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Some Results from Russian Studies on Diet of Redfishes (*Sebastes spp.*) and Cod (*Gadus morhua*) on the Flemish Cap

by

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Introduction

In 2011, the NAFO Fisheries Commission (FC) formulated the following request to the Scientific Council (SC): *"On the Flemish Cap, there seems to be a connection between the most recent decline of the shrimp stock, the recovery of the cod stock and the reduction of the redfish stock. The Fisheries Commission requests the Scientific Council to provide an explanation on the possible connection between these phenomena"*.

To respond to the Fisheries Commission's request, the SC requested the NAFO Contracting Parties to study the available data on diet of redfish and cod on the Flemish Cap.

Russian studies on the diet of cod and redfish on the Flemish Cap extend back over 40 years and were extensively conducted in the 1970-1980s. The results from the studies are presented within the framework of developing an ecological model of the region (Konstantinov *et al.*, 1985). This report contains the data on the diet of cod for 1970-1982 and of redfishes for 1979-1982. Subsequently, issues related to the diet were also addressed by some scientists (Albikovskaya and Gerasimova, 1993). Material on the diet was further collected but no papers on this subject have been published.

This report aims at presenting results from the historical and recent Russian studies on the diet of cod and redfishes on the Flemish Cap. The contents of this report can be useful for studying the dynamics of target species abundance and for producing a response to the FC's request.

Materials and Methods

Materials collected during 123 Russian scientific, exploratory and commercial cruises in 1981-2011 were used as the basis for preparing this report. The studies covered almost the entire area of the Flemish Cap at depths of 127-731 m (Figure 1). Samples to study the diet of redfishes were collected during 121 cruises from catches taken at depths of 127-731 m and to study that of cod during 62 cruises at depths of 127-549 m. The data on redfishes were collected without separating them by species.

Various bottom trawl designs, both Russian and foreign, were used. Research vessels used trawls having a minimum mesh size of 16-24 mm (Bulatova and Chumakov, 1986) and a minimum mesh size in trawls used by exploratory and commercial trawlers was 130 mm. Coordinates at the start point of the tow (the point of the trawl set) were identified as sample positions. The data were filtered taking peculiarities of fish distribution into account. Data on trawling at depths 250-1000 m were used for redfishes, and at depths of 120-600 m for cod. A proportion of the data that did not meet those requirements was relatively low and made approximately 10% of the total volume of data.

The materials were collected in accordance with Russian guidelines and methods (Anon, 1974; Anon, 2004) to identify the following parameters:

- feeding intensity;
- a proportion of fish feeding;
- prey species composition;
- frequency of occurrence of prey organisms.

The feeding intensity was analyzed based on a visual estimation of the stomach fullness using the following five-unit scale:

0 – empty stomach, excluding mucus and water;

1- very loose stomach, there are one or several small organisms in the stomach, there is no food in the major part of the stomach, the stomach walls contracted. The stomach looks empty.

2 – loose stomach, the stomach walls contracted, the entire stomach cavity is not full with stomach contents;

3 – full stomach, the stomach is filled with prey, but there are gastric folds;

4 – stretched stomach, there are no gastric folds, the stomach walls are stretched in such a manner that prey can be seen;

5 – inverted stomachs.

The mean index for stomach fullness (MISF) calculated as a weighted average for indices of fullness of all the stomachs dissected excluding inverted stomachs.

A proportion of feeding fish was calculated as a ratio of the number of stomachs containing prey to the total number of stomachs dissected excluding inverted ones.

Frequency of occurrence of each prey organism was estimated as its proportion (%) to the total number of all the prey items recorded.

Studies on the diet of redfishes are associated with additional difficulties resulting from a partial or entire rejection of food from the stomach due to a substantial change in pressure which occurs when the trawl is hauled up from great depth to the surface. Moreover, this also explains why stomachs in many redfishes are often inverted. This phenomenon was relatively rare observed in cod. Records on stomachs inverted were not used in the calculations in all cases.

The systematic status of prey items was identified to the lowest taxonomical level possible.

In total, 47,953 stomachs of redfishes and 12,315 stomachs of cod were studied during the entire period of investigations. Representativeness of the material collected by years differed considerably. The number of the stomachs of redfishes studied varied from 8 in 1998 to 5,858 in 2008, and those of cod ranged from 30 in 2005 to 1,712 in 1982. Moreover, no samples to study the diet were collected during some years. The material years yielding 100 stomachs or more was used to reduce the likelihood of errors occurring due to the lack of primary data and to study temporal dynamics of feeding.

Results

Redfishes

According to the data collected over the entire period of studies, food in the stomachs of redfish was recorded in 28.1% of the total number of observations. The diet of redfishes was rather diverse and included about 40 prey items where crustaceous occurred most often, i.e. calanus, shrimps, euphausiids and amphipods (Table 1).

In the 1980s, calanus and shrimps were the main prey items (Table 2 and Figure 2). In the 1990s and early 2000s, the value of calanus in the diet decreased while occurrence of shrimps remained unchanged.

From 2002, a proportion of calanus in the stomachs of redfishes increased again and they dominated in the diet of redfishes for most of the subsequent five year period. From 2005, shrimps in the diet of redfishes decreased and the minimum was recorded in 2010-2011 (Table 2 and Figure 2). Redfishes mainly preyed on amphipods and various fish species, including own juveniles.

The feeding intensity in redfishes was on the whole low. The MISF ranged from 0 to 2.3 (Table 3 and Figure 2) and averaged 0.7 for the whole period of observations. The lowest amount of food in the stomachs was recorded in 1982-1987 when the MISF did not exceed 0.3. Some increase in the feeding intensity was observed in 1989-1990, then however it decreased again and remained low during subsequent 8 years (Table 3 and Figure 2). In the late 1990s, the redfish condition factor somewhat increased and the average stomach fullness index was mainly 0.7-1.2 further on.

An attempt to find a relationship between the feeding intensity of redfishes and occurrence of shrimps in their stomachs was not successful (Figure 2).

Cod

According to the data available for the entire period of observations, food was found in 67% of the cod stomachs studied. There were 50 prey items in cod diet. Redfishes, amphipods and shrimps frequently occurred most frequently in their stomachs (Table 4).

In the 1980s, amphipods and redfishes were mainly in the cod ration (Table 5 and Figure 3). In the early 1990s, occurrence of shrimps and redfishes in cod stomachs increased but then amphipods were predominant in stomachs during several years. From 2001, shrimps and redfishes again were predominant prey species for cod (Table 5 and Figure 3).

The feeding intensity was generally low - the MISF mainly ranged from 1.0 to 1.6 (Table 6 and Figure 3) – excluding 1981, 1990, 1998 and 2005-2008 when the feeding intensity increased while MISF was 2.00-2.8.

A relationship between the feeding intensity in cod and occurrence of redfishes and shrimps in the cod stomachs was not found (Figure 3).

Discussion

Results from the previous studies (Anisimova, Lavrovskiy, 1983) suggest that age, seasonal changes in habitats and environmental conditions (temperature and oxygen content) are among the factors governing the feeding intensity and diet composition in fish. The feeding intensity also depends on a physiological

condition of fish, a degree of alimentary tract fullness and a quality of food items available. For the reasons given, changes in fish diet do not indicate always changes in the status of food supply.

In addition to natural factors, some subjective circumstances have to be taken into account when studying feeding in fish. Among them, qualification of those specialists who collect primary biological materials and a quality and volume of their work are important.

Thus, results of trophological studies can be influenced by both objective and subjective factors. Credibility of materials on feeding in fish can be therefore provided under the condition of quite large amount and high quality of sampling.

Russia did not conduct trophological studies or conducted limited studies on the Flemish Cap during some years. Therefore, the use of the materials from the studies to investigate a dynamics of the diet of redfishes and cod is associated with certain difficulties. More full and accurate information on the ration of these fish species can be apparently produced by aggregating the primary data from all NAFO Contracting Parties.

The results of this report largely correspond to the relevant data from Russian studies and those conducted by other countries in the 1970-1990s (Konstantinov et al., 1985; Albikovskaya and Gerasimova, 1993; Paz et al., 1993; Casas and Paz, 1994). Some differences found between our data and historical materials were with regard to the occurrence of prey items in stomachs but the trends in interannual variations in the composition of prey items appeared to be similar in all cases.

In the 1980-1990s, according to data from trawl surveys, abundance of redfishes was low but no trend in its fluctuations was observed (NAFO, 2011). Occurrence of shrimps in redfish stomachs during that time ranged largely (Figure 2). In 2005-2007, there was a notable increase in abundance of redfishes accompanied by a decrease in the proportion of shrimps in their diet. From 2007, a sharp decline in abundance of redfishes was recorded while the occurrence of shrimps in redfish stomachs continued decreasing.

After a decade of depression, abundance of cod in 2005-2009 increased constantly (NAFO, 2011). A proportion of redfish increased and occurrence of shrimps decreased in cod diet simultaneously with an increase in the cod stock (Figure 3).

Data from the 1998-2007 surveys suggest that the shrimp stock was high (Casas, 2011). In 2008-2011, abundance of shrimps decreased considerably and reached the minimum over the last 10 years. The decline in the shrimp stock was accompanied by a decreased occurrence of shrimps in redfish and cod stomachs.

Conclusions

1. A considerable body of data on the diet of redfishes and cod was collected during Russian studies on the Flemish Cap. However, existing gaps make it difficult to use the data for research.
2. Results from the analysis of the Russian data allow to make the following preliminary conclusions:
    - a decrease in the proportion of shrimps in the redfish and cod diet supports the decrease of the shrimp stock during the second half of the 2000s;
    - the dynamics of occurrence of redfishes in cod stomachs is indicative of the increase in redfish stocks during the second half of the 2000s and the decrease over last years;

- Russian data support the previously suggested hypothesis about the existence of relationships between the stocks of redfishes, cod and shrimps in the Flemish Cap ecosystem.

3. To get a comprehensive view of the relationships in the Flemish Cap ecosystem, an analysis of aggregated data from NAFO Contracted Parties having information on the diet of redfishes and cod needs to be undertaken.

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Table 1.

Occurrence of various food objects in Flemish Cap redfish stomachs for 1981-2011

Components of food	**%**
Calanus	27,10
Shrimp	19,90
Euphasiidae	16,02
Amphipods	14,62
Digested food	7,10
Myctophids	4,73
Digested fish	3,92
Arrow worms	2,05
Redfish fry	0,86
Comb jellies	0,57
Gonostomatidae	0,49
Squids	0,36
Mysidae	0,34
Other fish fry	0.34
Ooze	0,23
Benthic organisms: Actinia, Mollusca, Bryozoa	0,18
Pteropods	0,13
Paralepis	0,12
Other fish	0,11
Other plankton	0,10
Pearlsides	0,08
Viperfish	0,06
Crustaceans	0,05
Octopi	0,04
Eels	0,04
Slender snipe eel	0,04
Grenadiers	0,04
Limacinas	0.03
Worms: Nemertea, Sipuncula	0,03
Fish remains (scale, etc.)	0,03
Fishery waste	0,03
Fish larvae	0,02
Cod fry	0,02
American plaice	0,02
Pycnogonids	0.01
Polychaetes	0.01
Total stomachs	**37828**
Total stomachs containing food	**13405**

Table 2.

Occurrence of various food objects in Flemish Cap redfish stomachs on year-by-year basis, %

Year	Shrimp	Euphasiidae	Amphipods	Calanus	Anchovies	Arrow worms	Dig. food	Dig. fish	Redfish fry	Comb jellies	Others	Total
1981	3,7	5,3	23,8	44,6	2,0	14,6	1,7		1,0		3,3	1028
1982	12,0	9,0	20,5	39,3	4,8	1,6	1,0	6	2,4		4,4	4352
1983	50,1	0,9	8,6	13,1	14,5		2,2	2,8	3,1		4,7	2232
1984	33,8	1,3	7,5	16,3	1,3		3,8	17,5	8,8		9,7	1344
1985	15,3		8,9	50,8	1,7	6,7		16,6				568
1986	No data available											532
1987	No data available											828
1988		*2,5*	*17,9*	*40,5*		*38,1*					*1,0*	*77*
1989	1,9	3,3	16,6	51,2	2,8		19,0	3,3		10,0	1,9	552
1990	4,0	5,4	27,4	47,9		4,4	9,4	1,2			0,3	583
1991	38,5		15,5					45,5			0,5	426
1992	No data available											517
1993	No data available											
1994	No data available											
1995	21,7	26,4	23,6	7,6			1,0	7,6		1,9	10,2	391
1996	47,5	2,5	10	2,5		10	15	5,0		2,5	5,0	490
1997	No data available											
1998	50						*50*					*8*
1999	52,5	2,5		16,5			17,1	7,0			4,4	498
2000	36,2	10,6	16,8	7,8			3,9	21,6			10,9	1246
2001	37,6	13,8	4,3	6,3	14,8		9,8	6,2			7,2	2257
2002	16,6	21	10,0	18,2			25,6	3,6			5,0	4023
2003	15,2	7	11	59,5	3,3		3,3				0,7	237
2004	*57,1*						*14,3*	*28,6*				*42*
2005	25,5	19,2	18,1	6,4	13,1	7,1		4,8			5,8	4051
2006	17,4	6,9	15,1	44,4		1,7	10,4		0,8		3,3	2454
2007	33,8	6,1	9	30,4	7,8	1,3	3,0	5,4	1,0		2,2	2908
2008	11,4	30,0	17,2	36,6				1,8			3,0	5858
2009	No data available											
2010	10,0		41,7	13,3		10		23,3	1,7			195
2011	14,3		31,5				14,1	23,9		13,0	3,2	131

Note:

Non-representative data is shown in *italics*.

Table 3.

Intensity of redfish feeding on the Flemish Cap in 1981-2011

Year	Stomach fullness index						Total	MISF
	0	1	2	3	4	5		
1981	608	101	191	109	19	28	1028	0,9
1982	3513	443	280	95	21	31	4352	0,3
1983	1887	103	134	82	26	14	2232	0,3
1984	1275	14	20	24	11	572	1344	0,1
1985	526	4	10	17	11	7	568	0,2
1986	484	12	9	7	20	-	532	0,2
1987	826	2				17	828	0
1988	*17*	*23*	*27*	*9*	*1*	*16*	*77*	*1,4*
1989	356	81	86	24	5	-	552	0,6
1990	307	115	93	58	10	2	583	0,9
1991	414	2	6	2	2	-	426	0,1
1992	517	-	-	-	-	-	517	0
1993	No data available							
1994	No data available							
1995	316	25	26	13	11		391	0,4
1996	453	22	9	3	3	134	490	0,1
1997	No data available							
1998	*6*			*2*	*11*		*8*	*1,0*
1999	361	48	31	17	41	177	498	0,7
2000	687	63	263	187	46	547	1246	1,1
2001	1582	318	195	81	81	1766	2257	0,6
2002	1613	799	809	633	169	1278	4023	1,2
2003	38	20	58	65	56	24	237	*2,3*
2004	*35*	*2*	*2*	*3*	-	*58*	*42*	*0,4*
2005	2805	276	470	284	216	916	4051	0,7
2006	1368	374	379	158	175	1404	2454	0,9
2007	1532	193	494	332	357	304	2908	1,2
2008	2686	979	1658	401	134	2490	5858	1,0
2009	No data available							
2010	135	10	35	8	7	162	195	0,7
2011	76	22	18	13	2	167	131	0,8
Total	**24423**	**4051**	**5303**	**2625**	**1426**	**10125**	**37828**	**0,7**

Note:

Non-representative data is shown in *italics*.

Table 4. Occurrence of various food objects in Flemish Cap cod stomachs for 1981-2011

Components of food	%
Amphipods	29,21
Redfishes	28,15
Shrimp	16,20
Digested fish	11,70
Euphausiidae	2,50
Comb jellies	2,34
Digested food	1,60
Calanus	1.03
Arrow worms	1.00
Squids	0,81
Cod fry	0,75
Ophiuroids	0.65
Myctophids	0,60
Stones, sand, silt, ground	0,54
Jellyfish	0,53
Other fish	0,48
Fishery waste	0,48
Polychaetes	0,43
Viperfish	0,40
Worms: Nemertea, Sipuncula	0,21
Myctophids	0.20
Benthic organisms: Actinia, Mollusca, Bryozoa	0,20
Lumpenus	0,20
Lycodes	0,15
Roughhead grenadier	0,15
Slender snipe eel	0,14
Crabs	0,12
Fish remains (scale, etc.)	0,11
Mysidae	0,11
Gastropods	0.10
Demersal crustaceans: decapods, anisopods	0,10
Paralepis	0,10
Macruridae	0,07
Ooze	0,07
Spider crabs	0,05
Hermit crabs	0,05
Hakes	0,05
Marlin-spike grenadier	0,04
Octopuses	0.04
Fish larvae	0,04
Pearlsides	0.03
Other fish fry	0,03
American plaice	0,03
Sea urchins	0,03
Fish eggs	0,02
Capelin	0,02
Isopods	0,01
Total stomachs	**12230**
Total stomachs containing food	**8574**

Table 5.

Occurrence of various food objects in Flemish Cap cod stomachs on year-by-year basis, %

Year	Shrimp	Redfish	Hakes	Dig. fish	Fishery waste	Dig. food	Myctophids	Amphipods	Comb jellies	Cod fry	Euphasiidae	Others	Total
1981	7,8	24,7		5,7				42,5	6,3		1,8	11,2	710
1982	9,8	26,8		5,8				45,4	5,8	2,5	0,1	3,8	1712
1983	21,2	60,4		2,0				5,6	1,2	1,0	0,5	8,1	1034
1984	8,3	32,1		39,0				2,5	1,0	0,4	5,4	11,3	1259
1985	No data available												437
1986	5,0	7,3		8,9				69,2			0,7	9,6	494
1987	3,0	12,9		9,0				36,9	10,3	12,0	6,0	9,9	484
1988	1,7	18,4		4,7		2,1	0,3	55,7	6,1	0,8	2,0	8,2	355
1989	2,6	3,5		2,8				77,1	5,4		1,5	7,1	1465
1990	2,4	1,3		1,9		10,1	2,9	72,2			1,1	9,2	423
1991	26,8	27,3		12,6			1,5	13,7			3,5	14,6	297
1992	28,4	25,5		2,0		11,8		17,6		1,0	2,0	11,7	138
1994	No data available												
1995	No data available												
1995	7,2			6,3		15,7	0,9	33,9	0,9	0,3	23,5	11,3	302
1996	37,1	2,9		19,6		5,7		14,3	1,4		7,1	11,9	115
1997	No data available												
1998	17,8	1,0		21,2		1,0		35,1			13,0	10,9	128
1999	No data available												
2000	No data available												
2001	*55,3*	*10,5*		*23,7*		*5,3*		*2,6*				*2,6*	*45*
2002	19,5	23,4	0,5	40,7		1,0	1,5	3,4			0,5	9,5	143
2003	No data available												
2004	No data available												
2005	*42,1*	*31,6*	*7,9*	*13,2*								*5,2*	*30*
2006	42,2	39,9	0,3	11,1	0,3		0,3	0,8				5,4	350
2007	40,7	34,0		4,1	6,6	0,4		0,4			0,6	13,2	412
2008	26,8	46,9		22,6	0,8			0,6			0,2	2,7	1637
2009	No data available												
2010		*45,0*	*5,0*	*45,0*								*5,0*	*28*
2011	18,5	9,2		29,7	0,4		13,7	10,8	1,6		2,8	13,0	232

Note:

Non-representative data is shown in *italics*.

Table 6.

Intensity of cod feeding on the Flemish Cap in 1981-2011

Year	Stomach fullness index						Total	MISF
	0	1	2	3	4	5		
1981	133	68	245	217	47	3	710	2,0
1982	680	153	368	326	185	5	1712	1,5
1983	319	133	280	196	106	0	1034	1,6
1984	516	230	188	172	153	16	1259	1,4
1985	263	35	49	46	44	0	437	1,0
1986	215	44	86	77	72	0	494	1,5
1987	290	21	69	64	40	0	484	1,1
1988	66	49	129	66	45	0	355	1,9
1989	321	333	528	226	57	1	1465	1,6
1990	45	67	118	97	96	0	423	2,3
1991	154	31	50	34	28	0	297	1,2
1992	49	28	30	20	11	0	138	1,4
1993		No data available						
1994		No data available						
1995	105	79	67	32	19	0	302	1,3
1996	64	32	10	3	6	2	115	0,7
1997		No data available						
1998	12	19	26	34	37	5	128	2,5
1999		No data available						
2000		No data available						
2001	*13*	*5*	*14*	*11*	*2*	*0*	*45*	*1,6*
2002	6	12	26	62	37	1	143	2,8
2003		No data available						
2004		No data available						
2005	*3*	*1*	*6*	*10*	*10*	*0*	*30*	*2,8*
2006	21	24	93	100	112	0	350	2,7
2007	31	15	131	151	84	4	412	2,6
2008	288	186	660	197	306	34	1637	2,0
2009		No data available						
2010	*8*	*1*	*14*	*3*	*2*	*0*	*28*	*1,6*
2011	54	32	63	52	31	14	232	1,9
Total	**3656**	**1598**	**3250**	**2196**	**1530**	**85**	**12230**	**1,7**

Note:

Non-representative data is shown in *italics*.

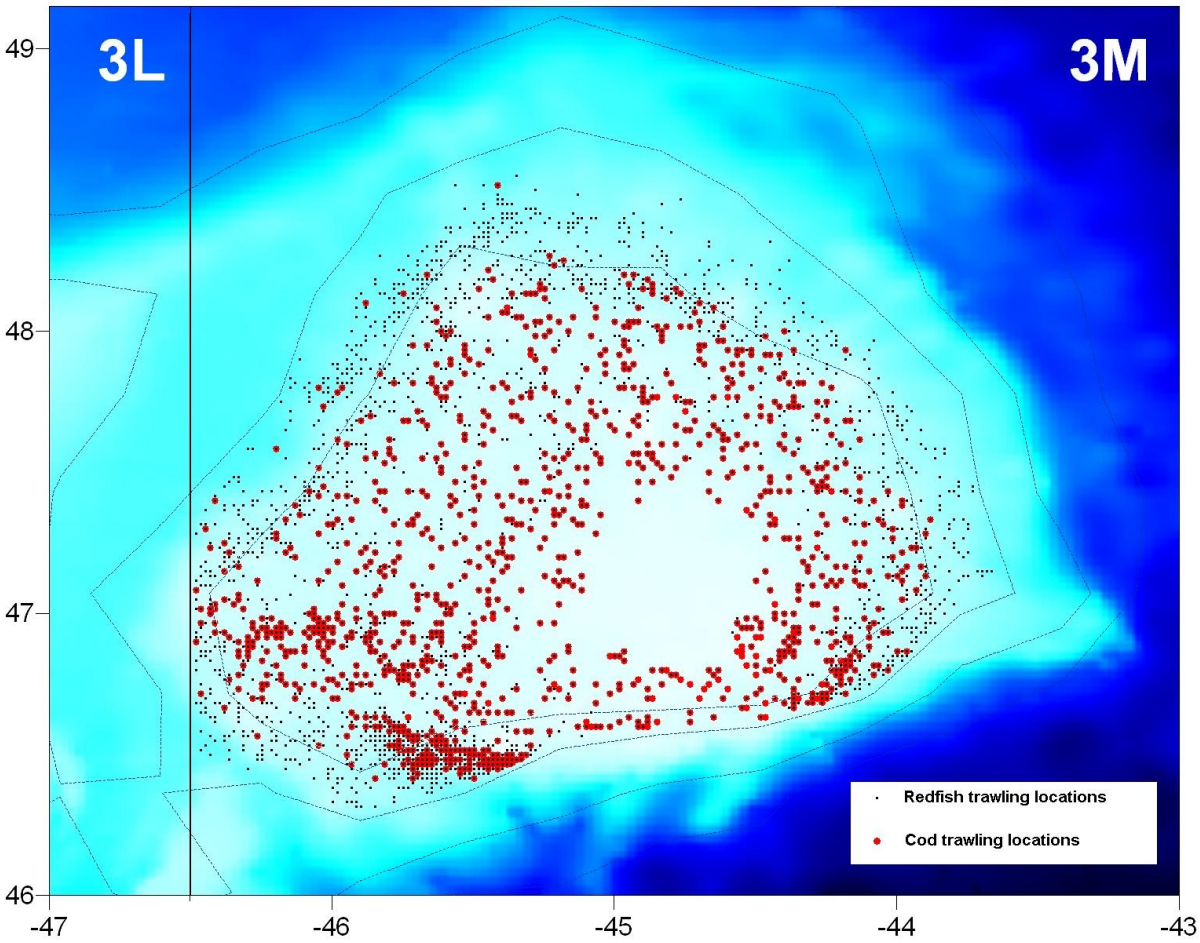

Fig. 1. Locations of the Russian sampling of cod and redfishes at Flemish Cap in 1981-2011

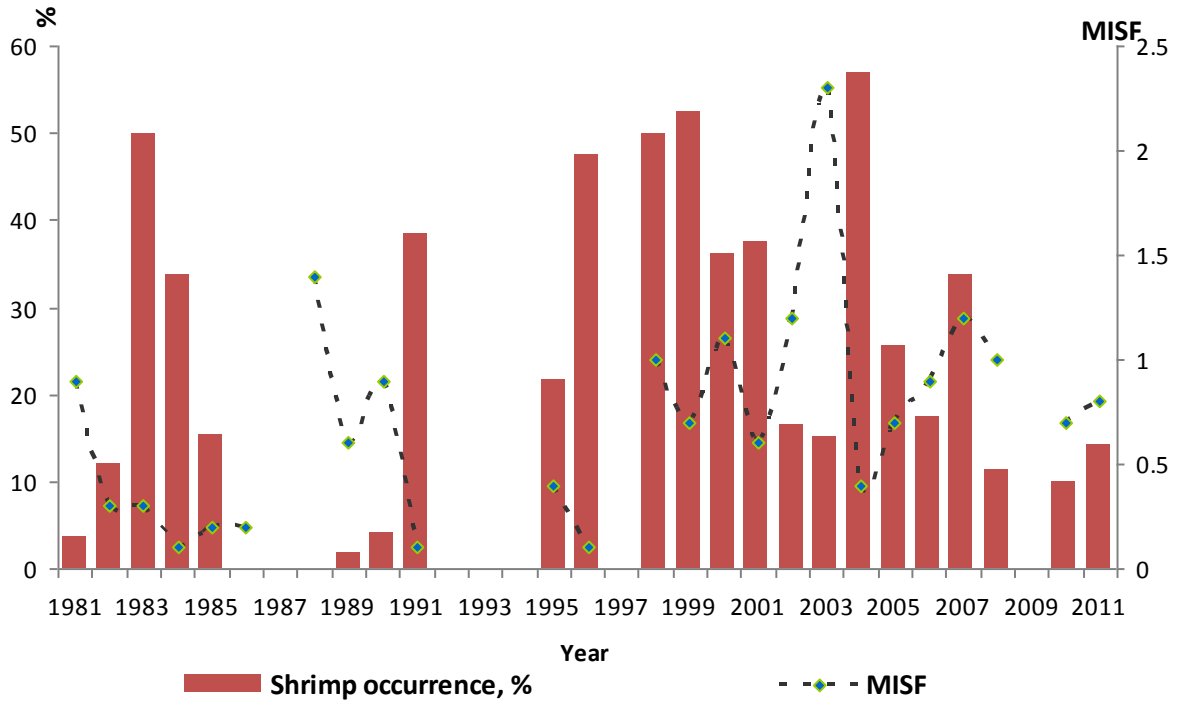

Fig. 2. MISF and shrimp occurrence in redfish stomachs on Flemish Cap by the Russian data in 1981-2011

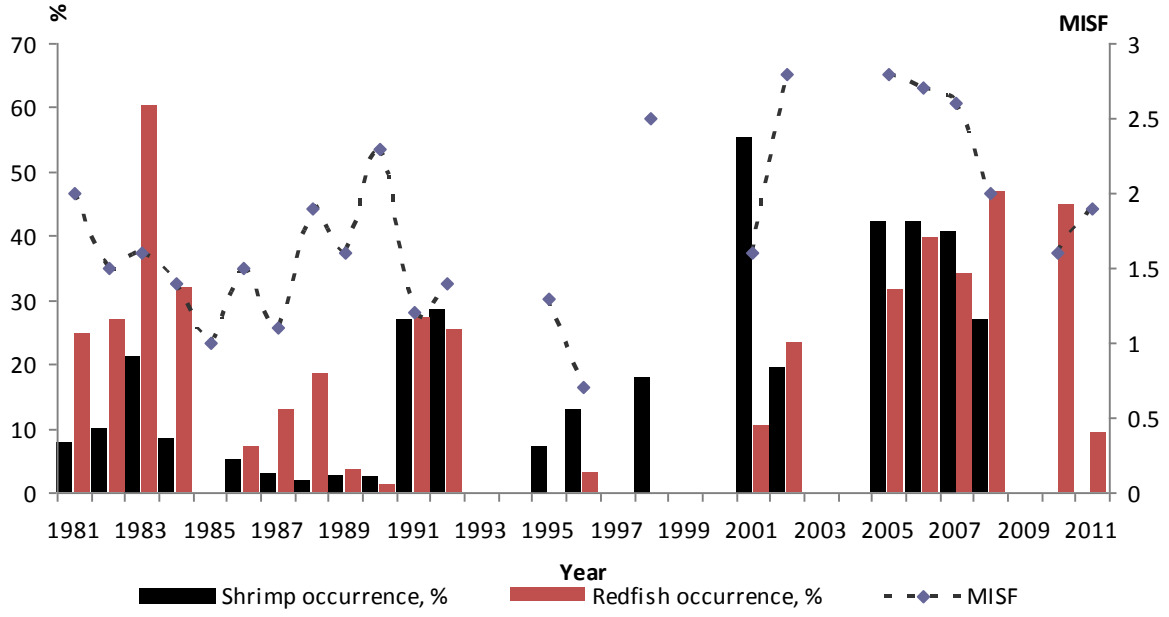

Fig. 3. MISF and occurrence of shrimp and redfish in cod stomachs on Flemish Cap by the Russian data in 1981-2011