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Division 3M Northern shrimp (*Pandalus borealis*) – Interim Monitoring Update
By

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Abstract

This document updates some of the indices for northern shrimp (*Pandalus borealis*) harvested within NAFO Divisions 3M. The last assessment (biannual) for this resource was completed, within Scientific Council during autumn 2017. Scientific Council recommended that the fishing mortality for 2018 and 2019 be set as close to zero as possible. The indices of biomass in the 2019 EU survey increase, confirming recent upward trend. The stock size is now well above B_{lim} and it is from 2018 outside the collapse zone defined by the NAFO PA framework. In the 2019 EU summer survey the 3M total and female biomass index was 9273 and 8486 t respectively. The abundance at age 2 was similar to the estimated in 2018 at levels next to reported in 2009 and 2010, but unlike in 2018 the abundance at age 1 in the small mesh size bag attached on the cod-end was the second value highest in the series. If this strong year-class was confirmed in 2020 it would improve the state of impaired recruitment, 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.

UE Bottom Trawl Research Survey Trends

Summer multi-species research surveys have been conducted onboard the Spanish vessels R/V Cornide de Saavedra since 1988 and R/V Vizconde de Eza since 2003. From 1988 to 2002 the indexes estimated by the R/V Cornide de Saavedra were calibrated and transformed to the R/V Vizconde de Eza following the Warren's method. Fishing sets of 30 minute duration, with a tow speed of 3 knots, were randomly allocated to strata covering the Flemish Cap Bank to a depth of 1462 m since 2004, with the number of sets in a stratum proportional to its size (Figure 1). Both vessels used the same gear (Lofoten) with a codend mesh size of 35 mm. In order to obtain information about the juvenile fraction of the stock, since 2001 a small bag with 10 mm mesh size was attached to the cod-end of the Lofoten gear. Different sensors (SIMRAD ITI, SCANMARK, MARPORT) were employed along the historical surveys to monitor the net geometry. Details of the survey design and fishing protocols are outlined in (Casas, 2008).

In 2019 the survey was carried out from June 29th to July 29th. As previous years, the area prospected in Flemish Cap was spread up to 1450 meters. 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 increasing of shrimp biomass from 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 from 1998 to 2008 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 markedly decreased 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 to 2014 the total and female biomass decreased successively and were recorded the lowest values in the historical series showing the worsening and



depletion state of the shrimp stock. Since 2015 the biomass indexes increased year after year and they are now above B_{lim} (Figure 2). The total and female biomasses estimated in 2019 were 9273 t and 8486 t respectively (Table 1). This upward trend in the size of the shrimp stock started in 2015 and it is probably The biomass estimated in 2019 was mainly represented by female and big specimens with sizes around 20-27 mm (Figure 4); the abundance at age 2 (around 17 mm CL) was similar to 2018 survey with values below average. Unlike previous years the youngest specimens (age 1, around 10 mm CL) appeared in the catches of the main gear but specially were present in the small mesh size bag attached on the cod-end where the second highest values of the historical series was estimated, suggesting the appearance of a strong year class that it would improve the state of impaired recruitment of the last years associated with the decline of the cod and redfish stocks in the last years (Figure 3).

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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 2, Figure 5a) were estimated and the index average-weighted. Since 2005, both indices showed low values indicating the succession in recent years of weak year classes. However the presence of the youngest specimens (age 1, around 10 mm CL) in the catches of the main gear but specially in the small mesh size bag attached on the cod-end (with the second highest values of the historical series), suggests the appearance of a strong year-class that it would improve the state of impaired recruitment of the last years (Figure 5b)

Fishery and Management

Catch trends

The fishery for northern shrimp at Flemish Cap began in the spring of 1993 and has since continued with estimated annual catches (as estimated by STACFIS, Table 3 and Figure 6) of approximately 26 000 t to 48 000 t in the years 1993 through 1996. After 1996 the catches were lower and rising slowly from 26 000 t in 1997 to 53 000 t in 2000 and 2001. There was 50 000 t taken in 2002. The catch increased in 2003, reaching the highest value in the catches series (64 000 t), declining in the following years to about 1766 t in 2010. From 2011 following the NAFO SC recommendation no effort was directed to shrimp fishery in Flemish Cap and removals to September 2019 have not been recorded.

Exploitation rate

Considering the Exploitation rate estimated as nominal catches divided by the EU survey biomass index of the same year (Table 4 and Figure 7), this was high in the years 1994-1997 when biomass was generally lower. In the years 1998-2004 the catch rate has been rather stable at a lower level. From 2005 to 2008 despite the exploitation rate remained stable at relative low values (between 1.9-1.5), the UE survey indexes estimated decreased year after year. This trend continued in the following years despite the moratorium established on 3M shrimp stock from 2011. Since 2015 there has been a change in the downward trend and the survey indexes have increased successively. In October 2011 Scientific Council notes that there are indications of factors other than fishery that may be involved in the evolution of the stock.

Effort and TAC regulation

From 2011 meeting, Scientific Council (NAFO 2011) noted the stock was at very low level in the time series: bellow B_{lim} and remaining in a state of impaired recruitment. Therefore, Scientific Council recommended that fishing mortality be set as close to zero as possible.

From EU Survey summer in 2019, after five years of continuous increases of biomass, it is now well above B_{lim} . Also the strong year class of 2018 (age 1 in 2019) could improve the recruitment in the fishable stock in 2020 and 2021 (age 2 and 3 respectively).

Scientific council considers that there is sufficient evidence to allow 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.

The incipient recovery of the shrimp stock in recent years coincides with the decline of redfish and cod stocks and suggests that the historic evolution of shrimp biomass may also not be related only to fishing mortality. Accordance to this, studies based in multispecies model developed in Gadget which covers the main commercial stocks in Flemish Cap over the period 1988-2012 (Pérez-Rodríguez et al. 2016) and 1988-2016 (Pérez-Rodríguez and D. González-Troncoso 2018), suggest that, predation by redfish, together with fishing have been the main factors driving the shrimp stock to the collapse (Figure 2). In the last years, the decreasing of redfish and cod stocks has provoked a decline in the predation mortality on shrimp and as consequence favoring its recovery.

Conclusions

The estimated value of Female biomass index from 2019 is well above B_{lim} proxy. Also the appearance of the 2018 strong year-class (age 1 in 2019) and the decreasing trend of the cod stock (one of the most important predators) would improve the state of impaired recruitment of the last years and confirm the recovery of the stock.

Based on the information available in October 2017 Scientific Council recommended that the fishing mortality for 2018 and 2019 was set as close to zero as possible. The new information from EU Survey summer in 2019 suggests the recovery of the stock and the Scientific Council considers that there is sufficient evidence to allow 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.

References

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- Pérez-Rodríguez, A.; Howell, D.; Casas, M.; Saborido-Rey, F.; Ávila-de Melo, A. 2016. Dynamic of the Flemish Cap commercial stocks: use of a gadget multispecies model to determine the relevance and synergies between predation, recruitment and fishing. (*doi: 10.1139/cjfas-2016-0111*).
- Pérez-Rodríguez, A. and D. González-Troncoso. 2018. Update of the Flemish Cap multispecies model GadCap as part of the EU SC05 project: "Multispecies Fisheries Assessment for NAFO". NAFO SCR Doc.18/024, Serial No.N6808.

Table 1. Total and Female Biomass (tons) of shrimp estimated by swept area method in the years 1988-2019 on EU Flemish Cap surveys.

Year	Total Biomass (t)	Total Mean Catch per tow (kg)	Female Biomass (t)	Female Mean Catch per tow (kg)
1988	5615	6.98	4525	5.63
1989	2252	2.80	1359	1.69
1990	3405	4.23	1363	1.69
1991	11352	14.12	6365	7.91
1992	24508	30.48	15472	19.24
1993	11673	14.52	6923	8.61
1994 ¹	3879	4.82	2945	3.66
1995	7276	9.05	4857	6.04
1996	10461	13.01	5132	6.38
1997	7449	9.26	4885	6.07
1998 ²	39367	48.95	11444	14.23
1999	24692	30.70	13669	17.00
2000	19003	23.63	10172	12.65
2001	27204	33.83	13336	16.58
2002	36510	45.40	17091	21.25
2003	21087	26.22	11589	14.41
2004	20182	25.10	12081	15.02
2005	30675	38.14	14381	17.88
2006	16235	20.19	11359	14.27
2007	17046	21.20	12843	15.97
2008	11092	13.79	8630	10.73
2009	2797	3.48	1764	2.19
2010	4894	6.09	3819	4.31
2011	1621	2.02	1132	1.39
2012	1055	1.31	791	0.98
2013	844	1.05	691	0.86
2014	900	1.12	716	0.89
2015	1551	1.93	1079	1.34
2016	2520	3.08	1982	2.46
2017	2885	3.54	2304	2.86
2018	4394	5.31	4051	4.90
2019	9273	11.53	8486	10.55

Table 2. Abundance indices at age 1 and 2 from the EU survey main gear (Lofoten) and small mesh size bag attached on the cod-end (juvenile bag). Each series was standardized to its mean.

Year	Lofoten gear				Juvenile bag			
	Age 1		Age 2		Age 1		Age 2	
	('00000)	Av. pond.	('00000)	Av. pond.	('000)	Av. pond.	('000)	Av. pond.
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996	0	0.00	3424	1.06				0.00
1997	0	0.00	629	0.19				0.00
1998								
1999	13	0.14	4735	1.46				0.00
2000	89	0.94	1069	0.33				0.00
2001	28	0.30	3321	1.03	380	0.06	1361	0.33
2002	1806	19.08	11004	3.40	6044	0.92	2125	0.52
2003	142	1.50	12572	3.89	48165	7.32	0	0.00
2004	0	0.00	27415	8.48	2314	0.35	41818	10.18
2005	0	0.00	1792	0.55	9515	1.45	3741	0.91
2006	0	0.00	582	0.18	953	0.14	7498	1.82
2007	0	0.00	301	0.09	5123	0.78	3824	0.93
2008	0	0.00	221	0.07	5916	0.90	4969	1.21
2009	0	0.00	1177	0.36	1504	0.23	3011	0.73
2010	77	0.81	1103	0.34	6102	0.93	954	0.23
2011	0	0.00	601	0.19	1050	0.16	2440	0.59
2012	0	0.00	229	0.07	42	0.01	160	0.04
2013	10	0.11	63	0.02	195	0.03	102	0.02
2014	0	0.00	0	0.00	239	0.04	56	0.01
2015	0	0.00	1111	0.34	61	0.01	427	0.10
2016	2	0.02	230	0.07	1592	0.24	390	0.09
2017	0	0.00	695	0.21	6669	1.01	1411	0.34
2018	0	0.00	1049	0.32	327	0.05	552	0.13
2019	10	0.10	1028	0.32	28862	4.39	3230	0.79

Table 3. Annual nominal catches (t) by country of northern shrimp (*Pandalus borealis*) caught in NAFO Div. 3M.

Nation	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011*	2012*	2013*	2014*	2015*	2016*	2017*	2018*	2019*		
Canada	3724	1041	970	906	807	484	490 ²	618 ²	295 ¹	16				10 ¹															
Cuba							119	46 ¹	1037 ¹	1537 ¹	1462 ¹	969 ¹	964 ¹	1126 ¹	446 ¹	11													
EU/Estonia		1081	2092	1900	3240	5694	10835 ¹	13256 ²	9851 ¹	14215 ²	12851 ¹	13444 ¹	12009 ¹	8466 ²	10607 ²	10255 ²	2152 ²	266 ²											
EU/Denmark	800	400	200			437	235		93 ¹	359 ¹																			
EU/Latvia		300	350	1940	997 ¹	1191 ¹	3080 ¹	3105 ¹	2961 ¹	1892 ¹	3533 ¹	3059 ¹	2212 ¹	1330 ¹	1939 ¹	1285 ¹	1194 ¹	611 ¹											
EU/Lithuania		1225	675	2900	1785 ¹	3107 ¹	3370 ¹	3529 ¹	2701 ¹	3321 ¹	3744 ¹	4802 ¹	3652 ¹	1245 ¹	1992 ¹	485 ¹													
EU/Poland					824	148 ¹	894 ¹	1692 ¹	209 ¹			1158 ¹	458 ¹	224 ¹															
EU/Portugal	300		150		170 ¹	203 ¹	227 ¹	289 ¹	420 ¹	16 ¹		50 ¹					3												
EU/Spain	240	300	158	50	423 ¹	912 ¹	1020 ¹	1347 ¹	855 ¹	674 ¹	857 ¹	1049 ²	725 ²	997 ²	768 ¹	406 ²	537 ¹	507 ²											
EU/United Kingdom											547 ¹																		
Faroe Is.	7333	6791	5993	8688	7410	9368	9199	7719 ²	10228 ²	8516 ²	12676 ²	4952 ¹	2457 ¹	1102 ¹	2303 ¹	1201	1349 ¹	495 ¹											
France (SPM)					150			138 ¹	337 ¹	161 ¹			487		741 ¹		193 ¹												
Greenland	3788 ¹	2275 ¹	2400 ¹	1107 ¹	104 ¹	866 ¹	576 ¹	1734 ¹		644 ¹	1990 ²		12 ¹	778 ²															
Iceland	2243	2355 ¹	7623	20680 ¹	7197 ¹	6572 ¹	9277 ²	8912 ²	5265 ²	5754 ¹	4715 ¹	3567 ¹	4014 ¹	2099 ¹															
Japan								114 ¹	130	100 ¹	117 ¹																		
Norway	7183	8461	9533	5683	1831 ¹	1339 ¹	2975 ¹	2669 ²	12972 ¹	11833 ¹	21238 ¹	11738 ¹	223 ¹	890 ²	1914 ¹	321 ²													
Russia		350	3327	4445	1090		1142	7070 ¹	5687 ¹	1176 ¹	3 ¹	654 ¹	266 ¹	46 ¹	73 ¹	21 ¹	20 ¹	7 ¹											
Ukraine									348 ¹		237 ¹	315 ¹		282 ¹															
USA								629 ¹																					
Total	25611	24579	33471	48299	26028	30321	43439	52867	53389	50214	63970	45757	27479	18595	20741	13985	5448	1988	0	0	0	0	0	0	0	0	0	0 ³	

¹ NAFO Statlant 21 A² From the fisheries biologist of respective countries³ Reported to NAFO provisionally

* Moratorium

Table 4. Exploitation Rate of Shrimp (Div. 3M) as Nominal Catches (tons) divided by UE Survey Female Index (tons).

Year	Nominal Catches	UE Survey Female Index	Exploitation Rate
1993	25611	6923	3.7
1994	24579	2945	8.3
1995	33471	4857	6.9
1996	48299	5132	9.4
1997	26028	4885	5.3
1998	30321	11444	2.6
1999	43439	13669	3.2
2000	52867	10172	5.2
2001	53389	13336	4.0
2002	50214	17091	2.9
2003	63970	11589	5.5
2004	45757	12081	3.8
2005	27479	14381	1.9
2006	18595	11359	1.6
2007	20741	12843	1.6
2008	13985	8630	1.6
2009	5448	1764	3.1
2010	1988	3819	0.5
2011*	0	1132	0.0
2012*	0	791	0.0
2013*	0	691	0.0
2014*	0	716	0.0
2015*	0	1079	0.0
2016*	0	1982	0.0
2017*	0	2304	0.0
2018*	0	4051	0.0
2019*	0	8486	0.0

*moratorium on fishing shrimp in 3M

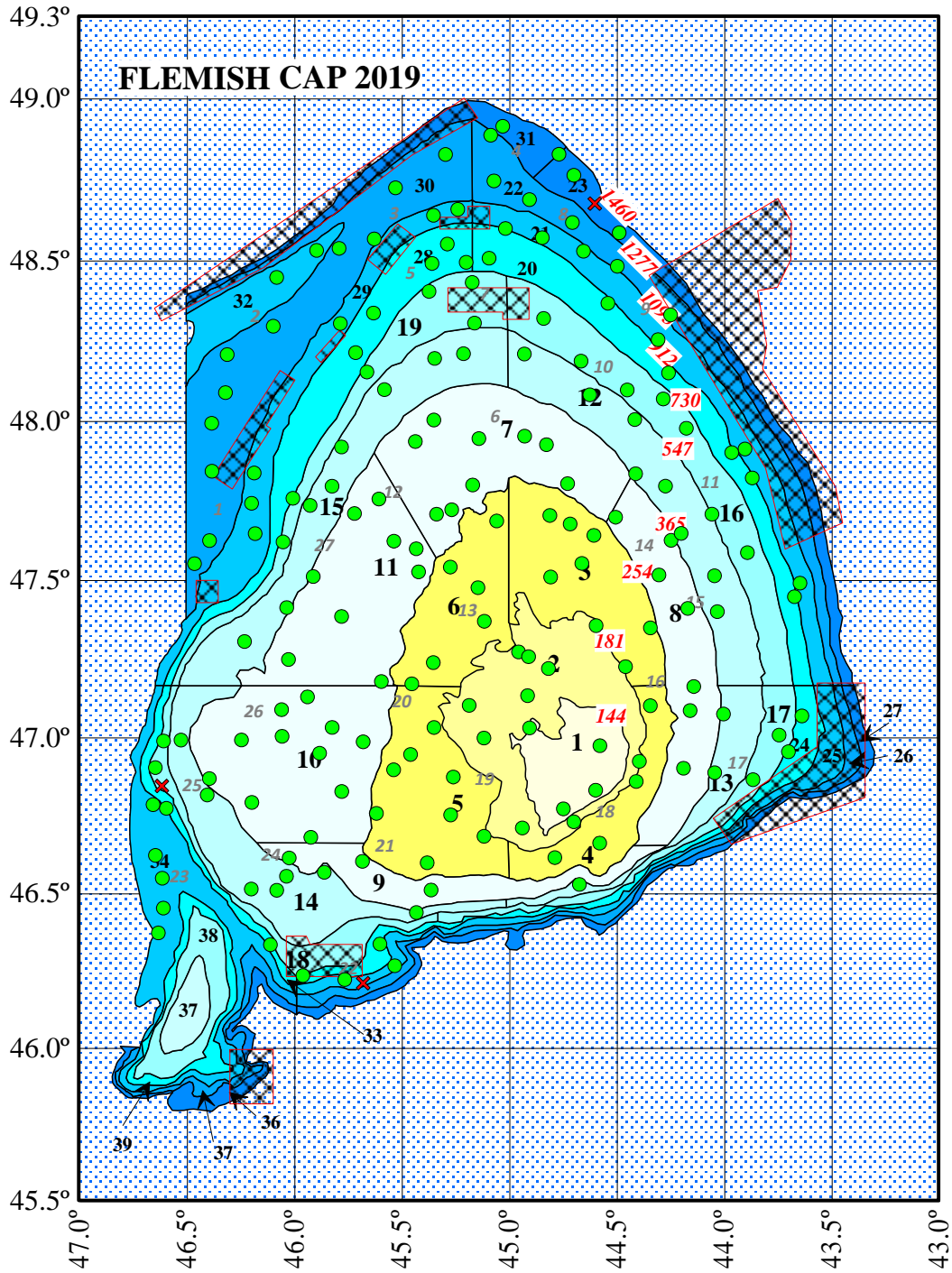


Figure 1. Chart with the positions of the hauls carried out in EU Flemish Cap survey 2019.

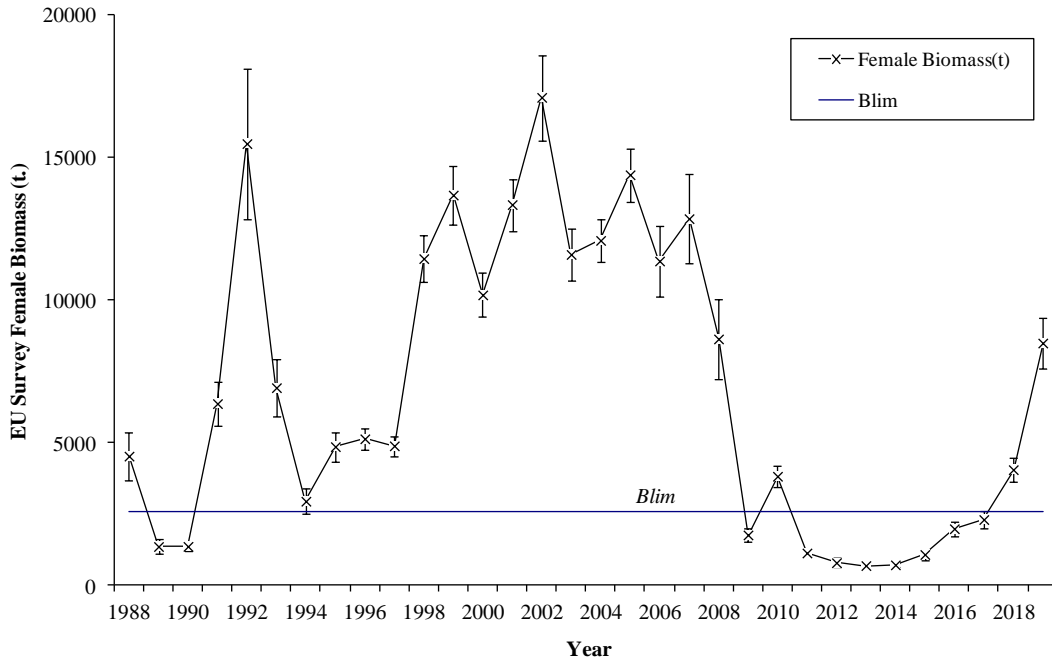


Figure 2. EU survey female shrimp biomass in the years 1988-2019 on Flemish Cap and *Blim* proxy of 3M shrimp stock.

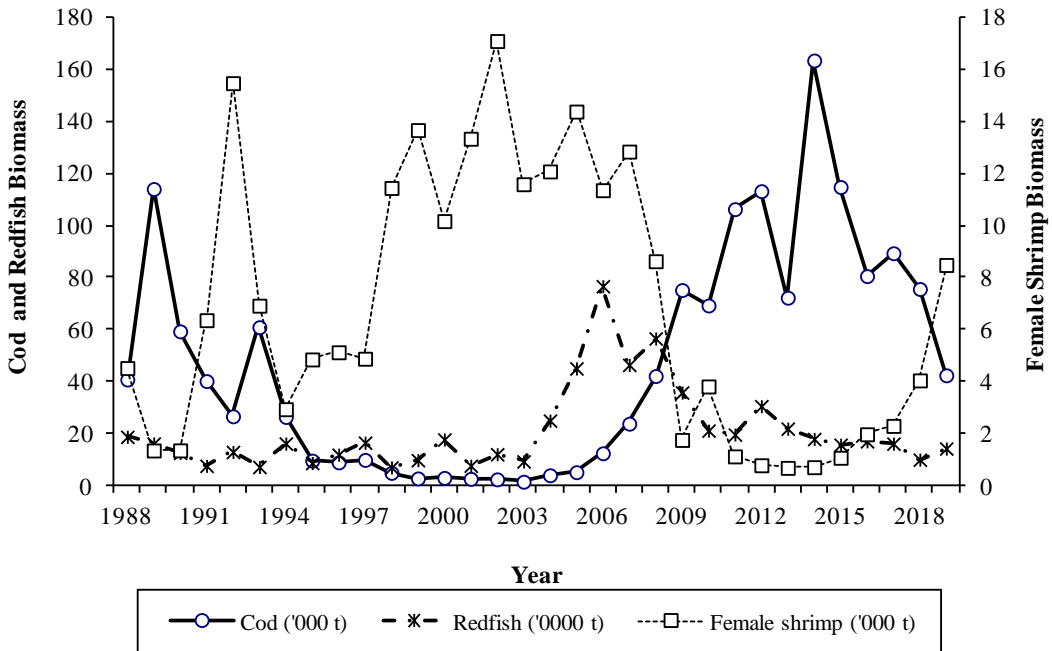


Figure 3. Cod, Redfish and Female shrimp biomass from EU trawl surveys on Flemish Cap, 1988-2019.



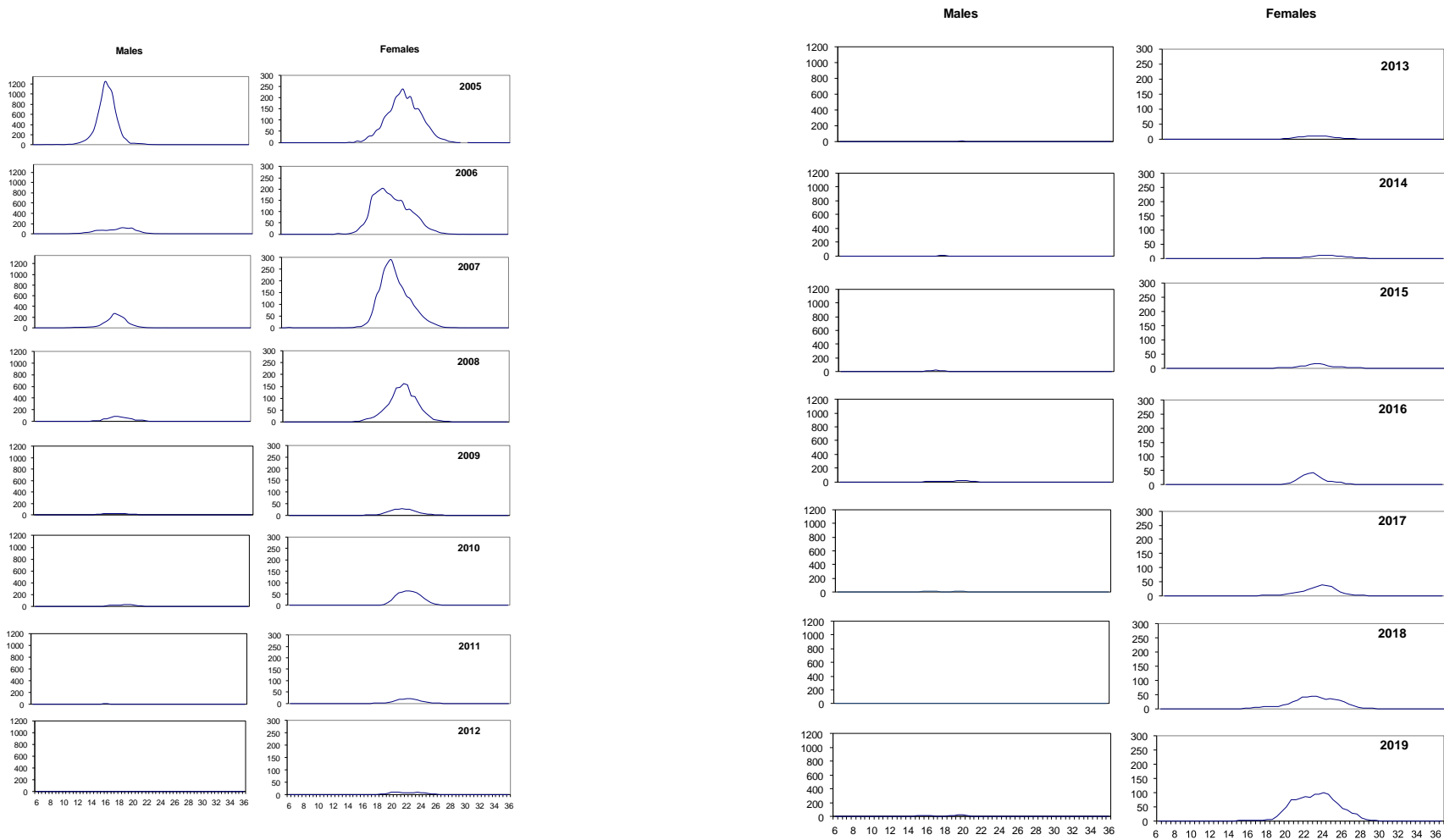


Figure 4. Shrimp size distribution from Flemish Cap 2005 -2019 surveys. Y-Axis=Frequency (10⁶), X-Axis=Carapace Length (mm).

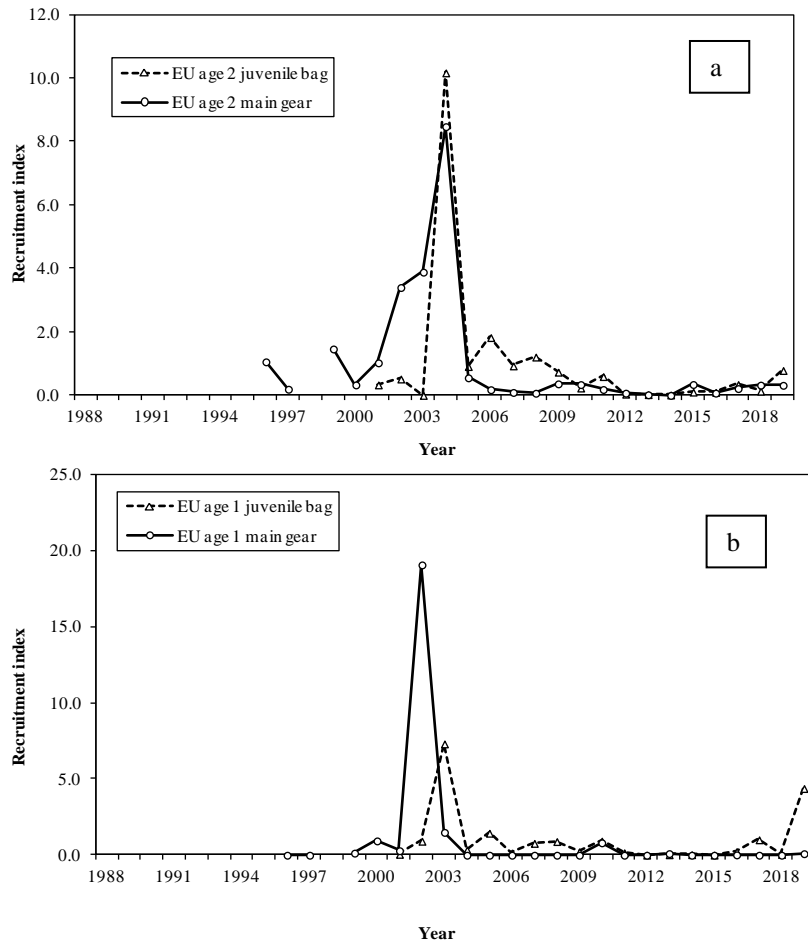


Figure 5. Abundance indexes at age 2 (a) and 1 (b) obtained in EU Flemish Cap surveys from Lofoten gear (black line) and Juvenile bag (dotted line).

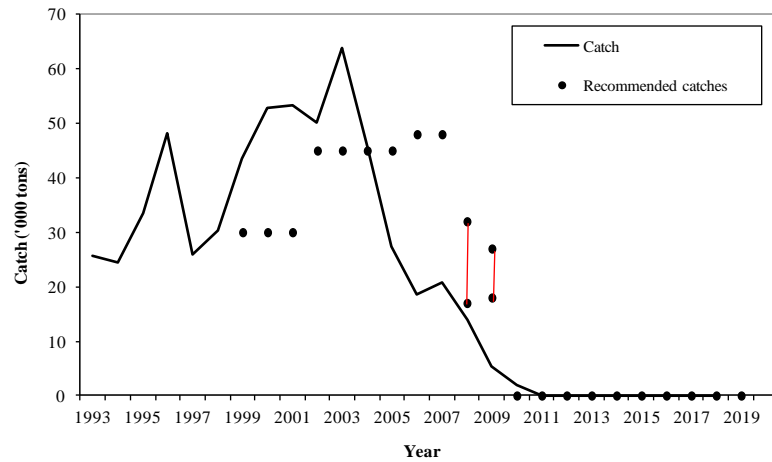


Figure 6. Trends in NAFO Div. 3M northern shrimp (*Pandalus borealis*) catch (t) and Recommended catches over the period 1993-2019.

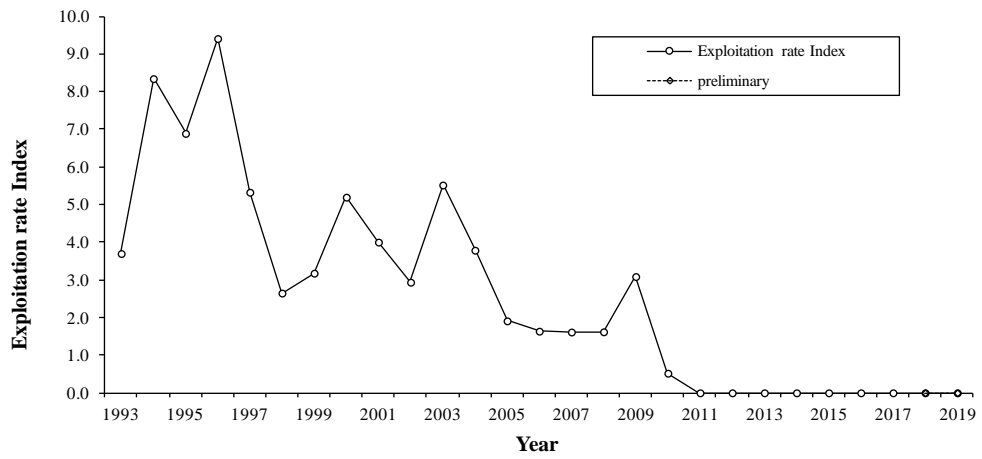


Figure 7. Exploitation rates as nominal catch divided by the EU survey female biomass index of the same year.