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Distribution, Biomass, Abundance and Some Biological Characteristics of Shrimp (*Pandalus borealis*) in NAFO Divisions 3LNO Inferred from Data Obtained during Canadian Research Trawl Surveys, 1995-1997

by

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INTRODUCTION

Canadian research trawl surveys were conducted in NAFO Div. 3LNO during fall 1995, 1996 and 1997. All surveys followed a stratified-random design to determine distribution, biomass and abundance for various groundfish species. A shrimp trawl was used as the sampling device and the depths sampled (to 800 fm) included the range within which northern shrimp (*Pandalus borealis*) are known to occur. Data pertaining to shrimp in the catches were analysed to provide information on distribution, temporal and spatial changes in stock size (i.e. abundance, biomass) and length/age/sex composition.

Little is known about northern shrimp in Div. 3LNO, although their occurrence throughout the area has been documented (e.g. Squires, 1990). Nicolajsen (1994a,b, 1996 and 1997) estimated biomass and described some biological characteristics but was restricted to the area outside the Canadian 200-mile limit. The data presented, analysed and interpreted in this paper provide a brief time series for the whole area, allowing a more comprehensive evaluation of the resource.

MATERIALS AND METHODS

The surveys were conducted onboard the Canadian research vessels **Wilfred Templeman** and **Teleost**. Fishing sets of 15 minutes duration at towing speed of 3 knots were randomly allocated to strata which covered the Grand Bank and slope waters to 800 fm (Fig. 1). Additional inshore strata (not shown in Fig. 1) were included in the survey design after 1995. The trawl used on both vessels was a Campelen 1800 shrimp trawl with a codend mesh size of 40 mm and a 13-mm liner. Mean wingspread was estimated by SCANMAR at 16.8 m. Details of the survey design and fishing protocols are given in Brodie (1996).

Numbers and weights of *Pandalus borealis* were obtained from each set in which they occurred. In addition, frozen samples were retained from most sets and subsequently analysed at the Northwest Atlantic Fisheries Centre for length, sex, maturity and potential age composition. The distributions (catch weights) from the surveys were mapped using Spatial Analysis System (SPANS), which contoured shrimp density over 15 intervals and produced estimates of biomass (see Kulka et al., 1995 for analytical details). Shrimp biomass (weight) and abundance (numbers) also were estimated by areal expansion for all surveys using Stratified Analysis Programs - STRAP (Smith and Somerton, 1981).

Oblique carapace lengths of shrimp were measured to 0.1 mm using Vernier calipers and grouped to 0.5 mm intervals for presentation. Females, when not ovigerous, were separated from males on the shape of the endopod of the first pleopod (Rasmussen, 1953). A composite size distribution from each survey describing the estimated abundance of males and females at length was constructed and interpreted for possible age structure.

RESULTS

Distribution, biomass and abundance

1995 Survey

A total of 337 successful survey sets was analysed within the Div. 3LNO stratified area. Shrimp occurred in 67 sets and catches per standard tow were highly variable, ranging from <0.01 kg (n=1) to 58.33 kg (n=8551). Best catches occurred primarily in Div. 3L at depths between 150 and 200 fm but the largest was taken between 200 and 300 fm in Div. 3N. Bottom temperatures ranged between –1.4 and 6.8^0 C in depths where shrimp were present and, in most instances, were 2^{0}C or greater in areas of highest shrimp density.

Shrimp catch weights were mapped over 15 density intervals using the SPANS software (Fig. 2). The results showed that shrimp occurred primarily on the northern and northeastern slopes of the Grand Bank in Div. 3L. Generally, the eastern slope was sparsely populated but there were occasional high catches in Div. 3N. Shrimp were scarce in Div. 3O. Most (>95%) of the estimated biomass of about 7400 tons was confined to less than 15% of the survey area (Table 1, upper section).

Traditional, design-based, areal expansion estimates (STRAP) of biomass (weight) and abundance (numbers) were calculated using the groundfish stratification scheme. Biomass was estimated at roughly 6300 tons and abundance at 2.1 billion animals (Table 2). The 95% confidence intervals were 3900 and 8700 tons for biomass and 0.7 and 3.5 billion for abundance. Stratified mean number and weight per tow were 190 and 0.57 kg, respectively. Div.3L accounted for 86% of the estimated biomass.

1996 Survey

Seventeen new inshore strata were included in the survey area beginning in 1996. Shrimp occurred in 158 of the 336 successful sets completed during the survey. Catches per standard tow again were variable, ranging from <0.01 kg (n=1) to 102.23 kg (n=14,119). Most of the larger catches occurred in Div. 3L at depths between 100 and 200 fm. The largest was taken inshore in Div. 3L (Trinity Bay) between 200 and 300 fm. Bottom temperatures were between −1.2 and 8.4^0 C in depths where shrimp occurred and were greater than 0.5^0 C in areas of highest density.

The results of SPANS mapping (Fig. 2) showed that shrimp occurred over a larger area in 1996 compared to 1995 (more shaded area) and that density was higher (more dark shaded area). The eastern slope again appeared to be sparsely populated, except for occasional high catches in Div. 3N, and shrimp density remained low in Div. 3O. About 95% of the estimated 26,700 ton biomass occurred in less than 15% of the survey area (Table 1, middle section).

STRAP estimates of biomass and abundance were roughly 20,800 tons and 6.0 billion animals (Table 2). The 95% confidence intervals were 10,900 and 30,700 tons for biomass and 2.1 and 9.9 billion for abundance. Stratified mean number and weight per tow increased from the previous year to 504 and 1.74 kg, respectively. Most (93%) of the biomass was found in Div. 3L and the new inshore strata accounted for only about 3% of the total.

1997 Survey

Shrimp occurred in 194 of the 352 successful sets completed during the survey. Catches per standard tow ranged from <0.01 kg (n=1) to 179.16 kg (n=38,998) with larger catches occurring in Div. 3L at depths between 100 and 200 fm. The largest was taken offshore in Div. 3L on the northern slope of the Grand Bank between 100 and 150 fm. Bottom temperatures ranged between −1.3 and 6.7^0 C in depths where shrimp were caught and generally were between 1 and 4^0 C in areas of highest shrimp density.

SPANS mapping (Fig. 2) indicated a continued expansion of the resource within Div. 3L (north of 46^0 N) but no trend in Div. 3NO. More than 95% of the estimated biomass of 48,400 tons in 1997 occurred within about 15% of the survey area (Table 1, lower section).

STRAP estimates of biomass and abundance were 47,200 tons and 10.8 billion animals (Table 2). The 95% confidence intervals were 26,500 and 67,900 tons for biomass and 6.5 and 15.0 billion for abundance. Stratified mean number and weight per tow again increased to 894 and 3.91 kg, respectively. Virtually all (99%) of the biomass was found in Div. 3L and inshore strata accounted for only 2% of the total.

Length, sex and age composition

Length distributions representing the estimated abundance of shrimp from each survey (Fig. 3) showed major changes in size and sex composition over time. In 1995, small male shrimp were well represented at modal length of approximately 11 mm CL and components of larger males were evident near 17 and 20 mm. Transitionals, included with the female component, spanned a broad size range from about 14 to 24 mm with a distinct size group at 16 mm and indications of others at 20 and 22 mm. Ovigerous females formed a minor group near 25 mm.

Data from the 1996 survey showed dominance of a male size group at 15.5 mm and another prominent component at 19 mm. Transitionals and females occurred over sizes ranging from about 18 to 26 mm, the former around 20 mm and the latter 25.

In 1997, two prominent modes of males were present at 16 and 18.5 mm and a minor component was observed at 11 mm CL. Transitionals formed a clear mode at 21 mm and ovigerous females showed bimodality at 23 and 25 mm.

Interpretation of the age structure from composite size distributions is uncertain but the time series enables some inference because of similarity in the occurrence of modes and evidence of modal progression for a few size/age groups between years. We assume that the substantial component with modal length of 11 mm in 1995 comprise animals (males) of the same age and further assume that the age of those animals is 1+ years (i.e. hatched in spring 1994). This 1994 year class appears again as males at 15.5 mm in 1996 and at 18.5 mm in 1997. The mode at 16-17 mm in 1995 (1993 year class?) can be followed to 19 mm in 1996 (although

the apparent change in male/female ratio is difficult to explain) and likely comprises part of the female component in 1997. The presumed 1995 year class was poorly represented in 1996 but was clearly evident at 16 mm in 1997. Likewise, the 1996 year class appeared weak in fall 1997 (11 mm).

The following table presents our first interpretation, albeit cursory, of the length/age/sex relationship for shrimp in Div. 3LNO.

Age	1	2	3	4	5+
Sex	Male	Male and/or Transitional	Male and/or Transitional	Transitional	Female
CL (mm)	11	16	19-20	21-22	>22

DISCUSSION

Northern shrimp (*Pandalus borealis*) occur along the slope of the Grand Bank in Div. 3LNO primarily in depths between 150 and 500 m where temperatures usually fall within the range of 1 to 4^{0}C. Research trawl surveys showed that distribution was widespread and densities were greatest in Div 3L. Occasional large catches were taken in Div. 3N but shrimp were scarce in Div. 3O.

Biomass and abundance indices from 1995 to 1997 showed that most of the resource was located within Div. 3L and that it increased substantially over that period. Sampling data indicated that the increase was due to the recruitment of three year classes (possibly those of 1993, 1994 and 1995).

Age and growth of shrimp in Div. 3LNO has not been resolved. A thorough examination of sampling data over appropriate temporal and spatial scales is required before definitive statements can be made. Nevertheless, growth inferred here generally agrees with that described by Nicolajsen (1994 and 1997) for Div. 3L. Our cursory analyses also indicate that growth of male shrimp in Div. 3LNO shows some similarity to that observed on the adjacent Flemish Cap (e.g. see Parsons and Veitch, 1993; Parsons et al., 1997; Skuladottir and Einarsson, 1993) but there appears to be differences for females.

The time series of sampling data also shows that sex change can occur over several ages which confounds the age interpretation. In 1995, a strong component of transitionals occurred at 16 mm CL, indicating that a proportion of a year class (possibly 1993) changed sex between ages 2 and 3.

Although this paper deals only with information on *Pandalus borealis* in Div. 3LNO, it is worth noting that the striped shrimp, *P. montagui*, also occurred frequently in research trawl catches, especially in near-shore areas. Preliminary estimates of biomass for that species were 14,600, 16,600 and 16,000 tons in 1995, 1996 and 1997, respectively.

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Table 1. Density and biomass of shrimp in Div. 3LNO estimated by SPANS from fall research trawl surveys, 1995 – 1997.

1995 Density	Count	Area	Mean g per tow	Biomass kg	Biomass t	1995 Stdev	% of Biomass		% of Area
1	192	170,560	0	0	0	0	0.00%	100.00%	100.00%
2	13	7,224	0	0	0	0	0.00%	100.00%	37.04%
3	9	5,636	0	0	0	0	0.00%	100.00%	34.37%
4	6	6,226	0.01	2,665	3	0.01	0.04%	100.00%	32.29%
5	10	5,215	0.01	2,232	2	0.01	0.03%	99.96%	29.99%
6	12	7,542	0.02	6,456	6	0.03	0.09%	99.93%	28.07%
7	9	7,603	0.01	3,254	3	0.02	0.04%	99.85%	25.28%
8	10	5,852	0.04	10,018	10	0.06	0.14%	99.80%	22.48%
9	7	5,501	0.12	28,251	28	0.24	0.38%	99.67%	20.31%
10	14	8,301	0.26	92,368	92	0.47	1.26%	99.28%	18.28%
11	9	7,632	0.65	212,309	212	0.85	2.89%	98.02%	15.22%
12	14	11,347	1.48	718,721	719	2.35	9.77%	95.14%	12.40%
13	20	13,401	3.1	1,777,937	1,778	4.04	24.18%	85.36%	8.21%
14	12	8,849	11.88	4,499,126	4,499	15.76	61.18%	61.18%	3.27%
15		0	0	0	0		0.00%	0.00%	0.00%
Sum	337	**270,889**	1.17	**7,353,336**	***7,353***	1.70	**100.00%**	**0**	**0**

1996 Density	Count	Area	Mean kg per tow	Biomass kg	Biomass t	1996 Stdev	% of Biomass		% of Area
1	83	91,868	0	0	0	0	0.00%	100.00%	100.00%
2	15	12,749	0	0	0	0	0.00%	100.00%	67.77%
3	16	15,192	0.01	6,502	7	0.01	0.02%	100.00%	63.30%
4	33	21,014	0.01	8,993	9	0.01	0.03%	99.98%	57.97%
5	15	19,672	0.01	8,419	8	0.01	0.03%	99.94%	50.59%
6	15	8,831	0.01	3,779	4	0.01	0.01%	99.91%	43.69%
7	13	15,368	0.02	13,154	13	0.03	0.05%	99.90%	40.59%
8	10	9,034	0.05	19,332	19	0.03	0.07%	99.85%	35.20%
9	17	10,123	0.06	25,994	26	0.1	0.10%	99.77%	32.03%
10	24	17,908	0.35	268,246	268	0.44	1.01%	99.68%	28.48%
11	25	13,184	0.58	327,260	327	0.77	1.23%	98.67%	22.20%
12	12	9,801	1.09	457,209	457	1.53	1.72%	97.44%	17.57%
13	21	13,842	2.64	1,563,941	1,564	3.56	5.87%	95.73%	14.13%
14	30	19,392	14.64	12,150,137	12,150	22.57	45.59%	89.86%	9.28%
15	7	7,048	39.12	11,800,006	11,800	30.35	44.27%	44.27%	2.47%
Sum	336	**285,026**	3.91	**26,652,971**	***26,653***	3.96	**100.00%**	**0**	**0**

1997 Density	Shrimp Count	3LNO Area	Mean kg per tow	Biomass kg	Biomass t	1997 Stdev	% of Biomass		% of Area
1	71	69,839	0	0	0	0	0.00%	100.00%	100.00%
2	18	13,687	0	0	0	0	0.00%	100.00%	75.51%
3	20	13,799	0	0	0	0.01	0.00%	100.00%	70.71%
4	17	16,166	0.01	6,919	7	0	0.01%	100.00%	65.87%
5	15	19,011	0.01	8,136	8	0.01	0.02%	99.99%	60.20%
6	19	14,547	0.01	6,226	6	0.02	0.01%	99.97%	53.54%
7	13	18,494	0.03	23,745	24	0.02	0.05%	99.96%	48.43%
8	21	15,543	0.06	39,912	40	0.05	0.08%	99.91%	41.95%
9	22	14,761	0.1	63,173	63	0.12	0.13%	99.82%	36.50%
10	17	14,769	0.19	120,094	120	0.21	0.25%	99.69%	31.32%
11	35	15,729	0.48	323,117	323	0.96	0.67%	99.45%	26.14%
12	24	13,509	1.54	890,351	890	2.09	1.84%	98.78%	20.63%
13	23	13,307	3.09	1,759,771	1,760	4.89	3.64%	96.94%	15.89%
14	18	14,715	10.04	6,322,829	6,323	8.71	13.07%	93.30%	11.22%
15	19	17,291	52.46	38,820,925	38,821	36.61	80.23%	80.23%	6.06%
Sum	352	**285,167**	4.53	**48,385,199**	***48,385***	3.58	**100.00%**	**0**	**0**

Table 2. STRAP estimates of shrimp abundance and biomass (95% confidence intervals) in Div. 3LNO determined from trawl survey data, 1995-1998.

Year	Estimate	3LNO		3L	3N	3O
1995	N ($x10^{-6}$)	2 102	(702-3 503)			
	Wt (tons)	6 308	(3 942-8 673)	5 452	826	30
	Mean N&Wt/Tow	190, 0.57				
1996	N ($x10^{-6}$)	6 028	(2 144-9 912)			
	Wt (tons)	20 802	(10 906-30 699)	19 279	1514	9
	Mean N&Wt/Tow	504, 1.74				
1997	N ($x10^{-6}$)	10 789	(6 544-15 033)			
	Wt (tons)	4 7221	(26 538-67 904)	46 777	427	17
	Mean N&Wt/Tow	894, 3.91				

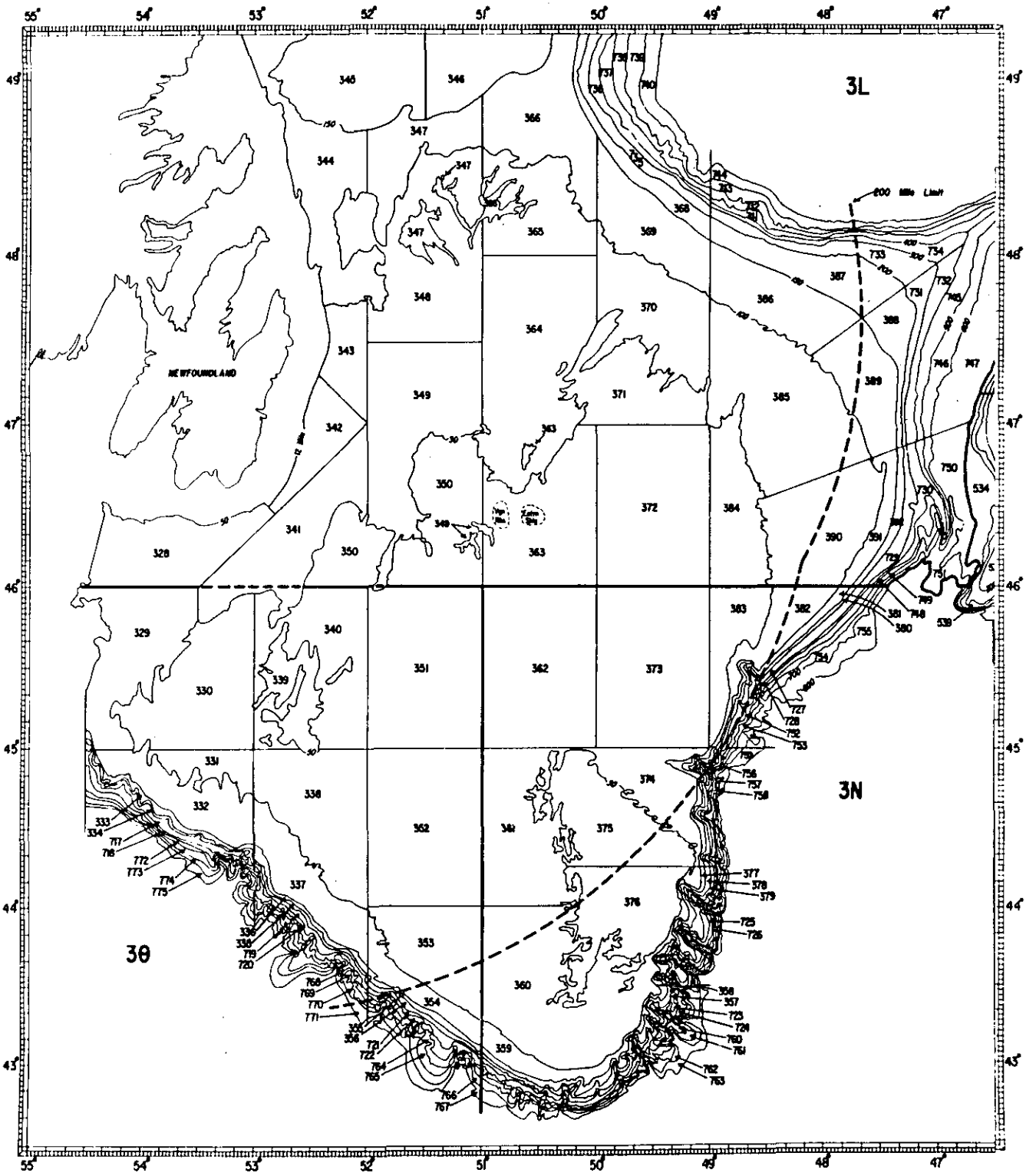

Figure 1. Stratified area for Canadian research trawl surveys in NAFO Div. 3LNO.

Figure 2. Distribution and density of northern shrimp (*P. borealis*) in Div. 3LNO estimated by SPANS from research trawl survey data, 1995 – 1997.

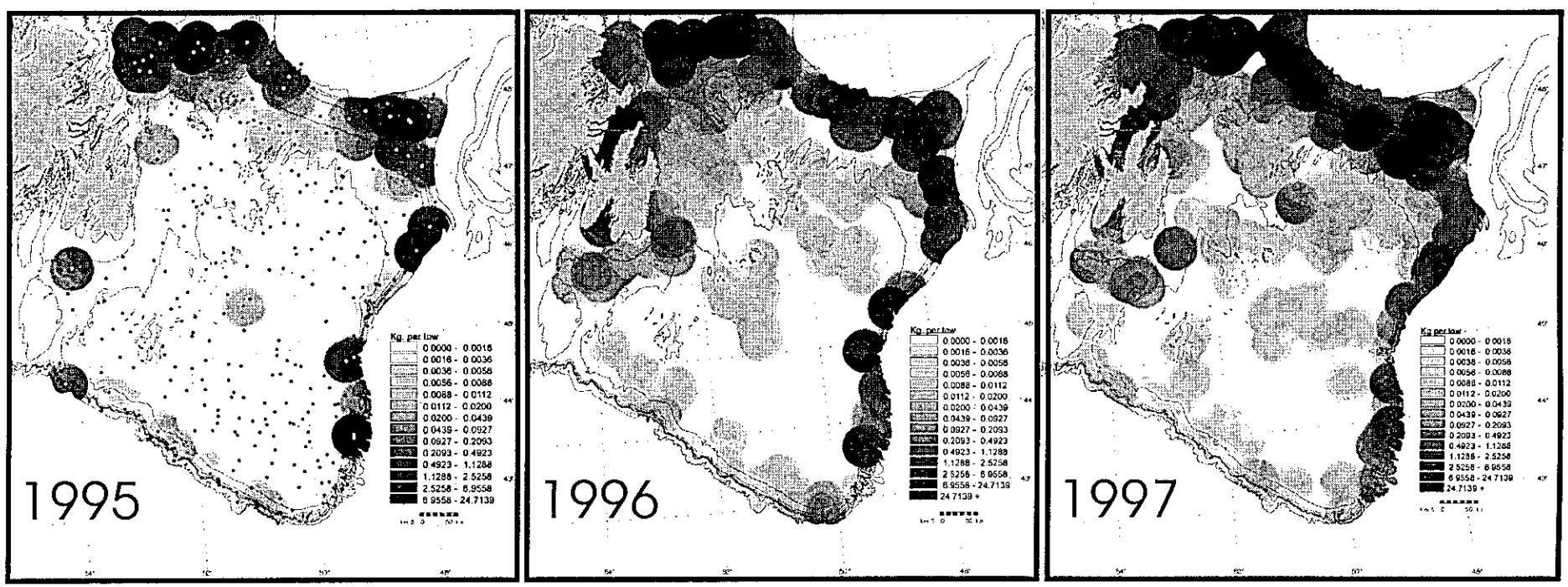

Fig. 3 Number-per-thousand in NAFO Div.3LNO, 1995-1997.
(Solid line=males, N=Abundance in millions, W=Biomass in t.)