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Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2021

by

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Abstract

A stratified random bottom trawl survey on Flemish Cap was carried out from July 6th to August 15th 2021. 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. The total biomass index decreased 69% compared to 2020, confirming the downward trend started last year and leads the stock bellow B_{lim} to the collapse zone defined by the NAFO PA framework. The abundance at age 3, corresponding to the relatively strong 2018 year class, was 43% lower than estimated in 2020 and revealed a weaker recruitment than expected. Also the abundance at age 2 (2019 year class), estimated from the main gear and the small bag attached on the cod-end, decreased around 92 % and 74 % respectively compared with 2020 showing the weakness of 2019 year class.

The stock is now below B_{lim} and it is in the collapse zone defined by the NAFO PA framework. To be consistent with the precautionary approach, fishing mortality should be kept as close to zero as possible when a stock is in the collapse zone. Therefore, considering the decline of the stock and the poor prospects for recruitment to the fishable stock in the coming years, Scientific Council advises that the fishing mortality and catch be set as close to zero as possible by 2022.

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 2021. Also they are compared with that obtained between years 2003-2020 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 2021 the survey was carried out from July 6th to August 15th. The area prospected in Flemish Cap was spread up to 1450 meters. In 2020 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 the hauls were carried out outside of the closed areas by presence of VME following the SC recommendation. 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 further 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

The length frequency distribution by sex group were analysed by package for fitting finite mixture distribution *Rmix* 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 (FCV) at 0.045 or keeping it constant (CCV).

This year the analysis by *Rmix* of the historical length distribution from the survey series was reviewed and mean lengths, abundance and biomass by age estimated.

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 weighed 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 2021 are presented in Table 2 and Figure 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 shrimp 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 series showing the worsening and depletion state of the shrimp stock. Since 2015 the biomass indexes increased year after year and they were above B_{lim} from 2018. In 2020 the shrimp fishery was resumed, and the female biomass experienced some decrease but remained above B_{lim}. In 2021 the total and female biomass with 2101 t and 1 792 t respectively, decreased for the second consecutive year and it is now bellow B_{lim}.

Biomass estimated by depth strata from 1988 to 2021 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, from 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 (0.1% of the total biomass in 2011). 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 once again been among the lowest recorded (< 2%). According to this, the catch distributions observed during the 2021 survey (Fig. 3) showed a patched distribution around the central area of the bank but with greater presence in depth strata 201-300 fth and 301-400fth (56.5% and 27.8% of the biomass respectively).

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2021 (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. 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 2021 was 1 445 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 2021 the estimated female biomass (1 792t) was about 70 % lower than 2020 and it is now well below the average value of 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. From 2006 to 2010 the increasing trend changes and difference between total biomass and adult biomass decreased to levels prior 1997 year. Since then the differences have varied without a clear trend. The male percentages along the years showed a similar picture. The high value estimated 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.), varied without trend between 2010 and 2017 and decreased in 2019 and 2021 to the lowest value in the historical series (17.4 mm). The length at maturity (L_{50MF}) (Fig. 5b), showed a similar and decreasing trend until 2006. After that year the L_{50MF} showed an increasing trend reaching in 2015 26.8 mm. Since then the length at maturity have decreased around 2009-2010 levels.

Length frequencies

The length frequencies and percentages by sex for 2021 are shown in the Table 4. These length frequencies are split into males, primiparous females, multiparous females and ovigerous.

The figure 6 shows the length distribution by sex on EU Flemish cap 2005-2021 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 mm 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 caused a drastic fall in the frequencies of practically all the length groups compared with those obtained in previous years.

The biomass estimated in 2021 was mainly represented by female and specimens with sizes around 17-26 mm (Figure 7). Young specimens (mainly males) decreased (around 60% in number) compared to 2020 and remain well below average.

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. The estimated biomass and length distributions obtained with the small mesh size bag in 2021 survey are presented in Table 6. The estimated biomass was 18 t and the length distribution showed three clear modes at 8 mm, 13 mm and 17 mm CL, corresponding to age-classes 1, 2 and 3 respectively (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 2021.

Age assessment was carried out using the Rmix library from the shrimp length distributions estimated every year in the survey series. The result of the modal analysis for annual survey 2021 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 2021 identified 5 age groups (ages 2 to 6). The age at sex change was smaller than in previous years (3 years old with 17.4 mm CL). The total biomass in 2021 decreased 69% compared to 2020 and the estimated values by age remain at very low level.

At the beginning of the series (1988-1997) the youngest shrimp were considered to be two year olds with lengths between 14.5 and 18.0 mm. The shrimps with one year old appeared at first time in 1998 and were present up to 2003 with lengths around 9-10 mm. Since then this age class was rarely present in the main gear and many years could not to be identified from the length distributions. 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. From 2007 this trend changed increasing the mean lengths at age up to 2010. From 2010 to 2018 varied without a clear trend and since then are decreasing.

Some strong year-classes may be followed according the abundance by age groups from 1988 to 2006 (Table 10 and 11). If the assignation of the age is right, the 1987 year-class stand out in the beginning of historical series with 4 and 5 years old in the years 1991 and 1992. The individuals with 3-6 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

the residual presence of age group 1 in the catches and very low values for the ages 2 and 3 showed the absence of strong year classes between 2004 and 2018.

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 have showed high variability in the estimated values but at lower level than in previous years, confirming the absence of strong year classes. A similar trend can be observed from juvenile bag's indexes. From 2015 although the recruitments (age 2) were rather weak, they improved somewhat, allowing the recovery of the stock. The significant increase of shrimps with one year old recorded from the juvenile bag in 2019 (Table 13 and Fig. 11) was confirmed in 2020 indicating the entry of a relative strong year-class 2018 (age 2 in 2020, Fig. 10). In 2021, the abundance at age 3 estimated from the main gear (Table 10), corresponding to the relatively strong 2018 year class, was not so stronger than expected (43% lower than estimated in 2020) and revealed a weaker recruitment than expected. Also the abundance at age 2, estimated this year from the main gear and the small bag attached on the cod-end, decreased around 92 % and 74 % respectively compared with 2020 showing the weakness of 2019 year class.

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Table 1. Technical data of bottom trawl research surveys on EU Flemish Cap 2021.

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 1988-2021 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
2018	5.31	4394	3628	4051	4.90
2019	11.53	9273	7753	8486	10.6
2020	8.37	6734	5444	6048	7.52
2021	2.61	2101	1445	1792	2.23

[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	2003	2004
1	70-80																3	
2	81-100											175			69	112	690	217
3	101-140				10					148	39	639	450	1486	2169	5527	1817	2107
4	101-140											239	596	306	1099	1942	637	785
5	101-140					8				26	110	1107	1948	2135	2782	2445	3780	867
6	101-140				32	2	5		20	422	161	2915	1142	657	2112	2951	1667	1250
7	141-200		30	400	1265	3763	2704	117	506	1336	988	4056	3072	2213	3006	4632	1521	3108
8	141-200			88	248	1662	826	4	248	676	393	2402	2507	1140	2900	4257	1110	2043
9	141-200	133	69	35			135		613	459	412	3981	1139	1110	1483	1754	819	673
10	141-200	275	75	321	2103	3235	1778	752	1315	1148	1099	7186	4052	2771	3760	3748	4685	2489
11	141-200	263		148	1144	4096	1335	447	650	1235	1018	6049	3017	3005	4091	3460	3003	2350
12	201-300	2170	505	512	2361	4654	2115	636	1201	1295	1195	2042	2127	1082	845	1468	378	1222
13	201-300		66	64	89	38	136		28	687	554	1580	1465	43	620	217	23	230
14	201-300	618	375	623	995	2543		679	792	1076	426	3034	1717	689	843	2014	303	726
15	201-300	963	451	855	2004	3605	2292	1078	1370	1278	478	2575	1156	1753	837	1108	483	993
16	301-400	777	253	355	179	420	139	49	57	237	168	515	172	464	375	506	92	696
17	301-400						35									3		
18	301-400						175			43	9			6		44		42
19	301-400	134	359		792	388		118	467	397	404	887	109	121	229	311	61	366
20	401-500																	6
21	501-600																	
24	401-500																	
25	501-600																	
28	401-500																	
29	501-600																	52
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	40.8	25.8

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

Table 3. cont.

Stratum	Depth (Fathoms)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	70-80								198					0	1			
2	81-100	193	8	50			1	0	0	0		0		1	0	0	1	0
3	101-140	1207	477	20	11	1	21	1	0	5	0	1	12	14	13	51	2	7
4	101-140	2739	1195	11	1	3	15	0	1	0	1	0	1	4	6	0	0	0
5	101-140	847	664	558	11	28	21	1	8	5	2	1	5	23	24	116	3	4
6	101-140	1080	299	462	23	1	43	0	3	7	1	3	18	19	30	14	13	6
7	141-200	3202	1370	1642	468	32	495	8	46	81	29	74	277	635	245	366	76	39
8	141-200	5747	3084	709	1938	308	326	6	31	56	17	65	364	206	261	444	262	31
9	141-200	808	1435	1277	1159	48	235	31	21	32	10	36	32	137	122	386	266	37
10	141-200	2935	614	3248	671	154	467	58	31	36	25	223	246	428	359	968	315	57
11	141-200	2728	1086	2878	368	174	712	16	64	48	73	124	113	358	478	639	271	27
12	201-300	1980	1524	1965	1585	569	1060	242	208	204	263	219	649	488	857	1729	1208	485
13	201-300	903	691	373	1080	149	80	56	67	92	152	378	275	122	376	709	317	126
14	201-300	2750	923	1481	1593	215	305	460	79	118	141	150	158	110	308	825	900	347
15	201-300	1374	1539	1597	1944	649	824	407	133	101	113	177	257	243	1027	2197	2319	310
16	301-400	1587	840	526	108	145	188	208	115	34	37	60	30	59	69	531	374	381
17	301-400	10	196	56	33	2		8	0	0		1	33	2	10	0	39	82
18	301-400	56	115	8	10	3	20	9	0	0		0		0			1	15
19	301-400	530	173	187	61	278	77	172	35	25	36	16	8	35	209	298	367	146
20	401-500	353	29	20	5	1	0	39	0		0		0				51	77
21	501-600	2						0		0	0							0
22	501-600													1				
24	401-500							0						0		3	11	
25	501-600								0									
28	401-500	138	175	54	71	26		11	7	11	0			11	10	49	73	68
29	501-600						1				0						0	
30	601-700						0			0	0		0			0		
31	601-700								0									
32	501-600						0											
33	401-500	6				7				0		0						0
34	501-600	12			1		0		0				0		0	0	1	0
%	<140 ftm.	19.5	16.1	6.4	0.4	1.2	2.1	0.1	20.1	2.0	0.4	0.3	1.4	2.1	1.7	1.9	0.3	0.8

Table 4. Shrimp length frequencies (x 10^4) and percentages by sex and maturity stage from EU Flemish Cap 2021.

LENGTH (mm CL)	MALES	FEMALES		
		Primiparous	Multiparous	Ovigerous
8.5				
9				
9.5		2		
10	6			
10.5	3			
11	22			
11.5	14			
12	36			
12.5	82	1		
13	127	4		
13.5	236	26		
14	257	32		
14.5	243	41		
15	334	75		
15.5	552	127	4	
16	905	385	3	
16.5	1346	601	2	
17	1561	990	10	
17.5	1310	1218	26	3
18	980	1353	53	2
18.5	572	1299	58	
19	348	1244	81	13
19.5	196	1064	119	2
20	198	1071	127	1
20.5	149	1347	268	18
21	134	1590	310	36
21.5	56	1762	544	41
22	82	1763	720	120
22.5	23	1584	829	79
23	2	1088	889	40
23.5	3	875	915	46
24	1	561	963	81
24.5		398	904	48
25		204	718	23
25.5		158	615	2
26		83	325	30
26.5		16	239	11
27		15	127	
27.5		6	92	6
28			67	
28.5		2	19	
29			14	1
29.5			6	
30			3	
30.5				
31				
31.5			1	
32				
32.5				
33			1	
33.5				
34				
Total	9777	20989	9049	605
Percentage %	24.2%	51.9%	22.4%	1.5%

Table 5. Males percentage as total biomass of northern shrimp from EU Flemish Cap 1988 - 2021 surveys.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998[1]	1999	2000	2001	2002	2003	2004
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	38.0	40.4
<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	45.0	40.1

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Males (%)	55.6	47.2	31.8	29.2	36.3	14.8	24.9	30.4	15.4	15.9	31.1	20.9	20.1	7.8	8.5	10.2	14.7
<20mm CL (%)	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	17.4	16.4	19.2	31.2

[1] codend mesh-size 25 mm liner

Table 6. Shrimp length frequencies (x 10^3) estimated from the small mesh size bag attached to the cod-end in 2021 survey.

Length (CL) mm	Frequency	Length (CL) mm	Frequency
5.5		17	305
6	21	17.5	284
6.5	56	18	110
7	194	18.5	113
7.5	309	19	42
8	712	19.5	42
8.5	905	20	9
9	971	20.5	17
9.5	674	21	
10	454	21.5	
10.5	218	22	
11	141	22.5	
11.5	423	23	
12	783	23.5	
12.5	1050	24	
13	1422	24.5	
13.5	1322	25	
14	906	25.5	
14.5	426	26	
15	208	26.5	
15.5	230	27	
16	224		
16.5	332	Total	12930
	Biomass	18 t	

Table 7. Shrimp modal groups by sexes and ages with Lofoten gear and bag in the codend in 2021 from EU Flemish Cap survey interpreted from size distributions.

LOFOTEN			
Age	Modal groups		Cohort
	Males	Females	
1	-	-	I
2	14.0	-	H
3	17.0	18.5	G
4	-	21.5	F
5	-	24.5	E
6	-	26.5	D
7	-	27.5	C

BAG ON THE CODEND		
Age	Modal groups	Cohort
1	8	I
2	13	H
3	17	G

Table 8. Results of the modal analysis (MIX) by sex and maturity stage from EU Flemish Cap surveys 2021 with Lofoten gear and juvenile bag.

Sex and Maturity	**Juvenile bag (6mm)**		**Lofoten gear (35 mm.)**					
			Males		**Primimarous females**		**Multiparous females**	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1	0.3618	0.0022						
2	0.5036	0.0025	0.1012	0.0037	0.0090	0.0016		
3	0.1346	0.0013	0.8181	0.0057	0.3749	0.0056	0.0383	0.0033
4			0.0807	0.0046	0.5428	0.0330	0.3680	0.0266
5					0.0734	0.0355	0.5539	0.0227
6							0.0398	0.0204
7								
Age			***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***
1	9.09	0.0131						
2	13.35	0.0080	13.90	0.0377	15.19	0.1664		
3	17.15	0.0752	17.26	0.0161	18.27	0.0260	19.17	0.0970
4			20.47	0.0759	21.91	0.0823	22.47	0.1021
5					23.47	0.2771	24.56	0.0966
6							26.66	0.3480
7								
Age			***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1	1.0212	0.0113						
2	0.8989	0.0070	0.8717	0.0098	0.9785	0.0160		
3	1.1680	0.0537	1.0828	CCV	1.1774	CCV	1.0280	0.0484
4			1.2841	CCV	1.4121	CCV	1.2050	CCV
5					1.5121	CCV	1.3170	CCV
6							1.4300	CCV
7								

Table 9. Mean length (mm.) at age by years in EU Flemish Cap surveys

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	2018	2019	2020	2021
1											10.6	8.5	10.4	10.5	10.2	9.3						11.1	11.7	11.4		12.5	10.7		12.1			9.9		
2		14.5		18.0		15.8	17.4	16.8	14.4	16.0	14.3	14.4	14.5	14.2	15.1	15.7	14.4	12.9	13.0	12.5	14.0	16.2	17.6	16.8	16.0	17.4	15.6	16.8	16.3	16.4	16.7	15.8	15.0	14.1
3	20.1	20.5	20.7	20.0	18.9	20.4	21.6	21.5	20.8	20.2	18.9	17.7	18.3	16.6	18.2	19.7	19.0	16.6	17.6	15.3	17.2	18.8	20.8	20.6	20.1	19.5	18.0	20.2	19.7	20.2	20.9	20.8	19.2	17.8
4	24.9	23.9	23.4	24.4	24.2	24.2	24.8	23.1	24.6	24.2	21.9	21.7	20.7	20.4	20.4	21.1	22.2	19.9	19.3	18.9	19.9	20.9	23.3	22.6	23.4	21.8	21.4	22.4	21.7	23.2	23.0	23.7	22.6	22.0
5	26.7	25.5	26.2	26.6	27.6	26.3	27.9	26.0	25.7	26.3	24.8	23.8	23.8	22.8	22.5	23.4	24.1	21.9	21.9	20.6	22.0	23.0	24.5	24.4	25.1	23.8	23.5	24.4	24.3	24.4	25.1	26.5	25.1	24.3
6	29.6	28.8	29.3	29.7	30.6	28.3	30.3	28.4	27.5	28.0	26.6	26.1	25.1	25.4	24.6	26.3	26.7	24.1	24.0	23.1	23.9	25.2	26.3	28.0	28.0	25.7	25.7	26.2	26.9	28.0	28.3	28.0	26.8	26.7
7	32.3	31.8	32.4	31.2					29.6	30.1	29.1	28.7	27.3	30.6	27.4	29.0	28.0	26.4	26.3	25.2	26.4	27.3					27.5	26.7				29.5	27.6	
8																																31.5		
9																																33.5		
10																																35.0		
Total	25.9	24.7	22.3	24.5	25.9	20.5	24.8	23.1	20.8	22.7	17.4	19.6	20.2	19.7	19.1	19.7	18.0	18.0	19.4	20.0	20.7	19.7	21.2	21.0	21.0	21.9	22.1	20.2	21.2	21.6	21.8	22.2	21.3	20.8

[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.

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	2018	2019	2020	2021
1											122	1	9	3	181	15						1	8	0		1	0		0			1		
2		1		44		788	43	236	342	70	5608	474	115	371	1100	1387	2742	179	81	30	47	151	111	61	22	6	2	109	23	66	105	101	145	13
3	136	82	365	265	304	376	88	268	956	337	3892	2392	1714	1867	4468	1647	960	6903	1813	387	471	178	418	89	89	19	34	39	109	110	248	592	260	170
4	55	69	39	468	475	205	73	128	183	508	1379	1496	1274	1733	717	559	643	524	1056	1221	503	124	275	106	54	61	18	92	214	202	194	544	572	162
5	182	19	91	388	1373	446	181	215	152	98	534	601	534	1388	1287	909	783	1050	745	1276	686	100	24	33	15	38	69	15	49	61	156	144	175	71
6	164	74	27	100	128	49	8	122	57	26	201	204	165	387	800	231	133	758	370	588	401	24	0	0	0	4	18	16	6	3	4	4	15	4
7	13	13	1	32					44	8	15	8	67	1	55	5	21	141	62	129	28	7	0									2	0	
8										0																						1		
>8																																1		
Total	549	258	523	1296	2280	1864	391	968	1734	1046	11750	5177	3878	5750	8608	4752	5281	9554	4126	3631	2137	585	836	290	179	128	140	271	401	442	706	1391	1167	419

[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.

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	2018	2019	2020	2021
1		0									84	1	6	2	114	7						1	9	0		1	0		0			1		
2		1		151		2144	145	665	609	161	9367	832	201	638	2178	2913	4660	187	88	38	80	410	373	181	59	22	4	352	65	188	285	229	281	21
3	615	389	1824	1240	1304	2083	554	1609	5174	1590	14892	7811	6005	5049	15341	6773	3730	15782	5047	837	1407	720	2230	461	446	87	121	213	535	569	1301	3085	1044	550
4	475	519	280	3868	4065	1823	681	962	1654	4197	8146	9016	6417	8491	3423	2830	3969	2109	3866	4764	2255	668	2054	705	408	386	103	666	1395	1549	1357	4254	3706	943
5	1933	173	906	4107	17010	4948	2374	2313	1593	1045	4557	4784	4118	9410	8233	6250	6206	5702	4037	6330	4075	702	227	267	136	306	505	140	450	546	1402	1569	1541	547
6	2356	946	376	1453	2130	675	124	1728	731	333	2122	2138	1483	3605	6602	2250	1430	5531	2669	3971	2995	216	0	4	6	42	168	181	75	33	48	55	161	39
7	236	224	19	534					700	123	199	112	772	11	616	64	254	1365	592	1105	279	78	0			0	0					32	0	
8																																15		
>8																																35		
Total	5615	2252	3405	11352	24508	11673	3879	7276	10461	7449	39365	24695	19002	27206	36508	21087	20248	30675	16299	17045	11092	2794	4893	1619	1055	844	900	1551	2521	2885	4394	9273	6734	2101

[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	3711	0.26	1.13
2002	2125	11004	0.40	3.36
2003	0	13869	0.00	4.24
2004	41818	27415	7.96	8.38
2005	3741	1792	0.71	0.55
2006	7498	809	1.43	0.25
2007	3824	282	0.73	0.09
2008	4969	473	0.95	0.14
2009	3011	1514	0.57	0.46
2010	954	1106	0.18	0.34
2011	2440	611	0.46	0.19
2012	160	216	0.03	0.07
2013	102	63	0.02	0.02
2014	56	242	0.01	0.07
2015	427	1111	0.08	0.34
2016	390	230	0.07	0.07
2017	1411	676	0.27	0.21
2018	552	1048	0.11	0.32
2019	3536	1010	0.67	0.31
2020	25332	1449	4.82	0.44
2021	6582	125	1.25	0.04

Table 13. Abundance at age 1 and average-weighted in the survey from juvenile bag.

year	R (age 1) juvbag ('000)	R(age1)juvbag Av_weighed
2001	380	0.06
2002	6044	0.92
2003	48165	7.30
2004	2314	0.35
2005	9515	1.44
2006	953	0.14
2007	5123	0.78
2008	5916	0.90
2009	1504	0.23
2010	6102	0.93
2011	1050	0.16
2012	42	0.01
2013	195	0.03
2014	239	0.04
2015	61	0.01
2016	1592	0.24
2017	6669	1.01
2018	327	0.05
2019	31594	4.79
2020	5912	0.90
2021	4729	0.72

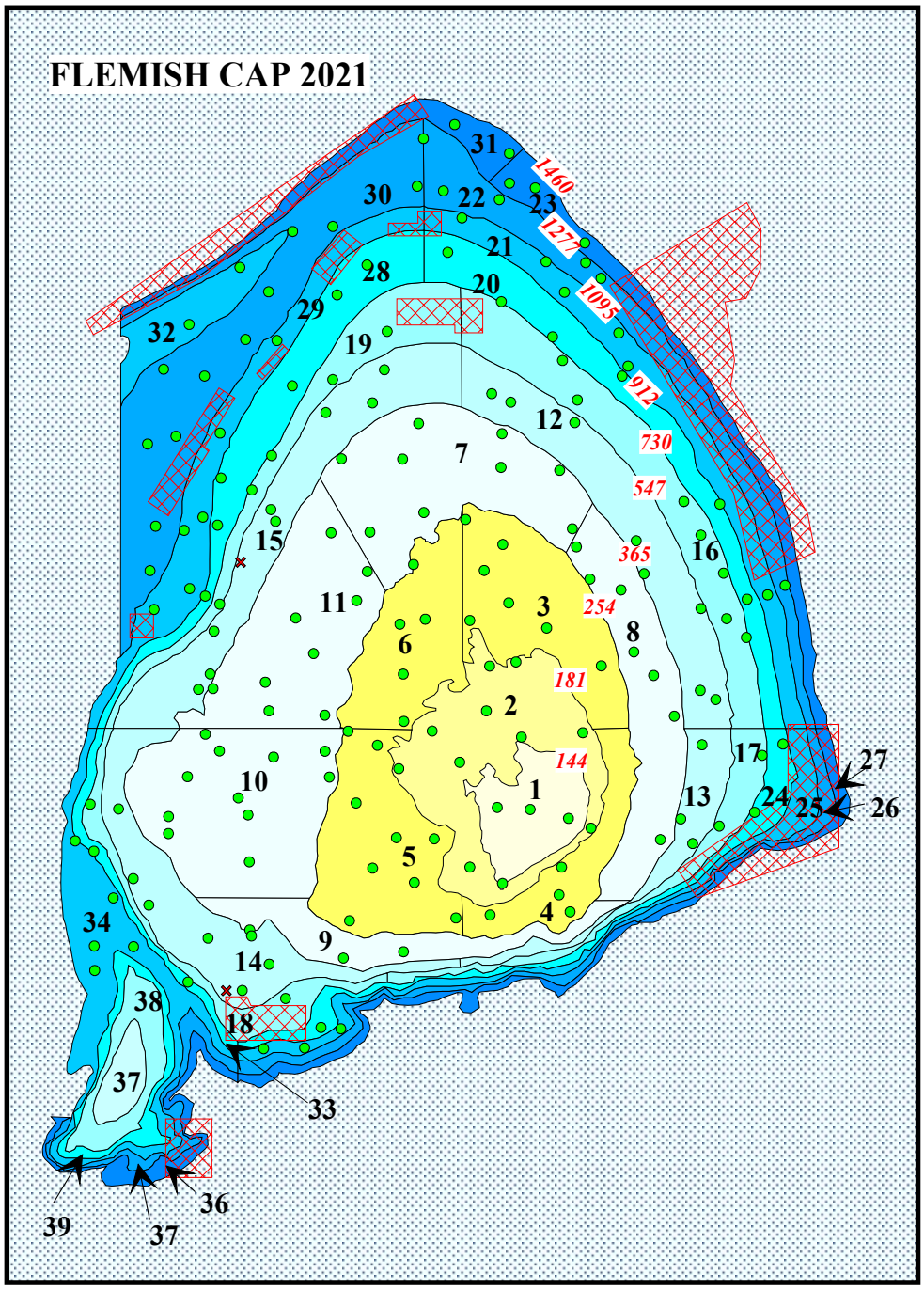

Figure 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2021.

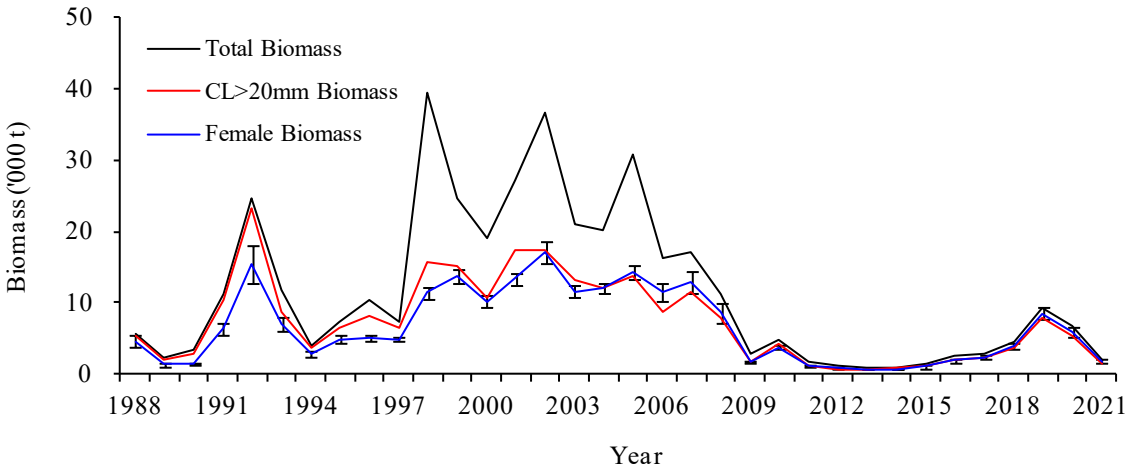

Figure 2. Total, female and adult biomass (shrimp bigger than 20 mm CL) from EU Flemish Cap 1988-2021 surveys.

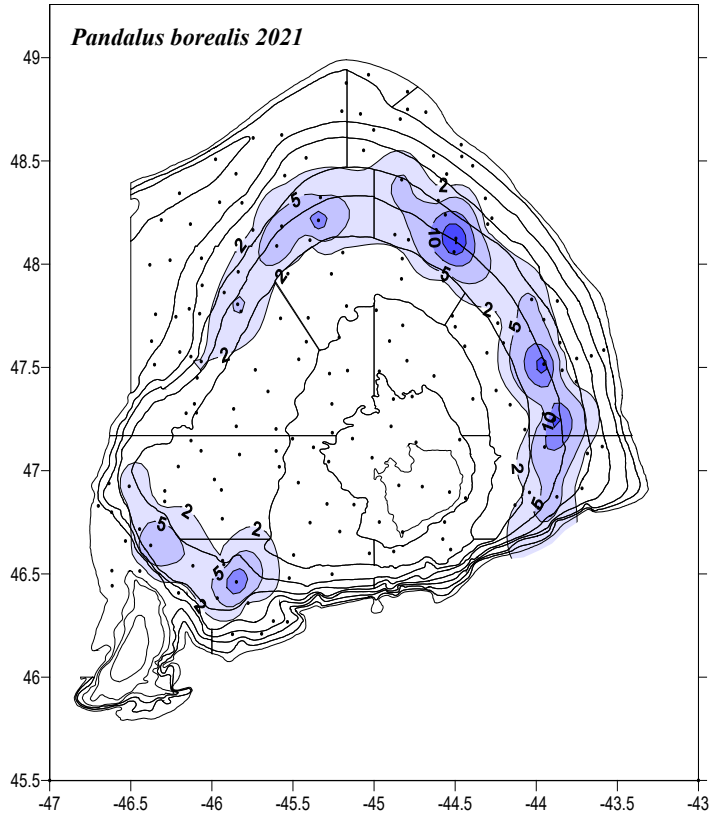

Figure 3. Shrimp catches distribution (kg/tow) from EU Flemish Cap survey in summer 2021.

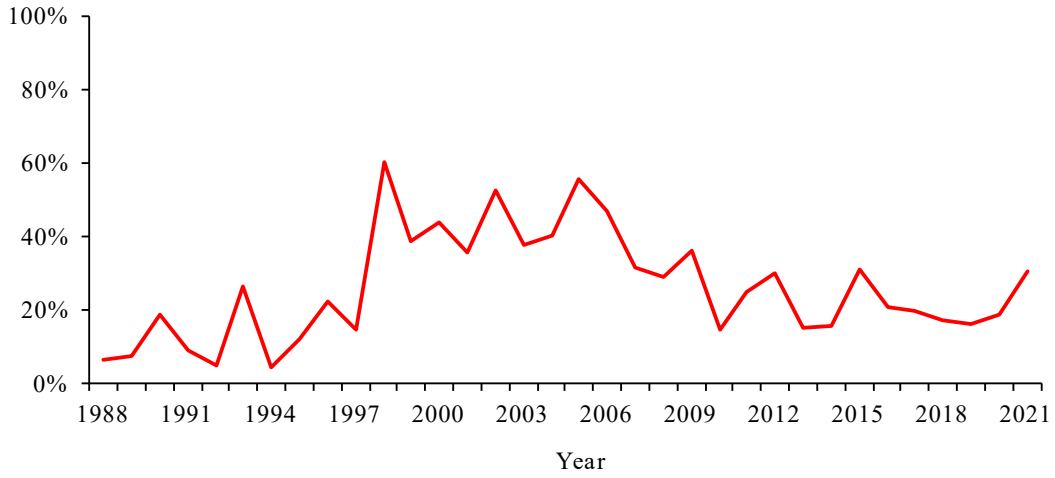

Figure 4. Differences between total biomass and adult biomass (>20 mm CL) as percentage of Total biomass from EU Flemish Cap 1988-2021 surveys.

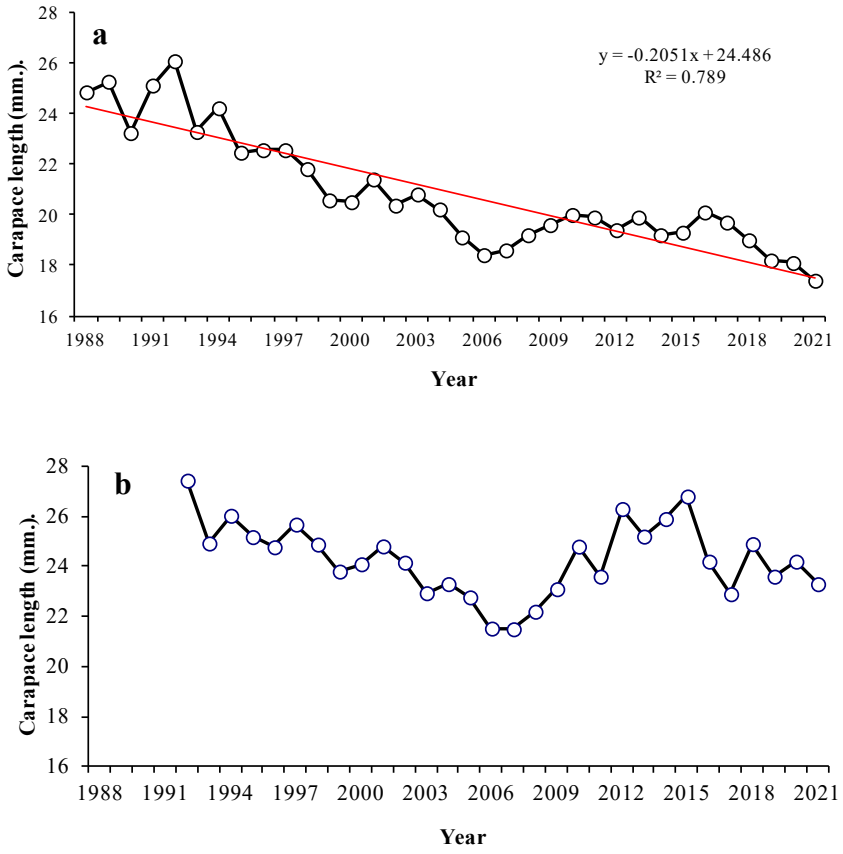

Figure 5. Lengths (CL) at sex change (a) and maturity (b) of shrimp in EU Flemish Cap surveys

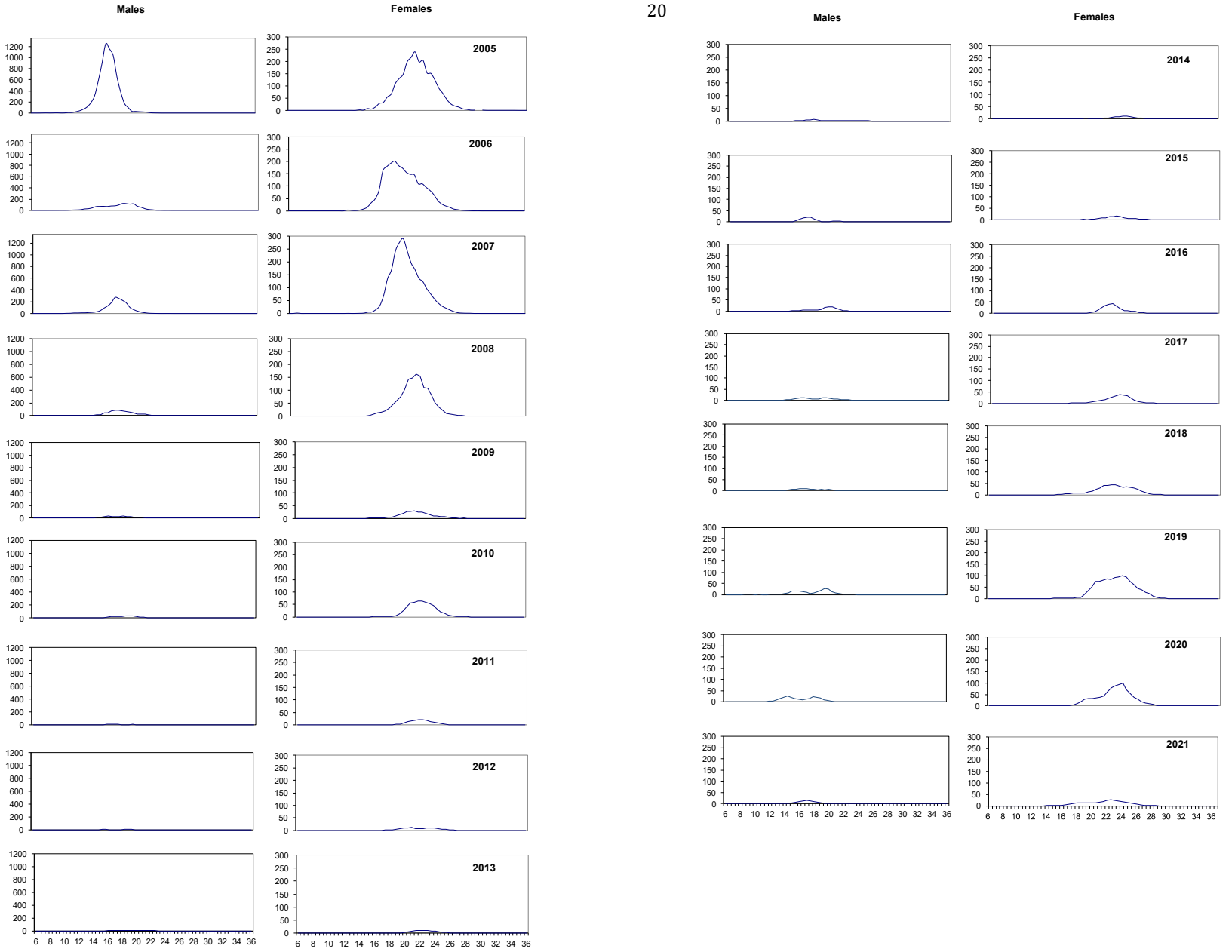

Figure 6. Shrimp size distribution from Flemish Cap 2006 -2021 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).

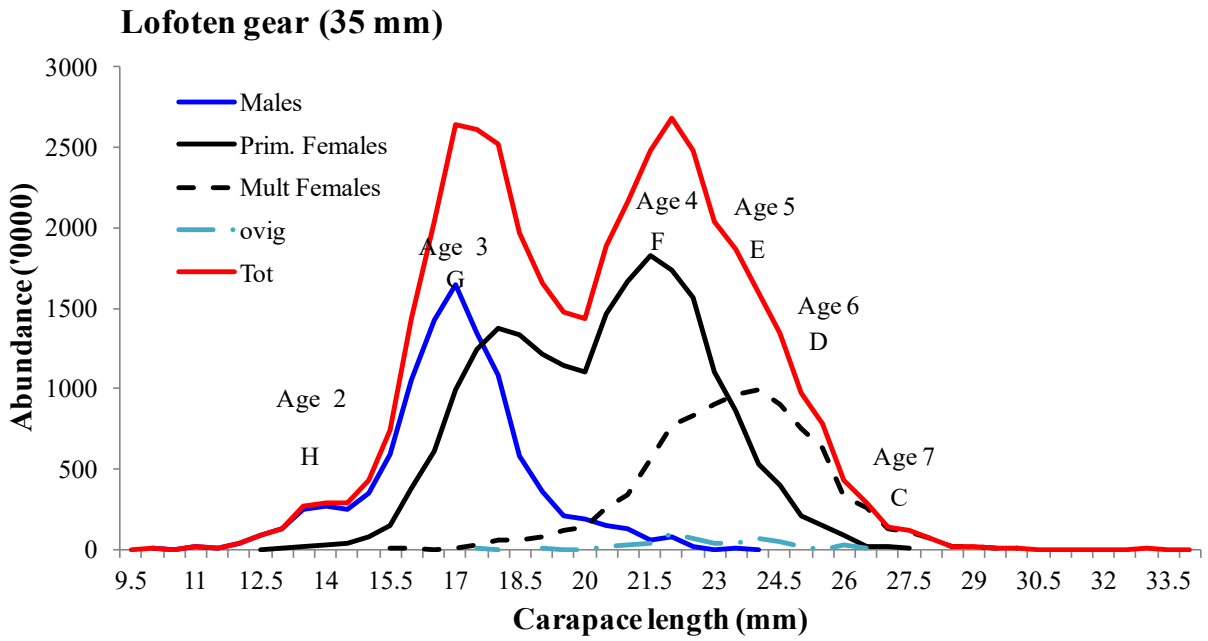

Figure 7. Shrimp modal and age groups in 2021 EU Flemish Cap survey (letters from table 7).

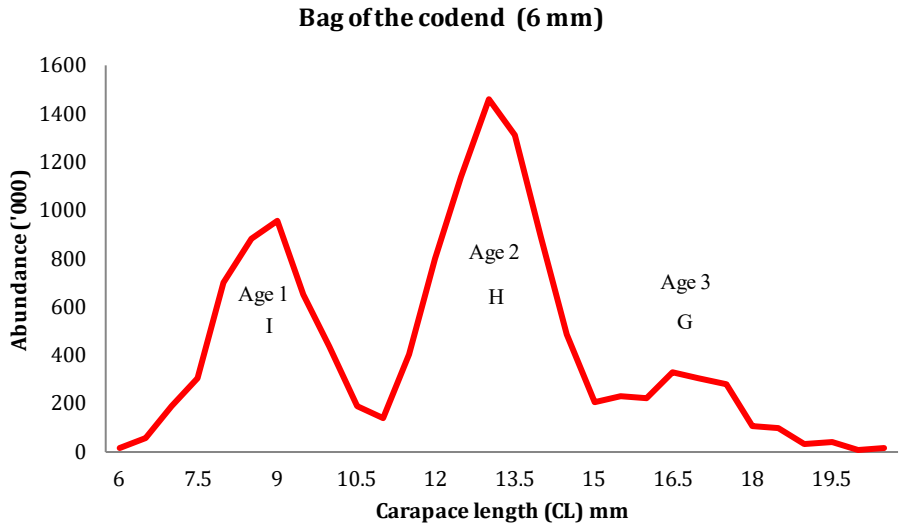

Figure 8. Shrimp modal and age groups in 2021 EU survey on Flemish Cap from juvenile bag. (letters from Table 7).

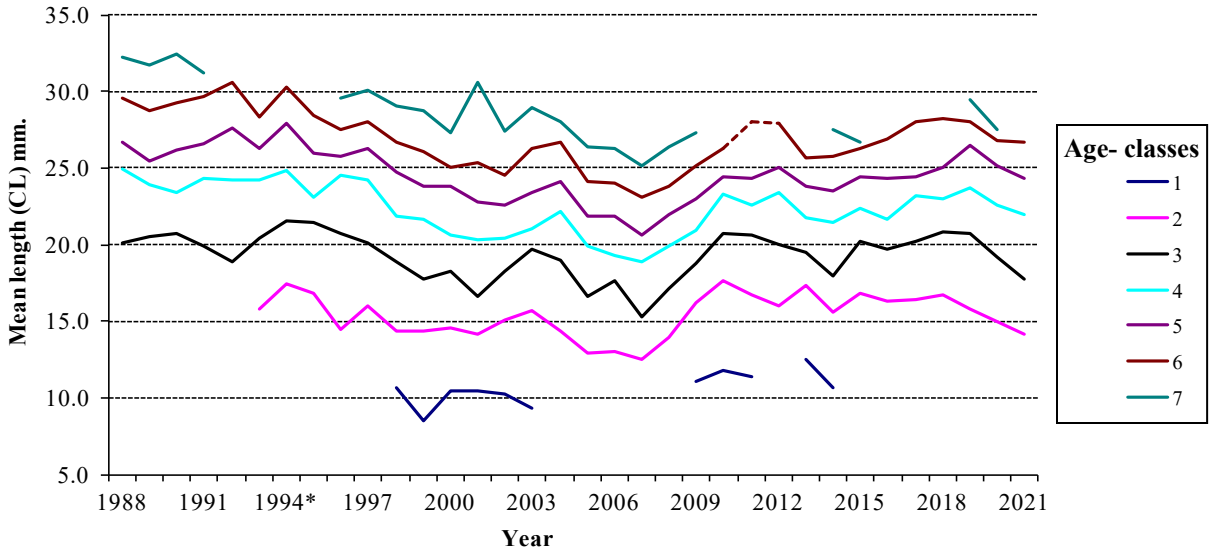

Figure 9. Shrimp mean lengths at age in the series of EU surveys on Flemish Cap.

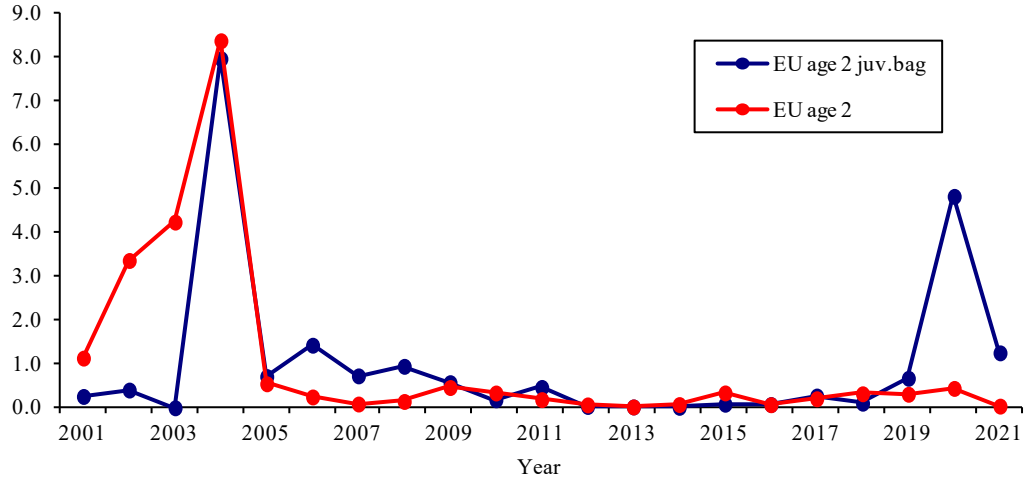

Figure 10. Abundance indexes at age 2 (weigthed-average) obtained in EU Flemish Cap surveys from Lofoten gear (red line) and Juvenile bag (blue line).

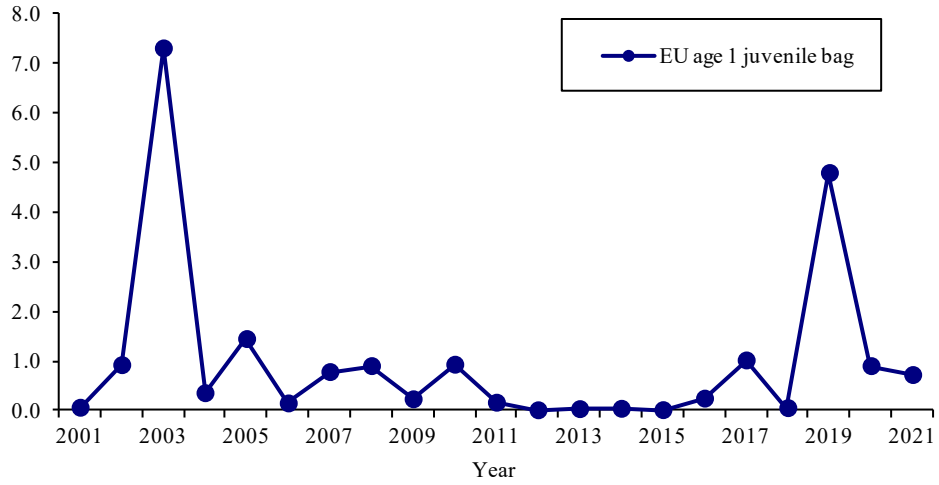

Figure 11. Abundance indexes at age 1 (weigthed-average) obtained in EU Flemish Cap surveys from Juvenile bag .