# Stock Annex: Cod (*Gadus morhua*) in subdivisions 25–32, eastern Baltic stock (eastern Baltic Sea)

Stock specific documentation of standard assessment procedures used by ICES.

**Stock:** Cod

**Working Group**: Baltic Fisheries Assessment Working (WGBFAS)

**Created:**

**Authors**:

**Last updated:** 31 March 2015

**Last updated by:** Joakim Hjelm

---

## A. General

### A.1. Stock definition

Since 2003, the management of cod in the Baltic is based on two stock units, Western Baltic Cod (ICES SD 22–24) and Eastern Baltic Cod (ICES SD 25–32). The distribution area of the Eastern Baltic cod stock is defined as the ICES Subdivisions 25–32 of the Baltic Sea. The stock is considered biologically distinct from the adjacent Western Baltic cod stock distributed in Subdivisions 22–24, although the stocks overlap in the border area. The stock separation has been confirmed by genetic studies (Nielsen *et al*., 2001; Nielsen *et al*., 2003; Nielsen *et al*., 2005) and is maintained primarily through differences in spawning areas, spawning time and egg characteristics. However, tagging programs have documented that eastern and western Baltic cod stocks co-occur in the Arkona Basin (SD 24) (Aro, 1989; Nielsen *et al*., 2013). Qualitative evidence of occurrence of juvenile cod in the Bornholm Sea, but spawned in the western Baltic Sea, is also given by a study based on the microstructure analyses of otoliths (Oeberst and Böttcher, 1998). In recent years, the abundance of adult cod in SD 24 has rapidly increased, and genetic analyses of 2011 data revealed that a large part of the cod found in SD 24 is genetically eastern Baltic cod (Eero *et al*., 2014). This was confirmed by otolith shape analyses (ICES, 2015) and new genetic analyses of both juveniles and adults from 2014 (Hemmer-Hansen *et al*., unpublished). The presence of eastern cod in SD 24 has resulted in large spatial differences in cod abundance and biological parameters in the western Baltic management unit, i.e. between SD 22 and SD24 (Eero *et al*., 2014). WKSIBCA (ICES, 2014) decided that splitting the assessment input data according to the proportions of eastern and western Baltic cod found in SD 24 would be appropriate. This was based on the assumption that, given the evidence available, the present assignment of cod according the area of capture is obviously biased. The splitting approach was implemented at WKBALTCOD in 2015.

### A.2. Spawning and distribution

Historically, the timing of spawning differs between the two stocks separating the stocks. Spawning of the eastern stock is confined to the deep areas where salinities in the deeper water are sufficiently high to allow egg fertilisation and to keep the fertilised eggs afloat. The eggs of Baltic cod reach neutral buoyancy at lower salinities (approximately 12–14 PSU) than other cod stocks, which is an essential adaptation to living in a brackish water area. Sufficient oxygen content in the deep, saline water layer where the fertilised eggs float is crucial to egg survival and recruitment success. Different studies suggest that a homing migration take place when the development of sexual products starts (Müller, 2002; Bleil and Oeberst, 2002). The stock is distributed over a large area of the Baltic Sea (up to the Gulf of Riga, Gulf of Finland and Bothnian Sea) when the stock size was high and reproduction was occurring in all the main deep basins, as in the late 1970s–early 1980s. At low stock sizes and reduced extension of spawning habitat, the stock is mainly concentrated in the southern Baltic where hydrological conditions are more favourable, as occurred after the mid-1980s (Casini *et al.*, 2012). The stock distribution is currently limited to Subdivision 25, and to minor degree Subdivision 26 and the southern part of Subdivision 27 and 28.

### A.3. Fishery

Cod in the eastern Baltic have traditionally been caught in a directed fishery and catches of cod, as bycatch in pelagic fisheries, has been very limited. The main fisheries for cod in the Eastern Baltic use demersal trawls, semi-pelagic trawls and gillnets. The cod fishery was intensified in the early 1980s when the stock biomass substantially increased due to favourable reproductive environmental conditions with particularly abundant year classes in 1976, 1977 and 1980, and landings increased to 350–400.000 tons in the mid-1980s. During this time, a considerable share of the catches was taken in Subdivisions 28–32. However, the spawning stock subsequently declined from the highest level on record (1982–1983) to an extremely low level in the early 1990s as a result of the increased effort of the traditional bottom-trawl fishery, introduction of gillnet fishery, and decreased egg survival due to deteriorating environmental conditions including oxygen depletion of deep-water layers. During the 1990s, when the proportion of older cod in the stock was large, the gillnet fisheries expanded. However, with the change in the stock age- and size-composition in late 1990s and early 2000, towards younger ages, the share of the total catch of cod taken by gillnets has decreased while that of demersal trawls increased. During the recent two decades, the cod catches were largely taken in Subdivisions 25 and 26 with less than 30% being taken by gillnets. A cod fishery with longlines has been developed in the recent years in some countries but is not taking a large share of the quota. The total reported landings has ranged between 35 000 and 100 000 t, however the landing estimates are considered to some extent inaccurate due to landing misreporting and discards.

### A.4. Fishery regulations

A BACOMA codend with a 120 mm mesh was introduced by IBSFC in 2001 in parallel with an increase in diamond mesh size to 130 mm in traditional codends (Table 1). In October 2003 the regulation was changed to a 110 mm BACOMA exit window or a T90 codend (in which the mesh in the codend and extension piece is turned by 90°). These were expected to enhance the compliance by the fishing industry and to be in better accordance with the minimum landing size, which was changed from 35 to 38 cm in the same year. There is no clear evidence of a difference in the selectivity between the two gears. Implementation of the BACOMA window in the new EU countries (Estonia, Lithuania and Poland) was made in May 2004. In 2010 the BACOMA 120 mm was reintroduced in the Western Baltic. Since 2015, a discard ban is in place, obliging the fisheries to land the entire catch of cod, and cod with a size of ≥35 cm (minimum conservation reference size) are for commercial use.

**Table 1. Changes in gear regulations in Baltic cod trawls during the last two centuries.**

| Year | Regulation change |
|---|---|
| pre 1994 | Min. Mesh size (MMS) 105 mm, Minimum Landing Size (MLS) 33 cm |
| 1994 | MMS increase to 120 mm or 105 mm exit window (two variants) |
| 1994 | MLS increase to 35 cm |
| 2002 | MMS increase to 130 mm or 120 mm Bacoma panel |
| 2003 | MLS increase to 38 cm |
| 2003 | 110 mm Bacoma panel only |
| 2006 | 110 mm T90 introduced as alternative to Bacoma |
| 2010 | MMS increase to 120 mm in T90 and Bacoma |
| 2010 | Amendments of some technical specifications in council reg 2187/2005 |

### A.5. Effort

Effort limitations for the Baltic Sea cod fisheries were included in the 2006 TAC regulation (EC No. 52/2006). The intention was to reduce the allowed days at sea by 10% each year until the cod stocks were within safe biological limits. Effort was primarily limited by seasons closed for fishery. The main closed season was included in the regulation but member states (MS) were also given a number of days of closure to implement when suitable in the national fisheries. For Eastern Baltic cod, fisheries were prohibited between June 15th and September 14th with an additional 27 days of closure to be allocated individually by the Member States. Three closed areas in the eastern part of the Baltic was also introduced which are closed for fishing from May 1th to October 31th. In 2007 three closed seasons January 1st to 7th, 5th–10th April, and December 31st were included in the TAC regulation (EC No. 1941/2006) and MS were given an extra 67 days to allocate individually. In 2008 the management plan for the Baltic Sea cod (EC No. 1098/2007) was introduced and the effort limitation scheme changed. The closed season in the western Baltic was restricted from July 1st to August 30th. There three closed areas are still present. Rules for how the number of allowed fishing days change from year to year are coupled to fishing mortality and the F targets in the management plan.

### A.6. Ecosystem aspects

The eastern Baltic Sea is a brackish water area with an estuarine circulation with a low salinity surface layer (approximately 7 PSU) and deeper saline layer (between 12–18 PSU). A permanent halocline separates the low and high saline layers. The salinity and oxygen contents largely depend on the frequency and intensity of inflows of saline oxygenated water from the North Sea. The water volume suitable for egg fertilisation and development is defined as the volume of water with a PSU >12 PSU and oxygen content >2 ml/l, i.e. the reproductive volume. The critical stages for the recruitment success are the egg and early larval stage (Köster *et al.*, 2003a). Low oxygen content- in ambient water increases egg mortality and predation by clupeids is another mortality factor, while prey availability is crucial to the survival at the first-feeding larval stage.

A substantial predation on cod eggs by sprat and herring has been described for the Bornholm Basin, the most important spawning area. Egg predation is most intense at the beginning of the cod spawning season, with sprat being the major predator (Köster and Möllmann, 2000). The shift of cod peak spawning time from spring to summer (Wieland *et al.*, 2000) resulted in a decreasing predation pressure on cod eggs by sprat, due to a reduced temporal overlap between predator and prey. Predation pressure on cod eggs appears to be higher in stagnation periods. Cod egg predation by clupeids appears to be less important in the more easterly spawning areas. This has been explained by a more limited vertical overlap between predator and prey in these areas (STORE, 2003).

Copepod nauplii and copepodites are the dominant prey organisms of cod larvae in the Central Baltic (Voss *et al.*, 2003). The composition and distribution of the zooplankton is important for larval survival and growth. The calanoid copepod *Pseudocalanus elongates* that is related to more saline water is preferable to *Temora longicornis* and *Acartia* spp., which dominate at low salinities. The strong decline in *P. elongatus* abundance during the last two decades, as a result of low salinities (Möllmann *et al.*, 2000) and high predation by the increased sprat stock (Casini *et al.*, 2010), meant that early cod larvae changed from a non-food limited to a food-limited state. Thus, low *P. elongatus* availability is likely to have contributed to the reduced recruitment of cod since the late 1980s.

After cod settles, the share of fish in their diet increases and sprat and herring become the main food for the larger cod. However, at present, there is limited geographical overlap between cod and the pelagic stocks, and thus the mutual predator–prey interactions could also be affected (Casini *et al.*, 2011). At high stock sizes, the cod could be food limited. Currently, the cod stock is mainly concentrated in Subdivision 25 where the low biomass of pelagic prey seem to affect negatively cod growth and condition (Eero *et al.*, 2012). At the present, therefore, cod seems to be negatively affected by density-dependence and food limitation, although other causes could be involved, such as extent of anoxic areas. Juvenile cod also suffer from cannibalism (Sparholt, 1994; Neuenfeldt and Köster, 2000). As in other cod stocks, the intensity of cannibalism is related to the abundance of large cod, but also the juvenile concentrations, which depend upon the habitat volume occupied and the overall abundance of cod. Apart from medium- to long-term distribution changes related to stock size, interannual variability in cannibalism may be influenced by changing hydrographic conditions (Uzars and Plikshs, 2000).

## B. Data

### B.1. Stock separation in SD 24

Time-series of estimated proportions of eastern and western Baltic cod within SD 24 are available from 1996 onwards from otolith shape analyses, using genetically validated baselines (ICES, 2015). Data for population splitting is not available for all years in the time-series; the extrapolations and assumptions made for years for which these data were missing are described in detail in ICES, 2015. Systematic differences in the proportion of mixing were found by subareas within SD 24, with a larger proportion of eastern cod closer to SD 25. The proportions of mixing in the easternmost rectangles in SD 24 and those in the middle of SD 24 were relatively similar (covering the Arkona basin). Thus, the proportions of eastern and western cod in SD 24 were estimated separately for two subareas, marked as Area 1 (Darss sill and entrance of SD 23) and Area 2 (Arkona basin) in Figure 1.

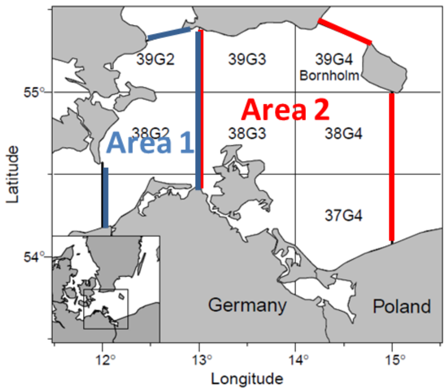


**Figure 1. Map of SD 24 (mixing area of western and eastern cod) and subareas (Area1 and Area 2) for which separate mixing proportions were estimated.**

## B.2.Commercial catch

National landings and estimates of catch composition in numbers and weights-at-age data are available from national sampling programs back to 1966, although data prior to about 1970 are of unknown and possibly poor quality. Since the mid-1990s, CANUM, WECA and CATON for landings are compiled by the national institutes. Data are in this stage nationally aggregated to quarter, subdivision and gear type (active, passive) although the sampling in each country is often stratified on several fisheries (métiers). Not all landings strata have matching biological information and biological information must therefore be extrapolated from other subdivisions, quarters or fisheries. On the national level, data extrapolations of biological data are only done for strata for which additional biological information from other countries are not relevant. If additional biological information from other countries is relevant, only total landings in tons are given. The national data are submitted to the ICES InterCatch database. The national data are aggregated to stock level by quarter and subdivision and gear type. Applying the compiled data based on the countries that have performed sampling in the strata makes the remaining extrapolations of age distributions and mean weight-at-age. All data extrapolations are logged for later documentation.

Misreporting has been a significant problem from 1993–1996 and 2000–2006 and the reported catches have been increased by 35–40%. Catch misreporting, mostly in the form of unreported landings, resulted from a combination of restrictive quotas, the absence of other fishing opportunities, and inadequate inspection. However, the precise circumstances can differ between countries, so information is obtained from representatives of each of the countries contributing data to the WG. The information supplied by each country is summarised to illustrate the nature of the information available, and to allow the reliability of the estimates to be evaluated.

The raising factor (RF) used to calculate the WG estimate of landings from the officially reported figures was obtained from WG experts. For 1993–1996 and 2000–2005 the RF was applied to the overall CANUM. In 2006–2008 country-specific RFs were applied to the national CANUM data. If information about misreporting is available then the landings are adjusted by applying the same factor to all age groups in the landings. The resolution for the misreporting is by quarter, subdivision, gear type and country. After 2009 misreporting has decreased because of fishery control and low catchability of cod.

Information about discard data that are available from internationally coordinated sampling since 1996 was introduced in the assessment in 2001. Discard data follow two alternative compilation methods depending if disaggregated sampling data are uploaded to FishFrame or not. If data are uploaded to FishFrame the estimation of the weight-based discard rate is done centrally and the output is imported to EXCEL for further compilation by the data coordinator. The stratification follows the same stratification as the landings and the discard is raised by the landings. Because not all countries that have uploaded discard data have uploaded landings statistics in FishFrame, the landings statistics used for raising are taken from the spreadsheets submitted for landings (including added misreporting). Only age groups below three years are adjusted with the misreporting factor, assuming that the increased discard induced by the misreporting mostly is due to highgrading. No extrapolation module is available in FishFrame version 4.3 and the necessary data extrapolation is done manually in the spreadsheet. All data extrapolations are logged for later documentation. The extrapolation of age distributions and mean weight-at-age are made taking into account the following priorities:

1 ) Same country, same quarter, adjacent subdivision.

2 ) Same quarter, same subdivision, another country.

3 ) Another country, same quarter, adjacent subdivision.

If a country does not upload discard information into FishFrame, all data compilation of discard to national level must be done before the data are submitted to the data coordinator. All data from both sources are then aggregated to stock level on the same stratification as for the landing data. Landing and discard data are finally aggregated to stock catch level and extracted to XSA input format. All data extrapolations are logged for later documentation.

It is now possible to do all data processing from disaggregated data to final stock estimates for both landings and discards within FishFrame. This means that the use of EXCEL for data processing is no longer necessary if each country uploads data to FishFrame. At the same time it is now possible to do the data extrapolation of discard data on a sufficiently low aggregation level, which allows a more precise extrapolation based on fisheries having similar discard patterns. In each extrapolation the data coordinator is able to judge the data based on information of extrapolated data.  This system will make it possible by time to update and quality improve the whole discard dataseries and result in a general improvement of the assessment.

The discard in numbers by age for years prior to 1996 have been estimated assuming fixed discarding rates at-age based on the mean values for the period 1996 to 2001. Discard estimates for 2015 are assumed to be uncertain due to the landing obligation.

### B.3. Biological information

Catch weights are derived from landings and the discards combined (weighted by numbers). Mean weights in the stock since 1991 are available from the DATRAS database. The weight-at-age is estimated using the mean weight-at-age per subdivision weighted by survey cpue estimates by Subdivisions 25, 26 and 28. Weights-at-age in the stock for ages 1–3 are taken from survey data (DATRAS) from 1991 to present. Weights-at-ages 4–8 in the stock are set equal to the annual weights in catches from 1991 to present.

In 1998, variable combined maturity ogives were introduced for the period 1966–1997 based on national data from the first quarter BITS survey. The ogives were based on compiled national sex-specific data, sex ratios, and number sampled at-age per subdivision (Tomkiewicz *et al*., 1997). Data for the period 1980–1994 were averaged over five year periods due to low sample sizes, while the years 1995–1998 were annual estimates. The average for the period 1980–1984 was used for the period prior to 1980. The annual estimates were updated in 1998 and 1999, but not subsequently and the average maturity-at-age for the years 1997 to 1999 has been used for 2000 onwards. The assessment currently uses a combined female and male maturity ogive, but sex-specific ogives and sex ratios are available. Maturation is dimorphic in this stock with females maturing on average one year later than males, which makes the female-only SSB a more reliable estimator of the egg production (Köster *et al*., 2003) than the combined SSB due to the large changes in age composition stock. A fecundity time-series and model also exists for the Eastern Baltic cod based on relative fecundity estimates and prey availability.

A constant natural mortality of 0.2 is assumed for all years and ages. Predation mortalities (cannibalism) have been estimated by the SMS for the Baltic Sea, but are currently not used in the stock assessment as the values for ages 2+ differ only slightly from 0.2. However, during WKBALTCOD (2015), natural mortality has been assumed to increase, but it is unclear how much.

Otoliths from cod in the Eastern Baltic generally do not show well-defined seasonal growth zones. Recent investigations show that the development of winter rings differs between the eastern and western Baltic Sea probably due to differences in the ambient water temperature. The later spawning time in the eastern Baltic compared with the western Baltic and Kattegat is reflected in a smaller nucleus and a less evident juvenile ring as the growth period during winter is shorter (Hüssy *et al*., 2003). These features cause substantial age-reading problems and the problems have increased later years. Age-reading problems were one of the main reasons for that eastern Baltic cod was assumed “data-poor” 2014.

### B.4. Surveys

Stock abundance indices are available from Baltic International Trawl Surveys (BITS) conducted in 1st quarter of the year from 1991 and additionally in 4th quarter since 2001. Denmark, Germany, Latvia, Poland, Russia and Sweden participate with research vessels. The survey has been internationally coordinated since 2001, when major standardisations in the survey and gear design were introduced. Prior to this year, all research vessels used different trawls and the change to a standardised trawl implies that indices from the period 2001–2008 are not directly comparable with indices from earlier surveys. Therefore this survey is divided into two parts 1991–2000 and 2001 onwards. Intercomparison trials were made before the new gear was implemented as the survey standard gear and the results have been used to estimate conversion factors among gears. The issue of estimating conversion factors is considered by WGBIFS.

In case of inadequate survey conditions the survey index in a given year can be excluded from the cod abundance index calculation. This should be verified by WGBIFS and a reason documented in WG report.

Ichthyoplankton surveys exist from the spawning area in the Bornholm Basin, the Gdańsk Deep and the Gotland Basin. The time-series for the Bornholm Basin based on German and Polish surveys during the spawning period is comprehensive and allows estimation of the average daily egg production indices and the seasonal egg production. These time-series have been use to validate estimates the egg production of Baltic cod (Kraus *et al*., 2002; Köster *et al*., 2002). Ichthyplankton data also exist for the Gdańsk Deep and the Gotland Deep but survey frequency and coverage is more limited. These data are not used in the standard assessment.

### B.5. Commercial cpue

Age disaggregated tuning data since 1997 are available from Danish trawlers. The Danish vessels take the majority of their catch in SD 25, with a smaller proportion taken in SD 26. The fleet cpue indices are standardised to account for factors affecting both relative abundance and fishing efficiency, to achieve a time-series of catch and effort data that represent trends in population abundance.

The standardization procedure was based on the following criteria:

1) subset the cod-specialist activity; i.e. all activities exclusively directed to cod catches in order to get an unbiased cpue time-series based on the effort targeting cod (otherwise, possible underestimation of the cod cpue in case of effort directed toward other species);
2) subset all activities acting with a given and unique fishing gear combination since firstly the variance in catch rates per species is mainly impacted by the gear used, and secondly the use of the similar combination of gears is likely to reflect a homogeneous fishing behaviour pattern;
3) subset all activities exclusively included in the area delimitation of the stock reflecting similar fishing behaviour pattern;
4) remove all activities subject to misreported landings and discarding for which effort and catch data are not reliable.

These criteria are used to achieve the most homogeneous subset of activities (especially in terms of fishing behaviour pattern) relevant to tuning the cod assessment. The available data to run the subset are the trip-based Danish DFAD database merging logbook information with sales slip. The database lists the catches trip by trip for each vessel and by ICES squares. Before 2009, point 4 has not been undertaken due to lack of data on the misreporting aspect.

The same arrangement is run for each year over the desired year range of the tuning fleets. Note that, processing by year, a fleet may not be constituted by the same vessels over the years. The total cod landings of each trip were then converted to landings per age using an allocation key from the data analysis. The decomposition of landings in age group is deduced from harbour sampling of fish length and fish ageing from otolith reading after building an age–length key.

Inside each selected fleet, a standardisation procedure is applied to extract the year effect on which index of abundance can be based using Generalized Linear Models (GLMs) with log-link. The minimal efficient model found in the model selection was for the trawler fleet was:

Cpue = year + kw + year:age

The landings decomposition by age group was possible from 1997 onwards, data from earlier years being considered less reliable. This conditions the final range of years of the time-series of the abundance indices. The main result of the effort standardization is that the correction is low and this could be explained by the fact that the fleet selection had already succeeded in setting up homogeneous fleets. For trawlers, the fleet selection procedure enabled setting a fleet with homogeneous vessels as the low effort correction demonstrated. Further, the visual inspection of the internal consistency of the proposed fleets (Den_Trawl) suggests that this fleet is consistent. However, at WKBALTCOD (2015) the common view was that the commercial tuning fleet from Denmark was not adequate due to age-reading difficulties. However, during WKBALTCOD (2015), the Danish tuning fleet was considered not useful because of aging problems and low spatial coverage. Currently no cpue data of other countries are used but there are different time-series available. There is at the moment a now reason for including a commercial tuning fleet due to the ageing and catchability problems.

## C. Model settings

The model decided in the previous assessment (WKBALT benchmark 2013) was SAM (State–Space Assessment Model, Nielsen, 2008; 2009). However, The WG (WKBALTCOD 2015) could not reach a decision which model to use and hence different models are to be analysed at the WGBFAS in 2015. The models include SAM with same settings as WKBALT (2013) but only as a comparison, XSA but only as a comparison, SAM with same settings as WKBALT (2013) but applying a Swedish ALK, SAM with same settings as WKBALT (2013) but applying a Swedish ALK with age measurement error, SAM but length based, Stock synthesis (SS3) and a stock production model.

## D. Short-term projection

Because the WKBALTCOD (2015) did not decide which model to use, no short-term forecasts are made.

## E. Medium-term projections

## F. Long-term projections

## G. Biological reference points

Because the WKBALTCOD (2015) did not decide which model to use, no biological reference points have been determined.

## H. Other issues

## I. References

Aro, E. 1989. A review of fish migration patterns in the Baltic. Rap. Proc. Verb. Réun. Cons. Int. Explor. Mer 190, 72–96.

Casini M., Bartolino, V., Molinero, J.C. and Kornilovs, G. 2010. Linking fisheries, trophic interactions and climate: threshold dynamics drive herring *Clupea harengus* growth in the central Baltic Sea. Marine Ecology Progress Series, 413: 241–252.

Casini, M., Blenckner, T., Möllmann, C., Gårdmark, A., Lindegren, M., Llope, M., Kornilovs, G., Plikshs, M. and Stenseth, Nils Chr. 2012. Predator transitory spillover indices trophic cascades in ecological sinks. Proceedings of the National Academy of Sciences of the USA, 109: 8185–8189.

Darby, C.D. and Flatman, S. 1994. Virtual Population Analysis: version 3.1 (Windows/Dos) user guide. Information Technology Series, n 1, Lowestoft.

Eero, M., Vinther, M., Haslob, H., Huwer, B., Casini, M., Storr-Paulsen, M. and Köster, F.W. 2012. Spatial management of marine resources can enhance the recovery of predators and avoid local depletion of forage fish. Conservation Letters, 5: 486–492.

Eero, M., Hemmer-Hansen, J., Hüssy, K. 2014. Implications of stock recovery for a neighbouring management unit: experience from the Baltic cod. ICES J. Mar. Sci. 71, 1458–1466.

Hinrichsen, H.-H, C. Möllmann, R. Voss, F.W. Köster, and G. Kornilovs. 2002. Biophysical modeling of larval Baltic cod (*Gadus morhua*) growth and survival Can. J. Fish. Aquat. Sci, 59, 1858–1873.

Hinrichsen, H.-H., Möllmann, C., Voss, R., Köster, F.W. and Kornilovs, G. 2002a. Bio-physical modeling of larval Baltic cod (*Gadus morhua* L.) growth and survival. Can. J. Fish. Aquat. Sci. In press.

Hüssy, K., Mosegaard, H., Hinrichsen, H.-H., Böttcher, U. 2003. Factors determining variations in microincrement width of demersal juvenile Baltic cod (*Gadus morhua* L.) otoliths. Mar. Ecol. Progr. Ser. Accepted.

ICES. 2003. Report of the Baltic International Fish Survey Working Group. ICES CM 2003/G:05.

ICES. 2008. Report of the Working Group on Integrated Assessment of the Baltic Sea (WGIAB) ICES, Baltic Committee CM 2008/BCC:04; 145 pp.

ICES. 2008. Report of the Workshop on Reference Points in the Baltic Sea (WKREFBAS), ICES Advisory Committee C.M 2008/ACOM:28, 26 pp.

ICES. 2008. Report of the Working Group on Integrated Assessment of the Baltic Sea (WGIAB) ICES, Baltic Committee CM 2008/BCC:04; 145 pp.

ICES. 2015. Report of Benchmark Workshop on Baltic cod stocks (WKBALTCOD), 2–6 March 2015, Rostock, Germany. ICES CM 2025/35.

Köster, F. W; Hinrichsen, H-H; Schnack, D; St John, M.A; Mackenzie, B.R.; Tomkiewicz, J; Möllmann, C; Kraus, G; Plikshs, M; Makarchouk, A and Aro, E. 2003. Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock–recruitment relationships. Scientia Marina, 67 (Suppl. 1): 129–154.

Köster, F.W, Hinrichsen, H.-H., St John, M.A. Schnack, D. MacKenzie, B.R., Tomkiewicz, J. and Plikshs. M. 2001. Developing Baltic cod recruitment models. II. Incorporation of environmental variability and species interaction. Can. J. Fish. Aquat. Sci. 58: 1534–1556.

Köster, F.W. and Möllmann, C. 2000. Trophodynamic control by clupeid predators on recruitment success in Baltic cod? ICES J. Mar Sci. 57 (2): 310–323.

Köster, F.W., Schnack, D., Möllmann, C. 2003. Scientific knowledge on biological processes potentially useful in fish stock predictions. Scientia Marina, 67 (Suppl. 1). In press.

Kraus, N., Tomkiewicz, J., and Köster, F.W. 2002. Egg production of Baltic cod in relation to variable sex ratio, maturity and fecundity. Canadian Journal of Fisheries and Aquatic Sciences, 59: 1908–1920.

Matthäus, W. and Lass, H.U. 1995. The recent salt inflow into the Baltic Sea. J. Phys. Oceanogr. 25: 280–286.

Möllmann, C., Kornilovs, G. and Sidrevics L. 2000. Long-term dynamics of main mesozooplankton species in the Central Baltic Sea. J. Plank. Res. 22 (11): 2015–2038.

Neuenfeldt, S., and Köster, F.W. 2000. Trophodynamic control on recruitment success in Baltic cod: the influence of cannibalism. ICES J. Mar Sci. 57(2): 300–309.

Nielsen, E.E, Hansen, M.M., Schmidt, C., Meldrup, D. and P. Grønkjær. 2001. Population of origin of Atlantic cod. Nature, Vol. 413, no 6853: 272.

Nielsen, E.E., Grønkjær, P., Meldrup, D. and Paulsen, H. 2005. Retention of juveniles within a hybrid zone between North Sea and Baltic Sea Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 62, 2219–2225.

Nielsen, E.E., Hansen, M.M., Ruzzante, D.E., Meldrup, D. and Grønkjær, P. 2003. Evidence of a hybrid-zone in Atlantic cod (*Gadus morhua*) in the Baltic and the Danish Belt Sea revealed by individual admixture analysis. Mol. Ecol. 12, 1497–1508.

Nielsen, B., Hüssy, K., Neuenfeldt, S. Tomkiewicz, J., Behrens, J.W., Andersen, K.H. 2013. Individual behaviour of Baltic cod *Gadus morhua* in relation to sex and reproductive state. Aquat. Biol. 1, 197–207.

Oeberst, R., Böttcher, U. 1998. Development of juvenile Baltic cod described with meristic, morphometric and Sagitta otolith parameters. ICES CM 1998/CC:15, 29pp.

Sparholt, H. 1994. Fish species interactions in the Baltic Sea. Dana 10: 131–162.

STORE. 2003. Environmental and fisheries influences on fish stock recruitment in the Baltic Sea. EU-Project FAIR CT98 3959, Final Report, 401 pp.

Tomkiewicz, J., Eriksson, M., Baranova, T, Feldman, V. and Müller H. 1997. Maturity ogives and sex ratios for Baltic cod: establishment of a database and time-series. ICES CM. 1997/CC:20.

Uzars, D. and Plikshs, M. 2000. Cod (*Gadus morhua callarias* L.) cannibalism in the Central Baltic: Interannual variability and influence of recruitment, abundance and distribution. ICES J. Mar. Sci. 57: 324–329.

Voss, R., Köster, F.W. and Dickmann, M. 2003. Comparing the feeding habits of co-occurring sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) larvae in the Bornholm Basin, Baltic Sea. Fish. Res. In press.

Wieland, K., Jarre-Teichmann, A. and Horbowa, K. 2000. Changes in the timing of spawning of Baltic cod: possible causes and implications for recruitment. ICES J. Mar. Sci. 57 (2): 452–464.