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**Assessment of the International Fishery for Shrimp (*Pandalus borealis*)
in Division 3M (Flemish Cap), 1993-2013**

by

J. M. Casas

Instituto Español de Oceanografía, Apdo. 1552, 36200 Vigo, Spain

e-mail: mikel.casas@vi.ieo.es

Abstract

The development of the international shrimp (*Pandalus borealis*) fishery in NAFO Division 3M is described. Various indices show that even the stock was in high levels in 2006 and 2007 the lack of good recruitments in the last years and the progressive disappearance of the strong year classes 2001 and 2002 have caused a drastic decline of the stock. Although the fishing effort in recent years was low and from 2011 a moratorium over shrimp fishery was established, the increase of cod biomass (the most important predator of northern shrimp in 3M) has probably been the cause of the successive bad recruitments and resulting decline of the stock. The revised Nominal catches declined from 63 970 tonnes in 2003 to 5 448 tonnes in 2009 and 1 988 in 2010. No catches have been recorded since 2011 due to the moratorium. The female biomass from EU survey was variable though without trends at a relative high level from 1998 to 2007 but since then the estimated biomass initiated a drastic decline to lowest levels in the EU survey series in 2011, 2012 and 2013. Also after the strong 2002 year-class (i.e. age 2 in 2004), all the subsequent year classes have been weak and the recruitment prospects remain uncertain.

Considering the 15% of the maximum survey female biomass index as a limit reference point for biomass (B_{lim}), the stock remain since 2011 in the collapse zone defined by the NAFO PA framework. The low exploitation rates in the recent past years and the moratorium in 2011, 2012 and 2013 have not provoked changes in the state of the stock. Also the recruitment prospects remain uncertain and therefore the fishing mortality would be set as close to zero as possible in 2014.

1. INTRODUCTION

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 1) 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). After 2003 the catches decreased all years to 1 988 t in 2010. Due to moratorium initiated in 2011 have not been recorded catches from that year and in 2013 are only expected very low catches from discards of other fisheries.

Since 1993 the number of vessels ranged from 40-110, and in 2006 there were approximately 20 vessels fishing shrimp in Div. 3M compared to 50 in 2004. There is not a lot of information on the number of vessels taking part in the shrimp fishery since 2007 but probably they do not exceeded 13 units in 2010. Since 2011 due to the moratorium there is no vessels directed to shrimp fishery in Div. 3M.

With the closure of the international shrimp (*Pandalus borealis*) fishery in NAFO Division 3M, various indices from the EU surveys are listed with the purpose of tracking the status of the Flemish Cap shrimp stock. Among these the indices of female stock from the EU surveys is used. The results from the ageing are presented and some recruitment indices from the EU survey are provided.

2. MATERIAL AND METHODS

Samples

From 2011 due to the moratorium shrimp samples were only taken from EU-Flemish Cap research summer surveys. They were separated into 3 categories namely, males, primiparous females (including transitional) and multiparous females according to the sternal spine criterion (McCrary. 1971), oblique carapace lengths were measured using sliding callipers and grouped into 0.5 mm length-classes.

Modal analysis (MacDonald and Pitcher, 1979) was conducted each year on length frequency distribution by sex group resulting from the survey. This analysis provided the proportion; mean lengths and standard deviations of the mean length (sigma) for each age component and sex group. The total number of individuals in every age/sex group according to the estimated biomass was calculated transforming the mean length to weight using the weight length relationship estimated each year during the survey. So, the mean lengths were converted to mean weights to estimate the annual abundance and biomass indices by year and sex group (Skúladóttir and Diaz, 2001).

3. CATCH and CPUE

The total catch per year is listed by nations in Table 1. The annual catches come mostly from Statlant 21A reports and in some cases from the shrimp specialists of individual countries. Because the moratorium no catches have been recorded from 2011 and to 10 September in 2013 the table was only revised and updated (Fig. 1).

The closure of shrimp fishery from 2011 and therefore the lack of commercial catches of shrimp do not permit to follow the evolution of the stock using the standardized CPUE series estimated from the international fleet directed to the fishing shrimp in Div. 3M.

4. EXPLOITATION RATE

Considering the Exploitation rate estimated as nominal catches divided by the EU survey biomass index of the same year (Figure 2 and Table 2), 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 recent years despite the moratorium established on 3M shrimp stock since 2011. In October 2011 Scientific Council noted that there are indications of factors other than fishery that may be involved in the current decline of the stock.

5. FEMALE INDICES

The biomass indices From EU surveys have been corrected in the years 1988 to 2002 for adjusting for the more efficient research vessel taken into use in 2003 (Casas *et al.* 2004). The spawning stock (female biomass) as determined from the EU survey biomass index (Figure 3 and Table 3) increased rapidly during the years prior to the fishery, from 1989 and 1990 to 1992. This may have been due to a gradual increase in stock size after the cod biomass declined in the area. But this was also a reflection of the very strong 1986 year class, most of which were female during 1992. With the beginning of the shrimp fishery in 1993 the biomass declined up to 1997. After that

the stock recovered reasonably well although with high annual variability (historical maximums in 2002 and 2005 were followed by years with lower biomass but at a relative high level). In 2009 the female biomass decreased to values close to the historical minimums in the survey series. In 2010 despite of the biomass increase about 77% compared to 2009 this was still among the lowest in the historical series. The female biomass estimated in the last three years 2011, 2012, and 2013 around 1132 t, 791 t and 691 t. respectively were the lowest values in the EU survey series, well below B_{lim} proxy and shows the depletion state of the shrimp stock. These low values in the size of the shrimp stock are likely associated to the increase of the cod stock experimented in recent years (Table 3 and Figures 4 and 5). Although in 2013 the decline of cod biomass was not followed by the corresponding increase in the shrimp biomass as occurred in 2010, the significant and inverse correlation between cod and female shrimp biomass can still be observed.

6. SHRIMP PREDATION BY COD

In 2013 was not carried out studies on feeding of cod and there is no new information since 2012 about the predation on shrimp by cod in Flemish Cap and the impact of the cod stock recovery in recent years on shrimp stock.

7. AGE ASSESSMENTS

Age analysis and sex composition was carried out on biological samples obtained from commercial fishery of a few nations in the past years (1993-2005). Since 2006 the samples obtained from the fishery were insufficient to assess the age of the catches and from 2011 due to the moratorium no sampling is available. So, the perception of the age composition and evolution of different year class along the years in the shrimp stock come from the age composition estimated in EU surveys (tables 4 and 5).

From that tables, some strong year-classes may be followed according the abundance by age groups from EU surveys (1988- 2012). If the assignation of the age is right, the 1986 year-class stand out in the beginning of historical series with 4, 5 and 6 years olds in the years 1990, 1991 and 1992. The individuals with 4 year olds were also especially abundant in the years 1999-2002 indicating the strong of year-classes 1995, 1996, 1997 and 1998. The 1999 year-class stand out especially judging by the high number of 3 and 6 year olds in 2002 and 2005 years respectively. In these two years both the biomass and the abundance reached out the highest values in the series, especially in 2005 where the strong 2002 year class with 3 years old was also present. From 2004 to present the virtual absence of age group 1 in the catches and very low values for the ages 2 and 3 show the weakness of the 2003 -2012 year classes.

8. RECRUITMENT

Considering the abundance at age 2 as indicator of recruitment, the EU survey provided two recruitment indices. The abundance of two years olds obtained in the main trawl since 1996 and the abundance for this age group in the juvenile shrimp bag attached to the gear since 2001. Both are presented together in table 6 and Figure 6. The early years of the series showed very small numbers of age 2 but from 2002 the abundance increased. Also, from 2003 when automatic winches were introduced in the EU bottom trawl survey, the gear was considered to catch much more young shrimp than before.

Although the evolution of these two recruitment indices showed some differences along the years, the 2002 year-class, 2 year old in 2004 was the biggest seen in both gears and was also very conspicuous as seen in deviations and length frequencies as 3 year olds in 2005 and as 4 year olds in 2006 (Skúladóttir, 2006). The following year-classes (2003-2011) were weak and well below average.

9. PRECAUTIONARY APPROACH

In the absence of other suitable methods to indicate a limit reference point for biomass the EU survey biomass female index was used (SCS Doc. 04/12). The point at which a valid index of stock size has declined by 85% from the maximum observed index level provides a proxy for B_{lim} .

The EU survey of Division 3M provides an index of female shrimp biomass from 1988 to 2013 with a maximum value of 17 091t in 2002 and a similar value of 15 500 in 1992. An 85% decline in this value would give a $B_{lim} = 2 600$ t. The female biomass index was below this value before the beginning of the fishery (1989 and 1990) and most recently in 2009 and since 2011. If this method is accepted to define B_{lim} the index in 2013 it is remain in the collapse zone (Figure 7).

10. SUMMARY

Catches of shrimp on the Flemish Cap have been maintained at a high level averaging 43 000 t. between 1995 and 2005. However since 2006 they decreased gradually being in 2010 around 1 990 t. No catches have been reported since 2011 as consequence of the moratorium of this fishery.

After some years with exploitation rates stables at relative low values (1.9-1.5 from 2005 to 2008) the UE survey indexes estimated decreased year after year. This trend continued in the recent years despite the moratorium established on 3M shrimp stock from 2011.

The female biomass index from the EU survey decreased between 1993 and 1994, increased since 1997 to 1998 and stayed stable to 2007. The strong decline of the female biomass index from 2008 to the present year confirms the decreasing trend of this stock, mainly caused by the weak recruitment in the last nine years.

Considering the 15% of the maximum survey female biomass index as a limit reference point for biomass (B_{lim}), the stock continues in 2013 in the collapse zone defined by the NAFO PA framework.

11. ACKNOWLEDGEMENT

Appreciation is expressed to those who provided data for inclusion in this paper .

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Table 1. 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*	
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					102 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	

- 1 NAFO Statlant 21 A
2 From the fisheries biologist of respective countries
* Provisional to 10 September

Table 2.- Exploitation Rate of Shrimp (Div. 3M) as Nominal Catches (tons) divided by UE Survey Female Index (tons).

	Nominal Catches	UE Survey 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 ¹	0	691	0.0

¹Provisional to 10 September

Table 3.- Shrimp Female and Cod biomass Indices from the EU survey series.

Year	Northern shrimp		Cod
	Biomass (t)	St error	Biomass (t)
1988	4525	842	40839
1989	1359	256	114050
1990	1363	172	59362
1991	6365	750	40248
1992	15472	2623	26719
1993	6923	995	60963
1994	2945	445	26463
1995	4857	521	9695
1996	5132	383	9013
1997	4885	345	9966
1998	11444	816	4986
1999	13669	1038	2854
2000	10172	775	3062
2001	13336	909	2695
2002	17091	1493	2496
2003	11589	921	1593
2004	12081	761	4071
2005	14381	933	5242
2006	11359	1238	12505
2007	12843	1564	23886
2008	8630	1399	42195
2009	1764	238	75228
2010	3819	381	69295
2011	1132	133	106314
2012	791	166	113218
2013	691	58	72289

Table 4. Abundance (10⁶) at age by years in EU Flemish Cap surveys.

Year Age-class	1988	1989	1990	1991	1992	1993	1994 ¹	1995	1996	1997	1998 ²	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
1											94	1	9	3	181	14							8				1
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	118	110	60	23	6	
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	161	387	90	89	18	
4	123	82	404	260	146	376	88	276	153	241	707	1496	1074	2015	1128	548	643	524	1949	1221	857	169	236	109	56	60	
5	233	81	92	465	440	205	73	120	273	322	789	601	572	1184	1047	907	783	1050	1205	1276	575	91	80	31	12	40	
6	163	83	33	389	1129	446	181	215	65	115	414	204	349	323	311	243	133	758	522	588	40	25	15	0	1	3	
7	15	11	2	103	398	49	8	122	44	16	15	8	61	16	55	9	21	141	65	129		7					
8				33																							
total ('000000)	548	258	530	1296	2271	1864	391	976	1734	1046	11751	5177	3876	5750	8608	4753	5281	9554	4098	3631	2141	570	836	290	179	128	

¹Codend mesh-size 40 mm.²Codend mesh-size 25 mm.**Table 5. Biomass estimated (tons) at age by years in EU Flemish Cap surveys.**

Year Age-class	1988	1989	1990	1991	1992	1993	1994 ¹	1995	1996	1997	1998 ²	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013		
1											60	0.5	6	2	114	6								9				1
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	303	372	177	63	21		
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	600	2029	461	450	83		
4	575	387	2053	1214	705	2083	554	1658	1071	1705	4099	9016	5233	9992	6436	2762	3969	2109	5882	4764	4491	892	1690	726	431	313		
5	2377	626	888	3843	3683	1823	681	892	2703	2853	5719	4784	3838	8321	7758	6197	6206	5702	5547	6330	4084	635	644	250	104	362		
6	2334	1053	436	4094	13637	4948	2374	2313	827	1249	4038	2138	3112	3087	2696	2339	1430	5531	3606	3971	390	224	149	5	7	63		
7	285	183	28	1478	5801	675	124	1728	700	234	207	112	706	215	616	108	254	1365	621	1105		81						
8				557																								
total (ton.)	5615	2252	3405	11352	24436	11673	3879	7276	10461	7449	39365	24695	19002	27206	36508	21087	20248	30675	16299	17045	11092	2735	4893	1619	1055	844		

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

Table 6.- Estimated recruitment index as number of Age 2 in the EU Survey series.

Year	Age 2	
	Main gear (10 ⁵)	Juvenile bag
1996	3424	
1997	629	
1998	54968*	
1999	4735	
2000	1069	
2001	3321	1361
2002	11004	2125
2003	12572	0
2004	27415	41818
2005	1792	3741
2006	582	7498
2007	301	3824
2008	221	4969
2009	1177	3011
2010	1103	954
2011	601	2440
2012	229	160
2013	70	102

*1998 mesh size 25 mm was used instead of 35 mm. in EU survey, main gear.

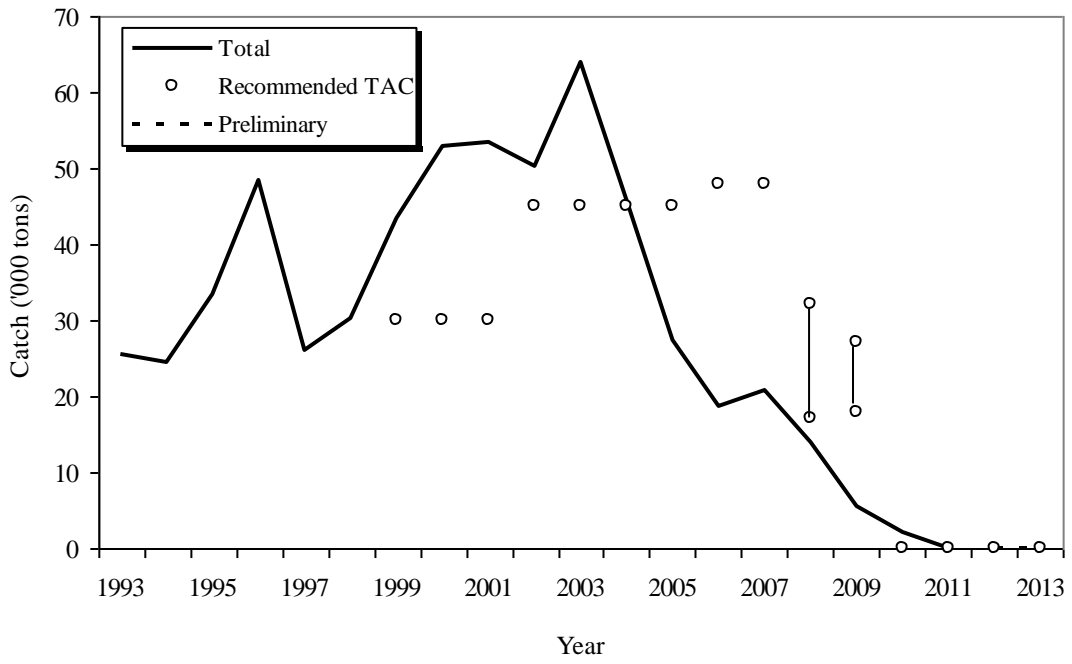


Fig.1. Shrimp in Div. 3M: catch.



Fig. 2. Exploitation rates as nominal catch divided by the EU survey biomass index of the same year.

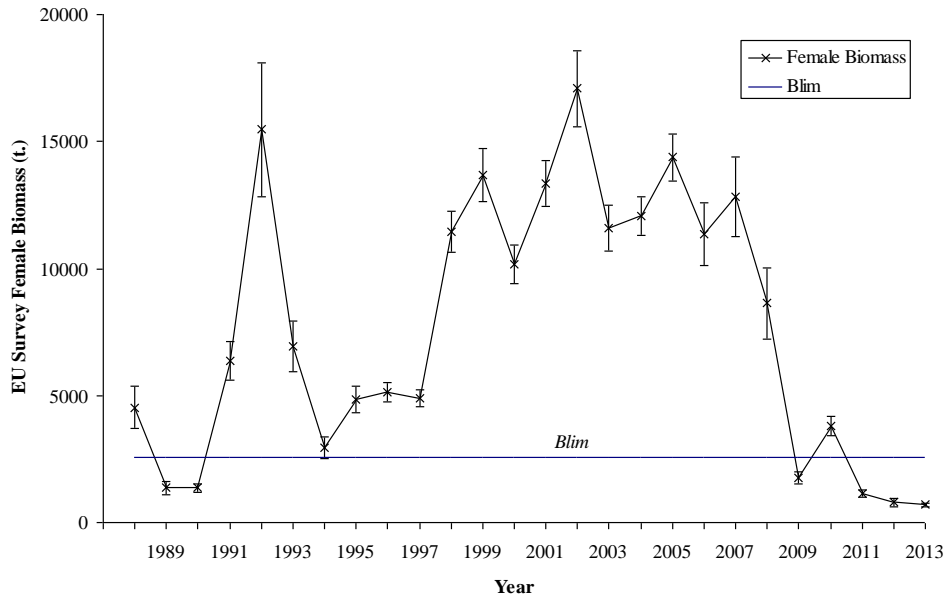


Fig. 3.

Shrimp in Div. 3M: Female biomass index from EU surveys, 1988-2013.

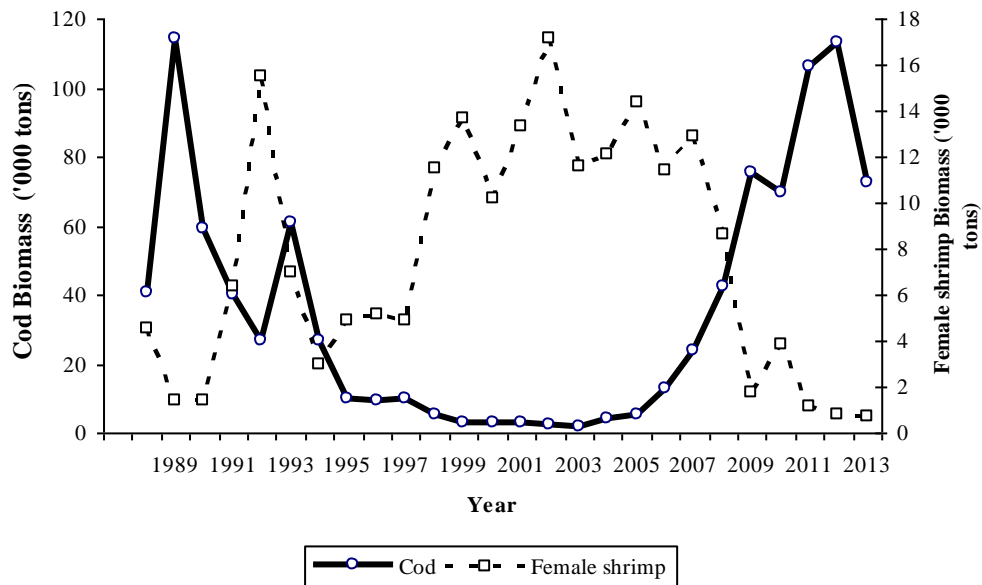


Figure 4. EU survey cod biomass (black line) and female shrimp biomass (dotted line) in the years 1988-2013 on Flemish Cap.

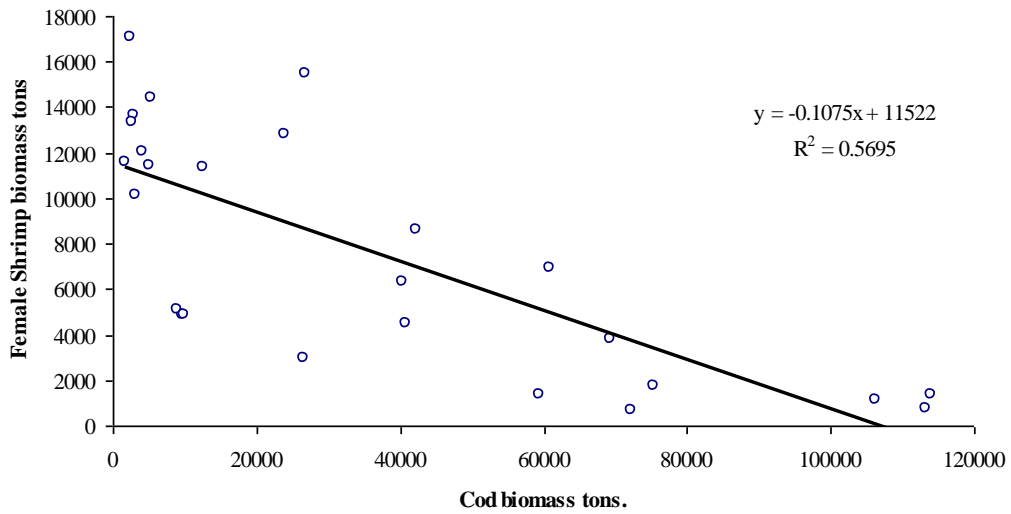


Figure 5 Relationship from cod biomass and female shrimp biomass from EU Survey indexes estimated in the years 1988-2013 on Flemish Cap.

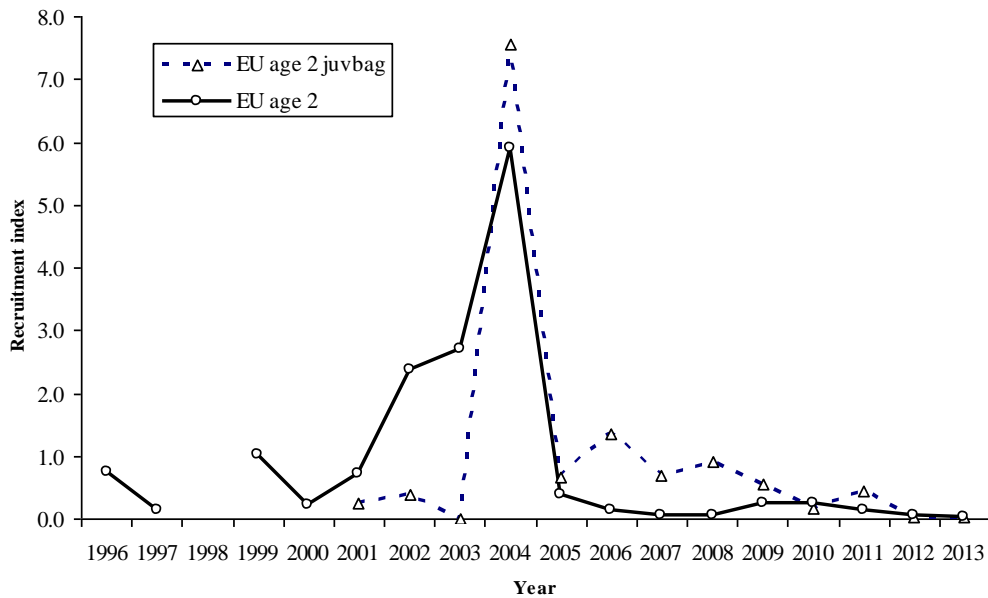


Fig. 6. Recruitment indices, abundances of age 2 in EU Survey from main gear and juvenile bag.. Each series was standardized to its mean.

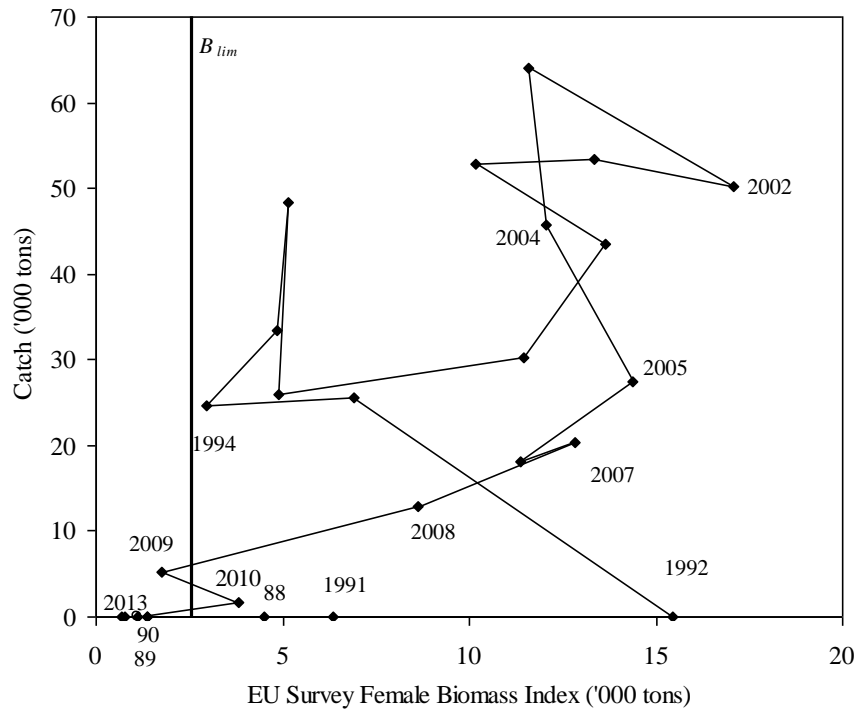


Fig. 7. Catch plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 85% lower than the maximum point in 2002. Due to moratorium on shrimp fishery the expected catch in 2013 is 0 t.