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OGive MAPping (ogmap) as an Alternative Means of Estimating Indices and Setting TACs

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Abstract:

Since 1995, the status of NAFO Divisions 3LNO northern shrimp (*Pandalus borealis*) has been monitored using stratified areal expansion calculations. Total Allowable Catch (TAC) has been determined as 15% of the average lower 95% biomass confidence limit over a series of surveys. However, it has been pointed out that this may not be appropriate because the method assumes that data are normally distributed. This may not always be the case, especially when the survey includes one or two very high catches. In such cases, the confidence intervals may be broad and the lower limits may be negative. Therefore, Scientific Council (SC) requested that alternative tools be used in estimating indices and setting TACs.

OGive MAPping (ogmap) is presented as an alternative method of calculating indices. Abundance/ biomass indices and population adjusted length frequencies derived using this method are compared with the more traditional stratified area expansion estimates. TACs are then derived using the average of the lower ogmapped biomass confidence limits from the most recent four surveys. This report also provides an example of how ogmapped fishable biomass indices could be used in producing a TAC.

Introduction

Since 1995, northern shrimp (*Pandalus borealis*), in NAFO Div. 3LNO (Fig. 1), have been collected as part of the Canadian research bottom trawl surveys. Survey stations are assigned using a depth stratified random survey design that was originally developed to monitor the status of commercially important gadoid and flatfish stocks. Biomass and abundances estimates have been calculated using areal expansion equations (Cochran, 1997). This method makes use of three main assumptions:

1. catches are normally distributed;
2. there is no correlation between catches in adjacent strata; and
3. the within stratum environment is uniform; therefore catches within a stratum may be averaged and extrapolated to entire stratum.

Unfortunately these assumptions are not always realized. Data are probably not normally distributed if the survey includes one or two very large catches. For example, the spring 2000 survey included two anomalously high catches (500 and 511 kg) while the spring 2004 survey included one anomalously high catch (1 060 kg). These catches resulted in biomass and abundance indices that were thought to be imprecise because 95% confidence intervals were broad with negative lower confidence limits (Table 1). As noted in Evans *et al.* (2000), the survey makes use of a groundfish stratification scheme therefore the sample design may not be suited to monitor shrimp stock status. It is likely that observations in adjacent strata but nearby locations (taking depth into account) are more similar than observations within the same stratum but at opposite ends of the stratum (Fig. 1). Therefore a continuous approach to index calculation may be more appropriate.

Additionally, Total Allowable Catches (TAC) for Div. 3LNO northern shrimp are calculated as 15% of the average lower confidence limit below biomass indices from a series of surveys. During 2003, Scientific Council (SC) felt that it was not reasonable to derive TACs using the present method because, as noted above, lower confidence limits may be negative.

For these reasons, the biomass and abundance indices as well as population adjusted length frequencies were re-calculated using OGive MAPping (ogmap). This paper compares indices, length frequencies and TACs calculated by stratified areal expansion methods with those calculated using ogmap.

Methods and Materials

Canadian spring and autumn multi-species research surveys:

Shrimp abundance, biomass, maturity and carapace length data have been collected since autumn 1995, as part of the Canadian multi-species bottom trawl surveys. These research surveys are conducted each spring and autumn using the CCG Wilfred Templeman, CCG Alfred Needler and CCG Teleost. Fishing sets of 15 minute duration and a tow speed of 3 knots were randomly allocated to strata covering the Grand Banks and slope waters to a depth of 1 500 m (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 estimated that the mean wingspread was 16.8 m. Details of the survey design and fishing protocols are outlined in (Brodie, 1996; McCallum and Walsh, 1996).

Prior to autumn 2003, shrimp were frozen and returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage was made, and number and weight per set were calculated. Beginning with the autumn 2003 survey, most of the shrimp samples have been processed at sea. Samples that could not be processed at sea were frozen and processed in the lab upon return. The maturity of the shrimp was defined by 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 (Fig. 1).

Data Analysis

Stratified areal expansion:

Stratified abundance/ biomass indices and population adjusted length frequencies were estimated *via* areal expansion using programs based upon Cochran (1997) and written in SAS (D. Orr unpublished).

OGive MAPping (ogmap):

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

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

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

Ogmap is then used to compute the expected value of the distribution at every vertex in each Delauney triangle. The expected value for shrimp biomass within each triangle is integrated using bilinear interpolation. The expected biomass within Div. 3LNO is the sum over all triangles. A Monte Carlo simulation resamples the whole probability distribution at every survey point to provide a new biomass point estimate. Five hundred such simulations are run to provide a probability distribution for the estimated biomass. The point estimate is provided from the entire survey dataset, while the probability distribution is determined through Monte Carlo simulation. Non-parametric 95% percent confidence intervals are then read from the probability distribution (Fig. 5).

Indices calculated using ogmap were compared with respective indices calculated using stratified areal expansion.

As requested by Scientific Council during November 2003, TACs were estimated using the average of a series of non-negative lower 95% biomass confidence limits, and fishable biomass point estimates. The fishable component of the population was defined as males with carapace lengths =>17 mm and all females. Male biomass was determined by converting abundances to biomass using the spring length weight regression:

$$Wt. = 0.000966CL^{2.84166}$$ (Orr and Sullivan, 2004).

Results and Discussion

Comparison between estimates derived using stratified areal expansion and ogmap calculations:

The distribution of shrimp catches from the four most recent Canadian research bottom trawl surveys are presented in Fig. 6. These data were used in both stratified areal expansion and ogmap calculations. There is good agreement between the size and location of catches and the degree of shading within the density plots from the ogmap analysis (Fig. 7) indicating that ogmap provides a realistic representation of Div. 3LNO shrimp distributions.

Table 1 presents biomass and abundance indices from the spring and autumn surveys over the period 1995-2004 as determined by areal expansion methods. Confidence intervals around the spring 2000 and 2004 indices were broad, with negative lower 95% confidence limits, because the method assumes that data are normally distributed and the results were heavily influenced by a few anomalously high catches (500 and 511 kg sets during spring 2000; and a 1 060 kg set during spring 2004).

Ogmapped biomass and abundance indices with their respective confidence intervals over the same periods are presented in Table 2. Figures 8 and 9 compare biomass and abundance indices obtained using the two methods. In general, the point estimates are very similar regardless of the method used; however, the difference lies in the confidence intervals. Ogmap does not rely upon the assumption that data are normally distributed and calculations are made over hundreds of small triangles, therefore the method may in principle take finer spatial detail into account (Evans *et al.*, 2000). For these reasons, ogmap confidence intervals may be narrower than those calculated by areal expansion. Additionally, ogmap confidence intervals are taken from a probability distribution plot ensuring that the lower confidence limits can never be negative.

Biomass point estimates for the entire study region were then compared with those from outside the 200 Nmi limit in Tables 3 and 4 for estimates derived using areal expansion, and Tables 5 and 6 for estimates derived using ogmap calculations. Once again both methods provided similar results within respective time periods and areas. Over the study period, the area outside 200 Nmi accounted for between 12 and 31% of the 3LNO biomass point estimates.

Similarly, there is good agreement between length frequencies using either method of calculation (Fig. 9 and 10).

TAC Calculations

Based upon significant increases in biomass and recruitment over the period 1999-2002, Scientific Council recommended that the 2003 TAC increase from 6 000 t to 13 000 tons. The new TAC was calculated by applying a 15% exploitation rate to the lower 95% biomass confidence limits, averaged over the autumn 2000-2001 and spring 2001-2002 surveys. Similar results are obtained using either areal expansion and ogmap methods (Table 7). A 15% exploitation rate is consistent with the management strategy in an adjacent shrimp fishing area, Hawke + Div. 3K

(Shrimp Fishing Area 6). The 2004 SFA 6 shrimp quota is 77 932 tons which when applied to the average of the last four lower 95% ogmap biomass confidence limits results in an exploitation rate of 14.75% (Table 8).

Purely as an example, the TAC was re-evaluated based upon the four most recent surveys. By applying Stratified areal expansion calculations to the average of the last four surveys with non-negative lower confidence limits, on obtains a TAC of 17 000 tons. By applying ogmap calculations to the last four surveys one obtains a TAC of 15 000 tons. Alternatively, as an example, one obtains a TAC of 16 000 tons by applying a 10% removal to the average ogmap fishable biomass from the past four surveys (Table 10).

Summary

Ogmap was presented as a method to determine abundance/ biomass indices and population adjusted length frequencies. Comparisons between ogmap and stratified areal expansion methods demonstrated that the point estimates were similar. Since ogmap makes estimates within a dense mesh of triangle, it is possible for the method to account for a finer spatial detail than fixed stratification.

In the present case, shrimp stock status is being monitored using a stratification scheme designed to monitor gadoid and flatfish stocks. There is no reason to believe that shrimp should be distributed similarly to these finfish. Therefore, the continuous approach developed within the ogmap framework may be more appropriate to index estimation than the rigid stratum boundaries assumed by stratified areal assumption. Ogmap makes use of a decaying function that giving greater weight to nearby samples (taking depth and horizontal distance into account) than to distant samples. This makes intuitive sense. As opposed to stratified areal expansion methods which assume that the environment within a stratum is uniform and that samples from opposite ends of a stratum may be averaged and then extrapolated to the entire stratum. Stratified methods assume that there is no relationship between samples from nearby strata.

Additionally, stratified areal expansion calculations assume that the data are normally distributed. As demonstrated in the present paper, 95% confidence intervals may be wide and lower limits may be negative when the data include one or two outlying catches. Alternatively, ogmap does not make distributional assumptions and confidence limits can never be negative because they are taken from a probability distribution ogive.

Finally, an example was provided of how TACs could be derived from ogmap biomass confidence limits and fishable biomass indices.

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Table 1. Northern shrimp stock size estimates in NAFO Div. 3LNO as calculated using stratified areal expansion methods. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1995-2004. (Offshore strata only with standard 15 min. tows).

Spring stock size estimates

	Biomass (tons)			Abundance (numbers x 10^{-6})			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	12,564	55,317	98,069	3,178	12,702	22,227	313
2000	-15,869	121,815	259,498	-54,743	25,012	104,768	298
2001	62,359	102,566	142,773	13,417	24,845	36,272	300
2002	121,067	159,491	197,916	28,311	37,512	46,714	300
2003	112,299	193,766	275,233	21,857	46,295	70,732	300
2004	-529,764	110,827	751,418	-97,747	21,696	141,395	296

Autumn stock size estimates

	Biomass (tons)			Abundance (numbers x 10-6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1995	3,639	5,921	8,202	659	2,054	3,449	337
1996	10,230	20,088	29,948	1,985	5,867	9,748	304
1997	25,530	46,202	66,875	6,280	10,523	14,766	318
1998	40,011	59,914	79,816	10,787	15,326	19,866	347
1999	36,202	53,144	70,086	9,588	13,060	16,533	313
2000	93,132	118,180	143,227	25,840	32,066	38,292	337
2001	77,563	223,995	370,427	20,177	54,077	87,978	362
2002	126,180	215,008	303,837	30,469	50,257	70,044	365
2003	106,338	223,568	340,798	29,708	47,281	64,853	316

Table 2. Northern shrimp stock size estimates in NAFO Div. 3LNO as calculated using ogmap. Data were obtained from annual spring and autumn Canadian multi-species bottom trawl surveys, 1995-2004. (Offshore strata only with standard 15 min. tows).

Spring stock size estimates

	Biomass (tons)			Abundance (numbers x 10-6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1999	27,080	49,500	76,520	6,592	11,437	17,310	313
2000	65,710	113,300	176,700	13,150	21,356	31,590	298
2001	52,680	82,500	117,000	12,240	19,714	28,540	300
2002	87,390	133,800	204,700	20,730	31,260	47,660	300
2003	118,300	169,600	237,500	26,210	38,998	57,840	300
2004	4,080	100,900	178,200	8,213	19,444	33,820	296

Autumn stock size estimates

	Biomass (tons)			Abundance (numbers x 10^{-6})			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1995	6,944	8,300	14,630	2,056	2,659	4,789	337
1996	21,700	24,700	35,150	5,324	6,575	9,370	304
1997	32,410	44,000	61,940	7,545	9,911	13,860	318
1998	48,310	60,700	76,640	11,950	14,975	19,120	347
1999	43,160	54,900	72,390	10,620	12,993	16,510	313
2000	83,990	107,000	139,200	20,890	27,898	35,830	337
2001	155,300	215,400	259,600	36,890	51,730	62,040	362
2002	135,500	191,700	239,500	31,100	44,472	54,750	365
2003	143,300	191,100	244,900	29,880	39,293	48,850	316

Table 3. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using stratified areal expansion calculations with data obtained from annual spring Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Biomass estimate (Kg x 1000)	Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Spring	1999	3L	53,934	97.50	14,731	91.74		27.31	27.31
Spring	2000	3L	119,521	98.12	36,127	94.30		30.23	28.77
Spring	2001	3L	102,493	99.93	18,397	99.75		17.95	25.16
Spring	2002	3L	155,061	97.22	47,288	92.79		30.50	26.22
Spring	2003	3L	190,718	98.43	38,473	93.13		20.17	22.87
Spring	2004	3L	109,590	98.88	27,262	96.37		24.88	25.18
			Overall average	**98.35**			Overall average	**25.17**	
Spring	1999	3N	1,349	2.44	1,327	8.26		98.37	98.37
Spring	2000	3N	2,248	1.85	2,178	5.69		96.89	97.63
Spring	2001	3N	53	0.05	45	0.24		84.91	93.39
Spring	2002	3N	4,395	2.76	3,670	7.20		83.50	88.43
Spring	2003	3N	2,853	1.47	2,834	6.86		99.33	89.25
Spring	2004	3N	1,099	0.99	1,019	3.60		92.72	91.85
			Overall average	**1.59**			Overall average	**92.62**	
Spring	1999	3O	34	0.06	0	0.00		0.00	0.00
Spring	2000	3O	46	0.04	6	0.02		13.04	6.52
Spring	2001	3O	20	0.02	2	0.01		10.00	7.68
Spring	2002	3O	35	0.02	4	0.01		11.43	11.49
Spring	2003	3O	196	0.10	2	0.01		1.02	7.48
Spring	2004	3O	138	0.12	8	0.02		5.80	6.08
			Overall average	**0.06**			Overall average	**6.88**	
	all divisions								
Spring	1999		55,317		16,057			29.03	29.03
Spring	2000		121,815		38,310			31.45	30.24
Spring	2001		102,566		18,444			17.98	26.15
Spring	2002		159,491		50,962			31.95	27.13
Spring	2003		193,766		41,310			21.32	34.23
Spring	2004		110,827		28,289			25.53	32.26
							Overall average	**26.21**	

Table 4. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using stratified areal expansion calculations with data obtained from annual autumn Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Division Biomass estimate (Kg x 1000)	Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1995	3L	5,357	90.48	1,039	67.63		19.40	19.40
Autumn	1996	3L	18,566	92.42	4,506	76.86		24.27	21.84
Autumn	1997	3L	45,758	99.04	5,115	92.83		11.18	18.28
Autumn	1998	3L	56,485	94.28	8,707	75.66		15.42	16.95
Autumn	1999	3L	52,863	99.47	8,734	97.38		16.52	14.37
Autumn	2000	3L	117,902	99.77	28,447	99.16		24.13	18.69
Autumn	2001	3L	223,149	99.62	52,292	98.47		23.43	21.36
Autumn	2002	3L	210,451	97.88	35,702	91.48		16.96	21.51
Autumn	2003	3L	220,711	98.72	43,986	94.76		19.93	20.11
			Overall average	**96.85**			Overall average	**19.03**	
Autumn	1995	3N	533	9.00	497	32.34		93.29	93.29
Autumn	1996	3N	1,514	7.54	1,356	23.12		89.52	91.40
Autumn	1997	3N	427	0.92	391	7.09		91.52	91.44
Autumn	1998	3N	3,360	5.61	2,786	24.21		82.91	87.98
Autumn	1999	3N	272	0.51	232	2.59		85.57	86.67
Autumn	2000	3N	270	0.23	240	0.84		88.80	85.76
Autumn	2001	3N	836	0.37	809	1.52		96.77	90.38
Autumn	2002	3N	4,444	2.07	3,295	8.44		74.14	86.57
Autumn	2003	3N	2,785	1.25	2,421	5.22		86.93	85.95
			Overall average	**3.06**			Overall average	**87.72**	
Autumn	1995	3O	31	0.52	1	0.04		1.82	1.82
Autumn	1996	3O	9	0.04	1	0.02		12.50	7.16
Autumn	1997	3O	17	0.04	4	0.07		23.79	12.70
Autumn	1998	3O	69	0.12	15	0.13		21.23	19.17
Autumn	1999	3O	9	0.02	3	0.03		33.59	26.21
Autumn	2000	3O	8	0.01	1	0.00		8.02	20.95
Autumn	2001	3O	10	0.00	3	0.01		30.00	23.87
Autumn	2002	3O	113	0.05	32	0.08		28.32	22.11
Autumn	2003	3O	72	0.03	8	0.02		11.11	23.14
			Overall average	**0.09**			Overall average	**18.93**	
	all divisions								
Autumn	1995		5,921		1,537			25.96	25.96
Autumn	1996		20,088		5,862			29.18	27.57
Autumn	1997		46,202		5,509			11.92	22.36
Autumn	1998		59,914		11,508			19.21	20.11
Autumn	1999		53,144		8,969			16.88	16.00
Autumn	2000		118,180		28,687			24.27	20.12
Autumn	2001		223,995		53,104			23.71	21.62
Autumn	2002		215,008		39,029			18.15	22.04
Autumn	2003		223,568		46,416			20.76	20.87
							Overall average	**21.12**	

Table 5. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using ogmap calculations with data obtained from annual autumn Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Division Biomass estimate (Kg x 1000)	Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Outside 200 Nmi limit Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Spring	1999	3L	47,500	95.38	10,200	85.71		21.47	21.47
Spring	2000	3L	108,700	95.77	23,800	87.18		21.90	21.68
Spring	2001	3L	82,700	99.64	11,400	99.13		13.78	19.05
Spring	2002	3L	128,100	95.60	34,300	91.47		26.78	20.82
Spring	2003	3L	165,400	96.73	29,900	86.92		18.08	19.55
Spring	2004	3L	99,500	98.61	27,100	97.48		27.24	24.03
			overall average	**97**			Overall average	**21.54**	
Spring	1999	3N	2,200	4.42	1,700	14.29		77.27	77.27
Spring	2000	3N	4,700	4.14	3,500	12.82		74.47	75.87
Spring	2001	3N	300	0.36	100	0.87		33.33	61.69
Spring	2002	3N	5,800	4.33	3,200	8.53		55.17	54.32
Spring	2003	3N	5,400	3.16	4,500	13.08		83.33	57.28
Spring	2004	3N	1,200	1.19	700	2.52		58.33	65.61
			overall average	**3**			Overall average	**63.65**	
Spring	1999	3O	100	0.20	0	0.00		0.00	0.00
Spring	2000	3O	100	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	100	0.07	0	0.00		0.00	0.00
Spring	2003	3O	200	0.12	0	0.00		0.00	0.00
Spring	2004	3O	200	0.20	0	0.00		0.00	0.00
			overall average	**0**			Overall average	**0.00**	
	all divisions								
Spring	1999		49,800		11,900			23.90	23.90
Spring	2000		113,500		27,300			24.05	23.97
Spring	2001		83,000		11,500			13.86	20.60
Spring	2002		134,000		37,500			27.99	21.96
Spring	2003		171,000		34,400			20.12	20.65
Spring	2004		100,900		27,800			27.55	25.22
							Overall average	**22.91**	

Table 6. NAFO Div. 3LNO northern shrimp (*Pandalus borealis*) biomass estimates for entire Divisions and outside the 200 Nmi limit. The estimates were derived using ogmap calculations with data obtained from annual autumn Canadian research bottom trawl surveys. (Standard 15 min. tows taken with a Campelen 1800 shrimp trawl.)

Season	Year	Division	Entire Biomass estimate (Kg x 1000)	Entire Percent by division	Outside 200 Nmi limit Biomass estimate (Kg x 1000)	Outside 200 Nmi limit Percent biomass by division		percent biomass in NRA	3 year running average percent biomass in NRA
Autumn	1995	3L	7,500	90.36	1,000	62.50		13.33	13.33
Autumn	1996	3L	22,900	92.71	4,000	85.11		17.47	15.40
Autumn	1997	3L	43,400	98.64	5,500	91.67		12.67	14.49
Autumn	1998	3L	56,000	92.26	8,900	81.65		15.89	15.34
Autumn	1999	3L	54,500	99.27	8,000	96.39		14.68	14.41
Autumn	2000	3L	105,800	98.88	22,100	98.22		20.89	17.15
Autumn	2001	3L	213,700	99.21	40,800	97.14		19.09	18.22
Autumn	2002	3L	187,800	97.97	35,200	92.39		18.74	19.57
Autumn	2003	3L	185,300	96.96	35,300	91.69		19.05	18.96
			Overall average	**96.25**			Overall average	**16.87**	
Autumn	1995	3N	900	10.84	600	37.50		66.67	66.67
Autumn	1996	3N	2,000	8.10	700	14.89		35.00	50.83
Autumn	1997	3N	700	1.59	500	8.33		71.43	57.70
Autumn	1998	3N	4,700	7.74	2,000	18.35		42.55	49.66
Autumn	1999	3N	500	0.91	300	3.61		60.00	57.99
Autumn	2000	3N	700	0.65	400	1.78		57.14	53.23
Autumn	2001	3N	1,700	0.79	1,200	2.86		70.59	62.58
Autumn	2002	3N	4,000	2.09	2,900	7.61		72.50	66.74
Autumn	2003	3N	4,700	2.46	3,200	8.31		68.09	70.39
			Overall average	**3.91**			Overall average	**60.44**	
Autumn	1995	3O	0	0.00	0	0.00		0.00	0.00
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	100	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	100	0.05	0	0.00		0.00	0.00
Autumn	2003	3O	200	0.10	0	0.00		0.00	0.00
			Overall average	**0.04**			Overall average	**0.00**	
	all divisions								
Autumn	1995		8,300		1,600			19.28	19.28
Autumn	1996		24,700		4,700			19.03	19.15
Autumn	1997		44,000		6,000			13.64	17.31
Autumn	1998		60,700		10,900			17.96	16.87
Autumn	1999		54,900		8,300			15.12	15.57
Autumn	2000		107,000		22,500			21.03	18.03
Autumn	2001		215,400		42,000			19.50	18.55
Autumn	2002		191,700		38,100			19.87	20.13
Autumn	2003		191,100		38,500			20.15	19.84
							Overall average	**18.40**	

Table 7. A comparison between the most recent TAC based upon stratified areal expansion calculations and the TAC had it been based upon ogmap calculations.

Survey	Stratified areal expansion: Biomass lower 95% C.L.	Ogmap: Biomass lower 95% C.L.
Autumn 2000	93,132 t	83,990 t
Autumn 2001	77,563 t	155,300 t
Spring 2001	62,359 t	52,680 t
Spring 2002	121,067 t	87,390 t
Average of the lower C.L.	88,530 t	94,840 t
15% of the average lower C.L.	13,280 t	14,226 t

Table 8. The TAC within Hawke Channel + 3K (SFA 6) as a percentage of the average lower 95% confidence limit for ogmap biomass indices from the last four autumn Canadian research bottom trawl surveys.

Survey	Ogmap: Biomass Lower 95% C.L.
Autumn 2000	503,700 t
Autumn 2001	566,400 t
Autumn 2002	536,700 t
Autumn 2003	506,700 t
Average of lower C.L.	528,375 t
Present TAC	77,932 t
Exploitation rate (catch/lower C.L.) expressed as a percentage	14.75%

Table 9. Revised TACs based upon stratified areal expansion calculations and ogmap calculations using the most recent Canadian research bottom trawl surveys with non negative lower confidence limits.

Survey	Stratified areal Expansion: Biomass Lower 95% C.L.	Survey	Ogmap: Biomass Lower 95% C.L.
Autumn 2002	126,180 t	Autumn 2002	135,500 t
Autumn 2003	106,338 t	Autumn 2003	143,300 t
Spring 2002	121,067 t	Spring 2003	118,300 t
Spring 2003	112,299 t	Spring 2004	4 080 t
Average of lower C.L.	116,471 t		100,295 t
15% of the average lower C.L.	17,471 t		15,044 t

Table 10. Revised TACs based upon ogmap calculations of fishable biomass (males >17 mm, and all females) using data collected during the most recent Canadian research bottom trawl surveys.

	Autumn 2002	Autumn 2003	Spring 2003	Spring 2004
Fishable male biomass	109,214 t	98,809 t	84,854 t	54,821 t
Female biomass	69,500 t	82,400 t	78,500 t	44,900 t
Total fishable biomass	178,714 t	181,209 t	163,354 t	99,721 t
Average fishable biomass	155,750 t			
TAC based upon 10% of the average fishable biomass	16,000 t			

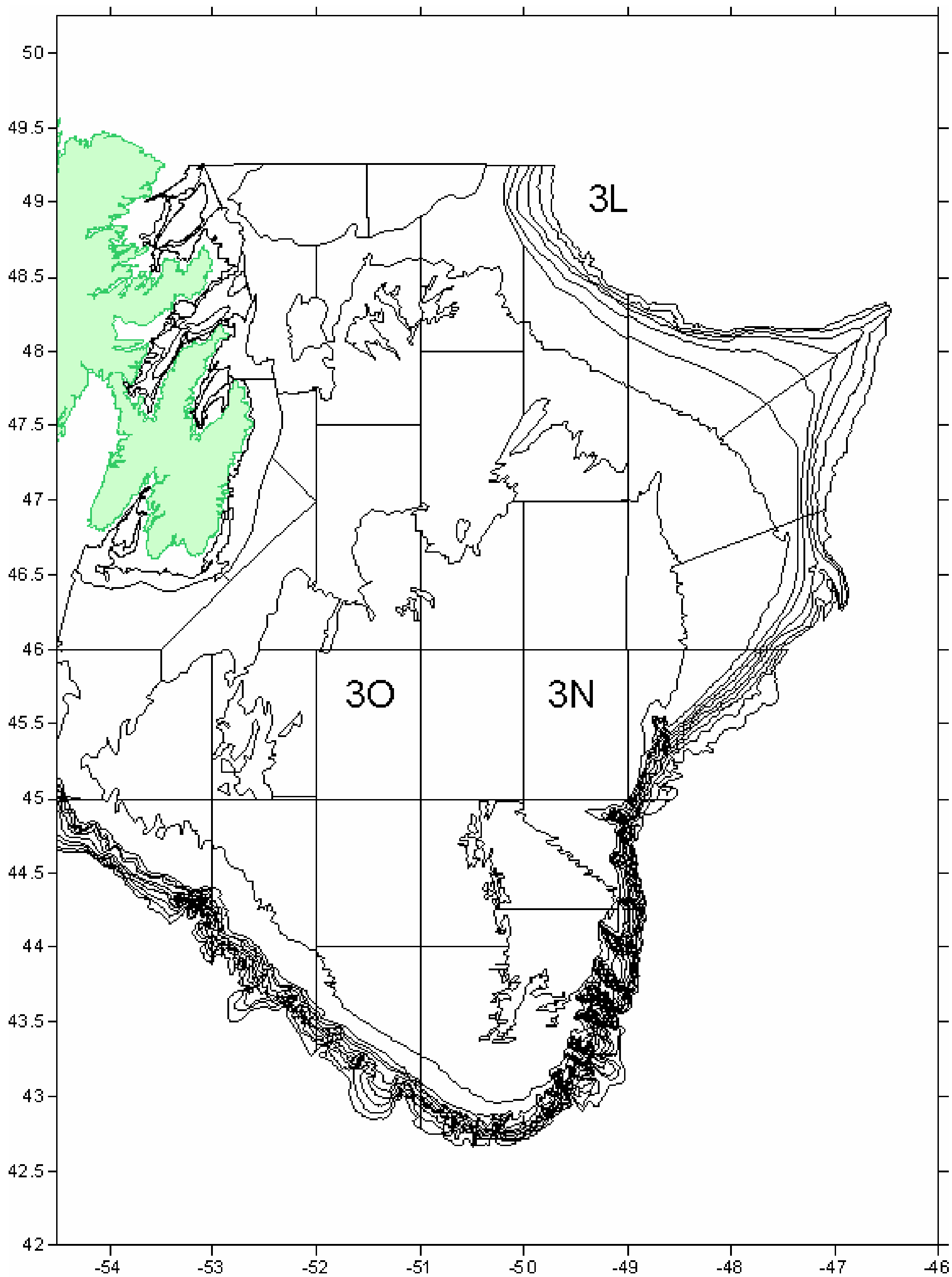

Fig. 1. The NAFO Div. 3LNO stratification scheme used in Canadian research bottom trawl survey set allocation.

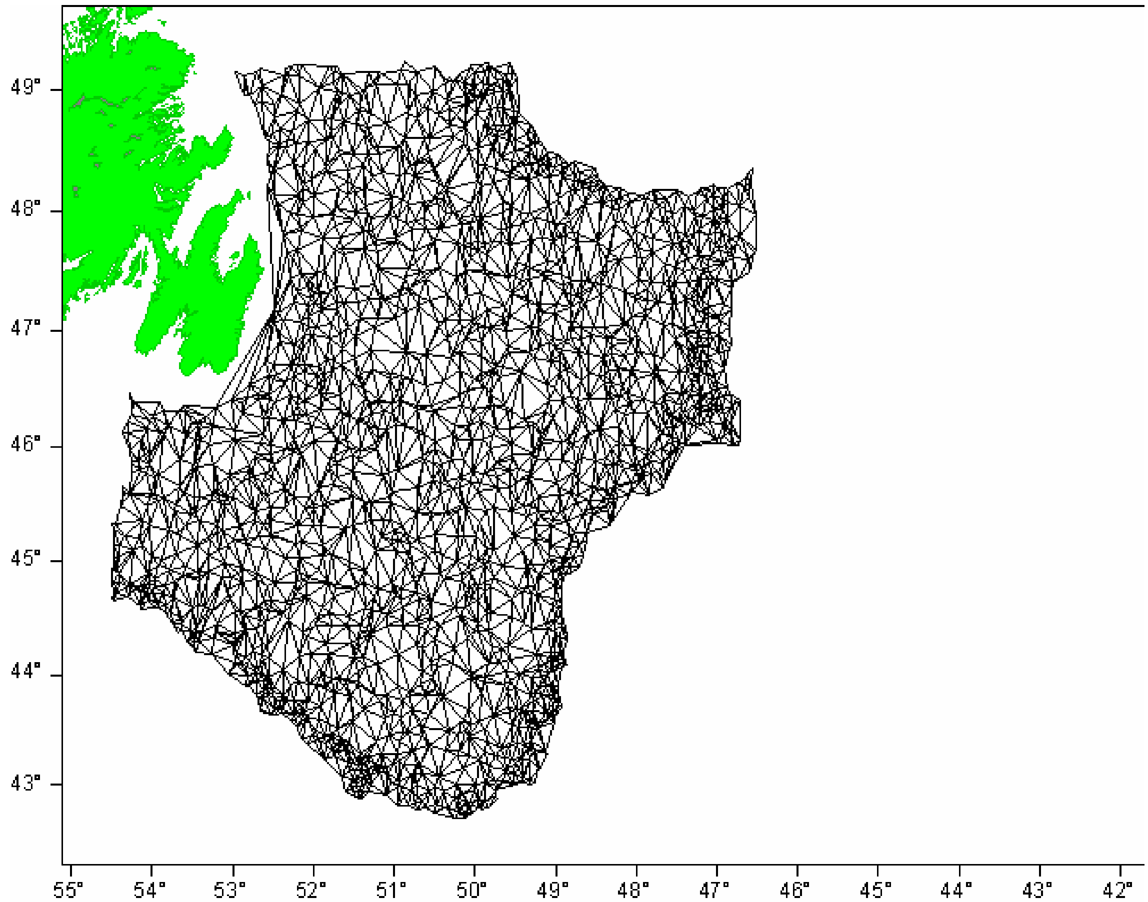

Fig. 2. The Delauney triangulation used by ogmap to derive shrimp biomass, abundance indices and population adjusted length frequencies within NAFO Div. 3LNO.

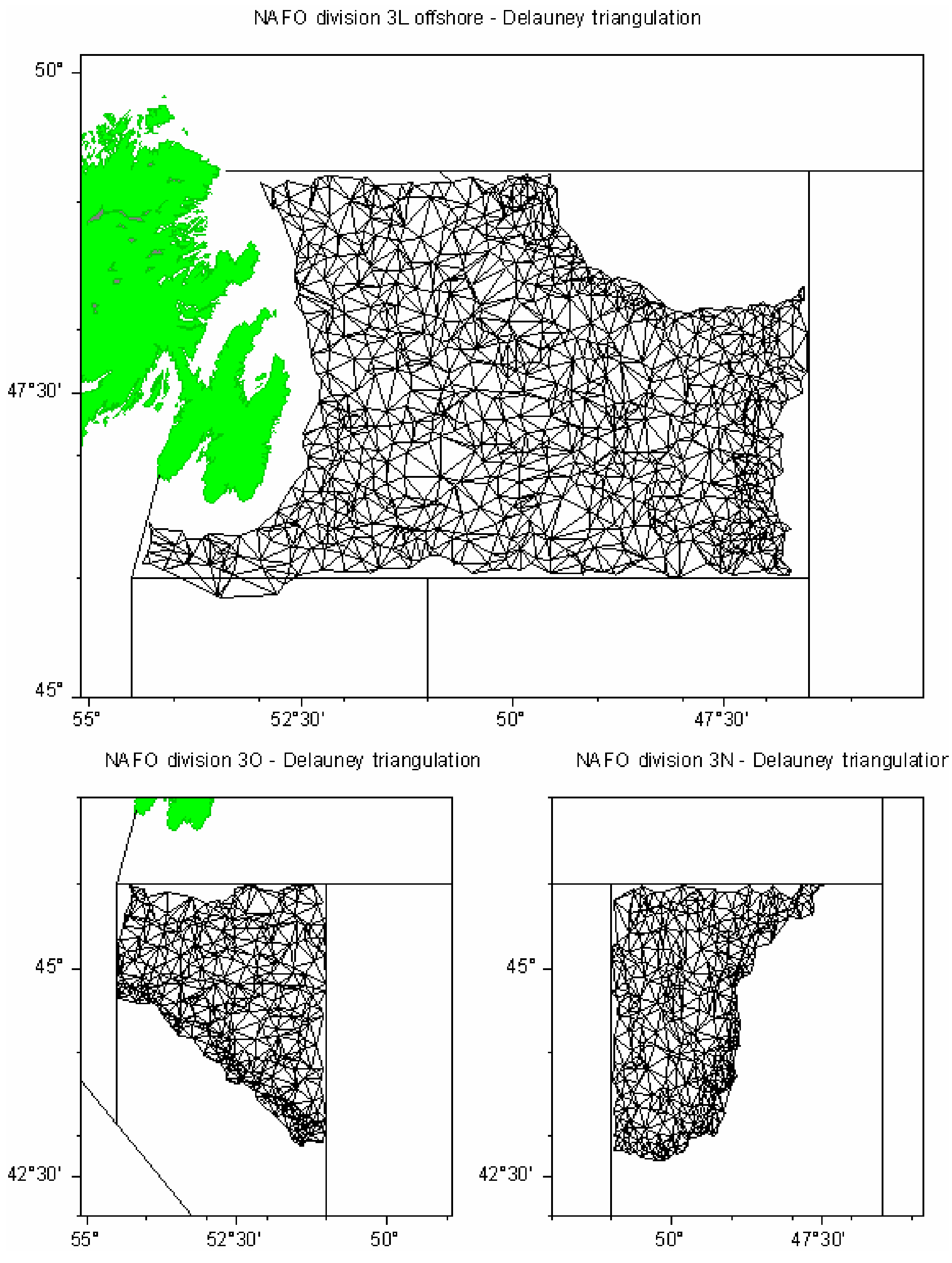

Fig. 3. The Delauney triangulation used to derive within NAFO Division ogmap biomass and abundance indices.

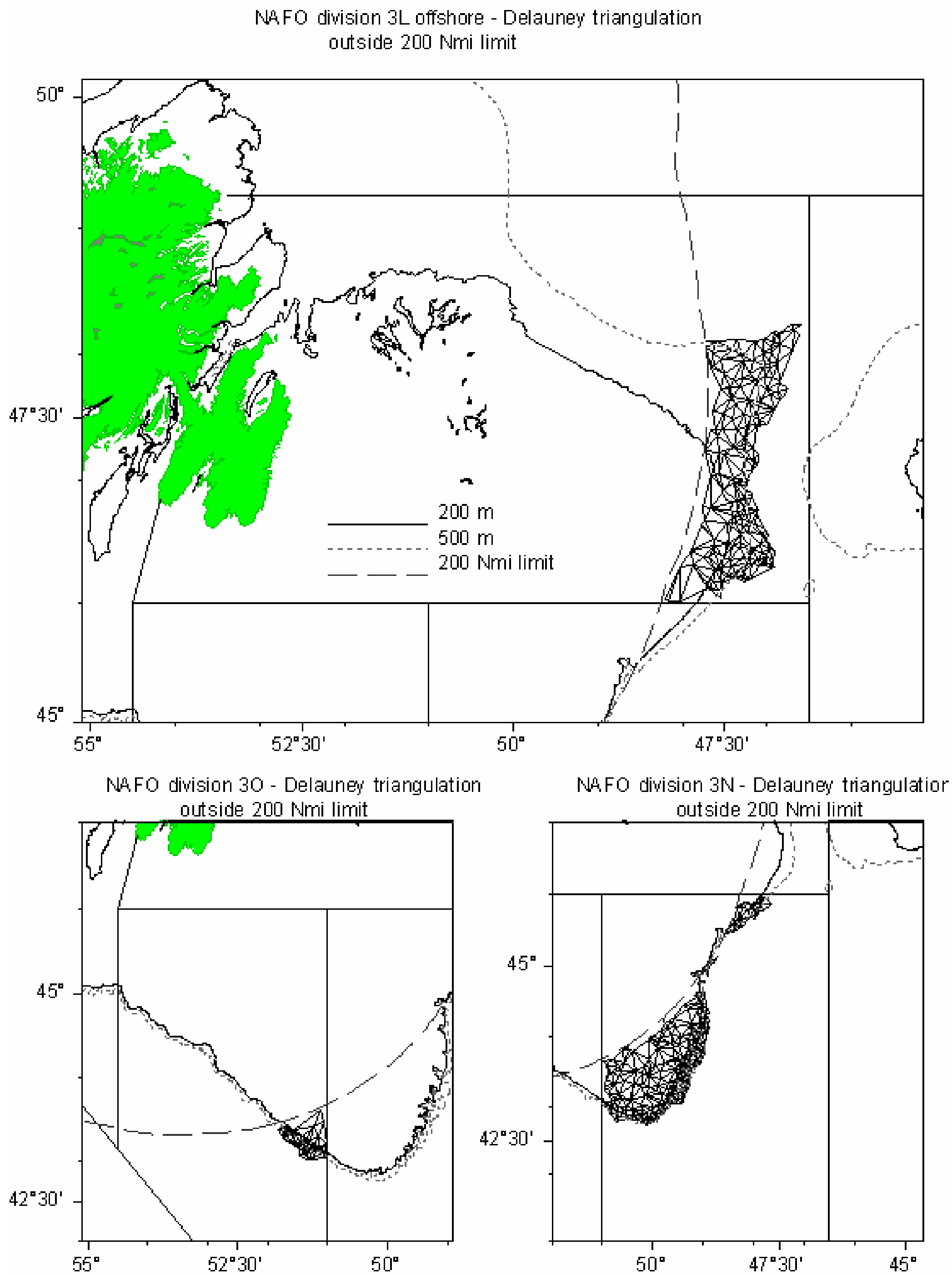

Fig. 4. The Delauney triangulation used to derive the outside 200 Nmi limit ogmap biomass and abundance indices.

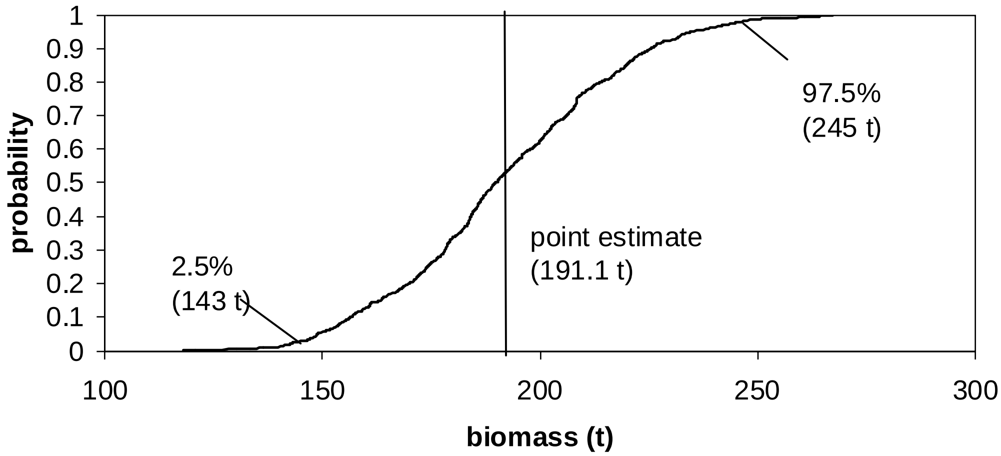

Fig. 5. The Monte Carlo distribution for expected biomass of northern shrimp (*Pandalus borealis*) integrated over NAFO Div. 3LNO. Please note that the expected biomass index is calculated from the entire distribution rather than from the Monte Carlo simulations. The 95% confidence limits are found on the distribution ogive. The data used in this analysis were obtained during the autumn 2003 Canadian research bottom trawl survey.

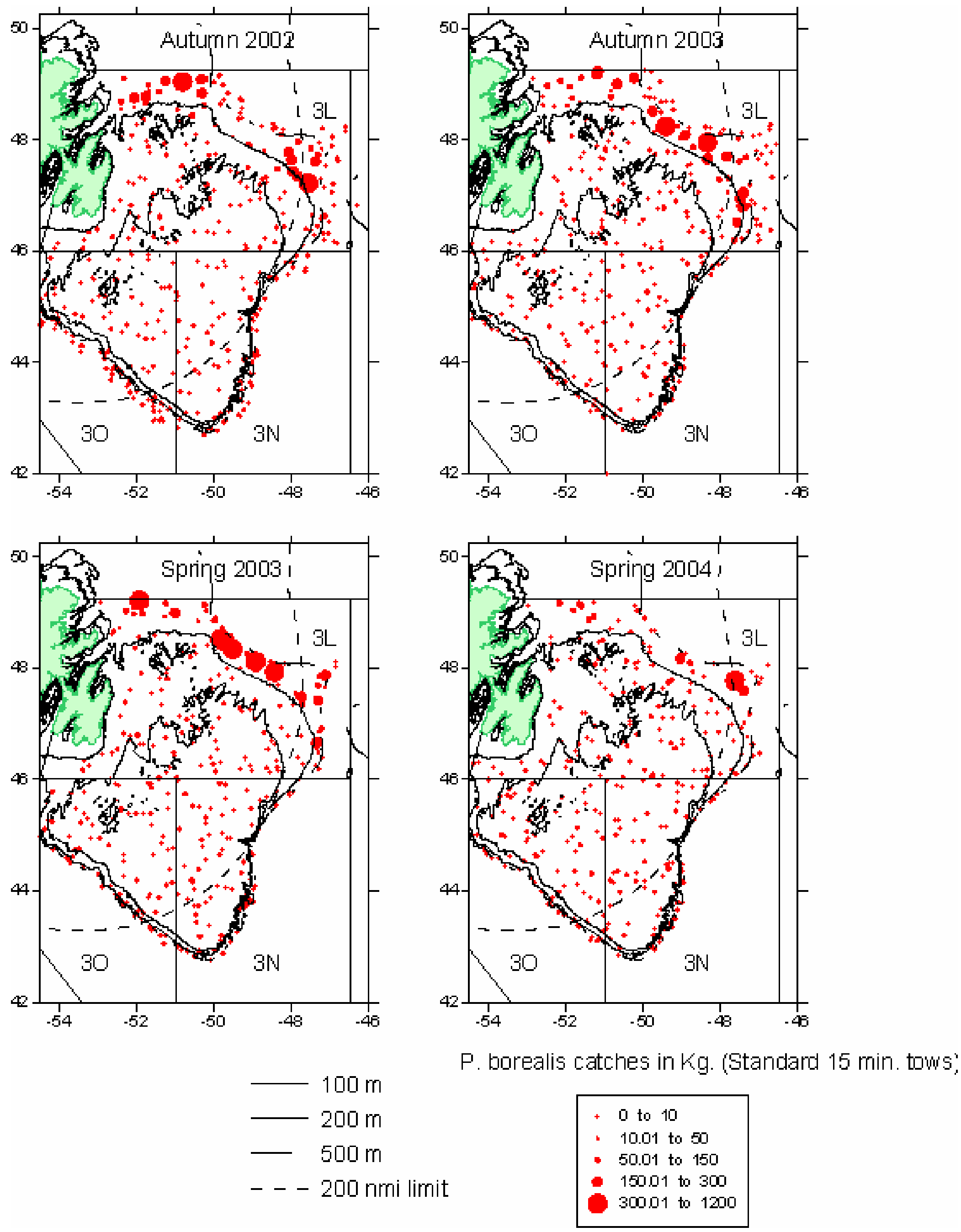

Fig. 6. Distribution of NAFO Div. 3LNO northern pink shrimp (*Pandalus borealis*) catches (kg/tow) as obtained from spring and autumn Canadian research bottom trawl surveys conducted over the period 2002-2004 using a Camplen 1800 shrimp trawl.

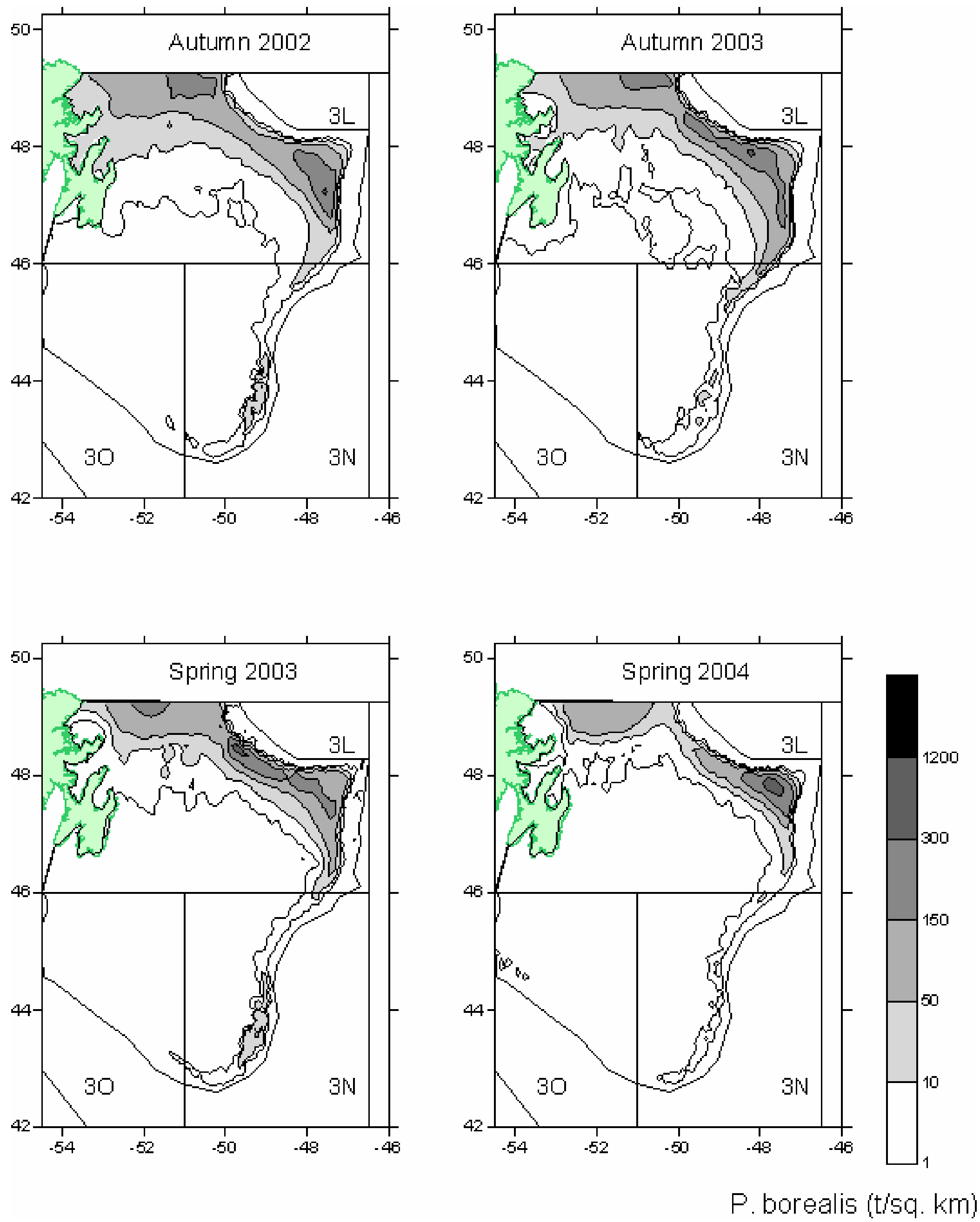

Fig. 7. The estimated northern shrimp (*Pandalus borealis*) densities (t/sq. km) as calculated using ogmap. The data were obtained from spring and autumn Canadian research bottom trawl surveys conducted over the period 2002-2004 using a Camplen 1800 shrimp trawl.

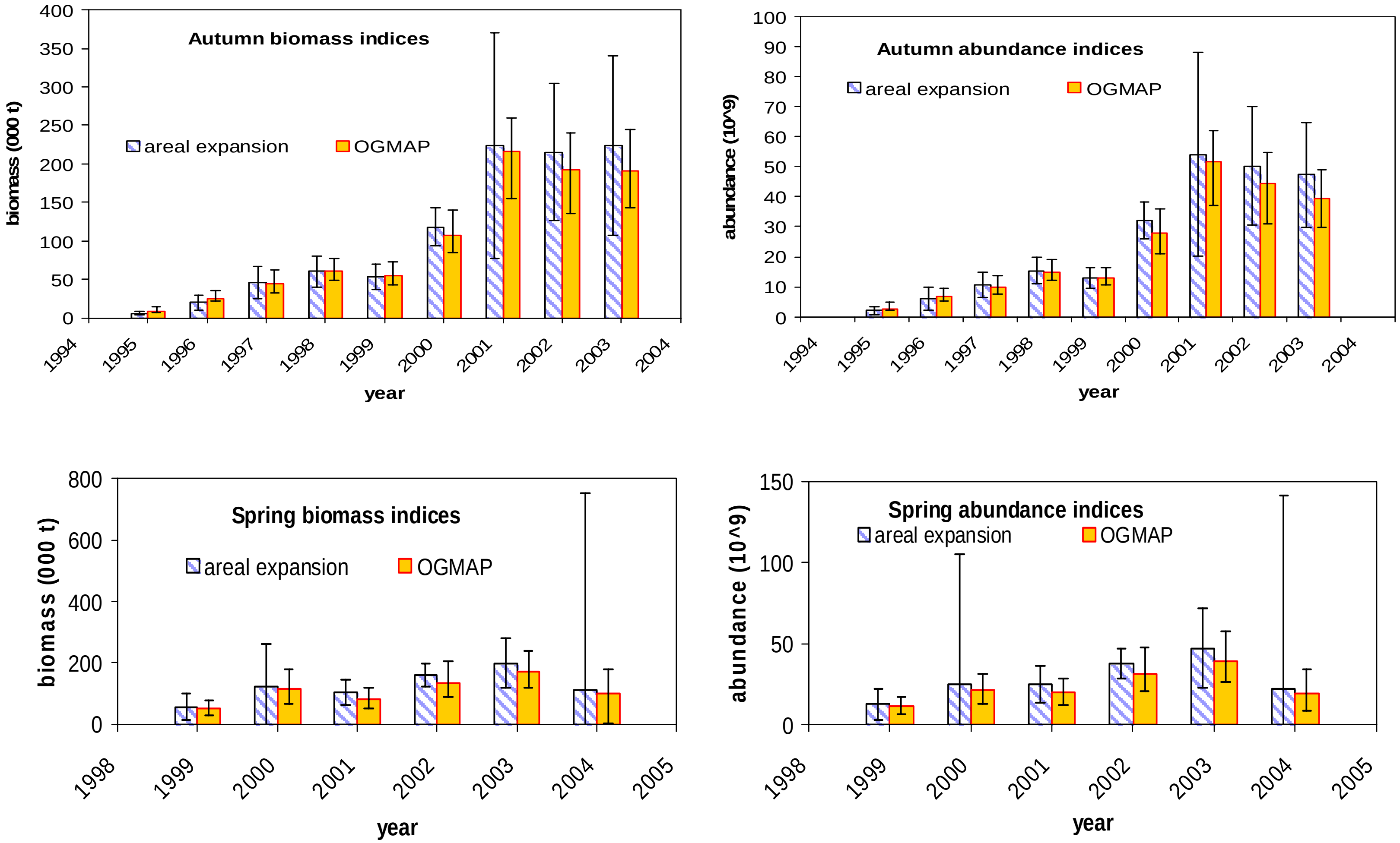

Fig. 8. NAFO Div. 3LNO northern shrimp biomass and abundance indices with 95% confidence intervals as calculated using stratified areal expansion and ogmap methods. The data were obtained from annual spring and autumn Canadian research.

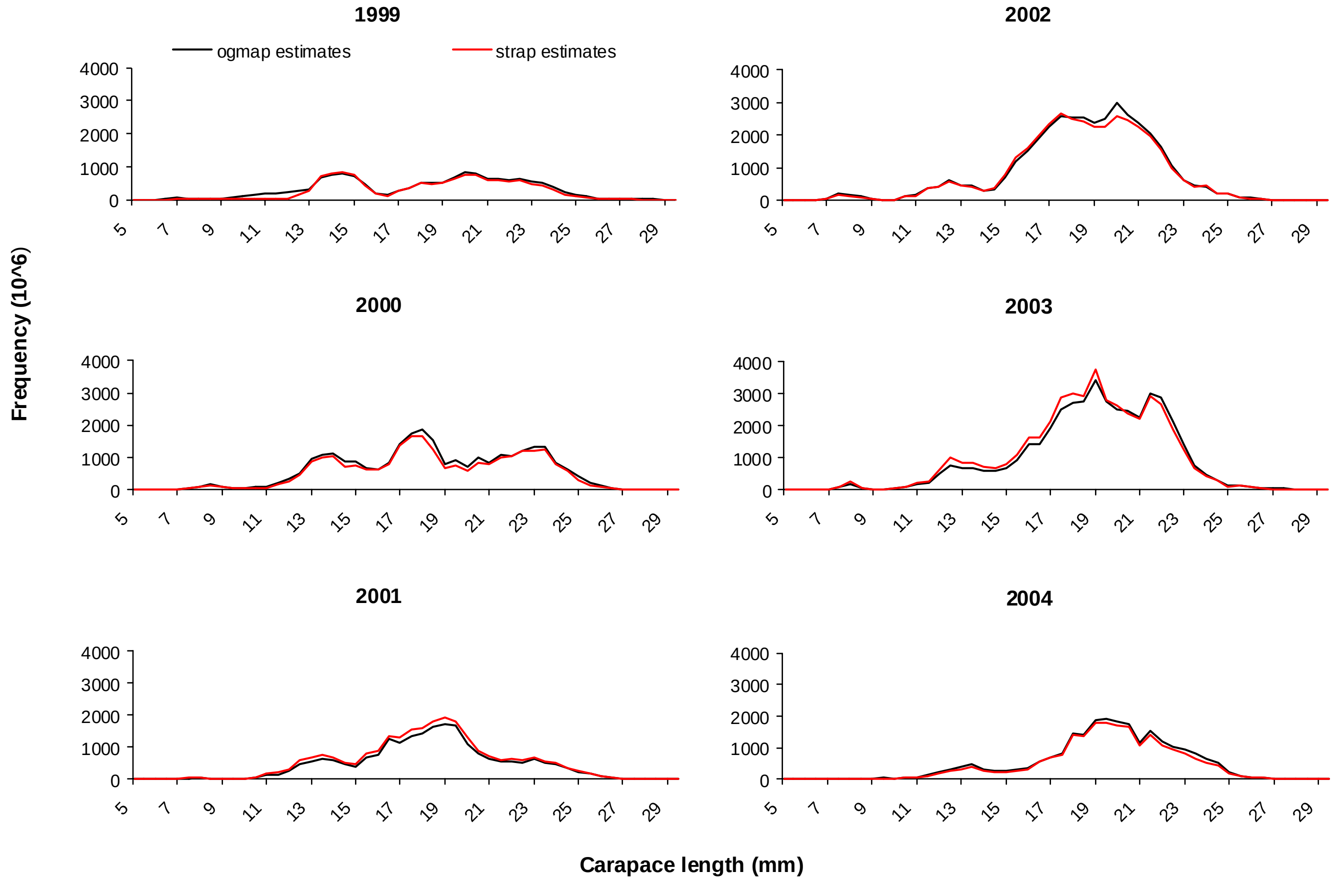

Fig. 9. NAFO Div. 3LNO northern shrimp carapace length frequencies as calculated using stratified areal expansion and ogmap calculations. The data were obtained from annual spring Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only. Standard 15 min. tows.)

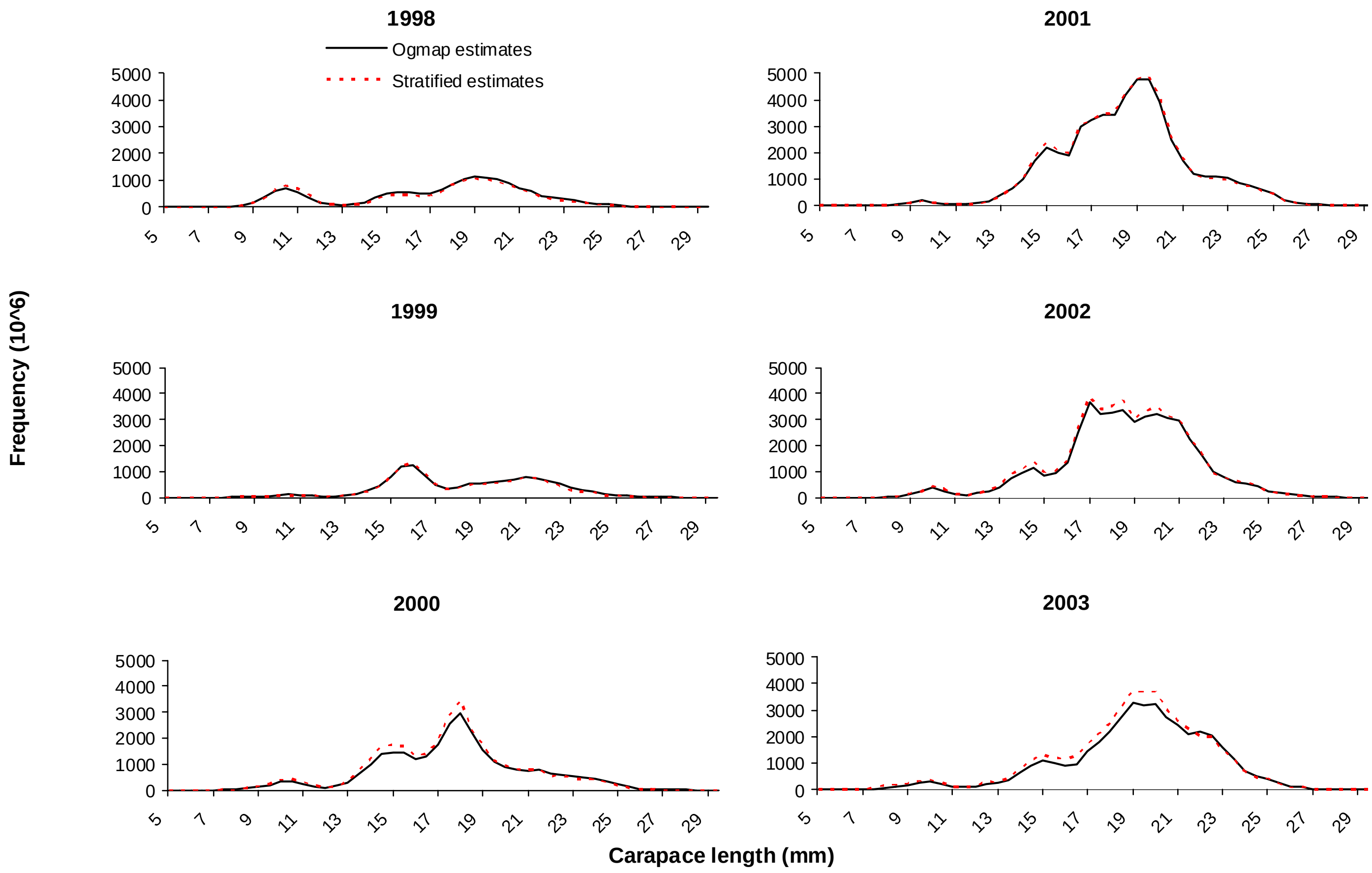

Fig. 10. NAFO Div. 3LNO northern shrimp carapace length frequencies as calculated using stratified areal expansion and ogmap calculations. The data were obtained from annual autumn Canadian research bottom trawl surveys using a Campelen 1800 shrimp trawl. (Offshore strata only. Standard 15 min. tows.)