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Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2009

by

J. M. Casas

[1]Instituto Español de Oceanografía, Apdo. 1552, 36200 Vigo, Spain
e-mail:mikel.casas@vi.ieo.es

Abstract

A stratified random bottom trawl survey on Flemish Cap was carried out from June 21st to July 20th 2009. The area surveyed was extended up to depths of 800 fathoms (1400 meters) following the same procedures as in previous years and increasing the number of hauls planned (181). A total of 178 valid hauls were made by the vessel *R/V Vizconde de Eza* with the usual survey gear (Lofoten), 119 up to 730 meters depth. 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 1400 m.). From this year 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 2009 decreased markedly from 2008 (75 % and 73 % respectively). These values are next to the lowest values estimated in the beginning of the EU survey series. In the other side, as in previous years (2004-2008) 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.

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 2009 and they are compared with that obtained in the past years 2003-2008 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 2009 the survey was carried out from 21st of June to 20th of July. As previous years, the area prospected in Flemish Cap was spread up to 1450 meters. From this year the strata 26 and 27 in the southeast of the Flemish Cap

with depths between 1095 and 1450 m. will not be prospected due to the presence in the bottoms of great quantities of mud and sponges which prevent carrying out the planned hauls. The area with depths higher than 740 m. was sampled by means of 59 additional hauls proportionally distributed in the new 13 strata. The haul number carried out in the traditional 19 strata with depths minor than 740 m. was of 119.

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_{50FM}) 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 6 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 178 valid bottom trawls were completed with Lofoten trawl gear in Flemish Cap survey, 119 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 2009 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 in the last years (historical maximums in 2002 and 2005 were followed by years with lower biomass but at a relative high level). The total and female biomass 2 797 t and 1 782 t respectively estimated in 2009 (Table 2), were around 75 % lower than the estimated in 2008 and next to the historical minimum in the EU series carried out in 1989 confirming the dramatic decline of this stock (Fig. 2). The decrease of shrimp biomass is likely due to the recovery of the cod stock (their most important predator), more than an effect of the shrimp fishery, which has declined in recent years both in effort and in catches (Casas, 2009).

Biomass estimated by depth strata from 1988 to 2009 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 year where 12 978 tons, about the 36% of the total biomass were estimated in depths lesser than 140 fathoms (Table 4). After 2002 the biomass estimated in these depths declined each year and in 2008 and 2009 was residual (about 0.4 % and 1.9 % respectively of the total biomass). In accordance with this, the catch distributions observed during the 2009 survey (Fig. 3) showed a distribution around the central area of the bank but in depths higher than in previous years.

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2009 (Table 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. was 1 782 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 2009 the estimated female biomass (1 764 t.) was about 80 % lesser than 2008.

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 although in 2009 the percentage increased in respect to 2008. 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.

From the Figure 2 can be also observed as the female biomass from 2004 to 2008 become bigger than the adult biomass (>20 mm.). The reason for that are the low values in the length at sex-change (L_{50F}) from those years.

In that sense, the decrease in the length at sex change is a general trend since 1992 to 2006. After that the trend changed and the length at sex change increased all years (Fig.5a.). The length at maturity (L_{50MF}) (Fig. 5b), showed a similar pattern to the length at sex change in the years analyzed.

Length frequencies

The length frequencies and percentages by sex for 2009 are shown in the Table 5. These length frequencies are split into males, primiparous females, multiparous females and ovigerous. The rise of the smallest sizes along the years, fit in general way with the increase of the male percentage in number, 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 2008 survey the lowest percentage of males (34%) in the historical series of the EU survey. In 2009 the percentage of males increased up to 51% as consequence of the disappearance from the stock of the last strong year classes 2002 and 2003.

Length frequencies by depth strata in 2009 were shown in Table 6. As in previous years, the results indicated that the mean shrimp size increases with depth (Table 7). The small size individuals (males) dominated shallowest strata and the large size individuals (females) were present in deepest strata.

The Fig. 6 shows the length distribution by sex on EU Flemish cap 2001-2009 surveys. In 2002 year the youngest modal group (age 1) appeared for first time 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. In 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 the obtained in previous years.

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 2009 survey are presented in Table 8. The estimated biomass was 8 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 2009 are illustrated in Fig. 8. Length-weight equations by sex group for this period were:

For males:	$W = 0.00104 \times CL^{2.8239}$	(N= 975, r^2=0.96)
For primiparous females:	$W = 0.00133 \times CL^{2.7310}$	(N= 1001, r^2=0.92)
For multiparous females:	$W = 0.00103 \times CL^{2.8093}$	(N= 631, r^2=0.89)
All sexes combined:	$W = 0.00143 \times CL^{2.7097}$	(N= 2607, r^2=0.98)

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

Age structure

Table 9 and Figures 7 y 9 show the preliminary and visual interpretation of shrimp modal groups and ages from the length distribution obtained by the gear Lofoten and juvenile bag used in 2009.

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 2009 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 results of the modal analysis in 2009 indicated the presence of six age groups (ages 2 to 7) and the age at sex change around 4 years old. The mean lengths by age were generally bigger than the estimated in the last years. With the exception of the age 2 both the abundance and biomass from all age groups decreased markedly in 2009.

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. Seven years old (exceptionally eight years old in 1991) was the greatest age estimated in the whole of the series with lengths between 26.3 and 32.2 mm. 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 all 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. In 2008 and 2009 after several years with weak year-classes and successive decline of abundance this trend changes and the mean lengths at age increase next to the average values.

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 5 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. In the last years 2004-2009 without presence of 1 year old individuals in the catches and with very low values for the ages 2 and 3 show the 2004-2007 and probably 2008 year classes as weak and below average.

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 2009 as well as 2003 y 2006 the trends showed by both indexes were different. Anyway considering the low values estimated from both indexes the 2003-2007 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 2009.

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	$10 \times \text{depth (m.)}^{0.775}$
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	6.00 to 22.00 hours
Species for sampling	All fish, squid and shrimp

Table 2. Different indexes of shrimp estimated by swept area method in the years 1988-2009 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

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

Table 3. Total shrimp biomass estimated by strata (tons) in the years 1988-2009 from 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
1	70-80																3	0			0		
2	81-100											175			69	112	690	217	164	8	50	0	
3	101-140				10					148	39	639	450	1486	2169	5527	1817	2107	1023	477	20	11	
4	101-140											239	596	306	1099	1942	637	785	2395	1195	11	1	23
5	101-140					8				26	110	1107	1948	2135	2782	2445	3780	867	695	664	558	11	2
6	101-140				32	2	5		20	422	161	2915	1142	657	2112	2951	1667	1250	883	299	462	23	25
7	141-200		30	400	1265	3763	2704	117	506	1336	988	4056	3072	2213	3006	4632	1521	3108	2607	1370	1642	468	28
8	141-200			88	248	1662	826	4	248	676	393	2402	2507	1140	2900	4257	1110	2043	4585	3084	709	1938	278
9	141-200	133	69	35			135		613	459	412	3981	1139	1110	1483	1754	819	673	583	1435	1277	1159	
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
11	141-200	263		148	1144	4096	1335	447	650	1235	1018	6049	3017	3005	4091	3460	3003	2350	2284	1086	2878	368	179
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
13	201-300		66	64	89	38	136		28	687	554	1580	1465	43	620	217	23	230	689	691	373	1080	131
14	201-300	618	375	623	995	2543		679	792	1076	426	3034	1717	689	843	2014	303	726	2155	923	1481	1593	206
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
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
17	301-400						35									3			5	196	56	33	2
18	301-400						175			43	9			6		44		42	42	115	8	10	5
19	301-400	134	359		792	388		118	467	397	404	887	109	121	229	311	61	366	402	173	187	61	257
20	401-500																	6	250	29	20	7	
28	401-500																	52	130	175	54	71	12
29																						0	
33	401-500																		5		0	0	
21	501-600																		0			0	
34	501-600																		13		0	1	

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

Table 4. Shrimp Biomass in depths lower than 140 fathoms (257 meters) and percentage of total biomass from EU Flemish Cap 1995 - 2009 surveys.

Year	1995	1996	1997	1998[1]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Biomass (tons) **(< 140 fathoms)**	20	596	309	5075	4136	4584	8231	12978	8594	5226	5160	2643	1101	46	50
% of Total biomass **(< 140 fathoms)**	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%	1.9%

[1] codend mesh-size 25 mm liner

Table 5. Shrimp length frequencies (x 10^4) and percentages by sex and maturity stage from EU Flemish Cap 2009.

LENGTH (mm CL)	MALES	FEMALES		
		Primiparous	Multiparous	Ovigerous
8	3			
8.5				
9				
9.5	10			
10	5			
10.5	14			
11	11			
11.5	3			
12	17			
12.5	29	4		
13	90	17		
13.5	204	12		
14	539	23		
14.5	1189	59		
15	1744	58	4	
15.5	2442	105		
16	2839	142	3	
16.5	2717	155	29	
17	2749	146	23	
17.5	2483	312	25	
18	3008	382	21	
18.5	2690	520	45	
19	2000	939	30	
19.5	1507	1422	186	
20	1432	1902	202	
20.5	868	2248	437	
21	588	2155	536	
21.5	276	2227	733	
22	175	1693	861	
22.5	54	1481	1144	
23	59	1041	981	
23.5	8	654	957	
24	30	358	704	
24.5		252	624	
25		97	561	
25.5	30	127	488	
26		53	360	
26.5		1	171	
27		3	322	
27.5			33	
28			128	
28.5			97	
29			1	
29.5			31	
30			3	
Total	29813	18588	9740	
Percentage %	51.28	31.97	16.75	0

Table 6. Shrimp length frequencies (x 10^4) by strata in 2009 from EU Flemish Cap survey.

Length	STRATA																		
mm (CL)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	28	TOTAL
8			3																3
8.5																			
9																			
9.5					1			8											10
10			3		2														5
10.5	4		3		3	3		1											14
11			3		5	2													11
11.5					3														3
12	4				5	7		1											18
12.5	4		6		2	10		10											33
13	13		9		30	15		13	19				6						107
13.5	18		15		61	25		18	38				36				2		216
14	22	1	28		112	54		87	120	1		24	95				8		564
14.5	128	1	46		165	149		121	210	71		135	201						1253
15	239	3	57		192	308		225	393	41	12	81	229						1815
15.5	243	1	48		182	419		258	725	119	23	74	416						2558
16	221	4	34		94	425		335	715	292	23	119	661				16		2996
16.5	84	1	57		52	323		180	780	129	24	288	928				14		2914
17	31	2	51		20	279		258	489	262	35	311	1078	29			31		2931
17.5	9	1	43		21	287		207	287	331	46	242	1242				61		2832
18		2	83		16	217		263	310	501	92	463	1347			2	64	6	3432
18.5		4	54		19	220		231	376	472	81	464	1179				105	6	3276
19	9	1	63		17	331		216	164	490	219	282	993	29			111		2981
19.5		5	55		35	287		253	177	754	104	364	883	59			95	3	3131
20		4	37		27	500		272	277	448	254	509	1018	29			111		3551
20.5	4	4	29		23	567		312	181	463	266	359	1060	29		2	201	6	3574
21		3	23		15	549		280	55	701	185	280	768	147	2		224	8	3303
21.5		4	9		6	414		196	90	696	231	347	786	117		5	287	8	3259
22		2	15		16	346		154	74	748	231	87	687	58		5	266	20	2761
22.5		1	3		2	277		125	53	961	231	196	420	29		2	338	12	2703
23		4			3	251		31	35	733	127	123	304	58	4	2	376	15	2107
23.5		3	3			163		23	18	520	104	101	226	59	4	5	368	9	1636
24		4				20		15	52	395	58	12	70	117	4	20	309	9	1107
24.5						81		7		291	58	15	74	59	6	11	260	19	899
25						40			34	275	35	4	32	59	3	8	159	9	671
25.5										83	35	26	25	235	1	7	223	19	667
26										66	12	2	10	176		5	135	2	416
26.5										47				59	1		63	12	186
27										8				264	2		46		326
27.5										3							29		33
28										3				117			6	3	132
28.5														88			8		98
29																	1		1
29.5														29			2		32
30																	3		3
Total	1033	55	780		1129	6569		4100	5672	9904	2486	4908	14774	1846	27	74	3922	166	58568

Table 7.- Mean lengths by depth range from EU Flemish Cap surveys 2009

Strata	Depth range		Mean lengths (mm CL)
	Meters	Fathoms	
2	147-182	81-100	
3 to 6	183-256	101-140	16.3
7 to 11	257-360	141-200	18.1
12 to 15	361-547	201-300	19.7
16 to 19	548-733	301-400	23.2
20 to 34	734-1464	401-800	23.2
Total	147-1464	80-800	19.5

Table 8. Shrimp length frequencies taken by the small mesh size bag attached to the cod-end in 2009 survey.

Length (CL) mm	Frequency
6	1
6.5	1
7	
7.5	4
8	3
8.5	14
9	22
9.5	31
10	42
10.5	37
11	24
11.5	14
12	12
12.5	9
13	17
13.5	30
14	64
14.5	67
15	66
15.5	49
16	22
16.5	21
17	9
17.5	11
18	7
18.5	5
19	4
19.5	3
20	2
20.5	3
21	
21.5	1
22	1
Total	596
Catch weight (gr)	1125
Sampled weigth (gr)	1109

Table 9. Shrimp modal groups and ages with Lofoten gear and bag in the codend in 2009 from EU Flemish Cap survey interpreted from size distributions.

LOFOTEN

Age	Modal groups		Cohort
	Males	Females	
1	-	-	
2	16.5	-	V
3	18.0	18.5	U
4	20.0	21.0	T
5	-	23.0	S
6	-	25.0	R
7	-	27.0	P

BAG ON THE CODEND

Age	Modal groups	Cohort
1	10.0	X
2	15.0	V
3		

Table 10. Results of the modal analysis (MIX) by sex and maturity stage from EU Flemish Cap surveys 2009 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	0.317	0.007						
2	0.635	0.009	0.374	0.008	0.026	0.001		
3	0.048	0.006	0.466	0.009	0.110	0.004	0.012	0.001
4			0.161	0.011	0.613	0.007	0.147	0.011
5					0.248	0.007	0.499	0.013
6							0.266	0.011
7							0.076	0.008
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1	10.17	0.028						
2	14.91	0.032	15.89	0.022	15.78	0.040		
3	18.75	0.187	18.17	0.045	18.69	0.044	17.63	0.092
4			20.11	0.058	21.00	0.021	20.93	0.067
5					23.15	0.030	22.89	0.053
6							25.10	0.089
7							27.36	0.107
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1	0.889	Fixed CV						
2	1.303	Fixed CV	1.001	Fixed CV	0.710			
3	1.639	Fixed CV	1.150	Fixed CV	0.841	Fixed CV	0.743	Cons. CV
4			1.272	Fixed CV	0.945	Fixed CV	0.882	Cons. CV
5					1.042	Fixed CV	0.965	Cons. CV
6							1.058	Cons. CV
7							1.153	Cons. CV

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	Mean CL
1											10.3	8.5	10.3	10.5	10.2	9.3							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	15.8	14.6
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	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	20.8	20.7
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	23.2
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	25.8
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		27.5	28.3
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	20.1	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*	1995	1996	1997	1998**	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1											94	1	9	3	181	14						
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	112
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	154
4	123	82	404	260	146	376	88	276	153	241	707	1496	1074	2015	1128	548	643	524	1949	1221	857	169
5	233	81	92	465	440	205	73	120	273	322	789	601	572	1184	1047	907	783	1050	1205	1276	575	92
6	163	83	33	389	1129	446	181	215	65	115	414	204	349	323	311	243	133	758	522	588	40	25
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	559

[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*	1995	1996	1997	1998**	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1											60	0.5	6	2	114	6						
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	284
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	573
4	575	387	2053	1214	705	2083	554	1658	1071	1705	4099	9016	5233	9992	6436	2762	3969	2109	5882	4764	4491	898
5	2377	626	888	3843	3683	1823	681	892	2703	2853	5719	4784	3838	8321	7758	6197	6206	5702	5547	6330	4084	644
6	2334	1053	436	4094	13637	4948	2374	2313	827	1249	4038	2138	3112	3087	2696	2339	1430	5531	3606	3971	390	223
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	2704

[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	0.18	0.46
2002	2125	11004	0.28	1.54
2003	0	12572	0.00	1.76
2004	41818	27415	5.51	3.83
2005	3741	1792	0.49	0.25
2006	7498	582	0.99	0.08
2007	3824	301	0.50	0.04
2008	4969	221	0.65	0.03
2009	3011	1179	0.40	0.16

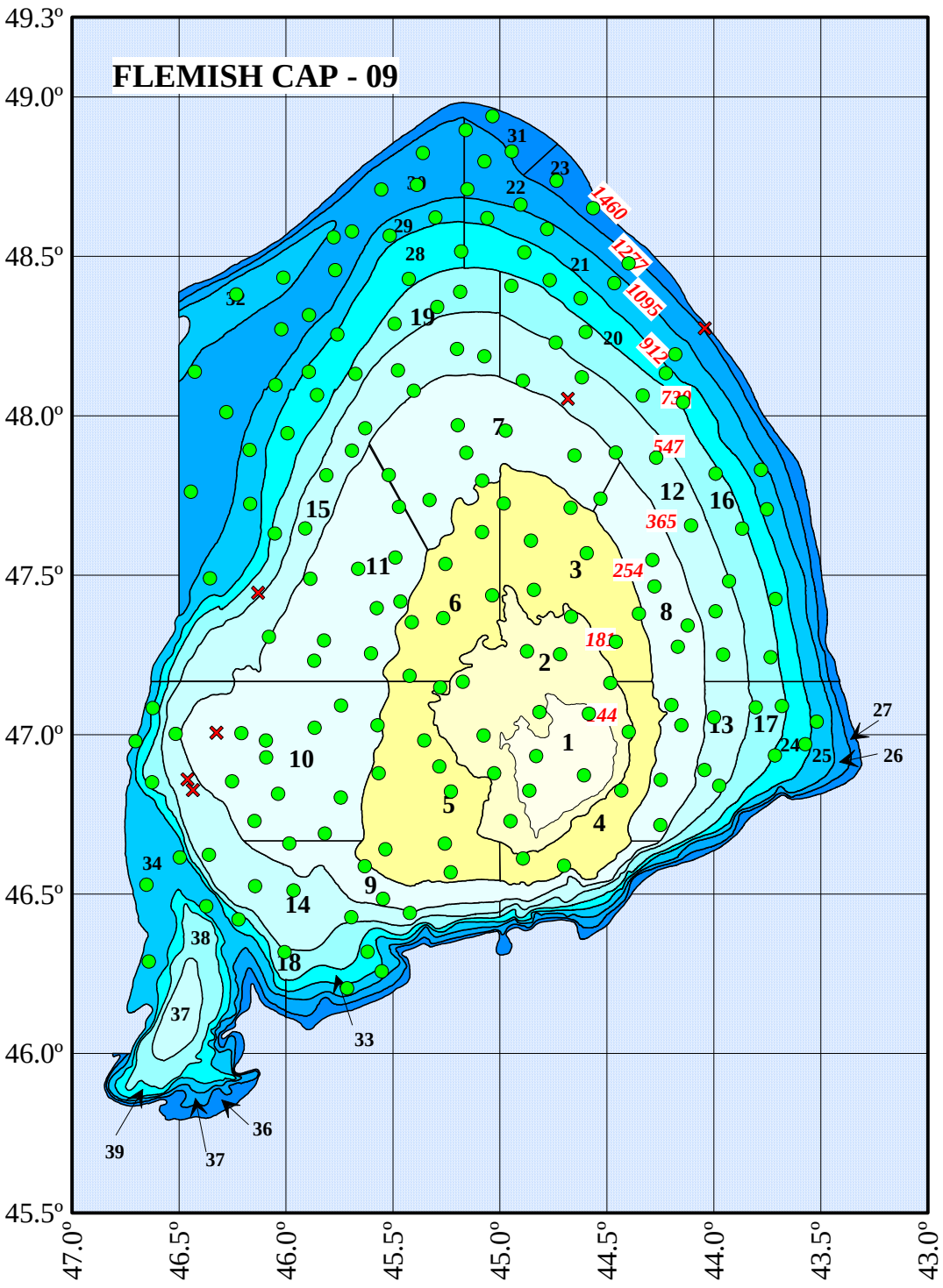

Figure 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2009.

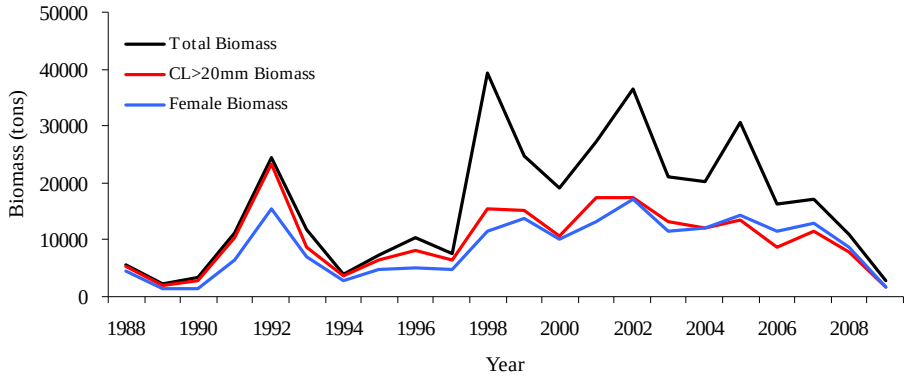

Figure 2. Total, female and adult biomass (shrimp bigger than 20 mm CL) from EU Flemish Cap 1988-2009 surveys.

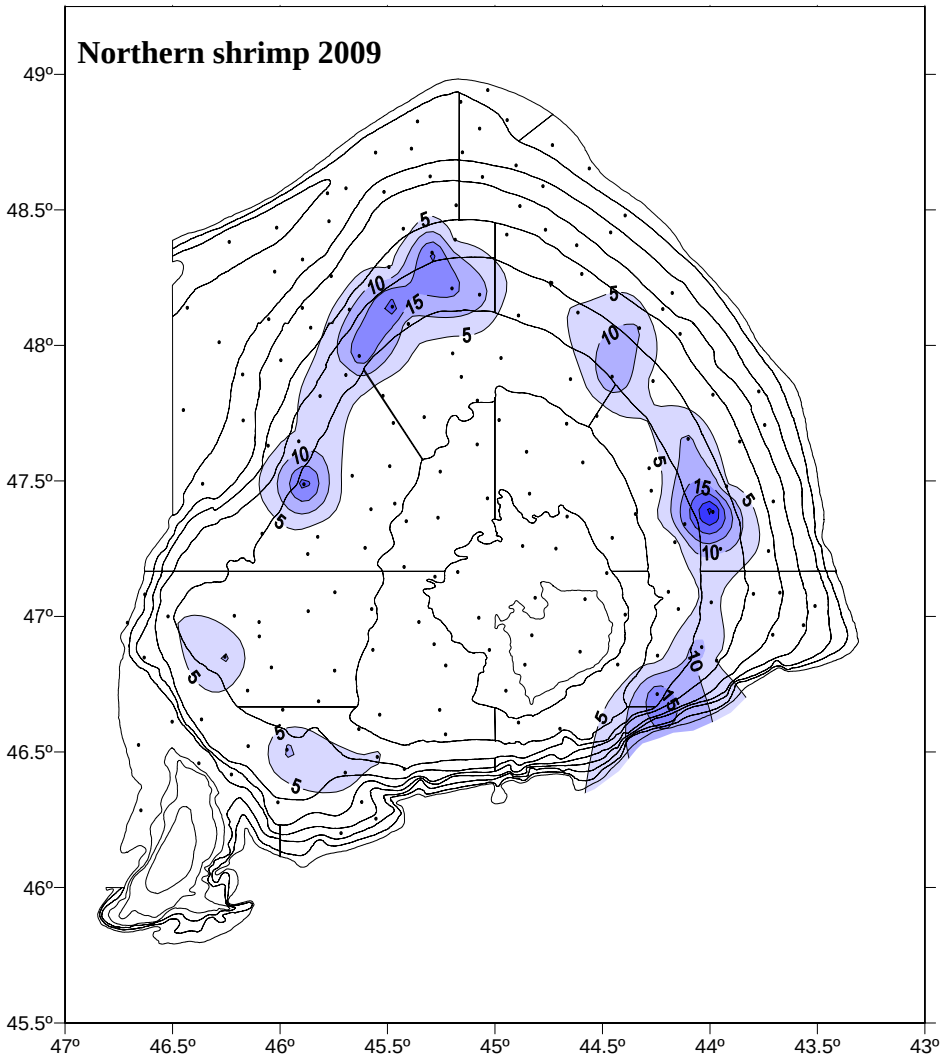

Figure 3. Shrimp catches distribution (kg/tow) from EU Flemish Cap survey in summer 2009.

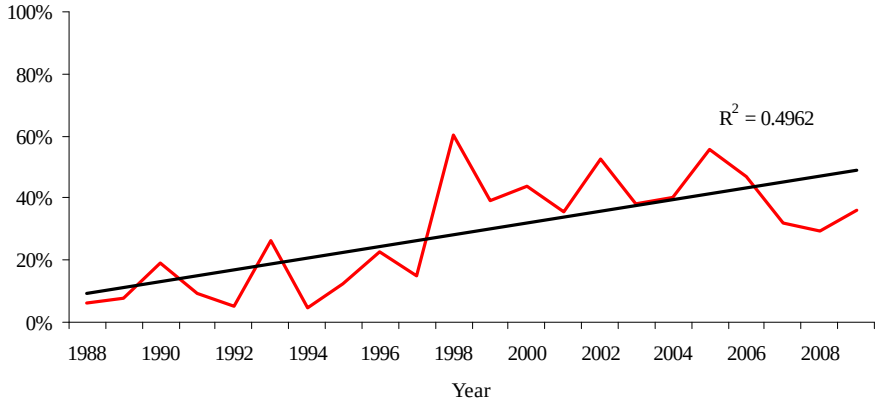

Figure 4. Differences between total biomass and adult biomass (>20 mm.) as percentage of Total biomass.

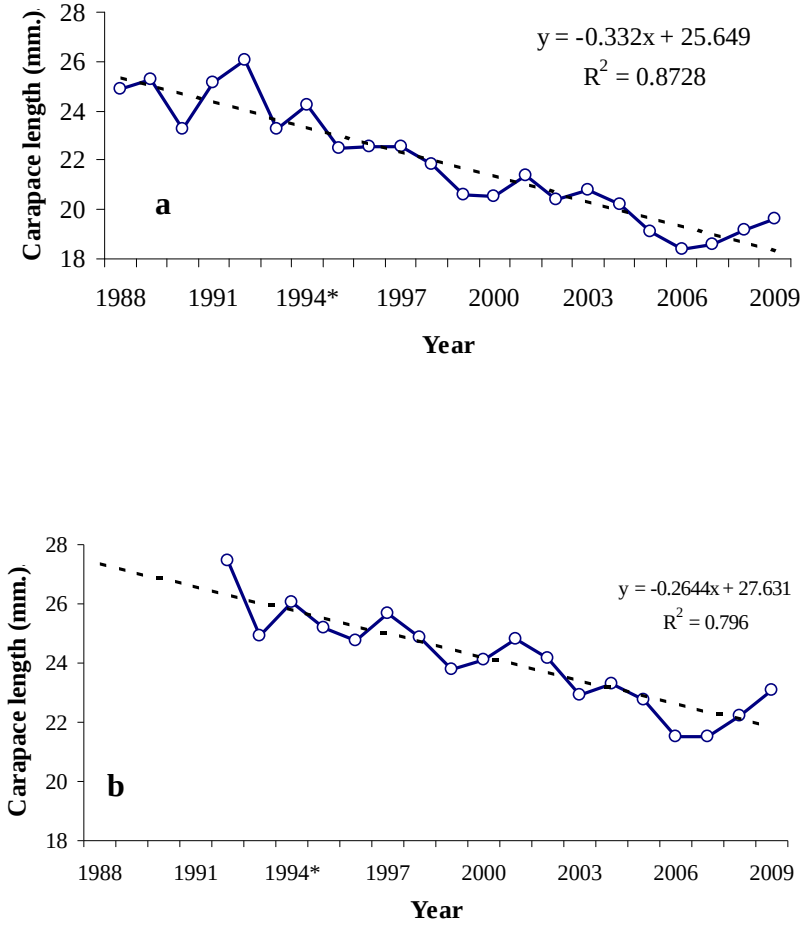

Figure 5.- Lengths (CL) at sex change (a) and maturity (b) of shrimp in the series of EU Flemish Cap surveys

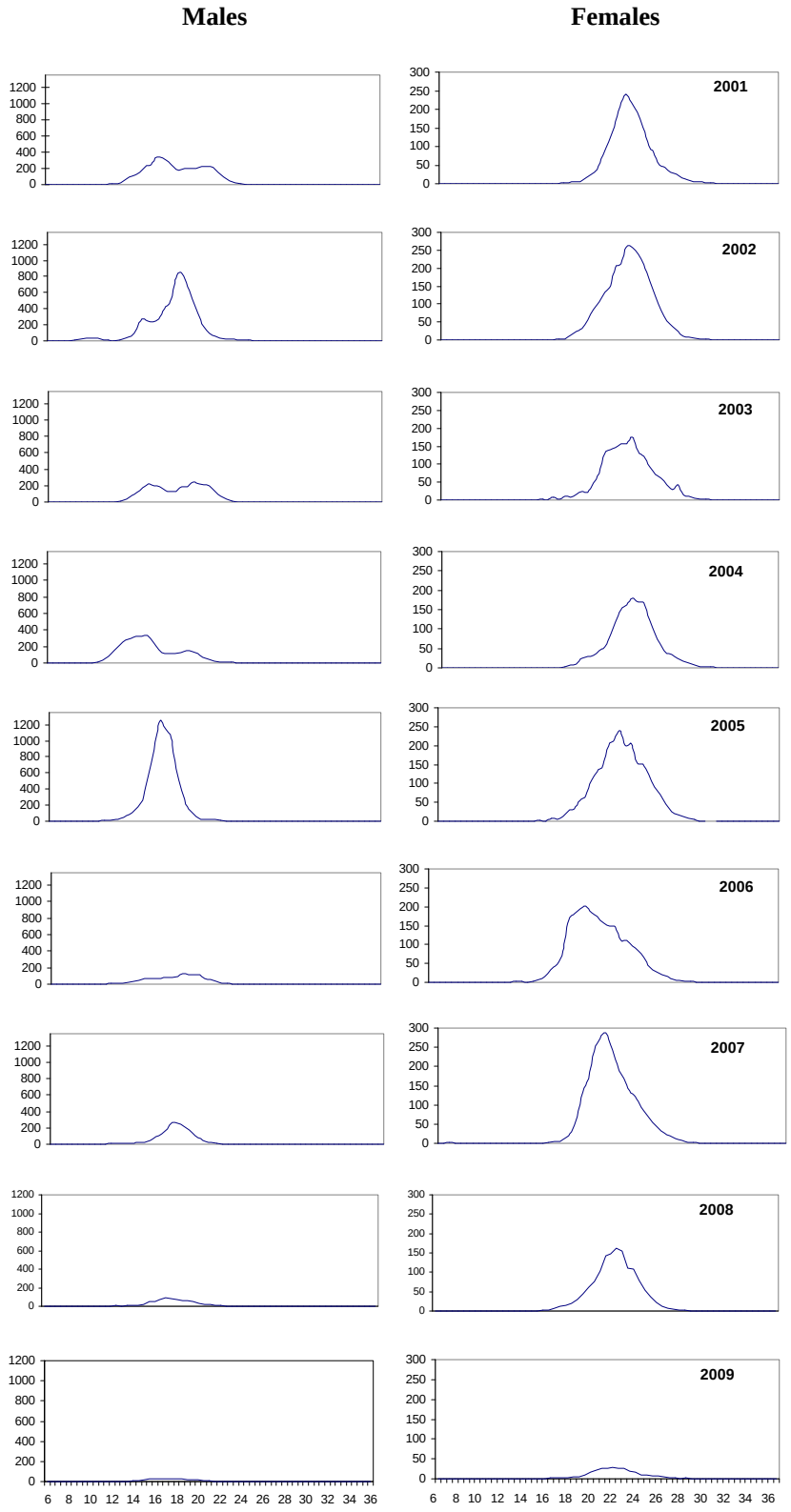

Figure 6. Shrimp size distribution from Flemish Cap 2001-2009 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).

Bag on the codend (6 mm.)

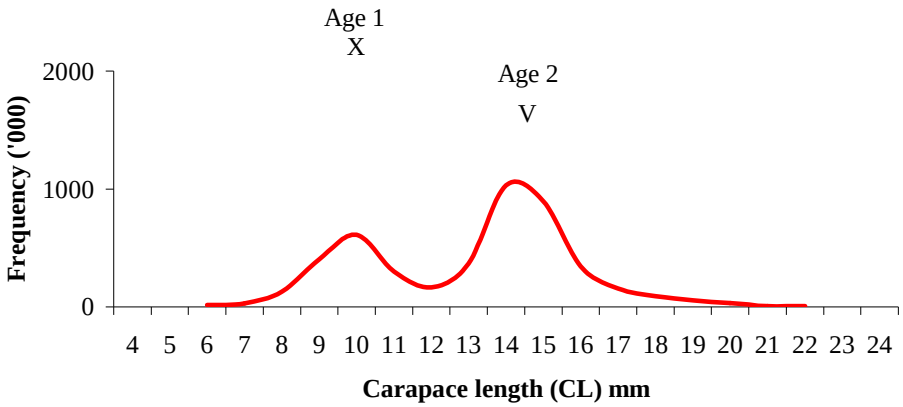

Figure 7. Shrimp modal and age groups in 2009 EU survey on Flemish Cap from juvenile bag. (letters from Table 9) .

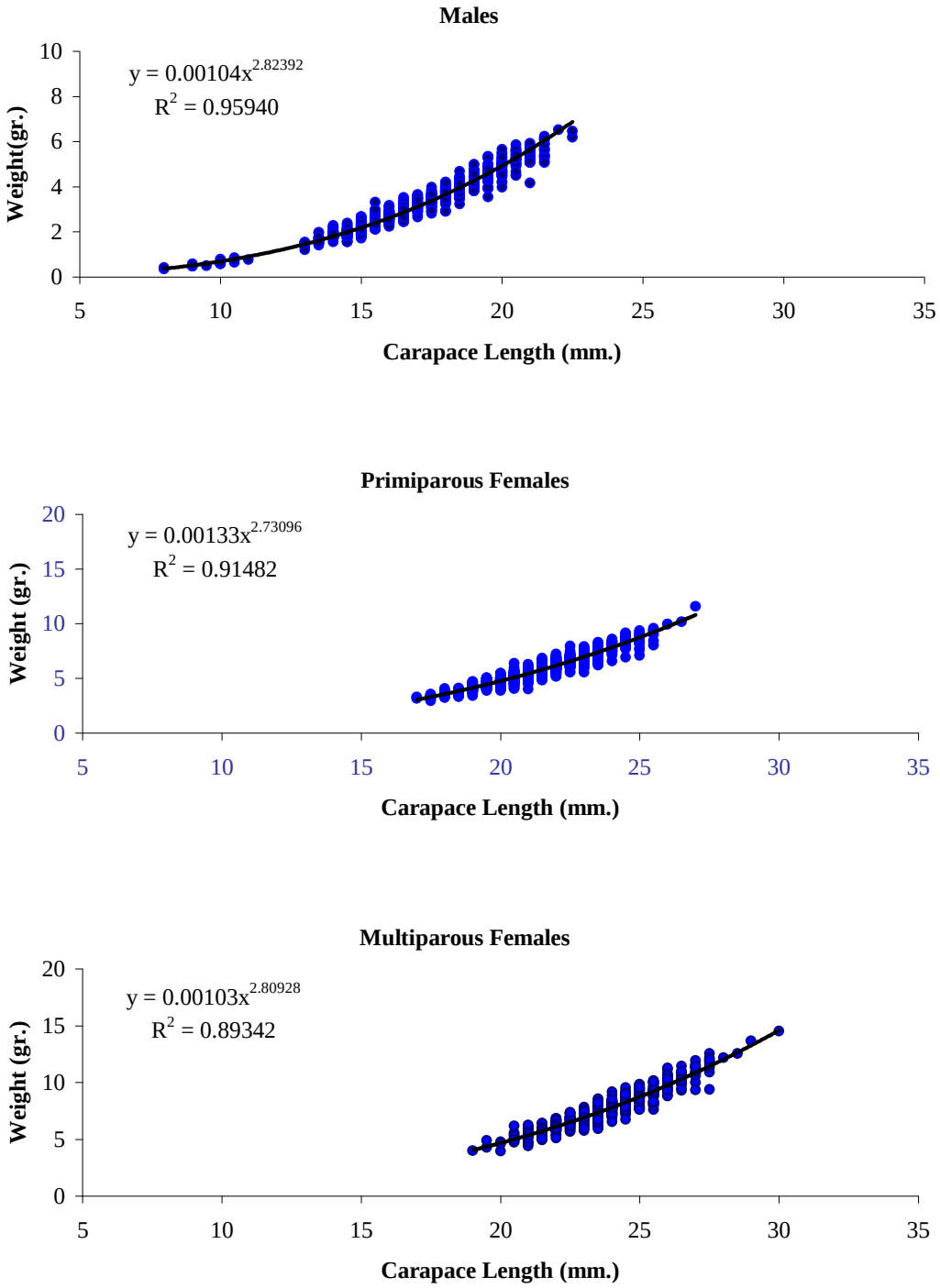

Figure 8. Shrimp length-weight relationships by sex and maturity stages in 2009 on EU Flemish Cap survey.

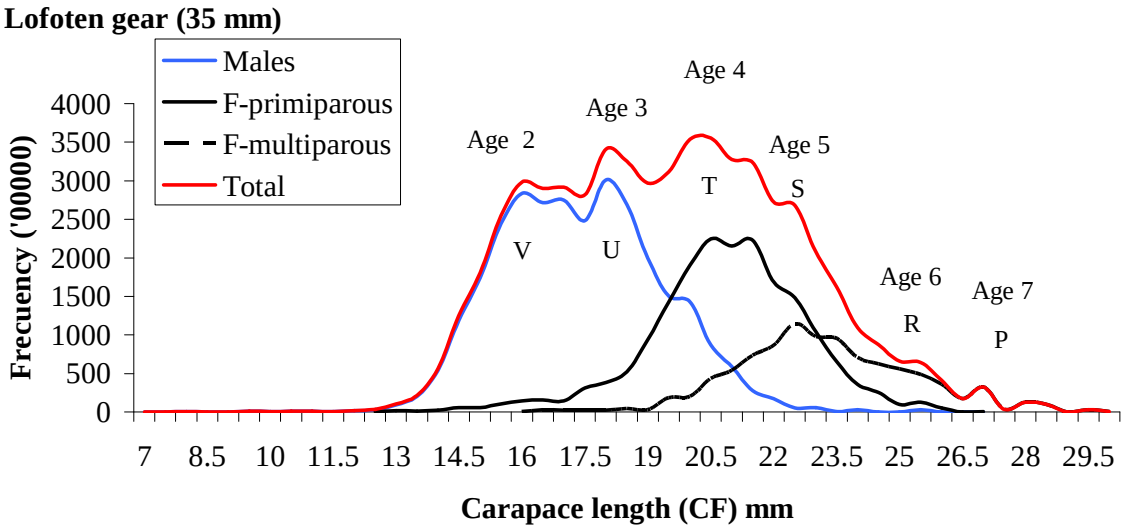

Figure 9. Shrimp modal and age groups in 2009 EU Flemish Cap survey (letters from table 9).

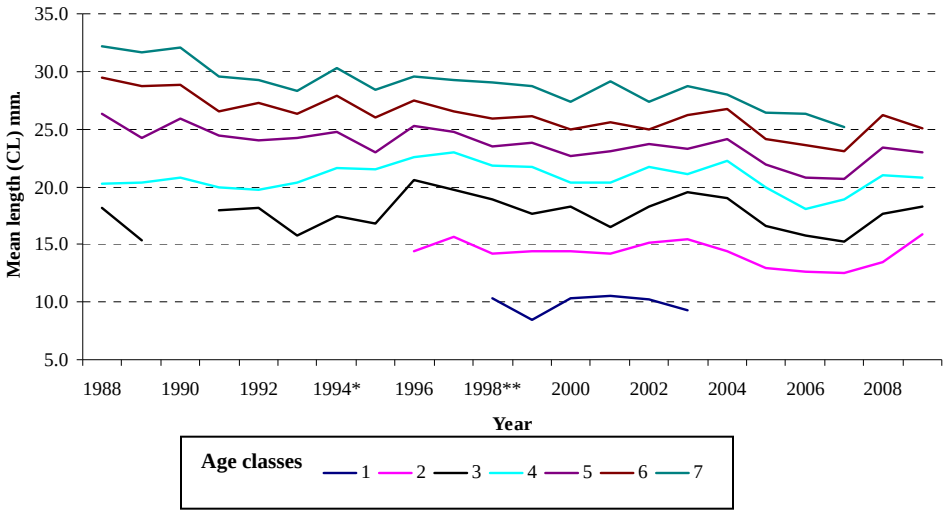

Figure 10. Shrimp mean lengths at age in the series of EU surveys on Flemish Cap.

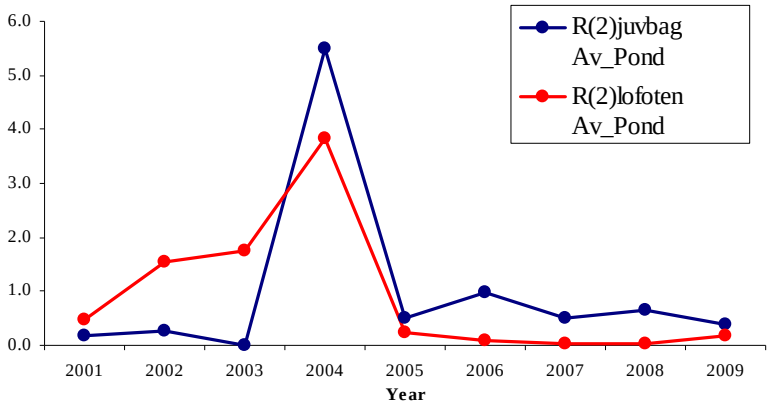

Figure 11. Abundance indexes at age 2 obtained in EU Flemish Cap surveys from Lofoten gear (red line) and Juvenile bag (blue line).