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The 2012 assessment of the Northern Shrimp (*Pandalus borealis*, Kroyer) resource in NAFO Divisions 3LNO

by

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ABSTRACT:

This paper describes the 2012 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 2012) and biomass estimates (autumn 1996 – spring 2012) are updated within this report. Preliminary data indicate that 14 047 t of shrimp were taken against a 19 200 TAC in 2011 while 8 561 t were taken against a 12 000 t TAC by September 30, 2012.

The autumn 2011 3LNO biomass index was estimated to be 73 500 t which was similar to the autumn 2011 index of 75 100 t. The spring 2012 biomass index was estimated to be 58 500 t which was a 16% decrease since 2011 when the index was estimated to be 69 900 t.

The autumn 2011 3LNO female spawning stock biomass (SSB) index was estimated to be 35 600 t, which was similar to the 2010 autumn index which was estimated to be 35 900 t. The spring SSB index decreased by 15% from 32 800 t in 2011 to 28 000 t in 2012.

The autumn 3LNO fishable biomass index was estimated to be 61 500 t in 2011, an increase of 6% from 57 900 t in 2010. The spring fishable biomass index decreased by 16% from 56 300 t in 2011 to 47 400 t in 2012.

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 the 2012 standardized CPUE was at the lowest level in the thirteen year time series. The Canadian small vessel standardized CPUE has been following a decreasing trend since 2005 and by October 2012 was significantly below the long term average and that catch rates over the 2001 – 2002 and 2010 – 2012 periods were statistically similar to 2001 values.

INTRODUCTION:

The northern shrimp (*Pandalus borealis*) stock, in Div. 3LNO, extends beyond Canada's 200 Nmi limit and therefore is a NAFO regulated stock (Fig. 1). Northern shrimp, within NAFO divisions 3LNO, have been under TAC regulation since 1999. TACs have increased in a stepwise fashion from 6 000 t in 2000 to 30 000 t in 2009 and 2010 but then decreased to 12 000 t by 2012 due to continued declines in survey and commercial fishery indices. During the 2012 Fishery Commission meeting, the 2013TAC was set at 8 600 t.

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 2012.

The present document was produced for the October 2012 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:

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

Where: $\mathrm{CPUE}_{\mathrm{ijkml}}$ 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. By limiting the dataset to vessels with a history in the fishery we are able to increase 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 = 69’ as determined from observer data

Double trawl data:

Catch-per-unit-effort = (catch X ((2.5/speed) X (139/footrope length))/effort)/conversion factor to single trawl units

Conversion factor to single trawl units = 1.4557 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. 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:

Catch information was provided by Contracting Party, the use of Canadian surveillance data, as well as, NAFO Statlant 21A and B as well as 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. An attempt was made to use the Statlant21B dataset in producing a standardized catch rate model. Since the Statlant21B data is provided by all of the Contracting Parties, it was hoped that it would allow the development of more representative models of resource status in 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.

von Bertalanffy Growth Model

A von Bertalanffy growth model was developed using modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) was conducted on male and female research length frequencies. The von Bertalanffy growth model is defined as:

$$L_t = L_\infty \left[1 - e^{-k(t-t_o)}\right]$$

where L_t = carapace length in mm at time t.

L_∞ = the asymptotic maximum carapace length that most animals will achieve in their lifetimes

K = Brody growth coefficient which provides the slope of the ascending curve.

t = time in years

t_o = the theoretic time at which the animals had a carapace length of 0 mm.

Recruitment indices

Two recruitment indices were estimated from the multi-species research survey bottom trawl dataset. In the first case, a recruitment index was defined as the abundance of age 2 animals derived from modal analysis. In the second case, recruitment was estimated as the population estimates of all males and females with 11.5 – 17 mm carapace lengths.

Fishable biomass

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

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

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

Spring samples

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

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 rate indices

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.

Female Spawning Stock biomass

Spawning stock biomass was defined as the weight of all transitionals + primiparous females and ovigerous + multiparous females). All survey 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).

<u>Mortality</u>

Survival, annual mortality and instantaneous mortality estimates were calculated by various methods to gain a better understanding of the life history of the shrimp. Mortality estimates are important inputs for resource assessments. The survival of age 4+ males and total female abundances were compared with the surviving age 5 + males and total female abundances. Median values for these statistics are presented 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. The female mortality indices were derived from both the observer and research survey trawl datasets.

It is important to note that both of these methods provide survival statistics for the final years of the shrimp's life. There is no reason to believe that rates of mortality would not change throughout the life of a cohort. Lorenzen (1996) and Hewitt *et al*. (2007) point out that fisheries assessments would be more realistic through inclusion of M varying through the life history of the animal of interest. The Lorenzen mortality estimator was used to define mortality as a function of weight thereby providing an estimate of changes in mortality over the lifespan of the shrimp. Hewitt et al. (2007) made use of the Lorenzen mortality estimator as one of the various indirect methods to determine the natural mortality of Blue Crab within Chesapeake Bay. The Lorenzen mortality estimator provides an indirect means of determining mortality and is defined as:

$M = 3Wt^{-0.288}$
In which M = natural mortality and
W = weight in grams

The combined maturity shrimp length weight model used in this relationship was

$Wt(g) = 0.00031*lt(mm)^{3.22442}$

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

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

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

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

Ogmap is then used to compute the expected value of the distribution at every vertex in each Delauney triangle. The expected value 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.

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

Catches increased dramatically since 1999, with the beginning of a regulated fishery (Fig 5). Table 1 and the following discussion provide the available numbers to date. Over the period 2002-2009, catches increased from 6 960 to 27 914 t. Due to declines in resource indices, the TACs have been steadily decreasing with the 2013 TAC being set at 8 600 t during the 2012 Fishery Commission meeting. Preliminary catch records indicate that 14 046 t of shrimp were taken from a 19 200 t TAC in 2011. By October of 2012, 8 561 t of shrimp had been taken, down from the 11 434 t taken by the same time in the previous year. As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 5 402 t in 2002 to 20 147 t in 2008 but have since decreased to 8 246 t in 2011. Canadian vessels had taken 7 867 t of shrimp by October 2012 down from the 8 945 t taken by this time last year.

Catches by other contracting parties increased from 661 t in 2000 to 7 703 t in 2006 and between 2006 and 2011 have ranged between 3 844 and 7 703 t. Preliminary data indicate that non Canadian vessels took 694 t of Northern Shrimp by October 2012 while they took 2 489 t by the same period in the previous year. Table 1 provides a breakdown of catches by contracting party and year since 2002, 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 - 11) 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. 12). In 2012, the small vessel fleet took its quota by August 21 and by the time that the analysis was run for this assessment, over 70% of the logbook data had been keypunched and edited. The large vessel fleet had taken only 50% of its quota by October 1, 2012.

Small vessel CPUE (2000 – 2012) was modeled using year, month 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 2001, class 3 and July values. The logbook dataset that was used in this analysis accounted for between 60% and 95% of the catch within any one year (Table 3). The final model explained 82.2% of the variance in the data and indicated that the annual, standardized catch rates increasing from near 300 kg/hr over 2000 – 2002 to 570 kg/hr by 2005 before gradually decreasing to 250 kg/hr by 2012. The 2001 catch rate index was similar to the 2002 and 2010 - 2012 indices while being significantly lower than all intervening indices (Tables 2 and 3; Fig. 13). No clear trends were found in the plots of residuals (Fig. 14).

Seasonality among the large vessel fleet has varied greatly over the years (Fig. 12). The data were analyzed by multiple regression using data standardized against data from 2001, single trawls, the vessel with the longest history and 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 40% and 100% of the catch within any one year (Table 5). The final model explained 70% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean between 2004 and 2008, increased in 2009 but have since been decreasing. The 2001 standardized catch rate index (1 356 kg/hr; Table 5 and Fig. 13) was similar to the 2003, 2005-09 and 2010 values but significantly higher than the 2011 and 2012 values. The 2012 CPUE index was 459 kg/hr (Tables 4 and 5; Fig. 13). There were no trends in the residuals around parameter estimates (Fig. 15).

Table 6 provides trends in mean catch rate (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 fluctuated between 11 and 17 strata since 2012 (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 16 provides a map of these strata. Since 2008, none of the strata had mean catch rates above .6 t/ hr and since 2010 the lowest mean catch rate in some strata dropped to below .3 t/hr. The mean catch rate (t/hr) increased from .47 t/hr in 2003 to .76 t/hr in 2006 but decreased to .35 t/hr by 2012 (Table 7).

Table 8 provides indices of mean catch rate as determined from large vessel observed catch and effort information. This table clearly shows that the large vessel fishery is maintained in few strata compared to the small vessel fishery as is confirmed in figures 9 - 11 and that most of the catch is taken in 274 m – 549 m depth ranges.

International fleet

The Statlant21B data was used to create a standardized international fleet CPUE model. Most of the data were from Faroese vessels that were tonnage class 6 (1000 – 1999.99 t) therefore the model was produced for these vessels only. The model accounted for 72% of the variance in the data and was standardized to 2001 and December. The index for 2001 was statistically similar to indices for 2002 and 2003 while all others were significantly higher (Tables 9 and 10; Fig. 17). The catch rate was 77 kg/hr, in 2001, fell to 33 kg/hr during 2003 and then rose 566 kg/hr by 2004 and has been near or above the long term mean (366 kg/hr) until 2010 when the catch rate increased to 669 kg/hr. There were no trends in the residuals around parameter estimates; however, there was an anomalously high catch in May 2002 (Fig. 18).

Catch rate data provided by researchers accounted for 1 – 45% of the non Canadian catch in any one year and it was felt that these percentages of the entire catch were not high enough to construct a meaningful standardized CPUE model. The data were therefore used to create an unstandardized international CPUE series. 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 1 264 by 2009 and subsequently dropping to 640 kg/hr by 2011 and remaining at that level in 2012 (Table 10; Fig. 17). It is not clear how representative these commercial catch rates are of the international fishery in the 3L NRA since in any one year there may be data from only one or two countries.

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. 19). 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 presented in figure 20. 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 17.1 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.

Figure 21(a) is a plot of carapace length frequencies taken from 9 tows on Spanish fishing vessels during January of 2011. The 2011 Spanish commercial catch was taken during January in 87 tows. Figure 21(b) shows the percent carapace length frequencies from the Estonian fishing fleet for the years 2010 – 2012. While the plot may be representative of catch taken by these fleets, there were no other length frequency data from the NRA so we are not sure whether the length frequency is representative of entire fleet catch. However, this plot does provide evidence of at least male and female modes agreeing with the Canadian commercial length frequencies that more than one year class was evident within the catch.

RESEARCH SURVEY DATA

Stock size

The autumn 2007 – 2011 and spring 2008 – 2012 research catches were concentrated within NAFO Div. 3L at depths between 200 and 500 m (Figs 22 and 23). The autumn 2011 3LNO biomass index was estimated to be 73 500 t which was similar to the autumn 2011 index of 75 100 t. The spring 2012 biomass index was estimated to be 58 500 t which was a 16% decrease since 2011 when the index was estimated to be 69 900 t (Table 11; Fig 24). 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 12 and 13 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 22 and 23 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. It is important to note that the number of large sets (100 kg/set) has been decreasing since 2007 within the autumn series and 2008 in the spring series. Figures 25 and 26 illustrate the trends in time 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 12 and 13). 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. 13).

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 11.0 and 32.6% of the estimated total 3LNO biomass (Tables 14 and 15; Figs. 22 and 23; Orr et al. 2007). During the autumn, the percent biomass within the NRA ranged between 11.0 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 15). Over the period 1996 – 2011 the overall average autumn percent biomass within the NRA was 16.1%. During the spring, the percent biomass within the NRA ranged between 6.4 and 32.6% (three year running average ranged between 18.7 and 27.5%) (Table 14). Over the period 1999 – 2012 the average spring percent biomass with the NRA was 21.5%. It must be noted that variances around the spring indices are greater than around autumn indices (Table 11; Fig. 24).

In all surveys, Division 3N accounted for 0.1-8.1% of the total 3LNO biomass (Tables 14 and 15). Between 0 and 100% 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 2012 surveys are presented in figures 27 and 28. 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 16 and 17 provide the modal analysis and the estimated demographics from each survey series. 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 autumn survey, 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 16 and 17; Figs. 27 - 29).

Shrimp aged 3 - 5 dominated the male component of the length frequencies in spring 2012 (2009, 2008 and 2007 year classes respectively) survey with carapace length frequency modes at 14.64 mm, 17.11 mm and 19.78 mm as males respectively and as age 5 females at 23.17 mm (Table 16; Fig. 27). Abundance estimates from the autumn 2011 survey were dominated by shrimp aged 2 - 4 (2009, 2008 and 2007 year classes respectively) with modes at 15.40 mm, 18.766 mm and 20.59 mm as males respectively and as females at 19.94 mm. 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 2011. This appeared to be the strongest year class that could be tracked through time. The successive year classes appeared weaker.

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 72% to 31 000 t (9 billion animals) in 2012 (Table 18; Fig. 30). 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 18; Fig. 30). 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. The autumn male survey biomass index remained near this level in 2012.

The autumn 2011 3LNO female spawning stock biomass (SSB) index was estimated to be 35 600 t, which was similar to the 2010 autumn index which was estimated to be 35 900 t. The spring SSB index decreased by 15% from 32 800 t in 2011 to 28 000 t in 2012 (Table 19; Fig. 31).

The autumn 3LNO fishable biomass index was estimated to be 61 500 t in 2011, an increase of 6% from 57 900 t in 2010. The spring fishable biomass index decreased by 16% from 56 300 t in 2011 to 47 400 t in 2012 (Table 20; Fig.32).

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 11.5-17 mm in carapace length from spring and autumn surveys.

from the autumn 1996-2011 and spring 1999 - 2012 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 and 09 year classes were the weakest recorded (Tables 17 and 21; Figs. 28 and 33). Even though the 04 – 07 year classes appear strong, there is a downward trend in that portion of the series. Similar to the autumn times series, the 98 and 04 – 06 year classes appeared strong in the spring time series. (Tables 16 and 21; Figs. 27 and 33). The spring time series shows a downward trend in abundances of age 2 animals from the 05-08 cohorts with 08- 10 being the weakest in the time series.

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 and 2011 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 1999, 2004 and 2012 indices were the lowest in the time series, 2007 and 2008 were the highest while all other indices were average (Table 22; Fig. 33).

Figure 34 presents the relationship between spring and autumn recruitment indices using either modal analysis or size class method. When the autumn recruitment index is predicted from spring index, 60 and 38 percent of the variance are accounted for in the relationships for modal and size class methods respectively.

Figure 35 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 43 percent of the variance was accounted for in the relationship. It is likely that age 2 abundance may not be a good predictor of fishable biomass because we are comparing the abundance from one cohort against abundances from 2 or 3 cohorts combined.

When similar relationships were developed between fishable biomass and recruitment based upon size classes, the within year relationships were the strongest (Fig. 36). The percent variance accounted for based on no lag between fishable biomass and recruitment index were 78 and 80 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 = .63).

Figures 37 – 40 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 = .69)

Large vessel CPUE lagged by one year vs autumn fishable biomass (r^2 = .36)

Small vessel CPUE lagged by one year vs autumn 11.5 – 17 mm recruitment index (r^2= .33) and

Large vessel CPUE lagged by one year vs autumn 11.5 – 17 mm recruitment index (r^2= .35)

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 23). 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 26%. Accordingly, Fishery Commission lowered the TAC to 19 200 t and 12 000 t for the 2011 and 2012 management years respectively. Even though only 14 046 t of shrimp were taken in 2011, the exploitation rate was 25%. Preliminary results indicated that 8 561 t of shrimp were taken by October 2012 resulting in an exploitation rate was 14%. The 2012 exploitation rate index 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 12 000 t quota was to be taken, the exploitation rate index would increase to 20% (Fig. 41).

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 8 600 t in 2013.

Mortality Estimates

Table 24 presents mortality estimates derived from the abundances of age 5+ animals in one year divided by the abundances of age 4+ animals from the previous year as obtained from the modal analysis in Table 17. These data were from the autumn survey time series as it was the longest survey time series. The median survival, and instantaneous rates of total, fishing and natural mortality are 0.49, 0.72, 0.19 and 0.63 respectively (Table 24). As demonstrated in table 24, an instantaneous natural mortality rate of 0.63 is relates to an annual mortality rate of 0.47 which reasonable as it would allow the animals to survive at least 6 years which fits the demographics presented in tables 16 and 17. These mortality rates are within the range of values presented in Shumway (1985) and Bergström (2000).

Table 25 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 observer 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 0.38, 0.62 (annual mortality = 0.46) and 0.99 respectively (Table 25).

Figure 42 provides the Lorenzen mortality curve of instantaneous natural mortality as well as annual natural mortality for shrimp over the size range 5 mm – 35.5 mm. The annual natural mortality decreases in a linear fashion from 0.99 for the smallest animals to 0.67 for the largest. It must be noted that the annual mortality estimates from the first two methods were very similar (0.46 – 0.47) and included fishing mortality. However, the Lorenzen mortality estimator for annual mortality was also 0.47 but it did not include fishing mortality.

Von Bertalanffy Growth Curve Model

Figure 43 provides the 3LNO Northern shrimp von Bertalanffy growth curve model using autumn survey data. The L_{∞} is estimated to be 35.5 mm with a t_o of -1.055 mm and a Brody growth coefficient of 0.173. These values are within the range of values provided by Shumway (1985) and Bergström (2000).

Precautionary Approach

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Figure 44 presents the precautionary plot of exploitation rate on the ordinate axis and female spawning stock biomass on the abscissa. The lower 95% confidence interval of the 2011 female spawning stock biomass is above but close to the B_{Lim} giving reason for concern.

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.

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.

The autumn 2011 3LNO biomass index was estimated to be 73 500 t which was similar to the autumn 2011 index which was estimated to be 75 100 t. The spring 2012 biomass index was estimated to be 58 500 t which was a 16% decrease since 2011 when the biomass index was estimated to be 69 900 t.

The autumn 2011 3LNO female spawning stock biomass (SSB) index was estimated to be 35 600 t, which was similar to the 2010 autumn index which was estimated to be 35 900 t which is above the Blim limit reference point which is at 19 300 t. The spring SSB index decreased by 15% from 32 800 t in 2011 to 28 000 t in 2012.

The autumn 3LNO fishable biomass index was estimated to be 61 500 t in 2011, an increase of 6% from 57 900 t in 2010. The spring fishable biomass index decreased by 16% from 56 300 t in 2011 to 47 400 t in 2012.

It is important to note that spring and autumn biomass indices have dropped significantly since 2007 and are now at pre-2002 levels.

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 2002 and October 2012.

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Canada	5,402[1]	9,953[1]	10,313[1]	11,495[1]	17,996[1]	18,027[1]	20,147[1]	19,885[1]	13,212[1]	8,246[10]	7,867[2]	
Cuba	70[1]	81[1]	145[3]	136[1]	239[1]	240[1]	207[3]	334[3]	.	.		
Estonia	450[5]	299[5]	271[5]	569[5]	1,098[5]	1,453[5]	1,452[1]	1,607[1]	2,001[5]	1,336[5]	321[5]	
European Union											134[3]	
Faroe Islands	620[4]	25[1]	1,050[1]	1,055[1]	1,521[1]	1,798[1]	2,273[1]	2,949[1]	2,503[10]	1,446[10]	239[3]	
Germany										301[1]		
Iceland	54[1]	133[1]	104[10]	140[1]	226[7]				184[1]	126[10]		
Latvia	59[1]	144[1]	143[1]	144[1]	244[1]	310[1]	278[1]	330[1]	384[1]	325[1]		
Lithuania	67[10]	142[1]	144[1]	216[1]	486[1]	245[1]	278[1]		340[10]			
Norway	78[1]	145[8]	165[8]	144[8]	272[8]	250[8]	345[1]	664[1]	320[1]			
Poland		145[1]	144[1]	129[1]	245							
Portugal								329[1]	15[1]			
Russia	67[1]		141[1]	146[10]	248[10]	112[10]	278[10]	335[1]	28[1]			
Spain		151[1]	140[1]	154[1]	305[4]	190[1]	187[1]	272[1]	347[1]	292[1]		
St. Pierre and Miquelon	36[1]	144[1]				245[1]	278[1]	334[1]	334[1]			
Ukraine		144[1]	145[1]		121[1]							
United States	57[1]	144[1]		136[1]	245[1]	245[1]	278[3]		334[1]	214[3]		
West Greenland		671[1]	299[1]	311[1]	453[9]	455[9]	648[9]	488[9]	534[9]			
Estimated additional catch					2,000							
Total catch	6,960	12,321	13,204	14,775	25,696	23,570	26,649	27,527	20,536	12,286	8,561	
TAC (tonnes)	6,000	13,000	13,000	13,000	22,000	22,000	25,000	30,000	30,000	19,200	12,000	8 600

Sources:

[1] NAFO Statlant21B
[2] Canadian Atlantic Quota Report
[3] NAFO monthly records of provisional catch
[4] Observer datasets
[5] Estonian logbook data
[6] Canadian surveillance reports
[7] Icelandic logbook data
[8] Norwegian logbook data
[9] Greenlandic logbook data
[10] NAFO Statlant21A

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 2001 – 2012. (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 2001 values.

The GLM Procedure

Class Level Information

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

Number of Observations Read 189

Number of Observations Used 189

Dependent Variable: lncpue

Weight: wfactor

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	14999.00753	714.23845	36.81	<.0001
Error	167	3240.04186	19.40145		
Corrected Total	188	18239.04939			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.822357	71.70555	4.404708	6.142771

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	11	11807.81714	1073.43792	55.33	<.0001
month	8	2542.93073	317.86634	16.38	<.0001
size_class	2	648.25966	324.12983	16.71	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	11	9471.535913	861.048719	44.38	<.0001
month	8	2776.231539	347.028942	17.89	<.0001
size_class	2	648.259660	324.129830	16.71	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		6.034623009 B	0.07020117	85.96	<.0001
Year	2002	0.076324096 B	0.08178252	0.93	0.3520
Year	2003	0.223491327 B	0.07256810	3.08	0.0024
Year	2004	0.341399364 B	0.08047038	4.24	<.0001
Year	2005	0.722220409 B	0.08360363	8.64	<.0001
Year	2006	0.586514169 B	0.07541362	7.78	<.0001
Year	2007	0.440332742 B	0.07353976	5.99	<.0001
Year	2008	0.514421537 B	0.07365343	6.98	<.0001
Year	2009	0.329556296 B	0.07015193	4.70	<.0001
Year	2010	0.078790527 B	0.07329689	1.07	0.2839
Year	2011	-0.064584742 B	0.07448489	-0.87	0.3871
Year	2012	-0.119650086 B	0.07776661	-1.54	0.1258
Year	2013	0.000000000 B	.	.	.

(Table 2 continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Month	4	-0.213920142 B	0.07550626	-2.83	0.0052
Month	5	-0.312966466 B	0.04027893	-7.77	<.0001
Month	6	-0.075849670 B	0.03132239	-2.42	0.0165
Month	8	-0.077814566 B	0.03158034	-2.46	0.0148
Month	9	-0.326132594 B	0.04491398	-7.26	<.0001
Month	10	-0.461808471 B	0.05803424	-7.96	<.0001
Month	11	-0.424564406 B	0.08678462	-4.89	<.0001
Month	12	-0.908556160 B	0.33156542	-2.74	0.0068
Month	99	0.000000000 B	.	.	.
size_class	1	-0.179266751 B	0.04288416	-4.18	<.0001
size_class	2	-0.112698658 B	0.02408424	-4.68	<.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	95% Confidence Limits	
2002	5.702335	5.567972	5.836698
2003	5.849502	5.738815	5.960190
2004	5.967410	5.846478	6.088342
2005	6.348231	6.219474	6.476989
2006	6.212525	6.104063	6.320987
2007	6.066344	5.963080	6.169607
2008	6.140432	6.037514	6.243351
2009	5.955567	5.858594	6.052540
2010	5.704801	5.600213	5.809389
2011	5.561426	5.459023	5.663829
2012	5.506361	5.391289	5.621432
2013	5.626011	5.479244	5.77277

Table 3. Catch rate indices for **Canadian small vessels** (<=500 t; <65') fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2001 – 2012. All data were standardized to class 3 vessels, July and 2001 values.

YEAR	TAC (t)	[1] FLEET CATCH (t)	[2] PERCENT OF CATCH DATA CPUE	UNSTANDARDIZED Geometric mean CPUE) (KG/HR)	CPUE RELATIVE TO 2001	[3] EFFORT (HR)	STANDARDIZED CPUE RELATIVE TO 2001	MODELLED CPUE (KG/HR)	EFFORT (HRS)
1999		17	CPUE model begins in 2001						
2000	2,500	3,422							
2001	2,500	2,674	58.1%	304	1.000	8,808	1.000	278	9,634
2002	2,500	4,226	58.9%	339	1.116	12,468	1.079	300	14,107
2003	6,566	6,663	79.9%	377	1.243	17,655	1.250	347	19,198
2004	6,566	6,517	85.1%	515	1.697	12,650	1.407	390	16,689
2005	6,566	7,186	86.5%	727	2.394	9,888	2.059	571	12,574
2006	12,297	12,159	78.3%	609	2.005	19,976	1.798	499	24,369
2007	12,297	12,576	88.2%	546	1.798	23,041	1.553	431	29,172
2008	14,209	14,933	89.5%	602	1.982	24,813	1.673	464	32,166
2009	14,209	13,944	94.3%	438	1.442	31,842	1.390	386	36,134
2010	17,369	8,857	82.5%	358	1.178	24,762	1.082	300	29,493
2011	10,514	6,506	95.5%	306	1.008	21,259	0.937	260	25,004
2012	5,985	6,143	73.9%	316	1.040	19,448	0.887	246	24,946

[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 2001 – 2012. (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).

The GLM Procedure

Class Level Information

Class	Levels	Values
year	12	2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
month	12	1 2 3 4 5 6 7 8 9 10 11 12
CFV	14	
gear	2	66 99 (66 = double trawl; 99 = single trawl)

Number of Observations Read	198
Number of Observations Used	198

Dependent Variable: lncpue

Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	36	3600.947269	100.026313	10.20	<.0001
Error	161	1578.825325	9.806368		
Corrected Total	197	5179.772594			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.695194	43.28000	3.131512	7.235472

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	11	1872.263258	170.205751	17.36	<.0001
month	11	837.208127	76.109830	7.76	<.0001
CFV	13	566.984904	43.614223	4.45	<.0001
gear	1	324.490981	324.490981	33.09	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	11	1246.225425	113.293220	11.55	<.0001
month	11	908.010851	82.546441	8.42	<.0001
CFV	13	495.570774	38.120829	3.89	<.0001
gear	1	324.490981	324.490981	33.09	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.329073011	B	0.18537237	34.14	<.0001
year	2002	0.274863852	B	0.18138402	1.52	0.1316
year	2003	0.844039699	B	0.18550805	4.55	<.0001
year	2004	0.123169822	B	0.16251107	0.76	0.4496
year	2005	0.117925387	B	0.16135535	0.73	0.4659
year	2006	0.248705932	B	0.16390393	1.52	0.1311
year	2007	0.197572146	B	0.15916346	1.24	0.2163
year	2008	0.147057816	B	0.16575684	0.89	0.3763
year	2009	0.386549844	B	0.16580431	2.33	0.0210
year	2010	-0.088014090	B	0.16056267	-0.55	0.5843
year	2011	-0.574284120	B	0.18658206	-3.08	0.0025
year	2012	-1.083200066	B	0.21541129	-5.03	<.0001
year	2013	0.000000000	B	.	.	.

(Table 4. Continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
month	1	0.846401956 B	0.10085352	8.39	<.0001
month	2	0.783898823 B	0.11025237	7.11	<.0001
month	3	0.533430174 B	0.10180243	5.24	<.0001
month	4	0.490844593 B	0.12918380	3.80	0.0002
month	5	0.562991203 B	0.13972531	4.03	<.0001
month	6	0.436179308 B	0.12207598	3.57	0.0005
month	7	0.436292736 B	0.15612583	2.79	0.0058
month	8	0.376569108 B	0.19587494	1.92	0.0563
month	9	0.174439750 B	0.22572250	0.77	0.4408
month	10	0.165827278 B	0.10885501	1.52	0.1296
month	11	0.084247651 B	0.11303244	0.75	0.4572
month	12	0.000000000 B	.	.	.
gear	66	0.413672727 B	0.07191338	5.75	<.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.

year	lncpue LSMEAN	95% Confidence Limits	
2002	7.487463	7.195876	7.779049
2003	8.056638	7.763277	8.350000
2004	7.335768	7.099681	7.571856
2005	7.330524	7.118449	7.542599
2006	7.461305	7.251873	7.670737
2007	7.410171	7.238119	7.582223
2008	7.359656	7.173748	7.545565
2009	7.599149	7.415697	7.782601
2010	7.124585	6.946799	7.302370
2011	6.638315	6.423997	6.852632
2012	6.129399	5.826504	6.432293
2013	7.212599	6.938646	7.486551

gear	lncpue LSMEAN	95% Confidence Limits	
66	7.468967	7.329215	7.608720
99	7.055294	6.952773	7.157816

Table 5. Catch rate indices for **Canadian large vessels** (>500 t) fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2001 – 2012.

YEAR	TAC	CATCH[1] (t)	PERCENT OF CATCH DATA CAPTURED IN MODEL[2]	UNSTANDARDIZED GEOMETRIC MEAN CPUE (KG/HR)	CPUE RELATIVE TO 2000	EFFORT[3] (HR)	STANDARDIZED CPUE RELATIVE To 2000	MODELLED CPUE	EFFORT (HRS)
2000	1,686	960	Model begins with 2001 data						
2001	2,500	2,336	60%	1,010	1.000	2,313	1.000	1,356	1,722
2002	2,500	1,176	122%	1,542	1.527	763	1.316	1,786	659
2003	4,267	4,038	72%	3,749	3.712	1,077	2.326	3,155	1,280
2004	4,267	3,796	75%	1,214	1.202	3,128	1.131	1,534	2,474
2005	4,277	4,224	72%	1,511	1.496	2,796	1.125	1,526	2,768
2006	5,273	5,835	44%	578	0.572	10,099	1.282	1,739	3,355
2007	5,907	5,451	92%	1,061	1.051	5,137	1.218	1,653	3,298
2008	6,568	5,214	86%	1,560	1.545	3,342	1.158	1,571	3,318
2009	6,022	5,941	88%	1,100	1.089	5,403	1.472	1,996	2,976
2010	7,594	4,355	107%	821	0.813	5,303	0.916	1,242	3,506
2011	5,480	2,439	110%	611	0.605	3,994	0.563	764	3,194
2012	4,015	1,678	87%	409	0.405	4,100	0.339	459	3,654

[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 (2001 – 2012). (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											
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
		.	.	.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM												
91	371	.	.	.	.	.	.	0.41	.	.	.	.	.
183	348	.	.	.	.	.	0.88	0.42	0.43	.	.	.	.
	349	.	.	.	.	.	.	.	0.51	0.43	.	.	.
	364	.	.	.	.	.	.	0.95	.	.	.	.	.
	365	.	.	.	.	.	0.55	.	.	.	.	.	.
	370	.	.	.	.	0.65	0.64	0.46	.	0.31	.	0.4	.
	385	.	.	0.34	0.7	.	.	0.44	0.6	0.48	0.34	0.38	0.24
274	344	.	.	.	.	.	.	.	.	.	.	0.32	0.37
	347	.	.	.	.	.	.	.	.	0.01	.	.	.
	366	.	.	0.45	0.47	.	0.79	1	.	0.28	.	0.37	.
	369	.	.	.	0.53	0.74	0.52	0.52	0.39	0.44	0.28	0.23	0.32
	386	0.39	1.1	0.53	0.58	0.9	0.87	0.63	0.71	0.54	0.43	0.38	0.36
	389	.	.	.	0.48	0.9	0.9	0.64	0.95	0.65	0.46	0.41	0.37
366	345	.	.	0.53	0.62	0.37	0.8	0.72	0.72	0.53	0.51	0.44	0.36
	346	0.29	0.45	0.43	0.58	0.77	0.73	0.72	0.74	0.47	0.4	0.37	0.39
	368	0.32	0.34	0.48	0.52	0.71	0.66	0.47	0.32	0.51	0.39	0.24	0.32
	387	0.45	0.45	0.45	0.56	0.78	0.72	0.57	0.53	0.46	0.57	0.47	0.3
	388	.	.	.	.	.	.	.	1.54	0.58	0.52	0.35	0.41
400	638	.	.	.	.	.	0.61	.	.	.	.	0.46	.
549	731	.	.	.	.	.	.	1.23	0.58	0.41	0.56	0.26	.
	733	1.05	.	0.25	0.39	0.65	0.57	0.5	0.56	0.39	0.34	0.34	0.31
	735	.	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	.	.	0.25	.
Overall mean		0.46	0.65	0.43	0.57	0.7	0.72	0.64	0.6	0.42	0.42	0.38	0.33

B) Index Strata

Small vessel Shrimp Index Strata Mean CPUE (t/hr)		year									
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
		.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM										
274	386	0.53	0.58	0.9	0.87	0.63	0.71	0.54	0.43	0.38	0.36
366	345	0.53	0.62	0.37	0.8	0.72	0.72	0.53	0.51	0.44	0.36
	346	0.43	0.58	0.77	0.73	0.72	0.74	0.47	0.4	0.37	0.39
	368	0.48	0.52	0.71	0.66	0.47	0.32	0.51	0.39	0.24	0.32
	387	0.45	0.56	0.78	0.72	0.57	0.53	0.46	0.57	0.47	0.3
549	733	0.25	0.39	0.65	0.57	0.5	0.56	0.39	0.34	0.34	0.31
Overall mean		0.47	0.57	0.66	0.76	0.64	0.65	0.5	0.46	0.4	0.35

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 – 2012). These analyses were limited to index strata. The analysis was limited to the period April – August of each year.

Year	Commercial Data			Mean	Number
	Lower 95% C.I.	Biomass estimate (t)	Upper 95% C.I.	(t/hr)	Sets
2003	26,256	32,251	32,251	0.47	613
2004	3,995	66,585	66,585	0.57	1,351
2005	34,571	47,860	47,860	0.66	1,180
2006	43,892	50,197	50,197	0.76	1,777
2007	37,223	42,182	42,182	0.64	1,801
2008	34,509	46,003	46,003	0.65	2,298
2009	28,796	32,666	32,666	0.50	3,777
2010	25,574	31,475	31,475	0.46	2,549
2011	21,472	27,825	27,825	0.40	3,071
2012	17,092	25,874	25,874	0.35	2,702

Table 8. Trends in northern shrimp mean catch (t/hr) per stratum and year using standardized large vessel (>500 t) observed catch information (2000 – 2012). (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	2012
		.	.	.	.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM													
274	366	1.14	0.5	.	.	.	.	.	.	.	.	.	.	.
	369	.	.	.	.	.	.	1.94	.	1.84	.	.	.	.
	386	.	.	.	.	.	1.6	2.15	2.24	2.12	2.32	.	0.89	0.87
	389	.	.	.	.	.	.	.	.	.	.	.	0.2	0.41
366	345	0.25	.	.	.	.	.	.	.	.	.	.	.	.
	346	0.92	.	.	.	.	.	.	.	.	.	.	0.44	.
	368	0.97	0.45	.	.	.	.	1.6	.	1.94	.	.	1.2	0.15
	387	0.63	1.5	2.12	2.58	2.3	2.52	2.39	2.45	2.06	2.25	2.32	1.67	0.39
400	638	1.08	.	.	.	.	.	.	.	.	.	.	.	.
549	733	.	1.62	2.34	2.82	2.54	2.53	3.3	2.82	2.36	.	.	1.84	.
731	734	.	.	.	.	.	2.28	.	.	.	.	.	.	.

Table 9. Multiplicative year and month model for Faroese (> 500 t) vessels fishing northern shrimp (Pandalus borealis) in NAFO Division 3L Regulatory Area (NRA) over the period 2001 – 2010. (Statlant 21B data weighting by effort).

The GLM Procedure

Class Level Information

Class	Levels	Values
Year	10	2002 2003 2004 2005 2006 2007 2008 2009 2010 2013
month	12	1 2 3 4 5 6 7 8 9 10 11 12

Number of Observations Read	62
Number of Observations Used	62

Dependent Variable: lncpue

Weight: hrs

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	9829.65521	491.48276	5.22	<.0001
Error	41	3858.01275	94.09787		
Corrected Total	61	13687.66796			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.718140	-826.9558	9.700406	-1.173026

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	9	5943.281500	660.364611	7.02	<.0001
month	11	3886.373707	353.306701	3.75	0.0009

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	9	6528.942462	725.438051	7.71	<.0001
month	11	3886.373707	353.306701	3.75	0.0009

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		-2.732589859 B	0.43791993	-6.24	<.0001
Year	2002	-0.769675296 B	0.50963662	-1.51	0.1387
Year	2003	1.132532046 B	1.24379211	0.91	0.3679
Year	2004	2.070190523 B	0.52474057	3.95	0.0003
Year	2005	1.493092064 B	0.45210992	3.30	0.0020
Year	2006	1.391556097 B	0.43332998	3.21	0.0026
Year	2007	1.770453034 B	0.46190342	3.83	0.0004
Year	2008	1.874662995 B	0.60432891	3.10	0.0035
Year	2009	1.473242481 B	0.43709443	3.37	0.0016
Year	2010	2.237902727 B	0.65355149	3.42	0.0014
Year	2013	0.000000000 B	.	.	.

Table 9 (Continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
month	1	-0.141510891 B	0.25572381	-0.55	0.5830
month	2	-0.102117455 B	0.30757397	-0.33	0.7416
month	3	0.749841609 B	0.32640904	2.30	0.0268
month	4	0.507608782 B	0.46933324	1.08	0.2858
month	5	-2.361301049 B	0.69806828	-3.38	0.0016
month	6	0.082370013 B	0.69558482	0.12	0.9063
month	7	0.544294641 B	0.34024511	1.60	0.1173
month	8	0.931332739 B	0.33301573	2.80	0.0078
month	9	0.949558205 B	0.29898823	3.18	0.0028
month	10	-0.001014809 B	0.31317699	-0.00	0.9974
month	11	-0.048626391 B	0.26782340	-0.18	0.8568
month	12	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

Year	lncpue LSMEAN	95% Confidence Limits	
2002	-3.409729	-4.066788	-2.752669
2003	-1.507522	-3.879607	0.864564
2004	-0.569863	-1.208997	0.069271
2005	-1.146962	-1.606508	-0.687415
2006	-1.248497	-1.636674	-0.860321
2007	-0.869601	-1.342151	-0.397050
2008	-0.765391	-1.669868	0.139087
2009	-1.166811	-1.504793	-0.828829
2010	-0.402151	-1.358332	0.554030
2013	-2.640054	-3.472160	-1.807947

Table 10. Standardized catch rate indices were produced from Faroese Statlant21B data. These data were standardized by year and month over the period 2001 – 10 and unstandardized catch rate indices for non Canadian vessels fishing northern shrimp in the NAFO Division 3L NRA over the period 2000 – 2012. The unstandardized indices included data from Estonia, Greenland, Iceland, Norway, Spain, and Russia.

A) Faroese unstandardized and model CPUE from Statlant21B data

		UNSTANDARDIZED			STANDARDIZED		
YEAR	CATCH (T)	GEOMETRIC MEAN CPUE (KG/HR)	CPUE RELATIVE TO 2000	EFFORT (HR)	CPUE RELATIVE TO 2000	MODELED CPUE (KG/HR)	EFFORT (HR)
2001	157	242	1.00	648	1.00	71	2,200
2002	122	179	0.74	681	0.46	33	3,691
2003	26	365	1.51	71	3.10	221	117
2004	1051	501	2.07	2,097	7.93	566	1,858
2005	1054	327	1.35	3,220	4.45	318	3,319
2006	1521	401	1.66	3,790	4.02	287	5,301
2007	1798	499	2.06	3,604	5.87	419	4,290
2008	208	400	1.65	521	6.52	465	447
2009	2949	400	1.65	7,376	4.36	311	9,471
2010	667	547	2.26	1,219	9.37	669	997

B) All non Canadian vessel unstandardized CPUE data provided by researchers

				UNSTANDARDIZED		
YEAR	**TAC**	**CATCH (t)**	**PERCENT OF CATCH CAPTURED IN DATASET**	**CPUE (KG/HR)**	**CPUE RELATIVE TO 2000**	**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	1,558	4	650	0.871	2,399
2003	2,167	2,368	45	724	0.971	3,271
2004	2,167	2,891	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	6,502	17	1,122	1.504	5,796
2009	5,100	7,695	19	1,264	1.694	6,090
2010	4,676	7,324	33	1,175	1.575	6,236
2011	3,206	5,801	30	640	0.858	9,063
2012	2,200	939	34	625	0.838	1,503

Table 11. 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 – 2012. (Offshore strata only with standard 15 min. tows).

Spring

Year	Biomass (tons)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	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
2012	32,338	58,495	88,468	7,040	12,387	18,737	289

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 14 and 15; Figs. 22 and 23).

Autumn

Year	Biomass (tonnes)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
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
2011	51,578	73,496	94,720	10,853	15,298	19,270	261

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

Table 12. 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 – 2012). (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	2012
		.	.	.	.	.	.	.	.	.	.	.	.	.	.
Depth Range (m)	STRATUM	0	0	0	0	0.02	0	0	0	0.01	0.01	0	0	0	0
57 - 92	350														
	363	0	0	0	0	0.02	0	0	0	0	0.07	0	0	0	0
	371	0	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	0
	384	0.01	0	0	0.02	0	0	0	0	0	0	0	0.01	0	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	0
	341	0.01	0.03	0	0.02	0.02	0.25	0	0	0.01	0.02	0	0.01	0	0
	342	0.04	0.01	0	0.09	0.02	0.06	0.01	0	0.11	0	0.08	0.04	0	0
	343	0.04	0	0.08	0	0.03	0.06	0.03	0.01	0.11	0.02	0.08	.	0	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	2.02
	349	0.03	0.01	0	0.01	0.02	0.03	0	0.03	0	0.01	0.01	0.18	0.03	0
	364	0	0.01	0.02	0.03	0.02	0	0	0	0	0	0	0.02	0	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	0
	370	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0
	385	0	0	0.02	0.06	0	0.03	0	0	0.09	130.4	0.01	0.03	0	0
	390	0.01	0.01	0.01	0.01	0	0.04	0.11	0	0	0	0.02	0	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	0
	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	16.29
	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	63.17
	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	56.36
	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	37.38
	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	0.09
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	164.2
	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	19.08
	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	9.41
	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	49.25
	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	7.17
	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	0.17
367 - 549	729	0	0.27	0.58	0.08	12.41	0.1	4.25	11.39	0.03	5.92	0	.	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	0.95
	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	3.58
	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	0.36
550 - 731	730	0	0.04	0	0.02	0.05	0.01	0	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	.	0.06
	734	0.11	0	2.35	0.21	0.03	0	0	0.04	0.09	.	0	0	0	0.98
	736	0.11	0.1	0.29	0.25	0.38	0	0	0	0.11	0.62	0	0	0	0.07

Table 13. 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 – 2011). (Green=<40 kg/tow; 40kg/tow<White<=100 kg/tow.; 100 kg/tow< Pink; Black= not sampled).

Survey Fall SFA 7 Shrimp Mean (kg/15 min. tow)		YEAR															
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	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	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	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	0
	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	0.03
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	0.01
	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	0
	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	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	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	10.77
	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	0
	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	0.04
	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	3.03
	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	2.5
	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	6.82
	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	0.38
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	14.74
	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	17.14
	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	17.91
	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	65.23
	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	186.5
	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	10.32
	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	0.03
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	66.74
	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	26.76
	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	0.73
	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	58.11
	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	64.87
	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	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	0.01
	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	0.13
	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	0.27
550 - 731	730	0.04	0.02	0	0	0	0.04	0	0	0	1.18	0.02	0	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	0.17
	734	0	0.02	0	0.01	0	0.04	0.26	0	.	0.03	0	0.03	0	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	0.36
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	.
Overall mean		0.34	1.82	1.63	1.56	2.78	29.82	33.04	34.25	4.32	25.59	14.17	48.80	43.03	15.09	2.85	3.92

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 1999 – 2012 **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			3 year running
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	average percent biomass in NRA
Spring	1999	3L	47,823	96.15	10,269	86.44	2147	
Spring	2000	3L	109,439	95.94	23,962	87.18	2190	
Spring	2001	3L	83,262	97.07	11,478	99.13	13.78	19.05
Spring	2002	3L	128,971	95.74	34,533	9147	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	2012	3L	58,495	100.00	3,624	100.00	17.83	25.18
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	6133
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	7143	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	2012	3N	101	0.17	101	2.70	100.00	50.00
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	1007	???	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
Spring	2012	3O	0	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	2187
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	1124	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	2171
Spring	2009		113,265	98.58	36,950	100.00	32.62	25.35
Spring	2010		131589	99.62	42,286	100.00	32.13	26.75
Spring	2011		69,872	99.57	12,384	100.00	17.72	27.49
Spring	2012		58,495	100.17	3,725	2.70	6.37	18.74

Table 15. NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1996 – 2011 **autumn** Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min. tows). All indices were estimated using Ogmap calculations.

			Entire Division		Outside 200 Nmi limit			
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1996	3L	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	2011	3L	72,590	98.77	7,853	97.50	10.82	12.74
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	2011	3N	503	0.68	201	2.50	40.00	41.11
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
Autumn	2011	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
Autumn	2011		73,496	99	8,054	100	10.96	12.84

Table 16. 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 – 2012). Abundance at length determined using Ogmap calculations.

NAFO Divisions 3LNO
Mean Carapace Length (Standard Error)

Year	Male Age						Female Age		
	0	1	2	3	4	5	4	5	6
1999		12.43 (.454)	14.63 (.055)	18.15 (.069)	20.51 (.053)		19.20 (.280)	22.54 (.122)	24.45 (.580)
2000		8.73 (.044)	14.22 (.034)	18.00 (.024)	20.74 (.070)		20.44 (.216)	23.27 (.032)	25.80 (.419)
2001		8.39 (.131)	13.45 (.027)	16.82 (.008)	19.13 (.024)		20.84 (.17)	23.26 (.16)	26.15 (.41)
2002		8.27 (.061)	12.85 (.029)	16.97 (.021)	19.43 (.018)		21.50 (.042)	23.52 (.38)	26.59 (.119)
2003		8.37 (.065)	13.09 (.003)	16.01 (.091)	17.96 (.086)	19.69 (.040)	20.55 (.92)	21.69 (.041)	23.40 (.052)
2004		8.55 (.288)	13.66 (.094)	17.13 (.299)	18.47 (.090)	19.96 (.026)	20.09 (.154)	22.18 (.034)	24.06 (.041)
2005		8.93 9.078)	14.10 (.052)	17.07 (.130)	18.69 (.212)	20.59 (.088)	21.0 (.276)	22.69 (.044)	24.36 (.061)
2006		9.57 (.148)	13.84 (.019)	17.53 (.189)	18.83 (.412)	20.52 (.054)	19.58 (.107)	23.05 (.049)	24.55 (.054)
2007		9.37 (.157)	13.48 (.018)	16.89 (.025)	19.46 (.063)	21.08 (.041)		23.04 (.086)	25.17 (.290)
2008		8.85 (.072)	13.39 (.032)	16.14 (.036)	18.46 (.038)	20.78 (.038)	19.88 (.093)	22.81 (.043)	25.35 (.172)
2009			11.87 (.037)	15.67 (.058)	18.20 (.070)	20.12 (.059)	19.89 (.153)	22.56 (.033)	25.27 (.061)
2010		9.35 (.086)	13.54 (.053)	16.16 (.042)	18.43 (.042)	20.25 (.064)	21.73 (.118)	23.27 (.135)	25.54 (.096)
2011		11.32 (.115)	13.10 (.066)	15.25 (.066)	17.53 (.067)	19.74 (.052)		22.86 (.038)	25.24 (.092)
2012			12.21 (.096)	14.64 (.119)	17.11 (.117)	19.78 (.044)		23.17 (.043)	25.56 (.176)

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

Year	Male Age							Female Age			
	0	1	2	3	4	5	Total	4	5	6	Total
1999		.067 (.024)	.389 (.026)	.165 (.015)	.379 (.014)		1.0	.020 (.006)	.855 (.098)	.125 (.095)	1.0
2000		.023 (.001)	.353 (.006)	.454 (.012)	.170 (.008)		1.0	.042 (.010)	.933 (.019)	.025 (.014)	1.0
2001		.006 (.001)	.201 (.004)	.294 (.008)	.499 (.009)		1.0	.209 (.090)	.765 (.119)	.026 (.032)	1.0
2002		.018 (.001)	.100 (.002)	.399 (.006)	.482 (.006)		1.0	.737 (.066)	.256 (.070)	.007 (.004)	1.0
2003		.013 (.001)	.131 (.003)	.137 (.010)	.304 (.013)	.415 (.017)	1.0	.125 (.032)	.735 (.029)	.140 (.010)	1.0
2004		.004 (.001)	.129 (.007)	.150 (.050)	.119 (.051)	.598 (.014)	1.0	0.035 (.007)	.603 (.013)	.362 (.014)	1.0
2005		.017 (.001)	.162 (.006)	.352 (.042)	.272 (.037)	.197 (.020)	1.0	.029 (.017)	.668 (.016)	.303 (.018)	1.0
2006		.005 (.001)	.303 (.004)	.188 (.052)	.147 (.043)	.357 (.025)	1.0	.016 (.002)	.514 (.025)	.470 (.026)	1.0
2007		.003 (.000)	.196 (.003)	.325 (.005)	.255 (.010)	.221 (.011)	1.0		.735 (.065)	.265 (.065)	1.0
2008		.011 (.001)	.140 (.003)	.336 (.006)	.372 (.006)	.141 (.005)	1.0	.042 (.005)	.740 (.033)	.218 (.029)	1.0
2009			.109 (.003)	.227 (.009)	.403 (.070)	.261 (.016)	1.0	.051 (.009)	.757 (.012)	.192 (.010)	1.0
2010		.003 (.000)	.045 (.003)	.302 (.010)	.324 (.017)	.326 (.020)	1.0	.440 (.052)	.406 (.046)	.154 (.014)	1.0
2011		.015 (.003)	.100 (.005)	.206 (.008)	.343 (.010)	.336 (.013)	1.0		.819 (.018)	.181 (.018)	1.0
2012			.093 (.008)	.216 (.011)	.265 (.011)	.426 (.012)	1.0		.887 (.021)	.113 (.021)	1.0

Table 16 (Continued)

Distributional Sigmas (Standard Error and constraints)

Year	Male Age						Female Age		
	0	1	2	3	4	5	4	5	6
1999		1.130 (.186)	.912 (.040)	.769 (.059)	.998 (.031)		.727 (.206)	.959 (.072)	.864 (.199)
2000		.708 (.036)	1.317 (.026)	.917 (.026)	1.023 (.038)		1.249 (.031) Sigmas Eq.		
2001	1.063 (.012) Sigmas Eq.						.818 (.113)	1.419 (.215)	.612 (.354
2002	1.064 (.009) Sigmas Eq.						.824 (.024)	1.275 (.225)	.362 (.146)
2003	1.011 (.015) Sigmas Eq.						.764 (.0235) Sigmas Eq.		
2004		1.086 (.220)	1.314 (.070)	.888 (.192)	.540 (.096)	1.00 (Fixed)	0.861 (.0203) Sigmas Eq.		
2005	1.094 (.025) Sigmas Eq.						.812 (.022)	.887 (.022)	.953 (.022)
2006	1.029 (.014) Sigmas Eq.						.890 (.019)	1.047 (.019)	1.115 (.019)
2007	1.028 (.010) Sigmas Eq.							1.237 (.028)	1.335 (.088)
2008	1.054 (.013) Sigmas Eq.						.679 (.049)	1.101 (.037)	1.205 (.064)
2009	1.135 (.018) Sigmas Eq.						1.1854 (.023) Sigmas Eq		
2010		.562 (CV=.012)	.814(CV=.0123)	.971(CV=.0123)	1.107(CV=.0123)	1.217(CV=.0123)	1.105 (.041) Sigmas Eq.		
2011		.650 (CV=.016)	.752 (CV=.016)	.876 (CV=.016)	1.001 (CV=.016)	1.133 (CV=.016)	1.148 (.023) Sigmas Eq.		
2012	1.1382 (.0237) Sigmas Eq.							1.201 (.026)	1.328 (.026)

Population at Age Estimates (10^6)

Year	Male Ages						Female Ages			Total
	0	1	2	3	4	5	4	5	6	
1999	57	635	3,377	1,432	3,304	0	45	2,066	561	11,477
2000	0	337	5,251	6,747	2,540	13	285	6,151	169	21,492
2001	0	93	3,034	4,444	7,566	18	1,038	3,505	134	19,832
2002	0	419	2,274	9,037	10,922	0	6,514	2,233	61	31,460
2003	0	342	3,496	3,658	8,093	11,065	906	8,449	3,212	39,221
2004	0	48	1,597	1,858	1,478	7,399	219	3,407	2,102	18,108
2005	0	252	2,415	5,249	4,062	2,942	383	7,059	3,384	25,743
2006	4	133	6,331	3,923	3,069	7,683	358	6,673	6,162	34,336
2007	0	93	6,638	11,014	8,658	7,525	64	18,510	6,812	59,314
2008	16	365	4,093	9,809	10,849	4,143	833	12,493	3,684	46,286
2009	0	8	1,763	3,660	6,514	4,206	458	6,393	1,620	24,622
2010	1	50	797	5,323	5,704	5,753	3,921	3,598	1,470	26,617
2011	5	168	1,065	2,187	3,662	3,621	36	3,554	785	15,083
2012	0	32	845	1,885	2,308	3,713	37	3,142	412	12,374

Table 17. 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 – 2011). Abundance at length determined using Ogmap calculations.

Mean Carapace Length (Standard Error)

	Males Age				Females Age		
Year	1	2	3	4	4	5	6
1996	11.19 (.074)	15.92 (.035)	19.32 (.070)	21.44 (.404)	20.52 (.138)	23.08 (.228)	25.44 (.189)
1997	11.01 (.063)	16.11 (.067)	18.83 (.317)	20.01 (1.28)	19.76 (.629)	21.37 (.122)	24.18 (.109)
1998	10.74 (.018)	15.91 (.115)	18.90 (.172)	20.68 (.225)	21.27 (.113)	23.10 (.087)	25.20 (.155)
1999	11.09 (.067)	15.99 (.019)	18.98 (.047)	20.89 (.041)		22.24 (.062)	24.36 (.132)
2000	10.49 (.029)	15.23 (.033)	18.16 (.021)	20.56 (.122)	21.01 (.097)	23.51 (.061)	26.61 (1.11)
2001	10.17 (.043)	15.07 (.026)	17.37 (.038)	19.58 (.018)	20.59 (.101)	22.53 (.092)	24.26 (.094)
2002	10.44 (.032)	14.49 (.021)	17.65 (.014)	20.06 (.014)	21.63 (.045)	23.88 (.096)	25.91 (.519)
2003	10.10 (.034)	15.10 (.030)	18.02 (.065)	19.95 (.030)	18.80 (.074)	22.53 (.036)	25.04 (.182)
2004	Incomplete survey						
2005	10.63 (.028)	14.61 (.075)	17.83 (.052)	20.86 (.095)	20.33 (.175)	23.19 (.047)	25.04 (.139)
2006	10.67 (.019)	14.84 (.019)	17.88 (.123)	19.97 (.029)	20.60 (.109)	23.29 (.039)	25.01 (.067)
2007	11.27 (.040)	15.21 (.023)	17.87 (.023)	20.66(.017)	19.36 (.155)	22.51 (.041)	24.76 (.048)
2008	10.24 (.031)	14.95 (.026)	17.86 (.027)	20.17 (.024)		22.91 (.075)	25.10 (.270)
2009	9.42 (.053)	14.31 (.051)	17.75 (.151)	19.31 (.440)	21.60 (.098)	23.94 (.222)	25.40 (.484)
2010	9.90 (.044)	14.40 (.268)	16.96 (.072)	20.04 (.074)	21.81 (.173)	23.21 (.209)	25.56 (.135)
2011	11.46 (.077)	15.40 (.045)	18.76 (.110)	20.59 (.107)	19.94 (.193)	22.85 (.059)	25.53 (.084)

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

	Male Age					Female Age			
Year	1	2	3	4	Total	4	5	6	Total
1996	.074 (.004)	.635 (.011)	.231 (.036)	.060 (.020)	1.0	.286 (.032)	.387 (.042)	.327 (.047)	1.0
1997	.069 (.003)	.425 (.020)	.331 (.301)	.174 (.289)	1.0	.047 (.063)	.714 (.055)	.239 (.017)	1.0
1998	.234 (.004)	.211 (.016)	.335 (.079)	.220 (.068)	1.0	.230 (.031)	.639 (.029)	.131 (.022)	1.0
1999	.055 (.002)	.546 (.007)	.150 (.011)	.249 (.009)	1.0		.805 (.032)	.195 (.032)	1.0
2000	.061 (.002)	.342 (.007)	.460 (.015)	.137 (.011)	1.0	.289 (.022)	.703 (.022)	.008 (.009)	1.0
2001	.016 (.001)	.185 (.004)	.299 (.006)	.500 (.007)	1.0	.128 (.017)	.501 (.024)	.371 (.032)	1.0
2002	.035 (.010)	.133 (.002)	.468 (.004)	.364 (.004)	1.0	.713 (.028)	.234 (.052)	.053 (.029)	1.0
2003	.047 (.001)	.178 (.004)	.247 (.012)	.528 (.013)	1.0	.018 (.002)	.854 (.022)	.128 (.021)	1.0
2004	Incomplete survey								
2005	.039 (.001)	.097 (.012)	.637 (.036)	.227 (.025)	1.0	.033 (.007)	.848 (.031)	.119 (.029)	1.0
2006	.059 (.001)	.296 (.004)	.161 (.011)	.484 (.013)	1.0	.043 (.005)	.726 (.021)	.231 (.021)	1.0
2007	.035 (.001)	.239 (.004)	.401 (.004)	.325 (.004)	1.0	.020 (.003)	.491 (.014)	.489 (.015)	1.0
2008	.048 (.001)	.195 (.003)	.434 (.005)	.323 (.006)	1.0		.763 (.055)	.237 (.055)	1.0
2009	.028 (.001)	.384 (.010)	.202 (.129)	.386 (.127)	1.0	.405 (.031)	.513 (.058)	.082 (.080)	1.0
2010	.059 (.003)	.233 (.042)	.436 (.050)	.272 (.013)	1.0	.367 (.077)	.408 (.071)	.225 (.024)	1.0
2011	.058 (.003)	.371 (.009)	.373 (.022)	.198 (.026)	1.0	.062 (.011)	.672 (.017)	.267 (.017)	1.0

Table 17 (Continued)

Distributional Sigmas (Standard Error and constraints)

	Male Age				Female Age		
Year	1	2	3	4	4	5	6
1996	1.18 (Fixed)	1.25 (.032)	0.83 (.072)	1.01 (.184)	.976 (.068)	1.100 (.068)	1.210 (.068)
1997	1.150 (.050)	1.043 (.043)	.843 (.167)	1.00 (.0305)	.981 (.040)	1.061 (.040)	1.200 (.040)
1998	0.89 (.014)	1.23 (.071)	0.95 (.128)	0.89 (.068)	.893 (.047)	.970 (.047)	1.058 (.047)
1999	1.231 (.054)	.975 (.017)	.698 (.052)	.997 (fixed)	1.182 (.0335) Sigmas Eq.		
2000	0.90 (.023)	1.11 (.024)	0.84 (.023)	1.20 (.057)	1.316 (.044) Sigmas Eq.		
2001	1.046 (.009) Sigmas Eq.				.958 (.036)	1.048 (.036)	1.129 (.036)
2002	0.97 (.006) Sigmas Eq.				.888 (.022)	.861 (.144)	.936 (.193)
2003	1.12 (.012) Sigmas Eq.				.577 (.056)	1.060 (.024)	1.008 (.077)
2004	Incomplete survey						
2005	0.86 (.022)	0.85 (.044)	1.50 (.086)	1.10 (.036)	1.187 (.032) Sigmas Eq.		
2006	0.80 (CV=.075)	1.11 (CV=.075)	1.34 (CV=.075)	1.49 (CV=.075)	1.023 (.025) Sigmas Eq.		
2007	1.11 (.008) Sigmas Eq.				1.050 (.018)	1.221 (.018)	1.343 (.018)
2008	1.15 (.010) Sigmas Eq.					1.140 (.029)	1.225 (.091)
2009	0.84 (.038)	1.43 (.038)	1.05 (.158)	1.49 (.125)	1.140 (.044)	1.263 (.044)	1.340 (.044)
2010	.791 (.033)	1.34 (.140)	1.04 (.071)	1.15 (.040)	1.037 (.057)	1.103 (.057)	1.215 (.057)
2011	1.261 (.026) Sigmas Eq.				1.259 (.037) Sigmas Eq.		

Population at Age Estimates (10^6)

	Male Ages					Female Ages			Total
Year	0	1	2	3	4	4	5	6	
1996	0	439	3,765	1,369	375	195	248	222	6,613
1997	3	500	3,057	2,382	1,254	139	1,926	663	9,924
1998	0	3,026	2,735	4,328	2,838	522	1,340	284	15,073
1999	2	560	5,488	1,513	2,556	20	2,410	592	13,141
2000	3	1,466	8,135	10,949	3,291	1,242	3,000	37	28,123
2001	4	704	8,071	13,488	21,606	1,116	4,052	3,023	52,068
2002	0	1,243	4,665	16,434	12,767	6,902	2,242	518	44,771
2003	0	1,364	5,163	7,160	15,339	241	9,218	1,410	39,895
2004	Incomplete survey								
2005	7	1,340	3,303	21,720	7,779	399	9,413	1,404	45,365
2006	0	2,298	11,415	6,078	17,873	484	6,932	2,284	47,364
2007	0	1,459	9,870	16,535	13,396	321	7,785	7,775	57,134
2008	0	2,119	7,921	17,616	13,264	19	9,624	3,000	53,563
2009	0	655	9,003	4,744	9,056	2,543	3,156	515	29,672
2010	5	754	2,944	5,511	3,447	1,656	1,806	998	17,121
2011	16	655	4,031	4,047	2,214	279	2,869	1,194	15,305

Table 18. Male biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2012) and autumn (1996 – 2011) 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 (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	13,662	29,600	49,142	4,635	8,816	14,065	313
2000	25,915	47,219	74,171	8,940	14,896	21,636	298
2001	27,737	50,340	74,856	8,665	15,172	22,562	300
2002	47,763	79,739	130,280	14,266	22,659	35,178	304
2003	58,978	91,719	128,367	16,632	26,667	39,467	300
2004	19,240	52,052	103,197	5,293	12,390	22,864	296
2005	33,154	52,958	73,043	9,668	14,909	20,498	289
2006	43,816	76,517	104,607	12,978	21,135	28,684	195
2007	71,302	112,661	156,960	20,005	31,548	43,141	295
2008	69,026	95,243	119,709	21,314	29,296	37,141	273
2009	30,234	53,864	76,960	8,951	16,148	23,609	299
2010	36,587	65,341	95,968	10,642	17,632	25,150	288
2011	19,794	37,050	58,102	6,382	10,710	15,183	297
2012	16,250	30,607	50,944	4,542	8,793	14,045	289

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 (tonnes)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1996	14,881	19,029	26,751	4,704	5,947	8,438	304
1997	19,119	24,969	34,553	5,676	7,246	10,044	318
1998	31,664	42,789	55,847	10,078	12,933	16,542	347
1999	25,341	33,426	42,960	7,965	10,065	12,676	313
2000	54,246	75,007	96,905	16,803	23,813	31,191	337
2001	101,787	153,034	188,372	30,446	43,890	53,290	362
2002	82,970	123,132	150,819	24,032	35,117	42,950	365
2003	80,403	108,936	139,140	21,948	29,051	36,396	316
2004			???				
2005	100,881	128,770	152,430	26,368	34,167	40,785	333
2006	101,888	133,703	156,054	27,878	37,651	45,296	312
2007	111,553	148,704	190,487	30,436	41,351	52,706	361
2008	107,929	145,080	186,862	29,922	40,958	52,223	256
2009	44,782	71,583	93,018	14,790	23,473	29,368	315
2010	27,858	39,165	50,602	8,978	12,720	16,401	318
2011	25,603	37,956	47,622	7,400	10,957	13,954	261

Table 19. Female biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2012) and autumn (1996 – 2011) 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
2012	15,011	27,989	41,359	1,961	3,594	5,351

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
2011	24,214	35,641	50,018	3,012	4,341	6,097

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

Table 20. 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 – 2012. 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
2012	25,140	47,420	74,503	4,207	8,108	13,139

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
2011	42,316	61,515	83,272	4,207	8,108	13,139

Table 21. Recruitment indices as determined from modal analysis of population adjusted northern shrimp length frequencies from spring (1999 – 2012) and autumn (1996 – 2011) 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	Recruitment indices (10^6)		Cohort
Year	Spring	Autumn	Year
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	4,031	2009
2012	845		2010

Table 22. Recruitment indices derived from the abundances of males and females with 11.5 – 17 mm carapace lfs using Ogmap calculations of spring (1999 – 2012) and autumn (1996 – 2011) Canadian research survey data.

Spring

Year	11.5 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1999	2,108	4,159	6,712
2000	4,370	7,140	9,755
2001	3,772	6,703	10,219
2002	5,262	8,516	13,703
2003	4,646	9,384	16,753
2004	1,830	2,898	4,257
2005	4,033	6,374	8,973
2006	5,725	8,730	12,474
2007	7,914	13,688	19,320
2008	9,829	14,729	19,431
2009	2,945	6,451	10,702
2010	4,353	6,879	9,781
2011	3,374	5,142	6,834
2012	1,840	3,979	6,104

Autumn

Year	Lower C.I.	Estimate (10^6)	Upper C.I.
1996	2,744	3,588	5,210
1997	2,474	3,073	4,164
1998	2,407	3,324	4,409
1999	4,052	5,378	6,600
2000	6,773	10,479	13,924
2001	11,679	16,089	18,948
2002	8,586	12,433	15,253
2003	5,822	7,833	10,088
2004			
2005	9,157	12,722	16,512
2006	10,310	14,966	19,079
2007	10,934	16,138	21,535
2008	9,775	14,927	20,136
2009	6,950	11,533	14,246
2010	4,554	6,843	8,994
2011	2,875	4,819	6,370

Table 23. Exploitation rate indices for NAFO Divisions 3LNO northern shrimp as determined using Canadian autumn survey and total catch over the period 1997 – 2012. 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 2012 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	175	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	6,960	136,421	69,973	159,880
2003	12,321	144,979	83,363	169,746
2004	13,204			
2005	14,775	178,707	95,445	179,915
2006	25,699	174,076	83,162	173,774
2007	23,570	216,059	128,870	239,719
2008	26,649	197,131	105,915	206,394
2009	27,527	80,020	47,722	95,042
2010	20,536	56,572	35,943	57,891
2011	12,286	51,578	35,641	61,515
2012	8,561			

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	0.090	0.176	0.077
2004	0.091	0.158	0.078
2005			
2006	0.144	0.269	0.143
2007	0.135	0.283	0.136
2008	0.123	0.207	0.111
2009	0.140	0.260	0.133
2010	0.257	0.430	0.216
2011	0.217	0.342	0.212
2012	0.166	0.240	0.139

Table 24. Survival, annual mortality and instantaneous mortality rate indices for northern shrimp (Pandalus borealis) within NAFO Divisions 3LNO. Indices were calculated using fishable abundance, age 4+ and age 5+ abundances as well as estimates of total removals. Survey data were obtained from the Canadian autumn bottom trawl survey (1996 – 2011).

Survey Year	Autumn survey fishable abundance (10^6)	Age 4+males and total female abundance (millions; year = t)	Age 5+males and total female abundance (millions; year = t)	Survival rate = Total age 5 males + female abundance $_{(t+1)}$/ age 4+ males + female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)	Catch year	Catch count (10^6)	U Exploitation rate index catch/fishable biomass from previous year	F = (U*Z)/ (1-exp(-Z))	M=Z-F
1996	2,777	1,040	470				1997			Fishery began in 2000	
1997	6,488	3,982	2,589	2.49	-1.49	-0.91	1998				
1998	9,253	4,984	1,624	0.41	0.59	0.90	1999				
1999	7,325	5,578	3,002	0.60	0.40	0.51	2000				
2000	16,332	7,570	3,037	0.54	0.46	0.61	2001	1074	0.066	0.09	0.52
2001	35,359	29,797	7,075	0.93	0.07	0.07	2002	1130	0.032	0.03	0.03
2002	31,249	22,429	2,760	0.09	0.91	2.38	2003	2286	0.073	0.19	2.19
2003	30,866	26,208	10,628	0.47	0.53	0.75	2004	2248	0.073	0.10	0.64
2004							2005	2275			
2005	31,528	18,995	10,817				2006	3767	0.119		
2006	30,386	27,573	9,216	0.49	0.51	0.72	2007	4127	0.136	0.19	0.53
2007	39,905	29,277	15,560	0.56	0.44	0.57	2008	4608	0.115	0.15	0.42
2008	36,731	25,907	12,624	0.43	0.57	0.84	2009	5352	0.146	0.22	0.63
2009	17,247	15,270	3,671	0.14	0.86	1.95	2010	3740	0.217	0.49	1.46
2010	9,549	7,907	2,804	0.18	0.82	1.69	2011	2454	0.257	0.53	1.16
2011	8,108	6,556	4,063	0.51	0.49	0.67	2012				

Survival statistics	Median values
Survival	0.49
Instantaneous rate of total mortality (Z)	0.72
Instantaneous rate of fishing mortality (F)	0.19
Instantaneous rate of natural mortality (M)	0.63

if instantaneous natural mortality = 0.63 then

annual mortality = 1-$\exp^{-M}$

annual mortality = 0.47

rate of decline in population = 0.47

N_o = 1,000

N_1 = 530

N_2 = 281

N_3 = 149

N_4 = 79

N_5 = 42

N_6 = 22

Table 25. 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 0.38, 0.62 and 0.99 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	Number sets	Abundance of all females	Abundance of multiparous females	Survival rate = Abundance multiparous females $_{(t+1)}$/ abundance $_{(t+1)}$/ abundance of all females $_{(t)}$	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
2000	37	162	53			
2001	67	170	30			
2002	53	162	50	0.31	0.69	1.18
2003	27	179	48	0.27	0.73	1.32
2004	39	124	56	0.45	0.55	0.80
2005	37	198	40			
2006	1		.			
2007	12	126	47			
2008	9	121	95	0.79	0.21	0.24
2009	12	124	16	0.13	0.87	2.07
2010	53	209	102	0.49	0.51	0.71
2011	12	62	22			

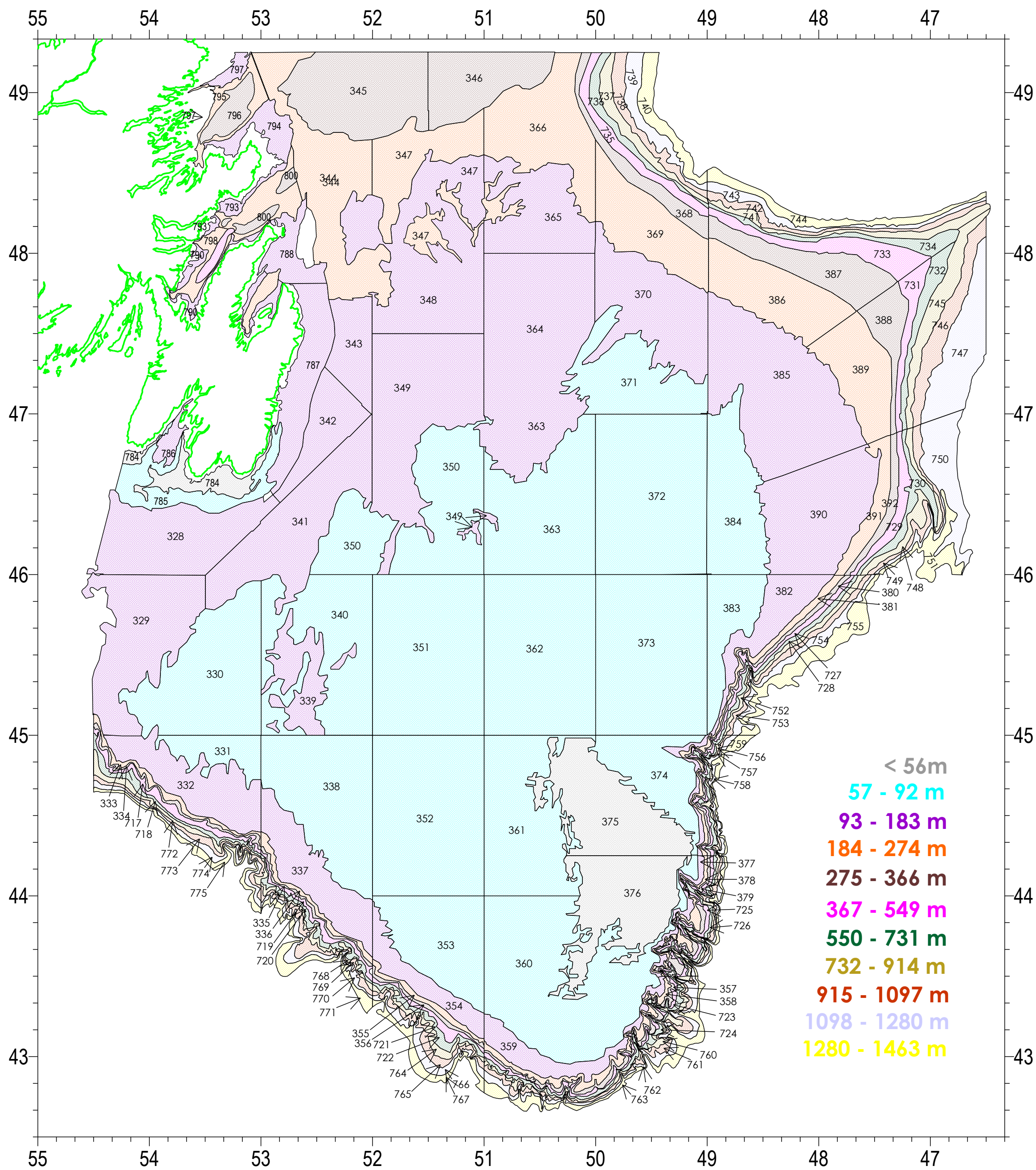


Figure 1. The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species research bottom trawl survey set allocation (G. Cossitt).

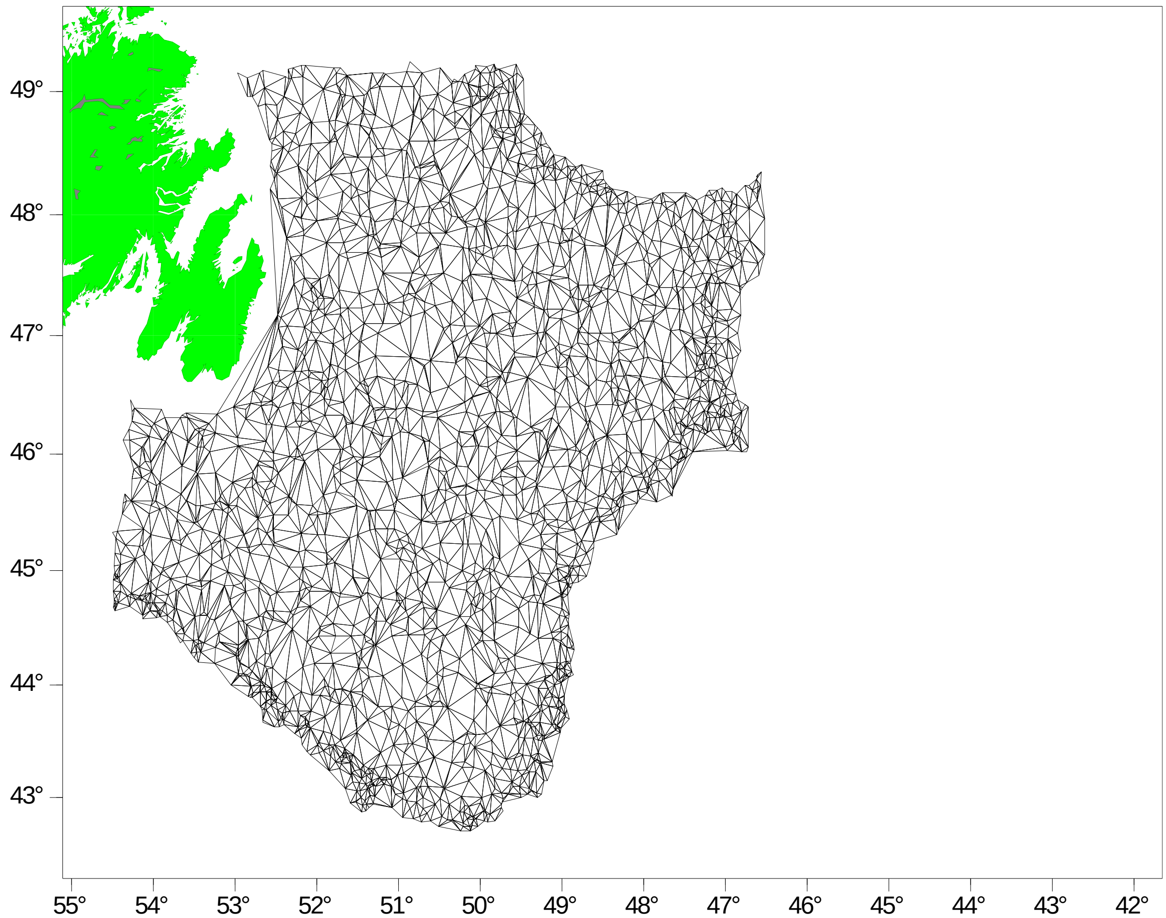


Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Omap.

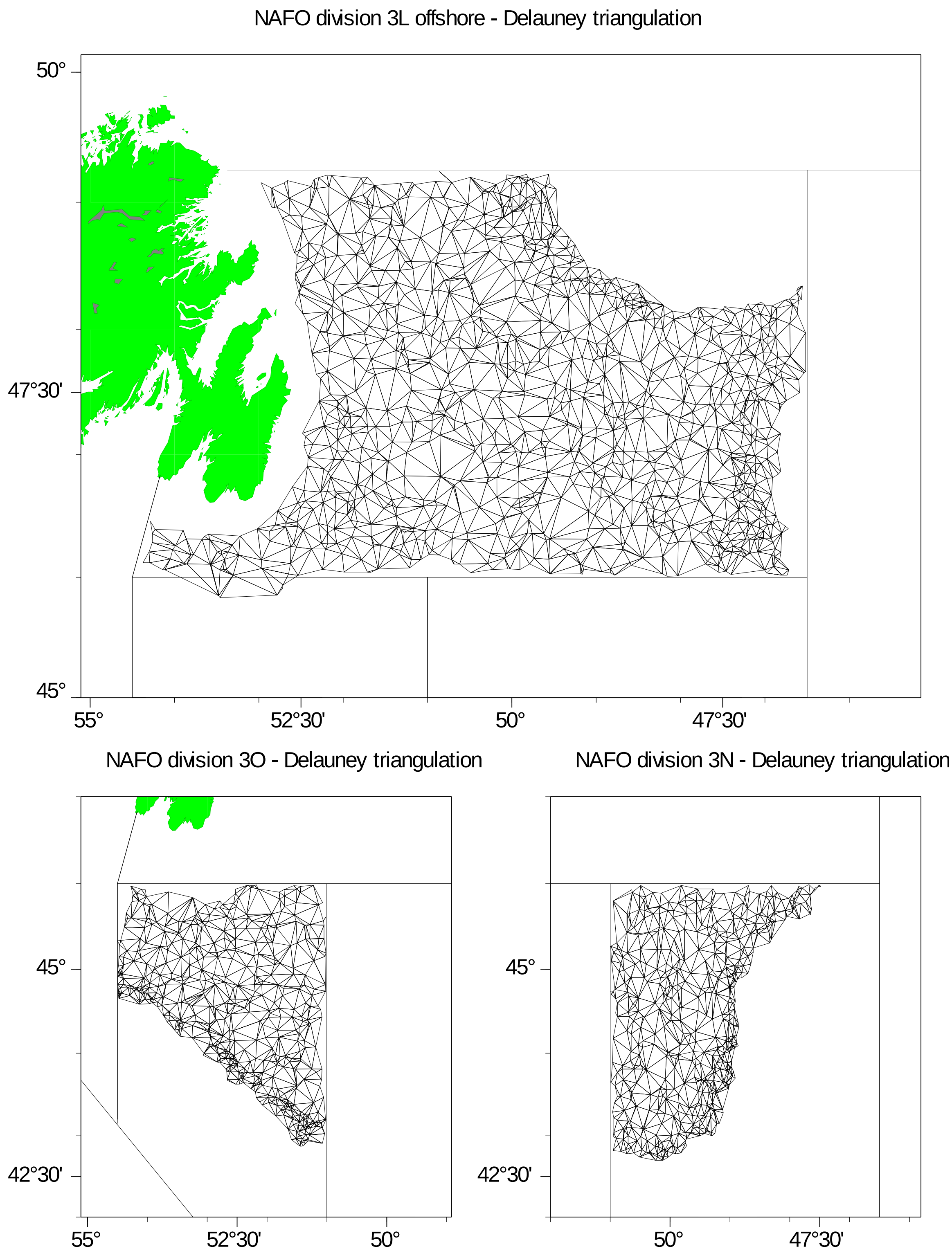


Figure 3. The Delauney triangulation used to derive within NAFO division Ogmap biomass and abundance indices.

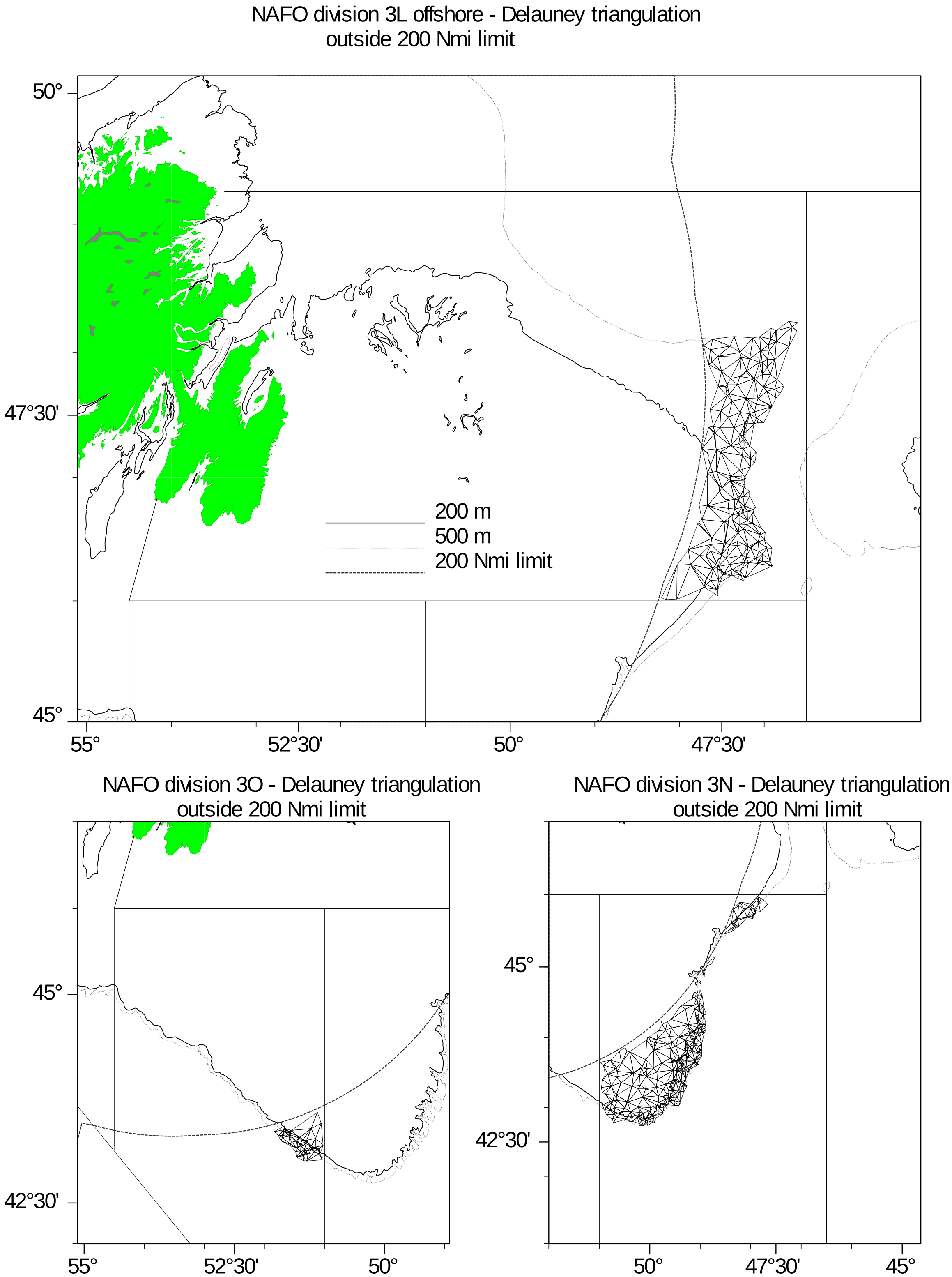


Figure 4. The Delauney triangulation used to derive the outside 200 Nmi limit Ogmap biomass and abundance indices.

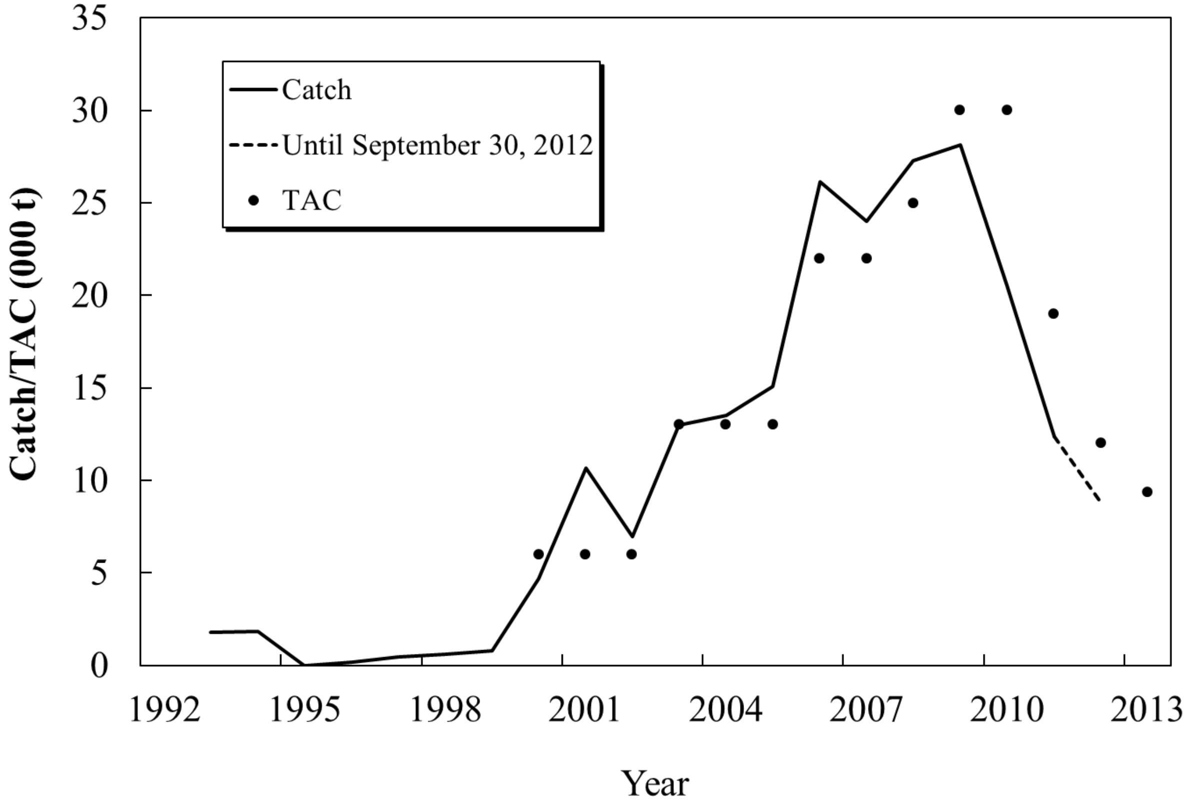


Figure 5. Trends in NAFO Division 3L Northern Shrimp (*Pandalus borealis*) catch and TAC over the period 1993-2013.

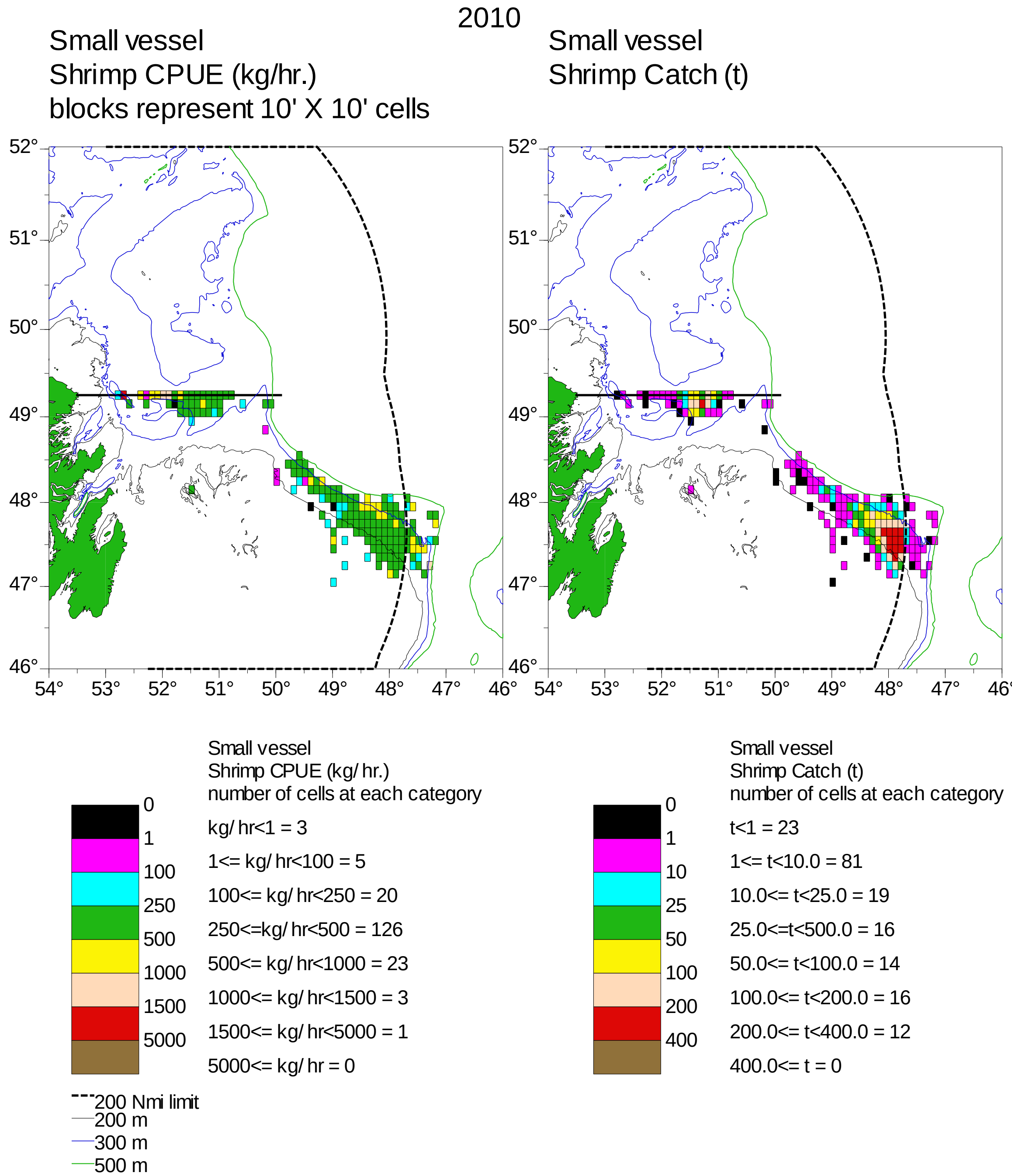


Figure 6. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2010. (Logbook data aggregated into 10 min X 10 min cells).

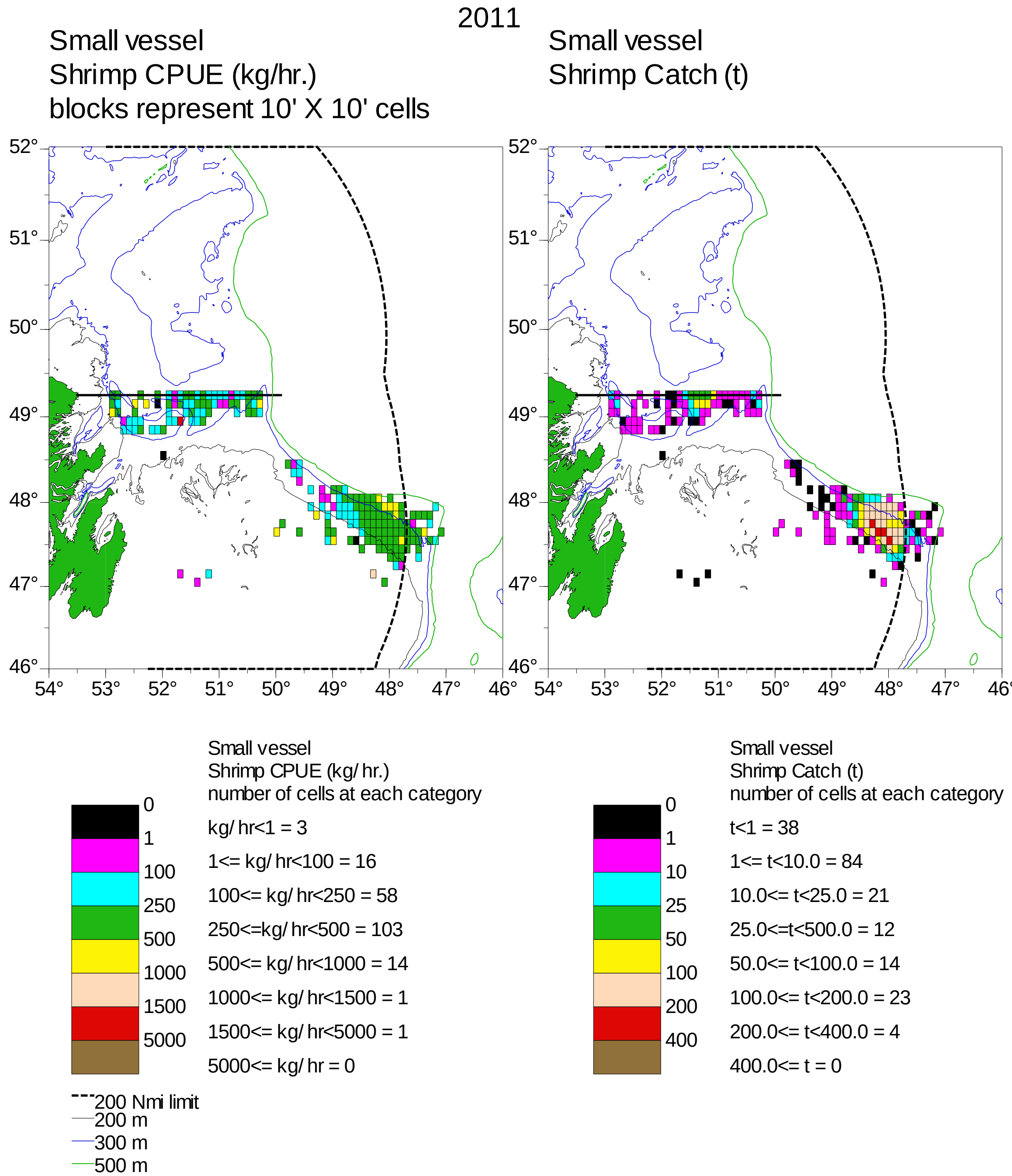


Figure 7. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2011. (Logbook data aggregated into 10 min X 10 min cells).

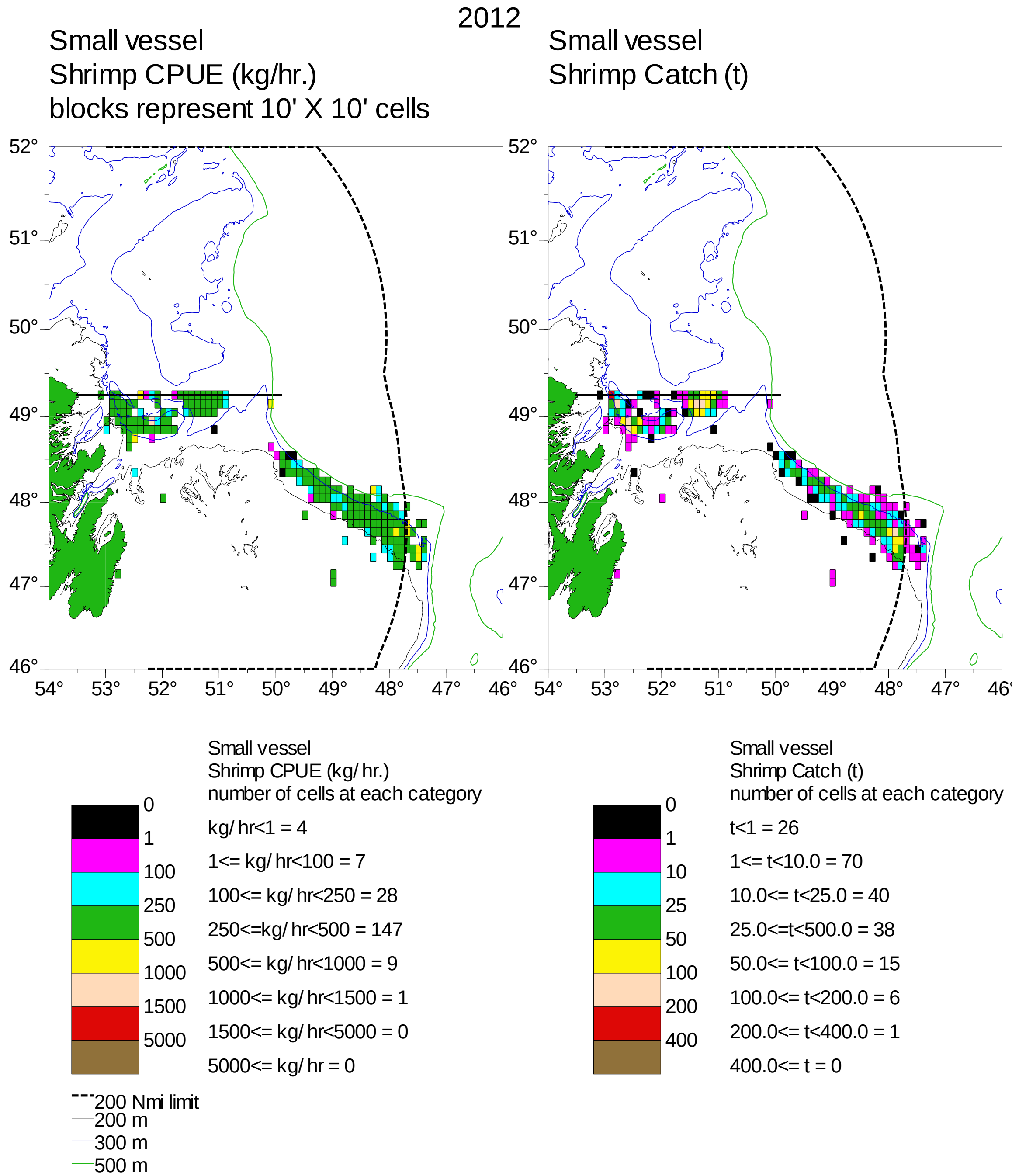


Figure 8. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2012. (Logbook data aggregated into 10 min X 10 min cells).

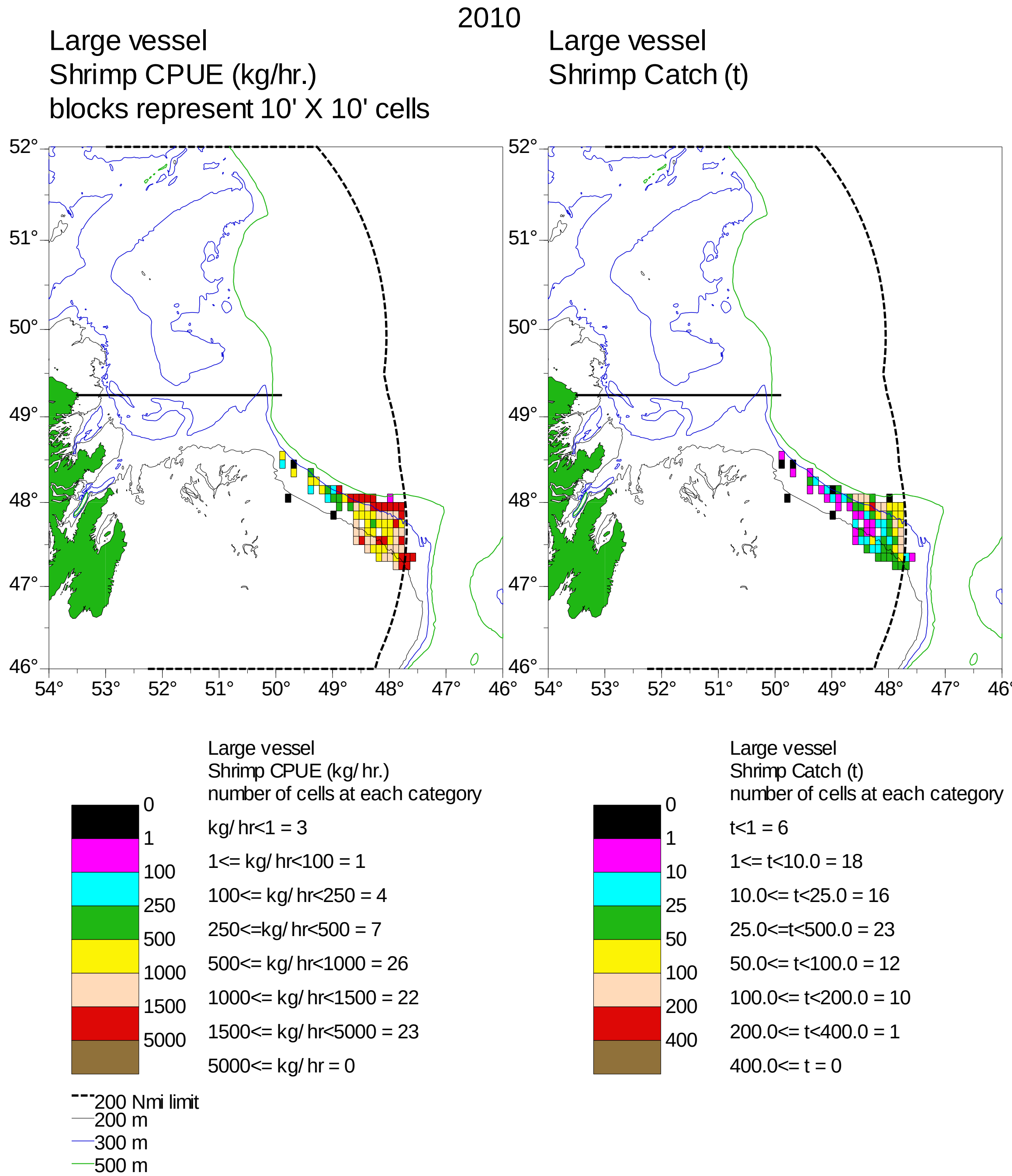


Figure 9. Distribution of **Canadian large vessel (>500 t)** shrimp CPUE and catches in NAFO Division 3L during 2010. (Logbook data aggregated into 10 min X 10 min cells).

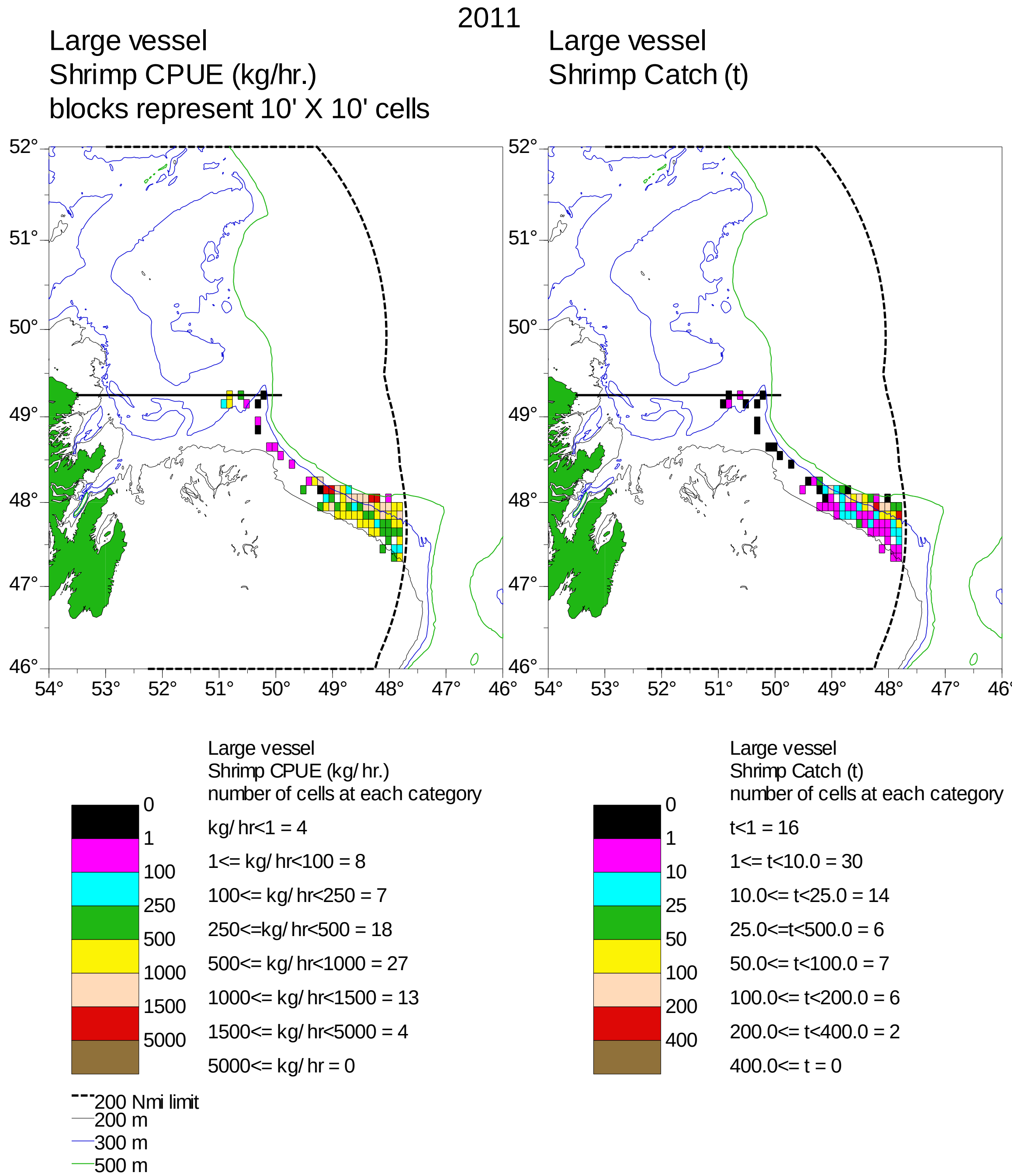


Figure 10. Distribution of **Canadian large vessel (>500 t)** shrimp CPUE and catches in NAFO Division 3L during 2011. (Logbook data aggregated into 10 min X 10 min cells).

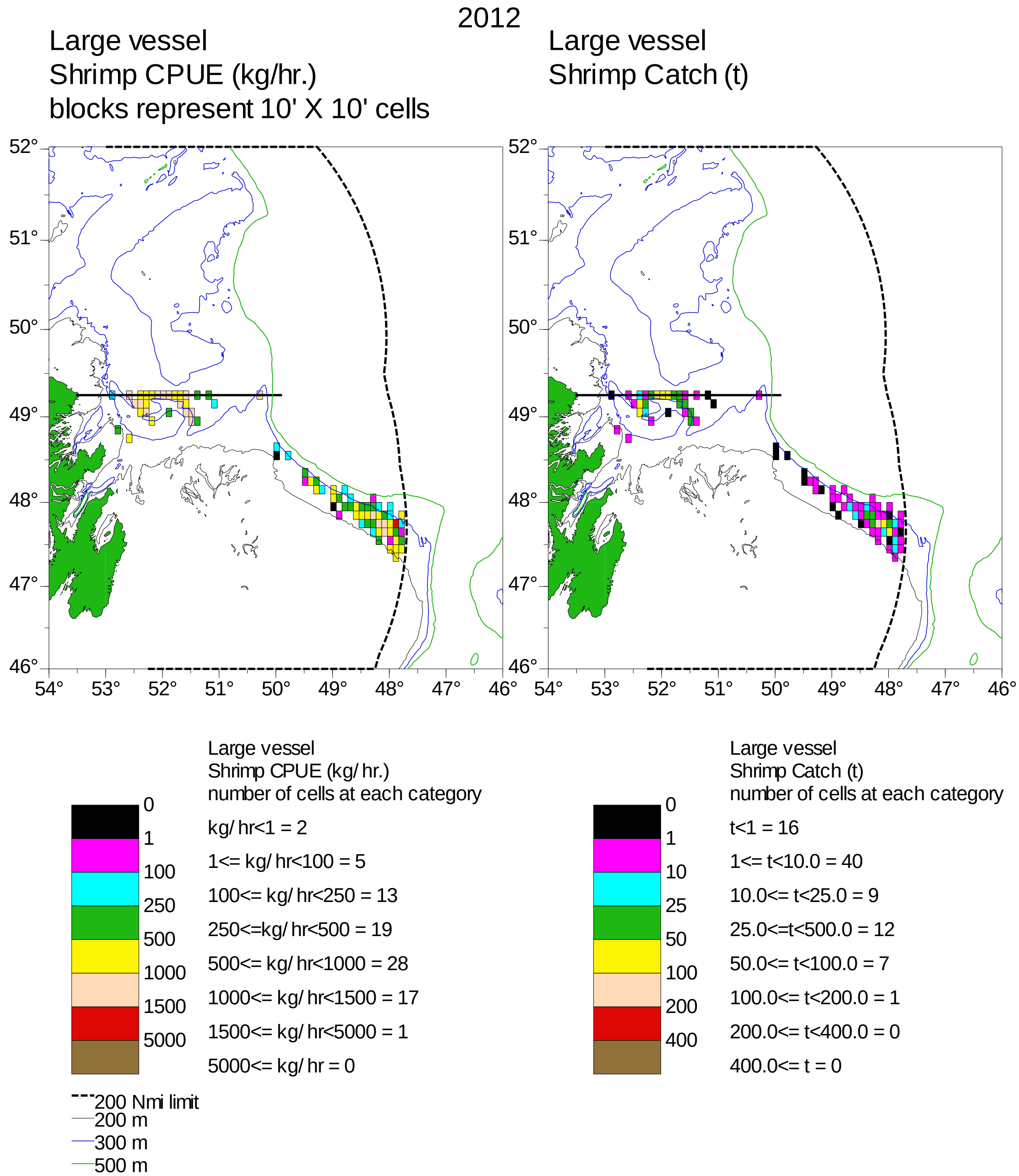


Figure 11. Distribution of **Canadian large vessel (>500 t)** shrimp CPUE and catches in NAFO Division 3L during 2012. (Logbook data aggregated into 10 min X 10 min cells).

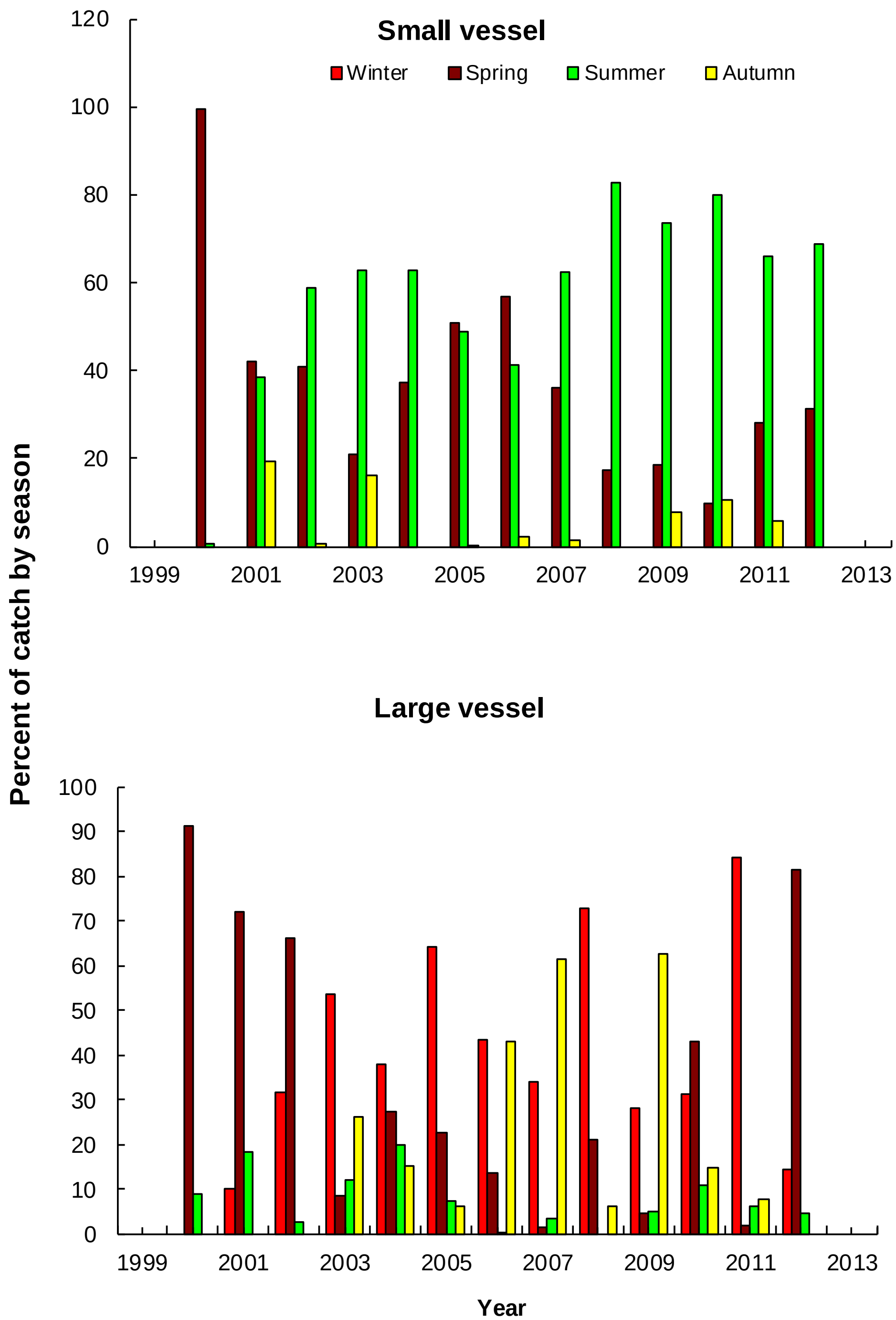


Figure 12. Seasonality of the large and small vessel Northern Shrimp (*Pandalus borealis*) fishery in NAFO Division 3L over the period 2000 – 2012. Please note that the 2012 values are preliminary with data up to the end of September 2012.

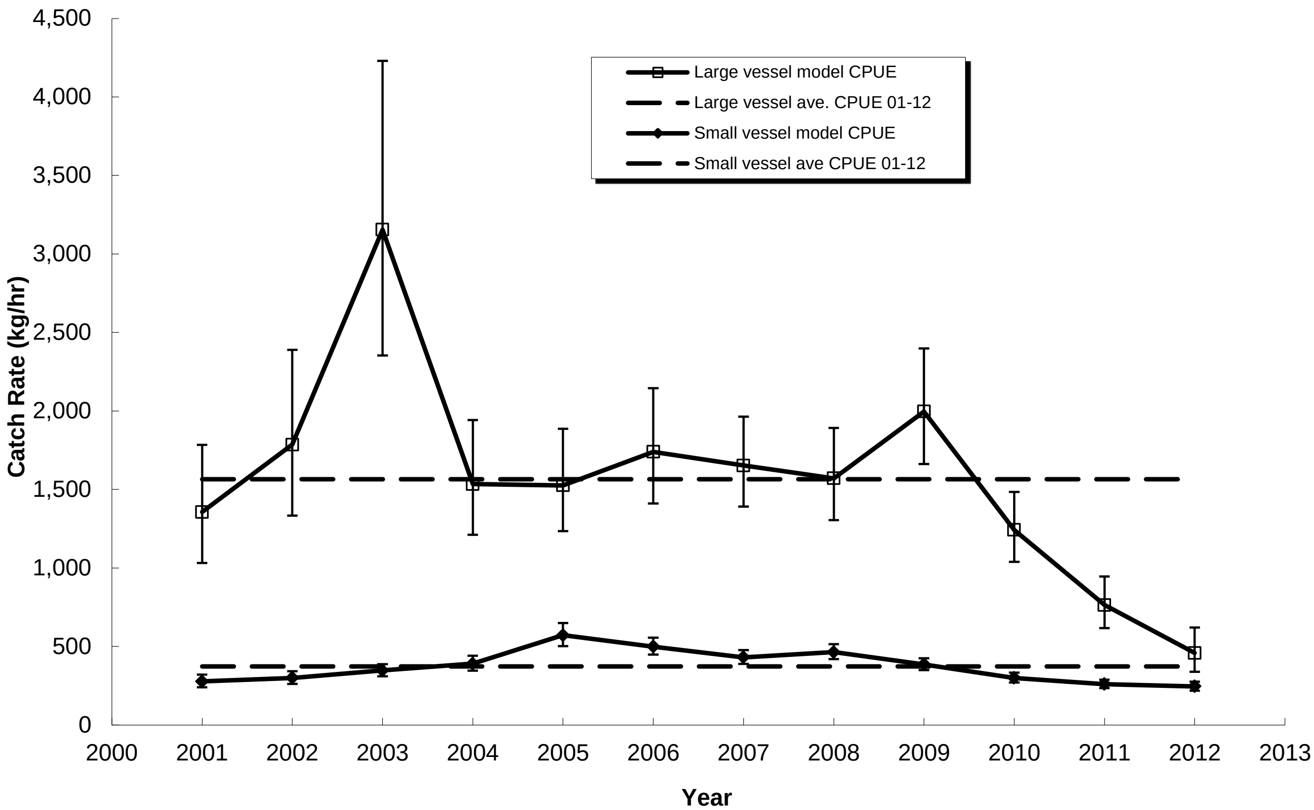
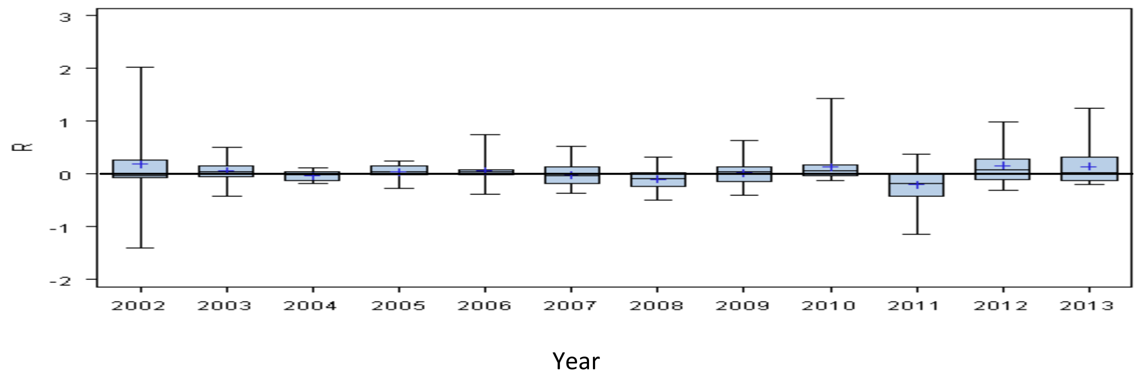
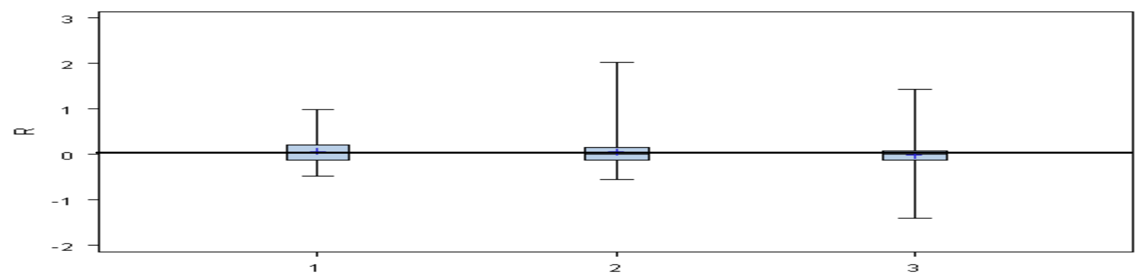


Figure 13. Model catch rates for Canadian large (>500 t) and small (<= 500 t; <65') vessels fishing for shrimp in NAFO Div. 3L over the period 2001 – 2012. Bars represent 95% confidence intervals around model values.





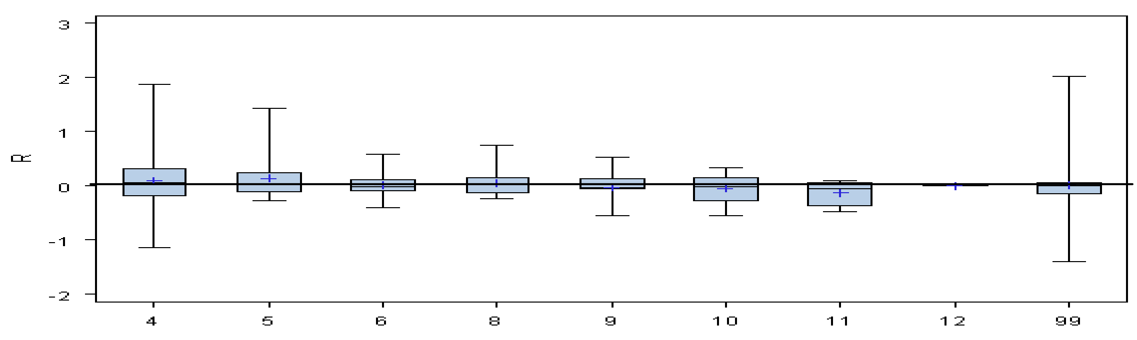


Figure 14. Distribution of residuals around estimated values for parameters used to model **Canadian small vessel** shrimp catch rates, 2001 – 2012.

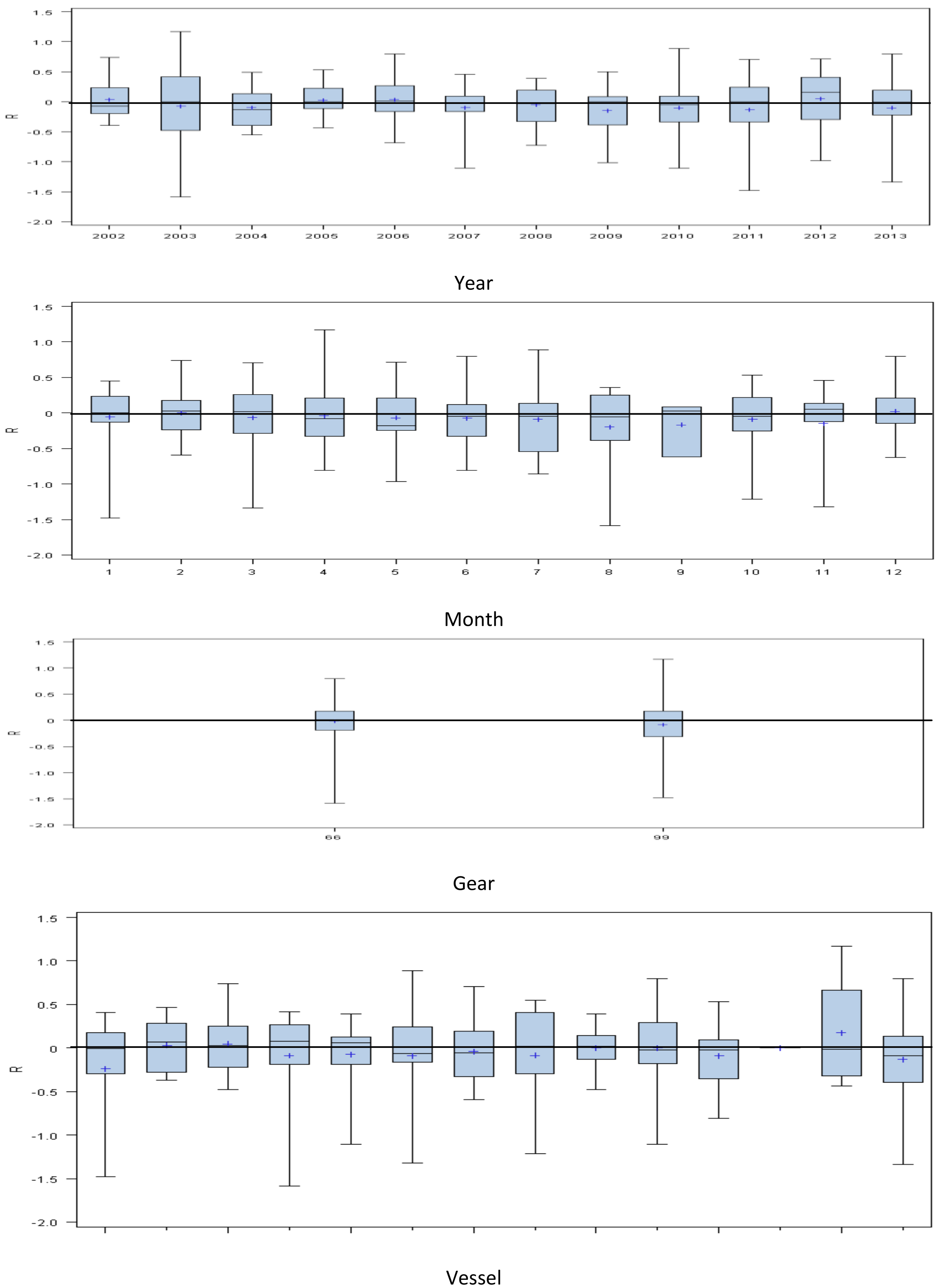


Figure 15. Distribution of residuals around estimated values for parameters used to model **Canadian** **large vessel** shrimp catch rates, 2001 – 2012.

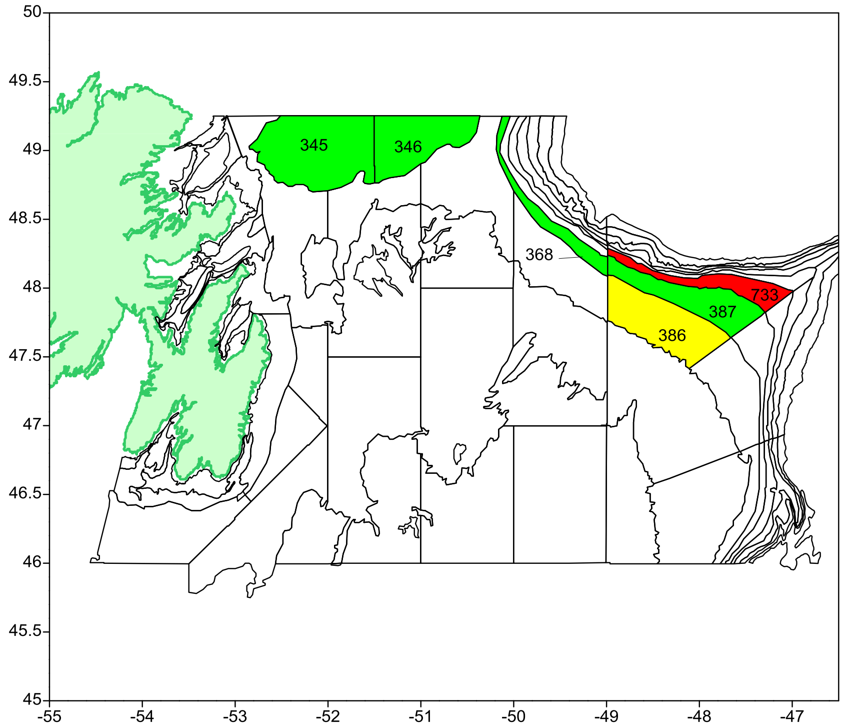
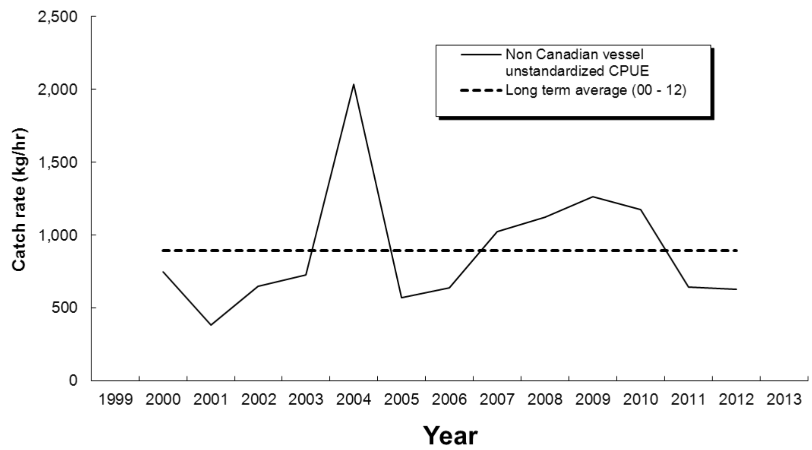


Figure 16. NAFO Divisions 3L index strata consistently fished by the small vessel (<=500 t; <65') shrimp fishing fleet, over the period 2003 – 2010. Numbers indicate the strata designations as per figure 1. Depth zones are as follows:Yellow = 184 – 274 m; Green = 375 – 366 m and Red = 367 – 549 m.

A) Unstandardized catch rates of Non Canadian vessels fishing in the NRA



B) Standardized catch rates of Faroese vessels fishing in the NRA

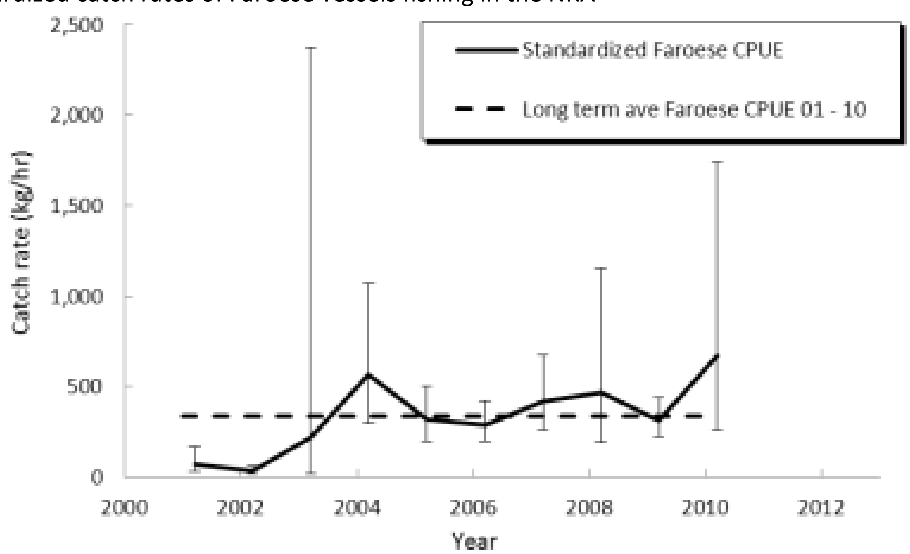
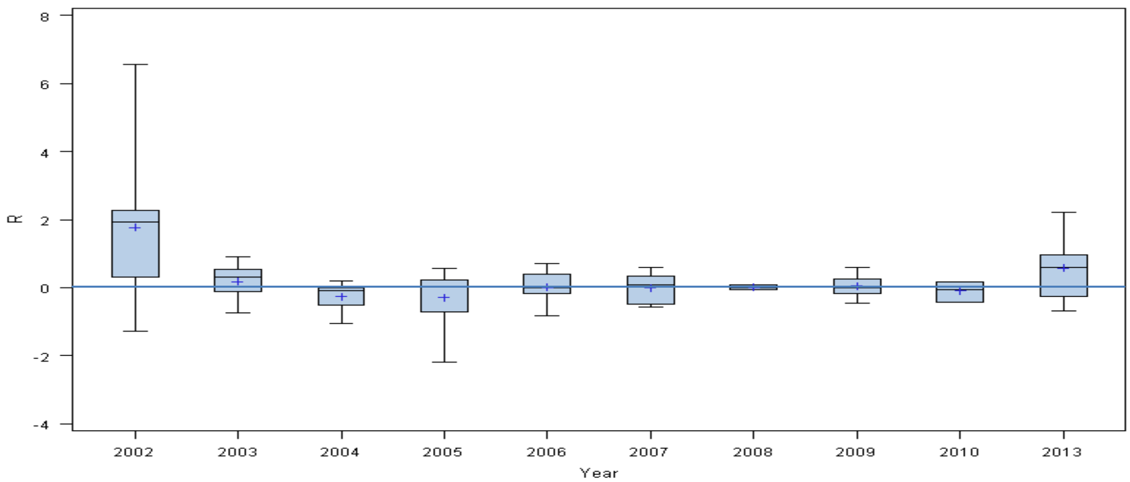
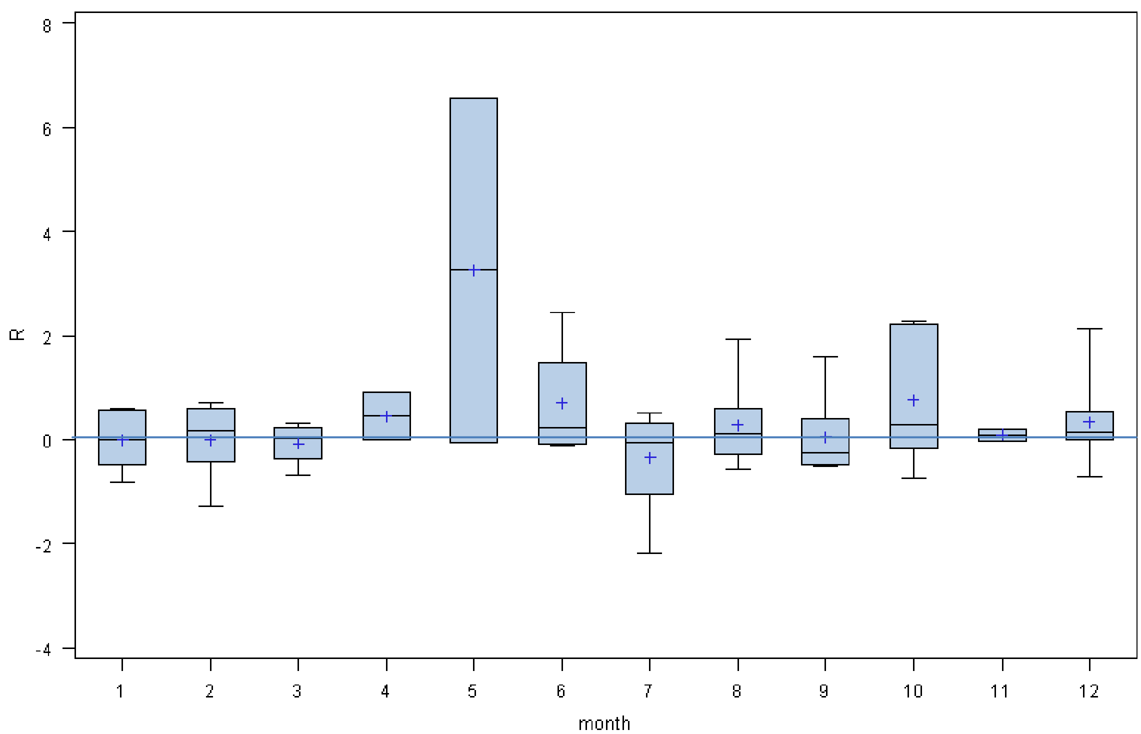


Figure 17. Unstandardized and standardized catch rates for non Canadian vessels fishing northern shrimp within the NAFO Division 3L NRA over the period 2000 – 2012. This unstandardardized catch rate series made use of data from Estonia, Greenland, Iceland, Norway, Spain and Russia. Please note that the 2012 data were provided by Estonia only and we are not sure whether they are representative of entire fleet catch rates. The standardized catch rate made use of Faroese Statlant21B data.



Year



Month

Figure 18. Distribution of residuals around estimated values for parameters used to model Faroese vessel shrimp catch rates, 2001 – 2010.

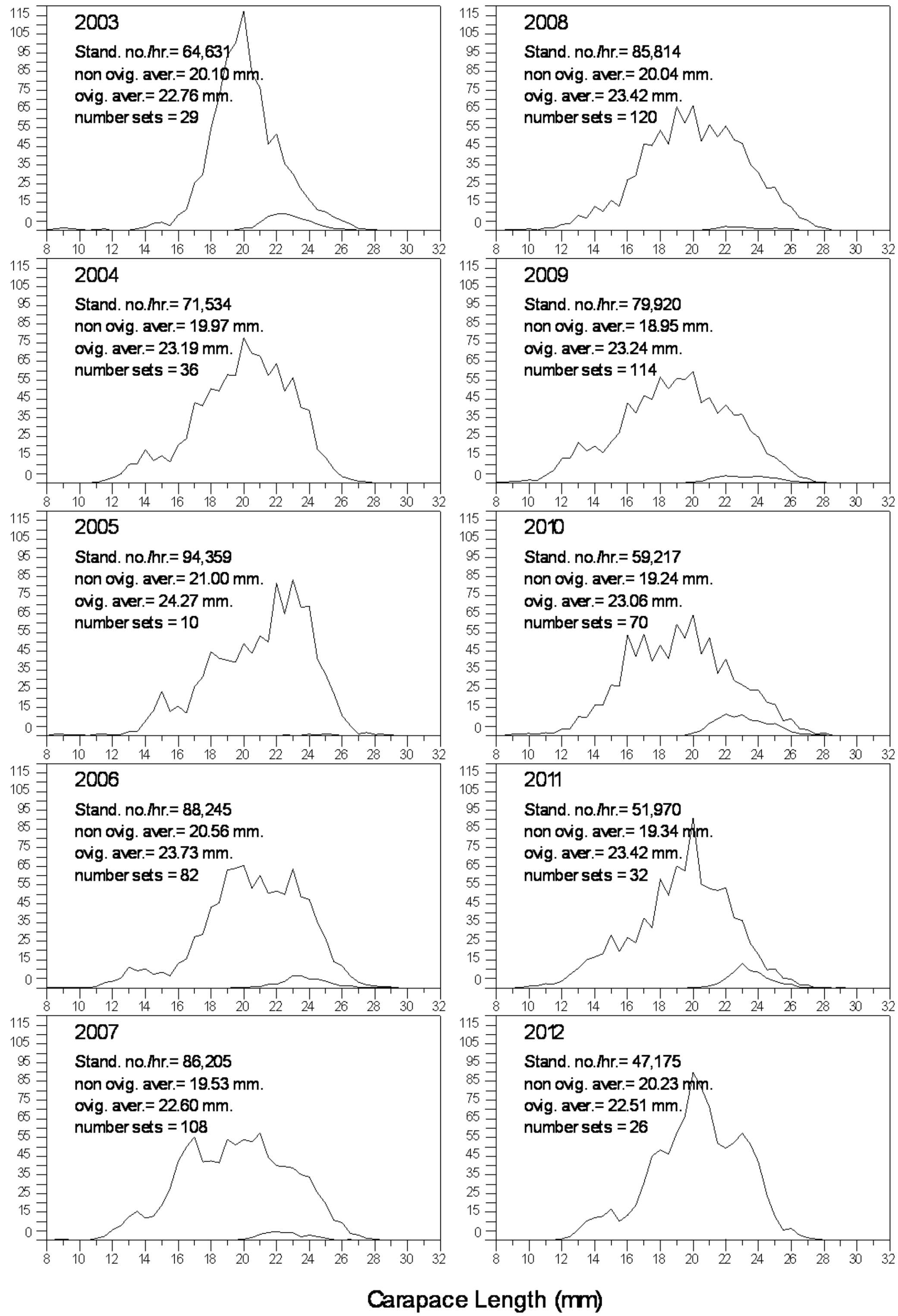


Figure 19. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

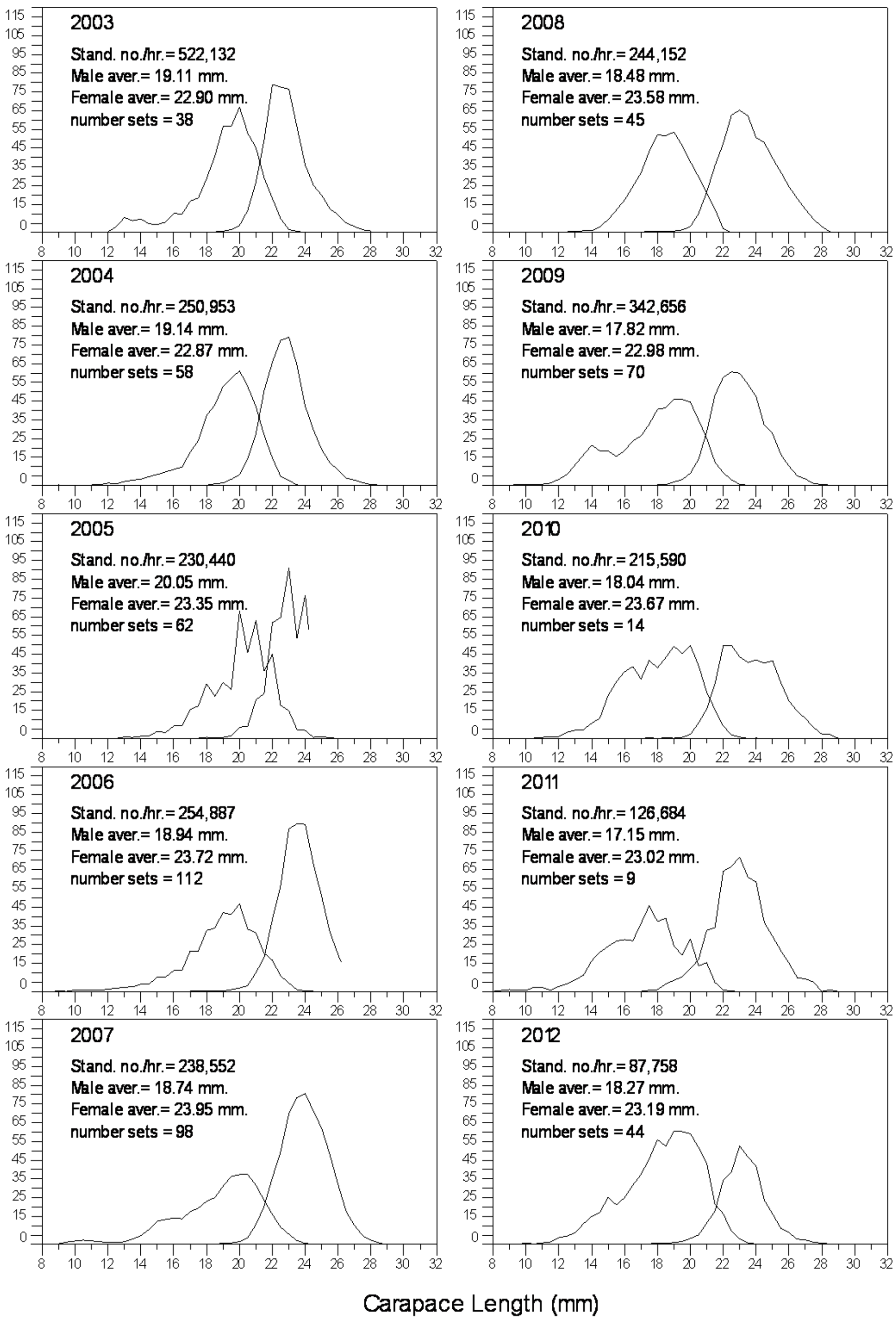
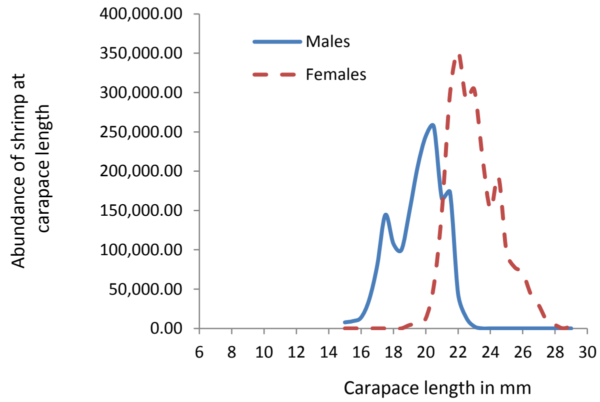


Figure 20. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

A) Spanish commercial carapace length frequencies for 2011



B) Estonian commercial carapace length frequencies for 2010 – 2012

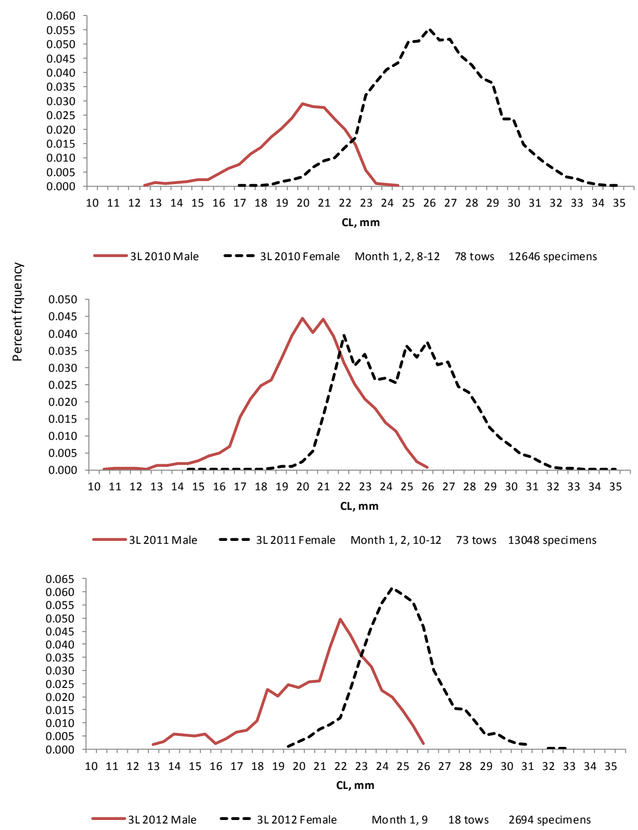


Figure 21. (a) Carapace length frequencies from the Spanish fishing fleet sampled during January 2011. A total of 1492 shrimp were measured from 9 tows. (b) Percent length frequencies from the Estonian fishing fleet sampled during 2010 – 2012.

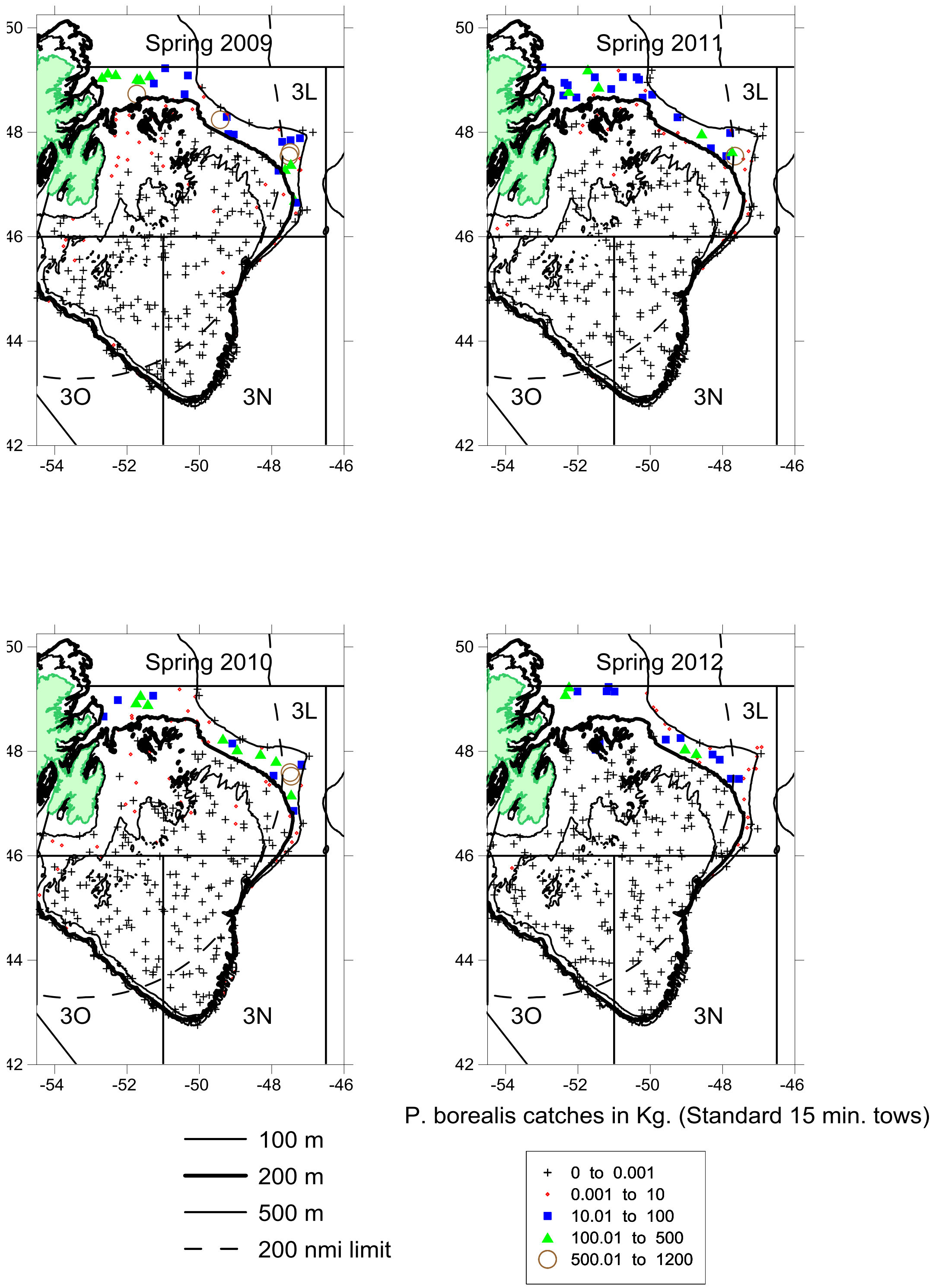


Figure 22. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **spring** Canadian research bottom trawl surveys conducted over the period 2009 – 2012.

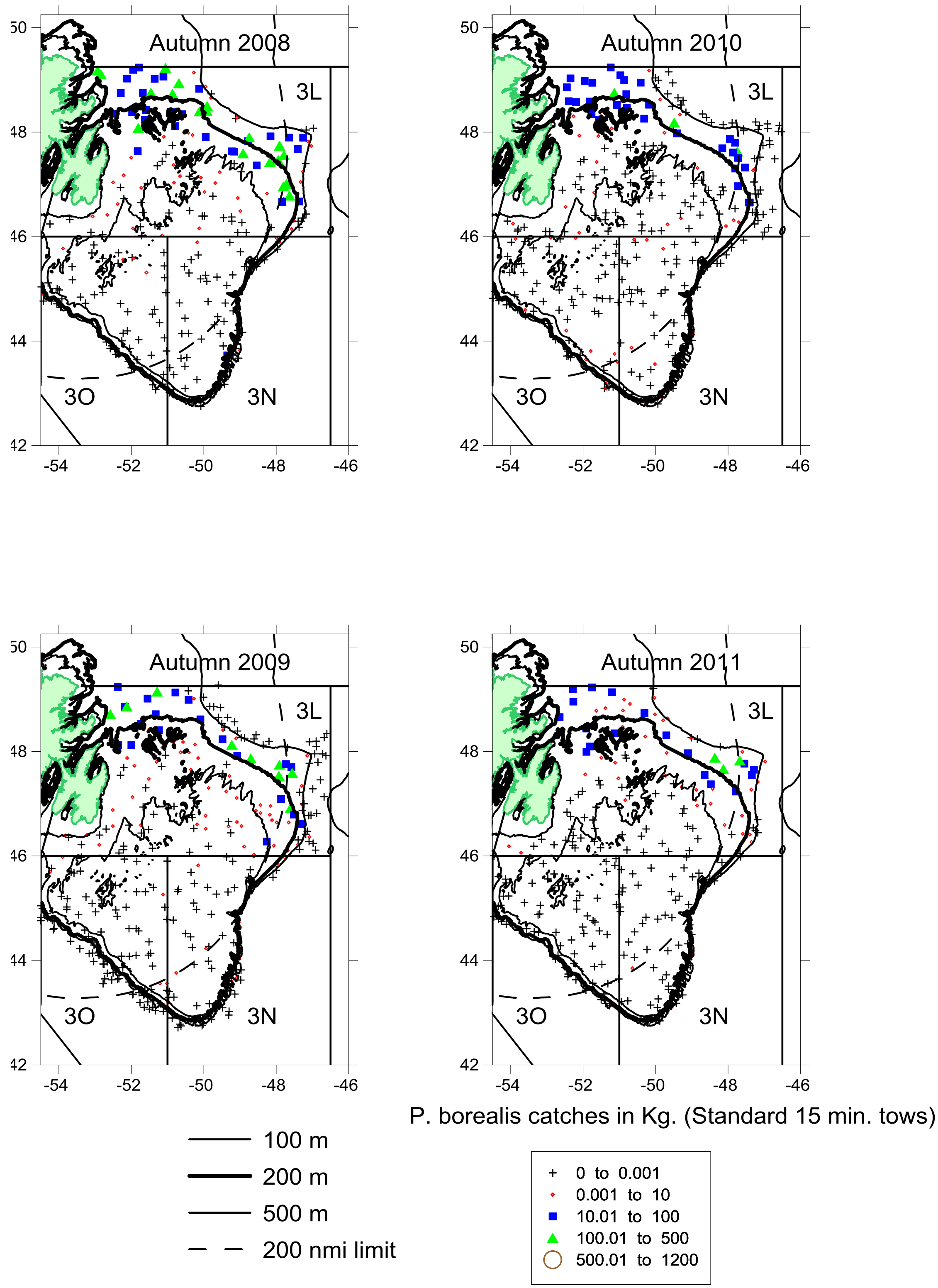


Figure 23. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **autumn** Canadian research bottom trawl surveys conducted over the period 2008 – 2011.

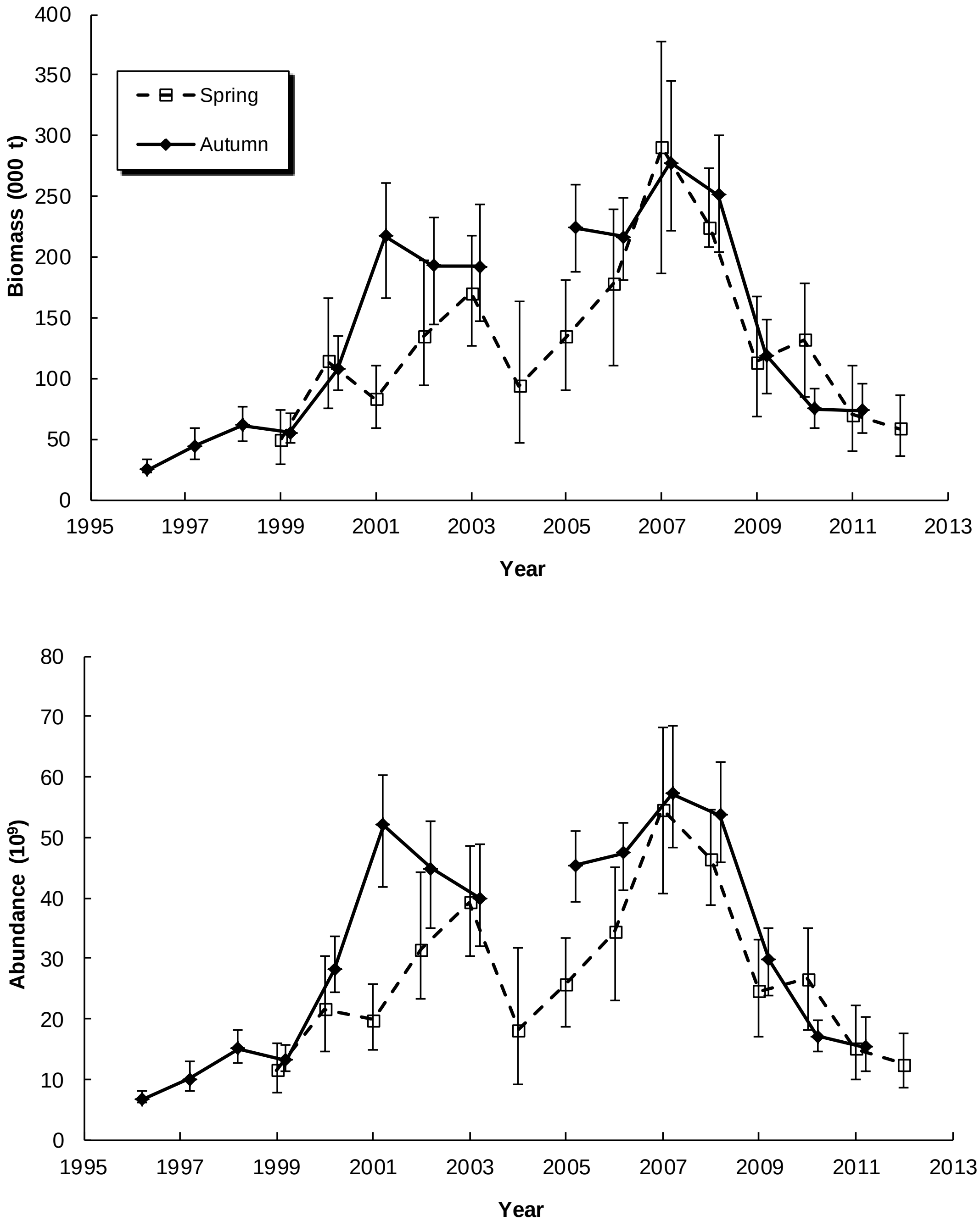


Figure 24. Northern shrimp biomass and abundance indices within NAFO Divisions 3LNO over the period 1996 – 2012. The data are from spring 1999 – 2012 and autumn 1999 – 2011 Canadian multispecies research bottom trawl surveys. (Standard tow 15 min.). Estimates were made using Ogmap calculations and bars represent 95% confidence intervals.

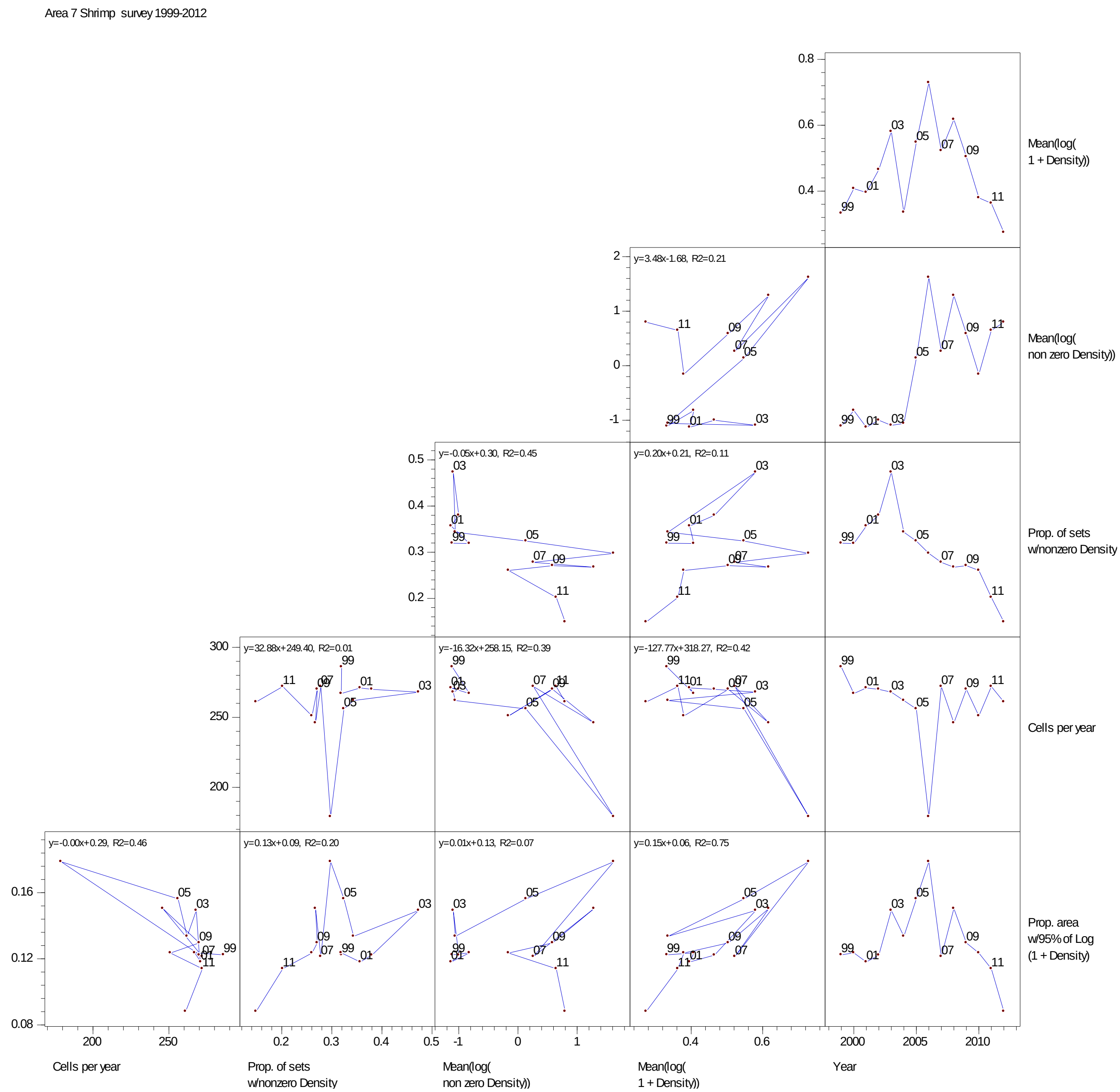


Figure 25. Distributional indices for 3LNO Northern Shrimp as estimated from Canadian spring research survey bottom trawl multi-species survey catches (1999 – 2012). Estimates were calculated using ACON (Black, pers. comm.).

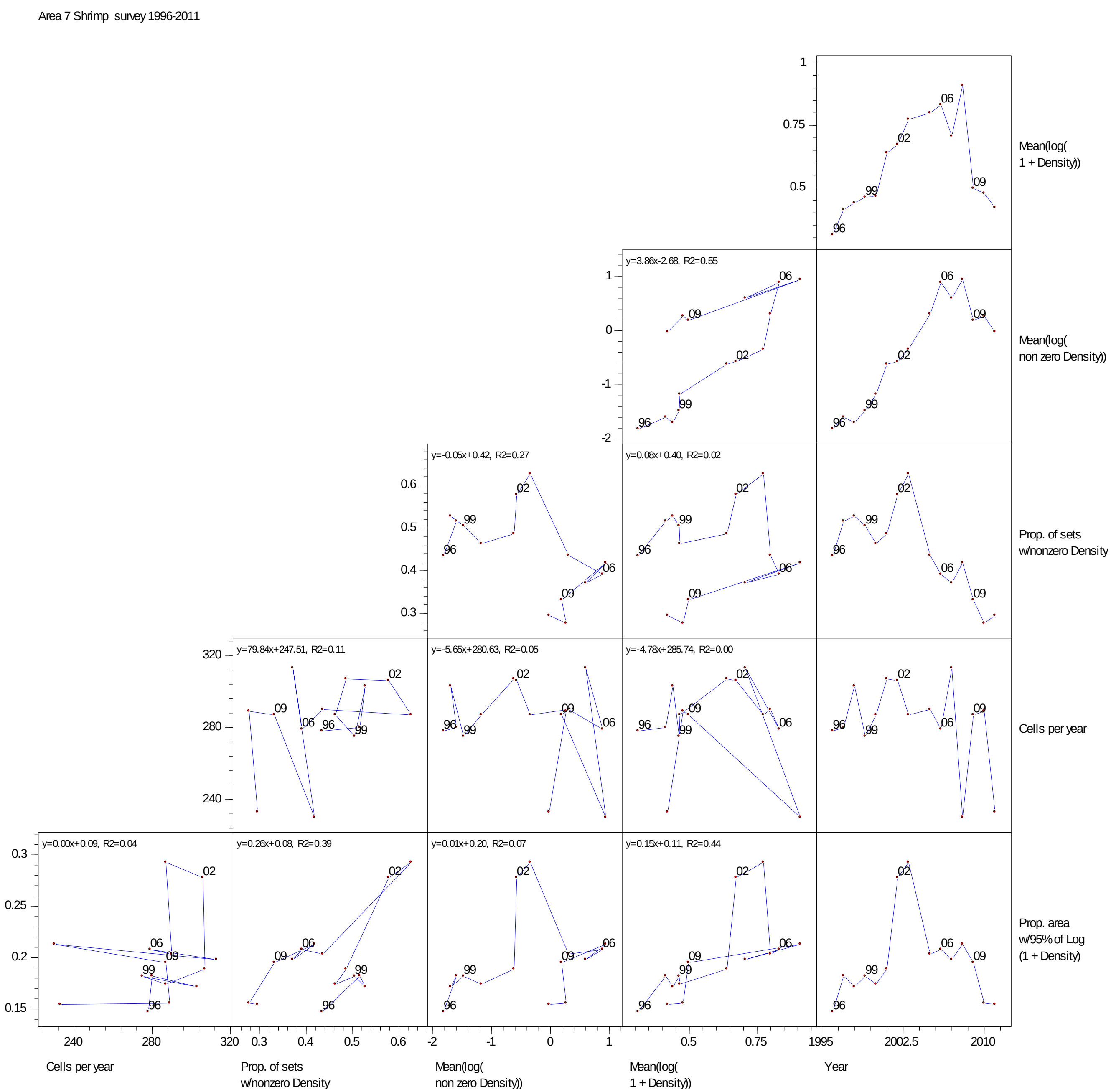


Figure 26. Distributional indices for 3LNO Northern Shrimp as estimated from Canadian autumn research survey bottom trawl multi-species survey catches (1996 – 2011). Estimates were calculated using ACON (Black, pers. comm.). Please note that 2004 was an incomplete survey and is not included in this figure. The line joins the survey points from 2003 directly to 2005 points.

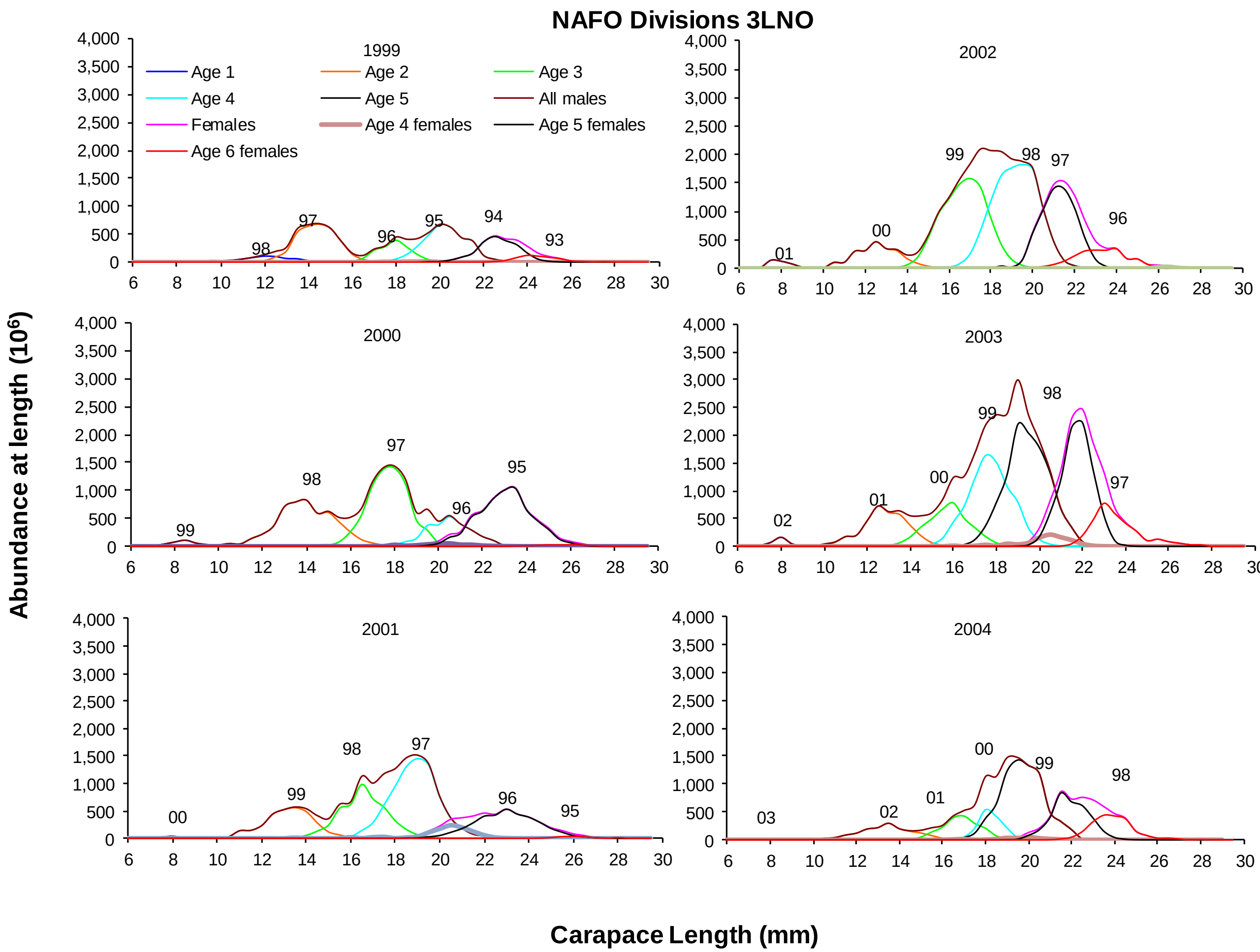


Figure 27. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **spring** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

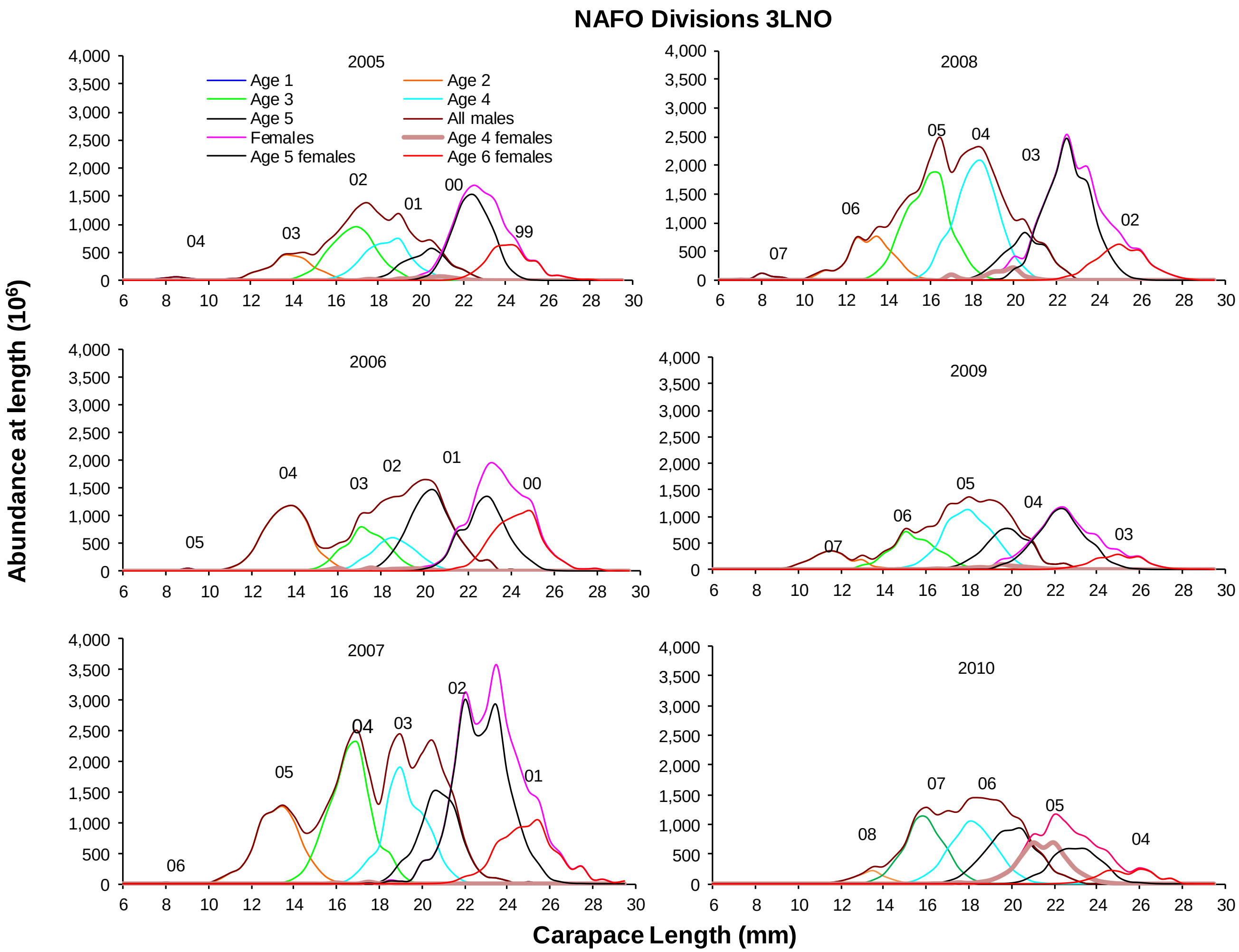


Figure 27. (Continued)

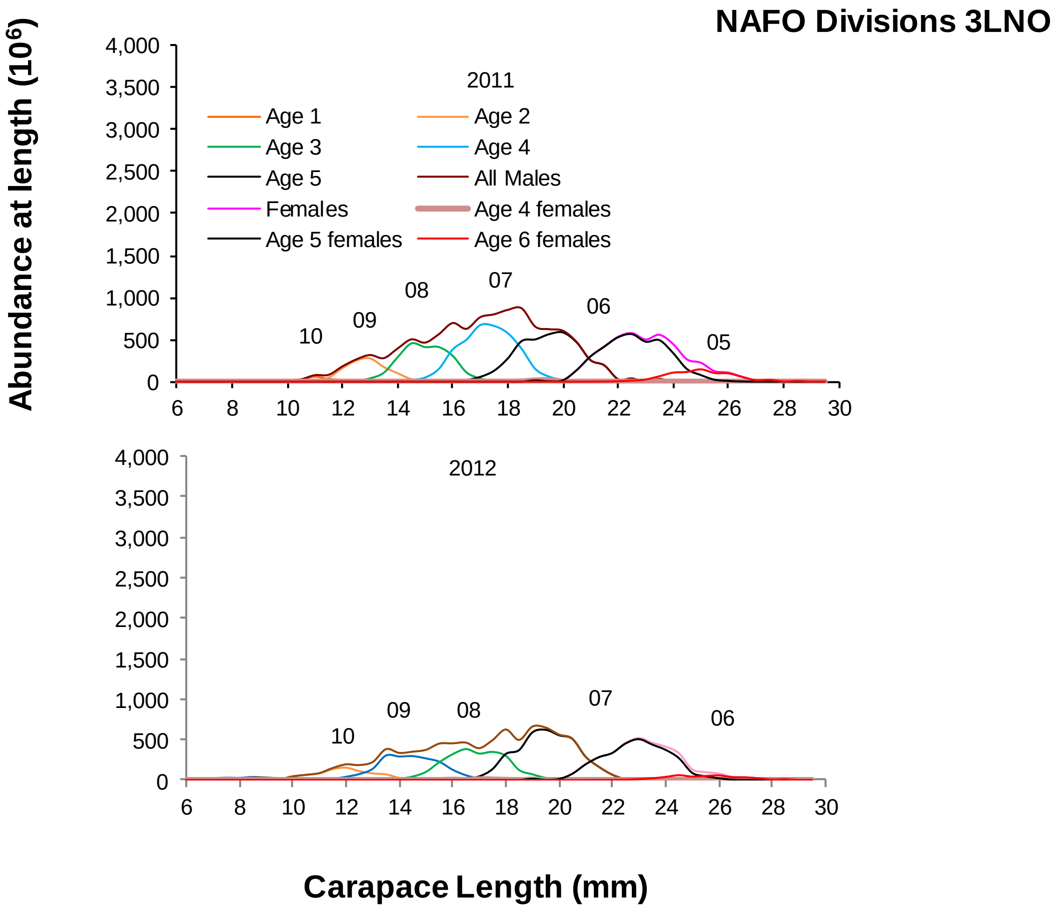


Figure 27. (Continued)

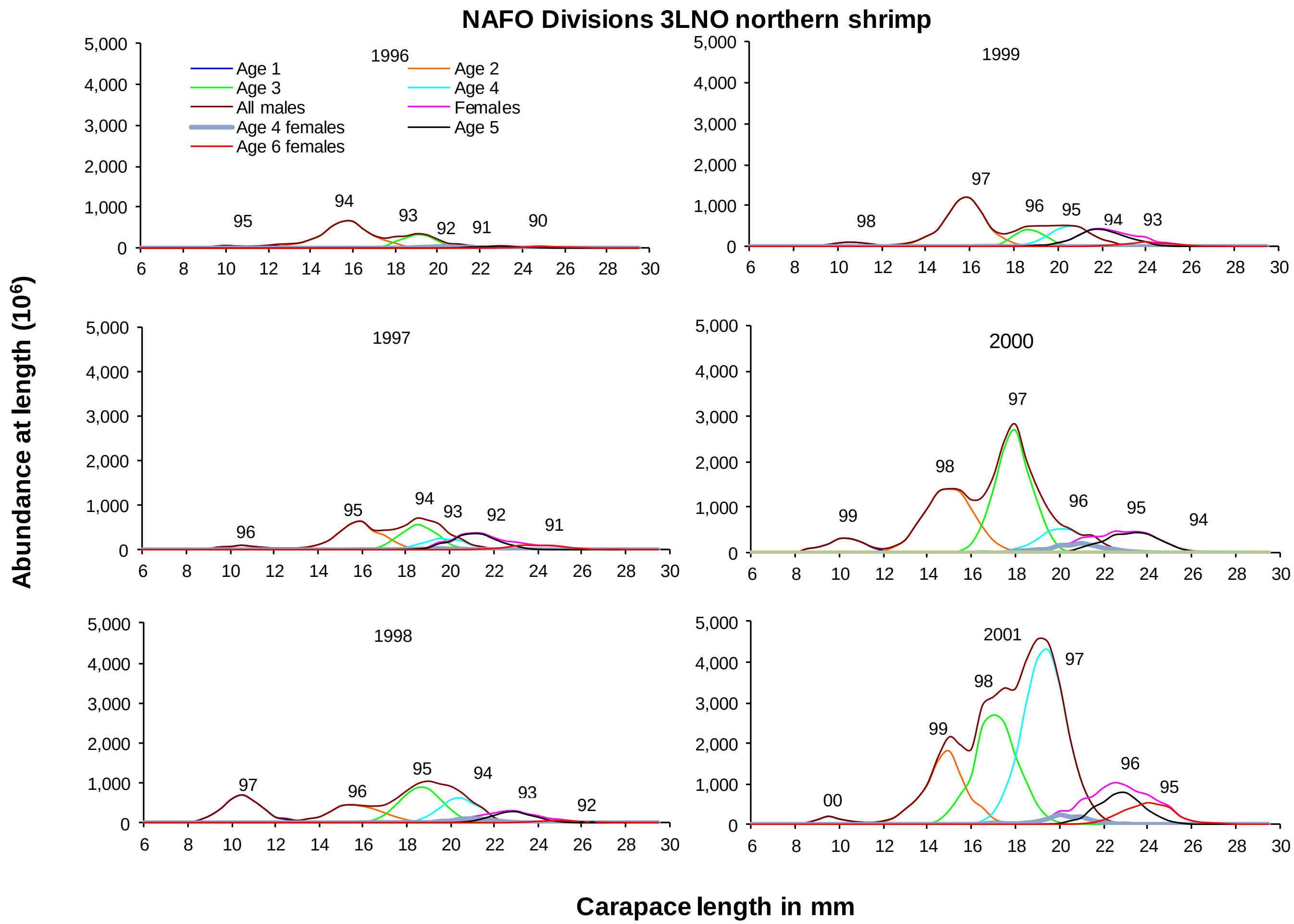


Figure 28. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

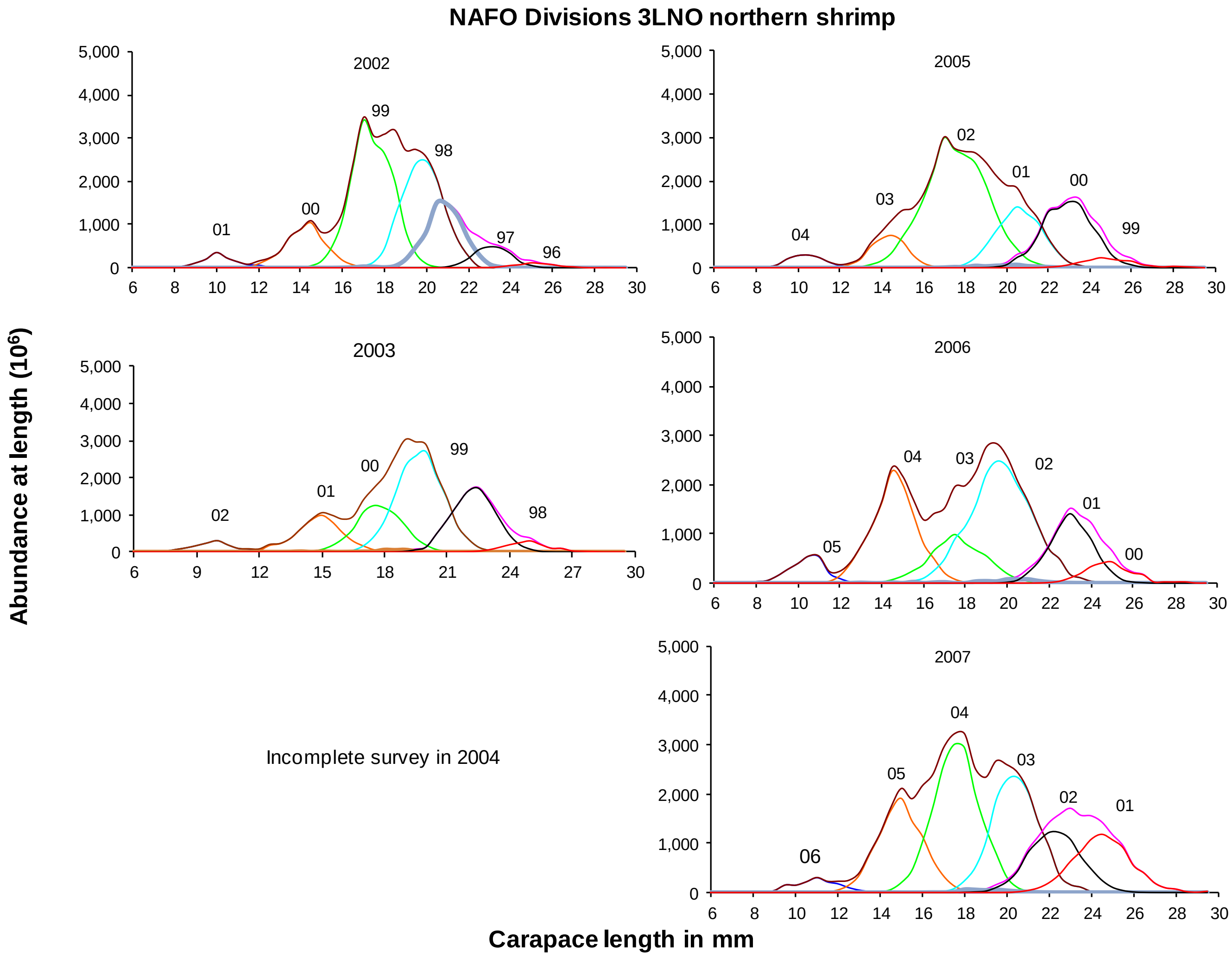


Figure 28. (Continued)

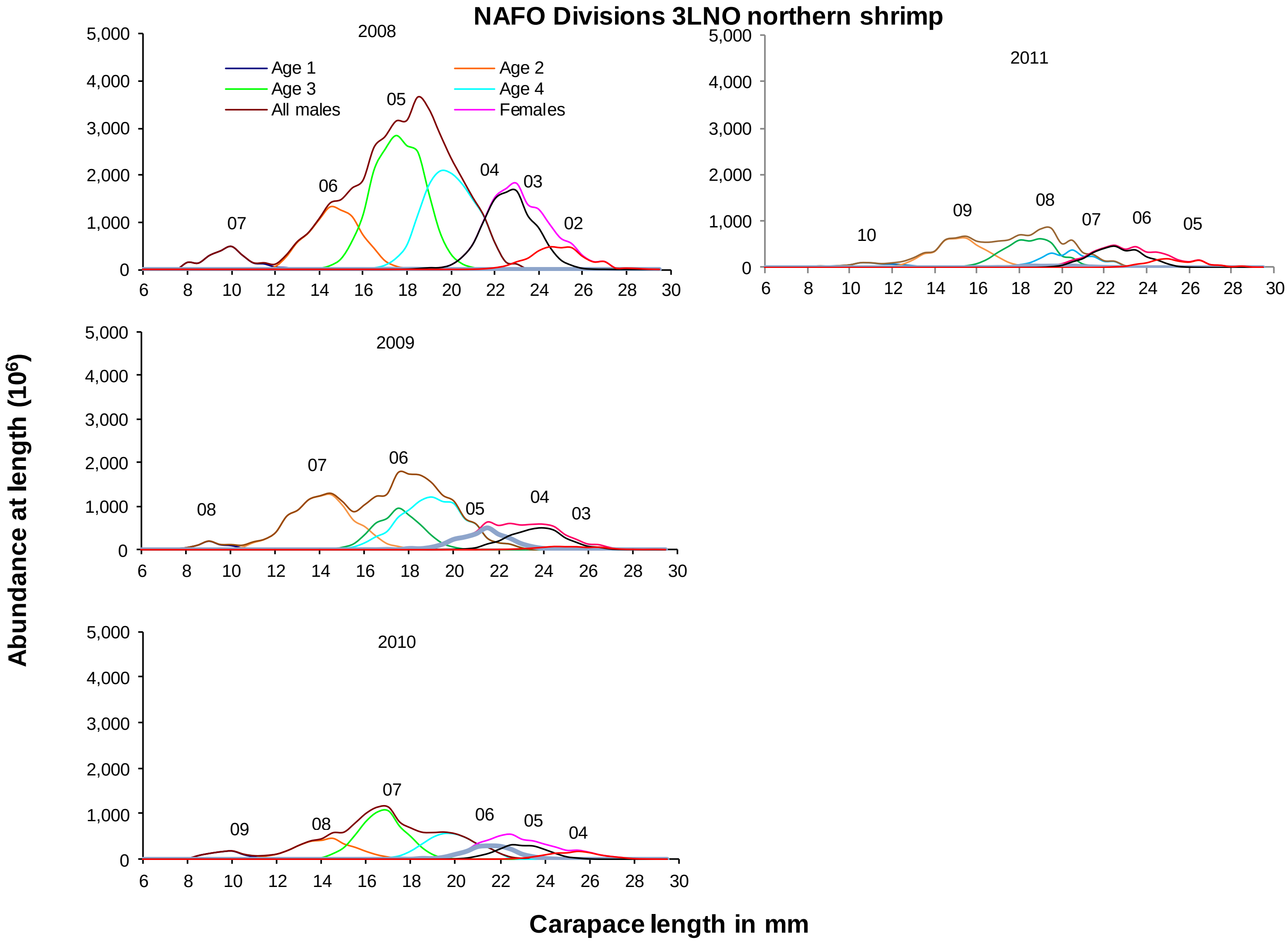
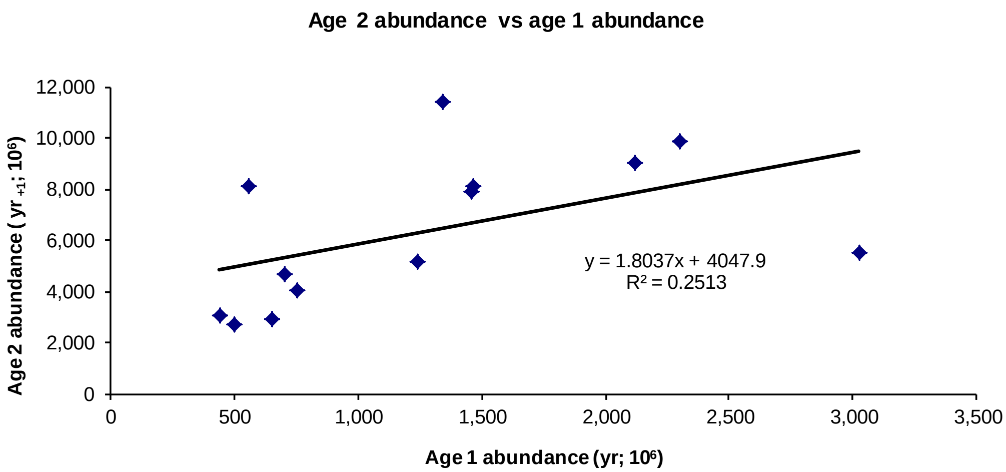
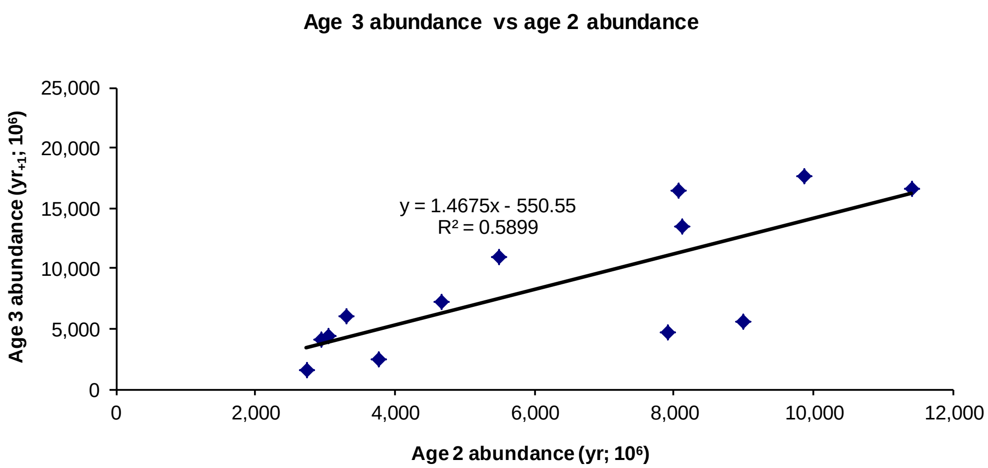


Figure 28. (Continued)





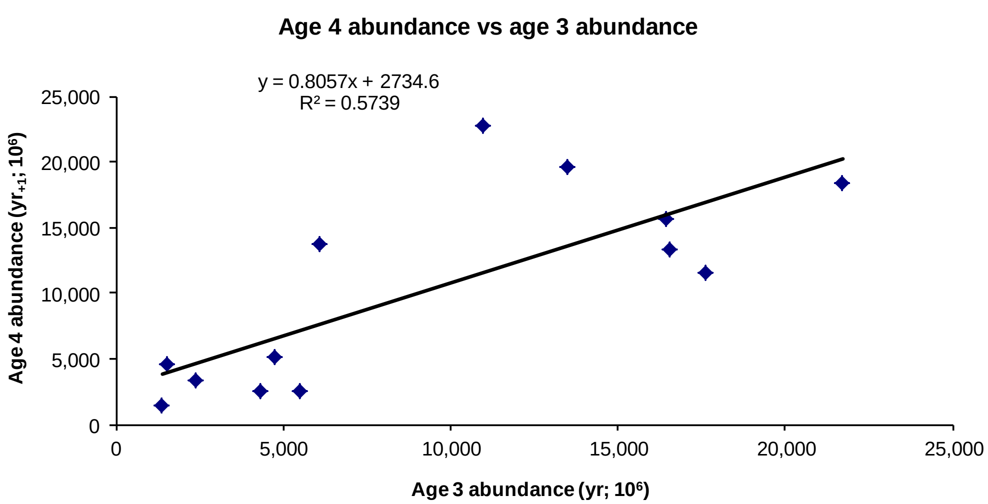
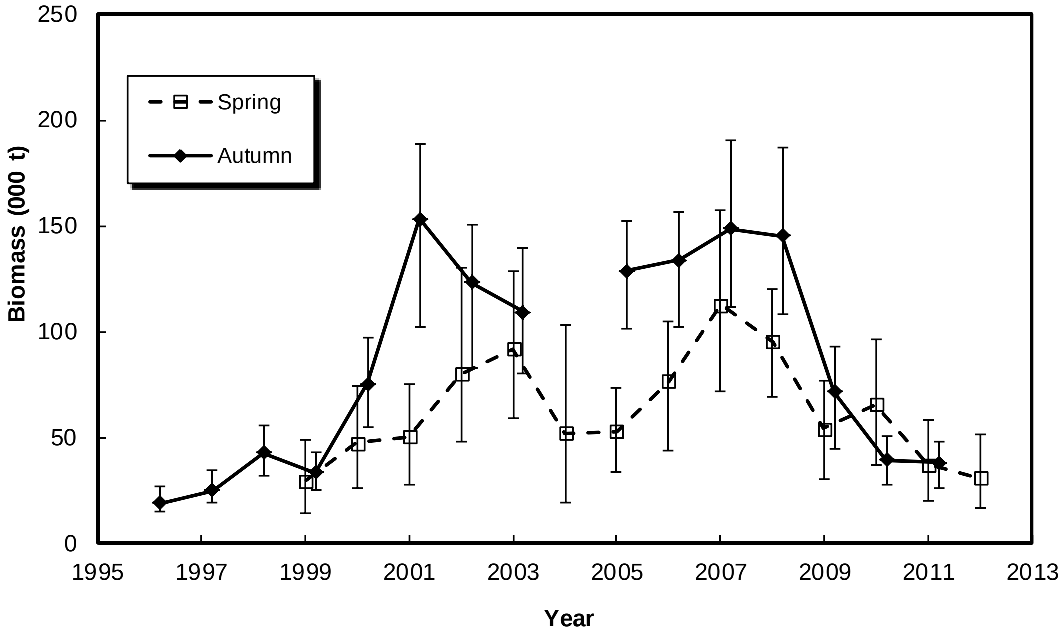


Figure 29. Relationship between abundance in one year and abundance in the successive year. These data came from the autumn modal analysis provided in table 17.



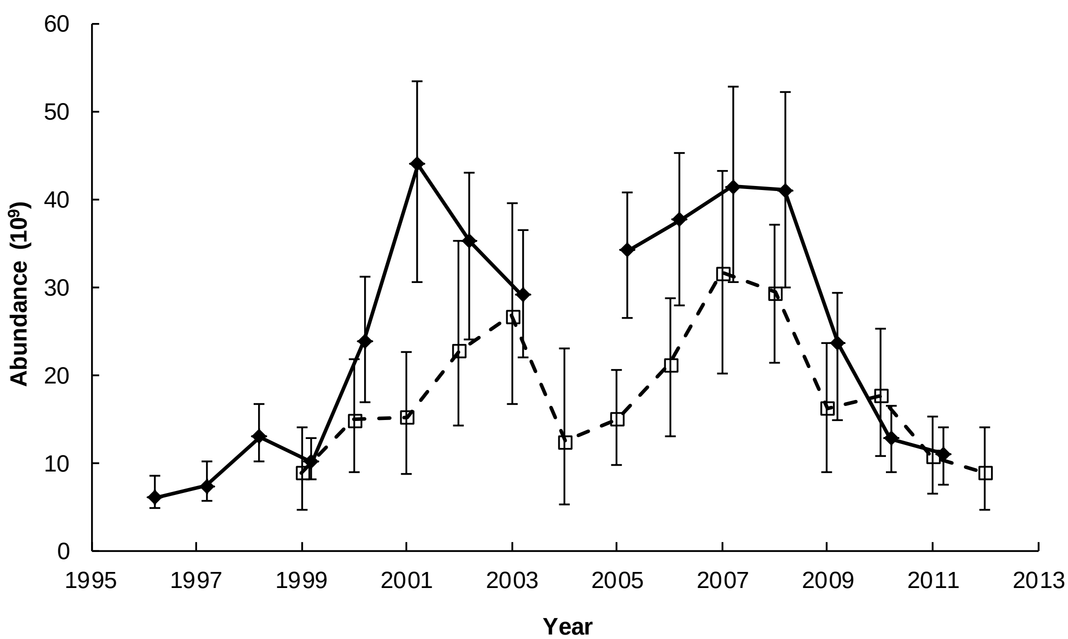


Figure 30. Abundance and biomass of male shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

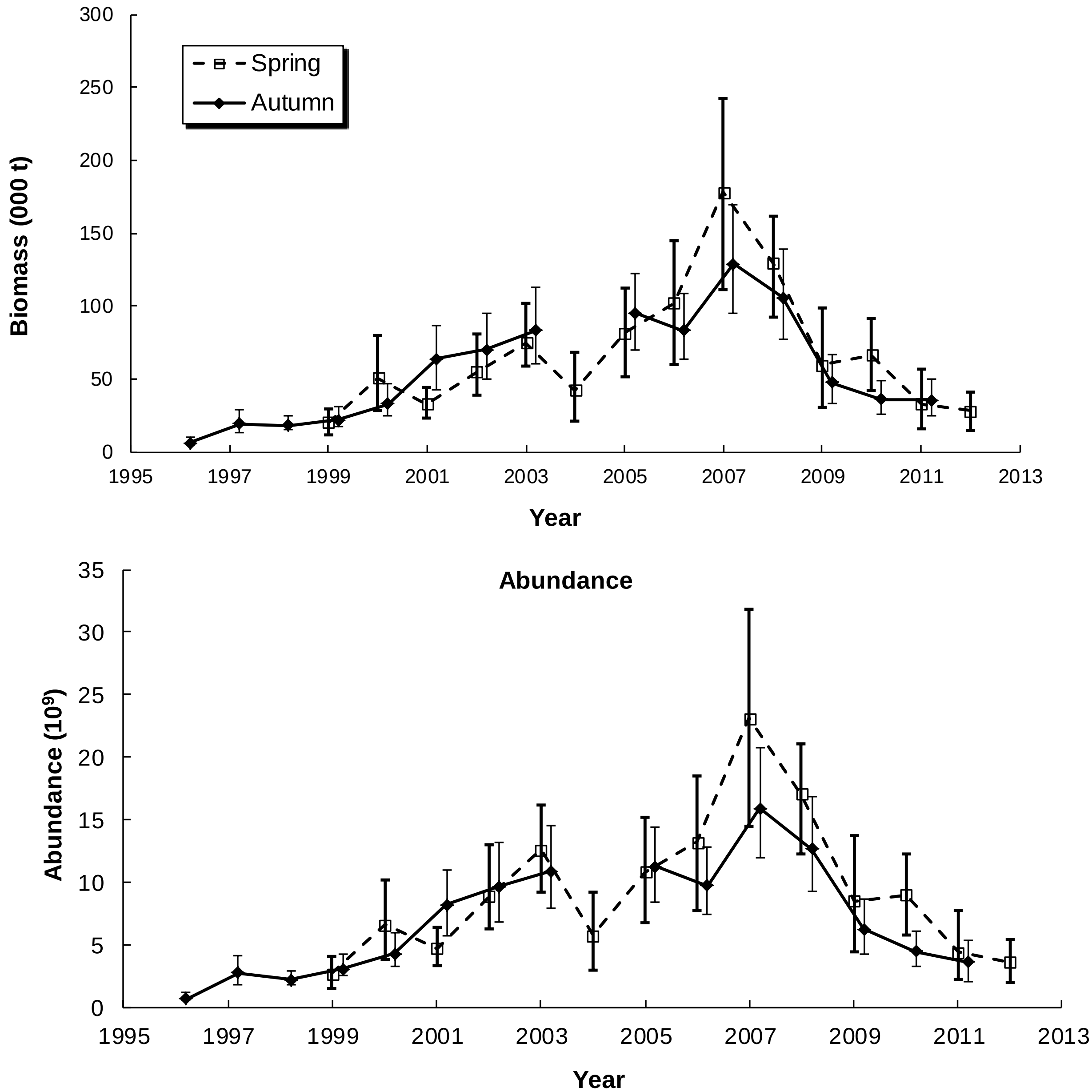


Figure 31. Abundance and biomass of female shrimp (SSB) within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

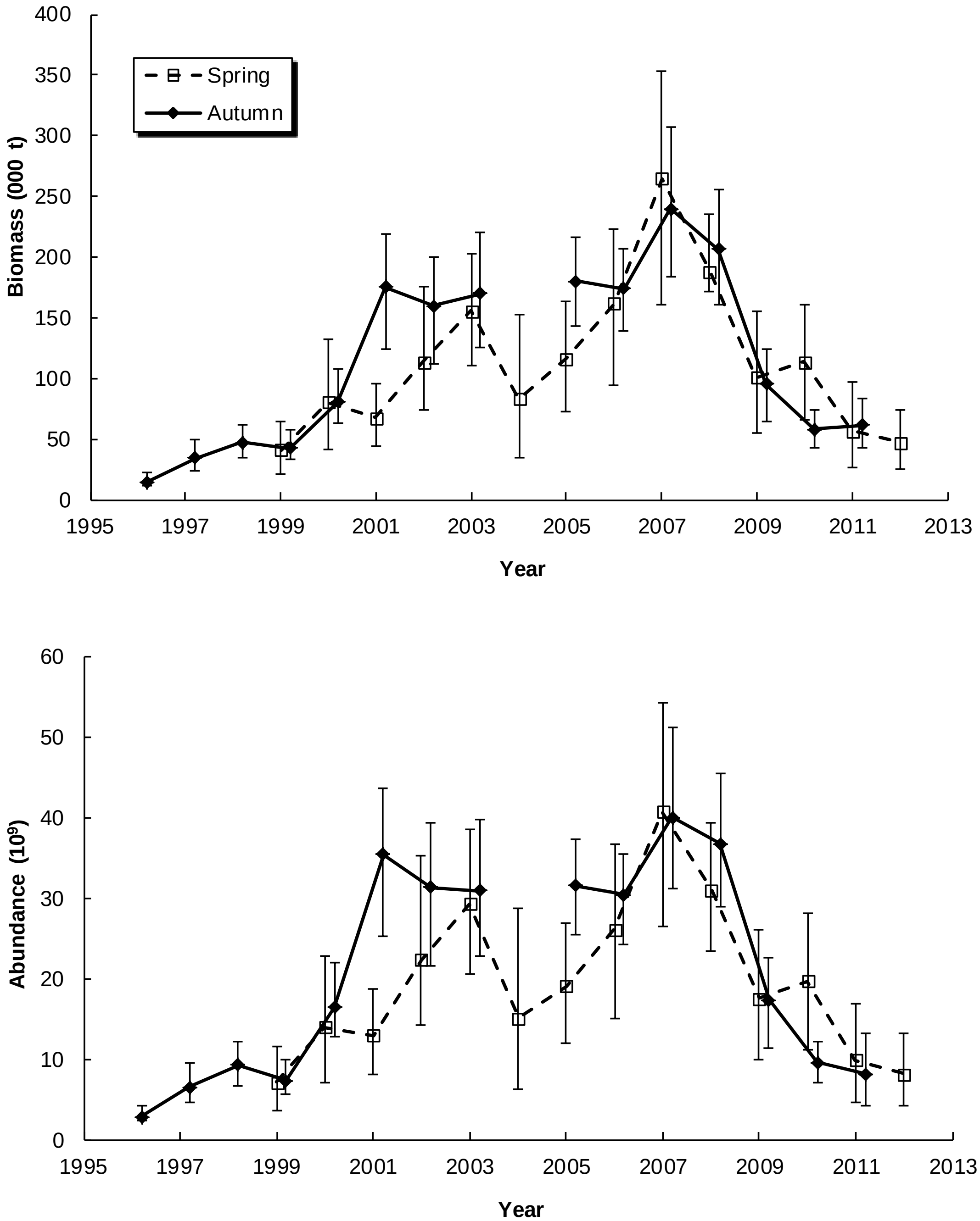


Figure 32 Fishable biomass (t) indices (weight of all females and males with carapace lengths => 17.5mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2012. The bars represent 95% confidence intervals around the fishable biomass indices.

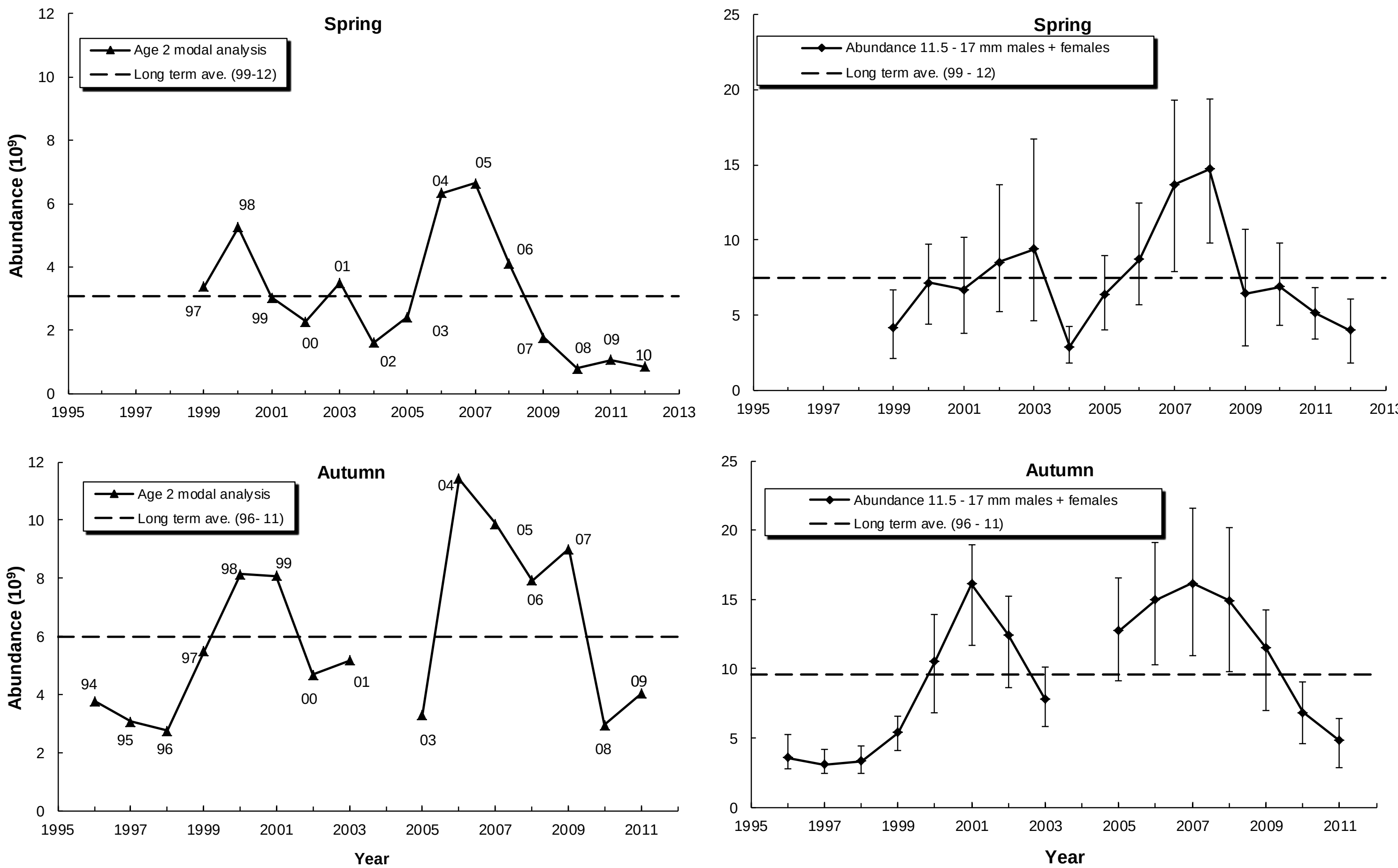


Figure 33. Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, autumn 1996 – spring 2012. The bars represent 95% confidence intervals around the index. Numbers within the modal analysis graphs are cohort years.

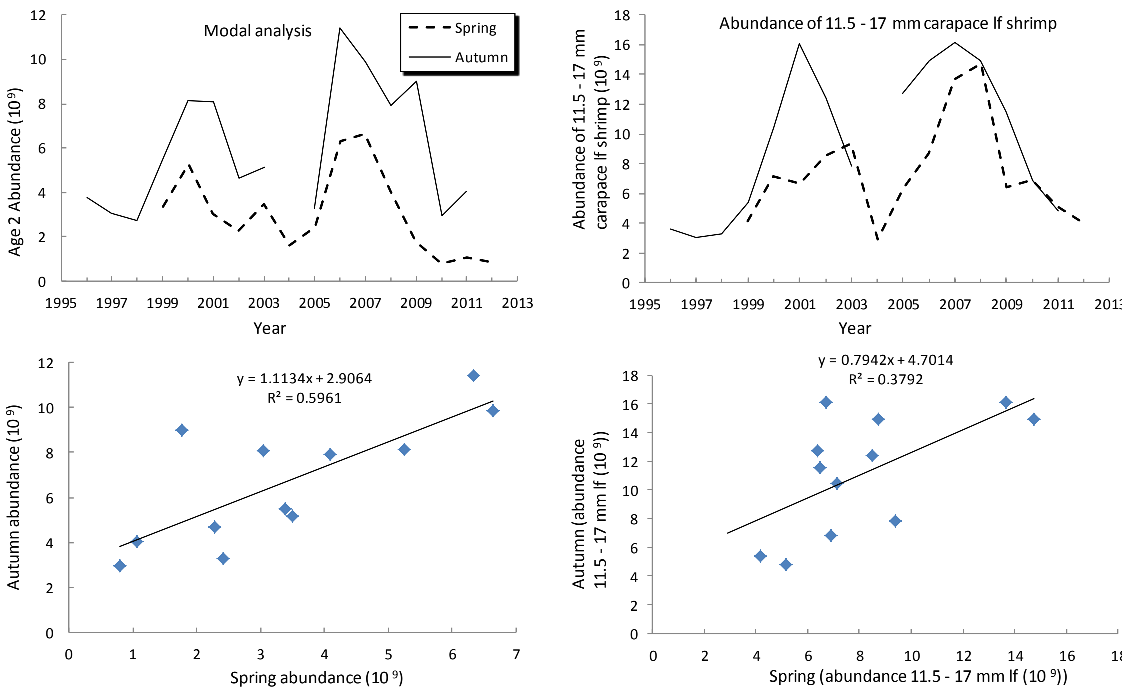


Figure 34. The relationship between spring and autumn recruitment indices created using modal analysis and size range methods.

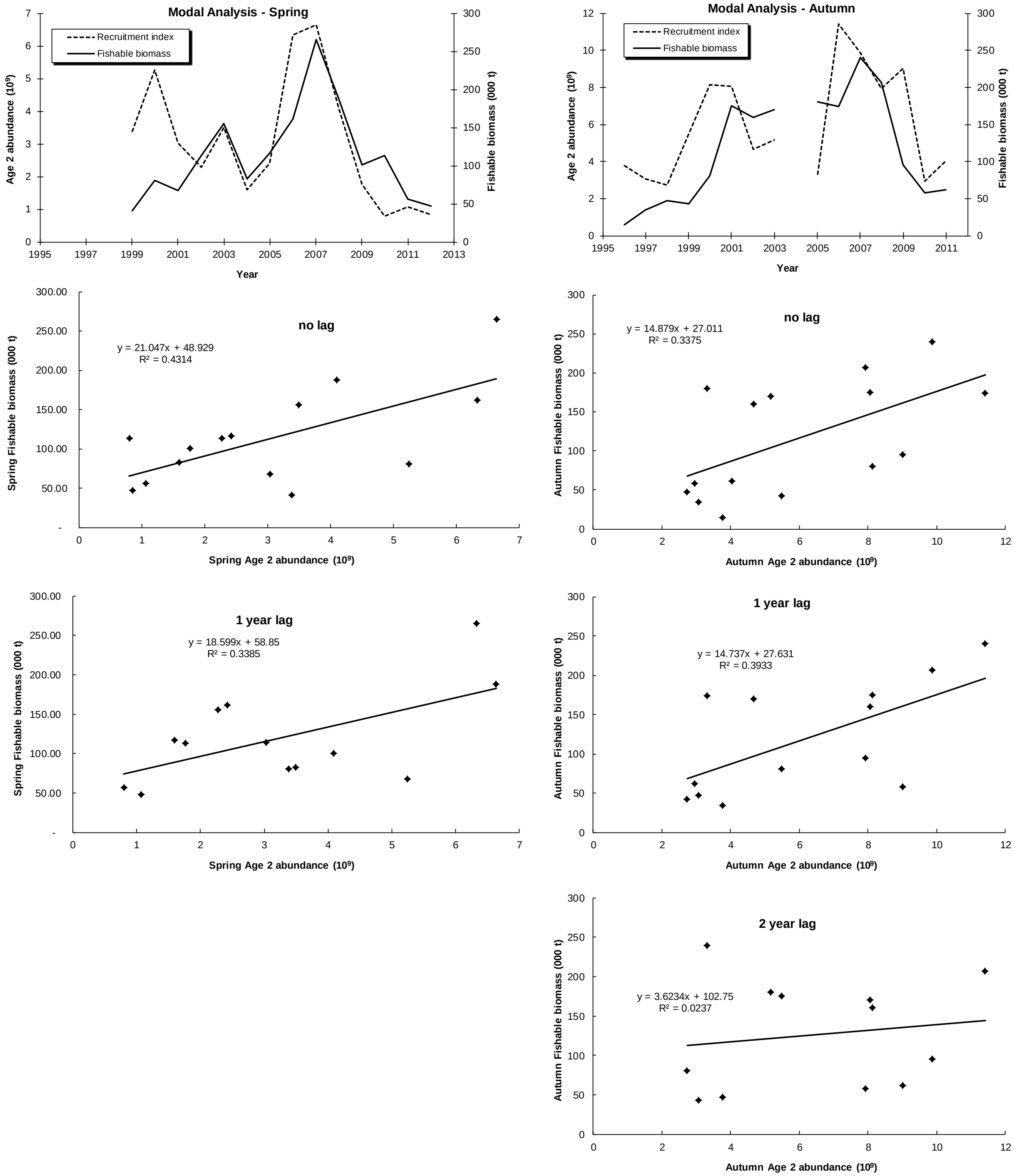


Figure 35. Predicting NAFO Divisions 3LNO northern shrimp fishable biomass from modal analysis age 2 abundance using various lags.

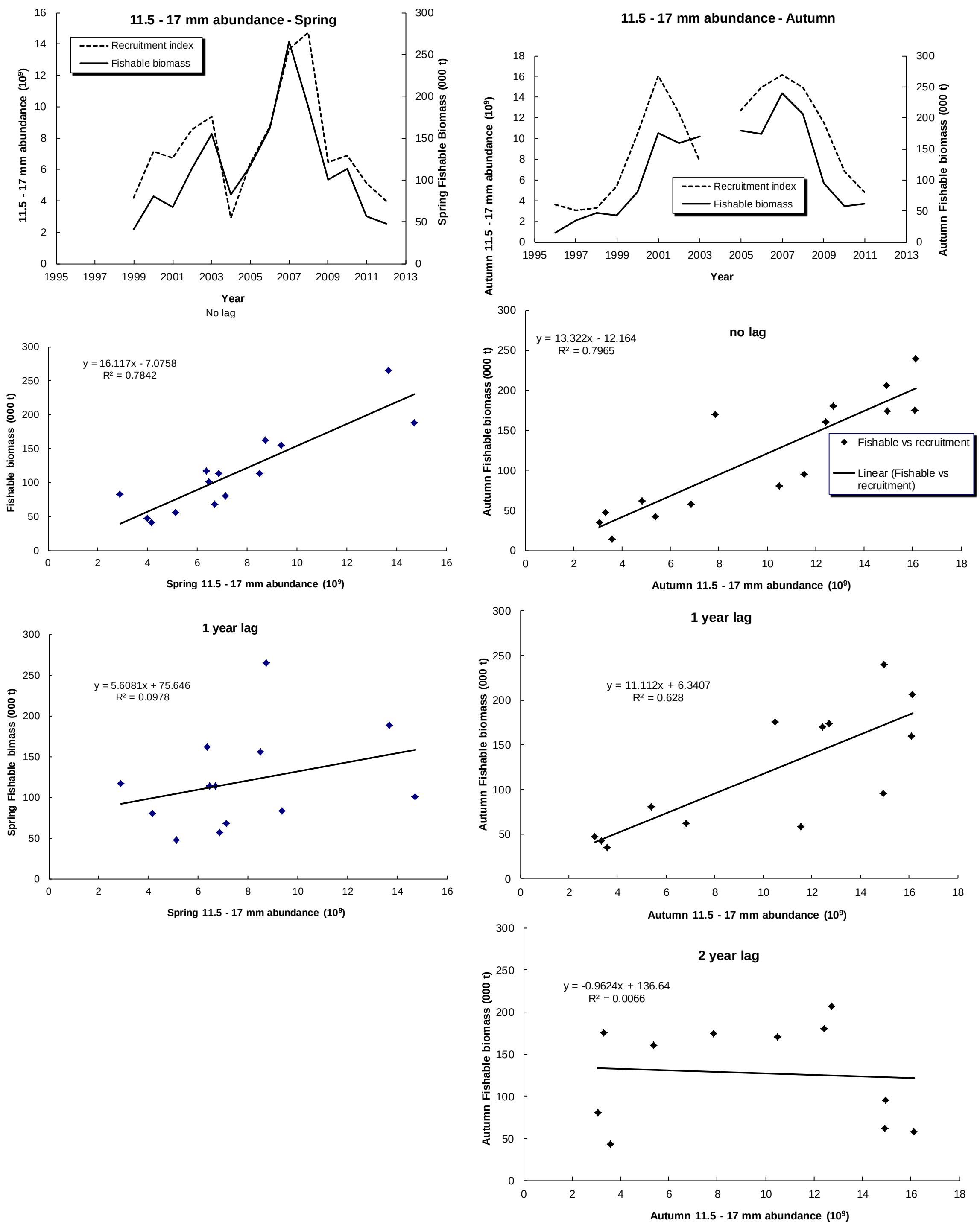


Figure 36. Predicting NAFO Divisions 3LNO Northern shrimp fishable biomass from abundance of shrimp with 11.5 – 17 mm carapace lengths.

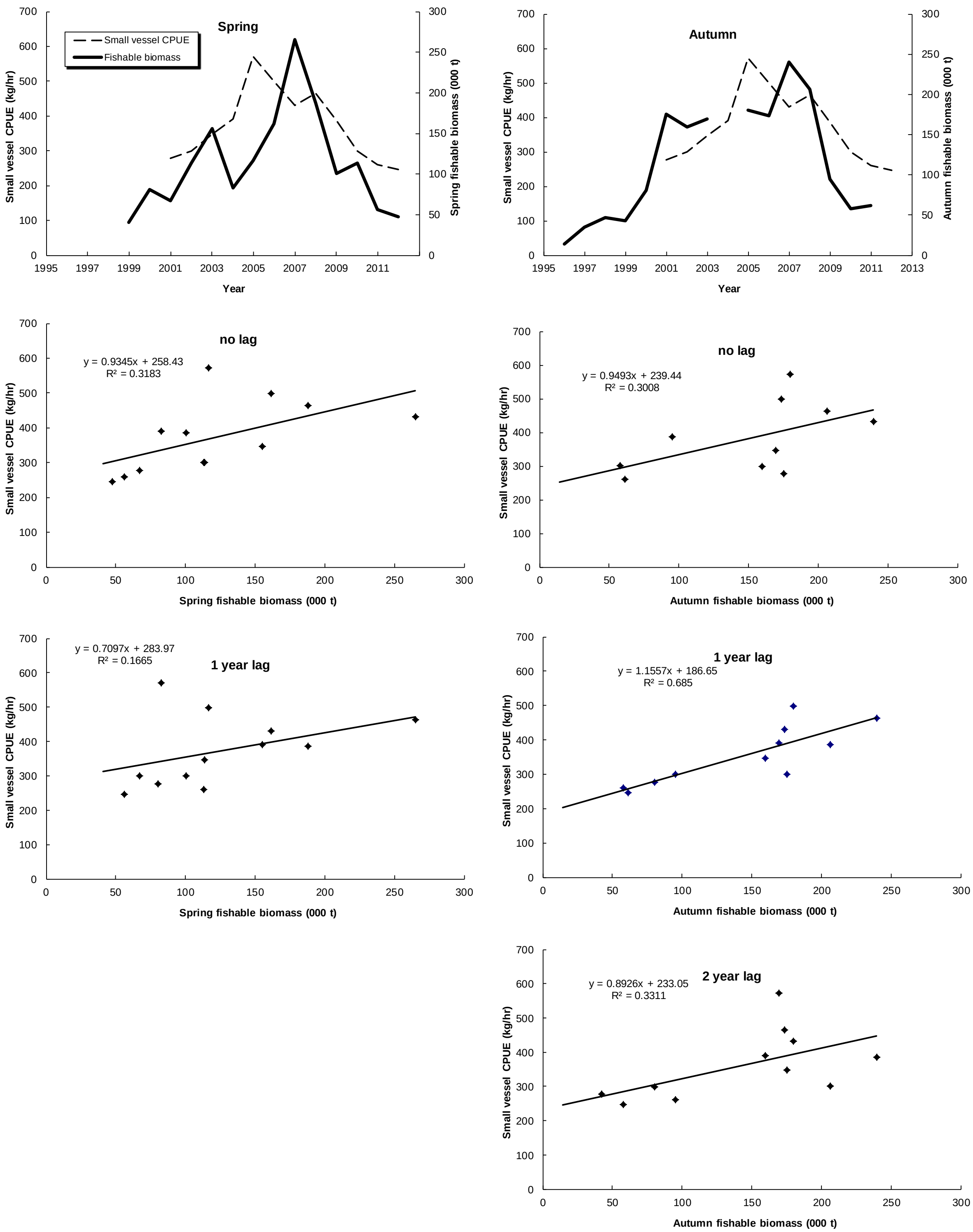


Figure 37. Predicting small vessel catch rates from NAFO Divisions 3LNO fishable biomass.

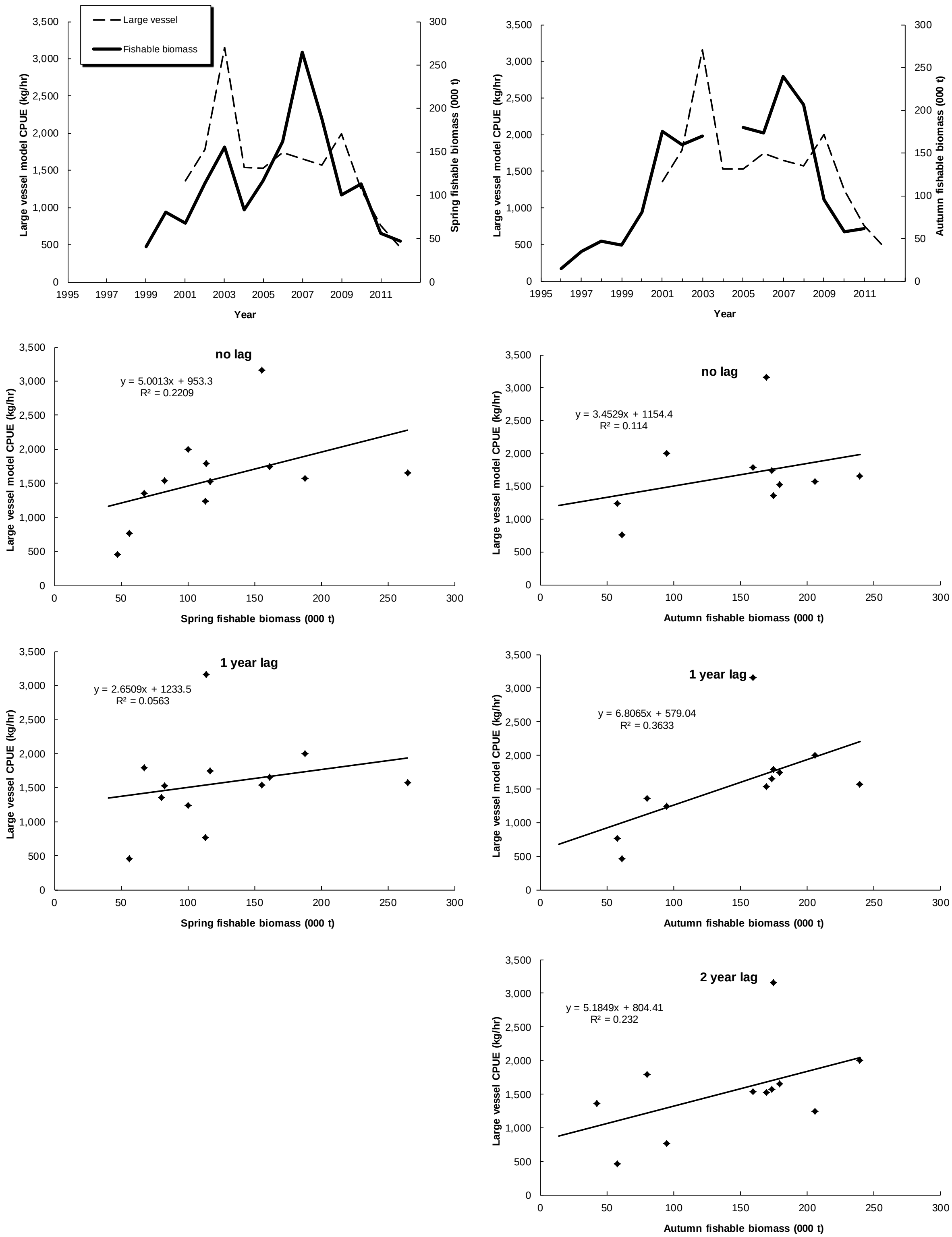


Figure 38. Predicting large vessel catch rates from NAFO Divisions 3LNO fishable biomass.

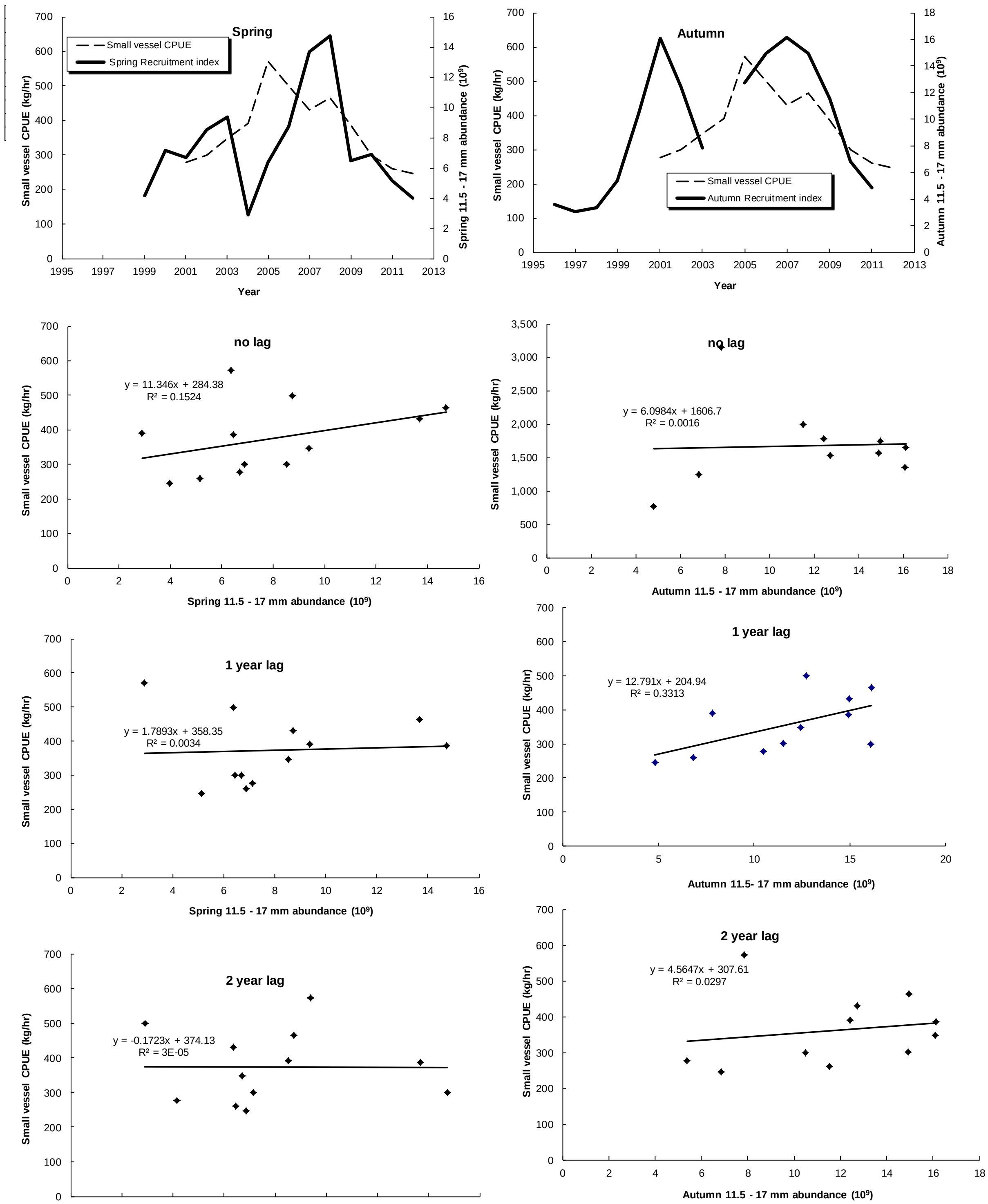


Figure 39. Predicting small vessel catch rates from abundances of 11.5 – 17 mm carapace lf shrimp.

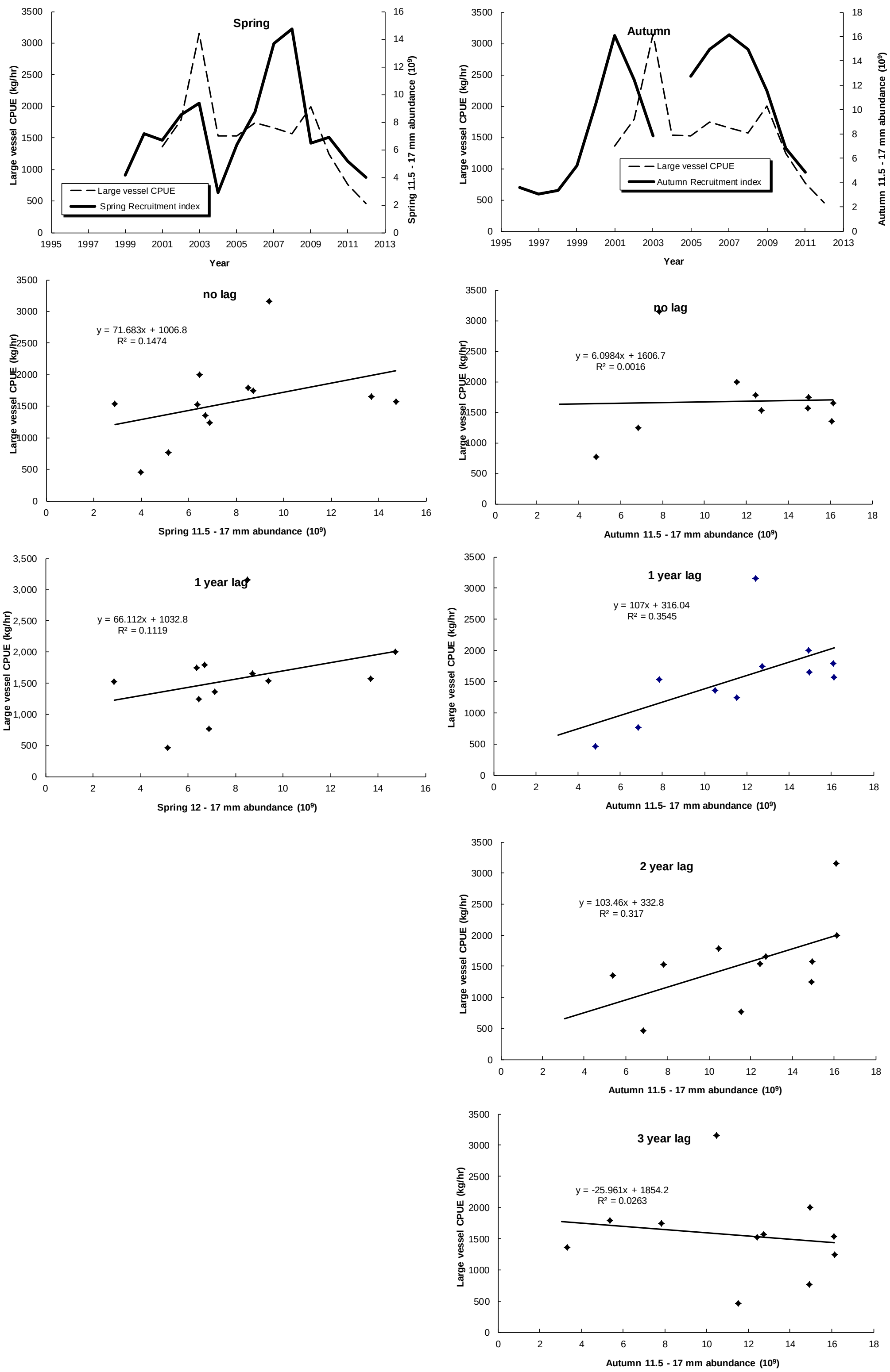


Figure 40. Predicting large vessel catch rates from abundances of 11.5 – 17 mm carapace lf shrimp.

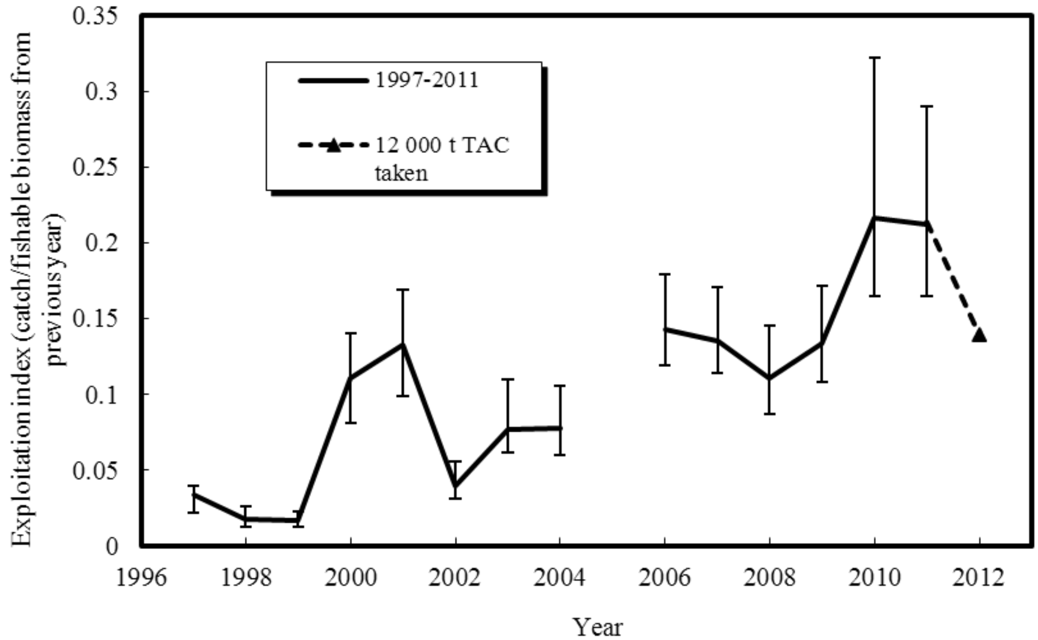


Figure 41. Trends in exploitation as derived by catch divided by the previous year's **autumn** fishable biomass index. The bars represent 95% confidence intervals around the exploitation rates for the proposed method.

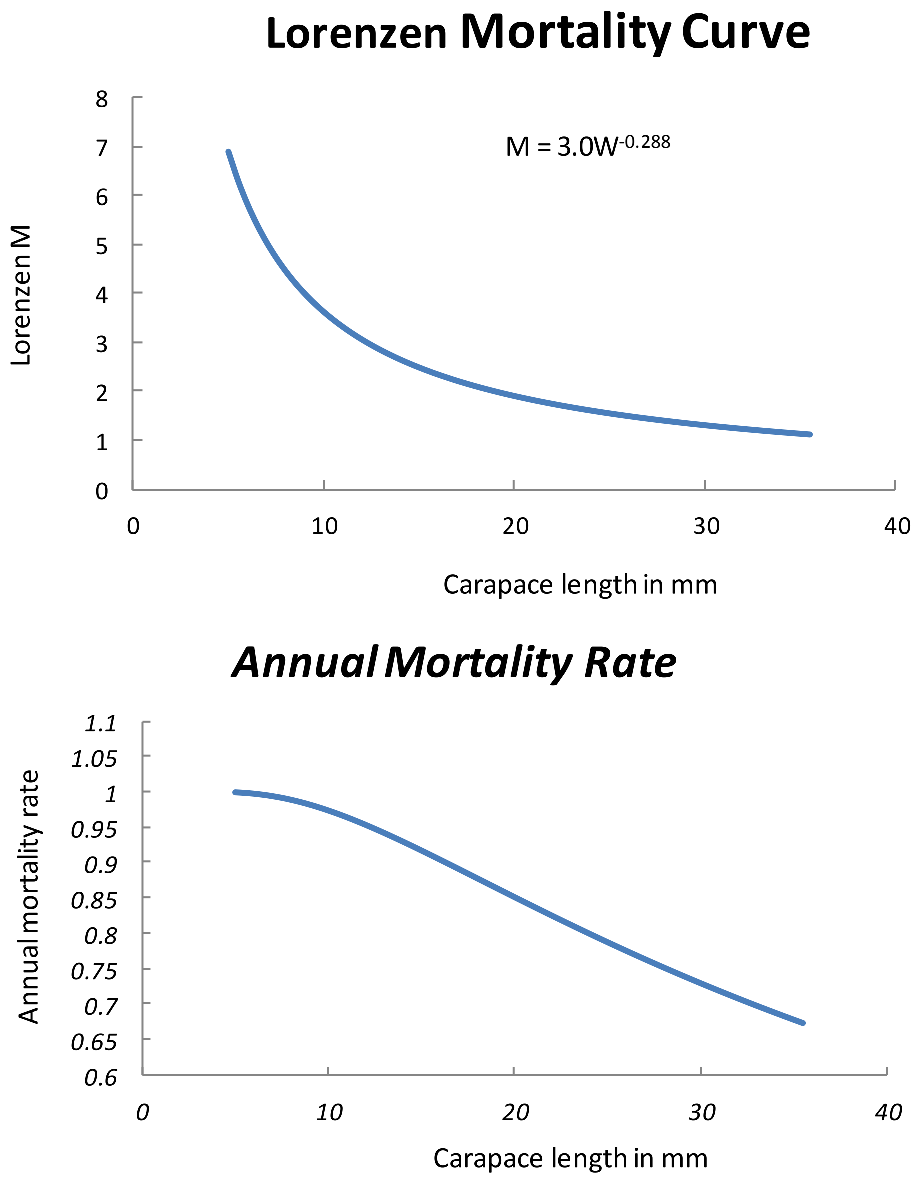


Figure 42. Lorenzen mortality curve and annual mortality for Northern Shrimp in 3LNO.

Median carapace length in mm at age

age	1	2	3	4	5	6
carapace length in mm	10.63	14.84	17.86	20.33	23.19	25.1

using L=35.5

K= Brody growth coefficient

K = 0.1732

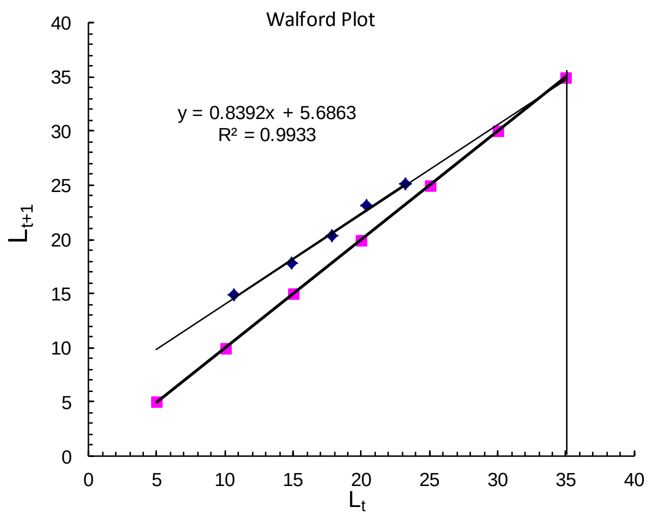
t_o = 1+1/0.173*LN((35.5 - 10.63)/35.5)

t_o = -0.35587

lt pred = 1+ (0.644/0.173)

= -1.05468

	predicted lt	observed	residuals
-1.055	0.00		
1	10.63	10.63	0.00
2	14.59	14.84	-0.25
3	17.91	17.86	0.05
4	20.71	20.33	0.38
5	23.06	23.19	-0.13
6	25.04	25.1	-0.06



L∞ is determined from Walford plot a x = 0.8392x + 5.6863

0.1608x = 5.6863

x= 35.362

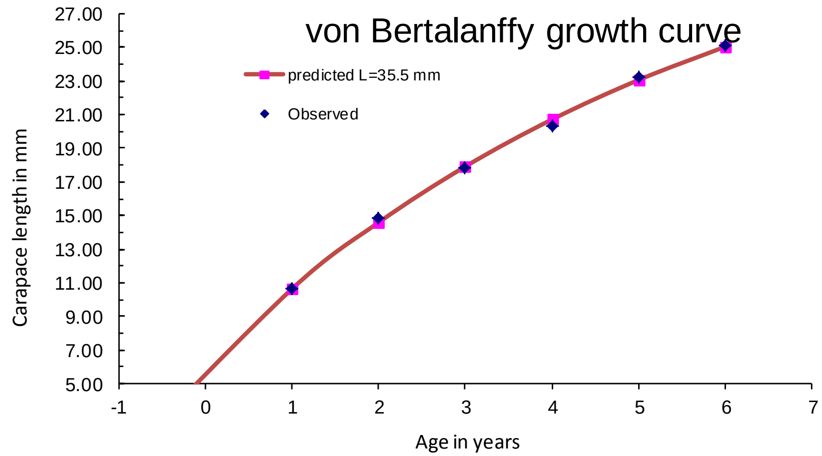


Figure 43. Derivation of the 3LNO Northern shrimp von Bertalanffy growth curve using autumn survey data.

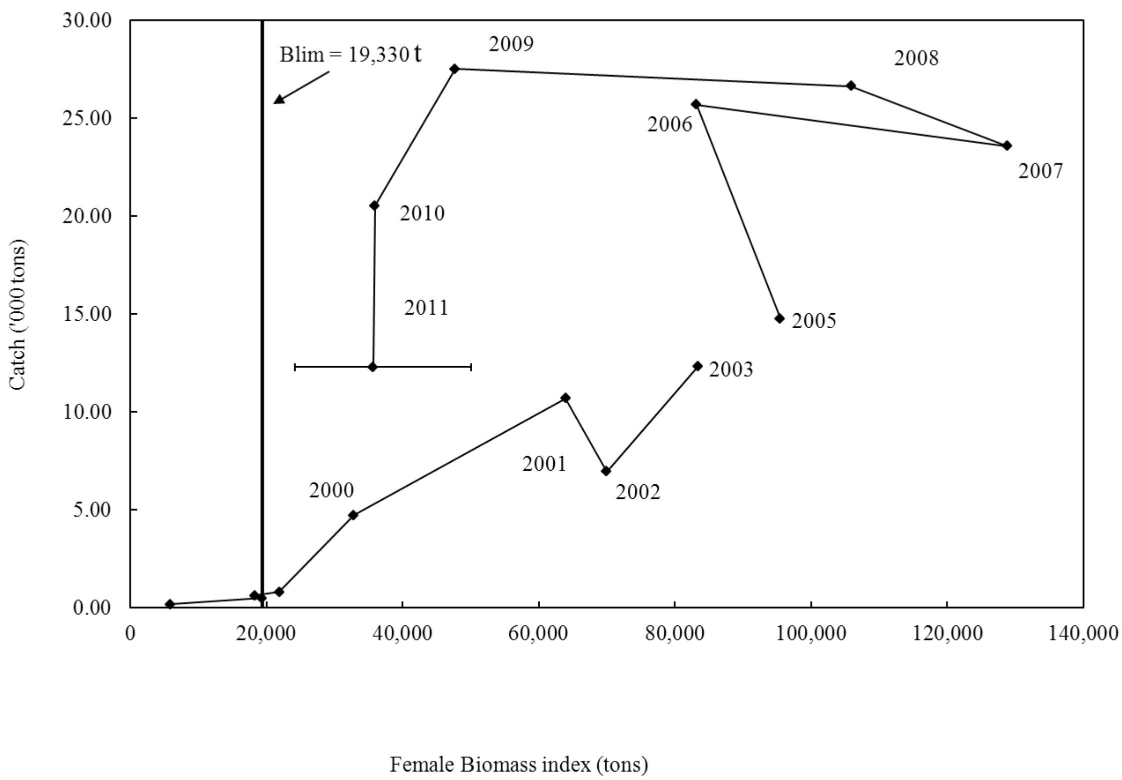


Figure 44. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).