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The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970-2003

by

C. Hvingel

Pinngortitaleriffik, Greenland Institute of Natural Resources
Box 570, DK-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 150-600 m. The stock is assessed as a single population and managed by catch control. Greenland and Canada exploit the stock in Subarea 1 and Div. 0A, respectively.

Following a maximum in 1992 of 105 000 tons catches decreased to around 80 000 tons in 1998 due to management measures. Since then stepwise increases of catch quotas have been followed by increased catches. The projected catch of 2003 is expected to be the highest ever amounting to about 132 000 tons. The inshore fishery (vessels below 80 GRT) accounts for around 16% of the total landings. Reported discard and by-catch is low.

A standardized CPUE series indicate an increasing trend of stock biomass since the early-1990s. The estimated 2003 median value is the highest of the time series. Standardized effort based on biomass indicated a decrease in harvest rate from 1992 to 2000 by about 35%. However, when based on numbers only a 13% decrease was evident. For 2003 the indices indicate a harvest rate at the level of the preceding two years.

The mean size of shrimp caught has declined since 1991. In spite of these changes, the proportions of female to male shrimp in the catches seem relatively stable since the mid-1990s. The length-frequency distribution of the 2001 catches shows a large peak of males around 20 mm carapace length. The female component is less prominent, however, with representation of all sizes normally present. Sparse sampling in 2002 does not indicate major changes from that. The 2003 catch composition could not be evaluated due to incomplete sampling.

Introduction

Northern shrimp (*Pandalus borealis*) occurs on the continental shelf off West Greenland in NAFO Div. 0A and 1A–1F. The stock is continuously distributed from Cap Farewell to about 74°N, with highest concentrations in depths between 150 and 600 m (Fig. 1). There is no evidence of distinct sub-populations and since 1993 this stock is assessed as a single population (Anon., 1993).

The fishery for shrimp began in inshore areas in 1935. In 1970 the development of a multinational offshore fishery started and during the following 30-years landings increased, reaching approximately 130 000 tons in 2002. Since 1981 access to the stock was limited to Greenlandic vessels in Subarea 1 and Canadian vessels in Div. 0A. Catch restrictions were imposed in 1977 and since then the stock has been managed by a Total Allowable Catch (TAC).

Two Greenlandic fleet components exploit the stock in Subarea 1: an offshore fleet, which at present consists of 15 large factory trawlers (500-4 000 GRT) and a small vessel fleet composed of about 60 vessels below 80 GRT. The offshore fleet

component is restricted to offshore areas and by quotas. With a few exceptions vessels below 80 GRT were unrestricted by areas and quotas until 1997 when catch regulation was introduced also for this fleet component. Since 1986 logbooks have been mandatory for vessels above 50 GRT. Since 1997 logbooks are available for all vessels. An Internal Transferable Quota system (ITQ) was introduced as a management tool in 1991.

The Canadian fleet exploits the stock component in Div. 0A. Seventeen companies are currently licensed to fish in the area but in recent years only 6-7 vessels (2 000-4 000 GRT) have participated. Catches are restricted by quotas. Vessel logs are available since 1979.

The present paper updates time series of catch, effort, catch composition, standardized CPUE-indices and spatial distribution of the Greenlandic and Canadian trawl fishery for shrimp off West Greenland.

Materials and Methods

Total catches were estimated from vessel logs and weekly reporting to Greenlandic authorities, corrected for "over-packing" and converted to live weight (Hvingel, 2003). Logbook data were analysed to show the spatial and temporal distribution of the fishery. Unstandardized CPUE was calculated using a factor 1.6 as a multiplier for recorded effort by vessels using twin-trawl. Unstandardized effort was calculated by dividing total catch with mean CPUE. Standardized effort was calculated by dividing total catch by the standardized CPUE-index (see below).

CPUE data from Greenlandic vessels above 50 GRT fishing in Subarea 1 and Canadian vessels fishing in Div. 0A were used in multiplicative models to calculate standardized annual catch rate indices. Four separate indices covering four different fleets were derived (Hvingel *et al.*, 2000). These indices were then combined in a single series representing the total area. Annual CPUE indices for the total area cannot be derived from a single GLM (General Linear Model) run including all fleets as they had no or too little overlap either in time or in space and thus such a model will not be able to estimate the relative fishing power of the individual vessels.

The four indices included the following variables: (1) individual vessel fishing power, (2) seasonal availability of shrimp, (3) spatial availability of shrimp and (4) annual mean CPUE. The calculations were done using the SAS statistical software (Anon., 1988). The main criterion for including an individual vessel in either of the multiplicative models was three years of participation in the fishery covered by the index. Hauls by twin-trawls (two complete trawls towed simultaneously) were excluded from the analysis. The area definition used is based on distinct fishing grounds (Fig. 1). The multiplicative model was represented in logarithmic form either as:

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

or with a MONTH*AREA interaction (see appendix 1) implying an annual migratory or behavioural pattern:

Model 2 $$\ln(CPUE_{mjki}) = \ln(u) + \ln(V_k) + \ln(Y_i) + \ln(A_m * S_j) + e_{mjki}$$

Where $CPUE_{mjki}$ is the mean CPUE for vessel k, fishing in area m in month j during year i (k = 1,...,n; m = 1,…,a; j = 1,…,s; i = 1,…,y); ln(u) is overall mean ln($CPUE$); A_m is effect of the m^{th} 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; e_{mjki} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in the cell. The standardized CPUE indices are the antilog of the year coefficient.

Parameter estimates of the vessel, month and area variable from a first run of the main effects model (model 1) were compared. Levels within each variable were combined in subsequent analyses if the parameter estimates did not differ by more than 5%. This was done to reduce the number of empty cells in the models. For further details on model construction and analyses see Hvingel *et al.* (2000).

The '1BCDEF index' largely covers the NAFO Div. 1B to F (area 1A was not included due to misreporting from that particular area). 40 vessels were included providing data since 1987. These data were grouped into 9 areas (Area 4-12, Fig. 1). Based on the exploratory run of the main effects model (model 1) the vessel effect was collapsed into 27 groups consisting of 1-3 vessels with similar fishing power. The month effect was reduced to 10 levels by grouping adjacent months with similar indices of relative shrimp availability. Areas 7 and 8, and area 9 and 10 were grouped.

The 'KGH index': The initial offshore fishery was executed by 7 sister trawlers (722 GRT) all operated by the Kongelige Grønlandske Handel (KGH). This early fishery only covered Div 1A and part of Div. 1B and data from Area 3, 4, 6 and 7 (Fig. 1) for the years 1976-1990 were considered for this index. 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 area 4, 6 and 7 combined.

Data for **the '0A index'** is available since 1981. The fishery in Div. 0A takes place in a very limited area (Fig. 1) thus no areal segregation was required for the 0A-index. Although the fishery takes place in June-December, the analysis was confined to July-November because effort was sparse in June and December, especially in recent years. Effort in 1997 was low and an unknown proportion was due to twin trawling thus 1997 was not included. The 29 levels of the vessel variable were reduced to 10 consisting of 1-7 individual vessels of similar fishing power. The months August-November were grouped into one level before subsequent analyses.

The 'small vessel index' is based on vessels below 80 GRT, which have exclusive rights for fishing in "inshore" areas. This fishery is almost exclusively confined to areas around Disko Island in Div. 1A and 1B. The areas included were those shown as areas 1, 2 and 3 in Fig. 1. Comprehensive data are available since 1988 and 27 vessels were used in the model. The fishery occurs from March/April to December. The vessel variable was reduced to 9 levels consisting of groupings of 1-5 vessels due to similarity of estimated fishing power. The month variable was reduced from 9 to 5 levels.

For this years', analyses the indices were revised and the following changes relative to the 2002 analyses (Hvingel, 2002), were made:

- 1BCDEF index: addition of 6 new vessels
- Small vessel index: addition of 1new vessel
- KGH index: No changes
- Div. 0A index: No changes

One unified time series of standardized CPUE, covering 1976-2002, was derived by aggregating the four available indices. A Monte Carlo Markov Chain (MCMC) sampling process was used to construct distributions of likelihoods of possible values of this combined index. This was done within the programming framework WinBUGS v.1.4, (www.mrc-bsu.cam.ac.uk/bugs). The individual CPUE series for the pth fleet, μ_{pi}, was assumed to reflect an overall biomass series, Y_i, and a constant fleet coefficient, v_p, so that:

$$\mu_{pi} = v_p Y_i \exp(e_{pi}).$$

The error, e_{pi}, were considered to be distributed with mean zero and variance σ_{pi}^2. I assumed that e_{pi}, had variances inversely proportional to the area of fishing ground, a_p, covered by fleet p. The factor, a_p, was taken to be the area of sea bottom between 150-600 m. Hence, σ_{pi}^2 was calculated by:

$$\sigma_{pi}^2 = \frac{cv_{pi}^2}{a_p}$$

Where cv_{pi} is the annual fleet specific coefficient of variation as calculated in the GLM run. The area weighting factor, a_p, for the 1BCD, KGH, 0A and Small vessel indices was estimated to 0.46, 0.36, 0.05 and 0.13, respectively.

Annual size compositions of shrimp catches were obtained from samples taken before processing by fisheries observers onboard offshore vessels. Onboard the vessel or later in the laboratory samples were sorted by sexual characteristics (McCrary, 1971) and measured to the nearest 0.1 mm (Greenland) and 0.5 mm (Canada) carapace length. The data were pooled in 0.5 mm length groups and adjusted by the weight of the catch to the number caught in the set. Numbers from all sets for the month were totalled and adjusted by weight to the monthly catch by NAFO Division. The numbers from all months and areas were totalled and adjusted by weight to the total or projected catch of the year. Sex specific indices of abundance were calculated by dividing the numbers caught of each sex by the standardized effort.

Results and Discussion

Catch

Catches of shrimp taken in the Greenland Exclusive Economic Zone (EEZ) have so far been reported without accounting for "over-packing" – the quantum of surplus weight in a certain packaging (e.g. in 5 kg cartons) – or the difference between the product weight and live weight. January 1st 2004 this practice will change by the enforcement of new legislation to ensure that total removals by fishing are reported in units of live weight. The catch series was therefore revised compared to the one previously used in the assessments. Details are given in Hvingel, 2003.

In conjunction with the development of the offshore shrimp fishery total annual catch has increased from about 10 000 tons in the early-1970s to more than 105 000 tons in 1992 (Fig. 2, Table 1). Government restrictions to reduce effort and fishing opportunities elsewhere for the Canadian fleet then made catches decrease to about 80 000 tons in 1998. However, when measured in numbers caught, the catch level of 1992 was maintained (Fig. 2A). Since then raises of the annual quotas (Table 1) has been accompanied by increased catches. The projected catch of 2003 is expected to be about 132 000 tons (projected from Oct. to the end of the year).

Since the beginning of the 1970's catches in the inshore areas have been fluctuating between 8000 and 23000 tons (Table 1). Limited access for vessels above 80 GRT was the only management related restraint on inshore catch levels until 1997 when ITQ's were enforced also for the small vessel fleet. Subsequently catches decreased substantially while a major reorganisation of the fleet took place. During most of the nineties the inshore fishery had accounted for 19-24% of the total catches, but in 1998 only 13% (10 500 tons) were taken inshore. By 1999 catches were back up around 20 000 tons. However, while the catches of the offshore fishery kept increasing the catches of inshore fishery has remained stable. Thus for the recent two years the inshore fleets' share of total catches has declined to 16%.

The Canadian catches in Div. 0A have fluctuated between 17 00 and 5 400 tons during 1979-1983 after which they increased from 2 100 tons in 1984 to the highest recorded level of around 6-7 000 tons in the late-1980s to early-1990s (Table 1). Catches thereafter declined to around 1 000 tons in 1998 coincident with the increased fishing opportunities off Labrador. During the mid-1990s to early-2000s catches in Div. 0A have accounted for less than 4% of the total catches off West Greenland. The 2003 catches are expected to be about 4 000 tons i.e. 3% of total catches.

The fishery takes place in all months (Table 2). In general the monthly amount of shrimp caught tracks a dome shaped curve over the year with a maximum in midsummer (June-July). In some years (1991-1994) a second maximum occur in October. In Div. 0A the fishery usually begins in late June - early July and continues into late November. However, most of the catch and effort occurs in August-October.

By-catch and discard

The reported discard of shrimp has remained less than 1% (weight) of total catch throughout the period 1987-2003 (Table 5). The discard of fish has shown a slightly increasing trend from about 1 to 3% of total catch in the years 1987-1998. The introduction of observers on all offshore vessels in 1991 has most likely contributed to this development by the increasing incentive to report discard. An improved market for smaller shrimp may have offset the corresponding effect of observers on the reported discard of shrimp. In the most recent years, registered annual discard of fish have been around 1% of total catch. Sorting grids with 22mm grid space are mandatory for stern trawlers.

From 1995 to 2003 vessels have reported annual catches of *P. montagui* in the range of about 100 to 1 000 tons (Table 5). Landings of *P. montagui* are allowed to include up to 70% *P. borealis*. As *P. montagui* can be landed outside the quota it has therefore been possible to "hide" catches of *P. borealis* within these landings. Hence, it is difficult to use the emergence and disappearance of *P. montagui* in the catches to infer changes in targeting strategy of the fishery or as an indication of increased availability of this species. However there have been indications of increased biomass of *P. montagui* during the mid-1990s (Kanneworff, 2003).

Effort

Since 1975, when the offshore fishery was well established, until 1984 annual unstandardized effort showed a slightly

increasing trend from about 75 000 hr's to about 93 000 hr's (Fig. 2B). In the subsequent years a considerable enlargement of the offshore fleet took place and effort went up by almost a factor three reaching 250 000 hr's in 1991-1992. Hereafter unstandardized effort has decreased as a result of management measures, reduced activity in Div. 0A (Table 3) and a general increased fishing efficiency of the participating vessels. The increase in the overall unstandardized effort and in particular effort in Div. 1A from 1996 to 1997 is caused by the addition of logbooks from vessels below 50 tons to the database (introduction of new logbook system). In 2002 about 168 000 trawling hr's were registered and preliminary data suggest that the year 2003 figure will decrease to around 130 000 hr's.

The course of the weight based standardized effort time series agrees trend wise with the unstandardized (Fig. 2B). Since 1992, when it reached its highest value, standardized effort has shown a continuous decrease until 2000 by a total of about 35%. A corresponding effort index based on number of individuals (Fig. 2B) showed a similar decreasing trend of the 1990s however the reduction was less i.e. about 13%. Std. effort then increased marginally from 2000 to 2002. For 2003 the indices is down again indicating a harvest rate at the 2000 level.

Catch-per-unit-effort

The unified standardized CPUE index is an aggregate of four individual indices (Table 4) derived by GLM (Appendix 1-4). All fleets included in the analysis mainly exploit shrimp greater than 16 mm cpl. The CPUE indices are therefore indicative of the older male and the female stock combined.

The overall combined index (Fig. 2C, Table 4) fluctuated without trend by a factor of 2 between 1976 and 1987. It then dropped precipitously to the lowest level of the time series in 1990-91. The marked spike in 1987 is likely the result of some very strong year-classes produced in the early-1980s (Anon., 1991). Since 1990 the index has shown an increasing trend. The revised 2002 median index value, using the complete set of data for the year, was slightly lower than the value reported in Hvingel (2002) based on partial data for the year. The estimated median value for 2003 is up by 11% compared to the 2002-median value and is the highest of the time series.

The standardisation method used accounts for the increase in efficiency from renewal of the fleet but does not account for the technological improvements, which result from upgrading of older vessels. However, the YEAR*VESSEL term had low importance in the individual models which suggested that this term could be ignored and the YEAR-effect therefore interpreted as a biomass indicator. Still, the standardized CPUE time series is expected to give a slightly optimistic view of the stock development (for further discussion of the CPUE index as a stock indicator see Hvingel *et al.*, 2000).

Spatial distribution of the fishery

The fishery has been conducted on the continental shelf of Greenland between 59 and 74°N, mainly between 150 and 600 m depth (Fig. 1). However, during the period of logbook recordings (since 1975) a substantial change in the relative importance of the different areas is indicated. Since the mid-1970s until the early-1980s the vast majority of the annual fishing effort was allocated to Div. 1A and 1B. Div. 1C and 0A received some attention but almost no effort was spent in Div. 1D, 1E and 1F (Table 3). Since then the fishery has gradually expanded southward to include also these three southern-most Divisions in Subarea 1. Incomplete logbook coverage of the small vessel component causes underestimation of the fishery in Div. 1A and 1F until 1997. Alternating quota restrictions in offshore areas of Div. 1A may also have biased data for this area.

The southward expansion/displacement of the offshore fishery 1987-1998 is summarized by a decreasing mean latitude of effort allocation as shown in Fig. 3. Indications of biomass distribution from the German groundfish survey (Rätz, 1997) and the Greenlandic trawl survey (Carlsson and Kanneworff, 1997) may suggest that the fishery was tracking a southward shift in shrimp biomass. However, development of improved trawling gear for accessing the more difficult trawling grounds in the southern areas may also have been an important factor. Since then the distributional pattern of the fishery has stabilised. The preliminary data for 2003 do not suggest any significant changes in the distribution of the fishery in Subarea 1 and Div. 0A as compared to that of year 2002 (Fig. 6).

Catch composition

The mean shrimp size caught has declined during the 1990s. In Subarea 1 it declined by 3 mm cpl. from 1991to 1999

corresponding to a mean individual weight reduction of about 30% (Fig. 5). Mean shrimp size caught in the Canadian fishery in Div. 0A showed a similar declining trend since 1981 (Fig. 5). In spite of these changes, the proportions of female to male shrimp in the catches seem relatively stable since the mid-1990s

The reduced size may be partly due to better market prices for small shrimp along with a thorough restructuring of the Greenlandic offshore fleet during this time period, leaving most vessels with enough quota to make 'high-grading' less profitable. However, the decline of shrimp size in the catches was temporarily reversed in year 2000 by the presence of a relative high proportion of female shrimp (table 6). The length frequency distribution of year 2000 shows a large peak of female shrimp at around 25 mm cpl. (Fig. 7).

The data of 2001 does not indicate an equally good catch quality. The length frequency distribution shows a dominant peak of male shrimp at around 20 mm cpl. (Fig. 7). The female component is less prominent, however, with representation of all sizes normally present in the catches. Thus, the standardized catch rates indicate a decrease in the abundance of females compared to 2000 (Fig. 4) while abundance indices of males indicate an increase.

For 2002 only three samples were available and therefore numbers on annual catch composition derived from these samples should be viewed with reservation. However, no major changes from the previous year were indicated. The 2003 catch composition was not evaluated due to sparse sampling.

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Table 1. Total Allowable Catch (TAC), catch, effort and Catch per Unit of Effort (CPUE) of the shrimp fishery in NAFO SA 1 and Div. 0A 1970-2003. Catch are in tons, effort in 000 hr's (unstandardized) or as an index (standardized to 1 for1976). CPUE is given in kg/hr (unstandardized) or as an index (standardized to 1 for1976).

Year	TAC			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's)			Std. (index)	Unstd. (kg/hr)			Std. (index)
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	1.00
1977	-	-	36000	42578	8580	51158	457	51615	73.1	-	73	0.93	699	-	706	0.90
1978	-	-	41000	33835	8360	42195	122	42317	84.2	-	84	0.98	501	-	503	0.70
1979	-	-	31500	32852	8250	41102	1732	42834	72.4	7.3	80	1.10	568	236	537	0.63
1980	-	-	32000	44916	8250	53166	2726	55892	80.0	7.6	88	1.18	665	358	638	0.77
1981	35000	5000	40000	40295	8250	48545	5284	53829	88.2	17.7	106	1.18	551	299	509	0.74
1982	34800	5000	39800	43979	8250	52229	2064	54293	81.1	6.2	87	0.94	644	335	622	0.94
1983	34625	5000	39625	42553	8250	50803	5413	56216	89.0	19.1	108	1.14	571	284	520	0.80
1984	34925	5000	39925	42414	8250	50664	2142	52806	85.0	7.7	93	1.13	596	280	570	0.76
1985	42120	6120	48240	54889	8250	63139	3069	66208	128.0	9.9	138	1.33	493	309	480	0.81
1986	42120	6120	48240	65623	8250	73873	2995	76868	132.8	6.7	140	1.54	556	445	551	0.81
1987	40120	6120	46240	64222	7613	71836	6095	77931	136.1	12.4	149	1.22	528	491	525	1.04
1988	40120	6120	46240	56479	11256	67735	5881	73616	150.7	12.6	163	1.74	449	468	451	0.69
1989	45245	7520	52765	58890	14546	73436	7235	80671	176.9	18.5	195	2.16	415	391	413	0.61
1990	45245	7520	52765	62800	14993	77793	6177	83970	207.0	15.2	222	2.38	376	405	378	0.57
1991	46225	8500	54725	66818	17884	84701	6788	91489	229.1	20.5	250	2.56	370	330	366	0.58
1992	44200	8500	52700	75341	22653	97994	7493	105487	233.7	17.6	251	2.73	419	425	420	0.63
1993	40600	8500	49100	65894	19627	85522	5491	91013	206.1	13.6	220	2.40	415	404	414	0.62
1994	42300	8500	50800	68109	19930	88039	4766	92805	209.8	16.3	226	2.48	420	292	410	0.61
1995	39500	8500	48000	66955	18072	85027	2361	87388	184.6	7.2	192	2.16	461	329	456	0.66
1996	63922	8500	72422	62368	19095	81463	2632	84095	164.2	8.7	173	2.04	496	303	487	0.67
1997	64600	10200	74800	62743	14868	77611	517	78128	185.2	1.2	186	1.95	419	443	419	0.65
1998	60729	7650	68379	69156	10406	79562	933	80495	152.7	3.1	156	1.80	521	300	517	0.73
1999	71000	9350	80350	71197	18948	90145	2046	92191	164.4	4.0	168	1.85	548	507	547	0.81
2000'	71000	9350	80350	72291	23133	95424	1782	97206	154.6	2.4	157	1.81	617	743	619	0.88
2001'	82000	9350	91350	79174	19981	99156	3625	102781	158.1	4.8	163	1.95	627	748	631	0.86
2002'	91150	12040	101000	104258	21636	125894	6247	132141	164.6	6.2	171	2.06	765	1003	774	1.04
2003"	100000	14667	114667	107000	21000	128000	7000	135000	128.2			1.89	999			1.16

* 1981-1995 The TACs are for the offshore areas only.

' Preliminary.

'' Projected.

Table 2. Shrimp catch in SA 1 by month 1987-2003, summed from vessel logs and weighted up to total catch.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	5793	740	0	0	131	10846	10454	11543	11238	8232	1960	87
1977	3063	3145	2232	2783	3723	5558	5955	4979	4139	6317	5666	3597
1978	975	369	156	778	5823	6617	6126	6331	4455	3563	3522	3481
1979	2429	542	5244	6444	6184	5250	4298	3905	2349	1566	3005	1619
1980	4650	4597	4873	5892	6384	6887	7926	5224	5493	2507	0	1459
1981	3563	3553	2965	4280	7156	5109	6780	6220	4563	3655	3783	2200
1982	3422	708	0	2443	8342	7736	6966	7659	4629	6731	4488	1170
1983	36	247	575	2031	7657	7810	8850	7216	5993	6943	5503	3355
1984	43	494	4425	7258	7824	8476	8275	3954	2124	4223	4295	1414
1985	2138	3562	5437	3467	5392	7610	7600	6439	6540	9396	6168	2462
1986	3375	3188	3591	5372	4739	9352	8916	7251	8778	14264	5096	2947
1987	2888	1704	4815	6253	7721	8201	10395	8938	8489	10581	4993	2952
1988	2354	2959	3644	7504	7528	7735	8969	8845	8662	7205	5462	2749
1989	2560	3087	4426	7889	6590	10494	13319	10159	7024	7480	4352	3291
1990	4130	4321	4993	8475	8956	8854	8777	8361	7555	6871	8098	4577
1991	4021	3599	4073	3851	6444	9455	11605	10152	8531	10268	11127	8361
1992	4643	3453	6057	6747	8491	11234	11820	11037	11308	13255	10208	7233
1993	2640	3164	4357	5950	7671	7990	8651	9633	10292	12596	11089	6980
1994	4321	3905	6567	8553	7342	7165	9606	9345	10830	11749	7857	5565
1995	3869	5293	7721	10228	8177	7806	8771	9265	8194	7948	6113	4002
1996	4060	6460	7948	9217	8944	8864	8889	9265	8367	6048	3327	2706
1997	3657	6035	6086	6514	7714	8237	9576	8117	7740	7325	5065	2061
1998	8626	6420	5896	9980	10438	10505	10306	5014	5356	3547	2649	1758
1999	5025	5643	7375	8133	9369	8564	11077	8744	8366	8198	6620	5078
2000*	4396	6464	7418	9028	9643	11314	11601	8581	7838	6854	8295	5774
2001*	4281	5463	6239	5754	8611	11178	13486	11926	9280	10714	8152	7697
2002*	8608	5828	7796	11205	12022	11687	16125	13612	9928	11186	12043	9153
2003*	7032	6549	8689	9699	10415	9071	7699	5311	856	0	0	0

*Preliminary.

Table 3. Annual catch, effort and CPUE of the shrimp fishery in Subarea 1 and Div. 0A by NAFO Divisions. Data was derived from vessel logs and weighted up to total catch of the year.

Year	Catch ('000 tons)							Effort ('000 hr's)							CPUE (kg/hr)						
year	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	-	0	780	785	0	0	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	7.3	6.7	64.1	1.5	0.1	0.0	0.0	236	719	557	348	112	-	-
1980	2.7	14.6	35.0	3.3	0.3	0.0	0.0	7.6	21.2	53.3	4.9	0.5	0.0	0.0	358	690	655	668	596	0	-
1981	5.3	5.7	37.5	5.3	0.0	0.0	0.0	17.7	11.2	66.4	10.4	0.1	0.0	0.0	299	511	564	510	409	-	-
1982	2.1	0.8	43.2	8.2	0.0	0.0	0.0	6.2	1.7	65.7	13.5	0.1	0.0	0.0	335	472	657	604	388	-	-
1983	5.4	0.5	40.5	9.4	0.5	0.0	0.0	19.1	0.9	69.5	17.8	0.9	0.0	0.0	284	559	582	528	531	0	614
1984	2.1	1.2	30.4	17.0	2.1	0.0	0.0	7.7	2.7	51.1	28.4	2.7	0.0	0.1	280	431	595	598	785	0	47
1985	3.1	8.2	35.3	14.9	4.7	0.0	0.0	9.9	29.0	64.8	25.4	8.8	0.0	0.0	309	282	545	586	541	-	-
1986	3.0	26.6	32.1	9.1	6.1	0.0	0.0	6.7	54.8	54.1	13.9	9.8	0.1	0.1	445	485	593	655	624	-	-
1987	6.1	19.7	43.7	7.3	1.1	0.0	0.0	12.4	55.2	67.1	10.5	3.4	0.0	0.0	491	357	651	695	343	0	-
1988	5.9	12.6	47.4	7.1	0.5	0.0	0.1	12.6	41.6	92.3	14.1	1.8	0.0	1.0	468	302	514	502	282	0	153
1989	7.2	16.6	34.0	12.8	9.5	0.0	0.5	18.5	48.4	77.9	29.7	16.6	0.0	4.3	391	344	437	431	572	0	111
1990	6.2	12.3	30.2	22.6	12.2	0.0	0.5	15.2	42.7	78.1	54.3	29.1	0.0	2.8	405	288	387	417	419	0	165
1991	6.8	12.7	33.0	18.8	19.4	0.6	0.2	20.5	37.2	90.3	51.9	47.6	0.7	1.3	330	341	365	362	408	824	191
1992	7.5	16.4	32.9	20.0	23.2	4.9	0.6	17.6	49.5	76.3	48.1	51.1	7.5	1.3	425	330	431	415	455	661	498
1993	5.5	7.6	36.2	15.8	18.1	4.5	3.2	13.6	23.0	82.0	41.3	44.3	8.0	7.6	404	331	442	383	410	559	425
1994	4.8	7.3	33.6	15.9	19.9	7.0	4.2	16.3	23.4	84.0	40.9	42.7	9.6	9.3	292	313	401	390	467	736	450
1995	2.4	7.0	27.2	15.4	22.0	8.5	4.9	7.2	21.1	69.2	33.6	40.7	12.0	7.9	329	331	393	459	540	706	625
1996	2.6	5.4	22.4	16.8	23.3	8.2	5.3	8.7	18.6	51.2	34.7	39.0	11.5	9.2	303	293	439	484	596	711	579
1997	0.5	7.4	20.2	11.4	22.5	8.4	7.7	1.2	44.3	53.6	23.9	39.1	11.5	12.7	443	167	377	478	575	732	605
1998	0.9	4.5	22.6	13.5	21.1	8.7	9.0	3.1	20.1	48.8	25.4	34.2	10.6	13.5	300	226	463	532	618	817	671
1999	2.0	9.1	28.3	14.6	19.0	8.3	10.8	4.0	34.4	58.3	22.5	27.0	9.2	12.9	507	263	485	650	704	902	839
2000*	1.8	14.8	28.7	14.8	18.8	6.9	11.3	2.4	36.3	50.8	20.1	25.9	7.6	14.0	743	409	565	737	727	909	810
2001*	3.6	14.5	27.3	17.1	20.8	8.0	11.6	4.8	41.2	48.9	21.1	27.3	7.7	11.8	748	351	558	810	760	1029	980
2002*	6.2	15.0	42.3	25.9	24.4	8.3	10.0	6.2	41.1	55.1	25.7	25.9	6.6	10.1	1003	366	767	1005	942	1250	989
2003**		15.0	43.9	28.7	20.4	8.0	12.0		33.1	43.1	19.8	16.6	5.2	10.4		454	1019	1449	1227	1542	1153

*Preliminary.
**Projected.

Table 4. Time series of the four standardized CPUE indices included in the combined CPUE index for NAFO Subarea 1 + Div. 0A. Estimates based on data until September 2003.

	1BCD		KGH		Small ves.		0A		Combined		
Year	mean	se	mean	se	mean	se	mean	se	25%	median	75%
1976	-	-	1.66	0.15	-	-	-	-	0.84	1.00	1.19
1977	-	-	1.56	0.09	-	-	-	-	0.81	0.90	1.01
1978	-	-	1.23	0.07	-	-	-	-	0.64	0.70	0.77
1979	-	-	1.11	0.07	-	-	-	-	0.58	0.63	0.69
1980	-	-	1.34	0.08	-	-	-	-	0.70	0.77	0.85
1981	-	-	1.27	0.07	-	-	1.15	0.08	0.68	0.74	0.81
1982	-	-	1.61	0.10	-	-	1.36	0.11	0.84	0.94	1.05
1983	-	-	1.42	0.09	-	-	1.08	0.07	0.73	0.80	0.88
1984	-	-	1.34	0.08	-	-	0.99	0.09	0.69	0.76	0.84
1985	-	-	1.43	0.08	-	-	0.86	0.12	0.73	0.81	0.89
1986	-	-	1.49	0.09	-	-	0.88	0.07	0.73	0.81	0.90
1987	1.83	0.09	1.79	0.11	-	-	1.38	0.07	0.99	1.04	1.09
1988	1.16	0.03	1.47	0.09	1.29	0.06	1.22	0.07	0.67	0.69	0.71
1989	1.04	0.02	1.09	0.07	1.05	0.04	0.90	0.04	0.59	0.61	0.62
1990	1.00	-	1.00	-	1.00	-	1.00	-	0.57	0.57	0.57
1991	1.01	0.02	-	-	0.89	0.03	0.88	0.04	0.57	0.58	0.60
1992	1.09	0.02	-	-	0.94	0.03	1.01	0.05	0.61	0.63	0.64
1993	1.06	0.02	-	-	1.03	0.03	0.95	0.05	0.60	0.62	0.64
1994	1.07	0.02	-	-	0.88	0.02	0.74	0.04	0.59	0.61	0.62
1995	1.17	0.02	-	-	0.88	0.03	0.82	0.06	0.64	0.66	0.68
1996	1.20	0.03	-	-	0.86	0.03	0.76	0.04	0.65	0.67	0.69
1997	1.17	0.03	-	-	0.85	0.02	0.58	0.10	0.64	0.65	0.67
1998	1.29	0.03	-	-	1.00	0.03	0.69	0.07	0.71	0.73	0.75
1999	1.46	0.04	-	-	1.04	0.03	1.15	0.09	0.79	0.81	0.84
2000	1.50	0.05	-	-	1.37	0.04	1.22	0.12	0.85	0.88	0.90
2001	1.51	0.05	-	-	1.21	0.04	1.31	0.15	0.83	0.86	0.88
2002	1.83	0.05	-	-	1.50	0.05	1.51	0.72	1.01	1.04	1.08
2003	2.06	0.07	-	-	1.58	0.06	-	-	1.12	1.16	1.20

Table 5. Annual discard of shrimp and fish in tons and percent of total shrimp catch, and landed by-catch of *P. montagui* (tons) as reported in vessel logs from Subarea 1 1987-2003.

Year	P. borealis		Fish		P. montagui
	discard (tons)	discard (%)	discard (tons)	discard (%)	landed (tons)
1987	180	0.3	881	1.2	0
1988	196	0.3	1065	1.6	0
1989	190	0.3	1342	1.8	0
1990	262	0.3	1267	1.6	0
1991	407	0.5	2060	2.4	0
1992	327	0.3	2150	2.2	0
1993	250	0.3	1906	2.2	0
1994	331	0.4	2671	3.0	5
1995	478	0.6	2698	3.2	565
1996	323	0.4	2701	3.3	779
1997	312	0.4	2334	3.0	425
1998	314	0.4	2183	2.7	1253
1999	197	0.2	0	0.0	4
2000*	265	0.3	678	0.7	302
2001*	382	0.4	1120	1.1	881
2002*	634	0.5	1244	1.0	220
2003**	647	0.5	1348	1.1	990

*Preliminary
**Projected

Table 6. Composition of shrimp catches in NAFO SA 1 as derived from sub-samples weighted up to the total catch. Numbers caught were divided by standardized effort to produce abundance indices.

Mean size

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cpl (mm)	23.5	23.5	22.9	22.3	21.8	21.9	21.2	21.2	21.2	21.6	20.8	20.5
Weight (g)	9.4	9.6	9.5	9.0	9.1	8.4	7.8	8.0	7.4	8.0	6.7	7.3
Count (no/kg)	107	104	106	111	110	119	128	126	135	125	149	137

Proportion of total catch

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Males	46%	33%	51%	56%	64%	64%	64%	66%	64%	55%	69%	77%
Primi	9%	3%	1%	11%	15%	9%	12%	8%	12%	15%	10%	8%
Multi	45%	63%	48%	33%	21%	27%	24%	26%	24%	30%	21%	15%
Females total	54%	67%	49%	44%	36%	36%	36%	34%	36%	45%	31%	23%

Number caught (millions)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Males	5109	4133	5563	6713	7284	7616	7769	8031	9503	7942	12504	16275
Primi	1006	427	117	1302	1689	1005	1460	1019	1772	2246	1781	1753
Multi	4918	7921	5332	3925	2394	3189	2883	3151	3522	4309	3753	3063
Females Total	5924	8348	5449	5227	4083	4194	4343	4170	5294	6555	5534	4817
Total	11034	12481	11012	11939	11367	11811	12112	12201	14798	14497	18037	21092

Abundance index

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Males	1.00	0.76	1.16	1.36	1.69	1.87	2.00	2.24	2.58	2.21	3.47	4.18
Primi	1.00	0.40	0.12	1.33	1.99	1.25	1.91	1.44	2.44	3.17	2.51	2.29
Multi	1.00	1.51	1.16	0.82	0.58	0.81	0.77	0.91	0.99	1.24	1.08	0.82
Females total	1.00	1.32	0.98	0.91	0.82	0.89	0.96	1.00	1.24	1.57	1.33	1.07

Table 7. Information on biological samples taken in the Greenlandic fishery 2000-2002.

2000

Month	Division	Number of samples	Sample weight	Numbers measured	Catch (kg)
2	1B	5	8	1006	17988
2	1C	4	4.79	877	10945
3	1C	5	12.03	875	15693
4	1B	4	9.15	1021	11481
4	1D	7	10.68	1979	21645
6	1C	1	3.27	557	1503
6	1D	7	16.9	2914	24445
7	1B	15	47.8	6886	51789
7	1C	10	33.64	4707	34410
8	1B	1	1.64	241	1556
9	1B	3	7.83	1120	6867
9	1C	5	23.19	2809	10713
9	1D	12	44.6	6712	29371
9	1E	3	9.44	1014	19931
10	1B	8	23.4	3054	28866
10	1E	4	14.66	2125	6296
11	1C	5	21.04	2962	15706
11	1D	8	28.78	4860	26574
	Total	107	321	45719	335779

2001

Month	Division	Number of samples	Sample weight	Numbers measured	Catch (kg)
1	1C	5	15.23	2521	30341
1	1D	4	12.46	1830	14669
1	1E	5	22.56	3623	15788
2	1C	1	2.87	466	10218
2	1D	2	11.21	1527	29388
4	1B	6	11.86	2149	32403
4	1C	5	12.58	1253	9741
4	1D	8	20.21	2909	26821
5	1B	13	24.88	3943	46090
5	1C	11	18.58	2811	61074
5	1D	14	25.17	3582	44358
6	1D	12	22.82	3256	57178
7	1B	1	4.04	861	790
7	1D	13	19.61	2602	45465
7	1E	8	10.73	1664	37916
8	1B	3	5.28	775	18942
8	1C	6	10.03	1755	34411
10	1B	3	6.22	1093	16142
10	1D	6	8.44	1761	9592
10	1E	2	3.52	537	2768
11	1B	3	4.57	743	6748
11	1C	3	4.56	684	13576
11	1D	3	5.2	713	13506
	Total	137	283	43058	577925

2002

Month	Division	Number of samples	Sample weight	Numbers measured	Catch (kg)
3	1D	7	9.01	1502	17881
3	1F	1	1.28	225	1805
	Total	8	10	1727	19686

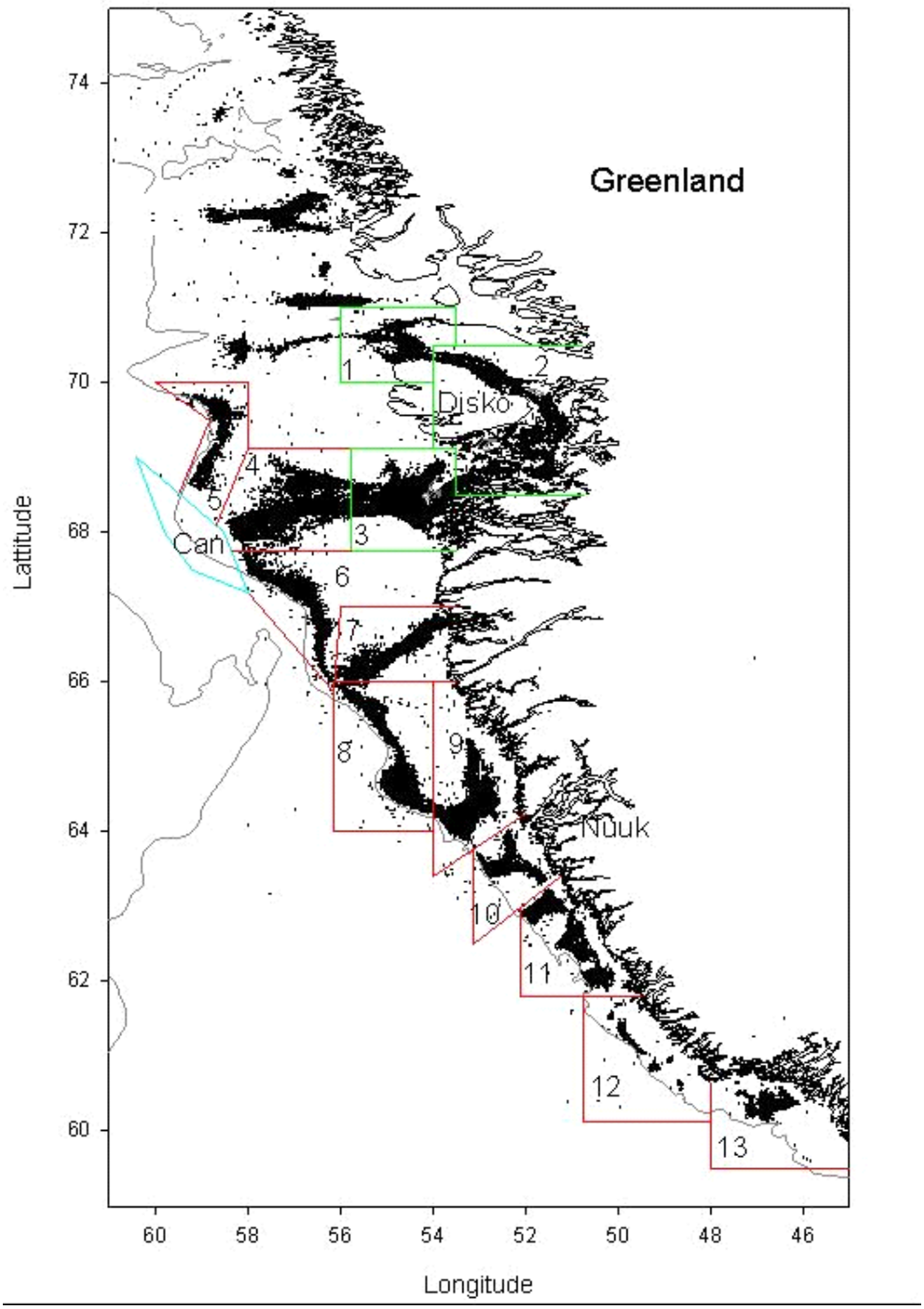

Fig. 1. Distribution of hauls by Greenlandic shrimp trawlers fishing off West Greenland, based on available logbooks 1975-2003. Dots represent individual hauls. 600m depth contour is shown as the bold line. The boxed areas numbered 1-13 or labelled Can. (Canadian fishery area) are the area segregation used in the models for standardising the catch-per-unit-effort data (see text).

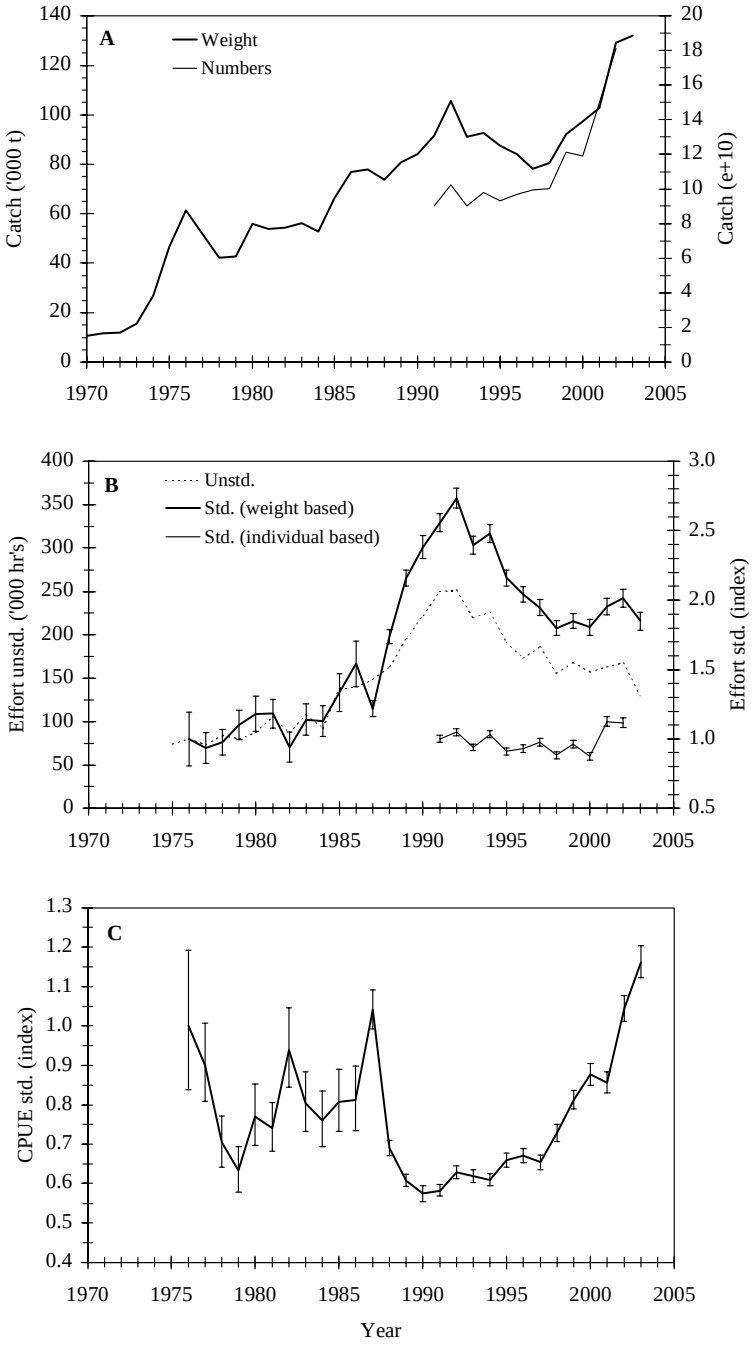

Fig. 2. Total catch (A), standardized and unstandardized effort (B) and standardized CPUE indices (C) of the shrimp fishery in NAFO SA 1 + Div. 0A. Estimates of std. effort and CPUE are medians with 25 and 75 percentile error bars and are based on data series until September 2003. Catch for 2003 are projected from September to the end of the year.

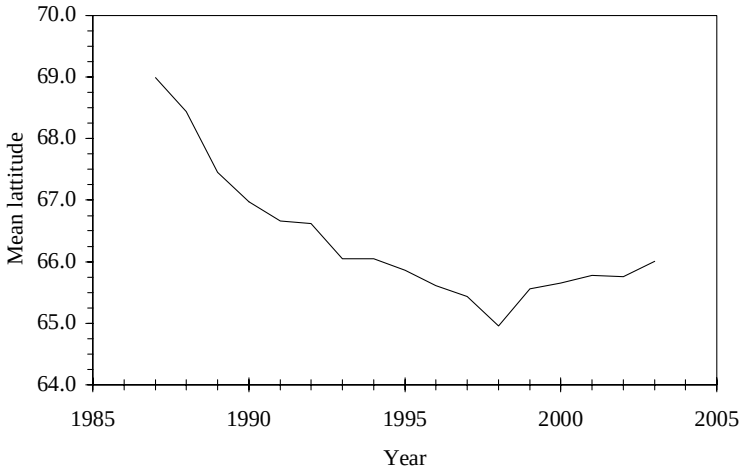

Fig. 3. Mean latitude (°N) of allocated effort by vessels fishing offshore in Subarea 1, 1987-2003.

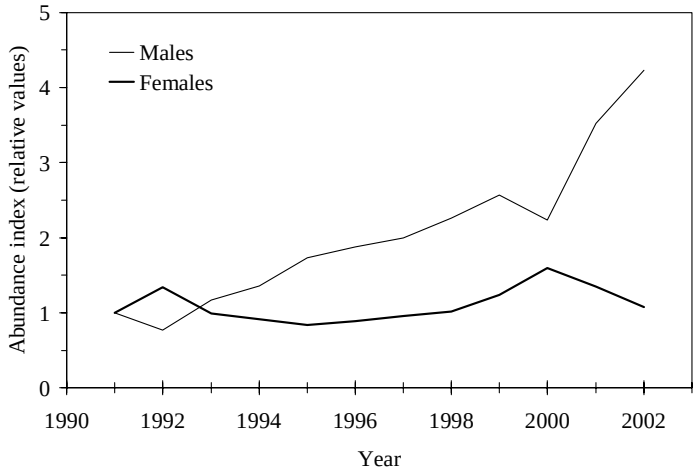

Fig. 4. Standardized CPUE indices of the male and female component of the West Greenland shrimp stock 1991-2002, both standardized to their value in 1991.

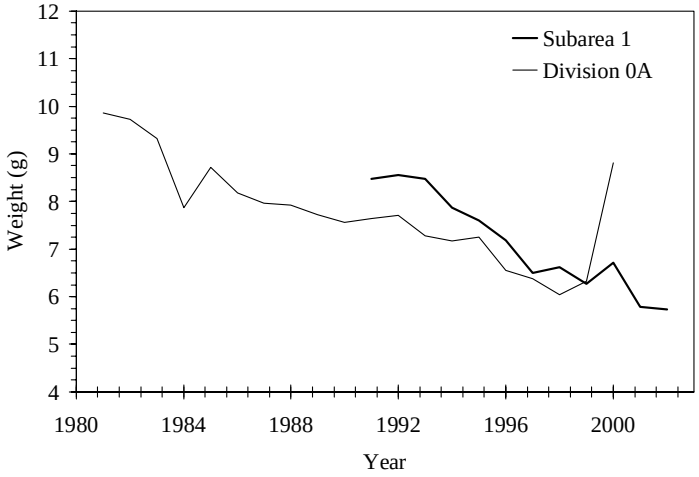

Fig. 5. Mean shrimp size (g) in catches in Subarea 1, 1991-2002, and Div. 0A, 1981-2000.

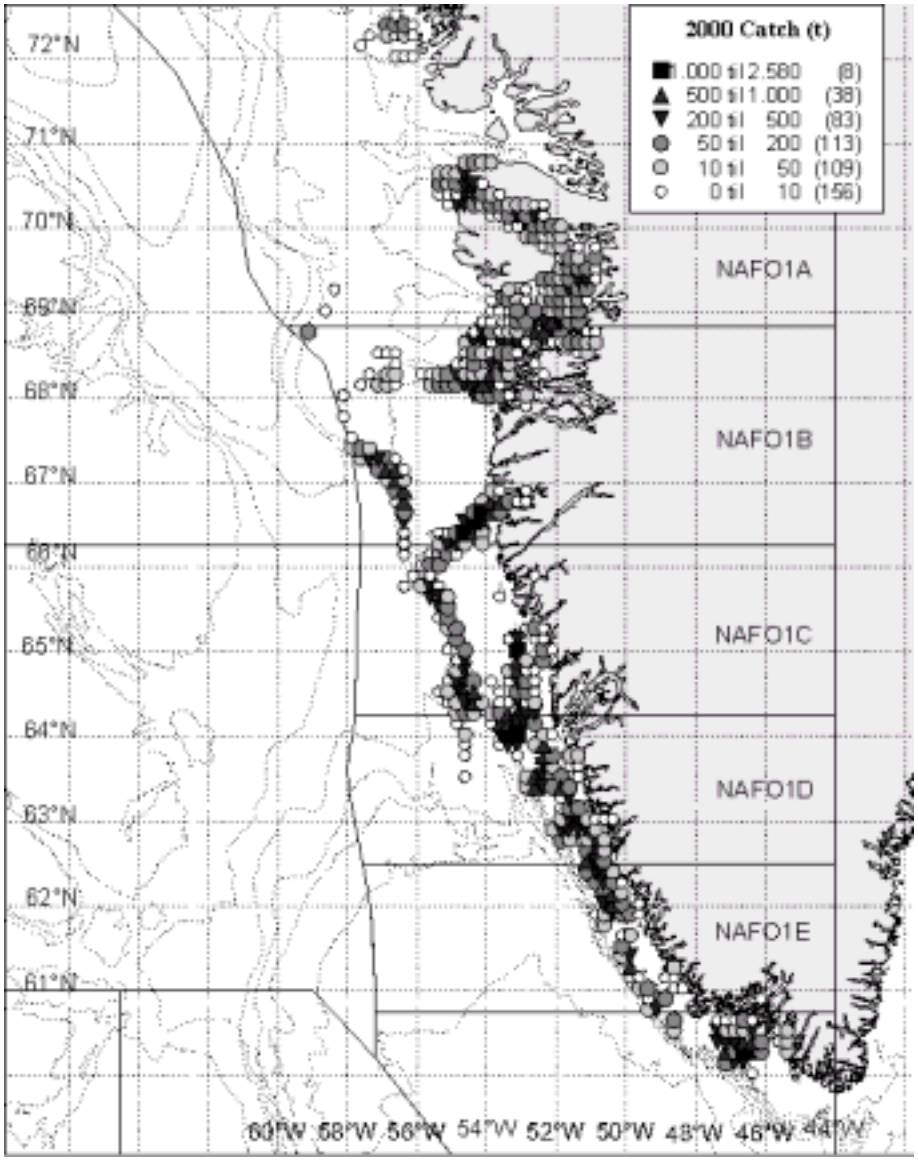

Fig. 6a. Spatial distribution of the Greenlandic shrimp catches in Subarea 1, 2000.

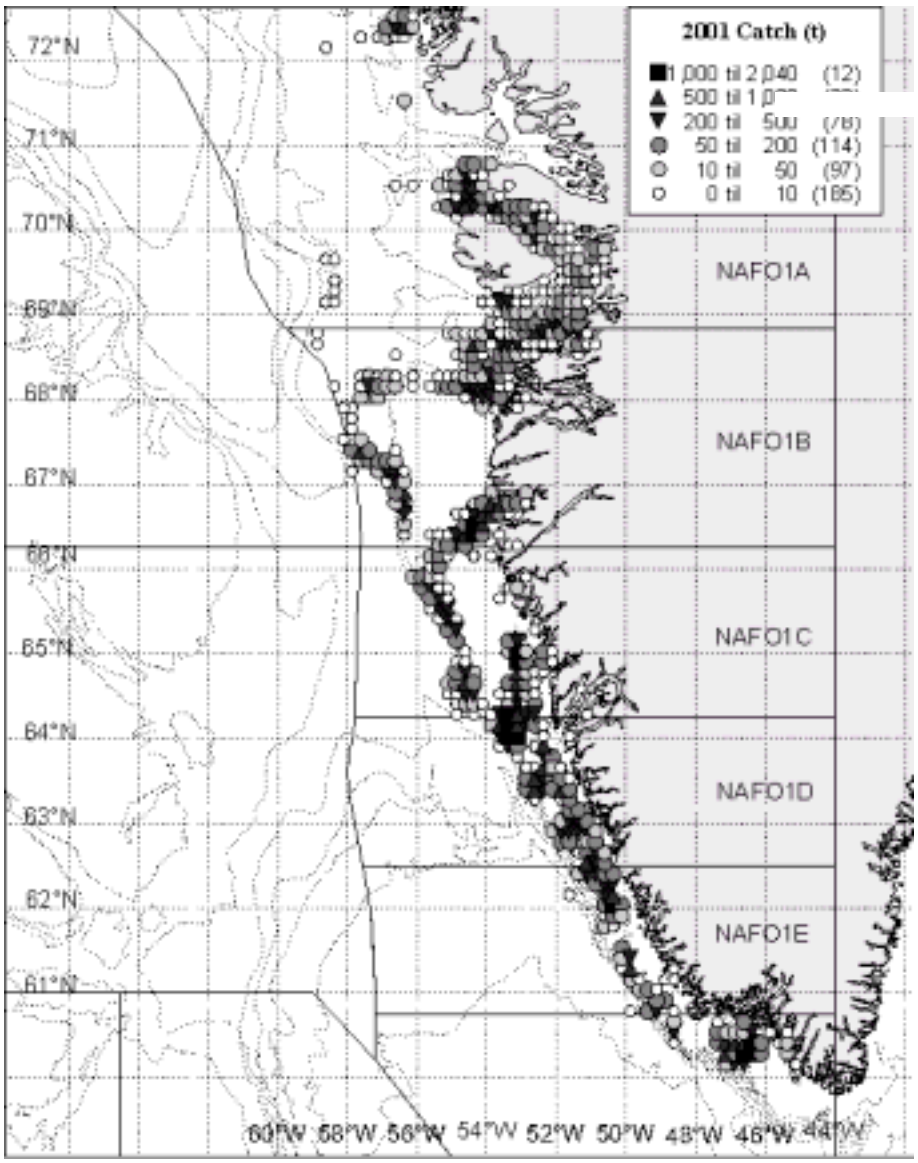

Fig. 6b. Spatial distribution of the Greenlandic shrimp catches in Subarea 1, 2001.

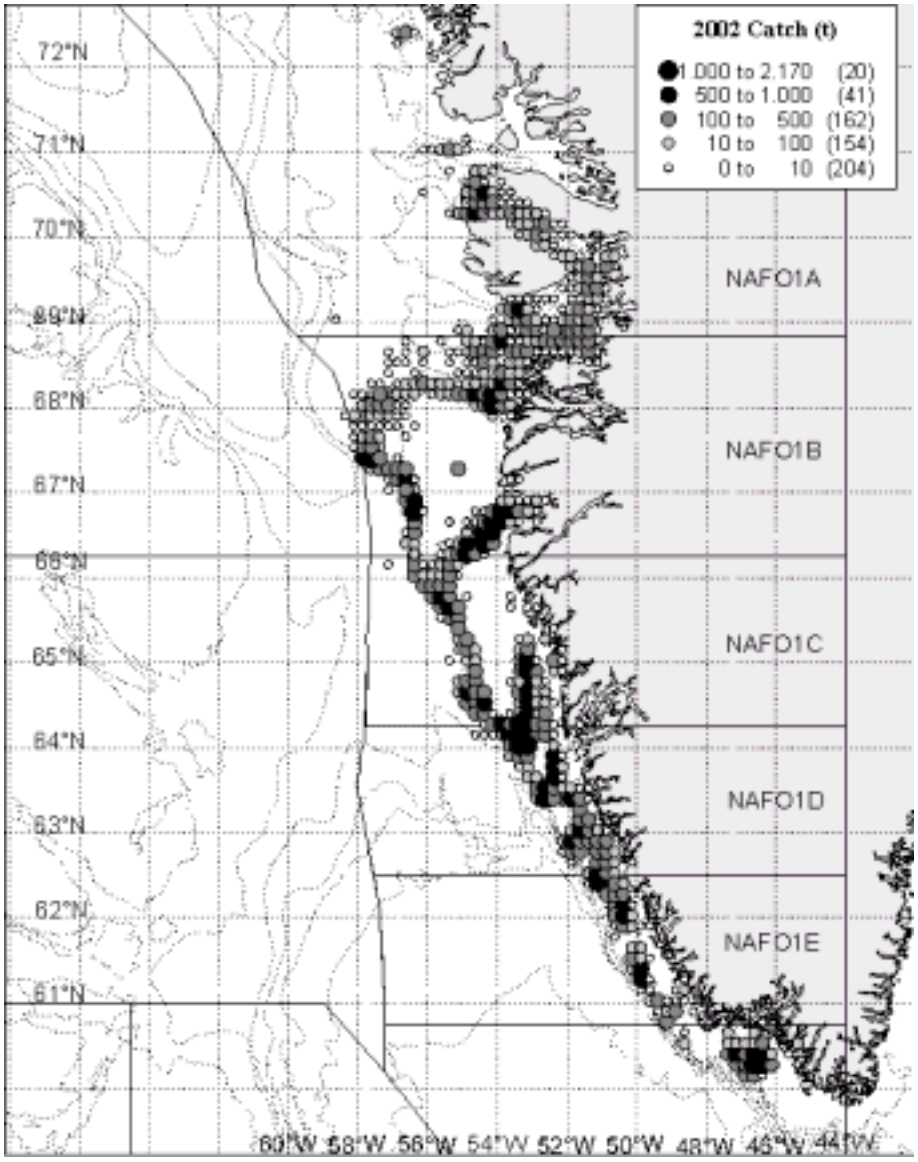

Fig. 6c. Spatial distribution of the Greenlandic shrimp catches in Subarea 1, 2002.

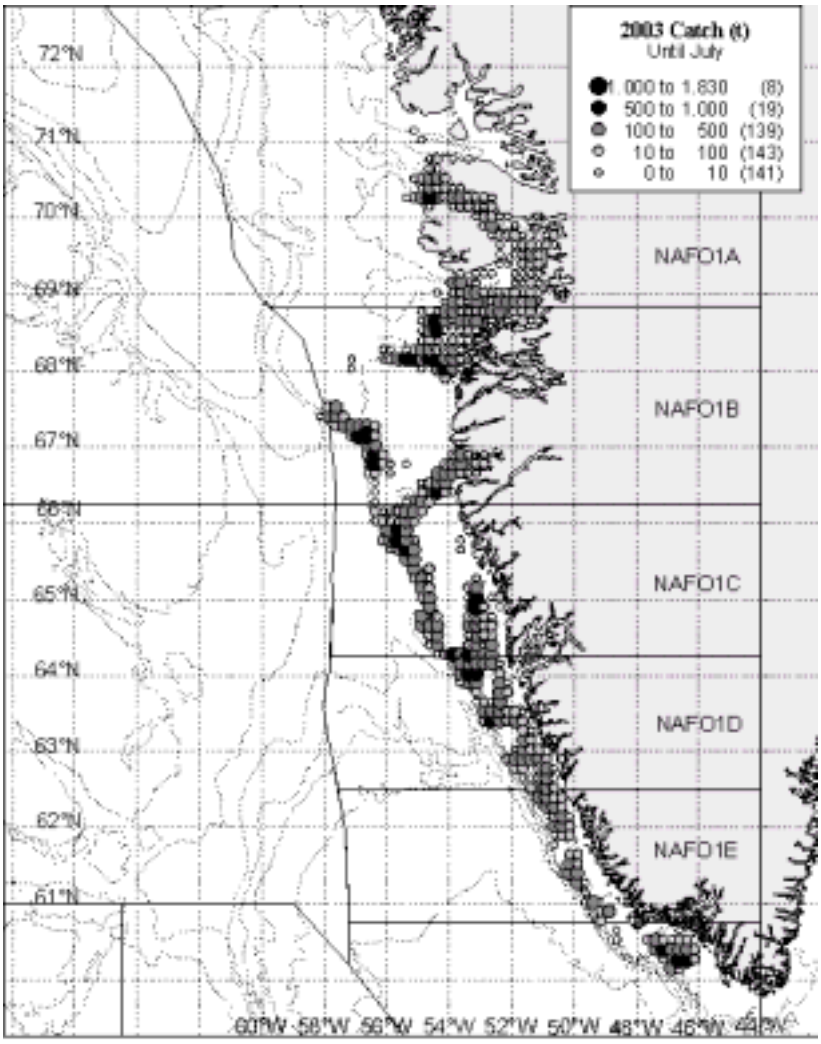

Fig. 6d. Spatial distribution of the Greenlandic shrimp catches in Subarea 1, 2003 until July

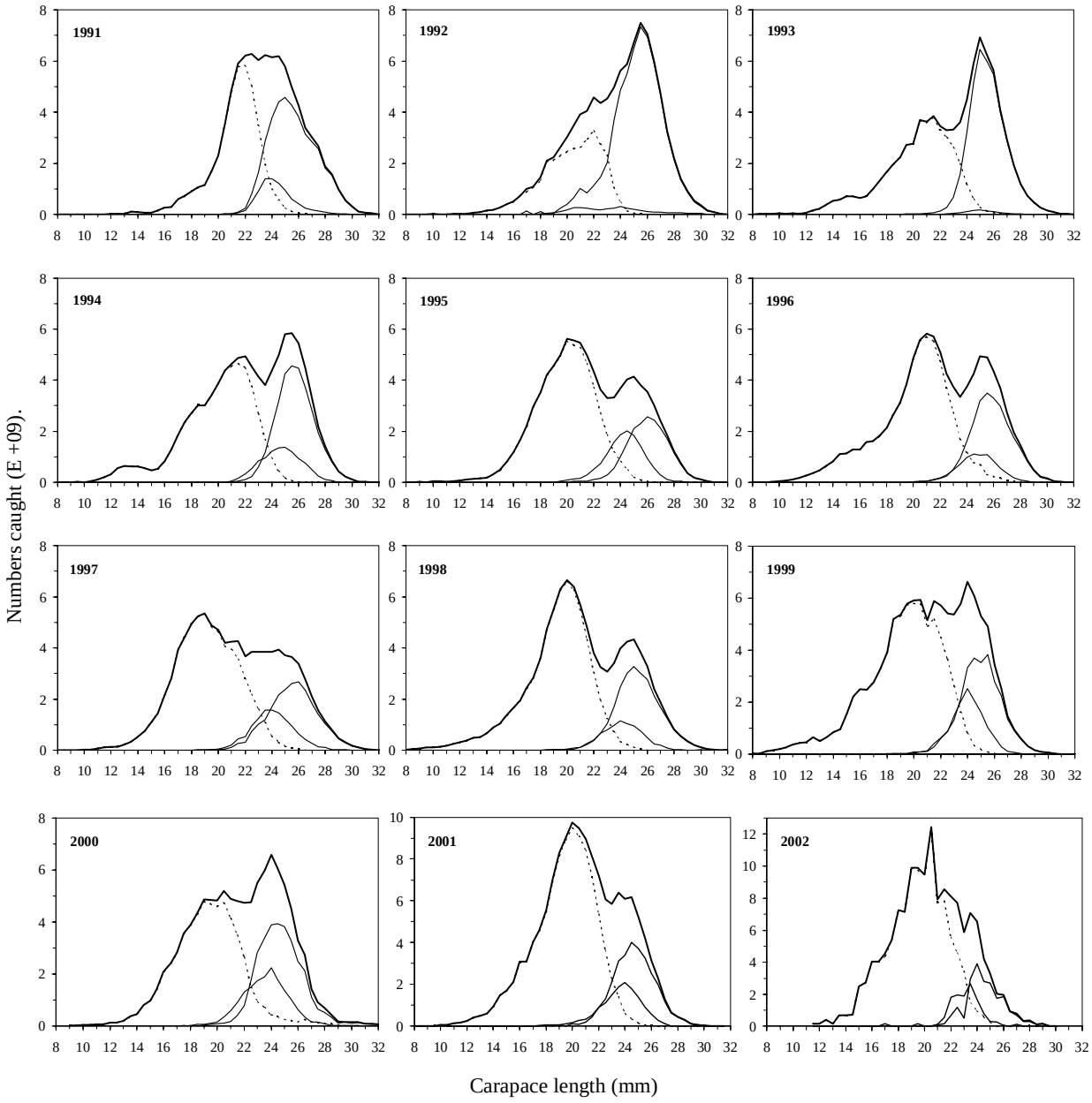

Fig. 7. Length frequency distribution of commercial shrimp catches in Subarea 1 and Div. 0A, 1991-2002. The distribution of male shrimp is shown by a dotted line, primiparous and multiparous each as a thin line where the primiparous is distinguished as the smallest component of the two. The sum, i.e. the total distribution, is shown by a bold line.

Appendix 1. Diagnostical output from GLM-run of 1BCDEF index.

The GLM Procedure
Class Level Information

Class	Levels	Values
VESSEL	27	AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH IIII JJJJ OUIQ OUKV OVZM OWLQ OWUD OWVM OYBZ OYCZ OYFF OYKK OYPK OYRK OYRT OZMA OZWQ OZWR ZZZZ
YEAR	17	87 88 89 91 92 93 94 95 96 97 98 99 100 101 102 103 109
MONTH	10	1 2 3 4 6 7 8 9 10 12
AREA	8	4 5 6 8 10 11 12 13

Number of observations 9096

Dependent Variable: LNCPUE
Weight: HAULS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	116	45954.56586	396.16005	123.89	<.0001
Error	8979	28712.20909	3.19771		
Corrected Total	9095	74666.77496			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.615462	91.02545	1.788213	1.964520

Source	DF	Type I SS	Mean Square	F Value	Pr > F
VESSEL	26	38423.74255	1477.83625	462.16	<.0001
MONTH	9	942.63518	104.73724	32.75	<.0001
AREA	7	1123.60603	160.51515	50.20	<.0001
YEAR	16	3814.91686	238.43230	74.56	<.0001
MONTH*AREA	58	1649.66525	28.44250	8.89	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
VESSEL	26	12846.42417	494.09324	154.51	<.0001
MONTH	9	506.84935	56.31659	17.61	<.0001
AREA	7	720.89033	102.98433	32.21	<.0001
YEAR	16	3740.29000	233.76812	73.10	<.0001
MONTH*AREA	58	1649.66525	28.44250	8.89	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		0.837948849	B	0.06796230	12.33	<.0001
VESSEL	AAAA	0.603043021	B	0.03580635	16.84	<.0001
VESSEL	BBBB	0.392947426	B	0.03805559	10.33	<.0001
VESSEL	CCCC	0.436433823	B	0.03610490	12.09	<.0001
VESSEL	DDDD	0.522441377	B	0.03599227	14.52	<.0001
VESSEL	EEEE	1.122018416	B	0.03841080	29.21	<.0001
VESSEL	FFFF	0.219813228	B	0.04104610	5.36	<.0001
VESSEL	GGGG	0.971192622	B	0.03633425	26.73	<.0001
VESSEL	HHHH	0.664316930	B	0.03820501	17.39	<.0001
VESSEL	IIII	1.171828976	B	0.03534299	33.16	<.0001
VESSEL	JJJJ	0.554526622	B	0.03669730	15.11	<.0001
VESSEL	OUIQ	0.837325750	B	0.04627496	18.09	<.0001
VESSEL	OUKV	1.206042653	B	0.03836871	31.43	<.0001
VESSEL	OVZM	1.148711710	B	0.06839705	16.79	<.0001
VESSEL	OWLQ	0.165964262	B	0.05564891	2.98	0.0029
VESSEL	OWUD	0.478696979	B	0.04073573	11.75	<.0001
VESSEL	OWVM	0.320947238	B	0.05032090	6.38	<.0001
VESSEL	OYBZ	0.900989384	B	0.04001638	22.52	<.0001
VESSEL	OYCZ	0.892720915	B	0.05313515	16.80	<.0001
VESSEL	OYFF	0.934105542	B	0.05256465	17.77	<.0001
VESSEL	OYKK	0.739050096	B	0.03877820	19.06	<.0001
VESSEL	OYPK	1.327615939	B	0.06499963	20.42	<.0001
VESSEL	OYRK	0.784862277	B	0.03883785	20.21	<.0001
VESSEL	OYRT	0.627279662	B	0.04380857	14.32	<.0001
VESSEL	OZMA	1.065646833	B	0.06457525	16.50	<.0001
VESSEL	OZWQ	1.291490274	B	0.06828888	18.91	<.0001
VESSEL	OZWR	1.493622265	B	0.07895481	18.92	<.0001
VESSEL	ZZZZ	0.000000000	B	.	.	.
MONTH	1	0.472026280	B	0.11792372	4.00	<.0001
MONTH	2	0.473173871	B	0.13124510	3.61	0.0003
MONTH	3	0.617625605	B	0.12755785	4.84	<.0001
MONTH	4	0.700943616	B	0.13768983	5.09	<.0001
MONTH	6	0.627125374	B	0.13492143	4.65	<.0001
MONTH	7	1.117399639	B	0.11780885	9.48	<.0001
MONTH	8	0.691630484	B	0.09847516	7.02	<.0001
MONTH	9	0.488237673	B	0.14475386	3.37	0.0007
MONTH	10	0.329217396	B	0.11495579	2.86	0.0042
MONTH	12	0.000000000	B	.	.	.
AREA	4	0.164640191	B	0.06258738	2.63	0.0085
AREA	5	0.713780552	B	0.10043075	7.11	<.0001

AREA	6	0.101037952	B	0.07114800	1.42	0.1556
AREA	8	0.193372665	B	0.06235233	3.10	0.0019
AREA	10	0.054877502	B	0.06179297	0.89	0.3745
AREA	11	0.167037460	B	0.06293100	2.65	0.0080
AREA	12	0.212382297	B	0.08663820	2.45	0.0143
AREA	13	0.000000000	B	.	.	.
YEAR	87	0.603168471	B	0.04772147	12.64	<.0001
YEAR	88	0.145990369	B	0.02405390	6.07	<.0001
YEAR	89	0.043690821	B	0.02074399	2.11	0.0352
YEAR	91	0.005744218	B	0.01898833	0.30	0.7623
YEAR	92	0.090368029	B	0.01975937	4.57	<.0001
YEAR	93	0.060715366	B	0.01965842	3.09	0.0020
YEAR	94	0.065423806	B	0.01966684	3.33	0.0009
YEAR	95	0.153620241	B	0.02052167	7.49	<.0001
YEAR	96	0.184375576	B	0.02213072	8.33	<.0001
YEAR	97	0.153394615	B	0.02358026	6.51	<.0001
YEAR	98	0.253785881	B	0.02526038	10.05	<.0001
YEAR	99	0.381230876	B	0.02529371	15.07	<.0001
YEAR	100	0.408400001	B	0.02998840	13.62	<.0001
YEAR	101	0.411717066	B	0.02990212	13.77	<.0001
YEAR	102	0.603236210	B	0.02892600	20.85	<.0001
YEAR	103	0.723548270	B	0.03281281	22.05	<.0001
YEAR	109	0.000000000	B	.	.	.
MONTH*AREA	1 4	-0.252430992	B	0.47789415	-0.53	0.5974
MONTH*AREA	1 6	-0.268340521	B	0.14858461	-1.81	0.0710
MONTH*AREA	1 8	-0.489955785	B	0.12434590	-3.94	<.0001
MONTH*AREA	1 10	-0.465967597	B	0.12243337	-3.81	0.0001
MONTH*AREA	1 11	-0.578230287	B	0.12645747	-4.57	<.0001
MONTH*AREA	1 12	-0.516760171	B	0.16273931	-3.18	0.0015
MONTH*AREA	1 13	0.000000000	B	.	.	.
MONTH*AREA	2 4	-4.742755570	B	1.79461942	-2.64	0.0082
MONTH*AREA	2 6	0.069846930	B	0.17571265	0.40	0.6910
MONTH*AREA	2 8	-0.521147230	B	0.14071355	-3.70	0.0002
MONTH*AREA	2 10	-0.350393148	B	0.13504479	-2.59	0.0095
MONTH*AREA	2 11	-0.457973513	B	0.13725280	-3.34	0.0009
MONTH*AREA	2 12	-0.389829994	B	0.16142823	-2.41	0.0158
MONTH*AREA	2 13	0.000000000	B	.	.	.
MONTH*AREA	3 6	-0.074304481	B	0.15909526	-0.47	0.6405
MONTH*AREA	3 8	-0.419098977	B	0.13166387	-3.18	0.0015
MONTH*AREA	3 10	-0.439456679	B	0.13130461	-3.35	0.0008
MONTH*AREA	3 11	-0.614779219	B	0.13330121	-4.61	<.0001
MONTH*AREA	3 12	-0.438401348	B	0.15764715	-2.78	0.0054
MONTH*AREA	3 13	0.000000000	B	.	.	.
MONTH*AREA	4 4	-0.252768724	B	0.24405271	-1.04	0.3004
MONTH*AREA	4 6	-0.372873561	B	0.14855711	-2.51	0.0121
MONTH*AREA	4 8	-0.691047480	B	0.14064290	-4.91	<.0001
MONTH*AREA	4 10	-0.537225598	B	0.14126602	-3.80	0.0001
MONTH*AREA	4 11	-0.621594510	B	0.14319629	-4.34	<.0001
MONTH*AREA	4 12	-0.387658528	B	0.17241785	-2.25	0.0246
MONTH*AREA	4 13	0.000000000	B	.	.	.
MONTH*AREA	6 4	-0.730761511	B	0.14033060	-5.21	<.0001
MONTH*AREA	6 5	-1.545496943	B	0.22501005	-6.87	<.0001
MONTH*AREA	6 6	-0.507364783	B	0.14276882	-3.55	0.0004
MONTH*AREA	6 8	-0.715103356	B	0.13784614	-5.19	<.0001
MONTH*AREA	6 10	-0.485247957	B	0.13742798	-3.53	0.0004
MONTH*AREA	6 11	-0.562976437	B	0.13893594	-4.05	<.0001
MONTH*AREA	6 12	-0.599358548	B	0.17130342	-3.50	0.0005
MONTH*AREA	6 13	0.000000000	B	.	.	.
MONTH*AREA	7 4	-1.153563566	B	0.12473827	-9.25	<.0001
MONTH*AREA	7 5	-1.800899711	B	0.15146776	-11.89	<.0001
MONTH*AREA	7 6	-0.831807240	B	0.12834085	-6.48	<.0001
MONTH*AREA	7 8	-1.011380392	B	0.12259458	-8.25	<.0001
MONTH*AREA	7 10	-0.946966604	B	0.12226562	-7.75	<.0001
MONTH*AREA	7 11	-0.805846803	B	0.12485826	-6.45	<.0001
MONTH*AREA	7 12	-0.608302668	B	0.16755888	-3.63	0.0003
MONTH*AREA	7 13	0.000000000	B	.	.	.
MONTH*AREA	8 4	-0.735884725	B	0.10561264	-6.97	<.0001
MONTH*AREA	8 5	-1.490170063	B	0.13397314	-11.12	<.0001
MONTH*AREA	8 6	-0.645606802	B	0.11029235	-5.85	<.0001
MONTH*AREA	8 8	-0.783989261	B	0.10530139	-7.45	<.0001
MONTH*AREA	8 10	-0.598357569	B	0.10537794	-5.68	<.0001
MONTH*AREA	8 11	-0.541995942	B	0.10623301	-5.10	<.0001
MONTH*AREA	8 12	-0.352852797	B	0.13614954	-2.59	0.0096
MONTH*AREA	8 13	0.000000000	B	.	.	.
MONTH*AREA	9 4	-0.439455690	B	0.14882796	-2.95	0.0032
MONTH*AREA	9 5	-1.243526908	B	0.16966250	-7.33	<.0001
MONTH*AREA	9 6	-0.598676823	B	0.15697254	-3.81	0.0001
MONTH*AREA	9 8	-0.666277875	B	0.15100044	-4.41	<.0001
MONTH*AREA	9 10	-0.527999817	B	0.15171624	-3.48	0.0005
MONTH*AREA	9 11	-0.381385758	B	0.14965503	-2.55	0.0108
MONTH*AREA	9 12	-0.336744240	B	0.17562791	-1.92	0.0552

MONTH*AREA 9 13	0.000000000	B	.	.	.
MONTH*AREA 10 4	-0.310719673	B	0.11970398	-2.60	0.0095
MONTH*AREA 10 5	-1.076923239	B	0.14576637	-7.39	<.0001
MONTH*AREA 10 6	-0.332368686	B	0.13504182	-2.46	0.0139
MONTH*AREA 10 8	-0.328677919	B	0.12457746	-2.64	0.0083
MONTH*AREA 10 10	-0.314769014	B	0.12671639	-2.48	0.0130
MONTH*AREA 10 11	-0.322786494	B	0.12067282	-2.67	0.0075
MONTH*AREA 10 12	-0.250153290	B	0.14964476	-1.67	0.0946
MONTH*AREA 10 13	0.000000000	B	.	.	.
MONTH*AREA 12 4	0.000000000	B	.	.	.
MONTH*AREA 12 5	0.000000000	B	.	.	.
MONTH*AREA 12 6	0.000000000	B	.	.	.
MONTH*AREA 12 8	0.000000000	B	.	.	.
MONTH*AREA 12 10	0.000000000	B	.	.	.
MONTH*AREA 12 11	0.000000000	B	.	.	.
MONTH*AREA 12 12	0.000000000	B	.	.	.
MONTH*AREA 12 13	0.000000000	B	.	.	.

Appendix 2. Diagnostical output from GLM-run of KGH index.

```
                              The GLM Procedure
                          Class Level Information
Class         Levels    Values
VESS               2    32 33
YR                15    76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
MO                10    1 2 4 6 7 8 9 10 11 12
AREA               2    3 6

                           Number of observations    1371

Dependent Variable: LNCPUE
Weight: WEIGHT

                                    Sum of
Source                      DF         Squares     Mean Square    F Value    Pr > F
Model                       24     2959.662874      123.319286      54.70    <.0001
Error                     1346     3034.342633        2.254341
Corrected Total           1370     5994.005506

                R-Square     Coeff Var      Root MSE    LNCPUE Mean
                0.493770      24.03387      1.501446       6.247210

Source                      DF       Type I SS     Mean Square    F Value    Pr > F
VESS                         1      265.265065      265.265065     117.67    <.0001
MO                           9     2028.491712      225.387968      99.98    <.0001
YR                          14      665.906096       47.564721      21.10    <.0001

Source                      DF     Type III SS     Mean Square    F Value    Pr > F
VESS                         1      176.702927      176.702927      78.38    <.0001
MO                           9     1741.943810      193.549312      85.86    <.0001
YR                          14      665.906096       47.564721      21.10    <.0001

                                                    Standard
Parameter                 Estimate                     Error    t Value    Pr > |t|
Intercept          5.519584121 B      0.05972433       92.42      <.0001
VESS       32      0.162995969 B      0.01841047        8.85      <.0001
VESS       33      0.000000000 B       .                 .          .
MO         1       0.315289464 B      0.05377667        5.86      <.0001
MO         2       0.380992526 B      0.05721325        6.66      <.0001
MO         4       0.707713228 B      0.04492019       15.75      <.0001
MO         6       0.567510541 B      0.04043884       14.03      <.0001
MO         7       0.465709628 B      0.04266259       10.92      <.0001
MO         8       0.354247454 B      0.04281827        8.27      <.0001
MO         9       0.150752249 B      0.04470863        3.37      0.0008
MO         10      0.023991093 B      0.04412360        0.54      0.5867
MO         11      0.097217900 B      0.04500646        2.16      0.0309
MO         12      0.000000000 B       .                 .          .
YR         76      0.506924682 B      0.08804812        5.76      <.0001
YR         77      0.442223706 B      0.05909604        7.48      <.0001
YR         78      0.206741848 B      0.05869672        3.52      0.0004
YR         79      0.107151428 B      0.05734955        1.87      0.0619
YR         80      0.292689676 B      0.05909863        4.95      <.0001
YR         81      0.235455267 B      0.05533503        4.26      <.0001
YR         82      0.476527068 B      0.05941174        8.02      <.0001
YR         83      0.352758060 B      0.05834257        6.05      <.0001
YR         84      0.291241348 B      0.05675027        5.13      <.0001
YR         85      0.359175071 B      0.05565256        6.45      <.0001
YR         86      0.398675904 B      0.05561951        7.17      <.0001
YR         87      0.580394317 B      0.05754350       10.09      <.0001
YR         88      0.381897562 B      0.05674461        6.73      <.0001
YR         89      0.082618304 B      0.06351394        1.30      0.1936
YR         90      0.000000000 B       .                 .          .
```

Appendix 3. Diagnostical output from GLM-run of the 0A index.

```
                              The GLM Procedure
                          Class Level Information
 Class         Levels    Values
 Year              22    81 82 83 84 85 86 87 88 89 91 92 93 94 95 96 97 98 99 100 101 102 109
 Month              2    7 13
 Vessel            13    1 70 72 73 75 111 222 444 555 666 777 888 999

                           Number of observations    576
Dependent Variable: LNCPUE
Weight: WFACTOR

                                        Sum of
      Source                    DF       Squares     Mean Square    F Value    Pr > F
      Model                     34   3791.431115      111.512680      31.42    <.0001
      Error                    541   1919.767625        3.548554
      Corrected Total          575   5711.198740

                  R-Square     Coeff Var      Root MSE    LNCPUE Mean
                  0.663859      32.09658      1.883761       5.869038

      Source                    DF       Type I SS     Mean Square    F Value    Pr > F
      Month                      1    493.978473      493.978473     139.21    <.0001
      Vessel                    12   2194.915163      182.909597      51.54    <.0001
      Year                      21   1102.537479       52.501785      14.80    <.0001

      Source                    DF     Type III SS     Mean Square    F Value    Pr > F
      Month                      1    220.328117      220.328117      62.09    <.0001
      Vessel                    12   1610.989648      134.249137      37.83    <.0001
      Year                      21   1102.537479       52.501785      14.80    <.0001

                                                    Standard
            Parameter                Estimate           Error    t Value    Pr > |t|
            Intercept          5.577291717 B      0.04337368     128.59      <.0001
            Month     7        0.221179551 B      0.02806957       7.88      <.0001
            Month     13       0.000000000 B       .                .          .
            Vessel    1       -0.456878154 B      0.10488379      -4.36      <.0001
            Vessel    70      -0.116031664 B      0.08915741      -1.30      0.1937
            Vessel    72       0.999949470 B      0.23281381       4.30      <.0001
            Vessel    73       1.078637169 B      0.22934782       4.70      <.0001
            Vessel    75       0.482120091 B      0.44110540       1.09      0.2749
            Vessel    111     -0.240886537 B      0.05294594      -4.55      <.0001
            Vessel    222      0.103522151 B      0.04448189       2.33      0.0203
            Vessel    444      0.626450209 B      0.04025721      15.56      <.0001
            Vessel    555      0.376954526 B      0.03505130      10.75      <.0001
            Vessel    666      0.574795577 B      0.04049231      14.20      <.0001
            Vessel    777      0.478271198 B      0.05939407       8.05      <.0001
            Vessel    888      0.233509593 B      0.03603136       6.48      <.0001
            Vessel    999      0.000000000 B       .                .          .
            Year      81       0.142630671 B      0.06340239       2.25      0.0249
            Year      82       0.307081422 B      0.07664888       4.01      <.0001
            Year      83       0.077850600 B      0.05968118       1.30      0.1926
            Year      84      -0.007434367 B      0.08322212      -0.09      0.9289
            Year      85      -0.149480715 B      0.12797579      -1.17      0.2433
            Year      86      -0.123155851 B      0.07654773      -1.61      0.1082
            Year      87       0.325458329 B      0.05238540       6.21      <.0001
            Year      88       0.202082471 B      0.05254931       3.85      0.0001
            Year      89      -0.107079717 B      0.04661543      -2.30      0.0220
            Year      91      -0.125485556 B      0.04648505      -2.70      0.0072
            Year      92       0.013891922 B      0.04458370       0.31      0.7555
            Year      93      -0.047019784 B      0.04792740      -0.98      0.3270
            Year      94      -0.297373787 B      0.04644666      -6.40      <.0001
            Year      95      -0.198435133 B      0.06727727      -2.95      0.0033
            Year      96      -0.277052936 B      0.05446166      -5.09      <.0001
            Year      97      -0.537790331 B      0.15502429      -3.47      0.0006
            Year      98      -0.373518020 B      0.09071233      -4.12      <.0001
            Year      99       0.137607863 B      0.07411676       1.86      0.0639
            Year      100      0.196019425 B      0.09474109       2.07      0.0390
            Year      101      0.272763482 B      0.10936794       2.49      0.0129
            Year      102      0.412298388 B      0.38973677       1.06      0.2906
            Year      109      0.000000000 B       .                .          .
```

Appendix 4. Diagnostical output from GLM-run of the small vessel index.

```
                                The GLM Procedure
                           Class Level Information
         Class         Levels    Values
         VESSEL             9    AAAA BBBB CCCC DDDD EEEE FFFF GGGG HHHH OUHK
         YEAR              16    88 89 91 92 93 94 95 96 97 98 99 100 101 102 103 109
         AREA               3    1 2 3
         MONTH              4    4 5 8 11

                                Number of observations    3497

Dependent Variable: LNCPUE
Weight: HAULS
                                          Sum of
      Source                     DF         Squares     Mean Square    F Value    Pr > F
      Model                      28      8349.00830       298.17887     127.59    <.0001

      Error                    3468      8104.74684         2.33701
      Corrected Total          3496     16453.75515

                    R-Square     Coeff Var      Root MSE    LNCPUE Mean
                    0.507423      93.59910      1.528728       1.633272

      Source                     DF       Type I SS     Mean Square    F Value    Pr > F
      AREA                        2     1226.410636      613.205318     262.39    <.0001
      MONTH                       3     2315.252005      771.750668     330.23    <.0001
      VESSEL                      8     1925.032683      240.629085     102.96    <.0001
      YEAR                       15     2882.312980      192.154199      82.22    <.0001

      Source                     DF     Type III SS     Mean Square    F Value    Pr > F
      AREA                        2     1145.391407      572.695703     245.05    <.0001
      MONTH                       3     1233.971138      411.323713     176.00    <.0001
      VESSEL                      8     2069.681774      258.710222     110.70    <.0001
      YEAR                       15     2882.312980      192.154199      82.22    <.0001

                                                        Standard
            Parameter                Estimate              Error    t Value    Pr > |t|
            Intercept          2.021234271 B      0.04183039      48.32      <.0001
            AREA       1      -0.214763082 B      0.01281791     -16.75      <.0001
            AREA       2      -0.286707909 B      0.01405891     -20.39      <.0001
            AREA       3       0.000000000 B       .              .          .
            MONTH      4       0.511482688 B      0.02251283      22.72      <.0001
            MONTH      5       0.183597732 B      0.01692037      10.85      <.0001
            MONTH      8       0.126339931 B      0.01232467      10.25      <.0001
            MONTH      11      0.000000000 B       .              .          .
            VESSEL     AAAA   -0.321518303 B      0.03532297      -9.10      <.0001
            VESSEL     BBBB   -0.390889120 B      0.03616220     -10.81      <.0001
            VESSEL     CCCC   -0.771776192 B      0.04435666     -17.40      <.0001
            VESSEL     DDDD   -0.535352227 B      0.03976425     -13.46      <.0001
            VESSEL     EEEE   -0.606564903 B      0.03676739     -16.50      <.0001
            VESSEL     FFFF   -0.218859211 B      0.03663458      -5.97      <.0001
            VESSEL     GGGG   -0.487020566 B      0.03725169     -13.07      <.0001
            VESSEL     HHHH   -0.666896609 B      0.04998073     -13.34      <.0001
            VESSEL     OUHK    0.000000000 B       .              .          .
            YEAR       88      0.256982288 B      0.04248199       6.05      <.0001
            YEAR       89      0.052685297 B      0.03306206       1.59      0.1111
            YEAR       91     -0.118857523 B      0.02809370      -4.23      <.0001
            YEAR       92     -0.065527531 B      0.02804380      -2.34      0.0195
            YEAR       93      0.030980731 B      0.02873769       1.08      0.2811
            YEAR       94     -0.128056789 B      0.02782616      -4.60      <.0001
            YEAR       95     -0.126101312 B      0.02836231      -4.45      <.0001
            YEAR       96     -0.145344915 B      0.02953358      -4.92      <.0001
            YEAR       97     -0.162524134 B      0.02857594      -5.69      <.0001
            YEAR       98      0.002486308 B      0.03382243       0.07      0.9414
            YEAR       99      0.043433112 B      0.02888861       1.50      0.1328
            YEAR       100     0.316521153 B      0.02948857      10.73      <.0001
            YEAR       101     0.193459822 B      0.02902307       6.67      <.0001
            YEAR       102     0.408325141 B      0.02959652      13.80      <.0001
            YEAR       103     0.459832764 B      0.03766467      12.21      <.0001
            YEAR       109     0.000000000 B       .              .          .
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