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Northern Shrimp (*Pandalus borealis*, Krøyer) in Spanish Bottom Trawl Survey 2003 in NAFO Divisions 3LNO

by

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Abstract

The results on northern shrimp (*Pandalus borealis*) obtained from a Spanish bottom trawl survey in the NAFO Regulatory Area (Divisions 3NO) in spring 2003, carried out by the Instituto Español de Oceanografía (Spanish Oceanographic Institute, Vigo Centre), are presented and compared with those from previous surveys from the same series. Catch obtained (324.8 kg.) is the second highest in the series, thus maintaining the catch increase noted in 2002 (total of 408.1 kg.) relative to previous years.

For the first time, the IEO has enlarged the sampling area to Div. 3L, where important shrimp catches were obtained (5835.8 kg.).

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 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 180 to 550 metres, although the majority of the stock is found in Div. 3L. Temperature, salinity, depth and substratum determine the distribution pattern and abundance of this species, (Allen, J.A.1959). This species is found in areas with temperatures generally ranging from 3ºC to 8ºC (Rasmussen, B.1965).

Most of the scientific literature on the northern shrimp in the NAFO Regulatory Area corresponds to Div. 3M, where the most important fishery is conducted (Skuladottir *et al*., 1999; Skuladottir, 2000; Bakanev, 2001; Nicolajsen and Brynjolfsson, 2001; Kristjansson, 2001; Skuladottir and Diaz, 2001). Bibliography for shrimp from Div. 3N can be found chiefly in works dealing with Div. 3NLO, (Orr *et al*., 2002; Orr *et al*., 2003; Colbourne and Orr, 2003).

Since 1995, Canadian multi-species stratified random surveys have been used to estimate northern shrimp biomass and abundance indices within NAFO Div. 3LNO (NAFO SCR Doc. 02/61). In this series of surveys, Div. 3N accounts for between 0.5 and 9% of the total biomass in Div. 3LNO; over 82% of the biomass in Div. 3N is located beyond the 200 mile limit (Orr *et al*., 2003). The biomass in Division 3O accounts for less than 1% of the biomass in Div. 3LNO and for only 0.34% of the biomass in Div. 3O is beyond the 200 mile limit (Orr *et al*., 2003).

The Vigo Centre of the Instituto Español de Oceanografía has been conducting research cruises since 1995 in the

NAFO Regulatory Area in Div. 3NO beyond the 200 mile exclusive economic zone. 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 by the Instituto Español de Oceanografía in the period 1995-2000, catches of northern shrimp were insignificant. This may be explained by the low efficiency of the fishing gear used, a "pedreira", with this species (Paz *et al*., 1995).

During 2001 and 2002, the survey was carried out on board the oceanographic research vessel "*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 were poor, i.e., 14.62 kg.

A significant increase in catches (totalling 408.1 kg) of northern shrimp was noted for the first time on the 2002 Spanish bottom trawl survey in Div. 3NO. In 2003, catch was 324.8 kg., a fact that led to invalidating the notion of sporadic catch in 2002.

Enlargement of the sampling area to the Southeast and East of Div. 3L in the NAFO Regulatory area has made it possible to determine the geographical distribution of northern shrimp with greater precision.

This work presents data on the geographical distribution in the NAFO Regulatory Area (Div. 3LNO), on biomass, length frequencies, age structure and mean weight by length-class of catch of northern shrimp on Spanish bottom trawl survey 2003.

Materials and Methods

The 2003 Spanish bottom trawl survey was carried out in two phases from the 11th of May to the 6th of June, following set guidelines previously established for the series of I.E.O. research surveys (Paz and Durán, 2001). The first part of the survey, "Platuxa 03", took place from 11th May to 1st June, in Div. 3NO, with a total of 122 hauls, covering a depth range of 38 to 166 metres, noting the presence of northern shrimp in 39 of hauls. The second part of the study is conducted in Div. 3L, from 2nd June to 6th June, with 35 hauls covering a depth range of 118 to 1100 metres. The presence of northern shrimp was noted in 25 hauls.

In each of the sampling station positions, CTD profiles were made (Sea-bird SBE 25) throughout the water column, to obtain temperatures, conductivity and salinity. Temperature is one of the most import abiotic factors that determine the distribution of this species.

Samples of approximately 1.5 kilograms were taken to determine length frequencies in hauls with the highest catches.

Males and females were separated with reference to the endopodite of the first pleopod (Rasmussen, 1953). Following this criterion, individuals that were in the middle of a sex change were considered as males. 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 -OCL- (Shumway *et al*., 1985). Such measurements were made to the lower half millimetre using electronic callipers.

Samples were taken from eleven hauls with the presence of shrimp in Div. 3NO and 15 in Div. 3L. Depths of the sampled hauls varied from 184 to 549 metres in Div. 3NO. Depth range of the sampled hauls in Div. 3L was broader, ranging from 185 to 707 metres. Data were used to obtain an estimate of the size distributions of the population in the area.

Furthermore, some samples were frozen onboard to determine the length-weight relationship in the laboratory.

Seven hundred and fifty-five in Div. 3NO and nine hundred thirty-five in Div. 3L, individuals were selected, dried and weighed with a precision of 0.1g to calculate the length-weight relationship.

The Spanish bottom trawl survey data are presented as sampled values.

Data of the samples taken is as follows:

Division 3NO		
Depth (m.)	**No. of sampled lengths (No. of individuals)**	**No. of biological samples (No. of individuals)**
184-274	2 (419)	2 (222)
275-366	8 (1094)	6 (456)
367-540	1 (148)	1 (77)

Division 3L		
Depth (m.)	**No. of sampled lengths (No. of individuals)**	**No. of biological samples (No. of individuals)**
184-274	9 (1660)	6 (419)
275-366	3 (487)	5 (374)
367-540	2 (334)	1 (87)
541-720	1 (173)	1 (55)

Results and Discussion

Table 1 shows the catches of northern shrimp from the multi-species surveys, carried out by IEO Vigo, in the NAFO 3NO area during the spring season from 1995-2003. In the year 2002 an abrupt increase with respect to earlier years occurred, both in terms of catches and the number of hauls with the presence of this species (Diaz *et al*., 2002). These initial data were considered with caution due to the fact that, until 2001, the "Pedreira" method used as a sampler (Paz *et al*., 1995) is not efficient for catching shrimp. In 2001, this method was changed for a "Campelen" 1800 (Walsh *et al*., 2001) with high efficiency for catching this species (Vazquez, 2002).

For the second consecutive year, an increase in northern shrimp catch was noted, in terms of the period 1995-2001, this level being maintained at a level approaching that obtained in 2002, with a distribution of abundances similar to that noted for 2002.

Figure 1: The map shows the distribution of northern shrimp catches in the Spanish trawl survey of 2003 in Div. 3NO and 3L. The main catches in Div. 3NO are located in a small area to the Northwest of 3N, in latitudes higher than 45ºN, as in the 2002 survey.

For the first time, the Spanish survey covered an area belonging to NAFO Regulation area 31, beyond the 200 mile limit. This recently incorporated area in the survey plan includes the area known as Flemish Pass, where high concentrations of shrimp were found, i.e. a maximum of 1723 kilograms in a 30 minute trawling operation..

Table 2 shows total northern shrimp catches for the 2003 survey and details of depths and numbers of hauls per depth with the presence of this species. Total catches during this survey in Div. 3NO were 324.88 Kg. and presence was noted in 39 hauls. In Div. 3NO the most important catches were concentrated in latitudes higher than 45ºN (Fig.1) and 90.5% of the catches were made at depths of between 278 and 380 metres.

In Table 3 in Div. 3L, catches were 5835.91 kg. in 25 with the presence of shrimp of the total of 35 hauls, 95.45% of the total shrimp catches being between 184 and 366 meters. The most important catches were located at depths of between 242 and 392 metres, with 6 hauls which represented the 82.40% of the total catch in this area.
75% of the catch was obtained in positions where the bottom temperature was in a temperature range of 2.7ºC-

3.6ºC. This coincides with the results obtained in the Canadian spring survey series in Div. 3LNO where the larger catches are obtained in temperature ranges of 2º-4ºC, with small catches in the ranges of 1º-2ºC and 4º-5ºC (Colbourne and Orr, 2003).

The percentages by sex and maturity in Div. 3NO were: males 43.87%, immature females 48.89%, mature females 6.64% and ovigerous 0.59% (Fig. 2). The length range for male varied between 11 and 24 mm.; that for immature females between 19.5 and 26 mm.; that for multiparous females 21 and 28 mm. and that for the females on ovigerous stage between 20.5 and 27.5 mm. (Table 4).

Northern shrimp catch in Div. 3L presents some different percentages: males 52.52%, immature females 38.73%, multiparous females 8.66% and ovigerous 0.1% (Fig. 2). The length range for males are between 11.5 and 23 mm.; that for immature females between 19.5 and 25.5mm.; that for mature females 18 and 28 mm. and that for ovigerous between 21 and 23 mm, only 3 specimens (Table 5).

Figure 3 shows the size distribution by sex and maturity state in the samples in Div. 3NO catch. A mode can be seen in 20 and 20.5 mm. males, 23 mm. immature females, 24 mm. mature females. Only eleven ovigerous females were found with a mode in 21.5 mm.

Figure 4 shows the size distribution by sex and maturity state in the samples on Div. 3L. The males with a mode in 18.5 mm., in 22.5 mm. immature females, in 23 mm. mature females and only three ovigerous females were found.

A modal size analysis programme could not be used due the low number of sampled individuals. An age-length key was used (Orr *et al*., 2003) to spring season, based on observations made in adjacent waters (Nicolajsen, 2001; Skuladottir, 2001; Skuladottir and Diaz, 2001; Orr, *et al*., 2002; Orr, *et al*., 2003)

Aged (years)	OCL (mm.)
0	<7.5
1	7.5-11
2	11.5-15
3	15.5-17.5
4	18-22
5 +	>22

According to the enclosed age-length key, we can observe that in Div. 3NO the males with two modal lengths in 20 and 20.5 mm. would belong to the 1999 year-class (age 4). The immature females dominated by the 1998 annual class (age 5+) and the mature females dominated by the 1998 annual class (age 5+) with the 58.53% to this state. The 54.54 % of the ovigerous females were between 21.5 and 22.5 mm (OCL) belonging to the 1999 and 1998 year-class (age 4 and 5+).

In the size distributions of the catches sampled in Div. 3L, we can note that 67.93% of the males have sizes ranging from 17.5 to 20 mm (OCL). Thus, the males would be dominated by the annual classes of 200 and 1999 (age 3 and 4 respectively). Immature females with a model size of 22.5 mm, would be dominated by the annual class of 1998 (age 5+), this age class accounting for 64.22% of the total of immature females. The multiparous females with a modal size of 23 and 23.5 mm would belong to the 5+ age class, annual class of 1998 and previous years. Only three ovigerous females were found. The strong annual classes of 1997-1999 compared with those of previous years may keep the fisher for the next few years (Orr *et al*., 2003.).

The weight-size relationships calculated from the shrimps sampled from the catches in Div. 3NO and 3L show a clear difference. Specimen from Div. 3NO present higher weights for each size as opposed to those in area Div. 3L prospected.

Table 5 shows weights versus length and number of individuals obtained by length-weight relationship in Div. 3NO

(Fig. 5.).

Table 6 shows weight versus length and number of individuals obtained by length-weight relationship in Div. 3L (Fig. 6.).

By comparing the sex and maturity stage data between the catch in Div. 3NO and 3L of the 2003 survey, in two very close areas and dates, significant differences are noted in the percentage of males and immature females. The percentages are similar for the multiparous females. The low number of ovigerous females does not make it possible to establish any comparison whatsoever. These percentages are presented in the table below.

Sex and maturity stage	3NO	3L
Males	43.87 %	52.52%
Immature females	48.89 %	38.73%
Mature females	6.64 %	8.62%
Ovigerous	0.59 %	0.1 %

The difference existing in the percentages of males and immature females, in dates so close together and in such nearby areas, is coherent with the size distributions observed for these sexual states between the two areas sampled. It is noted that the distributions are displaced towards larger sizes in Div. 3NO, ($\bar{x}$=21.71) as opposed to 3L ($\bar{x}$=20.96). (Fig. 7, 8 and 9). This may be explained by the effect of temperature and latitude on the growth of the species (NOAA Technical Report NMFS 30).

Modal sizes by age vary with the years reflecting different growth rates for the different cohorts. Since 2000, the average size of females and the sex inversion size have fallen, indicating a change in the growth pattern in the area. (Orr *et al*., 2003).

Figure 10 shows the distributions for the total of the specimen sampled in the two areas Div. 3NO and 3L.

Comparing the data obtained in Div. 3NO in the 2002 survey with those for 2003, an increase in modal sizes is noted for males and immature females, this remaining the same for mature females. The low number of ovigerous females caught in both years does not make it possible to establish a comparison.

As a result of this size increase, the percentage of immature females and the decrease in the percentage of males are noted in 2003 in terms of the previous year.

The following table shows the percentages, range of sizes and modal size per sexual stage for the 2002-2003 surveys in Div. 3NO.

	2002			2003		
Sexual stage	**%**	**Length range**	**Modal Length**	**%**	**Length range**	**Modal Length**
Males	58.07	10.5-255	20	43.87	11-24	20/20.5
I.Females	30.99	19.5-26	22.5	48.89	19.5-26	23
M.Females	10.21	19-27	24	6.64	21-28	24
Ovigerous	0.73	18-26.5	23.5	0.59	20.5-27	21.5

Figure 11 shows the increase in sizes and modal size noted in the catches in Div. 3NO for 2003 in terms of those observed in 2002. Modal size in 2002 was 21.5 mm (OCL) and in 2003 was 23.5 mm (OCL).

Northern shrimp is an important component in the diet of various species (Rodríguez-Marín *et al*., 1994; Albikovskaya and Gerasimova, 1993; Lilly, MS 1993; Paz *et al*., 1993). Since 1999, a significant increase has been noted in the biomass of this species in NAFO areas Div. 3LNO (Orr *et al*., 2002; Orr *et al*., 2003) and an increase in its spatial area of distribution in Div. 3L (Orr *et al*., 2003) and in other areas such as Flemish Cap (Div. 3M) (Díaz, 2001; Del Rio *et al*., 2002).

Diverse works have been presented attempting to link changes in northern shrimp biomass and a greater distribution with a possible release in predation pressure on this species by commercially exploited species such as cod with which it shares its area of distribution (Lilly *et al*., 2000); Berenboin *et al*., 2000) and due to the more favourable abiotic conditions for northern shrimp.

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Table 1. Northern shrimp catch (kg.) on Spanish bottom trawl survey 1995-2003.

3NO

Year	Catch (kg.)	No. hauls
1995 [1]	4.6	1
1996 [1]	2.4	1
1997 [1]	0.14	1
1998 [1]	4.95	5
1999 [1]	13.29	13
2000 [1]	3.95	13
2001 [2]	14.62	16
2002 [2]	408.1	39
2003 [2]	324.88	39

3L

Year	Catch (kg.)	No. hauls
2003 [2]	5835.83	25

[1] Pedreira codend 35 mm. mesh size.
[2] Campelen codend 20 mm. mesh size.

Table 2. Northern shrimp catches (kg.) by strata (m) on Spanish bottom trawl survey2003 in Div. 3NO.

Depth strata (m)	Catch (kg.)	No. hauls
<=56	0	0
57-92	0.3	6
93-183	0.5	5
184-274	8.62	8
275-366	280.67	7
367-549	34.57	6
550-731	0.17	3
732-914	0.05	2
915-1097	0	0
1098-1280	0.01	1
1281-1463	0.01	1

Table 3. Northern shrimp catches (kg.) by strata (m) on Spanish bottom trawl survey 03 in Div. 3L.

Depth strata (m)	Catch (kg.)	No. hauls
<=56	0	0
57-92	0	0
93-183	0.15	5
184-274	1417.05	7
275-366	4153.56	6
367-549	261.7	3
550-731	1.7	1
732-914	1.73	2
915-1097	0.02	1
1098-1280	0	0
1281-1463	0	0

Table 4. Northern shrimp size distribution by sex and state maturity in Spanish bottom trawl survey 2003 in 3NO.

OCL (mm)	Males	Inmature females	Mature females	Ovigerous	Total
11,0	1	0	0	0	1
11,5	0	0	0	0	0
12,0	1	0	0	0	1
12,5	11	0	0	0	11
13,0	5	0	0	0	5
13,5	6	0	0	0	6
14,0	7	0	0	0	7
14,5	7	0	0	0	7
15,0	2	0	0	0	2
15,5	7	0	0	0	7
16,0	4	0	0	0	4
16,5	5	0	0	0	5
17,0	5	0	0	0	5
17,5	11	0	0	0	11
18,0	20	0	0	0	20
18,5	39	0	0	0	39
19,0	59	0	0	0	59
19,5	84	1	0	0	85
20,0	112	2	0	0	114
20,5	126	12	0	1	139
21,0	126	17	1	0	144
21,5	96	50	3	3	152
22,0	54	112	3	1	170
22,5	16	148	8	2	174
23,0	8	199	19	0	226
23,5	0	165	19	1	185
24,0	1	126	21	2	150
24,5	0	46	13	0	59
25,0	0	25	21	0	46
25,5	0	1	5	0	6
26,0	0	2	4	0	6
26,5	0	0	3	0	3
27,0	0	0	0	0	0
27,5	0	0	1	1	2
28,0	0	0	2	0	2
TOTAL	813	906	123	11	1853

Table 5 .Northern shrimp size distribution by sex and state maturity in Spanish bottom trawl survey in Div. 3L.

OCL (mm.)	Males	I. Females	M. Females	Ovigerous	Total
11.0	0	0	0	0	0
11.5	1	0	0	0	1
12.0	5	0	0	0	5
12.5	4	0	0	0	4
13.0	3	0	0	0	3
13.5	9	0	0	0	9
14.0	8	0	0	0	8
14.5	8	0	0	0	8
15.0	8	0	0	0	8
15.5	8	0	0	0	8
16.0	15	0	0	0	15
16.5	23	0	0	0	23
17.0	36	0	0	0	36
17.5	71	0	0	0	71
18.0	140	0	1	0	141
18.5	191	0	0	0	191
19.0	180	0	0	0	180
19.5	185	2	1	0	188
20.0	180	10	1	0	191
20.5	175	24	2	0	201
21.0	80	82	5	2	169
21.5	44	144	19	0	207
22.0	16	207	21	0	244
22.5	3	213	30	0	246
23.0	1	191	34	1	227
23.5	0	95	23	0	118
24.0	0	43	23	0	66
24.5	0	13	16	0	29
25.0	0	3	20	0	23
25.5	0	1	13	0	14
26.0	0	0	8	0	8
26.5	0	0	5	0	5
27.0	0	0	4	0	4
27.5	0	0	2	0	2
28.0	0	0	1	0	1
28.5	0	0	0	0	0
29.0	0	0	0	0	0
TOTAL	1394	1028	229	3	2654

Table 6. Northern shrimp weights at length from Spanish bottom trawl survey 2003 in 3NO, obtained by Length-weight relationship.(y= 0,0013x $^{2,7436)}$

OCL mm.	Weight (gr.)
7.5	0.327
10	0.720
12.5	1.328
15	2.191
17.5	3.344
20	4.824
22.5	6.664
25	8.898
27.5	11.558
30	14.674

Table 7. Northern shrimp weight at length obtained by Length-weight relationship on Spanish bottom trawl Survey 2003 in 3L.(y=0,0012x $^{2,7498)}$.

OCL mm.	Weights (gr.)
7.5	0.305
10	0.674
12.5	1.245
15	2.056
17.5	3.142
20	4.536
22.5	6.272
25	8.379
27.5	10.890
30	13.834

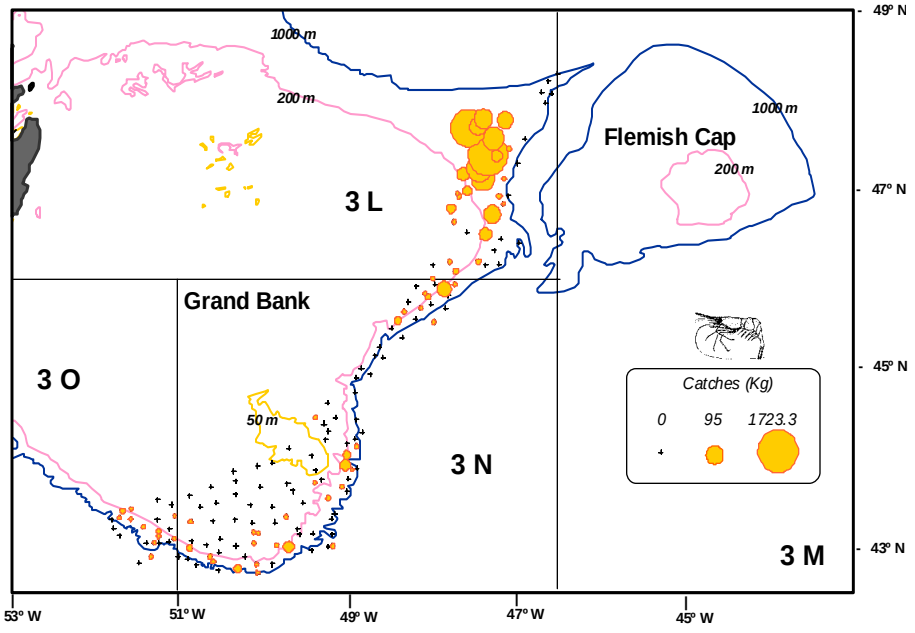

Figure 1. Geographic distribution of Northern shrimp catch on Spanish bottom trawl survey 2003.

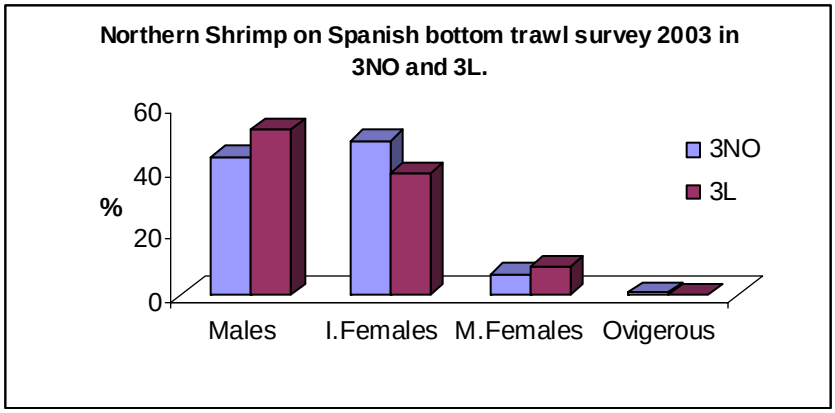

Figure 2. Northern shrimp % by sex and maturity stage on Spanish bottom trawl 2003 Div. 3NO and 3L.

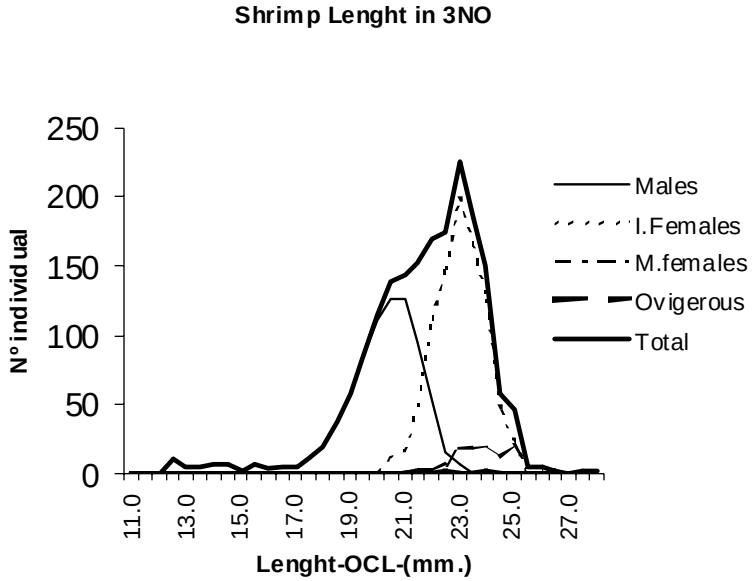

Figure 3. Northern shrimp size distribution by sex and maturity stage on Spanish bottom trawl 2003 in 3NO.

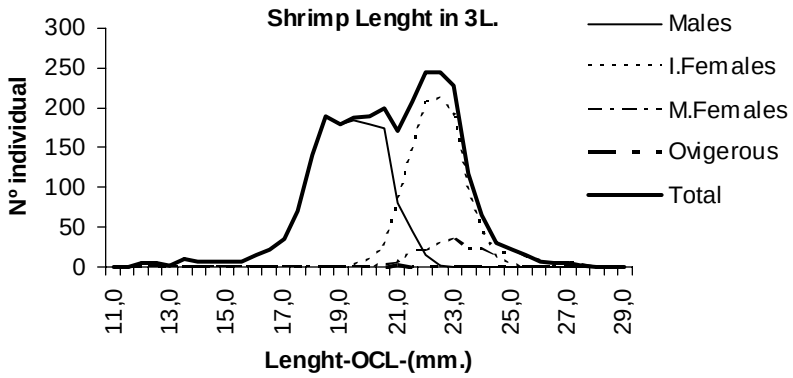

Figure 4. Northern shrimp size distribution by sex and maturity stage on Spanish bottom trawl 2003 in Div. 3L.

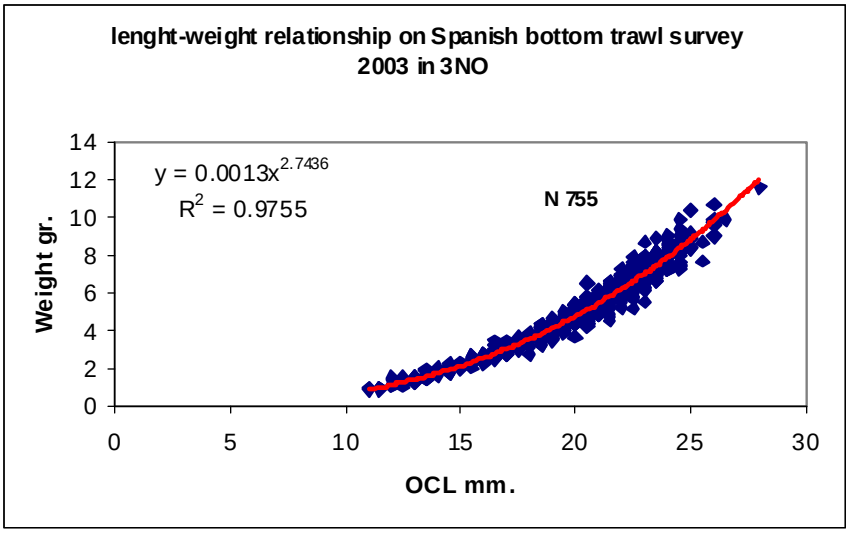

Figure 5. Northern shrimp Length-weight relationship on Spanish bottom trawl survey 2003 in Div. 3NO.

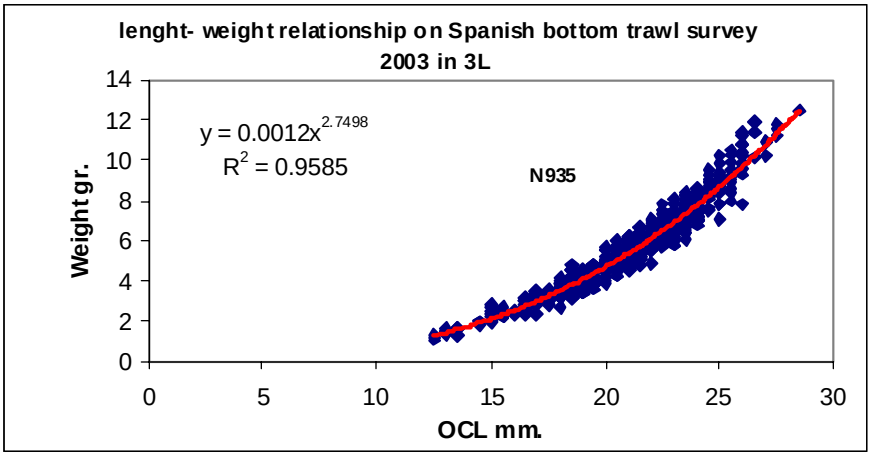

Figure 6. Northern shrimp Length-weight relationship on Spanish bottom trawl survey 2003 in Div. 3L.

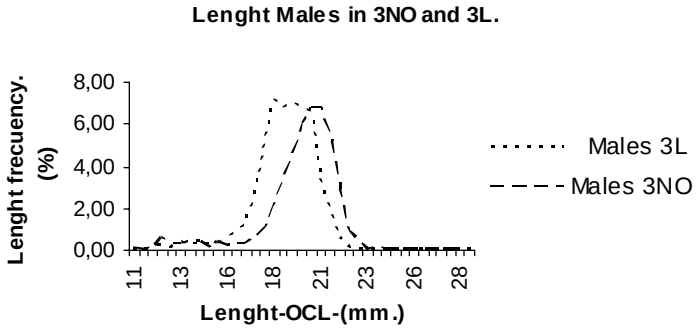

Figure 7. A comparative Length frequencies of males in 3NO and 3L on Spanish Survey 2003.

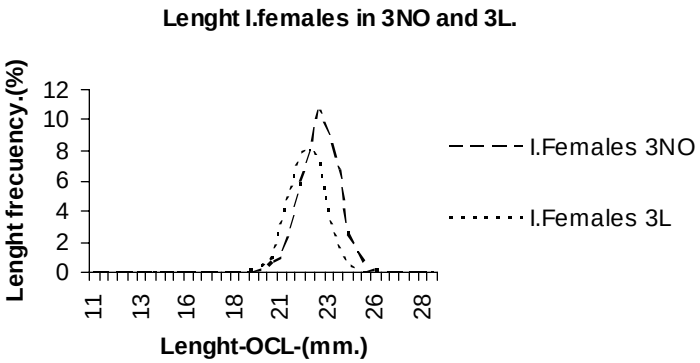

Figure 8. A comparative Length frequencies of immature females in Div. 3NO and 3L on Spanish Survey 2003.

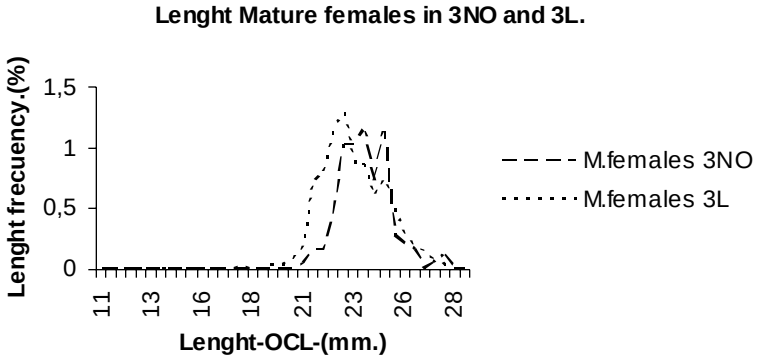

Figure 9. A comparative length frequencies of mature females in Div. 3NO and 3L on Spanish Survey 2003.

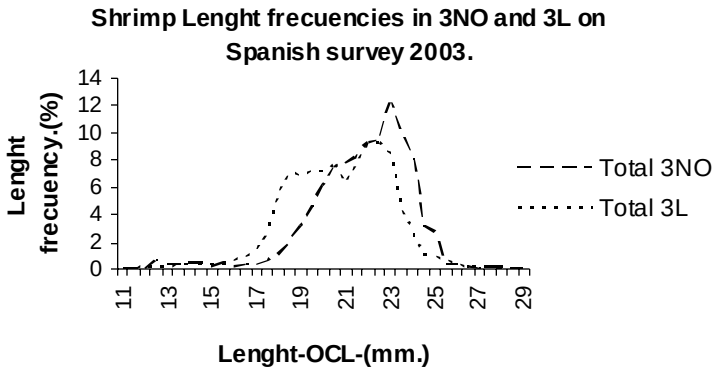

Figure 10. A comparative length frequencies of total shrimp in Div. 3NO and 3L on Spanish Survey 2003.

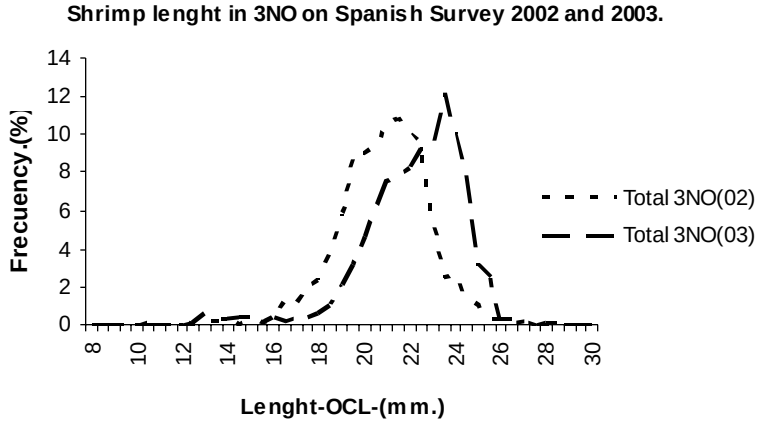

Figure 11. A comparative length frequencies of total shrimp on Spanish Survey in Div. 3NO 2002 and 2003.