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The 2010 assessment of the Northern Shrimp (*Pandalus borealis*, Kroyer) resource
in NAFO Divisions 3LNO

by

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ABSTRACT:

This paper describes the 2010 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 2010) and biomass estimates (autumn 1996 – spring 2010) are updated within this report. Preliminary data indicate that 27,598 t of shrimp were taken against a 30,000 TAC in 2009 while 15,560 t were taken against a 30,000 t TAC by October 1, 2010.

The autumn 2009 3LNO biomass index was estimated to be 119,200 t, a drop of 57% since 2007 when the autumn biomass index was 277,580 t. The spring biomass index decreased by 61% from 290,560 t in 2007 to 113,270 t in 2009 but has since increased by 16 % to 131,590 t in 2010.

The autumn 2009 3LNO female spawning stock biomass (SSB) index was estimated to be 47,720 t, a drop of 63% since 2007 when the autumn SSB index was 128,870 t. The spring SSB index decreased by 67% from 177,900 t in 2007 to 59,400 t in 2009, but has since increased by 12% to 66,250 t in 2010.

Similarly, the autumn 2009 3LNO fishable biomass index was estimated to be 95,040 t in 2009, a drop of 60% from 239,720 t in 2007. The spring fishable biomass index decreased by 62% from 264,990 t in 2007 to 100,580 t in 2009, but has since increased by 13% to 113,370 t in 2010.

Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean since 2004 with the 2010 catch rate near term average and similar to the 2001 and 2004- 2009 catch rates. The Canadian small vessel standardized CPUE for 2009 was near the long term average and similar to the 2003 and 2004 catch rates.

INTRODUCTION:

The northern shrimp (*Pandalus borealis*) stock, in Div. 3LNO, extends beyond Canada's 200 Nmi limit, therefore, it is a NAFO regulated stock. Northern shrimp, within NAFO divisions 3LNO, have been under TAC regulation since 1999. At that time, a 6,000 t quota was established and fishing was restricted to Division 3L, at depths greater than 200 m. The 6,000 t quota was established as 15% of the lower confidence limit of the autumn 1998 3L biomass index. This harvest level approximated those estimated for shrimp fishing areas along the coast of Labrador and off the east coast of Newfoundland (NAFO divs. 2HJ3K) (Orr *et al.* 2007). It was recommended that this harvest level be maintained for a number of years until the response of the resource to this catch level could be evaluated (NAFO, 1999). The proportion of biomass in 3LNO within the NAFO Regulatory Area (NRA), over the period 1995 – 1998, was approximately 17%. Therefore, a 5,000 t quota was established in the Exclusive Economic Zone (EEZ) for Canada while a 1,000 t quota was established in the NRA for all other Contracting Parties.

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

In 2004, an analysis was completed to determine a TAC for the 2006 fishery. Due to the highly variable nature of the spring survey indices, Scientific Council (SC) felt it was necessary to change the methodology used in determining TACs. The TAC within an adjacent Canadian stock had been 12% of the fishable biomass since 1997. Applying this percentage to the inverse variance weighted average fishable biomass from the autumn 2002 – spring 2004 surveys resulted in a TAC of 22,000 t. Had this new method been used in 2003, it is likely that the advised TAC calculated for 2005 would have been around 22,000 t instead of the 13,000 t actually advised. However, SC noted that the TAC recommendation for this stock has always included advice that "the development of any fishery in the Div. 3L area take place in a gradual manner with conservative catch limits imposed and maintained for a number of years in order to monitor stock response." The initial TAC of 6 000 t was in place for 3 years, however the 13,000 t TAC had been in place since the beginning of 2003. A two year period was insufficient to determine the impact of a 13,000 t catch level upon the stock; therefore SC recommended that the 13,000 TAC be maintained through 2005. Scientific Council recommended that the 2006 TAC for shrimp in Divs. 3LNO should not exceed 22,000 t. At that time, SC reiterated its recommendation that the fishery be restricted to Div. 3L and that the use of a sorting grate with a maximum bar spacing of 22 mm be mandatory for all vessels in the fishery. During the November 2007 shrimp assessment, SC was asked to determine exploitation rates for various catch options assuming that the fishable biomass remains at the 2007 level. During May 2008, a special session of FC decided that the 2008 and 2009 quotas should be increased to 25,000 t and that the advice would be reviewed in September 2008. Subsequently the 2009 and 2010 TACs were set at 30,000 t.

Full assessments of this stock are completed during the annual October - November shrimp assessment meetings. Results from these assessments provide necessary input for quota decisions made during Fishery Commission meetings, held during September. Canadian autumn and spring multi-species bottom trawl surveys are completed in 3LNO in the time between the assessment and the commission meetings. The additional biomass information derived from these surveys is provided, within interim monitoring reports, to NAFO SC just prior to the annual Fishery Commission meetings. The last interim monitoring report was presented to NAFO SC during September 2010.

Various TAC options, based upon exploitation of fishable biomass were presented to FC during September 2010. TACs of 19,000 and 17,200 t were chosen for the 2011 and 2012 management years respectively.

The present document was produced for the October 2010 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:

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

Where: $CPUE_{ijkml}$ is the CPUE for grt k, fishing x number of trawls, in month j during year l (k=1,.....,a; j=1,.....,s; l=1,.....,y);

$ln(u)$ is the overall mean ln(CPUE);

S_j is the effect of the jth month;

V_k is the effect of the kth cfv;

T_m is the effect of m number of trawls;

Y_l is the effect of the lth 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 2010 YEAR parameter estimate and those of previous years was inferred from the output statistics.

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

Canadian logbook database:

The small vessel CPUE dataset was created using logbook data because all shrimp fishing vessels must complete logbooks, whereas, observer coverage in the small vessel shrimp fishery may be as low as 3%.

The landings by small and large vessels allowed a comparison with the total observed catches for each fleet. This comparison provided an indication of percent of total catch captured in each CPUE model.

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 = 2.5 Nmi/hr as determined from observer data

Average footrope length = 145' as determined from observer data

Double trawl data:

Catch-per-unit-effort = (catch X ((2.5/speed)X(145/footrope length))/effort)/conversion factor to single trawl units

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

Average wingspread = 103.5'

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

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

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

Spatial distribution of the northern shrimp fishery

Logbook and observer catches were plotted using Surfer 9.11 (Golden Software 2010). The area fished each year was divided into 10 min. X 10 min. cells, catches were aggregated by cells, and aggregated catches were organized into a cumulative percent frequency (cpf). The cpf was used to determine the number of cells accounting for 95% of the catch each year (Swain and Morin 1996). Area occupied by cells accounted for changes in latitude by way of the following great circle distance formula using decimal degrees:

$$3963.0 * \arccos[\sin(lat1/57.2958) * \sin(lat2/57.2958) + \cos(lat1/57.2958) * \cos(lat2/57.2958) * \cos(lon2/57.2958 - lon1/57.2958)]$$

(online available at: http://www.meridianworlddata.com/Distance-Calculation.asp)

The area necessary to account for 95% of the catch was compared with the amount of area available within each SFA.

The amount of area trawled was estimated from speed in Nmi/hr, footgear breadth and time trawled using observer dataset information. The start position was the only positional information available for the assessment and was used to place the fishing set in a cell. The amount of area necessary to account for 95% of the trawled effort was then determined and compared with the amount of area available within each SFA as determined above.

The plots and quantification of spatial coverage were used in describing changes in fishing patterns and practices that might affect CPUE interpretations.

International observer and logbook information:

These data were made available by Contracting Parties that fish shrimp in Div. 3L NRA. They were used in CPUE calculations and catches were added to the Canadian catches when determining a total catch. Where no information was provided by a Contracting Party, information was augmented through the use of Canadian surveillance data, as well as, NAFO Statlant 21A and monthly provisional catch tables.   Greenland, Iceland, Norway, Spain and Russia provided catch and effort data over a number of years making it possible to derive catch rates for the NRA.

Canadian spring and autumn multi-species research surveys:

Spring and autumn multi-species research surveys, using a Campelen 1800 shrimp trawl, have been conducted onboard the Canadian Coast Guard vessels Wilfred Templeman, Teleost and Alfred Needler since 1995. Fishing

sets of 15 minute duration, with a tow speed of 3 knots, were randomly allocated to strata covering the Grand Banks and slope waters to a depth of 1,462 m in the autumn and 731 m in the spring, with the number of sets in a stratum proportional to its size (Fig. 1). All vessels used a Campelen 1800 shrimp trawl with a codend mesh size of 40 mm and a 12.7 mm liner. SCANMAR sensors were employed to monitor net geometry. Details of the survey design and fishing protocols are outlined in Brodie, (1996), Brodie and Stansbury (2007), as well as McCallum and Walsh (1996).

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

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

Due to operational difficulties it was not possible to survey all of the strata within NAFO Div. 3NO during spring 2006. Strata 373 and 383 as well as most 3NO strata deeper than 92 m were not surveyed. Analyses indicate that at least 90% of the shrimp are found in NAFO Division 3L (this report), therefore the spring 2006 indices were calculated for 3L only.

Since 2003, shrimp species and maturity stage identifications, as well as length frequency determinations have been made at sea, whenever possible. Otherwise, shrimp were frozen and returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage was made. Shrimp maturity was defined by the following five stages:

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

as defined by Ramussen (1953), Allen (1959) and McCrary (1971). Oblique carapace lengths (0.1 mm) were recorded while number and weight per set were estimated from the sampling data. Inshore strata were not sampled in all years; therefore, the analysis was restricted to data collected from offshore strata only. Total biomass, abundance and length frequency estimates were determined using OGive MAPping calculations (Evans *et al.* 2000). During spring and autumn of 2004, carapace lengths and live weights of approximately 1500 *Pandalus borealis* were measured within 24 hours of capture. Lengths and weights were converted to $\log_{10}$ values, and regression models were developed for males, transitionals ovigerous and non-ovigerous females.

Modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) was conducted on male research length frequencies. The population estimate of age 2 animals provided a recruitment index. Previously recruitment was also estimated as the population of males from the spring and autumn surveys with 12-17 mm carapace lengths. These animals are thought to represent age 2 and 3 animals that enter the fishery during the following year. We are now proposing that recruitment should be estimated for all males and females with 12 – 17 mm carapace lengths.

Previously, fishable biomass had been estimated by first determining the weight of fishable males (>17 mm carapace length) + weight of all females on a set by set basis before conducting Ogmap calculations. We are now proposing that fishable biomass should be 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 biomass using the male 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 indices were developed by dividing total catch by each of the following estimates:

lower 95% confidence interval below the biomass index,

female biomass (SSB), and

fishable biomass.

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

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

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

OGive MAPping (ogmap):

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

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

- nearby distributions are related.

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

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

indices were multiplied by 1.0068 to correct for this discrepancy. For this reason there may be a slight difference between indices reported here and those reported in previous assessments.

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

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

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

Catches increased dramatically since 1999, with the beginning of a regulated fishery. Since then, sixteen contracting nations have exercised their privileges to fish shrimp in 3L. Over the period 2000 – 2008, catches increased from 4 700 t in 2000 to over 27,000 t by 2008 (Table 1; Fig. 5). Preliminary data indicate that 27,598 t were taken against a quota of 30,000t in 2009 while 15,560 t were taken against a 30,000 t quota in 2010. It is doubtful that the 2010 quota will be taken.

As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 4 050 t in 2000 to 21,187 t in 2008. The Canadian large and small vessel fleets took 20,494 t and 11,981 t in 2009 and by Oct 2010 respectively. Catches by non Canadian vessels increased from 661 t to 7 673 t by 2006, remaining near 6 000 t until 2009. Preliminary data indicate that by October 2010, 3 579 t had been taken against a non Canadian TAC of 5 100 t.

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 - 8) from the northern border with 3K south east along the 200 – 500 m contours to the NRA border. The percent area occupied by the large vessel fishery has been increasing since 2002, but is still less than 4% of the total area available. The small vessel fleet has occupied no more than 8% of the total available area and has also shown an increasing trend, however, the percent area occupied has varied greatly. It is important to note that an increasing trend does not necessarily mean that the total area occupied by the fishery has increased, rather it means that the catches are more evenly distributed.

The small vessel fleet fishes shrimp mainly during the spring and summer months, while seasonality of the large vessel fleet varied over time (Fig. 9).

Due to a lack of data (Fig. 6) it was not possible to model small vessel CPUE up to and including 2010. Small vessel CPUE (2000 – 2009) was modeled using month, year and size class (class 1 = <50' LOA; 50' LOA <=class 2< 60' LOA; class 3 => 60' LOA) as explanatory variables (Table 2). The logbook dataset that was used in this analysis accounted for between 57.2% and 93.7% of the catch within any one year (Table 3). The final model explained 85.0% of the variance in the data and indicated that the annual, standardized catch rates increasing from near 350 kg/hr over 2000 – 2002 to 690 kg/hr by 2005 before gradually decreasing to 434 kg/hr by 2009. The 2009 catch rate index was similar to the 2003 and 2004 indices while being significantly lower than all intervening indices (Tables 2 and 3; Fig. 10). No clear trends were found in the plots of residuals (Fig. 11).

Seasonality among the large vessel fleet has varied greatly over the years (Fig. 9); therefore large vessel catch rates were analyzed by multiple regression using data collected throughout the entire year. 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 26% and 88% of the catch within any one year (Table 5). The final model explained 66% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean since 2004 with the 2010 standardized catch rate index (1 479 kg/hr; Tables 4 and 5; Fig. 10) near the long term average (1 620 kg/hr) and similar to the catch rates for 2001 and 2004 - 2009 indices (Tables 4 and 5; Fig. 10). There were no trends in the residuals around parameter estimates (Fig. 12).

Table 6 provides trends in mean catch (kg/hr) per stratum determined from small vessel logbook catch and effort data. The number of strata fished by the small vessel fleet increased from 7 in 2001 to 16 in 2007 and remained near that level through to 2009 (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 13 provides a map of these strata. Neither the panel showing all strata nor that showing index strata provide an indication of contraction of the fishery. This is confirmed figure 6 which indicates the fishing set locations for the period 2006 – 2010 and figure 8 which indicates that the area occupied by the fishery has been trending upward. Table 7 indicates that the biomass within the index strata increased from 29 000 t in 2003 to 47 000 t in 2006 but has subsequently decreased to 31 000 t by 2009. Similarly mean catch (t/hr) increased from .47 t/set in 2003 to .76 t/set in 2006 but decreased to .50 t/set by 2009.

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

The small vessel fishery covers a larger portion of the resource (Table 6; Figs 6 - 8) whereas the large vessel fleet has always fished near the 200 Nmi limit and along the northern edge of 3L (Table 8; Figs. 7 and 8). For this reason, the small vessel fleet information may provide a better indicator of resource status than the large vessel fleet.

International fleet

A standardized international fleet CPUE model is not presented here as the percent catch data accounted for in the international dataset ranged from 1 – 45% and in most years was less than 20% of that year's catch. Unstandardized international indices increased from 381 kg/hr in 2001 to 2 035 kg/hr in 2004, decreased to 570 kg/hr in 2005, remained near that level in 2006 before increasing to 1 021 kg/hr in 2007 and finally reaching 1 395 by 2009 (Table 9; Fig. 14). It is not clear how representative these commercial catch rates are of the international fishery in the 3L NRA.

Size composition

Relatively few length frequencies were collected by observers of small vessel fishing activities therefore it is not certain whether the length frequencies are representative of fleet activities (Fig. 15). The low number of length frequencies resulted in very jagged length distributions that could not be aged using modal analysis. However, it is noteworthy that the length frequencies for both non-ovigerous and ovigerous animals were broad for each year implying that more than one year class was evident within the catch.

On the other hand, several length frequency observations were taken from large vessel catches (Fig. 16). Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females believed to be at least three years of age. The male modes overlapped to the extent that it was not possible to complete Mix distribution analysis; however, there were often two faint sub-peaks implying the presence of more than one year class. Given that the modes were usually near 17 and 20 mm, these animals were probably 3 - 5 years of age. The female length frequency distributions were also broad indicating that the female portion of the catch probably consists of more than one age group. In most years since 2000, catch rates had been maintained at over 200,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 17.8 mm and 19.7 mm, while the weighted average carapace lengths for females ranged between 22.7 mm and 23.8 mm. There were no trends in the average size of either males or females.

Figure 17 presents the length frequencies from the 2007 - 2010 Estonian catches. As with the Canadian size compositions, this figure also shows a broad range in sizes of shrimp, probably from at least three year classes. Given the fact that the length frequencies are from only one nation and relatively few samples were taken each year, it is not clear whether they are representative of non Canadian catches.

RESEARCH SURVEY DATA

Stock size

The autumn 2006 – 2009 and spring 2007 – 2010 research catches are concentrated within NAFO Div. 3L at depths between 200 and 500 m (Figs 18 and 19). The autumn 2009 3LNO biomass index was estimated to be 119,200 t, a drop of 57% since 2007 when the autumn biomass index was 277,580 t. The spring biomass index decreased by 61% from 290,560 t in 2007 to 113,270 t in 2009 but has since increased by 16 % to 131,590 t in 2010. (Table 10;

Figs 18 and 19). 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. Figure 18 clearly indicates that very few large catches were taken along the northern edge of 3L during the 2009 and 2010 spring surveys relative to previous autumn and spring surveys, which normally held high catches in this area. Figure 8 illustrates the percent of the total area occupied to obtain 95 % of the catch. This figure clearly shows that the percent area has been decreasing in both spring and autumn surveys since 2008 and 2005 respectively. The fact that the spatial index has been decreasing should not be interpreted to mean that the area occupied by the fishery has been decreasing, rather it means that the resource is less evenly distributed.

Tables 11 and 12 provide the mean catch (kg/standard 15 min tow) per stratum as determined respectively from spring and autumn Canadian bottom trawl survey data. It is noteworthy that a few very high mean catches were recorded during the spring surveys (Table 11) relative to the autumn surveys (Table 12). This would account for the broad confidence intervals sometimes evident in the spring indices relative to the autumn indices and because the resource is more evenly distributed during the autumn, the percent area occupied by autumn resource is broader than it is for the resource surveyed during the spring (Fig. 8).

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 184 to 550 m. Over the study period, the area outside 200 Nmi accounted for between 11.2 and 32.6% of the estimated total 3LNO biomass (Tables 13 and 14; Figs. 18 and 19; Orr *et al.* 2007). During the autumn, the percent biomass within the NRA ranged between 12.1 and 21.0%. Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 12.1 – 21.3% of the total 3LNO autumn biomass was within the NRA (Table 14). Over the period 1996 – 2009 the overall average autumn percent biomass within the NRA was 16.8%. During the spring, the percent biomass within the NRA ranged between 11.2 and 32.6% (three year running average ranged between 18.7 and 26.6%) (Table 13). Over the period 1999 – 2010 the average spring percent biomass with the NRA was 23.2%. It must be noted that variances around the spring indices are greater than around autumn indices (Table 10; Figs. 18 - 20).

In all surveys, Division 3N accounted for .26-8.1% of the total 3LNO biomass (Tables 13 and 14). Between 33.3 and 77.4% of the 3N biomass was found outside the 200 Nmi limit. Division 3O accounted for less than 1% of the 3LNO biomass. A negligible amount of the Division 3O biomass was found outside the 200 Nmi limit.

Stock composition

Length distributions representing abundance – at – length from the autumn 1996 - spring 2010 surveys are presented in figures 21 and 22. Generally, modes increase in height as one moves from ages 1 – 3 indicating that modes become more overlapping and that shrimp catchability probably improves with size. Tables 15 and 16 provide the modal analysis and the estimated demographics from each survey. These time series provide a basis for comparison of relative year-class strength and illustrate the changes in stock composition over time. There appear to be three regimes; one prior to 2000 at a time during which abundances at age were low and a second period from 2000 - 2007 during which abundances were much higher and then a third period after 2007 when abundances at all ages appear low again. The 1997 year-class first appeared in the 1998 survey as one year old shrimp and was the first in a series of strong year-classes and could be followed throughout the next three years. However, it is important to note that the age 1 modes do not always give a clear recruitment signal. For instance, the 1998 cohort appeared weak in 1999, but appeared strong over the next few years. Conversely, if an age 2 mode appeared strong, in any one year, that cohort remained strong throughout its history. Weak year classes such as the 1995 and 1996 appeared weak as age 2 modes and remained weak throughout their history.

Modal length at age varies between years reflecting different growth rates for the different cohorts. However, there is some inter-annual consistency in modal positions and the relative strength of cohorts is maintained from one year to the next (Tables 15 and 16; Figs. 21 and 22).

Shrimp aged 2 - 4 dominated the male component of the length frequencies in spring 2010 (2007, 2006 and 2005 year classes respectively) survey with carapace length frequency modes at 13.54 mm, 16.16 mm and 18.43 mm respectively (Table 15; Fig. 21). Likewise, abundance estimates from the autumn 2009 survey were dominated by shrimp aged 2 - 4 (2007, 2006 and 2005 year classes respectively) with modes at 14.31 mm, 17.75 mm and 19.31 mm respectively. The 2005 year class first appeared as a strong year classes in the spring of 2007 as two year old

animals. This year class remained strong in the male distributions through to spring 2010. The 2006 year class appears average from spring 2008 as two year old animals until spring 2010 as four year old animals.

The autumn surveys showed an increase in biomass of male shrimp from 33,430 t (10 billion animals) in 1999 to 153,000 t (44 billion animals) in 2001, remaining at a high level until 2008 (Table 17; Fig. 23). The autumn 2009 male survey biomass index was estimated to be 71,600 t (23 billion animals), a drop of 52% since 2007 when the male biomass peaked at 148,700 t. 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 52% to 53,500 t (16 billion animals) in 2009. The spring male biomass index was 65,300 t in 2010, an increase of 21% since 2009 (Table 17; Fig. 23).

Autumn and spring female biomass and abundance indices (transitionals and all females = SSB) followed trends similar to the respective male indices. The autumn 2009 3LNO female spawning stock biomass (SSB) index was estimated to be 47,720 t, a drop of 63% since 2007 when the autumn SSB index was 128,870 t. The spring SSB index decreased by 67% from 177,900 t in 2007 to 59,400 t in 2009, but has since increased by 12% to 66,250 t in 2010 (Table 18; Fig. 24).

Table 19 and figure 25 provide a comparison between the previous (weight of males with carapace lengths =>17.5 mm + weight of all females) and proposed (weight of all males and females with carapace lengths => 17.5 mm) methods. The two methods produced similar results therefore from here on, the results will be based upon the proposed methods. The autumn 2009 3LNO fishable biomass index was estimated to be 95,040 t in 2009, a drop of 60% from 239,720 t in 2007. The spring fishable biomass index decreased by 62% from 264,990 t in 2007 to 100,580 t in 2009, but has since increased by 13% to 113,370 t in 2010 (Table 19; Figs. 25 and 26).

Recruitment Index

Recruitment indices were determined using two methods:

1. age 2 abundance as determined from modal analysis of population adjusted length frequencies, and

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

from the autumn 1996-2009 and spring 1999 - 2010 survey time series. Previous to this assessment recruitment was based upon males with carapace lengths between 12 and 17 mm. It is being proposed that this definition should be extended to include all shrimp with carapace lengths between 12 and 17 mm. Table 21 and figure 27 demonstrate that the two methods provide similar results. The modal analysis and proposed abundance of all shrimp with 12 – 17 mm carapace lengths will be discussed in the following paragraph.

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 and 03 year classes were the weakest recorded (Tables 16 and 20; Figs. 22 and 28). Even though the 04 – 07 year classes appear strong, there is a downward trend. Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series (Tables 15 and 21; Figs. 21 and 28). Similar to the autumn recruitment signal, there is a downward trend in abundances of age 2 animals from the 05-08 cohorts. The 07 and 08 cohorts from the spring survey modal analysis have the lowest abundances on record.

The size class method allows the direct calculation of confidence intervals, but will not allow the identification of age classes because each index probably consists of a combination of age 2 and 3 animals. The autumn 1996 – 1999 indices were the lowest in the time series, the 2000, 2002, 2003 and 2009 values were near the mean while the 2001 and 2005 – 2008 were the highest. Similarly, the spring indices followed an increasing trend between 1999 and 2003, the 2004 value was the lowest in this time series but since then the recruitment indices have gradually increased to a record level in 2008 with a decrease in recruitment to mean levels during 2009 and 2010 (Table 21; Fig. 28).

Figure 29 presents the relationship between spring and autumn recruitment indices using either modal analysis or size class method. When autumn recruitment index is predicted from spring index, the correlation coefficients were .44 and .31 for modal and size class methods respectively.

Figure 30 provides a series of regressions between fishable biomass with various lags versus abundances of age 2 males. The relationship using autumn data with a one year lag provided the strongest relationship. However, the correlation coefficient was only .54.

When similar relationships were developed between fishable biomass and recruitment based upon size classes, the within year relationships were the strongest (Fig. 31). This makes sense because recruitment based upon size class is based upon probably age 2 and some age 3 animals. Figures 21 and 22 illustrate that this type of recruitment index should be strongly correlated with the fishable component of the resource. The correlation coefficients based on no lag between fishable biomass and recruitment index were .75 and .78 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 = .70).

Figures 32 – 35 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 = .37)

Large vessel CPUE lagged by one year vs autumn fishable biomass (r^2 = .25)

Small vessel CPUE no lag vs autumn 12 – 17 mm recruitment index (r^2= .09) and

Large vessel CPUE lagged by two years vs autumn 12 – 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. In general, they all follow similar trajectories (Table 22). Overall, exploitation has been low even though catches have increased over time because the stock parameters also increased. Figure 36 presents the exploitation rate index determined as catch/ previous year's autumn fishable biomass. By October 2010, the 2009 exploitation rate was 0.164. If the entire 30 000 t quota was to be taken, the exploitation rate index would increase to 0.316.

Mortality Estimates

The median survival, annual mortality and instantaneous mortality rates were 0.800, 0.200 and 0.223 respectively (Table 23). These values are reasonable as the survival from one year to the next is high enough to allow the present population to exist and are within the range of values presented in Shumway (1985) and Bergström (2000). It is important to note that survival has been decreasing since 2001. In 2001, 87% of the animals survived from one year to the next, however, this number decreased to 57% by 2008.

Precautionary Approach

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the SSB is estimated to be above but approaching B_{lim} (Figure 37).

Sources of Uncertainty in the Assessment

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

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

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

Attempts have been made to determine shrimp mortality rates; however, they have been based upon ratios over several cohorts. It is probable that mortality is dependent upon age therefore further work must be completed.

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

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

There are ongoing 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

Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean since 2004 with the 2010 catch rate near term average and similar to the 2001 and 2004- 2009 catch rates. The Canadian small vessel standardized CPUE for 2009 was near the long term average and similar to the 2003 and 2004 catch rates.

The percent area occupied by the large vessel fishery has been increasing since 2002, but is still less than 4% of the total area available. The small vessel fleet has occupied no more than 8% of the total available area and has also shown an increasing trend, however, the percent area occupied has been more variable. It is important to note that an increasing trend does not necessarily mean that the total area occupied by the fishery has increased, rather it means that the catches are more evenly distributed. The percent area occupied by the resource, as indicated by spring and autumn survey data, also followed increasing trajectories until 2005. After 2005 and 2006 the spatial index has decreased in the autumn and spring respectively. As noted earlier, the decreasing trend in the spatial indices should not be interpreted to mean that the area occupied by the resource has been decreasing. Rather it means that the resource is becoming less evenly distributed and may mean that there is contraction into certain areas. This index should be interpreted with caution and in conjunction with other indices to get a full picture of what is happening in the environment.

Regardless of whether the spatial indices have been increasing, the area occupied has never been higher than 8% of the available area. While the shrimp fishery may still have impacts upon some non target species, the chance of doing serious harm to the habitat is probably low because the foot print of the fishery is relatively low. However, it is still important to determine the actual impact of the fishery upon the ecosystem.

Unstandardized catch rates, from the non Canadian vessels, fluctuated along the long term mean over the short time series. Unstandardized international indices increased from 381 kg/hr in 2001 to 2 035 kg/hr in 2004 but decreased to 570 kg/hr in 2006, remained at that level in 2007 then increased to 1 395 by 2009. As noted above, the percentage of the fishery captured in the catch rate data set was usually less than 25% for any one year. It is not clear whether this data is representative of fleet conditions.

Based on Canadian surveys, over 90% of the biomass was found in Div. 3L, distributed mainly along the northeast slope in depths from 185-550 m. Plots of research survey catches clearly indicated that very few large catches were taken along the northern edge of 3L during the 2009 and 2010 spring surveys, relative to previous autumn and spring surveys, which normally held high catches in this area. As noted above, this decrease was evident in the spatial indices from spring research survey catches.

The autumn 2009 3LNO biomass index was estimated to be 119,200 t, a drop of 57% since 2007 when the autumn biomass index was 277,580 t. The spring biomass index decreased by 61% from 290,560 t in 2007 to 113,270 t in 2009 but has since increased by 16 % to 131,590 t in 2010.

Autumn and spring female biomass and abundance indices (transitionals and all females = SSB) followed trends similar to the respective male indices. The autumn 2009 3LNO female spawning stock biomass (SSB) index was estimated to be 47,720 t, a drop of 63% since 2007 when the autumn SSB index was 128,870 t. The spring SSB index decreased by 67% from 177,900 t in 2007 to 59,400 t in 2009, but has since increased by 12% to 66,250 t in 2010.

Similarly, the autumn 2009 3LNO fishable biomass index was estimated to be 95,040 t in 2009, a drop of 60% from 239,720 t in 2007. The spring fishable biomass index decreased by 62% from 264,990 t in 2007 to 100,580 t in 2009, but has since increased by 13% to 113,370 t in 2010.

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. The autumn 2009 male survey biomass index was estimated to be 71,600 t (23 billion animals), a drop of 52% since 2007 when the male biomass peaked at 148,700 t.   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) the next year then increased to 112,700 t (32 billion animals) by 2007 after which biomass dropped by 52% to 53,500 t (16 billion animals) in 2009. The spring male biomass index was 65,300 t in 2010, an increase of 21% since 2009.

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 and 03 year classes were the weakest recorded.   Even though the 04 – 07 year classes appear strong, there is a downward trend. Spring recruitment indices have been fluctuating around the mean with the 04 and 05 year classes being the strongest in the time series. Similar to the autumn recruitment signal, there is a downward trend in abundances of age 2 animals from the 05-08 cohorts. The 07 and 08 cohorts from the spring survey modal analysis have the lowest abundances on record.

Shrimp aged 2 - 4 dominated the male component of the length frequencies in spring 2010 (2007, 2006 and 2005 year classes respectively) survey with carapace length frequency modes at 13.54 mm, 16.16 mm and 18.43 mm respectively. Likewise, abundance estimates from the autumn 2009 survey were dominated by shrimp aged 2 - 4 (2007, 2006 and 2005 year classes respectively) with modes at 14.31 mm, 17.75 mm and 19.31 mm respectively. The 2005 year class first appears as a strong year classes in the spring of 2007 as two year old animals. This year class remained strong in the male distributions through to spring 2010. The 2006 year class appears average from spring 2008 as two year old animals until spring 2010 as four year old animals.

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

However, the spring and autumn biomass indices and all ages within the length frequencies as well as survival indices have been trending downward over the past three years. It is important to note that these indices decreased at the same time. There was no lag between the decrease in recruitment and the decrease in biomass (total, male, female and fishable) indices. This means that the declines seen in biomass are not simply due to poor recruitment. Poor recruitment will have an impact on future status of the stock but in this case there are other contributing factors. These should be taken as a warning that conditions may be changing in 3LNO northern shrimp resource.

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Currently, the SSB is estimated to be above but approaching B_{lim}. It is important to note that shrimp are important forage for several species and therefore it is good that Fishery Commission reduced the TAC from 30 000 t to 19 000 t for 2011 and further to 17 200 t for 2012.

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Table 1. Annual nominal catches (t) by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3L between 2000 and September 2010.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Canada	4,050[2]	4,984[2]	5,417[2]	10,701[2]	10,560[2]	11,109[2]	18,128[2]	18,316[2]	21,187[2]	20,494[2]	11,981[2]
Cuba		46[1]	70[1]	81[1]	145[3]	136[1]	239[1]	240[1]	207[3]	334[3]	
EU/Estonia	64[1]	2,264[4]	450[5]	299[6]	271[6]	569[6]	1,098[10]	1,453[10]	1,458[10]	1659[10]	
European Union											689[3]
Faroe Islands	42[1]	2,052[4]	620[5]	25[1]	1,050[1]	1,055[1]	1,521[1]	1,798[1]	2,273[1]	2948[3]	1,459[3]
France (SPM)	67[1]	67[1]	36[1]	144[1]				245[1]	278[1]	334[1]	
Greenland	34[1]			671[1]	299[1]	311[1]	453[8]	455[8]	648[8]	488[8]	741[8]
Iceland	99[1]	55[7]	54[7]	133[7]	105[7]	140[1]	226[7]				
EU/Latvia	64[1]	67[1]	59[1]	144[1]	143[1]	144[1]	244[1]	310[1]	278[1]		
EU/Lithuania	67[1]	67[1]	67[1]	142[1]	144[1]	216[1]	486[1]	245[1]	278[1]		
Norway	77[1]	78[6]	70[6]	145[9]	165[9]	144[3]	272[9]	250[9]	345[1]	672[1]	664[9]
EU/Poland	40[1]	54[1]		145[1]	144[1]	129[1]	245[1]				
Portugal		61[5]									
Russia	67[1]	67[1]	67[1]		141[1]	146[1]	248[1]	112[1]	278[1]	335[3]	26[3]
EU/Spain	40[1]	699[4]		151[1]	140[1]	154[1]	305[6]	190[1]	183[1]		
Ukraine		57[1]		144[1]	145[1]		121[1]			334[3]	
USA		66[1]	57[1]	144[1]		136[1]	245[1]	245[1]	278[3]		
Estimated additional catch							2,000[5]				
GRAND TOTAL	4,711	10,684	6,967	13,069	13,452	14,389	25,831	23,859	27,691	27,598	15,560
TAC (tons)	6,000	6,000	6,000	13,000	13,000	13,000	22,000	22,000	25,000	30,000	30,000

Sources:

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

Table 2. Multiplicative year, month and vessel size model for **Canadian small vessels (<=500 t; <65')**
fishing northern shrimp in NAFO Div. 3L over the period 2000 – 2009. (Weighted by effort,
single trawl, no windows, logbook data, history of at least two years in the fishery).

```
                         The GLM Procedure
                      Class Level Information
        Class        Levels    Values
        year             10     2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
        month             5     5 6 8 9 99  (model standardized to July)
        size_class        3     1 2 3

                   Number of Observations Read        118
                   Number of Observations Used        118
Dependent Variable: lncpue
Weight: wfactor
                              Sum of
    Source                    DF         Squares     Mean Square     F Value    Pr > F
    Model                     15     8177.831516      545.188768       38.49    <.0001
    Error                    102     1444.954955       14.166225
    Corrected Total          117     9622.786471
                 R-Square     Coeff Var     Root MSE     lncpue Mean
                 0.849840      60.06465     3.763805        6.266256
    Source                    DF       Type I SS     Mean Square     F Value    Pr > F
    Year                       9     6418.105957      713.122884       50.34    <.0001
    Month                      4     1143.395668      285.848917       20.18    <.0001
    size_class                 2      616.329891      308.164946       21.75    <.0001

    Source                    DF      Type III SS     Mean Square     F Value    Pr > F
    Year                       9     3538.249700      393.138856       27.75    <.0001
    Month                      4     1285.187154      321.296788       22.68    <.0001
    size_class                 2      616.329891      308.164946       21.75    <.0001
                                              Standard
        Parameter                 Estimate       Error    t Value    Pr > |t|
        Intercept            6.325724502 B    0.03232965     195.66     <.0001
        Year      2000      -0.182519127 B    0.06054388      -3.01     0.0032
        Year      2001      -0.228371138 B    0.06603105      -3.46     0.0008
        Year      2002      -0.217811641 B    0.05772488      -3.77     0.0003
        Year      2003      -0.091667176 B    0.04684917      -1.96     0.0531
        Year      2004       0.089910723 B    0.04658574       1.93     0.0564
        Year      2005       0.466867960 B    0.05070117       9.21     <.0001
        Year      2006       0.342885922 B    0.04137244       8.29     <.0001
        Year      2007       0.162734197 B    0.03834803       4.24     <.0001
        Year      2008       0.219199816 B    0.03818087       5.74     <.0001
        Year      2009       0.000000000 B         .               .        .
        Month     5         -0.301120553 B    0.03622355      -8.31     <.0001
        Month     6         -0.132808423 B    0.03168176      -4.19     <.0001
        Month     8         -0.023364929 B    0.03387949      -0.69     0.4920
        Month     9         -0.259892607 B    0.04559672      -5.70     <.0001
        Month     99         0.000000000 B         .               .        .
        size_class 1        -0.203395943 B    0.03947369      -5.15     <.0001
        size_class 2        -0.121841403 B    0.02383453      -5.11     <.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.
```

```
Table 2 (continued)

                          lncpue
              year        LSMEAN        95% Confidence Limits

              2000       5.891356       5.784236      5.998476
              2001       5.845504       5.725577      5.965430
              2002       5.856063       5.754702      5.957424
              2003       5.982208       5.903404      6.061011
              2004       6.163785       6.084712      6.242859
              2005       6.540743       6.453553      6.627932
              2006       6.416761       6.351080      6.482441
              2007       6.236609       6.175536      6.297682
              2008       6.293075       6.230622      6.355527
              2009       6.073875       6.017407      6.130343
```

Table 3. Catch rate indices for **Canadian small vessels** (<=500 t; <65') fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2009.

YEAR	TAC[1]	FLEET CATCH	PERCENT OF CATCH DATA CAPTURED IN MODEL[2]	UNSTANDARDIZED			STANDARDIZED		
				CPUE	CPUE RELATIVE TO 2009	EFFORT[3]	CPUE RELATIVE TO 2009	MODELLED CPUE	EFFORT
	(t)	(t)		(KG/HR)		(HR)		(KG/HR)	(HRS)
1999		17							
2000	2,500	3,217	69.0%	384	0.792	8,388	0.833	362	8,889
2001	2,500	2,590	57.2%	345	0.713	7,508	0.796	346	7,493
2002	2,500	2,961	76.0%	342	0.707	8,657	0.804	349	8,476
2003	6,566	6,663	66.7%	409	0.845	16,290	0.912	396	16,812
2004	6,566	6,524	93.4%	550	1.136	11,867	1.094	475	13,728
2005	6,566	7,070	93.7%	778	1.606	9,091	1.595	693	10,205
2006	12,297	12,112	85.5%	658	1.358	18,418	1.409	612	19,790
2007	12,297	12,571	85.6%	580	1.198	21,680	1.177	511	24,595
2008	14,209	14,873	81.3%	637	1.316	23,352	1.245	541	27,501
2009	14,209	12,873	85.7%	484	1.000	26,589	1.000	434	29,637
2010	17,369	7,118	8.0%						

[1]
FISHERY AND FROM YEAR-END QUOTA REPORTS AND/OR LOGBOOK RECORDS.

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

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

Table 4. Multiplicative year, month, ship and gear type model for **Canadian large (> 500 t)** vessels fishing
northern shrimp (*Pandalus borealis*) in NAFO Division 3L over the period 2000 – 2010.
(Weighting by effort, no windows, observer data, history of at least 2 years in the fishery).

```
                            Class Level Information
Class        Levels  Values

year            11   2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
month           12   1 2 3 4 5 7 8 9 10 11 12 99 (Standardized to June)
CFV             13
gear             2   66 99  (double trawl = 66; single trawl = 99)


                     Number of Observations Read          212
                     Number of Observations Used          212
Dependent Variable: lncpue
Weight: effort
                                     Sum of
      Source               DF       Squares    Mean Square    F Value    Pr > F
      Model                34   2278.273137      67.008033      10.29    <.0001
      Error               177   1152.110461       6.509099
      Corrected Total     211   3430.383598

                 R-Square     Coeff Var     Root MSE     lncpue Mean
                 0.664145     34.75966      2.551294       7.339811

      Source               DF     Type I SS    Mean Square    F Value    Pr > F
      year                 10   883.9845928     88.3984593      13.58    <.0001
      month                11   482.1732348     43.8339304       6.73    <.0001
      CFV                  12   591.9242743     49.3270229       7.58    <.0001
      gear                  1   320.1910352    320.1910352      49.19    <.0001

      Source               DF   Type III SS    Mean Square    F Value    Pr > F
      year                 10   568.1655359     56.8165536       8.73    <.0001
      month                11   463.9317682     42.1756153       6.48    <.0001
      CFV                  12   348.9662787     29.0805232       4.47    <.0001
      gear                  1   320.1910352    320.1910352      49.19    <.0001

                                           Standard
      Parameter                Estimate       Error    t Value    Pr > |t|

      Intercept            7.164201292 B    0.16677396     42.96     <.0001
      year    2000        -0.640518459 B    0.17923725     -3.57     0.0005
      year    2001        -0.189704322 B    0.14943096     -1.27     0.2059
      year    2002         0.345075105 B    0.16086448      2.15     0.0333
      year    2003         0.618506874 B    0.15338917      4.03     <.0001
      year    2004         0.000531642 B    0.13735280      0.00     0.9969
      year    2005         0.154414186 B    0.13238217      1.17     0.2450
      year    2006         0.040871349 B    0.12327556      0.33     0.7406
      year    2007        -0.085740643 B    0.12570807     -0.68     0.4961
      year    2008         0.142604635 B    0.11994372      1.19     0.2361
      year    2009         0.054448497 B    0.12717143      0.43     0.6691
      year    2010         0.000000000 B    .               .        .
```

Table 4. (Continued)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
month	1	0.448349810 B	0.10366488	4.32	<.0001
month	2	0.438734310 B	0.10662785	4.11	<.0001
month	3	0.197122942 B	0.10620925	1.86	0.0651
month	4	0.120071055 B	0.10417557	1.15	0.2506
month	5	0.013589905 B	0.10875813	0.12	0.9007
month	7	0.109736976 B	0.13109009	0.84	0.4037
month	8	-0.005134403 B	0.17021816	-0.03	0.9760
month	9	-0.100309296 B	0.24517569	-0.41	0.6829
month	10	-0.037455064 B	0.12362601	-0.30	0.7623
month	11	0.025043684 B	0.10585998	0.24	0.8133
month	12	-0.080464522 B	0.10358551	-0.78	0.4383
month	99	0.000000000 B	.	.	.
CFV		-0.151062044 B	0.13573252	-1.11	0.2672
CFV		-0.319169038 B	0.19473128	-1.64	0.1030
CFV		-0.264112582 B	0.09276957	-2.85	0.0049
CFV		-0.071309502 B	0.09875787	-0.72	0.4712
CFV		-0.051295942 B	0.12984837	-0.40	0.6933
CFV		-0.001717058 B	0.13641295	-0.01	0.9900
CFV		-0.112966068 B	0.09071405	-1.25	0.2147
CFV		-0.128287220 B	0.09048105	-1.42	0.1580
CFV		-0.219168622 B	0.10882726	-2.01	0.0455
CFV		0.292383814 B	0.18142971	1.61	0.1088
CFV		-0.053971874 B	0.08514805	-0.63	0.5270
CFV		-0.966880733 B	0.16277061	-5.94	<.0001
CFV		0.000000000 B	.	.	.
gear	66	0.396009671 B	0.05646270	7.01	<.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	
2000	6.658290	6.377859	6.938722
2001	7.109105	6.921410	7.296799
2002	7.643884	7.419465	7.868303
2003	7.917316	7.706943	8.127688
2004	7.299341	7.128309	7.470372
2005	7.453223	7.300321	7.606125
2006	7.339680	7.218017	7.461343
2007	7.213068	7.082019	7.344117
2008	7.441414	7.308738	7.574089
2009	7.353257	7.225074	7.481441
2010	7.298809	7.064847	7.532771

Table 5. Catch rate indices for **Canadian large vessels** (>500 t) fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2000 – 2010.

YEAR	TAC	CATCH[1]	PERCENT OF CATCH DATA CAPTURED IN MODEL[2]	UNSTANDARDIZED			STANDARDIZED		
				CPUE	CPUE RELATIVE	[3] EFFORT	CPUE RELATIVE	MODELLED	EFFORT
		(t)		(KG/HR)	TO 2010	(HR)	To 2009	CPUE	(HRS)
2000	1,686	833	42%	747	0.487	1,115	0.527	779	1,069
2001	2,500	2,394	83%	1,146	0.746	2,090	0.827	1,223	1,957
2002	2,500	2,456	80%	1,742	1.135	1,410	1.412	2,088	1,176
2003	4,267	4,038	66%	3,290	2.143	1,227	1.856	2,744	1,471
2004	4,267	4,036	69%	1,392	0.907	2,900	1.001	1,479	2,728
2005	4,277	4,039	88%	1,836	1.196	2,200	1.167	1,725	2,341
2006	5,273	6,016	81%	1,452	0.946	4,142	1.042	1,540	3,906
2007	5,907	5,743	71%	1,210	0.788	4,748	0.918	1,357	4,232
2008	6,568	6,314	87%	1,784	1.162	3,540	1.153	1,705	3,703
2009	6,022	6,550	74%	1,398	0.911	4,684	1.056	1,561	4,195
2010	7,594	4,863	26%	1,535	1.000	3,168	1.000	1,479	3,289

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

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

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

Table 6. Trends in northern shrimp mean catch (kg/hr) per stratum, April – August of each year using standardized small vessel (<500 t; <65') logbook catch information (2000 – 2009). (Green=<.3 t; .3 t <White<=.6 t; .6 t<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 wgt (t/hr)		year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		.	.	.	.	.	.	.	.	.	.
Max depth (m)	STRATUM								0.41		
91	371										
183	348							0.88	0.42	0.46	
	349										0.43
	364								0.95		
	365						0.55				
	370						0.65	0.64	0.46		0.31
	385	0.34				0.34	0.7		0.44	0.6	0.48
274	347										0.01
	366	0.22				0.45	0.47	0.79	1		0.28
	369	0.26				0.53	0.74	0.52	0.52	0.39	0.44
	386	0.34	0.39	1.1	0.53	0.58	0.9	0.87	0.63	0.71	0.54
	389					0.48	0.9	0.9	0.64	0.94	0.65
366	345	0.14			0.53	0.62	0.37	0.8	0.72	0.72	0.53
	346	0.35	0.29	0.45	0.43	0.58	0.77	0.73	0.72	0.74	0.46
	368	0.28	0.32	0.34	0.48	0.52	0.71	0.66	0.47	0.32	0.51
	387	0.44	0.45	0.45	0.45	0.56	0.78	0.72	0.57	0.53	0.46
	388									1.54	0.58
400	638							0.61			
549	731								1.23	0.58	0.41
	733		1.05		0.25	0.39	0.65	0.57	0.5	0.56	0.39
	735	0.13			0.47	0.48	0.95	0.51	0.67		0.16
731	734					0.37					0.33
	736							0.54			
914	745								0.44		

B) Index strata

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

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 – 2009). These analyses were limited to index strata. The analysis was limited to the period April – August of each year.

Year	Biomass			Mean t	Number of
	Lower C.I.	Estimate	Upper C.I.	per set	sets
2003	26,255.53	29,253.33	32,251.14	0.472	613
2004	3,995.04	35,289.82	66,584.61	0.569	1,351
2005	34,570.82	41,215.62	47,860.41	0.665	1,180
2006	43,892.21	47,044.84	50,197.47	0.759	1,777
2007	37,222.76	39,702.44	42,182.12	0.640	1,801
2008	34,500.48	40,247.41	45,994.34	0.649	2,296
2009	28,625.06	30,626.83	32,628.60	0.494	3,754

Table 8.   Trends in northern shrimp mean catch (t/hr) per stratum and year using standardized large vessel (>500 t) observed catch information (2000 – 2009). (Green=<1 t; 1 t <White<=2 t; 2<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 wgt (t/hr)		year										
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Max depth (m)	STRATUM	1.14	0.5									
274	366											
	369							1.87		1.86		
	386						1.61	2.07	2.22	2.15	1.89	
366	345	0.61										
	346	0.86										
	368	0.98	0.45		1.26			1.7		2.4		
	387	0.63	1.45	2.1	2.5	2.33	2.42	2.34	2.47	2.16	2.56	2.61
400	638	1.12										
549	733		1.41	2.26	2.72	2.49	2.53	3.3	2.82	2.51	2.55	
	735				1.34	0.35				3.11		
731	734						2.28					

Table 9. Unstandardized catch rate indices for non Canadian vessels fishing northern shrimp in the NAFO Division 3L NRA over the period 2000 – 2009. Indices included data from Greenland, Iceland, Norway, Spain, and Russia.

YEAR	TAC	CATCH (t)	PERCENT OF CATCH CAPTURED IN MODEL DATASET	UNSTANDARDIZED CPUE (KG/HR)	CPUE RELATIVE TO 2009	EFFORT (HR)
2000	1,000	661	21	746	0.535	886
2001	1,000	5,700	1	381	0.273	14,978
2002	1,000	1,550	4	650	0.466	2,386
2003	2,167	2,368	45	724	0.519	3,271
2004	2,167	2,892	10	2,035	1.459	1,421
2005	2,167	3,280	5	570	0.409	5,753
2006	3,675	7,703	7	636	0.456	12,103
2007	3,675	5,543	16	1,021	0.732	5,430
2008	3,815	6,504	17	1,122	0.804	5,798
2009	5,100	7,104	20	1,395	1.000	5,093

Table 10.   NAFO Divisions 3LNO northern shrimp biomass and abundance indices as calculated using Ogmap. Data were   obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1996 – 2010. (Offshore strata   only with standard 15 min. tows).

Spring

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

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

Autumn

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

Year	Biomass (tons)			Abundance (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

Area compared each year = 272,766.3 sq. km.

Table 11.   Trends in mean northern shrimp catch (kg/15 min tow) per stratum and year from **spring** Canadian research bottom trawl multi-species survey data (1999 – 2010). (Green=<40 kg; 40Kg<White<=100 kg.; 100 kg< Pink; Black= not sampled).

Divs. 3LNO survey spring shrimp mean wgt/tow		year											
		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		.	.	.	.	.	.	.	.	.	.	.	.
Depth Range (m)	stratum	0	0	0	0	0.02	0	0	0	0.01	0.01	0	0
57 - 92	350												
	363	0	0	0	0	0.02	0	0	0	0	0.07	0	0
	371	0	0	0	0	0	0	0	0	0	0	0	0
	372	0	0	0	0	0	0	0	0	0	0	0.02	0
	384	0.01	0	0	0.02	0	0	0	0	0	0	0	0.01
93 - 183	328	0	0.06	0	0.01	0.04	0.09	0.07	0.05	0.04	■	0.02	0.03
	341	0.01	0.03	0	0.02	0.02	0.25	0	0	0.01	0.02	0	0.01
	342	0.04	0.01	0	0.09	0.02	0.06	0.01	0	0.11	0	0.15	0.04
	343	0.04	0	0.08	0	0.03	0.06	0.03	0.01	0.11	0.02	0.15	■
	348	0.02	0.08	0.02	0.03	0.04	0.03	0.05	0.04	0.11	0.42	0.12	0.15
	349	0.03	0.01	0	0.01	0.02	0.03	0	0.03	0	0.01	0.02	0.18
	364	0	0.01	0.02	0.03	0.02	0	0	0	0	0	0.01	0.02
	365	0	0.01	0.06	0.02	0.04	0	0.02	0.18	0	9.07	0.21	1.09
	370	0	0	0	0	0	0	0	0	0	0	0	0
	385	0	0	0.02	0.06	0	0.03	0	0	0.09	130.4	0.02	0.03
	390	0.01	0.01	0.01	0.01	0	0.04	0.11	0	0	0	0.04	0
184 - 274	344	0.16	0.05	0.24	0.81	4.11	0.06	13.98	4.28	0.81	16.57	1.3	8.72
	347	0.11	0	9.05	0.93	0.17	0.86	49.41	20.99	53.62	43.42	185.7	2.55
	366	3.85	93.34	59.22	179.1	36.98	1.95	66.49	17.68	32.17	51.94	16.51	5.68
	369	0.05	11.21	0	22.86	275.6	2.6	144.6	32.18	115.6	32.94	227.6	37.54
	386	15.7	60.75	12.05	0.23	3.39	13.29	29.49	183.6	92.55	162.9	0.08	58.07
	389	84.13	283.7	8.31	43.38	129.9	9.9	125.7	445.8	262.7	202.5	202.5	82.4
	391	0.01	0	2.46	0	78.51	0.99	3.08	2.5	949.8	26.45	1054	0.02
275 - 366	345	30.77	67.13	159.7	49.94	193.1	92.71	163	204.1	386.9	388.5	189.8	162.3
	346	104.7	121.9	164	213.8	117.1	86.54	292.2	60.97	443	187.6	83.12	82.99
	368	76.56	202.9	21.46	70.57	320.1	109.7	15.52	67.53	61.86	50.97	15.33	30.62
	387	126.6	13.18	189	352.9	380	516.2	137.3	221.6	85.21	220.6	50.79	206.5
	388	64.25	258.7	170.8	581	158.9	69.91	53.33	175.1	242.4	21.56	545.7	651.7
	392	3.27	7.67	36.3	0.67	50.02	6.29	34.63	8.24	4.44	0.62	7.56	0.18
367 - 549	729	0	0.27	0.58	0.08	12.41	0.1	4.25	11.39	0.03	5.92	0	■
	731	3.5	14.55	21.69	3.54	143.9	0.69	18.46	25.43	47.65	6.4	4.23	9.46
	733	1.72	6.18	2.56	3.15	39.37	0.17	1.82	2.68	13.13	0.87	28.83	0.32
	735	0.49	3.25	0.42	1	0.08	0.04	1.75	1.71	0.41	4.69	3.89	0.59
550 - 731	730	0	0.04	0	0.02	0.05	0.01	0	0	0	0	0	0
	732	2.39	1.37	0.35	3.27	0.29	0	0	0.07	0	0	1.36	0.03
	734	0.11	0	2.35	0.21	0.03	0	0	0.04	0.09	■	0	0
	736	0.11	0.1	0.29	0.25	0.38	0	0	0	0.11	0.62	0	0

Table 12.   Trends in mean northern shrimp catch (kg/15 min tow) per stratum and year from **autumn** Canadian research bottom trawl multi-species survey data (1996 – 2009). (Green=<40 kg; 40Kg<White<=100 kg.; 100 kg< Pink; Black= not sampled).

Survey Fall SFA 7 Shrimp Mean wgt (kg/tow)		YEAR													
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
		.	.	.	.	.	.	.	.	.	.	.	.	.	.
Depth Range (m)	STRATUM														
57 - 92	350	0	0	0.01	0	0	0.01	0.1	0.13	0.01	0.01	0.02	0.03	0.01	0
	363	0	0.01	0.01	0	0.03	0.07	0.07	2.38	0	0	0	0.02	0.01	0.01
	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
	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
	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
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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
550 - 731	730	0.04	0.02	0	0	0	0.04	0	0	0	1.18	0.02	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
	734	0	0.02	0	0.01	0	0.04	0.26	0	.	0.03	0	0.03	0	0
	736	0	0.3	0.09	0.08	1.05	0.49	0	■	.	0.05	0.07	0	0.04	0
732 - 914	737	0	0	0	0	0.02	0.01	0	0.01	■	■	0.04	0	0	0
	741	0	0	0	0	0	0	0.01	0.65	.	■	■	0	0	0
	745	0	0.01	0	0	0.01	0.19	0	0.15	.	■	■	0	0	0
	748	0	0.02	0.01	0	0.03	0.12	0	0.03	.	■	■	0	0.01	0
915 -1097	738	0	0	0	0	0.01	0	0	0	.	■	■	0	0	0
	742	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
	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	0
1281 -1463	740	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

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Table 13.	NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1999 – 2010 **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 percen biomass in NRA
Spring	1999	3L	47,823	96.15	10,269	86.44	21.47	
Spring	2000	3L	109,439	95.94	23,962	87.18	21.90	
Spring	2001	3L	83,262	100.24	11,478	99.13	13.78	19.05
Spring	2002	3L	128,971	95.74	34,533	91.47	26.78	20.82
Spring	2003	3L	166,525	97.52	30,103	86.92	18.08	19.55
Spring	2004	3L	92,626	98.40	23,861	97.13	25.76	23.54
Spring	2005	3L	134,106	99.85	14,297	94.67	10.66	18.17
Spring	2006	3L	180,620	???	43,695	???	24.19	20.20
Spring	2007	3L	284,018	97.75	78,732	97.02	27.72	20.86
Spring	2008	3L	224,114	99.73	34,533	99.13	15.41	22.44
Spring	2009	3L	110,949	97.96	36,446	98.64	32.85	25.33
Spring	2010	3L	130,683	99.31	42,084	99.52	32.20	26.82
Spring	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	0.36	101	0.87	33.33	61.33
Spring	2002	3N	5,839	4.33	3,222	8.53	55.17	54.32
Spring	2003	3N	5,437	3.18	4,531	13.08	83.33	57.28
Spring	2004	3N	1,208	1.28	705	2.87	58.33	65.61
Spring	2005	3N	1,410	1.05	805	5.33	57.14	66.27
Spring	2006	3N	???	???	???	???	???	57.74
Spring	2007	3N	3,121	1.07	2,416	2.98	77.42	67.28
Spring	2008	3N	604	0.27	302	0.87	50.00	63.71
Spring	2009	3N	705	0.62	503	1.36	71.43	66.28
Spring	2010	3N	403	0.31	201	0.48	50.00	57.14
Spring	1999	3O	101	0.20	0	0.00	0.00	
Spring	2000	3O	101	0.09	0	0.00	0.00	
Spring	2001	3O	0	0.00	0	0.00	0.00	0.00
Spring	2002	3O	101	0.07	0	0.00	0.00	0.00
Spring	2003	3O	201	0.12	0	0.00	0.00	0.00
Spring	2004	3O	201	0.21	0	0.00	0.00	0.00
Spring	2005	3O	101	0.07	0	0.00	0.00	0.00
Spring	2006	3O	1,007	???	101	???	10.00	0.00
Spring	2007	3O	0	0.00	0	0.00	0.00	0.00
Spring	2008	3O	0	0.00	0	0.00	0.00	0.00
Spring	2009	3O	0	0.00	0	0.00	0.00	0.00
Spring	2010	3O	101	0.00	0	0.00	0.00	0.00
	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		83,061	100.61	11,578	100.00	13.94	20.64
Spring	2002		134,710	100.15	37,755	100.00	28.03	22.02
Spring	2003		170,753	100.83	34,634	100.00	20.28	20.75
Spring	2004		94,136	99.89	24,566	100.00	26.10	24.80
Spring	2005		134,307	100.97	15,102	100.00	11.24	19.21
Spring	2006		???	???	???	???	???	18.67
Spring	2007		290,562	98.82	81,148	100.00	27.93	19.59
Spring	2008		224,718	100.00	34,835	100.00	15.50	21.71
Spring	2009		113,265	98.58	36,950	100.00	32.62	25.35
Spring	2010		131,589	99.62	42,286	100.00	32.13	26.75

Table 14.   NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1996 – 2009 **autumn** Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min. tows). All indices were estimated using Ogmap calculations.

| Season | Year | Division | Entire Division | | Outside 200 Nmi limit | | | |
			iomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percen biomass in NRA
Autumn	1996	3L	23,056	92.71	4,027	85.11	17.47	17.47
Autumn	1997	3L	43,695	98.64	5,537	91.67	12.67	15.07
Autumn	1998	3L	56,381	92.26	8,961	81.65	15.89	15.34
Autumn	1999	3L	54,871	99.27	8,054	96.39	14.68	14.41
Autumn	2000	3L	106,519	98.88	22,250	98.22	20.89	17.15
Autumn	2001	3L	215,153	99.21	41,077	97.14	19.09	18.22
Autumn	2002	3L	189,077	97.97	35,439	92.39	18.74	19.57
Autumn	2003	3L	186,459	97.01	35,842	91.75	19.22	19.02
Autumn	2004	3L	???	???	???	???	???	???
Autumn	2005	3L	222,704	99.37	26,378	97.40	11.84	15.53
Autumn	2006	3L	215,153	99.21	27,284	96.44	12.68	12.26
Autumn	2007	3L	273,346	98.48	50,038	98.42	18.31	14.28
Autumn	2008	3L	247,874	98.76	33,124	97.92	13.36	14.78
Autumn	2009	3L	117,594	98.65	18,223	97.84	15.50	15.72
Autumn	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	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
	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

Table 15.   Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *Pandalus borealis* in NAFO Divs. 3LNO from   **spring** Canadian multi-species bottom trawl surveys (1999 – 2010). Abundance at length determined using Ogmap   calculations.

NAFO Divisions 3LNO
Mean Carapace Length (Standard Error)

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

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

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

Table 15 (Continued)

Distributional Sigmas (Standard Error and constraints)

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

Population at Age Estimates (10^6)

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

Table 16.   Modal analysis using Mix 3.01 (MacDonald and Pitcher, 1993) of *Pandalus borealis* in NAFO
Divs. 3LNO from   **autumn** Canadian multi-species bottom trawl surveys (1996 – 2009).
Abundance at length determined using Ogmap   calculations.

Mean Carapace Length (Standard Error)

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

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

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

Table 16. (Continued)

Distributional Sigmas (Standard Error and constraints)

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

Population at Age Estimates (10^6)

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

Table 17.   Male biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2010) and autumn (1996 – 2009) research bottom trawl survey data.

Spring

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

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

Autumn

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

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

Table 18.   Female biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2010) and autumn (1996 – 2009) research bottom trawl survey data.

Spring

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

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	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

Autumn

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

Year	Biomass (tons)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	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

Table 19.   A comparison between the fishable biomass indices with previously used (total weight of all females + weight of all males with carapace lengths => 17.5 mm) and proposed methods (weight of all males and females with carapace lengths =>17.5 mm). Indices were calculated from spring and autumn Canadian multi-species bottom trawl survey data 1996 – 2010.

Spring previous method

Year	Biomass (tonnes)		
	Lower C.I.	Estimate	Upper C.I.
1999	20,590	40,700	64,080
2000	42,080	80,900	133,300
2001	42,750	66,300	93,630
2002	71,350	110,600	172,700
2003	106,300	148,500	193,100
2004	35,000	83,300	152,900
2005	73,190	116,100	161,200
2006	91,250	158,300	218,900
2007	183,500	280,900	415,300
2008	137,600	188,200	237,500
2009	53,190	97,600	151,500
2010	65,680	112,700	159,100

Spring proposed method

Year	Biomass (tonnes)			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	171,055	264,990	352,682	26,529	40,625	54,246
2008	137,529	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

Autumn previous method

	Biomass (tonnes)		
Year	Lower C.I.	Estimate	Upper C.I.
1996	12,390	14,600	22,790
1997	23,670	34,100	48,900
1998	36,080	48,300	63,770
1999	32,230	41,000	56,470
2000	61,970	79,100	105,200
2001	123,400	173,200	217,600
2002	111,000	157,000	198,700
2003	123,700	167,300	217,300
2004		???	
2005	143,500	180,700	216,600
2006	138,300	173,100	205,500
2007	176,500	230,800	297,200
2008	157,400	204,600	251,300
2009	61,400	91,800	120,100

Autumn proposed method

Year	Biomass (tonnes)			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

Table 20. Recruitment indices as determined from modal analysis of population adjusted northern shrimp length frequencies from spring (1999 – 2010) and autumn (1996 – 2009) Canadian multi-species bottom trawl surveys. All indices were estimated using Ogmap calculations and then modal analysis using Mix 3.01.

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

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

Table 21.   A comparison between previously used (abundance of males with 12 – 17 mm carapace lfs) and proposed methods (abundances of males + females with 12 – 17 mm carapace lfs) of estimating northern shrimp recruitment indices from spring (1999 – 2010) and autumn (1996 – 2009) Canadian bottom trawl multi-species surveys. All indices were estimated using Ogmap calculations.

Spring

Previous

Year	12 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1999	2,027	4,068	6,570
2000	4,246	6,994	9,607
2001	3,725	6,507	9,857
2002	4,968	8,196	13,129
2003	4,514	9,163	16,381
2004	1,751	2,790	4,081
2005	3,980	6,325	8,921
2006	5,596	8,370	11,790
2007	7,713	13,428	18,968
2008	9,614	14,459	19,079
2009	2,785	6,063	10,051
2010	4,336	6,856	9,716

Proposed

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

Autumn

Year	12 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1996	2,659	3,538	4,968
1997	2,446	3,006	4,047
1998	2,241	2,955	3,839
1999	3,994	5,297	6,615
2000	7,012	10,336	13,733
2001	11,558	15,985	18,767
2002	8,317	12,336	14,941
2003	5,715	7,665	9,443
2004			
2005	9,087	12,573	16,058
2006	10,062	14,665	19,482
2007	11,296	16,138	21,978
2008	9,951	14,787	20,327
2009	7,469	11,293	14,166

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

Table 22.Exploitation rate indices for NAFO Divisions 3LNO northern shrimp as determined using Canadian autumn survey and total catch over the period 1997 – 2010. 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 2010 exploitation rate index will be higher once all of the catch has been updated at the end of the calendar year.

Year	Catch (t)	Lower 95% CL of biomass index (t)	Spawning Stock biomass (SSB) (t)	Fishable biomass (t)
1996	179	20,287	5,839	14,297
1997	485	32,630	19,331	34,433
1998	626	48,649	18,324	47,219
1999	795	43,453	21,848	42,487
2000	4,711	84,561	32,822	80,443
2001	10,684	156,356	63,932	175,083
2002	6,967	136,421	69,973	159,880
2003	13,069	144,979	83,363	169,746
2004	13,452			
2005	14,389	178,707	95,445	179,915
2006	25,831	174,076	83,162	173,774
2007	23,859	216,059	128,870	239,719
2008	27,691	197,131	105,915	206,394
2009	27,598	80,020	47,722	95,042
2010	15,560			

Year	Catch / lower CL biomass	Catch/SSB	Catch/fishable biomass
1997	0.024	0.083	0.034
1998	0.019	0.032	0.018
1999	0.016	0.043	0.017
2000	0.108	0.216	0.111
2001	0.126	0.326	0.133
2002	0.045	0.109	0.040
2003	0.096	0.187	0.082
2004	0.093	0.161	0.079
2005			
2006	0.145	0.271	0.144
2007	0.137	0.287	0.137
2008	0.128	0.215	0.116
2009	0.140	0.261	0.134
2010	0.194	0.326	0.164

Table 23.   Survival, annual mortality and instantaneous mortality rate indices for northern shrimp
          (*Pandalus borealis*) within NAFO Divisions 3LNO. Indices were calculated by
          combining 3 years of data in order to account for vagaries within the survey data and
          errors in ageing by modal analysis. The survival, S, in the light green box is the age 4 +
          males and total female abundance shaded orange divided by the sum of the age 3 + males
          and total female shrimp shaded blue. Median survival, annual mortality and
          instantaneous mortality rates were 0.800, 0.200 and 0.223 respectively.

Year	Age 3+males and total female abundance (millions; year = t)	Age 4+males and total female abundance (millions; year = t)	Survival rate = Total age 4 males + female abundance $_{(t+1)}$/ age 3+ males + female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1996	2,410	1,041			
1997	6,365	3,983			
1998	9,313	4,985	0.8042	0.1958	0.2179
1999	7,091	5,578	0.7963	0.2037	0.2277
2000	18,518	7,569	1.2297	-0.2297	-0.2068
2001	43,285	29,797	0.8679	0.1321	0.1416
2002	38,863	22,429	0.7792	0.2208	0.2495
2003	33,369	26,209			
2004					
2005	40,714	18,994			
2006	33,651	27,573			
2007	45,806	29,271	0.6886	0.3114	0.3731
2008	43,524	25,908	0.5728	0.4272	0.5572
2009	20,013	15,269			
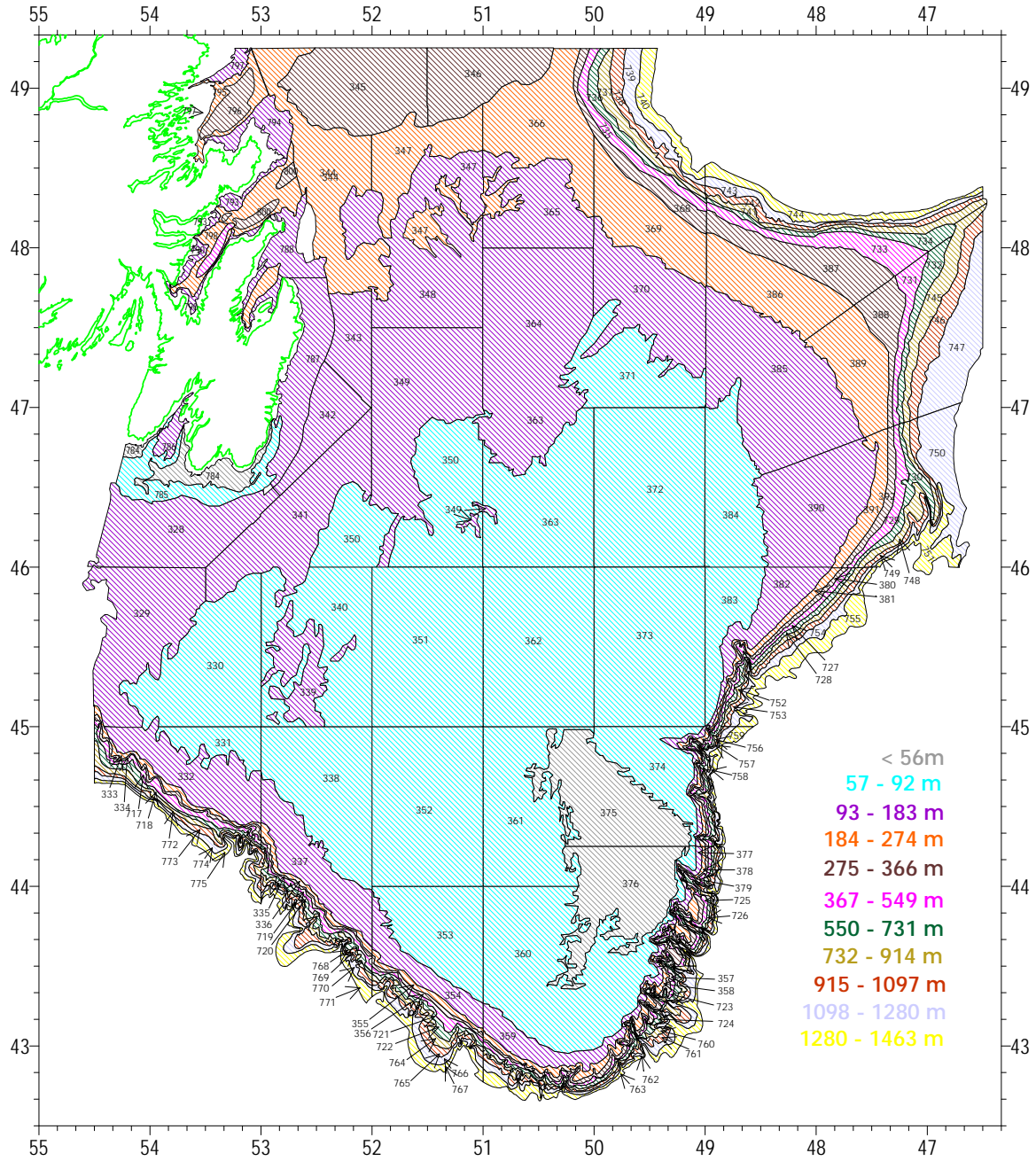
Figure 1.   The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species
research bottom trawl survey set allocation (G. Cossitt).
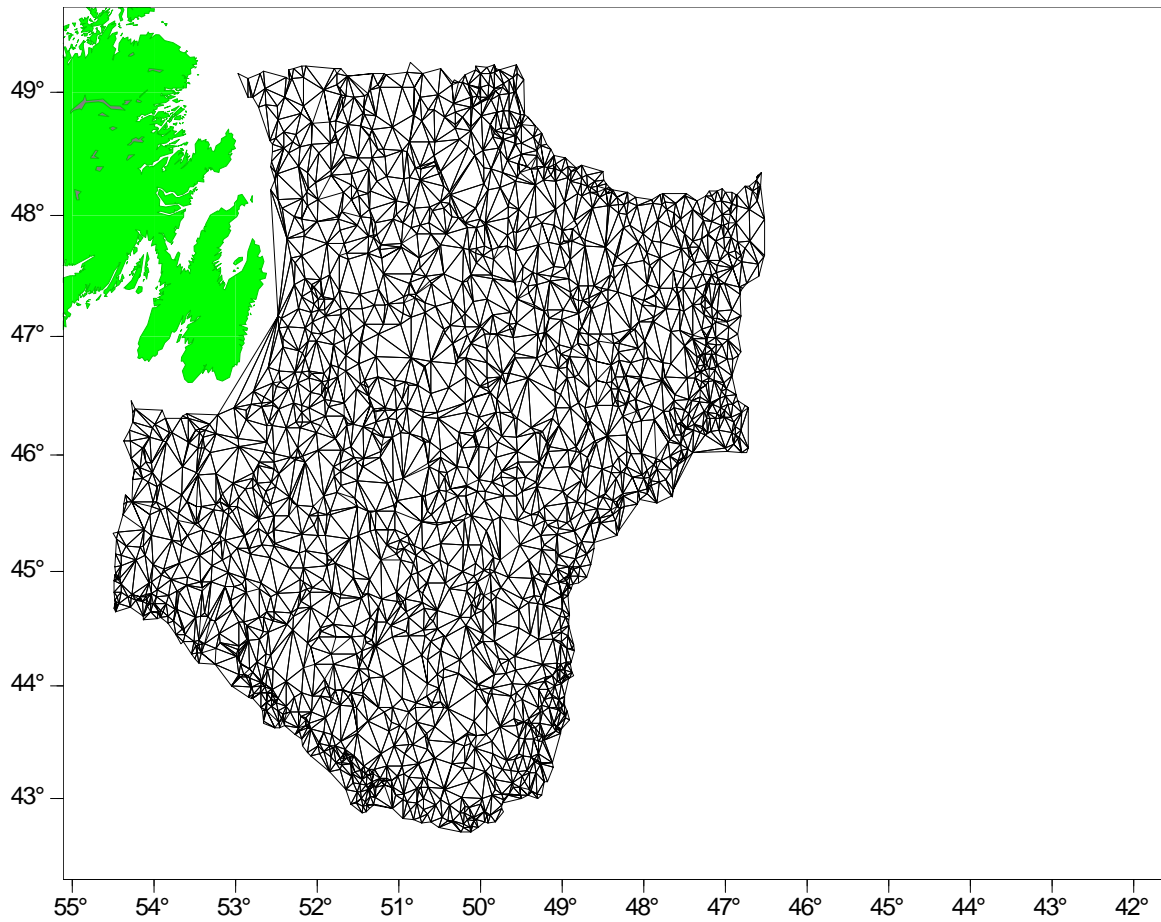
Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Omap.

NAFO division 3L offshore - Delauney triangulation
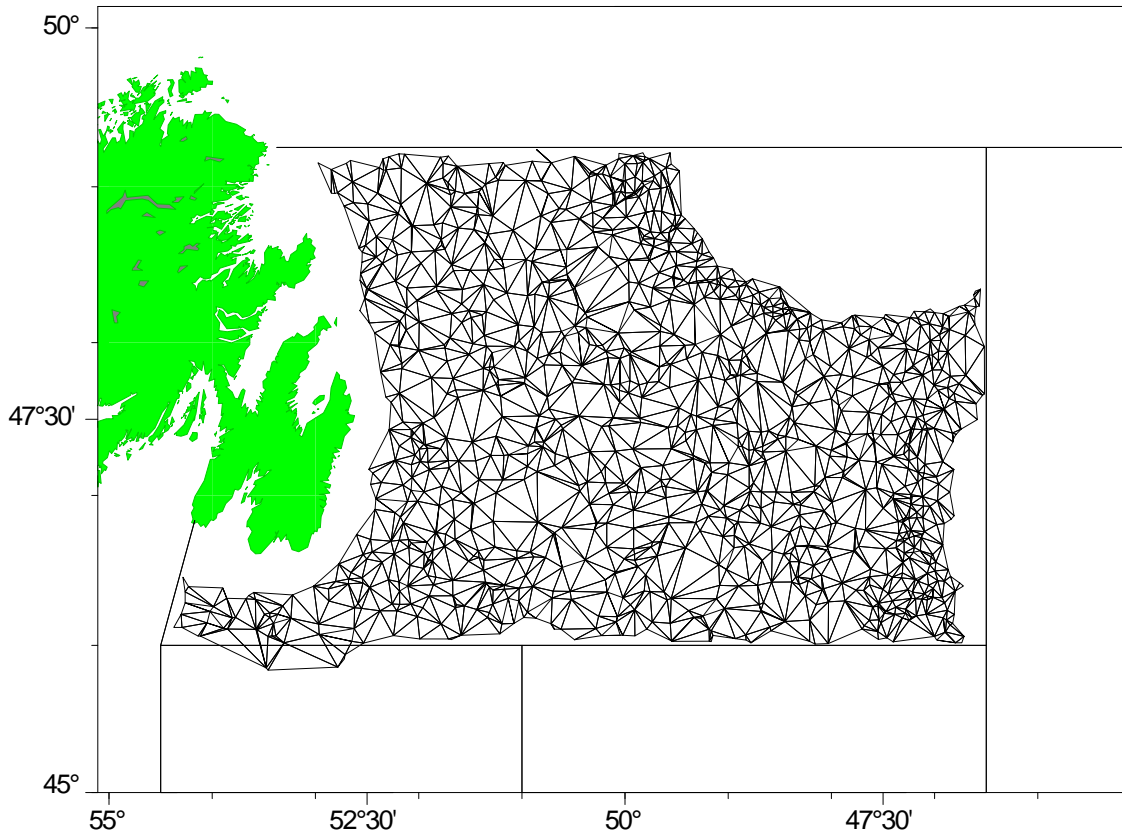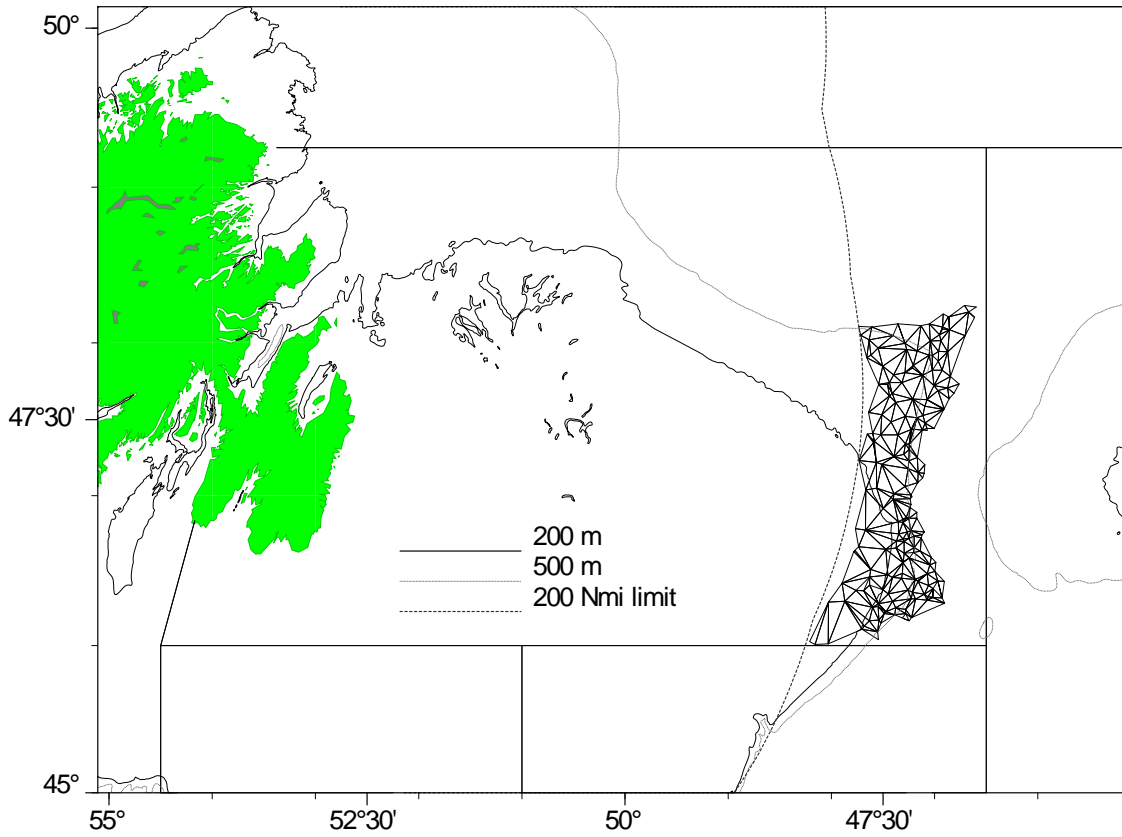
NAFO division 3O - Delauney triangulation
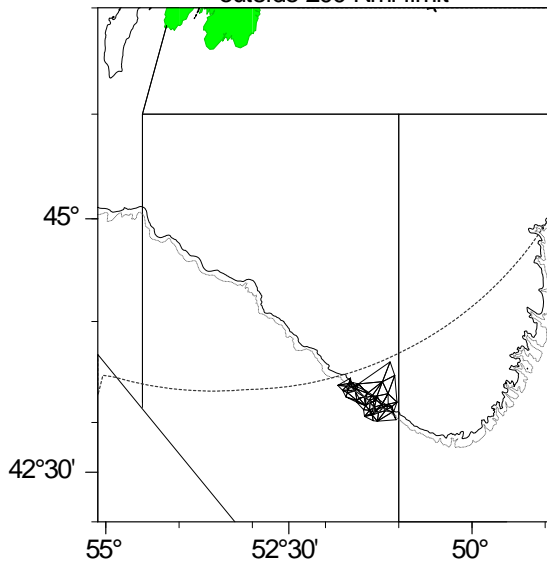
NAFO division 3N - Delauney triangulation

Figure 3.   The Delauney triangulation used to derive within NAFO division Ogmap biomass and abundance indices.
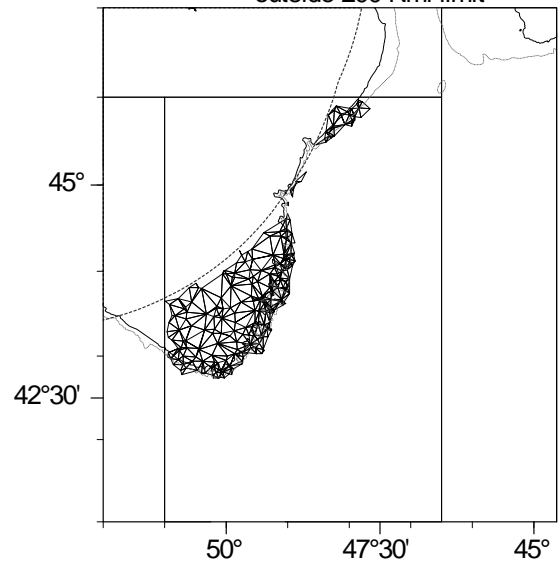
Figure 4.   The Delauney triangulation used to derive the outside 200 Nmi limit Ogmap biomass and abundance indices.
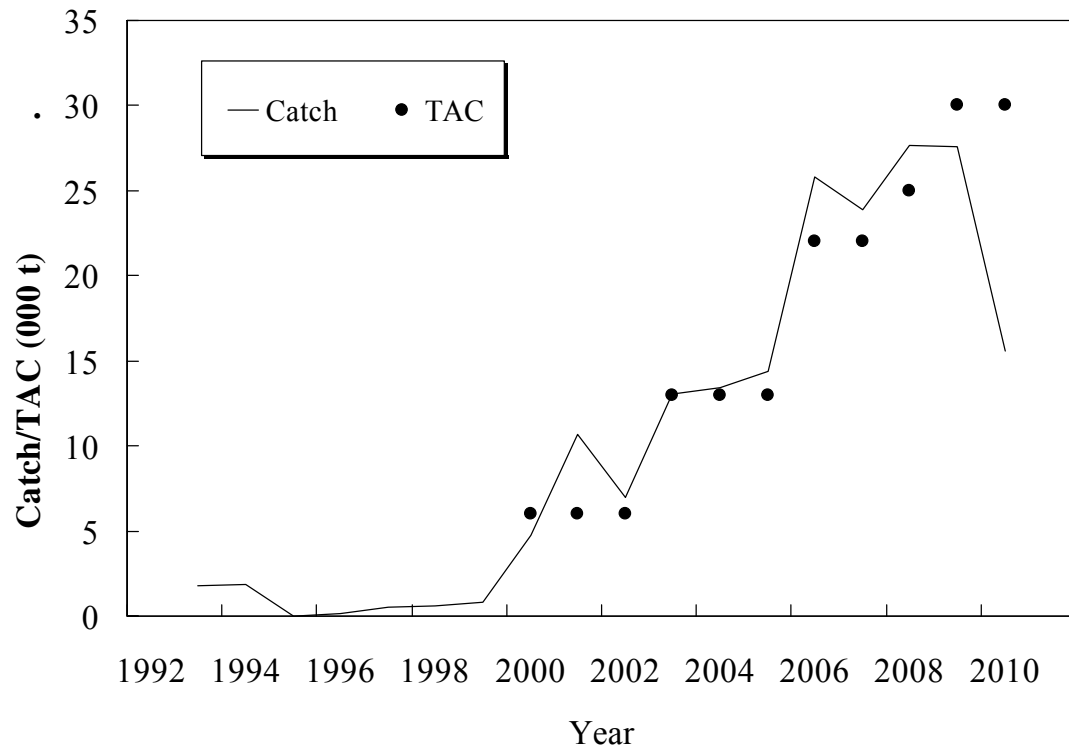
Figure 5.   Trends in NAFO Division 3L Northern Shrimp (*Pandalus borealis*) catch and TAC over the period 1993-2010.

2006

2009

2007

2010

2008

P. borealis catches in tons

+ 0 to 5
• 5.01 to 50
■ 50.01 to 250
▲ 250.01 to 500
○ 500.01 to 2000

—— 200 m

- - - 500 m

—·— 200 Nmi Limit
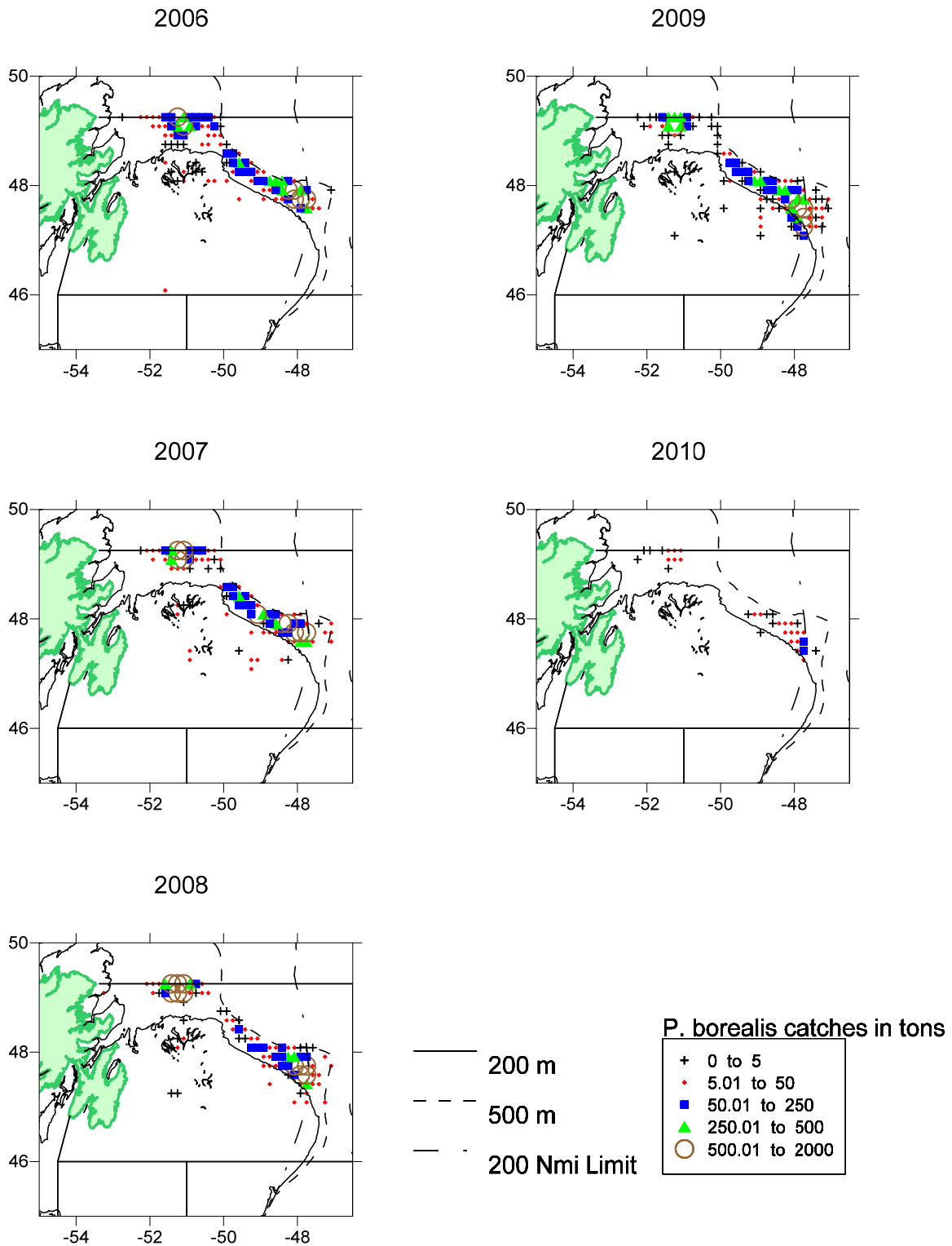
Figure 6.   Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp catches in NAFO Division 3L, 2006 – 2010. (Logbook data aggregated into 10 min X 10 min cells).
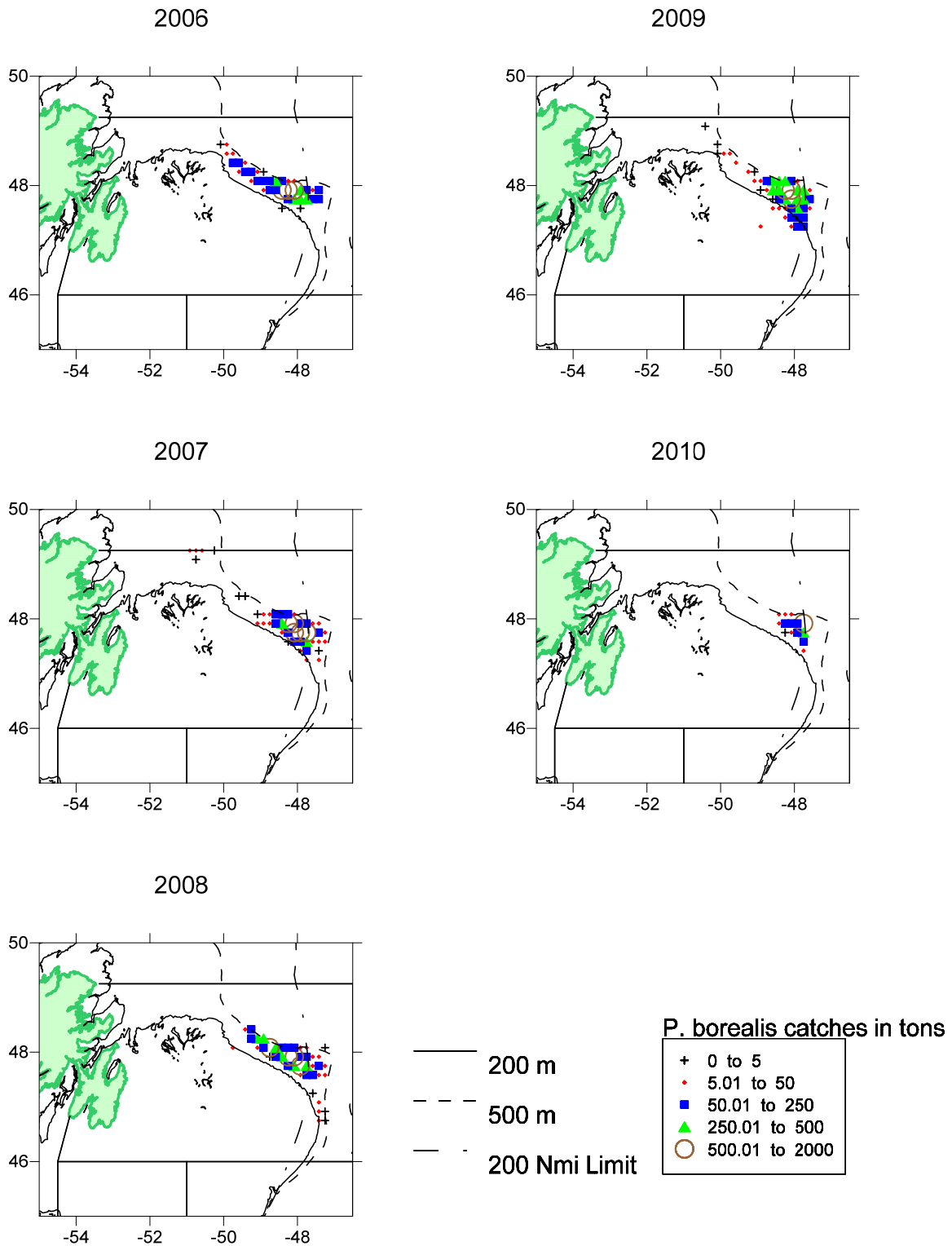
Figure 7.   Distribution of **Canadian large vessel (>500 t)** shrimp catches in NAFO Division 3L, 2006 – 2010. (Observer data aggregated into 10 min X 10 min cells).
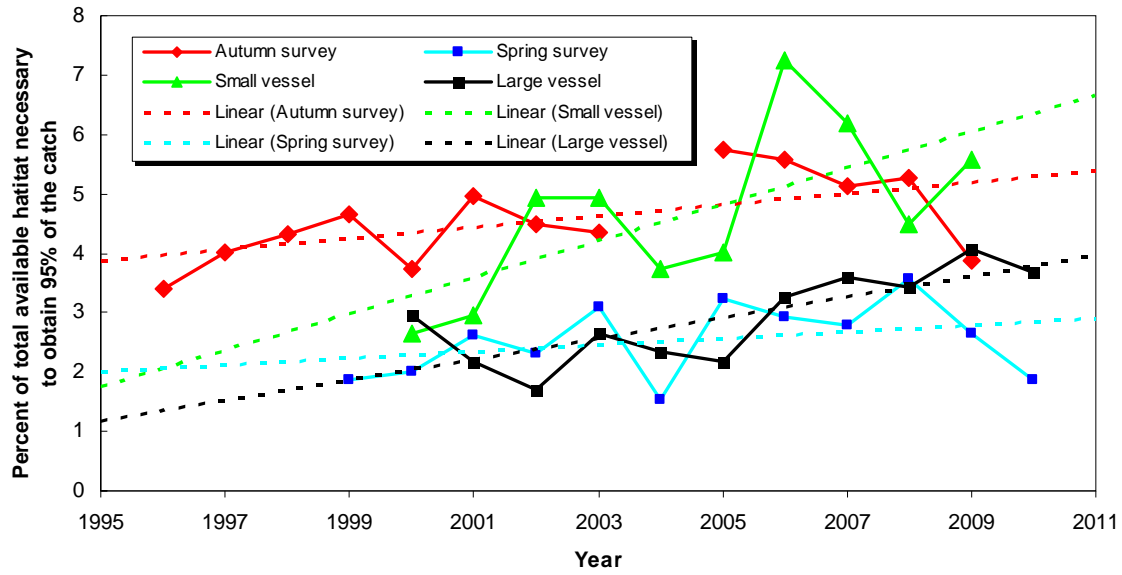
Figure 8. Trends in percent area occupied by the northern shrimp (*Pandalus borealis*) resource as well as large and small vessel shrimp fisheries in relation to total area available within NAFO Divisions 3LNO.
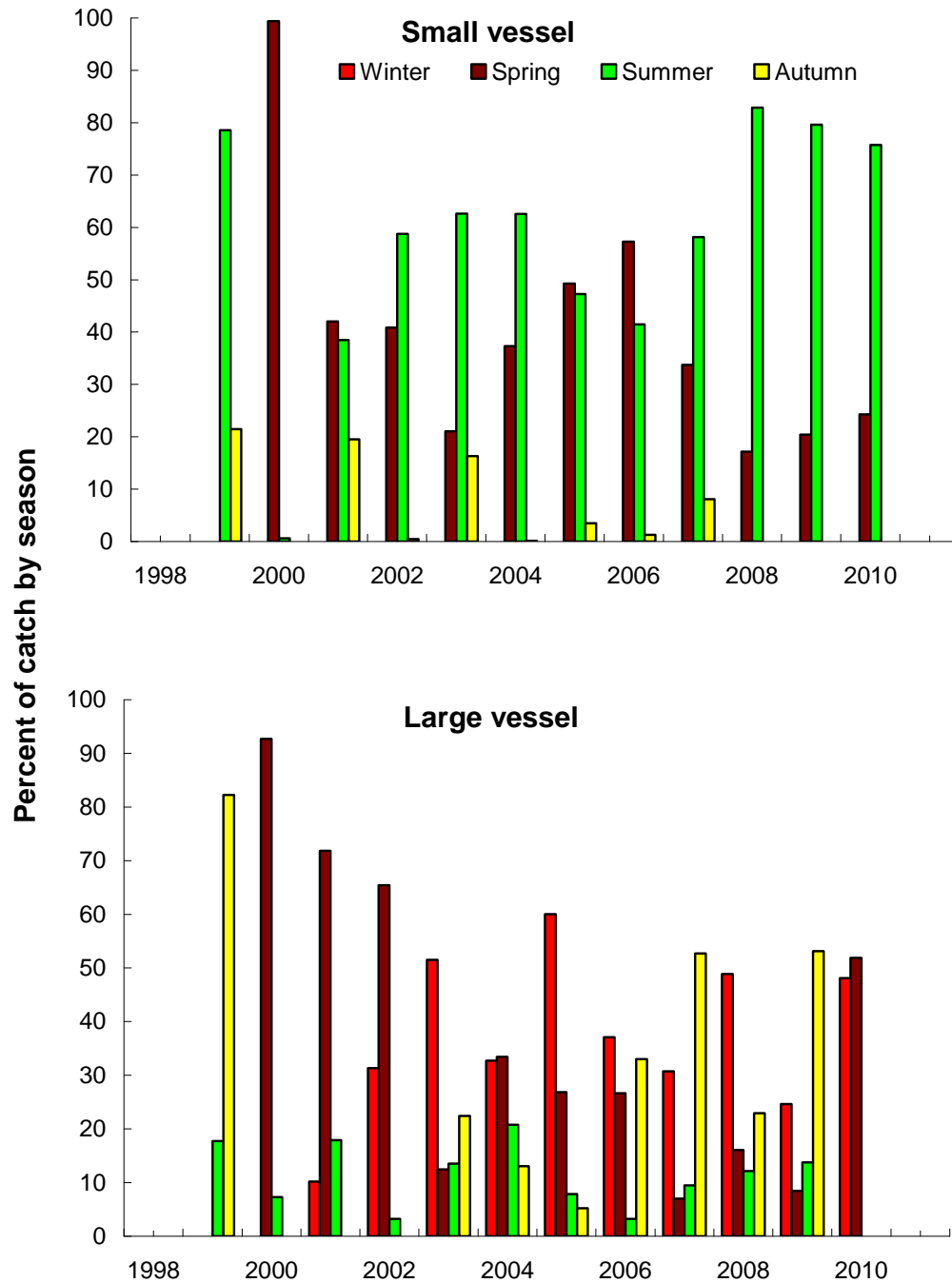
Figure 9.   Seasonality of the large and small vessel Northern Shrimp (*Pandalus borealis*) fishery in
NAFO Division 3L over the period 2000 – 2010. Please note that the 2010 values are
preliminary with data up to the end of August 2010.
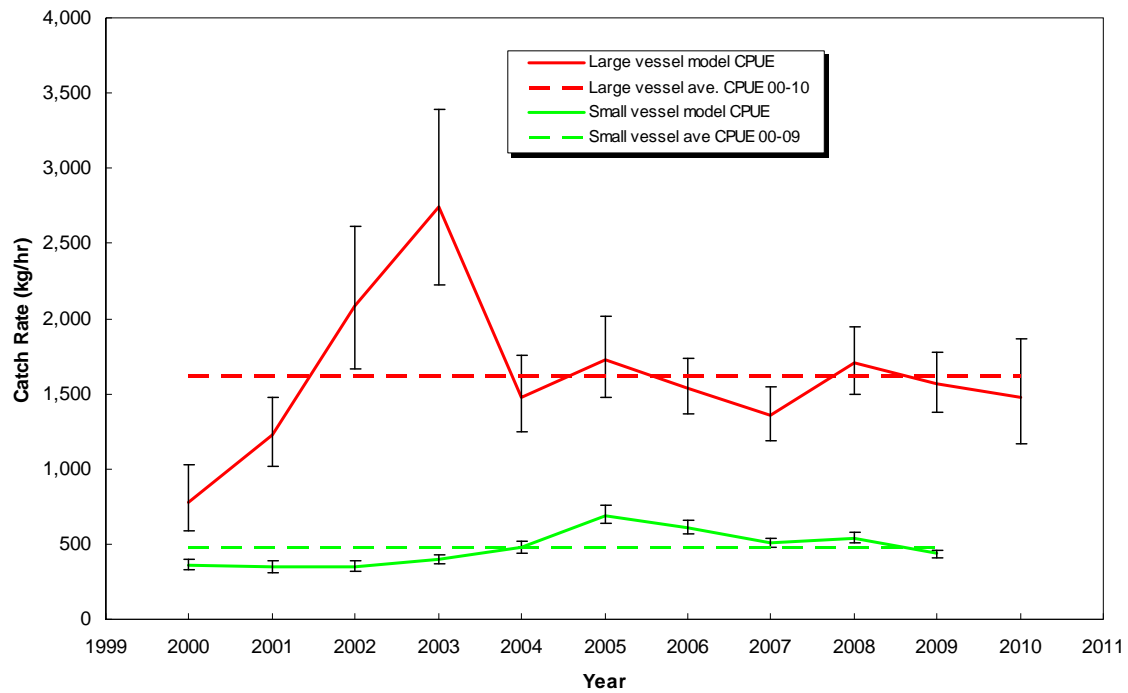
Figure 10.   Model catch rates for Canadian large (>500 t) and small (<= 500 t; <65') (2000 – 2009)
                vessels fishing for shrimp in NAFO Div. 3L over the periods 2000 – 2010 and 2000 –
                2009 respectively. Bars represent 95% confidence intervals around model values.
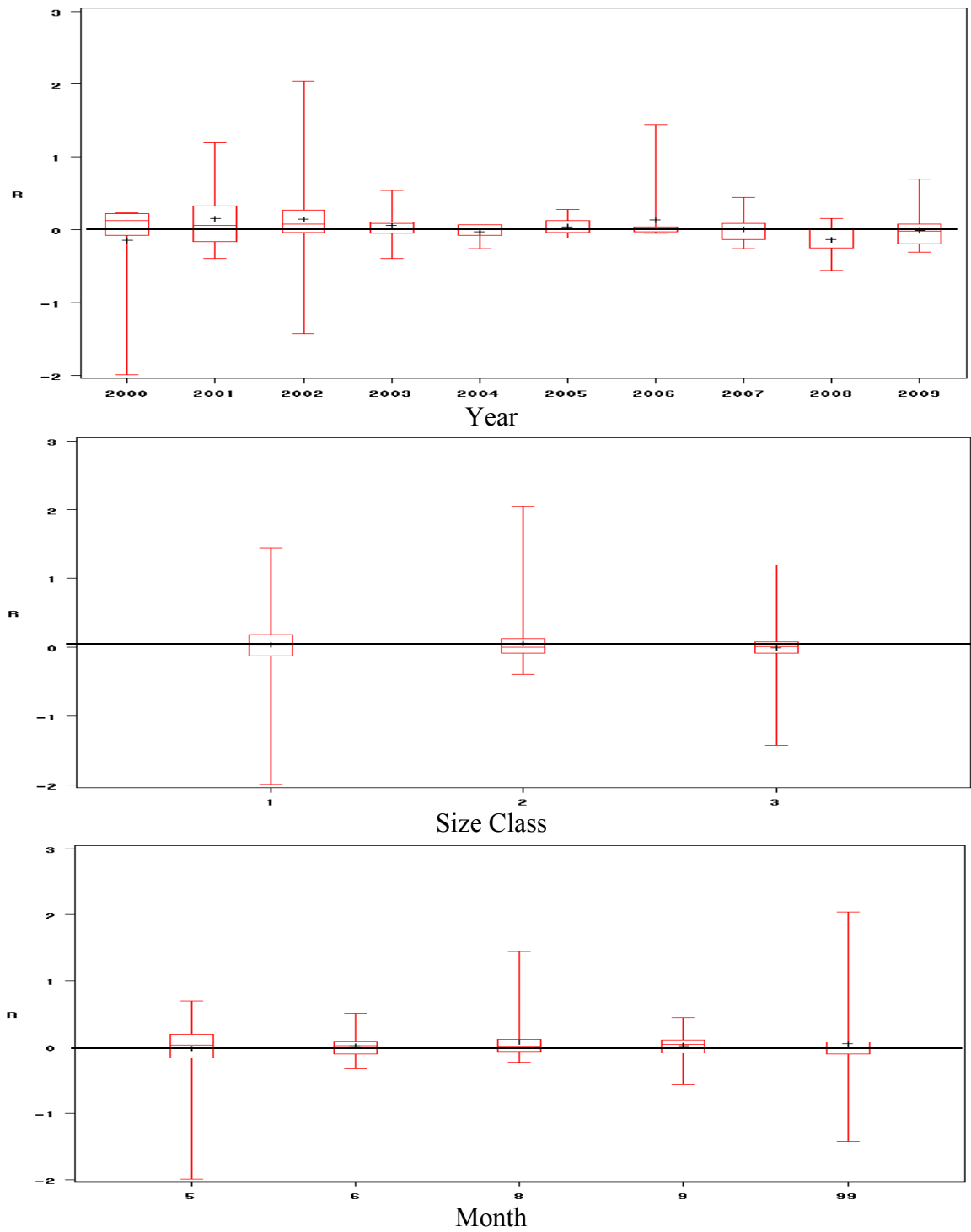
Figure 11.   Distribution of residuals around estimated values for parameters used to model **Canadian small vessel** shrimp catch rates, 2000 – 2009.
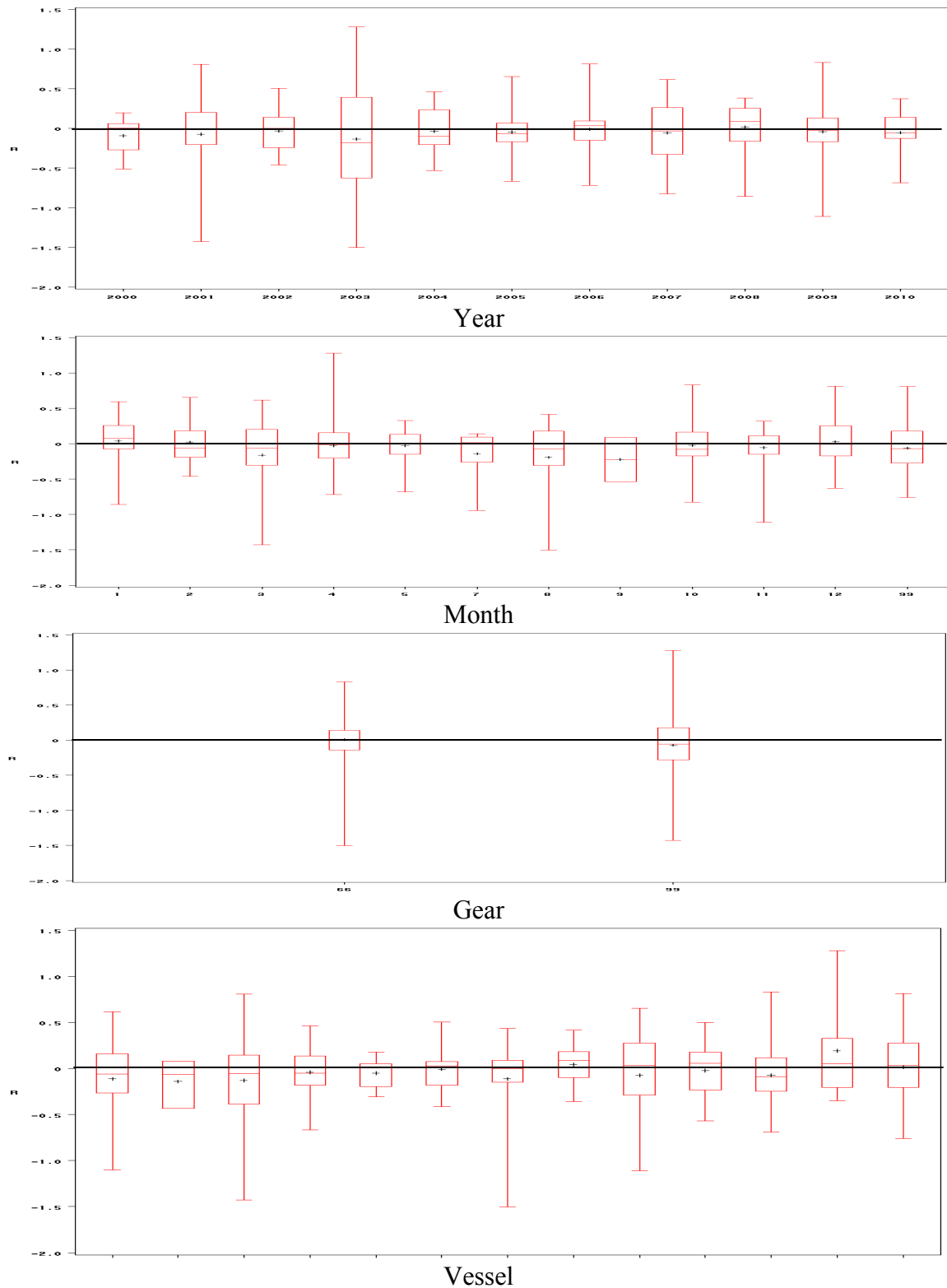
Figure 12.   Distribution of residuals around estimated values for parameters used to model **Canadian large vessel** shrimp catch rates, 2000 – 2010.
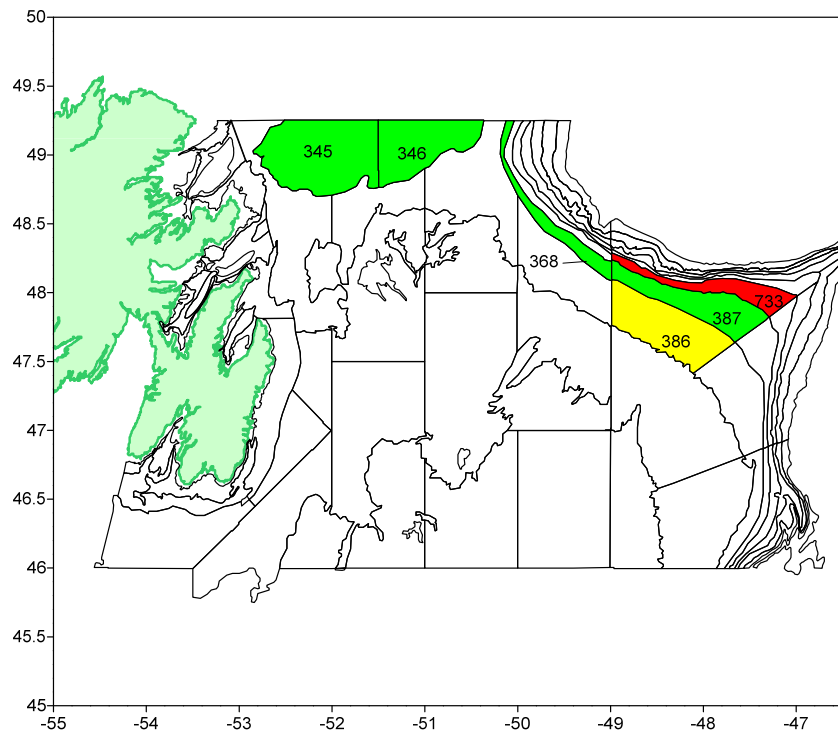
Figure 13.　　NAFO Divisions 3L index strata consistently fished by the small vessel (<=500 t; <65') shrimp fishing fleet, over the period 2003 – 2009. Numbers indicate the strata designations as per figure 1. Depth zones are as follows:Yellow = 184 – 274 m; Green = 375 – 366 m and Red = 367 – 549 m.
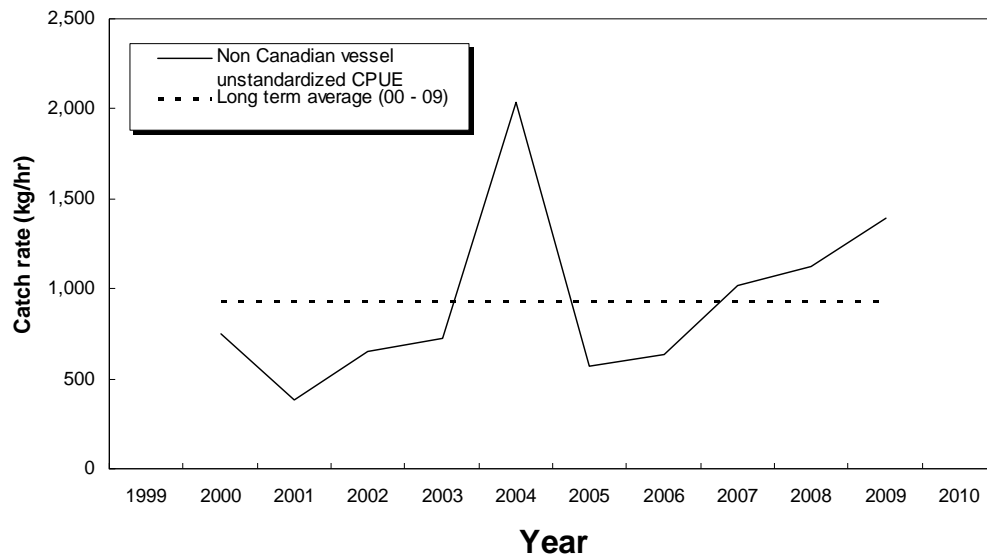
Figure 14.　　Unstandardized catch rates for non Canadian vessels fishing northern shrimp within the NAFO Division 3L NRA over the period 2000 – 2009. This catch rate series made use of data from Greenland, Iceland, Norway, Spain and Russia.
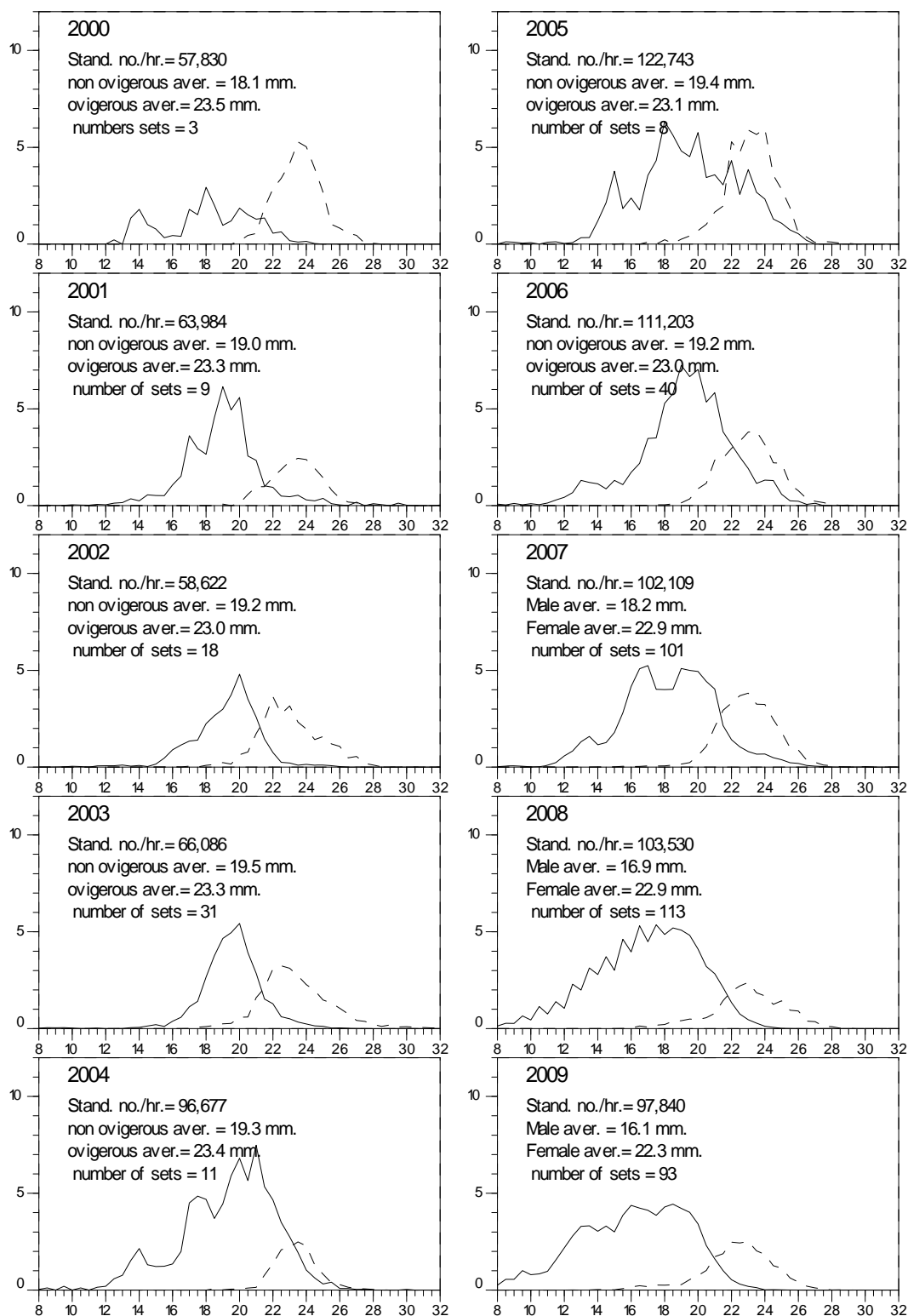
Figure 15.   Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing in NAFO Div. 3L over the period 2000 – 2009.
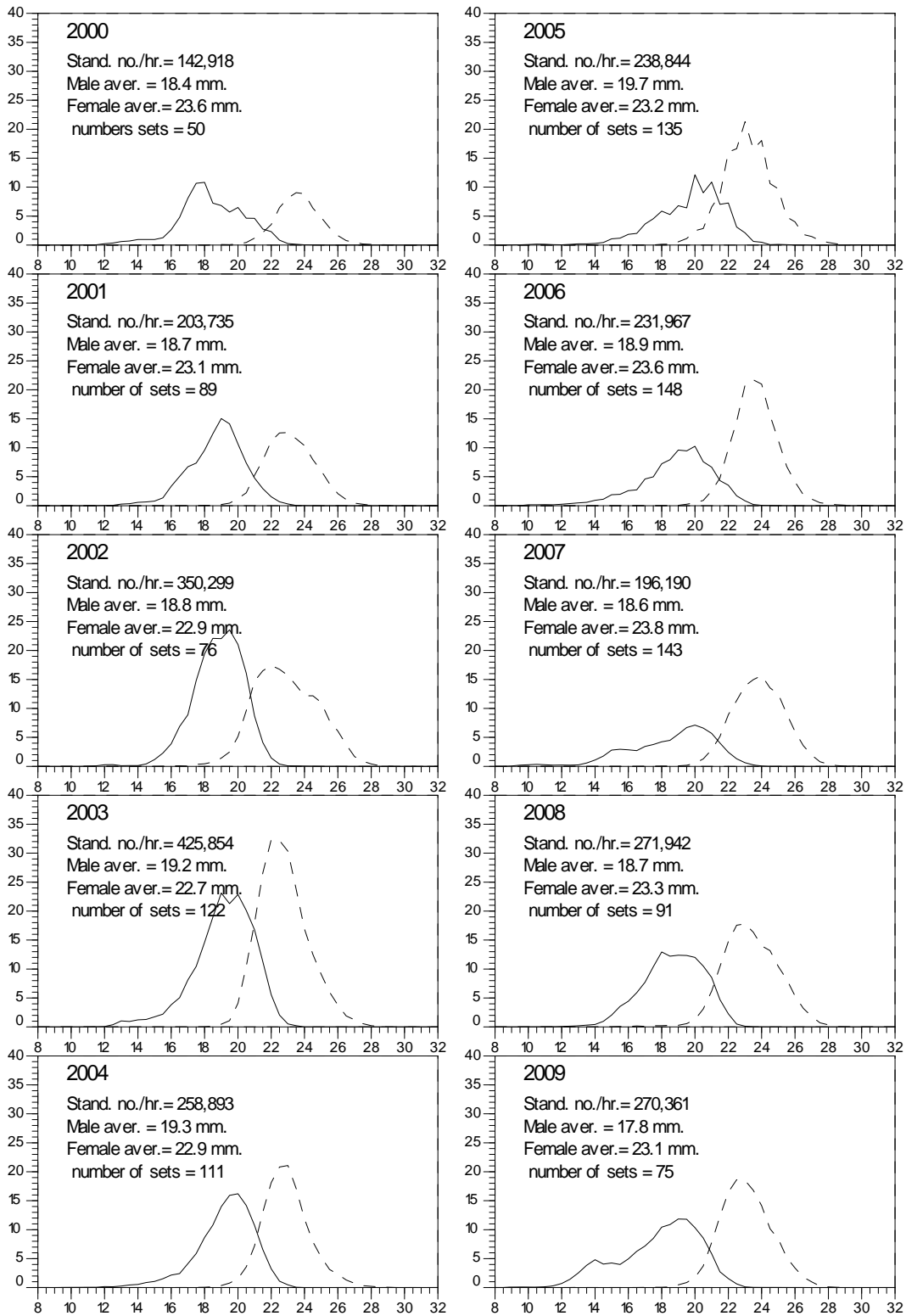
Figure 16. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing in NAFO Div. 3L over the period 2000 – 2009.
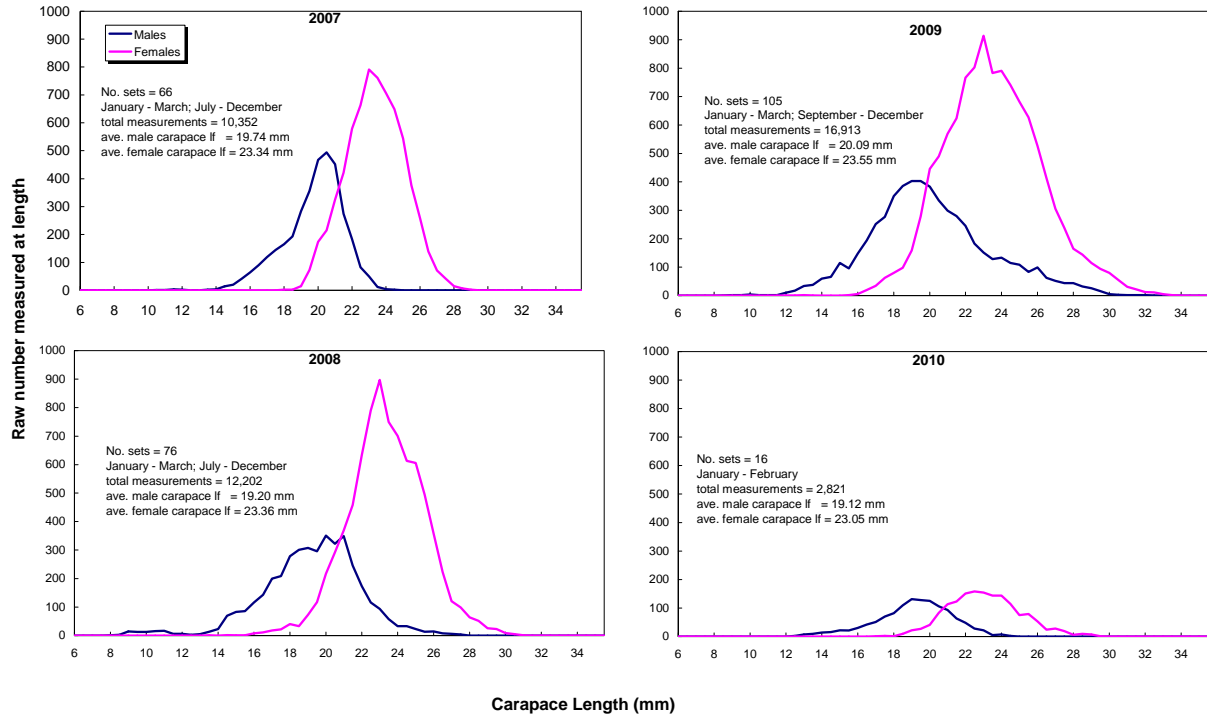
Figure 17.   Observed length frequencies from the **Estonian** northern shrimp fishery in NAFO Div. 3L NRA over the period 2007 – 2010.
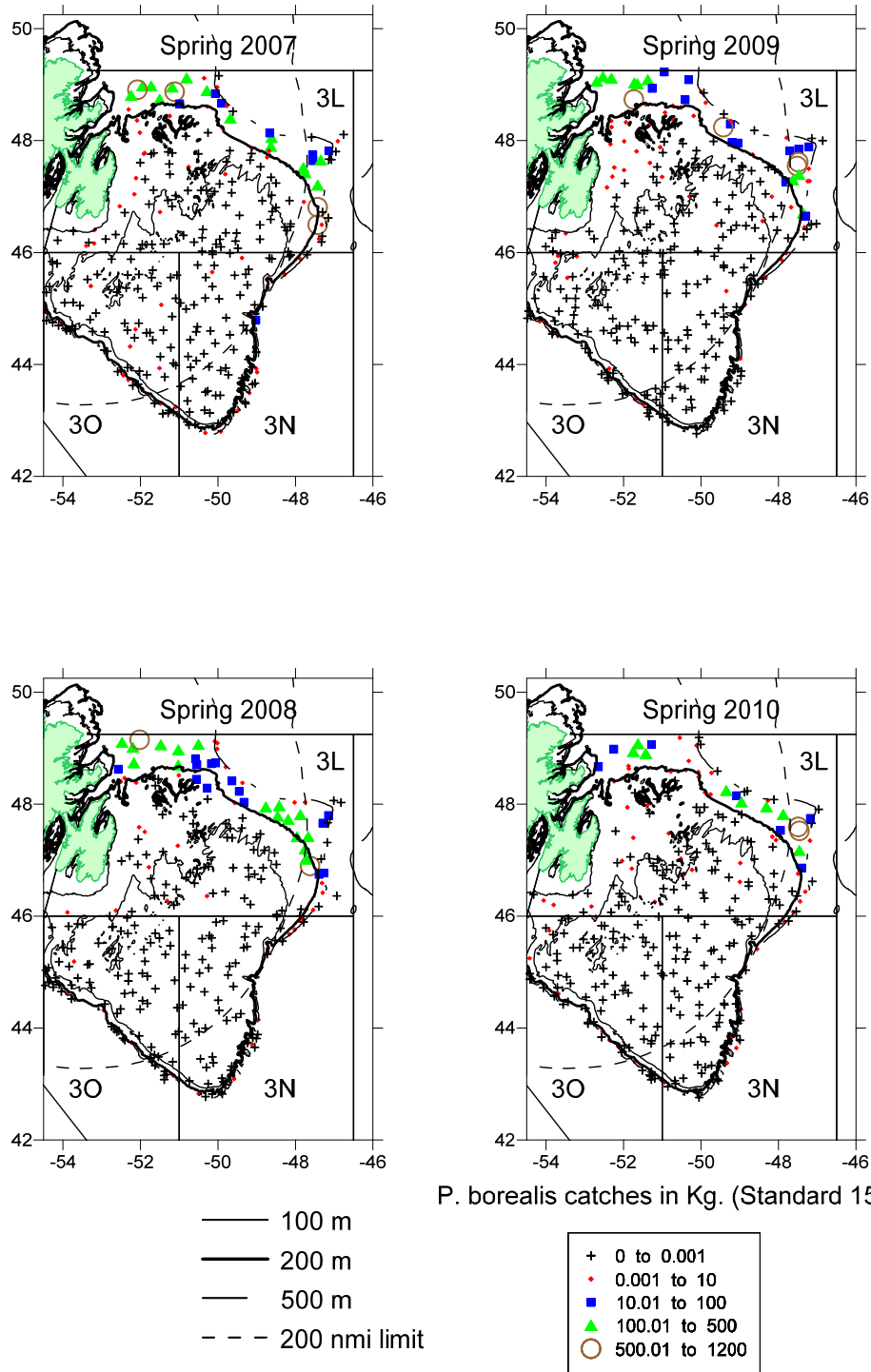
Figure 18.   Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **spring** Canadian research bottom trawl surveys conducted over the period 2007 – 2010.
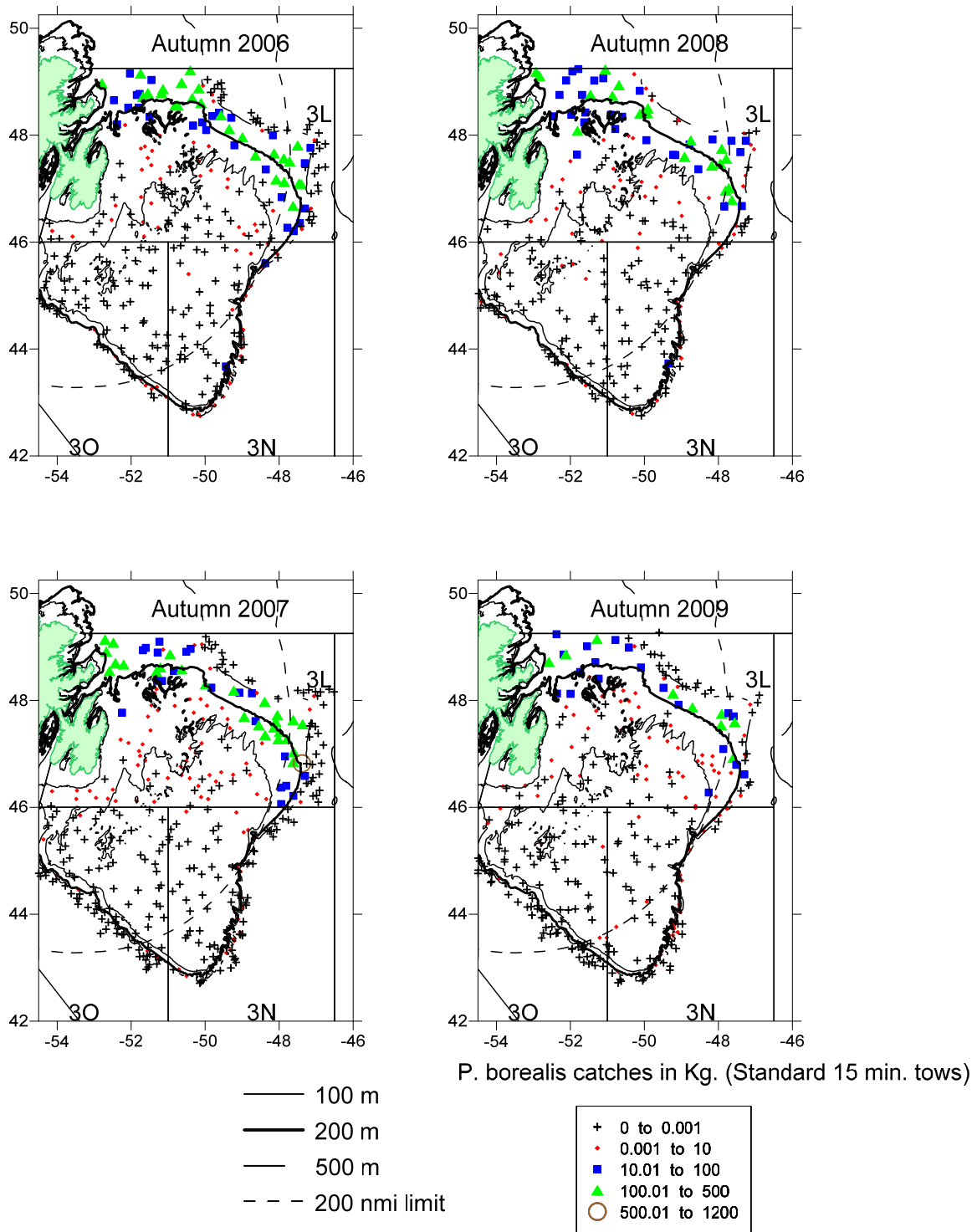
Figure 19.   Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches
kg/tow as obtained from **autumn** Canadian research bottom trawl surveys conducted
over the period 2006 – 2009.

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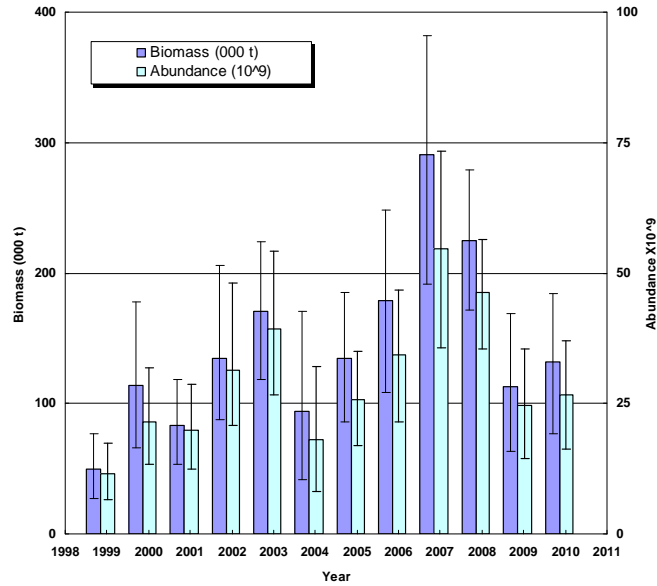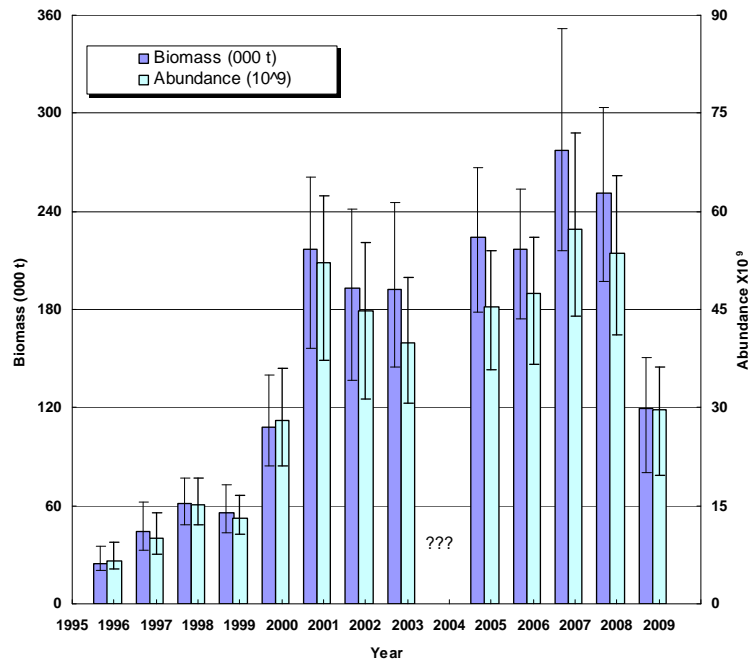
A)   **Spring**

B)   **Autumn**

Figure 20.   Northern shrimp biomass and abundance indices within NAFO Divisions 3LNO over the
period 1996 – 2010. The data are from spring 1999 – 2010 and autumn 1999 – 2009
Canadian multispecies research bottom trawl surveys. (Standard tow 15 min.). Estimates
were made using Ogmap calculations and bars represent 95% confidence intervals.

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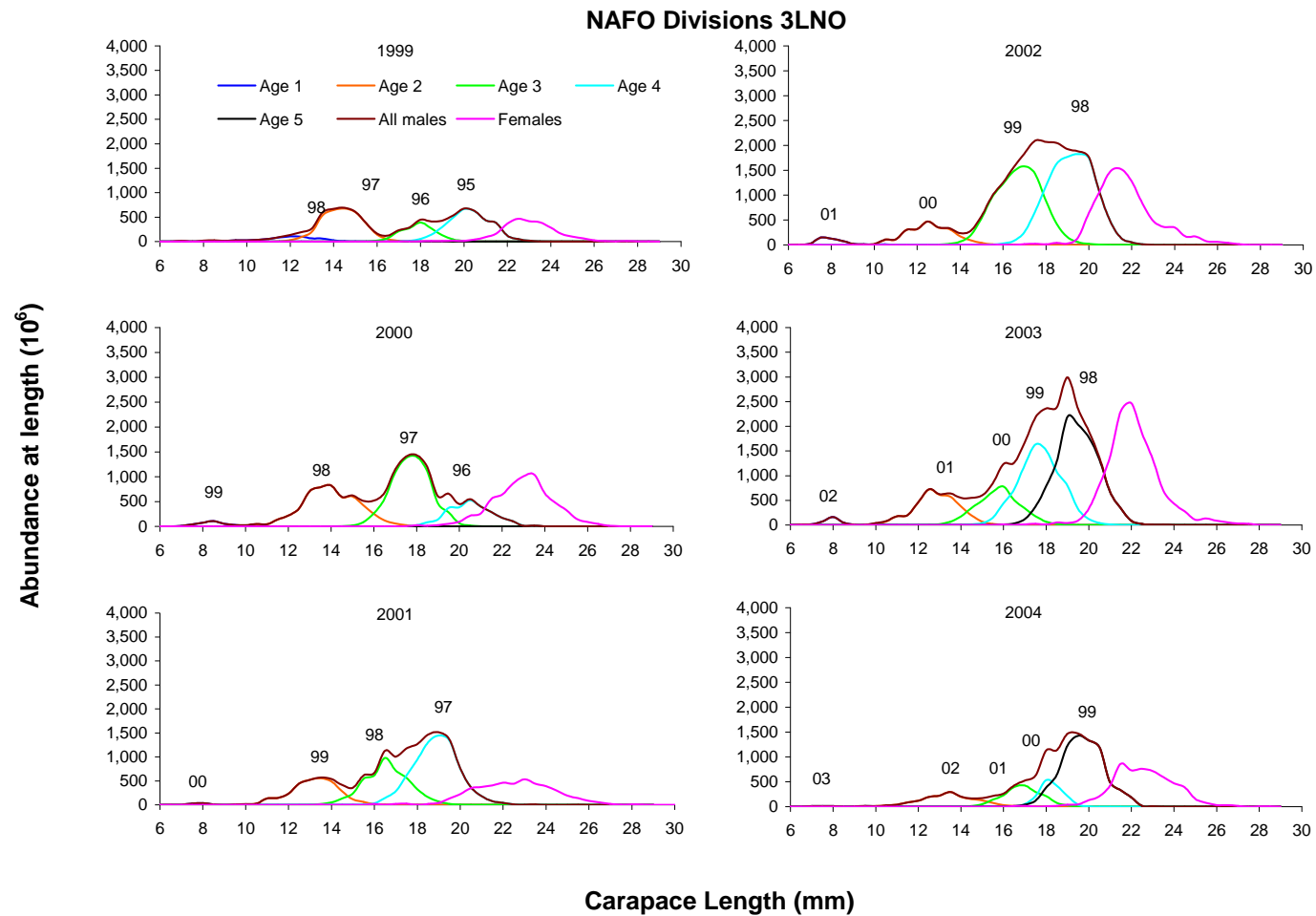
Figure 21.   NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **spring** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within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

Figure 21.   (Continued)
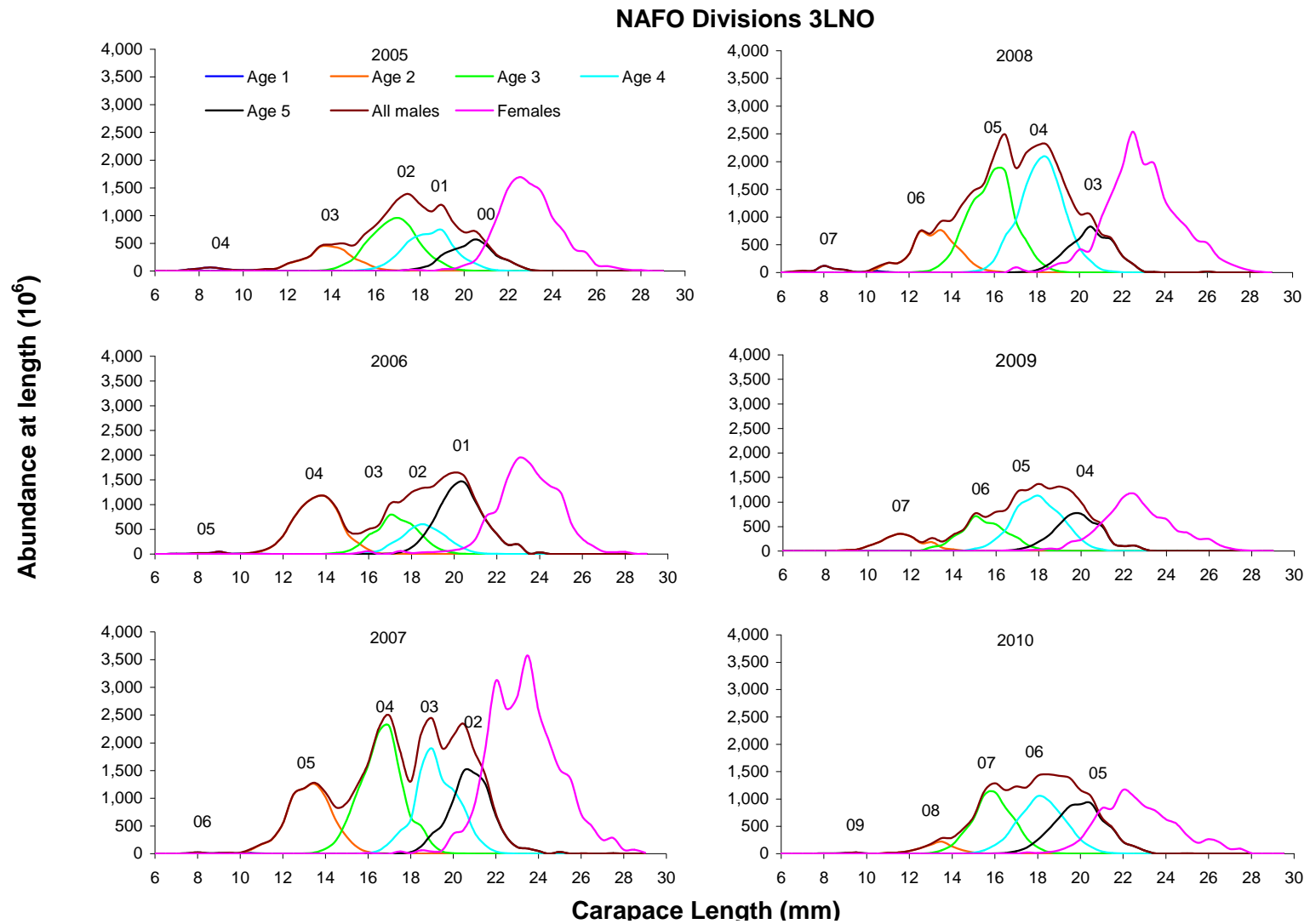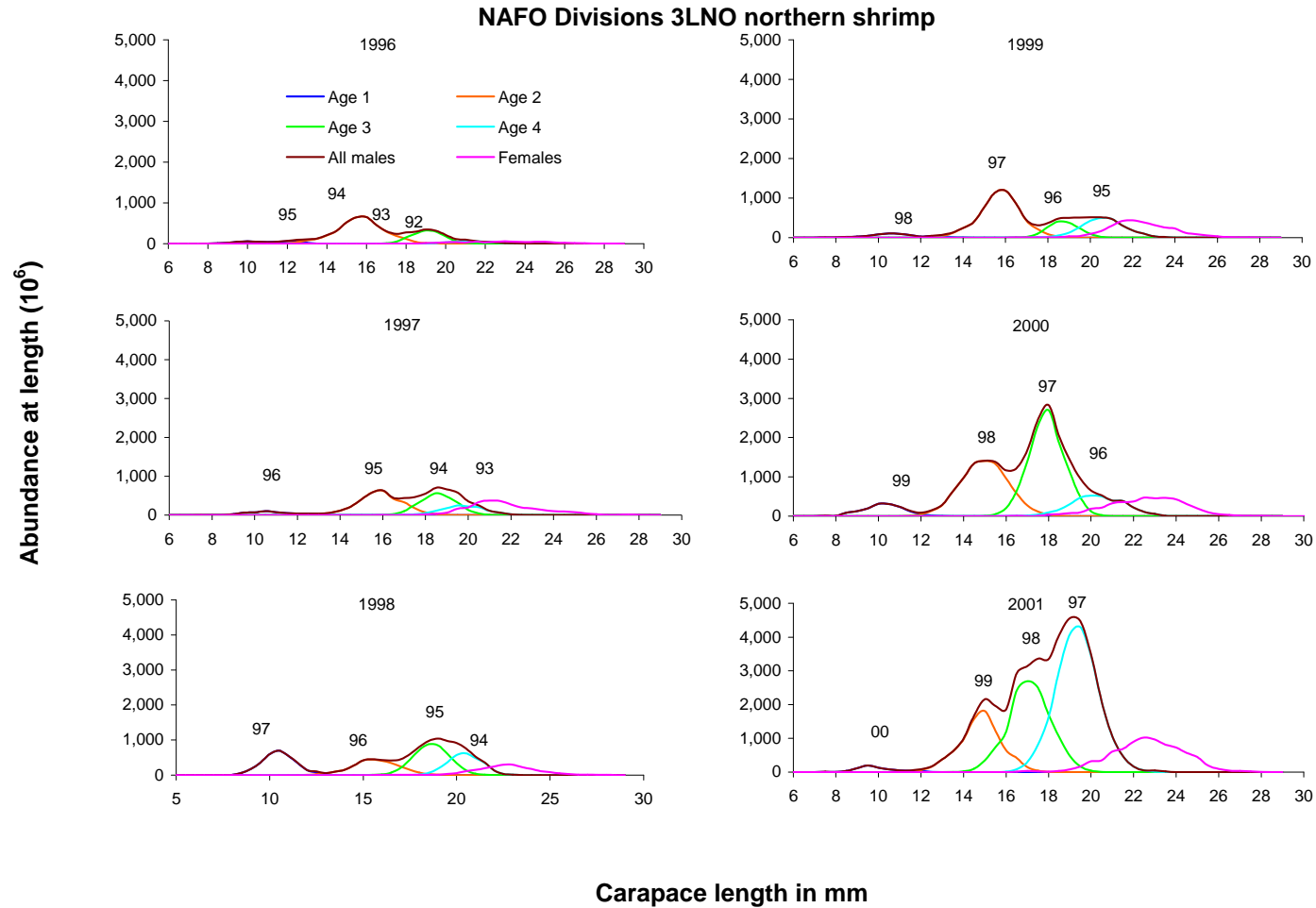
Figure 22.   NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993).

NAFO Divisions 3LNO northern shrimp

Incomplete survey in 2004

Carapace length in mm

Figure 22.   (Continued)

NAFO Divisions 3LNO northern shrimp
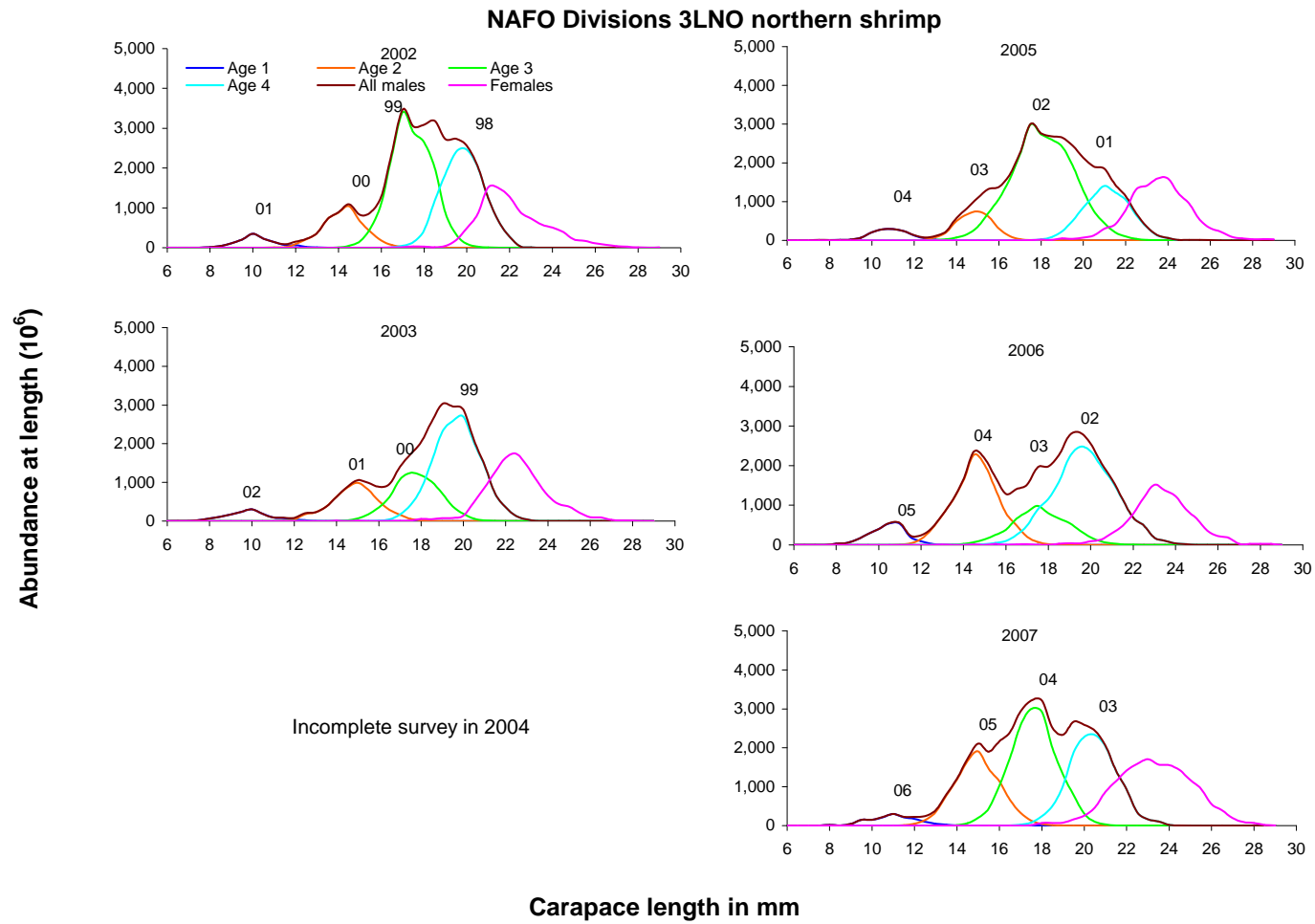
Figure 22.   (Continued)

Figure 23.   Abundance and biomass of male shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.
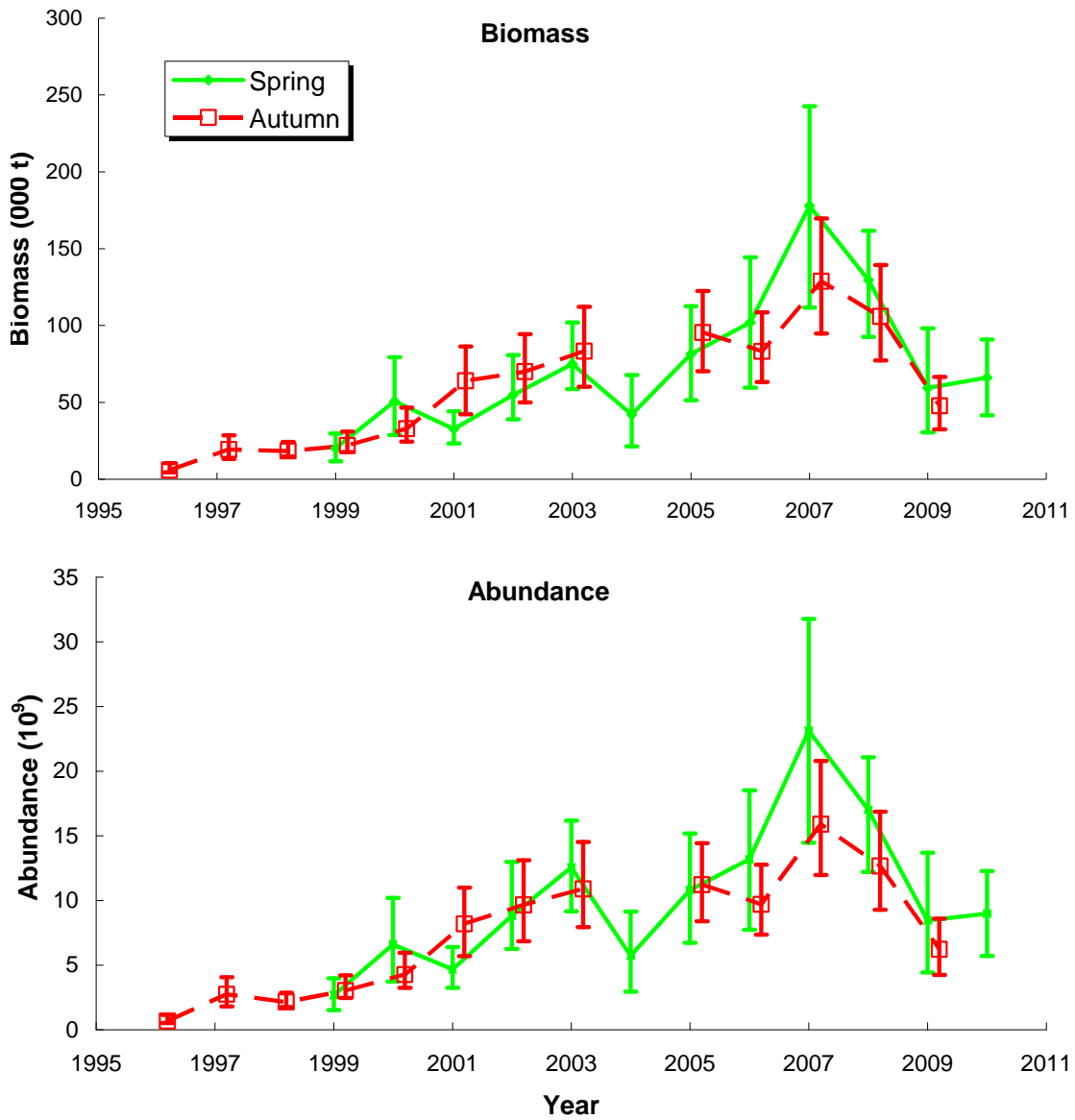
Figure 24.   Abundance and biomass of female shrimp (SSB) within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.
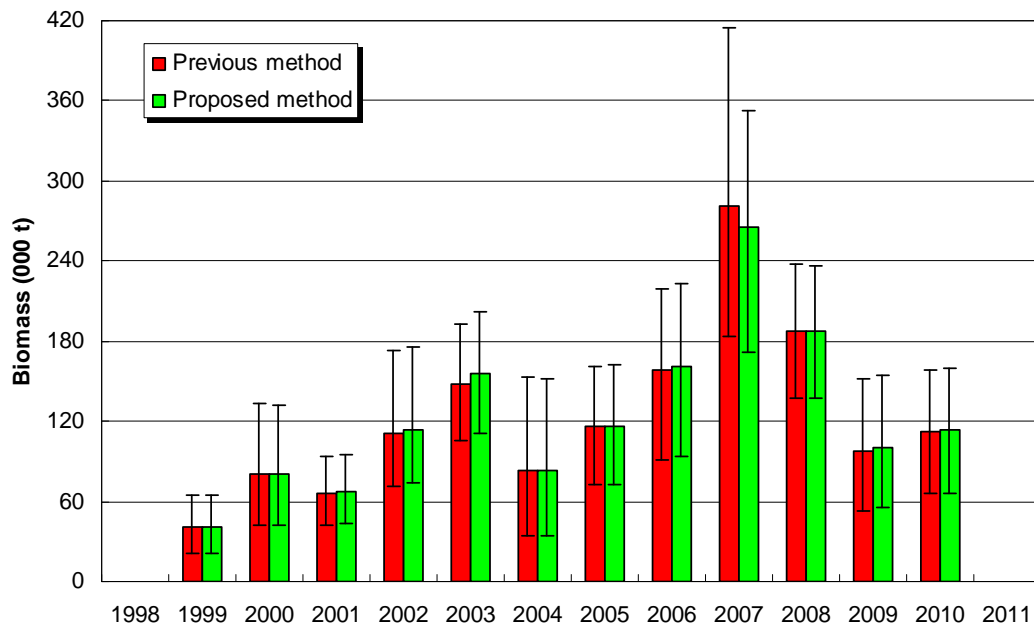
A) **Spring**
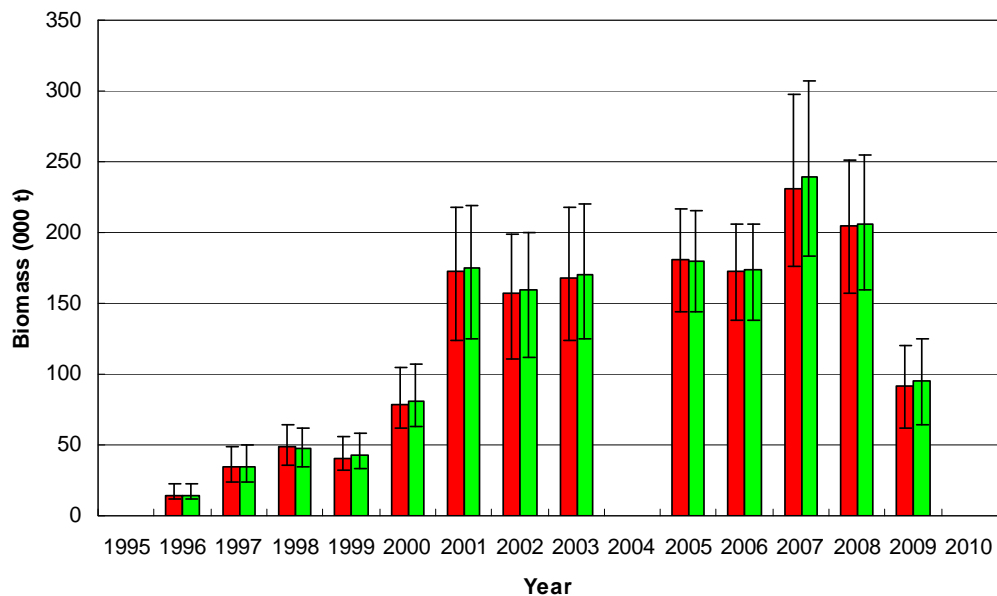
B) **Autumn**

Figure 25.   A comparison between the fishable biomass indices with previously used (total weight of all females + weight of all males with carapace lengths => 17.5 mm) and proposed methods (weight of all males and females with carapace lengths =>17.5 mm). Indices were calculated from spring and autumn Canadian multi-species bottom trawl survey data 1996 – 2010.
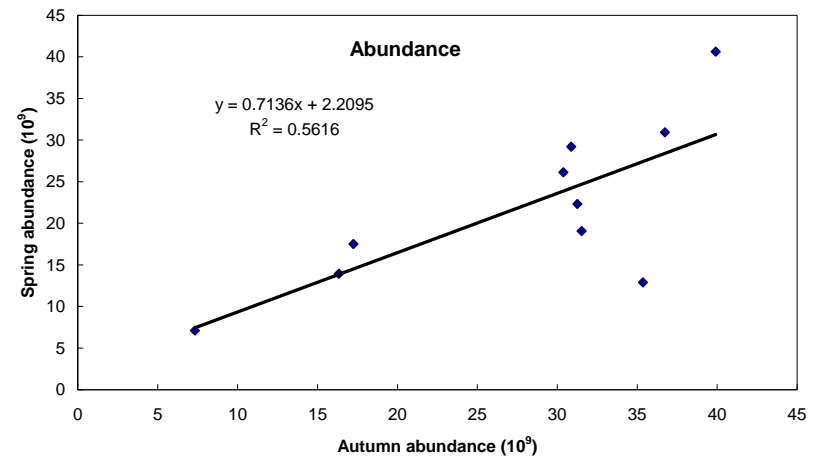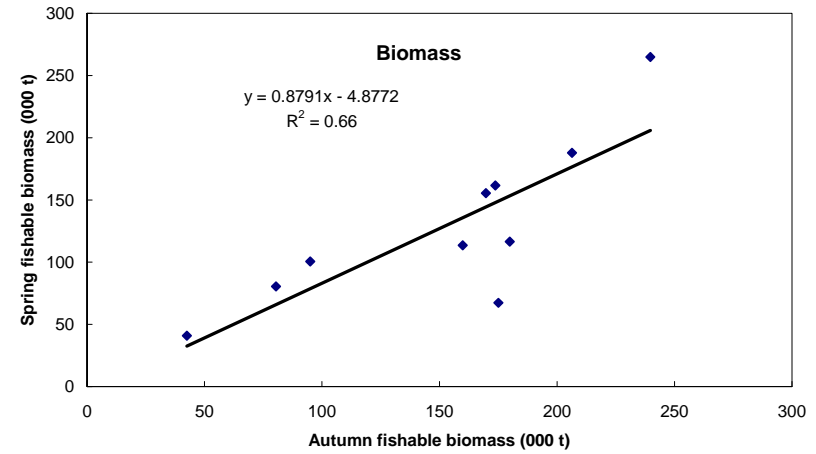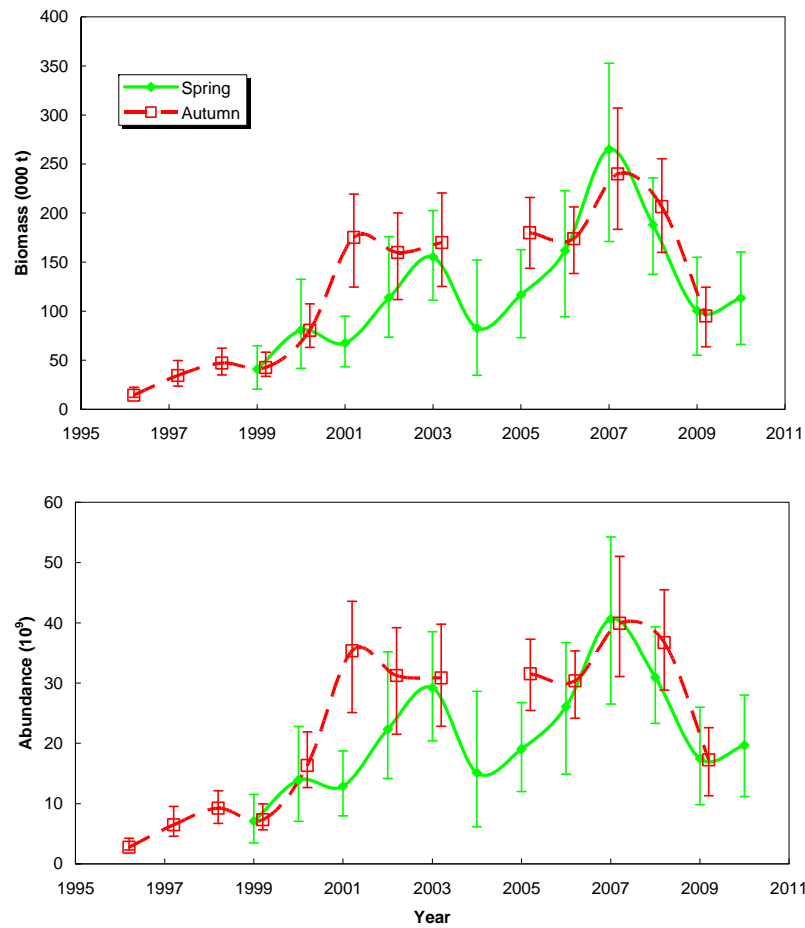
Figure 26.   Proposed fishable biomass and abundance indices (all males and females with carapace lengths =>17.5 mm) estimated by way of Ogmap calculations using spring (1999 – 2010) and autumn (1996 – 2009) Canadian multi-species bottom trawl survey. (Standard tows 15 min.)
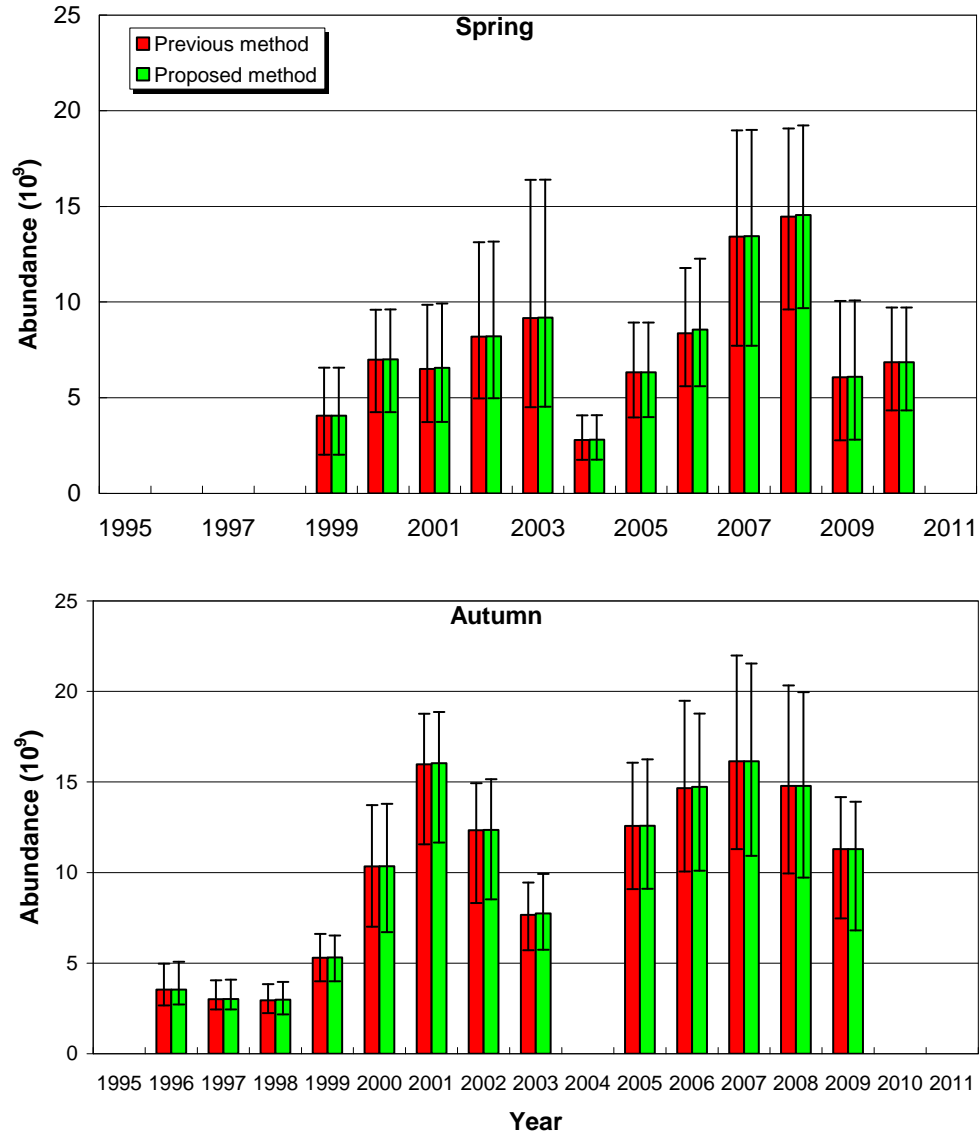
Figure 27.   Recruitment indices as determined using Ogmap calculations from spring (1999 – 2010) and autumn (1996 – 2009) Canadian multi-species bottom trawl survey data. Previously recruitment was determined as the abundance of males with 12 – 17 mm Carapace lengths. The proposed recruitment indices are determined as the abundance of both male and female shrimp with 12 – 17 mm carapace lengths.
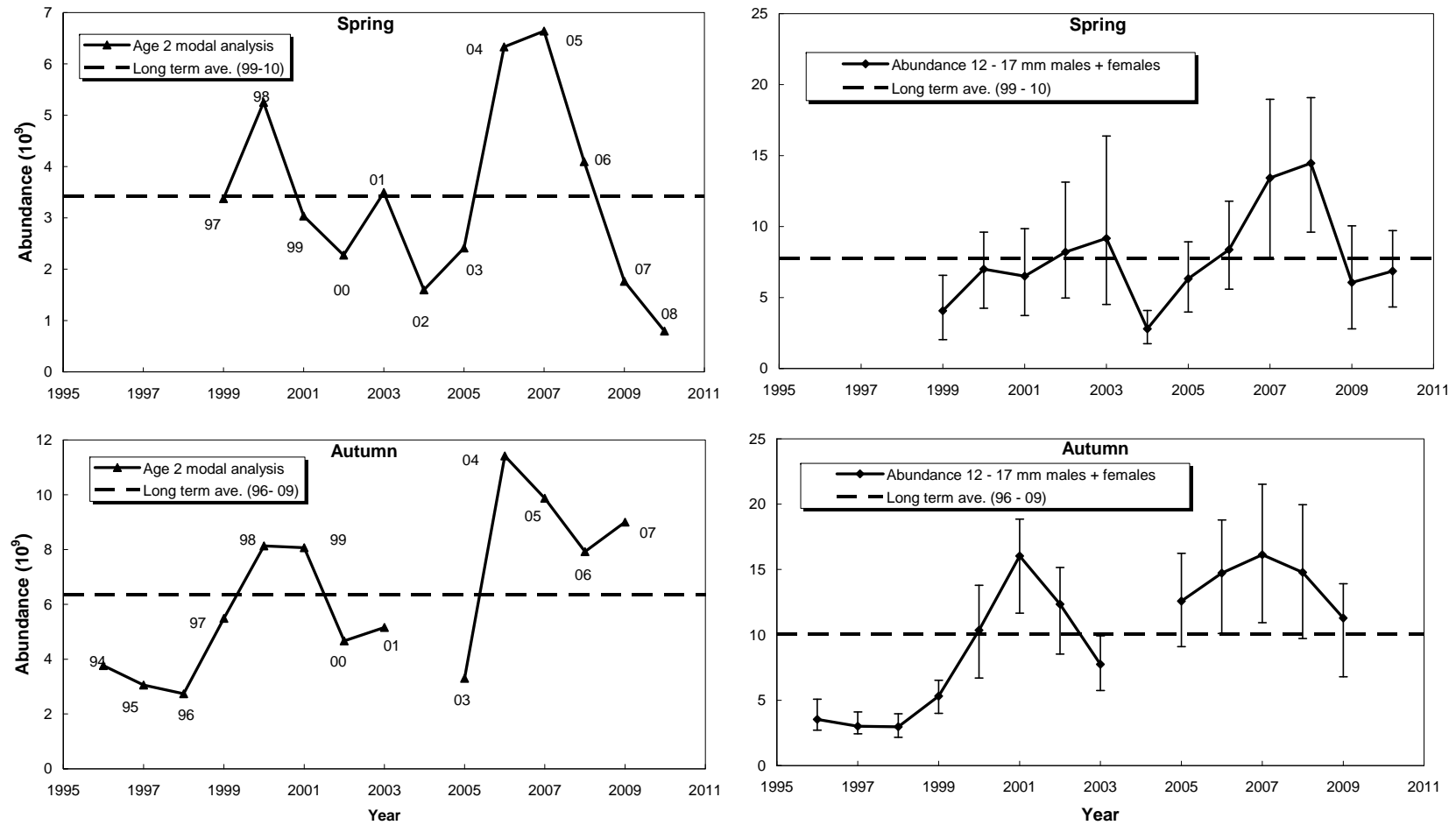
Figure 28.   Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, autumn 1996 – spring 2010. The bars represent 95% confidence intervals around the index. Numbers within the modal analysis graphs are cohort years.
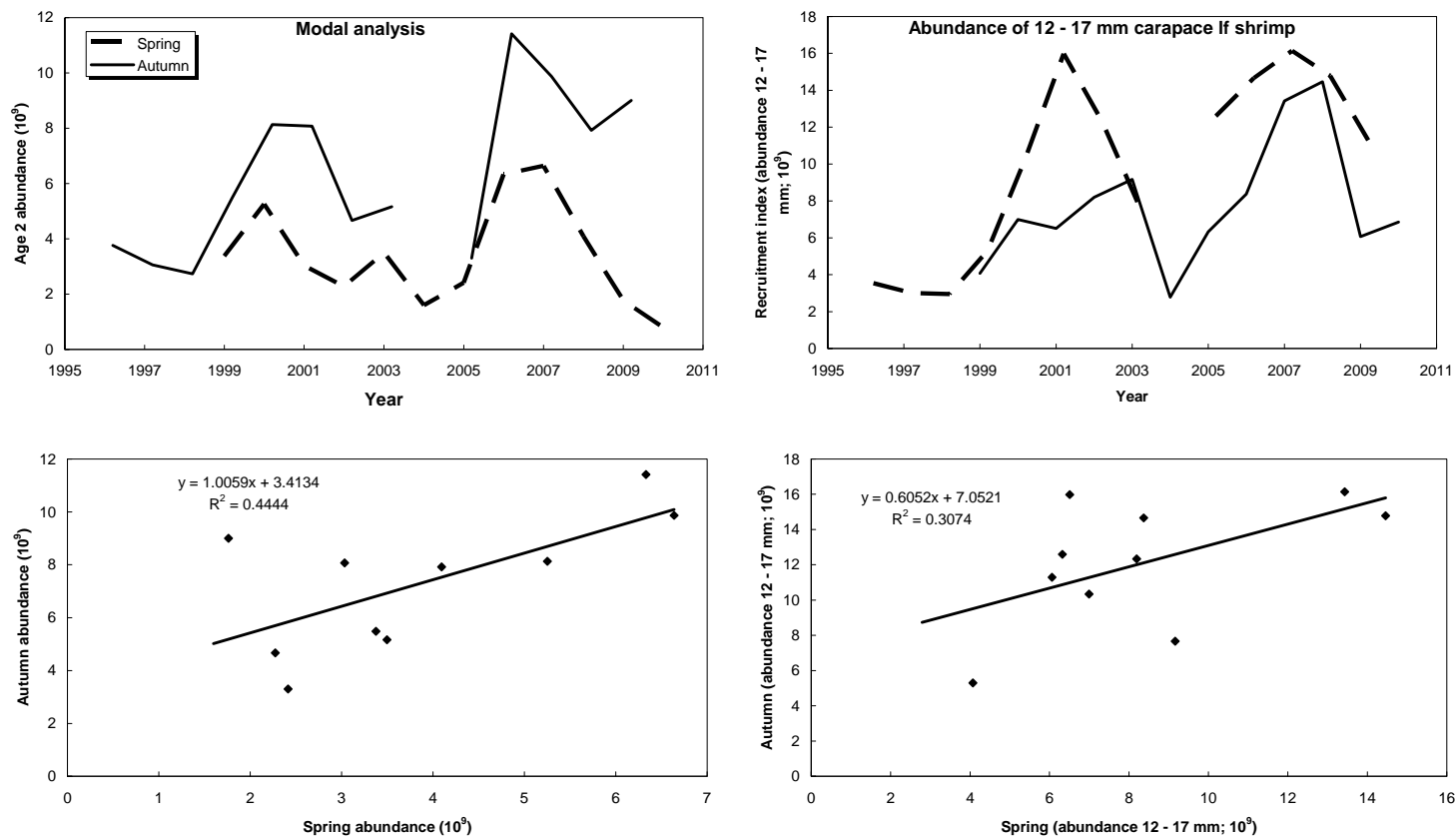
Figure 29. The relationship between spring and autumn recruitment indices created using modal analysis and size range methods.
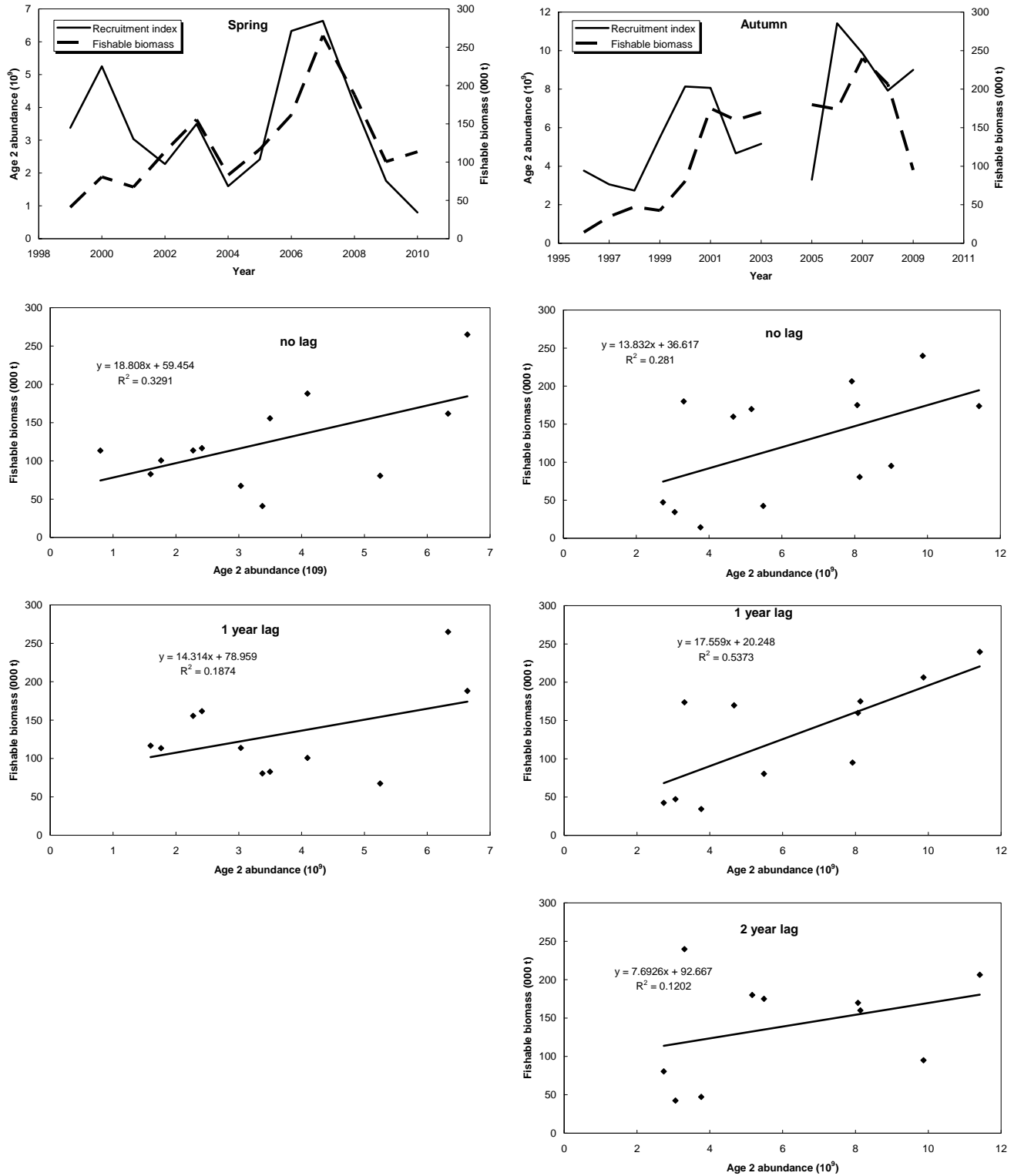
Figure 30.   Predicting NAFO Divisions 3LNO northern shrimp fishable biomass from age 2 abundance using various lags.
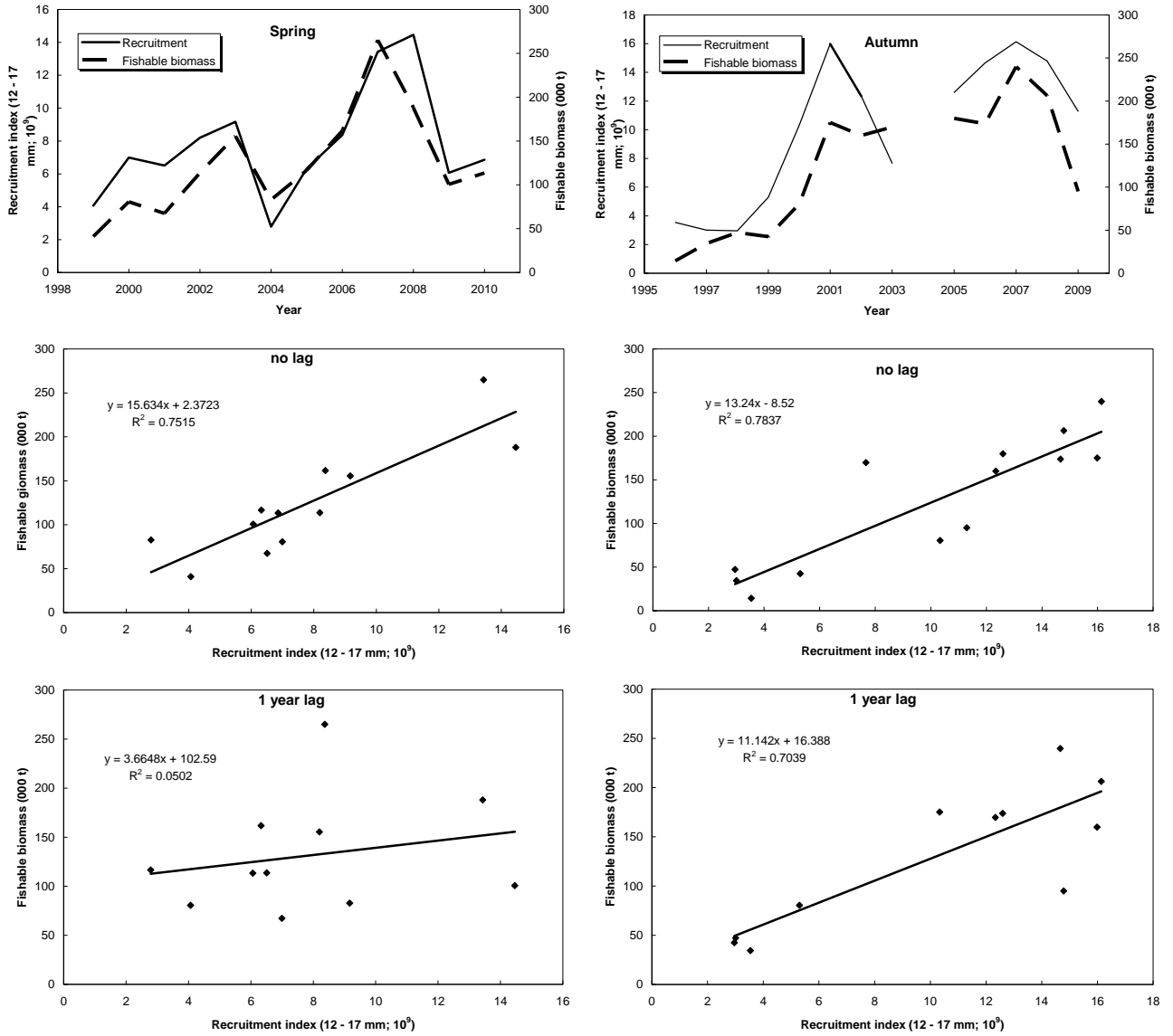
Figure 31.Predicting NAFO Divisions 3LNO Northern shrimp fishable biomass from abundance of shrimp with 12 – 17 mm carapace lengths.
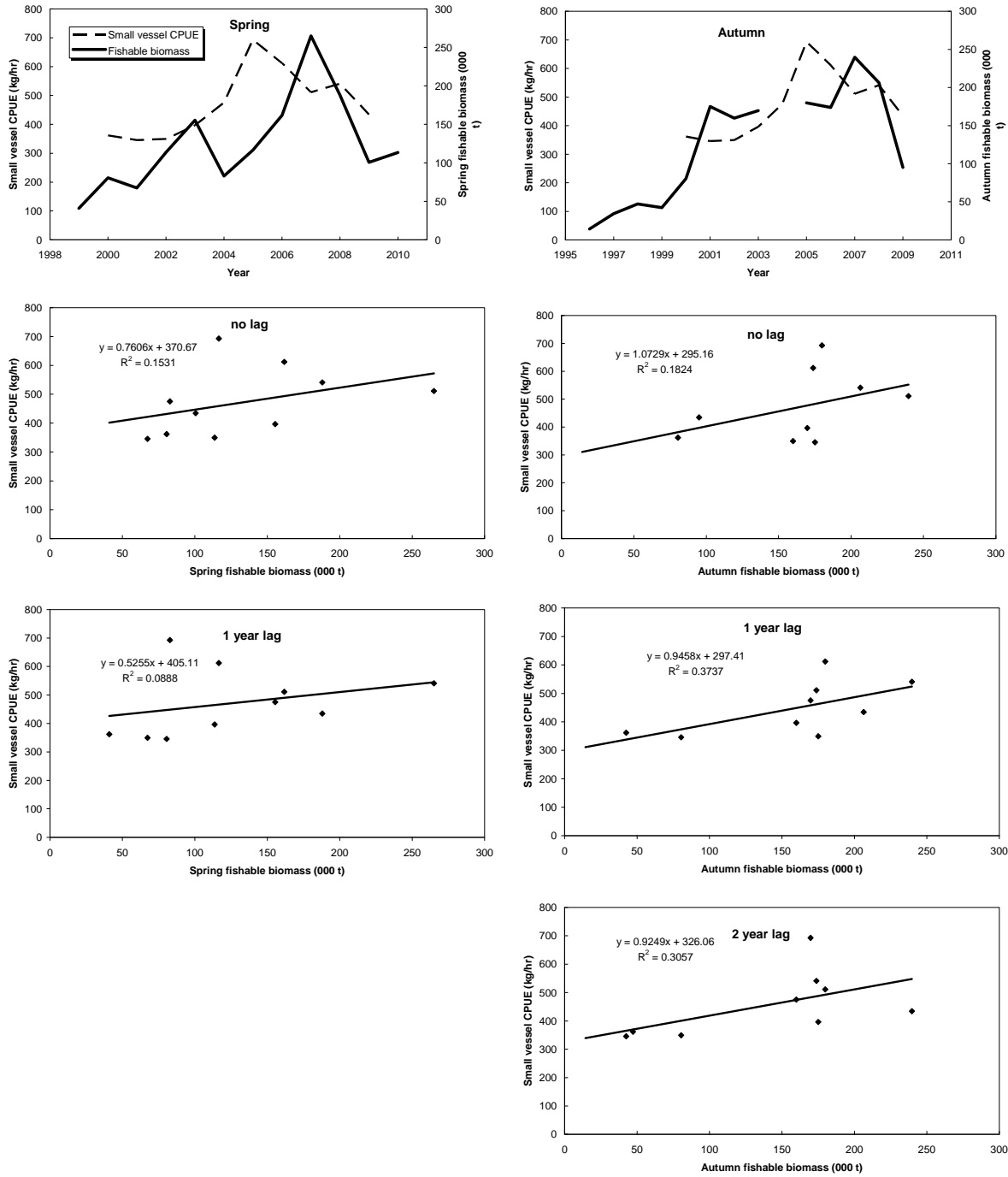
Figure 32.   Predicting small vessel catch rates from NAFO Divisions 3LNO fishable biomass.
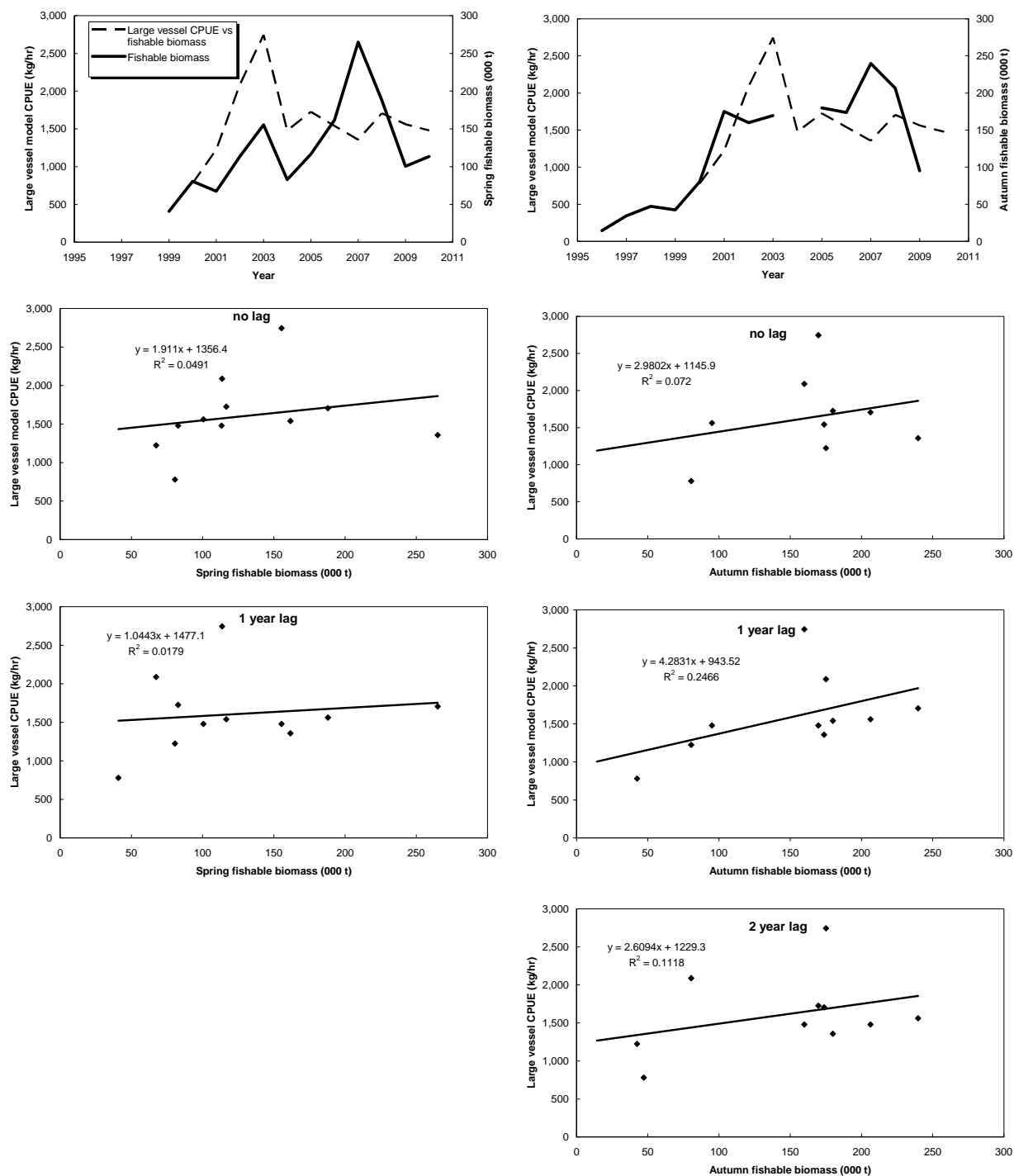
Figure 33.   Predicting large vessel catch rates from NAFO Divisions 3LNO fishable biomass.
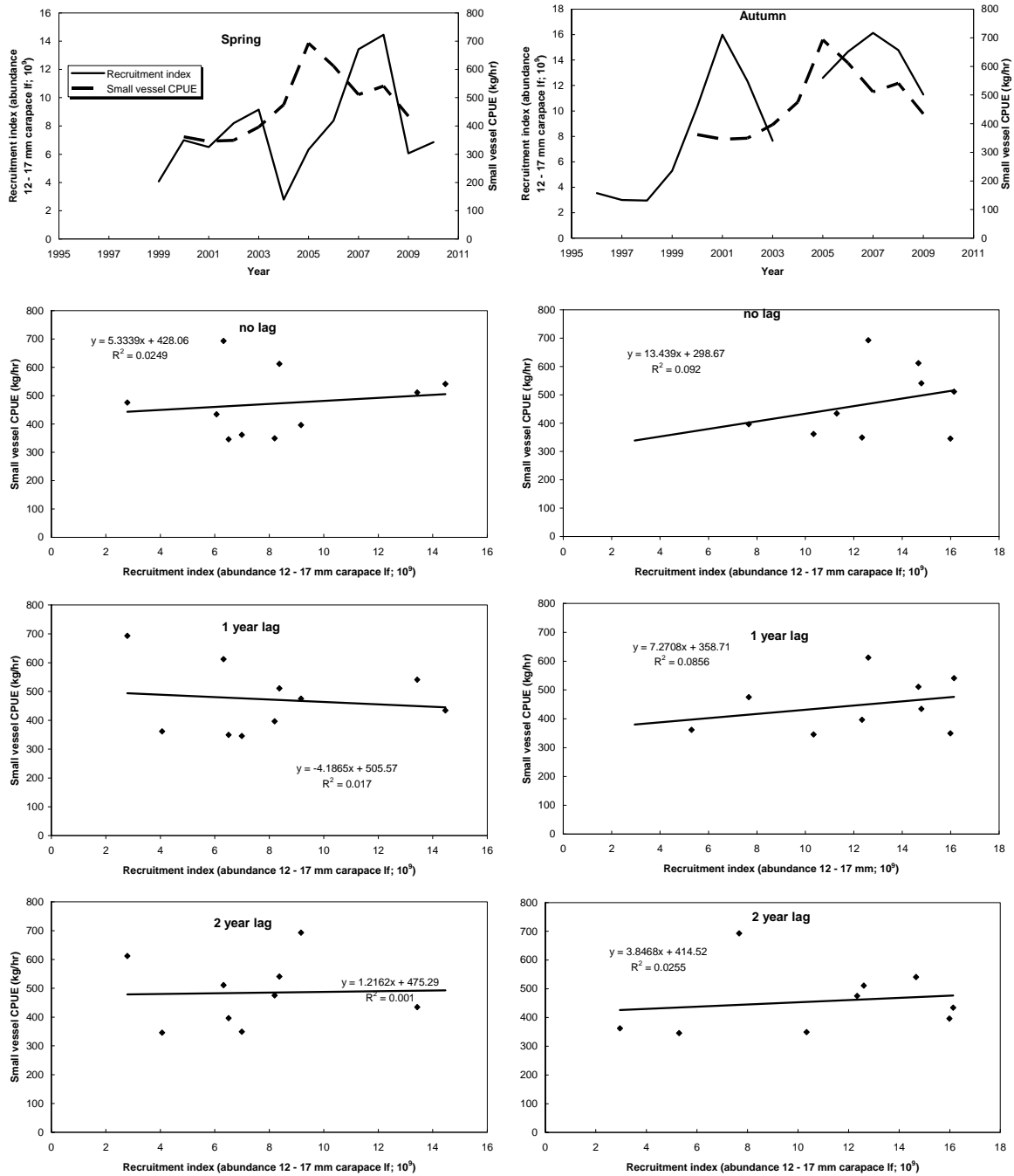
Figure 34.　　　Predicting small vessel catch rates from abundances of 12 – 17 mm carapace lf shrimp.
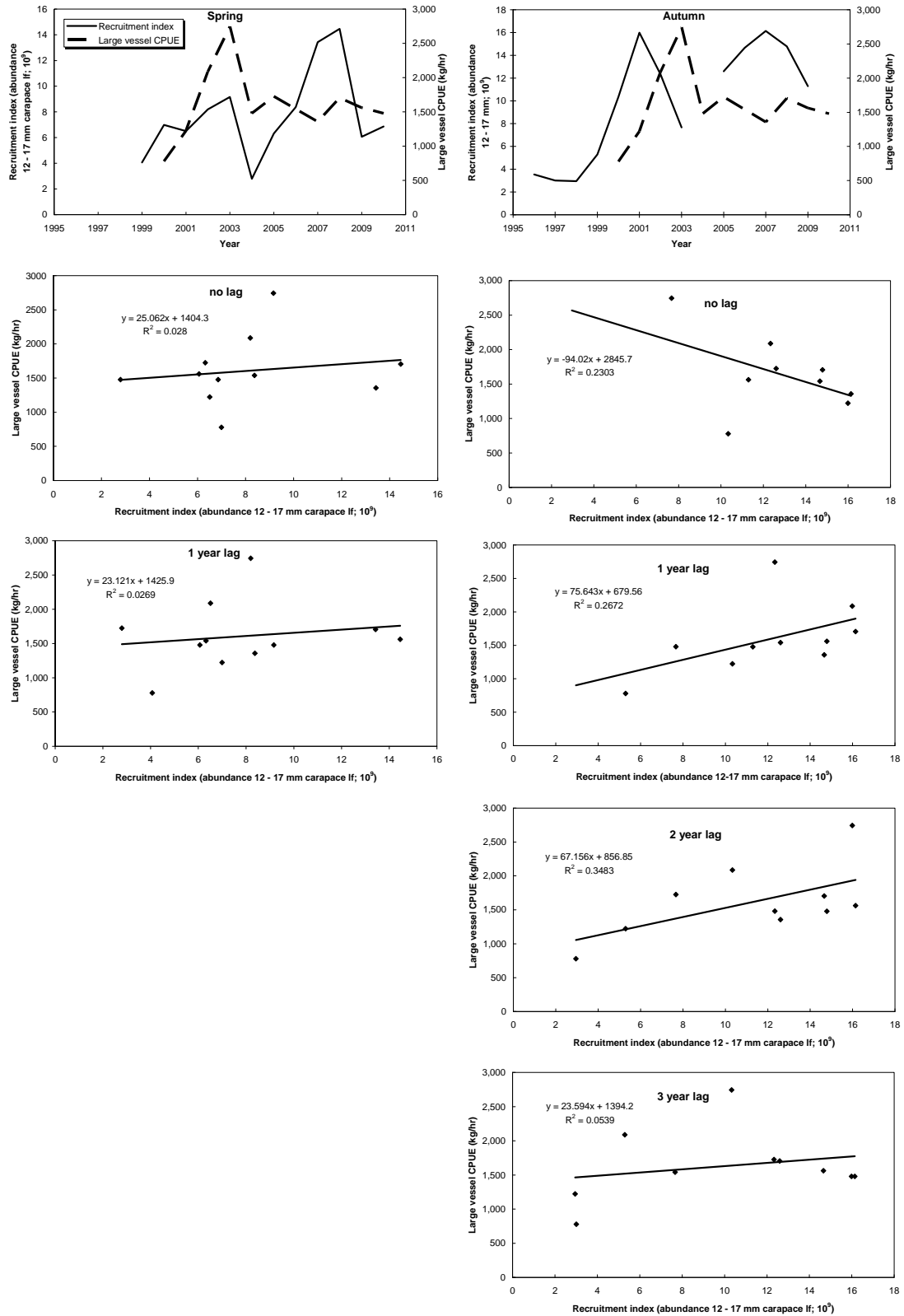
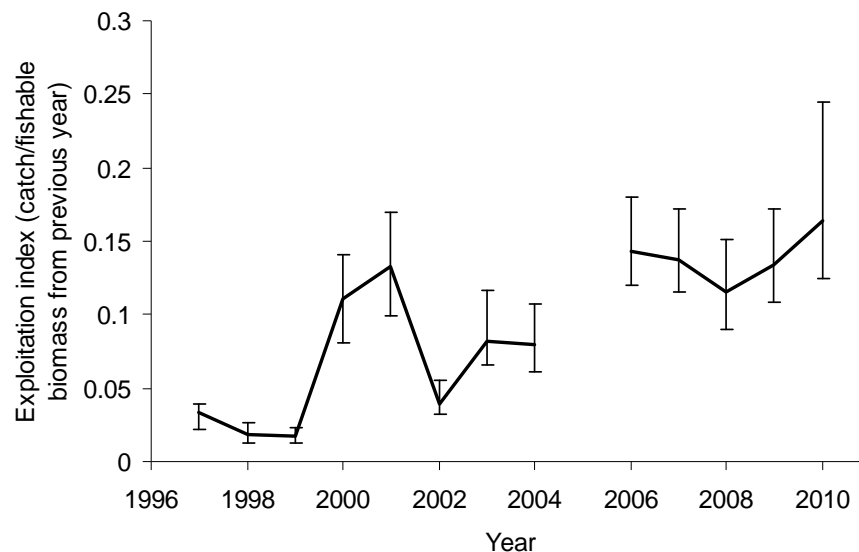Figure 35.   Predicting large vessel catch rates from abundances of 12 – 17 mm carapace lf shrimp.

Figure 36.　　　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.
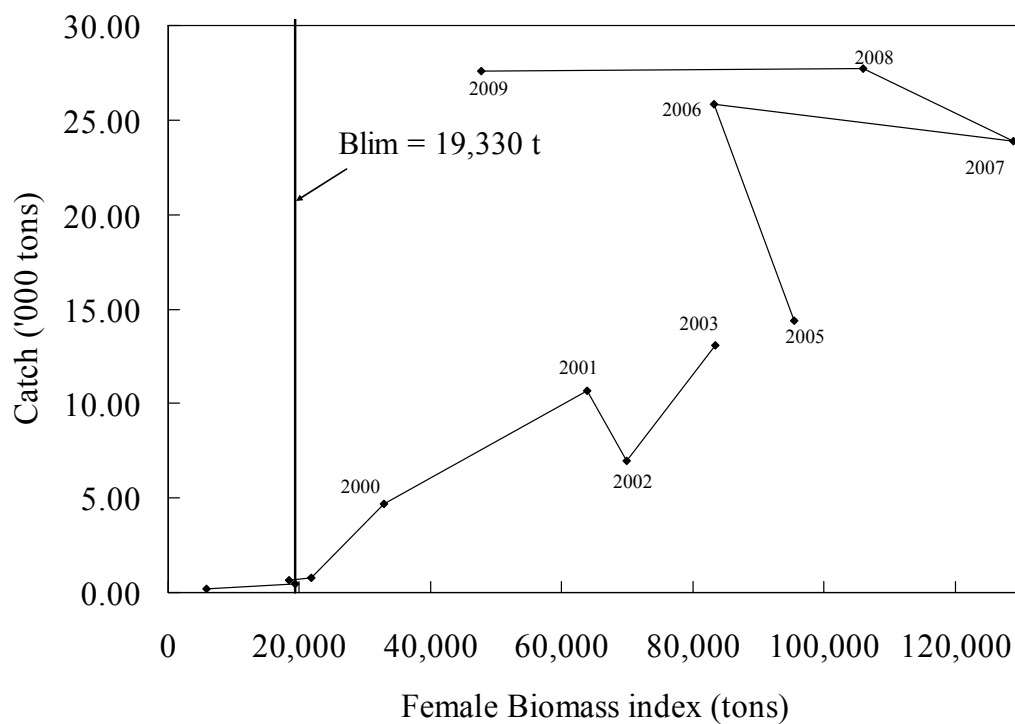

Figure 37.　　　Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B*lim* is drawn where the female biomass is 85% lower than the maximum point (2007 value).