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Northern Shrimp (*Pandalus borealis*, Krøyer) from EU-Spain Bottom Trawl
Survey 2015 in NAFO Div. 3LNO

by

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Abstract

The Spanish Institute of Oceanography carried out in 2015 two bottom trawl surveys in the NAFO Regulatory Area in Division 3NO and 3L during the months of June and August respectively. The results on Northern shrimp (*Pandalus borealis*) are presented and compared with those from previous surveys from the same series. As recent years in 2015 the shrimp catch (0.532 kg.) and estimated biomass (1.96 t.) in Divisions 3NO remain between the lowest of the series, confirming the decrease of shrimp importance from 2004. In a similar way, northern shrimp indices estimated from 2015 in 3L Division declined 22% with respect to 2014 and confirm the downward trend initiated in 2009. The biomass estimated in 2015 (8434.8 t.) was the lowest value in the historical series.

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 46°N. 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. The proportion of biomass in 3LNO within the NAFO Regulatory Area (NRA), over the period 1996 – 2014, accounted for between 4 and 32.6% (Orr and Sullivan, 2014).

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 0 and 100% of the 3N biomass was located outside the 200 Nmi limit. 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 and Sullivan, 2014).

The Oceanographic Spanish Institute (IEO) 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 have declined to levels next to the lowest in the historical series.

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 2009 year the catches have declined to low levels staying in the last years between 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 and age structure of catches of northern shrimp on EU-Spanish bottom trawl surveys 2015.

Materials and Methods

In 2015 the EU-Spanish bottom trawl surveys were carried out in 3NO (from 31th May to 19th June) and 3L (from 28th July to 17th August) following set guidelines previously established for the series of Spanish research surveys (Walsh *et al.*, 2001). These surveys took place in Div. 3NO and 3L, with a total of 122 and 97 valid hauls respectively ranging depths between 45 and 1458 m approximately. This year all strata were surveyed.

Shrimp samples of approximately 1.5 kg were taken to determine length frequencies. 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 2015 survey some samples were frozen onboard to determine the length-weight relationship in the laboratory.

Results and Discussion

The Table 1 shows the catches, biomass and standard errors estimated by swept area method of northern shrimp from the EU-Spanish multi-species surveys, carried out by IEO Vigo from 1995-2015 in the NAFO Div. 3NO and from 2003-2015 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.

From 2002 to 2006, the increase of shrimp catches in 3NO was confirmed, in terms of the period 1995-2001. After that, in the last eight years the catches and estimated biomasses of shrimp have decreased markedly and they are now at levels of the beginning of the series. The estimated biomass in 2015 was around 1.96 t. (Figure 1).

Unlike 3NO, the estimated biomass in 3L Division 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 since then the biomass decreased. In 2015 the biomass decreased again by 22% (8434.75 t.) compared to 2014 and it is the lowest value in the survey series (Figure 1).

The distribution of northern shrimp catches in the EU-Spanish trawl surveys 2015 is shown in Figure 2. As in previous years the catches in 3NO Division were residuals.

The Tables 2 and 3 show the shrimp biomass by depth strata from 1995 to 2015 surveys in 3NO Divisions and from 2003 to 2015 in 3L Division. 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 51 to 300 fathoms (93-550 m.), the depth of the bulk of biomass in 3L Division was generally in depths lower than 200 ft (>95% of the biomass). This general pattern has changed in recent years and the percentage of the estimated biomass in depths lower than 200 ft decreased up to 44% in 2013, increasing again in 2014 and 2015 (77% and 85% of the biomass respectively). In 3NO the percentage of the estimated biomass in depths lower than 200 ft. varied along the years, showing a deeper distribution in 2004, 2005 and 2011 (26%, 34% and 21% respectively).

The length distribution by sex estimated in 3NO and 3L Divisions are presented in the tables 4, 5 and Figure 3. In 3NO, the main modes were around 11.5 mm. for males and 20 mm. for females; and 14 and 19.5 mm. for males and 22.5 mm. for females in 3L Division. In 2015 the sex ratio was similar in both Divisions, showing a higher percentage of the males (74%).

The MIX modal size analysis programme was used with the length distribution by sex estimated in 3L Divisions (Table 6). From the cited analysis the males presented three modes at 13.92, 17.44 and 19.90 mm. corresponding with ages 2, 3 and 4 respectively. The females showed several modes at 17.25, 20.56, 22.78, 24.54 and 26.77 (ages 3, 4, 5, 6 and 7 respectively).

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Table 1. Northern shrimp biomass estimated by swept area (t), standard error and catches (kg) from EU-Spanish bottom trawl surveys in NAFO Div. 3NO, 1995-2015 and 3L 2003-2015.

3NO			
Year	Biomass		Catch (kg)
	tons	Std. err.	
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	140	111	33
2010 ²	114	35	21
2011 ²	37	24	9
2012 ²	4	3.04	1
2013 ²	38	15	9
2014 ²	3	0.63	1
2015 ²	2	0.60	1

3L			
Year	Biomass		Catch (kg)
	tons	Std. err	
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	48490	23720
2009 ²	74091	37999	12173
2010 ²	37803	9836	6103
2011 ²	24346	4449	4092
2012 ²	10784	3724	1838
2013 ²	17438	5363	3101
2014 ²	10846	2764	1860
2015 ²	8435	1930	1450

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 1995-2015 in NAFO Div. 3NO.

Strat	Ar	Dept	199	199	199	199	199	200	200	200	20	2004	200	200	200	200	200	201	201	201	20	201	201
375	27	0-30	0	0	0	0	0	0	345	0	25	0	0	198	0	0	0	0	0	0	0	0	0
376	13	0-30	0	0	0	0	0	0	127	0	0	0	341	420	0	0	0	0	34	0	0	0	0
353	26	31-	0	0	0	0	0	0	79	0	48	0	0	0	126	0	16	0	0	0	0	0	0
360	27	31-	0	0	0	0	0	0	264	145	34	24	0	0	445	0	110	131	129	0	50	0	0
374	21	31-	0	0	0	0	0	0	178	0	0	0	0	0	62	0	0	0	0	0	0	0	0
354	24	51-	0	0	0	0	0	0	876	0	29	6917	0	0	14	0	0	55	86	0	29	0	0
359	42	51-	0	0	0	138	0	634	847	13	43	41	22	98	42	0	543	47	0	30	28	0	0
377	10	51-	0	0	0	208	44	0	202	75	1471	374	370	83	60	40	0	0	0	0	0	0	0
382	34	51-	0	0	0	213	206	0	112	30	297	825	944	191	413	0	0	0	0	0	0	0	0
355	74	101-	0	0	0	0	0	151	147	76	6146	618	917	262	204	0	961	0	148	89	11	37	0
358	22	101-	0	0	0	301	0	717	326	39	1028	325	258	235	290	0	172	196	0	27	0	0	0
378	13	101-	0	0	896	109	119	170	680	11	772	398	100	135	481	73	192	0	0	0	0	0	0
381	14	101-	0	0	63	112	122	0	849	20	2252	148	751	303	114	466	254	87	111	41	78	347	0
356	47	151-	0	0	0	0	0	137	0	13	1293	804	268	213	635	39	409	33	0	0	0	41	0
357	16	151-	0	180	0	0	0	606	164	42	1636	387	114	930	124	959	148	29	0	0	144	0	0
379	10	151-	0	0	720	0	135	0	125	703	25	7709	329	116	121	223	507	157	19	28	89	175	47
380	96	151-	0	0	102	934	102	100	69	2586	120	607	648	113	125	265	726	348	26	108	663	0	0
721	65	201-	0	0	0	0	0	288	328	11	852	256	305	0	257	318	6	633	11	31	569	596	0
723	15	201-	0	0	0	168	0	0	126	92	4404	333	537	146	90	0	916	335	0	98	132	0	0
725	10	201-	143	0	0	0	0	271	527	91	1814	748	206	471	578	239	774	0	0	21	231	69	0
727	96	201-	0	0	132	0	114	286	21	9847	326	626	124	317	179	632	226	83	93	512	158	0	0
722	84	301-	0	0	0	37	734	289	60	15	0	36	0	0	0	0	0	0	0	0	0	0	0
724	12	301-	0	0	0	0	0	0	55	62	58	165	53	213	0	0	0	32	0	0	0	0	0
726	72	301-	0	0	0	0	0	0	7	54	2048	0	406	170	0	535	146	0	0	0	0	0	0
728	78	301-	0	0	0	0	167	728	0	0	86	135	0	0	41	146	0	0	40	0	0	0	0
752	13	401-	0	0	0	0	0	86	0	49	222	58	309	0	143	136	0	0	79	0	0	0	0
756	10	401-	0	0	0	0	0	0	46	42	869	84	27	84	391	0	0	0	0	0	0	0	0
760	15	401-	0	0	0	0	0	0	28	49	0	0	590	0	0	0	0	0	0	0	0	0	0
764	10	401-	0	0	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
753	13	501-	0	0	0	0	0	0	0	0	0	0	166	0	0	0	0	0	0	0	0	0	0
757	10	501-	0	0	0	0	0	204	0	0	27	0	67	0	0	14	0	0	0	0	0	0	0
761	17	501-	0	0	0	0	0	0	0	0	0	99	0	0	0	0	0	0	0	0	0	0	0
765	12	501-	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
754	18	601-	0	0	0	0	0	0	0	0	0	0	0	0	207	0	96	0	0	0	0	0	0
758	99	601-	0	0	94	0	163	0	19	88	0	0	0	0	0	0	0	0	0	0	0	0	0
762	21	601-	0	0	0	0	0	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
766	14	601-	0	0	0	0	19	58	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0
755	38	701-	0	0	89	0	17	0	68	0	0	183	0	0	0	0	0	0	0	0	0	0	0
759	12	701-	0	0	0	0	17	0	48	0	0	0	0	0	0	965	0	0	0	0	0	0	0
763	26	701-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
767	15	701-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass			14	18	1	23	81	26	178	204	16	2654	162	127	401	144	139	114	37	3.8	38	2.97	1.9
Std. Error			13	17	1	17	36	9	72	814	71	1693	590	352	285	98	111	35	24	3.0	15	0.63	0.6
Biomass % <			0	100	100	43	79	46	97	97	88	26	34	74	84	96	95	91	21	98	73	51	58

Table 3. Northern shrimp biomass (kg.) by strata from Spanish bottom trawl survey 2003-2015 in NAFO Div. 3L.

Stratum	Area Mn ²	Depth range fth.	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
385	118	51-100	420	175		2485867	2416545	8265541	140724	12046	975	4998	31	68	0
390	815	51-100	1014	3780		2577958	5404325	317330	37466118	145874	2020	49686	414	2340	492
389	509	101-150	14397492	41654297		53639329	49120205	74404070	25997291	21705956	979731	630153	149429	318135	148994
391	282	101-150	1116135	1299793		3712072	12397477	24948041	28071	120096	11940	99221	3115	16223	9267
387	256	151-200	17618619	21721973		29967360	11782827	14287154	6473372	7874303	15006844	6644446	5206921	3955026	4608862
388	357	151-200	25169595	24779540		32585066	26954928	21602795	2348269	5096163	8113071	2136050	1979045	3858773	1811165
392	145	151-200	2821419	1866379		193967	1199955	3675300	1564098	1608469	24550	118649	329956	155247	553694
729	186	201-300	20371	1465049		88481	172095	16126	11533	95976	149	2618	11348	2331	18320
731	216	201-300	2449416	1467221		177357	666240	1501056	54100	1083034	2647	799077	2191919	1644180	875000
733	234	201-300		4077		390052	3281339	240647	6718	51397	194095	285343	7544711	833091	400587
730	170	301-400	0	876		1485	76	32	20	581	92	0	36	907	0
732	231	301-400	34907	5643		14535	4723	1905	226	4266	1349	596	3229	34455	1088
734	153	301-400		408		10554	136	2144	70	129	4910	1553	15628	16075	2625
741	100	401-500	0	56		1379	22	486	0	0	662	189	402	1893	3429
745	348	401-500	17642	0		1699	186	1950	0	2716	1911	250	1613	5068	591
748	159	401-500	292	696		366	499	66	0	49	108	0	21	83	0
742	64	501-600	0	0		462	0	0	0	1718	57	11202	9	0	473
746	392	501-600	0	0		134	0	74	70	225	381	0	395	1068	0
749	126	501-600	0	23		99	0	0	0	0	11	0	0	140	28
743	51	601-700		0		1020	0	23	0	0	2	20	0	18	0
747	724	601-700		0		147	0	41	201	51	32	0	116	753	21
750	556	601-700		0		58	0	132	295	0	308	0	37	178	95
744	66	701-800		0		185	0	0	0	0	0	0	0	9	18
751	229	701-800				0	0	0	0	0	0	0	21	21	0
Biomasa (t.)			63647	94270		125850	113402	149265	74091	37803	24346	10784	17478	10846	8435
Std. Error (t)			20105	40332		12690	13445	48490	37999	9836	4449	3724	5363	2764	1930
Biomass % < 200 fth			96	97		99	96	99	100	97	99	90	44	77	85

Table 4. Northern shrimp size distribution ('000) by sex from Spanish bottom trawl survey 2015 in NAFO Div. 3NO.

CL (mm)	Males	Females	Total
6	0	0	0
6.5	0	0	0
7	0	0	0
7.5	0	0	0
8	9	0	9
8.5	0	0	0
9	9	0	9
9.5	9	0	9
10	22	0	22
10.5	9	0	9
11	53	0	53
11.5	77	0	77
12	32	0	32
12.5	47	0	47
13	26	0	26
13.5	16	0	16
14	13	0	13
14.5	18	0	18
15	16	0	16
15.5	8	0	8
16	7	0	7
16.5	24	9	32
17	15	0	15
17.5	3	7	10
18	7	0	7
18.5	5	7	12
19	17	7	24
19.5	3	4	7
20	3	24	27
20.5	0	11	11
21	0	14	14
21.5	0	15	15
22	0	9	9
22.5	0	15	15
23	0	0	0
23.5	0	7	7
24	0	10	10
24.5	0	4	4
25	0	3	3
25.5	0	3	3
26	0	5	5
26.5	0	7	7
27	0	0	0
27.5	0	0	0
28	0	0	0
29	0	0	0
29.5	0	0	0
30	0	0	0
30.5	0	0	0
Total	447	161	608
	74%	26%	

Table 5. Northern shrimp size distribution ('000) by sex from Spanish bottom trawl survey 2015 in NAFO Div. 3L.

CL (mm)	Males	Females	Total
6	0	0	0
6.5	0	0	0
7	0	0	0
7.5	0	0	0
8	0	0	0
8.5	0	0	0
9	0	0	0
9.5	15	0	15
10	0	0	0
10.5	131	0	131
11	633	0	633
11.5	3624	0	3624
12	7625	0	7625
12.5	9697	0	9697
13	14286	0	14286
13.5	24877	0	24877
14	21561	0	21561
14.5	29202	0	29202
15	16526	0	16526
15.5	21510	0	21510
16	31922	0	31922
16.5	53666	1031	54697
17	84719	122	84841
17.5	80216	866	81082
18	84412	201	84612
18.5	88055	546	88601
19	113499	974	114472
19.5	124183	1856	126039
20	102189	3301	105491
20.5	79023	9852	88875
21	55232	13624	68856
21.5	35859	26094	61953
22	20110	40704	60814
22.5	11786	52570	64356
23	2790	49952	52742
23.5	509	41483	41992
24	520	47806	48326
24.5	0	38345	38345
25	0	23525	23525
25.5	0	17702	17702
26	0	13740	13740
26.5	0	6075	6075
27	0	3302	3302
27.5	0	2439	2439
28	0	2703	2703
29	0	387	387
29.5	0	387	387
30	0	0	0
30.5	0	0	0
Total	1118377	399586	1517964
	74%	26%	

Table 6. Results of the modal analysis (MIX) by sex and maturity stage Spanish bottom trawl survey 3L 2015.

<i>3L</i>				
	<i>Males</i>		<i>Females</i>	
<i>Age</i>	<i>Prop.</i>	<i>St. Dev.</i>	<i>Prop.</i>	<i>St. Dev.</i>
1				
2	0.107			
3	0.294		0.006	
4	0.599		0.027	
5			0.520	
6			0.406	
7			0.041	
<i>Age</i>	<i>Mean CL</i>	<i>St. Dev.</i>	<i>Mean CL</i>	<i>St. Dev.</i>
1				
2	13.92			
3	17.44		17.25	
4	19.90		20.56	
5			22.78	
6			24.54	
7			26.77	
<i>Age</i>	<i>Sigma</i>	<i>St. Dev.</i>	<i>Sigma</i>	<i>St. Dev.</i>
1				
2	0.898	Const.CV.		
3	1.125	Const.CV.	0.776	Fixed C.V.
4	1.283	Const.CV.	0.925	Fixed C.V.
5			1.025	Fixed C.V.
6			1.104	Fixed C.V.
7			1.205	Fixed C.V.

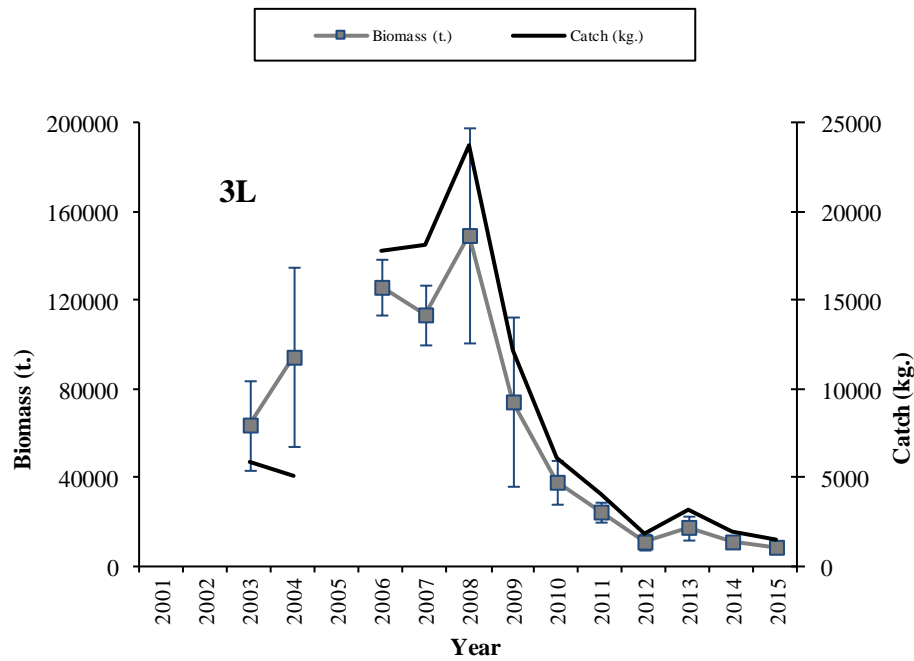
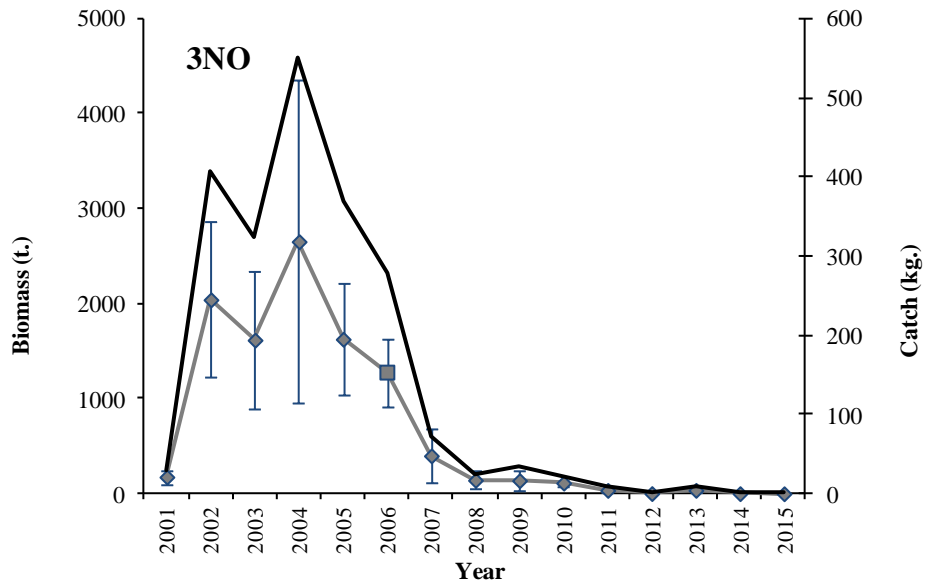


Fig. 1. Northern shrimp biomass (tons) and catch (kg) from Spanish research surveys in NAFO Div. 3NO 2001-2015 and 3L 2003-2015.

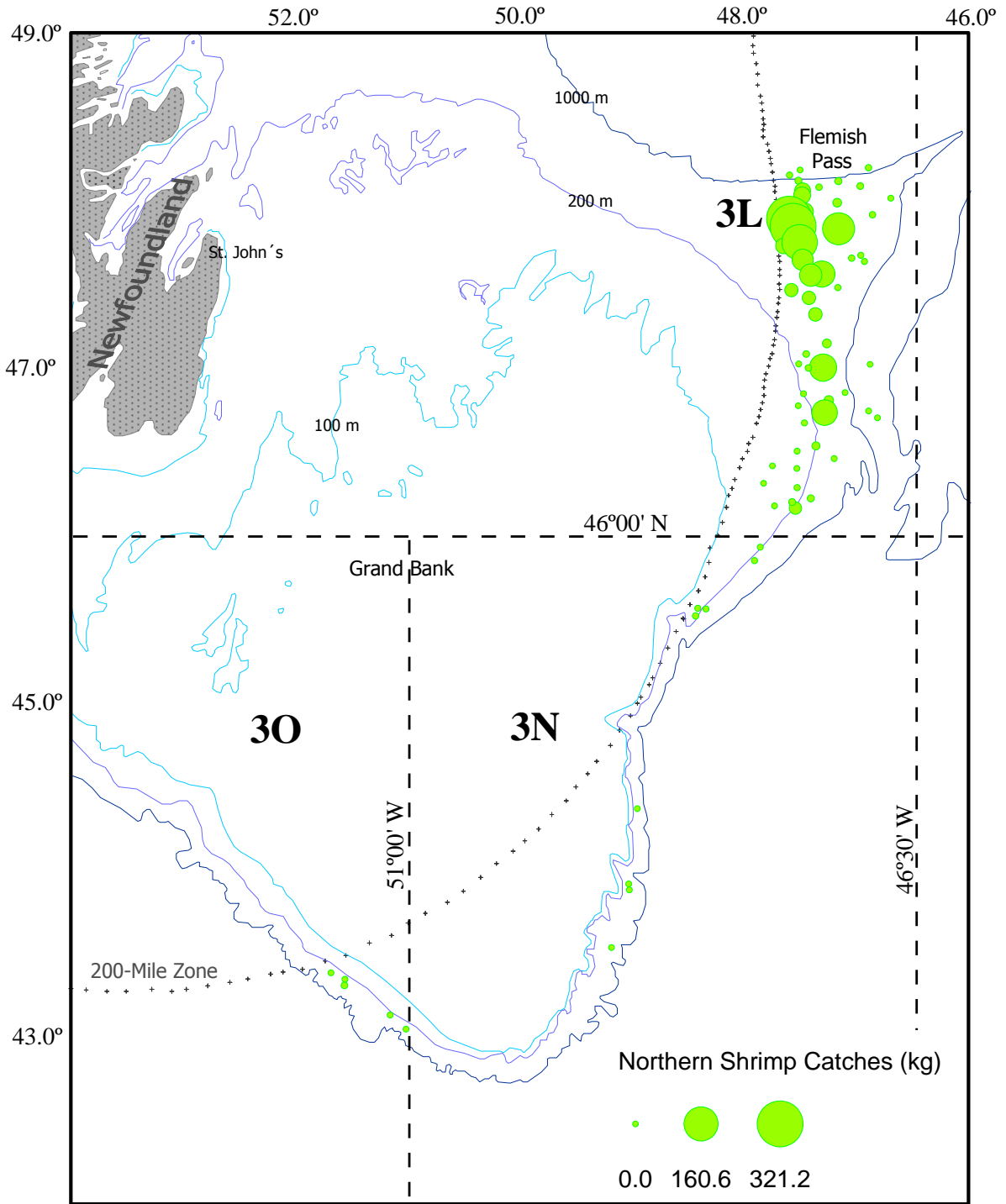


Fig. 2. Geographic distribution of Northern shrimp catches from Spanish bottom trawls surveys 2015.

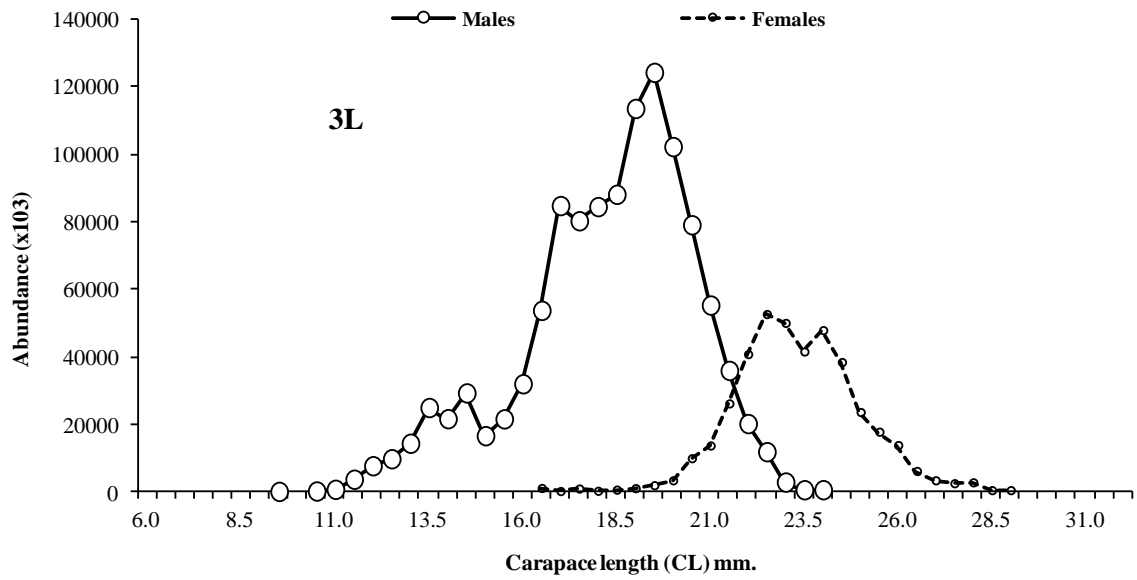
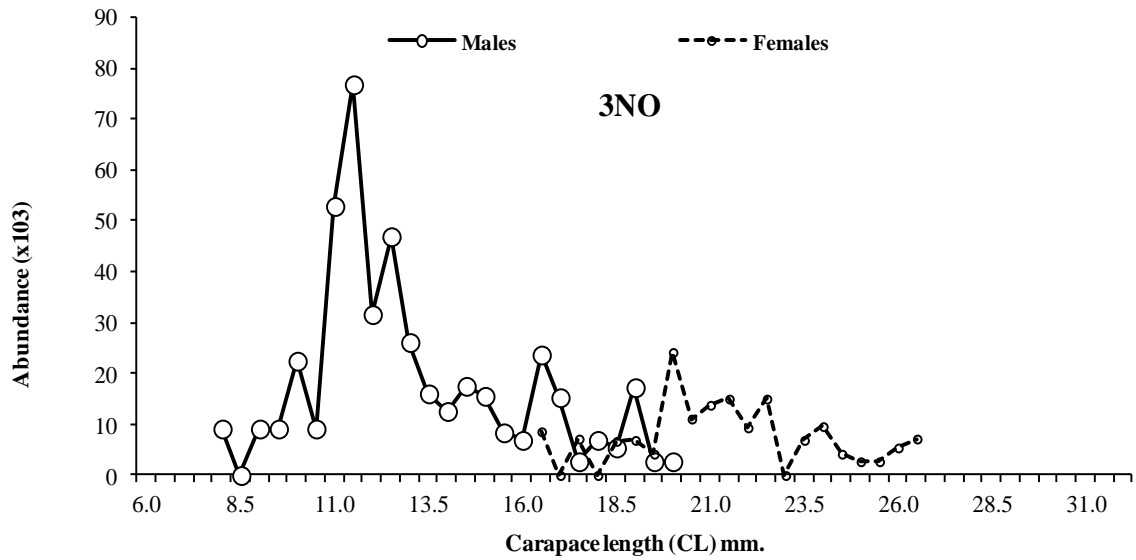


Fig. 3. Northern shrimp size distribution, by sex from Spanish bottom trawl survey (2015) in Divs. 3NO and 3L.