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Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2017

by

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Abstract

A stratified random bottom trawl survey on Flemish Cap was carried out from June 14th to July 18th 2017. 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 181 valid hauls were made by the vessel *R/V Vizconde de Eza* with the usual survey gear (Lofoten), 120 up to 730 meters depth. The surveyed area has properly prospected the 32 strata planned. 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 the last years 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. In recent years 2015, 2016 and 2017 the total biomass indexes increased significantly compared to previous year (around 72%, 62% and 14% respectively) but remain at very low level. The total and female biomasses estimated in 2017 were 2885 t and 2304 t respectively (Table 1). As in previous years the youngest specimens (age 1, around 10 mm CL) barely appeared in the catches and the abundance at age 2 (around 16 mm CL) was weakly presents suggesting the absence of any strong year classes since 2004. This poor situation of the shrimp stock is associated, as in previous years with the good condition 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 2017. Also they are compared with that obtained between years 2003-2016 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 2017 the survey was carried out from June 14th to July 18th. As previous years, the area prospected in Flemish Cap was spread up to 1450 meters. In 2017 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. The haul number carried out in the traditional 19 strata with depths minor than 740 m. was of 120. The area with depths higher than 740 m. was sampled by means of 61 additional hauls proportionally distributed in the new 13 strata.

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

Wherever it was possible 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 181 valid bottom trawls were completed with Lofoten trawl gear in Flemish Cap survey, 120 of them were carried out in the traditional strata prospected from 1988 with depths up to 740 m. (400 ftm.) (Fig. 1).

Total shrimp biomass, estimated by swept area method and mean catch per tow from 1988 to 2017 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 that year. 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. From 2011 the total biomass decreased successively and were recorded the lowest values in the historical series showing the worsening and depletion state of the shrimp stock. In recent years 2015, 2016 and 2017 the total biomass indexes increased significantly compared to previous year (around 72%, 62% and 14% respectively) but remain at very low level. The total biomass estimated in 2017 was 2885 t (Table 2 and Fig. 2).

Biomass estimated by depth strata from 1988 to 2017 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 to 2011 they were residual (in 2011 the 0.1% of the total biomass). In 2012 the biomass in these strata increased strongly (20%) mainly due to the presence of shrimp in only one tow in the shallowest strata (70-80 fth.). Since 2013 the biomass has been again among the lowest recorded (< 2%). According to this, the catch distributions observed during the 2017 survey (Fig. 3) showed a patched

distribution around the central area of the bank but with greater presence (61% of the biommass) in depth strata (141-200 ftm.).

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2017 (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 2017 was 2208 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 2017 the estimated female biomass (2304 t) was about 16% bigger than 2016. However, both indices (females and shrimp bigger than 20 mm biomass) remained at low level 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 the figure 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 and from the male and shrimps smaller than 20mm CL percentages (Table 5). 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 male percentages along the years showed a similar picture. The high value founded in 1998 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 from 1992 to 2006 (Fig.5a). After that the length at sex change increased year after year up to 2010 (20 mm.). Since 2011 the length at sex change has remained stable at 2009-2010 level, varying without trend. The length at maturity (L_{50MF}) (Fig. 5b), showed a similar and decreasing trend up to 2006. After that year the L_{50MF} shows an increasing trend reaching in 2015 26.8 mm and decreasing in the last two years around 2009-2010 levels.

Length frequencies

The length frequencies and percentages by sex for 2017 are shown in the Table 4. These length frequencies are split into males, primiparous females, multiparous females and ovigerous.

The Fig. 6 shows the length distribution by sex on EU Flemish cap 2005-2017 surveys. 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. The importance of the youngest individuals decreased markedly from 2006 and 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 2017 the absence of strong year classes persisted and the increase of biomass was mainly caused by the bigger presence of individuals with size around 22-24 mm CL.

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 has been 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 2017 survey are presented in Table 6. The estimated biomass was 7 t and the length distribution showed two modes at 9 and 14.5 mm. CL, corresponding to age-classes 1-2 (Table 7 and Fig. 7).

Age structure

The Table 7 and the Figures 7 y 8 show preliminary and visual interpretation of shrimp modal groups and ages from the length distribution obtained by the gear Lofoten and juvenile bag used in 2017.

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 survey 2017 is shown in Table 8. The proportions within each sex group are listed as well as mean lengths and standard deviation (sigma) by age-classes.

The results of Table 8 were then used to calculate the mean length, abundance and biomass at age Tables 9, 10 and 11. The modal analysis in 2017 identified 4 age groups (ages 2 to 5). The age at sex change was similar to the last year (3 years old with 19.7 mm CL). Although the biomass in 2017 increased 14% compared to 2016, the estimated values by age remain at low level.

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 17.6 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 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. 9). This trend was mainly pronounced from 2004 to 2007, 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 up to 2010. Since then the mean lengths changes without a clear trend at different ages.

Some strong year-classes may be followed according the abundance by age groups from 1988 to 2006 (Table 10) 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 -2016 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 8) were estimated and the index average-weighted (Fig. 10 and Table 12). Since 2005, the survey indices from Lofoten gear showed high variability in the estimated values but lower than in previous years, and confirming the absence of strong year classes. A similar trend can be observed from juvenile bag's indexes. In 2017 these indexes increased but remain low and confirm the weakness of the last recruitments.

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Table 1. Technical data of bottom trawl research surveys on EU Flemish Cap 2017.

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		3-3.5 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	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 1988-2017 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	6.09	4894	4171	3818	4.31
2011	2.02	1621	1322	1132	1.39
2012	1.31	1055	795	791	0.98
2013	1.05	844	714	691	0.86
2014	1.12	900	757	717	0.89
2015	1.93	1551	1068	1079	1.34
2016	3.08	2520	1994	1982	2.46
2017	3.54	2885	2208	2304	2.86

[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 ftm. 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	1995	1996	1997	1998	1999	2000	2001	2002
1	70-80															
2	81-100											175			69	112
3	101-140				10					148	39	639	450	1486	2169	5527
4	101-140											239	596	306	1099	1942
5	101-140					8				26	110	1107	1948	2135	2782	2445
6	101-140				32	2	5		20	422	161	2915	1142	657	2112	2951
7	141-200		30	400	1265	3763	2704	117	506	1336	988	4056	3072	2213	3006	4632
8	141-200			88	248	1662	826	4	248	676	393	2402	2507	1140	2900	4257
9	141-200	133	69	35			135		613	459	412	3981	1139	1110	1483	1754
10	141-200	275	75	321	2103	3235	1778	752	1315	1148	1099	7186	4052	2771	3760	3748
11	141-200	263		148	1144	4096	1335	447	650	1235	1018	6049	3017	3005	4091	3460
12	201-300	2170	505	512	2361	4654	2115	636	1201	1295	1195	2042	2127	1082	845	1468
13	201-300		66	64	89	38	136		28	687	554	1580	1465	43	620	217
14	201-300	618	375	623	995	2543		679	792	1076	426	3034	1717	689	843	2014
15	201-300	963	451	855	2004	3605	2292	1078	1370	1278	478	2575	1156	1753	837	1108
16	301-400	777	253	355	179	420	139	49	57	237	168	515	172	464	375	506
17	301-400						35									3
18	301-400						175			43	9			6		44
19	301-400	134	359		792	388		118	467	397	404	887	109	121	229	311
20	401-500															
21	501-600															
24	401-500															
25	501-600															
28	401-500															
29	501-600															
30	601-700															
31	601-700															
32	501-600															
33	401-500															
34	501-600															
%	<140 ftm.	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

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

Table 3. cont.

Stratum	Depth (Fathoms)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	70-80	3									198					0
2	81-100	690	217	193	8	50			1	0	0	0		0		1
3	101-140	1817	2107	1207	477	20	11	1	21	1	0	5	0	1	12	14
4	101-140	637	785	2739	1195	11	1	3	15	0	1	0	1	0	1	4
5	101-140	3780	867	847	664	558	11	28	21	1	8	5	2	1	5	23
6	101-140	1667	1250	1080	299	462	23	1	43	0	3	7	1	3	18	19
7	141-200	1521	3108	3202	1370	1642	468	32	495	8	46	81	29	74	277	635
8	141-200	1110	2043	5747	3084	709	1938	308	326	6	31	56	17	65	364	206
9	141-200	819	673	808	1435	1277	1159	48	235	31	21	32	10	36	32	137
10	141-200	4685	2489	2935	614	3248	671	154	467	58	31	36	25	223	246	428
11	141-200	3003	2350	2728	1086	2878	368	174	712	16	64	48	73	124	113	358
12	201-300	378	1222	1980	1524	1965	1585	569	1060	242	208	204	263	219	649	488
13	201-300	23	230	903	691	373	1080	149	80	56	67	92	152	378	275	122
14	201-300	303	726	2750	923	1481	1593	215	305	460	79	118	141	150	158	110
15	201-300	483	993	1374	1539	1597	1944	649	824	407	133	101	113	177	257	243
16	301-400	92	696	1587	840	526	108	145	188	208	115	34	37	60	30	59
17	301-400			10	196	56	33	2		8	0	0		1	33	2
18	301-400		42	56	115	8	10	3	20	9	0	0		0		0
19	301-400	61	366	530	173	187	61	278	77	172	35	25	36	16	8	35
20	401-500		6	353	29	20	5	1	0	39	0		0		0	
21	501-600			2						0		0	0			
22	501-600															1
24	401-500									0						0
25	501-600										0					
28	401-500		52	138	175	54	71	26		11	7	11	0			11
29	501-600								1				0			
30	601-700								0			0	0		0	
31	601-700										0					
32	501-600								0							
33	401-500			6				7				0		0		
34	501-600			12			1		0		0				0	
%	<140 ftm.	40.8	25.8	19.5	16.1	6.4	0.4	1.2	2.1	0.1	20.1	2.0	0.4	0.3	1.5	2.1

Table 4. Shrimp length frequencies (x 10^4) and percentages by sex and maturity stage from EU Flemish Cap 2017.

LENGTH (mm CL)	MALES	FEMALES	
		Primiparous	Multiparous
8.5	4	0	0
9	0	0	0
9.5	5	0	0
10	2	0	0
10.5	3	0	0
11	5	0	0
11.5	10	0	0
12	0	0	0
12.5	43	0	0
13	54	0	0
13.5	92	0	0
14	258	6	0
14.5	405	9	0
15	793	11	0
15.5	1045	30	5
16	1169	61	0
16.5	1139	83	19
17	983	102	10
17.5	594	126	23
18	626	225	32
18.5	694	296	13
19	1174	460	96
19.5	1180	742	175
20	1037	868	224
20.5	794	902	388
21	540	974	574
21.5	462	1253	922
22	298	1348	1371
22.5	298	1332	1874
23	179	1410	2497
23.5	93	1291	2356
24	46	1137	2151
24.5	30	692	1455
25	19	439	979
25.5	5	180	488
26	9	72	301
26.5	1	28	240
27	0	11	142
27.5	0	2	99
28	0	7	55
28.5	0	1	40
29	0	1	29
29.5	0	1	30
30	0	0	13
30.5	0	1	2
31	0	0	1
31.5	0	0	1
32	0	0	0
Total	14090	14101	16606
Percentage	31.5%	31.5%	37.1%

Table 5. Males percentage of northern shrimp from EU Flemish Cap 1995 - 2017 surveys.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998[1]	1999	2000	2001	2002
Males (%)	6.4	7.5	19.1	9.2	5.3	26.4	4.6	12.3	22.7	14.8	60.5	39.0	44.0	35.8	52.6
<20mm CL	19.4	39.7	60.0	43.9	36.9	40.7	24.1	33.2	50.9	34.4	70.9	44.6	46.5	51.0	53.2

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Males (%)	38.0	40.4	55.6	47.2	31.8	29.2	36.3	14.8	24.9	30.4	15.4	15.9	31.1	20.9	23.5
<20mm CL (%)	45.0	40.1	53.1	29.3	24.7	22.2	36.9	22.0	28.9	25.0	18.1	20.3	30.4	21.3	20.1

[1] codend mesh-size 25 mm liner

Table 6. Shrimp length frequencies taken by the small mesh size bag attached to the cod-end in 2017 survey.

Length (CL) mm	Frequency	Length (CL) mm	Frequency
5.5	3	14	25
6		14.5	21
6.5	2	15	25
7	17	15.5	23
7.5	56	16	8
8	79	16.5	5
8.5	132	17	4
9	141	17.5	3
9.5	124	18	1
10	91	18.5	5
10.5	51	19	1
11	19	19.5	2
11.5	14	20	
12	4	20.5	1
12.5	6	21	
13	12	21.5	
13.5	7	22	1
		Total	883
Catch weight (gr)			1095

Table 7. Shrimp modal groups by sexes and ages with Lofoten gear and bag in the codend in 2017 from EU Flemish Cap survey interpreted from size distributions.

LOFOTEN

Age	Modal groups		Cohort
	Males	Females	
1	-	-	-
2	16.0		D
3	19.5	20.0	C
4	-	23.0	B
5	-	25.5	A
6	-	-	-
7	-	-	

BAG ON THE CODEND

Age	Modal groups	Cohort
1	9	E
2	14.5	D
3	-	-

Table 8. Results of the modal analysis (MIX) by sex and maturity stage from EU Flemish Cap surveys 2017 with Lofoten gear and juvenile bag.

Sex and Maturity	Juvenile bag (6mm)		Lofoten gear (35 mm.)					
			Males		Primimarous		Multiparous	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1	0.825	0.0044						
2	0.175	0.0044	0.454	0.0054	0.032	0.0023		
3			0.490	0.0094	0.305	0.0077	0.085	0.0037
4			0.056	0.0095	0.663	0.0084	0.851	0.0044
5							0.064	0.0036
6								
7								
Age			***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***
1	9.3	0.0143						
2	15.2	0.0480	16.16	0.0189	17.12	0.0784		
3			19.91	0.0418	20.35	0.0407	20.51	0.0471
4			22.26	0.1753	23.20	0.0244	23.57	0.0146
5							26.77	0.0754
6								
7								
Age			***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1	1.070	0.0116						
2	1.591	0.0378	1.131	Fixed. CV	0.952	0.0106		
3			1.394	Fixed. CV	1.131	Cons. CV	0.923	Fixed. CV
4			1.558	Fixed. CV	1.290	Cons. CV	1.061	Fixed. CV
5							1.205	Fixed. CV
6								
7								

Table 9. 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	2012	2013	2014	2015	2016	2017	Mean CL
1											10.3	8.5	10.3	10.5	10.2	9.3							11.7			12.4			12.1		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	16.1	17.2		16.8	16.3	16.2	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	20.1	19.4	18.1	20.4	19.7	20.1	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	23.5	21.8	22.6	22.5	21.7	23.4	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	24.4	24.5	25.0	23.9	24.4	25.4	24.3	26.8	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	27.8	26.0	26.1	26.1	26.9		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	21.3	22.1	22.4	20.4	21.2	21.8	20.1

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

Table 10. 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	2012	2013	2014	2015	2016	2017
1											94	1	9	3	181	14							8			1			0	
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	118	110	60	23	6		111	23	69
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	161	387	90	89	18	35	41	109	128
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	56	60	43	93	214	245
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	12	40	42	17	49	11
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	1	3	6	9	6	
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	179	128	126	271	401	452

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

Table 11. 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	2012	2013	2014	2015	2016	2017
1											60	0.5	6	2	114	6							9			1			0.3	
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	303	372	177	63	21		359	65	190
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	600	2029	461	450	85	141	228	535	651
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	431	379	316	687	1395	1920
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	104	323	379	179	450	124
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	35	64	98	75	
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	1055	844	900	1551	2521	2885

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

Table 12. Abundance at age 2 and average-weighted as indicator of recruitment (R) in the survey (lofoten gear) and from juvenile bag.

year	R (age 2) juvbag ('000)	R (age 2) Lofoten ('00000)	R(2)juvbag Av_weighed	R(2)lofoten Av_weighed
2001	1361	3321	0.31	0.90
2002	2125	11004	0.49	3.00
2003	0	12572	0.00	3.42
2004	41818	27415	9.57	7.47
2005	3741	1792	0.86	0.49
2006	7498	582	1.72	0.16
2007	3824	301	0.88	0.08
2008	4969	221	1.14	0.06
2009	3011	1177	0.69	0.32
2010	954	1106	0.22	0.30
2011	2440	601	0.56	0.16
2012	160	229	0.04	0.06
2013	102	63	0.02	0.02
2014	56	0	0.01	0.00
2015	427	1111	0.10	0.30
2016	390	230	0.09	0.06
2017	1411	695	0.32	0.19

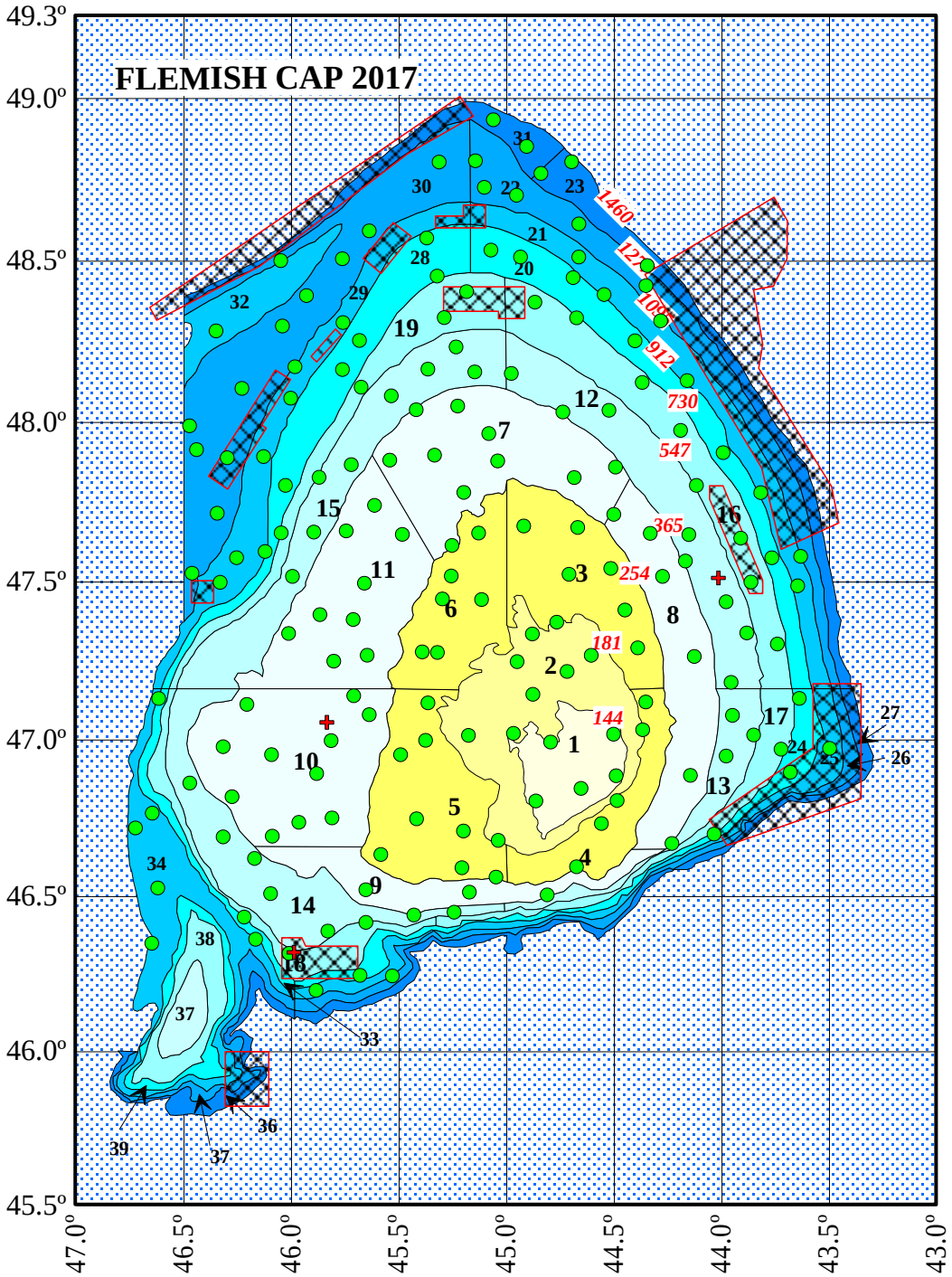


Fig. 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2017.

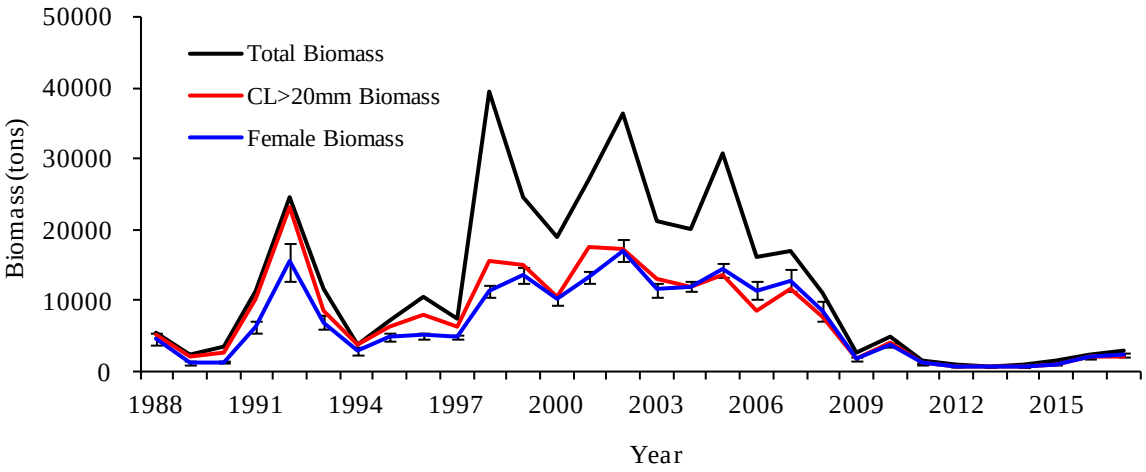


Fig. 2. Total, female and adult biomass (shrimp bigger than 20 mm CL) from EU Flemish Cap 1988-2017 surveys.

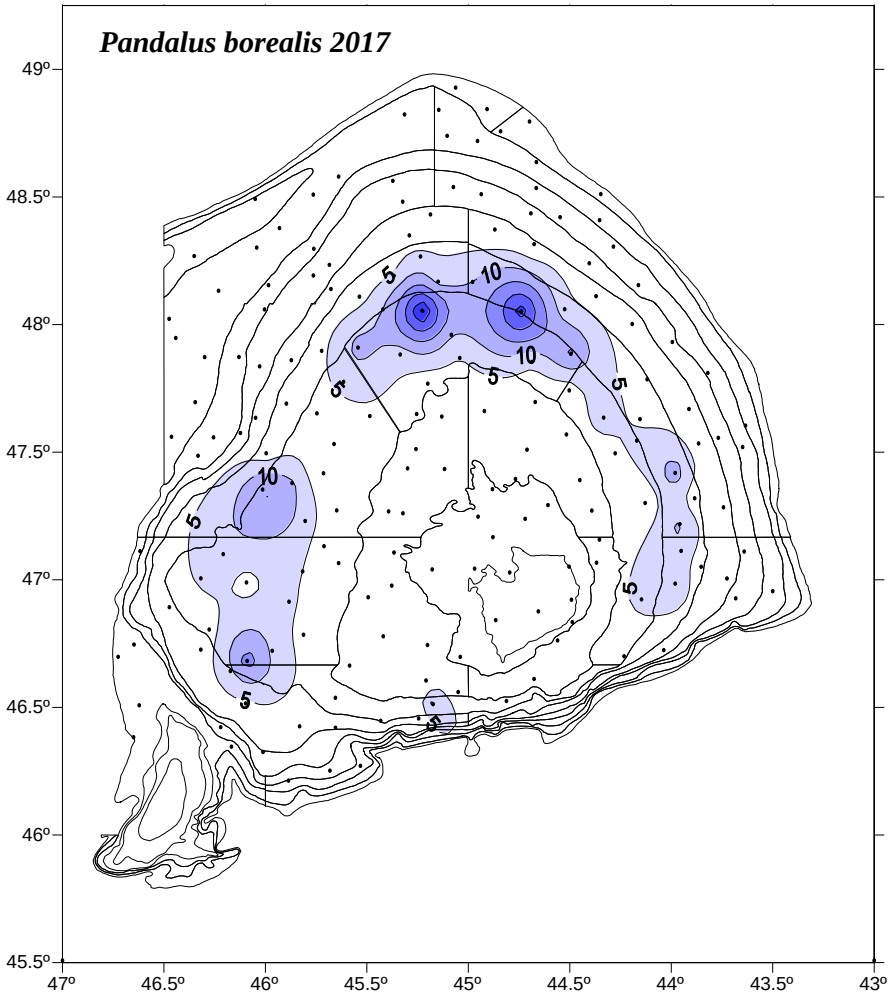


Fig. 3. Shrimp catches distribution (kg/tow) from EU Flemish Cap survey in summer 2017.

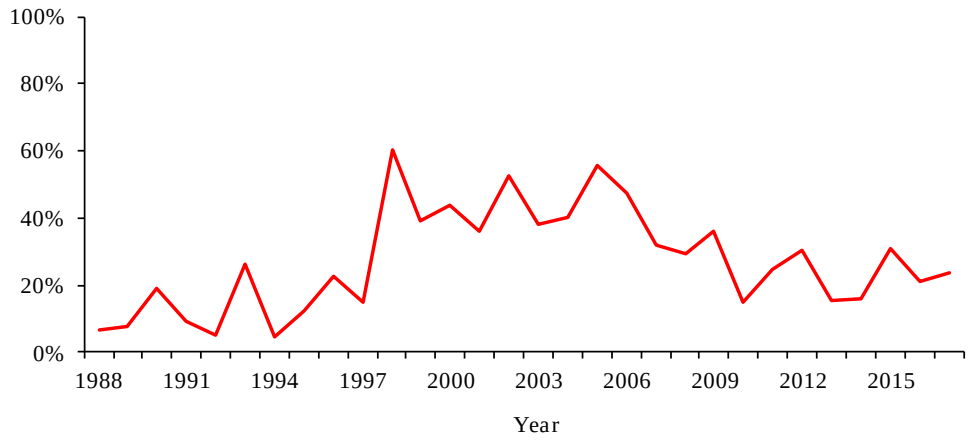


Fig.4. Differences between total biomass and adult biomass (>20 mm CL) as percentage of Total biomass from EU Flemish Cap 1988-2017 surveys.

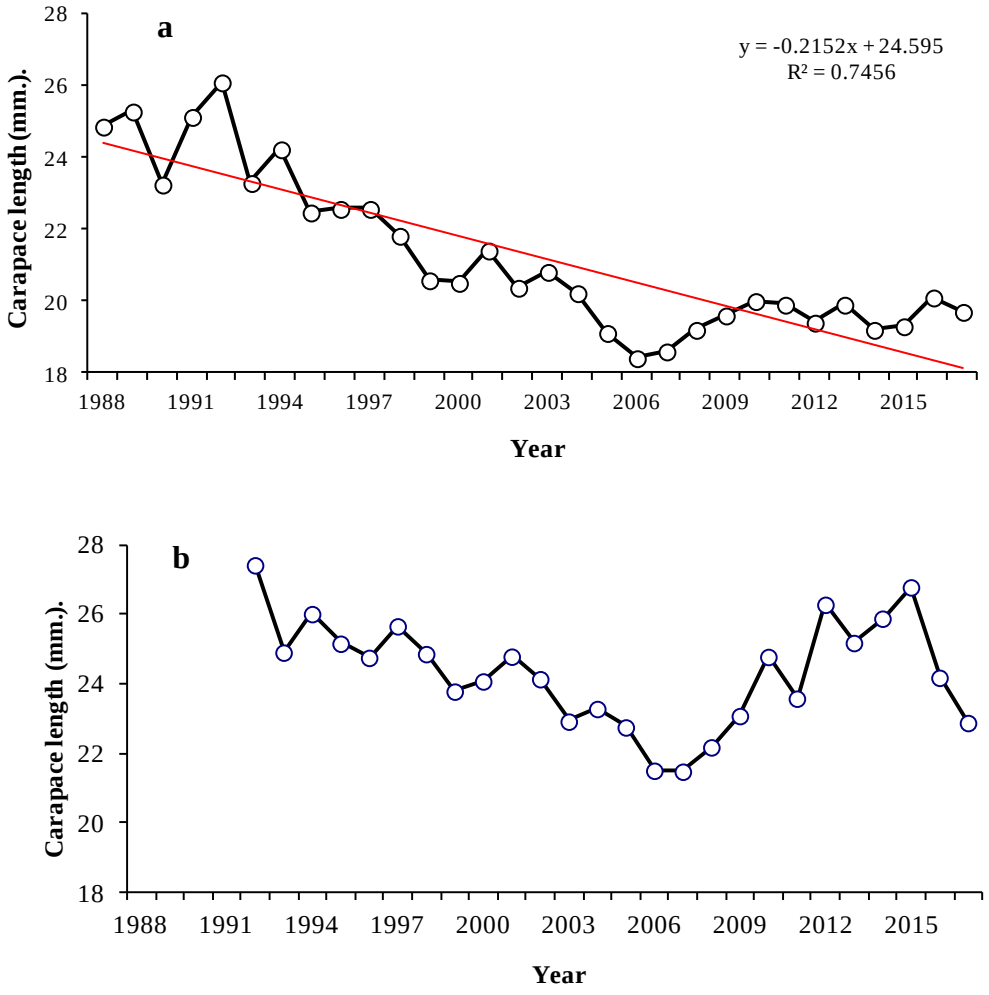
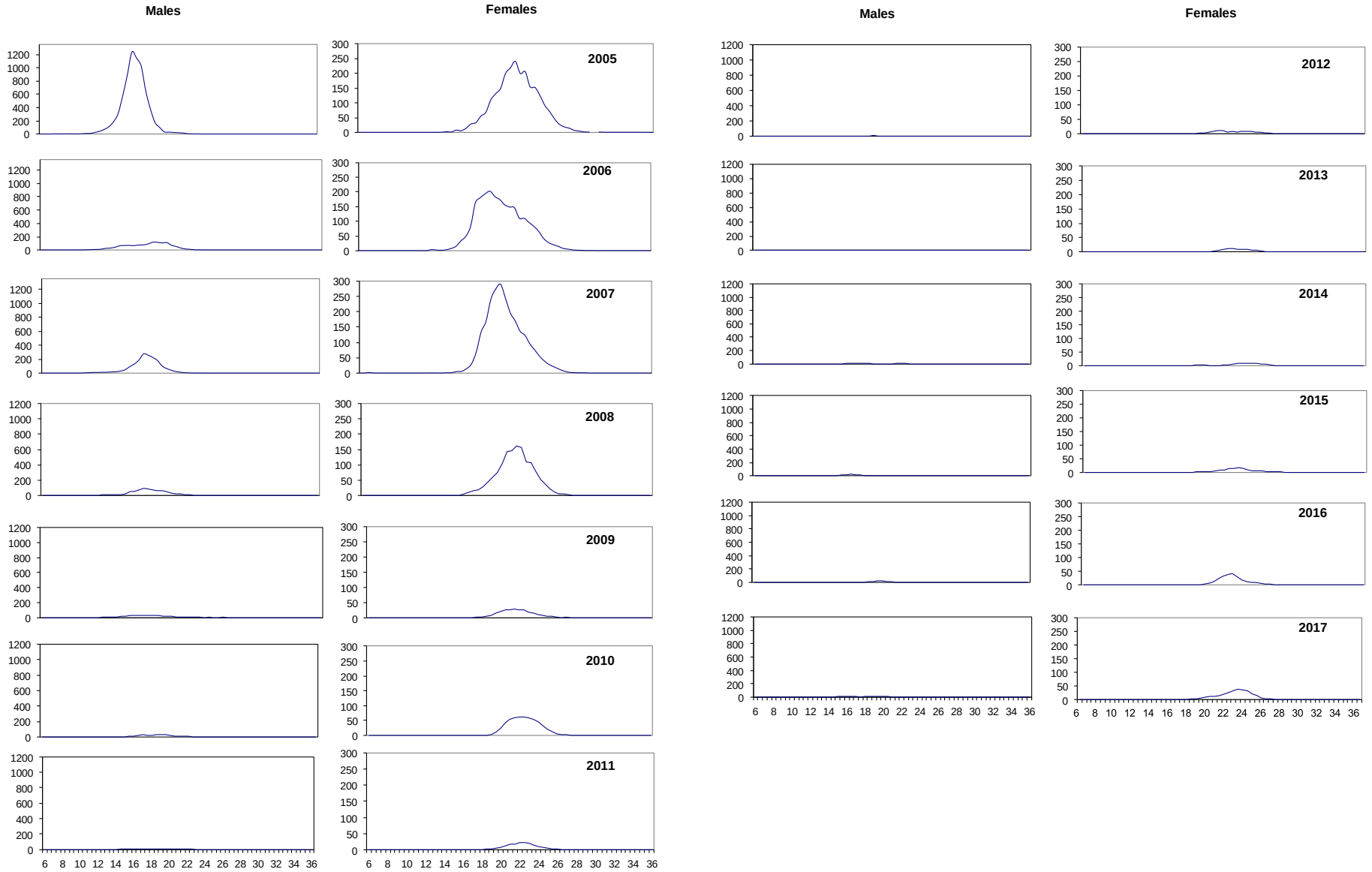


Fig.5. Lengths (CL) at sex change (a) and maturity (b) of shrimp in EU Flemish Cap surveys

Fig.6. Shrimp size distribution from Flemish Cap 2005 -2017 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).



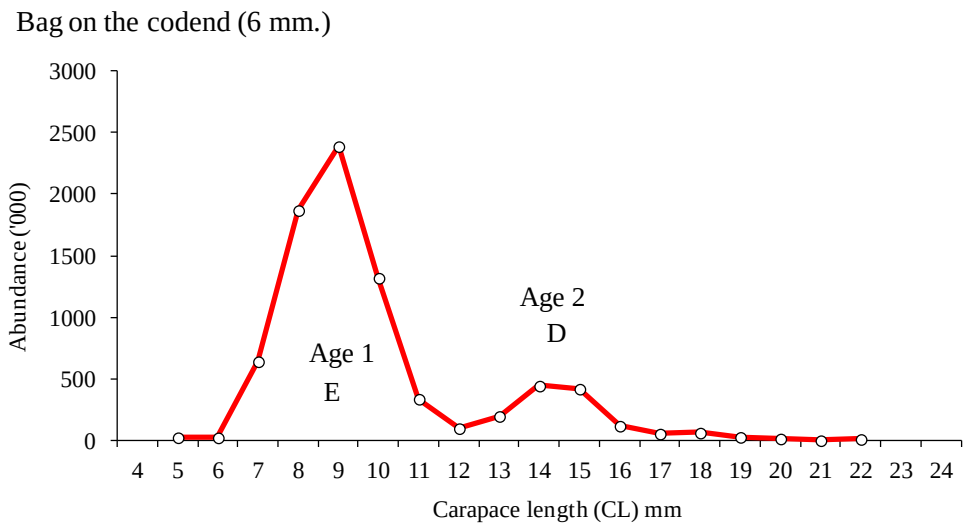


Fig.7. Shrimp modal and age groups in 2017 EU survey on Flemish Cap from juvenile bag. (letters from Table 7).

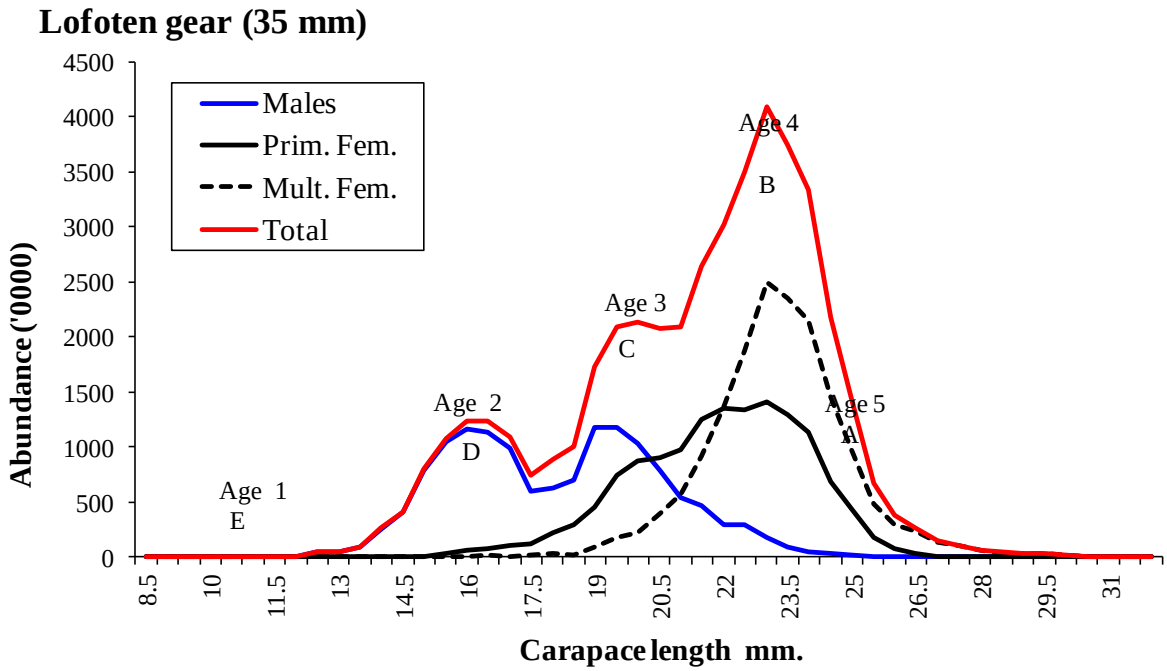


Fig.8. Shrimp modal and age groups in 2017 EU Flemish Cap survey (letters from table 7).

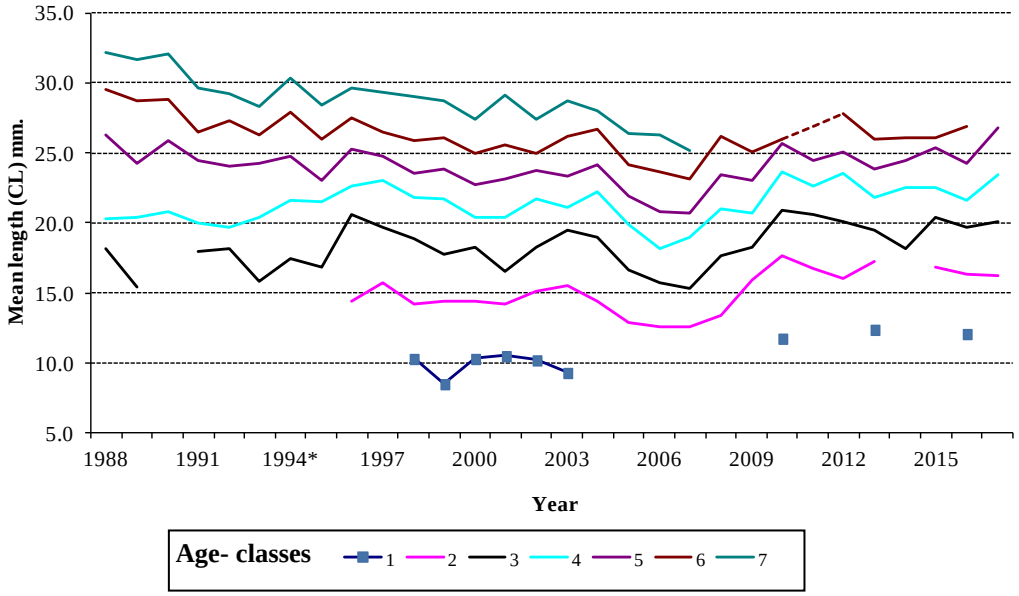


Fig. 9. Shrimp mean lengths at age in the series of EU surveys on Flemish Cap.

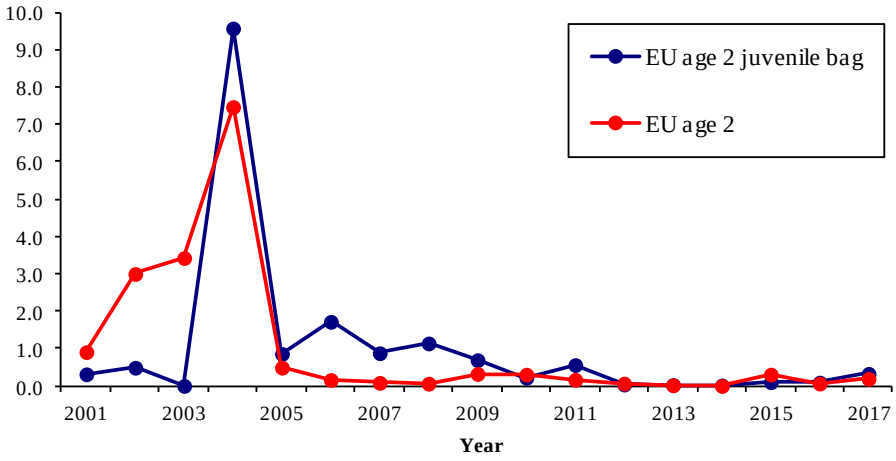


Fig. 10. Abundance indexes at age 2 (weigthed-average) obtained in EU Flemish Cap surveys from Lofoten gear (red line) and Juvenile bag (blue line).