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Northwest Atlantic Fisheries Organization

Serial No. N5987 **NAFO SCR Doc.11/062**

NAFO/ICES *PANDALUS* ASSESSMENT GROUP—OCTOBER 2011

Assessment of the International Fishery for Shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-2011

by

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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, 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 63970 tonnes in 2003 to 5448 tonnes in 2009 and 1988 in 2010. No catches have been recorded in 2011 due to the moratorium. This pessimistic picture is in according with the observed trend in the standardized CPUE that shows a decreasing trend from 2006. 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. 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 is now in the collapse zone defined by the NAFO PA framework. The low exploitation rates in the recent past years and the moratorium in 2011 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 2012.

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 26000 t to 48000 t in the years 1993 through 1996. After 1996 the catches were lower and rising slowly from 26000 t in 1997 to 53000 t in 2000 and 2001. There was 50000 t taken in 2002. The catch increased in 2003, reaching the highest value in the catches series (64000 t). After 2003 the catches decreased all years to 1988 t in 2010. Due to moratorium in 2011 have not

been recorded catches to October 2011 and are only expected very low catches from discards and bycatch 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.

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

Background on the assessment and management of this resource since 1993 can be found in Parsons (1998), Gudmundsdóttir (2003), Gudmundsdóttir and Nicolajsen (2003) Skúladóttir and Pétursson (2005) and NAFO Scientific Council Reports (2005).

2. MATERIAL AND METHODS

Standardization of CPUE

The standardized dataset, consisting of data from Canada, Faroe Islands, Greenland, Iceland, Norway, Russia, Estonia and Spain from 1993 to 2010 was updated. Only Estonian and Spanish data were available from 2009 and 2010. Data were selected from the standardized data file where catch >0 kg and/or effort >10 hours. As area is not defined in some of the reported data and it has been noticed that area is not important to the regression (Gudmundsdottir, 2003) area is not used in the regression. As in previous years there was cause for concern about the correct locations of some catches between 3M and 3L Divisions. Up to 2009 the followed criterion was to analyse those trips where the catches were carried out exclusively in 3M Division. Following this criterion the Estonian vessels data were not used in 2009 and 2010 because they presented all the trips with catches in both divisions 3M and 3L. In the same way from Spanish data in 2010 was removed the vessel data from months with catches in both divisions.

As in previous years, possible outliers were identified by Cock's distances estimated from a preliminary linear regression carried out with the updated CPUE dataset. The CPUE was modelled against year, vessel, month and gear and all the cases with Cock's distances bigger than 0.0008 were remove and the international data base rebuilt.

With the updated international dataset the CPUE was again modelled against year, vessel, month and gear, but using the Generalized Linear Model function glm in Splus (version 6) where the modelled CPUE is log-linked. Effort is used as the weighting factor. As previous years the model was standardized to data from 1993, June, single trawl and Icelandic data.

Samples

Traditionally shrimp samples were taken from commercial fishery and EU 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 calipers and grouped into 0.5 mm length-classes. From commercial fishery, these data formed the International shrimp aging database as recommended Appendix II of the 1999 NAFO Scientific Council meeting on shrimp (NAFO, 2003). However since 2006 could not be adequately sampled the shrimp catches in the commercial fishery. Also the concerns about the correct location of some samples between 3M and 3L made even more difficult the correct interpretation of the length distributions and consequently the modal analysis could not be carried out and the age composition from commercial catches could not be estimated.

An attempt was carried out using the length distributions and the lengths-weight relationship estimated in the EU survey carried out in summer on Flemish Cap each year. However, the age composition (proportion by age and sex) estimated by modal analysis from the random EU survey samples was not a suitable substitute to estimate the

age composition in the commercial catches. Because of that from 2006 was only available information about length distribution from EU summer survey

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

The total catch per year is listed by nations in Table 1. The catch is mostly as it is reported to NAFO either provisionally in monthly reports or annually by the Statlant 21A reports. Also, in some cases information are got from the shrimp specialists of individual countries. Because the moratorium no catches have been recorded to 10 October in 2011 and the table was only revised and updated with total catches in 2010 (1988 t.)

4. CPUE MODEL

Table 2 shows the no. of data records used in the model by year and country. A summary table was made from the data, shown in Table 3. To test the constant variance of the analysed data, the standard errors versus mean CPUE was plotted (Smith and Showell, 1996) and a line was fitted through the points (Figure 2). Since the coefficients of variance were constant (Table 4) a gamma distribution could be used; so the family parameter in glm was set as Gamma. The model was run and the diagnostic plots inspected. Some results from the model fit and the analysis of the deviance are shown in Tables 5 and 6. Standard Splus diagnostic plots for the fit are shown in Figure 3. From the deviance residuals plots it can be seen that the right link function as well as the assumed variance function has been chosen. In spite of the right tail being broad the model is considered appropriate. From the analysis of deviance shown in Table 6, it can be observed that most of the variation is explained by year and vessel factors (79%). The resulting index is shown in Table 7 and Figure 4. The index declined from 1993 to 1994 and was at low levels until 1997. Since 1998 it gradually increased up to 2006, declining in the following years up to 2009. In 2010 this index seems to stabilize at 2008-2009 levels.

In spite of the efforts to discriminate in 2009 and 2010 the correct allocation (between 3L and 3M Divisions) of the Estonian catches, there is a severe concern about the reliability of this data and thus they could not be used in the analysis. In the same way for 2010 the Spanish vessel records with monthly catches in both divisions 3M and 3L were removed from the database international. The wider range of the 95% confidence level in 2009 and 2010 shows a higher uncertainty of the glm carried out these years where the number of cases in the International CPUE data base was lower than the others years.

5. EXPLOITATION RATE

Exploitation rate estimated as nominal catches divided by the EU survey biomass index of the same year is shown in Figure 5 and Table 8. 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 although the exploitation rate remained stable at relative low values (between 1.9-1.5), the UE survey indexes estimated decreased year after year. Despite low catches carried out in 2009 the exploitation rate increased about twice due to the low biomass estimated that year. The exploitation rate in 2010 was the lowest of the observed in the series as a result of the low catches and the small increase in the estimated biomass that year. The exploitation rate in 2011 will be very close to zero because the moratorium for this fishery.

6. 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 6 and Table 9) 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 2011, around 1132 t. was the lowest value 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 the last years (Table 9 and Figures 7A,B). These figures show the significant and inverse correlation between cod and female shrimp biomass.

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). For these years number/hour caught per age-class was calculated for each year by applying a weight/age relationship and age proportions in the catches to the annual standardized CPUE data (Casas, 2010). From 2006 the samples obtained from the fishery have been insufficient to assess the age of the catches and so was not possible to estimate the disaggregated CPUE (number/hour or kg/hour) by age and sex since 2006 to the present. Since then 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 from EU surveys (tables 10 and 11).

From that tables, some strong year-classes may be followed according the abundance by age groups from EU surveys (1988- 2011). 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 -2010 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 12 and Figure 8. The first 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 (2003-2009) 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 2011 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 2011. If this method is accepted to define B_{lim} the index in 2011 it is now again in the collapse zone (Figure 9).

10. SUMMARY

Catches of shrimp on the Flemish Cap have been maintained at a high level averaging 43000 t. between 1995 and 2005. However since 2006 they decreased gradually being in 2010 around 1990 t. No catches have been reported in 2011 as consequence of the moratorium of this fishery.

The CPUE model shows a general declined between 1993 and 1996, increasing the catch rate from 1997 up to 2006. After then the CPUE show a decreasing trend in the following years up to 2009. In 2010 this index seems to stabilize at 2008-2009 levels. However the low number of cases in the last two years (2009 and 2010) increases the uncertainty of the glm carried out these years.

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. Despite low catches carried out in 2009, the exploitation rate increased about twice as consequence the low biomass estimated that year. The exploitation rate in 2010 was the lowest of the observed in the series.

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 seven years.

The drastic stock decline on Div. 3M shrimp is associated to the rebuilding of the cod stock in 3M Division.

10 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*
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

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

Table 2. Number of data records which are used in the final model fit by year and country.

Year	CAN	EST	FRO	GRL	ICE	NOR	RUS	SP
1993	55			75	41	74		
1994	38			44	50	104		
1995	53		86	37	172	111	13	
1996	27		236	32	466	65	102	
1997	17		175	7	153	13	11	
1998	16		155	15	130	9		
1999	10		119	8	178	18	26	
2000	8		121	27	167	19	35	
2001	8				127	75	65	
2002				15	90	64	25	
2003		88		13	61	77		
2004		80			32	50		
2005		82			20	2		22
2006		24		9	6	2		18
2007		16				7		18
2008		10				1		12
2009								12
2010								6

Table 3. Analysis about the CPUE data

year	No. of obs	Mean CPUE	Std. dev	Min	Max	CV
1993	245	357	149	44	895	0.417
1994	236	235	104	10	709	0.443
1995	472	270	129	48	1182	0.477
1996	928	227	114	45	848	0.503
1997	376	286	97	92	602	0.337
1998	325	374	144	78	1316	0.384
1999	359	380	146	58	837	0.384
2000	377	419	165	48	1153	0.394
2001	275	411	140	59	966	0.342
2002	194	502	163	25	932	0.325
2003	239	600	234	129	1371	0.390
2004	162	564	206	227	1425	0.366
2005	126	567	176	65	1145	0.310
2006	59	606	228	56	1021	0.377
2007	41	599	274	183	1353	0.457
2008	23	450	178	57	683	0.395
2009	12	377	173	18	653	0.458
2010	6	574	397	141	1200	0.692

Table 4. Results of fitting standard error versus mean CPUE.

Call: lm(formula = std ~ mean, data = table10, na.action = na.exclude)
Residuals:

Min	1Q	Median	3Q	Max
-58.84	-22.39	-8.82	15.5	159.2

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.9964	39.5762	-0.0757	0.9406
cpue	0.4195	0.0877	4.7854	0.0002

Residual standard error: 47.29 on 16 degrees of freedom
Multiple R-Squared: 0.5887

F-statistic: 22.9 on 1 and 16 degrees of freedom, the p-value is 0.0002023

Table 5. Results from the multiplicative model. The ship factors are not shown.

Call: glm(formula = cpue ~ year + vessel + month + gear, family = Gamma(link = log), data = standcpue2010, weights = effort, na.action = na.exclude, control = list(epsilon = 0.0001, maxit = 50, trace = F), contrasts = list(year = contr.treatment, vessel = contr.treatment, month = contr.treatment, gear = contr.treatment))

Deviance Residuals:

Min	1Q	Median	3Q	Max
-21.27366	-1.942781	-0.3604753	1.293819	14.37164

Coefficients:

	Value	Std. Error	t value
(Intercept)	5.98931645	0.0786971	76.105938
year1994	-0.35793238	0.02186525	-16.369918
year1995	-0.20017157	0.02218456	-9.023011
year1996	-0.32854998	0.02340883	-14.035303
year1997	-0.31384087	0.02550184	-12.306597
year1998	-0.06427916	0.02671121	-2.406449
year1999	-0.02991336	0.02641478	-1.132448
year2000	0.08039803	0.02706345	2.970723
year2001	0.05508122	0.0311741	1.766891
year2002	0.07250816	0.03307479	2.192249
year2003	0.23852837	0.03387099	7.042262
year2004	0.14754202	0.03543131	4.16417
year2005	0.26252268	0.03804966	6.899476
year2006	0.41564106	0.04471019	9.296339
year2007	0.30646756	0.05079143	6.033844
year2008	0.1998232	0.06047144	3.304423
year2009	0.13796533	0.12814014	1.0766754
year2010	0.1824241	0.17034854	1.0708874
month2	0.02156712	0.03398948	0.6345234
month3	0.04281602	0.03078548	1.3907864
month4	0.01372536	0.02934886	0.4676627
month5	0.04074883	0.0287847	1.4156421
month6	0.10487368	0.02836538	3.6972417
month7	0.0258019	0.02835705	0.9098937
month8	-0.08169819	0.02878841	-2.8378851
month9	-0.14868026	0.02913706	-5.1027889
month10	-0.1302509	0.02940883	-4.428973
month11	-0.1606168	0.03073586	-5.225713
month12	-0.1199189	0.03385572	-3.542059
gear2	0.1778047	0.01843671	9.644061
gear3	0.1917904	0.06306148	3.041324

Dispersion Parameter for Gamma family taken to be 9.325338

Null Deviance: 216436.6 on 4454 degrees of freedom

Residual Deviance: 39594.02 on 4218 degrees of freedom

Number of Fisher Scoring Iterations: 4

Table 6.- Analysis of deviance table for generalized linear models fitted to shrimp catch rate data from 1993 to 2010 in Flemish Cap.

Source of variation	df	Deviance	Resid.Df	Resid.Dev	F Value	Pr(F)	% explained
NULL			4454	216436.6		<0.001	
year	17	104622.7	4437	111814	659.9521	<0.001	48.3%
vessel	206	66173.3	4231	45641	34.447	<0.001	30.6%
month	11	5202.9	4220	40438	50.7207	<0.001	2.4%
gear	2	843.7	4218	39594	45.2393	<0.001	0.4%

Table 7. CPUE index by year and the approximate 95% confidence interval

		Confidence limits	
Year	Index	upper 95%	Lower 95%
1993	1.0000	1.0000	1.0000
1994	0.6991	0.7297	0.6698
1995	0.8186	0.8550	0.7838
1996	0.7200	0.7538	0.6877
1997	0.7306	0.7681	0.6950
1998	0.9377	0.9881	0.8899
1999	0.9705	1.0221	0.9216
2000	1.0837	1.1428	1.0277
2001	1.0566	1.1232	0.9940
2002	1.0752	1.1472	1.0077
2003	1.2694	1.3565	1.1878
2004	1.1590	1.2423	1.0812
2005	1.3002	1.4009	1.2068
2006	1.5153	1.6541	1.3882
2007	1.3586	1.5008	1.2299
2008	1.2212	1.3749	1.0847
2009	1.1479	1.4757	0.8930
2010	1.2001	1.6758	0.8595

Table 8.- Exploitation Rate of Shrimp (Div. 3M) as Nominal Catches (tons) divided by UE Survey 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	3818	0.5
2011[1]	0	1132	0.0

[1]Provisional to 10October

Table 9.- 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

Table 10. Abundance (10^6) 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
1											94	1	9	3	181	14							8	
2									342	63	5497	474	107	332	1100	1257	2742	179	58	30	22	118	110	60
3	13	1		47	159	788	43	243	857	289	4235	2392	1704	1877	4787	1774	960	6903	301	387	646	161	387	90
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
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
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
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

[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.

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
1											60	0.5	6	2	114	6							9	
2									609	139	9039	832	183	572	2178	2541	4660	187	57	38	33	303	372	177
3	44	2		166	610	2144	145	685	4552	1270	16203	7811	5924	5018	16710	7134	3730	15782	586	837	2094	600	2029	461
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
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
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	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

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

Table 12.- Estimated recruitment index as number of Age 2 and the Biomass and Abundance Index for age 3 and older in the EU Survey series.

	Age 2	
Year	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

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

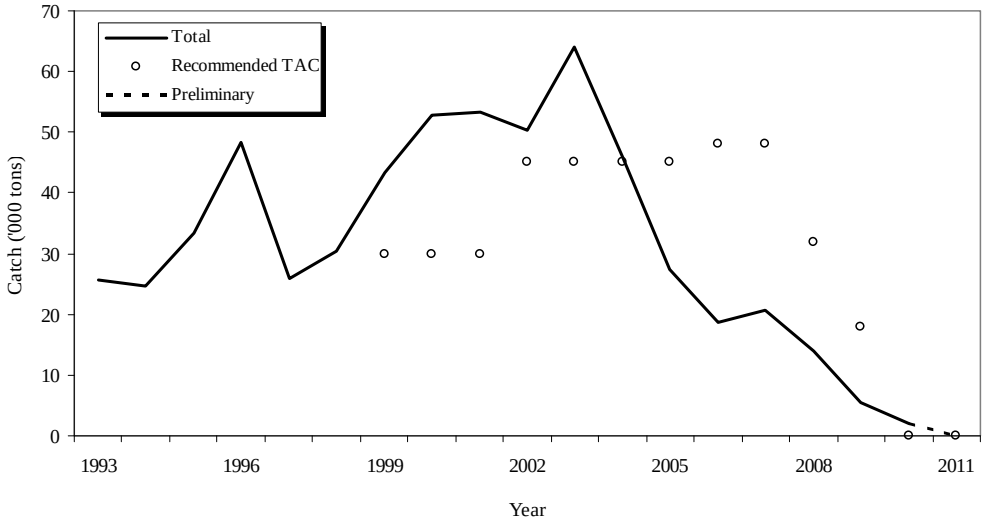


Fig.1. Shrimp in Div. 3M: catch.

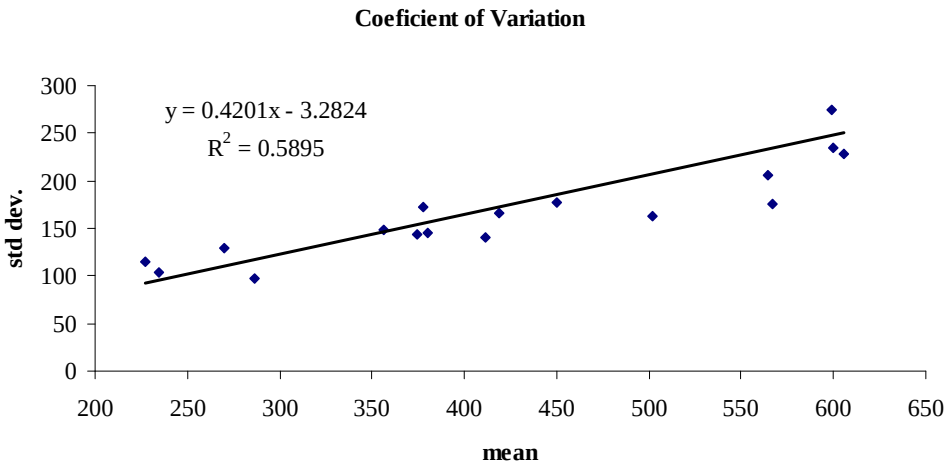


Fig. 2. Coefficient of variation around the annual means CPUE.

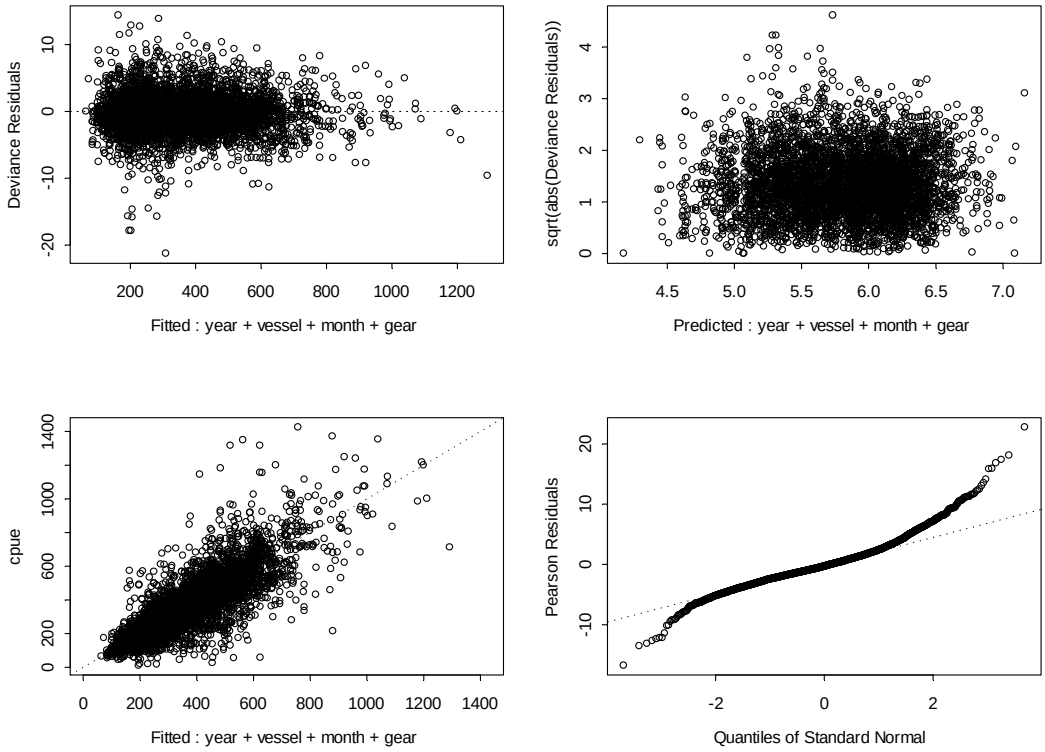


Fig.3. Plots of the generalized linear model of CPUE predicted by year, vessel, month and gear.

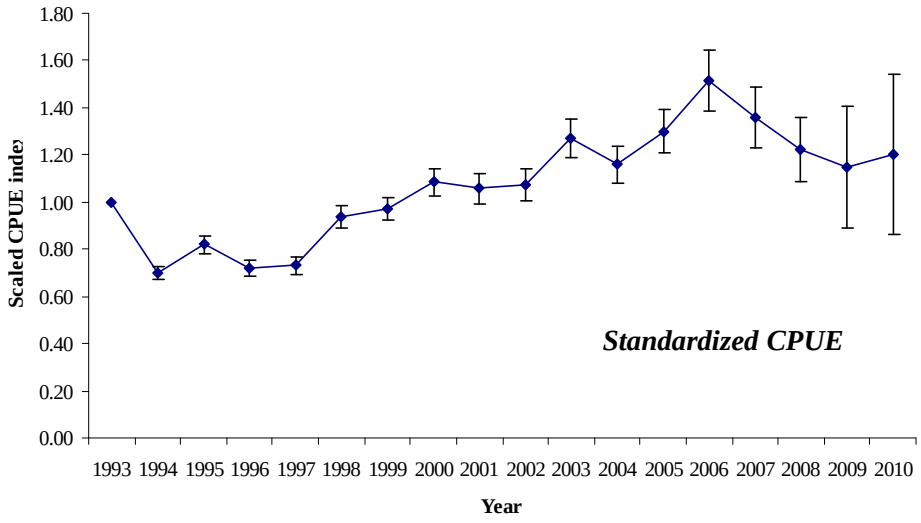


Fig. 4. Standardized CPUE series for shrimp in 3M Division, scaled to CPUE in 1993 with approximate 95% confidence limits.

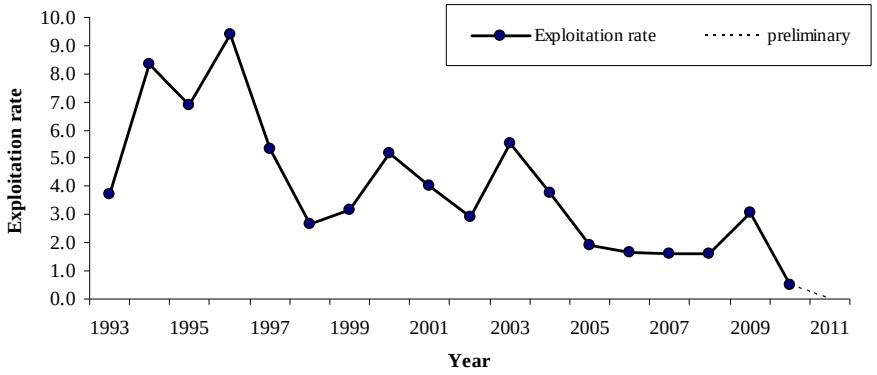


Fig. 5. Exploitation rates as nominal catch divided by the EU survey biomass index of the same year.

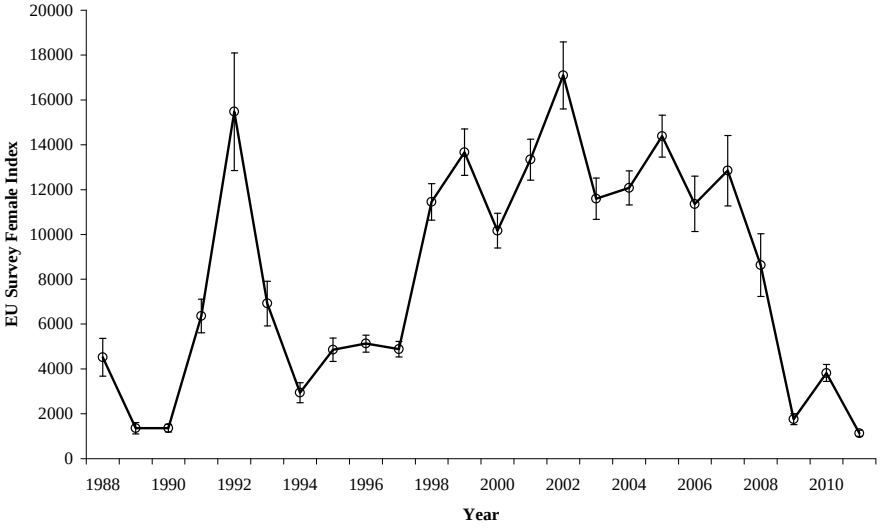
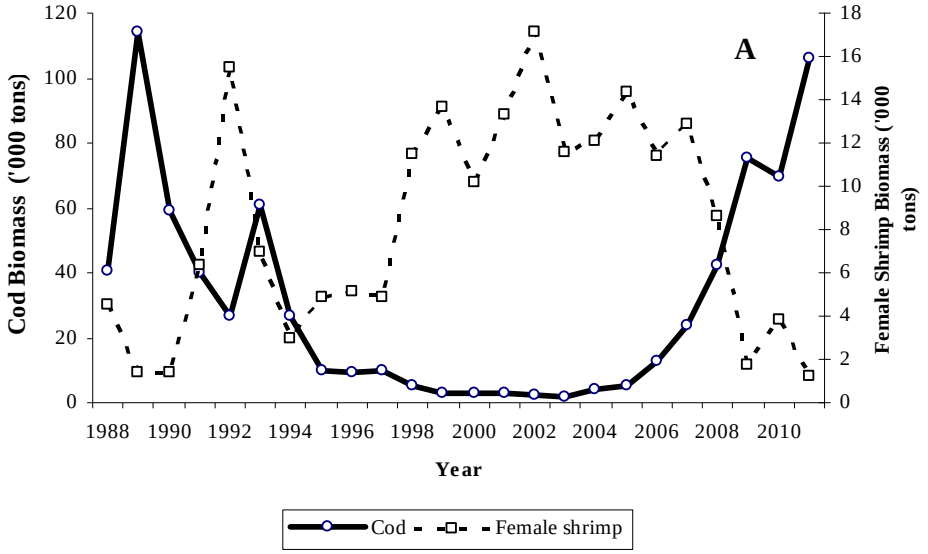


Fig. 6. Shrimp in Div. 3M: Female biomass index from EU surveys, 1988-2011.



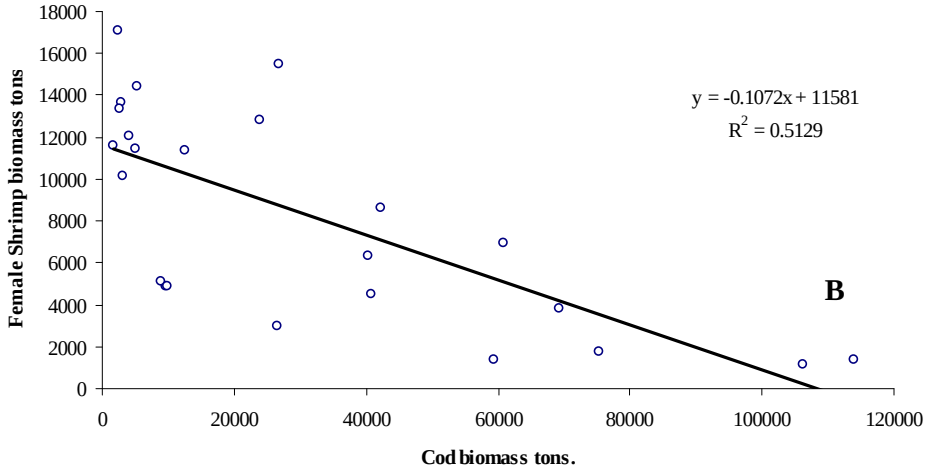


Figure 7. **A**) EU survey cod biomass (black line) and female shrimp biomass (dotted line) in the years 1988-2011 on Flemish Cap. **B**) Relationship from cod biomass and female shrimp biomass from EU Survey indexes estimated in the years 1988-2011 on Flemish Cap.

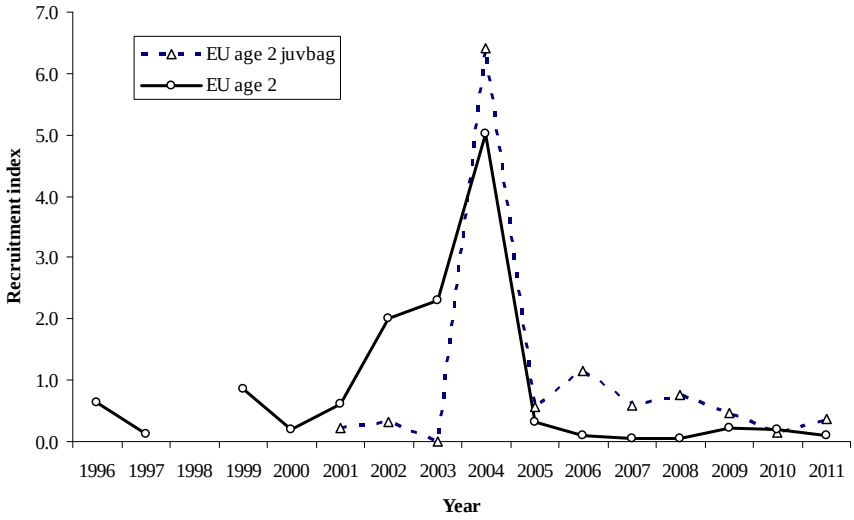


Fig. 8. Recruitment indices, abundances of age 2 in EU Survey from main gear and juvenile bag.. Each series was standardized to its mean.

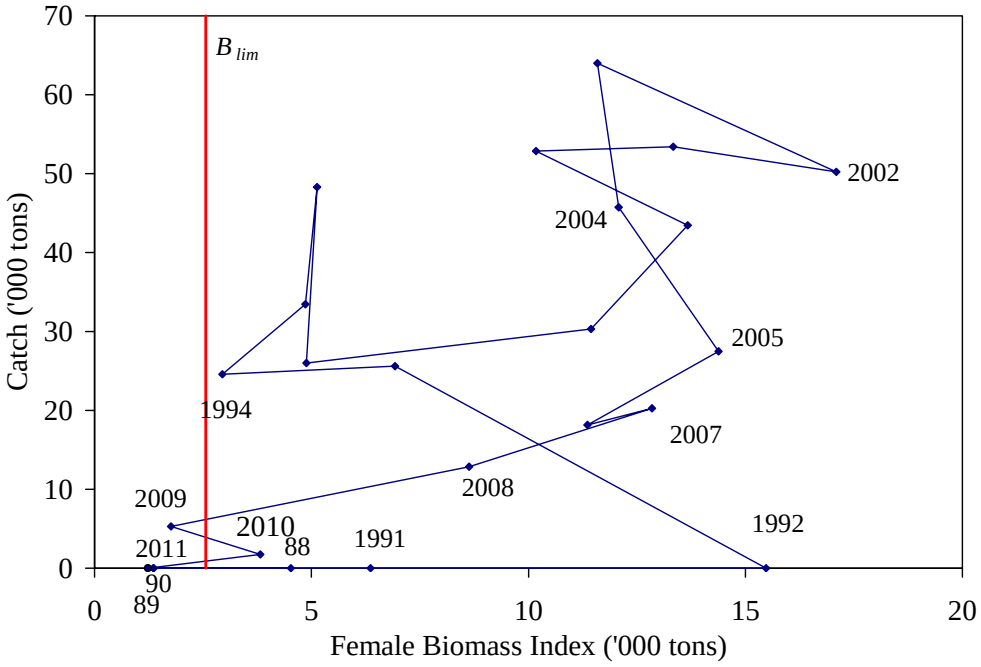


Fig. 9. Catch plotted against female biomass index from EU survey. Line denoting B_{lim} is drawn where biomass is 85% lower than the maximum point in 2002. Due to moratorium on shrimp fishery the expected catch in 2011 is 0 t.