
24-28 April 2017
Lisbon, Portugal
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Executive summary

The ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) meeting was held in Lisbon (Portugal) 24–28 April 2017, back-to-back with the ICES Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS) and the ICES Working Group on Comparative Analyses between European Atlantic and Mediterranean marine ecosystems to move towards an Ecosystem-based Approach to Fisheries (WGCOMEDA). 31 participants from 7 countries attended this meeting, which was chaired by Laura Uusitalo, Finland, Saskia Otto, Germany, Martin Lindegreen, Denmark, and Lena Bergström, Sweden.

This was the second year of the new three-year Terms of Reference (ToR) for WGIAB. The main working activities in 2017 were to i) continue with the trait-based integrated trend analysis across multiple trophic levels and scope the possibility to extend the spatial range to cover multiple basins, to ii) explore new statistical tools to analyse spatio-temporal dynamics, and to iii) continue developing conceptual models that integrate the social dimension. All these activities were partly carried out together with WGCOMEDA and WGEAWESS through plenary sessions and three smaller group integration sessions.

The study on changes in the Baltic Sea ecosystems and functional traits composition in relation to external drivers is expected to feed into the development of methods to assess the environmental status of foodwebs, and to ecosystem-based advice for fisheries management. The work to develop integrated assessments of social-ecological systems is anticipated to feed into integrated management towards the objectives of the common fisheries policy and the Marine Strategy Framework Directive (MSFD).
1 Administrative details

<table>
<thead>
<tr>
<th>Working Group name</th>
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<td>ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea</td>
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**Year of Appointment within the current cycle:** 2015

**Reporting year within the current cycle (1, 2 or 3):** 2

**Chair(s)**
- Laura Uusitalo, Finland
- Saskia Otto, Germany
- Martin Lindegren, Denmark
- Lena Bergström, Sweden

**Meeting venue**
Portuguese Institute for the Sea and the Atmosphere (IPMA), Lisbon, Portugal

**Meeting dates**
24–28 April 2017

Participants group photo of the back-to-back meeting in Lisbon (IPMA). Members of WGIAB, WGCOMEDA, and WGEAWESS appear in the photo.
### Terms of Reference a) - b)

<table>
<thead>
<tr>
<th>ToR</th>
<th>Description</th>
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<tr>
<td>a</td>
<td>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;</td>
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<td>b</td>
<td>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.</td>
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## 3 Summary of Work plan

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
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<tr>
<td>Year 1</td>
<td>Annual meeting, intersessional work on research articles, interaction with suggested WKDEMO to develop on the outcomes of the DEMO project.</td>
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<tr>
<td>Year 2</td>
<td>Annual meeting, intersessional work on research articles</td>
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<td>Annual meeting, intersessional work on research articles</td>
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4 List of Outcomes and Achievements of the WG in this delivery period

5 Trait-based integrated trend analysis - a continuation and spatial expansion (ToR a) [Lead: M. Lindegren]

5.1 Summary of activities and discussions
During this year’s meeting, we continued working on a case study applying the previously developed concepts for IEAs in the Baltic Sea, but extending it beyond considering changes in abundances of dominant species, to account for community-wide changes in a number of key traits across multiple trophic levels. The underlying rationale of this so-called trait-based IEA (tIEA) is that using traits, either separately, or in combination, can represent ecosystem functions, which are key to providing important ecosystem services. To identify whether or not functional changes have occurred in the Central Baltic Sea, as a result of the pronounced changes in species composition (regime shift) in the late 1980s (Möllmann et al., 2009), we investigated temporal changes in the community weighted mean (CWM) traits of phytoplankton, zooplankton, zoobenthos and fish and identified their underlying abiotic drivers in the Gotland Basin (ICES Subdivision 28). The results of our tIEA case study show pronounced temporal trends in CWM traits with a marked decline in “ecosystem state” (i.e. characterized by PC1) occurring in the late 1980s (Figure 5.1.1), hence coinciding with the previous changes observed when considering only key species abundances (Möllmann et al., 2009). This may indicate that functional changes at the level of communities may be involved in the community reorganizations – pointing towards a discontinuous regime shift. However, groups of organisms with particular traits show rather different dynamics, as illustrated by the different temporal trajectories in PC1-PC4 (Figure 5.1.2). The PCs represent the dominant modes of variability based on the Principal Component Analysis (PCA) of CWM traits time-series for all organism groups. Furthermore, our results show that changes in ocean drivers – represented by decadal fluctuation and changes in Baltic Sea salinity, temperature and oxygen and nutrients explain a large part of the variability for each PC (Figure 5.1.3).

Figure 5.1.1. A traffic-light plot summarizes the temporal trajectories of CWM traits in the Gotland Basin. The variables are transformed to quintiles and sorted according to their loadings on the first principal component of a PCA including all CWM trait time-series. Hence, variables listed at the top are positively correlated to the first principal component and vice versa. The first principal component is shown by a solid black line.
Figure 5.1.2. Long-term ecosystem dynamics in the Central Baltic Sea illustrated by the dominant modes of variability (PC1 to PC4) from a PCA of CWM trait time-series. Vertical dashed lines indicate significant breakpoints detected by STARS.

Figure 5.1.3. The primary abiotic drivers of ecosystem dynamics in the Central Baltic Sea. The functional relationship between PC1 and surface salinity (a), PC2 and bottom oxygen (b), PC3 and bottom salinity (c) and PC4 and winter silica concentrations (d). Black lines show fitted relationships and the grey shaded area the 95% confidence intervals.
In addition to continuing our work on the tITAs, two short integration sessions were conducted. These were inspired by a number of presentations directly or indirectly using traits as a means to understand changes in the state and dynamics of marine communities and ecosystems (see titles and abstracts in section 8.1 and 8.2.1 below). The objective of these integration sessions was to foster an initial exchange of ideas and discussion about the experiences of using traits across the three WGs and the respective areas and geographical domains they cover. Among the many interesting issues and aspects discussed a couple of key points were emphasized: (i) Greater care should be taken with regards to the selection of traits so that the traits included in any analysis reflect the specific objective of the study conducted. As an example, studies on aggregated measures of functional diversity should include a broad set of traits that to the best extent possible reflect the ecology of the organisms studied with respect to traits involved in feeding, survival and reproduction. Other studies may select a restricted set of key traits that are meaningful for a narrower focus, for instance on life-history strategies. (ii) Most studies estimating community weighted mean (CWM) traits or aggregated functional diversity indices are based on methods assuming a fixed trait value for a given species. However, traits have been shown to demonstrate substantial intra-specific variability both throughout ontogeny and across space and time. Hence, greater care should be taken to account for spatial differences and temporal changes in trait values, e.g. the decrease in size and age at maturity of many commercially exploited fish species. (iii) Given the complementary work on traits being conducted across the three WGs future studies should strive towards cross-system comparisons of trait changes and their underlying drivers across European Seas. Naturally, such comparative analysis will hinge upon data availability across areas but could as a starting point focus on fish for which monitoring data (albeit with varying length and spatial coverage) is available for many if not most areas. (iv) While studying changes in traits and functional diversity within a given organism group has yielded important knowledge and insight, future work should strive towards cross-trophic comparisons of trait changes in order to identify both external and internal drivers and processes of change affecting the state and dynamics of marine ecosystems. Such a broader perspective is indeed challenging given the large amount of trait and abundance data needed across organisms but would greatly benefit the development towards a holistic understanding of marine ecosystem dynamics which can inform future ecosystem-based approaches to marine (and fisheries) management.

5.2 Data collection

In order to increase the spatial scope of the tITA and facilitate a comparison of trends and drivers of functional changes across sub-basins, as well as allow a comparison between the traditional IEAs based on key species abundances, an overview of data availability in other Baltic Sea areas was conducted. For each of the biotic variables (fish, benthos, zooplankton and phytoplankton), information about the availability of monitoring data (spatially and temporally), as well as spatially explicit trait information was noted. Furthermore, metadata over environmental monitoring in the Baltic Sea was collated in order to identify potential abiotic drivers of change in each sub-basin. The currently incomplete inventory showed that similar studies are possible also for other Baltic subareas, and would also allow cross-system comparisons of temporal changes in functional traits in parallel with analyses of changes in the abiotic environment and in pressures. As an example of data available for further analysis within the tITA framework is shown in Annex 3 (Figure 1), demonstrating time-series of CWM traits of phytoplankton, benthos and fish, based on available traits and monitoring data.
from Kattegat. Please note that due to the current absence of a complete zooplankton trait dataset for all occurring species this group is not shown.
Expansion of IEA methods to analyse spatio-temporal dynamics (ToRa)

[Lead: S. Otto]

Summary of activities and discussions

Current IEA methods and approaches greatly focus on the temporal component of ecosystem dynamics and account for spatial differences by repeating the analyses for the different subsystems. However, understanding changes of entire communities requires the application of novel approaches that fully account for the interactions between the dimensions of species, time and space (Mørup, 2011). The body condition of Baltic sprat (Sprattus sprattus) and its proposed linkage to the distributional shift of the Eastern Baltic cod stock (Gadus morhua) (Casini et al., 2014) clearly demonstrates the need to broaden our set of IEA tools to incorporate spatio-temporal dynamics.

In the WGIAB method theme we discussed various new techniques also presented during the back-to-back sessions with WGCOMEDA and WGWEAWESS, including required data and challenges. Since all spatio-temporal tools require sufficiently long time-series over several spatial data points, first attempts to try these new methods were made on the most complete dataset currently available, i.e. the environmental conditions in the Baltic Sea offshore regions. With the ending of the ICES study group on spatial analysis for the Baltic Sea, the group agreed to set its focus on the coupling of spatial and temporal dynamics in future analyses.

Use of tensor decomposition to identify spatio-temporal patterns in environmental conditions

In the Baltic Sea, significant changes in the foodweb during the late 1980s were caused by the combined effects of changing physical oceanographic conditions, eutrophication and unsustainable fishing pressure. During the past two decades, Baltic Sea foodwebs have been continuously subject to long periods of poor oxygen conditions, with only occasional saltwater inflows alleviating the salinity and oxygen conditions, while winter phosphate concentrations and summer temperature continued to increase. These recent trends have so far not been documented and compared in relation to changes at the lower trophic level. During the 2015 WGIAB meeting, time-series of environmental variables were updated and analysed by applying Principal Component Analyses (PCAs) different sub-basins, carried out separately (i.e. for the Central Baltic Sea, Gulf of Riga, Gulf of Finland, Bothnian Sea and Bothnian Bay, see also Torres et al., as mentioned in section 4). Tensor decomposition (TD) is an extension of a two-dimensional multivariate analysis (such as Principal Component Analysis with environmental variables and time as the two dimensions) in multiple dimensions. TD allows the synchronized study of multiple ecological variables measured repeatedly through time as well as space (Leibovici, 2010). A first preliminary application of this technique on the basin-specific environmental data identified three principal tensors (PT) that explained together 31% of the spatio-temporal pattern in summer conditions. Two major temporal trends were present across the entire Baltic Sea study area (PT1 and PT2) and one spatial gradient divided mainly the Central Baltic Sea basins from areas further north (PT3) (Figure 6.2.1). PT1 showed a strong change in the late 1980s that occurred in all stations but at slightly different magnitudes. This change was mainly attributed to an increase in summer temperature (Temp_surf_sum and Temp_deep_sum) and Chl a with a simultaneous decrease in surface salinity conditions (Sal_surf_sum) (Figure 6.2.2 and Figure 1 in Annex 4). PT2 showed a similar broad-scale shift in the early 1990s but also a return to the former state in the late 1990s. This development was particularly driven by the nutrient concentrations, which changed from high phosphate (DIP_deep_sum)
and silicate (SILI\_deep\_sum) to higher nitrate concentrations (DIN\_deep\_sum) and vice versa. These shifts were particularly pronounced in the Gotland Basin (GB) and Northern Baltic Proper (NBP2). Stronger spatial patterns were captured in PT3 (Figure 1 in Annex 4), which showed reversed trends for the most northern and southern areas. A sharp drop in the late 1980s and a constant increase with high interannual fluctuations since then, also in the most recent years (Figure 6.2.1, middle right panel), was positively related to Chl \(a\) and negatively related to phosphate concentrations (Figure 6.2.2). However, this strong temporal pattern was only found in the Bornholm and Gotland Basins (Figure 6.2.1, upper right panel), while in the Bothnian Bay an opposite but more moderate trend occurred. This division between the two Central Baltic Sea basins and the northern areas was also captured in the hierarchical cluster analysis on the 3 PTs (Figure 2 in Annex 4). Together with the dynamics captured by PT1 and PT2 this interprets as changes in hydrographical conditions acting at broader scales with little changes in recent years, while nutrient concentrations and primary productivity vary distinctly between the Central Baltic Sea and the northern areas.

Figure 6.2.1. Results of the Principal Tensor Analysis with 3 principal tensors (PT) explaining together 31\% of the total variability of the environmental conditions of Baltic Sea offshore regions. PT-specific results are shown in terms of their station-specific time-trends (upper row), their overall temporal dynamics (middle row), and their general spatial patterns (lower row), which is the same for both PT1 and PT2.
Figure 6.2.2. Environmental loadings on the first 3 principal tensors.
7 Exploring the social-ecological system (ToR b)

[Lead: L. Uusitalo]

7.1 Summary of activities and discussions

The SES subgroup discussed different modelling and analysis approaches to study the complex socio-economic system. It was agreed that different management and research questions call for different methodologies and problem framings.

The group continued to work on the conceptual/semi-quantitative model of Baltic pelagic foodweb and the ecosystem services it delivers. Some commonalities were found with models being developed e.g. in the MareFrame project, and these links were discussed in order to find synergies between these tasks.

The major challenges in this work are to find a reasonable problem scoping that would include different ecological, social aspects of the system in a balanced way, while being able to be expressed in comparable/combinable units of measurement. This has caused a lot of discussion within the group and led to iterative modification rounds of the model. While this process may appear slow and inefficient, these discussions provide an important learning experience for people working on the relatively new topic of SES.

7.2 Presentations relating to this scheme

Matilda Valman - “Challenges and benefits of social indicators in ecosystem-based management”

There are many different social indicators. They vary both spatially and in time. It is therefore important to make your choices and selection of variables you have made clear and also couple the selection to the research questions you have. Depending on what your chosen indicators are aiming at contributing to you should consider whether you e.g. want to assess human behaviour, the consequences of human behaviour or human dependence/interlinkage with nature. The selection of social indicators can be either qualitatively or quantitatively driven, or a combination of the two. It can also be necessary to mix not only methods but also theories for the later analyse of social indicators.

Annukka Lehikoinen and Päivi Haapasari - “Ecosystem-based management to reduce dioxin concentrations in Baltic salmon and herring and the risks to human health: main challenges”

Baltic herring and salmon provide a rich source of protein, Omega3 fatty acids and vitamin D for humans, but they also contain high levels of dioxins, which questions their positive health effects. Owing to dioxins, selling Baltic herring and salmon within the EU is restricted, and export outside the EU is difficult. BONUS GOHERR project (Integrated governance of Baltic herring and salmon stocks involving stakeholders) combines biological, public health and social scientific perspectives to explore the potential of ecosystem-based/integrated management of Baltic salmon and herring in reducing dioxins and the related risk to humans. Thus the project contributes to developing the ecosystem-based approach to fisheries management, which requires holistic thinking and comprehensive representations of the ecosystem, including social components. One of the main challenges of the project relates to understanding the system and its functioning, and to analysing how the system could be manipulated. For this, a decision support model is being built that integrates probabilistic information on 1) the
predator–prey interaction between salmon and herring and the impact of this on bioaccumulation of dioxins, and 2) the impacts of fish intake on humans, given the dioxin concentrations. The model allows assessing the effectiveness of alternative fisheries management actions to decrease the dioxin concentration, and the effectiveness of alternative fish-eating recommendations on the consumption of Baltic herring and salmon. The model evaluates the utility of different decision combinations from the perspectives human health, sustainable fishing, ecosystem health, and social effects, in parallel. Another major challenge of the project relates to analysing the role, scale and scope of governance to support the ecosystem-based/integrated management of these fisheries and the dioxin risk, taking into account societal values.

Sieme Bossier and Stefan Neuenfeldt - “Evaluation of sustainable exploitation of major Baltic fish stocks based on an integrated end-to-end modelling framework”

The newly developed Baltic spatially-explicit end-to-end Atlantis ecosystem model is in its phase of implementation. We will present preliminary results from an updated model with new and existing, significant knowledge of fish recruitment, growth, consumption processes and species interactions. The RCO-SCOBI model (Rossby Center Ocean Model – Swedish Coastal and Ocean Biogeochemical Model) will be linked with the Atlantis model, which will be used to provide physical and bio-geo-chemical and hydrodynamic forcing. This will replace the physical forcing of Atlantis from the HBM-ERGOM model (Hiromb-BOOS model coupled to the Ecological Regional Ocean Model) developed so far. Furthermore, we will integrate socio-economic parameters, dynamics and fisheries (technical) interactions in the holistic ecosystem and fisheries system model instead of using the current constant fishing mortality rates. This integrates dynamics on catch, effort, revenue, costs, fish prices, profit, fleet capacity, and exit-entry dynamics, as well as fuel consumption according to area, time, and Baltic fishing fleets. Accordingly, this involves estimation of economic and energetic processes and efficiency, e.g. greenhouse gas emissions and carbon footprint minimization potentials. The model application will evaluate impacts of eutrophication and climate forcing scenarios on biological interactions, resource availability and fisheries bioeconomic dynamics with a high resolution according to space, time and fleet components on a long-term strategic basis.
8 Back-to-back activities with WGIAB and WGEAWESS

Plenary presentations and integration time for discussion of the three groups were divided in 3 research schemes:

**Group 1:** Trait-Based Integrated Trend Analysis - a continuation and spatial expansion [trait scheme].

**Group 2:** Expansion of IEA methods to analyse spatio-temporal dynamics and developing trait-based indicators [method scheme].

**Group 3:** Exploring the social-ecological system [SES scheme].

8.1 Plenary presentations

*Rita Vasconcelos* - “Current limitations of global conservation to protect higher vulnerability and lower resilience fish species” [trait scheme].

Estuaries and coastal areas are threatened by intense and continuously increasing human activities. Here we estimated the sensitivity of fish assemblages in a set of 378 estuaries distributed worldwide (based on species vulnerability and resilience), and the exposure to cumulative stressors and coverage by protected areas in and around those estuaries (from marine, estuarine and freshwater ecosystems, due to their connectivity). Vulnerability and resilience of estuarine fish assemblages were not evenly distributed globally and were driven by environmental features. Exposure to pressures and extent of protection were also not evenly distributed worldwide. Assemblages with more vulnerable and less resilient species were associated with estuaries in higher latitudes (in particular Europe), and with higher connectivity with the marine ecosystem, moreover such estuaries were generally under high intensity of pressures but with no concomitant increase in protection. Current conservation schemes pay little attention to species traits, despite their role in maintaining ecosystem functioning and stability. Results emphasize that conservation is weakly related with the global distribution of sensitive fish species in sampled estuaries, and this shortcoming is aggravated by their association with highly pressured locations, which appeals for changes in the global conservation strategy (namely towards estuaries in temperate regions and highly connected with marine ecosystems) (Figure 8.1.1).
Figure 8.1.1. Relationships between fish traits (i.e. relative taxa richness of trait categories) of fish assemblages in sampled estuaries distributed worldwide and ecosystem features, according to fitted linear models. Traits considered are vulnerability, i.e. species intrinsic extinction vulnerability to fishing (Low, Low-Medium, Medium-High, High-Very High, Very High) and resilience, i.e. species productivity or resilience to fishing (High, Medium, Low, Very Low). Ecosystem features represented are: continent (1 - North America, 2- South America, 3- Europe, 4- Africa, 5- Asia, 6- Oceania), marine biogeographical realm (1- Temperate Northern Pacific, 2- Tropical Eastern Pacific, 3- Temperate South America, 4 - Temperate northern Atlantic, 5- Tropical Atlantic, 6- Temperate Southern Africa, 7- Western Indo-Pacific, 8- Central Indo-Pacific, 9- Temperate Australasia), latitude (for representation purposes only), sea surface temperature (SST), terrestrial net primary productivity (Ter NPP), marine chlorophyll a (Mar Chl), continental shelf width (Shelf), tidal regime (Mi-microtidal, Me-mesotidal, MA-macrotidal), estuary type (TO-temporarily open, O-open) and salinity type (R-regular, R-H-regular to hyperhaline, H-hyperhaline). Only predictors with relative importance above 0.5 in linear models are represented.

Romain Frelat - "Spatio-temporal dynamics of fish communities revealed by tensor decomposition" [method scheme].

Marine ecosystem-based fisheries management requires a holistic understanding of the dynamics of fish communities and their responses to external pressures such as fisheries exploitation and climate change. However, characterizing multispecies community dynamics in heavily exploited large marine ecosystems over time and space is difficult and requires specialized multivariate statistical approaches. We applied COSTATIS, a mathematical framework that allows the simultaneous analysis of a sequence of paired ecological tables (in our case species abundances and the environmental variables). We used this comprehensive approach to investigate link between the spatio-temporal dynamics of 31 fish species and 13 environmental variables, including hydro-climatic conditions (temperature, salinity, oxygen), biological variables (primary production) and fishing pressure (Figure 8.1.2). The study was performed on the 7 subdivisions of the Baltic Sea on the recent decade: from 2003 to 2014. A strong gradient from the Southwest to the Northeast was found to shape the fish communities and most of the environmental variables, with higher salinity, temperature and oxygen content in the SW than in the NE. This spatial gradient was strong and stable across years. In contrast, the temporal dynamics of fish communities were more heterogeneous and not significantly linked with the temporal dynamics of the environmental variables. Finally, we
identified 5 sub-communities of fish species, favoured by similar environmental conditions and sharing similar spatial distribution across the Baltic Sea. Using an innovative statistical approach, our study contributes to a better understanding of the patterns and drivers of the Baltic Sea fish communities, information that is key to inform a sustainable management of the ocean.

Complex systems, spanning from populations and ecosystems to societies and economies, often exhibit abrupt reorganizations in response to changing stressors, known as regime shifts or critical transitions. The theory of critical transitions suggests that such systems feature folded stability landscapes with fluctuating resilience, fold bifurcations, and alternate basins of attraction (Scheffer, 2009). However, the implementation of such features to elucidate response mechanisms in an empirical context is scarce, due to the lack of generic approaches to quantify resilience dynamics of individual systems. For this, we have introduced an Integrated Resilience Assessment (IRA) framework: a three-step analytical process to assess resilience dynamics and construct stability landscapes of empirical complex systems. The proposed framework involves a multivariate analysis to estimate holistic system indicator variables, non-additive modelling to estimate alternate attractors, and a quantitative resilience assessment to scale stability landscapes. The applicability of this framework is illustrated on empirical complex systems at different levels of biological organization, namely at the population and the community level. At the population level, an IRA was carried out for the Barents Sea cod population in 1949–2009 revealing a folded stability landscape with two basins of attraction shaped by the combined effects of fishing and climate change (Vasilakopoulos and Marshall, 2015; Figure 8.1.3). At the community level, IRAs were applied to the marine communities in the eastern and western Mediterranean Sea to reveal folded stability landscapes and multivariate shifts to regimes dominated by thermophilic species in response to sea warming during 1985–2013 (Vasilakopoulos et al., in review). The approach exemplified for a fish population and two
marine communities, revealing previously unknown resilience dynamics driven by anthropogenic and climate forcing, can be applied in other complex systems to elucidate discontinuous dynamics in a fast-changing world.

Figure 8.1.3. The folded stability landscape of Barents Sea cod during 1949–2009. The x-axis is the first PC of a PCA carried out on 5 stressor variables (PC1str) and the y-axis is the first PC of a PCA carried out on 13 population variables (PC1pop). Continuous black lines indicate the linear attractors, dotted black line indicates the possible extension of the lower branch, dashed grey lines indicate the approximate position of the basin’s borders and \( F_1, F_2 \) indicate the tipping points. Colours represent the relative resilience contour interpolated from the relative resilience of each year. Circles and arrows indicate the 1981 regime shift. From Vasilakopoulos and Marshall, 2015.

Additional talks presented in the plenary time were:

**Martin Lindegren** - "A trait-based assessment towards understanding long-term changes in ecosystem functioning: the Central Baltic Sea as a case study" [trait scheme].

Marine scientists, managers and the general public are rightly concerned that the structure, functioning and services of marine ecosystems are threatened by natural and anthropogenic pressures, e.g. eutrophication, overfishing and climate change. In order to understand pronounced ecosystem changes (i.e. regime shifts), assessing long-term trends in ecosystem components and their response to natural and anthropogenic pressures is a key part of Integrated Ecosystem Assessments (IEAs) and ecosystem-based management approaches. In this study, we apply previously developed concepts for IEA in the Baltic Sea, but extend it beyond considering changes in abundances of dominant species, to account for community-wide changes in a number of key traits across multiple trophic levels. The underlying rationale is that these traits, either separately, or in combination, represent ecosystem functions, which are key to providing important ecosystem services. By investigating temporal changes in the community weighted mean (CWM) traits of phytoplankton, zooplankton, zoobenthos and fish we demonstrate whether or not functional changes have occurred in the Baltic Sea as a result of the pronounced changes in species composition (regime shift) in the late 1980s. To that end, our trait-based approach not only strives to highlight and answer some fundamental ecological questions regarding the functioning of marine ecosystems and
the underlying processes of regime shifts, but places the findings in a framework that can provide guidance and advice to ecosystem-based marine management.

**Tessa B. Francis - “Incorporating traditional knowledge and human dimensions into Pacific herring management: the Ocean Modeling Forum” [SES scheme].**

Pacific herring range in the North Pacific Ocean from Alaska to California and play important roles as a fisheries target and prey for birds, mammals, and other fish. They are also a cultural keystone species for a number of indigenous communities. Herring populations are naturally highly variable and have also been greatly affected by human stressors including fishing, contaminants, and oil spills. Many herring fisheries have been closed or severely limited through much of their range for more than a decade. Evaluating management strategies for herring fisheries is hampered by a poor understanding of the factors affecting herring productivity, poor forecasting by stock assessment models, and the lack of a social-ecological framework that would facilitate the integration of traditional knowledge and cultural ecosystem services into fisheries management decision-making. Here we present preliminary results from a working group convened by the Ocean Modeling Forum, including modelers, empiricists, managers and representatives of indigenous and commercial fishing communities, to evaluate the social, cultural and ecological consequences of herring fisheries by using multiple models and diverse knowledge streams, including traditional ecological knowledge. In a comparative framework we also assess the important role of spatial scale in evaluating trade-offs between social, cultural and economic services provided by herring in Haida Gwaii, British Columbia (Canada) and Sitka, Alaska (USA). We will discuss how the Ocean Modeling Forum framework can be applied across ecosystems and management issues.

**Margarita Rincon - "Testing environmental, economic and social criteria in a co-creation process with stakeholders: An example model for European anchovy using shiny R package" [SES scheme].**

In this communication we describe 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. By using shiny R package we were able to show the outputs of a bioeconomic model (Ruiz et al., 2017) for anchovy population dynamics in the Gulf of Cádiz using an interactive tool (http://mareframe.mapix.com/gulf-of-cadiz-modeloutput.html).

The interactive tool allows to explore the consequences of the following management scenarios predefined by stakeholders:

1. Option 1: “TAC Fija” represents the Current path (status quo), where the quota value is fixed at the reference value given by the user. The stock size changes according to simulated environmental conditions but the quota does not account for that variation.
2. Option 2: “TAC adaptativa vs. TAC fija” compares the performance of the Current path with an Adaptation scenario. Under Adaptation, the reference quota value given by the user is modified according to the simulated environmental conditions. The stock size and TAC changes according to those conditions.
3. Option 3: “Con seguro: TAC fijavs.Adaptativa” compares the performance Guarantee scenario and Adaptation & guarantee scenario. Under the first, quota value is fixed at the reference value given the user and there is insurance coverage as defined in (Rincón et al., 2016), but environmental variation is not accounted. Under the last the reference quota value given by the user is modified according to the simulated environmental conditions and insurance coverage is available.
The scenarios are assessed based on the performance of biological and socio-economic indicators, associated to the criteria selected by the stakeholders as relevant:

a) To continue fishing, therefore minimizing the risk of collapse of the fishery. Risk collapse is defined as the proportion of simulations where the average spawning biomass between May and July drops below one thousand tons at least once.

b) To maximize profit, measured as average profit in € per vessel and vessel length overall (LOA).

c) To make stable and continuous profit, hence minimizing the risk of income instability measured as the profit standard deviation.

d) To keep stable employment levels, measured as the number of jobs at risks.

e) To minimize economic losses by means of an insurance system, where the risk associated to the fluctuations of the stock is measured by the insurance premium.

In general, the tool allows users to explore a range of relevant scenarios and how environmental forcing and fishing pressure impacts on the resource and those people and societies exploiting it. This in combination with its simplicity and user friendliness result in the creation of a tool that can support well the implementation of EAFM. Stakeholders give 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.

8.2 Integration sessions

The integration sessions were framed under the same research schemes aforementioned, and consisted in several short (5 min) talks plus discussions. Here below a summary of the talks presented within each scheme.

8.2.1 Trait scheme

Anna Törnroos - “General introduction to trait-based approaches”

Trait-based approaches have risen as an important tool to understand biodiversity patterns under environmental change. Here I provide a brief background to the trait concept, highlight some terminological aspects, and outline the two prevailing frameworks: the “community-based, common trait approach” and the “individual-based, mechanistic trait approach”. I also present an overview of what type of questions the two approaches have successful answered, within three topics; i) Biodiversity and ecosystem functioning, ii) Functional trait ecology and iii) Trophic ecology. To conclude, I point towards gaps and potential future directions, generally, and also specifically within and across the three working groups presented at the meeting. I particularly highlight the need for understanding coastal vs. offshore functional patterns across taxonomic levels, trait biogeography and linkage between traits and ontogenetic shifts as future avenues for using trait-based approaches.

Esther Beukhof - “A trait-based approach to understand fish species distributions through trait-environment relationships”

In this study, a trait-based approach was used to understand fish species distributions across European shelf seas. When focusing on taxonomy only one may miss the mechanistic understanding of what underlies these distributions. Trait-based ecologists argue that traits are useful in explaining where species occur, since it is the traits that
determine how species respond to the environment. We used a unique dataset containing the spatial occurrence of over 250 marine fish species across Europe's continental shelf seas – ranging from Iceland and southern Greenland to Portugal with a high spatial resolution of \( \frac{1}{4} \) degree. The main aims were to identify key traits for marine fish that explain fish species distributions and to identify the most important relationships between marine fish traits and the environment. Three-matrix approaches (RLQ and fourth-corner analysis) were used to investigate the relationships between species traits and environmental variables through the information on species occurrences. We demonstrated that marine fish species can be characterized according to their traits along a fast-slow continuum mainly characterized by age at maturity, lifespan and growth. This is continuum is then determined by a coastal to offshore gradient, implying that depth, temperature, productivity and seasonality are important factors for structuring marine fish communities.

**Lauréne Pécuchet - "From traits to life-history strategies"**

The life history of a species is determined by trade-offs between growth, survival and reproduction to maximize fitness in a given environment. Following a theoretical model, we investigate whether the composition of marine fish communities can be understood in terms of a set of life-history strategies and whether the prevalence of the strategies follows specific spatial patterns that can be related to the environment. We assembled an extensive number of surveys in the European seas and collected reproductive traits for more than 300 fish species present in these surveys. Based on their traits, fish species could be categorized into three strategies that reflect the evolutionary and environmental constraints acting on the species. The strategies' prevalence exhibited strong geographical patterns, which could be explained by spatial variability of annual sea surface temperature, temperature seasonality, depth, and fishing intensity. Due to their tight coupling to the environment, notably temperature and fishing, life history strategies could be a suitable tool to monitor and understand community changes in response to natural and anthropogenic stressors, including climate change.

**8.2.2 Methods scheme**

**Saskia Otto - "Lessons learned - SWOT analysis on IEA methods"**

The utility of integrated ecosystem assessments (IEA) for managing marine resources sustainably has been widely recognized over the past decade. How to conduct such an assessment, however, is still a matter of scientific perspective with no common code of conduct agreed upon. The methods being used range from quantitative to qualitative and from an ecological to a socio-economical basis. Most of these methods are linked to the same management themes and some might have the same underlying research question. Within ICES, several working groups targeting IEA for different geographical areas have been established over the recent years. However, there is only a limited degree of exchange of knowledge of methodological expertise and experiences among the groups. Based on the project “IEA Exchange”, supported by the ICES science fund, a review of IEA methods used in these working groups including their evaluation based on individual SWOT analyses was presented. A SWOT analysis is a common tool in business and industry but is equally useful in any type of project and method evaluation. It helps to identify strengths and weaknesses (S-W), as well as broader opportunities and threats (O-T) for strategic planning and decision-making.
Manuel Hidalgo - "A trait-based approach to understand fish species distributions through trait-environment relationships"

Understanding the stability of marine ecosystems has been one of the main topics of research from the beginning of WGCOMEDA. As a first approach and during the first WGCOMEDA cycle, we investigated the main structural properties and drivers affecting emergent properties (e.g. properties of groups that cannot be entirely explained by their individual components) such as the stability of fish communities. To do that, we applied the portfolio analytical framework to compare five types of systems across Mediterranean and Atlantic demersal communities: Arctic, Upwelling, Mediterranean, East and West Atlantic. The Portfolio Effect (PE) is a measure of the stabilizing effect of the diversity that can be also affected by other external (anthropogenic and environmental) drivers. PE estimates were estimated in close relation with community synchrony estimates, and both related to external drivers. Our results show that synchrony is affected negatively by the heterogeneity of Primary Production and a Global Indicator of Anthropogenic Impact, while the PE effect is positively affected by the mean value of Primary Production and negatively affected by the seasonal range of the bottom temperature. In addition, we investigated the partitioning of these effects for different groups of the ecosystems attending to mean life-history traits: somatic growth rate, length at maturity and trophic level.

David Reid - “Generating knowledge to support EBFM: WKIRISH/FishKOSM - Progress and future direction”

8.2.3 SES scheme

Jörn Schmidt - "Update on the integration of the human dimension in ICES IEA"

8.2.4 Future cooperation with ICES IEA WGs

This WGIAB meeting was held as a back-to-back meeting to maintain the ambition of the group to have active experience exchange with other ICES WGs. This format is proposed to be repeated again due to the important feedback and stimulating activities developed across groups. However, such setup should preferably occur at certain intervals, for example every two or three years, to make it possible to focus on the independent commitments of each WG at the regular meetings. The possibility was discussed to extend the back-to-back meetings with other IEA WGs around selected themes or partially overlapping seminar days to foster collaboration between all IEA WGs.
9 References


10 Next meetings

The next WGIAB meeting is intended to take place at the Institute for Hydrobiology and Fisheries Science, University of Hamburg, Germany, or at the Estonian Marine Institute, Tartu University, Estonia in spring 2018 (date to be decided). The final decision with regards to venue is subject to final approval by the organizers.
## Annex 1: List of participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna Törnroos</td>
<td>Centre for Ocean Life, DTU-Aqua, Denmark</td>
<td><a href="mailto:anna.m.tornroos@abo.fi">anna.m.tornroos@abo.fi</a></td>
</tr>
<tr>
<td>Annukka Lehikoinen</td>
<td>Helsinki University, Finland</td>
<td><a href="mailto:annukka.lehikoinen@helsinki.fi">annukka.lehikoinen@helsinki.fi</a></td>
</tr>
<tr>
<td>Barbara Bauer</td>
<td>Stockholm University, Baltic Sea Centre, Sweden</td>
<td><a href="mailto:barbara.bauer@su.se">barbara.bauer@su.se</a></td>
</tr>
<tr>
<td>Camilla Sguotti</td>
<td>University of Hamburg, Institute of Hydrobiology and Fishery Science, Germany</td>
<td><a href="mailto:camilla.sguotti@uni-hamburg.de">camilla.sguotti@uni-hamburg.de</a></td>
</tr>
<tr>
<td>Heikki Peltonen</td>
<td>Marine Research Centre, Finnish Environment Institute, Finland</td>
<td><a href="mailto:heikki.peltonen@ymparisto.fi">heikki.peltonen@ymparisto.fi</a></td>
</tr>
<tr>
<td>Ivars Putnis</td>
<td>Institute of Food Safety, Animal Health and Environment BIOR, Latvia</td>
<td><a href="mailto:ivars.putnis@bior.gov.lv">ivars.putnis@bior.gov.lv</a></td>
</tr>
<tr>
<td>Iveta Jurgensoone</td>
<td>Latvian Institute of Aquatic Ecology, Latvia</td>
<td><a href="mailto:iveta.jurgensoone@lhei.lv">iveta.jurgensoone@lhei.lv</a></td>
</tr>
<tr>
<td>Jens Olsson</td>
<td>Swedish University of Agricultural Sciences, Sweden</td>
<td><a href="mailto:jens.olsson@slu.se">jens.olsson@slu.se</a></td>
</tr>
<tr>
<td>Jörm Schmidt</td>
<td>Kiel University, Germany</td>
<td><a href="mailto:jschmidt@economics.uni-kiel.de">jschmidt@economics.uni-kiel.de</a></td>
</tr>
<tr>
<td>Konstantin Podgorny</td>
<td>Atlantic Institute of Fisheries and Oceanography (AtlantNIRO), Russia</td>
<td><a href="mailto:kapborok@mail.ru">kapborok@mail.ru</a></td>
</tr>
<tr>
<td>Laura Uusitalo</td>
<td>Finnish Environment Institute, Marine Research Centre, Finland</td>
<td><a href="mailto:laura.uusitalo@ymparisto.fi">laura.uusitalo@ymparisto.fi</a></td>
</tr>
<tr>
<td>Laurene Pecuchet</td>
<td>Centre for Ocean Life, DTU-Aqua, Denmark</td>
<td><a href="mailto:laupe@aqua.dtu.dk">laupe@aqua.dtu.dk</a></td>
</tr>
<tr>
<td>Lena Bergstrom</td>
<td>Swedish University of Agricultural Sciences, Sweden</td>
<td><a href="mailto:lena.bergstrom@slu.se">lena.bergstrom@slu.se</a></td>
</tr>
<tr>
<td>Maciej Tomczak</td>
<td>Stockholm University, Baltic Sea Centre, Sweden</td>
<td><a href="mailto:maciej.tomczak@su.se">maciej.tomczak@su.se</a></td>
</tr>
<tr>
<td>Maria Angeles Torres Leal</td>
<td>Universidade do Algarve, Centro de Ciências do Mar (CCMAR), Portugal</td>
<td><a href="mailto:matorres@ualg.pt">matorres@ualg.pt</a></td>
</tr>
<tr>
<td>Martin Lindegren</td>
<td>Centre for Ocean Life, DTU-Aqua, Denmark</td>
<td><a href="mailto:mli@aqua.dtu.dk">mli@aqua.dtu.dk</a></td>
</tr>
<tr>
<td>Matilda Valman</td>
<td>Stockholm Resilience Centre, Stockholm University, Sweden</td>
<td><a href="mailto:Matilda.Valman@su.se">Matilda.Valman@su.se</a></td>
</tr>
<tr>
<td>Name</td>
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</tr>
<tr>
<td>Olga Dmitrieva</td>
<td>Atlantic Institute of Fisheries and Oceanography (AtlantNIRO) Russia</td>
<td><a href="mailto:kapborok@mail.ru">kapborok@mail.ru</a></td>
</tr>
<tr>
<td>Outi Heikinheimo</td>
<td>Natural Resources Institute Finland Finland</td>
<td><a href="mailto:outi.heikinheimo@luke.fi">outi.heikinheimo@luke.fi</a></td>
</tr>
<tr>
<td>Phillip Levin</td>
<td>University of Washington United States</td>
<td><a href="mailto:plevin@uw.edu">plevin@uw.edu</a></td>
</tr>
<tr>
<td>Päivi Haapasaari</td>
<td>University of Helsinki Finland</td>
<td><a href="mailto:paivi.haapasaari@helsinki.fi">paivi.haapasaari@helsinki.fi</a></td>
</tr>
<tr>
<td>Romain Frelat</td>
<td>University of Hamburg, Institute of Hydrobiology and Fishery Science Germany</td>
<td><a href="mailto:romain.frelat@uni-hamburg.de">romain.frelat@uni-hamburg.de</a></td>
</tr>
<tr>
<td>Saskia Otto</td>
<td>University of Hamburg, Institute of Hydrobiology and Fishery Science Germany</td>
<td><a href="mailto:saskia.otto@uni-hamburg.de">saskia.otto@uni-hamburg.de</a></td>
</tr>
<tr>
<td>Stefan Neuenfeldt</td>
<td>DTU-Aqua, Section for Oceans and Arctic Denmark</td>
<td><a href="mailto:stn@aqua.dtu.dk">stn@aqua.dtu.dk</a></td>
</tr>
<tr>
<td>Susa Niiranen</td>
<td>Stockholm Resilience Centre, Stockholm University Sweden</td>
<td><a href="mailto:susa.niiranen@su.se">susa.niiranen@su.se</a></td>
</tr>
<tr>
<td>Susanna Jernberg</td>
<td>Finnish Environment Institute, Marine Research Centre Finland</td>
<td><a href="mailto:susanna.jernberg@helsinki.fi">susanna.jernberg@helsinki.fi</a></td>
</tr>
<tr>
<td>Tessa Francis</td>
<td>University of Washington United States</td>
<td><a href="mailto:tessa@uw.edu">tessa@uw.edu</a></td>
</tr>
<tr>
<td>Thorsten Blenckner</td>
<td>Stockholm Resilience Centre, Stockholm University Sweden</td>
<td><a href="mailto:thorsten.blenckner@su.se">thorsten.blenckner@su.se</a></td>
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## Annex 2: Agenda

### Monday 24/04/17

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>12.30–13.30</td>
<td><strong>Arrival of participants</strong></td>
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<tr>
<td>13.30–14.00</td>
<td><strong>Welcome</strong> by Maria de Fatima Borges, Instituto Português do Mar e da Atmosfera Lisbon (IPMA)</td>
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<tr>
<td>14.00–15.00</td>
<td><strong>Practical information, goals and setup of the WGIAB/WGEA-WESS/WGCOMEDA back-2-back meeting</strong></td>
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<td></td>
<td>Practical info and social activities by Marian Torres (CCMAR)</td>
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<td>Discussion of the general framework of the agenda (Fatima Borges with chairs)</td>
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<td>Introduction of WGs</td>
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<td></td>
<td>• History and future of WGIAB (Lena Bergström)</td>
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<td></td>
<td>• History and future of WGEAWESS (Steven Beggs)</td>
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<td></td>
<td>• History and future of WGCOMEDA (Manuel Hidalgo)</td>
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<tr>
<td>15.00–15.15</td>
<td><strong>Coffee &amp; Tea</strong></td>
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<td>15.15–16.00</td>
<td><strong>Discussion of WGIAB agenda, introduction to subgroups &amp; grouping of participants</strong></td>
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<td><strong>Group 1:</strong> Trait-Based Integrated Trend Analysis - a continuation and spatial expansion (trait scheme) [Lead: Martin Lindegren]</td>
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<td><strong>Group 2:</strong> Expansion of IEA methods to analyse spatio-temporal dynamics and developing trait-based indicators (method scheme) [Lead: Saskia Otto]</td>
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<td><strong>Group 3:</strong> Exploring the social-ecological system (SES scheme) [Lead: Laura Uusitalo]</td>
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<td>16.00–17.30</td>
<td><strong>Parallel work in WGIAB subgroups</strong></td>
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<td>Subgroup presentations (timing tbd; more presentations welcome)</td>
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<td></td>
<td>• Saskia Otto: &quot;INDperform - development of an R package for validating ecological indicator performances&quot; [method scheme]</td>
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<td>• Matilda Valman: Challenges and benefits of social indicators in ecosystem-based management [SES scheme]</td>
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<td>• Stefan Neuenfeldt: Baltic implementation of the ATLANTIS model [SES scheme]</td>
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<td>• Annukka Lehikoinen and Päivi Haapasaari: GOHERR-project: Ecosystem based management to reduce dioxin concentrations in Baltic salmon and herring and the risks to human health: main challenges</td>
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<td>• Phil Levin: Update on the fuzzy logic analysis</td>
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<td>17.30–18.00</td>
<td><strong>WGIAB Plenary</strong></td>
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<td>• Laura Uusitalo: Quick introduction to the BONUS project BLUE-WEBS (5 minutes)</td>
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<td>• Reports on progress in groups</td>
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<td>• Summary and preparation of next day</td>
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<tr>
<td>20.00</td>
<td><strong>Common Dinner if wanted</strong></td>
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Tuesday 25/04/17

09.00–10.30 **Scientific Presentations** (back-2-back with WGEA-WESS/WGCOMEDA; 15min each)
- Martin Lindegren: "A trait-based assessment towards understanding long-term changes in ecosystem functioning: the Central Baltic Sea as a case study" [trait scheme]
- Sofia Henriques: "Global patterns of resilience and vulnerability of these fish species and explored their match with protected areas and anthropogenic threats (from marine, estuarine and freshwater ecosystems)" [trait scheme]
- Tessa Francis: "A multi-model approach to incorporating traditional ecological knowledge and human dimensions into Pacific herring management: an Ocean Modeling Forum case study" [SES scheme]

10.30–10.45 Coffee & Tea

10.45–12.30 **Parallel work in WGIAB subgroups**

12.30–13.30 Lunch

13.30–15.00 **Parallel work in WGIAB subgroups**

15.00–15.15 Coffee & Tea

15.15–16.15 **WGIAB subgroup work in parallel with two group integration sessions in parallel** (back-to-back with WGCOMEDA/WGEAWESS; 5min speed talks)
- Trait scheme:
  - Anna Törnroos: "General introduction to trait-based approaches"
  - Lauréne Pécuchet: "Life-history strategies of European Seas’ fish communities"
  - Esther Beukhof: “Exploring trait-environment relationships using Europe’s marine fish communities”
- SES scheme:
  - Jörn Schmidt: Update on the integration of the human dimension in ICES IEA

16.15–18.00 **Parallel work in WGIAB subgroups**

Wednesday 26/04/17

09.00–10.30 **Scientific Presentations** (back-2-back with WGEA-WESS/WGCOMEDA; 15min each)
- Margarita Rincon: "Testing environmental, economic and social criteria in a co-creation process with stakeholders: An example model for European anchovy using shiny R package" [SES scheme]
- Romain Frelat: "Spatio-temporal dynamics of fish communities revealed by tensor decomposition" [method scheme]
- Paris Vasilakopoulos: "An Integrated Resilience Assessment framework to quantify non-linear dynamics of complex natural systems" [method scheme]

10.30–10.45 Coffee & Tea
10.45–11.15  Short risk assessment exercise and Parallel work in WGIAB subgroups
11.15–12.30 Parallel work in WGIAB subgroups
12.30–13.30 Lunch
13.30–15.00 Parallel work in WGIAB subgroups
15.00–15.15 Coffee & Tea
15.15–16.15 WGIAB subgroup work in parallel with one group integration session (method scheme; back-to-back with WGCOMEDA/ WGEAWESS; 5min speed talks)
   IEA methods:
   • Manuel Hidalgo: "Stability on demersal fish communities: embracing temporal and spatial scales"
   • Dave Reid: "Generating knowledge to support EBFM: WKIRISH/ FishKOSM–Progress and future direction"
   • Saskia Otto: "Lessons learned - SWOT analysis on IEA methods"
   SES:
   • Jörn Schmidt: Update on the integration of the human dimension in ICES IEA
16.15–18.00 Parallel work in WGIAB subgroups
20.00–
   Common social event with WGEAWESS/WGCOMEDA Dinner with live fado music, traditional Portuguese food. 28 €, not including drinks.

Thursday 27/04/17
09.00–10.30 Summaries and discussions of the group work (only WGIAB)
10.30–10.45 Coffee & Tea
10.45–12.30 Parallel work in WGIAB subgroups
12.30–13.30 Lunch
13.30–15.00 Parallel work in WGIAB subgroups
15.15–16.45 Closing common plenary (back-2-back with WGEAWESS/WGCOMEDA)
18.00 Tejo River tour (20 €)

Friday 28/04/17
09.00–10.30 Final WGIAB session
   • Wrap-up of subgroup work
   • Discussion on venue for the next meeting
   • Planning of the report
   • Report writing
10.30–11.00 Coffee & Tea
11.00–13.00 Final WGIAB session cont.
13.00- Closure of the meeting
Annex 3: An example of data available for future tITAs and cross-system comparisons between Baltic Sea basins.

Figure 1. An example of data available for future tITAs and comparative analysis across basins, here illustrated by derived time-series of CWM traits for phytoplankton (a), benthos (b) and fish (c), based on long-term monitoring and trait data in the area. To facilitate a comparison among traits the variables are shown as anomalies with mean zero and unit variance.
Annex 4: Spatio-temporal pattern in environmental summer conditions

Figure 1. Results of the Principal Tensor Analysis with 3 principal tensors (PT) explaining together 31% of the total variability of environmental conditions. The upper panels show the time and space component projected on PT1 vs. PT2 (left) and PT1 vs. PT3 (right). The lower panels show the environmental variables in these PT domains. While PT1 and 2 show greater differences in the time component, PT3 features greatest variability of the spatial component reflected by differences in Chl $a$ and phosphate concentrations.
Figure 2. Classification of stations based on their environmental dynamics over time showing a strong North–south division. (a) Dendogram of the Hierarchical Agglomerative Clustering and the cutting at 2 clusters. (b) The clusters represented on the principal tensors PT1 and PT 2 and (c) on PT1 and PT3. (AS = Archipelago Sea, BB = Bornholm Basin, BoB = Bothnian Sea, BoS = Bothnian Sea, GB = Gotland Basin, NBP = Northern Baltic Proper)