Northwest Atlantic Fisheries Organization

Serial No. N6117 **NAFO SCR Doc.12/55**

NAFO/ICES PANDALUS ASSESSMENT GROUP—OCTOBER 2012

Atlantic Cod Predation on Northern shrimp in Flemish Cap (NAFO Div. 3M)

by

González Iglesias, C.[1] and Casas, J. M.
Instituto Español de Oceanografía, P.O. Box 1552, Vigo, Spain
[1]conchi.gonzalez@vi.ieo.es

Abstract

The aim of this study is to estimate the predation on shrimp by Atlantic cod in Flemish Cap in the period 2000-2010 and the impact of the cod stock recovery in recent years on the prey stock. Stomach content samples of Atlantic cod were taken in the Flemish Cap survey (NAFO Div. 3M). The analysis was done jointly from all individuals, undifferentiated sexes. They were established four size groups of Atlantic cod with a different predation rate on shrimp: 10-79 cm, 80-89 cm, 90-109 cm and ≥110 cm. Results show a clear increasing trend in the daily consumption of shrimp by cod related with increasing of shrimp biomass. Males and females show the same pattern of consumption of this prey. However consumption changes with the predator size, being highest in individuals over 16 cm to 79 cm. Cod less than 16 cm does not consume shrimp. The maximum consumption of this prey was observed in the period 1999-2008; this period was followed by the fall of this prey biomass in recent years as the cod biomass increased.

Introduction

Consumption estimation by predation is an important factor in stock under fishery when it has an important trophic role for other species. This happens with redfish (*Sebastes*) or northern shrimp (*Pandalus borealis*) distributed in Flemish Cap, which are important components of food for cod (*Gadus morhua*). Further given the high feeding intensity of this predator, their characteristics of food composition and biomass at age should be considered. It has also been indicated the impact of abundance changes of the main prey in the cod diet in the feeding intensity and therefore in the daily ration (Orlova and Chumakov, 1993).

Description of the summer diet of Flemish Cap cod from sampling carried out in the EU-Research Survey series in this area was presented in several studies covering different time periods: 1989-1990 (Paz *et al*., 1993), 1988-1993 (Casas and Paz, 1994), 1993-1994 (Rodríguez-Marín *et al*., 1994; Rodríguez-Marín, 1995), 1993-2000 (Torres *et al*., 2000), 2001-2003 (Román *et al*., 2004). All these studies underline the high feeding intensity of this species and the importance three preys (redfish, shrimp and hyperiids) in their diet.

Northern shrimp is a prey that plays a key trophic role in various areas of the North Atlantic for many species (Parsons, 2005a), such as with the Flemish Cap cod and the feeding studies previously cited with data EU-Flemish Cap survey reflect. The impact of predation on northern shrimp by cod and other species has been analyzed through the consumption estimated from different methods and data sources, as reflected in the studies of Parsons (2005a, 2005b) and Lilly *et al*. (2000) and other studies discussed by these authors.

The aim of this study is to estimate the predation by cod on shrimp in Flemish Cap in the period 2000-2012 and the impact of the cod stock recovery in recent years on the prey stock.

Materials and Methods

Stomach content samples of Atlantic cod (*G. morhua*) were taken in the EU-Flemish Cap survey (NAFO Div 3M) throughout the period 1993-2012. This survey has been carried out in summer since 1988 (Casas and González-Troncoso, 2011). Table 1 shows the sampled individuals (7995 individuals), indicating the

length range (total length to the nearest lower cm) by sex, depth range of sampling, and individuals with stomach content (7590). Table 2 shows the number of cod individuals with shrimp (*P. borealis*) presence in the stomach contents (2181 individuals) and sample characteristics in relation to size range of predator and depth of samples. Food sampling was not carried out in 2007, 2009 and 2011.

Samples were gathered through a random sampling stratified by sex and predator length. Cod individuals were grouped by size ranges of 10 cm (0-9, 10-19, 20-29, 30-39 cm, etc), sampling 50 females and 50 males by length range and year. The sampling was carried out on board during the survey and the volume of the stomach content was measure using a trophometer (Olaso, 1990), and the percentage of each prey in the total volume was recorded.

Two indices were used to analyse the feeding activity:

- Feeding Intensity Index (FI): percentage of individuals with stomach content.

$$FI = \frac{n}{N} 100$$

where n is the number of individuals of cod with stomach content and N is the total number of individuals sampled.

- Mean Weight Fullness Index (MWFI): percentage of stomach content weight in terms of the predator weight.

$$MWFI = \frac{\sum \frac{W_{sc}}{W_p} 100}{n}$$

where W_{sc} is the stomach content wet weight of the preys, and W_p is the wet weight of predator p.

Shrimp consumption was measured also with both indices: FI_{shrimp} and $MWFI_{shrimp}$. The first indicates the percentage of individuals of cod who eat shrimp, and the second index quantifies the mean amount (g) of shrimp consumed per 100 g of wet weight of predator.

Differences between sexes in FI index values (according to the frequency of empty stomachs, stomachs with shrimps and stomachs with other preys) were tested with χ^2 test. Also the differences between sexes and length in $MWFI_{shrimp}$ values were tested with Kruskal-Wallis test.

Ontogenic changes of cod in the feeding on shrimp was determined using Bray-Curtis similarity matrix applying a square root transform and cluster analysis through group average.

The approach to estimate the predation on shrimp by the Atlantic cod was:

1) Calculate the percentage of this prey ($MWFI_{shrimp}$) regarding the total consumption (MWFI).
2) We have not own cod daily ration information, so we use the value indicated in the review of Livingston and Goiney (1984) obtained by Braaten and Gokstad (1980) with a mean value 1.9. The mean value is more suitable to the following considerations:
    - Cod eats shrimp and other foods throughout the year but diminishes the feeding intensity in winter (Albikovskaya and Gerasimova, 1993), however we assume a constant shrimp mortality rate by predation throughout the year.
    - Daily ration varies with size but nevertheless we apply the same daily ration to all individuals.
3) Knowing that the daily ration is the daily food amount (g) that an individual needs for every 100 g of body weight, we assume that the percentage of $MWFI_{shrimph}$ regarding the MWFI at the sampling time could be

applied to daily ration to estimate the daily consumption of shrimp by cod. It was assumed that the percentage obtained in EU summer survey, is constant throughout the year.

Results

Feeding Intensity of Atlantic cod and feeding percentage on shrimp (FI_{shrimp}). Atlantic cod showed a general high feeding intensity (average 95%) in the period corresponding to summer in Flemish Cap (Table 3). Males and females showed a similar pattern and no significant differences were found between them when the number of empty stomachs, with shrimp as prey or with other prey was considered (Table 4).

In the studied period 27% individuals sampled ate shrimp on average. Feeding intensity on shrimp was low between 1993 and 1995; increased after 1995 and staying at high values between 1998 and 2006 with the exception of 2004. Since 2006, consumption of this prey decreased year by year to the lowest value for the current year 2012 (Table 3 and Figure 1).

The sudden drop of FI_{shrimp} in 2004 coincided with the increase in the presence of hyperiids in the stomachs of cod. A similar process is observed in the early years of the period analyzed, however, the response between both prey in the last years has not been the same (Figure 1).

Shrimp consumption by cod ($MWFI_{shrimp}$). The quantitative predation index on shrimp $MWFI_{shrimp}$ showed a similar pattern to FI_{shrimp}. It was low before 1995 and increased later staying variable at high levels from 2000 to 2006. Since 2006 the shrimp consumption by cod decreased year after year to lowest value estimated in 2012. This picture is in general agreement with the total and female biomass of shrimp estimated by the EU surveys (Figure 2).

As the FI_{shrimp} the $MWFI_{shrimp}$ did not show significant differences by sexes ($\chi^2_{(1)} = 3.35$, $p>0.05$). However the consumption of shrimp by cod showed differences between the different cod size groups considered ($\chi^2_{(10)} = 377.5$, $p\leq 0.01$). Four size groups of cod were distinguished from the cluster analysis carried out on Bray-Curtis similarity matrix at an arbitrary similarity level of 90%: 10-79 cm, 80-89 cm, 90-109 cm and $\geq$ 110 cm (Figure 3).

Estimate of daily and annual shrimp consumption by Atltantic cod population. Table 5 shows the shrimp rate consumption ($MWFI_{shrimp}$) observed in the EU survey sampling, and their percentage as regards total food ($\%MWFI_{shrimp}$) in the four size groups considered. Also is calculated the daily shrimp ration assuming the mean daily ration of 1.9 g of food per 100 g of predator per day.

From that table it can be observed the high level of predation on shrimp by cod sizes between 10 and 79 cm from 1999 to 2008; the predation on shrimp by cod with sizes of 80 to 109 cm only was important between 2001 and 2003 and was minimal in those specimens bigger than 110 cm.

Table 6 shows the estimated biomass of Atlantic cod at different ages based on the 2011 assessment results (González-Troncoso and Vázquez, 2011). These results correspond to the begining of the year and they were transformed at middle of the year adding the initial and final year biomass and dividing by two. To estimate the daily shrimp consumption by cod age groups, the mean year biomass at age was multiplied by the value obtained by applying the daily ration of shrimp as percentage ($MWFI_{srhimp}$) to the assuming daily ration for cod (1.9 g of food per 100 g of predator per day). Finally, the daily consumption of shrimp was raised to the annual consumption assuming a constant rate.

Figure 4 shows the shrimp biomass consumed by cod ages $1\text{-}8^+$ estimated by $MWFI_{shrimp}$ and the female shrimp biomass estimated from EU research survey on Flemish Cap both average standardized. It can be observed as the increase of shrimp consumed by cod from 2005-2010 is associated with the declining of shrimp female biomass in that years.

Discussion

The feeding studies on cod in Flemish Cap show the high feeding intensity experimented in summer during the studied period (Paz *et al*., 1993; Casas and Paz, 1994; Rodríguez-Marín *et al*., 1994; Rodríguez-Marín, 1995; Torres *et al*., 2000; Román *et al*., 2004). However when it is analyzed one of its most important

prey (Northern shrimp), only 27% of the sampled cod showed this species between their preys. This relative low value is the result of a strong variation along the years. So shrimp was of little importance in the early years of the series (1993-1995), it was outstanding between 1998 and 2006 to return to minimum values in the recent years.

In a general picture, the high presence of shrimp in the cod diet between 1998 and 2006 coincides with the increase of the shrimp biomass. On the contrary when the shrimp biomass declines its importance as prey in the cod diet decrease too. The exception of this pattern in 2004 was probably due to changes in the spatial distribution of cod to shallower depths where the greatest abundance of hyperiids favours their occurrence in the diet.

Males and females of cod showed a similar feeding pattern. However the predation on shrimp changed with size and therefore the changes in the abundance of different size or age groups of cod could to provoke changes in the shrimp biomass. Particularly after recovery of the cod stock in recent years (González-Troncoso and Vázquez, 2011). The cod with size below 16 cm does not eat shrimp; this size was similar to observed by Lilly (Lilly *et al*., 2000) for the northeast cod stock in Newfoundland. The shrimp is a very important prey for cod sizes ranged between 16 and 79 cm (age groups 1 to 6). Beyond 80 cm it change the trophic habits to more piscivorous diet mainly on redfish (González-Iglesias *et al*., 2012). These changes in the diet at different sizes or ages (<3, 3-5 and ≥ 6 years old) have already been cited in the past (Paz *et al*., 1993).

We find a correspondence between the biomass increase of shrimp and the bigger consumption of this prey by the cod, where the availability of this prey determine their feeding behaviour (Paz *et al*., 1993; Floeter and Temming, 2003). This situation is reversed as cod biomass increases in the recent years.

The absence of predators and preys with a particular size can interact in the trophic dynamics and to explain the increase of the consumption rates by predator and the prey biomass simultaneously. The low biomass of cod age groups 1-6 (10-79 cm) in the period 2000-2006 could have caused a relatively low mortality of shrimp due to predation and this way to permit the high level of biomass of this prey and the high rates of cod consumption. The subsequent increase in the biomass of cod groups (1-6 years old), initiated in 2005-2006, and very remarkable from 2008, marks the beginning of an opposite process, corresponding to the drop in shrimp biomass, and so in a minor importance in the cod diet.

The average daily consumptions (g /100 g predator per day) of shrimp by cod were: 0.39 for cod sizes between 10-79 cm, 0.18 for sizes between 80-89 cm and 0.04 for cod ≥ 90 cm. These values are similar to the estimated by Lilly *et al*. (2000) for the northern cod stocks (2J+3KL): 0.31(g per day), 0.19 y 0.05 considering the same size groups.

In spite of this general dependence between shrimp and cod biomass, a different pattern was observed from 1993 to 1997, a period with low biomass of both predator and prey, and where the cod feeding was mainly represented by the hyperiids consumption. Lilly *et al*. (2000) and Parsons (2005b) also advance this shrimp-cod biomass relationship but they did not reach a clear conclusion. Others factors (climate, biomass of others predators, fishing, etc.) can interact in the dynamics of shrimp population as well the methodological aspects in the estimate of daily consumption.

Conclusions

Males and females of cod show the same pattern of consumption on shrimp. However consumption changes with the predator size, being highest in individuals over 16 cm to 79 cm. Cod less than 16 cm does not consume shrimp.

Results show a clear increasing trend in the daily consumption of shrimp by cod related with increasing of shrimp biomass. The maximum consumption of this prey was observed in the period 1999-2008; this period was followed by the fall of this prey biomass in recent years as the cod biomass increased.

References

Albikovskaya, L. K.; 0. V. Gerasimova and S. M. Kotlyarov. 1988. Feeding peculiarities of the main commercial fishes on the Flemish Cap and northern Newfoundland Banks in spring-summer 1987. *NAFO SCR Doc.* 88/22, Serial No. N1458.

Braaten, B. and S. L. Gokstad. 1980. Appetite feeding experiments with cod – preliminary results. *Int. Count. Explor. Sea, Maricult. Comm. C. M*. 1980/F:20, 11p.

Casas, J. M. and J. Paz. 1994. Diet of Flemish Cap cod with particular referente to predation on redfish: 1988-93. *NAFO SCR* 94/24, Serial No. N2390.

Casas, J. M. and D. González-Troncoso. 2011. Results from bottom trawl survey on Flemish Cap of june-july 2010. *NAFO SCR* 11/021, Serial No. N5904.

Floeter, J. and A. Temming. 2003. Explaining diet composition of North Sea cod (*Gadus morhua*): prey size preference vs. prey availability. *Can. J. Fish. Aquat. Sci.* **60**: 140-150.

González Iglesias, C., F. González–Costas and D. González–Troncoso. 2012. Atlantic cod predation on redfish in Flemish Cap. *NAFO SCR Doc*. 12/027, Serial No. N6053

González-Troncoso, D. and A. Vázquez, 2011. Assessment of the cod stock in NAFO Division 3M. *NAFO SCR Doc*. 11/38, Serial No. N5926.

Lilly, G. R., D. G. Parsons and D. W. Kulka. 2000. Was the increase in shrimp biomass on the northeast Newfoundland shelf a consequence of a realease in predation pressure from cod?. *J. Northw. Atl. Fish. Sci.* **27**: 45-61.

Livingston, P. A., and B. J. Goiney, Jr. 1984. Bibliography on daily food ration of fishes. NOAA Technical Memorandum NMFS F/NWC-63.

Parsons, D. G. 2005a. Predators of northern shrimp, *Pandalus borealis* (Pandalidae), throughout the North Atlantic. *Marine Biology Research*, 1: 48-58.

Parsons, D. G. 2005b. Interactions between northern shrimp, *Pandalus borealis* (Pandalidae), and its key predators within the eastern Newfoundland and Labrador marine ecosystem. *Marine Biology Research*, 1: 59-67.

Olaso, I. 1990. Distribución y abundancia del megabentos invertebrado en fondos de la plataforma Cantábrica. *Bol. Inst. Esp. Oceanogr. Publ. Esp*. No. 5, 128 p.

Orlova, E. L., and A. K. Chumakov. 1993. Comparative study of the intensity of feeding of cod (*Gadus morhua*) off Newfoundland and of the southern Barents Sea. *NAFO Sci. Coun. Studies*, 18: 91-92.

Paz, J.; M. Casas and G. Pérez-Gándaras. 1993. The feeding of Cod (*Gadus morhua*) on Flemish Cap 1989-90. N*AFO Scientific Coun. Studies,* **19**: 41-50.

Rodríguez-Marín. 1995. Feeding relationships of demersal fish in Flemish Cap in summer, 1993-1994. *NAFO SCR Doc* 95/104, Serial No. N2627.

Rodríguez-Marín, E., A. Punzón , J. Paz and I. Olaso. 1994. Feeding relationships of demersal fish in Flemish Cap in summer, 1993-1994. *NAFO SCR Doc*. 94/35, Serial No. N2403.

Román, E., C. González and E. Ceballos. 2004. Food and feeding of most abundant fish species in Flemish Cap. *NAFO SCR Doc*. 04/58, Serial No. N5018.

Torres, P., E. Rodríguez-Marín and I. Loureiro. 2000. Preliminary results from feeding analysis for the most abundant demersal fishes in Flemish Cap during summer (1993-2000). *NAFO SCR Doc*. 00/60, Serial No. N4302.

Table 1.Characteristics of Atlantic cod (*G. morhua*) sampling in the bottom trawl Survey on Flemish Cap 1993-2012.

Year	Month	No. individuals			Size range (TL, cm)				Depth (m) of sampling		Indivs. with stomach content		
					Males		Females						
		Males	Females	Total	Min.	Max.	Min.	Max.	Min.	Max.	Males	Females	Total
1993	Jun/July	406	474	880	14	95	14	98	132	389	386	459	845
1994	July	250	283	533	14	98	16	94	151	337	250	283	533
1995	July	248	235	483	15	86	14	102	126	308	248	235	483
1996	Jun/July	196	258	454	17	68	18	73	135	315	190	250	440
1997	Jun/Aug.	202	288	490	20	99	19	74	133	315	198	282	480
1998	Jul/Aug.	70	106	176	19	70	24	90	139	306	70	101	171
1999	July	70	106	176	30	90	23	74	133	332	68	106	174
2000	July	107	127	234	15	111	18	113	135	330	107	127	234
2001	July	161	208	369	17	80	16	106	132	343	155	205	360
2002	July	109	133	242	32	102	30	92	130	332	109	133	242
2003	June	65	91	156	16	94	17	92	130	449	57	79	136
2004	Jul/Aug.	183	233	416	32	97	27	99	136	306	183	230	413
2005	July	167	216	383	15	106	15	91	132	256	154	203	357
2006	July	345	341	686	15	98	15	116	134	439	311	315	626
2008	June	397	434	831	14	106	13	108	131	431	387	400	787
2010	Jun/July	261	319	580	15	110	15	117	132	484	233	286	519
2012	Jun/July	401	505	906	13	111	13	125	139	624	351	439	790
Total		3638	4357	7995	13	111	13	125	126	624	3457	4133	7590

Table 2. Characteristics of Atlantic cod individuals with *P. borealis* in the stomach contents sampled in the bottom trawl Survey on Flemish Cap 1993-2012.

Year	Indivs. with *P. borealis* in the stomach contents			Size range (cm)				Depth (m) of sampling	
				Males		Females			
	Males	Females	Total	Min.	Max.	Min.	Max.	Min.	Max.
1993	23	32	55	27	83	16	81	148	389
1994	38	37	75	17	83	18	91	151	337
1995	12	18	30	29	61	30	69	145	308
1996	25	42	67	30	68	24	68	135	315
1997	37	69	106	32	99	19	67	158	315
1998	32	54	86	31	70	24	77	160	306
1999	21	45	66	44	64	39	72	133	332
2000	56	70	126	21	92	25	80	155	330
2001	70	106	176	21	80	20	106	149	343
2002	66	72	138	32	102	30	84	130	332
2003	31	52	83	18	94	18	90	130	447
2004	75	85	160	32	97	31	91	138	278
2005	97	127	224	19	106	16	86	132	256
2006	166	196	362	15	97	17	107	141	439
2008	143	119	262	17	99	20	100	131	431
2010	58	79	137	17	89	18	116	161	464
2012	10	18	28	19	88	32	116	257	518
Total	960	1221	2181	15	106	16	116	130	518

Table 3. Feeding Intensity FI, FI_{shrimp} and $FI_{hyperids}$ of Atlantic cod by year in Flemish Cap (Div. 3M, NAFO).

	Feeding Intensity (FI)			**FI_{shrimp}**			**$FI_{hyperiids}$**
	Males	Females	Total	Males	Females	Total	Total
1993	95.1	96.8	96.0	5.7	6.8	6.3	78.8
1994	100	100	100	15.2	13.1	14.1	94.0
1995	100	100	100	4.8	7.7	6.2	92.5
1996	96.9	96.9	96.9	12.8	16.3	14.8	84.1
1997	98.0	97.9	98.0	18.3	24.0	21.6	62.4
1998	100	95.3	97.2	45.7	50.9	48.9	76.1
1999	97.1	100	98.9	30.0	42.5	37.5	77.8
2000	100	100	100	52.3	55.1	53.8	66.7
2001	96.3	98.6	97.6	43.5	51.0	47.7	71.0
2002	100	100	100	60.6	54.1	57.0	75.2
2003	87.7	86.8	87.2	47.7	57.1	53.2	8.3
2004	100	98.7	99.3	41.0	36.5	38.5	90.1
2005	92.2	94.0	93.2	58.1	58.8	58.5	60.1
2006	90.1	92.4	91.3	48.1	57.5	52.8	23.0
2008	97.5	92.2	94.7	36.0	27.4	31.5	54.0
2010	89.3	89.7	89.5	22.2	24.8	23.6	46.0
2012	87.5	86.9	87.2	2.5	3.6	3.1	32.5
Total	95.0	94.9	94.9	26.4	28.0	27.3	62.4

Table 4. χ^2 test results.

		Male	Female	Total
Nº individuals	Without stomach content	270	334	604
	With other prey	2408	2802	5210
	With *P. borealis*	960	1221	2181
	Total	3638	4357	7995

	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	3.176	2	0.204
N of valid cases	7995		

Table 5. Shrimp consumption (**MWFI** $_{shrimp}$) by cod observed in EU-survey series on Flemish Cap (NAFO Div. 3M), their percentage regard the total food MWFI $_{Total}$ **(% MWFI** $_{shrimp}$) and shrimp daily ration (g of shrimp/100 g cod predator per day) (**DR** $_{shrimp}$).

Size range of cod		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2008	2010	2012
	$MWFI_{shrimp}$	0.08	0.09	0.02	0.07	0.17	0.33	0.39	0.77	0.46	0.78	0.40	0.27	0.65	0.81	0.37	0.23	0.03
10-79 cm	% $MWFI_{shrimp}$	5.18	4.01	1.03	2.96	7.49	12.89	22.92	37.30	32.78	37.92	40.46	12.20	38.30	48.29	24.92	14.19	3.61
	DR $_{shrimp}$	0.10	0.08	0.02	0.06	0.14	0.24	0.44	0.71	0.62	0.72	0.77	0.23	0.73	0.92	0.47	0.27	0.07
	$MWFI_{shrimp}$	0.08	0.01	0					0.03	0.36	0.23	0.77	0	0.02	0.13	0.17	0.04	0.001
80-89 cm	% $MWFI_{shrimp}$	5.79	0.30	0					1.25	28.45	7.05	61.81	0	1.28	4.82	7.02	3.25	0.093
	DR $_{shrimp}$	0.11	0.006	0					0.02	0.54	0.13	1.17	0	0.0	0.09	0.13	0.06	0.002
	$MWFI_{shrimp}$	0	0.01	0		0.31	0	0	0.08	0.31	0.01	0.13	0.02	0.01	0.08	0.02	0.01	0.01
90-109 cm	% $MWFI_{shrimp}$	0	0.3	0		10.0	0	0	1.5	17.6	0.6	9.2	0.6	0.2	2.6	0.7	1.1	0.40
	DR $_{shrimp}$	0	0.01	0		0.2	0	0	0.03	0.3	0.01	0.2	0.01	0.004	0.1	0.01	0.02	0.01
	$MWFI_{shrimp}$								0						0		0.01	0.01
≥ 110 cm	% $MWFI_{shrimp}$								0						0		0.9	0.25
	DR $_{shrimp}$								0						0		0.02	0.005
Total	$MWFI_{shrimp}$	0.08	0.09	0.02	0.07	0.17	0.33	0.39	0.74	0.46	0.75	0.41	0.27	0.63	0.75	0.33	0.18	0.03

0 = no consumption on shrimp
mixing data = no sampling

Table 6. Atlantic cod biomass (tons) at age and daily and annual consumption (tons) of shrimp.

Atlantic cod mean year biomass at age									
Size (cm)	10-79	10-79	10-79	10-79	10-79	10-79	80-89	>=90	
Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8+**	**Total**
2000	31	12	106	102	94	502	1645	5	2497
2001	44	125	18	116	136	144	633	846	2060
2002	0	197	245	17	138	160	190	1460	2406
2003	58	18	360	278	29	167	226	1549	2685
2004	5	601	67	708	509	45	259	2078	4271
2005	74	40	1177	98	917	615	0	1658	4579
2006	738	2210	48	1737	120	1151	720	220	6943
2008	491	2783	8055	5993	75	2211	152	524	20284
2010	1476	3850	5058	7805	11331	7094	137	4323	41074
Estimate of shrimp daily ration by Atlantic cod at age (gr of shrimp per 100 gr of cod)									
2000	0.71	0.71	0.71	0.71	0.71	0.71	0.02	0.03	
2001	0.62	0.62	0.62	0.62	0.62	0.62	0.54	0.33	
2002	0.72	0.72	0.72	0.72	0.72	0.72	0.13	0.01	
2003	0.77	0.77	0.77	0.77	0.77	0.77	1.17	0.18	
2004	0.23	0.23	0.23	0.23	0.23	0.23	0.00	0.01	
2005	0.73	0.73	0.73	0.73	0.73	0.73	0.02	0.00	
2006	0.92	0.92	0.92	0.92	0.92	0.92	0.09	0.05	
2008	0.47	0.47	0.47	0.47	0.47	0.47	0.13	0.01	
2010	0.27	0.27	0.27	0.27	0.27	0.27	0.06	0.02	
Shrimp annual consumption (tons) by Atlantic cod at age									
2000	80	31	274	264	243	1299	143	1	2334
2001	100	284	41	264	309	327	1249	1030	3605
2002	0	518	644	45	363	421	93	60	2143
2003	163	51	1010	780	81	469	969	990	4512
2004	4	508	57	599	430	38	0	84	1720
2005	197	106	3126	260	2436	1633	0	25	7783
2006	2472	7402	161	5817	402	3855	241	40	20389
2008	848	4809	13918	10355	130	3820	74	25	33979
2010	1453	3790	4979	7682	11153	6983	31	343	36413

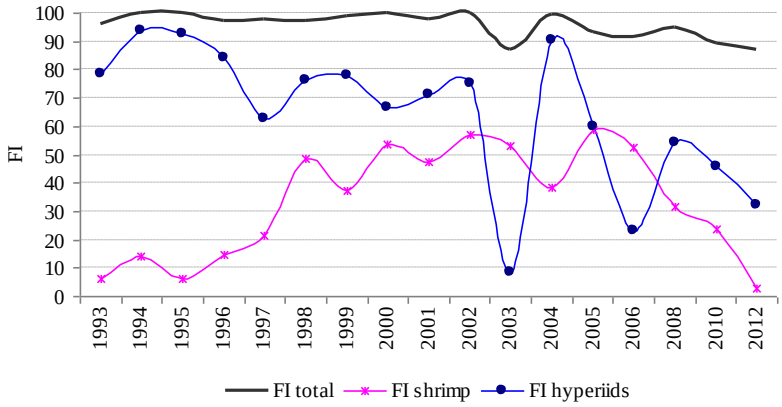

Figure 1. Feeding Intensity: FI_{total}, FI_{shrimp} and $FI_{hyperids}$ of Atlantic cod by year in Flemish Cap (NAFO, Div. 3M) in the historical series.

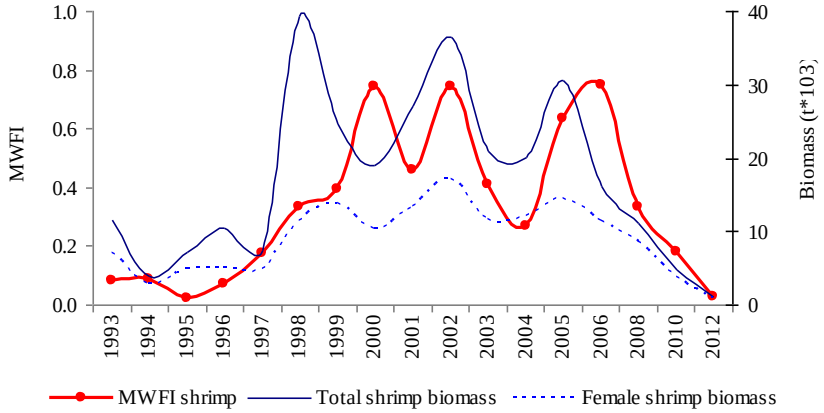

Figure 2. Shrimp consumption by cod along the years, and Total and Female biomass of *P. borealis* in NAFO Div. 3M.

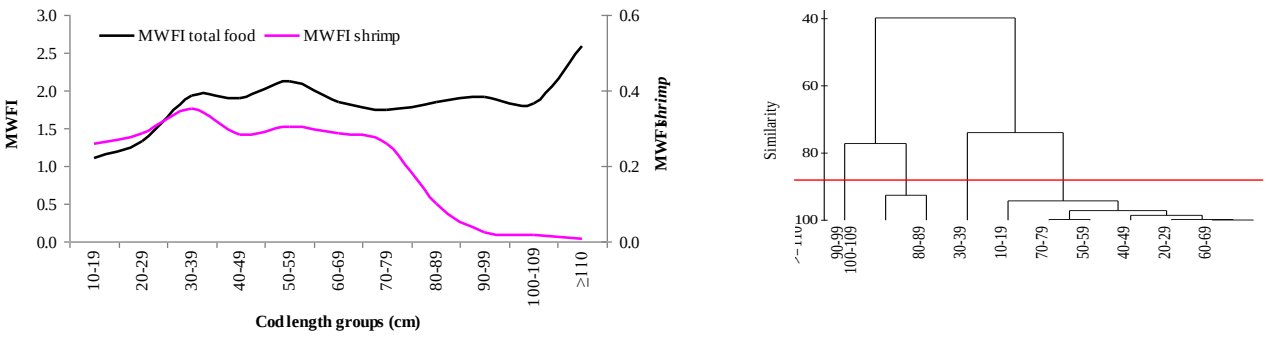

Figure 3. Total and Shrimp consumption by different cod size groups. Bray–Curtis Similarity of the size ranges of cod in relation to shrimp preyed

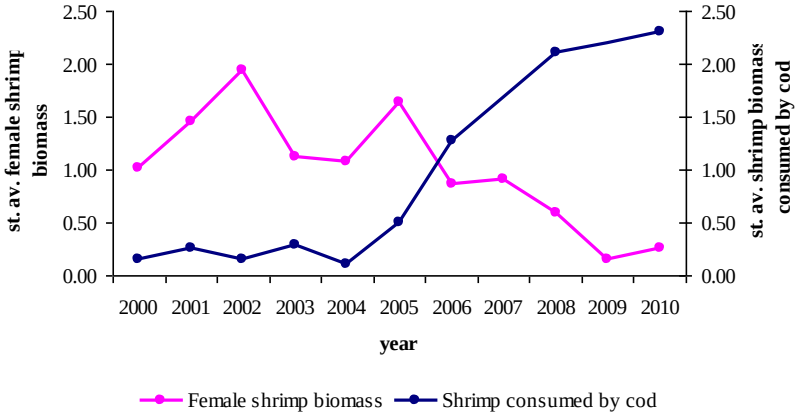

Figure 4. Standardized female shrimp biomass and shrimp biomass consumed by cod between 2000 and 2010 (values from shrimp predated in 2007, 2009 and 2011 were not available because the food sampling was not carried out that years).