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An Update of Information Pertaining to Northern Shrimp (*Pandalus borealis*, Koyer) and Groundfish in NAFO Divisions 3LNO

By

D.C. Orr, P.J. Veitch and D.J. Sullivan

ABSTRACT

This paper describes the 2004 northern shrimp (*Pandalus borealis*, Koyer) assessment completed for NAFO divisions 3LNO. Status of the resource was inferred by examining trends in commercial catch, catch per unit effort, fishing pattern and size, sex and age compositions of catches. Canadian spring and autumn multi-species stratified random bottom trawl surveys have been used to estimate northern shrimp (*Pandalus borealis*, Kroyer) biomass and abundances in 3LNO. These findings were compared with results from previous surveys.

Biomass and abundance of shrimp increased significantly since 1999 and remained broadly distributed over the study area. Consequently catch rates by Canadian and international shrimp fishing fleets remained sTable or have increased since the fishery began in 2000.

The shrimp resource within 3LNO is currently healthy with high abundances of males and females that should support the fishery over the next few years.

Both multi-species survey and observer datasets were used in quantifying the potential impact of the shrimp fishery upon various commercially important groundfish species.

INTRODUCTION:\

The northern shrimp (*Pandalus borealis*) stock, in Div. 3LNO, extends beyond Canada's 200 Nmi limit, therefore, it is a NAFO regulated stock. Northern shrimp, within NAFO divisions 3LNO, have been under TAC regulation since 1999. At that time a 6,000 ton quota was established and fishing was restricted to Division 3L, at depths greater than 200 m. The 6,000 ton quota was established as 15% of the lower confidence limit below the autumn 1998 3L biomass index. This harvest level approximates those estimated for shrimp fishing areas along the coast of Labrador and off the east coast of Newfoundland (NAFO divs. 2HJ3K) (Orr *et al.* 2003). It was recommended that this harvest level be maintained for a number of years until the response of the resource to this catch level could be evaluated (NAFO, 1999). The proportion of biomass in 3LNO within the NAFO Regulatory Area (NRA), over the period 1995 – 1998, was approximately 17%. Therefore, a 5,000 ton quota was established in the Exclusive Economic Zone (EEZ) for Canada while a 1,000 ton quota was established in the NRA for all other Contracting Parties.

During November 2002, Scientific Council (SC) noted that there had been a significant increase in biomass and recruitment in Div. 3LNO shrimp since 1999. Applying a 15% exploitation rate to the lower 95% confidence interval of biomass estimates, averaged over the autumn 2000-2001 and spring 2001-2002 surveys, resulted in a catch of approximately 13,000 tons. Accordingly, SC recommended that the TAC for shrimp in Div. 3LNO in 2003 and 2004 should not exceed 13,000 tons. At that time, SC reiterated its recommendation that the fishery be restricted to Div. 3L and that the use of a sorting grate with a maximum bar spacing of 22 mm be mandatory for all vessels in the fishery (NAFO, 2002).

It should be noted that until the present assessment, biomass and abundance indices were estimated using stratified area expansion calculations (Cochran, 1997; using SAS programs written by D. Orr). Indices within the present assessment were obtained using OGive MAPping (Ogmap) as explained in Evans 2000 and Evans *et al.* (2000). The conversions from stratified areal expansion to ogmap indices is described within Orr *et al.* (2004).

The present assessment includes indices of condition factor, size at sex transition and mortality as aids used in the precautionary approach to setting future quotas.

Poor condition is usually associated with poor feeding and/ or environmental conditions. Ultimately poor condition may result in reduced reproductive capacity or increased mortality (Morgan, 2004). Therefore, weight length relationships are presented in this document and it is hoped that over time, a series of weight/length relationships can be created and changes in slope can be used to infer changes in shrimp condition.

Numerous studies indicate that pandalid shrimp have neither a fixed size nor a fixed age at sex change and that age or size at sex change alters in response to yearly changes in their environment. These changes may include age and size distribution of breeding adults, in which case, size at sex change may be positively correlated with size of mature shrimp (Charnov and Anderson, 1989; Skúlladóttir and Pétursson, 1999; Charnov and Skúlladóttir, 2000). Localized decreases in size at sex change could be related to temporary decreases in female biomass or a very large year class of males to compensate for a reduction in reproductive potential (Charnov, 1982). Faster growth and earlier maturation are positively related to higher temperatures (Skúlladóttir and Pétursson, 1999;Wieland, in prep; Wieland, 2004), within the optima of 1-6^{o}C (Shumway *et al.*, 1985). Koeller *et al.* (2000) and Wieland (2004) found that size at sex change could decrease at times of high density when there is competition for resources. Regardless of the mechanism(s) causing changes of growth rates and size at sex reversal, faster growth and early maturation are normally associated with lower fecundity, higher natural mortality and shorter life span. Therefore it is important that 3LNO shrimp stock assessments include change in maturation schedule.

Full assessments of this stock are completed during the annual November shrimp assessment meetings. Results from these assessments provide necessary input for quota decisions made during Fishery Commission meetings, held during September. Autumn and spring Canadian multi-species surveys are completed in 3LNO in the time between the assessment and the commission meetings. The additional biomass information derived from these surveys is provided, within interim monitoring reports, to NAFO SC just prior to the annual Fishery Commission meetings. The last interim monitoring report was presented to NAFO SC during September 2004.

The present document was produced for the November 2004 SC assessment meeting and therefore provides a full assessment of the Div. 3LNO shrimp resource.

The fishery overlaps the distribution of several groundfish stocks that are presently under moratoria. Hence, this paper also assesses the impact that the fishery may have upon groundfish co-existing in the area.

METHODS AND MATERIALS

Data were collected from the following sources:

1) Canadian observer databases;
2) Canadian logbook databases;
3) International observer/ logbook databases; and
4) Canadian autumn and spring multi-species research surveys.

1) <u>Canadian observer database:</u>

Approximately 12 large (=>500 ton) fishing vessels and more than 300 smaller (<500 ton; <100’) vessels fish shrimp within Davis Strait, along the coast of Labrador and off the east coast of Newfoundland. There is 100% mandatory observer coverage of the large vessels, but less than 10% coverage of the small vessels.

Observers working on large vessels collect detailed maturity stage length frequency information from random sets. Those working on small vessels collect ovigerous/ non-ovigerous length frequencies from random sets and one detailed maturity stage length frequency per trip. Observers on both types of vessels record: shrimp catches, effort, amount of discarding, weights and length frequencies of by-caught species.

The Observer database was used to determine the catch-per-unit effort (CPUE) for the large vessel (>500 t) shrimp fishing fleet. Observed data were used because we wanted to present results that account for number of trawls and usage of windows (escape openings). The number of trawls and usage of windows are captured in the observer data set but not in the logbooks. Raw catch/ effort data for each SFA were standardized by multiple regression, weighted by effort, in an attempt to account for variation due to factors such as year, month, gross registered tonnage (grt). The multiplicative model has the following logarithmic form:

$$\mathrm{Ln}(\mathrm{CPUE}_{ijkl}) = \ln(u) + \ln(\mathrm{S}_j) + \ln(\mathrm{V}_k) + \ln(\mathrm{Y}_l) + e_{ijkl}$$

Where: CPUE_{ijkl} is the CPUE for grt k, fishing in month j during year l (k=1,…..,a; j=1,…..,s; l=1,…..,y);
$ln(u)$ is the overall mean ln(CPUE);
S_j is the effect of the j^{th} *month;*
V_k is the effect of the k^{th} grt;
Y_l is the effect of the l^{th} *year;*
e_{ijkl} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in a cell and σ^2 is the variance.

The standardized CPUE indices are the antilog of the year coefficient. Final models included all significant class variables with the YEAR effect used to track the trend in stock size over time. The difference (or similarity) between the 2004 YEAR parameter estimate and those of previous years was inferred from the output statistics.

In order to track only experienced fishers, the standard data set included only data from vessels with more than two years of shrimp fishing experience. This increased our confidence when interpreting results.

The observer database also provides information used to determine the potential impacts that shrimp fishing may have upon groundfish species. Groundfish by-catch is recorded to 1 kg. precision for all observed fishing sets. Wherever possible, sexed length frequencies (1 cm. precision) were taken from randomly selected samples of commercial groundfish species. Using a ratio of weight of fish measured to by-catch weight, the length frequencies were corrected on a set by set basis. Length frequencies were added together on a species by species basis. An average length frequency distribution per kg. of by-catch was produced and then merged with the catch records. The frequencies were multiplied by the by-catch weights in an effort to produce length frequency data on a set by set, species by species, basis. The length frequencies were aggregated to obtain total removals by species, year and size of vessel. Length frequencies were then applied to species specific population adjusted age length keys, from the previous autumn survey, to obtain estimates of number at age.

2) Canadian logbook database:

Logbooks must be completed for all fishers exploiting shrimp stocks within the northwest Atlantic. Data were used in standardized small vessel CPUE calculations as explained above for large vessels. The small vessel CPUE dataset was created using logbook data because all shrimp fishing vessels must complete logbooks, whereas, observer coverage in the small vessel shrimp fishery may be as low as 2%.

The landings by small and large vessels allowed a comparison with the total observed catches for each fleet. This comparison provided an indication of percent of total catch observed. This percentage was used in estimating total groundfish by-catch on a species by species basis.

3) International observer and logbook information:

These data were made available by Contracting Parties that fish shrimp in Div. 3L. They were used in CPUE calculations and were added to the Canadian catches when determining a total catch. Where no information was provided by a Contracting Party, information was augmented through the use of Canadian surveillance data, as well as, NAFO Statlant 21A and monthly provisional catch Tables. Many of the international datasets required extensive editing; therefore no attempt was made to obtain a standardized CPUE model for catch rates within the NRA.

4) Canadian spring and autumn multi-species research surveys:

Shrimp abundance, biomass, maturity and carapace length data have been collected since autumn 1995, as part of the Canadian multi-species bottom trawl surveys. These research surveys are conducted each spring and autumn using the CCG Wilfred Templeman, CCG Alfred Needler and CCG Teleost. Fishing sets of 15 minute duration and a tow speed of 3 knots were randomly allocated to strata covering the Grand Banks and slope waters to a depth of 1500 m (Fig. 1). All vessels used a Campelen 1800 shrimp trawl with a codend mesh size of 40 mm and a 12.7-mm liner. SCANMAR sensors estimated that the mean wingspread was 16.8 m. Details of the survey design and fishing protocols are outlined in (Brodie, 1996; McCallum and Walsh, 1996).

Shrimp were frozen and returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage was made. The maturity of the shrimp was defined by five stages:

males;
transitionals;
primiparous females;
ovigerous females,
and multiparous females

as defined by Ramussen (1953), Allen (1959) and McCrary (1971). Oblique carapace lengths (0.1 mm) were recorded while number and weight per set was estimated from the sampling data. Abundance and biomass indices were estimated using ogmap calculations. Inshore strata were not sampled in all years; therefore, the analysis was restricted to data collected from offshore strata only (Fig. 1). Evans (2000), Evans *et al.* (2000) and Orr *et al.* (2004) are the companion pieces for this document providing a complete description of methods with a set of comparisons between stratified areal expansion and ogmap indices.

During spring 2004 approximately 300 live northern shrimp of various carapace lengths and maturities were brought to the NWAFC wet lab, within 24 hrs. of capture, to determine weight/length relationships. Lengths and weights were converted to $\log_{10}$ values and a male and a non-ovigerous female (transitionals + primiparous females + multiparous female) regression models.

Modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) was conducted on combined maturity research length frequencies. The is a departure from the normal way that modal analysis is completed. Usually the males are aged separately from the transitionals and primiparous+multiparous+ovigerous females. However, this does not account for the fact that age 3, 4 and 5 male modes may not be Gaussian due to the fact that some of these animals would have changed sex. Male and female length frequencies were overlain upon the combined length frequency as an aid in determining modal positions (fig. 2).

Abundances of age 2 males were plotted against fishable biomass to determine whether a recruitment – stock relationship exists. Such a relationship could be used to predict stock prospects.

Exploitation indices were developed by dividing total catch by each of the following estimates:

lower 95% confidence interval below the biomass index,
spawning stock biomass (SSB), and
fishable biomass.

The fishable component of the population was defined as all animals greater than 17 mm CL. Male biomass was determined by converting abundances to biomass using the male model:

$$Wt. = 0.000966Lt^{2.84166} \text{ (this paper).}$$

Spawning stock biomass (transitionals + primiparous females and ovigerous + multiparous females) was determined *via* ogmap calculations. Female and male biomasses were added together to obtain total fishable biomass.

Trends in size at sex change were examined by comparing male and female spawning stock length frequencies from both the research and observer datasets. A logistic model with a logit link function and a binomial error was fit to the data to estimate the size at 50% maturity by year. Estimation of parameters was performed using SAS Proc Probit. The hypothesis that size at transition changed over time was tested using SAS Proc Genmod with a logit link function and binomial error (SAS version 8.01, 1993). The model had the general form:

$$Pfe_{(Lt)} = 1/(1 + e^{(-(Int + Lteff(Lt) + Yreff))}$$

Where $Pfe_{(Lt)}$ = percent female at length
Int = intercept
Lteff = length effect
Lt = length
Yreff = year effect

The instantaneous rate of mortality (Z) was determined first estimating three year running average abundance indices of age 4+ and age 5+ shrimp from the autumn surveys. The running average for age 4+ shrimp is compared with the running average for age 5+ shrimp the following year as follows:

$$N_1/N_o = e^{-Z}$$

$$Z = -\log_e(1-A)$$

Where N_o = three year running average index for autumn age 4+ shrimp
N_1 = three year running average index for autumn age 5+ shrimp the following year.
Z = instantaneous mortality rate
A = annual mortality rate (Ricker, 1975).

Distribution maps of juvenile Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), Greenland halibut (*Rheinhardtius hippoglossoides*) and redfish (*Sebastes mentella*) were overlain with plots of survey shrimp catches to determine the degree of overlap. The term juvenile refers to the modal length of a species (LC_{50}) passing through a 22 mm Nordmore Grate. The respective LC_{50} values for Atlantic cod, Greenland halibut, redfish and American plaice were: 19 cm (Orr *et al*. 2000 and Hickey *et al* 1993), 24 cm (Nicolajsen, 1997), 14-18 cm (Hickey *et al.*1993, Kulka and Power, 1996, Kulka, 1998, Nicolajsen, 1997 and Skúladóttir, 1997) and 23 cm (Orr *et al*. 2000). Potential for impact was assessed through observations of these plots and previously discussed by-catch analyses using observer datasets.

Both the observer and logbook data sets complement the research trawl survey data sets. Research data are collected during the spring and autumn using stratified random set allocations that cover the Grand Banks. Conversely, the observer and logbook data sets are representative of the commercial fishery. They focus upon fishing areas and cover a much broader seasonal scale than the research data. All three were used in determining an exploitation index (catch/biomass), which is a proxy for fishing mortality. These datasets also provide insight for the impact of shrimp fishing upon groundfish.

Logbook and research catches were plotted using Surfer 8.0 (Golden Software, 2002). The area fished each year was divided into 10 min. X 10 min. cells, catches were aggregated by cells, and aggregated catches were organized into a cumulative percent frequency (cpf). The cpf was used to determine the number of cells accounting for 95% of the catch each year (Swain and Morin, 1996). The plots and quantification of spatial coverage were used in describing changes in distribution thereby aiding the interpretation of CPUE trends.

RESULTS AND DISCUSSION

FISHERY DATA

Catch trends

Canadian vessels caught 11 tons of shrimp in division 3L during 1989. However, Faroese fishermen are generally credited with starting the exploratory fishery for 3LNO shrimp within the NRA. The Faroese exploratory fishery began in 1993 and lasted until 1999. Over this 7 year period, the Faroese catches were 1789, 1865, 0, 171, 485, 544 and 706 tons respectively (Statlant 21A).

During autumn 1995, the Canadian multi-species surveys began to use a Campelen 1800 shrimp trawl. It was at this time that shrimp were included in the multi-species survey data collections. As a result of Faroese and Canadian multi-species survey efforts, various nations became interested in exploiting shrimp in Div. 3LNO. During 1999, one Spanish and four Canadian exploratory fishing trips were made in 3LNO. The combined catch was 89 tons.

Catches increased dramatically since 1999, with the beginning of a regulated fishery. Since then, sixteen contracting nations have exercised their privileges to fish shrimp in 3L. Over the period 2000 – 2003, catches were 4 869, 10 566, 6 977 and 11,947 tons respectively (Table 1; Fig. 3). The 13,000 t quota will probably be taken during 2004 because preliminary data indicate that 12,144 tons of shrimp had been caught by October 20, 2004.

As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 4 250 tons in 2000 to 10,137 tons in 2004. Fishing vessels from contracting nations took 619, 5 437, 1 563, 1 939 and 2 007 tons of shrimp during each respective year.

Canadian fleet

During 2001, large (>500 t) and small (<=500 t) shrimp fishing vessels catches were taken from a broad area (Fig. 4 – 6) from the northern border with 3K south east along the 200 – 500 m contours to the NRA border. The area fished contracted as large quantities of big shrimp were discovered in the northeastern corner of 3L, near the 3K border, and at then NRA border. The distribution of fishing activity is much lower than the distribution of the stock (fig. 6), therefore, the catch rate models should not be used as a proxy for shrimp biomass and abundance. Large and small vessel catch rates were modeled in order to describe fishing activities.

Large vessel catch rates were analyzed by multiple regression, weighted by effort, for year, month, number of trawls and vessel effects. The number of trawls was found to have an insignificant influence upon model results (P=.3006) and therefore was not included in the final model. The final model explained 85% of the variance in the data and indicated that the annual, standardized catch rates for 2000 - 2003 were similar to the 2004 CPUE estimate (1,455 kg/hr; Table 2; fig.7). There were no trends in the residuals around parameter estimates (fig. 8).

Preliminary data exploration indicated that there was no relationship between length of small vessel (<=500 t) and tonnage or horse power. Therefore small vessel CPUE was modeled using month and year as explanatory variables. The final model explained 80% of the variance in the data and indicated that the annual, standardized catch rates have been increasing since 2001 with only the 2003 CPUE estimate being statistically similar to 2004 estimate (494 kg/hr; Table 3; fig. 7). There were no trends in the residuals around parameter estimates (fig. 9).

International fleet

Catch rate data were obtained from Estonia, Greenland, Iceland, Norway and Russia. It was not possible to use the Estonian data in a catch rate exercise because it required extensive editing and it was not certain which tows made use of single or double trawls. Unstandardized data from Greenland, Iceland, Norway and Russia were plotted against time (fig. 10). In all cases, each fleet began using single trawls but over time switched to mainly double trawls. In general, catch rates have been increasing over time. Average Icelandic and Russian single (391 kg/hr) and double trawl catch rates (639 kg/hr) were much lower than the respective average Greenlandic and Norwegian catch rates (single trawl = 1,780 kg/hr.; double trawl = 2,151 kg/hr.). No positional information was provided therefore it was not possible to determine whether the distribution of the fishery was expanding or contracting.

Size composition

Several length frequency observations were taken from large vessel catches (fig. 11). Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females generally beginning with three year old animals. The relatively strong 1997 – 1999 year classes could easily be tracked over the short time series. The 2000 year class appeared strong as three year old animals compared to the preceding three year classes at that age. It is felt that the 1998 - 2000 year-classes will be able to sustain the present fishery over the next few years.

The average size of female shrimp decreased between 2000 and 2002 because remnants of the strong 1993 and 1994 year classes were dying and being replaced by the weaker 1995 and 1996 year classes. Subsequently these were followed by the relatively strong 1997 – 1999 year classes. The average size of females decreased further as these successive strong year classes changed from male to female. However, the average size of females in the 2003 commercial catches increased as females from the 1997 – 1999 year classes grew.

Probit analyses indicate that the size at transition, as determined from large vessel commercial samples, has remained sTable at approximately 21 mm over the period 2000 – 2003 (fig 12).

RESEARCH SURVEY DATA

Stock size

Ogmap calculations from the autumn 2003 survey data indicated that the 3LNO trawlable biomass index remained sTable at 191,000 tons (39 billion animals) (Table 4, Fig. 13 and 14).

Analyses from the spring 2004 survey indicated that the 3LNO trawlable biomass index was 101,000 tons (19 billion animals) considerable less than that derived from the previous autumn survey (Tables 4 and 5; Fig.. 13 – 15). As was the case in 2000, the spring 2004 biomass and abundance indices are thought to be imprecise, because the 95% confidence intervals were very broad. The spring 2000 results were heavily influenced by two anomalously high catches (500 and 511 kg) while the spring 2004 results were heavily influenced by one high catch (1060 kg).

The 95% confidence intervals around the autumn 2003 indices overlap the 95% confidence intervals for the respective indices since spring 2000; therefore, biomass and abundance indices have not changed significantly since spring 2000.

Distribution of shrimp in Divisions 3L, 3N and 3O

Between 90.5 and 99.9% of the total 3LNO biomass was found within Division 3L, mostly within depths from 185 to 550 m. Over the study period, the area outside 200 Nmi accounted for between 13 and 28% of the total 3LNO biomass estimates (Tables 6 & 7; fig. 13). Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 16 – 25% of the total 3LNO autumn biomass is within the NRA. Over the period 2000 – 2003 the overall average autumn percent biomass within the NRA was 18%. However, during the spring, the percent biomass within the NRA ranged between 14 and 28%. Over the period 1999 – 2003 the average spring percent biomass with the NRA was 24%.

In all surveys, Division 3N accounted for .4-11% of the total 3LNO biomass. More than 34% of the 3N biomass was found outside the 200 Nmi limit. Division 3O accounted for less than 1% of the 3LNO biomass. All of the Division 3O biomass was found within the 200 Nmi limit.

Stock composition

Length distributions representing abundance – at – length from the autumn 1995 to autumn 2003 surveys are compared in figure 16. As noted above, there may be a seasonal difference in catchability of shrimp; therefore, this document describes trends in only autumn length frequencies. Tables 8 and 9 provide the detailed length frequency data obtained from each autumn survey. Modes increase in height as one moves from ages 0 – 3 indicating that catchability of the research trawl improves as the shrimp get older. Tables 10 and 11 provide the modal analysis and the estimated demographics from each survey.

This time series provides a basis for comparison of relative year-class strength and illustrate the changes in stock composition over time. There appear to be two regimes; prior to 2000 the abundances at age are much lower than in the post 1999 time period. Since the 1997 year-class was first seen, in 1998 at age 1, it has appeared to be the strongest year-class since the multi-species survey began. The 1998 - 2000 year classes appear moderately strong compared others. Modal length at age varies between years reflecting different growth rates for the different cohorts. However, there is some inter-annual consistency in the modal identification as noted by the vertical lines in figure 16.

Abundances within the autumn 2003 survey data were dominated by males with a modal length of 19.0-mm CL, believed to have been the 2000 year-class (age 3). The 2001 year-class was evident near 15.0 mm while the 2002 year-class had a mode at 9.5 mm. The largest males (>19 mm) and smallest females (< 22 mm) are thought to belong to the 1999 year-class. The broad female distribution suggests that it consists of more than one year-class. The relative strength of the 1998 - 2000 year-classes and the breath of the female distributions are consistent with the observations pertaining to the commercial large vessel length frequencies. It is predicted that the moderately strong 1998 – 2000 year-class will be able to sustain the fishery for the next few years.

Recruitment Index

There is a strong relationship between the fishable biomass lagged by two years and the age two recruitment index (fig. 17). The linear regression model created from this relationship can be used to predict future fishable biomass. Using the 2002 and 2003 recruitment indices, we are predicting that the 2004 and 2005 fishable biomasses will be 120,000 t and 165,000 t respectively.

Annual change in size at sex transition

The size at sex transition (L_{50}) increased from 17.1 mm during 1995 to 21.2 mm during 2001 and remained sTable since (fig. 12). Size at transition during 1997 and 2001 were statistically similar to the size at transition during 2003, while the index was lower during all other years (Table 12). Since 1999, commercial L_{50} indices have remained near 21 mm.

Exploitation Rates

Exploitation levels using ratios of catch/lower 95% confidence interval below the biomass estimate, catch/spawning stock biomass (SSB) and catch/fishable biomass follow similar trajectories (Table 13). Overall, exploitation has been low. TAC for this stock was set in 1999 and again during 2002 by applying a 15% exploitation rate to the lower 95% confidence interval below recent biomass estimates, therefore, it is useful to discuss exploitation in terms of catch/ lower 95% confidence intervals below the biomass indices. This index was below 5% during the mid – late 1990s, increased to 12.6% during 2000 reflecting the start of the fishery under TAC regulation, and then decreased as biomass indices increased. The ratio has never exceeded 15% of the minimum trawlable biomass and is presently 8.8%. It is important to note that these ratios are believed to over estimate the exploitation rate because the catchability of the research trawl is thought to be less than 1.

Mortality indices

Mortality rates for age 4+ shrimp remained less than 54% between 1998 and 2001 but have since increased to approximately 70% during 2002 and 80% during 2003 (Table 14). Higher mortalities in the latter years coincide with the beginning of the 3L shrimp fishery. Canadian observer data indicate that much of the catch consists of age 4+ shrimp (fig. 11).

Weight *versus* length relationships

Weight *versus* carapace length relationships for live males and non-ovigerous females are presented in figure 19. It is hoped that over time a series of such relationships may be derived and that the slope in the relationships may provide insight into changes in shrimp condition.

By-catch

Tables 14 and 15 indicate that low numbers and weights of Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*) and redfish (*Sebastes* spp.) had been taken by Canadian shrimp fishing fleets. The 2003 total estimated by-catch of Atlantic cod was approx. 2 tons compared to an average trawlable biomass (over the 1999 – 2002 period) of 28 000 tons (DFO, 2003). The 2003 total estimated by-catch of American plaice was 5 tons compared to a NAFO division 3L biomass index of 44 000 tons in 2002 (Morgan *et al.* 2003). Similarly, the total estimated by-catch of redfish was 12 tons compared to an average trawlable biomass (over the 1996 – 2002 period) of 21 000 tons in NAFO division 3L (Power, 2003). The 2004 observer data had not been completely keypunched in time to provide accurate estimates of by-catch; however, preliminary estimates indicate that by-catch remains low.

Relative to other species, high levels of Greenland halibut (*Rheinhardtius hippoglossoides*) are taken in the shrimp fishery. The 2003 total estimated by-catch of Greenland halibut was 24 tons compared to a NAFO division 3L autumn 2002 biomass index of 22 377 tons (Dwyer and Bowering, 2003). High spatial overlap with shrimp, fusiform shape and the fact that Greenland halibut swim upright allowing relatively large animals to pass through the Nordmore Grate, result in a higher Greenland halibut by-catch within the shrimp fishery. As with the other groundfish species, the biomass of Greenland halibut in 3L has been declining over the past few years.

Tables 14 and 15 provide an estimate of groundfish removals at age. This is important because each kg of fish removed may represent several juvenile fish. Caution should be used in reading these Tables because observed weights are recorded in kilograms. A fish weighing 5 grams would be recorded as being 1 kg. Thus by-catch levels presented in this document may be artificially high.

Levels of observer coverage are provided by the correction factors (logbook catch/ observer catch). Almost 100% of the large vessel fishing sets were observed, as indicated by correction factors that were just slightly above 1. Thus there should be high confidence in the large vessel by-catch values for the period 2001 – 2003. As noted above, the 2004 data was not available in its entirety; however, the data are probably representative of fleet by-catch.

Small vessel observer coverage ranged between 1.9% (correction factor = 53 in 2003) and 5.9% (correction factor = 17 in 2002). There is less confidence in whether the small vessel by-catch estimates are representative of the fishery.

Due to the number of tasks undertaken by observers, and because conditions on vessels are not always conducive for detailed sampling of several species, few length measurements were taken. Where number of fish measured are low (<200), it is not clear whether the number at age were representative of the by-catch.

Distribution of shrimp in relation to various commercially important groundfish species

Atlantic cod

Relatively few juvenile cod (<=19 cm total length) have been caught during recent years, although, young cod were often found within Conception, Trinity and Bonavista Bays where their distribution overlapped with shrimp (fig. 20). Concentrations appeared within divisions 3NO and the southern portion of 3L. Few shrimp were found in these areas.

American plaice

Figure 21 indicates that juvenile American plaice (<=16 cm total length) are dispersed throughout the Grand Banks and that there is overlap between American plaice and large shrimp catches. However, most American plaice were found in water shallower than 200 m with the largest concentrations in the southern Grand Banks.

Redfish

Both shrimp and juvenile redfish (<=16 cm total length) are commonly found along the edge of the Grand Banks in water between 200 and 500 m (fig. 22). Areas of overlap occur where juvenile redfish have traditionally been found, particularly in the Sackville Spur and on the nose of the Grand Banks. These are areas of highest shrimp concentrations. However, the largest concentrations of redfish are found along the southern edge of divisions 3NO.

Greenland halibut

Figure 23 indicates that large concentrations of juvenile Greenland halibut (<=24 cm total length) are sympatric with large concentrations of shrimp.

Information provided by these plots is in agreement with by-catch levels provided in Tables 15 and 16. Levels of by-catch are generally in relation to abundances of juvenile groundfish and degrees of overlap between the species. There are relatively few Atlantic cod which for the most part are distributed away from the shrimp fishery; consequently by-catch of Atlantic cod has been approx. 2 tons. Juvenile American plaice are more abundant, but highest concentrations are in shallow water south of the fishery, consequently by-catch levels are higher than they are for cod but were still less than 3 tons during 2003. There is more overlap between juvenile redfish, Greenland halibut and the shrimp fishery. By-catch is greatest for these species.

Resource Status

Canadian large (>500 t) and small (<=500 t) vessel catch rates are near the historic average while spatial distribution of the Canadian catches has decreased such that most of the fishery now occurs near the northeastern border with NAFO Div. 3K and at the 200 Nmi limit. In contrast, survey data suggest that the resource expanded spatially between 1995 and 1998 but has since stabilized at a high level. Both biomass and abundance indices increased over the period 1995 to 2001 and has since stabilized at a high level.

The international fleets were able to maintain or increase catch rates over time. Thus there is stability in the catch rate information. The fact that Canadian fleet activities are concentrated does not imply that the stock is in decline, but is an indication that this fleet found a pocket of large shrimp.

The autumn biomass and abundance indices increased significantly until 2000 followed by a period of stability at a high level. The average fishable biomass from the last four autumn surveys was 160,000 t (24 billion animals). As a result of increases in biomass/ abundance, exploitation in terms of catch/fishable biomass remained 8% during 2003 even though the TAC more than doubled.
Age 4+ mortality rates were less than 54% prior to the beginning of the fishery. However, after 5 years of fishing shrimp, the age 4+ mortality rate rose almost 80% during 2003.

Analyses from research survey and commercial catch data indicate that the size at transition increased from 17 mm in 1995 to 21 mm in 2001 and has remained sTable near 21 mm. Increased female size usually implies an increase in individual fecundity. Increased size also implies that the environmental conditions are good.

The present autumn survey female length distribution is broad suggesting that it consists of more than one year-class. The relative strength of the 1998 - 2000 year-classes and the breath of the female distributions are consistent with the observations pertaining to the commercial large vessel length frequencies. It is predicted that the moderately strong 1998 – 2000 year-class will be able to sustain the fishery for the next few years.

Additionally there is a strong relationship between the fishable biomass lagged by two years and the age two recruitment index. Using the 2002 and 2003 recruitment indices, we are predicting that the 2004 and 2005 fishable biomasses will be 120,000 t and 165,000 t respectively.

With the exception of the increased age 4+ mortality rates, the stock appears healthy and sTable at high biomass/ abundance index levels. There should be caution but the stock can probably sustain modest increases harvest increases in the near future.

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Table 1. Annual nominal catches by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3L.

Country	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Canada	11[1]				2[1]					82[1]	78[1]	4,250[2]	5,129[2]	5,414[2]	10,008[2]	10,137[2]
Cuba														70[3]	146[1]	145[1]
Estonia												64[1]	2,264[4]	450[5]	152[1]	87[1]
European Union															117[1]	159[1]
Faroe Islands					1,789[1]	1,865[1]		171[1]	485[1]	544[1]	706[1]	42[1]	2,052[4]	620[5]		614[1]
France (SPM)												67[1]		36[3]		
Greenland												34[1]			672[8]	294[1]
Iceland												97[1]	55[7]	55[7]	133[7]	105[7]
Latvia												64[1]	67[1]	59[3]	144[1]	105[1]
Lithuania												67[1]	51[3]	67[3]	142[1]	62[1]
Norway												77[1]	78[6]	70[6]	145[9]	148[1]
Poland												40[1]	54[1]			144[1]
Portugal													61[5]			
Russia												67[1]	67[1]	67[3]		
Spain											11[1]		699[4]			
Ukraine													57[1]		144[1]	144[1]
USA														69[3]	144[1]	
GRAND TOTAL	11	0	0	0	1,791	1,865	0	171	485	567	795	4,869	10,566	6,977	11,947	12,144
TAC (tons)												6,000	6,000	6,000	13,000	13,000

Sources:

1 NAFO Statlant 21A
2 Canadian Quota Report, or other preliminary sources
3 NAFO monthly records of provisional catches
4 Value agreed upon in Stacfis
5 Canadian surveillance reports
6 Observer datasets
7 Icelandic logbook dataset.
8 Greenlandic logbook dataset.
9 Norwegian logbook dataset.

Table 2. Multiplicative, year, month, vessel model for Canadian large (>500 t) vessels fishing northern shrimp in NAFO divisions 3LNO over the period 2000 - 2004. (Weighting by effort, single + double trawl, no windows, observer data)

The GLM Procedure
Class Level Information

Class	Levels	Values
Year	5	2000 2001 2002 2003 2004
Month	6	1 2 3 4 5 6
CFV	7	

Number of observations 43

Dependent Variable: lncpue
Weight: wfactor

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	710.9410310	47.3960687	9.97	<.0001
Error	27	128.3487660	4.7536580		
Corrected Total	42	839.2897970			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.847075	29.93634	2.180289	7.283083

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	4	328.5027562	82.1256891	17.28	<.0001
Month	5	222.5370544	44.5074109	9.36	<.0001
CFV	6	159.9012204	26.6502034	5.61	0.0007

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	4	59.2722610	14.8180652	3.12	0.0313
Month	5	95.3796882	19.0759376	4.01	0.0075
CFV	6	159.9012204	26.6502034	5.61	0.0007

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		7.280257141	B	0.18033430	40.37	<.0001
Year	2000	-0.244422170	B	0.17466223	-1.40	0.1731
Year	2001	-0.002738652	B	0.16222747	-0.02	0.9867
Year	2002	0.166447738	B	0.18232131	0.91	0.3694
Year	2003	0.404039615	B	0.19965484	2.02	0.0530
Year	2004	0.000000000	B	.	.	.
Month	1	0.732712666	B	0.20909677	3.50	0.0016
Month	2	0.518923878	B	0.16574139	3.13	0.0042
Month	3	-0.219440308	B	0.17493483	-1.25	0.2204
Month	4	-0.117942504	B	0.13914258	-0.85	0.4041
Month	5	-0.000370552	B	0.14295359	-0.00	0.9980
Month	6	0.000000000	B	.	.	.
CFV		-0.097891620	B	0.11840792	-0.83	0.4156
CFV		-0.132118274	B	0.15562080	-0.85	0.4034
CFV		0.030749959	B	0.11181175	0.28	0.7854
CFV		0.338359703	B	0.24248278	1.40	0.1743
CFV		-0.386837168	B	0.22191946	-1.74	0.0927
CFV		-0.799806008	B	0.16018212	-4.99	<.0001
CFV		0.000000000	B	.	.	.

Year	lncpue LSMEAN	95% Confidence Limits	
2000	7.038500	6.775436	7.301564
2001	7.280183	7.070203	7.490163
2002	7.449370	7.224998	7.673741
2003	7.686962	7.437031	7.936893
2004	7.282922	6.957418	7.608426

Table 3. Multiplicative, year, month model for Canadian small (<=500 t) vessels fishing northern shrimp in NAFO divisions 3LNO over the period 2000 - 2004. (Weighting by effort, single trawl, no windows, logbook data)

The GLM Procedure
Class Level Information

Class	Levels	Values
Year	5	2000 2001 2002 2003 2004
Month	7	4 5 7 8 9 10 6

Number of observations 27

Dependent Variable: lncpue
Weight: wfactor

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	1217.950888	121.795089	6.39	0.0006
Error	16	304.833883	19.052118		
Corrected Total	26	1522.784770			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.799818	73.96664	4.364873	5.90113

```
Source                    DF       Type I SS     Mean Square    F Value     Pr > F
Year                      4     870.2455021     217.5613755      11.42     0.0001
Month                     6     347.7053855      57.9508976       3.04     0.0351

Source                    DF     Type III SS     Mean Square    F Value     Pr > F
Year                      4     448.3347390     112.0836848       5.88     0.0041
Month                     6     347.7053855      57.9508976       3.04     0.0351

                                                 Standard
Parameter                Estimate                Error          t Value    Pr > |t|
Intercept                6.333450206 B           0.09128178      69.38     <.0001
Year      2000          -0.404986670 B           0.10412229      -3.89     0.0013
Year      2001          -0.405354325 B           0.11109008      -3.65     0.0022
Year      2002          -0.348209490 B           0.10977444      -3.17     0.0059
Year      2003          -0.203326665 B           0.10510080      -1.93     0.0709
Year      2004           0.000000000 B            .                .        .
Month     4             -0.089869215 B           0.11075647      -0.81     0.4290
Month     5             -0.154381528 B           0.09368420      -1.65     0.1189
Month     7             -0.012236188 B           0.10956194      -0.11     0.9125
Month     8             -0.094535510 B           0.11344195      -0.83     0.4169
Month     9             -0.266522548 B           0.07231186      -3.69     0.0020
Month     10            -0.293649144 B           0.09535065      -3.08     0.0072
Month     6              0.000000000 B       .                     .          .

                lncpue
   Year         LSMEAN      95% Confidence  Limits
   2000        5.798293        5.653560     5.943026
   2001        5.797925        5.675465     5.920386
   2002        5.855070        5.724317     5.985823
   2003        5.999953        5.904064     6.095842
   2004        6.203280        6.012242     6.394317
```

Table 4. Northern shrimp stock size estimates in NAFO Div. 3LNO from offshore Canadian autumn bottom trawl research surveys, 1995 – 2003.

	Biomass (tons)			Abundance (numbers x 10^6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1995	6,944	8,300	14,630	2,056	2,659	4,789	195
1996	21,700	24,700	35,150	5,324	6,575	9,370	238
1997	32,410	44,000	61,940	7,545	9,911	13,860	232
1998	48,310	60,700	76,640	11,950	14,975	19,120	234
1999	43,160	54,900	72,390	10,620	12,993	16,510	233
2000	83,990	107,000	139,200	20,890	27,898	35,830	241
2001	155,300	215,400	259,600	36,890	51,730	62,040	252
2002	135,500	191,700	239,500	31,100	44,472	54,750	253
2003	143,300	191,100	244,600	29,880	39,293	48,850	235

	Biomass (tons)			Abundance (numbers x 10^6)		
	Males	Females	Total	Males	Females	Total
1995	4,000	4,300	8,300	1,905	736	2,641
1996	18,900	5,800	24,700	5,904	659	6,564
1997	24,800	19,200	44,000	7,192	2,719	9,911
1998	42,500	18,200	60,700	12,842	2,133	14,975
1999	33,200	21,700	54,900	9,994	2,999	12,993
2000	74,500	32,600	107,100	23,649	4,249	27,898
2001	152,000	63,500	215,500	43,593	8,137	51,730
2002	122,300	69,500	191,800	34,878	9,595	44,472
2003	107,600	82,400	190,000	28,630	10,663	39,293

Table 5. Northern shrimp stock size estimates in NAFO Div. 3LNO from offshore Canadian spring bottom trawl research surveys, 1999 – 2004.

	Biomass (tons)			Abundance (numbers x 10^6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	27,080	49,500	76,520	6,592	11,437	17,310	313
2000	65,710	113,300	176,700	13,150	21,356	31,590	298
2001	52,680	82,500	117,000	12,240	19,714	28,540	312
2002	87,390	133,800	204,700	20,730	31,260	47,660	304
2003	118,300	169,600	237,500	26,210	38,998	57,840	313
2004	4,080	100,900	178,200	8,213	19,444	33,820	308

	Biomass (tons)			Abundance (numbers x 10^6)		
	Males	Females	Total	Males	Females	Total
1999	29,400	20,100	49,500	8,767	2,670	11,437
2000	46,900	50,300	97,200	14,795	6,561	21,356
2001	50,000	32,500	82,500	15,066	4,648	19,713
2002	79,200	54,600	133,800	22,503	8,757	31,260
2003	91,100	78,500	169,600	26,516	12,482	38,998
2004	56,100	44,900	101,000	13,330	6,114	19,444

Table 6. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using ogmap calculations with data obtained from annual autumn Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Division Biomass estimate (Kg x 1000)	Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Outside 200 Nmi limit Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Spring	1999	3L	47,500	95.38	10,200	85.71		21.47	21.47
Spring	2000	3L	108,700	95.77	23,800	87.18		21.90	21.68
Spring	2001	3L	82,700	99.64	11,400	99.13		13.78	19.05
Spring	2002	3L	128,100	95.60	34,300	91.47		26.78	20.82
Spring	2003	3L	165,400	96.73	29,900	86.92		18.08	19.55
Spring	2004	3L	99,500	98.61	27,100	97.48		27.24	24.03
			overall average	**97**			Overall average	**21.54**	
Spring	1999	3N	2,200	4.42	1,700	14.29		77.27	77.27
Spring	2000	3N	4,700	4.14	3,500	12.82		74.47	75.87
Spring	2001	3N	300	0.36	100	0.87		33.33	61.69
Spring	2002	3N	5,800	4.33	3,200	8.53		55.17	54.32
Spring	2003	3N	5,400	3.16	4,500	13.08		83.33	57.28
Spring	2004	3N	1,200	1.19	700	2.52		58.33	65.61
			overall average	**3**			Overall average	**63.65**	
Spring	1999	3O	100	0.20	0	0.00		0.00	0.00
Spring	2000	3O	100	0.09	0	0.00		0.00	0.00
Spring	2001	3O	0	0.00	0	0.00		0.00	0.00
Spring	2002	3O	100	0.07	0	0.00		0.00	0.00
Spring	2003	3O	200	0.12	0	0.00		0.00	0.00
Spring	2004	3O	200	0.20	0	0.00		0.00	0.00
			overall average	**0**			Overall average	**0.00**	
	all divisions								
Spring	1999		49,800		11,900			23.90	23.90
Spring	2000		113,500		27,300			24.05	23.97
Spring	2001		83,000		11,500			13.86	20.60
Spring	2002		134,000		37,500			27.99	21.96
Spring	2003		171,000		34,400			20.12	20.65
Spring	2004		100,900		27,800			27.55	25.22
							Overall average	**22.91**	

Table 7. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using ogmap calculations with data obtained from annual autumn Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Biomass estimate (Kg x 1000)	Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1995	3L	7,500	90.36	1,000	62.50		13.33	13.33
Autumn	1996	3L	22,900	92.71	4,000	85.11		17.47	15.40
Autumn	1997	3L	43,400	98.64	5,500	91.67		12.67	14.49
Autumn	1998	3L	56,000	92.26	8,900	81.65		15.89	15.34
Autumn	1999	3L	54,500	99.27	8,000	96.39		14.68	14.41
Autumn	2000	3L	105,800	98.88	22,100	98.22		20.89	17.15
Autumn	2001	3L	213,700	99.21	40,800	97.14		19.09	18.22
Autumn	2002	3L	187,800	97.97	35,200	92.39		18.74	19.57
Autumn	2003	3L	185,300	96.96	35,300	91.69		19.05	18.96
			Overall average	**96.25**			Overall average	**16.87**	
Autumn	1995	3N	900	10.84	600	37.50		66.67	66.67
Autumn	1996	3N	2,000	8.10	700	14.89		35.00	50.83
Autumn	1997	3N	700	1.59	500	8.33		71.43	57.70
Autumn	1998	3N	4,700	7.74	2,000	18.35		42.55	49.66
Autumn	1999	3N	500	0.91	300	3.61		60.00	57.99
Autumn	2000	3N	700	0.65	400	1.78		57.14	53.23
Autumn	2001	3N	1,700	0.79	1,200	2.86		70.59	62.58
Autumn	2002	3N	4,000	2.09	2,900	7.61		72.50	66.74
Autumn	2003	3N	4,700	2.46	3,200	8.31		68.09	70.39
			Overall average	**3.91**			Overall average	**60.44**	
Autumn	1995	3O	0	0.00	0	0.00		0.00	0.00
Autumn	1996	3O	0	0.00	0	0.00		0.00	0.00
Autumn	1997	3O	0	0.00	0	0.00		0.00	0.00
Autumn	1998	3O	100	0.16	0	0.00		0.00	0.00
Autumn	1999	3O	0	0.00	0	0.00		0.00	0.00
Autumn	2000	3O	0	0.00	0	0.00		0.00	0.00
Autumn	2001	3O	0	0.00	0	0.00		0.00	0.00
Autumn	2002	3O	100	0.05	0	0.00		0.00	0.00
Autumn	2003	3O	200	0.10	0	0.00		0.00	0.00
			Overall average	**0.04**			Overall average	**0.00**	
	all divisions								
Autumn	1995		8,300		1,600			19.28	19.28
Autumn	1996		24,700		4,700			19.03	19.15
Autumn	1997		44,000		6,000			13.64	17.31
Autumn	1998		60,700		10,900			17.96	16.87
Autumn	1999		54,900		8,300			15.12	15.57
Autumn	2000		107,000		22,500			21.03	18.03
Autumn	2001		215,400		42,000			19.50	18.55
Autumn	2002		191,700		38,100			19.87	20.13
Autumn	2003		191,100		38,500			20.15	19.84
							Overall average	**18.40**	

Table 8. Abundances (10^6) of male northern shrimp (*Pandalus borealis*) collected in NAFO Divs. 3LNO during autumn Canadian research surveys during 1995 - 2003. (Offshore strata only)

Length in mm	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	3
5.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0	6
7	6	0	0	0	2	0	0	0	4
7.5	19	2	4	2	5	10	15	1	23
8	12	8	4	6	5	6	6	11	69
8.5	35	14	9	70	20	88	41	47	116
9	71	26	26	186	25	128	115	116	180
9.5	114	50	66	372	47	203	198	213	250
10	199	67	72	623	88	324	132	369	314
10.5	251	55	100	723	112	320	82	232	196
11	252	52	77	570	98	246	54	151	99
11.5	188	67	59	366	68	134	49	85	89
12	144	93	42	155	30	95	88	161	86
12.5	82	126	47	116	47	156	175	231	202
13	93	140	48	69	77	298	387	378	233
13.5	105	156	66	119	135	652	628	739	370
14	80	239	119	184	257	1,009	1,015	913	627
14.5	127	357	224	343	412	1,386	1,704	1,120	885
15	149	579	420	517	798	1,459	2,189	845	1,067
15.5	202	716	605	542	1,178	1,428	1,992	914	1,014
16	194	725	661	538	1,237	1,219	1,892	1,350	895
16.5	151	527	469	521	899	1,280	2,978	2,510	974
17	124	355	461	506	461	1,749	3,198	3,655	1,435
17.5	77	288	482	656	326	2,564	3,425	3,192	1,802
18	58	333	574	845	390	2,930	3,417	3,258	2,144
18.5	54	354	735	1,040	504	2,131	4,152	3,350	2,678
19	56	419	687	1,123	524	1,492	4,676	2,881	3,199
19.5	65	386	598	1,039	524	1,001	4,580	2,906	3,122
20	67	257	371	976	533	683	3,594	2,716	3,067
20.5	49	140	258	799	531	553	2,144	2,205	2,217
21	40	119	121	556	491	417	1,096	1,349	1,558
21.5	24	79	67	381	323	401	491	695	772
22	19	58	19	140	185	228	174	298	404
22.5	10	45	10	39	111	110	56	34	148
23	5	25	1	18	31	57	50	5	50
23.5	1	18	1	2	21	14	20	0	3
24	0	4	0	0	3	5	0	0	0
24.5	0	2	0	0	1	0	0	0	3
25	0	0	0	0	0	0	0	0	0
25.5	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
26.5	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
27.5	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
28.5	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
29.5	0	0	0	0	0	0	0	0	0
total	3,121	6,881	7,503	14,140	10,498	24,775	44,813	36,926	30,303

Table 9. Abundances (10^6) of female northern shrimp (*Pandalus borealis*) collected in NAFO Divs. 3LNO during autumn Canadian research surveys during 1995 - 2003. (Offshore strata only)

Length in mm	1995	1996	1997	1998	1999	2000	2001	2002	2003
5	0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
8.5	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
9.5	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
10.5	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
11.5	0	0	0	0	0	0	0	0	0
12	0	0	0	0	1	0	2	0	0
12.5	1	0	1	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
13.5	3	0	0	0	2	0	1	0	3
14	11	0	1	0	0	0	0	0	12
14.5	9	1	0	0	0	0	0	0	0
15	42	1	0	0	0	0	0	0	12
15.5	108	1	0	0	0	0	1	0	2
16	96	2	4	5	0	1	2	0	0
16.5	82	2	2	6	5	10	13	4	5
17	57	1	5	8	9	2	37	10	9
17.5	39	8	5	5	7	5	24	29	13
18	20	4	17	8	8	42	18	24	59
18.5	16	8	34	8	9	55	38	12	52
19	28	22	63	6	29	75	78	43	76
19.5	34	32	170	40	40	95	167	193	79
20	39	49	206	55	96	195	325	503	141
20.5	38	54	345	117	168	227	353	883	517
21	49	40	384	156	304	343	616	1,595	892
21.5	63	57	375	213	434	371	698	1,577	1,322
22	64	47	279	259	458	387	921	1,355	1,755
22.5	87	58	204	312	405	493	1,050	942	1,869
23	75	71	176	323	335	479	988	778	1,568
23.5	55	59	138	245	274	495	836	609	1,131
24	55	51	104	196	242	455	754	529	720
24.5	54	60	100	125	127	334	590	415	487
25	39	60	81	95	96	215	457	217	413
25.5	54	41	47	60	59	108	208	182	234
26	34	31	29	31	31	55	97	115	116
26.5	32	25	8	18	13	38	50	82	114
27	26	18	7	15	9	13	36	39	32
27.5	9	10	11	6	8	9	20	25	20
28	12	5	4	6	4	6	5	7	11
28.5	6	8	3	2	1	1	1	1	0
29	3	5	3	1	1	0	1	4	3
29.5	5	5	1	0	0	2	0	0	0
30	0	3	0	0	0	0	0	0	2
30.5	0	3	0	0	0	0	0	0	0
31	0	0	0	0	0	2	0	0	0
31.5	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
total	1,345	841	2,802	2,323	3,176	4,512	8,387	10,170	11,668

Table 10. Modal analysis using MIX 3.1a (MacDonald and Pitcher, 1993) of *P. borealis* collected during the autumn 1995 – 2003 Canadian research bottom trawl surveys in 3LNO.

Mean carapace length (Standard error/ constraints)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
1991	22.19								
1992	19.73	22.18	23.50						
1993	15.56	18.78	20.42	22.54					
1994	10.59	15.44	18.13	19.81	22.48				
1995		12.68	15.29	18.18	20.95	23.12 (.030)			
1996			10.46	15.50	18.84	20.24 (.035)	22.87		
1997				10.24	15.46	17.51 (.011)	19.14	23.78	
1998					10.70	14.41 (.010)	16.68	20.36	24.14 (.101)
1999						10.02 (.014)	14.28	17.40	21.71 (.048)
2000							9.60	14.08	18.81 (.024)
2001								9.96	14.95 (.026)
2002									9.67 (.040)

Estimated proportion (Standard error/ constraints) contributed by each year class

Year Class	1995	1996	1997	1998	1999	2000	2001	2002	2003
1991	.091 (0.167)								
1992	.129 (0.022)	.079 (0.010)	.077 (0.004)						
1993	.434 (0.012)	.350 (0.020)	.284 (0.007)	.126 (0.034)					
1994	.346 (0.008)	.465 (0.023)	.331 (0.007)	.287 (0.182)	.174 (0.057)				
1995		.106 (0.014)	.261 (0.004)	.177 (0.162)	.171 (0.058)	.111 (0.002)			
1996			.047 (0.002)	.218 (0.014)	.201 (0.010)	.151 (0.003)	.132 (0.002)		
1997				.193 (0.032)	.410 (0.055)	.450 (0.003)	.458 (0.003)	.059 (0.002)	
1998					.044 (0.072)	.237 (0.003)	.263 (0.003)	.380 (0.003)	.042 (0.005)
1999						.051 (0.001)	.135 (0.002)	.430 (0.003)	.290 (0.005)
2000							.012 (0.000)	.104 (0.020)	.481 (0.006)
2001								.027 (0.001)	.153 (0.002)
2002									.034 (0.000)

Table 10 (Cont.) Modal analysis using MIX 3.1a (MacDonald and Pitcher, 1993) of *P. borealis* collected during the autumn 1995 – 2003 Canadian research bottom trawl surveys in 3LNO.

Distribution Sigmas (Standard error/ constraints)

Year Class	1995	1996	1997 (CV=.05)	1998	1999	2000 (CV=.05)	2001 (CV=.05)	2002 equal	2003 equal
1991	0.80 (0.100)								
1992	1.01 (0.181)	1.06 (0.099)	1.17						
1993	1.31 (0.054)	1.17 (0.082)	1.02	1.42 (0.145)					
1994	1.15 (0.031)	0.91 (0.044)	0.91	1.08 (0.345)	1.44 (.158)				
1995		1.14 (0.108)	0.76	0.83 (0.179)	0.84 (0.107)	1.16			
1996			0.53	1.27 (0.065)	1.02 (fixed)	1.01	1.14		
1997				0.89 (0.014)	0.95 (0.016)	0.88	0.96	1.13 (0.008)	
1998					1.29 (0.058)	0.72	0.83	1.13 (0.008)	1.277 (0.011)
1999						0.50	0.71	1.13 (0.008)	1.277 (0.011)
2000							0.48	1.13 (0.008)	1.277 (0.011)
2001								1.13 (0.008)	1.277 (0.011)
2002									

Table 11. Estimated demographics of the *P. borealis* population (10^6) in 3LNO from Canadian autumn research bottom trawl survey data, 1995 – 2004.

Age	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	24.90	222.50	8.8		11.8	15.7	20.9	0.80	8.2
1	1,423.03	765.71	482.96	3,168.17	600.08	1,491.19	637.38	1,271.43	1,425.18
2	1,784.96	3,359.02	2,681.98	3,578.56	5,591.70	6,929.64	7,170.51	4,897.36	6,414.83
3	530.55	2,528.30	3,401.29	2,905.53	2,741.30	13,157.55	13,969.22	20,248.70	20,166.89
4	374.26	570.67	2,918.33	4,711.22	2,332.15	4,415.09	24,326.62	17,894.20	12,158.83
5	328.00	275.90	791.24	2,068.34	2,373.06	3,245.53	7,011.17	2,778.31	1,760.93
6+			20.7	48.4	23.6	32.1	63.4	5.10	35.80
Total	4,465.70	7,722.10	10,305.30	16,480.22	13,673.69	29,286.80	53,199.20	47,095.90	41,971.66

Table 12. The Proc Genmod analysis to determine whether there were significant annual changes in size at sex transition of northern shrimp collected during Canadian autumn multi-species surveys over the period 1995 – 2003.

Model Information

Data Set	WORK.PERCENT_FE
Distribution	Binomial
Link Function	Logit
Response Variable (Events)	num_fem
Response Variable (Trials)	total
Observations Used	426
Number Of Events	31475.9468
Number Of Trials	100445.0000

Class Level Information

Class	Levels	Values
year	9	1995 1996 1997 1998 1999 2000 2001 2002 2003

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	416	6221.9818	14.9567
Scaled Deviance	416	416.0000	1.0000
Pearson Chi-Square	416	31820.4772	76.4915
Scaled Pearson X2	416	2127.5084	5.1142
Log Likelihood		-1568.8647	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	-25.1504	0.6888	-26.5003	-23.8004	1333.37	<.0001
length		1	1.1755	0.0325	1.1117	1.2392	1305.75	<.0001
year	1995	1	5.3311	0.2745	4.7931	5.8690	377.23	<.0001
year	1996	1	0.2692	0.2448	-0.2106	0.7490	1.21	0.2715
year	1997	1	4.0468	0.1848	3.6846	4.4090	479.49	<.0001
year	1998	1	1.1989	0.1803	0.8456	1.5522	44.23	<.0001
year	1999	1	3.2466	0.1940	2.8664	3.6268	280.07	<.0001
year	2000	1	0.7600	0.1867	0.3941	1.1258	16.58	<.0001
year	2001	1	-0.1268	0.1805	-0.4806	0.2270	0.49	0.4823
year	2002	1	0.3521	0.1654	0.0280	0.6762	4.53	0.0332
year	2003	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		0	3.8674	0.0000	3.8674	3.8674		

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	84198.6472						
length	25901.1305	1	416	3897.76	<.0001	3897.76	<.0001
year	6221.9818	8	416	164.47	<.0001	1315.74	<.0001

Least Squares Means

Effect	year	Estimate	Standard Error	DF	Chi-Square	Pr > ChiSq
year	1995	2.2826	0.2183	1	109.33	<.0001
year	1996	-2.7792	0.2202	1	159.27	<.0001
year	1997	0.9984	0.1165	1	73.43	<.0001
year	1998	-1.8495	0.1406	1	173.16	<.0001
year	1999	0.1982	0.1344	1	2.17	0.1404
year	2000	-2.2885	0.1508	1	230.16	<.0001
year	2001	-3.1752	0.1509	1	442.67	<.0001
year	2002	-2.6963	0.1299	1	430.63	<.0001
year	2003	-3.0484	0.1344	1	514.26	<.0001

Table 13. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) exploitation rates based upon the ratios of commercial catch to the previous autumn Canadian multi-species bottom trawl survey indices. The indices were derived using Ogmap calculations.

Year	catch (t)	Lower 95% CL of biomass index (t)	spawning stock biomass (SSB) (t)	fishable biomass (t)
1995		6,944	4,300	6,652
1996	171	21,700	5,800	16,894
1997	485	32,410	19,200	35,577
1998	567	48,310	18,200	52,119
1999	795	43,160	21,700	42,873
2000	4,869	83,990	32,600	83,913
2001	10,566	155,300	63,500	182,162
2002	6,977	135,500	69,500	167,637
2003	11,947	143,300	82,400	176,861

Year	catch/lower CL biomass	catch/SSB	catch/fishable biomass
1995	0.025	0.040	0.026
1996	0.022	0.084	0.029
1997	0.017	0.030	0.016
1998	0.016	0.044	0.015
1999	0.113	0.224	0.114
2000	0.126	0.324	0.126
2001	0.045	0.110	0.038
2002	0.088	0.172	0.071
2003			

Table 14. Mortality estimates based upon comparisons of age 4+ abundances from autumn Canadian research bottom trawl surveys against age 5+ abundances from the next autumn survey.

Year		1997	1998	1999	2000	2001	2002	2003
3 yr running average	age 4+	1,760	3,802	5,096	6,416	14,608	19,924	22,011
	age 5+		1,068	1,775	2,597	4,250	4,379	3,885
S			0.6070	0.4669	0.5096	0.6623	0.2997	0.1950
Z			0.4992	0.7616	0.6740	0.4120	1.2048	1.6348

Table 15. Estimated bycatch within the large vessel (>500 t) fleet fishing shrimp in 3L over the period 2001 - 2004.

	Atlantic cod				American plaice			
Year	2001	2002	2003	2004	2001	2002	2003	2004
Observed shrimp catch (t)	2314	2342	1049	1505	2314	2342	4071	1505
Logbook shrimp catch (t)	2394	2455	3349	3584	2394	2455	3956	3584
correction factor	1.03	1.05	3.19	2.38	1.04	1.05	1.00	2.38
estimated bycatch (kg)	227	137	70	38	115	312	605	312
Bycatch (kg)/(t) shrimp	0.09	0.06	0.02	0.01	0.05	0.13	0.15	0.09
Number of fish measured	17	0	37	0	0	0	251	131
	estimated number at age				estimated number at age			
age								
0.00	0	0	0	0	0	0	0	0
1.00	187	0	45	0	0	0	2	62
2.00	309	0	73	0	0	0	804	1,803
3.00	35	0	10	0	0	0	2,094	5,977
4.00	20	0	3	0	0	0	2,921	5,726
5.00	3	0	0	0	0	0	824	986
6.00	0	0	0	0	0	0	437	14
7.00	0	0	0	0	0	0	309	5
8.00	0	0	0	0	0	0	158	2
9.00	0	0	0	0	0	0	36	0
10.00	0	0	0	0	0	0	10	0
11.00	0	0	0	0	0	0	3	0
12.00	0	0	0	0	0	0	0	0
13.00	0	0	0	0	0	0	0	0
14.00	0	0	0	0	0	0	0	0
15.00	0	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0	0
total	555	0	131	0	0	0	7,598	14,576

	redfish				Greenland halibut			
Year	2001	2002	2003	2004	2001	2002	2003	2004
Observed shrimp catch (t)	2314	2342	4071	1505	2314	2342	4071	1505
Logbook shrimp catch (t)	2394	2455	3956	3584	2394	2455	3956	3584
correction factor	1.04	1.05	1.00	2.38	1.04	1.05	1.00	2.38
estimated bycatch (kg)	993	1685	2148	2930	5818	4293	6533	7215
Bycatch (kg)/(t) shrimp	0.41	0.69	0.54	0.82	2.43	1.75	1.65	2.01
Number of fish measured	0	0	217	0	2732	1333	1555	873
	estimated number at age				estimated number at age			
age								
0.00	0	0	0	0	3,793	4,273	2,333	2,885
1.00	0	0	0	0	4,256	12,413	9,935	37,671
2.00	0	0	914	0	23,689	11,438	22,297	52,137
3.00	0	0	7,420	0	12,638	9,254	12,066	7,313
4.00	0	0	27,107	0	7,051	3,848	4,791	1,103
5.00	0	0	15,211	0	830	437	1,255	0
6.00	0	0	4,808	0	140	38	70	0
7.00	0	0	1,217	0	12	0	24	0
8.00	0	0	777	0	0	4	1	0
9.00	0	0	247	0	0	0	0	0
10.00	0	0	26	0	0	0	0	0
11.00	0	0	0	0	0	0	0	0
12.00	0	0	0	0	0	0	0	0
13.00	0	0	0	0	0	0	0	0
14.00	0	0	0	0	0	0	0	0
15.00	0	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0	0
total	0	0	57,727	0	52,410	41,704	52,774	101,109

Table 16 Estimated bycatch within the small vessel (<=500 t; LOA <100') fleet fishing shrimp in 3L over the period 2001 - 2004.

	Atlantic cod				American plaice			
Year	2001	2002	2003	2004	2001	2002	2003	2004
Observed shrimp catch (t)	91	175	103	124	91	175	248	124
Logbook shrimp catch (t)	2,735	2,959	6,228	6,523	2,735	2,959	5,972	6,523
correction factor	30.18	16.95	60.58	52.63	30.18	16.95	24.04	52.63
estimated bycatch (kg)	272	153	1,878	0	1,177	559	3,990	1,895
Bycatch (kg)/(t) shrimp	0.10	0.05	0.30	0.00	0.43	0.19	0.67	0.29
Number of fish measured	1	0	48	0	0	0	0	0
	estimated number at age				estimated number at age			
age								
0.00	0	0	242	0	0	0	0	0
1.00	272	0	3,575	0	0	0	0	0
2.00	0	0	1,272	0	0	0	0	0
3.00	0	0	61	0	0	0	0	0
4.00	0	0	0	0	0	0	0	0
5.00	0	0	0	0	0	0	0	0
6.00	0	0	0	0	0	0	0	0
7.00	0	0	0	0	0	0	0	0
8.00	0	0	0	0	0	0	0	0
9.00	0	0	0	0	0	0	0	0
10.00	0	0	0	0	0	0	0	0
11.00	0	0	0	0	0	0	0	0
12.00	0	0	0	0	0	0	0	0
13.00	0	0	0	0	0	0	0	0
14.00	0	0	0	0	0	0	0	0
15.00	0	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0	0
total	272	0	5,150	0	0	0	0	0

	redfish				Greenland halibut			
Year	2001	2002	2003	2004	2001	2002	2003	2004
Observed shrimp catch (t)	91	175	248	124	91	175	248	124
Logbook shrimp catch (t)	2,735	2,959	5,972	6,523	2,735	2,959	5,972	6,523
correction factor	30.18	16.95	24.04	52.63	30.18	16.95	24.04	52.63
estimated bycatch (kg)	1,388	1,305	9,638	3,579	2,113	2,898	17,138	5,000
Bycatch (kg)/(t) shrimp	0.51	0.44	1.61	0.55	0.77	0.98	2.87	0.77
Number of fish measured	0	0	311	0	58	0	616	0
	estimated number at age				estimated number at age			
age								
0.00	0	0	0	0	1,419	0	11,033	0
1.00	0	0	12,883	0	3,893	0	89,270	0
2.00	0	0	46,077	0	2,414	0	83,429	0
3.00	0	0	71,988	0	1,237	0	41,174	0
4.00	0	0	159,407	0	1,268	0	11,153	0
5.00	0	0	29,925	0	60	0	337	0
6.00	0	0	11,008	0	0	0	0	0
7.00	0	0	1,755	0	0	0	0	0
8.00	0	0	144	0	0	0	0	0
9.00	0	0	0	0	0	0	0	0
10.00	0	0	0	0	0	0	0	0
11.00	0	0	0	0	0	0	0	0
12.00	0	0	0	0	0	0	0	0
13.00	0	0	0	0	0	0	0	0
14.00	0	0	0	0	0	0	0	0
15.00	0	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0	0
total	0	0	333,187	0	10,292	0	236,394	0

Correction factor = logbook shrimp catch/ observed shrimp catch;
Estimated by-catch = observed by-catch * correction factor.

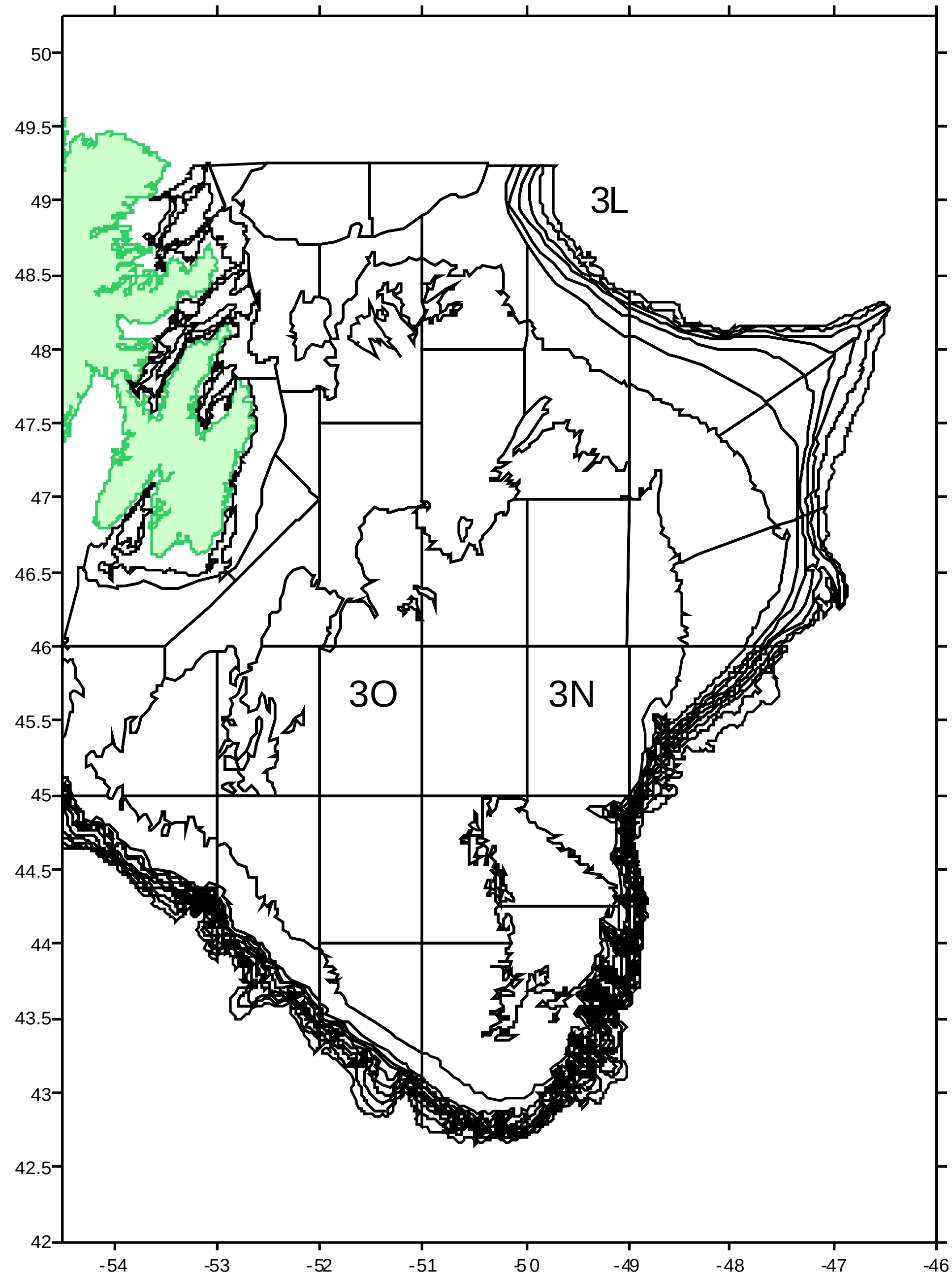

Figure 1. The NAFO 3LNO stratification scheme used in Canadian research bottom trawl survey set allocation.

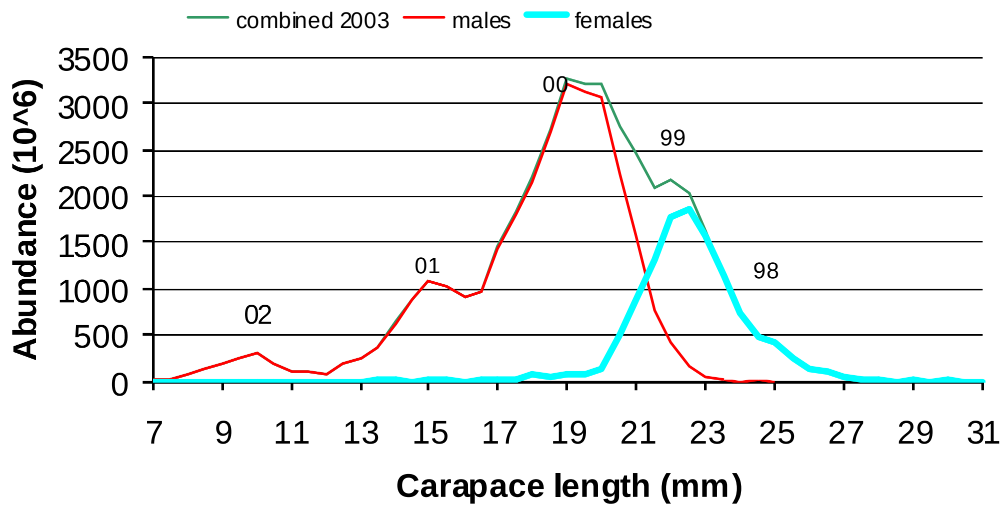

Figure 2. An example of the combined maturity carapace length frequency used in modal analysis. Length frequency estimates were derived from Ogmap calculations using autumn 2003 Canadian research bottom trawl survey data.

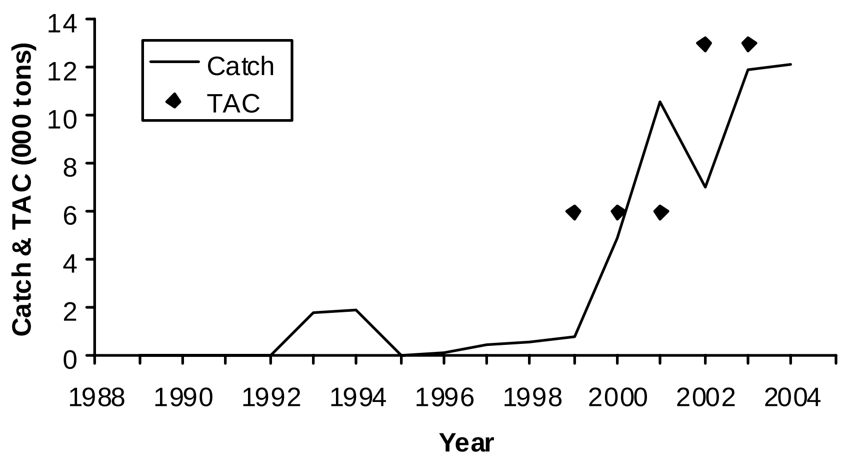

Figure 3. Trends in NAFO div. 3LNO northern shrimp (*Pandalus borealis*) catch and TAC over the period 1988 – 2004.

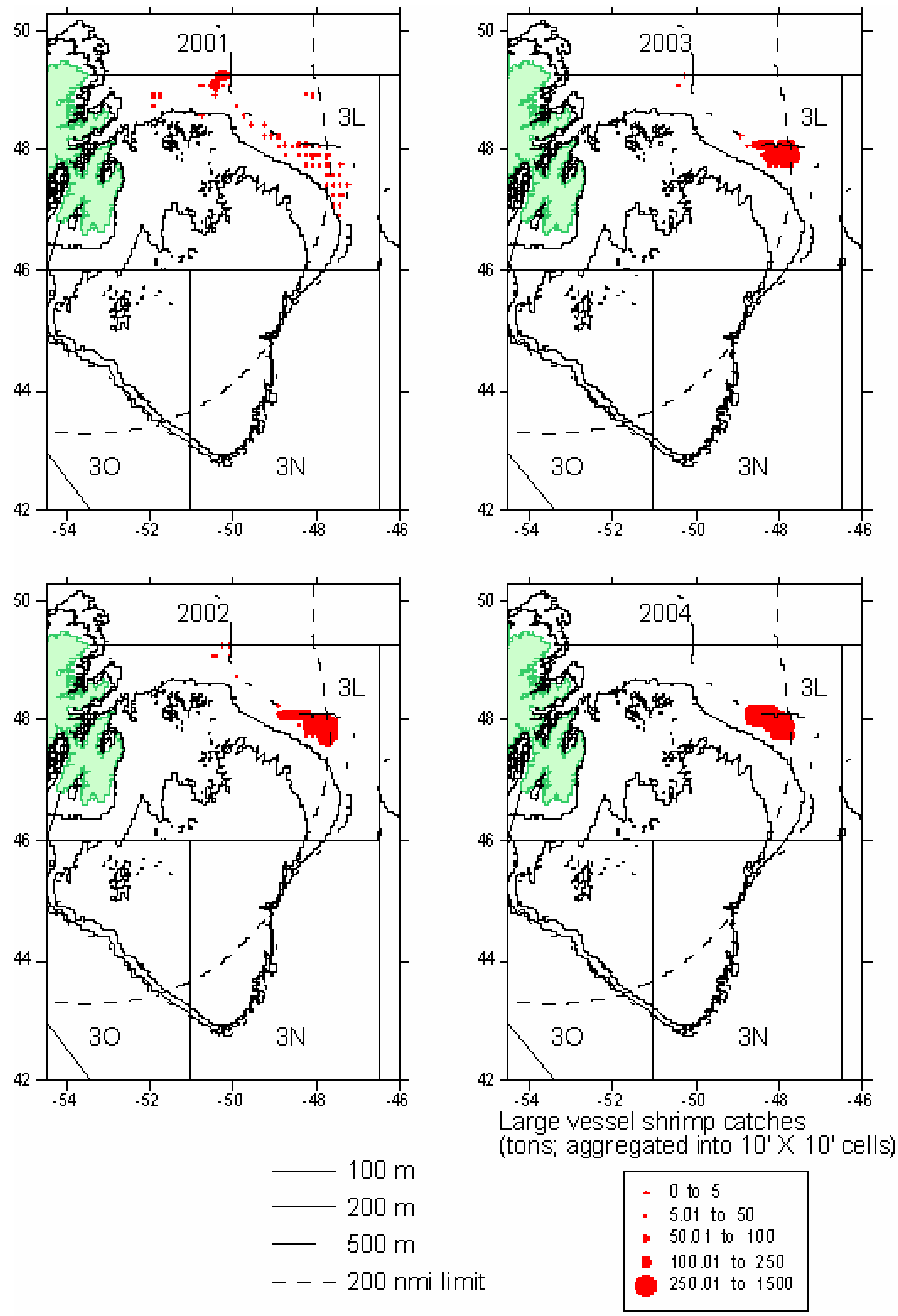

Figure 4. Distribution of Canadian large vessel (>500 t) shrimp catches in NAFO Div. 3LNO, 2001 – 2004. (Observer data aggregated into 10 min. squares).

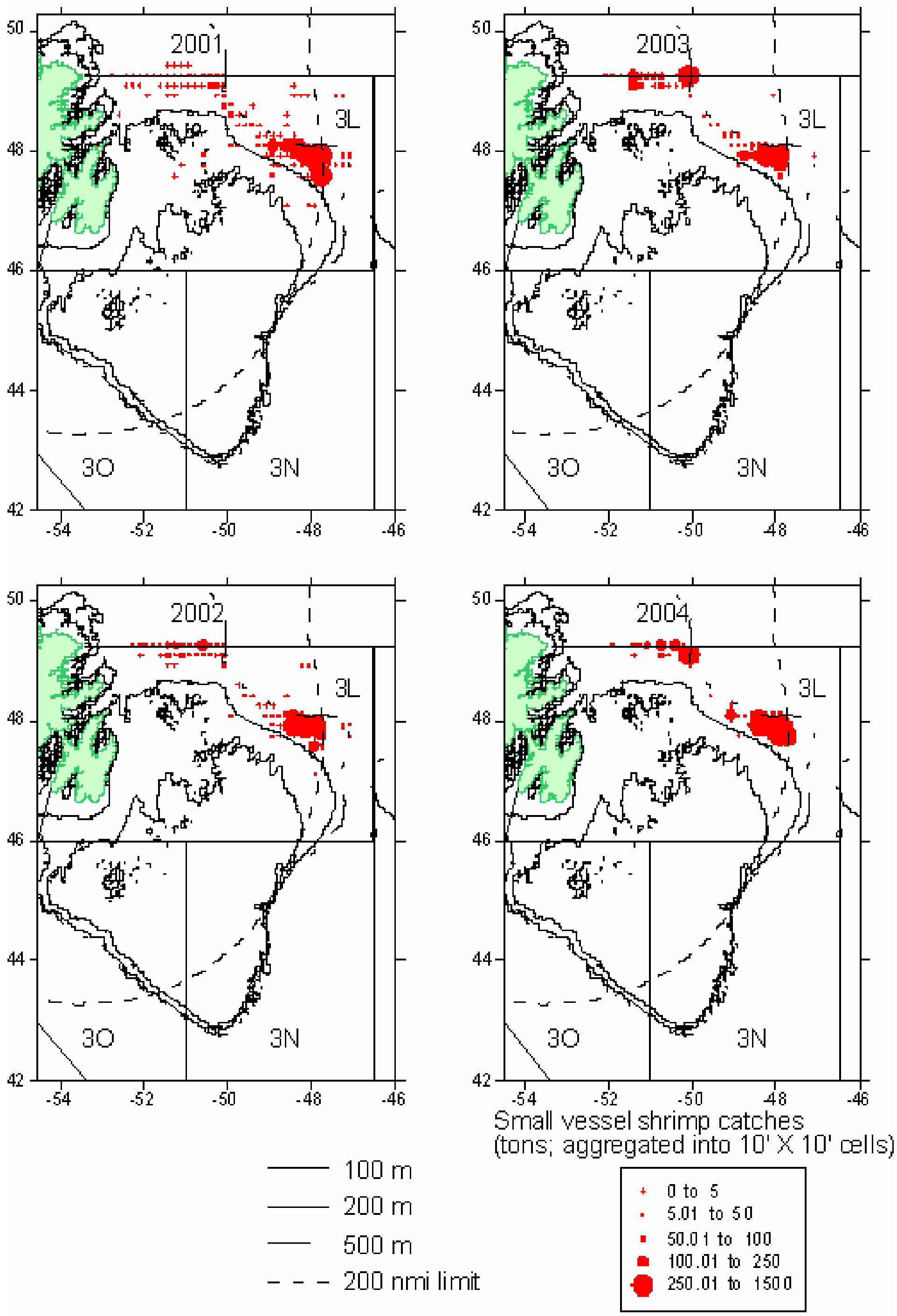

Figure 5. Distribution of Canadian small vessel (<=500 t) shrimp catches in NAFO Div. 3LNO, 2001 – 2004. (Logbook data aggregated into 10 min.squares).

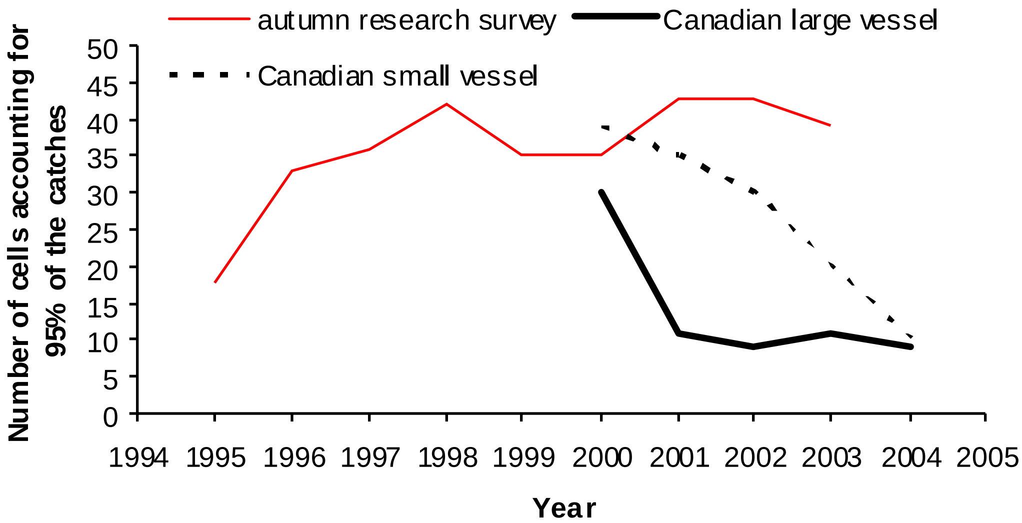

Figure 6. The number of cells required to account for 95% of the 3LNO autumn Canadian research survey and commercial catches over time.

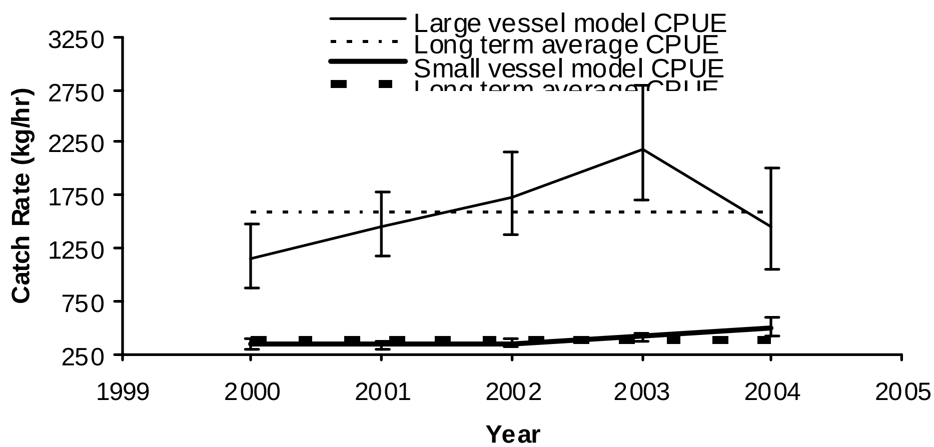

Figure 7. Model catch rates by Canadian large (>500 t) and small (<=500 t) vessel fleets fishing for shrimp in NAFO Div. 3LNO.

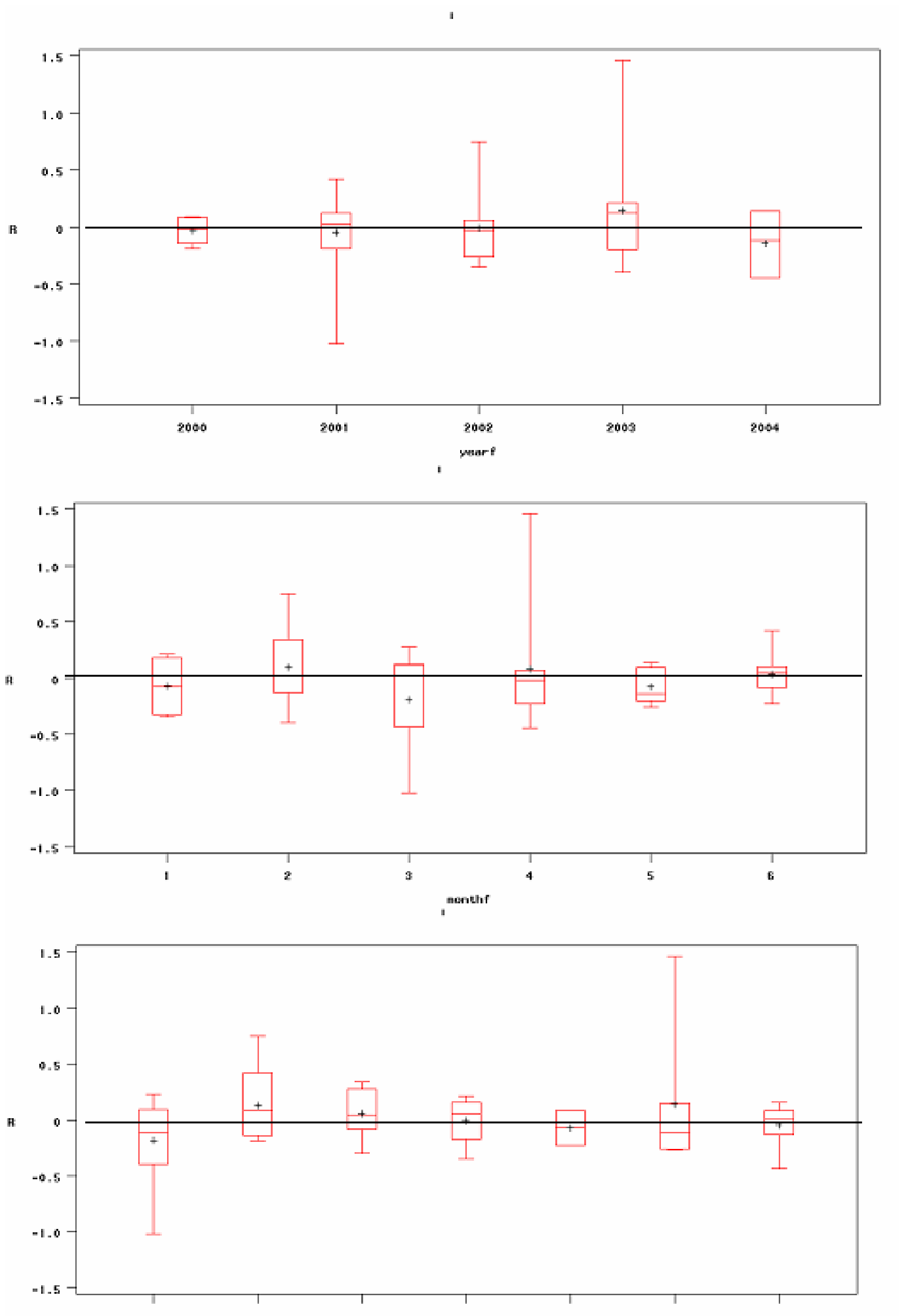

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Figure 8. The distribution of residuals around estimated values for various parameters used in the catch rate model for large Canadian (>500 t) vessels fishing shrimp in NAFO Div. 3LNO over the period 2000 – 2004.

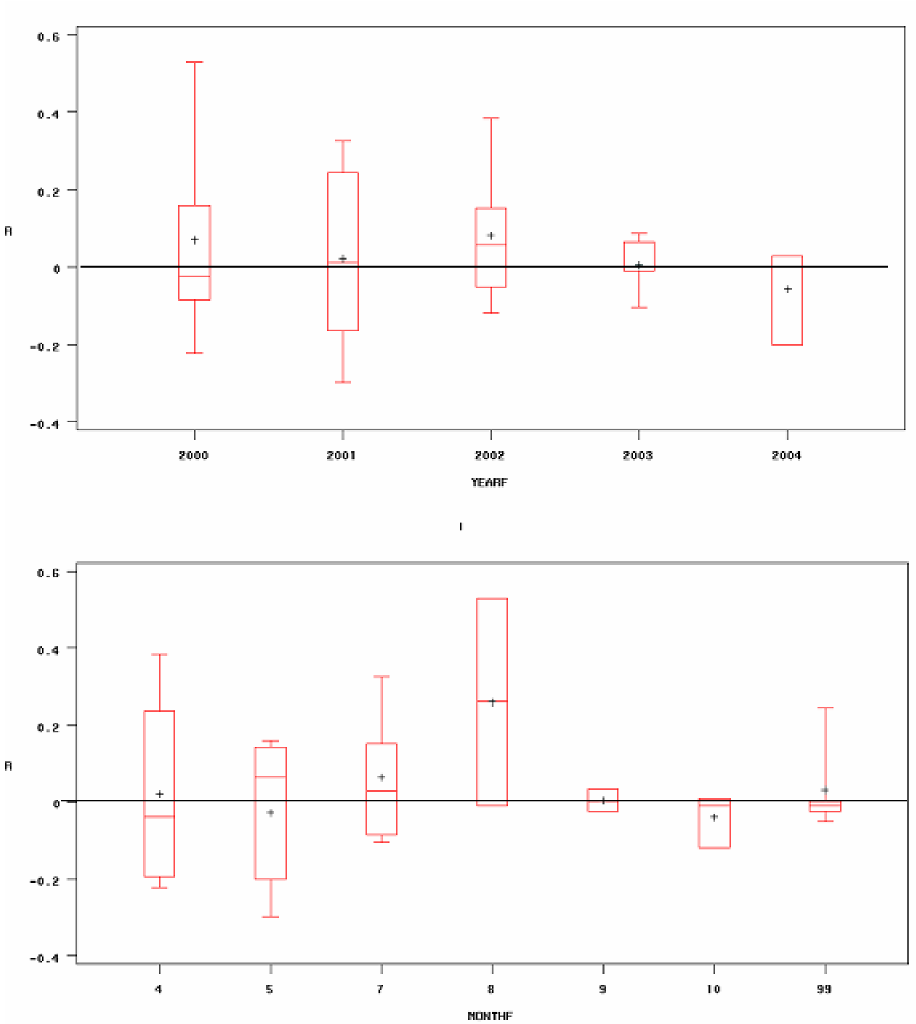


Figure 9. The distribution of residuals around estimated values for various parameters used in the catch rate model for small Canadian (<=500 t) vessels fishing shrimp in NAFO Div. 3LNO over the period 2000 – 2004.

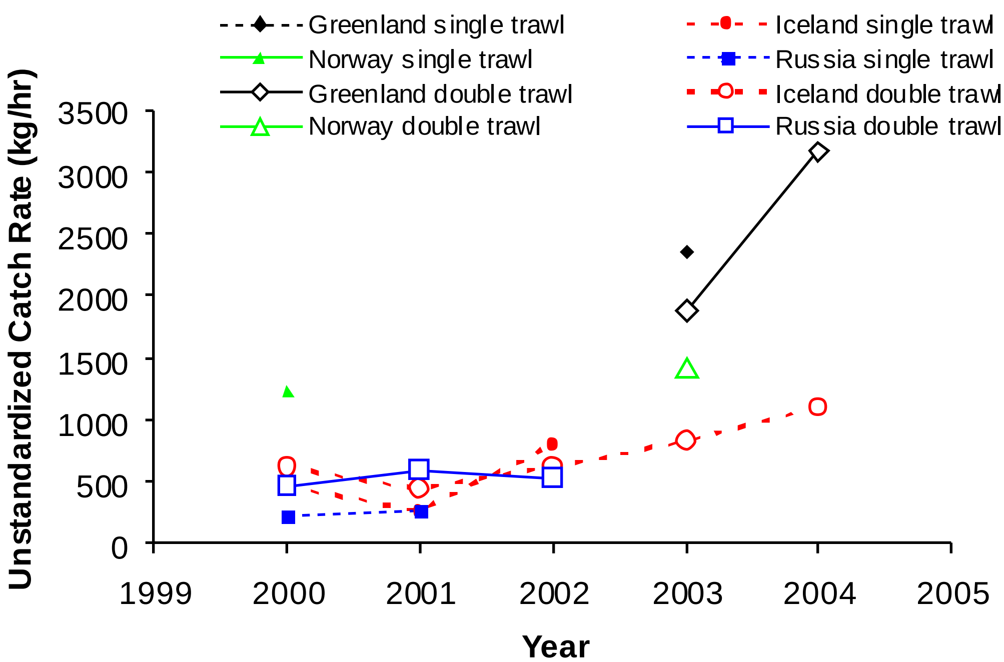


Figure 10. Unstandardized catch rates by internationals fleets fishing northern shrimp in the NAFO Div. 3LNO NRA over the period 2000 – 2004.

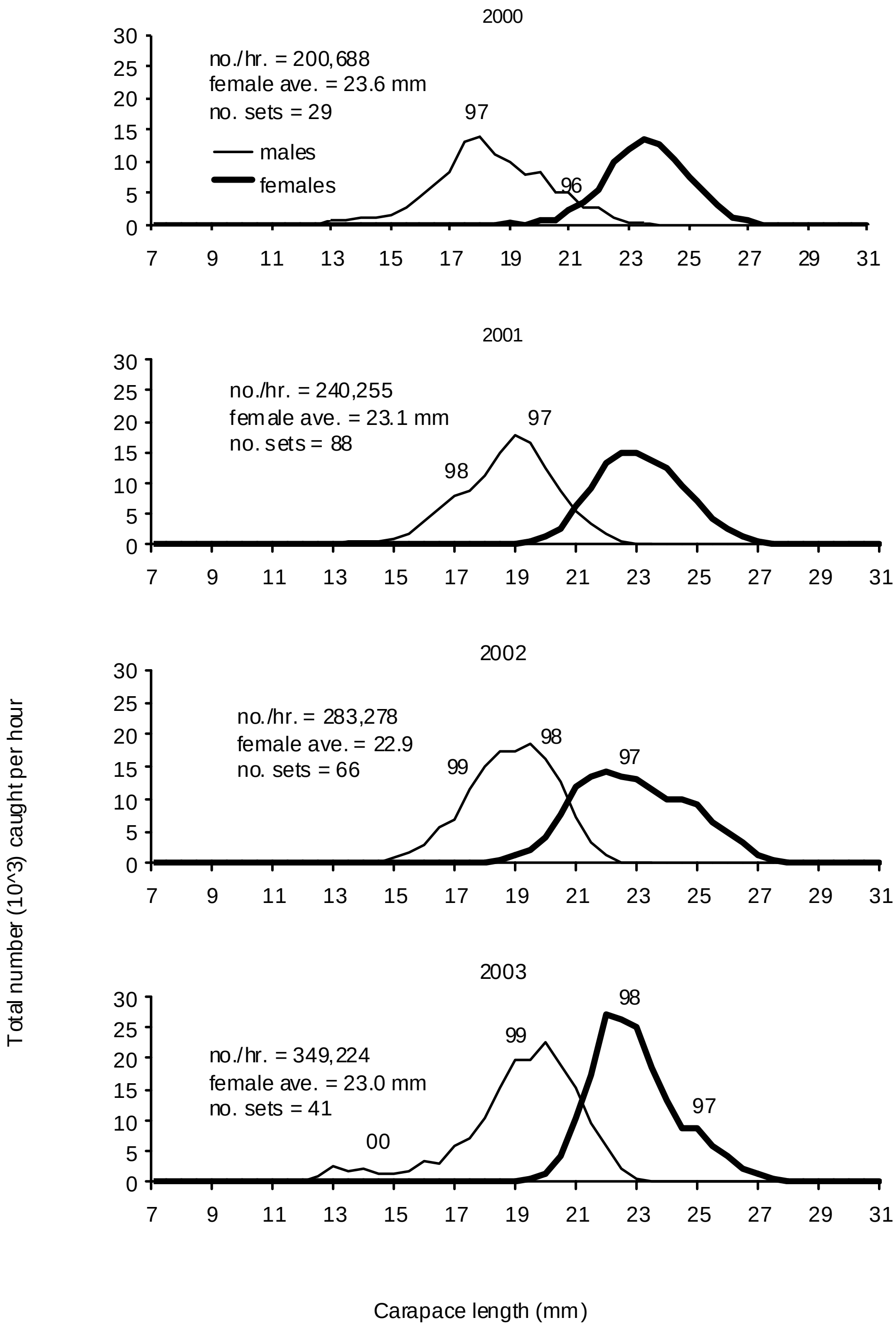


Figure 11. Observed northern shrimp length frequencies from the large vessel (>500 t) fleet fishing shrimp in NAFO Div. 3LNO over the period 2000-2003.

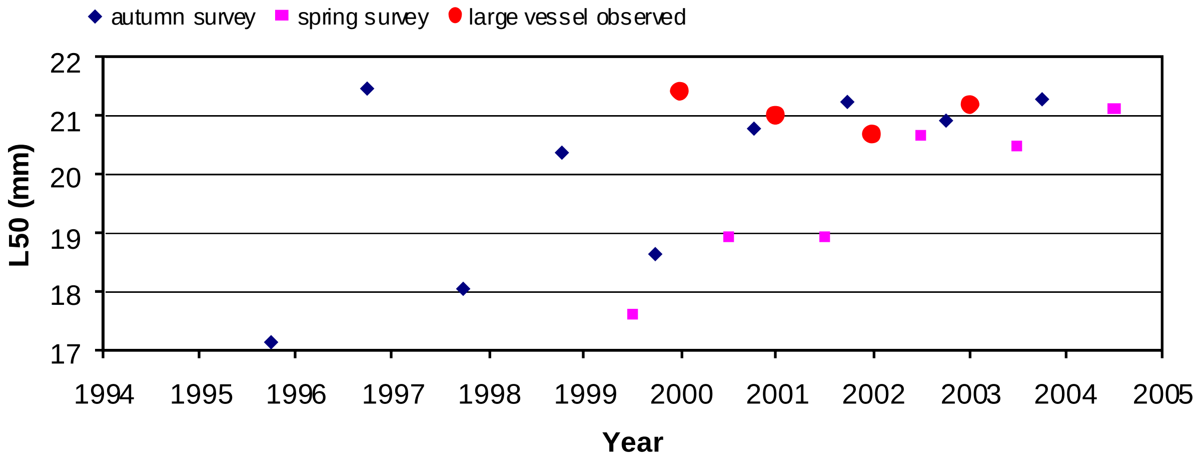


Figure 12. A comparison between L_{50} values derived from Canadian autumn and spring research bottom trawl surveys and those derived from large vessel (>500 t) commercial length frequencies. L_{50} refers to the size at which 50% of the shrimp population changes from male to female.

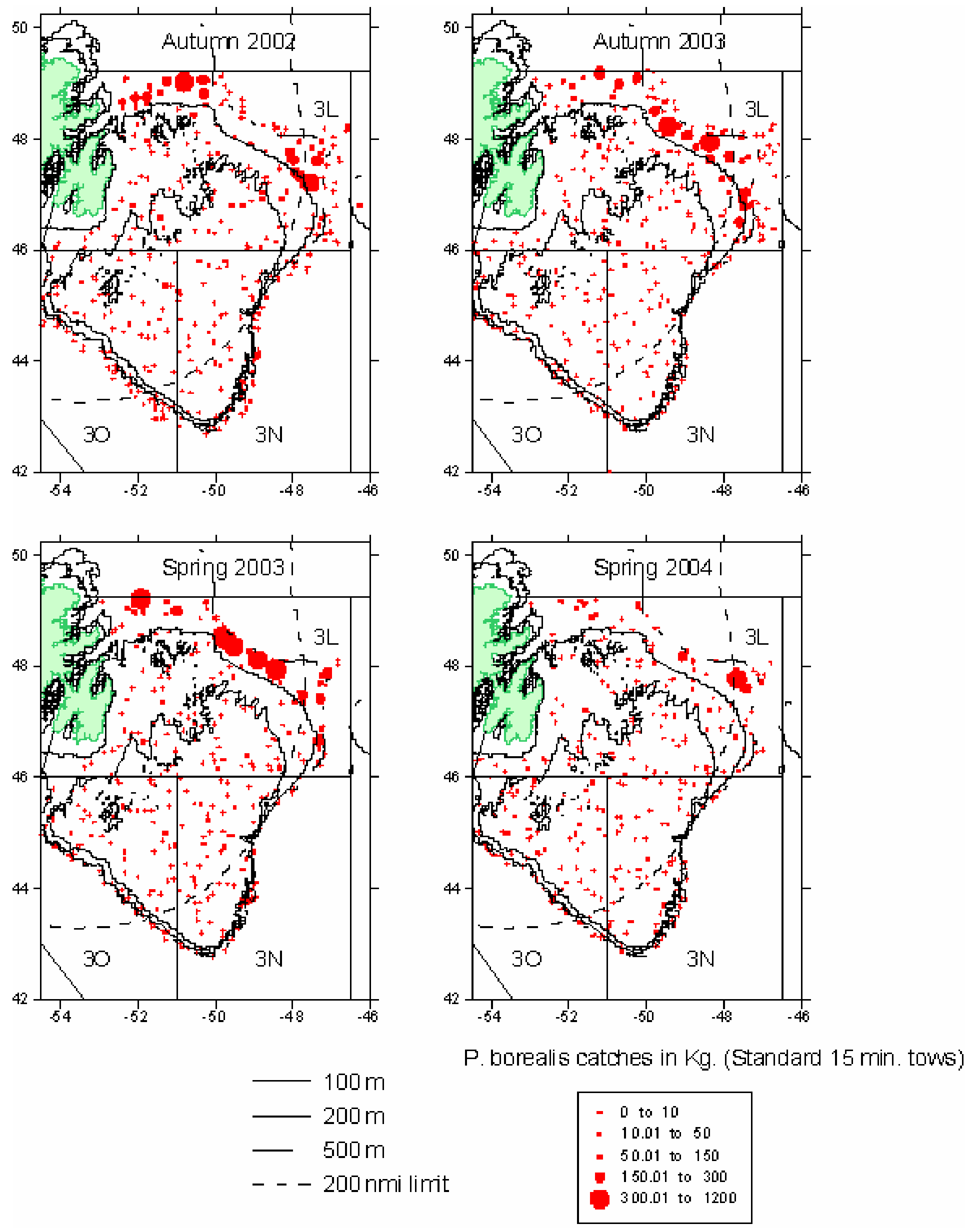


Figure 13. Distribution of NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) catches (kg/tow) as obtained from spring and autumn Canadian research bottom trawl surveys conducted over the period 2002 – 2004 using a Campelen 1800 shrimp trawl.

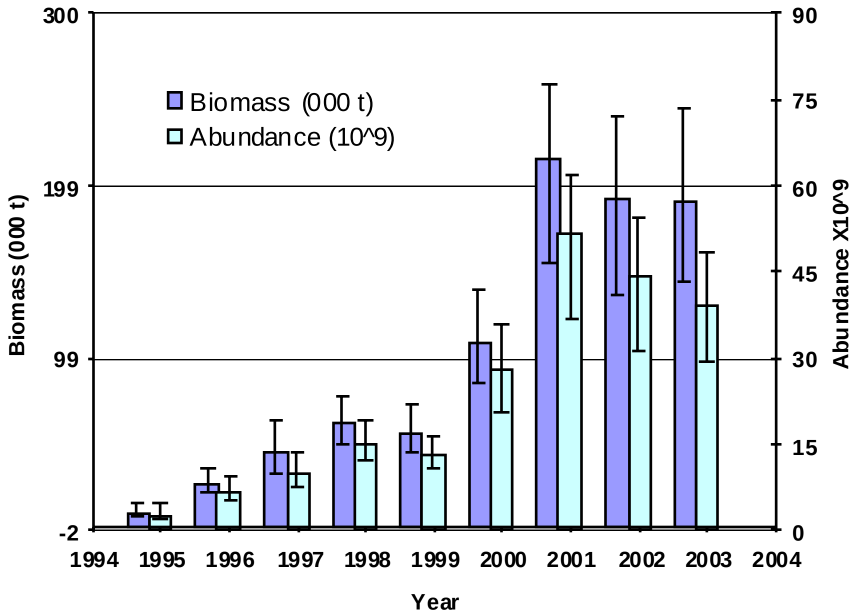


Figure 14. Autumn northern shrimp (*Pandalus borealis*) abundance and biomass indices within NAFO Div. 3LNO, as determined using Ogmap calculations. Data were from Canadian multi-species bottom trawl surveys using a Campelen 1800 shrimp trawl. (standard 15 min. tows).

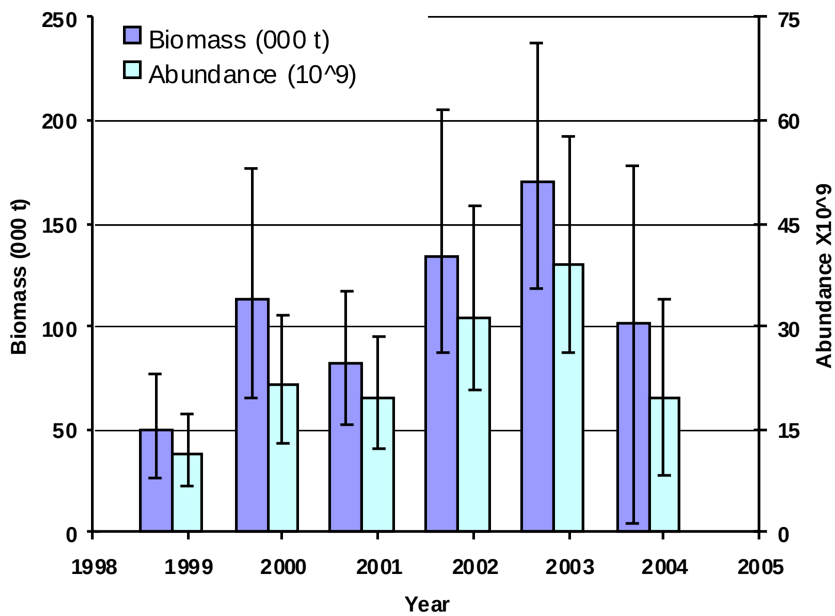


Figure 15. Spring northern shrimp (*Pandalus borealis*) abundance and biomass indices within NAFO Div. 3LNO, as determined using Ogmap calculations. Data were from Canadian multi-species bottom trawl surveys using a Campelen 1800 shrimp trawl. (standard 15 min. tows).

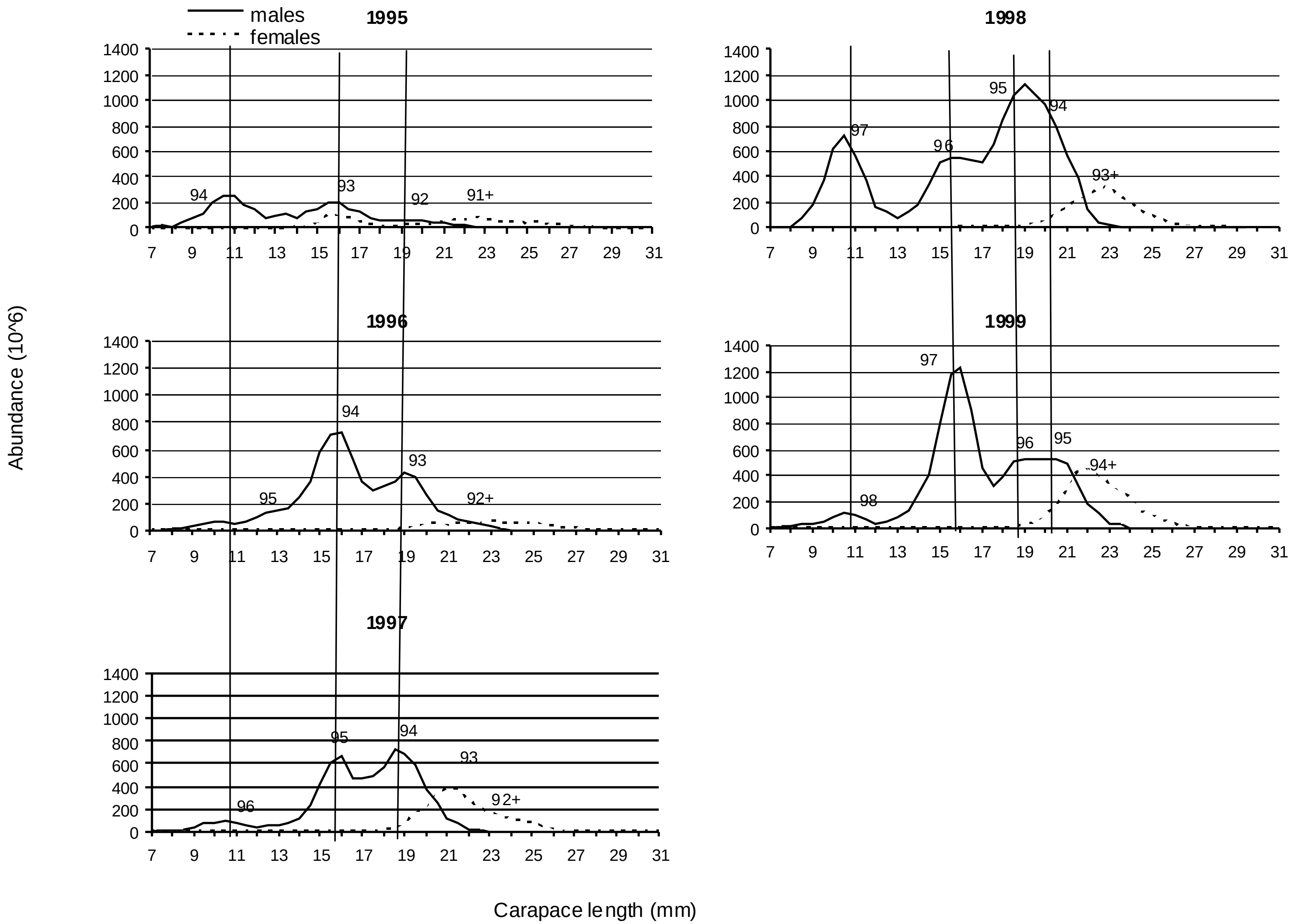


Figure 16. Abundance at length for NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) estimated by ogmap analysis of Canadian autumn multi-species bottom trawl survey data 1995 – 2003. Vertical lines indicate that there is inter-annual consistency in the Mix 3.01 modal analysis.

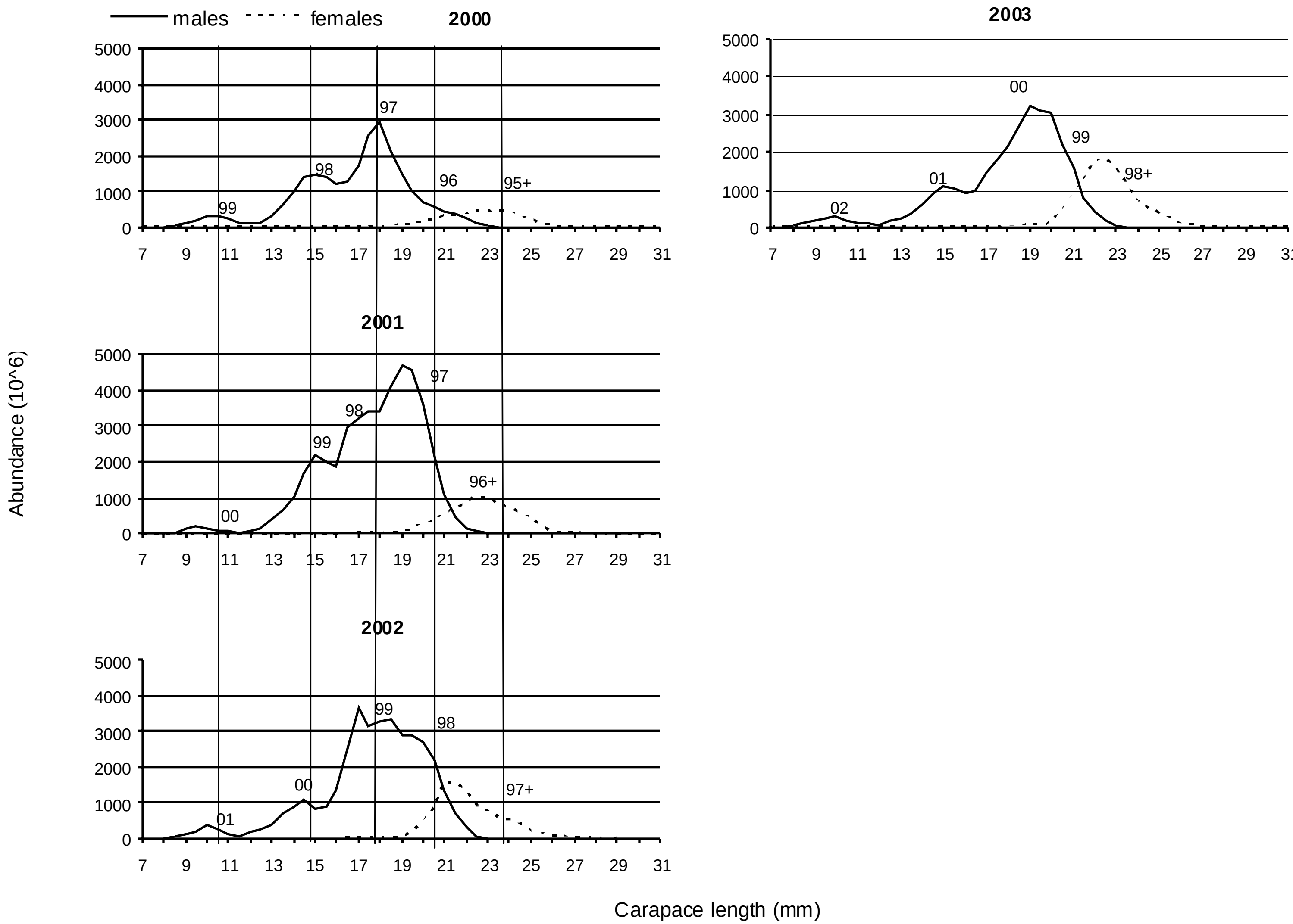


Figure 16 (cont.). Abundance at length for NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) estimated by ogmap analysis of Canadian autumn multi-species bottom trawl survey data 1995 – 2003. Vertical lines indicate that there is inter-annual consistency in the Mix 3.01 modal analysis.

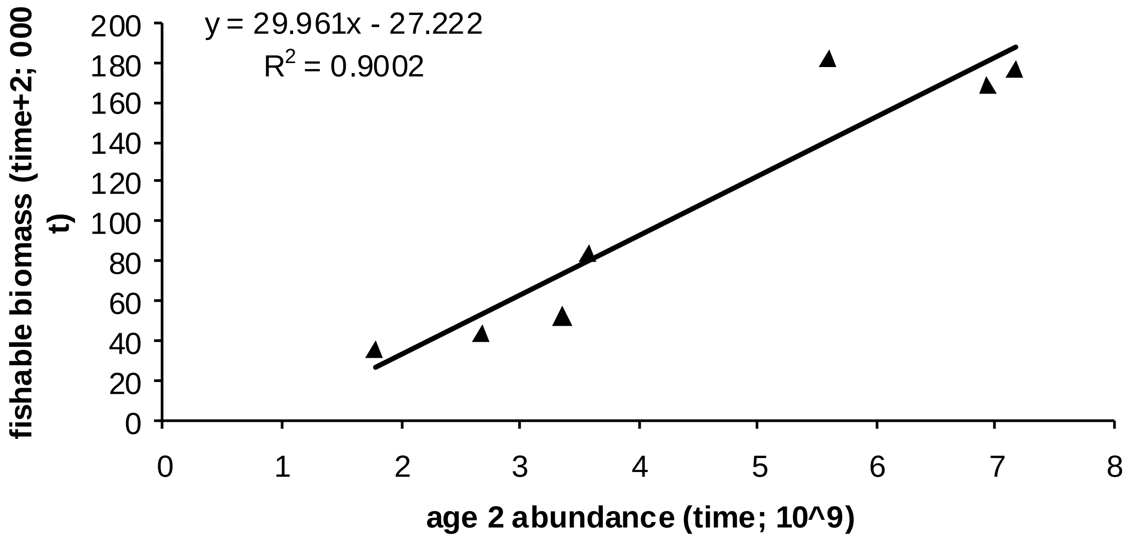


Figure 17. A relationship between fishable biomass with a two year lag and the age 2 recruitment index.

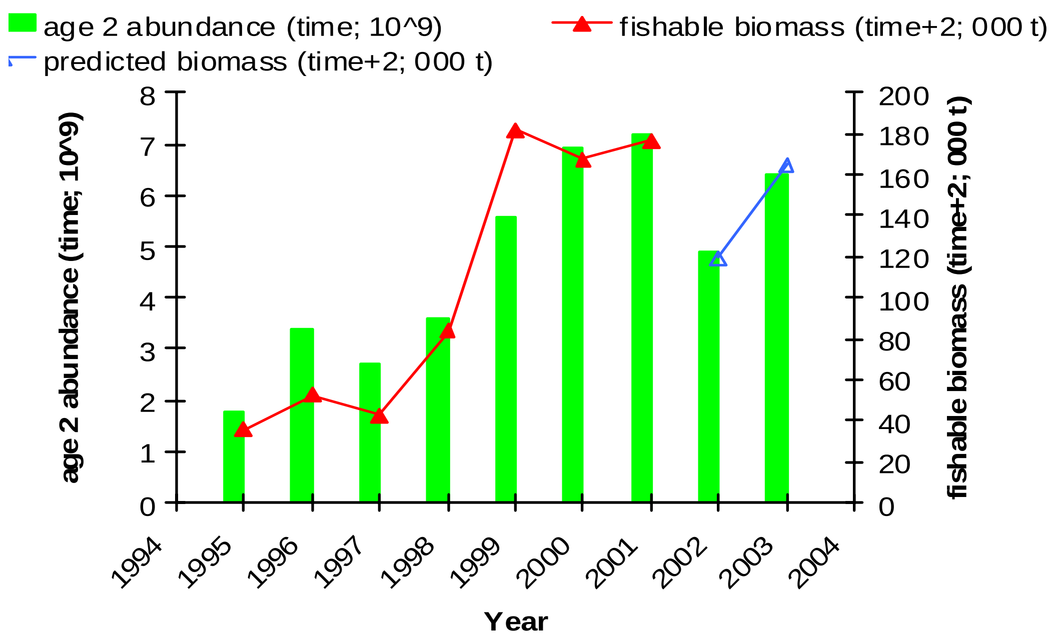
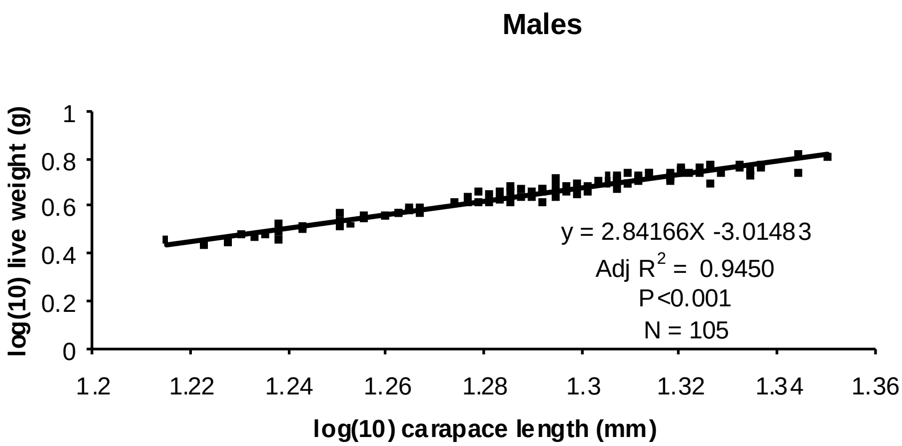


Figure 18. Using the age 2 recruitment index ($time_o$) to predict future fishable biomass ($time_{t+2}$). The 2002 and 2003 age 2 recruitment indices are used in predicting the 2004 and 2005 fishable biomasses.



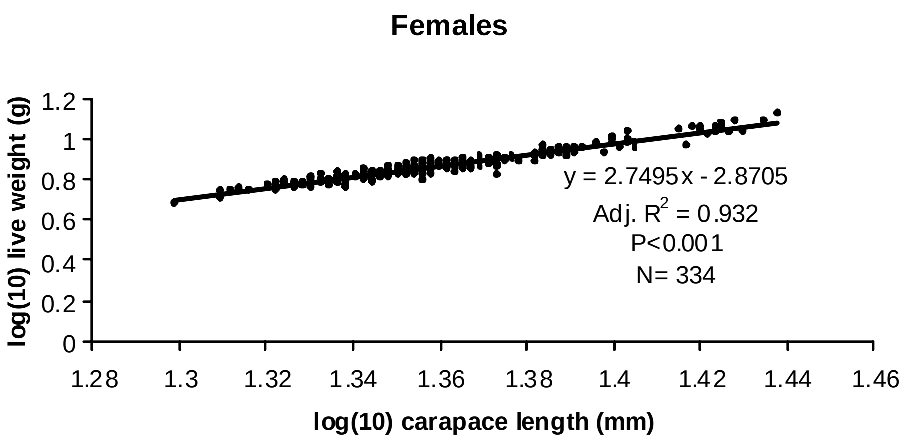


Figure 19. Male and non-ovigerous female northern shrimp live weight versus carapace length relationships. Data were obtained from the Canadian 2004 spring research

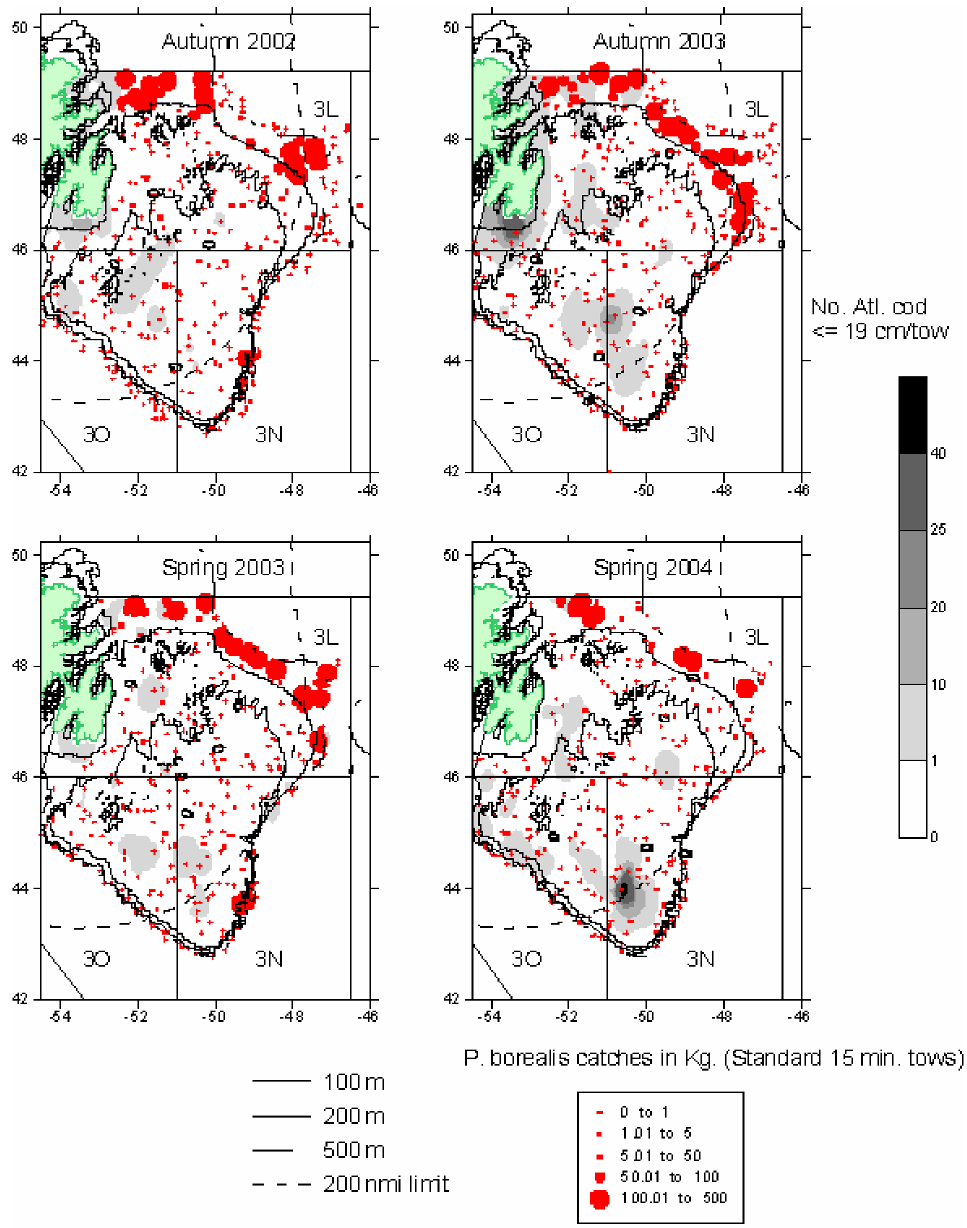


Figure 20. Distribution of northern shrimp in relation to Atlantic cod (TL<=19 cm) collected during Canadian autumn 2002 – spring 2004 multi-species bottom trawl surveys. (Catches were made using a Campelen 1800 shrimp trawl; standard 15 min. tows).

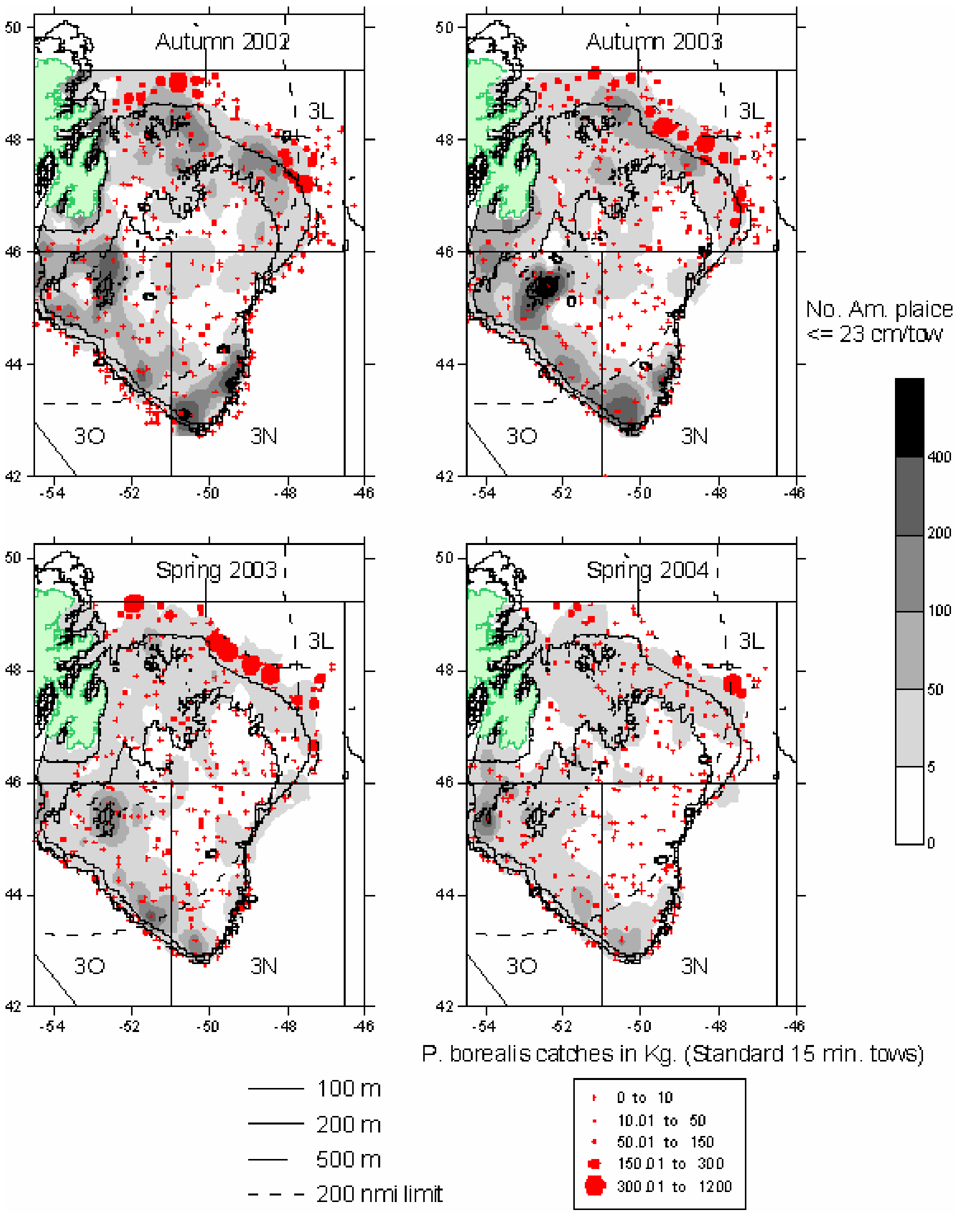


Figure 21. Distribution of northern shrimp in relation to American plaice (TL<=23 cm) collected during Canadian autumn 2002 – spring 2004 multi-species bottom trawl surveys. (Catches were made using a Campelen 1800 shrimp trawl; standard 15 min. tows).

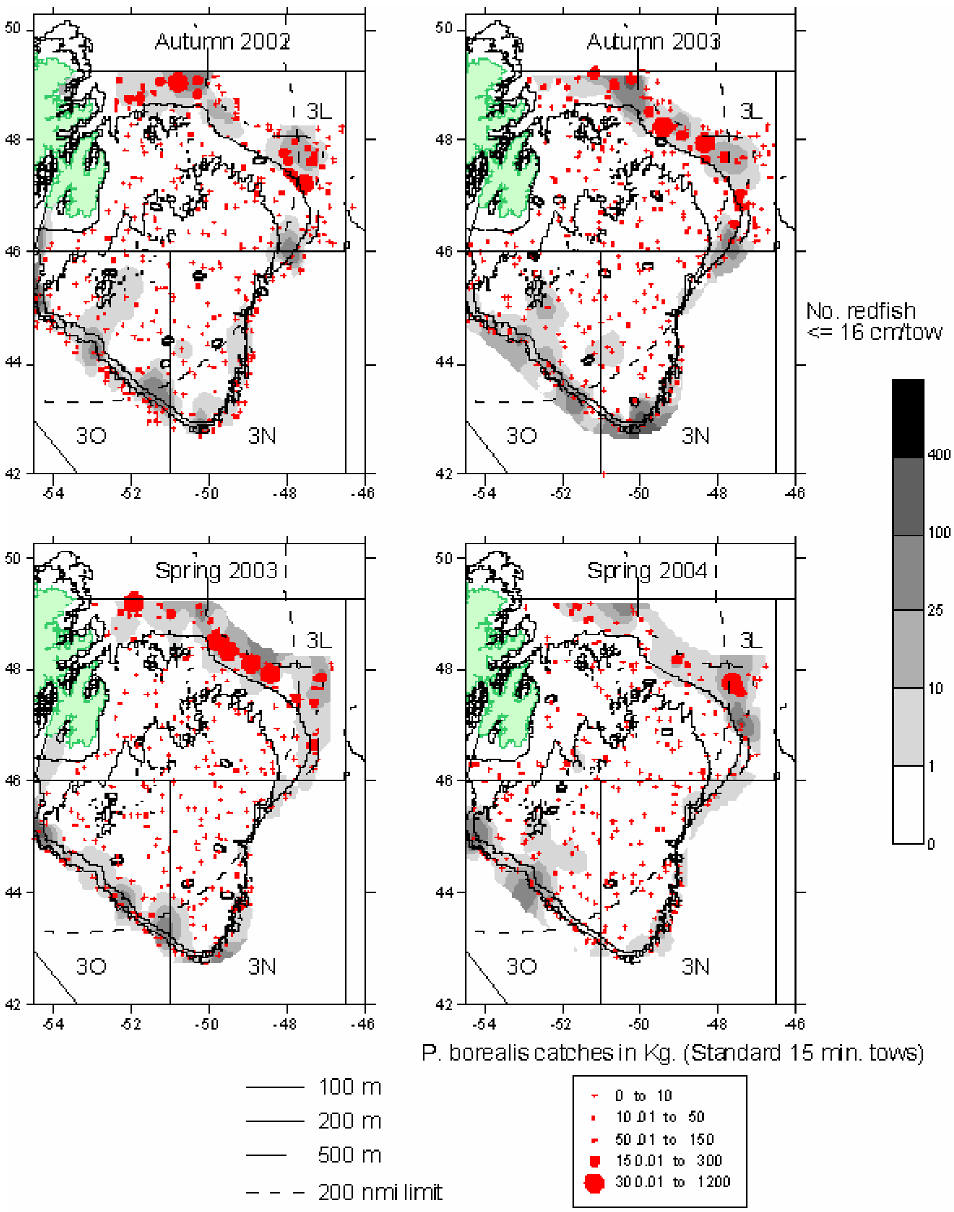


Figure 22. Distribution of northern shrimp in relation to redfish (*Sebastes* spp.) (TL<=16 cm)collected during Canadian autumn 2002 – spring 2004 multi-species bottom trawl surveys. (Catches were made using a Campelen 1800 shrimp trawl; standard 15 min. tows).

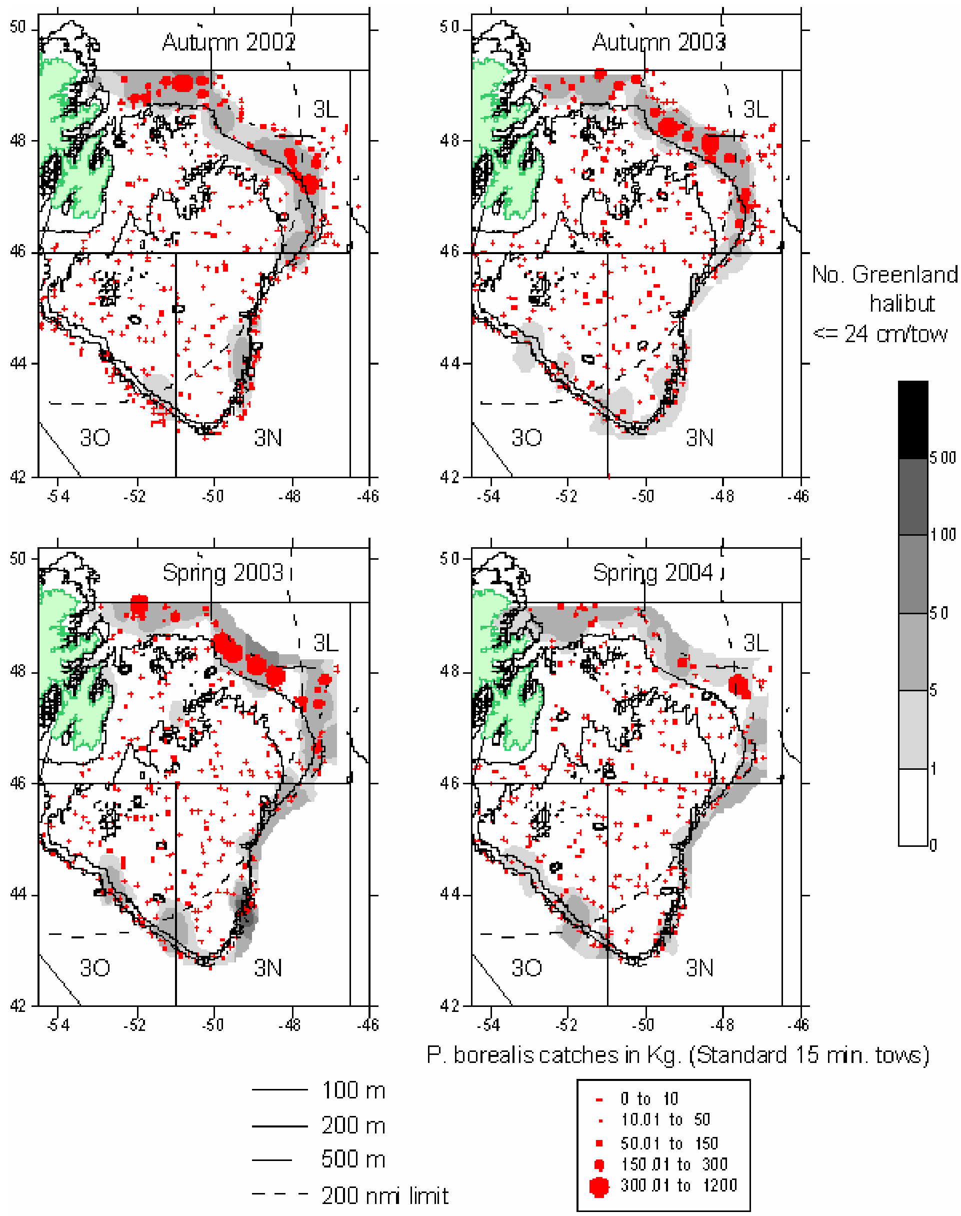


Figure 23. Distribution of northern shrimp in relation to Greenland halibut (TL<=24 cm)collected during Canadian autumn 2002 – spring 2004 multi-species bottom trawl surveys. (Catches were made using a Campelen 1800 shrimp trawl; standard 15 min. tows).