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REPORT OF THE STUDY GROUP ON MULTISPECIES ASSESSMENT IN THE BALTIC (SGMAB)

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Conseil International pour l'Exploration de la Mer

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Executive Summary

The Study Group addressed the full range of Terms of References, although it should be recognized that the variety and complexity of the ToRs overstretched the capabilities of the group. Recognizing this, the technical effort concentrated on i) reviewing and updating the multispecies databases, ii) conducting a multispecies key run for the eastern Baltic to be used by WGBFAS, iii) performing spatially dis-aggregated MSVPA runs for the eastern Baltic and iv) testing fishing mortalities for cod suggested by AGLTA to result in low risk to reproduction and high long-term yields. For central Baltic herring, the multispecies assessment unit has not been directly comparable to the units used by WGBFAS, as the single species assessment excludes Gulf of Riga herring. Thus, the multispecies database was re-arranged by excluding the Gulf of Riga from Subdivision 28, making as well preliminary runs to test for the effect of the exclusion. An update of the Western Baltic MSVPA is still pending, as the revision of the western Baltic herring assessment by HAWG in 2002 is still not implemented in the multispecies database. Scientific oriented activities comprised i) a test for the impact of reduced oxygen concentration and consumption rates by cod on predation mortalities estimated by the MSVPA, ii) gathering of information on environmental processes affecting the temporal and spatial distribution and stock dynamics of herring and iii) explaining historical trends and changes in mean weight-at-age of herring. Strategic coordination and planning activities were conducted together with SGBFFI and addressed first specific actions like the organization of a common cod stomach sampling program, and data requirements from future ecosystem oriented surveys. Secondly structural requirements for conducting a regional integrated assessment of the Baltic Sea were discussed. This resulted in a suggestion to restructure the WG and SG group set-up underneath the Baltic and Advisory Committees. This suggestion should be seen as a starting point of a discussion in a broader forum rather than a well defined plan. Finally SGMAB outlined a work programme for the years to come.

1 Introduction

1.1 Participation

SGMAB and SGBFFI members

Eero Aro (Co-Chair)	Finland	(SGMAB)
Massimiliano Cardinale	Sweden	(SGBFFI and SGMAB)
Margit Eero	Estonia	(SGBFFI and SGMAB)
Valeri Feldman	Russia	(SGMAB)
Georgs Kornilovs	Latvia	(SGMAB)
Fritz Köster (Co-Chair)	Denmark	(SGMAB)
Christian Möllmann	Denmark	(SGBFFI and SGMAB)
Stefan Neuenfeldt	Denamrk	(SGMAB)
Henn Ojaveer	Estonia	(SGBFFI)
Wojciech Pelczarski	Poland	(SGBFFI)
Maris Plikshs	Latvia	(SGBFFI and SGMAB)
Morten Vinther	Denmark	(SGMAB)
Rüdiger Voss	Germany	(SGMAB)
Włodzimierz Grygiel	Poland	(SGBFFI and SGMAB)
Tiit Raid	Estonia	(SGBFFI and SGMAB)
Yvonne Walther	Sweden	(SGBFFI)

1.2 Terms of Reference

According to the ICES Annual Science Conference Resolution in 2004, the **Study Group on Multispecies Assessment in the Baltic [SGMAB]**, (Co-Chairs: E. Aro (Finland), (eero.aro@rktl.fi) and F. Köster (Denmark) (fwk@dfu.min.dk) will meet in Riga, Latvia from 13–17 June 2005 to undertake the tasks as specified in (C.Res 2004/2H06).

a) continue the implementation of multispecies interactions in the assessment of Baltic fish populations by updating the multispecies key runs up to 2004 in both the Western and Eastern Baltic, and by appropriate units;

b) review, revise and update the multispecies database (i.e., catch in numbers, maturity ogives, mean-weight-at age, stomach data etc.) and explain historical trends and changes in mean weight-at-age of key species;

c) report on available information on environmental processes, which are affecting the temporal and spatial changes in Baltic herring population dynamics;

d) develop, apply and validate ecosystem models for assessment and prediction of fish stock dynamics including:

   i) prediction of weight-at-age and proportion of maturation at age, potentially depending in a feed back loop on prey availability and environmental conditions, and

   ii) recruitment success in relation to parental stock status and environmental conditions.

e) validate the revised consumption rates (by quarter of years), which presently contain inter-annual and spatial variability in stomach content, predator weight and ambient temperature, but ignore an impact of reduced oxygen concentrations;

f) consider how the results of the Study Group on "Fish and Fisheries Issues in the BSRP (SGFFI)" can be incorporated into the work programme of this Study Group;

g) prepare a workplan, including a schedule for deliverables for the next two years;

h) propose contributions to the 2006 Theme Session on Regional Integrated Assessments, as described in the 2003 report of the Regional Ecosystem Study Group for the North Sea;

i) plan a meeting in 2006 as a joint or overlapping meeting with at least one other Baltic SG (e.g., SGPROD, SGGIB, SGBEM) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups;

j) based on an assessment of the multispecies interactions between cod, herring and sprat in ICES Subdivisions 25–32 to provide mortality estimates to be used in stock assessments, and to contribute through estimates of the mortality on cod eggs and larvae, to an improvement of the stock-recruitment relationship. The interactions should include an account of the variable physical forcing conditions.

SGMAB will report by 13 July 2005 for the attention of the Baltic Committee.

1.3 Background

In the Baltic Sea, the interacting fish community in the open sea is dominated by three species namely cod, herring, and sprat. The abundance of cod and herring in the Main Basin is currently low and the sprat stock is at high level. The impact of cod predation on prey species herring and sprat is at present at a low level. Multispecies interactions will however become important, when the predator population recovers. While cod biomass is low, there is the potential for herring and sprat to have an adverse effect on cod recruitment, through consumption of eggs and larvae.

The multispecies interactions in the Baltic are rather clear and strong, Thus it is relative easy to demonstrate how species interactions effect our assessments of the state of the stocks and our perception of the interactions.

Baltic multispecies assessment process started about 20 years ago and presently the following multispecies assessments and data are available for the Baltic Sea according to ICES Subdivisions (Figure 1.3.1):

- Baltic Main Basin: Years 1974–2004
  - cod in Subdivisions 25–29+32
  - sprat in Subdivisions 25–32,
  - herring in Subdivisions 25–29+32,
- Western Baltic: Data: Years 1977–2001, assessments: 1977–1997
  - cod in Subdivisions 22+24 (Subdivision 23 included in 1996–1997),
  - sprat in Subdivisions 22–24,
  - herring in Subdivisions 22–24 including Division IIIa.
- Baltic Main Basin: Years 1976–2003, area dis-aggregated MSVPA:
  - cod in Subdivisions 25, 26 and 28
  - sprat in Subdivisions 25, 26 and 28
  - herring in Subdivisions 25, 26 and 28

Figure 1.3.1: ICES Subdivisions in the Baltic.

The current catch-at-age in numbers database for cod in the Baltic Main Basin (SD 25–32) for the years 1974–1976 is based on very limited age distribution data, most of the landings have been split into age groups based on the data from only one country. Several datasets concerning the age distribution of the landings that have been collected by national laboratories for 1977–1985 are also not included in the current database. The work for compiling these additional data series for 1974–1985 has been ongoing and the data that have been made available are planned to be included into the database in the nearest future (by the next meeting of the Study Group).

In the case of Main Baltic herring, the multispecies assessment unit has not been directly comparable to the units used by the Baltic Fisheries Assessment Working Group, as the singlesspecies assessment excludes Gulf of Riga herring. Thus SGMAB re-arranged the multispecies database by excluding the Gulf of Riga from Subdivision 28, making as well preliminary runs to test for the effect of the exclusion.

An update of the Western Baltic MSVPA is still pending, as the revision of the western Baltic herring assessment by the Working Group on Herring Stocks South of 62°N in 2002 is still not implemented into the multispecies database. However, progress has been achieved in updating the database.

1.4 Supporting projects and background information

Under the ICES framework the SGMAB has benefited from the activities of the Baltic Fisheries Assessment Working Group (WGBFAS). WGBFAS compiles the main input information needed for SGMAB since 1997.

The WGBIFS (Baltic International Fish Surveys Working Group) reports information on weight-at-age in the stock for cod based on 1st quarter and 4 quarter bottom trawl surveys and compiles the information for VPA tuning files from the surveys. However there are serious concerns about the functioning and the quality of BITS (DATRAS) database held by ICES Headquarters. The database has not been ready for use by various assessment groups and extra analysis. This applies both WGBFAS and SGMAB meetings in the past.

Data on the abundance of herring and sprat as well as data on the weight-at-age in the stock is available from international hydroacoustic surveys, which are conducted “annually” in September/October. Both these data sets can be used to establish a stock specific weight-at-age database, however, not covering all quarters, which consequently requires modelling of seasonal growth to ensure complete seasonal coverage, potentially using the sprat hydroacoustic survey in May covering major parts of the Central Baltic.

There have been activities on modelling cod and sprat growth, sexual maturation and egg production in relation to food consumption, food availability and environmental conditions, especially temperature in the framework of STORE and SAP (Sustainable Fisheries) projects, which have been used by SGMAB.

The work of the SGMAB has been dependent upon the results of various European Union funded projects and some of ICES SGs and WGs. Within the European Union, SGMAB has benefited from results of number of completed or ongoing projects and study projects. Such projects are CORE (Cod Recruitment, completed at the end of 1997), ISDBITS (International Standardization of Baltic Bottom Trawl Surveys, completed in March 2001), BALTDAT (Baltic International Hydroacoustic Surveys, completed in March 2001), BITS (Baltic International Trawl Survey Database, completed in April 2001) and IBSSP (International Baltic Sea Sampling Project I-II, completed in July 2001) and STORE (Environmental and fisheries influences on fish stock recruitment in the Baltic Sea) completed in 2002.

European Union funded projects such as BECAUSE (2004–2007, “Critical interactions between species and their implications for a precautionary fisheries management in a variable Environment – a Modelling Approach”) and PROTECT (2005–2008, “MPAs as a tool for ecosystem conservation and fisheries management”) will play an important cooperative role in the future multispecies work. BECAUSE covers the development of stochastic multispecies model as well as coupling marine mammals and seabirds into the critical interactions. These critical biological interactions, which have a significant relevance for fisheries management and ecosystem functioning, are for example non-commercial top-predators, e.g. mammals and then important commercial species, e.g. cod/cod, cod/herring, cod/sprat, sprat/cod, seals/salmon interactions. In the new multispecies model (SMS model) it is possible to estimate parameters and their variances, but more work is needed on model formulation and the use of the full data set.

The PROTECT program, starting at the beginning of 2005, will concentrate among other things to develop a suite of implementation, monitoring and assessment tools in order to manage the fisheries impact on cod and clupeids stocks and the structure of upper trophic levels in the ecosystem.

At the beginning of year 2002 the European Union established a new framework for the collection and management of data needed to evaluate the situation of the fishery resources and the fisheries sector in general. This sampling directive will be renewed in 2006/2007. In the Baltic Sea area the sampling directive is covering almost the entire Baltic except the territorial waters of Russia, which form round 8% of the total Baltic area. In eight EU countries around the Baltic Sea, national programmes are defined for the collection and management of fisheries fish stock data. The programmes cover the information strictly necessary for the scientific evaluations and moreover to define an extended Community programme which includes, in addition to the information of the minimum programme, information likely to improve in a decisive way the scientific evaluations. There are also possibilities to include some extra sampling schemes on special issues under extended programme. The assessments of Baltic fish stocks will be very much dependent on these sampling schemes and minimum and extended programmes.

1.5 Overview of Baltic Sea multispecies modelling

It is obvious that there is a need for specific work to keep the capability of running updated multispecies models for the Baltic within the ICES community and to ensure further progress in multispecies modelling in the Baltic. Updated multispecies model results are used by WGBFAS annually for Baltic herring and sprat assessments. These single species assessments for cod, herring and sprat are presently the basis for management advice for IBSFC and European Community.

The maintenance of the multispecies database, database revision and updates, need input from various institutes as well as ICES working and study groups. Backwards extension of the MSVPA to periods before 1977 with the aim to enlarge the time series on stock developments especially for stock-recruitment modelling purposes is proved to be difficult because of lack of proper documentation and dis-aggregation of the primary data. The Eastern Baltic MSVPA covers the years 1974–2004 and the spatially dis-aggregated models the years 1974–2003, but results of multispecies assessments before 1977 should be used with caution. To update databases backwards to 1960s and early 1970s may not be possible, as there might be severe problems compiling quarterly data by subdivisions. In this process the most obvious limiting factor will be the poor quality quarterly catch-at-age and weight-at-age data, especially before 1974.

There are considerable amounts of stomach content data for the 1960s and 1970s and this information would be very useful for estimation of consumption rates and understand cod cannibalism. Some new stomach content data is presently sampled under the umbrella of BSRP ("Baltic Sea Regional Program" on Large Marine Ecosystems) and this activity is expected to intensify in 2005 and 2006.

From inspection of the original stomach content data, cannibalism appears to be related both to the prey sizes and spatial overlap. However, cannibalism is most likely also related to shifts in the distribution of predator and prey in response to changes in hydrological conditions, resulting in pronounced changes in the spatial overlap of predator and prey. This part of exploratory work is ongoing and there are plans to tackle these issues both in BECAUSE and BSRP.

The high intra- and inter-annual variability in stomach contents encountered in the multispecies database needs investigation, as consumption rates estimated with the presently implemented stomach evacuation model directly reflect this variability. Furthermore any test of these consumption rates based on a bioenergetics model is hampered by the high variability in stomach content. Explanations may either be an impact of hydrographic conditions on appetite/feeding rates or problems within the stomach sampling procedure. BECAUSE presently tackles this problem.

Our predictive models are sensitive to structural uncertainty. For example, as demonstrated early with inclusion of weight-at-age and maturity at age being dependent on the food supply, the projected medium-term yield at various combinations of fishing effort directed to both cod and clupeids stocks change considerably in comparison to ordinary standard multispecies predictions.

Spatially dis-aggregated MSVPA runs have been updated for the Central Baltic up to 2003. The results support the theory that passive transport of youngest life stages of cod and migration by juveniles into/out of their nursery areas as well as spawning migrations of adults between different subdivisions are likely to occur. The intensity between years varies and there is for the time being no clear estimates about the extent of these movements. Similarly for herring and sprat, the MSVPA output do not match the distribution pattern obtained from research surveys, indicating conflicting results caused probably by migration and movements.

However, the integrated results over the whole area coincide with the results of the assessed stock.

The 4M programme, which contains the MSVPA and it's routines including the tuning module, have been run without problems. The present programme package enables for example WGBFAS to run MSVPA's on a regular basis. An updated user manual giving specification and documentation of the 4M package is also available.

For development, application and validation of different types of multispecies prediction models, one of the key elements seems to be environmental variability. For example Baltic cod and sprat recruitment, feeding, growth and maturation processes are very much influenced by the heterogeneity of the physical environment. In the Baltic Sea environmental variability is strongly linked to the meteorological–, hydrological–, and hydrographical processes and their interaction. As a result, the impact or change of one factor may well be correlated with that of others. How they interact has been considered in some occasions in CORE and STORE projects, but the relationships between various processes and hydrodynamics need still exploration.

Baltic Sea oceanographic data usually consist of indices that reflect and integrate multiple processes. They often reflect the influence of remote forcing over a broad geographic area, while direct measurements reflect variability on local scales or predicted elements generated from detailed models of a specific area. The use of indices instead of local observations is often the result of limited monitoring resources or limited knowledge at the local scale. How to use these values or indices properly has not been explored.

Reference points, stated in terms of fishing mortality rates or biomass and management plans are key concepts in implementing ecosystem and precautionary approaches in fishery management. It has been agreed, but not fully understood, that reference points should be regarded as signposts giving information of the status of the stock. It has been possible to develop rather clear concepts and a "quantitative framework" with reference points and management models for single stock sustainability and precautionary. For multispecies situations the sustainability concept seems to be very different and difficult to overview. Although the Baltic Sea is considered to be a simple ecosystem, there is still little clarity on the conceptual level given the complexity and natural variability of that environment. Reference points are far away from being easily defined given the limited understanding of the processes in the environment, of the effects of human interaction and of what comprises a perturbation of the environment which is unsustainable or perhaps irreversible.

Medium- to long-term projection methodology is a problem for single species approach and for multispecies as well. However, the present version of 4M programme package is able to handle a variety of stock recruitment relationships with and without stochasticity, as well as stochastic recruitment derived from normal or log-normal distributions. The programme is not able to incorporate environmental processes into stock recruitment relationships. The inclusion of environmental variability in predictions is worthwhile when assessing the impact of various management and fishing strategies on the stock development under different environmental conditions.

2 Status of the database

2.1 Stock units

2.1.1 Stocks in the Central Baltic (Subdivisions 25–32)

Cod and sprat in Subdivisions 25–32

The stock units utilized in the present MSVPA for the Central Baltic are: i) cod in Subdivisions 25–29+32, ii) sprat in Subdivisions 25–32, and iii) herring in Subdivisions 25–29, 32 (Gulf of Riga included). As the sprat population in Subdivisions 30 and 31 is rather low (landings are less than 5000 t in most recent years), the stock estimate is basically also referring to Subdivision 25–29+32. To estimate the predation mortality on these stocks, the cod assessment unit was adjusted accordingly, thus not considering part of the stock in Subdivision 30 and 31. Landings reported in these Subdivisions are in general less than 1% and in maximum 3.5% of the total catch from the Central Baltic. Consequently the effect of ignoring the two Subdivisions should not hamper a direct comparison between single species and multispecies assessment output. For sprat, the multi- and single species assessment units are not directly comparable, as in the latter the sprat stock in entire Baltic is treated as a single stock unit.

Herring in Subdivisions 25–29 and 32

Until 2002 the herring stock assessment in the Central Baltic was based on Herring in the SD 25–29 and 32. Additionally an assessment of Herring in the Gulf of Riga has been performed to evaluate the stock development trends and provide catch options for this local herring stock. Assessment of herring in SD 25–29 and 32 without Gulf of Riga has been performed irregularly based on request from IBSFC. In 2002 the Main Basin herring stock assessment has been made on 3 different units:

- Herring in the SD 25–29 and 32 including Gulf of Riga;
- Herring in the SD 25–29 and 32 excluding Gulf of Riga;
- Herring in the Gulf of Riga.

Due to complexity of stock structure and that stock development trends in the Gulf of Riga and in the Main Basin are opposite; ACFM advice was based on assessments of Herring in SD 25–32–29 and 32 excluding Gulf of Riga and Herring in the Gulf of Riga and consequently single species assessments were conducted since then in this way. SGMAB so far used in the multispecies assessment and predictions in the Baltic the combined main basin herring stock data e.g. Herring in SD 25–29 and 32 including Gulf of Riga. As the herring in the Gulf of Riga presently constitute approximately 1/3 of all Central Baltic herring stocks, the growth of sea and gulf herring differs and there are no cod in the Gulf of Riga the estimated natural mortality for herring in the open sea can deviate significantly from previously used. Therefore tests were performed using data of the herring stock in SD 28 in– and excluding Gulf of Riga. However, it was not possible to compile the new set of quarterly dis-aggregated data for herring in the SD 25–29 and 32 excluding Gulf of Riga for the entire time series.

2.1.2 Stocks in the Western Baltic (Subdivisions 22–24 and Division IIIa)

Cod in Subdivisions 22–24

Subdivision 23 was up to 1995 not included in the assessment of the western cod stock. This corresponds to the procedure conducted by the Baltic Fisheries Assessment Working Group. Reasons were mainly that commercial catches were not sampled and application of the age-structure of the neighbouring Subdivision 24 was difficult, due to different fishing practise in the Sound (ban of trawl fishery). Since 1996, however, a sampling scheme of commercial catches was introduced and the data was included into the assessment (ICES 1998/ACFM:16). The exclusion before is expected to be of minor importance.

Herring in Subdivisions 22–24 and Division IIIa

The herring shows a complex distribution pattern. The major spawning grounds are found around Ruegen and in the Greifswalder Bodden. After spawning on their feeding migration (as 2 years of age and in proportions increasing with age) the herring enter Division IIIa through the Sound and Belt Sea and spread out into the Western part of Skagerrak and the Eastern North Sea. Towards the end of the summer the herring aggregate in the Eastern Skagerrak and Kattegat before they migrate to the main wintering areas in the southern part of Kattegat, the Sound and the Western Baltic. Due to this migration out of Subdivisions 22–24 only a fraction of the total herring stock is preyed upon by the Western cod stock in the 2nd and 3rd quarter. This must be kept in mind when looking at the predation mortality from the MSVPA, which may be biased downwards (at least for herring age-group 2+), as only some part of the predation mortality is accounted for due to the described distribution pattern of herring.

Sprat in Subdivisions 22–24

The Baltic Sea sprat inhabits the Baltic Sea from the Belt Seas and western Baltic (Subdivisions 22 and 24) up to the Quark area in the north (Subdivision 30) and to the north-eastern part of the Gulf of Finland (Subdivision 32). The western Baltic sprat stock inhabits the Belt Seas, Arkona region and the region of Bornholm Island (Subdivisions 22–24 and partly 25). The boundaries between this western stock and the eastern stock are not clear and the mixing of stocks during feeding and wintering is apparent. Mixing with the Kattegat and Skagerrak stock is considered to be very low, although there is no significant difference in morphometric characters and in the vertebrae counts. The mixing is probably prevented by the gradient and differences in many abiotic factors between the western Baltic and the Kattegat. The range and amplitude of the migration patterns of sprat stocks and their mixing in the Baltic is far from clear.

The main spawning grounds of the sprat stocks in the western Baltic are in Kiel Bay, Mecklenburg Bay and Arkona Basin, while the eastern stock generally spawns along the slopes of the deeps and also the deeps themselves. The spawning starts in the western Baltic usually in March-April and lasts until July-August in the northern Baltic proper. The spawning time in the southern Baltic is longer than in the northern Baltic.

2.2 Database update (catch-at-age and weight-at-age)

2.2.1 Central Baltic

Period 1974–1992:

During the meetings of the Study Group on Multispecies Model Implementation in the Baltic (ICES 1997/J:2 and ICES 1999/H:5) and the Study Group on Multispecies Predictions in the Baltic (ICES 2001/H:4) as the Study Group on Multispecies Assessment in the Baltic (ICES 2003/H:03) revised and corrected quarterly catch-at-age and weight-at-age in the catch data per Subdivision were compiled for cod, sprat and herring in the Central Baltic for the period 1974–1992. Additionally, the Gulf of Riga herring was excluded from the data for Subdivision 28 for the time period from 1980 onwards. This enables multispecies assessments to be carried out for stock units defined as appropriate.

Period 1992–2004:

Data for all three species were provided in the needed form by the Baltic Fisheries Assessment Working Group in most recent years, for minor deviations between the single- and multispecies database see ICES (1999/H:5). As in previous years, the data for the most recent year of the assessment year was implemented into the multispecies database as provided by the Baltic Fisheries Assessment Working Group up to 2004 (ICES 2005/ACFM:19). Data for the area dis-aggregated runs include 2003 as most recent year.

General:

The revision of the database needs allocation of additional effort. Work is needed especially for compilation of the new set of quarterly dis-aggregated data for herring in the SD 25–29 and 32 excluding Gulf of Riga (see Section 2.1.1) and for the years at the beginning of the time-series. For these still data exist in various national laboratories and with respect to potential corrections for age-reading discrepancies in cod. Furthermore, no discard estimates are yet included in the data. A necessary step after incorporation of all available information and re-computation of quarterly data per Subdivision according to the agreed substitution scheme (ICES 1997/J:2), is a further validation of the assessment data by comparison of SOP-values to actual reported landings. Based on this validation, a final revision of the database has to be conducted, before handing over the database to the Baltic Fisheries Assessment Working Group.

During its meeting in 1998 the Baltic Fisheries Assessment Working Group (ICES 1998/ACFM:16) has started a compilation of available weight-at-age in the stock data for cod, based on 1st quarter bottom trawl surveys. Similarly, data on weight-at-age in the stock for herring and sprat are available from international hydroacoustic surveys conducted annually in September/October. Both data sets can be used to establish a stock specific weight-at-age database, however, not covering all quarters, which consequently requires modelling of seasonal growth to ensure complete seasonal coverage.

2.2.2 Western Baltic

Cod and sprat stocks:

The database includes data from 1977–2001, updated by ICES (2003/H:03).

Herring stocks:

Herring catch-at-age and weight-at-age data were revised by ICES (2003/H:03) for the period 1991–2002, applying the data provided by the Herring Assessment Working Group for the Area South of 62°N (ICES 2003/ACFM:17). The revision of the database needs allocation of additional effort, especially to conduct a detailed comparison between the “old” and the updated dataset.

2.3 Stomach content information

The stomach content database contains the major part of the information available for the period 1977–1993. Stomach sampling activity has been limited in most recent years, and this data material has not been incorporated into the database so far, but the Study Group initiated the process of compilation. Likewise available information for the period before 1977 has not been included in the database. Backwards extension of the MSVPA to periods before 1974 with the aim to enlarge the time series on stock developments especially for recruitment modelling purposes is in principal possible, as considerable amounts of stomach content data exist for the 1960s and 1970s. However, the limiting factor of such an extension will probably be the insufficient reliability of quarterly catch-at-age and weight-at-age data available.

Maintenance of the database needs limited input from the Danish Fisheries Research Institute presently holding the database.

3 MSVPA key run for 1974–2004 in the Baltic Main Basin

The 4M software package (Vinther *et al.,* 2001) was applied to make a MSVPA "key-run" for cod, sprat and herring in the Central Baltic for the period 1974–2004. This run estimates natural mortality for use in the single species assessment.

3.1 MSVPA set-up

Following basic input data have been used for the MSVPA key-run:

- Catch-at-age and weight-at-age in the catch and in the stock for 1974–2000 as outlined in ICES (2003/H:03), i.e., for herring in Subdivision 25–29 and 32 with Gulf of Riga included. Catch-at-age and weight-at-age in the catch and in the stock for 2002–2004 from the reports of the single species working group (ICES 2002/ACFM:17; ICES 2003/ACFM:23, ICES 2004/ACFM:22 and ICES 2005/ACFM:19).
- quarterly cod stomach content data (1977–93) by Subdivision as revised previously (ICES 1997/J:2), intra-cohort cannibalism of cod was excluded by changing prey age to predator age minus 1 and omitting cod in 0-group cod stomachs,
- maturity ogives for cod in different Subdivisions represent averages over the periods 1980–84 (applied also prior 1980), 1985–89, 1990–94 and annual data for 1995–99 for combined sexes as presented in single species assessment (ICES 1998/ACFM:16; ICES 2000/ACFM:14), and for 2000 to 2004 an average over the years 1997–1999 as utilized by the Assessment WG (ICES 2002/ACFM:17); for herring maturity ogives were used as given in ICES (1998/ACFM:16) being constant over the entire period. For sprat maturity ogives were used as given in ICES (2002/ACFM:17).
- suitability sub-model as introduced in ICES (1992/Assess:7).
- quarterly consumption rates for cod as revised in ICES (2001/H:04), quarterly consumption rates for 2001–2004 according to the same method,
- residual mortalities of 0.2 per year, equally distributed over quarters,
- a constant biomass of other food,
- oldest age-groups in the analyses were: 8+ for cod, 8+ for herring and 7 for sprat.

The terminal F-tuning of MSVPA was performed with the 4M-programme routine developed and implemented iteratively running XSAs and MSVPAs (Vinther, 2001). XSA settings were identical to the ones used in assessment runs by Baltic Fisheries Assessment Working Group (ICES 2005/ACFM:19). Fishing mortalities in the terminal year for the 0-groups (and the 1-group for cod) are not estimated in the XSA tuning and values were given such that the final estimated MSVPA stock numbers for herring and sprat were close to the average values estimated in period 2001–2003. For cod the terminal F were derived by relating the BITS abundance index for age-group 2 to the earlier MSVPA output.

3.2 Results of the key run for 1974–2004

Cod

The main results of the MSVPA key-run for the Central Baltic are given in summary Figures 3.1–3.3 and summary Tables 3.4–3.5. The spawning stock biomass of Eastern Baltic cod derived by the MSVPA run shows a pronounced increase from 1977 to 1980, remaining on a high level during the first half of the 1980s, afterwards declining to a low level in 1992, showing a restricted intermediate increase in the mid 1990s being presently on the historic minimum. An exceptional high fishing mortality in the MSVPA output in 1989 is probably caused by missing records in the catch data set for age-group 7 in the 3rd and 4th quarter of 1990, although in the same cohort in previous and following years catches were recorded. As a result fishing mortality in age-group 6 in the 4th quarter 1989 exceeded 1.5. Natural mortalities of 0-, 1- and 2-group cod (Figure 3.4) are in the same order of magnitude as derived by earlier MSVPA runs. Annual predation mortalities are listed in Table 3.7.

Comparing the old MSVPA key-run (ICES 2003/H:03) with the present one revealed minor deviations between cod biomass and recruitment during the 1990s which are due to the tuning procedure. In comparison to the output of the single species assessment (ICES 2005/ACFM:19), stock biomass and spawning stock biomass are slightly lower in the key-run. The difference is to the largest extent driven by the usage of quarter 1 weight-at-age in the MSVPA as compared to yearly average weights in the single species assessment. Furthermore, the peak of biomass is occurring 4 years later. The slight deviation is probably a consequence of the lack of relative age composition of Polish catches in the input data for the key-run. These data have been used by the single-species WG.

Sprat

The estimated spawning stock biomass of sprat shows a pronounced decline from the mid 1970s to the early 1980s followed by an increase peaking in the end 1990s, declining again afterwards (Figure 3.2). The increase in spawning stock biomass in 2003 and 2004 has also been seen by the single species WG (ICES 2005/ACFM:19), but it is maybe an artefact of the tuning procedures. Predation mortalities of sprat showed a continuous decline from the mid 1970s to early 1990s and remained rather constant afterwards (Figure 3.5 and Table 3.8).

Generally the SSB values of sprat from the new MSVPA run show no discrepancies when compared to the earlier analysis (ICES 2003/H:03).

Herring

Spawning stock biomass estimates of Central Baltic herring derived by the MSVPA key-run show a continuous decline (Figure 3.3), which is to a large extend caused by reduction in weight-at-age. Single–species SSB values are generally lower than the MSVPA derived values, being a result of different age-specific weight input. Recruitment at age 1 derived by the MSVPA shows a high level in the early 1980s and a declining trend afterwards (Figure 3.3). Predation mortalities of herring follow closely the time trend described for sprat. However, a substantial difference between the species is that predation mortalities of adult herring is very low, reaching seldom 0.1 per year (Figure 3.6 and Table 3.9).

Major differences between old and new multispecies assessments for herring were only visible for recruitment and fishing mortality in the latest years, which is a result of the tuning procedure.

The estimates for SSB and biomass do not entirely match the single-species assessment values, however, the tuning with Gulf of Riga included (as opposed to GoR excluded in the single-species assessment) makes a difference, and natural mortality applied in the single species assessment is higher than the actual values from this key-run, contributing to a lower biomass than in the single species assessment.

Natural mortalities

Natural mortalities estimated by MSVPA are routinely used in the single assessment (ICES 2001/ACFM:8). The values estimated by the last iteration of the multispecies tuning are presented in Tables 3.1–3.3.

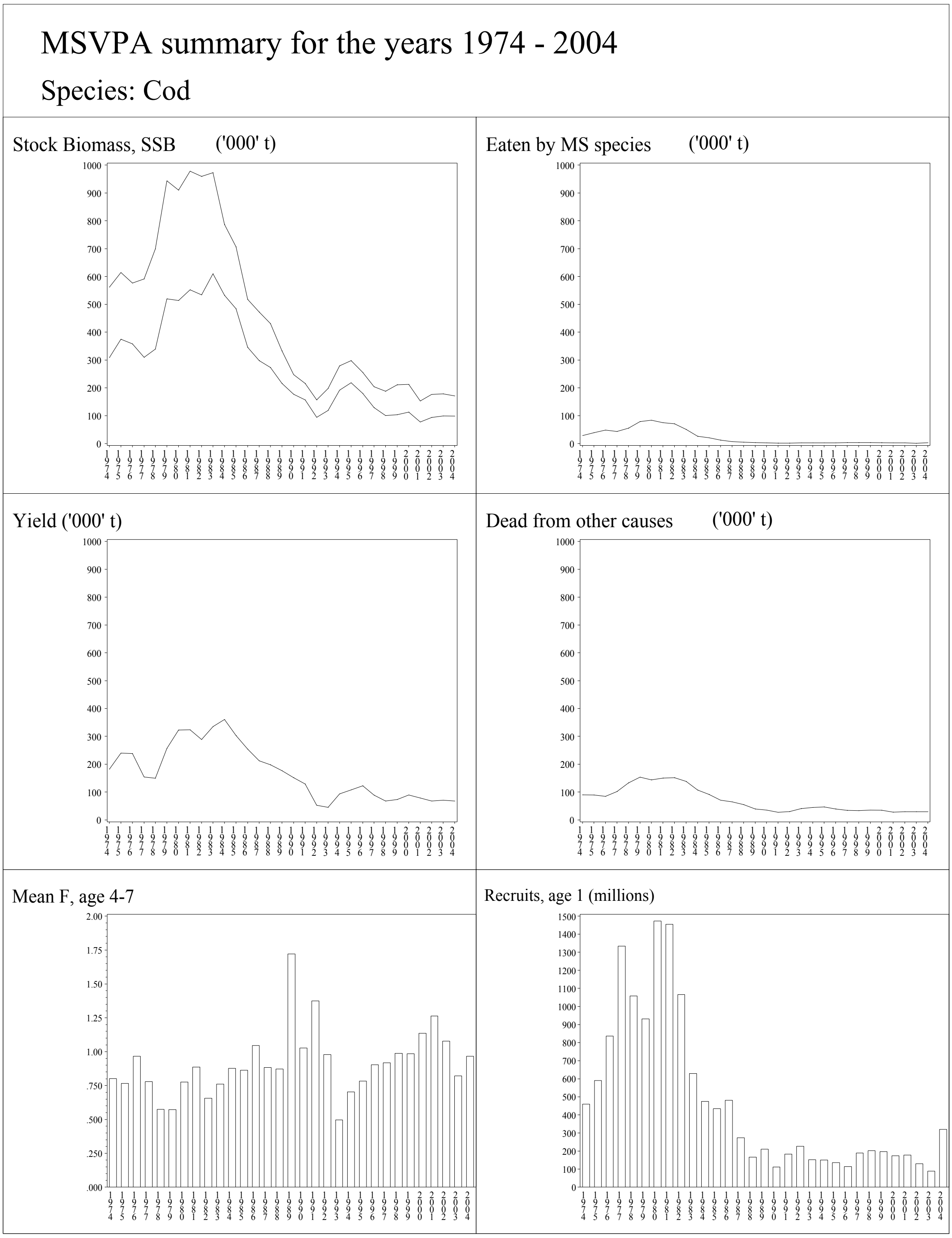


Figure 3.1: Key-run summary for cod.

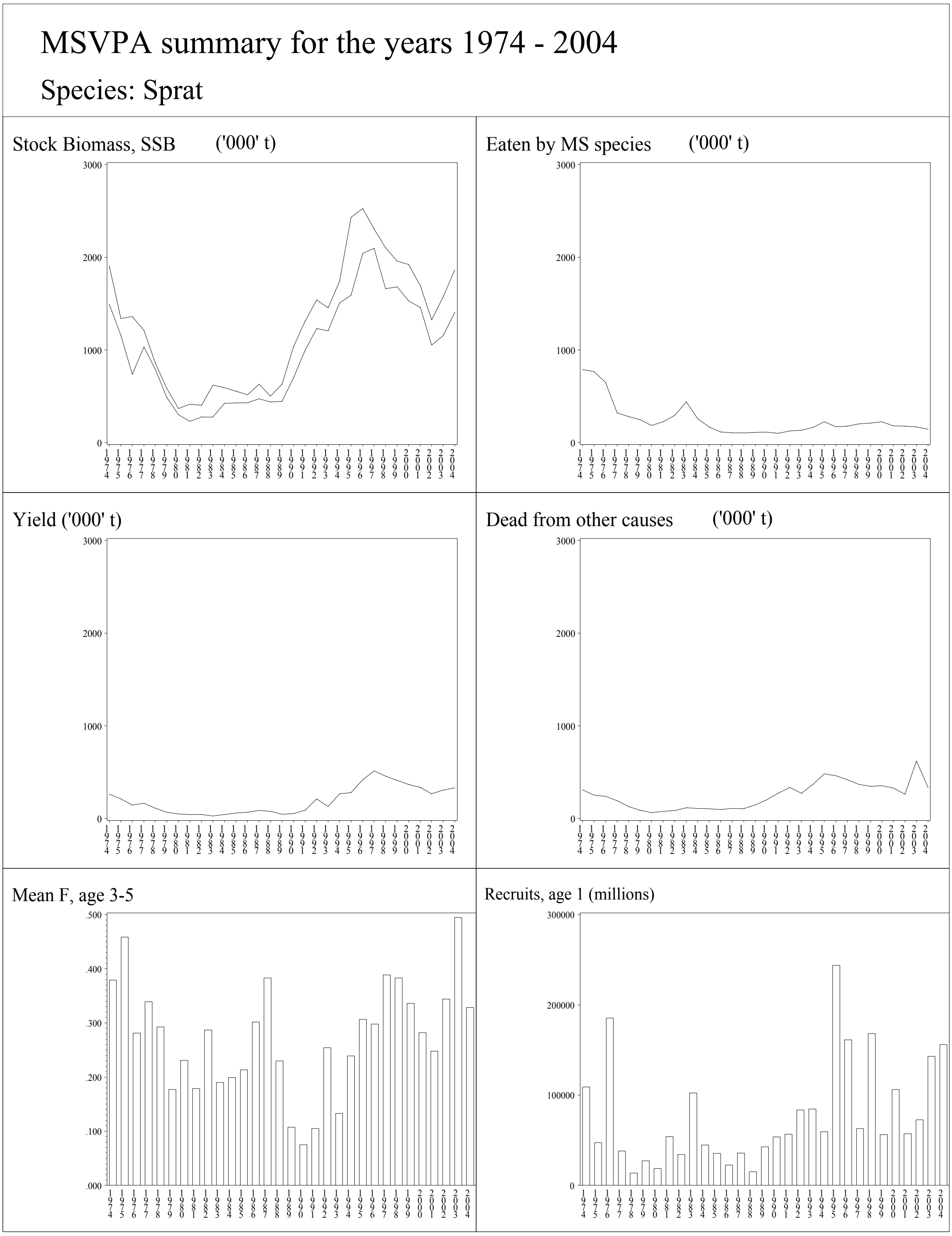


Figure 3.2: Key-run summary for sprat.

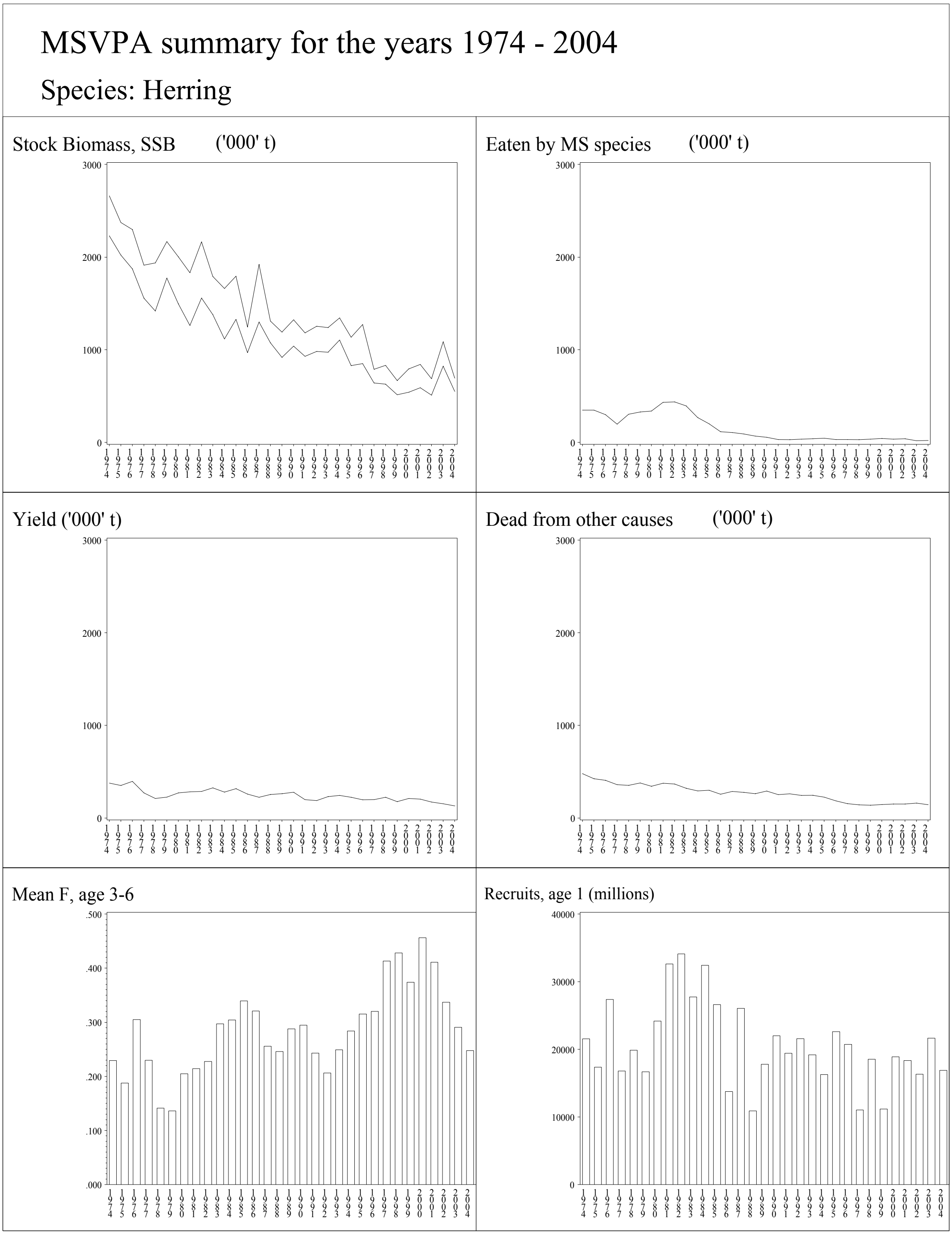


Figure 3.3: Key-run summary for herring.

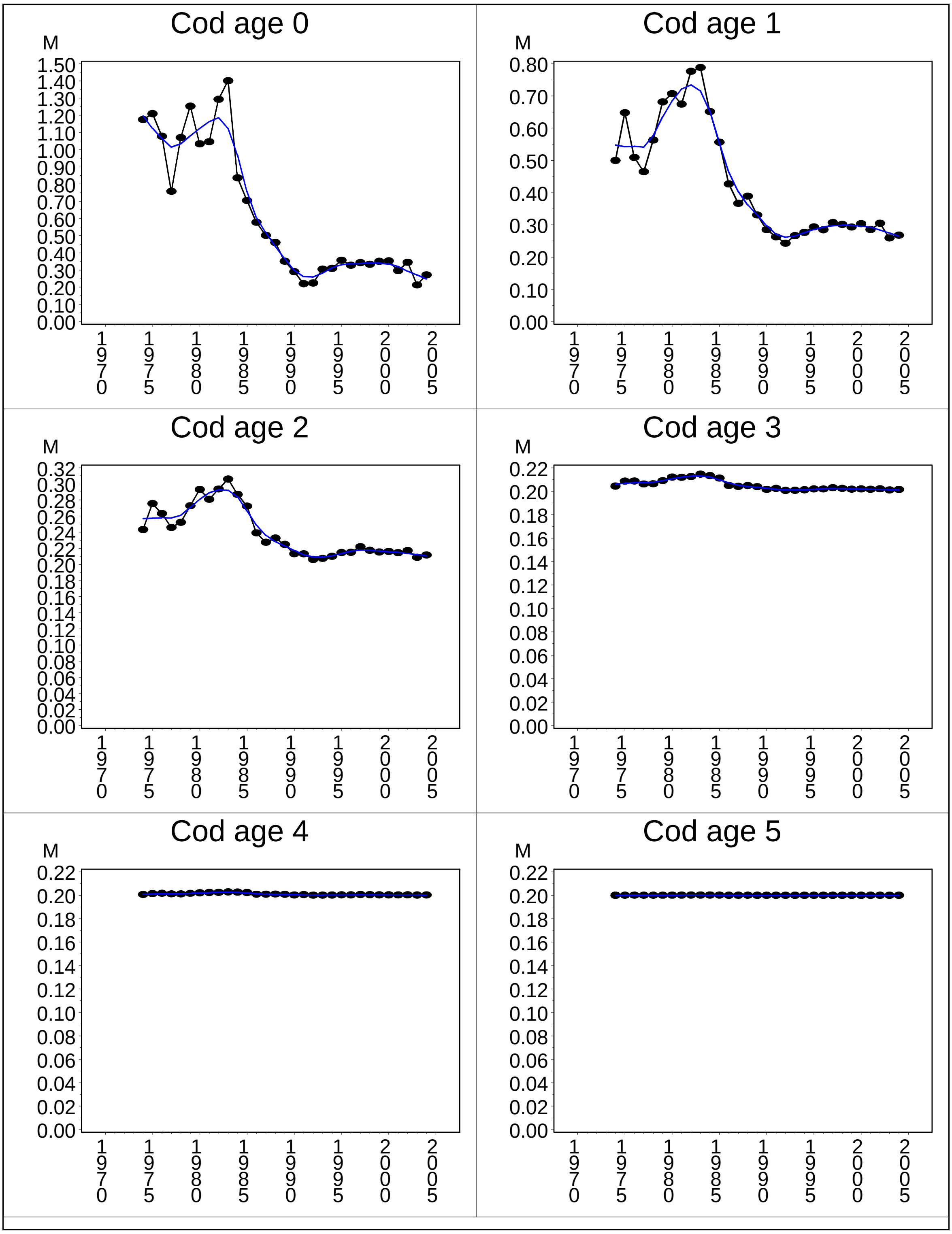


Figure 3.4: Natural mortality for cod. Mortality due to other cause than predation (M1) set to 0.2.

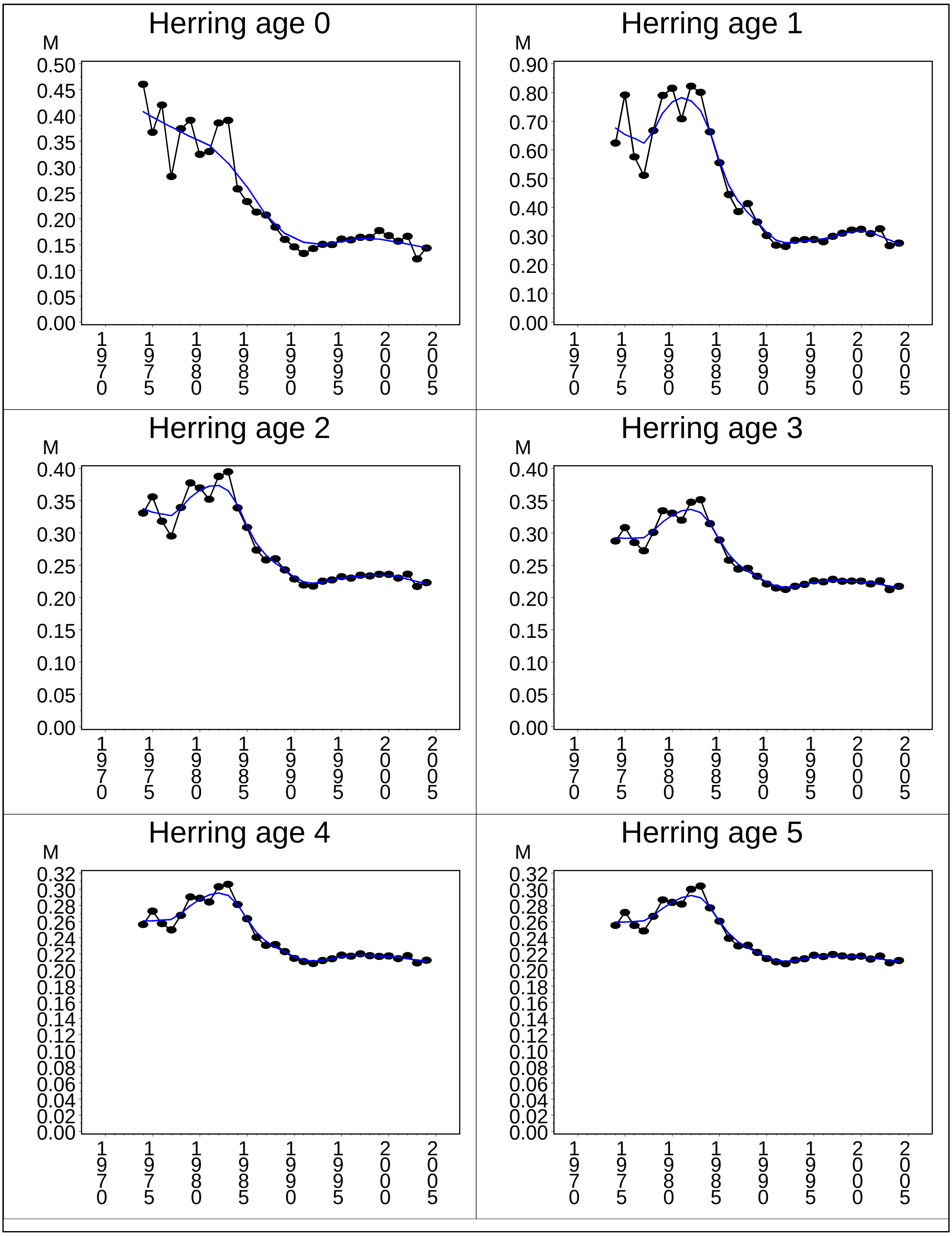


Figure 3.5: Natural mortality for herring. Mortality due to other cause than predation (M1) set to 0.2.

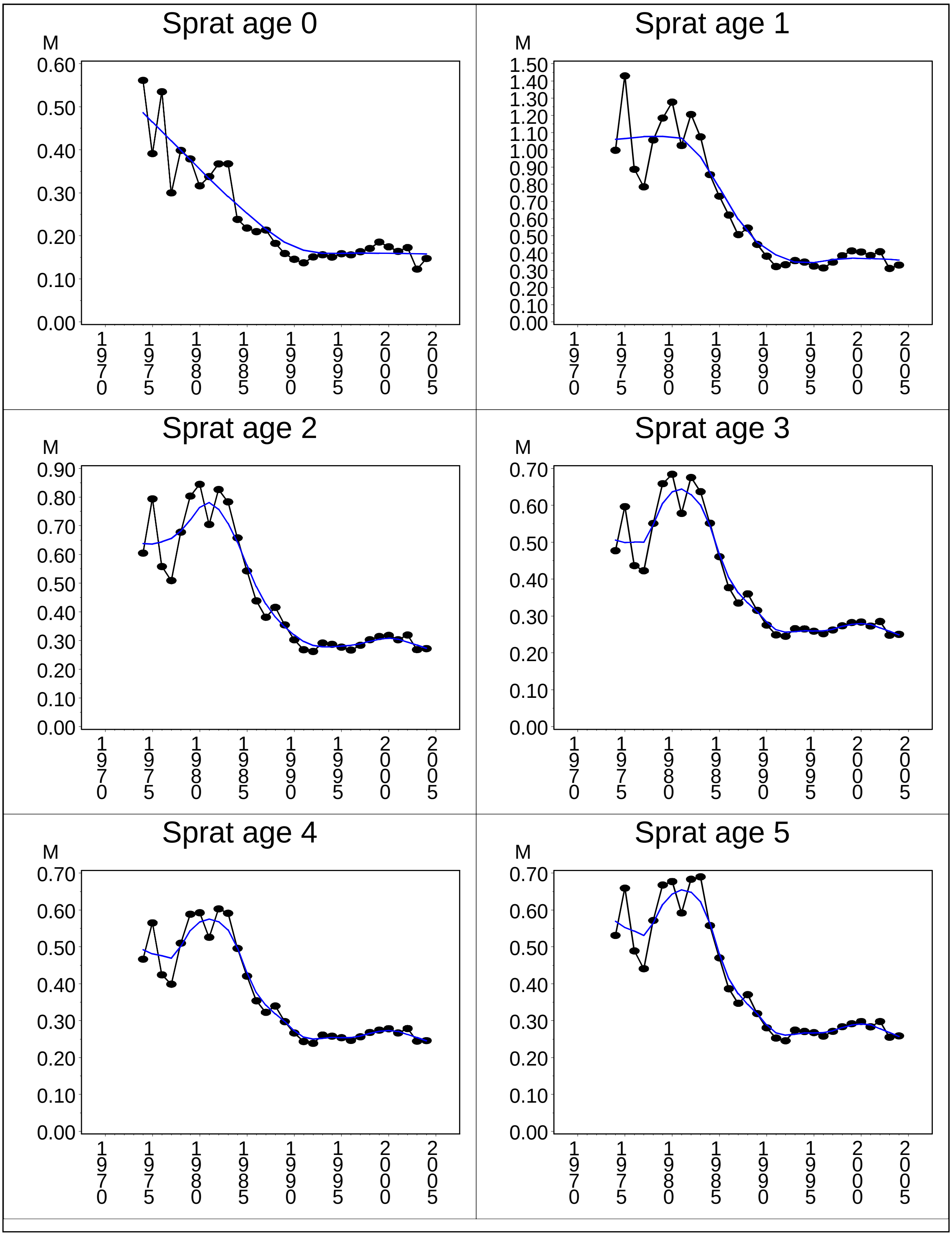


Figure 3.6: Natural mortality for sprat. Mortality due to other cause than predation (M1) set to 0.2.

Table 3.1: Annual natural mortality M (= M1 + M2) for cod.

YEAR	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
1974	0.243382	0.204446	0.200712	0.200047	0.200004	0.200001	0.200000
1975	0.275716	0.208678	0.201471	0.200096	0.200008	0.200002	0.200000
1976	0.263277	0.208787	0.201724	0.200122	0.200009	0.200002	0.200000
1977	0.246000	0.206196	0.201220	0.200083	0.200007	0.200002	0.200000
1978	0.252429	0.206370	0.201184	0.200085	0.200007	0.200002	0.200000
1979	0.272964	0.209070	0.201680	0.200110	0.200011	0.200003	0.200000
1980	0.293146	0.212118	0.202159	0.200131	0.200009	0.200002	0.200000
1981	0.280997	0.211878	0.202394	0.200153	0.200012	0.200002	0.200000
1982	0.293682	0.212560	0.202515	0.200183	0.200015	0.200005	0.200000
1983	0.306122	0.214616	0.202926	0.200218	0.200021	0.200003	0.200000
1984	0.287069	0.213389	0.202740	0.200183	0.200018	0.200005	0.200000
1985	0.272522	0.211256	0.202375	0.200162	0.200015	0.200005	0.200000
1986	0.239272	0.204938	0.200913	0.200063	0.200004	0.200001	0.200000
1987	0.227614	0.204180	0.200922	0.200071	0.200007	0.200002	0.200000
1988	0.232770	0.204897	0.201055	0.200077	0.200008	0.200002	0.200000
1989	0.224917	0.203963	0.200871	0.200065	0.200007	0.200002	0.200000
1990	0.213375	0.201584	0.200279	0.200017	0.200001	0.200001	0.200000
1991	0.213278	0.202478	0.200617	0.200050	0.200006	0.200002	0.200000
1992	0.206337	0.200711	0.200124	0.200008	0.200001	0.200000	0.200000
1993	0.207560	0.200825	0.200151	0.200010	0.200001	0.200000	0.200000
1994	0.210225	0.201257	0.200236	0.200015	0.200001	0.200000	0.200000
1995	0.214899	0.202003	0.200397	0.200027	0.200002	0.200001	0.200000
1996	0.215108	0.201934	0.200374	0.200026	0.200002	0.200000	0.200000
1997	0.222084	0.203099	0.200660	0.200054	0.200006	0.200002	0.200000
1998	0.217635	0.202507	0.200537	0.200042	0.200005	0.200002	0.200000
1999	0.215445	0.201791	0.200348	0.200026	0.200003	0.200001	0.200000
2000	0.216222	0.201956	0.200371	0.200027	0.200003	0.200001	0.200000
2001	0.214655	0.201703	0.200308	0.200021	0.200002	0.200001	0.200000
2002	0.217293	0.202089	0.200387	0.200027	0.200003	0.200001	0.200000
2003	0.208896	0.201121	0.200221	0.200016	0.200002	0.200001	0.200000
2004	0.211820	0.201534	0.200293	0.200022	0.200002	0.200001	0.200000

Table 3.2: Annual natural mortality M (= M1 + M2) for sprat.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
1974	0.997253	0.604868	0.477076	0.466663	0.531064	0.493082	0.587286	0.587286
1975	1.429538	0.794201	0.596511	0.565126	0.659215	0.627959	0.766979	0.766979
1976	0.886882	0.558067	0.436550	0.424272	0.488990	0.473493	0.572424	0.572424
1977	0.784788	0.509288	0.422493	0.398895	0.440848	0.436309	0.529247	0.529247
1978	1.057025	0.678050	0.550971	0.510158	0.571612	0.555568	0.680182	0.680182
1979	1.184708	0.803584	0.658766	0.588608	0.667725	0.675705	0.842699	0.842699
1980	1.277183	0.844818	0.684439	0.592748	0.677277	0.722414	0.905180	0.905180
1981	1.025413	0.704966	0.578487	0.526060	0.591933	0.606312	0.759146	0.759146
1982	1.205712	0.826733	0.675502	0.603211	0.683382	0.699089	0.883475	0.883475
1983	1.075386	0.783400	0.637059	0.591248	0.689803	0.687374	0.866458	0.866458
1984	0.855799	0.658111	0.551542	0.496113	0.557694	0.594144	0.739610	0.739610
1985	0.730402	0.542933	0.460786	0.420831	0.470152	0.497766	0.610783	0.610783
1986	0.620712	0.438308	0.376791	0.353847	0.386552	0.390404	0.463906	0.463906
1987	0.507064	0.381345	0.335026	0.322419	0.347145	0.341712	0.394762	0.394762
1988	0.545072	0.415918	0.359962	0.339711	0.370615	0.370640	0.426972	0.426972
1989	0.450365	0.354588	0.315146	0.297488	0.319257	0.324568	0.367888	0.367888
1990	0.382110	0.302793	0.275384	0.266543	0.280655	0.278595	0.305889	0.305889
1991	0.321827	0.267882	0.248733	0.243434	0.252797	0.253870	0.272950	0.272950
1992	0.332632	0.262107	0.244896	0.238583	0.245487	0.245797	0.260860	0.260860
1993	0.356346	0.291364	0.265459	0.260894	0.274145	0.262602	0.284272	0.284272
1004	0.347777	0.286889	0.264828	0.257912	0.270758	0.265963	0.289475	0.289475
1995	0.324467	0.277025	0.258604	0.253774	0.267565	0.265964	0.292595	0.292595
1996	0.313603	0.266810	0.251925	0.246346	0.258060	0.260805	0.285805	0.285805
1997	0.347214	0.283655	0.262040	0.256221	0.270964	0.276518	0.305697	0.305697
1998	0.384674	0.303168	0.273335	0.268000	0.283621	0.281666	0.309290	0.309290
1999	0.412824	0.313976	0.282255	0.274343	0.291605	0.290283	0.318173	0.318173
2000	0.406502	0.318173	0.283589	0.278288	0.297726	0.291449	0.319286	0.319286
2001	0.386116	0.303054	0.272675	0.266716	0.283377	0.281344	0.305129	0.305129
2002	0.408209	0.319416	0.285015	0.278692	0.297752	0.293867	0.322770	0.322770
2003	0.311222	0.268243	0.247971	0.244572	0.255083	0.250313	0.265678	0.265678
2004	0.330533	0.272016	0.250261	0.245882	0.258698	0.257314	0.276701	0.276701

Table 3.3: Annual natural mortality M (= M1 + M2) for herring.

YEAR	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8
1974	0.623873	0.331036	0.287647	0.256435	0.255316	0.238366	0.233248	0.210206
1975	0.791239	0.356053	0.308369	0.272952	0.271282	0.248688	0.242076	0.212815
1976	0.575498	0.318247	0.285358	0.257618	0.255186	0.238637	0.232636	0.209860
1977	0.511237	0.295402	0.272478	0.249766	0.248382	0.234701	0.228476	0.208603
1978	0.667133	0.339655	0.300989	0.267698	0.266483	0.247149	0.239346	0.212005
1979	0.789753	0.377644	0.334577	0.290609	0.287002	0.262034	0.250789	0.215266
1980	0.814906	0.369984	0.330852	0.288995	0.283834	0.259440	0.248421	0.214413
1981	0.708244	0.352358	0.319869	0.284247	0.281691	0.257007	0.246343	0.213939
1982	0.821805	0.387688	0.347679	0.303189	0.300059	0.272183	0.258304	0.217578
1983	0.800221	0.394828	0.351762	0.306250	0.304084	0.273793	0.261350	0.218587
1984	0.662912	0.339035	0.314501	0.281183	0.277015	0.254680	0.243183	0.212754
1985	0.555193	0.308688	0.289261	0.263498	0.260480	0.243195	0.234531	0.210259
1986	0.444283	0.273668	0.257957	0.240526	0.239363	0.228365	0.223204	0.206993
1987	0.385012	0.258406	0.244250	0.230548	0.229964	0.221339	0.217498	0.205302
1988	0.412518	0.260137	0.245351	0.231559	0.230591	0.221261	0.217414	0.205239
1989	0.348738	0.242851	0.232979	0.222821	0.221807	0.215368	0.212477	0.203722
1990	0.301707	0.228848	0.221109	0.214412	0.214173	0.209897	0.208366	0.202554
1991	0.267704	0.219422	0.214846	0.210474	0.210075	0.207169	0.205783	0.201728
1992	0.263563	0.217812	0.212558	0.208131	0.207720	0.205560	0.204628	0.201398
1993	0.284817	0.225461	0.217477	0.211806	0.212203	0.208264	0.207251	0.202268
1004	0.287227	0.227454	0.220392	0.213991	0.213942	0.209638	0.208227	0.202529
1995	0.287450	0.232419	0.226016	0.218442	0.218316	0.212958	0.210927	0.203346
1996	0.279832	0.230145	0.224432	0.217118	0.216664	0.212214	0.210089	0.203064
1997	0.298907	0.234657	0.228272	0.220068	0.219304	0.214535	0.211763	0.203531
1998	0.309530	0.233557	0.225315	0.217763	0.217420	0.212475	0.210301	0.203134
1999	0.320812	0.236163	0.225681	0.216871	0.216135	0.211607	0.209734	0.202942
2000	0.323142	0.236045	0.225551	0.217377	0.217152	0.211773	0.210118	0.203098
2001	0.308025	0.230270	0.221174	0.214106	0.213579	0.209403	0.208025	0.202433
2002	0.324934	0.236357	0.226026	0.217702	0.217342	0.212039	0.210250	0.203126
2003	0.266238	0.217414	0.212397	0.208784	0.208890	0.205930	0.205099	0.201573
2004	0.275118	0.223169	0.217477	0.212148	0.211838	0.208258	0.206993	0.202124

Table 3.4: MSVPA summary sheet for cod.

Species Cod

Year	Mean F Ages 4 to 7	Recruits Age 0 ('000')	Yield ('000' t)	Stock Biomass ('000' t)	Spawning Stock Biomass ('000' t)	Eaten by MS species ('000' t)	Dead by other causes ('000' t)
1974	0.801	1913970	182	561	308	28	90
1975	0.766	2804652	239	614	374	39	89
1976	0.967	3921216	238	576	358	48	84
1977	0.778	2258694	153	591	309	43	101
1978	0.574	2716732	149	699	339	55	133
1979	0.573	5160265	256	943	519	78	153
1980	0.775	4093114	322	910	513	84	143
1981	0.887	3033359	323	978	552	75	149
1982	0.656	2293878	288	959	533	71	151
1983	0.761	1926454	335	973	609	50	138
1984	0.877	1002577	360	786	532	26	107
1985	0.863	972816	303	706	484	20	91
1986	1.045	488331	253	517	345	12	70
1987	0.884	273862	211	472	298	6	64
1988	0.872	333454	197	430	273	5	55
1989	1.722	158196	176	332	215	3	39
1990	1.027	244258	151	247	176	2	35
1991	1.375	282366	129	215	156	1	27
1992	0.978	190278	52	156	94	1	29
1993	0.496	204174	44	197	118	1	40
1994	0.703	184389	93	279	191	2	44
1995	0.783	162721	107	297	218	2	46
1996	0.903	263356	121	255	180	2	38
1997	0.918	284541	88	204	129	3	33
1998	0.988	274727	67	187	100	3	33
1999	0.985	246630	72	211	103	3	35
2000	1.134	252405	89	212	112	3	35
2001	1.263	173762	78	152	77	2	27
2002	1.077	125175	67	176	93	2	29
2003	0.821	396217	71	178	99	1	29
2004	0.967	289987	67	170	98	2	29
Avg.	0.910	1191179	170	457	274	22	70

Table 3.5: MSVPA summary sheet for sprat.

Species Sprat

Year	Mean F Ages 3 to 5	Recruits Age 0 ('000')	Yield ('000' t)	Stock Biomass ('000' t)	Spawning Stock Biomass ('000' t)	Eaten by MS species ('000' t)	Dead by other causes ('000' t)
1974	0.379	83119430	263	1907	1491	789	308
1975	0.459	274177800	212	1340	1157	765	251
1976	0.281	65481130	144	1360	738	648	240
1977	0.339	18459410	166	1210	1033	322	192
1978	0.292	40663400	112	860	792	282	129
1979	0.177	27413060	66	584	490	249	90
1980	0.231	74337370	48	368	301	185	62
1981	0.179	47875730	43	414	230	225	76
1982	0.287	148130600	42	403	277	292	85
1983	0.190	64518150	26	620	274	440	117
1984	0.199	44850010	42	594	425	258	108
1985	0.213	27947670	58	556	427	170	103
1986	0.302	44129320	66	517	431	114	98
1987	0.383	18745800	87	631	473	108	107
1988	0.230	51560990	76	503	438	104	106
1989	0.107	63073330	46	631	447	110	147
1990	0.075	65455760	53	1036	700	113	201
1991	0.105	96681110	89	1310	996	99	274
1992	0.254	98515200	209	1541	1230	127	335
1993	0.133	69380440	132	1453	1207	133	273
1994	0.239	283798000	265	1738	1505	163	368
1995	0.307	189489300	279	2431	1592	225	480
1996	0.298	73491850	418	2526	2042	171	459
1997	0.389	199504500	513	2306	2095	179	418
1998	0.383	66701960	456	2100	1661	203	369
1999	0.336	129689800	412	1959	1680	211	346
2000	0.282	68499160	366	1921	1527	225	353
2001	0.248	86167840	336	1691	1457	179	329
2002	0.344	172434800	266	1324	1052	177	261
2003	0.495	176219900	307	1573	1155	170	622
2004	0.328	49999990	331	1861	1405	145	335
Avg.	0.273	94210090	191	1267	991	245	247

Table 3.6: MSVPA summary sheet for herring.

Species Herring

Year	Mean F Ages 3 to 6	Recruits Age 0 ('000')	Yield ('000' t)	Stock Biomass ('000' t)	Spawning Stock Biomass ('000' t)	Eaten by MS species ('000' t)	Dead by other causes ('000' t)
1974	0.229	27538020	377	2660	2228	347	479
1975	0.188	39650680	350	2373	2021	349	423
1976	0.305	25595970	394	2297	1872	300	408
1977	0.230	26355120	270	1912	1556	196	359
1978	0.141	24354210	210	1936	1417	304	351
1979	0.136	35779320	226	2166	1773	329	379
1980	0.205	45350530	269	2004	1494	338	341
1981	0.214	47633370	282	1830	1262	433	373
1982	0.228	40950110	287	2164	1558	435	366
1983	0.297	48256070	326	1791	1378	393	321
1984	0.304	34659790	281	1662	1116	268	292
1985	0.339	17451410	317	1794	1326	202	298
1986	0.321	32375450	257	1246	969	114	256
1987	0.256	13430380	222	1921	1298	108	286
1988	0.246	21471340	252	1309	1076	89	276
1989	0.288	25936030	262	1190	917	67	261
1990	0.295	22494740	279	1324	1038	55	290
1991	0.243	24754860	197	1182	927	32	252
1992	0.206	22295570	188	1253	980	29	259
1993	0.249	19028960	231	1239	974	36	243
1994	0.284	26459370	242	1344	1104	38	245
1995	0.315	24418330	222	1134	830	46	225
1996	0.320	13007520	195	1271	849	31	184
1997	0.413	22030530	198	789	641	31	155
1998	0.428	13269990	222	832	630	29	140
1999	0.374	22827930	175	668	515	35	136
2000	0.456	21911650	210	792	540	41	145
2001	0.411	19409150	204	841	589	36	150
2002	0.337	26112500	172	685	509	40	150
2003	0.291	19339000	154	1085	822	18	160
2004	0.248	20000130	130	693	551	20	143
Avg.	0.284	26585420	245	1464	1121	154	269

Table 3.7: MSVPA predation mortalities (M2) for cod by age-group and year.

Species Cod - Predation mortality (M2)

Age	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	1.0758	1.1100	0.9785	0.6582	0.9713	1.1536	0.9346	0.9466	1.1938	1.3013	0.7365	0.6052
1	0.3000	0.4483	0.3093	0.2653	0.3635	0.4817	0.5074	0.4750	0.5768	0.5885	0.4518	0.3567
2	0.0434	0.0757	0.0633	0.0460	0.0524	0.0730	0.0931	0.0810	0.0937	0.1061	0.0871	0.0725
3	0.0044	0.0087	0.0088	0.0062	0.0064	0.0091	0.0121	0.0119	0.0126	0.0146	0.0134	0.0113
4	0.0007	0.0015	0.0017	0.0012	0.0012	0.0017	0.0022	0.0024	0.0025	0.0029	0.0027	0.0024
5	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0	0.4779	0.4016	0.3599	0.2514	0.1903	0.1206	0.1245	0.2051	0.2093	0.2569	0.2278	0.2430
1	0.2272	0.1670	0.1894	0.1308	0.0855	0.0630	0.0432	0.0668	0.0770	0.0939	0.0851	0.1073
2	0.0393	0.0276	0.0328	0.0249	0.0134	0.0133	0.0063	0.0076	0.0102	0.0149	0.0151	0.0221
3	0.0049	0.0042	0.0049	0.0040	0.0016	0.0025	0.0007	0.0008	0.0013	0.0020	0.0019	0.0031
4	0.0009	0.0009	0.0011	0.0009	0.0003	0.0006	0.0001	0.0002	0.0002	0.0004	0.0004	0.0007
5	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Age	1998	1999	2000	2001	2002	2003	2004
0	0.2332	0.2506	0.2532	0.1965	0.2450	0.1134	0.1717
1	0.1018	0.0934	0.1039	0.0857	0.1052	0.0597	0.0682
2	0.0176	0.0154	0.0162	0.0147	0.0173	0.0089	0.0118
3	0.0025	0.0018	0.0020	0.0017	0.0021	0.0011	0.0015
4	0.0005	0.0003	0.0004	0.0003	0.0004	0.0002	0.0003
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 3.8: MSVPA predation mortalities (M2) for sprat by age-group and year.

Species Sprat - Predation mortality (M2)

Age	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.4613	0.2911	0.4349	0.2000	0.2986	0.2788	0.2164	0.2378	0.2675	0.2676	0.1383	0.1181
1	0.7972	1.2296	0.6869	0.5848	0.8570	0.9846	1.0770	0.8253	1.0056	0.8754	0.6557	0.5303
2	0.4048	0.5941	0.3580	0.3092	0.4779	0.6034	0.6446	0.5048	0.6265	0.5833	0.4580	0.3428
3	0.2770	0.3964	0.2365	0.2225	0.3509	0.4586	0.4843	0.3784	0.4754	0.4370	0.3514	0.2607
4	0.2666	0.3651	0.2243	0.1989	0.3101	0.3885	0.3926	0.3260	0.4031	0.3912	0.2961	0.2208
5	0.3311	0.4592	0.2890	0.2409	0.3716	0.4677	0.4772	0.3919	0.4834	0.4898	0.3577	0.2701
6	0.2932	0.4281	0.2736	0.2364	0.3557	0.4759	0.5225	0.4064	0.4992	0.4875	0.3943	0.2978
7	0.3873	0.5671	0.3725	0.3293	0.4802	0.6428	0.7053	0.5592	0.6835	0.6666	0.5397	0.4108

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0	0.1098	0.1136	0.0826	0.0590	0.0456	0.0373	0.0511	0.0561	0.0507	0.0585	0.0558	0.0633
1	0.4207	0.3070	0.3450	0.2503	0.1821	0.1218	0.1326	0.1563	0.1478	0.1245	0.1136	0.1472
2	0.2382	0.1813	0.2159	0.1545	0.1028	0.0679	0.0621	0.0913	0.0869	0.0770	0.0668	0.0836
3	0.1767	0.1350	0.1599	0.1151	0.0754	0.0487	0.0449	0.0654	0.0648	0.0586	0.0519	0.0620
4	0.1538	0.1224	0.1397	0.0975	0.0665	0.0434	0.0386	0.0609	0.0579	0.0538	0.0463	0.0562
5	0.1866	0.1471	0.1706	0.1193	0.0807	0.0528	0.0455	0.0742	0.0708	0.0676	0.0581	0.0710
6	0.1905	0.1418	0.1707	0.1246	0.0786	0.0539	0.0458	0.0626	0.0660	0.0660	0.0608	0.0765
7	0.2639	0.1948	0.2270	0.1679	0.1059	0.0730	0.0609	0.0843	0.0895	0.0926	0.0858	0.1057

Age	1998	1999	2000	2001	2002	2003	2004
0	0.0707	0.0856	0.0746	0.0640	0.0728	0.0227	0.0475
1	0.1847	0.2128	0.2065	0.1861	0.2082	0.1112	0.1305
2	0.1031	0.1140	0.1181	0.1030	0.1194	0.0682	0.0720
3	0.0733	0.0822	0.0836	0.0727	0.0850	0.0480	0.0503
4	0.0680	0.0743	0.0783	0.0667	0.0787	0.0446	0.0459
5	0.0836	0.0916	0.0977	0.0834	0.0978	0.0551	0.0587
6	0.0817	0.0903	0.0915	0.0814	0.0939	0.0503	0.0573
7	0.1093	0.1182	0.1193	0.1051	0.1228	0.0657	0.0767

Table 3.9: MSVPA predation mortalities (M2) for herring by age-group and year.

Species Herring - Predation mortality (M2)

Age	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
0	0.3605	0.2675	0.3202	0.1820	0.2743	0.2908	0.2247	0.2301	0.2856	0.2905	0.1579	0.1333
1	0.4240	0.5914	0.3756	0.3113	0.4673	0.5899	0.6150	0.5084	0.6220	0.6004	0.4630	0.3553
2	0.1311	0.1561	0.1183	0.0954	0.1397	0.1777	0.1700	0.1524	0.1877	0.1949	0.1391	0.1087
3	0.0877	0.1084	0.0854	0.0725	0.1010	0.1346	0.1309	0.1199	0.1477	0.1518	0.1145	0.0893
4	0.0564	0.0730	0.0576	0.0498	0.0677	0.0906	0.0890	0.0842	0.1032	0.1063	0.0812	0.0635
5	0.0553	0.0713	0.0552	0.0484	0.0665	0.0870	0.0838	0.0817	0.1001	0.1041	0.0770	0.0605
6	0.0384	0.0487	0.0386	0.0347	0.0471	0.0620	0.0594	0.0570	0.0722	0.0738	0.0547	0.0432
7	0.0332	0.0421	0.0326	0.0285	0.0393	0.0508	0.0484	0.0463	0.0583	0.0613	0.0432	0.0345
8	0.0102	0.0128	0.0099	0.0086	0.0120	0.0153	0.0144	0.0139	0.0176	0.0186	0.0128	0.0103

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0	0.1129	0.1073	0.0838	0.0599	0.0455	0.0328	0.0423	0.0504	0.0499	0.0606	0.0591	0.0642
1	0.2444	0.1851	0.2126	0.1488	0.1017	0.0677	0.0636	0.0848	0.0873	0.0875	0.0799	0.0989
2	0.0737	0.0584	0.0602	0.0429	0.0289	0.0194	0.0178	0.0255	0.0275	0.0324	0.0302	0.0347
3	0.0580	0.0443	0.0454	0.0330	0.0211	0.0148	0.0126	0.0175	0.0204	0.0260	0.0244	0.0283
4	0.0405	0.0305	0.0316	0.0228	0.0144	0.0105	0.0081	0.0118	0.0140	0.0184	0.0171	0.0201
5	0.0394	0.0300	0.0306	0.0218	0.0142	0.0101	0.0077	0.0122	0.0139	0.0183	0.0167	0.0193
6	0.0284	0.0213	0.0213	0.0154	0.0099	0.0072	0.0056	0.0083	0.0096	0.0130	0.0122	0.0145
7	0.0232	0.0175	0.0174	0.0125	0.0084	0.0058	0.0046	0.0072	0.0082	0.0109	0.0101	0.0118
8	0.0070	0.0053	0.0052	0.0037	0.0026	0.0017	0.0014	0.0023	0.0025	0.0033	0.0031	0.0035

Age	1998	1999	2000	2001	2002	2003	2004
0	0.0639	0.0771	0.0673	0.0566	0.0660	0.0222	0.0432
1	0.1096	0.1209	0.1232	0.1081	0.1250	0.0663	0.0751
2	0.0336	0.0362	0.0361	0.0303	0.0364	0.0174	0.0232
3	0.0253	0.0257	0.0256	0.0212	0.0260	0.0124	0.0175
4	0.0178	0.0169	0.0174	0.0141	0.0177	0.0088	0.0121
5	0.0174	0.0161	0.0172	0.0136	0.0173	0.0089	0.0118
6	0.0125	0.0116	0.0118	0.0094	0.0120	0.0059	0.0083
7	0.0103	0.0097	0.0101	0.0080	0.0102	0.0051	0.0070
8	0.0031	0.0029	0.0031	0.0024	0.0031	0.0016	0.0021

4 Updated area dis-aggregated MSVPA for 1974–2003

Introduction

This chapter gives a short overview about the inter-sessional work performed by Teschner (2005) and includes besides an updated area dis-aggregated MSVPA for the Subdivisions 25, 26 and 28, an assessment of an alternative consumption model considering oxygen limitation on stomach evacuation. In- and Output data are stored at the IFM-GEOMAR, please contact Eske Teschner (eteschner@ifm-geomar.de), Gerd Kraus (gkraus@ifm-geomar.de) or Rudi Voss (rvoss@ifm-geomar.de) for further information.

Background

In the Baltic Sea the spatial and temporal suitability of the spawning habitats of cod (*Gadus morhua*) vary dramatically with the oxygen conditions at the depth of incubation of the eggs (e.g., Wieland *et al.,* 1994). As a consequence, the population dynamics of cod exhibit distinct trends in different areas of the Central Baltic (Sparholt and Tomkiewicz 2000), with a corresponding variation in predation pressure on its major prey species, sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) (Sparholt 1994). In turn the population development of these planktivores determines the predation intensity on early life stages of cod (Köster and Möllmann 2000). Hence in order to develop sustainable management strategies for the Central Baltic stocks, assessments and stock projections should resolve and incorporate the effects of environmental variability and species interactions on reproductive success, in particular the potential for different spawning localities to contribute to recruitment success. At present MSVPAs are run for two areas in the Baltic, a Western and Central Baltic component to match the stock units used in the regular stock assessments, with the Central Baltic component dominating in terms of biomass and abundance (ICES 1998/ACFM:16). Within these two regions, the abundance and biological characteristics of the three species are heterogeneous both spatially (between subdivisions) and temporally (inter and intra annually). For example, population sizes of Central Baltic cod, as resolved by international bottom trawl (Sparholt and Tomkiewicz 2000) and ichthyoplankton surveys (Köster *et al.,* 2001a), have revealed distinct distributional trends. Furthermore, for cod substantial differences in weight-at-age and maturity ogives have been reported for different subdivisions (ICES 1997/Assess:12, Tomkiewicz *et al.,* 1997). The abundance and characteristics of herring and sprat have also been observed to vary spatially and temporally in the different subdivisions of the Central Baltic (e.g., Ojaveer 1989). The herring stock in the Central Baltic is comprised of a number of different spawning components exhibiting variations in spawning period and growth rates as well as meristic, morphometric and otolith characteristics (e.g., Parmanne *et al.,* 1994). For sprat the existence of distinct populations is controversial as deviations in growth rates observed between subareas have been explained by immigration from the western Baltic and by migration between different basins (Parmanne *et al.,* 1994). However, other authors state that sprat in the eastern Central Baltic form local populations (Ojaveer 1989), which can be separated, primarily by otolith characteristics (Aps 1981).

4.1 MSVPA-setup

4.1.1 Reduced ambient oxygen conditions

The consumption model used so far in the MSVPA does not account for a potential effect of reduced ambient oxygen conditions on stomach evacuation rates. For the area-disaggregated MSVPA runs, an alternative conceptual model was developed, which should account for a slower stomach evacuation rate under reduced oxygen concentrations, as indicated by a laboratory experiment (Brach 1999). Exponential decay functions were fitted to the experimental data (Figure 4.1.1.1) and from these functions the stomach evacuation rates per hour were calculated for different oxygen conditions.

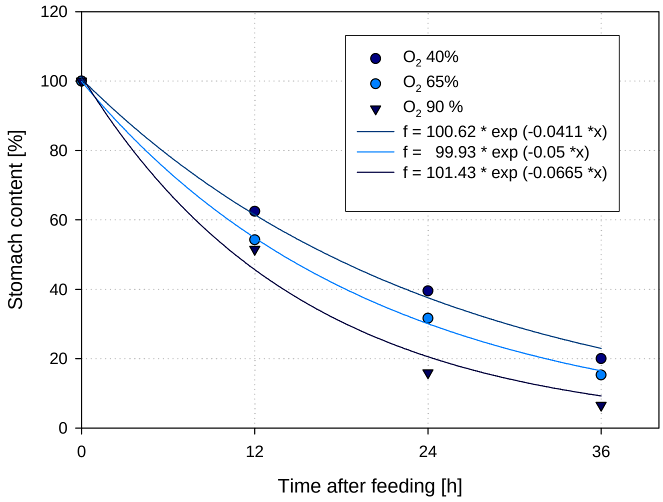


Figure 4.1.1.1: Oxygen-dependant stomach evacuation. Fitted exponential functions to the results of Brach (1999).

After assuming a negative linear relationship between evacuation rates and reduction in ambient oxygen concentration, the function was scaled to give an intercept of 1, i.e., assuming no influence on the evacuation rate at 100% oxygen saturation (Figure 4.1.1.2).

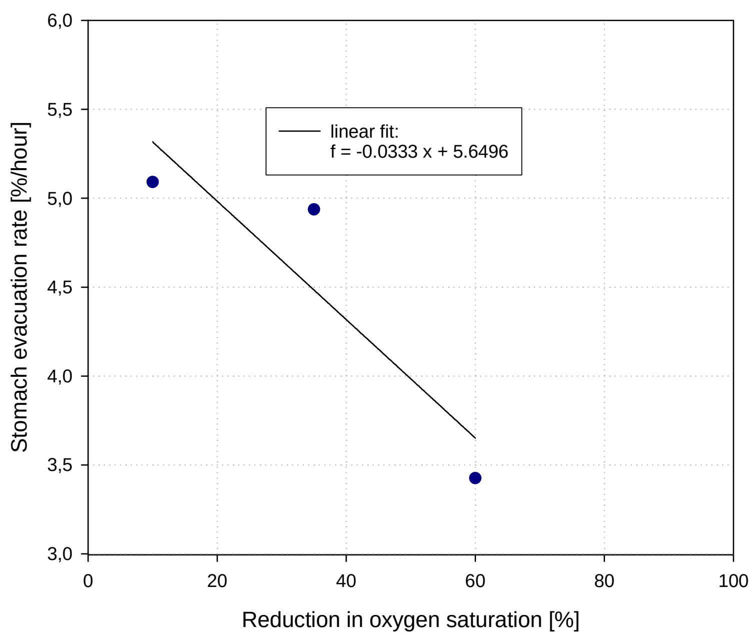


Figure 4.1.12: Stomach evacuation rate in relation to ambient oxygen saturation (expressed as % reduction from full saturation)

Resulting linear function was y = 1 + (-0.0059 x).

This function was incorporated as a multiplicative term in the new, oxygen-sensitive conceptual consumption model:

$K_q = R' * (\mathbf{(1+ (a*S_a)) *} W^C * e^{A*T} * S^B * 24 * k * 91$

With S_a = Reduction in ambient oxygen concentration in % and

a = -0.0059

4.1.2 Alternative distribution patterns of adult cod

Ambient temperatures and oxygen concentrations

Ambient temperatures, as needed for input in the consumption model, were calculated based on the ICES hydrographic database. For the period 1976–2003 quarterly mean temperatures were calculated for each subdivision (25, 26 and 28). In a first step mean temperatures were calculated for depth strata (0–20m, 21–40m, 41–60m, 61–80m und >80 m) and afterwards weighted ambient temperatures were obtained by accounting for the distribution of cod over depth strata. The relative depth-specific distribution of cod was determined for 3 different groups independently (i) cod age-class 1, (ii) cod age-class 2 and (iii) cod age 3+. In the standard MSVPA setup the distribution patterns are derived from an analysis of the Baltic International Trawl Survey (BITS) database which is based on catches of the 1st quarter.

The derived distribution is then kept constant for the rest of the year (**standard method (S))**.

We investigated additionally two alternative distribution patterns for the spawning stock (age-class 3+):

Alternative 1 (A1) accounts for changes in the distribution pattern during spawning time. Available distribution data of the 2nd quarter from the BITS database were used for the 2nd and 3rd quarters. Missing data were substituted by mean values. 4th quarter distributions were assumed to equal the 1st quarter distribution of the next year.

For **Alternative 2 (A2)** the time-series is divided in two parts to account for a delay in the peak spawning time since the late 80ies:

1977–1989: In the 2nd quarter ambient temperatures were calculated for the depth layers >60m, assuming the spawning stock to be distributed in the deep basins for spawning. During the 3rd and 4th quarters the distribution of next years 1st quarter is used.

1990–2003: The 2nd quarter has the same distribution as the 1st quarter. In the 3rd quarter ambient temperatures were again calculated for the depth layers >60m, assuming the spawning stock to be distributed in the deep basins. 4th quarter distribution is assumed to equal the distribution of next years 1st quarter.

See Table 4.1.2.1 for an overview.

Table 4.1.2.1: Assumed distribution patterns of cod age-class 3+ for calculation of ambient temperatures to be used in the consumption model.

	S	A1	A2	
			1977–1989	**1990–2003**
1. Quarter	Distribution of 1.Quarters	Distribution of 1.Quarters	Distribution of 1.Quarters	Distribution of 1.Quarters
2. Quarter	Distribution of 1.Quarters	Distribution of 2.quarters	MW from T> 60m	Distribution of 1.Quarters
3. Quarter	Distribution of 1.Quarters	Distribution of 2.quarters	Verteilung des 1. Quartals des folgenden Jahres	MW from T> 60m
4. Quarter	Distribution of 1.Quarters	Distribution of 1.quarter of next year	Distribution of 1.quarter of next year	Distribution of 1.quarter of next year

Mean weighted oxygen saturations were calculated accordingly.

4.1.3 MSVPA set-up

Stock structure

Cod, sprat and herring in Subdivision 25, 26 and 28 were assumed to be unit stocks.

Age structure

Oldest age-groups in the analyses were: 8+ for cod, 8+ for herring and 7 for sprat.

Catch-at-age and weight-at-age (update to 2003)

Quarterly catch-at-age in numbers and weight-at-age in the catch according to subdivisions were revised and updated for years 1976–2003 following the compilation scheme presented in ICES (1997/J:2). Updated information for the period 2000–2003 were used as reported by the national laboratories to the Baltic Fisheries Assessment Working Group (ICES 2001/ACFM:18; ICES 2002/ACFM:17; ICES 2003/ACFM:23 and ICES 2004/ACFM:22) with following changes:

Missing values on weight-in-the-catch were substituted by a mean of neighbouring years for herring and sprat and by a weighted mean of the subdivisions for cod.

Weight-in-the-catch was set to be equal to weight-in-the-sea. Only for cod age-classes 0–2 constant values were used for the complete time series (Table 4.1.3.1)

Table 4.1.3 1: Weight-in-the-sea for cod age-classes 0–2. Values were applied for all Subdivisions.

	AK 0	AK 1	AK 2
Q1	——	0.052	0.262
Q2	——	0.09	0.339
Q3	0.005	0.138	0.425
Q4	0.028	0.195	0.52

Revision of the herring data set in Subdivision 28

The standard databases, as used up to now in the MSVPA, included the Gulf of Riga (GoR) herring. A revision of the database showed some mistakes, which were corrected:

- Catch numbers in 1993–1996 were by mistake excluding the GoR herring. The catch data series for the area dis-aggregated MSVPA was there inconsistent. The catch data were corrected accordingly;
- In 1980, 4th quarter, the catch numbers had also to be corrected for including the GoR herring;
- In 1981, 1st quarter as well as in 1986, 3rd and 4th quarter, the age-distribution had to be shifted for one age-class to match independently calculated catch numbers of the GoR.

Alternative herring data set for Subdivision 28

For the years 1980–2003 an alternative catch-at-age data-set was developed for Subdivision 28, now excluding the Gulf of Riga herring. The data-set is based on quarterly estimates of Gulf of Riga herring catches by Georgs Kornilovs (LATFRA), which were then subtracted from the original data-set (including the GoR herring).

Residual mortality

Residual mortality was set to 0.2 per year, being evenly distributed over quarters (Sparholt 1991).

Maturity ogives

Maturity ogives for cod in different Subdivisions represent averages over the periods 1980–84 (applied also before 1980), 1985–89, 1990–94 and 1995–97 for combined sexes as presented in ICES (1998/ACFM:16), updated with data for 1998 and 1999 presented in ICES (1999/H:5) and ICES (2000/ACFM:14). For sprat and herring maturity ogives were used as given in ICES (1996/Assess:2), being constant over time. For the updated years 2000–2003 the values of 1999 were used.

Stomach content data

Quarterly cod stomach content data according to Subdivision as revised in ICES (1997/J:2) were utilized as input. Intra-cohort cannibalism in cod was excluded by changing prey age to predator age minus 1 and omitting 0-group cod in 0-group cod stomachs.

Quarterly food intake by cod

Consumption rates with and without the effect of oxygen on evacuation and assuming different distributions when calculating ambient temperature and oxygen concentrations.

Suitability model

Suitability sub-model as introduced in ICES (1992/Assess:7).

Tuning

The tuning of the MSVPAs was performed for each Subdivision utilizing the procedure developed by Vinther (2001), iteratively running MSVPAs and XSAs with automatic recursive data exchange. The XSA settings were as follows:

Cod:

- including age-groups 2–8 abundance indices from international bottom trawl surveys 1994–2003,
- catchability was set to be dependent of stock size for ages < 3 and independent of age > 5,
- shrinkage of the terminal population towards a mean F over last 5 years and 3 oldest ages was applied with a standard error of 0.5–0.8,
- otherwise default settings of the Lowestoft assessment programme package were used.

Sprat:

- using international hydroacoustic survey results as tuning fleets; depending on the performance covering 1987 or 1992 to 2003 with year 1993 excluded, as insufficient area coverage and problems in the intercalibration of the equipment occurred (ICES 1997/Assess:12),
- catchability was set to be dependent of stock size for ages < 3 and independent of age > 4,
- shrinkage of the terminal population towards a mean F over last 3–5 years and 3–5 oldest ages was applied with a standard error of 0.5–0.8,
- otherwise default settings of the Lowestoft assessment programme package were used.

Herring:

- using international hydroacoustic survey results as tuning fleets; depending on the performance covering 1982 or 1986 to 2003 with 1992/1993 excluded in Subdivision 25, 1993 in Subdivision 26, 1993 and 1997 in Subdivision 28 as insufficient area coverage and problems in the intercalibration of the equipment occurred (ICES 1997/Assess:2; ICES 2000/ACFM:14),
- catchability was set to be dependent of stock size for ages < 3 and independent of age > 5,
- shrinkage of the terminal population towards a mean F over the last 5–6 years and 6–7 oldest ages was applied with a standard error of 0.8–1.0,
- otherwise default settings of the Lowestoft assessment programme package were used.

Other input data and setting

The constant biomass of other food was assumed to be 1 mill. tonnes, similar to ICES (1996/Assess:2).

4.2 Results

4.2.1 Ambient temperature and oxygen

The ambient oxygen concentrations and temperatures show opposite trends in all Subdivisions (Figure 4.2.1.1). Mean temperatures were highest in SD 25. The first part of the time-series displays high year-to-year variability in SD 25. Lowest temperatures were recorded in the inflow-years 1993/1994. Highest oxygen saturation was found in 1993, strongly decreasing afterwards to ca. 20%. For all Subdivisions a trend to warmer temperatures and lower oxygen levels is obvious since the inflow event in 1993.

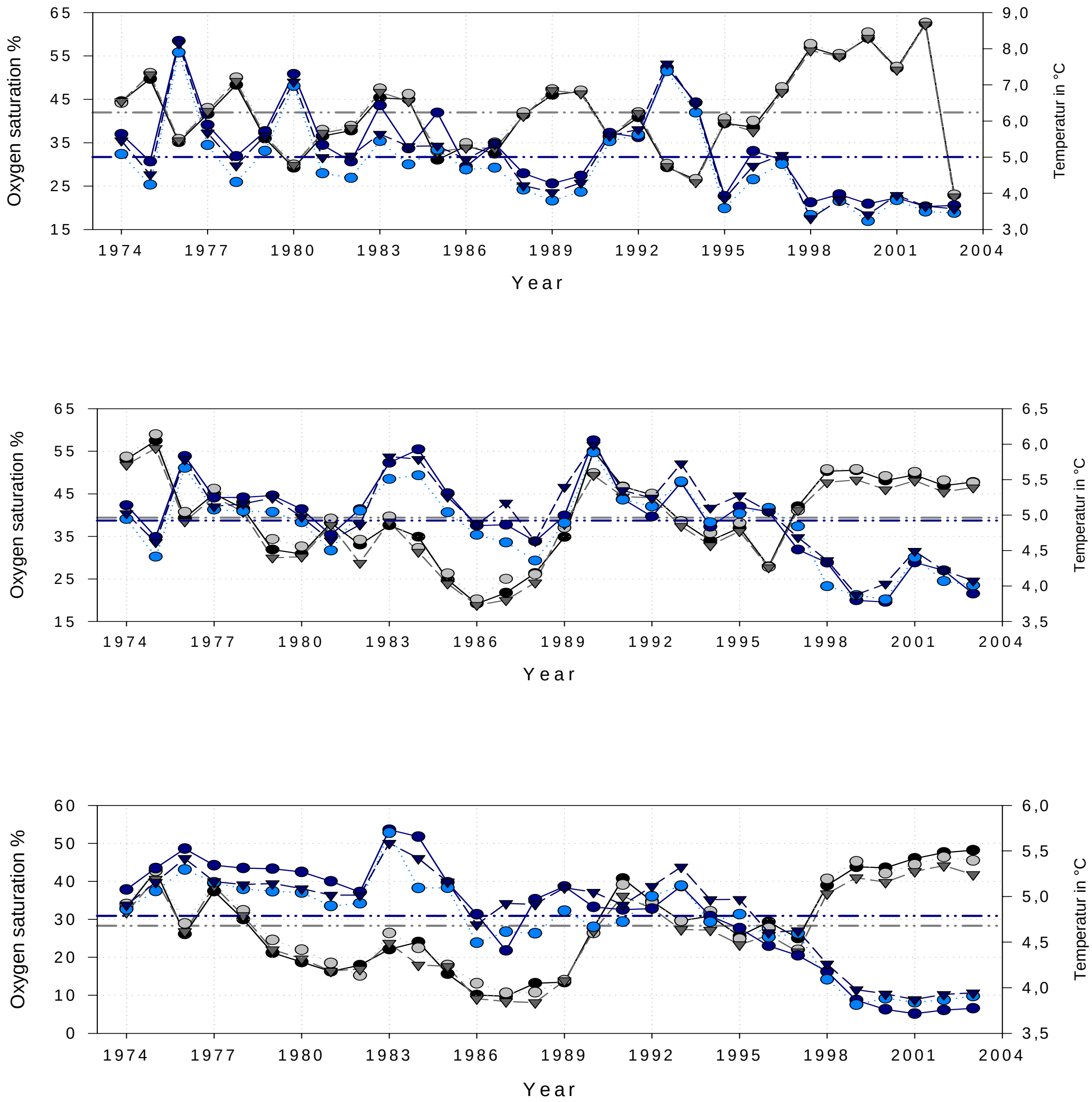
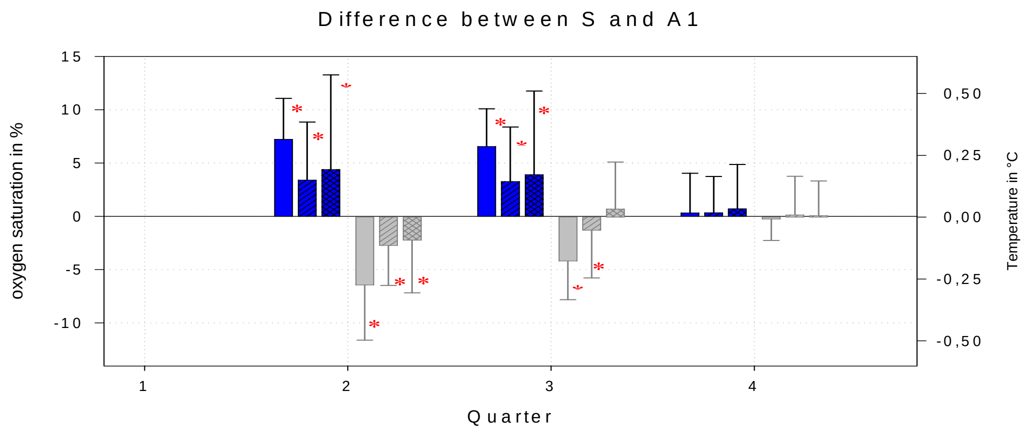


Figure 4.2.1.1: Comparison of ambient temperatures and oxygen levels (mean over quarters) for cod age classes 3+ in ICES Subdivisions 25 (upper panel), 26 (middle panel) and 28 (lower panel) in the years 1974 to 2003. Oxygen saturation is in marked blue, while temperature is marked grey, mean values are given as horizontal lines.



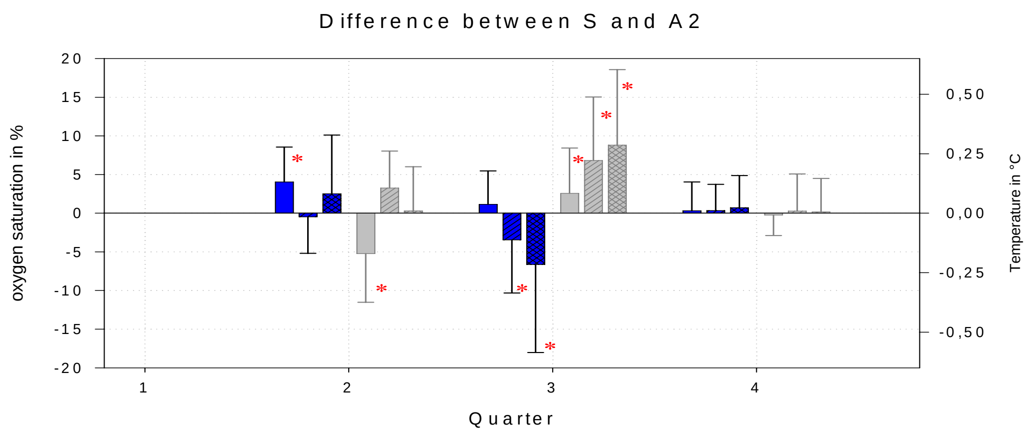


Figure 4.2.1.2: Deviations in ambient temperatures and oxygen saturation between the standard method and two alternatives (means over the time series); Oxygen saturation is marked blue, while temperature is marked grey, significant differences are marked by *.

Differences in ambient temperatures as well as oxygen saturation between the standard and alternative distribution models are rather small. Highest deviations could be found in SD 25 in the second quarter (A1) and in SD 26 in the third quarter (A2). Some of the differences were, however, statistically significant (Figure 4.2.1.2).

4.2.2 Impact of oxygen deficiency on consumption rates

Consumption was calculated for the three different distribution model (S, A1, A2) with and without accounting for an oxygen-effect. So we reached a total of 6 consumption time-series to be compared. In principle, all the consumption time-series show a parallel trend. Accounting for the oxygen-effect yielded substantially lower consumption rates. Consumption was by 39.9–46.2% lower in SD 25, 34.3–39% lower in SD 26 and 39.5–41.6% lower in SD28. As an example, figure 4.2.2.1 shows the time-series for SD 25. In contrast, differences between the three distribution models were only low.

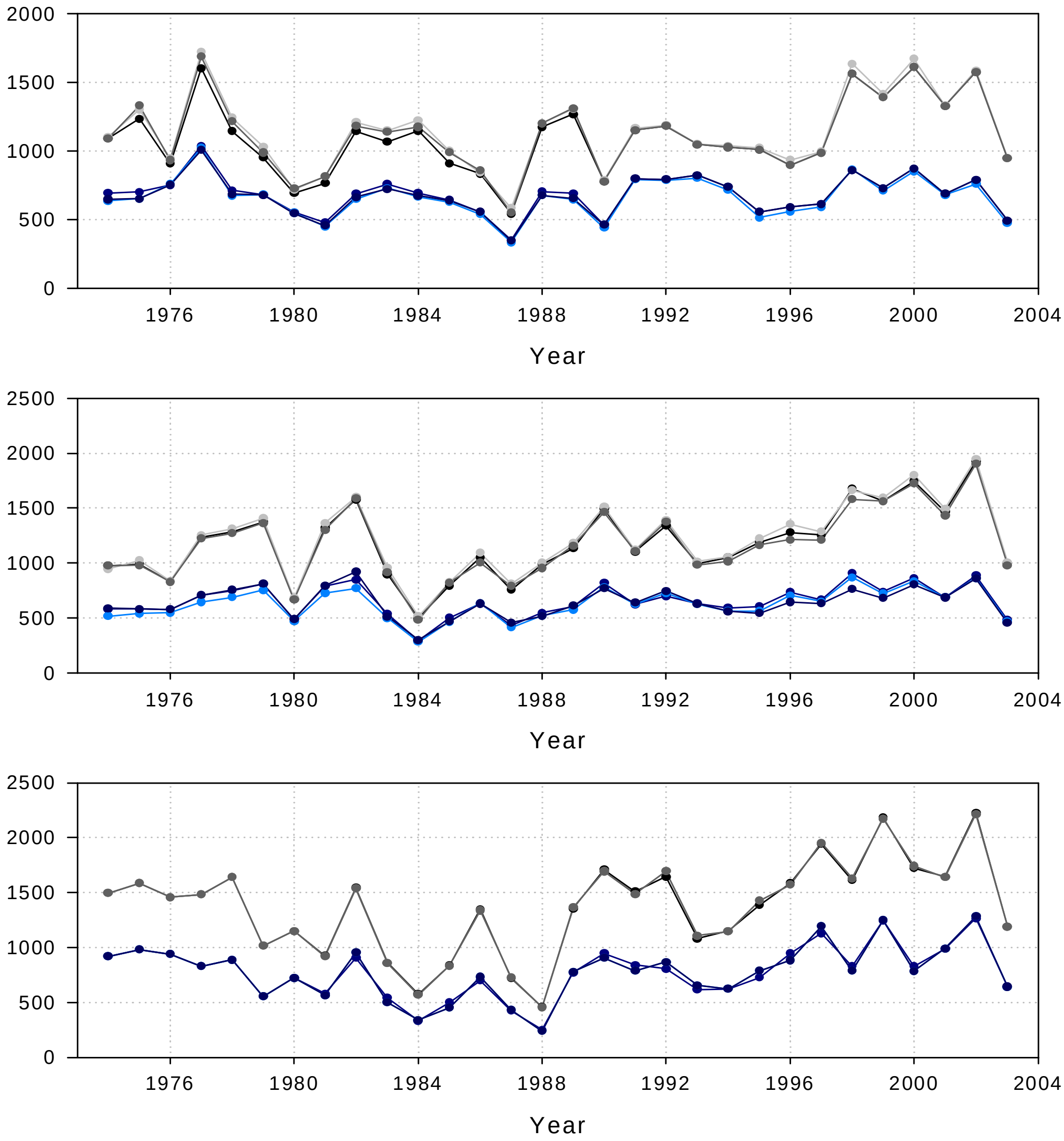


Figure 4.2.2.1: Mean consumption of cod (age-class 3+) in the 2nd quarter (above), 3rd quarter (centre) and 4th quarter (below) in SD 25 for the years 1974–2003. Standard consumption model is marked grey; oxygen-sensitive model is marked blue.

4.2.3 Area dis-aggregated MSVPA runs

Stock numbers and stock biomass

Generally, an opposite trend in the stock performance of cod and sprat was obvious (Figures. 4.2.3.1 and 4.2.3.2), with a decreasing cod stock and an increasing sprat stock. Sprat showed a slight decrease after peak population sizes in the mid 90ies in SD 26 and 28.In SD 25 sprat abundance as well as biomass decreased sharply up to 2003. High sprat stock sizes in the beginning of the time series in SD 26 and 28 are not confirmed as tuning problems were encountered in the oldest age-group. Herring populations were decreasing in SD 25 and 26, while in SD 28 a slight increase could be observed. Presently, highest population numbers were calculated for cod in SD 25, for sprat in SD 26 and for herring in SD 28.

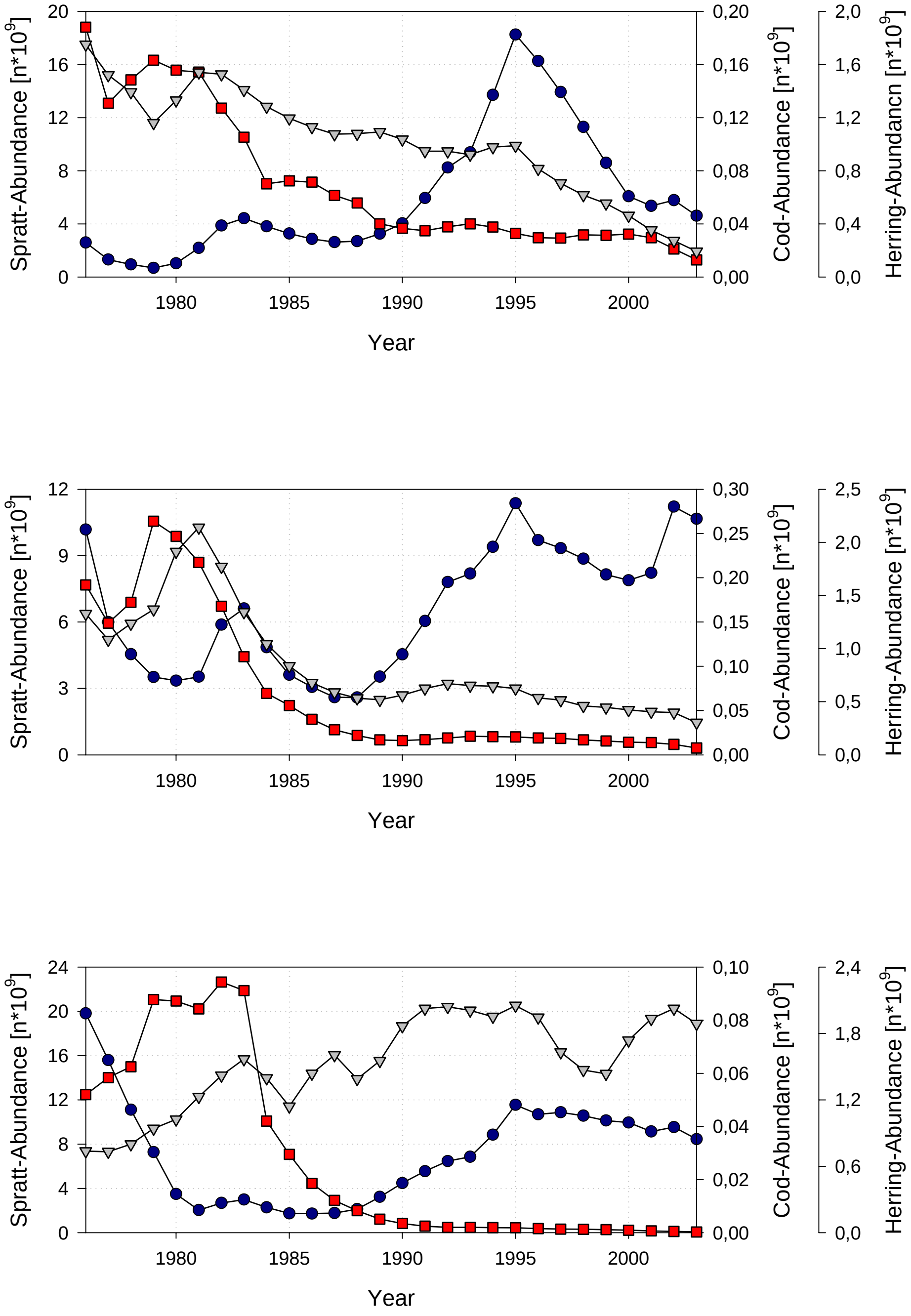


Figure 4.2.3.1: Stock abundance of cod (red square), herring (blue dot) and sprat (grey triangle) in SD 25 (above), SD 26 (centre) and SD 28 (below) for standard settings.

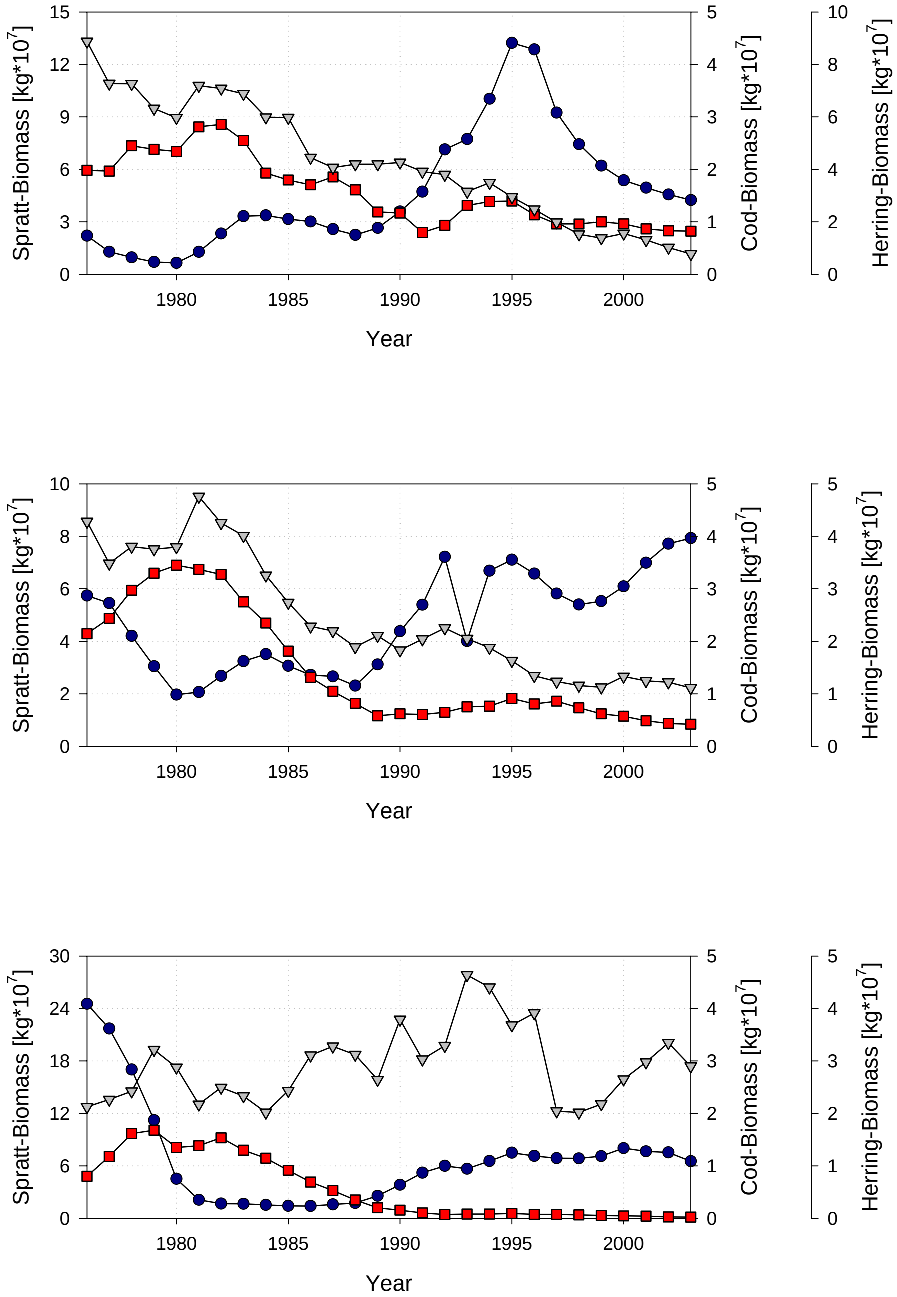


Figure 4.2.3.2: Stock biomass of cod (red square), herring (blue dot) and sprat (grey triangle) in SD 25 (above), SD 26 (centre) and SD 28 (below) for standard settings.

Influence of the distribution models on MSVPA output

Differences in the population estimates between the three applied distribution models can be regarded as marginal. As an example Figure 4.2.3.3 displays the results for cod. The alternative A1 results in higher population numbers (0.12 to 1.71 millions) compared to the standard. However, compared to a mean total abundance of 115 million fish, these differences are not large. Biomass estimates diverge in maximum by 20 tons. Deviations for alternative A2 were even lower. Also for sprat and herring populations, the deviations between the three methods were of only minor importance.

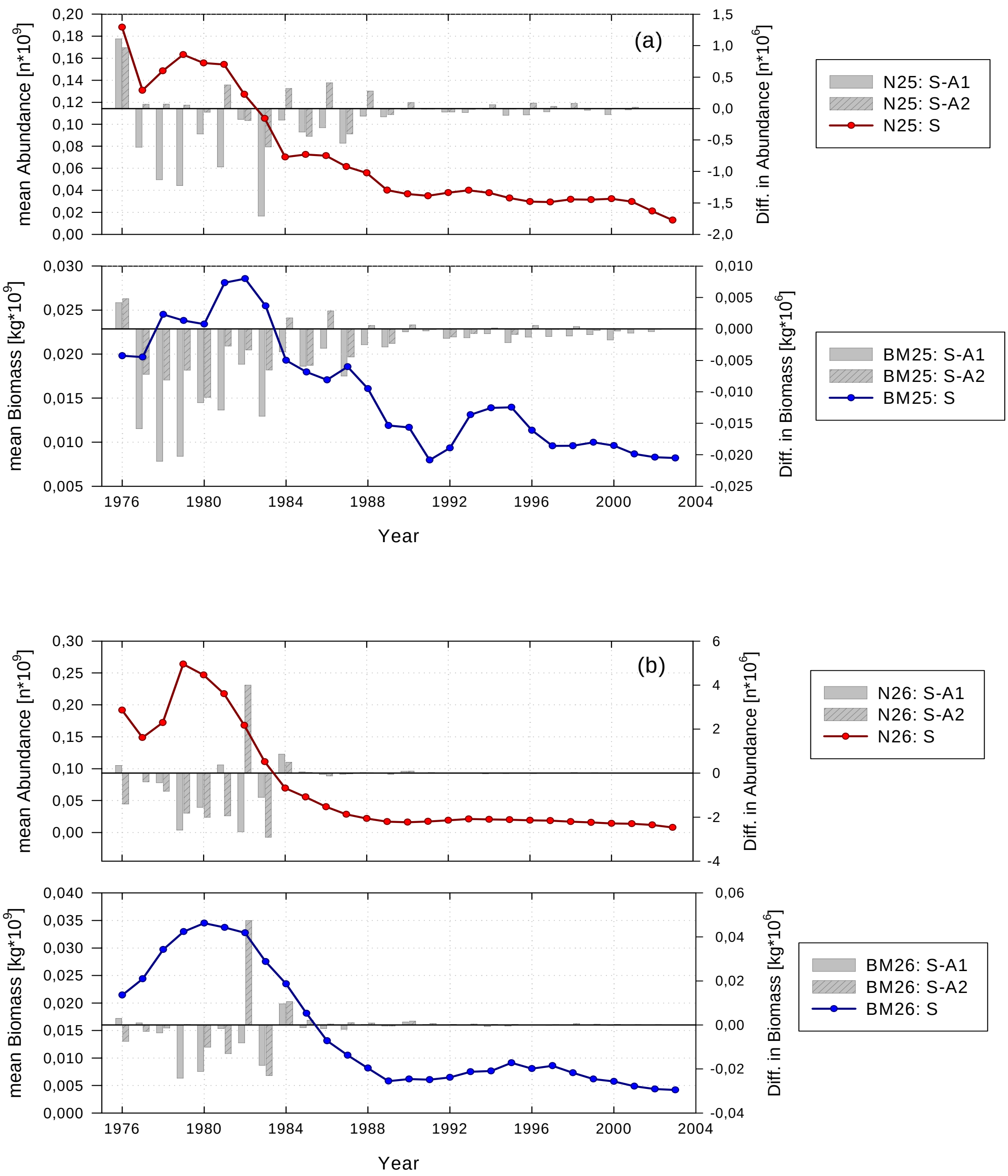


Figure 4.2.3.3: Population estimates of cod according to the different distribution models S, A1 and A2 for numbers (above) and biomass (below); SD 25 (a), SD26 (b) and SD 28 (c). Standard methods are displayed as line while the differences due to alternative settings A1 and A2 are displayed as vertical bars.

Influence of the oxygen-sensitive consumption model on MSVPA output

The impact of reduced consumption rates, which were derived by the oxygen-sensitive consumption model, was comparably large. For cod the resulting differences showed the same time trend in all Subdivisions (Figure 4.2.3.4.). Maximum deviation were found in the early years of the time-series up to the mid 80ies with maximum population sizes, while they decreased towards the end of the time-series with low stock sizes. Reduction in estimated population numbers is approximately 6fold higher than reduction in biomass (19.7% vs. 3.2% reduction). While for herring the highest deviation were also found at the beginning of the time-series, for sprat they were found in the second half of the time-series (not shown).

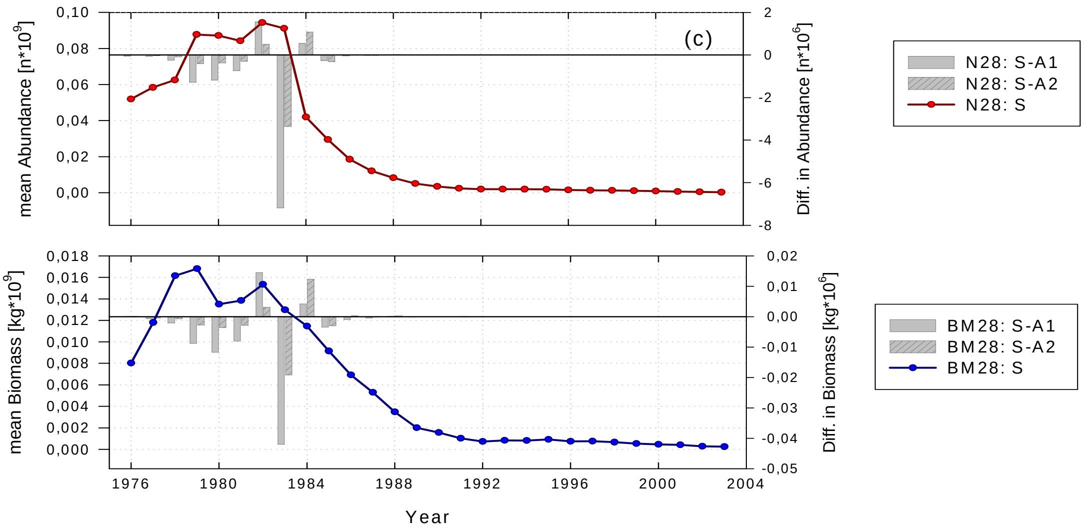


Figure 4.2.3.3 (cont): Population estimates of cod according to the different distribution models S, A1 and A2 for numbers (above) and biomass (below); SD 25 (a), SD26 (b) and SD 28 (c). Standard methods are displayed as line while the differences due to alternative settings A1 and A2 are displayed as vertical bars.

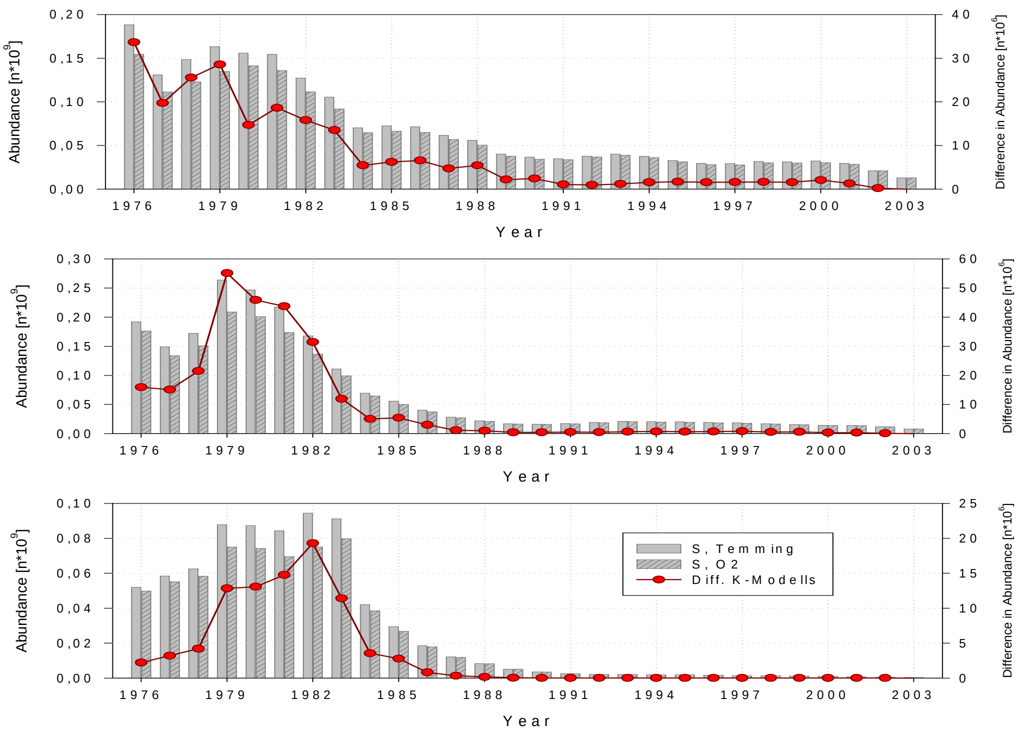


Figure 4.2.3.4: Population estimates of cod according to the different consumption models (standard vs. oxygen-sensitive); SD 25 (above), SD26 (centre) and SD 28 (below). Abundance estimates are displayed as vertical bars; differences between the methods are displayed as line.

Results for SD 28, excluding the Gulf of Riga herring

Because of missing data in the early years, the time-series had to be shortened by 4 years (start: 1980). This led to changed suitability coefficients (early years with high cod cannibalism were excluded from the stomach content data set) which influenced not only herring population estimates but also those for cod and sprat (Figure 4.2.3.5).

Excluding the Gulf of Riga herring from the catch-at-age database resulted in on average 60% lower stock abundance and 59% lower stock biomass of open sea herring in SD 28. Relative differences were higher in more recent years.

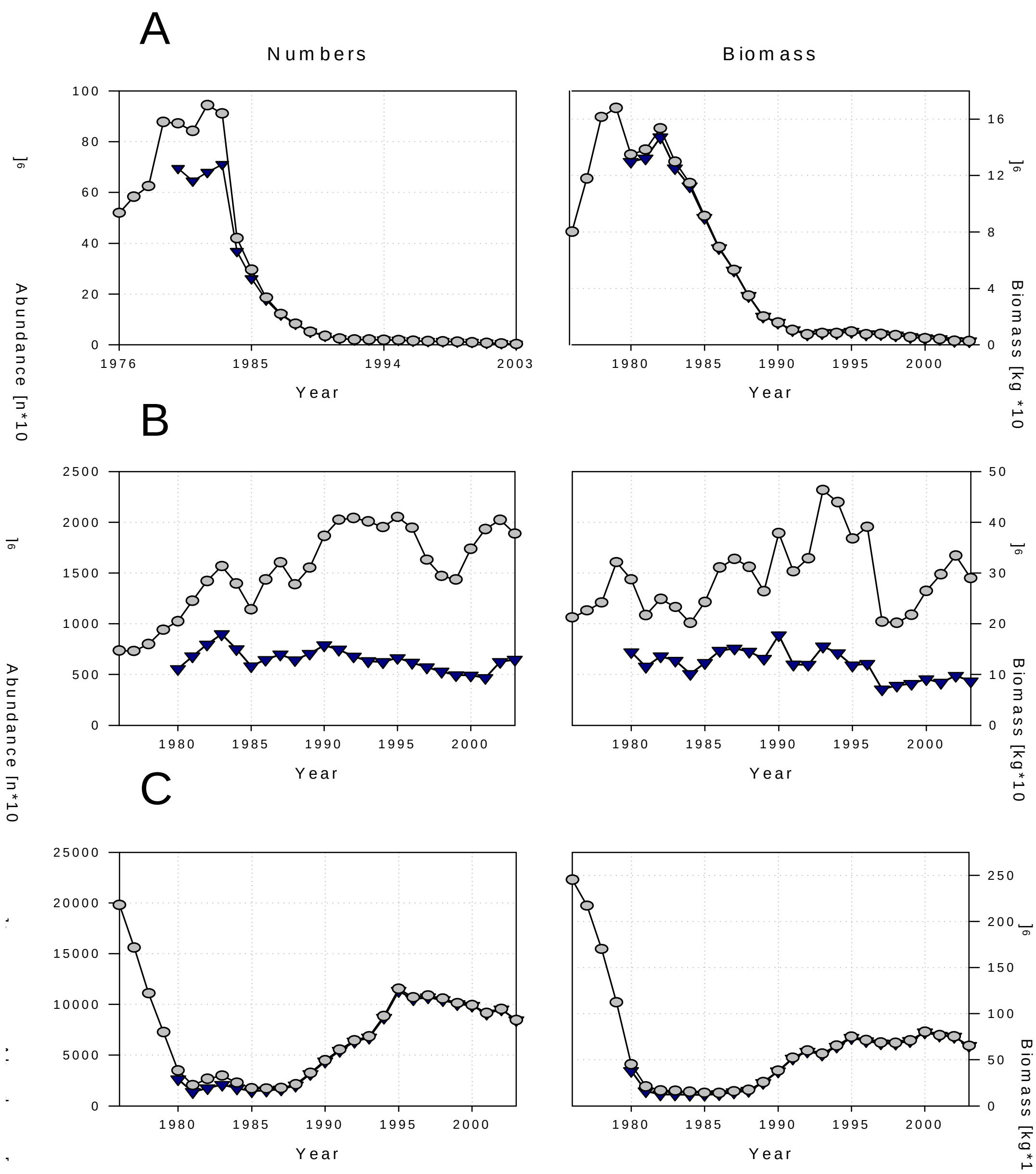


Figure 4.2.3.5: Comparison of abundance and biomass estimates for cod (A), herring (B) and sprat (C) when including (grey dots) or excluding (black triangles) the Gulf of Riga herring in SD 28.

Validation with survey data

The results of the area dis-aggregated MSVPA results were validated against independent survey data following the procedure outlined in Köster *et al.* (2001b): cod abundance estimates were compared to the Baltic International Trawl Survey database (BITS) giving estimates for the 1st quarter; herring and sprat estimates were compared to the Baltic International Acoustic Survey (BIAS), giving estimates fir the 4th quarter. For cod and sprat the fit of the linear regressions as well as the intercept did not change substantially. However, for herring improved results were found. Including the oxygen-sensitive consumption model did not enhance the fit of the regression, but the intercept was reduced. Excluding the Gulf of Riga herring led to a substantially better fit of the regression (r^2=0.46 to r^2=0.63).

4.3 Conclusions

The performed area disaggregated MSVPA runs confirmed distinct trends in population abundance, spawning biomass, recruitment, predation mortalities and partly also fishing mortalities of cod, herring and sprat in different areas of the Central Baltic. As outlined in ICES (1999/H:5) a number of data related and methodological problems are involved in the present approach. The catch-at-age data for cod and sprat showed in some age-groups, quarters and years considerable fluctuations. High variability in the catch in numbers of the last age-group caused problems in tuning the terminal-F values for cod and especially sprat. For herring similar problems were not encountered. Beside catch-at-age and tuning problems, migration between different areas of the Central Baltic is expected to have an impact on the MSVPA results. Explicit inclusion of the migration process into the MSVPA-context is difficult and at present no adequate methodology is available (ICES 1999/H:5). Apart from this, reliable migration rates are missing for all stocks under consideration Thus, presently the only feasible way of spatial dis-aggregation is to run a suite of independent MSVPAs for the different Subareas, as performed here. By doing this, migration is accounted for by fluctuations in the catch-at-age data only.

5 Long-term forecasts for cod, herring and sprat

The 4M forecast software was used to evaluate different scenarios. Various forecasts were made for the period 2005–2035 using stochastic recruitment with 100 replications. Basically, the scenarios tried to mimic various fishing levels assuming two hydrographical conditions. One with good conditions for cod recruitment and poor conditions for sprat recruitment as observed from the mid 1970'ies to mid 1980' and one situation with poor conditions for cod recruitment and good conditions for sprat recruitment as observed after the mid 1980'.

Cod cannibalism was significant in the period with good hydrographical conditions and high cod stock. This is simulated using food suitabilities estimated with only stomach contents data from 1977–1983. Sprat predation mortality was high as well in that period and recruitment might have been limited by the size of SSB. In the forecast, this is implemented as Ricker S/R estimated from observations from the key-run for year classes 1973–1986 at age 1. Cod recruitment seems to be virtually independent of SSB in that period and recruitment in the forecast was estimated from a geometric mean.

The bad hydrographical conditions for cod recruitment after the mid 1980'ies is simulated in the forecast by using the geometric mean of cod recruitment at age 1 over the year classes 1987–2003. The same was done for sprat as the sprat recruitment is not assumed limited by the relatively high SSB in this period.

Herring is less influenced by cod predation and a Ricker S/R was fitted to key-run data for the whole period.

Four scenarios were made using combinations of the setting given below.

Default settings

1) Mean weight in the sea, the residual natural mortalities and food rations were kept constant in the prediction and derived from the average values for 1995–2003 from the key run.
2) Initial stock numbers for prediction were taken from the key-run for 2004
3) Exploitation pattern as average for 2003–2004 using key-run results
4) F *status quo* level as average for 2003–2004 using key-run results
5) Herring recruitment: age-group 1 from Ricker relationship from key-run 1974–2003

Bad environmental conditions settings for cod.

6) Food suitability: from MSVPA 1974–2004 using 1984–1993 stomach data
7) Cod recruitment: GM age-group 1 from key-run 1988–2003
8) Sprat recruitment: GM age-group 1 from key-run 1988–2003

Good environmental conditions settings for cod.

1) Food suitability from VPA using 1977–1983 stomach data
2) Cod recruitment: GM age-group 1 from key-run 1974–1987
3) Sprat recruitment: age-group 1 from Ricker relationship from key-run 1974–1987

Status quo fishing mortality, and F values scaled to Fpa and 0.5* Fpa are shown in Table 5.1.

Scenario 1, F *status quo*, poor environmental conditions for cod

Settings 1–5 and 6–8.

The relatively high 2003 year class of cod gives an initial increase in stock size (Figure 5.1). Cod SSB stabilises afterwards at about 90.000 t and with a yield at 65.000 t. There is increase in herring SSB up to level of about 900.000 with a yield at 225.000 t. Long term sprat SSB and yield are at the level for observed in 2004.

Scenario 2, Fpa, poor environmental conditions for cod

Settings 1–5 and 6–8. F status quo scaled to Fpa.

Fpa is slightly lower than F *status quo* for cod and herring and at the same level for sprat (Table 5.1). Cod yield is at the same level as for the Fpa scenario, but SSB is increased by approximately 50.000 t (Figure 5.2). The same unchanged yield and increase in SSB can be seen for herring. There is almost no difference in the sprat prediction for scenario 1 and 2.

Scenario 3, "Target F" poor environmental conditions for cod

Settings 1–5 and 6–8. F status quo scaled to 0.5*Fpa.

With a 0.5*Fpa cod SSB increases to above 200.000 t, but staying still below Bpa. Yield is predicted at 60.000 t. This is both lower than predicted by ICES 2005/ACF:25 at a fishing mortality of 0.3 in a medium-term simulation not considering the effect of cannibalism. Long term herring and sprat yield are slightly lower than for the Fpa scenario even though the total biomass and SSB are higher.

Scenario 4, Fpa, good environmental conditions for cod

Settings 1–5 and 9–10. F status quo scaled to Fpa.

With a high cod recruitment, the biomass of cod increases very fast up to a level of 1.700.000 t after 5 years (Figure 5.4). With such a large cod stock, cod cannibalism becomes significant and the stock biomass decreases afterwards to 500.000t and stabilises at a level of 600.000 t. SSB stabilises at 350.000 t. With such a high cod stock, the model predicts a depletion of the stocks of herring and sprat. Herring and sprat recruitment are assumed to follow a Ricker S/R relation. The very high cod stock predicted after 5 years will reduce the SSB of the prey species to so much, that a recovery of these species is not possible even with a the much reduced cod stock later on in the prediction. There is delay in the depletion of herring as cod has a preference for sprat as prey and environmental condition does not favour good recruitment. After the crash of the sprat stock, cod shifts towards the herring stock as prey.

The predicted depletion of herring and sprat seems unrealistic. Part of the result is due to the model keeps all “parameters” fixed in the prediction. Mean weight-at-age are for example kept constant for all years where a decrease in e.g. cod mean weight is expected when the main food sources are depleted. The model assumes fixed food suitability coefficients which among other things imply a fixed overlap of the stock’s distribution areas. This assumption will probably be violated with stock sizes very different for the one observed. The biomass of “other food” is also kept constant in the prediction. This is unrealistic, as the availability of makrozoobenthos depends on the hydrographic conditions as well, sustaining much more food for cod in periods favourable for cod recruitment.

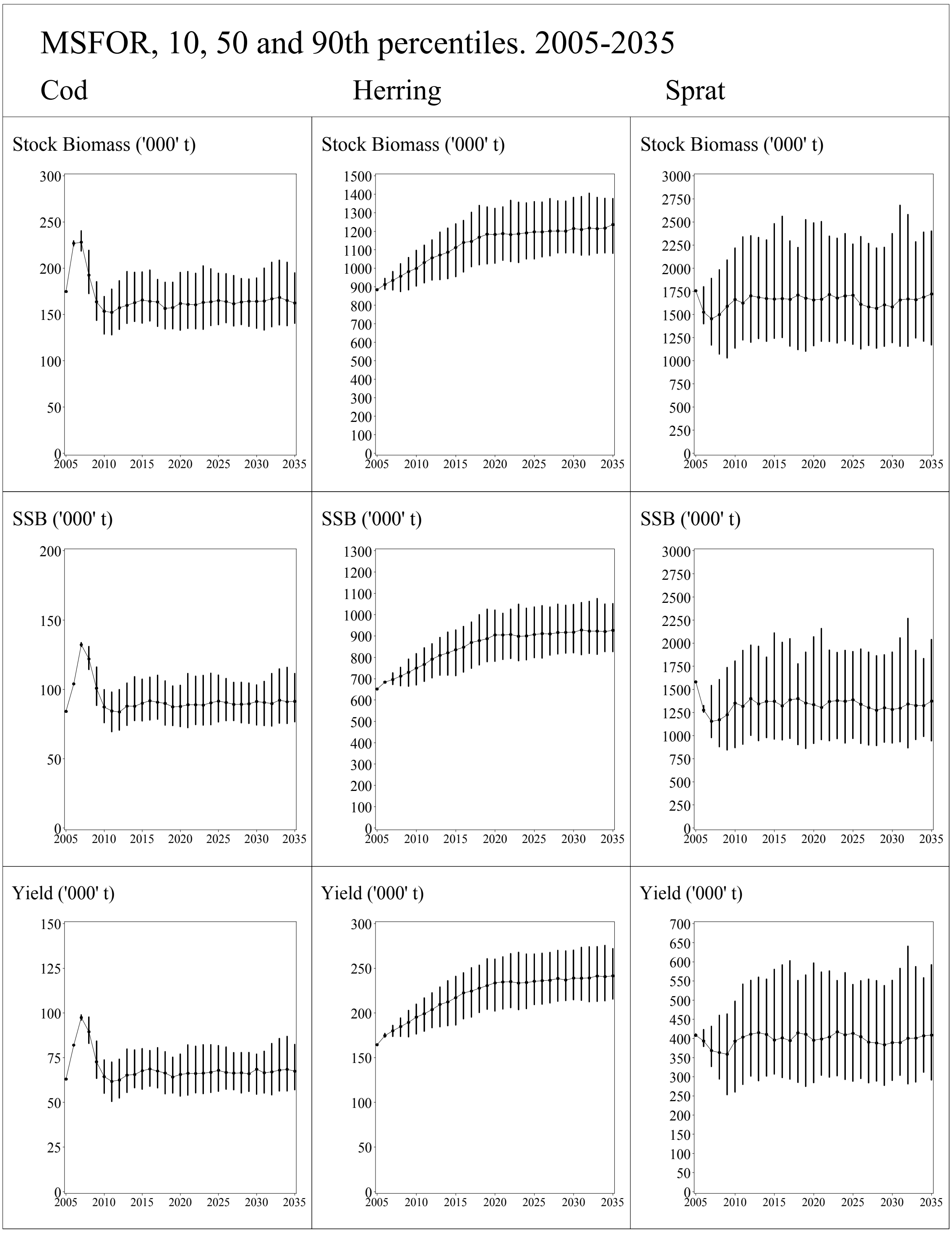


Figure 5.1: Scenario 1, F status quo and bad environmental conditions for cod recruitment.

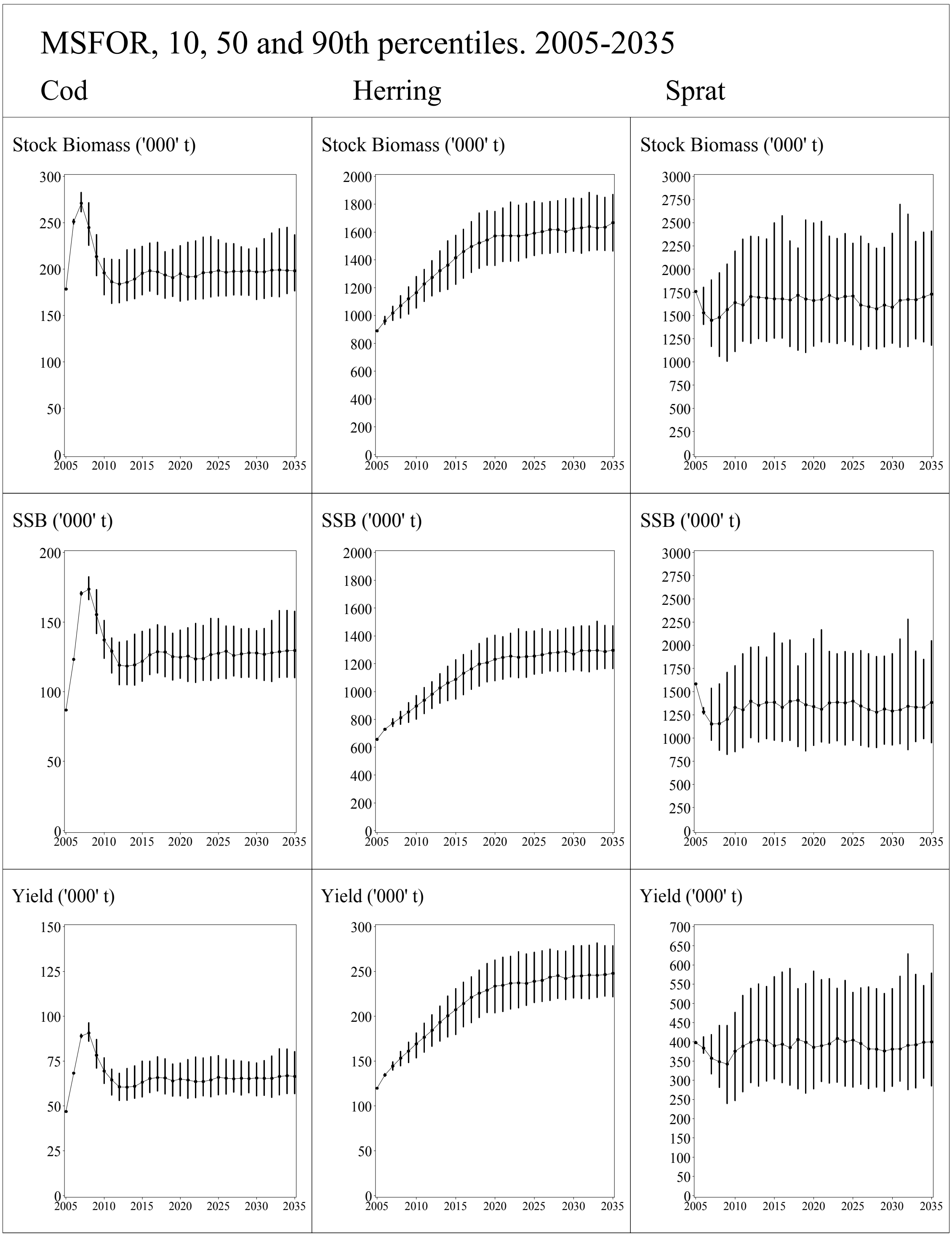


Figure 5.2: Scenario 2, Fpa and bad environmental conditions for cod recruitment.

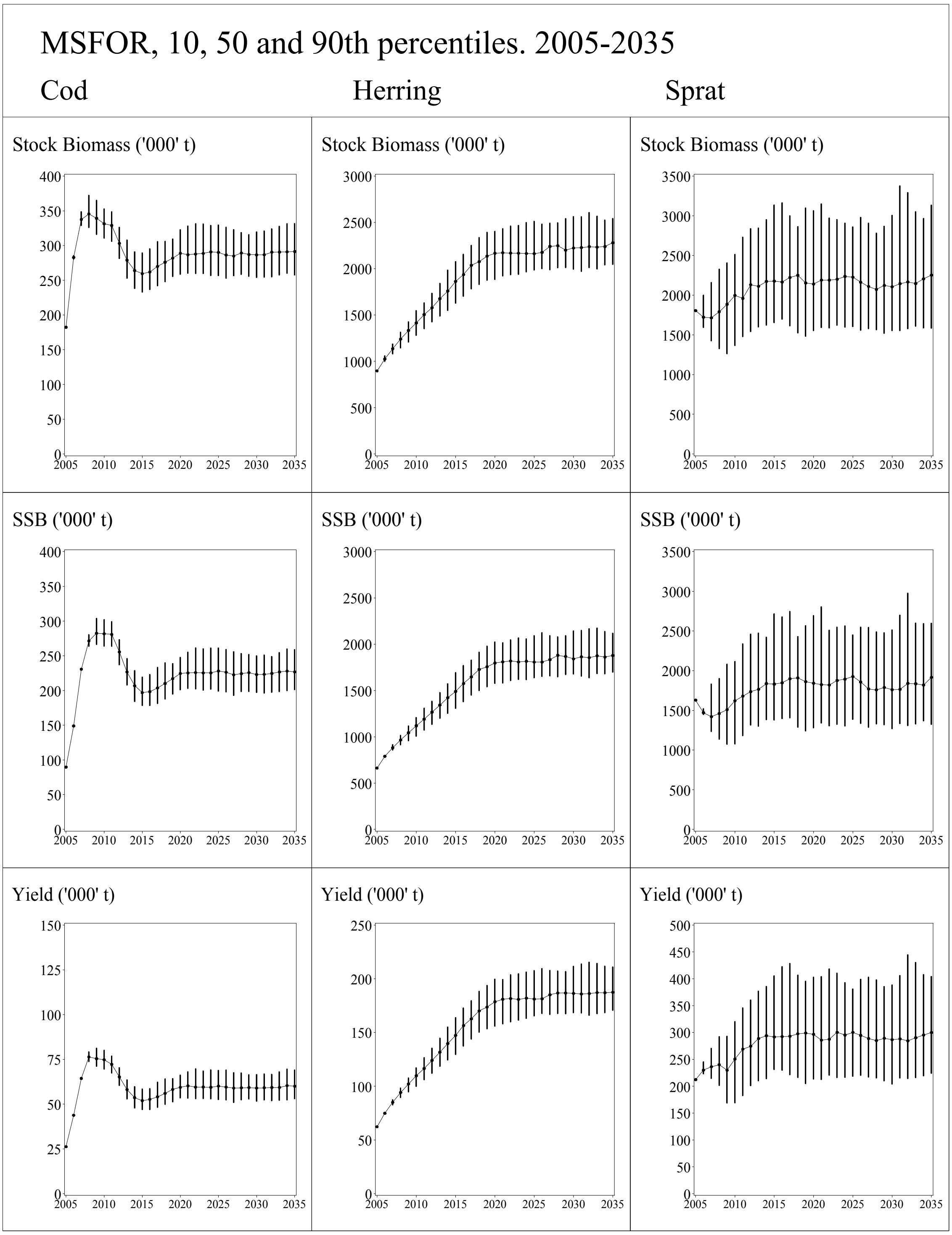


Figure 5.3: Scenario 3, 0.5*Fpa and bad environmental conditions for cod recruitment.

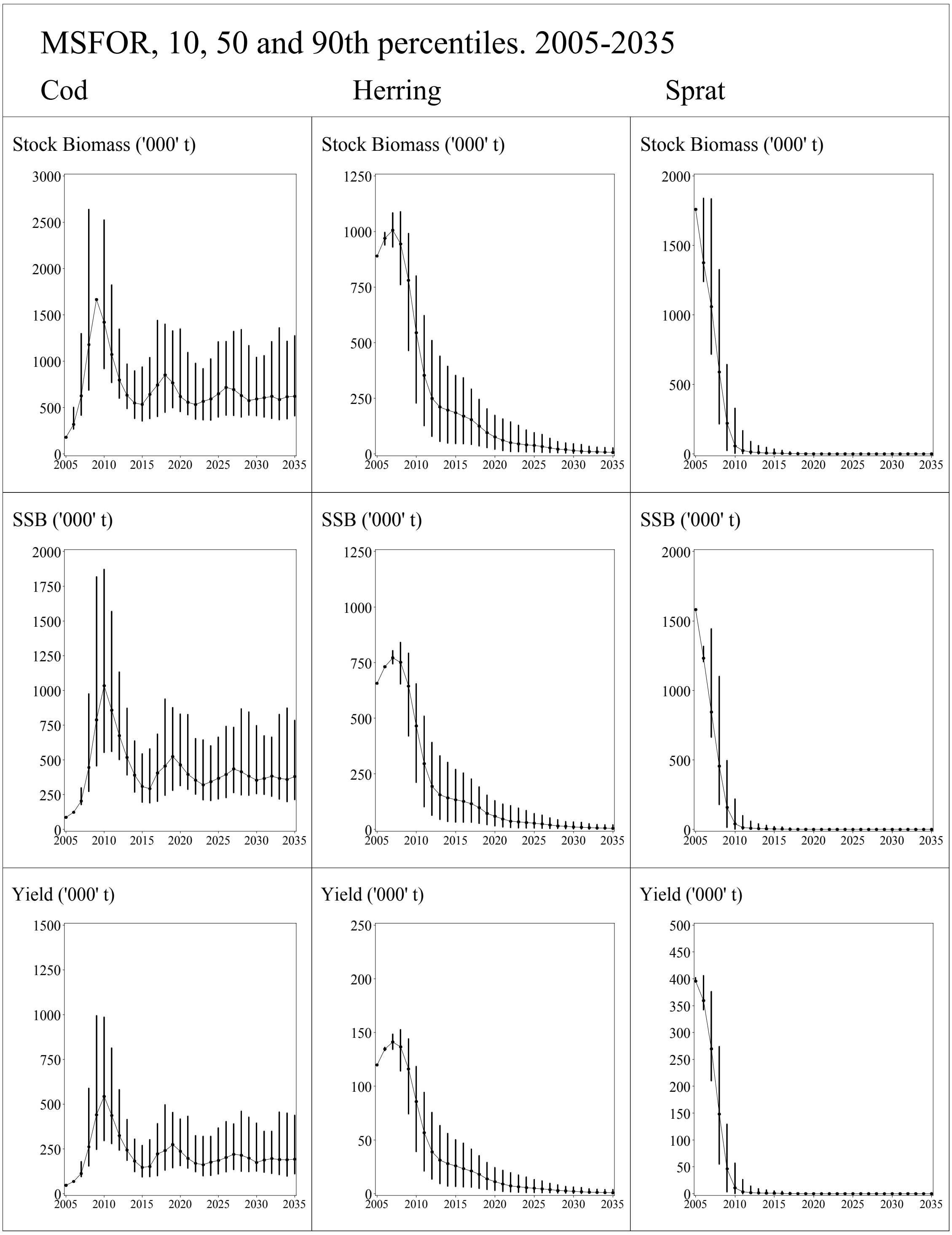


Figure 5.4: Scenario 5, Fpa and good environmental conditions for cod recruitment.

Table 5.1: Scenario Fishing mortality.

Species Cod

Age	F *staus quo* year 2005	Fpa year 2005	0.5*Fpa year 2005
0	0.000	0.000	0.000
1	0.005	0.003	0.002
2	0.099	0.066	0.033
3	0.457	0.306	0.153
4	0.873	0.586	0.293
5	1.019	0.684	0.342
6	0.837	0.562	0.281
7	0.846	0.568	0.284
8	0.849	0.570	0.285

Herring

Age	F *staus quo* year 2005	Fpa year 2005	0.5*Fpa year 2005
0	0.010	0.007	0.003
1	0.087	0.061	0.031
2	0.175	0.124	0.062
3	0.217	0.153	0.076
4	0.281	0.199	0.099
5	0.268	0.189	0.095
6	0.311	0.219	0.110
7	0.291	0.205	0.103
8	0.289	0.204	0.102

Sprat

Age	F *staus quo* year 2005	Fpa year 2005	0.5*Fpa year 2005
0	0.002	0.002	0.001
1	0.095	0.092	0.046
2	0.175	0.170	0.085
3	0.297	0.289	0.144
4	0.334	0.324	0.162
5	0.604	0.587	0.294
6	0.490	0.476	0.238
7	0.446	0.433	0.217

6 Stomach sampling and ecosystem surveys

6.1 Historical stomach content data

Cod stomach content data which are so far not included in the multispecies database exist at different laboratories around the Baltic. Digitized data from 1994 to 2004 exist, while data from before 1977 are available as paper copies. These data have to be digitized, and all data have to be incorporated in the cod stomach database. Intersessional work will be allocated to determine the best possible report format of the data. Generally, the level of aggregation of the data should be as low as possible, keeping information both on the single prey items in single stomachs, and also sampling station, date, daytime, depth and position of sampling as precise as possible. If possible data should be made available on individual trawl haul (station) level on the abundance of herring, sprat and other fish to allow a study on the causes of variability in cod stomach content.

6.2 Cod stomach sampling 2005/2006

The Study Group recommends sampling of cod stomachs on all standard surveys in the Eastern Baltic Sea. The standard surveys include the BITS survey in March and November and the hydroacoustic surveys in May and Sept./Oct. Sampling every 3rd year or alternatively after an inflow is considered necessary in order to reflect possible changes in the cod feeding due to fluctuations in prey abundances or in environmental boundary conditions. Stomach sampling could start during the hydroacoustic survey in autumn 2005 and continue throughout 2006.

Sampling stations have to be randomly distributed over the survey area. Stomachs should be taken stratified by 10 cm cod total length groups. Measuring the cod to the nearest cm below, the length-groups are <10 cm, 10–19 cm, 20–29 cm, 30–39 cm, 40–49 cm, ≥ 50 cm . From each length-group maximally 10 cod stomachs will be collected per station. Cod are processed immediately after the sample got on board. Stomachs that have obviously been partially or completely regurgitated during trawling as well as stomachs indicating trawl feeding are excluded from the analysis. Each individual cod stomach gets an identification number, linking the stomach to the fish and single fish data. For the station at least date, time of the day, GPS position of catch, catch-depth and number of the trawl station are recorded. Recording the number of the trawl station aims at enabling the link between stomach data and catch composition data. All stomachs sampled are preserved in at least 70–80% ethyl alcohol and transported to LATFRA.

6.3 Summer survey 2006

The group considered the additional collection of cod stomachs during an ichthyoplankton survey conducted by the Kiel Institute useful to gather stomach data from the second and third quarter of the year. Summer contains the period of peak cod spawning. Data from stomachs during this period are in general scarce, and the period is not at all covered by present routine surveys. Yet, data on cod stomach contents during cod spawning are necessary to run multispecies models.

6.4 Data requirements from ecosystem surveys

To facilitate a future ecosystem approach to the management of marine resources, SGMAB and SGBFFI recommend during its common session to initiate an ecosystem-oriented surveying of the Baltic Sea. The Baltic International Trawl Survey (BITS) and the Baltic International Acoustic Survey (BIAS) could be extended to provide a holistic view of the state of the ecosystem. This includes not only recording the physical environment (i.e., hydrography), but also simple indicators of productivity within the phyto- and zooplankton.

A trial example of an "ecosystem survey" was conducted by the Baltic Sea Regional Project (BSRP) during May 2005, where additional sampling was integrated into the Latvian/Russian Hydroacoustic survey in the Eastern Gotland Basin (ICES 2005; SGPROD-Report). Tables 6.1 and 6.2 provide a proposal for sampling the ecosystem.

Additional sampling on Baltic fish surveys required to provide an assessment of the state of the ecosystem is listed in Table 6.2. As evident from Table 6.2 there is a lack of observation during summer. Since summer is a highly dynamic period within the ecosystem this gap has to be overcome, e.g. through bilateral surveys as proposed for 2006.

Table 6.1: A proposal for a sampling scheme for the ecosystem survey in the Baltic.

VARIABLE	GEAR	FREQUENCY OF SAMPLING	OTHER SPECS.
Hydrography	CTD + O_2	Every fishing station	5m-Resolution (2.5m in the euphotic zone)
Nutrients	Rosette-sampler	2 stations per ICES-rectangle	
Chl a (Phytoplankton)	Probe attached to CTD	Every fishing station	5m-Resolution (2.5m in the euphotic zone)
Phytoplankton species composition	Rosette-sampler	2 stations per ICES-rectangle	
Mesozooplankton	WP-2 (100 µm)	2 stations per ICES-rectangle	Vertically-integrated
Ichthyoplankton	Bongo (335 µm)	2 stations per ICES-rectangle	Vertically-integrated
Herring and sprat stomachs	Trawl	Every fishing station	Length-stratified sampling
Cod stomachs	Trawl	Every fishing station	Length-stratified, every second year
Nektobenthos	IKMT	8 transects per SD	During night
Macrozoobenthos	Van Veen Grab	2 stations per ICES-rectangle	During daytime <70m

Table 6.2: Present annual surveys and sampling on Baltic fish. Additional sampling required to provide an assessment of the state of the ecosystem.

SURVEY	MONTH/ QUARTER	NUTRIENTS	CHL A/ PHYTOPLANKTON	ZOO-/ ICHTHYOPLANKTON	COD STO-MACHS	CLUPEID STOMACHS	NEKTO-BENTHOS	MACRO-ZOOBENTHOS
BITS	March/1	X	X	X	X	X	X	
BIAS	May/2	X	X	X	X	X	X	X
BIAS	October/4			X	X	X	X	X
BITS	November/4	X			X	X	X	

7 Spatial and temporal distribution of herring in the Baltic

7.1 General overview

The results of historical tagging experiments, catch observations and international acoustic surveys are the main source of information on distribution pattern of clupeids in the Baltic (e.g. Otterlind, 1961, Aro, 1989.and others). Different herring populations can be distinguished by certain annual migration pattern between spawning, feeding and wintering areas.

7.2 Herring in Subdivisions 22–24

Spawning takes place in March-April around the Danish and German coast. The main spawning area is around the Rügen Island. During the feeding season the adult herring migrate to the Kattegat, the Skagerrak and in the North Sea, The main over-wintering areas are in the Sound and Arkona Basin.

7.3 Herring in Subdivisions 25–27

Three different stocks inhabit the area: spring spawning coastal herring, spring spawning open sea herring and autumn spawning herring.

The fast-growing **southern coast herring (coastal spring spawning herring)** spawns in the coastal regions of Poland from the area east of Rügen, in the Pomeranian Bay and the Vistula Lagoon. The spawning starts in March in the western areas and continues in April in the Gulf of Gdansk. The main feeding grounds of the stock are situated around the Island of Bornholm, in the Gdansk Basin and sometimes in the Arkona region. The feeding migration lasts from July to December. The young age groups distribute in the area of coastal slope.

The spawning grounds of the slow-growing **Swedish coast herring** (**open sea herring)** are mainly situated along the Swedish east coast from Hanö Bay up to the Åland Archipelago. The spawning period lasts from April to June. In the northern areas spawning starts usually in May and lasts until the beginning of July. In general, this stock spawns in deeper water than the coastal spring spawners. A very large proportion of older herring migrates after spawning to their feeding grounds in the Bornholm Basin, sometimes to the regions south of Skåne also to the Gdansk Basin and offshore regions of Klaipeda. The northward migration (to the Bothnian Sea) is insignificant. During the late autumn and early winter the spawning migration starts from the feeding grounds back to the spawning places where the main part of the stock is found from November onwards. Some part of the stock does not return to their spawning area at Swedish east coast. They have been found on the spawning grounds in the Southern Baltic spawning together with the local spring spawning stock.

The spawning migration of the **autumn spawning** herring starts in June. It spawns on the banks and the coastal slope mainly in August-September and is back on its feeding grounds in October-November. The size of autumn herring stock is low at present.

7.4 Herring in Subdivision 28

In the open part of the Subdivision 28 both spring and autumn spawning herring stocks exist. The abundance of the **autumn spawning herring** component is very low at present (below 3% of the total stock).

Spring spawning herring of the open part of the Subdivision 28 spawn at the coasts of Saaremaa and other islands west of Estonia, at the Latvian open sea coasts and in the Gulf of Riga. Spawning period lasts from April to June. After spawning the stock feeds in the open

Baltic, probably mainly in the areas of high biological productivity west of the Irbe Sound and Saaremaa. Supposedly the stock performs only rather short migrations.

A certain component of the herring stock of Subdivision 28 is distributed in the near-coast areas of the Gotland Island, west of the Gotland Deep. The data on this component are very insufficient.

7.5 Gulf of Riga herring (28.1)

This assessment unit includes one well-defined population of Gulf of Riga **spring-spawning herring (the Gulf of Riga herring)**. The Gulf herring has the smallest length and weight-at-age between other populations of Baltic herring. It does not perform long migrations (e.g., Northcote, 1978). Only minor part of the older herring leaves the gulf after spawning season in summer –autumn period but afterwards returns to the gulf. There is evidence, that the migrating fishes mainly stay close to the Irben Strait region in Subdivision 28 and do not perform longer trips. The extent of this migration depends on the stock size and the feeding conditions in the Gulf of Riga. In 1970s and 1980s when the stock was on a low level the amount of migrating fishes was considered negligible. In the beginning of 1990s when the stock size increased also the number of migrating fishes increased.

The abundance of **autumn spawning** component of the Gulf of Riga herring has been low since 1970s.

7.6 Herring in the Subdivisions 29 and 32

Herring in the Subdivisions 29 and 32 include several smaller local stocks (e.g. Gulf of Finland herring (gulf herring), locating mainly in the central and eastern parts of that gulf, Åland and Archipelago stock, Hiiumaa-Saaremaa stock).

The spawning grounds of the Gulf of Finland herring are located along the southern and northern coasts and in the archipelago of the eastern part of the Gulf of Finland. After the spawning period in May-June, the bulk of the stock remains in the eastern and central part of the gulf. Still, a fraction of gulf herring (particularly older and bigger specimens) are performing feeding migrations into the western part of the gulf and partly also into the Subdivision 29. The seasonal migrations are assumed from the changes in length composition of trawl catches (e.g. Parmanne *et al.*, 1997).

The main spawning areas of the open sea herring stocks from the Northern Baltic are located in the Åland Archipelago and in the Western Estonian Archipelago, but also in the western and central parts of the Gulf of Finland, and in the Gulf of Riga, which is well documented by the observed structure of pound-net catches in the respective areas.

Shortly after spawning this herring returns to the open sea for feeding in Subdivisions 28 and 29, remaining partly also in the westernmost part of the Gulf of Finland, what is evident from the results of acoustical investigations, catch composition observations and also from tagging experiments (Aro *et al.*, 1990, Parmanne, 1990, Parmanne *et al.*, 1997). Tagging experiments conducted in the Åland Sea have shown an extensive eastward dispersion of herring from that area (Otterlind, 1961). A considerable part of migration was directed also towards south. No northward migration (to the Subdivision 30) were observed (Otterlind, 1961). Migrations and mixing occur every year, but their extent has a strong year-to-year variation. Due to the wide migrations and active mixing of herring, the western part of the Gulf of Finland can be treated as big transition area where herring from different stocks can be found most of the year.

7.7 Results of International Acoustic Surveys as a source of information on distribution of herring

The Baltic International Acoustic Survey (BIAS), performed annually in October in order to obtain tuning data for herring and sprat assessment only partly covers the distribution area of Baltic herring omitting the Gulf of Riga, part of SD 29, the Gulf of Finland, the Bothnian Sea and Botnian Bay (Figure 7.7.1). Therefore the results of BIAS only partly describe the instantaneous distribution pattern of herring and sprat.

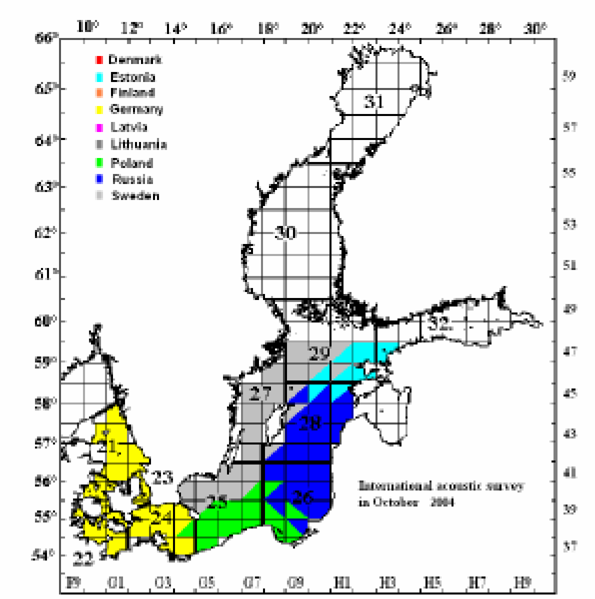


Figure 7.7.1: Area coverage by International Acoustic survey in autumn 2004.

The abundance estimates of 2004 October survey are shown in Table 7.7.1.

Table 7.7.1: Estimated numbers of herring and sprat in October 2004 by the Subdivisions. (ICES, 2005).

Estimated numbers (millions) of herring October 2004.

SD	TOTAL	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8+
21	254.48	89.86	118.29	37.16	4.83	2.26	1.94	0.13	0.00	0.01
22	1021.63	826.98	126.58	51.53	5.80	6.72	2.45	1.57	0.00	0.00
23	868.26	0.00	258.89	234.97	134.85	81.45	74.20	60.37	14.00	9.53
24	3800.19	2383.89	579.31	344.93	258.50	101.69	90.06	25.50	12.56	3.75
25	7476.52	872.90	753.51	1871.57	1567.05	1141.63	832.74	161.21	131.96	143.94
26	4974.83	803.41	289.42	671.89	780.50	765.27	695.42	354.98	305.35	308.57
27	7437.16	0.00	1343.01	4066.70	1218.51	577.31	171.89	43.66	12.06	4.02
28	8484.28	24.92	473.36	2684.62	1976.61	1732.90	665.50	527.18	169.02	230.18
29	4879.64	9.92	1309.62	2471.27	672.04	291.71	85.18	31.52	3.93	4.45
32	86.31	0.95	25.51	42.49	12.27	4.51	0.57	0.00	0.00	0.00
Total	39283.30	5012.83	5277.50	12477.13	6630.97	4705.44	2619.94	1206.12	648.88	704.44

Estimated numbers (millions) of sprat October 2004

SD	TOTAL	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8+
21	1568.74	1307.80	169.90	47.88	32.27	9.24	0.66	0.99	0.00	0.00
22	2032.07	308.07	1473.55	170.65	64.33	10.88	2.47	0.00	2.12	0.00
23	64.80	0.76	32.58	11.62	11.45	6.23	1.94	0.22	0.00	0.00
24	5076.94	572.74	3690.88	441.68	183.82	131.31	25.44	19.77	5.65	5.65
25	17229.25	25.35	8493.19	3115.53	1706.30	1796.42	613.55	713.35	242.97	522.58
26	36865.45	1817.90	19909.21	8489.20	3285.80	764.09	1528.11	264.89	492.83	313.42
27l	22620.90	0.61	10696.99	7066.08	1048.46	1727.52	353.36	757.78	264.91	705.20
28	66990.37	411.21	41240.47	13844.32	4349.77	2136.74	2022.06	388.11	1114.96	1482.74
29	30970.24	331.62	20499.87	8166.76	593.01	638.42	237.52	135.58	155.00	212.47
32	4475.24	8.34	3464.74	855.35	133.35	5.48	2.42	2.53	2.42	0.60
Total	187894.01	4784.41	109671.37	42209.07	11408.56	7226.32	4787.53	2283.22	2280.87	3242.65

The Baltic Fish Survey WG has proposed to increase the coverage to the northern part of the Subdivision 29 as well as to the Gulf of Finland during the autumn survey of 2006

8 Baltic herring growth

The Study Group made an inventory on available time-series on zooplankton abundance, hydrography and mean weights at-age to start a meta-analysis of growth changes of Baltic herring and sprat and suggested possible ways of growth modelling for stock development forecasts.

8.1 Herring growth database

A unique database on herring growth data (i.e., weight, length, age) has been assembled intersessionally and during the meeting. Presently the database contains 129875 single fish entries collected during the Baltic International Acoustic Survey (BIAS) in October 1986–2003 (Table 8.1.1). Data are available for ICES Subdivisions (SD) 25 – 29S and were provided by Sweden, Poland, Latvia and Germany. Further data from Russia will be submitted shortly after the meeting and included into the database. A separate analysis of the Russian data, which in contrast to data from the other countries contain population type (coastal vs.

open-sea), indicated significant differences in growth rates between the populations. This difference will be considered when conducting spatio-temporal comparison of growth rates.

Table 8.1.1: Number of individual herring growth records from hydroacoustic surveys per Subdivision (SD).

YEAR	SD 25	SD 26	SD 27	SD 28	SD29	TOTAL
1986	3023	3379	2906	2879	1739	13926
1987	1064	2089	2723	2656	1007	9539
1988	4030	2996	1766	3785	271	12848
1989	2804	2590	3663	2098	1226	12381
1990	2189	1240	3883	2979	1707	11998
1991	-	-	-	-	-	-
1992	2461	1222	1975	659	632	6949
1993	-	659	-	574	-	1233
1994	1874	688	1101	2079	683	6425
1995	1165	580	615	2527		4887
1996	2073	1885	965	1837	710	7470
1997	329	1258	-	1958	-	3545
1998	1538	1282	812	2420	431	6483
1999	1239	1247	538	2806	480	6310
2000	1282	3469	383	2545	186	7865
2001	1848	1449	677	2902	506	7382
2002	1040	361	873	70	587	2931
2003	1661	1209	1077	2835	921	7703
Total	29620	27603	23957	37609	11086	129875

(- no data)

A second database on herring growth data from the commercial fishery for the years 1980–2003 is presently under construction. Because of the success of the effort for herring, a similar initiative for sprat is envisaged for the meeting of SGBFFI in 2006.

8.2 Environmental data

Previous analyses in different areas of the Baltic Sea demonstrated the importance of hydrographic variability, zooplankton population size and community composition as well as competition for growth and condition of herring (Cardinale and Arrhenius 2000, Möllmann *et al.,* 2003; 2005;, Rönkkönen *et al.,* 2004). Hence, the group decided to base the analysis of the effect of abiotic and biotic environmental conditions on clupeid fish growth on these variables for which already existing and easily accessible databases are available. These are the ICES-hydrographic database, hydrography and zooplankton time-series from LatFRA and SD-specific stock sizes of herring and sprat from MSVPA-runs conducted during SGMAB. The possibility of getting data-series of especially zooplankton standing stocks from other areas will be further explored. Especially access to the HELCOM zooplankton database hold by ICES is needed.

8.3 Analysis of temporal and spatial variability

During the meeting a preliminary analysis of changes in herring condition was conducted using the hydroacoustic survey data. As condition of fish is regarded as the best descriptor of growth we adopted the approach to use a (double logarithmic) length-weight regression as an index of condition (Cardinale and Arrhenius, 2000; Winters and Wheeler, 1994; Tanasichuk, 1997). Regressions were performed on an annual basis and condition was calculated as the weight at 15 and 20 cm (CF_{15} and CF_{20}). CF at both lengths showed a similar time-trend with a decline in condition from the mid-1980s to the mid-1990s (Figure 8.3.1). An increase is visible after the year 2000 for all SDs. The downward trend in condition since the mid 1980s is even more pronounced for herring of 20cm length (Figure 8.3.2).

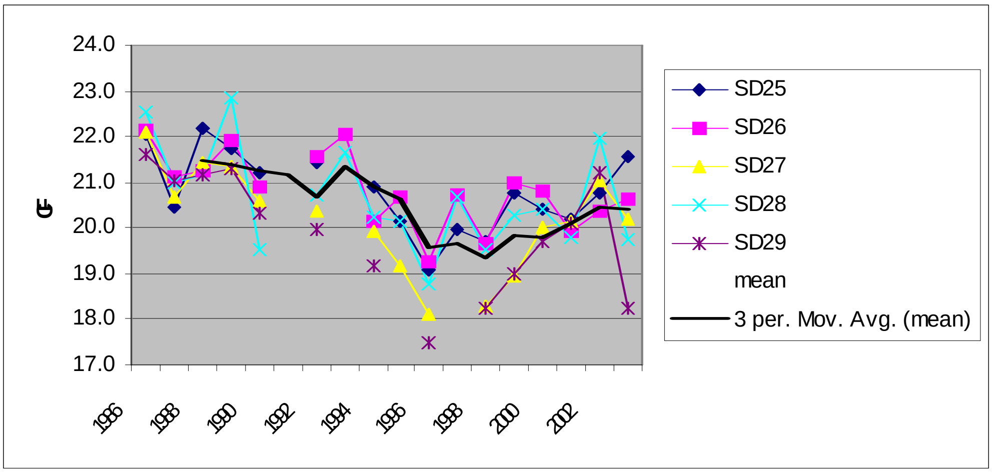


Figure 8.3.1: Condition coefficient for herring at 15cm length for different SDs and the mean as a 3 point moving average.

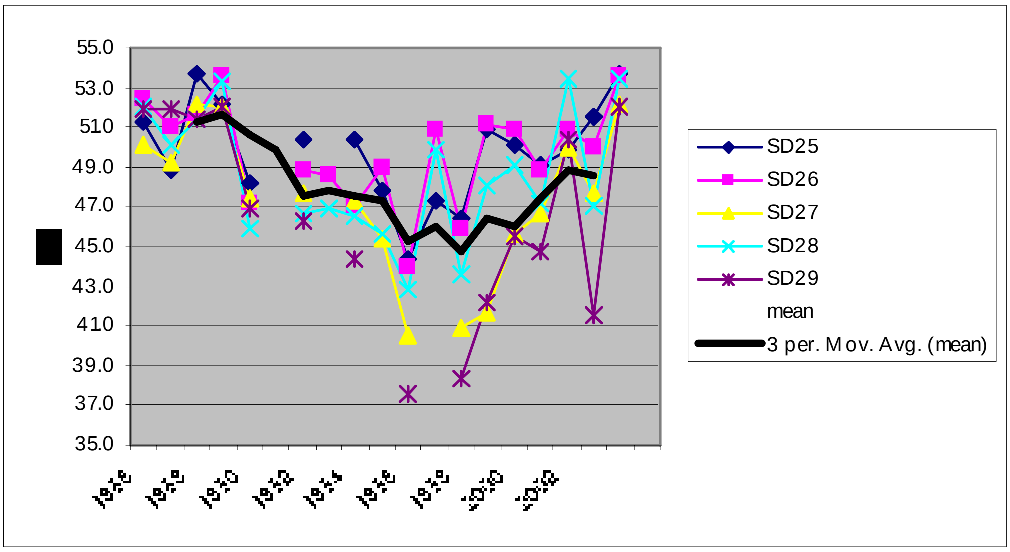


Figure 8.3.2: Condition coefficient for herring at 20cm length for different SDs and the mean as a 3 point moving average.

Cluster Analysis (Wards Method of Squared Euclidean Differences) was used to investigate spatial differences (Figure 8.3.3). Clearly, SDs 27 and 29 differ from the SDs 25, 26 and 28. Within the latter group the highest similarity exists between SDs 25 and 26. The differences between the two “area-groups” are maximal when condition is lowest during the late 1990s.

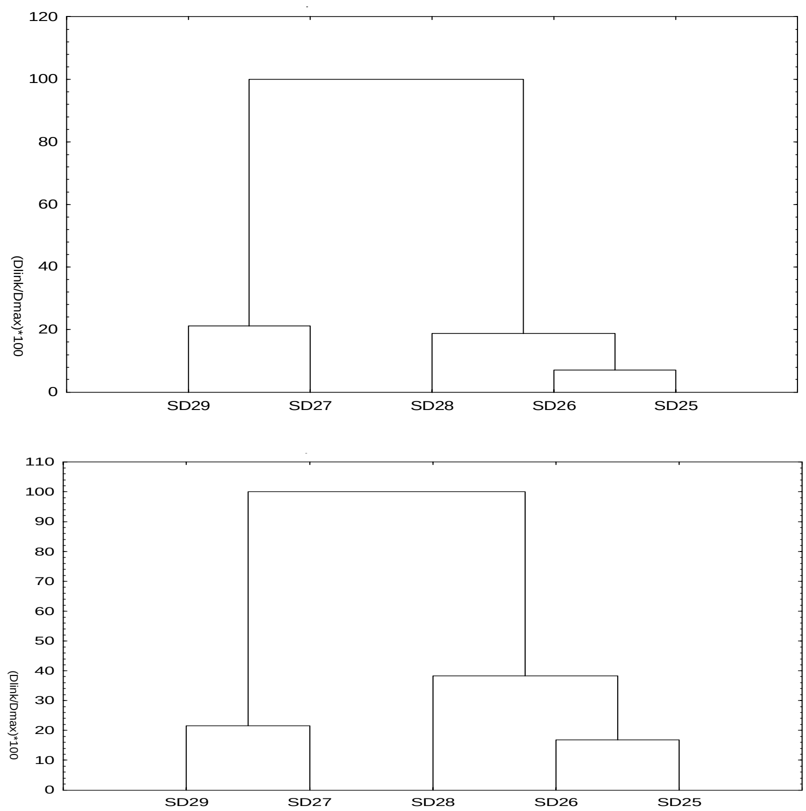


Figure 8.3.3: Results of the Cluster-Analysis of the spatial difference in CF_{15} (above) and CF_{20} (below).

8.4 Analysis of the effect of environmental variables on CF_{20}

Due to the best data available, SD 28 was selected as a case study for investigating the influence of the abiotic and biotic environment on CF_{20}. The following time-series for the years 1986–2003 were available for the analysis:

- Annual herring, sprat and total clupeid abundance and biomass of the 1^{st} quarter from area-disaggregated MSVPA;
- *Pseudocalanus* sp. and *Temora longicornis* abundance and biomass of copepodites C4–5 and adults C6 in spring (May) and summer (August) from the LatFRA database;
- Temperature and salinity in 0–50m and 50–100m in spring (May) and summer (August) from the LatFRA database.

Trends in environmental variables Sprat biomass and stock numbers increased drastically until 1995, levelling off afterwards (Figure 8.4.1). Herring stock numbers were relatively stable during the considered period while biomass was considerably lower during the second half of the 1990s. Due to the present dominance of the sprat stock, the development of the total clupeid stock resembles mostly the sprat stock.

Abundance and biomass of the dominating copepod species in the Central Baltic are displayed in Figure 8.4.2. Both in terms of numbers and biomass *Acartia* spp. is the prevailing species in spring with an increasing trend. *T. longicornis* and *Pseudocalanus* sp. are on a lower level, decreasing slightly since the late-1990s. Also in summer *Acartia* spp. is the most abundant copepod, while in biomass *T. longicornis* dominates. The *Pseudocalanus* sp. summer population declined during the considered period, while the two other copepods are relatively stable.

The hydrographic situation during the considered period is described in Figure 8.4.3. While the thermal conditions remained stable in both water layers, salinity showed differing trends. Surface salinity declined continuously, while deep water salinity increased after 1993.

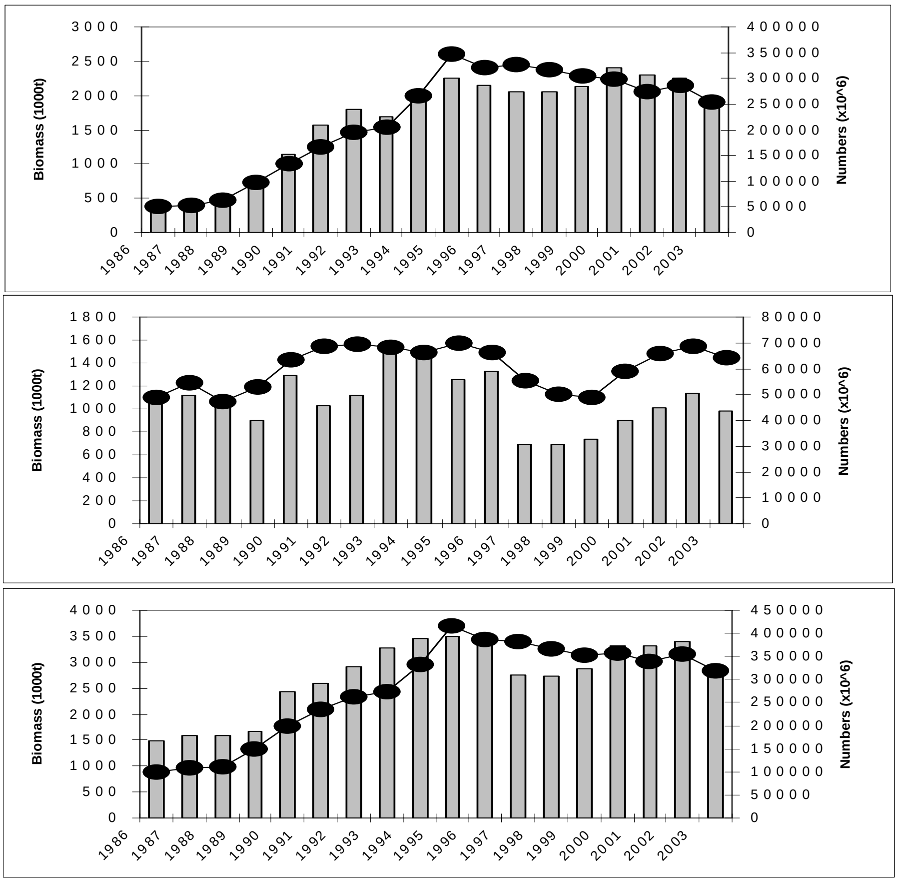


Figure 8.4.1: Biomass (bars) and stock numbers (dots and lines) for sprat (upper panel), herring (middle panel) and both summed (lower level).

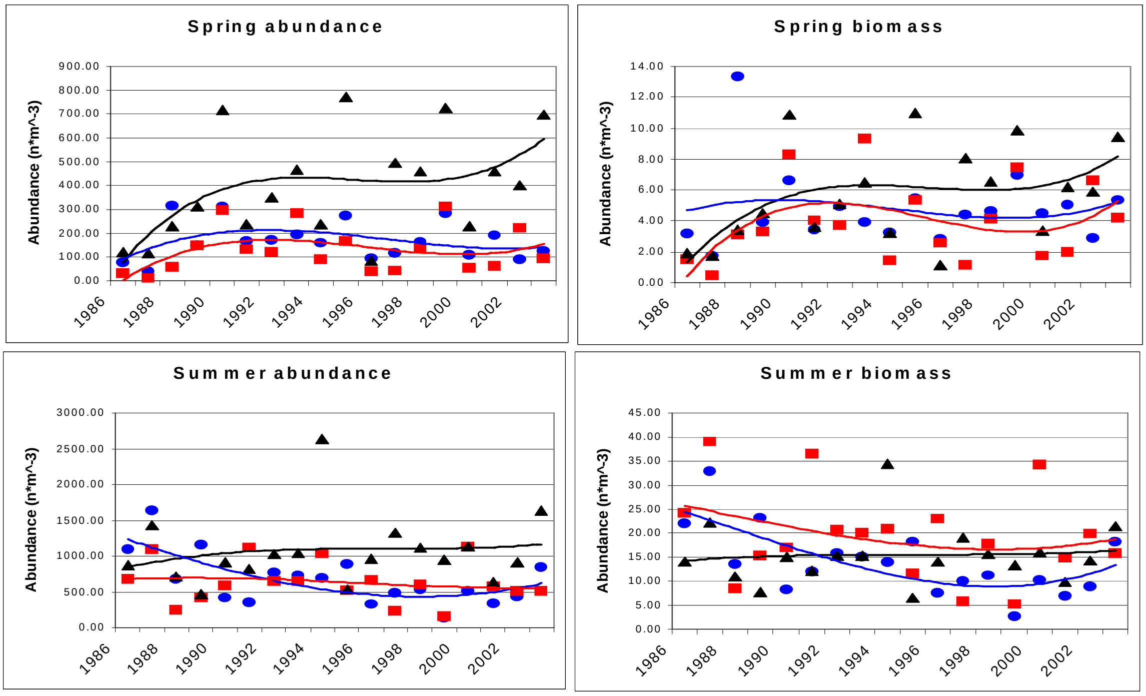


Figure 8.4.2: Abundance and biomass of *Acartia* spp. (black), T. longicornis (red) and *Pseudocalanus* sp. (blue). Lines represent a 3rd order polynomial fit.

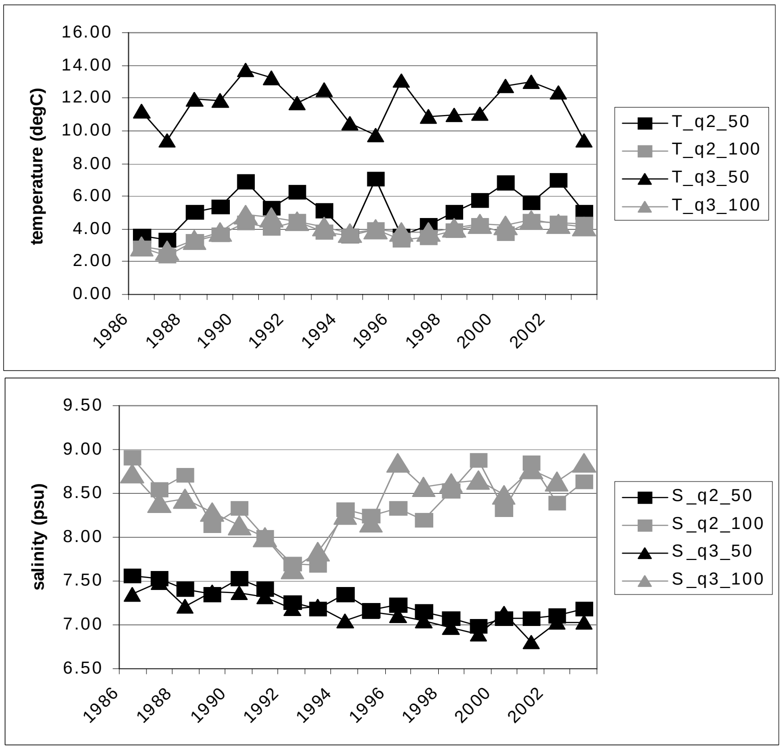


Figure 8.4.3: Temperature and salinity in 2nd and 3rd quarters in 0–50m (50) and 50–100m (100) depths.

8.5 Statistical modelling

For the statistical analyses time-series were normalized by using the natural logarithm (ln+1). General Linear Models (GLM) were used for modelling the influence of different variables on herring condition. Firstly, a stepwise selection of influential variables was performed within the three categories, i.e., clupeid stock sizes, zooplankton standing stocks and hydrography. Identified significant variables were clupeid abundance (clupnumb), *Pseudocalanus* sp. abundance (SpPsab) in spring and *T. longicornis* (SuTeab) in summer. No hydrographic variable was found to significantly relate to CF_{20}.

As the next step of the analysis a model selection approach was adopted. CF_{20} was modelled as a function of all possible combinations (1, 2 and 3-parameter models) of above identified variables. Models were compared with the Akaike Information Criterion (AIC), containing information on the explained variance, but incorporating a penalty for the numbers of parameters (Akaike, 1974). The results of the model selection exercise are given in Table. 8.5.1.

Table 8.5.1: Results of the GLM-modelling of CF_{20}. Models are ordered according to the value of the AIC.

MODEL	VARIABLES			DF	P	N	AIC	%VAR
3			Clupnumb	15	1	17	85.2	0.31
1	clupnumb	SpPsab	SuTeab	13	3	17	85.4	0.45
4		Clupnumb	SuTeab	14	2	17	86.3	0.37
2		Clupnumb	SpPsab	14	2	17	86.4	0.33
5		SpPsab	SuTeab	15	1	17	91.5	0.20

Df-degrees of freedom, p-number of parameters, n-number of data points, %Var-explained variance.

The model with lowest AIC was a simple 1-parameter model with the total stock of clupeids as the explaining variable (Model 3). The model explaining the highest variance in the data is the 3-parameter model using both copepod variables and the clupeid abundance (Model 1). For the model with the selected three variables, clupeids number explained 56%, *T. longicornis* 26% and *Pseudocalanus* sp. 18% of total variance of the model.

8.6 Discussion

The results of this preliminary analysis support recent analyses on herring growth using different datasets. Although the time-series used is relatively short, clupeids number (hypothesis of density dependence) explained the largest part of the variance, with low growth rates associated to period of large stock size of clupeids. At the same time, while *T. longicornis* has a positive effect on the herring growth, *Pseudocalanus* sp. was found to have a negative effect which is in contrast with other studies. Rönkkönen *et al.* (2004) and Möllmann *et al.* (2003; 2005), using longer time-series, showed the importance of *Pseudocalanus* sp. for herring growth in the Gulf of Finland and the Central Baltic, respectively. Also the population of *Pseudocalanus* sp., which is the main food source for herring in spring (Möllmann *et al.,* 2004a), decreased in parallel to salinity (Möllmann *et al.,* 2000), and it was pointed out as the main cause of the decline in herring growth. This inconsistency needs further exploration.

Also competition was shown to influence herring growth (Cardinale and Arrhenius 2000, Möllmann *et al.,* 2005). Competition increased drastically during the 1990s because of the high sprat stock (see above), thus decreasing the food availability for individual fish. Contrary Rönkkönen *et al.* (2004) could not find density-dependent growth in the Gulf of Finland, which is probably due to not considering the interaction with the sprat stock.

A new result from this analysis is the importance of *T. longicornis* in summer for herring condition. This is explainable by the dominance of this copepod in the diet of herring in summer, while in spring *Pseudocalanus* sp. dominates (Möllmann *et al*., 2004). Contrary to former studies (Rönkkönen *et al*., 2004); no direct influence of salinity on herring condition could be found using the present dataset. In all previous studies no effect of temperature on herring growth and condition could be detected, which is confirmed by the present analysis.

8.7 Future growth modelling for stock development forecasts

Intersessionally the present preliminary analysis of environmental variables affecting herring growth will be continued. Further analyses on sprat growth will be started as soon as the database is completed.

The final goal of these analyses is the identification of the main drivers for Baltic clupeid fish growth and incorporates these in models for stock forecasts. Our preliminary analyses point to the importance of density-dependence and zooplankton food availability for herring growth. As the density-dependence integrates in a way also the food supply, the easiest and probably most operational growth model would just a density-dependent one. A way of incorporating environmental factors would be to modify e.g. the von Bertanlanffy growth model by adding terms for the influential variable. The different possibilities of constructing growth models for herring will be further explored and preliminary models will be constructed for herring. These will be available for the next meeting of SGBFFI.

9 Environmental parameters affecting herring population dynamics

The Study Group of Herring Assessment Units in the Baltic has distinguished 11 local herring stocks in the Baltic (ICES, 2001). These local stocks differ from each other to a smaller or larger extent both in morphology as well as in dynamics of stock parameters (Figure 9.1)

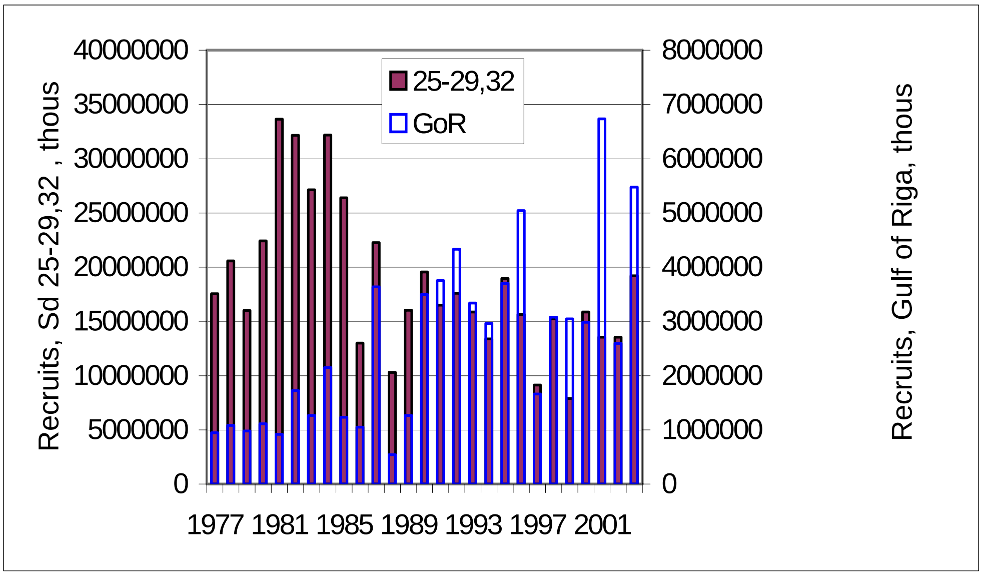


Figure 9.1: Recruitment dynamics in herring in SD 25.29,32 and in the Gulf of Riga (ICES, 2004).

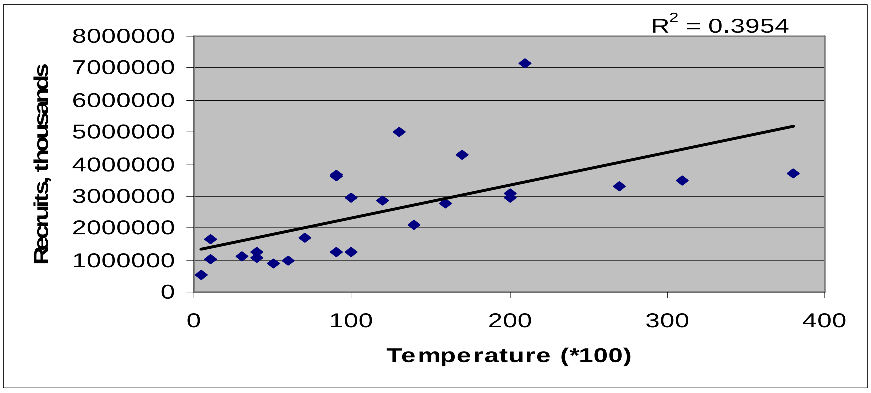
The local populations are affected by different environmental conditions prevailing in the main area distribution of every particular stock. Temperature, salinity and trophic interactions are the key factors directly and/or indirectly affecting the population dynamics. The observations have indicated that the populations inhabiting the Baltic larger gulfs have somewhat different dynamics compared to those located in the Baltic proper.

9.1 Gulf of Riga herring

Gulf of Riga herring is a slow-growing herring with one of the smallest length and weight-at-age in the Baltic and thus considerably differs from the neighbouring herring stock in the Baltic Proper (Subdivisions 25–29).

The recruitment fluctuated at the level of 1,000–3,000 millions in the 1970s and 1980s. In the 1990s the recruitment increased, reaching values above 3,000–6,000 millions In 2000s two record high year classes appeared reaching values of 7,000 millions at age 1 in the beginning of the year.

Environmental factors, particularly the winter temperature and zooplankton abundance are believed to have significant effect on the recruitment of the Gulf of Riga herring (e.g. ICES, 1995). The severity of winter significantly influences the year-class strength; already observed by L. Rannak since 1950s (Rannak, 1971). Since 1989 a period of mainly mild winters resulted in series of rich year classes and increase in SSB. After severe winters of 1996 and 2003 poor year classes appeared. It is considered that after mild winters the spawning of herring is distributed more evenly and spawning period is longer, the zooplankton abundance is higher improving the feeding conditions of herring larvae.The linear regressions plots between of estimated recruits abundance and mean surface temperature in April and mean zooplankton abundance are shown in Figure 9.2.



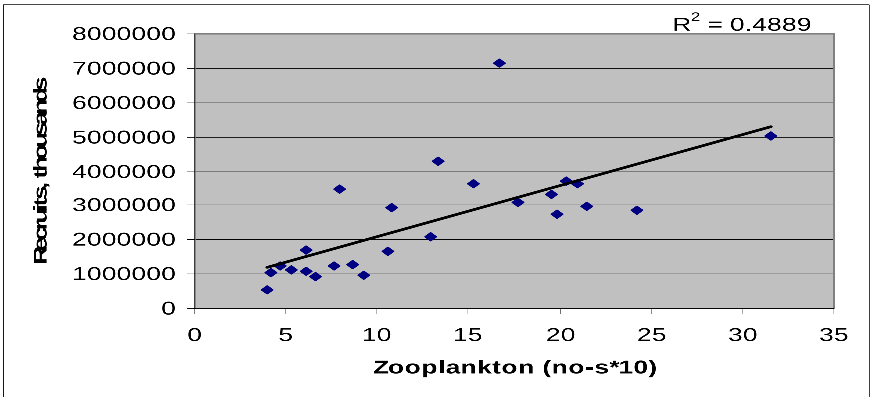


Figure 9.2: Recruitment estimates of the Gulf of Riga herring plotted against of mean zooplankton abundance in May (upper panel) and mean surface temperature in April (lower panel) (ICES, 2005.

9.2 Herring in the Bothnian Sea

The comparison of trends in recruitment (Figure 9.3) in the Gulf of Riga and the Bothnian Sea indicate that the similar hydro-meteorological conditions may favour the origin of abundant year classes in both Gulfs (Figure 9.3). The general trends in SSB are also relatively coherent over the recent decades (ICES, 2005)

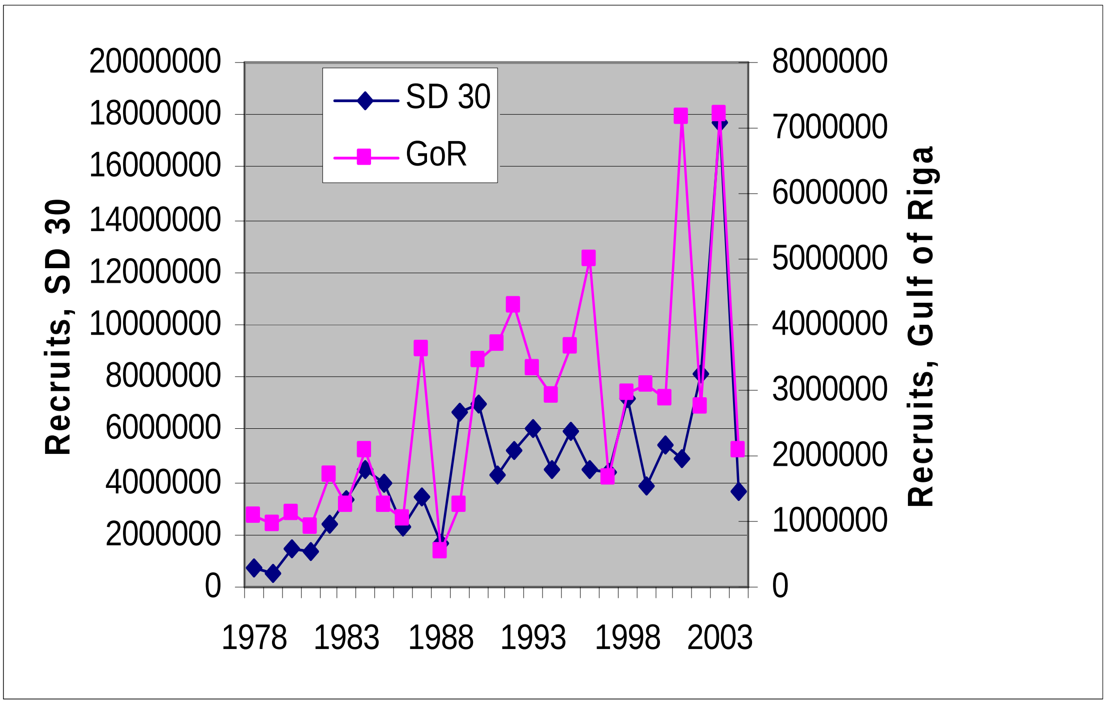


Figure 9.3: Herring recruitment dynamics in the Bothnian Sea and the Gulf of Riga (ICES, 2004).

9.3 Herring in the Gulf of Finland

The dynamics of reproduction success in the Gulf of Finland was similar to that of in the Gulf of Riga with respect to the year-class abundance during the period of the separate assessments prior to 1991 (ICES, 1992). Also in recent years rich year classes in the Gulf of Riga herring in 2000 and 2002 appeared to be abundant in the Gulf of Finland as well.

9.4 Herring stocks in the Baltic proper

The mechanisms affecting on year-class formation of herring stocks in the Central Baltic proper are not fully understood, but they seem to differ from those in gulf herring stocks. The separate assessments for three separate units in the Central Baltic performed by the Study Group on Baltic Herring Assessment Units (ICES, 2003) revealed similar general pattern in recruitment dynamics, however, the magnitude of fluctuations was higher for the southern coast herring. In 1990s mainly average or poor year classes appeared in the Central Baltic (Figure 9.4).

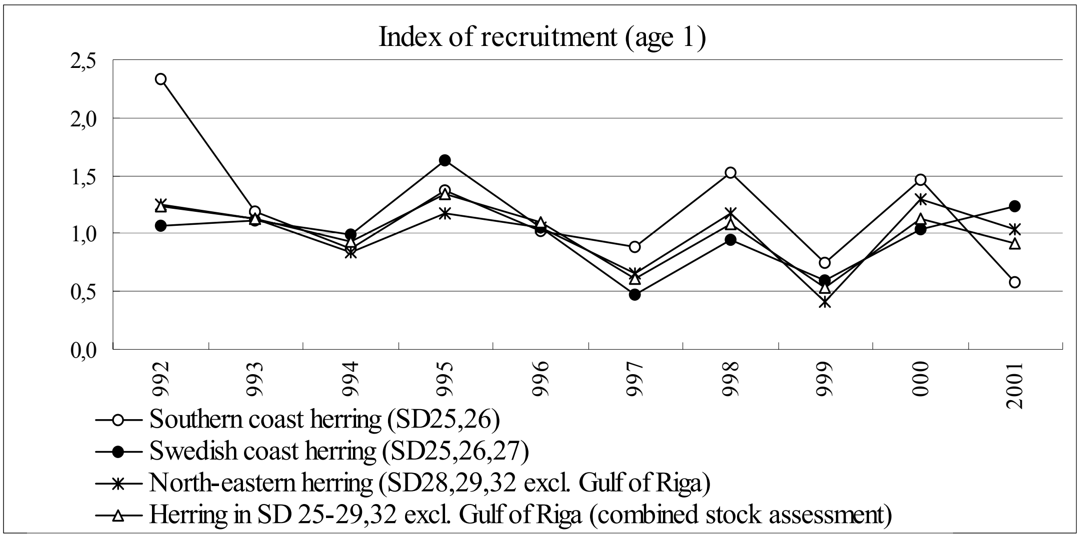


Figure 9.4: Recruitment estimates of different herring stock components and that of Central Baltic herring from 1992 to 2001 (ICES 2003)

The effect of increased sprat stock as food competitor of the herring is more obvious in the Baltic proper than compared to the large gulfs, where abundance of sprat is lower. The decrease in mean weight-at-age of herring, supported by increased competitive effect of sprat stock, possibly has effected also on reproductive capacity of herring stocks in the Baltic proper.

10 Maturation and egg production of clupeoids in the Baltic

10.1 Maturity ogives

The Baltic Fisheries Assessment Working Group [WGBFAS] has used the same maturity ogive already for many years. However, there have been major changes in hydrological conditions of the Baltic Sea and in the mean weight-at-age of herring and sprat as well as in their stocks size and relative importance of stock components in catches. Therefore one would expect the effect of those changes on maturity ogives of clupeids.

An attempt was made to apply new Baltic sprat maturity estimates, covering most of the period 1980–2001 and the ICES Subdivisions 22–26, 28–29, and 32 during the WGBFAS meeting in 2002 (Anon. 2002a). The data were supplied by the Study Group on Baltic Herring and Sprat Maturity [SGBHSM] (Anon. 2002b).

The provided maturity estimates were averaged within former sprat assessment units, i.e., the ICES Subdivisions 22–25, 26+28, and 27, 29–32 with weighting factor taken as long-term proportion of catches in the Subdivisions. The collected materials show that the all sprat individuals at age 3 and older can be assumed as mature. The maturation at age 1 and 2 were analysed using generalised linear interactive models (GLIM, Francis *et al.*, 1993). The obtained estimates showed that the interactions between area and year vs. maturation are probably not significant as the observed maturation and GLIM estimates correlate well, and the slopes of the relation are close to 1. The international results for sprat at age 1 did not show significant differences between the ICES Subdivisions 26+28 and 27, 29–32, and between years 1980–1999. The estimates basing on GLIM minimal model showed that 15% (by number) of sprat were mature at age 1 in 1980–1998, and 44% were mature in 1999–2001 (Anon. 2002b). Moreover, it was also evident that the proportion mature in age groups 1 and 2 estimated by the SGBHSM (arithmetic mean of 1996–2000) was higher than those of the maturity ogive used by WGBFAS.

From the Polish investigations of coastal spring spawning herring (1980–1999) and sprat (1980–2001) in the Bornholm Basin and the Gdansk Basin (only the Polish EEZ of the ICES Subdivisions 24+25 and 26) concerning maturity ogives it was concluded that there were considerable changes of maturity at age during the last two decades (Grygiel and Wyszynski, 2002, 2003). Along with the decrease of the mean weight-at-age of herring in the period 1980–1999 the proportion mature at age 2 decreased from 79.5 to 74.8% in the Bornholm Basin and from 91.8 to 82.2% in the Gdansk Basin. For sprat at age 1 there was an increase of the mean proportion mature in the nineties in comparison with the eighties, in the Bornholm Basin from 25.8 to 38.4% and in the Gdansk Basin from 14.5 to 18.2%. Analysis of the Bornholm Basin sprat maturation by individual years shows that there was not a linear trend but there were periods with high (1982–1984, 1991–1992 and after 1996) and low (1985–1988 and 1993–1995) proportions mature at age 1.

In 2002 the WGBFAS was aware that the statistical analysis of herring and sprat maturity can be much improved. In the analysis binomial errors should be assumed and sample size taken into account. In addition, factors such as sex, survey time (ranged from February/March to June), country, and possibly some environmental variables could be included into the maturity model. The limited time and the availability of the data did not allow the WGBFAS to conduct such an extensive analysis. Therefore it was recommended that such analysis can be undertaken by the SGBHSM. However in the following years (2003–2005) no any further international investigations related to the matters mentioned above was conducted and the SGBHSM was dissolved.

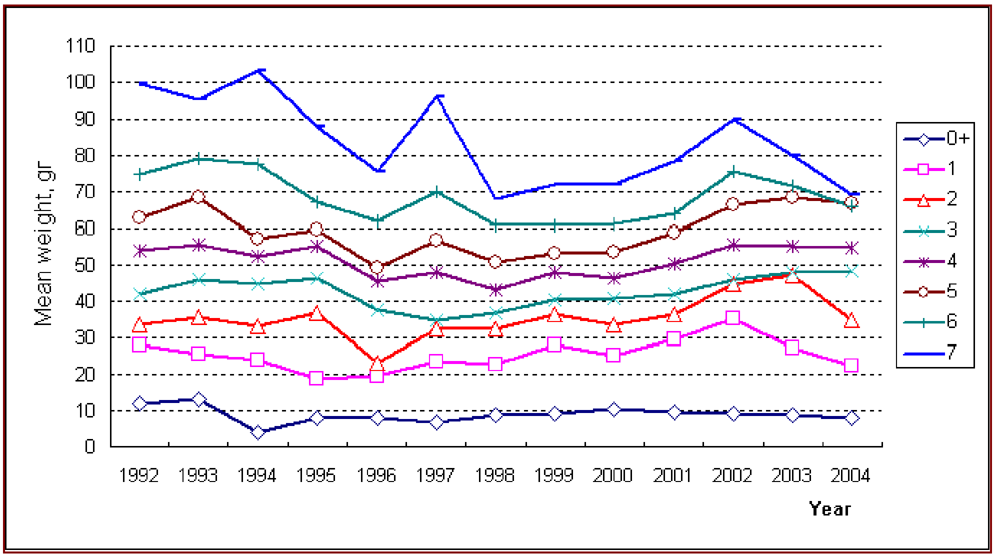
The WGBFAS has decided that until the results of further analyses are not available , the overall averages of GLIM estimates i.e., 17 and 93% mature at age 1 and 2, respectively are applied for sprat maturity at ages 1 and 2.

An analysis of herring maturity ogives based on the data from Study Group on Baltic Herring and Sprat Maturity (ICES CM 2002/ACFM:2) showed that the proportion mature at age varies from year to year and between the subdivisions.

From the Polish investigations of coastal spring spawning herring (1980–1999) in the Bornholm Basin and Gdansk Basin (only Polish EEZ of ICES Subdivisions 24+25/26) it was concluded that there were considerable changes of maturity at age during the last two decades (Grygiel and Wyszynski, 2001; Grygiel, 2002).

Along with the decrease of the mean weight-at-age of herring in the period 1980–1999 the proportion mature at age 2 decreased from 79.5% to 74.8% in the Bornholm Basin and from 91.8% to 82.2% in the Gdansk Basin.

According to the data of the Russian acoustic surveys in Subdivision 26 for the period from 1992 to 1996–1997 the mean weight-at-age of herring at the age of 2 years and older decreased, however from 1998 the stable trend towards its increase was recorded up to 2002. Further the mean weight-at-age again decreased slightly, which coincided with the appearance of very strong year-classes of sprat in 2002–2003 ad that of herring in 2002 (Feldman and Nazarov, 2005 working paper at SFBFFI) (Figure10.1).



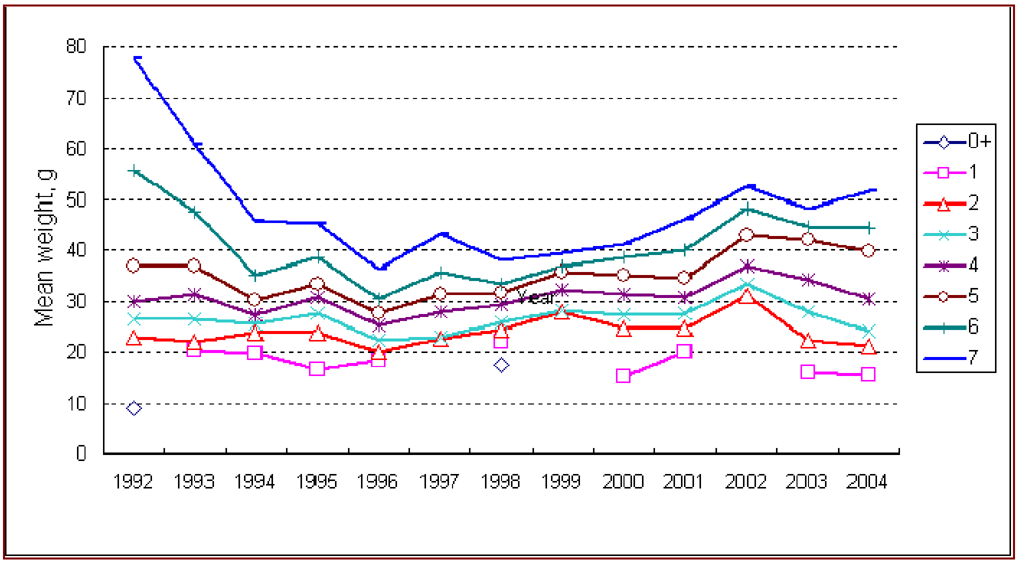


Figure 10.1: Mean weight-at-age of coastal (upper panel) and open sea (lower panel) herring in SD 26 (Hydro-acoustic surveys in 1992–2004).

10.2 Individual egg production

Egg production models for herring in the Baltic are presently not used in stock assessment, partly because the necessary input data for key parameters (e.g., individual fecundity, maturity ogives) are available for some populations and for not sufficient number of years, or are not available on an annual basis.

An analyses of individual herring fecundity revealed that the relative fecundity for herring from the Central Baltic is dependent of body size and age (Alekseeva, 2002). The specific generative production expressed in eggs numbers per gram of body weight is higher in open sea herring by 20–25% as compared to coastal herring.

No significant inter-annual variability in relative fecundity was found as it average value varied between 690–760 eggs/g in Open Sea herring and between 550–610 eggs/g in Coastal herring (Table 10.1). Relative fecundity slightly increased from January to May-June in coastal herring being stable within spawning period for the open sea herring.

Table 10.1: Mean relative individual fecundity (eggs/g) for Southern coast herring (Coastal) and Swedish coast herring (Open Sea) in different months of 1999–2001 (Alekseeva, 2002).

MONTH	1999	2000	2001
	Coastal herring		
January	-	-	**516**
February-March	**607**	**556**	**574**
May-June	**623**	**668**	**604**
	Open Sea herring		
February-March	**700**	**769**	**775**
May-June	**687**	**757**	**725**

11 Predation on cod eggs by clupeids: the impact of the environment

Predation by herring and sprat has a significant impact on cod egg survival although being variable in time and space (Köster and Möllmann, 2000). In spring and early summer sprat predation on cod is important due to the spatio-temporal overlap in sprat spawning time with cod. In summer, herring is the principal predator of cod after returning from their coastal spawning areas to their deep water feeding grounds, while sprat have mainly left the area. Because the population of herring is presently substantially lower than that of sprat, predation pressure is higher in spring than in summer (Köster and Möllmann, 2000). Egg predation was found to be considerably lower in the Gdańsk Deep and Gotland than in the Bornholm Basin (CORE, 1998), the reasons being likely a more limited vertical overlap between predator and prey.

Comparing daily cod egg consumption rates by sprat and herring populations in the Bornholm Basin during cod spawning periods with daily production rates and standing stocks of cod eggs confirmed high predation by sprat during the early 1990s, when the cod spawning season was still in spring and early summer (Figure 11.1a). Predation was estimated to be above daily production and standing stocks in 1990–1992 and above the production in 1993.

After the shift of cod spawning to summer, the importance of predation by herring increased, consuming 50 to >100% of the daily production and up to 50% of the standing stock. Assuming these consumption estimates were unrealistically high, and expressing the predation pressure in relative terms, i.e., as the ratio of daily consumption to production scaled to the maximum value determined for sprat in spring 1992 (Figure 11.1b), revealed a minimum of egg predation in 1993–1995. This can be explained by a combination of limited vertical overlap between predator and prey after the 1993 major inflow and the shift of cod spawning time to summer.

The effect of the shift in spawning time can be inferred from a seasonal comparison of the relative predation pressure during May/June and July/August 1994–1997 respectively. The predation pressure by sprat was approximately 2.5 times higher in spring/early summer than in summer, while the predation pressure by herring was approximately 8 times higher in summer than in spring (Figure 11.1b). The effect of the vertical predator–prey overlap can be deduced from a comparison between May/June 1990–1992 and 1993–1996. Sprat and herring predation decreased by a factor of 6.0 and 3.5, respectively (Figure 11.1b).

Comparing average daily rations of cod eggs by individual sprat and herring with egg abundance (Figure 11.1c), confirms that the individual egg predation by sprat follows closely the predator-prey overlap (Figure 11.1d), while the relationship is less obvious for herring.

Comparing an oxygen related egg mortality during stomach sampling cruises (Köster *et al.*, 2005) revealed a similar trend in hydrography induced egg mortality and predator - prey overlap and hence predation pressure (Figure 11.1d). This can be explained by the same hydrographic parameters affecting the vertical predator/prey overlap and oxygen related egg mortality, i.e., salinity and oxygen concentration. In stagnation periods, when oxygen and salinity conditions are low, the vertical overlap between predator and prey is high, while opposite conditions release cod eggs from clupeid predation.

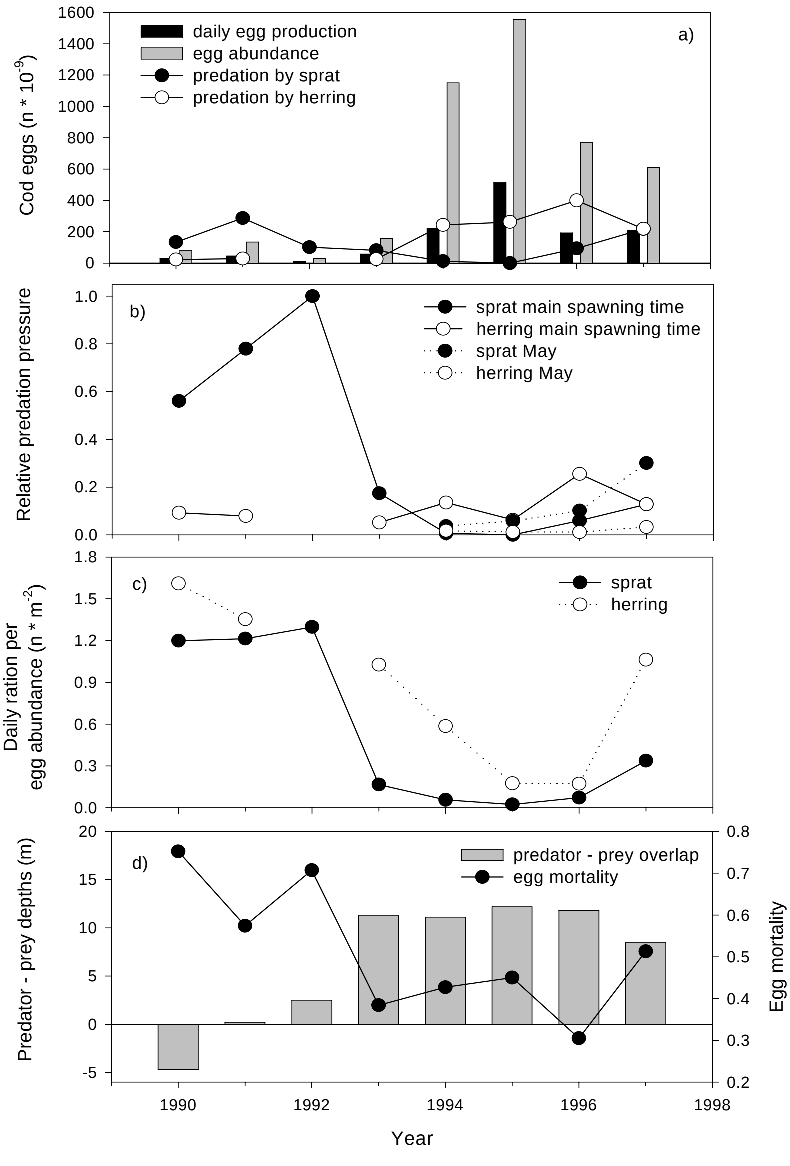


Figure 11.1: Daily cod egg consumption by clupeids in the Bornholm Basin during main spawning periods in comparison to daily production rates and standing stocks of eggs (a); corresponding relative predation pressure (b); daily ration by individual sprat and herring per egg abundance (c); spatial overlap between predator and prey and cod egg mortality based on vertical resolving ichthyoplankton and hydrography sampling during stomach sampling cruises (d).

12 Workplan for 2006–2007

Progress in multispecies modelling oriented work in the Baltic is coupled to various scientific activities within ICES, i.e., to i) multispecies model development (follow-up on SGMSNS), ii) Baltic fish stock assessment (WGBFAS, WGBIFS and related Study Groups SGABC), iii) Baltic ecosystem assessment (BSRP related Study Groups and suggested initiatives), but also activities outside ICES, i.e., the EU project BECAUSE. The interaction between these various groups and their coordination is discussed under Section 12. Tasks, which specifically SGMAB has planned to address in 2006 and 2007, comprise the following:

12.1 Technically oriented activities

This includes a validation, maintenance and update of the various input databases.

Stock structure

The Gulf of Riga herring is included in the key-run for the central Baltic, while it is excluded in the single species assessment. Gulf of Riga herring has been excluded in the area disaggregated MSVPA for Subdivision 28 by subtracting catch-at-age data for Gulf of Riga from the total catch-at-age in Subdivision 28 for periods since 1980. However, the group is of the opinion that the exercise should be done from scratch, i.e., split the landings and apply age-length keys. Independent of the decision how to tackle this, a recompilation of weight-at-age is pending.

Age structure

Any potential corrections for age-reading discrepancies in cod developed by SGABC and implemented by WGBFAS needs to be conducted for the multispecies databases as well.

Catch-at-age

The catch-at-age data of cod, herring and sprat as input into the Central Baltic MSVPA needs to be quality checked for periods before 1980 and especially data before 1976 has to be considered as unreliable at present. Additional age composition data for cod catches have been compiled for the period 1980–1985, and need to be incorporated into the database.

The single-species assessment of the western Baltic herring has been revised by the Herring Assessment WG (ICES 2002/ACFM:12), applying a revised methodology of splitting catches between North Sea and Western Baltic herring in Kattegat/Skagerrak. This revised catch-at-age matrix is available only backwards until 1990, which hampers Western Baltic MSVPA runs for periods with good stomach sampling, i.e., needed to estimate prey suitabilities.

Catch-at-age and related weight-at-age data for cod and sprat in the western Baltic are regularly compiled by WGBFAS, these need to be integrated into the database for 2002–2004.

Discards are included in the singles species assessments of cod, but discard data are not included in the multispecies database. This is expected to have a minor impact on eastern Baltic cod, but for Western Baltic cod, a revision of catch-at-age data needs to be conducted. In this respect an initiative which not only compiles the available discard data, but tries to model is highly encouraged.

Weight-at-age in the stock and maturity ogives

WGBFAS has compiled weight-at-age in the stock data for cod, based on first quarter bottom trawl surveys. Data on weight-at-age in the stock for herring and sprat are available from international hydroacoustic surveys conducted annually in September/October. More data is available from fourth quarter BITS and second quarter hydroacoustic surveys respectively, however, not covering all quarters, which consequently requires modelling of seasonal growth to ensure complete seasonal coverage.

For modelling growth and sexual maturation there are different avenues to proceed. Firstly, for all three species simple relationships between i) weight-at-age and stock size may be used, ii) weight-at-age may be predicted from weight-at-age within a cohort at an earlier age. Secondly, historical variation in weight-at-age and coupled to it maturity at age may be modelled by taking into account temperature and size selective predation by cod as well as fishing activity, see section on scientific issues below.

Stomach contents

The present stomach content database contains information for the eastern and western Baltic from 1977–1994, while information from preceding and later periods is not included. Intersessional work coordinated with SGBFFI should be allocated to digitize information prior to 1977. The level of integration for all new and old data to be included in the database should be as low as possible, i.e., keeping information on single stomach contents as well as date and location of sampling before aggregating on age, quarter and subdivision level. The initiative will be closely coordinated with SGBFFI.

SMS utilizes prey length information and this should be considered when compiling the new stomach content data. For converting existing data, age-length keys need to be compiled by the national laboratories. Within the EU project BECAUSE a corresponding guideline will be written.

Consumption rates

A revision of the consumption rate model used for western Baltic cod is still pending, i.e., the revised North Sea model introduced in 1999 for eastern Baltic cod has not been introduced. This requires estimation of ambient temperatures based on depth-specific distribution and hydrographic data.

12.2 Scientifically oriented activities

Consumption rates

Exploratory analyses indicated a considerable impact of oxygen concentration on cod stomach evacuation, leading to lower consumption rates than previously estimated and thus even larger discrepancies to results from bioenergetic models. These deviations need to be explored considering the impact of low oxygen concentration on metabolism and growth as well. In this respect stomach content data on lower level of integration is needed, see above, to explore the reasons for the high intra- and interannual variability in Baltic cod stomach contents.

Spatial heterogeneity

Spatially disaggregated MSVPA runs have been conducted for the Central Baltic. The results have indicated that passive transport of youngest life stages of cod and migration by juveniles into/out of their nursery areas as well as spawning migrations of adults between different subdivisions are likely to occur. Similarly for herring and sprat, the MSVPA output did not match the distribution pattern as obtained from research surveys, also indicating migratory behaviour, although correction of catch-at-age input data improved the match for herring considerably. The impact of variability on smaller scales, e.g. within subdivisions, has not been explored yet, see next section.

Suitability model

The selection of the suitability sub-model has only limited impact on the population dynamics of major prey species and independent of the model in use relative stock developments will be similar, as long as suitability coefficients are kept constant over time.

For cod cannibalism, which shows considerable fluctuations in intensity, both available suitability sub-models overestimate the predation mortality acting on juvenile cod in the majority of years and underestimate the predation mortalities in the few years with relatively high occurrence of cod in cod stomachs.

Modelling of suitability coefficients considering environmental factors triggering predator/prey overlap appears to be a rewarding approach, which should include an investigation of the occurrence and intensity of prey switching.

The present assumption of constant suitability coefficients appears to be inconsistent with observed changes in growth. SMS will model size specific prey preferences, avoiding this assumption.

Coupling growth, maturation and reproductive potential

Models on growth and maturation of cod coupled to food availability are implemented into 4M, but do not include environmental variables, i.e., temperature and oxygen, affecting food consumption and food conversion.

Growth modelling of pelagic fishes (herring and sprat) will be conducted intersessionally in cooperation with SGBFFI and EU BECAUSE project considering environmental variables (e.g. hydrology and zooplankton).

Any potential impact of nutritional condition on egg production and viability of offspring and thus on recruitment is not resolved and consequently missing in projections utilizing stock recruitment relationships.

Stock recruitment

The present version of the 4M programme package is able to handle a variety of stock recruitment relationships with and without stochasticity, as well as stochastic recruitment derived from normal or log-normal distributions. However, environmental impact on reproductive success which is substantial in Baltic stocks is not yet considered.

Environmentally sensitive stock recruitment relationships are available and may be used to model recruitment. Changes in major environmental conditions may prove to be impossible to predict, even a generation time ahead, leading to the conclusion that stochastic approaches or choosing scenarios, e.g. utilization of historic time series, may be the only way to proceed.

Recruitment processes are highly complex, i.e., include maternal impacts, direct hydrographic impact on egg and larval mortality, zooplankton/fish interactions and predation on early life stages. How these interacting and partly successive processes are represented in the models, i.e., via simple indicators (temperature, salinity) or in complex formulations, needs to be explored.

12.3 Management oriented activities

The implementation of suitable medium- to long-term projection methodology for simulation of stock and catch development under different fishery actions and environmental scenarios is a major work task. These projections will be used to explore harvesting strategies and harvest control rules and to test for fishing strategies having a high probability of sustaining both stable stock sizes and high yield. The exploratory long-term forecasts conducted by the present group demonstrated for cod that considering cannibalism reduces the expected increases in yield and stock considerably when fishing at 0.5 * F_{PA} in comparison to simulations conducted by ICES (2005/ACFM:25) and utilised in the 2005 ACFM advice. Furthermore, the impact of a cod stock recovery on clupeid stocks needs to be evaluated.

ACFM has suggested the establishment of a Study Group with the task to revise biological reference points for Baltic fish stocks. To test these reference points utilizing medium- to long-term multispecies projection methodology is a further important work task. These tests require clarification of management objectives, e.g. maximum or stable yield in quantity or economics, stable upper trophic level structure etc.

Furthermore, methodology to evaluate the impact of technical measures, e.g. mesh size changes, closed areas or seasons, on stock and fisheries development needs to be developed. SGMAB expects that the WG on Fisheries Systems as well as related EU projects EFIMAS and COMMIT will cover this task for Baltic cod, while SGMAB will develop biological interaction model components to be used in the evaluation frameworks.

13 Regional integrated assessment and research organisation in the Baltic Sea within and outside ICES

This document is a result of the joint meeting of SGMAB and SGBFFI in Riga, June 2005. While reviewing TORs f) – i) of SGMAB in 2005 (see below) dealing mainly with the future of the SG, the coordination with other SGs (especially those related to the BSRP) and contributions to the 2006 Theme Session on Regional Integrated Assessments, the need to re-organise the Baltic Sea research within ICES was discussed. The main arguments for re-organising the WG/SG-structure were:

1) the need for advancing towards an Integrated Assessment (IA) of the Baltic Sea ecosystem similar as initiated for the North Sea (i.e., REGNS), as a basis for implementing the Ecosystem Approach to Fisheries Management (EAF) in the Baltic;

2) the need to react on the changing advisory requests after the replacement of IBFSC by bilateral negotiations between the EU and Russia;

3) the need for an improvement of coordination of the WG/SG-work with other environmental organisations (e.g. HELCOM, EU Marine Strategy);

4) the need for an improvement of coordination of the WG/SG-work with the multitude of activities/research projects outside ICES (e.g. EU-funded projects such as EFIMAS, BECAUSE, PROTECT).

Presently the research in the Baltic Sea is conducted within a variety of fora ranging from ICES WGs and SGs, EU-funded research projects and STECF WGs, to HELCOM WGs and projects (see Appendix 2). Between these different working frames, tasks and duties are either partly overlapping, although often conducted by the same institutions and/or scientists (e.g. ICES vs. STECF), or a tight connection on the working level is yet to be established (ICES vs. HELCOM). Even within the ICES Baltic community, activities are diversified in several sub-groups either overlapping in themes or being widely separated, thus hampering an integrated view on the ecosystem.

ICES presently faces the challenge to implement an EAF for which an IA of the ecosystem is needed as a basis. Consequently a regional ecosystem SG has been implemented North Sea (REGNS). In the Baltic Sea community a step towards this goal was made by implementing the GEF Baltic Sea Regional Project (BSRP). The project and its affiliated ICES SGs (SGBFFI, SGPROD, SGBEH and SGBEM) made considerable improvements in widening the perspective within the ICES Baltic community from rather “fish and physical environment – focused” to a more integrated view including lower trophic levels, ecosystem health issues and alternative approaches to ecosystem modelling. The project further initiated the development of indicator sets for assessing the state of the ecosystem and initiated progressive initiatives which should be templates for the future work, e.g. a combined ecosystem hydroacoustic open-sea survey. BSRP has further strengthened the communication and cooperation with HELCOM.

Despite of these successes, the present approach of implementing an IA using BSRP as a vehicle, has several shortcomings: (i) the participation of non-funded “western” countries is limited and decreasing, which has the risk of separating communities, (ii) the different “discipline groups” work still largely separated hampering an IA, and (iii) as the future funding of BSRP is unclear; there is a risk to loose the first steps towards an IA when not implemented in the broader community.

The above discussed challenges the present organisation of the work within the ICES Baltic science community. A new structure should consequently be developed providing the following:

1) a platform for conducting an IA;

2) a concentration of the work in a reduced number of WGs/SGs;

3) a better “outside communication/cooperation” with the EU-commission (i.e., STECF, JRC and EU-funded projects), as well as HELCOM and other international initiatives (e.g. BALTEX, BOOS, GLOBEC);

4) flexible tools to react on “hot topics” or “short-notice tasks”.

In Figure 13.1 a suggestion for a new ICES working group structure in the Baltic is sketched. This structure is suggested as a basic discussion frame which needs involvement of the different WG/SGs, the Baltic Committee as well as the three ICES advisory committees.

The structure is centred on two assessment groups, one for fish stocks and fisheries (FA WG) and one for the IA (IAWG). Both groups will be supported by observational data from an “Ecosystem Survey Group” (ESWG). This group will be central in implementing the IA and the EAF as it should develop in cooperation with HELCOM the present trawl and hydroacoustic surveys into ecosystem surveys which provide both “tuning” and “ecosystem” data.

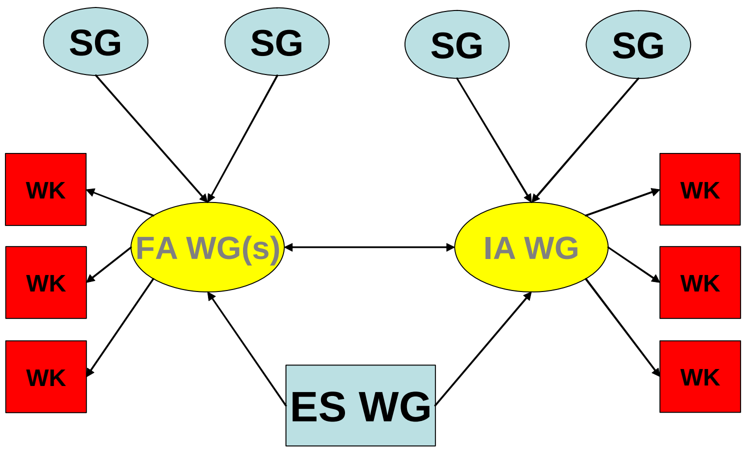


Figure 13.1: Suggestion of a new structure for the ICES Baltic Sea assessment and scientific activities. [SG-Study Group, WK-Workshop, FA-Fish stock assessment, IA-Integrated assessment, ES-Ecosystem survey].

Both assessment groups will be supported by a limited number of SGs providing them with additional knowledge and information. On the “fish-side” this should include assessments and related issues, like multispecies modelling and age-determination. For the “ecosystem-side” this should include physical, chemical, lower trophic level (phyto- and zooplankton) and ecosystem modelling expertise, thus integrating the present BSRP-groups. A major task of these groups will be to facilitate the communication to scientific activities outside ICES, e.g. to EU-funded projects (from the “fish-side”) and to HELCOM (from the “ecosystem-side”).

An important part of this suggested structure should be the increased use of workshops (WK). These should be vehicles to tackle “hot topics” or “short-notice tasks” coming up in various groups and should be solved in common, avoiding diversification and doubled work.

The most important change in this structure is the implementation of an IAWG. This will (i) assure the conservation, further development and the integration of the work done within BSRP in the broader scientific community, (ii) fulfil the request for an IA, which (iii) enables ICES to react on the new requirements in terms of advice which is due to the change in the management system of the Baltic and European waters.

A second important issue will be the development of a common monitoring programme combining all available resources to effectively survey the whole ecosystem as a basis for an IA.

A selection of SGMAB TORs which initiated the discussion

f) consider how the results of the Study Group on “Fish and Fisheries Issues in the BSRP (SGFFI)” can be incorporated into the work programme of this Study Group;

g) prepare a workplan, including a schedule for deliverables for the next two years;

h) propose contributions to the 2006 Theme Session on Regional Integrated Assessments, as described in the 2003 report of the Regional Ecosystem Study Group for the North Sea;

i) plan a meeting in 2006 as a joint or overlapping meeting with at least one other Baltic SG (e.g., SGPROD, SGGIB, SGBEM) in order to promote the development of integrated ecosystem knowledge and the integration of work across expert groups;

A table listing a selection of different groups presently involved in Baltic Sea research, monitoring and advisory tasks within ICES, the EU and HELCOM.

ICES	**ICES**	**EU**	**EU**	**HELCOM**
Scientific side	Advisory side	Advisory side	Scientific side	Groups and projects
Baltic Committee Study Group on Multispecies Assessment in the Baltic ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic	ACFM Baltic Fisheries Assessment Working Group Baltic Salmon and Trout Assessment Working Group Study Group on Ageing Issues in Baltic Cod	STECF Sub-group on Research Needs and Data Collection: Regional Coordination Meeting (RCM) for the Baltic Sea Area	EFIMAS Operational Evaluation Tools for Fisheries Management Options. COMMIT Creation of multiannual management plans for commitment	Working programme for the Monitoring and Assessment Group (HELCOM MONAS) Nature Protection and Biodiversity Group (HELCOM HABITAT)
BSRP Study Group on Baltic Sea Productivity Issues Study Group on Baltic Ecosystem Health Issues Study Group on Baltic Ecosystem Model Issues Study Group on Baltic Fish and Fisheries Issues	ACME ICES/HELCOM Study Group on Quality Assurance of Chemical Measurements in the Baltic Sea ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea	STECF Sub group on review of stocks.	BECAUSE: Critical Interactions Between Species and their Implications for a Precautionary Fisheries Management in a variable Environment – a Modelling Approach PROTECT Marine Protected areas as a tool for ecosystem conservation and fisheries management	Projects Development of tools for a thematic eutrophication assessment (HELCOM EUTRO) Zooplankton Expert Network Project for preparation of the Fifth Baltic Sea Pollution Load Compilation
Fishing Technology Committee Study Group on Target Strength Estimation in the Baltic Sea	ACE Working Group on Marine Mammal Ecology Working Group on Ecosystem Effects of Fishing Activities	STECF Sub-group on Fisheries and Environment	EU Sampling Directive Commission Regulation establishing the minimum and extended programmes for the collection of data in the fisheries sector	Review the HELCOM monitoring and assessment programmes (HELCOM MON-PRO) Development of Ecological Quality Objectives within the Baltic Sea (HELCOM EcoQO)
Living Resources Committee Baltic International Fish Survey Working Group				Implementation of the Joint HELCOM/OSPAR Work Programme on Marine Protected areas (HELCOM-BSPA) Developing a harmonized reporting form for ICZM (Integrated Coastal Zone Management) (HELCOM ICZM)

14 Evaluation of first joint SGMAB and SGBFFI meeting

One of the main tasks of the BSRP in relation to fish stocks is to progress from single to multi-species assessments. To facilitate this process, a joint meeting of SGMAB and SGBFFI was planned during the ICES Annual Science Conference in Vigo 2004. A joint meeting seemed to be appropriate as SGBFFI has i) initiated several data compilation initiatives, e.g. mean weight-at-age of Baltic herring and sprat, cod otolith weight, ii) started a revision of the cod stomach database, and iii) performs or plans several activities in relation to the update of assessment databases including environmental data sets. These data are of prime importance for multispecies assessments and forecasts conducted by SGMAB.

Taking into account the close link between SGMAB and SGBFFI the joint meeting allowed:

1) a verification of progress made in SGBFFI and BSRP towards multispecies assessments;
2) adjustments and modifications of SGBFFI future activities within the BSRP;
3) the coordination of Baltic Sea ecosystem related data collections;
4) the participation of and an increased number of participants and expertise in both meetings.

However, taking into account the SGBFFI terms of reference, it is clear that they can be separated into two groups: related to coastal and open sea activities. The link between open sea and costal work is relatively weak and international coordination is done on different levels. Open sea activities directed to the main internationally assessed and managed Baltic commercial fish species (cod, herring and sprat) have a significantly higher international coordination via ICES Working/Study Groups and EU research projects (e.g. BECAUSE, PROTECT, UNCOVER). International cooperation in the field of research and monitoring of other fish, both commercial and non-commercial (often also called as ‘coastal fish’) is less advanced. Coastal fish data collection and research depends on national interests and is almost exclusively based on national funding. Only for some countries coastal fish is integrated into monitoring programmes coordinated by HELCOM. It can be stressed that SGBFFI may serve as an essential forum for international coordination of coastal fish activities in the Baltic Sea. In addition, HELCOM is also interested in the outcome of coastal fish assessments and there exists an agreed sampling format for coastal fish within HELCOM. However, based on the currently rather weak international cooperation and in some countries very low national funding, it is very problematic to form self-standing, effective and in a long-run operating ‘coastal fish’ study group.

Above mentioned considerations raised a discussion during the joint meeting about the future role of both groups in the framework of ICES and the Baltic Committee. The result of discussions, how we see the future is presented in chapter “Regional integrated assessment and research organization in the Baltic sea within and outside ICES” (see chapter 13).

A shortcoming of the joint meeting of SGMAB and SGBFFI to be mentioned was the significant time problem for several members participating in both groups. Taking into account the high work load of Baltic scientists involved, related to other ICES activities, EU funded research projects and *ad hoc* groups, this lead to the situation that some members were able to participate only part time in the meetings.

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Annex 2: Draft 2005 Resolution (Category 2)

The **Study Group on Multispecies Assessment in the Baltic** [SGMAB] (Co-Chairs: E. Aro, Finland, and F. Köster, Denmark) will meet in Helsinki, **XXXX** May 2006 to:

a) review the progress of the stomach sampling program, its sampling protocols and set-up of formats for inclusion of new information in the international stomach content database;

b) update and correct the multispecies database (i.e., catch in numbers, maturity ogives, mean weight-at-age) for the Eastern and Western Baltic to enable bi-annual key-runs for both areas,

c) validate of the consumption rates for Eastern Baltic, cod considering the impact of low oxygen concentration, and revise the Western Baltic consumption rates;

d) develop a concept for inclusion of environmental sensitive and spatially explicit stock recruitment relationships into multispecies predictions;

e) include coupled weight-at-age, proportion of maturity at age and consumption process models in multispecies prediction models;

f) evaluate biological reference points by suitable medium- to long-term projection methodology simulating stock and catch development under different fishery scenarios and management objectives;

g) coordinate multispecies and ecosystem modelling activities with relevant BSRP Study Groups, ICES multispecies groups and EU-projects.

SGMAB will report by **XXXXXXX** for the attention of the Baltic Committee.

Supporting Information

Priority:	The activities of this Study Group will produce updated information on predator-prey relationships in the Baltic, it develops enhanced multispecies models and medium- to long-term projection methodology enabling an evaluation of biological limit and target reference points in a multispecies context which should be considered to have a high priority in future management advice.
Scientific Justification and relation to Action Plan:	As approved in 2003 and 2004 the Study Group will concentrate on issues related to historical stock developments by traditional multispecies modelling and more sophisticated stochastic modelling as well as on medium- to long-term multispecies prediction methodology. The Group furthermore takes into account environmental processes, which are affecting growth, maturation and subsequent recruitment success in their multispecies prediction models.
Resource Requirements:	For the 2006 meeting (May) computer and printing facilities as well as copy machine should be made available from organising institute (Helsinki, FGFRI). In order to have the latest information available at the meeting it is necessary to have the meeting after the WGBFAS meeting in April 2006.
Participants:	The Group is normally attended by some 10–15 members and guests
Secretariat Facilities:	None
Financial:	No financial implications
Linkages To Advisory Committees:	ACFM, The quality of stock assessments and management advice of Baltic herring, sprat and cod stocks.
Linkages To other Committees or Groups:	WGBFAS, WGBIFS, Resource Management Committee, SGFFI and other ICES BSRP groups
Linkages to other Organisations:	EU DG Fish
Secretariat Marginal Cost Share:	ICES 100%

Annex 3: MSVPA Input data on catch in numbers and cod consumption

Table 1 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Cod

Age	1974				1975				1976	
	1	2	3	4	1	2	3	4	1	2
0	_	_	_	_	_	_	_	_	_	_
1	15	_	_	294	26	_	_	386	45	20
2	2862	1994	1964	5185	3823	2567	2582	6781	3824	406
3	31672	15297	10656	13863	42261	19710	13983	18130	33923	6261
4	44653	31334	7264	9949	59583	40401	9534	13029	61044	25154
5	7592	6336	2385	2881	10148	8194	3124	3790	16009	18467
6	3321	1998	893	532	4435	2575	1166	702	5200	7908
7	1285	227	72	8	1714	293	96	14	1088	1370
8	734	_	22	2	979	_	29	4	483	118
9	_	_	_	_	_	_	_	_	_	_
0	_	_	_	_	_	_	_	_	_	_
10	_	_	_	_	_	_	_	_	_	_
11	_	_	_	_	_	_	_	_	_	_

(Continued)

Age	1976		1977				1978			
	3	4	1	2	3	4	1	2	3	4
0	_	_	_	_	_	_	_	_	_	_
1	55	902	6	1	6	712	17	3	473	207
2	538	2479	2940	968	597	1161	1368	2097	8939	7628
3	6322	6680	15861	10132	2486	4169	19069	14843	11064	14864
4	8058	8621	20728	14558	2760	4350	16562	13478	5708	10906
5	1528	4136	11561	12639	2378	4224	11318	9425	2307	5078
6	903	1450	5710	4630	986	1226	3526	3417	847	1868
7	352	558	1619	1139	409	580	931	822	165	541
8	123	228	428	361	41	199	262	128	21	100
9	_	_	49	27	5	79	108	43	13	60
0	_	_	_	_	_	_	_	_	_	_
10	_	_	49	27	5	10	77	31	9	38
11	_	_	_	_	_	_	_	_	_	_

(Continued)

Age	1979				1980				1981	
	1	2	3	4	1	2	3	4	1	2
0	_	_	_	_	_	_	_	_	_	_
1	_	_	176	621	_	9	20	643	122	300
2	6982	6240	3381	3849	15920	8582	3181	6038	10831	5596
3	65189	48402	21934	25702	53034	44210	19526	18620	27845	15931
4	42146	29678	14556	11520	54495	54456	34561	27856	40427	30888
5	13448	12030	7414	5697	17087	26645	11248	9734	35727	35160
6	2840	3035	1654	1465	4371	10408	3775	1840	12296	13929
7	617	1401	1184	603	2483	1043	701	185	4074	2077
8	185	360	541	43	1152	512	25	9	749	230
9	91	65	16	21	1	3	_	_	128	4
0	_	_	_	_	_	_	_	_	_	_
10	_	_	_	_	1	2	_	_	125	1
11	_	_	_	_	_	_	_	_	_	_

(Continued)

Table 2 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Cod

Age	1981		1982				1983			
	3	4	1	2	3	4	1	2	3	4
0	_	_	_	_	_	_	_	_	_	_
1	852	1404	_	7	423	4629	13	_	_	1467
2	4769	5551	17695	13908	10250	8748	15363	11478	9322	6292
3	9324	9826	65124	31987	18704	20663	59045	36820	11177	13005
4	22464	14865	44241	20101	11248	12731	57702	52753	18634	15881
5	6859	6362	20195	11015	5733	3386	12909	19024	8300	5845
6	2168	1548	12445	5902	3504	1171	6520	10268	3794	2009
7	121	477	2342	1733	1383	312	1938	6576	647	330
8	_	27	936	858	159	236	621	939	15	55
9	_	19	54	326	132	16	3	202	_	13
0	_	_	_	_	_	_	_	_	_	_
10	_	2	7	154	132	4	2	6	_	6
11	_	_	_	_	_	_	_	_	_	_

(Continued)

Age	1984				1985				1986	
	1	2	3	4	1	2	3	4	1	2
0										
1			2041	476			369	1495	237	180
2	6148	971	3668	2184	13519	14009	5858	2710	4984	2497
3	59831	22162	11806	10741	28191	19373	9365	6553	19195	9719
4	91869	41045	17719	15257	40970	23925	7333	8936	32098	17809
5	38367	17656	6712	7043	26663	16746	4912	5311	27150	9761
6	8718	6581	673	1254	14973	5844	1978	2538	16610	7075
7	5488	2504	434	513	3026	1499	546	597	3249	1858
8	2052	1934	46	199	1400	521	226	111	864	748
9	139	213	6	15	901	248	38	33	424	96
0										
10	3	6	6	5	236	68	5	31	94	81
11										

(Continued)

Age	1986		1987				1988			
	3	4	1	2	3	4	1	2	3	4
0										
1	263	460	16	21	160	754			388	
2	7501	9523	13786	5283	8532	17898	5244	6074	9370	7449
3	9727	10865	28740	15070	4650	10081	38024	22275	13778	13682
4	3087	4606	27558	10476	1163	2474	23445	18017	2860	3566
5	2404	2392	14029	5770	1030	1326	10304	4942	1172	1675
6	1327	913	6781	3347	613	362	3916	1814	493	753
7	385	309	3005	1436	770	89	1903	821	145	279
8	56	89	623	527	197	31	631	348	71	164
9	28	23	203	159	226	13	219	101	45	7
0										
10	7	9	102	90	7	10	101	47	8	2
11										

(Continued)
Table 3 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Cod

Age	1989				1990				1991	
	1	2	3	4	1	2	3	4	1	2
0										
1		3	*	*			900	475		1
2	1073	453	2644	1664	2261	12811	12840	17073	3228	1782
3	21314	16967	6015	6228	10172	6470	4768	7102	26421	12547
4	27227	25820	4231	3992	22903	13854	485	797	19505	4405
5	9773	9805	1719	1733	10322	3922	382	235	6281	1980
6	3517	3669	1002	984	1253	530	73	8	1861	403
7	1005	1024	247	380	247	50	3	2	1230	202
8	197	476	87	153	102	221	*	1	655	328
9	172	298	7	80	38	5	*	*	168	274
0										
10	45	98	1	*	35	7		*	85	12
11										

(Continued)

Age	1991		1992				1993			
	3	4	1	2	3	4	1	2	3	4
0										
1	85			1		63		12	122	241
2	1710	1120	534	3716	1805	3475	5642	476	2786	1306
3	4895	3477	4954	7502	1165	882	7928	2428	6916	2997
4	5683	1596	4232	3956	1000	1516	4243	1382	2815	1570
5	1251	647	2692	1350	531	676	1425	291	1904	474
6	792	231	1006	448	117	46	550	75	315	29
7	504	69	453	286	52	18	113	31	96	9
8	182	54	38	15	15	8	41	2	42	4
9	36	5	24	30	4	2	27	*	17	*
0										
10	38	4	14	12	1	3	2			*
11										

(Continued)

Age	1994				1995				1996	
	1	2	3	4	1	2	3	4	1	2
0										
1	14	14	7	83		*	11	59	3	2
2	3075	1101	2329	3308	1260	308	805	4751	2331	596
3	19404	7875	4196	6244	9077	3566	1584	6400	12899	7409
4	13433	6446	831	3963	12880	7607	2378	10627	9939	8571
5	4288	4097	453	1930	5179	5351	1359	5288	8524	7541
6	860	831	115	518	909	1598	300	1022	2451	2290
7	117	269	29	75	262	412	111	323	577	579
8	25	127	10	30	70	120	31	80	74	164
9	20	39	3	1	64	64	7	18	12	33
0										
10	14	52		2	37	89	7	8	6	6
11										

(Continued)

Table 4 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Cod

Age	1996		1997				1998			
	3	4	1	2	3	4	1	2	3	4
0						1				1
1	3	151	1		11	60	1	39	63	225
2	1538	6206	1166	270	499	673	639	1411	1697	3922
3	3160	7074	11350	7656	2292	3947	4193	3851	2692	5757
4	2277	5460	7796	6018	2836	5395	4442	5660	2446	4936
5	1670	3816	4723	4101	1354	2194	2956	3466	1370	2250
6	569	625	1308	1692	740	933	770	760	378	634
7	124	140	387	913	369	331	329	366	198	349
8	30	30	112	436	108	96	130	129	112	205
9	10	8	41	88	73	44	42	32	63	122
0										
10	5	*	29	28	21	19	7	13	6	15
11							4	4	2	12

(Continued)

Age	1999				2000				2001	
	1	2	3	4	1	2	3	4	1	2
0				1				1		
1	1	28	11	30	25	45	14	345	0	1
2	877	2121	1517	4028	923	1625	1214	6509	1309	2222
3	12002	11554	2834	5282	14718	12763	3447	8111	14455	20278
4	7648	6460	1344	3033	12101	9935	3624	8370	12709	15671
5	4217	2858	611	1267	2921	3137	1515	2581	4592	4037
6	771	632	183	398	536	687	308	444	797	670
7	227	266	73	98	127	237	132	119	253	196
8	149	171	38	30	173	275	107	131	69	78
9	96	75	13	15					30	40
0										
10	73	77	11	15					20	25
11										

(Continued)

Age	2001		2002				2003			
	3	4	1	2	3	4	1	2	3	4
0		0			0	0			91	0
1	1	385	0	10	13	52	0	567	86	31
2	1998	6810	948	1964	981	2595	948	188	885	3983
3	3914	6542	11521	10008	2742	5473	14452	7256	3384	8174
4	2527	5200	8488	8725	2570	6967	11053	7306	4541	5562
5	1273	1817	2814	3000	1258	2275	3687	1949	1324	1556
6	403	338	697	544	279	450	785	353	229	307
7	107	136	236	168	110	152	258	113	75	84
8	47	38	79	64	68	130	94	73	34	36
9	16	15	30	25	15	22	23	26	17	13
0										
10	11	7	25	35	10	18	4	15	5	5
11										

(Continued)

Table 5 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Cod

Age	2004			
	1	2	3	4
0			0	1
1	0	0	23	256
2	2722	1331	242	2670
3	9166	7536	2334	5537
4	9757	8028	2435	5029
5	2650	3278	996	2116
6	752	1309	390	716
7	207	297	124	246
8	84	117	59	104
9	32	18	12	22
0				1
10	10	11	4	7
11				

Species Herring

Age	1974				1975				1976	
	1	2	3	4	1	2	3	4	1	2
0			1421	3406			3344	73773		
1	35592	88555	165289	257760	57979	80883	123822	468469	87193	117148
2	337969	715303	214024	355470	280179	685208	181522	269607	51845	346403
3	261471	645532	200429	323913	217448	646759	183684	229112	146550	487037
4	230434	692744	158344	315562	147574	422021	136451	149047	209487	536595
5	94645	218043	364695	249868	143916	407848	423417	251517	114853	384736
6	41418	131760	125476	96220	30532	111911	136981	74425	113601	460091
7	20193	102765	46668	58187	22651	66896	47597	39071	64190	183351
8	37819	85280	117445	86454	44564	112215	130215	73358	28590	127673
9	34299	107009	114611	91127	37865	112958	123007	53359	90821	286642
10										

(Continued)

Age	1976		1977				1978			
	3	4	1	2	3	4	1	2	3	4
0	464	8253			30509	2794			67800	37103
1	180030	390692	27855	42520	246867	235214	47201	87969	262114	217980
2	189976	264060	183309	474424	323278	324192	202003	555119	185295	187896
3	334165	302628	134770	418091	160819	131468	178342	493470	132199	143696
4	310299	185193	91809	280793	91494	88092	74828	219101	46826	48538
5	258221	128603	104548	339018	119185	113091	56984	141883	32418	38755
6	255841	127332	35866	205082	60220	59453	45175	108342	55037	35462
7	127976	49055	34069	192171	71700	60709	27135	83803	29302	24193
8	63490	28116	22115	90044	57280	35330	20818	81097	23677	16939
9	155894	57181	16837	77782	30701	22801	12481	34317	20755	10262
10			10123	96217	57069	30990	15125	65802	30097	15949

(Continued)

Table 6 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Herring

Age	1979				1980				1981	
	1	2	3	4	1	2	3	4	1	2
0			400	27400			23875	140891		
1	5814	14763	66754	76582	207066	292032	185780	415806	48966	161685
2	171501	318779	146642	128321	151567	557902	153985	168135	232765	730386
3	130145	359663	129165	90480	168744	522678	151490	147254	125920	412875
4	71945	334076	151749	95039	96277	266465	110178	75915	108918	307928
5	22009	118783	50980	27194	90316	413789	119288	98111	57263	183718
6	16837	67261	54558	34229	22805	88486	48717	30813	70808	258030
7	25019	101173	62790	38905	23446	100964	37819	30044	31859	50996
8	12372	56831	45689	28710	39741	119163	49191	27282	25756	62980
9	10439	53863	28559	19802	12480	51548	19097	14313	35019	58739
10	18892	69497	81867	54470	29963	102022	52210	25288	38016	85038

(Continued)

Age	1981		1982				1983			
	3	4	1	2	3	4	1	2	3	4
0	2725	145520	_	_	700	100512	_	_	3833	241613
1	381379	437872	67943	167905	197843	422596	109998	375500	158988	393003
2	247539	256136	399144	1239380	358432	390686	384860	785153	314659	415189
3	112260	80178	199274	729129	108557	119536	473859	953251	343902	253973
4	120965	81837	46937	270091	60785	60883	150467	396499	113318	98918
5	79374	45691	42849	226857	58476	54616	58880	136938	52766	36882
6	87792	42979	23208	112284	43039	43399	60834	148128	45657	35090
7	35964	15943	32298	162617	43643	35469	42429	80294	45215	17524
8	49793	15786	11671	38997	22464	18823	34012	100438	41681	24538
9	38772	14566	11975	39474	31383	17694	21709	28963	30569	6413
10	60959	28920	31321	109080	28483	28645	51217	70727	51362	15529

(Continued)

Age	1984				1985				1986	
	1	2	3	4	1	2	3	4	1	2
0	_	_	4436	184487	_	_	7209	60987	_	_
1	111336	293850	199787	436647	172642	103080	226170	787937	82345	179351
2	263853	620896	195917	303606	165637	994339	354581	714556	232337	878185
3	258419	778985	198991	299041	125036	667193	218737	235512	274913	967179
4	214402	629867	181908	182950	86326	581734	164898	150161	128411	516262
5	52161	224621	62063	61193	50107	475460	117267	86325	93169	363447
6	24914	89733	34456	29149	15137	170502	48526	34216	39420	185976
7	24329	106740	27802	18803	5257	78195	33160	20815	7752	58089
8	15479	67389	28784	11772	3109	64335	28216	16812	3589	31897
9	13552	51437	19623	16725	1644	42371	28405	6570	3424	25560
10	26752	58803	52036	10792	2859	78456	49919	18119	5110	28423

(Continued)

Table 7 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Herring

Age	1986		1987				1988			
	3	4	1	2	3	4	1	2	3	4
0	7180	115920	_	_	1441	16411	_	_	7060	80856
1	66059	234266	38163	125475	212312	443966	172527	68697	70654	116529
2	344996	384797	53462	291431	185441	134805	233564	1043978	293183	633597
3	283628	323093	89801	732342	209138	244040	91435	449993	134912	148128
4	193197	111572	76848	619386	209393	231907	136269	578447	134981	132719
5	152712	71877	44766	301405	138455	77578	111147	516074	122240	122942
6	83969	30454	35684	205712	88139	54550	48622	206780	67292	44366
7	39185	17744	8773	111855	37944	32285	31153	152936	51628	19444
8	35946	7157	5225	32503	21119	8698	11155	58224	31497	11420
9	18825	5543	1170	13918	9047	3910	2926	23483	7075	3280
10	39506	9715	5435	29257	11087	4813	11496	25889	8436	2219

(Continued)

Age	1989				1990				1991	
	1	2	3	4	1	2	3	4	1	2
0	_	_	26391	83847	_	_	3667	17440	_	_
1	84593	71028	240346	370295	67746	30442	229805	294963	40547	26247
2	139607	210609	108615	102979	433059	397519	363267	399392	408591	540229
3	758459	961751	231111	404088	165431	212581	200844	242920	279059	475699
4	183028	277212	108057	105385	432078	647207	192195	497230	117390	199864
5	211435	334172	116160	151185	114140	168080	147570	166207	228964	444781
6	159016	306036	99817	101716	112846	229923	95589	157377	79227	104156
7	44864	103746	44450	46508	79225	138008	34020	71511	76074	128887
8	28259	66958	44337	30729	25079	63726	21893	23143	38349	68454
9	7378	37756	13227	11174	10419	33487	5100	21478	17950	23191
10	9196	21257	8043	10273	4259	14678	3135	2781	10190	35360

(Continued)

Age	1991		1992				1993			
	3	4	1	2	3	4	1	2	3	4
0	6200	105510	_	_	13989	136351	_	_	57760	59023
1	97130	312273	124250	71971	236458	733182	140973	201108	143306	533114
2	281557	531998	459946	419256	144230	272860	559690	773236	235248	665781
3	217791	360071	667798	788661	160926	225234	488764	639977	212713	459608
4	86135	118151	222454	360701	92090	122790	420668	769923	188476	318767
5	104017	177466	91261	123810	41370	42190	141387	282260	103377	155486
6	44188	72720	180018	257200	34680	48980	46329	130887	53955	61869
7	35311	45678	55420	64560	18660	15050	57680	150923	32098	35569
8	18184	27309	25102	57860	9430	6900	14755	34791	10929	10017
9	9036	6237	38010	52300	5610	4310	6226	36256	4630	3239
10	4689	3239	5211	28050	1380	680	9399	32329	2650	1691

(Continued)
Table 8 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Herring

Age	1994				1995				1996	
	1	2	3	4	1	2	3	4	1	2
0	_	_	22300	148500	_	_	2100	67600	_	_
1	80300	134500	82700	352800	264300	208700	164700	415100	288627	142626
2	176600	554900	194200	499700	453800	376400	141200	305700	359379	670133
3	257100	787300	305400	574800	861100	620300	231000	393400	266098	572297
4	252900	587400	190000	294800	794600	598200	221100	368400	286426	642212
5	341000	571600	133900	191500	253100	356100	140400	173300	204850	499547
6	181600	240900	52800	60200	152100	246300	103500	109500	141012	334720
7	86800	80100	28300	25400	50700	125500	32400	36000	74027	228711
8	52600	157100	18300	25400	15700	45200	13900	15500	24469	96001
9	7600	22100	6300	5200	32000	79300	10100	13900	10496	22970
10	4800	30300	4600	3300	5300	14600	8300	9800	17380	59238

(Continued)

Age	1996		1997				1998			
	3	4	1	2	3	4	1	2	3	4
0	5960	72475	_	_	24671	132483	_	_	13727	78600
1	213844	769480	106525	170055	95937	380871	488181	245300	345500	1058500
2	283680	578236	589481	716110	241829	733577	355153	335800	196000	356454
3	197799	341058	577994	683358	299118	737893	695147	640900	396200	594714
4	208243	327334	369477	496436	194095	459301	831302	605500	238600	390400
5	175217	209519	259689	407833	153231	326885	408741	333900	87100	157100
6	104504	95515	126884	270785	89891	191692	200377	227900	65000	104777
7	52756	51219	53476	144603	46321	90373	106457	131000	34000	30450
8	19937	13563	25195	74351	24423	43374	53800	66500	16200	17300
9	4149	2604	8256	23863	5575	6956	14500	34000	7600	4500
10	6914	3039	5390	21690	2998	5112	9900	119000	7600	2700

(Continued)

Age	1999				2000				2001	
	1	2	3	4	1	2	3	4	1	2
0	_	_	55096	190168	_	_	19142	179631	_	_
1	319187	142943	181986	346586	572535	284102	355318	889292	489461	317197
2	843455	498062	203324	561987	667931	363497	152313	308574	724395	586396
3	259692	378075	138590	329982	765385	524051	190985	561136	274285	302987
4	644743	472695	103916	402899	341718	259765	69285	271944	463791	357641
5	451415	287211	78778	289946	405925	314074	75212	327379	185345	113628
6	157695	132563	38107	95543	258309	156292	49008	187548	184881	144918
7	86279	84994	20789	54552	72963	59307	25024	69102	147867	81281
8	37400	47300	9500	20300	34105	25892	11885	31101	52742	38327
9	14700	27300	4700	9200	28887	60467	11643	34468	15756	21698
10	5800	18900	1900	4300	_	_	_	_	17808	33429

(Continued)

Table 9 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Herring

Age	2001		2002				2003			
	3	4	1	2	3	4	1	2	3	4
0	74490	220075	_	_	81858	406774	_	_	52247	192434
1	456685	608601	355173	306364	243613	433639	352269	295157	240608	1056058
2	392056	688789	796974	695350	160698	542671	172119	487534	131859	387270
3	172637	233304	618848	524030	134631	422870	169508	777785	230566	432457
4	173471	276795	212594	269661	50016	126695	243097	379402	112945	182404
5	58562	99467	247641	210896	60339	122534	82907	146889	43173	95722
6	93451	88850	86943	79457	17519	32119	73867	107743	38546	77163
7	62136	68000	85286	80005	25651	26997	31929	45240	15196	17553
8	28378	28340	57280	59771	26838	23055	37172	50618	24278	19439
9	7742	9316	6120	18944	5316	6642	12718	29740	8781	13173
10	7409	9416	8647	36184	5715	8982	19857	30576	7174	7472

(Continued)

Age	2004			
	1	2	3	4
0	_	_	13100	83400
1	165900	109400	80000	468100
2	852500	579400	237400	915700
3	315500	326600	79700	258100
4	397000	387200	89700	199900
5	177500	143500	65000	127800
6	82200	76900	26500	41100
7	52600	46200	21500	32600
8	14200	17600	11300	10400
9	55500	26400	10000	10300
10	1300	2500	3500	500

Species Sprat

Age	1974				1975				1976	
	1	2	3	4	1	2	3	4	1	2
0	_	_	6424	168982	_	_	_	_	_	_
1	128150	545350	24527	1118371	162244	509768	800	26596	781146	1015330
2	1695967	1228683	467561	943827	2322244	568985	558657	543147	763750	482588
3	3297727	2710808	1216291	2310125	2140759	1208578	1012423	1031329	1537073	1205584
4	1378903	1101411	400373	441911	1389053	1068724	995002	482560	772777	655390
5	198131	259147	99085	237629	451943	306882	296987	158657	94842	111759
6	154349	215380	55750	145413	278105	165626	151582	165902	64366	100884
7	145368	115744	50482	137297	171025	98495	87087	132761	71752	71733
8	_	_	_	_	_	_	_	_	_	_
9	_	_	_	_	_	_	_	_	_	_
10	_	_	_	_	_	_	_	_	_	_

(Continued)

Table 10 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Sprat

Age	1976		1977				1978			
	3	4	1	2	3	4	1	2	3	4
0	35257	338740	_	_	846	35864	_	_	_	71987
1	388835	1220963	436947	227584	249162	788481	132451	65070	38541	113912
2	151962	414665	2817085	1824728	837468	1285786	955714	774102	338050	197818
3	488306	1028790	539916	306408	139697	174642	1525632	1848504	473370	586419
4	265067	438403	529225	611165	324236	320433	108002	272401	27907	18725
5	57370	115906	1141952	526084	167206	199618	322202	413912	74250	45856
6	35955	37348	175778	159526	62865	26882	247127	285178	44741	118134
7	42110	86129	91686	104152	63648	84042	39031	28521	6609	7403
8	_	_	129943	78566	30332	51486	10494	26214	9812	9199
9	_	_	108939	69172	21264	50984	20310	21630	19074	18763
10	_	_	246937	25414	22388	61968	40938	19648	18718	24409

(Continued)

Age	1979				1980				1981	
	1	2	3	4	1	2	3	4	1	2
0	_	_	38	43930	_	_	_	42913	_	_
1	152994	126280	53240	409434	156231	20721	63301	229086	73108	167881
2	68338	123027	28445	78218	738772	191320	65909	126504	196246	143512
3	268208	337650	88217	120736	192166	60051	34494	45955	107070	76034
4	754722	864568	366849	536055	324149	93615	22490	37026	15064	33733
5	25280	72576	6947	14921	575799	324497	114959	182773	31457	28462
6	55595	59604	16899	42744	63900	63755	20019	15983	154857	115997
7	105102	113999	52955	94325	40061	11681	6733	10066	2287	4636
8	12698	498	1107	5266	62625	51508	19844	24567	12974	16484
9	4716	7950	1123	2445	4023	603	807	2620	13548	3420
10	14625	17979	4702	14258	16554	8434	4914	5136	7240	1105

(Continued)

Age	1981		1982				1983			
	3	4	1	2	3	4	1	2	3	4
0	1701	20653	_	_	_	29997	_	_	3267	135821
1	183711	1503962	87724	11972	22821	105674	55957	61109	159025	1128023
2	90694	193795	1859479	192479	87451	273010	74400	22262	20900	121041
3	71821	108350	247126	41890	16822	48396	169994	68203	35507	240903
4	17469	27081	176422	30677	13065	27198	33058	12141	9109	51875
5	24634	23116	61470	9456	2395	6615	20860	9009	5032	30660
6	88765	145320	44055	9343	3960	7614	5477	3024	1745	2670
7	3537	3649	70211	76696	36964	60451	12995	3775	2041	6837
8	7149	5960	2723	1320	208	986	38189	38527	21688	38713
9	11180	15045	2987	1468	1	705	303	200	_	716
10	3422	3201	19088	11491	5548	6142	6061	2961	1858	4953

(Continued)
Table 11 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Sprat

Age	1984				1985				1986	
	1	2	3	4	1	2	3	4	1	2
0	_	_	1033	71998	_	_	400	33328	_	_
1	76272	5443	169942	493512	55897	42865	67566	281666	111067	101952
2	1415390	100594	115822	683570	791885	165230	45806	420314	471458	131168
3	218837	20279	11054	90596	1531453	271655	71436	489793	671335	351744
4	313182	27911	8663	98260	237326	108585	12502	69555	1120413	500926
5	58092	6921	1338	8859	138502	30108	9955	47531	154801	120907
6	28650	3271	421	3916	11128	5808	612	5548	95565	46515
7	6331	1263	205	426	7490	2926	508	4224	3439	5274
8	22065	4387	305	1532	_	611	530	1786	6685	4704
9	16856	17286	3542	16774	200	1008	_	400	216	202
10	1872	1044	210	1434	8315	8818	1500	12717	6400	5500

(Continued)

Age	1986		1987				1988			
	3	4	1	2	3	4	1	2	3	4
0	_	17091	_	_	_	4202	_	_	25623	123658
1	11771	79071	20456	73852	60500	561113	46667	11574	3342	12359
2	71101	291963	139388	75451	10069	106942	1828358	483908	35398	332885
3	71545	193850	533931	428765	36986	196641	479429	167289	9568	73275
4	111094	314951	887191	695891	10043	91436	720045	222164	27261	131758
5	24765	40715	893965	699085	15687	93311	522366	151540	11422	48763
6	13306	28873	102899	92839	2293	11408	495987	107318	15424	98035
7	1256	5408	57349	58214	6005	12675	40402	7912	1610	7736
8	1702	1711	19220	5332	666	1400	24686	9934	5631	15005
9	101	119	200	1000	500	300	5758	902	1110	1500
10	7000	10000	4300	8500	9407	1923	3901	5100	4900	13300

(Continued)

Age	1989				1990				1991	
	1	2	3	4	1	2	3	4	1	2
0	_	_	14886	49193	_	_	6	16201	_	_
1	166838	23608	9197	153458	293427	65027	173963	172479	276881	148198
2	503585	121873	15528	194888	631040	771753	112698	260946	1097924	663499
3	328609	179051	36638	123084	169663	90114	9041	46156	1111905	688044
4	242694	93723	14593	49679	278813	249884	49053	81760	211296	79892
5	253137	116897	35540	60813	100085	66263	2015	20355	254160	132761
6	243330	98659	22205	33104	95655	98775	20966	20943	51918	40285
7	65221	36825	15227	23031	46832	41630	520	3136	63579	40340
8	11018	6079	2389	3522	29127	46247	4262	6878	21017	42008
9	6808	6258	6106	2000	1209	12915	_	609	11425	11673
10	5000	9001	9000	3027	6979	10116	4280	1461	5939	1466

(Continued)
Table International catch numbers ('000') at age 12:32 Friday, September 2, 2005
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Species Sprat

Age	1991		1992				1993			
	3	4	1	2	3	4	1	2	3	4
0	51064	661264	_	_	18829	187507	_	_	8700	52817
1	36376	380468	607556	55821	273517	1299587	472163	183151	57030	936986
2	38106	492174	2309070	931996	148298	672851	2423634	1246108	272586	1389022
3	28293	278752	2749905	1156469	174738	654264	1519396	735266	111455	662071
4	1101	19327	1676853	559199	113480	360738	758975	488059	74059	455151
5	7467	62080	327431	161386	25092	103864	417755	219817	28613	215045
6	450	19100	263560	116050	16160	79379	77538	88125	5700	45498
7	3733	59753	93615	59780	4171	24057	88384	69560	6481	52850
8	2670	20869	136755	51877	5061	18181	42309	54887	3657	43943
9	3576	27796	10407	3530	1067	5482	1	1	1	1
10	1579	83355	8017	5839	2000	5056	1	1	1	1

(Continued)

Age	1994				1995				1996	
	1	2	3	4	1	2	3	4	1	2
0	_	_	4996	220419	_	_	11600	518800	_	_
1	184988	166439	98985	452301	1175400	700300	191100	3589800	4803600	979000
2	2550390	2781715	459050	1662156	495700	636400	179600	696900	14926300	5905000
3	3602528	2490472	399228	1350830	2453600	1848300	374200	1499100	2404800	947900
4	1662029	1102853	132320	519500	2496800	2077500	228000	1370600	3334400	1460700
5	1053593	692362	64555	310474	1318800	977000	57800	778100	1630900	953200
6	375516	275882	23353	90436	656500	674300	47300	384700	634600	418800
7	91817	47183	6974	37435	293100	205500	20700	63800	296600	232500
8	39682	47112	8170	18368	50800	54200	12400	34100	109500	90000
9	31333	20139	700	3600	33300	21100	200	12400	18900	10100
10	12578	9190	1537	11326	98000	28900	2600	35500	11500	7800

(Continued)

Age	1996		1997				1998			
	3	4	1	2	3	4	1	2	3	4
0	8700	62500	_	_	31449	1314149	_	_	14714	63229
1	411800	2072200	308665	119971	119220	882689	4176088	1786117	1026947	3881149
2	1139600	5203200	10549843	5459671	1050910	5938031	1323446	969781	340876	1076477
3	229700	1076200	9984762	5463338	1083407	6685709	9072441	3697761	1033220	3662033
4	279000	1411700	3678008	1631765	185796	803310	10420410	4989385	835430	3146603
5	188300	531500	2228149	1047644	173289	635697	1277630	779099	142028	426137
6	93000	347700	961214	365627	60969	255143	767068	725154	76162	183556
7	32800	124800	362148	171026	27770	117506	626602	682573	31334	107380
8	11900	129200	91648	79788	10784	63571	_	_	_	_
9	2400	4200	14417	4719	1274	1404	_	_	_	_
10	100	6300	4397	3229	462	2211	_	_	_	_

(Continued)

Table 13 International catch numbers ('000') at age 12:32 Friday, September 2, 2005

Species Sprat

Age	1999				2000				2001	
	1	2	3	4	1	2	3	4	1	2
0	_	_	15538	1432710	_	_	25419	354089	_	_
1	354982	42146	277498	1403963	3823054	2080033	1015190	3370030	1377148	444342
2	9057146	3698242	1510693	5530080	1133481	543867	159092	606266	7023179	2115524
3	2708889	1126183	382301	1572184	6930157	4176410	771158	2667703	1140794	893750
4	5324245	2563236	359892	1646180	1343922	846632	113924	545476	5228877	2225169
5	4361068	2669123	442347	1291421	2112384	1146971	181812	830183	1119031	504800
6	686200	285645	36518	163308	1987783	936475	294732	850708	1377257	594214
7	357814	200041	27953	96112	381465	222689	31429	71256	1437463	260043
8	_	_	_	_	_	_	_	_	192332	72812
9	_	_	_	_	_	_	_	_	67621	12367
10	_	_	_	_	_	_	_	_	24950	12285

(Continued)

Age	2001		2002				2003			
	3	4	1	2	3	4	1	2	3	4
0	68660	583979	_	_	251233	1771215	_	_	44295	7472
1	220348	733762	2461722	920992	820456	1799239	0	0	630436	3064338
2	628039	1790453	2086677	1743704	314233	1170012	3517224	1898802	406023	1168339
3	149570	486260	4611799	3578180	722613	1798734	3320150	1923549	184532	663660
4	367098	1431243	1486780	1789009	101418	444526	2400338	1503090	265905	737294
5	66502	308461	2069716	1095037	321057	797779	2633225	1394984	47693	334145
6	79361	600590	544506	254308	51769	142989	1634699	371402	110521	391733
7	110844	455159	328180	249587	81936	216079	831849	551998	26634	147941
8	18034	104674	608596	267482	200766	220146	319886	227332	53218	194120
9	747	9654	2124	0	278	3559	196576	80992	11151	115355
10	1237	5823	5101	1569	5592	17445	147068	15491	3448	17007

(Continued)

Age	2004			
	1	2	3	4
0	_	_	596	186559
1	7890753	3899740	1001979	6162567
2	6338700	2981078	900403	2639224
3	2533928	1501201	318821	917503
4	1536472	898335	79033	549980
5	1724501	992793	150437	364215
6	767767	311158	25308	224935
7	610385	339235	37078	152286
8	282771	185070	28472	169574
9	265705	88592	3879	94930
10	177295	49838	3955	12435

Table 14 Food comsumptions (kg) 12:32 Friday, September 2, 2005

Predator Cod

Age	1974				1975				1976				1977
	1	2	3	4	1	2	3	4	1	2	3	4	1
1	0.083	0.094	0.109	0.159	0.089	0.102	0.114	0.162	0.080	0.080	0.092	0.145	0.084
2	0.186	0.197	0.272	0.406	0.199	0.212	0.280	0.421	0.180	0.181	0.236	0.387	0.154
3	0.266	0.223	0.343	0.436	0.287	0.241	0.354	0.456	0.279	0.198	0.276	0.409	0.181
4	0.434	0.313	0.550	0.655	0.469	0.338	0.567	0.684	0.412	0.268	0.439	0.627	0.269
5	0.638	0.451	0.794	0.979	0.690	0.488	0.819	1.023	0.648	0.411	0.696	0.972	0.730
6	0.900	0.598	0.890	1.334	0.974	0.647	0.919	1.393	0.905	0.627	1.004	1.524	0.977
7	1.097	0.791	0.972	1.897	1.187	0.856	1.004	1.981	1.140	0.669	1.081	1.785	1.167
8	1.329	0.915	1.313	2.124	1.438	0.992	1.358	2.219	1.347	0.818	1.239	2.000	1.423
9	1.627	1.295	1.614	2.606	1.760	1.404	1.668	2.722	1.551	1.158	1.392	2.453	1.461

(Continued)

Age	1977			1978				1979				1980	
	2	3	4	1	2	3	4	1	2	3	4	1	2
1	0.062	0.098	0.112	0.050	0.065	0.069	0.104	0.044	0.059	0.111	0.082	0.063	0.082
2	0.141	0.272	0.290	0.113	0.141	0.230	0.309	0.116	0.153	0.210	0.255	0.125	0.181
3	0.295	0.388	0.463	0.147	0.266	0.352	0.533	0.113	0.209	0.310	0.474	0.140	0.233
4	0.473	0.589	0.748	0.222	0.414	0.526	0.761	0.163	0.364	0.486	0.739	0.232	0.324
5	0.765	0.858	1.125	0.638	0.600	0.749	1.053	0.588	0.674	0.690	0.902	0.692	0.449
6	1.119	1.163	1.512	0.910	0.811	1.003	1.333	0.785	0.991	0.878	0.923	0.888	0.591
7	1.481	1.420	1.819	1.148	1.112	1.247	1.515	1.024	1.175	0.922	0.948	1.022	0.766
8	1.811	1.692	2.029	1.268	1.213	1.777	1.692	1.291	1.291	1.065	0.966	1.159	0.892
9	1.931	1.642	2.441	1.503	1.454	1.779	2.047	1.854	1.370	1.257	1.113	1.536	1.110

(Continued)

Age	1980		1981				1982				1983		
	3	4	1	2	3	4	1	2	3	4	1	2	3
1	0.067	0.113	0.062	0.042	0.075	0.105	0.054	0.045	0.109	0.107	0.062	0.068	0.096
2	0.192	0.280	0.125	0.114	0.175	0.279	0.112	0.133	0.195	0.279	0.113	0.192	0.396
3	0.247	0.389	0.119	0.282	0.365	0.453	0.154	0.288	0.362	0.500	0.186	0.295	0.485
4	0.370	0.549	0.184	0.450	0.650	0.583	0.243	0.451	0.578	0.782	0.316	0.437	0.594
5	0.538	0.813	0.648	0.632	1.026	0.724	0.650	0.645	0.988	1.073	0.705	0.595	0.780
6	0.711	1.182	0.909	0.935	1.297	0.852	0.849	0.803	1.555	1.390	0.830	0.758	1.034
7	0.897	1.411	1.225	1.300	1.546	0.959	1.091	0.922	2.102	1.565	1.101	0.898	1.304
8	1.124	1.574	1.543	1.726	1.707	1.185	1.366	0.981	2.558	1.793	1.279	1.029	1.952
9	1.321	2.016	1.778	2.081	1.953	1.398	1.521	1.101	3.075	2.100	1.616	1.164	2.291

(Continued)

Table 15 Food comsumptions (kg) 12:32 Friday, September 2, 2005

Predator Cod

Age	1983	1984				1985				1986			
	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0.094	0.043	0.042	0.087	0.100	0.136	0.072	0.081	0.107	0.124	0.068	0.078	0.127
2	0.281	0.130	0.161	0.188	0.227	0.151	0.153	0.205	0.280	0.183	0.140	0.203	0.274
3	0.507	0.156	0.306	0.324	0.397	0.150	0.354	0.365	0.448	0.190	0.259	0.413	0.493
4	0.795	0.272	0.479	0.457	0.528	0.281	0.451	0.477	0.573	0.220	0.351	0.573	0.667
5	1.210	0.818	0.804	0.647	0.640	0.710	0.612	0.565	0.679	0.399	0.447	0.667	0.885
6	1.496	0.960	1.194	0.886	0.636	0.804	0.776	0.763	0.809	0.398	0.534	0.798	1.105
7	1.659	1.043	1.525	1.052	0.614	0.985	1.031	0.780	0.848	0.390	0.640	1.102	1.353
8	1.888	1.081	1.879	1.274	0.637	1.119	1.256	0.979	0.962	0.384	0.725	1.211	1.529
9	2.027	1.165	2.023	1.431	0.633	1.310	1.677	1.326	1.141	0.437	1.363	1.441	1.772

(Continued)

Age	1987				1988				1989				1990
	1	2	3	4	1	2	3	4	1	2	3	4	1
1	0.055	0.056	0.098	0.105	0.077	0.110	0.083	0.123	0.062	0.133	0.103	0.123	0.056
2	0.140	0.122	0.218	0.304	0.130	0.133	0.225	0.286	0.101	0.193	0.240	0.298	0.212
3	0.136	0.263	0.418	0.511	0.174	0.284	0.413	0.460	0.152	0.368	0.437	0.554	0.206
4	0.182	0.369	0.521	0.604	0.271	0.371	0.596	0.561	0.226	0.477	0.576	0.818	0.292
5	0.516	0.512	0.566	0.664	0.709	0.543	0.770	0.535	0.574	0.688	0.775	1.144	0.731
6	0.679	0.663	0.711	0.744	0.851	0.800	0.915	0.640	0.793	0.969	1.075	1.416	0.835
7	0.813	0.824	0.778	0.778	0.984	1.171	0.969	0.652	1.072	1.253	1.024	1.493	1.028
8	0.837	0.895	0.788	0.723	1.013	1.511	1.194	0.672	1.266	1.464	1.114	1.542	1.352
9	0.912	1.001	1.037	0.912	1.081	1.652	1.333	0.730	1.417	1.598	1.870	1.760	1.225

(Continued)

Age	1990			1991				1992				1993	
	2	3	4	1	2	3	4	1	2	3	4	1	2
1	0.170	0.104	0.112	0.062	0.101	0.132	0.195	0.087	0.106	0.064	0.229	0.037	0.100
2	0.193	0.260	0.257	0.186	0.236	0.297	0.395	0.175	0.239	0.147	0.436	0.097	0.213
3	0.370	0.476	0.530	0.197	0.385	0.438	0.614	0.185	0.360	0.318	0.690	0.119	0.390
4	0.591	0.913	0.765	0.278	0.473	0.574	0.715	0.251	0.493	0.564	0.984	0.161	0.479
5	0.761	1.015	1.014	0.758	0.584	0.725	0.770	0.611	0.672	0.806	1.443	0.470	0.599
6	0.820	1.589	1.793	1.067	0.900	0.977	1.097	0.727	1.016	1.298	2.009	0.717	0.831
7	0.965	1.464	2.132	1.465	1.133	1.327	2.044	0.819	1.270	1.470	2.950	1.118	1.023
8	1.186	1.818	2.559	1.711	1.533	1.731	2.756	0.847	1.339	1.909	1.933	1.468	1.243
9	1.049	1.830	2.409	1.877	1.345	1.810	2.182	0.911	1.550	1.783	1.425	1.548	1.363

(Continued)

Table 16 Food comsumptions (kg) 12:32 Friday, September 2, 2005

Predator Cod

Age	1993		1994				1995				1996		
	3	4	1	2	3	4	1	2	3	4	1	2	3
1	0.146	0.116	0.061	0.088	0.123	0.176	0.064	0.100	0.138	0.221	0.069	0.090	0.114
2	0.283	0.213	0.180	0.199	0.266	0.336	0.198	0.226	0.302	0.438	0.198	0.198	0.257
3	0.455	0.346	0.079	0.315	0.372	0.400	0.085	0.350	0.459	0.684	0.088	0.388	0.456
4	0.544	0.447	0.096	0.419	0.494	0.523	0.103	0.423	0.571	0.762	0.107	0.409	0.551
5	0.715	0.663	0.534	0.529	0.678	0.599	0.579	0.515	0.691	0.877	0.600	0.475	0.669
6	0.875	1.041	0.672	0.702	0.911	0.623	0.835	0.722	0.950	1.162	0.724	0.640	0.919
7	1.189	1.409	1.035	1.083	1.542	1.858	1.033	0.956	1.308	1.546	0.904	0.824	1.217
8	1.430	1.761	1.341	1.277	1.756	2.061	1.495	1.188	1.666	2.207	1.424	1.043	1.647
9	1.650	1.929	1.347	1.484	0.831	1.922	1.723	1.340	2.064	2.333	1.644	1.164	2.399

(Continued)

Age	1996	1997				1998				1999			
	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0.209	0.069	0.097	0.130	0.259	0.079	0.109	0.147	0.220	0.069	0.106	0.144	0.252
2	0.443	0.205	0.219	0.304	0.555	0.238	0.246	0.363	0.455	0.223	0.241	0.322	0.549
3	0.774	0.452	0.362	0.520	0.889	0.554	0.390	0.507	0.619	0.490	0.376	0.503	0.770
4	0.845	0.536	0.421	0.581	0.949	0.689	0.545	0.736	0.773	0.579	0.477	0.627	0.930
5	0.917	0.629	0.533	0.736	1.176	0.793	0.690	0.963	1.076	0.688	0.598	0.855	1.243
6	1.364	0.820	0.750	1.030	1.681	1.051	0.993	1.313	1.427	1.004	0.882	1.288	2.125
7	1.717	1.087	0.957	1.359	2.330	1.386	1.259	1.731	1.892	1.669	1.227	1.582	2.570
8	2.460	1.154	1.120	1.757	2.981	1.792	1.363	2.232	2.378	1.706	1.405	2.238	3.552
9	2.716	1.626	1.464	2.192	3.242	1.885	1.904	2.669	2.868	2.192	1.778	2.517	3.580

(Continued)

Age	2000				2001				2002				2003
	1	2	3	4	1	2	3	4	1	2	3	4	1
1	0.076	0.108	0.144	0.216	0.076	0.104	0.132	0.230	0.075	0.111	0.163	0.257	0.063
2	0.247	0.245	0.340	0.457	0.235	0.237	0.305	0.477	0.242	0.249	0.370	0.554	0.173
3	0.476	0.376	0.510	0.577	0.438	0.333	0.437	0.583	0.444	0.325	0.500	0.637	0.294
4	0.604	0.472	0.648	0.711	0.555	0.416	0.532	0.692	0.592	0.439	0.633	0.795	0.376
5	0.818	0.633	0.915	1.047	0.745	0.551	0.725	1.082	0.778	0.581	0.866	1.148	0.480
6	1.241	0.940	1.478	1.498	1.108	0.839	1.106	1.729	1.130	0.845	1.370	1.963	0.691
7	1.749	1.296	1.827	2.234	1.575	1.153	1.727	2.084	1.490	1.181	1.949	2.680	1.048
8	2.105	1.516	2.196	2.629	2.490	1.502	2.164	2.814	2.110	1.601	2.678	3.762	1.472
9	2.119	1.793	2.786	3.021	2.277	1.868	2.329	2.252	2.246	1.800	3.069	4.083	1.440

(Continued)

Table 17 Food comsumptions (kg) 12:32 Friday, September 2, 2005

Predator Cod

Age	2003			2004			
	2	3	4	1	2	3	4
1	0.092	0.108	0.185	0.069	0.100	0.125	0.176
2	0.212	0.249	0.390	0.195	0.231	0.288	0.348
3	0.274	0.352	0.444	0.359	0.287	0.392	0.457
4	0.345	0.378	0.462	0.454	0.423	0.499	0.537
5	0.449	0.577	0.720	0.556	0.511	0.640	0.682
6	0.633	0.908	1.162	0.719	0.644	0.828	0.851
7	0.964	1.208	1.607	1.102	0.918	1.225	1.275
8	1.217	1.521	1.766	1.365	1.234	1.634	1.573
9	1.369	1.713	2.090	1.805	1.580	2.377	2.344

Table 18 Food comsumptions (kg) 12:32 Friday, September 2, 2005

Predator Cod

Age	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	0.445	0.467	0.396	0.355	0.288	0.295	0.325	0.285	0.315	0.321	0.272	0.396	0.397
2	1.062	1.111	0.984	0.857	0.794	0.734	0.779	0.692	0.719	0.982	0.706	0.789	0.800
3	1.268	1.337	1.161	1.327	1.298	1.105	1.008	1.219	1.303	1.473	1.184	1.316	1.355
4	1.951	2.058	1.745	2.078	1.923	1.753	1.475	1.867	2.055	2.142	1.736	1.783	1.812
5	2.863	3.021	2.728	3.477	3.040	2.854	2.492	3.031	3.356	3.291	2.909	2.566	2.398
6	3.722	3.934	4.059	4.771	4.057	3.577	3.372	3.992	4.598	4.118	3.676	3.152	2.834
7	4.756	5.028	4.676	5.887	5.022	4.069	4.096	5.030	5.681	4.963	4.233	3.643	3.485
8	5.683	6.006	5.404	6.956	5.950	4.613	4.748	6.161	6.698	6.148	4.871	4.317	3.849
9	7.142	7.554	6.554	7.475	6.782	5.595	5.983	7.210	7.797	7.098	5.251	5.455	5.012

(Continued)

Age	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0.314	0.394	0.422	0.442	0.489	0.486	0.400	0.448	0.524	0.481	0.554	0.556	0.571
2	0.784	0.774	0.831	0.922	1.114	0.997	0.806	0.982	1.164	1.097	1.282	1.302	1.335
3	1.328	1.331	1.511	1.582	1.635	1.553	1.310	1.166	1.578	1.706	2.222	2.070	2.139
4	1.677	1.799	2.097	2.561	2.041	2.293	1.631	1.532	1.859	1.912	2.487	2.744	2.612
5	2.258	2.557	3.181	3.521	2.837	3.532	2.447	2.341	2.662	2.661	3.074	3.522	3.384
6	2.797	3.206	4.253	5.038	4.040	5.049	3.464	2.908	3.669	3.647	4.280	4.784	5.299
7	3.193	3.776	4.842	5.590	5.970	6.510	4.740	5.517	4.843	4.661	5.733	6.268	7.048
8	3.243	4.390	5.387	6.915	7.731	6.029	5.903	6.434	6.556	6.573	7.012	7.765	8.901
9	3.861	4.796	6.645	6.514	7.214	5.670	6.490	5.584	7.460	7.923	8.524	9.327	10.067

(Continued)

Age	2000	2001	2002	2003	2004
1	0.543	0.542	0.606	0.448	0.470
2	1.289	1.254	1.416	1.024	1.062
3	1.938	1.791	1.906	1.364	1.495
4	2.435	2.195	2.459	1.562	1.913
5	3.413	3.103	3.372	2.226	2.389
6	5.158	4.783	5.308	3.394	3.042
7	7.105	6.540	7.301	4.827	4.521
8	8.445	8.970	10.152	5.976	5.807
9	9.719	8.726	11.197	6.611	8.106