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9–13 March 2015

Cádiz, Spain

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International Council for the Exploration of the Sea
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Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

The ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) was established in 2007 as a forum for developing and combining ecosystem-based management efforts for the Baltic Sea. The group intends to serve as a scientific counterpart and support for the ICES Baltic Fisheries Assessment Working Group (WGBFAS) as well as for efforts and projects related to Integrated Ecosystem Assessments (IEA) within ICES and HELCOM. The group works in cooperation with similar groups within the ACOM/SCICOM Steering Group on Integrated Ecosystem Assessments (SSGIEA).

The 2015 WGIAB meeting was held in Cádiz, Spain, from 9–13 March, back-to-back with the meeting of its counterpart in the Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS). The meetings had joint sessions as well as WG specific work, and some participants effectively participated in both meetings. The WGIAB meeting was attended by 27 participants from nine countries. The meeting was chaired by Christian Möllmann, Germany, Laura Uusitalo, Finland and Lena Bergström, Sweden.

This was the last year of the ongoing three-year Terms of Reference (ToR) for WGIAB. The main working activities in 2015 were to i) conduct studies on Baltic Sea ecosystem functioning with the goal to publish case studies from different parts of the Baltic Sea in peer-reviewed journals, ii) work on the demonstration exercise to develop ecosystem-based assessment and advice for Baltic fish stocks focusing on cod (DEMO) with multiple approaches, iii) plan further how to integrate the social and economic aspects more tightly in the WGIAB work, and iv) discuss the future focus and format of the WGIAB work.

The Baltic ecosystem functioning activity focused on identifying and exploring key trends and linkages in the Baltic Sea foodweb. This was pursued by presentation and further discussion of ongoing intersessional work on foodweb modelling and integrated analyses, and by exercises to develop conceptual models Baltic Sea foodwebs and the links to ecosystem function. Long-term monitoring datasets on the abiotic and biotic parts of the Baltic Sea Proper ecosystem were updated for use in the continued work to develop environmental indicators for fisheries and marine management.

The focus of the DEMO 3 (DEMOnstration exercise for Integrated Ecosystem Assessment and Advice of Baltic Sea cod) was on finding a way to use the results from the DEMO1 and DEMO2 workshops in short and midterm projections/scenarios of Baltic cod dynamics based on different types of modelling, as well as designing methodology and modelling data for practical implementation of Integrated Advice for Baltic cod.

The WGIAB was positively inclined towards including social and economic aspects into the integrated assessment. Openings to this path were provided by presentation on ongoing project work, and discussing their linkages to ecological aspects. It was seen as crucial that experts on social and economic analysis should be included and take an active part in the future work of the group.

The group concluded that its upcoming work should focus more closely on functional diversity, which was identified as a recurring issue in the Baltic Sea. This approach was also identified as a useful connection point between scientific and management aspects in order for the group to continue serving as a forum for developing ecosystem-based management efforts in the Baltic Sea. A focus on functional diversity was also seen as

a potentially feasible way of bringing together management aspects for different sectors, by linking to ecosystem services concepts.

The group proposed Saskia Otto, Germany and Martin Lindegren, Denmark as new incoming Chairs, together with Lena Bergström, Sweden and Laura Uusitalo, Finland. Having four Chairs is justified due to the wide scope of the group's work, as well as the increased work load due to the planned new foci.

1 Administrative details

Working Group name

ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea

Year of Appointment: 2007 (2013 with respect to the ongoing three-year cycle)

Reporting year concluding the current three-year cycle: 2015

Chairs

Christian Möllmann, Germany

Lena Bergström, Sweden

Laura Uusitalo, Finland

Meeting venue(s) and dates

8–12 April 2013, Chioggia, Italy, (14 participants)

10–14 February 2014, Kiel, Germany (27 participants)

9–13 March 2015, Cádiz, Spain (27 participants)

Figure 1. Participants of WGIAB-WGEAWESS 2015.

2 Terms of Reference a) – e)

ToR	Description
A	Increase understanding of Baltic Sea ecosystem structure and functioning, with a focus on species interactions and trends over different temporal and spatial scales, and the identification of key species and processes for maintaining functioning ecosystems and sustainable use of these;
B	Support development of a framework for integrated advice for fisheries management, by data exchange, model evaluation and scientific interaction with the Baltic Sea assessment working groups.
C	Further develop the integrated ecosystem assessment cycle, and apply case studies to investigate trade-offs between different management objectives, including effects on ecosystem services and effects at different spatial and temporal scales.
D	Identify potential regional observing assets (both inside and outside ICES) necessary to support development of regional ecosystems assessments.
E	Produce an approach for monitoring and developing assessment methods for the top three anthropogenic pressures on ecological characteristics described in the national MSFD reports (submitted in October 2012) for the appropriate regions.

3 Summary of Work plan

2013	Annual meeting, intersessional work on research articles, Focus on ToR a and b Additional ToR d and e
2014	Annual meeting, intersessional work on research articles, Focus on ToR b and c
2015	Annual meeting, intersessional work on research articles Focus on ToR b and c

4 Summary of Achievements of the WG during 3-year term

4.1 Publications based on WGIAB activities, published 2013–2014

Blenckner, T., Llope, M., Möllmann, C., Voss, R., Quaas, M. F., Casini, M., Lindegren, M., Folke, C. Chr., Stenseth, N. 2015. Climate and fishing steer ecosystem regeneration to uncertain economic futures. Proc. R. Soc. B, 282: 20142809. http://dx.doi.org/10.1098/rspb.2014.2809

Gårdmark, A., Lindegren, M., Neuenfeldt, S., Blenckner, T., Heikinheimo, O., Müller-Karulis, B., Niiranen, S., Tomczak, M., Aro, E., Wikström, A., and Möllmann, C. 2013. Biological Ensemble Modelling to evaluate potential futures of living marine re-sources. Ecological Applications, 23(4): 742–754.

Möllmann, C., Lindegren, M., Blenckner, T., Bergström, L., Casini, M., Diekmann, R., and Gårdmark, A. 2013. Implementing ecosystem-based fisheries management: from single-species to integrated ecosystem assessment and advice for Baltic Sea fish stocks. ICES Journal of Marine Science, 71 (5): 1187–1197; doi: 10.1093/icesjms/fst123.

Olsson, J., Tomczak, M. T., Ojaveer, H., Gårdmark, A., Põllumäe, A., Müller-Karulis, B., Ustups, D., Dinesen, G.E., Peltonen, H., Putnis, I., Szymanek, L., Simm, M., Heikinheimo, O., Gayukov, P., Axe, P., and Bergström, L. Temporal development of coastal ecosystems in the Baltic Sea over the past two decades. Accepted. ICES Journal of Marine Science.

Otto, S. A., Kornilovs, G., Llope, M., and Möllmann, C. 2014. Interactions among density, climate, and food web effects determine long-term life cycle dynamics of a key copepod. Marine Ecology Progress Series, 498: 73-U408.

Otto, S. A., Diekmann, R., Flinkman, J., Kornilovs, G., and Möllmann, C. 2014. Habitat Heterogeneity Determines Climate Impact on Zooplankton Community Structure and Dynamics. PloS one, 9(3): e90875.

Niiranen, S., Yletyinen, J., Tomczak, M. T., Blenckner, T., Hjerne, O., MacKenzie, B. R., and Meier, H. E. 2013. Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web. Global Change Biology, 19(11): 3327–3342.

Tomczak, M. T., Heymans, J. J., Yletyinen, J., Niiranen, S., Otto, S. A., and Blenckner, T. 2013. Ecological Network Indicators of Ecosystem Status and Change in the Baltic Sea. PloS one, 8(10), e75439.

Tomczak, M. T., Dinesen, G. E., Hoffmann, E., Maar, M., and Støttrup, J. G. 2013. Integrated trend assessment of ecosystem changes in the Limfjord (Denmark): Evidence of a recent regime shift? Estuarine, Coastal and Shelf Science, 117: 178–187.

Walther, Y. M., and Möllmann, C. 2013. Bringing integrated ecosystem assessments to real life: a scientific framework for ICES. ICES Journal of Marine Science, 71 (5): 1183–1186. doi: 10.1093/icesjms/fst161

Viitasalo, M., Blenckner, T., Gårdmark, A., Kaartokallio, H., Kautsky, L., Kuosa, H., Lindegren, M., Norkko, A., Olli, K., Wikner, J. 2015. Second Assessment of Climate Change for the Baltic Sea Basin, Edited by The BACC II Author Team, 04/2015: chapter 19. Environmental Impacts—Marine Ecosystems: pages 363–380; Springer International Publishing., ISBN: 978-3-319-16006-1

4.2 Advisory products

Indicators of recruitment environment for Eastern Baltic Cod for WGBFAS 2013 and 2014. Contribution to the ecosystem description section of WGBFAS 2015 (ToR B and Section 5.2 of this report).

4.3 Datasets

No datasets are produced, but time-series datasets on open sea and coastal foodwebs are regularly collated and updated for further analyses (Tor A and Section 5.1 of this report).

4.4 Methodological developments

The DEMO exercises (DEMOnstration exercise for Integrated Ecosystem Assessment and Advice of Baltic Sea cod) were initiated in 2013 and have been further developed as part of WGIAB and intersessional workshops. The aim of DEMO is to is to describe and simulate how the implantation process of EBFM for the Baltic Sea Cod using elements of the IEA approach could be done in practice (ToR C and Section 5.3 of this report)

4.5 Modelling outputs

Not relevant.

5 Summary of achievements in relation to the ToRs

5.1 Tor A: Baltic Sea ecosystem structure and functioning

"Increase understanding of Baltic Sea ecosystem structure and functioning, with a focus on species interactions and trends over different temporal and spatial scales, and the identification of key species and processes for maintaining functioning ecosystems and sustainable use of these"

The integrated analyses of time-series datasets on open sea and coastal foodwebs and ecosystems have been a core activity of WGIAB since its beginning. The datasets include time-series on biotic, environmental and anthropogenic pressures. The results have been presented in the WG reports and in some cases also in scientific papers and have also been used in further applications in models and assessments. Per subarea, the most recent assessments were presented in 2015 for the Central Baltic Sea and the Bothnian Bay, in 2014 for the Gulf of Riga, Gulf of Finland and Western Baltic Sea, in 2013 for coastal areas, and in 2012 for the Bothnian Sea (WGIAB 2012; 2013; 2014; 2015). The analyses of changes in foodweb components over time assess the presence of long-term changes and regime shifts in relation to climate-related drivers and fishing pressure, and eutrophication. Available data typically allow for analyses back to the 1970s or 1980s. Assessment further back in time would have to rely on the analyses of reconstructed time-series in combination with historical data (WGIAB 2014). Methodological developments have been associated with this work, such as producing R scripts for integrated trend analyses, statistical methodological development, and the further use of Bayesian network modelling (WGIAB, 2014).

5.1.1 Topics on Tor A of the 2015 meeting

Integrated analyses of the central Baltic Sea foodweb

The central Baltic Sea foodweb was assessed for the first time during the first meeting of WGIAB in 2007 (WKIAB). The time-series were updated with abiotic datasets now covering a total of 35 years from 1979 to 2014. The most recent year for the update of the biotic variables was 2013, with the exception of stock-assessment-based data on cod, which was 2012; due to uncertainties in the assessment outputs (ICES WGBFAS report 2014). The results are given in Annex 3.

Long term changes in the Bothnian Bay foodweb – by Zeynep Pekcan-Hekim, Anna Gårdmark, Agnes Karlson, Pirkko Kauppila, Lena Bergström

The Bothnian Bay is the northern most part of the Baltic Sea where salinity is low (1–3 psu). It is an important fishing and seal reproduction ground and the impact of anthropogenic pressure has not been as intense as it has been in the other basins of the Baltic Sea. We conducted an integrated trend assessment analyses in the Bothnian Bay for the period of 1980–2013. The aim was to detect changes in the abiotic and biotic environment of the Bothnian Bay during the last three decades. We applied a principal component analyses and chronological clustering in order to detect the changes in the abiota and biota during the last three decades (1980–2013). Further, we tried to understand the reasons behind the changes in the biota by looking at the changes that occurred in the abiotic environment using distance based-linear modelling and redundancy analysis. The abiotic data included variables representing the nutrient status, climate and fishing pressure in the Bothnian Bay. The biotic data covered all trophic levels from primary producers to top predators (seal). Two major changes were detected for the abiotic dataset, first in 1989 and a second in year 2004. These changes were characterized by the decline in salinity and ice cover days and also the decline in herring fishing effort. The changes in biota were observed in year 2000 and characterized by steep increase in the abundance of seals in the last decade. Overall, results indicate that salinity, Baltic Sea Index and fisheries effort were the main drivers of the changes in the biota; however, it is difficult to distinguish which is the main driver due to the high correlation between salinity and herring fishing effort. Nutrients and temperature did not play a role in the changes in the Bothnian Bay foodweb. We need to further explore the trophic interactions to understand the changes that have taken place in the Bothnian Bay ecosystem.

Linkages between pelagic fish indicators in the Baltic Sea – by Maria A. Torres, Michele Casini, Magnus Huss, Anna Gårdmark

Further development of Descriptor 4 indicators is resulting of a key challenge in the implementation of the MSFD. ICES recommends that these indicators need to be addressed considering the effects of biotic and abiotic drivers on considerations of GES. In this study we therefore apply a Multivariate Autoregressive (MAR) model for the period 1979–2012 to robustly test how pelagic fish indicators from two trophic levels are interlinked, and how they respond to changes in multiple interacting environmental pressures across Central Baltic Sea offshore regions. In this first analysis, we propose abundances of piscivorous (cod) and planktivorous (sprat, herring and stickleback) as indicator to assess and monitor the GES of the Bornholm Basin. To account for the environmental variability of the model we include the three top drivers affecting the Baltic Sea: fishery, eutrophication and climate. In order to avoid over-parameterization due to the large number of coefficients to be estimated by the model we made assumptions based on prior knowledge of the foodweb dynamics. We also lagged the climate covariates (i.e. temperature, oxygen in the reproductive volume and salinity) to show their effects on the recruitment of all pelagic fish. We compare our results to those of univariate analyses by means of Generalized Least Square (GLS) to show the effect of considering species interactions on relationships between drivers and each of the indicators. Finally, we ran an unlagged MAR model to detect possible differences in the directions of the relationships with all environmental drivers when comparing with the lagged version. The pelagic fish indicators respond to temperature and phosphorus when accounting for species interactions and environmental variability. These results differed of those obtained from the univariate analyses highlighting the importance of including species interactions in the ecological models. In the unlagged model, pelagic fish indicators were linked to all fisheries, eutrophication and climate drivers when accounting for biotic and abiotic pressures. To conclude, the major sources of uncertainty were associated to sprat and herring in all models fitted and this could affect the ability to determine Descriptor 4 indicator bounds and the interpretation of change in indicators in relation to GES. Further selection model analyses are needed to explain the best combination of multiple pressures to better explain the indicator development and behaviour. The next stage of this study is aimed to develop the abundance-based indicator in Gotland Basin as well as in the entire Central Baltic Sea. The same methodology will be used to develop and test the size-based indicator defined as Biomass of Large Fish (> 38 cm) vs. Biomass of Small Fish (< 10 cm) to be proposed for the MSFD. Finally, we will link these fish indicators to zooplankton indicators to provide a framework for developing foodweb indicators accounting for trophic interactions and environmental variability, including management strategy evaluation modelling.

5.2 ToR B: Support integrated advice for fisheries management

"Support development of a framework for integrated advice for fisheries management, by data exchange, model evaluation and scientific interaction with the Baltic Sea assessment working groups"

WGIAB has interacted with the Baltic Fisheries Assessment Working group (WGBFAS) concerning indicator of recruitment environment for Baltic cod, and worked on identifying indicators of the recruitment environment of Gulf of Riga herring. Information on environmental conditions relevant to recruitment of Eastern Baltic cod have been provided in order to supplement the regular assessment of cod since 2011 (ICES, 2011), based on indicators proposed by Gårdmark *et al.* (2011) to the residuals of a stock–recruitment relationship (for details see ICES, 2011). Updated information on the recruitment environment has been provided annually. Later work (Kroll *et al.*, in prep.) has shown that the depth of the 11 psu isosaline in the Gotland Basin is the only environmental variable that has a consistent significant relationship with variation in cod recruitment (not explained by cod SSB) across different periods.

Analyses of the relationships between the Gulf of Riga herring recruitment and environmental factors (WGIAB, 2013) show that highly variable recruitment success could depend mostly on feeding conditions during spring (biomass of zooplankton *Eurytemora affinis*), and to some lesser extent on water temperature in August. The results suggested that biomass of zooplankton *E. affinis* in May is a suitable environmental indicator of recruitment for this herring stock, especially for predict years with low recruitment (WGIAB, 2014).

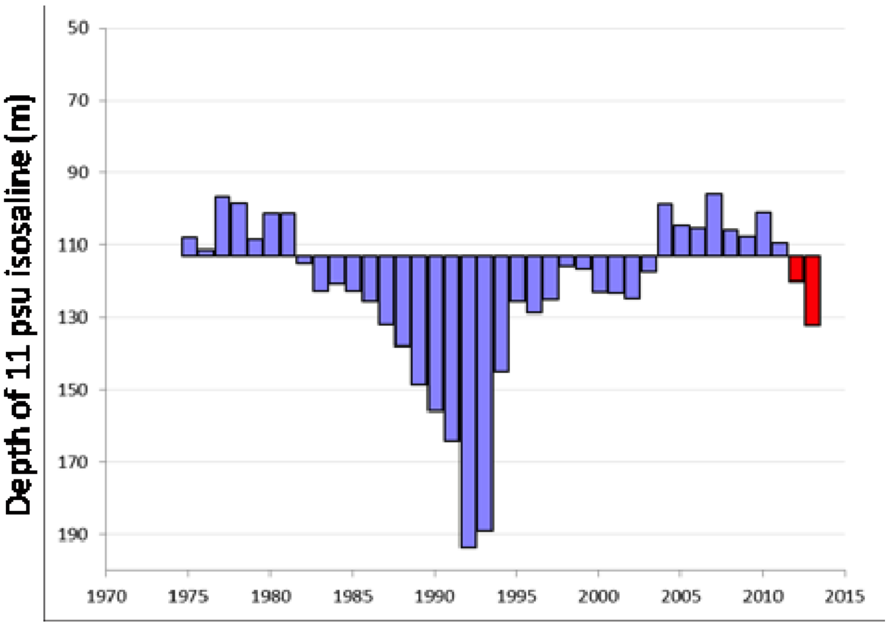

Figure 5.2. Time-series of the depth of the 11 psu isosaline as an indicator of the abiotic recruitment environment for Eastern Baltic cod. The indicator shows poor abiotic environmental conditions in 2012–2013, suggesting that the abundance of 2-year old cod recruiting to the fishable stock in 2014 and 2015 will be less than expected from cod spawning-stock biomass alone. Bars indicate the values relative to the reference value, derived from the fitted relationships on cod recruitment residuals from 1977–2009 (WGIAB, 2014; for further details on the methods, see also ICES, 2011; 2012a).

5.2.1 Topics on Tor B of the 2015 meeting

Multi-species interactions and MSY-reference points – by Noél Holmgren, Niclas Norrström, Michele Casini

Single-species MSY reference points (SMRP) have been implemented in the EU-fisheries since 2010. It is known that SMRP can be in conflict if species are competitors for the same food or related as predator and prey. Maximizing total biomass leads to a fishing-down-the food chain strategy. We analyse possible conditions for MSY given a constant spawning-stock biomass (SSB) or fishing mortality (F) of the other species, which we call joint-BMSY and joint-FMSY respectively. We have developed a multi-species model of the cod, herring and sprat stocks of the central Baltic Sea as a model case. Each stock is age-structured with numbers-at-age and weight-at-age as variables, hence incorporating growth by numbers and by weight. Reproduction was model with the influence of pressures from the reproductive volume on cod (salinity and oxygen), salinity and temperature on herring, and temperature on sprat. The species' interaction is mediated by the cod growth being a function of the spawning-stock biomass of herring and sprat. We found that joint-BMSY and joint-FMSY reference points are feasible for the cod-herring-sprat system in the central Baltic Sea. Compared with each other, the latter gives higher Fs for all species, lower SSB for cod and herring, a predatory release with higher SSB for sprat, lower yields for cod and higher yields for herring and sprat.

Life, the Universe, and Everything – by Laura Uusitalo

Modelling exercises done around the Baltic Sea were presented and discussed: Haapasaari and Karjalainen, 2010; Haapasaari *et al.*, 2013, and Uusitalo *et al.*, in prep. The papers by Haapasaari and colleagues are looking at Baltic fisheries management from the social perspective: the first one focuses at factors affecting fishers' commitment to Baltic salmon management policies, and the second one looks at different stakeholders' perceptions on aims of, and factors affecting, Baltic herring fishery management. The third application uses expert knowledge to scope the possible responses of the Baltic Sea to current and strengthened management measures of eutrophication and fisheries, and the uncertainty related to it.

P. Haapasaari and T.P. Karjalainen, 2010.Formalizing expert knowledge to compare alternative management plans: sociological perspective to the future management of Baltic salmon stocks. Marine Policy, 2010; 34: 477–486.

Haapasaari P., Mäntyniemi S., and Kuikka S. 2013. Involving stakeholders in building integrated fisheries models using Bayesian methods. Environmental Management 51(6): 1247–1261.

Uusitalo, L., Korpinen, S., Andersen, J. H., Niiranen, S., Valanko, S., Dickey-Collas, M. in prep. Predictions of ecosystem recovery under various management scenarios: a case study of marine eutrophication and fisheries.

5.3 ToR C: Develop the integrated ecosystem assessment cycle

"Further develop the integrated ecosystem assessment cycle, and apply case studies to investigate trade-offs between different management objectives, including effects on ecosystem services and effects at different spatial and temporal scales"

5.3.1 Developing a demonstration exercise for Integrated Ecosystem Assessment and Advice of Baltic Sea fish stocks (DEMO)

Theory behind ecosystem-based management (EBM) and ecosystem-based fisheries management (EBFM) is now well developed. However, the implementation of EBFM is still largely based on single-species assessments and ignores the wider ecosystem context and impact. The reason for the lack or slow implementation is the lack of a coherent strategy. Such a strategy is offered by the Integrated Ecosystem Assessment (IEA) framework, a formal synthesis tool to quantitatively analyse relevant natural and socio-economic factors in relation to specified management objectives (Levin *et al.,* 2009).

As one step towards practical implementation of the IEA, WGIAB decided to focus on implementing the approach for Baltic Sea fish stocks by combining both tactical and strategic management aspects into a single strategy that supports the fisheries advice conducted by ICES. A strategy towards this goal has been published in the ICES Journal of Marine Science (Möllmann *et al.,* 2014). The approach initially focused on the Central Baltic Sea and its three major fish stocks cod (*Gadus morhua*), herring (*Clupea harengus*), and sprat (*Sprattus sprattus*), but may be applied to other areas and fish stocks as well.

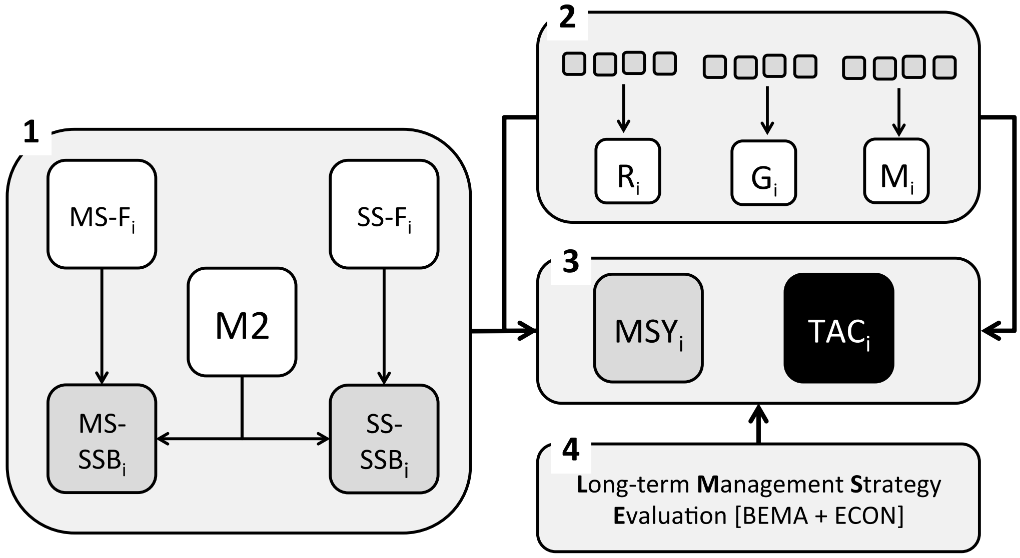

Figure 5.3.1.1. Conceptual schema of the work. 1: Combining Multi-Species (MS) and Single-Species (SS) assessments [F – Fishing Mortality, M2 – Predation Mortality]; 2: Environmental indicators (small squares) for biological process [R – Recruitment, G – Growth, M – Mortality]; 3: Estimating MSY [Maximum Sustainable Yield] and setting TAC [Total Allowable Catch]; 4: Long-term Management Strategy Evaluation using BEMA (Biological Ensemble Modelling; Gardmark *et al.,* 2013) and coupled ecological-economic modelling [ECON].

DEMO composes of three workshops dedicated for different parts of the schema of Möllmann *et al*. (2014). DEMO1 was related to general mechanisms driving cod dynamics, developing a portfolio of indicators for processes affecting stock recruitment, and understanding of key processes regulating the development of cod in the Baltic Sea. DEMO2 focused on identifying potential general mechanisms driving cod dynamics, comparative analyses of the Eastern Scotian Shelf cod stock and the Eastern Baltic cod stock, answering how and if life-stage- and size-specific growth and mortality can explain cod dynamics, and how these have been affected by stock redistributions; and DEMO3 in Cadiz looked at short and midterm predation/scenarios of Baltic cod dynamic based different types of modelling.

The DEMO3 workshop found it essential to find ways to use the environmental information in the advice framework of the three fish stocks. The modelling was planned the to unfold as follows: first, environmental information will be used to assess the credibility of the stock assessment and short-term projections in terms of SSB and recruitment. Second, environmental information will be used to assess the credibility of short-term projections used in advice process using (i) the "traditional approach" and (ii) the DEMO approach. Technical details of the approaches have been discussed and will be further developed during intersessional work (see arrows between 2 and 3 in Figure 5.3.1.1). A preliminary list of potential indicators based on expert knowledge, published results, DEMO1 and DEMO2 results as well as data availability has been developed (Table 5.3.1).

Table 5.3.1. Selected indicators to be included in the DEMO exercise.

Species	Recruitment	Growth	Mortality
Cod	Salinity in the Gotland Basin, RV, cod predation mortality at ages 0-1, mean weight at age, abundance (alt. frequence of) spawners at size (or skewness of size distribution of spawners), LFI, Pseudocalanus acupes biomass, abundance of small sprat & herring, zoobenthos, larval transport	Per capita abundance of sprat & herring & cod at a certain size, benthos	Grey seal consumption
Herring	August SST, mean weight at age, cod predation on age0, abundance (alt. frequence of) spawners at size (or skewness of size distribution of spawners), LFI, Pseudocalanus acupes biomass, abundance of small sprat & herring, zoobenthos, larval transport	Total zooplankton, amphipods, total zooplankton/capita of clupeids	Cod predation M2 that is based on cod stock size and accounts for spatial overlap of cod-sprat, grey seal consumption
Sprat	Temperature in 60 m during spring, August SST, cod predation on age 0, mean weight at age, abundance (alt. frequency of) spawners at size (or skewness of size distribution of spawners], LFI, Acartia spp. biomass, larval transport	Total zooplankton, total zooplankton/capita of sprat	Cod predation M2 that is based on cod stock size and accounts for spatial overlap of cod-sprat, grey seal consumption

An abstract presenting the DEMO work has been submitted to ICES ASC 2015 in Copenhagen under the title "Short-term prediction and harvest control rules for Baltic cod (*Gadus morhua*): A generic method to include state-of-the-art knowledge of environmental uncertainty and its consequences – would it make a difference for advice?"

5.3.2 Scope for social and economic analyses in WGIAB

The WGIAB was positively inclined towards including social and economic aspects into the integrated assessment. It was seen as crucial that experts on social and economic analysis should be included and take an active part in the future work of the group. A good opening for was given by presentations on ongoing activities in this emerging field, looking at how to select relevant societal indicators and how to combine different management objectives in a modelling framework.

Introductions to multispecies Ecological-economic modelling for the Baltic Sea IEA Framework were also given on the 2014 meeting by Rudi Voss, and discussed as a tool for the IEA framework and application in DEMO.

5.3.3 Topics on ToR C of the 2015 meeting

Using societal indicators to make drivers of the pressure on marine environments visible – by Anders Grimvall

Unsatisfactory states of the marine environment are usually strongly related to phenomena in the society. To mitigate such environmental problems the drivers that cause the pressures need to be identified. In general, this implies that many different groups of actors need to be addressed. Some of them are physical or legal persons using marine resources or being explicitly involved in activities causing physical, chemical, or biological disturbances of the marine environment. Other actors are individuals or organizations indirectly driving the use of marine resources or influencing the pressure on the marine environment. The latter group includes individual consumers as well as persons involved in supply chain management, competitive bidding or public procurement of goods or services. However, there are yet no established methods how to describe these phenomena.

Swedish Institute for the Marine Environment (SIME) proposes a four-step procedure that is based on the DPSIR (Driver, Pressure, Impact, State, Response) framework and the recently proposed variant BPSIR (Behaviour, Pressure, Impact, State, Response). 1. Use system analysis to develop models of the flow of substances (e.g. nutrients) and goods in society 2. Link actor categories and individual and actors to these physical flows. 3. Identify other actors by influence analyses. 4. Develop societal indicators of the behaviour of actors and flows of goods and substances through the society.

Societal indicators would:

- make societal phenomena visible,
- clarify which phenomena that are significant or insignificant
- help establish links to indicators of physical, chemical or biological pressures
- strengthen the follow-up of measures
- facilitate communication with actors.

SIME developed the abovementioned method as a desk product on behalf of the Swedish Agency for the Marine and Water Management, and tested it on drivers of eutrophication. Next suggested step is a pilot study involving a minimum of three countries.

Bayesian Networks for integrated assessment – by Annukka Lehikoinen

Integrated environmental modelling (IEM) is a discipline inspired by the need to solve increasingly complex real-world problems involving the environment and its relationship with human systems and activities. IEM involves integration of data, expert knowledge and results of the domain models to systemic metamodels, providing better conceptual understanding about the environmental systems in focus. The purpose of the approach is to describe the causalities in the system by studying the interactions and cross-linkages among its components, providing information that is useful in the environmental management context.

Bayesian networks (BN) and their expansions such as influence diagrams have several characteristics of optimal IEM tool. They provide a manageable platform for compiling and structuring knowledge of different types and forms. Because of their graphic nature, BNs are transparent and enable the visual representation of both the problem formulation and the results – including the uncertainty related to each element of the system. This makes BNs applicable also to supporting discussions both within the interdisciplinary research teams and with the external stakeholders. For constructing large integrated models, BNs are superior, having a modular nature that enables building large entities piece by piece by adding new variables or connecting whole BN models with each other to form a larger entity. This allows long-term development of holistic systems that can be expanded, fine-tuned and modified as new needs or information arise.

The presentation described the principle of a BN and demonstrated how the knowledge integration can be done in practice. Three example applications were presented in brief.

6 Cooperation

WGIAB has held its meeting back to back with other integrated assessment working groups during two of the three years. In 2013, WGIAB meeting was held in Chioggia, Italy, together with experts on integrated ecosystem analyses in the Mediterranean Sea, with the aim to facilitate the common development of core IEA concepts among different sea regions. In 2015, WGIAB meeting was held back to back with its counterpart from the Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS) with the same aim.

WGIAB has taken active part in the development of ecosystem based approaches to management within ICES, for example in the Workshop on Benchmarking Integrated Ecosystem Assessments (WKBEMIA) 27–29 November 2012, Copenhagen, the ACOM/SCICOM Workshop on Ecosystem Overviews (WKECOVER) 7–11 January 2013, Copenhagen, and the Workshop on Regional Seas Commissions and Integrated Ecosystem Assessment Scoping (WGRISCO) 17–20 November, 2014, where the Chairs of WGIAB have taken part and the topics of the workshops have been further discussed and considered at the regular meetings of WGIAB.

WGIAB has interacted with the development of advice for Baltic Fisheries management by cooperation with the working group for Baltic Fisheries Assessment Working Group (WGBFAS) during all the years, and by initiating and developing the demonstration project to develop integrated assessment and advice for Baltic Sea fish stocks (DEMO) during 2014 and 2015.

During 2013–2015, two regional scale initiatives have developed to assess the overall ecosystem health of the Baltic Sea. WGIAB has been taking part in the development of these initiatives and discussed the potential for contributing to these.

The initial holistic assessment of the ecosystem health of the Baltic Sea was published by HELCOM (2010), and is to be revisited in 2018 by a follow-up assessment to evaluate progress in relation to the Baltic Sea Action Plan. The assessment is also planned to for a roof report for MSFD reporting in the region by the Baltic Sea countries that are also EU member states (abstract below).

The Ocean Health Index was developed in the USA, and produced a comprehensive global measurement of ocean health. The OHI evaluates the world's oceans according to 10 goals that represent key benefits of healthy marine ecosystems. By integrating information from many disciplines and sectors, the Index is a significant advance over conventional single-sector approaches to assessing ocean condition. A regional scale application of the OHI was started in 2015 by a regional project lead by Stockholm University (WGIAB, 2014).

6.1 Topics on cooperation of the 2015 meeting

Developing a holistic assessment of ecosystem health in the Baltic Sea - by Lena Bergström and Ulla Li Zweifel

The HELCOM project for the second holistic assessment of ecosystem health in the Baltic Sea started in late 2014 and will continue until June 2018. The assessment will give an update of the overall environmental status of the Baltic Sea and evaluate progress in relation to the goals of the Baltic Sea Action Plan. It will be developed so that it can also be used in the reporting under the EU Marine Strategy Framework Directive. This is achieved by development of joint HELCOM tools and concepts. The assessment will be focusing on the regional scale, but performed in such a way that the results can also be used in national assessments of marine and coastal areas. The work of the project is guided by a core team with representation from the Contracting Parties to the Helsinki Convention i.e. the nine countries bordering the Baltic Sea and the European Union. The planned assessment is structured around the DPSIR framework. The assessment is set to cover all aspects within this cycle, with a focus on assessing pressures, status, and social and economic impacts. The main pressures addressed are related to inputs of nutrient loading and hazardous substances, fisheries and maritime activities. Marine litter, underwater noise and non-indigenous species are also considered. Status of the environment is based on key elements of biodiversity, focusing on marine mammals, fish, birds, the seabed, and the pelagic habitat. The assessment of impacts is carried out by environmental economic analyses to assess the cost of degradation, and addresses ways of optimizing the probability of success for different management measures to improve environmental status. The assessments will build on a regional set of indicators, developed jointly by HELCOM, and by ICES for commercial fish stocks. The methods and tools applied will be developed during the course of the project.

7 Summary of Working Group evaluation and conclusions

The conclusions below and the suggested terms of reference for WGIAB 2016–2018 (Annex 4) are based on the discussions at WGIAB 2015. The suggested terms of reference are in the core of the ICES strategic plan for 2014–2016, with respect to the goals: ”Develop an integrated, interdisciplinary understanding of the structure, dynamics, and the resilience and response of marine ecosystems to change” and “Understand the relationship between human activities and marine ecosystems, estimate pressures and impacts, and develop science-based, sustainable pathways”. During the past three years, WGIAB has developed further the understanding of patterns and processes in the Baltic Sea foodweb, and the results have been presented in the working group reports, in > 10 peer reviewed papers stemming from work of the group, and with several conference contributions. The group has taken part in workshops of relevance as arranged at ICES, and contributed to the further development of methods to integrate environmental information in fish stock assessments. The planned future work seeks the active participation of experts in socio-economy, fisheries biology, marine biology, oceanography and foodweb modelling.

Annex 1: List of participants

NAME	ADDRESS	E-MAIL
Lena Bergström **Chair**	Swedish Univeristy of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6, SE-742 42 Öregrund, Sweden	lena.bergstrom@slu.se
Thorsten Blenckner	Stockholm Resilience Centre, Stockholm University, Kräftriket 2B, SE-11419 Stockholm, Sweden	thorsten.blenckner@su.se
Anders Grimvall	Swedish Institute for the Marine Environment, Box 260, SE-405 30 Gothenburg, Sweden	anders.grimvall@liu.se
Anna Gårdmark	Swedish Univeristy of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6, SE-742 42 Öregrund, Sweden	anna.gardmark@slu.se
Henrik Hamrén	Baltic Sea Centre, Stockholm University, SE-106 91 Stockholm, Sweden	henrik.hamren@su.se
Noél Holmgren	School of Bioscience, University of Skövde, Box 408 SE-541 28 Skövde, Sweden	noel.holmgren@his.se
Ute Jacob	University of Hamburg, Institute of Hydrobiology and Fishery Science, Grosse Elbstrasse 133, D-22767 Hamburg, Germany	ute.jacob@uni-hamburg.de
Stuart Kininmonth	Stockholm Resilience Centre, Stockholm University, Kräftriket 2B, SE-11419 Stockholm, Sweden	stuart.kininmonth@su.se
Scott Large	ICES, H. C. Andersens Boulevard 44–46, DK- 1553 Copenhagen V, Denmark	scott.large@ices.dk
Phil Levin	Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA	phil.levin@noaa.gov

Name	Address	E-mail
Annukka Lehikoinen	Helsinki University, Kotka Maritime Research Centre Heikinkatu 7, FI-48100 Kotka, Finland	annukka.lehikoinen@helsinki.fi
Marcos Llope	Instituto Español de Oceanografía, Centro Oceanográfico de Cádiz, Spain	marcos.llope@cd.ieo.es
Anna Luzenczyk	National Marine Fisheries Research Institute, ul. Kołłątaja 1, 81–332, Gdynia, Poland	aluzenczyk@mir.gdynia.pl
Bärbel Müller-Karulis	Baltic Sea Centre, Stockholm university, SE-106 91 Stockholm, Sweden	barbel.muller.karulis@su.se
Christian Möllmann **Chair**	University of Hamburg, Institute of Hydrobiology and Fishery Science, Grosse Elbstrasse 133, D-22767 Hamburg, Germany	Christian.moellmann@uni-hamburg.de
Stefan Neuenfeldt	DTU Aqua, Jægersborg Allé 1, DK-2920 Charlottenlund, Denmark	stn@aqua.dtu.dk
Niclas Norrström	School of Bioscience, University of Skövde, Box 408 SE-541 28 Skövde, Sweden	niclas.norrstrom@his.se
Jens Olsson	Swedish Univeristy of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6, SE-742 42 Öregrund, Sweden	jens.olsson@slu.se
Saskia Otto	University of Hamburg, Institute of Hydrobiology and Fishery Science, Grosse Elbstrasse 133, D-22767 Hamburg, Germany	saskia.otto@uni-hamburg.de
Zeynep Pekcan-Hekim	Swedish Univeristy of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6, SE-742 42 Öregrund, Sweden	zeynep.pekcan.hekim@slu.se
Andrea Rau	Thuenen-Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, D–18069 Rostock, Germany	andrea.rau@ti.bund.de

NAME	ADDRESS	E-MAIL
David Reid	arine Institute,Rinville, Oranmore, Co. Galway, Ireland	avid.reid@marine.ie
Maciej T. Tomczak	Baltic Sea Centre, Stockholm university, SE-106 91 Stockholm, Sweden	maciej.tomczak@su.se
Marian Torres	Swedish Univeristy of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6, SE-742 42 Öregrund, Sweden	marian.torres@slu.se
Didzis Ustups	Institute of Food safety, Animal Health and Environment, 8 Daugavgrivas Str., Riga LV-1048, Latvia	Didzis.Ustups@bior.lv
Laura Uusitalo **Chair**	Finnish Environment Institute, Marine Research Centre, PO Box 140, 00251 Helsinki, Finland	laura.uusitalo@ymparisto.fi
Karin Wesslander	Swedish Meteorological and Hydrological Institute, Marine Environment, SE – 426 71 Västra Frölunda, Sweden	karin.wesslander@smhi.se

Annex 2: Recommendations

No recommendations.

Annex 3: Integrated trend analyses for the Central Baltic Sea 1979–2014

The central Baltic Sea foodweb was assessed for the first time during the first meeting of WGIAB in 2007 (WKIAB). The time-series were updated again at the 2015 meeting with abiotic datasets now covering a total of 35 years from 1979 to 2014. The biotic part of the dataset were not updated, due to the fact that data for 2014 were not yet available for the plankton data, and that approved model data on cod stock size were not available for the recent years due issues related to the stock assessment (See ICES WGBFAS report 2014).

Abiotic data

Hydrography

In the most recent years assessed, spring water temperatures in the Gotland and Bornholm Basin were in line with the long-term average and summer temperatures were higher than average (Figure A3-2).

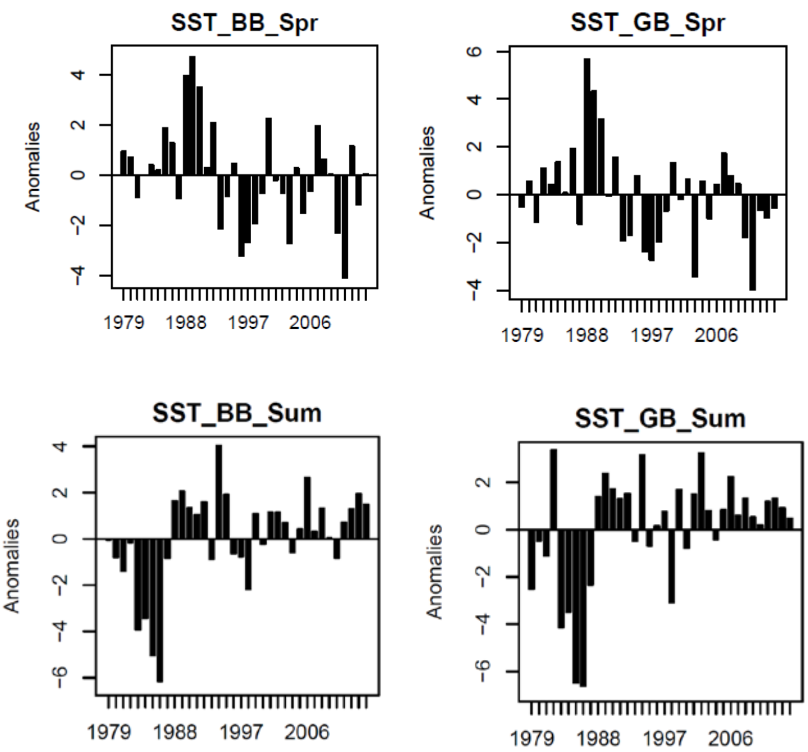

Figure A3-1. Temperature in the Central Baltic in 1979–2014. Anomaly plots show the surface water temperatures in the Bornholm (BB) and Gotland Basin (GB) in spring (May) and in summer.

A strong salt water inflow occurred in 2003 but after this, many years followed when no inflows occurred that were strong enough to replace the bottom water in the Gotland Deep. A major inflow in winter 2011/2012 reached only the Bornholm Basin and the southern part of the Gotland Basin (Nausch *et al*., 2013). Therefore, salinity in the halocline region and deep water of the Gotland Basin continued to decrease. Surface salinity is now close to its long-term average in the Bornholm basin and lower than average in the Gotland basin (Figure A3-2).

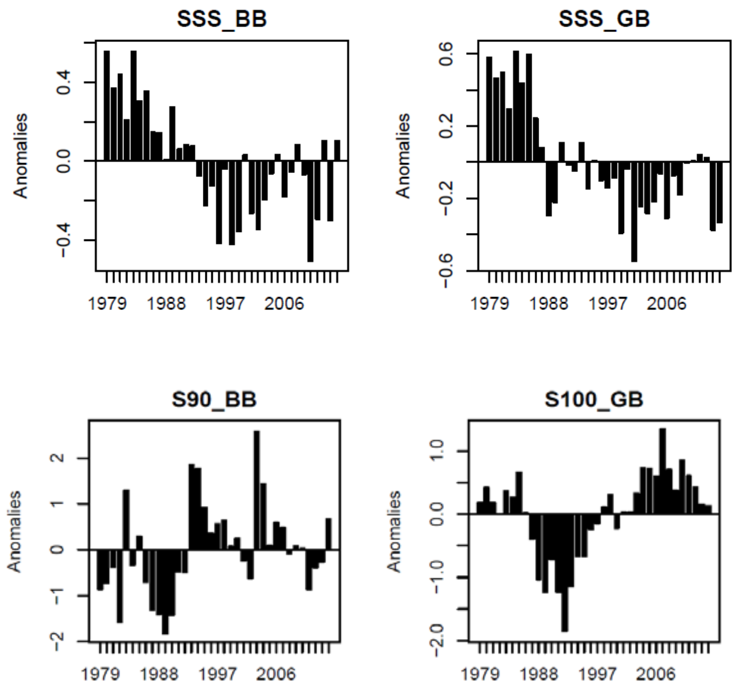

Figure A3–2. Salinity in the Central Baltic surface (upper row) and deeper (lower row) water in 1979–2014 in the Bornholm (BB) and Gotland Basin (GB).

Due to the lack of saltwater inflows, the anoxic bottom area is large. Oxygen conditions in the bottom water have decreased but were close to the long-term average in recent years. The reproductive conditions for cod are poor, as indicated by the 11 PSU isohaline, although the reproductive volume of cod showed some improvement during the most recent years (Figure A3-3).

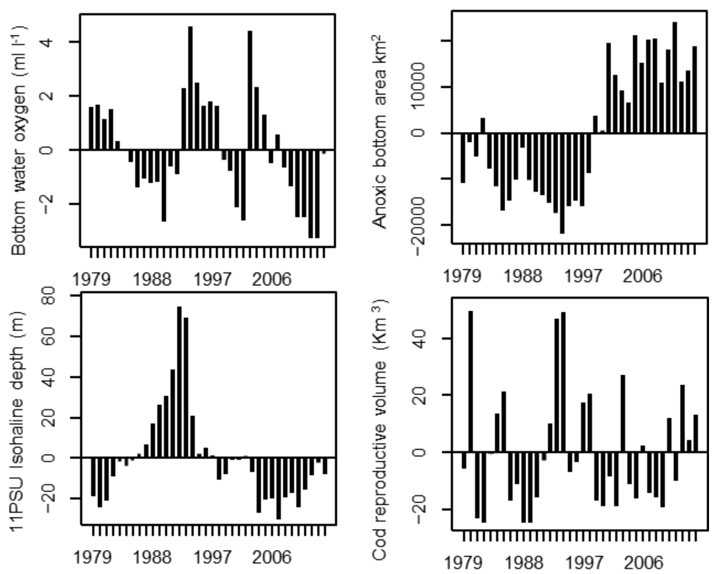

Figure A3–3. Oxygen conditions in the central Baltic Sea in 1979–2014. Anomaly plots show oxygen concentrations at 200–220 m depth in the Gotland deep (top left), area of anoxic bottom in the Baltic Sea, depth of the 11 PSU isohaline (bottom left) and cod reproductive volume (bottom right).

Nutrients

Both in the Bornholm and the Gotland Basin, surface winter DIN concentrations increased since 2006, but are still much lower than the peak values observed at the end of the 1980s. Winter DIP concentrations in 2014 were lower than the large winter DIP values observed during the last decade. In the bottom water, both DIN and DIP concentrations reflect saltwater inflow patterns.

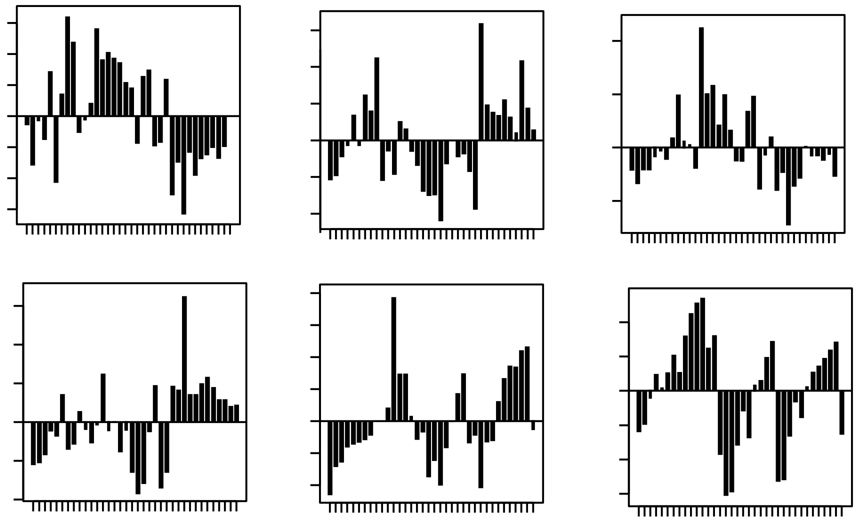

Figure A3–4. Nutrient conditions in the central Baltic Sea in 1975–2014. Anomaly plots show surface winter DIN and DIP concentrations in the Bornholm and Gotland Basin as well deep-water (200–220 m) nutrient concentrations in the Gotland Basin.

Biotic data

The latest year of update for the biotic data varies between variables.

Phytoplankton

Chlorophyll *a* data suggests a break from increasing summer phytoplankton biomass in the Gotland Sea after 2006 (Figure A3-5), while species data show large cyanobacteria biomass in 2009, 2011 and 2012. Patterns in the Bornholm basin differed from the Gotland Sea with fluctuating summer chlorophyll *a* and low cyanobacteria biomass during recent years.

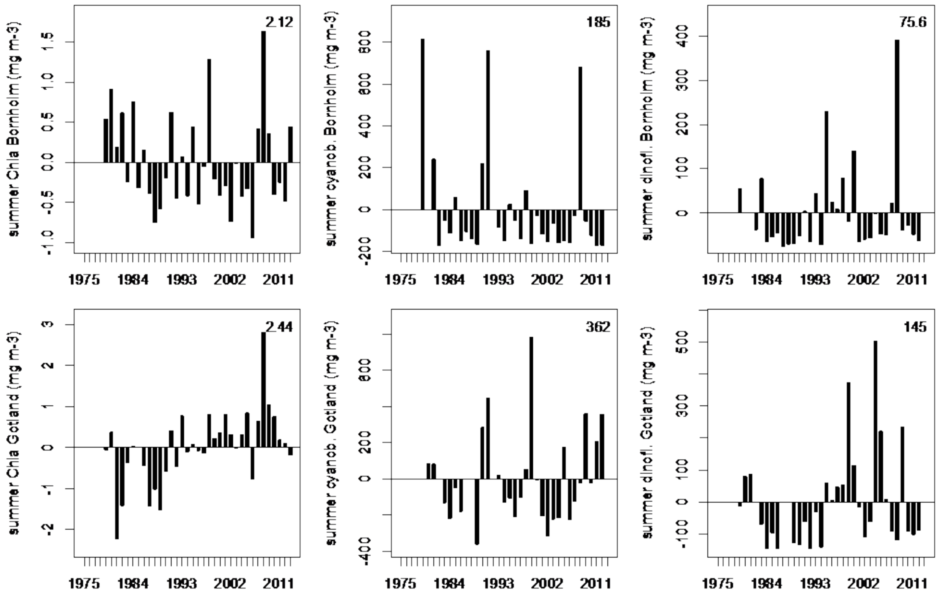

Figure A3–5. Summer chlorophyll a concentrations and phytoplankton group biomass in the Central Baltic Sea in 1979/1980–2012. Anomaly plots show chlorophyll a concentrations (left), cyanobacteria (middle) and dinoflagellate biomass (right) in the Bornholm (top row) and Gotland Basin (bottom row).

Zooplankton

The relatively cold winters since 2009 are reflected in low spring abundances of *Acartia* spp., while fluctuations are larger for *Temora longicornis* (6), the other dominating copepod species above the Central Baltic halocline. During summer, the abundance of both species remained low since 2010. *Pseudocalanus acuspes*, which is primarily distributed in the halocline region of the Central Baltic basins, has remained at low biomass levels since the beginning of the 1990s.

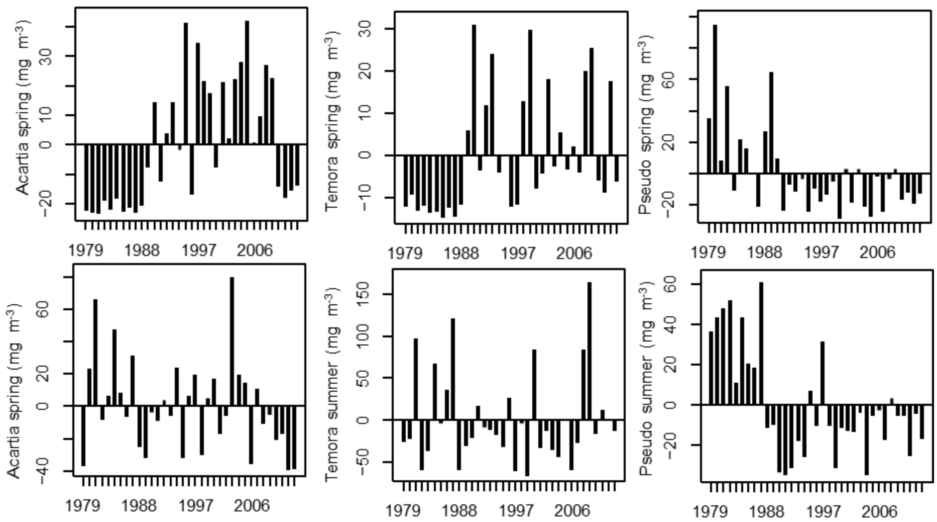

Figure A3–6: Zooplankton biomass in the Central Baltic Sea in 1975–2013. Anomaly plots show biomass in spring (top row) and summer (bottom row) for *Acartia* spp. (left), *Temora* spp. (middle) and *Pseudocalanus* spp. (right).

<u>Fish and fisheries</u>

Because of the reduced fishing pressure and consequently low fishing mortality, the recovery of the cod stock (Figure A3-7) continued despite still below-average recruitment. However, since the mid-1990s cod condition has declined. The sprat stock is currently at its time-series average, after record high biomasses in the mid-1990s. Recruitment conditions continue to be favourable for sprat, but highly variable. Since 2011, fishing mortality for the stock has declined. Central Baltic Sea herring SSB has stabilized slightly below its long-term average. Recruitment has been low since the mid-1980s, but low fishing mortality since the end of the 1990s has permitted a gradual recovery of the stock.

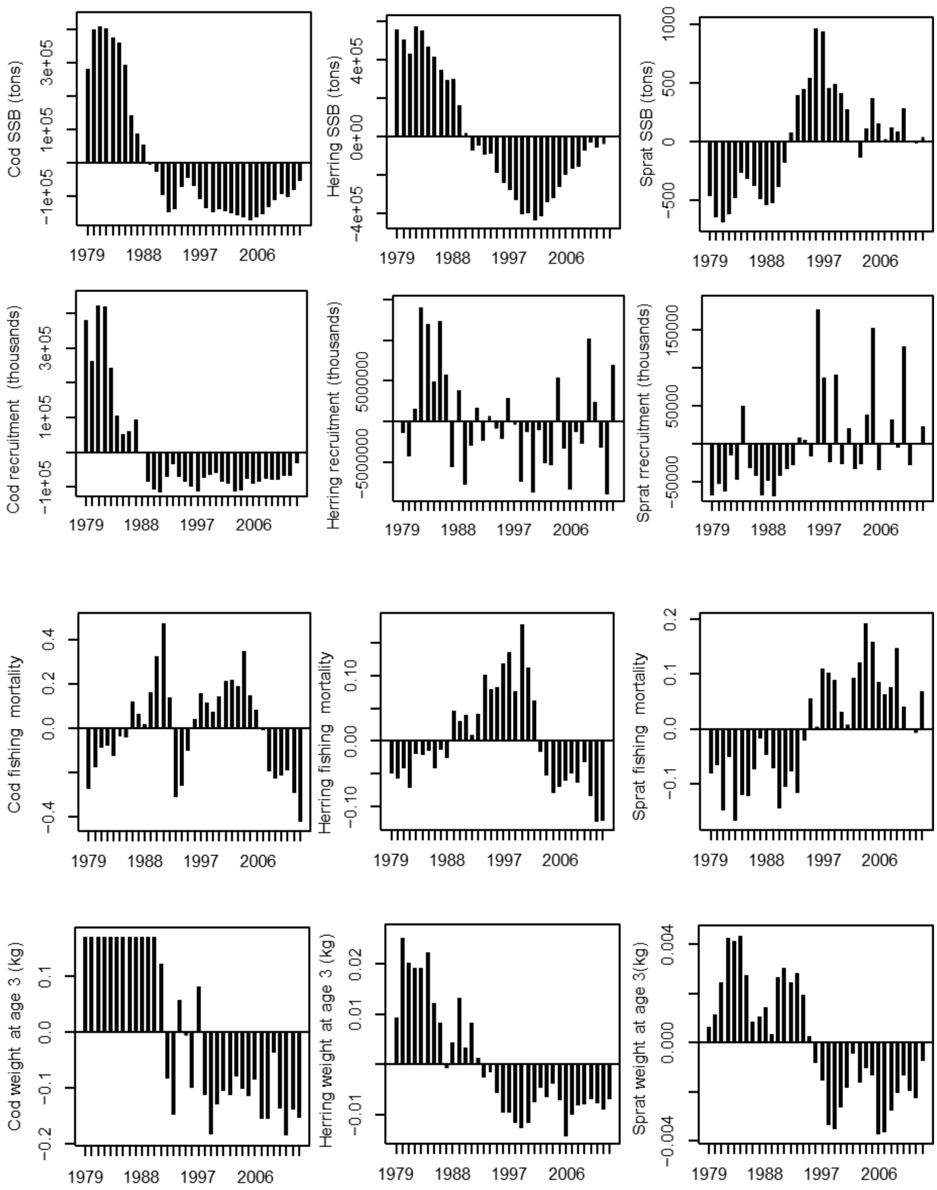

Figure A3–7. Fish and fishery indicators for the Central Baltic Sea in 1979–2013. Anomaly plots show spawning-stock biomasses (top row) of cod, herring and sprat, recruitment (second row), fishing mortality F (third row) and weight at age (bottom row).

Integrated analysis

In total, 54 variables were included in a multivariate analyses of integrated trends; 29 characterizing abiotic conditions (climate, hydrography, nutrients, oxygen) and 25 describing biotic conditions (phytoplankton, zooplankton, fish).

The PCA on abiotic variables structured temperature and salinity variables mainly along PC1 and nutrient/oxygen variables along PC2 (Figure A3-8). The coldest and most saline years occurred at the beginning of the time-series and the warmest and less saline in the late 1980s and early 1990s. Because the major Baltic inflows in 1993 and 2003 oxygenated the bottom water in the Gotland Sea, PC2 abiotic increased strongly for these years, followed by a fast return to the previous anoxic state. The years of the 2000s were phosphorus-rich and with below poor oxygen conditions, and the first years of the 2010s were in line with the long-term average for many of the variables.

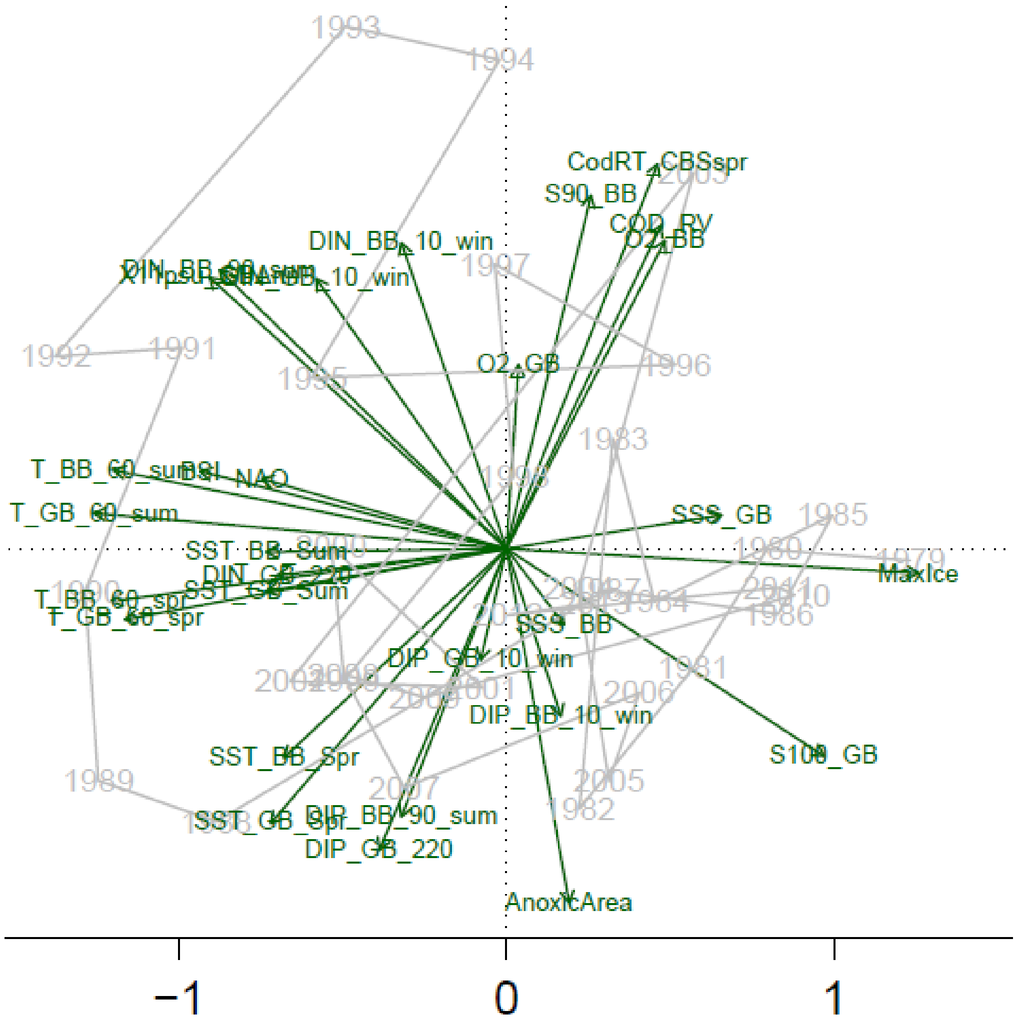

Figure A3-8. Biplots of variable loadings with time-trajectory of year scores in the in the PC1-PC2 plane for the Central Baltic Sea abiotic time-series 1979–2014.

The biotic variables were updated until 2013 and the PCA was run without including cod data. The results show a development over time towards increasing sprat, chlorophyll-a, and of the zooplankton *Acartia* and *Temora* during spring, and decrease in *Pseudocalanus*(spring and summer) as well as in herring, in parallel with a decreased weight at age for both sprat and herring. The more gradual changes in biotic variables compared to the abiotic are explained by the longevity of fish, where fish stocks integrate the fluctuations of several year classes. The second PC-axis mainly captured changes in zooplankton during summer and changes in cholorohyll-a.

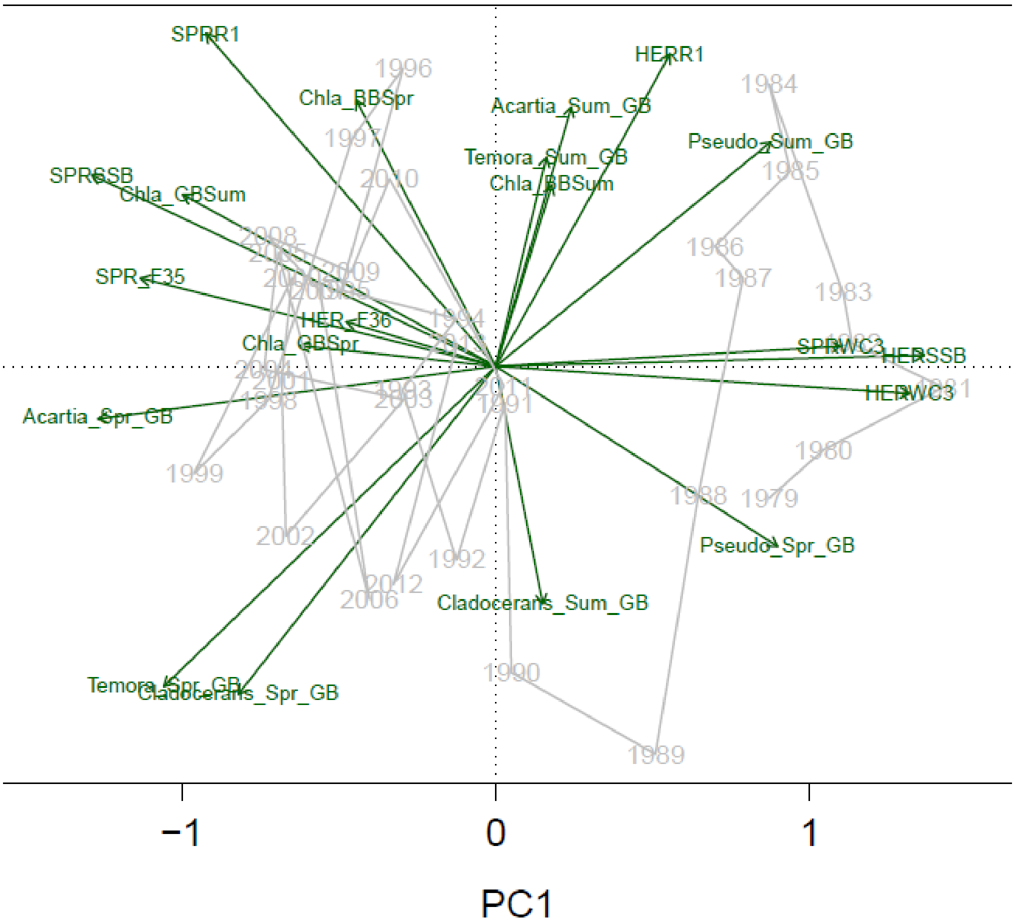

Figure A3–9: Biplots of variable loadings with time-trajectory of year scores in the in the PC1-PC2 plane for the Central Baltic Sea biotic time-series 1979–2013.

A Chronological clustering of all data up until 2013 identified the main shifts in the dataset to occur in 1987/1988 and in 1992/1993. The most recent years cluster within (data not shown).

Annex 4: WGIAB 2016–2018 terms of reference

The ICES/HELCOM **Working Group on Integrated Assessments of the Baltic Sea** (WGIAB), chaired by Laura Uusitalo, Finland, Saskia Otto*, Germany, Martin Lindegren*, Denmark, and Lena Bergström, Sweden, will meet in Helsinki, Finland, on 18–22 April 2016 and generate deliverables as listed in the Table below.

WGIAB will report on the activities of 2016 by 30 May 2016 to SSGIEA.

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Increase understanding of Baltic Sea ecosystem functioning, with a focus on functional diversity in relation to species diversity and changes of species traits over different temporal and spatial scales, and the identification of key traits and processes for maintaining functioning ecosystems and the services they provide;	This ToR will provide further knowledge of important functional linkages between ecosystem components, to support the development of an integrated marine management, including an ecosystem based fisheries management.	Develop an integrated, interdisciplinary understanding of the structure, dynamics, and the resilience and response of marine ecosystems to change	3-year	-Research articles to be decided within 2015 -Intermediate results reported in interim report 2016, 2017
b	Explore potential new options for management, including for example studies on indicators of foodweb status, implications for ecosystem functioning, and societal drivers, in order to support integrated fisheries advice and marine management, focusing on biodiversity and ecosystem function.	This ToR will develop on existing assessment tools and explore new options, based on cases studies. The work supports the assessment work of the working group for Baltic Sea fisheries assessment (WGBFAS), and other ongoing work within ICES and HELCOM.	Understand the relationship between human activities and marine ecosystems, estimate pressures and impacts, and develop science-based, sustainable pathways	3-year	- Research articles (to be decided within 2015) - Intermediate results reported in interim report 2016, 2017

Summary of the Work Plan

Year 1	Annual meeting, intersessional work on research articles, interaction with suggested WKDEMO to develop on the outcomes of the DEMO project.
Year 2	Annual meeting, intersessional work on research articles
Year 3	Annual meeting, intersessional work on research articles

"Supporting information

Priority	WGIAB aims to conduct and further develop Integrated Ecosystem Assessment cycles for the different subsystems of the Baltic Sea, in support of implementing the ecosystem approach in the Baltic Sea.
Resource requirements	Assistance of the Secretariat in maintaining and exchanging information and requirements data to potential participants. Assistance of especially the ICES Data Center to collect and store relevant data series.
Participants	The Group is normally attended by some 20 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	WGBFAS
Linkages to other committees or groups	WGINOSE, WGNARS, WGEAWESS, WGINOR, WGCOMEDA.
Linkages to other organizations	HELCOM

Annex 5: Copy of Working Group evaluation

1) **Working Group name:** ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea.

2) **Year of appointment**: 2008.

3) **Current Chairs**: Christian Möllmann, Germany, Laura Uusitalo, Finland and Lena Bergström, Sweden.

4) **Venues, dates and number of participants per meeting**: 8–12 April 2013, Chioggia, Italy, (14 participants); 10–14 February 2014, Kiel, Germany (27 participants); 9–13 March 2015, Cádiz, Spain (27 participants)

WG Evaluation

5) **If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution**: Develop an integrated, interdisciplinary understanding of the structure, dynamics, and the resilience and response of marine ecosystems to change; Understand the relationship between human activities and marine ecosystems, estimate pressures and impacts, and develop science-based, sustainable pathways

6) **In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc.** *: Around 10 peer reviewed papers published based on data and findings from the group, contribution on indicators of recruitment environment for Baltic cod to WGBFAS; integrated trend analyses of changes over time in the foodwebs of the main sub-basins of the Baltic Sea; combined assessment of coastal foodwebs areas around the Baltic Sea

7) **Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice:** Contribution on indicators of recruitment environment for Baltic cod to WGBFAS; Development of methods to integrate environmental information in fish stock assessment

8) **Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities;** DEMOnstration exercise for Integrated Ecosystem Assessment and Advice of Baltic Sea cod with four workshops for 2014–2015, funded by Stockholm University Baltic Sea Centre and Baltic Eye.

9) Please indicate what difficulties, if any, have been encountered in achieving the workplan: —

Future plans

10) **Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)**; Yes. There is a continued need for developing the understanding of Baltic Sea ecosystems and foodwebs in line with the planned activities of the group for the next three years. The results are foreseen to contribute to the development of integrated marine management in the core of the ICES strategic plan

11) **If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG**; NA

12) **What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR**?; Expertise on socio-economic aspects in order to contribute to the development of assessment of ecosystem services; Continued expertise on fisheries biology, marine biology, oceanography and foodweb modelling is fundamental.

13) **Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used**? (please be specific); Information on environmental indicators in support of the fisheries assessment; development of assessment tools