Northwest Atlantic Fisheries Organization

Serial No. N6603 **NAFO SCR Doc. 16/052**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP MEETING - SEPTEMBER 2016

Northern Shrimp (*Pandalus borealis*, Krøyer) from EU-Spain Bottom Trawl Survey 2016 in NAFO Div. 3LNO

by

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Abstract

The Spanish Institute of Oceanography carried out in 2016 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 2016 the shrimp catch (0.385 kg.) and estimated biomass (2.36 t.) in Divisions 3NO remain between the lowest of the series, confirming the decrease of shrimp importance from 2004. Northern shrimp catches in 3L Division have declined from 2009; however, in 2016 a significant increased of the catches was noted (3418 kg.). The biomass estimated in 2016 (20125.2 t.) remain between the lowest values 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 46ºN. The stock of this species in Div. 3LNO, NAFO is distributed along the entire edge of the Grand Bank, mainly in Div. 3L, 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 fishery began in 1993 and came under TAC control in 2000. The TAC was then reduced annually until no directed fishing was implemented for 2015. 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 2016.

Materials and Methods

In 2016 the EU-Spanish bottom trawl surveys were carried out in 3NO (from 30th May to 18th 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 115 and 98 valid hauls respectively ranging depths between 44 and 1447 m approximately. 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 2016 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 1995-2016 in the NAFO Div. 3NO and from 2003-2016 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 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 2016 was around 2.36 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 up to the historical minimum recorded in 2015 (8435 t.). In 2016 the biomass increased by 138% (20215 t.) compared to 2015, however it still remains between the values lowest in the survey series (Figure 1).

The distribution of northern shrimp catches in the EU-Spanish trawl surveys 2016 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 2016 surveys in 3NO Divisions and from 2003 to 2016 in 3L Division. Although it is considered that the shrimp in Div. 3LNO is distributed along the entire edge of the Grand Bank, 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 in 2016). From 2013 to 2015 this general pattern changed and the percentage of the estimated biomass in depths lower than 200 ft decreased up to 44%, 77% and 85% of the biomass in 2013, 2014 and 2015 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 14.5 mm. for males and 21.0 mm. for females; and 18.5 mm. for males and 24.0 mm. for females in 3L Division. In 2016 the sex ratio was similar in both Divisions, showing a higher percentage of the males (>71%).

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 13.9, 17.48 and 20.25 mm. corresponding with ages 2, 3 and 4 respectively. The females showed several modes at 18.88, 21.41, 23.9 and 26.18 mm (ages 3, 4, 5 and 6 respectively).

Acknowledge

The data used in this paper have been funded by the EU through the European Maritime and

Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

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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, 1995-2016 and 3L 2003-2016.

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]	3.86	3.04	0.92
2013[2]	38	15	9
2014[2]	2.97	0.63	0.84
2015[2]	1.96	0.60	0.53
2016[2]	2.36	1.93	0.39

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
2016[2]	20125	7903	3418

[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 1995-2016 in NAFO Div. 3NO.

Stratum	Area Mn²	Depth range fth.	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
375	271	0-30	0	0		0	0	0	3453	0	25	0	0	1989	0	0	0	0	0	0	0	0	0	0
376	1334	0-30	0	0		0	0	0	1270	0	0	0	341	4203	0	0	0	0	34	0	0	0	0	0
353	269	31-50	0	0		0	0	0	79	0	48	0	0	0	126	0	16	0	0	0	0	0	0	0
360	2783	31-50	0	0		0	0	0	2642	1457	3470	24	0	0	445	0	110	1317	129	0	50	0	0	70
374	214	31-50	0	0		0	0	0	178	0	0	0	0	0	62	0	0	0	0	0	0	0	0	0
354	246	51-100	0	0		0	0	0	8761	0	292	6917	0	0	14	0	0	55	86	0	292	0	0	0
359	421	51-100	0	0		0	1389	0	6348	847	1309	43	41	22	98	42	0	543	47	0	30	28	0	0
377	100	51-100	0	0		0	208	44	0	2020	751	1471	3742	3704	83	60	40	0	0	0	0	0	0	0
382	343	51-100		0		0	213	206		1126	302	297	825	944	191	4131	0	0	0	0	0	0	0	37
355	74	101-150		0		0	0	0	1517	147	7635	6146	6183	9179	262	204	0	961	0	148	89	11	37	0
358	225	101-150	0	0		0	3012	0	717	3261	3900	1028	3254	258	2357	2902	0	1722	196	0	27	0	0	0
378	139	101-150	0	0		8968	1099	1196	1700	6803	1142	772	3985	1006	1357	481	73	192	0	0	0	0	0	105
381	144	101-150		0		63	1120	122		8498	2064	2252	1486	7517	3033	11429	466	2540	87	111	41	78	347	1889
356	47	151-200		0		0	0	0	137	0	1337	1293	8046	2683	213	635	39	409	33	0	0	0	41	0
357	164	151-200	0	1809		0	0	0	606	1641	4251	1636	3879	1141	9307	1249	959	1487	29	0	0	144	0	21
379	106	151-200	0	0	720	0	135	0	1251	7034	2540	7709	3298	1169	1214	2238	5079	1570	19	28	897	175	47	51
380	96	151-200		0		1024	9346	1024		1000	6985	2586	1208	6073	6488	11379	1257	2651	7269	3483	2618	1086	663	37
721	65	201-300		0		0	0	0	2889	3282	1112	852	256	3054	0	257	318	6	6339	11	315	569	596	0
723	155	201-300		0		0	1687	0	0	1266	9283	4404	3333	5379	1461	90	0	916	335	0	98	132	0	0
725	105	201-300	1431	0		0	0	0	271	527	9180	1814	7483	2067	4713	578	239	7745	0	0	216	231	69	106
727	96	201-300		0		1321	0	1142		2866	2119	9847	3268	6263	1248	3172	179	632	2265	83	9350	512	158	38
722	84	301-400		0		0	37	734	2890	60	156	0	36	0	0	0	0	0	0	0	0	0	0	0
724	124	301-400	0	0		0	0	0	0	55	628	58	165	53	213	0	0	0	32	0	0	0	0	0
726	72	301-400	0	0		0	0	0	0	7	54	2048	0	406	170	0	5351	146	0	0	0	0	0	10
728	78	301-400		0		0	0	1671		7280	0	0	86	135	0	0	41	146	0	0	40	0	0	0
752	131	401-500		0		0	0	0		86	0	49	222	58	309	0	143	136	0	0	79	0	0	0
756	101	401-500		0		0	0	0	0	0	46	42	869	84	27	84	391	0	0	0	0	0	0	0
760	154	401-500		0		0	0	0	0	0	283	49	0	0	590	0	0	0	0	0	0	0	0	0
764	100	401-500		0		0	0	0	42	0	0	0	0	0	0	0	0		0	0	0	0	0	0
753	138	501-600		0		0	0	0		0	0	0	0	166	0	0	0		0	0	0	0	0	0
757	102	501-600		0		0	0	0		204	0	0	27	0	67	0	0	14	0	0	0	0	0	0
761	171	501-600		0		0	0	0	0	0	0	0	0	0	99	0	0	0	0	0	0	0	0	0
765	124	501-600		0		0	0	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0
754	180	601-700				0	0	0		0	0	0	0	0	0	207	0	96	0	0	0	0	0	0
758	99	601-700				0	0	94		1630	0	19	88	0	0	0	0	0	0	0	0	0	0	0
762	212	601-700				0	0	0	0	85	0	0	0	0		0	0	0	0	0	0	0	0	0
766	144	601-700				0	0	0		19	58	0	0	0		0	0	32	0	0	0	0	0	0
755	385	701-800				0	0	89		0	174	0	68	0	0	1839	0	0	0	0	0	0	0	0
759	127	701-800				0	0	0		17	0	48	0	0		0	0	965	0	0	0	0	0	0
763	261	701-800				0	0	0		0	0	0	0	0		0			0	0	0	0	0	0
767	158	701-800				0	0	0		0	0	0	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	37	3.86	38	2.97	1.96	2.36
Std. Error (t.)			13	17	1	17	36	9	72	814	716	1693	590	352	285	98	111	35	24	3.04	15	0.63	0.60	1.93
Biomass % < 200fth			0	100	100	43	79	46	97	97	88	26	34	74	84	96	95	91	21	98	73	51	58	93

Table 3.- Northern shrimp biomass (kg.) by strata from Spanish bottom trawl survey 2003-2016 in NAFO Div. 3L

Stratum	Area Mn^2	Depth range fth.	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
385	118	51-100	420	175		2485867	2416545	8265541	140724	12046	975	4998	31	68	0	0
390	815	51-100	1014	3780		2577958	5404325	317330	37466118	145874	2020	49686	414	2340	492	94
389	509	101-150	14397492	41654297		53639329	49120205	74404070	25997291	21705956	979731	630153	149429	318135	148994	176622
391	282	101-150	1116135	1299793		3712072	12397477	24948041	28071	120096	11940	99221	3115	16223	9267	8073
387	256	151-200	17618619	21721973		29967360	11782827	14287154	6473372	7874303	15006844	6644446	5206921	3955026	4608862	10305953
388	357	151-200	25169595	24779540		32585066	26954928	21602795	2348269	5096163	8113071	213605 0	1979045	3858773	1811165	8512571
392	145	151-200	2821419	1866379		193967	1199955	3675300	1564098	1608469	24550	118649	329956	155247	553694	174468
729	186	201-300	20371	1465049		88481	172095	16126	11533	95976	149	2618	11348	2331	18320	5156
731	216	201-300	2449416	1467221		177357	666240	1501056	54100	1083034	2647	799077	2191919	1644180	875000	288113
733	234	201-300		4077		390052	3281339	240647	6718	51397	194095	285343	7544711	833091	400587	653016
730	170	301-400	0	876		1485	76	32	20	581	92	0	36	907	0	0
732	231	301-400	34907	5643		14535	4723	1905	226	4266	1349	596	3229	34455	1088	453
734	153	301-400		408		10554	136	2144	70	129	4910	1553	15628	16075	2625	421
741	100	401-500	0	56		1379	22	486	0	0	662	189	402	1893	3429	82
745	348	401-500	17642	0		1699	186	1950	0	2716	1911	250	1613	5068	591	55
748	159	401-500	292	696		366	499	66	0	49	108	0	21	83	0	0
742	64	501-600	0	0		462	0	0	0	1718	57	11202	9	0	473	31
746	392	501-600	0	0		134	0	74	70	225	381	0	395	1068	0	45
749	126	501-600	0	23		99	0	0	0	0	11	0	0	140	28	0
743	51	601-700		0		1020	0	23	0	0	2	20	0	18	0	0
747	724	601-700		0		147	0	41	201	51	32	0	116	753	21	51
750	556	601-700		0		58	0	132	295	0	308	0	37	178	95	0
744	66	701-800		0		185	0	0	0	0	0	0	0	9	18	0
751	229	701-800				0	0	0	0	0	0	0	21	21	0	0
Biomasa (t.)			63647	94270		125850	113402	149265	74091	37803	24346	10784	17478	10846	8435	20125
Std. Error (t)			20105	40332		12690	13445	48490	37999	9836	4449	3724	5363	2764	1930	7903
Biomass % < 200 fth			96	97		99	96	99	100	97	99	90	44	77	85	95

Table 4.- Northern shrimp size distribution ('000) by sex from Spanish bottom trawl survey 2016 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	0	0	0
8.5	0	0	0
9	0	0	0
9.5	0	0	0
10	26	0	26
10.5	103	0	103
11	52	0	52
11.5	0	0	0
12	26	0	26
12.5	0	0	0
13	0	0	0
13.5	26	0	26
14	61	0	61
14.5	135	0	135
15	77	0	77
15.5	133	0	133
16	38	0	38
16.5	129	0	129
17	32	0	32
17.5	0	0	0
18	0	0	0
18.5	32	0	32
19	16	0	16
19.5	0	0	0
20	0	0	0
20.5	26	0	26
21	0	9	9
21.5	5	0	5
22	4	5	9
22.5	0	0	0
23	0	0	0
23.5	0	5	5
24	0	0	0
24.5	0	4	4
25	0	0	0
25.5	0	0	0
26	0	0	0
26.5	0	0	0
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	921	23	944
	98%	2%	

Table 5.- Northern shrimp size distribution ('000) by sex from Spanish bottom trawl survey 2016 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	21	0	21
8.5	122	0	122
9	33	0	33
9.5	54	0	54
10	39	0	39
10.5	291	0	291
11	392	0	392
11.5	861	0	861
12	1591	0	1591
12.5	2400	106	2506
13	8505	42	8547
13.5	16434	8	16443
14	7208	0	7208
14.5	20594	0	20594
15	40689	78	40767
15.5	75244	128	75373
16	114240	1040	115280
16.5	241456	1568	243024
17	228444	6469	234913
17.5	251516	6334	257850
18	241176	7208	248384
18.5	252406	14802	267207
19	194643	31838	226481
19.5	241771	27821	269593
20	208303	32444	240747
20.5	193476	50536	244012
21	131881	68789	200670
21.5	103166	62510	165677
22	66395	88393	154788
22.5	41316	96780	138096
23	21031	107422	128453
23.5	1414	108602	110015
24	6	118407	118414
24.5	723	100764	101487
25	0	57312	57312
25.5	0	29626	29626
26	0	31503	31503
26.5	0	15608	15608
27	0	5650	5650
27.5	0	6508	6508
28	0	120	120
29	0	1489	1489
29.5	0	1817	1817
30	0	6	6
30.5	0	0	0
Total	2707843	1081917	3789760
	71%	29%	

Table 6.- Results of the modal analysis (MIX) by sex and maturity stage Spanish bottom trawl survey 3L 2016.

		3L		
	Males		***Females***	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1				
2	0.01859	0.0001		
3	0.49328	0.0006	0.07484	0.0005
4	0.48812	0.0006	0.27267	0.0009
5			0.58837	0.0010
6			0.06412	0.0009
7				
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1				
2	13.9	0.0065		
3	17.48	0.0018	18.88	0.0059
4	20.25	0.0020	21.41	0.0065
5			23.90	0.0044
6			26.18	0.0136
7				
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1				
2	0.8967	0.0008		
3	1.1277	Const.CV.	0.8496	
4	1.3066	Const.CV.	0.9636	Fixed C.V.
5			1.0756	Fixed C.V.
6			1.1779	Fixed C.V.
7				

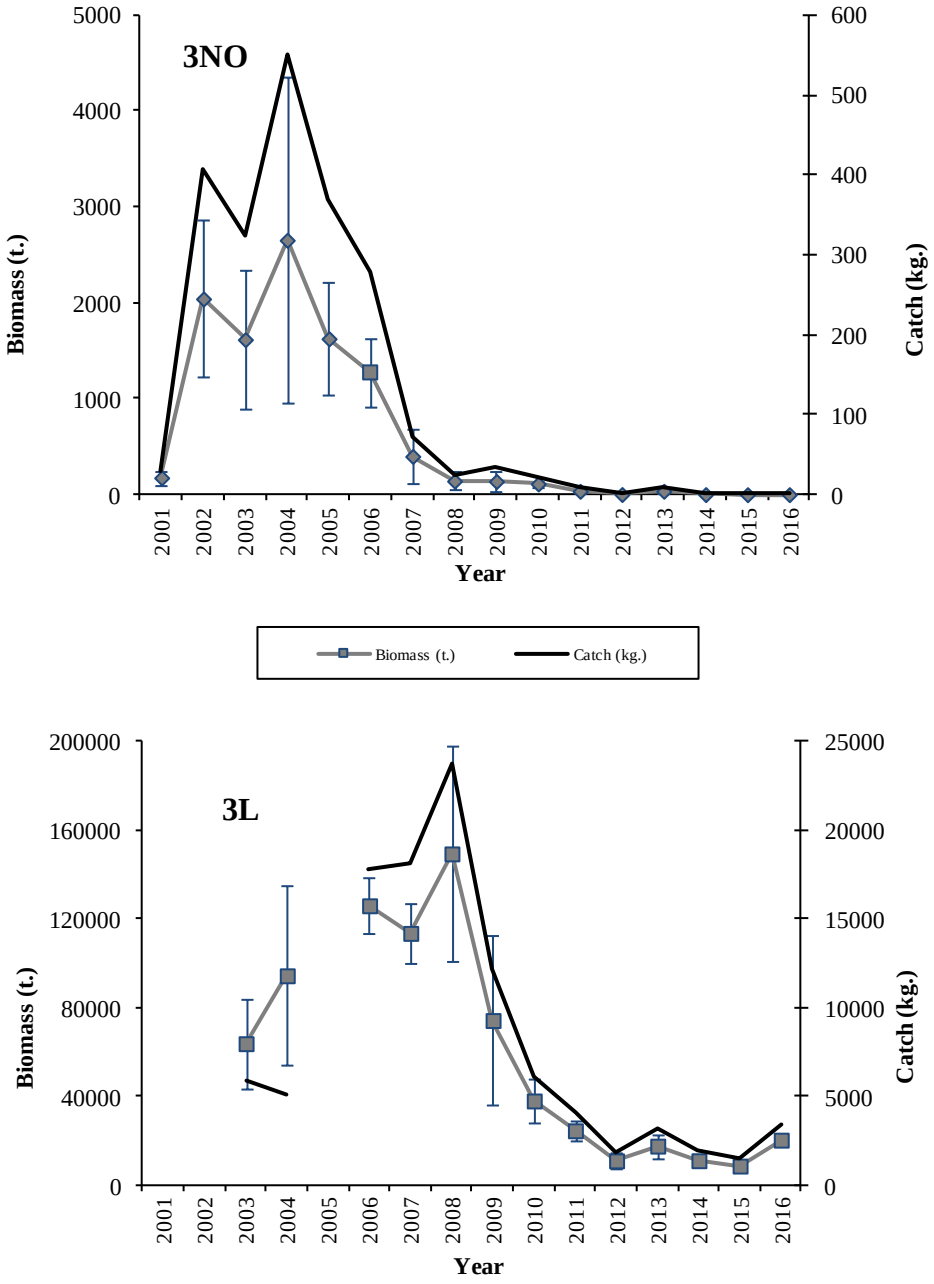

Fig.1. Northern shrimp biomass (tons) and catch (kg) from Spanish research surveys in NAFO Div. 3NO 2001-2016 and 3L 2003-2016.

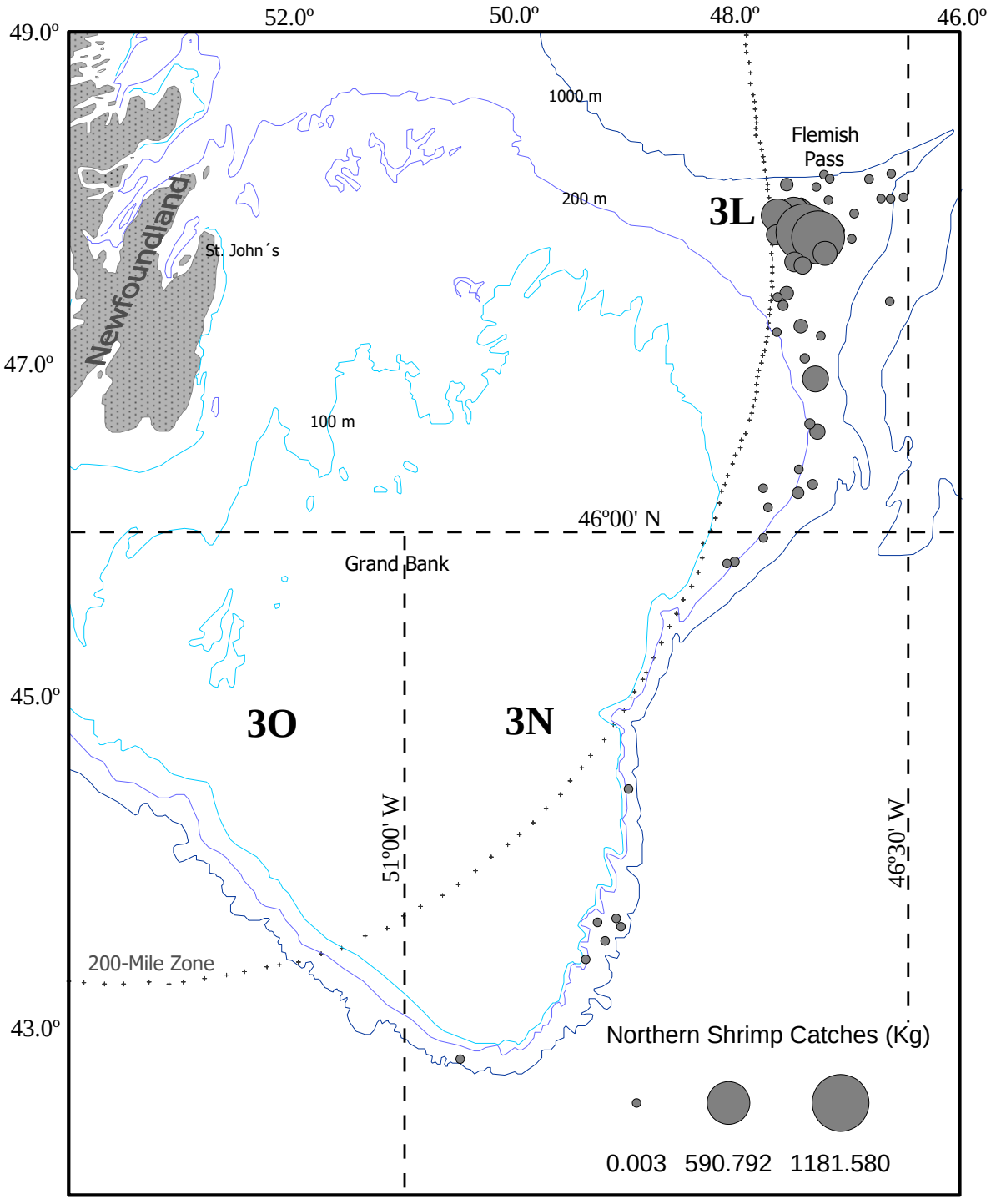

Fig. 2. Geographic distribution of Northern shrimp catches from Spanish bottom trawls surveys 2016.

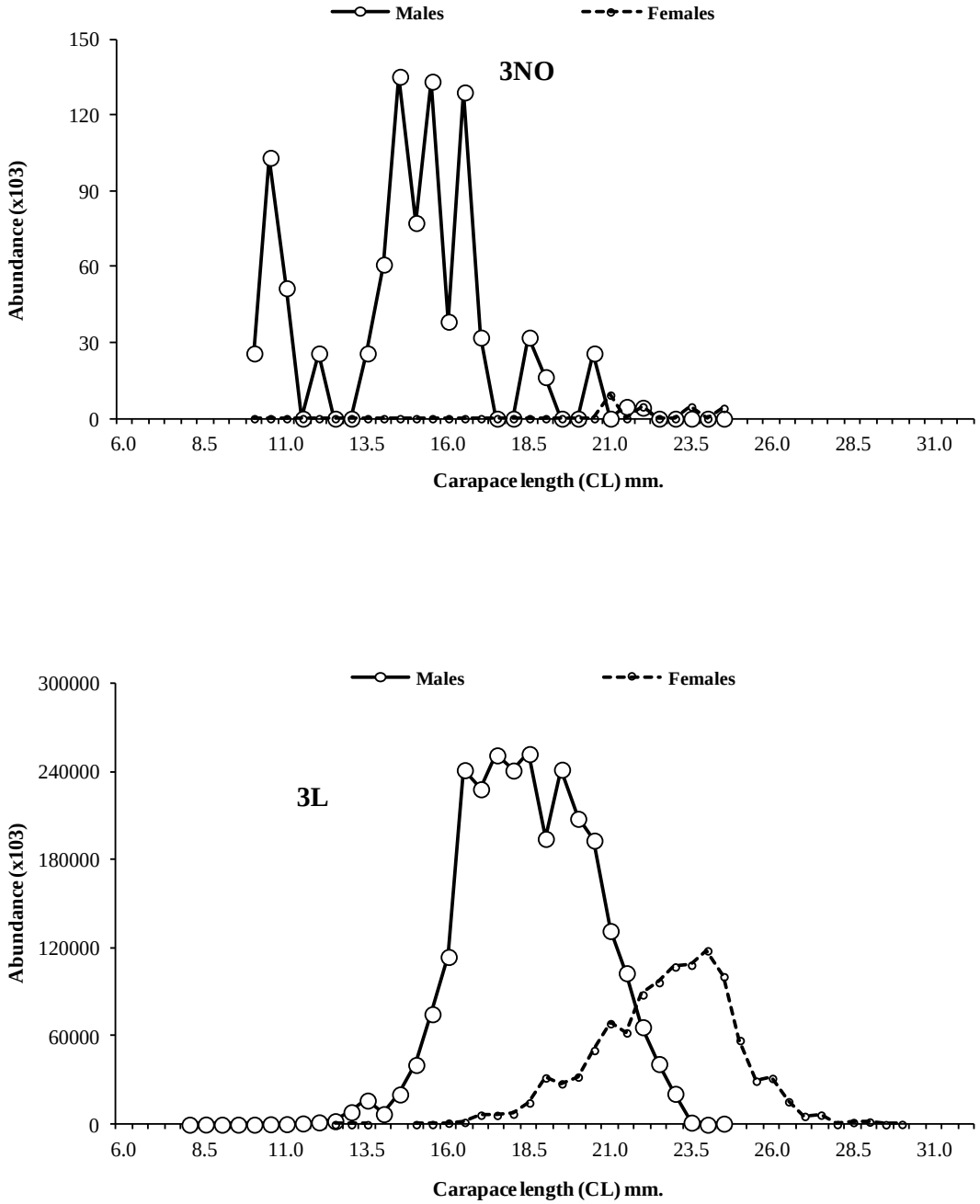

Fig. 3. Northern shrimp size distribution, by sex from Spanish bottom trawl survey (2016) in Divs. 3NO and 3L.