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The 2011 assessment of the Northern Shrimp (*Pandalus borealis*, Kroyer) resource in NAFO Divisions 3LNO

by

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ABSTRACT:

This paper describes the 2011 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 2011) and biomass estimates (autumn 1996 – spring 2011) are updated within this report. Preliminary data indicate that 20 612 t of shrimp were taken against a 30 000 TAC in 2010 while 11 434 t were taken against a 19 200 t TAC by October 1, 2011. There is concern that the 2011 TAC may not be taken.

The autumn 2010 3LNO biomass index was estimated to be 75 100 t, a drop of 73% since 2007 when the autumn biomass index was 277,600 t. Similarly, the spring biomass index decreased by 76% from 290,600 t in 2007 to 69 900 t in 2011.

The autumn 2010 3LNO female spawning stock biomass (SSB) index was estimated to be 35 900 t, a drop of 72% since 2007 when the autumn SSB index was 128,900 t. The spring SSB index decreased by 82% from 177,900 t in 2007 to 32 800 t in 2011.

Similarly, the autumn 3LNO fishable biomass index was estimated to be 57 900 t in 2010, a drop of 76% from 239,700 t in 2007. The spring fishable biomass index decreased by 79% from 265,000 t in 2007 to 56 300 t in 2011.

Standardized catch rates for large Canadian vessels had been fluctuating around the long term mean between 2004 and 2008 but have since followed a descending trajectory and preliminary data suggest that they were significantly below the mean and similar to 2000 and 2001 catch rates by October 1, 2011. The Canadian small vessel standardized CPUE has been following a decreasing trend since 2005 and by October 2011 was significantly below the long term average and similar to catch rates near the beginning of the time series.

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 of 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 advised 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. Subsequently the 2009 and 2010 TACs were set at 30 000 t.

Since 2007, the survey indices had been in decline therefore Fishery Commission requested that TAC options be presented prior to the September 2010 Fishery Commission meeting. The TACs for 2011 and 2012 were set at 19 200 t and 17 000 t respectively.

Full assessments of this stock are completed during the annual October - November NAFO – ICES Pandalus Assessment Group (NIPAG) 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 2011.

Various TAC options, based upon exploitation of fishable biomass were presented to FC during September 2011. TACs of 12 000 and 9 350 t were chosen for the 2012 and 2013 management years respectively.

The present document was produced for the October 2011 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; <65') 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 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, vessel (cfv) etc. The multiplicative model has the following logarithmic form:

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

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} cfv;

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 2000 YEAR parameter estimate and those of subsequent 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. The first year of the fishery for each vessel was removed from the dataset to account for learning. Limit the dataset to vessels with a history in the fishery 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.

In addition to the normal CPUE models produced for this stock, attempts were made to create more direct indices of resource biomass. This is possible because positional data is provided within both the observer and logbook datasets allowing one to assign catch and effort data to strata (Fig 1) that were fished through the years. Once the assignment is complete and catch data have been standardized it is possible to use areal expansion calculations (Cochran, 1997) to determine biomass indices. The biomass indices were calculated using SAS code developed by D. Stansbury (pers. comm.).

The catch data were standardized by way of:

Small vessel formulae

Catch-per-unit-effort = catch / effort

Effort is in terms of hours towed.

Trawlable unit = average speed in Nmi/hr X (average wingspread in ft /6080.2 ft/Nmi) * 1 hr

Average speed = 2.2 Nmi / hr. as determined from observer data

Average wingspread 56 ft (H. Delouche, pers. comm.).

Large vessel standardization formulae

Single trawl data:

Catch per unit of effort = catch X ((average speed/speed) X (average footrope length/footrope length))/effort

Average speed = 2.6 Nmi/hr as determined from observer data

Average footrope length = 226’ as determined from observer data

Double trawl data:

Catch-per-unit-effort = (catch X ((2.5/speed)X(456/footrope length))/effort)/conversion factor to single trawl units

Conversion factor to single trawl units = 1.3 as determined from the catch rate model provided in this report.

Average wingspread = 103.5’

Trawlable unit = 2.5 Nmi/hr X (103.5 ft/6080.2 ft/Nmi)*1 hr

Average speed was determined from the observer dataset while the average wingspread was provided by H. Delouche (pers. comm.).

The catch data and trawlable units for the respective fleets were used to estimate biomass and average catch within each strata using areal expansion methods described within Cochran (1997) and SAS code produced by D. Stansbury (pers. comm.).

Spatial distribution of the northern shrimp resource

As described in Zwanenburg *et al.* (2002) catch rate models should be described in relation to whether the resource is expanding or contracting. “Concentration is defined as the proportion of the total survey area occupied by the top nth percent of the total annual population estimate. Prevalence is defined as the proportion of the total number of standardized trawl hauls (sets) completed in year I containing > 0 individuals of the species of interest and indicates how widely the species is distributed in the survey without any reference to density. Local density or CPUE where present is the average number (or weight) of the species of interest only in those sets where a least one individual of the species of interest was caught “ Zwanenburg *et al.* (2002). Plots of survey data were produced for this analysis using ACON programs created by Jerry Black (pers. comm.). ACON may be found online at:

http://www2.mar.dfo-mpo.gc.ca/science/acon/download.html

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. Greenland, Iceland, Norway, Spain and Russia provided catch and effort data over a number of years making it possible to derive 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), Brodie and Stansbury (2007), as well as 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.

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. Analyses indicate that at least 90% of the shrimp are found in NAFO Division 3L (this report), therefore the spring 2006 indices were calculated for 3L only.

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). Over a number of years, carapace lengths and live weights of a few thousand *Pandalus borealis* were measured within 24 hours of capture. Lengths and weights were converted to natural log 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. Two recruitment indices were estimated from these population estimates. In the first case, the population estimate of age 2 animals provided a recruitment index. In the second case, recruitment was estimated as the population estimates of all males and females with 12 – 17 mm carapace lengths.

Fishable biomass was determined as the weight of males and females with carapace lengths greater than 17 mm.

Fishable biomass was determined by converting abundances at length to weight using the models:

Autumn samples

$$\text{Male shrimp: } Wt(g) = 0.00088 * lt(mm)^{2.857}$$

$$\text{Female shrimp: } Wt(g) = 0.00193 * lt(mm)^{2.663}$$

Spring samples

$$\text{Male shrimp: } Wt(g) = 0.000966 * lt(mm)^{2.842}$$

$$\text{Female shrimp: } Wt(g) = 0.001347 * lt(mm)^{2.750}$$

The fishable biomass index was used in regression analyses, with various lags, against the recruitment indices 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.

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

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

Similarly, an index of female mortality was derived as the count of multiparous females measured per set in one year divided by the count of all females (transitionals + primiparous + multiparous) measured per set from the previous year. Data came from the spring surveys as this is the only time of year for which primiparous and multiparous females can be identified.

OGive MAPping (ogmap):

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 within each triangle is integrated using bilinear interpolation. The expected biomass 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. Conversations with Dr. Evans indicated a discrepancy between calculations used to standardize input data and the calculations used within Ogmap. All indices were multiplied by 1.0068 to correct for this discrepancy. For this reason there may be a slight difference between indices reported here and those reported in previous assessments.

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

Catches increased dramatically since 1999, with the beginning of a regulated fishery. Table 1 and the following discussion provide the available numbers to date. Over the period 2001-2009, catches increased from 6 967 to 28 544 t. Preliminary catch records indicate that 20 612 t of shrimp were taken from a 30 000 t TAC in 2010. By October of 2011, 11 434 t of shrimp had been taken, down from 12 598 t at the same time in the previous year. There is concern that the 2011 quota of 19 200 t may not be taken. As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 4 984 t in 2001 to 21 187 t in 2008 but have since decreased to 13 515 t in 2010. By October 2011, Canadian vessels took 8 945 t of shrimp. While the Canadian large and small vessel shrimp fishing fleets have the capacity to catch the 15,997 t quota for 2011 there is concern that the quota may not be taken for the following reasons:

1. Large vessel catch rates over the 2010 and 2011 fishing seasons were generally lower than in previous years;
2. this fleet concentrated in more northern areas where catch rates were better and operators wished to avoid ice that may be present later in the year; and
3. generally they fish the 3L quota later in the year when catch rates, in that area, are generally much higher. Additionally there are no ice related concerns in this area.
4. The inshore fleet catch rates were good until the end of June. Since July, catch rates have been lower. To date, a much larger proportion of the quota has been harvested than in 2010. Harvesters believe that most of the small vessel quota will be harvested.

Catches by other contracting parties increased from 661 t in 2000 to 7 703 t in 2006 and between 2006 and 2010 have ranged between 5 543 and 8 029 t. Preliminary data indicate that non Canadian vessels took 2 489 t of Northern Shrimp by October 2011 while they took 3 240 t by the same period in the previous year. It is anticipated that the 3 579 t quota for non Canadian vessels will be taken by December 2011. Table 1 provides a breakdown of catches by contracting party and year since 2001, while figure 1 indicates catches and TAC since 1993.

Canadian fleet

Since 2000, small (<=500 t; LOA<65') and large (>500 t) shrimp fishing vessels catches have been taken from a broad area (Figs. 6 and 7) from the northern border with 3K south east along the 200 – 500 m contours to the NRA border.

The small vessel fleet fishes shrimp mainly during the spring and summer months, while seasonality of the large vessel fleet varied over time (Fig. 8).

Small vessel CPUE (2000 – 2011) 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 model standardized data to 2000, class 3 and July values. The logbook dataset that was used in this analysis accounted for between 7.7% and 96.7% of the catch within any one year (Table 3). The final model explained 82.4% of the variance in the data and indicated that the annual, standardized catch rates increasing from near 300 kg/hr over 2000 – 2002 to 650 kg/hr by 2005 before gradually decreasing to 300 kg/hr by 2011. The 2000 catch rate index was similar to the 2001, 2002, 2010 and 2011 indices while being significantly lower than all intervening indices (Tables 2 and 3; Fig. 9). No clear trends were found in the plots of residuals (Fig. 10).

Seasonality among the large vessel fleet has varied greatly over the years (Fig. 8); therefore large vessel catch rates were analyzed by multiple regression using data were standardized against December data. 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 55% and 99% of the catch within any one year (Table 5). The final model explained 61% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean between 2004 and 2008 but have since been decreasing. The 2000 standardized catch rate index (904 kg/hr; Tables 4 and 5; Fig. 9) was similar to the 2001 and 2011 values but significantly lower than the mean (1 494 kg/hr) (Tables 4 and 5; Fig. 10). There were no trends in the residuals around parameter estimates (Fig. 12).

Table 6 provides trends in mean catch (t/hr) per stratum determined from small vessel logbook catch and effort data. The number of strata fished by the small vessel fleet increased from 5 in 2001 to 16 in 2007 and remained near that level through to 2010 (Table 6). Table 6 clearly indicates that most of the small vessel commercial fishing is completed within 183 – 549 m depths. The lower panel provides mean catch per stratum within index strata (those consistently fished over the study period). Figure 12 provides a map of these strata. Neither the panel showing all strata nor that showing index strata provide an indication of contraction of the fishery. The mean catch rate (t/hr) increased from .47 t/set in 2003 to .76 t/set in 2006 but decreased to .46 t/set by 2010 (Table 7).

Table 8 provides indices of mean catch per tow as determined from large vessel observed catch and effort information. This table clearly shows that the large vessel fishery is restricted to few strata compared to the small vessel fishery as is confirmed in figures 6 and 7 and most of the catch is taken in 274 m – 549 m depth ranges.

The small vessel fishery covers a larger portion of the resource (Figs 6 and 7) whereas the large vessel fleet has always fished near the 200 Nmi limit and along the northern edge of 3L this reason, the small vessel fleet information may provide a better indicator of resource status than the large vessel fleet.

International fleet

A standardized international fleet CPUE model is not presented here as the percent catch data accounted for in the international dataset ranged from 1 – 45% but in most years was less than 30% of that year's catch. Unstandardized international indices increased from 381 kg/hr in 2001 to 2 035 kg/hr in 2004, decreased to 570 kg/hr in 2005, remained near that level in 2006 before increasing to 1 395 by 2009 and subsequently dropping to 873 kg/hr by 2011 (Table 9; Fig. 13). In 2011, the CPUE was near the long term mean CPUE of 915 kg/hr. It is not clear how representative these commercial catch rates are of the international fishery in the 3L NRA.

Size composition

Relatively few length frequencies were collected by observers of small vessel fishing activities therefore it is not certain whether the length frequencies are representative of fleet activities (Fig. 14). The jagged length distributions meant 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.

A time series of length frequencies from the large vessel catch is present on figure 15. Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females believed to be greater than two years of age. The male modes overlapped to the extent that it was not possible to complete Mix distribution analysis; however, there were often two faint sub-peaks implying the presence of more than one year class. Given that the modes were usually near 14 and 17 mm, these animals were probably 2 and 3 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. In most years since 2000, catch rates had been maintained at over 200,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 17.8 mm and 20.0 mm, while the weighted average carapace lengths for females ranged between 22.9 mm and 24.0 mm. There were no trends in the average size of either males or females.

RESEARCH SURVEY DATA

Stock size

The autumn 2007 – 2010 and spring 2008 – 2011 research catches were concentrated within NAFO Div. 3L at depths between 200 and 500 m (Figs 16 and 17). The autumn 2010 3LNO biomass index was estimated to be 75 100 t, a drop of 73% since 2007 when the autumn biomass index was 277,600 t. Similarly, the spring biomass index decreased by 76% from 290,600 t in 2007 to 69 900 t in 2011 (Table 10; Fig 18). 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. Tables 11 and 12 provide the mean catch (kg/ standard 15 min tow) per stratum as determined respectively from spring and autumn Canadian bottom trawl surveys. These tables as well as figures 16 and 17 clearly indicate that large samples are periodically found in the spring relative to autumn surveys. The presence of a large set in a survey with several much smaller sets will result in broad confidence intervals around point estimates thereby reducing our confidence in the biomass or abundance estimates. Figures 19 and 20 show the time trends and interactions between various indices of distribution. Trends in biomass are used as major indices of resource status. In this case, the proportion of area necessary to capture 95% of the survey catches generally increased from the beginning of each time series until 2006 in the spring and 2003 in the autumn but then declined in the respective indices. The lowest points are found at either end of each survey series. The overall prevalence of shrimp, as indicated by the proportion of non-zero sets in the survey, increased to 2003 and thereafter decreased to the lowest levels in both time series. The local density is measured as the average weight of shrimp caught in non-zero 10' X 10' cells. Local density increased to 2006, remained high through to the end of each times series. These trends can be interpreted to mean that the shrimp are becoming less broadly distributed (decreased prevalence) as confirmed by the decrease in proportion of cells needed to obtain 95% of the catch and resulting in localized pockets of shrimp of relatively high density. Trends in localized density are found in the stratified analysis of survey data (Tables 11 and 12). There was an increase in localized density of shrimp (increased number of pink cells) until 2006 and then a general decrease after 2007. This observation is consistent with the recent decreases found in the commercial CPUE (Tables 3 and 5; Fig. 9) as well as the concentration of the small and large vessel fishery into the area near the 200 Nmi limit (Figs. 6 and 7).

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

Over 92.7% of the total 3LNO biomass, from either spring or autumn surveys, 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 32.6% of the estimated total 3LNO biomass (Tables 13 and 14; Figs. 16 and 17; Orr *et al.* 2007). During the spring, the percent biomass within the NRA ranged between 11.2 and 32.6% (three year running average ranged between 18.7 and 27.5%) (Table 13). Over the period 1999 – 2011 the average spring percent biomass with the NRA was 22.8%. During the autumn, the percent biomass within the NRA ranged between 11.9 and 21.0%. Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 12.6 – 20.1% of the total 3LNO autumn biomass was within the NRA (Table 14). Over the period 1996 – 2010 the overall average autumn percent biomass within the NRA was 16.5

In all surveys, Division 3N accounted for 0.2-8.1% of the total 3LNO biomass (Tables 13 and 14). Between 33.3 and 83.3% 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 2010 surveys are presented in figures 21 and 22. Generally, modes increase in height as one moves from ages 1 – 3 indicating that modes become more overlapping and that shrimp catchability probably improves with size. Tables 15 and 16 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 three regimes; one prior to 2000 at a time during which abundances at age were low and a second period from 2000 - 2008 during which abundances were much higher and then a third period after 2008 when abundances at all ages appear low again. 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 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 cohort appeared weak in 1999, but appeared strong over the next few years. Conversely, if an age 2 mode appeared strong, in any one year, that cohort remained strong throughout its history. Weak year classes such as the 1995 and 1996 appeared weak as age 2 modes and remained 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 15 and 16; Figs. 21 and 22).

Shrimp aged 3 - 5 dominated the male component of the length frequencies in spring 2011 (2008, 2007 and 2006 year classes respectively) survey with carapace length frequency modes at 15.75 mm, 18.02 mm and 20.24 mm respectively (Table 15; Fig. 21). Abundance estimates from the autumn 2010 survey were dominated by shrimp aged 2 - 4 (2008, 2007 and 2006 year classes respectively) with modes at 14.90 mm, 17.56 mm and 20.54 mm respectively. The 2005 year class first appeared as a strong year classes in the spring of 2007 as two year old animals. This year class remained strong in the male distributions through to spring 2010. The 2007 year class appears relatively strong from spring 2008 as one year old animals until spring 2011 as four year old animals.

The spring survey male biomass indices showed a general increasing trend from 29,600 t (9 billion animals) in 1999 to 91,700 t (27 billion animals) in 2003, dropped to 52,100 t (12 billion animals) then increased to 112,700 t (32 billion animals) by 2007 after which biomass dropped by 67% to 37 000 t (11 billion animals) in 2011 (Table 17; Fig. 23). The autumn surveys showed an increase in biomass of male shrimp from 33,430 t (10 billion animals) in 1999 to 153,000 t (44 billion animals) in 2001, remaining at a high level until 2008 (Table 17; Fig. 23). The autumn 2010 male survey biomass index was estimated to be 39,200 t (13 billion animals), a drop of 74% since 2007 when the male biomass peaked at 148,700 t.

Autumn and spring female biomass and abundance indices (transitionals and all females = SSB) followed trends similar to the respective male indices. The spring SSB index decreased by 82% from 177,900 t in 2007 to 32 800 t in 2011. The autumn 2010 3LNO female spawning stock biomass (SSB) index was estimated to be 35 900 t, a drop of 72% since 2007 when the autumn SSB index was 128 900 t (Table 18; Fig. 24).

The spring fishable biomass index decreased by 79% from 265,000 t in 2007 to 56 300 t in 2011. The autumn 3LNO fishable biomass index was estimated to be 57 900 t in 2010, a drop of 76% from 239,700 t in 2007 (Table 19; Fig. 25).

It is important to note that the abundance and biomass indices for both the male, female SSB and fishable portions of the resource are significantly below the long term mean for each respective index. These indices are approaching the values found at the beginning of the survey time series.

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. abundance of shrimp 12-17 mm in carapace length from spring and autumn surveys.

from the autumn 1996-2009 and spring 1999 - 2010 survey time series.

Due to the incomplete survey in autumn 2004, this index was excluded from the autumn time series. In terms of modal analysis, the autumn 98, 99, 04 - 07 year classes were strong, the 97, 00 and 01 year classes were average while the 94 – 96, 03 and 08 year classes were the weakest recorded (Tables 16 and 20; Figs. 22 and 26). Even though the 04 – 07 year classes appear strong, there is a downward trend in that portion of the series. Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series (Tables 15 and 20; Figs. 21 and 26). Similar to the autumn recruitment signal, there is a downward trend in abundances of age 2 animals from the 05-08 cohorts with 09 similar to 08. The 08 and 09 cohorts from the spring survey modal analysis have the lowest abundances on record.

The size class 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 - 4 animals. The autumn 1996 – 1999 indices were the lowest in the time series, the 2000, 2002, 2003, 2009 and 2010 values were near the mean while the 2001 and 2005 – 2008 were the highest. Similarly, the spring indices followed an increasing trend between 1999 and 2003, the 2004 value was the lowest in this time series but since then the recruitment indices have gradually increased to a record level in 2008 with a decrease in recruitment to mean levels during 2009 - 2011 (Table 21; Fig. 26).

Figure 27 presents the relationship between spring and autumn recruitment indices using either modal analysis or size class method. When autumn recruitment index is predicted from spring index, 56 and 32 percent of the variance are accounted for in the relationships for modal and size class methods respectively.

Figure 28 provides a series of regressions between fishable biomass with various lags versus abundances of age 2 males. The relationship using spring data with a no year lag provided the strongest relationship. However, only 38 percent of the variance was accounted for in the relationship..

When similar relationships were developed between fishable biomass and recruitment based upon size classes, the within year relationships were the strongest (Fig. 29). This makes sense because recruitment based upon size class is based upon probably ages 2 - 4 animals. Figures 21 and 22 illustrate that this type of recruitment index should be strongly correlated with the fishable component of the resource. The percent variance accounted for based on no lag between fishable biomass and recruitment index were 76 and 79 for spring and autumn survey data respectively. When fishable biomass is lagged, the strongest relationship was with autumn data and a one year lag (r^2 = .61).

Figures 30 – 33 provide attempts to develop relationships between small and large vessel CPUE versus recruitment and fishable biomass indices with various lags. In all cases, the strongest relationships were between autumn survey data and the respective index being predicted. The strongest relationships were as follows:

Small vessel CPUE lagged by one year vs autumn fishable biomass (r^2 = .60)

Large vessel CPUE lagged by one year vs autumn fishable biomass (r^2 = .43)

Small vessel CPUE lagged by one year vs autumn 12 – 17 mm recruitment index (r^2= .24) and

Large vessel CPUE lagged by two years vs autumn 12 – 17 mm recruitment index (r^2= .38)

Exploitation Rate Indices

Exploitation rate indices were estimated using ratios of catch divided by the previous year's lower 95% confidence interval of the biomass estimate, spawning stock biomass and fishable biomass (Table 22). Until 2010, exploitation had been below 15% even though catches have increased over time because the stock parameters also increased. However, after 2009 the stock parameters began to decrease dramatically causing the 2010 exploitation rate to increase to 22%. Fishery Commission lowered the TAC to 19 200 t for the 2011 management year, however, by October 2011 11 434 t of shrimp had been taken against a 2010 autumn fishable biomass of 58 000 t. By October 2011, the exploitation rate was 20% and is expected to increase as this assessment was completed while the fishery was ongoing and fishers noted that they normally wait until later in the year to fish that part of their quota. If the entire 19 200 t quota was to be taken, the exploitation rate index would increase to 33% (Fig. 34).

For this reason, TAC options were recalculated, prior to the September Fishery Commission meeting, using the Autumn 2009 – Spring 2011 survey fishable biomass estimates (Orr and Sullivan, 2011). The Fishery Commission agreed to decreasing the TAC to 12 000 t in 2012 and further to 9 350 t in 2013.

Population Growth

Figure 35 presents a simple annual rate of change in abundance plot from the autumn survey time series that summarizes the overall change in all survey indices. It shows that between 1996 and 2001 the population more than doubled, remained relatively constant until 2007 and then decreased dramatically. Population growth can be either positive, zero or negative depending upon several factors which include immigration, emigration, mortality and environmental change. Chances of survival and therefore population growth are improved if the larvae hatch at a time when right kinds of food are available and temperatures are such as to allow somatic growth and development (Koeller *et al.* 2009). However, if the animal is an important forage species these conditions may also cause change in populations of both competitors for food and space as well as predators. These factors may have caused the changes in 3LNO Northern Shrimp population growth over the spring and autumn survey time series. The following section will deal with the mortality aspect.

Mortality Estimates

Table 23 presents mortality estimates derived from the abundances of age 4+ animals in one year divided by the abundances of age 3+ animals from the previous year as obtained from the modal analysis in Table 16. These data were from the autumn survey time series as it was the longest survey time series. The median survival, annual mortality and instantaneous mortality rates were 0.79, 0.21 and 0.24 respectively (Table 23). While there must have been a high survival rate to allow the population to increase to the extent that it did during the early 2000's an 80% survival rate appears abnormally high.

Table 24 presents mortality estimates derived from the numbers of multiparous females measured in one year divided by the numbers of all females measured from the previous year as obtained from the spring survey. Spring survey data had to be used in this case because that is the only time when most females are not carrying eggs and therefore it is possible to identify primiparous and multiparous females. The median survival, annual mortality and instantaneous mortality rates were 0.46, 0.54 and 0.79 respectively (Table 24). It makes sense that female mortality should be higher than age 3+ mortality as females are older whereas the age 3+ animals included males. Not only age, but also the stress of producing eggs and carrying eggs must result in higher death rates. The female mortality rates are within the range of values presented in Shumway (1985) and Bergström (2000).

It is important to note that regardless of method used, survival has been decreasing over the past few years. In 2001, 90% of the age 3+ animals survived from one year to the next, however, this number decreased to 40% by 2009. In 2006, survival of females was estimated to be 70%, however, survival of females decreased to 40% by 2011.

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. Figure 36 presents the precautionary plot as it has always been presented with catch during the current year SSB. However, the survey SSB is derived from a survey that takes place at the end of the fishing season, therefore it is proposed that the plot be re-drawn with catch lagged. This would be consistent with the derivation of exploitation which is catch divided by previous year survey index. Figure 37 presents the proposed plot. Regardless of the plot, the 2011 SSB is estimated to be above but approaching B_{lim} (Table 18 and Figs. 36 and 37).

Sources of Uncertainty in the Assessment

Several important strata, within NAFO Division 3L, were missed in the autumn 2004 Canadian multi-species survey therefore fishery independent indices could not be estimated for that year.

It was not possible to survey all of NAFO Divisions 3NO during the spring of 2006. Historically, at least 90% of the 3LNO shrimp biomass is found within Division 3L; therefore, the spring 2006 indices were for NAFO Division 3L only.

At times the NAFO Divisions 3LNO have been surveyed by the CCGS Wilfred Templeman, CCGS Alfred Needler and the CCGS Teleost. There have been no comparative analyses between the catches taken by each vessel therefore it is not known whether switching vessels has an impact upon the biomass/ abundances indices reported on in this assessment.

Work must be conducted to develop meaningful predictive relationships between shrimp and their environment.

It was not possible to model CPUE for the international fleet fishing in the NRA because the percentage of the fishery captured in the catch rate data set was usually less than 25% for any one year. It is not clear whether this data is representative of fleet conditions.

Previous to 2010 when the 3M Northern Shrimp resource came under moratorium, there were questions about mis-reporting of catch between the 3L NRA and 3M international fisheries.

The assessments are based upon evaluating various indices of stock conditions. There is no risk analysis for this resource because of the lack of limit reference points. Now that the trajectory of many indices is no longer increasing, it may be possible to complete meaningful analytical assessments.

There is imperfect knowledge information on sustainable exploitation rates; however, there is evidence that they may differ widely between stocks. When setting TACs, ecosystem considerations should be taken into account because shrimp is an important forage species.

Resource Status

There is reason for concern about the status of the Northern Shrimp resource within NAFO Divisions 3LNO.

Preliminary data indicate that 11 434 t of shrimp had been taken in the 3L shrimp fishery by October 2011; however, there is concern as to whether the entire 19 200 t TAC will be taken by the end of December 2011. Canadian as well as non Canadian commercial catch rates have been declining for the past few years and are at or below the long term mean

The autumn 2010 3LNO biomass index was estimated to be 75 100 t, a drop of 73% since 2007 when the autumn biomass index was 277,600 t. Similarly, the spring biomass index decreased by 76% from 290,600 t in 2007 to 69 900 t in 2011.

The autumn 2010 3LNO female spawning stock biomass (SSB) index was estimated to be 35 900 t. a drop of 72% since 2007 when the autumn SSB index was 128,900 t. The spring SSB index decreased by 82% from 177,900 t in 2007 to 32 800 t in 2011.

Similarly, the autumn 3LNO fishable biomass index was estimated to be 57 900 t in 2010, a drop of 76% from 239,700 t in 2007. The spring fishable biomass index decreased by 79% from 265,000 t in 2007 to 56 300 t in 2011.

Exploitation rates over the period 2006 – 2008 had been near 14% and were followed by stock decline. Given recent declines in stock biomass, exploitation rates at this level are likely to result in further declines. Exploitation rates below 14% will tend to reduce this risk. However, assessment models have not been developed for this stock; therefore, it is not possible to quantify the absolute magnitude of the risk associated with alternative TAC options.

Exploitation strategies for this resource should take into consideration the importance of shrimp as a forage species. Shrimp and capelin are key forage species in NAFO Divisions 2J3KL. Capelin abundance is at very low levels while some groundfish are increasing. Together this may increase predation pressure on shrimp.

Finally, 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. Using this definition of B_{lim}, the limit reference point is at 19 300 t. The 3LNO Northern Shrimp resource is above but approaching B_{lim}.

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Table 1. Annual nominal catches (t) by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3L between 2001 and October 2011.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Canada	4,984[2]	5,417[2]	10,701[2]	10,560[2]	11,109[2]	18,128[2]	18,316[2]	21,187[2]	20,515[2]	13,515[2]	8,945[2]
Cuba	46[1]	70[1]	81[1]	145[3]	136[1]	239[1]	240[1]	207[3]	334[3]		
EU/Estonia	2,264[4]	450[5]	299[6]	271[6]	569[6]	1,098[10]	1,453[10]	1,458[10]	1607[1]	1,427[10]	697[10]
European Union											
Faroe Islands	2,052[4]	620[5]	25[1]	1,050[1]	1,055[1]	1,521[1]	1,798[1]	2,273[1]	2949[1]	2,503[1]	1,287[3]
France (SPM)	67[1]	36[1]	144[1]				245[1]	278[1]	334[1]	334[1]	
Greenland			671[1]	299[1]	311[1]	453[8]	455[8]	648[8]	533[8]	536[8]	
Iceland	55[7]	54[7]	133[7]	105[7]	140[1]	226[7]				185[3]	
EU/Latvia	67[1]	59[1]	144[1]	143[1]	144[1]	244[1]	310[1]	278[1]	330[1]	384[1]	
EU/Lithuania	67[1]	67[1]	142[1]	144[1]	216[1]	486[1]	245[1]	278[1]		340[1]	
Norway	78[6]	70[6]	145[9]	165[9]	144[3]	272[9]	250[9]	345[1]	672[1]	664[9]	
EU/Poland	54[1]		145[1]	144[1]	129[1]	245[1]					
Portugal	61[5]								329[1]	15[1]	
Russia	67[1]	67[1]		141[1]	146[1]	248[1]	112[1]	278[1]	335[3]	28[1]	
EU/Spain	699[4]		151[1]	140[1]	154[1]	305[6]	190[1]	183[1]	272[11]	347[1]	291[11]
Ukraine	57[1]		144[1]	145[1]		121[1]			334[3]		
USA	66[1]	57[1]	144[1]		136[1]	245[1]	245[1]	278[3]		334[1]	214[3]
Estimated additional catch						2,000[5]					
GRAND TOTAL	10,684	6,967	13,069	13,452	14,389	25,831	23,859	27,691	28,544	20,612	11,434
TAC (tons)	6,000	6,000	13,000	13,000	13,000	22,000	22,000	25,000	30,000	30,000	19,200

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.
10 Estonian logbook dataset.
11 Spa

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 – 2011. (Weighted by effort, single trawl, logbook data, history of at least two years in the fishery with the first year of the fishery for any vessel removed). All data were standardized to class 3 vessels, July and 2000 values.

The GLM Procedure
Class Level Information

Class	Levels	Values
year	12	2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 (standardized to 2000)
month	8	4 5 6 8 9 10 11 99
size_class	3	1 2 3

Number of Observations Read 179
Number of Observations Used 179

Dependent Variable: lncpue
Weight: weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	11441.89324	572.09466	37.11	<.0001
Error	158	2435.43484	15.41414		
Corrected Total	178	13877.32808			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.824503	63.23690	3.926085	6.208536

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	11	9222.221174	838.383743	54.39	<.0001
month	7	1580.128794	225.732685	14.64	<.0001
ize_class	2	639.543272	319.771636	20.75	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	11	5786.608135	526.055285	34.13	<.0001
month	7	1799.900511	257.128644	16.68	<.0001
size_class	2	639.543272	319.771636	20.75	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.098757365	B	0.05392350	113.10	<.0001
Year	2001	-0.023690844	B	0.07014124	-0.34	0.7360
Year	2002	0.047689143	B	0.06926752	0.69	0.4922
Year	2003	0.184959711	B	0.06115865	3.02	0.0029
Year	2004	0.305663721	B	0.06086067	5.02	<.0001
Year	2005	0.675319987	B	0.06247006	10.81	<.0001
Year	2006	0.547788663	B	0.05555522	9.86	<.0001
Year	2007	0.405136980	B	0.05551726	7.30	<.0001
Year	2008	0.465303153	B	0.05679451	8.19	<.0001
Year	2009	0.253552669	B	0.05626071	4.51	<.0001
Year	2010	0.009451929	B	0.05929115	0.16	0.8735
Year	2011	-0.053795630	B	0.11906358	-0.45	0.6520
Year	2012	0.000000000	B	.	.	.

Table 2 (Continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Month	4	-0.207774431 B	0.06697712	-3.10	0.0023
Month	5	-0.305656974 B	0.03605117	-8.48	<.0001
Month	6	-0.115211381 B	0.03091551	-3.73	0.0003
Month	8	-0.085350608 B	0.03100408	-2.75	0.0066
Month	9	-0.290609163 B	0.04128351	-7.04	<.0001
Month	10	-0.357491115 B	0.05466109	-6.54	<.0001
Month	11	-0.366839933 B	0.09735782	-3.77	0.0002
Month	99	0.000000000 B	.	.	.
size_class	1	-0.191091079 B	0.03776583	-5.06	<.0001
size_class	2	-0.109946541 B	0.02230477	-4.93	<.0001
size_class	3	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The GLM Procedure
Least Squares Means

yearf	lncpue LSMEAN
2001	5.75860395
2002	5.82998393
2003	5.96725450
2004	6.08795851
2005	6.45761478
2006	6.33008345
2007	6.18743177
2008	6.24759794
2009	6.03584746
2010	5.79174672
2011	5.72849916
2012	5.78229479

year	lncpue LSMEAN	95% Confidence Limits	
2001	5.758604	5.657377	5.859831
2002	5.829984	5.727771	5.932196
2003	5.967255	5.892418	6.042091
2004	6.087959	6.000952	6.174965
2005	6.457615	6.363613	6.551617
2006	6.330083	6.260279	6.399888
2007	6.187432	6.119890	6.254973
2008	6.247598	6.178592	6.316604
2009	6.035847	5.975496	6.096198
2010	5.791747	5.720978	5.862516
2011	5.728499	5.506353	5.950645
2012	5.782295	5.680636	5.883954

Table 3. Catch rate indices for **Canadian small vessels** (<=500 t; <65’) fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2011. All data were standardized to class 3 vessels, July and 2000 values.

				UNSTANDARDIZED			STANDARDIZED		
YEAR	TAC[1] (t)	FLEET CATCH (t)	[2] PERCENT OF CATCH DATA CAPTURED IN MODEL	CPUE (KG/HR)	CPUE RELATIVE TO 2000	[3] EFFORT (HR)	CPUE RELATIVE TO 2000	MODELLED CPUE (KG/HR)	EFFORT (HRS)
1999		17							
2000	2,500	3,217	87.8%	302	1.000	10,668	1.000	325	9,914
2001	2,500	2,590	86.1%	346	1.148	7,479	0.977	317	8,173
2002	2,500	2,961	87.7%	381	1.264	7,768	1.049	340	8,700
2003	6,566	6,663	89.1%	527	1.746	12,652	1.203	390	17,066
2004	6,566	6,524	93.6%	726	2.406	8,992	1.358	441	14,810
2005	6,566	7,070	96.7%	612	2.029	11,556	1.965	638	11,090
2006	12,297	12,112	93.7%	547	1.813	22,159	1.729	561	21,582
2007	12,297	12,571	92.0%	599	1.987	20,981	1.500	487	25,835
2008	14,209	14,873	88.6%	437	1.449	34,033	1.592	517	28,781
2009	14,209	12,873	97.6%	362	1.199	35,606	1.289	418	30,785
2010	17,369	7,118	95.3%	333	1.105	21,371	1.009	328	21,729
2011	10,514	6,506	7.7%	353	1.172	18,413	0.948	308	21,157

[1] **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 (*Pandalus borealis*) in NAFO Division 3L over the period 2000 – 2011. (Weighting by effort, no windows, observer data, history of at least 2 years in the fishery with the first year of the fishery for any vessel removed).

Class Level Information
Class Level Information

Class	Levels	Values
year	12	2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 (standardized to 2000)
month	12	1 2 3 4 5 6 7 8 9 10 11 12 (standardized to December)
CFV	21	
gear	2	66 99 (99 = single trawl, 66 = double trawl)

Number of Observations Read	271
Number of Observations Used	271

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	43	3300.132733	76.747273	8.34	<.0001
Error	227	2089.253440	9.203760		
Corrected Total	270	5389.386173			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.612339	41.50049	3.033770	7.310202

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	11	1465.386749	133.216977	14.47	<.0001
month	11	654.259861	59.478169	6.46	<.0001
CFV	20	843.872561	42.193628	4.58	<.0001
gear	1	336.613562	336.613562	36.57	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	11	982.6825273	89.3347752	9.71	<.0001
month	11	631.9268057	57.4478914	6.24	<.0001
CFV	20	528.5536728	26.4276836	2.87	<.0001
gear	1	336.6135618	336.6135618	36.57	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.249278521	B	0.17610759	35.49	<.0001
year	2001	0.273056018	B	0.15575799	1.75	0.0809
year	2002	0.674309704	B	0.17825077	3.78	0.0002
year	2003	1.155098512	B	0.17806829	6.49	<.0001
year	2004	0.610743150	B	0.16821517	3.63	0.0003
year	2005	0.616929226	B	0.16038183	3.85	0.0002
year	2006	0.626106004	B	0.15696315	3.99	<.0001
year	2007	0.488335419	B	0.16184857	3.02	0.0028
year	2008	0.722437272	B	0.16156395	4.47	<.0001
year	2009	0.658709863	B	0.16013396	4.11	<.0001
year	2010	0.425387375	B	0.16737724	2.54	0.0117
year	2011	0.003536940	B	0.18370673	0.02	0.9847
year	2012	0.000000000	B	.	.	.

Table 4 (continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
month	1	0.551038350 B	0.08573835	6.43	<.0001
month	2	0.530463344 B	0.08946650	5.93	<.0001
month	3	0.289654738 B	0.08645632	3.35	0.0009
month	4	0.143787265 B	0.10137456	1.42	0.1575
month	5	0.099773313 B	0.11215033	0.89	0.3746
month	6	0.186929703 B	0.10031751	1.86	0.0637
month	7	0.129779250 B	0.15563884	0.83	0.4052
month	8	0.101801887 B	0.19353697	0.53	0.5994
month	9	-0.051308684 B	0.26843185	-0.19	0.8486
month	10	0.083775551 B	0.10843789	0.77	0.4406
month	11	0.066341961 B	0.08671984	0.77	0.4451
month	12	0.000000000 B	.	.	.
CFV		0.115991442 B	0.13749363	0.84	0.3998
CFV		0.294245170 B	0.36973074	0.80	0.4270
CFV		-0.016517739 B	0.21503673	-0.08	0.9388
CFV		0.234019770 B	0.08479959	2.76	0.0063
CFV		0.238098323 B	0.16116554	1.48	0.1410
CFV		0.342361633 B	0.16272768	2.10	0.0365
CFV		0.778160818 B	0.36867306	2.11	0.0359
CFV		0.202446838 B	0.10405097	1.95	0.0529
CFV		0.147221081 B	0.33419121	0.44	0.6600
CFV		0.139847562 B	0.08695345	1.61	0.1092
CFV		0.020963255 B	0.11306872	0.19	0.8531
CFV		0.513266474 B	0.41426934	1.24	0.2166
CFV		0.152616808 B	0.11212258	1.36	0.1748
CFV		0.552105228 B	0.18617191	2.97	0.0033
CFV		0.389616023 B	0.10051129	3.88	0.0001
CFV		0.226781039 B	0.08887419	2.55	0.0114
CFV		0.452329618 B	0.24624749	1.84	0.0675
CFV		-0.538692463 B	0.19603048	-2.75	0.0065
CFV		-0.240651722 B	0.19486668	-1.23	0.2181
CFV		0.131143835 B	0.41272515	0.32	0.7510
CFV		0.000000000 B	.	.	.
gear	66	0.365604592 B	0.06045448	6.05	<.0001
gear	99	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Table 4 (Continued)

The GLM Procedure
Least Squares Means

year	lncpue LSMEAN
2001	7.07972813
2002	7.48098181
2003	7.96177062
2004	7.41741526
2005	7.42360134
2006	7.43277811
2007	7.29500753
2008	7.52910938
2009	7.46538197
2010	7.23205949
2011	6.81020905
2012	6.80667211

year	lncpue LSMEAN	95% Confidence Limits	
2001	7.079728	6.862507	7.296949
2002	7.480982	7.227287	7.734677
2003	7.961771	7.710649	8.212892
2004	7.417415	7.196012	7.638819
2005	7.423601	7.236795	7.610408
2006	7.432778	7.267577	7.597979
2007	7.295008	7.131313	7.458702
2008	7.529109	7.355603	7.702616
2009	7.465382	7.297520	7.633244
2010	7.232059	7.022168	7.441951
2011	6.810209	6.575130	7.045288
2012	6.806672	6.549471	7.063873

The GLM Procedure
Least Squares Means

gear	lncpue LSMEAN
66	7.51069520
99	7.14509061

gear	lncpue LSMEAN	95% Confidence Limits	
66	7.510695	7.362326	7.659064
99	7.145091	7.032162	7.258020

Table 5. Catch rate indices for **Canadian large vessels** (>500 t) fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2011.

		[1]	[2]	UNSTANDARDIZED			STANDARDIZED		
YEAR	TAC	CATCH (t)	PERCENT OF CATCH DATA CAPTURED IN MODEL	GEOMETRIC MEAN CPUE (KG/HR)	CPUE RELATIVE TO 2000	[3] EFFORT (HR)	CPUE RELATIVE To 2000	MODELLED CPUE	EFFORT (HRS)
2000	1,686	833	99%	619	1.000	1,346	1.000	904	922
2001	2,500	2,394	99%	903	1.459	2,651	1.314	1,188	2,016
2002	2,500	2,456	67%	1,474	2.381	1,666	1.963	1,774	1,384
2003	4,267	4,038	72%	3,399	5.492	1,188	3.174	2,869	1,407
2004	4,267	4,036	65%	1,226	1.981	3,292	1.842	1,665	2,424
2005	4,277	4,039	94%	1,585	2.560	2,549	1.853	1,675	2,411
2006	5,273	6,016	88%	942	1.521	6,389	1.870	1,690	3,559
2007	5,907	5,743	85%	1,088	1.757	5,280	1.630	1,473	3,899
2008	6,568	6,314	98%	1,593	2.573	3,964	2.059	1,861	3,392
2009	6,022	6,550	86%	1,166	1.884	5,616	1.932	1,747	3,750
2010	7,594	5,583	56%	843	1.361	6,626	1.530	1,383	4,037
2011	5,480	2,439	55%	798	1.289	3,056	1.004	907	2,689

[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. Trends in northern shrimp mean catch (kg/hr) per stratum, April – August of each year using standardized small vessel (<500 t; <65') logbook catch information (2000 – 2010). (Green=<.3 t/hr; .3 t/hr <White<=.6 t/hr; .6 t/hr<Pink; Black = not sampled). All indices were determined using areal expansion calculations. Index strata are those that were consistently fished over the study period.

A) All Strata

Small vessel Shrimp Mean CPUE (t/hr)		year										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		.	.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM								0.41			
91	371											
183	348							0.88	0.42	0.43		
	349									0.51	0.43	0.24
	364								0.95			
	365							0.55				
	370						0.65	0.64	0.46		0.31	
	385	0.34			0.34	0.7			0.44	0.6	0.48	0.34
274	347										0.01	
	366	0.22			0.45	0.47		0.79	1		0.28	0.11
	369	0.26				0.53	0.74	0.52	0.52	0.39	0.44	0.28
	386	0.34	0.39	1.1	0.53	0.58	0.9	0.87	0.63	0.71	0.54	0.43
	389					0.48	0.9	0.9	0.64	0.95	0.65	0.46
366	345	0.14			0.53	0.62	0.37	0.8	0.72	0.72	0.53	0.53
	346	0.35	0.29	0.45	0.43	0.58	0.77	0.73	0.72	0.74	0.47	0.4
	368	0.28	0.32	0.34	0.48	0.52	0.71	0.66	0.47	0.32	0.51	0.39
	387	0.44	0.45	0.45	0.45	0.56	0.78	0.72	0.57	0.53	0.46	0.57
	388									1.54	0.58	0.52
400	638							0.61				
549	731								1.23	0.58	0.41	0.56
	733		1.05		0.25	0.39	0.65	0.57	0.5	0.56	0.39	0.3
	735	0.13		0.47	0.48		0.95	0.51	0.67		0.16	0.43
731	732											0.63
	734					0.37					0.33	
	736							0.54				
914	745									0.44		

B) Index Strata

Small vessel Shrimp Index Strata Mean CPUE (t/hr)		year							
		2003	2004	2005	2006	2007	2008	2009	2010
		.	.	.	.	.	.	.	.
Max depth (m)	STRATUM	0.53	0.58	0.9	0.87	0.63	0.71	0.54	0.43
274	386								
366	345	0.53	0.62	0.37	0.8	0.72	0.72	0.53	0.53
	346	0.43	0.58	0.77	0.73	0.72	0.74	0.47	0.4
	368	0.48	0.52	0.71	0.66	0.47	0.32	0.51	0.39
	387	0.45	0.56	0.78	0.72	0.57	0.53	0.46	0.57
549	733	0.25	0.39	0.65	0.57	0.5	0.56	0.39	0.3

Table 7. NAFO Division 3L annual northern shrimp biomass indices calculated using areal expansion calculations with standardized small vessel (>500 t; <65') logbook catch information (2003 – 2010). These analyses were limited to index strata. The analysis was limited to the period April – August of each year.

Year	Commercial CPUE (t/hr)			Mean (t/hr)	Number Sets
	Lower 95% C.I.	Mean	Upper 95% C.I.		
2003	26,256	29,253	32,251	0.47	613
2004	3,995	35,290	66,585	0.57	1,351
2005	34,571	41,216	47,860	0.66	1,180
2006	43,892	47,045	50,197	0.76	1,777
2007	37,223	39,702	42,182	0.64	1,801
2008	34,509	40,256	46,003	0.65	2,298
2009	28,796	30,731	32,666	0.50	3,777
2010	25,023	28,527	32,031	0.46	2,516

Table 8. Trends in northern shrimp mean catch (t/hr) per stratum and year using standardized large vessel (>500 t) observed catch information (2000 – 2011). (Green=<1 t/hr; 1 t/hr <White<=2 t/hr; 2 t/hr<Pink; Black = no sampled). All indices were determined using areal expansion calculations. The analysis was limited to the period January - April of each year.

Shrimp Large vessel Mean CPUE (t/hr)		year											
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		.	.	.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM												
274	366	1.1	0.5										
	369							1.74		1.84			
	386						1.6	1.98	2.22	2.11	1.8		0.89
	389												0.2
366	345	0.67											
	346	0.85											0.44
	368	0.98	0.45		1.26			1.55		2.29			1.2
	387	0.63	1.43	2.07	2.5	2.27	2.38	2.29	2.46	2.13	2.49	2.32	1.67
400	638	1.08											
549	733		1.41	2.26	2.72	2.47	2.53	3.3	2.82	2.5	2.45		1.84
	735				1.34	0.35				2.98			
731	734						2.28						

Table 9. Unstandardized catch rate indices for non Canadian vessels fishing northern shrimp in the NAFO Division 3L NRA over the period 2000 – 2011. Indices included data from Greenland, Iceland, Norway, Spain, and Russia.

YEAR	TAC	CATCH (t)	PERCENT OF CATCH CAPTURED IN DATASET	UNSTANDARDIZED CPUE (KG/HR)	UNSTANDARDIZED CPUE RELATIVE TO 2000	UNSTANDARDIZED EFFORT (HR)
2000	1,000	661	21	746	1.000	886
2001	1,000	5,700	1	381	0.510	14,978
2002	1,000	1,550	4	650	0.871	2,386
2003	2,167	2,368	45	724	0.971	3,271
2004	2,167	2,892	10	2,035	2.728	1,421
2005	2,167	3,280	5	570	0.764	5,753
2006	3,675	7,703	7	636	0.853	12,103
2007	3,675	5,543	16	1,021	1.369	5,430
2008	3,815	6,504	17	1,122	1.504	5,798
2009	5,100	7,104	21	1,264	1.694	5,622
2010	4,676	7,097	39	1,147	1.537	6,189
2011	3,206	2,230	31	873	1.170	2,555

Table 10. NAFO Divisions 3LNO northern shrimp biomass and abundance indices as calculated using Ogmap. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1996 – 2011. (Offshore strata only with standard 15 min. tows).

Spring

Year	Biomass (tons)			Abundance (numbers x 10^6)			Survey Sets
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	
1999	27,174	49,736	76,708	6,609	11,496	17,418	313
2000	66,157	114,070	177,902	13,239	21,502	31,805	298
2001	53,038	83,061	117,896	12,333	19,852	28,734	300
2002	87,984	134,710	206,092	20,871	31,476	47,984	304
2003	117,997	170,753	224,114	26,549	39,232	54,156	300
2004	41,239	94,136	170,250	8,228	18,121	32,107	296
2005	86,212	134,307	184,748	16,914	25,727	35,097	289
2006	108,130	178,405	247,975	21,405	34,318	46,655	195
2007	191,493	290,562	381,779	35,580	54,675	73,285	295
2008	171,961	224,718	279,085	35,389	46,310	56,361	273
2009	63,277	113,265	168,639	14,528	24,613	35,419	299
2010	76,557	131,589	184,043	16,220	26,625	37,070	288
2011	34,775	69,872	114,775	8,544	15,085	22,905	297

Please note that during 2006, it was not possible to sample all allocated stations within 3NO; however, all stations within 3L were sampled during that year. The 2006 estimates are for Div. 3L only since at least 90% of the biomass and abundance is found within that division (Tables 13 and 14; Figs. 18 and 19).

Autumn

Year	Biomass (tons)			Abundance (numbers x 10^6)			Survey Sets
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	
1996	20,287	24,868	35,248	5,378	6,625	9,454	304
1997	32,630	44,299	62,361	7,601	9,984	13,964	318
1998	48,649	61,113	77,171	12,031	15,082	19,260	347
1999	43,453	55,273	72,892	10,692	13,085	16,632	313
2000	84,561	107,728	140,147	21,032	28,091	36,074	337
2001	156,356	216,965	261,365	37,141	52,084	62,462	362
2002	136,421	193,004	241,129	31,322	44,777	55,132	365
2003	144,979	192,299	245,055	30,677	39,939	49,927	316
2004	???						
2005	178,707	224,114	266,399	35,731	45,390	54,095	333
2006	174,076	216,865	253,714	36,698	47,354	56,079	312
2007	216,059	277,575	352,179	43,917	57,239	71,946	361
2008	197,131	250,995	303,852	41,017	53,614	65,462	256
2009	80,020	119,205	150,215	19,713	29,688	36,184	315
2010	56,572	75,107	94,337	12,645	17,035	21,092	318

It was not possible to sample all of the Div. 3L stations during 2004 therefore there are not estimates for autumn 2004.

Table 11. Trends in mean northern shrimp catch (kg/15 min tow) per stratum and year from **spring** Canadian research bottom trawl multi-species survey data (1999 – 2011). (Green=<40 kg/tow; 40kg/tow<White<=100 kg./tow; 100 kg/tow< Pink; Black= not sampled).

Survey Spring SFA 7 Shrimp Mean (kg/ 15 min. tow)		YEAR												
		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		.	.	.	.	.	.	.	.	.	.	.	.	.
Depth Range (m)	STRATUM	0	0	0	0	0.02	0	0	0	0.01	0.01	0	0	0
57 - 92	350													
	363	0	0	0	0	0.02	0	0	0	0	0.07	0	0	0
	371	0	0	0	0	0	0	0	0	0	0	0	0	0
	372	0	0	0	0	0	0	0	0	0	0	0.01	0	0
	384	0.01	0	0	0.02	0	0	0	0	0	0	0	0.01	0
93 - 183	328	0	0.06	0	0.01	0.04	0.09	0.07	0.05	0.04		0.01	0.03	1.41
	341	0.01	0.03	0	0.02	0.02	0.25	0	0	0.01	0.02	0	0.01	0
	342	0.04	0.01	0	0.09	0.02	0.06	0.01	0	0.11	0	0.08	0.04	0
	343	0.04	0	0.08	0	0.03	0.06	0.03	0.01	0.11	0.02	0.08		0
	348	0.02	0.08	0.02	0.03	0.04	0.03	0.05	0.04	0.11	0.42	0.06	0.15	0.05
	349	0.03	0.01	0	0.01	0.02	0.03	0	0.03	0	0.01	0.01	0.18	0.03
	364	0	0.01	0.02	0.03	0.02	0	0	0	0	0	0	0.02	0
	365	0	0.01	0.06	0.02	0.04	0	0.02	0.18	0	9.07	0.1	1.09	0.66
	370	0	0	0	0	0	0	0	0	0	0	0	0	0.01
	385	0	0	0.02	0.06	0	0.03	0	0	0.09	130.4	0.01	0.03	0
	390	0.01	0.01	0.01	0.01	0	0.04	0.11	0	0	0	0.02	0	0
184 - 274	344	0.16	0.05	0.24	0.81	4.11	0.06	13.98	4.28	0.81	16.57	0.65	8.72	29.58
	347	0.11	0	9.05	0.93	0.17	0.86	49.41	20.99	53.62	43.42	92.86	2.55	13.6
	366	3.85	93.34	59.22	179.1	36.98	1.95	66.49	17.68	32.17	51.94	8.26	5.68	9.9
	369	0.05	11.21	0	22.86	275.6	2.6	144.6	32.18	115.6	32.94	113.8	37.54	1.69
	386	15.7	60.75	12.05	0.23	3.39	13.29	29.49	183.6	92.55	162.9	0.04	58.07	86.81
	389	84.13	283.7	8.31	43.38	129.9	9.9	125.7	445.8	262.7	202.5	101.2	82.4	172.6
	391	0.01	0	2.46	0	78.51	0.99	3.08	2.5	949.8	26.45	526.8	0.02	0.39
275 - 366	345	30.77	67.13	159.7	49.94	193.1	92.71	163	204.1	386.9	388.5	94.92	162.3	94.55
	346	104.7	121.9	164	213.8	117.1	86.54	292.2	60.97	443	187.6	41.56	82.99	53.13
	368	76.56	202.9	21.46	70.57	320.1	109.7	15.52	67.53	61.86	50.97	7.65	30.62	25.62
	387	126.6	13.18	189	352.9	380	516.2	137.3	221.6	85.21	220.6	25.41	206.5	92.04
	388	64.25	258.7	170.8	581	158.9	69.91	53.33	175.1	242.4	21.56	272.8	651.7	6.02
	392	3.27	7.67	36.3	0.67	50.02	6.29	34.63	8.24	4.44	0.62	3.79	0.18	3.52
367 - 549	729	0	0.27	0.58	0.08	12.41	0.1	4.25	11.39	0.03	5.92	0		0
	731	3.5	14.55	21.69	3.54	143.9	0.69	18.46	25.43	47.65	6.4	2.12	9.46	0.13
	733	1.72	6.18	2.56	3.15	39.37	0.17	1.82	2.68	13.13	0.87	14.41	0.32	0.45
	735	0.49	3.25	0.42	1	0.08	0.04	1.75	1.71	0.41	4.69	1.94	0.59	0
550 - 731	730	0	0.04	0	0.02	0.05	0.01	0	0	0	0	0	0	0
	732	2.39	1.37	0.35	3.27	0.29	0	0	0.07	0	0	0.68	0.03	
	734	0.11	0	2.35	0.21	0.03	0	0	0.04	0.09		0	0	0
	736	0.11	0.1	0.29	0.25	0.38	0	0	0	0.11	0.62	0	0	0

Table 12. Trends in mean northern shrimp catch (kg/15 min tow) per stratum and year from **autumn** Canadian research bottom trawl multi-species survey data (1996 – 2010). (Green=<40 kg/tow; 40kg/tow<White<=100 kg/tow.; 100 kg/tow< Pink; Black= not sampled).

Survey Fall SFA 7 Shrimp Mean (kg/hr)		YEAR														
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Depth Range (m)	STRATUM	0	0	0.01	0	0	0.01	0.1	0.13	0.01	0.01	0.02	0.03	0.01	0	0
57 - 92	350															
	363	0	0.01	0.01	0	0.03	0.07	0.07	2.38	0	0	0	0.02	0.01	0.01	0
	371	0	0.01	0	0	0.04	0.03	0.06	0.14	0	0.02	0.03	0.1	0.09	1.37	0
	372	0.01	0.03	0.02	0	0.02	0.02	0.29	0.46	0.02	0	0	0.05	0.2	1.03	0.01
	384	0.01	0.01	0	0.01	0.07	0.03	2.97	0.23	0.04	0	0.05	0.04	0.06	0.71	0
93 - 183	328	0.12	0.45	0.06	0.18	0.13	0.07	0.1	0.54	0.18	0.04	0.07	0.12	0.03	0.01	0.13
	341	0.42	0.18	0.02	0.08	0.14	0.09	0.24	0.3	0.17	0.01	0.08	1.01	0.08	0.4	0.18
	342	0.01	0	0.29	0.05	5.18	0.04	0.41	0.56	0.01	0	0	0	0.2	0.01	0
	343	0.01	0.01	0.06	0.02	0.07	0.05	0.07	0.06	0.24	0.31	0	0.79	0.12	0	0
	348	0.06	0.06	0.18	0.94	1.16	1.4	2.17	0.63	17.07	20.63	7.35	30.55	34.46	2.72	4.67
	349	0.01	0.02	0.05	0.04	0.1	0.13	1.5	0.96	0.13	0.12	0.61	1.04	0.02	0.06	0.55
	364	0.01	0.11	0.03	0.01	0.29	0.46	0.76	0.22	0.06	1.81	0.04	1	0.48	0.27	0
	365	0.02	0.69	1.17	0.41	.	22.16	22.29	0.65	.	66.53	140.1	25.54	61.32	4.41	13.02
	370	0.01	0.3	3.68	0.69	0.43	15.54	0.67	0.54	.	0.06	30.93	1.51	15.76	0.48	1.16
	385	0.03	4.26	0.59	3.69	6.01	12.46	10.5	13.47	16.55	24.33	58.32	92.97	108.4	11.74	9.09
	390	0	0.05	0.03	0.05	0.7	11.5	16.19	36.48	6.19	11.76	22.8	12.03	95.12	7	0.69
184 - 274	344	0.12	0.45	12.31	21.84	13.75	8.49	32.52	8.98	63.65	66.52	52.12	189.6	202.7	37.46	13.88
	347	0.31	0.17	33.63	10.73	51.12	72.45	59.04	12.08	151	95.32	98.24	159	97.88	36.57	60.98
	366	2.74	58.07	26.53	37.51	118.3	123.8	132.2	112.2	.	168.3	220.7	53.63	142.4	38.12	21.88
	369	1.29	13.07	44.81	27.94	23.78	76.89	47.47	156	.	203.2	112.8	156.7	158.2	99.03	45.62
	386	2.11	64.47	41.46	54.66	42.72	105.7	174.2	159.2	.	149.8	223.7	273	229.6	199.5	80.13
	389	16.66	13.53	57.42	83.55	208.3	269.3	284.9	165.8	88.48	102.4	210.5	227.3	334.2	143	76.16
	391	9.46	5.7	4.02	5.95	88.03	8.54	2.56	189.4	54.45	50.06	18	430.9	11.26	26.63	11.57
275 - 366	345	9.66	28.44	47.37	20.76	87.04	85.21	151.7	80.64	95.4	129.7	89.14	169.5	78.74	58.65	58.89
	346	55.7	44.18	27.66	41.98	49.25	149.6	282.7	237.6	87.11	278.3	98.99	41.18	99.9	67.03	64.31
	368	25.13	9.87	7.3	2.06	0.56	346.6	9.33	207.4	.	227.5	44.62	13.43	5.51	1.29	3.89
	387	22.72	40.41	68.32	37.09	114	415.7	112.9	424.5	.	219.3	104.6	216.2	93.65	35.31	70.27
	388	30.19	39.96	28.04	10.75	81.68	257	136	70.73	78.28	167	36.92	197.1	40.39	95.48	0.08
	392	15.21	3.45	8.77	5.76	18.19	15.03	2.07	41.43	39.58	32.6	26.3	38.5	0.06	11.14	0
367 - 549	729	0.13	0.06	0.01	1.85	0.02	22.11	0	0.54	0.04	0.03	0.27	0	0	0	0
	731	.	0.49	0.35	0.45	3.55	2.9	24.37	0	50.57	4.09	6.71	4.13	0.83	0.17	0.02
	733	3.09	2.48	0.18	0.96	0	3.54	0.06	0	3.36	0.47	0.04	1.6	10.19	2.58	0
	735	0.04	4.15	0.05	1.42	2.99	0.19	0.31	3.69	.	1.43	2.76	0.01	1.58	0	0
550 - 731	730	0.04	0.02	0	0	0	0.04	0	0	0	1.18	0.02	0	0	0	0
	732	0	0.01	0	0.02	0	0.07	0.27	0	0.04	0.12	0	0	0.72	0	0
	734	0	0.02	0	0.01	0	0.04	0.26	0	.	0.03	0	0.03	0	0	0
	736	0	0.3	0.09	0.08	1.05	0.49	0	.	.	0.05	0.07	0	0.04	0	0
732 - 914	737	0	0	0	0	0.02	0.01	0	0.01	.	0.04	0	0	.	0	0
	741	0	0	0	0	0	0	0.01	0.65	.	.	0	0	.	0	0
	745	0	0.01	0	0	0.01	0.19	0	0.15	.	.	0	0	.	0	0
	748	0	0.02	0.01	0	0.03	0.12	0	0.03	.	.	0	0.01	.	0	0
915 -1097	738	0	0	0	0	0.01	0	0	0	.	.	0	0	.	0	0
	742	0	0	0	0	0	0	0	0	.	.	0	0	.	0	0
	746	0	0	0	0	0.01	0.07	0	0.01	.	.	0	0	.	0	0
	749	0	0	0	.	0.01	0	0	0	.	.	.	0	.	0	0
1098 -1280	739	0	0	0	0	0	0.01	0	0	.	0	0	0	.	.	0
	743	0	0	0	0	0	0	0	0	.	.	0	0	.	0	0
	747	0	0	0	0	0	0	0.01	0	.	.	0	0	.	0	0
	750	0	0	0	0	0	0	.	0	.	.	.	0	.	0	0
1281 -1463	740	0	0	0	0	0	0	0	0	.	0	0	0	.	0	0
	744	0	0	0	.	0	0	0	0	.	.	0	0	.	0	0
	751	0	0	0	.	0	0	0	0	.	.	.	0	.	0	0

Table 13. NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1999 – 2011 **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 90% of the shrimp have been attributed to strata within 3L therefore the spring 2006 estimates are for 3L only. 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 percen biomass in NRA
Spring	1999	3L	47,823	96.15	10,269	86.44	21.47	
Spring	2000	3L	109,439	95.94	23,962	87.18	21.90	
Spring	2001	3L	83,262	97.07	11,478	99.13	13.78	19.05
Spring	2002	3L	128,971	95.74	34,533	91.47	26.78	20.82
Spring	2003	3L	166,525	97.52	30,103	86.92	18.08	19.55
Spring	2004	3L	92,626	98.40	23,861	97.13	25.76	23.54
Spring	2005	3L	134,106	99.85	14,297	94.67	10.66	18.17
Spring	2006	3L	180,620	???	43,695	???	24.19	20.20
Spring	2007	3L	284,018	97.75	78,732	97.02	27.72	20.86
Spring	2008	3L	224,114	99.73	34,533	99.13	15.41	22.44
Spring	2009	3L	110,949	97.96	36,446	98.64	32.85	25.33
Spring	2010	3L	130,683	99.31	42,084	99.52	32.20	26.82
Spring	2011	3L	69,469	99.42	12,384	100.00	17.83	27.63
Spring	1999	3N	2,114	4.25	1,611	13.56	76.19	
Spring	2000	3N	4,732	4.15	3,524	12.82	74.47	
Spring	2001	3N	302	0.35	101	0.87	33.33	61.33
Spring	2002	3N	5,839	4.33	3,222	8.53	55.17	54.32
Spring	2003	3N	5,437	3.18	4,531	13.08	83.33	57.28
Spring	2004	3N	1,208	1.28	705	2.87	58.33	65.61
Spring	2005	3N	1,410	1.05	805	5.33	57.14	66.27
Spring	2006	3N	???	???	???	???	???	57.74
Spring	2007	3N	3,121	1.07	2,416	2.98	77.42	67.28
Spring	2008	3N	604	0.27	302	0.87	50.00	63.71
Spring	2009	3N	705	0.62	503	1.36	71.43	66.28
Spring	2010	3N	403	0.31	201	0.48	50.00	57.14
Spring	2011	3N	101	0.14	0	0.00	0.00	40.48
Spring	1999	3O	101	0.20	0	0.00	0.00	
Spring	2000	3O	101	0.09	0	0.00	0.00	
Spring	2001	3O	0	0.00	0	0.00	0.00	0.00
Spring	2002	3O	101	0.07	0	0.00	0.00	0.00
Spring	2003	3O	201	0.12	0	0.00	0.00	0.00
Spring	2004	3O	201	0.21	0	0.00	0.00	0.00
Spring	2005	3O	101	0.07	0	0.00	0.00	0.00
Spring	2006	3O	1,007	???	101	???	10.00	0.00
Spring	2007	3O	0	0.00	0	0.00	0.00	0.00
Spring	2008	3O	0	0.00	0	0.00	0.00	0.00
Spring	2009	3O	0	0.00	0	0.00	0.00	0.00
Spring	2010	3O	101	0.00	0	0.00	0.00	0.00
Spring	2011	3O	101	0.00	0	0.00	0.00	0.00
	all divisions							
Spring	1999		49,736	100.61	11,880	100.00	23.89	
Spring	2000		114,070	100.18	27,486	100.00	24.10	
Spring	2001		85,779	97.42	11,578	100.00	13.50	20.49
Spring	2002		134,710	100.15	37,755	100.00	28.03	21.87
Spring	2003		170,753	100.83	34,634	100.00	20.28	20.60
Spring	2004		94,136	99.89	24,566	100.00	26.10	24.80
Spring	2005		134,307	100.97	15,102	100.00	11.24	19.21
Spring	2006		???	???	???	???	???	18.67
Spring	2007		290,562	98.82	81,148	100.00	27.93	19.59
Spring	2008		224,718	100.00	34,835	100.00	15.50	21.71
Spring	2009		113,265	98.58	36,950	100.00	32.62	25.35
Spring	2010		131,589	99.62	42,286	100.00	32.13	26.75
Spring	2011		69,872	99.57	12,384	100.00	17.72	27.49

Table 14. NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1996 – 2010 **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	iomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percen biomass in NRA
Autumn	1996	3L	23,056	92.71	4,027	85.11	17.47	17.47
Autumn	1997	3L	43,695	98.64	5,537	91.67	12.67	15.07
Autumn	1998	3L	56,381	92.26	8,961	81.65	15.89	15.34
Autumn	1999	3L	54,871	99.27	8,054	96.39	14.68	14.41
Autumn	2000	3L	106,519	98.88	22,250	98.22	20.89	17.15
Autumn	2001	3L	215,153	99.21	41,077	97.14	19.09	18.22
Autumn	2002	3L	189,077	97.97	35,439	92.39	18.74	19.57
Autumn	2003	3L	186,459	97.01	35,842	91.75	19.22	19.02
Autumn	2004	3L	???	???	???	???	???	???
Autumn	2005	3L	222,704	99.37	26,378	97.40	11.84	15.53
Autumn	2006	3L	215,153	99.21	27,284	96.44	12.68	12.26
Autumn	2007	3L	273,346	98.48	50,038	98.42	18.31	14.28
Autumn	2008	3L	247,874	98.76	33,124	97.92	13.36	14.78
Autumn	2009	3L	117,594	98.65	18,223	97.84	15.50	15.72
Autumn	2010	3L	74,503	99.20	8,860	98.88	11.89	13.58
Autumn	1996	3N	2,014	8.10	705	14.89	35.00	35.00
Autumn	1997	3N	705	1.59	503	8.33	71.43	53.21
Autumn	1998	3N	4,732	7.74	2,014	18.35	42.55	49.66
Autumn	1999	3N	503	0.91	302	3.61	60.00	57.99
Autumn	2000	3N	705	0.65	403	1.78	57.14	53.23
Autumn	2001	3N	1,712	0.79	1,208	2.86	70.59	62.58
Autumn	2002	3N	4,027	2.09	2,920	7.61	72.50	66.74
Autumn	2003	3N	4,732	2.46	3,222	8.25	68.09	70.39
Autumn	2004	3N	2,618	???	2,114	???	???	???
Autumn	2005	3N	1,007	0.45	705	2.60	70.00	69.04
Autumn	2006	3N	1,510	0.70	1,007	3.56	66.67	68.33
Autumn	2007	3N	1,309	0.47	805	1.58	61.54	66.07
Autumn	2008	3N	1,309	0.52	705	2.08	53.85	60.68
Autumn	2009	3N	805	0.68	403	2.16	50.00	55.13
Autumn	2010	3N	302	0.40	101	1.12	33.33	45.73
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	101	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	101	0.05	0	0.00	0.00	0.00
Autumn	2003	3O	201	0.10	0	0.00	0.00	0.00
Autumn	2004	3O	201	???	0	???	???	???
Autumn	2005	3O	101	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
Autumn	2008	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2009	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2010	3O	0	0.00	0	0.00	0.00	0.00
	all divisions							
Autumn	1996		24,868	101	4,732	100	19.03	19.03
Autumn	1997		44,299	100	6,041	100	13.64	16.33
Autumn	1998		61,113	100	10,974	100	17.96	16.87
Autumn	1999		55,273	100	8,356	100	15.12	15.57
Autumn	2000		107,728	100	22,653	100	21.03	18.03
Autumn	2001		216,865	100	42,286	100	19.50	18.55
Autumn	2002		193,004	100	38,359	100	19.87	20.13
Autumn	2003		192,198	100	39,064	100	20.32	19.90
Autumn	2004		???		???		???	???
Autumn	2005		224,114	100	27,083	100	12.08	16.20
Autumn	2006		216,865	100	28,291	100	13.05	12.56
Autumn	2007		277,575	99	50,843	100	18.32	14.48
Autumn	2008		250,995	99	33,828	100	13.48	14.95
Autumn	2009		119,205	99	18,626	100	15.63	15.81
Autumn	2010		75,107	100	8,961	100	11.93	13.68

Table 15. Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *Pandalus borealis* in NAFO Divs. 3LNO from **spring** Canadian multi-species bottom trawl surveys (1999 – 2011). Abundance at length determined using Ogmap calculations.

Mean Carapace Length (Standard Error)

Year	Age					
	0	1	2	3	4	5
1999		12.43 (.454)	14.63 (.055)	18.15 (.069)	20.51 (.053)	
2000		8.73 (.044)	14.22 (.034)	18.00 (.024)	20.74 (.070)	
2001		8.39 (.131)	13.45 (.027)	16.82 (.008)	19.13 (.024)	
2002		8.27 (.061)	12.85 (.029)	16.97 (.021)	19.43 (.018)	
2003		8.37 (.065)	13.09 (.003)	16.01 (.091)	17.96 (.086)	19.69 (.040)
2004		8.55 (.288)	13.66 (.094)	17.13 (.299)	18.47 (.090)	19.96 (.026)
2005		8.93 9.078)	14.10 (.052)	17.07 (.130)	18.69 (.212)	20.59 (.088)
2006		9.57 (.148)	13.84 (.019)	17.53 (.189)	18.83 (.412)	20.52 (.054)
2007		9.37 (.157)	13.48 (.018)	16.89 (.025)	19.46 (.063)	21.08 (.041)
2008		8.85 (.072)	13.39 (.032)	16.14 (.036)	18.46 (.038)	20.78 (.038)
2009			11.87 (.037)	15.67 (.058)	18.20 (.070)	20.12 (.059)
2010		9.35 (.086)	13.54 (.053)	16.16 (.042)	18.43 (.042)	20.25 (.064)
2011		11.82 (.115)	13.60 (.066)	15.75 (.066)	18.03 (.067)	20.24 (.052)

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

Year	Age						
	0	1	2	3	4	5	Total
1999		.067 (.024)	.389 (.026)	.165 (.015)	.379 (.014)		1.000
2000		.023 (.001)	.353 (.006)	.454 (.012)	.170 (.008)		1.000
2001		.006 (.001)	.201 (.004)	.294 (.008)	.499 (.009)		1.000
2002		.018 (.001)	.100 (.002)	.399 (.006)	.482 (.006)		.999
2003		.013 (.001)	.131 (.003)	.137 (.010)	.304 (.013)	.415 (.017)	1.000
2004		.004 (.001)	.129 (.007)	.150 (.050)	.119 (.051)	.598 (.014)	1.000
2005		.017 (.001)	.162 (.006)	.352 (.042)	.272 (.037)	.197 (.020)	1.000
2006		.005 (.001)	.303 (.004)	.188 (.052)	.147 (.043)	.357 (.025)	1.000
2007		.003 (.000)	.196 (.003)	.325 (.005)	.255 (.010)	.221 (.011)	1.000
2008		.011 (.001)	.140 (.003)	.336 (.006)	.372 (.006)	.141 (.005)	1.000
2009			.109 (.003)	.227 (.009)	.403 (.070)	.261 (.016)	1.000
2010		.003 (.000)	.045 (.003)	.302 (.010)	.324 (.017)	.326 (.020)	1.000
2011		.015 (.003)	.100 (.005)	.206 (.008)	.343 (.010)	.336 (.013)	1.000

Table 15 (Continued)

Distributional Sigmas (Standard Error and constraints)

Year	Age					
	0	1	2	3	4	5
1999		1.130 (.186)	.912 (.040)	.769 (.059)	.998 (.031)	
2000		.708 (.036)	1.317 (.026)	.917 (.026)	1.023 (.038)	
2001	1.063 (.012) Sigmas Eq.					
2002	1.064 (.009) Sigmas Eq.					
2003	1.011 (.015) Sigmas Eq.					
2004		1.086 (.220)	1.314 (.070)	.888 (.192)	.540 (.096)	1.00 (Fixed)
2005	1.094 (.025) Sigmas Eq.					
2006	1.029 (.014) Sigmas Eq.					
2007	1.028 (.010) Sigmas Eq.					
2008	1.054 (.013) Sigmas Eq.					
2009	1.135 (.018) Sigmas Eq.					
2010		.562 (CV=.0123)	.814(CV=.0123)	.971(CV=.0123)	1.107(CV=.0123)	1.217(CV=.0123)
2011		.650 (CV=.016)	.752 (CV=.016)	.876 (CV=.016)	1.001 (CV=.016)	1.133 (CV=.016)

Population at Age Estimates (10^6)

Year	Male Ages						Females	Total
	0	1	2	3	4	5		
1999	57	635	3,377	1,432	3,304	0	2,672	11,477
2000	0	337	5,251	6,747	2,540	13	6,604	21,492
2001	0	93	3,034	4,444	7,566	18	4,677	19,832
2002	0	419	2,274	9,037	10,922	0	8,808	31,460
2003	0	342	3,496	3,658	8,093	11,065	12,567	39,221
2004	0	48	1,597	1,858	1,478	7,399	5,728	18,108
2005	0	252	2,415	5,249	4,062	2,942	10,823	25,743
2006	4	133	6,331	3,923	3,069	7,683	13,193	34,336
2007	0	93	6,638	11,014	8,658	7,525	25,386	59,314
2008	16	365	4,093	9,809	10,849	4,143	17,011	46,286
2009	0	8	1,763	3,660	6,514	4,206	8,472	24,622
2010	1	50	797	5,704	5,753	5,753	8,989	26,617
2011	5	168	1,065	2,187	3,662	3,621	4,362	15,070

Table 16. Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *Pandalus borealis* in NAFO Divs. 3LNO from **autumn** Canadian multi-species bottom trawl surveys (1996 – 2010). Abundance at length determined using Ogmap calculations.

Mean Carapace Length (Standard Error)

	Age			
Year	1	2	3	4
1996	11.19 (.074)	15.92 (.035)	19.32 (.070)	21.44 (.404)
1997	11.01 (.063)	16.11 (.067)	18.83 (.317)	20.01 (1.28)
1998	10.74 (.018)	15.91 (.115)	18.90 (.172)	20.69 (.225)
1999	11.09 (.067)	15.99 (.019)	18.98 (.047)	20.89 (.041)
2000	10.49 (.029)	15.23 (.033)	18.16 (.021)	20.56 (.122)
2001	10.17 (.043)	15.07 (.026)	17.37 (.038)	19.58 (.018)
2002	10.44 (.032)	14.49 (.021)	17.65 (.014)	20.06 (.014)
2003	10.10 (.034)	15.11 (.030)	18.02 (.065)	19.95 (.030)
2004	Incomplete survey			
2005	10.63 (.028)	14.61 (.075)	17.83 (.052)	20.86 (.095)
2006	10.67 (.019)	14.84 (.019)	17.88 (.123)	19.97 (.029)
2007	11.27 (.040)	15.21 (.023)	17.87 (.023)	20.66(.017)
2008	10.24 (.031)	14.95 (.026)	17.86 (.027)	20.17 (.024)
2009	9.42 (.053)	14.31 (.051)	17.75 (.151)	19.31 (.440)
2010	10.40 (.044)	14.90 (.268)	17.56 (.072)	20.54 (.074)

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

	Age				
Year	1	2	3	4	Total
1996	.074 (.004)	.635 (.011)	.231 (.036)	.060 (.020)	1.000
1997	.069 (.003)	.425 (.020)	.331 (.301)	.174 (.289)	0.999
1998	.234 (.004)	.211 (.016)	.335 (.079)	.220 (.068)	1.000
1999	.055 (.002)	.546 (.007)	.150 (.011)	.249 (.009)	1.000
2000	.061 (.002)	.342 (.007)	.460 (.015)	.137 (.011)	1.000
2001	.016 (.001)	.185 (.004)	.299 (.006)	.500 (.007)	1.000
2002	.035 (.010)	.133 (.002)	.468 (.004)	.364 (.004)	1.000
2003	.047 (.001)	.178 (.004)	.247 (.012)	.528 (.013)	1.000
2004	Incomplete survey				
2005	.039 (.001)	.097 (.012)	.637 (.036)	.227 (.025)	1.000
2006	.059 (.001)	.296 (.004)	.161 (.011)	.484 (.013)	1.000
2007	.035 (.001)	.239 (.004)	.401 (.004)	.325 (.004)	1.000
2008	.048 (.001)	.195 (.003)	.434 (.005)	.323 (.006)	1.000
2009	.028 (.001)	.384 (.010)	.202 (.129)	.386 (.127)	1.000
2010	.059 (.003)	.233 (.042)	.436 (.050)	.272 (.013)	1.000

Table 16 (Continued)

Distributional Sigmas (Standard Error and constraints)

	Age			
Year	1	2	3	4
1996	1.18 (Fixed)	1.25 (.032)	0.83 (.072)	1.01 (.184)
1997	1.150 (.050)	1.043 (.043)	.843 (.167)	1.00 (.0305)
1998	0.89 (.014)	1.23 (.071)	0.95 (.128)	0.89 (.068)
1999	1.231 (.054)	.975 (.017)	.698 (.052)	.997 (fixed)
2000	0.90 (.023)	1.11 (.024)	0.84 (.023)	1.20 (.057)
2001	1.046 (.009) Sigmas Eq.			
2002	0.97 (.006) Sigmas Eq.			
2003	1.12 (.012) Sigmas Eq.			
2004	Incomplete survey			
2005	0.86 (.022)	0.85 (.044)	1.50 (.086)	1.10 (.036)
2006	0.80 (CV=.075)	1.11 (CV=.075)	1.34 (CV=.075)	1.49 (CV=.075)
2007	1.11 (.008) Sigmas Eq.			
2008	1.15 (.010) Sigmas Eq.			
2009	0.84 (.038)	1.43 (.038)	1.05 (.158)	1.49 (.125)
2010	.791 (.033)	1.34 (.140)	1.04 (.071)	1.15 (.040)

Population at Age Estimates (10^6)

	Male Ages					All females	Total
Year	0	1	2	3	4		
1996	0	439	3,765	1,369	375	666	6,615
1997	3	500	3,057	2,382	1,254	2,729	9,925
1998	0	3,026	2,735	4,328	2,838	2,147	15,075
1999	2	560	5,488	1,513	2,556	3,022	13,088
2000	3	1,466	8,135	10,949	3,291	4,278	28,111
2001	4	704	8,071	13,488	21,606	8,191	52,064
2002	0	1,243	4,665	16,434	12,767	9,662	44,770
2003	0	1,364	5,163	7,160	15,339	10,870	39,896
2004	Incomplete survey						
2005	7	1,340	3,303	21,720	7,779	11,215	45,363
2006	0	2,298	11,415	6,078	17,873	9,700	47,364
2007	0	1,459	9,870	16,535	13,396	15,875	57,134
2008	0	2,119	7,921	17,616	13,264	12,644	53,564
2009	0	655	9,003	4,744	9,056	6,213	29,671
2010	5	754	2,944	5,511	3,447	4,460	17,205

Table 17. Male biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2011) and autumn (1996 – 2010) research bottom trawl survey data.

Spring

Please note that during 2006, it was not possible to sample all allocated stations within 3NO; however, all stations within 3L were sampled that year. The 2006 estimates are for Div. 3L only since at least 90% of the biomass and abundance is found within that division.

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	13,662	29,600	49,142	4,635	8,816	14,065
2000	25,915	47,219	74,171	8,940	14,896	21,636
2001	27,737	50,340	74,856	8,665	15,172	22,562
2002	47,763	79,739	130,280	14,266	22,659	35,178
2003	58,978	91,719	128,367	16,632	26,667	39,467
2004	19,240	52,052	103,197	5,293	12,390	22,864
2005	33,154	52,958	73,043	9,668	14,909	20,498
2006	43,816	76,517	104,607	12,978	21,135	28,684
2007	71,302	112,661	156,960	20,005	31,548	43,141
2008	69,026	95,243	119,709	21,314	29,296	37,141
2009	30,234	53,864	76,960	8,951	16,148	23,609
2010	36,587	65,341	95,968	10,642	17,632	25,150
2011	19,794	37,050	58,102	6,382	10,710	15,183

Autumn

It was not possible to sample all of the Div. 3L stations during 2004 therefore there are not estimates for autumn 2004.

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	14,881	19,029	26,751	4,704	5,947	8,438
1997	19,079	24,969	34,553	5,676	7,246	10,044
1998	31,664	42,789	55,847	10,078	12,933	16,542
1999	25,341	33,426	42,960	7,965	10,065	12,676
2000	54,246	75,007	96,905	16,803	23,813	31,191
2001	101,787	153,034	188,372	30,446	43,890	53,290
2002	82,970	123,132	150,819	24,032	35,117	42,950
2003	80,403	108,936	139,140	21,948	29,051	36,396
2004						
2005	100,881	128,770	152,430	26,368	34,167	40,785
2006	101,888	133,703	156,054	27,878	37,651	45,296
2007	111,553	148,704	190,487	30,436	41,351	52,706
2008	107,929	145,080	186,862	29,922	40,958	52,223
2009	44,782	71,583	93,018	14,790	23,473	29,368
2010	27,858	39,165	50,602	8,978	12,720	16,401

Table 18. Female biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2011) and autumn (1996 – 2010) research bottom trawl survey data.

Spring

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	11,689	20,136	29,751	1,527	2,673	3,983
2000	28,734	50,642	79,356	3,747	6,606	10,199
2001	23,287	32,721	44,168	3,253	4,680	6,404
2002	38,993	54,971	80,685	6,251	8,816	12,978
2003	58,747	74,906	101,989	9,158	12,564	16,169
2004	21,384	42,084	67,778	2,951	5,731	9,156
2005	51,347	81,349	112,560	6,724	10,818	15,193
2006	59,552	101,888	144,375	7,744	13,182	18,525
2007	111,654	177,902	242,739	14,468	23,126	31,765
2008	92,545	129,474	161,591	12,223	17,014	21,082
2009	30,506	59,401	98,153	4,421	8,465	13,692
2010	41,490	66,247	90,773	5,719	8,992	12,283
2011	16,028	32,822	57,025	2,188	4,375	7,661

Please note that during 2006, it was not possible to sample all allocated stations within 3NO; however, all stations within 3L were sampled that year. The 2006 estimates are for Div. 3L only since at least 90% of the biomass and abundance is found within that division.

Autumn

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	4,431	5,839	10,370	522	665	1,167
1997	13,129	19,331	28,633	1,813	2,738	4,059
1998	14,770	18,324	24,354	1,774	2,148	2,863
1999	17,679	21,848	31,040	2,462	3,020	4,201
2000	24,506	32,822	46,565	3,251	4,278	5,965
2001	42,276	63,932	86,444	5,683	8,193	10,994
2002	49,887	69,973	94,438	6,848	9,661	13,119
2003	60,267	83,363	112,258	7,946	10,888	14,538
2004						
2005	70,265	95,445	122,528	8,393	11,223	14,438
2006	63,247	83,162	108,634	7,355	9,703	12,766
2007	94,710	128,870	169,646	11,971	15,888	20,790
2008	77,242	105,915	139,442	9,284	12,656	16,874
2009	32,550	47,722	66,499	4,243	6,214	8,594
2010	25,774	35,943	48,810	3,235	4,458	6,038

It was not possible to sample all of the Div. 3L stations during 2004 therefore there are not estimates for autumn 2004

Table 19. Fishable biomass (t) indices (total weight of all males + females with carapace lengths => 17.5 mm) as determined using ogmap calculations from spring and autumn Canadian multi-species bottom trawl survey data, 1996 – 2011. All indices were estimated using Ogmap calculations. Please note that the autumn 2004 survey did not occupy important strata within the shrimp resource therefore no estimations were made for that year. 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.

Spring

Year	Biomass (tons)			Abundance (numbers x 10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	20,488	40,876	64,647	3,473	7,103	11,538
2000	41,762	80,544	132,596	7,044	13,921	22,804
2001	43,423	67,355	94,951	7,978	12,884	18,747
2002	73,597	113,668	175,989	14,166	22,323	35,168
2003	111,151	155,450	202,467	20,428	29,220	38,510
2004	34,755	82,759	152,027	6,186	15,094	28,643
2005	73,124	116,587	162,800	12,011	19,072	26,771
2006	94,277	161,692	222,805	14,911	26,121	36,728
2007	160,484	264,990	352,682	26,529	40,625	54,246
2008	171,055	187,970	235,893	23,328	30,949	39,326
2009	55,132	100,579	155,047	9,801	17,501	26,026
2010	66,258	113,366	160,182	11,196	19,677	28,009
2011	26,429	56,280	96,331	4,583	9,807	16,904

Autumn

Year	Biomass (tons)			Abundance (numbers x 10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	12,192	14,297	22,381	2,331	2,777	4,257
1997	23,660	34,433	49,605	4,603	6,488	9,532
1998	34,896	47,219	62,230	6,713	9,253	12,142
1999	33,506	42,487	58,183	5,656	7,325	9,965
2000	63,086	80,443	107,526	12,676	16,332	21,908
2001	124,541	175,083	219,281	25,130	35,359	43,574
2002	111,755	159,880	200,051	21,515	31,249	39,205
2003	125,145	169,746	220,489	22,844	30,866	39,779
2004						
2005	143,670	179,915	215,959	25,472	31,528	37,292
2006	138,334	173,774	206,293	24,163	30,386	35,369
2007	183,439	239,719	306,973	31,100	39,905	51,025
2008	160,081	206,394	255,224	28,855	36,731	45,487
2009	63,741	95,042	124,440	11,306	17,247	22,613
2010	42,427	57,891	74,413	7,122	9,549	12,122

Table 20. Recruitment indices as determined from modal analysis of population adjusted northern shrimp length frequencies from spring (1999 – 2011) and autumn (1996 – 2010) Canadian multi-species bottom trawl surveys. All indices were estimated using Ogmap calculations and then modal analysis using Mix 3.01.

Age 2 from modal analysis. The cohort year is year – 2.

Survey Year	Recruitment indices (10^6)		Cohort Year
	Spring	Autumn	
1996		3,765	1994
1997		3,057	1995
1998		2,735	1996
1999	3,377	5,488	1997
2000	5,251	8,135	1998
2001	3,034	8,071	1999
2002	2,274	4,665	2000
2003	3,496	5,163	2001
2004	1,597		2002
2005	2,415	3,303	2003
2006	6,331	11,415	2004
2007	6,638	9,870	2005
2008	4,093	7,921	2006
2009	1,763	9,003	2007
2010	797	2,944	2008
2011	1,065		2009

Table 21. Recruitment indices derived from the abundances of males and females with 12 – 17 mm carapace lfs using Ogmap calculations of spring (1999 – 2011) and autumn (1996 – 2010) Canadian research survey data.

Spring

Year	12 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1999	2,028	4,069	6,571
2000	4,251	7,000	9,611
2001	3,741	6,559	9,922
2002	4,982	8,214	13,169
2003	4,535	9,184	16,401
2004	1,771	2,812	4,090
2005	3,983	6,328	8,922
2006	5,599	8,567	12,263
2007	7,721	13,442	18,998
2008	9,675	14,555	19,230
2009	2,801	6,098	10,078
2010	4,336	6,856	9,716
2011	3,301	5,061	6,750

Autumn

Year	12 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1996	2,717	3,537	5,085
1997	2,440	3,020	4,097
1998	2,166	2,975	3,971
1999	3,997	5,313	6,522
2000	6,707	10,348	13,793
2001	11,659	16,041	18,857
2002	8,530	12,350	15,152
2003	5,739	7,746	9,925
2004			
2005	9,099	12,588	16,250
2006	10,098	14,730	18,787
2007	10,934	16,138	21,535
2008	9,717	14,787	19,955
2009	6,804	11,293	13,914
2010	4,508	6,759	8,877

Table 22. Exploitation rate indices for NAFO Divisions 3LNO northern shrimp as determined using Canadian autumn survey and total catch over the period 1997 – 2011. Ogmap methods were used in determining resource indices. The fishery was still ongoing at the time of this analysis therefore it is expected that the 2011 exploitation rate index will be higher once all of the catch has been updated at the end of the calendar year.

Year	Catch (t)	Lower 95% CL of biomass index (t)	Spawning Stock biomass (SSB) (t)	Fishable biomass (t)
1996	179	20,287	5,839	14,297
1997	485	32,630	19,331	34,433
1998	626	48,649	18,324	47,219
1999	795	43,453	21,848	42,487
2000	4,711	84,561	32,822	80,443
2001	10,684	156,356	63,932	175,083
2002	6,967	136,421	69,973	159,880
2003	13,069	144,979	83,363	169,746
2004	13,452			
2005	14,389	178,707	95,445	179,915
2006	25,831	174,076	83,162	173,774
2007	23,859	216,059	128,870	239,719
2008	27,691	197,131	105,915	206,394
2009	28,544	80,020	47,722	95,042
2010	20,612	56,572	35,943	57,891
2011	11,434			

Year	Catch / lower CL biomass	Catch/SSB	Catch/fishable biomass
1997	0.024	0.083	0.034
1998	0.019	0.032	0.018
1999	0.016	0.043	0.017
2000	0.108	0.216	0.111
2001	0.126	0.326	0.133
2002	0.045	0.109	0.040
2003	0.096	0.187	0.082
2004	0.093	0.161	0.079
2005			
2006	0.145	0.271	0.144
2007	0.137	0.287	0.137
2008	0.128	0.215	0.116
2009	0.145	0.269	0.138
2010	0.258	0.432	0.217
2011	0.202	0.318	0.198

Table 23. 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 errors in ageing by modal analysis. The survival, S, in the light green box is the age 4 + males and total female abundance shaded orange divided by the sum of the age 3 + males and total female shrimp shaded blue. Median survival, annual mortality and instantaneous mortality rates were 0.79, 0.21 and 0.24 respectively. All data were obtained from the Canadian autumn bottom trawl survey (1996 – 2010).

Year	Age 3+males and total female abundance (millions; year = t)	Age 4+males and total female abundance (millions; year = t)	Survival rate = Total age 4 males + female abundance $_{(t+1)}$/ age 3+ males + female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1996	2,410	1,041			
1997	6,365	3,983			
1998	9,313	4,985	0.80	0.20	0.22
1999	7,091	5,578	0.80	0.20	0.23
2000	18,518	7,569	1.23	-0.23	-0.21
2001	43,285	29,797	0.87	0.13	0.14
2002	38,863	22,429	0.78	0.22	0.25
2003	33,369	26,209			
2004					
2005	40,714	18,994			
2006	33,651	27,573			
2007	45,806	29,271	0.69	0.31	0.37
2008	43,524	25,908	0.57	0.43	0.56
2009	20,013	15,269	0.45	0.55	0.80
2010	13,418	7,907			

Table 24. 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. The survival, S, in the light blue box is the abundance of multiparous females (green box) that survive from the previous year (yellow box). Median survival, annual mortality and instantaneous mortality rates were 0.46, 0.54 and 0.79 respectively. The data were total counts of each maturity stage measured per year divided by the total number of sets for that year in order to standardize the counts per year. Data came from the spring surveys as this is the only time of year for which primiparous and multiparous females can be identified.

Year	All females measured per set	All multiparous females measured per set	Survival rate = Multiparous females measured $_{(t+1)}$/ all females measured $_t$	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1999	67	29			
2000	74	37			
2001	57	30	0.42	0.58	0.86
2002	56	17	0.34	0.66	1.07
2003	49	17	0.31	0.69	1.18
2004	32	16	0.43	0.57	0.84
2005	52	26	0.61	0.39	0.50
2006	59	39	0.68	0.32	0.39
2007	55	32	0.64	0.36	0.45
2008	64	35	0.50	0.50	0.69
2009	43	22	0.48	0.52	0.73
2010	40	21	0.39	0.61	0.93
2011	31	15			

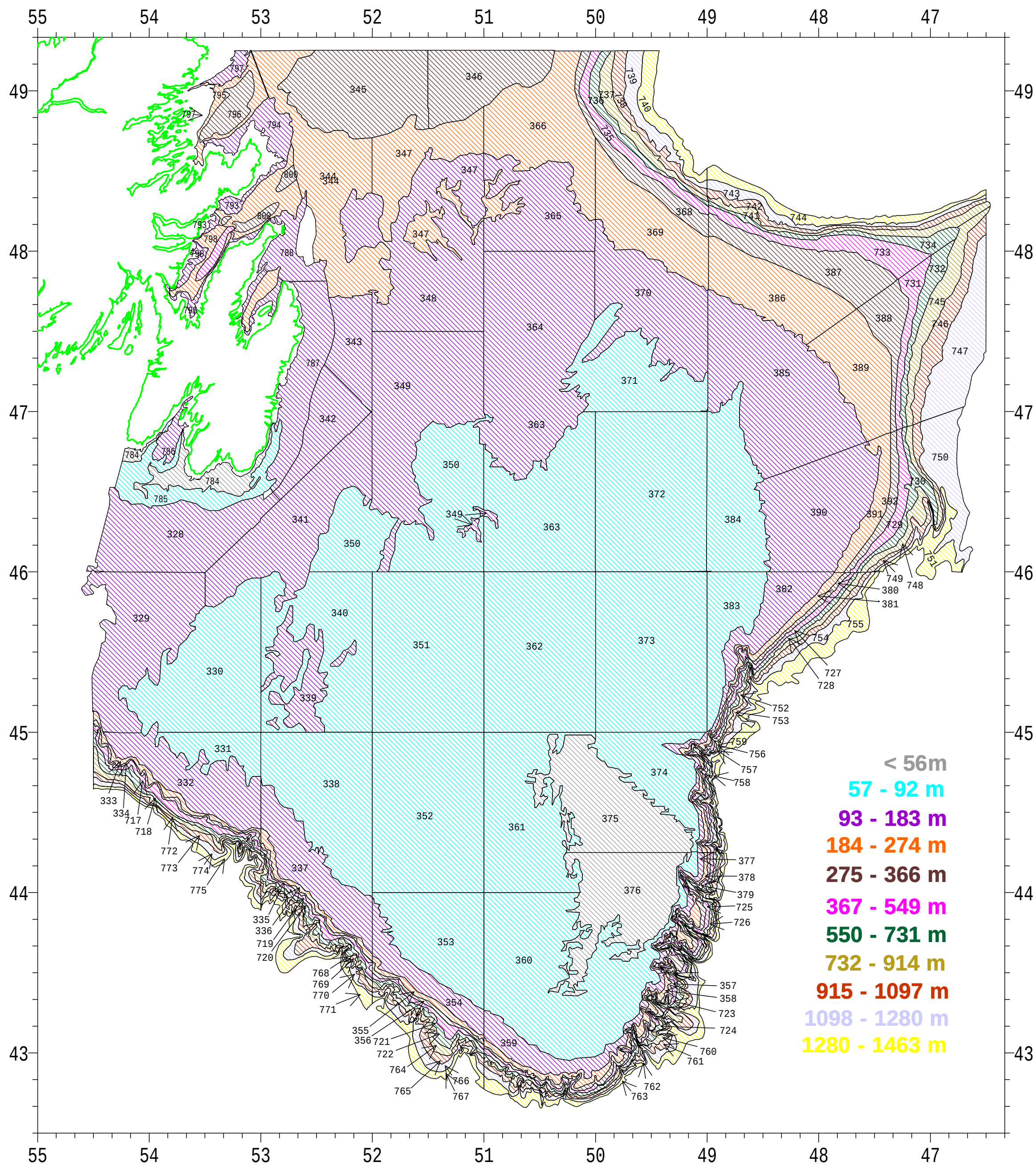


Figure 1. The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species research bottom trawl survey set allocation (G. Cossitt).

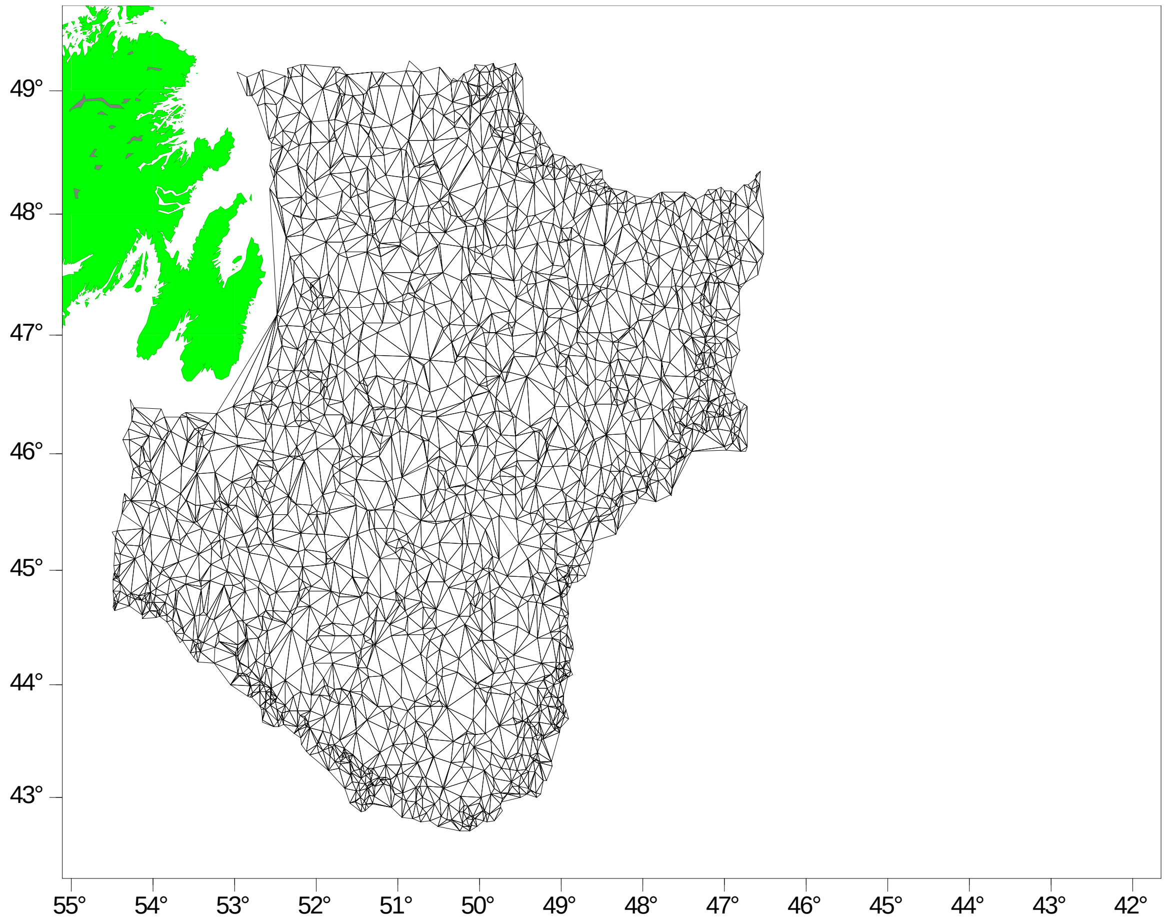


Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Omap.

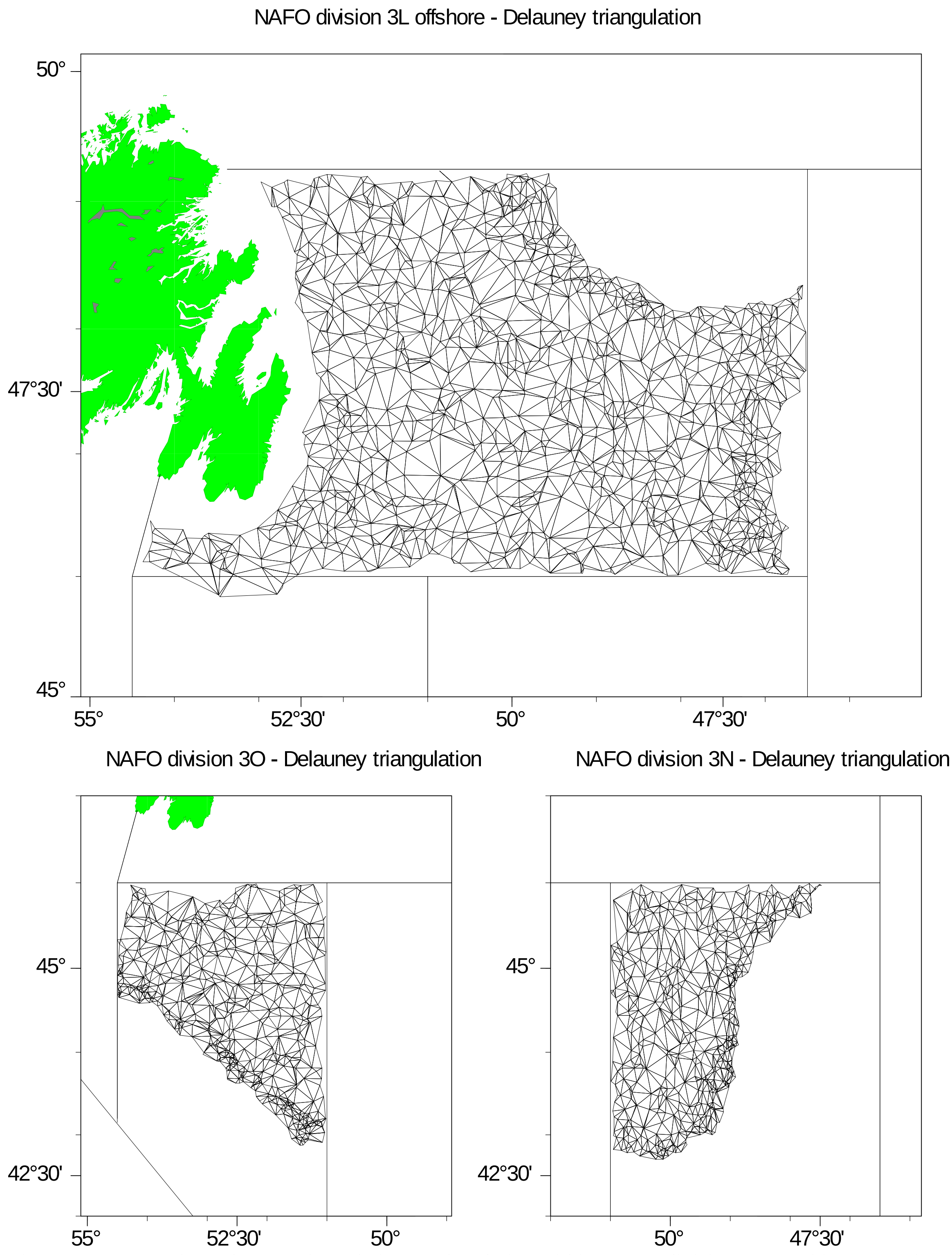


Figure 3. The Delauney triangulation used to derive within NAFO division Ogmap biomass and abundance indices.

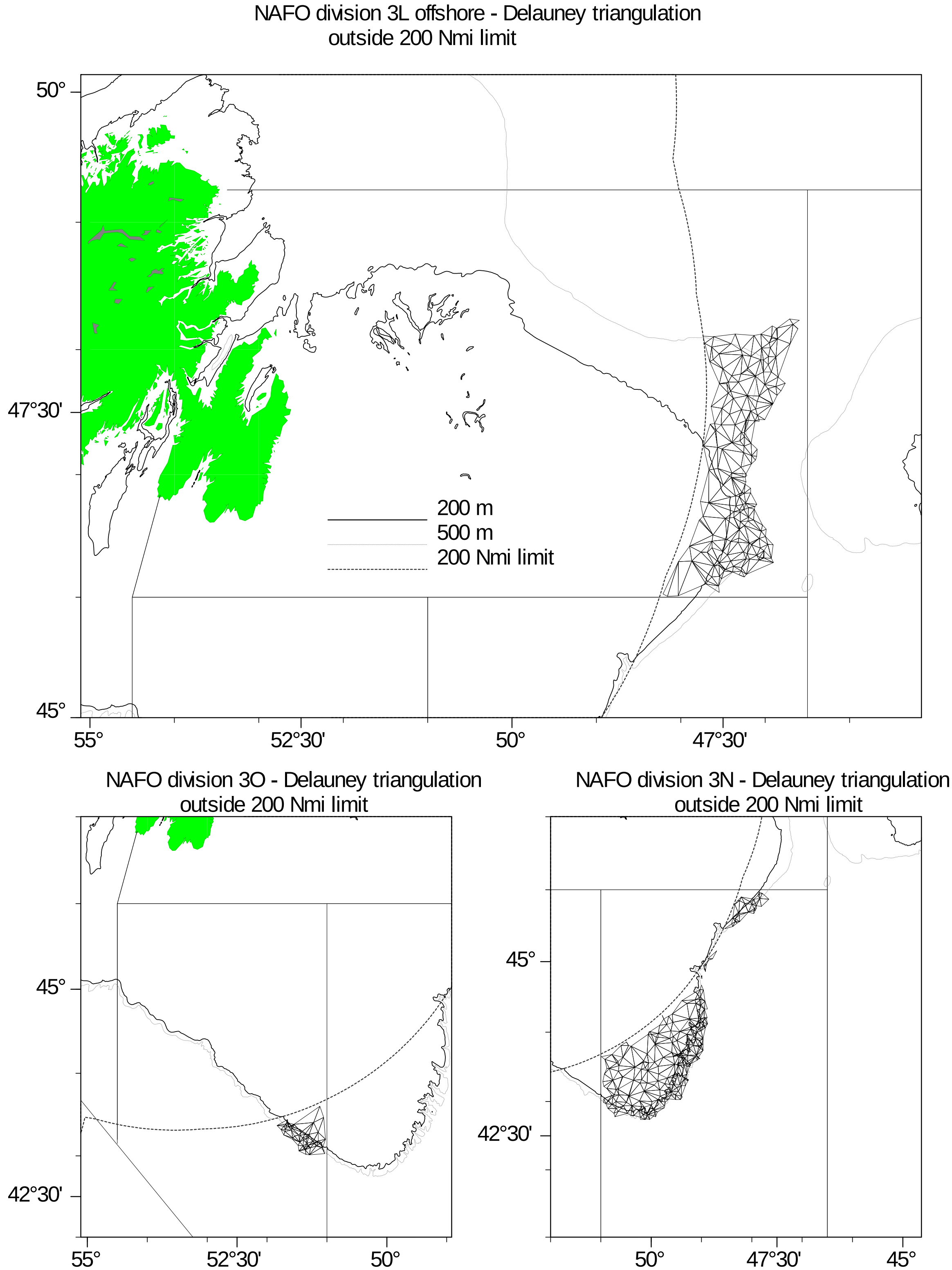


Figure 4. The Delauney triangulation used to derive the outside 200 Nmi limit Ogmap biomass and abundance indices.

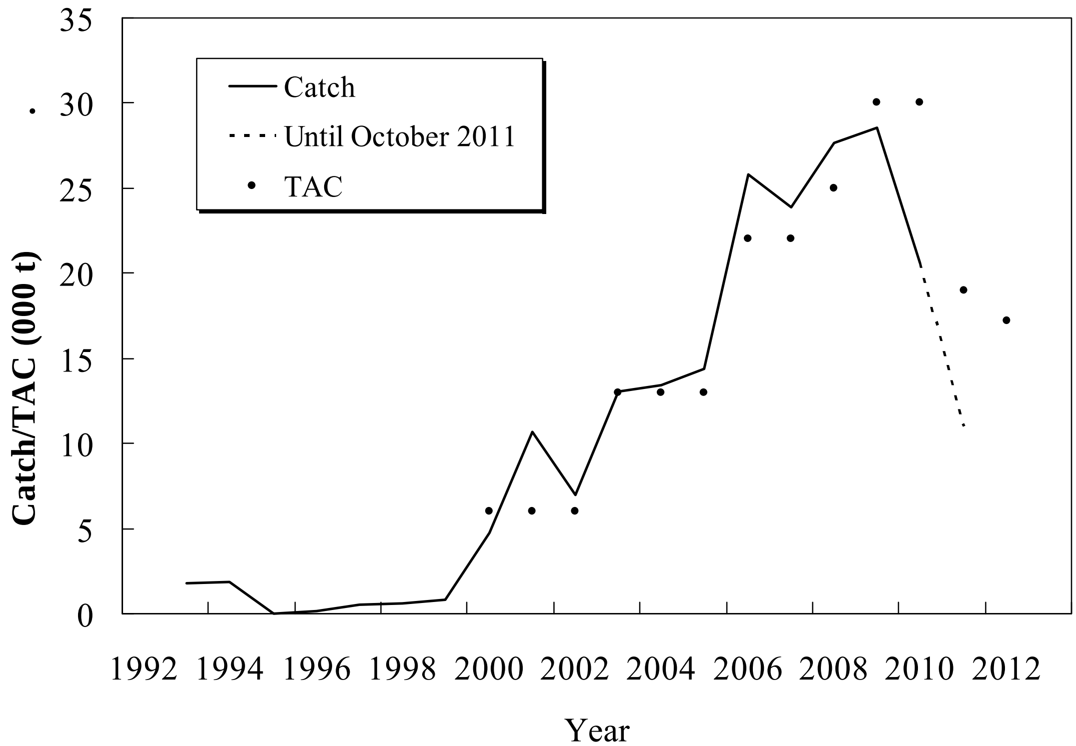


Figure 5. Trends in NAFO Division 3L Northern Shrimp (*Pandalus borealis*) catch and TAC over the period 1993-2011.

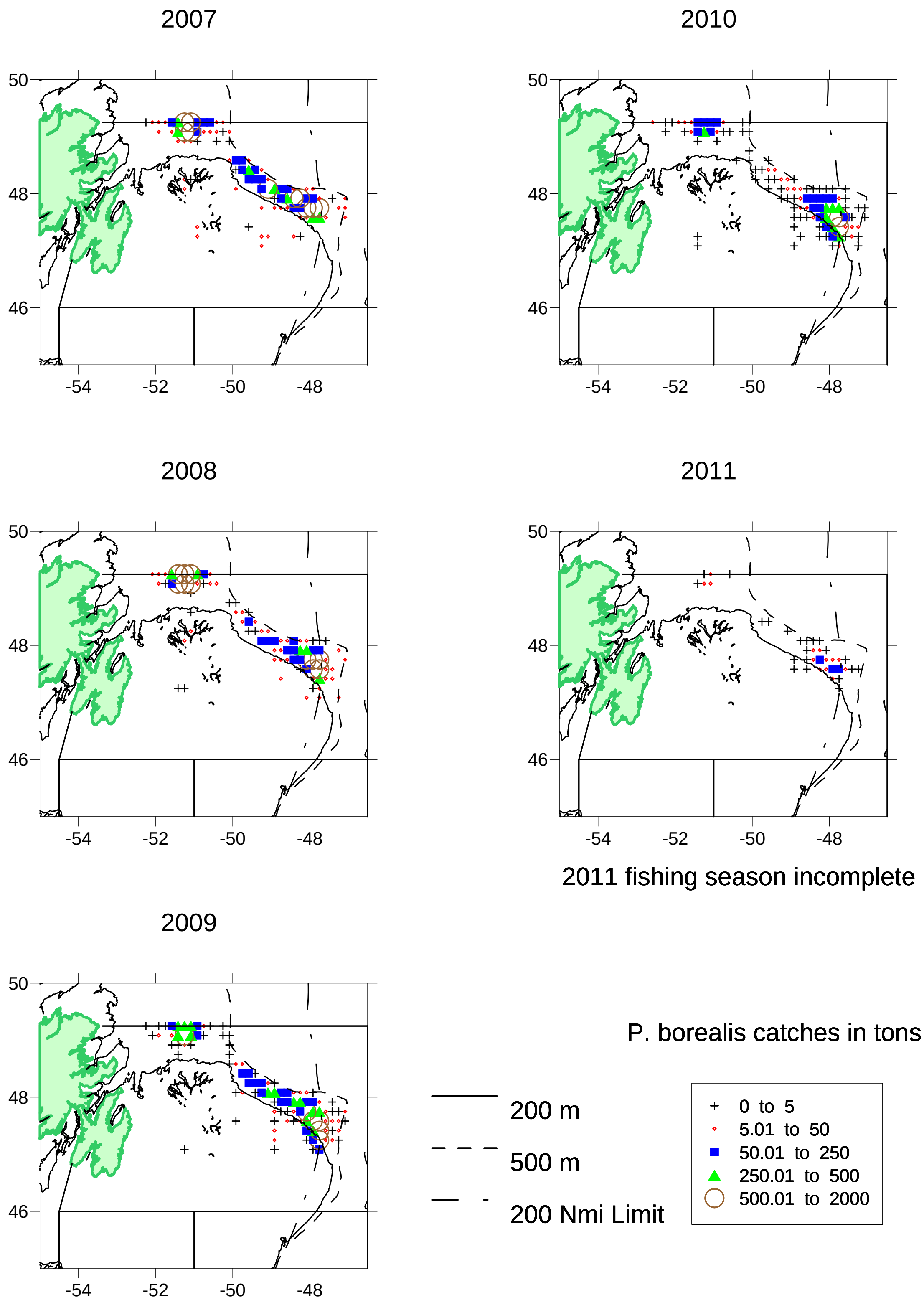


Figure 6. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp catches in NAFO Division 3L, 2007 – 2011. (Logbook data aggregated into 10 min X 10 min cells).

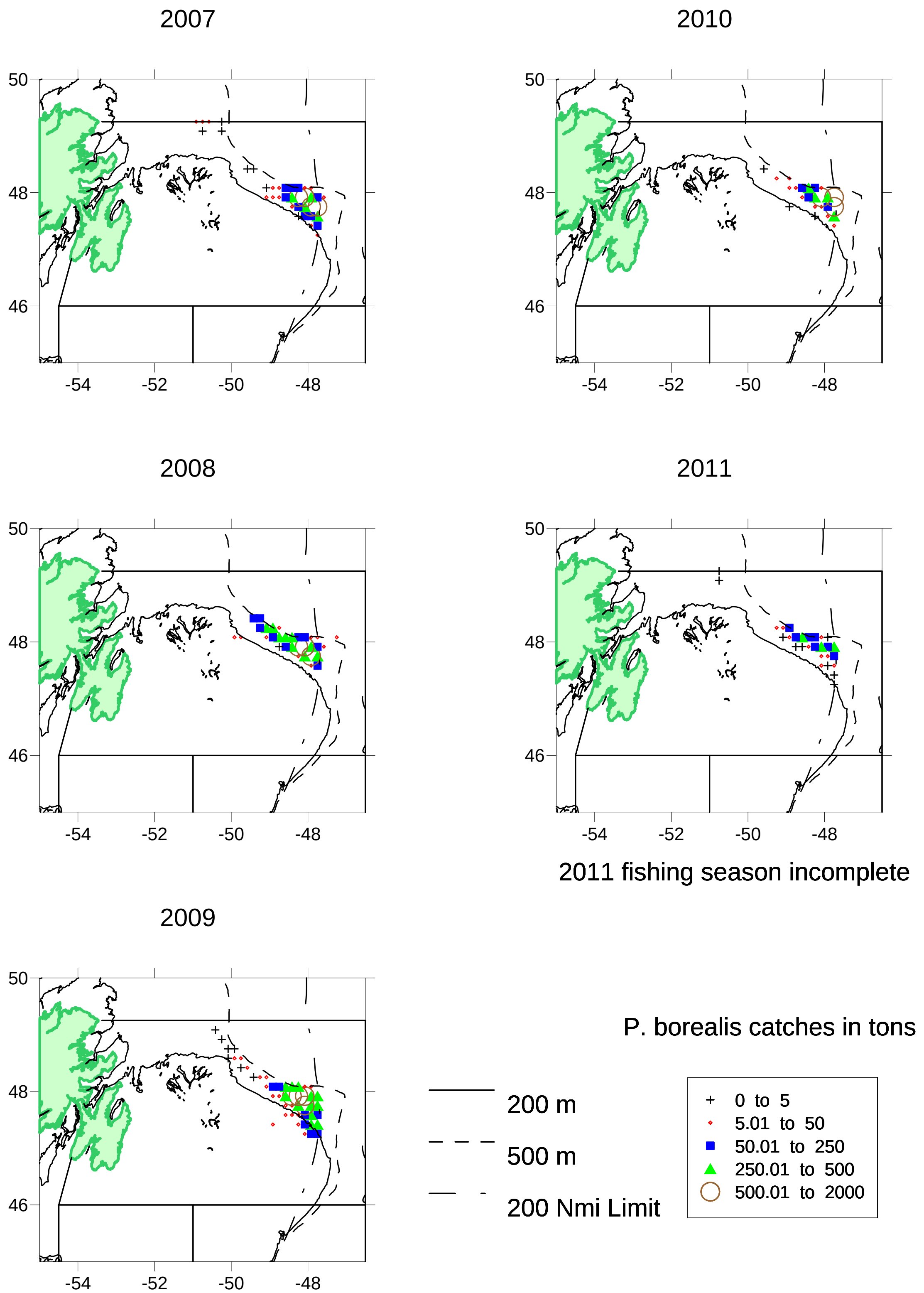


Figure 7. Distribution of **Canadian large vessel (>500 t)** shrimp catches in NAFO Division 3L, 2007 – 2011. (Observer data aggregated into 10 min X 10 min cells).

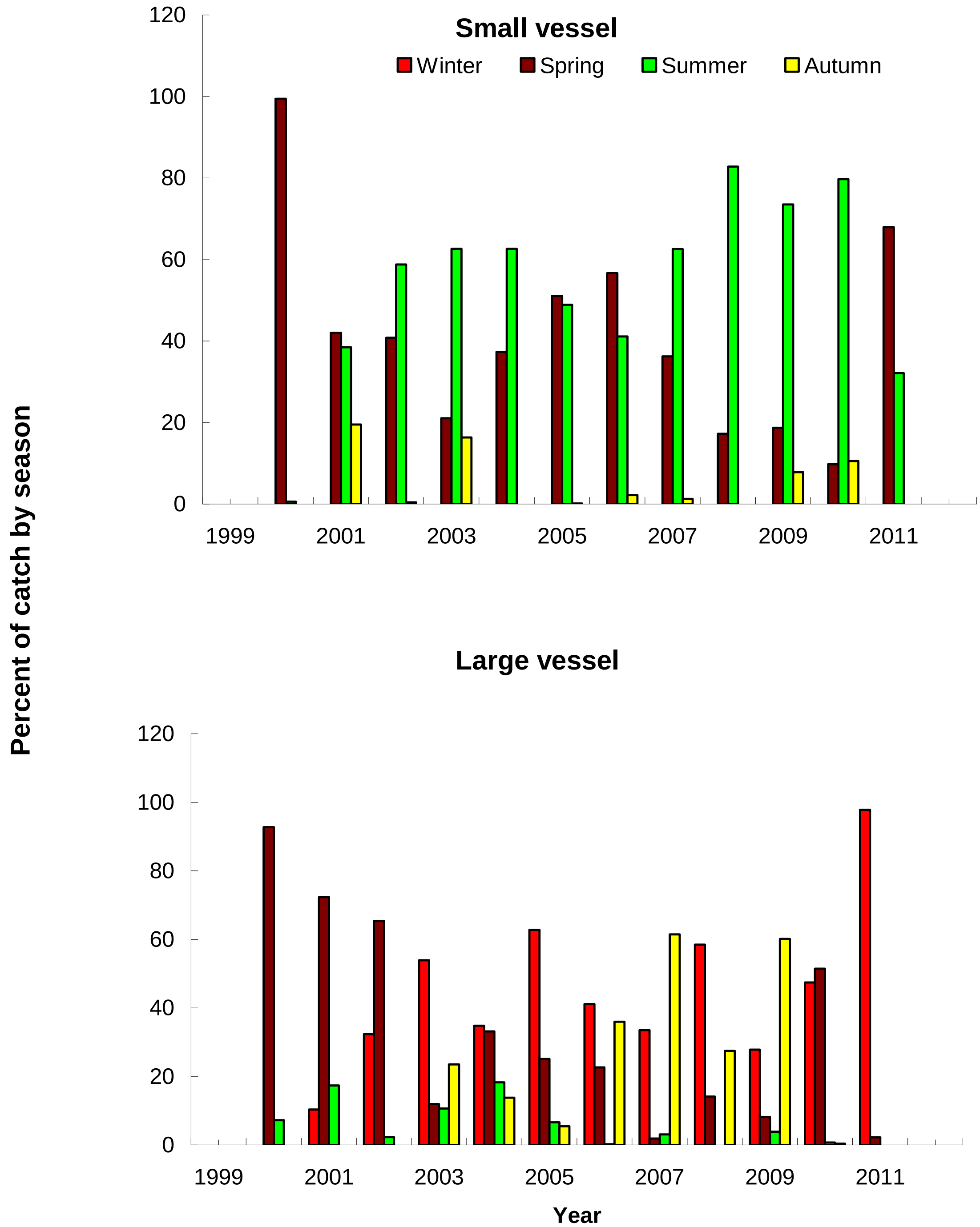


Figure 8. Seasonality of the large and small vessel Northern Shrimp (*Pandalus borealis*) fishery in NAFO Division 3L over the period 2000 – 2011. Please note that the 2011 values are preliminary with data up to the end of September 2011.

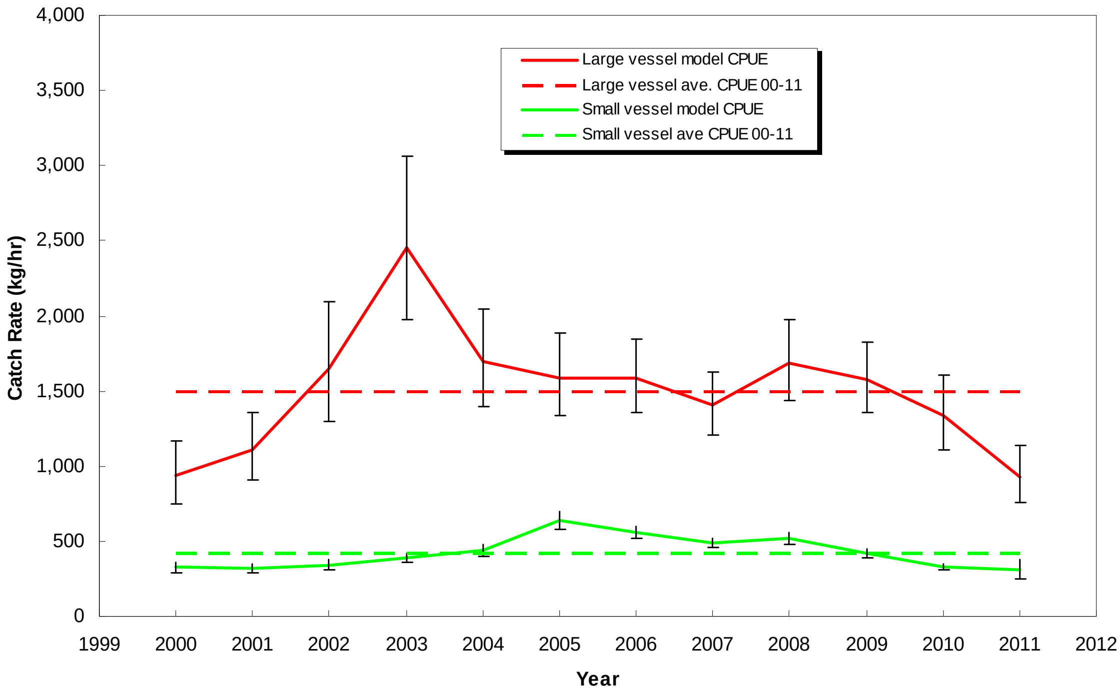


Figure 9. Model catch rates for Canadian large (>500 t) and small (<= 500 t; <65') (2000 – 2009) vessels fishing for shrimp in NAFO Div. 3L over the period 2000 – 2011. Bars represent 95% confidence intervals around model values.

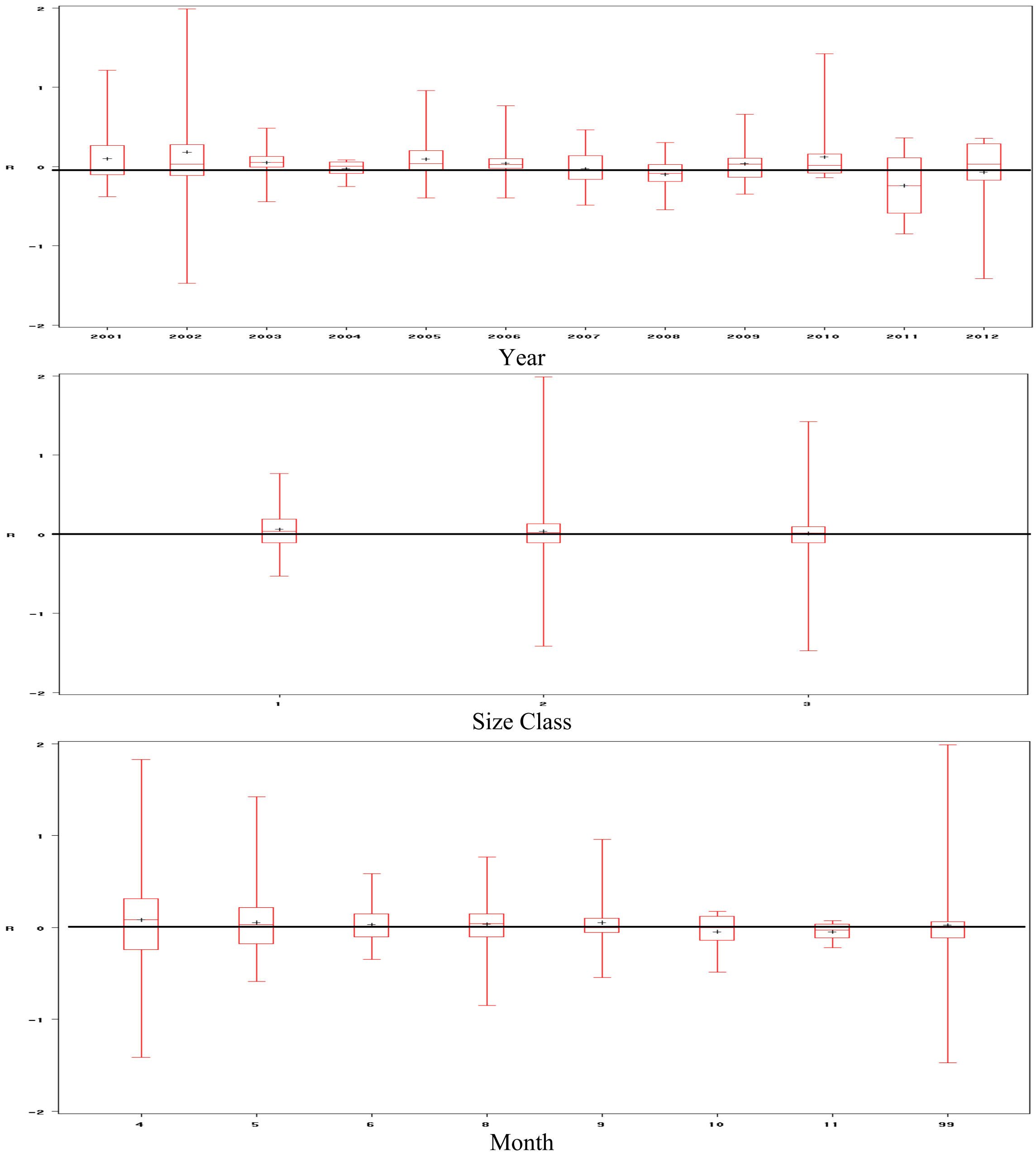


Figure 10. Distribution of residuals around estimated values for parameters used to model **Canadian small vessel** shrimp catch rates, 2000 – 2011.

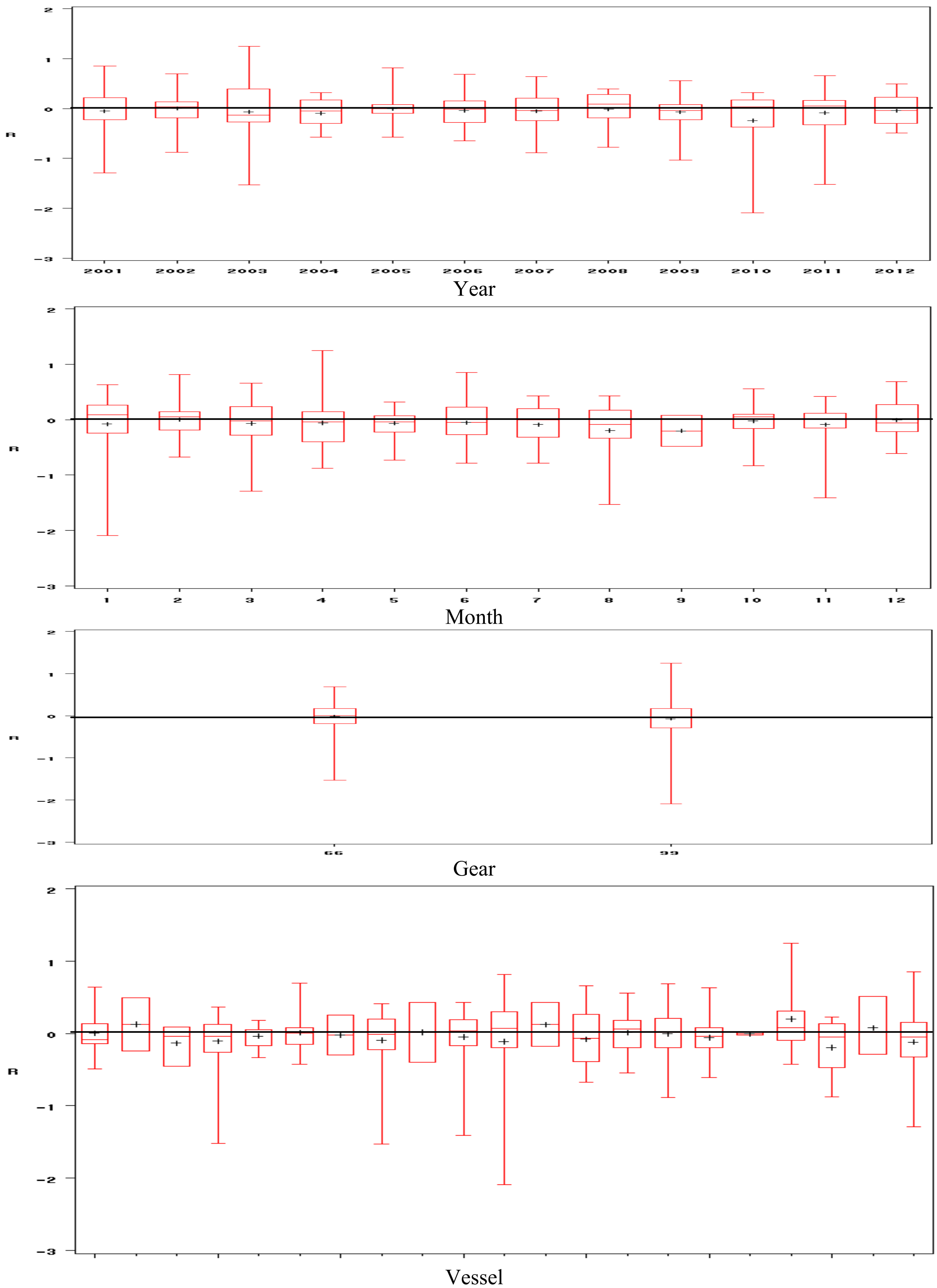


Figure 11. Distribution of residuals around estimated values for parameters used to model **Canadian large vessel** shrimp catch rates, 2000 – 2011.

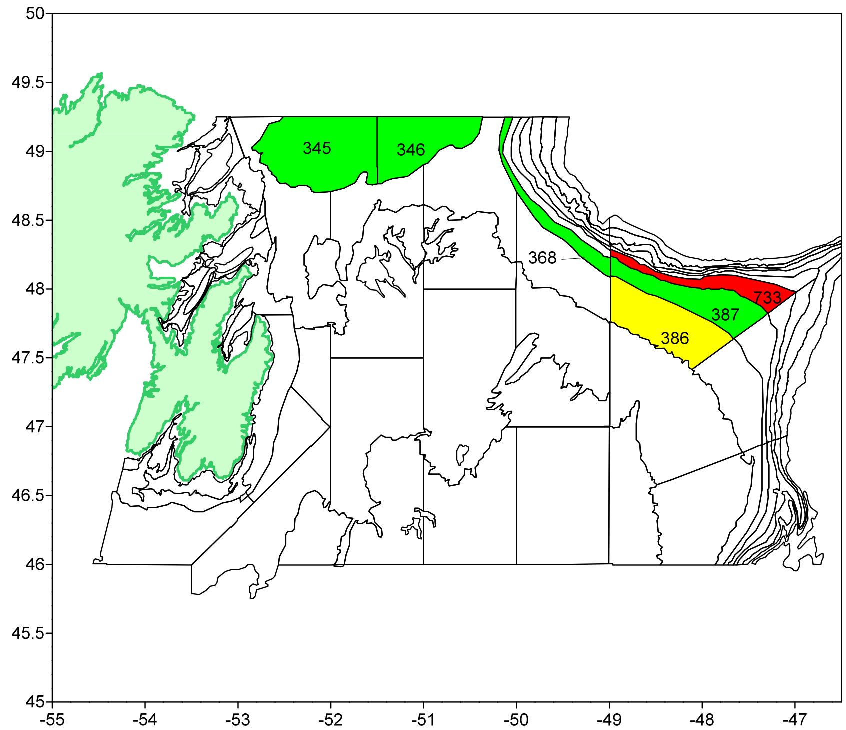


Figure 12. NAFO Divisions 3L index strata consistently fished by the small vessel (<=500 t; <65') shrimp fishing fleet, over the period 2003 – 2010. Numbers indicate the strata designations as per figure 1. Depth zones are as follows:Yellow = 184 – 274 m; Green = 375 – 366 m and Red = 367 – 549 m.

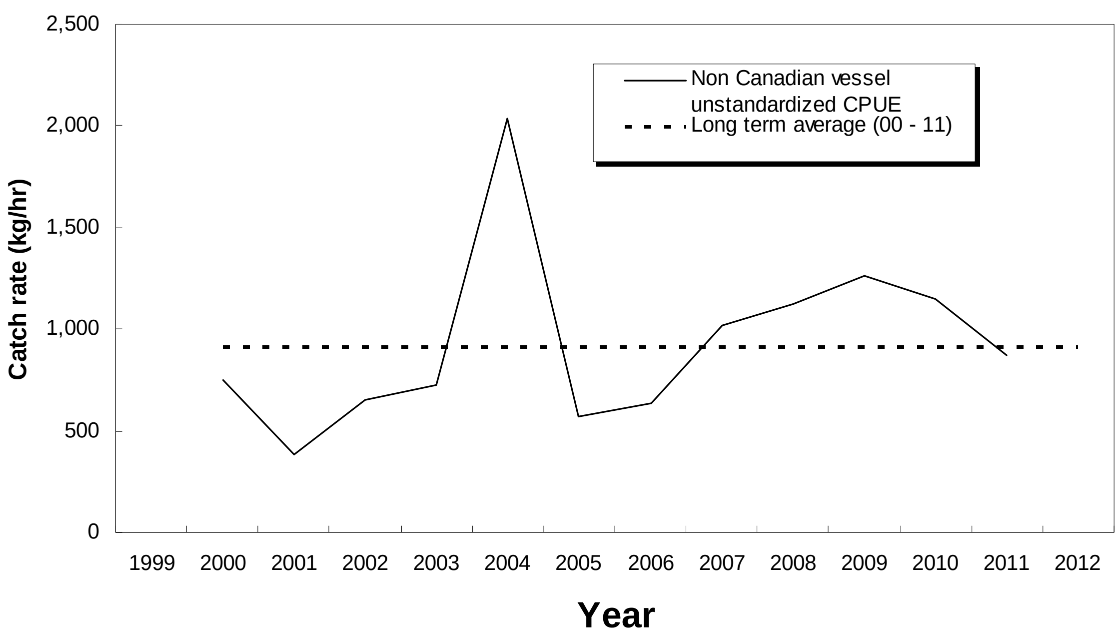


Figure 13. Unstandardized catch rates for non Canadian vessels fishing northern shrimp within the NAFO Division 3L NRA over the period 2000 – 2011. This catch rate series made use of data from Greenland, Iceland, Norway, Spain and Russia.

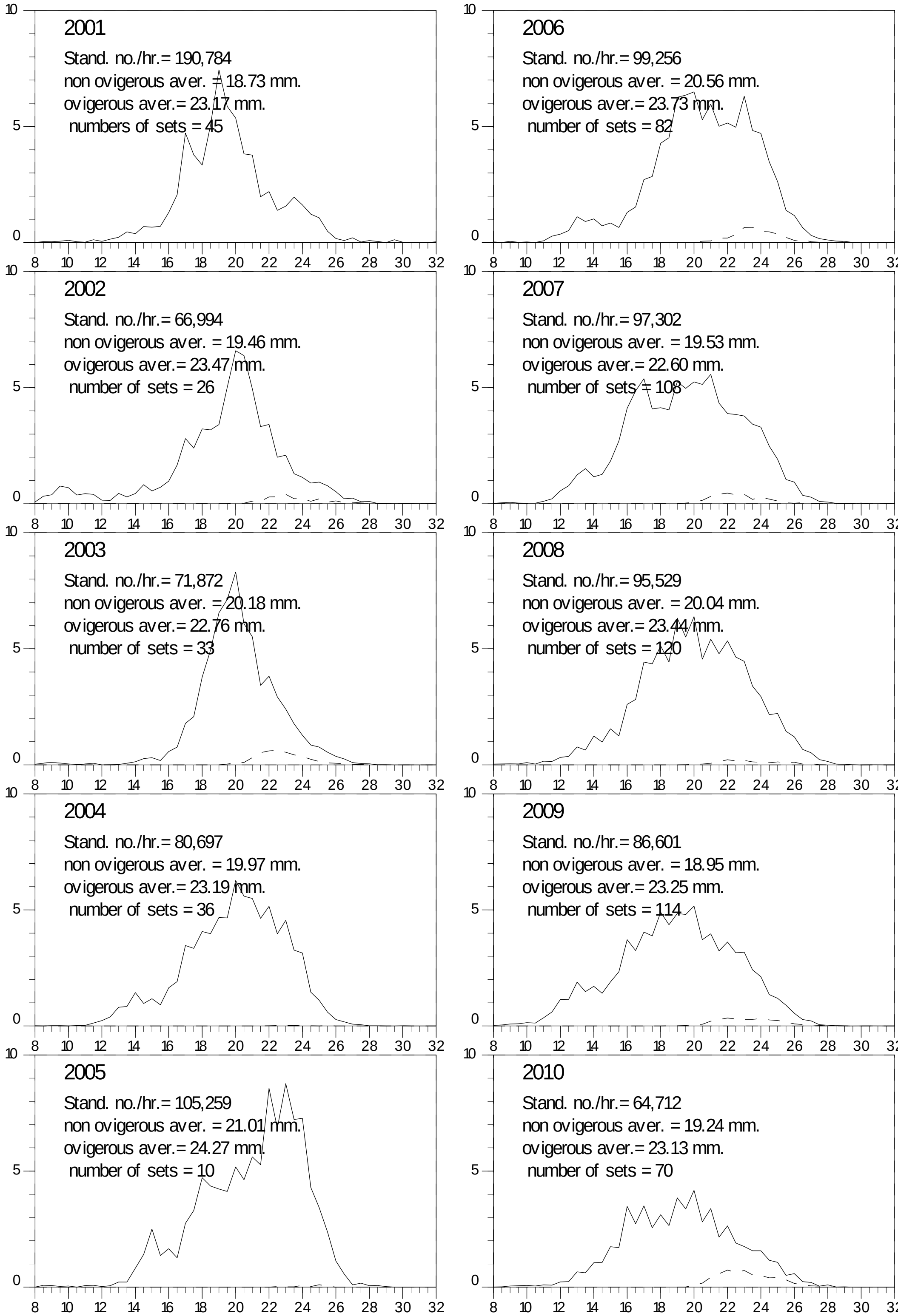


Figure 14. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing in NAFO Div. 3L over the period 2001 – 2010.

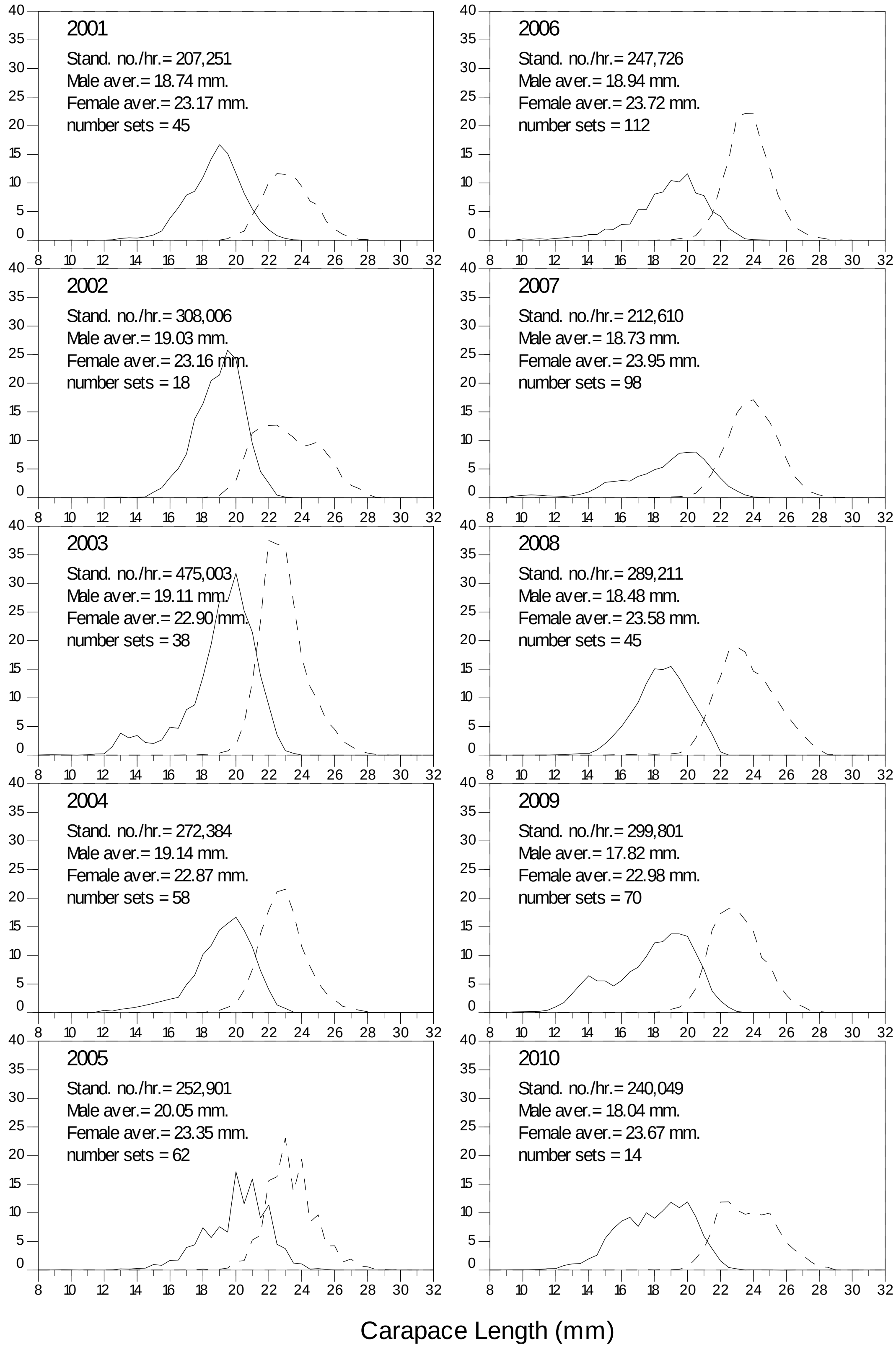


Figure 15. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing in NAFO Div. 3L over the period 2000 – 2010.

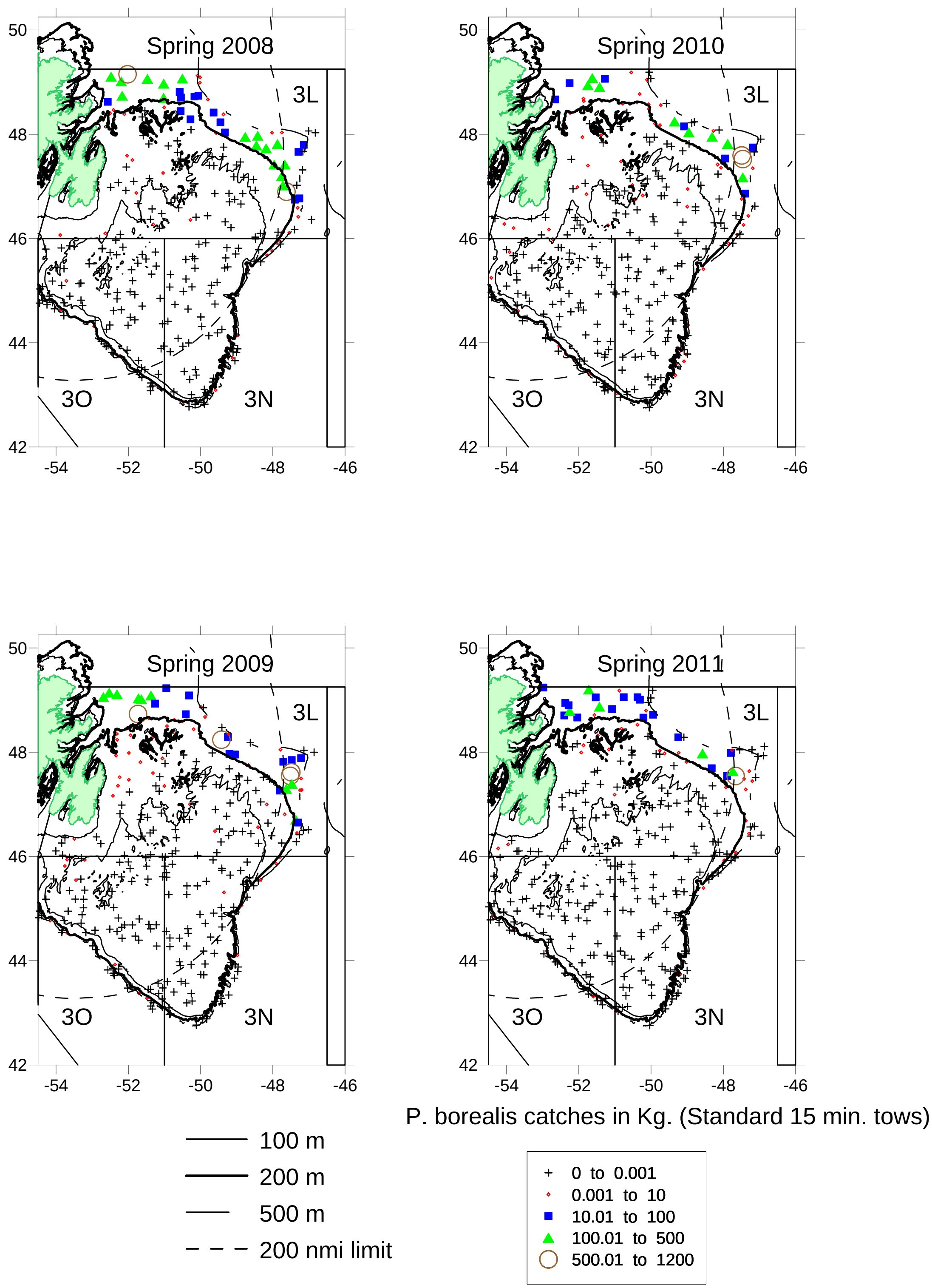


Figure 16. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **spring** Canadian research bottom trawl surveys conducted over the period 2008 – 2011.

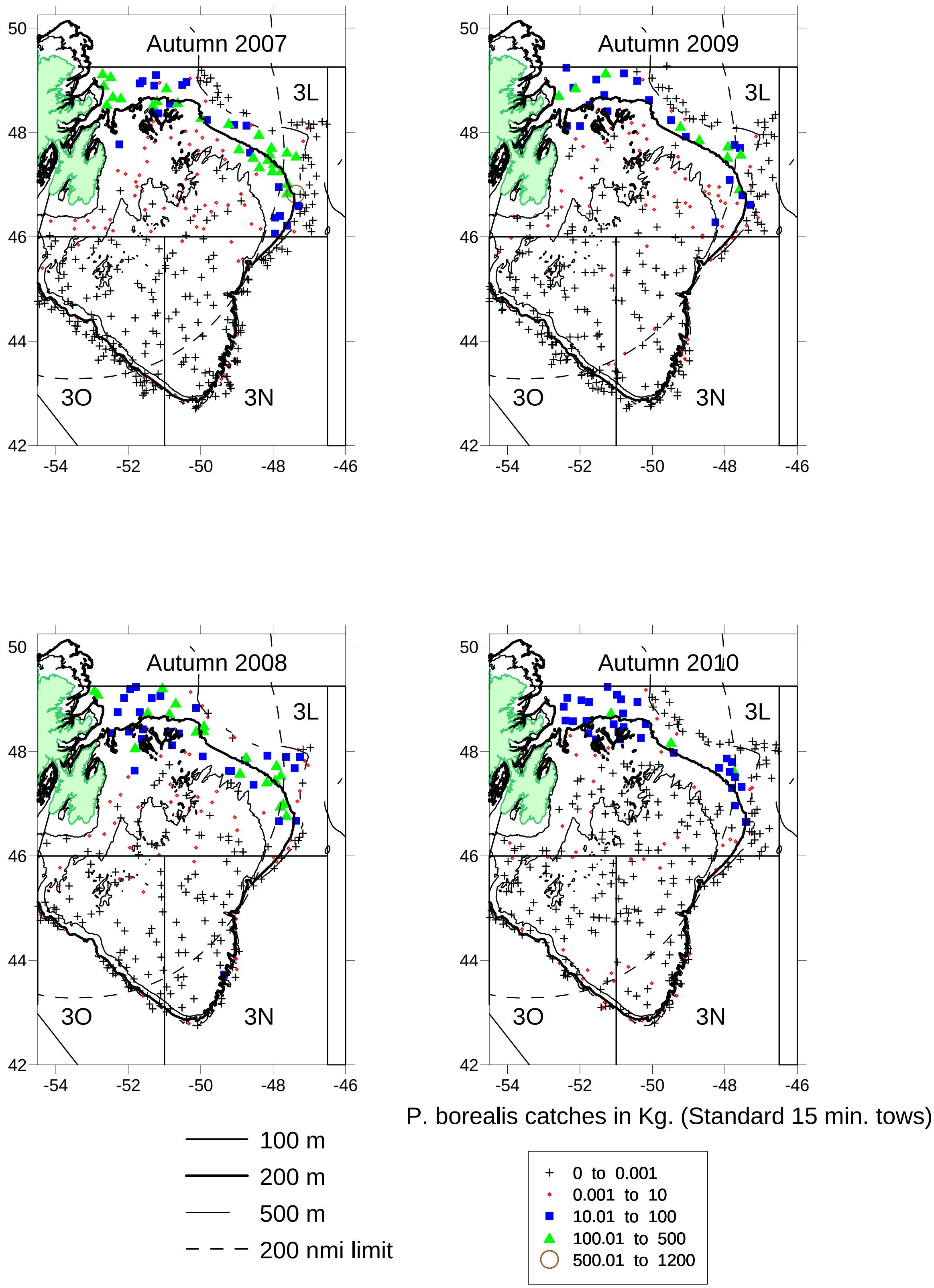
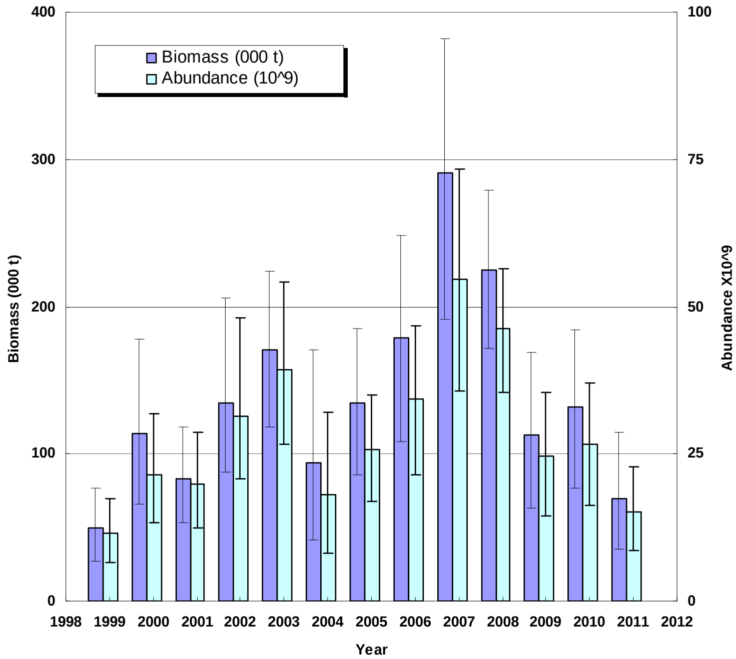


Figure 17. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **autumn** Canadian research bottom trawl surveys conducted over the period 2007 – 2010.

A) **Spring**



B) **Autumn**

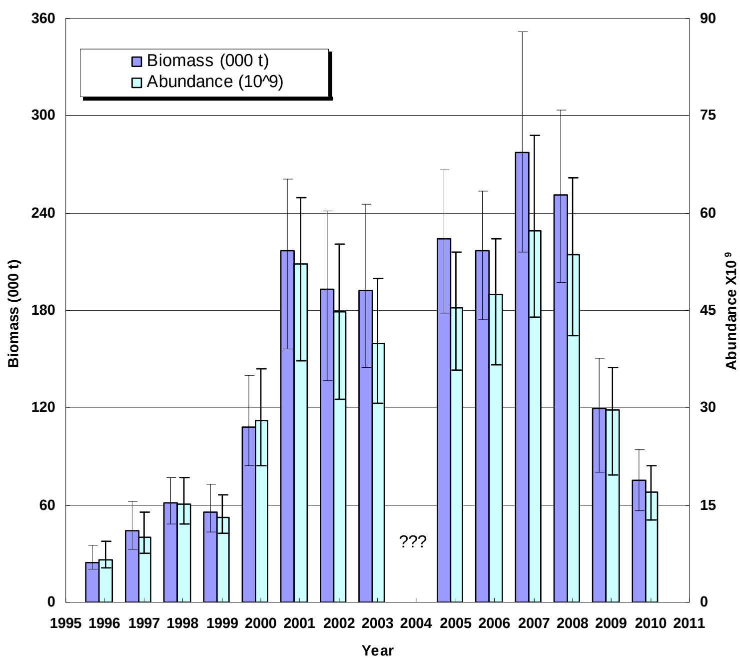


Figure 18. Northern shrimp biomass and abundance indices within NAFO Divisions 3LNO over the period 1996 – 2011. The data are from spring 1999 – 2011 and autumn 1999 – 2010 Canadian multispecies research bottom trawl surveys. (Standard tow 15 min.). Estimates were made using Ogmap calculations and bars represent 95% confidence intervals.

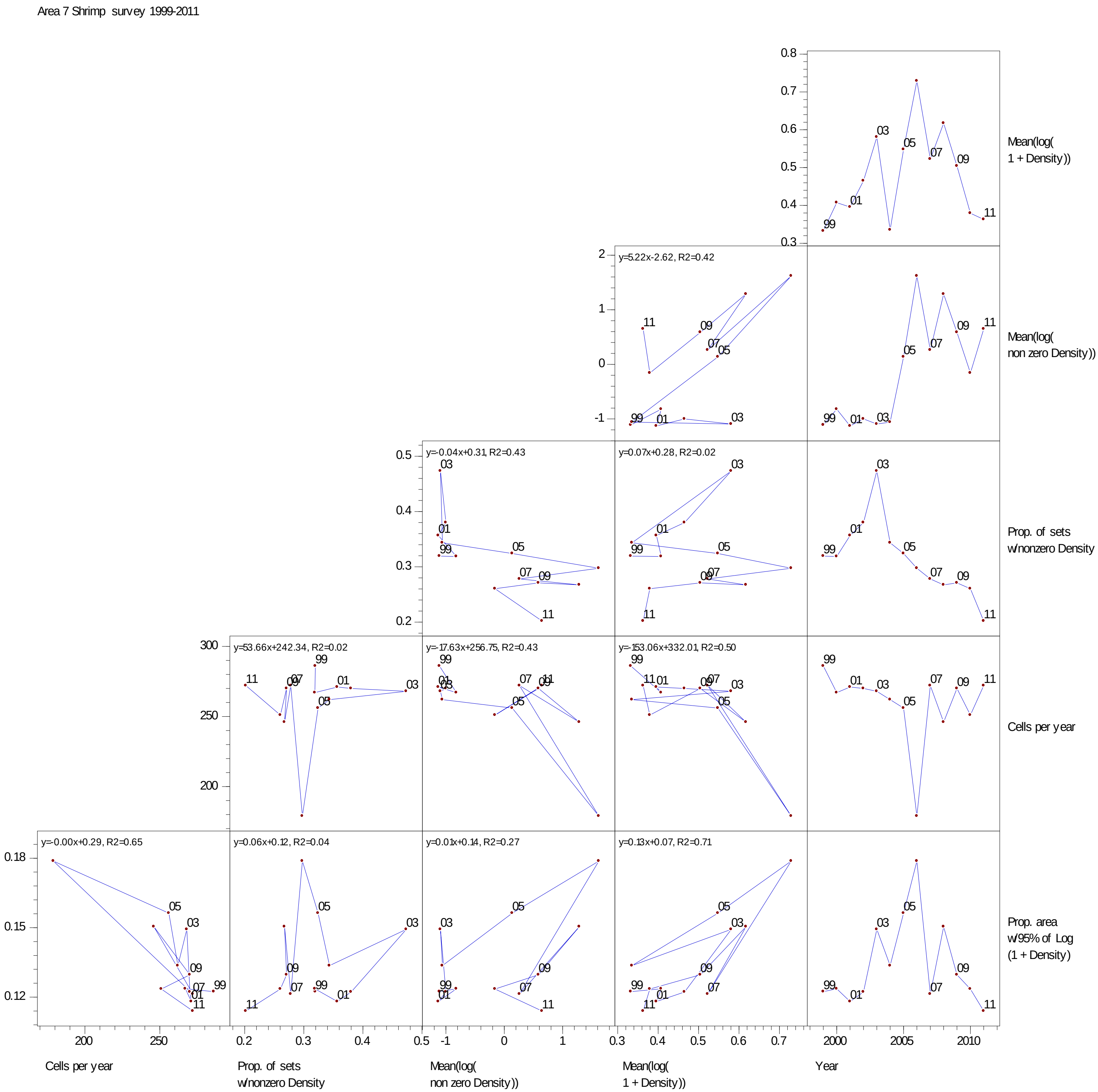


Figure 19. Distributional indices for 3LNO Northern Shrimp as estimated from Canadian spring research survey bottom trawl multi-species survey catches (1999 – 2011). Estimates were calculated using ACON (Black, pers. comm.).

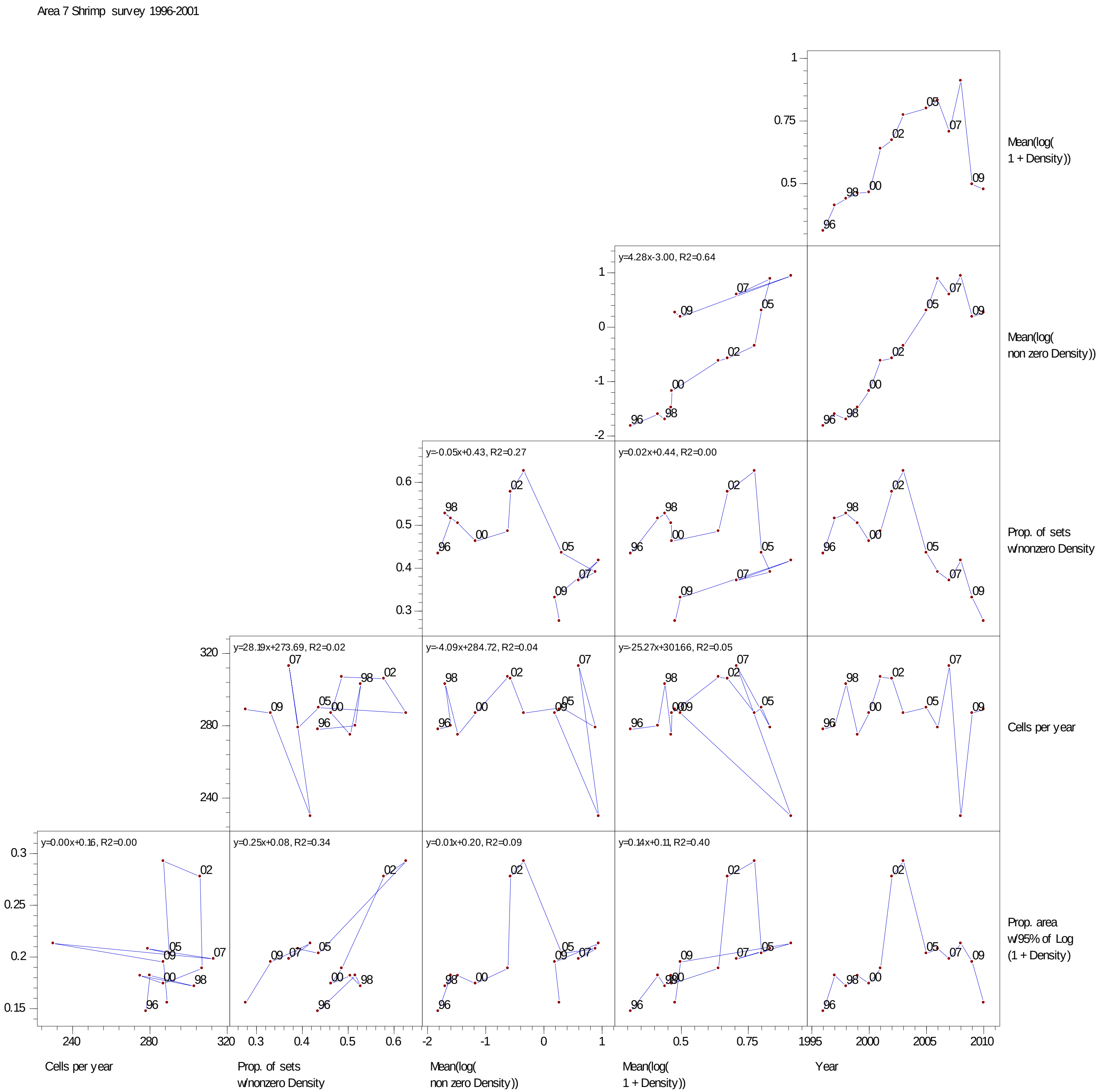


Figure 20. Distributional indices for 3LNO Northern Shrimp as estimated from Canadian autumn research survey bottom trawl multi-species survey catches (1996 – 2010). Estimates were calculated using ACON (Black, pers. comm.). Please note that 2004 was an incomplete survey and is not included in this figure. The line joins the survey points from 2003 directly to 2005 points.

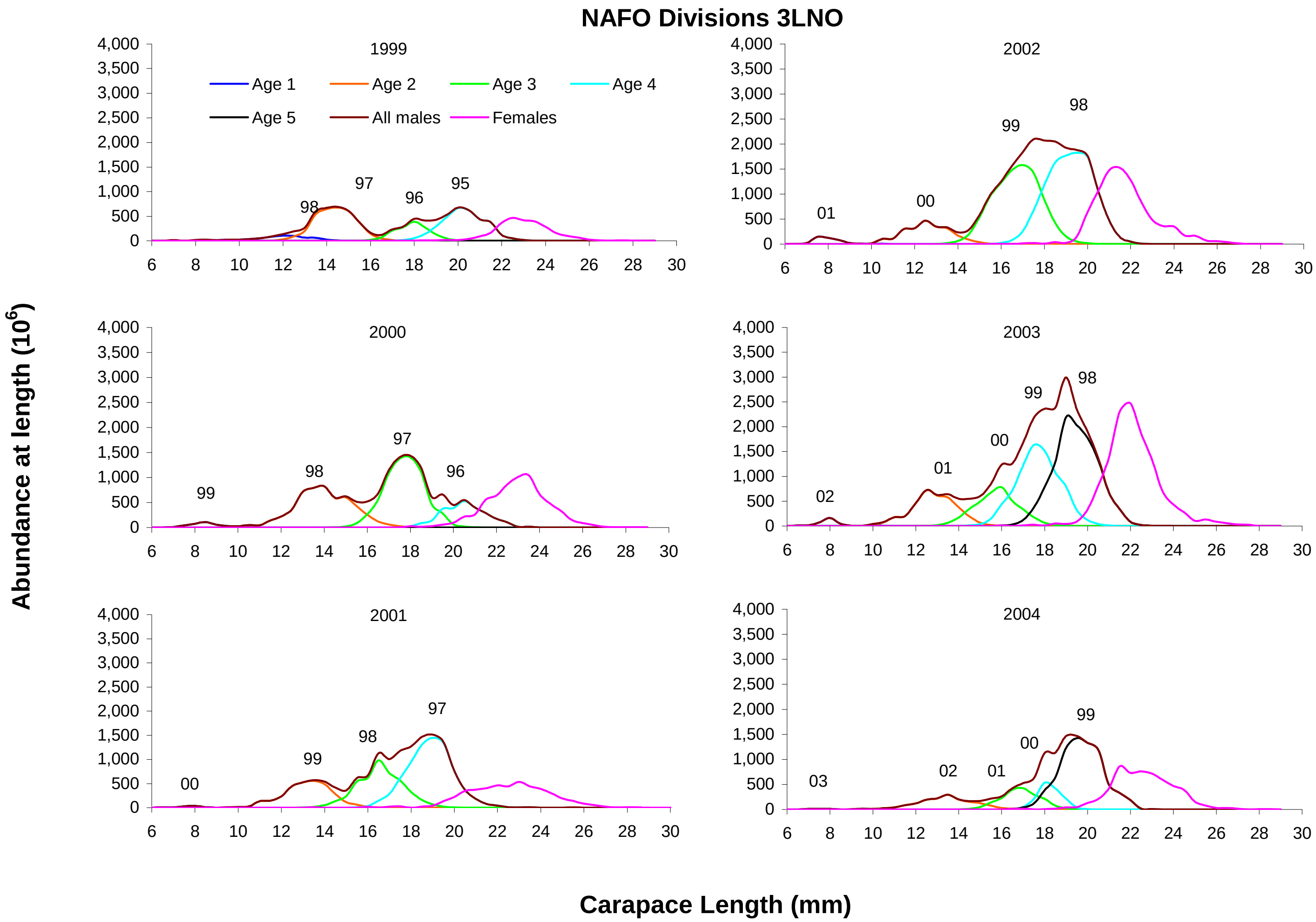


Figure 21. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **spring** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

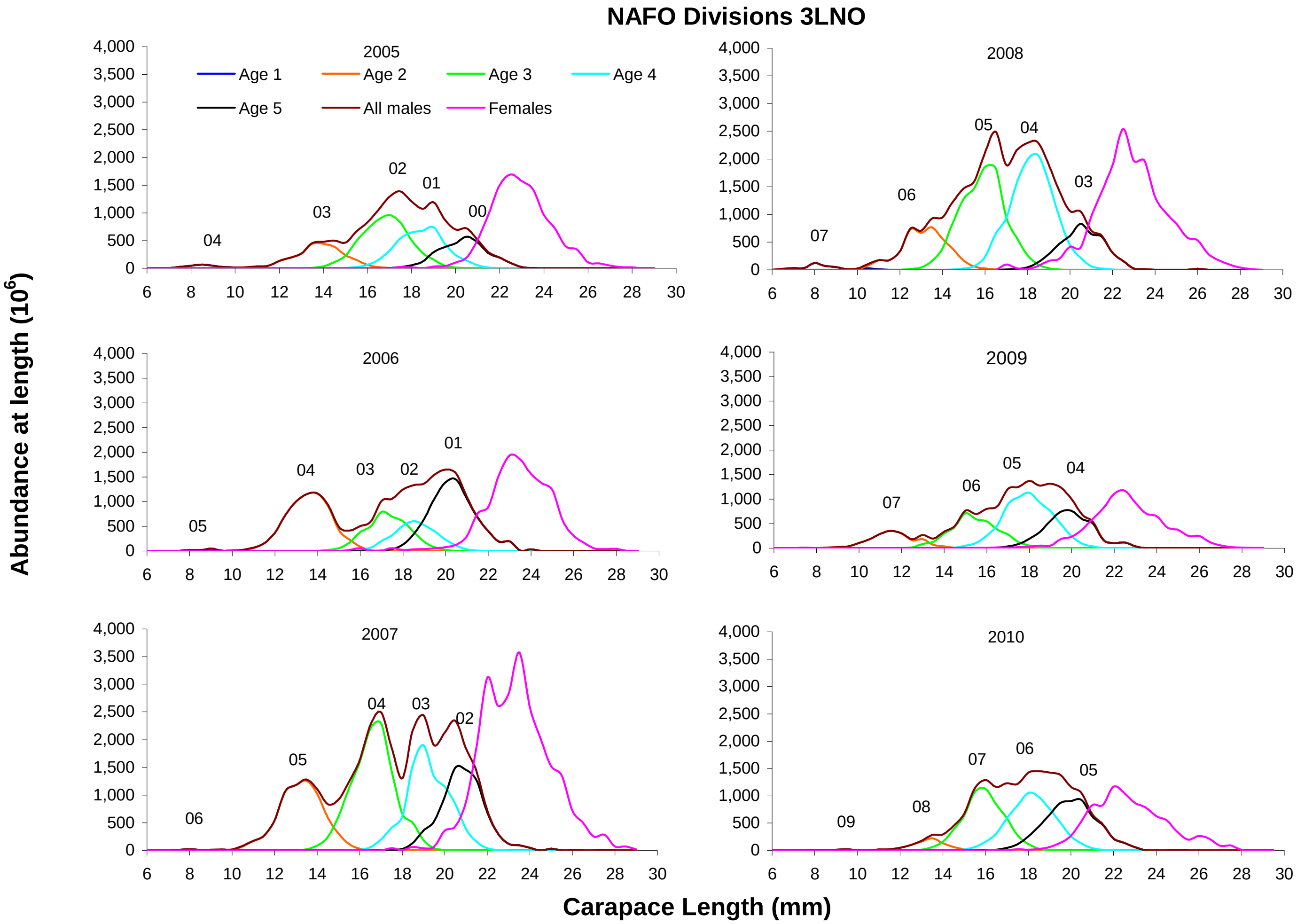


Figure 21. (Continued)

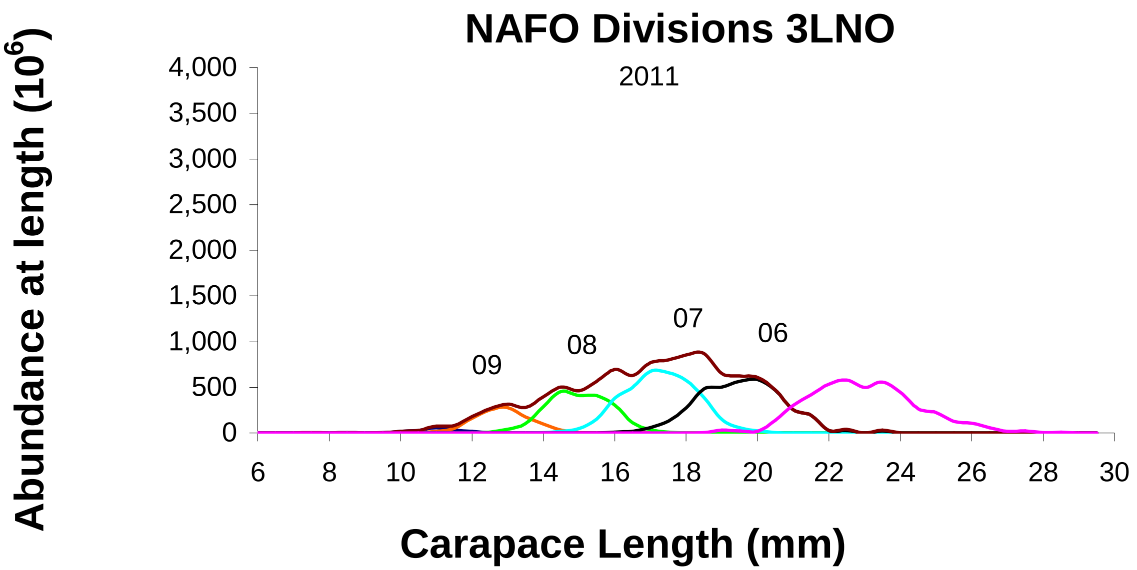


Figure 21. (Continued)

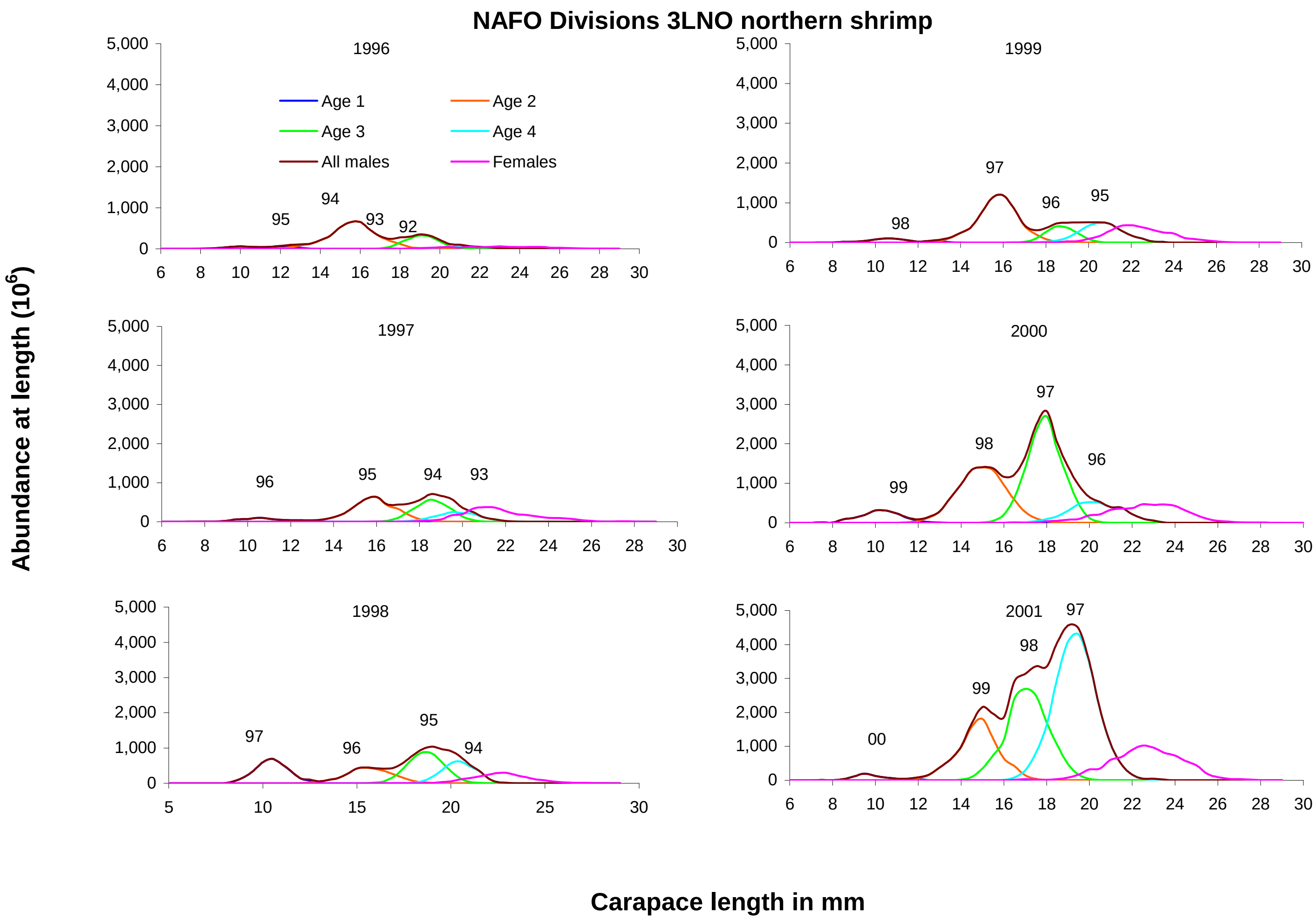


Figure 22. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

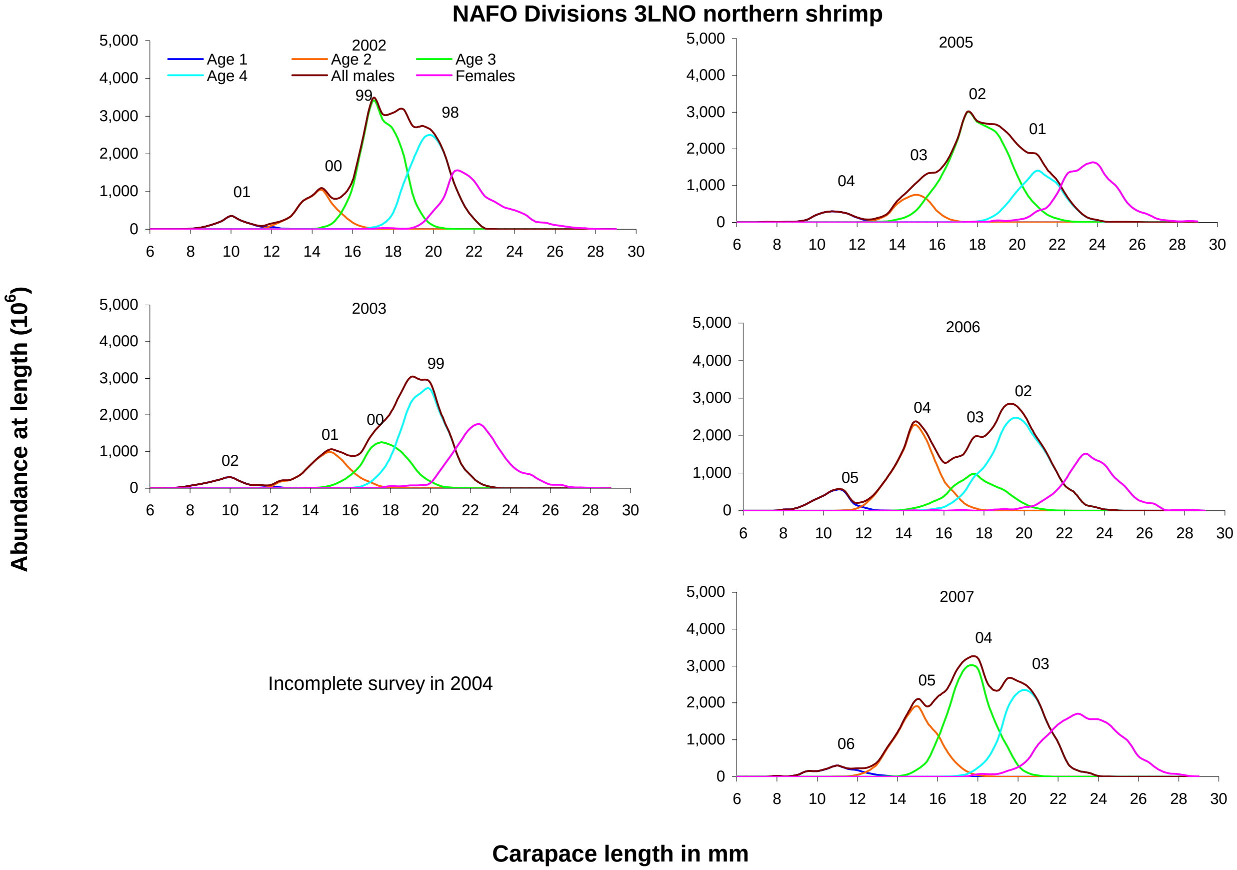


Figure 22. (Continued)

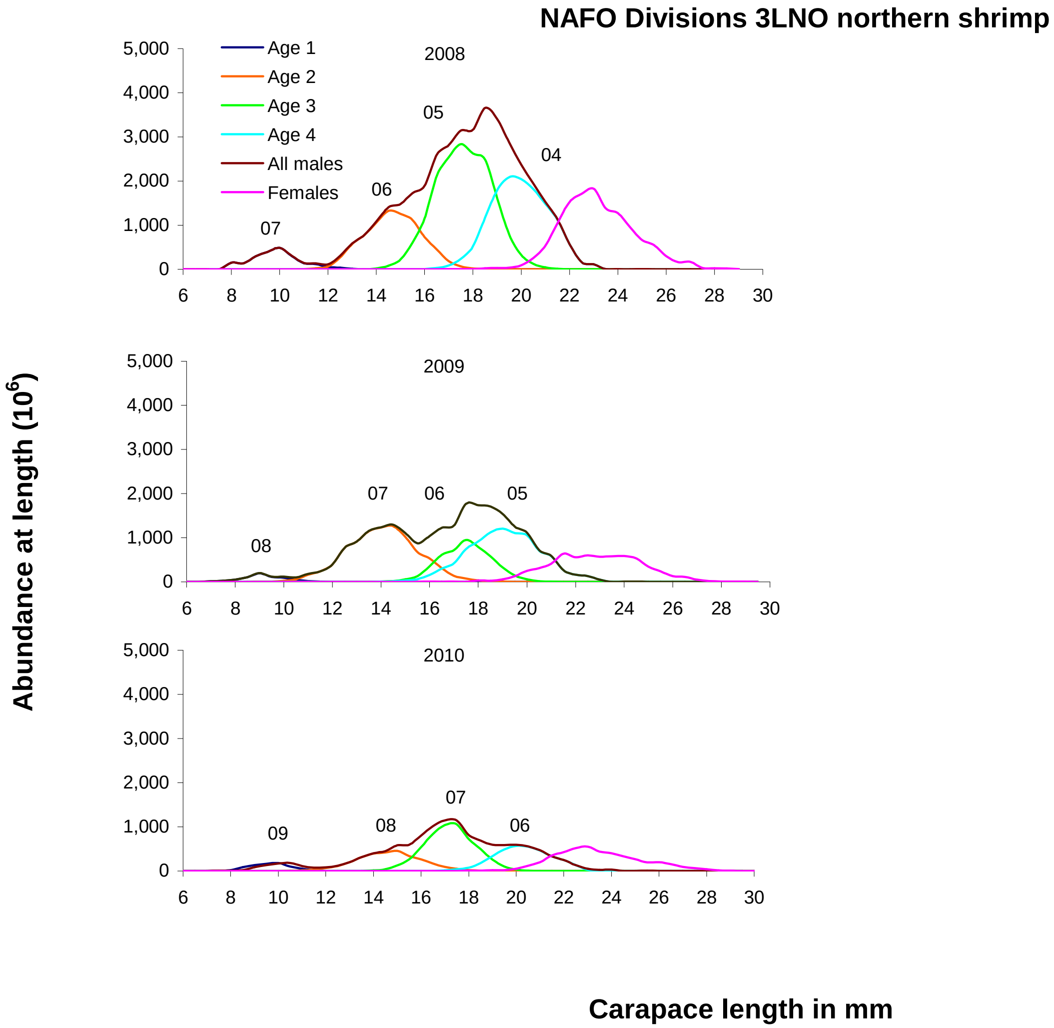


Figure 22. (Continued)

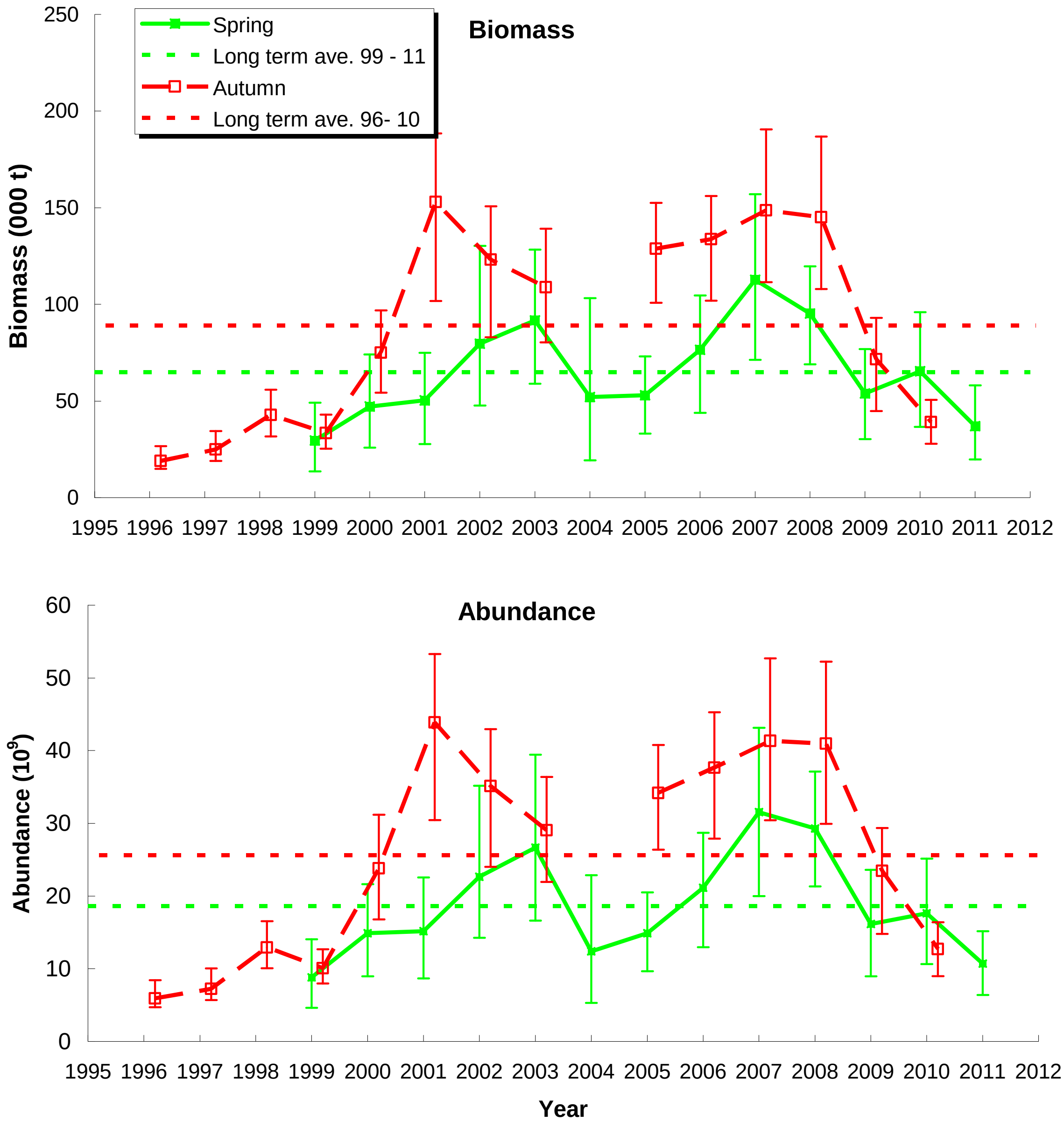


Figure 23. Abundance and biomass of male shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

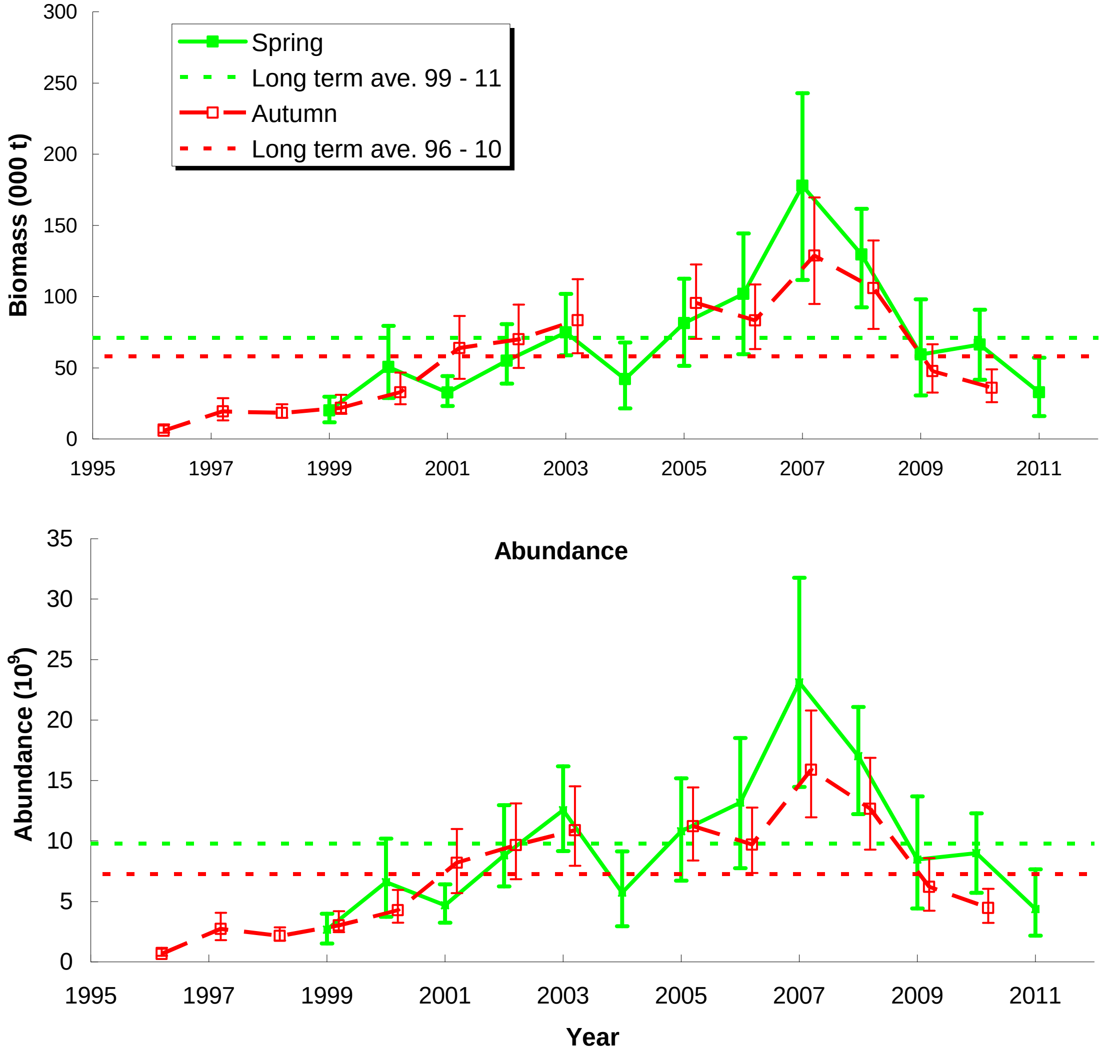


Figure 24. Abundance and biomass of female shrimp (SSB) within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

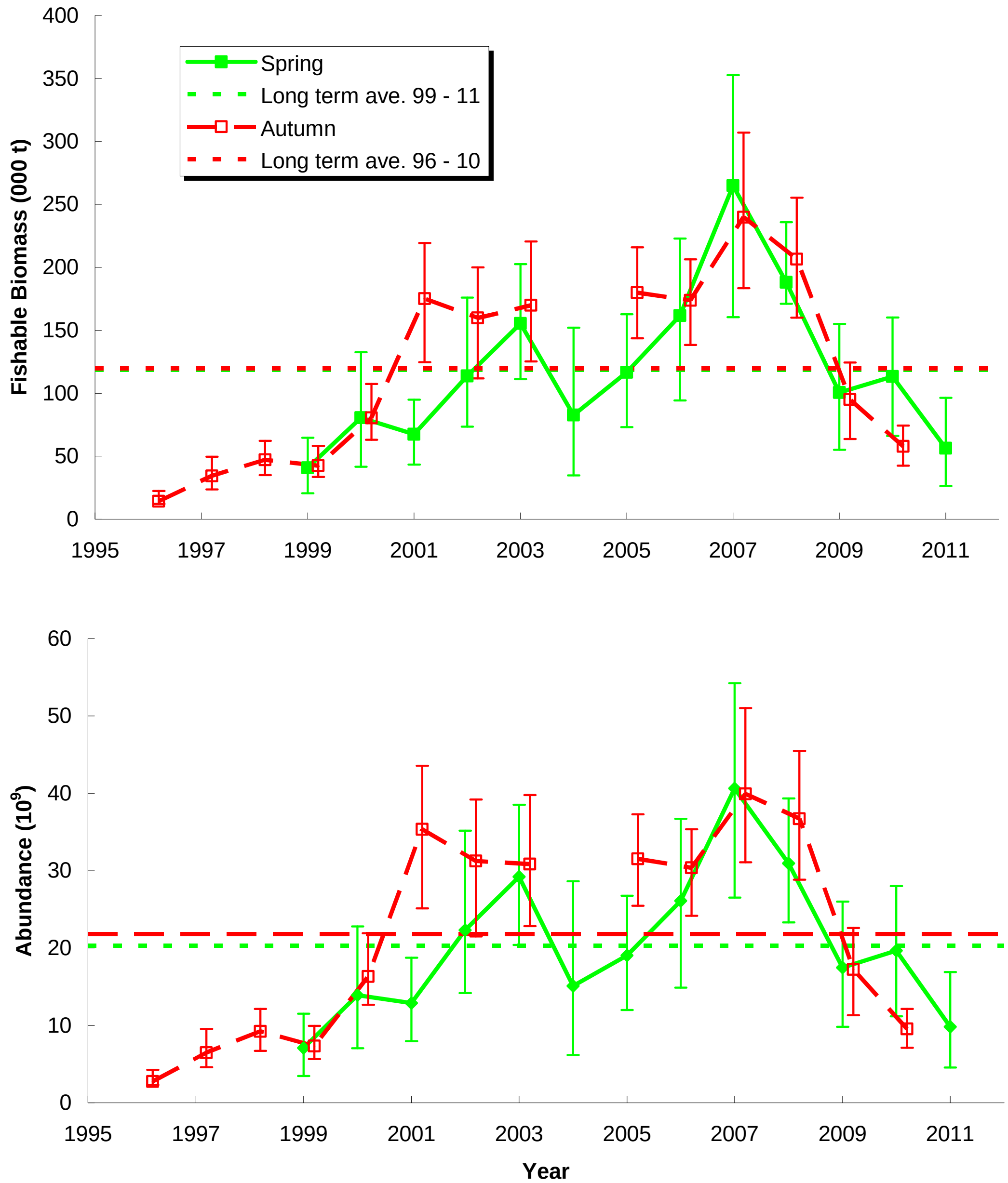


Figure 25 Fishable biomass (t) indices (weight of all females and males with carapace lengths => 17.5mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2011. The bars represent 95% confidence intervals around the fishable biomass indices.

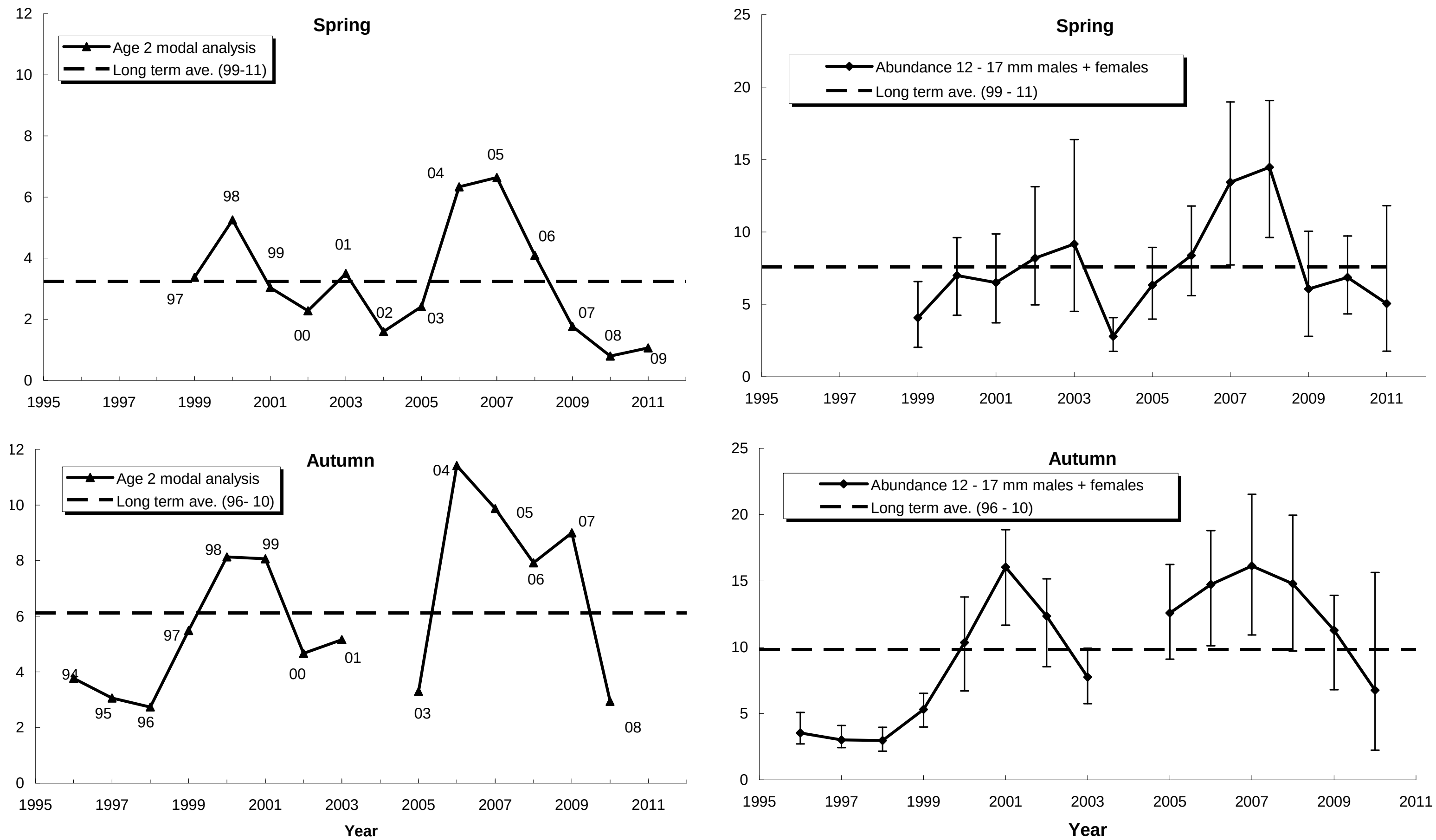


Figure 26. Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, autumn 1996 – spring 2011. The bars represent 95% confidence intervals around the index. Numbers within the modal analysis graphs are cohort years.

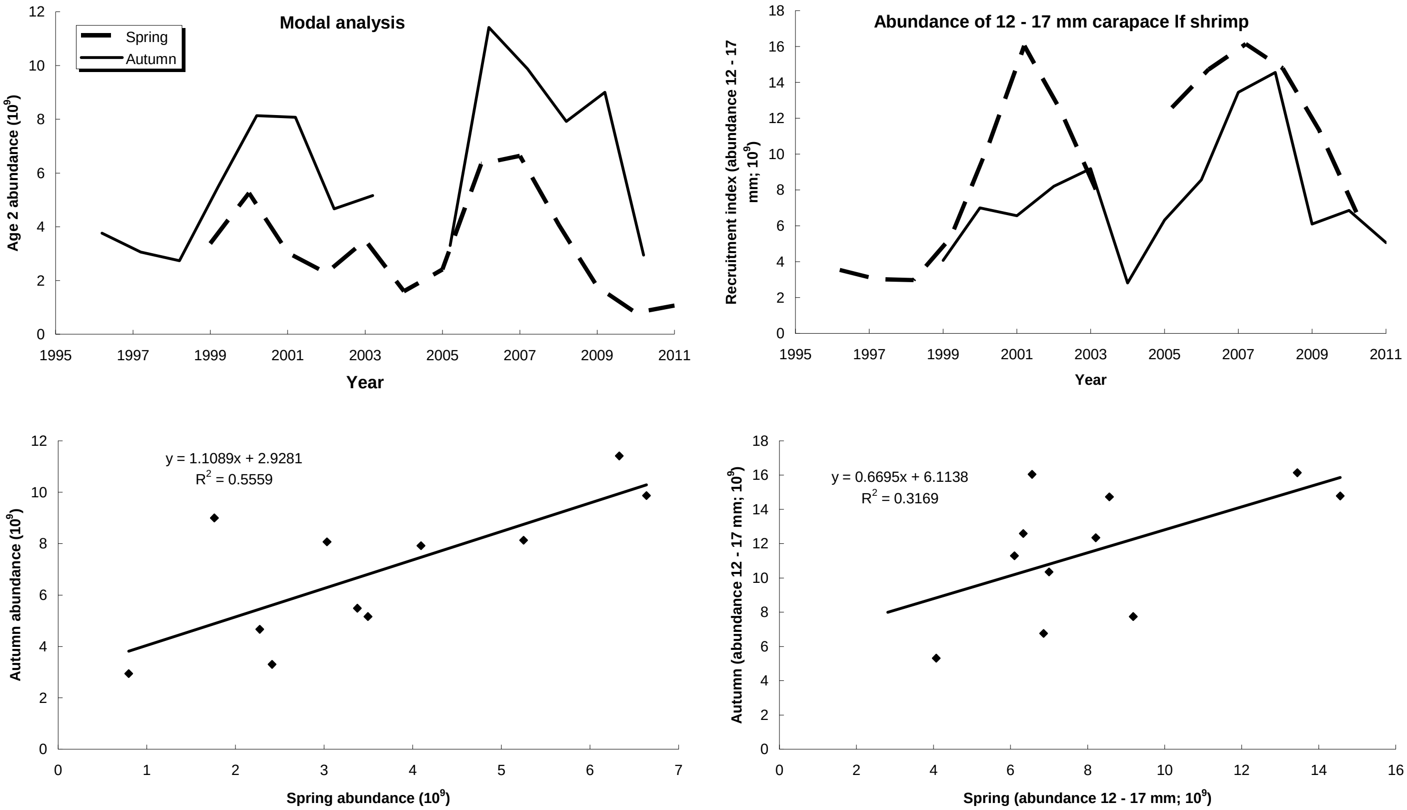


Figure 27. The relationship between spring and autumn recruitment indices created using modal analysis and size range methods.

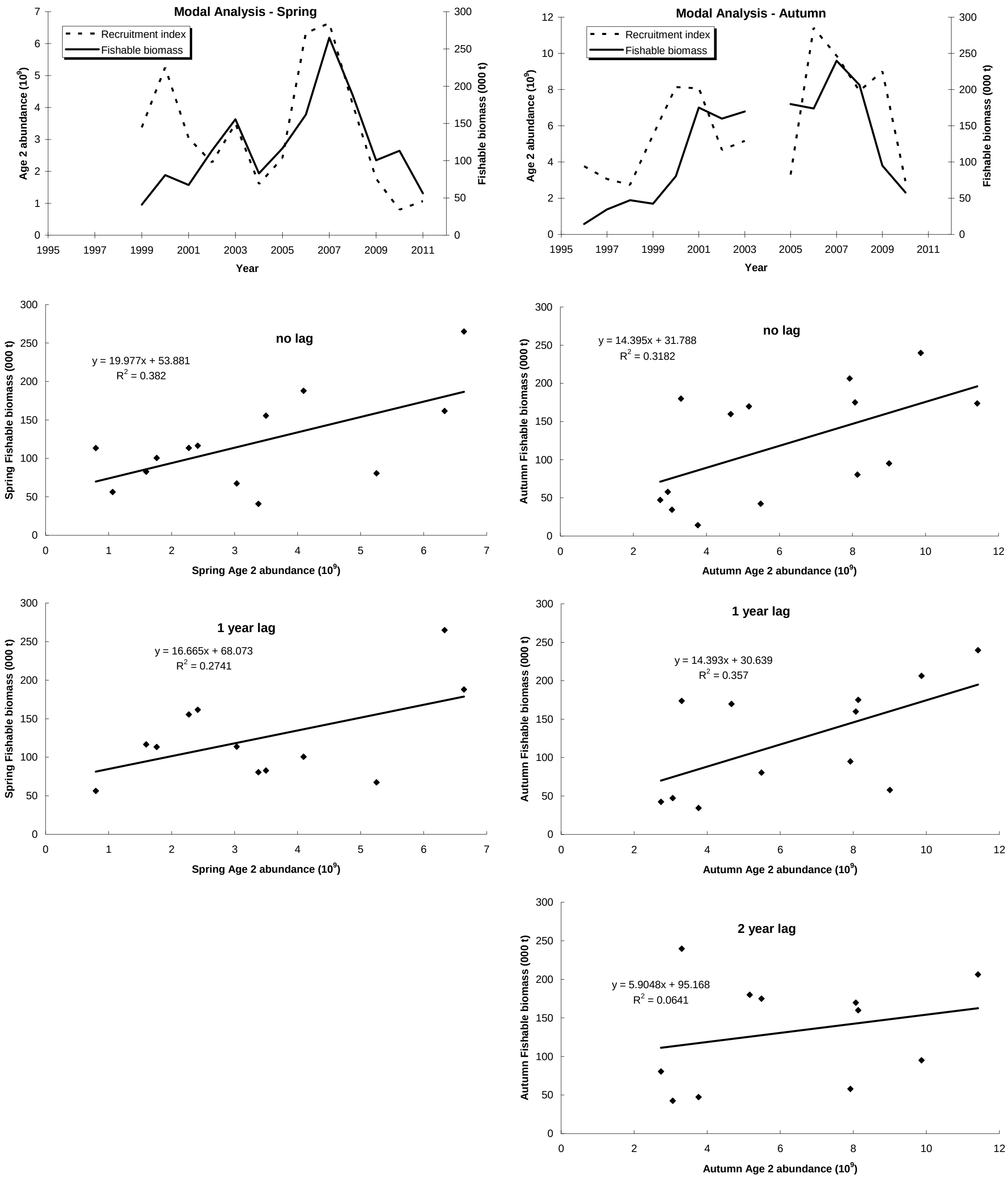


Figure 28. Predicting NAFO Divisions 3LNO northern shrimp fishable biomass from age 2 abundance using various lags.

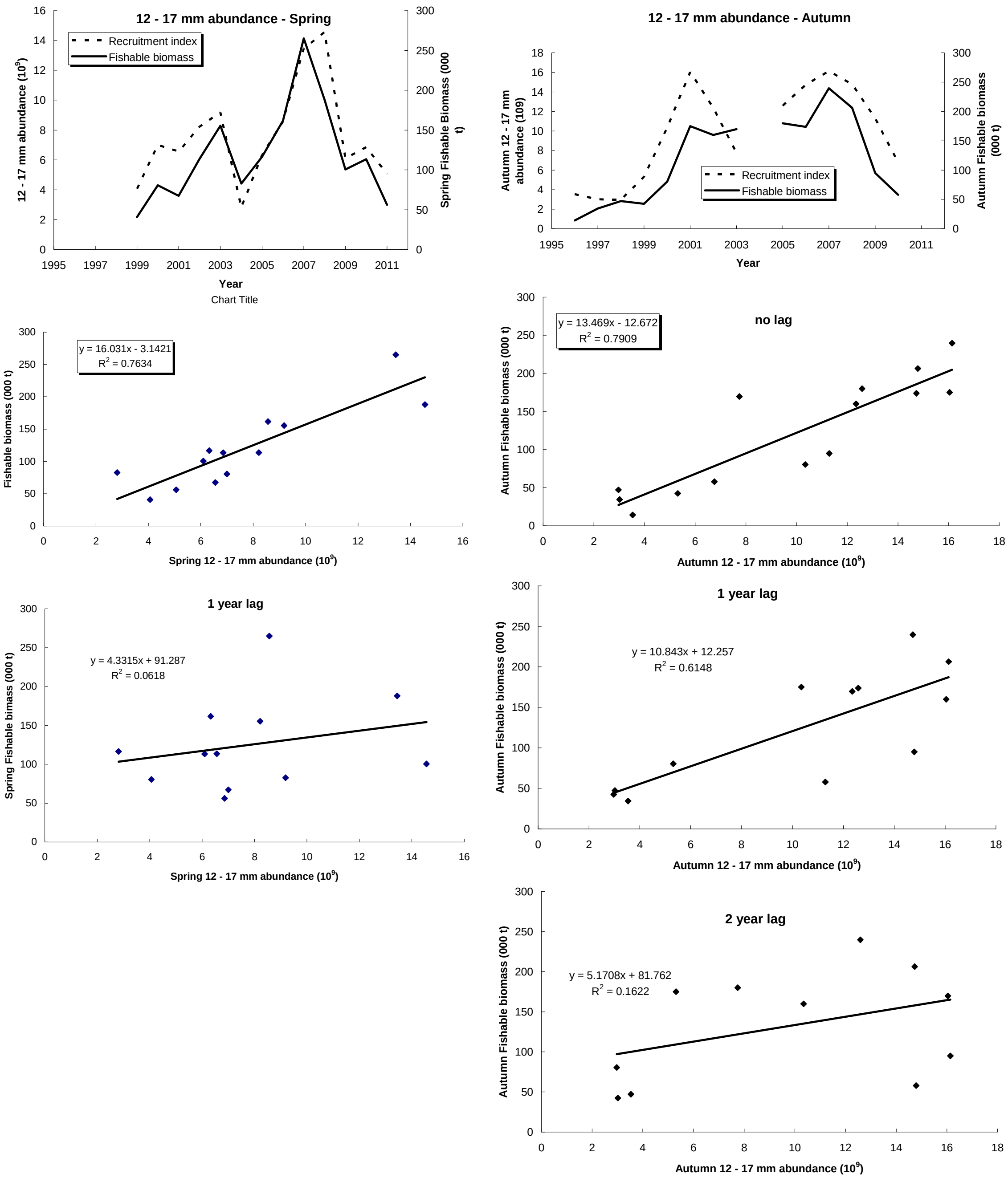


Figure 29. Predicting NAFO Divisions 3LNO Northern shrimp fishable biomass from abundance of shrimp with 12 – 17 mm carapace lengths.

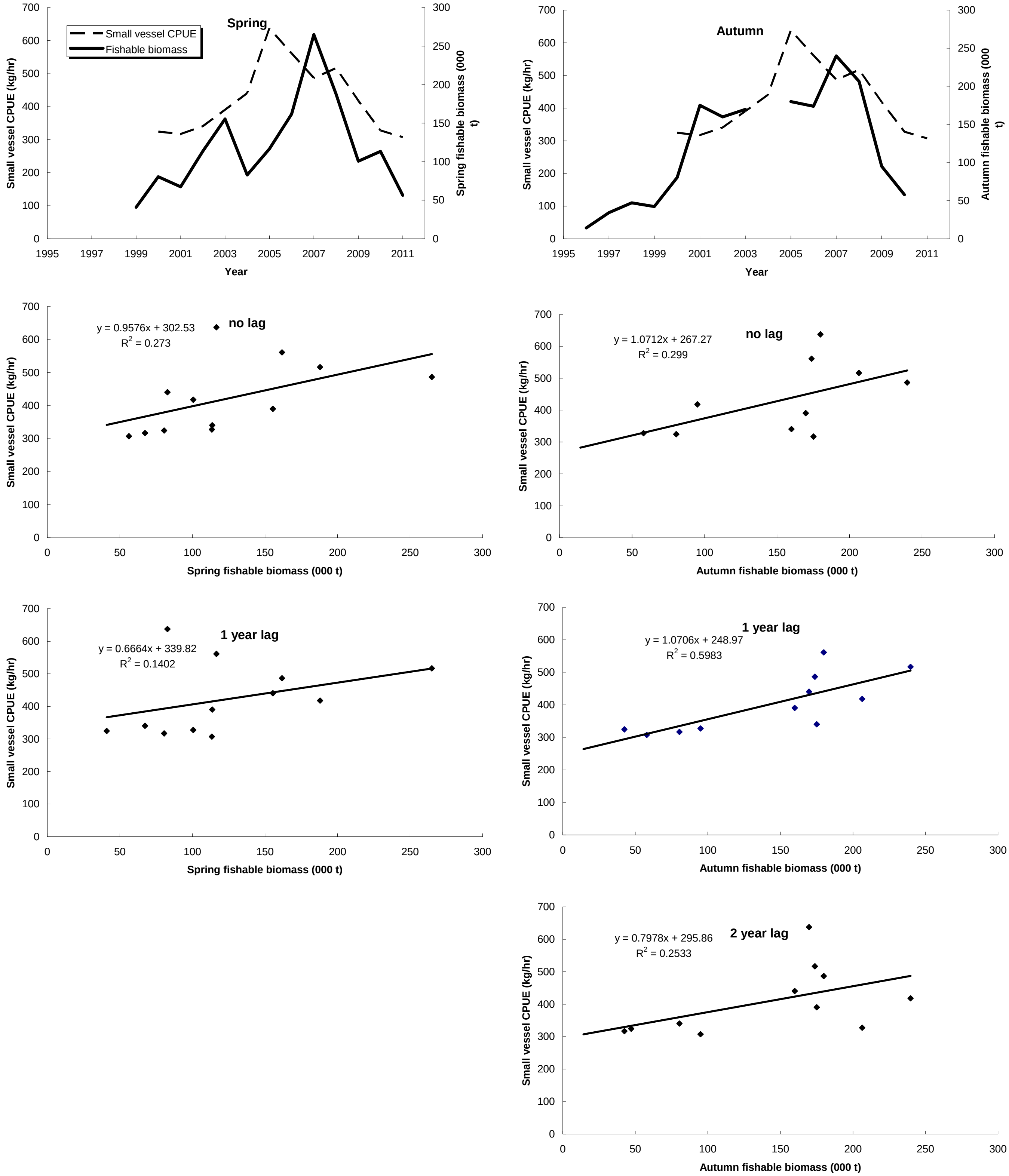


Figure 30. Predicting small vessel catch rates from NAFO Divisions 3LNO fishable biomass.

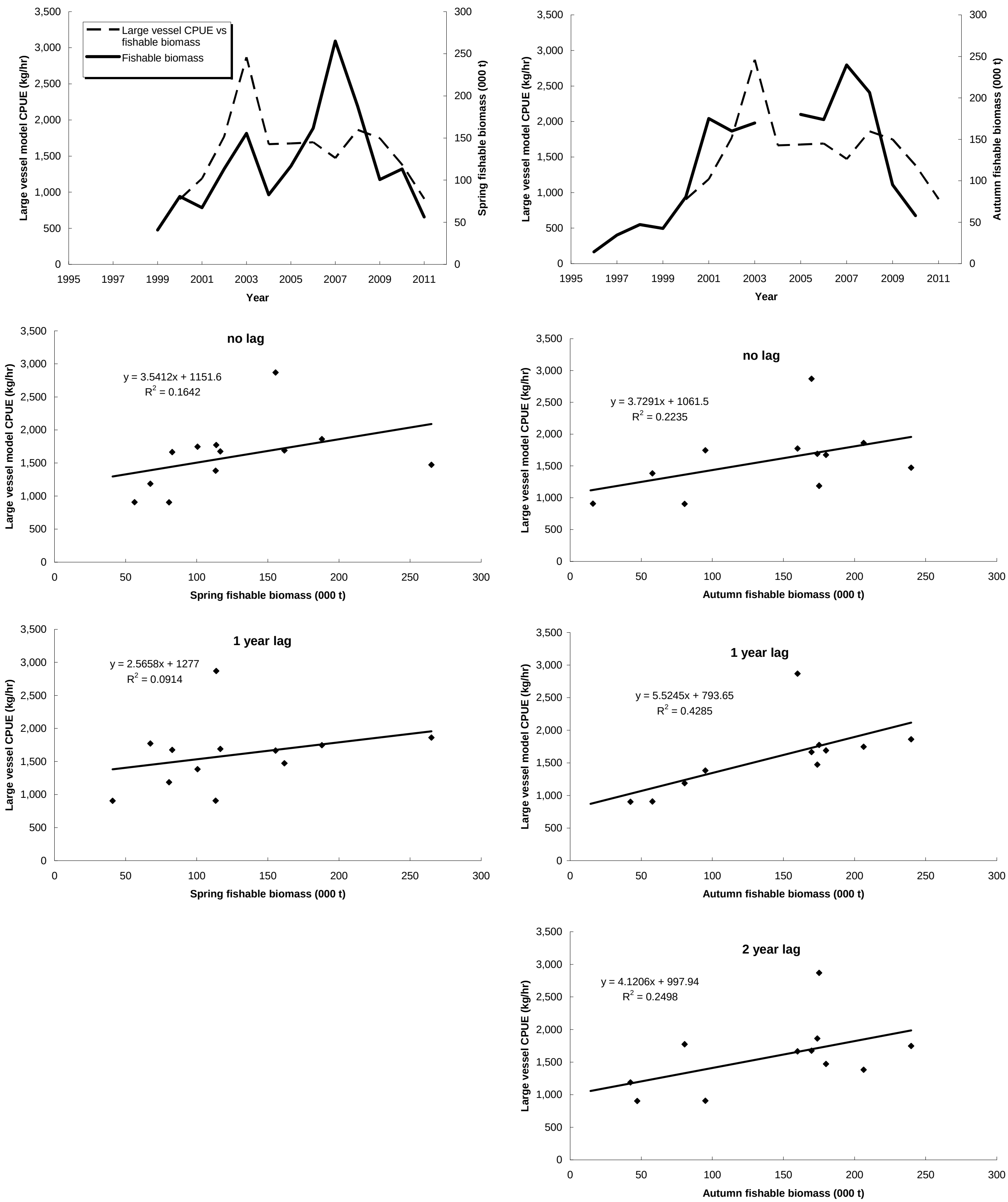


Figure 31. Predicting large vessel catch rates from NAFO Divisions 3LNO fishable biomass.

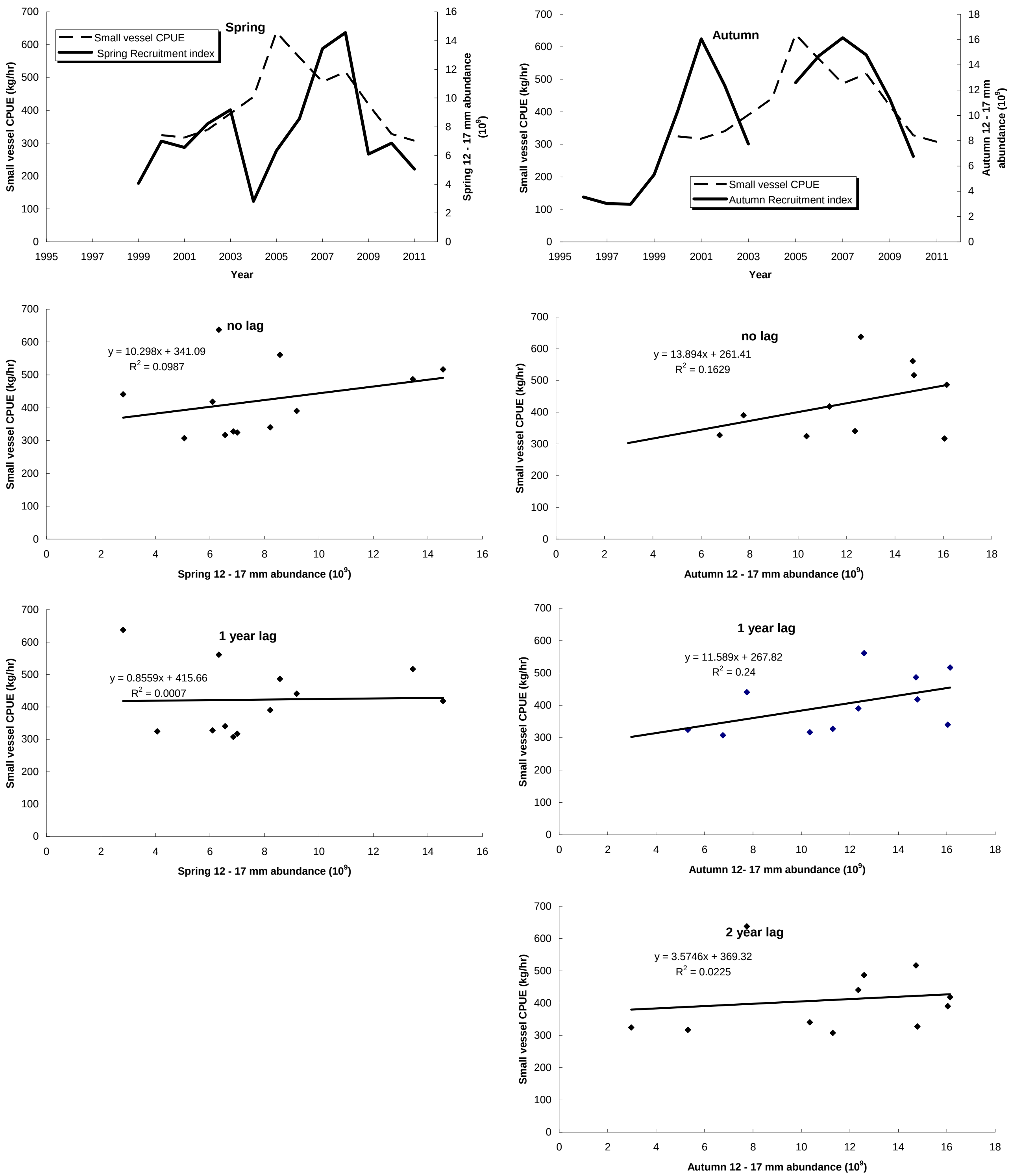


Figure 32. Predicting small vessel catch rates from abundances of 12 – 17 mm carapace lf shrimp.

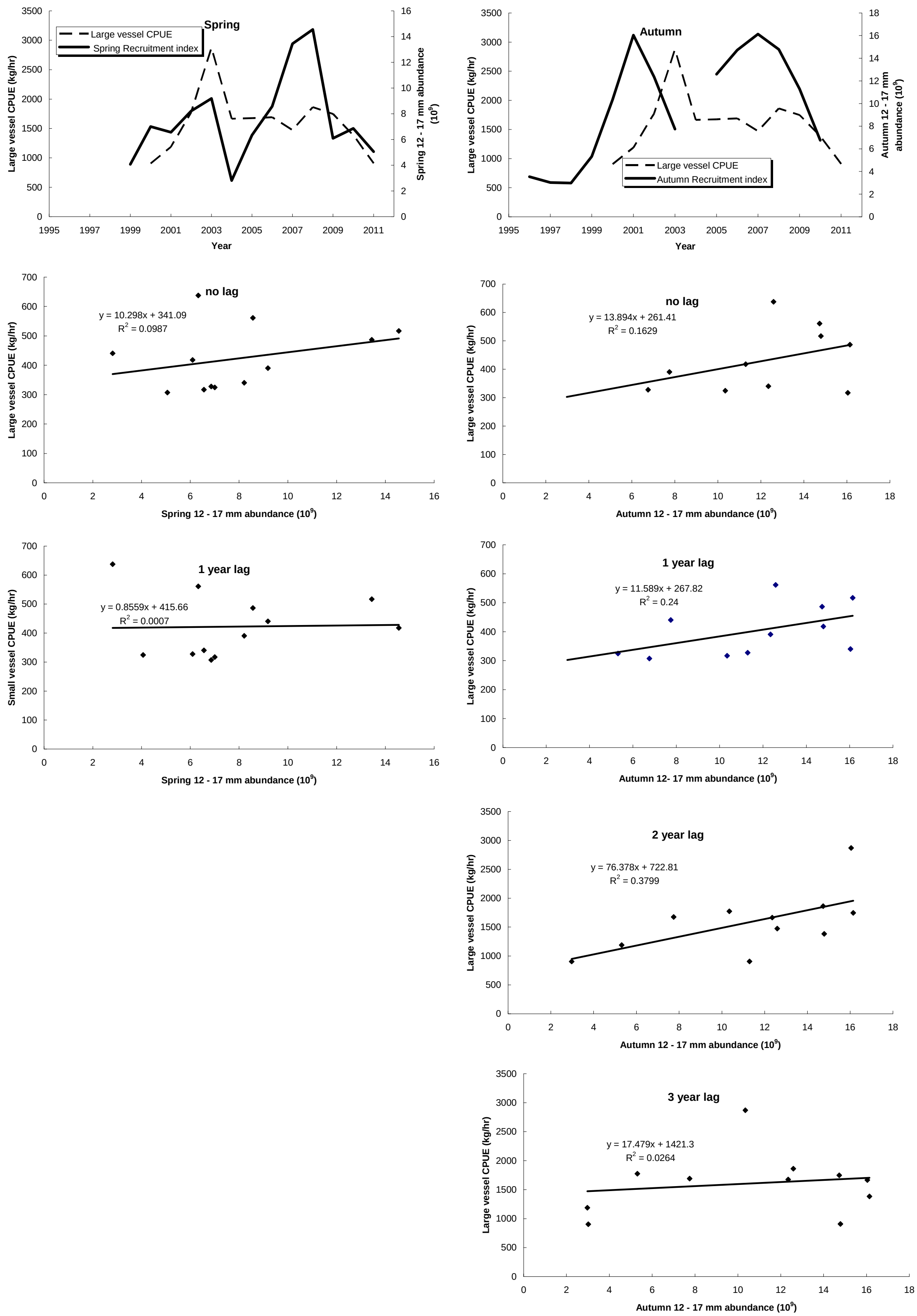


Figure 33. Predicting large vessel catch rates from abundances of 12 – 17 mm carapace lf shrimp.

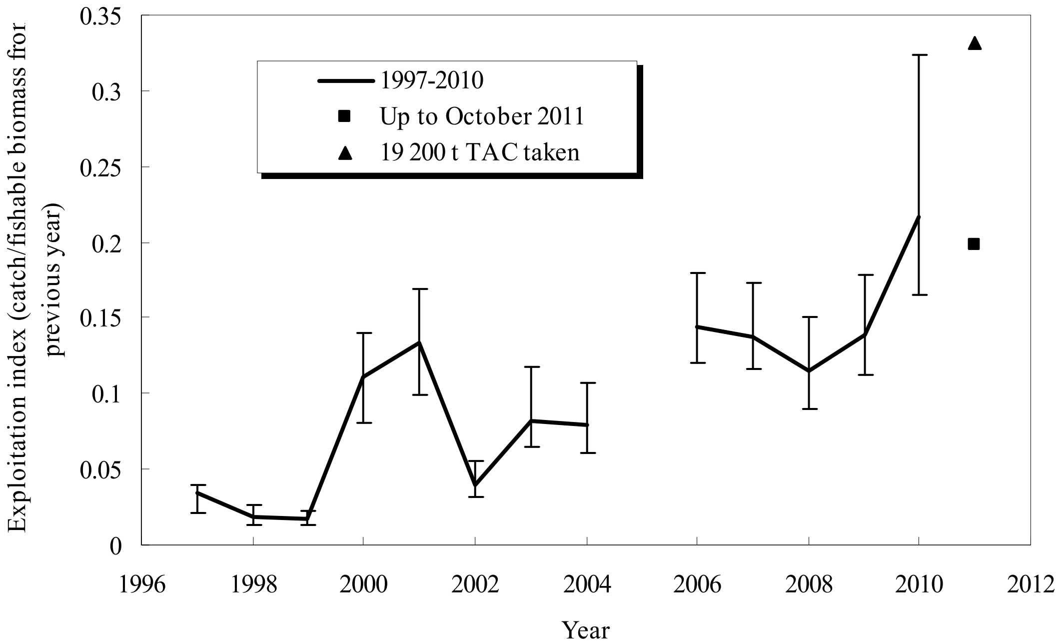


Figure 34. Trends in exploitation as derived by catch divided by the previous year's **autumn** fishable biomass index. The bars represent 95% confidence intervals around the exploitation rates for the proposed method.

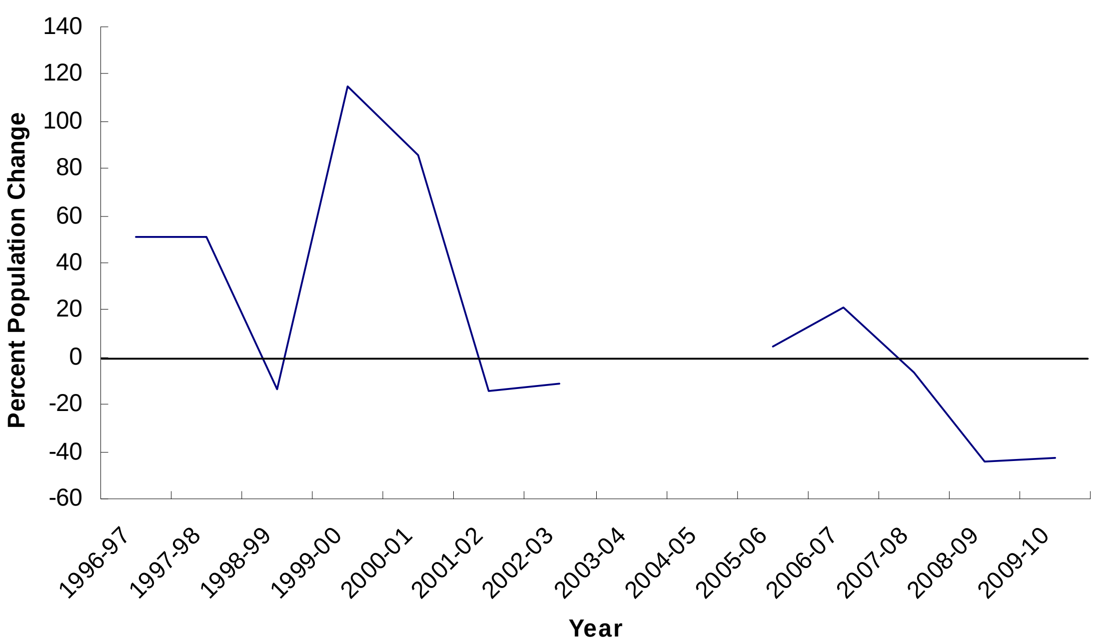


Figure 35. The change in abundance of 3LNO Northern Shrimp from one year to the next. These data are from the autumn survey time series.

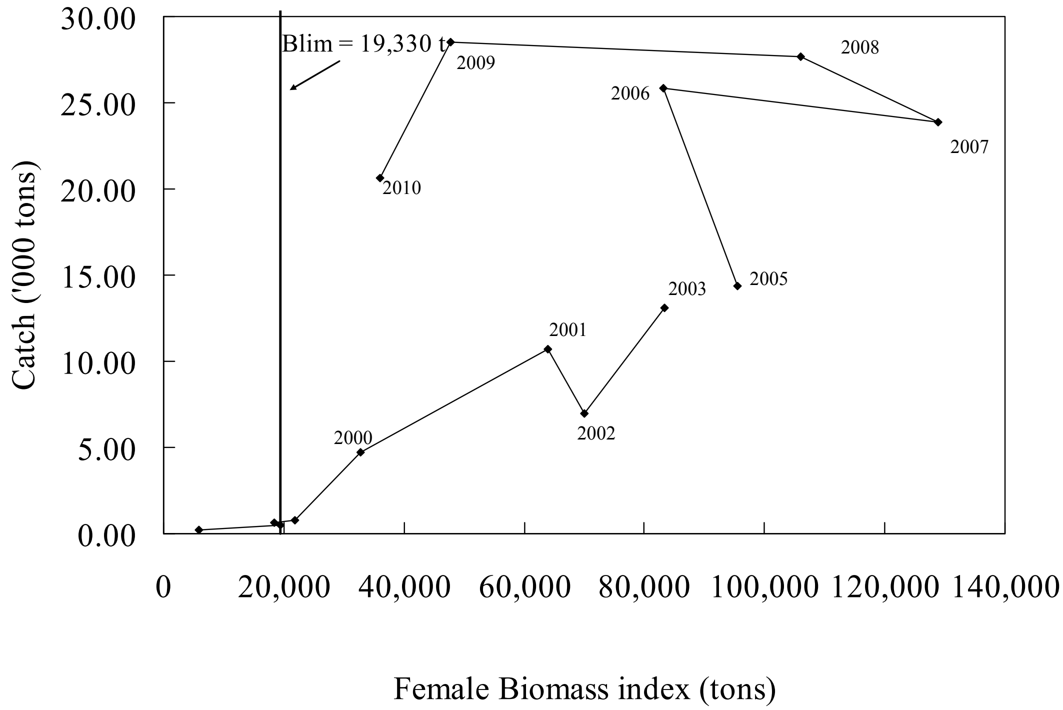


Figure 36. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).

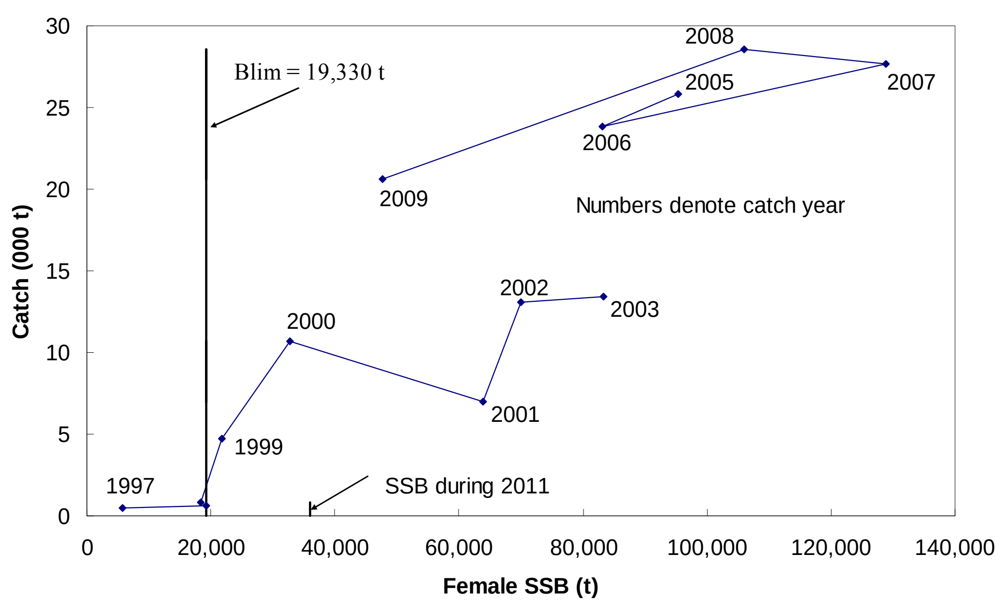


Figure 37. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Since the survey takes place at the end of the management year, the catch is plotted against previous year survey SSB. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).