PROBABLE DISCARDS OF COD IN THE BARENTS SEA AND AJACENT WATERS DURING RUSSIAN BOTTOM TRAWL

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ABSTRACT

Unaccounted discarding of small-sized fish is an important and acute problem in many fisheries because it affects the condition of stocks and reduces the reliability of fishery statistics. Such discards are regarded as a threat to intensively exploited species, such as the North-East Arctic cod *(Gadus morhua morhua L.)* which inhabits the Barents Sea and adjacent waters. In the present study an attempt is made to estimate of the quantity of small-sized cod discarded in the Russian bottom trawl fishery in 1996-2001. This work is based on cod length measurements onboard Russian commercial vessels in the period 1996-2001 and distributional features, such as density and size composition inferred from catch statistics.

The calculated annual discards of small cod were estimated to be in the range of 3-80 million individuals. Discards appeared to be highest in 1998 and lowest in 1996 and 2001. This was found to be related to the abundance of cod recruits and the portion of total catch taken in the Eastern-Central part of the Barents Sea. The features of spatial and seasonal distribution of small-sized cod, the depth and duration of trawling and catch of cod influence the catch of small cod per unit of effort and, as a consequence, discards of such fish.

Keywords: *North-East Arctic cod, Barents Sea, bottom trawl fishery, small fish,*

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1 INTRODUCTION

The cod *(Gadus morhua L.)* in the Barents Sea and its adjacent waters (partly including also the Norwegian, Greenland and White Seas) is managed as a separate stock, the North-East Arctic cod, here after referred to as cod. This fish is one of the dominant species in the fisheries of Norway and Russia. The bulk of the catch comes from the Barents Sea.

At the turn of this century the stock of cod stood at about 1.1 million tonnes. Each year Russia and Norway agree on a quota for the following year. Annual total landings during the last decade totalled more than 400,000 tonnes. The stock is considered heavily exploited. According to the Arctic Fishery Working Group of the International Council for the Exploration of the Sea (ICES AFWG) "fishing mortality exceeded upper limit of the reference point of the fishing mortality throughout the 8 latest years" (1993-2001) (Anon. 2002). This may be interpreted as a sign of the stock being at a risk of collapse.

The main regulatory tool, the cod quota, is given in tonnes and does not take into consideration the size of the fish. But there are also some accessory regulations aimed at protecting small-sized fish. There are regulations on minimum mesh size, minimum landing size as well as maximum allowable by-catch of undersized fish (Table 1). A specified area is temporarily closed to trawl fishing if the amount of undersized (less than minimum landing size) fish in the catches exceeds 15% by number. The minimum closure time is no less than one week.

At present, no agreement exists between Russia and Norway for the reciprocal enforcement of these fishery regulations within any section of the Exclusive Economic Zones (EEZ) in the Barents Sea. There are two permissible mesh sizes and minimum landing sizes for cod used in different fishing areas (Table 1). From the 1950s until the early 1980s the minimum mesh size was increased several times to reduce catches of small fish. At the same time the minimum landing size was also increased. It was not until 1982 that unified rules for the cod fishery in the Barents Sea and adjacent waters for all countries were adopted (125 mm mesh size for bottom trawl and 42 cm minimum landing size). Since then Norway has unilaterally increased these limits for the Norwegian Economic Zone (NEZ) up to 135 mm and 47 cm respectively. Such existing differences make additional difficulties for protecting young fish.

The main gear in the cod fishery are bottom trawl, long line, gill nets and hooks. The main gear in the Russian fishery is bottom trawl with a mesh size of 125 mm, equipped with a sorting grid device with an inter-bar distance of about 55 mm. Use of the sorting grid has been obligatory since 1998. About 90% of the annual Russian catch of cod is taken in bottom trawl.

Table 1: Present bottom trawl fishery regulations in different areas of the Barents Sea.

Area	Regulations		
	Bottom trawl minimum mesh size, mm	Minimum landing size for cod, cm	Allowable by-catch of undersized cod, % by number in catch*
EEZ of RF	125*	42*	15
NEZ	135*	47*	15
Spitsbergen area	125** 135***	42** 47***	15
Area of joint fishery Russia and Norway	125** 135***	42** 47***	15
Enclave	125** 135***	42** 47***	15

*- for the fishing vessels of all countries
** - for the Russian fishing vessels
*** - for the Norwegian and third countries' fishing vessels

In the Barents Sea, discarding fish of all species and sizes is officially banned by regulation. Despite this fact, the practice occurs in many cases, e.g. for the purpose of maximising catch value.

Discarding of small-sized fish is a common practice in most fisheries worldwide (Alverson *et al.* 1994) including the cod fisheries in the northern hemisphere (Hylen 1967, Dingsør 2001, Nakken 2001, Palsson 2003, Saila 1983). Discards of small fish may lead to decreased abundance of the species and misrepresentation of catch statistics. Lack of discard data is a source of unaccounted for mortality, and may pose a risk to stock assessment. Therefore, reliable discard data are required in order to improve long-term age-based fisheries stock assessment.

The cod fishery in the Barents Sea is relatively well investigated by Russian and Norwegian scientists. However, some aspects such as by-catches and discards of small specimens of cod are still inadequately understood and require further investigations. Discard data have still not been included in the cod stock assessment because the AFWG feels that it is necessary to study further existing methods to estimate discards before they can be reliably used in the assessment (Anon. 2002).

According to the Food and Agriculture Organisation's (FAO) Code of Conduct for Responsible Fisheries (FAO 1995): "States should collect reliable and accurate data which are required to assess the status of fisheries and ecosystems, including data on by-catch, discards and waste."

The main purpose of this study is to analyse the small-sized cod discard practices in the Russian fishery in the Barents Sea in relation to stock characteristics, such as catch per unit of effort (CPUE), mean length and proportion of small cod in the catches etc. The approach adopted is to map the spatial and seasonal distribution of the catchable stock and young cod and to explore the main factors affecting discards. A second objective is to develop a method to estimate discards and to calculate the potential cod discards during the period 1996-2001.

2 LITERATURE REVIEW

References to discards of small-sized cod in the Barents Sea and adjacent waters can be found in scientific literature dating back to the 1950s. According to Graham (1954) and Lundbeck (1954) about 25% of cod captured in the Barents Sea in 1952 by British and German trawlers were discarded. Norwegian trawlers discarded cod less than 49 cm in length (Hylen 1967). Discards by Soviet vessels were much smaller at that time, because all fish of 40-50 cm were processed (Ponomarenko 1965).

The first quantitative assessment of discards of small cod and haddock in the Barents Sea by Norwegian fishermen was published by Hylen (1967). According to this study, in 1967, discards of cod by Norwegian vessels accounted for up to 25% of the total number of captures and those of haddock up to 84%. Using the assessment results from trawl-acoustic survey of bottom fish, data on selectivity of trawl codend and reported catch, McBride and Fotland (1996) estimated that in 1989 about 7% of all cod captured in the Norwegian trawl fishery were discarded.

In recent years two methods of estimating cod discards in the Barents Sea have been developed by Norwegian and Russian scientists (Dingsør 2001, Sokolov 2001). Although Dingsør (2001) used different methods, his main approach was to use fishing gear selectivity and cod year-class strength to model discards. The calculated discards of 3, 4 and 5 year old cod in the commercial trawl fishery from1946-1998 were in the range of 9%-300% higher than the catches of cod of these ages reported to the ICES. In other words, in some years up to three quarters of the total catch of cod measuring less than 50-55 cm in length were thrown back into the sea.

2.1 Methods to estimate discard

Methods to estimate discards of undersized fish can be separated into direct and indirect methods, reflecting different availability of fishery data on by-catches and discards. Direct methods are based on the measurement of fish directly onboard the fishing vessels, while indirect methods use other kinds of data and assumptions to calculate discards.

Only one method can be considered as direct:

- Studying the discarding practice onboard fishing vessels (Hylen 1967, Hylen and Smedstad 1974, Jermyn and Robb 1981, Tamsett 1999). The method is based on the direct counting and measuring of fish selected for discarding by fishermen and raising the results of samples to the total catch. Such monitoring of discards is considered to provide the most reliable data. For such data to be representative, the sampling procedures should cover all seasons, main areas, fishing gears and vessel types. The implementation of these procedures carries a high financial cost.

Some of the methods which can be considered as indirect include:

- Comparison of length measurements by onboard observers and shore-based sampling of landings (Palsson *et al*. 2002, Palsson 2003). Comparison of two different sources of the size composition of the same catch can be used to estimate discards. The accuracy of this method depends on the extent to which the collection from both sources can be matched to a trip/haul level.

- Methods (models) based on gear selectivity. Such methods can be applied if selection curves of the gear and catch are known. Dingsør (2001) developed several methods to estimate cod discards based on selectivity of different types of gear used since 1946. He applied theoretical selection curves to the actual length and age distribution of the catch over the history of the cod fishery. The other main inputs for these methods are stock size, estimated by virtual population analysis (VPA) and numbers-at-age indices from surveys. Uncertainties in VPA stock assessment and abundance indices and possible errors in the survey data and scarcity of primary data for selection curves influence the final results. In some methods fish body girth is used to estimate net selectivity and then to find discards (Matsushita and Ali 1997). There is also the approach of McBride and Fotland (1996) based on a comparison of research and commercial trawls selectivity. It combines research surveys and commercial landings data to estimate the total catch of species, including discards, in a commercial trawl fishery.

- Methods based on length measurements of the catch before discarding. This method can be applied only if there is a large quantity of catch length structure observations. The observations should cover all fishing areas and seasons. The main assumption of this method is that all fish less than the minimum landing size (or any given size) are discarded (Sokolov 2001). This size depends on many factors and can be different by areas and types of vessels. This simplification allows only approximate estimate of discards.

- Model based approaches. Methods which use length-structured Yield-Per-Recruit (YPR) model (Chen and Gordon 1997) and statistical model-relationship (Helser *et al.* 2002) are known. YPR methods allow us to evaluate the impact of discarding and potential losses in YPR of demersal fish due to mortality caused by discarding. Authors of the statistical approach propose to use discard data obtained directly from discard surveys, to calibrate a statistical relationship for predicting discard levels. All these models require collection of discard data over a wide range of conditions.

- The interviewing of skippers on their return to harbour (Jermyn and Hall 1978, Nakken 2001). In practice, this method has proven difficult.

- Revising of discard data based on log books completed by skippers. This method consists of entering descriptive information about fish length, species composition and weight of discards in each haul into a special log-book. In the Falklands fishery such collecting of data is mandatory. In some countries compensation is envisaged, but the method has been found to be subjective (Alverson *et al.* 1994).

To summarise, the accuracy of different methods to estimate discards depends strongly on the number of trips or hauls for which observation on catch rates or length distributions are available, and the coverage of fishing grounds, seasons, gear, types of vessels, *etc*.

3 MATERIAL AND METHODS

In 1996-2001 researchers at the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) in Murmansk, Russia, collected extensive data on bottom trawl catches in the most important fishing grounds of the Barents Sea and adjacent waters. The area where the catches of the cod were obtained is divided into five national and international zones (Figure 1, Appendix).

The database is the basis of the analysis presented in this report. The extent of the data separated by zones and quarters of the year is shown in Tables 2 and 3. Most of the data were collected in the Exclusive Economic Zone of the Russian Federation (EEZ of RF), followed by the Spitsbergen area and the area of joint fishery between Russia and Norway ("Grey Zone" (GZ)). More limited data were collected in the Norwegian EEZ (NEZ) and negligible data were collected in the Enclave.

Mature, large cod reach the outer limits of their geographical distribution during times of migration. The rest of the time, they are mostly found in the waters of NEZ. Immature cod are not able to perform such long migrations and, due to the system of currents, are geographically separated into two components. One is distributed in the central and southern parts of the Barents Sea which includes waters of EEZ of RF and "Grey Zone". The second component is distributed in the Spitsbergen-Bear Island area in the waters of the fishery protected zone of the Kingdom of Norway and partly in the Enclave, the area outside national economic zones (Boritsov *et al*. 1996).

According to the distribution of small cod, four listed areas were combined to form two regions, the Northern and the Eastern-Central for the purposes of the discards calculation. They are very important for the Russian cod fishery and also very sensitive in terms of by-catch and discards. Discards in the NEZ were calculated separately.

Analysis of distribution patterns of the Russian cod catch was based on the bottom trawl database collected in 1999 and 2000 (Table 3). This database provides detailed information on the catch in each trawling, such as position, depth, time, length distribution of cod in catch prior to eventual discarding *etc*. Only data from productive hauls (with catch) were used in our analyses. Crash trawlings and zero-catch trawlings were excluded from the database. Length measurements from the landed catch are not available.

Table 2**:** Number of cod length measurements (thousands of fish) in 1996-2001 divided by national and international zones.

Year	Russian EEZ	Norwegian EEZ	Spitsbergen Area	Area of Joint Rus-Norw fishery	Enclave	Total
1996	311	29	126	147	5	619
1997	427	15	305	124	1	872
1998	426	93	220	144	2	884
1999	420	90	234	155	2	901
2000	177	17	182	116	1	473
2001	114	13	79	46	1	253
Total	1875	257	1146	732	12	4002

Table 3: Number of analysed bottom trawlings in 1999-2000, in different quarters of the year.

Year	Number of trawlings			
	I quarter	II quarter	III quarters	IV quarters
1999	20	238	538	779
2000	91	414	686	320

The vessels chosen for the investigations were selected randomly. They fished in the same areas and seasons as the majority of the Russian fleet. It is assumed that they reflect well the behavior of the total Russian fishing fleet. As a rule, the behavior and operation efficiency of the fishing fleet reflects the geographical distribution of the target species. Therefore, the data were also used to define the basic areas of spatial aggregations of cod and seasonal differences in distribution patterns.

To evaluate the spatial distribution of cod the catch per unit of effort (CPUE), defined as number of cod per hour of trawling, was used as a measure of density. The dynamics of spatial distribution are observed by quarters of the year. CPUE was grouped into four categories according to the size of the catch:

a) Less than 100 specimens of cod per hour of bottom trawling. As a rule, a fishery with such efficiency is not stable because such catches usually are the results of unsuccessful trial hauls. The vessels scout for new fishing areas.
b) 101 to 500 specimens. This is low, stable productivity which occurs in the fishing on weak aggregations of cod. The vessels do not change position.
c) 501 to 1000 specimens. This CPUE can be regarded as high and stable productivity. It occurs in the fishery on the ways of cod migrations.
d) More than 1001 specimens of cod per hour of bottom trawling. This is high but, as a rule, unstable productivity. It occurs suddenly and proceeds for a short time.

Catches of small-sized cod were divided into the three categories:

a) Insignificant by-catches when less than 50 specimens of small cod are caught per hour of bottom trawling.
b) Average level of CPUE - 51 to 300 small cod per hour of bottom trawling.
High level of CPUE when more than 301 small cod can be caught per hour of bottom trawling. As a rule such high by-catches are accidental. Fishing vessels should report it and change the position of trawling.

The term “discards” in this study will be used according to the definition given by FAO (Alverson *et al.* 1994) as “that part of the catch, returned to the sea as a result of economic, legal, or other considerations”.

As a rule foreign wholesale buyers of Russian cod refuse to purchase fish of less than 400 g, deheaded and eviscerated, and buy only small quantities of fish less than 500 g. Such limitation is an important factor inducing fishermen to throw away small fish. Weight of 400 g corresponds approximately to 44 cm total length. All cod 44 cm and smaller are therefore considered as potential discards. The analysis of seasonal and spatial distribution of individuals of these sizes is of interest for studying of dynamics of possible discards of small cod.

Based on this, the term “small” cod is in this study taken to include all specimens 44 cm and less.

It has been shown that the probability of discarding decreases with increasing length (Stratoudakis *et al.* 1999, Palsson *et al.* 2002, Palsson 2003). A simple logistic curve is used to describe this relationship.

The length at which discard is 50% of the number caught (DL_{50}) can vary from season to season and from area to area and may depend on many factors, such as the market, length distribution of cod in the catch, fishing efficiency *etc*. In the absence of further data it is not possible to decide on the exact value of this length. Therefore, in order to analyse the potential cod discards an interval of DL_{50} from 40 cm to 50 cm was used.

Proportion of fish in observed length distributions at each size discarded by length (PD_L) is modelled with accordance to the following logistic curve equation from Palsson (2003) (Figure 2, Appendix):

$$PD_L = \frac{1}{1+\exp(-b(L-DL_{50}))} \qquad (1.)$$

where L is the fish length, DL_{50} the length at which discard is 50% of the numbers caught and b a constant (slope). The value of b is borrowed from the paper of Palsson *et al.* (2002) and accepted as equal to -0.6.

The following equations represent the modified method of cod discards calculation, presented by Sokolov (2001).

At the first step of calculation the total numbers of cod caught are defined as:

$$N_{total} = n \times \frac{P}{p} \qquad (2.)$$

where n is a total number of cod in the sample, p the total weight of cod in the sample and P the total statistically recorded weight of the catch.

Numbers of cod in each length interval in total catch are calculated as:

$$N_L = prop_{Ls} \times N_{total} \qquad (3.)$$

where $prop_{Ls}$ is the numerical proportion of cod at length L in the sample to the total number of sampled fish.

Then, numbers of discarded cod at length L are obtained as:

$$N_{dL} = PD_L \times N_L \qquad (4.)$$

where PD_L is proportion of discarded fish at each length interval calculated from the logistic equation.

The total number of discarded cod is then calculated as the sum over all length

intervals:

$$N_{d\_total} = \sum_{L} N_{dL} \quad (5.)$$

The weights of discarded cod at each length interval are found from simple length-weight relationship:

$$W_{dL} = N_{dL} \times W_{L} \quad (6.)$$

where W_L is weight of one specimen of cod at length L.

Finally, the total weight of discarded cod are defined as the sum of W_{dL}:

$$W_{d\_total} = \sum_{L} W_{dL} \quad (7.)$$

All calculations and analyses were performed in Microsoft Excel 2000, mapping procedures were performed in Neuron Data ArcView GIS version 3.1.

The Pearson product moment correlation was used for the statistical regression analysis. Correlation was considered significant at level of significance $p <= 0.05$.

4 RESULTS

4.1 Spatial distribution of the Russian trawl catch 1999-2000

Few scientific trips on commercial vessels were performed in the first quarter of 1999 (Figure 3.I, Appendix). In the first quarter of 2000, which is richer in terms of observations, the majority of Russian fishing vessels worked in and around the NEZ (Figure 4.I, Appendix). At this time the highest CPUE occurred in the northern part of the NEZ and sometimes exceeded 1000 cod. Such high catch occurs suddenly and usually proceeds only for a short time. CPUE from 100 up to 1000 cod were most commonly recorded. This most frequent CPUE can be defined as high and stable fishing efficiency.

The second quarter of the year is a time of active post-spawning migrations of large cod to the feeding grounds which increase the CPUE (Boritsov *et al*. 1996). At this time cod begins to leave the NEZ by several migration routes later to mix with wintering aggregations of young cod. These routes can be traced by fishing fleet aggregations (Figures 3.II and 4.II, Appendix). Two routes are directed to the north, (in north-west and north-east directions) and two in an easterly direction, one of them is closer to the coastline of the Kola Peninsula and second along 71° N.

The Russian fleet at this time is generally concentrated in the “Grey Zone” and at the slope of the continental shelf of the Spitsbergen area, outside the NEZ (Figures 3.II 4.II, Appendix). The most common CPUE at this time is 500 to 1000. The fishery in the NEZ becomes less successful. In the second quarter of 1999 only a few trawlings were recorded with a CPUE exceeding 500 cod. In 2000 the CPUE of the trawl cod fishery in the NEZ was half that of the adjacent areas.

In the third quarter of the year large cod reach the boundaries of their distribution area and are actively feeding. At this time the Russian fleet operates mostly in distant areas

off Spitsbergen and in the "Grey Zone" (Figures 3.III and 4.III, Appendix). Some vessels start fishing in the EEZ of RF. As in the second quarter, the highest CPUE occurs in the Spitsbergen area. The most common efficiency of the fleet working in the third quarter in the Eastern-Central area is 500-800 cod while in North of the sea is 700-1000.

Large cod begin their spawning migrations back to the NEZ in the forth quarter. The efficiency of the Russian cod fishery is reduced. The most common CPUE is in the range 500-800 cod with the CPUE becoming unstable. In this quarter, the operations of the Russian fleet reflect the spatial distribution of fishable stock and rate of movement of the migrating fish. Thus, in 1999 the fishing in the Spitsbergen area was most productive, while in 2000 it was in the EEZ of RF (Figures 3.IV and 4.IV, Appendix).

In general, the Russian fishery targets cod 4 years of age and older (Figure 5, Appendix). Cod of the ages 4, 5 and 6 years old form the bulk of the catch. With increasing age the contribution of the year-classes is reduced and the proportion of fish 8 years of age and older in the catches is negligible.

Cod caught in the Eastern-Central area is on average younger than in the Northern area although 4 and 5 year olds form the bulk of the catch in both areas, around 70% by number (Figure 6, Appendix).

4.2 Spatial distribution of small cod CPUE in 1999-2000

In the first quarter of the year the fishery for large as well as small cod is observed in the NEZ. By-catches of small cod at this time are minor and mainly observed in the shallow waters around the Bear Island and in the "Grey Zone". The CPUE of small cod does not exceed 300 individuals (Figures 7.I and 8.I, Appendix). Young cod, being outside of the NEZ are rarely caught because the majority of the Russian fleet this time operates in the NEZ and surrounding areas.

In the second quarter, the Russian fishing fleet is generally located at the slope of the continental shelf in the Spitsbergen area and in the "Grey Zone". The fishing fleet starts to work in the more shallow waters near the Spitsbergen and areas located closer to the Kola coast, which are known habitats of small fish. This time the occurrence of high values of small cod CPUE increase and some accidental high by-catches with CPUE of more than 301 small cod are observed (Figures 7.II and 8.II, Appendix). In general, the small cod CPUE in the Eastern-Central as well as in the Northern parts of the Barents Sea, can be considered at a relatively high level.

In the third quarter of the year the Russian fleet operates in more distant waters. At this time high by-catches of small cod are usually observed in the coastal waters near the Spitsbergen archipelago, in the EEZ of RF and partly in the "Grey Zone" (Figures 7.III and 8.III, Appendix). Thus, in the third quarter of 1999 the highest catches of small cod were recorded in the Eastern-Central area and slightly lower catches - near the eastern coast of the Spitsbergen in the Northern part. In 2000, on the other hand, the highest catches and highest CPUE of small cod were observed in the Northern part of the sea.

In the forth quarter a decrease in the total CPUE as well as small cod CPUE was observed. The fishing fleet stays in the distant waters but the operational area becomes more limited, especially in the Northern area (Figures 7.IV and 8.IV, Appendix). The number of hauls with high CPUE of small cod decreases considerably in the Spitsbergen area and in the "Grey Zone". Large numbers of small cod are still occasionally caught in the EEZ of RF.

Overall, in 1999-2000 the spatial distribution of small cod CPUE reflects changes in the spatial distribution of the total cod CPUE. The first and fourth quarters are characterised by the low values of CPUE, both in total and of small cod. In the second and third quarters average and high values are observed.

There where, however, some geographical differences in changes of values of these CPUE between the areas. Thus, in the second quarters when the average level of total CPUE was higher in the waters close to the Spitsbergen than in the "Grey Zone", the CPUE rates of small cod in both of these areas were almost equal. In the third quarter of 1999 a relatively high small cod CPUE was found in the EEZ of RF but in the Spitsbergen area in 2000.

4.3 Length distribution of cod in 1996-2001

The spatial distribution of cod of various sizes can be inferred from the length frequency distribution of catches. In 1996-2001 the largest cod was found in the NEZ (Figure 9, Appendix). In other areas the proportions of large and small cod change by year.

It is possible to discern two main periods in 1996-2001: 1996 and 1997 were characterised by a relatively high presence of cod larger than 60 cm in the catches, and in the period 1999-2001 the majority of fish included specimens 46-60 cm long. The year 1998 is a transition between the two periods. These changes could be caused by the entering of the relatively rich 1995 and 1996 cod year-classes into the fishery in 1998-2001 (Anon. 2002). The appearance of rich cohorts has a pronounced influence on the length composition of the catch, and the proportion of possible discarded fish.

The mean length of cod in trawl catches in both parts of the Barents Sea as one of the basic parameters of the length distribution of cod shows a considerable decrease from 1996-1999, increasing again in 2000-2001 (Figure 10, Appendix). In the Northern part the mean length declined from approximately 62 cm in 1996 to 56 cm in 1999 and increased to approximately 60 cm in 2000-2001. In the Eastern-Central part the mean length of cod declined from 61 cm in 1996 to 52 cm in 1996 and rose again to approximately 57 cm in 2001. During the period of observation the mean length was higher in the Northern part (Table 4). The mean length of cod in catches taken in different seasons in the Northern part is rather higher than in the Eastern-Central part of the sea (Figure 10, Appendix). The largest difference is observed in the third quarter when the fishing fleet starts to operate in more distant and shallow waters, abundant in young fish.

In 1996-2001 the mean length of cod in the Eastern-Central part is more variable than in the Northern part. The largest standard deviation from the mean length is observed

in the first, second and fourth quarters in the Eastern-Central part and in the third quarter in the Northern part (Table 5).

Table 4: Mean length of cod from commercial trawl catches in the different parts of the Barents Sea, divided by quarters, cm

Year	Eastern-Central part				Northern part			
	I	II	III	IV	I	II	III	IV
1996	60.8	58.5	61.2	62.3	61.9	58.8	63.9	63.7
1997	59.7	56.2	58.5	58.6		58.3	63.1	61.0
1998	55.0	53.9	52.9	53.0	58.0	56.9	57.5	54.9
1999	50.3	52.1	53.2	54.0	56.4	54.0	56.0	55.8
2000	51.1	55.3	55.7	57.6	55.8	55.2	59.8	59.1
2001	53.5	56.1	57.4	59.1	57.1	59.6	59.1	59.3

Table 5: Values of standard deviation of the mean length of cod from commercial trawl catches in the different parts of the Barents Sea, divided by quarters

Year	Eastern-Central part				Northern part			
	I	II	III	IV	I	II	III	IV
1996	10.4	11.5	10.3	10.2	7.4	10.9	10.6	9.7
1997	11.1	10.4	11.1	11.2		10.4	11.2	10.4
1998	13.4	12.5	11.5	11.3	10.1	11.1	11.8	10.2
1999	8.6	10.1	9.6	9.7	9.7	10.1	10.1	5.0
2000	8.1	10.1	10.4	9.6	7.5	8.0	8.3	9.2
2001	9.4	10.9	11.1	10.4	7.9	9.6	9.6	9.7

4.4 Changes in the total cod CPUE in 1996-2001

The inter-seasonal variability of CPUE is much higher in the Northern area than in the Eastern-Central. Average total CPUE in 1996-2001 in the Northern area was almost 20% higher than in the Eastern-Central (Figure 11, Appendix). The main patterns of these dynamics are high variability of the CPUE within a year and relative constancy over the whole observed period.

During these years maximum CPUE was generally observed in the second and third quarters (April - October) in both areas and the minimum in the first or forth quarters. Only in 2001 was the pattern in the Northern part the reverse of that in the Eastern-Central part. This may have been caused by an earlier start of migration of large fish from the Spitsbergen and Enclave waters to the spawning grounds.

Overall, in 1996-2000 the Northern fishing grounds were more productive than the Eastern-Central.

4.5 Changes in the small cod CPUE in 1996-2001

The CPUE of small cod in the Eastern-Central area increased gradually from 1996 to 1998 and decreased again in 1999-2001 (Figure 12, Appendix).

In most years in the period 1996-2001, CPUE of small cod in the Eastern-Central part was less variable within a year but changed more over the whole period of observation. In the Northern part the values were more variable within a year but relatively constant over the whole period.
In 1996-2001 the CPUE of cod 44 cm and less fluctuated by seasons and by years in both parts of the Barents Sea (Figure 12, Appendix). The annual maximum numbers in the Eastern-Central part are observed in the first or second quarters and sometimes in the third, but in the third quarter and sometimes in second in the Northern part. The annual minimum rates of CPUE of small fish in both areas were usually observed in the forth quarters and sometimes in the first.

4.6 Relationship between CPUE of small cod and other factors

4.6.1 Relationship between CPUE of small cod and total CPUE

The total CPUE of less than 1000 and small cod CPUE of less than 200 specimens were observed in the majority of hauls in both parts of the Barents Sea. The hauls with total cod CPUE more than 1000 were observed more often in the Northern area than in the Eastern-Central area. The proportion of small cod was lower when catches were good.

There is a significant correlation between CPUE of small cod and total CPUE in the Eastern-Central and the Northern parts of the Barents Sea with the significance level $p< 0.01$ (Figure 13, Appendix). The calculated values of the Pearson correlation coefficients for all towing operations in 1999-2000 in both areas of the Barents Sea are almost equal (0.677 and 0.676).

Based on the lines of linear regressions (Figure 13, Appendix), in the Eastern-Central area were more small cod per total number caught than in the Northern area.

The same relationship was found between the average monthly values of total and small cod CPUE in both areas (Figure 14, Appendix). The values of the Pearson correlation coefficient show that the relationship between them is closer in the Northern part (r=0.885, p<0.01), than in the Eastern-Central part (r=0.686, p<0.02).

Overall, the Northern part of the sea is more productive in terms of CPUE for the cod fishery and less abundant in small fish.

4.6.2 Relationship between mean length and proportion of small cod

The significant linear relationship was found between the mean length and proportion of small cod in both areas as well as in the whole Barents Sea (p<0.01) (Figure 15, Appendix). As the proportion of small fish in catch increases the average length decreases. The relationship is stronger in the Eastern-Central part than in the Northern part (the Pearson correlation coefficients are -0.862 and -0.670 respectively).

According to the slope of the lines of linear regression, at the same mean lengths of cod in different parts of the Barents Sea, a portion of small cod in catches in the Eastern-Central part is higher than in the Northern part.

In 1996-2001, the mean lengths of cod in catches in the Northern part were not under 52 cm. In contrast, the mean length of cod in the Eastern-Central part varied more widely. The proportion of small cod in the Eastern-Central part is also more variable. The amplitude there sometimes reached almost 30%, while in the Northern part it did not exceed 23% (Figure 15, Appendix).

4.6.3 Interrelationship between small cod CPUE and depth of hauling

The most common depths for the bottom trawl fishery in the Northern part of the Barents Sea are in the interval from less than 100 m to more than 500 m while the maximum depth in the Eastern-Central part is about 400 m. The majority of fishing grounds in both parts have depths from 100 m to 400 m.

There is an overall reduction in small cod CPUE with an increase of depth of trawling (Figure 16, Appendix). In the areas of less depth than 100 m the highest values of small fish CPUE are observed. The lowest small cod CPUE were observed in hauls taken in depths more than 500 m.

The distribution of small cod CPUE by depths differs between the Eastern-Central and Northern parts of the Barents Sea (Figure 16, Appendix) with average values of CPUE of small cod in all depth ranges being much higher in the Eastern-Central than in the Northern area. Thus, in the Eastern-Central area in the most common range of depths (100-400 m), this value varied from 50 to 40 specimens while in the Northern part - from 32 to 29. In the Northern part of the sea with depths less than 100 m the greatest CPUE of small cod is observed. There is no data of small cod CPUE in the Eastern-Central area for depths less than 100 m because the majority of such fishing grounds are closed to the fishery.

Overall, small cod are more abundant in shallow areas of the Barents Sea (less than 100 m). CPUE of small cod are on an average level in depth ranges from 101-400 m. Some areas with depths more than 400 m can be characterized as almost free from by-catches of small cod. But fishing at this depth is usually performed in a relatively short period.

4.6.4 Interrelationship between small cod CPUE and duration of hauls

The most common duration of bottom trawling in the Russian cod fishery is from 2 to 4 hours. Hauls shorter than 2 hours can be considered as trials to locate schools of fish, their extent and movement. Hauls of more than 4 hours are rather uncommon and are usually performed in the well known and harmless fishing grounds.

There is a tendency of reduction in small cod CPUE with an increase in trawling time (Figure 17, Appendix). The highest CPUE values are observed when the trawling time is less than 2 hours and lowest CPUE - 4 hours and more.

The small cod CPUE is on average higher for the same hauls duration in the Eastern-

Central area than in the Northern area (Figure 17, Appendix). In absolute terms, the difference is greatest in the short hauls (less than 2 hours).

Generally, in both parts of the Barents Sea short hauls of less than 2 hours catch more small cod. Hauls with a duration from 2 to 4 hours can be attributed as with average level of the small cod CPUE. Some hauls with a duration of more than 4 hours can be characterised as least abundant of small cod.

4.7 Calculation of discards of small cod

The estimated annual discards of small cod in the Russian bottom trawl fishery in 1996-2001 range between 2.6 and 79.6 million specimens depending on assumed DL_{50} (Table 6). The weight of these discards is estimated to be in the range 1500 - 65100 t (Table 7). The wide intervals of the suspected discards are explained by the wide interval of values DL_{50} used in the calculations (40 to 50 cm).

Changes in annual small cod discards by years and also by areas were calculated. From 1996-1998 discards of small cod were found to be increasing, having a peak in 1998 when suspected discards were in the range 14.2 – 79.6 million cod (7.5 – 65.1 thousand t respectively) (Figure 18, Appendix). From 1999-2001 the discards of small cod declined and reached a minimum in 2001 (Table 6). Changes in abundance of 3 year old cod, which are in the length interval 30-40 cm, and in subject to the greatest discards explains this pattern. Thus, the number of 3 years old cod rose from 432 million in 1996 to 819 million. in 1998 and declined again to 462 million in 2001 (Anon. 2002).

The largest discards of small cod were found in the Eastern-Central part of the sea. In 1998 about 85% of the total number discarded small cod were discarded in this area (Table 6). The average discards in this area in 1996-2001 accounted for more than 68% of the annual total. The situation was much better in the Northern area, where in 1996-2001 discarded cod constituted about one fifth of the total discards. In 2000 in the Northern area one third of total discards was recorded. In 1996-2001 the situation was even better in the NEZ. The annual discards of cod in this area ranged from 4% to 5% of the total number discarded (Table 6).

Table 6: Calculated number of discarded small cod in the Barents Sea and adjacent waters in 1996-2001 separated by areas (values of DL50 40 cm and 50 cm are used), thou. spec.

Year	Numbers of discarded small cod, thou. spec.							
	Eastern-Central part		Northern part		NEZ		Whole Barents Sea	
	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50
1996	1700	14763	788	5007	452	2967	2940	22737
1997	3998	22193	1509	10614	303	2431	5810	35238
1998	12233	66450	1400	9187	611	3935	14244	79572
1999	4330	33989	1192	14924	772	9709	6294	58622
2000	2565	18058	1083	9539	522	5554	4170	33151
2001	1601	13014	769	8838	310	3619	2680	25471

Table 7: Calculated weight of discarded small cod in the Barents Sea and adjacent waters in 1996-2001 separated by areas (values of DL50 40 cm and 50 cm are used), thou. tonnes

Year	Weight of discarded small cod, thou. t.							
	Eastern-Central part		Northern part		NEZ		Whole Barents Sea	
	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50	DL_{50}=40	DL_{50}=50
1996	0.9	13.7	0.4	4.5	0.2	2.8	1.6	21.1
1997	2.1	19.2	0.8	9.7	0.2	2.4	3.1	31.2
1998	6.4	53.6	0.8	8.0	0.3	3.5	7.5	65.1
1999	2.4	29.6	0.7	14.5	0.5	9.3	3.6	53.4
2000	1.4	15.7	0.6	9.0	0.3	5.5	2.3	30.2
2001	0.9	11.7	0.5	8.6	0.2	3.6	1.6	23.8

Such pattern of distribution of calculated small cod discards by areas may be due to peculiarities of distribution of the species in the area where the fisheries are conducted. As known, the Eastern-Central part and areas close to Spitsberegen are areas where juvenile cod are predominantly distributed. The NEZ is the area of distribution of mature and large immature cod.

5 DISCUSSION

Large mature cod are mostly distributed in the waters of NEZ while small and young cod inhabit the shallow waters of the Barents Sea in the EEZ of RF, "Grey Zone" and Spitsbergen area (Nakken and Raknes 1987, Boritsov *et al.* 1994, Brander 1994). The spatial distribution of the young cod is driven by the system of currents (Boritsov *et al.* 1996). The fertilised cod eggs and larvae drift passively in two branches of the Norwegian current from the spawning grounds near the Lofoten Islands. The Atlantic branch of the Norwegian current carries them to the north and north-east up to the Bear Island and Spitsbergen archipelago and the Coastal branch, splits up into the Murman current and Murman Coastal current, takes them to the east up to the Novaya Zemlia and to south-east along the coast of the Kola peninsula (Tantsjura 1959, Atlas of the Arctic 1985).

Six months after hatching the young cod seek the bottom. For the first 2-3 years of their life, the distribution of cod is mainly influenced by the abiotic factors (water temperature, speed of currents etc.) within the Eastern-Central and Northern parts of the sea (Brander 1994). With increasing age, the extent of active migrations is gradually increased. At the onset of sexual maturity (4-5 years) cod starts long-distance spawning migrations.

The fishing grounds in the Eastern-Central and the Northern areas are the most important ones for the Russian cod fishery. The seasonal patterns of the Russian fleet operations in 1999-2000 have shown that the key areas in order of importance are the Spitsbergen area, the "Grey Zone" and the EEZ of RF (Figures 3 and 4, Appendix). Cod fishery in the Enclave is negligible. In 1996-2001 the cod fishery conducted in the Northern area was more productive in terms of total cod CPUE than the Eastern-Central (Figure 11, Appendix).

The spatial distribution of small cod CPUE in 1999-2000 and seasonal variations followed by the same pattern in spatial distribution as total cod CPUE (Figures 3, 4, 7 and 8, Appendix). The important difference between different fishing grounds is the value of observed small cod CPUE, which is commonly higher in the Eastern-Central area than in the Northern part. The biggest difference was observed in the period from 1998 to the beginning of 2000 (Figure 12, Appendix). During 1996-1997 and from the second half of 2000 to the end of 2001 the difference in small cod CPUE between areas was not high. The possible explanation of this is the drift of greater part of small cod of the rich 1995 year-class to the Eastern-Central part of the Barents Sea and, as a consequence, an appearance of these fish in the catches there in 1998-1999 and partly in 2000.

The changes in small cod CPUE are found to be related to the dynamic of the mean length (Figure 10 and 12, Appendix) because high presence of small cod in catches decreases the mean length. Such changes of small cod CPUE were not observed in the Northern area. The difference between areas could be caused by significant drift of young cod of 1995 year-class eastwards into the Eastern-Central part. In most years in 1996-2001 CPUE of small cod in the Eastern-Central part was less variable within a year but changed more over the whole period of observation. In the Northern part the values were more variable within a year but relatively constant over the whole period.

Overall, the spatial distribution of the total and small cod CPUE and length distribution of cod by areas confirm the existing knowledge concerning the features of the temporal and spatial distribution of cod in the Barents Sea and adjacent waters (Nakken and Raknes 1987, Boritsov *et al.* 1994). This study has identified a relatively favourable fishing area between 20° and 26° E longitude on northern side of the NEZ border. A small proportion of the cod less than 45 cm in catches in all seasons there was observed.

The mean length of cod in catches in different seasons in the Northern part is rather higher than in the Eastern-Central part of the sea (Figure 10, Appendix). Changes in mean length of cod in 1996-2001 can be a consequence of two factors: recruitment of the rich year-class of 1995 to the fishable stock in 1998-1999 and/or withdrawal of large cod by the fishery. The recruitment seems more important because 1998 was the only year when the minimum average length was observed in the second half of the year. Results of the small cod CPUE dynamics analyses indicate that at the end of 1998 the majority of cod of the 1995 year-class reached a length to be caught by bottom trawl and influenced the mean length.

A significant relationship between the total and small cod CPUE was found in both areas of the Barents Sea. The small cod CPUE increases with increasing total cod CPUE (Figures 13 and 14, Appendix), but the small cod CPUE is generally higher in the Eastern-Central area than in the Northern part.

The small cod CPUE is also significantly correlated to the mean length of cod in the catches. In the Eastern-Central area as well as in the Northern area the small cod CPUE decreases with increasing of the mean length (Figure 15, Appendix). This relationship was found to be more significant in the Eastern-Central part and can be explained by greater presence of small cod in this area than in the Northern part.

Small cod CPUE in the shallow waters (less 100 m) in the Barents Sea is considerably higher than in deeper waters (Figure 16, Appendix). These shallow waters are located near the Spitsbergen archipelago and Bear Island in the Northern part and in the coastal areas of the EEZ of RF. In all depth ranges in the Eastern-Central area the values of small cod CPUE are higher than in such depths in the Northern area. Therefore, the shallow waters of the EEZ of RF can be considered as most dangerous in terms of possible by-catch and discards of small cod.

The small cod CPUE varies depending on the duration of trawling. The small cod CPUE in the Eastern-Central area is higher than in the Northern area within all ranges of haul duration. The highest values of small cod CPUE were observed in hauls with trawl soaking time less than 2 hours and lowest in hauls performed in 4 and more hours (Figure 17, Appendix). This observation can be explained in two ways. First of all, it may be caused by the fishermen's behaviour. After performing such short trawling (which, as a rule, is a trial) and gathering a plenty of a small cod, fishermen aspire to seek fishing ground less abundant in small cod. A second probable explanation lies in the effect of the selectivity of the net. In the more prolonged hauls many more small fish can escape through the net.

To conclude, it should be emphasised that the Eastern-Central part of the sea, including the EEZ of RF and the "Grey Zone", is the most unfavourable for the fishery with respect to occurrence of by-catches of small fish. Having a choice of operating between the Eastern-Central and the Northern parts, the fishing fleet should preferably work in the Northern part. This can be illustrated by comparing the proportions of total catch of cod and calculated discards taken in different parts of the Barents Sea in 1996-2001. Thus, even in 2000, when the catch of cod in the Eastern-Central part was almost equal to the catch in the Northern part, the portion of discards in the first area was almost 20% higher than in the second (Table 8). In 1998, the worst year in terms of high small cod discards, two thirds of the total catch of cod were taken in the Eastern-Central part of the sea and 84% of the calculated total discards were recorded here.

Table 8: Proportions of total catch and calculated total discards taken in Eastern-Central (EC) and Northern (N) parts of the Barents Sea in 1996-2001, %

Year	Portion of total catch, %		Portion of total discards, %	
	EC	N	EC	N
1996	52.3	23.0	63.8	23.2
1997	50.9	29.2	65.6	28.4
1998	65.6	17.9	84.4	10.8
1999	40.9	33.0	61.7	22.9
2000	34.0	33.9	57.6	38.6
2001	37.3	43.0	54.2	37.4

The proportion of small cod discards calculated by areas for 1996-2001 with different values of $_{DL50}$ and presented in Table 8 is characterized by relatively constancy. But the absolute values of these discards, calculated for different $_{DL50}$ are quite variable with about 4-5 fold difference between years.

It is obvious, that the selection of cod individuals, unsuitable for processing in fishermen opinion, is subjective and depends on many factors (fishing efficiency, minimum landing size, length distribution of fish in the catch, markets *etc.)*. Therefore

it is difficult to precisely determine the value of DL_{50} and consequently also the amount of discarded small cod.

When discarding cod fishermen rely, as a rule, on the minimum landing size (Table 1). Reasoning from that and also taking into account the circumstance that a significant part of catch represented by fish of length 45-50 cm, suitable to be offered for sale, the most likely value of DL_{50} should be at the left side of interval from 40 to 50 cm.

To answer the question which exact value of calculated discards corresponds with reality, there is a need to analyse existing sources of small cod discards in the Barents Sea and adjacent waters. Two publications devoted to an estimation of the small cod discards in the Barents Sea are known (Dingsør 2001, Sokolov 2001). Results obtained by these authors together with numbers of discards estimated in the present work are presented in the Table 9.

Table 9: Number of small cod discarded during Russian bottom trawl cod fishery in Barents Sea and adjacent waters in 1996-2001 according to different sources, mill. sp.

Year	Number of discarded cod, mill. sp.			
	From Dingsør (2001)	From Sokolov (2001)	This work	
			DL_{50}=40 cm	DL_{50}=50 cm
1996	12-15	5	3	23
1997	12-14	9	6	35
1998	8-11	22	14	80
1999	-	11	6	58
2000	-	7	4	33
2001	-	3	3	25

According to Dingsør (2001), the discards in the Russian fishery declined from 1996 to 1998. The opposite trend was observed by Sokolov (2001) and in this study which both showed maximum discards in 1998. The probable reason for this difference is the influence of abundance of recruiting year-classes of cod which has been taken into account by Sokolov and not by Dingsør. The Norwegian author mentioned that “the discard rates are overestimated for the years 1996-1998” because the use of sorting grids has not been taken into consideration. Therefore, it is difficult to compare the obtained results to the results of Dingsør.

The method of small cod discards calculation developed in the present study is different from the method used for such calculations before (Sokolov 2001). Estimated discards using a value of DL_{50} equal to 42 cm correspond most closely to the results obtained earlier, when two knife edge selections of length for discarded cod were used (41 cm and 46 cm) for the freezing and cooling trawlers corresponding to the minimum landing sizes of cod (Table 1). About 90% of the cod are caught by freezing trawlers and the majority of calculated discards come from this group of vessels. It can be taken to support the opinion expressed earlier that the discards of the commercial fish depend on the minimum landing size (Stratiudakis *et al.* 1999).

Table 10: Number of discarded small cod in the Barents Sea and adjacent waters in 1996-2001 separated by areas (A. - Values for 1996-2000 are borrowed from Sokolov (2002), 2001 are calculated by old method; B. - Discards corresponds DL50=42 cm), thou. spec.

Year	Numbers of discarded small cod, thou. spec.							
	Eastern-Central part		Northern part		NEZ		Whole Barents Sea	
	A.	B.	A.	B.	A.	B.	A.	B.
1996	2915	2798	1599	1186	847	651	5362	4635
1997	6320	6000	2602	2275	573	455	9495	8730
1998	18084	18582	2406	2172	1188	965	21678	21719
1999	6547	7122	2045	2053	1925	1377	10518	10552
2000	3952	4159	1567	1770	1359	865	6879	6794
2001	1411	2701	1500	1359	576	543	3487	4603

It seems reasonable to assume that the most likely value of DL_{50} should be closer to 40 than 50 cm. With regard to the minimum landing size of cod for the Russian fishing fleet it is possible to make an assumption, that for all practical purposes (calculation of discards of small cod for stock assessment) between 41 cm and 43 cm values for DL_{50} should be used.

The annual discards of small cod in the Eastern-Central part in 1996-2001, calculated using a selectivity curve are, as a rule, higher than discards computed in accordance with the old method, while discards from the Northern part of the sea and NEZ are little less. It can be explained by the size distribution of cod in different fishing areas. If a considerable portion of fish belongs to the 5 cm length interval above the DL_{50}, as in the Eastern-Central part, the portion of fish discarded will be higher.

Overall, the method of calculation of small cod discards, presented in this report, can be a useful tool for the estimation of the annual discards. The undoubted advantage of this method is a possibility to model discards based on the different inputs. It can also be used for the calculation of discards for a period for which cod length measurements data exist. At the same time, there is a need for further investigations concerning the finding of the real DL_{50} and slopes of the selectivity curves which can be different between seasons and fishing areas.

6 CONCLUSION

The analysis of the Russian fleet CPUE in 1996-2001 has shown that the key areas are the Spitsbergen area, “Grey Zone” and EEZ of RF. In these years the cod fishery in the Northern area was more productive than in the Eastern-Central.

The spatial distribution of small cod CPUE and its seasonal dynamics these years correspond to the changes in spatial distribution of total cod CPUE.

Small cod are more concentrated in the Eastern-Central area, including the EEZ of RF and the “Grey Zone”, and, as consequence, discards are likely to be greater there than in the Northern area. Relatively low presence of small cod was also found in the some fishing grounds in the Spitsbergen area.

The small cod CPUE as a characteristic of suspected discards, was found dependant on various factors, such as total cod CPUE, mean length of cod in catches, depth and duration of trawling.

Annual discards in 1996-2001 during the Russian cod fishery were in the range 3 to 80 million fish depending on the value of $DL50.$ For practical purposes this value is assumed to be between 41 and 43 cm, resulting in discards of 4 to 22 million cod.

The discards are found to be related to the cod mean length, abundance of three years old cod and the total cod catch in different areas of the Barents Sea.

There is a need for further investigations concerning the actual value of $DL50$ and slopes of the selectivity curves which can be different by seasons and fishing areas.

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APPENDIX

FIGURES

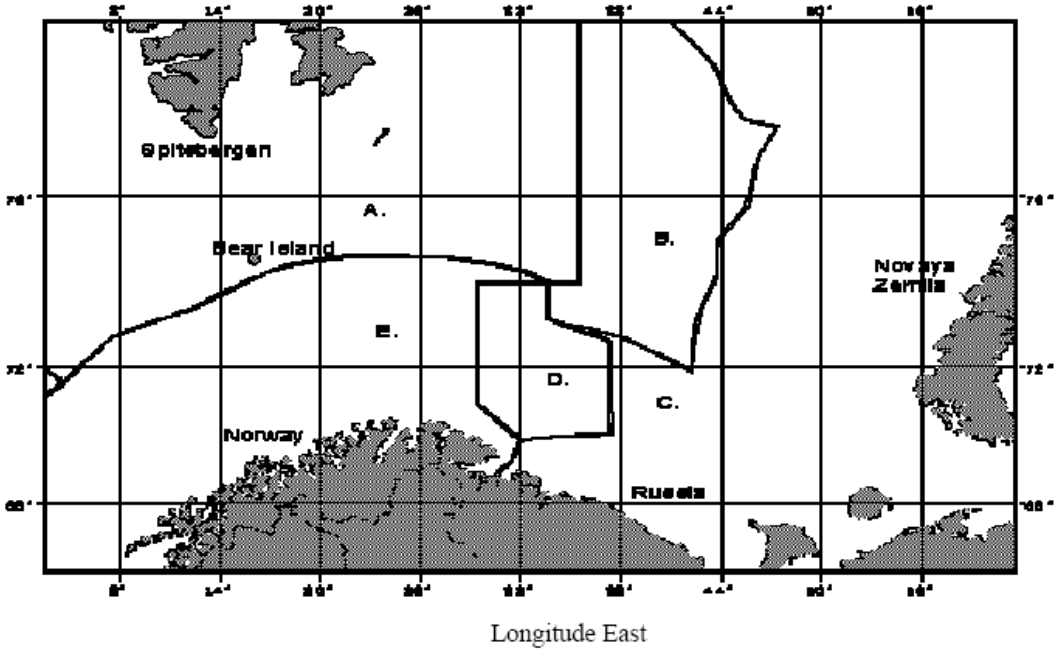

Figure 1. Division of the Barents and Norwegian Seas into national and international zones

A – area under the Spitsbergen Treaty of 1920
B – area outside economic zones of Russia and Norway (Enclave)
C – exclusive economic zone of the Russian Federation
D – area of joint fisheries between Russia and Norway ("Grey Zone")
E – exclusive economic zone of Norway

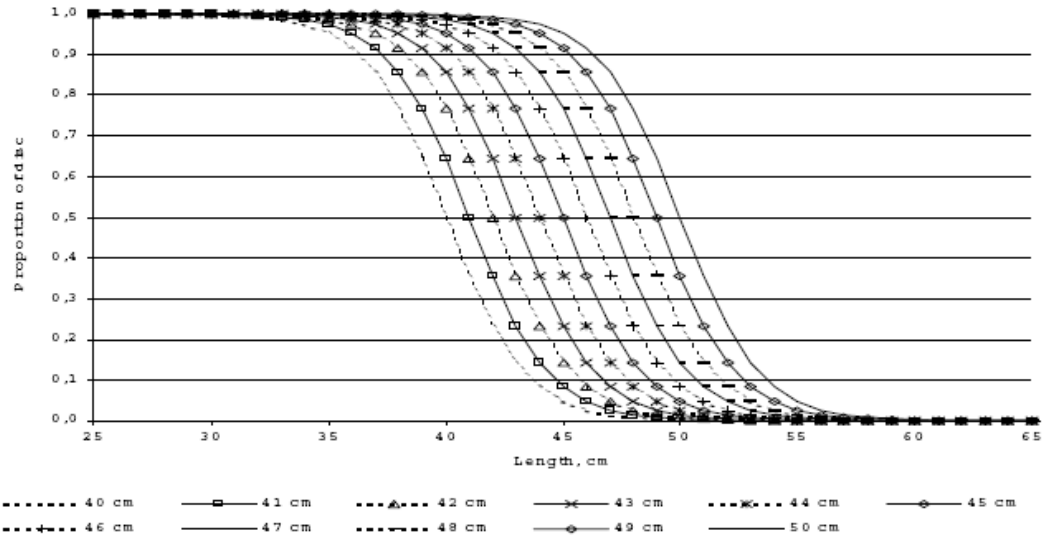

Figure 2. Set of logistic curves of the proportion of fish discareded by length for different values of DL_{50}.

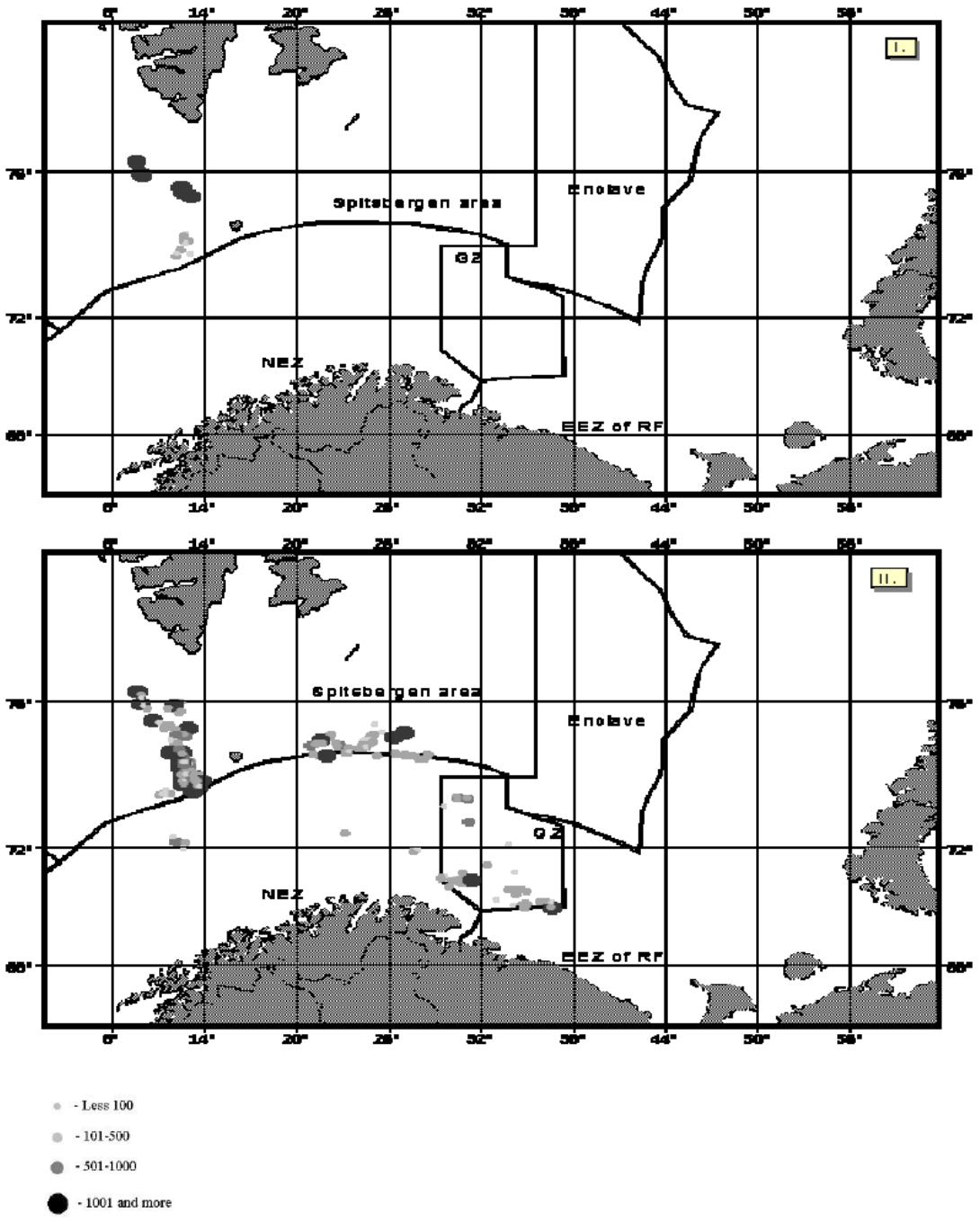

Figure 3. Catch of cod per 1 hour of bottom trawling in 1999 by quarters (numbers per 1 hour of trawling).

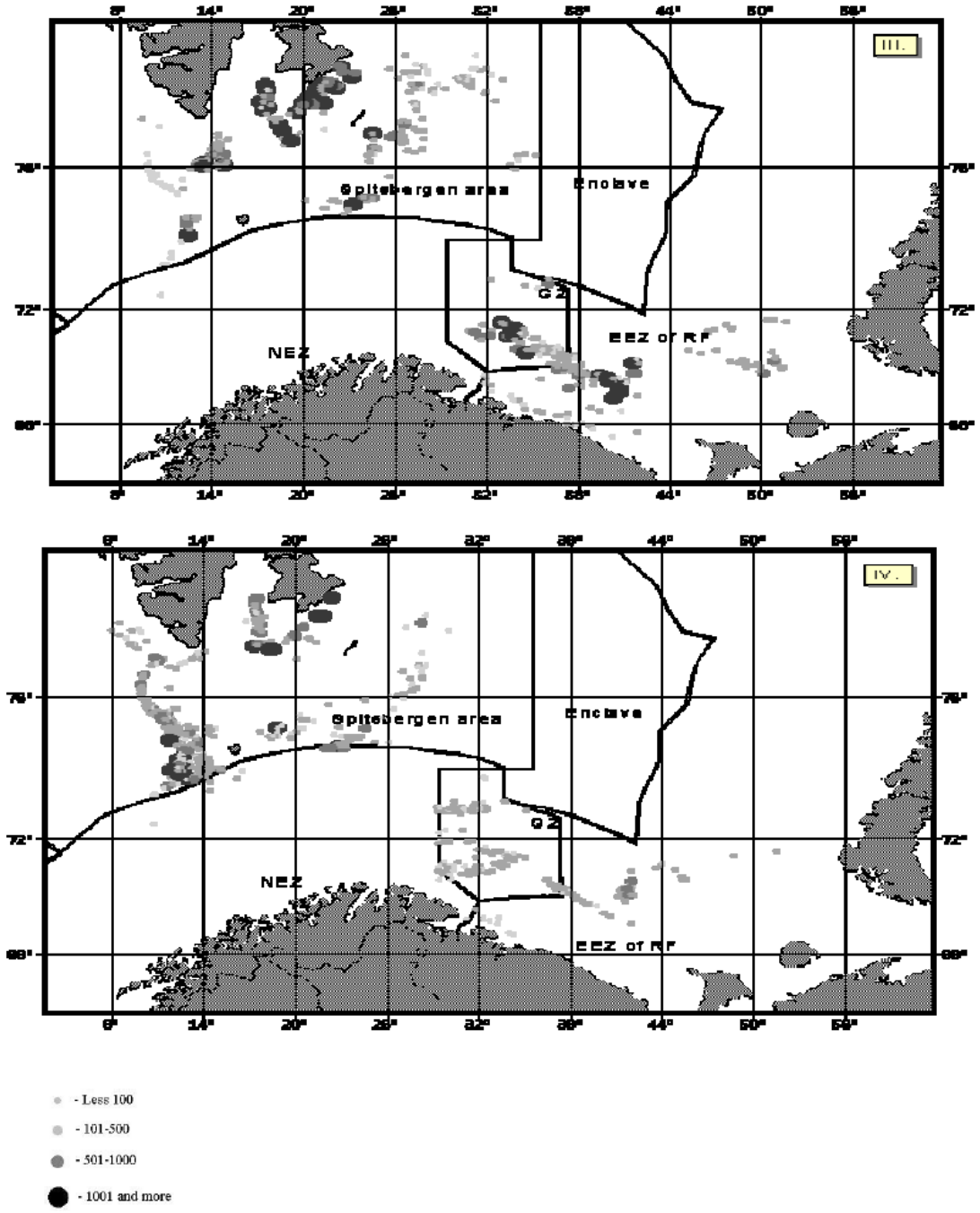

Figure 3 (Continued). Catch of cod per 1 hour of bottom trawling in 1999 by quarters (numbers per 1 hour of trawling.

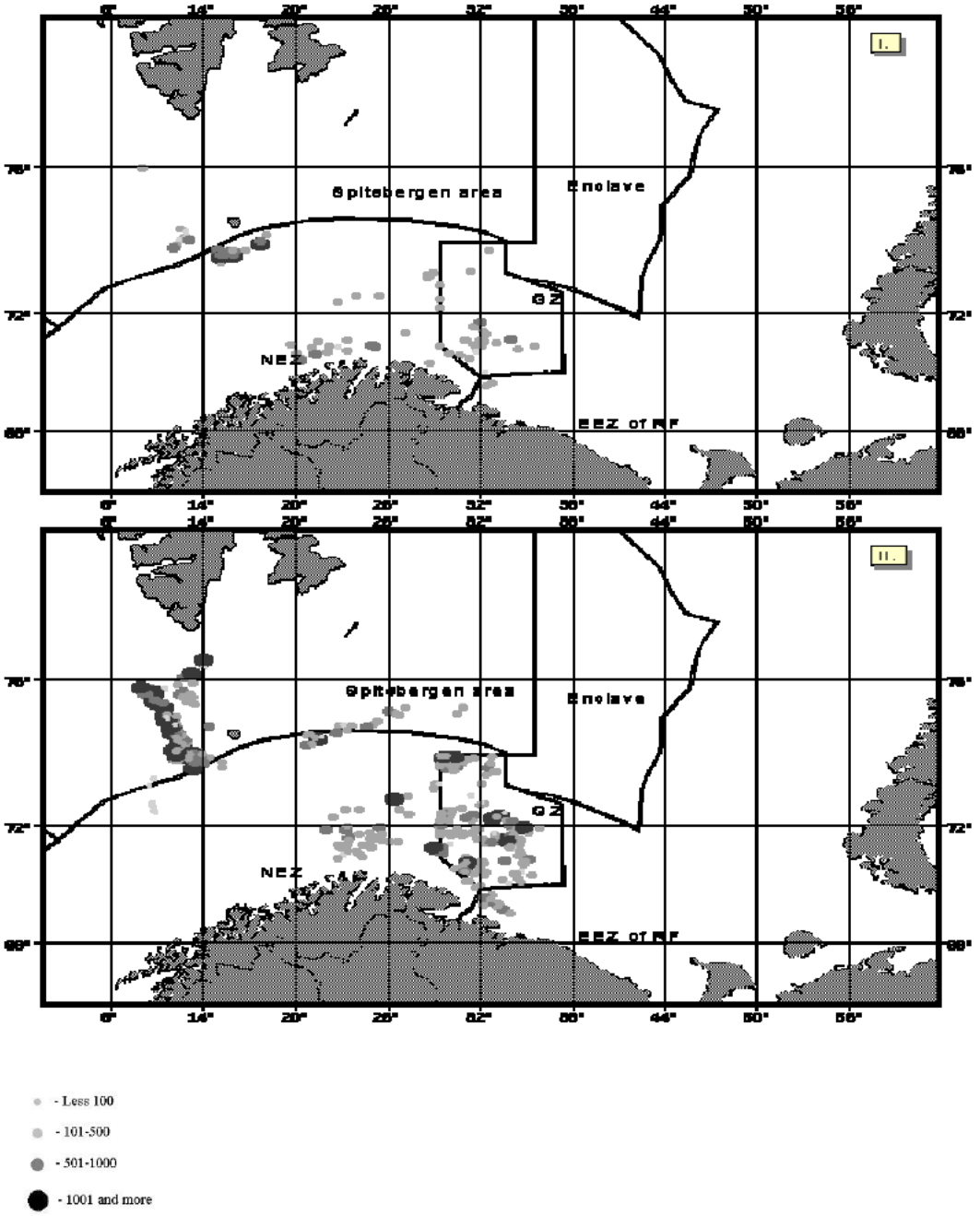

Figure 4. Catch of cod per 1 hour of bottom trawling in 2000 by quarters (numbers per 1 hour).

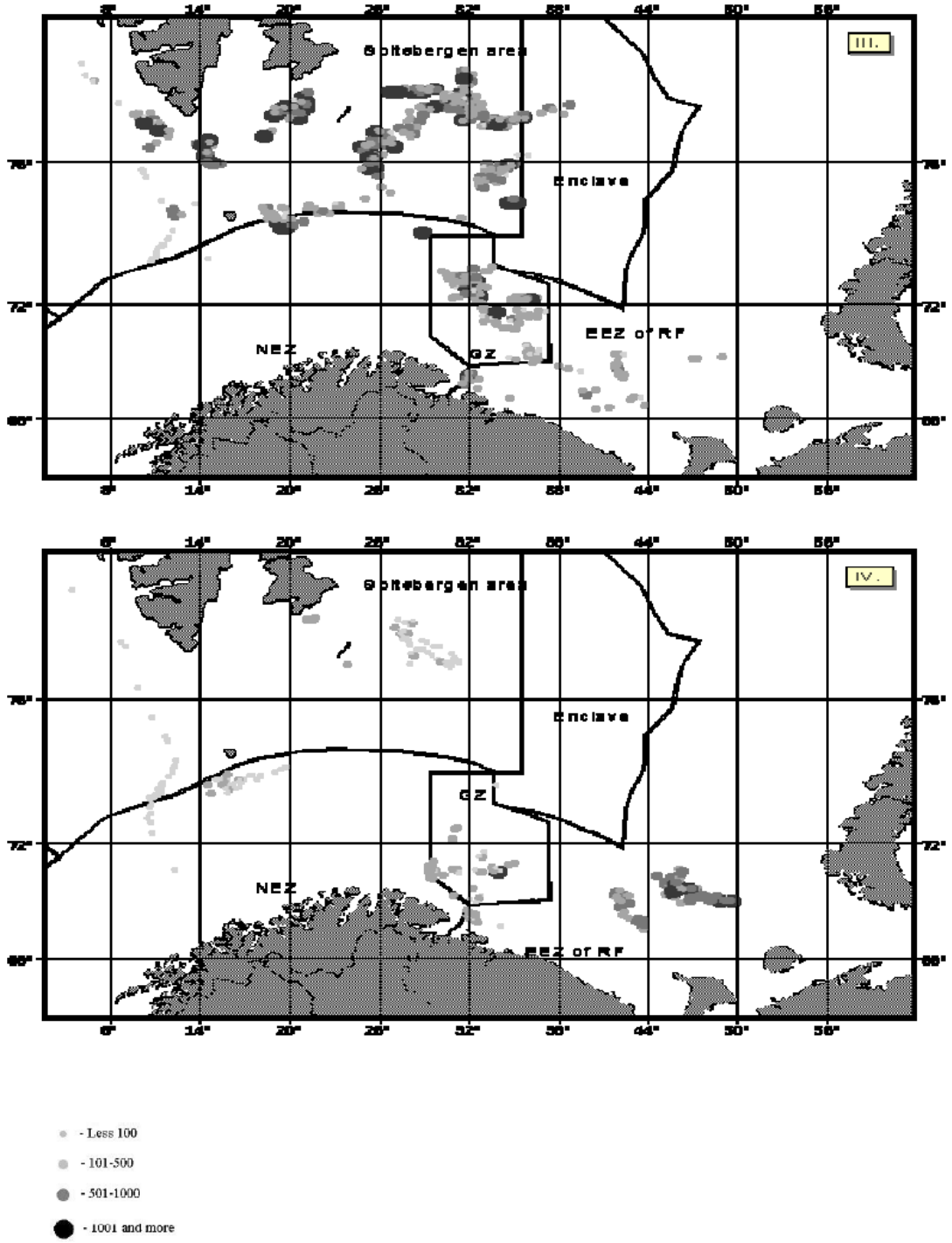

Figure 4 (Continued). Catch of cod per 1 hour of bottom trawling in 2000 by quarters (numbers per 1 hour).

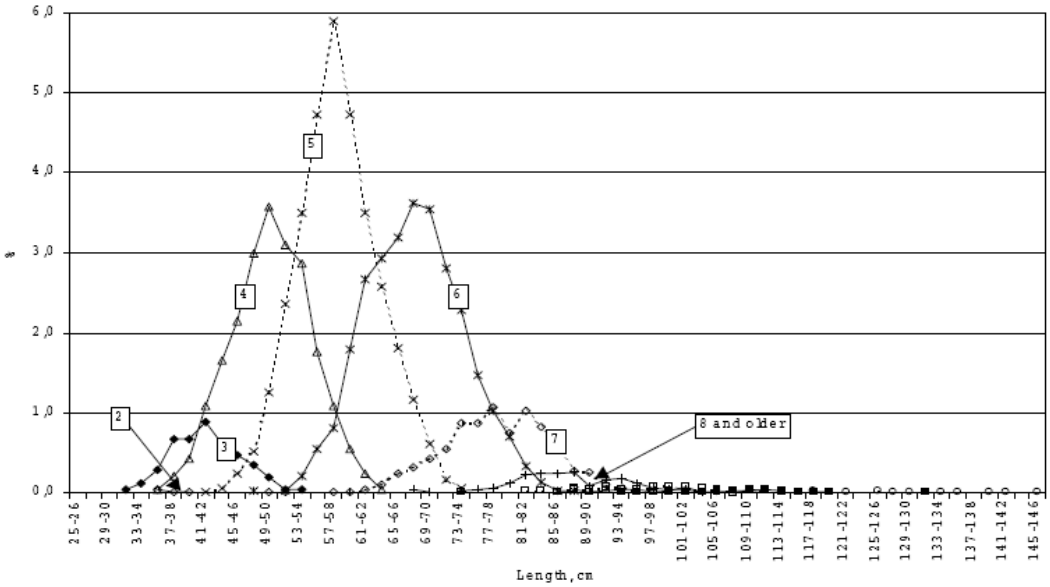

Figure 5. Age distribution of the cod from Rusian bottom trawl catches in 1996-2001, numbers correspond ages.

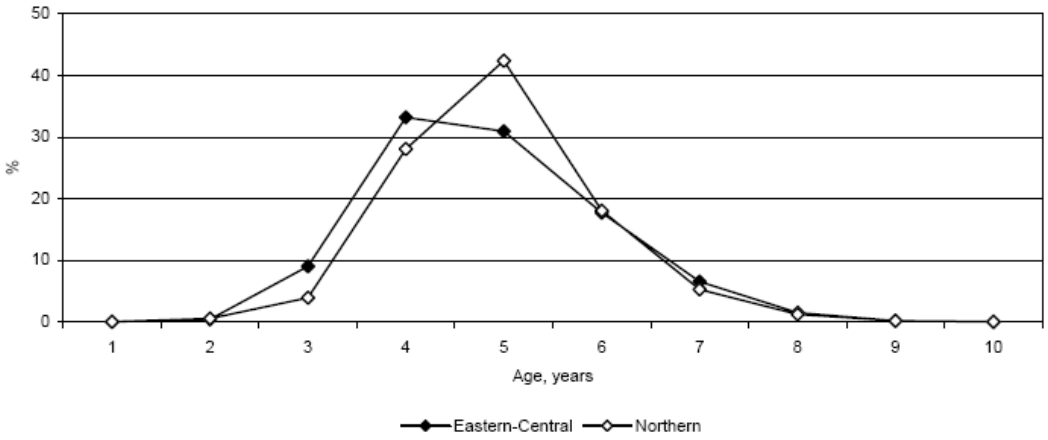

Figure 6. Age distribution of cod from the Russian trawl catches from Eastern-Central and Northern parts of the Barents Sea in 1996-2001.

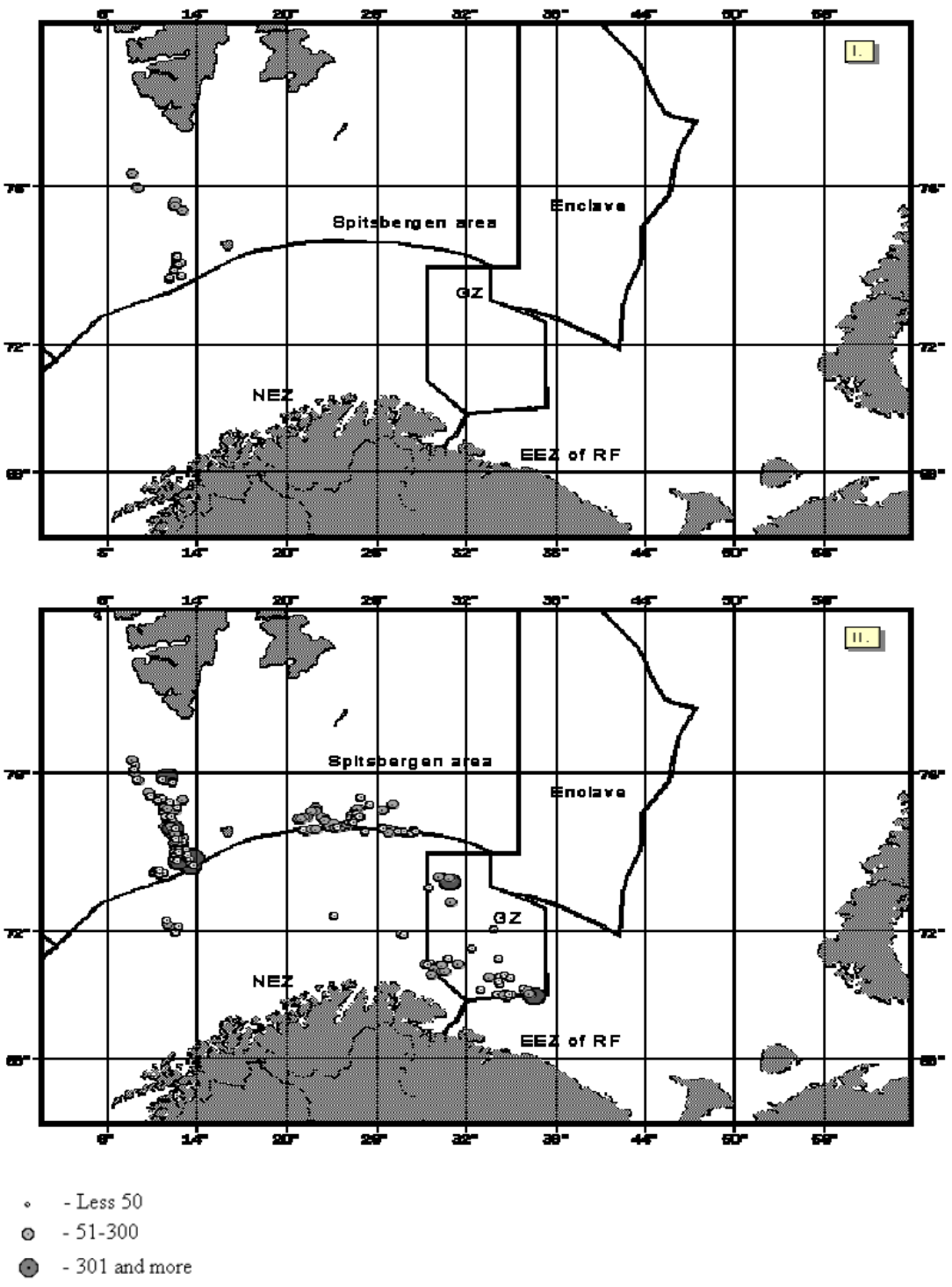

Figure 7. Catch of small cod (less than 45 cm) per 1 hour of bottom trawling in 1999 by quarters (numbers per 1 hour).

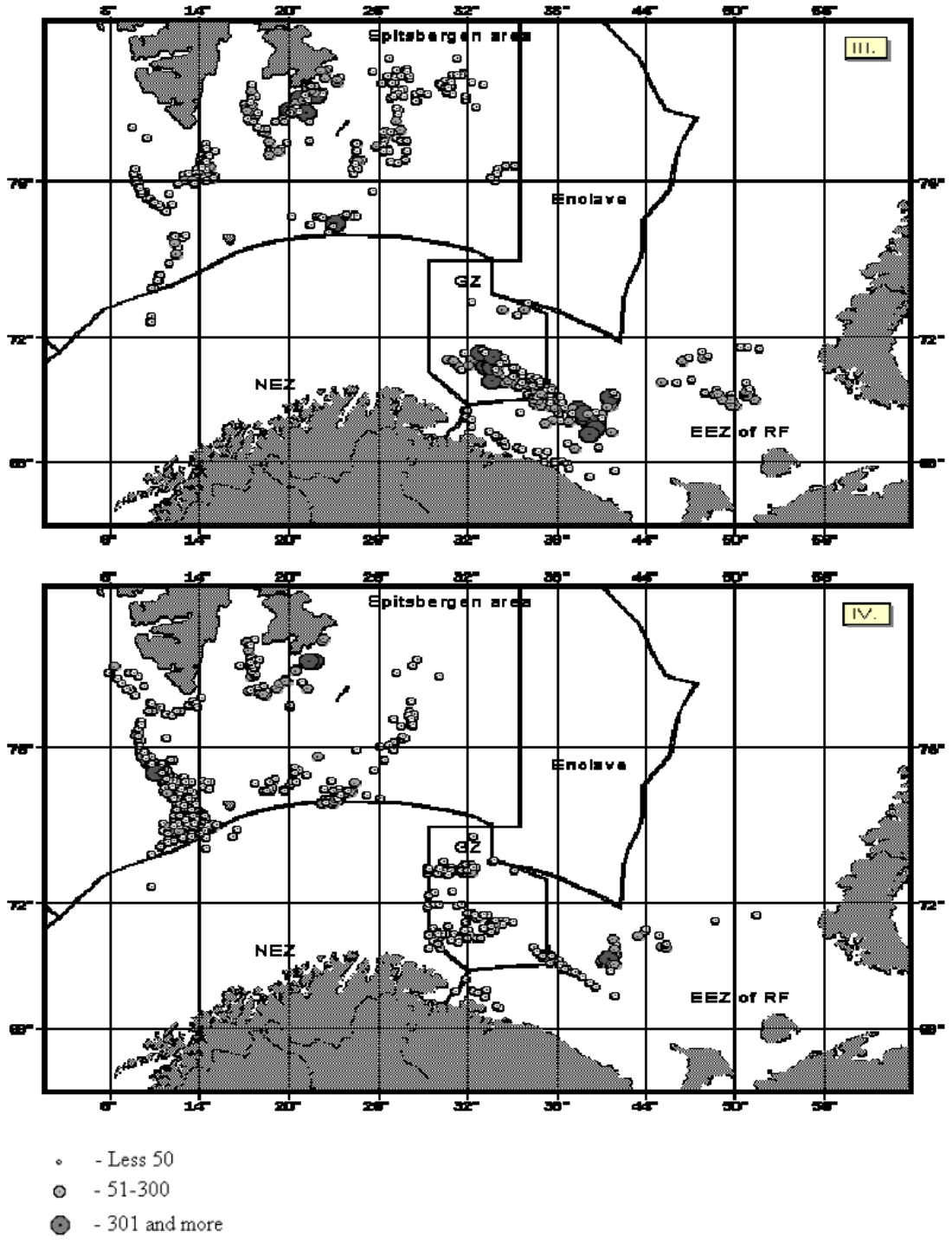

Figure 7 (Continued). Catch of small cod (less than 45 cm) per 1 hour of bottom trawling in 1999 by quarters (numbers per 1 hour).

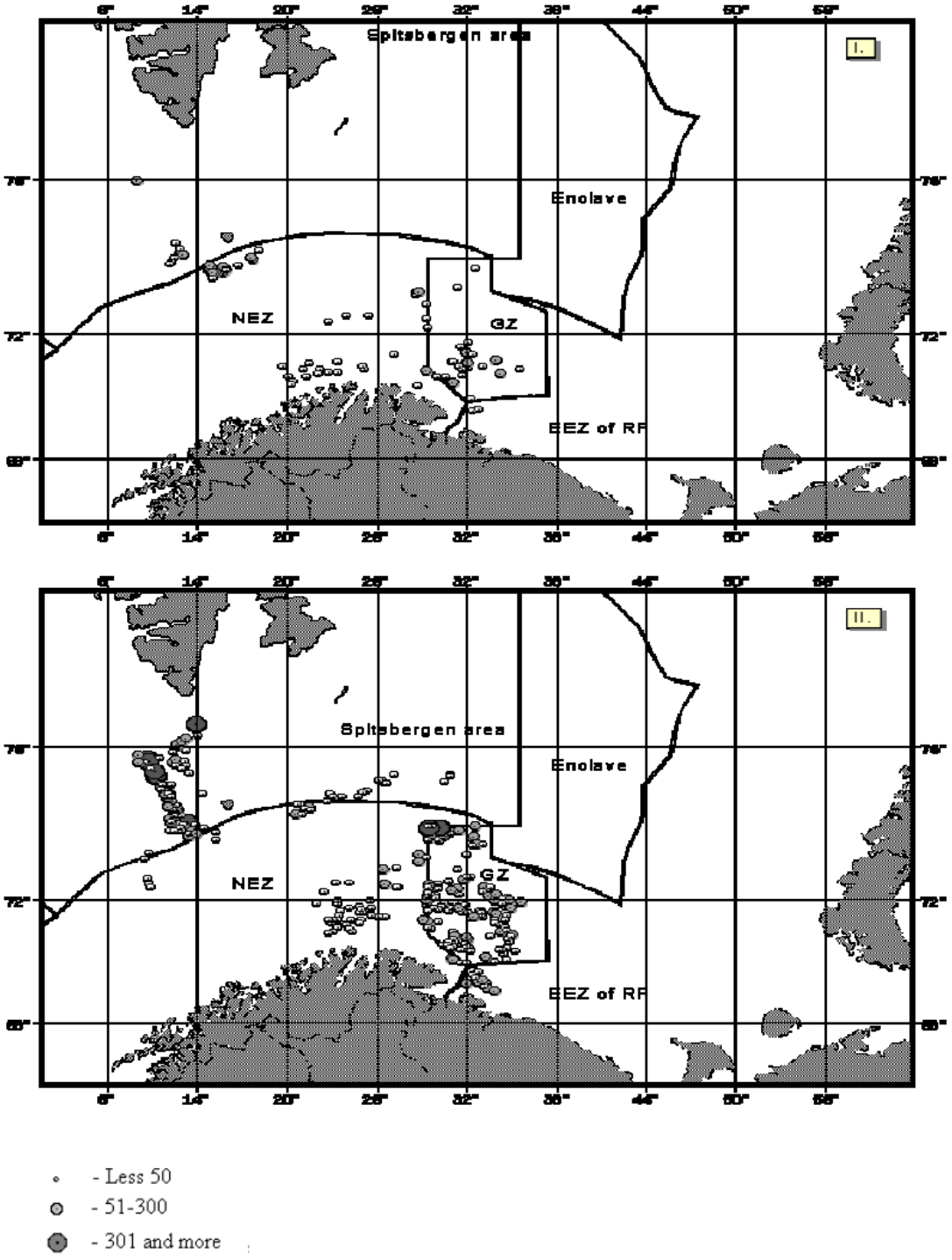

Figure 8. Catch of small cod (less than 45 cm) per 1 hour of bottom trawling in 2000 by quarters (numbers per 1 hour).

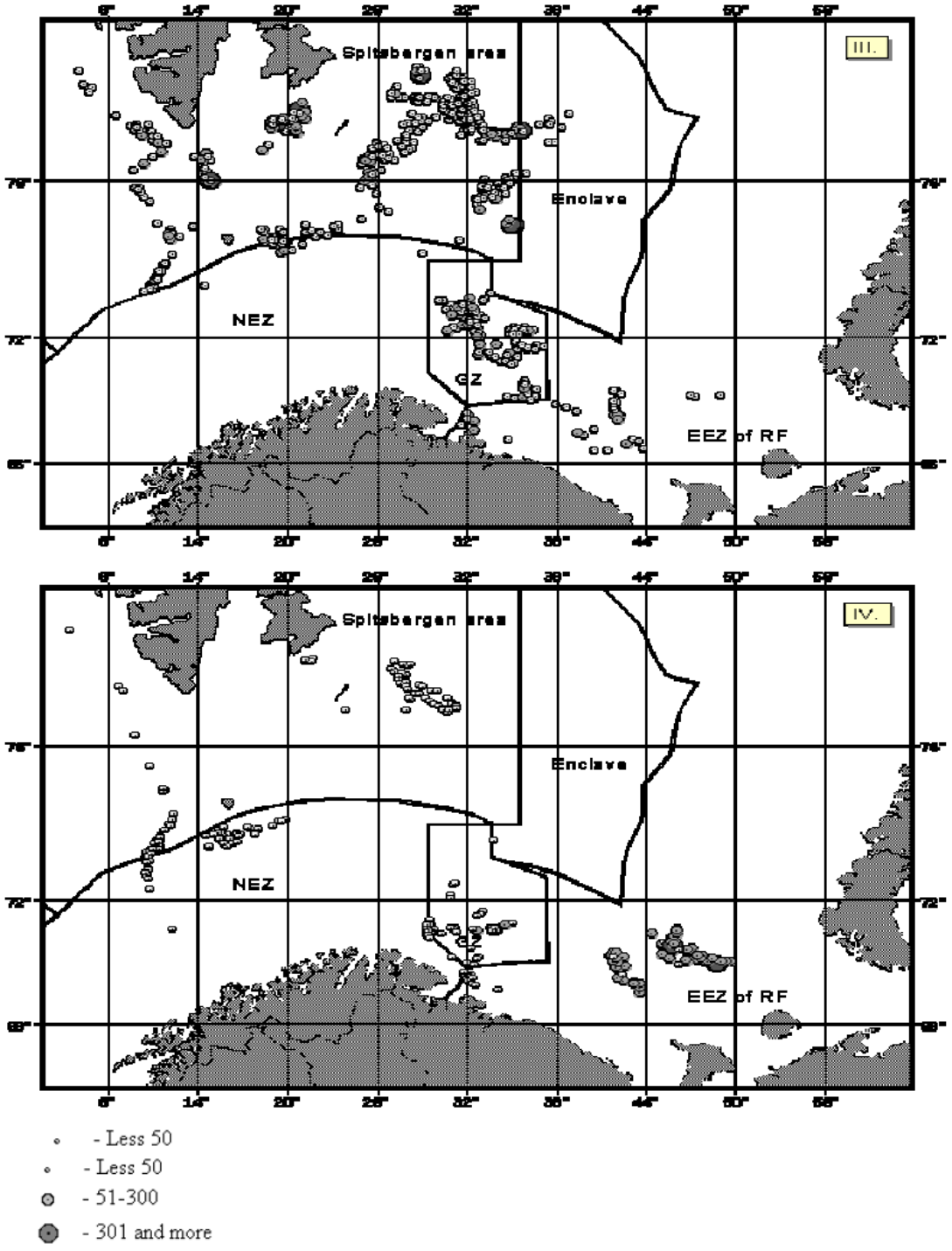

Figure 8. (Continued). Catch of small cod (less than 45 cm) per 1 hour of bottom trawling in 2000 by quarters (numbers per 1 hour).

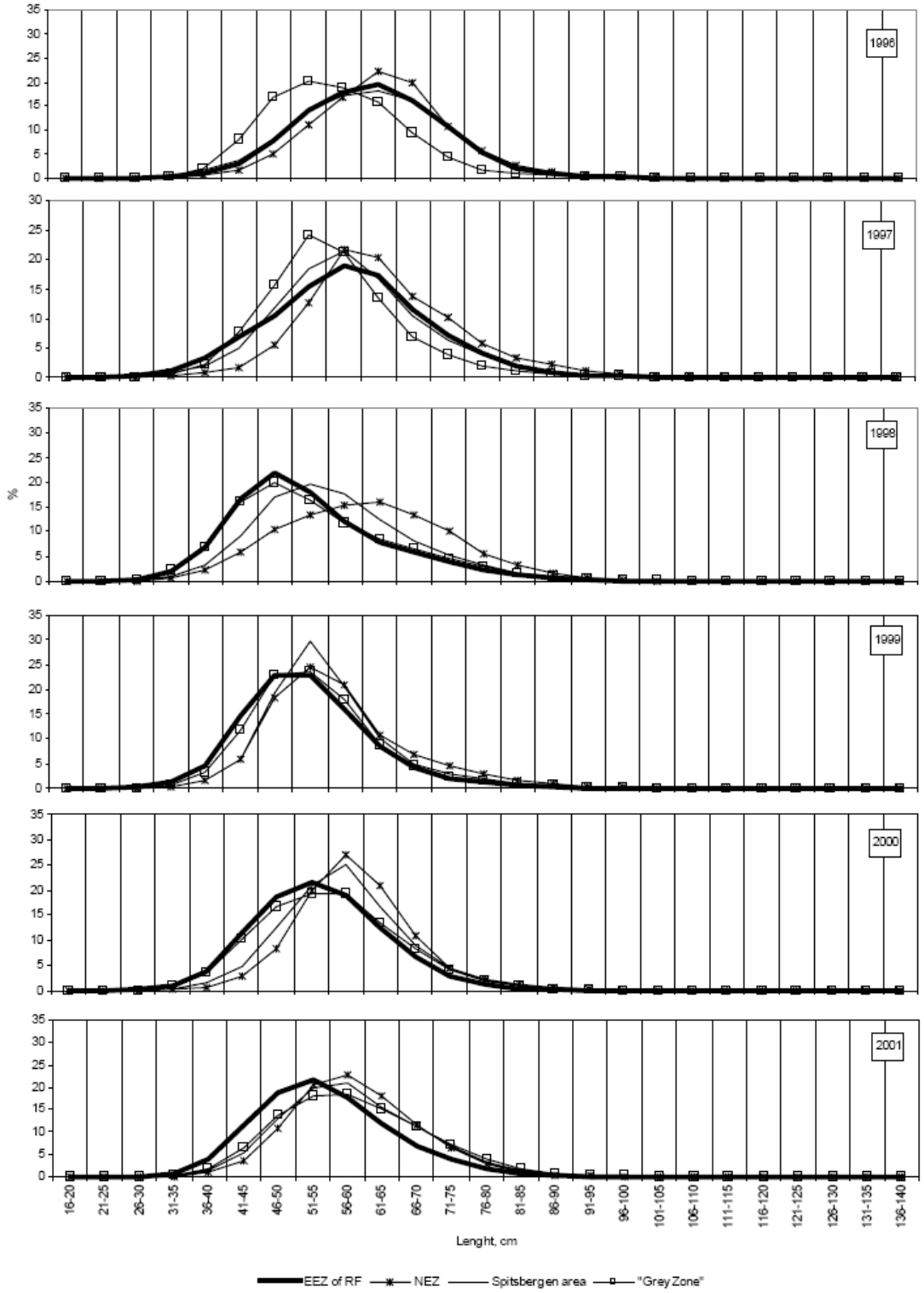

Figure 9. Length distribution of the cod from Russian bottom trawl catches in the Barents Sea and adjacent waters in 1996-2001 by national and international zones.

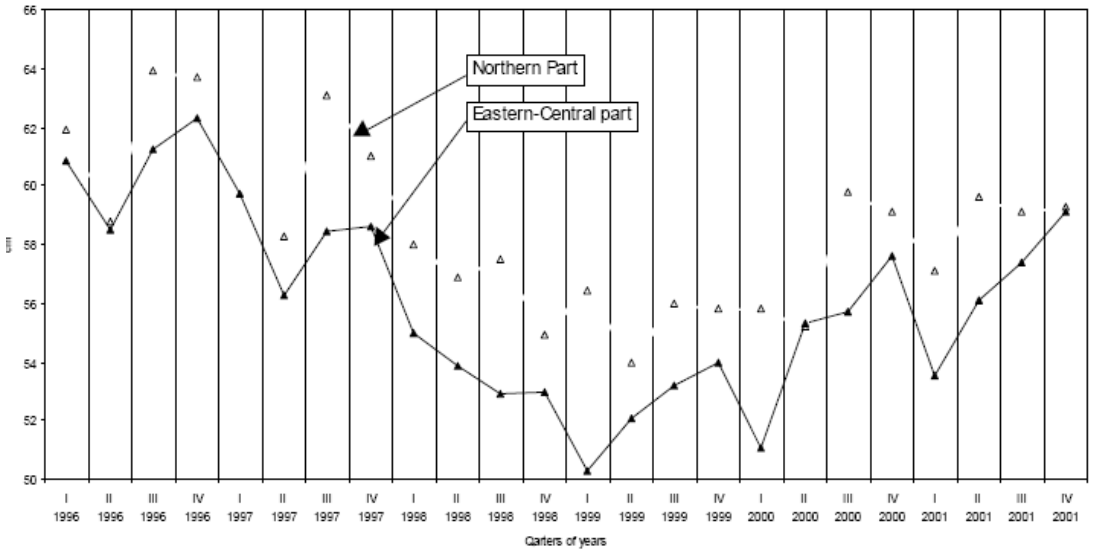

Figure 10. Temporal changes in the mean length of the cod in catches from the Eastern-Central and Northern parts of the Barents Sea in 1996-2001.

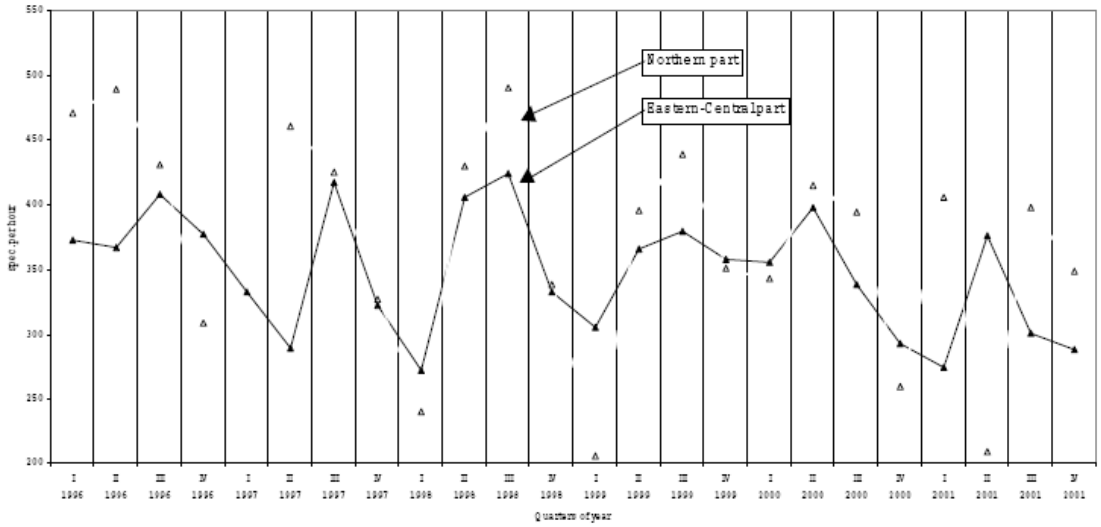

Figure 11. Temporal changes in the total cod CPUE in the different parts of the Barents Sea in 1996-2001.

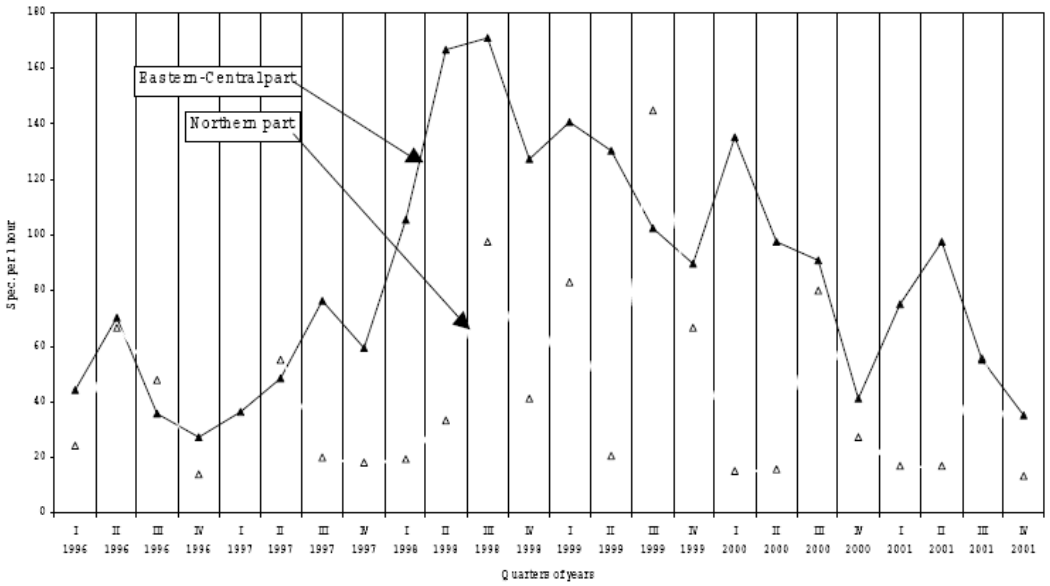

Figure 12. Dynamic of the CPUE of small cod in the Eastern-Central and Northern parts of the Barents Sea in 1996-2001, spec. per 1 hour of bottom trawling.

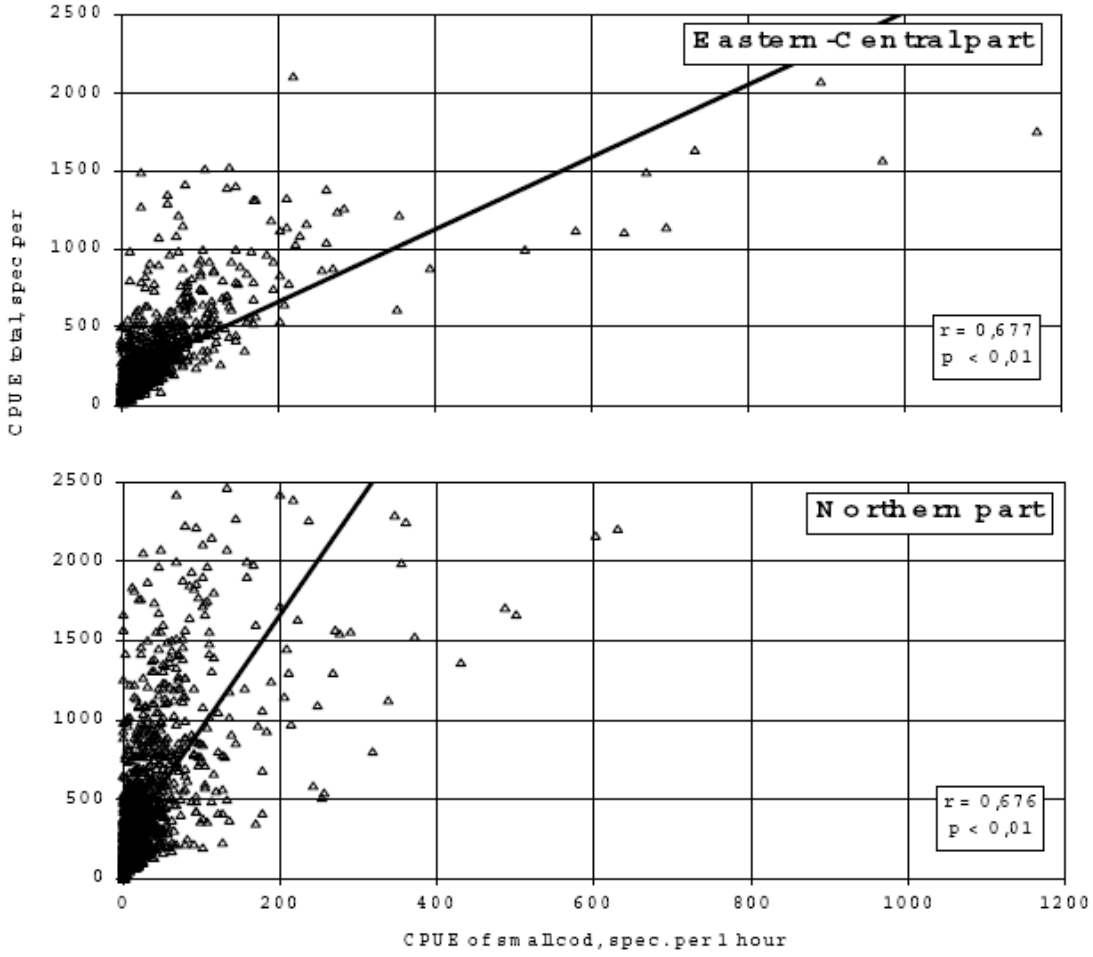

Figure 13. The total CPUE of cod in 1999-2000 plotted against CPUE of small cod in the Eastern-Central and Northern parts of the Barents Sea. Solid lines represent linear regressions. The Pearson correlation coefficient and significance levels are shown in frames.

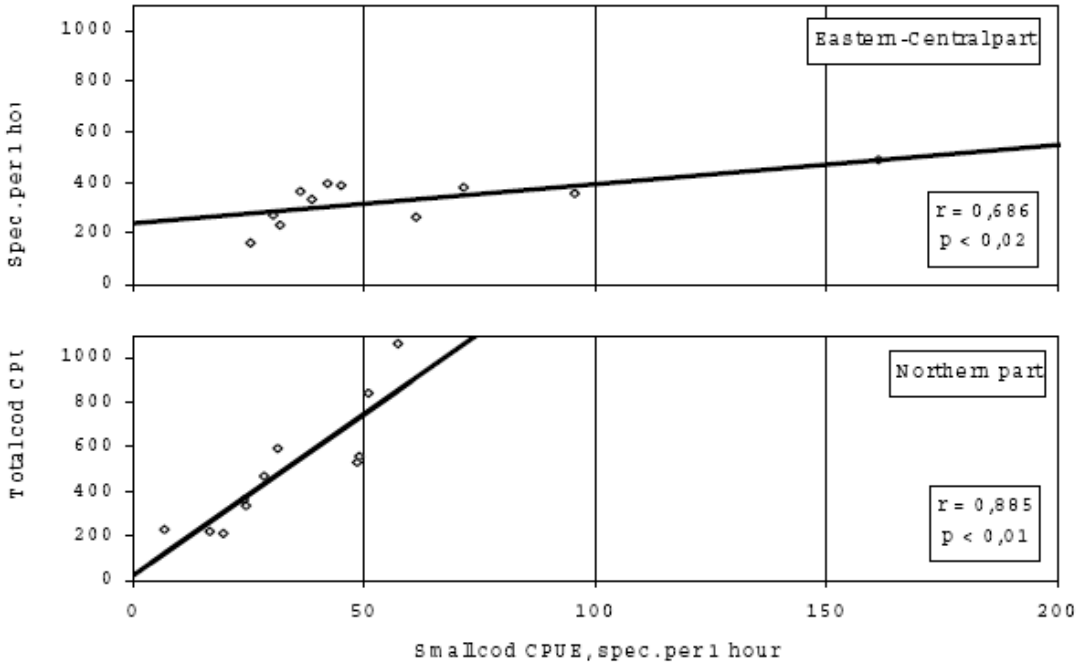

Figure 14. The average monthly values of the total CPUE of cod in 1999-2000 plotted against CPUE of small cod in the Eastern-Central and Northern parts of the Barents Sea. Solid lines represent linear regressions. The Pearson correlation coefficient and significance levels are shown in frames.

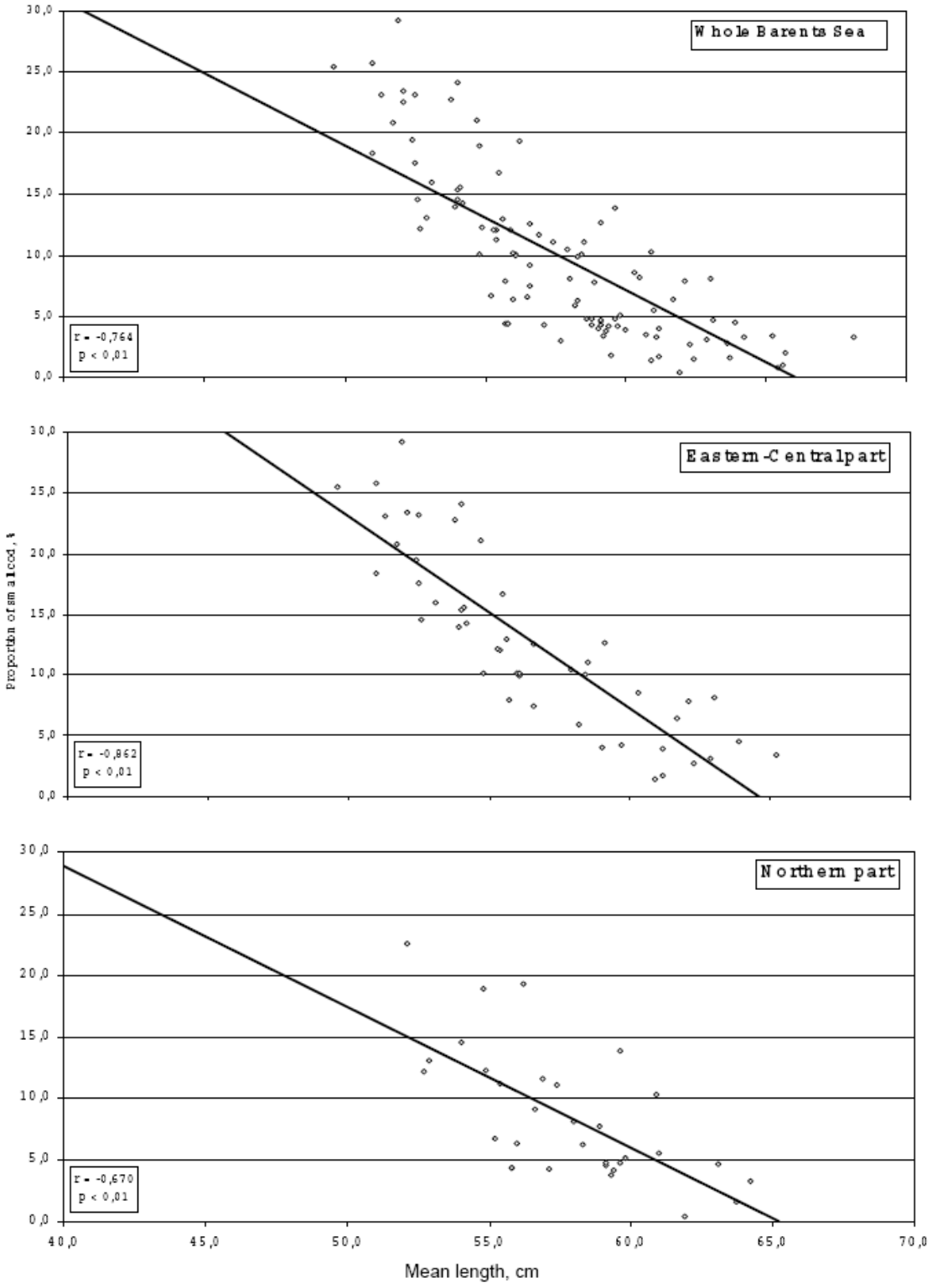

Figure 15. The mean length of the cod in different seasons in 1996-2001 plotted against the proportion of small cod in the Whole Barents Sea, Eastern-Central (EEZ of RF and "Grey Zone") and Northern (Sptisbergen area and Enclave) parts. Solid lines represent the linear regressions. The Pearson correlation coefficient and significance levels are shown in frames.

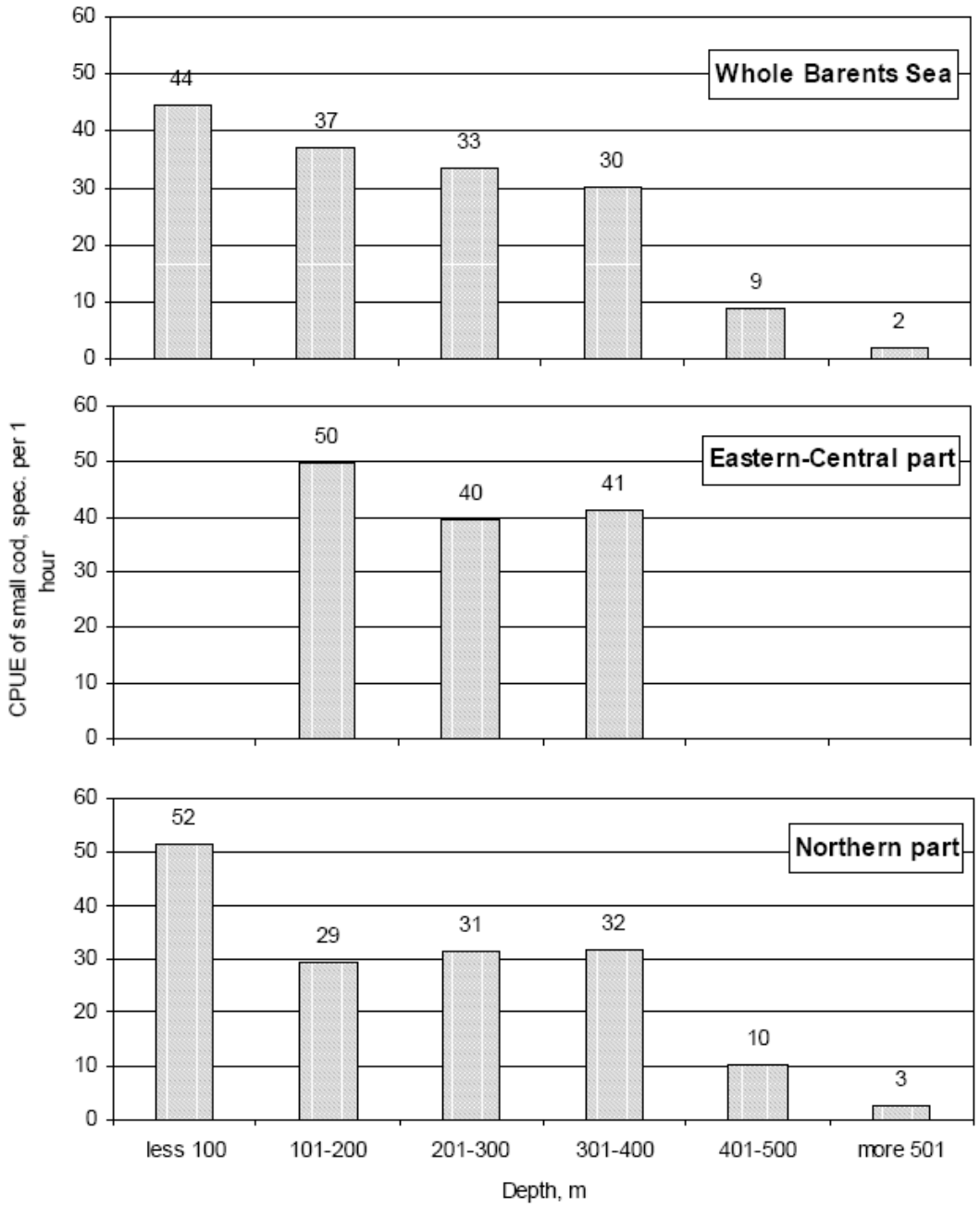

Figure 16. Average CPUE of small cod (specimens per 1 hour of trawling) in catches taken in different depths; A. – The whole Barents Sea; B.-Eastern-central area; C. Northern area.

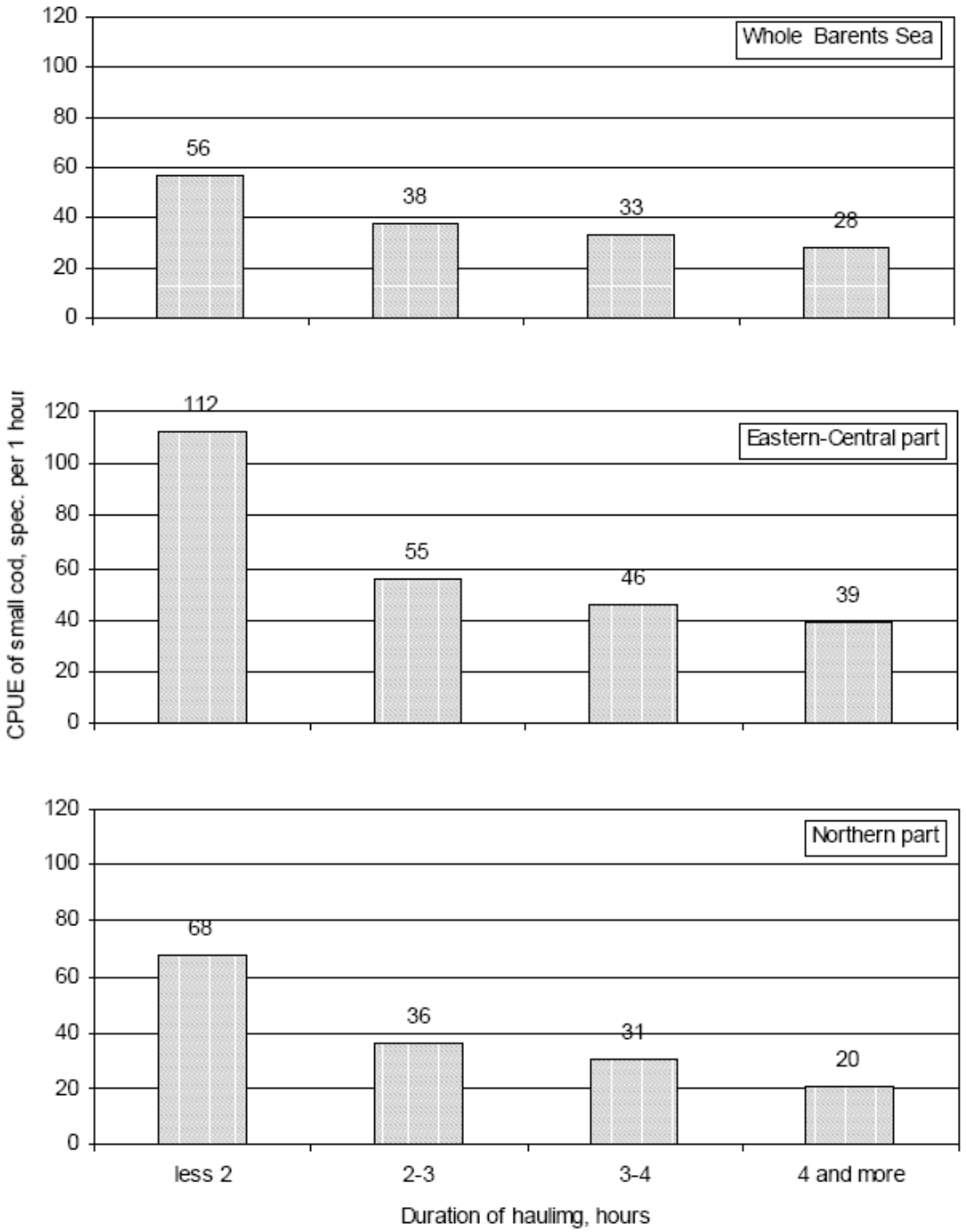

Figure 17. Average values of the CPUE of small cod (specimens per 1 hour of trawling) in the whole Barents Sea, the Eastern-Central and Northern areas, separated by the range of duration of hauling.

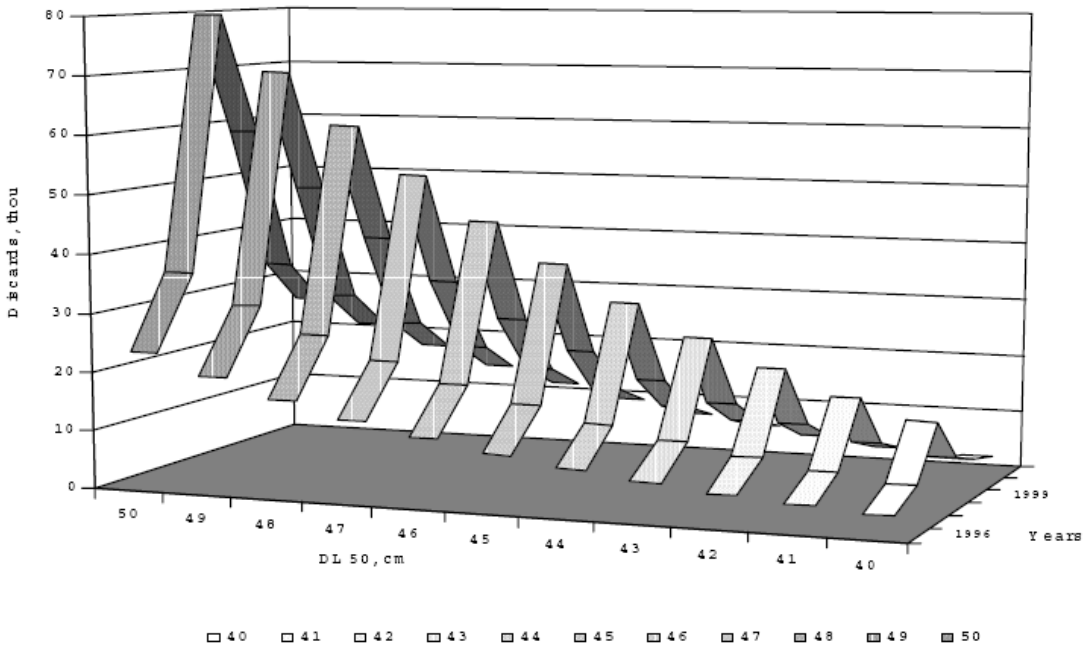

Figure 18. Number of small cod discarded in 1996-2001 during Russian trawl fishery calculated with different values of DL_{50}.