Northwest Atlantic Fisheries Organization

Serial No. N7017 **NAFO SCR Doc.19/053**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP—November 2019

Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2019

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 29th to July 29th 2019. 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 180 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 indexes have increased significantly since 2015 and they are now well above B_{lim}. The total and female biomasses estimated in 2019 were 9273 t and 8486 t respectively. 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 similar to the estimated in 2018 at levels next to reported in 2009 and 2010. However unlike 2018 the abundance at age 2 in the small mesh size bag attached on the cod-end showed a significantly increasing that it could confirm the upward trend in the recent recruitments initiated from 2014. Also in 2019 the estimated abundance at age 1 in the juvenile bag was the second highest value in the historical series. If this strong year-class (2018) was confirmed in 2020 it would improve the state of impaired recruitment and contribute to the recovery of stock. The stock after five years of continuous increases of biomass, now it has very low probability of being bellow B_{lim}, allowing a small amount of direct fishing on this stock. Considering the uncertainty about the future recruitments in the fishable stock the next years, Scientific Council advises that the exploitation level for 2020 not to exceed 2009 level.

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 2018. Also they are compared with that obtained between years 2003-2017 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 2019 the survey was carried out from June 29th to July 29th. The area prospected in Flemish Cap was spread up to 1450 meters. In 2019 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 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).

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 180 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 2019 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 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 total biomass index increased significantly year after year reaching 9 273 t in 2019 (Table 2 and Fig. 2).

Biomass estimated by depth strata from 1988 to 2019 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 (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 2019 survey (Fig. 3) showed a patched distribution around the central area of the bank but with greater presence (58% of the biomass) in depth strata (201-300 fth.).

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2019 (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 2019 was 7 753 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 2019 the estimated female biomass (8 486 t) was about 110 % higher than 2018 and it is now above 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. 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.), varied without trend between 2010 and 2017 and decreased in 2019 to the lowest value in the historical series (18.2 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 2019 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 2005-2019 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 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 2019 the absence of strong year classes from

the main gear persisted and the increase of biomass was mainly caused by the greater abundance of females with sizes around 20-26 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. The estimated biomass and length distributions obtained with the small mesh size bag in 2019 survey are presented in Table 6. The estimated biomass was 26 t and the length distribution showed one clear modes at 9 mm and another weaker around 14-16 mm. CL, corresponding to age-classes 1-2 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 2019.

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 2019 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 2019 identified 10 age groups (ages 1 to 10), but the youngest (1 year old) and the oldest (> 8 year old) were poorly estimated due to the scarce frequency in the length samples. The age at sex change was 3 years old with 18.2 mm CL. The increase of biomass estimated in 2019 (around 131% compared to 2018) was mainly due to the greater abundance of age classes 3 and 4.

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 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. From 2007 this trend changed and the mean lengths at age increase up to 2010. Since then the mean lengths have been changing 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 old 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 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 2017.

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. However, although the recruitments (age 2) has been rather weak since 2014, they have increased and allowed the recovery of the stock. Also in 2019 the significant increase of shrimps with one year old recorded from the juvenile bag seems to indicate the entry of a new and strong year-class 2018 (age 1 in 2019) that it could improve the recruitment in the fishable stock in 2020 and 2021 (age 2 and 3 respectively) (Fig. 11 and Table 13).

The data used in this paper have been funded by the EU through the European Maritime and Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

References

Casas, J. M. , J. L. del Rio, J. Teruel and A. Alonso. 2005. Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2005. *NAFO SCR Doc*., No.78. Serial No. N5183, 28 p.

Del Rio, J.L. 1998. Northern shrimp (*Pandalus borealis*) on Flemish Cap in July-August 1998. *NAFO SCR Doc*98/81 Serial Nº. 3082. 12 p.

Garabana, D. 1999. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July 1999. *NAFO SCR Doc*., No. 106. Serial No. 4186, 15 p.

McCrary, J.A. 1971. Sternal spines as a characteristic for differentiating between females of some pandalidae. *J. Fish. Res. Board Can*. 28: 98-100.

Rasmussen, B. 1953. On the geographical variation on growth and sexual development of the deep sea prawn (*Pandalus borealis*, Kroyer). *Fish. Dir. Skr. Ser Hav Unders*. 10 (3): 1-160.

Shumway, S.E., H.C. Perkins, D.F. Schick and A.P. Stikney**.** 1985. Synopsis of biological data on the Pink Shrimp (*Pandalus borealis*, Kroyer, 1838). *NOAA Techn. Rep. NMFS* 30, 57 p.

Skúladóttir, U. and P. Diaz. 2001. Age assessment of Northern Shrimp (*Pandalus borealis*) in EU surveys on Flemish Cap in 1988-2001. *NAFO SCR Doc*., No. 189. Serial No. 4579, 8 p.

Table 1. Technical data of bottom trawl research surveys on EU Flemish Cap 2019.

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 1988-2019 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

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

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

Table 3. cont.

Stratum	Depth (Fathoms)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	70-80									198					0	1	
2	81-100	217	193	8	50			1	0	0	0		0		1	0	0
3	101-140	2107	1207	477	20	11	1	21	1	0	5	0	1	12	14	13	51
4	101-140	785	2739	1195	11	1	3	15	0	1	0	1	0	1	4	6	0
5	101-140	867	847	664	558	11	28	21	1	8	5	2	1	5	23	24	116
6	101-140	1250	1080	299	462	23	1	43	0	3	7	1	3	18	19	30	14
7	141-200	3108	3202	1370	1642	468	32	495	8	46	81	29	74	277	635	245	366
8	141-200	2043	5747	3084	709	1938	308	326	6	31	56	17	65	364	206	261	444
9	141-200	673	808	1435	1277	1159	48	235	31	21	32	10	36	32	137	122	386
10	141-200	2489	2935	614	3248	671	154	467	58	31	36	25	223	246	428	359	968
11	141-200	2350	2728	1086	2878	368	174	712	16	64	48	73	124	113	358	478	639
12	201-300	1222	1980	1524	1965	1585	569	1060	242	208	204	263	219	649	488	857	1729
13	201-300	230	903	691	373	1080	149	80	56	67	92	152	378	275	122	376	709
14	201-300	726	2750	923	1481	1593	215	305	460	79	118	141	150	158	110	308	825
15	201-300	993	1374	1539	1597	1944	649	824	407	133	101	113	177	257	243	1027	2197
16	301-400	696	1587	840	526	108	145	188	208	115	34	37	60	30	59	69	531
17	301-400		10	196	56	33	2		8	0	0		1	33	2	10	0
18	301-400	42	56	115	8	10	3	20	9	0	0		0		0		
19	301-400	366	530	173	187	61	278	77	172	35	25	36	16	8	35	209	298
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		3
25	501-600									0							
28	401-500	52	138	175	54	71	26		11	7	11	0			11	10	49
29	501-600							1				0					
30	601-700							0			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		0	0
%	<140 ftm.	25.8	19.5	16.1	6.4	0.4	1.2	2.1	0.1	20.1	2.0	0.4	0.3	1.4	2.1	1.7	1.9

Table 4. Shrimp length frequencies (x 10^4) and percentages by sex and maturity stage from EU Flemish Cap 2019.

LENGTH (mm CL)	MALES	FEMALES		
		Primiparous	Multiparous	Ovigerous
8.5	12			
9	15			
9.5	26			
10	7			
10.5	29			
11	0			
11.5	2			
12	11			
12.5	126			
13	75	7		
13.5	248	57		
14	491	32		
14.5	741	133		
15	1531	207		
15.5	1621	176		
16	1636	294		
16.5	1214	243		
17	884	353	1	
17.5	517	414	0	
18	673	545	7	
18.5	1249	1583	19	
19	1837	3115	80	
19.5	2622	4860	80	
20	2375	6951	297	5
20.5	1269	7007	382	
21	848	7006	841	
21.5	297	6975	1451	
22	116	5698	2511	
22.5	70	5705	3417	7
23	37	4251	4944	
23.5	31	3774	6048	9
24	5	4426	4889	
24.5	5	3271	3985	2
25	1	2191	3797	
25.5	0	1219	3195	
26	4	612	3268	
26.5		351	2314	
27		136	2152	
27.5		14	964	
28		31	577	1
28.5		22	165	
29		3	130	
29.5		0	95	
30		16	66	
30.5		16	20	
31		0	35	
31.5		16	32	
32		16	0	
32.5		0	0	
33		0	16	
33.5		0	16	
34		16	0	
34.5		16	32	
35			48	
35.5			0	
36			16	
36.5			16	
Total	20628	71757	45907	25
Percentage %	14.9%	51.9%	33.2%	0%

Table 5. Males percentage as total biomass of northern shrimp from EU Flemish Cap 1988 - 2019 surveys.

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

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Males (%)	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	20.1	7.8	8.5
<20mm CL (%)	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	17.4	16.4

[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 2019 survey.

Length (CL) mm	Frequency	Length (CL) mm	Frequency
5.5	8	15	529
6	92	15.5	416
6.5	140	16	644
7	1005	16.5	270
7.5	1752	17	133
8	4248	17.5	128
8.5	6058	18	34
9	7527	18.5	141
9.5	5729	19	139
10	3766	19.5	93
10.5	1782	20	111
11	423	20.5	32
11.5	169	21	10
12	89	21.5	33
12.5	153	22	22
13	211	22.5	0
13.5	186	23	20
14	415		
14.5	557	Total	37065
Biomass	26 t		

Table 7. Shrimp modal groups by sexes and ages with Lofoten gear and bag in the codend in 2019 from EU Flemish Cap survey interpreted from size distributions.

LOFOTEN			
Age	Modal groups		Cohort
	Males	Females	
1	10	-	G
2	16.0	-	F
3	19.5	20.5	E
4	-	24.0	D
5	-	26.0	C
6	-	27.0	B
7	-	-	

BAG ON THE CODEND		
Age	Modal groups	Cohort
1	9	G
2	16	F
3	19.5	E

Table 8. Results of the modal analysis (MIX) by sex and maturity stage from EU Flemish Cap surveys 2019 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	0.885	0.0057	0.004	0.0005				
2	0.099	0.0062	0.412	0.0036	0.021	0.0006		
3	0.016	0.0035	0.583	0.0036	0.652	0.0047		
4					0.324	0.0046	0.673	0.0083
5					0.000	0.0000	0.312	0.0085
6					0.002	0.0003	0.005	0.0006
7							0.004	0.0011
8							0.002	0.0006
9							0.000	0.0000
10							0.003	0.0003
Age	***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***	***Media CL***	***St. Dev.***
1	9.2	0.0186	9.9	0.0700				
2	15.4	0.1038	15.8	0.0116	16.0	0.0337		
3	19.8	0.3760	19.8	0.0122	21.0	0.0143		
4					24.0	0.0196	23.5	0.0204
5					26.5	0.0527	26.5	0.0310
6					28.0	0.2389	28.0	NaN
7							29.5	NaN
8							31.5	NaN
9							33.5	NaN
10							35.0	0.1053
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1	0.922	0.0150	0.597	0.0054				
2	1.321	0.1007	0.948	CCV	0.977	0.0063		
3	1.395	0.2535	1.190	CCV	1.282	CCV		
4					1.465	CCV	1.063	0.0100
5					1.618	CCV	0.985	0.0170
6					1.709	CCV	1.002	NaN
7							1.003	0.1292
8							1.000	0.0943
9							1.000	NaN
10							1.000	0.0768

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

Age	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
1											10.3	8.5	10.3	10.5	10.2	9.3							11.7			12.4			12.1			10.8
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	17.7	16.7	16.1	17.2		16.8	16.3	16.2	16.5	16.4
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	20.9	20.6	20.1	19.4	18.1	20.4	19.7	20.1	20.3	20.9
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	23.7	22.6	23.5	21.8	22.6	22.5	21.7	23.4	22.6	23.5
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	25.7	24.5	25.0	23.9	24.4	25.4	24.3	26.8	24.9	25.9
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	26.9	27.8	26.0	26.1	26.1	26.9		25.8	27.2
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	28.5
8				31.2																												30.2
9																																31.9
10																																33.2
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	19.8	20.2	20.9	20.0	21.6	21.2	21.3	22.1	22.4	20.6	21.4	21.8	22.1	22.4

[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	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
1											94	1	9	3	181	14							8			1			0			1
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	118	111	60	23	6		111	23	69	91	107
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	161	418	90	89	18	35	41	109	128	163	606
4	123	82	404	260	146	376	88	276	153	241	707	1496	1074	2015	1128	548	643	524	1949	1221	857	169	275	109	56	60	43	93	214	245	191	539
5	233	81	92	465	440	205	73	120	273	322	789	601	572	1184	1047	907	783	1050	1205	1276	575	91	24	31	11	40	42	17	49	11	132	140
6	163	83	33	389	1129	446	181	215	65	115	414	204	349	323	311	243	133	758	522	588	40	25	0	0	1	3	6	9	6		29	4
7	15	11	2	103	398	49	8	122	44	16	15	8	61	16	55	9	21	141	65	129		7	0	0							5	2
8				33																												1
9+																																1
Total	548	258	530	1296	2271	1864	391	976	1734	1046	11751	5177	3876	5750	8608	4753	5281	9554	4098	3631	2141	570	828	290	179	128	125	271	401	452	612	1416

[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	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
1											60	1	6	2	114	6							9			1			0			1
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	303	373	177	63	21		359	65	190	267	243
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	600	2230	461	450	85	141	228	535	651	903	3152
4	575	387	2053	1214	705	2083	554	1658	1071	1705	4099	9016	5233	9992	6436	2762	3969	2109	5882	4764	4491	892	2054	726	431	379	316	687	1395	1920	1460	4215
5	2377	626	888	3843	3683	1823	681	892	2703	2853	5719	4784	3838	8321	7758	6197	6206	5702	5547	6330	4084	635	227	250	104	323	379	179	450	124	1353	1530
6	2334	1053	436	4094	13637	4948	2374	2313	827	1249	4038	2138	3112	3087	2696	2339	1430	5531	3606	3971	390	224	0	5	7	35	64	98	75		333	54
7	285	183	28	1478	5801	675	124	1728	700	234	207	112	706	215	616	108	254	1365	621	1105	0	81	0	0	0	0					79	31
8				557																												14
9+																																35
Total	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	4394	9273

[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	0.33	0.98
2002	2125	11004	0.52	3.24
2003	0	12572	0.00	3.70
2004	41818	27415	10.14	8.07
2005	3741	1792	0.91	0.53
2006	7498	582	1.82	0.17
2007	3824	301	0.93	0.09
2008	4969	221	1.20	0.07
2009	3011	1177	0.73	0.35
2010	954	1106	0.23	0.33
2011	2440	601	0.59	0.18
2012	160	229	0.04	0.07
2013	102	63	0.02	0.02
2014	56	0	0.01	0.00
2015	427	1111	0.10	0.33
2016	390	230	0.09	0.07
2017	1411	695	0.34	0.20
2018	552	912	0.13	0.31
2019	3536	1073	0.86	0.32

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

year	R (age 1) juvbag ('000)	R12)juvbag Av_weighed
2001	380	0.06
2002	6044	0.90
2003	48165	7.16
2004	2314	0.34
2005	9515	1.41
2006	953	0.14
2007	5123	0.76
2008	5916	0.88
2009	1504	0.22
2010	6102	0.91
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	0.99
2018	327	0.05
2019	31594	4.70

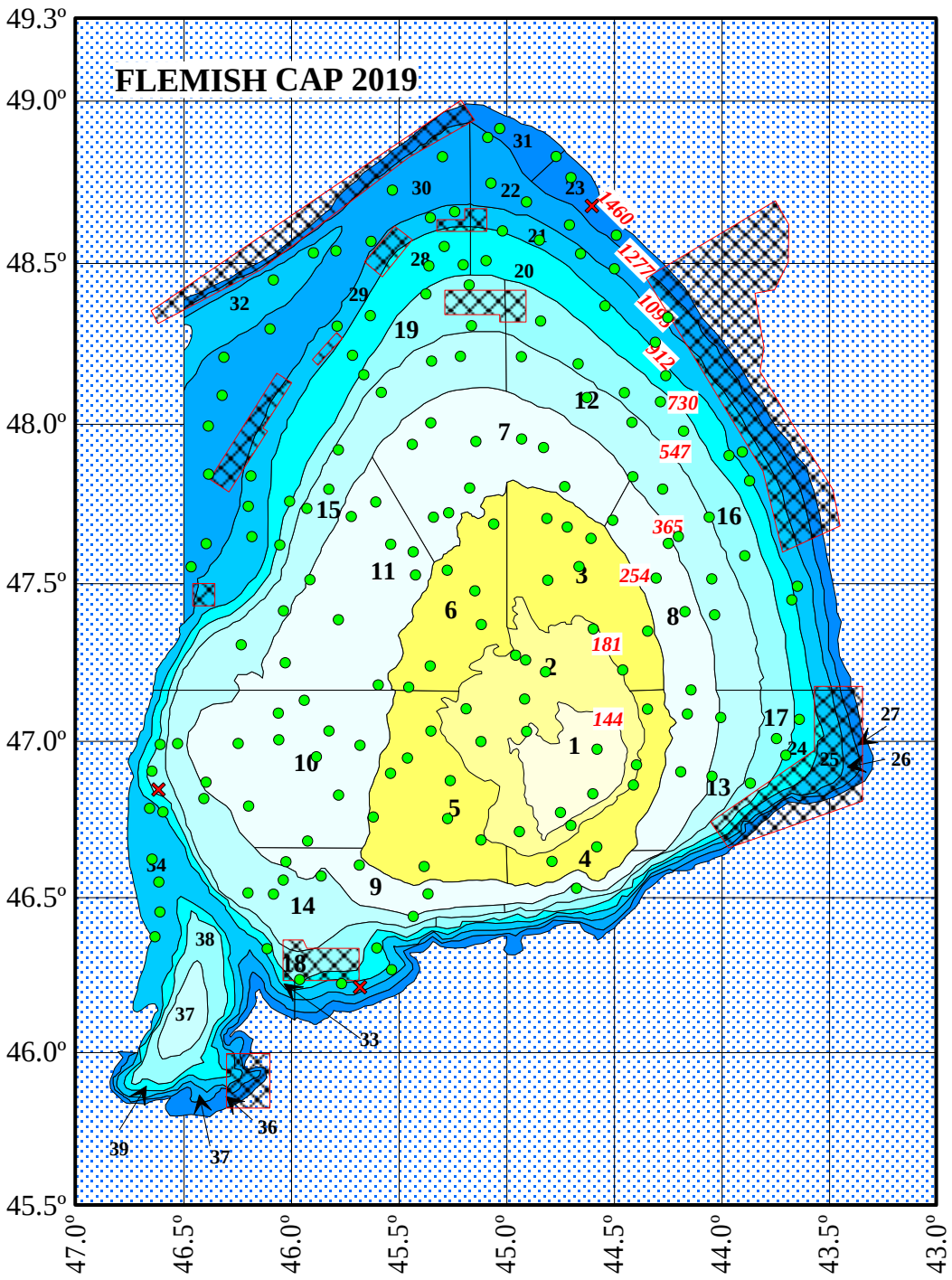

Figure 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2019.

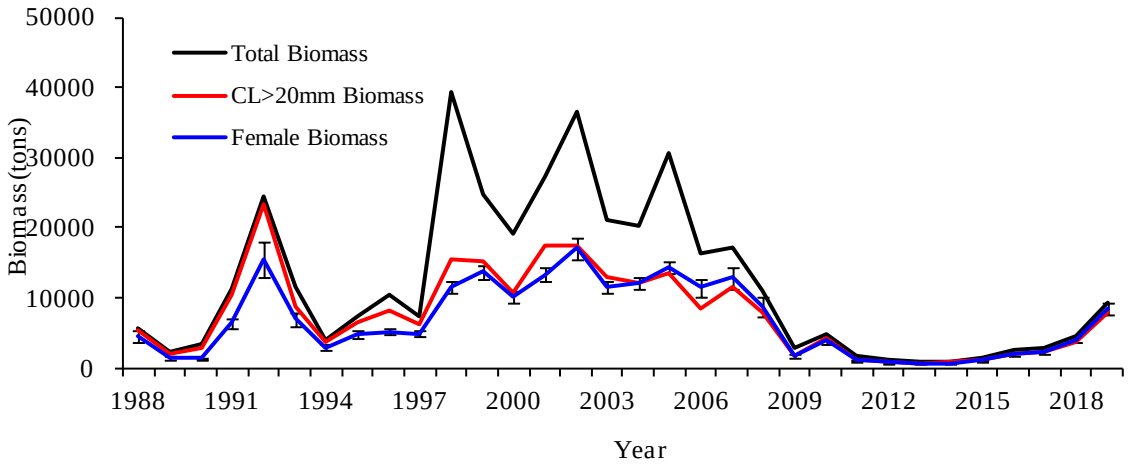

Figure 2. Total, female and adult biomass (shrimp bigger than 20 mm CL) from EU Flemish Cap 1988-2019 surveys.

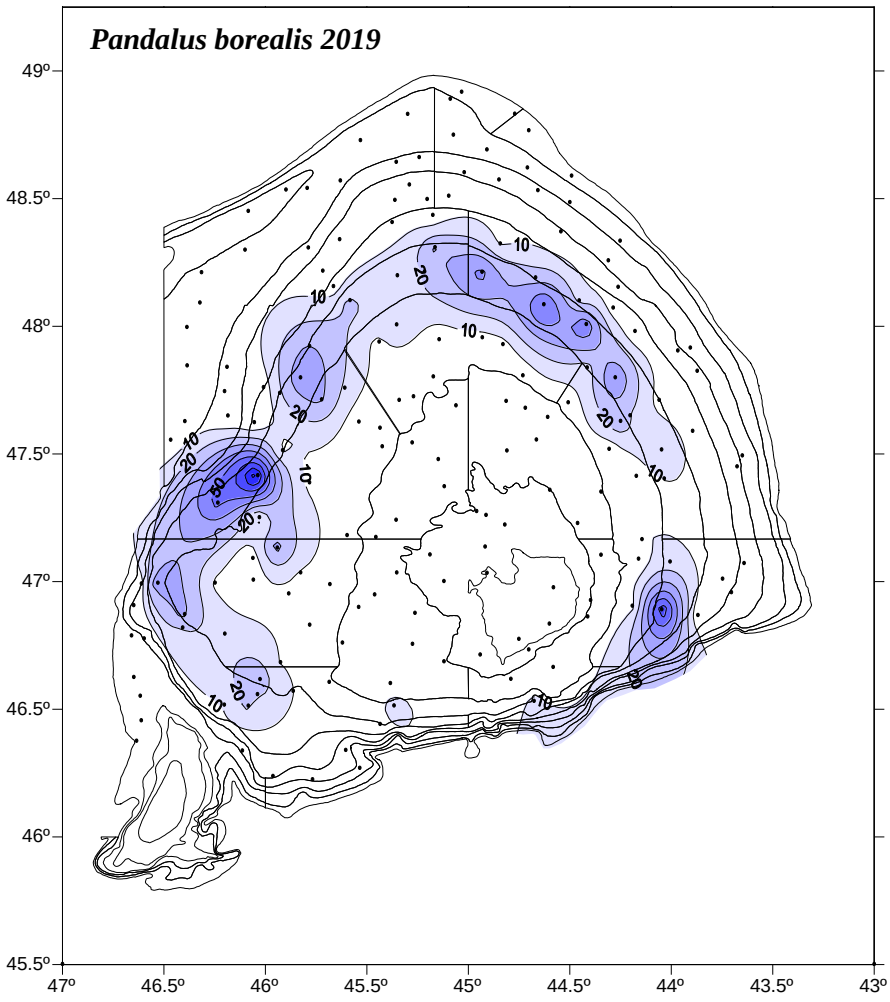

Figure 3. Shrimp catches distribution (kg/tow) from EU Flemish Cap survey in summer 2019.

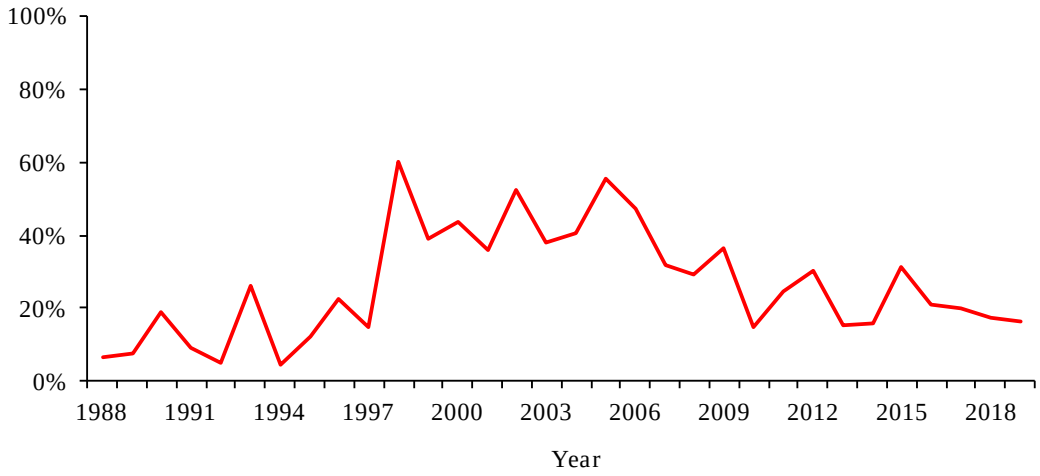

Figure 4. Differences between total biomass and adult biomass (>20 mm CL) as percentage of Total biomass from EU Flemish Cap 1988-2019 surveys.

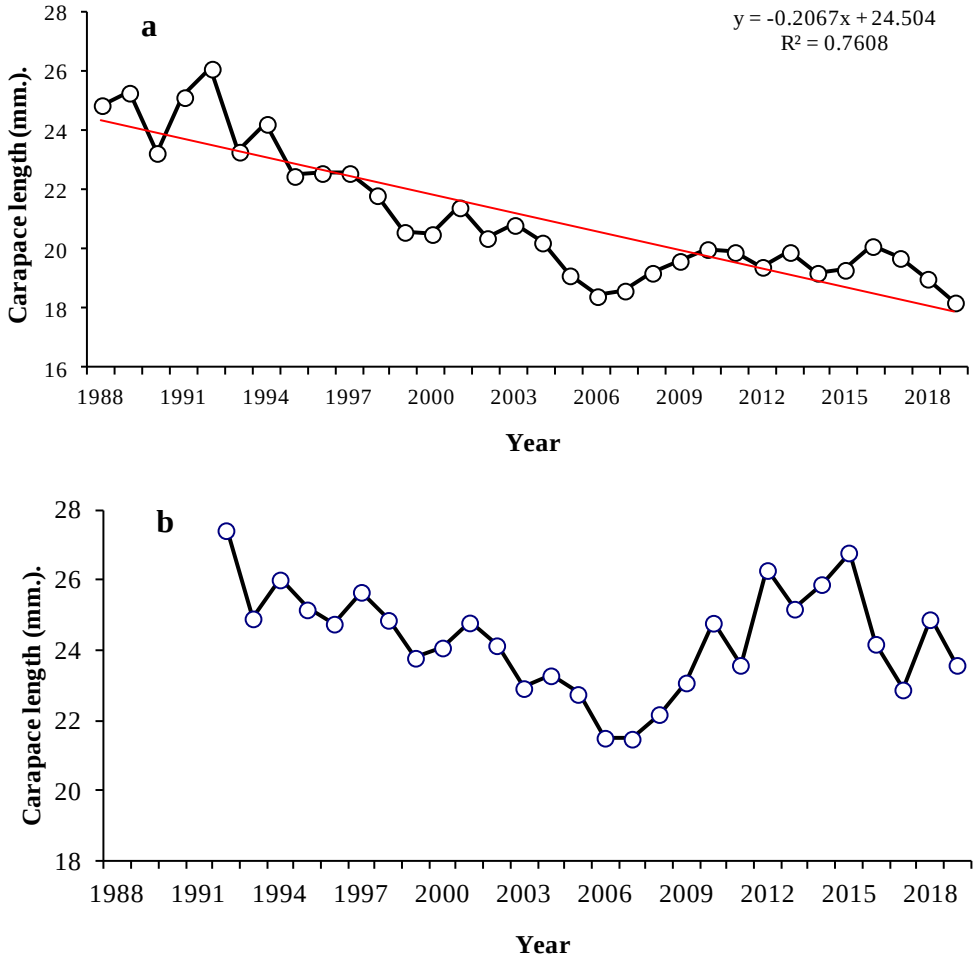

Figure 5. Lengths (CL) at sex change (a) and maturity (b) of shrimp in EU Flemish Cap surveys

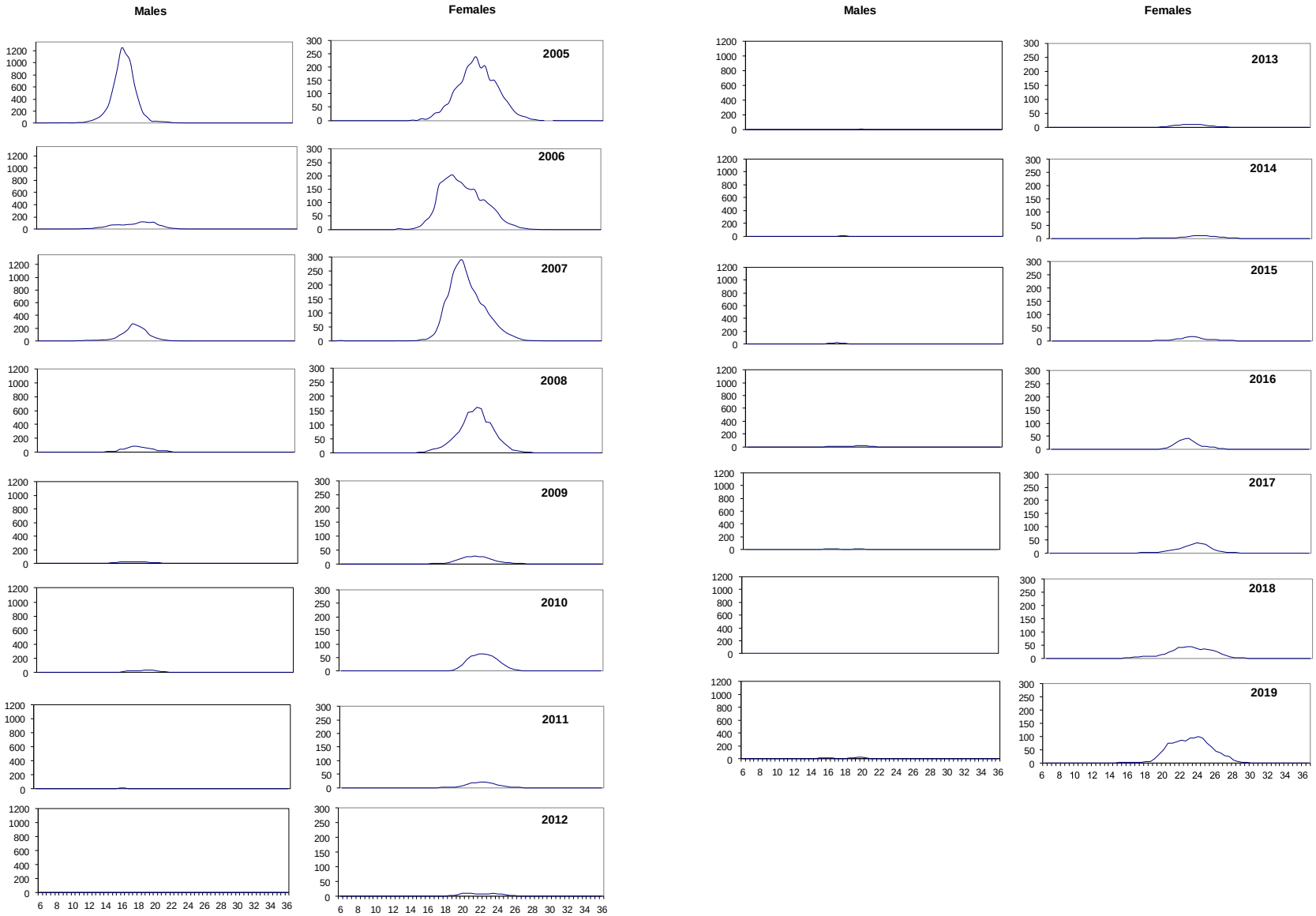

Figure 6. Shrimp size distribution from Flemish Cap 2006 -2019 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).

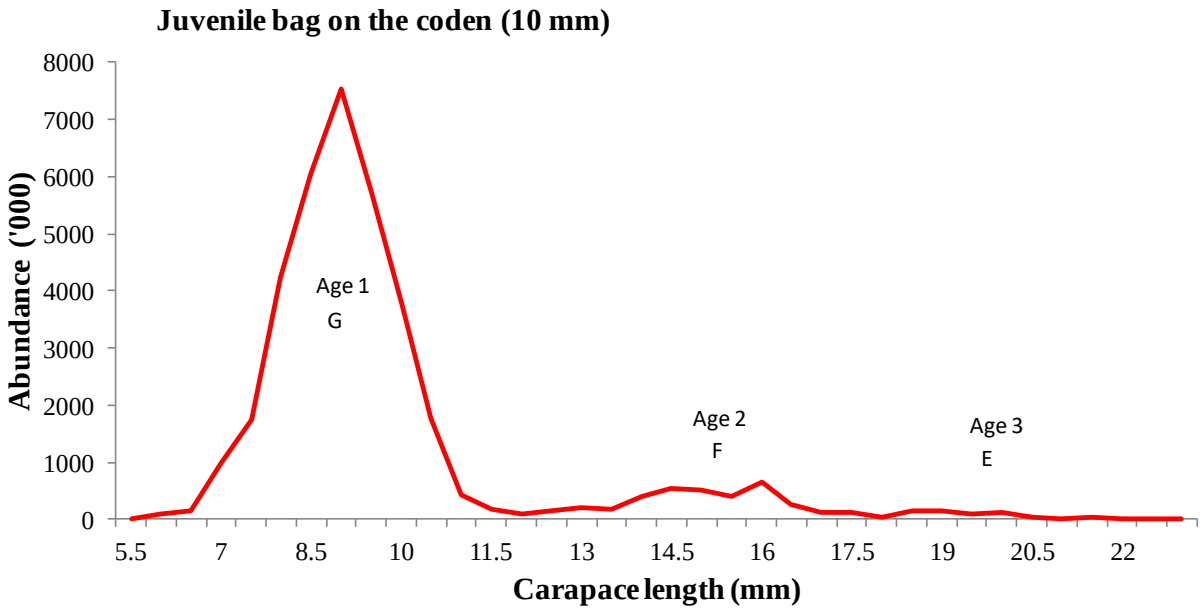

Figure 7. Shrimp modal and age groups in 2019 EU survey on Flemish Cap from juvenile bag. (letters from Table 7).

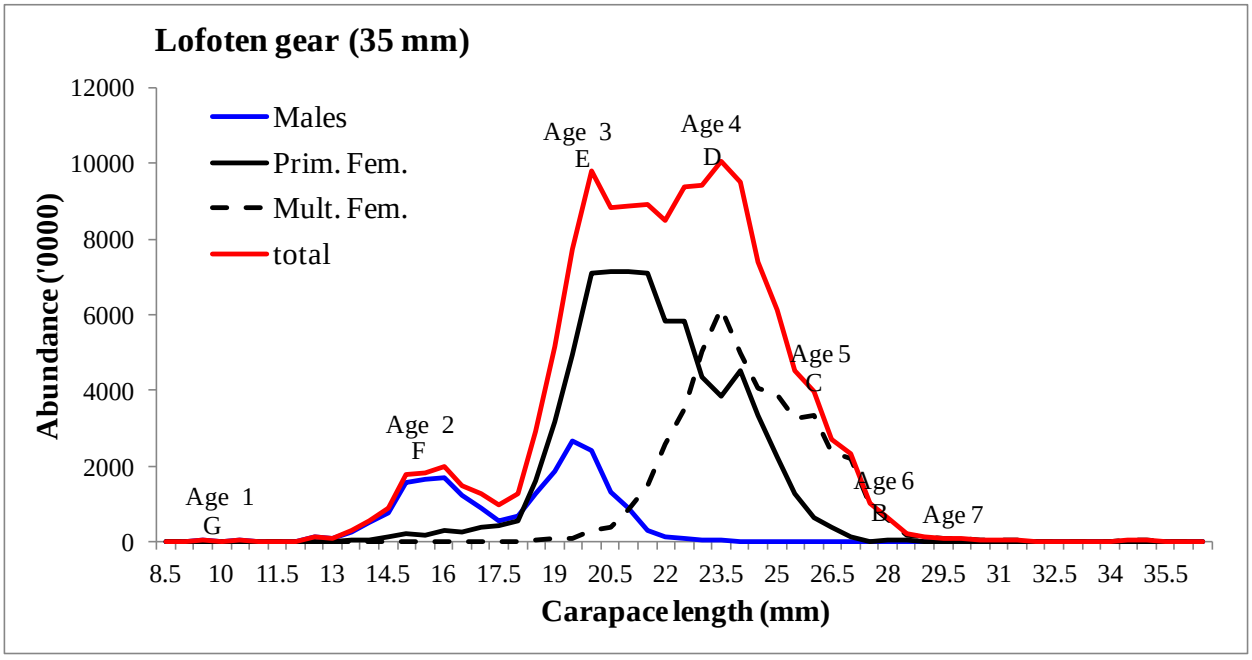

Figure 8. Shrimp modal and age groups in 2019 EU Flemish Cap survey (letters from table 7).

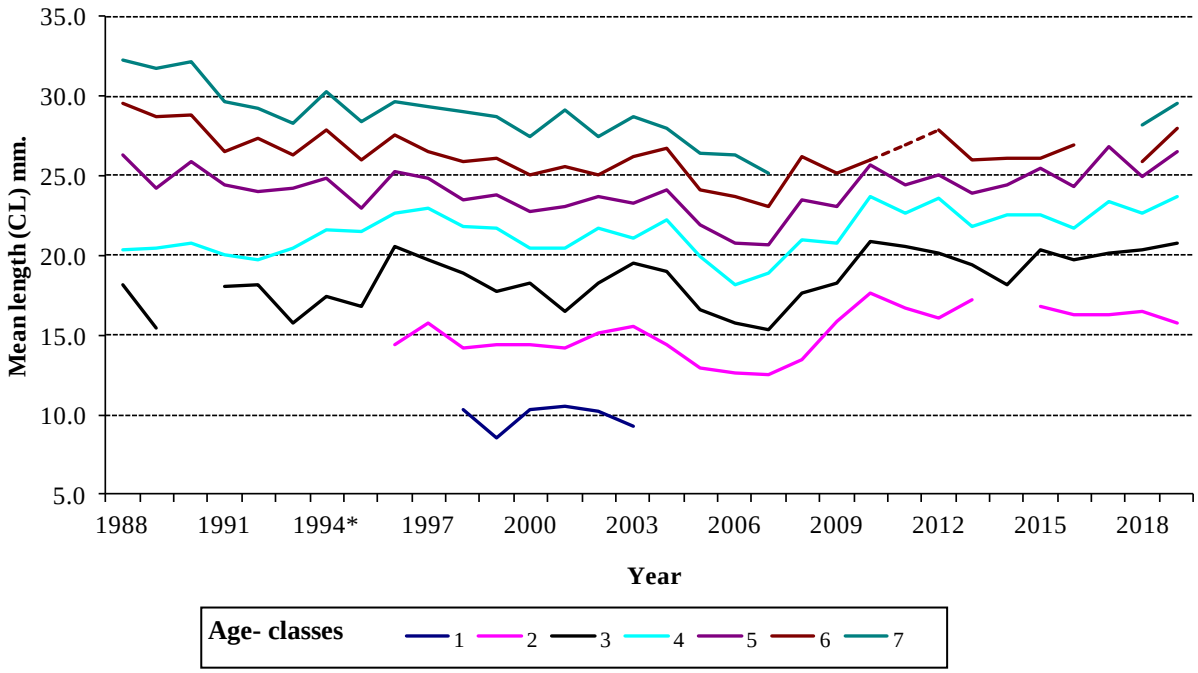

Figure 9. Shrimp mean lengths at age in the series of EU surveys on Flemish Cap.

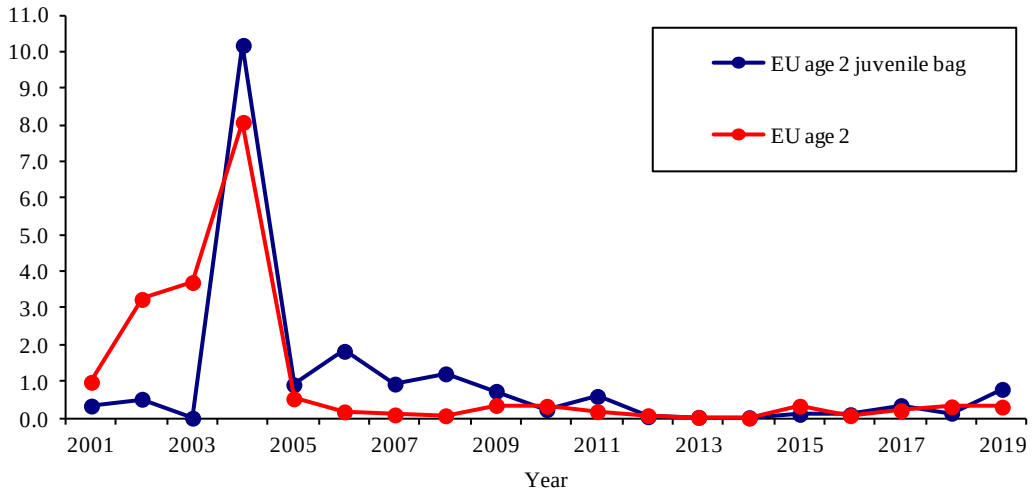

Figure 10. Abundance indexes at age 2 (weigthed-average) obtained in EU Flemish Cap surveys from Lofoten gear (red line) and Juvenile bag (blue line).

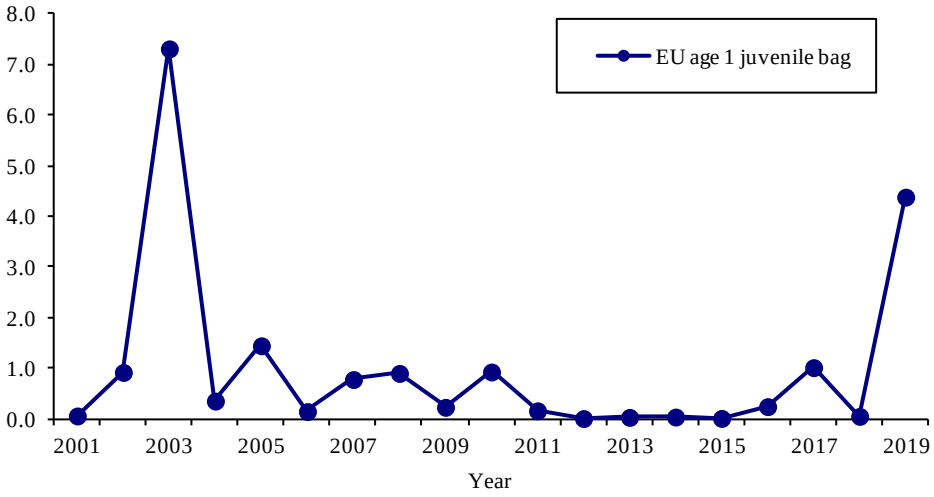

Figure 11. Abundance indexes at age 1 (weigthed-average) obtained in EU Flemish Cap surveys from Juvenile bag .