IMR/PINRO
JOINT REPORT SERIES
1
2006

SURVEY REPORT FROM THE JOINT NORWEGIAN/RUSSIAN ECOSYSTEM SURVEY IN THE BARENTS SEA IN AUGUST-OCTOBER 2005

Volume 2

Institute of Marine Research - IMR

Polar Research Institute of Marine Fisheries and Oceanography - PINRO

This report should be cited as:

Anon. 2006. Survey report from the joint Norwegian/Russian ecosystem
Survey in the Barents Sea in August-October 2005 (vol.2).
IMR/PINRO Joint Report Series, No. 1/2006. ISSN 1502-8828. 35 pp.

Joint IMR-PINRO report

SURVEY REPORT
FROM THE JOINT NORWEGIAN/RUSSIAN ECOSYSTEM SURVEY IN THE BARENTS SEA IN AUGUST-OCTOBER 2005

Volume 2

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ISSN 1502-8828

Murmansk
PINRO Press
2006

Preface

The third joint ecosystem survey was carried out during the period 1st of August to 5th of October 2005. This survey encompasses various surveys that previously have been carried out jointly or at national basis. Joint investigations include the 0-group survey, the acoustic survey for pelagic fish (previously known as the capelin survey), and the investigations on young Greenland Halibut north and east of Spitsbergen. Oceanographic investigations have always formed a part of these surveys, and studies on plankton have been included for many years. In recent years, observations of sea mammals, seabirds, bottom fishes, pollution and benthos have been included. Consequently, from 2003, these surveys were called "ecosystem surveys".

The present report is the second and final report on the initial results from the survey. It contains results that were not ready by the time of writing of volume 1 of the survey report in October 2005. Specifically this includes:

- Oceanographic analyses of water chemistry (oxygen and phosphorous levels).
- Age-based swept area assessment for demersal fishes.
- Diet composition of cod.
- Swept-area assessment of the demersal component of capelin.
- Diet composition of capelin.
- Zooplankton distribution and comparison of WP2 and Juday nets.
- Pollution levels.
- Ecological interactions

Besides the participants on the vessels, the following specialists took part in in preparing the survey report: PINRO: A.Dolgov, E. Orlova, G. Rudneva, V. Nesterova, A.Rakov. IMR: E. Eriksen, P.Dalpadado, E. Johannessen.

1. Oceanography

1.1. O_2 levels

In the coastal branch of the North Cape current percentage of saturation by oxygen was at the long-term mean level: 102-104 % in surface layer and about 92 % in bottom layer. In the North Cape current waters saturation was at the long-term mean level. Saturation of surface layers by oxygen in the Bear Island current was 2 % lower than mean long-term values (Fig. 1.1).

Saturation of surface layers by dissolved oxygen was lower than mean long-term values. In coastal waters aeration constituted 99-101 %. Depth of 100 % isooxygen in coastal waters was 10-15 m. Just north of coastal area the depth was greater (20-30 m), that made up 10-20 m less than mean depth (Fig. 1.2).

Content of dissolved oxygen in coastal branch of the North Cape current varied insignificantly. In the North Cape current absolute values of dissolved oxygen were 0,1-0,2 ml/l lower than mean long-term values. Cold waters of the Bear Island current contained 7,6 – 7,7 ml/l of dissolved oxygen, that was equal to the long-term mean level (Fig.1.3).

In the Murman coastal current oxygen content was on the average 6,3 ml/l (0,5 ml/l lower than mean long-term values) and in bottom layer 6,8 ml/l (0,1 ml/l lower than mean long-term values). The similar content was registered in the central branch of the North Cape current. Consequently, saturation of the Kola section waters by oxygen was lower as compared to long-term mean data. Dissolved oxygen deficiency reduced with depth (Fig. 1.4).

In the coastal branch of the North Cape current mineral phosphorus concentrations were 0,1-0,2 μM/l less than mean long-term values. In the North Cape current waters the same oxygen content and variation of phosphate concentrations with depth was registered. In waters of the Bear Island current phosphate concentrations varied within the range of 0,1 – 0,2-0,6 μM/l from surface to bottom (Fig. 1.5).

Mineral phosphorus content in waters of the Murman coastal current was in deficiency from surface to bottom as compared to mean long-term values. Maximum phosphorus deficiency was registered near the bottom and made up about 0,1-0,2 μM/l (Fig. 1.6).

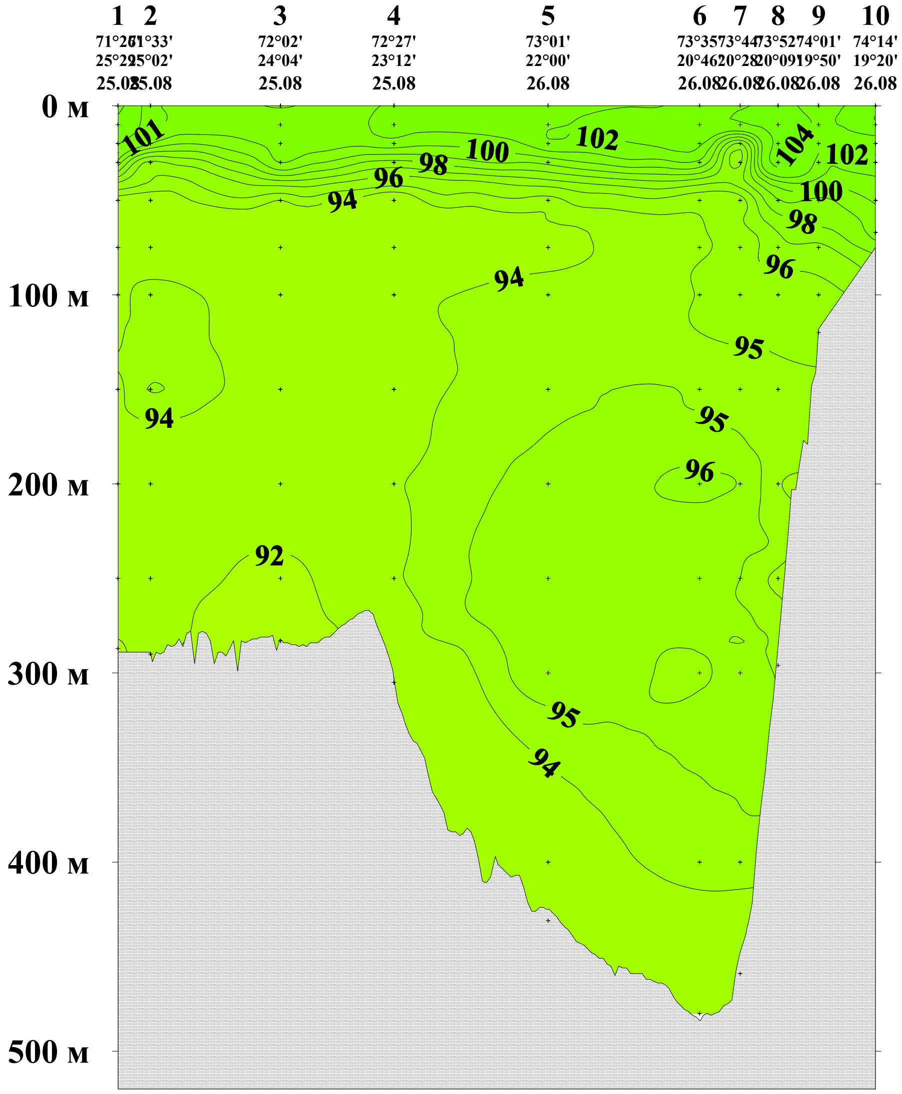


Figure 1.1. Distribution of dissolved oxygen (%l) on the section Nord Cap – Bear Island on August 2005

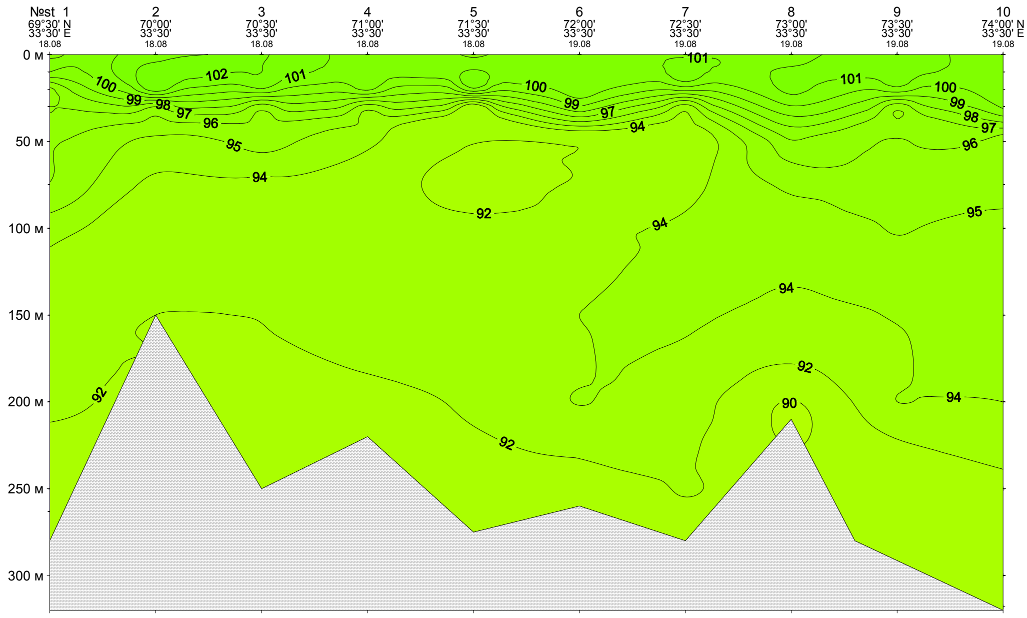


Figure 1.2. Distribution of dissolved oxygen (%) on the Kola section on August 2005

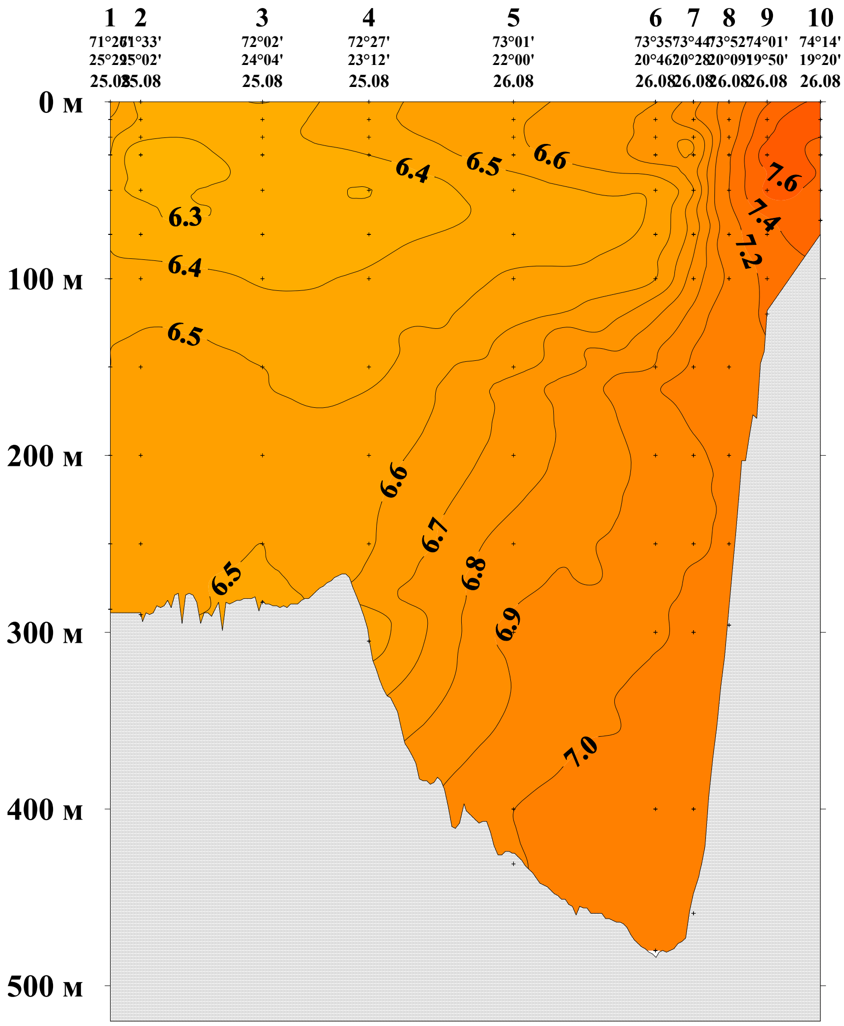


Figure 1.3. Distribution of oxygen (ml/l) on section Nord Cap – Bear Island on August 2005

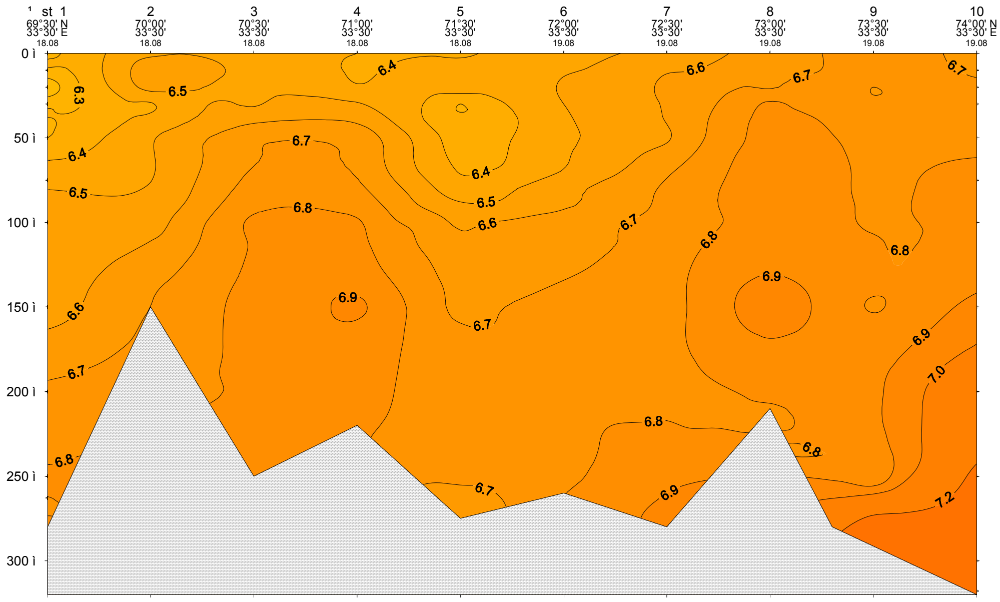


Figure 1.4. Distribution of oxygen (ml/l) on the Kola section on August 2005

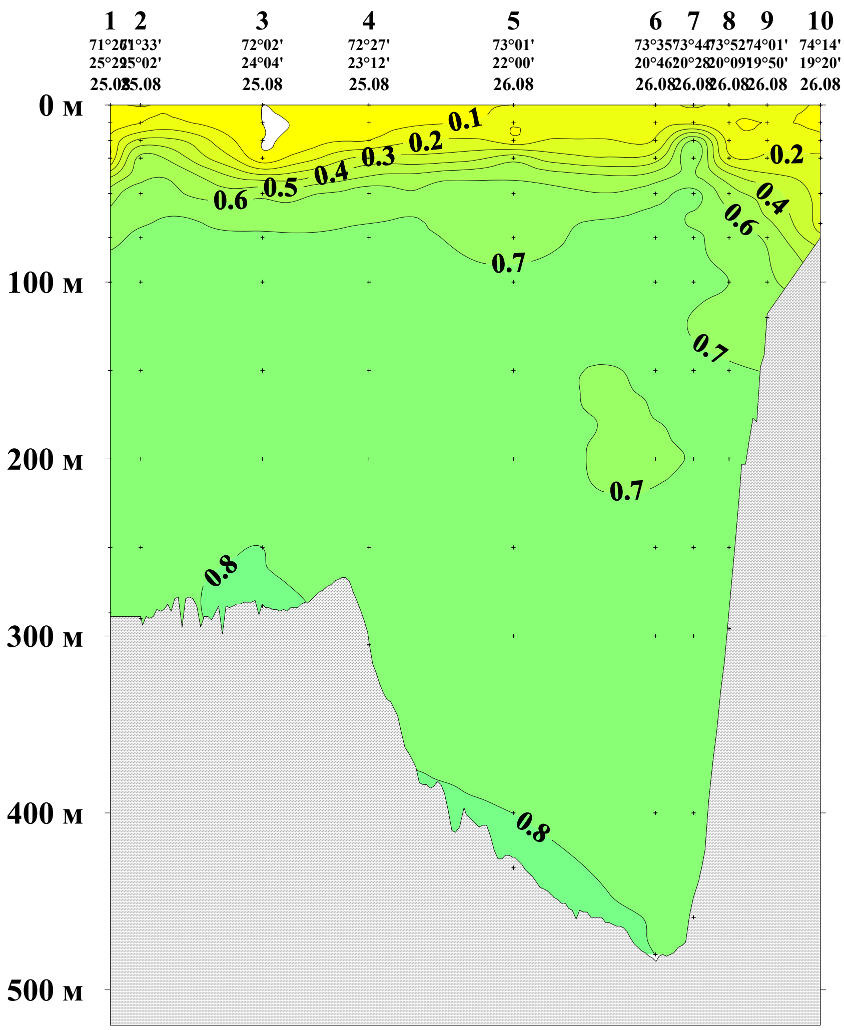


Figure 1.5. Distribution of phosphate (mkMol/l) on section Nord Cap – Bear Island on August 2005

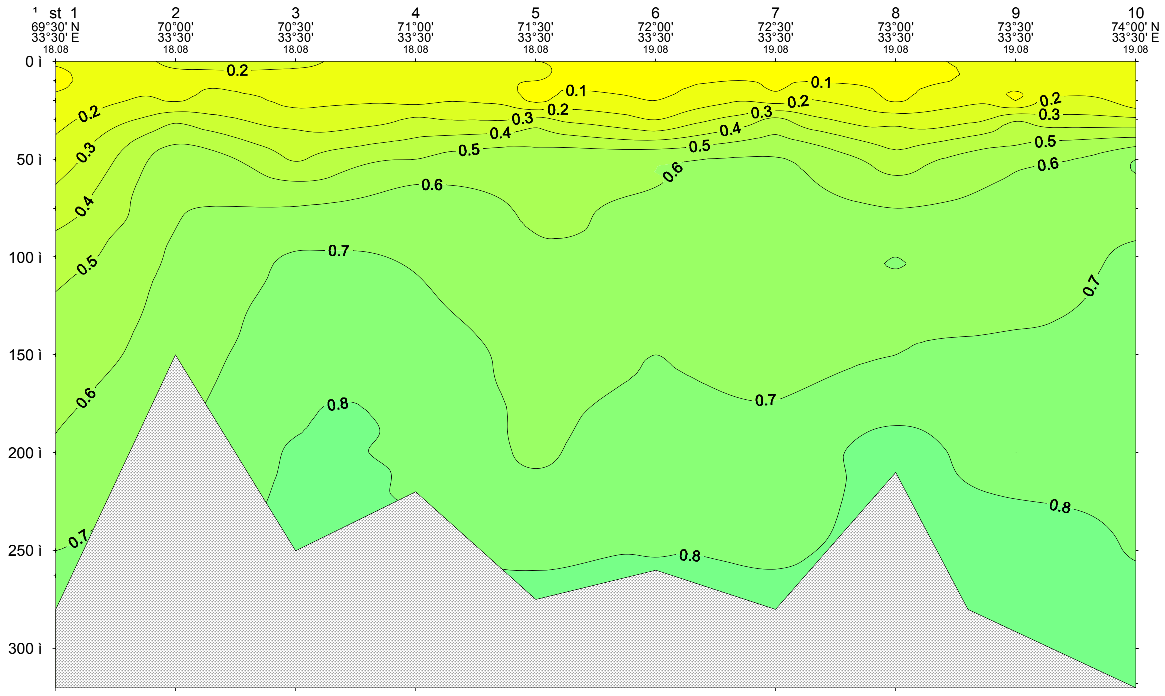


Figure 1.6. Distribution of phosphate (mkMol/l) on the Kola section on August 2005

2. Demersal fish

In the current volume of the survey report an aged-based swept-area analysis of the demersal fish species was carried out. The methods used are described in section 1.4, Volume 1 of the survey report.

2.1. Assessment by age groups

The age-groups based assessments are presented in Table 2.1, Table 2.2, Table 2.3, Table 2.4 and Table 2.5. The indices presented in this volume are somewhat lower than those presented in volume 1 of the survey report because 0-group fish were included in the length based assessment presented in volume 1, while 0-group fish were not included in the age-based assessment.

Table 2.1. Northeast Arctic cod. Bottom trawl indices (millions of individuals) pr region and age group during the ecosystem survey in autumn 2005 (0-group excluded from calculations)

NA-Cod	Age												Total*
Year	1	2	3	4	5	6	7	8	9	10	11	12+	
I (NEEZ+SVA)													
2004	151.9	69.7	30.9	34.4	14.4	19.3	12.2	4.7	1.1	0.4	0.1	0.1	339
2005	147.4	30.1	38.2	6.7	17.3	6.1	4.5	2.2	0.2	0.3	0.1	-	253
I (REEZ)													
2004	87.1	204.2	38.5	273.6	115.7	41.0	18.4	3.8	0.2	0.2	0.0	0.1	783
2005	115.2	45.2	121.4	20.6	42.4	18.0	6.7	3.4	0.7	0.3	-	0.1	374
IIa													
2004	10.6	5.7	1.7	6.5	2.0	2.4	0.5	0.3	0.1	-	-	-	30
2005	13.2	3.2	6.0	2.1	2.6	1.5	1.0	0.1	0.0	-	0.1	-	30
IIb													
2004	142.8	62.1	38.3	104.6	19.3	15.0	8.3	1.5	0.3	0.0		0.1	392
2005	150.0	81.8	97.3	27.7	52.3	7.4	4.7	0.8	0.3	0.1			422
Total													
2004	392.5	341.8	109.4	419.0	151.4	77.7	39.4	10.3	1.8	0.7	0.1	0.3	1 540
2005	425.8	160.3	262.9	57.1	114.6	32.9	16.8	6.4	1.1	0.7	0.1	0.1	1 080

* Rounded to three significant digits.

Table 2.2. Northeast Arctic haddock. Bottom trawl indices (millions of individuals) pr region and age group during the ecosystem survey in autumn 2005 (0-group excluded from calculations)

Haddock	Age												Total*
Year	1	2	3	4	5	6	7	8	9	10	11	12+	
I (NEEZ+SVA)													
2004	23.9	36.0	12.8	3.7	3.4	3.8	0.2	0.4	-	-	-	-	84
2005	87.9	12.6	16.2	4.4	1.8	1.4	1.5	0.1	0.1	-	-	-	126
I (REEZ)													
2004	35.5	150.9	142.2	71.2	73.5	20.1	1.6	0.3	-	0.1	-	0.3	496
2005	222.5	36.3	221.0	180.7	24.3	19.2	8.5	0.2	-	0.2	0.0	-	713
IIa													
2004	71.0	73.8	10.3	4.6	3.4	5.0	0.3	0.8	-	-	-	0.0	169
2005	208.1	28.1	21.5	5.9	1.4	2.0	1.8	0.1	0.4	0.1	-	0.1	269
IIb													
2004	24.3	5.9	2.2	1.5	3.6	3.0	0.1	1.1	-	-	-	-	42
2005	151.8	5.4	10.9	0.7	2.5	3.7	2.0	-	0.0	0.0	0.1	-	177
Total													
2004	154.7	266.5	167.6	80.9	83.9	31.9	2.2	2.6		0.1		0.3	791
2005	670.2	82.4	269.6	191.7	30.0	26.3	13.7	0.4	0.5	0.2	0.1	0.1	1 290

* Rounded to three significant digits.

Table 2.3. Greenland halibut. Bottom trawl indices (thousands of individuals) pr region and age group during the ecosystem survey in autumn 2005 (0-group excluded from calculations)

Greenland Halibut Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	Total
							I (NEEZ+SVA)						
2004	2912	8501	11392	2 165	1 344	765	1 490	-	262	24	20	56	28 900
2005	32274	7093	7573	5 643	3 131	2 596	1 708	631	296	287	-	286	61 500
							I (REEZ)						
2004	8 342	25230	37546	3 434	212	1 005	129	32	78	90	75	100	76 300
2005	103873	20020	21808	12 506	2 082	405	187	79	23	3	-	-	161000
							IIa						
2004	-	-	-	120	278	451	1 661	589	373	57	182	153	3 860
2005	-	-	-	452	946	402	1 787	417	358	102	306	347	5 120
							IIb						
2004	5 259	3 828	6 784	3 503	3 171	2 917	1 979	747	490	333	211	404	29 600
2005	46 603	13 213	8 722	12 990	8 981	4 854	2 804	1 727	326	354	160	215	101 000
							Total						
2004	16 513	37 559	55 722	9 221	5 005	5 138	5 259	1 368	1 203	505	488	714	139 000
2005	182750	40 326	38 103	31 590	15 139	8 257	6 485	2 854	1 004	747	467	849	329 000

* Rounded to three significant digits.

2.2. Composition of cod diet

Cod stomachs were sampled both by Norwegian and Russian vessels. The Norwegian data were analysed in the laboratory at IMR, while the Russian data were analysed onboard the vessel. The methods used for stomach sampling, analysis and data recording are given by Mehl (1989) and Mehl and Yaragina (1992). For each trawl station 1 stomach per 5 cm length group was collected by the Norwegian and Russian vessels.

Stomachs were sampled from 378 stations, of which 377 were taken by bottom trawl and 1 by pelagic trawl.

For each station, the mean Partial Fullness Index (PFI) was calculated to permit comparison of quantities of various prey groups in the stomachs of predators of various sizes (Lilly and Fleming 1981). This was done for cod age groups 1-2, 3-6 and 7+, respectively, and for each of the prey groups. The PFI by predator age group and prey species group was then averaged over all stations within each 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*.

Table 2.4. Deep-water redfish (*Sebastes mentella*). Bottom trawl indices (thousands of individuals) pr region and age group during the ecosystem survey in autumn 2005

S. mentella	Age																Total*
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	
									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	21 600
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	21 900
									I (REEZ)*								
2004		1 491	4 884	1 696	1 485	333	56	30	34	16			0	3	15	106	10 100
2005	1 392	1 999	517	189	61	23	23	30	33	5	1	0	1	10	19	34	4 340
									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	196 000
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	162 000
									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	90 800
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	134 000
									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	319 000
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	321 000

* Rounded to three significant digits
** No age information available. Age-length key from the three other areas combined was used.

Table 2.5. Golden redfish (*Sebastes marinus*). Bottom trawl indices (thousands of individuals) pr region and age group during the ecosystem survey in autumn 2005

S. marinus	Age																Total*
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	
									I (NEEZ+SVA)								
2004					303	215	215	335	77	71	71	464	185	389	214	365	2 910
2005		112				105	297	170	138	377			150		130	910	2 390
									I (REEZ)*								
2004			187		50	104	135	495	286	129	67	95	42	15	8	9	1 620
2005		71	55	72	108	144	47	293	297	327	118	253	240	244	247	661	3 180
									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	13 900
									IIb								
2004					4	7		354	63	473	126	311	368	337	120	300	2 460
2005			41				27	33	168	115	191	200	60	96	116	308	1 350
									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	20 800

* Rounded to three significant digits
** No age information available. Age-length key from the three other areas combined was used.

Figures 2.1 to 2.3 show the geographical distribution of diet (PFI) composition, for cod age groups 1-2 (N=620), 3-6 (N=1400) and 7+ (N=387), respectively.

For cod age 1 and 2, krill and amphipods were the most important prey groups. Shrimp and polar cod were also important in some areas. The most important fish prey (not shown as a separate group on Figure 2.1) was *Stichaeidae*.

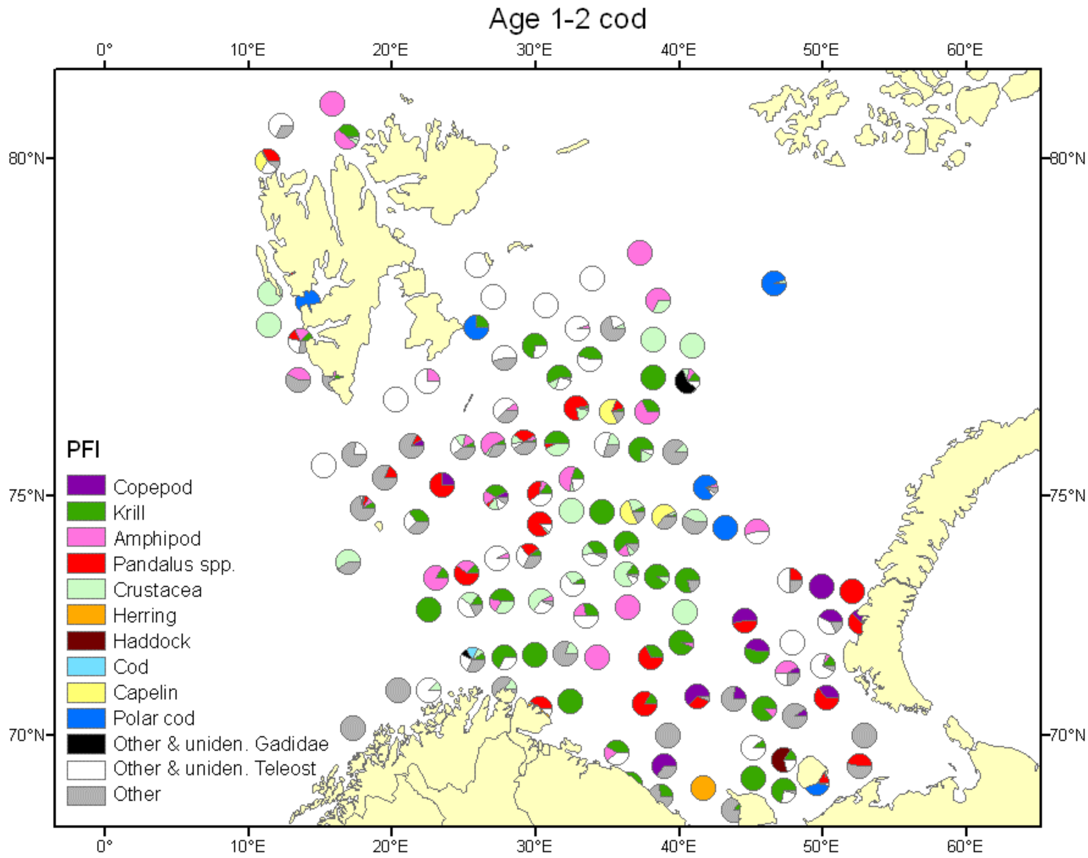


Figure 2.1. Geographical distribution of diet composition for age 1-2 cod during the ecosystem survey autumn 2005

For cod age 3-6, the diet composition was very variable between the areas, reflecting the difference in geographical distribution of the various prey items. Blue whiting was the dominant prey item in the south-western part, while herring, krill, shrimp and capelin dominated in the south-eastern part. In the central Barents Sea shrimp was the most important prey in a large area, while polar cod dominated in the area east of 42° E and between 73° and 76° N. North of 76° N, polar cod, capelin and amphipods dominated.

For cod age 7-13, the diet composition was to a large extent similar to that of age 3-6 cod. Thus, blue whiting dominated in the south-western part and polar cod, capelin and amphipods dominated north of 76° N, and polar cod dominated in the area east of 42° E and between 73° and 76° N. Shrimp was the dominant prey item in the central Barents Sea, but over a smaller area than for age 3-6 cod. Also, the proportion of cod and haddock in the diet was high in several parts of the central Barents Sea, with cod also being an important prey west of Svalbard.

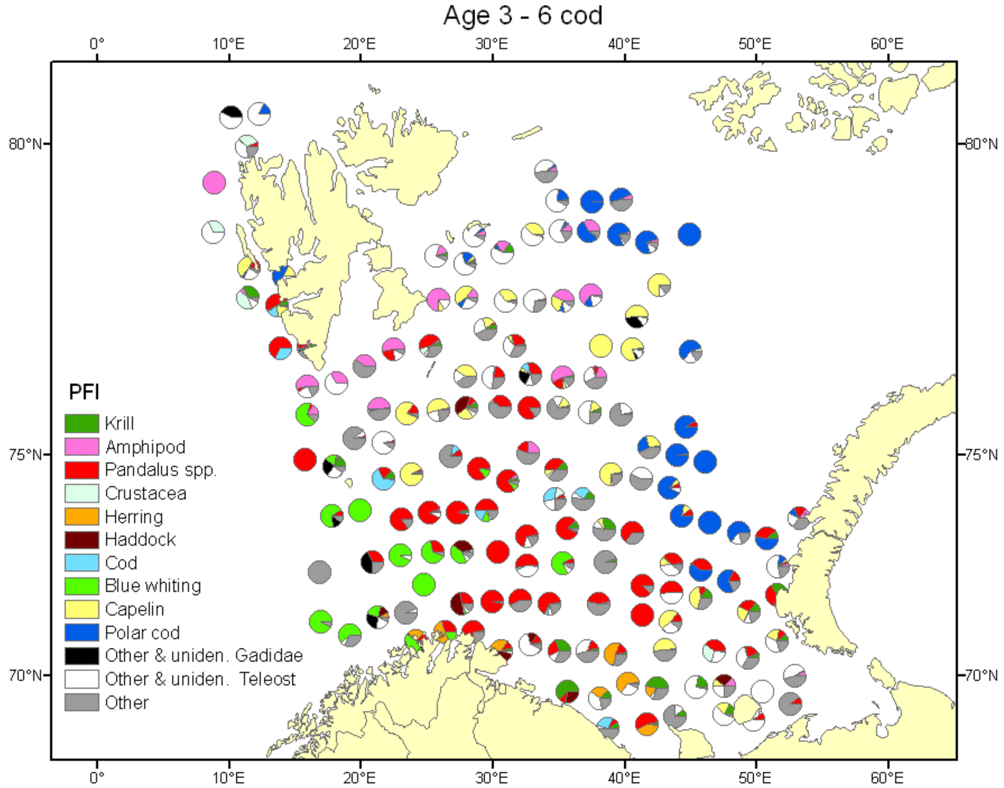


Figure 2.2. Geographical distribution of diet composition for age 3-6 cod during the ecosystem survey autumn 2005

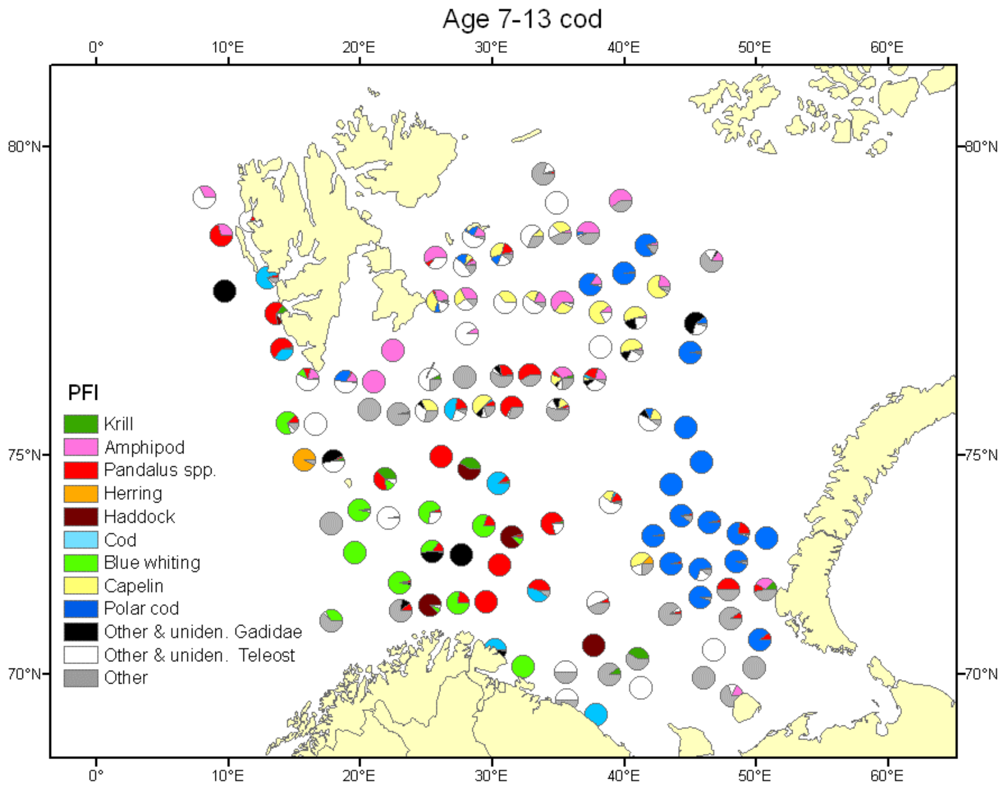


Figure 2.3. Geographical distribution of diet composition for age 7+ cod during the ecosystem survey autumn 2005

So far, 321 0-group cod stomachs from 24 stations sampled by 0-group trawl have been analysed, as well as 142 stomachs of 0-group cod sampled by the bottom trawl. The analysis showed generally the same pattern for the two sampling gears. The diet (PFI) composition of the 0-group cod sampled by the bottom trawl (all data pooled) is shown in Figure 2.4. Copepods and krill were the main food item for the 0-group cod, most of which were in the length range 7-11 cm. Only few stomachs contained fish and shrimp, but as these stomachs had a high content of food, these food items show up noticeably in the diet. The dominant copepod was *Calanus finmarchicus*, followed by *Metridia longa.* The krill species found were mainly *Thysanoessa inermis*.

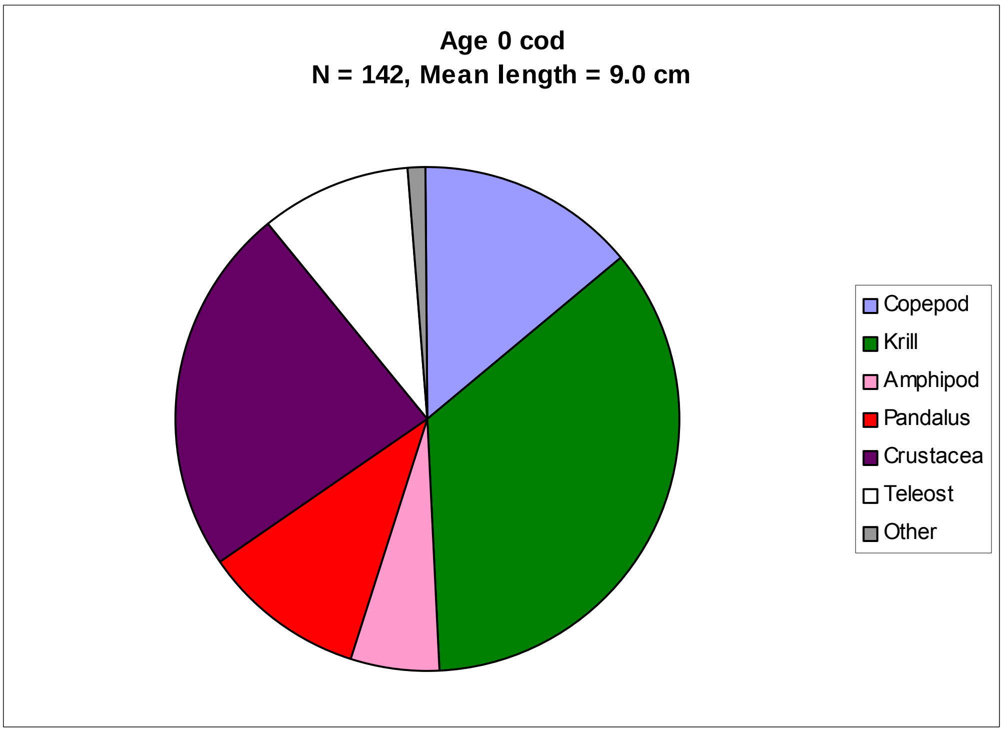
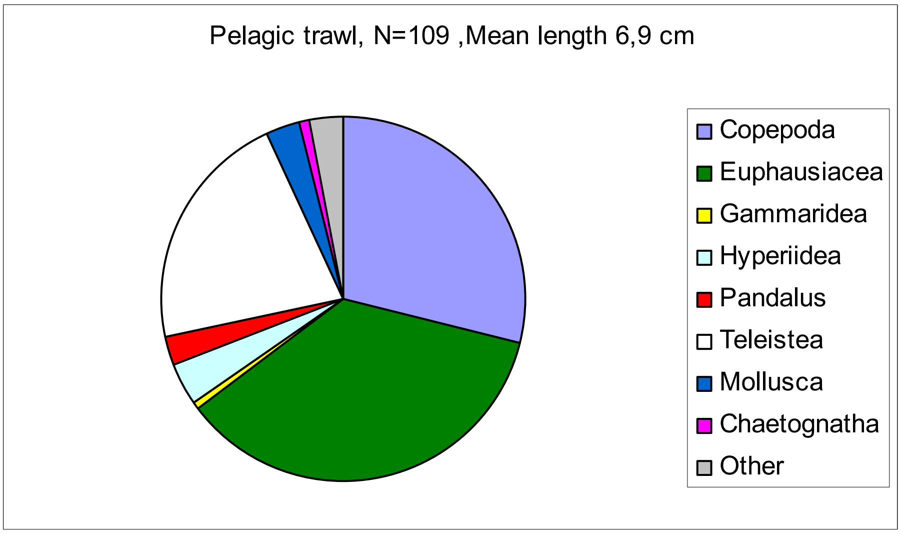


Figure 2.4. Diet composition for age 0 cod during the ecosystem survey autumn 2005 (only samples from 0-group trawl)



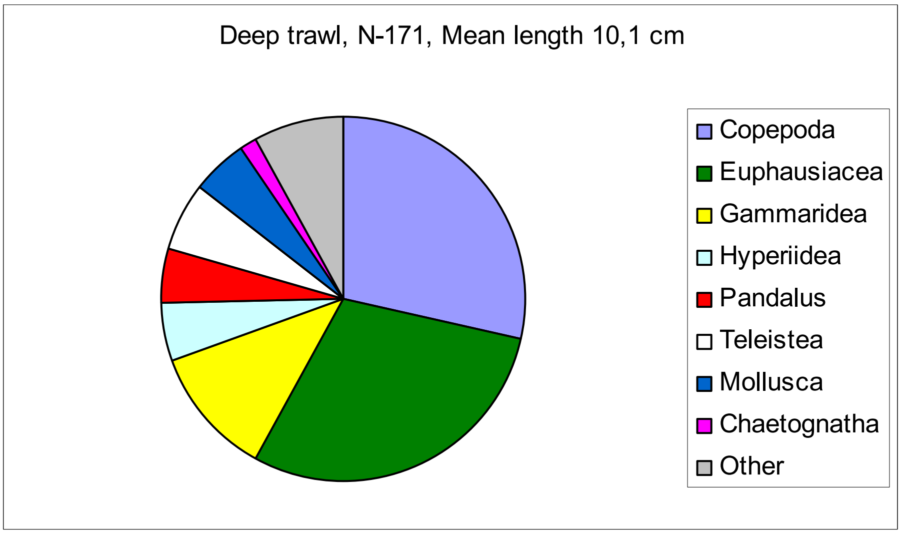


Figure 2.5. Diet composition for age 0 cod on different trawl during the ecosystem survey autumn 2005 from Russian date, % by weight.

3. Capelin, swept-area assessment based on bottom trawl data

A swept-area assessment of capelin caught in the bottom trawl was carried out (using the SAS Survey 5.2 program), and the bottom component of the capelin stock was estimated to 33 thousand tonnes (2.2×10^9 individuals). The estimate is strongly affected by the inclusion of a few large catches, eg. catches of whole schools caught by incident. This problem illustrates the need for a thorough evaluation of the suitability of the swept-area method for assessing the bottom component of the capelin stock. For the calculations based on the current survey data, capelin catches from 2 stations were excluded as these were of whole schools and would have increased the estimate to about 84 thousand tonnes (5.3×10^9 individuals). The distribution of capelin caught in the bottom trawl is shown in Figure 3.1.

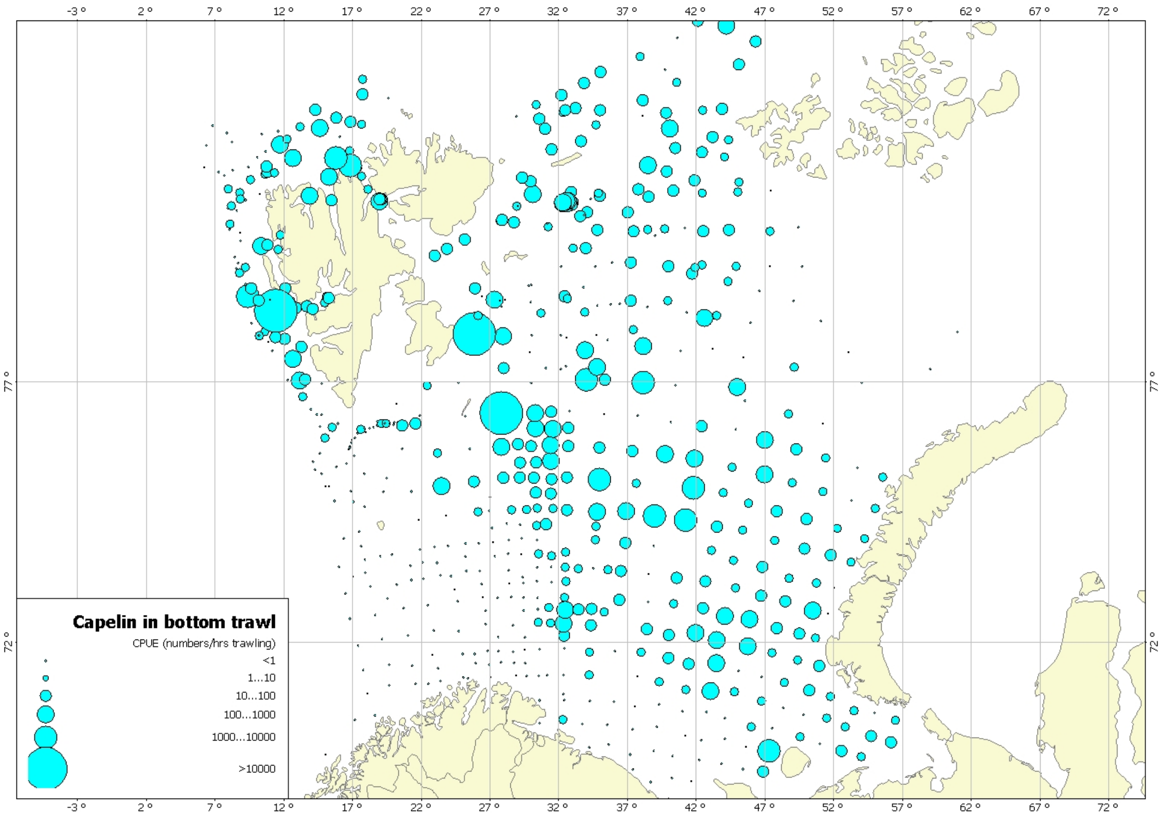


Figure 3.1. Distribution of capelin (Mallotus villosus) caught in demersal trawl during the ecosystem survey in the Barents Sea 2005

Table 3.1. Age-composition of capelin caught in the bottom trawl (in percent)

Age-groups	1	2	3	4	5
All stations	8.0%	60.2%	27.5%	4.3%	0.1%
Excluding 2 outlying stations	7.6%	63.5%	24.4%	4.3%	0.2%

3.1. Length distribution

Based on the stock estimate we found that 76% of the capelin were longer than 14 cm (considered to be the maturing part of the stock), which is a higher proportion compared with the acoustic estimate of the pelagic component (54% longer than 14 cm).

3.2. Preliminary results of the research on capelin feeding in the Barents Sea

The investigations were carried out in accordance with the agreement between IMR and PINRO achieved during the meeting in March 2005. Based on the processing of 40 capelin stomachs collected by the Norwegian vessel preliminary results are given. In total 70 capelin stomachs were sampled from 7 stations.

The analysis of four samples (10 fish in each one) of 15-20 September which were taken at 75º50´-76º30´N, 25-33ºE considerable differences in composition and intensity of food consumption by capelin in different parts and size groups was showed.

The first sample indicated (Figure 3.2) that capelin from two younger size groups (9.5-11 cm and 11.5-13 cm) fed poorly and, basically, on copepods. The index of fullness did not exceed 30 $^{0}/_{000}$, The percent of feeding individuals was also low (60%), while larger fish (13.5-15 cm) fed more intensively (Figure 3.2). Small size species *Temora longicaudata* and *Pseudocalanus minutus* predominated among the copepods of the first size group of capelin and the other food items were represented by small mollusks *Limacina helicina*. Larger crustaceans *Calanus finmarchicus* at stage IV-VIf and *Calanus glacialis* at stage V, as well as *Metridia longa* at stage IV were also presented in the diet of the other two size groups.

In the second sample (Figure 3.3) only small immature capelin up to 13 cm in length occurred and mainly copepods (64-81 % by weight) were in its diet. *Sagitta* spp. made up a considerable part (15-29 %) of the capelin diet whereas euphausiids did not exceed 3%. *C.finmarchicus* at stages III-V and *C. glacialis* at stage V predominated among the copepods in the food of capelin. Among the euphausiids juveniles were presented in the diet of capelin 9.5-11 cm and adult individuals of *Thysanoessa inermis* and *Th. longicaudata* were in the food items of capelin 11.5-13 cm. The index of fullness was high (especially of fish of 11.5-13 cm size group – about 350 $^{0}/_{000}$). All the individuals were feeding.

The greatest differences were observed in the third sample, where both small and large size groups of capelin occurred. The small individuals consumed various food items (e. g. copepods, euphausiids, hyperiids) and had a high index of fullness (about 150 $^{0}/_{000}$). Three species of *Calanus* (*C. finmarchicus* at stage III-IV, *C. glacialis* at stage II-III, *C. hyperboreus* at stage III), *Pareuchaeta norwegica*, as well as small species *P. minutus* and *Oithona similes* occurred among copepods, and they predominated in the diet of capelin. Euphausiids were mainly represented by *Th. inermis* and *Oikopleura* and juvenile *Limacina* were the “other food items” of capelin. Larger individuals of capelin primarily fed on copepods at stages IV-VI (capelin with length of 13.5-15 cm) and “other food items” (capelin with length 15.5-17 cm). The index of fullness was very low (Figure 3.4). Since all the fish contained food in the stomachs it may be assumed that food supply of different size groups of capelin in its feeding area differed.

Only large capelin (13.5-19 cm) was presented in the fourth sample and it fed mainly on *Sagitta* spp. (Figure 3.5). Copepods *C. finmarchicus* at stage IV-V, *C. glacialis* at stage IV-VIf and *Pseudocalanus* at stage VIf made up 11-18 % and *Themisto* spp. (up to 4 %) were in the stomachs of capelin of the two smallest size groups (<17 cm). The index of fullness varied from 200 to 550 $^{0}/_{000}$ and all the fish were feeding.

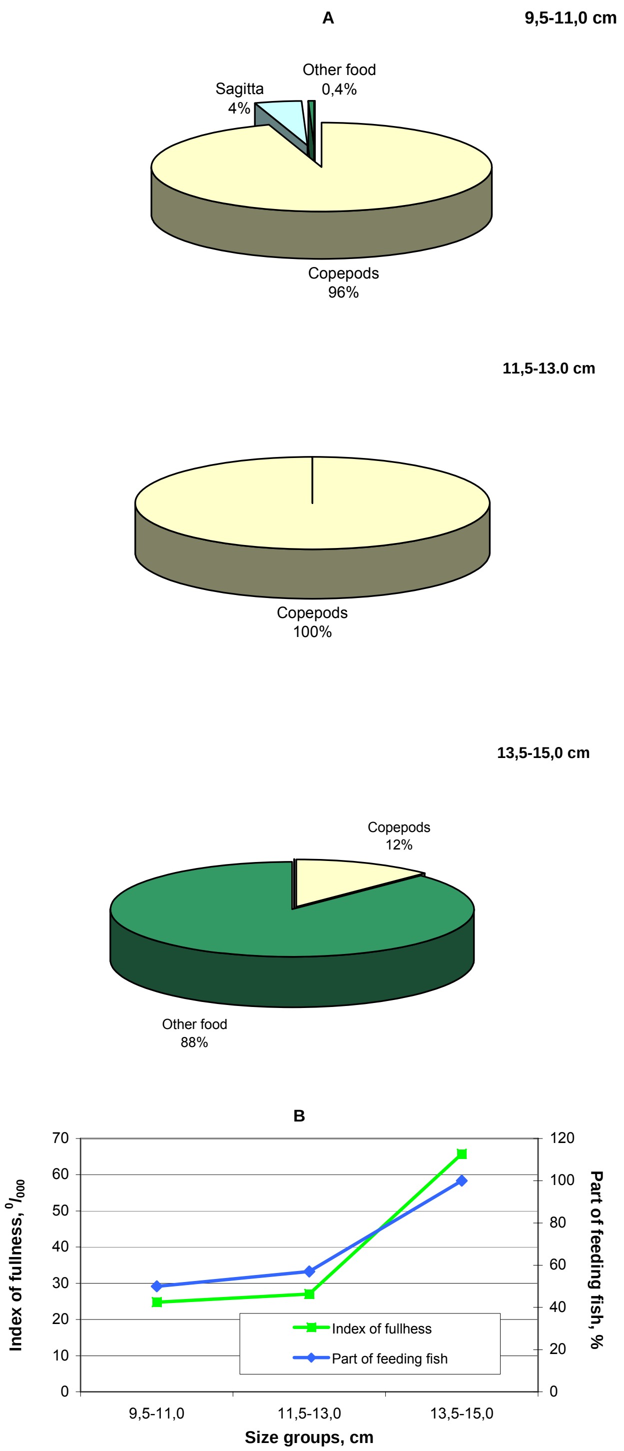


Figure 3.2. Food composition (A) and consumption intensity (B) by capelin from different size groups based on samples from 75º 50.8'N 25º 40.1'E collected by "G.O.Sars" in September 2005

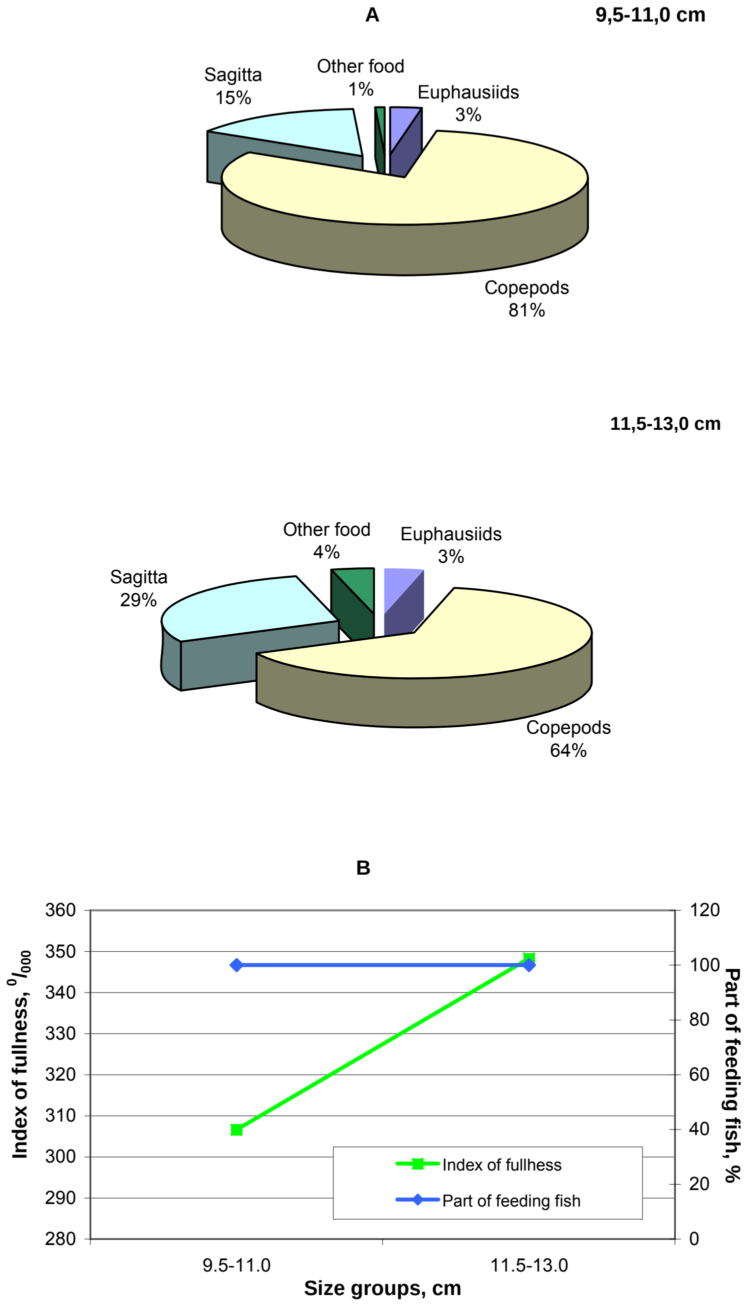


Figure 3.3. Food composition (A) and consumption intensity (B) by capelin from different size groups based on sample from 76º 27'N 32º 43.4'E collected by "G.O.Sars" in September 2005

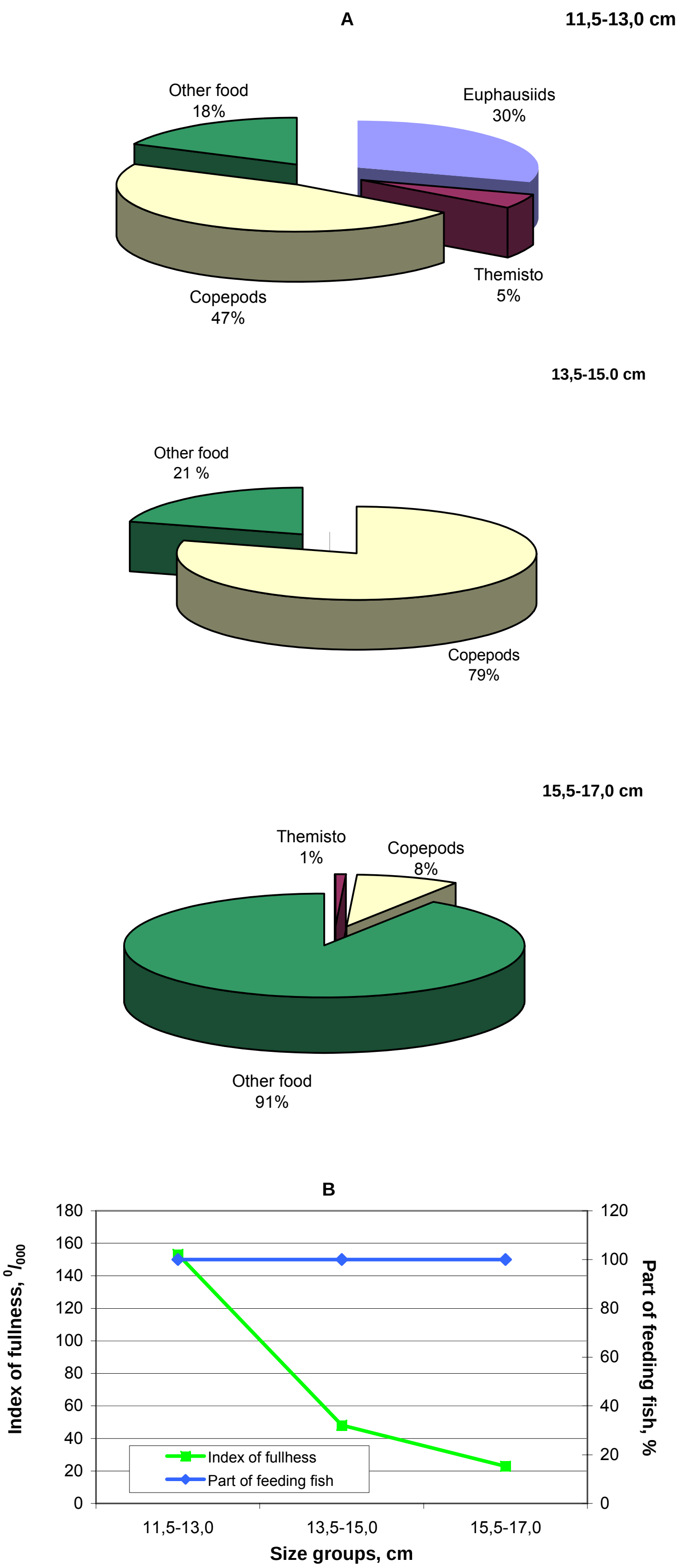


Figure 3.4. Food composition (A) and consumption intensity (B) by capelin from different size groups based on sample from 76º27.8'N 27º37.3'E collected by "G.O.Sars" in September 2005

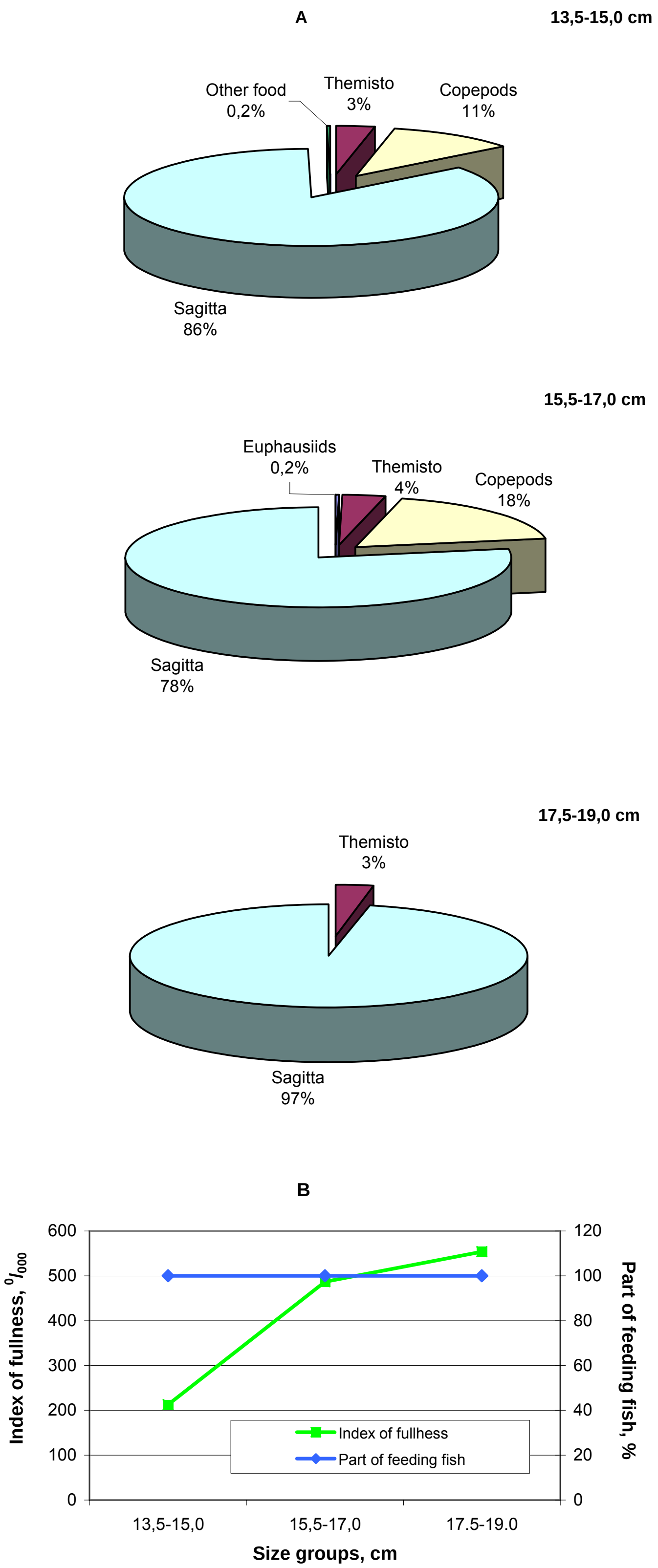


Figure 3.5. Food composition (A) and consumption intensity (B) by capelin from different size groups based on sample from 76º 24.5'N 25º 12.2'E collected by "G.O.Sars" in September 2005

4. Zooplankton

Since 2003 PINRO and IMR have had joint cruises for monitoring zooplankton in the Barents Sea in autumn. In total 536 samples from plankton stations were taken in the Barents Sea in 2005 using WP2, Juday and MOCNESS plankton gears. Results from the WP2 stations show a mean biomass of 7.8 g m^{-2}, quite similar to 2004 values (Figure 4.1 and Figure 4.2.6. from Report, 2005 volume 2). In the 2005 cruise, PINRO and IMR took 10 stations of WP2 and Juday net samples for making comparisons of the catchability of these two gears.

Figure 4.2 shows the horizontal distribution of zooplankton based on WP2 and MOCNESS. The biomass in the central and western entrance to the Barents Sea was higher than in 2004. This could be due to increase advection from the Norwegian Sea. Contrary to 2004, a low biomass belt was observed in 2005. Predation especially from the high biomass of 0+ herring (close to 11 million tones) could be reason for the low plankton biomass in the south in 2005. In general the zooplankton biomass was high in Atlantic/subarctic waters than Arctic waters (Table 4.1). In the Barents Sea, the Polar front separates Arctic species, *C.glacialis, Themisto libellula* from Atlantic/subarctic species *C. finmarchicus, M. norvegica, and Thysanoessa spp*. *Calanus* and krill species contribute to the high biomass of zooplankton observed in the western and central Barents Sea. The high biomass observed in the high Arctic waters is owing to the large hyperiid, *Th. libellula.*

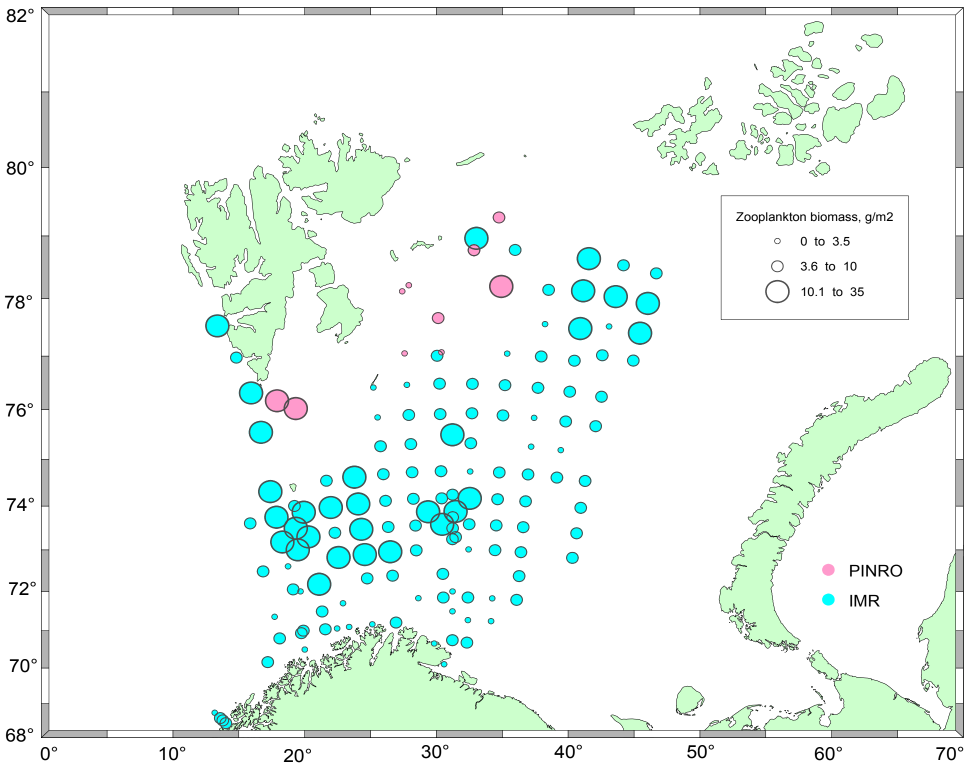


Figure 4.1. Horizontal distribution of zooplankton in 2005 (g m^{-2} of dry weight from bottom-0 m) based on WP2

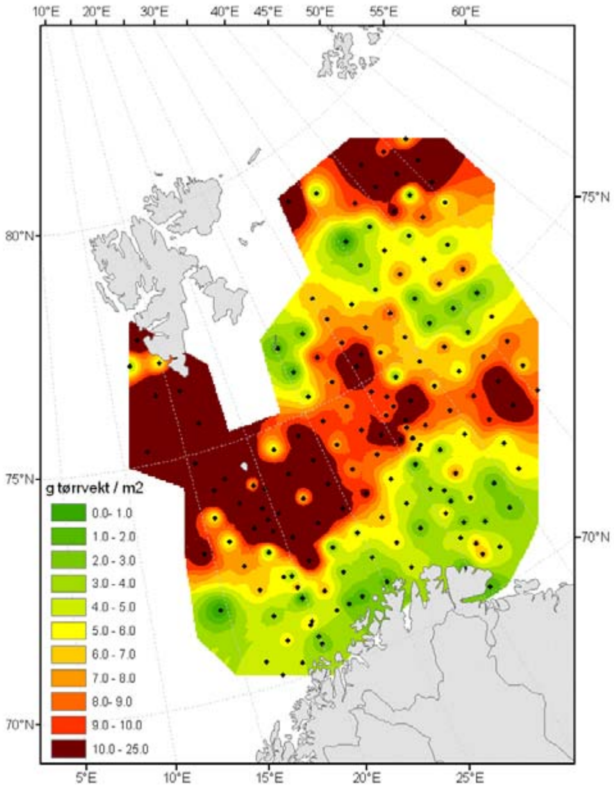


Figure 4.2. Horizontal distribution of zooplankton (g m^{-2}) dry weight from bottom–0 m in 2005, based on combined data from WP2 and MOCNESS

Table 4.1. Zooplankton dry weight (g m^{-2}) in different water mass categories in 2005

Vannmasse	Ant. stasjoner	Midlere tørrvekt	Standardavvik
Nordatlantisk vann	106	9,596	6,282
Kystvann	9	3,693	2,666
Kystvann/Nordatl. vann	12	3,975	1,848
Arktisk vann	16	8,532	5,695
Polarfrontvann	48	7,673	4,770

The preliminary data on composition (by length fractions) and biomass obtained with the use of the Juday and WP-2 nets showed both similarity and considerable differences in different aspects.

The similarity mainly reflected general character of distribution and the age composition of the Barents Sea plankton which was typical of September.

So, according to the data from the both nets, the zooplankton biomass was significantly higher in layer 0-bottom, comparing to that one in 0-100 m layer (Figure 4.3A,B). This may be indicative of maturation and descent of the main part of plankton to lower layers. Lower biomass due to small size fraction (1000-180 μm) in comparison with the total one of larger size fractions (1000-2000 and >2000 μm) also shows this.

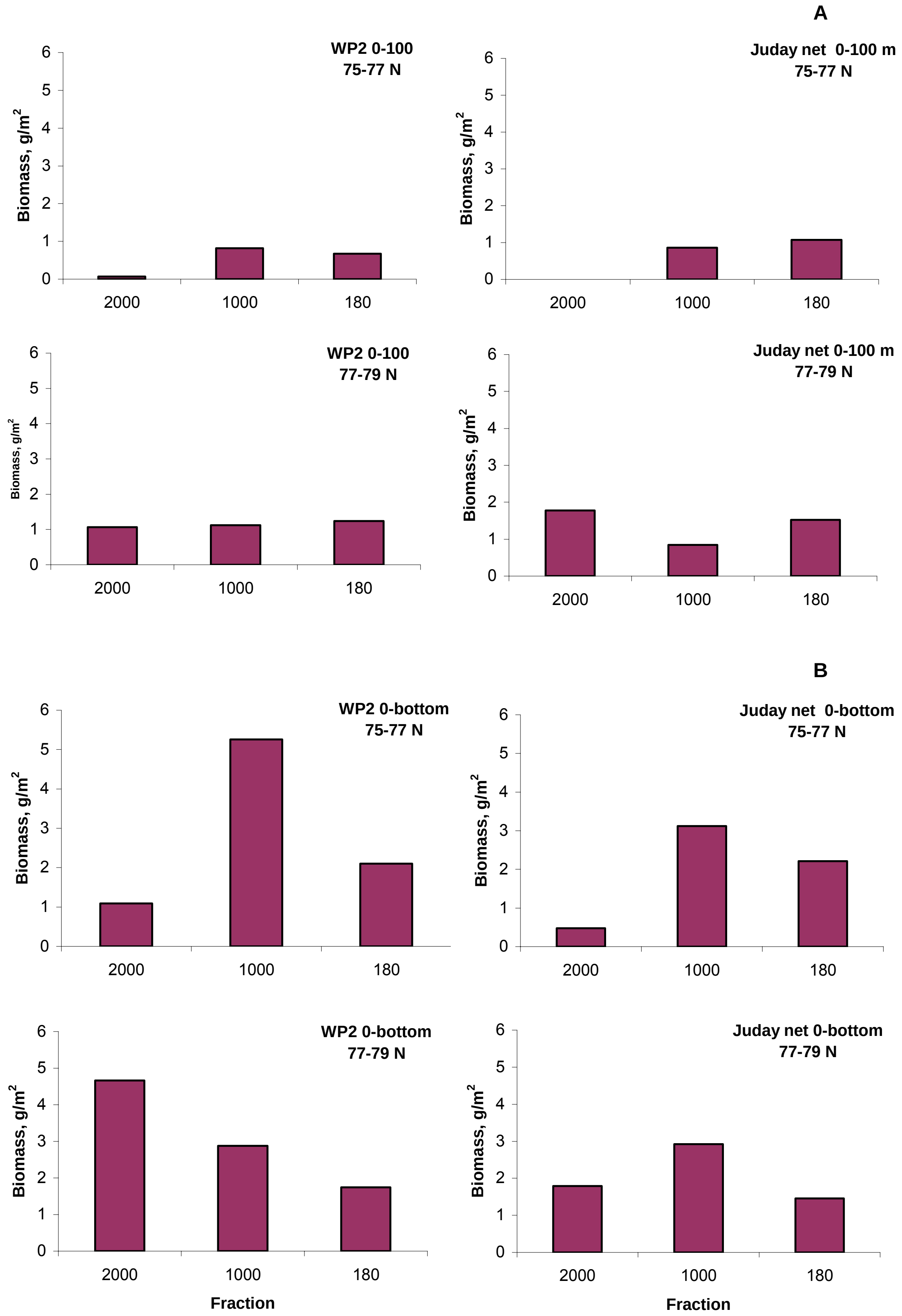


Figure 4.3. Biomass of zooplankton (g m^{-2} of dry weight) from different size fractions (μm) in 0-100 m layer (A) and 0-bottom layer (B) in different latitudinal ranges of the Barents Sea in September 2005

In accordance with the data from the both nets, in the layer 0-bottom, the similar trends in biomass distribution in the area of 75-77˚ N with clearly expressed predominance of the medium size fraction that showed its prevalence in plankton composition were revealed (Figures 4.3B).

Main differences were connected with the qualitative estimation of plankton biomass hwhich depended on net catchability.

With low biomass in 0-100 m layer the catches of both nets differed insignificantly irrespective of area (Figure 4.3A). In 0-bottom layer, in the area of 75-77˚ N, the zooplankters of medium size fraction were more successfully caught by WP-2 net (biomass made up more than 5g m^{-2} of the dry weight almost twice exceeding those ones obtained by the Juday net, (Figure 4.3B). More considerable differences were registered in the most northern areas (77-79˚ N), where in the catches small crustaceans of the large size fraction (about 5 g m^{-2}) predominated (Figure 4.3 B). As it is known, in these areas the portion of large arctic copepod species *Calanus glacialis* and *Calanus hyperboreus* is great and the biomass may be assumed to be provided due to these species.

In compliance with the data from plankton preliminary procession by species and stage composition (2004), the catches by the two nets, in the number of cases, the similarity in the catch size of the two abundant species *C. finmarchicus* and *C. glacialis* in different daytime was found. Basically the catches of *C. finmarchicus* were identical by small crustaceans at early stages (I-III) in the morning and afternoon time, but they prevailed by quantity in the WP-2 net. The main differences were observed in the night-time, when the Juday net caught large individuals (IV-V stages) better, as well as in the evening, when it caught smaller specimens better (Figure 4.4). It should be noticed for *C. glacialis* that its small specimens were better caught by the WP2 net in the evening and afternoon time (Figure 4.5). Position and time of the stations presented in Table 4.2.

Table 4.2. Position and time of the station

№ of station	Lat	Long	Time
66	72˚40' N	44˚08'E	2:10
99	76˚00' N	50˚00'E	0:30
67	72˚30' N	43˚15'E	5:50
95	75˚00' N	47˚00'E	4:50
94	75˚00' N	51˚00'E	13:00
96	75˚30' N	48˚00'E	12:40
98	75˚44' N	56˚36'E	22:10
119	77˚48' N	60˚30'E	21:25

To compare the catcability of the two nets the analysis of the total biomass of zooplankton and copepod biomass (77 couple samples collected by the Juday and WP-2 nets) was made. The results of the analysis are given in Figure 4.6. The biomass of copepod part of the sample shows good comparability. Using this equation and known biomass obtained by the Juday net the biomass taken by WP-2 may be calculated. The scatter of values by total biomass of plankton (Figure 4.6) may be explained by rarer occurrence of macroplankton objects and their considerable weight (Table 4.3). At that, the WP-2 net having a large opening catches large organisms better that explains a great scatter of values comparing with the Juday net (Table 4.4). On the whole, the catcability of the WP-2 net is slightly higher when catching mesoplankton.

Table 4.3. Composition of plankton samples collected by WP-2 and Juday nets in 0-50 m layer in 2004 ("F. Nansen")

№ Station	N	E	Net	Copepods		Large zooplankton								Total
				Weight, g	B_{dry}, g m^{-2}	*Sagitta*	*Themisto*	*Euphaus.*	*Jellyfish*	*Clione*	*L.helicina*	Weight, g	B_{dry}, g m^{-2}	B_{dry}, g m^{-2}
90	74º00’	47º00’	WP-2	0,18	0,15						0,55	0,55	0,45	0,59
94	75º00’	51º00’	WP-2	0,98	0,80					1,423	0,05	1,47	1,20	1,99
95	75º00’	47º00’	WP-2	0,73	0,59					1,401	1,09	2,49	2,02	2,62
96	75º30’	48º00’	WP-2	0,39	0,31						0,89	0,89	0,72	1,04
98	75º44’	56º36’	WP-2	2,33	1,89	0,18					0,71	0,88	0,72	2,61
99	76º00’	50º00’	WP-2	2,06	1,68	0,44	0,163			0,49	0,38	1,47	1,20	2,87
100	76º00’	47º30’	WP-2	0,86	0,70						1,15	1,15	0,93	1,63
116	77º03’	50º24’	WP-2	2,50	2,03	0,66		0,12				0,78	0,63	2,66
117	77º04’	53º49’	WP-2	0,44	0,35					11,57	10,15	21,72	17,65	18,00
118	77º17’	56º24’	WP-2	1,20	0,97					1,455	1,50	2,96	2,40	3,37
119	77º48’	60º30’	WP-2	1,85	1,50				0,048	0,55	2,25	2,84	2,31	3,81
124	78º05’	48º00’	WP-2	14,75	11,98	0,07	0,01			0,21		0,29	0,24	12,22
125	78º02’	50º58’	WP-2	1,98	1,61		0,26		0,382			0,64	0,52	2,13
127	78º30’	50º00’	WP-2	3,61	2,93							0,00	0	2,93
90	74º00’	47º00’	Juday	1,07	1,99			0,02		0,54		0,56	1,04	3,03
94	75º00’	51º00’	Juday	0,12	0,23					0,323	0,049	0,37	0,69	0,92
95	75º00’	47º00’	Juday	0,11	0,20						0,372	0,37	0,69	0,89
96	75º30’	48º00’	Juday	0,09	0,17						0,202	0,20	0,38	0,54
98	75º44’	56º36’	Juday	1,15	2,14	0,048	0,015			0,024	0,095	0,18	0,34	2,48
99	76º00’	50º00’	Juday	1,16	2,15	0,064					0,13	0,19	0,36	2,51
100	76º00’	47º30’	Juday	0,49	0,92			0,022			0,443	0,47	0,87	1,78
116	77º03’	50º24’	Juday	1,30	2,42	0,008			0,026	1,41	0,046	1,49	2,77	5,20
117	77º04’	53º49’	Juday	0,62	1,15					0,037	0,033	0,07	0,13	1,28
118	77º17’	56º24’	Juday	0,48	0,89		0,003			0,355	0,75	1,11	2,06	2,96
119	77º48’	60º30’	Juday	1,02	1,90				0,011	0,203	0,201	0,42	0,77	2,68
124	78º05’	48º00’	Juday	1,76	3,28			0,296	0,126	0,046		0,47	0,87	4,15
125	78º02’	50º58’	Juday	1,03	1,91				0,36	0,321		0,68	1,27	3,17
127	78º30’	50º00’	Juday	1,38	2,57				0,408	0,048		0,46	0,85	3,42

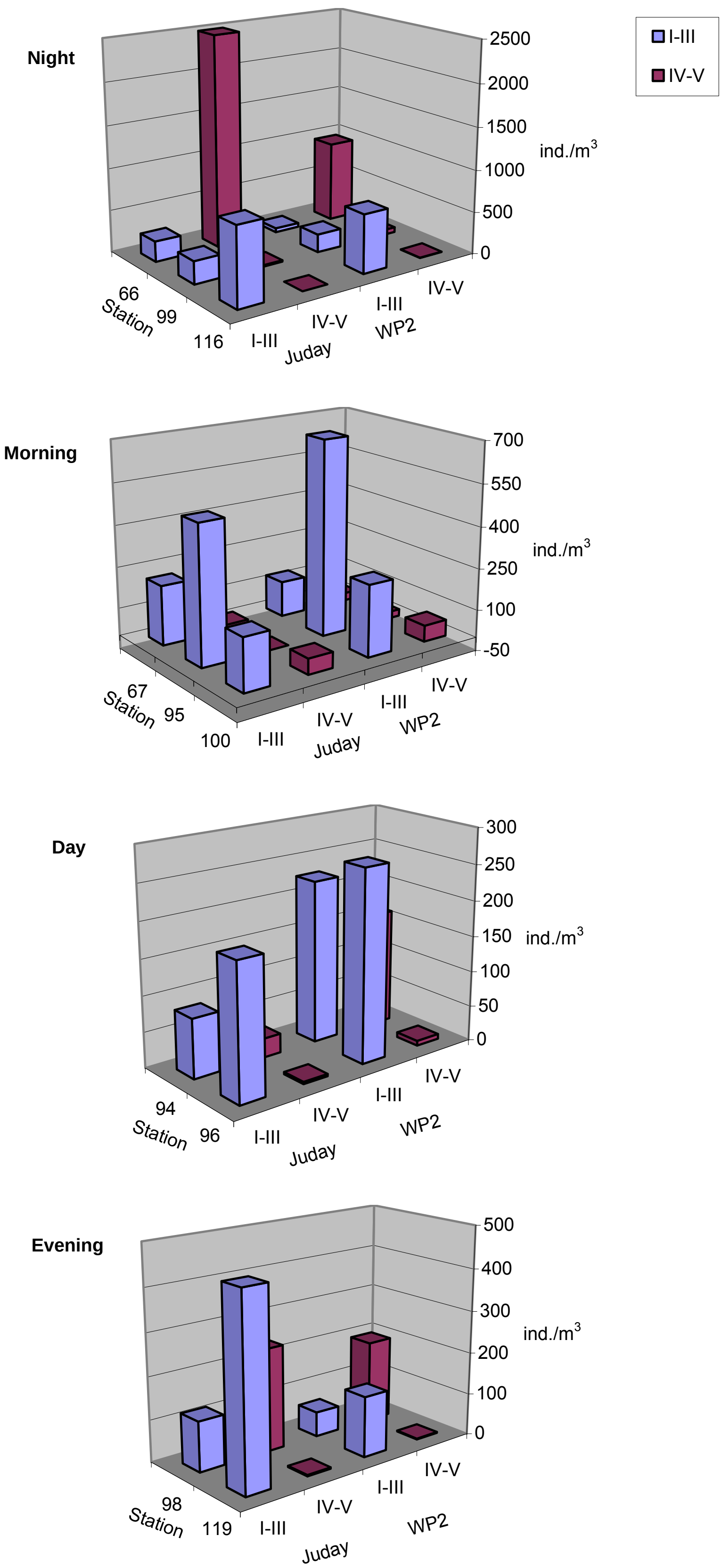


Figure 4.4. Distribution of *C. finmarchicus* concentrations at different development stages (by catches of Juday and WP-2 nets, ind./m^3)

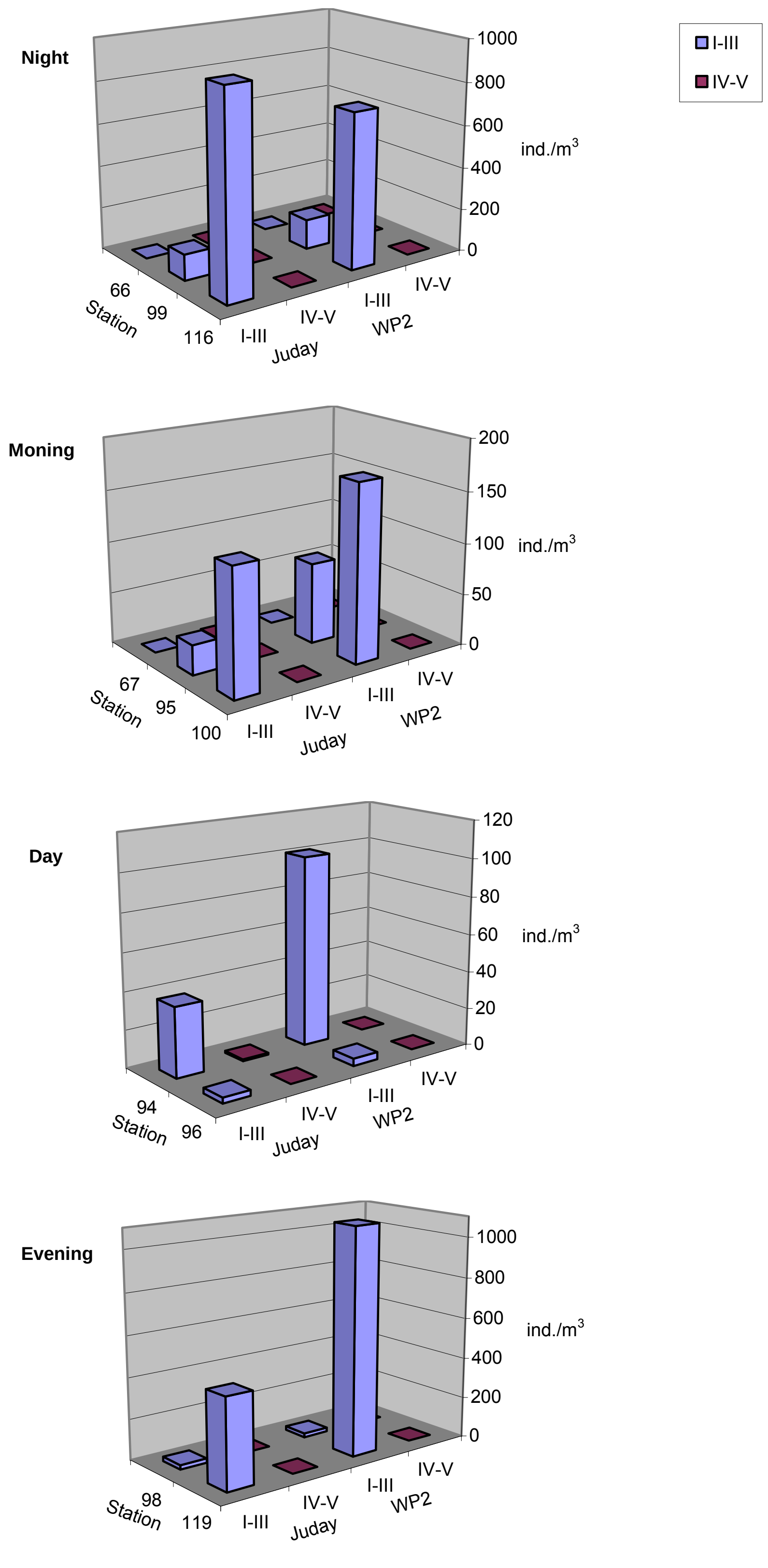
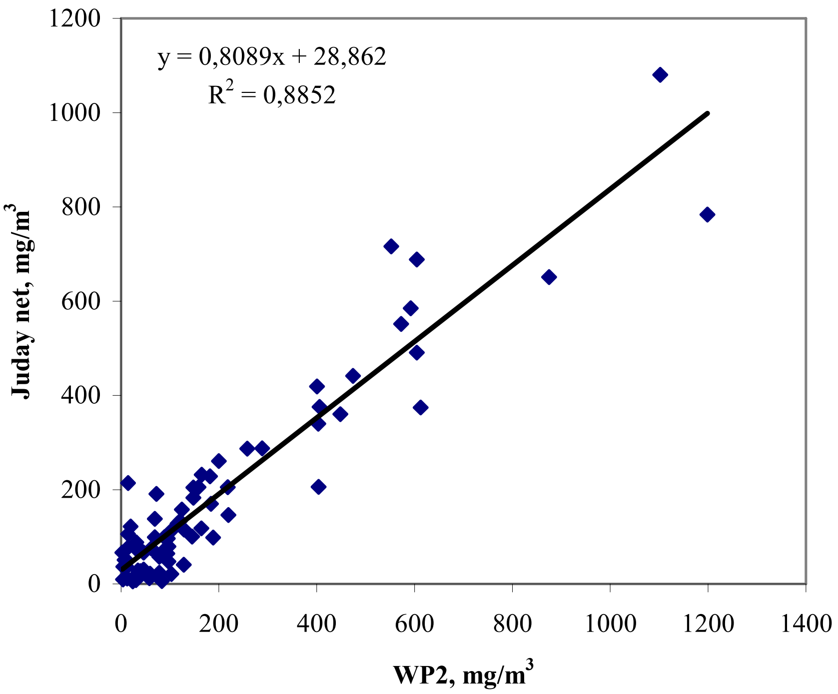
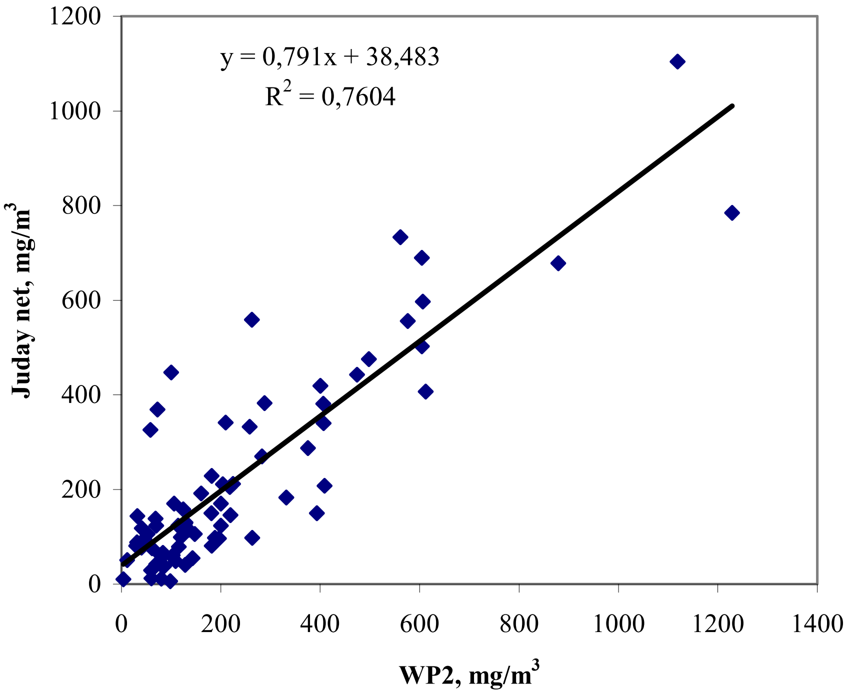


Figure 4.5. Distribution of *C. glacialis* concentrations at different development stages (by catches of Juday and WP-2 nets, ind./m^3)



For copepods



For all groups

Figure 4.6. Estimates of zooplankton wet weight obtained by the WP-2 and Juday nets at different stations and their trends

Table 4.5. Main parameters of net catchability

	Biomass of copepods, mg m^{-3}		Total biomass, mg m^{-3}	
	WP-2	*Juday*	*WP-2*	*Juday*
Mean	191	183	253	232
Standard error	28	24	34	26
Median	96	100	143	138
Standard deviation	245	211	295	229
Interval	1196	1077	1769	1098
Minimum	2	3	4	6
Maximum	1198	1080	1772	1104
Asymmetry	2	2	3	2

5. Pollution levels

The Institute of Marine Research, IMR, conducts monitoring of radioactivity and organic contaminants in the Barents Sea.

The main sources for radioactive contamination in the Barents Sea are fall-out from the bomb tests, run-off from European nuclear industry, the Sellafield plant in particular and fall-out from the Tsjernobyl accident. Monitoring radioactive contamination is also connected to the vicinity to Russian nuclear industry and problems with nuclear waste.

Monitoring the radioactive pollution is done by measurements on ^{137}Cs in seawater, sediments and biota. Measurements on Pu, Sr, Ra and Tc are also done.

Cod and haddock samples are analysed for organic contaminants.

The Barents Sea is monitored in a few stations every year, and every third year an extensive sampling is done. Biota samples are taken from the species available. Preferably cod, haddock, capelin, greenland halibut and long rough dab. Sediment samples are collected with sediment sampler Smøgen Boxcorer, which takes an undisturbed sample of the seabed. The upper 1-2cm is analysed. Sediment- and biota samples are frozen onboard the vessel and freeze-dried prior to analysis. Water samples are collected from the surface seawater intake on the vessel. Seawater is preconcentrated prior to analysis; this work is done onboard the vessel.

The sampling in 2005 was carried out onboard R/V “Johan Hjort” and R/V “G.O.Sars”. There were taken 40 biota samples of the species available for analysis of radioactive caesium and organic contaminants, 40 surface sediment samples and 40 sediment cores for analysis of radioactive caesium, 25 samples of surface water and 5 samples of bottom water for analysis of caesium, plutonium, radium, strontium and technetium. The sampling is distributed throughout the Barents Sea.

The analysis of the samples will take place in 2006 by Norwegian Radiation Protection Authority and Institute of Marine Research.

6. Ecological interactions

The synoptic data collected during the ecosystem survey offers unique opportunities to investigate the ecological interactions in the ecosystem. In the following chapter some initial, simple analyses of species overlap, and correlation analyses are presented.

6.1. Matrix of correlation maps

Geographical overlap between species in the pelagic is shown in Figure 6.1. Here the factors SST, zooplankton biomass, and CPUE (numbers per nmi) of capelin, herring and 0-group cod are plotted against each other. Also shown is the polar front as defined by a salinity range from 34.9-35.0 at 50 m depth. Figure 6.1 shows the largest degree of overlap between plankton and 0-group cod, and between plankton and capelin. The figure also shows how important the polar front and temperature is for the distribution of these selected pelagic species.

In Figure 6.2 the distribution of demersal species and bottom temperature is plotted against each other. Unlike the pelagic system (Figure 6.1) the surface polar front has less importance for the distribution, but rather bottom temperature has a large impact.

Cod is the most important fish predator in the Barents sea, and in Figure 6.3 the diet of cod is shown in relation to the demersal distribution of its main prey items.

In Table 6.1 the correlation between demersal fish species and the factors depth, latitude and longitude. Based on these correlation analyses the species were allocated to clusters using Ward's clustering method.

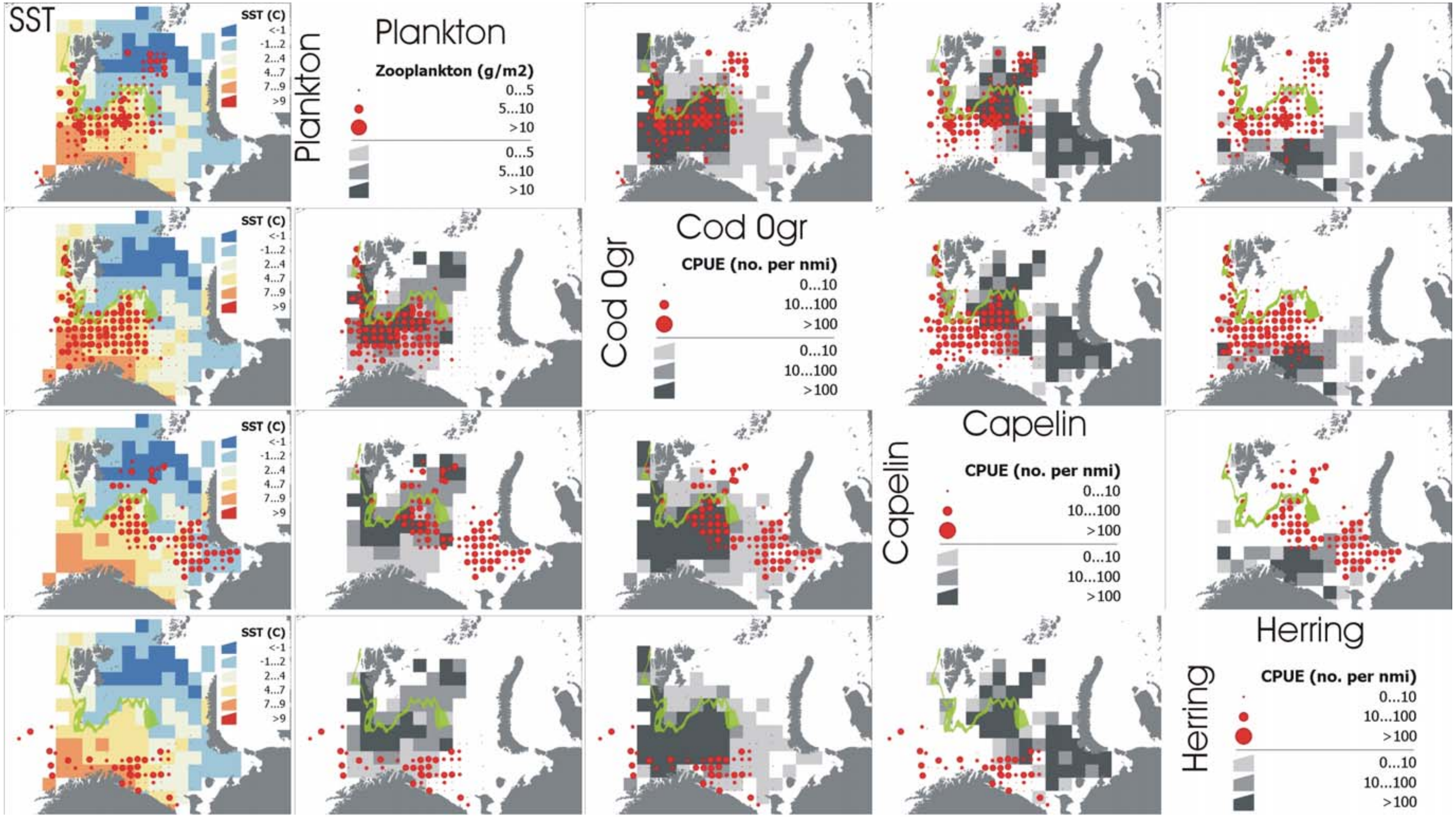


Figure 6.1. Bivariate plots of different ecological factors of the pelagic ecosystem. Data are either shown as points representing trawl stations, or gridded as average values in 60×60 nmi grid cells. The polar front is shown as the green area (as determined by salinity at 50 m depth)

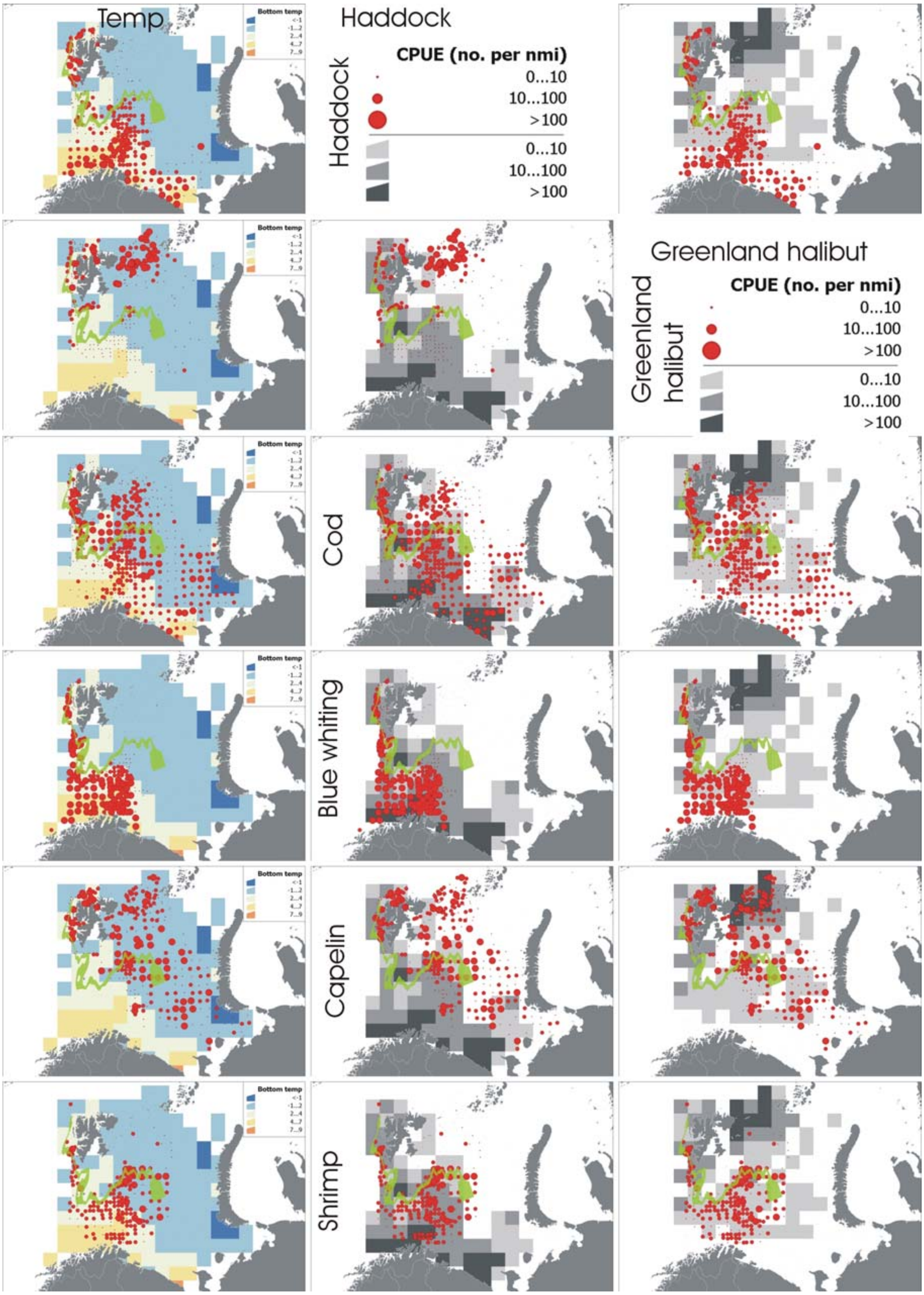


Figure 6.2. Bivariate plots of different ecological factors of the demersal ecosystem. Data are either shown as points representing trawl stations, or gridded as average values in 60×60 nmi grid cells. The polar front is shown as the green area (as determined by salinity at 50 m depth)

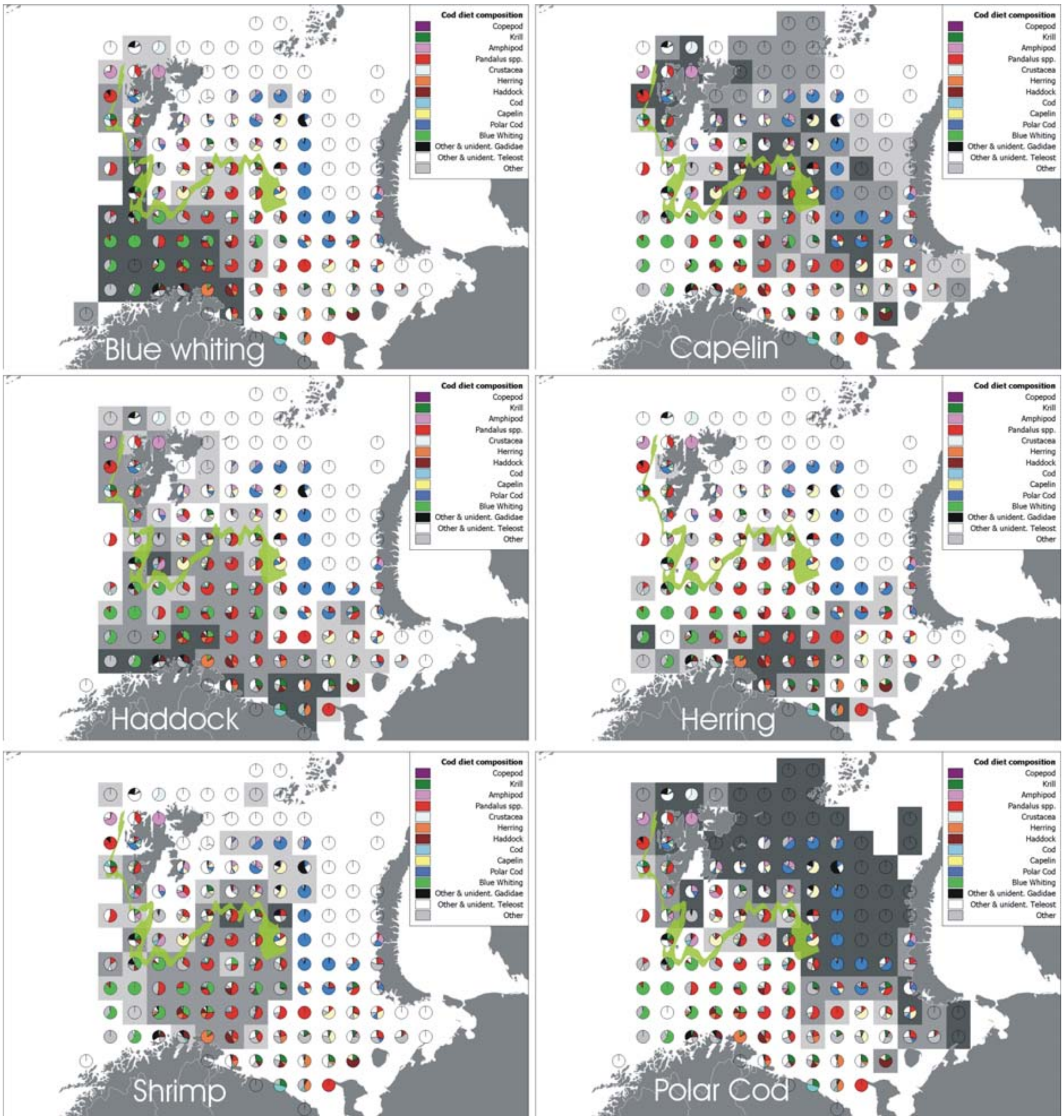


Figure 6.3. Diet of cod (ages 2+) aggregated in 60X60 nmi cells, in relation to the distribution of main prey items (aggregated to 60×60 nmi cells). Symbols for prey densities (CPUE, no. per nmi): Light gray: 0-10, Medium grey:10-100, dark grey: >100

Correlation tables

Table 6.1. Correlations between depth, latitude and longitude for species found in more than ten out of 642 bottom trawl stations 2005. The correlations are shown as 0=non-significant, -= significant negative correlation, += significant positive correlation. Species caught at the survey in more than ten stations were clustered with hierarchical cluster analysis (Euclidian distance matrix on log biomass, Ward's clustering method)

Species	Latin name	Depth	Latitude	Longitude	Cluster
Blue whiting	*Micromesistius poutassou*	+	-	-	1
Cod	*Gadus morhua*	-	-	0	1
Haddock	*Melanogrammus aeglefinus*	-	-	-	1
Thorny skate	*Amblyraja radiata*	+	-	-	1
Long rough dab	*Hippoglossoides platessoides*	-	-	+	1
Deep water redfish (?)	*Sebastes mentella*	+	0	-	1
Capelin	*Mallotus villosus*	-	+	+	2
Greenland halibut	*Reinhardtius hippoglossoides*	+	+	-	2
Triglops sp.	*Triglops sp.*	-	+	+	2
Atlantic hookear sculpin	*Artediellus atlanticus*	-	+	+	2
Snakeblenny	*Lumpenus lampretaeformis*	-	0	-	2
Threespot eelpout	*Lycodes rossi*	-	0	0	2
Polar cod	*Boreogadus saida*	-	+	+	2
Cyclopteridae sp.	*Cyclopteridae sp.*	0	+	+	2
Atlantic poacher	*Leptagonus decagonus*	-	+	+	2
Doubed shanny	*Leptoclinus maculatus*	-	+	+	2
Jelly catfish	*Anarhichas denticulatus*	+	-	-	3
Cusk	*Brosme bromse*	0	-	-	3
Spotted catfish	*Anarhichas minor*	-	-	-	3
Atlantic catfish	*Anarhichas lupus*	-	-	-	3
Norway redfish	*Sebastes viviparus*	0	-	-	3
Norway pout	*Trisopterus esmarkii*	-	-	-	3
Saithe	*Pollachus virens*	-	-	0	3
Vahl's eelpout	*Lycodes vahli*	+	-	-	3
Golden redfish	*Sebastes marinus*	0	-	-	3
Greater argentine	*Argentina silus*	0	-	-	3
Arctic alligator fish	*Ulcina olriki*	-	-	+	4
Doublelinee elpout	*Lycodes eudipleurosticus*	+	+	-	4
Pale eelpout	*Lycodes pallidus*	0	+	+	4
Arctic staghorn sculpin	*Gymnacanthus tricuspis*	-	-	+	4
Spiny-tail skate	*Bathyraja spincauda*	+	0	0	4
Herring	*Clupea harrengus*	-	-	+	4
Rough rattail	*Macrourus berglax*	+	0	-	4
Arctic skate	*Amblyraja hyperborea*	+	+	-	4
Ribbon barracudina	*Arctozenus rissoi*	+	+	-	4
Arctic eelpout	*Lycodes reticulatus*	-	+	+	4
Polar sculpin	*Cottunculus microps*	-	-	+	4
European plaice	*Pleuronectes platessa*	-	-	+	4
Lumpsucker	*Cyclopterus lumpus*	0	0	0	4
Stout eelblenny	*Anisarchus medius*	-	-	+	4
Round skate	*Rajella fyllae*	+	-	-	4
Arctic rockling	*Gaidropsarus argentatus*	+	+	-	4
Longear eelpout	*Lycodes seminudus*	+	+	+	4
Twohorn sculpin	*Icelus sp.*	-	-	+	4
Esmarks's eelpout	*Lycodes esmarkii*	+	+	-	4
Bull-rout	*Myoxocephalus scorpius*	-	0	0	4
Atlantic spiny lumpsucker	*Eumicrotremus spinosus*	-	+	0	4

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