5610.34142	400.73867	119.56	<.0001

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 117
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Dependent Variable: LNCPUE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	19	12350.58186	650.03062	193.94	<.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
a01 vs a02	1	4.608153	4.608153	1.37	0.2410
a02 vs a05	1	20.125394	20.125394	6.00	0.0143
a05 vs a06	1	5.499491	5.499491	1.64	0.2003
a06 vs a08	1	38.044292	38.044292	11.35	0.0008
a08 vs a11	1	59.460618	59.460618	17.74	<.0001
a11 vs a14	1	33.466209	33.466209	9.98	0.0016
a14 vs a19	1	8.155668	8.155668	2.43	0.1188
a19 vs a20	1	13.296314	13.296314	3.97	0.0464
a20 vs a22	1	9.301295	9.301295	2.78	0.0958
a22 vs a24	1	41.101366	41.101366	12.26	0.0005
a24 vs a27	1	17.988150	17.988150	5.37	0.0205
a27 vs a28	1	13.597706	13.597706	4.06	0.0440
a28 vs a29	1	4.504791	4.504791	1.34	0.2464
a29 vs a30	1	191.907157	191.907157	57.26	<.0001
area01 vs a02	1	75.751833	75.751833	22.60	<.0001
area02 vs a03	1	1109.128512	1109.128512	330.91	<.0001
area09 vs a11	1	73.304454	73.304454	21.87	<.0001
area11 vs a12	1	42.320456	42.320456	12.63	0.0004
mon.01 vs m03	1	216.272211	216.272211	64.53	<.0001
mon.03 vs m04	1	225.539895	225.539895	67.29	<.0001
mon.04 vs m05	1	160.318460	160.318460	47.83	<.0001
mon.05 vs m06	1	39.255768	39.255768	11.71	0.0006
mon.06 vs m07	1	10.451908	10.451908	3.12	0.0775

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 118
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Dependent Variable: LNCPUE

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
mon.07 vs m08	1	53.188648	53.188648	15.87	<.0001
mon.08 vs m09	1	89.518204	89.518204	26.71	<.0001
mon.09 vs m10	1	42.296023	42.296023	12.62	0.0004
mon.10 vs m01	1	30.499157	30.499157	9.10	0.0026

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		2.651620081	B	0.04179312	63.45	<.0001
AREA	1	-0.351435168	B	0.01674207	-20.99	<.0001
AREA	2	-0.423576443	B	0.01582803	-26.76	<.0001
AREA	3	-0.171729579	B	0.01476637	-11.63	<.0001
AREA	7	-0.306631416	B	0.01635073	-18.75	<.0001
AREA	9	-0.330029194	B	0.01938964	-17.02	<.0001
AREA	11	-0.140505719	B	0.03954158	-3.55	0.0004
AREA	12	0.000000000	B	.	.	.
MONTH	1	-0.046055389	B	0.01526763	-3.02	0.0026
MONTH	3	0.107118527	B	0.01842718	5.81	<.0001
MONTH	4	0.280837918	B	0.01735282	16.18	<.0001
MONTH	5	0.148272702	B	0.01558122	9.52	<.0001
MONTH	6	0.209125851	B	0.01571837	13.30	<.0001
MONTH	7	0.240949271	B	0.01596883	15.09	<.0001
MONTH	8	0.164412809	B	0.01676576	9.81	<.0001
MONTH	9	0.059837536	B	0.01684454	3.55	0.0004
MONTH	10	0.000000000	B	.	.	.
VESSEL	a01	-1.179783467	B	0.06753170	-17.47	<.0001
VESSEL	a02	-1.107399111	B	0.04005223	-27.65	<.0001

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 119
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
VESSEL	a05	-1.014476311	B	0.04525872	-22.42	<.0001
VESSEL	a06	-0.969672719	B	0.03791881	-25.57	<.0001
VESSEL	a08	-0.894313404	B	0.03481213	-25.69	<.0001
VESSEL	a11	-0.817938752	B	0.03512330	-23.29	<.0001
VESSEL	a14	-0.767411256	B	0.03405433	-22.53	<.0001
VESSEL	a19	-0.732969406	B	0.03888236	-18.85	<.0001
VESSEL	a20	-0.685153322	B	0.03514130	-19.50	<.0001
VESSEL	a22	-0.654065795	B	0.03566592	-18.34	<.0001
VESSEL	a24	-0.575095026	B	0.03629334	-15.85	<.0001
VESSEL	a27	-0.510977091	B	0.03914912	-13.05	<.0001
VESSEL	a28	-0.449653091	B	0.03926986	-11.45	<.0001
VESSEL	a29	-0.394001922	B	0.05207004	-7.57	<.0001
VESSEL	a30	0.000000000	B	.	.	.
year	88	0.124519165	B	0.04051944	3.07	0.0021
year	89	-0.113369759	B	0.02894703	-3.92	<.0001
year	91	-0.099173660	B	0.02598963	-3.82	0.0001
year	92	-0.023554360	B	0.02586934	-0.91	0.3626
year	93	0.005290884	B	0.02562466	0.21	0.8364
year	94	-0.070204129	B	0.02543527	-2.76	0.0058
year	95	-0.035421081	B	0.02600091	-1.36	0.1731
year	96	0.028305266	B	0.02732383	1.04	0.3003
year	97	0.031572919	B	0.02650363	1.19	0.2336
year	98	0.168191409	B	0.02989381	5.63	<.0001
year	99	0.287350034	B	0.02700891	10.64	<.0001
year	100	0.471278155	B	0.02726995	17.28	<.0001
year	101	0.412192743	B	0.02628192	15.68	<.0001
year	102	0.633099740	B	0.02642800	23.96	<.0001

Small vessel: All areas allowed to be included 17:05 Sunday, September 30, 2007 120
Areas 4, 5, 6 & 8 deleted, areas 9 & 10 combined, 12 & 13 combined
Feb. combined w. Jan., Nov. and Dec. with Oct.

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	103	0.638035561	B	0.02738593	23.30	<.0001
year	104	0.494977212	B	0.02618618	18.90	<.0001
year	105	0.487620828	B	0.02601588	18.74	<.0001
year	106	0.552232809	B	0.02650537	20.83	<.0001
year	107	0.622359669	B	0.02992884	20.79	<.0001
year	190	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: Output from a run of SAS PROC GLM to estimate a series of standardised annual CPUE values for the Canadian fleet fishing in SFA1.

Canadian data for SFA1; partial data from N.S. 09:17 Wednesday, October 10, 2007 1
June and July combined with May, Dec. combined with Nov.

The GLM Procedure

Class Level Information

Class	Levels	Values
YEAR	20	1987 1988 1989 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2090
MONTH	5	5 8 9 10 11
vessel	12	aa cc dd ee gg ii jj mm oo pp uu vv
TCLASS	3	5 6 7
GEAR	2	2 91

Number of Observations Read 577
Number of Observations Used 577

Canadian data for SFA1; partial data from N.S. 09:17 Wednesday, October 10, 2007 2
June and July combined with May, Dec. combined with Nov.

The GLM Procedure

Dependent Variable: LNCPUE

Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	35	6878.775451	196.536441	73.84	<.0001
Error	541	1439.933779	2.661615		
Corrected Total	576	8318.709229			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.826904	26.56217	1.631446	6.141989

Source	DF	Type I SS	Mean Square	F Value	Pr > F
MONTH	4	703.874484	175.968621	66.11	<.0001
TCLASS	2	1645.659932	822.829966	309.15	<.0001
vessel(TCLASS)	9	2236.687881	248.520876	93.37	<.0001
YEAR	19	2082.648542	109.613081	41.18	<.0001
GEAR	1	209.904612	209.904612	78.86	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	4	91.684338	22.921084	8.61	<.0001
TCLASS	2	488.055535	244.027767	91.68	<.0001
vessel(TCLASS)	9	376.599628	41.844403	15.72	<.0001

Canadian data for SFA1; partial data from N.S. 09:17 Wednesday, October 10, 2007 3
June and July combined with May, Dec. combined with Nov.

The GLM Procedure

Dependent Variable: LNCPUE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	19	1512.496074	79.605057	29.91	<.0001
GEAR	1	209.904612	209.904612	78.86	<.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
aa vs cc	1	21.08885736	21.08885736	7.92	0.0051
dd vs ee	1	24.48747907	24.48747907	9.20	0.0025
ee vs gg	1	6.05808977	6.05808977	2.28	0.1320
gg vs ii	1	3.19878118	3.19878118	1.20	0.2734
ii vs jj	1	42.11592368	42.11592368	15.82	<.0001
mm vs oo	1	5.00500561	5.00500561	1.88	0.1709
oo vs pp	1	3.35827000	3.35827000	1.26	0.2618
pp vs uu	1	5.18004199	5.18004199	1.95	0.1636
uu vs vv	1	6.53441491	6.53441491	2.46	0.1177
5 vs 8	1	19.78630707	19.78630707	7.43	0.0066
8 vs 9	1	13.12933108	13.12933108	4.93	0.0268
9 vs 10	1	22.49805261	22.49805261	8.45	0.0038
10 vs 11	1	13.09664446	13.09664446	4.92	0.0270

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		6.446351058 B	0.08117857	79.41	<.0001
MONTH	5	0.186468529 B	0.03810331	4.89	<.0001
MONTH	8	0.096932105 B	0.03219099	3.01	0.0027
MONTH	9	0.155227949 B	0.03185447	4.87	<.0001
MONTH	10	0.073727656 B	0.03323709	2.22	0.0270

Canadian data for SFA1; partial data from N.S. 09:17 Wednesday, October 10, 2007 4
June and July combined with May, Dec. combined with Nov.

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
MONTH	11	0.000000000	B	.	.	.
TCLASS	5	-0.742488604	B	0.08250316	-9.00	<.0001
TCLASS	6	-0.233898645	B	0.08076847	-2.90	0.0039
TCLASS	7	0.000000000	B	.	.	.
vessel(TCLASS)	aa 5	-0.225055642	B	0.07995323	-2.81	0.0051
vessel(TCLASS)	cc 5	0.000000000	B	.	.	.
vessel(TCLASS)	dd 6	-0.603734730	B	0.07922706	-7.62	<.0001
vessel(TCLASS)	ee 6	-0.394415305	B	0.04893026	-8.06	<.0001
vessel(TCLASS)	gg 6	-0.343518018	B	0.04988015	-6.89	<.0001
vessel(TCLASS)	ii 6	-0.279496973	B	0.07026298	-3.98	<.0001
vessel(TCLASS)	jj 6	0.000000000	B	.	.	.
vessel(TCLASS)	mm 7	-0.439086826	B	0.07492431	-5.86	<.0001
vessel(TCLASS)	oo 7	-0.316850112	B	0.11103548	-2.85	0.0045
vessel(TCLASS)	pp 7	-0.218045090	B	0.07030792	-3.10	0.0020
vessel(TCLASS)	uu 7	-0.134437948	B	0.08580076	-1.57	0.1177
vessel(TCLASS)	vv 7	0.000000000	B	.	.	.
YEAR	1987	-0.053682865	B	0.14124222	-0.38	0.7040
YEAR	1988	-0.041826116	B	0.08494699	-0.49	0.6227
YEAR	1989	-0.106520753	B	0.05366997	-1.98	0.0477
YEAR	1991	-0.179643143	B	0.04951579	-3.63	0.0003
YEAR	1992	-0.044753458	B	0.05050971	-0.89	0.3760
YEAR	1993	-0.040205705	B	0.05055212	-0.80	0.4268
YEAR	1994	-0.368266156	B	0.04910612	-7.50	<.0001
YEAR	1995	-0.256670560	B	0.05617955	-4.57	<.0001
YEAR	1996	-0.409573949	B	0.05374337	-7.62	<.0001
YEAR	1997	-0.106559018	B	0.12235770	-0.87	0.3842
YEAR	1998	-0.319423513	B	0.09454599	-3.38	0.0008
YEAR	1999	-0.108251915	B	0.06639745	-1.63	0.1036

Canadian data for SFA1; partial data from N.S. 09:17 Wednesday, October 10, 2007 5
June and July combined with May, Dec. combined with Nov.

The GLM Procedure

Dependent Variable: LNCPUE

Parameter		Estimate		Standard Error	t Value	Pr > |t|
YEAR	2000	0.128090288	B	0.08666651	1.48	0.1400
YEAR	2001	0.229598607	B	0.06845764	3.35	0.0009
YEAR	2002	0.383569925	B	0.05862900	6.54	<.0001
YEAR	2003	0.506116104	B	0.06183653	8.18	<.0001
YEAR	2004	0.207181067	B	0.05614685	3.69	0.0002
YEAR	2005	0.245912732	B	0.06284975	3.91	0.0001
YEAR	2006	0.536267734	B	0.08244924	6.50	<.0001
YEAR	2090	0.000000000	B	.	.	.
GEAR	2	0.287220151	B	0.03234272	8.88	<.0001
GEAR	91	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.