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Report of the Workshop on DEveloping Integrated AdviCE for Baltic Sea ecosystem-based fisheries management (WKDEICE2)

19–21 June 2017

Gdynia, Poland

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Executive summary

The Second ICES Workshop on DEveloping Integrated AdviCE for Baltic Sea ecosystem-based fisheries management (WKDEICE2) aimed to develop ways to include environmental and economic considerations into ICES advice on Baltic Sea fish stocks from operational and structural perspectives. The WKDEICE2 meeting was held in Gdynia, Poland, on 19–21 June 2017, with 11 participants from six countries and was chaired by Rudi Voss (Germany) and Maciej T. Tomczak (Sweden).

Focusing on the ICES advisory framework WKDEICE2 addressed three main topics:

1. developing a strategy and corresponding ICES structures for integrating environmental and economic information into ICES advice on Baltic fish stocks;
2. exploring potential ways to include economics, specifically ecological-economic modelling, in integrated advice;
3. conducting short-term projections informed by environmental and economic conditions to illustrate the added value of integrated advice.

A central point of the meeting was to discuss and design a concept of operationalized Integrated Advice Evaluation (IAE). The role of this process is to place the single species advice into environmental, multispecies and bioeconomic context, rather than replacing the single species advice. That could be done by the evaluation of risks and consequences of management following the advice for stocks, the ecosystem and fisheries under various environmental scenarios. We outline how the ICES advisory process for Baltic fish stocks could be modified, taking in to account already existing structures, solutions and ongoing changes at ICES. We propose to use already existing tools, approaches and knowledge to support the advisory process in new ways. The suggested framework also highlights gaps in knowledge and needs for novel tools.

We explored two options to include economics, specifically ecological-economic modelling, in integrated advice and ecosystem-based management. The first alternative is the use of a bioeconomic model to estimate economically 'optimal' management advice, which takes into account ecological criteria as well as short- to medium-term economic costs. We further illustrate what net cost reductions per year are possible applying such a strategy compared with the existing way of setting total allowable catches (TACs). The approach integrates the economic benefits for the fishery as well as society (consumers), while safeguarding precautionary stock sizes. The approach might offer a transparent basis for evaluating decision-making outcomes. A second alternative used the method of defining Harvest Control Rules (HCR) using an age structured bioeconomic model. Such an approach offers the direct combination of economics and biological stock assessment, as well as straightforward, easy to follow set of rules for decision-makers and stakeholders.

Encouraging results motivate further exploration of the use of bioeconomic models in ecosystem-based management of the Baltic. Further work of WKDEICE needs to focus on simulating the advice process and testing more advanced/a broader range of modelling tools (Management Strategy Evaluation - MSE, and Decision Support Tools - DST).

1 Opening of the meeting

The WKDEICE2 meeting was opened by the two chairs: Maciej T. Tomczak and Rudi Voss. Expected outcomes of the meeting were discussed and the agenda was adopted. A list of participants and the agenda can be found in Annexes 1 and 2, respectively.

Three main topics were addressed by WKDEICE2:

1. Developing a strategy for integrating environmental and economic information into the ICES advisory process and fish stock advice;
2. Conducting an example of simple stock dynamic simulations with integrated environmental and ecosystem factors;
3. Developing a socio-economic approach for the advisory process.

The Baltic cod and sprat stocks were selected as case studies in the WKDEICE, however, the discussions and exercises are relevant to all Baltic fish stocks assessed by ICES.

Based on the work conducted as preparation for the workshop, as well as during earlier meetings (e.g. ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB)WGIAB, external DEMO project workshops, see ICES WGIAB 2015), a strategy for integrating environmental and economic information in ICES advice was discussed. The goal was to (i) develop a general framework, which might be applicable for a variety of stocks in the ICES area, and (ii) specify potential ways forward in the operational stock assessment-forecast-advice routine of ICES.

2 Outlining the integrated advice framework approach – scoping the possibilities for evolving the current advisory process for Baltic Sea fish stocks

Based on the framework described by Möllmann *et al.* (2013), and the work conducted last year at WKDEICE (ICES WKDEICE 2016) and during earlier meetings (e.g. WGIAB, external DEMO project workshops, see ICES WGIAB 2015), a strategy for integrating environmental and economic information in ICES advice was discussed and developed further. The goal was to define and specify ways to place environmental and economic information in the ICES advisory process and thereby advance the operational stock assessment-forecast-advice routine.

We discussed Baltic cod stocks (Eastern Cod Stock – EBC Subdivision 25-32 and Western Cod Stock- WBC Subdivision 22-24) and sprat stock as our examples. The main reason for choosing these stocks is the relatively large availability of relevant information on their fisheries, environment and economics, as well as a fairly good general understanding of the ecological processes affecting them.

The defined cod stocks (EBC and WBC) and sprat stocks also represent different ICES stock assessment categories; WBC (category 1 but now depleted) and Sprat (category 1; good status) and EBC (category 3). This gave us an opportunity to discuss a potential Ecosystem Advice framework for stocks under different categories and under different frequency of ICES stock assessments.

At WKDEICE1 (ICES WKDEICE 2016), we identified four options in which it would be possible to make use of environmental and economic information and to include it in the advice (Figure 2.1):

1. Using environmentally-sensitive stock–recruitment functions in the short-term forecast; for the case of Eastern Baltic cod the size of the reproductive volume, influencing recruitment success, is the most obvious candidate;
2. Using environmentally-sensitive stock–recruitment functions in a bioeconomic model to evaluate economic conditions;
3. Using all relevant information from an environmental assessment to modify fishing mortalities in short-term forecast; depending on the state and trend in environmental conditions, F-multiplier is used, allowing for increased or decreased fishing opportunities, respectively;
4. Using the F-multiplier directly in the advice, giving process and reflecting environmental assessment outcomes.

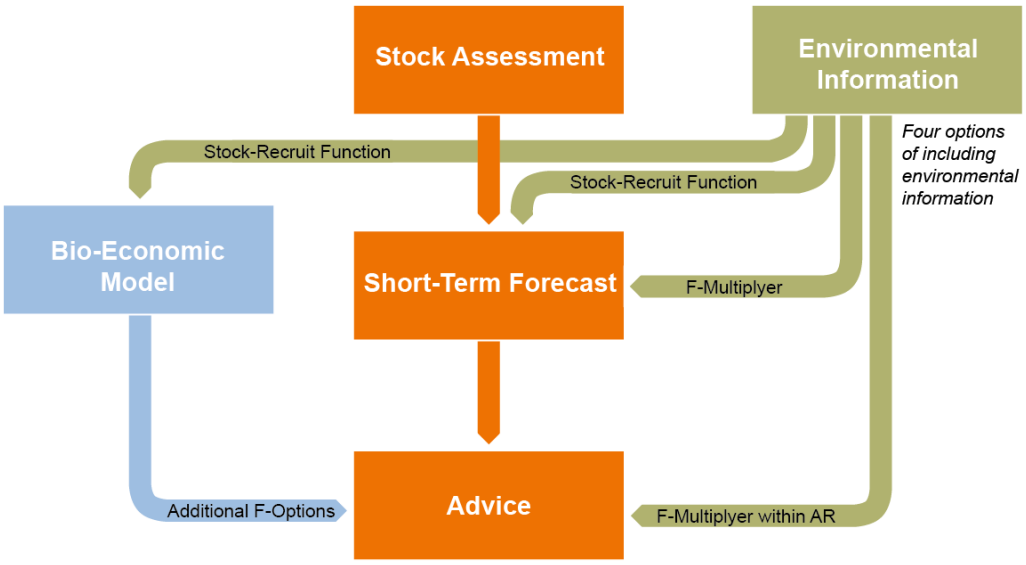

Figure 2.1. Schematic on ways to incorporate environmental information and bioeconomic modelling in the standard advice process leading to an integrated advice (ICES WKDEICE 2016).

During the WKDEICE2, the group also discussed the concept presented in the figure above (Figure 2.1) from a more operational point of view. One of the main questions was: "How to include ecosystem and economic aspects into the ICES advice process for Baltic Sea stocks as a way to implement an ecosystem approach?". The following key questions and issues for operational advice presented by ICES were addressed:

- What role do sprat and herring play as forage fish in the Baltic Sea, not only for cod, but also for charismatic top predators like salmon?
- The thiamine deficiency syndrome M74 is a reproductive disorder, which causes mortality among yolk-sac fry of Baltic salmon caused by diet dominated by sprat;
- Herring and sprat are managed through separate quotas but caught together in mixed fisheries. What consequences does this have for exploitation and ecosystem if the stocks are not managed appropriately?
- Fish in the Baltic Sea change their distribution in response to many interacting factors. Which distributional changes have strongest impact on species interactions and the effectiveness of management advice? When is it be relevant to adapt monitoring and assessment to these changes?
- The causes and consequences of changes in cod growth need to be assessed, and management advice has to be adapted;
- The Baltic Sea ecoregion has undergone and will continue to undergo changes caused by climate/environment and anthropogenic activities. When do relevant changes need to be monitored and at what point does it become imperative that the advice take these changes into account?

We conclude that the relevance of the questions and issues described above needs to be decided on a stock by stock basis. Furthermore, the usefulness of including environmental and economic information into the advice should be tested first on stocks where much ecological knowledge exists (i.e. Sprat or Cod stocks), focusing on questions that are possible to include in the quantitative advice and/or evaluate by Decision Support Tools (examples below section 3). It is important to prioritize the following factors and their consequences for advice: the stock's distribution, environmental changes (climate hydrography, nutrient) affecting the stock's production, species interactions and in case of clupeids mixed fisheries.

Recurrent advice from ICES on fishing opportunities is requested by European Commission and based on AA - Administrative Agreement (EU 2017) where the framework and advice requirements are stated. The current annual data-stock assessment-advice chain is mainly based on fisheries data (catches, landings, surveys) collected on national level and reported to ICES. Stock assessments are performed by Expert Groups (in Baltic case ICES Working Group of Baltic Fisheries Assessment - WGBFAS). WGBFAS is a crucial part of the advisory process, and delivers stock assessment (stock status, fishing pressures, reference points) and condition table with fishing opportunities pointing towards fishing advice, in accordance with ICES advice rules. The WGBFAS condition tables are based on short-term 3-year forecast, which in turn are based on recruitment assumptions (or Stock–recruitment relationship) for stock category 1 and 2. For stocks at lower categories, advice is given based on surveys trend and MSY proxies. The advice drafting group review the suggested advice in reference to ICES advice rules and current legislations. In the following step, the advice is approved by ICES Advisory Committee before the advice finally is made available for the client. Ecosystem Descriptions presenting major drivers and pressures on fish stocks is an ICES product that is currently under development at ICES and will provide an ecosystem context for the client together with fisheries advice.

Considering the current advice process and key questions outlined above, the group discussed why, how and at which stages ecosystem knowledge and ecological and bioeconomic indicators could be included in the advice process. The current ICES assessment-forecast-advice chain gives annual stock-by-stock advice. However, the current process includes very little or no environmental and ecosystem elements. This puts ICES advice in line with CA and MAP (Multi Annual management plan for Baltic fish stocks, EU 2016), but it is still very narrow and limited in regards to current EU legislation (i.e. Marine Strategy Framework Directive – MSFD, EC 2008) and the objectives of the Common Fisheries Policy (EU 2013). WGBFAS assesses stock status against F and SSB reference points, which are evaluated during a benchmark process (ICES 2017). However, there are no robustness assessment or quantitative risk assessment of stock dynamics or reference points under changing environmental conditions, or potential consequences of advice on the ecosystem expressed as probability of stock collapse or recovery, which is especially important in the Baltic Sea due to high environmental influence on stock dynamics (Möllmann *et al.*, 2009; Margonski *et al.*, 2012; MacKenzie *et al.*, 2012) and strong trophic interactions (i.e. Casini *et al.*, 2009; Möllmann *et al.*, 2009).

Möllmann *et al.* (2013) recommended ways of implementing Integrated Ecosystem Assessment elements with multispecies assessment. Their suggestions are to use short–term environmentally sensitive forecasts and ecosystem indicators approach for tactical purposes and MSE and bioeconomic models for setting goals and fisheries management plans. However, implementing their suggested approaches requires a fundamental change in how fish stock assessment and advice is conducted (Möllmann *et al.*, 2013; Casini *et al.*, 2011). They also suggest that more effort needs to be shifted from the regular single-species procedure towards implementing multispecies and ecosystem assessments. This potentially requires a reduction in the temporal frequency of single-species assessments, allowing more effort towards the development of ecosystem assessments. Moreover, fish stock and ecosystem assessments should be combined into an integrative, interdisciplinary framework. Some of those changes are already taking place in ICES in the form of a reduction in the temporal frequency of single-species assessments and moving towards multiannual assessments.

In order to move towards a more ecosystem-based advice within the current ICES framework, the ICES advisory system needs to evolve by placing the single species advice into environmental, multispecies and economic context. That could be done by evaluation risks and consequences of advice for stocks, ecosystem and fisheries under environmental scenarios. We outline how the ICES advisory process for Baltic fish stocks could be modify, taking in to account already existing structure, solutions and ongoing changes at ICES. We proposed to use already existing tools, approaches and knowledge to support the advisory process.

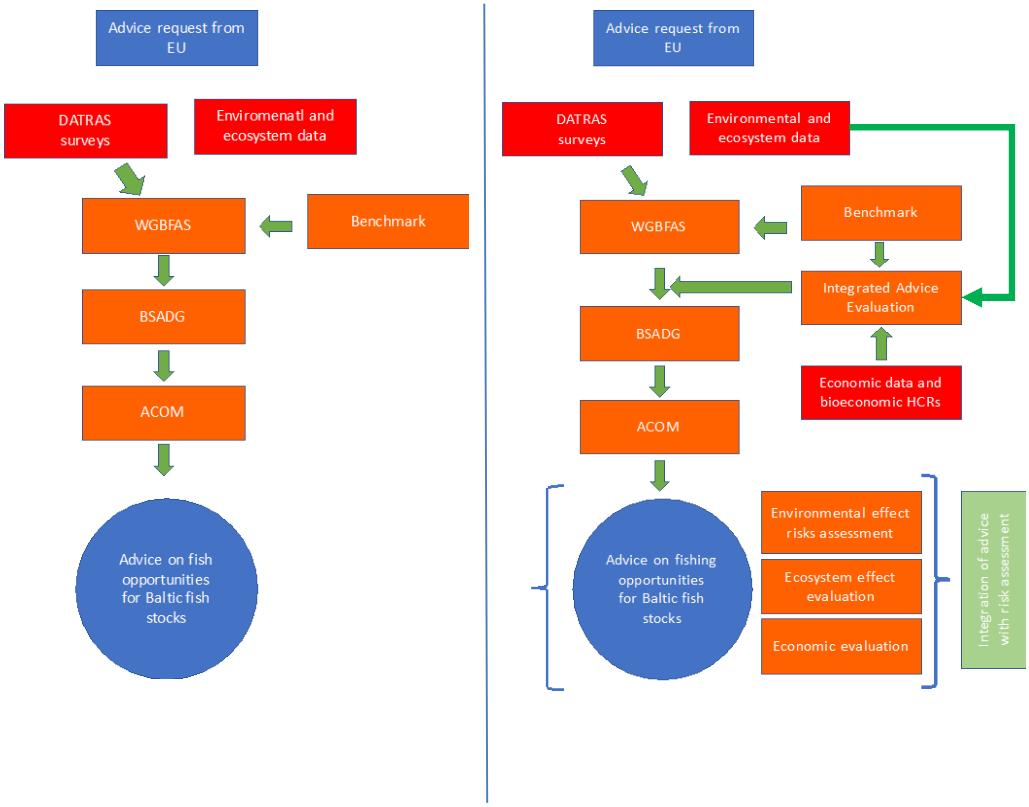

Figure 2.2. Schematic outline for Baltic fish stock advice i) existing on left and ii) proposed including steps supporting fisheries advice at environmental/ecosystem/integrated level(right).

The major difference between the current and the proposed advice system is the intermediate step called Integrated Advice Evaluation (IAE), between assessment EG (WGBFAS) and Advice drafting group (ADGBS), and the inclusion of the resulting integrated information and risk assessment in the final advice product (Figure 2.2). The IAE step in the process could be an integral part of WGBFAS or a separate EG. Depending on needs and the stock specific situation, the main general process? of the IAE should be:

- Assimilate environmental data from the ICES data centre;
- Incorporation of environmental indices into short-term predictions to support advice;
- Assessing the risk of a stock falling below reference points or stock recovery under environmental scenarios;
- Evaluate consequences of different advice options on the stock and ecosystem, also in multispecies, multifleet and spatial context;
- Use economic data and stock assessment data to model harvesting decisions and generate bioeconomic HCRs";

- Evaluate consequences of advice options in a bioeconomic context on a strategic level for better communication with stakeholders.

Those aspects could be addressed using different tools at the IAE (at the meeting or intersessional) depending on biological characteristics of the stock, available data and resources. We identified the following potential tools i) short-term forecast of stock dynamics under different environmental conditions affecting e.g. recruitment and/or growth, on top of fisheries options ii) full cycle Management Strategy Evaluation (MSE) with environmental aspects included in the short-term predictions (most likely stock–recruitment relationship) and/or environmentally sensitive Harvest Control Rules iii) full cycle survey based Management Strategy Evaluation with environmentally sensitive Harvest Control Rules iii) use of Decision Support Tools (Bayesian Influence Diagram, Multi-Criteria Analysis, Fuzzy-logic analysis), iv) use of bioeconomic modelling at MSE or bioeconomic indicators as an input to Decision Support Tools (DST). An example of existing tools please see section below and the previous report by WKDEICE 2016.

Right now, ICES is planning the multi-annual assessment period (ICES 2016a) and potentially multiannual advice for candidate stocks. For stocks with multiannual assessment (category 1 and 2) time between assessments could be used for performing MSE or using DSTs.

Tools run during Integrated Advice Evaluation (IAE) step should be subjected to the same benchmark process as stock assessment. Update of input information used at IAE should be multiannual for fisheries data, but annual for environmental data to be able evaluate advice under current conditions and support short-term prediction and/or environmental sensitive HCR. For stock categories 3 and lower i.e. survey indices data and used Integrated Advice Evaluation (IAE) step ideally should be updated annually, directly adopted from survey database as they prepared for assessment. See examples of survey based MSE at: DeM de Moor and Butterworth, 2016; Kell *et al.*, 2015; Rademeyer *et al.*, 2007.

It is important to stress that running IAE step in the process could decrease the workload and expectations put on assessment EG members and increase of IEA EG members' involvement in the advisory process.

IAE integrate stock assessment and ecosystem aspects in to advice product and operate under ACOM and SCICOM umbrella at the same time. However, goals should be restricted to evaluate WGBFAS advice under environmental/ecosystem scenarios, evaluate economic consequence at current ICES Advice Rules and with it legal management framework as Multiannual Management Plan for Baltic Fish Stock. Testing different alternative HCR should be on based on non-recurrent advice requests and be assign to other EG.

At the WKDEICE (ICES WKDEICE 2016) models related to Eastern Baltic Cod MSE and simulation scenarios have been reviewed. The main conclusion drawn from that for cod but also for other species, is that existing tools could be used within the ICES integrated advice framework, after modification to better serve tactical and strategic integrated advice. Nielsen *et al.* (2017) discussed bioeconomic models regarding their usefulness for fisheries advice. They concluded "that models that provide useful tactical advice may need to incorporate single-species biological models comparable to stock assessment models and may need to incorporate technical interactions in fisheries. Models useful for strategic advice need to consider how ecological, economic and social processes may change and interact over time, but these processes may be hard to parameterize in ways that provide both accurate short-term predictions and longer

term insights. For example, a statistically fitted stock assessment model may provide accurate short-term predictions, while an ecosystem model may be more useful for considering how the fishery system will react to changes in the environment over time". We argue that in the case of the Baltic Sea, where environmental conditions and trophic interactions strongly affect the state of fisheries resources (Casini *et al*., 2009; Möllmann *et al*., 2009), it is also important to evaluate tactical advice under different environmental conditions including an assessment of risks. Punt *et al.* (2014) and Szuwalski and Punt (2013) suggest that until the skill of stock projection models improves, it seems more appropriate to consider the implications of a broad range of plausible forecasts and future changes of biological parameters for the robustness of management strategies, rather than specific numerical results of projections. Our idea of the modification of ICES fisheries advice for the Baltic fish stocks using an IAE approach is well in line within Punt *et al*. (2014), referring biological parameters (of used models) for ecosystem conditions and presenting that as an option with associated probabilities of stock collapse/rebuilding and consequences on ecosystem.

Möllmann, C., Lindegren, M., Blenckner, T., Bergström, L., Casini, M., Diekmann, R., *et al.* M. (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.

Casini M., Möllmann C., Österblom H.. Belgrano A., Fowler C. 2011. Ecosystem approach to fisheries in the Baltic Sea: present and potential future applications in assessment and management, Ecosystem Based Management for Fisheries—an Evolving Perspective , 2011. Cambridge University Press, Cambridge, UK(pg. 9-31)

Casini M., Hjelm J., Molinero J. C., Lövgren J., Cardinale M., Bartolino V., Belgrano A., *et al.* 2009. Trophic cascades promote threshold-like shifts in pelagic marine ecosystems, Proceedings of the National Academy of Sciences of the USA , 2009, vol. 106 (pg. 197-202)

Nielsen, J. Rasmus, Eric Thunberg, Daniel S. Holland, Jorn O. Schmidt, Elizabeth A. Fulton, Francois Bastardie, Andre E. Punt et al. "Integrated ecological–economic fisheries models—Evaluation, review and challenges for implementation." Fish and Fisheries (2017).

Cody S. Szuwalski, André E. Punt; Fisheries management for regime-based ecosystems: a management strategy evaluation for the snow crab fishery in the eastern Bering Sea, *ICES Journal of Marine Science*, Volume 70, Issue 5, 1 September 2013, Pages 955–967, https://doi.org/10.1093/icesjms/fss182

EU 2017. Agreement in the form of Administrative Agreement (AA) between the European Commission and the International Council for the Exploration of the Sea 27 February 2017.

ICES. 2017. Report of the Benchmark Workshop on Baltic Stocks (WKBALT), 7–10 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:30. 108 pp.

ICES. 2016a. Report of the Annual Meeting between ICES, Advisory Councils and oth- er Observers (MIACO), 14–15 January 2016, ICES, Copenhagen, Denmark. ICES CM 2016/ACOM:03. 21 pp.

EU 2016. Regulation (EU) 2016/1139 of the European Parliament and of the Council of 6 July 2016 establishing a multiannual plan for the stocks of cod, herring and sprat in the Baltic Sea and the fisheries exploiting those stocks, amending Council Regulation (EC) No 2187/2005 and repealing Council Regulation (EC) No 1098/2007

EU 2013 REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC

EC 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)

Margonski, P., Hansson, S., Tomczak, M. T., & Grzebielec, R. (2010). Climate influence on Baltic cod, sprat, and herring stock–recruitment relationships. Progress in Oceanography, 87(1), 277-288.

MacKenzie, B. R., Meier, H. M., Lindegren, M., Neuenfeldt, S., Eero, M., Blenckner, T., *et al.* (2012). Impact of climate change on fish population dynamics in the Baltic Sea: a dynamical downscaling investigation. Ambio, 41(6), 626-636.

Moellmann, C., Diekmann, R., Müller‐Karulis, B., Kornilovs, G., Plikshs, M., & Axe, P. (2009). Reorganization of a large marine ecosystem due to atmospheric and anthropogenic pressure: a discontinuous regime shift in the Central Baltic Sea. Global Change Biology, 15(6), 1377-1393.

de Moor, C. L., & Butterworth, D. S. (2016). Incorporating technological interactions in a joint management procedure for South African sardine and anchovy. Management Science in Fisheries: An Introduction to Simulation-based Methods, 205

Kell, L. T., Hillary, R., Fromentin, J. M., & Bonhommeau, S. (2015). An example management strategy evaluation of a model free harvest control rule. ICCAT, Col. Vol. Sci. Pap, 71(6), 2790-2797

Rademeyer, R. A., Plagányi, É. E., & Butterworth, D. S. (2007). Tips and tricks in designing management procedures. *ICES Journal of Marine Science*, *64*(4), 618-625.

3 Tools and methods for ecosystem based and integrated advice

The group also discussed the potential tools for IAE based on specific examples of an interactive model for the European anchovy from the Gulf of Cádiz, a prototype decision support framework (DSF) for the Baltic Sea, quantification of potential benefits for the case of the eastern Baltic cod fishery and an example using bioeconomic models to define harvest control rules for Atlantic sardine and Western Baltic Cod.

3.1 An interactive model for the European anchovy from the Gulf of Cádiz

Presentation: Testing environmental, economic and social criteria in a co-creation process with stakeholders: An example model for European anchovy using shiny R package (Margarita María Rincón Hidalgo, Javier Ruiz Segura and Marta Ballesteros).

This communication described a successful example of how models can provide comprehensive outputs on the consequences of concrete management actions linking scientist knowledge with the experience and needs of stakeholders. A co-creation process with stakeholders is presented: Scientist from different fields (mathematics, biology, economy, political science) developed an interactive tool according to stakeholders needs and then they evaluate its performance.

By using shiny R package, the interactive tool shows the outputs of a bioeconomic model for anchovy population dynamics in the Gulf of Cádiz under different management strategies defined by the stakeholders.

The tool, available online at http://mareframe.mapix.com/gulf-of-cadiz-modeloutput.html, allows users to explore a range of relevant scenarios and how environmental forcing and fishing pressure impact on the resource and those people and societies exploiting it. This in combination with its simplicity and user friendliness result in a tool that can be useful for the implementation of the ecosystem approach in fisheries management.

Stakeholders gave a positive feedback about the relevance of the tool as evaluated in a structured manner and state explicitly trade-offs among different management strategies; furthermore, they suggested future steps to a process that is expected to lead to a reconsideration of the present management strategy.

Related publication: Ruiz J, Rincón MM, Castilla D, Ramos F, and García del Hoyo JJ (2017) "Biological and Economic Vulnerabilities of Fixed TACs in Small Pelagics: An Analysis of the European Anchovy (*Engraulis Encrasicolus*) in the Gulf of Cádiz." Marine Policy 78 (April): 171–80. doi:10.1016/j.marpol.2017.01.022.

3.2 A prototype decision support framework (DSF) for the Baltic Sea

Presentation: the MareFrame Decision Support Framework for the Baltic Sea EBFM and its potential uses (Barbara Bauer).

A DSF for the Baltic Sea, developed within the MareFrame project (Co-creating Ecosystem-based Fisheries Management Solutions - European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no.613571) was presented and discussed.

The decision support framework combines ecosystem models and decision support tools to make available a relatively wide array of ecosystem-related and economic information for stakeholders, in a format that is designed to aid decision-making.

The major elements of the framework are:

1. consultation with stakeholders to identify the most important EBFM issues;
2. develop alternative management strategies that address those issues;
3. scenario-based ecosystem model simulations of those strategies;
4. calculate relevant indicators of ecosystem state from model outputs;
5. use decision support tools (Bayesian Influence Diagram, Multi-Criteria Analysis) to integrate indicators with stakeholder preferences;
6. identify trade-offs among objectives, deliberate over management strategies that best satisfy all aims.

The framework illustrates possible steps towards solving some of the major challenges to achieve ecosystem-based fisheries management (EBFM). First, ecological interactions, environmental constraints and uncertainties are taken into account to a larger extent when using ecosystem models to define which management strategy is able to reach certain target (e.g. maximum yields, profit or a certain ecological state), compared to conventional models. Second, the framework aids an explicit consideration of multiple ecosystem-related benefits and costs together with the multiple viewpoints on the importance of those when evaluating management strategies. The ecosystem model simulations could be used to estimate the trade-offs inherent in any management plan or proposal for the Baltic Sea. The decision support tools help stakeholders to explore such trade-offs and formulate their own management plan proposals.

3.3 Ecological-economic fisheries management advice – quantification of potential benefits for the case of the eastern Baltic cod fishery

Presentation: Societal costs of deviating from integrated advice (Rudi Voss)

Fishing is a social and economic activity, and consequently socio-economic considerations are important for resource management. While this is acknowledged in the theory of Ecosystem-Based Management (EBM) and its sector-specific development Ecosystem-Based Fisheries Management (EBFM), currently applied fishery management objectives often ignore economic considerations.

Year-to-year management, often responds to short-term economic interests, and consequently, regularly resorts to tactical short-term rather than strategic long-term decisions.

We explored a new way of estimating management advice referred to as an 'ecologically-constrained Maximum Economic Yield' (eMEY) strategy, which takes into account ecological criteria as well as short- to medium-term economic costs. We further illustrate what net cost reductions per year are possible applying the eMEY strategy compared with the existing way of setting total allowable catches (TACs).

The eMEY approach aims at maximizing the economic benefits for the fishery as well as society (consumers), while safeguarding precautionary stock sizes. Using an age-structured optimization model parameterized for the Eastern Baltic cod case study, we find that application of eMEY advice results in more stability in catch advice. Quantification and visualization of the costs of deviating from eMEY advice offers a transparent basis for evaluating decision-making outcomes. The costs of overfishing are mainly borne by the commercial fishery, while fishing less than optimal is particularly costly for the processing industry and consumers.

WKDEICE discussed how to best foster the uptake of our eMEY approach in current advice system.

Related publication: Voss R, Quaas MF, Stoeven MT, Schmidt JO, Tomczak MT, Möllmann C (2017) Ecological-economic fisheries management advice – quantification of potential benefits for the case of the eastern Baltic cod fishery. Front. Mar. Sci., 30 June 2017 | https://doi.org/10.3389/fmars.2017.00209

3.4 Using bioeconomic models to define harvest control rules for Atlantic sardine and Western Baltic Cod

Presentation: Using bioeconomic models to define harvest control rules: the role of incorporating Allee effects in population dynamics (Rui Pedro Mota and Renato Rosa)

We explored an alternative methodology to integrate economics into fisheries' management. In particular, we propose a method to define Harvest Control Rules (HCR) using an age structured bioeconomic model. While HCRs typically define annual harvesting quotas as a function of the stock biomass, optimal harvesting in those models is not a function of biomass but of the initial distribution of individuals over age classes.

This methodology was originally developed and tested for Atlantic sardine. For that fishery, optimal paths for several initial conditions rapidly converge towards a common path in the Biomass/Harvest state space. Based on this result, we suggest that this common trajectory approximates the solution resulting from the application of the age class structured bioeconomic model and could therefore provide a HCR. In fisheries' policy, HCRs typically define Total Allowable Catch as a function of biological reference points. Economics are usually not embedded in these rules, which are occasionally ad-hoc evaluated regarding their performance concerning some economic criteria. In contrast, the methodology proposed in this study generates HCRs that endogenously take into account economics. During the workshop, the methodology was tested to be applied to western Baltic cod as a test case. Ecological and economic data were collected and first test runs started. Encouraging results lead to the wish of further exploring bioeconomic HCRs in the Baltic.

4 Short-term projections and harvest control rules exercise accounting for environment

The approach presented here has to be seen as a proof of concept exercise from last WKDEICE applied for the Baltic sprat stock – not as a ready tool for assessment and advice.

Sprat is a pelagic fish found in all European waters, including the Mediterranean and the Black Sea. Sprat grows best at 17.5°C and cold winter conditions affect its gonad development (Frisk *et al.*, 2015). Recruitment is therefore temperature dependent, and significant relationships haven been found with deep-water spring temperature (MacKenzie *et al*., 2004) and summer surface temperature (Margonski *et al.,* 2010).

In order to test, whether environmental information (in this case temperature) would be important for managing the sprat stock, we have constructed a temperature dependent Ricker model for sprat recruitment, validated the model by hindcasting the observed stock dynamics, and then demonstrated how the stock would develop based on high, low, and average temperature assumptions.

Temperature was incorporated into a sprat stock–recruitment model by adding a temperature-term to the Ricker equation:

$$r = a \cdot SSB \cdot \exp(-b \cdot SSB + c \cdot Temp)$$

where r is the number of recruits in millions, SSB the spawning-stock biomass at the time of recruitment, and $Temp$ the water temperature. a, b, and c are model coefficients that were fitted using the *nls* routine in the r software. Stock data were taken from WGBFAS (ICES WGBFAS 2017). Two sets of coefficients were created, using either observed or simulated water temperatures in different depth layers from the Gotland Sea. Simulated water temperatures were obtained from the BALTSEM biogeochemical model (Gustafsson *et al.,* 2012).

Table 4.1. Ricker model parameters for observed and simulated temperatures

	Observed temperatures	**Simulated temperatures**
Depth layer and month	August, 0–10 m	May, 30–40 m
Temperature range	13.71°C - 21.08°C	1.69°C - 4.27°C
RMSE	46 050	56 349
a	1.148	61.50
b	0.000859	0.000485
c	0.289	0.295

Best model fits were obtained to observed surface water temperatures in August and simulated water temperatures below the thermocline in May (Table 4.1). Temperature dependence is somewhat lower in the model fit to simulated temperatures, but has a clear impact on recruitment in both cases (Figure 4.1).

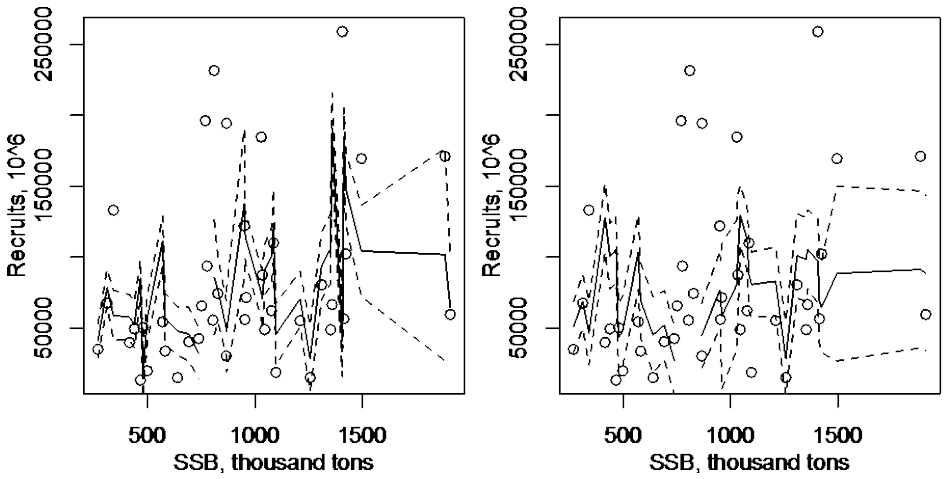

Figure 4. 1. Predicted and observed temperature-dependent sprat recruitment. Plots show best fit for observed temperatures (left) and simulated temperatures (right)

We initialized a simulation with the observed sprat stock in 1974 and forced an age-structured virtual population model by observed fishing and natural mortality, combined with recruitment terms predicted by the temperature-dependent Ricker models. In both models, the simulated stock dynamics (Figure 4.2) followed the observations well. The temperature dependence in sprat recruitment had in both models a large effect on stock dynamics. Already after three years, sprat SSB in warm conditions had increased by 60% (32%) and dropped by 24% (18%) in cold conditions, based on observed and simulated temperatures. The differences in stock also led to diverging catches in the simulations (Figure 4.2).

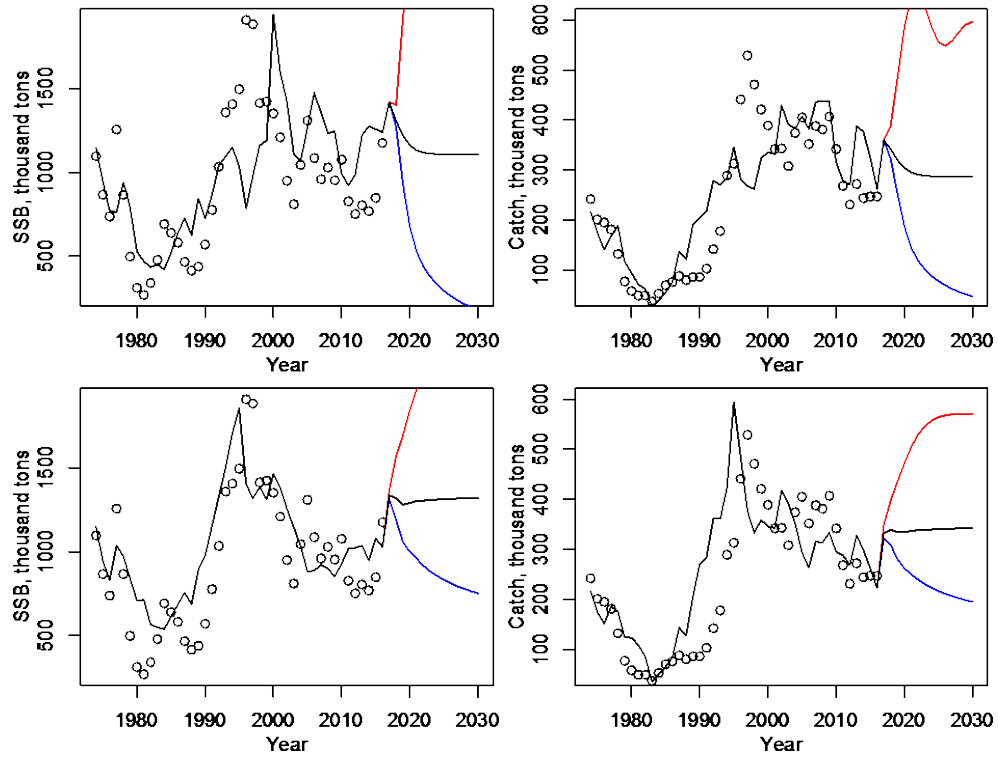

Figure 4.2. Simulated sprat SSB (left) and catches (right). Dots correspond to SSB estimated by stock assessment and to observed catches. Lines shows simulations with stock–recruitment forced by observed (top) and modelled (bottom) temperatures. Temperatures in 2015–2030 correspond to average (black), maximum (red) and minimum (blue) during 1974–2016.

The Baltic sprat stock case described above clearly shows how important it is to present environmental impacts on the stock in short and mid-term forecasts, as these caused huge differences in predicted stock status. Presenting such impact in the advice together with associated probabilities of stock collapse/rebuilding is an important step to operationalize an ecosystem approach for fisheries advice at ICES. Information on possible future developments of environmental factors (i.e. sea surface temperature in August within 3 years) could be obtained from scenario simulations, for example based on downscaled IPCC scenarios for Baltic Sea (Meier *et al.,* 2012; Meier *et al.,* 2014). An approach like presented here allows to:

- use ICES advice rules as they are (PA, MSY, MAP) but within an environmental context;
- present environmentally based advice with risks considering most likely future environmental conditions;
- provide advice for managers within a broader environmental context and associated quantitative risks.

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Annex 1: List of participants

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Annex 2: Agenda

WKDEICE 2 – Second Workshop on DEveloping Integrated AdviCE for Baltic Sea ecosystem-based fisheries management, Gdynia 19-21.06.2017

DRAFT AGENDA

Monday 19/06/17

1030 – 1100	Arrival of participants - Coffee & Tea
1100 – 1130	**Practical information**, setup of the workshop, goals and introductory talks by chairs Rudi Voss, Maciej Tomczak
1130 – 1200	**Discussion of WKDEICE2 agenda and work work-flow and splitting** Workshop background and ToRs (WKDEICE chairs) Theme 1: environmental indicators and way to incorporate in to advice (lead: CM) by correspondence. Theme 2: Economic stock size indicators and way to incorporate in to advice (lead: RV) Theme 3: short-term prediction and MSE (lead: BMK) Theme 4: Scoping for implementation of innovative advice (lead MTT)
1300 – 1430	Lunch
1430 – 1700	**Plenary** • Update on current ICES advice process and plans, in the WKDEICE context (MTT) • Testing environmental, economic and social criteria in a co-creation process with stakeholders. An example model for European anchovy using shiny R package. (Margarita Rincón Hidalgo) • The MareFrame Decision Support Framework for the Baltic Sea EBFM and its potential uses (Barbara Bauer)
1700 – 1800	**Discussion and preparation of next day**
2000 -	Common Dinner if wanted

Tuesday 20/06/17

0900 – 1100 **Plenary**

- Social costs of deviating from integrated advice (Rudi Voss)
- Performance evaluation of optimal and target reference harvest control rules for a stock with critical depensation (Rui Mota)
- "Using bioeconomic models to define harvest control rules: the role of incorporating Allee effects in population dynamics" (Renato Rosa)

1100 – 1130 Coffee and Tea

1130 – 1300 **Parallel work in subgroups**

1300 – 1430 Lunch

1400 – 1630 **Parallel work in subgroups**

1630 – 1700 Coffee and Tea

1700 – 1800 **Plenary**

- Short-term prediction examples and in Advice context and environmentally based MSE (BMK)
- reports on progress in groups
- summary and preparation of next day

2000 - Invited Dinner

Wednesday 21/06/17

0900 – 0930 **Summary and Report writing**

- Tasks allocation for report writing

0930 – 1030 **Parallel work in subgroups**

1030 – 1100 Coffee and Tea

1100 – 1300 **Final Session cont.**

Report writing

1300 - Closure of the meeting

Annex 3: WKDEICE2 Resolution

2016/2/SSGIEA06

The **Workshop on Developing Integrated Advice for Baltic Sea Ecosystem–Based Fisheries Management 2 (WKDEICE2)**, chaired by Maciej Tomczak, Sweden, Rudi Voss, and Christian Möllmann, Germany will meet in Gdynia, Poland, on 19–21 June 2017 to:

a) Further test the newly developed concept with model simulations

b) Broaden the environmental assessment to include pelagic species

c) Apply the concept to data poor assessments;

d) further develop the innovative advice document

WKDEICE2 will report by 1 August 2017 to the attention of SCICOM and ACOM.

Supporting Information

Priority	The planned activities of this new workshop are in line with the ICES strategic plan to progress towards integrated ecosystem assessments. This initiative was triggered by the need for a more comprehensive advice that considers environmental and socio–economic conditions and uses novel modelling multi–species and ecosystem modelling approaches. Consequently, these activities are considered to have a very high priority.
Scientific justification	Baltic fish stocks are known to be strongly dependant on environmental conditions. At the same time, present fish stock advice is largely depending on fisheries catch data bearing a number of shortcomings and flaws. Both facts may result in considerable uncertainty in fish stock assessments as exemplified by the present unclear situation of Eastern Baltic cod. The new WK will collect ongoing work on indicator approaches and environmental risk assessments as well as innovative modelling approaches to supplement the present single–species advice towards an advice that integrates traditional single–species fish stock with multi–species and indicator–based environmental assessments. The WK will furthermore do a first evaluation of including the human dimension into a future integrated advice by screening and evaluating socio–economic indicator and modelling approaches. This workshop is conceived as being the first in a series. The main aim for this first workshop will be the proactive provision of the type of information on fisheries and ecosystem interactions in the Baltic Sea that would be most useful in developing integrated advice for fish stocks. This is seen as an ongoing process where the advisory process would report back on the value and utility of the information, and perhaps suggest improvements. Ideally, this would lead to an active engagement of assessment scientists in the WK. The WK would be repeated based on the developing advice needs and on the developing ecosystem understandings. The likely outcome would likely be to ultimately benchmark the combined process.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	Experts on single and multi–species stock assessment, marine ecology and modelling, socio–economists.

Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are close links with WGBFAS, ACOM, and SCICOM. Thus, WKDEICE2 will report to WGBFAS in due time for the WGBFAS meeting (April 2017).
Linkages to other committees or groups	There is a very close working relationship with the ACOM/SCICOM Benchmarking Steering Group (BSG), WGIAB, WGBFAS, SGSPATIAL and other groups (WGISDAA, WGFTFB, WGSAM, WGMM,…) holding information about the Baltic Sea System.
Linkages to other organizations	HELCOM, BSAC

Annex 4: WKDEICE3 Resolution (DRAFT)

The third **Workshop on Developing Integrated Advice for Baltic Sea Ecosystem-Based Fisheries Management (WKDEICE3)**, chaired by Maciej Tomczak, Sweden and Rudi Voss, Germany tentatively will meet in Stockholm, Sweden, June 2018 to:

1. Test models for MSE/DST to evaluate theoretical ICES advice on case study stock
2. Develop and test ecosystem and bioeconomic sensitive HCR;
3. Discus of the innovative advice document

WKEICE3 will report by 30 August 2018 to the attention of the Advisory and Science Committee.

Supporting Information

Priority	The planned activities of this new workshop are in line with the ICES strategic plan to progress towards integrated ecosystem assessments. This initiative was triggered by the need for a more comprehensive advice that considers environmental and socio–economic conditions and uses novel modelling multi–species and ecosystem modelling approaches. Consequently, these activities are considered to have a very high priority.
Scientific justification	Baltic fish stocks are known to be strongly dependant on environmental conditions. At the same time, present fish stock advice is largely depending on fisheries catch data bearing a number of shortcomings and flaws. Both facts may result in considerable uncertainty in fish stock assessments as exemplified by the present unclear situation of Eastern Baltic cod. The new WK will collect ongoing work on indicator approaches and environmental risk assessments as well as innovative modelling approaches to supplement the present single–species advice towards an advice that integrates traditional single–species fish stock with multi–species and indicator–based environmental assessments. The WK will furthermore do a first evaluation of including the human dimension into a future integrated advice by screening and evaluating socio–economic indicator and modelling approaches. This workshop is conceived as being the first in a series. The main aim for this first workshop will be the proactive provision of the type of information on fisheries and ecosystem interactions in the Baltic Sea that would be most useful in developing integrated advice for fish stocks. This is seen as an ongoing process where the advisory process would report back on the value and utility of the information, and perhaps suggest improvements. Ideally, this would lead to an active engagement of assessment scientists in the WK. The WK would be repeated based on the developing advice needs and on the developing ecosystem understandings. The likely outcome would likely be to ultimately benchmark the combined process.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	Experts on single and multi–species stock assessment, marine ecology and modelling, socio–economists.
Secretariat facilities	None.

Financial	No financial implications.
Linkages to advisory committees	There are close links with WGBFAS, ACOM, and SCICOM.
Linkages to other committees or groups	There is a very close working relationship with the ACOM/SCICOM Benchmarking Steering Group (BSG), WGIAB, WGBFAS, SGSPATIAL and other groups (WGISDAA, WGFTFB, WGSAM, WGMM,…) holding information about the Baltic Sea System.
Linkages to other organizations	HELCOM, BSAC

Annex 5: Recommendations

Recommendation	Adressed to
1. Critically review the proposed approach (ecological as well as bioeconomic) and give a feedback to WKDEICE chairs.	ACOM; SICOM, Benchmark Steering Group (BSG); WGBFAS
2. Establish intersessional collaboration to develop proposed approach practically for ICES Advice framework.	ACOM, SCICOM, WGBFAS
3. Establish EG/WK where proposed approach (EBFM_MSE) coud be developed and tested within ICES advisory process	ACOM, SCICOM, WGBFAS, WGIAB
4. Incorporate aggregated ecological indicator series into ICES Data Centre.	ICES Data Centre