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Northwest Atlantic Fisheries Organization

Serial No. N5587 **NAFO SCR Doc. 08/058**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – OCTOBER 2008

An update of information pertaining to Northern Shrimp (*Pandalus borealis*, Kroyer)
in NAFO Divisions 3LNO

by

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

ABSTRACT:

This paper describes the 2008 northern shrimp (*Pandalus borealis*, Kroyer) 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, as well as, Canadian multi-species survey bottom trawl indices. The catch table (to October 2008) and biomass estimates (autumn 1995 – spring 2008) are updated within this report. Preliminary data indicate that 23,856 t of shrimp were taken against a 22 000 TAC in 2007 while 22 932 t were taken against a 25,000 t TAC in 2008.

The autumn 2007 biomass index was estimated to be 275 100 t, the highest in the autumn survey biomass time series. The spring 2008 3LNO biomass index was 232 400 tons, the second highest in spring survey biomass time series. Indices derived from spring surveys are thought to be less precise because the confidence intervals may be broad relative to confidence intervals around the respective autumn indices.

Biomass and abundance of shrimp increased significantly since 1999 and remained broadly distributed over the study area. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean since 2000 with the 2008 catch rate near term average and similar to the 2002 and 2004- 2007 catch rates. The Canadian small vessel standardized CPUE for 2007 was near the long term average and similar to the 2004 catch rate.

A new method of determining recruitment and fishable biomass indices is proposed. Additionally, the lowest female spawning stock biomass (B_{Loss}) and an upper productive period are proposed as reference points to be used in the precautionary approach toward then management of the northern shrimp resource.

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.

Additionally, during the September 2008 NAFO SC meeting, Fisheries Commission (FC) requested that Scientific Council (SC) provide a range of options, at various levels of exploitation, to assist FC in establishing a TAC for this stock in 2010. Therefore, this report provides the results of a TAC determination based upon the inverse variance weighted average fishable biomass from the four most recent Canadian bottom trawl surveys in NAFO Divisions 3LNO.

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 t quota was established and fishing was restricted to Division 3L, at depths greater than 200 m. The 6,000 t quota was established as 15% of the lower confidence limit below the autumn 1998 3L biomass index. This harvest level approximated those estimated for shrimp fishing areas along the coast of Labrador and off the east coast of Newfoundland (NAFO divs. 2HJ3K) (Orr *et al.* 2007). 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 t quota was established in the Exclusive Economic Zone (EEZ) for Canada while a 1,000 t 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 Divisions 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 t. Accordingly, SC recommended that the TAC for shrimp in Div. 3LNO in 2003 and 2004 should not exceed 13,000 t. 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).

In 2004, an analysis was completed to determine a TAC for the 2006 fishery. Due to the highly variable nature of the spring survey indices, Scientific Council (SC) felt it was necessary to change the methodology used in determining TACs. The TAC within an adjacent Canadian stock had been 12% of the fishable biomass since 1997. Applying this percentage to the inverse variance weighted average fishable biomass from the autumn 2002 – spring 2004 surveys resulted in a TAC of 22,000 t. Had this new method been used in 2003, it is likely that the adviced TAC calculated for 2005 would have been around 22,000 t instead of the 13,000 t actually advised. However, SC noted that the TAC recommendation for this stock has always included advice that “the development of any fishery in the Div. 3L area take place in a gradual manner with conservative catch limits imposed and maintained for a number of years in order to monitor stock response.” The initial TAC of 6 000 t was in place for 3 years, however the 13,000 t TAC had been in place since the beginning of 2003. A two year period was insufficient to determine the impact of a 13,000 t catch level upon the stock; therefore SC recommended that the 13,000 TAC be maintained through 2005. Scientific Council recommended that the 2006 TAC for shrimp in Divs. 3LNO should not exceed 22,000 t. 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. During the November 2007 shrimp assessment, SC was asked to determine exploitation rates for various catch options assuming that the fishable biomass remains at the 2007 level. During May 2008, a special session of FC decided that the 2008 and 2009 quotas should be increased to 25,000 t and that the advice would be reviewed in September 2008.

Until the 2007 shrimp stock assessment, biomass and abundance indices and length frequencies have been estimated using stratified area expansion calculations (Cochran, 1997; using SAS programs written by D. Orr). This method makes use of three main assumptions:

- catches are normally distributed,
- there is no correlation between catches in adjacent strata, and
- the within stratum environment is uniform; therefore catches within a stratum may be averaged and extrapolated to the entire stratum.

Unfortunately these assumptions are not always realized. Data are probably not normally distributed if the survey includes one or two very large catches. For example, the spring 2000 survey included two anomalously high catches (500 and 511 kg) while the spring 2004 survey included one anomalously high catch (1060 kg). These catches resulted in biomass and abundance indices that were thought to be imprecise because 95% confidence intervals were broad with negative lower confidence limits. As noted in Evans *et al.* (2000), the survey makes use of a groundfish stratification scheme therefore the sample design may not be suited to monitor shrimp stock status. It is likely that observations in adjacent strata but nearby locations (taking depth into account) are more similar than observations within the same stratum but at opposite ends of the stratum (Fig. 1). A continuous approach to index calculation may be more appropriate. Therefore, during the October – November 2006 NIPAG shrimp stock assessment meeting, it was decided that biomass/ abundance and population adjusted length frequencies could be calculated using Ogive Mapping (Evans *et* al. 2000). Orr *et al.* 2007, presents an assessment in which the results from indices derived using areal expansion are compared with those derived using Ogmap calculations

Full assessments of this stock are completed during the annual October - November shrimp assessment meetings. Results from these assessments provide necessary input for quota decisions made during Fishery Commission meetings, held during September. Canadian autumn and spring multi-species bottom trawl 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 2008.

The present document was produced for the October 2008 NAFO-ICES Pandalus Assessment Group (NIPAG) assessment meeting and therefore provides a full assessment of the Divs. 3LNO shrimp resource.

METHODS AND MATERIALS:

Data were collected from the following sources:

- Canadian observer databases;
- Canadian logbook databases;
- International observer/ logbook databases; and
- Canadian autumn and spring multi-species research surveys.
- Canadian observer database:

Approximately 13 large (>500 t) fishing vessels and more than 300 smaller (<=500 t; <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, while the small vessels have a target of 10% observer coverage. 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 shrimp fishing fleet. Observed data were used because that dataset includes the number of trawls and usage of windows (escape openings) whereas the logbook dataset does not. Raw catch-per-unit effort data was standardized by multiple regression, weighted by effort, in an attempt to account for variation due to year, month, number of trawls, gross registered tonnage (grt) etc. The multiplicative model has the following logarithmic form:

$$\mathrm{Ln}(\mathrm{CPUE}_{ijkml}) = \ln(u) + \ln(S_j) + \ln(V_k) + \ln(T_m) + \ln(Y_l) + e_{ijkml}$$

Where: CPUE_{ijkml} is the CPUE for grt k, fishing x number of trawls, 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;

T_m is the effect of m number of trawls;

Y_l is the effect of the l^{th} *year;*

e_{ijkml} 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.

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 2008 YEAR parameter estimate and those of previous years was inferred from the output statistics.

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

Canadian logbook database:

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 3%.

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 captured in each CPUE model.

International observer and logbook information:

These data were made available by Contracting Parties that fish shrimp in Div. 3L NRA. They were used in CPUE calculations and catches 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. Estonia, Greenland, Iceland, Norway, Spain and Russia provided catch and effort data over a number of years making it possible to derive standardized catch rates for the NRA.

Canadian spring and autumn multi-species research surveys:

Spring and autumn multi-species research surveys, using a Campelen 1800 shrimp trawl, have been conducted onboard the Canadian Coast Guard vessels Wilfred Templeman, Teleost and Alfred Needler since 1995. Fishing sets of 15 minute duration, with a tow speed of 3 knots, were randomly allocated to strata covering the Grand Banks and slope waters to a depth of 1,462 m in the autumn and 731 m in the spring, with the number of sets in a stratum proportional to its size (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 were employed to monitor net geometry. Details of the survey design and fishing protocols are outlined in (Brodie, 1996; McCallum and Walsh, 1996).

Due to operational difficulties it was not possible to survey all of the strata within NAFO Divisions 3LNO during autumn 2004 (Brodie, 2005). The deepwater strata (deeper than 731 m) within 3LNO as well as several shallow water strata within 3L were not surveyed. Historically very few northern shrimp have been taken from the deepwater strata; therefore, the impact of not sampling the deepwater was felt to be negligible. Analyses of the autumn 1995-2003 and 2005 survey data indicate that the 3L strata missed in 2004 (93-549 m) are important in determining the biomass indices. Typically these strata account for 25-61% of the 3L biomass (Orr *et al*., 2007).

Please note that all strata, within the NRA, that contained significant quantities of northern shrimp, in previous spring and autumn surveys, were surveyed during autumn 2004.

All strata were surveyed during autumn 2005 and 2006.

Due to operational difficulties it was not possible to survey all of the strata within NAFO Div. 3NO during spring 2006. Strata 373 and 383 as well as most 3NO strata deeper than 92 m were not surveyed.

Since 2003, shrimp species and maturity stage identifications, as well as length frequency determinations have been made at sea, whenever possible. Otherwise, shrimp were frozen and returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage was made. Shrimp maturity was defined by the following 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 were estimated from the sampling data. Inshore strata were not sampled in all years; therefore, the analysis was restricted to data collected from offshore strata only. Total biomass, abundance and length frequency estimates were determined using OGive MAPping calculations (Evans *et al.* 2000). During spring and autumn of 2004, carapace lengths and live weights of approximately 1500 *Pandalus borealis* were measured within 24 hours of capture. Lengths and weights were converted to $\log_{10}$ values, and regression models were developed for males, transitionals ovigerous and non-ovigerous females.

Modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) was conducted on male research length frequencies. As in previous assessments, fishable biomass was plotted against recruitment to determine whether a recruitment – stock relationship exists. This year, a new recruitment index was developed. Since the shrimp are thought to recruit to the fishery at age three and the fishable biomass is defined as the biomass of males > 17 mm in carapace length + the female biomass, the new recruitment index was the abundance of males with 12 – 17 mm carapace lengths. The proposed recruitment index size range is based upon the size range of animals that will probably recruit to the fishery within a year. We decided upon switching from an age based to a size based recruitment index because recruitment to the fishery is probably size rather than age based. Rather than determining fishable male biomass from the population adjusted male length frequency as in the past, the new fishable biomass index was determined by estimating the weight of fishable males + weight of females on a set by set basis and then estimating biomass using Ogmap calculations. The new methods of determining recruitment and fishable biomass allowed direct determination of confidence intervals. The new fishable biomass index was used in regression analyses, with various lags, against the new recruitment index to determine whether there was improvement in recruit – stock relationship. Such relationships 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,

female 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 models:

$Wt(g) = 0.00088*lt(mm)^{2.857}$ for autumn samples

$Wt(g) = 0.000966*lt(mm)^{2.842}$ for spring samples

(these models were derived from length weight relationships described above)

Spawning stock biomass (transitionals + primiparous females and ovigerous + multiparous females) was determined via both stratified area expansion and Ogmap calculations.

All indices (biomass, abundance, fishable biomass, female biomass (SSB)) as well as population adjusted shrimp carapace length frequencies were calculated using Ogmap (Evans *et al.* 2000).

Survival, annual mortality and instantaneous mortality estimates were calculated from the modal analysis results. The survival of age 4+ males and total females was compared with the surviving female abundances. This was completed by combining 3 years of data in order to account for vagaries within the survey data and due to aging by modal analysis. The survival results were then used to determine annual mortality (1-survival) and instantaneous mortality (Z=-ln(survival)).

<u>OGive MAPping (ogmap):</u>

OGive MAPping was developed by Dr. G. Evans (DFO – NL Region) to calculate abundance and biomass indices, and population adjusted length frequencies. The method described within Evans (2000) and Evans *et al.* (2000) assumes that:

- trawl sets are independent random samples from the probability distributions at set locations; and
- nearby distributions are related.

As a first step in the exercise, a dense set of Delauney triangles of known position and depth were developed from the 1995 – 2002 autumn surveys (Figs. 2 - 4). Catch information was then used to determine the appropriate horizontal and vertical steps used by Ogmap in weighting values according to distances (horizontal and vertical) from each sample location. Points closer to the sample location receive higher weights. Step determination is described in Evans *et al.* (2000). The appropriate horizontal and vertical steps for the present set of analyses were 30.81 km and .99 m respectively.

Ogmap is then used to compute the expected value of the distribution at every vertex in each Delauney triangle. The expected value for shrimp biomass within each triangle is integrated using bilinear interpolation. The expected biomass within 3LNO is the sum over all triangles. A Monte Carlo simulation resamples the whole probability distribution at every survey point to provide a new biomass point estimate. Five hundred such simulations are run to provide a probability distribution for the estimated biomass. The point estimate is provided from the entire survey dataset, while the probability distribution is determined through Monte Carlo simulation. Non-parametric 95% percent confidence intervals are then read from the probability distribution (Fig. 5).

TAC determinations:

TAC calculations were based upon the inverse variance weighted average fishable biomass from the four most recent Canadian bottom trawl multi-species surveys. The formula used was determined as follows:

Variance measure = Ogmap fishable biomass estimate – lower 95% confidence interval

inverse variance weighted average fishable biomass =

$$\sum_{i=4}^{1\ \text{to}\ 4} (\text{fishable biomass}_i/(\text{variance measure})^2)/\sum_{i=4}^{1\ \text{to}\ 4} 1/(\text{variance measure})^2$$

Catch rates were determined as the catches prescribed by Fisheries Commission divided by the inverse variance weighted average fishable biomass. Additionally, Shrimp Fishing Area (SFA) 6, which is adjacent to Division 3L, has an exploitation rate (catch/ fishable biomass from the previous survey) that has averaged 14.3% over the period 2003 - 2006; therefore one of the TAC's was based upon 14% of the inverse variance weighted average fishable biomass.

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

Canadian vessels caught 11 t 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 t respectively (Statlant 21A).

During autumn 1995, the Canadian multi-species surveys began to use a Campelen 1800 shrimp trawl and 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 t.

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 – 2004, catches were 4 711, 10,697, 6 994, 13 100 and 13,461 t respectively (Table 1; Fig. 6). Catch data indicate that 14 387t of shrimp were taken against a 13,000 t quota in 2005 while 23 587 t were taken against a 22,000 t TAC in 2006. Preliminary data indicate that 23,856 t had been taken against a 22,000 t TAC in 2007 while 22,932 t of shrimp had been taken against a 25,000 t TAC by October of 2008. It is anticipated that the 2008 quota will be taken.

As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 4 050 t in 2000 to 18,314 t in 2007. Catches by non Canadian nations increased from 661 t to 6 338 t over this period. Preliminary data indicate that by October 2008, 3 194 t had been taken against a non Canadian TAC of 3 815 t.

Canadian fleet

Since 2000, small (<=500 t) and large (>500 t) shrimp fishing vessels catches have been taken from a broad area (Figs. 7 - 9) from the northern border with 3K south east along the 200 – 500 m contours to the NRA border. The area occupied by the resource and Canadian fisheries has been increasing over the time series. However, the percent area occupied by the large vessel fishery and the resource as determined from spring survey data was less than 2% of the total available habitat of the entire time series while similar indices for the autumn survey and small vessel fisheries occupied less than 4% of the total available habitat.

The small vessel fleet fishes shrimp mainly during the spring and summer months, while seasonality of the large vessel fleet varies over time (Fig. 10).

Due to a lack of data (Fig. 7) it was not possible to model small vessel CPUE during 2008. Small vessel CPUE (2000 – 2007) was modeled using month, year and size class (class 1 = <50’ LOA; 50’ LOA <=class 2< 60’ LOA; class 3 => 60’ LOA) as explanatory variables (Table 2). The logbook dataset that was used in this analysis accounted for between 74.5% and 93.4% of the catch within any one year (Table 3). The final model explained 86% of the variance in the data and indicated that the annual, standardized catch rates increasing in 2005 with a gradual decrease to near the long term mean (431 kg/hr) since. The 2005 and 2006 catch rates were significantly higher than the 2007 index (454 kg/hr). The 2007 index was similar to the 2004 value but significantly higher than values previous to 2004 (Tables 2 and 3; Fig. 11). No clear trends were found in the plots of residuals (Fig. 12).

While the large vessel fleet has been fishing throughout the entire year over the entire 2000 – 2008 catch time series (Fig. 10), it appears to have changed from a winter spring to autumn in one year and winter in the next year fishery. However, most of the data came from the winter and spring therefore, large vessel catch rates were analyzed by multiple regression using data from the winter and spring months only. The model was weighted by effort, for year, month, number of trawls and vessel effects (Table 4). The observer dataset used in this analysis accounted for between 47% and 96% of the catch within any one year (Table 5). The final model explained 70% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean since 2004 with the 2008 standardized catch rate index (1846 kg/hr; Tables 4 and 5; Fig. 11) near the long term average (1798 kg/hr) and similar to the catch rates for 2002 and 2004 - 2007 indices (Tables 4 and 5; Fig. 10). There were no trends in the residuals around parameter estimates (Fig. 13).

The fact that the area fished by large and small vessels has increased over the past few years while the CPUE remained near the long term average implies that the resource is healthy.

International fleet

A standardized catch rate model was produced using data from Estonian, Greenlandic and Icelandic vessels fishing shrimp in the NRA. Ship, month and year were significant independent variables and produced a model that explained 76% of the variance. The number of trawls used had an insignificant influence upon model outcome. Unfortunately, the data used in this model accounted for between 1% and 29% of the catch within any one year (Table 7), therefore the results are thought to be less reliable than they were for the Canadian large and small vessel fleets. Catch rates fluctuated along the long term mean over the short time series (Tables 6 and 7; Fig. 14). The 2008 model catch rate index was similar to all but the 2004 index. The 2004 value was significantly higher than the 2008 value. The model did not include Norwegian or Spanish data as the vessels from both countries changed each year. There were no trends in the residuals around parameter estimates (Fig. 15). The unstandardized catch rates for the non-Canadian vessels were highly variable by country and year (Table 8).

Size composition

Relatively few length frequencies were collected by observers of small vessel fishing activities therefore we are not certain whether the length frequencies are representative of fleet activities (Fig. 16). The low number of length frequencies resulted in very jagged length distributions that could not be aged using modal analysis. However, it is noteworthy that the length frequencies for both non-ovigerous and ovigerous animals were broad for each year implying that more than one year class was evident within the catch.

On the other hand, several length frequency observations were taken from large vessel catches (Fig. 17). Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females believed to be at least three years of age. The male modes overlapped to the extent that it was not possible to complete Mix distribution analysis; however, the male modes often had two faint sub-peaks implying the presence of more than one year class. Given that the modes were usually near 17 mm and 20 mm, these animals were probably 3 and 4 years of age respectively. The female length frequency distributions were also broad indicating that the female portion of the catch probably consists of more than one age group. Catch rates had been maintained at over 200,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 18.6 mm and 19.7 mm, while the weighted average carapace lengths for females ranged between 22.9 mm and 23.8 mm. There were no trends in the average size of either males or females.

Figure 18 presents the length frequencies from the 2006 and 2007 Spanish catches. As with the Canadian size compositions, this figure also shows a broad range in sizes of shrimp, probably from at least three year classes. Given the fact that the Spanish catches represented 4% and 3.4% of the total catch in the NRA in 2006 or 2007 respectively, it is not clear whether the length frequencies are representative of the non-Canadian fleet catches. Unfortunately, length frequency data were not available from the non-Canadian fleet, for the year 2008.

RESEARCH SURVEY DATA

It must be noted that during the analysis of the data for this assessment, it was discovered that the tow durations that had been used for all previous assessments had not been corrected using CTD bottom times. The present data files have the corrected times against which data are standardized. Therefore, the survey estimates provided within the present assessment may not agree with previous assessments.

Stock size

As illustrated in figures 19 and 20, the autumn 2004 – 2007 and spring 2005 – 2008 research catches are concentrated within NAFO Div. 3L at depths between 200 and 500 m. The autumn 2007 survey resulted in a biomass estimate of 275,100 t (95% confidence range = 209,100 t – 359,200 t); the highest in the autumn time series (Table 9; Fig. 21), while the spring 2008 Div. 3LNO trawlable biomass was 232,400 t (95% confidence range = 171,800 t – 289,100 t); the second highest value in the spring time series Table 9; Fig 22). It must be noted that in general, the spring indices are thought to be less precise because the 95% confidence intervals are sometimes broad relative to autumn intervals.

Deepwater strata (deeper than 731 m) within Divisions 3LNO as well as several shallow water strata within Division 3L were not surveyed during autumn 2004 (Brodie, 2005; Healey and Dwyer, 2006) (fig. 19). Historically very few northern shrimp have been taken from the deepwater strata; therefore, the impact of not sampling the deepwater was felt to be negligible. Strata that were missed, in Division 3L, (autumn 2004); however, all NAFO Regulatory Area (NRA) strata containing significant quantities of northern shrimp have been surveyed consistently throughout the time series.

Analyses of the autumn survey data indicate that the shallow (93-549 m) 3L strata missed in 2004 are important in determining the biomass indices. Typically these strata account for 25-61% of the 3L biomass (Table 1 within Orr *et al.* 2006). Figures 19 and 20 confirms the importance of these strata and that catches, within these strata, vary annually. Therefore, it was not appropriate to use a multiplicative model to estimate 3L biomass and abundance indices from the autumn 2004 survey.

Throughout the history of the spring survey, it was possible to survey all important NAFO Division 3L strata (100 m - 751 m). However, due to operational difficulties it was not possible to survey all of the strata within NAFO Divisions 3NO during spring 2006. Strata 373 and 383 as well as most strata deeper than 92 m were not surveyed (Fig. 22). Therefore biomass and abundance indices were not determined for NAFO Divisions 3NO during spring 2006. Historically, at least 95.9% of the 3LNO shrimp biomass has been found within Division 3L (Tables 10 and 11); therefore, the spring 2006 indices were for NAFO Divisions 3L only.

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

Between 92.3 and 100% 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 11.2 and 28.0% of the estimated total 3LNO biomass (Tables 10 and 11; Figs. 19 and 20; Orr *et al.* 2007). Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 12.5 – 20.1% of the total 3LNO autumn biomass was within the NRA (Table 10). Over the period 1996 – 2007 the overall average autumn percent biomass within the NRA was 17.3%. However, during the spring, the percent biomass within the NRA ranged between 18.7 and 24.8% (Table 11). Over the period 1999 – 2008 the average spring percent biomass with the NRA was 21.2%. It must be noted that variances around the spring indices are greater than around autumn indices (Table 9; Figs. 21 and 22).

In all surveys, Division 3N accounted for 0.4-8.1% of the total 3LNO biomass (Tables 10 and 11). Between 33.0 and 77.4% of the 3N biomass was found outside the 200 Nmi limit. Division 3O accounted for less than 1% of the 3LNO biomass. A negligible amount of the Division 3O biomass was found outside the 200 Nmi limit.

Stock composition

Length distributions representing abundance – at – length from the autumn 1996 - spring 2008 surveys are compared in figures 23 and 24. Modes increase in height as one moves from ages 1 – 3 indicating that modes become more overlapping and that catchability of the research trawl probably improves as the shrimp increase in size. Tables 12 and 13 provide the modal analysis and the estimated demographics from each survey. These time series provide a basis for comparison of relative year-class strength and illustrate the changes in stock composition over time. There appear to be two regimes; one prior to 2000 at a time during which abundances at age were low and a second period after 1999 during which abundances were much higher. The 1997 year-class first appeared in the 1998 survey as one year old shrimp and was the first in a series of strong year-classes. This year class was strong and could be followed throughout the next three years. However, it is important to note that the age 1 modes do not always give a clear recruitment signal. For instance, the 1998 age 1 mode appeared weak in 1999, but was almost as strong as the 1997 year class in later years. Strong age 2 modes appear strong throughout their history, conversely weak year classes such as the 1995 and 1996 appear weak as 2 males and remain weak throughout their history.

Modal length at age varies between years reflecting different growth rates for the different cohorts. However, there is some inter-annual consistency in modal positions and the relative strength of cohorts is maintained from one year to the next (Tables 12 and 13; Figs. 23 and 24).

Shrimp aged 2 - 4 dominated the male component of the length frequencies in autumn 2007 (2005, 2004 and 2003 year classes respectively) survey with carapace length frequency modes at 14.64 mm, 17.33 mm and 20.15 mm respectively. Abundance estimates from the spring 2008 survey were dominated by shrimp aged 3 and 4 (2005 and 2004 year classes respectively) with modes at 15.66 mm and 17.96 mm respectively. The 2004 and 2005 year classes first appear as the strongest year classes in the spring of 2006 and 2007, respectively, as two year old animals. These two year classes remain strong in subsequent surveys.

The spring and autumn surveys showed an increase in the abundance of female (transitionals + females) shrimp over much of the time series. Autumn male abundance indices increased until 2001 and have since remained stable at a high level while spring male abundance indices have varied over time (Tables 14 and 15; Fig. 25).

Autumn and spring female biomass (transitionals and all females = SSB) indices followed similar trends (Tables 14 and 15; Fig. 26). The autumn female biomass was 128,900 t in 2007; the highest in the autumn time series. The 2007 spring female biomass index was 133,200 t; the second highest in the spring female biomass time series.

Fishable biomass has increased throughout much of the spring and autumn time series (Table 16; Fig. 27). The old method (makes use of a length-weight relationship to convert fishable length males (=>17.5 mm carapace length) from a population adjusted length frequency and then add the female spawning stock biomass) and the proposed method (makes use of a length-weight relationship to convert the abundance fishable length males within each set to fishable weight males then add the weight of females. Ogmap is then run to compute the fishable biomass). Both table 16 and figure 27 show that the indices within each year and season are similar regardless of calculation method. The main difference is that the proposed method provides a means of directly computing confidence intervals. Using the proposed method, autumn 2007 fishable biomass was 243,000 t (95% confidence range = 193,800 t – 312,400 t); the highest in the autumn time series while the spring 2008 fishable biomass was 187,800 t (95% confidence range = 137,100 – 236,700 t); the second highest in the spring fishable biomass time series.

Given the relative strength of the 2002 - 2005 year classes, fishable biomass has been increasing or remaining high and the female portion of the population is relatively abundant, probably consisting of more than one year class, the present fishery should be sustainable over the next few years.

Recruitment Index

Recruitment indices were determined using two methods:

1. age 2 abundance as determined from modal analysis of population adjusted length frequencies, and
2. the abundance of males 12-17 mm in carapace length

from the autumn 1996-2007 and spring 1999 - 2008 survey time series. Due to the incomplete survey in autumn 2004, this value was excluded from the autumn time series. In terms of modal analysis, the autumn 98, 99, 04 and 05 year classes were strong, the 97, 00 – 03 year classes were average while the 94 - 96 year classes were the weakest recorded (Tables 12 and 17; Figs. 23 and 28). Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series (Tables 13 and 17; Figs. 24 and 28).

The proposed method allows the direct calculation of confidence intervals, but will not allow the identification of age classes because each index probably consists of a combination of age 2 and 3 animals. The autumn 1996 – 1999 indices were the lowest in the time series, the 2000 – 2003 values fluctuate along the mean while the 2005 – 2007 were progressively stronger. Similarly, the spring indices followed an increasing trend between 1998 and 2003, the 2004 value was the lowest in this time series but since then the recruitment indices have followed an increasing trend.

Figure 29 presents a series of regressions between fishable biomass with various lags versus the age 2 abundance and the new recruitment index. In both cases, highest correlation coefficient was achieved when the fishable biomass was lagged by one year after the recruitment index. This is different from predictive models developed in previous assessments of this stock (Orr *et al.* 2006). Previous models indicated that the best fit was achieved with a two year lag. The difference could be due to the correction in data within the present dataset. It is worth noting that the age 2 abundance and fishable biomass indices track the present respective indices. The 2006 predictive model with a one year lag had an

$r^2 = .76$ while $r^2 = .79$ with a two year lag.

The combination of the proposed fishable biomass, with a one year lag, and recruitment indices resulted in a predictive model accounting for 85% of the variance in the data. This is higher than a fit of 68% achieved when fishable biomass was regressed against the age 2 abundance index. Increased fit from the new recruitment index should not be surprising because shrimp recruit to the fishery by size and not age. Animals recruiting to the fishery probably range from 2 – 3 years of age as is clearly illustrated from the modal analysis presented in figures 23 and 24. Similarly, the fishable biomass is made up of more than one year class.

This predictive relationship using the proposed indices is statistically significant and the model using may be written as follows:

Fishable $\text{biomass}_{\text{year}+1}$= 13.063 (autumn recruitment $\text{index}_{\text{year}}$) + 7.7243

If the autumn 2008 recruitment index (16.758 (10^9 animals) is applied to the simple model then the predicted fishable biomass would be 226,634 t in autumn 2008.

Exploitation Rates

Exploitation levels using ratios of catch divided by the previous year's lower 95% confidence interval for the biomass estimate, spawning stock biomass and fishable biomass. In general, they all follow similar trajectories (Table 18). The comparison between exploitation rates determined by catch divided by fishable biomass using the two methods of determining fishable biomass indicates that there is very little difference in the fishable biomass therefore there is very little difference in the exploitation rate index. The main difference between the two methods is that the proposed method allows the determination of confidence intervals around the exploitation rate. Overall, exploitation has been low even though catches have increased over time because the stock parameters also increased. Figure 30 presents the exploitation rate index determined as catch/ previous year's autumn fishable biomass. The 2007 exploitation rate index was 13.8% using Ogmap values. By October 2008, the 2008 exploitation rate index was 9.4%.

Mortality Estimates

The median survival, annual mortality and instantaneous mortality rates were 0.512, 0.488 and .670 respectively. These values are reasonable as the survival from one year to the next is high enough to allow the present population to exist and are within the range of values presented in Shumway (1985) and Bergström (2000).

Precautionary Approach

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the SSB is estimated to be well above B_{lim} (Figure 31).

We are proposing that the lowest observed female spawning stock biomass (SSB) be used as B_{Lim}. The geometric mean of the 1996 – 1999 SSB indices was 19,600 t and is being proposed as B_{Lim}. Over the period 2000 - 2006 SSB plateaued at a high level. It was a period during which biomass appeared to be both level and high and recruitment was good. The geometric mean SSB over this time period was 77,900 t and is being suggested as the Upper Stock Reference (USR) (Figure 32). The proposed reference points are consistent with the Canadian framework for the precautionary approach to fisheries management with a healthy (above the USR), cautious (between the USR and B_{Lim}) and a critical zone (below B_{Lim}) (DFO, 2006). This proposal avoids implying that we have an understanding of the productivity of the shrimp within the present environment and is a suggested method in (Cadrin *et al.* 2004). As with the NAFO approach, the SSB is well above the B_{Lim} or USR.

TAC:

Table 20 provides the TAC determinations for various exploitation options. If the inverse variance weighted average fishable biomass is 202,700 t then at 12.33%, 14.80% and 17.27% exploitation rates, the TACs would be 25,000 t, 30,000 t and 35,000 t respectively.

Biomass has remained at a high level since 2001, with no sign of decline, while the exploitation rate has remained below 15%. This rate of exploitation should not be raised for a number of years to allow time to monitor the impact of the fishery upon the Div. 3LNO shrimp stock. By maintaining an exploitation rate near this level, the TAC will be allowed to increase as the stock increases.

Unfortunately, there is no analytical assessment for this stock therefore there is no risk analysis.

Resource Status

Canadian large (>500 t) fishing vessel catch rates have fluctuated around the long term mean since 2000 with the 2008 catch rate index near the long term mean and similar to the 2002 and 2004 - 2007 catch rates. The Canadian small vessel standardized CPUE increased by 89% over the period 2001 – 2005 but has subsequently decreased to near the long term mean.

The area occupied by the resource and fished by the large and small vessel fleets has been increasing over time. The fact that the area fished has increased over the past few years while the CPUE remained near the long term average implies that the resource is healthy.

Even though the area occupied by the resource and fished by the large and small vessel fleets has been increasing over time, the area occupied has never been higher than 4% of the available area. While the shrimp fishery may still have impacts upon some non target species, the chance of doing serious harm to the habitat is probably low because the foot print of the fishery is relatively low. However, it is still important to determine the actual impact of the fishery upon the ecosystem.

The standardized non-Canadian CPUE made use of data from Estonia, Greenland and Iceland. Catch rates increased by 127% from 353 kg/hr in 2001 to 801 kg/hr in 2004 but then decreased by 34% over the next four years resulting in a 526 kg/hr catch rate during 2008. The non-Canadian CPUE indices have been fluctuating along the long term average over much of the time series.

Based on Canadian surveys, over 90% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185-550 m. There was a significant increase in autumn shrimp biomass indices between 1996 and 2001 and this index has since remained stabilize at a high level. The autumn 2007 index was 275,100 t (56 billion animals), the highest in the autumn time series. The spring 2008 biomass index was 232,400 t (48 billion animals), the second highest in the spring time series.

The spring and autumn surveys showed an increase in the abundance of female (transitionals + females) shrimp over much of the time series. Autumn male abundance indices increased until 2003 and have since remained stable at a high level while spring male abundance indices have varied over time.

With the exception of the 94 -96 year classes, the autumn 93 to 98 year classes appeared progressively stronger, the 99 year class remained strong; however, the 00 – 03 year classes were average while the 04 year class is the strongest recorded. Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series.

In terms of modal analysis, the autumn 98, 99, 04 and 05 year classes were strong, the 97, 00 – 03 year classes were average while the 94 - 96 year classes were the weakest recorded. Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series.

Shrimp aged 2 - 4 dominated the male component of the length frequencies in autumn 2007 (2005, 2004 and 2003 year classes respectively) survey with carapace length frequency modes at 14.64 mm, 17.33 mm and 20.15 mm respectively. Abundance estimates from the spring 2008 survey were dominated by shrimp aged 3 and 4 (2005 and 2004 year classes respectively) with modes at 15.66 mm and 17.96 mm respectively. The 2004 and 2005 year classes first appear as the strongest year classes in the spring of 2006 and 2007, respectively, as two year old animals. These two year classes remain strong in subsequent surveys.

A broad mode of females was present in all surveys implying the presence of more than one year class of females.

Fishable biomass has been increasing throughout much of the history within both the spring and autumn time series. Due to the increase in fishable biomass, the exploitation rate index has remained low in spite of increased catches.

Given the relative strength of the 2004 and 2005 year classes, fishable biomass has been increasing and the female portion of the population is relatively abundant, probably consisting of more than one year class, mortality rates have remained relatively low over the survey time series, the present fishery should be sustainable over the next few years.

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the SSB is estimated to be well above the limit reference point regardless of whether it is B_{lim} or the proposed B_{Loss} (Figure 31).

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Table 1. Annual nominal catches (t) by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3L between April 2000 and October 2008.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Canada	4,050[2]	4,984[2]	5,417[2]	10,701[2]	10,560[2]	11,109[2]	18,128[2]	18,314[2]	19,767[2]	
Cuba		46[1]	70[1]	81[1]	145[3]	136[1]	239[1]	240[1]	207[3]	
Estonia	64[1]	2,264[4]	450[5]	299[6]	271[6]	569[6]	1,099[6]	1,453[6]	721[6]	
European Union									757[3]	
Faroe Islands	42[1]	2,052[4]	620[5]	25	1050[1]	1055[1]	1521[1]	1798[1]	354[3]	
France (SPM)	67[1]	67[1]	36[1]	144[1]				245[1]	177[3]	
Greenland	34[1]			672[1]	296[8]	299[8]	453[8]	456[8]	488[3]	
Iceland	99[1]	68[7]	69[7]	163[7]	117[7]	150[1]	226[7]			
Latvia	64[1]	67[1]	59[1]	144[1]	143[1]	144[1]	244[1]	310[1]		
Lithuania	67[1]	67[1]	67[1]	142[1]	144[1]	216[1]	486[1]	245[1]		
Norway	77[1]	78[6]	70[6]	145[9]	165[9]	144[1]	272[9]	250[9]		
Poland	40[1]	54[1]		145[1]	144[1]	129[1]	245[1]			
Portugal		61[5]								
Russia	67[1]	67[1]	67[1]		141[1]	146[1]	248[1]	112[1]	278[3]	
Spain	40[1]	699[4]		151[1]	140[1]	154[1]	305[6]	188[1]		
Ukraine		57[1]		144[1]	145[1]		121[1]			
USA		66[1]	69[1]	144[1]		136[1]	245[1]	245[1]	183[3]	
GRAND TOTAL	4,711	10,697	6,994	13,100	13,461	14,387	23,587	23,856	22,932	
TAC (tons)	6,000	6,000	6,000	13,000	13,000	13,000	22,000	22,000	25,000	30,000

Sources:

1 NAFO Statlant 21A
2 Canadian Atlantic 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 and vessel size model for **Canadian small vessels (<= 500 t; <65') fishing** northern shrimp in NAFO Div. 3L over the period 2000 – 2007. (Weighted by effort, single trawl, no windows, logbook data, history of at least two years in the fishery).

The GLM Procedure

Class Level Information

Class	Levels	Values
Year	8	2000 2001 2002 2003 2004 2005 2006 2007
Month	6	5 7 8 9 10 99 (model was standardized against June therefore it was coded as 99)
Size_class	3	1 2 3

Number of Observations Read	100
Number of Observations Used	100

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	6648.993245	474.928089	38.33	<.0001
Error	85	1053.251668	12.391196		
Corrected Total	99	7702.244913			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.863254	57.47568	3.520113	6.124526

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	7	5655.855844	807.979406	65.21	<.0001
Month	5	892.018419	178.403684	14.40	<.0001
Size_class	2	101.118982	50.559491	4.08	0.0203

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	7	2733.137922	390.448275	31.51	<.0001
Month	5	936.526799	187.305360	15.12	<.0001
Size_class	2	101.118982	50.559491	4.08	0.0203

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.194010503	B	0.03648319	169.78	<.0001
Year	2000	-0.297677017	B	0.05427123	-5.48	<.0001
Year	2001	-0.335960506	B	0.06055163	-5.55	<.0001
Year	2002	-0.303534642	B	0.05911315	-5.13	<.0001
Year	2003	-0.182197885	B	0.04845428	-3.76	0.0003
Year	2004	-0.031911335	B	0.04550768	-0.70	0.4851
Year	2005	0.300107274	B	0.04787276	6.27	<.0001
Year	2006	0.230390273	B	0.04104516	5.61	<.0001
Year	2007	0.000000000	B	.	.	.

Table 2 (Continued)

Year	lncpue LSMEAN	95% Confidence Limits	
2000	5.819343	5.719295	5.919391
2001	5.781060	5.685569	5.876550
2002	5.813485	5.718029	5.908942
2003	5.934822	5.867244	6.002400
2004	6.085109	6.001043	6.169174
2005	6.417127	6.329495	6.504760
2006	6.347410	6.276260	6.418561
2007	6.117020	6.050434	6.183606

Table 3. Catch rate indices for **Canadian small vessels (<=500 t; <65')** fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2007.

YEAR	TAC[1] (t)	FLEET CATCH (t)	PERCENT OF CATCH CAPTURED IN LOGBOOK DATASET[2]	UNSTANDARDIZED CPUE (KG/HR)	UNSTANDARDIZED CPUE RELATIVE TO 2007	UNSTANDARDIZED EFFORT[3] (HR)	STANDARDIZED CPUE RELATIVE TO 2007	STANDARDIZED MODELLED CPUE (KG/HR)	STANDARDIZED EFFORT (HRS)
1999		17							
2000	2,500	3,247	79.0%	317	0.683	10,242	0.743	337	9,642
2001	2,500	2,482	84.6%	295	0.635	8,425	0.715	324	7,657
2002	2,500	2,861	87.3%	302	0.650	9,483	0.738	335	8,547
2003	6,566	6,457	88.5%	365	0.786	17,711	0.833	378	17,084
2004	6,566	6,576	93.4%	458	0.987	14,366	0.969	439	14,970
2005	6,566	7,147	93.3%	640	1.380	11,161	1.350	612	11,673
2006	12,297	12,112	78.7%	564	1.215	21,493	1.259	571	21,211
2007	12,297	12,571	74.5%	464	1.000	27,093	1.000	454	27,719
2008	14,209	14,632	19.9%						

[1] CATCH (TONS) AS REPORTED IN ECONOMIC ASSESSMENT OF THE NORTHERN SHRIMP FISHERY AND FROM YEAR-END QUOTA REPORTS AND/OR LOGBOOK RECORDS.

[2] PERCENT CATCH FROM LOGBOOK DATASETS AS CAPTURED BY THE MODEL FOR EACH CALENDAR YEAR.

[3] EFFORT CALCULATED (CATCH/CPUE) FROM SMALL VESSEL LOGBOOK DATASET, ALL WERE SINGLE TRAWL.

Table 4. Multiplicative year, month ship and gear type model for **Canadian large (>500 t)** vessels fishing northern shrimp in NAFO Div. 3L over the period 2000 – 2008. (Weighting by effort, no windows, observer data, history of at least 2 years in the fishery).

The GLM Procedure
Class Level Information

Class	Levels	Values
year	9	2000 2001 2002 2003 2004 2005 2006 2007 2008
month	6	1 2 3 4 5 99 (data standardized to June)
CFV	13	
gear	2	17 66

Number of Observations Read	143
Number of Observations Used	143

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	1550.180908	59.622343	10.63	<.0001
Error	116	650.895659	5.611169		
Corrected Total	142	2201.076567			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.704283	31.74204	2.368791	7.462629

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	8	774.0018507	96.7502313	17.24	<.0001
month	5	268.4811495	53.6962299	9.57	<.0001
CFV	12	428.0531875	35.6710990	6.36	<.0001
gear	1	79.6447206	79.6447206	14.19	0.0003

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	8	394.7851920	49.3481490	8.79	<.0001
month	5	256.0634472	51.2126894	9.13	<.0001
CFV	12	335.9836320	27.9986360	4.99	<.0001
gear	1	79.6447206	79.6447206	14.19	0.0003

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.881100319	B	0.20398751	33.73	<.0001
year	2000	-0.786367140	B	0.16308973	-4.82	<.0001
year	2001	-0.346655394	B	0.12563475	-2.76	0.0067
year	2002	0.102900362	B	0.12731292	0.81	0.4206
year	2003	0.458349684	B	0.12930564	3.54	0.0006
year	2004	-0.043946073	B	0.12130278	-0.36	0.7178
year	2005	-0.076712083	B	0.10104764	-0.76	0.4493
year	2006	-0.042827304	B	0.08408256	-0.51	0.6115
year	2007	0.067089355	B	0.09740804	0.69	0.4924
year	2008	0.000000000	B	.	.	.
gear	17	-0.261276035	B	0.06935021	-3.77	0.0003
gear	66	0.000000000	B	.	.	.

Table 4 (Continued)

year	lncpue LSMEAN	95% Confidence Limits	
2000	6.734522	6.477204	6.991839
2001	7.174234	7.002300	7.346167
2002	7.623789	7.434957	7.812622
2003	7.979239	7.764507	8.193971
2004	7.476943	7.293750	7.660136
2005	7.444177	7.305762	7.582592
2006	7.478062	7.346692	7.609432
2007	7.587978	7.404964	7.770993
2008	7.520889	7.363314	7.678464

Table 5. Catch rate indices for **Canadian large vessels (>500 t)** fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2008.

YEAR	TAC	CATCH [1] (t)	PERCENT OF CATCH CAPTURED IN OBSERVER DATASET [2]	UNSTANDARDIZED CPUE (KG/HR)	UNSTANDARDIZED CPUE RELATIVE TO 2008	UNSTANDARDIZED EFFORT [3] (HR)	STANDARDIZED CPUE RELATIVE TO 2008	STANDARDIZED MODELLED CPUE	STANDARDIZED EFFORT (HRS)
2000	1,691	833	47%	802	0.393	1,039	0.455	841	991
2001	2,500	2,394	93%	1,363	0.668	1,757	0.707	1,305	1,834
2002	2,500	2,456	95%	1,968	0.964	1,248	1.108	2,046	1,200
2003	4,267	4,038	70%	3,976	1.948	1,015	1.581	2,920	1,383
2004	4,267	4,036	68%	2,076	1.017	1,944	0.957	1,767	2,284
2005	4,277	4,039	96%	1,933	0.947	2,089	0.926	1,710	2,362
2006	5,273	6,016	86%	1,759	0.862	3,419	0.958	1,769	3,401
2007	5,278	5,743	83%	1,934	0.947	2,970	1.069	1,974	2,909
2008	6,976	5,135	76%	2,041	1.000	2,516	1.000	1,846	2,781

[1] CATCH (TONS) AS REPORTED IN ECONOMIC ASSESSMENT OF THE NORTHERN SHRIMP FISHERY AND FROM YEAR-END QUOTA REPORTS AND/OR LOGBOOK RECORDS.

[2] PERCENT CATCH OBSERVED IN CALENDAR YEAR AS REPORTED IN STANDARDIZED OBSERVER CPUE DATASET.

[3] EFFORT CALCULATED (CATCH/CPUE) FROM LARGE VESSEL OBSERVER DATA, SINGLE + DOUBLE TRAWL, NO WINDOWS.

Table 6. Multiplicative year, month and ship model for **non Canadian large vessels** fishing northern shrimp in NAFO Div. 3L NRA over the period 2000– 2007. (Weighted by effort). Data from Iceland, Greenland and Estonia were included in the model.

The GLM Procedure
Class Level Information

Class	Levels	Values
year	9	2000 2001 2002 2003 2004 2005 2006 2007 2008
ship	7	
month	12	1 2 3 4 5 6 7 8 9 10 11 12
trawls	2	1 2

Number of Observations Read 123
Number of Observations Used 121

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	2014.331709	80.573268	11.82	<.0001
Error	95	647.823620	6.819196		
Corrected Total	120	2662.155330			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.756654	39.70792	2.611359	6.576418

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	8	340.164121	42.520515	6.24	<.0001
ship	6	1478.651761	246.441960	36.14	<.0001
month	11	195.515827	17.774166	2.61	0.0061

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	8	94.779866	11.847483	1.74	0.0996
ship	6	1313.960937	218.993490	32.11	<.0001
month	11	195.515827	17.774166	2.61	0.0061

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.126251962	B	0.18514488	33.09	<.0001
year	2000	0.098390772	B	0.32517120	0.30	0.7629
year	2001	-0.397178185	B	0.28338082	-1.40	0.1643
year	2002	0.311659281	B	0.34128045	0.91	0.3634
year	2003	0.274386738	B	0.18633339	1.47	0.1442
year	2004	0.420581958	B	0.18801314	2.24	0.0276
year	2005	0.211986576	B	0.16809826	1.26	0.2104
year	2006	0.187931430	B	0.12531035	1.50	0.1370
year	2007	0.179679131	B	0.12397859	1.45	0.1506
year	2008	0.000000000	B	.	.	.

Table 6 (Continued)

year	lncpue LSMEAN	95% Confidence Limits	
2000	6.363112	5.866633	6.859591
2001	5.867543	5.408918	6.326167
2002	6.576380	6.037581	7.115179
2003	6.539108	6.205888	6.872327
2004	6.685303	6.341192	7.029413
2005	6.476707	6.187261	6.766154
2006	6.452652	6.181136	6.724168
2007	6.444400	6.165456	6.723344
2008	6.264721	5.936378	6.593064

Table 7. Catch rate indices for **non Canadian large vessels** fishing northern shrimp in NAFO Div. 3L NRA over the period 2000 – 2008. Data from Iceland, Greenland and Estonia were included in the model.

YEAR	TAC	CATCH (t)	PERCENT OF CATCH CAPTURED IN MODEL DATASET	UNSTANDARDIZED CPUE (KG/HR)	UNSTANDARDIZED CPUE RELATIVE TO 2008	UNSTANDARDIZED EFFORT (HR)	STANDARDIZED CPUE RELATIVE TO 2008	STANDARDIZED MODELLED CPUE	STANDARDIZED EFFORT (HRS)
2000	1,000	661	14	509	0.60	509	1.10	580	1,140
2001	1,000	5,700	1	381	0.45	381	0.67	353	16,130
2002	1,000	1,562	4	650	0.76	650	1.37	718	2,176
2003	2,167	2,186	29	1,169	1.38	1,169	1.32	692	3,160
2004	2,167	2,747	24	1,452	1.71	1,452	1.52	801	3,431
2005	2,167	2,993	27	993	1.17	993	1.24	650	4,606
2006	3,675	6,338	20	993	1.17	872	1.21	634	9,991
2007	3,675	5,543	25	852	1.00	852	1.20	629	8,810
2008	3,815	3,194	25	849	1.00	849	1.00	526	6,076

Table 8. Unstandardized northern shrimp catch rate indices (kg/hr) by countries fishing in the NAFO Division 3L NRA over the period 2000 – 2008. (single trawl/double trawl)

Country	Year 2000	2001	2002	2003	2004	2005	2006	2007	2008
Estonia				1,052/ 1,078	1,206/ 599	698/ 868	759/ 638	566/ 655	444/ 415
Greenland				1,349/ 1,818	1,824/ 3,261	/ 3,600	/ 3,927	/ 1,648	/ 2,543
Iceland	454/ 625	250/ 439	793/ 607	/ 838	/ 1,096	420/ 592	/ 552		
Norway	1,443			1,198/ 1,802	/ 5,173	/ 304	/ 918		
Spain							764	587	

Table 9. Northern shrimp stock size estimates in NAFO divisions 3LNO as calculated using ogmap. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1996 – 2008. (Offshore strata only with standard 15 min. tows).

Autumn stock size estimates

It was not possible to sample all of the Div. 3L stations during 2004 (Fig. 19) therefore there are no estimates for autumn 2004.

	Biomass (tons)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1996	20,150	24,700	35,090	5,337	6,571	9,373	304
1997	32,410	44,000	61,940	7,545	9,911	13,860	318
1998	48,310	60,700	76,640	11,950	14,975	19,120	347
1999	43,160	54,900	72,390	10,620	12,993	16,510	313
2000	83,990	107,000	139,300	20,890	27,898	35,830	337
2001	155,300	215,400	259,600	36,890	51,730	62,040	362
2002	135,500	191,700	239,500	31,100	44,472	54,750	365
2003	144,000	190,900	243,300	30,300	39,481	49,420	316
2004		???			???		
2005	178,400	223,700	266,300	35,620	45,269	53,930	333
2006	172,900	215,400	252,000	36,460	47,051	55,710	312
2007	209,100	275,100	359,200	43,220	56,396	71,810	361

Spring stock size estimates.

Please note that it was not possible to sample all allocated stations within divs. 3NO; however all stations were sampled in 3L during spring 1996 (Fig. 20). The 1996 estimates are for Div. 3L only since at least 90% of the shrimp biomass and abundance is found within that division.

Year	Biomass (tons)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	26,990	49,400	76,190	6,564	11,418	17,300	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	300
2002	87,390	133,800	204,700	20,730	31,260	47,660	300
2003	117,200	169,600	222,600	26,450	38,998	53,820	300
2004	40,950	93,500	169,100	8,176	18,003	31,890	296
2005	85,620	133,400	183,500	16,790	25,540	34,850	289
2006	107,400	179,400	246,300	21,820	34,601	46,940	195
2007	190,200	288,600	379,200	35,340	54,304	72,790	295
2008	171,800	232,400	289,100	36,100	48,204	60,090	273

Table 10. NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions and outside the 200 Nmi limit. Shrimp were collected during the 1996 – 2007 **autumn** Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min tows). All indices were estimated using Ogmap calculations.

			Entire Division		Outside 200 Nmi limit			
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1996	3L	22,900	92.71	4,000	85.11	17.47	17.47
Autumn	1997	3L	43,400	98.64	5,500	91.67	12.67	15.07
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	97.07	35,300	91.69	19.05	18.96
Autumn	2004	3L	???	???	???	???	???	???
Autumn	2005	3L	222,300	99.37	26,200	97.40	11.79	15.42
Autumn	2006	3L	213,700	99.21	27,100	96.44	12.68	12.23
Autumn	2007	3L	282,400	98.60	54,500	98.55	19.30	14.59
Autumn	1996	3N	2,000	8.10	700	14.89	35.00	35.00
Autumn	1997	3N	700	1.59	500	8.33	71.43	53.21
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
Autumn	2004	3N	2,600	???	2,100	???	???	???
Autumn	2005	3N	1000	0.45	700	2.60	70.00	69.04
Autumn	2006	3N	1500	0.70	1000	3.56	66.67	68.33
Autumn	2007	3N	1,400	0.49	800	1.45	57.14	64.60
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
Autumn	2004	3O	200	???	0	???	???	???
Autumn	2005	3O	100	0.04	0	0.00	0.00	0.00
Autumn	2006	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2007	3O	0	0.00	0	0.00	0.00	0.00
	all divisions							
Autumn	1996		24,700	101	4,700	100	19.03	19.03
Autumn	1997		44,000	100	6,000	100	13.64	16.33
Autumn	1998		60,700	100	10,900	100	17.96	16.87
Autumn	1999		54,900	100	8,300	100	15.12	15.57
Autumn	2000		107,000	100	22,500	100	21.03	18.03
Autumn	2001		215,400	100	42,000	100	19.50	18.55
Autumn	2002		191,700	100	38,100	100	19.87	20.13
Autumn	2003		190,900	100	38,500	100	20.17	19.85
Autumn	2004		???		???		???	???
Autumn	2005		223,700	100	26,900	100	12.03	16.10
Autumn	2006		215,400	100	28,100	100	13.05	12.54
Autumn	2007		286,400	99	55,300	100	19.31	14.79

Table 11. NAFO Divisions 3LNO Pandalus borealis biomass estimates for entire divisions and outside the 200 Nmi limit. Shrimp were collected during the 1999 – 2008 spring Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min tows). Please note that strata deeper than 93 m were not surveyed in 3NO during spring 2006. Historically more than 97% of the shrimp have been attributed to strata within 3L therefore the spring 2006 estimates are for 3L. All indices were estimated using Ogmap calculations.

			Entire Division		Outside 200 Nmi limit			3 year running
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	average percent biomass in NRA
Spring	1999	3L	47,500	96.15	10,200	86.44	21.47	21.47
Spring	2000	3L	108,700	95.94	23,800	87.18	21.90	21.68
Spring	2001	3L	82,700	100.24	11,400	99.13	13.78	19.05
Spring	2002	3L	128,100	95.74	34,300	91.47	26.78	20.82
Spring	2003	3L	165,400	97.52	29,900	86.92	18.08	19.55
Spring	2004	3L	92,000	98.40	23,700	97.13	25.76	23.54
Spring	2005	3L	133,200	99.85	14,200	94.67	10.66	18.17
Spring	2006	3L	179,400	???	43,400	???	24.19	20.20
Spring	2007	3L	282,100	97.75	78,200	97.02	27.72	20.86
Spring	2008	3L	231,700	99.70	34,300	99.13	14.80	22.24
Spring	1999	3N	2,100	4.25	1,600	13.56	76.19	76.19
Spring	2000	3N	4,700	4.15	3,500	12.82	74.47	75.33
Spring	2001	3N	300	0.36	100	0.87	33.33	61.33
Spring	2002	3N	5,800	4.33	3,200	8.53	55.17	54.32
Spring	2003	3N	5,400	3.18	4,500	13.08	83.33	57.28
Spring	2004	3N	1,200	1.28	700	2.87	58.33	65.61
Spring	2005	3N	1,400	1.05	800	5.33	57.14	66.27
Spring	2006	3N	???	???	???	???	???	57.74
Spring	2007	3N	3,100	1.07	2,400	2.98	77.42	67.28
Spring	2008	3N	600	0.26	300	0.87	50.00	63.71
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	0.21	0	0.00	0.00	0.00
Spring	2005	3O	100	0.07	0	0.00	0.00	0.00
Spring	2006	3O	???	???	???	???	0.00	0.00
Spring	2007	3O	0	0.00	0	0.00	0.00	0.00
Spring	2008	3O	0	0.00	0	0.00		
	all divisions							
Spring	1999		49,400	100.61	11,800	100.00	23.89	23.89
Spring	2000		113,300	100.18	27,300	100.00	24.10	23.99
Spring	2001		82,500	100.61	11,500	100.00	13.94	20.64
Spring	2002		133,800	100.15	37,500	100.00	28.03	22.02
Spring	2003		169,600	100.83	34,400	100.00	20.28	20.75
Spring	2004		93,500	99.89	24,400	100.00	26.10	24.80
Spring	2005		133,400	100.97	15,000	100.00	11.24	19.21
Spring	2006		???	???	???	???	???	18.67
Spring	2007		288,600	98.82	80,600	100.00	27.93	19.59
Spring	2008		232,400	99.96	34,600	100.00	14.89	21.41

Table 12. Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *P. borealis* in NAFO Divs. 3lNO from **autumn** Canadian multi-species bottom trawl surveys. Abundance at length determined using OGMap calculations.

Mean Carapace Length (Standard Error)

	Age			
Year	1	2	3	4
1996	10.37 (.067)	15.42 (.037)	18.84 (.062)	20.61 (.580)
1997	10.52 (.062)	15.60 (.067)	18.52 (.094)	20.32 (.446)
1998	10.24 (.018)	15.36 (.123)	18.62 (.135)	20.48 (.170)
1999	10.60 (.058)	15.50 (.019)	18.36 (.062)	20.18 (.089)
2000	9.99 (.029)	14.73 (.033)	17.66 (.021)	20.04 (.122)
2001	9.67 (.043)	14.52 (.022)	16.86 (.030)	19.10 (.014)
2002	9.82 (.028)	14.00 (.044)	17.09 (.030)	19.47 (.043)
2003	9.60 (.034)	14.61 (.031)	17.53 (.066)	19.44 (.029)
2004	Incomplete survey			
2005	10.08 (.021)	14.31 (.030)	17.04 (.027)	19.74 (.026)
2006	10.20 (.019)	14.28 (.021)	16.98 (.116)	19.36 (.024)
2007	10.67 (.045)	14.64 (.023)	17.33 (.023)	20.15 (.017)

Estimated Proportions (Standard Error and constraints) contributed by each year class

	Age				
Year	1	2	3	4	Total
1996	.060 (.003)	.664 (.011)	.193 (.036)	.083 (.033)	1.000
1997	.069 (.003)	.422 (.020)	.457 (.062)	.052 (.047)	0.999
1998	.234 (.004)	.204 (.018)	.428 (.068)	.133 (.018)	0.999
1999	.051 (.002)	.556 (.006)	.112 (.019)	.280 (.018)	0.999
2000	.061 (.002)	.342 (.007)	.460 (.015)	.137 (.000)	1.000
2001	.016 (.001)	.184 (.004)	.309 (.005)	.491 (.005)	1.000
2002	.033 (.010)	.139 (.005)	.435 (.017)	.393 (.014)	1.000
2003	.047 (.001)	.179 (.004)	.247 (.012)	.527 (.013)	1.000
2004	Incomplete survey				
2005	.038 (.001)	.136 (.004)	.449 (.005)	.377 (.000)	1.000
2006	.061 (.001)	.292 (.005)	.145 (.007)	.502 (.009)	1.000
2007	.027 (.001)	.238 (.004)	.407 (.004)	.328 (.017)	1.000

Table 12 (Continued)

Distributional Sigmas (Standard Error and constraints)

	Age			
Year	1	2	3	4
1996	1.0 (fixed)	1.37 (.033)	.74 (.072)	1.27 (.233)
1997	1.13 (.051)	1.04 (.043)	0.93 (.112)	0.70 (.156)
1998	.89 (.014)	1.21 (.073)	1.08 (.135)	.75 (.070)
1999	1.07 (.049)	.996 (.017)	.58 (.063)	1.04 (.047)
2000	.902(.023)	1.11 (.024)	.84 (.023)	1.20 (.057)
2001	.99 (Sigma eq. .008)			
2002	.782 (.022)	1.028 (.032)	.929 (.029)	1.021 (.020)
2003	1.123 (Sigma eq .012)			
2004	Incomplete survey			
2005	.70 (.022)	1.03 (CV=.069)	1.18 (CV=.069)	1.36 (CV=.069)
2006	.76 (CV=.075)	1.07 (CV=.075)	1.273 (CV=.075)	1.45 (CV=.075)
2007	1.108 (Sigma eq .008)			

Population at Age Estimates (10^6)

	Male Ages					All females	Total
Year	0	1	2	3	4		
1996	1	357	3,925	1,139	494	661	6,576
1997	3	495	3,007	3,257	385	2,710	9,847
1998	0	3,007	2,614	5,492	1,727	2,132	14,972
1999	1	535	5,514	1,114	2,832	3,001	12,997
2000	3	1,457	8,081	10,875	3,269	4,250	27,935
2001	4	700	7,976	13,429	21,467	8,136	51,712
2002	0	1,159	4,844	15,171	13,696	9,597	44,467
2003	0	1,344	5,114	7,079	15,098	10,747	39,382
2004	Incomplete survey						
2005	8	1,287	4,628	15,238	12,854	11,229	45,244
2006	1	2,287	10,879	5,413	18,844	9,636	47,060
2007	0	1,130	9,635	16,503	13,312	15,717	56,297

Table 13. Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *P. borealis* in NAFO Divs. 3lNO from **spring** Canadian multi-species bottom trawl surveys. Abundance at length determined using OGMap calculations.

Mean Carapace Length (Standard Error)

Year	Age				
	1	2	3	4	5
1999		13.94 (.030)	17.71 (.048)	19.94 (.042)	
2000	8.22 (.044)	13.73 (.034)	17.49 (.024)	20.24 (.070)	
2001	7.89 (.131)	12.95 (.027)	16.32 (.042)	18.62 (.024)	
2002	7.77 (.061)	12.35 (.029)	16.47 (.021)	18.92 (.018)	
2003	7.83 (.063)	12.60 (.030)	15.55 (.093)	17.49 (.091)	19.20 (.043)
2004	8.01 (.276)	13.16 (.094)	16.61 (.299)	17.97 (.094)	19.46 (.026)
2005	8.49 (.078)	13.58 (.050)	16.53 (.124)	18.15 (.188)	20.09 (.082)
2006	8.79 (.116)	13.34 (.018)	17.02 (.192)	18.30 (.395)	20.02 (.052)
2007	8.87 (.156)	12.98 (.018)	16.39 (.025)	18.96 (.063)	20.58 (.041)
2008	8.36 (.068)	12.92 (.031)	15.66 (.037)	17.96 (.038)	20.29 (.037)

Estimated Proportions (Standard Error and constraints) contributed by each year class

Year	Age					
	1	2	3	4	5	Total
1999		.487 (.006)	.115 (.011)	.398 (.010)		1.000
2000	.022 (.001)	.353 (.006)	.454 (.012)	.171 (.009)		1.000
2001	.006 (.001)	.200 (.004)	.294 (.008)	.499 (.009)		0.999
2002	.018 (.001)	.100 (.002)	.399 (.006)	.482 (.006)		0.999
2003	.013 (.001)	.132 (.003)	.140 (.011)	.305 (.141)	.410 (.018)	1.000
2004	.004 (.001)	.130 (.007)	.147 (.050)	.123 (.051)	.596 (.014)	1.000
2005	.017 (.001)	.160 (.006)	.342 (.038)	.282 (.034)	.199 (.018)	1.000
2006	.006 (.001)	.303 (.004)	.184 (.053)	.151 (.043)	.356 (.023)	1.000
2007	.003 (.000)	.196 (.002)	.325 (.005)	.256 (.010)	.221 (.011)	1.001
2008	.014 (.001)	.145 (.004)	.325 (.006)	.372 (.006)	.144 (.005)	1.000

Distributional Sigmas (Standard Error and constraints)

Year	Age				
	1	2	3	4	5
1999		1.474 (.023)	.571 (.045)	1.039 (.027)	
2000	.705 (.036)	1.317 (.026)	.916 (.026)	1.023 (.038)	
2001	1.063 (Sigma eq. .012)				
2002	1.064 (Sigma eq. .009)				
2003	1.019 (Sigma eq. .015)				
2004	1.062 (.213)	1.322 (.069)	.876 (.190)	.550 (.096)	1.000 (fixed)
2005	1.081 (Sigma eq. .024)				
2006	1.028 (Sigma eq. .013)				
2007	1.028 (Sigma eq. .010)				
2008	1.069 (Sigma eq. .013)				

Table 13. (Continued)

Population at Age Estimates (10^6)

Year	Male Ages						Females	Total
	0	1	2	3	4	5		
1999	23	113	4,160	1,000	3,452		2,659	11,407
2000	0	334	5,217	6,701	2,523	13	6,559	21,347
2001	0	92	3,012	4,414	7,507	25	4,645	19,695
2002	0	416	2,258	8,975	10,847	0	8,748	31,244
2003	0	338	3,494	3,718	8,059	10,861	12,481	38,951
2004	0	46	1,589	1,804	1,514	7,316	5,683	17,954
2005	4	248	2,376	5,056	4,181	2,949	10,741	25,555
2006	4	132	6,399	3,885	3,191	7,778	13,225	34,614
2007	0	92	6,593	10,939	8,599	7,474	25,214	58,911
2008	19	397	4,406	9,901	11,305	4,404	17,749	48,181

Table 14. Male and female biomass/ abundance indices estimated using Ogmap calculations from Canadian **autumn** research bottom trawl survey data, 1996 – 2007. Please note that there was an incomplete survey during 2004 therefore there are no values for that survey.

	Biomass (tons)			Abundance (numbers x 10^6)		
	Males	Females	Total	Males	Females	Total
1996	18,900	5,800	24,700	5,901	659	6,560
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	107,300	82,500	189,800	28,702	10,779	39,480
2004						
2005	128,400	95,300	223,700	34,032	11,238	45,270
2006	132,800	82,600	215,400	37,412	9,638	47,050
2007	146500	128,900	275,400	40,678	15,762	56,439

Table 15. Male and female biomass/ abundance indices estimated using Ogmap calculations from Canadian **spring** research bottom trawl survey data, 1999 – 2008. Please note that the survey was incomplete in Divs. 3NO during spring 2006; however, over 90% of the biomass/ abundance is found in 3L therefore the 2006 estimates are for 3L only.

	Biomass (tons)			Abundance (numbers x 10-6)		
	Males	Females	Total	Males	Females	Total
1999	29,400	20,000	49,400	8,756	2,662	11,417
2000	46,900	50,300	97,200	14,795	6,561	21,356
2001	50,000	32,500	82,500	15,066	4,648	19,714
2002	79,200	54,600	133,800	22,503	8,757	31,260
2003	91,100	78,400	169,500	26,520	12,478	38,998
2004	51,700	41,800	93,500	12,307	5,696	18,003
2005	52,700	80,700	133,400	14,803	10,737	25,540
2006	77,500	102,100	179,600	21,388	13,237	34,625
2007	111,900	176,700	288,600	31,334	22,970	54,304
2008	99,200	133,200	232,400	30,460	17,755	48,215

Table 16 Fishable biomass (t) indices (total weight of all females + weight of all males with carapace lengths => 17.5 mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2008.

(i) Male portion of the fishable biomass determined by applying a length-weight relationship to the fishable portion of a population adjusted male length frequency (=>17.5 mm carapace length) and adding the female biomass.

Year	Estimate (t)	
	Spring	Autumn
1996		14,591
1997		34,129
1998		48,346
1999	40,626	40,999
2000	80,959	79,194
2001	66,242	173,138
2002	110,647	157,054
2003	148,455	166,331
2004	83,147	
2005	115,991	181,348
2006	160,351	173,117
2007	263,878	230,829
2008	195,858	

(ii) Proposed method of determining fishable biomass by using a length-weight relationship to estimate weight of fishable males (=> 17.5 mm carapace length carapace length) and adding the weight of females on a set by set basis. Ogmap calculations are then run on the data.

Year	Spring			Autumn		
	Lower 95% C.I.	Estimate (t)	Upper 95% C.I.	Lower 95% C.I.	Estimate (t)	Upper 95% C.I.
1996				11,690	14,600	22,340
1997				24,610	34,100	47,150
1998				38,960	50,100	64,660
1999	20,630	40,700	64,080	32,160	41,000	57,810
2000	43,070	80,900	133,300	61,280	79,100	101,000
2001	42,750	66,300	93,630	125,500	173,100	216,500
2002	72,280	112,400	175,700	109,000	157,000	200,700
2003	106,900	148,500	204,200	121,800	166,300	212,500
2004	35,070	83,200	152,600		???	
2005	73,080	116,000	161,200	141,200	180,500	219,300
2006	91,180	158,200	218,900	137,900	173,100	204,100
2007	167,200	258,200	341,700	193,800	243,000	312,400
2008	137,100	187,800	236,700			

Table 17. Recruitment indices as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2008.

(i) Age 2 abundance from modal analysis of population adjusted length frequencies. Please note that the table presents survey year. The cohort year is survey year -2.

Year	Spring Abundance (10^6)	Autumn Abundance (10^6)
1996		3,925
1997		3,007
1998		2,614
1999	4,160	5,514
2000	5,217	8,081
2001	3,012	7,976
2002	2,258	4,844
2003	3,494	5,114
2004	1,589	
2005	2,376	4,628
2006	6,399	10,879
2007	6,593	9,635
2008	4,406	

(ii) The abundance of males 12-17 mm in carapace length

Year	Spring			Autumn		
	Lower 95% C.I.	Abundance (10^6)	Upper 95% C.I.	Lower 95% C.I.	Abundance (10^6)	Upper 95% C.I.
1996				2,641	3,515	4,934
1997				2,429	2,986	4,020
1998				2,226	2,936	3,813
1999	2,230	4,248	6,804	3,967	5,261	6,570
2000	4,423	7,207	9,826	6,965	10,266	13,640
2001	3,829	6,787	10,400	11,480	15,877	18,640
2002	5,408	8,667	13,950	8,261	12,253	14,840
2003	4,689	9,595	17,240	5,676	7,614	9,379
2004	2,058	3,242	4,736		????	
2005	4,071	6,391	8,991	9,088	12,513	16,010
2006	5,811	8,827	12,600	9,994	14,566	19,350
2007	8,022	13,839	19,470	11,770	16,758	22,800
2008	10,340	15,487	20,390			

Table 18. Exploitation rate indices for NAFO Divisions 3LNO as determined using Canadian autumn survey and total catch data over the period 1997 -2008. Ogmap methods were used in determining stock size indices. Two methods were used in determining fishable biomass;

i) the previous method in which a length weight relationship was used to convert the male portion of the fishable biomass (=> 17.5 mm carapace length carapace length) of the population adjusted length frequencies were converted to biomass and added to the SSB, and

ii) the proposed method of determining fishable biomass by using a length-weight relationship to determined weight of fishable males (=> 17.5 mm carapace length carapace length) and adding the weight to the weight of females on a set by set basis. Ogmap calculation are then run on the data.

Year	Catch (t)	Lower 95% CL of biomass index (t)	Spawning Stock biomass (SSB) (t)	Fishable biomass previous method (t)	Fishable biomass proposed method (t)
1996		20,150	5,800	14,591	14,600
1997	485	32,410	19,200	34,129	34,100
1998	626	48,310	18,200	48,346	50,100
1999	795	43,160	21,700	40,999	41,000
2000	4,711	83,990	32,600	79,194	79,100
2001	10,684	155,300	63,500	173,138	173,100
2002	6,979	135,500	69,500	157,054	157,000
2003	12,887	144,000	82,500	166,331	166,300
2004	13,307				
2005	14,102	178,400	95,300	181,348	180,500
2006	24,466	172,900	82,600	173,117	173,100
2007	23,857	209,100	128,900	230,829	243,000
2008	22,961				

Year	Catch / lower CL biomass	Catch/SSB	Catch/fishable (previous method) biomass	Catch/ fishable (proposed method) biomass
1997	0.024	0.084	0.033	0.033
1998	0.019	0.033	0.018	0.018
1999	0.016	0.044	0.016	0.016
2000	0.109	0.217	0.115	0.115
2001	0.127	0.328	0.135	0.135
2002	0.045	0.110	0.040	0.040
2003	0.095	0.185	0.082	0.082
2004	0.092	0.161	0.080	0.080
2005				
2006	0.137	0.257	0.135	0.136
2007	0.138	0.289	0.138	0.138
2008	0.110	0.178	0.099	0.094

Table 19. Survival, annual mortality and instantaneous mortality rate indices for Northern Shrimp (*Pandalus borealis)* within NAFO Divisions 3LNO. Indices were calculated by combining 3 years of data in order to account for vagaries within the survey data and due to aging by modal analysis. The survival, S, in the light green box is the female abundance shaded orange divided by the sum of the age 4+ shrimp shaded blue. Median survival, annual mortality, and instantaneous mortality rates were 0.512, 0.488 and 0.670 respectively.

Year	Age 4+males and total female abundance (millions; year = t)	Total female abundance (millions; year = t+1)	Survival rate = Total female abundance $_{(t+1)}$/ age 4+ female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1996	1,155	661			
1997	3,095	2,710			
1998	3,859	2,132	0.9672	0.0328	0.0334
1999	5,833	3,001	0.7338	0.2662	0.3095
2000	7,519	4,250	0.8940	0.1060	0.1120
2001	29,603	8,136	0.5118	0.4882	0.6699
2002	23,293	9,597	0.4714	0.5286	0.7520
2003	25,845	10,747	0.2584	0.7416	1.3534
2004			0.4472	0.5528	0.8047
2005	24,083	11,229	0.4179	0.5821	0.8725
2006	28,480	9,636	0.6960	0.3040	0.3625
2007	29,029	15,717			
	median values		0.5118	0.4882	0.6699

Table 20. Various TAC scenarios using the inverse variance weighted average fishable biomass from the four most recent Canadian research surveys into 3LNO. Please note that due to rounding, it may not be possible to derive exactly the same fishable biomass or catch rates using the numbers presented in the tables below; however, the derived values should be within a few percent of the values shown in the tables.

Variance weighting factor = fishable biomass/(measure of variance)^2÷Σ fishable biomass/(measure of variance)^2

Survey	Fishable biomass (t)	Fishable biomass – lower 95% C.I.= measure of variance	Fishable biomass/ (measure of variance^2)	1/measure of variance^2	Variance weighting factor
Autumn 2006	173,100	35,200	1.400E-4	8.07E-10	0.398
Spring 2007	258,200	91,000	3.120E-5	1.21E-10	0.089
Autumn 2007	243,000	49,200	1.07E-4	4.13E-10	0.304
Spring 2008	187,800	50,700	7.31E-5	3.89E-10	0.208
Grand total			3.5061E-4	1.7230E-9	0.999

Inverse variance weighted average fishable biomass = 3.5061E-4÷1.7230E-9
= 202,667 t

Inverse variance weighted average fishable biomass (t)	Catch options at various exploitation rates		
202,700	25,000	30,000	35,000
Exploitation rates (TAC/fishable biomass) expressed as percents	12.33%	14.80%	17.27%

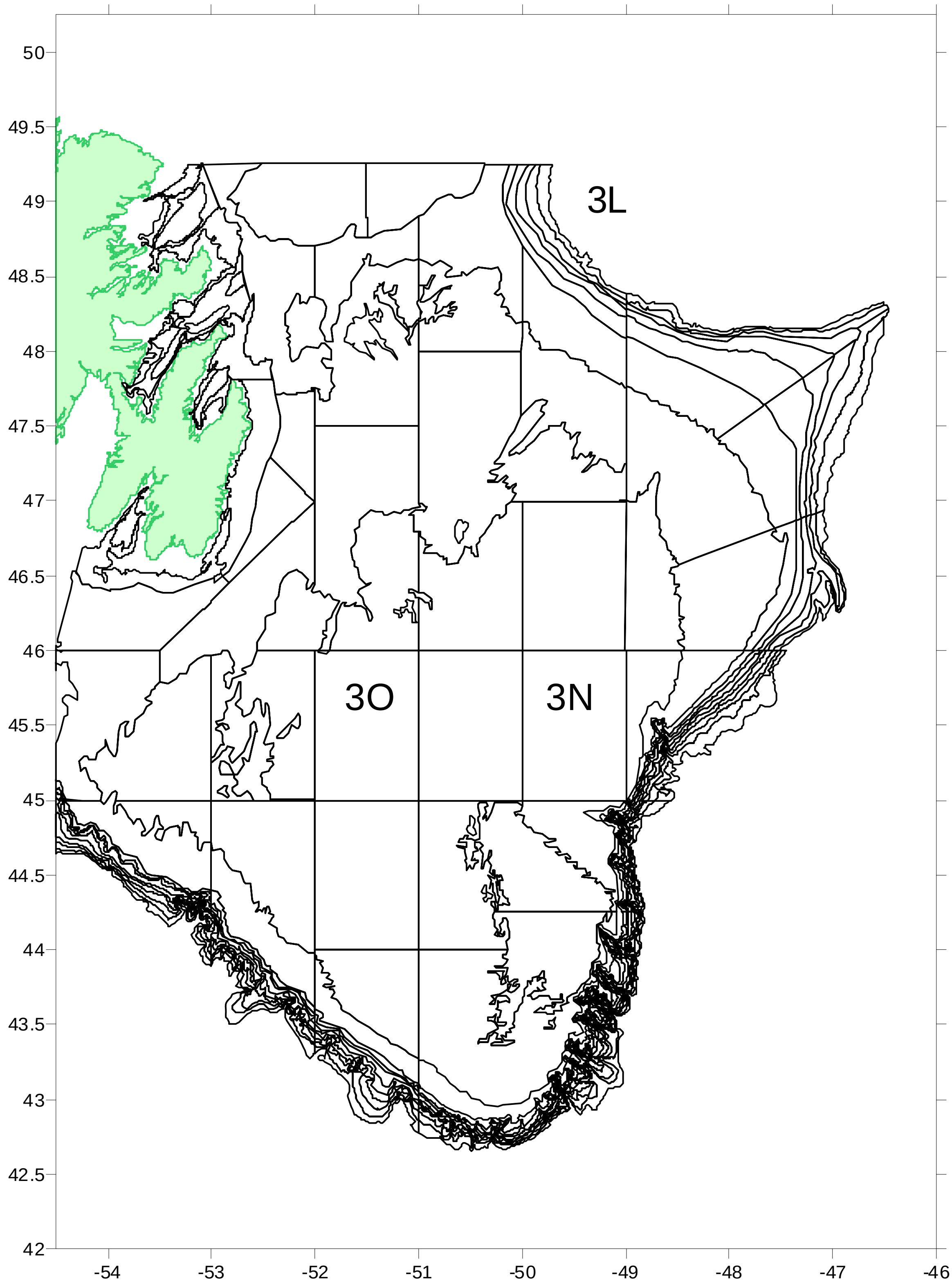

Figure 1. The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species research bottom trawl survey set allocation.

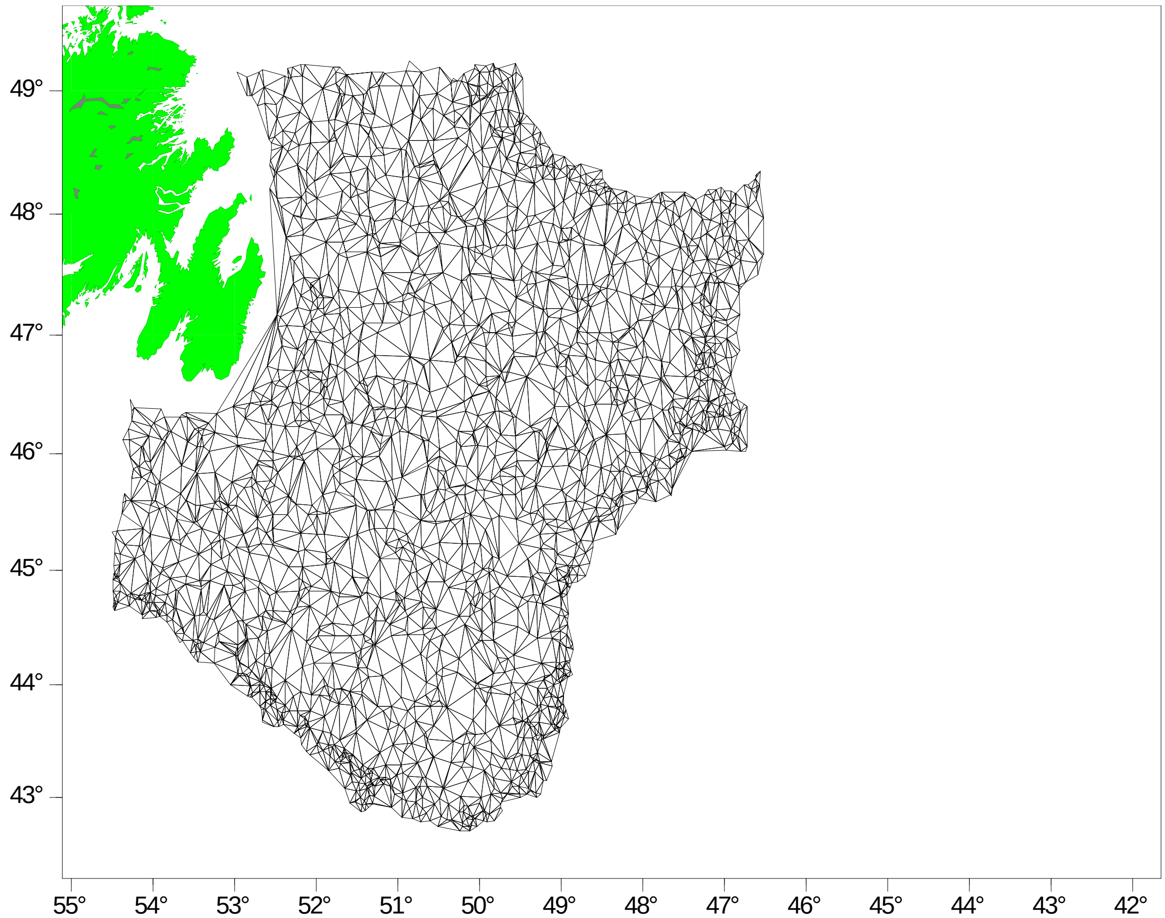

Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Ogmap.

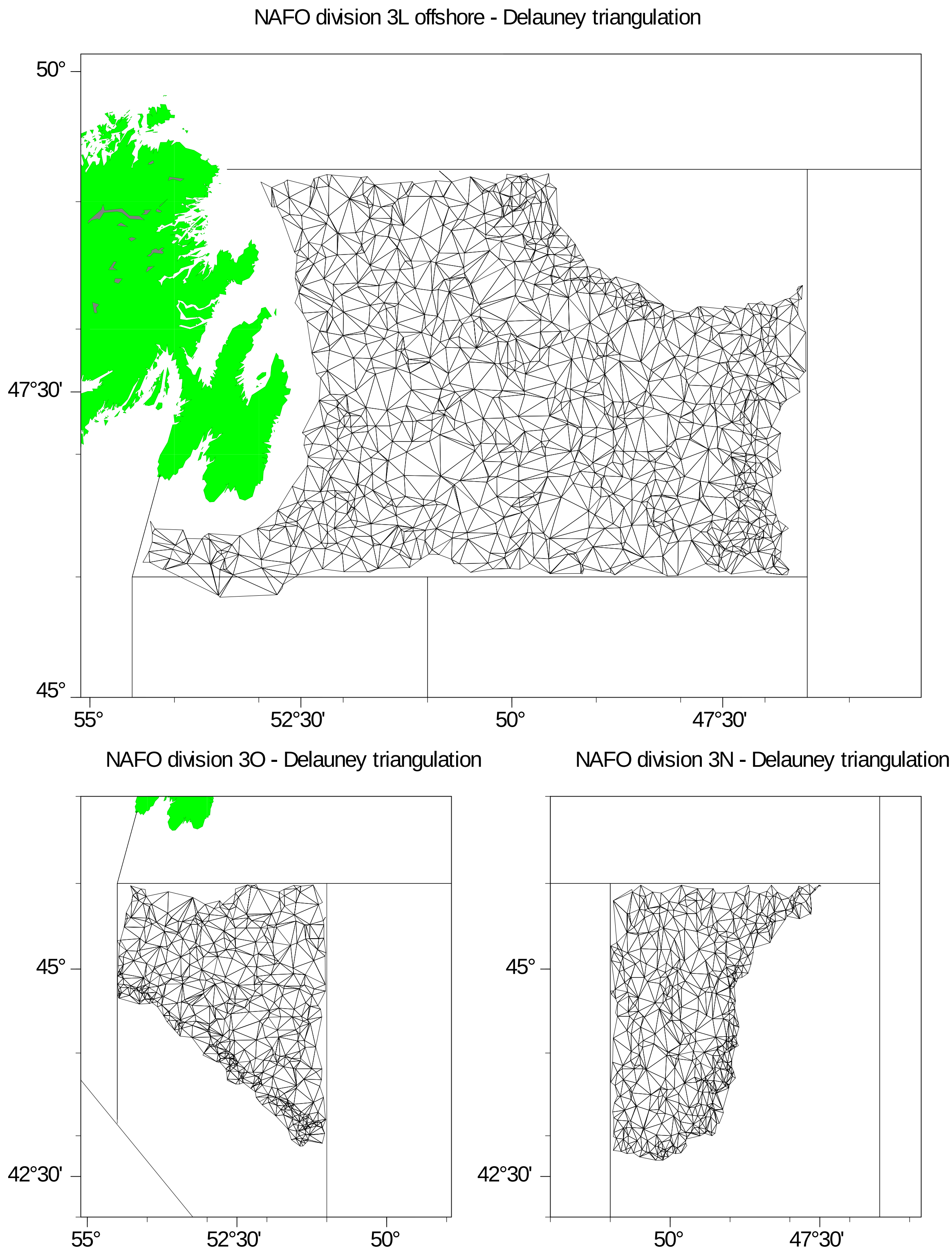

Figure 3. The Delauney triangulation used to derive within NAFO division ogmap biomass and abundance indices.

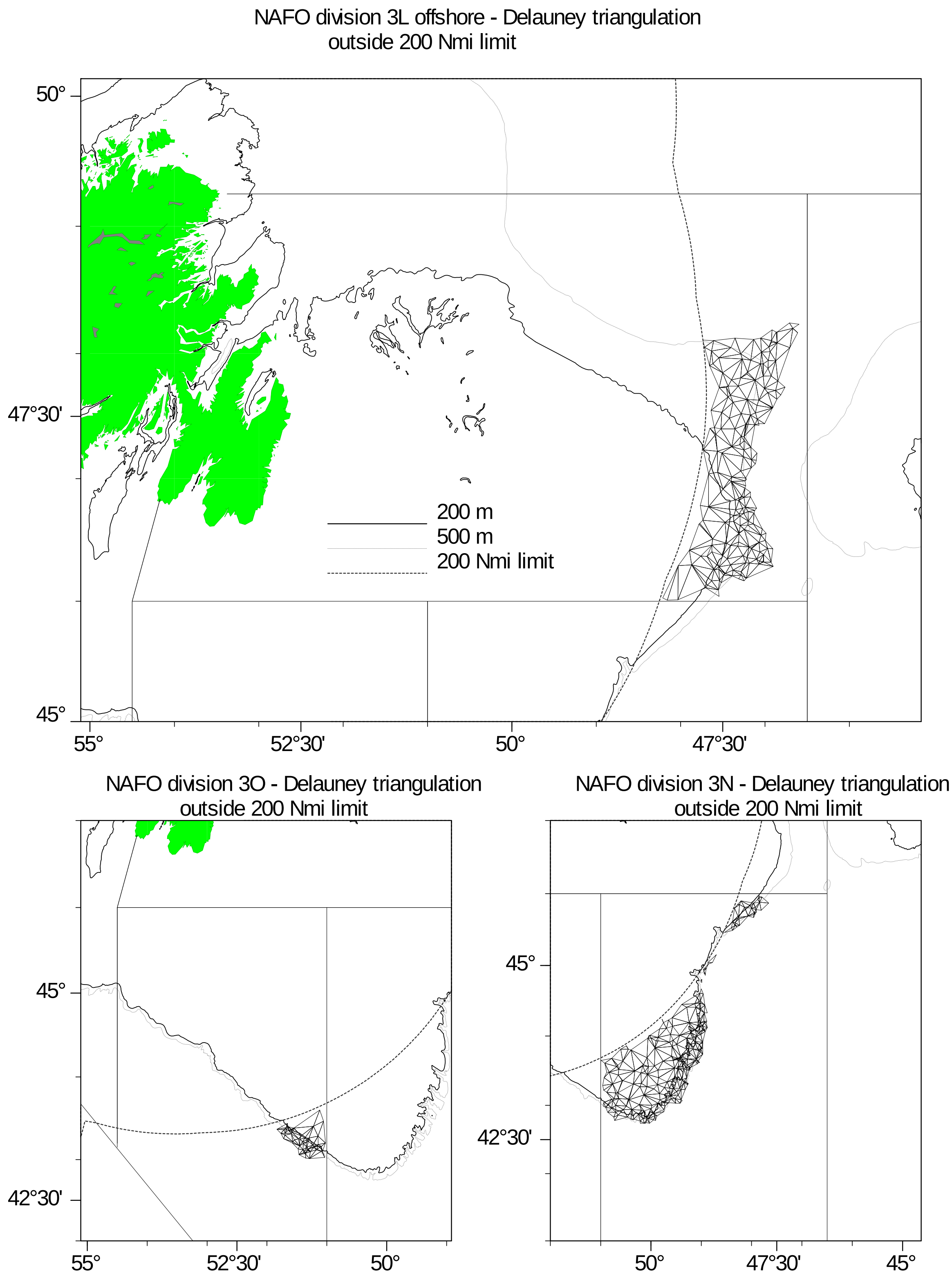

Figure 4. The Delauney triangulation used to derive the outside 200 Nmi limit ogmap biomass and abundance indices.

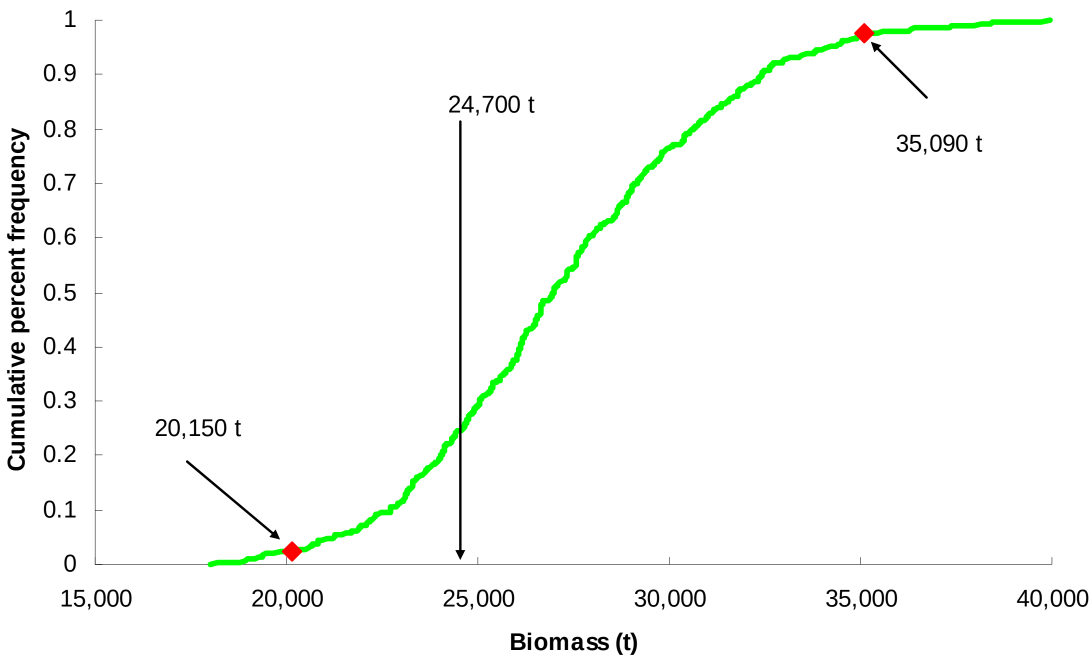

Figure 5. The Monte Carlo distribution for expected biomass of northern shrimp (*Pandalus borealis*) integrated over NAFO division 3LNO. Please note that the expected biomass index is calculated from the entire distribution rather than from the Monte Carlo simulations. The 95% confidence limits are found on the distribution ogive. The data used in this analysis were obtained during the autumn 2006 Canadian research bottom trawl survey.

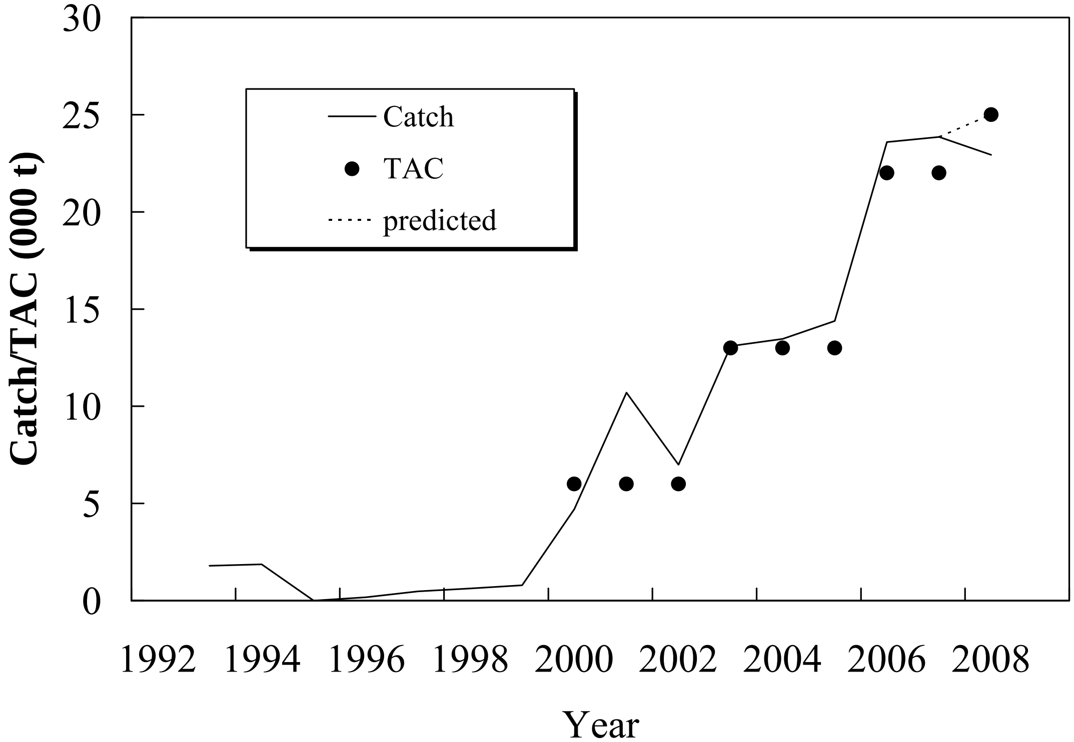

Figure 6. Trends in NAFO Division 3L northern shrimp (*Pandalus borealis*) catch and TAC over the period 1993 – 2008.

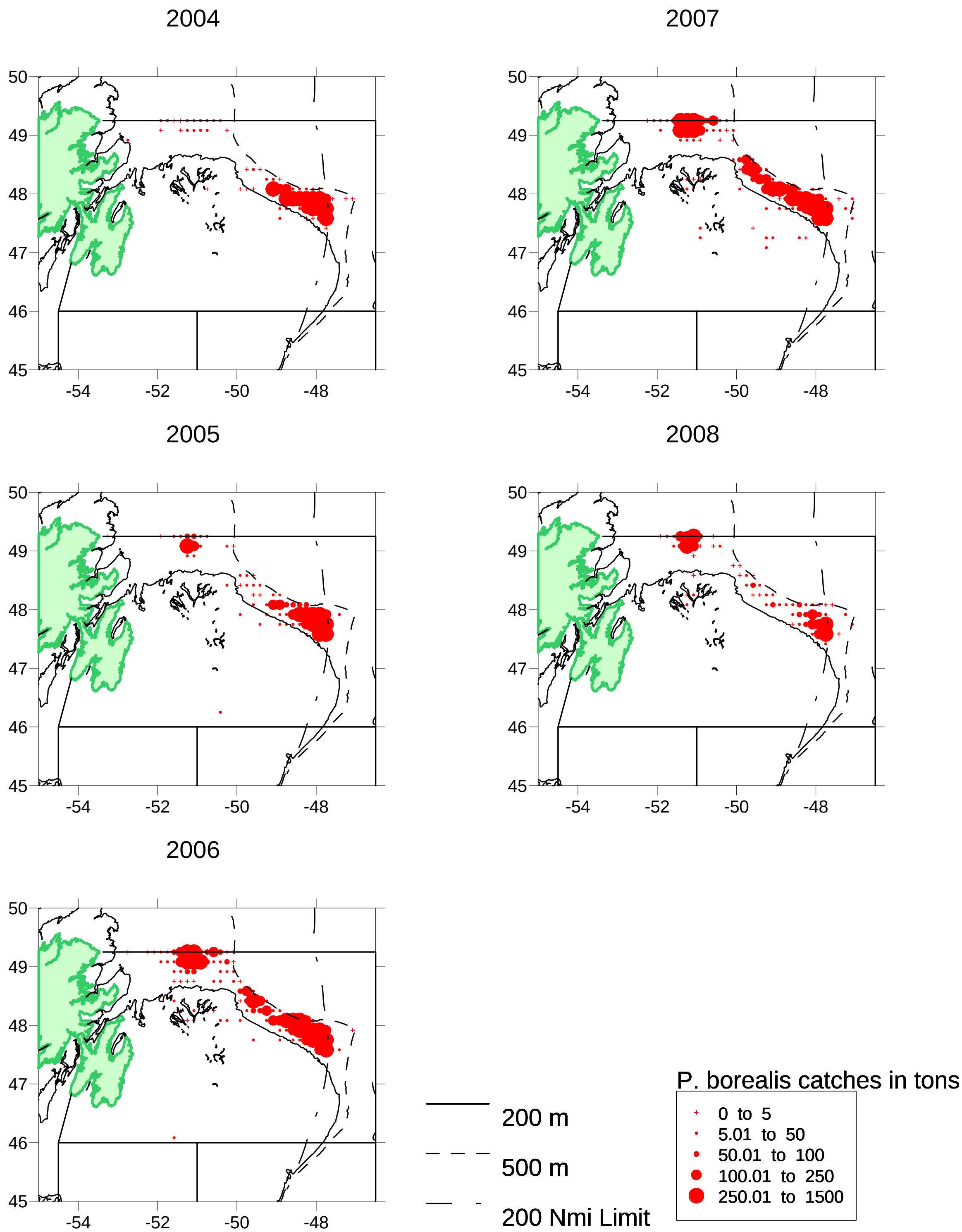

Figure 7. Distribution of **Canadian small vessel (<= 500 t)** shrimp catches in NAFO Division 3L, 2004 – 2008. (Logbook data aggregated into 10 min X 10 min cells).

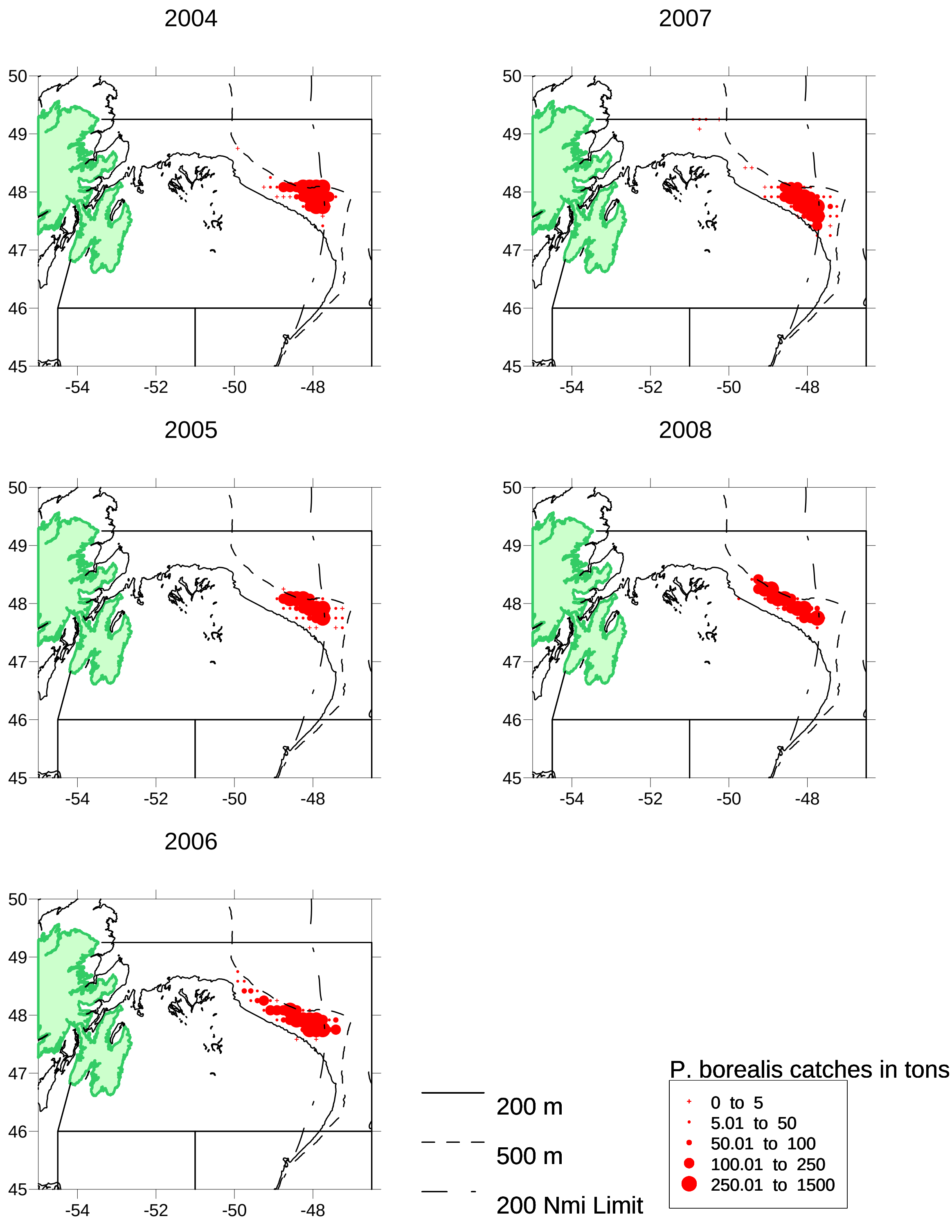

Figure 8. Distribution of **Canadian large vessel (>500 t)** shrimp catches in NAFO Division 3L, 2004 – 2008. (Observer data aggregated into 10 min X 10 min cells).

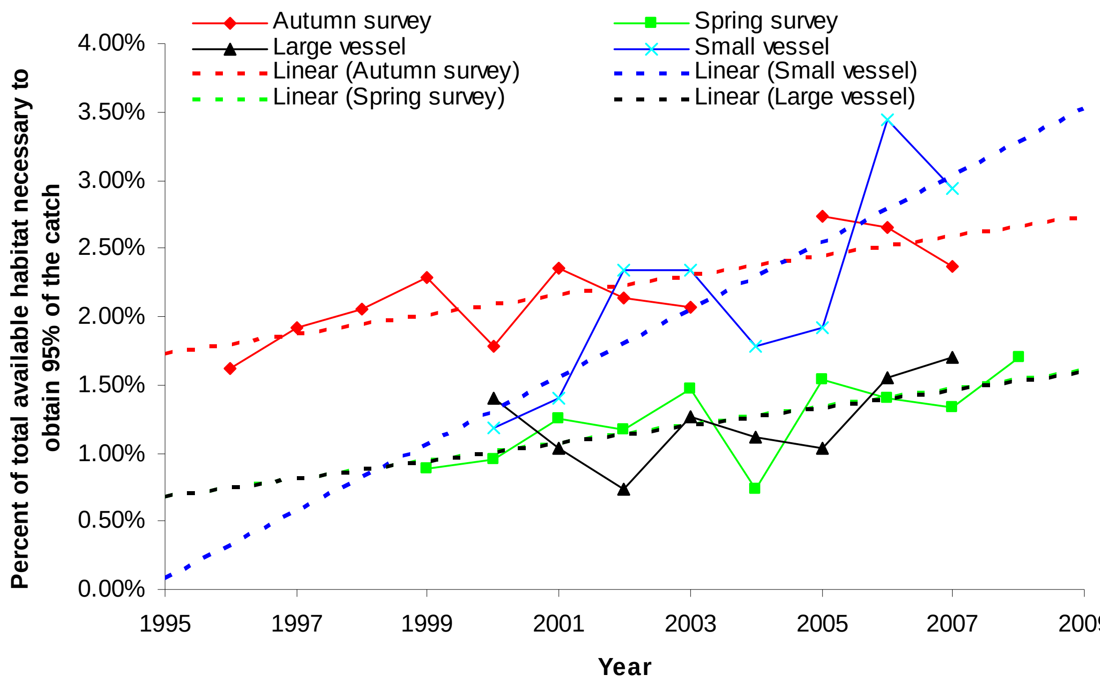

Figure 9. Trends in percent area occupied by the northern shrimp (*Pandalus borealis*) resource as well as large and small vessel shrimp fisheries in relation to total area available within NAFO Divisions 3LNO.

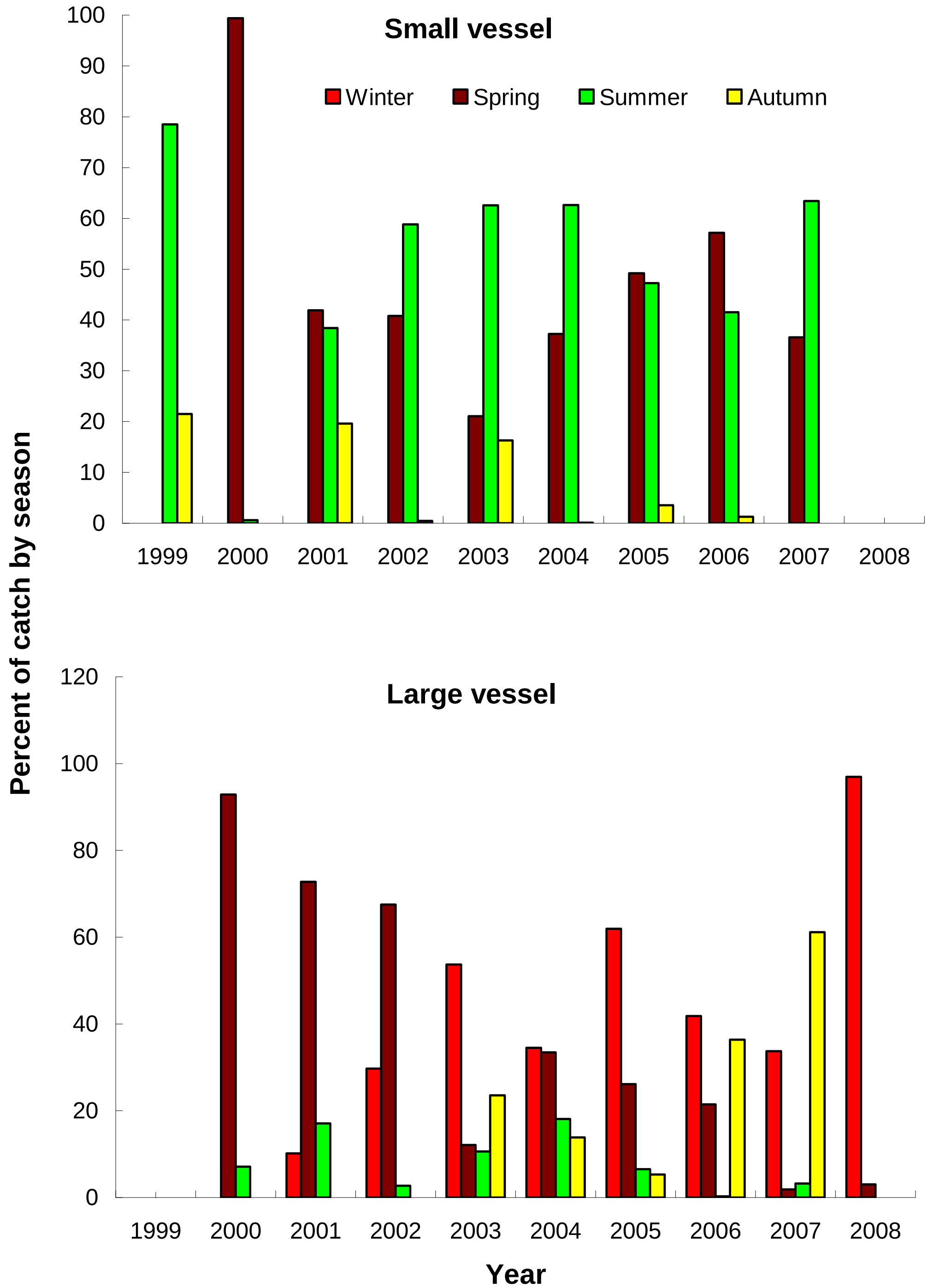

Figure 10. Seasonality of the large and small vessel northern shrimp (*Pandalus borealis*) fishery in NAFO Division 3L. Due to incomplete data, the small vessel panel extends from 2000 – 2007 rather than 2000 – 2008 as with the large vessel panel.

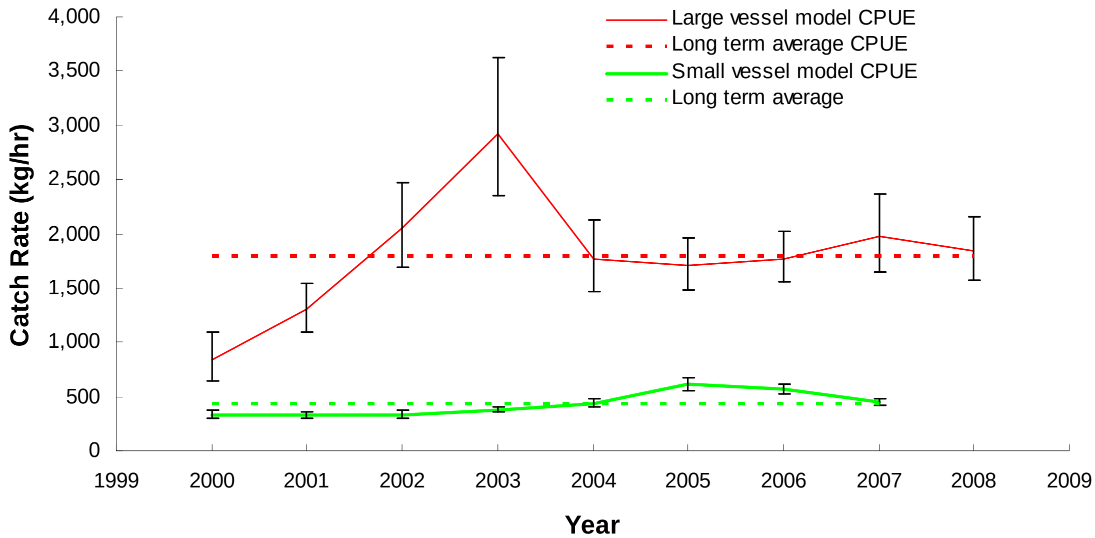

Figure 11. Model catch rates for Canadian large (>500 t) (2000 – 2008) and small (<=500 t; <65') (2000 – 2007) vessels fishing for shrimp in NAFO Div. 3L. Bars present 95% confidence intervals.

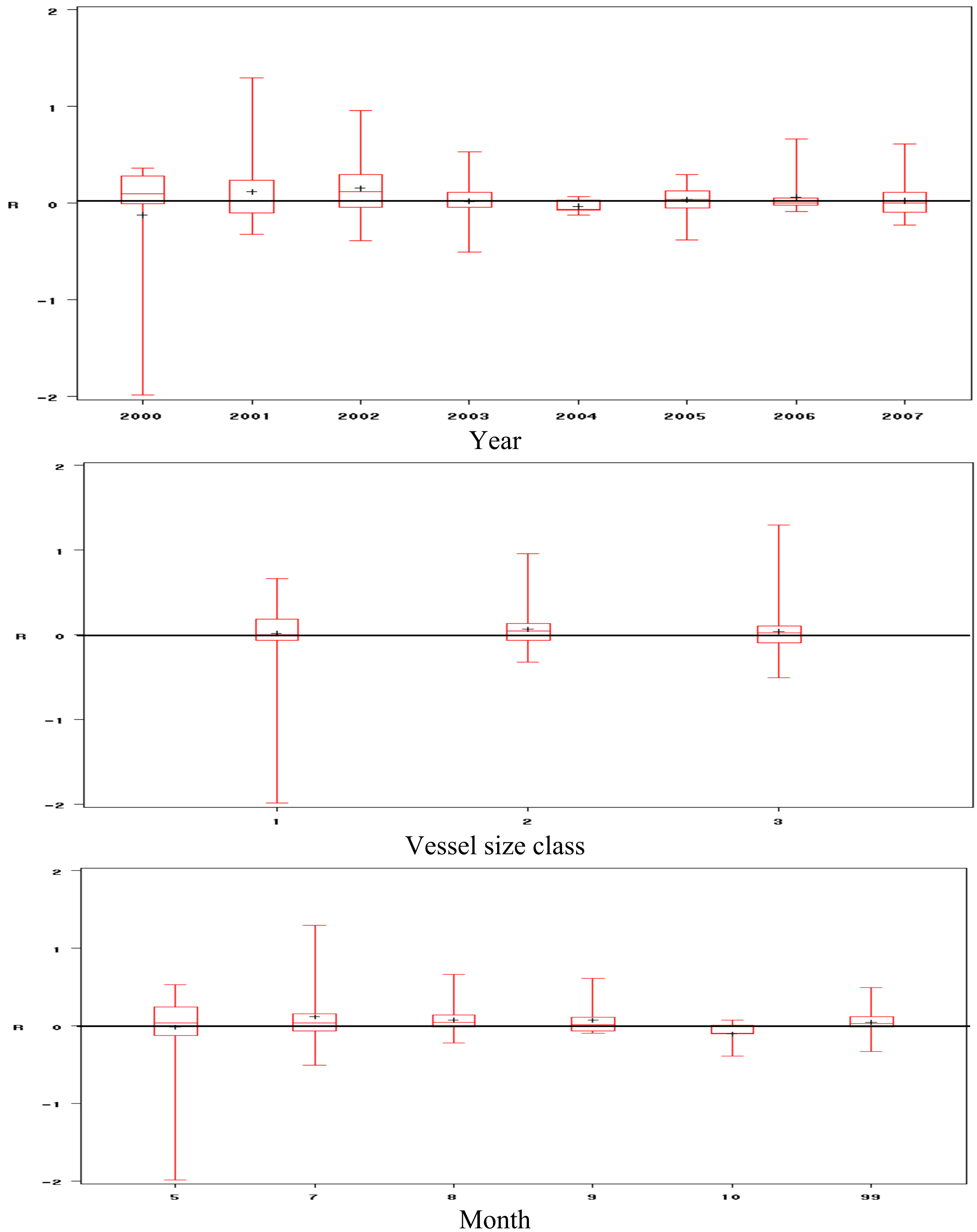

Figure 12. Distribution of residuals around estimated values for parameters used to model Canadian small vessel Div. 3L shrimp catch rates, 2000 – 2007.

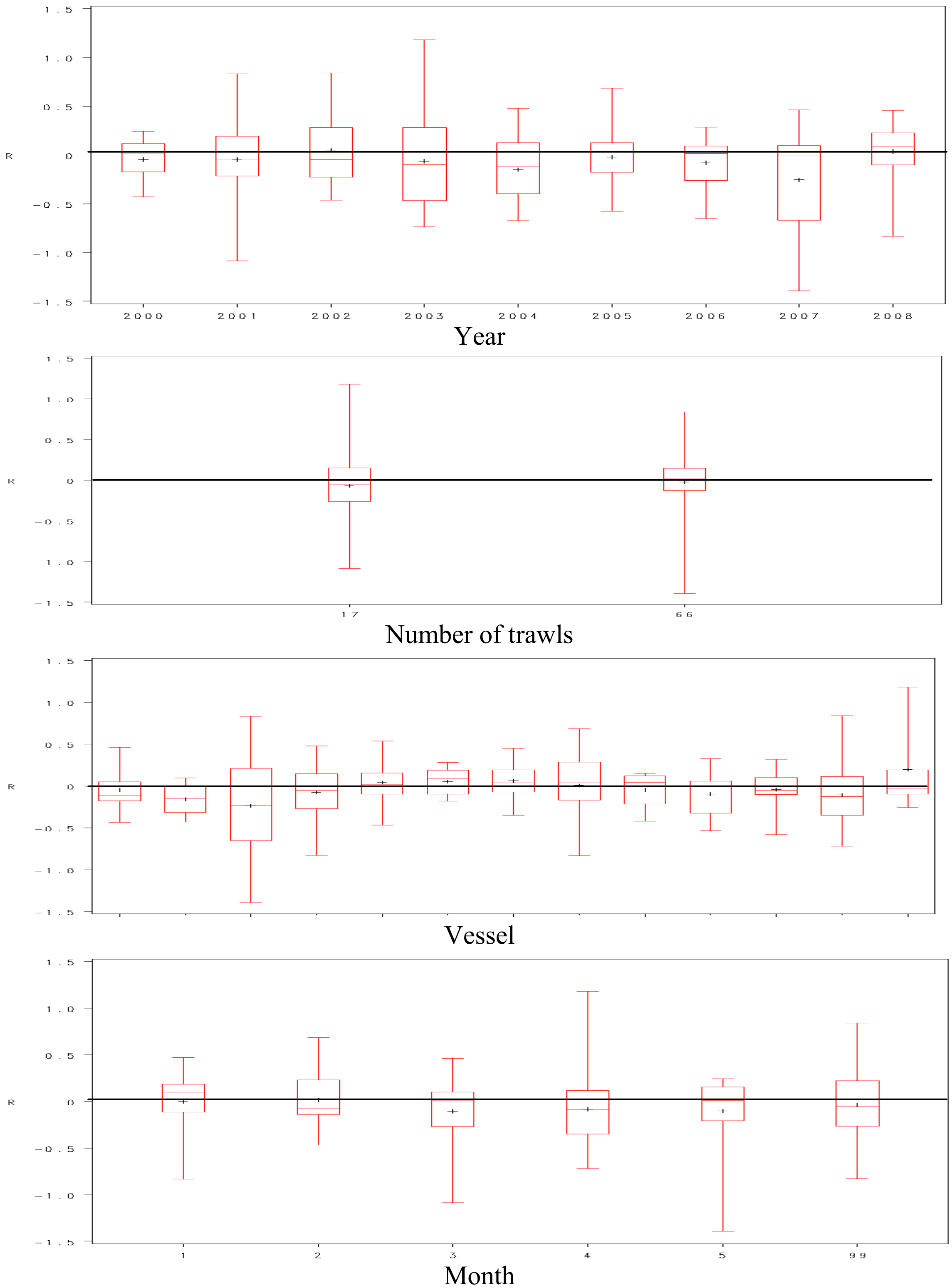

Figure 13. Distribution of residuals around estimated values for parameters used to model **Canadian large vessel** Div. 3L shrimp catch rates, 2000 –2008.

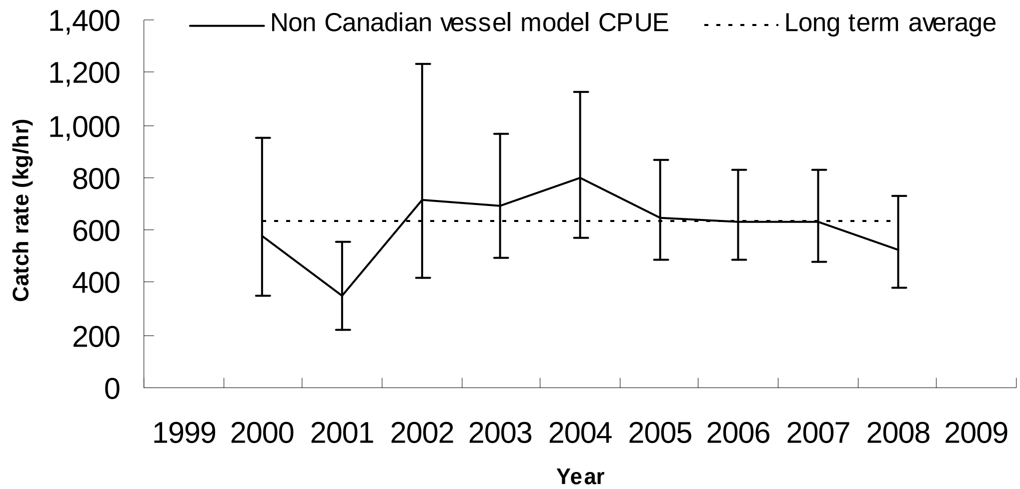

Figure 14. Model catch rates for **non-Canadian vessels** fishing for northern shrimp (*Pandalus borealis*) within the NAFO Division 3L NRA over the period 2000 – 2007. Bars present 95% confidence intervals.

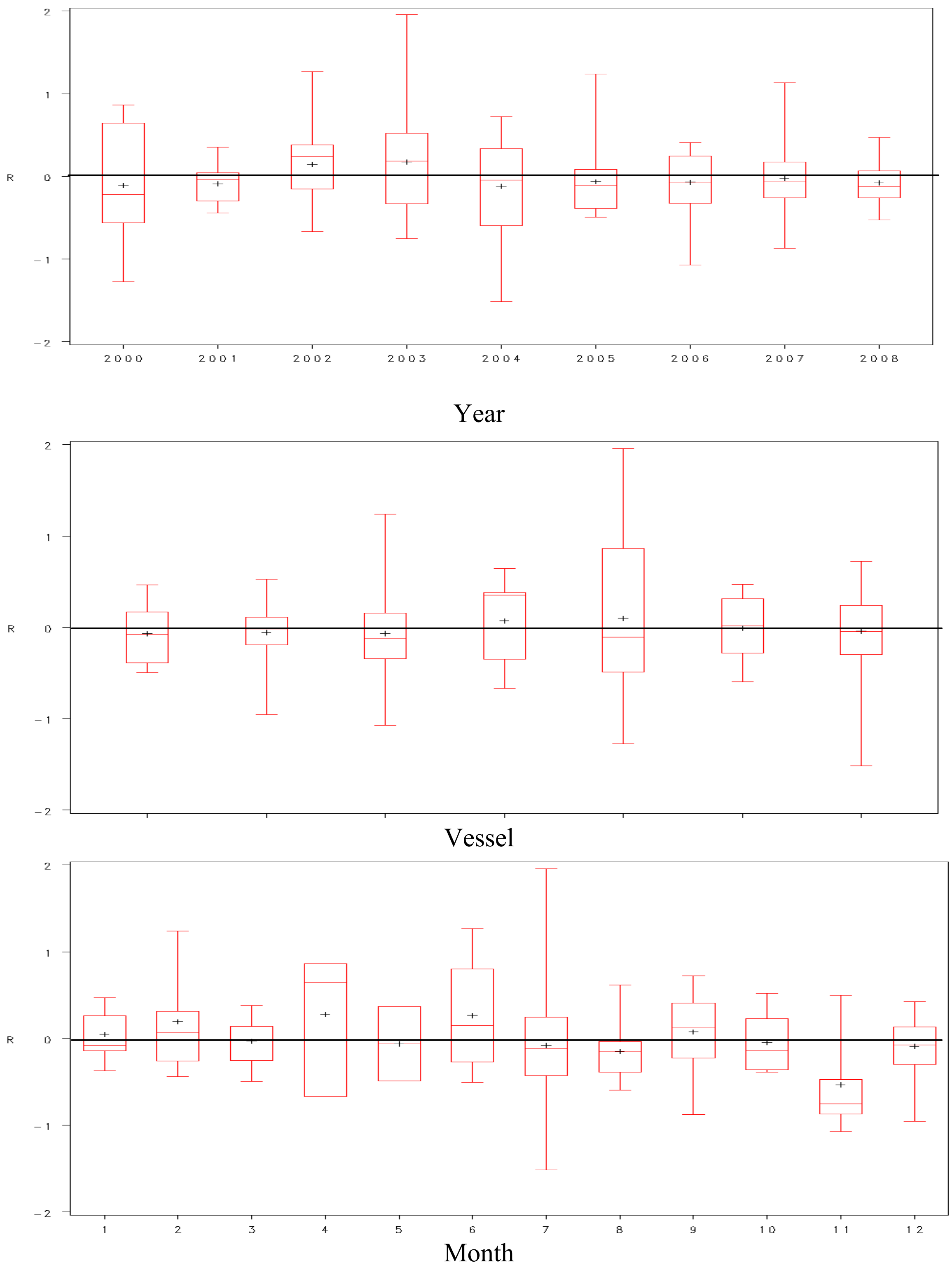

Figure 15. Distribution of residuals around estimated values for parameters used to model shrimp catch rates for **non-Canadian vessels** fishing shrimp in the NAFO Division 3L NRA over the period 2000 – 2007.

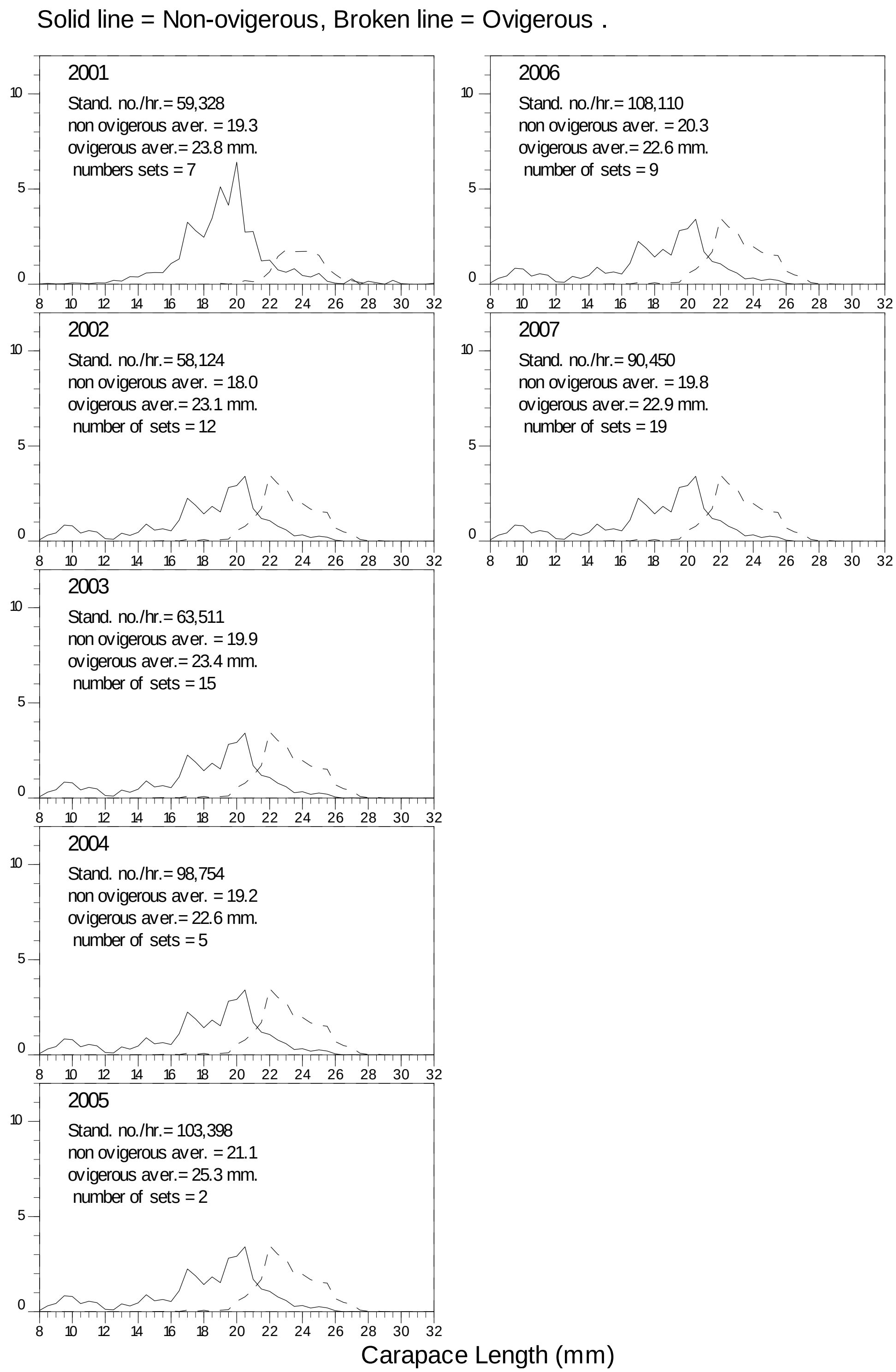

Figure 16. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing shrimp in NAFO Div. 3L over the period 2001 – 2007.

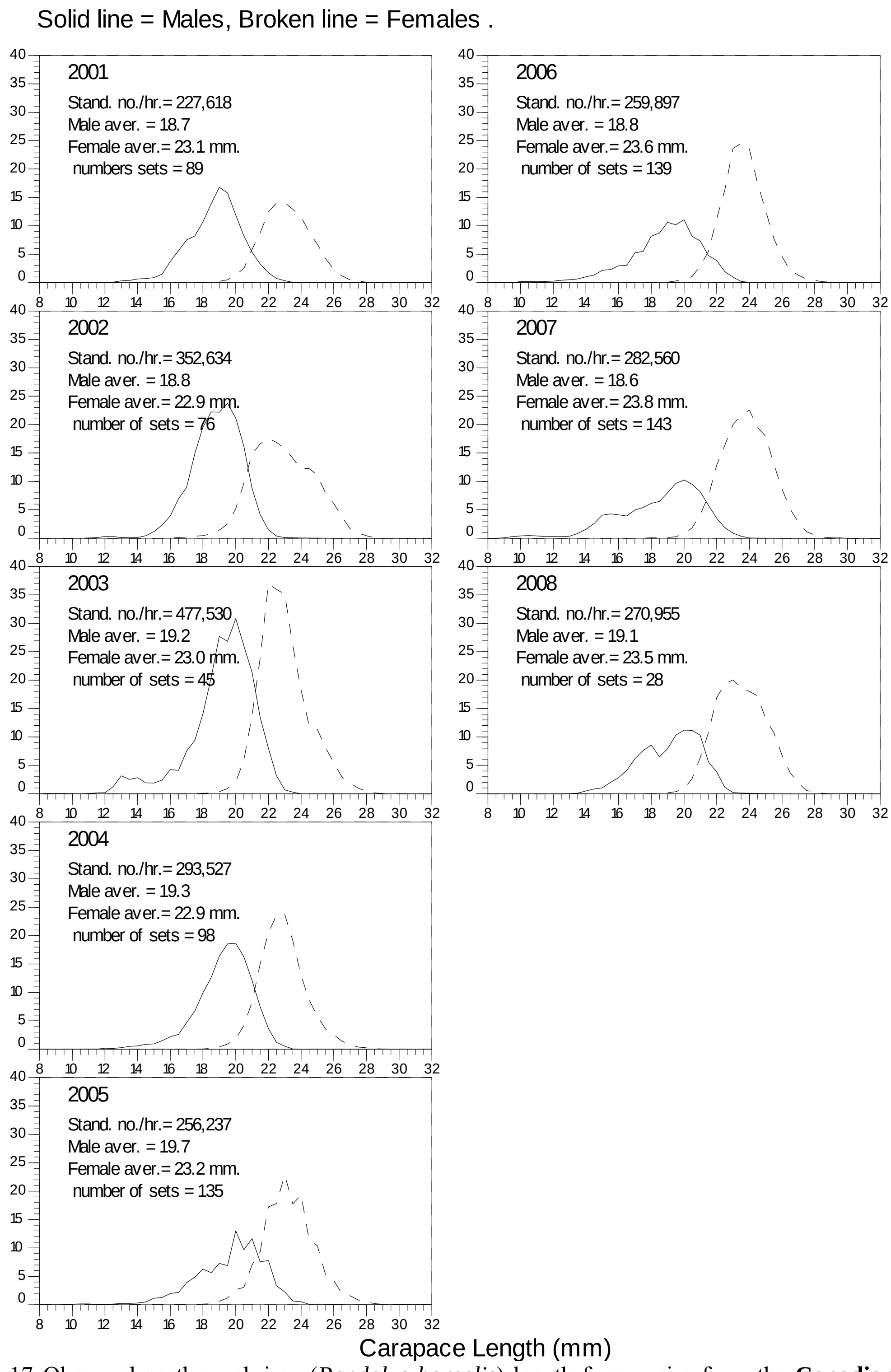

Figure 17. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing shrimp in NAFO Div. 3L over the period 2001 – 2007.

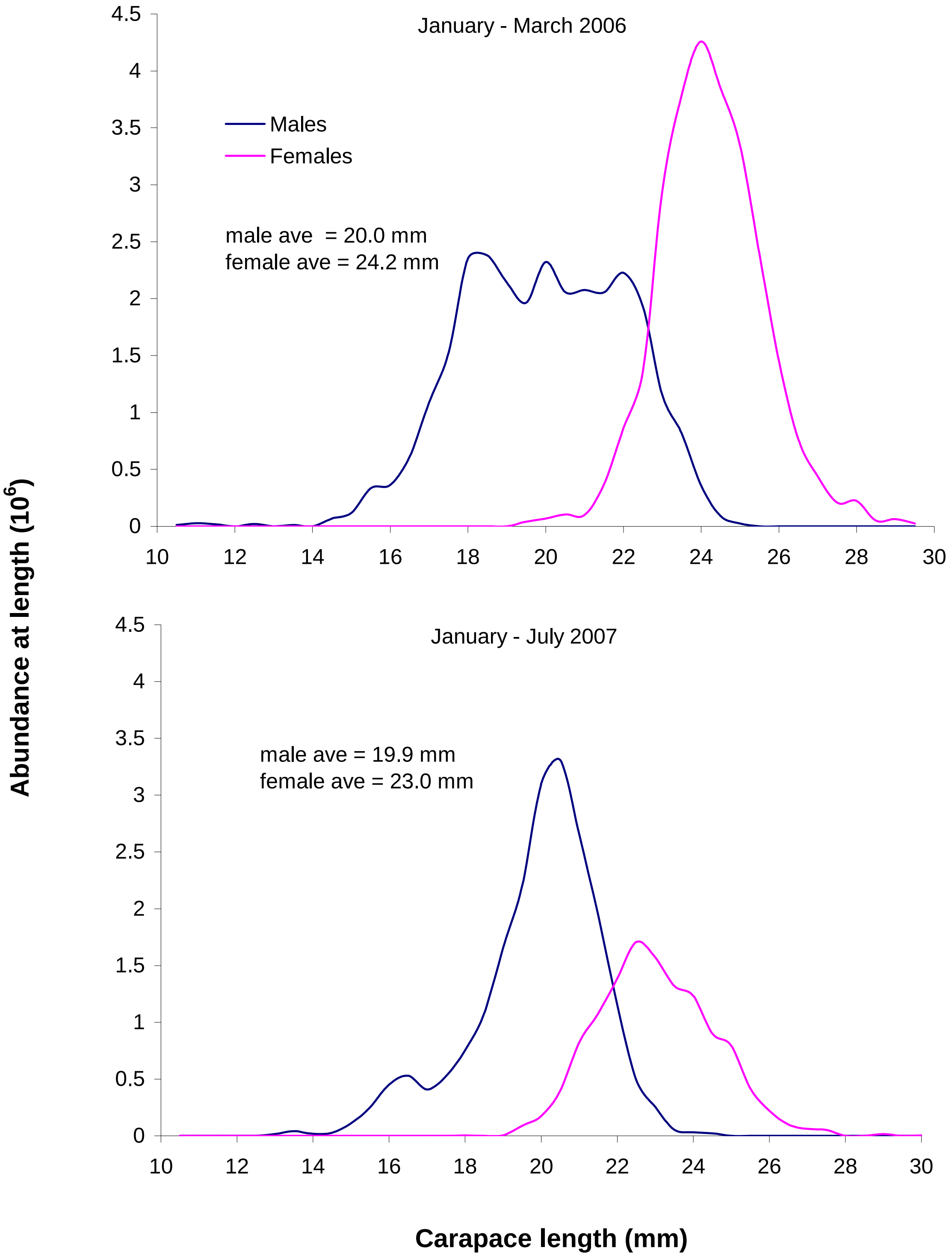

Figure 18. Observed length frequencies from the **Spanish** northern shrimp fishery in NAFO Div. 3L NRA over the period 2006 – 2007.

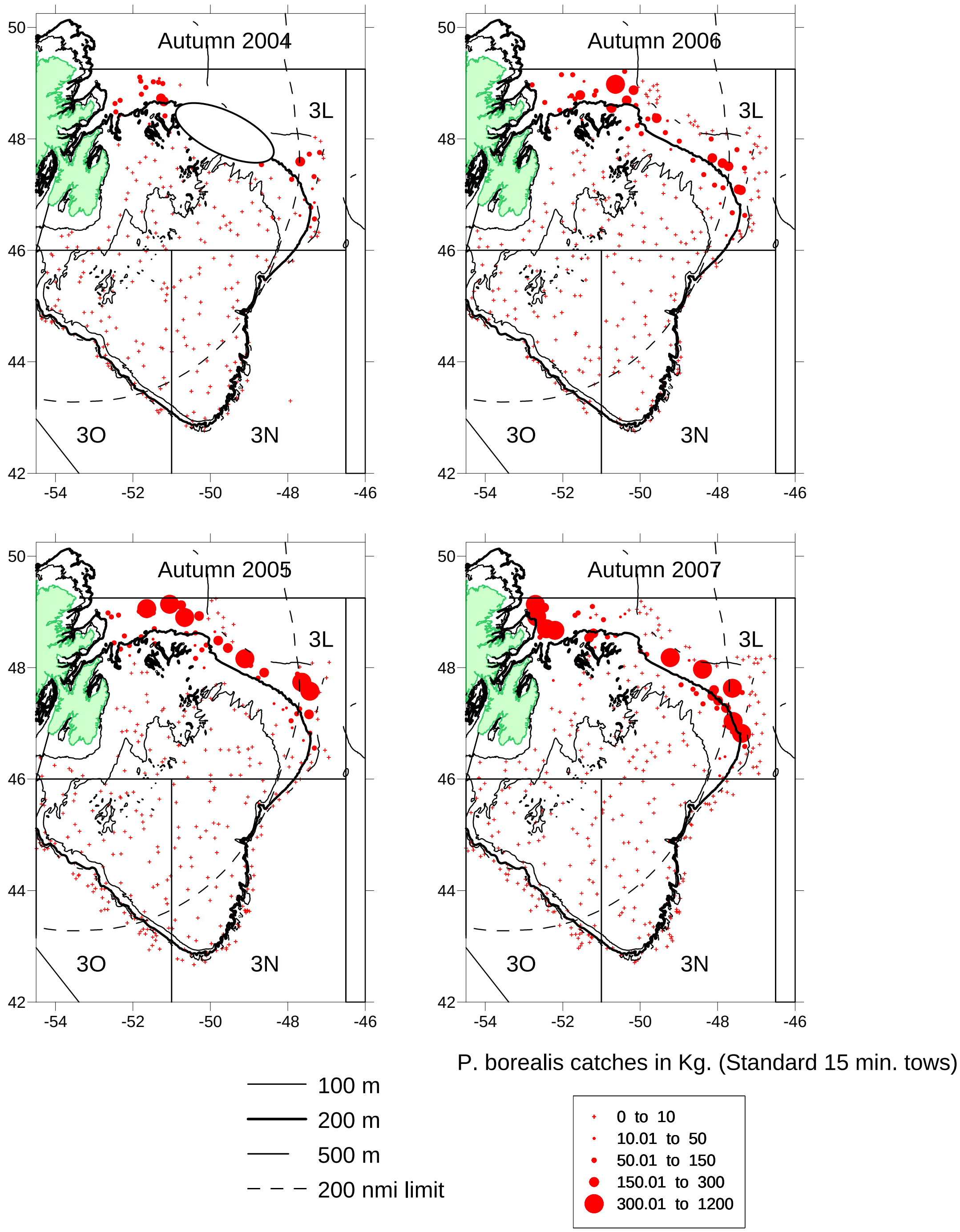

Figure 19. Distribution of NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) catches kg/tow) as obtained from **autumn** research bottom trawl surveys conducted over the period 2005-2007. Ellipse in top left panel indicates area not surveyed during autumn 2004.

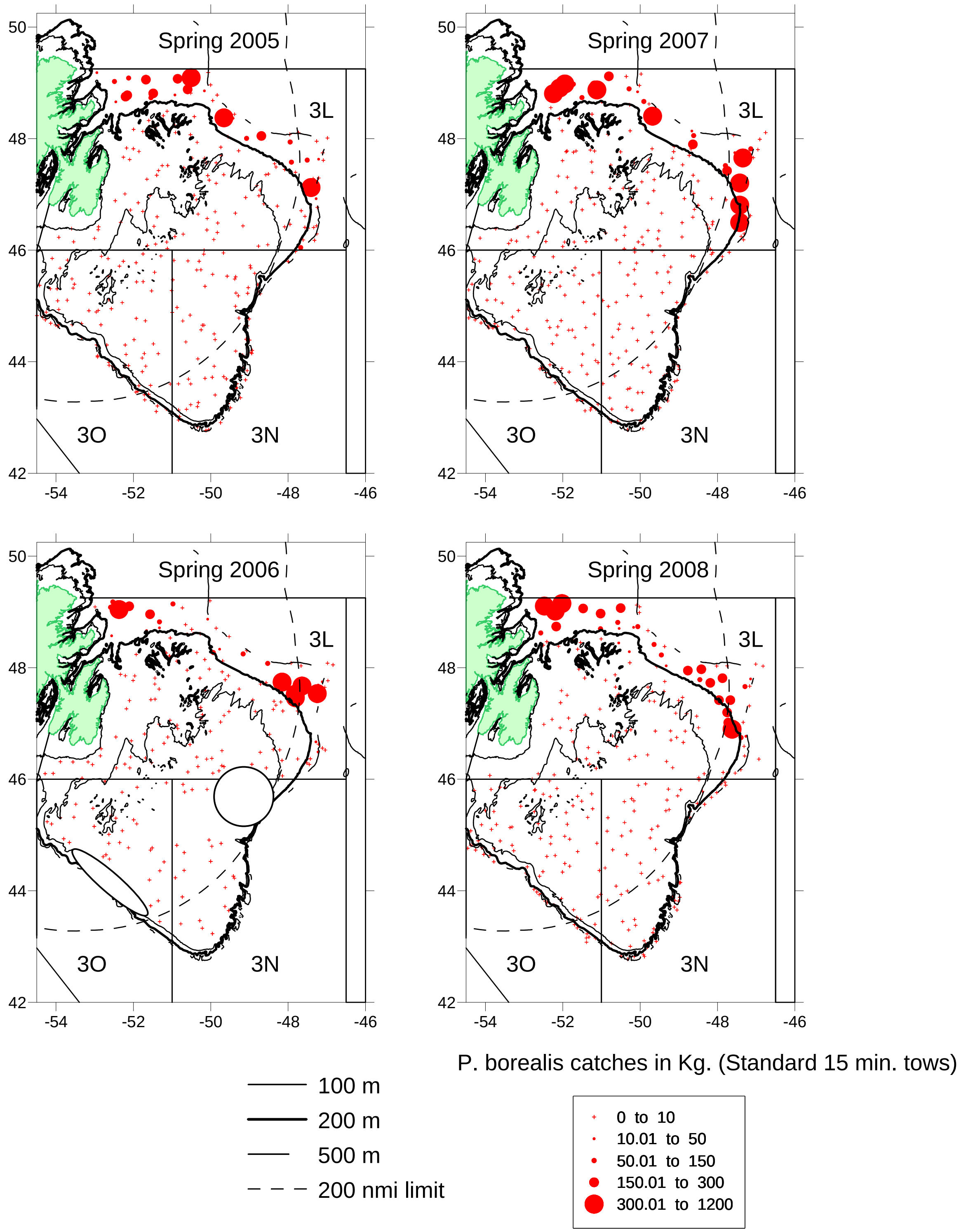

Figure 20. Distribution of NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) catches kg/tow) as obtained from **spring** research bottom trawl surveys conducted over the period 2005-2008. Ellipses in lower left panel indicates area not surveyed during spring 2006.

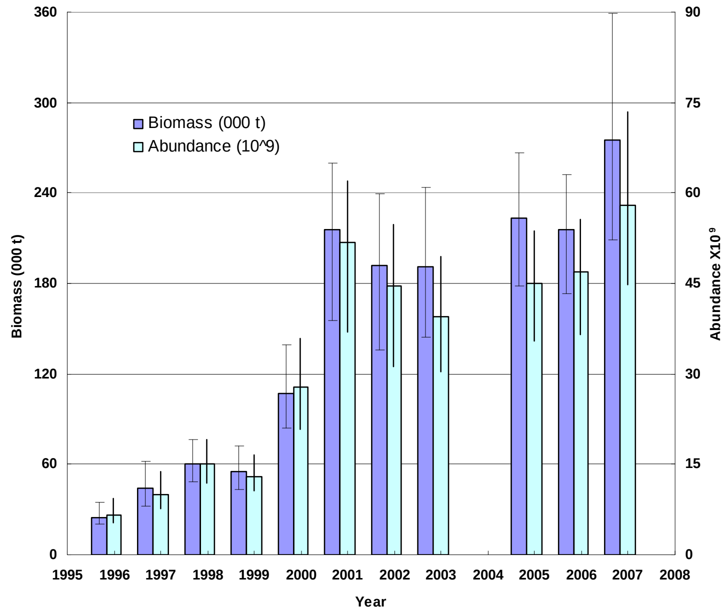

Figure 21. **Autumn** northern shrimp (*Pandalus borealis*) abundance and biomass estimates within NAFO Div. 3LNO. Data were from Canadian multi-species bottom trawl surveys using a Campelen 1800 trawl. (Standard 15 min. tows.). Bars present 95% confidence intervals.

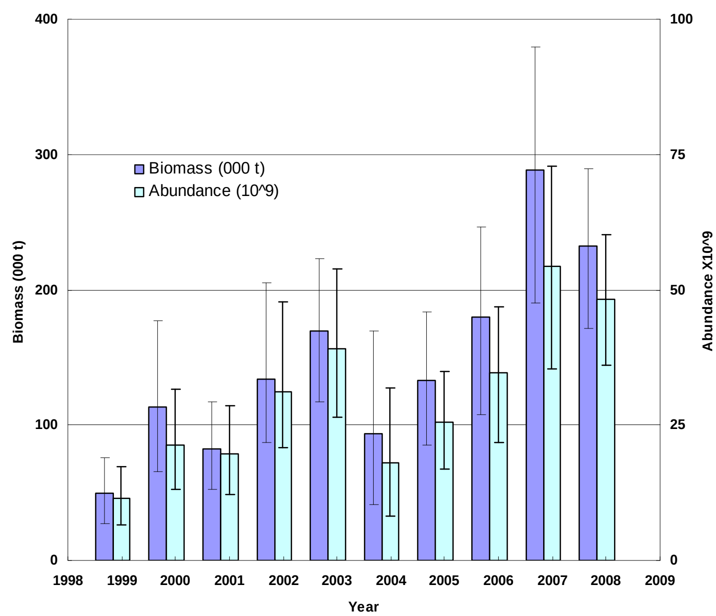

Figure 22. **Spring** northern shrimp (*Pandalus borealis*) abundance and biomass estimates within NAFO Div. 3LNO. Please note that due to operational problems, it was not possible to survey all of Div. 3NO during spring 2006. The indices for 2006 are for Div. 3L only. Data were from Canadian multi-species bottom trawl surveys using a Campelen 1800 trawl. (Standard 15 min. tows.). Bars present 95% confidence intervals

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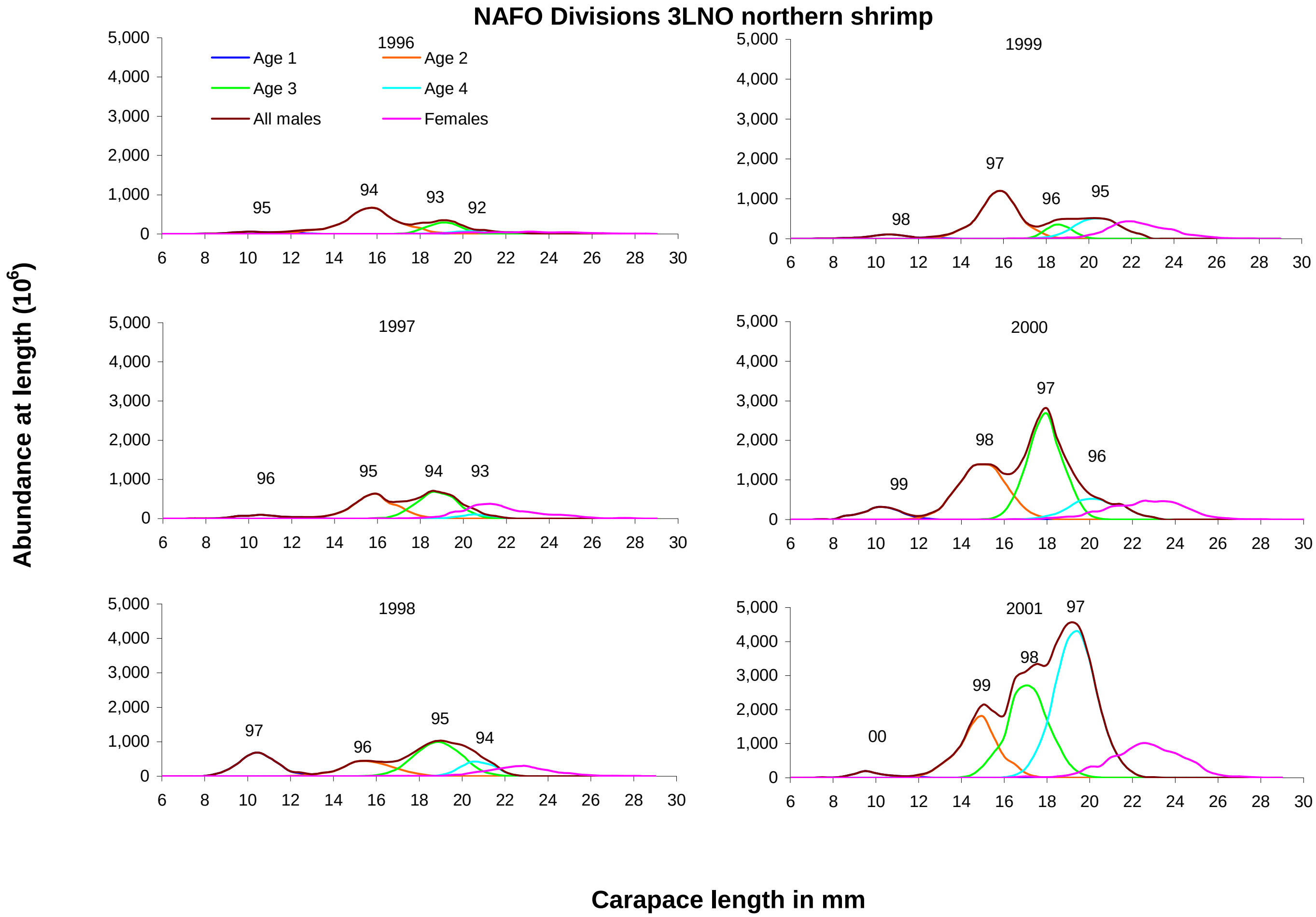

Figure 23. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only. Standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

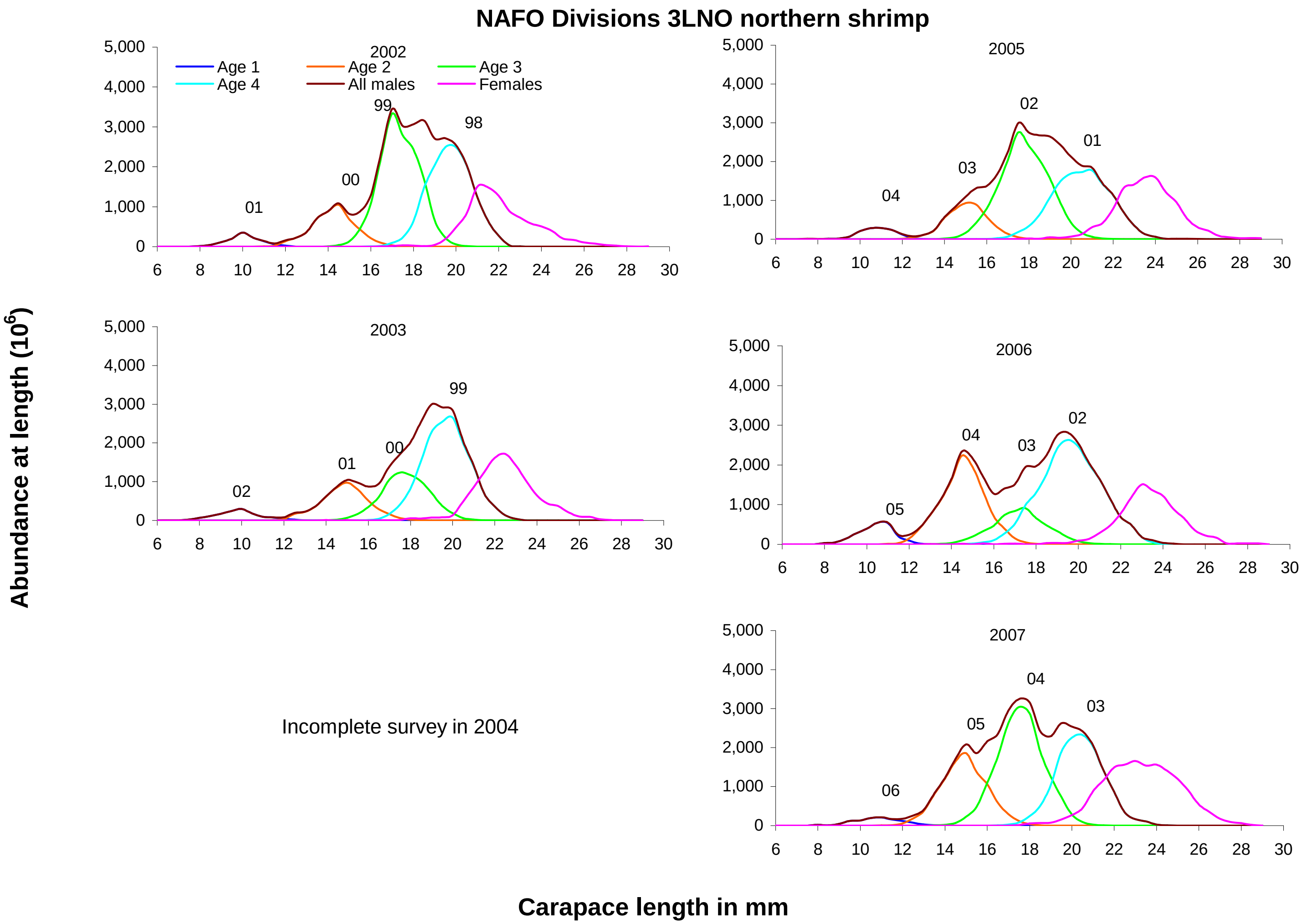

Figure 23. (Continued)

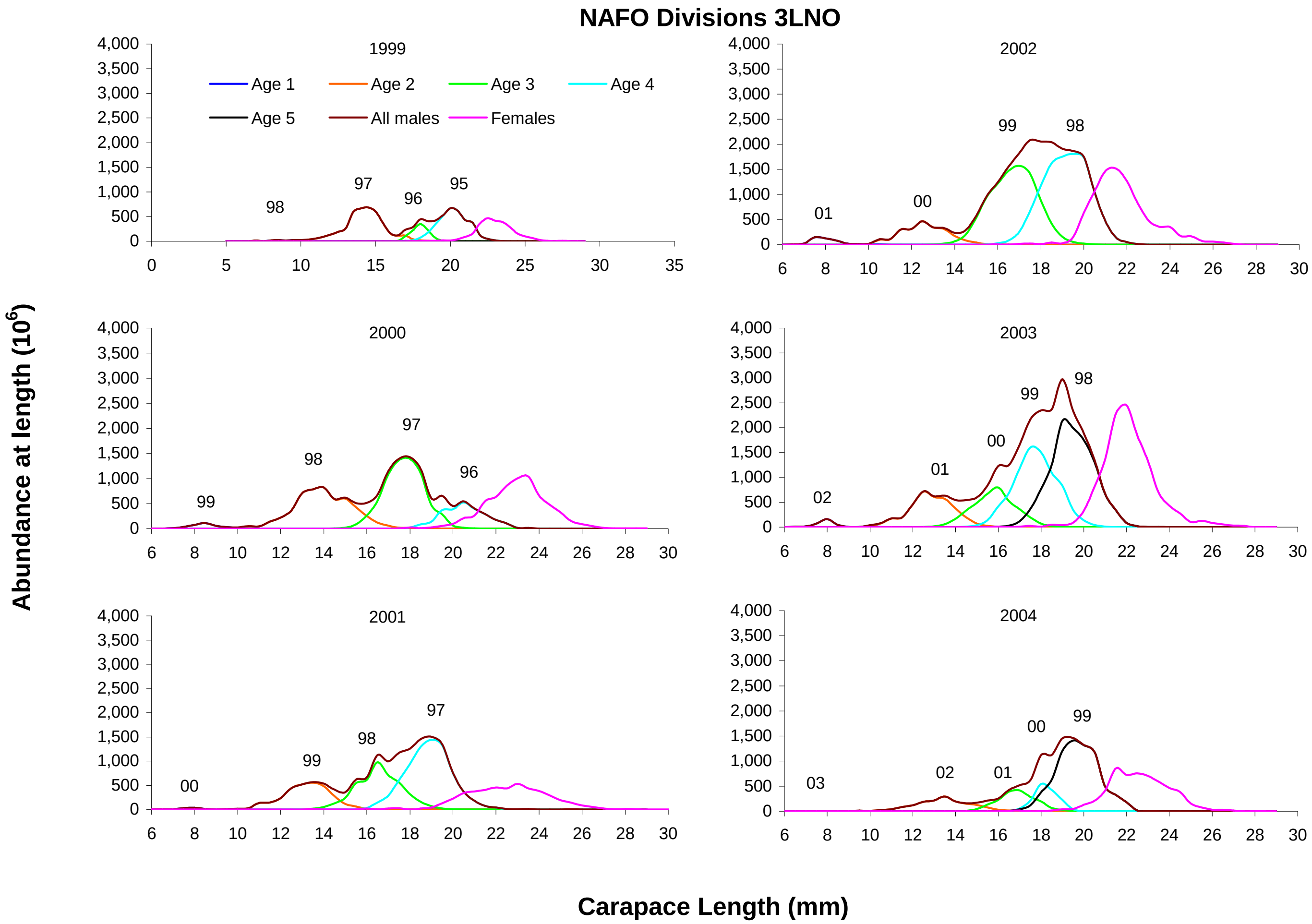

Figure 24. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **spring** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only. Standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

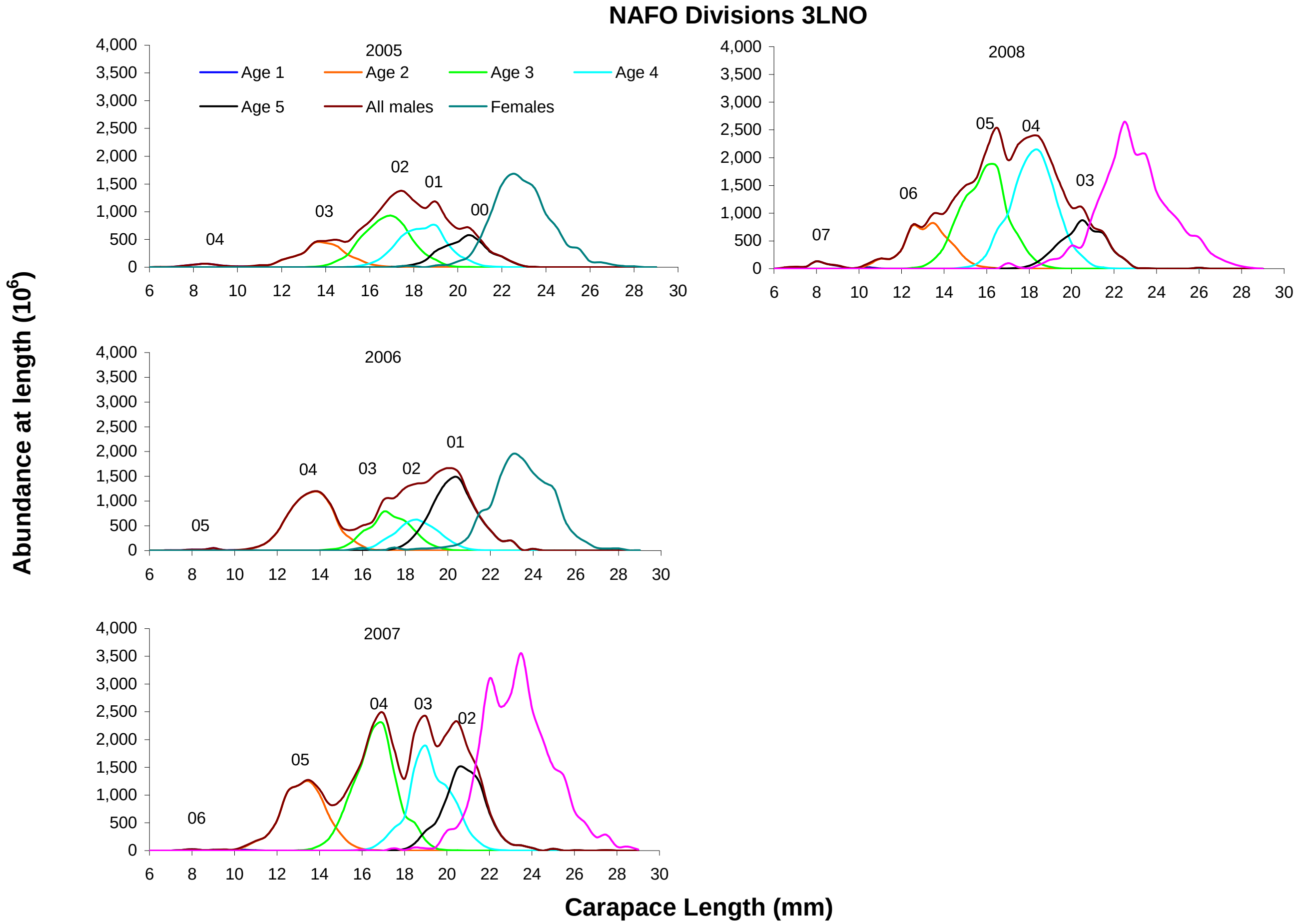

Figure 24. (Continued)

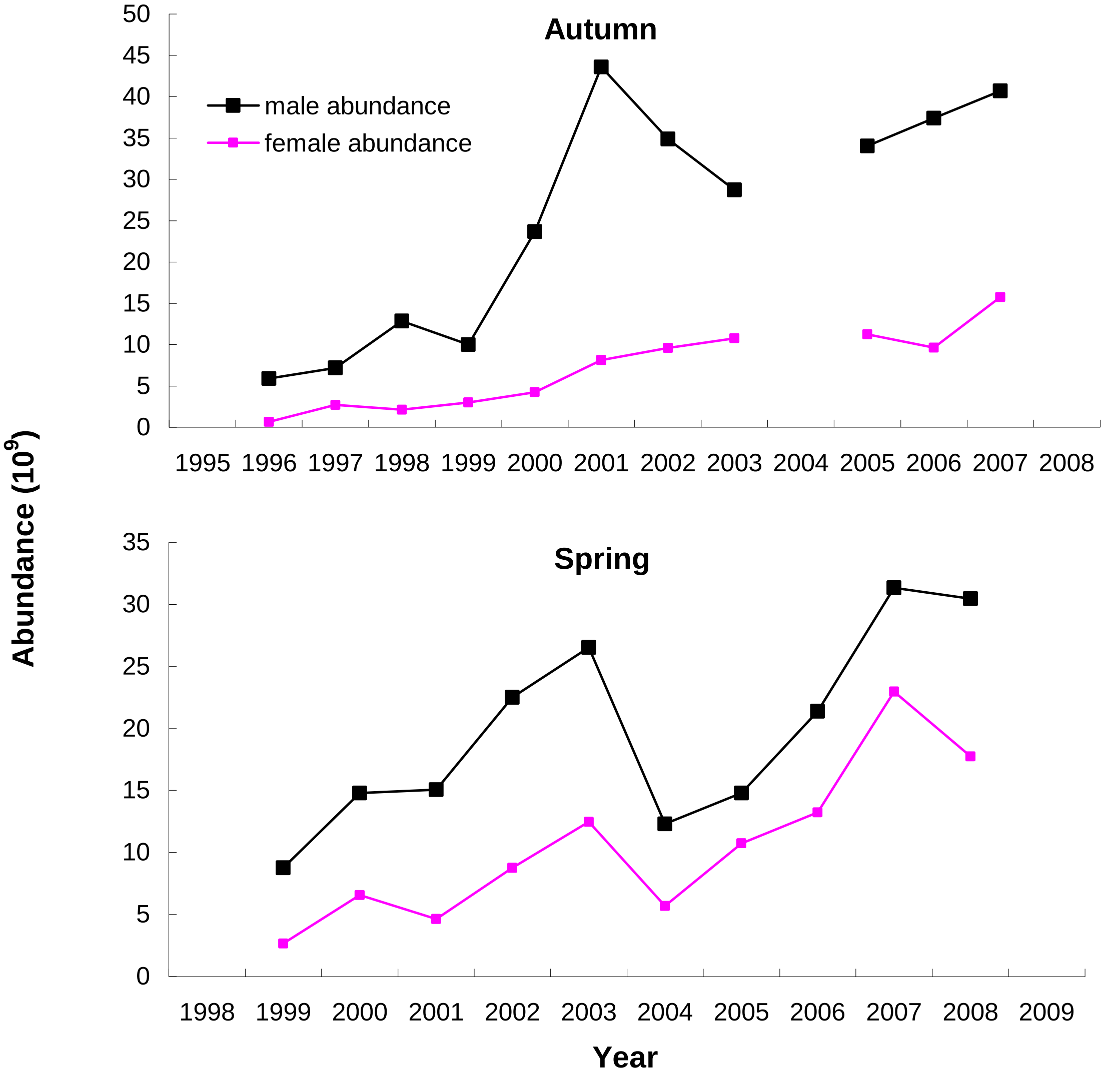

Figure 25. Abundance of male and female shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

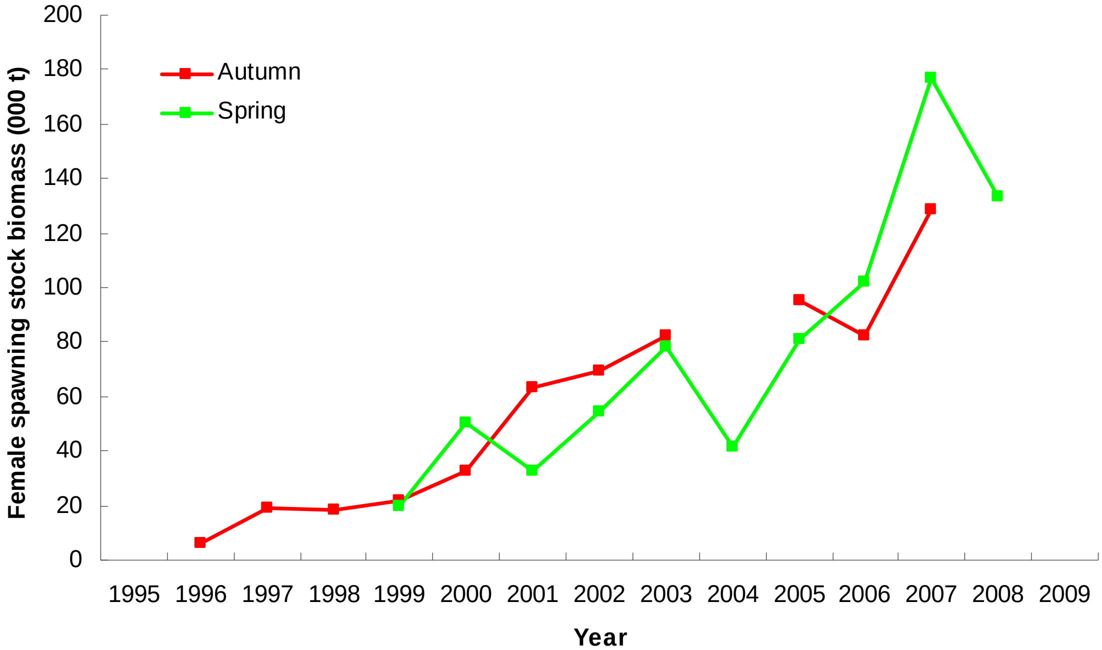

Figure 26. NAFO Divisions 3LNO female spawning stock biomass as determined from annual Canadian autumn and spring multi-species research bottom trawl survey data, 1996 – 2008 using Ogmap calculations.

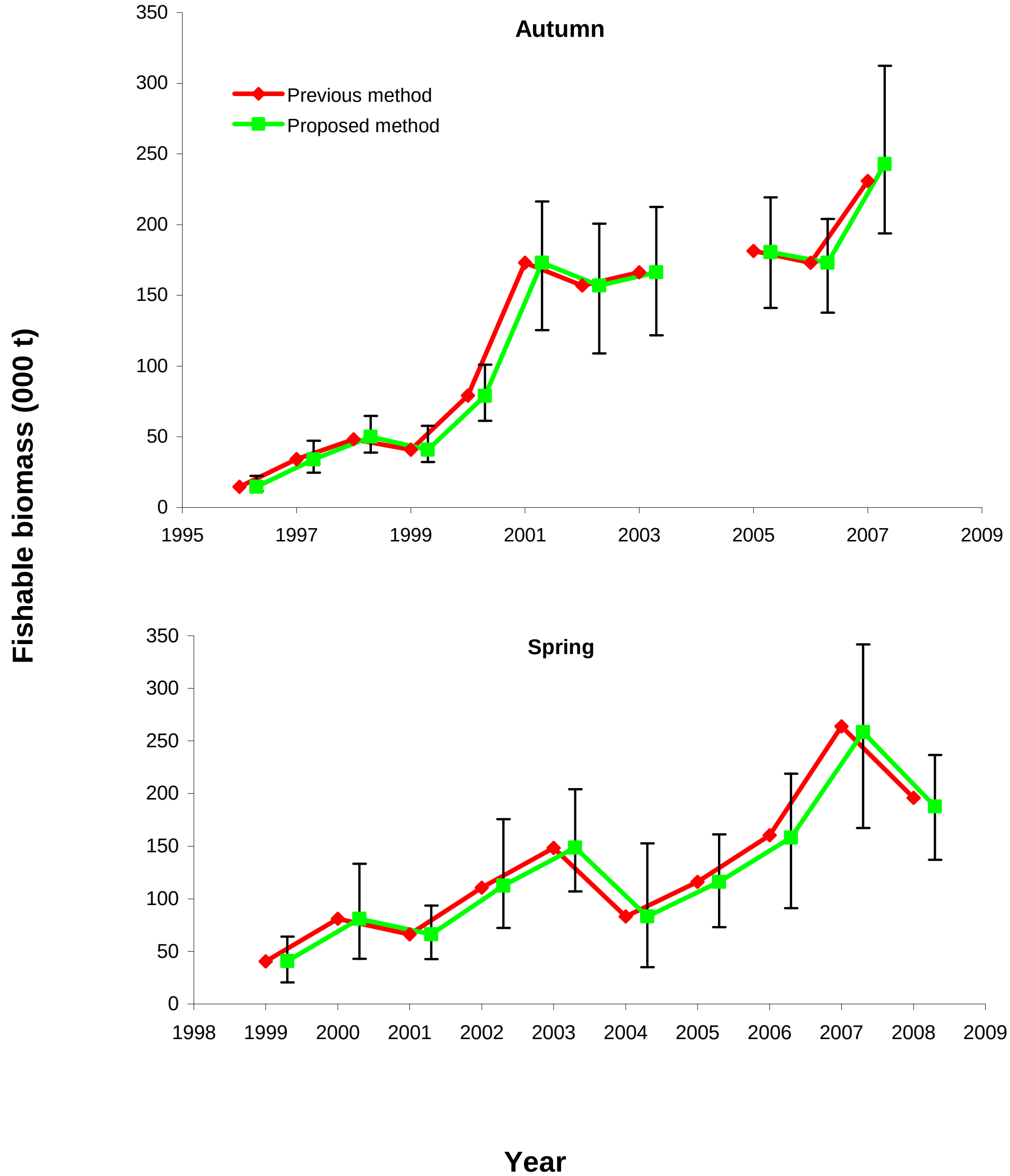

Figure 27. Fishable biomass (t) indices (total weight of all females + weight of all males with carapace lengths => 17.5 mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2008. The bars represent 95% confidence intervals around the proposed fishable biomass indices.

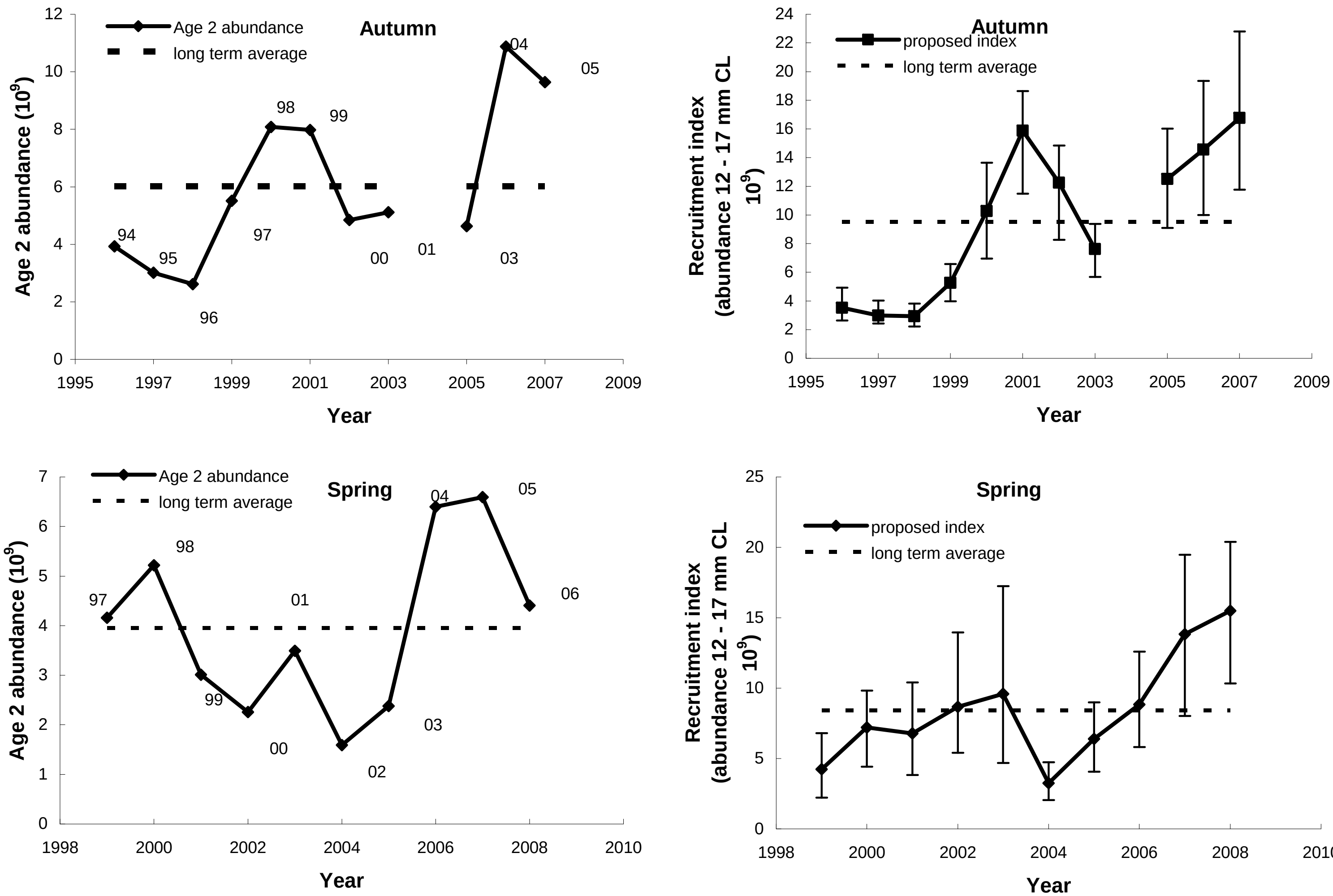

Figure 28. Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2008. The bars represent 95% confidence intervals around the proposed index.

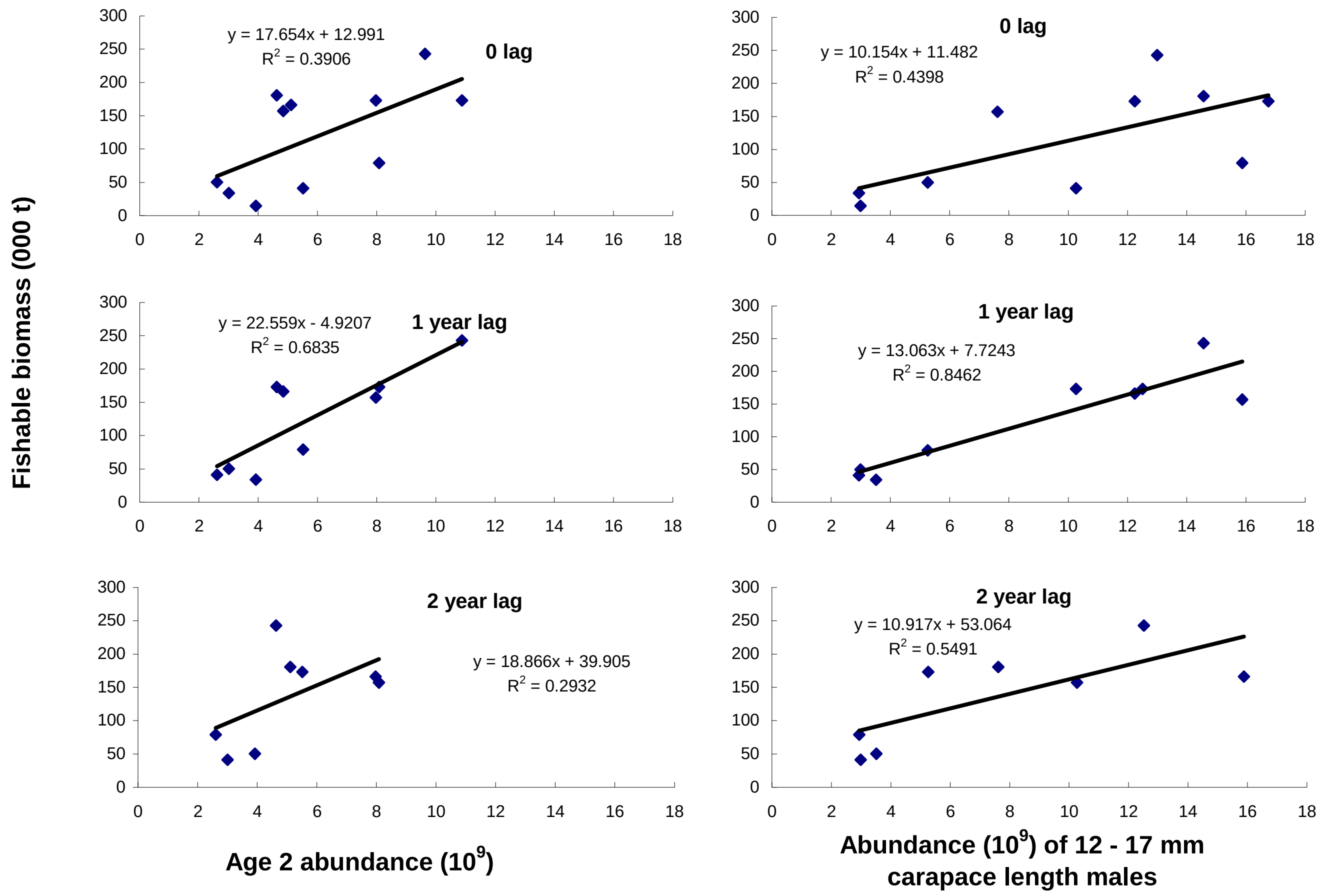

Figure 29. Regression analysis to determine the appropriate lag when predicting fishable biomass from recruitment index. The fishable biomass was determined using the proposed method while recruitment indices were determined by the previous method of stating age 2 abundance and the proposed method of determining recruitment based on a size range of animals that are likely to be fishable within a year. Data are from the **autumn** Canadian multi-species surveys.

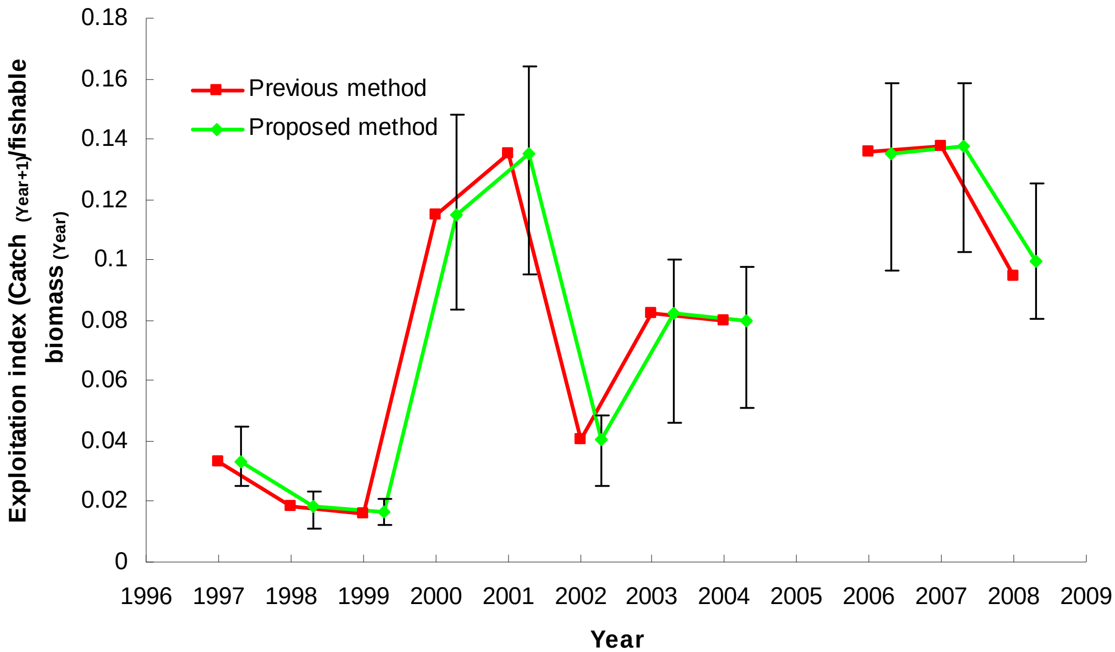

Figure 30. Trends in exploitation as derived by catch divided by the previous year's **autumn** fishable biomass index. The previous method made use of a length-weight relationship to convert population adjusted length frequencies of fishable sized males (=> 17 mm carapace length) to biomass and then adding female biomass. The proposed method converts the length frequency of fishable sized males to weights and adds that weight to the female weight on a set by set basis. Ogmap is then run to determine fishable biomass. The bars represent 95% confidence intervals around the exploitation rates for the proposed method.

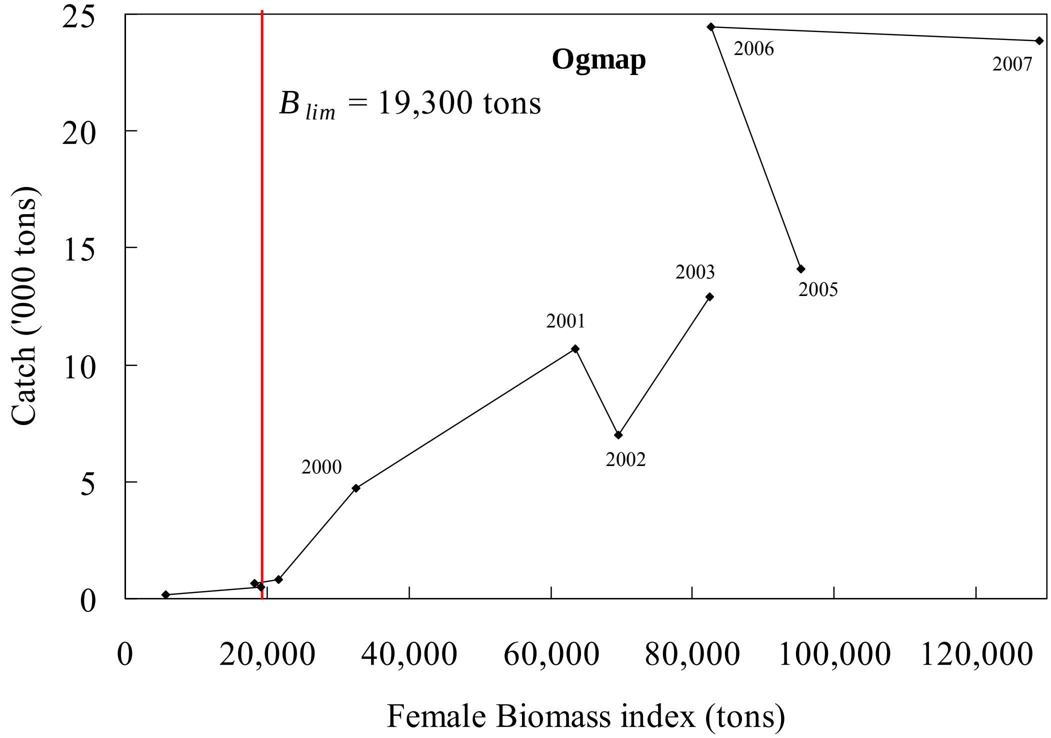

Figure 31. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).

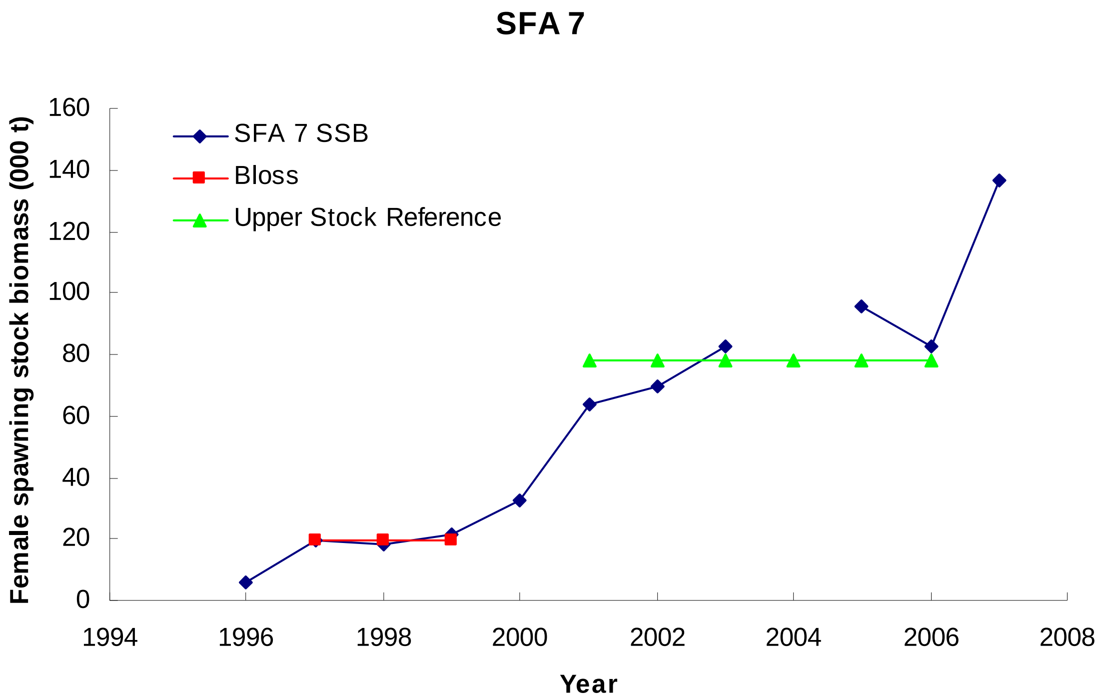

Figure 32. Use of **autumn** female spawning stock biomass to set reference points. The geometric mean of the lowest observed female spawning stock biomass (1996 – 1999) is set as the B_{loss} (19,600 t) while the geometric mean of a time period viewed as being productive (2001 – 2006) is set as the upper stock reference level (77,900 t).