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The 2013 assessment of the Northern Shrimp (*Pandalus borealis,* Kroyer) resource in NAFO Divisions 3LNO

by

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ABSTRACT:

This paper describes the 2013 northern shrimp (*Pandalus borealis,* Kroyer) assessment completed for NAFO divisions 3LNO. Status of the resource was inferred by examining trends in commercial catch, catch-per-unit effort, fishing pattern and size and sex compositions of catches, as well as, Canadian multi-species survey bottom trawl indices. The catch table (to September 10, 2013) and biomass estimates (autumn 1996 – spring 2013) are updated within this report. Preliminary data indicate that 10 100 t of shrimp were taken against a 12 000 TAC in 2012 while 6 000 t were taken against an 8 600 t TAC by August 23, 2013.

The spring female spawning stock biomass (SSB) index decreased by 90% from 177,900 t in 2007 to 18 100 t in 2013 while the autumn SSB index decreased by 84% from 128,900 t in 2007 to 20 400 t in 2012. The autumn 2012 SSB is very close to 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, while the autumn 3LNO total biomass index dropped by 85% from 277,600 t in 2007 to 41 700 t in 2012. Similarly, the spring fishable biomass index decreased by 95% from 265,000 t in 2007 to 24 700 t in 2012 while the autumn fishable biomass decreased by 87% from 239,700 t in 2007 to 31 700 t in 2012.

Standardized catch rates for large (>500 t) Canadian vessels had been fluctuating around the long term mean between 2004 and 2008 but have since followed a descending trajectory and preliminary data suggest that the 2012 standardized CPUE was at the lowest level in the thirteen year time series. The Canadian small vessel (≤ 500 t; <65') standardized CPUE has been following a decreasing trend from 2005 to 2010, remaining at the 2010 level since. Small vessel catch rates over the 2001 – 2002 and 2010 – 2012 periods were statistically similar to 2001 values. Raw international catch rates have been declining since 2010. However, the concensus from the meeting was that the commercial catch rates reflected fishing performance rather than resource status and therefore should not be a part of the resource assessment.

Instantaneous total and natural mortality rate indices have been increasing at a time when commercial catches have decreased from 28 000 t in 2009 to 6 000 t by 2013.

Due to the continued drop in biomass, it was felt prudent to recalculate the TAC options. The revised values and exploitation rate indices based on various TACs are presented within this document.

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 8 600 t by 2013 due to continued declines in survey and commercial fishery indices. During the 2012 Fishery Commission meeting, the 2013TAC was set at 8 600 t.

Full assessments of the Divs. 3LNO shrimp resource are completed during the annual September NAFO – ICES Pandalus Assessment Group (NIPAG) shrimp assessment meetings just prior to the annual Fishery Commission (FC) meeting and provide information used by FC in setting 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; and
- 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:

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

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

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

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

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

T_m is the effect of m number of trawls;

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

e_{ijkml} is the error term assumed to be normally distributed $\mathrm{N}(0,\sigma^2/n)$ 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.

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

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

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

Spring samples

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

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

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

<u>Exploitation rate indices</u>

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.

<u>Female Spawning Stock biomass</u>

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

<u>Mortality</u>

Survival, annual mortality and instantaneous mortality estimates were calculated by various methods to gain a better understanding of the life history of the shrimp. Mortality estimates are important inputs for resource assessments. The survival of age 4+ males and total female abundances were compared with the surviving age 5 + males and total female abundances. The survival estimates were then used to determine total annual mortality (1-survival) and instantaneous mortality (Z=-ln(survival)).

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

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

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

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

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

RESULTS AND DISCUSSION:

FISHERY DATA

Catch trends

Catches increased dramatically since 1999, with the beginning of a regulated fishery (Fig 5). Table 1 and the following discussion provide the available numbers to date. Over the period 2002-2009, catches increased from 6 960 to 27 527 t. Due to declines in resource indices, the TACs have been steadily decreasing with the 2013 TAC being set at 8 600 t during the 2012 Fishery Commission meeting. Preliminary catch records indicate that 10 108 t of shrimp were taken from a 12 000 t TAC in 2012. By September of 2013, 6 020 t of shrimp had been taken, down from the 8 760 t taken by the same time in the previous year. As per NAFO agreements, Canadian vessels took most of the catch during each year. Canadian catches increased from 5 402 t in 2002 to 20 147 t in 2008 but have since decreased to 7 982 t in 2012. Canadian vessels had taken 5 842 t of shrimp by September 2013 down from the 7 821 t taken by this time last year.

Catches by other contracting parties increased from 661 t in 2000 to 7 642 t in 2009, however, preliminary data show that catches decreased to 2 126 t by 2012. Preliminary data indicate that non Canadian vessels took 178 t of Northern Shrimp by September 2013 while they took 939 t by the same period in the previous year. Table 1 provides a breakdown of catches by contracting party and year since 2002, while figure 1 indicates catches and TAC since 1993.

Canadian fleet

Since 2000, small (<=500 t; LOA<65’) and large (>500 t) shrimp fishing vessel catches have been taken from a broad area (Figs. 6 - 10) 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.

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. 11). In 2013, the small vessel fleet took its quota by July 18 and by the time that the analysis was run for this assessment, over 60% of the logbook data had been keypunched and edited. The large vessel fleet had taken only 60% of its quota by September 1, 2013.

Small vessel CPUE (2000 – 2012) was modeled using year, month and size class (class 1 <50’ LOA; 50’ LOA <=class 2< 60’ LOA; class 3 => 60’ LOA) as explanatory variables (Table 2). The model standardized data to 2001, class 3 and July values. The logbook dataset that was used in this analysis accounted for between 60% and 95% of the catch within any one year (Table 3). The final model explained 82% of the variance in the data and indicated that the annual, standardized catch rates increased from nearly 300 kg/hr over 2000 – 2002 period to 570 kg/hr by 2005 then returned to the 300 kg/hr level by 2010 remaining near that level since. 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. 12). No clear trends were found in the plots of residuals (Fig. 13). 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.

Observer data for 2013 was not available at the time of this assessment therefore the large vessel CPUE index ends in 2012. 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 40% and 100% of the catch within any one year (Table 5). The final model explained 74% of the variance in the catch rate data. Standardized catch rates for large Canadian vessels have been fluctuating around the long term mean between 2004 and 2008, increased in 2009 but have since been decreasing. The 2001 standardized catch rate index (1 210 kg/hr; Table 5 and Fig. 12) was similar to the 2004-08 and 2010 values but significantly lower than the 2002, 2003 and 2009 indices while higher than the 2011 and 2012 values. The 2012 CPUE index was 408 kg/hr (Tables 4 and 5; Fig. 12). There were no trends in the residuals around parameter estimates (Fig. 14).

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 9-10), asked for and were granted permission to fish within the NRA. However, low catch rates persisted.

Due to the fact that fishing patterns changed over the year, the meeting felt that catch rates reflected fishery performance rather than resource status.

International fleet

Preliminary data indicate that the international fleet took 2 126 t of shrimp in 2012 from a quota of 2000 t while only 178 t of shrimp were taken by September 10, 2013 from a quota of 1 248 t. By the same time last year, the international fleet took 373 t of shrimp.

The provisional datasheets indicated that the Faroese, EU and France (St. Pierre and Miquelon) were the only non-Canadian countries that fished in 3L during 2013. Catch rate data was provided by Estonia and Spain for Northern Shrimp fishery till 2013 and 2012 respectively.

The Statlant21B data was explored to determine whether a standardized international catch rate model could be created. The data was rather scant and came mainly from the Faroese fishing fleet. There was no indication as to whether Faroese data was representative of international fishing patterns. Additionally, this dataset provided only catch, effort and vessel size on a monthly basis and there was no information as to whether the same vessels fished each year, where they fished or whether single or double trawls were used. Therefore it was felt that a standardized model would be meaningless. The Statlant21B data was updated to the 2011 fishery only.

Figure 15 provides the raw Northern Shrimp catch rates for the Estonian, Spanish and Faroese fishing fleets over the period 2000 – 2013. Faroese catch rates increased from 100 kg/hr in 2000 to 400 kg/hr in 2003 remained at that level until 2011 with the exception of an increase during 2009. Spanish catch rates increased from 550 kg/hr in 2008 to 1 000 kg/hr in 2010 but had decreased to 400 kg/ hr by 2012. Estonian catch rates decreased from 1 100 kg/hr in 2010 to 330 kg/hr in 2013. The reduction in international catch rates is in agreement with the reduction of catch rates found by the Canadian large vessel fleet fishing in within the 200 Nmi limit.

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 with a continual decrease to approximately 4 countries by 2013. As biomass indices decreased, the catches allotted to individual countries has decreased from 334 t in 2009 to 34 t by 2013 leaving interpretations of CPUE rates indicators of resource status more questionable.

Size composition

Figure 16 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 70,000 animals per hour in 2003 to 90,000 animals per hour in 2005 were maintained at above 80,000 animals per hour until 2009 but have decreased to 50,000 animals per hour by 2012.

A time series of length frequencies from the large vessel catch is presented in figure 17. 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.

Length frequency data was not provided by the international fishing fleet.

RESEARCH SURVEY DATA

Stock size

The autumn 2009 – 2012 and spring 2010 – 2013 research catches were concentrated within NAFO Div. 3L at depths between 200 and 500 m (Figs 18 and 19). The spring 3LNO total biomass index dropped by 90% from 290,600 t in 2007 to 28 800 t in 2012, while the autumn 3LNO total biomass index dropped by 85% from 277,600 t in 2007 to 41 700 t in 2012. The total biomass indices have dropped by more than 40% since the respective indices from the previous year (Table 6; Figs 18 and 20). 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 18 and 19 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.

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 5.3 and 32.6% of the estimated total 3LNO biomass (Tables 7 and 8; Figs. 18 and 19). During the autumn, the percent biomass within the NRA ranged between 5.3 and 21.0%. Three year running averages were estimated in order to smooth the peaks and troughs within the data. They indicate that 9.4– 20.1% of the total 3LNO autumn biomass was within the NRA (Table 8). Over the period 1996 – 2012 the overall average autumn percent biomass within the NRA was 15.4%. During spring, the percent biomass within the NRA ranged between 6.3 and 32.6% (three year running average ranged between 10.3 and 27.5%) (Table 7). Over the period 1999 – 2013 the average spring percent biomass with the NRA was 20.4%. It must be noted that variances around the spring indices are greater than around autumn indices (Table 6; Fig. 20).

In all surveys, Division 3N accounted for 0.2-8.1% of the total 3LNO biomass (Tables 6 and 7). 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 - 2012 and spring 1999 – 2013 surveys are presented in figures 21 and 22 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 21, 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. 21 and 22). Figures 23 and 24 provide 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. 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 2012 (2010, 2009 and 2008 year classes respectively) survey with carapace length frequency modes at 15.38 mm, 17.84 mm and 20.16 mm as males respectively and as age 4 and 5 females at 21.6 mm and 23.70 mm respectively (Table 9; Fig. 21). The 2005 year class first appeared as a strong year classes in the autumn of 2006 as one year old animals. This year class remained strong in the male and female distributions through to autumn 2011. This appeared to be the strongest year class that could be tracked through time. The successive year classes appeared weaker.

The spring survey male biomass indices showed a general increasing trend from 29 600 t (9 billion animals) in 1999 to 91 700 t (27 billion animals) in 2003, dropped to 52 100 t (12 billion animals) 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 (Table 11; Fig. 25). The autumn surveys showed an increase in biomass of male shrimp from 33 400 t (10 billion animals) in 1999 to 153,000 t (44 billion animals) in 2001, remaining at a high level until 2008. The autumn 2012 male survey biomass index was estimated to be 21 200 t (7 billion animals), a decrease of 86% since 2007 and a decrease of 44% since the previous year when the male biomass was 38 000 t (11 billion animals).

The spring female spawning stock biomass (SSB) index decreased by 90% from 177,900 t (23 billion animals) in 2007 to 18 100 t (2 billion animals) in 2013 while the autumn SSB index decreased by 84% from 128,900 t (16 billion animals) in 2007 to 20 400 t (2 billion animals) in 2012. The autumn 2012 SSB is very close to the B_{Lim} which is set as an autumn (SSB) of 19 330t (Table 12; Fig. 26). Figure 27 provides the predictive linear relationship between spring SSB and the following autumn SSB (adjusted r^2 = .76). Given a spring 2013 SSB of 18 100 t and this relationship, the autumn 2013 SSB is predicted to be 12 300 t which will be well below B_{Lim}, however, there are broad 95% predictive confidence limits this value.

As with the other biomass indices, the spring fishable biomass index decreased by 91% from 265,000 t in 2007 to 24 700 t in 2013 while the autumn fishable biomass decreased by 87% from 239,700 t in 2007 to 31 700 t in 2012 (Table 13; Fig. 28).

It is important to note that the abundance and biomass indices for both the male, female SSB and fishable portions of the resource are significantly below the long term mean for each respective index 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 1996-2012 and spring 1999 - 2013 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 - 10 year classes were the weakest recorded (Tables 9 and 14; Figs. 21 and 29). 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. 22 and 29). The spring time series shows a downward trend in abundances of age 2 animals from the 05-08 cohorts with 08- 11 being the weakest in the time series.

The size class method allows the direct calculation of confidence intervals, but will not allow the identification of age classes because each index probably consists of a combination of age 2 - 4 animals. The autumn 1996 – 1999 and 2011 - 2012 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. 29).

Figure 30 presents the relationship between spring and autumn recruitment indices using both modal analysis and size class methods. When the autumn recruitment index is predicted from spring index, 65 and 46 percent of the variance are accounted for in the relationships for modal and size class methods respectively.

Various correlation coefficient analyses were conducted to determine whether recruitment indices could be used to predict fishable biomass using various lags and whether fishable biomass could be used to predict commercial catch rates. The only significant correlation coefficients were from fishable biomass with either a 0 or 1 year lag versus age 2 or 11.5 – 17 mm abundances. While a 0 lag does not provide a useful prediction, it does make sense that a 0 lag would have a strong relationship because as noted earlier there appear to be three regimes, one in which abundances of all age groups was low followed by a time over which all sizes appeared more abundant and finally a return to the lower abundances of all animals. A partial correlation coefficient was run using Proc Reg (SAS 9.03) to determine whether apparently strong 1 year lags were being masked by 0 year lag relationships. The partial correlation coefficient of fishable biomass versus 11.5 – 17 mm abundances with a 1 year lag was insignificant. The partial correlation coefficient of fishable biomass versus age 2 abundance with a 1 year lag was the only significant relationship (Table 17). The final model had an adjusted r^2 value of 0.37 and is provided in table 18 and figure 31. Cook's d statistic provided evidence that the data points for the 2006 and 2010 survey points were influential (fig 31). An analysis of covariance (Table 19) indicated that the removal of these data points did not significantly alter the slope or the final model.

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 20). Until 2010, exploitation had been below 15% even though catches have increased over time because the stock parameters also increased. However, after 2007 the stock parameters began to decrease dramatically causing the 2010 exploitation rate to increase to 22%. The 2013 exploitation rate index is expected to increase as this assessment was completed while the fishery was ongoing and fishers noted that they normally wait until later in the year to fish that part of their quota. At the time of this assessment, the total catch was 6 020 t resulting in an exploitation rate of 19%. If the entire 8 600 t quota was to be taken, the exploitation rate index would increase to 27.1% (Fig. 32).

For this reason, TAC options were recalculated, prior to the September Fishery Commission meeting, using the Autumn 2011 – Spring 2013 survey fishable biomass estimates (Table 21). It is important to remind ourselves that the biomass has been in decline since 2007 and that the fishable biomass has declined by almost 50% in either of the spring or autumn surveys since the previous year, therefore the provision of TAC options based upon past averaging four surveys probably gives an erroneously positive view and if we believe that the autumn 2012 survey provides an accurate estimate then a TAC that gives a 15% exploitation rate will now be ((5 089 t/31 714 t)*100) 16%. More importantly, if the decreasing trend continues then the 2013 fishable biomass will be much lower than 31 714 t and the exploitation may be much higher than predicted in table 21.

Mortality Estimates

Table 22 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, exploitation rate based upon abundances, total annual mortality and instantaneous total mortality are 0.36, 0.12, 0.64 and 1.01 respectively (Table 21). As demonstrated in table 21, a total annual mortality rate of 0.64 which reasonable as it would allow the animals to survive at least 6 years which fits the demographics presented in tables 16 and 17. These mortality rates are within the range of values presented in Shumway (1985) and Bergström (2000). Both table 22 and figure 33 demonstrate that total instantaneous mortality indices have been increasing since 2007 regardless of exploitation rates.

Precautionary Approach

Scientific Council considers that the point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} for northern shrimp in Div. 3LNO. It is not possible to calculate a limit reference point for fishing mortality. Figure 34 presents the precautionary plot of exploitation rate on the ordinate axis and female spawning stock biomass on the abscissa. The autumn 2012 SSB index is 20 438 t which is slightly above 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 known whether switching vessels has an impact upon the biomass/ abundances indices reported on in this assessment.

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

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

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

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

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 for 2013 and therefore the Canadian large vessel commercial CPUE model could not be updated to include that year's fishery data.

The individual international fleet quotas have decreased from 334 t a few years ago to 34 t in 2013 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 is normally 2 years out of date, therefore the Faroese CPUE index could not be updated to include 2013 values.

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 90% from 177,900 t in 2007 to 18 100 t in 2013 while the autumn SSB index decreased by 84% from 128,900 t in 2007 to 20 400 t in 2012. The autumn 2012 SSB is very close to the BLim 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, while the autumn 3LNO total biomass index dropped by 85% from 277,600 t in 2007 to 41 700 t in 2012. Similarly, the spring fishable biomass index decreased by 95% from 265,000 t in 2007 to 24 700 t in 2012 while the autumn fishable biomass decreased by 87% from 239,700 t in 2007 to 31 700 t in 2012.

Mortality rate indices have been increasing since 2007 even though catches have been decreasing over this period.

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Table 1. Annual nominal catches (t) by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3L between 2002 and September 2013.

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Canada	5,402[1]	9,953[1]	10,313[1]	11,495[1]	17,996[1]	18,027[1]	20,147[1]	19,885[1]	13,212[1]	9,276[1]	7,982[2]	5,842[3]
Cuba	70[1]	81[1]	145[4]	136[1]	239[1]	240[1]	207[4]	334[4]	.	.		
Estonia	450[5]	299[5]	271[5]	569[5]	1,098[5]	1,453[5]	1,452[6]	1,607[6]	2,001[6]	1,336[6]	917[6]	23[6]
European Union												17[4]
Faroe Islands	620[4]	25[1]	1,050[1]	1,055[1]	1,521[1]	1,798[1]	2,273[1]	2,949[1]	2,503[1]	1,446[2]	1,036[2]	138[4]
Germany										301[1]		
Iceland	54[1]	133[1]	104[2]	140[1]	216[8]				184[1]	126[1]		
Latvia	59[1]	144[1]	143[1]	144[1]	244[1]	310[1]	278[1]	330[1]	384[1]	325[1]	134[2]	
Lithuania	67[10]	142[1]	144[1]	216[1]	486[1]	245[1]	278[1]		340[10]			
Norway	78[9]	145[9]	165[9]	144[9]	272[9]	250[9]	345[9]	664[9]	320[9]			
Poland		145[1]	144[1]	129[1]	245[1]							
Portugal								329[1]	15[1]		5[2]	
Russia	67[2]		141[1]	146[2]	248[2]	112[2]	278[2]	335[2]	28[2]			
Spain		151[5]	140[5]	154[5]	305[5]	190[5]	187[5]	272[5]	347[5]	292[5]	34[2]	
St. Pierre and Miquelon	36[1]	144[1]				245[1]	278[1]	334[1]	334[1]			
Ukraine		144[1]	145[1]		121[1]							
United States	57[1]	144[1]		136[1]	245[1]	245[1]	278[3]		334[1]	214[3]		
West Greenland		671[10]	299[10]	311[10]	453[10]	455[10]	648[10]	488[10]	534[10]			
Estimated additional catch					2,000							
Total catch	6,960	12,321	13,204	14,775	25,689	23,570	26,649	27,527	20,536	13,316	10,108	6,020
TAC (tonnes)	6,000	13,000	13,000	13,000	22,000	22,000	25,000	30,000	30,000	19,200	12,000	8 600

Sources:

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

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	13	2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Month	9	4 5 6 8 9 10 11 12 99
Size_class	3	1 2 3

Number of Observations Read	202
Number of Observations Used	202

The GLM Procedure

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	16156.26205	734.37555	36.57	<.0001
Error	179	3594.08409	20.07868		
Corrected Total	201	19750.34614			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.818024	72.99513	4.480924	6.138661

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	12	12819.33713	1068.27809	53.20	<.0001
Month	8	2633.08145	329.13518	16.39	<.0001
Size_class	2	703.84347	351.92174	17.53	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	12	10988.09053	915.67421	45.60	<.0001
Month	8	2900.16276	362.52035	18.05	<.0001
Size_class	2	703.84347	351.92174	17.53	<.0001

Table 2 (Continued)

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	6.058378352	B	0.06335854	95.62	<.0001
Year 2002	0.060355414	B	0.07584131	0.80	0.4272
Year 2003	0.214030723	B	0.06599183	3.24	0.0014
Year 2004	0.318027828	B	0.07366404	4.32	<.0001
Year 2005	0.690756217	B	0.07700870	8.97	<.0001
Year 2006	0.569344556	B	0.06757059	8.43	<.0001
Year 2007	0.420599665	B	0.06661962	6.31	<.0001
Year 2008	0.486371911	B	0.06723607	7.23	<.0001
Year 2009	0.301092329	B	0.06385953	4.71	<.0001
Year 2010	0.049450449	B	0.06734717	0.73	0.4637
Year 2011	-0.096326753	B	0.06828871	-1.41	0.1601
Year 2012	-0.135742568	B	0.06966348	-1.95	0.0529
Year 2013	-0.001205969	B	0.08354330	-0.01	0.9885
Year 2014	0.000000000	B	.	.	.
Month 4	-0.187113528	B	0.07387396	-2.53	0.0122
Month 5	-0.318434665	B	0.03912589	-8.14	<.0001
Month 6	-0.076045296	B	0.02969092	-2.56	0.0113
Month 8	-0.072387688	B	0.03104931	-2.33	0.0208
Month 9	-0.311845699	B	0.04363104	-7.15	<.0001
Month 10	-0.433264664	B	0.05517897	-7.85	<.0001
Month 11	-0.420202532	B	0.08635057	-4.87	<.0001
Month 12	-0.900569493	B	0.33725632	-2.67	0.0083
Month 99	0.000000000	B	.	.	.
Size_class 1	-0.175064040	B	0.04148791	-4.22	<.0001
Size_class 2	-0.111814178	B	0.02302168	-4.86	<.0001
Size_class 3	0.000000000	B	.	.	.

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

Table 2. (Continued)

Year	lncpue LSMEAN	95% Confidence Limits	
2002	5.720901	5.587749	5.854053
2003	5.874576	5.765235	5.983917
2004	5.978573	5.859289	6.097857
2005	6.351301	6.223749	6.478854
2006	6.229890	6.124387	6.335392
2007	6.081145	5.978270	6.184019
2008	6.146917	6.043295	6.250539
2009	5.961638	5.863699	6.059576
2010	5.709996	5.604626	5.815366
2011	5.564218	5.461171	5.667265
2012	5.524803	5.414032	5.635573
2013	5.659339	5.516025	5.802654
2014	5.660545	5.524706	5.796385

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 CPUE	UNSTANDARDIZED Geometric mean CPUE) (KG/HR)	UNSTANDARDIZED CPUE RELATIVE TO 2001	UNSTANDARDIZED [3] EFFORT (HR)	STANDARDIZED CPUE RELATIVE TO 2001	STANDARDIZED MODELLED CPUE (KG/HR)	STANDARDIZED EFFORT (HRS)
1999		17	CPUE model begins in 2001						
2000	2,500	3,422							
2001	2,500	2,674	79.3%	293	1.000	9,136	1.000	287	9,307
2002	2,500	4,226	64.0%	343	1.171	12,335	1.062	305	13,848
2003	6,566	9,347	65.8%	377	1.288	24,792	1.239	356	26,265
2004	6,566	6,517	93.1%	513	1.753	12,701	1.374	395	16,504
2005	6,566	7,271	92.1%	724	2.474	10,041	1.995	573	12,684
2006	12,297	12,159	92.9%	607	2.072	20,047	1.767	508	23,949
2007	12,297	12,576	95.1%	546	1.865	23,041	1.523	438	28,743
2008	14,209	14,933	91.5%	597	2.040	25,005	1.626	467	31,958
2009	14,209	15,093	87.6%	437	1.494	34,516	1.351	388	38,875
2010	17,369	8,857	83.6%	360	1.230	24,595	1.051	302	29,340
2011	10,514	7,110	87.9%	306	1.046	23,216	0.908	261	27,250
2012	5,985	6,190	92.8%	318	1.088	19,439	0.873	251	24,677
2013	4,007	4,031	61.1%	361	1.235	11,151	0.999	287	14,047

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

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

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

Table 4. Multiplicative year, month, ship and gear type model for **Canadian large (> 500 t)** vessels fishing northern shrimp (*Pandalus borealis*) in NAFO Division 3L over the period 2001 – 2012. (Weighting by effort, no windows, observer data, history of at least 2 years in the fishery with the first year of the fishery for any vessel removed).

Class Level Information

Class	Levels	Values
year	12	2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2014
month	12	1 2 3 4 5 6 7 8 9 10 11 12
CFV	17	
gear	2	66 99

Number of Observations Read	224
Number of Observations Used	224

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	39	4763.519209	122.141518	13.24	<.0001
Error	184	1696.978947	9.222712		
Corrected Total	223	6460.498156			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.737330	42.08923	3.036892	7.215365

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	11	2533.251373	230.295579	24.97	<.0001
month	11	1051.918899	95.628991	10.37	<.0001
CFV	16	774.104791	48.381549	5.25	<.0001
gear	1	404.244147	404.244147	43.83	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	11	1628.293059	148.026642	16.05	<.0001
month	11	1138.259874	103.478170	11.22	<.0001
CFV	16	709.466419	44.341651	4.81	<.0001
gear	1	404.244147	404.244147	43.83	<.0001

Table 4 (Continued)

Parameter	Estimate		Standard Error	t Value	Pr > |t|
Intercept	6.101229736	B	0.17425588	35.01	<.0001
year 2002	0.322487965	B	0.15966158	2.02	0.0449
year 2003	0.849886849	B	0.17223277	4.93	<.0001
year 2004	0.185192683	B	0.15198694	1.22	0.2246
year 2005	0.142702357	B	0.14836193	0.96	0.3374
year 2006	0.286205832	B	0.15083639	1.90	0.0593
year 2007	0.246003190	B	0.14982225	1.64	0.1023
year 2008	0.140292828	B	0.15959039	0.88	0.3805
year 2009	0.398426779	B	0.15948914	2.50	0.0134
year 2010	-0.209849780	B	0.16876079	-1.24	0.2153
year 2011	-0.581607401	B	0.18272558	-3.18	0.0017
year 2012	-1.087043829	B	0.18348140	-5.92	<.0001
year 2014	0.000000000	B	.	.	.
month 1	0.937837568	B	0.09487677	9.88	<.0001
month 2	0.807413880	B	0.10301244	7.84	<.0001
month 3	0.570123206	B	0.09414433	6.06	<.0001
month 4	0.507693211	B	0.11655026	4.36	<.0001
month 5	0.468630783	B	0.13529412	3.46	0.0007
month 6	0.523505445	B	0.11238210	4.66	<.0001
month 7	0.471180920	B	0.14765124	3.19	0.0017
month 8	0.334109826	B	0.18532271	1.80	0.0730
month 9	0.051117921	B	0.19761227	0.26	0.7962
month 10	0.269927832	B	0.10595498	2.55	0.0117
month 11	0.169009728	B	0.10682565	1.58	0.1153
month 12	0.000000000	B	.	.	.

Table 4. (Continued)

Parameter	Estimate		Standard Error	t Value	Pr > |t|
CFV	0.260848422	B	0.13543092	1.93	0.0556
CFV	0.386165258	B	0.16811234	2.30	0.0227
CFV	0.531874952	B	0.18768259	2.83	0.0051
CFV	0.342333441	B	0.11918991	2.87	0.0046
CFV	0.435484692	B	0.12242643	3.56	0.0005
CFV	0.396071677	B	0.13663151	2.90	0.0042
CFV	0.488715223	B	0.14423602	3.39	0.0009
CFV	0.695017201	B	0.20912942	3.32	0.0011
CFV	0.950175520	B	0.19727037	4.82	<.0001
CFV	0.662896288	B	0.12039375	5.51	<.0001
CFV	0.506967572	B	0.10263512	4.94	<.0001
CFV	0.509954989	B	0.38094778	1.34	0.1823
CFV	-0.435649903	B	0.22171016	-1.96	0.0509
CFV	-0.289606076	B	0.23973493	-1.21	0.2286
CFV	0.000000000	B	.	.	.
gear double	0.454695163	B	0.06867960	6.62	<.0001
gear single	0.000000000	B	.	.	.

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

year	lncpue LSMEAN	95% Confidence Limits	
2002	7.420906	7.166045	7.675766
2003	7.948305	7.688744	8.207865
2004	7.283610	7.073083	7.494137
2005	7.241120	7.053616	7.428624
2006	7.384624	7.202348	7.566899
2007	7.344421	7.190182	7.498659
2008	7.238711	7.053517	7.423904
2009	7.496845	7.318051	7.675638
2010	6.888568	6.686160	7.090976
2011	6.516810	6.284303	6.749317
2012	6.011374	5.773636	6.249112
2014	7.098418	6.849670	7.347166

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

YEAR	TAC	CATCH [1] (t)	PERCENT OF CATCH DATA CAPTURED IN MODEL [2]	UNSTANDARDIZED GEOMETRIC MEAN CPUE (KG/HR)	CPUE RELATIVE TO 2001	EFFORT [3] (HR)	STANDARDIZED CPUE RELATIVE To 2000	MODELLED CPUE	EFFORT (HRS)
2000	1,686	960	Model begins with 2001 data						
2001	2,500	2,336	64%	902	1.000	2,588	1.000	1,210	1,930
2002	2,500	1,176	135%	1,502	1.664	783	1.381	1,671	704
2003	4,267	4,038	66%	3,531	3.913	1,144	2.339	2,831	1,427
2004	4,267	3,796	69%	1,218	1.349	3,118	1.203	1,456	2,607
2005	4,277	4,224	71%	1,422	1.575	2,971	1.153	1,396	3,027
2006	5,273	5,835	54%	709	0.786	8,225	1.331	1,611	3,622
2007	5,907	5,451	87%	1,094	1.212	4,983	1.279	1,548	3,522
2008	6,568	3,972	99%	1,560	1.729	2,546	1.151	1,392	2,853
2009	6,022	3,165	127%	1,100	1.218	2,878	1.489	1,802	1,756
2010	7,594	4,355	46%	757	0.838	5,755	0.811	981	4,439
2011	5,480	2,439	43%	590	0.653	4,138	0.559	676	3,606
2012	4,015	1,829	41%	273	0.303	6,691	0.337	408	4,482

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

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

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

Table 6. NAFO Divisions 3LNO northern shrimp biomass and abundance indices as calculated using Ogmap. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1996 – 2013. (Offshore strata only with standard 15 min. tows).

Spring

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	27,174	49,736	76,708	6,609	11,496	17,418	313
2000	66,157	114,070	177,902	13,239	21,502	31,805	298
2001	53,038	83,061	117,896	12,333	19,852	28,734	300
2002	87,984	134,710	206,092	20,871	31,476	47,984	300
2003	117,997	170,753	224,114	26,549	39,232	54,156	300
2004	41,239	94,136	170,250	8,228	18,121	32,107	297
2005	86,212	134,307	184,748	16,914	25,727	35,097	290
2006	108,130	178,405	247,975	21,405	34,318	46,655	196
2007	191,493	290,562	381,779	35,580	54,675	73,285	295
2008	171,961	224,718	279,085	35,389	46,310	56,361	273
2009	63,277	113,265	168,639	14,528	24,613	35,419	299
2010	76,557	131,589	184,043	16,220	26,625	37,070	288
2011	34,775	69,872	114,775	8,544	15,085	22,905	297
2012	32,338	58,495	88,468	7,040	12,387	18,737	289
2013	17,387	28,794	39,205	3,389	5,350	7,222	292

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

percentage biomass decrease since 2007 90
percentage biomass decrease since 2012 51

Please note that during 2006, it was not possible to sample all allocated stations within 3NO; however, all stations within 3L were sampled during that year. The 2006 estimates are for Div. 3L only since at least 90% of the biomass and abundance is found within that division (Tables 14 and 15; Figs. 22 and 23).

Autumn

Year	Biomass (tonnes)			Abundance (numbers x 10^6)			Survey
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1996	20,287	24,868	35,248	5,378	6,625	9,454	304
1997	32,630	44,299	62,361	7,601	9,984	13,964	318
1998	48,649	61,113	77,171	12,031	15,082	19,260	347
1999	43,453	55,273	72,892	10,692	13,085	16,632	313
2000	84,561	107,728	140,147	21,032	28,091	36,074	337
2001	156,356	216,965	261,365	37,141	52,084	62,462	362
2002	136,421	193,004	241,129	31,322	44,777	55,132	365
2003	144,979	192,299	245,055	30,677	39,939	49,927	316
2004	???						
2005	178,707	224,114	266,399	35,731	45,390	54,095	335
2006	174,076	216,865	253,714	36,698	47,354	56,079	312
2007	216,059	277,575	352,179	43,917	57,239	71,946	361
2008	197,131	250,995	303,852	41,017	53,614	65,462	256
2009	80,020	119,205	150,215	19,713	29,688	36,184	332
2010	56,572	75,107	94,337	12,645	17,035	21,092	318
2011	51,578	73,496	94,720	10,853	15,298	19,270	261
2012	26,580	41,682	57,428	5,842	9,116	11,931	287

percentage biomass decrease since 2007 85
percentage biomass decrease since 2011 43

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

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 – 2013 **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.

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 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	97.07	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	100.00	6.20	???
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	0.35	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	???
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
	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	20.49
Spring	2001		85,779	97.42	11,578	100.00	13.50	21.87
Spring	2002		134,710	100.15	37,755	100.00	28.03	20.60
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		???	???	???	???	???	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	10.13
Spring	2013		28,794	100.35	1,812	100.00	6.29	???

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 – 2012 **autumn** Canadian multi-species surveys using a Campelen 1800 shrimp trawl (standard 15 min. tows). All indices were estimated using Ogmap calculations.

			Entire Division		Outside 200 Nmi limit			
Season	Year	Division	Biomass estimate (t)	Percent by division	Biomass estimate (t)	Percent biomass by division	percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1996	3L	23,056	92.71	4,027	85.11	17.47	???
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	19.02
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	???
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	???
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	1996	3O	0	0.00	0	0.00	0.00	0.00
Autumn	1997	3O	0	0.00	0	0.00	0.00	0.00
Autumn	1998	3O	101	0.16	0	0.00	0.00	0.00
Autumn	1999	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2000	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2001	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2002	3O	101	0.05	0	0.00	0.00	0.00
Autumn	2003	3O	201	0.10	0	0.00	0.00	0.00
Autumn	2004	3O	201	???	0	???	???	???
Autumn	2005	3O	101	0.04	0	0.00	0.00	0.00
Autumn	2006	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2007	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2008	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2009	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2010	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2011	3O	0	0.00	0	0.00	0.00	0.00
Autumn	2012	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		107,728	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	???

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 – 2012). 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)

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

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)

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

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

NAFO Divisions 3LNO
Mean Carapace Length (Standard Error)

Year	Male Age						Female Age		
	0	1	2	3	4	5	4	5	6
1999		12.43 (.454)	14.63 (.055)	18.15 (.069)	20.51 (.053)		19.20 (.280)	22.54 (.122)	24.45 (.580)
2000		8.73 (.044)	14.22 (.034)	18.00 (.024)	20.74 (.070)		20.44 (.216)	23.27 (.032)	25.80 (.419)
2001		8.39 (.131)	13.45 (.027)	16.82 (.008)	19.13 (.024)		20.84 (.17)	23.26 (.16)	26.15 (.41)
2002		8.27 (.061)	12.85 (.029)	16.97 (.021)	19.43 (.018)		21.50 (.042)	23.52 (.38)	26.59 (.119)
2003		8.37 (.065)	13.09 (.003)	16.01 (.091)	17.96 (.086)	19.69 (.040)	20.55 (.92)	21.69 (.041)	23.40 (.052)
2004		8.55 (.288)	13.66 (.094)	17.13 (.299)	18.47 (.090)	19.96 (.026)	20.09 (.154)	22.18 (.034)	24.06 (.041)
2005		8.93 9.078)	14.10 (.052)	17.07 (.130)	18.69 (.212)	20.59 (.088)	21.0 (.276)	22.69 (.044)	24.36 (.061)
2006		9.57 (.148)	13.84 (.019)	17.53 (.189)	18.83 (.412)	20.52 (.054)	19.58 (.107)	23.05 (.049)	24.55 (.054)
2007		9.37 (.157)	13.48 (.018)	16.89 (.025)	19.46 (.063)	21.08 (.041)		23.04 (.086)	25.17 (.290)
2008		8.85 (.072)	13.39 (.032)	16.14 (.036)	18.46 (.038)	20.78 (.038)	19.88 (.093)	22.81 (.043)	25.35 (.172)
2009			11.87 (.037)	15.67 (.058)	18.20 (.070)	20.12 (.059)	19.89 (.153)	22.56 (.033)	25.27 (.061)
2010		9.35 (.086)	13.54 (.053)	16.16 (.042)	18.43 (.042)	20.25 (.064)	21.73 (.118)	23.27 (.135)	25.54 (.096)
2011		11.32 (.115)	13.10 (.066)	15.25 (.066)	17.53 (.067)	19.74 (.052)		22.86 (.038)	25.24 (.092)
2012			12.21 (.096)	14.64 (.119)	17.11 (.117)	19.78 (.044)		23.17 (.043)	25.56 (.176)
2013			13.38 (.045)	16.51 (.093)	18.37 (.142)	20.14 (.069)	22.03 (.106)	23.53 (.096)	25.56 (.150)

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

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.		

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

Table 11. Male biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2013) and autumn (1996 – 2012) research bottom trawl survey data.

Spring

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

percentage decrease since 2007	91
percentage decrease since 2012	54

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

Autumn

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

percentage drop since 2007	86
percentage drop since 2011	44

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

Table 12. Female biomass/ abundance indices estimated using Ogmap calculations from Canadian spring (1999 – 2013) and autumn (1996 – 2012) research bottom trawl survey data.

Spring

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	6,606	10,199
2001	23,287	32,721	44,168	3,253	4,680	6,404
2002	38,993	54,971	80,685	6,251	8,816	12,978
2003	58,747	74,906	101,989	9,158	12,564	16,169
2004	21,384	42,084	67,778	2,951	5,731	9,156
2005	51,347	81,349	112,560	6,724	10,818	15,193
2006	59,552	101,888	144,375	7,744	13,182	18,525
2007	111,654	177,902	242,739	14,468	23,126	31,765
2008	92,545	129,474	161,591	12,223	17,014	21,082
2009	30,506	59,401	98,153	4,421	8,465	13,692
2010	41,490	66,247	90,773	5,719	8,992	12,283
2011	16,028	32,822	57,025	2,188	4,375	7,661
2012	15,011	27,989	41,359	1,961	3,594	5,351
2013	10,682	18,122	24,546	1,406	2,370	3,222

percent decrease since 2007	90
percent decrease since 2011	35

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

Autumn

Year	Biomass (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

percent decrease since 2007	84
percent decrease since 2011	43

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

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 – 2013. All indices were estimated using Ogmap calculations. Please note that the autumn 2004 survey did not occupy important strata within the shrimp resource therefore no estimations were made for that year. Strata deeper than 93 m were not surveyed in 3NO during spring 2006. Historically more than 97% of the shrimp have been attributed to strata within 3L therefore the spring 2006 estimates are for 3L.

Spring

Year	Biomass (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	160,484	264,990	352,682	26,529	40,625	54,246
2008	171,055	187,970	235,893	23,328	30,949	39,326
2009	55,132	100,579	155,047	9,801	17,501	26,026
2010	66,258	113,366	160,182	11,196	19,677	28,009
2011	26,429	56,280	96,331	4,583	9,807	16,904
2012	25,140	47,420	74,503	4,207	8,108	13,139
2013	14,337	24,667	33,899	2,281	3,969	5,474

percent decrease since 2007 91
percent decrease since 2012 48

Autumn

Year	Biomass (tonnes)			Abundance (numbers x 10^6)		
	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.
1996	12,192	14,297	22,381	2,331	2,777	4,257
1997	23,660	34,433	49,605	4,603	6,488	9,532
1998	34,896	47,219	62,230	6,713	9,253	12,142
1999	33,506	42,487	58,183	5,656	7,325	9,965
2000	63,086	80,443	107,526	12,676	16,332	21,908
2001	124,541	175,083	219,281	25,130	35,359	43,574
2002	111,755	159,880	200,051	21,515	31,249	39,205
2003	125,145	169,746	220,489	22,844	30,866	39,779
2004						
2005	143,670	179,915	215,959	25,472	31,528	37,292
2006	138,334	173,774	206,293	24,163	30,386	35,369
2007	183,439	239,719	306,973	31,100	39,905	51,025
2008	160,081	206,394	255,224	28,855	36,731	45,487
2009	63,741	95,042	124,440	11,306	17,247	22,613
2010	42,427	57,891	74,413	7,122	9,549	12,122
2011	42,316	61,515	83,272	10,853	15,298	19,270
2012	19,653	31,714	44,682	3,160	5,269	7,393

percent decrease since 2007 87
percent decrease since 2011 48

Table 14. Recruitment indices as determined from modal analysis of population adjusted northern shrimp length frequencies from spring (1999 – 2013) and autumn (1996 – 2012) 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		2011

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 – 2012) Canadian research survey data.

Spring

Year	11.5 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1999	2,108	4,159	6,712
2000	4,370	7,140	9,755
2001	3,772	6,703	10,219
2002	5,262	8,516	13,703
2003	4,646	9,384	16,753
2004	1,830	2,898	4,257
2005	4,033	6,374	8,973
2006	5,725	8,730	12,474
2007	7,914	13,688	19,320
2008	9,829	14,729	19,431
2009	2,945	6,451	10,702
2010	4,353	6,879	9,781
2011	3,374	5,142	6,834
2012	1,840	3,979	6,104
2013	880	1,344	1,888

Autumn

Year	11.5 - 17 mm recruitment index		
	Lower C.I.	Estimate (10^6)	Upper C.I.
1996	2,744	3,588	5,210
1997	2,474	3,073	4,164
1998	2,407	3,324	4,409
1999	4,052	5,378	6,600
2000	6,773	10,479	13,924
2001	11,679	16,089	18,948
2002	8,586	12,433	15,253
2003	5,822	7,833	10,088
2004			
2005	9,157	12,722	16,512
2006	10,310	14,966	19,079
2007	10,934	16,138	21,535
2008	9,775	14,927	20,136
2009	6,950	11,533	14,246
2010	4,554	6,843	8,994
2011	2,875	4,819	6,370
2012	1,957	3,238	4,239

Table 16. Predicting autumn fishable biomass from the previous year's autumn age 2 abundance index.

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	recruitment	Nolag	lag1	lag2	lag3
recruitment	1.00000	0.62647	0.63516	0.37363	-0.46154
		0.0094	0.0147	0.2086	0.1309
	16	16	14	13	12
nolag	0.62647	1.00000	0.71429	0.43956	0.10490
	0.0094		0.0041	0.1329	0.7456
	16	16	14	13	12
lag1	0.63516	0.71429	1.00000	0.67033	0.32168
	0.0147	0.0041		0.0122	0.3079
	14	14	15	13	12
lag2	0.37363	0.43956	0.67033	1.00000	0.62238
	0.2086	0.1329	0.0122		0.0307
	13	13	13	14	12
lag3	-0.46154	0.10490	0.32168	0.62238	1.00000
	0.1309	0.7456	0.3079	0.0307	
	12	12	12	12	13

Table 17. Regression analysis to determine whether the prediction of fishable biomass using age 2 abundance lagged by one year is being masked by within year age 2 abundance.

The REG Procedure
Model: MODEL1
Dependent Variable: fishable

Number of Observations Read	17
Number of Observations Used	14
Number of Observations with Missing Values	3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	44236325554	22118162777	10.74	0.0026
Error	11	22655783420	2059616675		
Corrected Total	13	66892108974			

Root MSE	45383	**R-Square**	0.6613
Dependent Mean	112524	**Adj R-Sq**	0.5997
Coeff Var	40.33174		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Squared Semi-partial Corr Type I	Squared Partial Corr Type I	Squared Semi-partial Corr Type II	Squared Partial Corr Type II
Intercept	**1**	-30255	33182	-0.91	0.3814	.	.	.	.
Nolag	**1**	12.88036	4.56505	2.82	0.0166	0.49454	0.49454	0.24512	0.41986
lag1	**1**	10.75750	4.62239	2.33	0.0401	0.16676	0.32993	0.16676	0.32993

Table 18. A regression model used to predict autumn fishable biomass from the previous year's age 2 abundance index.

The REG Procedure
Model: MODEL1
Dependent Variable: fishable

Number of Observations Read	17
Number of Observations Used	14
Number of Observations with Missing Values	3

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	27839844032	27839844032	8.55	0.0127
Error	12	39052264942	3254355412		
Corrected Total	13	66892108974			

Root MSE	57047	**R-Square**	0.4162
Dependent Mean	112524	**Adj R-Sq**	0.3675
Coeff Var	50.69746		

Parameter Estimates					
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	**1**	17767	35806	0.50	0.6287
lag1	**1**	15.71748	5.37381	2.92	0.0127

Table 19. Analysis of covariance to determine whether removal of influence data points had a significant effect upon the regression model prediction of fishable biomass lagged versus age 2 abundance from the previous year.

The GLM Procedure

Class Level Information		
Class	**Levels**	**Values**
group	3	1 2 3

Number of Observations Read	39
Number of Observations Used	39

The GLM Procedure

Dependent Variable: y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	110495774469	22099154894	9.07	<.0001
Error	33	80400353420	2436374346.1		
Corrected Total	38	190896127889			

R-Square	Coeff Var	Root MSE	y Mean
0.578827	43.39100	49359.64	113755.5

Source	DF	Type I SS	Mean Square	F Value	Pr > F
x	1	107941416992	107941416992	44.30	<.0001
group	2	631646476.12	315823238.06	0.13	0.8789
x*group	2	1922711001	961355500.48	0.39	0.6771

Source	DF	Type III SS	Mean Square	F Value	Pr > F
x	1	109803006040	109803006040	45.07	<.0001
group	2	1649948776.9	824974388.46	0.34	0.7152
x*group	2	1922711001	961355500.48	0.39	0.6771

Table 20. Exploitation rate indices for NAFO Divisions 3LNO northern shrimp as determined using Canadian autumn survey and total catch over the period 1997 – 2012. Ogmap methods were used in determining resource indices. The fishery was still ongoing at the time of this analysis therefore it is expected that the 2012 exploitation rate index will be higher once all of the catch has been updated at the end of the calendar year.

Year	Catch (t)	Lower 95% CL of biomass index (t)	Spawning Stock biomass (SSB) (t)	Fishable biomass (t)
1996	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	179,915
2006	25,697	174,076	83,162	173,774
2007	23,570	216,059	128,870	239,719
2008	25,407	197,131	105,915	206,394
2009	25,900	80,020	47,722	95,042
2010	20,536	56,572	35,943	57,891
2011	12,900	51,578	35,641	61,515
2012	10,108	26,580	20,438	31,714
2013	6,020			

Year	Catch / lower CL biomass	Catch/SSB	Catch/fishable biomass
1997	0.024	0.083	0.034
1998	0.019	0.032	0.018
1999	0.016	0.043	0.017
2000	0.108	0.216	0.111
2001	0.126	0.326	0.133
2002	0.045	0.109	0.040
2003	0.090	0.176	0.077
2004	0.091	0.158	0.078
2005			
2006	0.144	0.269	0.143
2007	0.135	0.283	0.136
2008	0.118	0.197	0.106
2009	0.131	0.245	0.125
2010	0.257	0.430	0.216
2011	0.228	0.359	0.223
2012	0.196	0.284	0.164
2013	0.226	0.295	0.190

Table 21. Inverse variance weighted average fishable biomass from the four most recent Canadian research surveys into 3LNO with exploitation rates based upon various TAC options.

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

Survey	Fishable biomass (t)	Fishable biomass – lower 95% C.I.= measure of variance	Fishable biomass/ (measure of variance^2)	1/measure of variance^2	Variance weighting factor
Autumn 2011	61,515	19,200	1.6688E-04	2.71277E-09	0.1293
Spring 2012	47,420	22,280	9.5525E-05	2.01442E-09	0.0960
Autumn 2012	31,714	12,061	2.1800E-04	6.87385E-09	0.3278
Spring 2013	24,667	10,330	2.3117E-04	9.37171E-09	0.4469
Grand total			7.1157E-04	2.097E-08	1.0

Inverse variance weighted average fishable biomass = 7.1157E-04/2.097E-08
= 33,928 t

TACs options at various percent exploitation rates (catch/fishable biomass)

inverse variance weighted average fishable biomass	5.00%	10.00%	15.00%	25.35%
33,928	1,696	3,393	5,089	8,600

Table 22. Survival, annual mortality and instantaneous mortality rate indices for northern shrimp (Pandalus borealis) within NAFO Divisions 3LNO. Indices were calculated using fishable abundance, age 4+ and age 5+ abundances as well as estimates of total removals. Indices were calculated by combining 3 years of data in order to account for vagaries within the survey data. The survival, S, in the light blue box is the abundance of age 5+ shrimp (green box) that survive from the previous year age 4+ shrimp (yellow box). Survey data were obtained from the Canadian autumn bottom trawl survey (1996 – 2012).

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 3+ males + female$_{(t)}$ abundance	Annual mortality rate = 1-survival	Instantaneous mortality rate = Z=-ln(survival)	Catch year	U Exploitation rate index catch abundance/fishable abundance from previous year
1996	1,040	470				1997	
1997	3,982	2,589				1998	
1998	4,984	1,624	0.72	0.28	0.33	1999	
1999	5,578	3,002	0.53	0.47	0.64	2000	
2000	7,570	3,037	0.72	0.28	0.32	2001	0.11
2001	29,797	7,075	0.30	0.70	1.20	2002	0.08
2002	22,429	2,760	0.34	0.66	1.07	2003	0.08
2003	26,208	10,628				2004	
2004						2005	
2005	18,995	10,817				2006	
2006	27,573	9,216				2007	0.14
2007	29,277	15,560	0.49	0.51	0.71	2008	0.13
2008	25,907	12,624	0.38	0.62	0.95	2009	0.12
2009	15,270	3,671	0.27	0.73	1.31	2010	0.13
2010	7,907	2,804	0.21	0.79	1.54	2011	
2011	6,556	4,063	0.29	0.71	1.24	2012	
2012	3,867	1,770				2013	

Survival statistics	Median values
Survival	0.36
Instantaneous rate of total mortality (Z)	1.01
exploitation rate	0.12
total annual mortality	0.64

rate total natural mortality = 0.64

N_o =	1,000
N_1 =	360
N_2 =	130
N_3 =	47
N_4 =	17
N_5 =	6
N_6 =	2

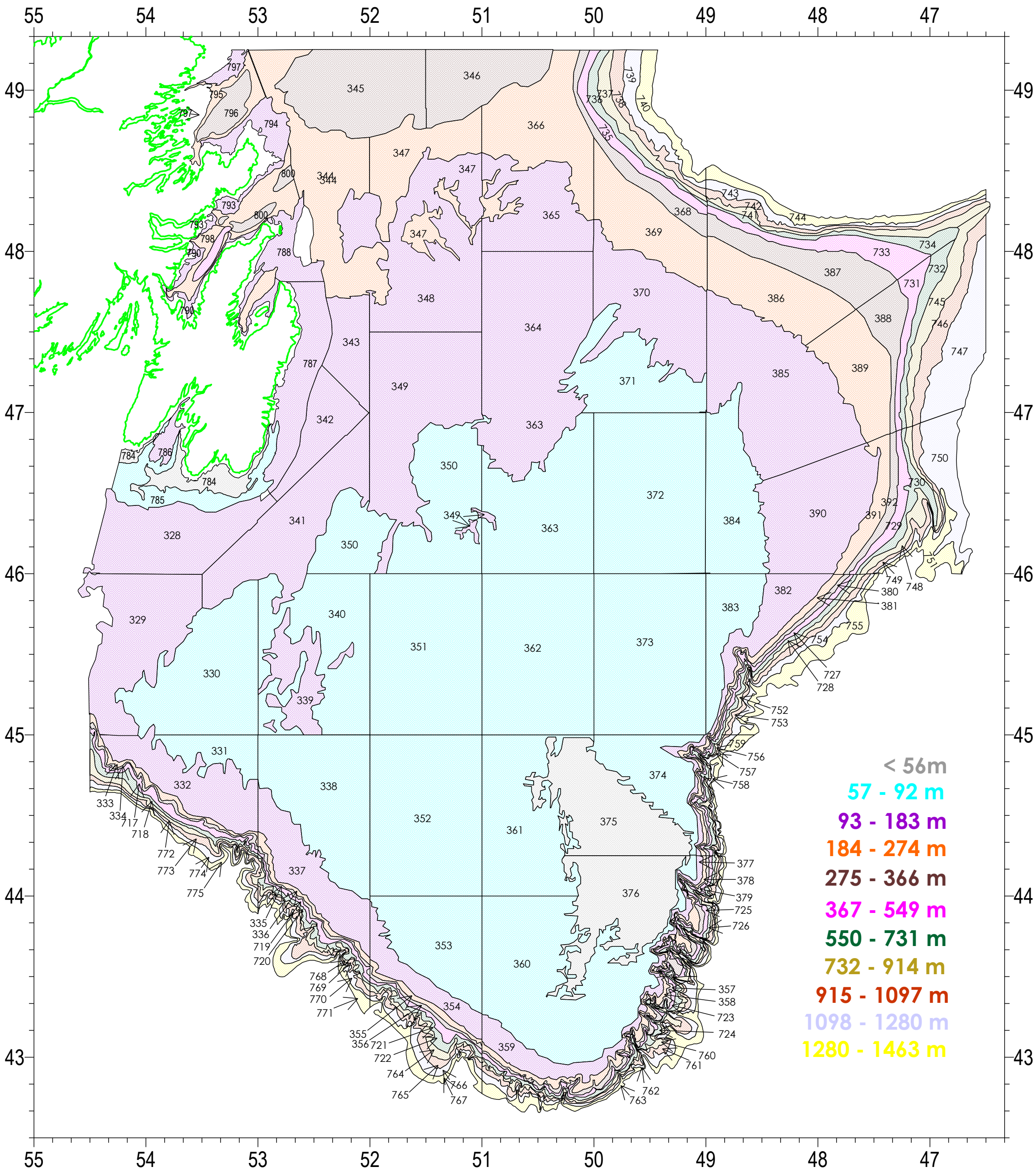


Figure 1. The NAFO Divisions 3LNO stratification scheme used in the Canadian multi-species research bottom trawl survey set allocation (G. Cossitt).

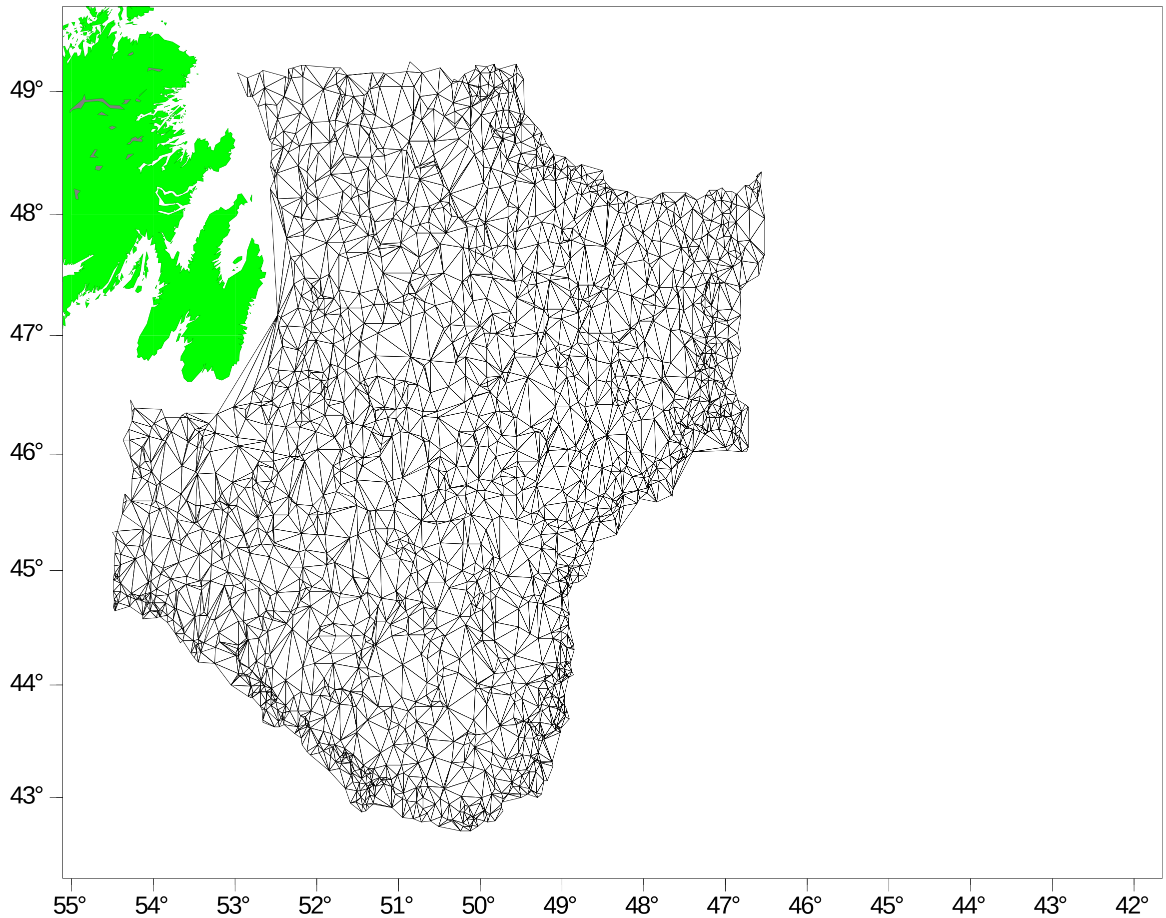


Figure 2. NAFO Divisions 3LNO – offshore Delauney triangulation used to derive the 3LNO biomass, abundance, fishable biomass, female biomass indices as well as population adjusted length frequencies using Omap.

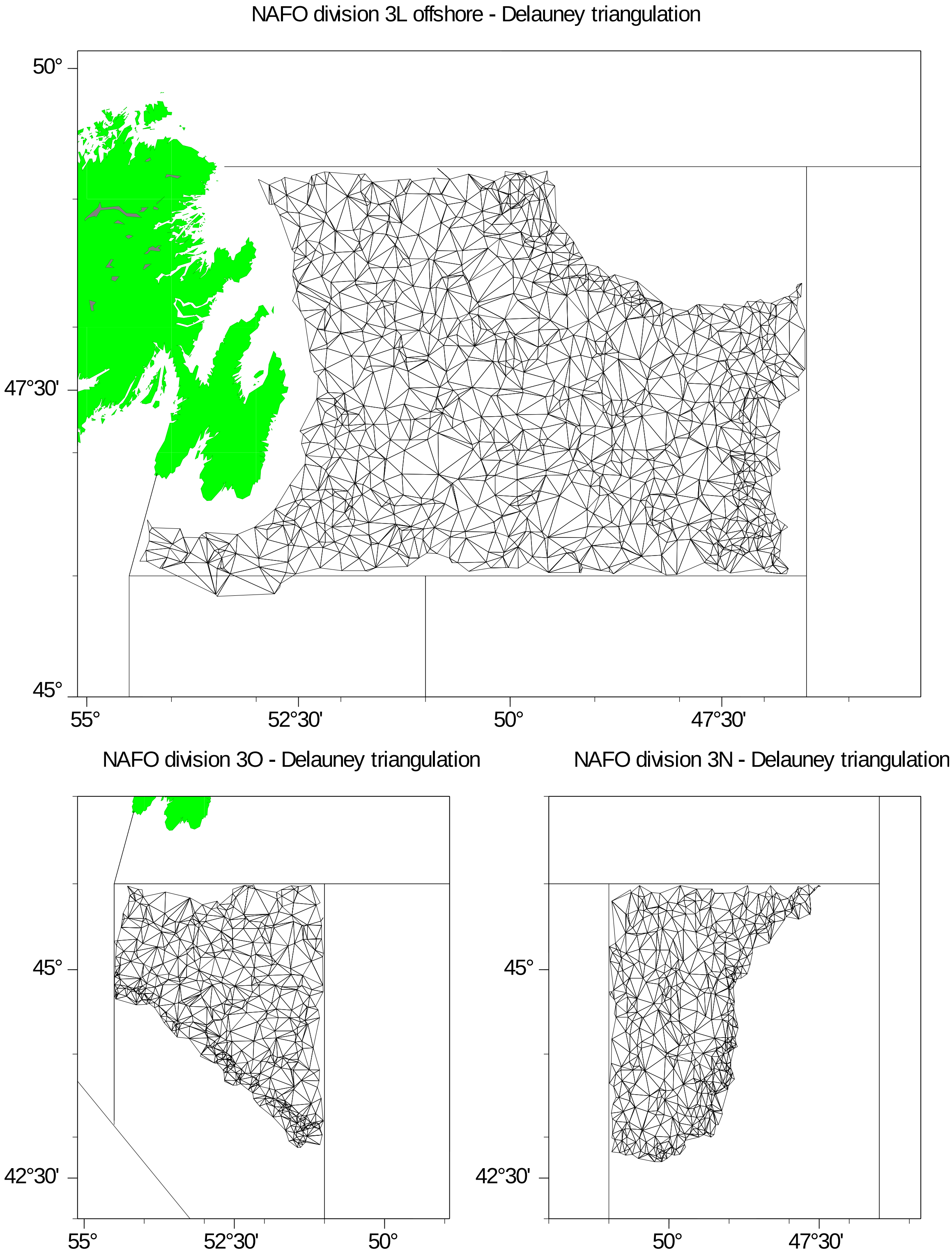


Figure 3. The Delauney triangulation used to derive within NAFO division Ogmap biomass and abundance indices.

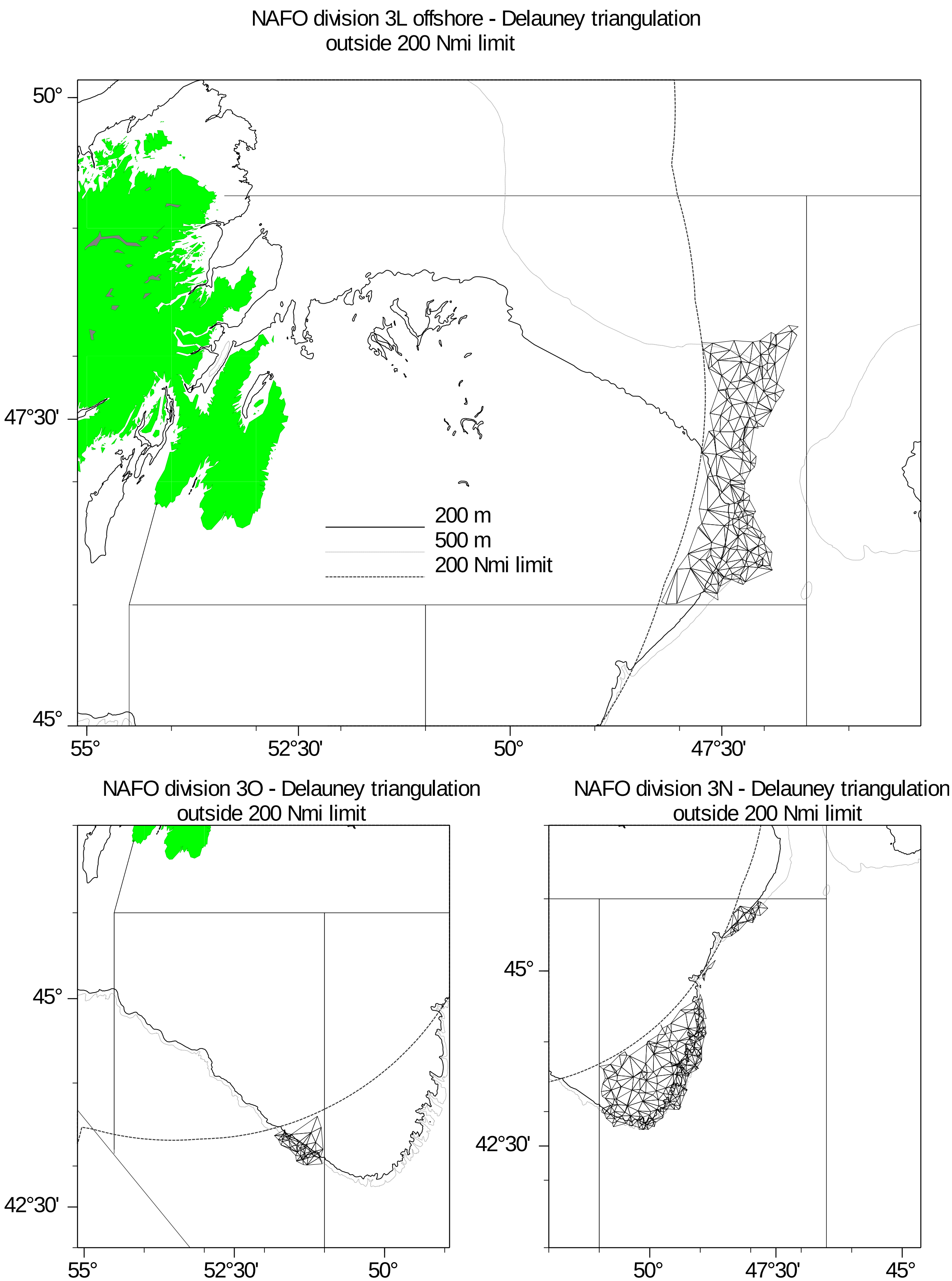


Figure 4. The Delauney triangulation used to derive the outside 200 Nmi limit Ogmap biomass and abundance indices.

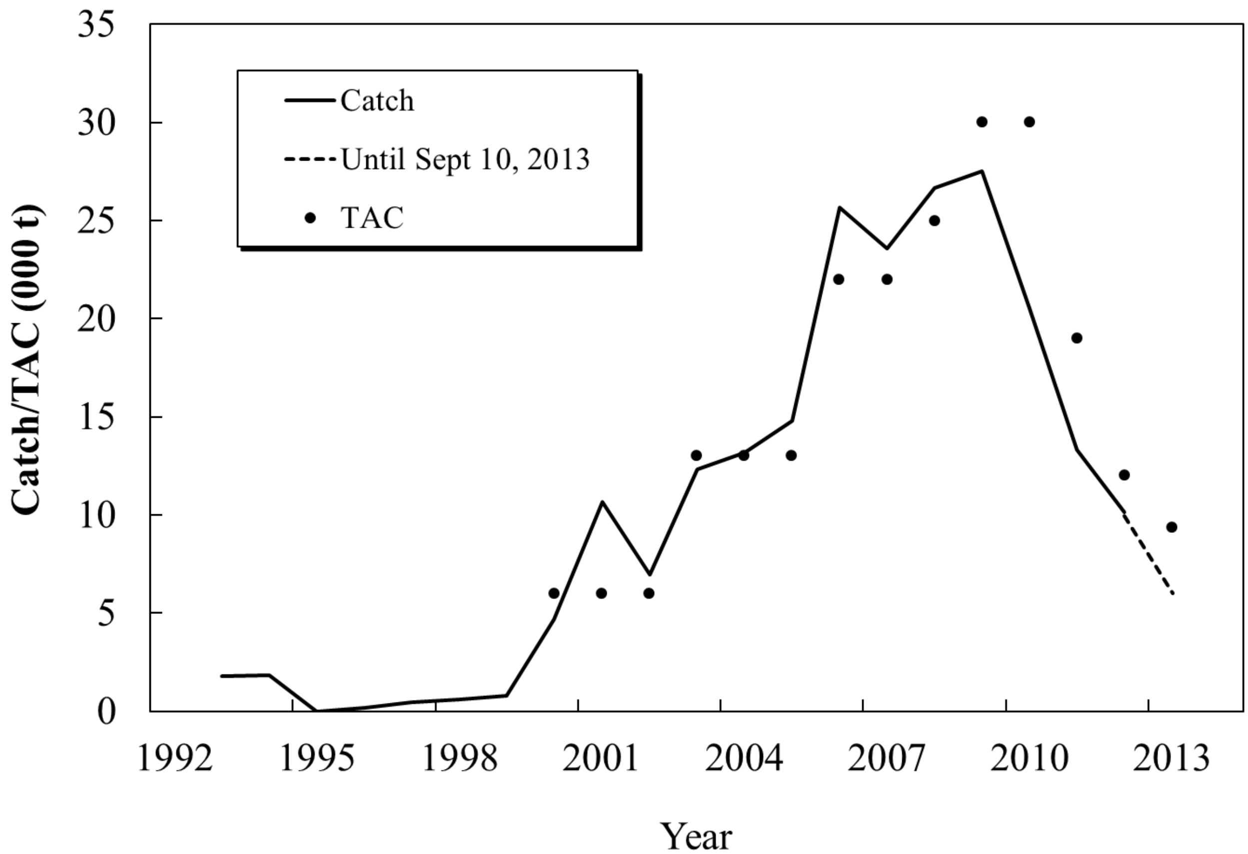


Figure 5. Trends in NAFO Division 3L Northern Shrimp (*Pandalus borealis*) catch and TAC over the period 1993-2013.

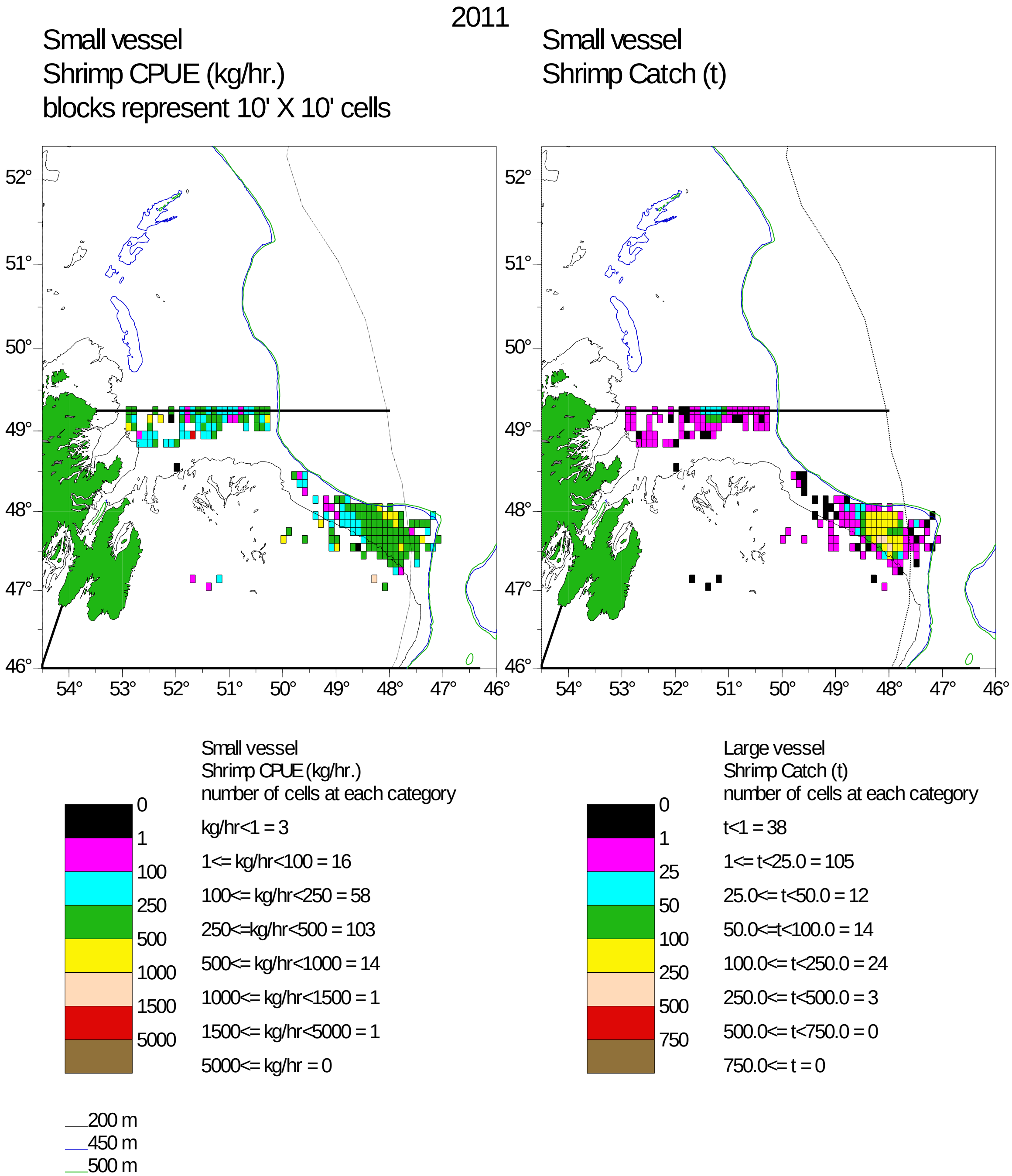


Figure 6. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2011. (Logbook data aggregated into 10 min X 10 min cells).

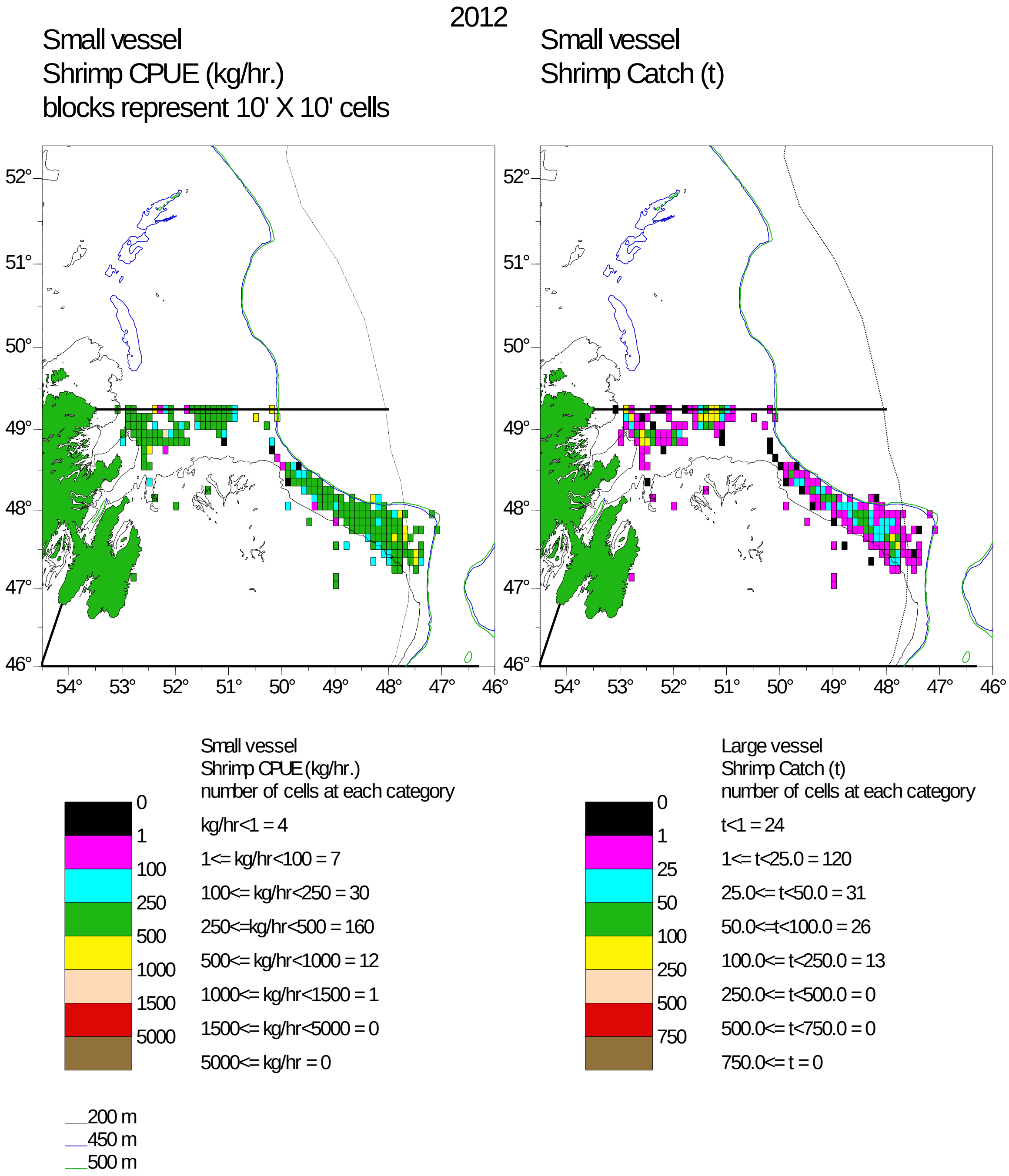


Figure 7. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2012. (Logbook data aggregated into 10 min X 10 min cells).

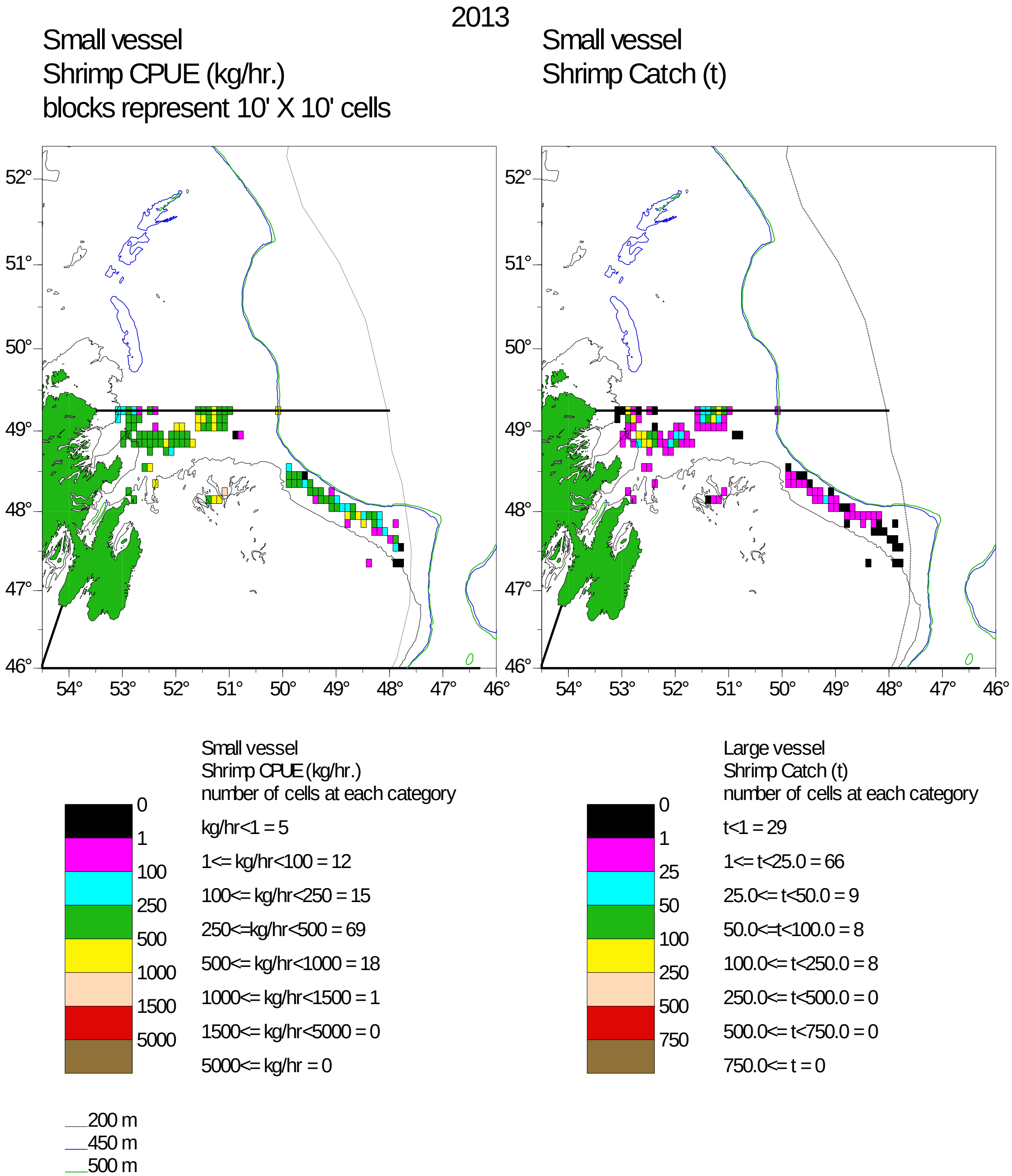


Figure 8. Distribution of **Canadian small vessel (<= 500 t; <65')** shrimp CPUE and catches in NAFO Division 3L during 2013. (Logbook data aggregated into 10 min X 10 min cells).

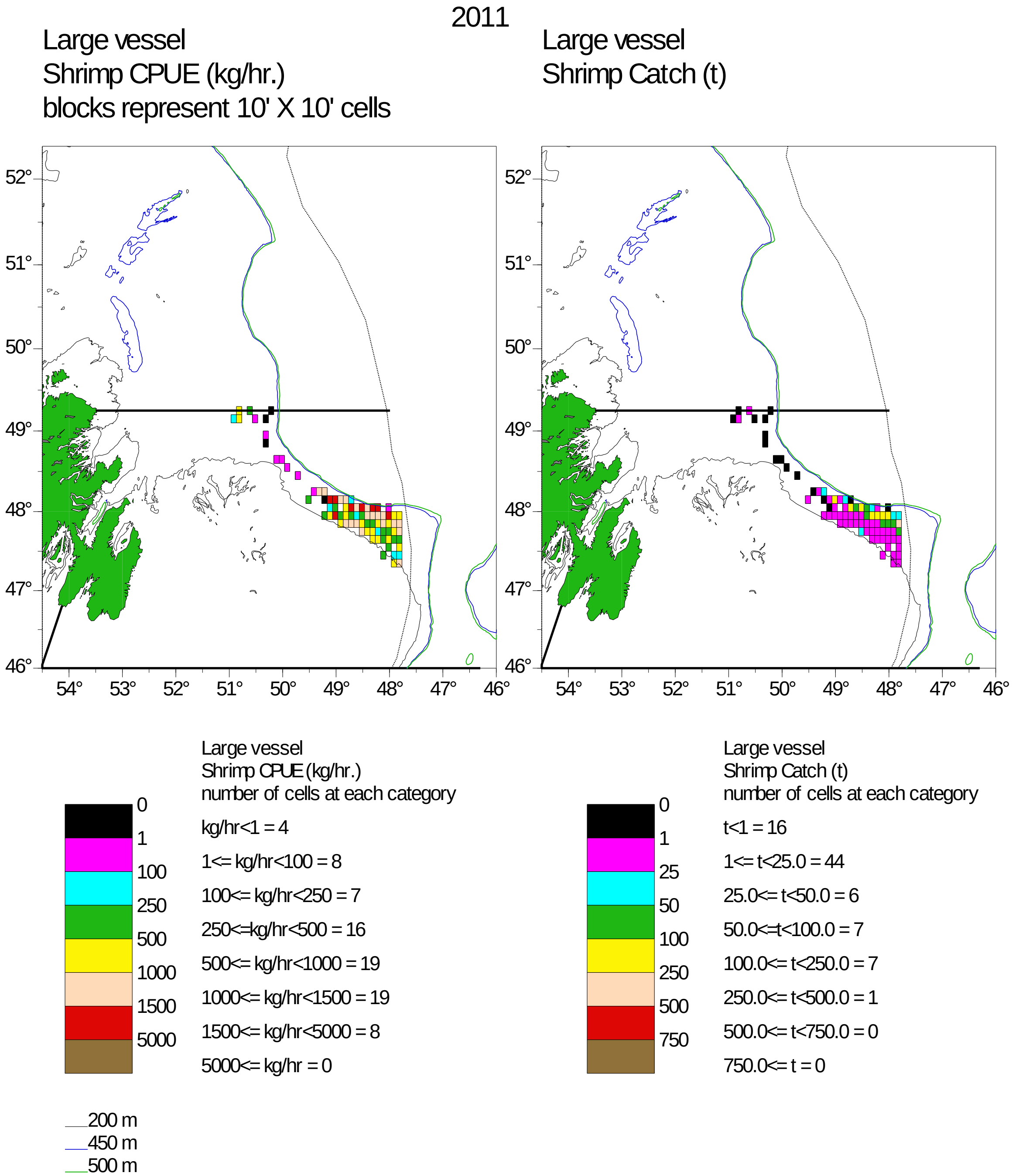


Figure 9. Distribution of **Canadian large vessel (>500 t)** shrimp CPUE and catches in NAFO Division 3L during 2011. (Logbook data aggregated into 10 min X 10 min cells).

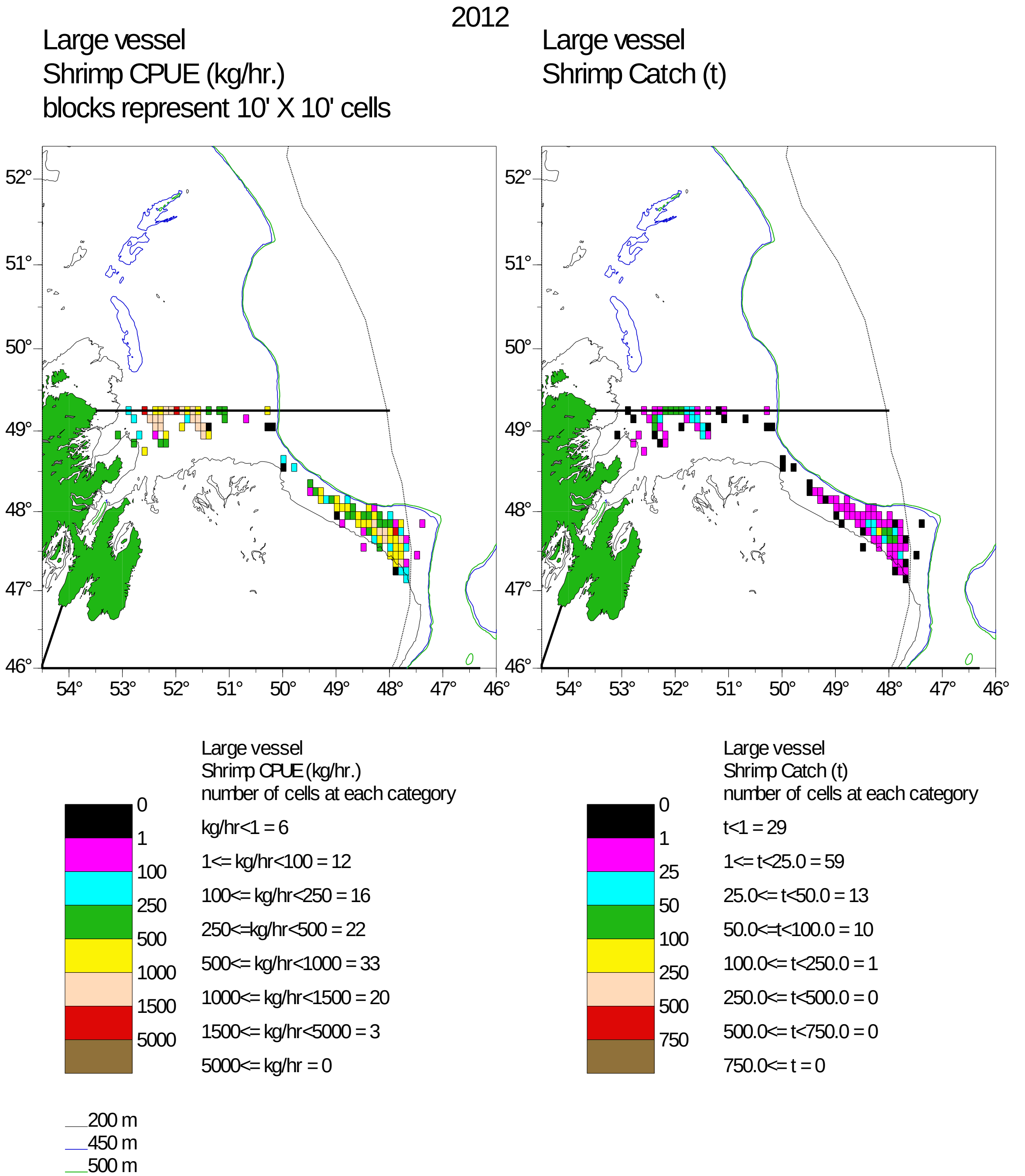


Figure 10. Distribution of **Canadian large vessel (>500 t)** shrimp CPUE and catches in NAFO Division 3L during 2012. (Logbook data aggregated into 10 min X 10 min cells).

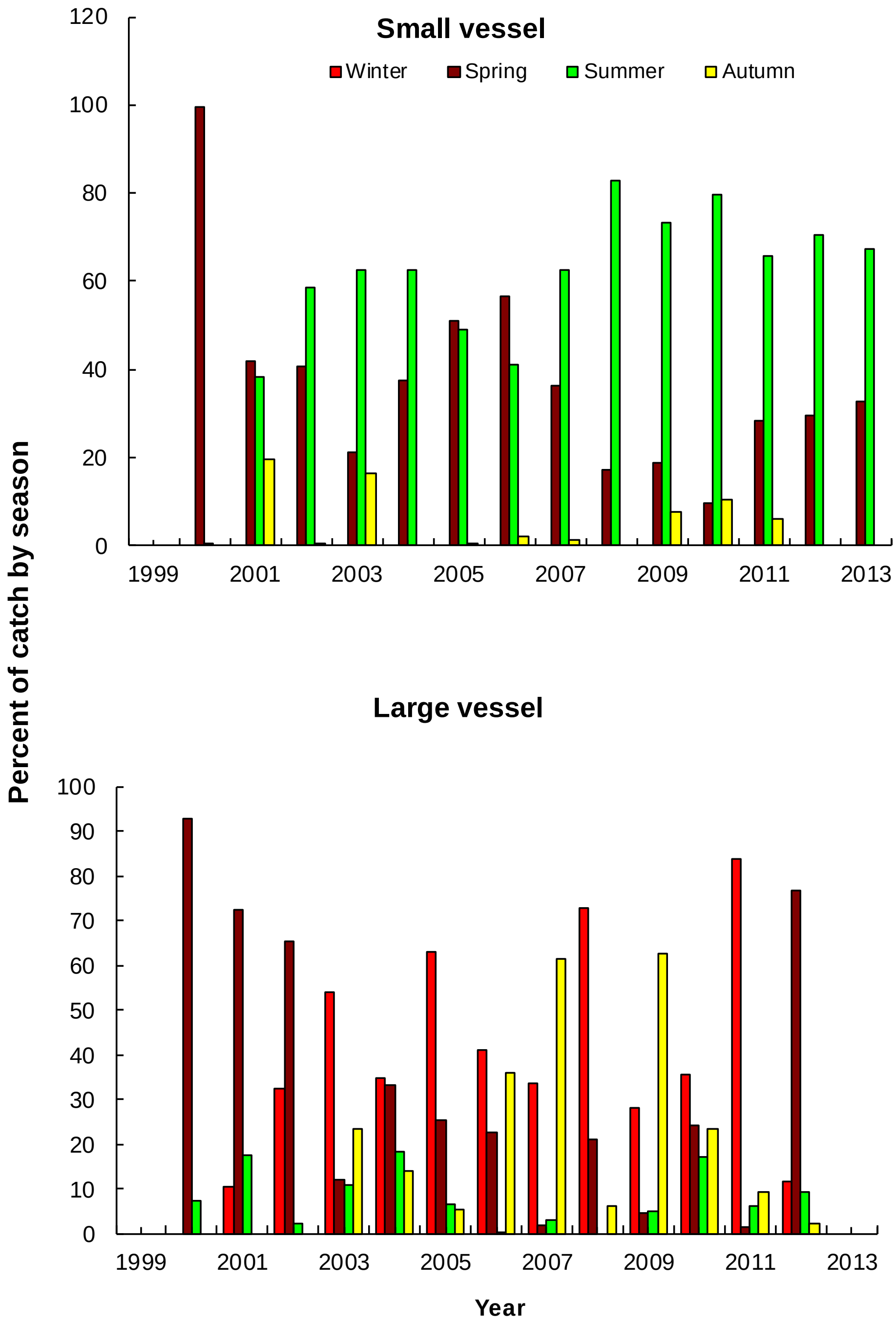


Figure 11. Seasonality of the large and small vessel Northern Shrimp (Pandalus borealis) fishery in NAFO Division 3L over the period 2000 – 2012. Please note that observer data were not available for the large vessel fleet in 2013 and small vessel logbook data were preliminary during September 2013.

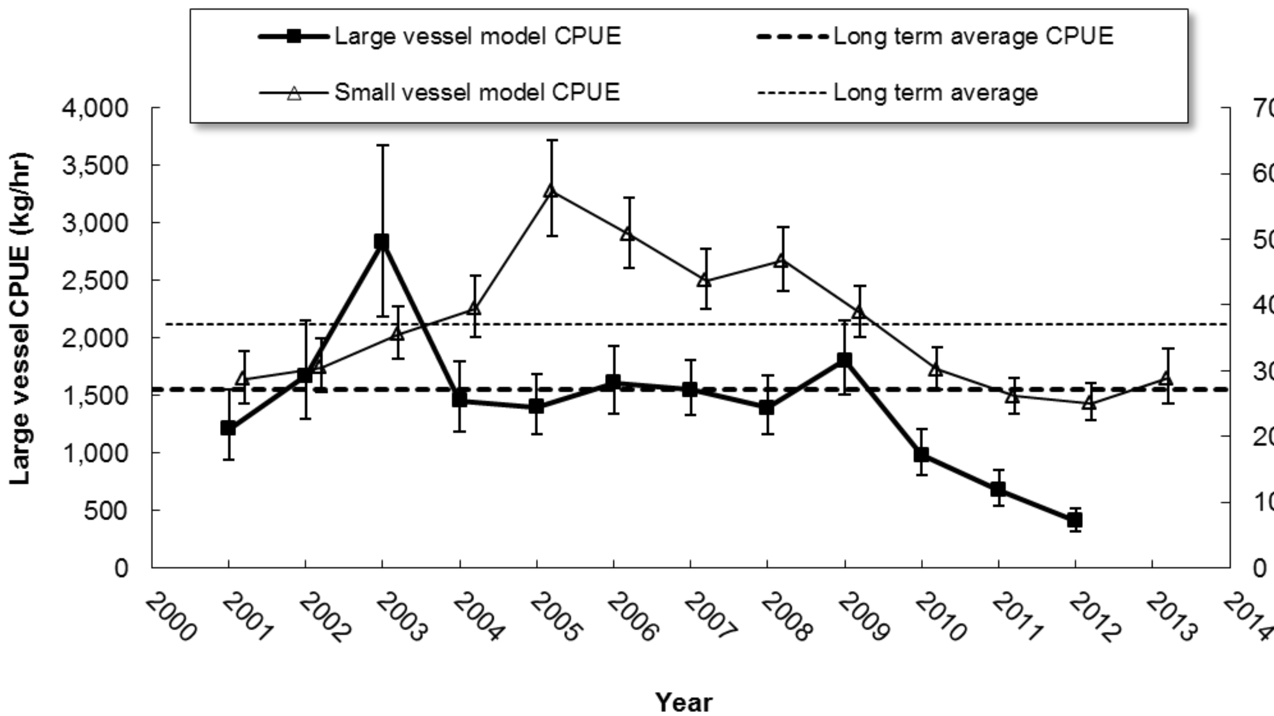


Figure 12. Model catch rates for Canadian large (>500 t) and small (<= 500 t; <65') vessels fishing for shrimp in NAFO Div. 3L over the period 2001 – 2013. Bars represent 95% confidence intervals around model values.

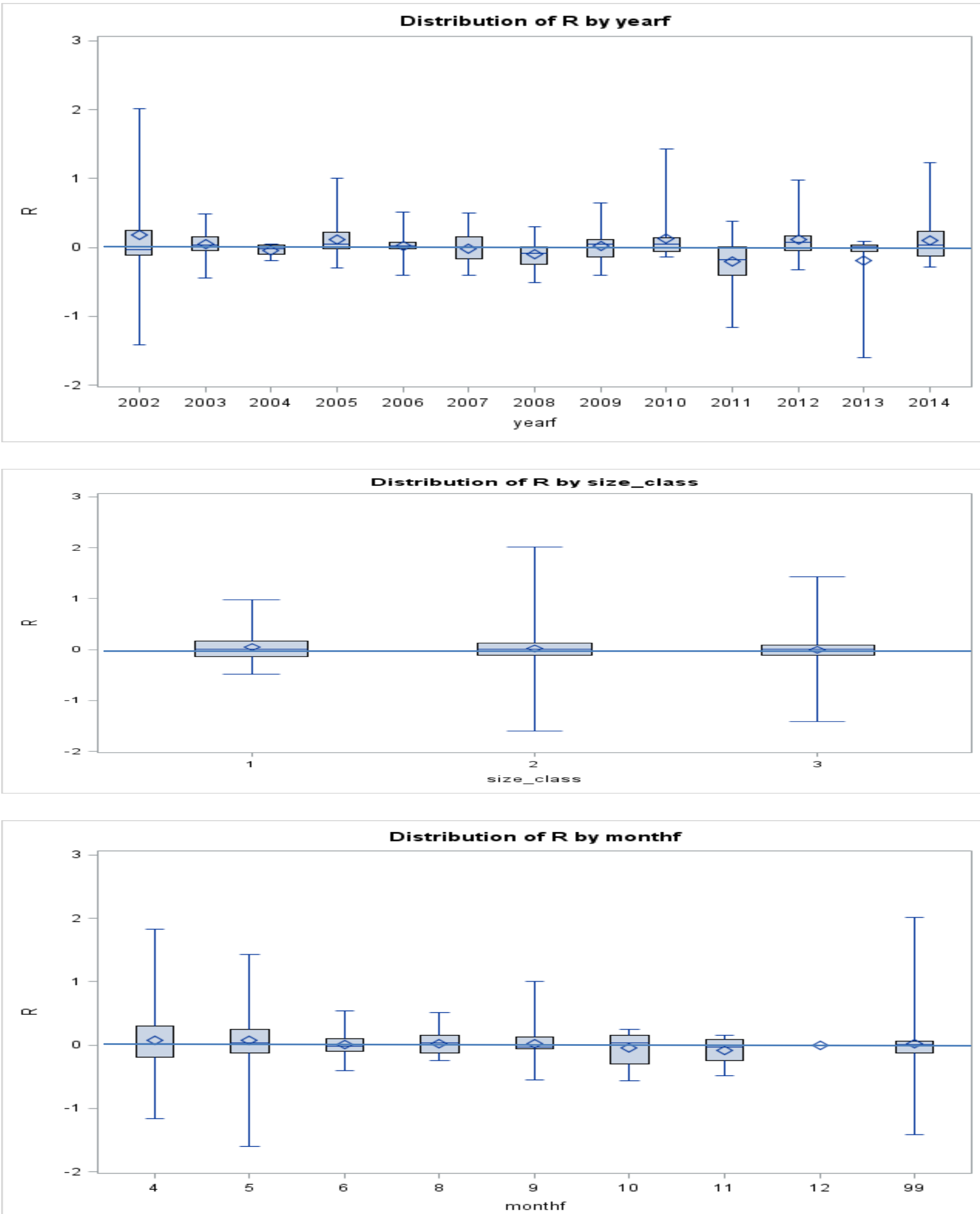


Figure 13. Distribution of residuals around estimated values for parameters used to model **Canadian small vessel** shrimp catch rates, 2001 – 2013.

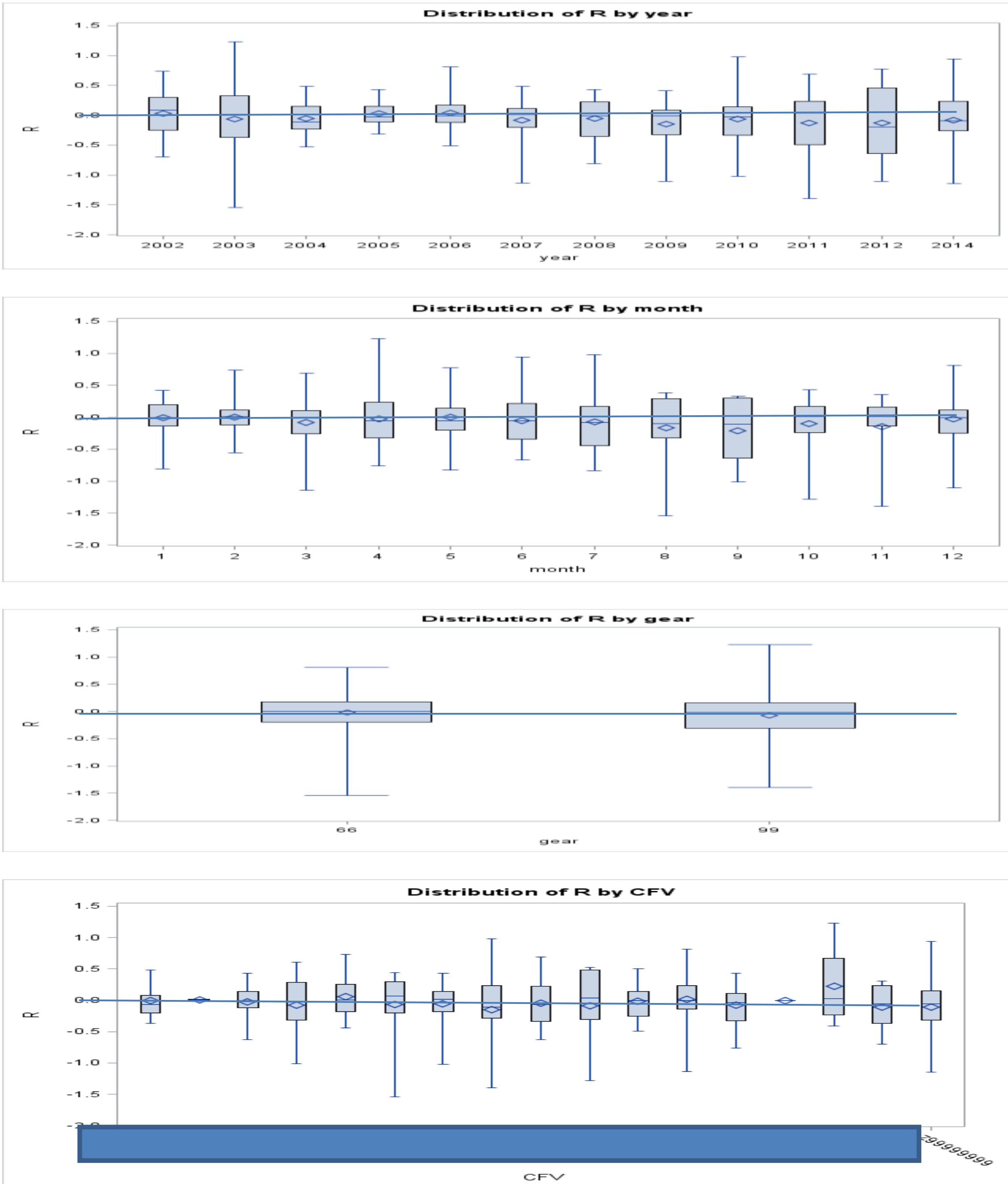
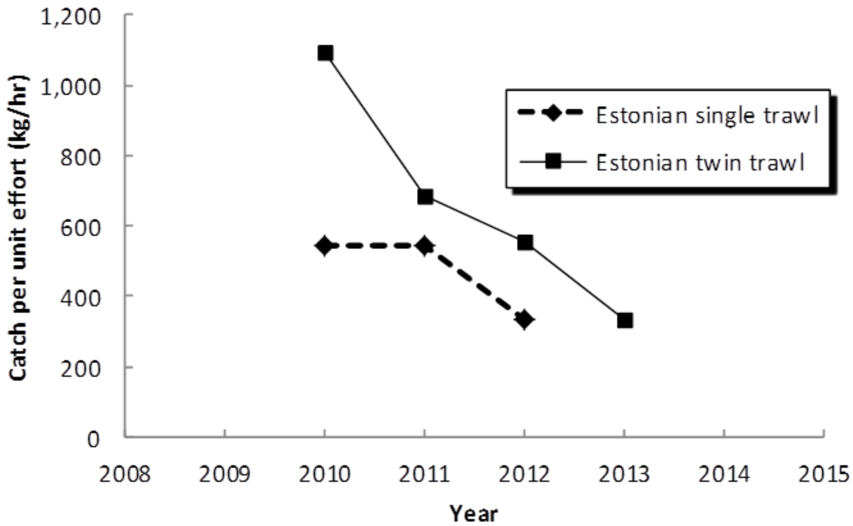


Figure 14. Distribution of residuals around estimated values for parameters used to model **Canadian large vessel** shrimp catch rates, 2001 – 2012.



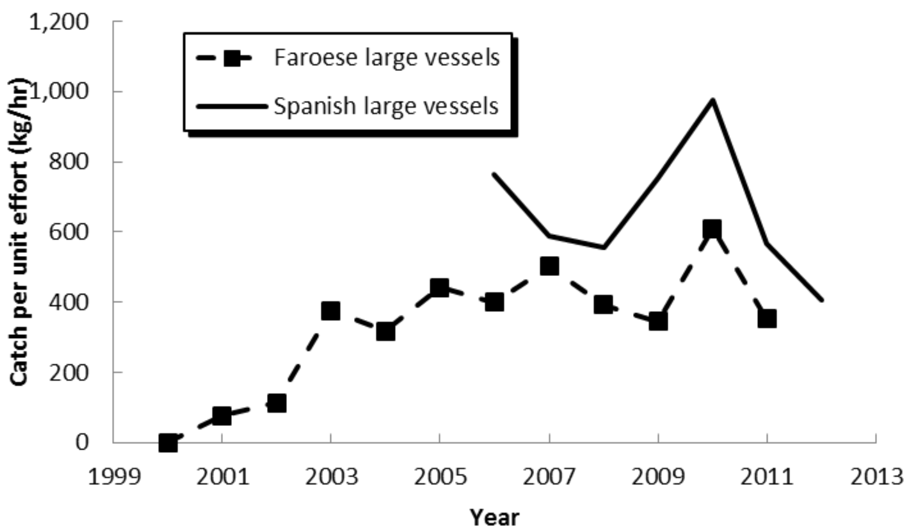


Figure 15. Northern Shrimp raw catch rates within the NAFO Division 3L NRA over the period 2000 – 2013. There was no information as to whether Faroese or Spanish data was from single or twin trawls.

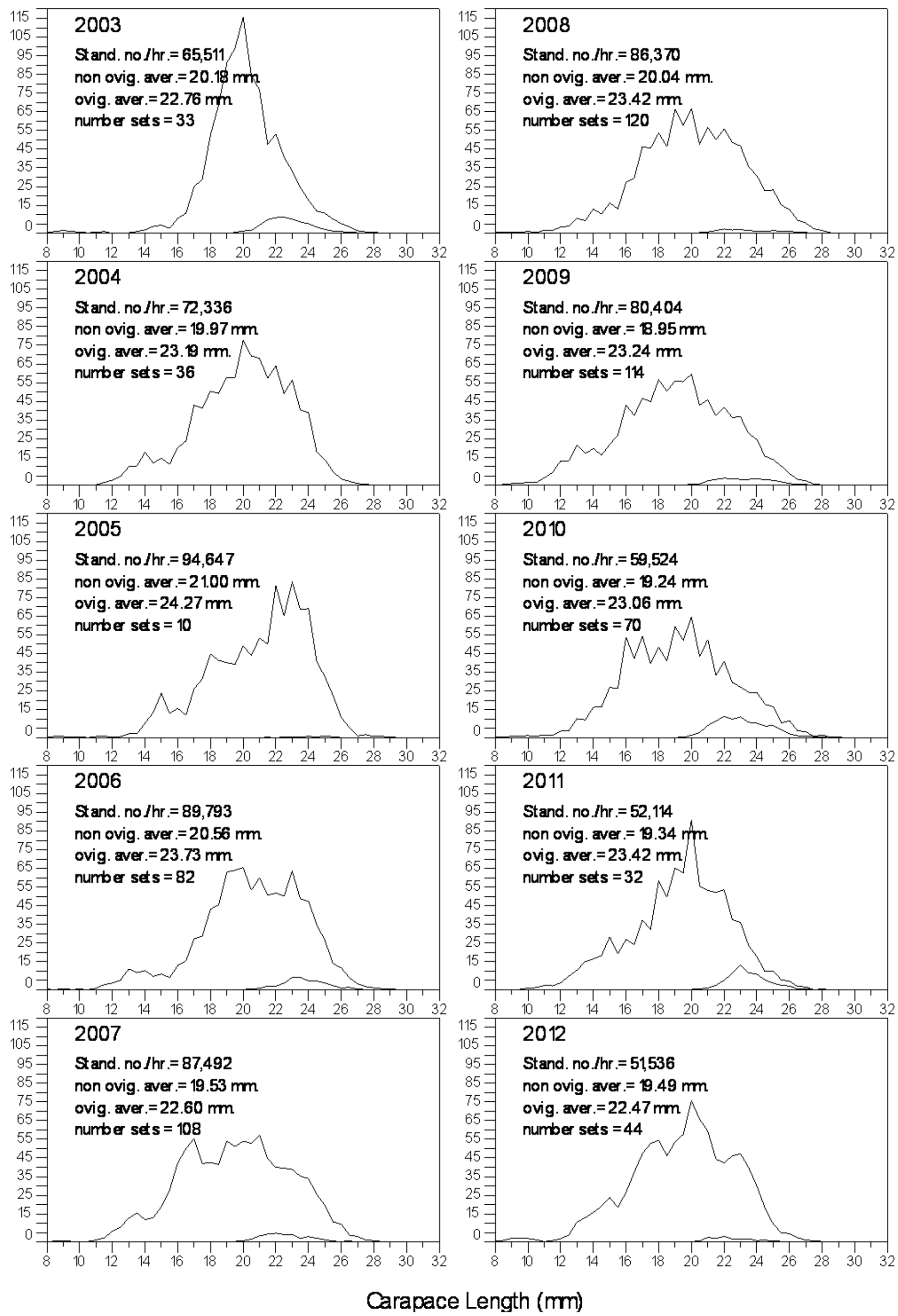


Figure 16. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian small vessel (<= 500 t; <65')** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

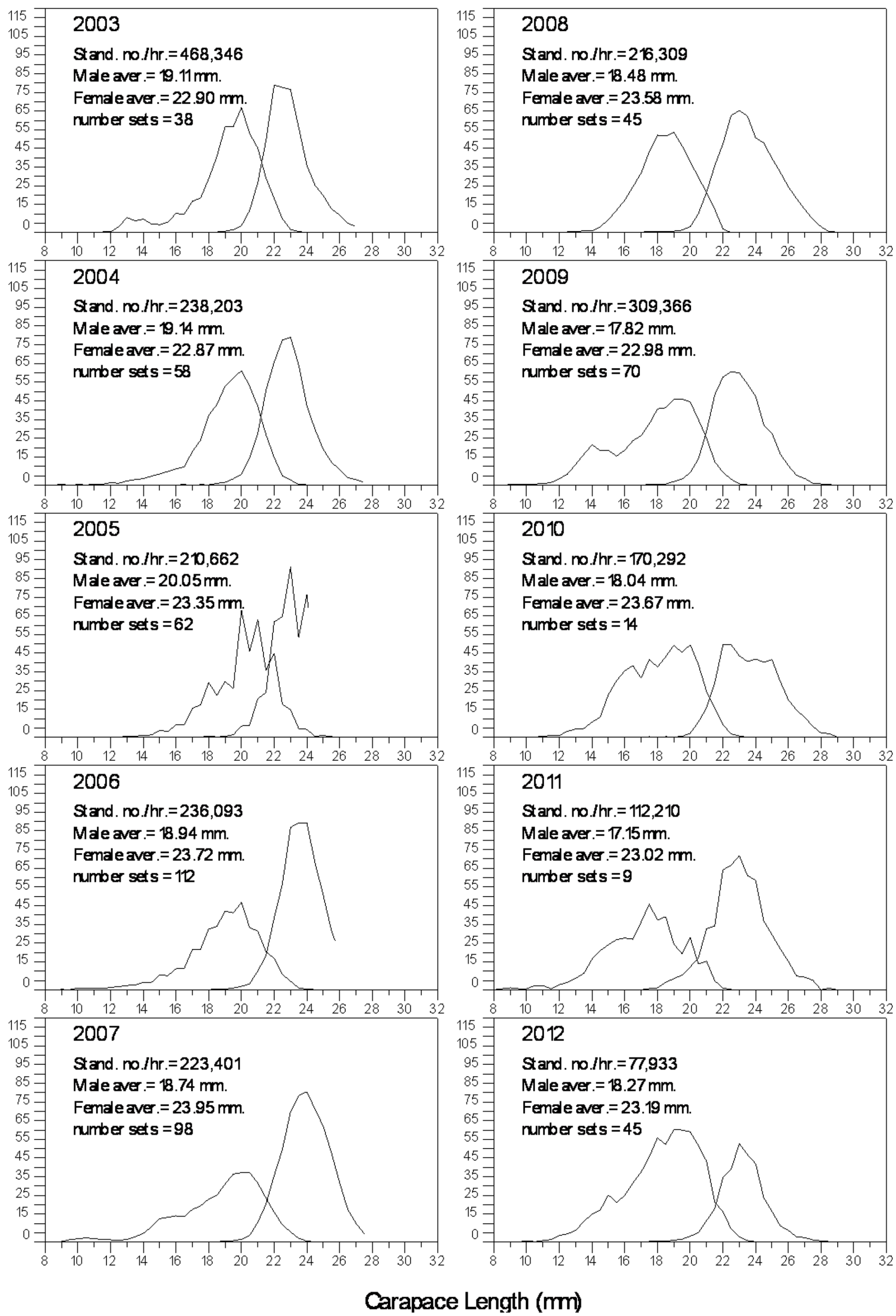


Figure 17. Observed northern shrimp (*Pandalus borealis*) length frequencies from the **Canadian large vessel (>500 t)** fleet fishing in NAFO Div. 3L over the period 2003 – 2012.

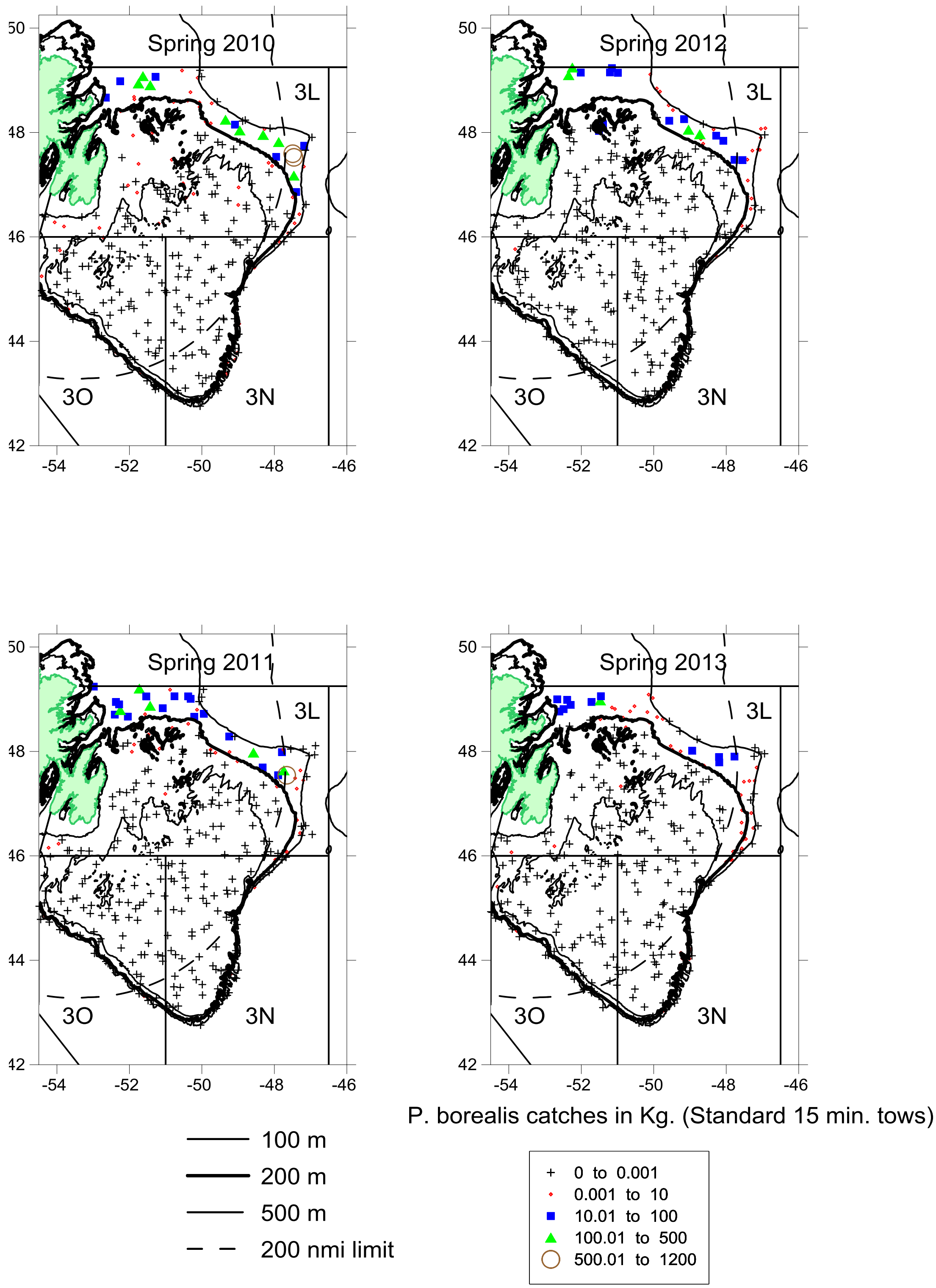


Figure 18. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **spring** Canadian research bottom trawl surveys conducted over the period 2010 – 2013.

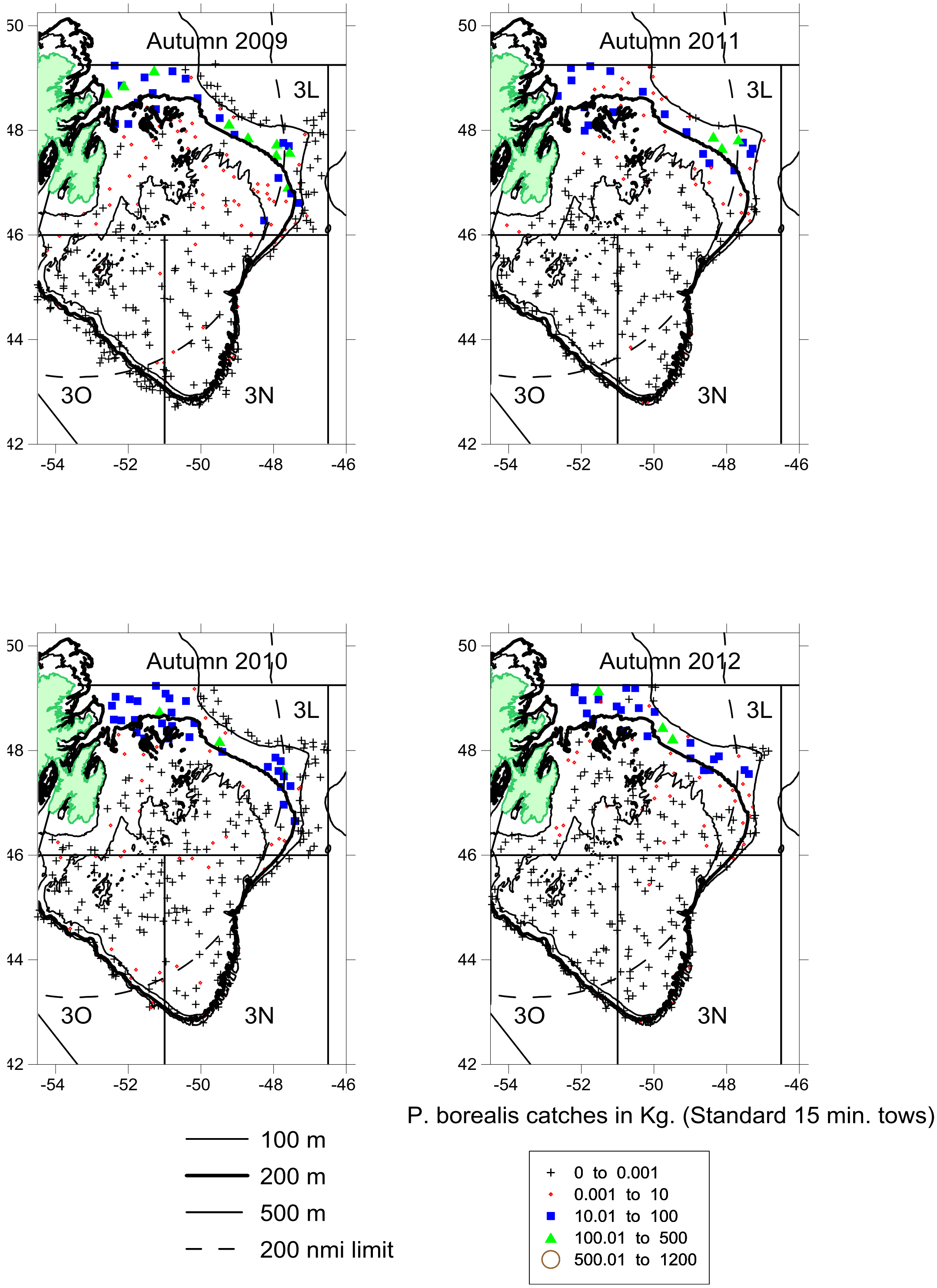


Figure 19. Distribution of NAFO Divisions 3LNO Northern Shrimp (*Pandalus borealis*) catches kg/tow as obtained from **autumn** Canadian research bottom trawl surveys conducted over the period 2009 – 2012.

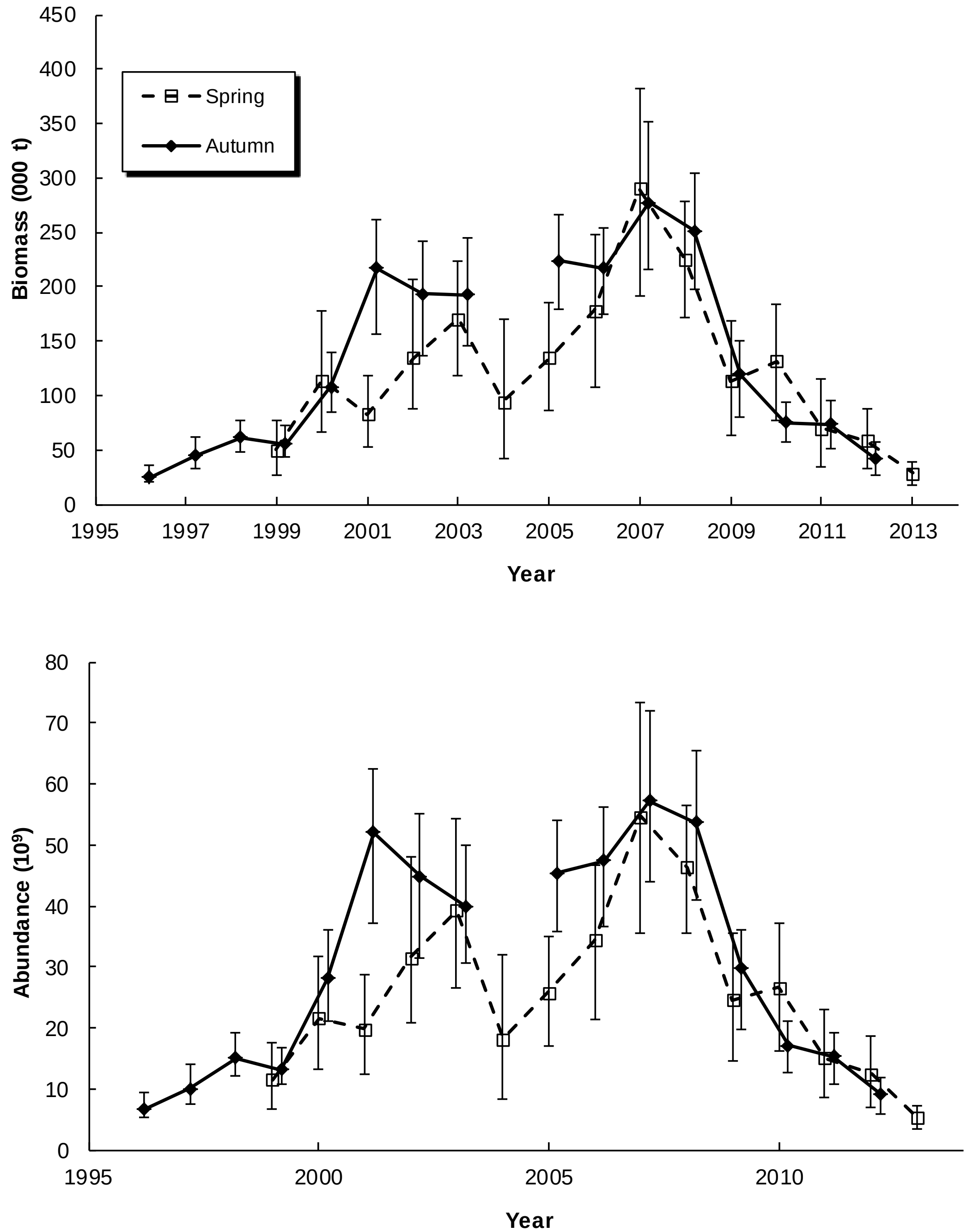


Figure 20. Northern shrimp biomass and abundance indices within NAFO Divisions 3LNO over the period 1996 – 2013. The data are from spring 1999 – 2013 and autumn 1999 – 2012 Canadian multispecies research bottom trawl surveys. (Standard tow 15 min.). Estimates were made using Ogmap calculations and bars represent 95% confidence intervals.

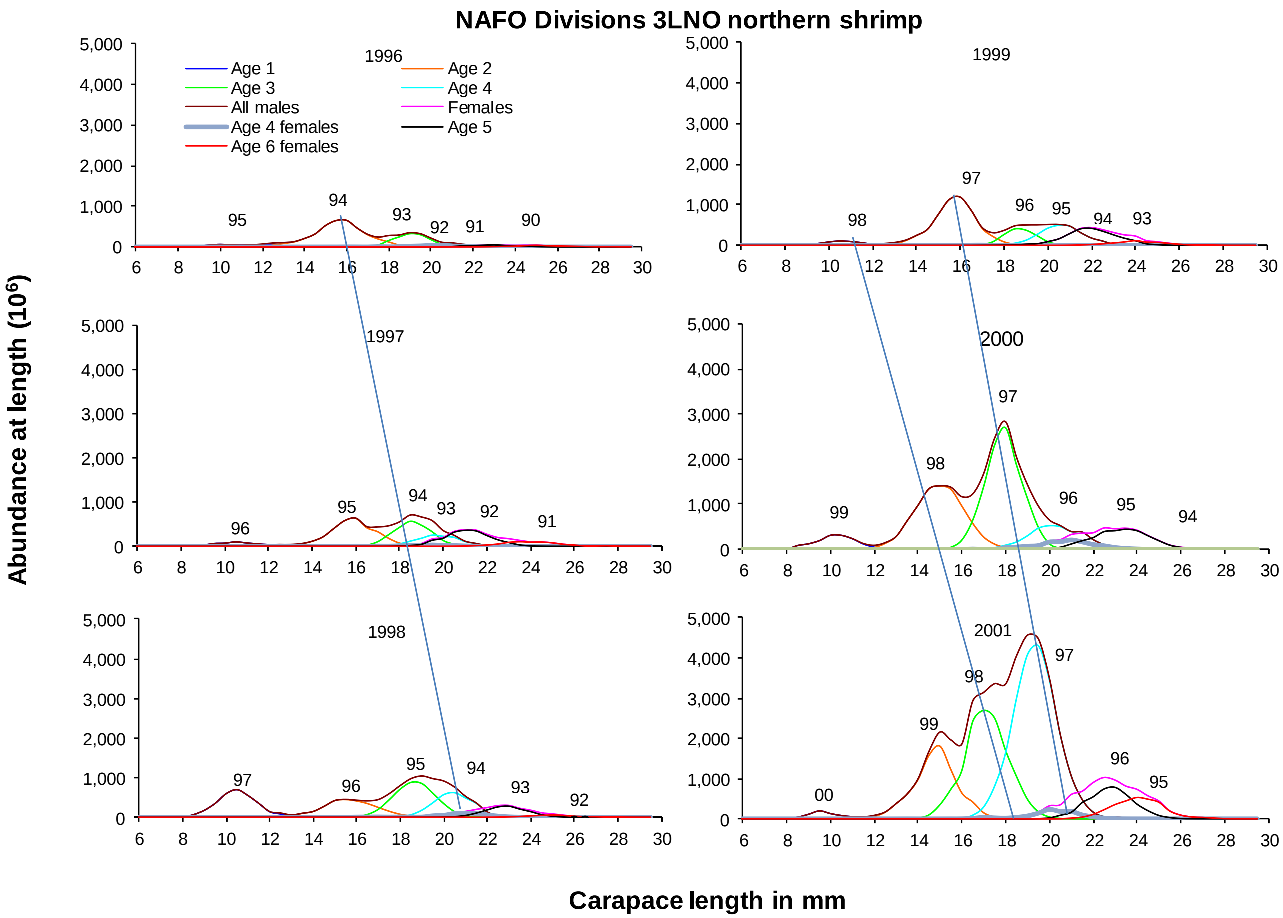


Figure 21. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual **autumn** Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within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

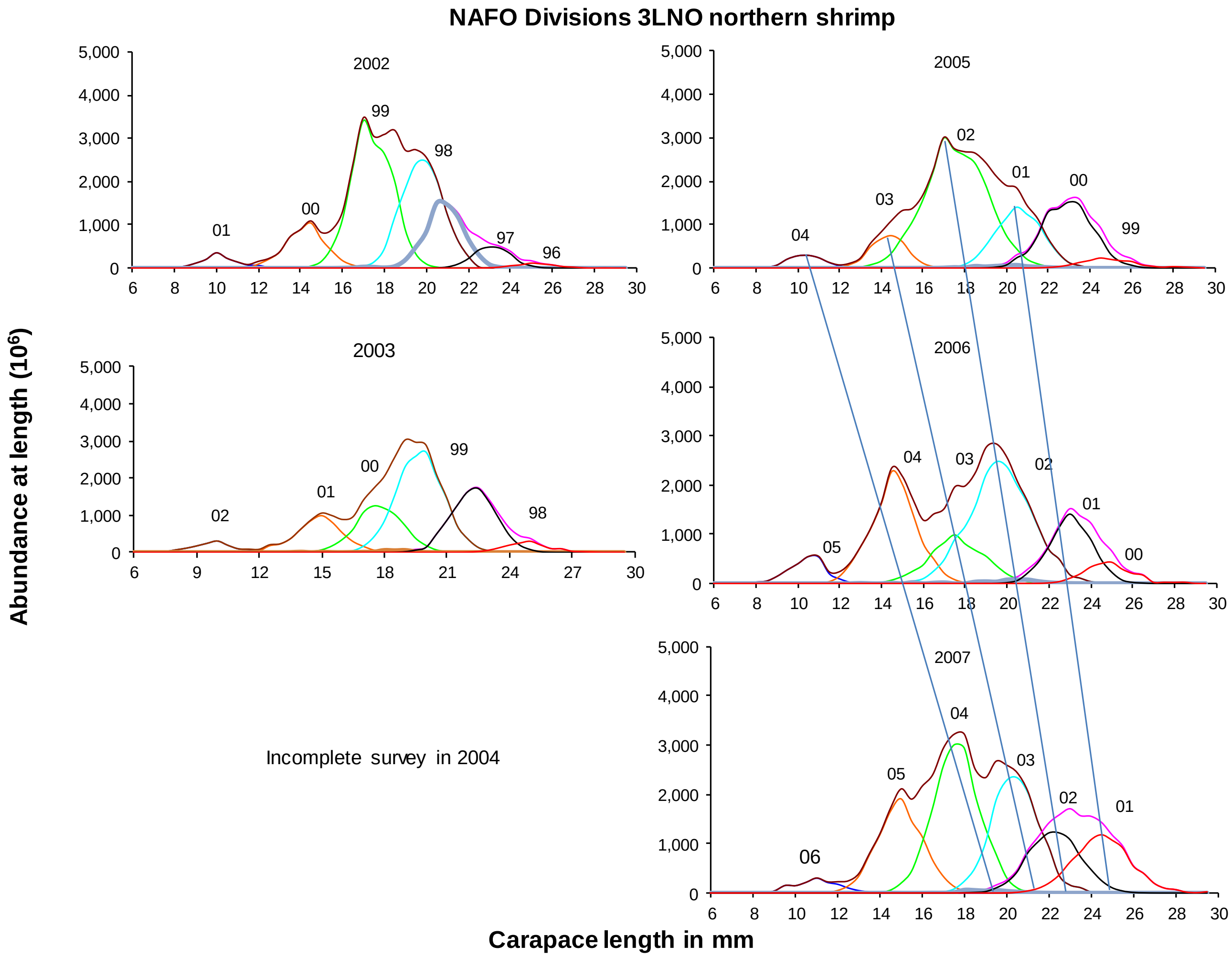


Figure 21. (Continued)

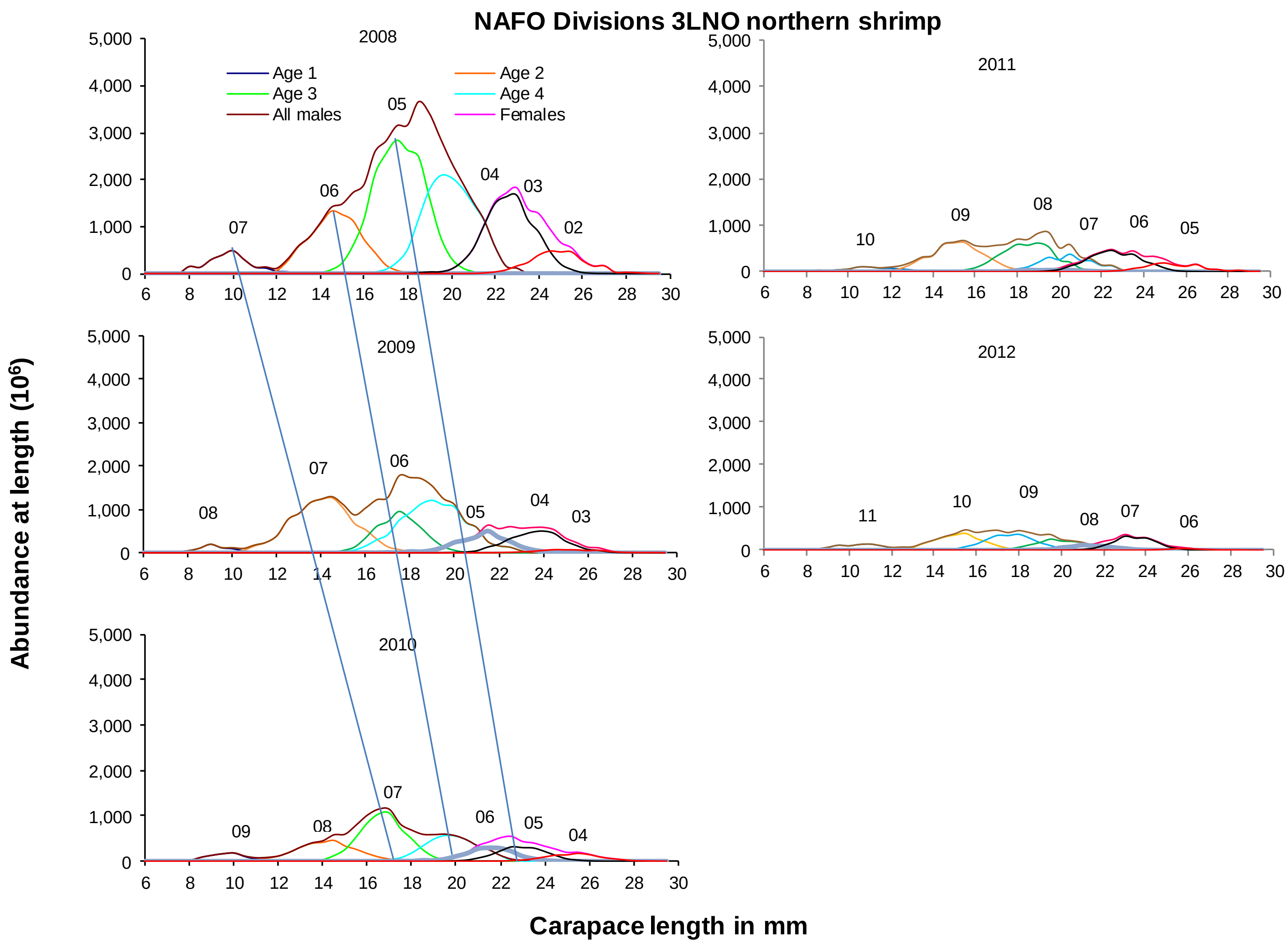


Figure 21. (Continued)

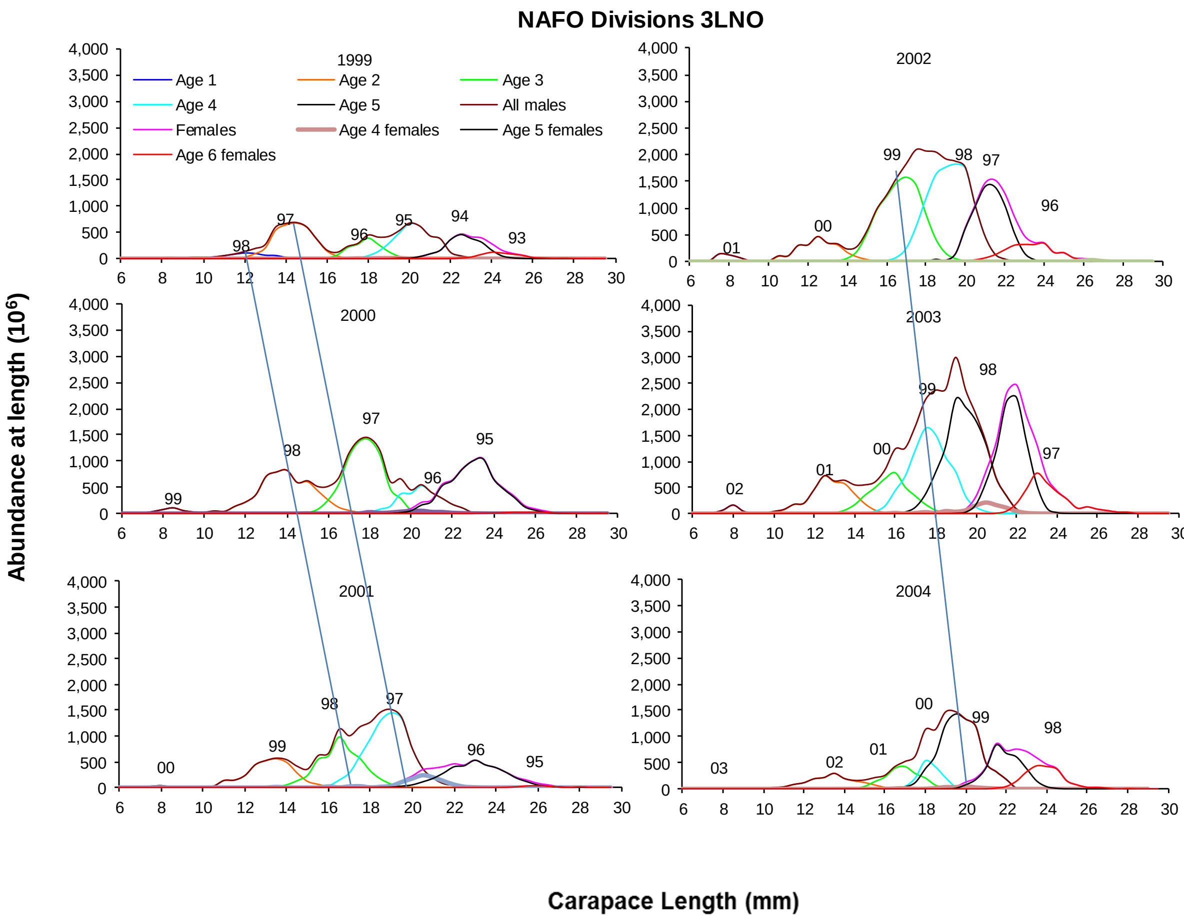


Figure 22. NAFO divisions 3LNO northern shrimp carapace length frequencies as calculated using ogmap calculations. The data were obtained from annual spring Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only; standard 15 min. tows.). The numbers within each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

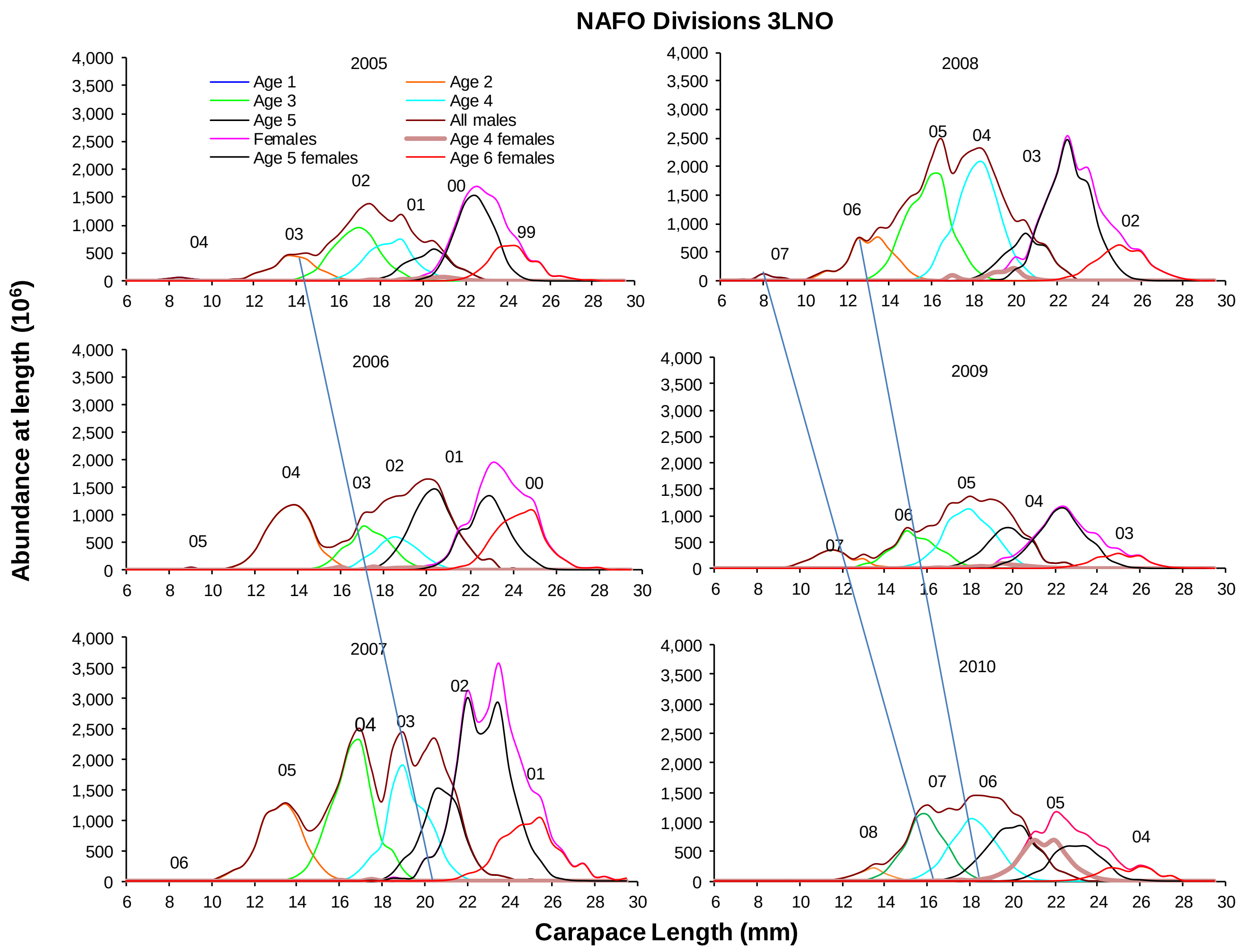


Figure 22 (Continued)

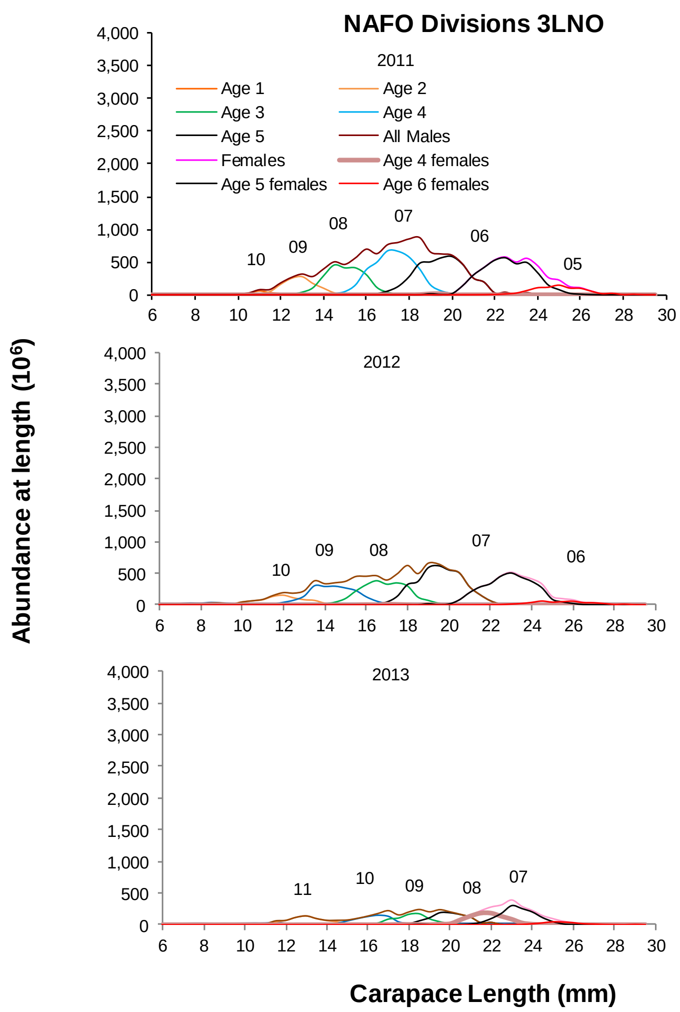


Figure 22 (Continued)

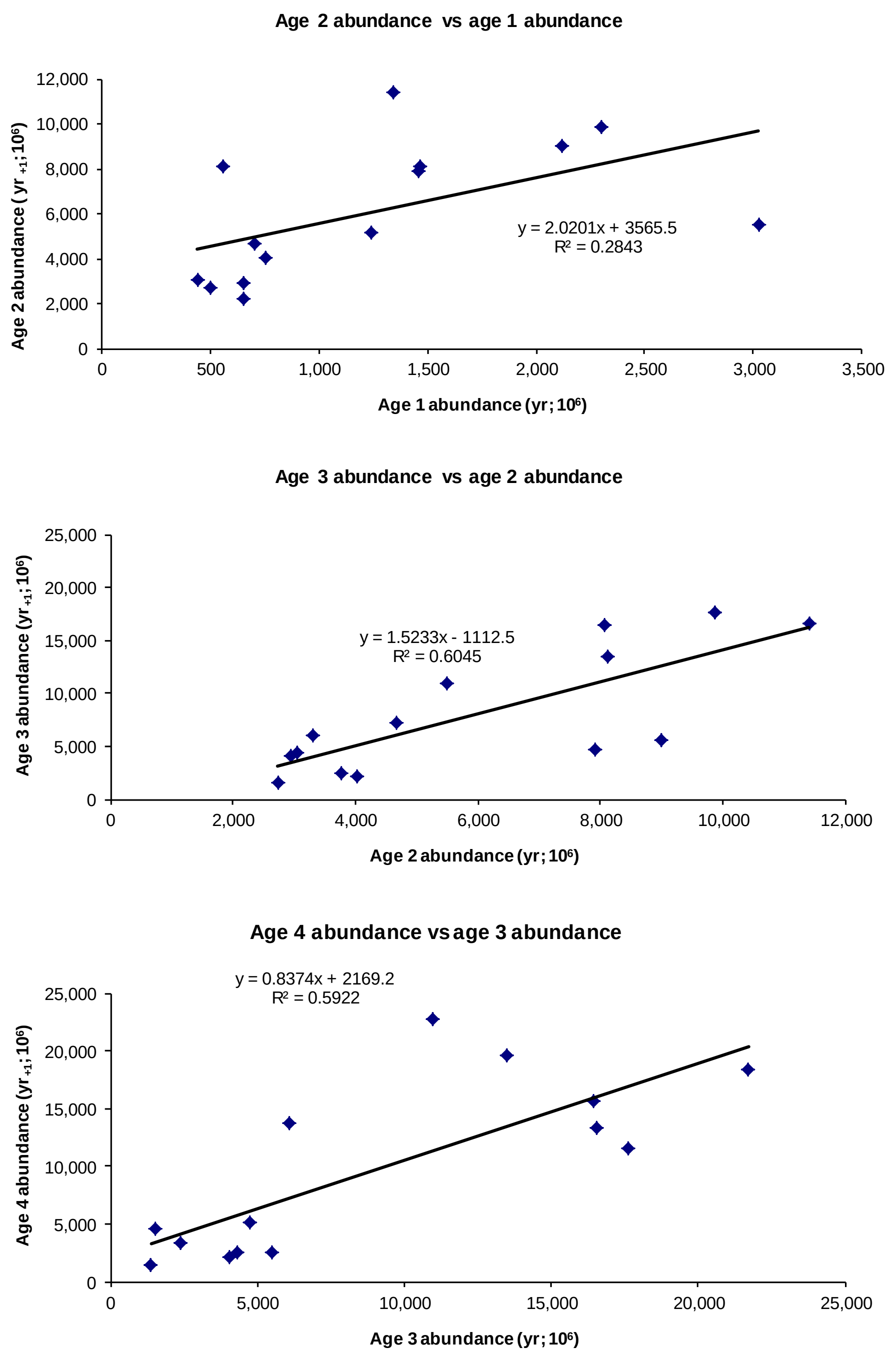


Figure 23. Relationship between abundance in one year and abundance in the successive year. These data came from the autumn modal analysis provided in figure 22 and table 12.

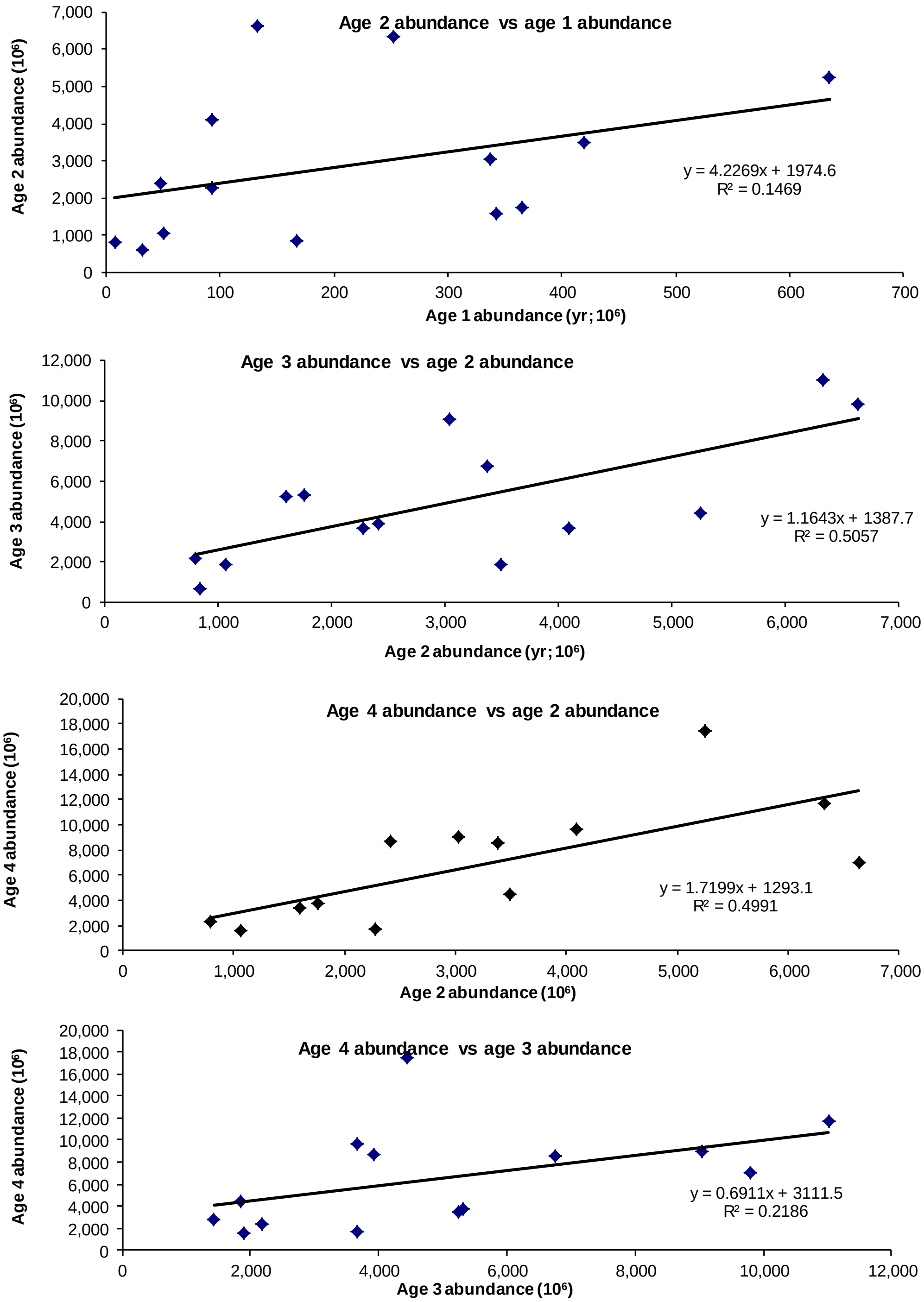
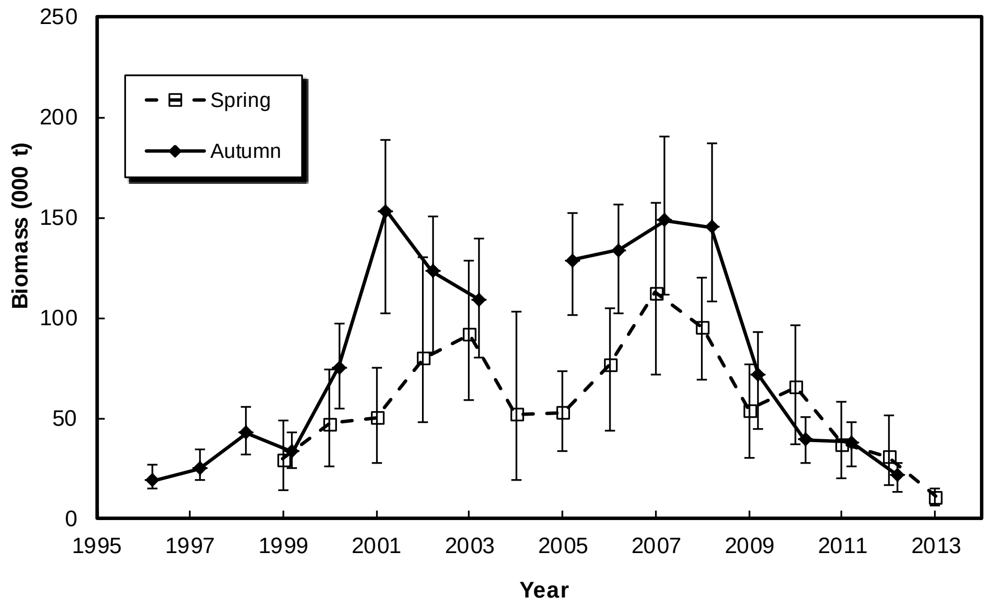


Figure 24. Relationship between abundance in one year and abundance in the successive year. These data came from the spring modal analysis provided in figure 23 and table 13.



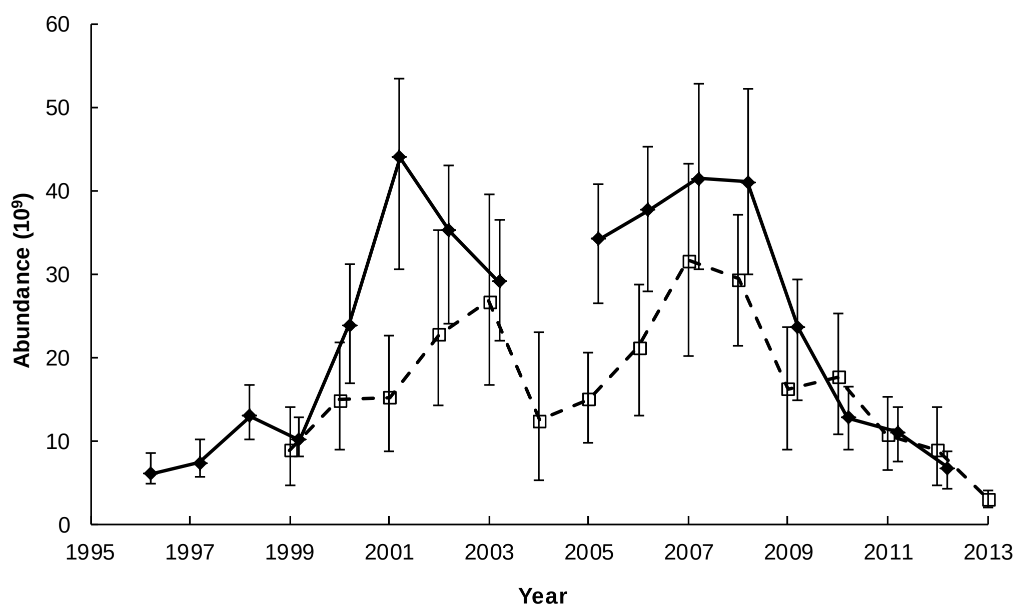


Figure 25. Abundance and biomass of male shrimp within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

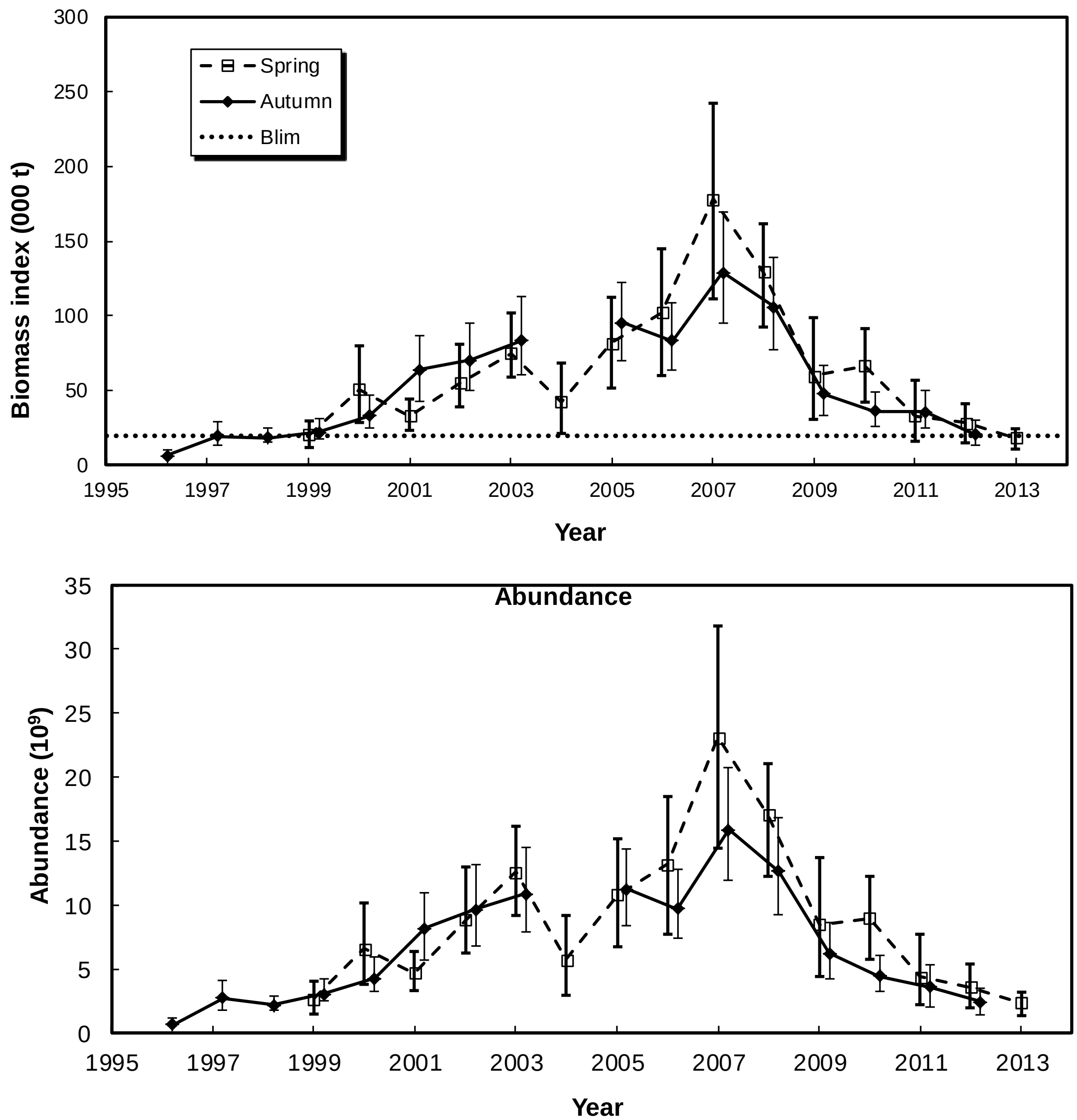


Figure 26. Abundance and biomass of female shrimp (SSB) within NAFO Divisions 3LNO as estimated from Canadian multi-species survey data using Ogmap calculations.

The REG Procedure
Dependent Variable: autumn_ssb

Number of Observations Read	13
Number of Observations Used	13

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	11073	11073	38.58	<.0001
Error	11	3157.49659	287.04514		
Corrected Total	12	14231			

Root MSE	16.94241	**R-Square**	0.7781
Dependent Mean	63.46712	**Adj R-Sq**	0.7580
Coeff Var	26.69478		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	**1**	15.99436	8.97218	1.78	0.1022
spring_ssb	**1**	0.67785	0.10914	6.21	<.0001

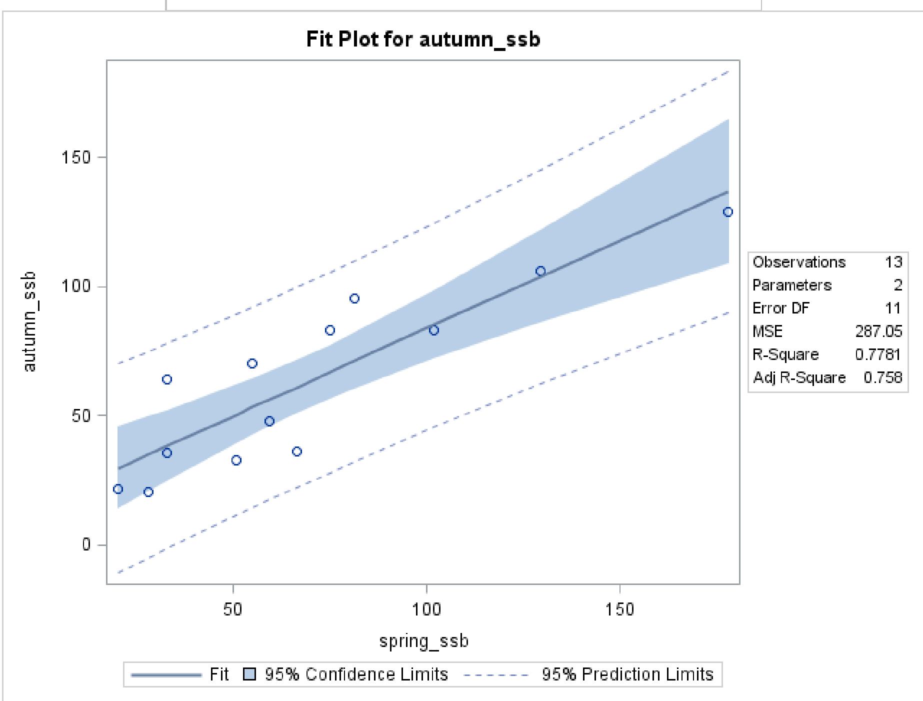


Figure 27. Predictive relationship between spring female spawning stock biomass (SSB) and the following autumn SSB.

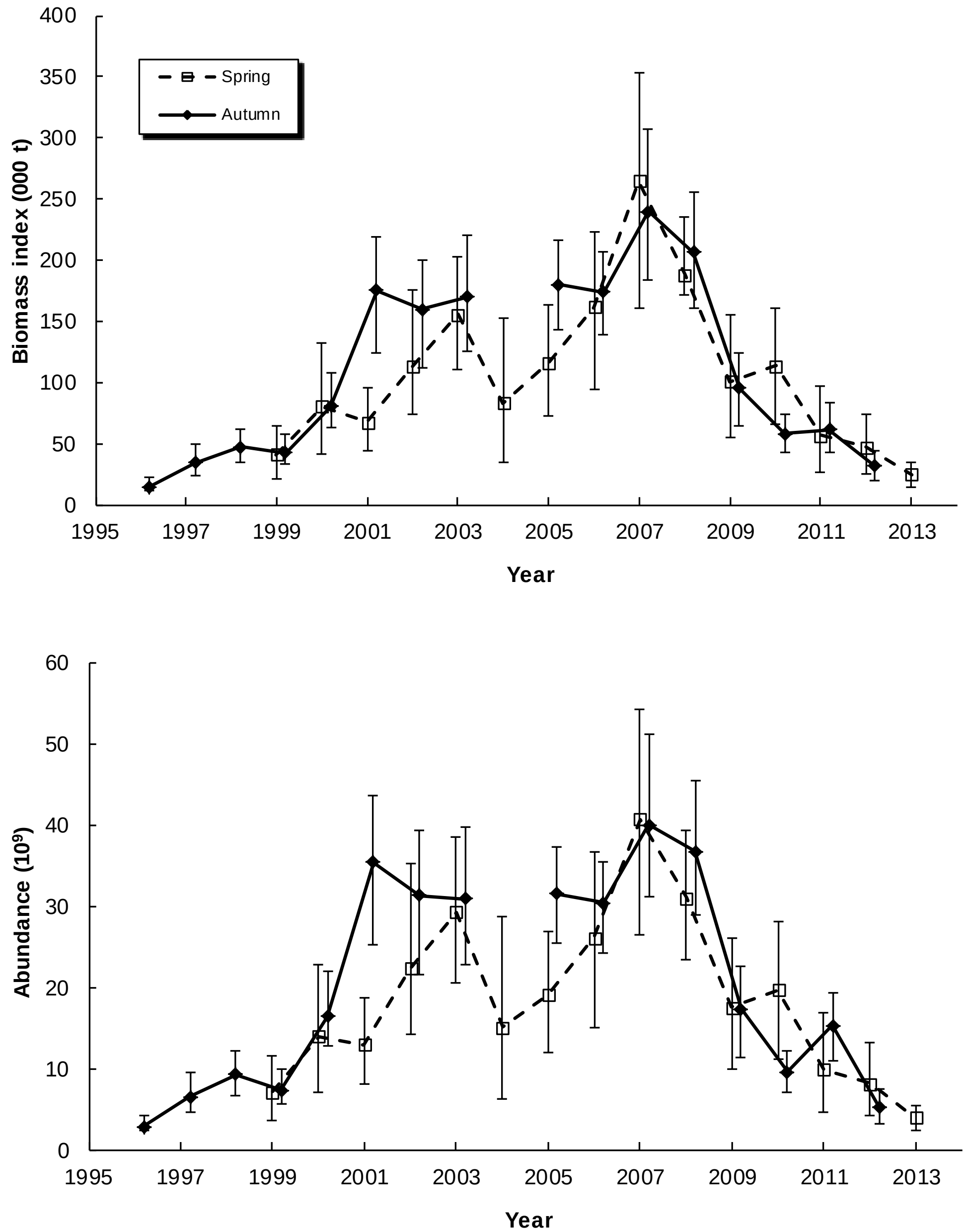


Figure 28 Fishable biomass (t) indices (weight of all females and males with carapace lengths => 17.5mm) as determined using ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, 1996 – 2013. The bars represent 95% confidence intervals around the fishable biomass indices.

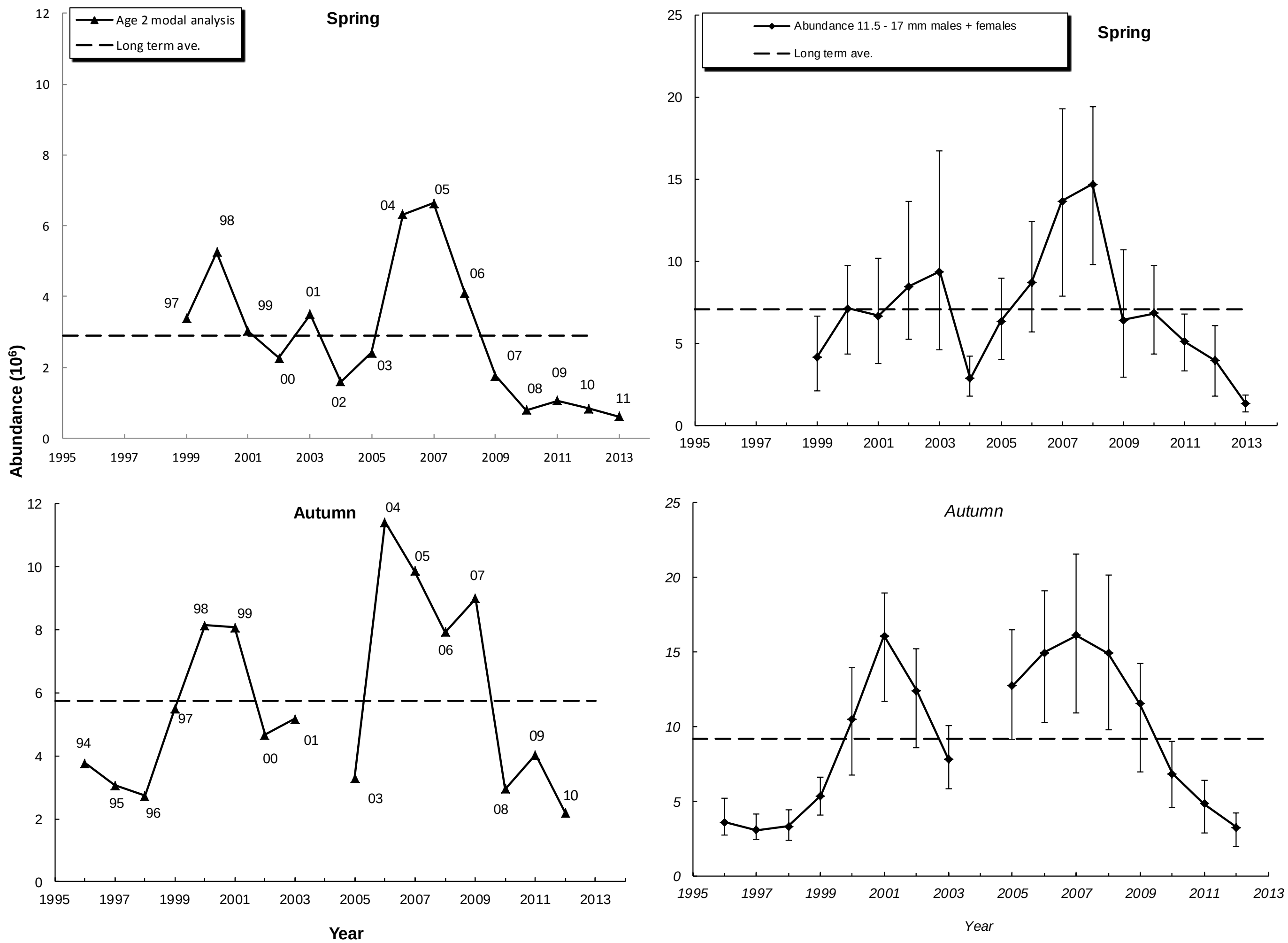


Figure 29. Recruitment indices as determined using Ogmap calculations from autumn and spring Canadian multi-species bottom trawl survey data, autumn 1996 – spring 2013. The bars represent 95% confidence intervals around the index. Numbers within the modal analysis graphs are cohort years.

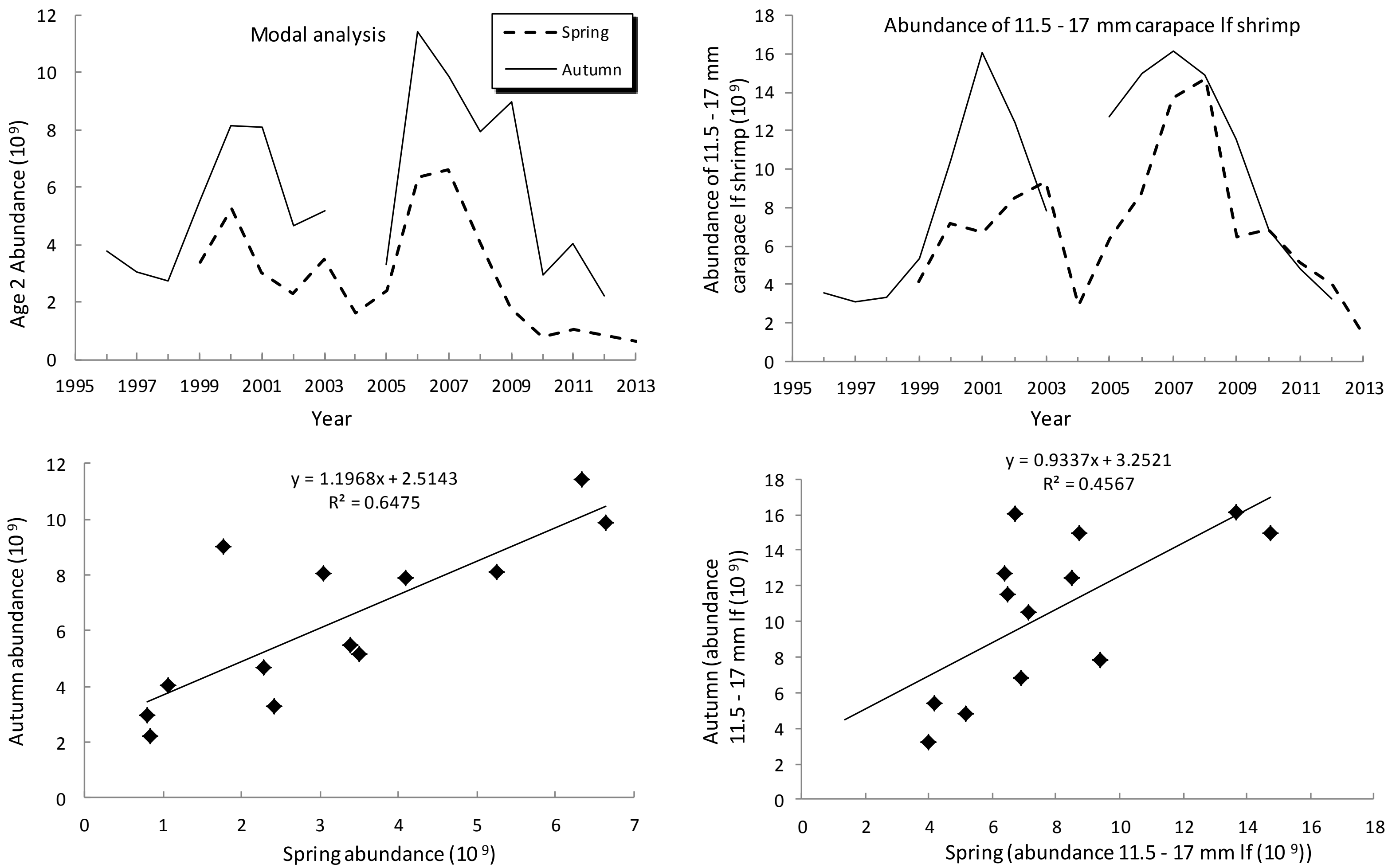
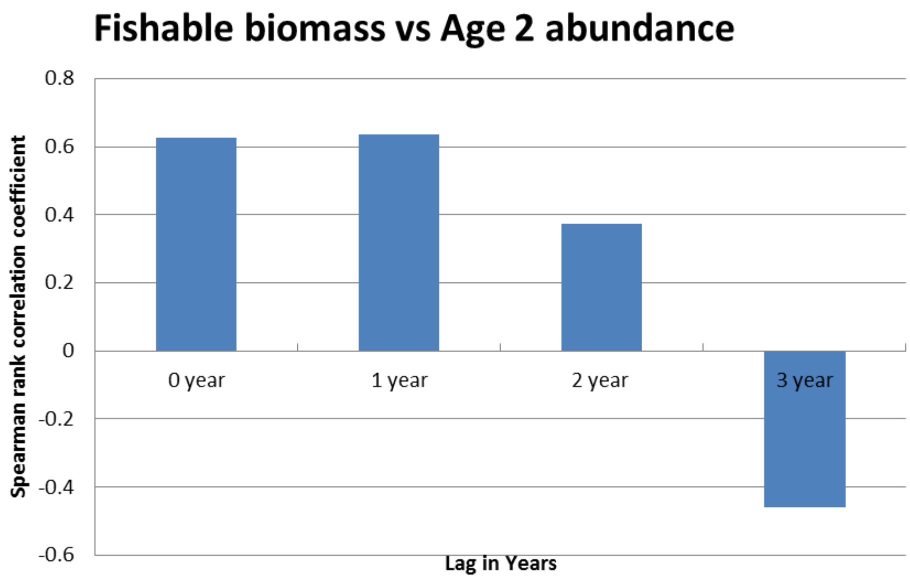


Figure 30. The relationship between spring and autumn recruitment indices created using modal analysis and size range methods.



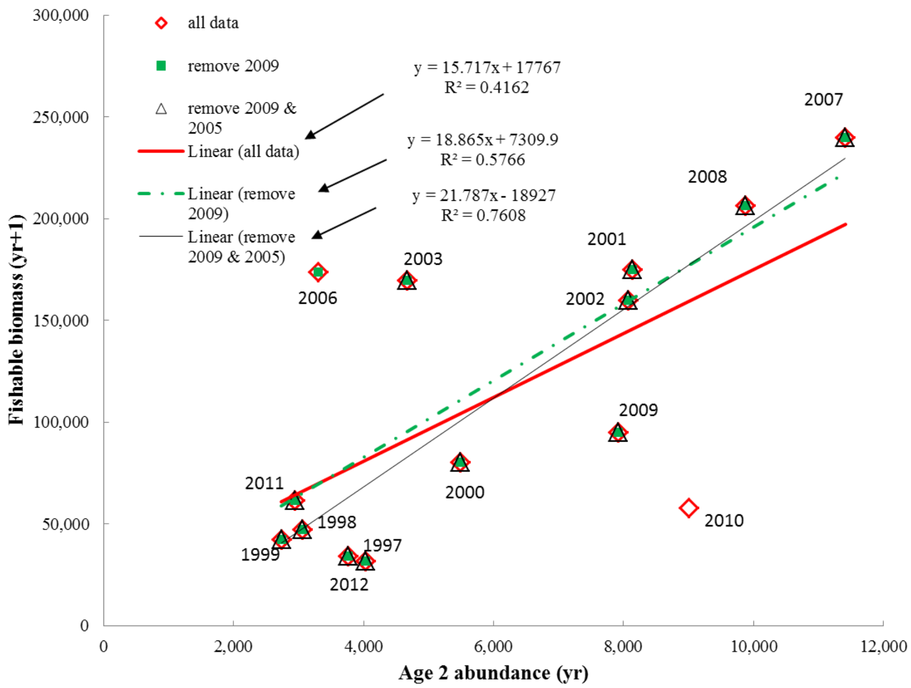


Figure 31. Predictions of fishable biomass from previous year's autumn age 2 abundance index with sequential removals of highly influential observations (years 2006 and 2010 data). The numbers at each point indicate survey year of fishable biomass.

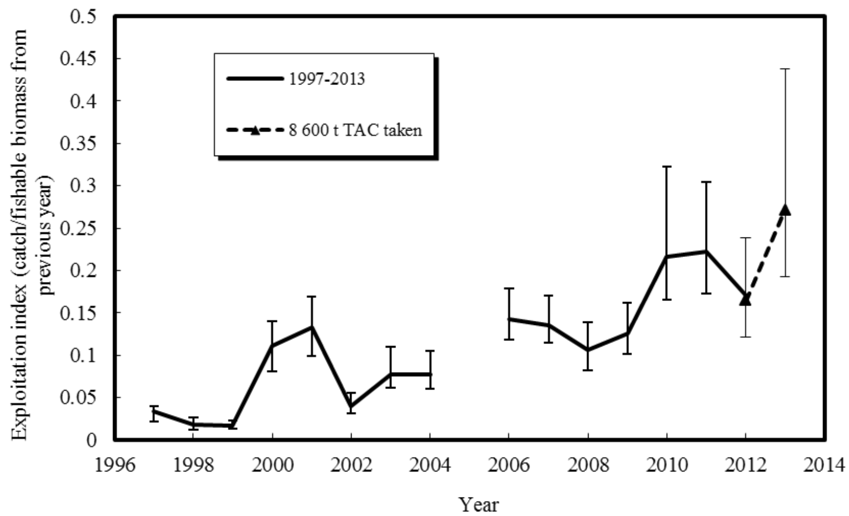


Figure 32. Trends in exploitation as derived by catch divided by the previous year's **autumn** fishable biomass index. The bars represent 95% confidence intervals around the exploitation rates for the proposed method.

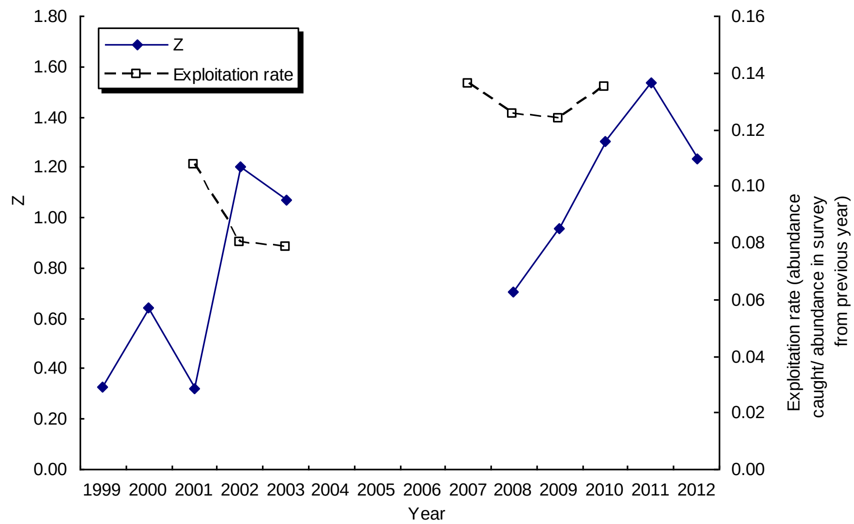


Figure 33. Instantaneous total mortality and exploitation rate indices of Northern Shrimp within NAFO Division 3LNO over the period 2000 – 2011. Please note that these indices are means over three year periods to account for vagaries in ageing and sample collection.

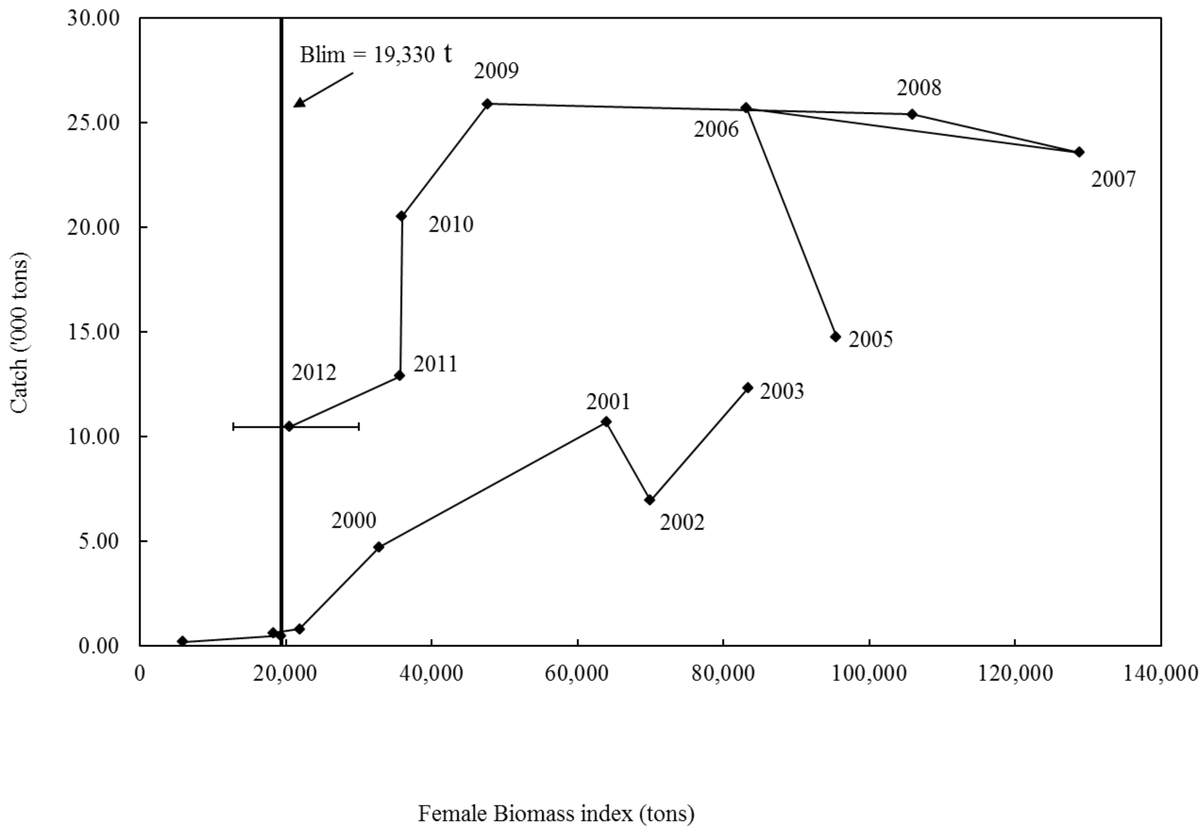


Figure 34. Catch plotted against female biomass index from the Canadian **autumn** multi-species survey data as derived using Ogmap calculations. Line denoting B_{lim} is drawn where the female biomass is 85% lower than the maximum point (2007 value).