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Reproduction areas of the cod stock in the western Baltic Sea

by

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Abstract

Analyses of the previous years showed that the reproduction of the Belt Sea cod stock (*Gadus morhua morhua*) is also very important for the cod stock of the central Baltic Sea (*Gadus morhua calarias).* Oeberst (1999, 2000) proved, that between 20 % and 50 % of the cods caught in the Bomholm Sea with age of 2 or 3 years between 1994 and 1998, were spawned in the Belt Sea. On account of this large significance of the Belt Sea cod stock information regarding the reproduction process are important.
In the last years extensive investigations concerning different aspect of the reproduction process of the Belt Sea cod were carried out by the Institute of Baltic Fishery, in Rostock. In addition to analyses to the maturity development, to the timing of spawning and to the quality of the cod eggs it was proved that the strength of a new year class is determined essentially by the portion of the active female spawners in the dominant length range of the spawning stock.
The goal of the article presented is the description of the actual spawning areas of the Belt Sea cod stock by means of the spatial distribution of the spawners based on characteristic parameters as the maturity stages and the proportion of the sexes. The inclusion of hydrographical parameters makes it possible to describe the conditions for the spawning activities. Additional information are given regarding the smallest length of maturity for both sexes and the maturity ogive.

The basis for these analyses are data sampled between 1992 and 1999. During the period from February to June, the period of the reproduction activities of the Belt Sea cod stock, altogether 31 194 individuals were caught and analysed.

The analyses showed that the actual main spawning areas in the western Baltic Sea were the deeper regions of the Kiel Bay, of the Fehmarn Bay and of the Mecklenburg Bay. In these regions spawning cods were regularly observed with high intensity. Furthermore, the deeper basin of the Arkona Sea is an important spawning area.

Key words. Baltic Sea, Belt Sea, cod, reproduction, spawning area, gonadosomatic index

Introduction

The Baltic Sea is brackish water and is characterized by specific hydrographical conditions, The salinity decreases from more than 22 PSU in Kiel Bay until about 8 PSU in the Gotland area. These hydrographical conditions require specific adaptations from the organisms which living there. This is valid specially for cod which live on the boundaries of its possible distribution area. Small fluctuations of the hydrographical conditions can lead to great changes in the reproduction success of the cod stocks. Particularly the early life stages, as eggs and larvae, react very sensitively regarding changes of the environmental conditions.
The Belt Sea which is located in the western part of the Baltic Sea (Wattenberg 1949, HELCOM 2000) is a transition zone between the Rattegat and the Baltic proper. This area is characterized by a high dynamics of the hydrographical processes and is the main area of distribution of the Belt Sea cod (Gadus morhua morhua).
The Belt Sea passes into the Arkona Sea, the first basin of the Baltic proper. The Arkona Sea is a region which is settled in by both cod stocks, the Belt Sea cod and the cod stock of the central Baltic (Gadus morhua callarias) (Bemer 1981, Bagge et al 1994, Müller 1994, Oeberst 1999).
The management of the exploited cod stocks requires an exact knowledge of the condition for a successful reproduction. If such knowledge is not available, the influence of biological and environmental factors regarding the variability of the reproductive success and the new year class strength can not be assessed with high accuracy (Hutchings et al. 1993).
Following this intention extensive analyses were carried out regarding the reproduction of the Belt Sea cod in the western Baltic Sea and in adjacent areas between 1992 and 1999. Analyses of the previous years showed that the reproduction of the western Baltic cod stock is not only important to the management of this stock. Oeberst (2000) showed that about 30% of the cod of the age group 2 and 3 in the eastern Baltic Sea were spawned in the western Baltic Sea

The actual knowledge regarding the timing of spawning, the spawning areas and the reproduction success of the central Baltic cod stock is extensively documented in various publications (Graumann 1974, Wieland et al. 1997, Anon. 1998, MacKenzie et al. 2000, Aro 2000). In contrast to this, newer information are not available concerning reproduction areas of the Belt Sea cod. Since the middle of the eighties investigations had not been carried out.
Various methods were used for describing the location of the spawning areas. Several authors (Kändler 1944, Graumann 1974, Müller et al. 1974; 1977, Bagge et al. 1977; 1994, Brandner 1994, Wieland 1995, Wieland et al. 1996, 1997) used ichtyoplankton surveys for describing the areas of spawning. The eggs sampled were separated regarding the development stages and then the occurrence of stage I eggs which were less than 3 days old (Thompson et.al. 198 1) were used for definition of the spawning areas.
Another method for locating the areas of spawning activities was used by Kändler (1944), Berner (1960, 1981), Birjukov (1970), Thurow (1970), Hutchings et al. (1993), Myers et al. 1993, Baranova (1995). They analysed the occurrence of potential spawners using the stages of maturity and the sex ratio. The regions with concentrations of male and female individuals with a maturity stage between 5 and 7 (see Table 2) were defined as spawning areas.

Since the western Baltic Sea, the area under investigations, is significantly influenced by high wind forces and inflow events, it must be assumed that the distribution patterns of the eggs can produce false interpretations of the spawning areas Therefore, the distribution of matured cods was used for this analyses

The goal of the paper is the location of the different spawning places of cod in the western Baltic Sea. **The** results were compared with previous observations in the same region (Kändler 1944, Bemer 1960, 1985 and Thurow 1970). Furthermore, **the** hydrographical conditions for the occurrence of cods with maturity stages 6 or 7 were analysed Additionally it was analyses whether the hydrographical situations during the spawning periods were suitable for the successful development of the spawned eggs or sometimes the hydrographical conditions did not allow a fertilization and development of the cod eggs.

Material and Methods

Surveys were carried out in different parts of the Baltic Sea for determining the areas of spawning activities of the western Baltic cod stock. Figure 1 presents the Baltic Sea with the ICES subdivisions (SD) **and** the area under investigation in **a** special map. In this part of Figure 1 the 40 m depth line is included, too. The surveys were concentrated in the Kiel Bay and in the Mecklenburg Bay (SD 22), as well as in the Arkona Sea (SD 24). Additional investigations have been carried out in the adjacent areas Bornholm Sea (SD 25) and in the Kattegat (SD 21) since 1996. The sampling program was design in such form that the main parts of the distribution area of **the** western Baltic cod stock were covered.
The stations were carried out in areas with a water depth of more than 7 m determined by the vessels used. Furthermore, demersal hauls were not available within the Danish **and** Swedish national zones of 3 nautical miles
The analyses included data of the period between 1992 and 1999. For the description of the spawning areas those databases were analyses which were already used for other investigations. The data of the periods between February and June were included in the analyses. During this period spawning activities were proved in the western Baltic Sea (Bleil et al. 1997, Oeberst et al, 1999, 2000). However, the densities of the samples were different in the several months. The focuses of **the** data sampling were the month **March,** as well as the period between end of May and beginning of June. During the other periods data could be sampled only with low intensity. Table 1 summarizes the number of cods analysed separated for years, months, areas and sexes.
The hauls were carried out with the research cutters "Solea" and "Clupea". Additionally data were used from commercial catches.
The analyses of the biological samples were carried out using the routine method of the Institute of Baltic Fishery, in Rostock. All parameters were measured by fresh fish. The following parameters were used during these analyses:
-total length
- whole weight
- age
- sex
- maturity stage

The determination of the maturity stages (MS) was carried out macroscopically using the 8 index scale of Maier (1908) revised by Bemer (1960). The description of the maturity stages is given in Table 2 Altogether 3 1 194 cods were analysed. The total length of the individuals varied between 10 cm and 116 cm, the age range from 1 to 8 years. The hydrographical parameters temperature (°C) and salinity (PSU) were sampled after each haul with the research vessel in the total water column using a CTD memory probe. Besides these parameters the **oxygen** saturation (percentage) was measured if possible For describing the spawning areas only **those** values close to the bottom were used.

The reproductive status of the male and female cods applied for the separation between the spawning areas and the surrounding regions. During the analyses maturity stages 6 and 7, cods with running sex products, were defined as reproductive status. The occurrence of at least one individual with reproductive status was applied for describing the area of spawning activities. For the definition of the main spawning areas two parameters were used. The first criterion was the catch of more than 10 individuals per catch hour with running sex products. Additionally it was required that the portion of male cods was higher than 70%. Since the goal of this paper is a more generalized description of the spawning areas of cod in the western Baltic Sea, the small variations of the spawning areas between the different months and different years were not analysed.

The distribution patterns of cod eggs with stage I, based on ichtyoplankton surveys, can not be used for defining the spawning areas of the western Baltic cod stock. This area is influenced by temporary high dynamics of the water transport processes determined by wind forces and inflow events. Measurements of the Institute of Baltic Research, in Warnemünde during the major influx in January 1993 proved that water flows with a velocity of about 20 cm per s are possible.

From these observations it can be concluded that cod eggs can be transported about 17 km per day. Such important changes of the distribution patterns of the cod eggs can lead to biased interpretations regarding the spawning areas. Therefore, results of ichtyopiankton surveys were not included in these analyses.

The minimum total lengths of sexual maturity were determined for the different subdivisions for separating the potential spawners and the juvenile individuals and for comparing the current results with the observations of other authors.

Results

The results are presented separately regarding the different aspects which are important to the reproduction process of the western Baltic cod stock. Besides the minimum length of sexual maturation the spawning areas are described and the influences of hydrographical parameters are investigated.

Minimum length of maturation

The determination of the minimum length of sexual maturation is necessary for separating the juvenile cods and the potential spawners. These estimates can be used for an exact assessment of the population of potential spawners. This information is a significant parameter for the stock assessment, independent of whether **the** individuals take part at the spawning activities or do not develop the sexual products influenced by different reasons. All further analyses based on the population of the potential spawners.

Table 3 presents the minimum length of sexual maturation for the different areas of investigations, years and for sexes. The data are given for the main areas and the adjacent regions, too. The analyses show that the male and female cods start the maturation with different minimum length, what means that the minimum length of sexual maturation is a sex-specific characteristic feature. Table 3 demonstrates furthermore, that only low variation of the minimum length of sexual maturation occurred between 1992 and 1999. The following estimates can be concludes as generalized minimum lengths for the different spawning areas in the western Baltic Sea:

Area	Male	Female
Kiel Bay	22 cm	28 cm
Mecklenburg Bay	23 cm	24 cm
Arkona Sea	21 cm	23 cm

For this generalized description, individuals were excluded which could be observed only in one single specimen during the investigation period. That concerns one male cod with 17 cm in the Kiel Bay 1997 and one female cod with 21 cm in the Arkona Sea 1997.
Analyses of tagging experiments (Bagge 1969, Berner 1971, 1981 Otterlind 1985, Aro 1989) showed migrations between the western Baltic Sea and the adjacent areas Kattegat and the Bornholm Sea. Therefore, the minimum lengths of sexual maturation were also presented for these regions in Table 3. The lowest length of maturation was 17 cm for male and 23 cm for female cods in the Kattegat between 1996 and 1999. During the whole period one male individual was caught with 15 cm and a maturity stage of more than 2. The smallest single specimen of female cod matured was 20 cm with a maturity stage 5.
FOJ the more eastern located Bornholm Sea the smallest length of sexual maturation was observed with 11 cm for males and with 25 cm for females. The very small length of 11 cm should be pointed out especially. Although only a low number of such male cod was caught this length is important because specimens were observed in 1995 and in 1998.
The data of Table 3 showed additionally that the minimum lengths of sexual maturation were comparable in the main distribution area of **the** western Baltic cod stock (Kiel Bay, Mecklenburg Bay and Arkona Sea).

Areas of spawning activities

The areas of spawning activities are described using the catches of cod with running sex products Figure 2a and 2b present the stations where male and female cods with maturity stages 6 or 7 were observed between February and June. The figures summarize the data which were sampled between 1992 and 1999. The figures illustrate that in the Kiel Bay, in the Mecklenburg Bay and in the Arkona Sea spawning **cods** could be observed in all years.
Besides the occurrence of cod with running sex products the relative abundance is a characteristic feature for the importance of the area as a spawning ground.
During these analyses, regions with a standardized catch of more than 10 specimens per hour with running sex products were defined as a main spawning ground. Figure 3a and 3b present the main spawning areas in the western Baltic Sea for sexes. The figures summarize the positions of all spawning seasons analysed for developing a more generalized description of the significant spawning areas.
The Kiel Bay is an important spawning region The highest concentrations of cod with maturity stages 6 or 7 were found in areas with a water depth of more than 20 m in all years. These deeper parts of the Kiel Bay, the trough, connect the Little Belt and the Great Belt with the more eastern located areas with deeper waters Male and female cods with running sex products were also found in shallower waters. However, in areas with a water depth of less than 16 m males and females in spawning conditions were not found
The Fehmarn Belt connects the Kiel Bay and the Great Belt with the Mecklenburg Bay The area of the Fehmarn Belt with a water depth of more than 20 m is also an important spawning area since cods with running sex products were observed with high densities.

The Mecklenburg Bay was a significant spawning area of cod in all years inverstigated. The highest concentrations of cod with running sex products were observed in the area with a

water depth of more than 20 m, too. In the southern part of the Mecklenburg Bay the depth line of 20 m is very close to the coast line. Therefore, the spawning area extents also to the coast line and is very sensitive regarding antropogen influences.
In this southern area spawning females were observed with low abundance until a water depth of 12 m. Male spawning cods were observed below a water depth of more than 16 m with low densities, too.
In contrast to this, spawning cods were seldom found in the Kadet Trough. Therefore, it can be concluded that this region was not important to the spawning activities of the western Baltic cod stock during the investigations presented.
Every year spawning cods were caught in large parts of the Arkona Sea (Figure 2a, 2b). The main area was the Arkona Basin with a water depth of more than 40 m. However, spawning cods were also found in areas with a water depth of more than 20 m, especially female spawners. Only sporadic spawning cods were observed in shallower waters. The lowest depth was 14 m. This depth corresponds with the observations in the Kiel Bay.
Besides the density of the spawning cods a spawning area is according to Kändler (1944), Berner (1960), Thurow (1970) and Bemer et al.(198 1) additionally characterized by a significant higher portion of male cods. Therefore, Figure 4 shows the stations in the western Baltic Sea and in the Arkona Sea where the portion of male cods was higher than 70%. The areas with high portions of male cods correspond with the regions of high densities. This result supports the assessment that these areas are the main spawning grounds.

Hydrographical data were measured additional to the biological samples and they were used for characterizing the conditions for spawning activities. A comprehensive description of the influence of the hydrographical conditions regarding the spawning activities of the western Baltic cod stock is difficult. This region is marked by the possibility of very high dynamics (Bemer et al. 1973, Matthäus et al. 1990, 1994, 1997, 1998, 1999, 2000, Nehring et al. 1995, 1996). Specially during inflow events large changes are possible However, it was not possible to sample the hydrographicai parameters with such data density that this high variability could be analysed with high accuracy. However, the available data were suitable for describing a more generalized relationship between the spawning activities and the hydrographical parameters.
Table 4 presents the observed minimal and maximal values of temperature and of salinity and the minimal values of oxygen saturation during the spawning seasons of the different years. The hydrographical data were always sampled close to the bottom in all spawning areas. Table 5 shows the minimal and maximal values which were observed on stations with spawning cods. From these data the boundaries for spawning activities of cod can be assessed.

Kiel Bav and Mecklenburg Bay (ICES SD 22)

Temperature	– 0.5°C	+ 11.8°C
Salinity	15,0 PSU	28.9 PSU
Oxygen saturation	> 48%	

Arkona Sea (ICES SD 24)

Temperature	– 0.6°C	+ 9.1°C
Salinity	8.3 PSU	23.9 PSU
Oxygen saturation	> 47.3%	

The saturation of oxygen was always higher than 45% and the oxygen content was never lower the 2 ml per 1, the critical value for a successful development of cod eggs (Ohldag

199 1, Wieland 1994). This result is supported by the reports of the Institute of Baltic Research, in Warnemünde and the hydrographical database of the Federal Maritime and Hydrographic Agency, in Hamburg. Since the spawning activities and the development of the cod eggs were not influenced negatively this parameter was not included in the further analyses

The hydrographical conditions are not only important to the spawning process, they also influence the successful fertilization and the development of the eggs significantly Spawning activities with unfavourable hydrographical conditions do not support the development of a strong year class. Westernhagen (1970), Laurence et al. (1976), Bleil & Oeberst (1998) described the limits for a successful fertilization They pointed out that a salinity of 15 PSU (Westemhagen 1970, Bleil & Oeberst 1998) is the minimum level for a fertilization of the cod eggs in the Belt Sea. Furthermore, a temperature between 0°C and 10°C (Westernhagen 1970, Laurence et al 1976) allows for the fertilization and for the development of the eggs.

The hydrographical conditions in the Kiel Bay and in the Mecklenburg Bay during the spawning seasons did not influence the successful fertilization and the following egg development negatively. The results of Table 5 show that the highest densities of spawning cods were observed in areas with favourable hydrographical conditions. An exception could be observed in spring 1996 since spawning cods of both sexes were caught in the Kiel Bay and in the Mecklenburg Bay in areas with a temperature of less than 0°C.

In contrast to this good conditions, critical values of salinity were found in the Arkona Sea, Spawning cods were caught in layers where the salinity was lower than 15 PSU and lower the 11 PSU, the critical value for the development of cod eggs of the central Baltic cod stock, determined by MacKenzie (2000). These observations are important because such sub optimal conditions were not an exception, they were also observed in all years between 1994 and 1999, Most positions with such conditions were located in the area southern of the Arkona Basin in water depth between 20 m and 40 m. However, in some years single stations were found, too, in the northern part of the Arkona Basin. The maximum depth was 49 m in 1994.

In contrast to these sometimes unfavourable values of the salinity, the temperature varied in ranges which were comparable to the observations in the Kiel Bay and in the Mecklenburg Bay.

As a summary it can be concluded that spawning cods were observed in the Kiel Bay, in the Fehmarn Belt, in the Mecklenburg Bay and in the Arkona Sea regularly each year. In the main spawning grounds high densities of cod with running sex products were also caught every year

The main spawning grounds are summarized in Figure 5. The areas are clearly defined by the depth line of 20 m in the Kiel Bay and in the Fehmarn Belt. The main spawning ground in the Arkona Sea is the basin with a water depth of more than 40 m.

Discussion

Minimum length of sexual maturation

The minimum length of sexual maturation is important to the separation between the potential spawners and the juveniles. This parameter is sex-specific and was used for avoiding a biased interpretation of the results by including of juvenile cods

A comparison of the estimates of the analyses presented (A) and the observations of other authors are given in Table 6 Estimates were included from Thurow (1970) for the period between 1958 and 1969 (B), from Berner et al. (1981) for the period from 1970 to 1977 (Cl) and from Berner et al. (1985) for the period from 1967 to 1977 (C2), as well as from Kändler

(1944) for the period from 1925 to 1938 (D). The data compare values from the different parts of the western Baltic Sea and from adjacent ICES subdivisions.
According to Bemer (1981) the minimum length at sexual maturity is a stock dependent biological limit which is relative constant during longer periods. The results of Table 6 support this assumption. For the Belt Sea cod stock in Kiel Bay and in Mecklenburg Bay comparable estimates were found during the period of 41 years (1958 - 1999). A significant shift of the minimum length of maturation could not be found.
In contrast to this constancy in the Belt Sea regarding the time clear differences were observed if the estimates of Kiel Bay and of Mecklenburg Bay were compared with the values of the adjacent regions. The different estimates suggest that the specimens in the Kattegat (ICES SD 21) and in the Bornholm Sea (ICES SD 25) start the maturity development with a significant smaller length.
The Arkona Sea (ICES SD 24) is described as a transition area (Berner 1980, 1985, Berner et al. 1985, 1990, Bagge et al. 1989, Müller 1994, Oeberst 1999, Aro 2000) where a mixing of both Baltic cod stocks occurs. The size of this mixing process probably varied from year to year (Berner 1985, Müller 1994, Oeberst 1999). However, Bemer (1985) pointed out that a reproductive mixing does not occur influenced by the different spawning periods. Therefore, it can be assumed for the interpretation of the results that individuals of both cod stocks were observed in the Arkona Sea. Since the specimen analysed can not be clearly assigned to one of both cod stocks it must be concluded that the estimates in Table 6 present a mixture of the minimum length of maturation of both cod stocks. Therefore, the values varied between the estimates of the Bornholm Sea and the more western located Kiel Bay and Mecklenburg Bay.

Spawning areas

The cod carries out migrations between the feeding areas and the spawning grounds of the Baltic Sea intensively (Aro 2000). Additionally a drift and migration of juvenile cods from the spawning areas in Kiel Bay and in Mecklenburg Bay into the eastern direction were proved by Hinrichsen et at. (1999) and Oeberst (2000).
According to Kändler (1941) spatial clear defined spawning areas can be observed influenced by the different hydrographical condition in the Baltic Sea. Such spatial clear defined spawning grounds were not observed in the North Sea and in the Atlantic since the salinity is relative homogenous distributed with optimal values for the reproduction of cod.
Contradictory statements regarding the spawning places in the western Baltic Sea were given in the past. It seems to be that since the first investigations by Strodtmann (1906) at the beginning of the century and Kändler (1944) changes of the spawning behaviour has been occurred.
The current analyses proved that the main spawning areas in the western Baltic Sea are located in the deeper parts of Kiel Bay, of the Fehmarn Belt and of Mecklenburg Bay (Figure 3a, 3b). Furthermore, spawning cods were observed in deeper Arkona Basin with high densities. In all years of investigation male and female cods with running sex products were found in these areas.
In contrast to this, the results of Kändler (1994), Thurow (1970) and Bagge et al. (1994) suggest that cod spawns only in Kiel Bay and in the Belts. However, Berner et al. (1973) also described intensive spawning activities in the Fehmarn Belt and in the Arkona Sea.

The main spawning grounds of cod in the Kiel Bay, in the Fehmarn Belt and in the Mecklenburg Bay are limited to the depth line of 20 m. These observations correspond with the results of Thurow (1970) for the Kiel Bay. He described the deeper parts of the northern Kiel Bay with high salinity as the spawning region.

In the Arkona Sea the main spawning ground is located in the area with a water depth of more than 40 m. However, spawning cods were regularly observed with lower density in the area with a water depth between 20 m and 40 m.

The hydrographical conditions, especially the salinity, were different in the different spawning areas. In the Kiel Bay and in the Mecklenburg Bay cods with running sex products were observed in water layers which were limited to the temperature range from -0.5°C and 11.8°C and to the range of salinity from 15.0 PSU and 28.9 PSU.
The temperature range in the Arkona Sea where spawning cods were caught, was comparable to the Kiel Bay and to the Mecklenburg Bay. The temperature varied between -0.6°C and 9.1°C. In contrast to this the range of salinity was different with values between 8.3 PSU and 23.9 PSU.
The observations of the Kiel Bay and of the Mecklenburg Bay correspond very well with the experimental results of Westernhagen (1970) and with the observations in marine hatcheries by Pickova (1992) and Bleil et al. (1998)
The lowest level of salinity for spawning activities was 15 PSU (Bleil unpublished) and 12°C (Pickova 1992, Bleil unpublished). For a successful fertilization and development of cod eggs the lowest limit of 15 PSU and the temperature range between 0°C and 10°C were determined by Westernhagen (1970). Values of temperature below 0°C were only measured in March 1996. During all other parts of the spawning seasons investigated the temperature was in the optimal range for the fertilization and the further egg development.

The observations show that the hydrographical conditions in the main spawning area of the Arkona Sea were more variable than in the Kiel Bay and in the Mecklenburg Bay. The temperature values were comparable to the more western located areas. However, the salinity, an important factor which influences the reproductive success significantly, fluctuated in a larger range. During all spawning seasons analysed values of salinity below 15 PSU and in many cases values below 11 PSU were observed. According to Westin et al. (1991), Nissling et al. (1991, 1997), Wieland et al. (1994) and MacKenzie et al. (2000) the lowest limit for a successful fertilization is 11 PSU for the eggs of the central Baltic cod stock However, values of salinity were sometimes observed below this limit and therefore, too low for a successful fertilization.
The analyses show, that the spawning also took place if the hydrographical conditions were not in the favourable ranges and a fertilization and development of the eggs spawned were not possible. It must be assumed that the success of the spawning activities in the Arkona Sea is substantially dependent on the hydrographical conditions.

Closing it must be pointed out that the spawning areas in the western Baltic Sea have not only local importance. The eggs which were spawned in these areas are also important to the eastern Baltic cod stock since some eggs are transported by water currents in the eastern direction until the Bornholm Basin (Hinrichsen et al. 1999) and furthermore, the settled juveniles carried out a migration in the same direction (Oeberst 1999, 2000).
These exchanges are very important since the recruitment of the central Baltic cod stock was low in the previous years (ICES 1999).
It can be concluded that the spawning areas of cod in the western Baltic Sea have a very high implication for both Baltic cod stocks. Therefore, it is necessary that these areas will not be influenced by antropogenic factors as dumping of organic and inorganic material or that the areas will not be stressed by offshore buildings in the water.

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Tables

Table 1: Number of analysed cods separated for years, months, areas and sexes

Kiel Bay												
Year	Month	February		March		April		May		June		total
	Sex	female	male	female	male	female	male	female	male	female	male	
1992												
1993			82	167						57	38	344
1994		134	30	205	261					17	22	669
1995				207	231							438
1996				49	73	114	146	65	49	66	62	624
1997		75	28	163	158	125	110	68	58			785
1998				149	198			166	161			674
1999		389	501	186	345	127	148	212	215	287	304	2714
total												**6248**

Mecklenburg Bay												
	Sex	female	male	female	male	female	male	female	male	female	male	
1992												
1993		76	14	35	42	8	26			112	180	493
1994		40	36	140	76					102	72	466
1995				325	267	41	18	115	56	65	85	972
1996		127	103	184	95	72	97			202	202	1082
1997				183	118			344	284			929
1998		89	168	194	182	121	137	363	398			1652
1999		37	36	236	385			127	137	208	203	1369
total												**6963**

Arkona Sea												
	Sex	female	male	female	male	female	male	female	male	female	male	
1992		69	87	182	121			60	0			519
1993		510	453	129	52	40	183	47	189	391	210	2204
1994				452	339					622	512	1925
1995		404	311	525	475	180	249	130	219			2493
1996				497	367	62	79	119	146	538	546	2354
1997		281	215	324	236			56	40	350	465	1967
1998		408	318	479	414	140	169	553	555			3036
1999		593	494	445	332	107	167			666	681	3485
total												**17983**

Table 2: Index scale for macroscopically determination of the gonadal maturity of Baltic cod according to Maier (1908) revised by Berner (1960).

Maturity stage	Female	Male
1 **Immature**	Ovaries glassy transparent or reddish translucent, small, elongated with tight walls and small lumen. Single eggs can not be distinguished; under microscope, egg diameter ≤ 0,2 mm	Testis very small, translucent, colourless or grey. Breadth of testis ≤ 4 mm.
2 **Resting**	Ovaries dimly translucent with reddish-grey colour; small with tight walls. Single eggs can not be distinguished with naked eyes; under microscope, egg diameter ≤ 0,3 mm	Testis translucent, colourless or grey. Breadth of testis 3 – 8 mm.
3 **Preparation I**	Ovaries completely non-transparent reddish-grey to orange; slightly larger than in stage II. Single to numerous larger (diameter 0,2-0,5 mm), non-transparent, orange eggs can be seen with naked eyes; yolk production has started	Testis non-transparent, grey to reddish-grey; begin to turn white. Testis grow gradually in size. Breadth of testis > 8 mm.
4 **Preparation II (Aggregation)**	Ovaries completely non-transparent orange to yellow-white. Ovaries larger than stage III. All eggs to be spawned are filled with yolk and are so compressed that they become polygonal	Testis white, no milt produced under pressure.
5 **Preparation III (Stretching)**	Ovaries completely non-transparent orange to yellow-white. Ovaries very large. Eggs appears as in stage 4, but completely round. Few hyaline ripe eggs are visible.	Testis white to yellow-white. Drops of milt produced under pressure.
6 **Spawning**	Ovaries translucent grey-reddish to grey-yellow, completely filled with hyaline eggs, only few patches with non-transparent eggs appear.	Testis very white and fully extended. Milt runs freely at the slightest pressure.
7 **Semi-spent**	Ovaries translucent dark red; somewhat shrunken; walls flabby and rich in blood; lumen very large and filled with eggs in excess fluid. No non-transparent eggs as in stage 5 are present. Most eggs have been spawned.	Testis flabby. Milt run under slight pressure; not completely empty.
8 **Spent**	Ovaries considerably shrunken with tight walls, but with thicker walls than stage 2. White eggs only appear as tiny reminiscences due to resorption. Stage 8 gradually changes into stage 2.	Testis shrunken and reddish; walls flabby. Stage 8 gradually changes into stage 2.

Table 3: Minimum length of sexual maturation for spawning areas, sexes and years

Area	Kattegat		Kiel Bay		Mecklenburg Bay		Arkona Sea		Bornholm Basin	
Year	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1992					24	29	27	29		
1993			28	32	23	24	24	23	13	30
1994			27	35	26	36	28	30	20	26
1995			31	35	26	31	22	30	11	31
1996	15	20	24	30	30	31	24	23	20	25
1997	24	30	17	32	28	33	24	21	24	30
1998	21	25	22	32	27	30	21	27	11	28
1999	24	24	23	28	28	28	22	23	20	26

Table 4: Extreme values of hydrographical conditions close to the bottom in the whole area of investigations between February and June for years

	Temperature		Salinity		Oxygen saturation
Year	Minimum	Maximum	Minimum	Maximum	Minimum
1993	0.6	12.0	7.7	28.9	37.2
1994	0.6	11.8	7.8	26.0	58.4
1995	3.0	3.4	9.8	21.7	100.0
1996	-0.6	9.0	7.6	28.2	56.0
1997	2.3	10.3	7.5	25.1	54.1
1998	3.9	10.1	7.5	26.5	80.0
1999	1.7	9.0	7.4	28.7	36.7

Table 5: Extreme values of hydrographical conditions close to the bottom in the spawning areas between February and June for years

	Temperature		Salinity		Oxygen saturation
Year	Minimum	Maximum	Minimum	Maximum	Minimum
1993	1.0	11.0	13.3	28.9	37.2
1994	0.6	11.8	9 2	26.0	58.4
1995	3.0	3.4	9 8	20.1	100.0
1996	-0.6	7.7	7 6	28.2	65.0
1997	2.3	9.5	7.5	25.1	54.1
1998	3.9	10.1	7.6	26.5	80.0
1999	2.0	9.0	7.0	28 0	48.0

Table 6: Comparison of the minimum length of sexual maturation (cm) for different spawning areas

Area	Sex	A	B	C1	C2	D
Kiel Bay	Male	22	24			
	Females	28	27			
Mecklenburg Bay	Male	23		23		
	Females	24		28		
Arkona Sea	Male	21		18		
	Females	23		22		
Adjacent areas:						
Bornholm Basin	Male	11			18	17
	Females	25			22	22
Kattegat	Male	17				
	Females	23				

Figures

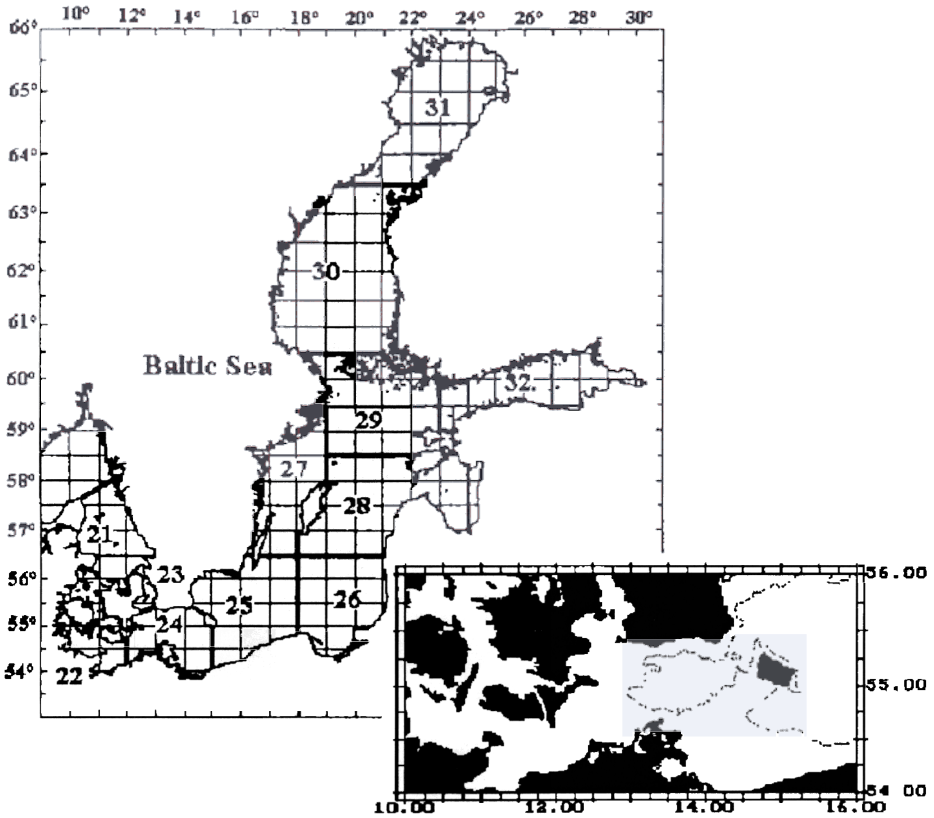


Figure 1: Baltic Sea with the ICES subdivisions and the area of investigations with the 40 m depth line

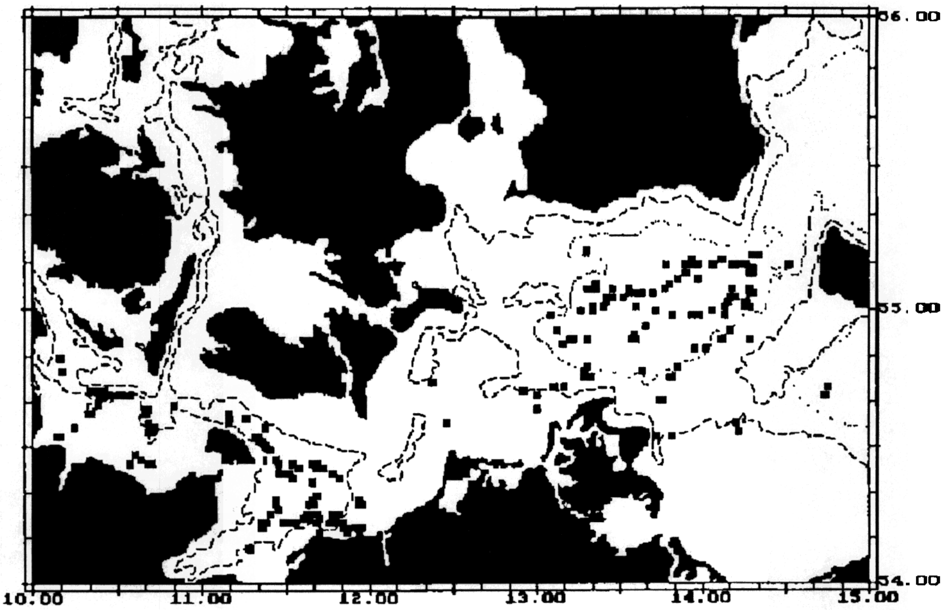


Figure 2a:Positions where male cods with maturity stages 6 or 7 were observed during the period from 1992 to 1999

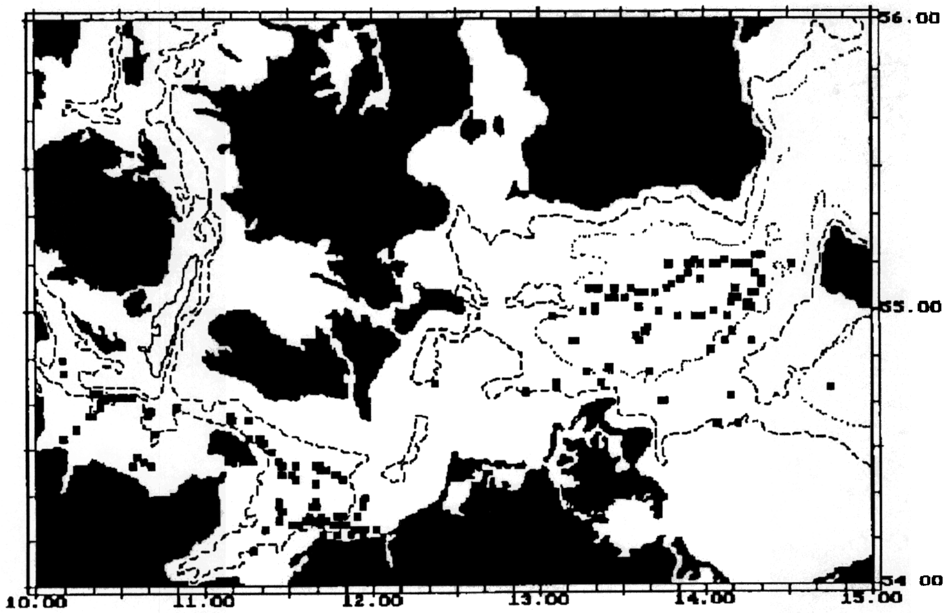


Figure 2b: Positions where female cods with maturity stages 6 or 7 were observed during the period from 1992 to 1999

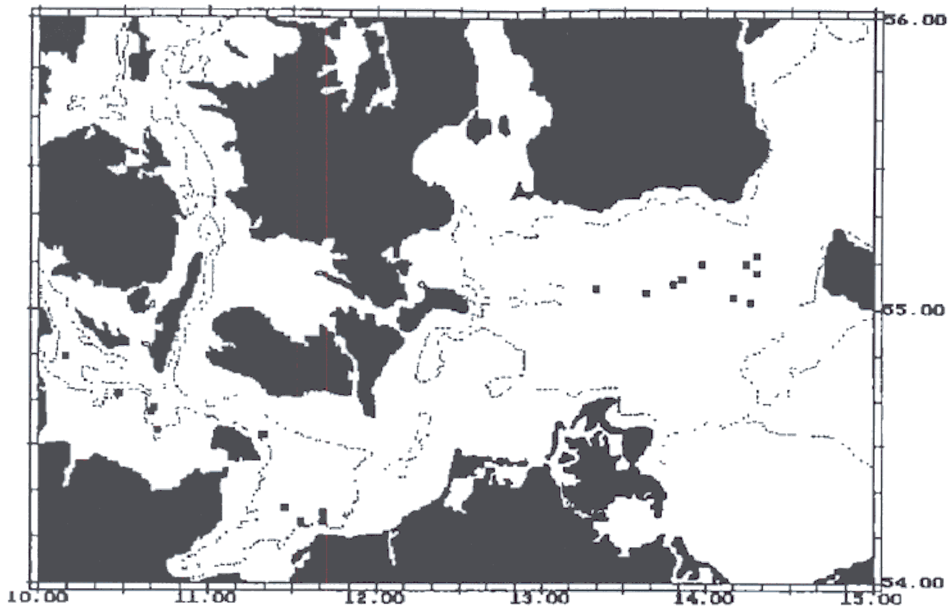
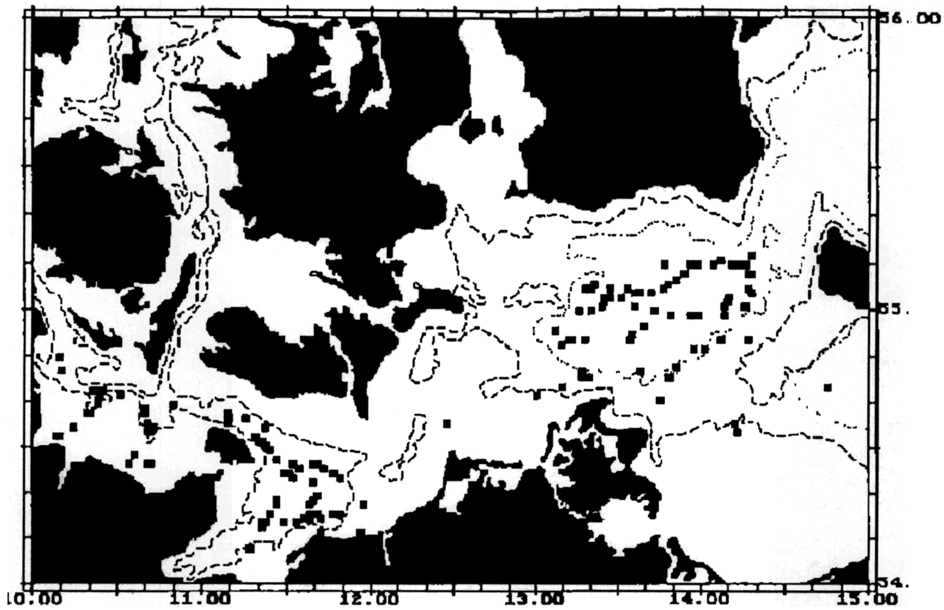


Figure 3a: Positions with more than 10 male spawning cods per hour during the period from 1992 to 1999

Figure 3b: Positions with more than 10 female spawning cods per hour during the period from 1992 to 1999



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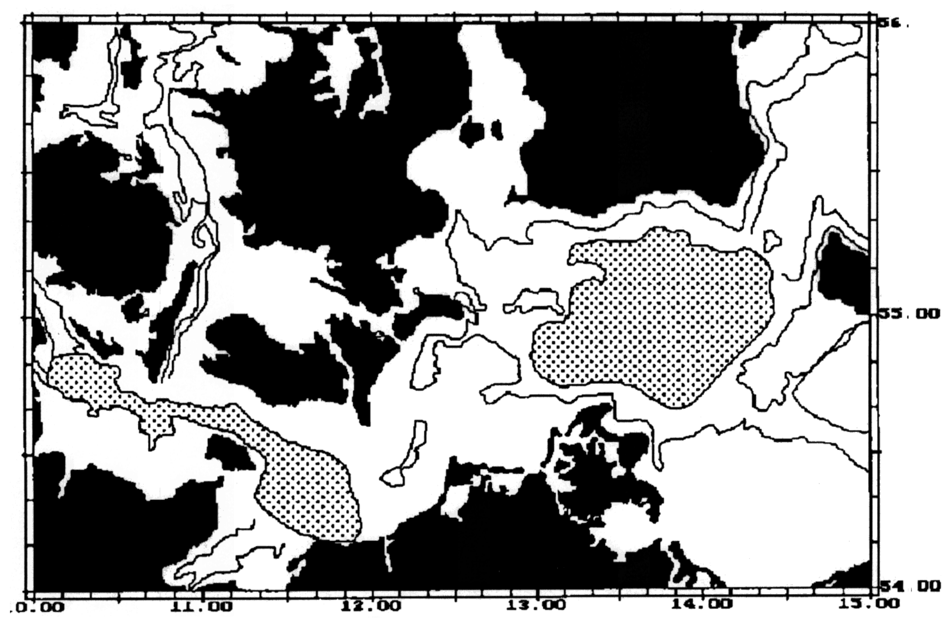

Figur Spa areas of co the estern Bal Sea and the Ark ona Sea