Northwest Atlantic Fisheries Organization

Serial No. N5306 **NAFO SCR Doc. 06/58**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – OCTOBER/NOVEMBER 2006

Results of the Greenland Bottom Trawl Survey for Northern shrimp (*Pandalus borealis*) off West Greenland (NAFO Subarea 1 and Division 0A), 1988-2006

by

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Abstract

Stratified-random bottom trawl surveys have been carried out since 1988 in NAFO Subarea 1 and a small part of NAFO Division 0A (east of 59°30'W) as a contribution to the assessment of the stock of Northern shrimp (*Pandalus borealis*) in West Greenland waters.

Survey estimates of total biomass of Northern shrimp off West Greenland showed little variation over the initial ten-year period, but after a comparatively low estimate of 178 000 tons in 1997 the biomass increased steadily to 598 000 tons in 2003. This record high value was followed by continuous decline to 484 000 tons in 2006. During the period of increase the biomass changed mainly offshore in depths between 200 and 300 m and inshore in the Disko Bay/Vaigat area. The decline in total biomass observed since 2003 occurred predominantly the in offshore area off southwest Greenland. However, the fishable biomass estimated for 2006 is still above long-term average. The length distribution in 2006 indicates that progression of males to the female group is secured for the next year, but a low abundance of recruits at age 2 suggest that a decrease in fishable biomass will occur in the coming years. Mean bottom temperature in the survey area increased in the mid-1990s and this relatively warm period continued in 2006, in particular in depths >300 m off southwest Greenland where the actual values seem to exceed the level preferred by Northern shrimp.

Introduction

Since 1988, the Greenland Institute of Natural Resources has conducted annual stratified-random trawl surveys off West Greenland between July and September to assess the *Pandalus borealis* stock biomass and recruitment. The objective of the survey is further to obtain information on the size and sex composition of the stock as well as on the environmental conditions. This document presents the results of the 2005 survey, and compares these with a revised survey time series from the previous.

During the field season in 2005, the *Skjervøy 3000* trawl that was used for the yearly shrimp survey since 1988 was substituted with a *Cosmos 2000* trawl. Against that background this paper also describes dimensions of the used trawls and the approximations on which the swept area calculation rests.

Material and Methods

Survey design and area coverage

The offshore survey area for Northern shrimp covers the depth interval of 150-600 m in NAFO Subarea 1 and a small part in the east of NAFO Div. 0A. Since 1991 the survey has also included the inshore areas Disko Bay and Vaigat in NAFO Div. 1A.

The survey strata correspond to geographical areas, which are based on the distribution of the commercial fishery according to logbook information (Carlsson *et al*., 2000). The geographical areas are sub-stratified in four depth zones: 150-200 m, 200-300 m, 300-400 m, and 400-600 m. Using depth data logged during the surveys since 2000, new depth contours were constructed for the offshore area as well as for the Disko Bay/Vaigat region and revised stratification schemes were introduced in 2004 (Wieland and Kanneworff, 2004). Major changes compared to previous years were made in region U, in which geographical borders were changed, and in the former areas D1 to D9 (Disko Bay/Vaigat), which were combined in two areas (I1 and I2), each sub-stratified by depth. Also, the former two areas C1 and C3 in the Canadian EEZ (NAFO Subarea 0) were combined into one (C0). For the survey in 2005, the depth contours in areas U1 to U3, I1 and I2, and W8 and W9 were updated with data collected in 2004, and the border between areas U2 and U3 was slightly changed. Due to these revisions, the total survey area (Fig. 1) increased from about 125 000 km² in 1995-2002 to 133 000 km² in 2003 and to 137 000 km² since 2004.

From 1988 through 1999, trawl stations were allocated to strata in proportion to stratum area, but since 2000 more stations have been allocated to strata where high densities and high biomass variances of Northern shrimp were observed in previous years, in order to improve the precision of the overall biomass estimate. An exponential smoothing technique for the allocation procedure was applied to give higher influence of more recent observations in the weight factors (Kingsley *et al*., 1999).

Station positions were selected based on a division of the survey area into elements with a spacing of about 2 nautical miles. Until 1998, trawl locations were selected by an adjusted random procedure, in which stations were rejected when allocated to adjacent elements. In 1999 a new method of choosing station positions for the survey was introduced. This method combines the use of a minimum between-station-distance rule ("buffer zone" rule) with a random allocation scheme (Kingsley *et al*., 2004).

From 1988 through 1998, all stations have been selected by re-placing sampling sites each year. Thereafter, about 50% of the randomly selected stations covered in preceding year, were repeated as fixed stations in the following year. This was done to evaluate the stability of the stock distribution and to assess the performance of a fixed-station design relative to that of re-sampling (Kingsley, 2001a). The remaining stations were re-selected applying the above-mentioned buffer zone method and treating the fixed stations as already chosen. The introduction of fixing station positions from one year to the next has not explicitly been taken into account in the analysis, i.e. data from the fixed and the re-placed stations have been used without distinction and the analysis is therefore similar to the ones carried out in years in which all stations were selected at random.

As observed densities of Northern shrimp in the region north of 69°30'N consistently have been low and because of severe difficulties in finding suiTab. bottom for trawling, a fixed-station sampling design in this area has been used since 1998. To cover all nine strata with a minimum of two stations in each, 20 possible trawl tracks were chosen. From these between 10 and 18 were realized annually in the years 1999 to 2002. Since 2003, after having obtained better bathymetric information, the same procedure for stratification and selection of stations as in the other offshore areas were introduced.

In 2006, 206 stations in depths between 150 and 600 m were allocated to the various strata according the distribution of Northern shrimp in the previous years while additional 20 stations were allocated based on the distribution of Greenland halibut and Atlantic cod (10 stations for each of the two species). Furthermore, 30 stations were planned at depths <150 m in NAFO Div. 1A-1F. Besides, CTD casts were made along standard transects in the offshore and the Disko Bay/Vaigat area. Both, the results of fish catches and the observations from the hydrographic transects will be reported as usual elsewhere, i.e. at the NAFO Scientific Council Meeting in June 2007.

Survey period

The trawl surveys have always been carried out at the same period of the year (June/July to August/September) with the ambition to minimize the effect of seasonal variation. In order to reduce the possible influence of light induced nocturnal vertical migrations of shrimp, trawling was carried out only between 0900 and 1930 UTC.

Tow duration

Tow duration at stations used for the estimation of Northern shrimp biomass has been changed through the years from 60 min in the years 1988 to 1997, and then stepwise shortened to a mixture of 30 and 15 min tows randomly distributed in the strata in the proportion 2:1 in the years 2001 to 2003. These reductions were made in order to optimise the sampling schedule (Carlsson *et al*., 2000). In 2004, equal proportions of 30 and 15 minutes tows were applied and in 2005 standard tow duration was set to 15 min on all stations.

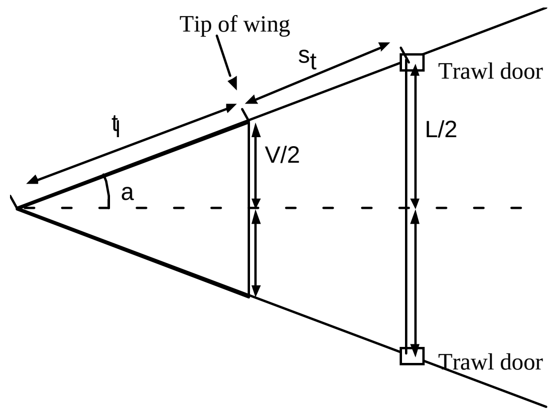
Results reported by Kingsley *et al*. (2002) have so far indicated that 15 min tows do not give more variable results than 30 min tows and hence no weighting was applied to tows of different durations. On the other hand, analyses of survey data from 1999 and 2000 have shown that the effective swept area is somewhat larger than estimated corresponding to 2.78 min in duration per haul (Kingsley *et al.*, 2002). This value, which is equal to 9 % of a 30 min tow but corresponds to 18 % of a 15 min tow, was estimated with a high variance (s.e.: 1.16 min) and could not be confirmed in a later study using a different methodological approach (Kingsley, 2001b). It is assumed that difficulties in determining the precise time of the beginning of a tow are the major cause for a considerable variability of this ‘end-error’. The start point of a tow is estimated by information from an acoustic sensor ('trawl eye') measuring the distance between the headline and the ground gear from the bottom. Because it takes some time for the trawl to 'land' completely on the bottom, the time of the beginning of a tow has been defined by the presence of a sTab. distance of the headline to the bottom. Judging when this occurs is difficult and to a certain degree subjective, in particular on rough bottom. Included in the 'end-effect' is also fishing time on that part of the shrimp stock which is swimming above the bottom at the time of setting the trawl. This is very difficult to assess and is assumed to vary substantially with time of day, composition of the stock etc. However, based on an more extended data set than available in previous studies, Wieland and Storr-Paulsen (2006) demonstrated that for Northern shrimp and Greenland halibut, neither total biomass density nor numerical densities of different size groups differed significantly between 15 and 30 min tows. Thus no indication was found that 15 min tows give less precise results than 30 min tows. Tow duration had also no significant effect on mean size and maximum length of catches of both species. These results indicate that the used mixture of 15 and 30 min tows can be replaced by 15 min tows on all stations without any impact on the continuity of the time series of survey estimates. This practice was implemented in 2005 and no corrections for different tow durations in the previous years have been included in the present analysis of the status of the stock.

Fishing practices

The survey was conducted with the research trawler *Paamiut* (722 GRT) since 1991 and similar vessels in the years 1988 to 1990. Initially, a 3000/20-mesh *Skjervøy* bottom trawl with a twin cod-end has been used. Mesh size in the cod-end was reduced from 44 mm to 20 mm (stretched) in 1993, and the fine mesh cod-end has been used thereafter. From 1988-1991estimates of door spread and height of the headrope over the bottom were based on results from tank experiments performed by the Danish Institute for Fisheries Technology and Aquaculture. From 1991and onwards these dimensions have been measured with *Scanmar* acoustic sensors mounted on the trawl doors, and a *Furuno* trawl-eye mounted on the head rope. From 1988 through 2003 the trawl doors were of the type *Greenland Perfect*, measuring 9.25 m² and weighing 2 420 kg. They were replaced in 2004 by *Injector International* 7.5 m² trawl doors with a weight of 2 800 kg to facilitate a change of survey trawl in 2005. In 2005 the *Skjervøy* 3000 trawl equipped with a heavy bobbin footrope was replaced by a ‘rockhopper’ *Cosmos* 2000 trawl with a bobbin / rubber disk ground gear. Towing speed was about 2.5 knots in all cases.

Swept area calculation

For both trawls the wingspread (i.e. the width of the swept area) V have been calculated based on the following principles, assumptions and approximations. The trawl and the trawl plus bridles are assumed to form two similar triangles:



The width between trawl doors (L) is monitored during towing by sensors ("SCANMAR HC4"). The total length of the trawl excluding the cod end (t_l) is known (measured on land) as well as the total length between the trawl door and the tip of the wing "bridle length" (s_t) (measured on land). Two expressions for sinus a can be formed and put equal to each other:

$$\sin(a) = (L/2) / (t_l + s_t) \text{ and } \sin(a) = (V/2) / t_l$$

This gives the opportunity to form an expression for V, the width of the swept area, as:

$$V = (t_l * L) / (t_l + s_t).$$

The length of the *Skjervøy* trawl is 67.15 m and the length of the *Cosmos* trawl is 71.8 m, both measures exclude the cod ends. In 2004 and thereafter, the bridle length, i.e. the total length of lines, chains and shackles between the trawl doors and the tip of the trawl wing, was 54 m for both trawls whereas other bridle lengths were used in earlier years (Table 1). In the case of the *Skjervøy* trawl a factor of 0.7 m have been added to the expression for V. This factor was added since the *Skjervøy* trawl is a three-winged trawl and the lower wings (the wings directly attached to the ground-rope) were estimated to spread 0,35 meters wider than the middle wings on each side in tank experiments at the Danish Institute for Fisheries Technology and Aquaculture (Per Kanneworff, pers. com.).

The distance between the trawl doors was recorded 3 or 5 times during each haul and mean wingspread for each tow was calculated from average door spread and the geometry of the trawl as described above. Nominal swept area was calculated as the straight-line track length between start and end-positions (GPS) multiplied by the mean wingspread for each tow.

Biomass estimation

For each tow, the catch was divided by the nominal swept area calculated from wingspread and track length to estimate the density. Mean stratum densities were multiplied by the stratum area to compute stratum biomass, and corresponding coefficients of variation (CV, in %) for each stratum were calculated from the swept area estimate of the biomass (B) and the standard deviation of the density times the stratum area (STD) according to:

$$CV = STD / B * 100.$$

Stratum biomasses and variances of these estimates were added to get regional and overall estimates. Overall error coefficients of variation (in %) were calculated as relative standard errors:

$$OECV = \sqrt{\sum \frac{STD^2{}_i}{n_i}} / \sum B_i * 100$$

where STD^2, n, and B denote variance , number of tows and biomass in stratum i, respectively. Standard deviations (STD) were calculated according to Cochran (1977) as B × 0.985 in cases in which only one tow per stratum has been available.

Biological samples

From each catch a sample of about 1.5 to 4 kg of shrimp was taken and sorted to species. All specimens of Northern shrimp were grouped into males, primiparous and multiparous females based on their sexual characteristics as defined by Allen (1959) and McCrary (1971), and oblique carapace length (CL) was measured to the nearest 0.1 mm using slide callipers.

The number of Northern shrimp in the samples was weighted by total catch and stratum area to obtain estimates of total number by sex and length group (0.5 mm intervals) for each stratum, for different inshore and offshore areas and the total survey area. These data were used to construct area-specific length frequencies and to calculate abundance indices for males and females as well as for small (<17 mm) specimens, which are expected to enter the fishery in the coming year.

Indices of male and female biomass were computed from the proportion of females in weight converted from the overall length distribution and the estimate of total survey biomass. Fishable biomass was calculated from the total number of specimens with a length equal to and greater than 17 mm CL converted to weight. In both cases length-weight relationships given in Carlsson and Kanneworff (2000) and Wieland (2002a) were used for the period prior to 2001 and the years 2001 and 2002, respectively. In 2003, 2004, 2005 and 2006 new length-weight data were collected from all parts of the survey area and male, female and fishable biomass were calculated from these annual length-weight relationships.

Abundance indices for age 2 were obtained by modal analysis of regional length frequencies for juveniles and males using the MIX 3.1A software (MacDonald and Pitcher, 1979; MacDonald and Green, 1988; release 3.1A by Ichthus Data Systems in 1993). The regions for pooling the original length frequencies were defined considering latitudinal gradients in bottom temperature (Wieland, 2004a). No smoothing of the length frequency histograms was applied prior to the analysis. Initial estimates of the modes and the number of age groups to be considered were obtained by visual inspection of the length frequencies. A constant coefficient of variation for length at age was used in the MIX analysis during a first run. However, because the first age group was not well represented in many of the samples, a part of the larger males had already changed sex and differences in growth between cohorts were likely, varying coefficients of variation were finally used.

Bottom temperature

Until 1994 bottom temperatures were measured with a *Seabird* CTD and thereafter with a *Seamon* sensor mounted on one of the trawl doors. The *Seamon* sensor records data in intervals of 30s with a resolution of 0.01°C. Average temperatures for each haul were calculated after retrieval of the sensor. All measurements taken at depths >150 m were used to calculate a mean bottom temperature weighted for the areas of the survey strata between 150 and 600 m depth.

Results and Discussion

Effect of the change of the survey trawl

Figure 2 compares wingspread and vertical opening of the *Skjervøy* trawl with the *Cosmos* trawl during experimental hauls conducted for calibration purposes (Rosing and Wieland, 2005). For the *Cosmos* trawl, average wingspread was about 8 m wider and vertical opening was about 1.5 m higher than for the *Skjervøy* trawl, both differences being statistically significant (Paired t-test, P <0.001). The calculation of the swept area takes the difference in wingspread into account while the vertical opening of the trawl has, as in previous years, not been considered in the biomass estimates. In addition to the trawl dimension, the change of the type of the groundgear seems to induce a size dependent effect on the catchability for Northern shrimp and length-dependent conversion factors were provided by Rosing and Wieland (2005). These values, however, were based on total catches in numbers by length-class in a tow (and not numerical densities by length-class) and did thus not include the effect of the different dimensions of the two trawls. Therefore, the length-dependent conversion factors were supplement by a length-independent adjustment based on the mean ration of the swept areas fished by the two trawls in the paired tows of the calibration experiment, which amounted to 0.8708 (s.e.: 0.0075).

Area coverage

As usual, a number of planned trawling sites had to be cancelled for various reasons. Because about half of the trawling sites are chosen at random some stations may have been placed in areas in which the conditions were not suiTab. for bottom trawling despite the fact that the new trawl has been proven to be much less sensitive to rough bottom conditions than the old one.

In 2006, 226 stations at depths between 150 and 600 m were planned of which five locations were not be covered due to a combination of unfavourable bottom condition, sea ice coverage or time restriction. Hence, in total 221 valid tows were available to describe the stock situation of Northern shrimp this year.

Total biomass and distribution

For all strata biomass estimates have been calculated (Tables 2a-d) on the basis of the nominal swept area. The biomass estimates (in tons) for the five main regions and the entire survey area in 2006 are:

Region	Biomass estimate (t)	Number of stations	OECV (%)
North	54 668	35	20.5
Canadian zone	45 788	5	79.0
West (incl. South)	272 853	156	18.5
Disko Bay / Vaigat	110 679	25	12.9
Total	483 984	221	13.4

The estimated total biomass for the period 1988 to 1997 was fairly sTab. around a mean of 200 000 tons. After 1997, the biomass increased steadily to a record high estimate of 598 000 tons in 2003 followed by a decline to 575 000 tons in 2004, 552 000 tons in 2005 and about 484 200 tons in 2006 (Table 3, Fig. 3 upper panel). Survey indices of biomass per unit area, which accounts for the extension of the survey area in 2003 and thereafter, indicate the same trend as the swept area estimates of total abundance (Fig. 3 lower panel).

After having optimised the sampling procedure, i.e. selection of sampling sites, reducing the tow duration and operating with a mixture of fixed and reallocated stations, the overall error coefficient of variation (OECV) of the biomass estimates has decreased during the past years (Table 4). The OECV for the total survey in 2004 and in 2005, however, was 16%, which is 1.5% above the average since all regions were included in the survey area in 1994. This is most likely due to the relative low number of stations covered in the past two years with a change in the distribution of Northern shrimp towards shallower depths (see below). In 2006, the number of stations was increased and the OECV declined again to 13.4%.

The total biomass in the five main survey regions exhibits large biomass changes throughout the last decade (Fig. 4). The change was most abrupt in the northernmost offshore region (U) whereas a more continuous increase was recorded in the Disko Bay/Vaigat area (I). An exceptional high value was found for the Canadian zone in 2006, but this value was estimated with a relative high uncertainty (OECV: 79%). The contribution of the southernmost offshore region (W8 and W9) to the overall biomass shows a negative trend since 1999, and for the remaining offshore area (W1 to W7) a sharp decline is indicated since 2004.

The distribution of the Northern shrimp density in 2006 (Fig. 1) followed an earlier observed pattern with high densities in the deeps between the shallow banks along the coast north from about 64°N, i.e. the Sukkertoppen Deep (≈64°30'N) and in particular in the Holsteinsborg Deep (≈66°30'N). High concentrations of Northern shrimp were predominantly found in the area north and west from Store Hellefiske Bank (≈68 to 69°N) as well as in the northern part of Disko Bay and Vaigat (inshore areas I1 and I2, ≈69 to 70°N). In contrast, low densities were observed at the offshore slope of the shelf between 64 and 67°N. Catches in the coastal part of the Julianehåb Bight (offshore areas W8 and W9, ≈60°N) were much lower in 2005 than in previous years (Tab. 3), but increased again in 2006. The largest catch of 1.9 t per 15 min tow (≅ 61 t/km²) was obtained in the Godthåb Deep (≈64°N) at 200-300 m depth.

The Disko Bay/Vaigat region has the longest history of commercial fishery for Northern shrimp in Greenland since it developed in the early 1950s. When the survey first included this area in 1991,a biomass of 43 000 tons was estimated (Table 3), corresponding to about 20% of the biomass for the total survey area at that time. The estimated biomass has increased steadily from a low in 1993 to the record high estimates of 140 000 tons in 2005 (25% of the total survey biomass). Estimated density of Northern shrimp in the Disko Bay/Vaigat region has always been very high compared to the offshore areas (Table 5) and ranged between 8.4 and 14.2 t/km² (or g/m²) in the five recent years. This is about three times higher than the average offshore density during the same period.

Relative distribution of the biomass in depth layers (Fig. 5) shows that the bulk of the biomass was found between 300 and 400 m depth until 1994. This has gradually changed and most of the biomass (70% of the overall biomass) was observed in the 200-300 m in 2001. Subsequently, the biomass increased in all depth intervals, but the 200-300 m depth interval still contributes the major part of the total biomass (≈70% in 2001 and 2004). Despite being the most important one, the contribution of the 200-300 m depth layer to the overall biomass decreased in 2005 and 2006 to about 50% while the proportion found in 150-200 m depth layer increased from less than 5% in 2004 to about 20% in 2005 and 15% in 2006, which are the highest value ever seen in the time series.

Size distribution by area in 2006

Males smaller than 11 mm CL were generally rare in the offshore areas U1 to U3, C0 and W1 to W9, and the offshore length frequency distributions indicate a dominance of males between 17 and 23 mm CL (Fig. 6a, b). In a few of these areas (i.e. areas W4 and W5), smaller (11 to 15 mm CL) males were also abundant while large (>23 mm CL) males and females were mainly found in the areas W6 to W8 but at relative low levels of abundance. Length frequencies for the inshore areas I1 and I2 differed from the offshore distributions showing a more pronounced presence of males between 11 and 15 mm CL (Fig. 6c).

Annual size distributions

Overall length distributions for the offshore and the inshore area in 1988 to 2005 are compared in Fig. 7a-d. The offshore length frequency distribution for 2006 shows a distinct mode of males at 21 mm CL (Fig. 7d). Abundance of males between 11 and 15 mm CL was higher in 2006 than in 2005 but is low compared to e.g. 2003 and in particular 2001. The primiparous females show a mode at about 23.5 mm CL, and a mode at 24 mm CL is discernable for multiparous females in the offshore areas in 2005 (Fig. 9d). The inshore length frequency for 2005 differed from that recorded in previous years, in particular concerning the presence of a pronounced peak for males at 18.5 mm CL (Fig. 7d). The inshore length frequency distributions were, however, similar to the offshore ones concerning the mode of the primiparous females at 23 mm CL in all years since 2003 (Fig. 7d).

Figure 8 shows overall length frequencies for the entire survey area combining the offshore and inshore data for the years 2002 to 2006. A progression of the 1999-year-class from about 17.5 mm CL in 2002 to 19.5 mm CL in 2003 is clearly visible. This year-class began to pass into the female group in 2004 and contributes likely to the majority of the primiparous females in 2005 and the multiparous females in 2006. Subsequent year-classes were weaker and more difficult to trace in the length frequency distributions. However, the considerable increase in the level of abundance of the 2002-year-class at the progressing modes of about 8 mm CL in 2003, 12 mm CL in 2004, 16 mm CL in 2005 and 18 mm CL in 2006 is striking. The corresponding abundance levels were about 0.2×10^{9} at age 1, 1.2×10^{9} at age 2, 4.3×10^{9} at age 3 and 5.8×10^{9} at age 4. Several processes, which include mesh selection of the trawl especially for shrimp smaller 11 mm CL (Wieland, 2002b), escapement of juveniles below the footrope

(Nilssen *et al.*, 1986) and immigration from nursery areas at depths shallower than intensively covered by the survey (Wieland and Carlsson, 2001) may explain this phenomenon.

High abundance of males between 17 and 21 mm CL in 2006 (Fig. 8) suggests that progression to the female group is secured for the next year, but there is no indication that a strong year-class will enter the fishable stock in the coming years.

Length-weight relationship

Measurements of individual length and weight were pooled for all sexual groups and survey areas as a visual inspection of the data did not suggest a separate treatment (Fig. 9 upper panel), and the resulting length-weight relationship for 2006 differed not very much from those used in previous years (Fig. 9 lower panel):

1988-2000:	$W = 0.000669 * L^{2.96}$
2001-2002:	$W = 0.000483 * L^{3.0576}$
2003:	$W = 0.000752 * L^{2.9177}$
2004:	$W = 0.000765 * L^{2.9092}$
2005:	$W = 0.000529 * L^{3.0213}$
2006:	$W = 0.000660 * L^{2.9461}$

where W is weight in g and L is carapace length in mm.

Total abundance, spawning stock biomass and fishable biomass

Total numbers and proportions of male and female shrimp in the survey area (including both inshore and offshore areas) estimated from overall length distributions are given in Table 6. The total number of males and females together for 2006 is below the value for 2005, but still exceeds considerably the long-term mean. Estimates of total stock biomass derived from a conversion of the length frequencies to weight are listed in Table 7. Total biomass calculated in this way differed by less than 1% from the direct estimates of the total survey biomass (Table 3), except for 2001 (-6.3%), 2005 (-4.2%) and 2006 (-4.0%). The proportion of females in 2006 is above the long-term average, both in terms of abundance and in biomass.

Table 8 shows the fishable biomass calculated from the number of individuals equal to and above 17 mm CL. This size limit is assumed to correspond roughly to the L_{50} value of a commercial shrimp trawl with a mesh size of 44 mm in the cod-end. The fishable biomass increased in 2003 to record high value of 548 000 tons for the offshore and the inshore area combined. In 2006, the fishable biomass index for the entire survey area amounts to about 440 000 tons, which is considerably lower than in the previous three years but it is still far above the long-term average.

Recruitment and mean length at age 2

Length frequencies of Northern shrimp (juveniles and males) by region with fitted Gaussian components for age 1, 2, and 3 in 2006 are shown in Fig, 10. Further results of the modal analysis, i.e. the mean length at age 2 in the years 1993 to 2006, are listed in Table 9. The Gaussian components fitted the observed distribution in the size range of the different age groups reasonably well in almost all cases. Regional differences and annual changes in the mean length at age 2 were observed. This was most pronounced in the in the Disko Bay/Vaigat region (inshore areas I1 and I2) with values ranging from 11.3 to 15.1 mm CL (Tab. 9). Both, the regional differences as well as the annual changes in mean length at age 2 have been related to changes in the temperature regime and stock density (Wieland, 2005).

For the initial period 1993 to 1995, low estimates of abundance at age 2 were obtained in particular for the inshore area (Fig. 11). This was followed by and exceptional high values in the offshore area in 1996 (Fig. 11). Age 2 abundance increased steadily since 1997 until a record high value in 2001, and declined thereafter to 3.4×10^{9} individuals in 2005. The 2006 estimates amounting to 4.5×10^{9} indicates a slight increase in recruitment, but is much below the long-term average of 7.34×10^9 individuals. It is worth to note that the Disko Bay/Vaigat area (inshore regions I1 and I2), which accounts only for about 7% of the total survey area, contributed between 28 and 45% to the total abundance of this age group in the period 1997 to 2002. Moreover, the proportion of recruits found in the inshore waters increased to 54 and 73% in 2004 and 2005, respectively, whereas the in 2006 the importance of the offshore regions increased again contributing 56% of the total abundance at age 2. However, the recruitment seen in 2005 and in particular in 2006 was considerably below what could have been expected from the high level of the female stock in the years these year classes were born (Fig. 12). This supports previous findings concerning environmental effects on the stock-recruitment relationship (Wieland 2004b).

The abundance indices for age 2 showed significant correlations with the fishable biomass (all individuals ≥ 17 mm CL) one, two and three years later (Fig. 13). The relative low recruitment observed in the past years suggests a decrease of the fishable biomass in the coming years (Fig. 14) to a level that is close the average recorded in the late 1990s. However, the large confidence and prediction intervals of the linear regression indicate that these estimates are attributed with a high uncertainty. Time lags of one to three years in the correlation between recruitment at age 2 and fishable biomass are reasonable considering that the main contribution in the fishable biomass comes from individuals in the size range of age 4 to 6. Although the relationship between recruitment at age 2 and fishable biomass are significant, it should be kept in mind that the predictions for coming years are only valid if the overall effect from the underlying processes like growth, natural mortality (e.g. predation by Greenland halibut and Atlantic cod) and the removal by the fishery relative to stock size (exploitation rate) do not substantially change.

Bottom temperature

Bottom temperatures ranged from 1.1°C in the shallow (<200 m) water of the Disko Bay to about 5.6°C in the deeper (>400 m) part southernmost offshore area in 2006 (Fig. 15). Values above 4.5 °C were frequently found at the offshore slope of the shelf in the area south of 60°30'N, but in contrast to 2005 lower values (<3.5°C) were dominated in the inner part of Julianehåb Bight (60°00' to 60°30'N) as well as in the coastal waters between 60°00' and 63°30'N. This resulted in a pronounced decrease of the mean value for the southern part of the survey area compared to the previous years (Fig. 16 upper panel). Such a change was not found in other parts of the survey area. A transition from a cold to a warm period has been recorded in the mid 1990s and was observed in all depth strata of the survey (Fig. 16 middle panel). The overall area weighted mean bottom temperature amounted to 3.03°C (Fig. 16 lower panel). This is close to the average observed since 1997 and indicates that the recent relative warm period has continued.

Conclusions

Estimates of Northern shrimp (*Pandalus borealis*) biomass derived from stratified random surveys performed West Greenland waters since 1988 showed little variation until 1997 with annual estimates of the standing stock of between 150 000 and 235 000 tons. Since 1997 a continuous increase in survey biomass has been observed with a record high values of 598 000 in 2003, followed by a gradual decline to 484 000 tons in 2006. Large variations from year to year both geographically and over depth zones were observed suggesting that the stock is highly migratory. The survey design has been evaluated and adjusted in the later years in order to reduce sampling variation. The contribution of the inshore component (Disko Bay and Vaigat) of the stock to the overall fishable biomass and recruitment has varied through the years and is actually 20% in terms of fishable biomass and 44% in terms of recruitment. These values are above the long-term average and indicate strongly the importance of the Disko Bay/Vaigat region despite its relative small area (7% of the total survey area). In contrast to previous years, low biomass was recorded in the southernmost offshore region since 2005, and catch rates increased considerably in relative shallow waters (<300 m) in almost all areas. This is likely a response to the increase in temperature of the bottom water in some areas and depth ranges to a level, which is at the upper limit that is assumed to be optimum for Northern shrimp (1-6°C, Shumway *et al.*, 1985). Indices of female biomass and fishable biomass for 2006 are above long-term average. The length distribution observed in 2006 indicates that progression of males to the female group is secured for the next year, but low abundance of recruits at age 2 suggests a decrease in stock size during the coming years to a level around 300 000 tons during the coming years.

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TABLE 1. Vessel, trawl types and rigging parameters used in the West Greenland Bottom Trawl Survey for shrimp and fish (*: from tank experiments (Per Kanneworff, pers.com.), **: average for all valid tows calculated from measures of door spread and approximated geometry of the trawl).

Year / period	Vessel name	Trawl type	Bridle total length (m)	Wingspread (m)	
1988	Elias Kleist	Skjervøy	59.9	23.1	*
1989	Sisimiut	Skjervøy	81.1	17.9	*
1990	Maniitsoq	Skjervøy	59.9	23.1	*
1991	Paamiut	Skjervøy	75.1	28.3	**
1992 - 2003	Paamiut	Skjervøy	60.1	20.1 - 25.2	**
2004	Paamiut	Skjervøy	54.0	25.7	**
2005 - 2006	Paamiut	Cosmos	54.0	28.1 - 28.6	**

TABLE 2a. Estimated trawlable biomass (tons) and sampling statistics for the survey strata in region U, 2006.

Stratum	Depth	Area (km²)	Biomass	Hauls	STD	CV (%)
U1-1	150-200	3302	24.7	2	28.6	115.8
U1-2	200-300	4494	3504.4	2	2390.5	68.2
U1-3	300-400	4646	2251.0	3	482.9	21.5
U1-4	400-600	5312	3217.1	2	3306.2	102.8
U2-2	200-300	6496	3705.4	3	1729.2	46.7
U2-3	300-400	8517	5442.8	3	6662.9	122.4
U2-4	400-600	7946	1946.7	4	2415.6	124.1
U3-1	150-200	2179	395.0	2	98.6	25.0
U3-2	200-300	3210	23889.2	6	23955.4	100.3
U3-3	300-400	1639	5781.3	5	2490.5	43.1
U3-4	400-600	2658	4510.1	3	3032.9	67.2
Total		50399	54667.7	35		

TABLE 2b. Estimated trawlable biomass (tons) and sampling statistics for the survey strata in region C, 2006.

Stratum	Depth	Area (km²)	Biomass	Hauls	STD	CV (%)
C0-2	200-300	897	607.7	2	729.4	120.0
C0-3	300-400	2126	43309.1	2	51080.7	117.9
C0-4	400-600	1213	1871.2	1	-	-
Total		4236	45788.0	5		

TABLE 2c. Estimated trawlable biomass (tons) and sampling statistics for the survey strata in region W, 2006

Stratum	Depth	Area (km²)	Biomass	Hauls	STD	CV (%)
W1-1	150-200	2968	392.2	2	547.2	139.5
W1-2	200-300	6035	44385.7	15	73910.8	166.5
W1-3	300-400	7515	13189.1	8	7771.5	58.9
W1-4	400-600	877	445.5	2	123.5	27.7
W2-1	150-200	1699	491.8	2	3.1	0.6
W2-2	200-300	2616	28350.3	8	23923.4	84.4
W2-3	300-400	1768	20380.7	4	34153.0	167.6
W2-4	400-600	965	1266.1	2	1373.4	108.5
W3-1	150-200	2160	14.4	4	22.8	158.2
W3-2	200-300	4698	39508.1	14	60282.6	152.6
W3-3	300-400	2119	4293.4	2	5758.0	134.1
W3-4	400-600	2921	4371.6	5	3434.7	78.6
W4-1	150-200	4255	35.3	2	46.2	130.7
W4-2	200-300	1695	9504.4	5	13031.4	137.1
W4-3	300-400	777	2773.6	4	5337.5	192.4
W4-4	400-600	1873	104.7	3	96.1	91.8
W5-1	150-200	3001	16846.1	7	38897.1	230.9
W5-2	200-300	3648	16813.3	11	33168.1	197.3
W5-3	300-400	1950	450.5	2	606.3	134.6
W5-4	400-600	3021	576.9	2	350.8	60.8
W6-1	150-200	1206	1661.1	3	2877.1	173.2
W6-2	200-300	2006	27671.8	5	52986.1	191.5
W6-3	300-400	1585	2441.9	4	3410.6	139.7
W6-4	400-600	1234	616.0	2	783.3	127.2
W7-1	150-200	2442	23691.5	4	44894.7	189.5
W7-2	200-300	891	33.2	7	87.8	264.3
W7-3	300-400	265	0.0	2	0.0	-
W7-4	400-600	317	0.0	2	0.0	-
W8-1	150-200	424	493.6	2	281.8	57.1
W8-2	200-300	567	10244.4	2	14062.3	137.3
W8-3	300-400	405	965.5	3	891.7	92.4
W8-4	400-600	718	834.8	3	300.5	36.0
W9-1	150-200	1711	0.0	4	0.0	-
W9-2	200-300	938	0.5	5	0.4	78.7
W9-3	300-400	516	0.4	2	0.6	141.4
W9-4	400-600	430	1.0	2	1.5	141.4
Total		72216	272849.4	156		

TABLE 2d. Estimated trawlable biomass (tons) and sampling statistics for the survey strata in region I, 2006.

Stratum	Depth	Area (km²)	Biomass	Hauls	STD	CV (%)
I1-1	150-200	397	7748.1	1	-	-
I1-2	200-300	1903	35951.8	2	13850.3	38.5
I1-3	300-400	2430	22497.8	5	13717.2	61.0
I1-4	400-600	1561	5877.7	3	5898.3	100.4
I2-1	150-200	432	3021.1	4	2796.3	92.6
I2-2	200-300	793	28603.9	4	6943.7	24.3
I2-3	300-400	1022	4870.2	3	4845.0	99.5
I2-4	400-600	1295	2108.8	3	2728.1	129.4
Total		9833	110679.4	25		

TABLE 3. Biomass estimates (in '000 tons) for combined strata and standard errors for the entire survey area 1988-2006.

Year	N1-N9	U1-U3 [1]	C1+C3	C0 [1]	W1-W2	W3-W4	W5-W7 [2]	S1+S2	W8-W9 [1]	D1-D9 [3]	I1-I2 [1]	Total	SE [4]
1988	22.6		9.5		55.1	85.5	17.7	-		39.2		229.7	24.7
1989	11.1		3.7		50.0	82.7	39.0	-		39.2		225.7	32.3
1990	11.0		9.1		78.6	53.9	23.5	-		39.2		215.3	32.6
1991	5.1		4.2		26.8	47.4	23.3	-		43.1		149.9	23.0
1992	18.1		22.2		46.2	30.6	45.8	-		41.4		204.4	32.5
1993	6.9		2.9		93.8	36.7	62.2	-		28.3		230.8	30.9
1994	6.6		6.0		95.0	44.5	32.6	16.7		34.0		235.4	51.7
1995	6.8		3.9		39.0	52.4	48.7	1.6		39.1		191.4	30.6
1996	8.8		1.5		46.4	31.5	80.0	3.3		44.3		215.9	40.4
1997	5.7		0.2		34.7	13.1	57.9	21.8		44.3		177.7	31.1
1998	7.0		0.4		37.8	100.6	45.1	18.6		51.8		261.2	57.6
1999	17.6		10.5		50.1	23.2	50.5	56.0		52.6		260.6	42.1
2000	8.4		10.7		62.1	69.8	71.0	21.8		73.0		316.9	40.3
2001	34.1		3.7		74.3	47.6	58.5	36.3		72.1		326.7	44.2
2002	17.4 [5]		5.4		114.0	62.1	94.9	40.5		85.8		420.2	60.0
2003		109.3	5.9		148.6	93.3	98.0		35.0	107.7		597.8	77.0
2004		111.2		3.5	152.8	96.5	102.6		15.4		81.4	563.4	103.7
2005		100.5		9.3	159.9	87.2	53.4		1.9		139.6	551.9	88.4
2006		54.7		45.8	108.9	60.6	90.8		12.5		110.7	484.0	64.6

[1]: New stratification introduced in 2003 (regions N and S) and in 2004 (regions U, C and D)

[2]: Areas W6 and W7 were sampled from 1990 and 1993, respectively

[3]: D1-D9 1988-90 not sampled, but set to mean of 1991-1997.

[4]: Standard error calculated excluding D1-D9 in 1988-1990

[5]: Probably underestimated due to poor coverage of the northern part of the area N

TABLE 4. Overall error coefficients of variation (%) for the biomass estimates of the five main survey regions and the entire survey area together with the corresponding number of hauls 1988-2006.

Year	N/U	C	W1-W7	S/W8-W9	D/I	Total suvey	Number of hauls
1988	31.4	40.0	16.6	-	-	14.41	131
1989	22.2	42.8	20.1	-	-	18.60	130
1990	43.5	39.9	20.3	-	-	18.30	109
1991	40.2	27.1	17.7	-	22.9	13.37	194
1992	16.9	68.9	18.5	-	15.7	13.84	167
1993	51.6	53.3	13.5	-	19.4	11.66	146
1994	48.7	18.3	23.7	99.2	26.0	19.11	157
1995	47.1	44.7	18.2	74.0	17.7	13.93	163
1996	52.6	91.0	21.8	95.0	10.6	16.31	148
1997	37.9	61.9	24.7	14.6	14.5	15.26	167
1998	40.4	44.0	26.1	58.8	18.4	19.19	209
1999	51.1	80.0	13.7	52.1	14.2	14.08	227
2000	36.1	7.8	15.4	56.8	12.9	11.08	198
2001	26.5	44.5	18.8	22.8	18.6	11.77	224
2002	56.0	45.4	16.0	55.0	18.7	12.44	216
2003	26.8	44.4	16.0	49.9	17.5	11.21	172
2004	24.9	22.6	24.1	71.4	11.6	16.03	187
2005	22.1	41.4	23.5	53.8	34.6	16.02	194
2006	20.5	79.0	21.1	30.1	12.9	13.35	221

TABLE 5. Estimated mean densities (t/km²) for combined strata in 1988-2006.

Year	N1-N9/U1-U3	C1+C3/C0	W1-W2	W3-W4	W5-W7	S1-S2/W8-W9	D1-D9/I1-I2
1988	0.54	2.77	2.34	3.94	1.76	-	-
1989	0.25	1.08	2.76	3.81	3.88	-	-
1990	0.25	2.65	3.33	2.48	1.59	-	-
1991	0.12	1.23	1.14	2.18	1.57	-	4.60
1992	0.44	6.46	1.96	1.41	3.09	-	4.42
1993	0.17	0.85	3.55	1.68	3.32	-	3.02
1994	0.17	1.76	3.59	2.03	1.74	3.22	3.63
1995	0.18	1.15	1.47	2.39	2.60	0.24	4.17
1996	0.23	0.44	1.75	1.44	4.27	0.51	4.73
1997	0.15	0.06	1.31	0.60	3.09	3.35	4.73
1998	0.18	0.11	1.43	4.59	2.41	2.85	5.54
1999	0.46	3.06	1.89	1.06	2.70	8.59	5.62
2000	0.22	3.10	2.35	3.18	3.79	3.35	7.80
2001	0.89	1.08	2.81	2.17	3.12	5.57	7.70
2002	0.45	1.57	4.31	4.46	5.07	6.21	9.16
2003	2.22	1.39	6.11	6.25	5.23	5.80	11.49
2004	2.20	0.82	6.25	4.71	4.76	2.65	8.37
2005	1.99	2.20	6.54	4.25	2.48	0.34	14.19
2006	1.08	10.81	4.47	2.96	4.21	2.20	11.26

Table 6. Abundance estimates (billions) for males and females from overall length distributions for the total survey area 1988-2006 (mean values for Disko Bay/Vaigat area in 1991-1997 used for 1988-1990.

Year	Males	Females	Total	Males %	Females %
1988	26.8	9.3	36.1	74.3	25.7
1989	39.0	6.9	45.9	85.0	15.0
1990	29.3	8.9	38.1	76.8	23.2
1991	19.6	5.1	24.7	79.3	20.7
1992	29.4	6.5	35.9	81.9	18.1
1993	34.8	8.3	43.1	80.7	19.3
1994	32.0	8.9	40.9	78.3	21.7
1995	27.7	6.5	34.2	80.9	19.1
1996	38.2	6.6	44.8	85.2	14.8
1997	27.2	6.3	33.5	81.2	18.8
1998	41.0	9.9	50.9	80.5	19.5
1999	42.5	9.9	52.3	81.1	18.9
2000	62.4	11.1	73.4	84.9	15.1
2001	56.6	11.8	68.4	82.7	17.3
2002	85.3	14.9	100.1	85.1	14.9
2003	99.4	24.9	124.4	80.0	20.0
2004	89.4	26.3	115.8	77.3	22.7
2005	91.3	24.2	115.5	79.0	21.0
2006	75.2	23.1	98.3	76.5	23.5
Average	49.8	12.1	61.9	80.6	19.4

Table 7. Biomass estimates for males and females ('000 tons) in the total survey area based on length-weight relationships applied to overall length-frequency distributions 1988-2006 (mean values for Disko Bay/Vaigat area in 1991-1997 used for 1988-1990).

Year	Males	Females	Total	Males %	Females %
1988	134.7	94.8	229.5	58.7	41.3
1989	157.1	68.6	225.7	69.6	30.4
1990	129.4	85.4	214.9	60.2	39.8
1991	100.5	49.4	149.9	67.0	33.0
1992	141.3	63.1	204.4	69.1	30.9
1993	149.2	81.9	231.1	64.6	35.4
1994	146.5	88.9	235.4	62.2	37.8
1995	124.5	66.9	191.4	65.0	35.0
1996	147.9	68.0	215.9	68.5	31.5
1997	114.7	62.9	177.7	64.6	35.4
1998	170.4	90.9	261.3	65.2	34.8
1999	166.7	93.9	260.6	64.0	36.0
2000	213.8	100.2	314.0	68.1	31.9
2001	199.1	108.3	307.4	64.8	35.2
2002	293.6	126.6	420.2	69.9	30.1
2003	389.2	208.6	597.8	65.1	34.9
2004	353.1	210.3	563.4	62.7	37.3
2005	340.1	189.6	529.7	64.2	35.8
2006	288.0	177.2	465.2	61.9	38.1
Average	192.9	103.2	296.1	65.2	34.8

TABLE 8. Estimates of fishable biomass (≥17 mm CL, '000 tons) in the offshore, the Disko/Vaigat and the total survey area 1988-2006 (mean values for Disko Bay/Vaigat area in 1991-1997 used for 1988-1990).

Year	Offshore	Disko	Total
1988	186.2	37.0	223.2
1989	171.9	37.0	209.0
1990	170.0	37.0	207.0
1991	104.7	41.3	146.0
1992	154.8	39.4	194.2
1993	189.4	27.1	216.5
1994	191.0	32.1	223.1
1995	144.9	38.3	183.2
1996	150.6	41.5	192.1
1997	127.7	39.4	167.1
1998	197.2	47.1	244.3
1999	195.0	42.3	237.3
2000	219.8	60.6	280.3
2001	216.8	63.7	280.5
2002	302.2	67.2	369.5
2003	454.0	94.3	548.3
2004	457.5	70.8	528.3
2005	371.3	108.2	479.5
2006	349.7	87.7	437.5
Average	222.5	51.4	261.8

TABLE 9. Mean carapace length (mm) for Northern shrimp at age 2 off West Greenland 1993-2005 and corresponding standard deviations and coefficients of variation from modal analysis (-: not present, ( ): fixed in the final MIX run).

mean:

	Region / Depth						
	U1 to U3	I1 and I2	C0 and W1 to W4		W5 and W6		W7 to W9
Year	150-600 m	150-600 m	150-300 m	300-600 m	150-300 m	300-600 m	150-600 m
1993	11.1	12.6	12.1	13.2	14.8	13.6	(14.0)
1994	12.4	11.6	12.3	13.1	14.8	13.7	-
1995	11.2	12.5	13.5	14.3	15.3	13.1	(12.5)
1996	11.9	13.0	14.2	14.0	13.7	14.9	(14.0)
1997	12.6	12.9	14.3	12.4	14.7	13.5	(13.0)
1998	11.0	14.0	14.0	14.9	15.8	16.4	(15.0)
1999	14.7	15.4	15.1	15.0	15.4	16.1	(15.5)
2000	13.3	14.9	15.0	15.0	14.8	16.7	(13.0)
2001	13.6	13.1	13.2	13.8	13.8	14.0	(13.5)
2002	13.1	12.6	12.8	12.6	14.9	15.3	(13.5)
2003	11.9	12.2	13.0	12.9	14.4	13.8	14.6
2004	11.9	11.6	12.3	13.0	14.3	(15.5)	(14.5)
2005	11.1	11.4	12.0	11.9	13.2	12.5	(16.0)
2006	11.8	11.3	11.8	12.3	12.9	14.0	(14.8)

standard deviation:

	U1 to U3	I1 and I2	C0 and W1 to W4		W5 and W6		W7 to W9
Year	150-600 m	150-600 m	150-300 m	300-600 m	150-300 m	300-600 m	150-600 m
1993	0.79	1.32	1.03	1.08	0.84	0.87	(0.80)
1994	(0.70)	1.04	1.17	1.20	1.09	1.54	-
1995	0.81	1.03	1.40	1.45	0.81	1.48	(0.70)
1996	0.79	1.09	0.91	1.23	1.48	1.29	(0.70)
1997	1.04	1.13	1.18	1.17	1.31	1.43	(0.70)
1998	1.07	1.40	1.03	1.35	1.31	1.10	(0.80)
1999	1.46	1.40	1.24	1.39	1.35	1.32	(0.70)
2000	1.30	1.39	1.26	1.44	1.46	1.26	(0.80)
2001	1.35	1.32	1.38	1.46	1.13	(0.80)	(0.70)
2002	1.33	1.49	1.37	1.46	1.52	(0.90)	(0.70)
2003	0.98	1.26	1.20	1.50	1.19	1.25	(0.90)
2004	1.05	1.01	1.14	1.49	1.27	(0.70)	(0.90)
2005	0.71	0.96	0.73	1.38	1.05	0.90	(0.85)
2006	1.14	1.28	1.11	1.15	1.17	(0.90)	(0.85)

coefficent of variation:

	U1 to U3	I1 and I2	C0 and W1 to W4		W5 and W6		W7 to W9
Year	150-600 m	150-600 m	150-300 m	300-600 m	150-300 m	300-600 m	150-600 m
1993	0.07	0.10	0.08	0.08	0.06	0.06	(0.05)
1994	(0.06)	0.09	0.10	0.09	0.07	0.11	-
1995	0.07	0.08	0.10	0.10	0.05	0.11	(0.05)
1996	0.07	0.08	0.06	0.09	0.11	0.09	(0.05)
1997	0.08	0.09	0.08	0.09	0.09	0.11	(0.05)
1998	0.10	0.10	0.07	0.08	0.08	0.07	(0.05)
1999	0.10	0.09	0.08	0.09	0.09	0.08	(0.05)
2000	0.10	0.09	0.08	0.10	0.10	0.08	(0.07)
2001	0.10	0.10	0.10	0.11	0.08	(0.06)	(0.05)
2002	0.10	0.12	0.11	0.12	0.10	(0.06)	(0.05)
2003	0.08	0.10	0.09	0.12	0.08	0.09	(0.06)
2004	0.09	0.09	0.09	0.11	0.09	(0.05)	(0.06)
2005	0.06	0.08	0.06	0.12	0.08	0.07	(0.05)
2006	0.10	0.11	0.09	0.09	0.09	(0.06)	(0.06)

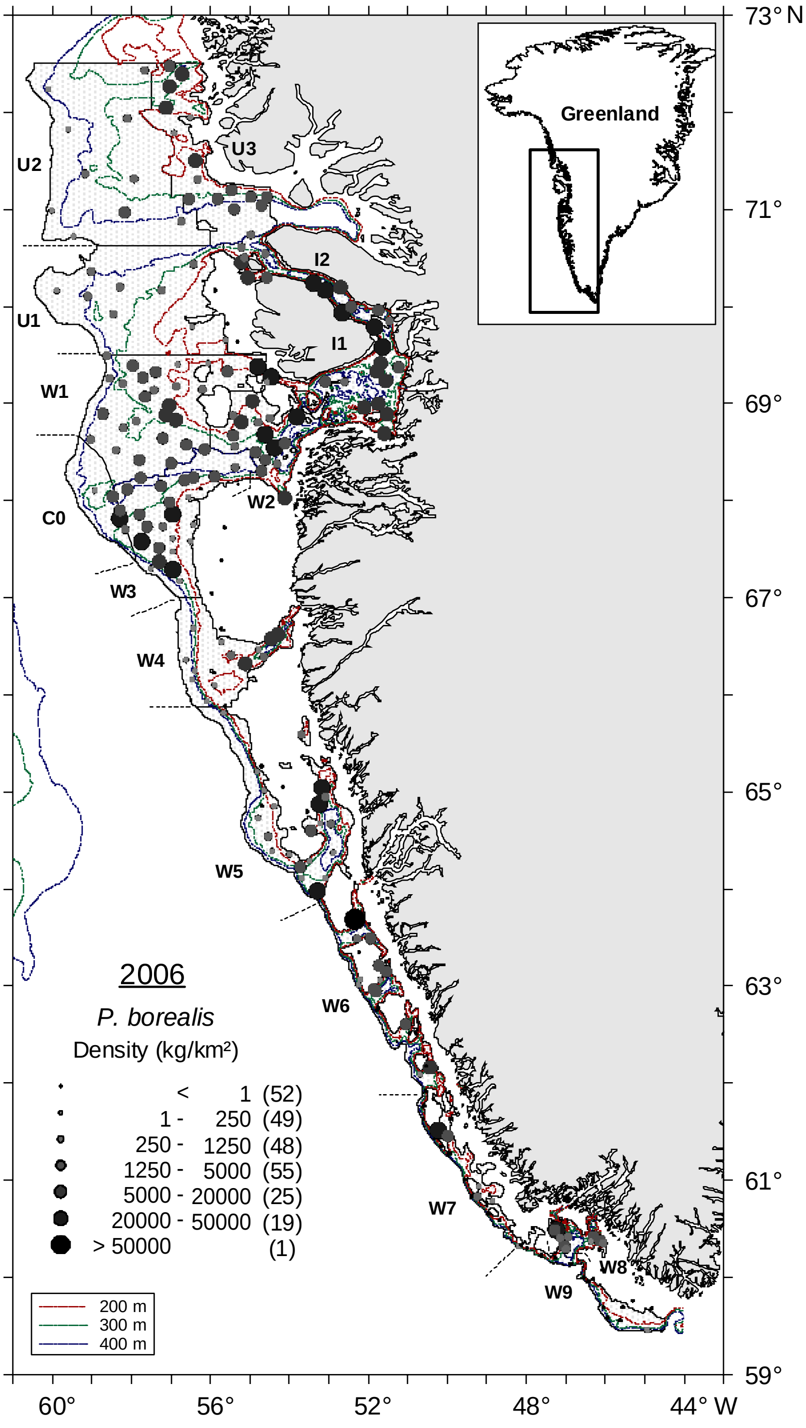


Fig. 1. Survey stratification and geographical distribution of Northern shrimp density in 2006.

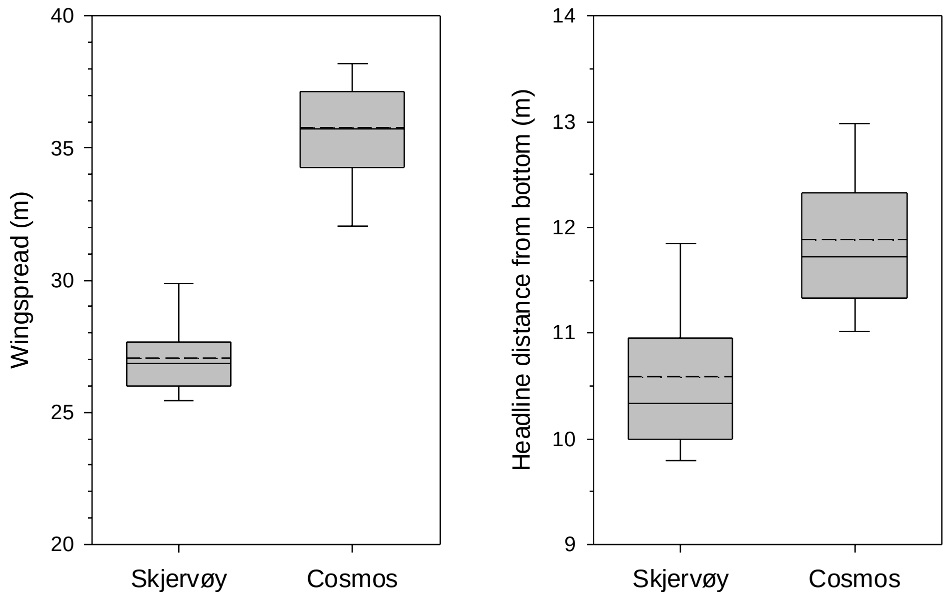


Fig. 2. Box whisker plots showing arithmetic means (stippled line) and medians (solid lines) of wingspread and headline distance to bottom for the two trawl types (*Skjervøy* 3000 and *Cosmos* 2000) with 95% confidence interval (upper and lower borders of grey box) and lower and upper quartiles (error bars) respectively. Results based on 39 hauls for each trawl (pairs of hauls made on the same track either with the *Skjervøy* or the *Cosmos* trawl first).

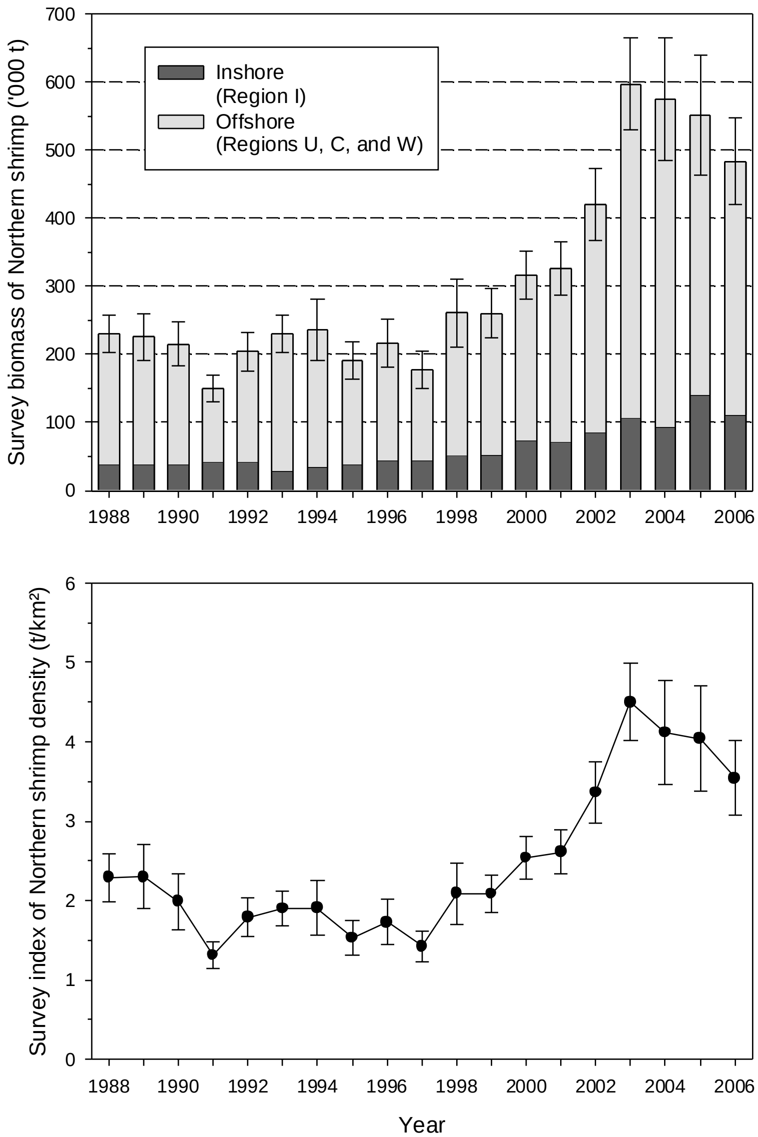


Fig. 3. Estimated total survey biomass and survey index for average density of Northern shrimp with standard errors 1988-2006 (Average biomass estimate for inshore areas 1991-1997 are used for 1988-1990 to facilitate between-year comparisons, see Table 3 for details).

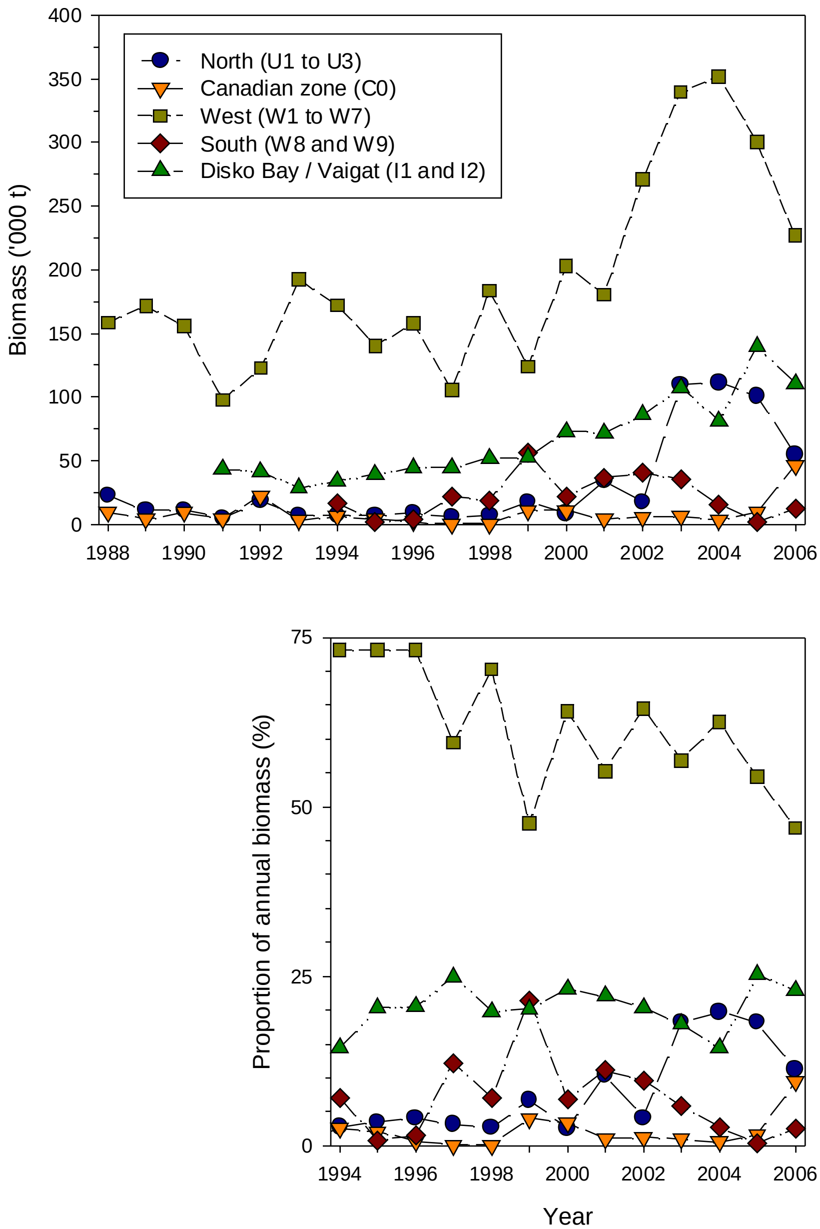


Fig. 4. Biomass in the five main survey regions 1988-2006 (area names are given in brackets, see Fig. 1 for location) and contribution of these regions to the total biomass 1994-2006.

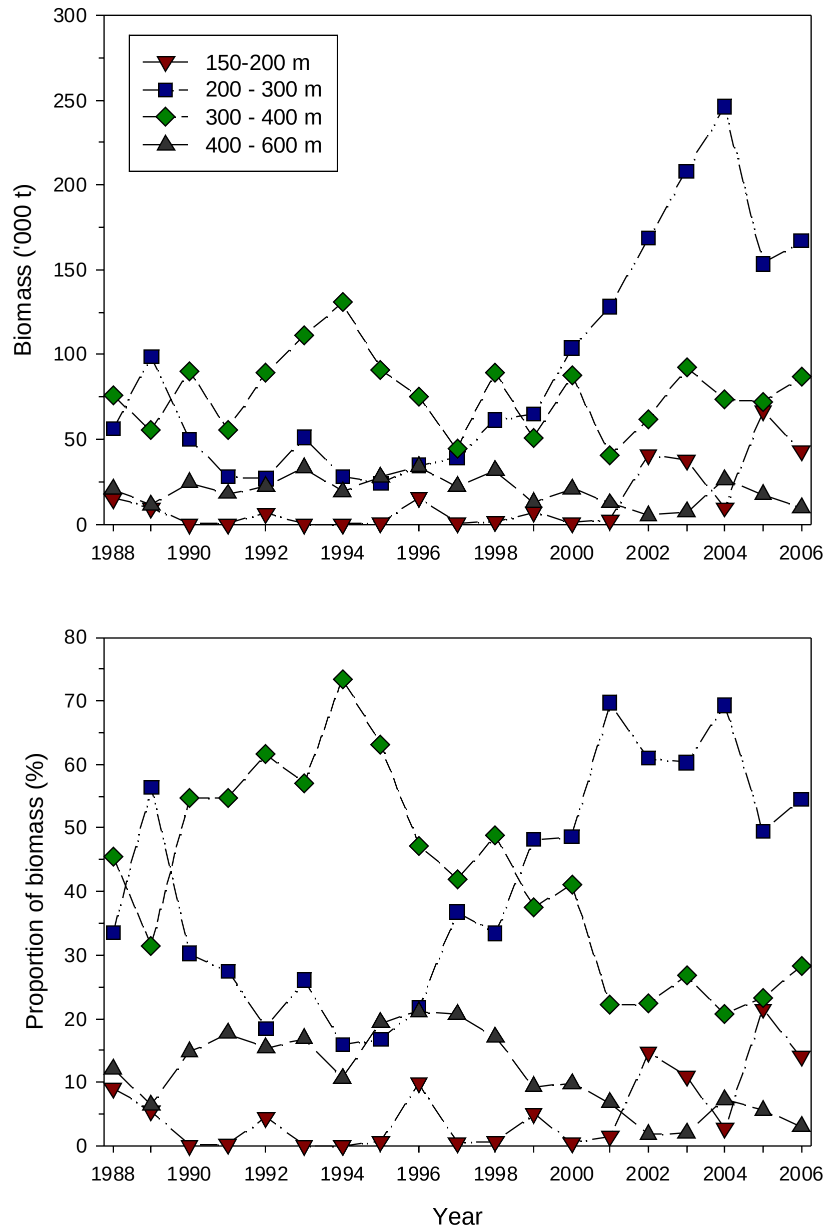


Fig. 5. Biomass distribution in the four depth strata in areas C and W1-W7 1988-2006.

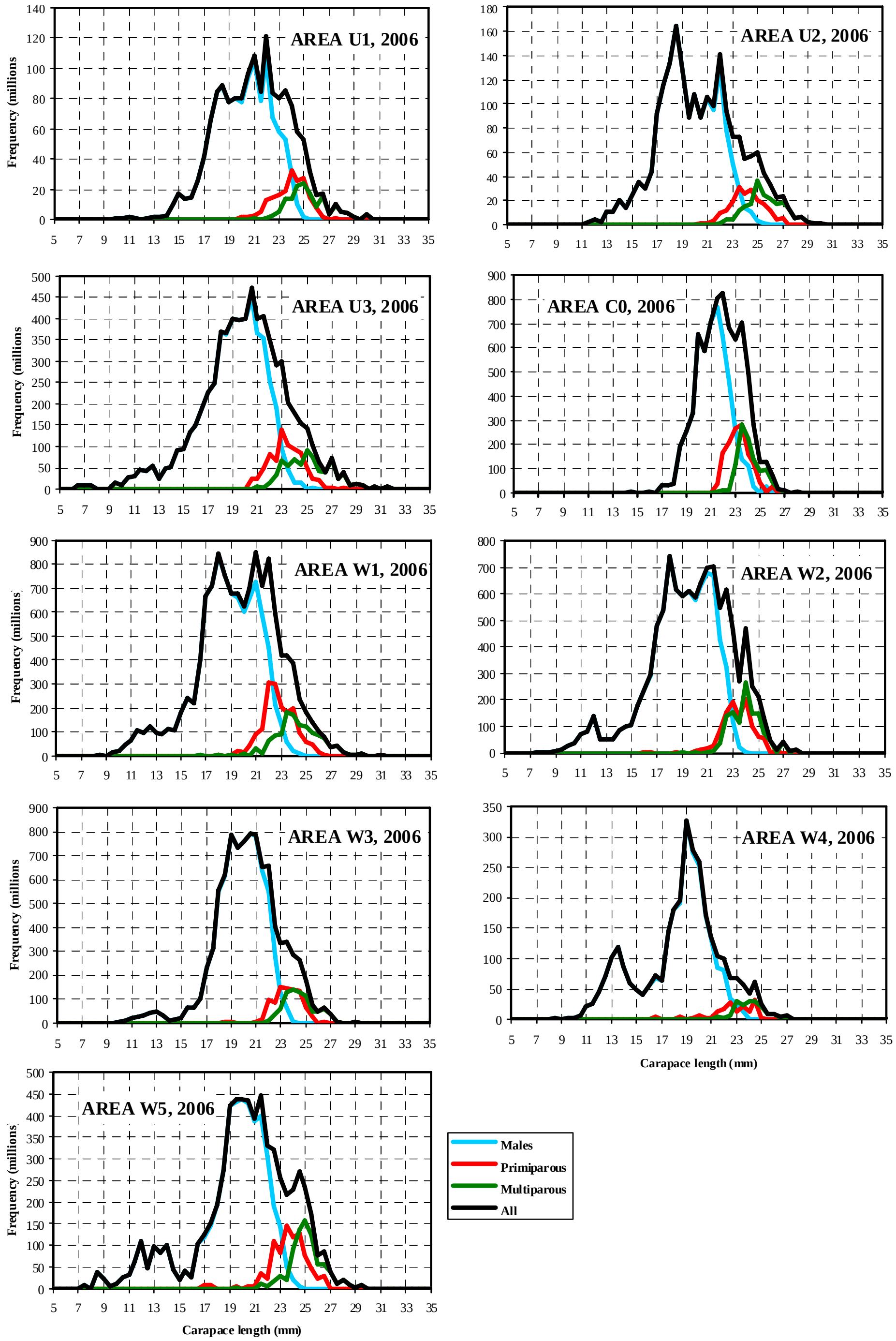


Fig. 6a. Length frequencies of Northern shrimp in offshore areas U1 to U3, C0 and W1 to W5 in 2006.

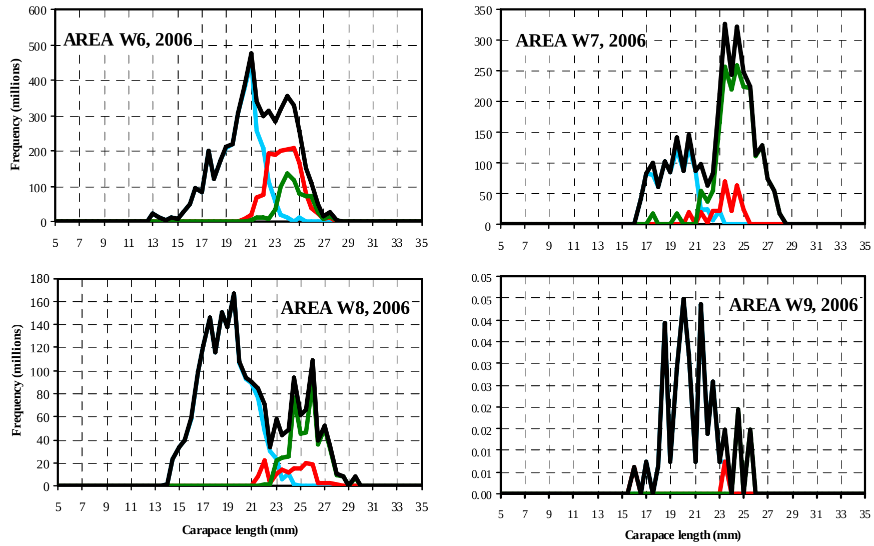


Fig. 6b. Length frequencies of Northern shrimp in offshore areas W6 to W9 in 2006.

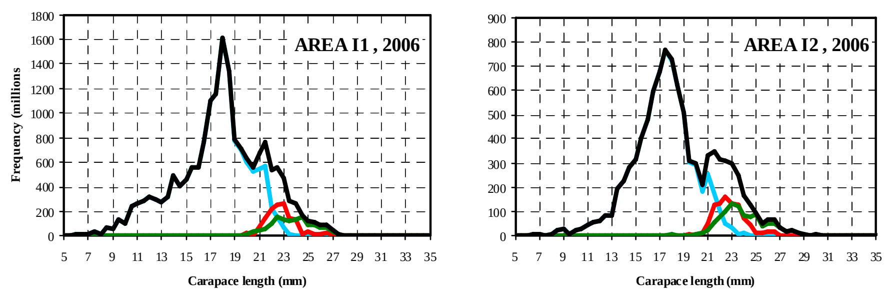


Fig. 6c. Length frequencies of Northern shrimp in inshore areas I1 and I2 (Disko Bay / Vaigat) in 2006.

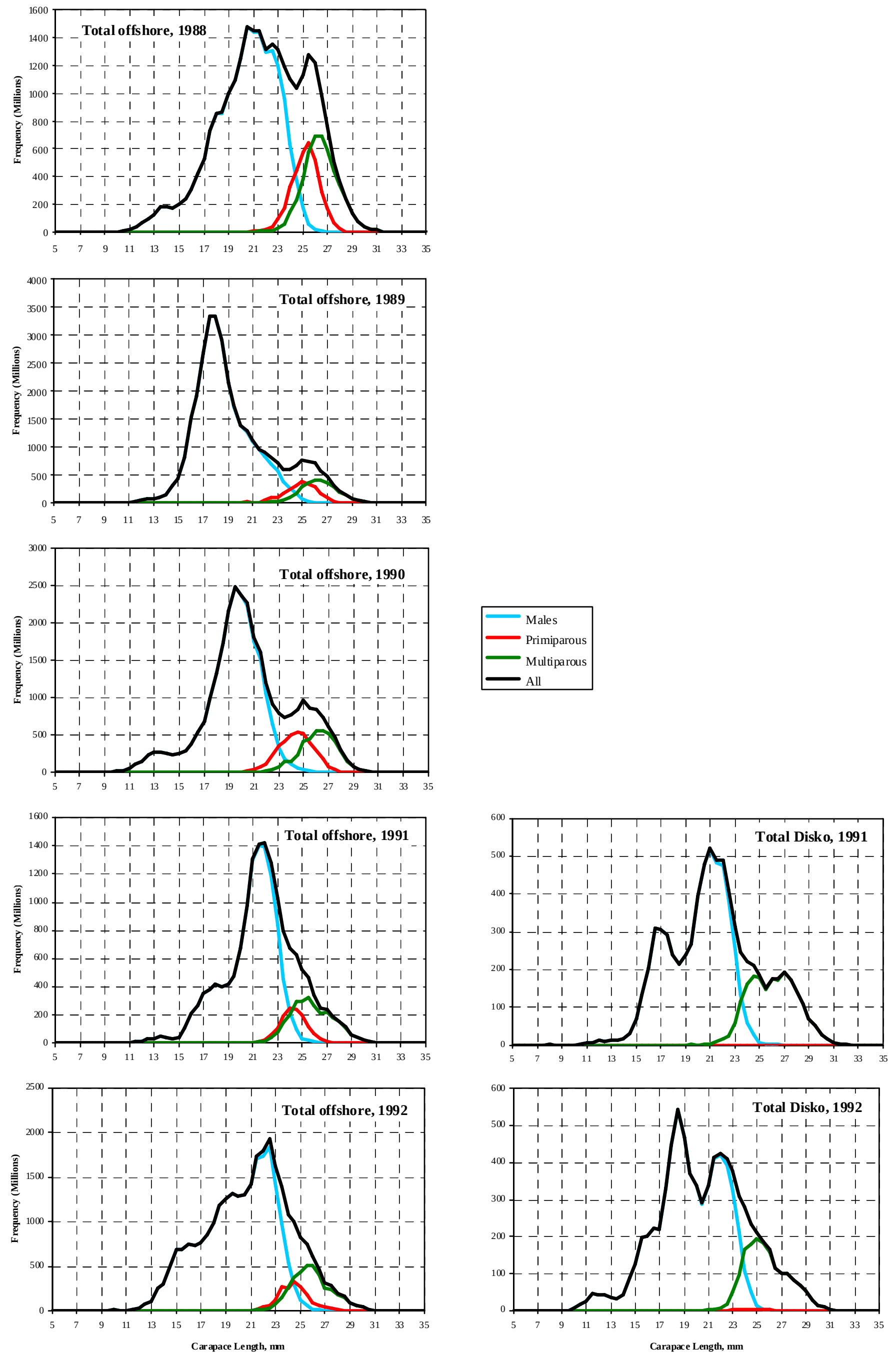


Fig. 7a. Length frequencies of Northern shrimp in the total offshore area, 1988 to 1992, and in the Disko Bay/Vaigat area, 1991 to 1992 (no surveys in Disko Bay/Vaigat area 1998-1990; unconverted data).

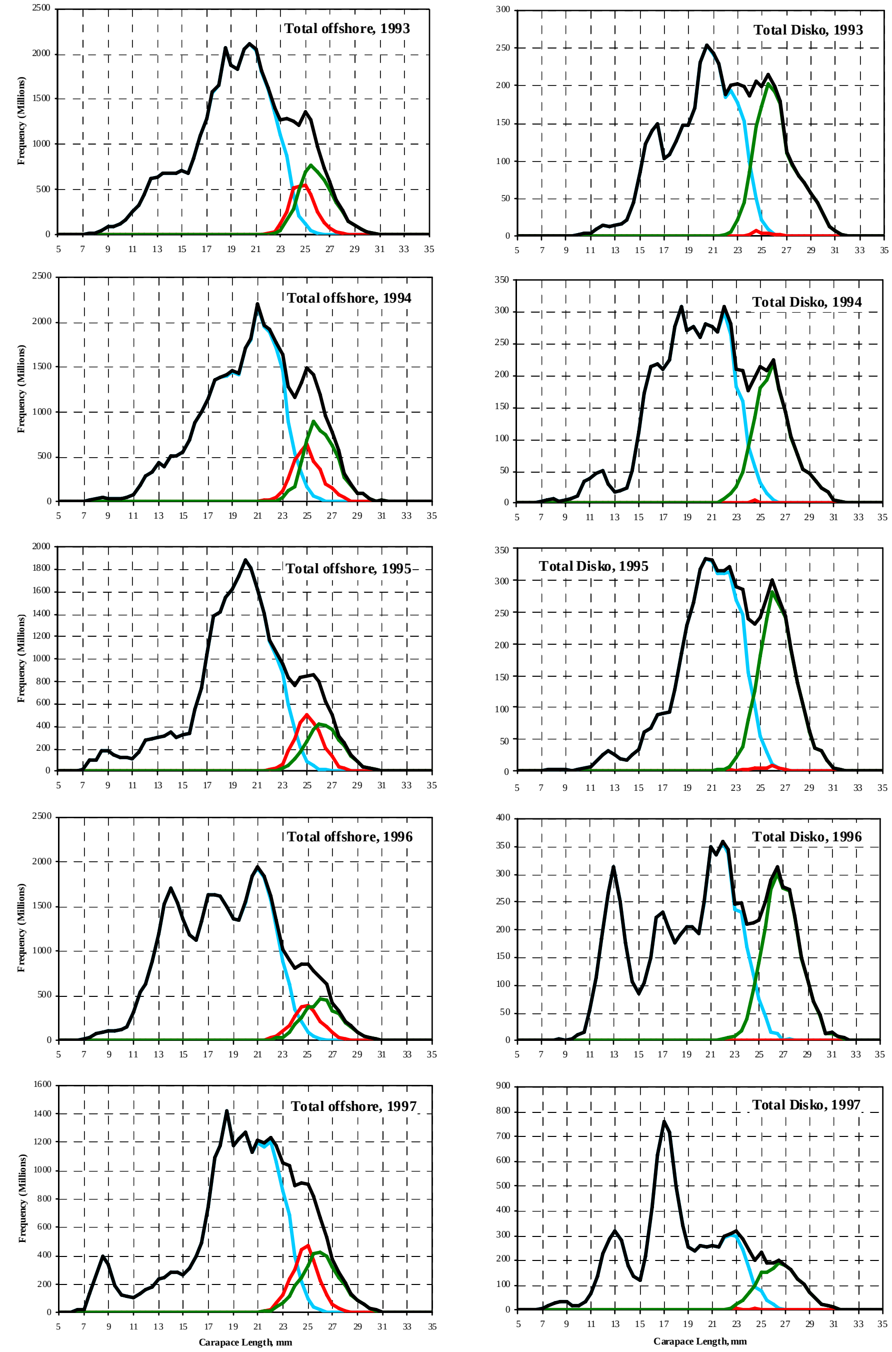


Fig. 7b. Length frequencies of Northern shrimp in the total offshore and the Disko Bay/Vaigat area, 1993 to 1997 (unconverted data).

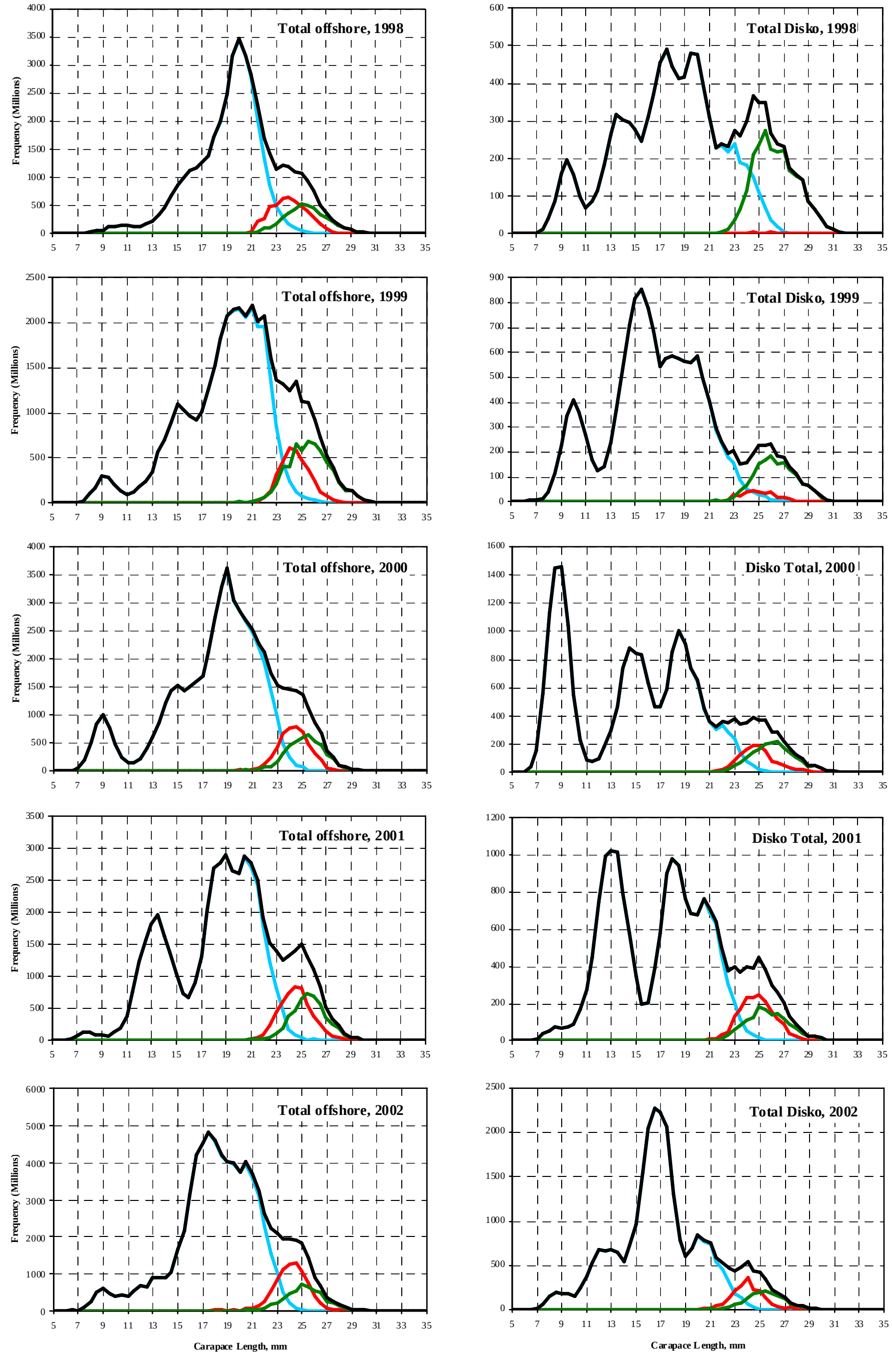


Fig. 7c. Length frequencies of Northern shrimp in the total offshore and the Disko Bay/Vaigat area, 1998 to 2002 (unconverted data).

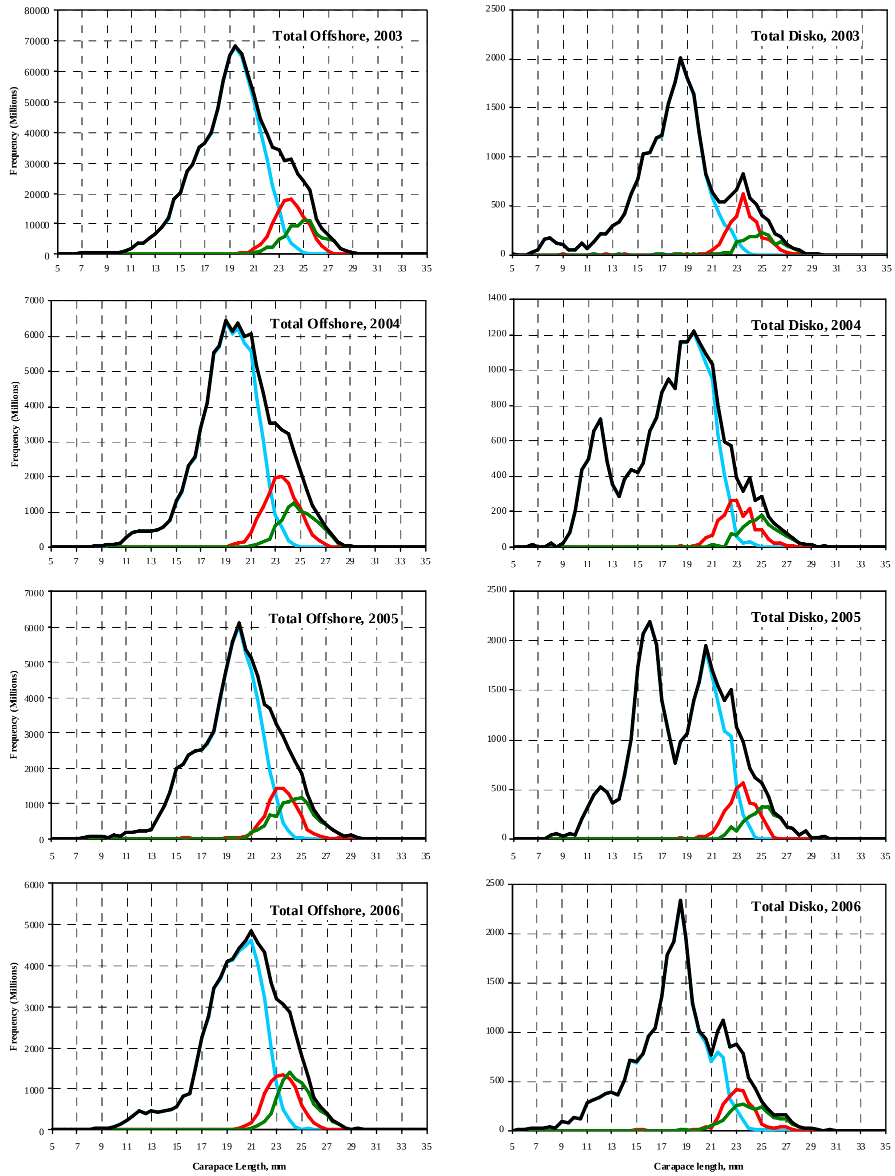


Fig. 7d. Length frequencies of Northern shrimp in the total offshore and the Disko Bay/Vaigat area, 2003 to 2006 (2003 and 2004 data converted from *Skjervøy* to *Cosmos* trawl).

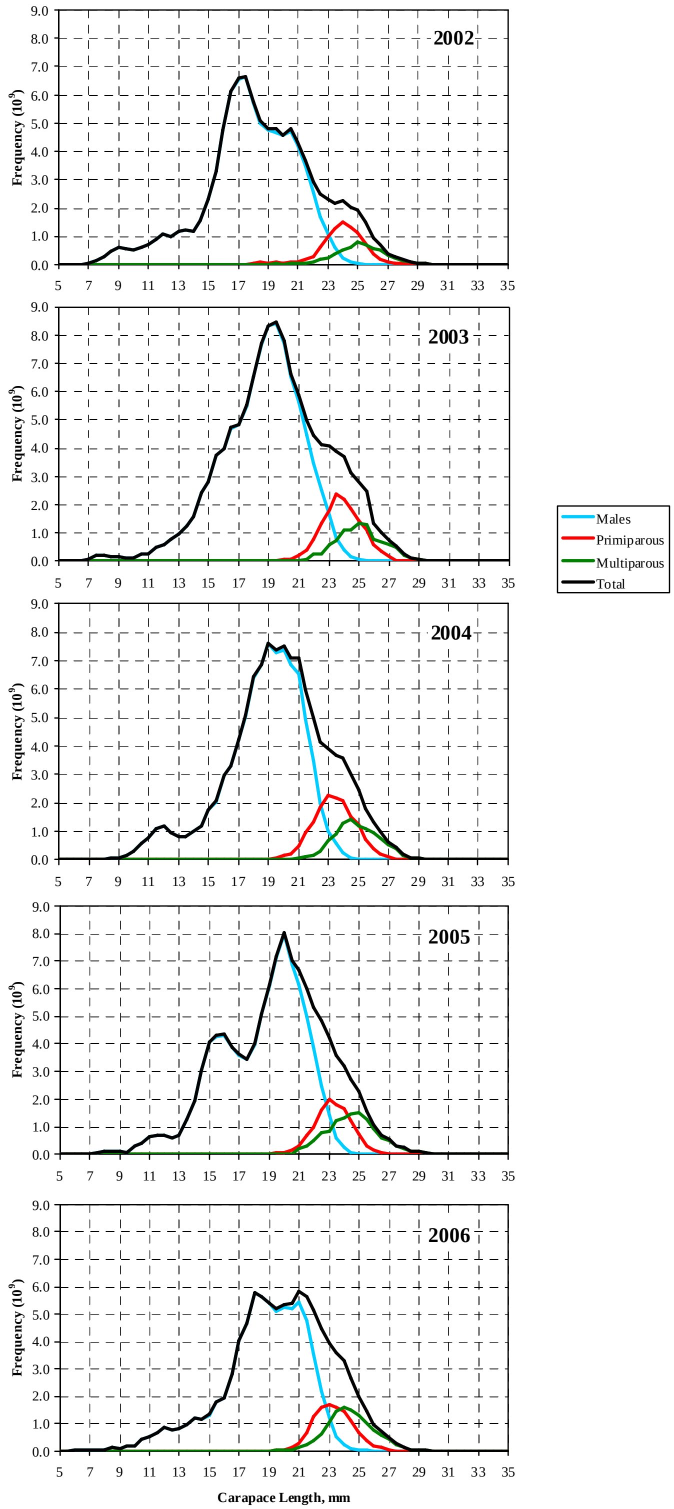
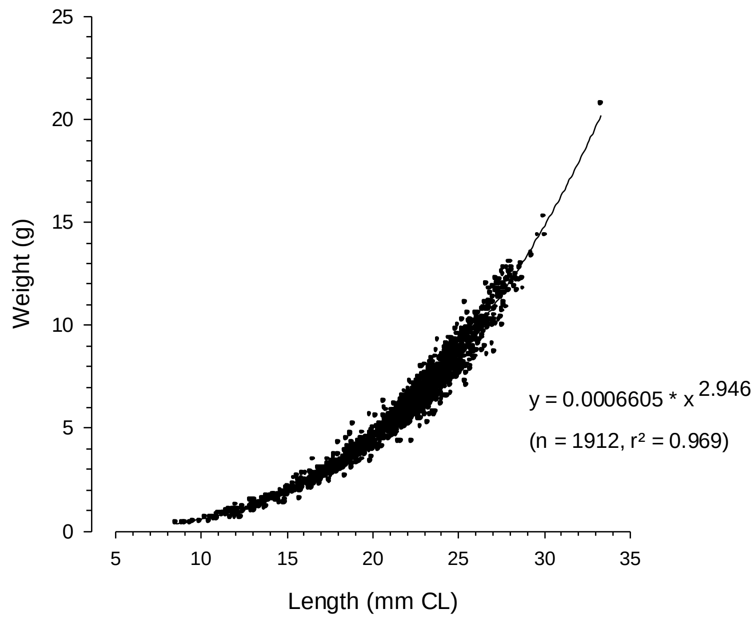


Fig. 8. Length frequencies of Northern shrimp in the total survey area (offshore and Disko Bay/Vaigat combined), 2002 to 2006 (Data from 2002 and 2004 converted from *Skjervøy* to *Cosmos* trawl).



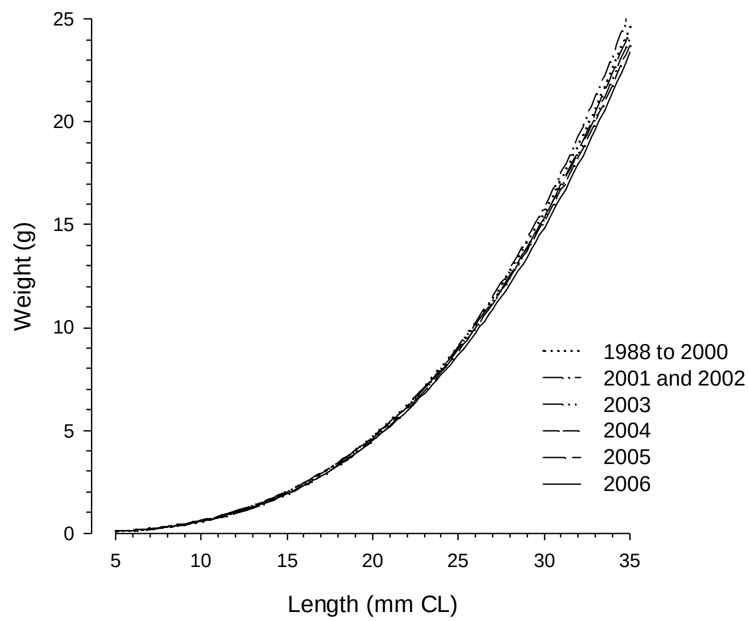


Fig. 9. Length-weight relationship of Northern shrimp off West Greenland in 2006 and comparison with length-weight relationships used in previous years.

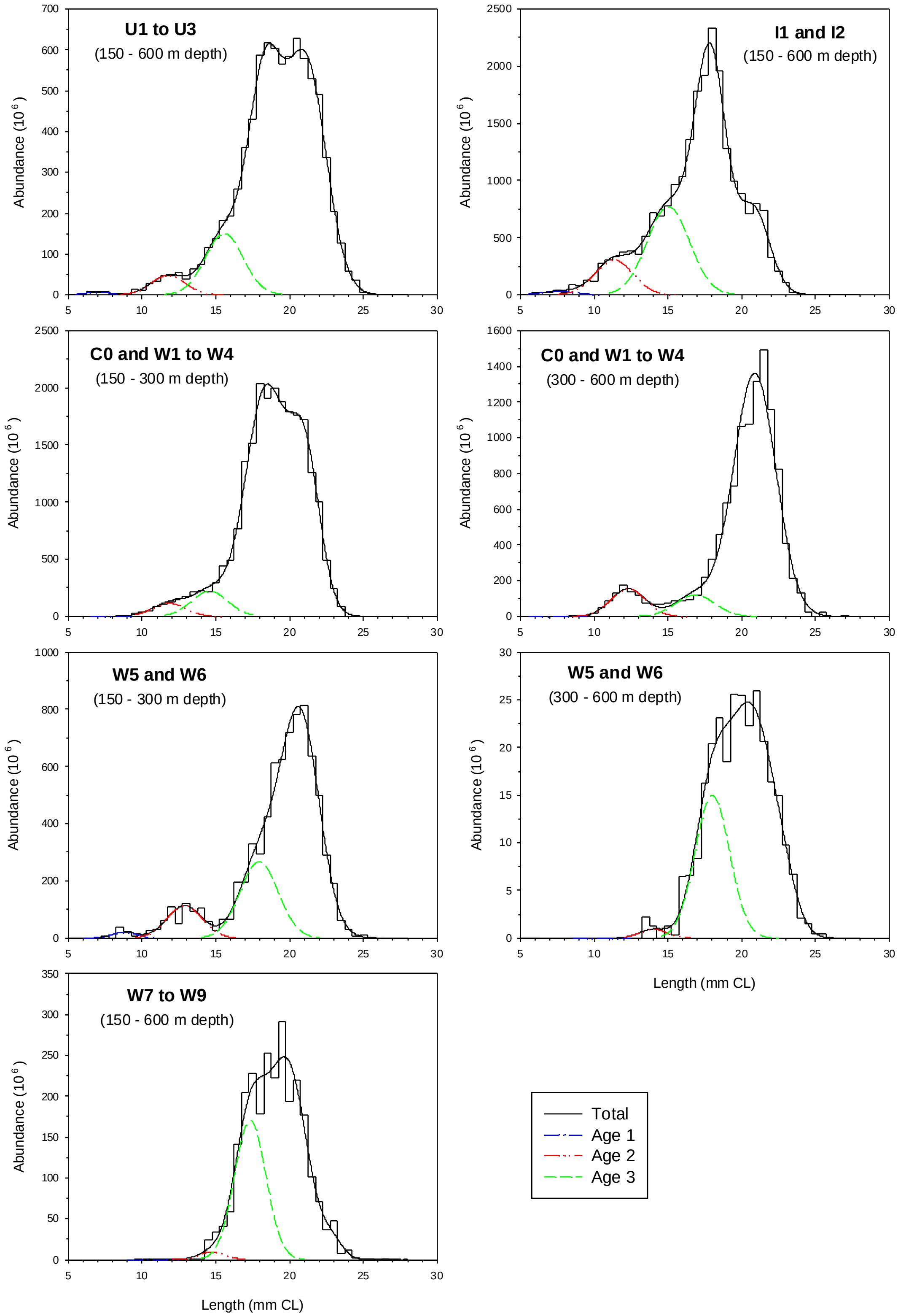


Fig. 10. Regional length frequencies of Northern shrimp (juveniles and males) off West Greenland in 2006.

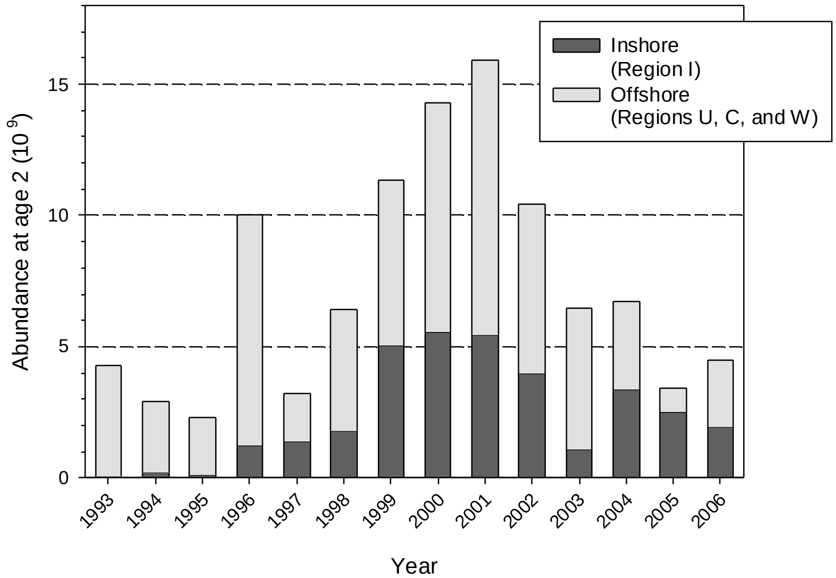


Fig. 11. Abundance indices for Northern shrimp at age 2 off West Greenland, 1993-2006.

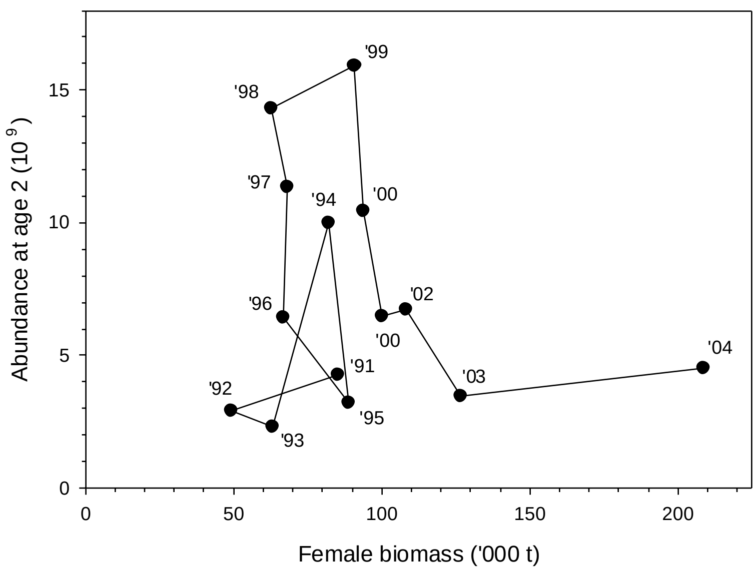


Fig. 12. Comparison of female stock biomass and recruitment at age 2 of Northern shrimp at age 2 off West Greenland (numbers at symbols denotes year-classes).

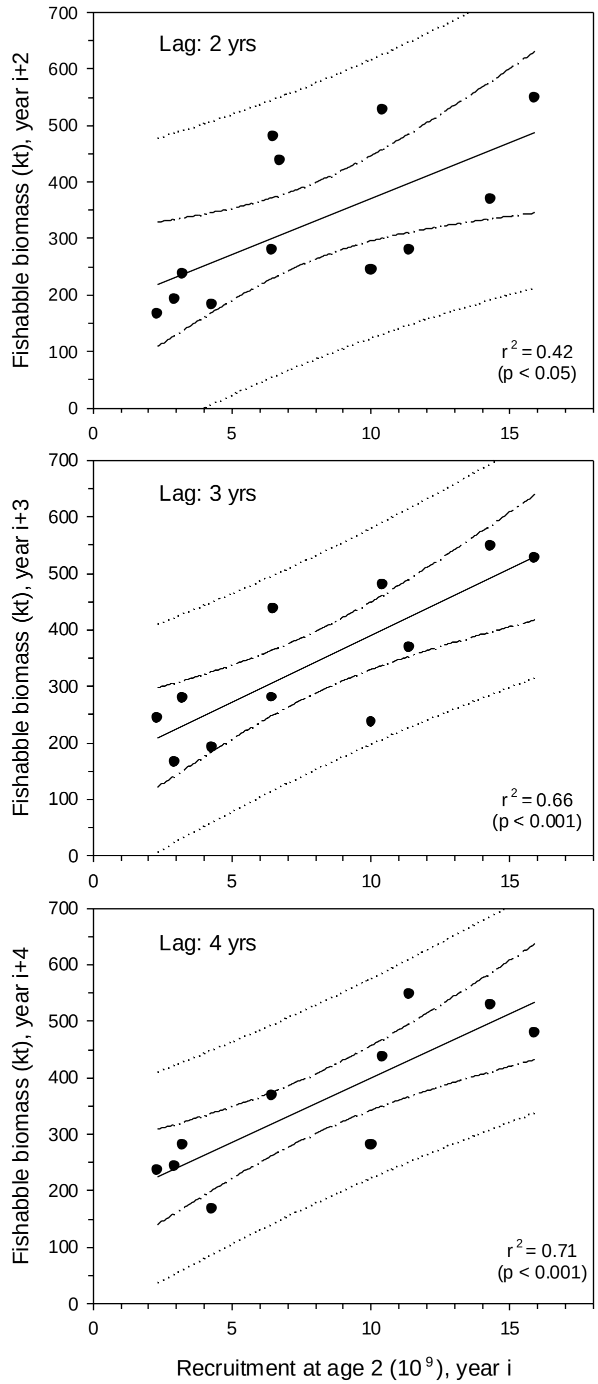


Fig. 13. Relation between abundance at age 2 and fishable biomass (all individuals ≥17 mm CL) lagged by one, two and three years for Northern shrimp off West Greenland in the period 1993 to 2006 (lines: linear regression with 95% confidence and prediction intervals).

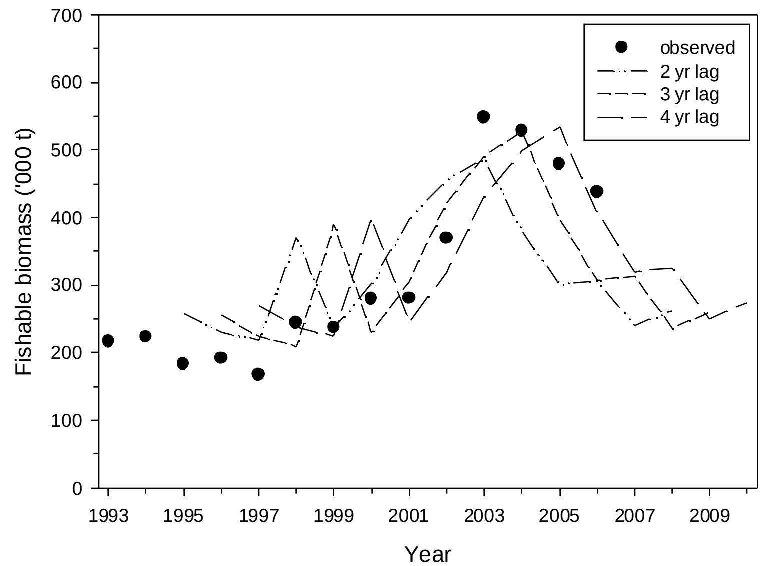


Fig. 14. Prediction of fishable biomass of Northern shrimp off West Greenland from recruitment at age 2 with time lags of 2, 3 and 4 years.

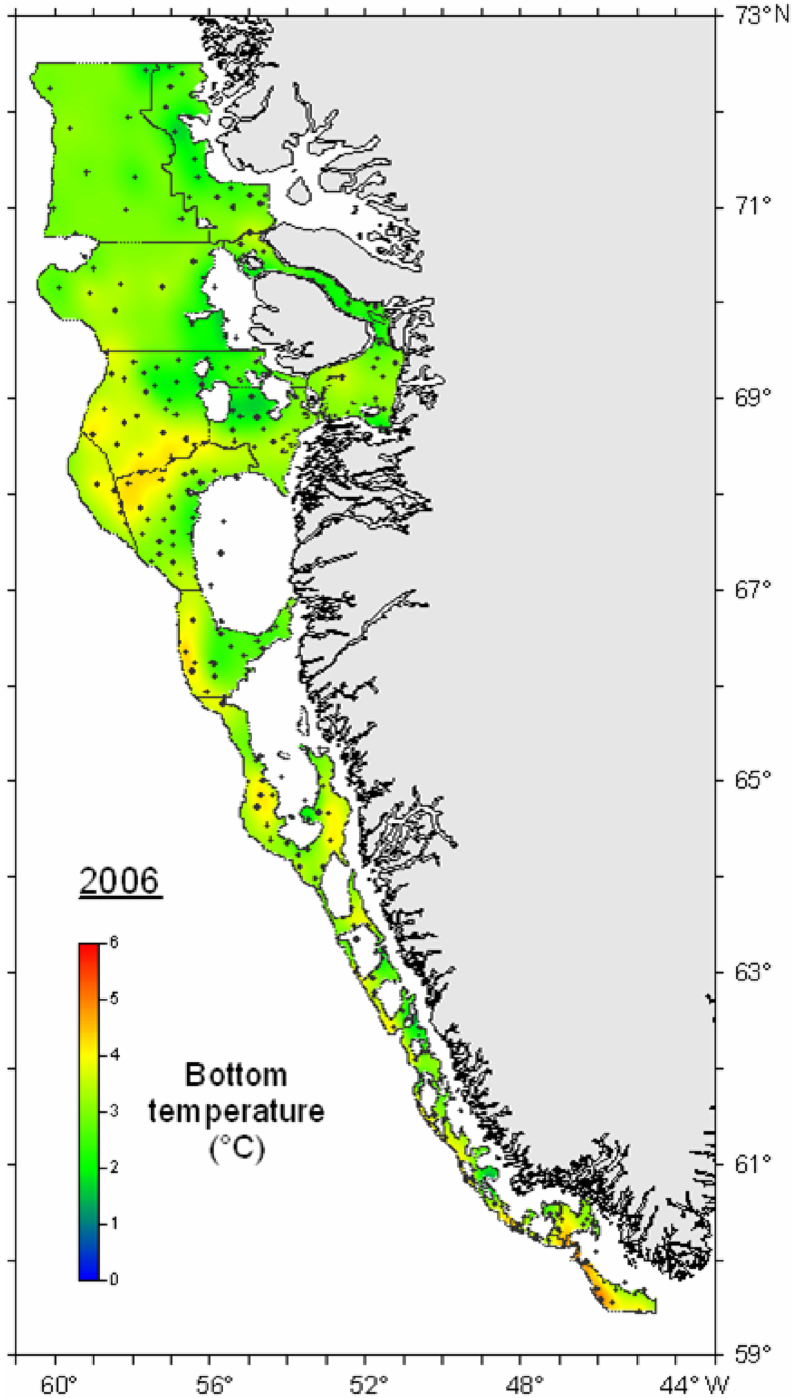


Fig. 15. Distribution of bottom temperature in the survey area between 150 and 600 m depth in 2006 (crosses indicate sampling locations).

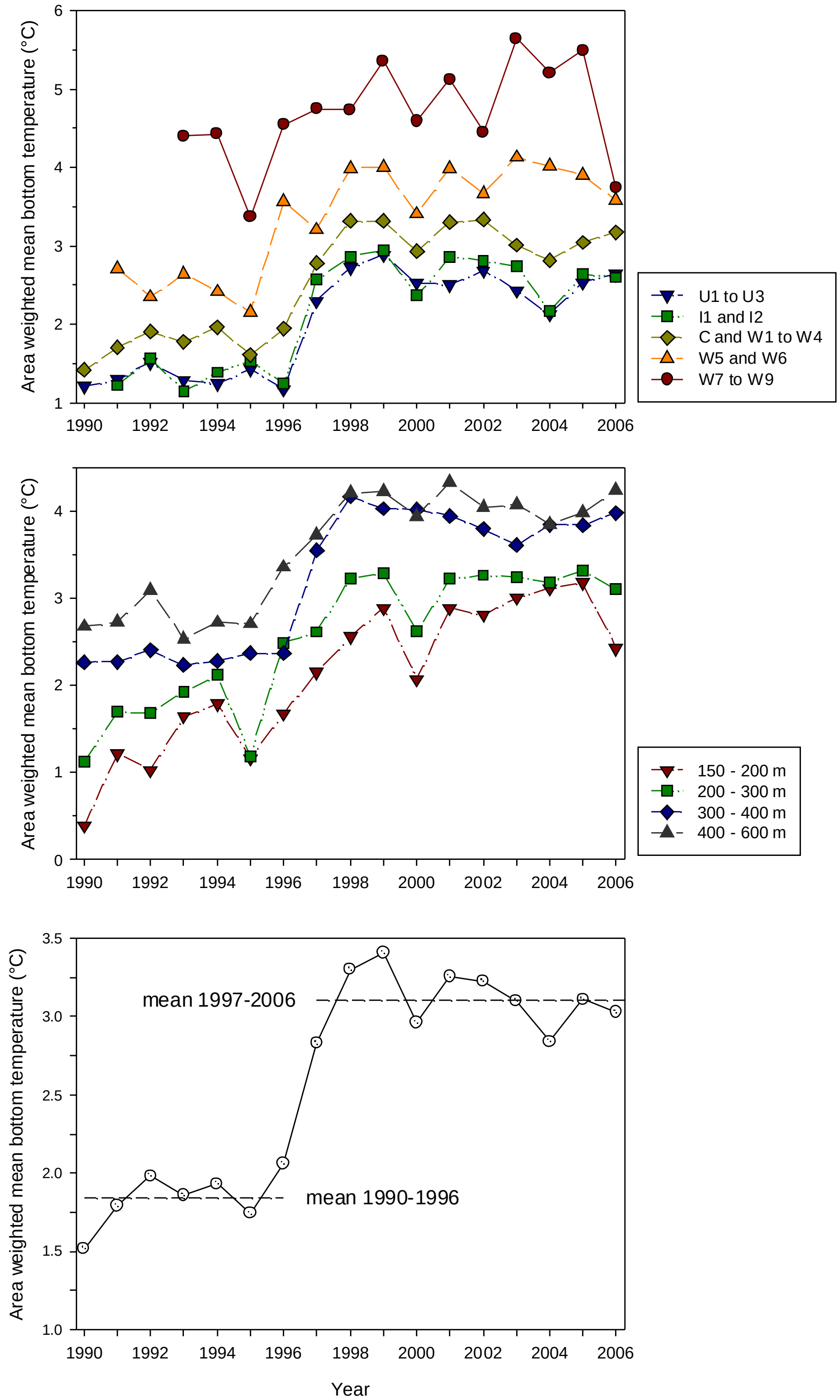


Fig. 16. Area weighted mean bottom temperature for the different survey regions (see Fig. 1 for locations), the various depth strata in offshore areas C and W1-W7 and the entire survey area in 1990 to 2006.