IMR/PINRO
JOINT REPORT SERIES
2
2008

Survey Report from the Joint Norwegian/Russian Ecosystem Survey in the Barents Sea August - September 2007

Volume 2

Institute of Marine Research - IMR

Polar Research Institute of Marine
Fisheries and Oceanography - PINRO

SURVEY REPORT
FROM THE JOINT NORWEGIAN/RUSSIAN ECOSYSTEM SURVEY IN THE BARENTS SEA
AUGUST – SEPTEMBER 2007

Volume 2

Content

1 Preface

The fifth Joint Norwegian/Russian Ecosystem Survey in the Barents Sea was carried out from the 8th of August through the 5th of October, 2006. Survey results from investigations of 0 age-group fish, acoustic estimates of pelagic fish stocks, and oceanographic conditions were included in Volume 1 of this Report (Anon. 2008). This volume holds additional results from the 2007 Ecosystem Survey: population studies of zooplankton, bottom fishes, and benthic organisms; studies of fish diet composition, and population age structure; and information describing levels of pollution/toxic contamination. Many of these components have been a part of the survey for many years. Since 2003, however, observations of sea mammals, seabirds, bottom fishes, and benthos have also been included, and the survey referred to as the "Ecosystem Survey".

A list of the participating vessels with their respective scientific crews is given in Survey report Volume 1. In addition, the following specialists took part in preparing the Survey report volume 2: K. Michalsen (IMR), C. Hvingel (IMR), E.L. Orlova (PINRO), B. Bogstad (IMR), A.V. Dolgov (PINRO), Å.Høines (IMR) and M.M. McBride (IMR).

Figure 1.1. The Barents Sea (Norwegian: *Barentshavet*, Russian: Баренцево море) is a part of the Arctic Ocean, located north of Norway and Russia. It is a rather deep shelf sea (average depth 230 m), bordered by the shelf edge towards the Norwegian Sea in the west, the island of Svalbard (Norway) in the northwest, and the islands of Franz Josef Land and Novaya Zemlya (Russia) in the northeast and east. Novaya Zemlya separates the Kara Sea from Barents Sea.

2 Oceanography

2.1 Hydrochemical characteristics

Hydrochemical observations indicate that during 2007 the southern Barents Sea continued to be characterized by a gradual increase in oxygen saturation of bottom layers; this trend started in 2002 (Figure 2.1).

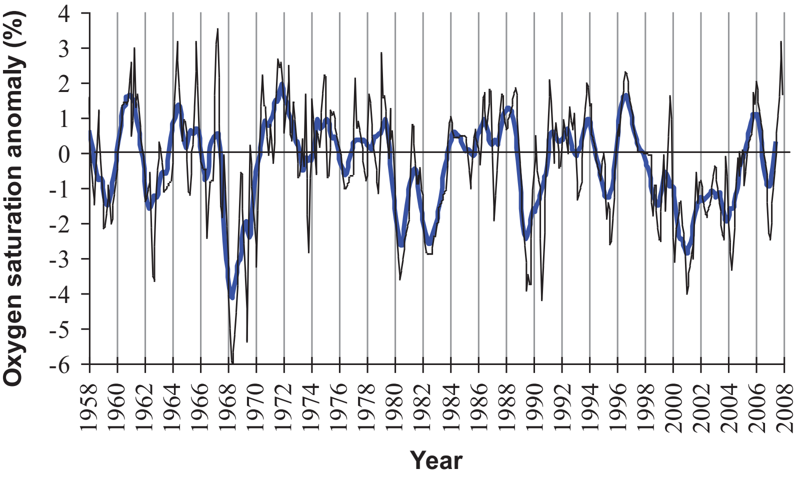


Figure 2.1 Monthly (▬ black line) and annual (▬ blue line) oxygen anomalies in the bottom layer of the Kola section.

2.2 Calculated volume fluxes

Monthly wind-driven fluxes in total volume and associated anomalies were estimated using a numerical oceanographic model for major currents of the Barents Sea during 2007 (Figure 2.2).

Relative to the long-term mean, general circulation in 2007 was weaker in the western part of the Barents Sea, stronger in the eastern part, and about average in the central part. Relative to the previous year (2006), general circulation was weaker in all areas. In 2007, total flux of water running through the section crossing the Novaya Zemlya Current was above average during the entire year, but less than observed during 2006. On the whole, wind-driven circulation in the Barents Sea was weaker than during 2006, and contributed to increased general circulation only in central and eastern parts.

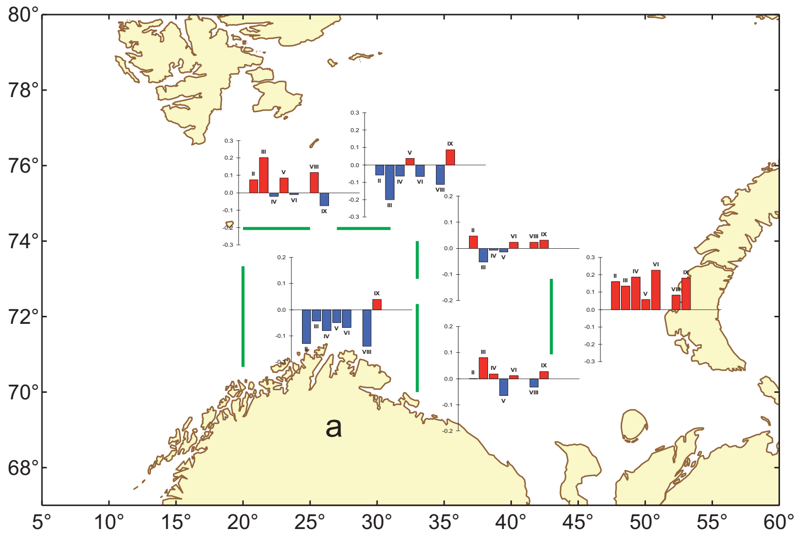


Figure 2.2. Monthly total flux anomalies in water volume (in Sv) in selected sections (green lines) in the Barents Sea in 2007 relative to the period of 1996-2007. The number above each bar represent the month.

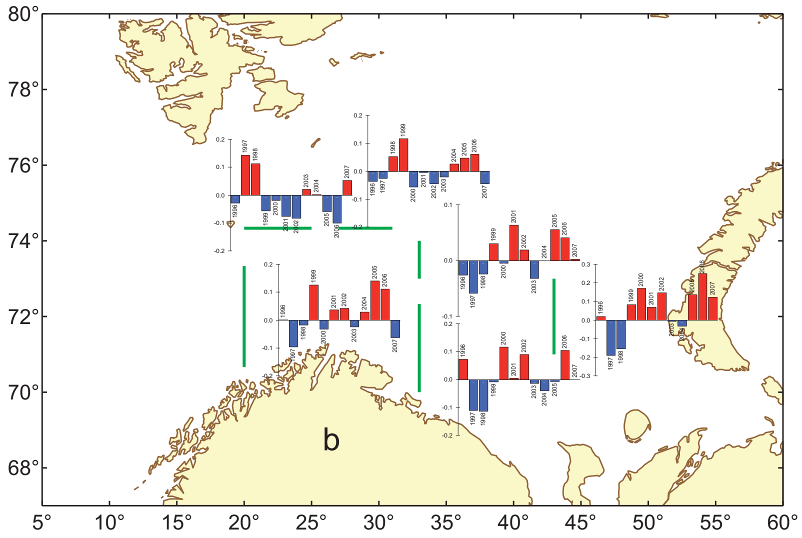


Figure 2.3. Annual total flux anomalies (Sv) in the Barents Sea in 2007 and for the period of 1996-2007.

3 Demersal fish

In this volume of the survey report, an age-based swept-area abundance estimate of demersal fish species is presented; this method is described in ”Extended Survey Report from the Joint Norwegian/Russian Ecosystem Survey in the Barents Sea August – October 2004 Volume 2”.

3.1 Assessment by age group

Problems with data conversion have been encountered in previous years; accordingly, the time series presented below should be regarded as preliminary. Age-based abundance indices for bottom fish species (Northeast arctic cod, northeast arctic haddock, deepwater redfish, golden redfish), and length-based assessment for Greenland halibut are presented in Tables 3.1. – 3.5. Note that the assessment for Greenland halibut is given by length groups.

Table 3.1. Age-based assessment of northeast arctic cod (*Gadus morhua*) in the Barents Sea in August – September 2004-2007. The numbers are given in million fish.

Region		Age												
	Year	1	2	3	4	5	6	7	8	9	10	11	12+	Total
I (NEEZ+SVA)														
	2004	151,93	69,70	30,93	34,40	14,37	19,32	12,23	4,71	1,14	0,40	0,06	0,08	339,27
	2005	147,43	30,10	38,17	6,65	17,31	6,11	4,48	2,18	0,21	0,27	0,07	-	252,98
	2006	243,30	188,24	34,12	19,69	5,21	9,78	4,36	2,38	1,08	0,42	0,05	0,02	508,65
	2007	115,23	168,40	125,35	15,75	10,56	1,71	5,96	0,94	0,94	0,18	0,07	0,09	445,18
I (REEZ)														
	2004	87,12	204,23	38,45	273,62	115,72	40,97	18,37	3,75	0,23	0,23	0,03	0,08	782,80
	2005	115,19	45,21	121,39	20,60	42,40	17,95	6,67	3,37	0,66	0,33	-	0,06	373,83
	2006	196,89	243,16	86,38	86,07	24,17	15,78	5,88	1,73	0,56	0,03	0,08	-	660,73
	2007	0,58	243,40	243,92	72,52	24,06	9,71	6,54	3,38	0,45	0,48	0,02	0,17	605,23
IIa														
	2004	10,57	5,72	1,74	6,45	2,01	2,41	0,49	0,32	0,12	-	-	-	29,83
	2005	13,15	3,22	6,00	2,08	2,60	1,46	0,95	0,14	0,01	-	0,05	-	29,66
	2006	8,79	4,67	4,98	4,52	3,34	4,77	1,14	0,59	0,14	0,04	0,04	-	33,02
	2007	4,08	3,31	6,92	3,72	4,73	1,14	1,48	0,14	0,06	0,06	-	-	25,64
IIb														
	2004	142,84	62,13	38,28	104,57	19,31	15,04	8,29	1,54	0,33	0,03	-	0,13	392,49
	2005	149,99	81,77	97,32	27,74	52,29	7,35	4,65	0,75	0,26	0,10	-	-	422,22
	2006	91,61	118,56	55,04	64,55	18,51	17,91	4,14	2,17	0,71	-	-	-	373,20
	2007	159,58	97,85	124,12	55,19	26,43	4,24	10,98	0,64	0,25	-	-	-	479,28
Total														
	2004	392,46	341,78	109,40	419,04	151,41	77,74	39,38	10,32	1,82	0,66	0,09	0,29	1 544,39
	2005	425,76	160,30	262,88	57,07	114,60	32,87	16,75	6,44	1,14	0,70	0,12	0,06	1 078,69
	2006	540,59	554,63	180,52	174,83	51,23	48,24	15,52	6,87	2,49	0,49	0,17	0,02	1 575,60
	2007	279,47	512,96	500,31	147,18	65,78	16,80	24,96	5,10	1,70	0,72	0,09	0,26	1 555,33

Table 3.2. Age-based assessment of northeast arctic haddock (*Melanogrammus aeglefinus*) in the Barents Sea in August–September 2004-2007. The numbers are given in million fish.

Region		Age												
	Year	1	2	3	4	5	6	7	8	9	10	11	12+	Total
I (NEEZ+SVA)														
	2004	23,92	35,99	12,84	3,65	3,38	3,79	0,22	0,36	-	-	-	-	84,15
	2005	87,85	12,64	16,24	4,42	1,82	1,40	1,45	0,10	0,10	-	-	-	126,02
	2006	641,03	171,69	17,95	17,77	3,63	3,17	2,19	0,46	0,05	0,09	0,06	-	858,09
	2007	141,04	267,86	150,82	4,02	3,14	0,86	0,15	0,89	-	-	-	0,14	568,92
I (REEZ)														
	2004	35,54	150,85	142,23	71,15	73,47	20,11	1,57	0,34	-	0,13	-	0,25	495,64
	2005	222,51	36,25	221,03	180,69	24,32	19,23	8,46	0,17	-	0,18	0,04	-	712,88
	2006	1 192,20	1 674,90	118,34	152,89	34,77	8,09	5,28	1,16	-	-	-	0,15	3 187,78
	2007	216,83	969,41	1 060,10	61,61	61,64	5,46	1,51	3,94	0,15	0,19	0,05	-	2 380,89
IIa														
	2004	70,99	73,76	10,33	4,61	3,39	4,98	0,30	0,80	-	-	-	0,04	169,20
	2005	208,11	28,08	21,48	5,87	1,42	2,03	1,80	0,09	0,43	0,05	-	0,10	269,46
	2006	435,65	72,59	13,90	12,70	4,86	0,62	1,34	1,17	0,48	0,48	-	-	543,79
	2007	336,39	102,07	19,59	3,28	10,51	3,74	6,14	0,57	-	0,29	0,10	0,10	482,78
IIb														
	2004	24,29	5,89	2,19	1,50	3,64	2,97	0,11	1,12	-	-	-	-	41,71
	2005	151,77	5,38	10,85	0,72	2,46	3,68	1,96	-	0,01	0,01	0,08	-	176,92
	2006	498,59	163,79	2,03	5,44	3,59	2,60	4,43	1,73	-	0,20	-	-	682,40
	2007	227,87	454,95	75,50	9,39	31,29	3,85	0,45	2,96	6,71	0,17	-	-	813,14
Total														
	2004	154,74	266,49	167,59	80,91	83,88	31,85	2,20	2,62		0,13		0,29	790,70
	2005	670,24	82,35	269,60	191,70	30,02	26,34	13,67	0,36	0,54	0,24	0,12	0,10	1 285,28
	2006	2 767,47	2 082,97	152,22	188,80	46,85	14,48	13,24	4,52	0,53	0,77	0,06	0,15	5 272,06
	2007	922,13	1 794,29	1 306,01	78,30	106,58	13,91	8,25	8,36	6,86	0,65	0,15	0,24	4 245,73

T**able 3.3.** Age-based assessment of deepwater redfish (*Sebastes mentella*) in the Barents Sea in August – September 2004-2007. The numbers are given in thousand fish.

Region		Age																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
I (NEEZ+SVA)																		
	2004		1 462	1 388	1 200	587	1 032	4 050	5 556	484	309	273	533	878	1 238	1 007	1 639	21 637
	2005	3 001		1 357	1 173	1 018	1 424	923	2 296	3 859	514	426	886	640	640	1 589	2 168	21 914
	2006		116 488		4 816	1 692	677	2 030	-	-	88	70	44	22	214	2 191	16 753	145 084
	2007	174 412	178 061	150 071		1 191	1 427	476	1 427	2 893	2 133	904		904	904		4 443	519 244
I (REEZ)*																		
	2004		1 491	4 884	1 696	1 485	333	56	30	34	16			0	3	15	106	10 148
	2005	1 392	1 999	517	189	61	23	23	30	33	5	1	0	1	10	19	34	4 336
	2006	412	2 594	1 432	586	245	41	40	152	122	144	87	55	27	92	249	785	7 063
	2007	12 284	4 009	420	2													16 715
IIa																		
	2004		714	1 572	1 546	734	2 152	2 520	2 613	11 741	17 967	26 372	26 970	15 216	25 779	28 272	31 876	196 045
	2005	433		1 576	3 035	895	1 534	2 393	5 548	4 960	3 820	11 408	12 121	19 382	34 814	24 581	35 035	161 534
	2006	34 510	19 498	1 279	413	1 719	2 545	593	5 754	1 714	1 105	8 721	9 437	1 480	7 535	25 292	65 706	187 301
	2007	267 055	37 487	37 487		4 025	5 976	358	2 111	6 225	2 343	3 758	1 414	368	38 049	6 471	195 625	608 751
IIb																		
	2004		4 527	6 048	3 056	5 196	486	2 836	208	5 058	4 079	14 323	6 127	1 390	8 343	969	28 110	90 756
	2005	427	5 371	1 945	1 939	4 187	2 663	6 019	6 578	11 057	9 621	10 259	8 208	13 768	12 566	13 184	25 919	133 710
	2006		60 866	13 821	3 013	3 300	2 509	4 513	19 404	17 967	62 652	37 600	19 818	13 113	27 185	45 009	62 608	393 378
	2007	81 385	6 015	28 018	1 764	1 151	2 880	1 730	3 785	2 232	6 496	4 692	4 485	7 137	14 656	13 497	55 537	235 460
Total																		
	2004		8 194	13 892	7 499	8 003	4 002	9 462	8 407	17 316	22 371	40 968	33 630	17 484	35 363	30 264	61 731	318 586
	2005	5 252	7 370	5 394	6 336	6 161	5 643	9 358	14 452	19 909	13 960	22 094	21 216	33 790	48 030	39 373	63 156	321 494
	2006	34 922	199 446	16 532	8 827	6 956	5 771	7 176	25 310	19 803	63 989	46 478	29 354	14 642	35 027	72 740	145 852	732 825
	2007	535 136	225 572	215 996	1 766	6 368	10 282	2 564	7 323	11 350	10 972	9 354	5 899	8 408	53 609	19 968	255 604	1 380 170

Table 3.4. Age-based assessment of golden redfish (*Sebastes marinus*) in the Barents Sea in August – September 2004-2007. The numbers are given in thousand fish.

Region		Age																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
I (NEEZ+SVA)																		
	2004					303	215	215	335	77	71	71	464	185	389	214	365	2 905
	2005		112				105	297	170	138	377			150		130	910	2 391
	2006**	352	1	0	12	18	69	95	355	312	857	268	259	259	257	354	3 536	7 005
	2007		3 228					656	134	248	27	80	17	121	160	33	641	5 344
I (REEZ)*																		
	2004			187		50	104	135	495	286	129	67	95	42	15	8	9	1 621
	2005		71	55	72	108	144	47	293	297	327	118	253	240	244	247	661	3 177
	2006**	450	1	0	15	23	84	66	133	67	202	61	46	41	20	17	123	1 350
	2007																0	0
IIa																		
	2004			102			228	225	276	413	177	303	391	341	136	609	1 809	5 010
	2005		82	1 098	469	702	2 456	1 552	2 985	769	726	189	348	326	461	411	1 306	13 881
	2006**							21	127	142	722	306	890	827	826	762	3 068	7 691
	2007		90					285	31	127	5	141	101	426	528	264	1 915	3 912
IIb																		
	2004					4	7		354	63	473	126	311	368	337	120	300	2 464
	2005			41				27	33	168	115	191	200	60	96	116	308	1 355
	2006**				16	24	56	35	96	71	288	99	159	149	135	130	404	1 663
	2007				25	37	50	1 217	279	660	53	325	195	776	951	465	3 355	8 389
Total																		
	2004			288		357	554	576	1 459	839	849	566	1 260	937	878	952	2 483	12 000
	2005		266	1 193	541	809	2 705	1 924	3 481	1 372	1 545	498	801	776	802	904	3 185	20 804
	2006**	802	2	0	43	65	209	217	711	592	2 069	734	1 355	1 276	1 238	1 263	7 130	17 709
	2007		3 317		25	37	50	2 158	444	1 036	84	546	313	1 323	1 639	761	5 911	17 645

** Very few age samples available, total age-length key from 2005 used.

Table 3.5. Length-based assessment of Greenland halibut (***Reinhardtius hippoglossoides***) in the Barents Sea in August – September 2004-2007. The numbers are given in thousand fish.

Region		**Length group (cm)**																	
	Year	**5.0-9.9**	**10.0-14.9**	**15.0-19.9**	**20.0-24.9**	**25.0-29.9**	**30.0-34.9**	**35.0-39.9**	**40.0-44.9**	**45.0-49.9**	**50.0-54.9**	**55.0-59.9**	**60.0-64.9**	**65.0-69.9**	**70.0-74.9**	**75.0-79.9**	**80.0-84.9**	**85.0-89.9**	**90 +**
I (NEEZ+SVA)																			
	2004	598	1 971	3 119	10 152	6 263	2 585	1 923	757	1 072	806	163	69	51					
	2005	462	28 972	7 172	2 560	3 805	7 422	4 226	2 849	2 110	736	640	250	190	34				
	2006		6 863	4 198	17 766	9 061	3 415	7 016	5 985	4 578	2 302	1 239	137	352	17	100			
	2007	22	7 327	6 776	8 992	8 924	11 517	3 268	3 549	3 941	1 964	946	381	332	251				
I (REEZ)																			
	2004	410	8 342	14 407	28 861	17 315	4 832	1 007	674	331	165	261	79						
	2005	417	86 380	20 931	6 839	16 169	15 604	3 954	1 355	751	87								
	2006	919			167							626	142	109					
			42 761	93 927	684	29 266	3 712	4 703	1 493	765	813								
	2007	452	12 008	8 894	14 293	38 381	14 619	6 616	2 935	905	983	639	262	160					
IIa																			
	2004							345	106	1 044	1 345	687	127	57	153				
	2005						215	566	650	592	1 303	995	552	72	81	92			
	2006		779	111				658	577	518	1 049	671	633	157	84				
	2007					92	226	1 323	1 814	1 440	1 946	1 299	352	119					
IIb																			
	2004	8 331	2 817	3 998	3 925	3 864	2 701	3 700	3 014	2 346	1 587	298	834	217	189	38	92	8	
	2005	723	34 337	21 272	3 536	5 612	10 337	9 708	6 940	4 581	2 339	841	295	266	44		42	32	
	2006	1 841	6 803	4 887	14 878	7 694	2 152	4 545	4 870	3 703	2 110	1 073	483	137	55	63	31		
	2007	414	7 174	10 056	4 863	5 176	9 137	4 971	6 104	4 391	2 608	1 212	537	252	143	60	13		13
Total																			
	2004	9 339	13 130	21 524	42 938	27 442	10 118	6 975	4 551	4 793	3 904	1 409	1 109	325	342	38	92	8	
	2005	1 602	149690	49 375	12 935	25 585	33 577	18 454	11 794	8 034	4 464	2 476	1 097	528	158	92	42	32	
	2006	2 760	57 205	103122	200328	46 021	9 279	16 922	12 925	9 564	6 274	3 610	1 395	756	156	164	31		
	2007	888	26 510	25 725	28 148	52 573	35 498	16 178	14 402	10 676	7 501	4 095	1 531	863	394	60	13		13

3.2 Diet composition

3.2.1 Cod diet

Cod (*Gadus morhua*) stomachs were sampled by both Norwegian and Russian vessels. Norwegian data were analyzed in the laboratory at IMR; Russian data were analyzed onboard the vessel. Methods used for stomach sampling, data recording, and analysis are described in Anon. (1974), Mehl (1989), Mehl and Yaragina (1992), and Dolgov (1996). At each trawl station, 1 stomach per 5 cm length-group was collected by both vessels. Stomachs samples were collected at 327 stations; a total of 3 058 cod stomachs were analyzed in 2007. Data on diet composition of 0 age-group fish sampled by demersal trawl (Campelen) are reported in this volume; 0 age-group cod sampled by pelagic trawl on Norwegian vessels are not included, as those stomachs have not yet been analyzed.

For each station, the mean Partial Fullness Index (PFI) was calculated to compare quantities of various prey groups in the stomachs of predators of various sizes (Lilly and Fleming 1981). The PFI is based on the assumption that stomach capacity is a power function of fish length. The index was estimated for cod age-groups: 1-2; 3-6; and 7-12, respectively, with prey grouped by either species or species group. The PFI by predator age group and prey species group was then averaged over all fish sampled within each World Meteorological Organization (WMO) square (1° N x 2° E).

The PFI of prey group *i* in predator *k* is given by

$$PFI_{i,k} = \frac{S_{i,k}}{(L_k)^3} \times 10^4$$

where $S_{i,k}$ is the weight (g) of prey species i found in the stomach of predator k, and L_k is the length (cm) of predator k. The Total Fullness index TFI (PFI summed over all prey) was also calculated.

Table 3.6 shows the diet composition (weight percentage, not PFI) by cod age groups (summed over the whole area), as well as the stomach fullness. It was observed that stomach fullness increased with increased age of predator. Figure 3.1 shows the geographical distribution of stomach fullness (TFI) for all cod age groups combined. In the figure data are not shown for WMO squares where less than 5 stomachs were sampled. The highest stomach fullness was observed in the south-eastern corner of the Barents Sea, between 77° and 79° N east of Spitsbergen, as well as in the south-western and north-eastern corners of the distribution area for cod.

Figures 3.2--3.4 show diet composition (PFI) for age groups 1-2, 3-6 and 7+, respectively; data are not shown for WMO squares with less than 3 stomachs sampled within each age group. Diet composition for cod ages 1 and 2 (Figure 3.2) varied significantly between areas. Shrimp (Pandalus), fish (primarily sand eels, polar cod, capelin and sculpin), and krill was the most important prey group (Table 3.6); krill was less important than in 2006 (not shown). For cod age 3-6, diet composition also varied significantly between areas (Figure 3.3), reflecting differences in geographic distribution of various prey items. In general shrimps (Pandalus and krill) fish (primarily polar cod, herring and capelin) dominated the diet of cod (Table 3.6).

The percent of total weight made up of capelin, cod, and haddock (*Melanogrammus aeglefinus*) juveniles was lower than in 2006. Fish, including blue whiting, was the dominant prey item in the southwestern region; shrimp, herring, krill, and capelin dominated in the southeastern. In the central Barents Sea, shrimp and capelin were the most important prey species; polar cod dominated near Novaya Zemlya. Euphausiids and haddock were dominant prey items for cod in some areas. For cod age 7-12, diet composition (Figure 3.4) was similar to that of age 3-6 cod; but percent weight of euphausiids and Pandalus was lower (Table 3.6). As such, fish (including cod and haddock juveniles) was the dominant prey item for cod in coastal areas near Russia. Polar cod, capelin, and amphipods were dominant north of 76° N; polar cod was dominant near Novaya Zemlya (east of 42° E, between 73° and 75° N). Pandalus was the dominant prey item for cod in the central Barents Sea; but over a smaller area for cod aged 3-6. Blue whiting was also found in cod stomachs in the western region.

Table 3.6. Food composition of cod during August-October 2007. Numbers are given in % of total stomach content (weight).

Prey species	Cod age, year			Total, incl. 0-group and unaged fish
	1-2	3-6	7+	
Amphipods	2.44	4.89	7.77	6.22
Euphausiids	11.70	6.15	1.54	4.04
Pandalus	21.66	6.27	4.23	5.61
Other and unid. crustaceans	8.20	4.54	6.14	5.10
Herring	-	12.35	7.93	9.94
Capelin	9.03	8.08	5.17	6.69
Polar cod	7.36	15.97	23.11	19.23
Cod	-	0.61	0.37	0.48
Haddock	-	2.96	9.22	5.92
Blue whiting	-	1.89	3.15	2.44
Norway pout	0.09	0.56	0.63	0.59
Redfish	-	0.33	0.30	0.31
Triglops	4.28	4.65	0.62	2.69
Cycloptera	-	0.90	5.92	3.30
Ammodytidae	12.00	0.85	0.11	0.73
Long rough dab	1.58	1.27	4.87	3.02
Other and unid. Fish	16.28	22.22	16.47	19.34
Other and unid. Food	5.38	5.51	2.45	4.35
Number of stomachs	992	1656	344	3058
Number of empty stomachs, %	32.8	21.6	11.6	24.6
Mean stomach fullness	1.6	2.0	2.5	1.9
Mean fullness index , $^{0}/_{000}$	171.3	249.8	271.1	229.7
Mean weight of cod (g)	137.5	1073.6	4878.3	1176.8

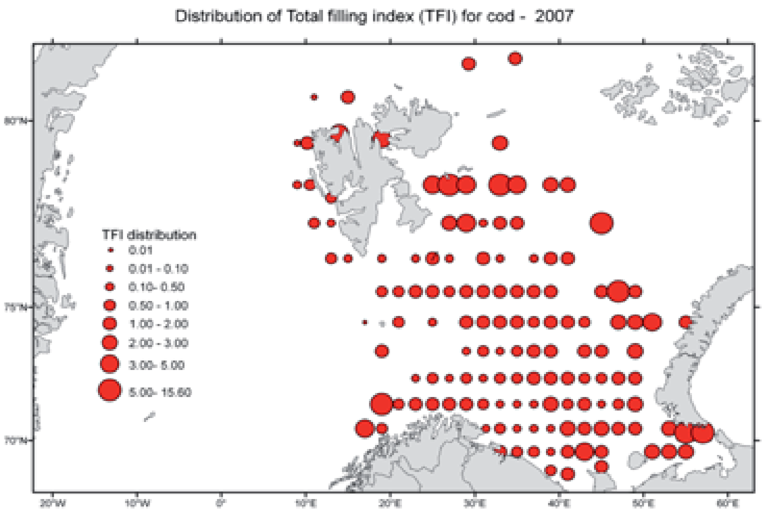


Figure 3.1. Geographic distribution of stomach fullness (TFI) for cod during the ecosystem survey autumn 2007. All age groups combined per WTO (World Meteorological Organization) square, but squares with < 3 stomachs are excluded from the plot.

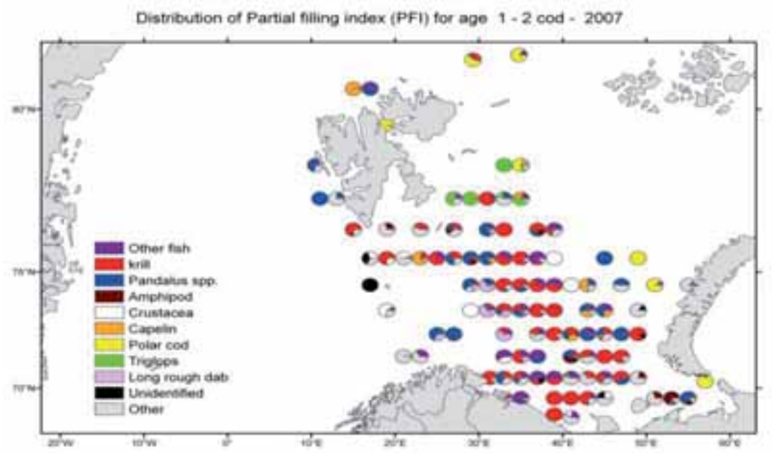


Figure 3.2. Geographical distribution of prey composition (PFI) in cod stomachs during the ecosystem survey autumn 2007, for age groups 1-2. WTO (World Meteorological Organization) squares with < 3 stomachs are excluded from the plot.

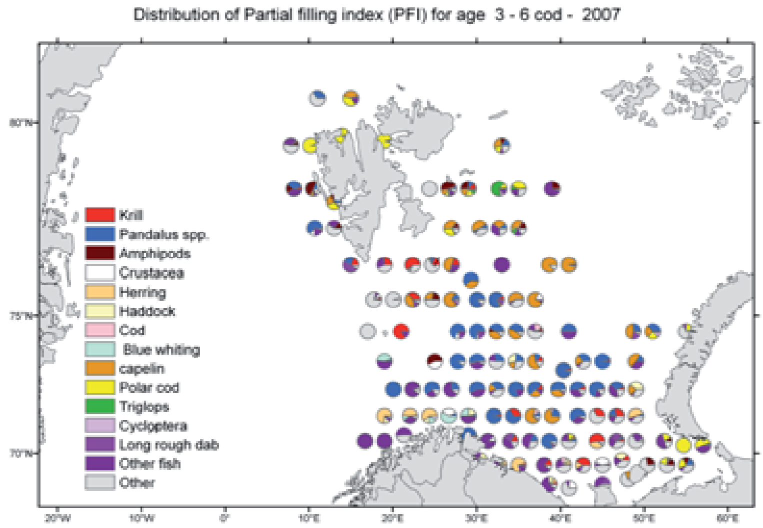


Figure 3.3. Geographical distribution of prey composition (PFI) in cod stomachs during the ecosystem survey autumn 2007, for age groups 3-6. WTO (World Meteorological Organization) squares with < 3 stomachs are excluded from the plot.

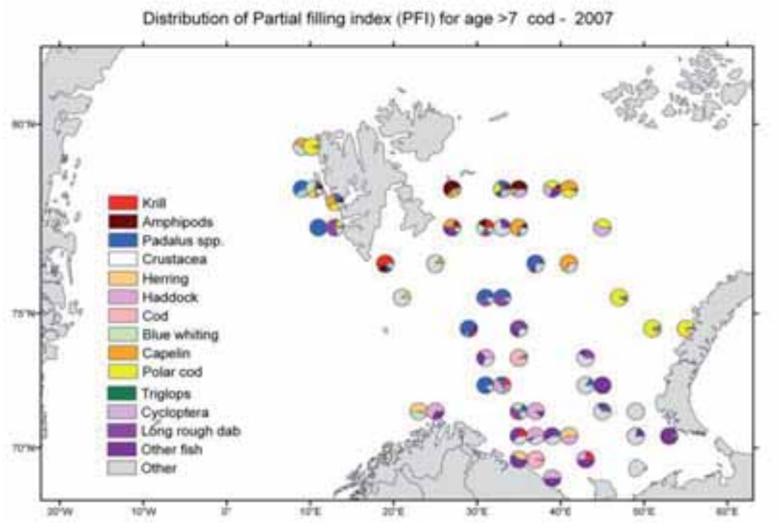


Figure 3.4. Geographical distribution of prey composition (PFI) in cod stomachs during the ecosystem survey autumn 2007, for age groups 7-12. WTO (World Meteorological Organization) squares with < 3 stomachs are excluded from the plot.

3.2.2 Haddock diet

Haddock (*Melanogrammus aeglefinus*) stomachs were sampled only by Russian vessels; data were analysed onboard. Methods used to sample, record, and analyze data were the same as for cod. At each trawl station, 1 stomach per 5 cm length-group was collected. Stomachs were sampled from 105 stations, 1152 haddock stomachs were analysed. Table 3.7 shows the diet composition and stomach fullness by age group (summed over the entire area).

For each station, the mean Partial Fullness Index (PFI) was calculated to compare quantities of various prey groups in the stomachs of predators of various sizes (Anon. 1974). This was done for all haddock age groups, and for each of the main prey groups.

The PFI of prey group *i* in predator *k* was calculated as

PFI = $(S_i / W) * 10000$

where $S_{i,}$ is the total weight (g) of prey species *i* found in all stomachs of predator for the station, and *W* is the total weight (g) of all haddock collected at the station. The Total Fullness Index (TFI), the PFI summed over all prey, was also calculated. Note that haddock indices are on a different scale than cod indices.

In general three taxa dominated in haddock diet in 2007: krill (10-51%); echinoderms (9-21%); and worms (10-17%) (Table 3.7). Fish and molluscs were also important prey species for haddock. In the northern Barents Sea (the Spitsbergen- Bear Island area), pelagic organism (fish, shrimp, hyperiids, and euphausiids) were the most important prey species (Figure 3.5). Krill were dominant in haddock stomachs in the central part of the southern Barents Sea, while in other areas (southern Barents Sea near both Bear Island and Novaya Zemlya) benthic organisms (echinoderms, worms, molluscs) were dominant. The number of haddock stomachs with benthic organisms as dominant prey was higher than the number of stomachs with krill as dominant prey.

For age 1-2 haddock, krill and worms were dominant in the diet; fish, including long rough dab, capelin and polar cod, were also consumed, but of less important. For haddock age 3-6, krill was the dominant prey species; echinoderms and worms were the second and third most important prey items. This is in contrast with age 1-2 haddock, which also preyed on fish. For age 7-12 haddock, fish and echinoderms and worms were dominant prey species (Table 3.7).

Table 3.7. Food composition of haddock during August-October 2007, % by total stomach content weight.

Prey species	Haddock age, year			Total, incl.
	1-2	3-6	7-12	0-group
Polychaeta	12.06	10.74	17.44	11.47
Mollusca	4.48	8.63	1.97	7.51
Hyperiids	1.36	-	-	0.31
Euphausiids	46.25	50.78	10.38	46.84
Shrimp	3.27	0.30	-	0.69
Echinodermata	9.51	18.21	21.09	17.19
Herring	-	1.58	-	1.23
Capelin	1.48	0.10	-	0.29
Polar cod	1.12	-	-	0.16
Long rough dab	2.45	0.61	-	0.82
Other fish	9.59	2.38	22.63	5.56
Other food	8.43	6.67	26.49	7.93
Number of stomachs	583	520	23	1152
Empty stomachs, %	44.6	23.8	8.7	34.4
Mean stomach fullness	0.8	1.4	1.7	1.1
Mean fullness index , $^{0}/_{000}$	134.2	139,7	111.0	136.1
Mean weight of haddock (g)	139.4	600.7	1813.0	378.8

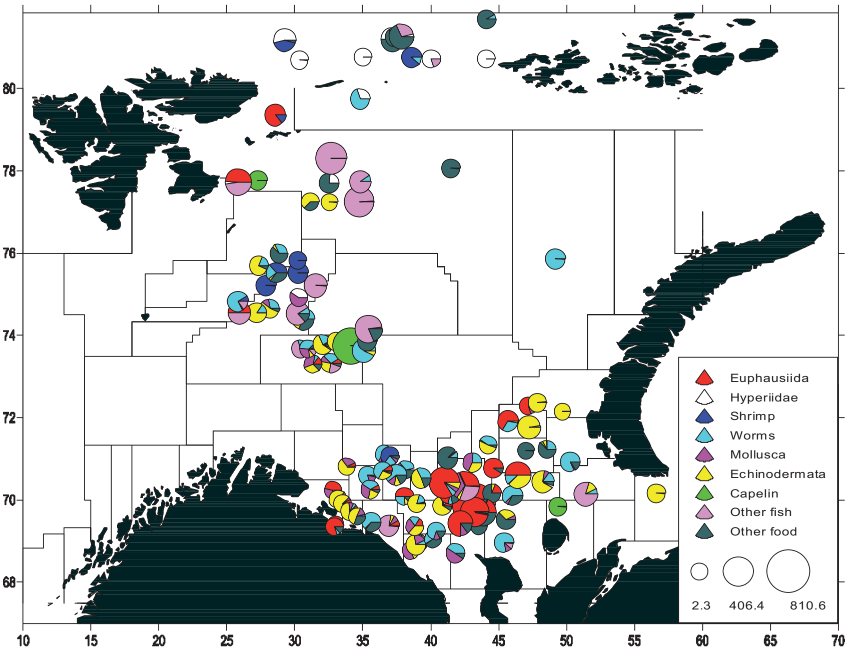


Figure 3.5. Geographical distribution of diet composition (PFI) for haddock during the ecosystem survey autumn 2007. All age groups combined.

4 Capelin

4.1 Capelin, swept-area assessment based on bottom trawl data

Capelin (*Mallotus villosus)* were distributed widely, and captured in most bottom trawl tows. The distribution of capelin in bottom trawl catches is shown in Figure 4.1.

A swept-area assessment of capelin caught by the Campelen bottom trawl was carried out using the same methods and strata system as for demersal fish species. The resulting estimate of capelin stock biomass was 133 thousand tons; stock abundance was estimated to be $7.6*10^{9}$ individuals. This is comparable to survey estimates from 2006 (147 thousand tons and $6.0*10^{9}$ individuals). The biomass estimate for mature capelin is 119.5 thousand tons. This it is approximately 14 % of the acoustic estimate of mature capelin.

Estimates of capelin biomass and abundance based on data from the area swept clear method were plausible due to the numbers of trawls in strata; the level of uncertainty increases using this rather than traditional acoustic methods, it is, however, the most feasible for older age groups.

Differences in estimates of stock age-composition based on acoustic and trawl data are shown in Figure. 4. 2.

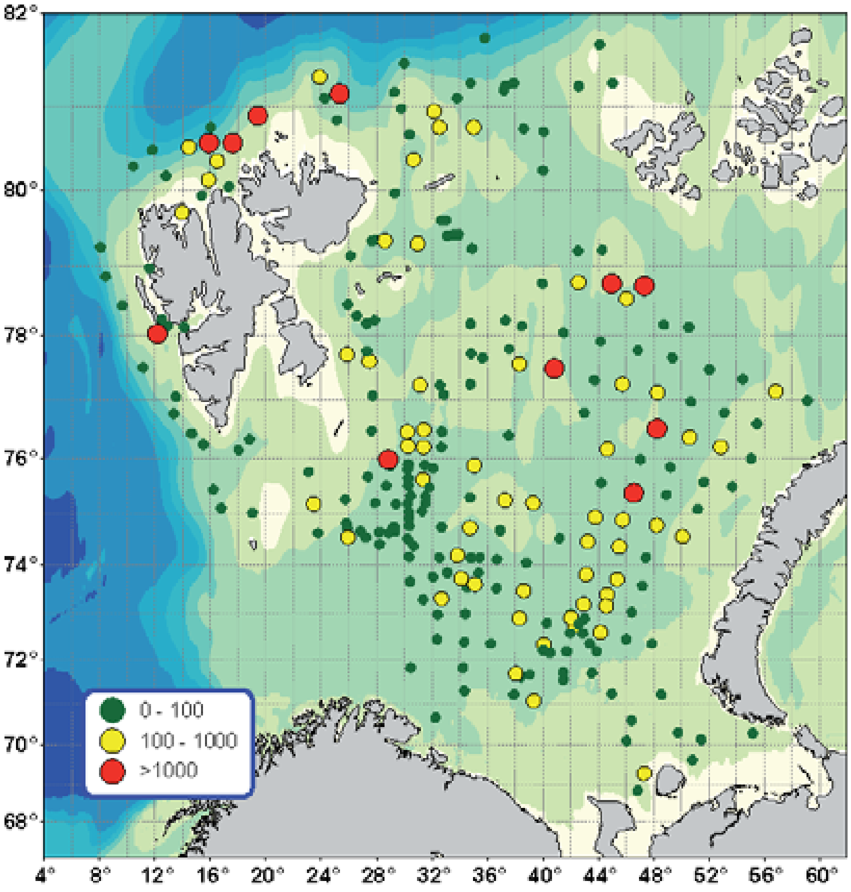


Figure 4.1. Distribution of capelin (*Mallotus villosus*) caught in demersal trawl during the ecosystem survey in the Barents Sea 2007 (numbers/n.mile trawling).

Table 4.1. Swept area abundance estimate of Barents Sea capelin in autumn 2007.

Length (cm)	Age/Year class					Numbers, (10^6 sp.)	Biomass, (10^3 t)	Mean weight (g)
	1	2	3	4	5+			
	2006	2005	2004	2003	2002			
8.0- 8.4	11.4	3.8				15.2	0.02	1.5
8.5- 8.9	30.5					30.5	0.07	2.4
9.0- 9.4	53.4					53.4	0.15	2.8
9.5- 9.9	76.2					76.2	0.24	3.2
10.0- 10.4	122.8	6.8				129.6	0.53	4.1
10.5- 10.9	88.1	3.4				91.5	0.44	4.8
11.0- 11.4	88.9	10.3				99.1	0.56	5.7
11.5- 11.9	77.4	6.5				83.9	0.55	6.5
12.0- 12.4	130.1	30.0				160.1	1.18	7.4
12.5- 12.9	140.5	42.5				183.0	1.57	8.6
13.0- 13.4	274.2	107.0				381.2	3.85	10.1
13.5- 13.9	172.2	155.6				327.9	3.93	12.0
14.0- 14.4	136.3	349.0	33.2			518.5	6.95	13.4
14.5- 14.9	69.6	676.0	39.8			785.3	11.62	14.8
15.0- 15.4	29.9	937.2	69.8			1036.9	17.32	16.7
15.5- 15.9	6.7	1043.3	110.7	13.4		1174.2	21.96	18.7
16.0- 16.4		729.3	162.4	23.2		915.0	19.40	21.2
16.5- 16.9	3.3	469.5	168.6	6.6		648.1	15.23	23.5
17.0- 17.4		201.7	145.5	26.4		373.6	9.90	26.5
17.5- 17.9		62.8	175.3	36.4		274.5	8.01	29.2
18.0- 18.4		23.6	114.5	3.4	3.4	144.9	4.68	32.3
18.5- 18.9			55.6	9.8	3.3	68.6	2.37	34.6
19.0- 19.4		3.3	39.2		3.3	45.7	1.76	38.5
19.5- 19.9			7.6			7.6	0.33	43.8
TSN (10^6)	1511.6	4861.6	1122.3	119.2	9.9	7624.6		
TSB (10^3 t)	13.0	88.1	28.1	3.1	0.3		132.7	
Mean length (cm)	12.1	15.3	16.8	17.1	18.6	15.0		
Mean weight (g)	8.7	18.1	25.2	25.9	33.5		17.4	
MSN (10^6)	245.8	4495.7	1122.3	119.2	9.9	5992.9		
MSB (10^3 t)	3.6	84.4	28.1	3.1	0.3		119.5	

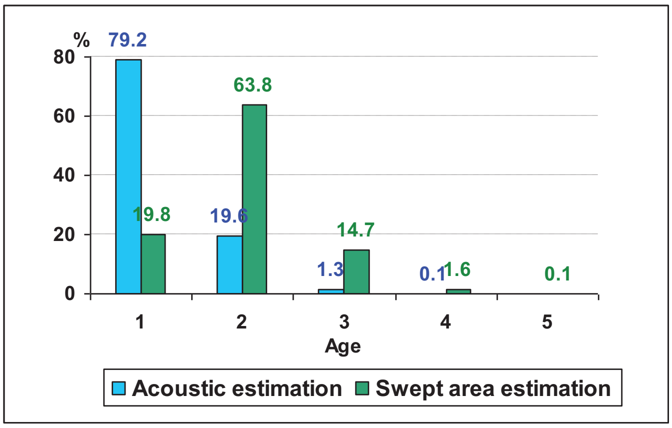


Figure 4.2. Age distribution of capelin stock calculated by acoustic and trawl method (numbers in % of total catch).

4.2 Capelin feeding - preliminary results

Results of preliminary studies on capelin feeding in the Barents Sea in 2006 appear in Volume 2 of the survey report from 2006 (Anon. 2007a). In this volume, more complete data are presented on capelin feeding in different areas of the Barents Sea in 2006.

In 2006 ecosystem survey results indicate that capelin distribution was concentrated between 74º40'-77º20'N and 26º-42ºE. Aggregations extended as far as 80ºN both east and west of Spitsbergen; small immature fish were mainly found south of 76ºN. Areas sampled for capelin feeding studies coincided with areas of concentration (Figure 4.3).

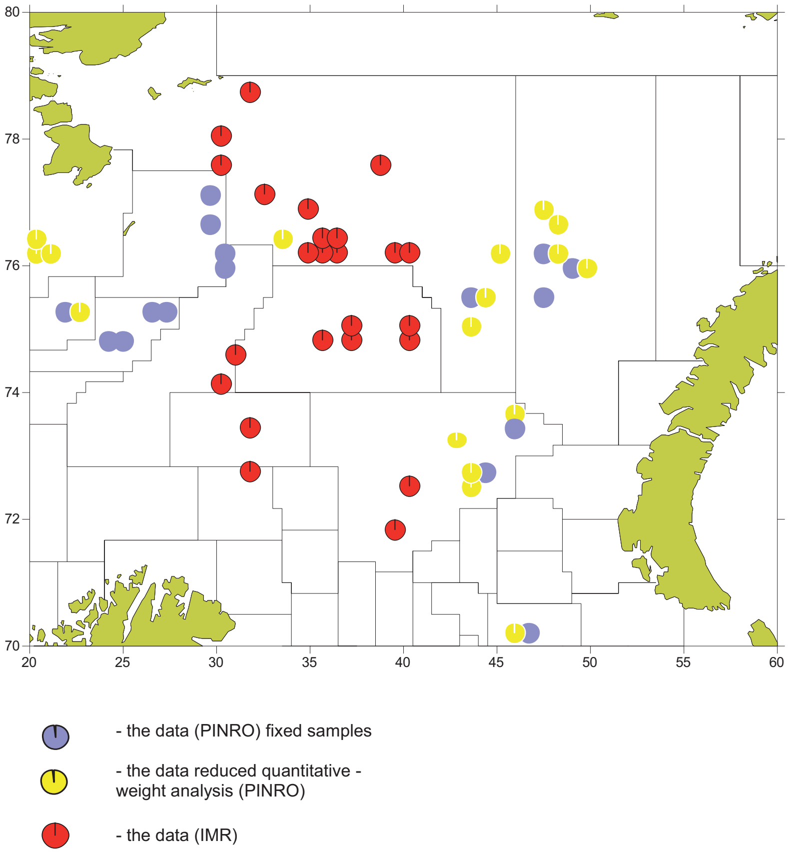


Figure 4.3. General sampling distribution and source of 2006 capelin feeding data. The data from PINRO have been fixed on formalin while IMR data are frozen.

During late August through October, capelin feeding intensity varied between areas: mature and immature fish of lengths ranging from 9-19 cm fed in the northwestern and central areas of the Barents Sea; while exclusively large mature capelin ranging from 13-19 cm fed in the eastern region.

Capelin fed intensively in the northwest region of the Barents Sea. On the eastern slope of Bear Island Bank, all capelin fed actively: the stomach fullness index (SFI) was 500-800 $^{0}/_{000}$ during night and 130-260 $^{0}/_{000}$ during afternoon (Figure 4.4). Large copepods *C. finmarchicus*, *C.glacialis* and *C.hyperboreus*, *M. longa* (represented by the CV in females sampled) made up the bulk of the diet (48-88%); euphausiids, *Sagittae*, hyperiids, and other species also were important components (52-12%).

In the Spitsbergen Bank area, the PFI for capelin ranged between 400-638$^{0}/_{000}$. Dominant species (68-100%) in the diet were copepods, *C. finmarchicus*, *C.glacialis*, *C.hyperboreus*, *M. longa* (represented by the CV in females sampled), and euphausiids (*Th. Inermis*) (Figure 4.5A). In the South Cape Deep, concentrations of large mature capelin at lengths of 13-19 cm were observed, but feeding was less intensive; the PFI ranged between 189 and 256 $^{0}/_{000}$). The diet consisted of euphausiids, exclusively (Figure 4.5B).

Capelin fed with less intensity in the Hopen Island area, where the diet was more varied. Mature fish fed primarily on euphausiids (*Th. inermis*, *Th. longicaudata* and *Meganyctiphanes norvegica*); the PFI increased to 72-77 $^{0}/_{000}$ (Figure 4.6A). When the diet primary consisted of copepods, the PFI did not exceed 15-27 $^{0}/_{000}$ (Figure 4.6B). In the Hopen Island area, capelin fed primarily on small copepod species (*M. longa*, *P. minutus*, *and Oithona spp*. *Oncoea borealis*). Even in large specimens, the proportion of small species was great. At CIV-V, *C.glacialis* and *C.finmarchicus* were also prevalent in large specimens; there the capelin diet also consisted of Themisto (*Th. abyssorum*, *Th. libellula*) and Sagitta spp.

During September, in central regions, capelin fed at different levels of intensity. In the Persey Elevation area, different feeding patterns were observed relative to both spatial distribution and size group. The two major constituents of the diet were copepods and euphausiids; the prevalence of these two species, however, was quite variable (Figure 4.7). The observation that not all the individuals fed, suggests the food supply was inadequate. In late September at stations furthest north, euphausiids were the dominant prey, for all except the 15-17 cm length group, for which copepods were the dominant prey. Fish with lower feeding intensity usually fed in the morning (Figure 4.8). In the northeastern region of the Barents Sea, capelin generally preyed on euphausiids (*Th. inermis* and *Th. longicaudata*) in the morning. For capelin with lower feeding intensity, the proportion of euphausiids consumed increased from 50 to 96% based on predator size. Other components of the capelin diet were Pteropoda (*Limacina helicina*), and comb jellies (*Beroe cucumis*); in the south, copepods were also in the diet of mature capelin (Figure 4.9). The PFI and the number of capelin feeding varied widely with fish size. This could indicate an inadequate food supply for smaller capelin.

For small concentrations of capelin on Novaya Zemlya Bank, where fish 13-21 cm in length occurred, feeding was highly variable; as indicated by substantial difference in the PFI, which varied from 654 $^{0}/_{000}$ for 13-15 cm size fish to 260 $^{0}/_{000}$ for larger individuals. This tendency was not observed in other indices for which the numbers of fish feeding might decrease the food supply for large fish. In a number of cases, however, fish feeding was consistent and moderate (small capelin consumed copepods, larger capelin consumed euphausiids, hyperiids, and Sagittae) (Figure 4.10).

In the Central Deep area, feeding for 9-19 cm length capelin was different: in the west, the PFI ranged from 300-590 $^{0}/_{000;}$ in the east it ranged from 22 to 484 $^{0}/_{000}$. In this instance, the diet composition was almost optimal, stomachs of small specimens were full of copepods (100%); stomachs of older larger specimens were full of euphausiids.

During 2006, in most regions, body fat in capelin was higher than during 2005. Particularly, in the northeastern region, the body fat index to 7.0-11.9% during 2006 from the 2.9-7.7% index during 2005. This may indicate favorable feeding conditions during critical periods (Table 4.2). The Hopen Island area was the exception; there food supply (particularly for immature capelin) was low.

Table 4.2. Fat content in the muscular tissue of capelin (%) from different size groups during August-September 2006.

Area	Positions	Date	Number ind.	Size group cm	Fat content %
Spitsbergen Bank	75°13’N 23°28’E	30.08.06	5	9,1-11,0	5,78
			20	11,1-13,0	6,13
Hopen Island Area	76°30’N 29°54’E	08.09.06	3	9,1-11,0	4,50
			8	11,1-13,0	5,93
			9	13,1-15,0	6,30
	75°54’N 30°17’E	06.09.06	6	9,1-11,0	4,50
	75°49’N 30°17’E	07.09.06	7	13,1-15,0	7,55
			14	15,1-17,0	8,24
			3	17,1-19,0	8,71
Eastern slope of the Bear Island Bank	75°15’N 25°55’E	05.09.06	13	9,1-11,0	5,49
			6	11,1-13,0	5,69
			4	13,1-15,0	7,21
			2	15,1-17,0	8,28
	75°11’N 27°11’E	05.09.06	11	9,1-11,0	5,87
			13	11,1-13,0	5,15
	74°35’N 23°30’E	30.08.06	6	13,1-15,0	9,04
			18	15,1-17,0	8,56
			7	17,1-19,0	9,58
	74°34’N 21°35’E	29.08.06	6	11,1-13,0	8,71
			16	13,1-15,0	9,67
			11	15,1-17,0	10,6
Persey Elevation	75°03’N 43°56’E	16.09.06	9	13,1-15,0	8,45
			13	15,1-17,0	8,50
			3	17,1-19,0	8,04
Novaya Zemlya Bank	75°16’N 48°39’E	23.09.06	5	13,1-15,0	11,21
			11	15,1-17,0	9,30
			2	17,1-19,0	10,51
	76°04’N 46°20’E	25.09.06	11	13,1-15,0	10,32
			13	15,1-17,0	9,50
			3	17,1-19,0	11,9
	75°59’N 47°15’E	22.09.06	5	13,1-15,0	9,19
			15	15,1-17,0	10,44
			5	17,1-19,0	10,07
Northern slope of the Kanin-Kolguev Shallows	70°03’N 46°16’E	30.08.06	4	13,1-15,0	8,35
			12	15,1-17,0	8,74

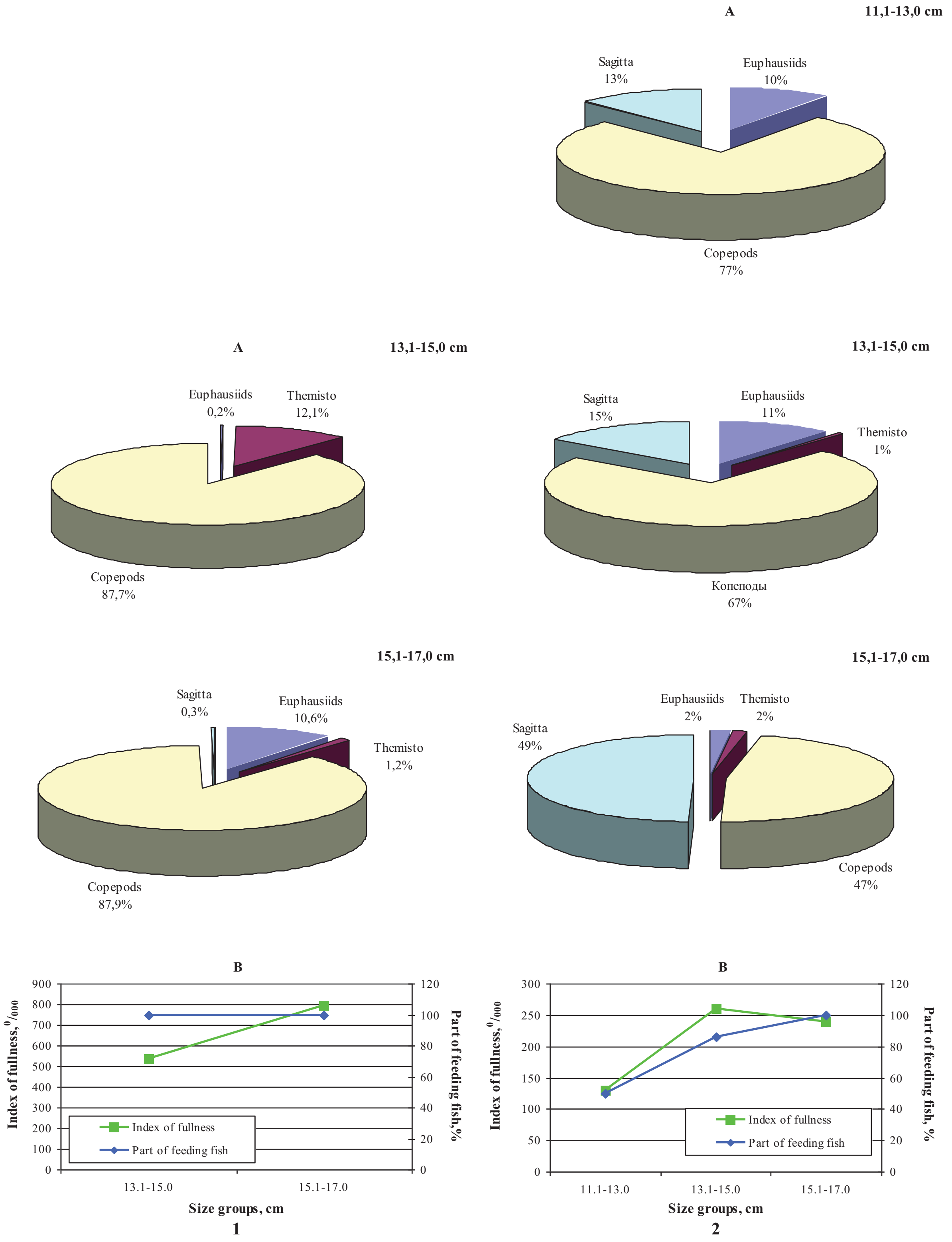


Figure 4.4. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the Eastern slope of the Bear Island Bank, at night (1) and during day time (2).

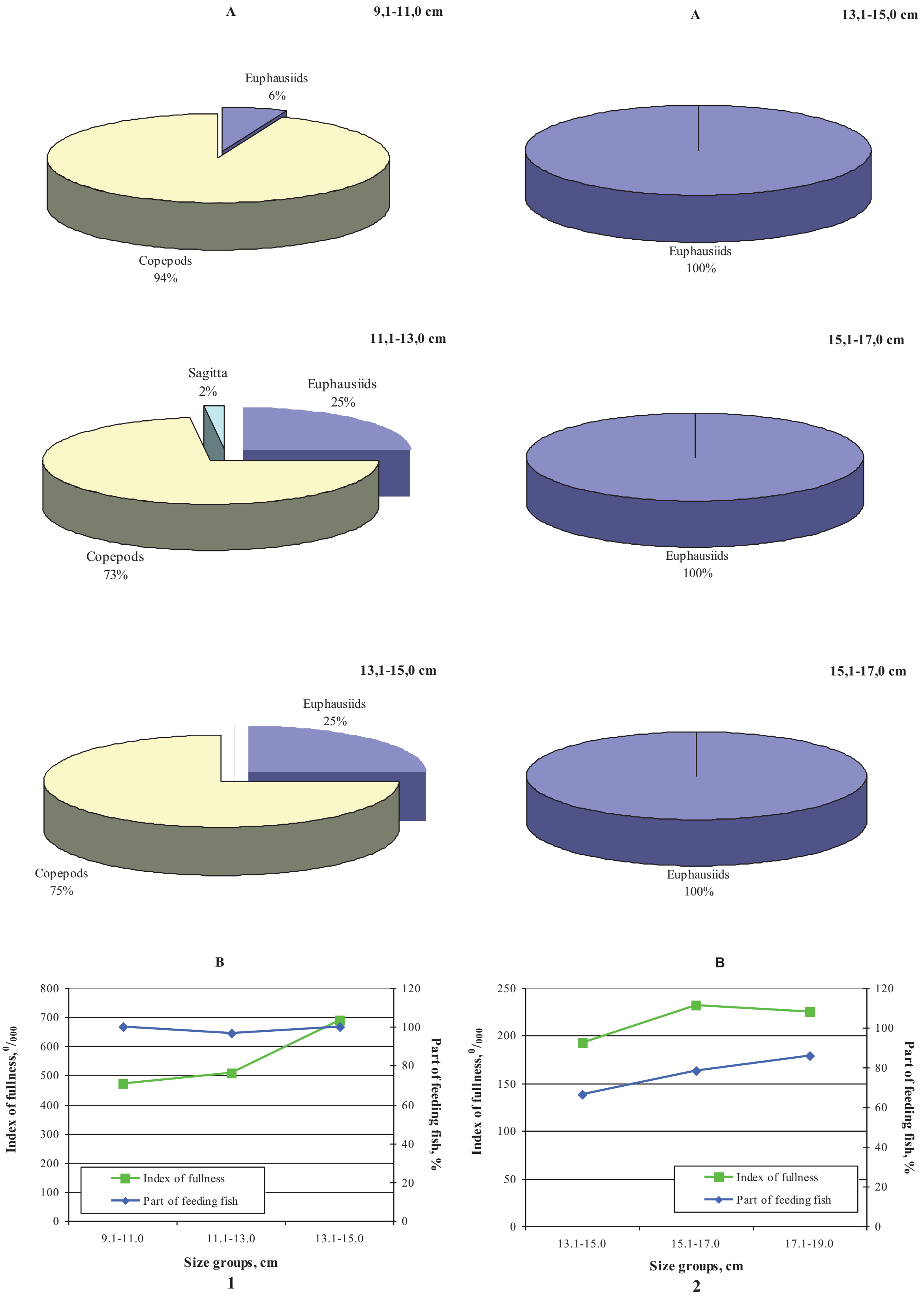


Figure 4.5. Food composition (A) and feeding intensity (B) of different size groups of capelin in the Spitsbergen Bank (1) and the South Cape Deep (2), during day time.

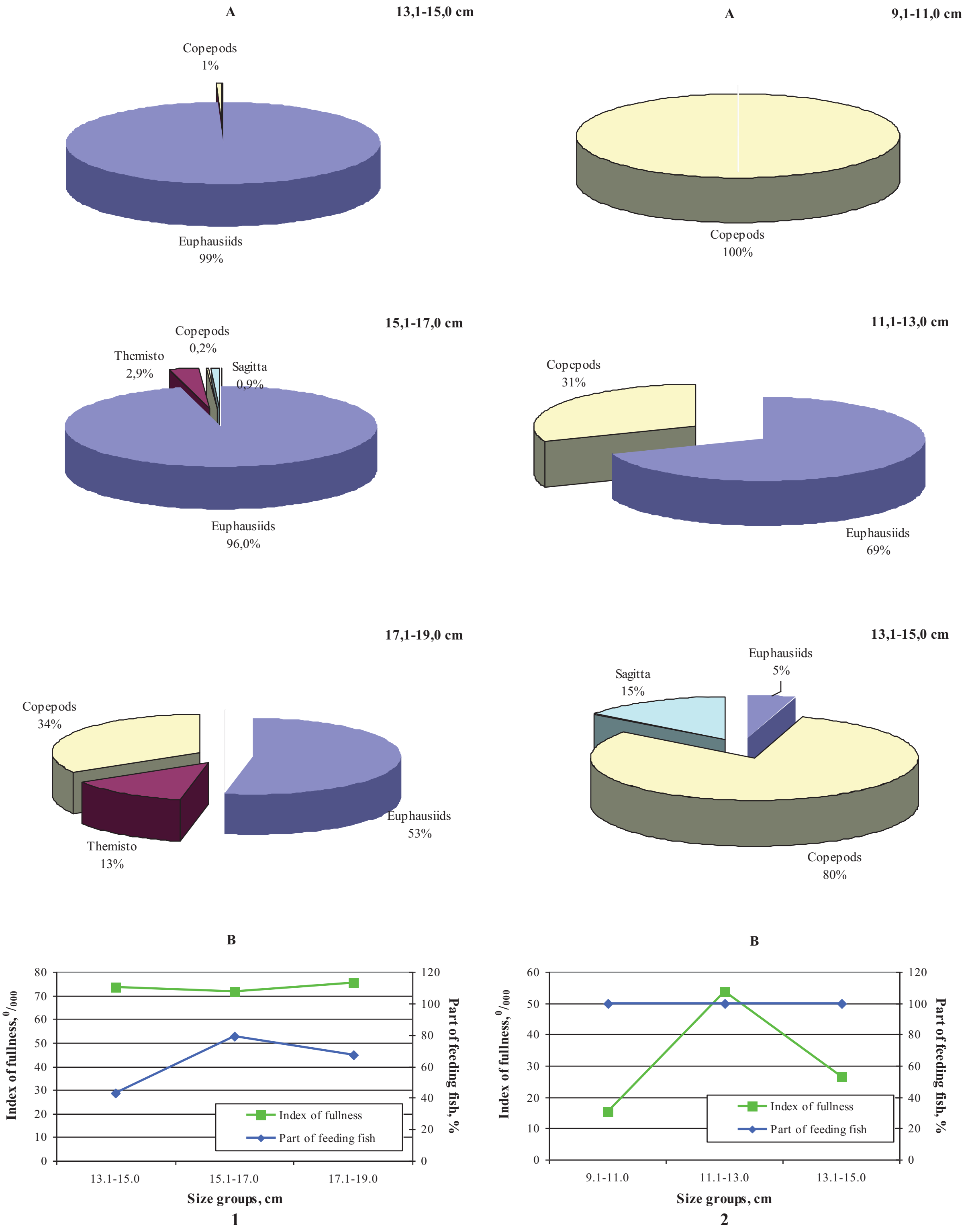


Figure 4.6. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the Hopen Island area, at night (1) and in the morning (2).

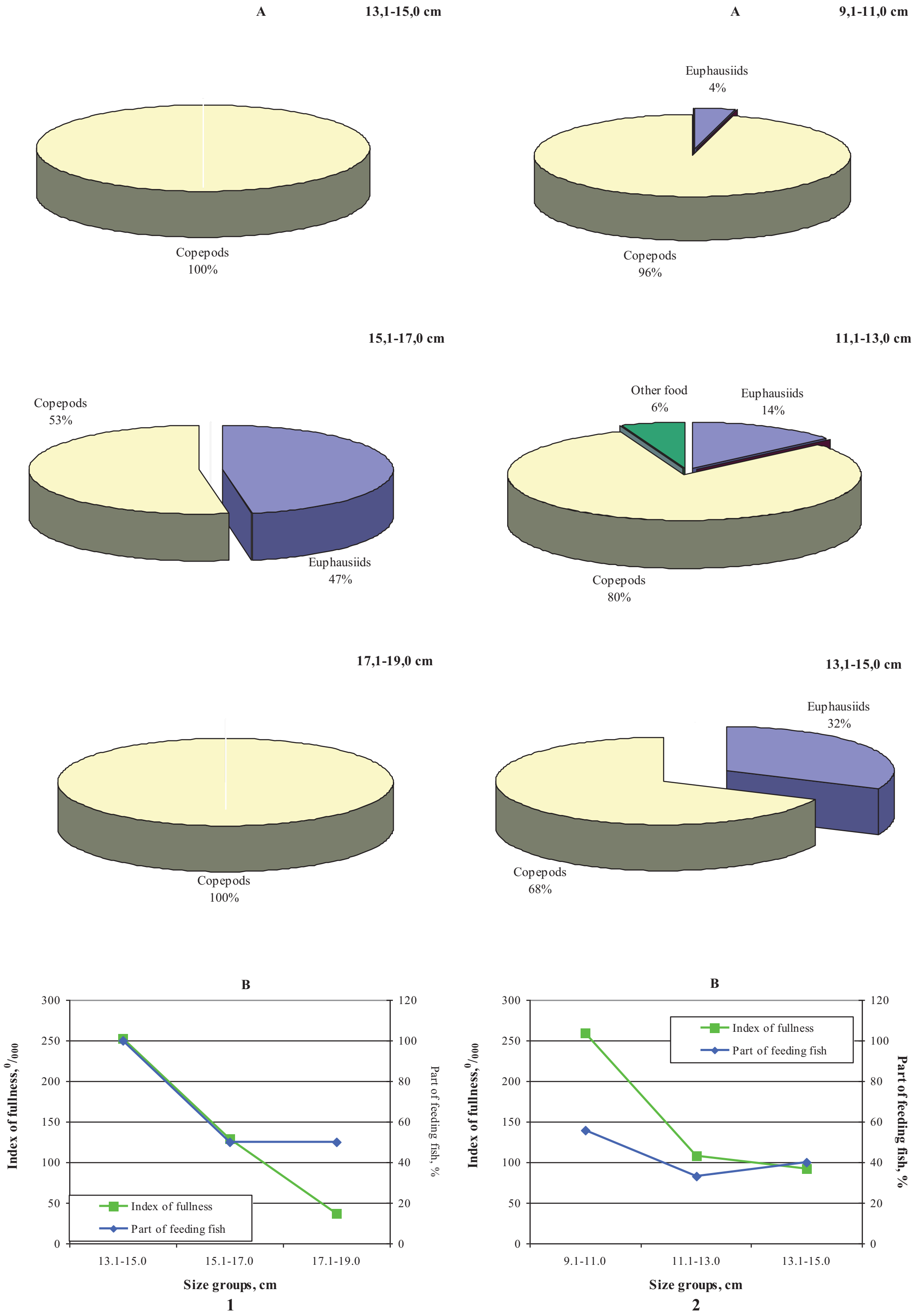


Figure 4.7. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the evening, in the southeast (1) and in the northwest (2) parts of the Persey Elevation.

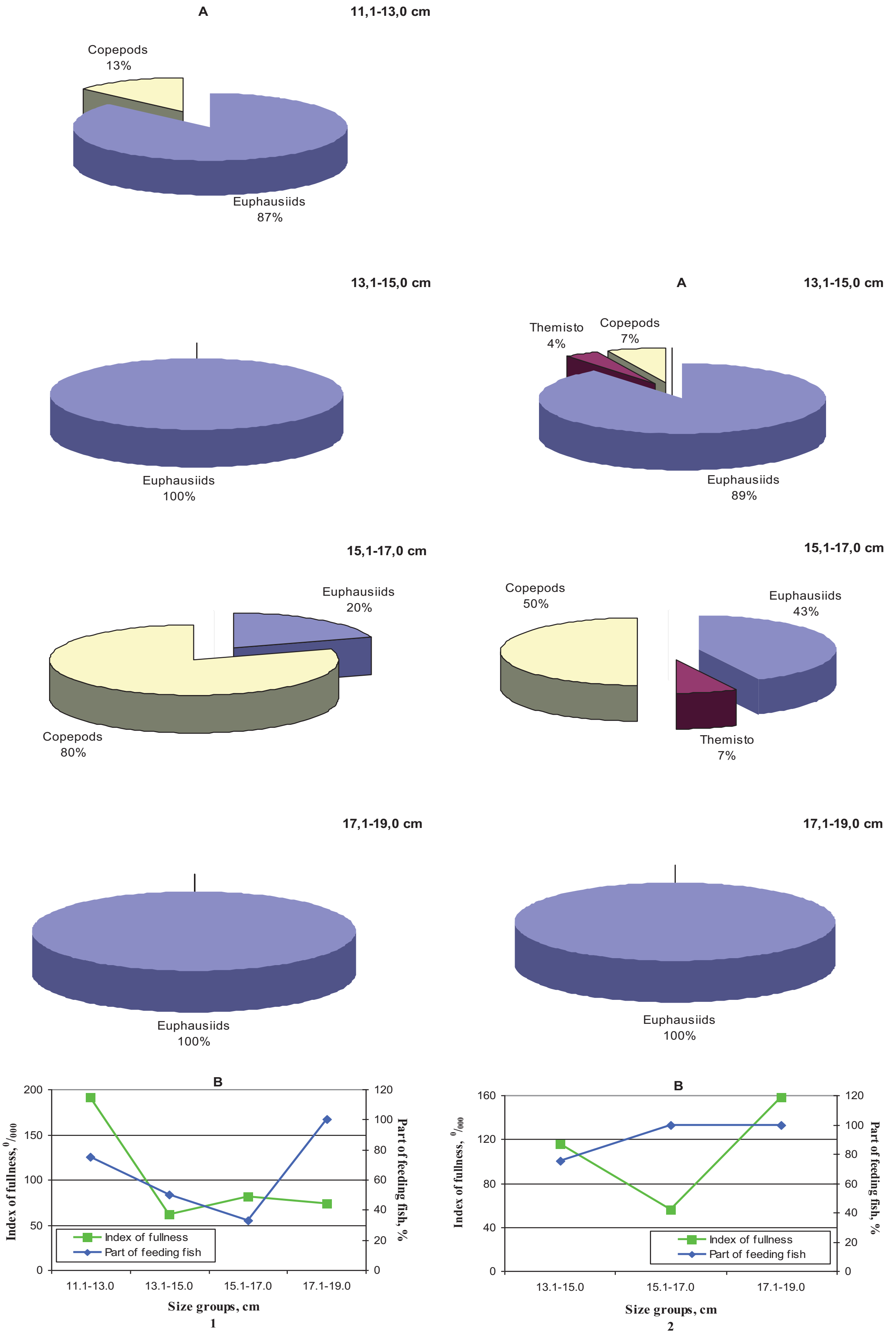


Figure 4.8. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the northern part of the Persey Elevation, in the evening (1) and in the morning (2).

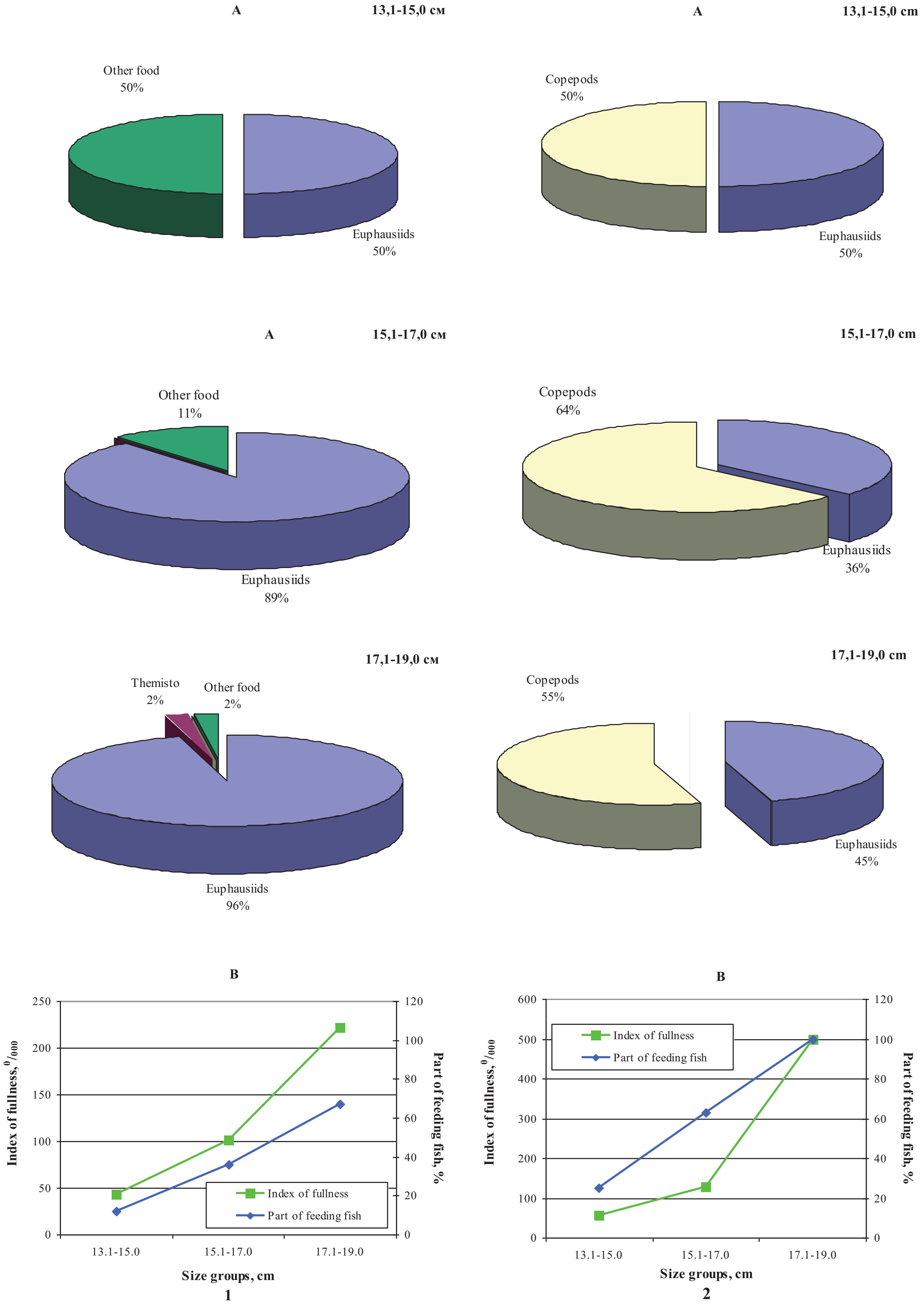


Figure 4.9. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the Persey Elevation, in the morning (1) and during day time (2).

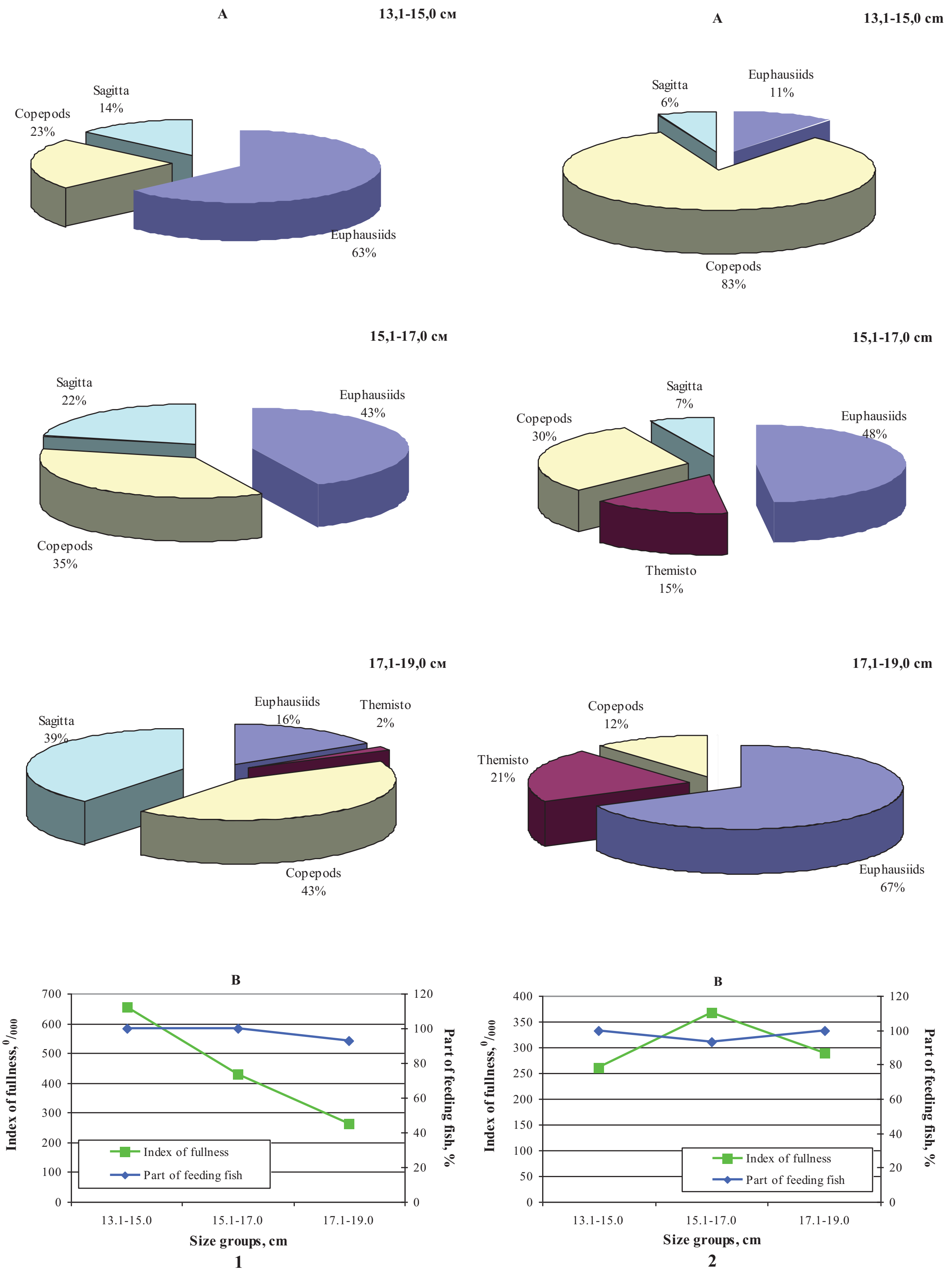


Figure 4.10. Food composition (A) and feeding intensity (B) of different size groups of capelin, in the Novaya Zemlya Bank, in the morning (1) and in the day time (2).

5 Northern shrimp in the Barents Sea

5.1 Background

5.1.1 Monitoring the stock

Northern shrimp (*Pandalus borealis*) are distributed throughout the Barents Sea. Since 1982, annual national trawl surveys were conducted (by both Norway and Russia) to gather information on shrimp stock biomass and demographic composition for assessments. From 2004 onward, this information has been obtained through the 'Joint Russian-Norwegian Ecosystem Survey of the Barents Sea' (Figure 5.1).

Shrimp catch during the 2007 survey ranged between 0.016 kg and 1.5 tons per haul. Data indicate a 28% decrease in stock size from 2006. Dense concentrations of shrimp biomass were observed in the central region of the Barents Sea around Svalbard (Spitsbergen) (Figure 5.1).

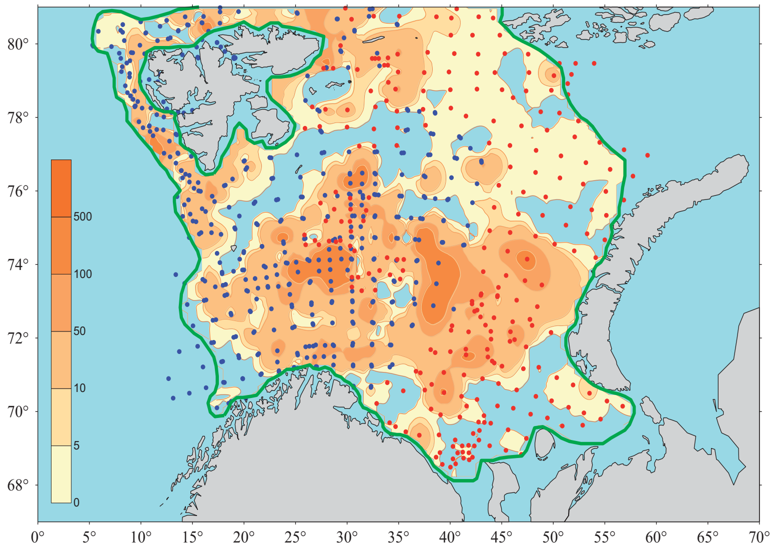


Figure 5.1. Russian-Norwegian Ecosystem survey 2007: Distribution of trawl stations (blue and red dots) and estimated densities of Northern shrimp in the Barents Sea and Spitsbergen region during August-September (kg/hour of trawling).

5.1.2. The fishery

Northern shrimp in the Barents Sea support a multi-national fishery. Landings peaked at an estimated 130,000 t/yr in the mid-1980s (Figure 5.2). During the recent decade catches varied between 28 000 and 83 000 t/yr – 70-90% of landings were taken by Norwegian vessels; the remaining portion by vessels from Russia, Iceland, Greenland and the European Union (EU). The preliminary estimate of total landings in 2007 is 30 000 tons (Hvingel and Thangstad 2007).

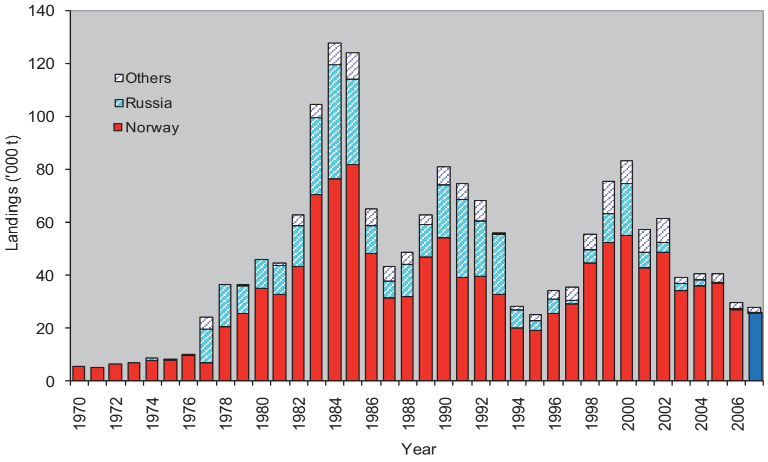
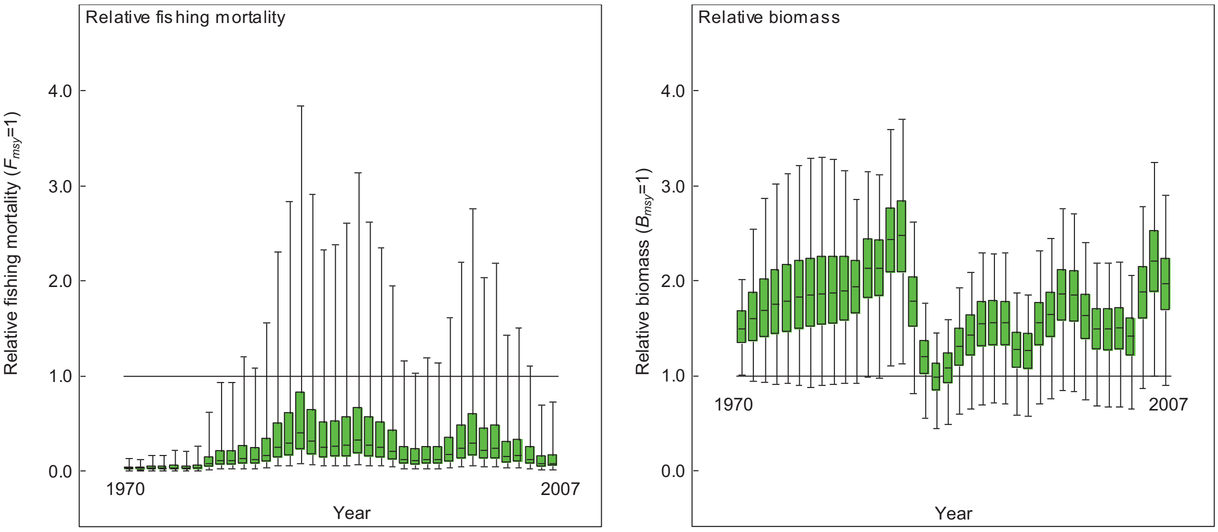


Figure 5.2. Total landings (2007 preliminary estimate based on partial data). (From Hvingel and Thangstad 2007).

5.2 Assessment results

5.2.1 Stock size and fishing mortality

Information on stock dynamics and exploitation rates was integrated in an assessment model; results are presented relative to maximum sustainable yield (MSY) reference points (Hvingel 2007). Stock biomass decreased to below optimum levels (B_{msy}, the biomass that produces MSY) during the mid-1980s (Figure 5.4) following a period with high catch levels (Figure 5.3). Since the late 1990s stock biomass has varied with an overall increasing trend. The estimated risk of stock biomass falling below B_{msy} in 2007 was 3%. Average fishing mortality (F-ratio) has been consistently below 1.0 throughout the time series (Figure 5.5). During 2007 there was a 2% risk of the F-ratio rising above 1.



Figures 5.3 and 5.4. Estimated relative fishing mortality (F_t/F_{msy}) and biomass (B_t/B_{msy}) 1970-2007. Boxes represent inter-quartile ranges; solid black line (at approximate centre of each box) is the median. The arms of each box extend to cover the central 95 per cent of the distribution. (From Hvingel 2007).

With respect to precautionary 'limit reference points' – which should be avoided with a high probability – stock biomass has been above B_{lim}, and fishing mortality ratio has been below F_{lim}, throughout the time series (Figure 5.5). At the end of 2007 there was less than 1% risk that stock biomass would fall below B_{lim}, while the risk that F_{lim} would be exceeded was 3% (Hvingel 2007).

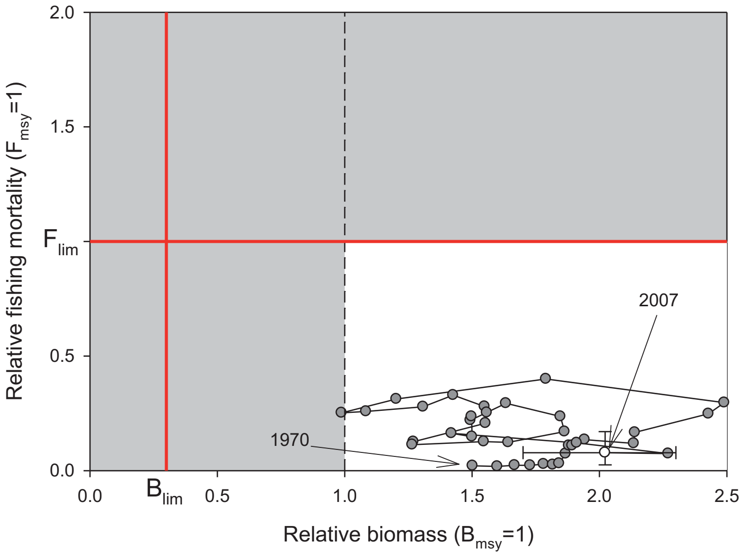


Figure 5.5. Estimated annual (1970-2007) median biomass-ratio (B/B_{msy}) and fishing mortality-ratio (F/F_{msy}). Reference points for stock biomas, B_{lim}, and fishing mortality, F_{lim}, are indicated by the red (bold) lines. Error bars on the 2007 value are inter-quartile range. (Hvingel 2007).

5.2.2. Stock production potential

Estimated probability distribution for MSY was positively skewed with a mode at 95 000 t (Figure 5.6), with upper and lower quartiles at 100 000 t and 309 000 t. The probability that MSY would exceed recently advised levels of total allowable catch (TAC) between 40 000 to 50000 tons was estimated to be 95% (Hvingel 2007).

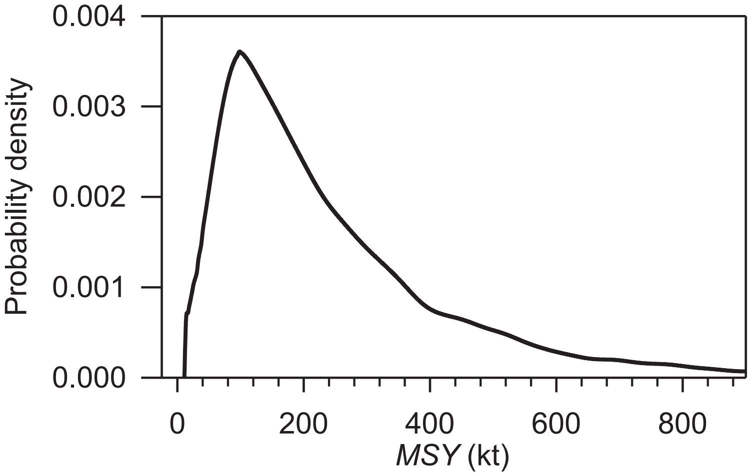


Figure 5.6. Estimated probability density distribution for MSY in kilotons (kt). (Hvingel 2007).

5.2.3 Predictions

The risk associated with six optional catch levels for 2008 are presented in Table 5.7. (Hvingel 2007).

Table 5.7. Risk associated with ten-year projections at six optional catch levels for 2008 are as follows (Hvingel 2007).

Catch options (ktons)	30	40	50	60	70	90
Risk of falling below B_{lim}	<1%	<1%	<1%	<1%	<1%	<1%
Risk of falling below B_{MSY}	4%	4%	4%	4%	4%	5%
Risk of exceeding F_{MSY}	2%	3%	4%	6%	7%	11%

For all options investigated, risk of the stock falling below B_{msy} in the short to medium term (1-5 years) is low (<11%) (Figure 5.7). It is less certain, however, that such catch levels can be sustained in the long term adding to the risk of exceeding F_{lim}. The stock has a less than 1% risk of falling below $B_{lim,}$ and none of the above-stated catch options are likely to increase that risk to above 5% over a 10 year period (Figure 5.7). Catch options up to 50 000 t have a low risk of exceeding $F_{lim,}$ and are likely to maintain the stock at its current high level.

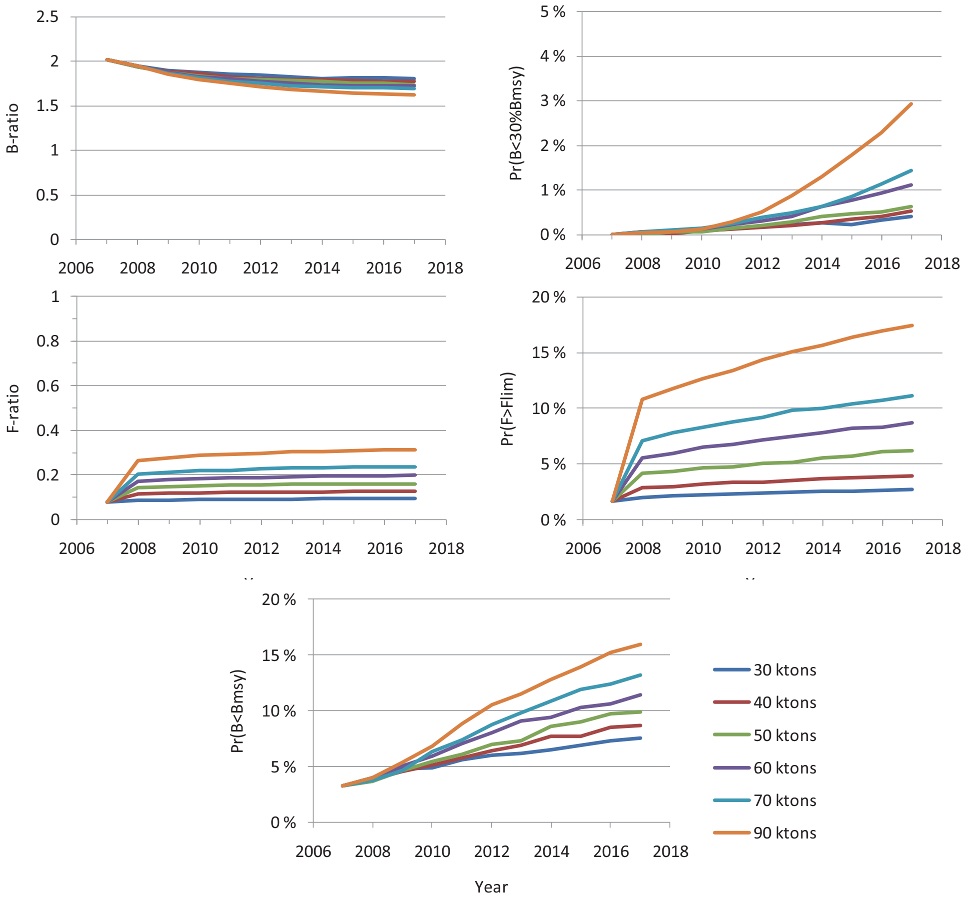


Figure 5.7. Projections: Medians of estimated biomass- and fishing mortality ratios (left); estimated risk (right and bottom) of exceeding F_{msy} and F_{lim} ($1.7F_{msy}$), or biomass falling below B_{lim} given catch options of 30 to 90 ktons. (Hvingel 2007).

5.2.4 Other considerations: predation

Both stock condition and rate of change in stock condition can be affected by changes in predation; this is particularly true with cod, which have been estimated to consume (on average) 5 times the amount caught. If cod predation on shrimp was to increase rapidly to levels outside the range during the period modeled (1970–2007), the shrimp stock might decrease more than the model has indicated. As the total predation depends on the relative abundance of both cod and its prey species, the likelihood of such a reduction would be difficult to quantify.

6 Zooplankton

6.1 Biomass, distribution, species composition, and age structure

Average zooplankton biomass in the Barents Sea during 2007 (7.17 g dry weight (dw) m^{-2}), estimated using Norwegian data for the entire water column at stations less than 500 m deep, decreased significantly from 2006 (8.63 g dry weight m^{-2}). This average is based on 145 stations evenly distributed throughout the region. If both Russian and Norwegian data are used, the 2007 estimate increases to 7.7 g m^{-2} dry weight; this estimate is somewhat higher than that based on Norwegian data, but markedly lower than the 2006 estimate which was also based on Norwegian data. Examination of the zooplankton composition indicated predominance of the three *Calanus* species (*Calanus finmarchicus, Calanus glacialis and Calanus hyperboreus*), *euphausiids* and *chaetognaths*, and in some cases *pteropods* that caused high biomass estimates (see details below).

Figure 6.1. shows the horizontal distribution of mesozooplankton from bottom-to sea surface, using combined data collected by Norway (using a WP2-net) and using (using a Juday net). Russian and Norwegian data complement each other. The distribution of zooplankton biomass, based on combined Norwegian and Russian biomass data, is very similar to that observed using only Norwegian surveys; Russian data add valuable information to describe central, northern, and eastern regions of the Barents Sea.

Examination of zooplankton composition indicated predominance of three *Calanus* species (*Calanus finmarchicus, Calanus glacialis and Calanus hyperboreus*), *euphausiids, chaetognaths*, and in some cases *pteropods,* that caused high biomass estimates (Figure 6.1).

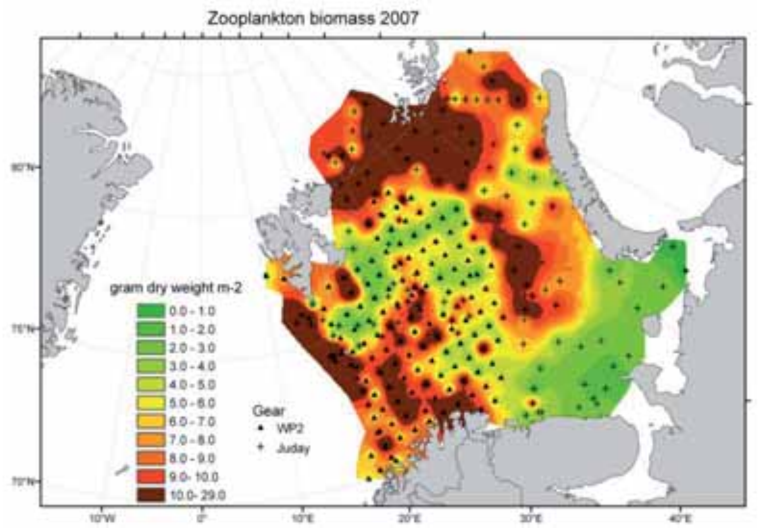


Figure 6.1. Distribution of zooplankton (g m^{-2} / dry weight) from bottom to sea surface in 2007. Data based on Norwegian WP2 and Russian Juday net samples.

If considering the Norwegian data only, plankton distribution in 2007 was distinctly different from 2006, but highest abundance was still observed in the western and southern regions of the Barents Sea. High levels of zooplankton biomass observed in southern and western regions during 2006, probably associated with influx of warmer Atlantic water penetrating north and east into the Bear Island Trough, were much less pronounced during 2007. During 2007, the region closest to the Norwegian coast had a zooplankton biomass comparable to that observed during 2006. The distribution pattern from the Norwegian survey reflects that the survey area east of 30ºE had low zooplankton biomass. If considering Russian data only (Figure 6.1.), high zooplankton biomass was observed north of Kong Karls Land (~¨78°45′N), from Nordaustlandet in Svalbard, and east of the Franz Josef Land Archipelago. A region of high biomass extended southwards and was particularly evident east and south-east of the Central Bank. *Calanus glacialis* were abundant in these areas of high zooplankton biomass; *C. hyperboreus* and *M. longa* were also important, but observed less consistently (Table 6.1). South of the central-eastern core of high zooplankton biomass, from Novaja Zemlja in the east, to the Varangerfjord in the west, to the Kola Peninsula in the south,very low zooplankton biomass was observed; this is typical for shallow shelf waters of this area.

The influence of physical water mass characteristics on zooplankton abundance is evident (Table 6.1). During 2007, higher levels of zooplankton biomass were observed in the North Atlantic offshore (8.6 g average dry-weight m^{-2}) and coastal (8.3 g average dry-weight m^{-2}.) than levels observed in coastal water masses (6.6 g dry-weight m^{-2}). This occurrence can also be observed in horizontal distribution patterns (Figure 6.1); the limited number of stations, however, suggests that results be interpreted with caution.

Table 6.1. Zooplankton average dry weight (g m^{-2}) in different water mass categories during 2007. Data based on WP2 net samples (Norwegian data only).

	No stations	Average dry weight (g m$^{-2)}$	Standard deviation
North Atlantic water	77	8.6	5.6
Coastal water	4	6.6	2.7
Coastal/North Atlantic water	10	8.3	5.6
Arctic water	7	5.4	5.1
Polar front water	45	5.0	4.3

It should be noted that Russian data has not been included in Table 6.1. Russian surveys routinely cover northern and eastern regions of the Barents Sea, and could supplement information on population dynamics and zooplankton biomass levels in Arctic waters and Polar front waters.

Long-term observations in the Barents Sea have established that zooplankton biomass directly depends on the season of year; periods of plankton reproduction and growth differ in various water masses during cold and warm years (Bogorov 1941; Degtereva, Nesterova, Panasenko 1990). Accordingly, in coastal waters, plankton reproduction takes place in April; in Arctic waters, reproduction takes place during July-August; and in high Arctic waters (78-80ºN) it takes place in September. Significant differences may occur during anomalous warm years (2002-2006), when the species composition and growth of Calanoid copepods is closely linked to latitudinal position and extent of ice in the Barents Sea. During September, crustaceans in southern regions typically reach larger size sizes; during September in northern regions, crustaceans typically reach a smaller maximum size (Orlova et al., 2007, 2008).

Being grazed by fish species also has an impact on plankton abundance and biomass (Hassel et al. 1991; Orlova, Boitsov, Ushakov, 2004).

The preliminary analysis presented in this report indicates significant differences in zooplankton biomass within the Barents Sea; separately occurring patches ranging between 10-29 g/m^2 were prevalent in western and coastal regions (c.f. Figure 6.1).

Levels of zooplankton biomass were relatively high (3-4 to 8-21 g/m^2) in the Frantz Josef Land (FJL) area to the North. Biomass levels were somewhat lower within the Persey Elevation (4-13 g/m^2) and Zhelaniya Cape (6-9 g/m^2) areas. In the FJL area, between 79°00’-81°40’N, *Pseudocalanus minutus, Calanus glacialis,* and *Metridia* longa were the most abundant species; whereas *Calanus finmarchicus* occurred only in the western region. Total abundance, however, seldom exceeded 100 thousand individuals per m^2 (Figure 6.2A). West of the Persey Elevation, abundance of copepods was low. North of 81°N, arctic species again predominated, but abundance of *C. finmarchicus* was higher. East of 35°E abundance of *C. finmarchicus* decreased, and *P. minutus* predominated (Figure 6.2B). Accordingly, in eastern regions, the abundance of *P. minutus* was as high and stable as that of *M. longa*; C. *finmarchicus* and *C. glacialis were less abundant* (Figure 6.2C).

Analysis of age structure of abundant species showed different phases of the life cycles. In areas where C. *finmarchicus* was prevalent (north of 78°N), its population primarily consisted of copepodites at Phase CIV, and occasionally at Phase CV). To the south, the portion of juveniles Phase CI-III increase (Figure 6.2A and B). In the eastern region, *C. finmarchicus* predominated in all but more southerly stations, where Phase CIV-V crustaceans predominated (Figure 6.2C). Among adult *C. finmarchicus*, mainly females occurred; poor reproduction of this species was observed in FJL.

Highest levels of species abundance were observed in western regions of FJL and the Persey Elevation. The population of *C. glacialis* was largely Phase CI-III juveniles, on and increased to the east (Figure 6.4A and B). In most areas, overwintering Phase CIV crustaceans (and occasionally Phase CV) were present. In northward areas of FJL, and southern areas of the Persey Elevation, mature individuals (primarily females) occurred frequently. Concurrently, in intensive reproduction of *C. glacialis* and *C. hyperboreus* was observed north of FJL; substantial reproduction of *C. glacialis* was also observed in the area east of FJL (59-61°E).

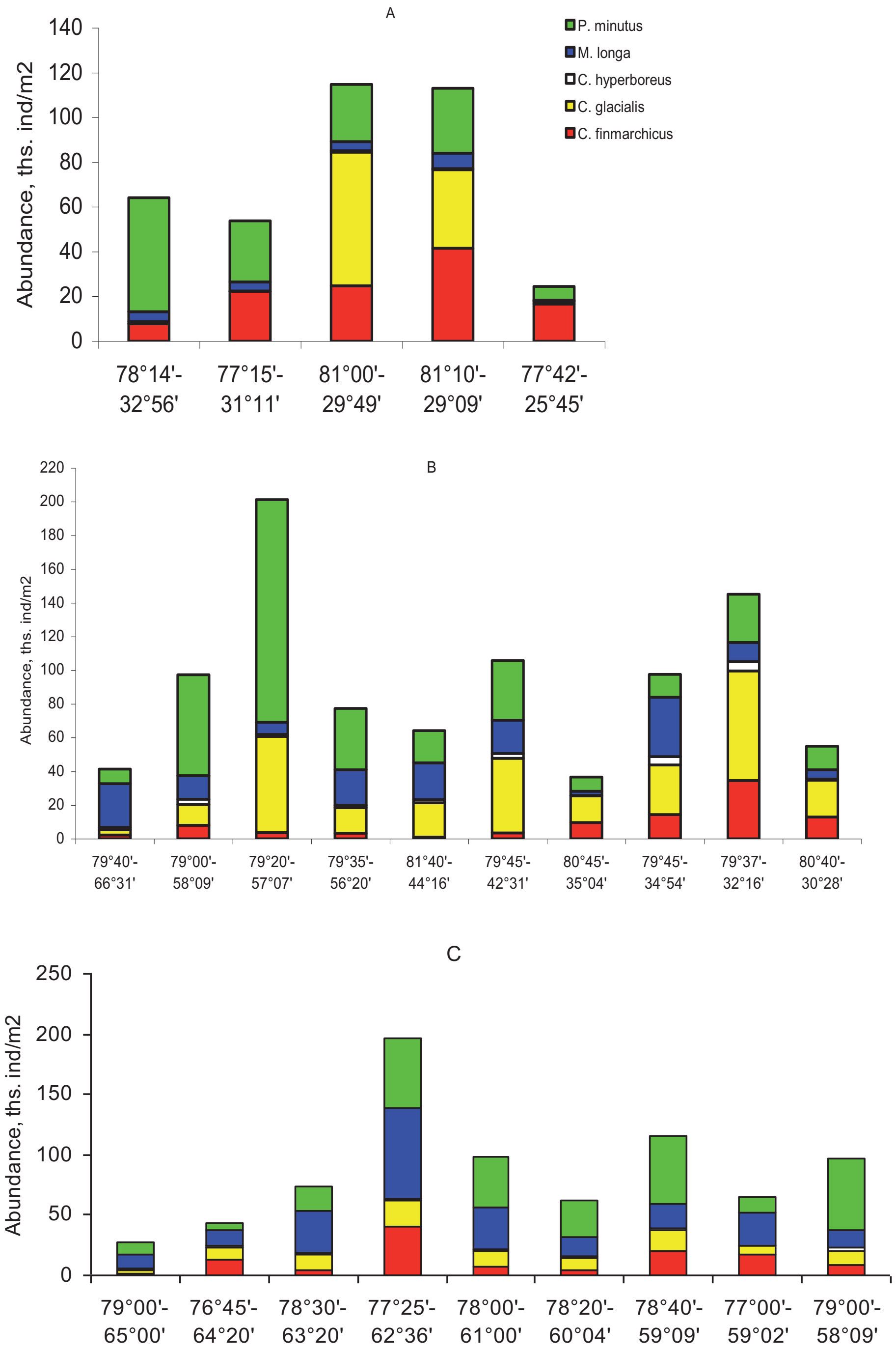


Figure. 6.2. Abundance of zooplankton in the Persey Elevation (A), the FJL area (B) and the Cape of Desire (north on Novaya Zemlya) area, (C) during August-September 2007. Abundance is given as 1000 ind./m^2.

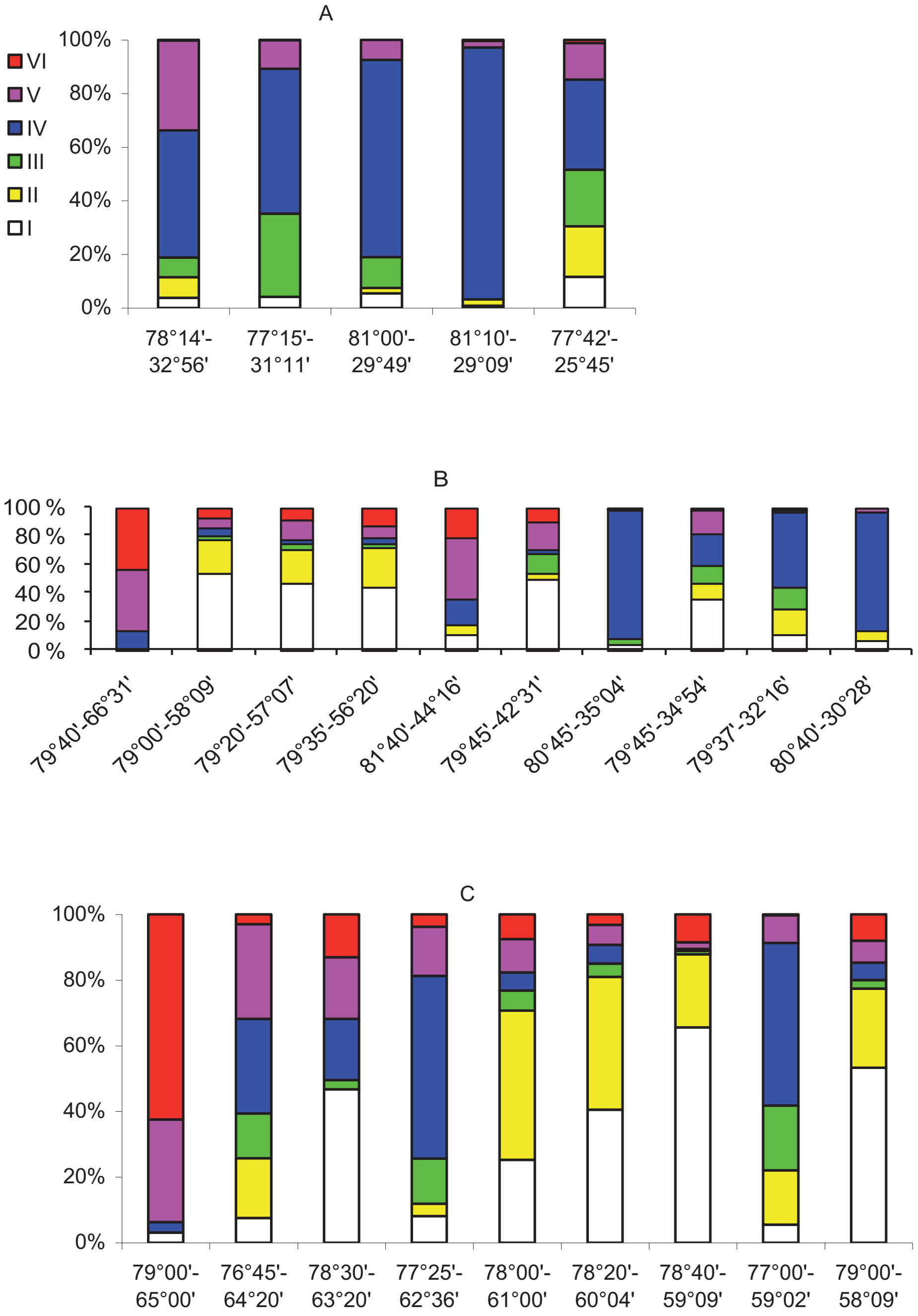


Figure. 6.3. Composition of *Calanus finmarchicus* at different stages of development in the Persey Elevation (A), the FJL area (B) and the Cape of Desire area (C) during August-September 2007.

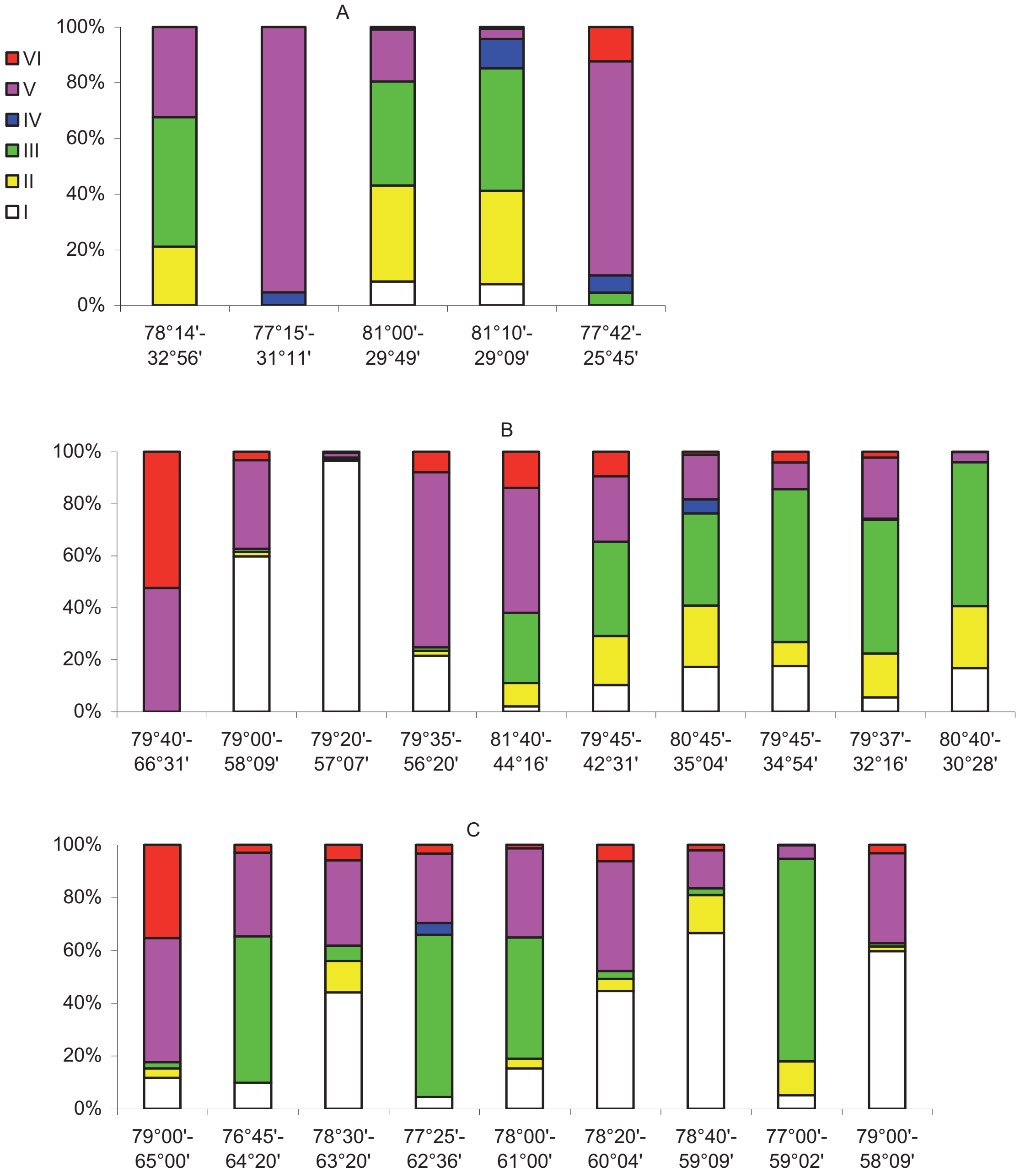


Figure 6.4. Composition of *Calanus glacialis* at different Phases of development in the Persey Elevation (A), the FJL area (B) and the Cape of Desire area (C) in August-September 2007.

In north and northeast regions, *C. glacialis* at Phases III-VI formed 50-60% of the total biomass. *C. hyperboreus*, *M. longa* and Pteropoda (*Clione limacina*) were well-represented. While, *C. finmarchicus* was less abundant; biomass of this species did not exceed 0.5-2.5 g/m^2. In the western region, variation in the level of biomass varied greatly between species (1.2-11 g/m^2). Biomass levels of Euphausiidae (0.2-0.6 g/m^2) and jellyfish (0.5-8.8 g/m^2) were also quite high.

During 2007, overall levels of zooplankton abundance and biomass in the Barents Sea were influenced by two factors: 1) less than normal combined discharge of water from the North Cape Current (including its northern branch) and the Bear Island Current; and 2) very dynamic ice conditions during summer. Water discharge influences transport of *C. finmarchicus* from the Norwegian Sea; discharge combined with ice condition influence patterns of distribution in the sea. Orlova et al. (2008) demonstrated that increased biomass of arctic species (*C. glacialis*, *P. minutus*) occurred in the northern Barents Sea during years (2004 and 2006) with quicker rates of ice retreat, while increased biomass of *C. finmarchicus* occurred in years with slower rates of ice retreat (2002 and 2005). Species composition, biomass, and distribution of zooplankton in the Barents Sea during 2007 are all consistent with Orlova's findings.

6.2 Calanus composition at Fugløya-Bear Island transect

The ecosystem survey transect that includes Fugløya - Bear Island (FB) in the western Barents Sea was covered five times during 2007 (January, March, June, August, and November). Stations within this transect are at fixed positions; the number of stations each year may vary from 5 to 8 depending on weather conditions and survey time schedule. Four stations within FB were selected from different water masses (coastal, Atlantic, and mixed Atlantic/Arctic). Samples from each station were analyzed for zooplankton species composition. Copepods formed the largest component of zooplankton biomass; specimens of the genus *Calanus* were the most abundant of all mesozooplankton species in the Barents Sea. This volume reports abundance of the three dominant *Calanus* species (*C. finmarchicus*, *C. hyperboreus*, and *C. glacialis)*. The occurrence of *C helgolandicus* during March and August is also reported. *Calanus helgolandicus* is similar in appearance to *C. finmarchicus*, but has a more southerly distribution in warmer waters, and has a different spawning period. During recent years, this species has frequently been observed in the North Sea, and southern parts of the Norwegian Sea within the Svinøy survey transect. With warming temperatures, *C. helgolandicus* is expected to advect into more northerly regions with Atlantic and coastal currents. A central objective of this project was to examine the effect of climate on zooplankton species composition, and determine the impact on higher trophic levels.

Of the three *Calanus* species examined, *C. finmarchicus* was the most abundant (90,000 ind/m^{-2}). Development of *C. finmarchicus* in the western Barents Sea began in April close to the coast, and progresses with time northwards along the survey transect (Figure 6.5). Recruitment of *C. finmarchicus* was particularly evident during June, August and November, at the two northernmost stations (73º30' and 74ºN); relatively, low abundances observed during the winter months. For the cold-water species (*C. glacialis*), low levels of abundance were observed in coastal and Atlantic waters (70º30' and 72 ºN); highest abundances of this species (10 000 ind. m^{-2}) was observed at shallow-water station (74 ºN) in Arctic waters. The population dynamics of *C. hyperboreus* were less consistent, with high abundances during June (72ºN) and November (74ºN); abundance levels for *C. hyperboreus* were generally much lower (650 ind. m^{-2}) than for *C. finmarchicus* and *C. glacialis*.

Samples taken from eight stations during March - August 2007 were examined to separate *C. helgolandicus* from *C. finmarchicus* taxonomically*;* C. *helgolandicus* was observed at only two stations made during March. The abundance ratio of *C. finmarchicus* to *C. glacialis* varied between stations taken: the ration was 9:1 at 72ºN; and 6:4 at 74ºN. This investigation will be ongoing in the coming years, and carried out in collaboration with the Norwegian and North Sea plankton investigations; historical samples will be analyzed to establish a baseline for future comparison. From 2008 onwards the species composition data will be exchanged with PINRO.

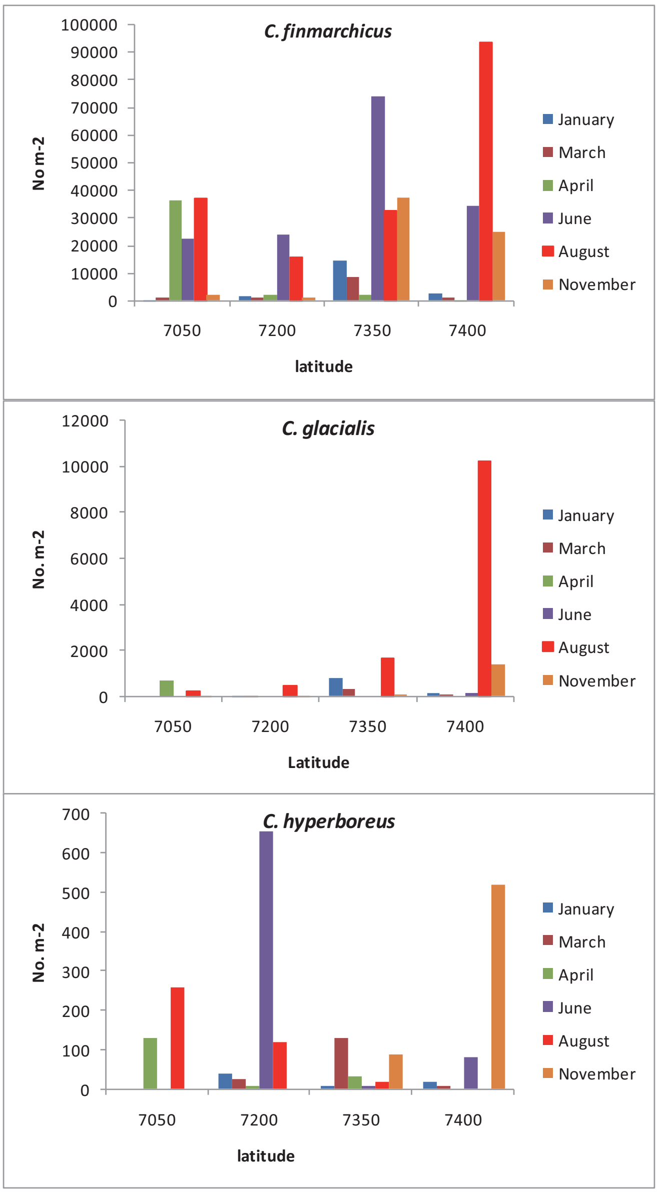


Figure 6.5. Within-year population dynamics of copepod abundance along the transect Fugløya-Bear Island in 2007.

7 Benthos

7.1 Benthic communities, biomass and distribution

Several bottom-dwelling species are anchored to or crawl about the sea floor, or live in between pre-existing communities of benthic animals; thus creating a multi-species habitat. The bottom dwellers are called “epibenthos”. Many epibenthic species are large, conspicuous, and robust organisms, including: sea stars; brittle stars; sea cucumbers; sea lilies; crangonid prawns; isopods; sponges; corals; mollusks; and sea anemones. Epibenthic organisms larger than 4 cm, are referred to as the “mega epibenthos”.

Several species within this group shave limited movement and a long life span; they can be found in the same area year after year.

Mega-epibenthic organisms are easily caught using bottom trawl gear, and often appear as by-catch.

Investigations of by-catch, however, indicate that the distribution of mega-benthos in the Barents Sea can be highly variable both spatially and temporally (figure 7.1). Biomass “hotspots” occurred each year in “shallow water areas” such as: the Tromsø Flaket (mainly sponges); Spitsberg Bank; Olga Strait; Goose Bank; and Novaya Zemlya Bank.

This observation corroborates previous studies from large-scale Russian expeditions conducted between the 1930´s and the 1990´s indicating that benthic biomass had spatial variation ranging from <10 to >500g wet weight (ww)/m^{-2}, and that highest biomass occurs in shallow waters of Spitsbergen, Central Banks, and banks within the Russian Zone. These high levels of biomass may be linked to high primary production on the western Banks, combined with strong water currents in these areas — that re-suspend food resources and hard substrates used for settlement, thus supporting a number of sessile filter-feeding species (Wassmann et al. 2006).

Survey results from the south eastern Barents Sea indicate an increase (both spatial and temporal) in the biomass of epibenthic organisms during 2006 and 2007. While results from the Hopen Deep indicate decreased epibenthic biomass (Figure 7.1.).

7.2 Establishment of monitoring areas

Analysis of Campelen trawl by-catch is time- and cost-effective, and is can be easily implemented during the annual joint ecosystem survey. Since 2005, benthic scientists from both countries have developed standardized methods used on both Russian and Norwegian research vessels. These methods need to be further developed, and must be validated quantitatively using the Campelen trawl to sample the benthos.

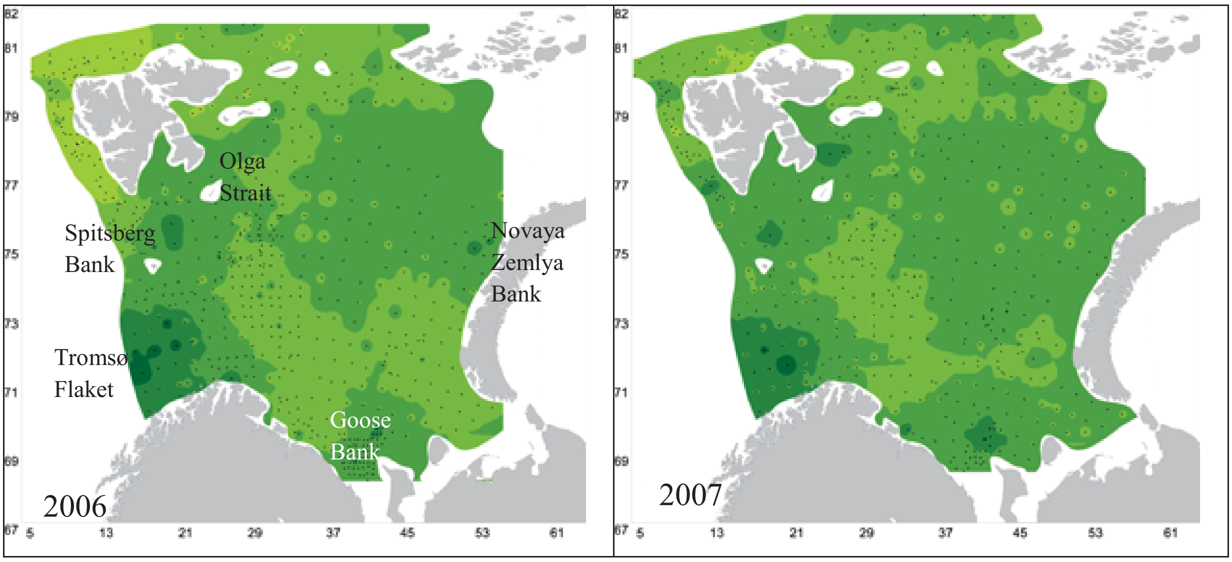


Figure 7.1. By-catch of bottom fauna during August-September 2006 and 2007. Dots in the background are by-catch stations. Dark green indicates maximum weight ; light green indicates minimum weight.

Long-term monitoring areas were established to design a method to follow fluctuations in biomass in the Barents Sea (Figure 7.2). These areas were selected using criteria such as: sampling time and costs; anthropogenic impacts; natural variation; and geographic variation.

Table 7.1. Areas chosen in the Barents Sea and adjacent water to monitor changes in biomass influenced by different factors.

	Factors Area	Fishery	Climate	Oil and gas exploitation	Introduced species
1	Western Slope	+	+		
2	North Cape Bank		+	+	
3	Murmansk Coast	+	+		+
4	Goose Bank	+	+		+
5	Shtokman Field		+	+	
6	Hopen Deep	+	+		

Data collected at all stations within each monitoring area (Figure 7.2) were summarized and a mean value calculated. The validity of the 2005-data is preliminary, as the method was still being developed on Norwegian vessels. Results (Figure 7.3) indicate a steady increase in benthic-biomass between 2005 and 2007 in all areas, except the Western Slope (Area 1) and Hopen Deep (Area 6).

On Western Slope (Area 1) decreased biomass was linked to reduced catch of sponges (Table 7.2.). In Hopen Deep (Area 6) a reduction in catch of sea stars(several species) was the likely cause. Increased biomass on North Cape Bank (Area 2) and Murmansk Coast (Area 3) could be related to an increasing population of red king crab *(Paralithodes camtschtica)*. On Goose Bank (Area 4) an increasing population of snow crabs (*Chionoecetes opilio*) is likely reason for increasing by-catch in this area. Increasing by-catch of several taxa (prawns, sea stars and sea cucumbers) are the probable cause for the similar increases on the Shtokman Field (Area 5).

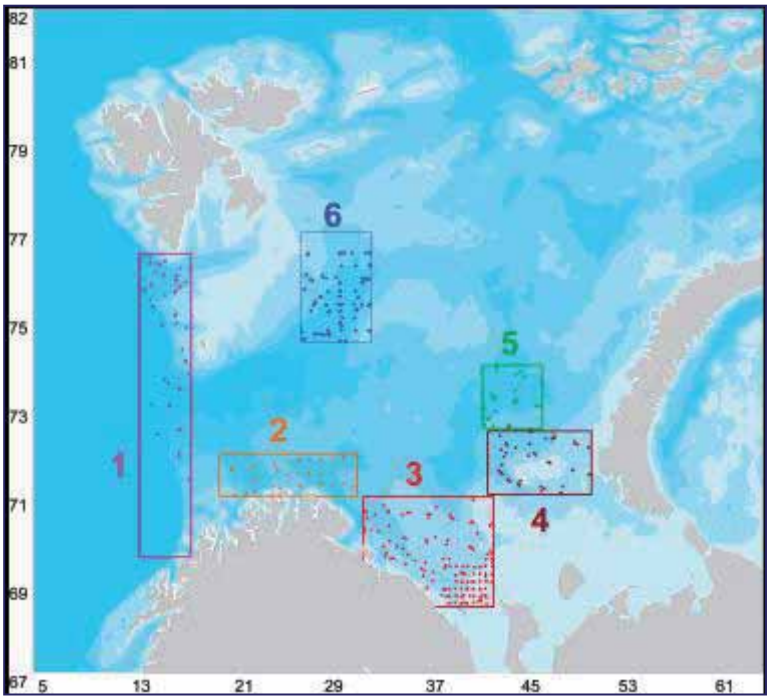


Figure 7.2. Established long-term, monitoring areas. Area 1: Western Slope. Area 2: North Cape Bank. Area 3: Kola Coast. Area 4: Goose Bank. Area 5: Shtokman Field. Area 6: Hopen Deep.

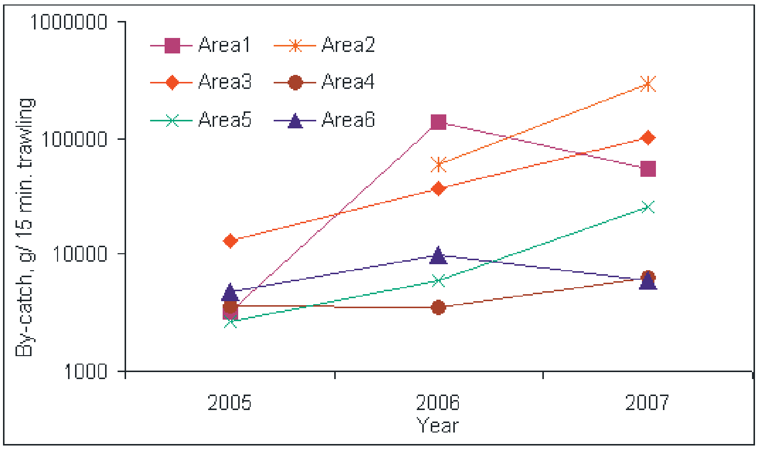


Figure 7.3. By-catch during 2005-2007: mean value of all stations combined within each monitoring area (gram wet weight, 15-minute tows)). Area 1: Western Slope, Area 2: North Cape Bank, Area 3: Murmansk Coast, Area 4: Goose Bank, Area 5: Shtokman Field, Area 6: Hopen Deep.

Table 7.2. The top five epibenthic taxa taken as by-catch (weight per 15-min. tow) by year and area monitored.

		2005	**2006**	**2007**
Area 1	Anthozoa g. sp.	0	586	28
Western Slope	Asteriidae g. sp.	283	826	155
	Echinoidea g. sp.	0	277	5
	Holothuroidea g. sp.	0	561	414
	Porifera g. sp.	425	134593	53866
Area 2	Anomura g. sp.	0	40	1997
North Cape Bank	Anthozoa g. sp.	0	1045	26
	Asteriidae g. sp.	0	573	1211
	Paralithodes camtschaticus	0	195	2786
	Porifera g. sp.	0	58094	283036
Area 3	Cucumaria frondosa	6	0	286
Murmansk Coast	Geodia barrette	0	382	0
	Hormathia digitata	0	63	159
	Paralithodes camtschaticus	12692	35878	100869
	Porifera g. sp.	0	442	14
Area 4	Chionoecetes opilio	85	364	493
Goose Bank	Ctenodiscus crispatus	19	249	714
	Cucumaria frondosa	348	0	1401
	Natantia g. sp.	0	1287	0
	Strongylocentrotus sp.	2417	97	0
Area 5	Ctenodiscus crispatus	210	468	3665
Shtokman Field	Gorgonocephalus arcticus	0	0	1818
	Molpadia borealis	0	0	8388
	Sabinea septemcarinata	698	590	2212
	Varia indet.	5	2	1656
Area 6	Asteriidae g. sp.	0	2180	1316
Hopen Deep	Ctenodiscus crispatus	1230	2044	405
	Icasterias panopla	790	384	93
	Molpadia borealis	10	440	20
	Polychaeta g. sp.	16	463	2124

8 Pollution levels

8.1 Radioactive pollution

Levels of radioactive pollution in the Barents Sea are relatively low. Concentrations of caesium-137 (Cs-137) in fish, seawater, and sediments are generally less than 0.3 becquerel per kilogram (Bq/kg) fresh weight (fw), 3.5 Bq/m^3 and 10 Bq/kg dry weight (dw), respectively. Concentrations of technetium-99 (Tc-99) in seawater are generally less than 1.0 mBq/m^3.

Radioactive pollution has been transported into the Barents Sea over several decades. The most important sources are fallout from nuclear weapons testing, the Chernobyl accident, and discharge from the European nuclear industry. Radioactive wastes dumped in the Barents and Kara Seas represent a potential source contamination for the marine environment. Caesium-137 and Tc-99 are two of the most important radionuclides originating from the above mentioned sources. Therefore, IMR's routine monitoring program focuses on levels of these two.

8.1.1 Caesium-137 in sediments and seawater

Analyses of sediment- and seawater-samples taken in the Barents Sea during 2007 are ongoing. We, therefore, present results of an investigation carried out in the same area during 2005 (Figures 8.1, 8.2, 8.4, 8.6, 8.7, 8.8 and 8.9). Figure 8.1 and 8.2 present concentrations of Ceasium-137 (Cs-137) in sediments and seawater, respectively. Preliminary results from analyses of 31 sediment samples collected in 2007 show concentrations ranging between 0.4 and 12.6 Bq/kg dry weight (dw). Concentrations between 1.7 and 2.6 Bq/m^3 were found in 6 seawater samples from 2007. It is evident that levels of Cs-137 in seawater and sediments of the Barents Sea are stable.

Levels of Cs-137 in seawater of the Barents Sea are lower than in the North Sea (Figures 8.1 and 8.2). This is due to the North Sea's proximity to the main source of Cs-137, namely the Baltic Sea, which still receives considerably amounts of Chernobyl-related Cs-137 as run-off from land.

8.1.2 Caesium-137 in fish

The following species of fish were collected during 2007 and analyzed to find levels of Cs-137: shrimp (*Pandalus borealis*); haddock (*Melanogrammus aeglefinus*); cod (*Gadhus morhua*); capelin (*Malotus villosus*); arctic cod (*Boreogadus saida*); saithe (*Pollachius virens*); herring (*Clupea harengus*); greenland halibut (*Reinhardtius hippoglossoides*); long rough dab (*Hippoglossoides platessoides*); and deep-sea redfish (*Sebastes mentella*). Highest concentrations of Cs-137 (0.2 Bq/kg fw) were found in cod, saithe and greenland halibut. Other species sampled contained substantially lower concentrations, or concentrations below the level of detection. The number of samples taken for each species varies between 1 and 12. Each sample consisted of 25 to 100 individuals.

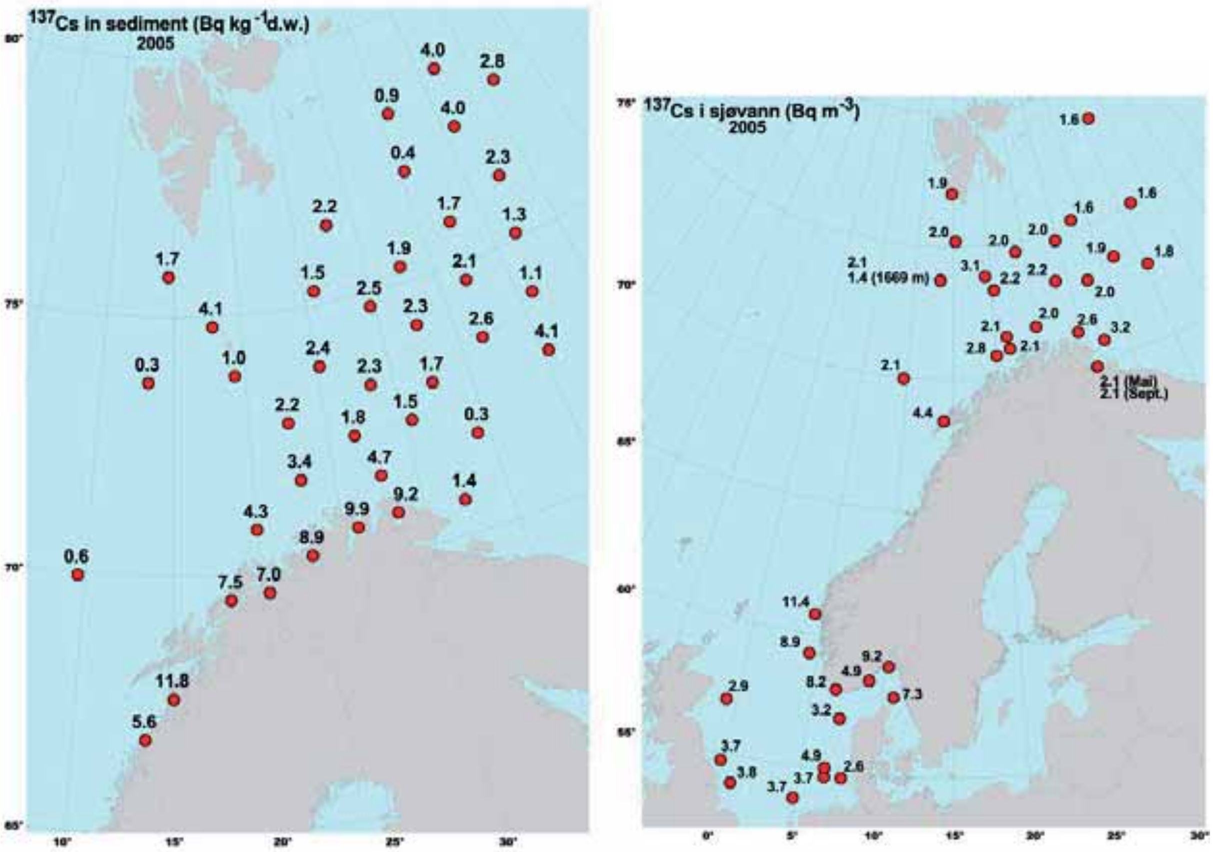


Figure 8.1. and 8.2. Cs-137 in sediments and seawater during 2005 (From Stråleverns Rapport 2007:10 - Figure 2).

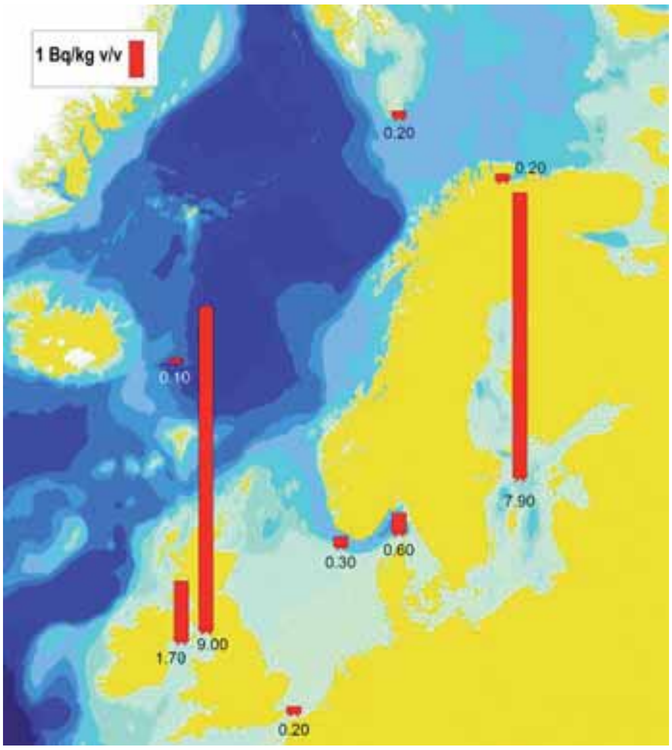


Figure 8.3. Cs-137 in cod in Northern Europe. Provided by Anne Lene Brungot, Norwegian Radiation Protection Authority (NRPA).

Concentrations of Cs-137 in fish are related to concentration in ambient seawater. Variations observed in cod sampled from different areas in Northern Europe (Figure 8.3) indicate that levels of Cs-137 in the Barents Sea are relatively low (see also Klungsøyr and Sværen, 2006).

8.1.3 Technetium-99 in sediments and seawater

Figure 8.4 shows the levels of Tc-99 in the Barents Sea in 2005. Seawater samples collected in 2007 are still being analyzed.

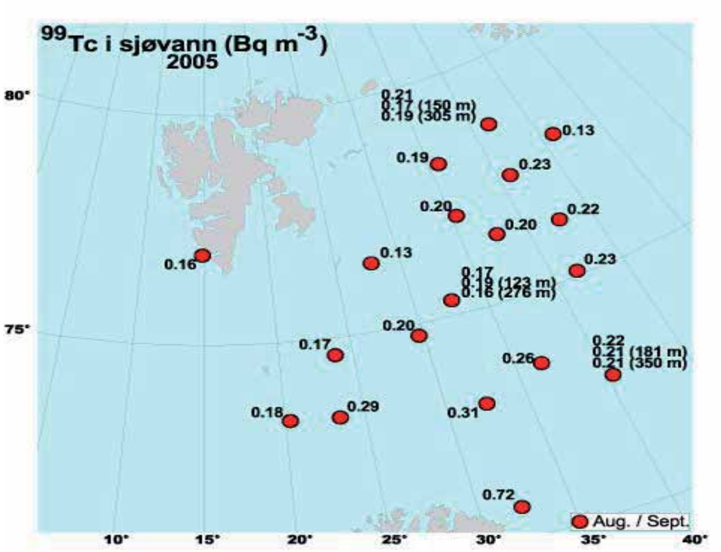


Figure 8.4. Tc-99 in seawater in 2005 (From Strålevernsrapport 2007:10).

In well oxygenated seawater, as in open ocean areas, Tc-99 is found to be very little particle reactive. Therefore, we have decided not to measure Tc-99 in sediments.

8.2 Sunken submarine Komsomolets

On April 7 1989, the Soviet nuclear submarine Komsomolets caught fire and sank 180 km southwest of Bear Island. The wreck rests at present at a depth of ca. 1680 m. The sunken submarine contains one nuclear reactor and two nuclear torpedoes with mixed uranium/plutonium warheads. Minor releases from the reactor compartment have been detected in the wrecks' close vicinity by Russian expeditions. Once a year since 1993, samples of seawater and sediments have been collected in the vicinity of the wreck and analysed for Cs-137, as part of IMR's routine monitoring program (Figure 8.5).

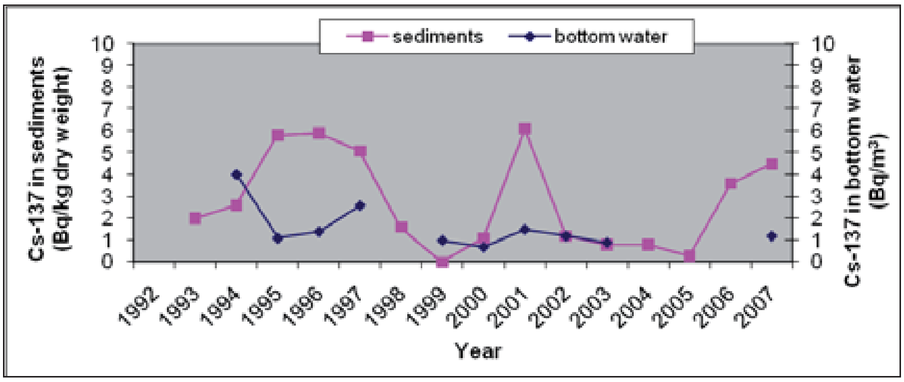


Figure 8.5. Levels of Cs-137 in sediments and bottom water near the wreck of Komsomolets.

8.3 The Norwegian National Monitoring Program

IMR is a participant in the Norwegian National Monitoring Program (RAME), coordinated by the Norwegian Radiation Protection Authority (NRPA). Within this program, the radionuclides plutonium-239+249 (Pu-239,240), americium-241 (Am-241), strontium-90 (Sr-90) and radium-226+228 (Ra-226,228) are also included. Figures 8.6-8.8 show the levels of Pu-239,240, Am-241 and Ra-226 in seawater in 2005. The samples are collected from IMR's research vessels F/F G. O. Sars and F/F Johan Hjort.

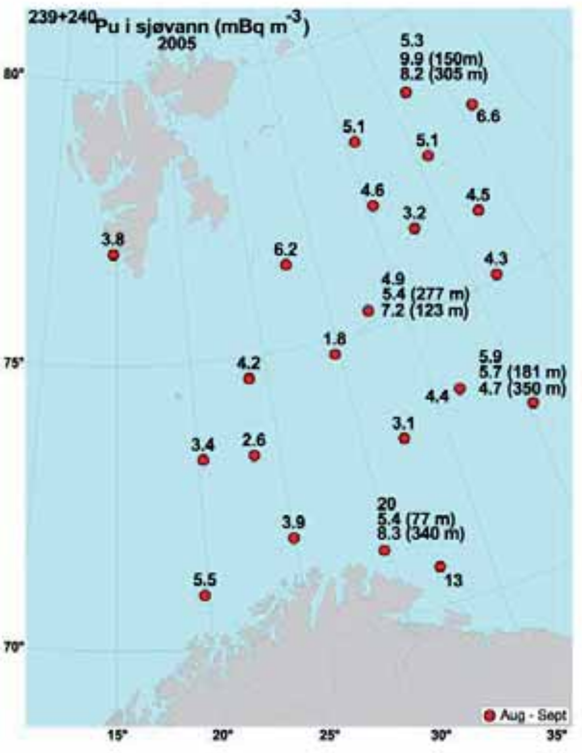
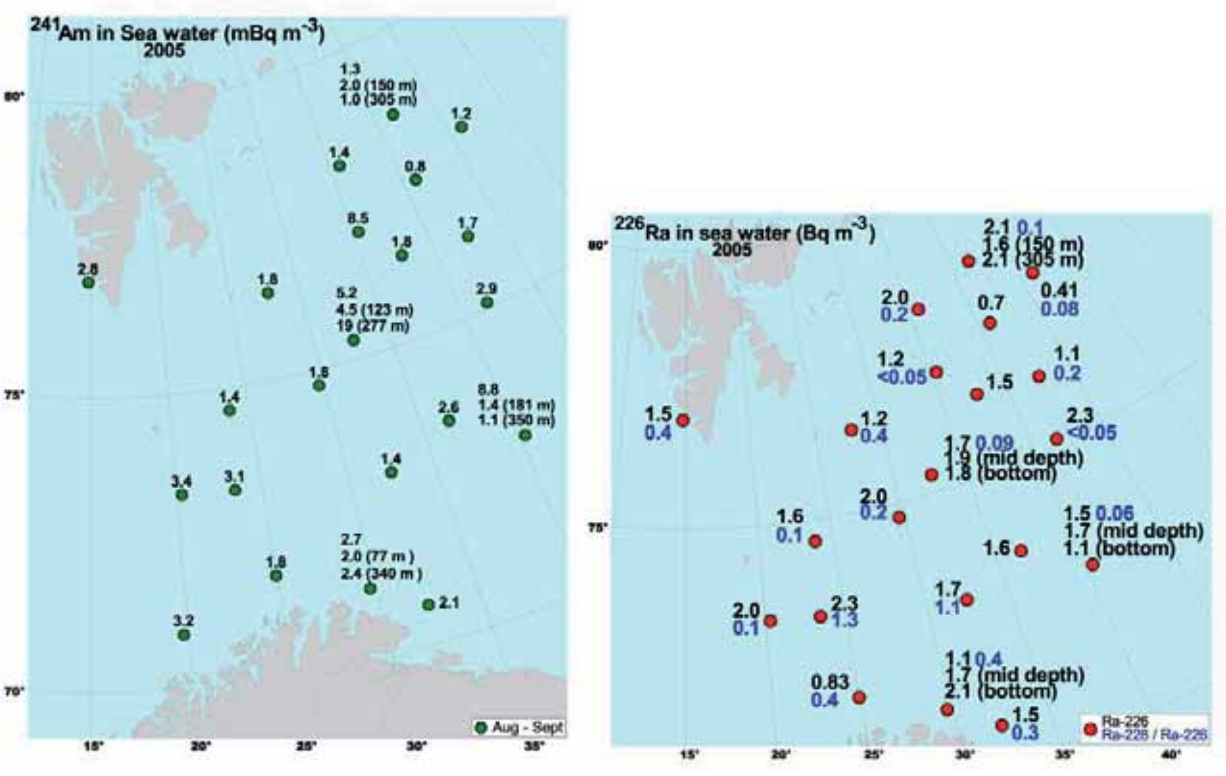


Figure 8.6. 239,240-Pu in seawater in the Barents Sea in 2005 (From Stråleverns-Rapport 2007:10).



Figures 8.7 and 8.8. Levels of Am-241and Ra-228 in seawater in the Barents Sea in 2005 (From StrålevernsRapport 2007:10).

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