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Northwest Atlantic Fisheries Organization

Serial No. N6350 **NAFO SCR Doc. 14/048**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – SEPTEMBER 2014

The 2014 assessment of the Northern Shrimp (*Pandalus borealis*, Kroyer) resource in NAFO Divisions 3LNO

by

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ABSTRACT:

This paper describes the 2014 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, and fishing pattern, as well as, Canadian multi-species survey bottom trawl indices. The catch table (to August 25, 2014) and biomass estimates (autumn 1996 – spring 2014) are updated within this report. Preliminary data indicate that the 8 600 TAC was taken in 2013 while 1 700 t were taken against a 4 300 t TAC by August 29, 2014.

The spring female spawning stock biomass (SSB) index decreased by 91% from 265,000 t in 2007 to 25 000 t in 2013 and slightly increased to 31 100 t in 2014. The autumn SSB index decreased by 91% from 128,900 t in 2007 to 12 000 t in 2012 which is below the B_{lim} set at 19,330 t. The spring 3LNO total biomass index dropped by 90% from 290,600 t in 2007 to 28 800 t in 2013 but increased to 50 300 in 2014, while the autumn 3LNO total biomass index dropped by 91% from 277,600 t in 2007 to 25 400 t in 2013. Similarly the spring fishable biomass index decreased by 91% from 265,000 t in 2007 to 24 700 t in 2012 but increased to 31 100 t in 2014 while the autumn fishable biomass decreased by 92% from 239,700 t in 2007 to 18 300 t in 2013.

While there is evidence that the male and female estimates have increased during spring 2014 it must be noted that these levels are still very low in the time series.

Standardized catch rates for large (>500 t) Canadian vessels have been fluctuating along the long term mean over the period 2004 to 2008, increased in 2009, but have since followed a descending trajectory until 2012 with a slight increase during 2013. The Canadian small vessel (≤ 500 t; <65') standardized CPUE has been following a decreasing trend from 2005 to 2012 with a slight increase during 2013 but then decreased to the lowest time series level during 2014. Raw Estonian and Spanish catch rates have been declining since 2010. However, it should be noted that the commercial catch rates reflect fishing performance rather than resource status.

Instantaneous total and total annual mortality rate indices have been increasing at a time when commercial catches have decreased from 25 400 t in 2009 to 8 600 t by 2013.

INTRODUCTION:

The northern shrimp (*Pandalus borealis*) stock, in Div. 3LNO, extends beyond Canada's 200 Nmi limit and therefore is a NAFO regulated stock (Fig. 1). Northern shrimp, within NAFO divisions 3LNO, have been under TAC regulation since 1999. TACs have increased in a stepwise fashion from 6 000 t in 2000 to 30 000 t in 2009 and 2010 but then decreased to 4 300 t by 2014 due to continued declines in survey and commercial fishery indices.

Full assessments of the Divs. 3LNO shrimp resource are completed and then presented at the annual September NAFO – ICES Pandalus Assessment Group (NIPAG) shrimp assessment meetings just prior to the annual Fishery Commission (FC) meeting and therefore may be used by Fishery Commission (FC) to set Total Annual Catches (TAC) for the upcoming fishery.

METHODS AND MATERIALS:

Data were collected from the following sources:

- Canadian observer databases;
- Canadian logbook databases;
- International observer/ logbook databases;
- NAFO Statlant21a and Statlant21b data as well as
- Canadian autumn and spring multi-species research surveys.

Canadian observer database:

Approximately 13 large (>500 t) vessels and more than 300 smaller (<=500 t; <65') vessels fish shrimp within Davis Strait, along the coast of Labrador and off the east coast of Newfoundland. There is 100% mandatory observer coverage of the large vessels, while the small vessels have a target of 10% observer coverage. Observers working on large vessels collect detailed maturity stage length frequency information from random sets. Those working on small vessels collect ovigerous/ non-ovigerous length frequencies from random sets and one detailed maturity stage length frequency per trip. Observers on both types of vessels record: shrimp catches, effort, amount of discarding, weights and length frequencies of by-caught species.

The Observer database was used to determine catch-per-unit effort (CPUE) for the large vessel shrimp fishing fleet. Observed data were used because that dataset includes the number of trawls and usage of windows (escape openings) whereas the logbook dataset does not. Raw catch-per-unit effort data was standardized by multiple regression, weighted by effort, in an attempt to account for variation due to year, month, number of trawls, vessel (cfv) etc. The multiplicative model has the following logarithmic form:

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

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

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

S_j is the effect of the j^{th} *month;*

V_k is the effect of the k^{th} cfv;

T_m is the effect of m number of trawls;

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

e_{ijkml} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in a cell and σ^2 is the variance.

Standardized CPUE indices are the antilog of the year coefficient. Final models included all significant class variables with the YEAR effect used to track the trend in stock size over time. The difference (or similarity) between the 2001 YEAR parameter estimate and those of subsequent years was inferred from the output statistics.

In order to track only experienced fishers, the standard dataset included only data from vessels with more than two years of shrimp fishing experience. The first year of the fishery for each vessel was removed from the dataset to account for learning. By limiting the dataset to vessels with a history in the fishery we are able to increase our confidence when interpreting results.

However, it should be noted that in 2012 the large vessel observer program that worked on vessels licenced by Newfoundland and Labrador was taken over by a Nova Scotian company. Due to data errors, no Newfoundland and Labrador observer data has been accepted by the Newfoundland and Labrador Region of Fisheries and Oceans Canada. Data was collected from Nova Scotia, New Brunswick and Quebec Regions for these analyses.

Canadian logbook database:

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

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

International observer and logbook information:

Catch information was provided by Contracting Party, NAFO Statlant 21A and B, as well as, monthly provisional catch tables.

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).

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

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

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

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

Recruitment indices

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

Fishable biomass

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

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

Autumn samples

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

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

Spring samples

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

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

The fishable biomass index was used in regression analyses, with various lags, against the recruitment indices to determine whether there was improvement in recruit – stock relationship. Such relationships could be used to predict stock prospects.

Exploitation rate indices

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

lower 95% confidence interval below the biomass index,

female biomass (SSB), and

fishable biomass.

Female Spawning Stock biomass

Spawning stock biomass was defined as the weight of all transitionals + primiparous females and ovigerous + multiparous females). All survey indices (biomass, abundance, fishable biomass, female biomass (SSB), recruitment) as well as population adjusted shrimp carapace length frequencies were calculated using Ogmap (Evans *et al.* 2000).

Mortality

Survival, annual mortality and instantaneous mortality estimates were calculated by comparing survival of age 4+ males and total female abundances with the survival of age 5 + males and total female abundances during the next year. The survival estimates were then used to determine total 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 within each triangle is integrated using bilinear interpolation. The expected biomass is the sum over all triangles. A Monte Carlo simulation resamples the whole probability distribution at every survey point to provide a new biomass point estimate. Five hundred such simulations are run to provide a probability distribution for the estimated biomass. The point estimate is provided from the entire survey dataset, while the probability distribution is determined through Monte Carlo simulation. Non-parametric 95% percent confidence intervals are then read from the probability distribution.

Spatial distribution of northern shrimp within the multi-species survey:

Survey 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)

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

Catches increased dramatically since 1999, with the beginning of a regulated fishery (Fig 5). Table 1 and the following discussion provide the available numbers to date. Over the period 2004-2009, catches increased from 13 200 to 26 000 t. Due to declines in resource indices, the TACs have been steadily decreasing with the 2014 TAC being set at 4 300 t during the 2013 Fishery Commission meeting. Preliminary catch records indicate that the 8 600 t TAC was taken in 2013. By August 25, 2014, 1 700 t of shrimp had been taken, down from the 6 000 t taken by the same time in the previous year. As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 10 300 t in 2004 to 18 900 t in 2008 but have since decreased to 6 100 t in 2013.

Catches by other contracting parties increased from 2 900 t in 2004 to 7 700 t in 2006, however, preliminary data show that catches decreased to 2 552 t by 2013. These contracting parties fish in 3L outside the 200 Nmi limit known as the Nafo Regulatory Area (NRA). Preliminary data indicate that non Canadian vessels took 7 t of Northern Shrimp by September 2014 while they took 170 t by the same period in the previous year. Table 1 provides a breakdown of catches by contracting party and year since 2003, while figure 5 indicates catches and TAC since 1993.

Canadian fleet

Since 2000, small (<=500 t; LOA<65’) and large (>500 t) shrimp fishing vessel catches have been taken from a broad area near the northern border with 3K south east along the 200 – 500 m contours to the NRA border. However, discussions with fishing Captains indicate that fishing patterns have been changing over the past few years. Since 2012 the small vessel Captains indicated that they usually fished at the 3L-3K border as it was closer to their ports than going as far away as the 200 Nmi line. They felt that shrimp was available throughout much of the 3L area in depths of 200 – 500 m (Figs. 6 and 7).

The small vessel fleet takes most of their quota during the spring and summer of each year while the large vessel fleet fishes mainly in the late fall and early winter although this has varied over time (Fig. 8). In 2014, the small vessel fleet took its quota during the summer while the large vessel fleet had taken only 12% of its quota by August 25, 2014.

Small vessel CPUE (2001 – 2014) was modeled using year, month and size class (class 1 <50’ LOA; 50’ LOA <=class 2< 60’ LOA; class 3 => 60’ LOA) as explanatory variables (Table 2). The model standardized data to 2001, class 3 and July values. The logbook dataset that was used in this analysis accounted for between 79% and 95% of the catch within any one year (Table 3). The final model explained 82% of the variance in the data and indicated that the annual, standardized catch rates increased from nearly 300 kg/hr over 2001 – 2002 period to 570 kg/hr by 2005 then returned to the 300 kg/hr level by 2010 remaining near that level until 2013 then decreased to 230 kg/hr during 2014. The 2001 catch rate index was similar to the 2002 and 2010 - 2013 indices while being significantly lower than all intervening indices (Tables 2 and 3; Fig. 9). The 2014 CPUE is significantly lower than the 2001 estimate. No clear trends were found in the plots of residuals (Fig. 10). Discussions with small vessel fleet Captains indicated that fishing patterns changed over the most recent few years as large volumes of shrimp were discovered in holes near the 3K border. These holes are closer to Newfoundland and Labrador than is the 200 Nmi limit therefore for economic reasons the fishery moved to these locations. This change in location could have impacted catch rates since 2011 and therefore the CPUE model should be used to describe changes in fishery performance rather than changes in resource status.

Observer data for 2014 was not available at the time of this assessment therefore the large vessel CPUE index ends in 2013. The large vessel fleet data were analyzed by multiple regression using data standardized against 2001, single trawl, the vessel with the longest history and December data. The model was weighted by effort, for year, month, number of trawls and vessel effects (Table 4). The observer dataset used in this analysis accounted for between 30% and 100% of the catch within any one year (Table 5). The final model explained 73% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating along the long term mean between 2004 and 2008, increased in 2009, but have since decreased to a minimum level in 2012 with a slight increase during 2013. The 2001 standardized catch rate index (1 210 kg/hr; Table 5 and Fig. 9) was similar to the 2004-08 and 2010 values but significantly lower than the 2003 and 2009 indices while higher than the 2011-2013 values. The 2013 CPUE index was 639 kg/hr (Tables 4 and 5; Fig. 9). There were no trends in the residuals around parameter estimates (Fig. 11).

As with the small vessel fleet, large vessels also changed their fishing patterns over the past three years. As commercial catch rates decreased this fleet started to follow the small vessel fleet into the area near the 3K border (Figs 6 and 7), asked for and were granted permission to fish within the NRA. However, low catch rates persisted.

The changes in fishing location could have impacted catch rates since 2011 and therefore the CPUE model should be used to describe changes in fishery performance rather than changes in resource status.

International fleet

Preliminary data indicate that the international fleet took 2 552 t of shrimp in 2013 from a quota of 1 438 t while only 7 t of shrimp were taken by June 2014 from a quota of 672 t. By the same time last year, the international fleet took 178 t of shrimp.

Figure 12 provides the raw Northern Shrimp catch rates for the Estonian and Spanish fishing fleets over the period 2006 – 2014. Spanish catch rates increased from 560 kg/hr in 2008 to 1 000 kg/hr in 2010 but had decreased to 130 kg/ hr by 2013. Similarly, the Estonian catches were at high levels during 2010 but have since decreased to roughly 100 kg/hr in 2013 for single trawls and 2014 for double trawls.

It is important to note that the number of countries fishing shrimp in the 3L NRA has been decreasing from a maximum of 16 during 2006 to 12 by 2009 and to probably a single country by 2014. As biomass indices decreased, the catches allotted to individual countries has decreased from 334 t in 2009 to 48 t by 2014 leaving interpretations of CPUE rates indicators of resource status more questionable.

Size composition

Figure 13 presents the length frequency distributions from observed data onboard the small vessel fishing fleet. The jagged length distributions meant that they 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. Standardized catch rates increased from 65 500 animals per hour in 2003 to 94 700 animals per hour in 2005 were maintained at above 80,000 animals per hour until 2009 but have decreased to 51 500 animals per hour by 2012.

A time series of length frequencies from the large vessel catch is presented in figure 14. Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females most of which are believed to be greater than two years of age. The male modes overlapped to the extent that it was not possible to complete Mix distribution analysis; however, there were often two faint sub-peaks implying the presence of more than one year class. Given that the modes were usually near 14 and 17 mm, these animals were probably 2 and 3 years of age respectively. The female length frequency distributions were also broad indicating that the female portion of the catch probably consists of more than one age group. Between 2003 and 2009 catch rates were maintained at greater than 200,000 animals per hour however since then catch rates have decreased to 80,000 per hour by 2012. The within year frequency weighted average carapace lengths for males ranged between 17.1 mm and 20.0 mm, while the weighted average carapace lengths for females ranged between 22.9 mm and 24.0 mm. There were no trends in the average size of either males or females.

Figure 15 is a series of graphs illustrating the percent length frequencies caught, in the NRA, by the Estonian fishing vessels over the period 2010 – 2014. As with the Canadian length frequencies the male length frequencies were broad demonstrating that several year classes were taken. However, the female distributions are much broader during 2010 and 2011 than during subsequent years.

RESEARCH SURVEY DATA

Stock size

The spring 2011 – 2014 and autumn 2010 – 2013 research catches were concentrated within NAFO Div. 3L at depths between 200 and 500 m (Figs 16 and 17). Figure 18 shows that since 2005 there has been a trend of decreasing area containing 95% of the resource during either the spring or autumn. The spring 3LNO total biomass index dropped by 90% from 290,600 t in 2007 to 28 800 t in 2013 then increased to 50 300 t in 2014. The autumn 3LNO total biomass index dropped by 91% from 277,600 t in 2007 to 25 400 t in 2014 (Table 6; Fig 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. Figures 16 and 17 confirm that large samples are periodically found in the spring relative to autumn surveys. The presence of a large set in a survey with several much smaller sets will result in broad confidence intervals around point estimates thereby reducing our confidence in the biomass or abundance estimates. As well the 2014 value is the third lowest in the spring total biomass time series.

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

Over 92.7% of the total 3LNO biomass, from either spring or autumn surveys, was found within Division 3L, mostly within depths from 185 to 550 m. Over the study period, the area outside 200 Nmi accounted for between 4.0 and 32.6% of the estimated total 3LNO biomass (Tables 7 and 8; Figs. 16 and 17). During the autumn, the percent biomass within the NRA ranged between 5.3 and 20.3%. Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 8.6– 19.9% of the total 3LNO autumn biomass was within the NRA (Table 8). Over the period 1996 – 2013 the overall average autumn percent biomass within the NRA was 15.3%. During spring, the percent biomass within the NRA ranged between 4.0 and 32.6% (three year running average ranged between 5.7 and 27.5%) (Table 7). Over the period 1999 – 2014 the average spring percent biomass with the NRA was 19.4%. It must be noted that variances around the spring indices are greater than around autumn indices (Table 6; Fig. 19).

In all surveys, Division 3N accounted for 0.2-8.1% of the total 3LNO biomass (Tables 7 and 8). Between 0 and 100% of the 3N biomass was found outside the 200 Nmi limit. Division 3O accounted for less than 1% of the 3LNO biomass. A negligible amount of the Division 3O biomass was found outside the 200 Nmi limit.

Stock composition

Length distributions representing abundance – at – length from the autumn 1996 - 2013 and spring 1999 – 2014 surveys are presented in figures 20 and 21 respectively. Generally, modes increase in height as one moves from ages 1 – 3 indicating that shrimp catchability probably improves with size. Tables 9 and 10 provide the modal analysis and the estimated demographics from these survey series and provide a basis for comparison of relative year-class strength as well as illustrating the changes in stock composition over time. There appear to be three regimes; one prior to 2000 at a time during which abundances of all ages were low and a second period from 2000 - 2008 during which abundances were much higher and then a third period after 2008 when abundances at all ages returned to low levels again. As demonstrated by the blue lines in figure 20, the 1997 year-class first appeared in the 1998 survey as one year old shrimp and was the first in a series of strong year-classes and could be followed throughout the next three years. However, it is important to note that the age 1 modes do not always give a clear recruitment signal. For instance, the 1998 cohort appeared weak in 1999 autumn survey, but appeared strong over the next few years. Conversely, if an age 2 mode appeared strong, in any one year, that cohort remained strong throughout its history. Weak year classes such as the 1995 and 1996 appeared weak as age 2 modes and remained weak throughout their history. Generally cohorts that were strong in the autumn series were also strong in the spring series.

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 9 and 10; Figs. 20 and 21). Figure 21 provides further evidence of internal consistency in the ageing by demonstrating predictive relationships from numbers at age versus numbers from the successive ages in the following year(s). Kilada *et al.* 2012, obtained similar results when comparing counts of calcified rings on shrimp eyestalks with ageing from modal analysis.

Shrimp aged 2 - 4 dominated the male component of the length frequencies in autumn 2013 (2011, 2010 and 2009 year classes respectively) survey with carapace length frequency modes at 14.08 mm, 17.55 mm and 20.36 mm as males respectively and as age 4 and 5 females at 22.42 mm and 23.77 mm respectively (Table 9; Fig. 20). It is important to note that there may be a length frequency year affect between years. If one compares a length frequency between years such as 2008 – 2013 you will notice that the entire length frequencies decrease from one year to the next. If there are normal distributions then abundant age 2 animals would become abundant age 3 animals. The 2013 length frequency indicates that there are very few animals of any size or age. It is important to note that the year affect could be due to predation because shrimp is an important forage species for groundfish of which some species have increased over recent years.

While one should note that there is a low abundance of shrimp found during the 2014 spring survey, there was an abundance increase of age 3 males (Table 10 and Fig. 21).

The fact that regression analyses demonstrate age 3 abundances can be predicted in the following year after age 2 estimates and that an age 4 prediction can be made two years after an age 2 estimate provides evidence that ageing is probably reliable (Fig 22). As well it is now possible to make predictions from modal analysis that is being completed for both the spring and autumn length frequencies.

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 91% to 10 700 t (3 billion animals) in 2013. There was an increase to 30 200 t during 2014 (Table 11; Fig. 23). The autumn surveys showed an increase in biomass of male shrimp from 19 000 t (6 billion animals) in 1996 to 153,000 t (44 billion animals) in 2001, remaining at a high level until 2008. The autumn 2013 male survey biomass index was estimated to be 13 500 t (5 billion animals), a decrease of 91% since 2007 and a decrease of 36% since the previous year.

The spring female spawning stock biomass (SSB) index decreased by 91% from 265,000 t (41 billion animals) in 2007 to 12 000 t (1 billion animals) in 2014. The autumn SSB index decreased by 91% from 128,900 t (16 billion animals) in 2007 to 11 800 t (1 billion animals) in 2013. The autumn 2013 SSB is below the B_{Lim} which is set as an autumn (SSB) of 19 330t (Table 12; Fig. 24).

Similarly, the spring fishable biomass decreased by 91% from 265,000 t (41 billion animals) in 2007 to 24 600 t (4 billion animals) during 2013. The fishable biomass increased to 31 000 t in 2014. Similar to other indices, the autumn survey analysis resulted in a decrease from 238 100 t (40 billion animals) during 2007 to 18 300 t (3 billion animals) during 2013 (Table 13; Fig. 25).

As with all estimates that include males (Tables 6, 10 11 and 12; Figs. 19, 21 - 25) from spring surveys illustrate an increase from 2013 to 2014. It is important to note that the abundance and biomass indices for both the male, and fishable portions of the resource are significantly below the long term mean for each respective index and are near or below the values found at the beginning of each respective survey time series.

Recruitment Index

Recruitment indices were determined using two methods:

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

2. abundance of shrimp 11.5-17 mm in carapace length from spring and autumn surveys.

from the autumn 1996-2013 and spring 1999 - 2014 survey time series.

Due to the incomplete survey in autumn 2004, this index was excluded from the autumn time series. In terms of modal analysis, the autumn 98, 99, 04 - 07 year classes were strong, the 97, 00 and 01 year classes were average while the 94 – 96, 03 and 08 - 11 year classes were the weakest recorded (Tables 9 and 14; Figs. 20 and 26). Even though the 04 – 07 year classes appear strong, there is a downward trend in that portion of the series. Similar to the autumn times series, the 98 and 04 – 06 year classes appeared strong in the spring time series (Tables 10 and 14; Figs. 21 and 26). The spring time series shows a downward trend in abundances of age 2 animals from the 05-08 cohorts with 08- 12 being the weakest in the time series.

The size class method allows the direct calculation of confidence intervals, but will not allow the identification of age classes because each index probably consists of a combination of age 2 - 3 animals. The autumn 1996 – 1999 and 2011 - 2013 indices were the lowest in the time series, the 2000, 2003, 2009 and 2010 values were near the mean while the 2001 and 2005 – 2008 were the highest. Similarly, the spring 1999, 2004, 2012 and 2013 indices were the lowest in the time series, 2007 and 2008 were the highest while all other indices were average (Table 15; Fig. 26). While there is a 367% increase in the spring recruitment indices between 2013 and 2014 it must be noted that the increase is to 13 000 t which is the fourth lowest biomass level.

Figure 27 presents a correlation coefficient and regression analyses that demonstrate that the 11.5 – 17 mm recruitment indices can be used to predict fishable biomass in the following year. Similarly if abundances of age 2 and 3 animals from modal analysis are added together they can be used to determine the fishable biomass in the following year (Fig 28).

Exploitation Rate Indices

Exploitation rate indices were estimated using ratios of catch divided by the previous year's lower 95% confidence interval of the biomass estimate, spawning stock biomass and fishable biomass (Table 16). Until 2009, exploitation had been below 15% even though catches have increased over time because the stock parameters also increased until 2007. However, after 2007 the stock parameters began to decrease at a quicker rate than reductions in catch resulting in the 2011 exploitation rate to increase to 22%. The 2013 exploitation rate index increased to 28% even though the total catch was reduced to 8 600 t. If the entire TAC of 4 300 t is taken by 2014 t the exploitation rate will be 24%. (Fig. 29).

Mortality Estimates

Table 17 presents mortality estimates derived from the abundances of age 5+ animals in one year divided by the abundances of age 4+ animals from the previous year as obtained from the modal analysis. These data were from the autumn survey time series as it was the longest survey time series. The median survival, total annual mortality and instantaneous total mortality are 0.37, 0.98, 0.63 respectively. Table 18 illustrates the female mortality estimates from the spring survey. It was important to limit this mortality estimate to only spring samples because it was necessary to use a time in which all primiparous and multiparous females could be found. In this case, the total abundance was compare with the multiparous abundance in the following year to determine the mortality rate. The median survival, total annual mortality and instantaneous total mortality rates are 0.39, 0.61 and 0.95 respectively. These are in agreement with the mortality rates for the age 5 shrimp presented in table 17. These mortality rates are within the range of values presented in Shumway (1985) and Bergström (2000). This table demonstrates that total instantaneous mortality indices have been increased since 2007. Increased exploitation rates must have an impact upon mortality.

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 (SCS Doc. 04/12). . It is not possible to calculate a limit reference point for fishing mortality. Figure 30 presents the precautionary plot of exploitation rate on the ordinate axis and female spawning stock biomass on the abscissa. The autumn 2013 SSB index is 11 780 t which is below the B_{lim} set at 19,330 t.

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 determine whether switching vessels has an impact upon the biomass/ abundances indices reported on in this assessment.

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

Validity of using the commercial catch rate models is becoming more questionable. The Canadian small and large vessel fishing fleets have changed their fishing patterns. The small vessel fleet is now fishing in the holes near the 3K border, for economic reasons, rather than fishing along the 3L shelf edge near the NRA as they had previously been fishing. Due to low catch rates, the large vessel fleet asked for and has been granted permission to fish in the NRA as well as moving toward the 3K border to fish for shrimp. The observer dataset was not available since 2013and therefore the Canadian large vessel commercial CPUE model could not be updated to include that year's fishery data. Therefore the catch rate analyses should be used to describe fishery performance rather than changes in resource status.

The individual international fleet quotas have decreased from 334 t a few years ago to 48 t in 2014 resulting is fewer countries fishing in the NRA. As well with smaller catches it is less likely that catch rates will be representative of resource status. The statlant21B dataset was updated to 2011 values therefore the foreign catch rate model could not be run.

Resource Status

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

The spring female spawning stock biomass (SSB) index decreased by 91% from 177,900 t in 2007 to16 000 t in 2014 while the autumn SSB index decreased by 91% from 128,900 t in 2007 to 11 800 t in 2013. The autumn 2013 SSB is 39% below the B_{lim} which has been set at 19,330 t. The spring 3LNO total biomass index dropped by 90% from 290,600 t in 2007 to 28 800 t in 2012, but increased to 50 300 t in 2014. This increase was also found in the spring fishable biomass and age 3abundance during modal analysis. The autumn 3LNO total biomass index dropped by 91% from 277,600 t in 2007 to 25 400 t in 2013. Similarly, the spring fishable biomass index decreased by 91% from 265,000 t in 2007 to 24 700 t in 2012 and increased to 31 100 t in 2014. The autumn fishable biomass decreased by 92% from 238,100 t in 2007 to 18 300 t in 2013.

It is important to note that the spring 2014 survey indices of biomass and abundance of males and females have increased, however, these levels are still near the lowest sets of indices over the time series.

Exploitation and mortality rate indices have been increasing since 2007 even though catches have been decreasing over this period.

Acknowledgements:

We would like to thank Mr. Gus Cossitt for contributing Figure 1, the stratification scheme.

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Table 1. Annual nominal catches (t) by country of Northern Shrimp (*Pandalus borealis*) caught in NAFO Div. 3L between 2004 and 2014.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Canada	10,313[1]	11,495[1]	17,996[1]	18,027[1]	18,905[1]	18,258[1]	13,212[1]	8,860[1]	7,982[2]	6,095[2]	1,681[3]
Cuba	145[4]	136[2]	239[2]	240[2]	207[4]	334[4]	.	.			
Estonia	271[4]	569[4]	1,098[4]	1,453[4]	1,452[5]	1,659[5]	2,009[5]	1,248[5]	780[5]	926[1]	
European Union										740[4]	7[4]
Faroe Islands	1,050[1]	1,055[1]	1,521[1]	1,798[1]	2,273[2]	2,949[1]	2,503[2]	1,446[1]	1,036[2]	592[2]	
Germany								301[1]			
Iceland	104[6]	140[6]	216[6]				184[1]	126[1]		92[2]	
Latvia	143[1]	144[1]	244[1]	310[1]	278[1]	330[1]	384[1]	325[1]	134[2]		
Lithuania	144[2]	216[1]	486[1]	245[1]	278[2]		340[2]				
Norway	165[7]	144[7]	272[1]	250[1]	345[1]	664[1]	320[1]				
Poland	144[1]	129[1]	245[1]								
Portugal						329[2]	15[2]		5[2]		
Russia	141[1]	146[2]	248[2]	112[2]	278[2]	335[2]	28[2]				
Spain	140[8]	154[8]	305[8]	190[8]	187[8]	272[8]	347[8]	292[8]	34[8]	24[8]	
St. Pierre and Miquelon				245[1]	278[1]	334[1]	334[1]			178[2]	
Ukraine	145[1]		121[1]								
United States		136[2]	245[2]	245[2]	278[2]		334[2]	214[2]			
West Greenland	299[9]	311[9]	453[9]	455[9]	648[9]	488[9]	534[9]				
Estimated additional catch			2,000								
Total catch	13,204	14,775	25,689	23,570	25,407	25,952	20,544	12,812	9,977	8,647	1,688
TAC (tonnes)	13,000	13,000	22,000	22,000	25,000	30,000	30,000	19,200	12,000	8,600	4,300

Sources:
[1] NAFO Statlant21B
[2] NAFO Statlant21A
[3] Canadian Atlantic Quota Report
[4] NAFO monthly records of provisional catch
[5] Estonian logbook data
[6] Icelandic logbook data
[7] Norwegian logbook data
[8] Spanish logbook data
[9] Greenlandic logbook dat

Table 2. Multiplicative year, month and vessel size model for Canadian small vessels (<=500 t; <65') fishing northern shrimp in NAFO Div. 3L over the period 2001 – 2013. (Weighted by effort, single trawl, logbook data, history of at least two years in the fishery with the first year of the fishery for any vessel removed). All data were standardized to class 3 vessels, July and 2001 values.

The GLM Procedure
Class Level Information

Class	Levels	Values
Year	14	2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Month	9	4 5 6 8 9 10 11 12 99
Size class	3	1 2 3

Number of Observations Read	209
Number of Observations Used	209

Dependent Variable: lncpue
Weight: wfactor

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	16984.82462	738.47064	37.37	<.0001
Error	185	3655.84202	19.76131		
Corrected Total	208	20640.66663			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.822882	72.54629	4.445369	6.127631

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	13	13647.08720	1049.77594	53.12	<.0001
Month	8	2624.28230	328.03529	16.60	<.0001
Size class	2	713.45512	356.72756	18.05	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	13	12127.68228	932.89864	47.21	<.0001
Month	8	2891.27129	361.40891	18.29	<.0001
Size class	2	713.45512	356.72756	18.05	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.059829982	B	0.06276425	96.55	<.0001
Year	2002	0.060999267	B	0.07523825	0.81	0.4186
Year	2003	0.213982443	B	0.06546665	3.27	0.0013
Year	2004	0.318256121	B	0.07307040	4.36	<.0001
Year	2005	0.692247385	B	0.07639065	9.06	<.0001
Year	2006	0.568881637	B	0.06703266	8.49	<.0001
Year	2007	0.420110660	B	0.06608731	6.36	<.0001
Year	2008	0.485495704	B	0.06668768	7.28	<.0001
Year	2009	0.299448165	B	0.06333451	4.73	<.0001
Year	2010	0.048999572	B	0.06679637	0.73	0.4641
Year	2011	-0.096105104	B	0.06773450	-1.42	0.1576
Year	2012	-0.135746710	B	0.06908982	-1.96	0.0509
Year	2013	0.002805528	B	0.07581980	0.04	0.9705
Year	2014	-0.242980458	B	0.09207632	-2.64	0.0090
Year	2015	0.000000000	B	.	.	.

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Month	4	-0.188405631	B	0.07324303	-2.57	0.0109
Month	5	-0.315081667	B	0.03862097	-8.16	<.0001
Month	6	-0.082863156	B	0.02892569	-2.86	0.0047
Month	8	-0.073501654	B	0.03075379	-2.39	0.0179
Month	9	-0.313355435	B	0.04322448	-7.25	<.0001
Month	10	-0.434496848	B	0.05469276	-7.94	<.0001
Month	11	-0.420955881	B	0.08564610	-4.92	<.0001
Month	12	-0.902242772	B	0.33457283	-2.70	0.0076
Month	99	0.000000000	B	.	.	.

Size class 1	-0.173190972 B	0.04100751	-4.22	<.0001
Size class 2	-0.111271510 B	0.02240550	-4.97	<.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.

year	lncpue LSMEAN
2002	5.72257475
2003	5.87555793
2004	5.97983160
2005	6.35382287
2006	6.23045712
2007	6.08168614
2008	6.14707119
2009	5.96102365
2010	5.71057506
2011	5.56547038
2012	5.52582877
2013	5.66438101
2014	5.41859503
2015	5.66157548

year	lncpue LSMEAN	95% Confidence Limits	
2002	5.722575	5.590534	5.854616
2003	5.875558	5.767131	5.983985
2004	5.979832	5.861560	6.098104
2005	6.353823	6.227353	6.480292
2006	6.230457	6.125842	6.335073
2007	6.081686	5.979680	6.183692
2008	6.147071	6.044340	6.249803
2009	5.961024	5.863948	6.058099
2010	5.710575	5.606130	5.815020
2011	5.565470	5.463320	5.667620
2012	5.525829	5.416042	5.635616
2013	5.664381	5.538527	5.790235
2014	5.418595	5.254564	5.582626
2015	5.661575	5.526860	5.796291

Table 3. Catch rate indices for Canadian small vessels (<=500 t; <65’) fishing Northern Shrimp (*Pandalus borealis*) in NAFO Division 3L, 2001 – 2013. All data were standardized to class 3 vessels, July and 2001 values.

YEAR	TAC (t)	[1] FLEET CATCH (t)	[2] PERCENT OF CATCH DATA	UNSTANDARDIZED			STANDARDIZED		
				Geometric mean CPUE (kg/hr)	CPUE RELATIVE TO 2001	EFFORT (hr) [3]	CPUE RELATIVE TO 2001	MODELLED CPUE (kg/hr)	EFFORT (hr) [3]
1999		17	CPUE model begins in 2001						
2000	2,500	3,422							
2001	2,500	2,590	81.87	293	1.000	8,849	1.000	288	9,006
2002	2,500	2,961	91.27	343	1.171	8,643	1.063	306	9,686
2003	6,566	6,663	92.33	377	1.288	17,673	1.239	356	18,705
2004	6,566	6,524	93.03	513	1.753	12,714	1.375	395	16,501
2005	6,566	7,070	94.71	724	2.474	9,763	1.998	575	12,302
2006	12,297	12,112	93.30	607	2.072	19,969	1.766	508	23,843
2007	12,297	12,573	95.15	546	1.865	23,036	1.522	438	28,721
2008	14,209	14,873	91.90	597	2.040	24,905	1.625	467	31,824
2009	14,209	13,965	94.64	437	1.494	31,937	1.349	388	35,992
2010	17,396	7,932	93.37	360	1.230	22,026	1.050	302	26,261
2011	10,514	7,074	88.39	306	1.046	23,098	0.908	261	27,078
2012	5,985	6,190	92.86	318	1.088	19,445	0.873	251	24,652
2013	4,007	4,053	94.39	367	1.254	11,042	1.003	288	14,053
2014	1,791	1,594	79.25	268	0.914	5,958	0.784	226	7,067

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

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

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

Table 4. Multiplicative year, month, ship and gear type model for **Canadian large (> 500 t)** vessels fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L over the period 2001 – 2013. (Weighting by effort, no windows, observer data, history of at least 2 years in the fishery with the first year of the fishery for any vessel removed). Please note that gear 99 is single trawl.

The GLM Procedure

Class Level Information

Class	Levels	Values
year	13	2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
month	12	1 2 3 4 5 6 7 8 9 10 11 12
CFV	17	10101 10296 10407 10579 12508 13165 13475 13835 13849 13877 13936 15890 17608 17611 17694 17786 4043
gear	2	66 99

Number of Observations Read 231

Number of Observations Used 231

Dependent Variable: lncpue

Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	40	4806.215995	120.155400	12.72	<.0001
Error	190	1795.126838	9.448036		
Corrected Total	230	6601.342833			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.728066	42.65968	3.073766	7.205318

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	12	2592.094074	216.007840	22.86	<.0001
month	11	1052.226971	95.656997	10.12	<.0001
CFV	16	745.103123	46.568945	4.93	<.0001
gear	1	416.791827	416.791827	44.11	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	12	1658.656860	138.221405	14.63	<.0001
month	11	1150.063455	104.551223	11.07	<.0001
CFV	16	696.640928	43.540058	4.61	<.0001
gear	1	416.791827	416.791827	44.11	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		5.822112707	B	0.23104704	25.20	<.0001
year	2002	0.328973783	B	0.16156851	2.04	0.0431
year	2003	0.845229922	B	0.17406890	4.86	<.0001
year	2004	0.174881035	B	0.15355669	1.14	0.2562
year	2005	0.142273628	B	0.14999134	0.95	0.3441
year	2006	0.267940949	B	0.15197556	1.76	0.0795
year	2007	0.235742828	B	0.15132161	1.56	0.1209
year	2008	0.123996167	B	0.16112475	0.77	0.4425
year	2009	0.388504695	B	0.16108874	2.41	0.0168
year	2010	-0.218746027	B	0.17058719	-1.28	0.2013
year	2011	-0.596530754	B	0.18455000	-3.23	0.0014
year	2012	-1.101379410	B	0.18516434	-5.95	<.0001
year	2013	-0.638613934	B	0.25009440	-2.55	0.0114
year	2014	0.000000000	B	.	.	.

Table 4. (continued)

Parameter		Estimate		Standard Error	t Value	Pr > |t|
month	1	0.939870026	B	0.09596621	9.79	<.0001
month	2	0.810794497	B	0.10425400	7.78	<.0001
month	3	0.564092581	B	0.09520971	5.92	<.0001
month	4	0.546352902	B	0.11622428	4.70	<.0001
month	5	0.450994315	B	0.13631899	3.31	0.0011
month	6	0.502573627	B	0.11261687	4.46	<.0001
month	7	0.461858372	B	0.14937107	3.09	0.0023
month	8	0.322681118	B	0.18752089	1.72	0.0869
month	9	0.051811755	B	0.19995530	0.26	0.7958

month	10	0.266499358 B	0.10723111	2.49	0.0138
month	11	0.166695787 B	0.10810592	1.54	0.1247
month	12	0.000000000 B	.	.	.
CFV		0.671263093 B	0.26557402	2.53	0.0123
CFV		0.368441378 B	0.32778886	1.12	0.2624
CFV		0.276795988 B	0.24245647	1.14	0.2550
CFV		0.545817969 B	0.26153847	2.09	0.0382
CFV		0.583164914 B	0.26844385	2.17	0.0311
CFV		0.811919868 B	0.27153554	2.99	0.0032
CFV		0.625777109 B	0.23056934	2.71	0.0073
CFV		0.726773182 B	0.23985044	3.03	0.0028
CFV		0.699468212 B	0.24938805	2.80	0.0056
CFV		0.779181895 B	0.25457161	3.06	0.0025
CFV		0.997230510 B	0.29235958	3.41	0.0008
CFV		1.159321402 B	0.27880169	4.16	<.0001
CFV		0.947147831 B	0.24081536	3.93	0.0001
CFV		0.787051252 B	0.24071655	3.27	0.0013
CFV		0.798394567 B	0.41714708	1.91	0.0571
CFV		-0.156113602 B	0.29554542	-0.53	0.5980
CFV		0.000000000 B	.	.	.
gear	66	0.456269350 B	0.06869616	6.64	<.0001
gear	99	0.000000000 B	.	.	.

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

Table 4 (Continued)

The GLM Procedure
Least Squares Means

year	lncpue LSMEAN
2002	7.42770862
2003	7.94396476
2004	7.27361587
2005	7.24100846
2006	7.36667578
2007	7.33447766
2008	7.22273100
2009	7.48723953
2010	6.87998881
2011	6.50220408
2012	5.99735543
2013	6.46012090
2014	7.09873484

year	lncpue LSMEAN	95% Confidence Limits	
2002	7.427709	7.170211	7.685207
2003	7.943965	7.681595	8.206334
2004	7.273616	7.060658	7.486574
2005	7.241008	7.051374	7.430643
2006	7.366676	7.183188	7.550163
2007	7.334478	7.178548	7.490407
2008	7.222731	7.035576	7.409886
2009	7.487240	7.306481	7.667998
2010	6.879989	6.675193	7.084785
2011	6.502204	6.267124	6.737284
2012	5.997355	5.757624	6.237086
2013	6.460121	6.035763	6.884479
2014	7.098735	6.847495	7.349975

Table 5. Catch rate indices for **Canadian large vessels** (>500 t) fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L, 2001 – 2013.

YEAR	TAC (t)	[1] FLEET CATCH (t)	[2] PERCENT OF CATCH DATA	UNSTANDARDIZED			STANDARDIZED		
				Geometric mean CPUE (kg/hr)	CPUE RELATIVE TO 2001	[3] EFFORT (hr)	CPUE RELATIVE TO 2001	MODELLED CPUE (kg/hr)	[3] EFFORT (hr)
1999		17	CPUE model begins in 2001						
2000	1,686	960							
2001	2,500	2,394	62.62	896	1.000	2,672	1.000	1,210	1,978
2002	2,500	2,456	65.41	1498	1.671	1,640	1.390	1,682	1,460
2003	4,267	4,038	78.56	3531	3.940	1,144	2.329	2,819	1,433
2004	4,267	4,036	78.00	1185	1.322	3,406	1.191	1,442	2,799
2005	4,277	4,039	83.19	1413	1.577	2,858	1.153	1,395	2,894
2006	6,023	6,016	59.07	708	0.790	8,501	1.307	1,582	3,802
2007	5,907	5,743	99.82	1090	1.217	5,267	1.266	1,532	3,748
2008	6,615	6,314	70.62	1556	1.737	4,057	1.132	1,370	4,608
2009	7,594	6,550	80.04	1096	1.223	5,975	1.475	1,785	3,669
2010	7,594	5,583	66.34	753	0.840	7,415	0.804	973	5,740
2011	5,480	2,643	86.54	588	0.657	4,493	0.551	667	3,965
2012	4,015	1,829	96.23	272	0.303	6,734	0.332	402	4,546
2013	3,155	2,066	29.43	259	0.289	7,967	0.528	639	3,233
2014	1,791	87	10.36						

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

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

[3] EFFORT CALCULATED (CATCH/CPUE) FROM LARGE VESSEL OBSERVER DATASET, MADE USE OF SINGLE AND DOUBLE TRAWL DATA.

Table 6. NAFO Divisions 3LNO Northern Shrimp total biomass and abundance indices as calculated using Ogmap. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1996 – 2014. (Offshore strata only with standard 15 min. tows).

Autumn Survey

Year	Biomass (tonnes)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	20,287	24,868	35,339	5,378	6,624	9,454
1997	32,630	44,299	62,361	7,601	9,984	13,964
1998	48,649	61,113	77,171	12,031	15,081	19,260
1999	43,453	55,273	72,892	10,692	13,085	16,632
2000	84,561	107,728	140,147	21,032	28,091	36,074
2001	156,356	216,965	261,365	37,141	52,083	62,462
2002	136,421	193,004	241,129	31,322	44,777	55,132
2003	144,979	192,299	245,055	30,677	39,939	49,927
2004						
2005	178,707	224,114	266,399	35,731	45,390	54,095
2006	174,076	216,865	253,714	36,698	47,354	56,079
2007	216,059	277,575	352,179	43,917	57,239	71,946
2008	197,131	250,995	303,852	41,017	53,614	65,462
2009	80,020	119,205	150,215	19,713	29,688	36,184
2010	56,572	75,107	94,337	12,847	17,178	21,294
2011	51,578	73,496	94,720	10,853	15,298	19,270
2012	26,580	41,682	57,428	5,842	9,116	11,931
2013	18,485	25,371	33,688	4,016	5,819	7,851

biomass drop from 2007 91
biomass drop from 2012 39

Spring Survey

Year	Biomass (tonnes)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	27,174	49,736	76,708	6,609	11,495	17,418
2000	66,157	114,070	177,902	13,239	21,503	31,805
2001	53,038	83,061	117,896	12,333	19,852	28,734
2002	87,984	134,710	206,092	20,871	31,475	47,984
2003	117,997	170,753	224,114	26,549	39,232	54,156
2004	41,239	94,136	170,250	8,228	18,121	32,107
2005	86,212	134,307	184,748	16,914	25,727	35,097
2006	109,137	182,835	255,425	21,807	35,064	48,286
2007	191,493	290,562	381,779	35,580	54,675	73,285
2008	171,961	224,718	279,085	35,389	46,310	56,361
2009	63,277	113,265	168,639	14,528	24,613	35,419
2010	76,557	131,589	184,043	16,220	26,625	37,070
2011	34,775	69,872	114,775	8,544	15,085	22,905
2012	32,338	58,495	88,468	7,040	12,387	18,737
2013	17,387	28,794	39,205	3,389	5,350	7,222
2014	24,586	50,340	78,369	4,952	12,091	20,267

biomass drop from 2007 - 2013 90
biomass increase since 2013 75

Table 7. NAFO Divisions 3LNO Pandalus borealis biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1999 – 2014 spring Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min. tows). Please note that strata deeper than 93 m were not surveyed in 3NO during spring 2006. Historically more than 90% of the shrimp have been attributed to strata within 3L therefore the spring 2006 estimates are for 3L only. All indices were estimated using Ogmap calculations.

			Entire Division		Outside 200 Nmi limit			
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent 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	19.05
Spring	2001	3L	83,262	100.24	11,478	99.13	13.78	20.82
Spring	2002	3L	128,971	95.74	34,533	91.47	26.78	19.55
Spring	2003	3L	166,525	97.52	30,103	86.92	18.08	23.54
Spring	2004	3L	92,626	98.40	23,861	97.13	25.76	18.17
Spring	2005	3L	134,106	99.85	14,297	94.67	10.66	20.20
Spring	2006	3L	180,620	???	43,695	???	24.19	20.86
Spring	2007	3L	284,018	97.75	78,732	97.02	27.72	22.44
Spring	2008	3L	224,114	99.73	34,533	99.13	15.41	25.33
Spring	2009	3L	110,949	97.96	36,446	98.64	32.85	26.82
Spring	2010	3L	130,683	99.31	42,084	99.52	32.20	27.63
Spring	2011	3L	69,469	99.42	12,384	100.00	17.83	22.62
Spring	2012	3L	58,495	100.00	3,624	97.30	17.83	13.95
Spring	2013	3L	28,794	100.00	1,812	94.74	6.20	9.35
Spring	2014	3L	50,139	99.60	2,014	100.00	4.02	???
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	61.33
Spring	2001	3N	302	0.36	101	0.87	33.33	54.32
Spring	2002	3N	5,839	4.33	3,222	8.53	55.17	57.28
Spring	2003	3N	5,437	3.18	4,531	13.08	83.33	65.61
Spring	2004	3N	1,208	1.28	705	2.87	58.33	66.27
Spring	2005	3N	1,410	1.05	805	5.33	57.14	57.74
Spring	2006	3N	???	???	???	???	???	67.28
Spring	2007	3N	3,121	1.07	2,416	2.98	77.42	63.71
Spring	2008	3N	604	0.27	302	0.87	50.00	66.28
Spring	2009	3N	705	0.62	503	1.36	71.43	57.14
Spring	2010	3N	403	0.31	201	0.48	50.00	40.48
Spring	2011	3N	101	0.14	0	0.00	0.00	50.00
Spring	2012	3N	101	0.17	101	2.70	100.00	33.33
Spring	2013	3N	101	0.35	0	0.00	0.00	33.33
Spring	2014	3N	201	0.40	0	0.00	0.00	???

Table 7 (Continued)

Season	Year	Division	Entire Division Biomass estimate (t)	Percent by division	Outside 200 Nmi limit Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent biomass in NRA
Spring	1999	3O	101	0.20	0	0.00	0.00	???
Spring	2000	3O	101	0.09	0	0.00	0.00	0.00
Spring	2001	3O	0	0.00	0	0.00	0.00	0.00
Spring	2002	3O	101	0.07	0	0.00	0.00	0.00
Spring	2003	3O	201	0.12	0	0.00	0.00	0.00
Spring	2004	3O	201	0.21	0	0.00	0.00	0.00
Spring	2005	3O	101	0.07	0	0.00	0.00	0.00
Spring	2006	3O	1,007	???	101	???	10.00	0.00
Spring	2007	3O	0	0.00	0	0.00	0.00	0.00
Spring	2008	3O	0	0.00	0	0.00	0.00	0.00
Spring	2009	3O	0	0.00	0	0.00	0.00	0.00
Spring	2010	3O	101	0.00	0	0.00	0.00	0.00
Spring	2011	3O	101	0.00	0	0.00	0.00	0.00
Spring	2012	3O	0	0.00	0	0.00	0.00	0.00
Spring	2013	3O	0	0.00	0	0.00	0.00	0.00
Spring	2014	3O	0	0.00	0	0.00	0.00	0.00
	all divisions							
Spring	1999		49,736	100.61	11,880	100.00	23.89	???
Spring	2000		114,070	100.18	27,486	100.00	24.10	20.64
Spring	2001		83,061	100.61	11,578	100.00	13.94	22.02
Spring	2002		134,710	100.15	37,755	100.00	28.03	20.75
Spring	2003		170,753	100.83	34,634	100.00	20.28	24.80
Spring	2004		94,136	99.89	24,566	100.00	26.10	19.21
Spring	2005		134,307	100.97	15,102	100.00	11.24	18.67
Spring	2006		182,835	???	???	???	???	19.59
Spring	2007		290,562	98.82	81,148	100.00	27.93	21.71
Spring	2008		224,718	100.00	34,835	100.00	15.50	25.35
Spring	2009		113,265	98.58	36,950	100.00	32.62	26.75
Spring	2010		131,589	99.62	42,286	100.00	32.13	27.49
Spring	2011		69,872	99.57	12,384	100.00	17.72	18.74
Spring	2012		58,495	100.17	3,725	100.00	6.37	10.25
Spring	2013		28,794	100.35	1,913	94.74	6.64	5.67
Spring	2014		50,340	100.00	2,014	100.00	4.00	???

Table 8. NAFO Divisions 3LNO *Pandalus borealis* biomass estimates for entire divisions as well as outside the 200 Nmi limit. Shrimp were collected during the 1996 – 2013 **autumn** Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min. tows). All indices were estimated using Ogmap calculations. Please note that the survey was not complete within NAFO Division 3L during 2004.

			Entire Division		Outside 200 Nmi limit			
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1996	3L	23,056	92.71	4,027	85.11	17.47	???
Autumn	1997	3L	43,695	98.64	5,537	91.67	12.67	15.34
Autumn	1998	3L	56,381	92.26	8,961	81.65	15.89	14.41
Autumn	1999	3L	54,871	99.27	8,054	96.39	14.68	17.15
Autumn	2000	3L	106,519	98.88	22,250	98.22	20.89	18.22
Autumn	2001	3L	215,153	99.16	41,077	97.14	19.09	19.57
Autumn	2002	3L	189,077	97.97	35,439	92.39	18.74	???
Autumn	2003	3L	186,459	96.96	35,842	91.75	19.22	???
Autumn	2004	3L	???	???	???	???	???	???
Autumn	2005	3L	222,704	99.37	26,378	97.40	11.84	12.26
Autumn	2006	3L	215,153	99.21	27,284	96.44	12.68	14.28
Autumn	2007	3L	273,346	98.48	50,038	98.42	18.31	14.78
Autumn	2008	3L	247,874	98.76	33,124	97.92	13.36	15.72
Autumn	2009	3L	117,594	98.65	18,223	97.84	15.50	13.58
Autumn	2010	3L	74,503	99.20	8,860	98.88	11.89	12.74
Autumn	2011	3L	72,590	98.77	7,853	97.50	10.82	9.28
Autumn	2012	3L	41,279	99.03	2,114	95.45	5.12	8.40
Autumn	2013	3L	24,969	98.41	2,316	95.83	9.27	
Autumn	1996	3N	2,014	8.10	705	14.89	35.00	
Autumn	1997	3N	705	1.59	503	8.33	71.43	49.66
Autumn	1998	3N	4,732	7.74	2,014	18.35	42.55	57.99
Autumn	1999	3N	503	0.91	302	3.61	60.00	53.23
Autumn	2000	3N	705	0.65	403	1.78	57.14	62.58
Autumn	2001	3N	1,712	0.79	1,208	2.86	70.59	66.74
Autumn	2002	3N	4,027	2.09	2,920	7.61	72.50	70.39
Autumn	2003	3N	4,732	2.46	3,222	8.25	68.09	???
Autumn	2004	3N	2,618	???	2,114	???	???	???
Autumn	2005	3N	1,007	0.45	705	2.60	70.00	???
Autumn	2006	3N	1,510	0.70	1,007	3.56	66.67	66.07
Autumn	2007	3N	1,309	0.47	805	1.58	61.54	60.68
Autumn	2008	3N	1,309	0.52	705	2.08	53.85	55.13
Autumn	2009	3N	805	0.68	403	2.16	50.00	45.73
Autumn	2010	3N	302	0.40	101	1.12	33.33	41.11
Autumn	2011	3N	503	0.68	201	2.50	40.00	35.56
Autumn	2012	3N	302	0.72	101	4.55	33.33	???
Autumn	2013	3N	101	0.40	101	4.17	100.00	

Table 8 (Continued)

Season	Year	Division	Entire Division: Biomass estimate (t)	Entire Division: Percent by division	Outside 200 Nmi limit: Biomass estimate (t)	Outside 200 Nmi limit: Percent biomass by division	percent biomass	3 year running average percent biomass
Autumn	1997	3O	0	0.00	0	0.00	0.00	0.00
Autumn	1998	3O	101	0.16	0	0.00	0.00	0.00
Autumn	1999	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2000	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2001	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2002	3O	101	0.05	0	0.00	0.00	0.00
Autumn	2003	3O	201	0.10	0	0.00	0.00	0.00
Autumn	2004	3O	201	???	0	???	???	???
Autumn	2005	3O	101	0.04	0	0.00	0.00	0.00
Autumn	2006	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2007	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2008	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2009	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2010	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2011	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2012	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2013	3O	0	0.00	0	0.00	0.00	???
	all divisions							
Autumn	1996		24,868	101	4,732	100	19.03	???
Autumn	1997		44,299	100	6,041	100	13.64	16.87
Autumn	1998		61,113	100	10,974	100	17.96	15.57
Autumn	1999		55,273	100	8,356	100	15.12	18.03
Autumn	2000		107,726	100	22,653	100	21.03	18.55
Autumn	2001		216,965	100	42,286	100	19.49	20.13
Autumn	2002		193,004	100	38,359	100	19.87	19.89
Autumn	2003		192,299	100	39,064	100	20.31	???
Autumn	2004			???	???	???	???	???
Autumn	2005		224,114	100	27,083	100	12.08	???
Autumn	2006		216,865	100	28,291	100	13.05	14.48
Autumn	2007		277,575	99	50,843	100	18.32	14.95
Autumn	2008		250,995	99	33,828	100	13.48	15.81
Autumn	2009		119,205	99	18,626	100	15.63	13.68
Autumn	2010		75,107	100	8,961	100	11.93	12.84
Autumn	2011		73,496	99	8,054	100	10.96	9.40
Autumn	2012		41,682	100	2,215	100	5.31	8.60
Autumn	2013		25,371	99	2,416	100	9.52	???

Table 9. 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 – 2013). Abundance at length determined using Ogmap calculations.

Mean Carapace Length (Standard Error)

	Males Age				Females Age		
Year	1	2	3	4	4	5	6
1996	11.19 (.074)	15.92 (.035)	19.32 (.070)	21.44 (.404)	20.52 (.138)	23.08 (.228)	25.44 (.189)
1997	11.01 (.063)	16.11 (.067)	18.83 (.317)	20.01 (1.28)	19.76 (.629)	21.37 (.122)	24.18 (.109)
1998	10.74 (.018)	15.91 (.115)	18.90 (.172)	20.68 (.225)	21.27 (.113)	23.10 (.087)	25.20 (.155)
1999	11.09 (.067)	15.99 (.019)	18.98 (.047)	20.89 (.041)		22.24 (.062)	24.36 (.132)
2000	10.49 (.029)	15.23 (.033)	18.16 (.021)	20.56 (.122)	21.01 (.097)	23.51 (.061)	26.61 (1.11)
2001	10.17 (.043)	15.07 (.026)	17.37 (.038)	19.58 (.018)	20.59 (.101)	22.53 (.092)	24.26 (.094)
2002	10.44 (.032)	14.49 (.021)	17.65 (.014)	20.06 (.014)	21.63 (.045)	23.88 (.096)	25.91 (.519)
2003	10.10 (.034)	15.10 (.030)	18.02 (.065)	19.95 (.030)	18.80 (.074)	22.53 (.036)	25.04 (.182)
2004	Incomplete survey						
2005	10.63 (.028)	14.61 (.075)	17.83 (.052)	20.86 (.095)	20.33 (.175)	23.19 (.047)	25.04 (.139)
2006	10.67 (.019)	14.84 (.019)	17.88 (.123)	19.97 (.029)	20.60 (.109)	23.29 (.039)	25.01 (.067)
2007	11.27 (.040)	15.21 (.023)	17.87 (.023)	20.66(.017)	19.36 (.155)	22.51 (.041)	24.76 (.048)
2008	10.24 (.031)	14.95 (.026)	17.86 (.027)	20.17 (.024)		22.91 (.075)	25.10 (.270)
2009	9.42 (.053)	14.31 (.051)	17.75 (.151)	19.31 (.440)	21.60 (.098)	23.94 (.222)	25.40 (.484)
2010	9.90 (.044)	14.40 (.268)	16.96 (.072)	20.04 (.074)	21.81 (.173)	23.21 (.209)	25.56 (.135)
2011	11.46 (.077)	15.40 (.045)	18.76 (.110)	20.59 (.107)	19.94 (.193)	22.85 (.059)	25.53 (.084)
2012	10.80 (.048)	15.38 (.067)	17.84 (.109)	20.16 (.077)	21.60 (.588)	23.70 (.160)	26.05 (.541)
2013	10.11 (0.11)	14.08 (0.55)	17.55 (.100)	20.36 (.088)	22.42 (.688)	23.77 (.454)	25.94 (.623)

Table 9 (Continued)

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

	Male Age					Female Age			
Year	1	2	3	4	Total	4	5	6	Total
1996	.074 (.004)	.635 (.011)	.231 (.036)	.060 (.020)	1.000	.286 (.032)	.387 (.042)	.327 (.047)	1.000
1997	.069 (.003)	.425 (.020)	.331 (.301)	.174 (.289)	0.999	.047 (.063)	.714 (.055)	.239 (.017)	1.000
1998	.234 (.004)	.211 (.016)	.335 (.079)	.220 (.068)	1.000	.230 (.031)	.639 (.029)	.131 (.022)	1.000
1999	.055 (.002)	.546 (.007)	.150 (.011)	.249 (.009)	1.000		.805 (.032)	.195 (.032)	1.000
2000	.061 (.002)	.342 (.007)	.460 (.015)	.137 (.011)	1.000	.289 (.022)	.703 (.022)	.008 (.009)	1.000
2001	.016 (.001)	.185 (.004)	.299 (.006)	.500 (.007)	1.000	.128 (.017)	.501 (.024)	.371 (.032)	1.000
2002	.035 (.010)	.133 (.002)	.468 (.004)	.364 (.004)	1.000	.713 (.028)	.234 (.052)	.053 (.029)	1.000
2003	.047 (.001)	.178 (.004)	.247 (.012)	.528 (.013)	1.000	.018 (.002)	.854 (.022)	.128 (.021)	1.000
2004	Incomplete survey								
2005	.039 (.001)	.097 (.012)	.637 (.036)	.227 (.025)	1.000	.033 (.007)	.848 (.031)	.119 (.029)	1.000
2006	.059 (.001)	.296 (.004)	.161 (.011)	.484 (.013)	1.000	.043 (.005)	.726 (.021)	.231 (.021)	1.000
2007	.035 (.001)	.239 (.004)	.401 (.004)	.325 (.004)	1.000	.020 (.003)	.491 (.014)	.489 (.015)	1.000
2008	.048 (.001)	.195 (.003)	.434 (.005)	.323 (.006)	1.000		.763 (.055)	.237 (.055)	1.000
2009	.028 (.001)	.384 (.010)	.202 (.129)	.386 (.127)	1.000	.405 (.031)	.513 (.058)	.082 (.080)	1.000
2010	.059 (.003)	.233 (.042)	.436 (.050)	.272 (.013)	1.000	.367 (.077)	.408 (.071)	.225 (.024)	1.000
2011	.058 (.003)	.371 (.009)	.373 (.022)	.198 (.026)	1.000	.062 (.011)	.672 (.017)	.267 (.017)	1.000
2012	.123 (.043)	.329 (.015)	.331 (.014)	.217 (.015)	1.000	.260 (.145)	.675 (.180)	.065 (.045)	1.000
2013	.061 (.005)	.422 (.011)	.317 (.012)	.200 (.013)	1.000	.236 (.252)	.683 (.223)	.081 (.063)	1.000

Table 9. (Continued)

Distributional Sigmas (Standard Error and constraints)

	Male Age				Female Age		
Year	1	2	3	4	4	5	6
1996	1.18 (Fixed)	1.25 (.032)	0.83 (.072)	1.01 (.184)	.976 (.068)	1.100 (.068)	1.210 (.068)
1997	1.150 (.050)	1.043 (.043)	.843 (.167)	1.00 (.0305)	.981 (.040)	1.061 (.040)	1.200 (.040)
1998	0.89 (.014)	1.23 (.071)	0.95 (.128)	0.89 (.068)	.893 (.047)	.970 (.047)	1.058 (.047)
1999	1.231 (.054)	.975 (.017)	.698 (.052)	.997 (fixed)	1.182 (.0335) Sigmas Eq.		
2000	0.90 (.023)	1.11 (.024)	0.84 (.023)	1.20 (.057)	1.316 (.044) Sigmas Eq.		
2001	1.046 (.009) Sigmas Eq.				.958 (.036)	1.048 (.036)	1.129 (.036)
2002	0.97 (.006) Sigmas Eq.				.888 (.022)	.861 (.144)	.936 (.193)
2003	1.12 (.012) Sigmas Eq.				.577 (.056)	1.060 (.024)	1.008 (.077)
2004	Incomplete survey						
2005	0.86 (.022)	0.85 (.044)	1.50 (.086)	1.10 (.036)	1.187 (.032) Sigmas Eq.		
2006	0.80 (CV=.075)	1.11 (CV=.075)	1.34 (CV=.075)	1.49 (CV=.075)	1.023 (.025) Sigmas Eq.		
2007	1.11 (.008) Sigmas Eq.				1.050 (.018)	1.221 (.018)	1.343 (.018)
2008	1.15 (.010) Sigmas Eq.					1.140 (.029)	1.225 (.091)
2009	0.84 (.038)	1.43 (.038)	1.05 (.158)	1.49 (.125)	1.140 (.044)	1.263 (.044)	1.340 (.044)
2010	.791 (.033)	1.34 (.140)	1.04 (.071)	1.15 (.040)	1.037 (.057)	1.103 (.057)	1.215 (.057)
2011	1.261 (.026) Sigmas Eq.				1.259 (.037) Sigmas Eq.		
2012	1.157 (.024) Sigmas Eq.				1.09 (.196)	.986 (.173)	.803 (.210)
2013	1.282 (.030) Sigmas Eq.				1.255 (.243) Sigmas Eq.		

Table 9. (Continued)

Population at Age Estimates (10^6)

	Male Ages					Female Ages			Total
Year	0	1	2	3	4	4	5	6	
1996	0	439	3,765	1,369	375	195	248	222	6,613
1997	3	500	3,057	2,382	1,254	139	1,926	663	9,924
1998	0	3,026	2,735	4,328	2,838	522	1,340	284	15,073
1999	2	560	5,488	1,513	2,556	20	2,410	592	13,141
2000	3	1,466	8,135	10,949	3,291	1,242	3,000	37	28,123
2001	4	704	8,071	13,488	21,606	1,116	4,052	3,023	52,068
2002	0	1,243	4,665	16,434	12,767	6,902	2,242	518	44,771
2003	0	1,364	5,163	7,160	15,339	241	9,218	1,410	39,895
2004	Incomplete survey								
2005	7	1,340	3,303	21,720	7,779	399	9,413	1,404	45,365
2006	0	2,298	11,415	6,078	17,873	484	6,932	2,284	47,364
2007	0	1,459	9,870	16,535	13,396	321	7,785	7,775	57,134
2008	0	2,119	7,921	17,616	13,264	19	9,624	3,000	53,563
2009	0	655	9,003	4,744	9,056	2,543	3,156	515	29,672
2010	5	754	2,944	5,511	3,447	1,656	1,806	998	17,121
2011	16	655	4,031	4,047	2,214	279	2,869	1,194	15,305
2012	9	824	2,200	2,213	1,475	622	1,605	165	9,113
2013	0	271	1883	1412	901	322	912	117	5,818

Table 10. 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 – 2014). Abundance at length determined using Ogmap calculations.

Mean Carapace Length (Standard Error)

Year	Male Age						Female Age		
	0	1	2	3	4	5	4	5	6
1999		12.43 (.454)	14.63 (.055)	18.15 (.069)	20.51 (.053)		19.20 (.280)	22.54 (.122)	24.45 (.580)
2000		8.73 (.044)	14.22 (.034)	18.00 (.024)	20.74 (.070)		20.44 (.216)	23.27 (.032)	25.80 (.419)
2001		8.39 (.131)	13.45 (.027)	16.82 (.008)	19.13 (.024)		20.84 (.17)	23.26 (.16)	26.15 (.41)
2002		8.27 (.061)	12.85 (.029)	16.97 (.021)	19.43 (.018)		21.50 (.042)	23.52 (.38)	26.59 (.119)
2003		8.37 (.065)	13.09 (.003)	16.01 (.091)	17.96 (.086)	19.69 (.040)	20.55 (.92)	21.69 (.041)	23.40 (.052)
2004		8.55 (.288)	13.66 (.094)	17.13 (.299)	18.47 (.090)	19.96 (.026)	20.09 (.154)	22.18 (.034)	24.06 (.041)
2005		8.93 9.078)	14.10 (.052)	17.07 (.130)	18.69 (.212)	20.59 (.088)	21.0 (.276)	22.69 (.044)	24.36 (.061)
2006		9.57 (.148)	13.84 (.019)	17.53 (.189)	18.83 (.412)	20.52 (.054)	19.58 (.107)	23.05 (.049)	24.55 (.054)
2007		9.37 (.157)	13.48 (.018)	16.89 (.025)	19.46 (.063)	21.08 (.041)		23.04 (.086)	25.17 (.290)
2008		8.85 (.072)	13.39 (.032)	16.14 (.036)	18.46 (.038)	20.78 (.038)	19.88 (.093)	22.81 (.043)	25.35 (.172)
2009			11.87 (.037)	15.67 (.058)	18.20 (.070)	20.12 (.059)	19.89 (.153)	22.56 (.033)	25.27 (.061)
2010		9.35 (.086)	13.54 (.053)	16.16 (.042)	18.43 (.042)	20.25 (.064)	21.73 (.118)	23.27 (.135)	25.54 (.096)
2011		11.32 (.115)	13.10 (.066)	15.25 (.066)	17.53 (.067)	19.74 (.052)		22.86 (.038)	25.24 (.092)
2012			12.21 (.096)	14.64 (.119)	17.11 (.117)	19.78 (.044)		23.17 (.043)	25.56 (.176)
2013			13.38 (.045)	16.51 (.093)	18.37 (.142)	20.14 (.069)	22.03 (.106)	23.53 (.096)	25.56 (.150)
2014		9.74(.440)	12.05 (.196)	15.35 (.111)	17.68 (.290)	19.83 (.174)		23.38 (no mix)	

Table 10. (Continued)

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

Year	Male Age							Female Age			
	0	1	2	3	4	5	Total	4	5	6	Total
1999		.067 (.024)	.389 (.026)	.165 (.015)	.379 (.014)		1.000	.020 (.006)	.855 (.098)	.125 (.095)	1.000
2000		.023 (.001)	.353 (.006)	.454 (.012)	.170 (.008)		1.000	.042 (.010)	.933 (.019)	.025 (.014)	1.000
2001		.006 (.001)	.201 (.004)	.294 (.008)	.499 (.009)		1.000	.209 (.090)	.765 (.119)	.026 (.032)	1.000
2002		.018 (.001)	.100 (.002)	.399 (.006)	.482 (.006)		.999	.737 (.066)	.256 (.070)	.007 (.004)	1.000
2003		.013 (.001)	.131 (.003)	.137 (.010)	.304 (.013)	.415 (.017)	1.000	.125 (.032)	.735 (.029)	.140 (.010)	1.000
2004		.004 (.001)	.129 (.007)	.150 (.050)	.119 (.051)	.598 (.014)	1.000	0.035 (.007)	.603 (.013)	.362 (.014)	1.000
2005		.017 (.001)	.162 (.006)	.352 (.042)	.272 (.037)	.197 (.020)	1.000	.029 (.017)	.668 (.016)	.303 (.018)	1.000
2006		.005 (.001)	.303 (.004)	.188 (.052)	.147 (.043)	.357 (.025)	1.000	.016 (.002)	.514 (.025)	.470 (.026)	1.000
2007		.003 (.000)	.196 (.003)	.325 (.005)	.255 (.010)	.221 (.011)	1.000		.735 (.065)	.265 (.065)	1.000
2008		.011 (.001)	.140 (.003)	.336 (.006)	.372 (.006)	.141 (.005)	1.000	.042 (.005)	.740 (.033)	.218 (.029)	1.000
2009			.109 (.003)	.227 (.009)	.403 (.070)	.261 (.016)	1.000	.051 (.009)	.757 (.012)	.192 (.010)	1.000
2010		.003 (.000)	.045 (.003)	.302 (.010)	.324 (.017)	.326 (.020)	1.000	.440 (.052)	.406 (.046)	.154 (.014)	1.000
2011		.015 (.003)	.100 (.005)	.206 (.008)	.343 (.010)	.336 (.013)	1.000		.819 (.018)	.181 (.018)	1.000
2012			.093 (.008)	.216 (.011)	.265 (.011)	.426 (.012)	1.000		.887 (.021)	.113 (.021)	1.000
2013			.194 (.008)	.237 (.019)	.258 (.020)	.311 (.022)	1.000	.372 (.045)	.542 (.038)	.086 (.016)	1.000
2014		.015 (.008)	.119 (.007)	.488 (.032)	.222 (.032)	.156(.024)	1.000		1.000		1.000

Table 10. (Continued)

Distributional Sigmas (Standard Error and constraints)

Year	Male Age						Female Age		
	0	1	2	3	4	5	4	5	6
1999		1.130 (.186)	.912 (.040)	.769 (.059)	.998 (.031)		.727 (.206)	.959 (.072)	.864 (.199)
2000		.708 (.036)	1.317 (.026)	.917 (.026)	1.023 (.038)		1.249 (.031) Sigmas Eq.		
2001	1.063 (.012) Sigmas Eq.						.818 (.113)	1.419 (.215)	.612 (.354
2002	1.064 (.009) Sigmas Eq.						.824 (.024)	1.275 (.225)	.362 (.146)
2003	1.011 (.015) Sigmas Eq.						.764 (.0235) Sigmas Eq.		
2004		1.086 (.220)	1.314 (.070)	.888 (.192)	.540 (.096)	1.00 (Fixed)	0.861 (.0203) Sigmas Eq.		
2005	1.094 (.025) Sigmas Eq.						.812 (.022)	.887 (.022)	.953 (.022)
2006	1.029 (.014) Sigmas Eq.						.890 (.019)	1.047 (.019)	1.115 (.019)
2007	1.028 (.010) Sigmas Eq.							1.237 (.028)	1.335 (.088)
2008	1.054 (.013) Sigmas Eq.						.679 (.049)	1.101 (.037)	1.205 (.064)
2009	1.135 (.018) Sigmas Eq.						1.1854 (.023) Sigmas Eq		
2010		.562 (CV=.012)	.814(CV=.0123)	.971(CV=.0123)	1.107(CV=.0123)	1.217(CV=.0123)	1.105 (.041) Sigmas Eq.		
2011		.650 (CV=.016)	.752 (CV=.016)	.876 (CV=.016)	1.001 (CV=.016)	1.133 (CV=.016)	1.148 (.023) Sigmas Eq.		
2012	1.1382 (.0237) Sigmas Eq.							1.201 (.026)	1.328 (.026)
2013	.847 (.0270) Sigmas Eq.						0.883 (.046) Sigmas Eq.		
2014	1.3004 (.0592) Sigma Eq.						----		

Table 10. (Continued)

Population at Age Estimates (10^6)

Year	Male Ages						Female Ages			Total
	0	1	2	3	4	5	4	5	6	
1999	57	635	3,377	1,432	3,304	0	45	2,066	561	11,477
2000	0	337	5,251	6,747	2,540	13	285	6,151	169	21,492
2001	0	93	3,034	4,444	7,566	18	1,038	3,505	134	19,832
2002	0	419	2,274	9,037	10,922	0	6,514	2,233	61	31,460
2003	0	342	3,496	3,658	8,093	11,065	906	8,449	3,212	39,221
2004	0	48	1,597	1,858	1,478	7,399	219	3,407	2,102	18,108
2005	0	252	2,415	5,249	4,062	2,942	383	7,059	3,384	25,743
2006	4	133	6,331	3,923	3,069	7,683	358	6,673	6,162	34,336
2007	0	93	6,638	11,014	8,658	7,525	64	18,510	6,812	59,314
2008	16	365	4,093	9,809	10,849	4,143	833	12,493	3,684	46,286
2009	0	8	1,763	3,660	6,514	4,206	458	6,393	1,620	24,622
2010	1	50	797	5,323	5,704	5,753	3,921	3,598	1,470	26,617
2011	5	168	1,065	2,187	3,662	3,621	36	3,554	785	15,083
2012	0	32	845	1,885	2,308	3,713	37	3,142	412	12,374
2013	3	26	621	671	730	928	888	1,274	209	5,349
2014	0	68	737	4,090	2,685	2,496		1,360		11,436

Table 11. Male biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2014) and autumn (1996 – 2013) research bottom trawl survey data.

Autumn Survey

Year	Biomass (tonnes)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1996	14,881	19,029	26,751	4,704	5,947	8,438	304
1997	19,119	24,969	34,553	5,676	7,246	10,044	318
1998	31,664	42,789	55,847	10,078	12,933	16,542	347
1999	25,341	33,426	42,960	7,965	10,065	12,676	313
2000	54,246	75,007	96,905	16,803	23,813	31,191	337
2001	101,787	153,034	188,372	30,446	43,890	53,290	362
2002	82,970	123,132	150,819	24,032	35,117	42,950	365
2003	80,403	108,936	139,140	21,948	29,051	36,396	316
2004			???				
2005	100,881	128,770	152,430	26,368	34,167	40,785	335
2006	101,888	133,703	156,054	27,878	37,651	45,296	312
2007	111,553	148,704	190,487	30,436	41,351	52,706	361
2008	107,929	145,080	186,862	29,922	40,958	52,223	256
2009	44,782	71,583	93,018	14,790	23,473	29,368	332
2010	27,858	39,165	50,602	8,978	12,720	16,401	318
2011	25,603	37,956	47,622	7,400	10,957	13,954	261
2012	13,229	21,243	27,234	4,263	6,724	8,579	287
2013	8,275	13,491	18,968	2,691	4,468	6,326	271

percentage drop since 2007 91
percentage drop since 2012 36

Spring Survey

Year	Biomass (tonnes)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	13,662	29,600	49,142	4,635	8,816	14,065	313
2000	25,915	47,219	74,171	8,940	14,896	21,636	298
2001	27,737	50,340	74,856	8,665	15,172	22,562	300
2002	47,763	79,739	130,280	14,266	22,659	35,178	304
2003	58,978	91,719	128,367	16,632	26,667	39,467	300
2004	19,240	52,052	103,197	5,293	12,390	22,864	296
2005	33,154	52,958	73,043	9,668	14,909	20,498	289
2006	43,816	76,517	104,607	12,978	21,135	28,684	195
2007	71,302	112,661	156,960	20,005	31,548	43,141	295
2008	69,026	95,243	119,709	21,314	29,296	37,141	273
2009	30,234	53,864	76,960	8,951	16,148	23,609	299
2010	36,587	65,341	95,968	10,642	17,632	25,150	288
2011	19,794	37,050	58,102	6,382	10,710	15,183	297
2012	16,250	30,607	50,944	4,542	8,793	14,045	289
2013	6,215	10,672	14,800	1,976	2,980	4,023	292
2014	12,615	30,204	50,914	4,049	10,027	16,985	243

percentage decrease from 2007 - 2013 91
percentage increase since 2013 183

Table 12. Female biomass (SSB) / abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2014) and autumn (1996 – 2013) research bottom trawl survey data.

Autumn Survey

Year	Biomass (tonnes)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	4,431	5,839	10,370	522	665	1,167
1997	13,129	19,331	28,633	1,813	2,738	4,059
1998	14,770	18,324	24,354	1,774	2,148	2,863
1999	17,679	21,848	31,040	2,462	3,020	4,201
2000	24,506	32,822	46,565	3,251	4,278	5,965
2001	42,276	63,932	86,444	5,683	8,193	10,994
2002	49,887	69,973	94,438	6,848	9,661	13,119
2003	60,267	83,363	112,258	7,946	10,888	14,538
2004		???			???	
2005	70,265	95,445	122,528	8,393	11,223	14,438
2006	63,247	83,162	108,634	7,355	9,703	12,766
2007	94,710	128,870	169,646	11,971	15,888	20,790
2008	77,242	105,915	139,442	9,284	12,656	16,874
2009	32,550	47,722	66,499	4,243	6,214	8,594
2010	25,774	35,943	48,810	3,235	4,458	6,038
2011	24,214	35,641	50,018	1,961	3,594	5,351
2012	12,806	20,438	29,972	1,465	2,391	3,546
2013	8,616	11,780	16,501	996	1,351	1,928

percent decrease since 2007 91
percent decrease since 2012 42

Spring Survey

Year	Biomass (tonnes)			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	6,608	10,199
2001	23,287	32,721	44,168	3,253	4,680	6,404
2002	38,993	54,971	80,685	6,251	8,816	12,978
2003	58,747	74,906	101,989	9,158	12,564	16,169
2004	21,384	42,084	67,778	2,951	5,731	9,156
2005	51,347	81,349	112,560	6,724	10,818	15,193
2006	59,552	101,888	144,375	7,744	13,182	18,525
2007	111,654	177,902	242,739	14,468	23,126	31,765
2008	92,545	129,474	161,591	12,223	17,014	21,082
2009	30,506	59,401	98,153	4,421	8,465	13,692
2010	41,490	66,247	90,773	5,719	8,992	12,283
2011	16,028	32,822	57,025	2,188	4,375	7,661
2012	15,011	27,989	41,359	1,961	3,594	5,351
2013	10,682	18,122	24,546	1,406	2,370	3,222
2014	6,574	16,008	25,462	819	2,064	3,286

percent decrease since 2007 91
percent decrease since 2013 12

Table 13. Fishable biomass (t) indices (total weight of all males + females with carapace lengths => 17.5 mm) as determined using ogmap calculations from spring and autumn Canadian multi-species bottom trawl survey data, 1996 – 2014. All indices were estimated using Ogmap calculations. Please note that the autumn 2004 survey did not occupy important strata within the shrimp resource therefore no estimations were made for that year. Strata deeper than 93 m were not surveyed in 3NO during spring 2006. Historically more than 97% of the shrimp have been attributed to strata within 3L therefore the spring 2006 estimates are for 3L.

Autumn Survey

Year	Biomass (tonnes)			Abundance (numbers x 106)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	12,142	14,297	22,270	2,331	2,777	4,257
1997	23,237	33,728	48,498	4,603	6,488	9,532
1998	34,604	46,917	61,797	6,713	9,253	12,142
1999	32,902	41,883	57,408	5,656	7,325	9,965
2000	62,563	79,739	106,419	12,676	16,332	21,908
2001	123,635	173,774	217,469	25,130	35,359	43,574
2002	111,755	157,766	198,642	21,515	31,249	39,205
2003	123,635	167,733	217,972	22,844	30,866	39,779
2004		???			???	
2005	142,462	178,405	214,046	25,472	31,528	37,292
2006	137,730	172,767	204,682	24,163	30,386	35,369
2007	182,130	238,108	304,758	31,100	39,905	51,025
2008	159,074	204,884	253,110	28,855	36,731	45,487
2009	63,096	94,136	123,132	11,306	17,246	22,613
2010	41,873	57,287	73,436	7,122	9,549	12,122
2011	41,994	61,113	82,779	6,960	10,094	13,260
2012	19,482	31,412	44,108	3,160	5,269	7,393
2013	12,998	18,324	25,875	2,060	2,969	4,173

percent decrease since 2007 92.30
percent decrease since 2012 41.67

Spring Survey

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
2011	26,429	56,280	96,331	4,583	9,807	16,904
2012	25,140	47,420	74,503	4,207	8,108	13,139
2013	14,337	24,667	33,899	2,281	3,969	5,474
2014	12,806	31,110	50,843	2,255	5,691	9,457

percent decrease since 2007 91
percent increase since 2013 26

Table 14. Recruitment indices as determined from modal analysis of population adjusted northern shrimp length frequencies from spring (1999 – 2014) and autumn (1996 – 2013) 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 survey year – 2.

Survey	Recruitment indices (10^6)		Cohort
Year	Spring	Autumn	Year
1996		3,765	1994
1997		3,057	1995
1998		2,735	1996
1999	3,377	5,488	1997
2000	5,251	8,135	1998
2001	3,034	8,071	1999
2002	2,274	4,665	2000
2003	3,496	5,163	2001
2004	1,597		2002
2005	2,415	3,303	2003
2006	6,331	11,415	2004
2007	6,638	9,870	2005
2008	4,093	7,921	2006
2009	1,763	9,003	2007
2010	797	2,944	2008
2011	1,065	4,031	2009
2012	845	2,200	2010
2013	621	1,883	2011
2014	477		2012

Table 15. Recruitment indices derived from the abundances of males and females with 11.5 – 17 mm carapace lfs using Ogmap calculations of spring (1999 – 2013) and autumn (1996 – 2013) Canadian research survey data.

Autumn

Year	Biomass (tonnes)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	5,889	7,652	11,095	2,741	3,584	5,206
1997	5,569	6,947	9,316	2,461	3,060	4,143
1998	4,952	6,746	9,019	2,395	3,304	4,387
1999	9,040	11,981	14,699	4,033	5,361	6,582
2000	14,961	22,552	30,184	6,761	10,467	13,904
2001	26,247	36,446	43,302	11,629	16,035	18,908
2002	19,592	28,694	35,540	8,571	12,420	15,243
2003	12,625	17,015	21,686	5,803	7,791	10,044
2004		???			???	
2005	21,042	29,298	37,795	9,141	12,707	16,501
2006	20,690	30,103	38,248	10,269	14,896	19,018
2007	24,667	36,144	48,055	11,155	16,358	21,827
2008	22,311	33,325	44,581	9,771	14,921	20,126
2009	14,095	22,452	27,395	6,943	11,518	14,226
2010	9,963	15,001	19,965	4,549	6,840	8,989
2011	6,088	10,068	13,119	2,859	4,805	6,348
2012	8,723	14,196	18,354	1,957	3,238	4,238
2013	2,757	4,833	7,164	1,413	2,568	3,847

percent decrease since 2007 87
percent decrease since 2012 66

Spring

Year	Biomass (tonnes)			Abundance (10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1999	3,887	7,954	12,796	2,107	4,159	6,712
2000	8,871	14,901	20,579	4,364	7,135	9,750
2001	8,284	14,498	21,646	3,757	6,651	10,159
2002	12,072	19,834	31,332	5,247	8,498	13,662
2003	10,410	20,539	35,671	4,630	9,364	16,733
2004	3,887	6,242	9,036	1,803	2,876	4,249
2005	9,125	14,800	21,274	4,030	6,371	8,972
2006	11,115	16,814	23,942	5,696	8,641	12,303
2007	16,723	30,003	43,715	7,906	13,674	19,290
2008	22,059	32,922	42,960	9,768	14,633	19,290
2009	6,461	14,397	23,841	2,927	6,414	10,662
2010	10,390	16,612	23,599	4,343	6,872	9,775
2011	7,379	11,377	15,434	3,374	5,142	6,834
2012	3,979	8,256	12,958	1,812	3,960	6,094
2013	2,005	2,819	3,876	877	1,341	1,885
2014	4,087	13,189	23,469	2,003	6,023	10,451

percent decrease 2008-2013 91.43731
percent increase since 2013 367.8571

Table 16. Exploitation rate indices for NAFO Divisions 3LNO northern shrimp as determined using Canadian autumn survey and total catch over the period 1997 – 2014. 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 2014 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	6,960	136,421	69,973	159,880
2003	12,321	144,979	83,363	169,746
2004	13,204			
2005	14,775	178,707	95,445	178,405
2006	25,689	174,076	83,162	172,767
2007	23,570	216,059	128,870	238,108
2008	25,407	197,131	105,915	204,884
2009	25,900	80,020	47,722	94,136
2010	20,536	56,572	35,943	57,287
2011	12,900	51,578	35,641	61,113
2012	10,108	26,580	20,438	31,412
2013	8,647	18,485	11,780	18,327
2014	4,300***			

*** assumes a full 4 300 t TAC will be taken

Year	Catch / lower CL biomass	Catch/SSB	Catch/fishable biomass
1997	0.024	0.083	0.034
1998	0.019	0.032	0.018
1999	0.016	0.043	0.017
2000	0.108	0.216	0.111
2001	0.126	0.326	0.133
2002	0.045	0.109	0.040
2003	0.090	0.176	0.077
2004	0.091	0.158	0.078
2005			
2006	0.144	0.269	0.144
2007	0.135	0.283	0.136
2008	0.118	0.197	0.107
2009	0.131	0.245	0.126
2010	0.257	0.430	0.218
2011	0.228	0.359	0.225
2012	0.196	0.284	0.165
2013	0.325	0.423	0.275
2014	0.233	0.365	0.235

Table 17. 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 5 + males and total female abundance shaded orange divided by the sum of the age 4 + males and total female shrimp shaded blue.

Year	Age 4+males and total female abundance (millions; year = t)	Age 5+males and total female abundance (millions; year = t)	Survival rate = Total age 4 males + female abundance $_{(t+1)}$/ age 5+ males + female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1996	1,040	470			
1997	3,982	2,589			
1998	4,984	1,624	0.72	0.28	0.33
1999	5,578	3,002	0.53	0.47	0.64
2000	7,570	3,037	0.72	0.28	0.32
2001	29,797	7,075	0.30	0.70	1.20
2002	22,429	2,760	0.34	0.66	1.07
2003	26,208	10,628			
2004					
2005	18,995	10,817			
2006	27,573	9,216			
2007	29,277	15,560	0.49	0.51	0.71
2008	25,907	12,624	0.38	0.62	0.95
2009	15,270	3,671	0.27	0.73	1.31
2010	7,907	2,804	0.21	0.79	1.54
2011	6,556	4,063	0.29	0.71	1.24
2012	3,867	1,770	0.37	0.63	0.98
2013	2,252	1,029			

Survival statistics	Median values
Survival	0.37
Instantaneous rate of total mortality (Z)	0.98
total annual mortality	0.63

Table 18. Survival, annual mortality and instantaneous mortality rate indices for female northern shrimp (*Pandalus borealis*) within NAFO Divisions 3LNO sampled during the spring survey. The survival, S, in the light green box is the abundance of multiparous females divided by the shaded orange divided by the sum of total female shrimp shaded blue.

Year	total female abundance (billions; year = t)	multiparous female abundance (billions; year = t+1)	Survival rate = multiparous females/ total female abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)
1999	2,646	583			
2000	6,558	1,984	0.75	0.25	0.29
2001	4,272	1,735	0.26	0.74	1.33
2002	8,272	1,663	0.39	0.61	0.94
2003	10,525	3,185	0.38	0.62	0.95
2004	5,543	2,558	0.24	0.76	1.41
2005	10,544	4,973	0.90	0.10	0.11
2006	12,635	8,251	0.78	0.22	0.25
2007	20,310	9,629	0.76	0.24	0.27
2008	14,879	7,889	0.39	0.61	0.95
2009	6,303	2,163	0.15	0.85	1.93
2010	8,446	2,591	0.41	0.59	0.89
2011	4,328	1,750	0.21	0.79	1.57
2012	3,550	1,701	0.39	0.61	0.93
2013	2,220	896	0.25	0.75	1.38
2014	1,988	804	0.36	0.64	1.02

Survival statistics	Median values
Survival	0.39
Instantaneous rate of total mortality (Z)	0.95
total annual mortality	0.61

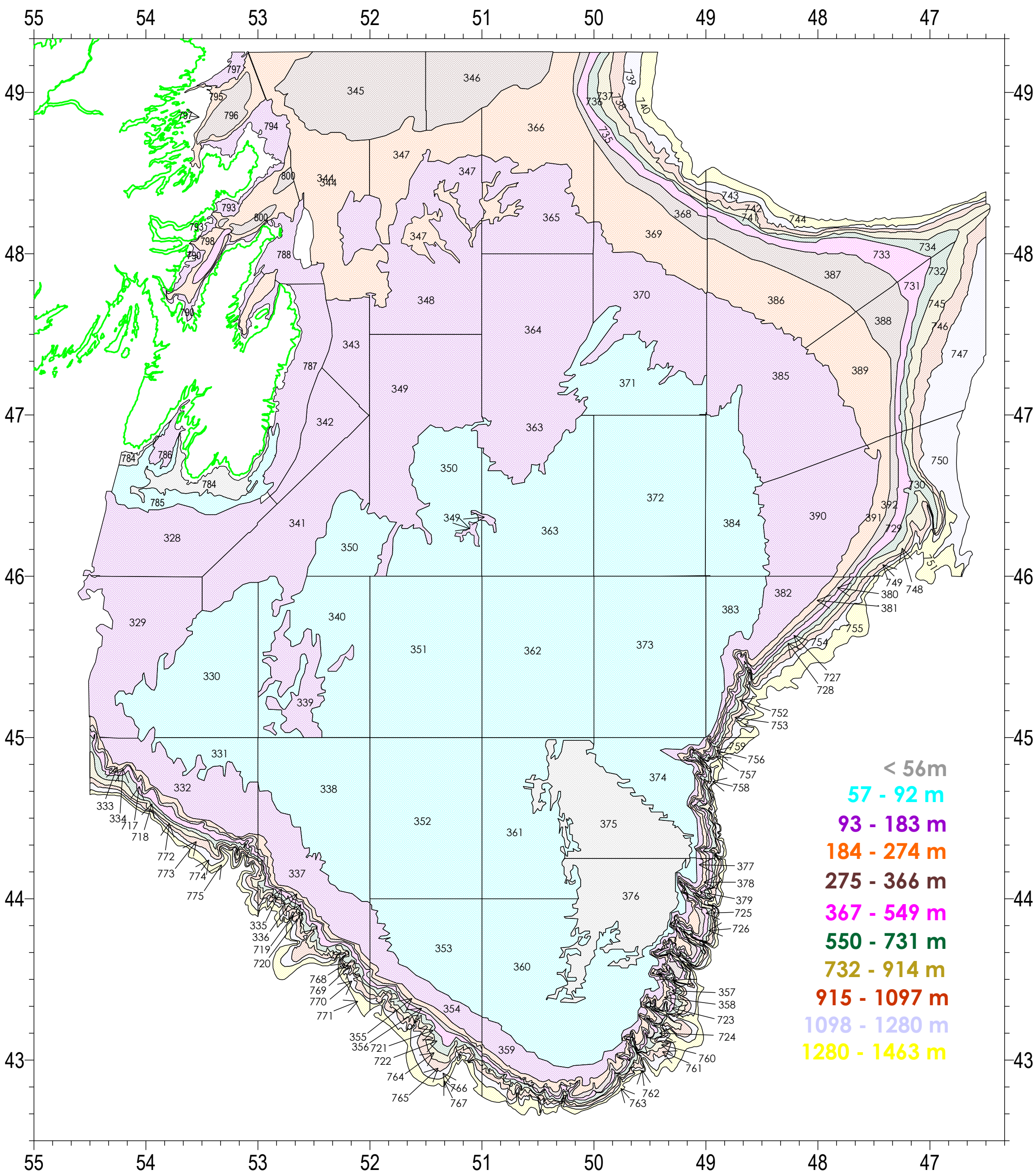


Figure 1. The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species research bottom trawl survey set allocation (G. Cossitt).

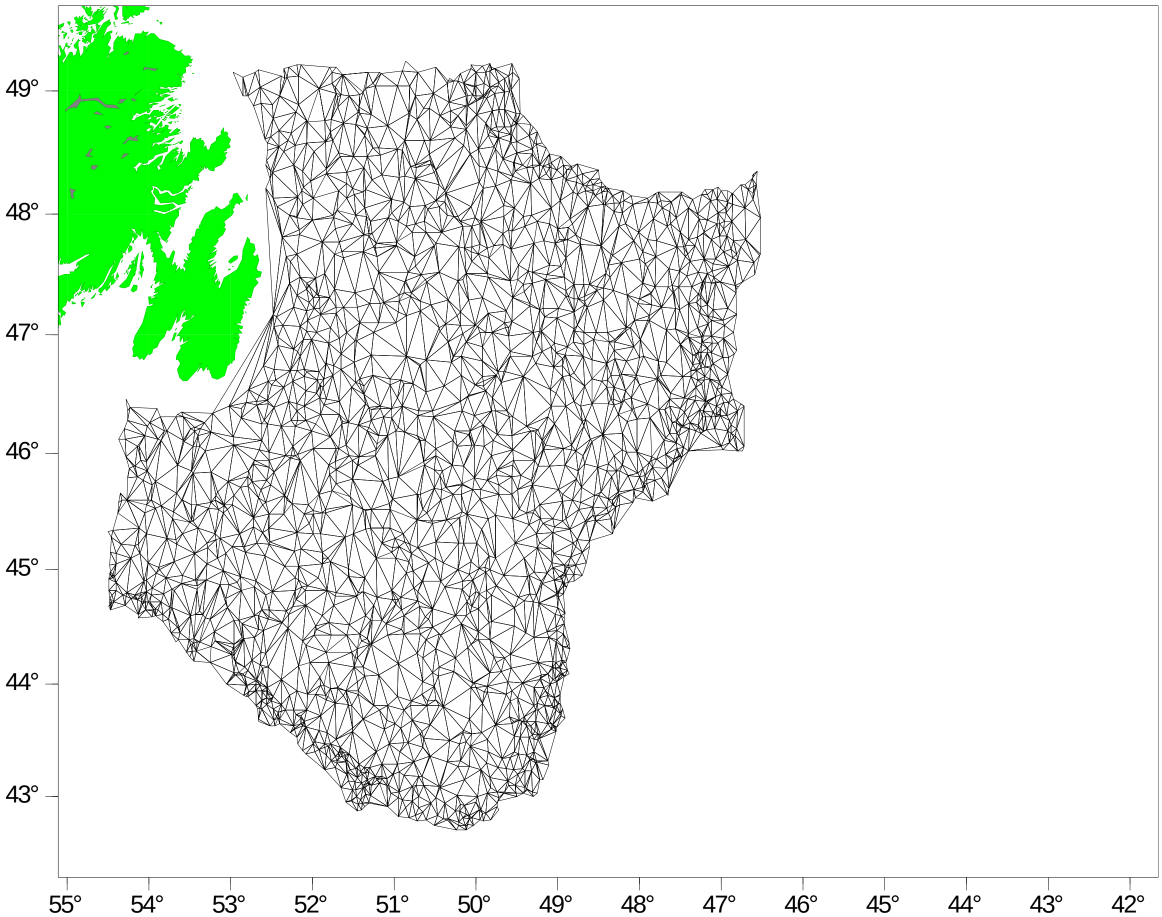


Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Omap.

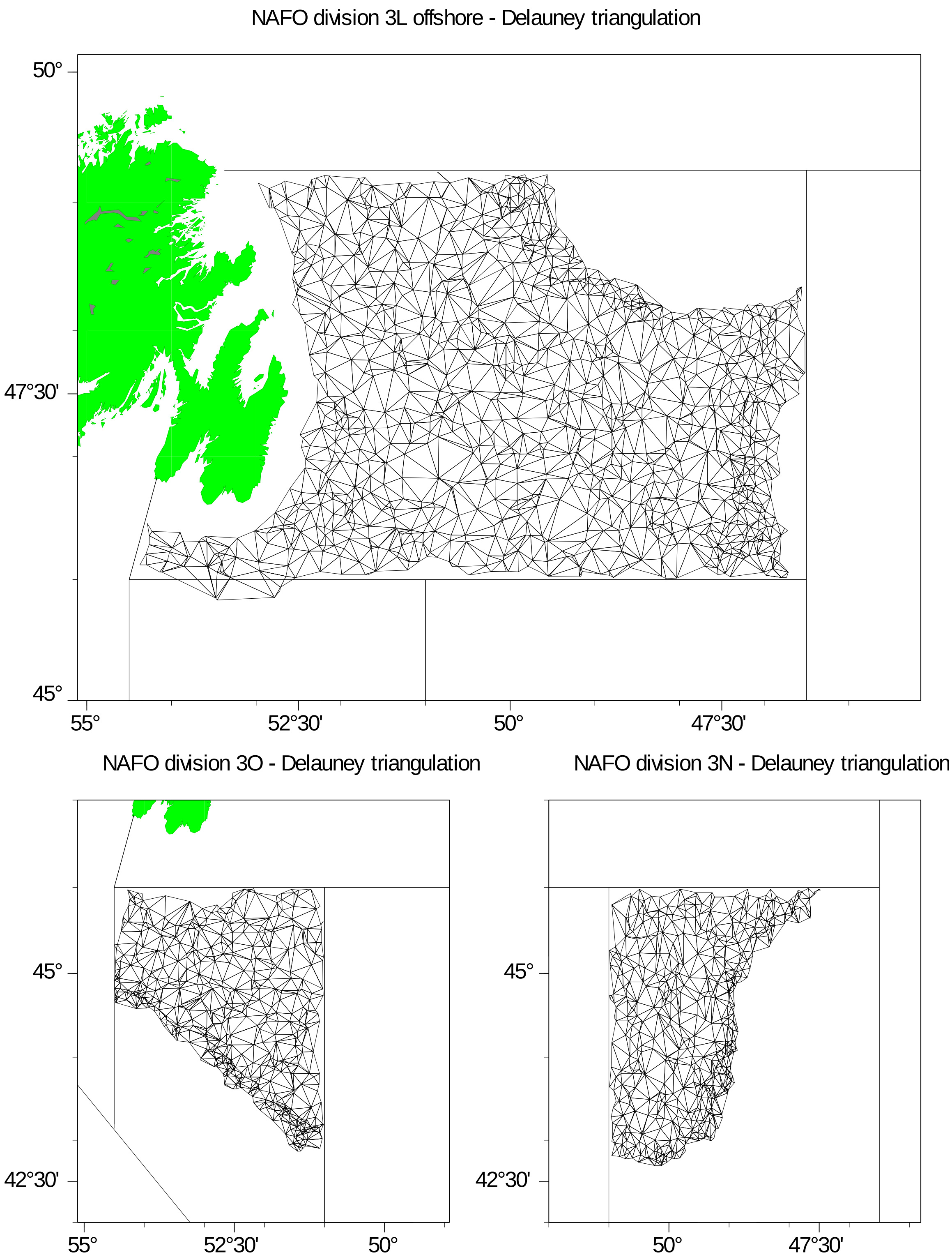


Figure 3. The Delauney triangulation used to derive within NAFO division Ogmap biomass and abundance indices.

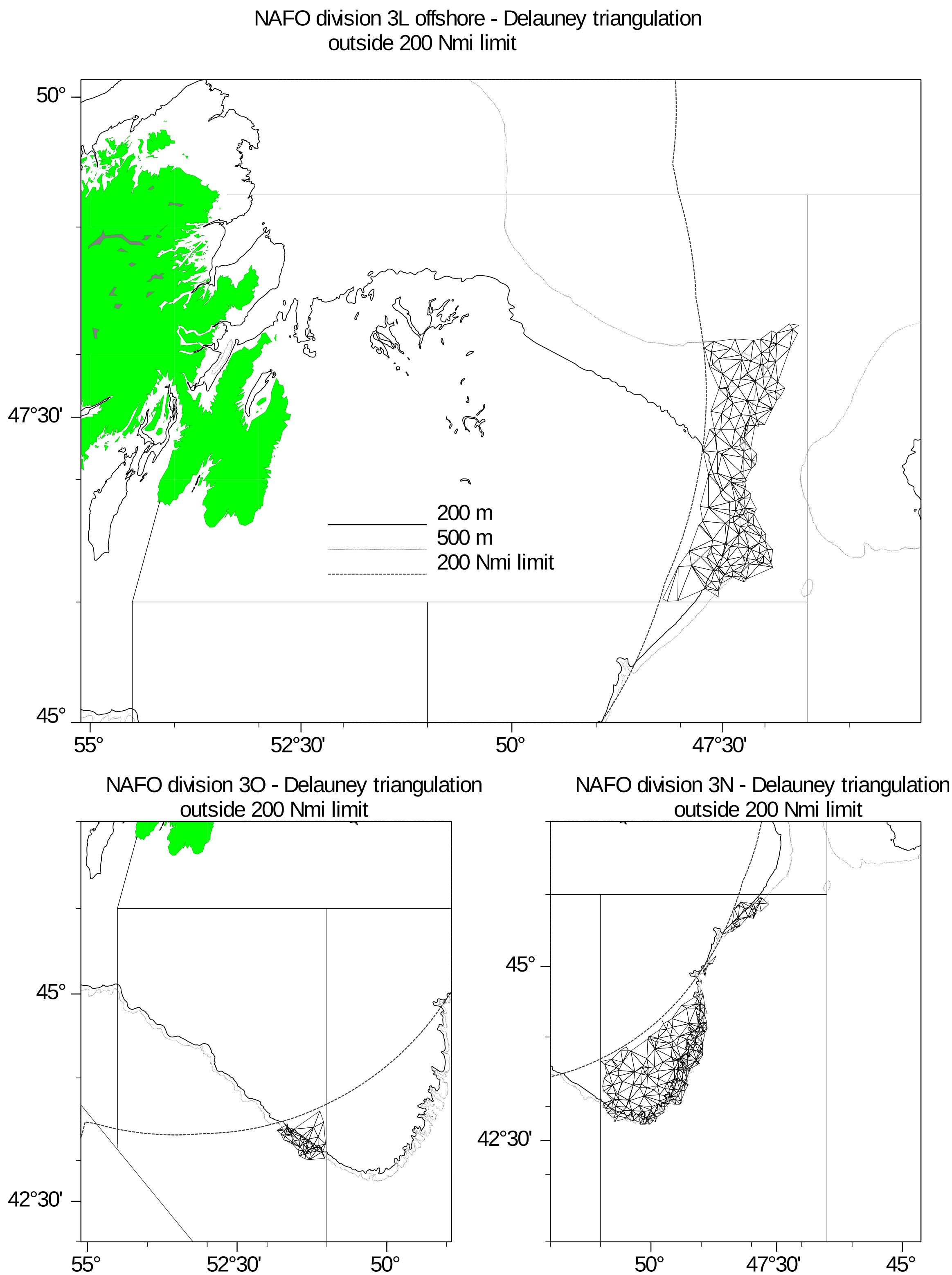


Figure 4. The Delauney triangulation used to derive the outside 200 Nmi limit Ogmap biomass and abundance indices.

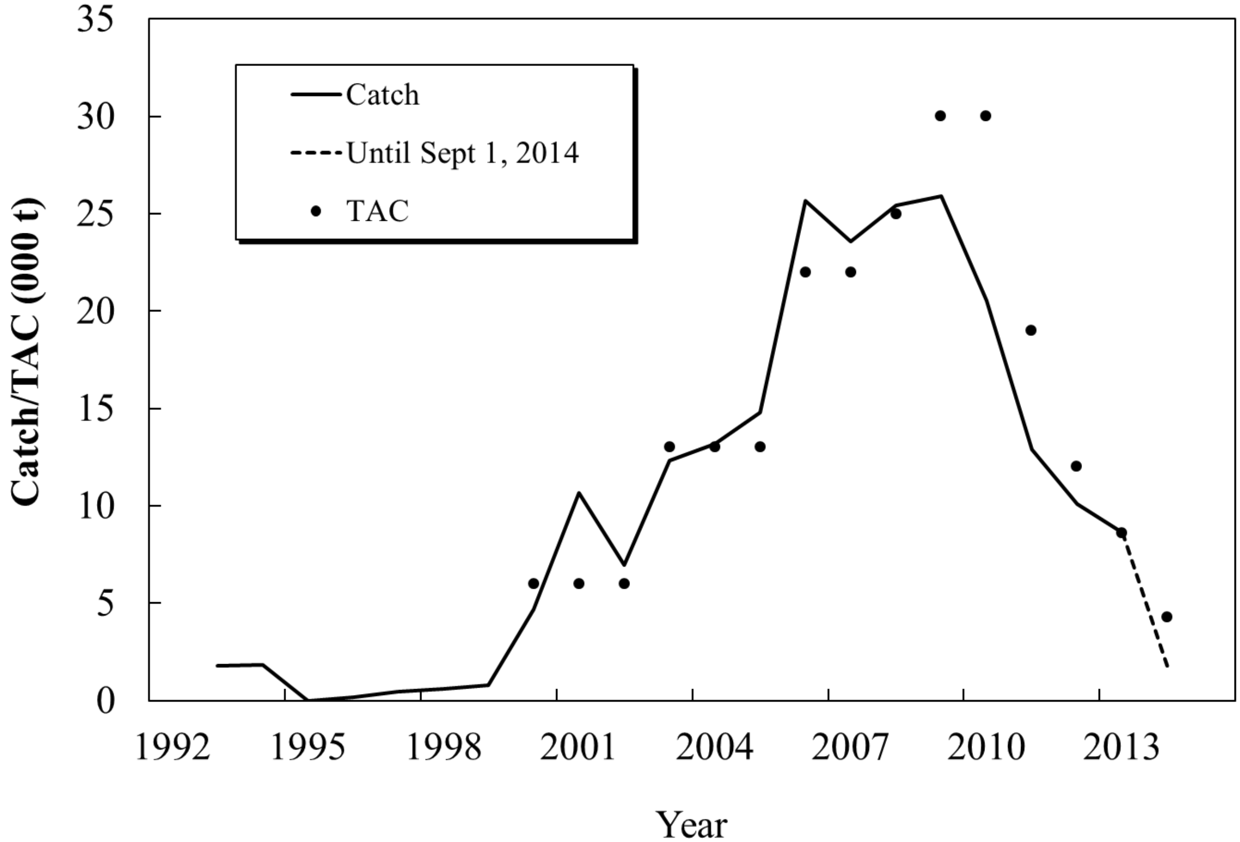


Figure 5. Trends in NAFO Division 3L Northern Shrimp (*Pandalus borealis*) catch and TAC over the period 1993-2014.

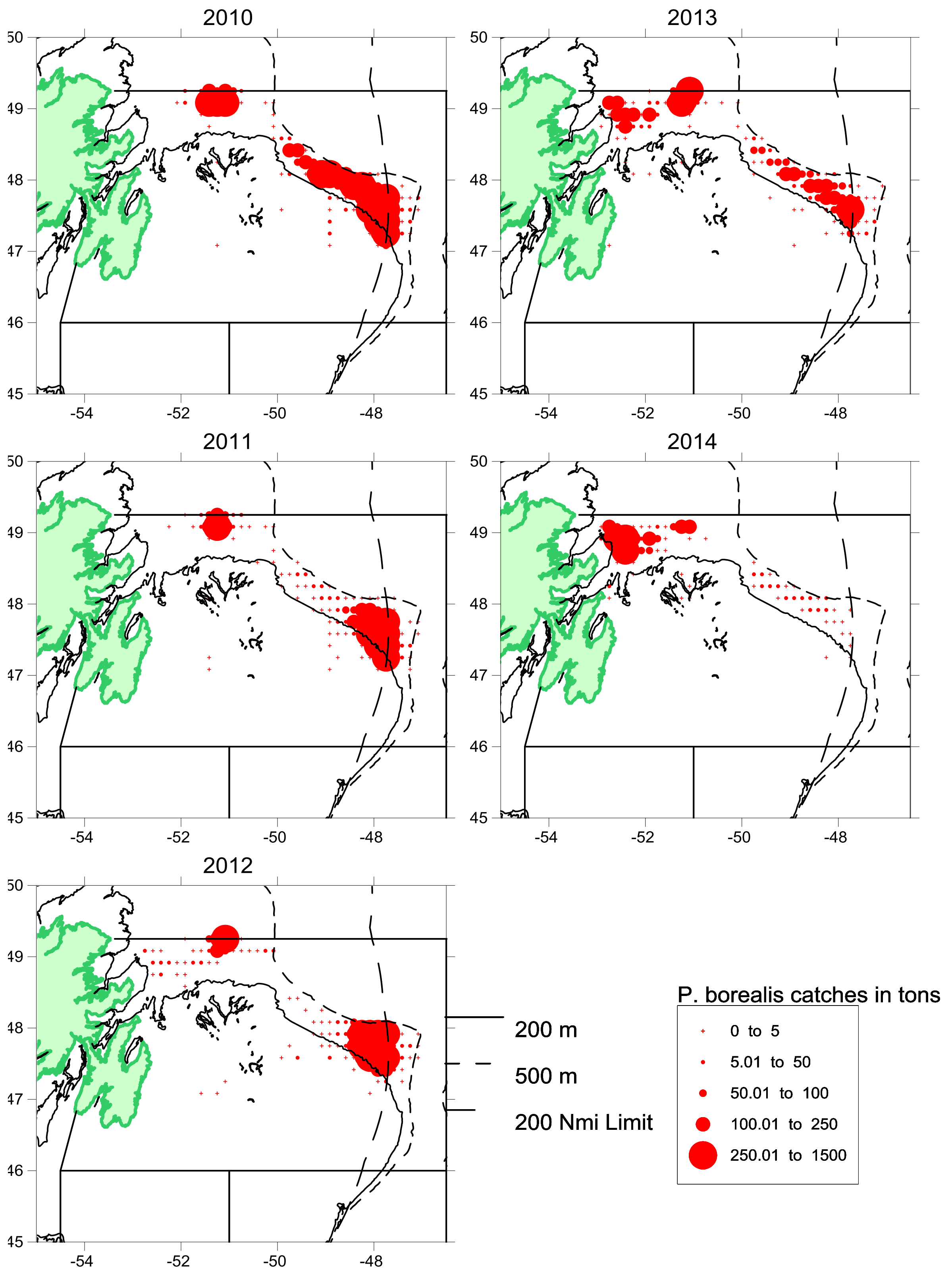


Figure 6. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2010- 2014. (Logbook data aggregated into 10 min X 10 min cells).

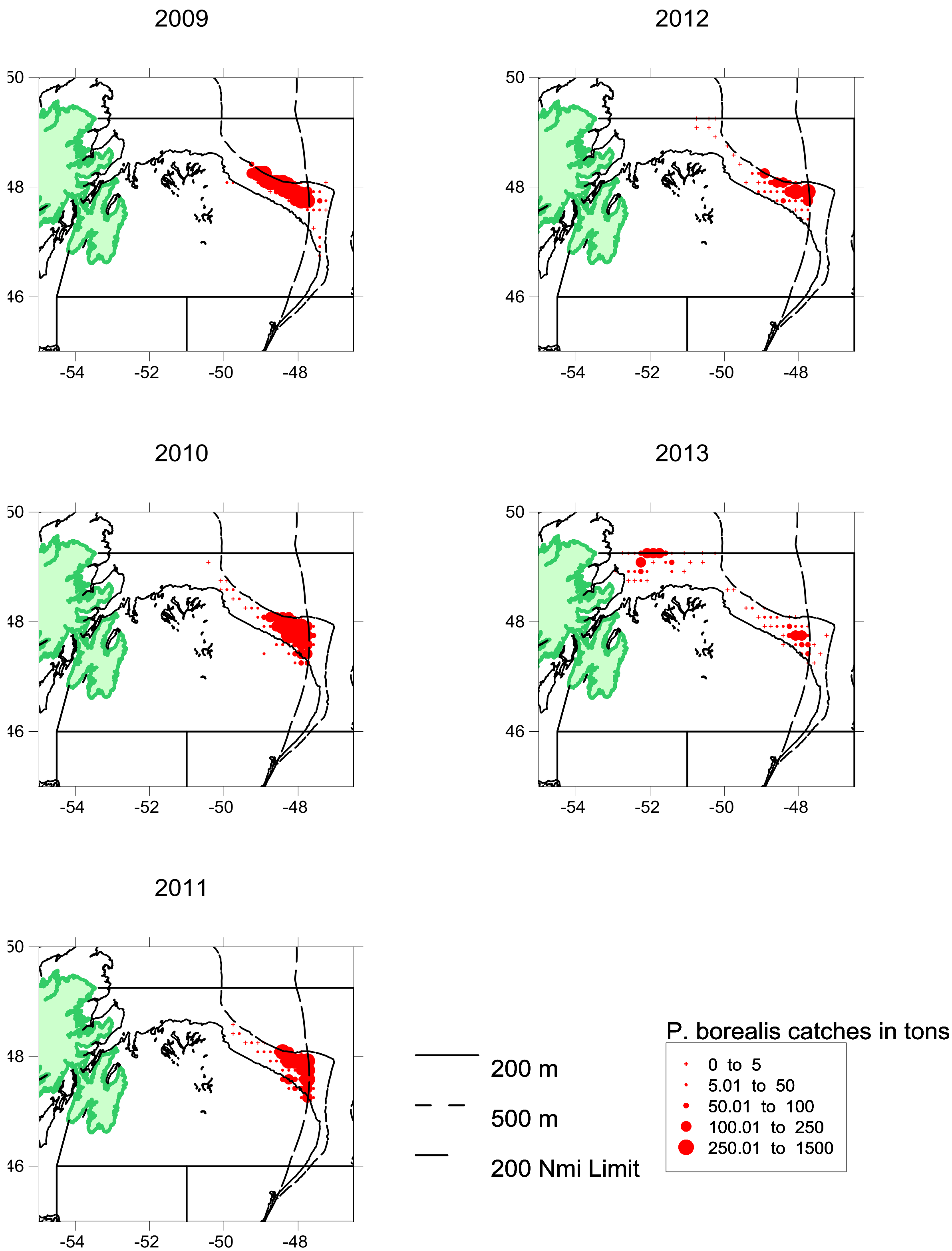


Figure 7. Distribution of Canadian large vessel (>500 t) shrimp CPUE and catches in NAFO Division 3L during 2010 - 2014. (Logbook data aggregated into 10 min X 10 min cells).

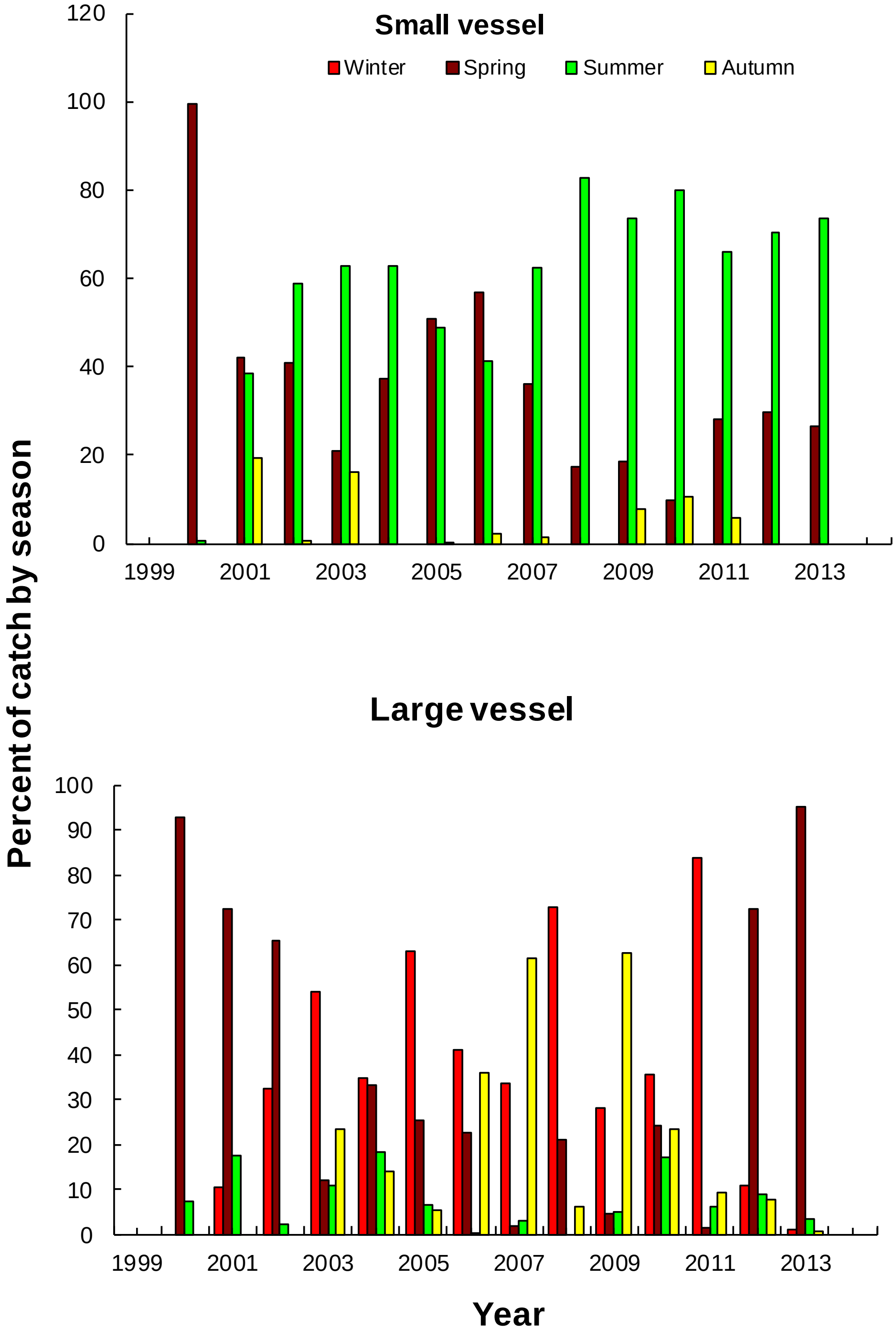


Figure 8. Seasonality of the large and small vessel Northern Shrimp (Pandalus borealis) fishery in NAFO Division 3L over the period 2000 – 2012. Please note that observer data were not available for the large vessel fleet in 2014 and small vessel logbook data were preliminary during September 2014.

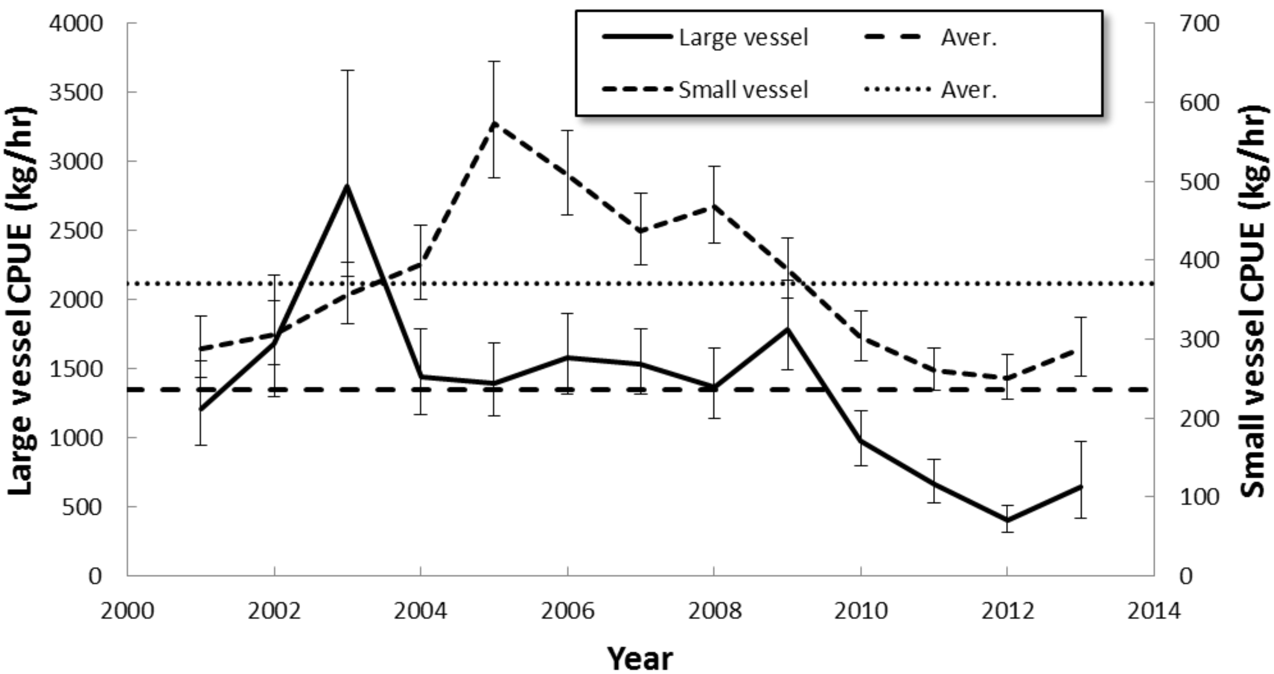


Figure 9. Model catch rates for Canadian large (>500 t) and small (<= 500 t; <65') vessels fishing for shrimp in NAFO Div. 3L over the period 2001 – 2013. Bars represent 95% confidence intervals around model values.

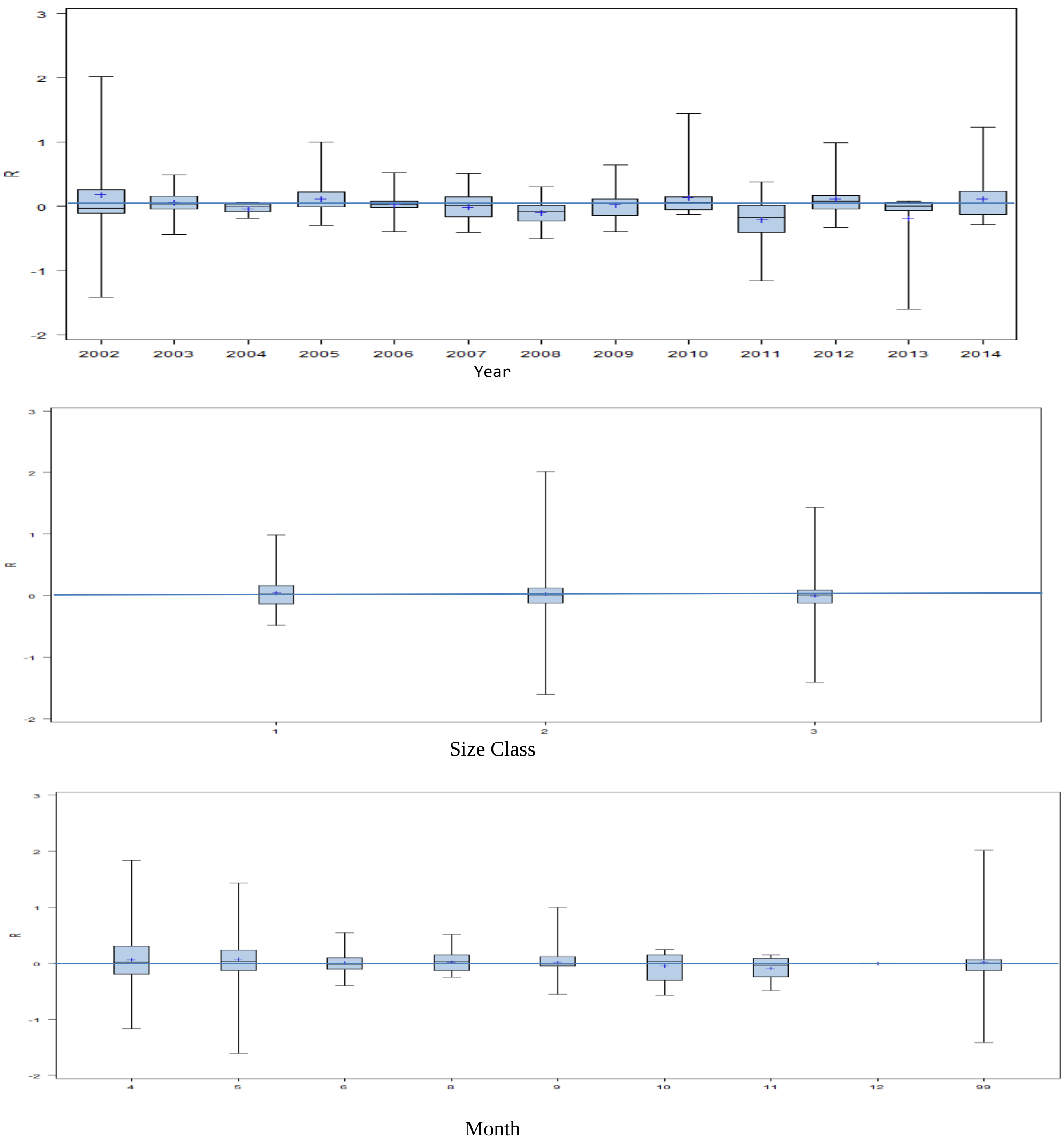


Figure 10. Distribution of residuals around estimated values for parameters used to model **Canadian small vessel** shrimp catch rates, 2001 – 2013.

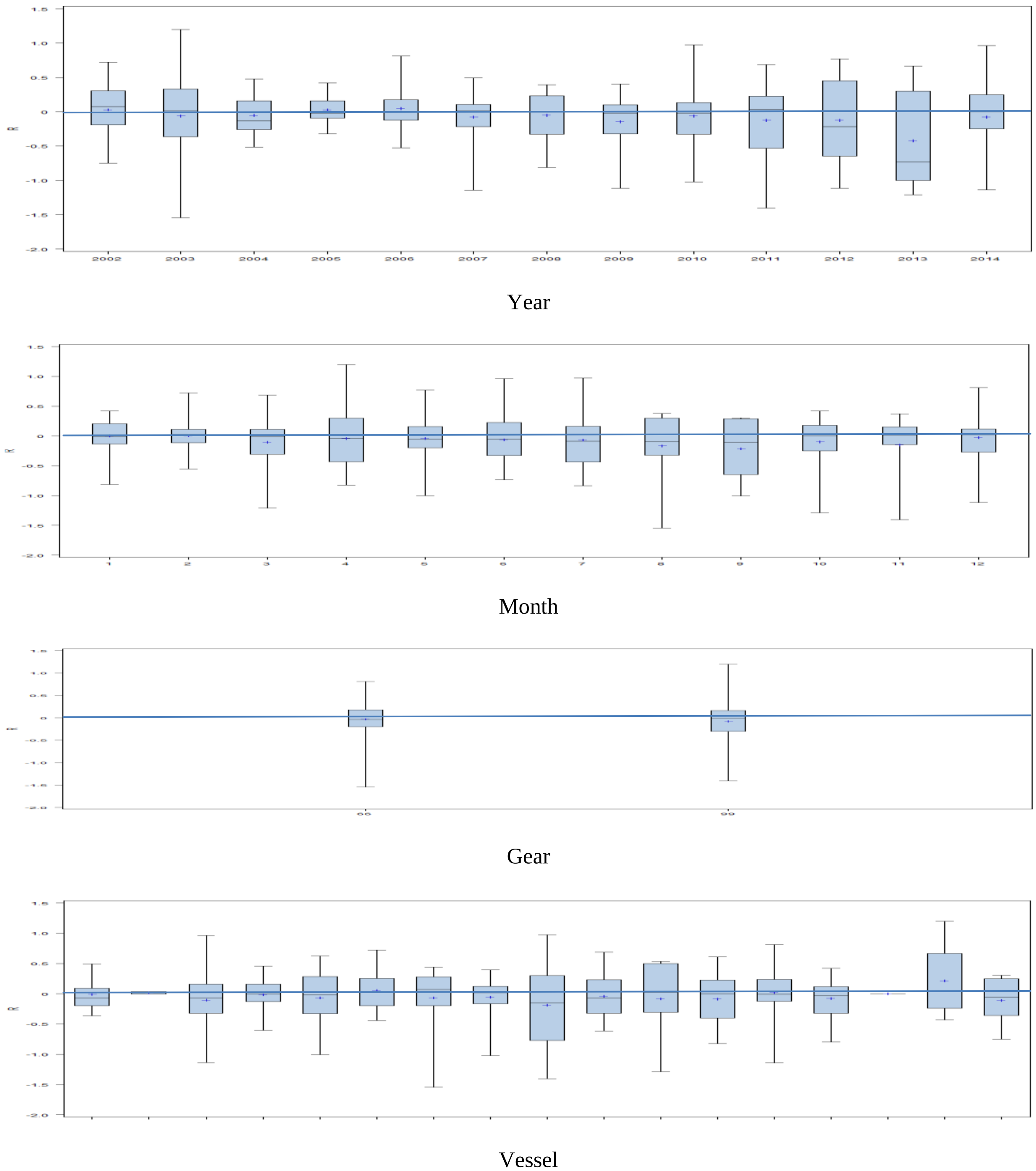


Figure 11 Distribution of residuals around estimated values for parameters used to model **Canadian large vessel** shrimp catch rates, 2001 – 2013.

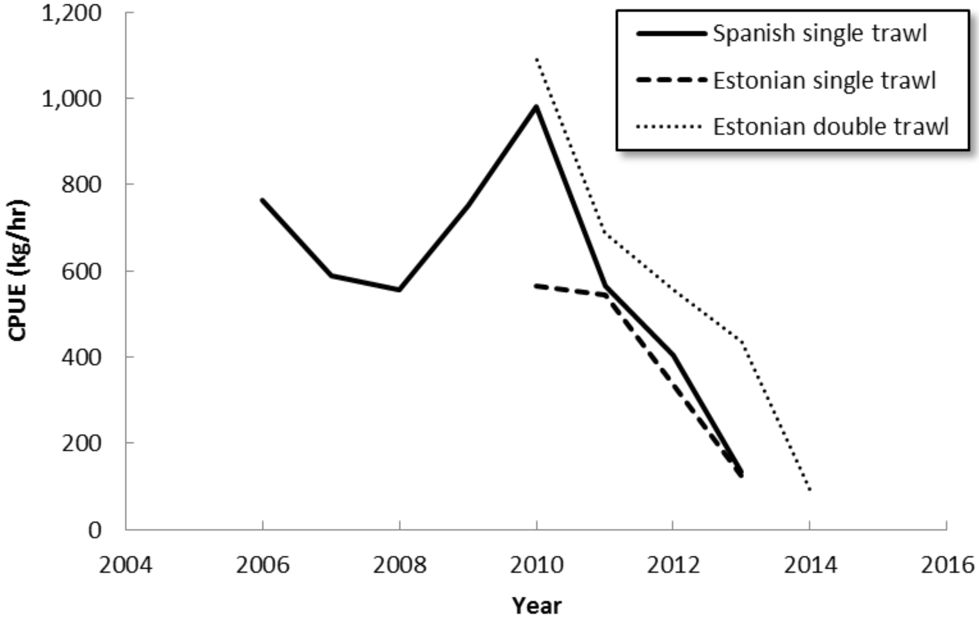


Figure 12. Raw data Estonian and Spanish Northern Shrimp raw catch rates within the NAFO Division 3L NRA over the period 2006 – 2014.

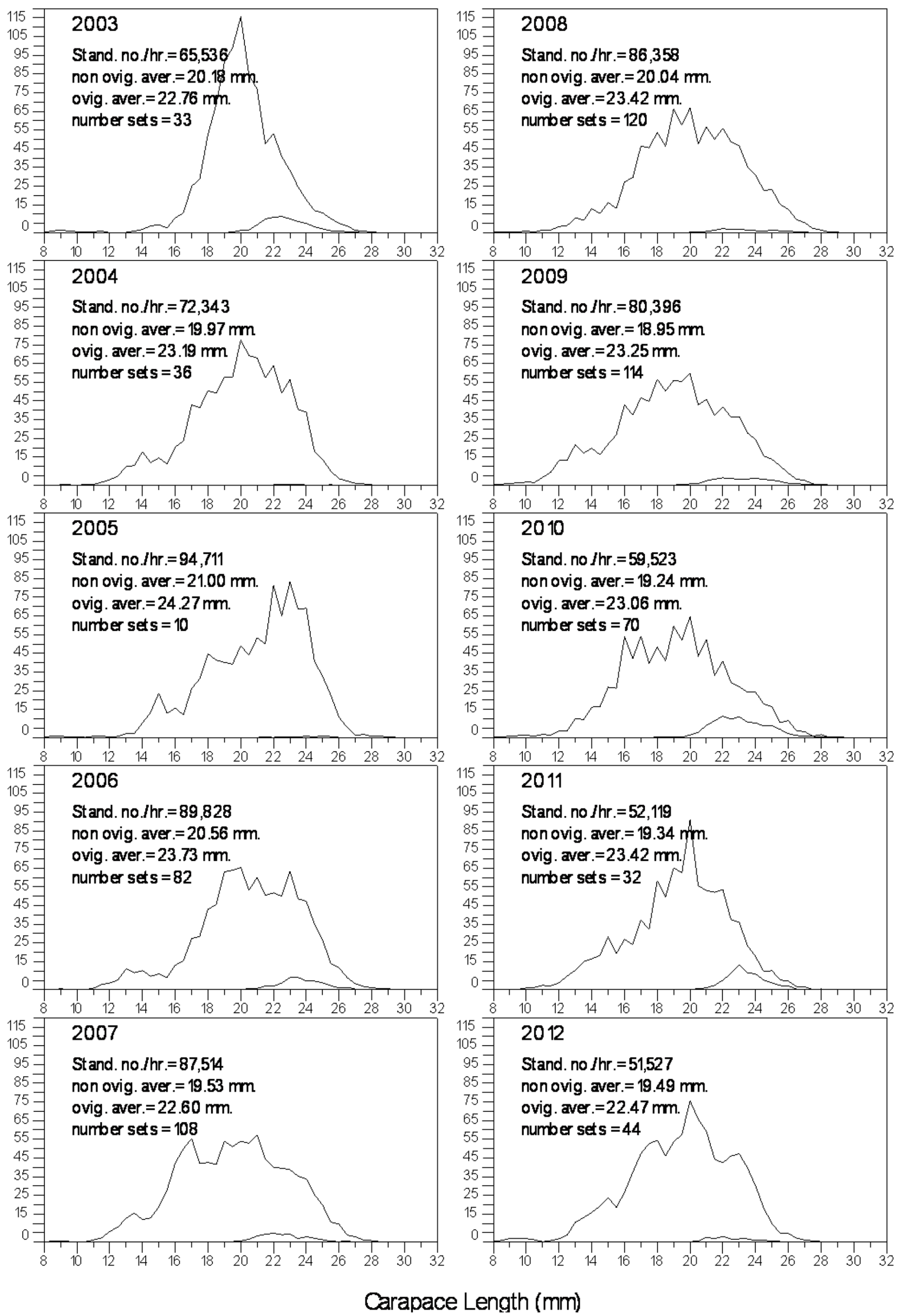


Figure 13. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

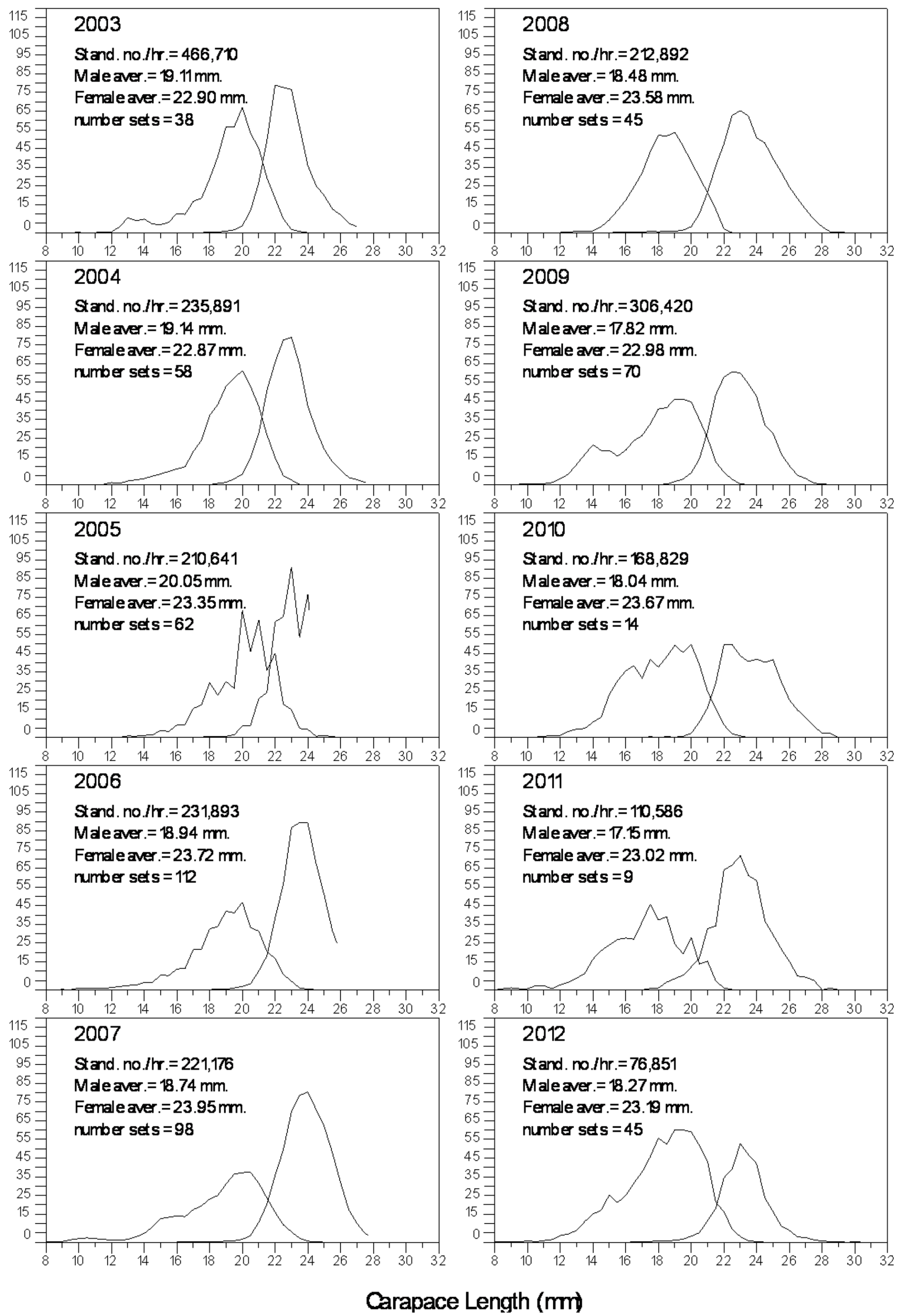


Figure 14, Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

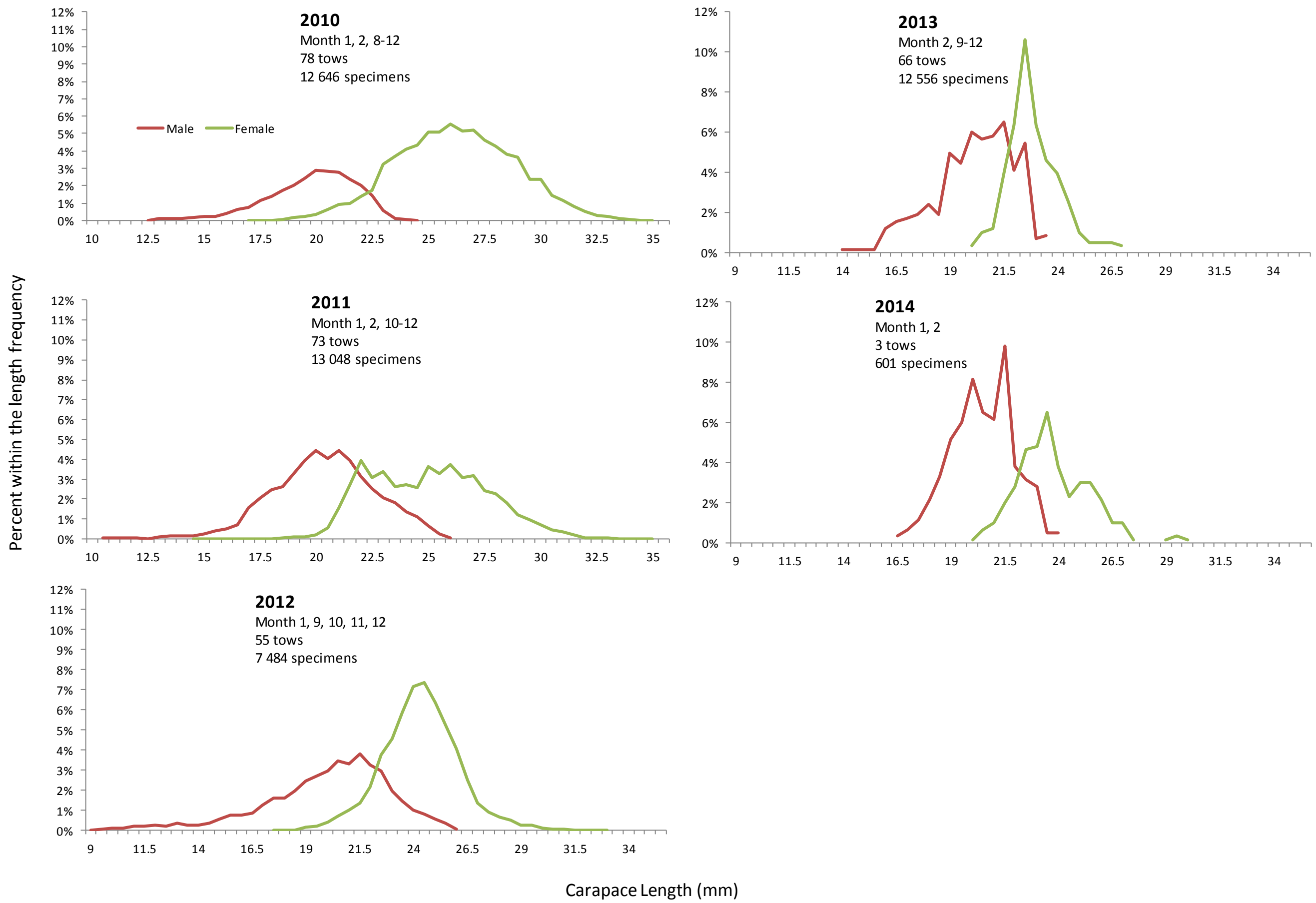


Figure 15. Observed northern shrimp (Pandalus borealis) length frequencies from the Estonian fleet fishing in Div. 3L NRA over the period 2010 – 2014.

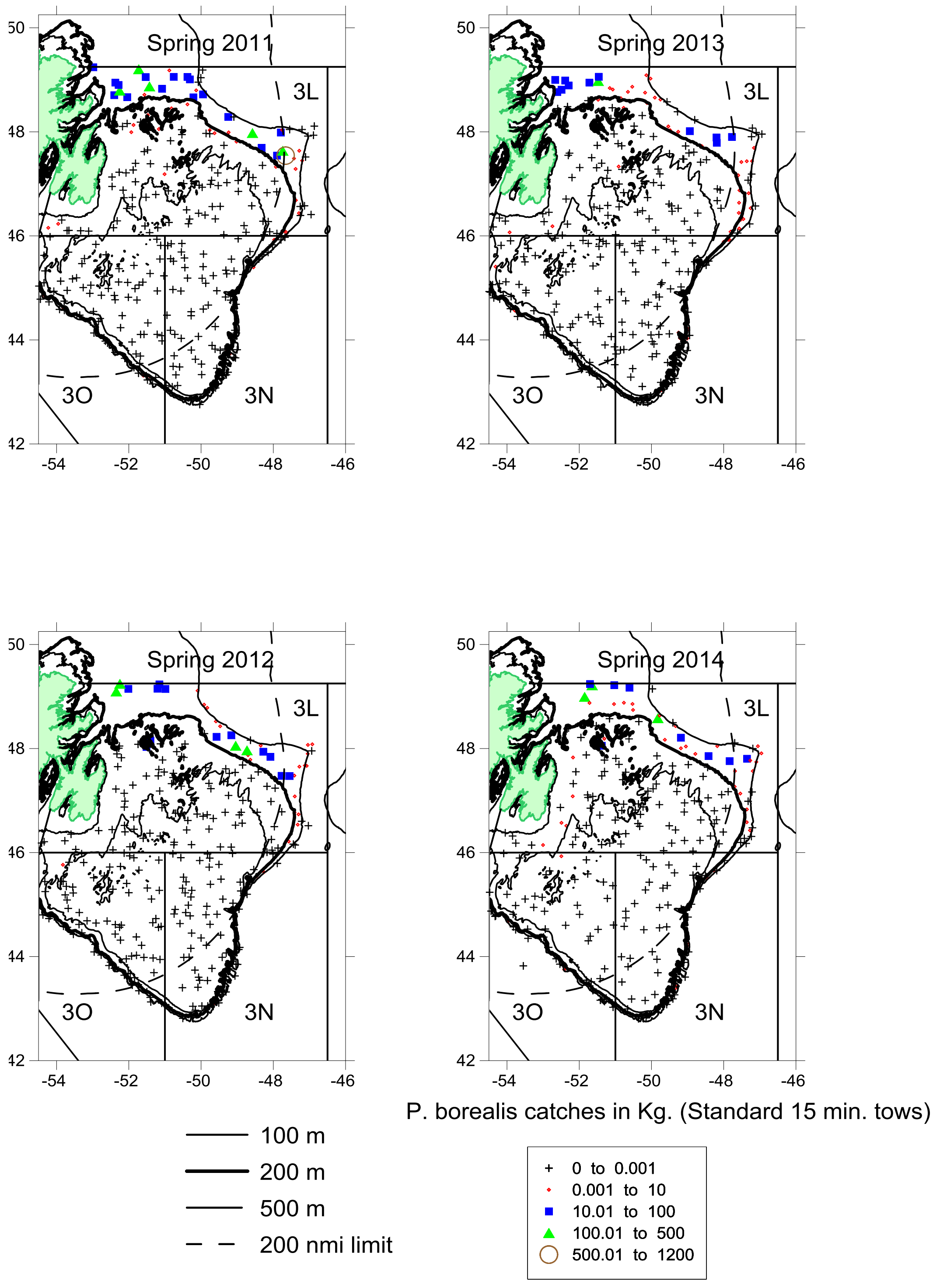


Figure 16. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **spring** Canadian research bottom trawl surveys conducted over the period 2011 – 2014.

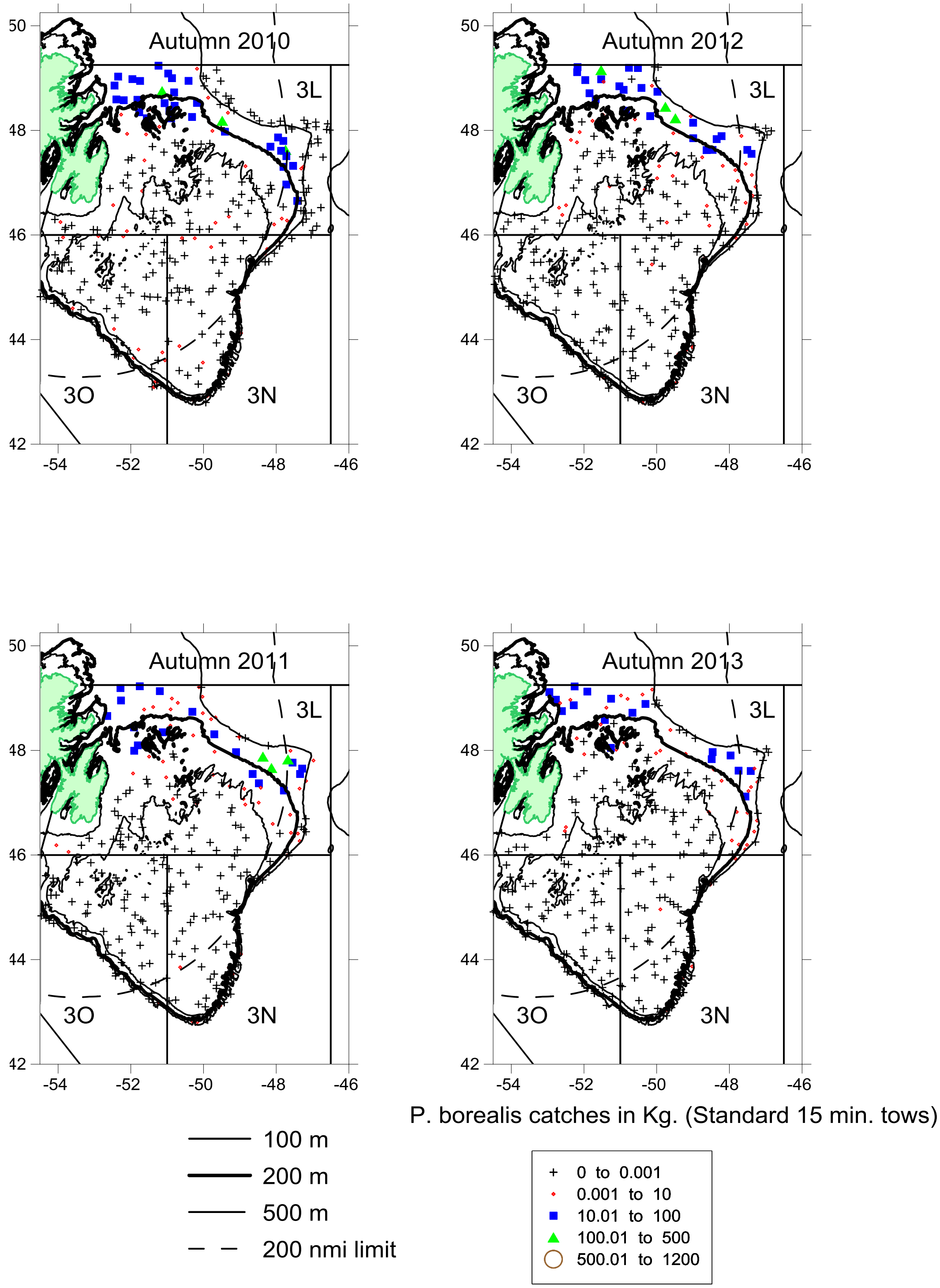


Figure 17. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **autumn** Canadian research bottom trawl surveys conducted over the period 2010 – 2013.

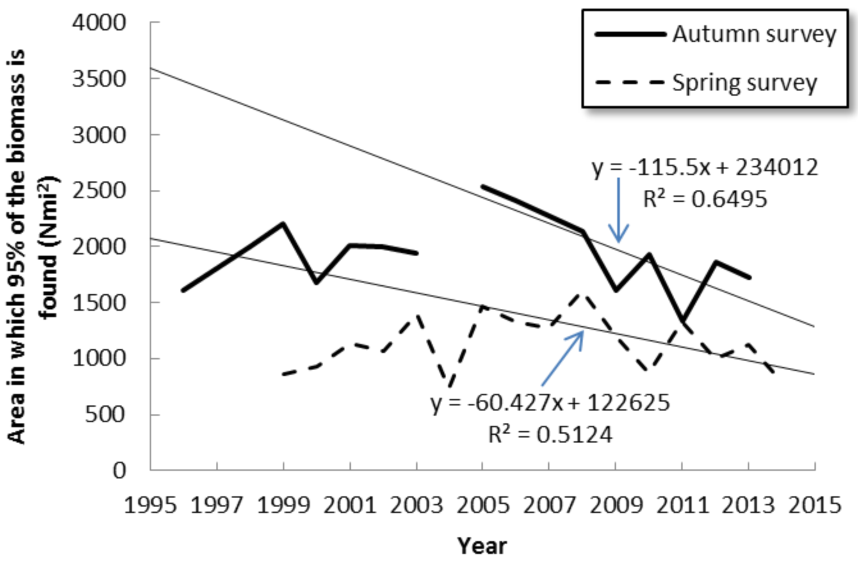


Figure 18. Area occupied by 95% of the northern shrimp (*Pandalus borealis*) resource within NAFO Divisions 3LNO.

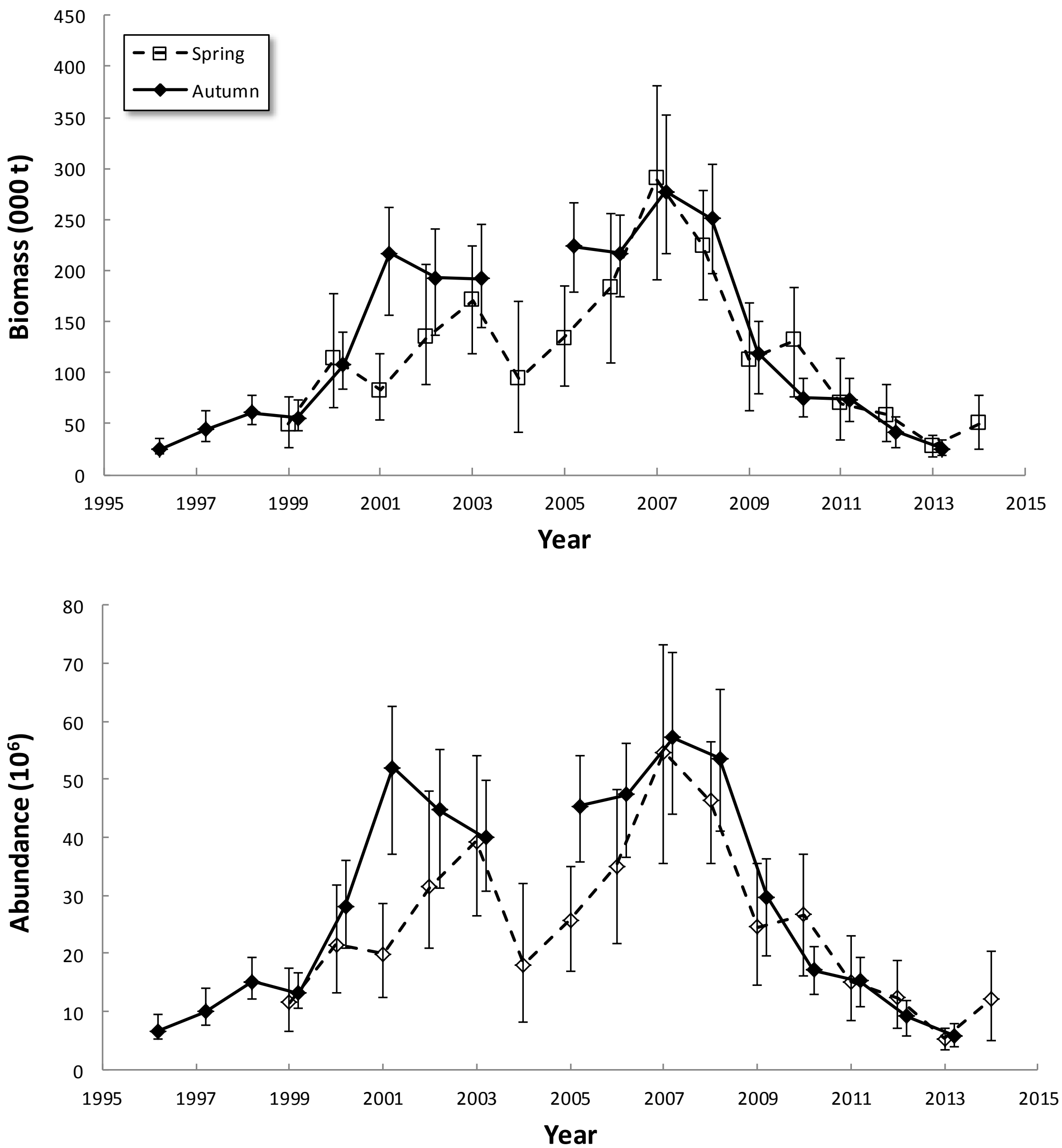


Figure 19. Northern shrimp biomass and abundance indices within NAFO Divisions 3LNO from spring 1999 – 2014 and autumn 1996 – 2013 Canadian multispecies research bottom trawl surveys. (Standard tow 15 min.). Estimates were made using Ogmap calculations and bars represent 95% confidence intervals.

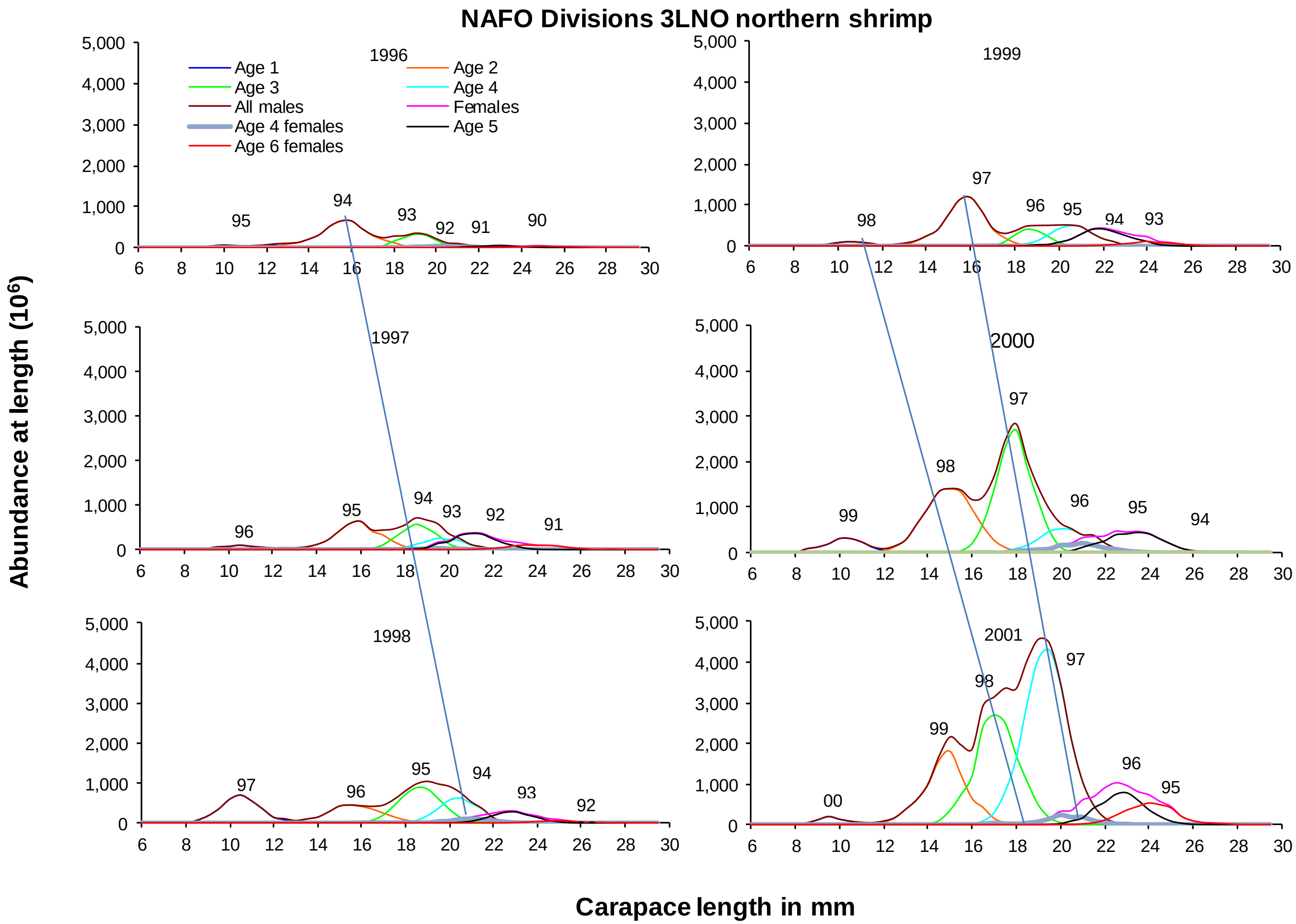


Figure 20. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each plot indicate year classes as determined using Mix 3.01 (Pitcher and MacDonald, 1993). Blue lines join within cohort modes between survey years.

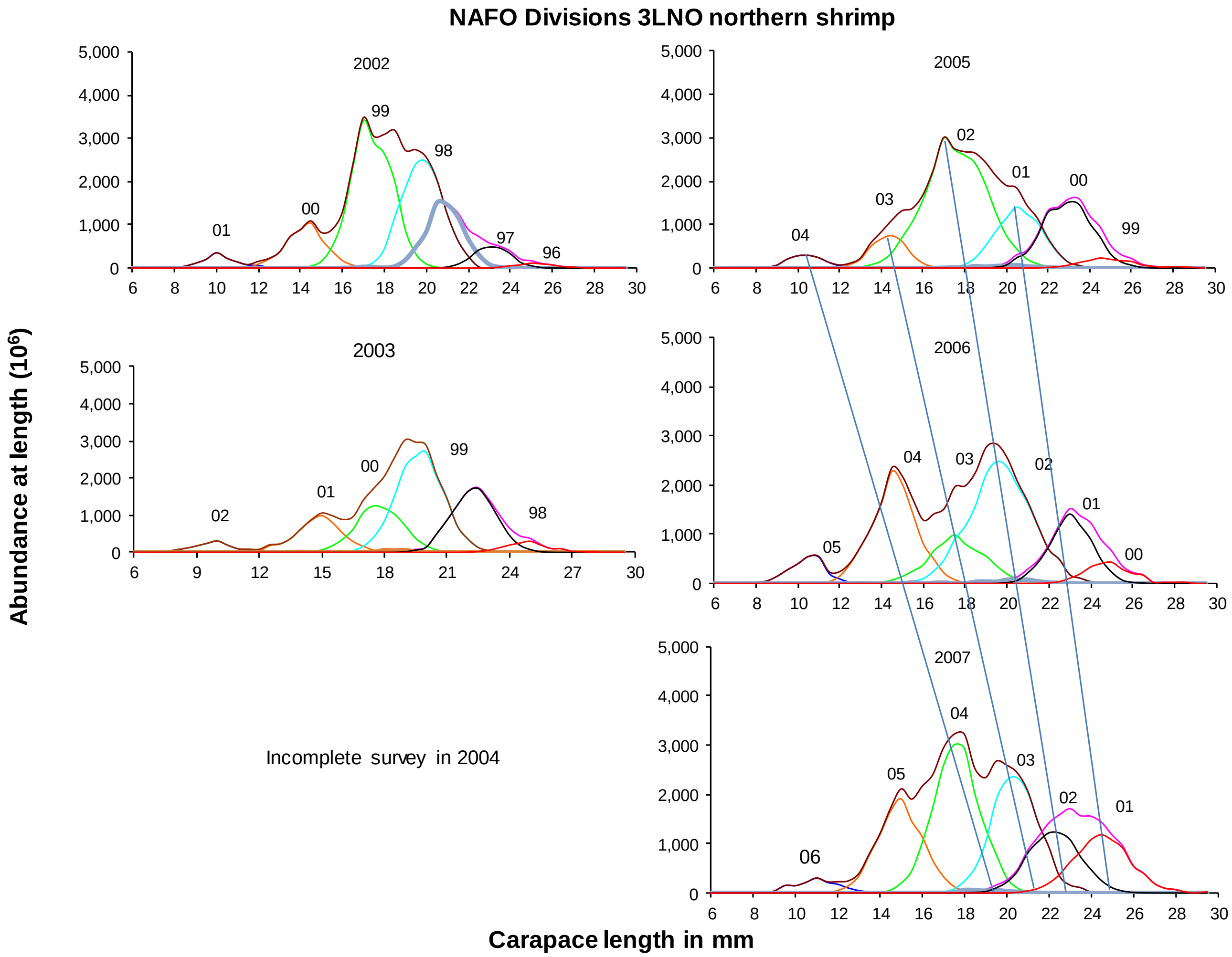


Figure 20. (Continued)

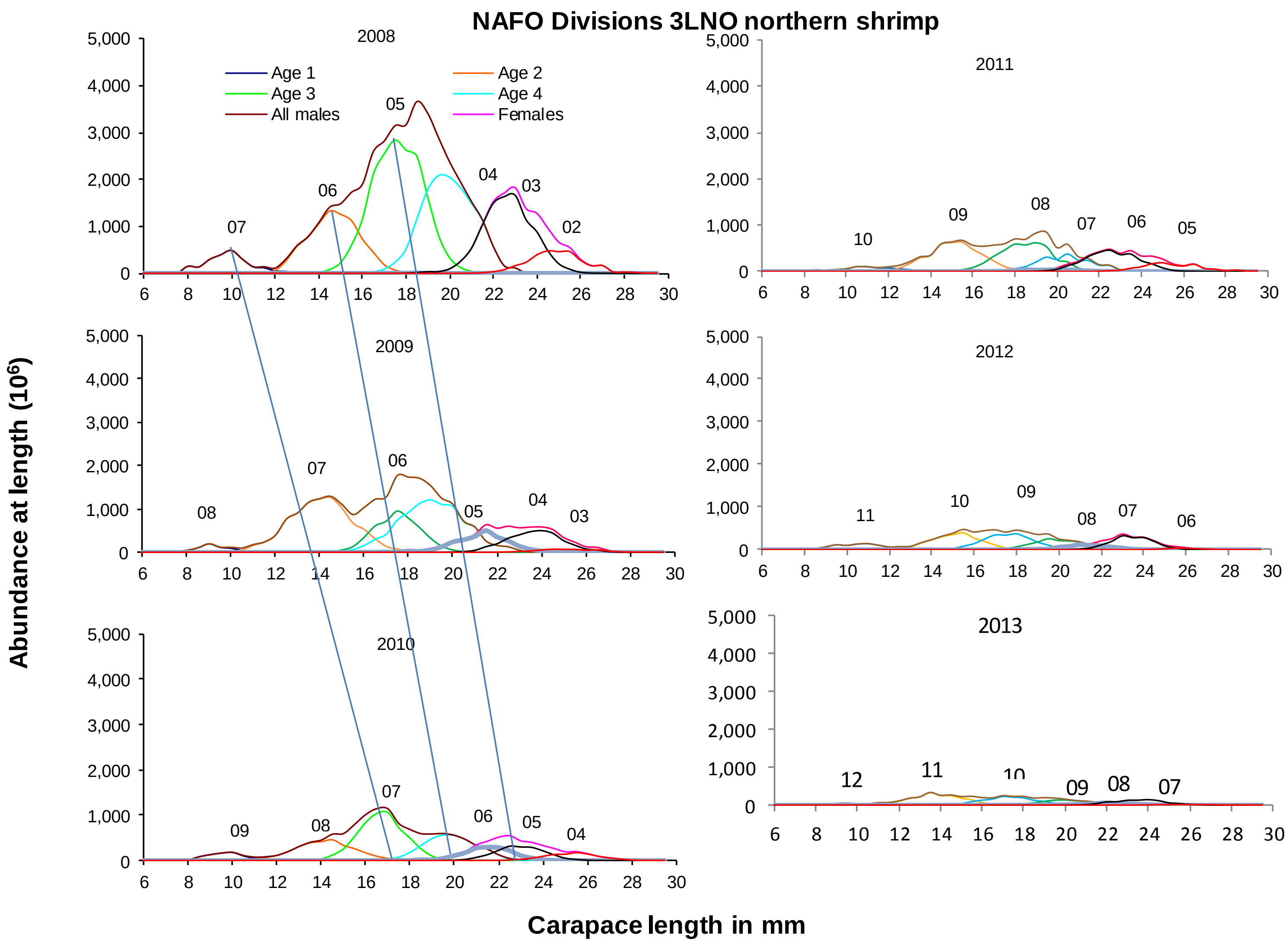


Figure 20. (Continued)

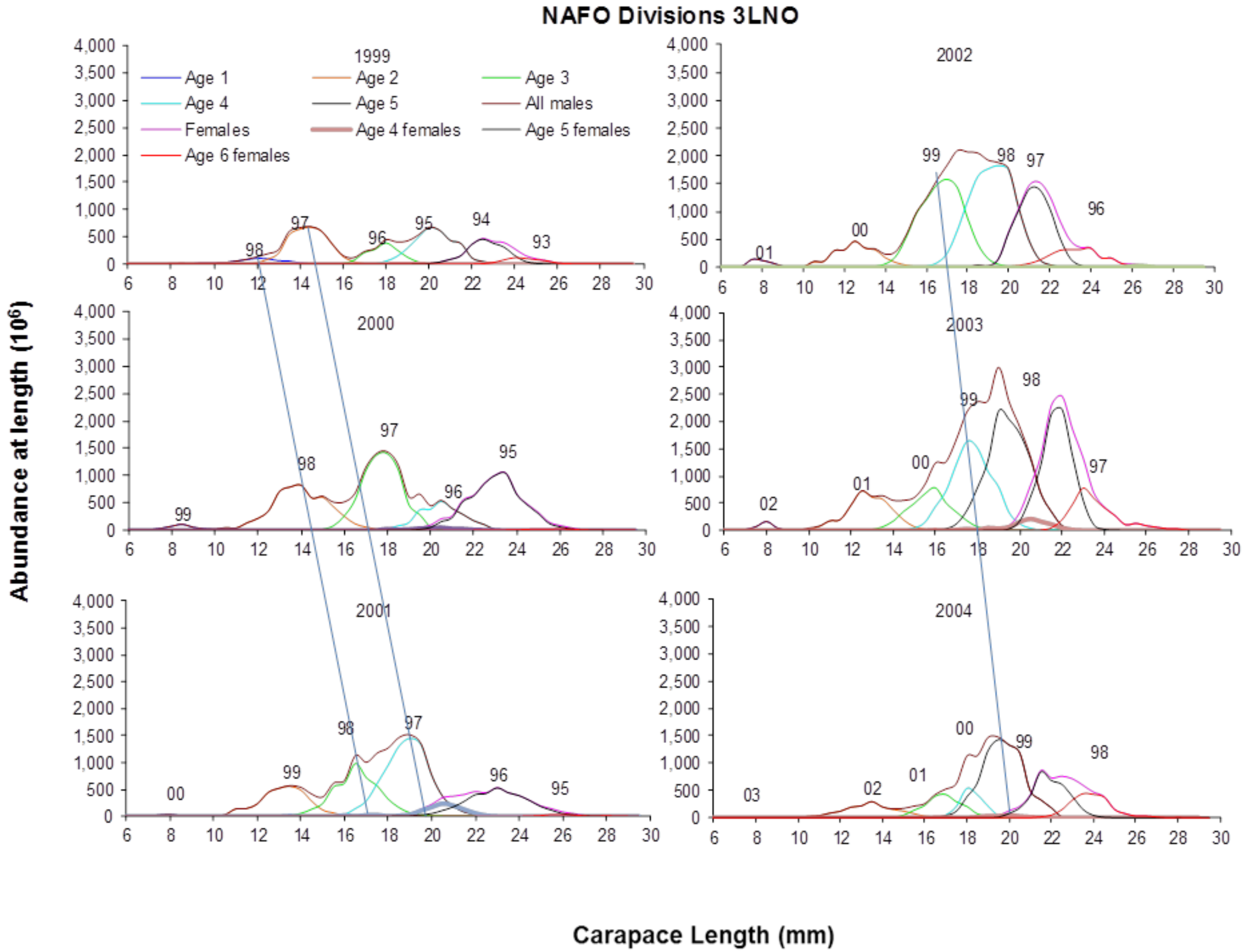


Figure 21. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual spring Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each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

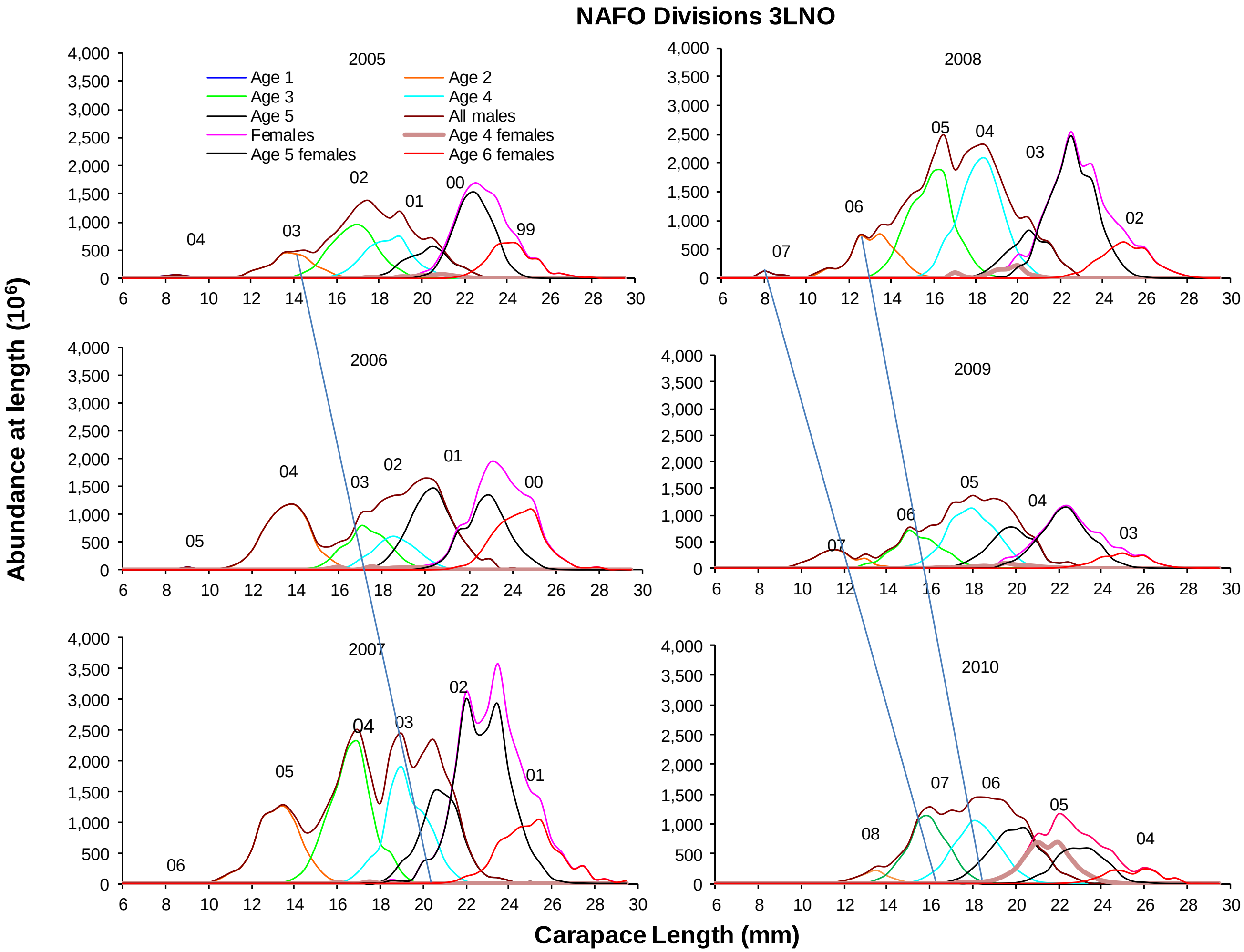


Figure 21 (Continued)

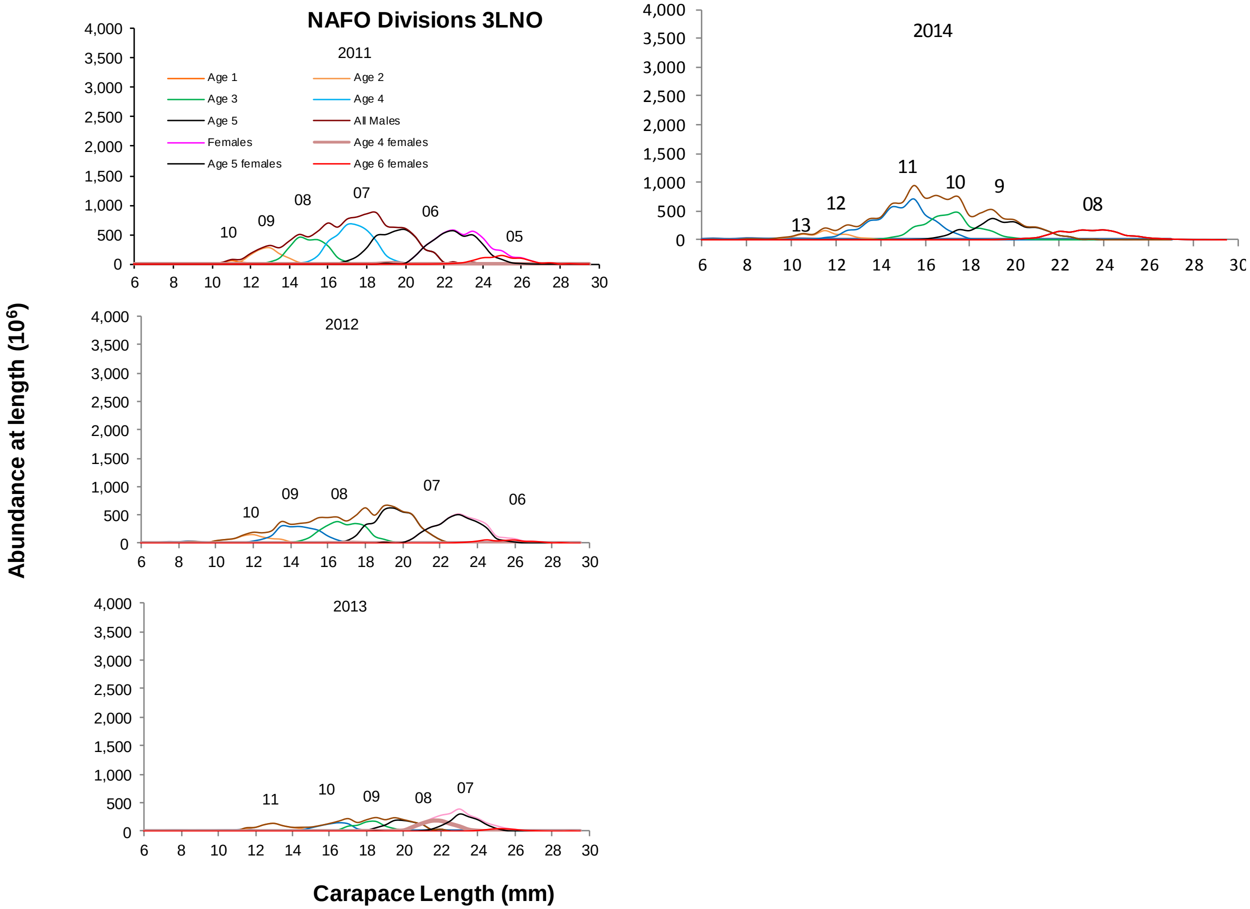


Figure 21 (Continued)

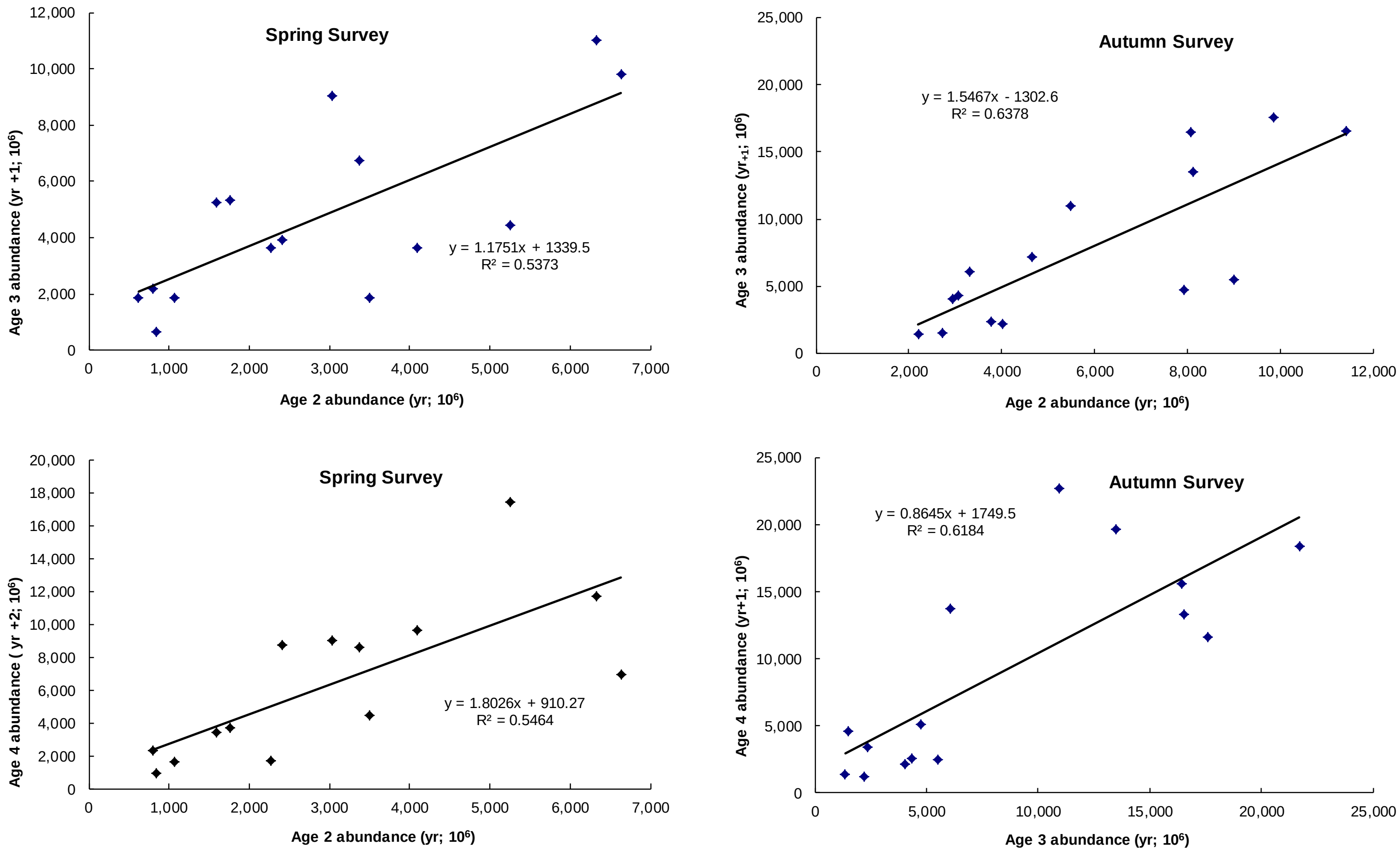


Figure 22. Relationship between abundance in one year and abundance in the successive year's). These data came from the autumn modal analysis provided in figures 21and 22 as well as tables 9 and 10.

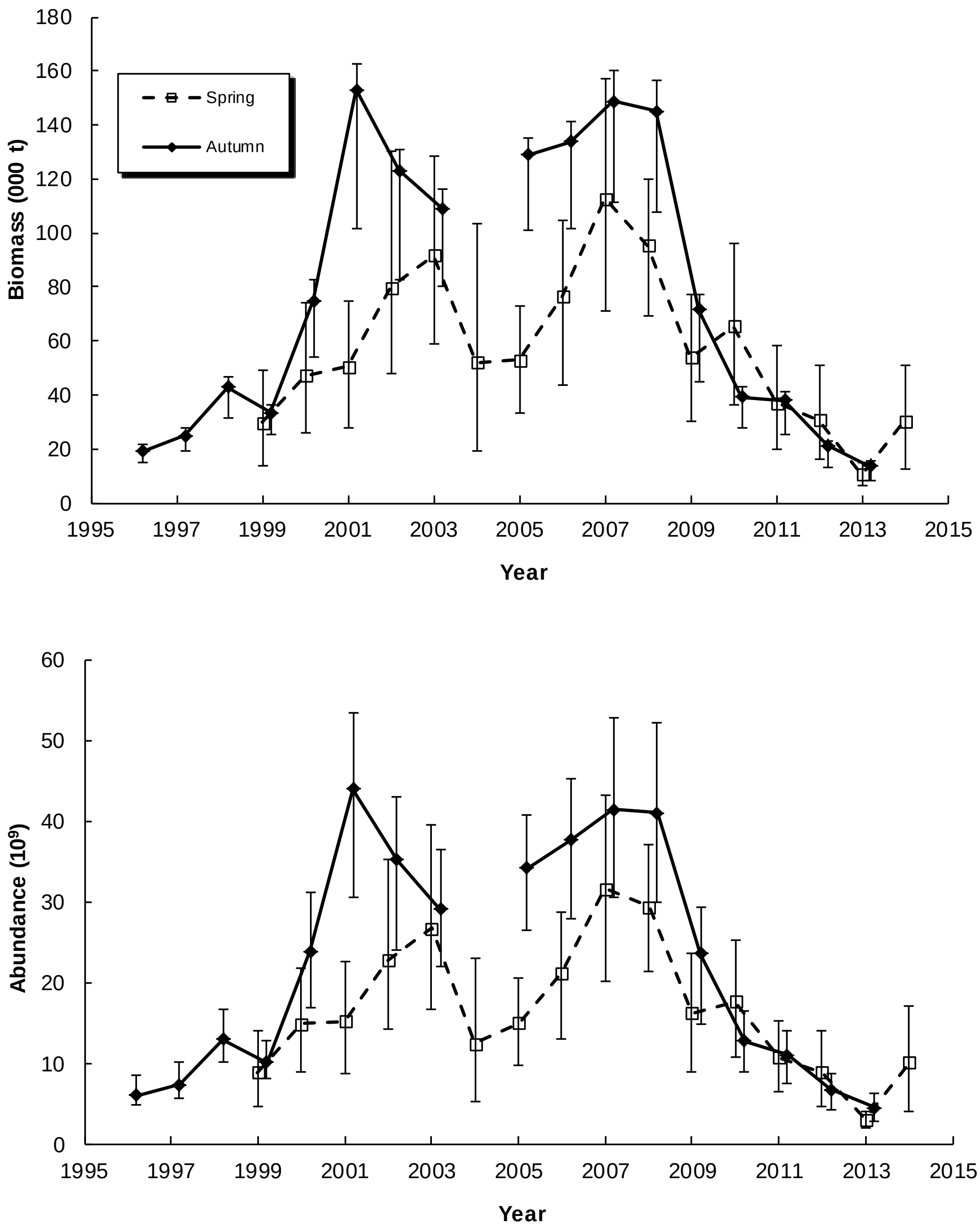


Figure 23. Abundance and biomass of male shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

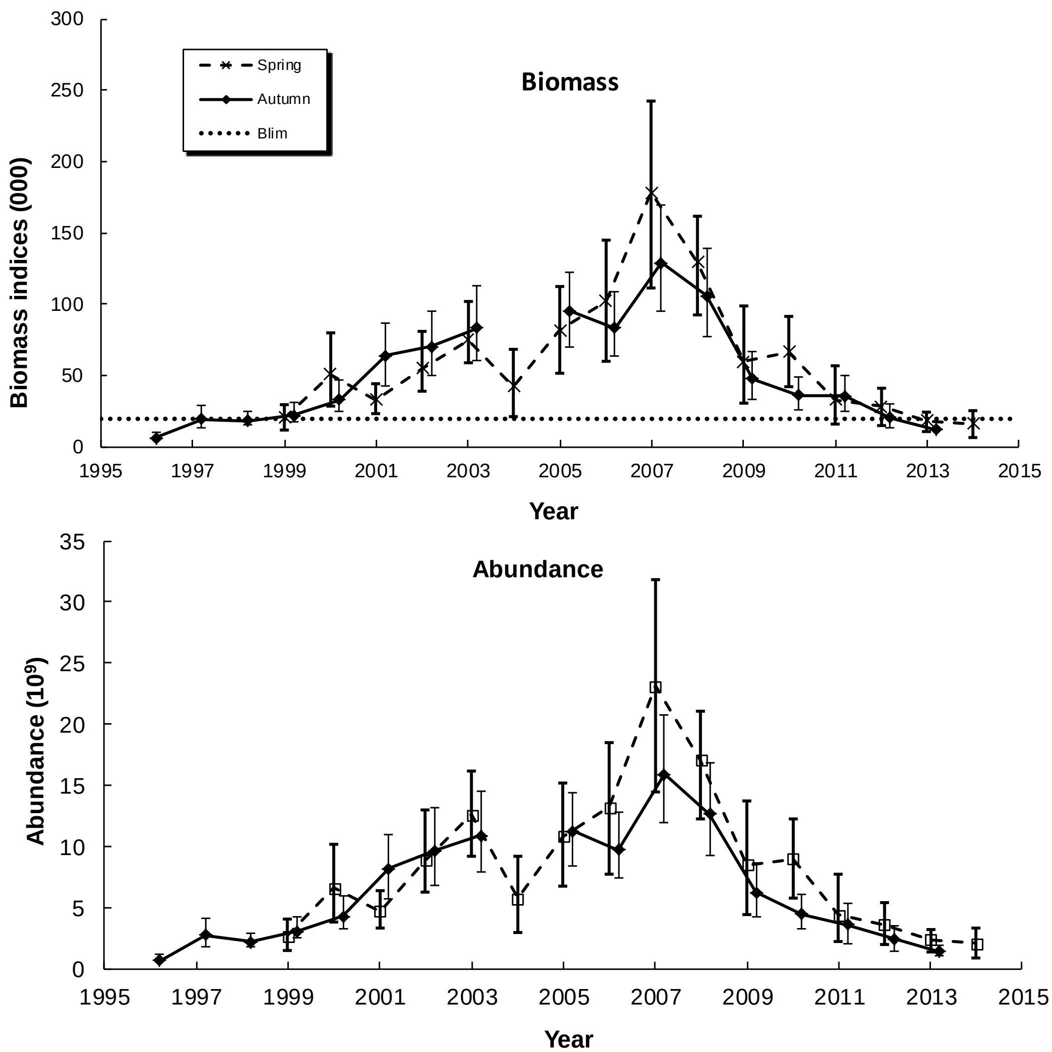
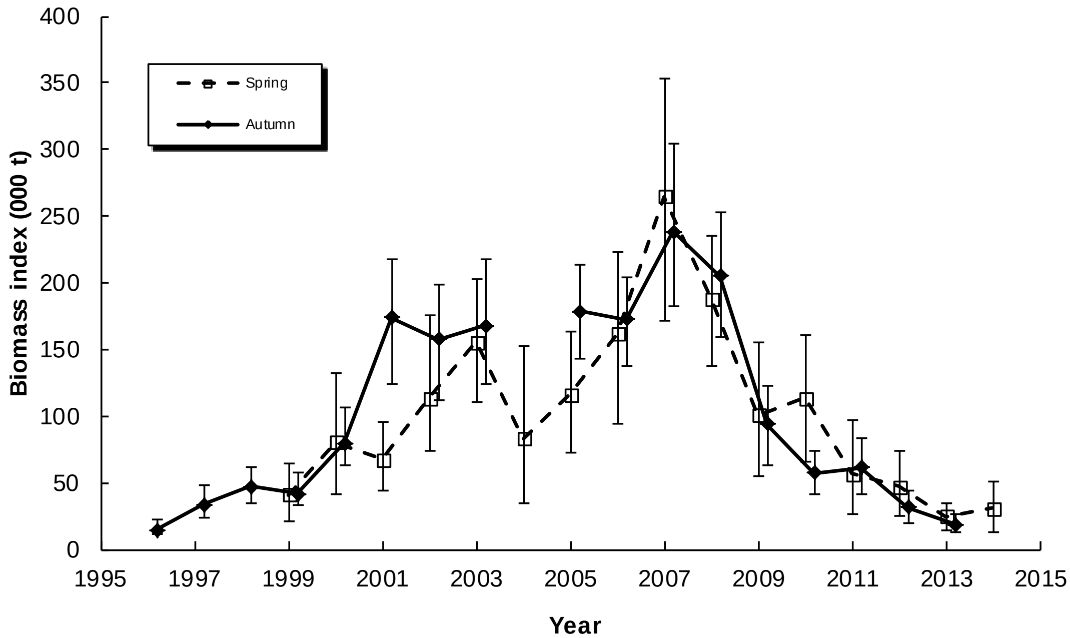


Figure 24. Abundance and biomass of female shrimp (SSB) within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations. The precautionary approach B_{lim} (19,300 t) is presented on the SSB presented from the autumn survey.



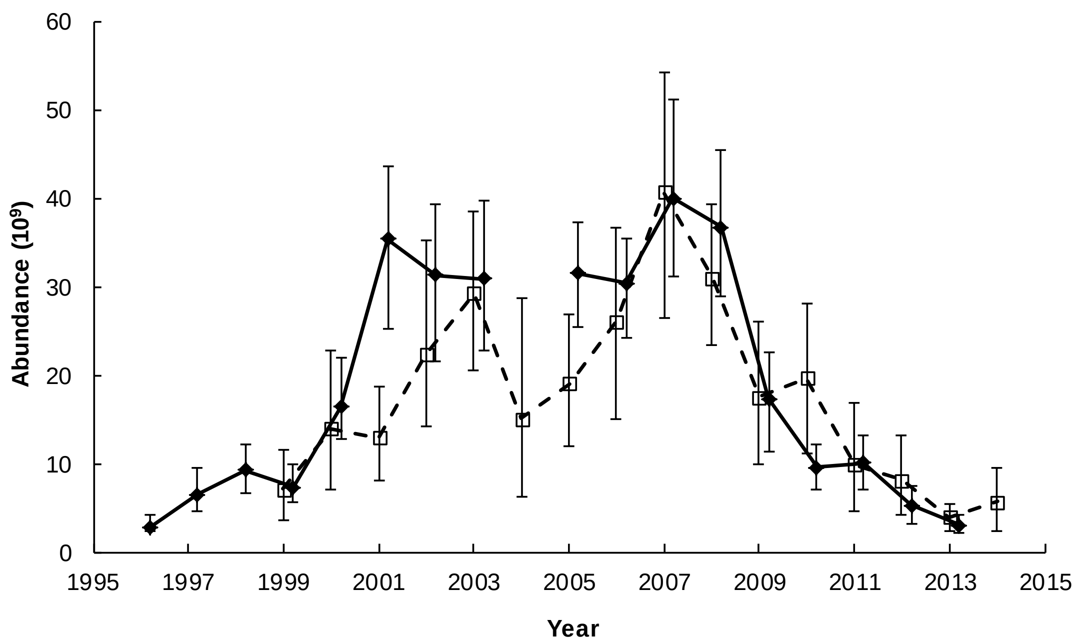


Figure 25. Fishable biomass (t) indices (weight of all females and males with carapace lengths =>17.5mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2014. The bars represent 95% confidence intervals around the fishable biomass indices.

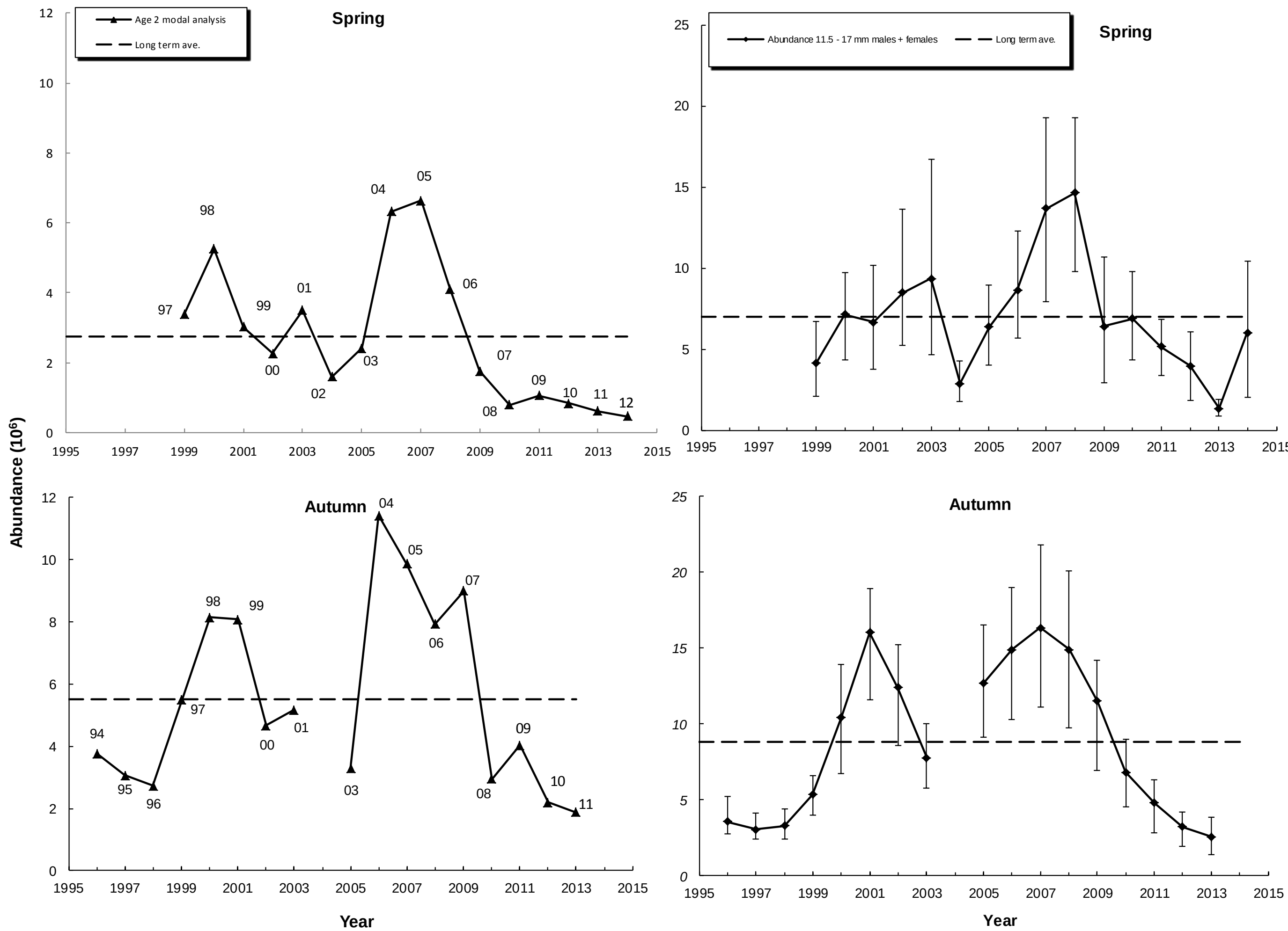
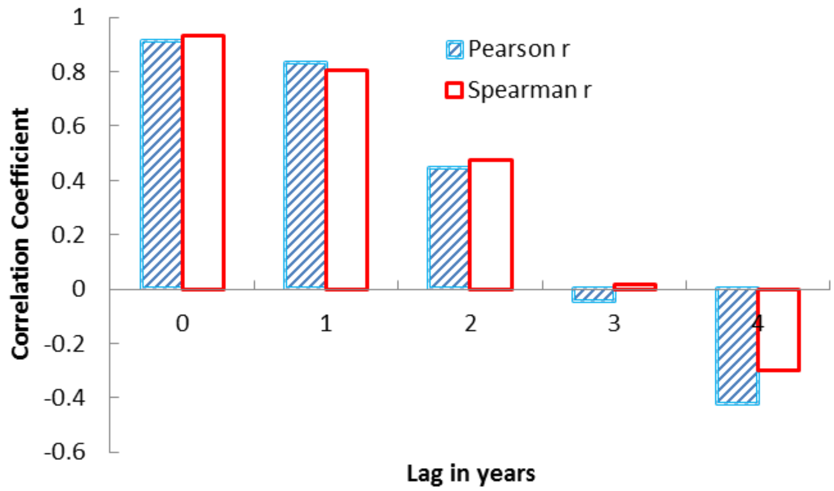


Figure 26. Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, autumn 1996 – spring 2014. The bars represent 95% confidence intervals around the index. Numbers within the modal analysis graphs are cohort years.



Spearman correlation

r =	0.93137	0.80357	0.47253	0.01648	-0.3007
p =	<.0001	0.0003	0.088	0.9574	0.3423

Pearson correlation

				-	-
r=	0.91272	0.83036	0.4434	0.04464	0.42196
p =	<.0001	0.0001	0.1123	0.8849	0.1718

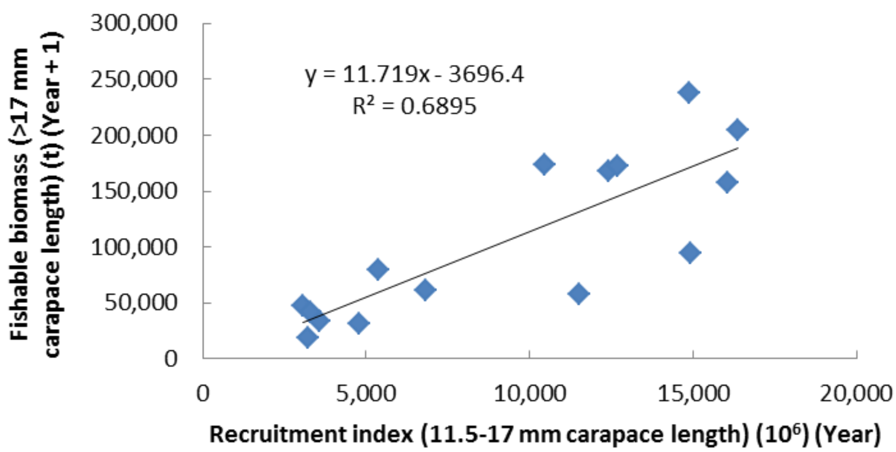
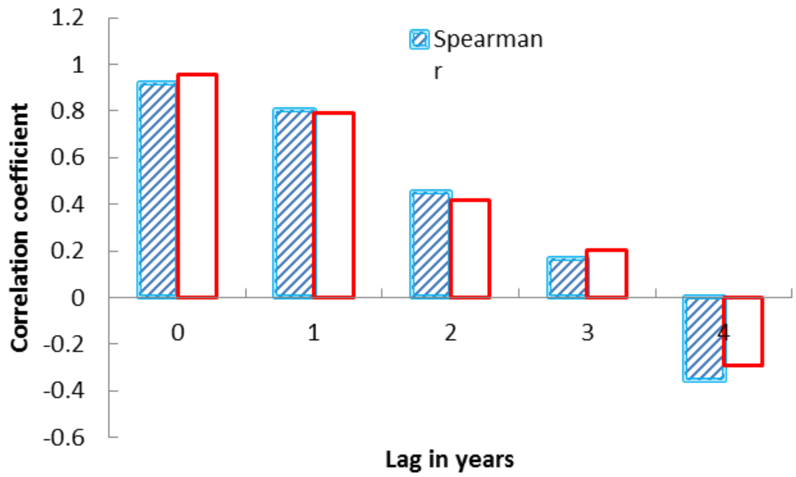


Figure 27. Correlation coefficient and regression analysis making use of recruitment index to determine fishable biomass in the following year. The recruitment abundance and fishable biomass were estimated from the autumn survey data sets.



Spearman correlation

r =	0.91911	0.80503	0.45077	0.16512	-0.35952
p =	<.0001	0.0003	0.1057	0.5898	0.251

Pearson correlation

r =	0.95833	0.78929	0.41538	0.2033	-0.29371
p =	<.0001	0.0005	0.1397	0.5053	0.3541

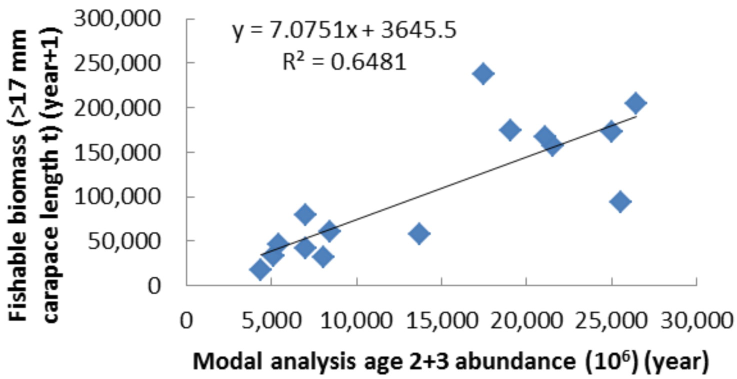


Figure 28. Correlation coefficient and regression analysis making use of age 2+3 modal abundance to determine fishable biomass in the following year. The modal abundance and fishable biomass were estimated from the autumn survey data sets.

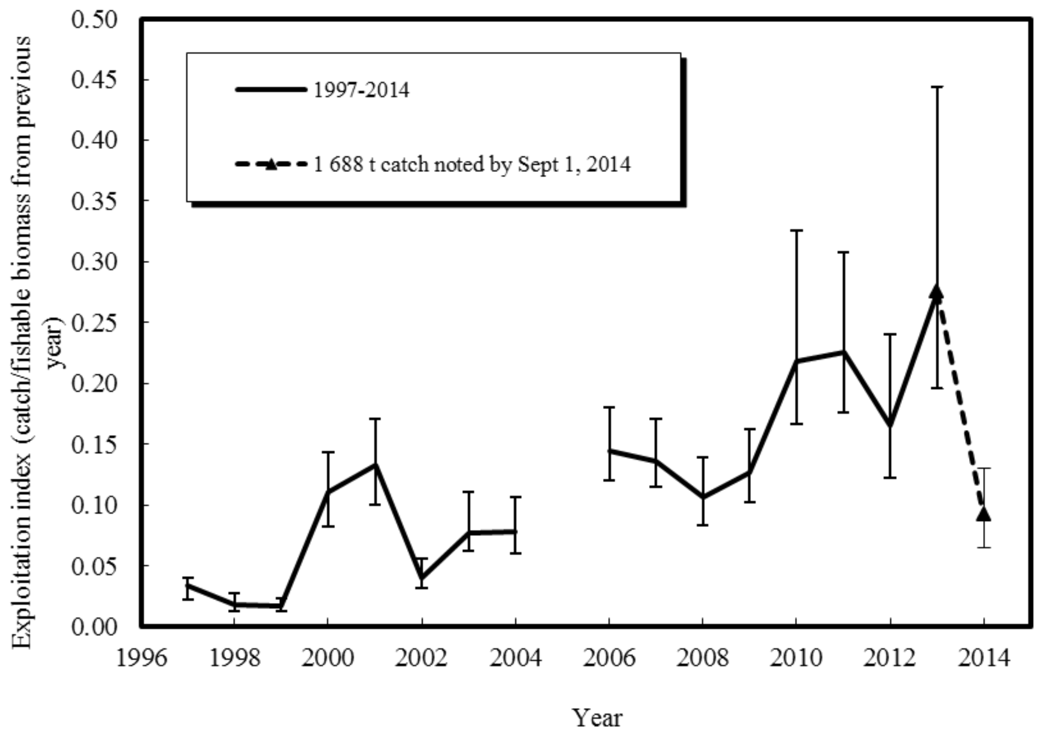


Figure 29. Trends in exploitation as derived by catch divided by the previous year's **autumn** fishable biomass index. The bars represent 95% confidence intervals around the exploitation rates for the proposed method.

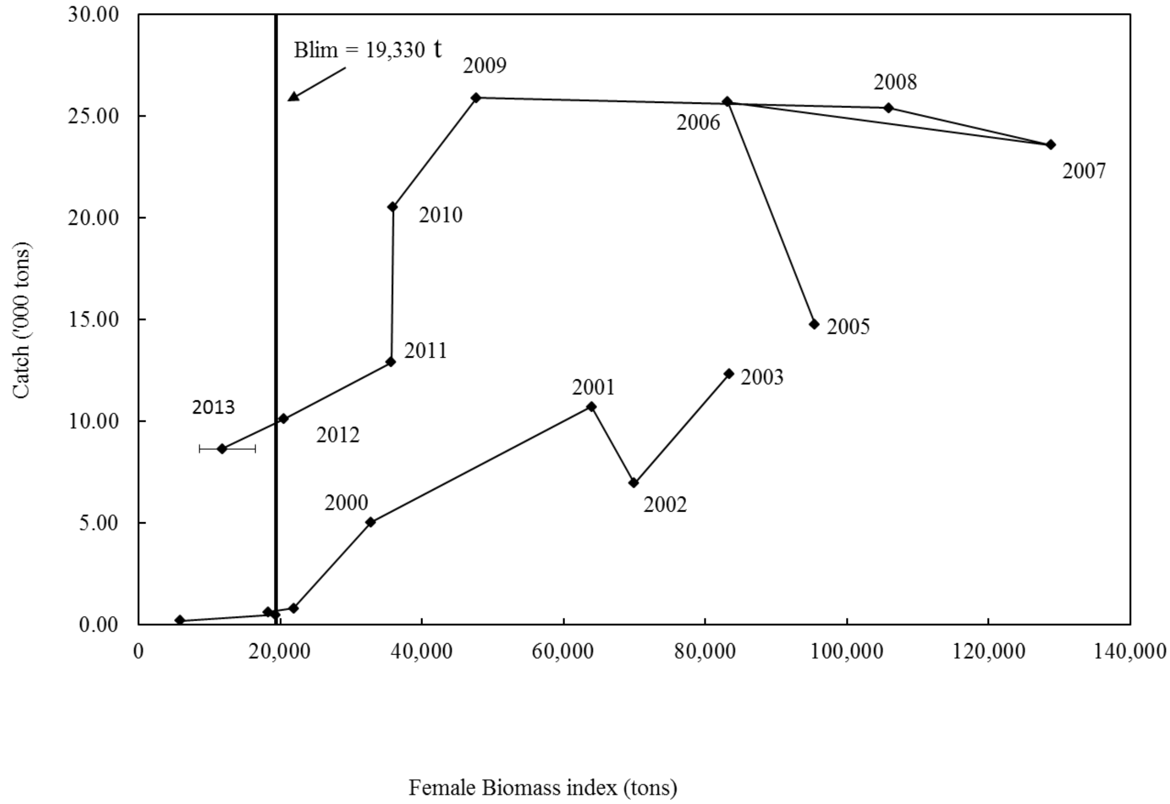


Figure 30. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).