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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 for this resource was completed, within Scientific Council in September 2020. The shrimp fishery was resumed in 2020 and Scientific Council in the last assessment completed in September 2020, recommended that since the estimated biomass was above B_{lim} and there were indications of improvement in recruitment from the survey in 2020, there was sufficient evidence to allow a small amount of directed fishing on this stock. Considering the uncertainty about the future recruitments and the response of the resource to resumed exploitation, Scientific Council advised that the catch in 2021 remain at the same level that 2020 (5 448 t).

Unlike 2020 where the catches and effort directed at shrimp were marginal, in 2021 the preliminary catches (until 6 September) were 5 791 t carried out in 420 days of fishing. The biomass indices from EU survey decreased by 69 % compared to 2020, confirming the downward trend that began in 2020. In 2021 the total and female biomass indexes were 2101 t and 1797 t respectively. 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.

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 2021 the survey was carried out from 1 July to 15 August. 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 were above B_{lim} from 2018 (Figure 2). 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 1 797 t respectively (Table 1), decreased for the second consecutive year and it is now below B_{lim} . Unlike the last years the decrease in shrimp biomass was not associated with the improvement in cod and redfish stocks and it could be due to the resumed shrimp fishery (Figure 3).

The biomass and abundance estimated in 2021 EU survey were mainly represented by female (Figure 4); Young specimens (mainly males) around 24% in number remain well below average.

Considering the abundance at age 2 as indicator of recruitment, the number of shrimp of two years old in the EU survey from the main gear and from the juvenile bag were estimated and the index average-weighted (Table 2, Figure 5a). Since 2005, both indices showed low values indicating the succession in recent years of weak year classes. In 2020 the abundance at age 2 (around 15 mm CL) increased by 26% compared to 2019. This increase suggested the appearance of a relative strong year-class (2018), supported by the high catches recorded from the small mesh size bag attached on the cod-end where the second highest value in the historical series was recorded. However, in 2021 the 2018 year class (age 3) was not as strong as expected and the 2019 year class (age 2) was very much lower indicating the entry of a weak year class (Figure 5a).

The youngest specimens (age 1, around 8 mm CL) do not appear in the catches of the main gear but they were present in the small mesh size bag attached on the cod-end. However, the estimated abundance for these specimens (2020 year class) was in a similar level to 2019 year class. (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 1 766 t in 2010. Since 2011 following the NAFO SC recommendation no effort was directed to shrimp fishery in Flemish Cap and in 2020 the NAFO Scientific Council advised to resume the shrimp fishery with catches not exceeding the 2009 level (5 448 t). Preliminary data in 2020 showed a very low effort direct to shrimp (around 19 days) and provisional catches of 79 t. In 2021 the provisional catches (until 6 September) were 5 791 t carried out in 420 days of fishing.

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. From 2015 there has been a change in the downward trend and the survey indexes increased successively. In 2020, the fishery was resumed but the effort directed to shrimp fisheries and catches were residual resulting in a very low exploitation rate (0.01). In 2021 the exploitation rate increased notably (3.2) due to the increase in catches (provisional catches until June of 5 791 t) and the decrease in the UE survey index.

Effort and TAC regulation

The shrimp fishery in 3M is actually managed by effort regulation and new information of catch rates and the posterior standardizing CPUE are needed to provide annual indices of stock biomass related with the stock exploitation.

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. In 2019 after five years of continuous increases of biomass the stock was well above B_{lim} NAFO SC advised to resume the fishery in 2020 with catches not to exceed 2009 level (5448 t). Finally at the annual meeting in September 2019, NAFO FC agreed to re-open the shrimp fishery by regulating the effort with 2640 days.

The SC noted at the SC/NIPAG meeting in November 2019 its concern about the goodness of effort regulation for shrimp on 3M in a context of mixed fisheries managed by quotas and TACs, as well as the difficulty to include the “technology creep” as one relevant factor to include in the analyses of the CPUE series with more than 10 years. (Palomares et al. 2019). With the resumed exploitation in 2020, in a medium term it can be carried out the assessment that will permit a sustainable management method based on quota or TACs allocation that it would allow overcome those problems.

From EU Survey summer in 2021, the shrimp biomass decreased by 69% compared to 2020. This decrease confirms the downward trend that began in 2020 and that places the stock below B_{lim} in 2021. Also the relative strong year class of 2018 (age 3) was not present in the catches as much as expected. Considering the decline of the stock in 2021 (below B_{lim}) and the poor prospects about the future recruitments in the fishable stock the next years, Scientific Council is concerns that the stock will remain at low levels and advises that the catch for 2022 be set as close to zero as possible.

Shrimp predation by cod and redfish

From 2015 to 2019, the incipient recovery of the shrimp stock coincided with the decline of redfish and cod stocks suggesting 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), suggested that, predation by redfish and cod, together with fishing have been the main factors driving the shrimp stock to the collapse (Figure 2). However, the decline of the shrimp stock in Flemish Cap in 2021 does not coincide as previous years with the recovery of redfish and cod stocks (with decreases of 23% and 34% respectively compared to 2020).

Conclusions

The estimated value of Female biomass index decreased by 69% in 2021 and it is now bellow B_{lim} proxy. The relative strength of 2018 year-class (age 3 in 2021) was not as strong as expected and the weak 2019 year class (age 2) raises serious concerns that the stock will remain at low levels.

The decrease of shrimp biomass in 2021 was not related with the recovery of redfish and cod stocks (their most important predators) and it is probably due to the resumed exploitation of the shrimp fishery in 2021.

Based on the information available in September 2019 and 2020, Scientific Council recommended a small amount of direct fishing on this stock and that the exploitation level for 2021 not to exceed 2009 level. The new information from EU Survey summer in 2021 indicates the worsening of the shrimp stock that it is now inside of the collapse zone and the poor prospects for recruitment in a short time in the fishable stock. Therefore, Scientific Council advises that the fishing mortality and catch be set as close to zero as possible by 2022.

References

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Table 1. Total and Female Biomass (tons) of shrimp estimated by swept area method in the years 1988-2021 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
2020	6734	8.37	6048	7.52
2021	2101	2.61	1797	2.23

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.
1996	0	0.00	3424	1.09				
1997	0	0.00	695	0.22				
1998								
1999	13.0	0.15	4735	1.50				
2000	94.0	1.07	1148	0.36				
2001	27.5	0.31	3711	1.18	380	0.06	1361	0.26
2002	1805.6	20.58	11004	3.49	6044	0.92	2125	0.40
2003	145.7	1.66	13869	4.40	48165	7.30	0	0.00
2004			27415	8.70	2314	0.35	41818	7.96
2005			1792	0.57	9515	1.44	3741	0.71
2006			809	0.26	953	0.14	7498	1.43
2007			282	0.09	5123	0.78	3824	0.73
2008			473	0.15	5916	0.90	4969	0.95
2009	6.1	0.07	1514	0.48	1504	0.23	3011	0.57
2010	76.5	0.87	1106	0.35	6102	0.93	954	0.18
2011	2.4	0.03	611	0.19	1050	0.16	2440	0.46
2012		0.00	216	0.07	42	0.01	160	0.03
2013	10.3	0.12	63	0.02	195	0.03	102	0.02
2014	0.4	0.00	242	0.08	239	0.04	56	0.01
2015			1111	0.35	61	0.01	427	0.08
2016	2.4	0.03	230	0.07	1592	0.24	390	0.07
2017			676	0.21	6669	1.01	1411	0.27
2018			1048	0.33	327	0.05	552	0.11
2019	9.3	0.11	1010	0.32	31594	4.79	3536	0.67
2020			1449	0.46	5912	0.90	25332	4.82
2021			109	0.03	4766	0.72	6634	1.26

Table 3. Annual nominal catches (mt) 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*	2020	2021		
Canada	3724	1041	970	906	807	484	490 ²	618 ²	295 ¹	16				10 ¹															0.1 ³	1772 ⁴	
Cuba								119	46 ¹	1037 ¹	1537 ¹	1462 ¹	969 ¹	964 ¹	1126 ¹	446 ¹	11													20 ⁴	
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																		
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													1142 ⁴
France (SPM)					150			138 ¹	337 ¹	161 ¹			487		741 ¹		193 ¹														167
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																							163 ⁴
Total	25611	24579	33471	48299	26028	30321	43439	52867	53389	50214	63970	45757	27479	18595	20741	13985	5448	1988	0	79³	5791⁴										

¹ NAFO Statlant 21 A² From the fisheries biologist of respective countries³ Reported to NAFO provisionally⁴ Reported to NAFO provisionally until 6 September

* 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
2020	79	6048	~0.01
2021 ¹	5791	1797	3.2

*moratorium on fishing shrimp in 3M

¹ provisional to 6 September

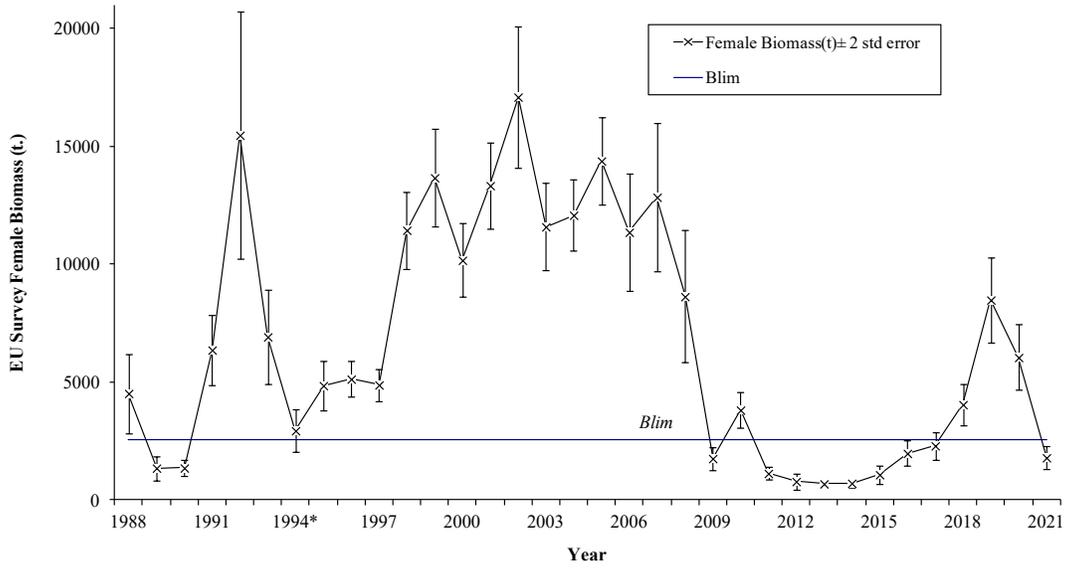


Figure 2. EU survey female shrimp biomass in the years 1988-2021 on Flemish Cap and B_{lim} proxy of 3M shrimp stock.

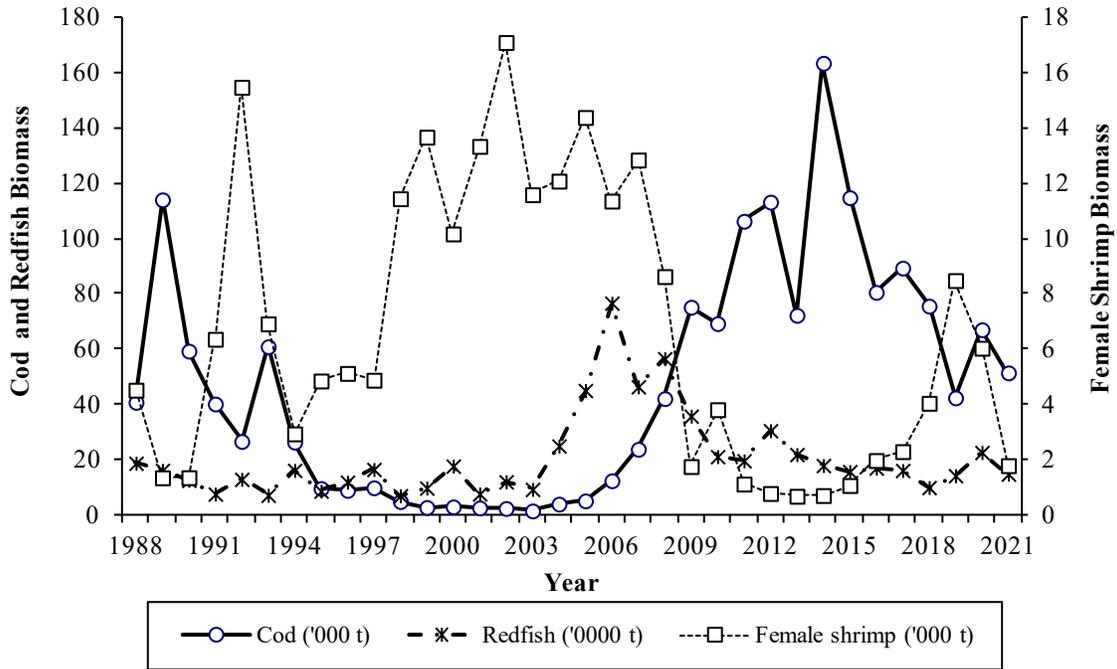


Figure 3. Cod, Redfish and Female shrimp biomass from EU trawl surveys on Flemish Cap, 1988-2021.

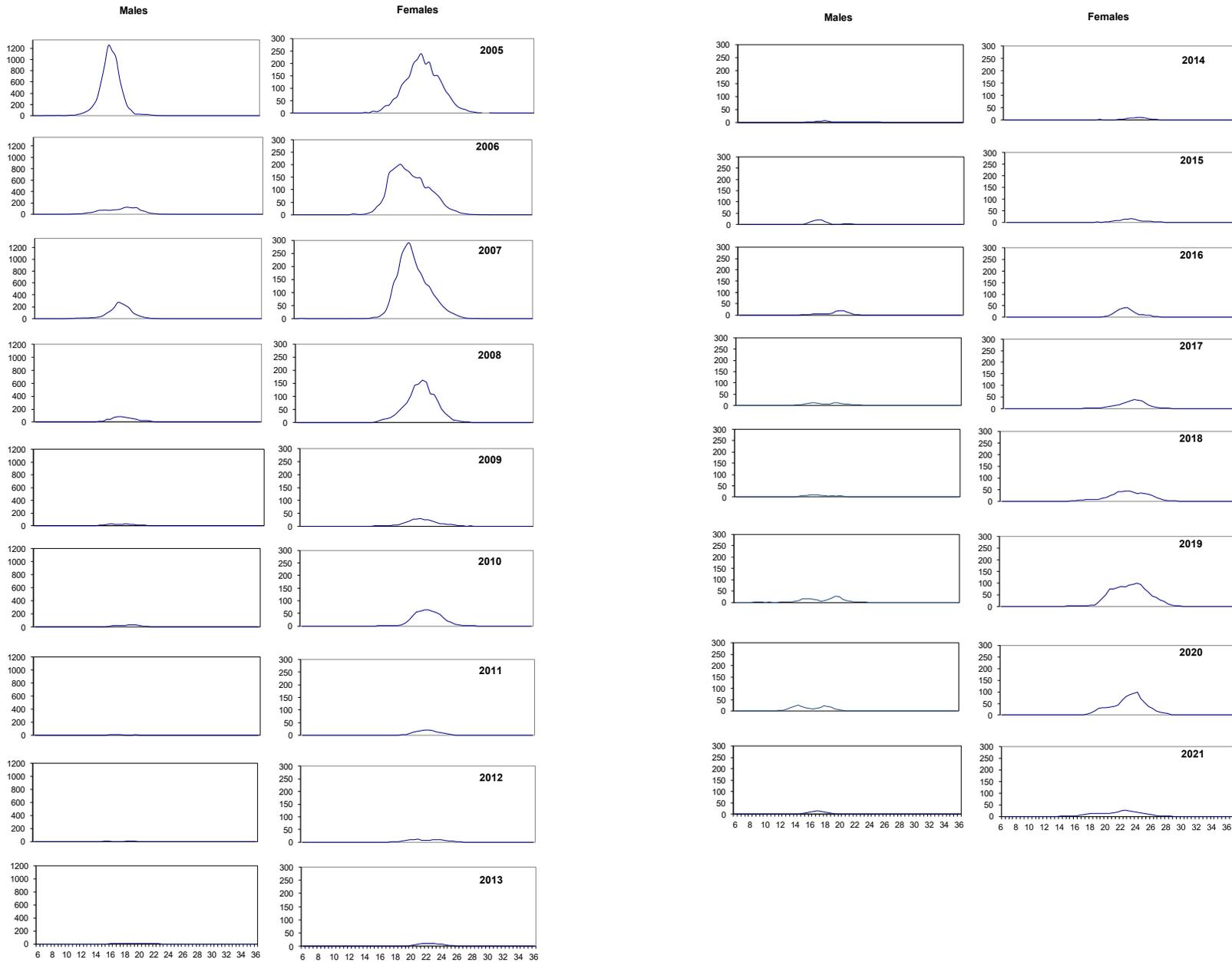


Figure 4. Shrimp size distribution from Flemish Cap 2005 -2021 surveys. Y-Axis=Frequency (10^6), X-Axis=Carapace Length (mm).

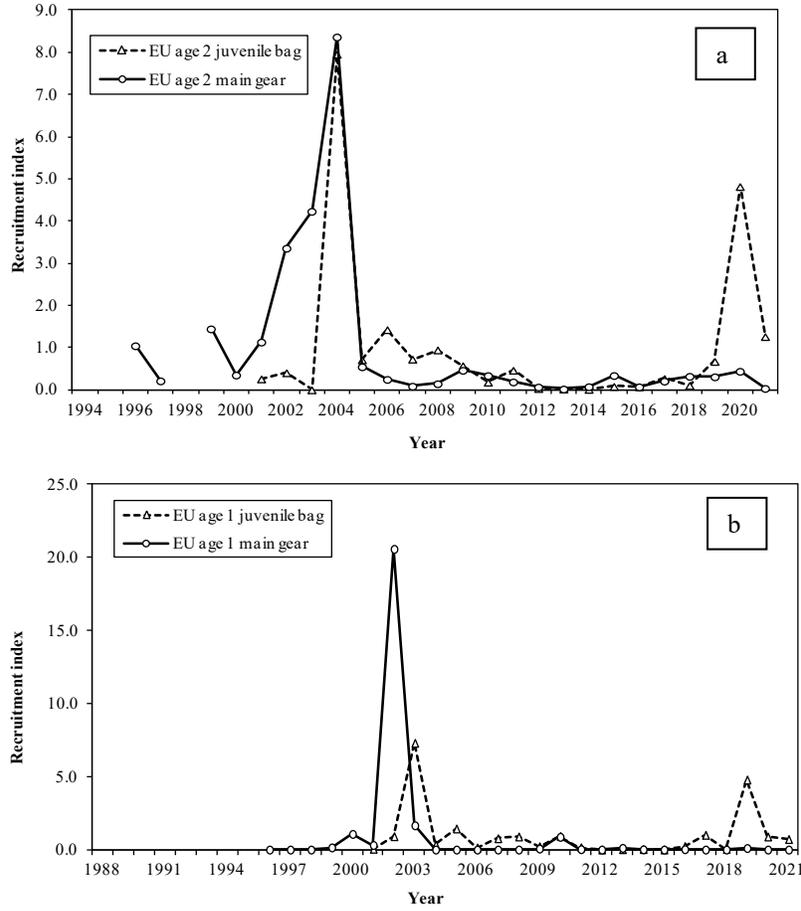


Figure 5. Abundance indexes at age 2 (a) and age 1 (b) obtained in EU Flemish Cap surveys from Lofoten gear (black line) and Juvenile bag (dotted line).

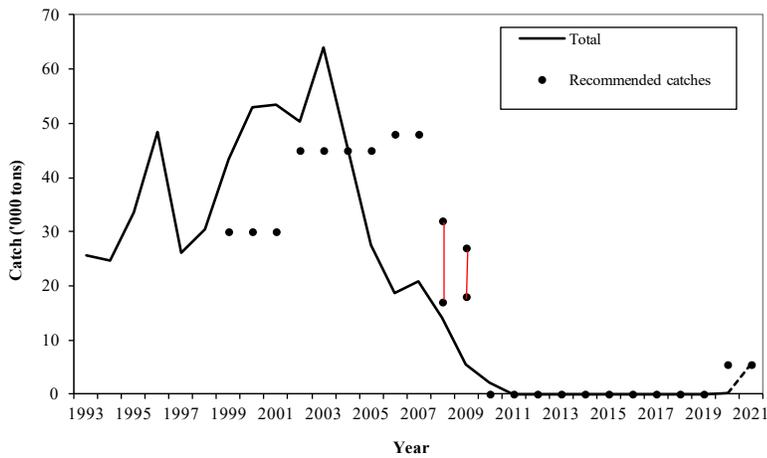


Figure 6. Trends in NAFO Div. 3M northern shrimp (*Pandalus borealis*) catch (t) and recommended catches over the period 1993-2021

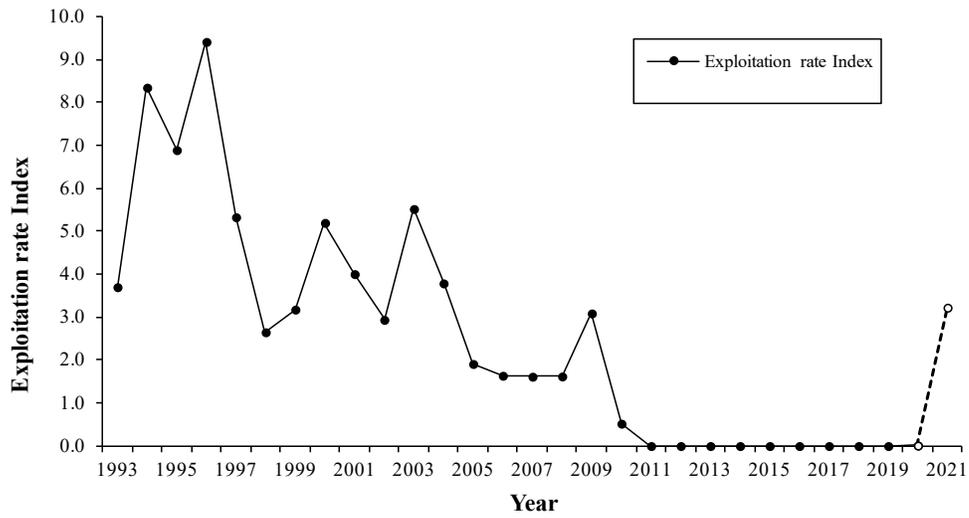


Figure 7. Exploitation rates as nominal catch divided by the EU survey female biomass index of the same year.