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BALTIC COD

GDYNIA, POLAND
MARCH 21-22, 1995

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The logo on the title-page represents Bronze Age fishermen; from a rock-carving at Ödsmål, parish of Kville, Bohuslän, Sweden. From thousands of rock-carvings in western Sweden this is the only known scene showing fishing. Originally described by Åke Fredsjö, 1943: "En fiskescen på en bohuslänsk hällristning" - Göteborgs och Bohusläns Fornminnesförenings tidskrift 1943. 61-67. Later documentationby the same author in: "Hällristningar i Kville härad i Bohuslän. Kville socken. Del 1 och 2." - Studier i nordisk arkeologi 14/15. Göteborg 1981, 303 pp., Pl. 158 II. Published by Fornminnesföreningen i Göteborg.

SCIENTIFIC PAPERS PRESENTED AT THE POLISH-SWEDISH SYMPOSIUM ON

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The Symposium was organized by

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Preface

At a meeting between representatives for the Sea Fisheries Institute (MIR) in Gdynia, Poland and the Institute of Marine Research (IMR) in Lysekil, Sweden held in Lysekil in October 1994, an agreement for co-operative research was made. One matter discussed was the state of the Baltic cod stocks, a matter of considerable concern to scientists, managers and fishermen. The recruitment to these stocks has been poor and its mechanisms are not fully understood. Additional problems in the assessment of the Baltic cod stocks are caused by the difficulties in collecting basic data and the deterioration of fishery statistics.

With the aim to compile and present the current knowledge and on-going as well as planned research activities about the Baltic cod, a symposium was planned. This was also the beginning of a fruitful co-operation that has evolved between our two institutes. The Polish-Swedish Symposium on Baltic cod was successfully held at the Sea Fisheries Institute in Gdynia, Poland, during March 21-22, 1995.

The Baltic cod stocks are an international resource that we must secure for future generations. It is our intensive belief that we with joint forces, both in science and management, can work together to increase the knowledge about the Baltic cod, and thereby be able to make better predictions about recruitment and, on a long term basis, put the Baltic cod stocks to an optimal use.

It is now our pleasure to convey to you the full papers of most of the presentations made at our symposium.

The conveners

Zygmunt Polanski
Director, MIR

Jan Thulin
Director, IMR

Vertical distribution of cod eggs and medusae in the Bornholm Basin

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Abstract

Samples were collected by Multinet (0.25 m^2 opening and five 300 μm mesh size nets), in the Bornholm Basin, during r/v "Baltica" cruises in 1993 and 1994. During the 1993 cruise (July 22 - August 7) three transects were chosen and during the 1994 cruises (August 17-28 and September 1-9) one transect for each cruise was covered. In 1993, an abundant occurrence of *Aurelia aurita* was observed, mainly in the 50-60 meter layer which was associated with a warm-water intrusion (8-12°C) from the Arkona Basin. Much less abundant occurrence of *Cyanea capillata* was found in the depth range 50-80 meters. In 1994, only a few specimens of *C capillata* were recorded in the Multinet samples. During these cruises, the highest biovolume of *A. aurita* (ml/1000 m3) was observed in the 50-70 meter water layer and, to a lesser extent, in the depth range 0-20 meters. The average biovolume of *A. aurita* (ml per specimen) in all samples was several times higher in water deeper than 50 meters, when compared to shallower water layers. Cod eggs were distributed mainly in the 60-70 and 70-80 m depth strata in 1993, and the 50-60 and 60-70 m water layers during the 1994 cruises. The abundance of cod eggs in September 1994 was approximately 6 times lower than in August 1994. The results of preliminary studies on medusae food suggest that these animals, being potential predators, may threaten the late spawning of cod. They tend to feed on eggs while residing in the same water layers with the spawning material.

Key Words: cod eggs, scyphomedusae, Aurelia aurita, Cyanea capillata, Bornholm Basin, co-occurrence

Introduction

There are two species of scyphomedusae in the Baltic Main Basin -*A urelia aurita* (L.) and *Cyanea capillata* (L.). Studies carried out in the Polish EEZ in 1983-1991 indicated that *A. aurita* was found regularly while *C. capillata* sporadically (Janas and Witek 1993); the mass occurrence of *A. aurita* was limited to the period from August to November. The presence of *C.capillata* was restricted mainly to the open sea and deeper water layers (Janas and Witek 1993).

Numerous authors pointed to the predatory impact of medusae on fish eggs (Fancett 1988, Lebour 1922, Matsakis and Conover 1991, Purcell et al. 1994).

Kerstan (1977; cited by Schneider 1993) concluded that the entire spectrum of plankton organisms occurring in Kiel Bight is used by *A. aurita*. The mucous masses in the food pouches examined in freshly captured specimens of *A. aurita*, usually contained plankton typical of the place of capture (Southward 1955). Fraser (1969) described medusae as active carnivores and concluded that copepods and other small Crustacea seemed to be the dominant food of most medusae but there was some evidence of selectivity. Typically, fish eggs were an incidental prey of several pelagic scyphozoans (Purcell et al. 1994) but on the other hand, Fancett (1988) mentioned that both analysed by him species of scyphomedusae (*C. capillata* and *Pseudorhiza haeckli* from Port Phillip Bay, Australia) showed strong positive selection for fish eggs and yolk-sac larvae and negative selection for other prey items. Fancett (1988) suggested that it may have been related to the limited response of that kind of prey and that the egg stage could be the most vulnerable to predation by scyphomedusae. Purcell et al. (1994) concluded that in case of fish eggs and yolk-sac larvae, selection was positive because they were large as compared with the most of other zoo plankton (increasing probability of encounter), and they had little or no escape ability.

The extreme patchiness of distribution of medusae was described by Fancett (1988), Hay et al. (1990), Janas and Witek (1993), Möller (1977, 1978), Schneider (1993). It was noted also that the abundance varied from year to year (Fancett 1988, Janas and Witek 1993). Purcell et al. (1994) stated that importance of predation was determined by the spatial overlap of predator and prey populations. The relative vertical distribution of predator and prey may be the most important factor controlling the predator - prey relationship *in situ* (de Lafontaine and Leggett 1987).

The Bornholm Basin is, most likely, the last area of effective spawning of the eastern Baltic cod stock. During routine ichthyoplankton surveys there is usually little emphasis put on spatial and temporal co-occurrence of medusae and cod eggs. We would like to address this problem because it may have an impact on the recruitment success of this cod population.

Materials and Methods

Samples were collected during the following r/v "Baltica" cruises in the Bornholm Basin area:

22 July - 7 August 1993,
17 - 28 August 1994,
1 - 9 September 1994.

In the first part of each cruise, a standard grid of Bongo-net stations was performed. The fish larvae and fish eggs were sorted out on board to identify areas where especially large abundance of cod eggs was observed. During the 1993, cruise three transects were chosen in the area of the Bornholm Basin. During the cruises in August and September 1994, location of the transects was almost the same (only one transect per each cruise; Fig. 1). The geographical co-ordinates were as follows:

1993 (I) 55°15.5'N, 15°24.0'E - 55°19.0'N, 15°20.4'E

1993 (II) 55°17.7'N, 15°59.8'E - 55°21.7'N, 16°00.4'E

1993 (III) 55°12.2'N, 15°51.1'E - 55°13.7'N, 15°57.5'E

1994.08 55°13.9'N, 15°58.6'E - 55°17.8'N, 15°52.7'E

1994.09 55°14.0'N, 15°59.1'E - 55°17.8'N, 15°53.5'E

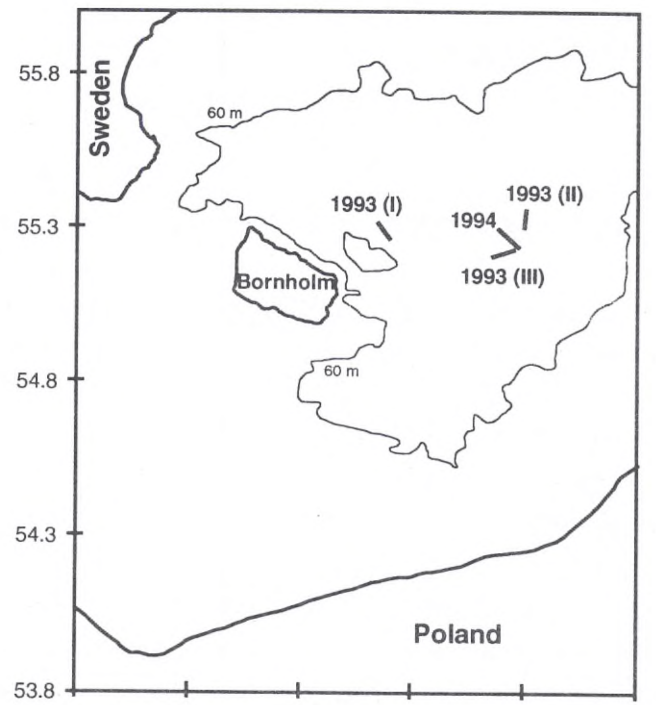

Figure 1. Map with the location of Multinet transects

Along these transects the stratified hauls with a Multinet were taken at depth range from 0 to 80 m (20-minute hauls, repeated five times in each 10-meter layer). The environmental parameters were recorded by the CTD probe coupled with the sampler.
The Multinet has an opening of 0.25 m^2 and 5 nets (the last one cannot be closed). Nets of 300 μm mesh size were used.

During the 1993 cruise, when medusae constituted only a small part of a zooplankton sample, the whole sample was preserved in 4% buffered formaldehyde. In this case the measurements were carried out in the lab. Otherwise, medusae were counted (each species separately), measured (their total volume was registered) and then discarded. In 1994, all captured medusae were counted and their diameter and volumes were measured.

The alimentary canals of medusae were examined to determine the presence of cod eggs. In case of the samples from 1993, this kind of analysis was carried out only for preserved medusae (smaller than average). During the cruise in August 1994, a gut content analysis of some medusae was carried out onboard. Other medusae were preserved in 4% buffered formaldehyde and their gut content was analysed in the laboratory after the cruise. During the cruise in September 1994, all medusae were preserved after the measurements were performed.
The results for the year 1993 are reported as averages from three transects.

Results

During the 1993 r/v "Baltica" cruise, an advection of exceptionally warm water from the Arkona Deep into the Bornholm Basin was observed. The warm water usually appeared at the depth of 45-55 meters but, in some cases, occurred even below 60 meters (Fig. 2). Cod eggs were distributed mainly at depth between 50 and 80 meters, with the peak abundance at the 60-70 meter layer (almost 5500 eggs per 1000m^3). *Aurelia aurita* was found in the whole water column but it was most abundant (28 ind./1000m^3) in the depth range 50-60 meters (warm-water intrusion). *Cyanea capillata* was less numerous and occurred at depth between 40 and 80 meters (Fig. 2).

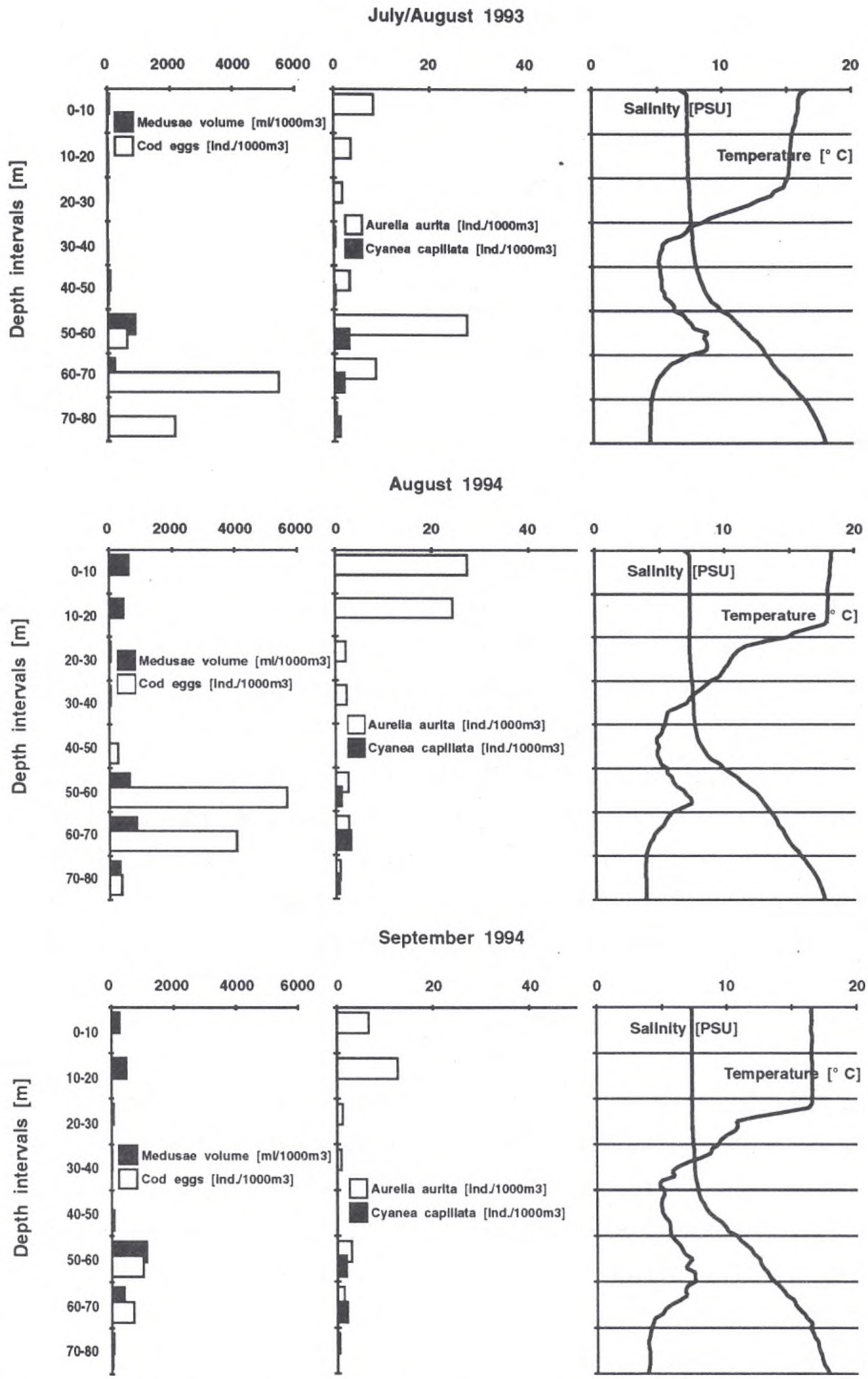

Figure 2. The abundance of cod eggs and medusae on the background of hydrological situation

In August 1994, the vertical distribution pattern was similar but there were some exceptions. Cod eggs were found approximately 10 meters closer to the surface (40-80 meters) and *C. capillata*, on the other hand, 10 meters deeper (50-80 m). Most of the cod eggs was distributed in water at depth between 50 and 70 meters (4000 to more than 5600 eggs/1000m^3). The peak abundance of *A. aurita* was found in the near-surface water (depth up to 20 meters). Its abundance ranged from 24 to 27 individuals per 1000 cubic meters.

During the September cruise, no significant differences were observed in the vertical distribution of medusae. The abundance of cod eggs was 5-6 times lower than during the August cruise.
The average biovolume of *A. aurita* (ml / ind.) varied with depth in all samples. In water layers deeper than 40 or 50 meters the volume of specimens could be even 10 times greater than in the shallower layers (Fig. 3). The data from 1993 are not representative because the sampling procedure was not designed for medusae collection (only smaller medusae were preserved and their volume was measured for both species together).

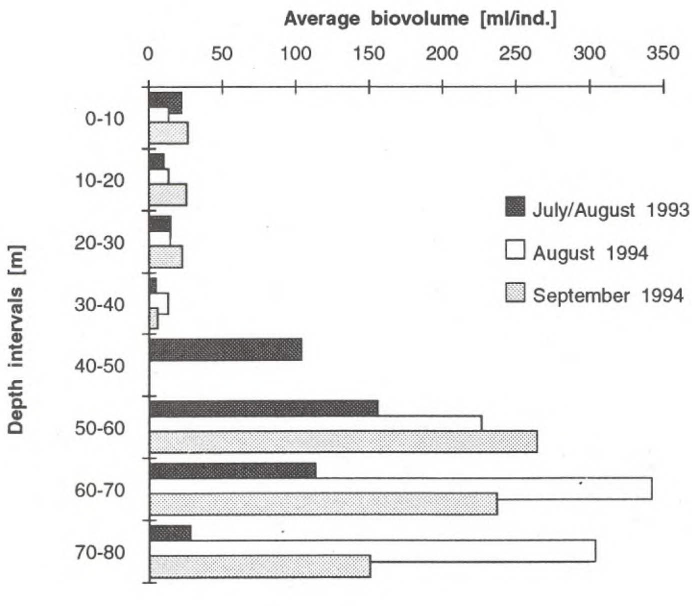

Figure 3. Aurelia aurita - average biovolume [ml / ind.]

Cod eggs were found in alimentary canals of medusae in all 10-meter layers in which they were abundant. Important differences were observed between two species of medusae. A significant number of *A. aurita* (6 to 71%) distributed at the depth range 50-70 meters had cod eggs in their guts. In case of *C. capillata*, all or almost all of them had cod eggs in their alimentary canals (Figures 4 and 5).

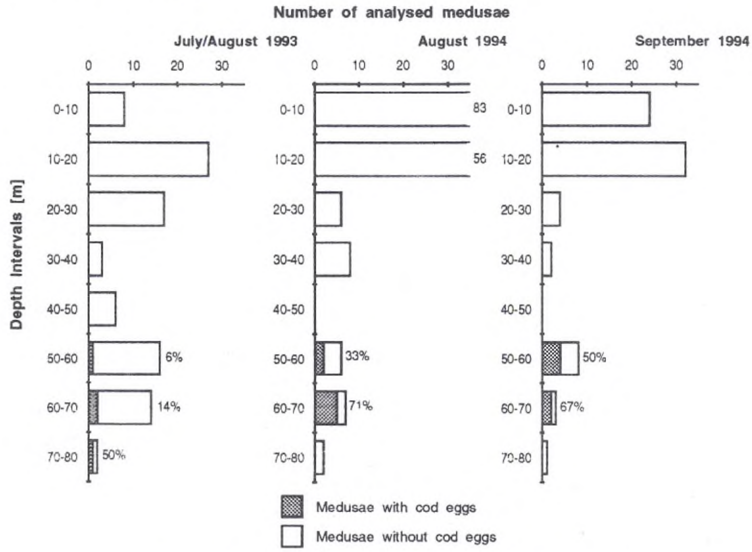

Fig. 4. Number of analysed *Aurelia aurita*

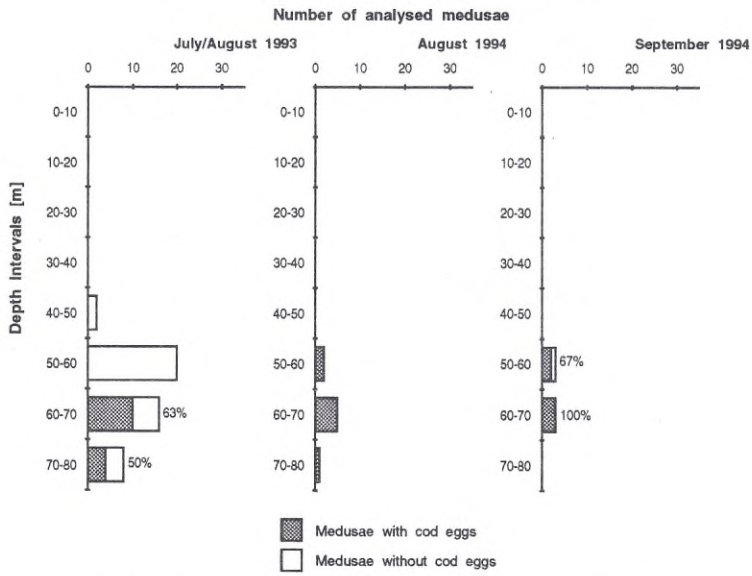

Figure 5. Number of analysed *Cyanea capillata*

Discussion

The information concerning the vertical distribution of both analysed species of medusae is very limited. Möller (1978), using oblique hauls, did not find any correlation between water depth and the *Aurelia* biovolume per m^3, during his studies in the Kiel Bight in 1978 .

The data presented in this paper, indicate that the abundance of *A. aurita* was the highest in the 50-60m depth layer in 1993 while during the 1994 cruises the medusae of this species were most abundant in the near-surface water. In 1993, a warm-water intrusion at depth 45-55 meters seemed to be an underlying cause of this phenomenon. *Cyanea capillata* were distributed at depth between 50 and 80 meters. Herra (1988), on the basis of samples collected during a survey in the southern Baltic in August 1987, concluded that *C. capillata* occurred only in the near-bottom zone at deep water stations and *A. aurita* was usually observed in the near-shore zone. During the 1993 and 1994 cruises, Multinet transects were located in the open sea and *A. aurita* was observed in the whole water column. The analysed data confirmed that *C. capillata* preferred deeper waters but the peak of its abundance was wider.

The abundance of *A. aurita* was lower than in the Kiel Bight (Möller 1977, 1978), especially taking into account that our estimates were obtained from stratified samples, but also the biovolume was smaller than the mean biovolume for the period August - November calculated by Janas and Witek (1993) for the Polish EEZ on the basis of Bongo oblique hauls.

It should be stressed that *A. aurita* medusae sampled in the same water layers as cod eggs were much larger than those from shallower water. Purcell et al. (1994) stated that number of bay anchovy eggs (*Anchoa mitchilli*) in each medusa (*Chrysaora quinquecirrha*) was significantly and positively related to medusa size. In the present study, the number of medusae with cod eggs in their guts was too small to estimate a relationship between medusae size and cod eggs occurrence in their alimentary canals.

lso *C. capillata*, even less numerous than *A. aurita*, may have had an mpact as a predator on cod eggs during the summer spawning of the East 3altic cod stock. In the samples from 1994, all or almost all of *C. capillata* ad cod eggs in their guts. The 1993 data may be an example of mismatching n vertical distribution of *C. capillata* and cod eggs. None of *C. capillata*, ampled in the 50-60 meter water layer, had cod eggs in their alimentary anals.

The analysed data are too sparse for reaching final conclusions regarding an impact of medusae on cod eggs. However, due to observed overlapping of their vertical distribution during the late summer cod spawning, more emphasis should be put on this issue during routine ichthyoplankton surveys.

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Advection of warm water from the Arkona Basin into the Bornholm Basin during the summer peak of cod spawning in 1993-94.

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Abstract

The biological studies carried out in the Baltic Sea in July and August 1993, and in August and September 1994, focused mainly on evaluation of commercial fish species and were supplemented with hydrological investigations. The obtained results allowed to establish the occurrence of an advection of warmer water from the Arkona Basin into the Bornholm Basin. In July and August 1993 the advective water was moving in the upper part of the halocline positioned at depth between 40 and 65 m. The maximal temperature of that water mass (12.21 °C) was observed at 50 m depth. In August 1994, the maximal temperature reached 9.69 °C and it could be traced at 60 m depth while in September 1994, the temperature of water brought by the next advection event was 12.13 °C at depth 56 m. Earlier, in the years 1989-1992, three events of a warm water advection were observed in the following periods: October 1989, October 1990, July 1992. The advection of warmer water occurred during the stagnation period of deep waters (up to 1992) and after the inflows in the years 1993-1994. The advective water occupies the depth layers of abundant occurrence of cod eggs and larvae. We consider this spatial phenomenon an interesting factor that might influence the recruitment of Baltic cod.

Key Words: physical oceanography, advection, Bornholm Basin

Introduction

The water temperature is one of the main factors influencing the development of cod eggs and larvae. Normal development of early developmental stages of cod takes place in sea water at temperature below 6 °C. The mortality rates of eggs and larvae increase significantly in the water of higher temperature (Iversen and Danielssen, 1984). The salinity above 12 PSU and oxygen concentration not lower than 2 ml/l are necessary for the normal development of cod eggs (Wieland et al., 1994).

The inflow of water from Kattegat is the main mechanism responsible for the regeneration of water in the southern Baltic. Besides inflows, the advective events take place in the summer during the spawning season of cod, bringing water at high temperature and, usually, of higher oxygen content. Advective processes are observed in the Bornholm Basin and Slupsk Furrow and, sporadically, in the Gdansk Basin. Warm advective water from the Bornholm Basin moves from the deep layer in the Arkona Basin. The highest yearly temperature values (above 10 °C) at the bottom of the Arkona Basin occur from July to October; the maximal temperature of 12.5 °C is usually observed from September to October (Matthaus, 1975, 1985). The salinity of the upper layer in this area is slightly higher (8.003 PSU) than in the southern Baltic (Matthaus, 1985). Whereas in the deep layer, the salinity on average ranges from 10 PSU at 35 m depth to 16 PSU at the bottom (mean values for the period 1903-1983; Matthaus, 1985). The advective water from the Arkona Basin does not reach the bottom because its density is lower than the density of the deep water in the Bornholm Basin; the advective water forms an intermediate layer, localized in the halocline zone at depth from 40 to 70 m.

The movement mechanism of the advective water of raised temperature in the Bornholm Basin is similar to the weak inflow (influx), particularly when influx is preceded by an inflow of large volume (Nering and Matthaus, 1994).

The Bornholm Basin is a sort of a buffer zone in which the inflow water of high salinity remains in the deep layer. Inflowing water of density lower than the deep water (weak inflows, advective water) moves in the intermediate layer and quickly reaches the eastern Baltic basins.

Material and Methods

The results of scientific investigations of the Sea Fisheries Institute in the years 1989-1994 were used to analyse the advective events. The temperature and salinity measurements were performed by means of the CTD probe aboard r/v Profesor Siedlecki, r/v Oceania and r/v Baltica.

Horizontal distribution of maximal temperature of the advective water was determined based on the temperature measurements at all stations for one time period. Moreover, the vertical temperature profiles for chosen cross-sections transecting the areas of the occurrence of warm advective water were determined. In figures, the shaded areas indicate water at temperature higher than 7 and lower than 14 °C to clearly display the warm advective water.

In addition, the hydrological measurements for chosen stations were presented as temperature profiles and T-S curves. For the same time period for different research cruises, the conditions in the following areas were presented: the Bornholm Gate (thick broken line), the Bornholm Basin (thin line) and the Slupsk Furrow (thick line).

The state of the environmental conditions was determined with respect to mean temperature, salinity and the oxygen values, calculated on basis of the earlier investigations carried out by the Sea Fisheries Institute in the years 1946-1993.

Besides the advective events observed during the investigations on the spawning of cod in 1993-1994, earlier situations preceding this period and starting in 1989 were described in this study.

Results

Data concerning the parameters of the advective water in the area of the Bornholm Basin, collected during the investigations of the Sea Fisheries Institute, are presented in Table I. The listed parameters are maximal temperature of the warm advective water and the depth of its occurrence, its

Table 1. Parameters of advective waters in period 1989-1994.

Year Month	Tmax (°C) and depth (m)	layer (m/m) with advective water	Sal. (PSU) range in adv. water	O_2 (ml/l) range in adv. water
1989 october	9.5 65 .	50-70	9-13	-
1990 Otober	10.14 60	45-63	11.4-12.6	-
1992 July	8.0 60	40-65 beginning	11-13.5	1.36-4.54
1992 September	12.26 60	50-70 cont.of adv.	12.5-14.5	2.0-2.5
1992 Otober	12.73 65	45-70 ont.of adv.	11.5-14.3	≈1.6
1993 July	12.21 55	42.5-65	12-14	3.4-5.7
1994 August	9.69 55	42.5-65	11-14	2.75-5.63
1994 September	12.13 56	42-65	11-14	1.4-3.97

salinity and the oxygen content.

Before proceeding with a detailed description of the particular hydrological situations it should be mentioned that from 1983 until January 1993 no inflows had occurred which resulted in the advanced stagnation of deep waters (Wojewodzki, 1991; Matthaus, 1993).

In 1989, the warm advective water at temperature 9.5 °C was detected during the research cruise in October (Table 1). However, this water had been already present in the Bornholm Basin at depth 50-70 m and its temperature had reached 10 °C. The initial parameters of the advective water originating from the bottom of the Arkona Basin in July and August were: temperature

12 °C, salinity 14.8 PSU and the oxygen content 4 ml/l (Schulz, 1989).

In 1990, the initial phase of the event was observed in June when the warm advective water occurred only in the Bornholm Gate (maximal temperature 7.9 °C). During the next research cruise in October, the maximal water temperature was 10.14 °C and the extent of this water mass had increased significantly; it filled the southern part of the Bornholm Basin and the entire area of the deep layer in the Slupsk Furrow. Most likely, this water mass extended as far as the Gdansk Basin because the oxygen content at the bottom of the Gdansk Basin in 1990 increased to more than 3 ml/l (Wojewodzki and Grelowski, 1992).

In 1991, the advection of warm water into the Bornholm Basin did not occur. Only in March the elevated water temperature in the halocline zone was noted which probably resulted from the fall advection a year before. Lack of the advective inflow in 1991 was confirmed by the situation in May 1992 when no remaining warm advective water from the preceding fall season could be detected.

In July 1992, the presence of the warm advective water reaching the maximal temperature of about 8 °C was detected in the south-west part of the Bornholm Basin. In September, this water extended to the entire area of the Bornholm Basin and Slupsk Furrow. The maximal temperature of the warm advective water in the Bornholm Basin ranged from 7 to 11 °C. In the same month, the maximal temperature of the advective water measured in the Bornholm Gate was 12.26 °C. Therefore, a beginning of the inflow of the new warm water mass was registered as confirmed by the hydrological situation in October (Table 1, Figures 1 and 2).

In April 1993, after the January 1993 inflow from Kattegat, the significantly lower water temperature was measured in the halocline zone; the water temperature at depth 55-60 m was 6 °C (to be compared with 12.73 °C measured in the fall at the same depth). In the deep layer of the Slupsk Furrow the water from the fall advection was replaced, after transformation, with the inflow water at low temperature (about 4 °C), high salinity (above 14 PSU) and particularly high oxygen content (4-6 ml/l; Grelowski and Wojewodzki, 1994).

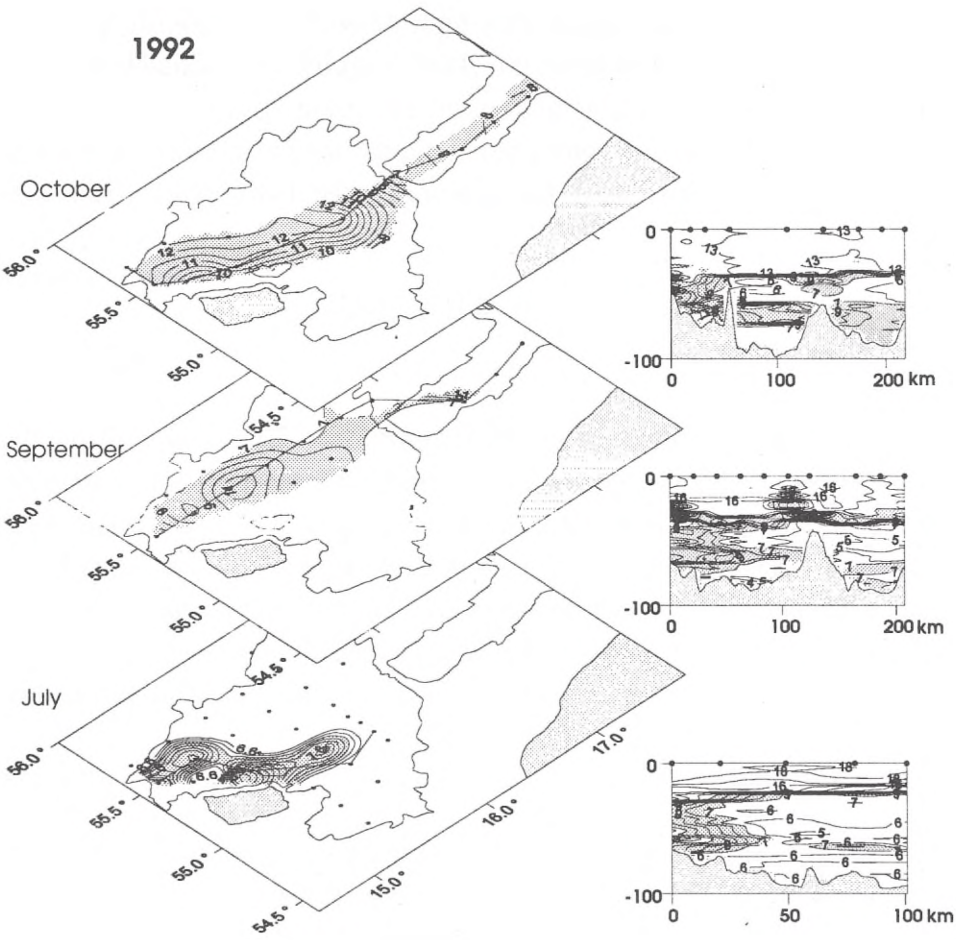

Figure 1. Extent of advective water (>7°C) in the Bornholm Basin in 1992 and vertical profiles of water temperature at chosen cross- sections.

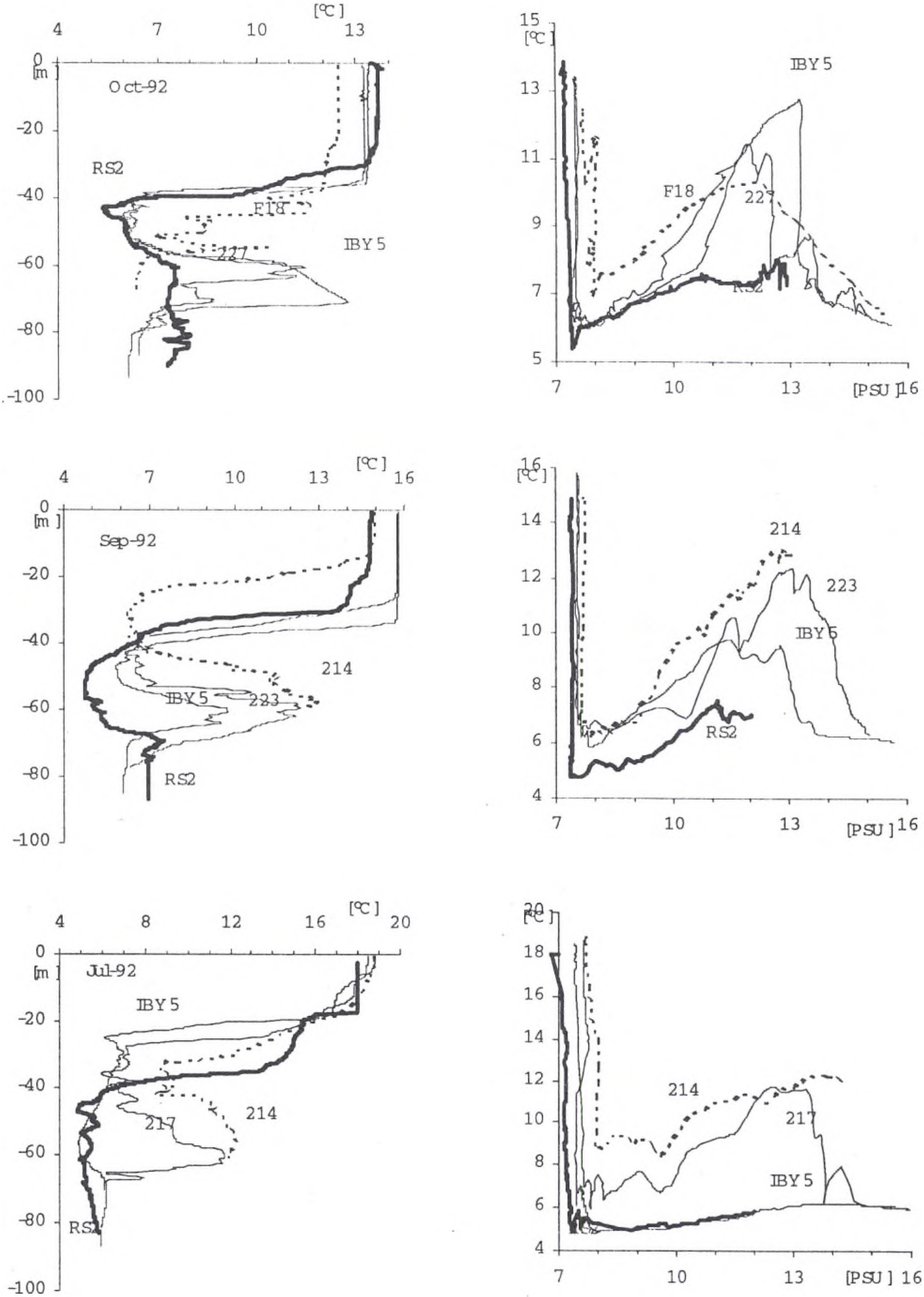

Figure 2. Vertical profiles of water temperature and T-S curves at chosen stations in the Bornholm Basin and Slupsk Furrow in 1992.

In July 1993, (Table 1, Figures 3 and 4) the next advective event was observed which had started earlier as indicated by the spread of the advective water into the southern part of the Bornholm Basin. The main current of warm water at temperature 10.5-11.5 °C (maximal temperature 12.21 °C at depth 55 m) and salinity 11.5-12.0 PSU was moving along the west slopes of the Bornholm Basin.

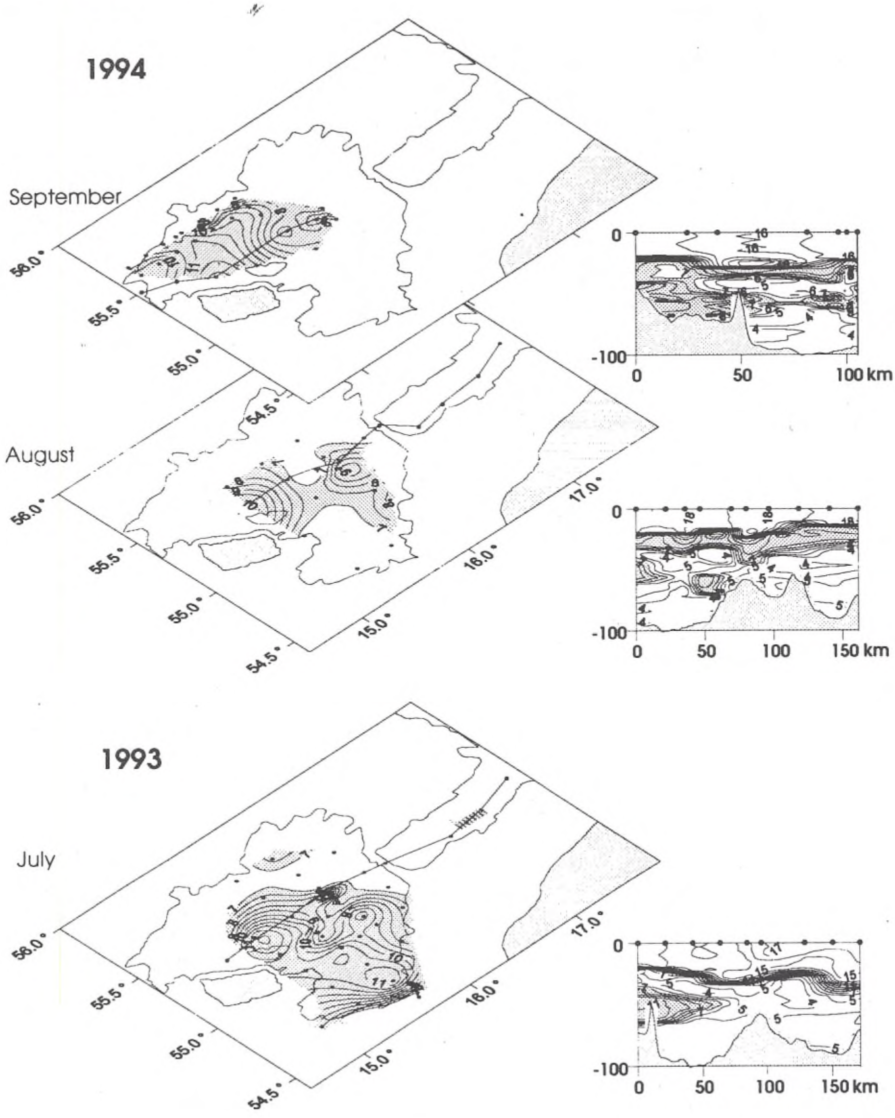

Figure 3. Extent of advective water (>7°) in the Bornholm Basin in 1993 and 1994, and vertical profiles of water temperature at chosen cross- sections

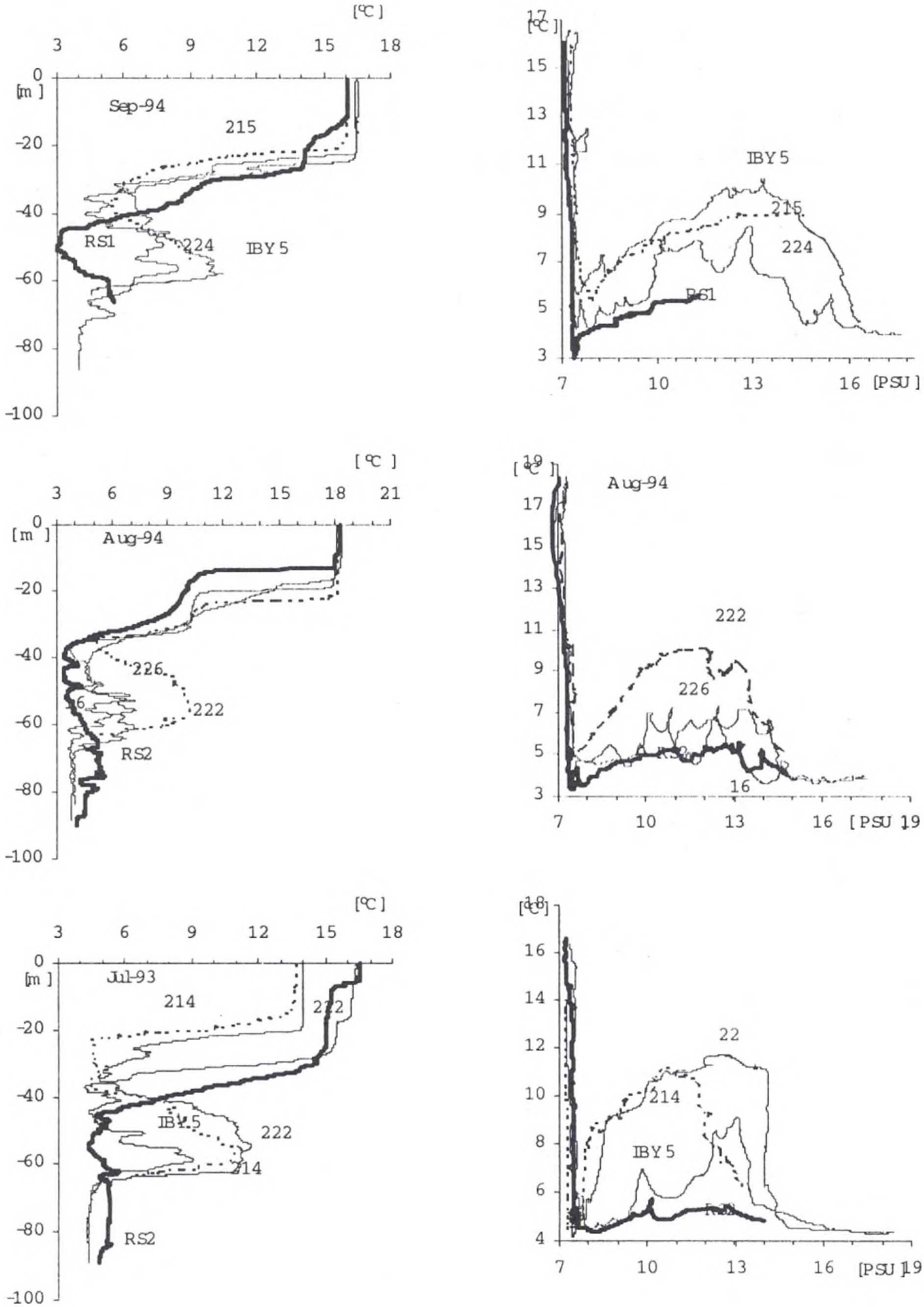

Figure 4. Vertical profiles of water temperature and T-S curves at chosen stations in the Bornholm Basin and Slupsk Furrow in 1993 and 1994.

In September 1994, another advective inflow into the Bornholm Basin brought water of temperature lower than the previous inflows (Figures 3 and 4). The maximal temperature of water localized in the closest distance from the point of entry (Bornholm Gate) was 9.69 °C. The oxygen content at the depth of the maximal temperature occurrence ranged from 3 to 7 ml/l; it was the highest oxygen content in the south-east part of the Bornholm Basin.
In September 1994, next advective inflow took place and the temperature of the advective water was much higher than in August. The maximum temperature of this water was 12.13 °C, its salinity was much higher (13.4-14.2 PSU) and its oxygen content much lower than in August (2.2-2.6 ml/l).

Conclusions

1) Advection of warm water from the Arkona Basin into the Bornholm Basin usually takes place during the summer and fall (July-October).
2) Temperature, salinity and the oxygen level of the advective water moving into the Bornholm Basin are similar to the parameters of the near-bottom layer (40-45 m) in the Arkona Basin.
3) Salinity of the advective water (10-14 PSU) causes that this water mass does not reach the bottom of the Bornholm Basin but moves in the halocline zone of the deep layer (from 40-60 m).
4) Temperature is a parameter that allows to distinguish the warm advective water mass of a particular salinity, inflowing into the Bornholm Basin. The high water temperature (>7 °C) is an indicator of advection in the summer and fall. On the basis of the differences of water density, it can be speculated that advection also occurs during the other seasons. In case of advection of water at temperature close to the in situ water temperatures in the Bornholm Basin it is impossible to localize the advective water based on the vertical temperature profiles.
5) Advection of warm water is essential for the process of regeneration of the deep water in the south Baltic, particularly during stagnation periods (lack of inflows from Kattegat). In the Bornholm Basin, due to advection, the inflow of water of higher oxygen content into the halocline of the deep layer takes place while in the Slupsk Furrow and Gdansk Basin, depending on

salinity, the advective water may extend down to the bottom of these basins causing the salinity, temperature and, most importantly, oxygen content increase.

6) On the basis of the conducted research, it was concluded that the water temperature of a considerable volume of the Bornholm Basin in the summer of 1992, 1993 and 1994, was not favourable for the development of cod eggs. The intermediate layer characterized by raised temperature (above 10 °C) was most extended in October 1992, in July 1993 and in September 1994, and it could possibly negatively influence the development of cod eggs in the Bornholm Basin at depth 50-60 m.

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The effect of different exploitation levels, varying recruitment and natural mortality on catches of Baltic cod. A simulation study.

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Abstract

The catches of the eastern Baltic cod stock under fishing effort in the range of 5 to 100% of the 1993 value are simulated for the next 20 years. The stochasticity of the process is contained in recruitment and cod cannibalism. The recruitment (age 1) has two components: deterministic, resulting from the Beverton and Holt curve, which explains 33% of the recruitment variation, and stochastic, resulting from the unexplained variation. The predation mortality (cannibalism) is applied to age 1 and 2, and is considered to be linearly related to spawning stock biomass. This explains about 90% of the predation mortality variance, but still error component (though small) is simulated. Two options for the error component in recruitment are considered: constant error variance and error variance hyperbolically related to the mean. To determine deterministic and stochastic components of the recruitment and cannibalism the data were taken from the multispecies VPA.

For each option of fishing effort 400 stochastic simulations were performed. The analysis shows that reduction of the fishing effort to about 30-40% of its present value could increase the catches to about 250 thousand tons on average (4-5 times increase of the 1993 official catches). The gain in catches could be achieved already in the third year of the effort reduction. Option with variance related to the mean shows, that continuing the present fishing effort will probably further decrease the catches.

Key Words: Baltic, cod, optimum catches, recruitment, uncertainty

Introduction

The catches from the stock depend on the following factors: recruitment to the stock, natural mortality, individual growth rate and fishing mortality or, equivalently, fishing effort. The first three factors are not directly controlled by the man, although they can be influenced by him in a number of ways. For instance, the increasing pollution may lead to unfavourable spawning condition and low recruitment. Next, a high fishing pressure on the predators of the species in question can decrease its natural mortality. Similarly, an intensive fishing for food components of a given species can slower its growth rate. The forth factor, that is the fishing effort, is the only factor that can be directly controlled by the man.

The Baltic cod landings have decreased from over 400,000 t in 1984 to about 40,000 t in a record low year 1993. The low recruitment to the stocks in the last several years is thought to be the main reason for this decrease, while the lack of inflows of the North Sea water to the Baltic is generally blamed for poor recruitment. Little attention is paid to the way of exploitation of the stock, though the stock is very heavily exploited. The aim of this paper is to investigate whether higher catches of cod could be achieved if fishermen changed their fishing effort.

Materials and methods

The future catches of the eastern Baltic cod stock (areas east off Bornholm) are simulated for the period of 20 years, under the fishing mortality values ranging from 5% to 100% of the 1993 value, estimated at 1.28. For each option of the fishing mortality 400 simulations were performed, each extending for a 20 year period. The biomass and fishing mortality in 1993 were taken from Anon. (1994b). In the simulations the individual growth rate was kept constant while recruitment to the stock (age 1) and natural mortality were subject to deterministic and stochastic changes:

recruitment = deterministic component + random component

and

natural mortality = deterministic component + random component

After many attempts to estimate the stock - recruitment relationship, the Baltic cod researchers expressed the opinion that there was no such relationship. However, Sparholt (in press) has shown that recruitment has significant linear component for the recruit estimates taken from the multi-species VPA (MSVPA) and for a given set of environmental conditions. The MSVPA model takes into account cod cannibalism and, when this effect is significant, the estimates are quite different from those arrived from the single species VPA and constant natural mortality. Therefore, in the present paper deterministic component of recruitment follows the Beverton and Holt (1957) hyperbolic model (Fig. 1) with recruit numbers based on MSVPA (Anon., 1994a). The model explains 33% of the recruitment variation.

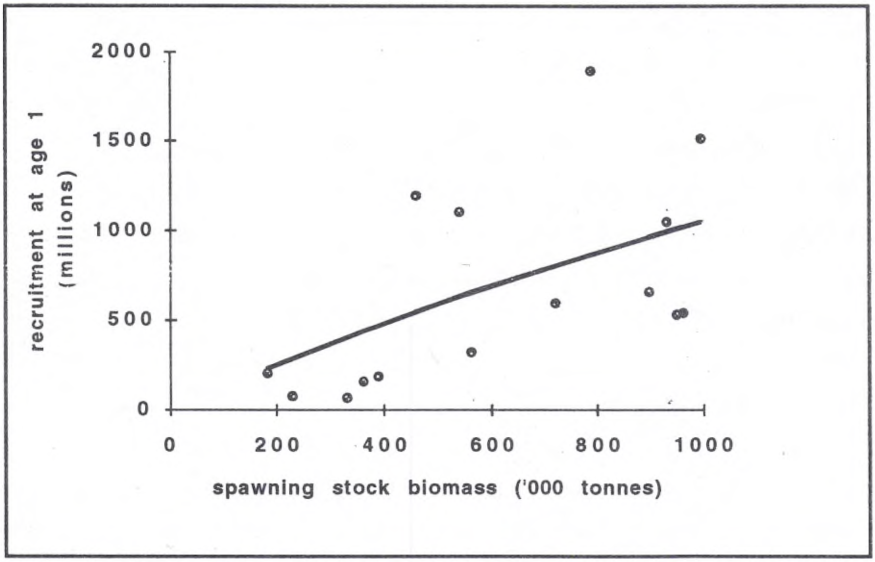


Figure 1. The stock - recruitment relationship for Baltic cod. Data are taken from the multispecies VPA (Anon., 1994a).

The normally distributed variable with zero mean and two options for variance was selected as a random component. The first option assumes constant variance while in the second option variance increases with the mean in such a way that the standard deviation (SD) (square root of the variance) is a hyperbolic function of the mean. The value of the constant variance and the relation between the variance and the mean were estimated during fitting of the deterministic component of the model.

The natural mortality of cod can be separated into natural mortality caused by predation of bigger cods and residual natural mortality. Linear regressions of the predation mortality estimates on spawning stock biomass explain 90% of the mortality variation for age 1 and 2 (Fig. 2). The results of MSVPA (Anon., 1994a) were used as the input data for this regression. For the older ages the predation mortality was assumed to be zero. The residual natural mortality was assumed to be constant for all ages. Finally, the deterministic component of the natural mortality is a linear function of the spawning stock biomass. The random component is a normally distributed variable with zero mean and a constant variance, estimated when fitting the regression for the deterministic component. In cases when a deterministic plus random component produced negative values, zero was assumed for number of recruits or natural mortality.

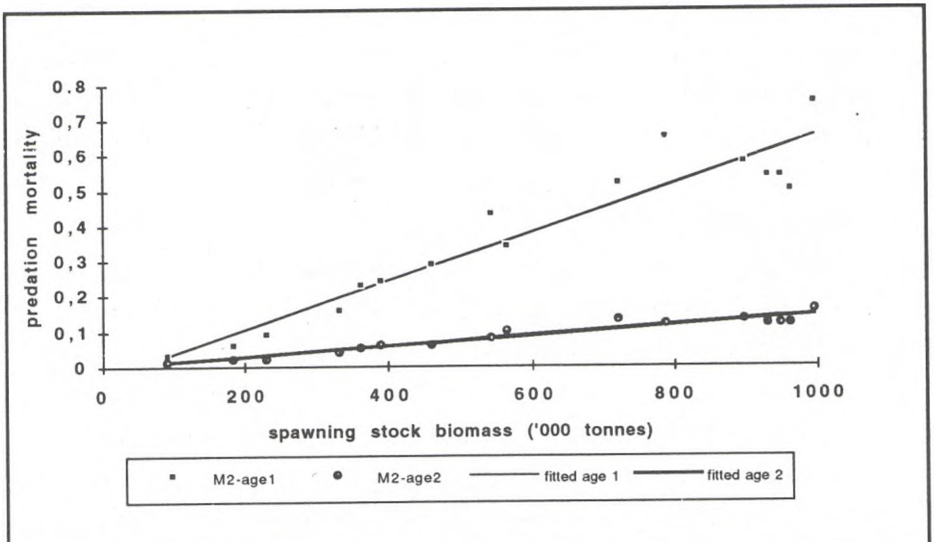


Figure 2. The dependence of the predation mortality, M2, of younger cods on the spawning stock biomass of cod. Data are taken from the multispecies VPA (Anon., 1994a).

Results and discussion

The results of the simulations are presented in Fig. 3 and 4 as the percentiles of the projected cod catches in 1995-2014. In Fig. 5 the percentiles of the 20 year averages of the catches are shown. The simulations indicate that the present fishing mortality is too high when one aims to maximize the catches. The reduction of the fishing mortality by 30-40% of its present value could, on average, increase the catches to about 250,000 t. The fishing mortality corresponding to this reduction would be in the range of 0.4-0.5. For comparison, the Fmax, being the value of fishing mortality maximizing the yield per recruit, is 0.35 (Anon., 1994b). The medium exploited biomass would be about 700,000 t. The gain in catches could be already achieved in the third year of the mortality reduction. The results of the option with the variance related to the mean suggest, that continuation of the fishery with present fishing mortality will probably further decrease the catches in the long term.

Some simulations of cod catches under different options for recruitment and fishing mortality were performed in Anon. (1994a) using the program MSFOR - projection version of the MSVPA. Both deterministic and stochastic options for recruitment were taken into account. In the deterministic approach three levels of constant recruitment were assumed: low, medium and high. Fishing mortality was in the range of 0.2 to 1.2 of the 1992 value. The results indicated that for medium level of recruitment the mean catches in 1997-2001 would be in the range 200,000-300,000 t, 300,000-500,000 t, and 400,000-550,000 t for fishing mortality being 20%, 60%, and 100% of the 1992 value, respectively. These simulations are quite different from those performed in the present paper; they do not show growth over fishing, producing the highest catches at fishing mortality being equal to the 1992 value, estimated at 1.03. The level of projected catches is also much higher than in the present simulations. Similar calculations were done by Horbowy (1989), using the model based on the Andersen and Ursin approach (1977) with some amendments and re-formations. These calculations showed, however, that the maximum long-term catch of about 290,000 t could be obtained by reducing fishing mortality to 70% of the

1974-1984 mean. It seems that the main qualitative difference between simulations by Anon. (1994a) and Horbowy (1989) is caused by different level of cannibalism; in Horbowy (1989) it is 6-7 times lower than in Anon. (1994a) for comparable time periods. In Anon. (1994a) the cannibalism is so high that intensive fishing, leading to significant decline of exploited stock biomass, is compensated by higher survival of young cods, which are then able to rebuild the stock.

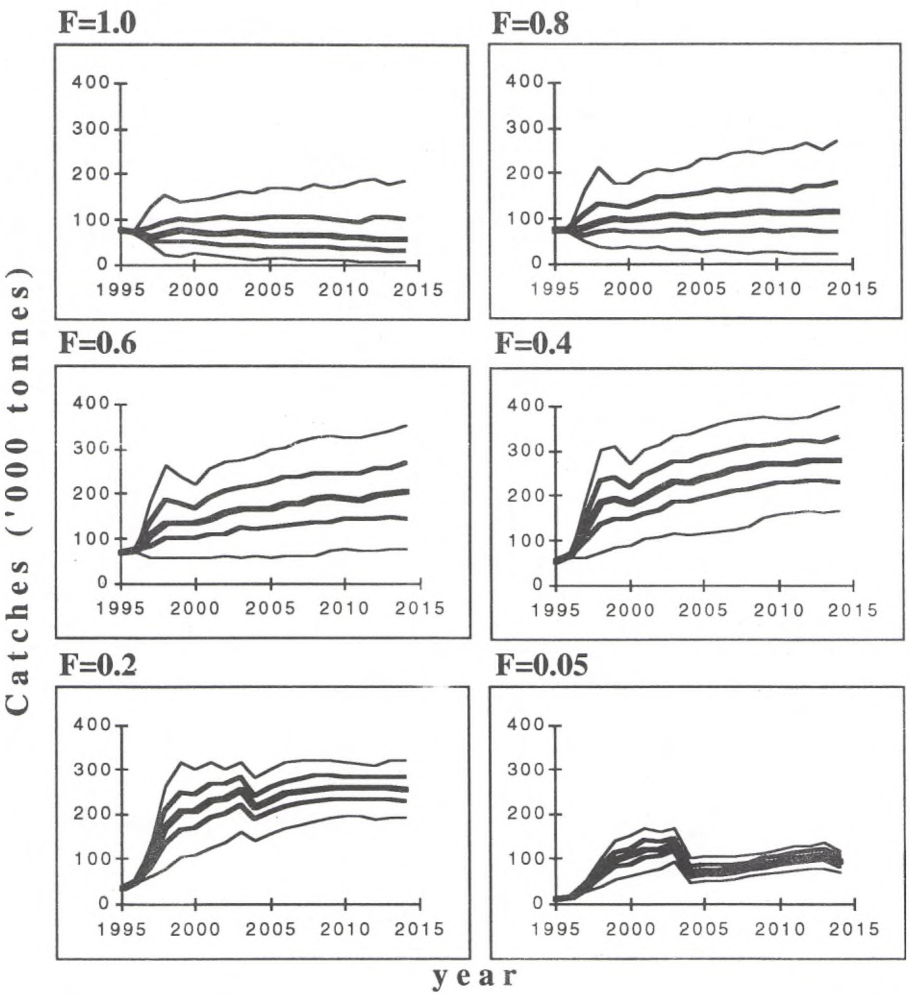


Figure 3. The percentiles (5, 25, 50, 75, and 95%, respectively) of the cod catches for a range of fishing mortalities (F=1 denotes fishing mortality in 1993). Option with deterministic component in recruitment and variance of random component increasing with the mean.

For stochastic option of recruitment it was assumed in Anon. (1994a) that recruitment follows the log normal distribution and three levels of the mean of this distribution were adopted: low, medium, and high. The calculations were done only for fishing mortality at the 1992 level; the projected mean of the cod catches ranged from 400,000 to 550,000 t in 1997-2001 for a medium level of the recruitment mean. These values are much more optimistic than the results in the present paper. Therefore, for

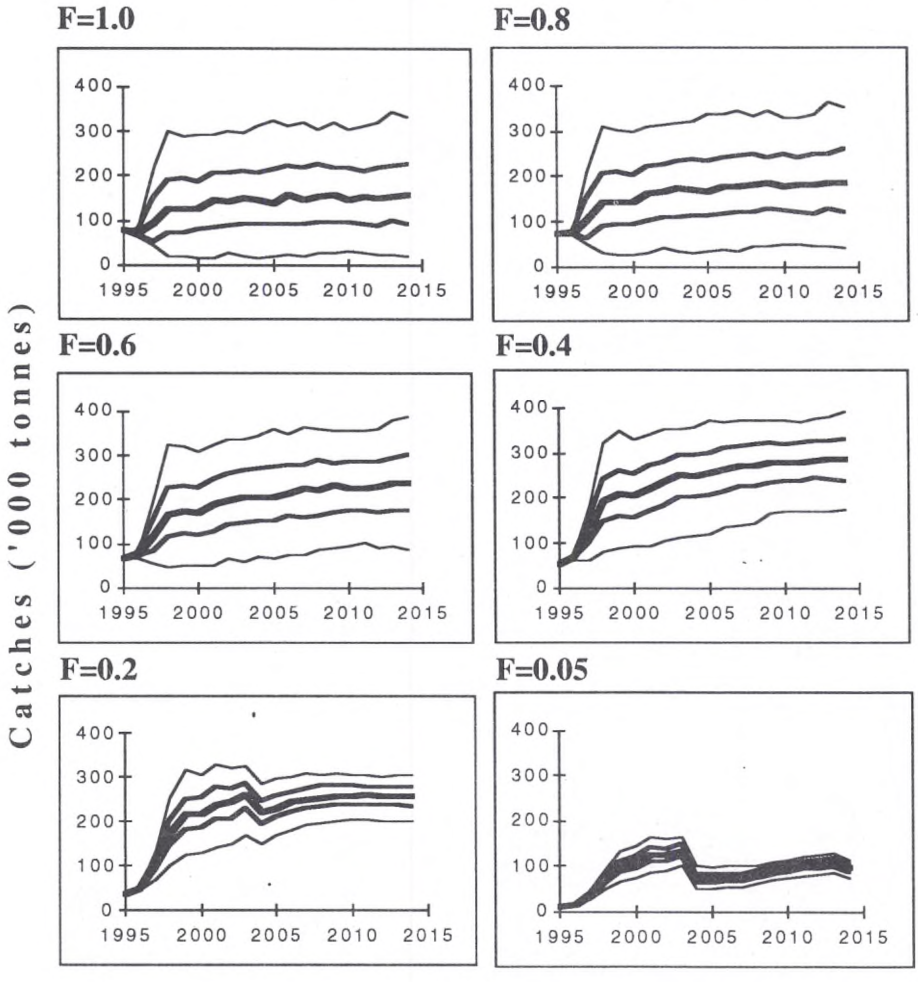
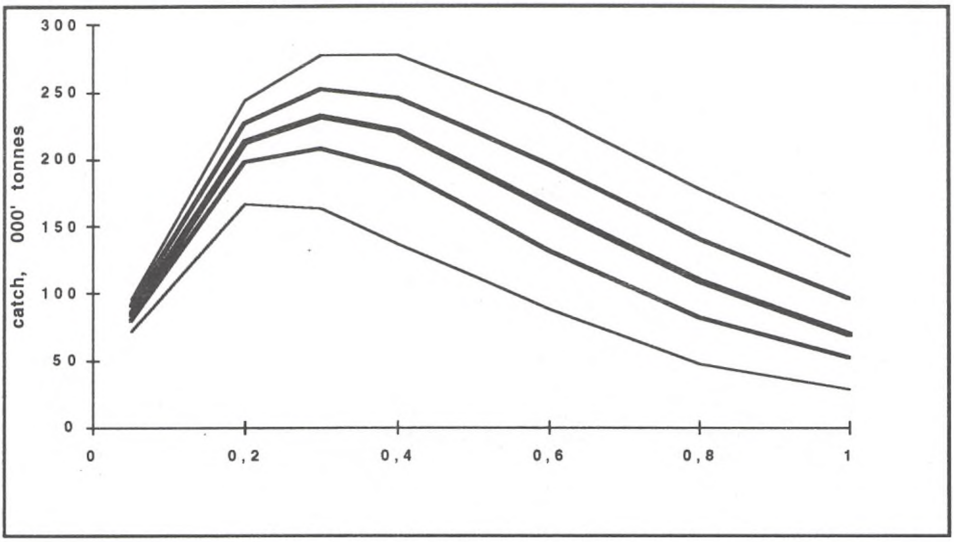


Figure 4. The percentiles (5, 25, 50, 75, and 95%, respectively) of the cod catches for a range of fishing mortalities (F=1 denotes fishing mortality in 1993). Option with deterministic component in recruitment and constant variance of random component.

variance increases with the mean



constant variance

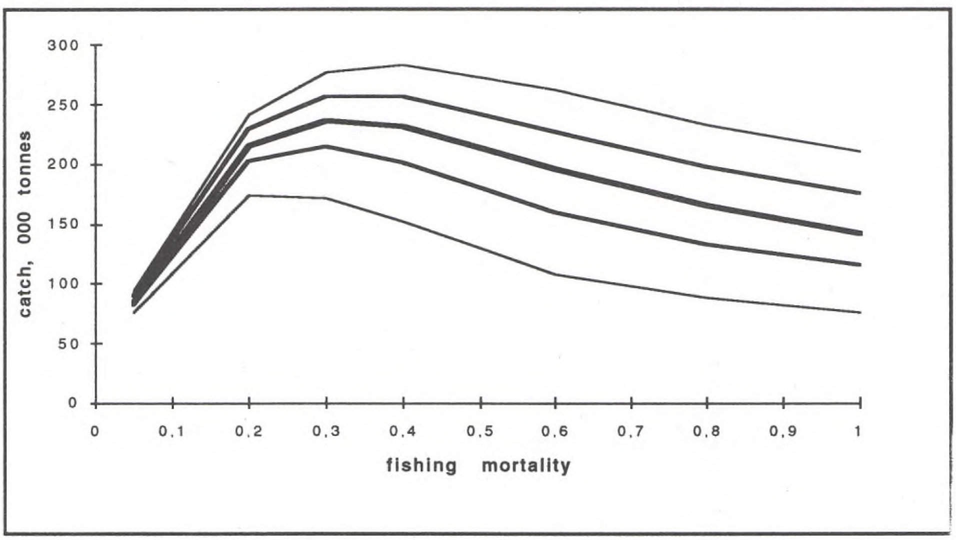


Figure 5. The percentiles (5, 25, 50, 75, and 95%, respectively) of the 20 years' averages of the catches for a range of fishing mortalities (F=1 denotes fishing mortality in 1993).

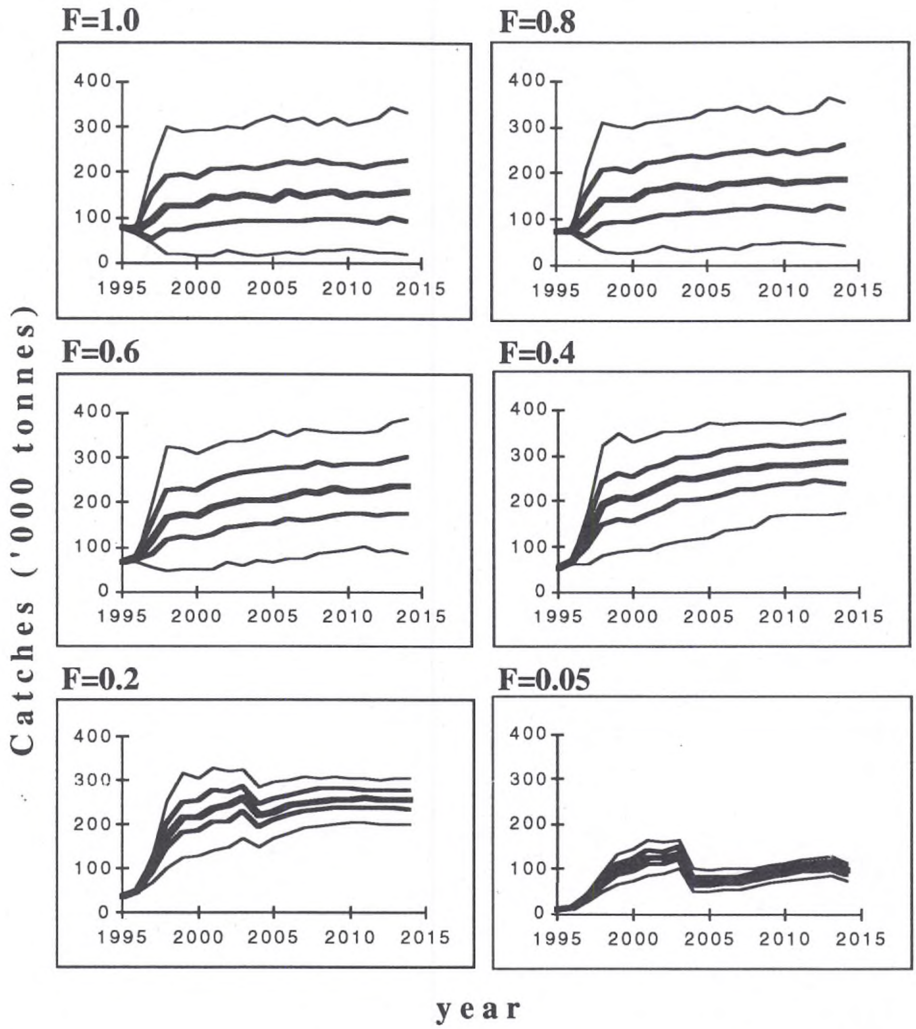


Figure 6. The percentiles (5, 25, 50, 75, and 95%, respectively) of the cod catches for a range of fishing mortalities (F=1 denotes fishing mortality in 1993). Option with totally random recruitment.

comparison, additional simulations were performed with totally random recruitment following log normal distribution (Fig. 6). Now, fishing mortalities ranging from 40 to 100% of the 1993 value gave similar percentiles of the catches, with exception of the 5% percentile, which was higher for higher mortality values. The average catch would be about 240,000 - 250,000 t, without clearly defined maximum concerning fishing mortality. Therefore, it may still be profitable to reduce fishing mortality, as similar catches can be obtained with a much lower fishing effort.

The final conclusion from the performed simulations is that reducing present fishing mortality of cod by 2-3 times could give higher catches, or at least reduce the cost of the catches, irrespective of existence or non-existence of the stock recruitment relationship.

Acknowledgement

I thank the General Secretary of ICES for the permission to cite the Reports of the ICES working groups.

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The state of the eastern Baltic cod stock in relation to biological reference points: review of published results

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Abstract

In the past years several authors used different mathematical models to assess the Baltic cod resources. The results of these assessments are compared. They consistently show the decline of the cod biomass since the middle of the eighties. The catches and the fishing mortality are compared with the relevant values resulting from the biological reference points. It is concluded that high fishing mortality is one of the reasons of decline of cod biomass and catches.

Key Words: Baltic, cod, biomass, recruitment, catches, fishing mortality

Introduction

The Baltic cod fishery was developing very intensively in the last two decades. The landings increased from about 200,000 t at the beginning of the eighties to 440,000 t in 1984. Since that time landings have systematically decreased reaching a record low level of about 40,000 t in 1993. The 1994 landings again increased to 74,000 t. These are, however, official figures, which differ substantially from the true landings in the last years. The estimates of true landings indicate that they were 50-100% higher in the last two years than the official data. Also, it should be mentioned, that the Total Allowable Catch (TAC) of cod set up by the International Baltic Sea Fishery Commission (IBSFC) was substantially higher in last several years than the values of TAC estimated and recommended by scientists. This shows the insistence of the fishermen on catching cod and the importance of this species for the Baltic fishery.

Two major Baltic cod stocks may be distinguished: the western Baltic cod stock (areas west off Bornholm) and the eastern Baltic cod stock (areas east off Bornholm). The highest cod catches come from the eastern Baltic cod stock, constituting 80-90% of the total catches, and very little information was found in the literature concerning the assessment of the western stock, therefore, the focus of the present paper will be on the eastern cod stock.

The aim of this paper is:

i) to check the consistency of cod biomass estimates produced by different models and methods,

ii) to compare the stock exploitation with the so called biological reference points (BRP).

To achieve these aims, the results published in the last several years are reviewed.

The biomass of the eastern Baltic cod stock and recruitment to the stock

A variety of methods have been used when evaluating the state of this stock. Both analytical and synthetic models have been applied. Surveys were conducted to assess the biomass and recruitment to the stock. The biomass estimates, based on different methods, are presented in Fig. 1.

The ICES working group for assessment of demersal stocks in the Baltic has been using ordinary virtual population analysis (VPA) tuned to CPUE, and the survey data by the Extended Survivor Analysis (XSA) method (Anon., 1994b). The method has been extensively tested and it is similar to the integrated methods concerning robustness. The stock has also been assessed using the multispecies VPA (MSVPA), including cod cannibalism (Anon., 1994a). These estimates of stock biomass show trends similar to the former estimates (Fig. 1) but produce higher values for the first half of the eighties, when cod biomass was high, leading to a substantial effect of cannibalism. Then, predation mortality of younger cods was high which, for a given catch, produced bigger biomass figures.

The simplest method of stock assessment was the "bio-statistical

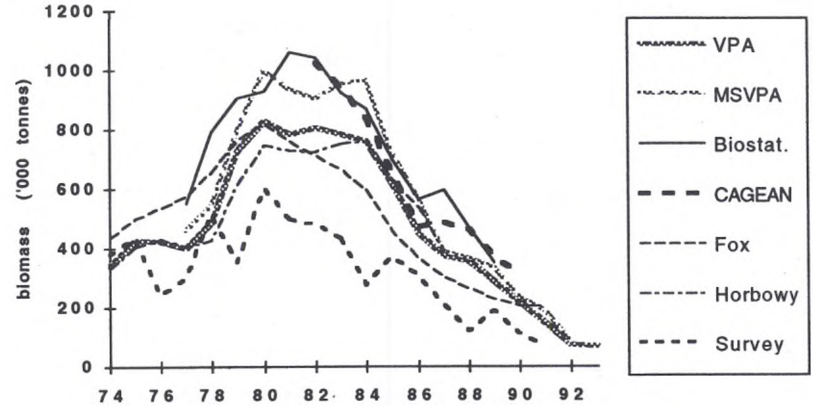

Figure 1. The estimates of the biomass of the eastern Baltic cod stock using different methods.

method" (Malkin and Plikshs, 1993) used to estimate exploited stock in numbers (Fig. 1). The method uses catch at age numbers to determine stock size and recruitment. The stock in a given year is the stock in the former year minus catch, plus recruitment. As an estimate of recruitment the total catches of a year-class during its life-span are taken. For the applicability of the method it is necessary for fishing effort to be stable. The method neglects the natural mortality, therefore, it underestimates stock size and recruitment figures, giving only its indices. In Fig. 1 the results of Malkin and Plikshs are presented in terms of biomass, which was calculated by multiplying numbers by mean weights in the spawning stock. These weights are higher than the mean weights of the exploited stock, therefore, the biomass estimates are comparable with other estimates and in some years they are even higher.

Draganik et al. (1992) used VPA tuned to the Polish and German CPUE series by Laurec-Shepherd method. The results were very similar to the estimates of the ICES working group.

Horbowy and Netzel (1992) applied the CAGEAN model (Deriso et al., 1985) to determine the stock size in 1982-1990 (Fig. 1). This model belongs to the family of so called, integrated methods, which have better statistical basis than VPA tuning methods, because they allow for errors in both catch and effort data. Additionally, the computer program developed by Deriso et al., which was available to the authors, estimates the surplus production. It appeared that in each of the analysed years the catches had been, on average, 50% higher than the surplus production (range from 10 to 200%).

Draganik et al. (1992) used both Schaefer (1954) and Fox (1970) production models to evaluate the state of stock in 1961-1990 (Fig. 1) and to estimate the optimum fishing effort and catches. The models were fitted assuming non-equilibrium conditions.

Horbowy (1992) developed the differential alternative to the Deriso production model and applied it to estimate the biomass of cod in 1970-1987 (Fig. 1). The advantage of this model is the reduction of number of parameters to be estimated within the model to three: initial biomass, catchability, and proportionality constant for rescaling the recruitment indices into absolute values.

A number of countries (Denmark, Germany, Latvia, Poland, Sweden) conduct groundfish surveys and young fish surveys in the Baltic. The German groundfish surveys have been the most extensive, being conducted in the Bornholm Basin since 1975. Usually, the surveys have been repeated 2-3 times during the year, covering different quarters (Thurow and Weber, 1992). In Fig. 1 the average of the cod CPUE for the first half of the year is presented.

The results of the models and approaches presented above, allow for some conclusions. First, all the models show decline of cod biomass since the middle of the eighties. The absolute values of the biomass estimates moderately differ but the rates of biomass change are rather similar. The indices of stock biomass derived from groundfish surveys show a trend similar to the models' estimates of biomass. This observation is important because of deterioration of cod catch statistics (being the basis for models used in assessment), which raises some doubts about the reliability of assessment. Although the biggest under reporting of the cod catches refers to 1993-1994 the substantial under reporting probably began in 1990. Age reading of the Baltic cod also presents some problems, leading to inconsistencies among readers, especially when they come from different countries (Anon., 1993). However, these problems do not seem to have bigger influence on the assessment because age structured models and production models give similar results.

In Fig. 2 the recruitment values obtained in some models mentioned above, are presented. Additionally, the recruitment indices based on the young fish surveys and smoothed by GLM are shown. All estimates exhibit consistent decline of recruitment since the beginning of the eighties. The recruitment figures arrived at by using MSVPA (age 1) are much bigger than other values (age 2) in the first half of eighties; then, the biomass of cod was high, leading to a pronounced cannibalism effect. This difference decreases with decreasing cod biomass. Sparholt (in press) showed that stock - recruitment relationship had a linear component when the recruitment figures were estimated by MSVPA. No one demonstrated such a relationship, taking the recruitment estimates from single species VPA.

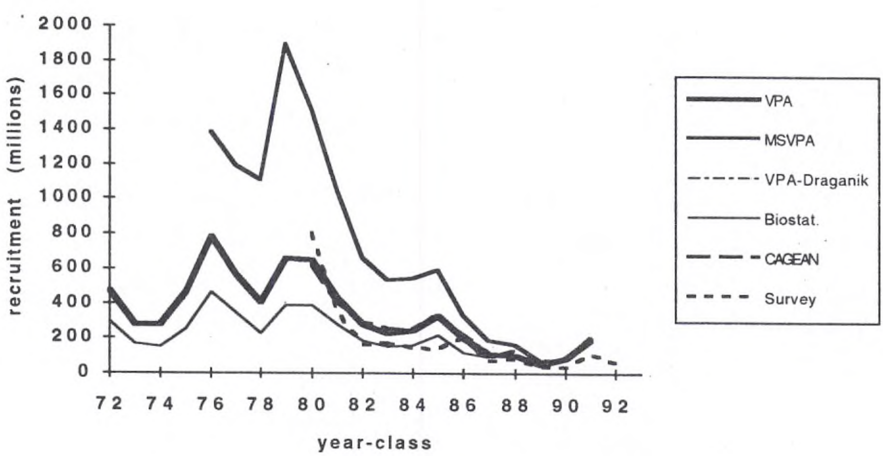

Figure 2. The estimates of the recruitment to the eastern Baltic cod stock using different methods. The MSVPA estimates refer to age 1, other estimates refer to age 2.

The biological reference points and actual exploitation of the stock.

The biological reference points (BRP) represent the value of fishing mortality or fishing effort often referred to when evaluating the way of exploitation of the stock. The so called, Fmax and F-0.1 are related to yield per recruit relationship. The Fmax is the fishing mortality that maximizes the long-term yield from one recruit, the F-0.1 is the fishing mortality under which the CPUE is 1/10 of the potential CPUE from the unexploited stock. The F-0.1 is usually considerably lower than Fmax, but it generates catches only slightly lower than catches associated with Fmax.

Fishing mortality maximizing the equilibrium yield determined on the basis of production models, is usually referred to as Fopt, while the catch associated with it is called MSY (maximum sustainable yield). The other BRP called Flow, Fmed and Fhigh represent the levels of fishing mortality at which probability that recruitment will not compensate the loses due to mortality in the long term is low, medium, and high, respectively (Anon., 1992). In Fig. 3a the fishing mortality of cod (Anon., 1994b) is presented and compared with some BRP. The values of Fmax, F-0.1, and Fmed are taken from Anon. (1994b). The Fhigh - not shown in Fig. 3a - is close to 2.0. The BRP named FincreaseB is a "safe" fishing mortality leading to increase of stock biomass at any level of recruitment (Horbowy, 1992); if recruitment is zero, then the stock biomass is constant in two consecutive years. In all the years since 1974, the fishing mortality has been higher than any of the shown BRP values.

In Fig. 3b the observed catches and the catches simulated on the basis of some BRP are presented. The catch resulting from yield per recruit analysis is obtained by multiplying the yield from one recruit by the long-term average number of recruits. The values of MSY arrived at by using Schaefer and Fox model (Draganik et al., 1992), refer to the simulations mentioned already in section 2. The most optimistic MSY figures were obtained by Draganik and Horbowy (1989) by the means of General Production Model. The authors were aware that this was an overestimate of the MSY level. The reasons for such an overestimate could be the following: the catch and effort data do not contain enough information to estimate parameter describing curvature of the model, and the age structure of the stock was very unstable because after average in number year-classes in the seventies, a series of very abundant year-classes appeared in the first half of the eighties.

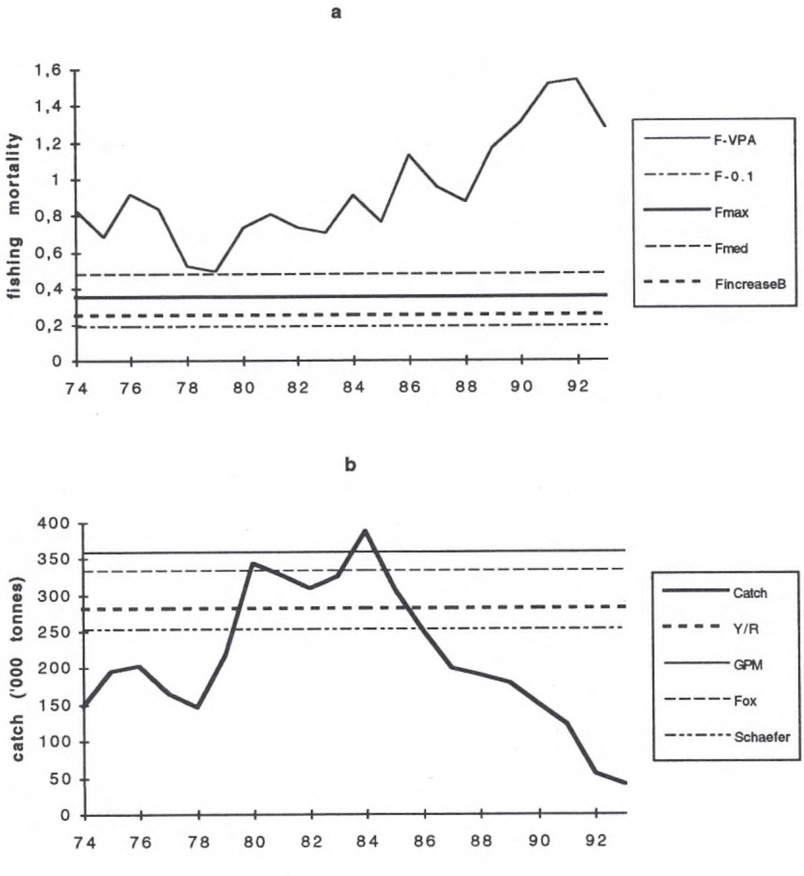

Figure 3. a. Fishing mortality of the eastern Baltic cod stock and the values of the Biological Reference Points (BRP). *b.* The observed catches of the eastern Baltic cod stock and the simulated catches based on the BRP.

An inspection of the Fig. 3 leads to some conclusions. First, fishing mortality was high in the last two decades, highly exceeding the values of BRP in most of the years. It was substantially higher than Fmax, leading to the growth over fishing. The fishing mortality was also substantially higher than Fmed, while the stock - recruitment relationship has a significant stock size component. Therefore, very intensive exploitation probably also led to recruitment over fishing. As an effect, the observed catches in the second half of the eighties and in the nineties were much lower than the values resulting from the BRP, and the reason for that was not only poor recruitment in the last several years but too intensive exploitation of the stock as well.

Acknowledgements

I thank the General Secretary of ICES for the permission to cite the Reports of the ICES working and study groups.

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Increase of cod biomass in the southern Baltic observed during 1994/5 autumn acoustic surveys

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Abstract

During October 1994 R/V "Baltica" took a part in an international acoustic survey of pelagic fish. The survey area covered the Polish fishery zone and most of the southern Baltic (1300 NM of acoustic transects and 29 sample hauls). The state of cod stocks determined on the basis of data collected showed significant increase of its mean density in comparison to other surveys when identical methods of cod estimate were applied. Mean cod density increased from 1.52 t/NM^2 in 1990 to 3.57 t/NM^2 in 1994 in comparable area. The main increase took a place in the western part of the area while the cod was absent in the eastern traditional fishing grounds. The latest cruise in October 1995 gave a little bit lower value of cod density (3.01 t/NM^2). Comparisons of cod distributions over the period 1981-1995 are given and discussed.

Key Words: Acoustics, Baltic, cod, biomass.

Introduction

Polish acoustic surveys of Baltic fish stocks commenced in 1981 by July cruise of R/V "Profesor Siedlecki". Eight such cruises were carried out aboard that vessel till 1990. Last three ones were made during the autumn international acoustic survey of pelagic fish, planned by ICES. In 1994, R.V. "Baltica" replaced the R.V. PROFESOR SIEDLECKI, joining the previous schedule. All mentioned cruises, which represent different seasons and years, delivered a rich material to describe the state of herring, sprat and cod stocks over the period 1981-1995, including an analysis of fish distribution vs. environmental conditions. Details were published by Orlowski(1989, 1990, 1991, 1993, 1994).

Cruise of R.V. "Baltica" carried out in October 1994 (1300 NM of acoustic transects, 29 sample hauls and 13 oceanographic stations) covered significant area of the Southern Baltic Sea (approximately 15 thousand NM^2), including the whole Polish fishery zone. Because areas of described cruises were different, main comparisons are made for the Polish fishery zone, which was permanent for all surveys. For the same reason a biomass density in tons per square nautical mile was chosen as the best magnitude to express the biomass measure.

Methods

Acoustic methods are widely applied in respect to description of pelagic fish resources. Problems with limitations of penetration zone within depths closely to the bottom are well known and their effect on weakness of acoustic method as the tool for accurate estimation of demersal fish biomass. On the other hand, if we take into consideration that demersal fish are present in sample pelagic hauls and respectively recorded by echo-integration systems, the information collected in such a way can be interpreted and treated as an auxiliary factor to describe demersal fish resources too. It can be simply deduced that biomass density of demersal fish observed by acoustic methods should be proportional to the real value of that magnitude and by such a way it can be applied for a quality but not quantity characteristics of cod stocks.

The acoustic survey was performed 24 hours a day with the EK400 scientific echo-sounder and the QD SIMRAD digital echo integrator (Orlowski 1993). In order to identify the recordings and to collect biological samples, 29 pelagic hauls with a WP 53/64x4 trawl, with a bar length of 12 mm in a codend were carried out.

Calibration of the vessel's acoustic system was carried out in the Swedish fjord Hogön with the help of N. Håkansson from the Institute of Marine Research in Lysekil. Acoustic calibration constant SL + VR was estimated as 128.51 dB.

Cruise data were recalculated for each ICES statistical rectangle (1 degree longitude and 0.5 degree latitude) on the basis of results of two or more sample hauls made in each of such units or their neighbouring vicinity.

Cod Distribution

Geographic distribution of cod, calculated on the basis of data collected during October 1994 cruise is shown in Fig. 1. Mean density of cod biomass for the Polish fisheries zone achieved 3.57 t/NM^2 with confidential interval 0.716 t/NM^2. The same magnitude for the whole southern Baltic area, covered during by R.V. "Baltica" cruise (double in comparison to the Polish fishery zone) was a little bit higher (3.77 t/NM^2, C.I. = 0.638 t/NM^2). Main cod areas were identified as Kolobrzeg fishing grounds (S and S-E from Bornholm), Hanö Bay and Bornholm Deep. In all mentioned areas the mean density of cod biomass exceeded 4 t/NM^2. Cod was practically absent in the eastern part of the Baltic. Only some cod was located in Gdansk Deep, Gdansk Bay and Wladyslawowo fishing grounds. Total biomass of cod in the area of the Southern Baltic, covered by cruise, was estimated as 55.7 thousand tons (22.7 thousand tons in the Polish fishery zone).

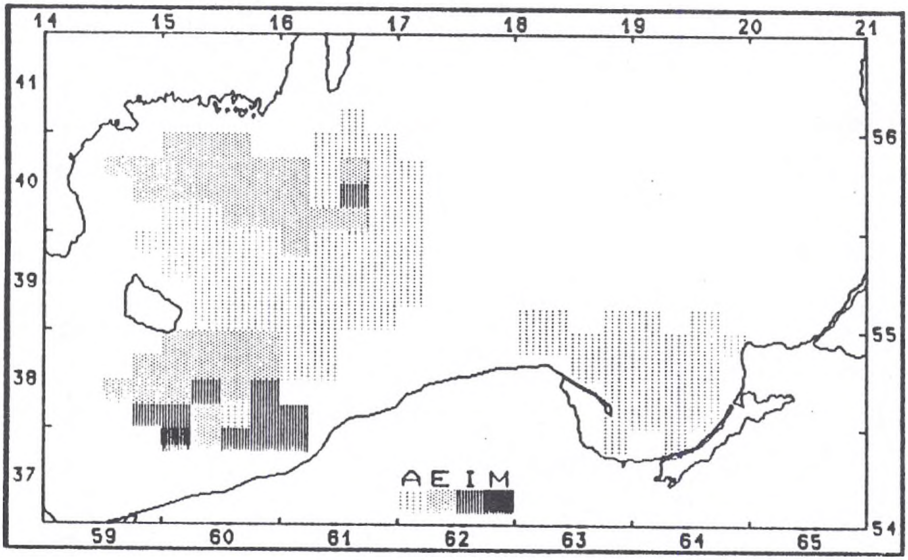

Figure 1. Distribution of cod stocks in the Southern Baltic in October 1994 (average biomass density per ICES statistical rectangle). Scale of graphic symbols: A: 0 - 4 t/NM^2, E: 4 - 14 t/NM^2, I: 14 - 40 t/NM^2, M> 40 t/NM^2.

Most of cod concentrations were found below the halocline, in isotherm waters with temperatures between 7.5°Cand 8.5°C, below 50 m depth. Adequate oxygen level was exceeding 1.75 ml/l.

Taking into account cod distribution characteristics, obtained over the period 1981-1994 by exactly the same methods, based on acoustic and pelagic trawl sampling, the analysis of cod biomass conditions can be provided to complete and to confirm the knowledge of cod stocks, compiled by other ways.

At first it could be interesting to compare cod distribution patterns in the Southern Baltic determined during successive cruises over the reported period.

In Fig. 2. a picture of time-varying cod distribution is given by eight consecutive maps, corresponding to each survey. In order to make the comparison more effective, two classes of densities were projected to the maps only. Graphic character A, shows areas where cod densities were higher than zero and lower than 4 t/NM^2, while character Q corresponds with densities over 4 t/NM^2.

Cod densities 1981 - 1994

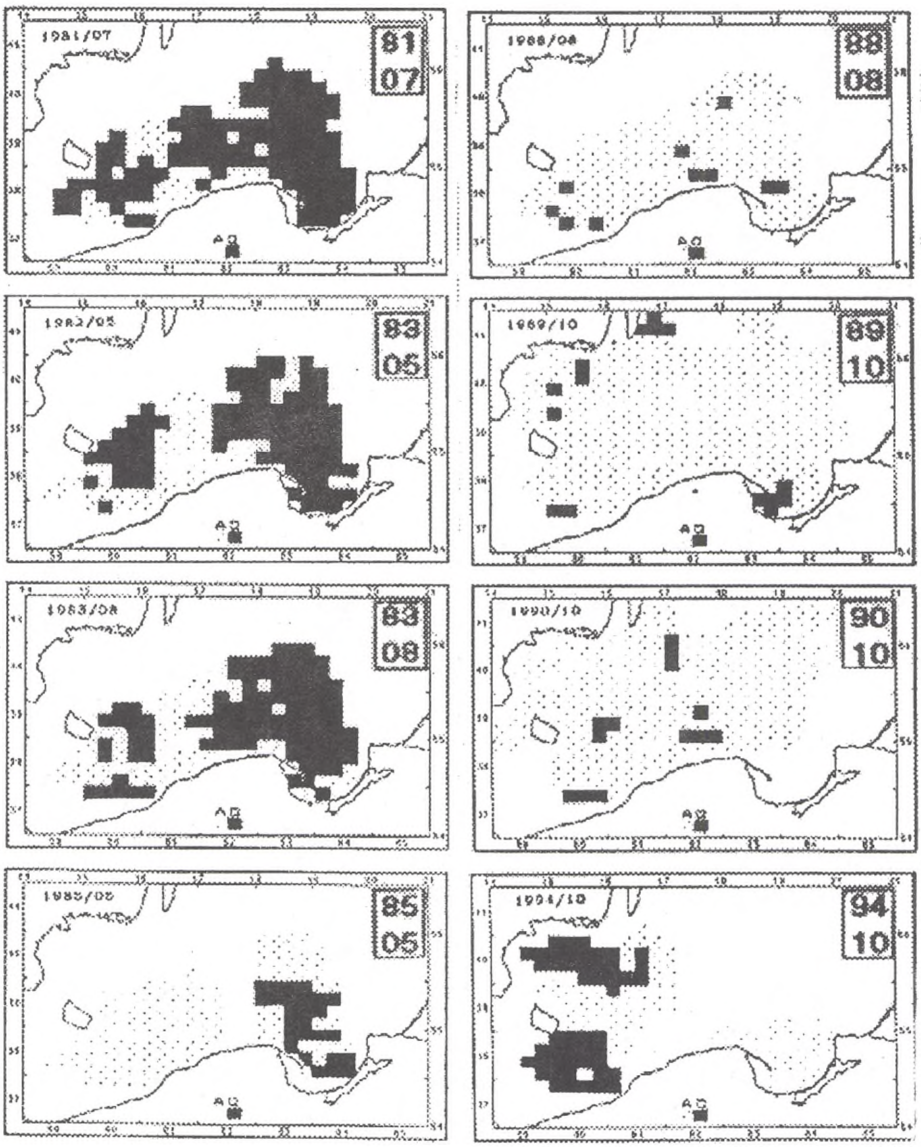

Figure 2. Distribution of cod stocks in the Southern Baltic, determined by acoustic successive surveys over the period 1981 - 1994. Scale of graphic symbols : A: 0 - 4 t/NM², Q (dark rectangle) > 4 t/NM².

Maps are supplemented by Fig. 3, showing a graphical diagram of mean values of cod density during the period 1981-1995. Table I gives adequate mean values of herring, sprat and cod densities.

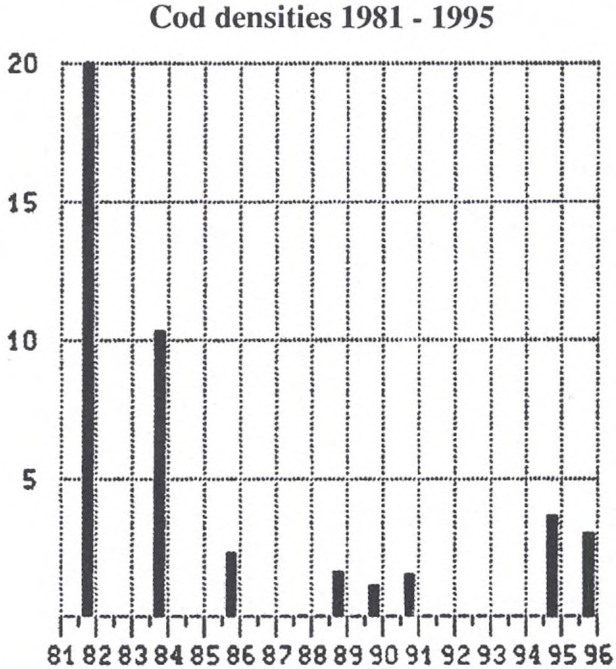

Figure 3. Mean cod biomass densities in tons per square nautical mile, determined for the Southern Baltic during the period 1981 - 1995.

Table I: Mean densities of cod, herring and sprat in Polish fishery zone in period 1981-1994.

Year and month	Mean density in tons/NM^2 Cod	Herring	Sprat
1981 July	20.00	41.41	8.26
1983 May	10.51	26.65	43.34
1983 August	10.04	43.42	46.46
1985 May	2.34	1.37	18.30
1988 August	1.60	13.71	3.73
1989 October	1.09	33.47	11.29
1990 October	1.52	28.24	17.48
1994 October	3.57	23.65	37.07
1995 October	3.01	31.44	20.60

Successive cod distribution patterns show three phases of cod biomass state. During the period 1981-1983 cod was widely present in the whole surveyed area (western and eastern parts) and its mean density, exceeding 10 t/NM^2, was comparable with herring and sprat (high density phase).
In 1985, cod reduced its presence to eastern zone of the Southern Baltic, while a mean biomass density decreased to a value 2.34 t/NM^2 (transient phase).
During the period 1986-1990 cod was randomly distributed over the whole area. Significant concentrations were not observed, while its mean density was extremely low, below 2 t/NM^2 (low density phase).

The distribution of cod in 1994 indicated appearance of concentration zones in the areas of Hanö Bay, Bornholm Deep and Kolobrzeg fishing grounds - all in the western part of the Baltic. Mean density of biomass exceeded 3 tons per square nautical mile. It can be supposed that the picture corresponds to transient phase.
As it is seen from Table I, cod densities over the period 1981-1994 were varying in a wide range, from 20.00 t/NM^2 in 1981 to 1.09 t/NM^2 in 1989 (a minimum value). Since the year 1990 a moderate increase of cod density is observed. Increase of cod density is accompanied up to 1994 by decrease of herring and increases of sprat densities (Table I). Positive gradient of sprat biomass gives an optimistic base for increase of population of cod.

Figure 4 gives a detailed comparison of cod mean densities in ICES statistical rectangles, expressed by proportional bars for each rectangle. Comparisons represent the high density phase (July 1981), a low density phase (October 1990). The cruise from October 1994 can be identified, as a transient phase. Due to a limitation of the 1981 survey to the Polish fishery zone, a comparison is not full in respect to Hanö Bay. It is important to identify areas, where cod was permanently present during the period reported (during three called phases). Fig. 4. shows three such areas: Kolobrzeg fishing grounds, Hanö Bay and Bornholm Deep. It must be underlined that the density of cod in October 1994 in the areas mentioned above is comparable to its densities determined in 1981 (rectangles 3760,3860,3960).

Alleastern areas of cod concentrations from 1981 disappeared during the low density and transient phases. An absence of cod in the eastern area of the Baltic in 1994 can be joined with strong presence of cold "winter waters", with temperatures below +4°C, with minimum value +2.82°C (50 m depth), ranging from 40 m depth, down to the bottom depth.

Cod densities in T/ Nm²

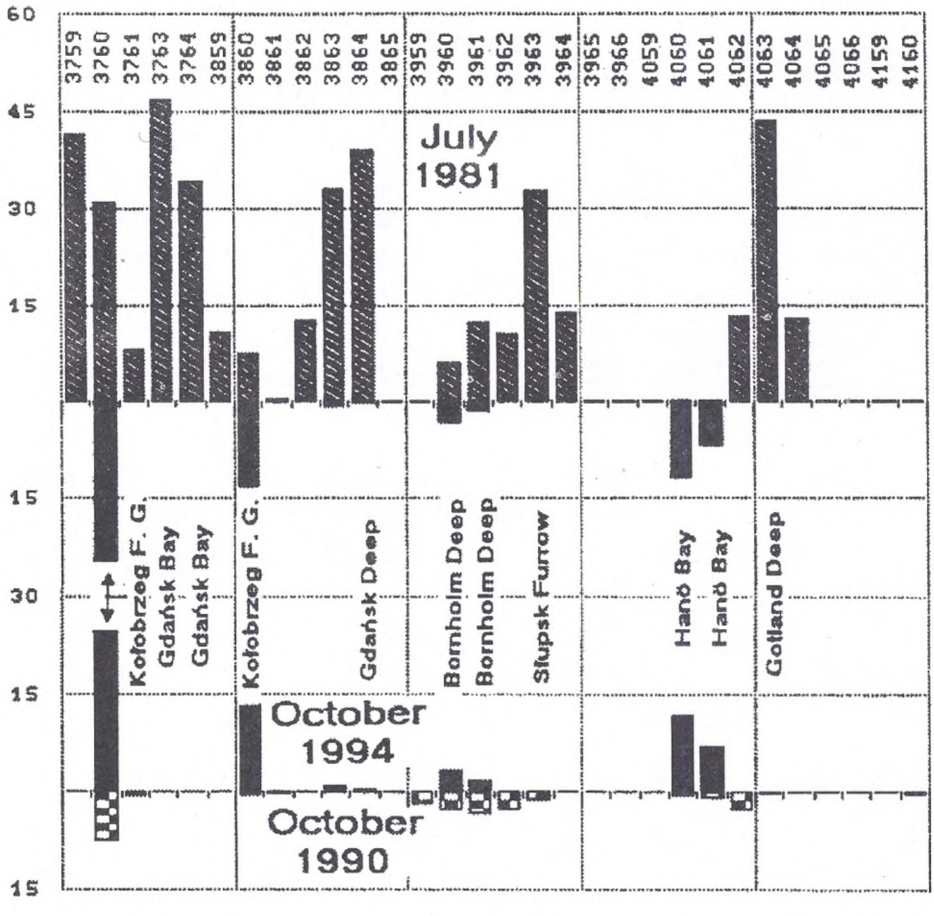

Figure 4. Comparisons of mean cod biomass densities in tons per NM², for each of ICES statistical rectangles in the Southern Baltic in the years 1981, 1990 and 1994. Main geographical areas and fishing grounds are identified.

Conclusions

The results of investigations presented above allow for the formulation of the following conclusions:

* increase of cod biomass density in the Southern Baltic from 1.09 t/NM^2 in 1989 to 3.57 t/NM^2 in 1994 and 3.01 t/NM^2 in 1995, mainly in the western part, was observed,
* in 1994 cod was practically absent in the eastern traditional fishing grounds, what can be partly caused by appearance of "winter water" masses, ranging from 40 m depth down to the bottom,
* according to comparisons presented, cod stocks are in a transient phase, with a small year by year fluctuation of its biomass density,
* duration of the transient phase will be closely correlated with intensity of cod fishery and its reproduction conditions,
* acoustic methods of fish stock assessment, are able to enrich the knowledge on cod biomass and its distribution, in the sense presented above.

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Is variation in size at age an effect of differences in growth rates or hatching times?

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Abstract

Short mean length was registered for one-year old Baltic cod (*Gadus morhua*) of year-classes -91 and -92. This made it interesting to study possible differences in growth rates or differences in hatching times.

The results were based on data collected from 1988 to 1994 on R/V Argos surveys. Length at age was determined from otolith readings, for younger fish verified from length distributions.

The study showed that year-classes -91 and -92 were significantly shorter as one-year olds. No significant difference in growth rates could be seen, compared to the other analysed year-classes.

The results indicate a late hatching in both 1991 and 1992. Anomalies in age-reading of cod otoliths were obvious in the material, but did not affect the one- and two-year olds.

Significant variation between hauls was caused by small catches of one-year old cods. The catches were also unevenly distributed amongst hauls. The result indicated that the sampling strategy used might be unsuitable for collecting data of one-year old cod.

Key Words: Baltic cod, growth, hatching time, ageing, otolith

Introduction

Size at age is an important parameter in fish stock assessment. Variation in size at age is normally rather high for several reasons, e.g. inter- and intraspecific competition, density dependence in growth rate and selective fishing. In the last few years this variation has been especially large in Baltic cod, which has initiated this investigation.

Wide fluctuations in the Baltic cod stocks have been reported (Otterlind, 1984). During a period from the late 1970s to the mid 1980s high catches were taken, but from 1984 there has been a continuos, sharp decline of the stocks to the lowest level recorded, due to poor recruitment and heavy fishing (Sjöstrand, 1994). The decreasing recruitment is mainly caused by declining spawning biomass, small reproduction volume, the latter limited by low salinity and oxygen concentration (Larsson, 1993, Nissling et al., 1994).

The long spawning period of cod (east of Bornholm) may compensate the sometimes critical abiotic conditions. The spawning period normally begins in February - March and ends in August (Bagge, 1981). In the last few years later and prolonged spawning has been registered. The 1990 year-class had its bulk of recruits from June to August, and the 1992 year-class had a distinct shift towards the later months of hatching, i.e. into September and October. The hatching period of the 1991 year-class was more prolonged and lasted 7 - 8 months with the majority hatching in May - August according to polish investigations (Linkowski and Kowalewska-Pahlke, 1993). According to swedish observations the peak was in August (Larsson, 1992).

The difficulties in otolith age reading are much discussed. Otoliths from Baltic cods are characterized by a diffuse growth pattern, and the annual rings are therefore difficult to distinguish (Anon, 1994; Ernst et al., 1995).
The aim of this study is to analyse differences in size at age of Baltic cod, and try to find out whether the variation in size is an effect of differences in growth rate or in hatching time.

Materials and Methods

The data included in this study were collected between 1988 and 1994 from Baltic cod trawling surveys with the swedish R/V Argos. Only ICES Subdivisions 25-28 were included in the analyses (eastern cod stock). The Subdivisions and the trawl stations usually visited during a survey in the Baltic sea are shown in Figure 1. Surveys were performed in March, August and December, but all three months were not represented every year. A GOV trawl and a Fotö cod bottom trawl were used, both with 16 mm mesh size (stretched) in the codend, both comparable in fishing efficiency.

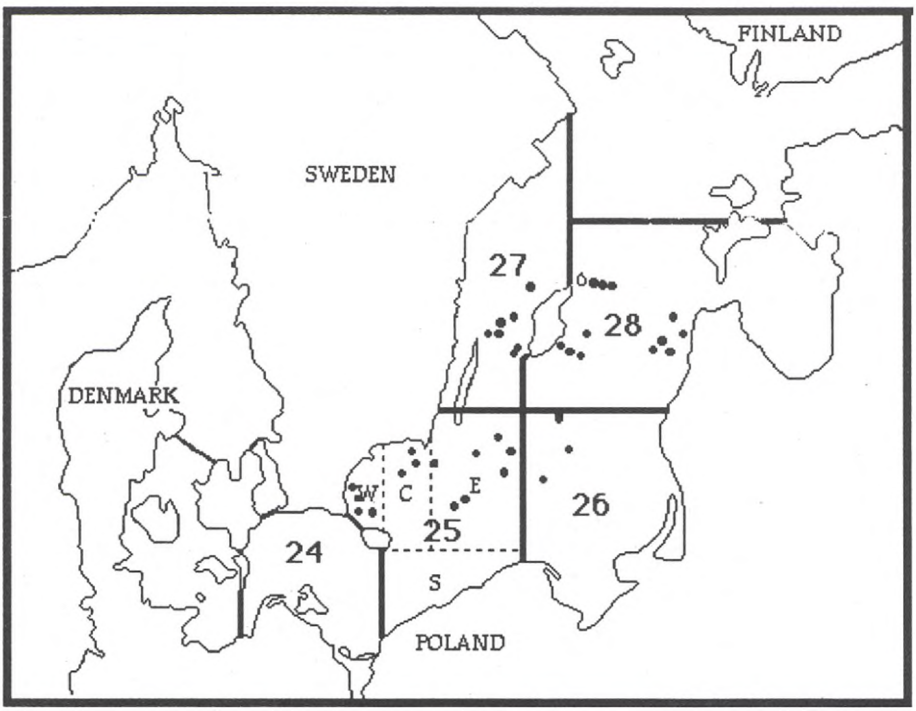


Figure 1. Map of Baltic Sea with Subdivisions 24-28. Subdivision 25 is seperated in Western, Central, Eastern and Southern part. Typical example of trawlstations during a Baltic cod expedition with the research vessel Argos are marked with a dot.

Size at age

The catch was weighted and all cod were measured in length to the nearest cm below. In addition, individual data including length, weight, sex, maturity and age were registred on five fish per cm and Subdivision (note that SD 25 was divided in three subareas). The collected individual data resulted in 300-1000 aged cod per survey.

The otoliths were cleaned and broken in two. The crossection was studied under a compound microscope with 10-16 x magnification using reflected light to enhance the contrasts between the hyaline and opaque zones. Once the ages were determined (all ageings being adjusted to the same birthday, First of January) an Age-Length-Key (ALK) was made, from which the proportion and the mean length of each year-class were calculated.

To detect possible differences in mean length of the one-year olds and the two-year olds between year-classes, a nested ANOVA was designed. To obtain a balanced ANOVA from the collected data only SD 25W, 25E, 27 and 28 were included, three hauls representing each Subdivision.

Growth rate

The observed differences in mean lengths of one-year olds between year-classes made it interesting to study possible differences in growth rate. The observation was analysed in two different ways.

a) In the first approach, lengths were plotted against time, but only lengths of one-, two- and three-year olds were included and analysed in a linear regression for each year-class. The slope, b, for each regression was used as a measure of growth rate and analysed in a t-test.

b) In the second approach, the von Bertalanffy growth equation was used to study the growth pattern.

$$L_t = L_\infty(1 - e^{-K(t - t_0)})$$

for length L_t at age t (von Bertalanffy, 1957).
L_∞(asymptotic standard length in cm), K (Brody growth coefficient) and t_0 (age at length 0).

Growth parameters which were suggested as relevant for Baltic cod, L_∞= 105, K=0.15 and t_0=0.5 (Bagge, 1981) were used in the equation and plotted as a predicted growth curve. The mean lengths at age calculated from the ALKs were plotted against the predicted growth curve and the difference between the two growth patterns was tested in a x^2-test.

Results

Length distribution

Length distributions of cod for the surveys in December 1991 to December 1993 were plotted in Figure 2. Year-class 91, could easily be followed from 9112 (December 1991), with a peak at five to six cm (in the lowest end of the selectivity curve for the trawl used, four to five cm cod being the minimum size caught), and onwards until 9312. The year-classes 92 and 93 were lower in abundance and could hardly be detected in the diagrams. The results indicated a relatively strong year-class 1991.

Age-Length-Key

ALKs from 15 surveys are presented in Table I. The proportion calculated for each year-class made it possible to study the age distribution within a year. Year-class 91 emerged as the one-year olds in March 92 (9203 in Table I) with a dominating proportion of 0.54. The year-class could be followed in time through its proportion and mean length. Again year-class 91 was indicated to have a high abundance, but it also seemed to have a shorter mean length as one-year olds compared to earlier studied year-classes. An obviously smaller size at age made it interesting to study the data in details.

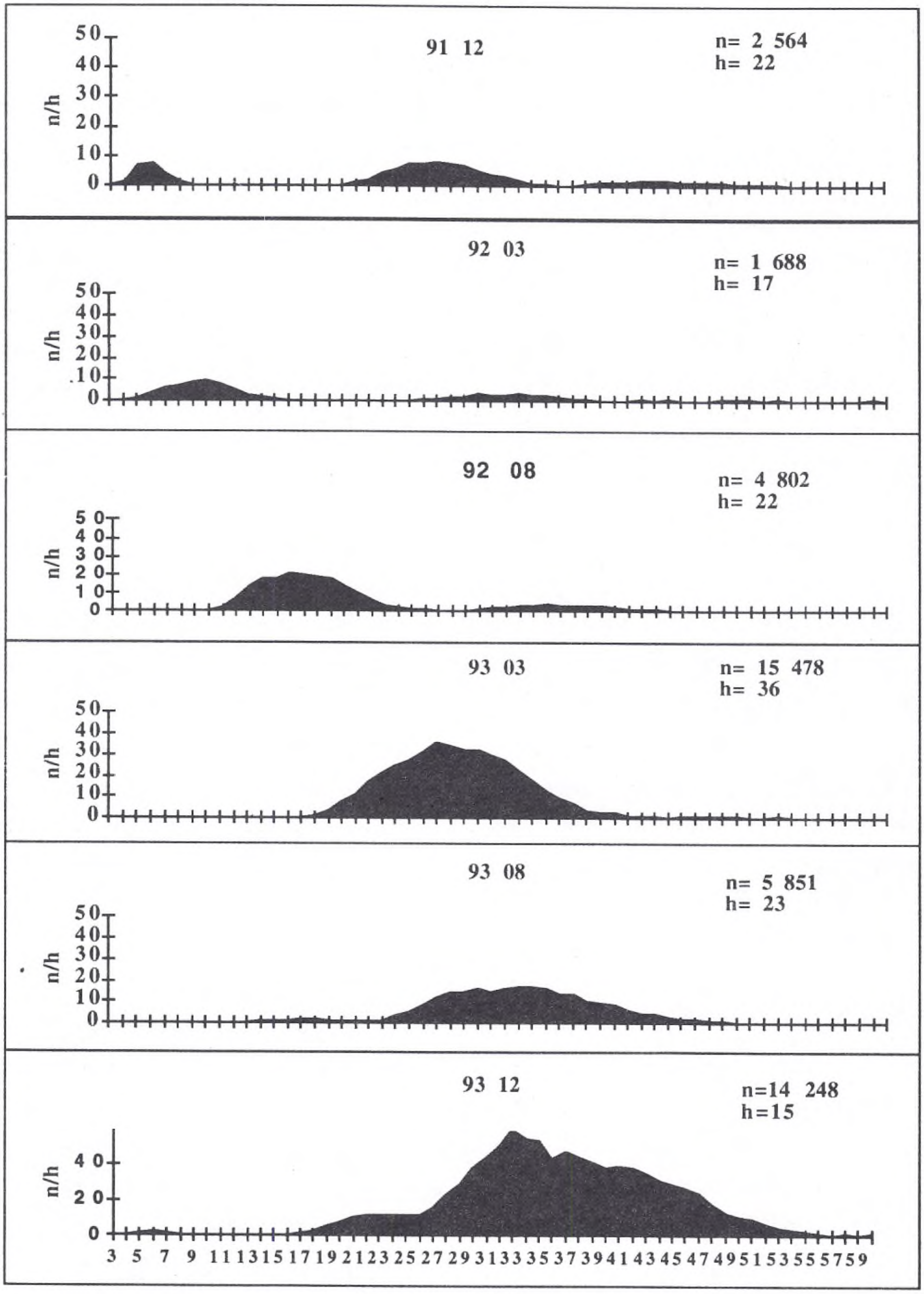


Figure 2. Length distribution diagrams from 9112 to 9312. Cod caught in Subdivision 25-28 are included. Number of cod (n) measured and number of trawl hours (h) are presented for each epedition.

Size at age

The mean lengths at age illustrated the growth pattern for each year-class. Frequent negative growth rates, especially for year-class 88 and 89, indicated unrealistic size at age (Fig.3). Variation in mean lengths increased with age. The patterns indicated problems in the age-determining process, especially for older, less sampled cod. In most cases, however, the mean lengths of the one-and two-year olds could be verified from distinct peaks in the length distribution.

Mean lengths of the one-year olds of year-classes 91 and 92 were significantly shorter than one-year olds of other year-classes ($p<0.05$), (Fig.4). The ANOVA design also presented a significant difference between hauls within a Subdivision within a year, with the sampling strategy used, (Table II).

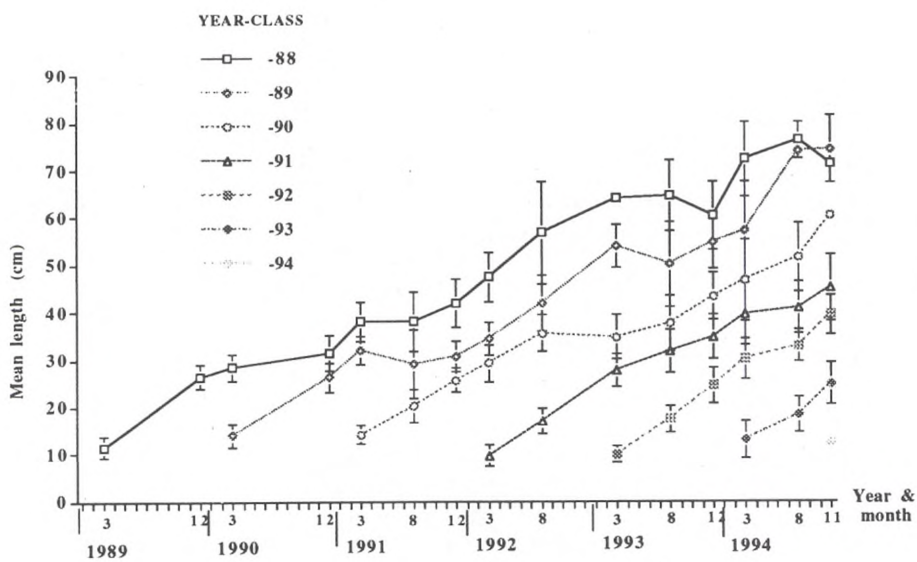


Figure 3. Mean length at age plotted for year-classes 1988-1994.

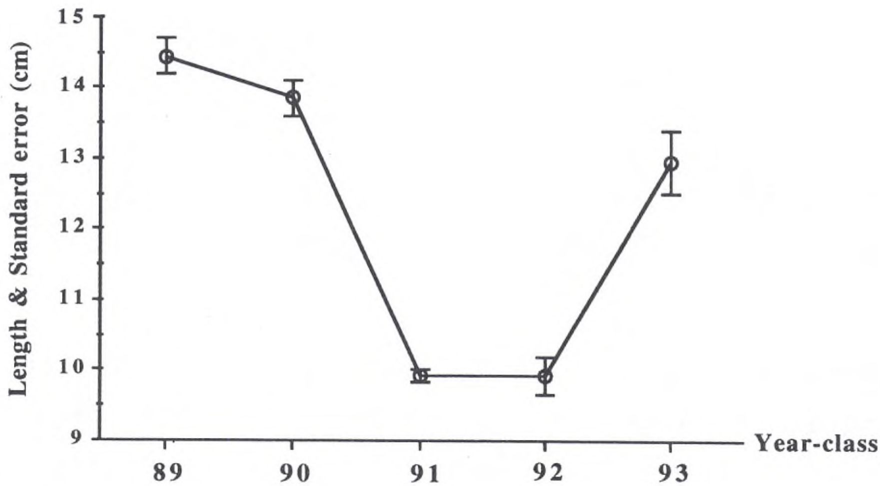


Figure 4. Mean lengths of one-year old cod. Year-class 91 and 92 were significantly shorter, $p<0.05$.

The two-year olds of the same year-classes were also studied regarding their growth pattern. A variance analysis was used and the results are shown in Table III. Year-class 91 was still significantly shorter as two-year olds compared to the others and year-class 88 and 90 differed significantly from 89, 91 and 92, which indicated a changed pattern, (Fig. 5). The design also indicated a significant difference caused by factor Subdivision as well as a significant interaction between the two factors, (Fig. 6 and 7).

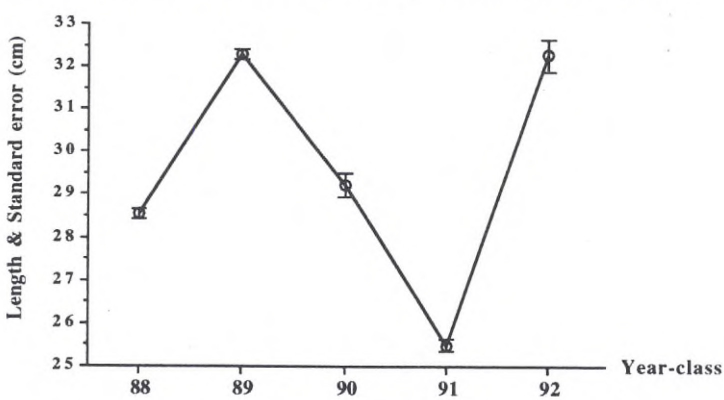


Figure 5. Factor Year-class plotted against mean lengths for two-year old cod.

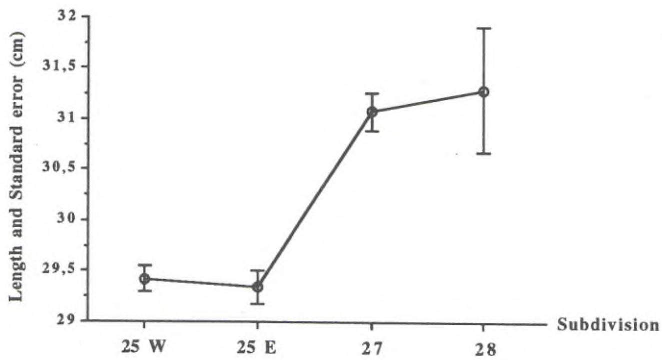


Figure 6. Factor Subdivision plotted against mean length for two-year old cod.

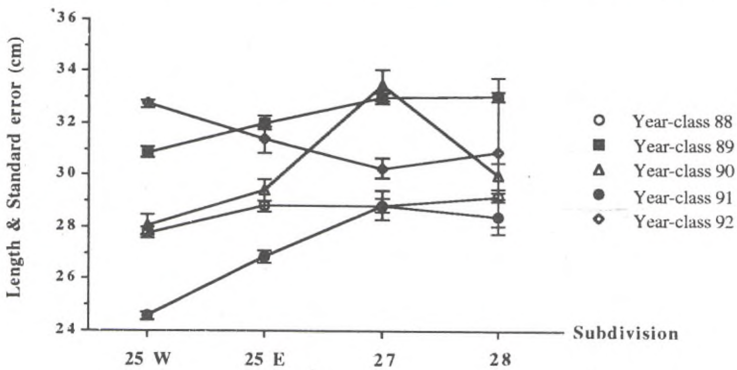


Figure 7. The Interaction between Year-class and Subdivision. The plot shows how the results should be analysed.

Growth rate

Growth rates for the different year-classes were analysed in two ways.

a) Mean lengths were plotted against time in regression analyses and the results are presented in Table IV. ($p<0.05$ for each regression).

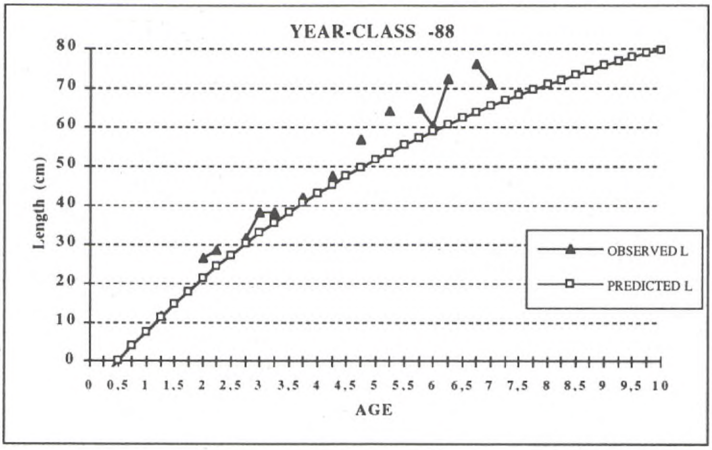
TABLE IV: r^2 and b-values as a result of five regression analyses.

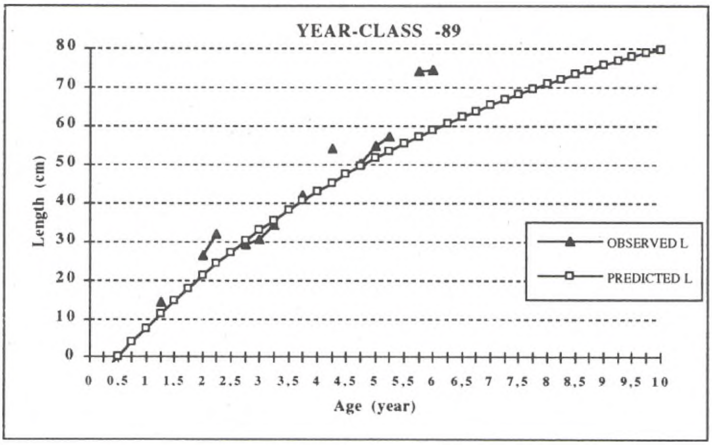
Year-class	r^2	Slope b
88	0.90	0.97
89	0.99	1.42
90	1.00	1.26
91	0.99	1.21
92	0.98	1.33

A constant high r^2 (0.90-1.00) made it relevant to use the b-value as a measure of growth rate for each year-class. The results from a t-test showed no significant difference in growth rates up to three-years of age for the different year-classes, ($p>0.05$).

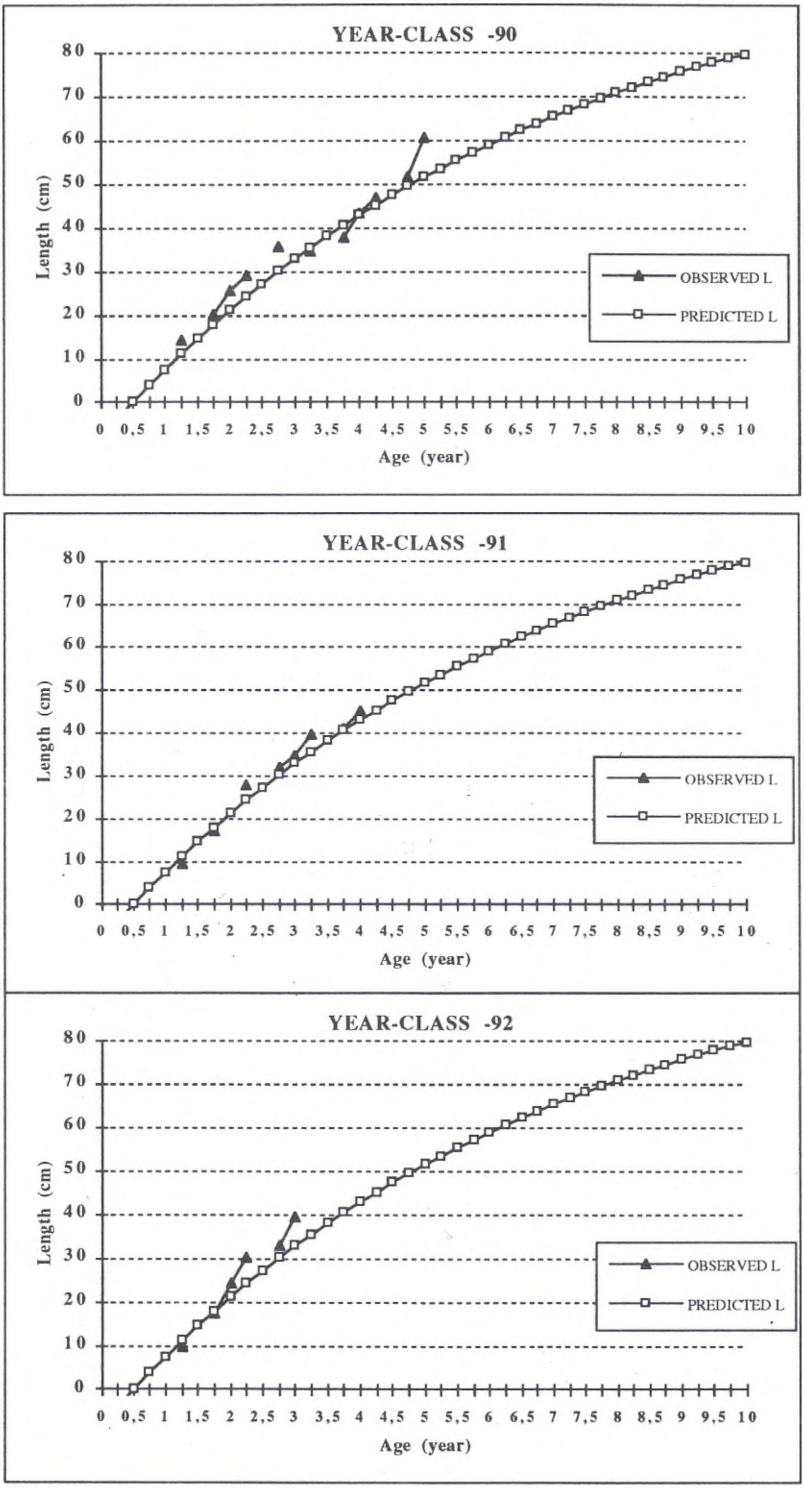
b) The growth pattern was also analysed by applying the von Bertalanffy growth equation. The predicted lengths obtained from the equation were plotted against observed mean lengths calculated from the ALK, (Fig. 8 - 12).

Also, by applying the von Bertalanffy growth equation on observed lengths, values were obtained for L_{∞}, K and t_0 and are presented for each year-class in Figures 8-12. No significant difference between observed and predicted lengths were shown for any of the year-classes, (x^2 -test, $p>0.05$).





Figures 8. and 9. Observed lengths plotted against predicted lengths. Predicted lengths obtained by applying the von Bertalanffy growth equation with growth parameter values L_∞ =105, K=0.15 and t_0=0.5, (Bagge, 1981). Observed lengths growth parameters are shown in each Figure. Age is separated in quarters of a year.



Figures 10-12. Observed lengths plotted against predicted lengths. Predicted lengths obtained by applying the von Bertalanffy growth equation with growth parameter values L_∞=105, K=0.15 and t_0=0.5, (Bagge, 1981). Observed lengths growth parameters are shown in each figure. Age is separated in quarters of a year.

Discussion

Age reading problems

Differences between otolith readers are well known, and are shown at reoccuring workshops for co-reading otoliths, for example the Gdynia age reading workshop 1994 (Anon., 1994).
The results obtained in this study confirm the difficulties in interpreting cod otoliths, especially in older fish. For younger fish the average size is possible to estimate from the length distributions, and we feel confident about the sizes at age for one-and two-year old cod.
The difficulties in the age reading process was reflected both in the "proportion" and the "mean length" and shown in Table I.
A year-class could be followed in time by its proportion, at least up to three-years when length distribution became too much overlapping to the next year-class, partly because it was recruited to the fishery. For instance, the three-year olds in ALK 8903 seemed to turn to be the two-year olds in ALK 8912 (with the proportion values 0.53 and 0.41 respectively, Table I).
Mean lengths at age showed illogical pattern. Table I and Figure 3 illustrate a negative growth rate of especially year-class 88 and 89. Prolonged spawning and large individual variation in growth is characteristic for cod and cause variations in body length within age groups (Baranova, 1992). To measure growth by mean length at ages could therefore be questioned. The mean lengths analysed here seemed to increase constantly with age from 9203 onwards. The result indicated a more consequent age determination since 1992. The abundant year-class 91 but also year-classes 92 and 93 were easy to follow both in proportion and mean length at age (Table I).
More objective methods are important in the development of more reliable ageing methods.

Bias in sampling

The low number of older cod caught as well as one-year old cod caught, on some surveys, apparently tended to bias the results. A small number of measured older cod resulted in large variation in mean length (Fig. 7). For one-year olds the variations in mean length were seen between year-classes but not within, except for year-class 93 (Fig. 3) which might be explained by an inflow of bigger (earlier hatched) larvae from the western stock (Larsson and Rudolphi, 1994).

Figures 8-12 indicated the same pattern, showing that older fish deviated more from the predicted von Bertalanffy growth curve than younger fish, which could be a consequence of few age-determined older cod.

Regarding the one-year old cod the significant variation between hauls was caused by small catches and catches unevenly distributed amongst hauls. This was not observed for two-year old cod. The result indicated that the sampling strategy used might be unsuitable for collecting data of one-year old cod.

Growth of Baltic cod

The growth of cod is determined by food supply, year-class abundance and stock size. Body length in year-classes fluctuates by years and areas, and fish from strong year-classes generally have smaller body size (Baranova, 1992). Year-class 91 and 92 as one-year olds were significantly shorter in this study. The short mean length of year-class 92 could be explained by late hatching as Linkowski and Kowalewska-Pahle (1993) suggested. The year-class 91 was relatively strong and showed an unusual high abundance in a limited area. The small size at age could be explained by either late hatching (suggested by Larsson) and/or a competition situation. Also for two-year old cod significant differences were seen between year-classes. The confusing interaction plot showed that both Subdivision and Year-class should be considered when studying differences in mean length of two-year old cod, (Fig. 7). No multiple comparison was done. No difference could be seen between hauls within a Subdivision and year for two-year olds which could indicate that the sampling strategy used was less selective for bigger cod compared to the one-year olds. Bigger sized cod in Subdivision 27 and 28 compared to 25 could be explained by less competition during the period investigated.

The growth parameters obtained from the observed lengths differed between year-classes. Only year-class 88 matched Bagge´s suggested values, but that was also the year-class with the highest number of measured lengths. The other year-classes showed a higher K (>0.26) and lower L_∞ (<77), except for year-class 89. K and L_∞ are negatively correlated. Thurow (1974) showed that K = 0.1-0.25 with corresponding L_∞ = 90-120 cm. were relevant for Baltic cod. The values in this study seem to be unrealistic.

To equal the data, only lengths up to the three-year olds were plotted for each year-class and tested in the equation. The parameter K increased and L_∞ decreased for all the changed data sets. The result indicated that the amount of data put in the growth equation are of importance for the result, and it seems to be very sensitive for small changes.

General comments and conclusions

ICES Subdivisions have no biological significance by themselves, and parameters like trawling depth and trawl-equipment might be of higher importance for the age-structure in the catches. With the present survey design there are trawl stations at different depths as well as different trawls in use. These parameters would be interesting to analyse but could not be analysed in an ANOVA.

* Development of more objective age reading methods are extremely necessary.

* The sampling strategy used in these surveys might be unsuitabe for collecting data of one-year old cod.

* Because of the uncertainty in the present age reading methodology the data are not suitable for further analyses, and the results should be considered carefully. They do however indicate late hatching to be the cause of smaller size at age one and two for the year-classes 1991 and 1992 rather than slower growth.

Acknowledgments

We wish to thank Per Jonsson and Mats Lindegarth at the Tjärnö Marine Laboratory, who helped us with the statistical design. We also want to thank Barbara Jonsson for correcting the english.

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Table I. Age-Length-Key results from 1989-1994. Proportion, mean lengths and standard deviation (S.D.) are presented for each age and expedition. n=number of fish from wich otoliths were taken for age reading.

YEAR & MONTH		AGE 0	1	2	3	4	5	6	7	8	9+
ALK 8903	**Proportion**		0,03	0,05	0,53	0,32	0,05	0,01	0,00	0,00	0,00
(n=648)	**Mean length**		11,5	29,5	37,0	42,2	50,0	52,4	64,8	70,0	72,0
	S.D.		2,3	4,6	5,0	7,3	8,1	10,4	4,9	2,6	0,0
ALK 8912	**Proportion**	0,04	0,31	0,41	0,10	0,10	0,03	0,01	0,00	0,00	
(n=963)	**Mean length**	10,5	26,5	30,4	41,5	48,1	54,2	61,6	65,3	69,4	
	S.D.	2,8	2,5	2,9	4,0	3,8	4,9	6,0	7,6	4,6	
ALK 9003	**Proportion**		0,03	0,27	0,48	0,14	0,07	0,01	0,00	0,00	0,00
(n=499)	**Mean length**		14,0	28,4	33,0	43,4	51,3	62,5	59,5	66,7	85,4
	S.D.		2,5	2,8	3,2	6,8	9,5	9,3	12,0	5,8	21,6
ALK 9012	**Proportion**	0,00	0,05	0,32	0,27	0,28	0,06	0,01	0,00	0,00	0,00
(n=408)	**Mean length**	6,5	26,3	31,5	41,1	46,6	51,0	58,6	66,9	70,1	72,7
	S.D.	1,7	3,0	3,7	3,9	3,6	5,7	2,9	6,2	8,7	4,4
ALK 9103	**Proportion**		0,01	0,28	0,40	0,22	0,05	0,01	0,01	0,00	0,00
(n=366)	**Mean length**		14,2	32,0	38,1	47,0	53,3	63,2	71,6	75,2	76,5
	S.D.		2,0	2,9	4,1	4,5	4,5	5,7	4,8	3,8	13,4
ALK 9108	**Proportion**		0,07	0,27	0,41	0,18	0,04	0,01	0,00	0,00	0,00
(n=297)	**Mean length**		20,3	29,1	38,1	44,7	53,1	71,3	70,0	78,6	113,5
	S.D.		3,5	7,3	6,3	7,8	14,0	13,2	5,1	9,2	9,2
ALK 9112	**Proportion**	0,19	0,38	0,22	0,11	0,08	0,01	0,01	0,01	0,00	0,00
(n=284)	**Mean length**	6.1	25.7	30.6	41.8	48.6	55.2	61.4	72.1	79.3	133.0
	S.D.	1.6	2.6	3.2	5.1	4.1	4.8	5.6	7.1	3.2	0.0
ALK 9203	**Proportion**		0.54	0.15	0.17	0.06	0.04	0.02	0.01	0.01	0.00
(n=290)	**Mean length**		9.6	29.2	34.4	47.4	54.6	63.6	73.0	74.3	78.8
	S.D.		2.3	3.8	3.4	5.2	5.2	5.1	4.8	7.0	7.8
ALK 9208	**Proportion**		0.81	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00
(n=268)	**Mean length**		17.1	35.6	41.9	56.8	70.2	74.8	51.0	84.6	76.0
	S.D.		3.3	3.8	5.8	10.9	8.3	8.5	22.3	4.7	6.4
ALK 9303	**Proportion**		0.09	0.70	0.19	0.01	0.00	0.00	0.00	0.00	0.00
(n=885)	**Mean length**		21.5	27.8	34.8	54	64	72	79	84	78
	S.D.		2.9	3.5	4.7	4.5					
ALK 9308	**Proportion**		0.04	0.74	0.20	0.02	0.01	0.00	0.00	0.00	0.00
(n=809)	**Mean length**		17.5	31.8	37.7	50.1	64.6	78.2	80.0	78.5	83.9
	S.D.		2.8	4.6	5.9	8.9	7.5	7.5	12.4	9.8	9.8
ALK 9312	**Proportion**	0.01	0.12	0.56	0.30	0.01	0.00	0.00	0.00	0.00	0.00
(n=836)	**Mean length**	7.0	24.5	34.8	43.3	54.7	60.3	80.4			87.6
	S.D.	2.3	3.8	4.7	5.0	5.6	7.2	4.2			18.3
ALK 9403	**Proportion**		0.02	0.43	0.46	0.08	0.01	0.00	0.00	0.00	0.00
(n=1 128)	**Mean length**		17.0	30.1	39.6	46.7	57.1	72.3	85.1	84.3	75.7
	S.D.		7.0	4.2	6.5	8.5	10.5	7.8	6.9	9.2	9.8
ALK 9408	**Proportion**	0.00	0.11	0.38	0.47	0.03	0.00	0.00	0.00	0.00	0.00
(n=464)	**Mean length**	9.0	18.4	32.9	40.9	51.6	74.0	76.3	77.0	90.7	
	S.D.	0.0	3.7	3.4	5.5	7.3	1.2	4.0	0.0	11.1	
ALK 9411	**Proportion**	0.03	0.30	0.52	0.14	0.01	0.00	0.00	0.00	0.00	0.00
(n=957)	**Mean length**	12.6	24.8	39.4	45.2	60.5	74.4	71.3	85.4		95.0
	S.D.	1.7	4.4	4.2	7.0	8.8	7.5	17.2	10.5		0.0

Table II. 2-factor nested ANOVA-table showing the design and the results of the analysis. Factor Year-class ass well as the nested factor Haul had p<0.05.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value	Error Term
Year-class	4	446,2	111,5	8,21	,0001	Haul (Year-class, S...
Sub Division	3	4,1	1,3	,10	,9599	Haul (Year-class, S...
Year-class * Sub Division	12	139,2	11,6	,85	,5981	Haul (Year-class, S...
Haul (Year-class, Sub Div...	40	543,7	13,6	2,52	,0001	Residual
Residual	720	3887,7	5,4			

Dependent: Length

Table III. 2-fator nested ANOVA-table showing the design and the result of the analysis. Factor Year-class, Subdivision and their interaction had all p<0.05 (P-Value column).

Sourse	df	Sum of Squares	Mean Square	F-Value	P-Value	Error Term
Year-class	4	2378,5	594,6	16,9	,0001	Haul (Year-class, S...
Subdivision	3	320,1	106,7	3,0	,0404	Haul (Year-class, S...
Year-class * Subdivision	12	1450,1	120,8	3,4	,0016	Haul (Year-class, S...
Haul (Year-class, Subdivi...	40	1409,3	35,2	,83	,7592	Residua
Residual	2783	117427,4	42,1			

Dependent: Length

Studies of mesh size in cod gillnets with respect to protection requirements.

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Abstract

In 1994, experimental studies of the dependence between length of caught cod and gillnet mesh size were carried out on a 24 m, 165 kW, commercial fishing cutter in the Southern Baltic. The study covered a set of gillnets of mesh bar sizes 45, 50 and 55 mm.
As a result of this study, a relationship between the mesh size in gillnets and length of caught cod was observed. On the basis of analysis, gillnets with a mesh bar size not less than 50 mm may be recommended for use by commercial fisheries.

Key Words: *cod, gillnet, selectivity, mesh size, fishing*

Introduction

Cod is the most valuable fish in the *Baltic Sea* and it is exposed to extensive fishing. As the fishing pressure targeted at this species is exceptionally great, frequent attempts aiming at successful protection of juvenile cod against the fishing mortality are being made. To fulfil this task, studies focused on improving the effectiveness of cod selection by both mobile (i.e. trawls) and set (i.e. gillnets) fishing gear, are undertaken. In 1994, gillnets became a subject of studies aimed to determine the influence of mesh size in gillnets on the size of caught cod. These investigations were performed to find out whether the protection of juvenile cod is attained.

The Aim of Studies

The aim of undertaken studies was to find the smallest mesh size of gillnets that can be used in exploitation, and at the same time, provide a sufficient protection of juvenile cod against fishing mortality. Fishing for cod with a gear of a mesh size below 105 mm is currently banned in the *Baltic*. This ban refers to the codend mesh size of trawls because only this fishing gear has been thoroughly investigated. However, the ban has been extended to other fishing gear, such as cod gillnets. In order to be able to give answers to the questions formulated in this project, three series of gillnet sets, with a mesh size of 45, 50 and 55 mm, were prepared. They were exploited comparatively and that allowed to determine the mean length of caught cod, and also, the number of undersized fish captured in each of the series. Unfortunately, when preparing the experimental net sets, some difficulties were encountered during the purchasing of monofilament netting. The gillnets of standard construction, multifilament, are made of yarn of 0.15 mm thickness, but this netting was not available at the time when the experimental nets were being constructed. The sets were constructed similarly to the standard gillnets but were made of 0.08 mm thick polyamide monofilament instead of 0.15 mm monofilament yarn. Consequently, this caused that the gillnets were more delicate and flabby, and at the same time, showed much greater mechanical vulnerability due to reduced breaking load.
The results presented in this paper concern thin cod gillnets (completely new) which ensured, to the highest degree, limitation of entangling properties, so, the gear captured the fish when they tried getting through the meshes of the gillnet.
This fact is of practical importance because with a gradual increase in net's wear its entangling properties appeared to result in less and less selective fishing, thus resulting in capturing both small and big fish.

Methods

Investigation of the experimental gillnet set consisted of laboratory material studies and of measurements conducted at sea, which included length of cod captured and mesh size.

Laboratory Tests

The following parameters of the net materials were determined:

- — mesh bar length,
- — thickness of mesh bar and single monofilament yarn of which mesh was made,
- — mesh breaking load,
- — elongation at mesh breaking load.

The mean values of parameters were determined in standard atmosphere, on the basis of 30 measurements, as specified by Polish standards. The principle of measurement of the above mentioned features remained in agreement with ISO requirements, because Polish standards follow the international requirements, and differ from them only in slight details concerning an application of own measuring apparatus.

The degree of net wear was determined in percentage, using an index expressing the length ratio of the upper and lower lines, along which the netting material was not present, or alternatively, an index expressing the ratio of the sum of "holes" along the net length to the full length of the upper line. A "hole" in the net is defined as a horizontal damage to the net, bigger than the four subsequent meshes.

Cod length was measured (longitudo totalis) to the nearest centimeter below. All cod specimens captured in all gillnet sets of a given mesh size were measured, and the mean length of fish was calculated. The fish length distribution was unimodal.

Laboratory analysis of Gillnets and Construction of an Experimental set of Gillnets

The actual mesh sizes, prior to fishing, were greater than their nominal values. The differences, in per cent, equalled to 1.1% for the smallest meshes, 3% for medium sized meshes, and 2.3% for the largest meshes. The mesh bar length prior to fishing, was characterized by large variability ranging from 0.8 to 1.26%. The variability increased after fishing to 1.24 - 1.69%, and the mesh size increased by 1.2% in the smallest mesh (45 mm), by 0.98% in the medium-sized mesh (50 mm), and by 0.36% in the largest mesh (55 mm). The mean mechanical properties of the nets are listed in Table 1.

Table 1. Main physical properties of cod gillnets prior to exploitation.

Nominal mesh bar length	Diameter of a single monofilament	Twine thickness	Breaking load	Breaking elongation	Degree of wear
(mm)	(mm)	(mm)	(daN)	(%)	(%)
45	0.08	0.21	2.48	52.3	37
50	0.08	0.21	2.48	52.3	16
55	0.08	0.21	2.48	52.3	25

As mentioned above, the tested nets were made of polyamide monofilament materials, with four parallel monofilaments making up the mesh bar. The thickness of a single monofilament was half that of the gillnets commonly used in the Baltic. Because of this the resistance of the mesh break was only 2.48 daN, i.e., it was four times lower than in the standard gillnets used by Polish fisherman. The stability of knots in experimental gillnets was very good. The mesh stretched out to 52.3% during breaking, which seems favourable from the point of exploitation requirements. The degree of net wear after the experiments varied for different net types from 16 to 37%.
Three gillnet sets, each consisting of 60 nets and differing in mesh size (40, 50 and 55 mm), were prepared for this study. Gillnet netting was purchased in Germany; it had 1000 meshes in length and 22.5 meshes in depth. The netting hanging ratio on the upper line was equal to 0.5. The upper and lower lines were made of polyethylene twisted or braided twine of a nominal

thickness 6 mm. Every net line consisted of two twines. On one twine of the upper line there were 10 cm long standard elongated floats mounted, while the lower line had lead line as one of its twines.

Tests at Sea

Tests at sea were carried out on a 24 m cutter (*Wla-151)* in March 1994. The gillnet fishing operations were conducted at depths of 35 - 55 m at the *Slupsk Furrow* fishing grounds. At the same time, the control fishing was conducted at depths of 80 - 90 m at the nearby fishing grounds, and a cod bottom trawl was used for those operations. The trawl was made in Denmark of polyethylene netting material 2.5 mm thick, with a mesh bar length of 65 mm and 60 mm. The ground rope was rigged with a bobbin rope, including 26 polyethylene bobbins. The codend was made of monofilament yarn of 5 mm nominal thickness. The mesh opening in a wet codend equalled to 104 mm.

A total of 5088 cod specimens were measured in trawl catches. As a result of length composition analysis of cod caught in 26 hauls (Fig. 1), it was found that the exploited stock was mainly represented by fish ranging in length from 23 to 66 cm (maximum length 90 cm). The number of undersized cod specimens, i.e. 33 cm (1994) in length, was relatively low, and did not exceed 2.5%, in each size class, with majority of cases at the level of 1%. The total

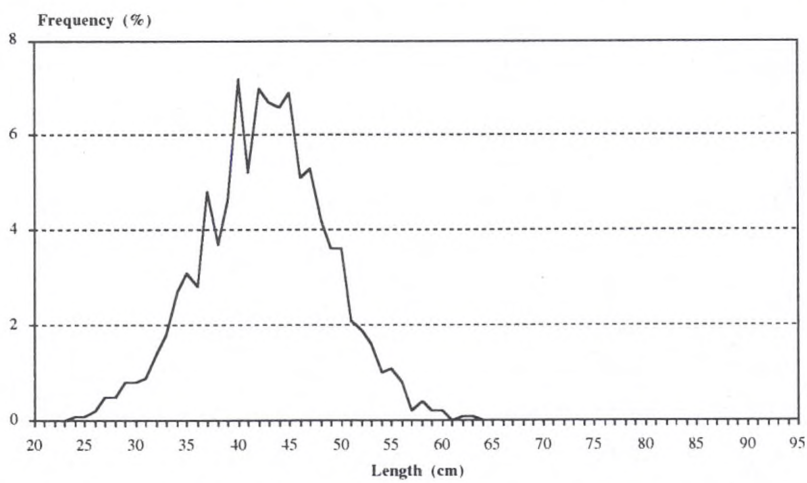

Figure 1. Length distribution of cod in bottom trawl catches (codend mesh size 104 mm - wet).

number of undersized cod equalled to 5%. The most abundant length classes were 40, 42, 43 44 and 45 cm (over 6% of all fish). In general, it can be stated that a dominant length of fish caught with a trawl was 44 cm.

In gillnet fishing (12 sets of gillnet), a total number of 5838 cod specimens were measured. A characteristic length distribution of the captured cod was obtained for each type of net (mesh size).

The analysis of length distribution of cod captured with the net set with a mesh bar size of 45 mm (Fig. 2) indicated that the gear caught few undersized specimens, because the total number of fish smaller than 33 cm constituted only 2.3%. This net, however, did not fulfil the requirement concerning

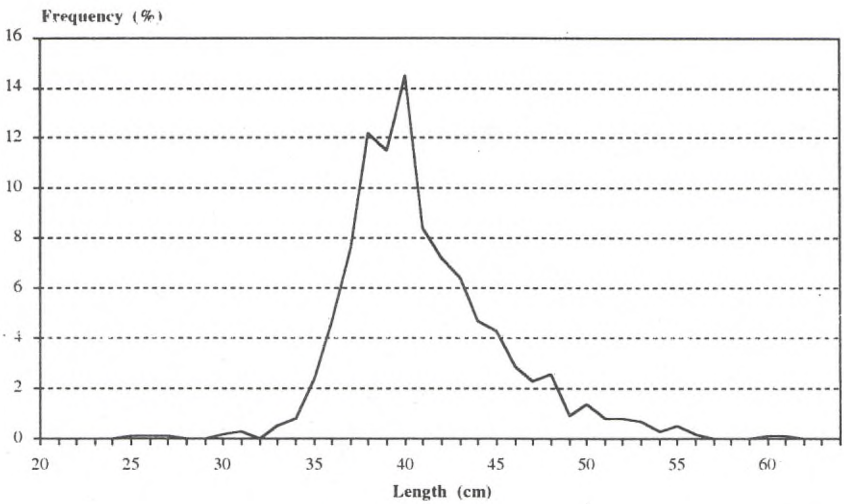

Figure 2. Length distribution of cod in gillnet catches (mesh bar length= 45 mm).

protection of cod smaller than 38 cm, because fish of this size made up 29.2% of all fish. The mean length of the captured cod specimens was 41.0 cm.

The analysis of length distribution of cod caught in gillnets with a mesh size of 50 mm (Fig. 3) indicated that 2.9% of all captured cod were undersized. The species protection requirements put forward by ecologists may be assumed as fulfilled by this type of net. The increased protection requirements, which include cod specimens up to 38 cm in length, are fulfilled because the number of caught fish from this length range amounted

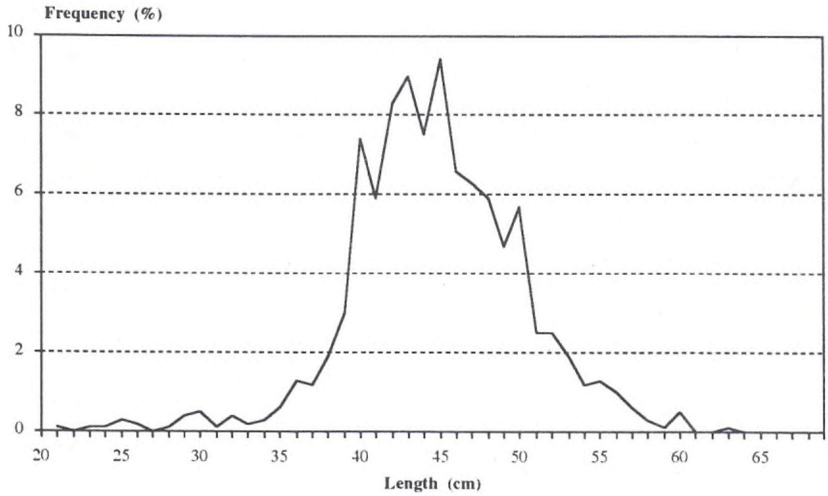

Figure 3. Length distribution of cod in gillnet catches (mesh bar length= 50 mm).

to 6.0%. The mean length of cod specimens captured was 44.8 cm.
The analysis of length distribution of cod caught in gillnet set with a mesh bar length of 55 mm (Fig. 4), indicates that the 4.2% of all captured cod were undersized. Therefore, the protection requirements may be considered as met by this type of net. Also, the increased protection requirements, referring to fish length up to 38 cm, may be accepted as complied with, because the total number of caught cod specimens in this length class was equal to 8.4% of all fish. The mean length of captured cod specimens was

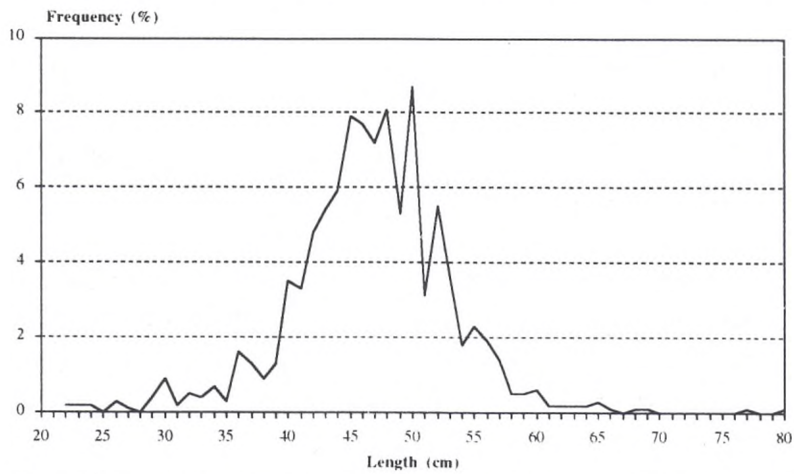

Figure 4. Length distribution of cod in gillnet catches (mesh bar length= 55 mm).

46.6 cm.

In the case of large catches the expenditure of work was found to be the highest for nets with a 45 mm mesh size, twice that of nets with a 55 mm mesh size, and also larger than for nets with a 50 mm mesh size. Nets with a mesh size of 45 mm capture the smallest cod of very low commercial value, thus they are usually rejected by fisherman.

Fishing with gillnets, occasionally carried out in difficult weather conditions (7 to 8 in Beaufort's scale), proved their small usefulness in commercial exploitation because they are too weak. They get damaged, mainly during hauling. An overall degree of net's wear was great, reaching up to 37% for small mesh size. Great flabbiness and delicacy of these nets created difficulties in pulling them aboard with a mechanical technological line; the lack of tension on the net caused that one of the essential devices, i.e. pulling machine, did not function properly.

Conclusion

1. A large impact of the gillnet mesh size on the length of caught cod and also, on the expenditure of fishermen's work for obtaining a given amount of fish, was observed.
2. All types of nets comply with the cod protection requirements. Only nets with a mesh size of 45 mm do not meet the extended protection requirements, i.e. protection of cod up to 38 cm in length.
3. The expenditure of labour when using the nets with different mesh sizes decreases with increasing mesh size. Therefore, gillnets of a 45 mm mesh size were evaluated negatively, while those with a mesh size of 55 mm positively.
4. Nets made of a single 0.08 mm polyamide monofilament should be considered as being too weak, not complying with the requirements of commercial exploitation, and difficult to handle with a mechanized technological line used on Polish cutters.

Summary

The study of cod gillnets made of thin polyamide multifilament netting material (a single monofilament 0.08 mm thick, used in 4), was aimed to find a dependence between the length of caught cod and the net mesh size. Nets with mesh sizes 45, 50 and 55 mm underwent tests. It was found that the nets with a mesh size of 45 mm comply with the requirements on protection of undersized cod, but cannot be recommended for commercial exploitation due to a great expenditure of labour. Nets with a mesh size of 50 mm can be exploited in a commercial fishery (from the biological protection point of view), but the best and recommended for this type of fishery are the nets with a mesh bar of 55 mm. The latter not only comply with the current and extended protection requirements but are superior to the nets with a small size mesh in regard to expenditure of labour and obtaining bigger, thus more valuable on the market cod.

Preliminary studies of vertical separation of cod in a trawl codend.

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Abstract

This paper presents the preliminary results of studies designed to investigate the possibilities of cod separation in herring - targeted catches (separation of a cod by-catch) during the cod fishing prohibition. In April 1994, the experiments were carried out by the Sea Fisheries Institute in the *Gulf of Gdansk* in an attempt to design a codend that would enable juvenile cod to escape from the codend during the herring - targeted fishing. The use of such codend would result in protection of cod.

Key Words: cod, herring, separation, trawl, codend

Introduction

Protection of juvenile fish requires designing and experimental testing of new constructions of codend because those used until now do not fulfil the requirement with respect to fish protection. The fish caught in codend remain there for a long time and can be properly selected.

The investigations of fish species separation during trawling have been carried out by numerous countries for many years. Those studies were mainly focused on separation of spindle-shaped fishes from flat fishes or *Crustacea,* and the latter brought about the greatest success. The most difficult task is to separate fish showing similar reaction to external impulses, or having similar motor features. These problems were a subject of interest for many (Main and Sangster, 1981, 1982; Prado, 1993; Robertson *et al.*, 1990; Valdemarson and Engas, 1985; Wileman and Main, 1994); their studies mainly concerned separation of fish from shrimp and N*orway lobster*, or separation of spindle-shaped fish from flat fish. These attempts brought about good results as to separation of fish from *Crustacea* or flat fish, and they were achieved by the horizontal separation of codend. Less satisfactory outcome was achieved during separation of fish representing similar species, e.g. *Gadidae* family.

The task of this project, being carried out in the Sea Fisheries Institute, is to design a codend construction that would enable separation of cod in herring trawling catches. In 1993, three codends were designed and constructed and later provided for testing of their effectiveness in protecting juvenile cod in herring catches. Out of these three codends two underwent preliminary testing in 1994, and the results are presented in this paper. Besides cod, two other fish species dominating in the experimental catches, namely, flounder (P*leuronectes fleus*) and four-bearded rockling (*Enchelyopus cimbrius*) which belongs to the *Gadidae* family, were analysed.

During the experimental catches typical mixed schools of herring and cod were not encountered (except for one case), therefore, the studies had to focus on cod's response to the horizontal division panel, mounted in the codend of the bottom trawl, *WD-20/25* (herring bottom trawl used for biological assessment of fish resources at the Sea Fisheries Institute).

Description of investigation and Results

Two codends were examined during a cruise to the *Gulf of Gdansk* and its deepest part, the *Gdansk Deep* (Fig. 1). The codends had meshes of nominal bar length 20 mm (upper and lower compartments) in the first codend, and 20 mm (upper) and 30 mm (lower) in the second codend. Both codends were equipped with a horizontal panel made of 20 mm nominal mesh bar size netting. Both codends had a length of about 12 m and a circumference of about 7 m (both dimensions for stretched meshes), and were made of polyamide netting PA 235/21 (diameter about 1.1 mm). The measurements

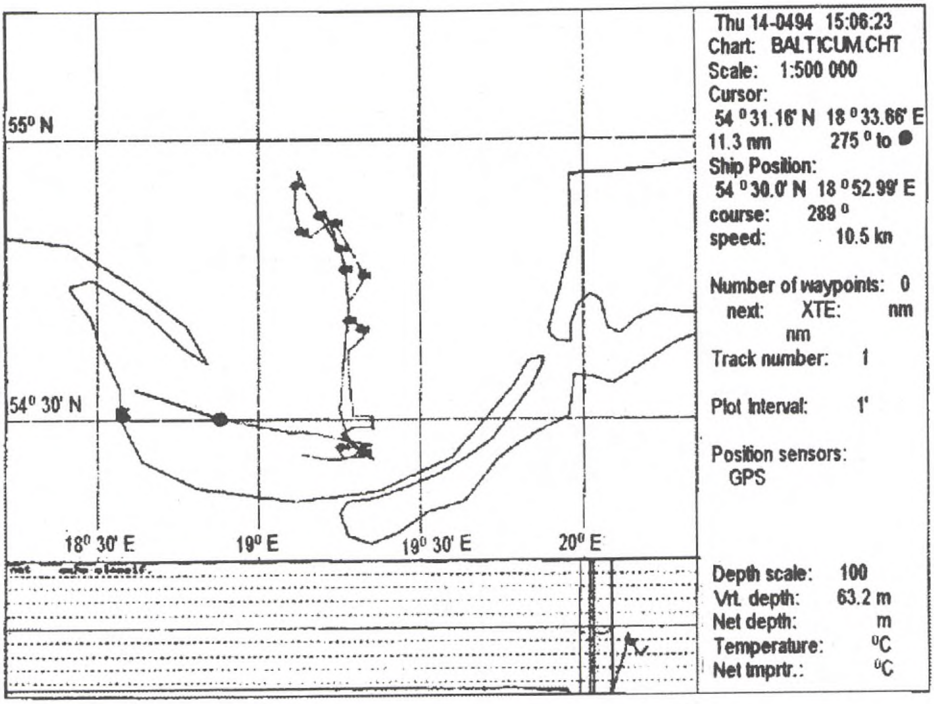

Figure 1. Area covered during experimental work on R/V BALTICA

of mesh bar length of both codends were made prior to the experiments, and the real length was determined on the basis of ten length measurements of five subsequent meshes (10 bars of meshes + knots). The mesh bar of the codend with a nominal value 20 mm was in reality equal to 20.8 mm, while that of a nominal value 30 mm, in reality 29.6 mm.

Twelve hauls, six with the use of each codend, were performed at the fishing grounds in the *Gulf of Gdansk*. In the first haul, the following fish species were present: adult herring, some juvenile herring and single specimens of cod. In both parts of the codend, there were found nearly the same numbers of fish. In the next haul performed in deeper waters, herring and some negligible by-catch were present; 2/3 of by-catch were found in upper part of codend.

Further investigations were conducted at the *Gdansk Deep* fishing grounds. The catches were mainly dominated by cod, flounder and four bearded rockling. The trawling was conducted at depths of 90-110 m, with a speed of 1.2-1.85 m/s and duration 35 min - 2 h 5 min.

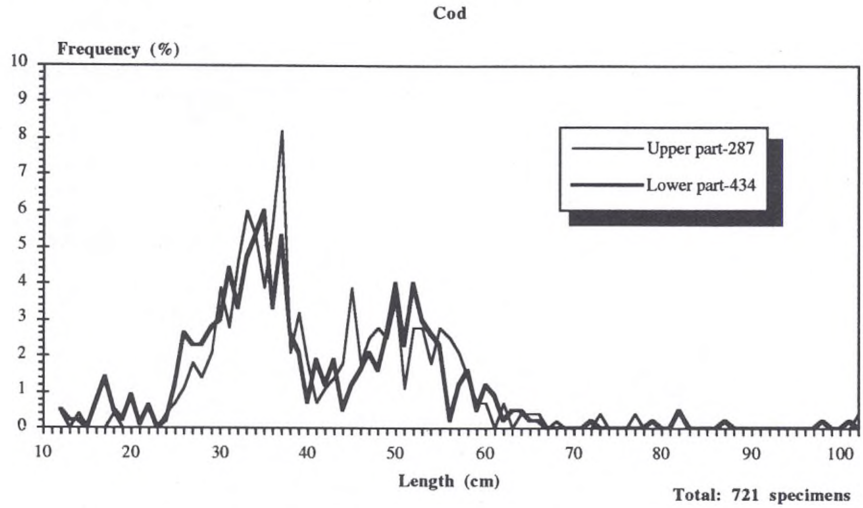

Figure 2. Frequency distribution of cod caught in horizontally devided codend.

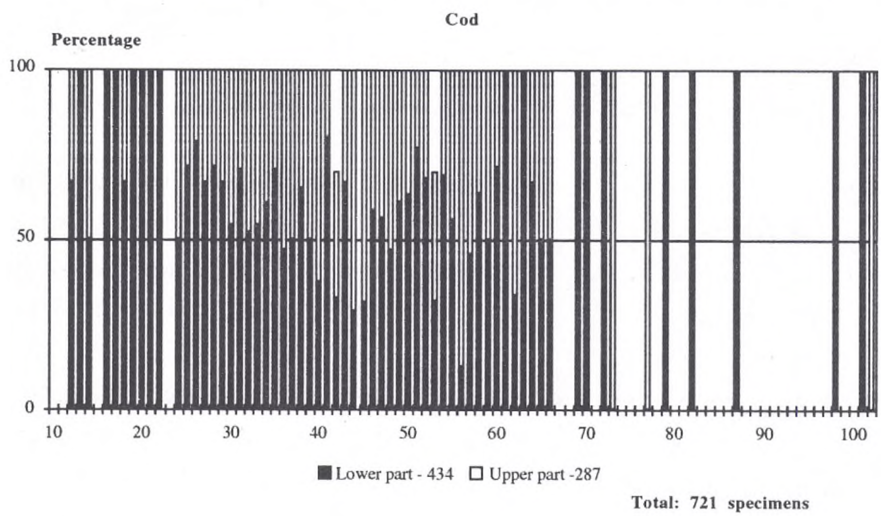

Figure 3. Percentage of cod caught in both parts of codend.

On the basis of the obtained results, the diagrams and figures for the main caught species were prepared (Fig. 2-7). Figure 2 illustrates the frequency of caught cod in length classes. In total, 721 cods were caught, the majority being in length class 30-37 cm. Out of this number, 287 specimens (about

40%) were found in the upper part of codend, and 434 (about 60%) in its lower part. The length distributions in both codend parts were nearly the same that is indicated in Fig. 2. A diagram in Fig. 3 illustrates the share of fish from different length classes, expressed in percentage, in both parts of the codend. The diagrams in Figures 4 and 5 are drawn for flounder. In total, 1856 specimens of this species were caught; out of this number, 521 (about 28%) were found in the upper part of codend and 1335 (about 72%) in its lower part. The frequency distributions of particular fish lengths in both parts were nearly the same as indicated in Fig. 4.

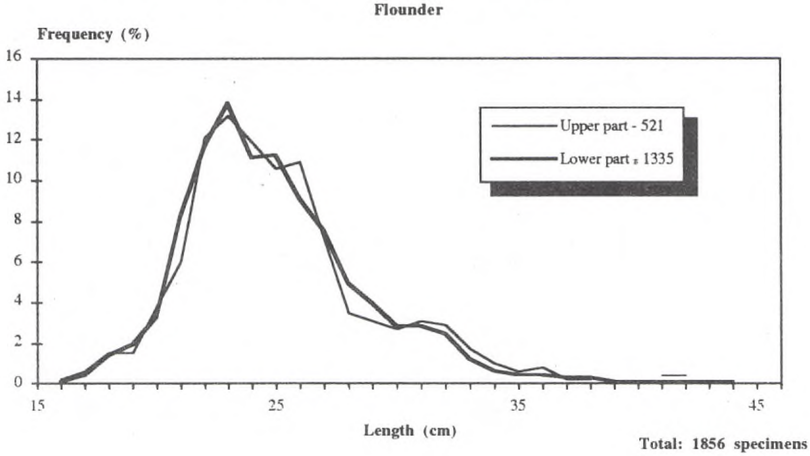

Figure 4. Frequency distribution of flounder caught in horizontally divided codend.

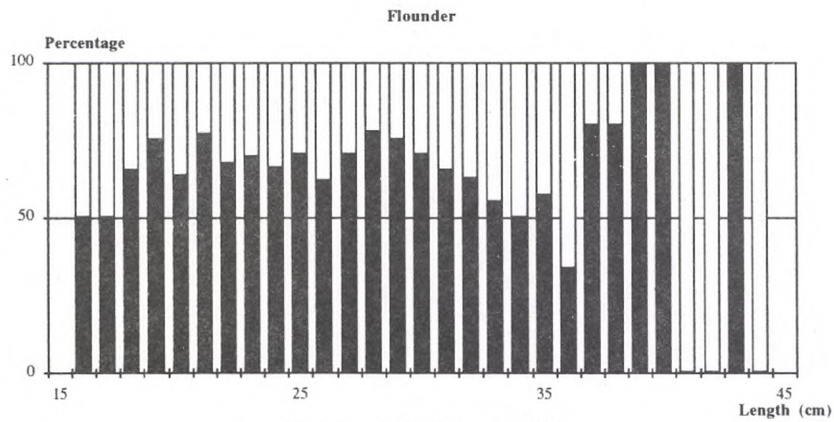

Figure 5. Percentage of flounder caught in both parts of codend.

Figures 6 and 7 show, similarly to previous figures, the frequency of occurrence of four-bearded rockling. In total, 1044 specimens were caught; 633 individuals (about 61%) were in the upper part of codend, and 411 (about 39%) in its lower part. Also in this case the frequency distributions of particular fish lengths were nearly identical in both parts of the codend.

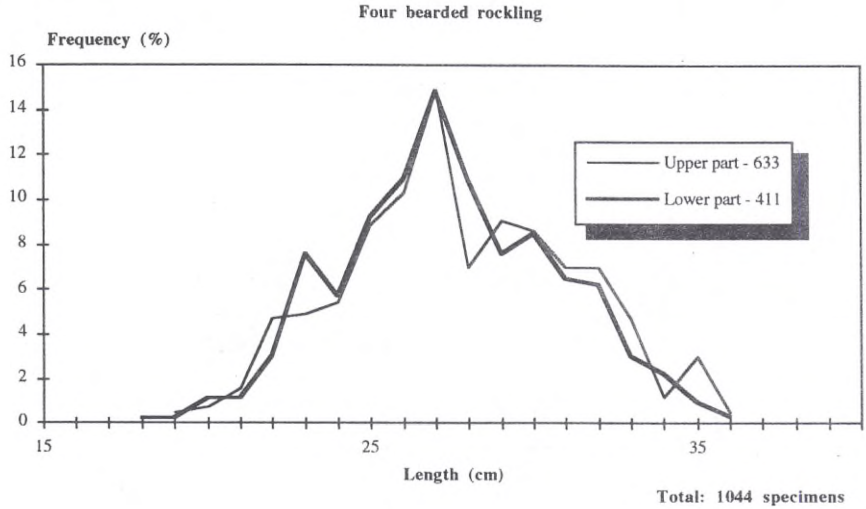

Figure 6. Frequency distribution of four-bearded rockling caught in horizontally divided codend.

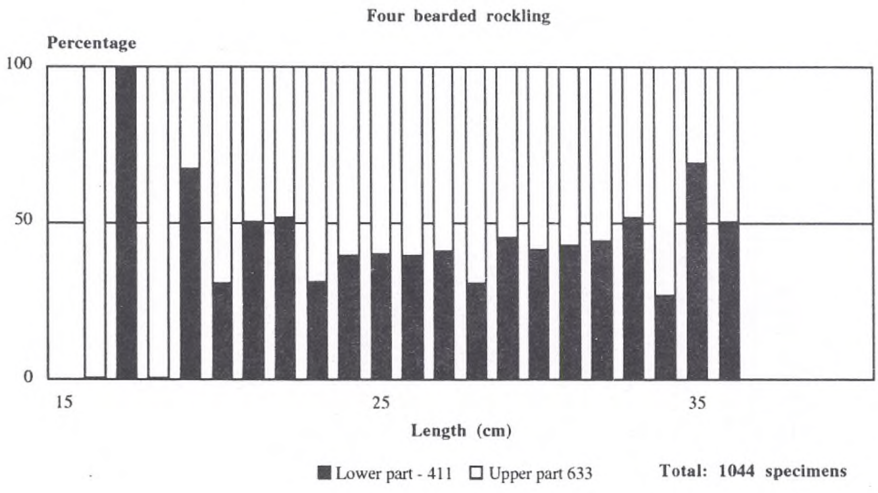

Figure 7. Percentage of four-bearded rockling caught in both parts of codend.

Figures 3, 5 and 7 indicate the preferred tendencies of fish movement in reaction to the perceived danger in particular fish species. Based on the presented preliminary results, it can be concluded that cod shows only slight tendency to move towards the lower part of the codend. In the case of flounder, a more distinct tendency to move in the same direction was found. Four-bearded rockling directs itself towards the upper part of codend.

The last catch, conducted at the Krynica Morska fishing grounds, consisted of a mixture of herring and cod. In total, 10 boxes of fish were caught, which were equally distributed between the upper and lower parts of codend. In the upper part, the catch consisted of 80% (by weight) of herring, 7 specimens of cod, and other by-catch. In the lower part, there were 55% of herring, 55 individuals of cod, and other by-catch.

Conclusions

The following conclusions and remarks can be drawn from the investigations of vertical fish distribution in the codend:

a the collected data on cod allow to state that this species shows a tendency of directing itself towards the lower part of codend, but this phenomenon is not as distinct as expected,

b diagrams of length frequency of fish occurring in experimental catches, in both upper and lower parts of codend made for cod, flounder and four-bearded rockling, indicate that, in the foremost part of the horizontal division panel, the direction of fish movement did not depend on fish length (age),

c the obtained results confirm that flounder and cod have tendencies to direct themselves toward the lower part of codend; four-bearded rockling shows just an opposite tendency,

d in herring catches no considerable differences in numbers of fish found in the upper and lower parts of codend were observed,

e based on performed preliminary studies of the possibilities of separating cod from herring in herring-targeted catches, the evaluation of usefulness of applied codend design for protection of juvenile cod can not be performed. If further investigations prove a more evident tendency of cod to move towards the lower part of codend, it may be expected that cod protection in herring catches will result in a loss of a part of herring catch during trawling.

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Bycatches of Cod in Swedish Trawl Fishery for Pelagic Species in the Baltic Sea
a summarized report for the Polish-Swedish Symposium on Baltic Cod,

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Abstract

Catches were sampled in two fishing methods; industrial fishing for sprat (*Sprattus sprattus*) using a pelagic trawl, and fishing for herring for consumption (*Clupea harengus*) using a bottom trawl, to investigate bycatches of cod (*Gadus morhua*) and other species. Sampling took place in 1993 and 1994 in the Baltic Sea. The industrial fishing was sampled in SD 25-28, and the herring fishing was sampled in SD 25. Bycatches in industrial fishing comprised; herring (17.8%), cod<33 cm (0.06%), and cod >33 cm (0.15%). The only discernible bycatches of cod in industrial fishing were found in SD 25. Other bycatches in industrial fishing were lumpsucker (*Cyclopterus lumpus*), three-spined stickleback (*Gasterosteus aculeatus*), flounder (*Platichthys flesus*), eel (*Anguilla anguilla*), and salmon (*Salmo salar*). Catches in herring fishing comprised bycatches of cod <33 cm (0.6%), and cod>33 cm (2.7%). Other species occurring as a bycatch in herring fishing were sprat, whiting (*Merlangius merlangus*), trout (*Salmo trutta*), and jellyfish (*Aurelia aurita*).

Key Words: Bycatch, cod, industrial fishing, herring fishing.

Introduction

Since 1985 the recruitment of the eastern cod (*Gadus morhua*) stock in the Baltic Sea has been very poor. This, combined with a high fishing mortality, has lead to a rapid decrease in the Baltic cod population (Anon., 1992). The cod stock east of Bornholm has, since 1992, been below the minimum biologically acceptable level (Sjöstrand, 1992).

Trawl fishing for herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) in the Baltic Sea is, according to some Swedish fishermen, responsible for substantial catches of young cod as a bycatch. Industrial fishing for sprat using a pelagic trawl, has frequently been accused of indiscriminate fishing in the Baltic Sea. According to the critics, a vast amount of undersized cod and herring is caught using this method. Bottom trawling for herring is another method connected with high bycatches of undersized cod.

The purpose of this project is to investigate bycatches in trawl fishing for sprat using a pelagic trawl (mesh size 16-22 mm), for industrial purposes, and fishing for herring using a bottom trawl (mesh size 32-40 mm), for consumption. Bycatches of cod, mainly undersized (<33 cm), are the main target, though other species are also considered. The project started in February 1993.

Materials and Methods

Samples from the catch were taken aboard commercial fishing vessels. The sample taken in each haul comprised three subsamples (about 30 kg each), spread throughout the catch. The fish in each sample were sorted according to species, and weighed. The cod were divided into two groups, above and below minimum length, and weighed separately. The length of all fish caught as a bycatch was length measured, as well as a minimum of 100 herring and sprat respectively. All calculations on the percentage of bycatches in the samples were based on weight.
Industrial fishing for sprat is carried out from October until May, depending

on the temperature of the water. Sampling took place in two periods during March-April 1993, and October 1993-May 1994. A total of 116 samples were taken in subdivision (SD) 25-28 (Fig 1).

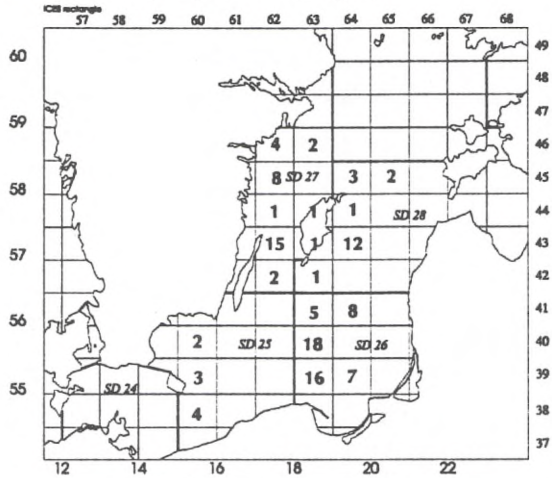

Figure 1. Number of samples per ICES rectangle from sprat fishing for industrial purposes using pelagic trawl (16-22 mm mesh size) , n=116.

Sampling aboard boats fishing for herring was carried out between May and October 1993 in the Hanö Bight (SD 25). A total of 28 samples were taken (Fig. 2).

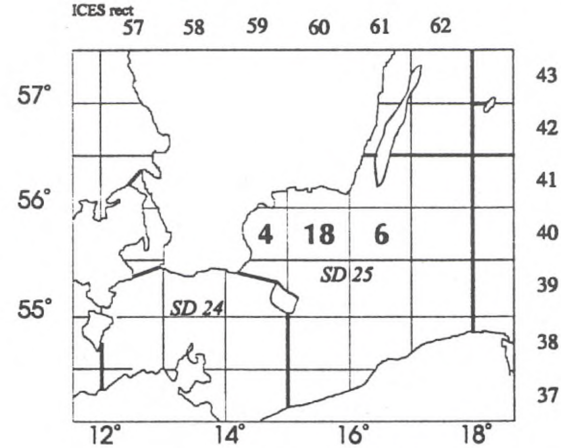

Figure 2. Number of samples per ICES rectangle from herring fishing using bottom trawl (32-40 mm mesh size), n=28.

Details such as position, depth, trawl depth, duration of haul and weather conditions were noted for each haul.

Results

Sprat fishing for industrial purposes

Bycatches of cod in industrial fishing comprised 0.0%-8.6% of the catch in one haul, and bycatches of herring comprised 0.0-97.4%. The composition of all samples shows that bycatches of herring were 17.8%, cod<33 cm were 0.06% and cod >33 cm were 0.15% of the sample (Fig. 3).

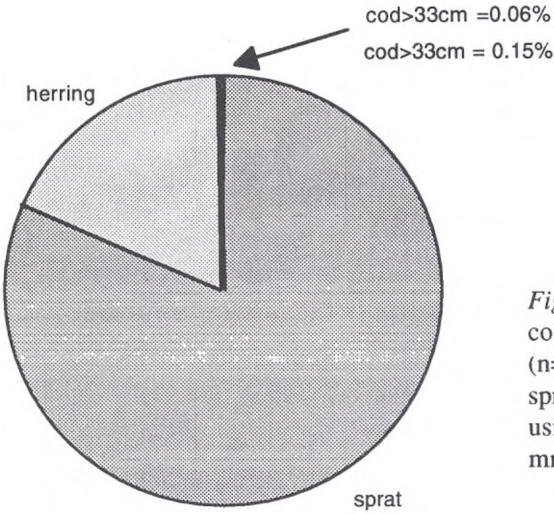

Figure 3. The weight-composition of all samples (n=116) from fishing for sprat for industrial purposes using pelagic trawl (16-22 mm mesh size).

Other species occurring as a bycatch in the samples were lumpsucker (*Cyclopterus lumpus*), three-spined stickleback (*Gasterosteus aculeatus*) and flounder (*Platichthys flesus*). These species comprised 0,016% of the samples. Other species observed as occasional specimens in the catch, although not in the samples, were eel (*Anguilla anguilla*) and salmon (*Salmo salar*).

The composition of all samples per subdivision shows that discernible bycatches of cod were only to be found in SD 25 (Fig. 4).

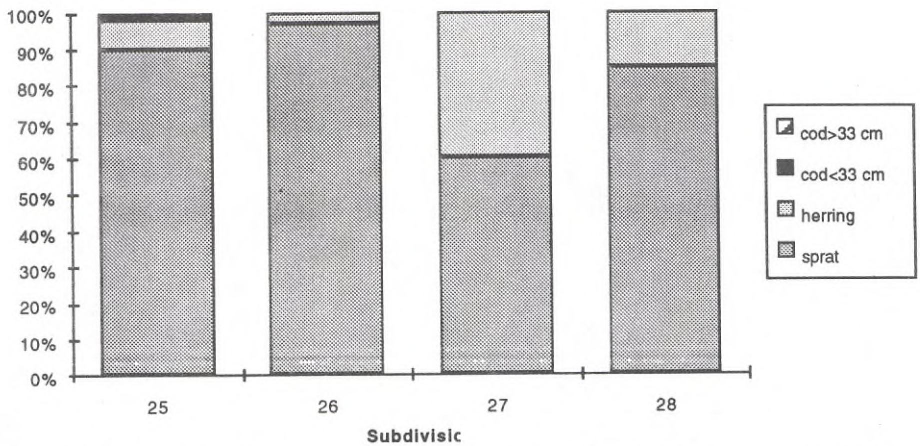

Figure 4. The weight-composition of all samples (n=116) from fishing for sprat for industrial purposes using pelagic trawl (16-22 mm mesh size), divided into sub-divisions, in SD 25 cod>33 cm =1.2% and cod<33 cm=0.8%

Herring fishing for consumption

Bycatches of cod in herring fishing comprised 0.0-17.4% of the catch in one haul. The composition of all samples shows that bycatches of cod <33 cm were 0.6%, and cod >33 cm were 2.7% of the sample (Fig. 5).

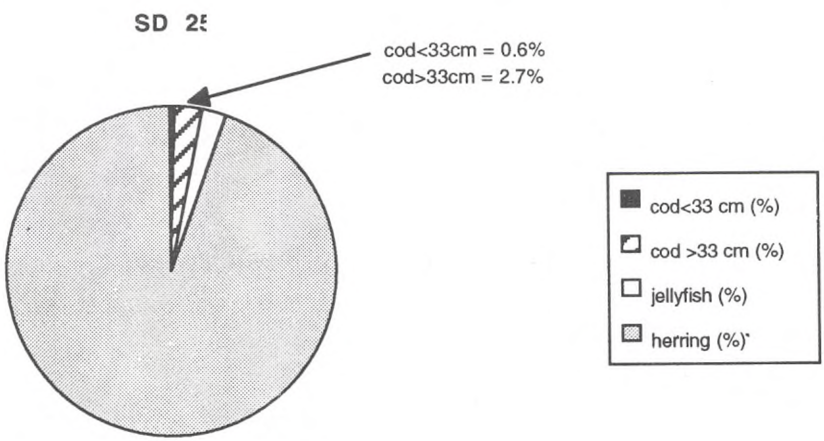

Figure 5. The weight-composition of all samples (n=28) from herring fishing using bottom trawl (32.40 mm mesh size).

Other species occurring as a bycatch in the samples were jellyfish (*Aurelia aurita*) (2.25%), sprat (2.25%), whiting (*Merlangius merlangus*) (0.03%), trout (*Salmo trutta*) (0.03%).

Discussion

The low bycatches of cod in industrial fishing in SD 26-28 were probably caused by the lack of cod in this area. The high bycatches of cod in the late 1970s and early 1980s were caused by the cod stock expanding its distribution to a much larger area than earlier (Anon., 1993). Sampling in SD 25 ought to be larger in order to evaluate the degree to which sprat fishing has an important impact on the cod stock. During this project, SD 25 was not believed by the fishermen to be the most favourable area for sprat fishing, with the result that alternative areas were chosen.

The occasionally rather large bycatches of herring in sprat fishing for industrial purposes show that it is impossible to know if a school of herring or sprat have been caught, or whether the fishermen have adapted their fishing techniques according to species. At present this is not a problem since the herring stock is above average size. The Advisory Committee on Fishery Management (ACFM) have suggested an increased Total Allowed Catch (TAC) for herring (Anon, 1995).

Bycatches during sampling of other species in sprat fishing have been so scarce that they are supposed not to have a notable impact on the populations.

It is probable that the bycatches of cod in herring fishing for consumption using bottom trawl varied as the amount of bycatch can be controlled with this type of fishing gear. Raising the fishing line from the sea bed can reduce cod catches in bottom trawling (van Marlen, 1993). The amount of other species caught as a bycatch during sampling in herring fishing with bottom trawl were so small that it can be reasonably assumed they had no impact on the population.

The fact that industrial fishing for sprat has increased in the last two years shows that this has become an important revenue for some fishermen. This investigation shows that fishing for sprat in SD 26-28 during 1993 and 1994 had little impact on the cod stock. In SD 25, the sampling is too sparse for evaluation. Fishermen have reported increased catches of cod in SD 25 during the Autumn 1994, which has probably lead to an increase in bycatches of cod in this area. It is thus of great importance that sampling continues, if not with the same intensity, then at least on a monitoring basis, preferably with combined sampling aboard ships and at landing sites.

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Swedish market sampling of Baltic cod

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Abstract

The Swedish programme on market sampling of Baltic cod (*Gadus morhua*) is presented. The programme covers ICES Subdivisions 24 - 28 and three different gears - bottom trawl, pelagic trawl and gillnets. The recent programme started in 1991. Since 1992, the number of length measurements aimed, about 20,000 per year, has been obtained. Since 1993, the number of otoliths collected is 1,500 to 2,000 per year. Results concerning length distribution of cod in the landings are presented.

Key words: Bottom trawl, commercial landings, Gadus morhua, gillnets, market sampling, otoliths.

Introduction

To sample fish from commercial landings is an activity that is necessary for the stock assessments. Market sampling is a method to get information about the age composition in the landings and to obtain information about mean weight at age. This information is necessary to assess the stock biomass.

The Swedish fishery for cod (*Gadus morhua*) in the Baltic was large in the mid-1980s, but has since then decreased. The Swedish landings of cod from the Baltic were about 66,000 tons in 1984 and 12,000 tons in 1993. In 1994 and 1995 landings have again increased. The cod stock and the fishery for cod have in recent years been concentrated to the southern Baltic due to low salinity and poor recruitment of cod to the central basin east of Gotland.
Information about the different gears used in the fishery is important for the sampling. The Swedish fishery for cod in the Baltic is in recent years

dominated by two gears - bottom trawl and gillnets. In the early 1980´s, gillnets accounted for about 15 % of the Swedish landings of cod from the Baltic. When the landings of cod decreased in the late 1980's the use of gillnets increased, and in 1992 about 60 % of the Swedish landings of cod from the Baltic were caught in gillnets. Figures 1 and 2 compare the landings from gillnets and bottom trawls in the first quarter of the years 1992 to 1994. In 1993 and 1994, bottom trawls are again increasing their share of the landings.

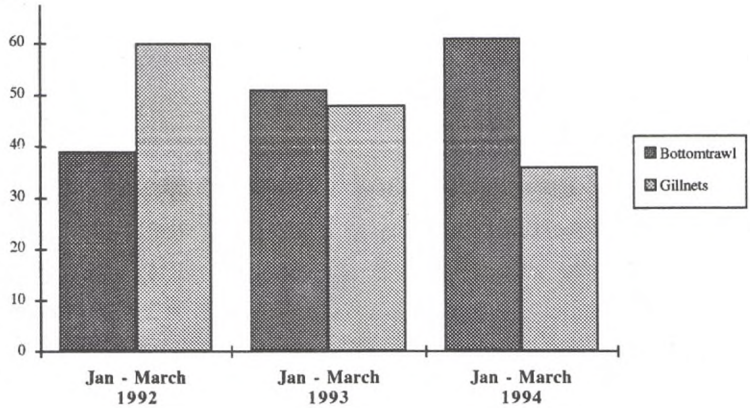

Figure 1. Use of gears in the first quarter of the years 1992 to 1994 in SD 24 - the western Baltic cod stock. Percentage of Swedish landings as recorded in fishery logbooks.

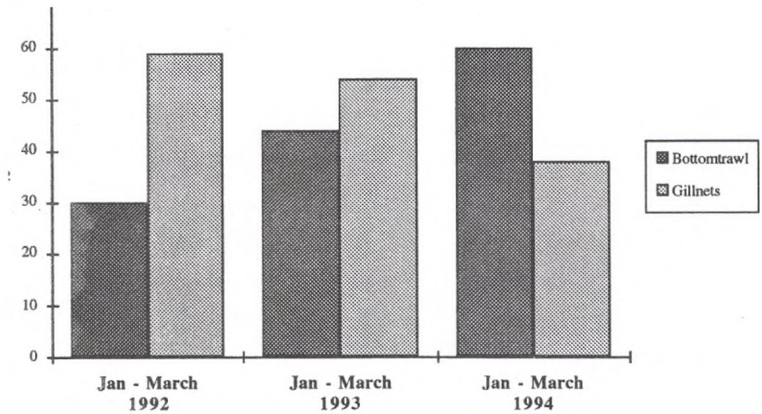

Figure 2. Use of gears in the first quarter of the years 1992 to 1994 in SD 25 to 28 - the eastern Baltic cod stock. Percentage of Swedish landings as recorded in fishery logbooks.

The sampling programme

Samples are collected from Subdivision 24 representing the western Baltic cod stock and Subdivisions 25, 27 and 28 representing the eastern Baltic cod stock (fig 3). All samples are collected in the harbours just after the cod is landed. The method used is a type of stratified sampling where at least 100 fishes are measured out of each size class in the catch. This means that a sample usually consists of 200 to 400 measured cods. All fishes are measured to the nearest cm below (total length).

From each of the four Subdivisions, at least 1500 cods from bottom trawls and 1000 cods from gillnets are measured every quarter of the year. This means about 4 to 6 samples from each gear. These figures have developed during the years and represent the number of samples needed to get a good description of the length distribution in the landings.

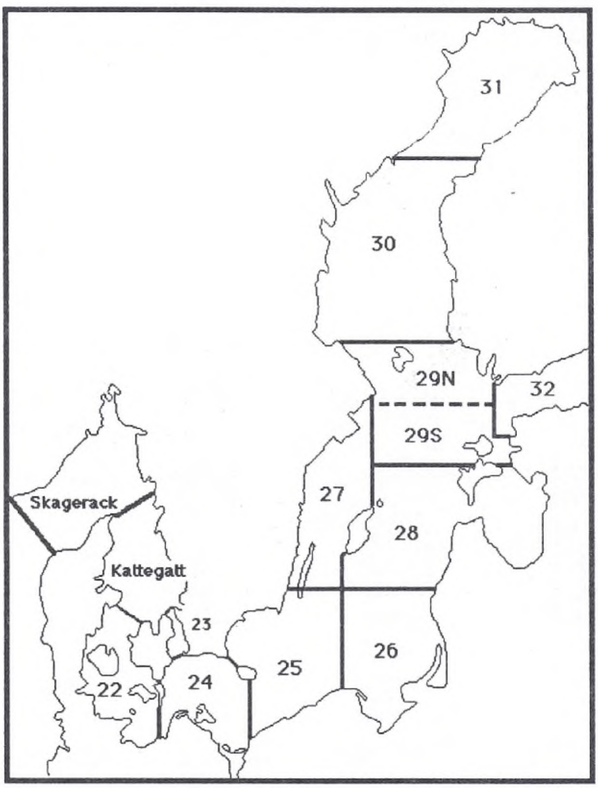

Figure 3. ICES Subdivisions in the Baltic.

Otoliths are sampled for age determination from the same Subdivisions. From each Subdivision 80 pairs of otoliths are collected from size classes 1 - 3 (> 2 kg), 40 pairs of otoliths are collected from size class 4 (1 - 2 kg) and 80 pairs of otoliths are collected from size class 5 (< 1 kg) every quarter of the year. This makes a total of 800 pairs of otoliths collected in every quarter.

Results and discussion

Table I shows the numbers of cods measured and otoliths collected since the start of the recent programme in 1991. The measurements have increased to 18 - 22 000 per year and 1500 - 2000 pairs of otoliths have been collected every year since 1993. The sampling has stopped at this level because of the short Swedish cod fishing season. In 1994 trawl fishing for cod in the Baltic was allowed only for about four months and fishing with gillnets in the same area was allowed for just over six months due to quota regulations.

Table I. Number of fish measured and otoliths collected since the start of the recent programme in 1991. The numbers for 1995 refer to the period 1 January to 15 March.

Year	Measured	Otoliths
1991	3468	0
1992	18668	1129
1993	18962	1668
1994	22316	1940
1995	10517	800

From the length distribution in the samples we can calculate the length distribution in the total landings. Figure 4 shows an example that illustrates the selectivity problems in the Baltic bottom trawl fishery for cod. The example is from Subdivision 25 in the first quarter in 1994. The median size of cods caught in bottom trawl were 40 cm and the median size of cods caught in gillnets in the same area were 49 cm. A 40-cm cod has a weight of just over 0.5 kg and a 49-cm cod has a weight of slightly more than one kg. When the cod stock is small and has reproduction problems we may need to have a discussion about what size of cod we want to catch. Do we want to catch it at 0.5 kg, at one kg or perhaps at an even larger size? We can also note in figure 4 that we have found very few large cods in the landings. The maximum registered size of Baltic cod is 120 - 140 cm and over 30 kg.

In the 1980s pelagic cod trawl was an important gear in the Baltic fishery. With the declining cod stock in the early 1990s the use of pelagic cod trawls almost disappeared though. Therefore we have very few samples from this gear.

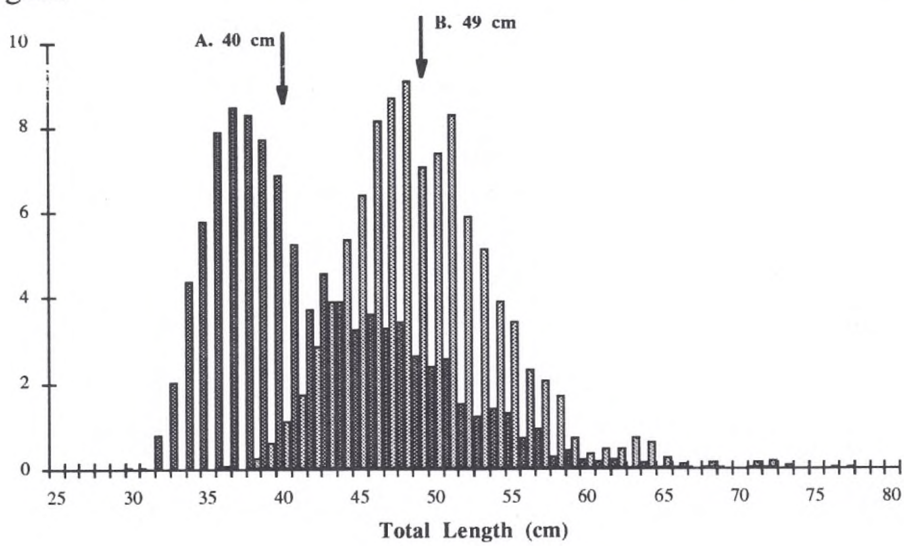

Figure 4. Cod caught in *A.* bottom trawls (cod trawls) and *B.* gillnets in Subdivision 25 during January to March 1994. 40 and 49 cm indicate the median sizes of cod caught in the two gear types

Figure 5 shows the length distributions in five landings from pelagic cod trawl fishery. The cods were caught in Subdivisions 26 and 28 during March and April 1992. When we look at this length distribution we must remember that pelagic cod trawls usually are used for fishing directly on the spawning cod stock. As a result of this, we find very few small cods in the catches from pelagic cod trawl. We can also note that we have a bad recruitment to this particular spawning stock. As you can see, we have found very few cods below 55 cm in length in these samples.

It is my opinion that what we here can see are the remains of the former large spawning stock in the central basin east of Gotland. This spawning stock was important for the large landings of cod in the 1980s. In 1992 this stock for some years has had very poor results of the spawning and for each year the stock is getting smaller and older. After 1992 we have found almost no Swedish fisheries with pelagic cod trawl in this area.

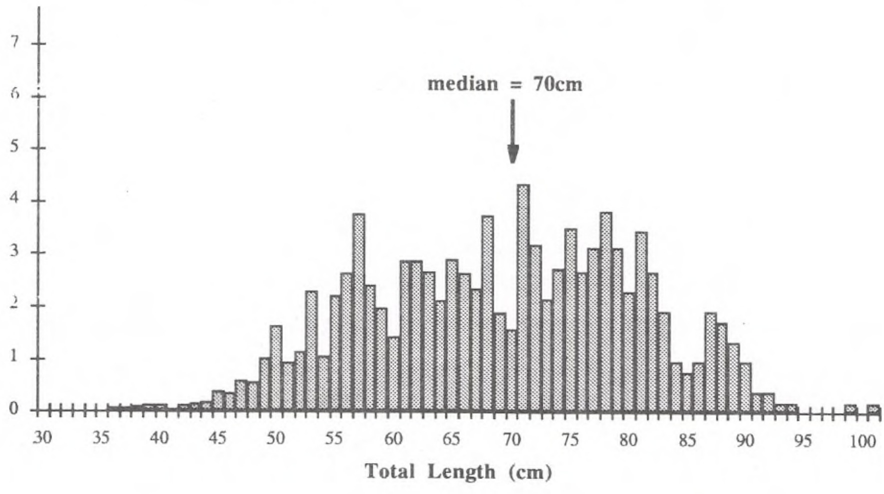

Figure 5. Cod caught in pelagic cod trawl in Subdivisions 26 and 28 during March and April 1992. Calculated from 5 samples, n = 1092.

Egg and larval quality of Baltic cod (Gadus morhua)

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Abstract

The Baltic eastern cod stock has been subjected to a substantial decline during the last decade. In the mid eighties the spawning stock biomass was assessed to above 800 000 tonnes compared to estimations below 100 000 tonnes in 1994. This dramatic decline is mostly due to high fishing mortality accompanied by poor recruitment. Recruitment failure for the Baltic cod stock is often considered as a factor of bad spawning conditions (insufficient salinity and oxygen deficit) in the major spawning grounds; the Bornholm-, the Gdansk- and the Gotland basin, but there are also other possibilities to keep in mind when considering reasons for poor recruitment of the eastern Baltic cod stock. The heavy fishing for cod in the Baltic during the last decade has caused a change in the age structure of the spawning stock. The share of well-established repeat-spawners has decreased and the spawning stock today consists mainly of younger spawners. These circumstances could have a significant influence on the recruitment of cod in the Baltic, particularly with the situation of a limited spawning stock existing in the Baltic today. Present project is an ongoing study aiming to elucidate effects of maternal status on the recruitment of Baltic cod. Definite results are not yet available but preliminary results indicate that maternal status (age/size) has obvious effects on several different parameters at the egg and larval yolk sac stage, e. g. egg size, larval size, buoyancy, growth and survival. Assessment of differences in egg and larval quality among females is, however, hampered since differences also occur between egg batches from the same female, i.e. the stage of spawning has to be taken into account.

Key words; Baltic, cod, viability, maternal status, recruitment, spawning stock

Introduction

Cod is the most valuable fish species in the Baltic and has, as a top predator, a significant structural function to the ecosystem by top-down control (Rudstam et al, 1994). A disturbance in natural recruitment dynamics of Baltic cod affects not only the species itself and thereby the fishing community but also interactions between other species and thus the entire ecosystem. During the last decade, the eastern Baltic cod stock has been subjected to a substantial decline. Biomass of the spawning stock was assessed to above 800 000 tonnes in the mid eighties compared to below 100 000 tonnes in 1992 (see Bagge & Thurow, 1994). This dramatic decline is mostly due to high fishing mortality and poor recruitment. As a result, the age structure of the Baltic cod population has changed. Today, older fish are more rare while the share of younger spawners has increased (Anon, 1991; Uzars et al., 1991). Recruitment failure of Baltic cod is considered to primarily be a matter of bad spawning conditions (insufficient salinity and oxygen deficit) in the major spawning grounds; the Bornholm-, the Gdansk- and the Gotland basin (Graumann, 1973; Kosior & Netzel, 1989; Nissling & Westin, 1991; Plikshs et al., 1993; Nissling, 1994; Nissling et al., 1994; Nissling & Vallin, in press). However, other factors are likely, in addition, of importance. Several investigations point out effects of maternal status on the viability of offspring of teleost fishes and thus recruitment (see Kamler, 1992). As preliminary results suggest (present study), is there a relation between egg size and female age/size and in investigations on cod caught off Norway indications exist that older females produce more viable eggs than younger ones (Kjesbu, personal communication). However, in cod, being a multiple batch spawner, egg size also differs among egg batches from the same female. Thus, stage of spawning might have considerable effects on different egg and larval parameters (Solemdal et al., 1992). The aim of present study is to get general knowledge about the variation in egg and larval quality among females of different age and size and to describe the effects of stage of spawning on viability of progeny from Baltic cod. The results could, hopefully, be used for recruitment prediction purposes in the future.

Materials and Methods

The study is carried out at two laboratories; at the Ar-laboratory on Gotland and at the Institute of Marine Research in Lysekil. At the Ar-laboratory, Baltic cod caught before and during spawning, are kept in indoor tanks supplied with running brackish water. In Lysekil groups of cod of different origin; Baltic cod, transferred to marine conditions in 1992 and in 1993; Baltic cod raised in marine conditions; and, as a reference group, cods from the Skagerrak, are kept in tanks with running sea water. The study includes assessment of a number of parameters concerning egg and larval quality; egg and larval size and dry weight, egg and larval buoyancy, fertilization rate, rate of irregularity in cell cleavages at early blastula stages, hatching rate and viability of larvae, larval mortality, larval growth, larval activity and feeding capacity during the yolk sac stage. All parameters are evaluated in relation to female size/age and stage of spawning. Fertilization is carried out artificially by stripping males and females followed by a standardized mixing of eggs and semen in filtered sea water (Baltic cod eggs - 17 ppt, marine cod eggs - 30 ppt salinity) at 7°C. The incubation water is prepared from filtered (0,2 µm cartridge filter) sea water and, at the Ar-laboratory, synthetic sea salt (hw Marinemix). Incubations are carried out at 7C and, to avoid bacterial growth and fungus during egg and larval development, the water is treated with antibiotics; Mycostatin (2500 IU/l), Streptomycin (0,05 g/l and Doctacillin (0,1 g/l).

Results

The project is in progress and definite results are not yet available but preliminary results suggest that egg size is significantly correlated to female size/age. A positive correlation also exists between egg size and egg buoyancy and preliminary results indicate further, a relation between egg size and larval size, growth and survival during the yolk-sac period. In addition, there is a wide variation in egg size, buoyancy, survival and growth in egg batches from the same female, which confirms that stage of spawning always has to be considered when studying effects of maternal age/size on the viability of cod eggs and larvae.

Discussion

The major inflow of saline water into the Baltic in the beginning of 1993 improved the spawning conditions (salinity and oxygen content) (Matthus & Lass, 1995) for the eastern Baltic cod stock. However, despite improved conditions for successful spawning, egg and larval surveys in the Baltic indicate that no abundant year-class has been produced during the period 1993-94. Likely, there are, in addition, other aspects than salinity and oxygen content to keep in mind when discussing conditions for recruitment of cod in the Baltic. Little is known about the causes of mortality in marine fish eggs, both for eggs spawned in the wild, and for eggs from captive spawners (Blaxter, 1989). Poor egg quality has often been regarded as a laboratory or a hatchery phenomenon and variations in egg quality are therefore regarded as unimportant in the wild (Kjörsvik, 1994). Recently, however, more attention has been paid to the impact of egg quality for recruitment of wild fish stocks since various field studies on early stages of fish eggs indicate that genetic defects and other biological factors may contribute largely to natural egg mortality (see Kjörsvik, 1994). Several of the cod stocks in the Atlantic, besides the Baltic stock, e.g the Labrador and Newfoundland stocks, the Greenland stock, the Icelandic stock and the Faroe stock, have, as a result of intense fishing and less abundant year classes, been subjected to considerable declines during the last decades (Garrod & Schumacher, 1994). As for the Baltic stock, these declines are followed by changes in age composition of the spawning stocks (Daan, 1994; Jakupsstovu & Reinert, 1994; Schopka, 1994; Taggart et al., 1994). The significance of this for the spawning success is a subject for current investigations, i.e. do well-established repeat-spawners contribute more to the recruitment than do younger spawners. The impact of egg and larval quality might be especially important in the Baltic where conditions for spawning vary substantially, both between years and among spawning areas. Several different mechanisms, both natural and induced by human activities, are working simultaneously on the dynamics of fish populations. In the Baltic Sea, a complex brackish ecosystem, recruitment of cod are affected by abiotic factors like salinity, oxygen content and temperature as well as by interactions between species, and by human activities including pollution and fishing pressure. Many of these processes are difficult to influence in a short-term perspective. However, implications of maternal effects on recruitment of Baltic cod, as a result of changes in age/size constitution of the spawning stock, as present study suggests, can, on the contrary, within some years be dealt with by lowering of the fishing pressure.

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The role of cod (*Gadus morhua* L.) in the life-cycle of *Anisakis simplex* (Rudolphi, 1802) (Nematoda, Anisakidae) in the Southern Baltic Sea - an overview.

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Abstract

Anisakis larvae are known to exist in a large number of marine fish. In the Baltic Sea mainly herring and cod are infected with *Anisakis simplex*, but these nematodes have also been found in salmon, pike-perch, garfish, goby and recently in three-spined stickleback. Recent findings suggest that fish are not the intermediate hosts, but serve only as paratenic hosts for the third stage of *Anisakis*. Plankton-feeding fish become infected by the third larval stage of *A. simplex* when preying upon crustaceans (mainly euphausids). Herring, the main food component for cod, is probably the source of the cod's infection with *A. simplex*. The final hosts are marine mammals, mainly cetaceans. In the Baltic Sea the following mammals occur: porpoise, grey seal, common seal and ringed seal, which raises the question - could cod be a source of infection of Baltic mammals? The possibility of closing the life cycle of *Anisakis simplex* in the Baltic Sea is discussed.

Key Words: Anisakis simplex, life cycle of A. simplex, Nematoda, Anisakidae, cod, Gadus morhua.

Introduction

Anisakis simplex is a common nematode parasite of marine organisms. The adult parasites are widely distributed in marine mammals, which serve as final hosts for these nematodes. The life history of *Anisakis simplex* and the role of various hosts is still being discussed (Fig. 1). The possibility of closing the life cycle of *Anisakis simplex* in the Baltic Sea, especially with reference to the role of cod in the dispersion of these parasites, is still unknown, but will be discussed in the present paper.

The eggs of *Anisakis simplex* are shed with the faeces of the final hosts and embryonated in the sea. Inside the egg the first moult takes place and *A. simplex* develops into its free living second stage (L_2).

The free living larvae are the stage at which *A. simplex* infect the intermediate hosts such as marine crustaceans, mainly euphausids. In European waters, the second larval stage of *Anisakis* has been reported in *Thysanoessa inermis*, *Thysanoessa longicaudata* and *Meganyctiphanes norvegica* from the northern North Sea (Smith, 1971) as well as in *Thysanoessa raschi* and *Nyctiphanes conchii* from the same region (Smith, 1983a; 1983b). These larval stages have been found also in Amphipoda, *Caprella septentrionalis*, and Decapoda, *Hyas araneus* (Uspenskaya, 1963). All these species live in highly saline waters. Of those mentioned, two species of euphausids, *Meganyctiphanes norvegica* and *Thysanoessa* sp., have occasionally been found in very small numbers in the Baltic Sea, and then only after an inflow of highly saline water from the North Sea through the Danish Straits (Maciejewska, Sea Fisheries Institute, Kollataja 1, 81-332 Gdynia, Poland - pers. comm.).

Euphausids are infected by feeding on the second stage of the larvae. The ingested larvae migrate to the haemocoel where they moult and develop into the third stage. Smith (1983b) suggested that the second stage larvae of *A. simplex* may be transferred to euphausids or to other crustaceans by copepods or other small crustaceans.

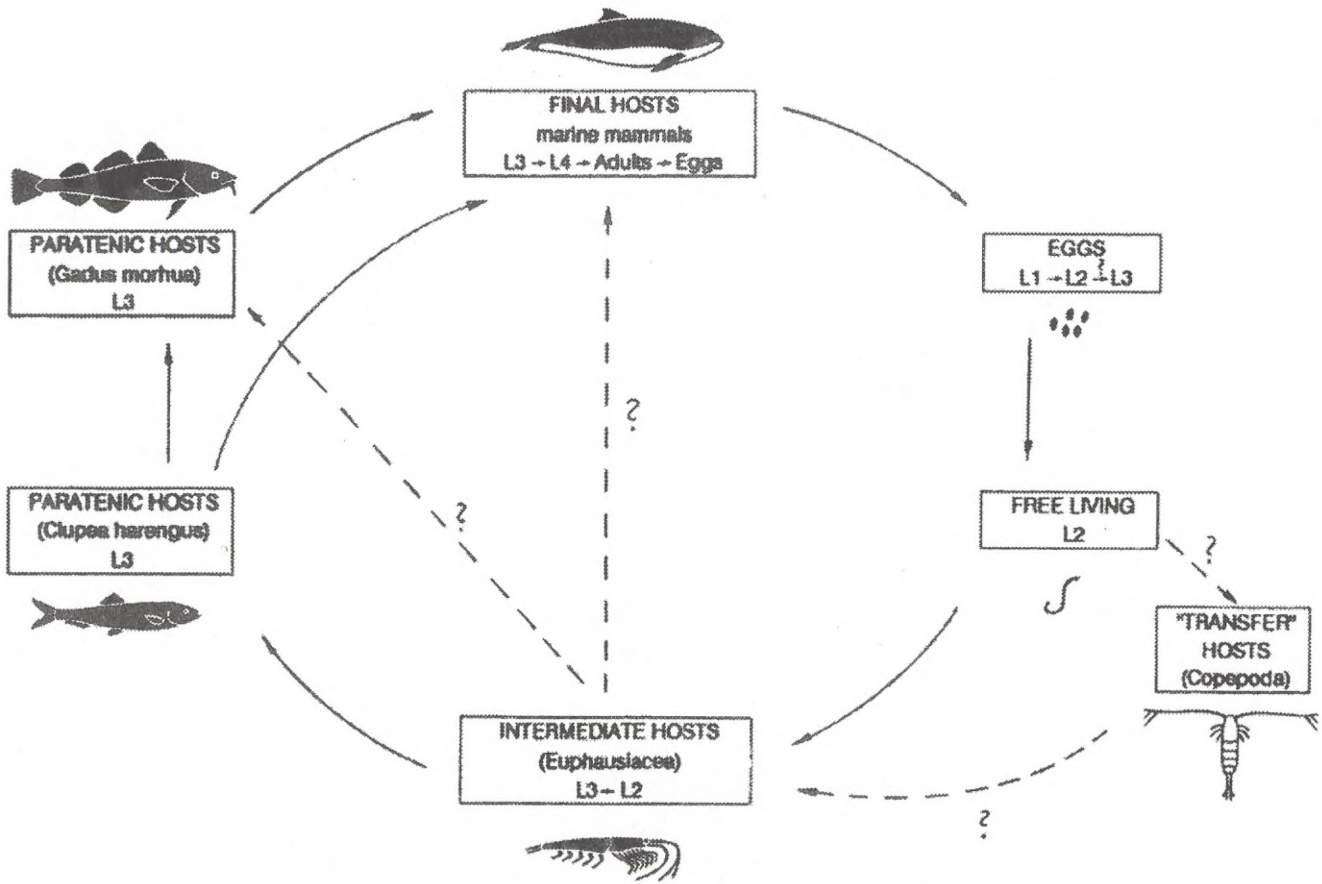

Figure 1. The life-cycle of *Anisakis simplex*

Some Japanese parasitologists have suggested that the larvae are only in their second stage in the euphausiids, (Kagei, 1969; Oshima, 1969) and moult from the second to the third stage when they are in fish and not in euphausiids (Kagei, 1969). Smith (1983b) suggested that the moulting of the larvae depends on the length of their bodies. Small larvae, less than 4-6 mm in length, could be in the second stage, larger in the third stage.

Køie and Fagerholm (1993) show that the second moult of *Contracaecum osculatum* takes place inside the egg, and that the larva can develop and emerge as a third stage larva. This suggests that euphausiids sometimes could be regarded as paratenic hosts. Euphausiids are one of the major sources of food for the fish most frequently infected with *Anisakis*. Fish, in turn, must be regarded as paratenic hosts if a moult from the second to the third stage of the nematode larva takes place in crustaceans or eggs.

Anisakis larvae are known from a large number of marine fish. In the Baltic Sea they have been reported mainly in herring *Clupea harengus* (Lubieniecki, 1972; Rokicki, 1972, 1973, 1975; Grabda, 1974) and cod *Gadus morhua* (Grabda, 1976b). *A.simplex* have been found also in salmon (Grabda, 1976a), pike-perch *Stizostedion lucioperca* (Feiler and Winkler, 1981; Piasecki and Sobecka, 1987), garfish *Belone belone* (Fagerholm, 1982), goby *Pomatoschistus minutus* (Zander and Döring, 1989) and recently in three-spined stickleback *Gasterosteus aculeatus* (Podolska and Morozinska, 1994). Plankton-feeding fish, like herring, become infected by the third larval stage of *Anisakis* by preying upon crustaceans (mainly euphausiids). Infection of the herring takes place in the North Sea and the Danish Straits, where the intermediate hosts of *Anisakis* (Euphausiacea) appear.

In spring, infected herring, which belong to the coastal spring population, usually spawn in the coastal waters of the southern Baltic . Clupeidae are the main component of the cod's food in this area (Strzyzewska, 1959). When herring are preyed upon by cod, the larvae may be transferred to the latter. Consequently, cod is a paratenic host, and the larvae never mature in this. Grabda (1976b) has shown that the prevalence of Baltic cod infected with

Anisakis is usually lower than that of herring. According to Myjak et al. (1994), the prevalence of infected Baltic cod was only 0.92% with an intensity of 3.73. The prevalence increased with the size of the cod. No seasonal pattern was detected in the occurrence of *A. simplex* larvae in Baltic cod. The prevalence of infection varied irregularly throughout the year and its intensity was not uniform over the Baltic area . The highest prevalence and intensity was recorded in the western Baltic, the Pomeranian Bay and adjacent fishing grounds (Grabda, 1976b). This was also the area with the maximum concentration of infected herring, with the prevalence decreasing towards the east. According to Myjak et al. (1993), the prevalence was relatively low (0.37%) in cod from Gdansk Bay.

Baltic cod do not migrate to the North Sea and thereby become infected by *A. simplex* only by feeding on herring. It must be pointed out, that euphausiids, which act as intermediate hosts, only appear sporadically in the Baltic Sea.

The final hosts for *Anisakis simplex* are marine mammals, mainly cetaceans which become infected by feeding on infected fish. The third and fourth moults occur in the stomach of marine mammals, where the larvae grow from the third stage through the fourth stage to sexually mature adults. In the North Sea, *Anisakis simplex* have been reported in porpoise, *Phocaena phocaena*; bottle-nosed dolphin, *Tursiops truncatus*, and in white-sided dolphin, *Lagenorhynhus albirostris* (Smith and Wootten, 1978). Adult *Anisakis* have been found also in pinnipeds, but only in a small number. Whether or not pinnipeds are true final hosts still remains unclear (Machida, 1969, 1971; Smith and Wootten 1978; Lang et al., 1990). In the Baltic Sea a few species of mammals occur: porpoise, *Phocaena phocaena*, grey seal, *Halichoerus grypus*, common seal, *Phoca vitulina*, and ringed seal, *Pusa hispida*. In the southern coast only porpoise, grey seal and common seal have been noted in the last few years (Skóra, Hel Marine Station, Morska 2, 84-150 Hel, Poland - pers. comm.). Up to now, *Anisakis simplex* has not been found in those marine mammals, occuring in the South Baltic. Rokicki and Berland (1995) examined 12 specimens of porpoise *Phocoena phocoena* from Polish waters, but did not find any *A. simplex*. The largest number of infected herring occurs in Polish waters in spring, whereas infected cods occur the whole year around. Theoretically, cod, being a component of the diet of marine mammals, could be one source of infection for these mammals in the Baltic, as well as a link in the life cycle of *Anisakis*. However, it is still unknown whether the life cycle of *Anisakis* can be closed or not in the Baltic Sea.

Although some authors have found cod to be an important host for A. *simplex* in a number of areas, thus playing a role in the life cycle of this parasite in the Baltic Sea, its role in this life cycle still needs more research.

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The role of cod, *Gadus morhua* L. in the life-cycle of *Contracaecum osculatum* (Rudolphi, 1802) (Nematoda, Anisakidae) - an overview

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Abstract

The life cycle of *Contracaecum osculatum* is not completely known. The intermediate hosts are crustaceans (*Copepoda, Amphipoda*) and fish are paratenic hosts. The nematodes mature in the stomach of seals, the final hosts. The infective third-stage larvae of C. *osculatum* are present first of all in the liver and less frequently on pyloric caeca or mesentery of several fish species (cod, salmon, burbot, herring, etc.). The intensity of infection is very high in Baltic cod. The cod is important in the life cycle of *C. osculatum* since it is preyed upon by seals which are the final hosts. Cods with the highest infection of larvae are found in the northern areas of the Baltic Sea. This is also where the highest concentration of grey seals, one of the final host, are found. If the infected cod and seals from the northern Baltic Sea occur along the southern coast, the life cycle may be closed also in this area.

Key Words: Contracaecum osculatum, life cycle of C. osculatum, Nematoda, Anisakidae, cod: Gadus morhua.

Introduction

Members of the genus *Contracaecum* are parasites of marine mammals and fish-feeding birds (Berland, 1961; Fagerholm, 1988). As adults they occur in the anterior regions of the gut of seals, cetaceans and birds. *Contracaecum osculatum* is a cosmopolitan marine parasite which normally matures in the stomach of pinnipeds (Likely and Burt, 1992). The infective third-stage larvae are parasites of marine fish. The life-cycle of *C. osculatum* is not completely known. The fish serve as paratenic hosts, transferring the infective stage larvae to the final hosts, which are the seals. *Contracaecum* larvae never mature in fish because they need "warm-blooded" hosts to mature (Khalil, 1969). There are six stages in the life-cycle of marine nematodes: egg, four larval stages and adult (Fig. 1.).

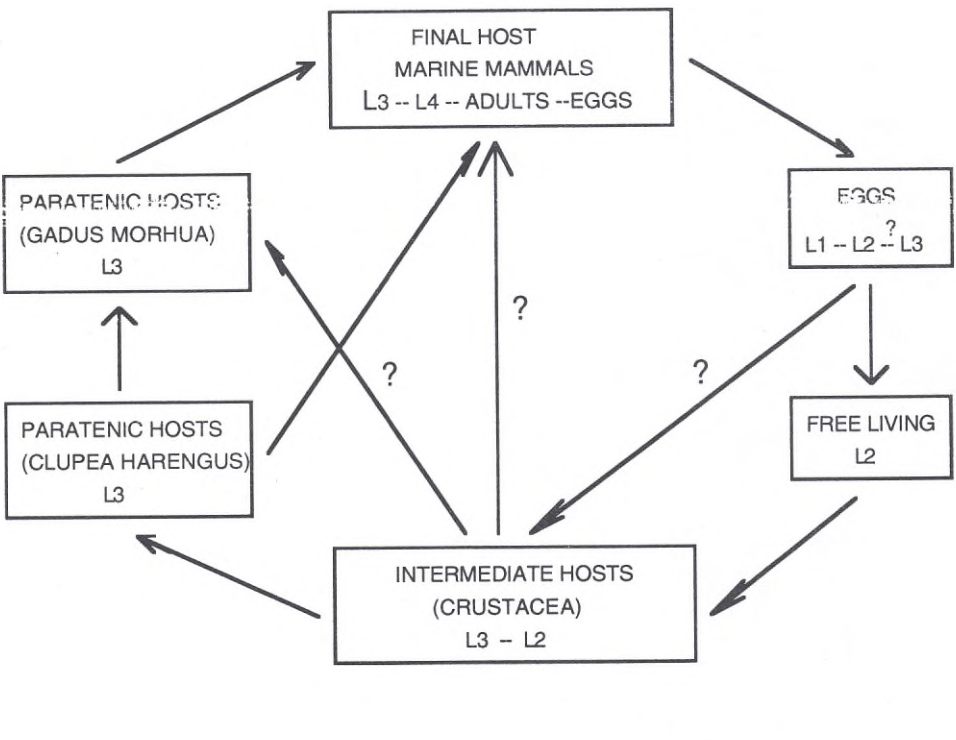

Figure 1. The life cycle of *Contracaecum osculatum*

Taxonomy

Contracaecum larvae from cod were described as *Hysterothylacium aduncum*, parasites that use fish as the final hosts. The two genera, C*ontracaecum* and *Hysterothylacium,* have similar morphology and anatomy which have caused taxonomical difficulties and in older literature they exist as synonyms (Lick, 1990). *Hysterothylacium aduncum* was, because of its opposed intestinal caecum and oesophageal appendix, placed in the genus *Contracaecum* and, for some years, in the genus *Thynnascaris*.

Anatomy and morphology

The L_3 larva of H. *aduncum* possess, as do the adults, an anterior intestinal caecum and a posterior ventricular appendix (Yoshinaga et al. 1987). Lips are absent but a bore tooth is present on the head. These characters are present also in the genus *Contracaecum.*

The fish are paratenic hosts for *Contracaecum* and the larvae never mature in the fish. The most favoured localisation in the fish body is the liver and the pyloric caeca or mesentery (Myjak et al., 1994). The L_3 larvae of *C. osculatum* from cod possess a pyramidal bore tooth situated between the primordial latero-ventral lips close to the slit-like opening of the excretory pore and opposite the large primordial dorsal lip (Likely and Burt, 1992). The tail of this species is conically elongated at the end (Lick, 1990).

It is possible to distinguish *Contracaecum* from *Hysterothylacium* larvae from the tail. The L_3 larvae of *Hysterothylacium* have an "onion-shaped" tail and the L_4 larvae have a "cactus-tail". Independent of the stage, the "cactus-tail" is visible (Køie, 1993). *Contracaecum* larvae are distinguished by having a slender tail without "cactus" at the end. The genera also differ in the distance of caecum from the anterior end of the body and in a difference in location of the excretory pore. *Contracaecum* has the excretory pore on the head, near the bore tooth, while *Hysterothylacium* has it located below the nerve ring (Yoshinaga et al., 1987).

Distribution and fish host

C. osculatum is dispersed over the Atlantic Arctic- Boreal region (Nascetti et al., 1993). The L_3 larva has also been found in Japanese waters (Rokicki et al., 1993).

In the Baltic Sea these nematode larvae occur commonly in the liver, particularly of cod (*Gadus morhua*), but also of several other fish species like salmon (*Salmo salar*), burbot (*Lota lota*), bull-rout (*Myxocephalus scorpius*), four-horned sculpin (*Myxocephalus quadricornis*), herring (*Clupea harengus*) and others (Fagerholm, 1982; Valtonen et al., 1988).

The distribution of cod with the highest infection of *Contracaecum* larvae appears to coincide with areas with the highest concentration of one of the final hosts, grey seals (*Halichoerus grypus*) in the northern Baltic (Fagerholm, 1982). This species of seal is the most heavily infected species by *Contracaecum osculatum* (Valtonen et al., 1988). Generally they occur near the Finnish coast and in the Bothnian Bay (Fagerholm, 1982; Valtonen et al. 1988; Rokicki et al. 1993). Infected cod occur also along the southern coast of the Baltic Sea.

The life-cycle of *C. osculatum*

The life-cycle of *C. osculatum* involves planctonic and benthic invertebrates as intermediate hosts and seals as final hosts (Moravec et al., 1985). Fish, like cod, are involved as paratenic hosts, transferring larvae to the final hosts. Moravec et al. (1985) suggested that fish may act as intermediate hosts. This, however, is not true because *C. osculatum* occurs in fish without moulting and morphological changes like it does in paratenic hosts. The nematodes complete their life-cycle only in marine or brackish waters. However, it is possible that nematodes can be carried to fresh water areas by migratory fish, being infected in brackish waters. For example, C. *osculatum* has been reported from a freshwater fish farm (Fagerholm, 1982).

Our knowledge of the life cycle of *C. osculatum* or of other marine ascaridoids is deficient (Smith et al., 1990). The problem is with the early stages. Discussions have concerned the number of moults which take place within the egg. The eggs are shed to the water with the faeces of infected seals. In the eggs one (Lick, 1990) or two moults (Smith et al., 1990; Køie & Fagerholm, 1993) take place. If only one moult takes place, it is, diagnosticly, an encapsulated L_2 larva, if two moults occur within the egg, it is an L_3 larva (Fig. 1).The second-stage larvae are still enclosed in the first-stage cuticle when liberated from the egg. The L_2 larvae are free-living before they reach the intermediate hosts, crustaceans, mainly copepods.In these, the second moult takes place which results in an L_3 larva. The intermediate hosts are important in the transfer of free living L_2 larvae to L_3 larvae in the fish. Wotten(1978) suggested that benthic invertebrates may be involved as intermediate hosts. However, L_3 larvae of *C. osculatum* occur, although rarely, in Baltic herring. Rokicki et al. (1993) suggested planctonic and benthic crustaceans as *Copepoda* and *Amphipoda* as intermediate hosts in this area. The fish become infected by the nematode larvae probably by eating infected crustaceans.
It is possible that cod can be infected by this nematode by preying on other fish such as herring which is common prey for cod. In the life cycle of *C. osculatum* fish serve as paratenic hosts, transferring the infective third stage larvae to the final hosts. However, infective larvae can also be transferred from fish to fish in a predator-prey relationship without morphological changes (Smith, 1974). The L_3 larvae from the fish are infective to the final hosts. When they enter the seals, the two last moults take place in the stomach of the seal. After the third moult *C. osculatum* develops to the L_4 in a few days. The last moult takes place between the L_4 and the adult stage. This model takes place if only one moult occurs within the egg.

According to Lick (1990) the first moult of marine ascaridoids occurs in the egg and the second in the intermediate hosts such as invertebrates. However, the findings of Køie and Fagerholm (1993) show that in *C. osculatum* the first and the second moults take place inside the egg. Larvae liberated from the eggs are surrounded by two cuticles from two previous moults. According to Smith et al. (1990) one or two moults occur in the egg of *C. osculatum* and free living larvae can develop to L_3 in the body cavity of fish without having used invertebrate hosts. It is usually the L_3 stage which is infective to the final host.

Consequently, since infective cod from the northern Baltic, as well as infected seals, may occur near our coast, the life cycle of *C. osculatum* can be completed in the southern Baltic. And cod, being one of the most infected fish and an important food item for seals, are, thus, important in the life cycle of this nematode.

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Changes in the parasite fauna of cod *Gadus morhua* L. in the Gdansk Bay

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Abstract

An investigation of cod caught near the mouth of the Vistula River, in the Gdansk Bay revealed one trematode (*Diplostomum* sp.), one cestode (*Bothriocephalus scorpii* Müller, 1776 (juvenile)), three nematodes (*Hysterothylacium aduncum* (Rudolphi, 1802) larva; *Anisakis simplex* (Rudolphi, 1809) larva; *Contracaecum osculatum* (Rudolphi, 1802) larva) and two acanthocephalan (*Echinorhynchus gadi* Zoega in Müller, 1776; *Pomphorhynchus* sp.) species. The prevalence and intensity of infection are compared with data from relevant literature regarding parasite species recorded in fish of the Gdansk Bay.

Key Words: parasites of cod, southern Baltic, Gadus morhua

Introduction

The water salinity of the Gdansk Bay oscillates between 3.5 and 8‰, while it drops to about 0 in the mouth of the Vistula River. The trophic situation in the bay has changed during the last decade due to water pollution (Dabrowski *et al.* 1993). This changed situation may be reflected in the parasite fauna of fish living in that area.

The aim of the present paper is to give a review of the possible changes in the degree of infection and in the species composition of cod parasites in this water region.

The parasite fauna of cod in the Gdansk Bay has been investigated by Markowski 1933, Janiszewska 1937, Studnicka 1965, Ganowiak 1968, Rokicki 1975, Rokicki *et al.* 1993, Myjak *et al.* 1994.

Materials and Methods

Cods were caught with commercial vessels on depths between 20-50m near the mouth of the Vistula River from January to April 1995. In all, 103 mainly small, 2-7 year old specimens were examined. They were dissected directly after being brought to the laboratory. The following organs were examined: skin, fins, eyes, gills, body cavity, liver, kidney and digestive tract. The parasites were identified microscopically and the site of the parasite in the host, the total prevalence and intensity of infection were recorded.

Results

The site in the host, the prevalence and the intensity of parasites found can be seen in Table I. In the following the parasite species are described and commented on one by one.

Table 1. Parasites in 103 cod (*Gadus morhua*) caught near the mouth of the Vistula River in the Gdansk Bay from January - April 1995.

Species	Site in host	Prevalence %	Intensity range	Intensity mean
Plathyelminthes				
Digenea				
Diplostomum sp. (metacercarie)	lens	2.6	1-3	2
Cestoda				
Bothriocephalus scorpii (Müller, 1776) (juv.)	intestine	0.9	1	1
Nematoda				
Hysterothylacium aduncum (Rudolphi, 1802) (larva)	intestine	43.5	1-11	2.3
Anisakis simplex (Rudolphi, 1802) (larva)	mesenteries	0.9	1	1
Contracaecum osculatum (Rudolphi, 1802) (larva)	liver	1.9	1	1
Acanthocephala				
Echinorhynchus gadi (Zoega in Müller, 1776)	intestine	40.2	1-14	2.6
Pomphorhynchus sp. (Zoega in Müller, 1776)	intestine	2.8	1-2	1.5

Diplostomum sp.:

Body (in µm): length 500-570, width 240-250; oral sucker: length 42, width 41-42; ventral sucker: length 41-60, width 60; brande´s organ: length 43-76, width 42-75; lime bodies 690-715. These specimens differ in the number of lime bodies from *D. spathaceum* that is commonly found in fish of the Gdansk Bay.

Bothriocephalus scorpii:
One juvenile was found.

Hysterothylacium aduncum:
Adult and non capsulated larvae were found in the intestine. The nematode was found in all length classes of cod, but the bigger the fish, the greater intensity of infection was observed.

Anisakis simplex:
This nematode was noticed only in one fish.

Contracaecum osculatum:
Two larval specimens were found in two cods.

Echinorhynchus gadi:
This species was noticed in all length classes, and the intensity increased with the length of the fish.

Pomphorhynchus sp.:
Three young specimens were found with the length of the body 7-8.1 mm. The number of hooks in the row was 11-12. The number of rows 15-16. There are differences in the morphology between *Pomphorhynchus* sp. and the descriptions of species known so far. The present specimens mostly resemble *Pomphorhynchus kostylewi* Petrocenko, 1956.

The occurrence of different parasites in cod as reported by different authors as well as the degree of infection is shown in Table II. In the same table some pathological changes found in cod by Grawinski et al. (1993) and during the present investigation is presented.

Table 2: Parasites and pathological changes of cod *Gadus morhua* in the Gdanska Bay
M=marine species, F=freshwater and brackish species
prevalence:+=<1%, ++=1-10%, +++= >10%

Species	Degree of infection	Authors
Diplostomum sp.	++ F	present investigation
Bothriocephalus scorpii	+ M	Markowski (1933) - *Bothriocephalus* sp. Rokicki (1975)
Anisakis simplex	+ M	Myjak *et al.* (1994)
Contracaecum osculatum	+ F	Rokicki *et al.* (1993); Myjak *et al.* (1994)
Hysterothylacium aduncum	+++ M	Markowski (1933); Janisazewska (1937); Studnicka (1965) - s. *Contracaecum clavatum*; Ganowiak (1968); Rokicki (1975), Myjak *et al.* (1994)
Ascarophis longispicula	+ F	Studnicka (1965)
Ascarophis sp.	+ F	Studnicka (1965)
Echinorhynchus gadi	+++ M	Markowski (1933); Studnicka (1965); Rokicki (1975)
Pomphorhynchus laevis	++ F	Studnicka (1965) - s. *Pomphorynchus tereticolis*
Corynosoma strumosum	+ M	Studnicka (1965)
Corynosoma semerme	+ M	Studnicka (1965)
Pathological changes		
hyperemias	++	Grawinski *et al.* (1993)
ecchymoses	++	-"-
ulceration	++	-"-
Skeletal deformation	+	present investigation

Discussion

The parasite fauna of cod in the southern Baltic shows a transitive picture between a more marine western Baltic parasite fauna (Pohl 1956; Möller 1975; Køie 1984; Buchmann 1986; Lang 1988; Thulin *et al.* 1989; Reimer *et al.* 1993) and a more freshwater fauna in the eastern Baltic (Shulman 1948; Gecevicjute 1955; Petruchewsky *et al.* 1955; Fagerholm 1982; Vismanis 1987; Valtonen *et al.* 1988).

Möller (1975) recorded 5 species and Køie (1984) 7 species of digenetic trematodes from cod from the Kiel Fjord and the Bornholm area respectively. Reimer and Walter (1993) recorded three species of digenea from cod, but only two in ICES subdivision 25 (including Bornholm) and none from subdivision 26 (including the Gdansk Bay). The only digenea found in cod from the Gdansk Bay is *Diplostomum* sp. (present investigations). *D. spathaceum* has been recorded in other fish from the Gdansk Bay as well as in cod caught north of Bornholm (Køie 1984, Buchmann 1986). However, my specimens differ from *D. spathaceum* mainly in the number of lime bodies and, according to Höglund and Thulin (1992), *D. spathaceum* (from the Baltic coast of Sweden) may include more than one species.

The intensity of nematodes in cod is uneven in the Baltic area. The highest prevalence and intensity of infection with *Anisakis simplex* and *Pseudoterranova decipiens* decrease towards east (Grabda 1976, Thulin *et al.* 1989, Reimer and Walter 1988, Myjak *et al.* 1994) and the infection with *Hysterothylacium aduncum* and *Contracaecum osculatum* increases towards east (Gecevicjute 1955, Valtonen *et al.* 1988). The source of invasion for the Baltic cod by *Anisakis simplex* larvae is the herring, entering the Baltic from west and the prevalence of this parasite has changed during the last years. Thus, no *Anisakis* larvae were found by Grabda in 1976 and Reimer and Walter (1993) in cod caught near the Gdansk Bay. In the same areas, Myjak *et al.* 1994 noted a prevalence of 3.0-4.6 % for all anisakid larvae and of 1.8-3.2 % for *C. osculatum*. In the present study the prevalence in cod caught at the mouth of Vistula River was 0.9% for *Anisakis simplex* and 1.9 % for *Contracaecum osculatum.*

Hysterothylacium aduncum and *Echinorhynchus gadi* appear commonly in the cod from the Gdansk Bay. Both larval and adult forms of *H. aduncum* were noted in the intestine of cod. From this we can state that cod, together with the eel-pout *Zoarces viviparus,* is the main host for *H. aduncum* in the Gdansk Bay. However, in the present study no L_3 larvae of this parasite were found in the liver or body cavity of the fish and this supports the opinion of Myjak *et al.* (1994), that *H. aduncum* (=*auctum*) larvae occur only sporadically in the body cavity of cod.

In the comparison with earlier studies in the area we can notice a decrease of infection with acantocephala during the years in the Gdansk Bay. Thus, both the prevalence and the intensity of infection by *Echinorhynchus gadi* are lower in the present study than those found by Studnicka (1965) and Rokicki (1975). The acantocephalean *Corynosoma semerme* and *C. strumosum* were not found in the present study, which, however, is more likely related to the decreased number of seals, the final host for this parasite, in the Gdansk Bay.

Besides the factors related to host specificity of a parasite, other major factors such as presence or absence of intermediate hosts, changes in salinity and pollution, are important in the regulation of the parasite fauna in cod.

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