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Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2011

by

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Abstract

A stratified random bottom trawl survey on Flemish Cap was carried out from June 29th to August 9th 2011. The area surveyed was extended up to depths of 800 fathoms (1450 meters) following the same procedures as in previous years. This year a total of 126 valid hauls were made by the vessel *R/V Vizconde de Eza* with the usual survey gear (Lofoten), 77 up to 730 meters depth. This year, mechanical failure in the winch did not allow to carry out the fishing according to the schedule of other years, causing a significant reduction in the number of sets if we compare them with those done in previous years. The surveyed area has properly prospected 30 of the 32 strata planned. The strata 17 and 18 only were prospected with one set in each. The general indexes for shrimp were estimated taken into account the traditional swept area (strata 1-19, up to depths of 730 m.) and the total area surveyed (strata 1-34, up to depths of 1450 m.). As in 2010 the strata 26 and 27sited in the southeast of the bank with depths from 600 to 800 fathoms (1100-1400 m.) will not be surveyed due to the presence in the bottoms of great quantities of mud and sponges.

The results concerning shrimp are presented and compared to those from previous years of the same series. The biomass and abundance in 2011 decreased from 2010 (67 % and 66% respectively), and they were the lowest values in the EU survey series. Also, as in previous years (2004-2010) the youngest specimens (age 1) didn't appear in the catches, and they were weakly presents in the small mesh size bag attached to the cod-end of the main gear, suggesting the absence of any strong year classes since 2003. As previous years, the sharp decline of shrimp biomass in Flemish Cap was associated with a strong increase of the cod stock.

Introduction

The aim of this paper is to show the results about shrimp obtained in the summer bottom trawl surveys in Flemish Cap (NAFO Regulatory Area of Div. 3M) in 2011 and they are compared with that obtained between years 2003-2010 by the R/V *Vizconde de Eza*, and with the transformed series previous to 2003 obtained by the R/V *Cornide de Saavedra*.

Material and Methods

Survey design and gear used

The surveys on Flemish Cap (NAFO Regulatory Area of Div. 3M) was initiated by UE in 1988 and carried out in summer (June-July), on board the Spanish Research vessel R/V *Cornide de Saavedra* until 2002 year. Since 2003, the R/V *Cornide de Saavedra* was replaced by the R/V *Vizconde de Eza*. The gear used was a bottom trawl net type Lofoten during the whole of period.

In 2011 the survey was carried out from June 29th to August 6th. As previous years, the area prospected in Flemish Cap was spread up to 1450 meters. In 2011 as in previous years the strata 26 and 27 in the southeast of the Flemish Cap with depths between 1095 and 1450 m. were not prospected due to the presence in the bottoms of great quantities of mud and sponges. Also, this year mechanical failure in the winch did not allow to carry out the fishing according to the schedule of other years, causing a significant reduction in the number of sets if we compare them with those done in previous years. The haul number carried out in the traditional 19 strata with depths minor than 740 m. was of 77. The area with depths higher than 740 m. was sampled by means of 49 additional hauls proportionally distributed in the new 13 strata. In the present survey 30 of the 32 strata were adequately prospected and only the strata 17 and 18 were covered by one set in each.

The bottom trawl surveys followed the same procedures as in previous years. The specifications about the main technical data of the survey are described in Table 1.

Sampling

Samples of approximately 1.5 kilogram shrimp were taken in each tow where this species was present for length frequency determination. Also, some samples were frozen for length-weight analysis in the laboratory.

Shrimps were separated into males and females according to the endopod of the first pleopod (Rasmussen, 1953). Individuals changing sex phase, according to this criterion, were included as females. Females were further separated as primiparous (first time spawners) and multiparous (spawned previously) based on the condition of the external spines (McCrary, 1971). Ovigerous females were considered as a group and were not included with multiparous females.

Oblique carapace length (CL), the distance from the base of the eye to the posterior dorsal edge of the carapace (Shumway *et al*., 1985), was measured to the lower 0.5 mm length-classes. Sampling length data were used to obtain an estimate of population length distributions in the whole area and to compare it with the estimates of the other years.

Sex reversal (L_{50F}) and length at maturity (L_{50MF})

In order to analyze changes in the length at maturity, from each length class the proportion (pi) of mature females against all specimens was calculated. The method used to estimate the maturity ogive and the length where the 50% of the specimens are mature females (L_{50MF}) was based on fitting of the sigmoid, so-called logistic curve.

The equation used was

$$Y = 1/(1+e^{-(a+bx)}).$$

With a y b being the intercept and slope respectively of the regression *Ln (pi/1-pi)* on length class.

The logistic curve was fitted each year using a non-linear method to estimate the parameters by iteratively minimizing the sum of squares of the deviations between observed and predicted proportions where the mature females were presents.

In the same way the sex ratio by length classes were estimated to obtain the length at sex change where 50% of the specimens are females (L_{50F}).

Age composition and MIX program

As previous years the length frequency distribution by sex group were analysed by MIX program and the proportion, mean lengths and standard deviations of the mean length (sigma) are calculated for each age component and sex group. When the modal components overlap and obscure one another, was necessary to reduce the number of parameters estimated in order to get the best and reasonable adjust. We have constrained sigma very often fixing the coefficient of variation (CV) at 0.045 or keeping it constant.

After getting the proportions and mean lengths for every age/sex group the results were used to calculate the total number of individuals in every age/sex group according to the biomass estimate. This was done by transforming the CL to weight using the weight length relationship estimated each year during the survey. So, the mean lengths were converted to mean weights to calculate the number of males, primiparous females and multiparous females (Skúladóttir and Diaz, 2001).

Small mesh size bag on the cod-end

Knowing that mean size of shrimp coincides with the selection range of the 35 mm mesh currently used, a bag with 10 mm mesh size was attached as last years to the cod-end of the Lofoten gear, just in a position where escapement is believed to be the highest. The base of the bag was a square of 36 cm in each side. The whole shrimp caught in the juvenile bag was weighted and measured.

Results

Biomass

This year a total of 126 valid bottom trawls were completed with Lofoten trawl gear in Flemish Cap survey, 77 of them were carried out in the traditional strata prospected from 1988 with depths up to 740 m. (Fig. 1).

Total shrimp biomass, estimated by swept area method and mean catch per tow from 1988 to 2010 are presented in Table 2. The values presented from 1988 to 2002 year are those resultants of the Warren's transformation of the lengths distribution obtained by the R/V *Cornide Saavedra* and the length-weight relationship estimated every year (Casas *et al.* 2005).

The increasing of biomass since 1988 to 1992, coincided with a period of time where there was not a directed fishery to shrimp and the cod stock began to decline. With the beginning of the shrimp fishery in 1993 the biomass declined up to 1997. After that the stock recovered reasonably well although with high annual variability (historical maximums in 2002 and 2005 were followed by years with lower biomass but at a relative high level). In 2009 the biomass decreased sharply with values close to the lowest of the historical series. In 2010 despite of the biomass increase about 77% compared to 2009 this was still among the lowest in the total of the historical series. The total and female biomass estimated in 2011, around 1621 and 1132 t. respectively were the lowest values of EU survey series showing the depletion state of the shrimp stock (Fig. 2).

Biomass estimated by depth strata from 1988 to 2011 is shown in Table 3. The presence of shrimp in shallowest strata, with depths less than 140 fathoms (257 m), was scarce in the first years (1988-1995). However, since 1996, a noticeable amount of shrimp occurred in these strata and the estimated biomass increased up to 2002 and 2003 years where the 36% and 41% respectively of the total biomass were estimated in depths lesser than 140 fathoms. After these years the biomass estimated in these depths declined each year and from 2008 they were residual (in 2011 the 0.1% of the total biomass). In accordance with this, the catch distributions observed during the 2011 survey (Fig. 3) showed a patched distribution around the central area of the bank at similar depths to 2009 and 2010 but at lower levels than in previous years.

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2011 (Table 2 and Fig. 2) are quite variable, due to the predominant sizes of the shrimp are in the selection range of the cod-end mesh size used (35 mm), so the biomass estimations are clearly affected by small changes in cod-end mesh size between years. To solve this problem it was proposed to use the shrimp bigger than 20 mm CL (Table 2). The biomass for

shrimp bigger than 20 mm CL tried to be an index of the adult biomass not affected by differences in the cod-end mesh size used. The 20 mm CL was chosen because it is approximately the limit between 3 and 4 years old shrimp in this season (Garabana, 1999). The biomass estimated for shrimp bigger than 20 mm. in 2011 was 1322 t.

The use of female biomass estimate is also an index not affected by small changes in mesh size, and it is the one used by the NAFO Scientific Council, so it was also included in Table 2. In 2011 the estimated female biomass (1132 t.) was about 70% lower than 2010. Both indices were the lowest value in the EU survey series.

The standard gear used in the surveys was a Lofoten with a cod-end mesh size of 35 mm with the exception of the 1994 and 1998 surveys when a 40 mm and 25 mm cod-end mesh size were used respectively. Consequently, the biomass index in 1994 is supposed to be underestimated and that of 1998 could have been overestimated by a factor of two (del Río, 1998).

In Fig. 2 the adult biomass estimates are compared with the total biomass and female biomass along the series. Differences between these quantities in every year correspond to the greater or smaller catch of young shrimp. These differences are showed as percentage of the total biomass in the Figure 4. Although the smaller size-classes are more directly affected by small changes in the cod-end mesh size the differences between the total biomass and the adult biomass (>20 mm.) showed an increasing trend in the period 1988-2005 from 6% in the beginning of the series to 56% in 2005. Since 2006 the increasing trend changes and difference between total biomass and adult biomass decreases to levels prior 1997 year. The increase in 2009 and 2011 were caused by the very low values estimated of the total biomass in that years. The high value founded in 1998 (60%) was due to the lesser mesh size of the linner codend used (25 mm.), and not comparable conclusions can be thrown.

The decrease in the length at sex change is a general trend since 1992 to 2006 (Fig.5a.). After that the length at sex change increased year after year and in 2011 the estimated value was similar to 2010 (19.9 mm.). The length at maturity (L_{50MF}) (Fig. 5b), showed a similar and decreasing trend up to 2006. After that year the L_{50MF} increased and in 2011 decreased at 2009 levels (23.6 mm.).

Length frequencies

The length frequencies and percentages by sex for 2011 are shown in the Table 4. These length frequencies are split into males, primiparous females, multiparous females and ovigerous. The table 5 shows the male percentage in number in the historical series from 1995 to present. It can be observed the increase of male percentage, getting in 2005 the biggest value in the historical series (75%), with the exception of 1998 (which can not be compared as it was before said). From 2006 the male percentage decreased showing in 2010 the lowest percentages of males (32.1 %) in the historical series of the EU surveys (Table 5). In 2011 survey the male percentage remains at low levels (37.6 %).

Length frequencies by depth strata in 2011 were shown in Table 6. Small size individuals were rare both in shallow and deeper strata. As in previous years, the results indicated that the mean shrimp size increases with depth (Table 7).

The Fig. 6 shows the length distribution by sex on EU Flemish cap 2003-2011 surveys. In 2003 year the youngest modal group (age 1) was well represented with a modal length about 9-10 mm. With the exception of 1998, where a lesser mesh size was used in the survey (25 mm.), the most important modal size in the historical series occurred in 2002 and 2005 around 18 and 16.5 mm CL respectively. Since 2006 the importance of the youngest individuals decreased markedly. Since 2009 the lack of strong year classes and the successive bad recruitments in the last years have caused a drastic fall in the frequencies of practically all the length groups compared with those obtained in previous years. In 2011 the absence of strong year classes persisted and the decrease of biomass was mainly caused by the depletion of both sexes.

The shrimp length distribution estimated in the surveys since 1988 with the Lofoten gear did not record adequately the small size groups in the beginning of the historical series. Since 1996 the age 2 was present in the catches in a significant way and the introduction of the new vessel in 2003 improved the catchability of this age; mainly due to the technological advances in maintaining more stable the performance of the fishing gear.

Since 2001 the routine use of a small mesh size bag attached to the cod-end to collect a portion of the small size shrimp escaping through the meshes was a common alternative. Total catch and length frequencies obtained with the small mesh size bag in 2011 survey are presented in Table 8. The estimated biomass was 9 t. and the length distribution showed two modes at 10 mm and 15 mm. CL, corresponding to age-classes 1 and 2 (Table 9 and Fig. 7).

Length-weight relationship

Length-weight relationships by sex group in year 2011 are illustrated in Fig. 8. Length-weight equations by sex group for this period were:

For males:	$W = 0.00130 \times CL^{2.7293}$	(N= 686,	$r^2=0.94$)
For primiparous females:	$W = 0.00205 \times CL^{2.5909}$	(N= 1051,	$r^2=0.83$)
For multiparous females:	$W = 0.00379 \times CL^{2.3960}$	(N= 615,	$r^2=0.77$)
All sexes combined:	$W = 0.00152 \times CL^{2.6873}$	(N= 2352,	$r^2=0.96$)

Where W is weight in g and CL is the oblique carapace length in mm.

Age structure

The Table 9 and the Figures 7 y 9 show one preliminary and visual interpretation of shrimp modal groups and ages from the length distribution obtained by the gear Lofoten and juvenile bag used in 2011.

Age assessment was carried out using the MIX software from the shrimp length distributions estimated every year in the survey series. The results of the modal analysis for annual surveys 2011 is shown in Table 10. The proportions within each sex group are listed as well as mean lengths and standard deviation (sigma) by age-classes.

The results of Table 10 were then used to calculate the mean length, abundance and biomass at age Tables 11, 12 and 13. The modal analysis in 2011 identified five age groups (ages 2 to 6). The mean lengths by age decreased to level of 2009 and the age at sex change was similar to the las year (3 years old with 19.9 mm.C.L.). The sharp decline of biomass in 2011 was due to the general decreasing in all age groups.

At the beginning of the series (1988-1995) the youngest shrimp were considered to be three year olds with lengths between 15.4 and 18.2 mm. Since 1996 shrimps with two years old have been present and the lengths ranged between 12.5 to 15.9 mm. The shrimps with one year old appeared at first time in 1998 and were present up to 2003 with lengths around of 10 mm. In 2010 and 2011 the shrimp with seven years old were not present enough to be identified from the MIX analysis. In spite of the variability of the length by age along the years, from the beginning of the series to 2007 it can be observed a decreasing trend in the mean length of the main age groups (Fig. 10). This trend was mainly pronounced since 2004, due to the presence in these years of the strong 2002 year class with mean lengths at age below average. Since 2007 this trend changed and the mean lengths at age increase significantly.

Some strong year-classes may be followed according the abundance by age groups from 1988 to 2006 (Table 12) if the assignation of the age is right. The 1986 year-class stand out in the beginning of historical series with 4, 5 and 6 years olds in the years 1990, 1991 and 1992. The individuals with 4 year olds were also especially abundant in the years 1999-2002 indicating the strong of year-classes 1995, 1996, 1997 and 1998. The 1999 year-class stand out especially judging by the high number of 3 and 6 year olds in 2002 and 2005 years respectively. In these two years both the biomass and the abundance reached out the highest values in the series, especially in 2005 where the strong 2002 year class with 3 years old was also present. From 2004 to present the virtual absence of age group 1 in the catches and very low values for the ages 2 and 3 show the weakness of the 2003 -2010 year classes.

Considering the abundance at age 2 as indicator of recruitment, the number of shrimp of two years old in the survey and from juvenile bag (Table 10) were estimated and the index average-weighed (Fig. 11 and Table 14). In 2011 both indices showed different trends: while the index from juvenile bag increased from the main gear the index declined. Anyway considering the low values estimated from both indexes the 2003-2009 year class ought to be considered as weak year classes.

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Table 1. Technical data of bottom trawl research surveys on EU Flemish Cap 2010.

Procedure	**Specification**
Vessel	*R/V Vizconde de Eza*
GT	1 400 t
Power	1 800 HP
Maximun trawling depth	1 450 m
Trawl winch	Automatic control on warp tension
Mean trawling speed	3.5 knots
Trawling time	30 minutes effective time
Fishing gear	type *Lofoten*
footrope / handrope	31.20 / 17.70 m
footgear	27 steel bobbins of 35 cm
mesh size in cod-end	35 mm
bridle	100 meters, 45 mm, 200 Kg/100m
trawl doors	polyvalent, 850 Kg
vertical opening	3.5 m
warp length	2 * Depth (m) + 250m
warp diameter	20
dan leno bobbin	not used
Type of survey	Stratified sampling
Station selection procedure	Random
Criterion to change position of a selected tow	- unsuitable bottom for trawling according to ecosonder register. - Information on gear damage from previous surveys.
Criterion to reject data from tow	- tears in cod-end - severe tears in the gear - less than 20 minutes tow - bad behaviour of the gear
Daily period for fishing	6.30 to 18:30 hours
Species for sampling	All fish, squid and shrimp

Table 2. Different indexes of shrimp estimated by swept area method in the years 1988-2011 on EU Flemish Cap surveys. From 1988-2002 the data were transformed by Warren method.

Year	Mean catch per tow (kg)	Total Biomass (tons)	Biomass CL>20mm (tons)	Female Biomass (tons)	Female Mean catch per tow (kg)
1988	6.98	5615	5255	4525	5.63
1989	2.80	2252	2082	1359	1.69
1990	4.23	3405	2756	1363	1.69
1991	14.12	11352	10306	6365	7.91
1992	30.48	24508	23214	15472	19.24
1993	14.52	11673	8596	6923	8.61
1994[1]	4.82	3879	3702	2945	3.66
1995	9.05	7276	6379	4857	6.04
1996	13.01	10461	8083	5132	6.38
1997	9.26	7449	6344	4885	6.07
1998[2]	48.95	39367	15562	11444	14.23
1999	30.70	24692	15073	13669	17.00
2000	23.63	19003	10649	10172	12.65
2001	33.83	27204	17462	13336	16.58
2002	45.40	36510	17319	17091	21.25
2003	26.22	21087	13070	11589	14.41
2004	25.10	20182	12027	12081	15.02
2005	38.14	30675	13609	14381	17.88
2006	20.19	16235	8578	11477	14.27
2007	21.20	17046	11632	12843	15.97
2008	13.79	11092	7857	8630	10.73
2009	3.48	2797	1782	1764	2.19
2010	5.15	4894	4171	3818	4.31
2011	1.98	1621	1322	1132	1.39

[1] codend mesh-size 40 mm
[2] codend mesh-size 25 mm liner

Table 3. Total shrimp biomass by strata (tons) and percentage of biomass in depths lesser than 140 fth. estimated in EU Flemish Cap surveys. Between 1988 and 2002 data were transformed by Warren's method.

Stratum	Depth (Fathoms)	1988	1989	1990	1991	1992	1993	1994[1]	1995	1996	1997	1998[2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1	70-80																3	0			0				
2	81-100											175			69	112	690	217	164	8	50	0		1	0
3	101-140				10					148	39	639	450	1486	2169	5527	1817	2107	1023	477	20	11		21	1
4	101-140											239	596	306	1099	1942	637	785	2395	1195	11	1	23	15	0
5	101-140					8				26	110	1107	1948	2135	2782	2445	3780	867	695	664	558	11	2	21	1
6	101-140				32	2	5		20	422	161	2915	1142	657	2112	2951	1667	1250	883	299	462	23	25	43	0
7	141-200		30	400	1265	3763	2704	117	506	1336	988	4056	3072	2213	3006	4632	1521	3108	2607	1370	1642	468	28	495	8
8	141-200			88	248	1662	826	4	248	676	393	2402	2507	1140	2900	4257	1110	2043	4585	3084	709	1938	278	326	6
9	141-200	133	69	35			135		613	459	412	3981	1139	1110	1483	1754	819	673	583	1435	1277	1159		235	31
10	141-200	275	75	321	2103	3235	1778	752	1315	1148	1099	7186	4052	2771	3760	3748	4685	2489	2447	614	3248	671	155	467	58
11	141-200	263		148	1144	4096	1335	447	650	1235	1018	6049	3017	3005	4091	3460	3003	2350	2284	1086	2878	368	179	712	16
12	201-300	2170	505	512	2361	4654	2115	636	1201	1295	1195	2042	2127	1082	845	1468	378	1222	1510	1524	1965	1585	528	1060	169
13	201-300		66	64	89	38	136		28	687	554	1580	1465	43	620	217	23	230	689	691	373	1080	131	80	56
14	201-300	618	375	623	995	2543		679	792	1076	426	3034	1717	689	843	2014	303	726	2155	923	1481	1593	206	305	460
15	201-300	963	451	855	2004	3605	2292	1078	1370	1278	478	2575	1156	1753	837	1108	483	993	1039	1539	1597	1944	602	824	407
16	301-400	777	253	355	179	420	139	49	57	237	168	515	172	464	375	506	92	696	1099	840	526	136	154	192	208
17	301-400						35									3			5	196	56	33	2		11
18	301-400						175			43	9			6		44		42	42	115	8	10	5	20	17
19	301-400	134	359		792	388		118	467	397	404	887	109	121	229	311	61	366	402	173	187	61	257	77	172
20	401-500																	6	250	29	20	7			39
24	401-500																								0
28	401-500																	52	130	175	54	71	12	6	11
33	401-500																		5		0	0			
29	501-600																					0		1	
21	501-600																		0			0			0
32	501-600																							0	
34	501-600																		13		0	1			0
30	601-700																							0	
	<140	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.3%	5.7%	4.2%	12.9%	16.8%	24.2%	30.2%	35.6%	40.8%	25.9%	21.0%	16.3%	6.5%	0.4%	2.4%	2.1%	0.1%

[1] codend mesh-size 40 mm
[2] codend mesh-size 25 mm liner

Table 4. Shrimp length frequencies (x 10^4) and percentages by sex and maturity stage from EU Flemish Cap 2011.

LENGTH (mm CL)	MALES	FEMALES		
		Primiparous	Multiparous	Ovigerous
8				
8.5				
9	2			
9.5	1			
10				
10.5	6			
11	3			
11.5	5			
12	2			
12.5				
13	3			
13.5	22			
14	58			
14.5	202			
15	456	4		
15.5	693	3		
16	1067	23		
16.5	1060	40	3	
17	906	31		
17.5	798	109		
18	491	89		
18.5	460	137	7	
19	579	280	8	
19.5	836	383	40	7
20	759	710	83	
20.5	778	1092	218	7
21	567	1272	336	
21.5	427	1251	632	
22	283	1446	799	6
22.5	211	1357	954	
23	94	918	1075	
23.5	55	752	837	2
24	19	479	665	2
24.5	14	286	561	7
25	5	162	337	
25.5		61	188	
26		21	179	
26.5		30	57	
27		6	17	
27.5		1	15	
28			12	
28.5			3	
29			4	
29.5			3	
30				
Total	10862	10942	7035	32
Percentage %	37.62%	37.90%	24.37%	0.11%

Table 5. Males percentage of northern shrimp from EU Flemish Cap 1995 - 2011 surveys.

Year	1995	1996	1997	1998[1]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Males %	53.7	70.1	48.9	87.2	63.4	61.6	67.8	70.8	62.6	68.1	74.9	42.7	35.1	34.1	52.8	32.1	37.6

[1] codend mesh-size 25 mm liner

Table 6. Shrimp length frequencies (x 10^4) by strata in 2011 from EU Flemish Cap survey.

Length mm (CL)	STRATA																			Total
	2	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	28	
9						2														2
9.5			1																	1
10																				
10.5					2			4												6
11						3														3
11.5								2					3							5
12								2												2
12.5																				
13										3										3
13.5							2	2		17										22
14							2	7		26		11	10							58
14.5			1		5		7	31		115	2	10	21	10						202
15		9			7	6	7	21	17	203	5	70	99	17						460
15.5		6	2		7	4	31	78	19	278	5	90	167	12				1		698
16		6			13	17	62	68	42	291	12	346	188	25		4	17			1091
16.5		6			7	13	56	105	46	165	22	494	162	4		7	17			1106
17		3	2		14	13	33	61	30	50	20	601	89	12		9				937
17.5		3			5	12	19	36	6	53	17	646	103	4	2	2				908
18		3	1		4	2	11	14	7	41	7	334	109			4	40			580
18.5					6	4	2	7	4	53	2	215	234	19	2		56			605
19					5	5	7	35	8	94	17	111	401	50		2	128			867
19.5					12	5	5	43	13	150	15	295	456	60	8	7	193	1		1267
20			5		24	10	25	60	28	230	37	300	595	95	6	4	135	1	2	1555
20.5			2		17	17	35	129	44	269	46	512	734	116	20	9	147	2		2099
21					19	5	50	106	41	337	72	622	527	185	19	7	186	7		2185
21.5					15	13	37	148	28	259	109	615	660	230	6	20	166	20		2331
22			2		4	7	91	121	24	287	121	705	663	211	10	18	272	18	4	2558
22.5					10	2	47	85	19	260	126	771	693	261	12	9	228	26	5	2555
23						4	36	51	4	149	107	675	585	299	4	6	165	50	17	2155
23.5			2		2		21	18	3	61	59	518	379	344	10	15	215	53	14	1712
24							11	2	5	33	31	336	215	326	8	20	174	64	20	1250
24.5							5			29	19	195	135	287	8	13	175	56	14	938
25										10	27	82	88	174		11	114	57	12	574
25.5											3	29	27	101	8	2	78	38	7	294
26											11	19	22	97	4	9	39	31	7	239
26.5										3	6			34	2	7	35	23	7	118
27														7		4	10	11	6	40
27.5																2	14	4	2	23
28														6			6	5	3	20
28.5														3				1	2	7
29																	4	1		5
29.5																	3			3
Total	0	37	19	0	181	147	603	1236	389	3464	899	8602	7366	2989	131	194	2618	469	124	29484

Table 7.- Mean lengths by depth range from EU Flemish Cap surveys 2011

Strata	Depth range		Mean lengths (mm CL)
	Meters	Fathoms	
2	147-182	81-100	
3 to 6	183-256	101-140	17.0
7 to 11	257-360	141-200	19.3
12 to 15	361-547	201-300	20.4
16 to 19	548-733	301-400	22.5
20 to 34	734-1464	401-800	24.3
Total	147-1464	80-800	20.8

Table 8. Shrimp length frequencies taken by the small mesh size bag attached to the cod-end in 2011 survey.

Length (CL) mm	Frequency
8	
8.5	3
9	7
9.5	13
10	22
10.5	17
11	12
11.5	8
12	3
12.5	2
13	1
13.5	3
14	8
14.5	13
15	31
15.5	37
16	38
16.5	26
17	9
17.5	14
18	9
18.5	4
19	2
19.5	6
20	3
20.5	4
21	3
21.5	1
22	1
22.5	1
23	3
23.5	7
Total	301
Catch weight (gr)	777
Sampled weigth (gr)	724

Table 9. Shrimp modal groups and ages with Lofoten gear and bag in the codend in 2011 from EU Flemish Cap survey interpreted from size distributions.

LOFOTEN

Age	Modal groups		Cohort
	Males	Females	
1	-	-	
2	16.0	17	X
3	20.0	20.5	W
4	22.5	22.5	V
5	-	24.5	U
6	-	26.0	T
7	-	-	

BAG ON THE CODEND

Age	Modal groups	Cohort
1	10.0	Y
2	15.0	X

Table 10. Results of the modal analysis (MIX) by sex and maturity stage from EU Flemish Cap surveys 2011 with Lofoten gear and juvenile bag..

	Juvenile bag (6mm)		**Lofoten gear (35 mm.)**					
Sex and maturity group	**Juvenile bag* (6mm**		**Males**		**Primimarous females**		**Multiparous females**	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1	0.265	0.002						
2	0.617	0.005	0.516	0.006	0.032	0.002		
3	0.118	0.004	0.454	0.022	0.313	0.024	0.082	0.031
4			0.030	0.024	0.544	0.018	0.653	0.025
5					0.111	0.019	0.259	0.034
6							0.006	0.002
7								
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1	10.61	0.010						
2	15.88	0.010	16.64	0.021	17.82	0.070		
3	19.02	0.071	20.32	0.075	20.75	0.065	21.34	0.222
4			22.06	0.491	22.44	0.076	22.91	0.098
5					24.14	0.117	24.67	0.118
6							27.81	0.480
7								
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1	0.912	0.0079						
2	0.901	0.0077	1.077	Cons. CV	0.802	Fixed CV		
3	1.318	0.0431	1.316	Cons. CV	0.934	Fixed CV	0.960	Fixed CV
4			1.428	Cons. CV	1.010	Fixed CV	1.031	Fixed CV
5					1.087	Fixed CV	1.110	Fixed CV
6							1.251	Fixed CV
7								

Table 11. Mean length (mm.) at age by years in EU Flemish Cap surveys

Year Age-class	1988	1989	1990	1991	1992	1993	1994[1]	1995	1996	1997	1998[2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean CL
1											10.3	8.5	10.3	10.5	10.2	9.3							11.7		10.2
2									14.4	15.7	14.2	14.4	14.4	14.2	15.1	15.5	14.4	12.9	12.6	12.5	13.4	15.9	17.6	16.7	14.5
3	18.2	15.4		18.0	18.2	15.8	17.4	16.8	20.6	19.7	18.9	17.7	18.3	16.5	18.3	19.5	19.0	16.6	15.7	15.3	17.7	18.2	20.8	20.6	17.9
4	20.3	20.4	20.8	20.0	19.7	20.4	21.6	21.5	22.6	23.0	21.8	21.7	20.4	20.4	21.7	21.1	22.2	19.9	18.1	18.9	21.0	20.7	23.3	22.6	20.6
5	26.3	24.2	25.9	24.4	24.0	24.2	24.8	23.0	25.3	24.8	23.5	23.8	22.7	23.1	23.7	23.3	24.1	21.9	20.7	20.6	23.4	23.0	24.4	24.5	23.0
6	29.5	28.7	28.8	26.5	27.3	26.3	27.9	26.0	27.5	26.5	25.9	26.1	25.0	25.6	25.0	26.2	26.7	24.1	23.7	23.1	26.2	25.1	26.0	27.8	25.7
7	32.2	31.7	32.1	29.6	29.2	28.3	30.3	28.4	29.6	29.3	29.0	28.7	27.4	29.1	27.4	28.7	28.0	26.4	26.3	25.2		27.4			28.2
8				31.2																					31.2
Total (mm)	26.4	25.2	22.5	24.9	26.2	21.4	25.3	23.0	21.5	23.1	18.1	20.1	20.5	20.1	19.6	20.2	18.9	18.5	19.79	20.2	20.9	20.0	21.6	21.2	20.2

[1]Codend mesh-size 40 mm.
[2]Codend mesh-size 25 mm.

Table 12. Abundance (10^6) at age by years in EU Flemish Cap surveys.

Year Age-class	1988	1989	1990	1991	1992	1993	1994[1]	1995	1996	1997	1998[2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1											94	1	9	3	181	14							8	
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	118	110	60
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	161	387	90
4	123	82	404	260	146	376	88	276	153	241	707	1496	1074	2015	1128	548	643	524	1949	1221	857	169	236	109
5	233	81	92	465	440	205	73	120	273	322	789	601	572	1184	1047	907	783	1050	1205	1276	575	91	80	31
6	163	83	33	389	1129	446	181	215	65	115	414	204	349	323	311	243	133	758	522	588	40	25	15	0
7	15	11	2	103	398	49	8	122	44	16	15	8	61	16	55	9	21	141	65	129		7		
8				33																				
total ('000000)	548	258	530	1296	2271	1864	391	976	1734	1046	11751	5177	3876	5750	8608	4753	5281	9554	4098	3631	2141	570	836	290

[1]Codend mesh-size 40 mm.
[2]Codend mesh-size 25 mm.

Table 13. Biomass estimated (tons) at age by years in EU Flemish Cap surveys.

Year Age-class	1988	1989	1990	1991	1992	1993	1994[1]	1995	1996	1997	1998[2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1											60	0.5	6	2	114	6							9	
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	303	372	177
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	600	2029	461
4	575	387	2053	1214	705	2083	554	1658	1071	1705	4099	9016	5233	9992	6436	2762	3969	2109	5882	4764	4491	892	1690	726
5	2377	626	888	3843	3683	1823	681	892	2703	2853	5719	4784	3838	8321	7758	6197	6206	5702	5547	6330	4084	635	644	250
6	2334	1053	436	4094	13637	4948	2374	2313	827	1249	4038	2138	3112	3087	2696	2339	1430	5531	3606	3971	390	224	149	5
7	285	183	28	1478	5801	675	124	1728	700	234	207	112	706	215	616	108	254	1365	621	1105		81		
8				557																				
total (ton.)	5615	2252	3405	11352	24436	11673	3879	7276	10461	7449	39365	24695	19002	27206	36508	21087	20248	30675	16299	17045	11092	2735	4893	1619

[1]Codend mesh-size 40 mm.
[2]Codend mesh-size 25 mm.

Table 14. Abundance at age 2 average-weighed as indicator of recruitment (R) in the survey (lofoten gear) and from juvenile bag.

year	R (age 2) juvbag	R (age 2) lofoten	R(2)juvbag Av_weighed	R(2)lofoten Av_weighed
2001	1361	3321	0.21	0.61
2002	2125	11004	0.33	2.02
2003	0	12572	0.00	2.30
2004	41818	27415	6.41	5.02
2005	3741	1792	0.57	0.33
2006	7498	582	1.15	0.11
2007	3824	301	0.59	0.06
2008	4969	221	0.76	0.04
2009	3011	1177	0.46	0.22
2010	954	1103	0.15	0.20
2011	2440	563	0.37	0.10

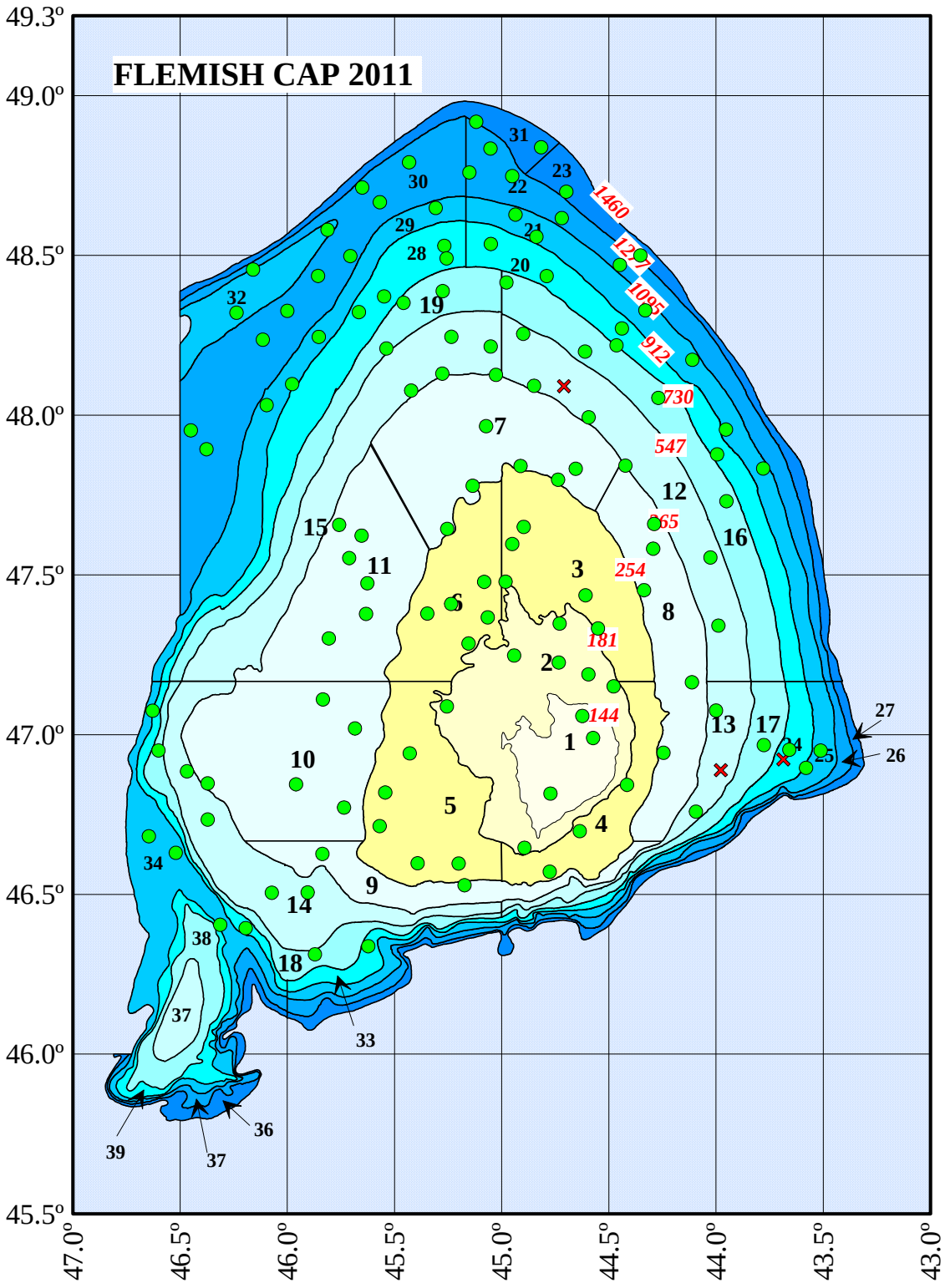

Figure 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2011.

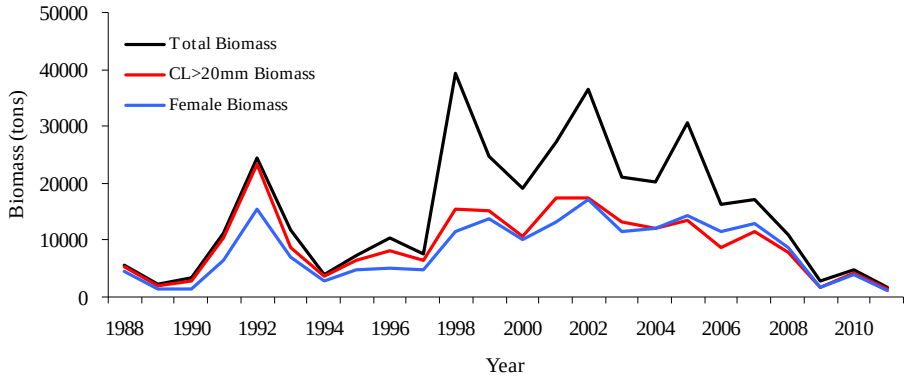

Figure 2. Total, female and adult biomass (shrimp bigger than 20 mm CL) from EU Flemish Cap 1988-2011 surveys.

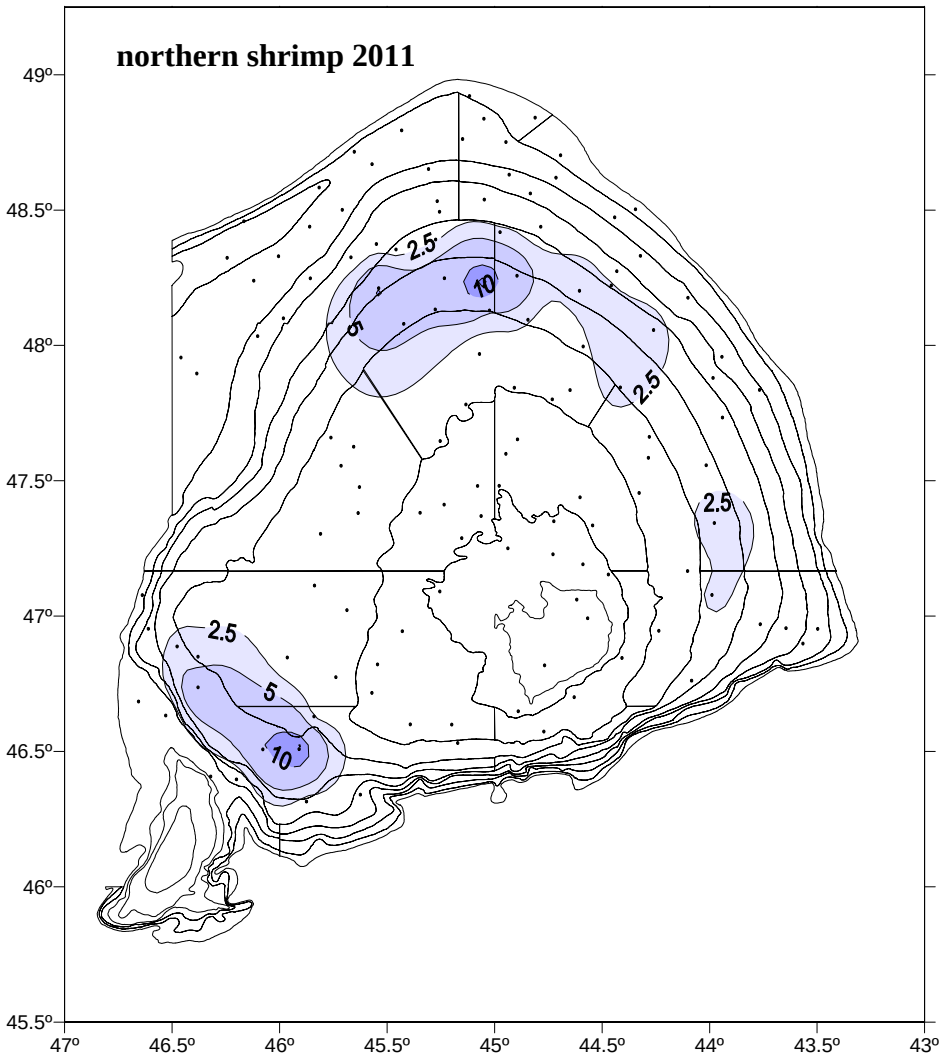

Figure 3. Shrimp catches distribution (kg/tow) from EU Flemish Cap survey in summer 2011.

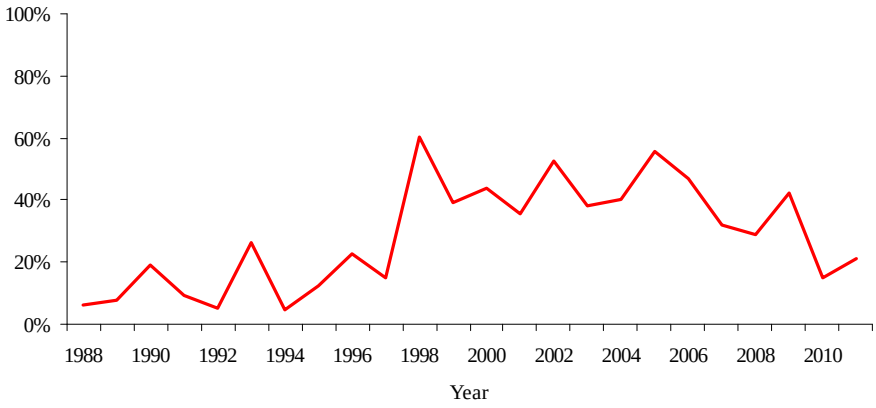

Figure 4. Differences between total biomass and adult biomass (>20 mm.) as percentage of Total biomass from EU Flemish Cap 1988-2011 surveys.

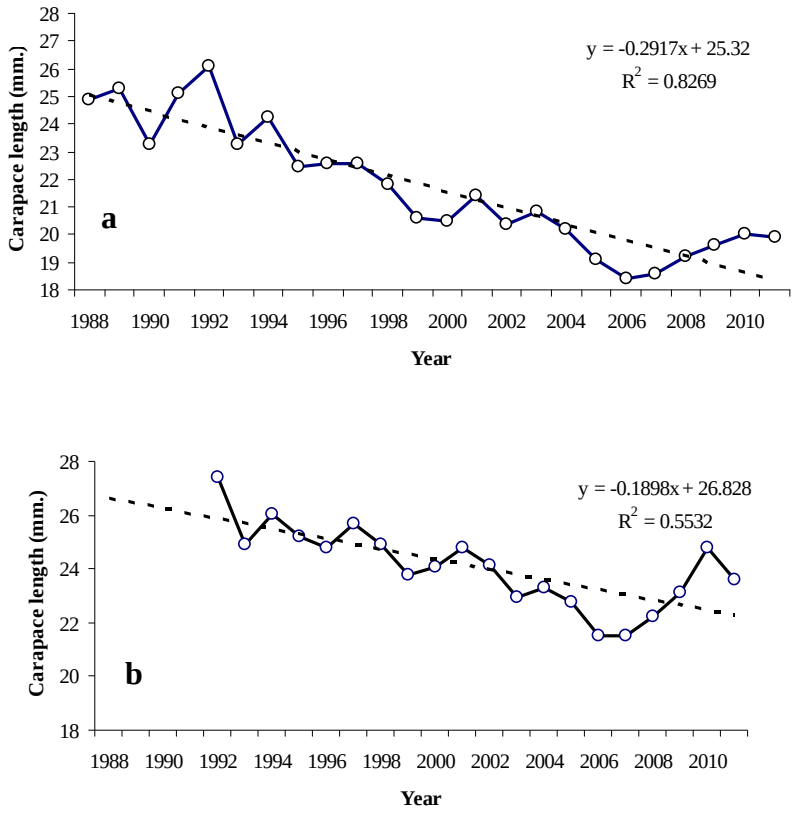

Figure 5.- Lengths (CL) at sex change (a) and maturity (b) of shrimp in EU Flemish Cap surveys

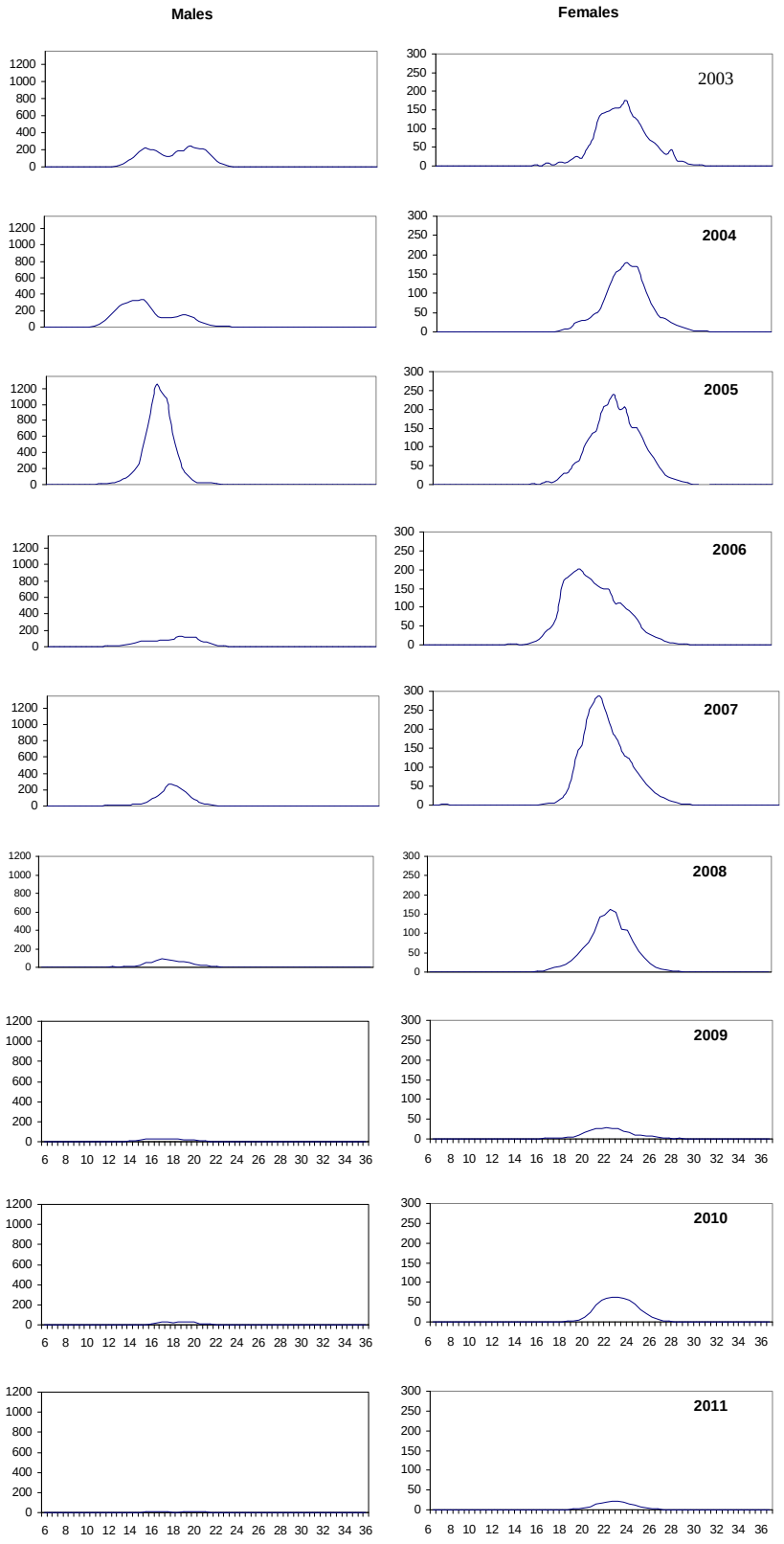

Figure 6. Shrimp size distribution from Flemish Cap 2002 -2011 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).

Bag on the codend (6 mm.)

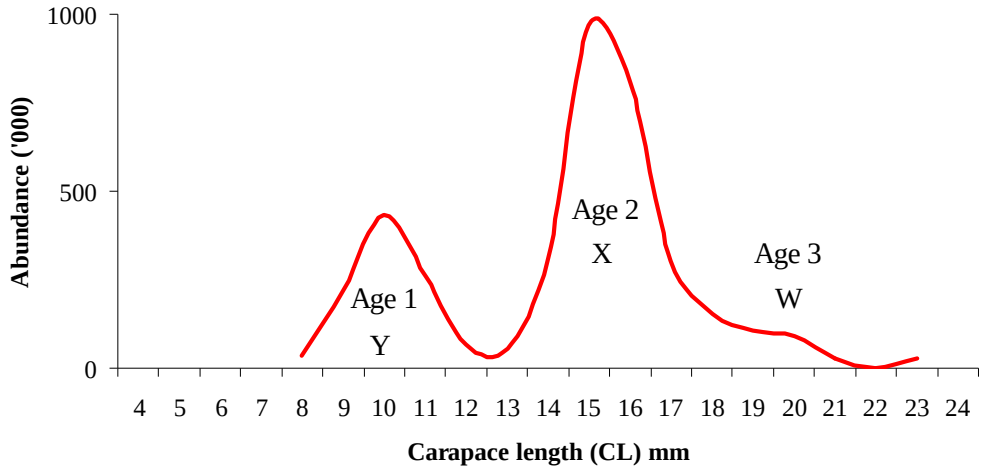

Figure 7. Shrimp modal and age groups in 2011 EU survey on Flemish Cap from juvenile bag. (letters from Table 9) .

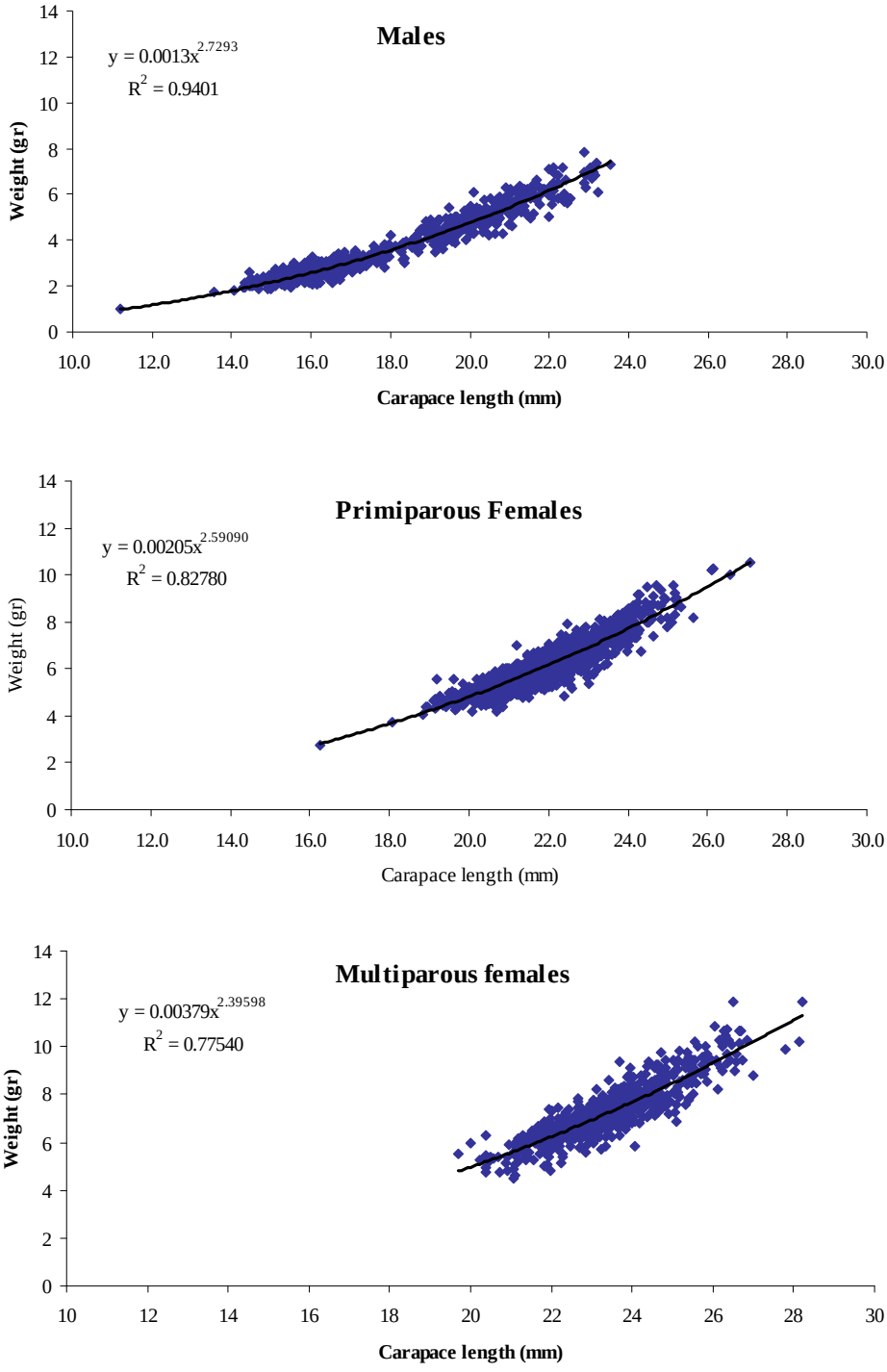

Figure 8. Shrimp length-weight relationships by sex and maturity stages in 2011 on EU Flemish Cap survey.

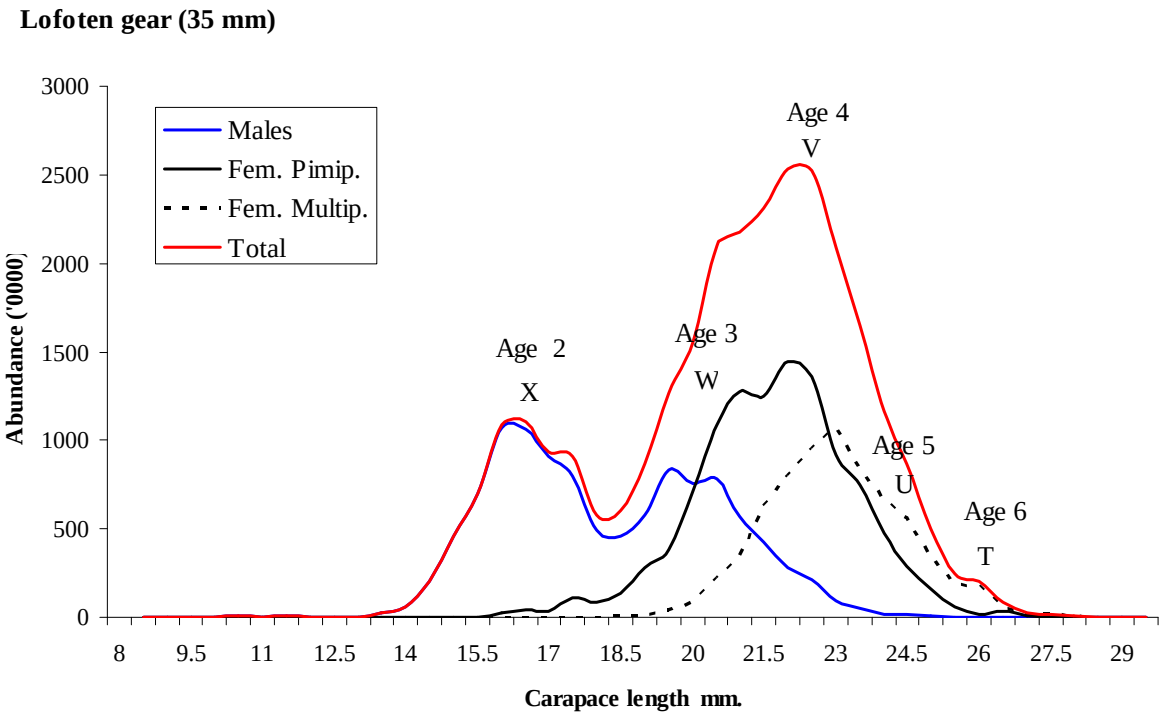

Figure 9. Shrimp modal and age groups in 2011 EU Flemish Cap survey (letters from table 9).

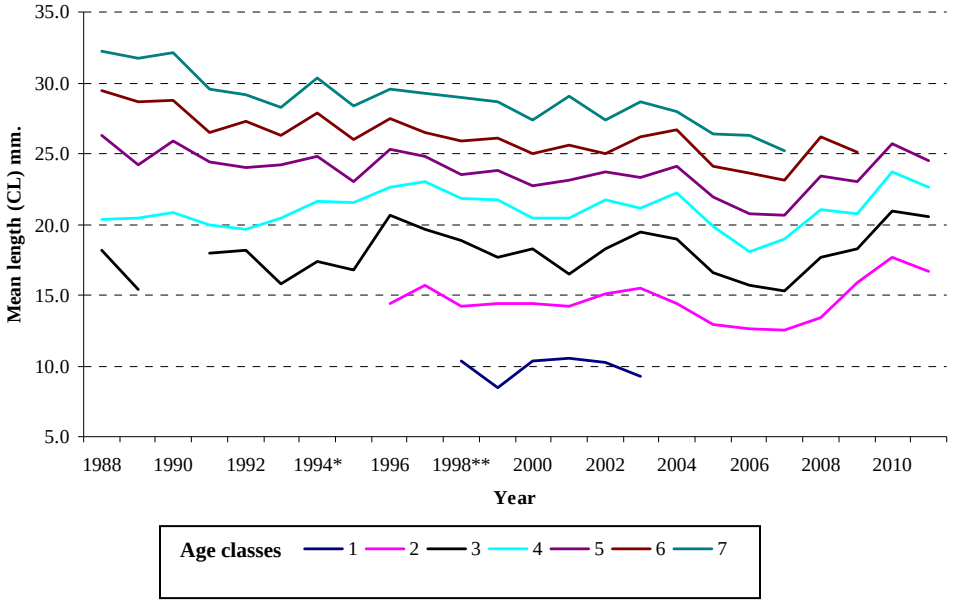

Figure 10. Shrimp mean lengths at age in the series of EU surveys on Flemish Cap.

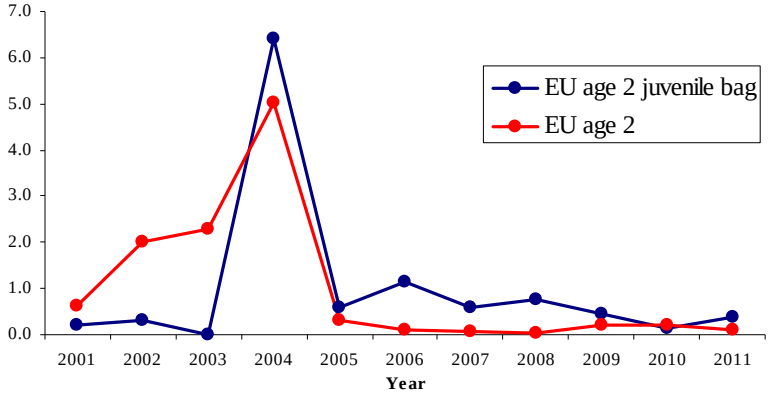

Figure 11. Abundance indexes at age 2 obtained in EU Flemish Cap surveys from Lofoten gear (red line) and Juvenile bag (blue line).