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Northern Shrimp (*Pandalus borealis*, Krøyer) from Spanish Bottom Trawl Survey 2009 in NAFO Div. 3LNO

by

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Abstract

The Spanish Institute of Oceanography carried out in 2010 two bottom trawl surveys in the NAFO Regulatory Area in Division 3NO and 3L during the months of June, July and August respectively. The results on Northern shrimp (*Pandalus borealis*) are presented and compared with those from previous surveys from the same series. In 2010 the catch (21 kg.) and estimated biomass (114 t.) confirm the decrease of shrimp importance from 2004 in 3NO. In 3L Division, northern shrimp indices show a drastic decline (49% with respect to 2009) and confirm the downward trend initiated in 2009. Estimated biomass increased from 2003-2006; then, the values of these indices declined in 2007 (about 10%) and increased again in 2008 up to its historical maximum (149265 t.). In 2010 the biomass estimated 37803 t in 3L and 114 t. in 3NO were the lowest in the time series of Spanish .

Catch results from the surveys and data analysis are discussed in this paper.

Introduction

Northern shrimp (*Pandalus borealis* Krøyer, 1883) is a protrandric, circumpolar species, discontinuously distributed in the North Atlantic and of considerable commercial importance. The greatest abundance is being in the Northwest Atlantic at latitudes above 46ºN. The stock of this species in Div. 3LNO, NAFO is distributed along the entire edge of the grand banks, at depths generally ranging from 185 to 550 metres, although historically at least 92.7% of the 3LNO shrimp biomass had been found within Division 3L (Orr *et al*, 2009).

Since 1995, Canadian multi-species stratified random surveys have been used to estimate northern shrimp biomass and abundance indices within NAFO Div. 3LNO. In this series of surveys, Div. 3N accounts for between 0.2 and 8.1% of the total 3LNO biomass. Between 33.0 and 83.3% of the 3N biomass is located beyond Canada's EEZ (Orr *et al*., 2009). The biomass in Division 3O accounts for less than 1% of the biomass in Div. 3LNO and only a negligible amount of the biomass in Div. 3O is beyond the 200 mile limit (Orr *et al*., 2009).

The Vigo Centre of Instituto Español de Oceanografía is conducting research cruises since 1995 in the NAFO Regulatory Area in Div. 3NO beyond Canada's EEZ. A stratified, random, bottom trawl, multi-species research sampling program was carried out to obtain abundance and biomass indices as well as other biological data for the most important commercial species present in the area. In the surveys conducted between 1995 and 2000, the catches of northern shrimp were insignificant. This could be explained by the low efficiency of the fishing gear "pedreira", with this species (Paz *et al*., 1995), used in those years.

Since 2001, the survey was carried out on board R/V "*Vizconde de Eza*" using a Campelen 1800 net (*Walsh et al., 2001*). Despite the improvements incorporated with the new vessel and the use of a Campelen 1800 net, which is highly efficient for this species (*Vazquez, 2002*), total catches in 2001 were poor, i.e., 29 kg.

In the following years a significant increase of the catches of northern shrimp was noted in 3NO Division where catches were higher than 300 kg. Since 2007 the catches decreased at levels next to 2001 year.

Also, since 2003 a new research survey was conducted in Division 3L as an extension of the survey carried out in 3NO (Román *et al.*, 2008). The estimated biomass in 3L Division always was very superior to that estimated in 3NO. Since 2008 year the catches have declined to levels next to the lowest in the historical series.

This work presents data on the geographical distribution in the NAFO Regulatory Area (Div. 3LNO), on biomass, length frequencies, age structure and length-weight relationship of catches of northern shrimp on Spanish bottom trawl surveys 2010.

Materials and Methods

The 2010 Spanish bottom trawl surveys were carried out from the 30th of May to 18th of June in 3NO and from 25th of July to 14th of August in 3L, following set guidelines previously established for the series of I.E.O. research surveys (Walsh *et al.*, 2001). These surveys took place in Div. 3NO and 3L, with a total of 95 and 97 valid hauls respectively ranging depths between 40 and 1450 m approximately. Due to operational difficulties it was not possible to survey all of the strata within NAFO Div. 3NO during spring 2010, the strata 764, 753, 763 and 767 were not surveyed.

Shrimp samples of approximately 1.5 kg were taken to determine length frequencies in hauls where the amount and good condition of the specimens caught permitted to sample them. Males and females were separated with reference to the endopod of the first pleopod (Rasmussen, 1953). Following this criterion, individuals that were in the middle of a sex change were considered as females. The females were differentiated into mature and immature, following the sternal spines criteria (McCray, 1971). Ovigerous females were considered as an independent group not included within the mature females.

Individuals were measured onboard by noting the distance from the base of the eye to the posterior mid dorsal point of the carapace -CL- (Shumway *et al*., 1985). Such measurements were made to the lower half millimetre using electronic callipers.

Furthermore, in 2010 survey some samples were frozen onboard to determine the length-weight relationship in the laboratory. 825 and 4605 individuals were selected in 3NO and 3L Divisions respectively, dried and weighed with a precision of 0.01g to calculate the length-weight relationship in each Division.

Results and Discussion

The Table 1 shows the catches, biomass and standard errors estimated by swept area method of northern shrimp from the multi-species surveys, carried out by IEO Vigo from 1995-2010 in the NAFO Div. 3NO and from 2003-2010 in Division 3L. In the summer of 2005 the research survey could not be carried out in Division 3L. From the year 2002 an abrupt increase with respect to earlier years occurred in 3NO Division, both in terms of catch and biomass (Diaz *et al*., 2002). These initial data were considered with caution due to the fact that, until 2001, the "Pedreira" gear used as a sampler (Paz *et al*., 1995) was not efficient for catching shrimp. However, although in 2001, the gear "type Pedreira" was changed for a new type "Campelen 1800" (Walsh *et al*., 2001) with high efficiency for catching this species (Vazquez, 2002), the catches and biomass estimated stayed at low levels.

After 2002 year, the increase in northern shrimp catch in 3NO was confirmed, in terms of the period 1995-2001 although in the last four years both the catches and estimated biomasses of shrimp have decreased markedly to levels of biomass in 2010 around 114 t. (Figure 1).

Unlike 3NO, the estimated biomass in Division 3L since the beginning of the new survey in 2003 showed a general upward trend from 63647 t. in 2003 to 149265 t. in 2008. This trend changed in 2009 with the strong decline of the biomass estimated (74091 t., about 50% with respect to 2008) and in 2010 the decrease is confirmed (37803 t., about 49% with respect to 2009).

The distribution of northern shrimp catches in the Spanish trawl survey 2010 is shown in Figure 2. As in previous years the main catches were located at medium depths from 100 to 200 fathoms (179-386 m.) in Div. 3L. In 3NO Division the catches were residuals.

Tables 2 and 3 show the shrimp biomass by depth strata from 1995 to 2010 surveys in Divisions 3NO and from 2003 to 2010 in 3L. Although it is considered that the shrimp in Div. 3LNO is distributed along the entire edge of the grand banks, at depths generally ranging from 100 to 300 fathoms (180-550 m.), the depth of the bulk of biomass present differences in 3L and 3NO Divisions. While in 3L Division practically the total of the biomass (>95%) was produced all years in depths lower than 200 ft., in 3NO the percentage of the estimated biomass in depths lower than 200 ft. varied along the years, showing a deeper distribution in 2004 and 2005 where the percentage of the shrimp catches in depths bigger than 200 ft. was around 74 and 66 % respectively.

The length distribution by sex estimated in the 3NO and 3L are presented in table 4 and figure 3. Tthe range of length distributions in 3L Division was wider than in 3NO Division where both smallest and largest were not presents. The main modes in both sexes, around 17 and 20 mm. for males and 22.5 mm. for females did not show important differences in the two Divisions. In 2010 sex ratio was different in both Divisions, showing a higher percentage of males (75%) in 3L Division.

The MIX modal size analysis programme was used with the length distribution by sex estimated in 3L Divisions (Table 5). From the cited analysis the males presented three modes at 14.06, 16.98 and 20.06 mm. corresponding with ages 2, 3 and 4 respectively. The sex change occurs at ages 3 and 4. The females showed several modes at 17.95, 22.09, 24.62 and 26.06 mm (ages 3, 4, 5 and 6 respectively).

The MIX analysis with length distributions from 3NO showed a similar pattern for males with mode at 12.81, 16.15 and 20.14 mm. However for female's length distribution the identified modes were well different showing uncertainty in the MIX analysis.

The Table 6 shows the length-weight relationship estimated in 2010 surveys by sex and maturity stage as well the parameters of the relationship, number of specimens sampled and determination coefficient R^2.

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Table 1.- Northern shrimp biomass estimated by swept area (t.), standard error and catches (kg.) from Spanish bottom trawl survey in NAFO Div. 3NO, 1995-2010 and 3L 2003-2010.

3NO

Year	Biomass		Catch
	tons	Std. err.	(kg.)
1995[1]	14	13	5
1996[1]	18	17	2
1997[1]	1	1	0
1998[1]	23	17	5
1999[1]	81	36	13
2000[1]	26	9	6
2001[2]	178	72	29
2002[2]	2043	814	408
2003[2]	1618	716	325
2004[2]	2654	1693	550
2005[2]	1627	590	368
2006[2]	1274	352	278
2007[2]	401	285	71
2008[2]	144	98	24
2009[2]	139	111	33
2010[2]	114	35	21

3L

Year	Biomass		Catch
	tons	Std. err	(kg.)
1995[1]			
1996[1]			
1997[1]			
1998[1]			
1999[1]			
2000[1]			
2001[2]			
2002[2]			
2003[2]	63647	20105	5836
2004[2]	94270	40332	5093
2005		Not surveyed	
2006[2]	125850	12690	17805
2007[2]	113402	13445	18098
2008[2]	149265	48489	23720
2009[2]	74091	37999	12173
2010[2]	37803	9836	6103

[1] Pedreira codend 35 mm. mesh size.
[2] Campelen codend 44 mm. mesh size. (inner codend 20mm)

Table 2.- Northern shrimp biomass (kg.) by strata from Spanish bottom trawl survey 1995-2010 in NAFO Div. 3NO.

Stratum	Area Mn^2	Depth range fth.	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
375	271	0-30	0	0		0	0	0	3453	0	25	0	0	1989	0	0	0	0
376	1334	0-30	0	0		0	0	0	1270	0	0	0	341	4203	0	0	0	0
353	269	31-50	0	0		0	0	0	79	0	48	0	0	0	126	0	16	0
360	2783	31-50	0	0		0	0	0	26423	1457	3470	24	0	0	445	0	110	1317
374	214	31-50	0	0		0	0	0	178	0	0	0	0	0	62	0	0	0
354	246	51-100	0	0		0	0	0	87612	0	292	6917	0	0	14	0	0	55
359	421	51-100	0	0		0	1389	0	6348	847	1309	43	41	22	98	42	0	543
377	100	51-100	0	0		0	208	44	0	2020	751	1471	3742	3704	83	60	40	0
382	343	51-100		0		0	213	206		112695	302	297	825	944	191	4131	0	0
355	74	101-150		0		0	0	0	15170	147	7635	6146	6183	9179	262	204	0	961
358	225	101-150	0	0		0	30129	0	717	3261	3900	10289	32548	258	2357	2902	0	17220
378	139	101-150	0	0		8968	10998	1196	17004	680353	11429	772	3985	10066	1357	481	73	192
381	144	101-150		0		63	11205	122		84984	20648	225280	1486	75176	303300	114294	466	25403
356	47	151-200		0		0	0	0	137	0	1337	12937	8046	2683	213	635	39	409
357	164	151-200	0	18097		0	0	0	606	16414	425145	163606	38796	114178	9307	1249	959	14877
379	106	151-200	0	0	720	0	135	0	12511	70342	254080	7709	329867	116970	12146	2238	5079	15709
380	96	151-200		0		1024	9346	10240		1000960	698502	258603	120866	607392	6488	11379	125767	26518
721	65	201-300		0		0	0	0	2889	3282	1112	852	256	3054	0	257	318	6
723	155	201-300		0		0	16872	0	0	12667	92831	44044	3333	53799	14615	90	0	916
725	105	201-300	14315	0		0	0	0	271	527	91803	1814540	748369	206794	47133	578	239	7745
727	96	201-300		0		13213	0	11429		28660	2119	98477	326841	62635	1248	3172	179	632
722	84	301-400		0		0	37	734	2890	60	156	0	36	0	0	0	0	0
724	124	301-400	0	0		0	0	0	0	55	628	58	165	53	213	0	0	0
726	72	301-400	0	0		0	0	0	0	7	54	2048	0	406	170	0	5351	146
728	78	301-400		0		0	0	1671		7280	0	0	86	135	0	0	41	146
752	131	401-500		0		0	0	0		86	0	49	222	58	309	0	143	136
756	101	401-500		0		0	0	0	0	0	46	42	869	84	27	84	391	0
760	154	401-500		0		0	0	0	0	0	283	49	0	0	590	0	0	0
764	100	401-500		0		0	0	0	42	0	0	0	0	0	0	0	0	-
753	138	501-600		0		0	0	0		0	0	0	0	166	0	0	0	-
757	102	501-600		0		0	0	0		204	0	0	27	0	67	0	0	14
761	171	501-600		0		0	0	0	0	0	0	0	0	0	99	0	0	0
765	124	501-600		0		0	0	0	0	37	0	0	0	0	0	0	0	0
754	180	601-700				0	0	0		0	0	0	0	0	0	207	0	96
758	99	601-700				0	0	94		16302	0	19	88	0	0	0	0	0
762	212	601-700				0	0	0	0	85	0	0	0	0		0	0	0
766	144	601-700				0	0	0		19	58	0	0	0		0	0	32
755	385	701-800				0	0	89		0	174	0	68	0	0	1839	0	0
759	127	701-800				0	0	0		17	0	48	0	0		0	0	965
763	261	701-800				0	0	0		0	0	0	0	0		0	-	-
767	158	701-800				0	0	0		0	0	0	0	0		0	-	-
Biomass (t.)			14	18	1	23	81	26	178	2043	1618	2654	1627	1274	401	144	139	114
Std. Error (t.)			13	17	1	17	36	9	72	814	716	1693	590	352	285	98	111	35
Biomass % > 200fth			0	100	100	43	79	46	97	97	88	26	34	74	84	96	95	91

Table 3.- Northern shrimp biomass (kg.) by strata from Spanish bottom trawl survey 2003-2010 in NAFO Div. 3L.

Division 3L

Stratum	Area miles^2	Depth range ft.	2003	2004	2005	2006	2007	2008	2009	2010
385	2356	51-100	420	175		2485867	2416545	8265541	140724	12046
390	1481	51-100	1014	3780		2577958	5404325	317330	37466118	145874
389	821	101-150	14397492	41654297		53639329	49120205	74404070	25997291	21705956
391	282	101-150	1116135	1299793		3712072	12397477	24948041	28071	120096
387	718	151-200	17618619	21721973		29967360	11782827	14287154	6473372	7874303
388	361	151-200	25169595	24779540		32585066	26954928	21602795	2348269	5096163
392	145	151-200	2821419	1866379		193967	1199955	3675300	1564098	1608469
729	186	201-300	20371	1465049		88481	172095	16126	11533	95976
731	216	201-300	2449416	1467221		177357	666240	1501056	54100	1083034
733	468	201-300		4077		390052	3281339	240647	6718	51397
730	170	301-400	0	876		1485	76	32	20	581
732	231	301-400	34907	5643		14535	4723	1905	226	4266
734	228	301-400		408		10554	136	2144	69	129
741	223	401-500	0	56		1379	22	486	0	0
745	348	401-500	17642	0		1699	186	1950	0	2716
748	159	401-500	292	696		366	499	66	0	49
742	206	501-600	0	0		462	0	0	0	1718
746	392	501-600	0	0		134	0	74	70	225
749	126	501-600	0	23		99	0	0	0	0
743	211	601-700		0		1020	0	23	0	0
747	724	601-700		0		147	0	41	201	51
750	556	601-700		0		58	0	132	294	0
744	280	701-800		0		185	0	0	0	0
751	229	701-800				0	0	0	0	0
Biomasa (ton.)			63647	94270		125850	113402	149265	74091	37803
Std. Error (tons)			27126	54044		15484	13445	48489	37999	9836
Biomass % > 200 fth			96	97		99	96	99	100	97

Table 4.- Northern shrimp size distribution (‘000) by sex from Spanish bottom trawl survey 2010 in NAFO Div. 3NO an 3L.

3NO			
CL (mm)	**Males**	**Females**	**Total**
8			
8.5			
9			
9.5			
10			
10.5			
11	22		22
11.5			
12	22		22
12.5	66		66
13	25		25
13.5	13		13
14	9		9
14.5	85		85
15	89		89
15.5	175		175
16	200		200
16.5	216		216
17	96	9	105
17.5	196		196
18	221	22	243
18.5	811	153	963
19	912	61	974
19.5	1410	84	1494
20	1291	262	1553
20.5	1093	465	1558
21	478	696	1174
21.5	593	1457	2050
22	150	1002	1152
22.5	287	1554	1841
23		1001	1001
23.5		606	606
24		505	505
24.5		243	243
25		290	290
25.5		66	66
26		22	22
26.5		79	79
27			
27.5		37	37
28			
28.5			
29			
29.5			
30			
30.5			
31			
31.5			
Total	8463	8613	17076
	50%	50%	

3L			
CL (mm)	**Males**	**Females**	**Total**
8	3922		3922
8.5	9		9
9	5075		5075
9.5	3922		3922
10			
10.5			
11	8		8
11.5	129		129
12	101		101
12.5	2743		2743
13	5406		5406
13.5	15596		15596
14	16256		16256
14.5	32668		32668
15	36337	255	36592
15.5	110072		110072
16	294931	45	294976
16.5	263265	1099	264364
17	269033	656	269689
17.5	252853	310	253163
18	391843	2062	393905
18.5	483774	1429	485203
19	571885	4149	576033
19.5	606189	6806	612995
20	666660	30004	696664
20.5	619474	104637	724112
21	473849	110458	584306
21.5	234509	149270	383779
22	130228	169651	299879
22.5	55597	229271	284869
23	16972	139435	156407
23.5	5393	150736	156129
24	2120	178283	180403
24.5		179734	179734
25		118406	118406
25.5		141814	141814
26		85042	85042
26.5		36919	36919
27		34991	34991
27.5		12685	12685
28		5097	5097
28.5		3017	3017
29		439	439
29.5		777	777
30		10	10
30.5			
31			
31.5			
Total	5570815	1897488	7468303
	75%	25%	

Table 5. Results of the modal analysis (MIX) by sex and maturity stage Spanish bottom trawl survey 2010 .

	3NO				*3L*			
	Males		*Females*		*Males*		*Females*	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1								
2	0.015	0.001			0.008	0.000		
3	0.102	0.004			0.240	0.000	0.003	0.000
4	0.883	0.004	0.042	0.003	0.752	0.000	0.464	0.001
5			0.813	0.010			0.437	0.002
6			0.145	0.010			0.096	0.002
7								
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1								
2	12.81	0.090			14.06	0.008		
3	16.15	0.047			16.98	0.002	17.95	0.016
4	20.14	0.015	19.35	0.086	20.06	0.001	22.09	0.002
5			22.31	0.022			24.62	0.007
6			24.50	0.069			26.06	0.014
7								
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1								
2	0.738	Cte. CV			0.829	0.002		
3	0.930	Cte. CV			1.002	0.003	0.808	Fixed CV
4	1.160	Cte. CV	0.871	Fixed CV	1.184	0.001	0.994	Fixed CV
5			1.004	Fixed CV			1.108	Fixed CV
6			1.102	Fixed CV			1.173	Fixed CV
7								

Table 6.-Northern shrimp length-weight relationship by sex, maturity stage and all combined from Spanish bottom trawl survey 2010 in NAFO Div. 3NO and 3L

Division 3NO

	a	b	R^2	N
Males	0.00108	2.77782	0.94446	446
Inmature females	0.00284	2.47071	0.78515	309
Mature females	0.00143	2.68869	0.82592	70
All combined	0.00109	2.77679	0.95464	825

Division 3L

	a	b	R^2	N
Males	0.00145	2.69226	0.91178	3337
Inmature females	0.00037	3.14809	0.90016	395
Mature females	0.00125	2.75850	0.83038	641
Ovigerous females	0.00282	2.52735	0.72126	232
All combined	0.00098	2.82712	0.95091	4605

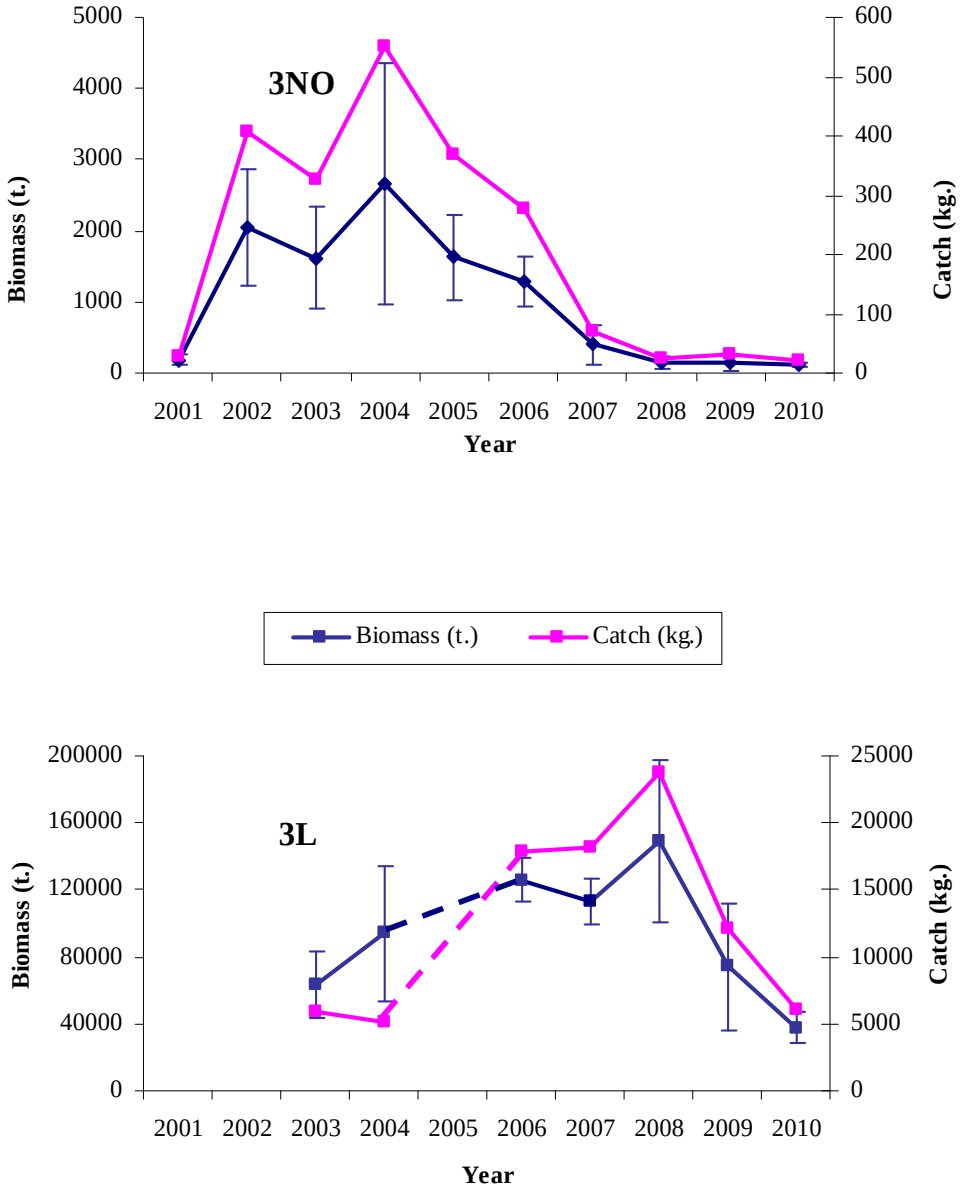

Figure 1.- Northern shrimp biomass (tons) and catch (kg) from Spanish research surveys in NAFO Div. 3NO 2001-2010 and 3L 2003-2010.

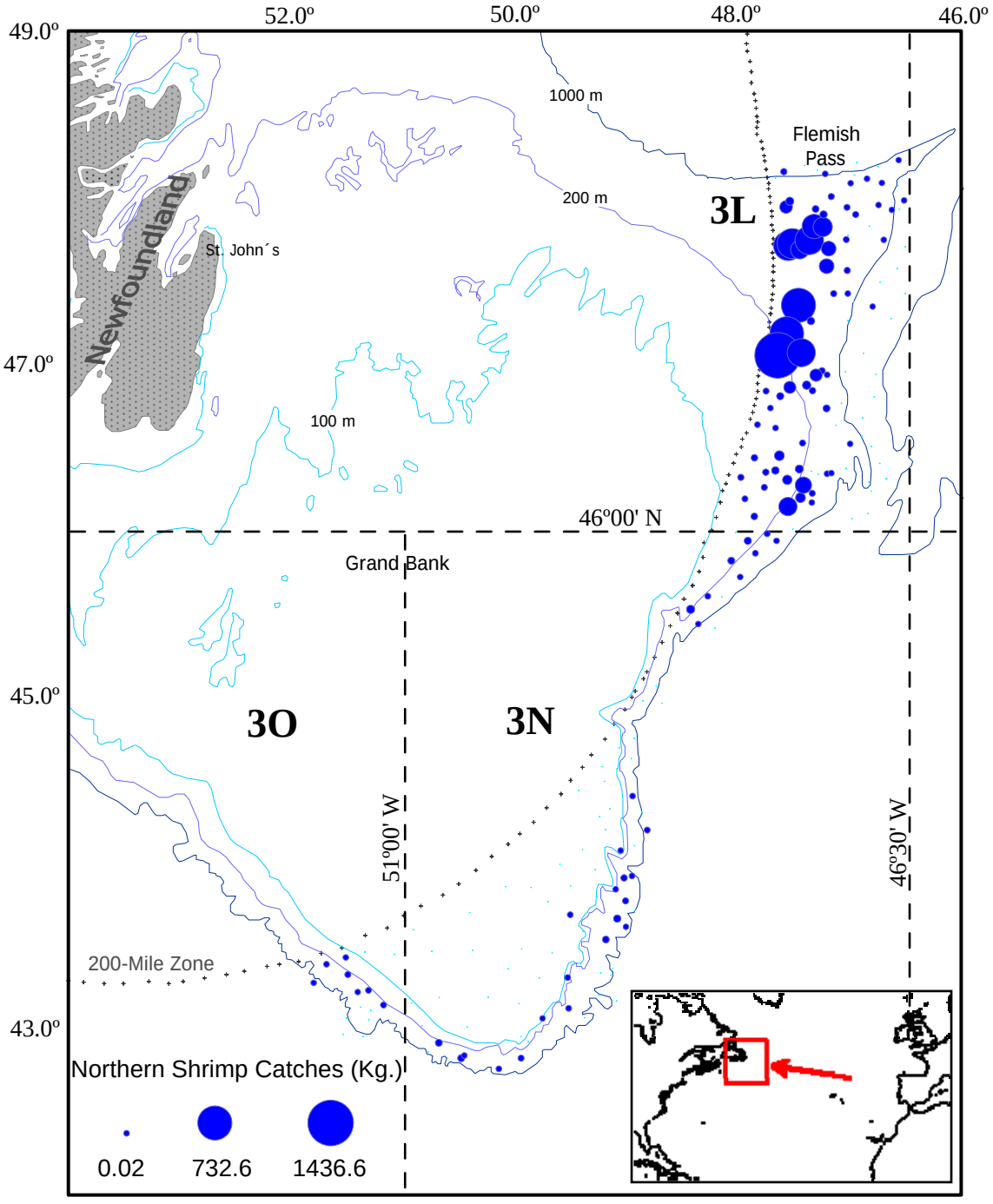

Figure 2.- Geographic distribution of Northern shrimp catches from Spanish bottom trawls surveys 2010.

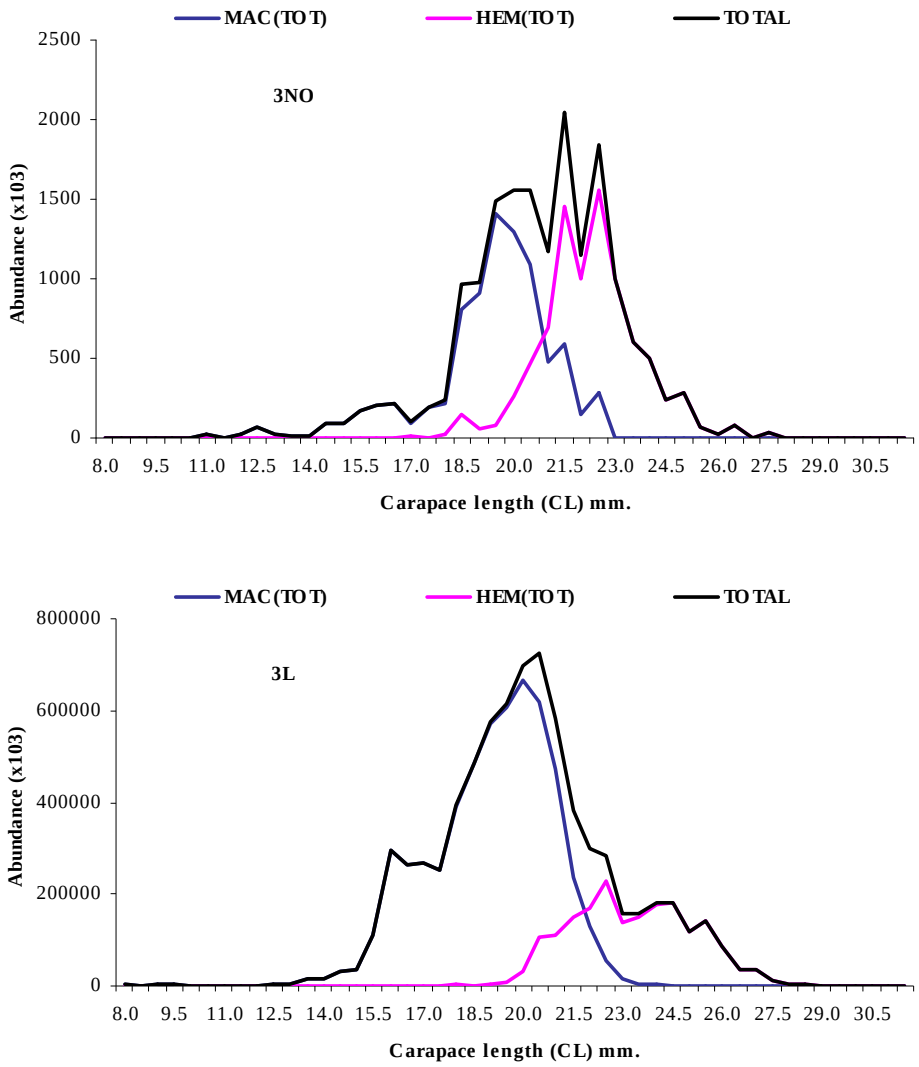

Figure 3.- Northern shrimp size distribution, by sex from Spanish bottom trawl surveys in Div. 3NO and 3L.