Book of Abstracts

BONUS SYMPOSIUM: Science delivery for sustainable use of the Baltic Sea living resources

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Invited presentations

Spatial and temporal dimensions in European marine biodiversity research: Geographic gradients in benthic biodiversity over the Baltic and Europe, and a reflection on European developments in marine biodiversity networking

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Open marine coastal waters are not restricted by national boundaries. Marine environmental issues in these waters are therefore best considered at the large, European, scale. In this presentation we will refer to some examples on gradients in biodiversity at European scale and on the large scale marine biodiversity research networks that are needed to achieve these results.
The results on the biodiversity for marine benthos, in confined lagoons as well as in open sea, showed no consistent linear pattern with e.g. latitude, salinity, or temperature. Along the European coastline the biodiversity of soft substrata benthos peaked at latitudes in between 40 and 50° North, and was lower at lower (south) as well higher (north) latitudes. Trends were related to tidal level, salinity, temperature, and sediment grain size. These factors also explain the trends found in the Baltic Sea, whereby the Baltic is not a mere outlier among other European seas.
Irrespective of two decades of intensified international European cooperation, knowledge of the marine realm is still fragmented between disciplines and nations and also in time.
Analysis of the European networks in marine sciences and biodiversity research showed that these European networks have strong parallels, or even overlaps. Key issues and topics of interest, like scope and aims, in several networks are similar.
Moreover, joint exercises to use harmonised tools and methods hardly have resulted in common standards at European level. A further development of harmonised tools in biodiversity research may however be hampered, since in the last calls of Horizon 2020 the topic of biodiversity observation largely disappeared. Ongoing activities in EC programmes related to biodiversity observation are at this moment mainly dedicated to automated observations in deeper waters (e.g. JERICO) or to the delivery of existing biodiversity data (e.g. EModNet)
This also means that a tremendous gap may appear in the harmonisation of approaches, indicators and tools with regard to the implementation of the obligations stemming from the MSFD, and its associated GES (the Good Environmental Status), in which biodiversity research, and the factual delivery of new biodiversity data, plays an important role.
Therefore, with regard to the coming calls of the EC, as the Horizon 2020 programme, joint action and enhanced networking are strongly needed to stimulate new biodiversity observation programmes in the coastal zone.

The response of North Sea flatfish populations to centuries of exploitation: lessons for management

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Flatfish has been exploited commercially since the late medieval time and has been affected by man made changes in habitat due to land reclamations and hydrological c. The history of exploitation is closely linked to the evolution of bottom trawling. Here we reconstruct the history of the flatfish fishery and the impact on the population biology based on a variety of sources including historic documents, flatfish remains in archaeological excavations and population modelling. The historic development in intensity and spatial extend of bottom trawling is presented. The selectivity of the fisheries is inferred from the fishing gear used (mesh size) and the spatial overlap of the fisheries and the various life history stages (eggs and larvae on spawning grounds, early juveniles on nursery grounds, late juvenile and adult feeding grounds) and the seasonal migrations between spawning and feeding grounds. The presentation will pay particular attention to the effect of fishing and habitat modification and discuss how anthropogenic activities may have affected density-dependent processes at different phases during the life cycle and will discuss the implications for management.

How to catch fish, preserve habitat, conserve other critters, derive energy, avoid too much bad stuff, have lots of tourists, utilize the ocean, and keep people happy all at once

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The discipline, science and practice of marine resource management has declared ecosystem approaches to management (EAM; aka ecosystem-based management, EBM) for multiple decades. Not assuming the rationales, definitions or benefits of EAM are necessarily clear or familiar, I briefly review the need for EBM. In short, dealing with multiple uses across multiple sectors with multiple parties that have multiple objectives in a multivariate dynamic environment with multiple indicators of success has made this 'multi-multi' issue effectively one that requires an EAM to deal with so many tradeoffs and the prioritization of action. That is, what is most at risk and what services are most important in a marine ecosystem. Yet, even recognizing the need for and value of EBM, full implementation and realization of EAM/EBM remains generally limited. Why? Not wanting to provide yet another set of (check)lists, another set of process diagrams, nor another tome of theoretical possibilities, here I provide a set of narrative-based stories, based on real-world examples (albeit with sufficient analytical context), that elucidate some of the major lessons we have learned as we have collectively attempted to overcome some common obstacles to implement EBM. There are potentially numerous lessons one could glean, but the salient point is this: until the cost, or societal perception of that cost, of not doing EAM outweighs continuing to conduct business-as-usual, EAM implementation will be lagging. My aim is to show that we are essentially at that place now.

Session 1: Potential and genetic basis for colonisation, acclimation and adaptation

Oral presentations

Physiological responses and phenotypic plasticity of salinity tolerance in *Temora longicornis* in the Baltic Sea

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The impact of future environmental change on copepod populations will depend on species' capacity to acclimatize and adapt to changing conditions, including salinity. Using the marine copepod *Temora longicornis* as a model species, we compared physiological responses of populations from meso- and polyhaline regions of the Baltic Sea to lowered salinity. Vital rates of polyhaline copepods were significantly lower at salinities ≤ 10. These tolerance differences could be a result of long-term acclimation or genetic variation in phenotypic plasticity. To test whether the wide distribution of *T. longicornis* in the Baltic Sea results from long-term acclimation or genetic differences, we assessed the effects of salinity on offspring of meso- and polyhaline populations reared at a common salinity of 15. In these common garden experiments, development and survival from nauplii to copepodite stage was estimated across a salinity gradient from 8-20. Results revealed higher tolerance in the mesohaline population, and suggest that the wide distribution of *T. longicornis* is not based on 'euryhalinity', but that the mesohaline populations in the Baltic Sea represent locally adapted populations. The response of *T. longicornis* to reduced salinity will thus be population-specific, which should be integrated when modelling the species' responses to future environmental change.

Stability of Eastern Baltic cod population structure and genetic diversity over a period with strong environmental fluctuations (1996-2016)

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The population structure of marine fishes can provide crucial information on stock delineation and connectivity. Most studies to date address spatial patterns of population structure at single or few time points. Here, we provide a long-term (1996-2016), bi-annually resolved study of the stock structure and genetic diversity of the commercially and ecologically important marine fish species Baltic cod over a period with strong fluctuations in salinity and oxygen concentration. Genetic analysis (SNPs and microsatellites) of DNA obtained from archived otoliths confirmed the strong genetic differentiation of Eastern and Western Baltic cod, and indicated the lack of additional sub-structure in Eastern Baltic cod from different spawning basins. Independent of environmental conditions, Western Baltic cod genotypes likely representing migrants

were detectable but rare in the eastern Baltic (0-3% per year), and there was little evidence for the presence of hybrids. Overall, the high temporal stability would be consistent with continuous negative selection against "out of place" genotypes and hybrids in all locations. For management, these results suggest that the current management of Baltic cod as two stock components is valid, but also, that "rescue" of one stock by supplementation from the other (e.g., after local population collapses) is unlikely to take place.

Using genetics to identify management units of European flounder in the Baltic Sea

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European flounder, *Platichthys flesus*, is one of the commercial most important flatfish species in the Baltic Sea. However, analytical assessments are hampered by the lack of understanding spatial distribution and stock separation. Flounder in the Baltic belong to different populations, or even subspecies, producing either pelagic or demersal eggs. There are most probably differential recruitment rates between the two ecotypes which thus contribute differently to the exploitable stock. In addition several separate sub-populations have been identified within these spawning types but their number is too high to be used as units in routine assessment. Hence there is a need to increase the understanding of stock structure and spatial distribution of flounder to develop analytical assessment tools for a sustainable management. In the BONUS INSPIRE project different tools, including genetics, morphology and otolith chemistry, are applied to a wide sampling scheme of spawning flounder in the Baltic Sea with the aim to identify appropriate management units. Here the results from a new genetic study using 16 microsatellites are presented and discussed from a management perspective.

Adaptive transgenerational plasticity in Baltic Sea sticklebacks.

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High levels of genetic diversity are critical to maintain the adaptive potential of species to climate change, which is essential for a species' viability. Transgenerational plasticity is a recently discussed mechanism that can buffer effects of environmental change through non-genetic inheritance. If adaptive phenotypes emerge rapidly without underlying genetic change such transgenerational non-genetic inheritance might even provide an accelerated pathway for subsequent adaptive evolution. Both, the buffering and the accelerating scenario, can have strong implications on the offspring's fitness and ultimately on population persistence. We studied this scenario within three populations of the model species *Gasterosteus aculeatus* along the salinity gradient of the Baltic Sea, as surrogate for predicted salinity changes in a space- for-time experiment. Given the overlapping distribution patterns of species and salinity gradients and the high costs of osmoregulation, salinity is an important abiotic driver of marine evolution. Our multi-generational experiment provides insights on how trait reaction norm of the offspring is mediated by the parental environment and demonstrate the costs and benefits of transgenerational plastic effects. Further, we show complex combinations of acceleration and buffering depending on the population, treatment and reaction norms involved.

Genotypic and phenotypic diversity of bacterioplankton in the Gulf of Finland (Baltic Sea)

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The largest biodiversity of the Baltic Sea belongs to microorganisms. Contrastingly to macroorganisms, their diversity does not decline along the salinity gradient and moreover, the presence of permanent anoxic bottom layer results in redox-driven niche partitioning of the bacterioplankton community. Different approaches were combined for this study in order to determine spatiotemporal patterns of bacterioplankton community. Multi-year flow cytometry data was used to discriminate and enumerate certain groups by their florescence 'footprint' (differences in genome size, granularity and autofluorescence). Epifluorescence microscopy with acridine-orange staining was used to identify and characterize different bacterioplankton morphotypes and their occurrence patterns. Phylogenetic diversity and its variability was determined from next-generation sequencing data (16S rRNA gene). The Gulf of Finland is hydrographically stratified (permanent halocline and temporary thermocline). Our results demonstrate corresponding structuring of the bacterioplankton community by its composition and abundance. We observed bimodal distribution of bacterial abundance with peaks in the surface layer and hypoxic bottom layer. In the surface layer contrasting seasonal changes took place, mainly substrate and temperature driven. The bottom layer exhibited higher genotypic and phenotypic diversity of bacterioplankton in most data points (presence of different metabolism types, including chemolitoautotrophic bacteria), but seasonal changes were considerably less pronounced.

The influence of salinity on reproductive success of round goby *Neogobius melanostomus* I. Egg development

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Round goby *Neogobius melanostomus* successfully invaded the Baltic Sea since the late 1980s. A broad prey field as well as nest guarding and a high flexibility in using different structures and substrates as habitat are qualifying round goby as a successful invader. However, the actual distribution within the Baltic Sea suggests that spreading is limited by salinity. We conducted experiments investigating the ability of round goby eggs to develop in different combinations of salinity and temperature. Our results show that temperature mainly effects the egg development time, whereas the hatching success is strongly influenced by the salinity. The time to hatch decreased continuously from ~ 60-120 days at 10°C down to ~11-17 days at 20°C. Hatching success is also influenced by temperature but with a maximum at 15°C. The effect of salinity on the hatching success resulted in a maximal survival rate of eggs at 15PSU and a decrease to lower and higher salinities. However, even at 0PSU a certain percentage of eggs developed and larvae could be reared successfully. In contrast, at 25PSU only one third of the egg batches developed and all larvae hatched died within 48h. Furthermore, first evidence was given that larvae at higher salinities hatched at an earlier developmental stage, indicated by bigger yolk sac.

Egg buoyancy of flounder, *Platichthys flesus*, in the Baltic Sea – adaptation to salinity and implications for egg survival

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Vertical distribution of eggs as determined by the egg buoyancy have profound implications for the reproductive success and hence recruitment in fish. Here variability in egg specific gravity of flounder, *Platichthys flesus*, was studied along a salinity gradient and by comparing two reproductive strategies, spawning pelagic or demersal eggs. Egg characteristics of 209 egg batches (covering ICES SD 22-29 in the brackish water Baltic Sea) was used to reveal the significance of egg diameter and egg dry weight for egg specific gravity (ESG), subpopulations, and egg survival probabilities of pelagic eggs following a major saline water inflow event. ESG differed between areas; three subpopulations of flounder with pelagic eggs: 1.0152±0.0021 (mean ± sd) g cm^{-3} in SD 22, 1.0116±0.0013 g cm^{-3} in SD 24 and 25, and 1.0096±0.0007 g cm^{-3} in SD 26 and 28, contrasting to flounder with demersal eggs, 1.0161±0.0008 g cm^{-3}. Egg diameter differed between subpopulations; from 1.08±0.06 mm (SD 22) to 1.26±0.06 mm (SD 26 and 28) for pelagic eggs and 1.02±0.04 mm for demersal eggs, whereas egg dry weight was similar; 37.9±5.0 µg (SD 22) and 37.2±3.9 µg (SD 28) for pelagic, and 36.5±6.5 µg for demersal eggs. Both egg diameter and egg dry weight were identified as explanatory variables, explaining 87% of the variation in ESG. Egg survival probabilities judged by combining ESG and hydrographic data suggested higher egg survival in SD 25 (26 vs 100%) and SD 26 (32 vs 99%) but not in SD 28 (0 and 3%) after the inflow event, i.e.

highly fluctuating habitat suitability. The results confirm the significance of ESG for egg survival and show that variability in ESG as an adaptation to salinity is determined mainly by water content.

Session 1, poster presentations

Salinity tolerance of brackish water round goby, *Neogobius melanostomus*

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When an invasive species is introduced into a new region, secondary dispersal is limited by the physiology of the organism in relation to the ambient environment and by complex interactions between factors such as presence of predators, competitors, and parasites. Aerobic scope (AS) in fish has been linked to various fitness-related parameters, and may be valuable in determining dispersal potential of invasive fish in novel environments. The invasive round goby, *Neogobius melanostomus*, thrives in brackish and fresh water, but its ability to survive in saltwater remains unknown. We show that its AS is reduced by 30% and blood plasma osmolality increased at salinities approaching oceanic conditions, as compared to in brackish waters. Survival was also reduced at the highest salinities yet more than half of the fish survived. Reduced physiological performance at the highest salinities may affect growth and competitive ability, but to what extent reduced AS and osmoregulatory capacity will slow the current rate of advance of the species through the steep salinity gradient from the brackish Baltic Sea and into the oceanic North Sea remains speculative. At the current rate of advance the species will reach the oceanic North Sea by 2018/2019.

Transcriptional responses of three-spined sticklebacks to simulated climate change in the Baltic Sea

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Climate change and accompanying environmental stress are challenging marine organisms worldwide. Particularly strong changes in salinity are anticipated in the Baltic Sea due to its semi-enclosed structure. As osmoregulation is costly, environmental salinity acts as a strong evolutionary force in marine species' evolution. The potential for a species to adapt to such drastic changes is mediated not only by its genetic diversity but also by its plasticity. To elucidate components of transgenerational plasticity, we studied gene expression responses to salinity acclimation in a multigenerational common-garden experiment using the Baltic three-spined stickleback as our model organism.
Our study provides insights on how the environment experienced by parental generations can influence gene expression in offspring. As Baltic sticklebacks are living

under various salinity regimes in the Baltic, we are able to compare acclimated treatment groups to already adapted populations, helping to unravel the genetic basis of acclimation to salinity change. Furthermore, as transcriptional changes may buffer offspring phenotype against environmental stress, our study helps predicting the potential for species to adapt to fast changing environments in the future.

Adaptive capacity of Baltic Sea copepod populations to changing environments

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Differentiation between spatially dispersed populations can arise over a gradient of environmental factors due to different local selective pressures. In The Baltic Sea temperature is expected to increase more compared to world oceans, while salinity is expected to decrease. A key question is whether populations will be able to adapt to changing conditions. We sampled populations of the copepod *Eurytemora affinis* across a temperature and salinity gradient and investigated their response to varying environmental factors in common garden experiments. Populations from warmer areas had higher developmental rates in warm temperatures and also higher survival when high temperature and low salinity interact. But we found no evidence of variation within populations in the development time reaction norm to temperature, thus there is little adaptive capacity. Also food type affected development time which also interacted with temperature on survival. Our findings suggest that development time is related to selection by temperature rather than seasonal time constraints, and that high food quality is important for populations with fast developmental rates. In conclusion, warm adapted populations seem to be better prepared for future elevated temperatures also in a scenario with decreased salinity, but food quality could hamper their relative benefit.

The influence of salinity on reproductive success of round goby *Neogobius melanostomus* II. Larval development

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Recruitment success as a prerequisite for establishing a new population in an unused environment is mainly determined by the ability of larvae and juvenile to grow sufficiently and finally to survive. In the Baltic Sea salinity seems to be the limiting factor for round gobies to disperse towards full marine environment, indicated by their recent distribution. We conducted experiments investigating first the ability of round goby eggs to develop in different combinations of salinity and temperature, and second to measure the growth and survival potential of larvae to early juveniles at the same environmental conditions the eggs were reared. Freshly hatched larvae were reared for 20 days feeding live copepods (Eurytemora affinis) ad libitum. At day 0, 10 and 20 length, wet and dry weight were measured to determine size at hatch, growth at the yolk sac stage and over first period of growth dependent exclusively on external food intake. As a result successful rearing was only possible at salinities up to 20PSU. At 25PSU larvae died

within 48h after hatch, before complete absorption of yolk indicating physiological limitation. We found first evidence for an influence of salinity on growth, with an increase from 12mm after 20 days at 5PSU to 17mm at 15PSU. First preliminary results indicate that growth is however limited at 20PSU. Additional much higher variability in egg development between egg batches at higher salinities may indicate a strong parental effect. This may lead to a higher tolerance to salinity and consequently to a further dispersion towards full marine habitats in future.

Session 2: Process-based knowledge on spatial population dynamics, species interactions and habitat connectivity

Oral presentations

Another critical period: Physiological limits determine recruitment success during the post-larval stage of a temperate clupeid (*Sprattus sprattus* L.)

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In most marine fish species recruitment is determined during the egg and larval stages when small changes in mortality have large effects on year-class strength. In Baltic sprat, however, previous studies showed that recruitment is determined in post-larval life-stages, which occur in coastal-near areas during summer and autumn. So far, research in the Baltic Sea concentrated on offshore areas where reproduction takes place and thus large knowledge gaps exist concerning the juvenile nurseries of sprat. Among the main factors influencing survival, predation and starvation, we found indications that starvation plays a dominant role. Laboratory studies with post-larval sprat revealed that food demand rapidly increases with size and temperature underlining the increasing risk of starvation. Thus, the timing of this food-demanding juvenile stage is probably of importance in regulating survival and subsequent year-class strength. To test this hypothesis, we performed a simulation of growth and food demand based on field otoliths and experimental data. The aim is to model the growth of seasonal cohorts and to detect those cohorts that experience best thermal conditions to fulfill maintenance and optimal growth at minimum food demand. Successful cohorts observed from otoliths of recruits represent those cohorts in the simulation that exhibit a low energy demand as juveniles. In contrast, earlier cohorts suffer from starvation due to high maintenance rations caused by large body size in combination with high temperature. The presented simulation approach enables us to study the seasonal plasticity of the sprat stock progeny thereby improving the understanding of recruitment variability.

Vertical migration patterns of *P. acuspes* in contrasting hydrographic conditions and predator densities in the Baltic Sea

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Recently, it has been shown by Möller (2013) that the calanoid copepod *Pseudocalanus acuspes* performs daily vertical migration (DVM) around the halocline in the central Baltic Sea. This results have been interpreted as a strategy to avoid predation by sprat (*Sprattus sprattus*). New Video Plankton Recorder (VPR) data have been collected in 2012 and 2015—before and after a mayor baltic inflow in 2014—to further investigate the DVM mechanisms of *P. acuspes*. It turned out that the DVM behaviour does not occur if sprat are absent. Furthermore, we demonstrated that the interaction between sprat and *P. acuspes* is also influenced by the hydrographic situation determining the spatial overlap between predator and prey. The typical DVM pattern of the planktivorous sprat is staying near the surface at night and migrating downwards at dawn to a depth with higher salinities and sufficient oxygen. At the end of the day light period, sprat migrate back to the surface. After an inflow, oxygen concentrations are sufficient for sprat down to the bottom of the basin—where they are then shoaling at day time—while the halocline has shifted upwards. With prolonged stagnation, oxygen gets depleted in the deep layers, leading to unfavourable conditions for sprat. They do not migrate as deep and stay closer to the halocline, which leads to an increased spatial overlap with *P. acuspes*, which in turn start showing a DVM behaviour.

Survival and dispersal of eggs and larvae of central and eastern Baltic flounder (*Platichthys flesus*) by biophysical modelling

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A hydrodynamic model coupled with a Lagrangian particle tracking technique was utilized to simulate spatially and temporally resolved long-term environmentally-related i) size of habitat suitable for reproduction, ii) egg/yolk-sac larval survival, iii) causes of mortality, and iv) connectivity between spawning areas of Baltic flounder with pelagic eggs. The highest reproduction habitat suitability was obtained for the ICES SD 26, followed by SD 25. Relatively low habitat suitability was obtained for the SDs 24 and 28. Eggs initially released in SDs 24 and 25 were strongly affected by sedimentation compared to those released in SDs 26 and 28. Highest relative survival of eggs occurred in SD 26 and 25. Relatively low survival rates in SD 28 were attributable to oxygen-dependent mortality. Oxygen content had almost no impact on survival in the SD 24. Buoyancy of eggs and yolk-sac larvae in combination with topographic features appear to

act as a barrier for the transport of eggs and yolk sac larvae and potentially limits the connectivity between the different spawning areas.
In a second study the drift from the first feeding larval stage until time of settlement was investigated by detailed drift model simulations, to examine the spatio-temporal dynamics of the probability to settle in a preferred nursery habitat. The study suggests that the majority of larvae drift towards coastal areas and settle at metamorphosis ≤20 km from a sandy habitat enabling further migration to a preferred nursery area, i.e. larval drift seem not to be a major bottleneck in recruitment of flounder in the Baltic Sea. Further, the drift model suggests that flounder hatching in the SDs 24 and 25 utilize nursery areas in mainly the SDs 22-25 and the Kattegat, whereas flounder hatching in the SDs 26 and 28 mainly utilize the southern and eastern coast of the SDs 25, 26 and 28. Thus, the two stock components, regarded as separate subpopulations, seem to use different areas following settlement.

Management of herring and sprat stocks in the Baltic taking into account spatial effects

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Several biological populations of herring and sprat exist in the Baltic. For stock assessment purposes some of them have been combined into larger assessment units (AUs), as a compromise between complex population structure and possibility to collect data and assess separate populations. However, changes in distribution of clupeids and cod over recent decades (increasing density of clupeids in north-eastern waters and distribution of cod constrained mainly to southern Baltic) are not considered in the standard ICES assessments.
Therefore, herring in the central Baltic (CBH) (sub-divisions 25-29+32) and sprat in the whole Baltic (sub-divisions 22-32) have been assessed by assessment units used up to early 1990s, *i.e.*, herring in sub-divisions 25-27, herring in sub-divisions 28-29+32, sprat in sub-divisions 22-25, sprat in sub-divisions 26+28, and sprat in sub-divisions 27,29-32. The overlap with cod (predator of sprat and herring) mainly distributed in sub-divisions 25-26 was taken into account by including area dependent predation mortalities. Sums of biomasses by AUs are similar to the biomasses of presently assessed stocks in the bigger areas. However, intensities of exploitation of sub-stocks differ markedly. Thus, the MSY parameters have been determined for each sub-stock and current exploitations have been evaluated in relation to these parameters.

Temperature and size-dependent functional response of *Sprattus sprattus* L.

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Functional response (per capita feeding rate as a function of prey concentration) is an essential component in larger ecosystem models to describe predator prey interactions. Despite its prominent ecological role in the Baltic Sea food web and various ecosystem modeling studies performed in the past, the effect of temperature and fish size on feeding rate of sprat is unknown. In contrast to most other clupeids, sprat is known as an exclusive particulate feeder from post larval stage on, showing no filter feeding even at highest prey concentrations. Here, we performed a comprehensive experimental study to quantify the size- and temperature-dependent functional response. Feeding rates were estimated by under-water video observations for different size groups of fish with means ranging from 3.6 to 8.7 cm total length at different temperatures (5 to 20°C). Non-evasive *A. salina* nauplii were used as prey starting each trial with high concentrations (330 L-1) to estimate the physiologically possible maximum feeding rate of sprat. The size-related parameter of feeding rate of larger sprat (> 9cm TL) was estimated by a stomach content evacuation model using field data. Sprat showed a functional response type II for all body sizes and temperatures. Feeding rate clearly increased with increasing body size and temperature (Q10 ≈ 1.5) and reached a maximum biting rate of about 2.0 s-1. Analyses of sprat stomach content from experiments and field revealed high individual variability of feeding activity.

Match-mismatch of the horizontal distribution of adult sprat and its eggs

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Baltic sprat has strongly variable year-class strength. Different environmental and biological factors have been used to explain this high variability including the distribution of the young-of-the-year sprat. Regular ichthyoplankton and hydro-acoustic surveys in the Central Eastern Baltic have started since 1970s. We have compared the horizontal distribution of the adult sprat in the Gotland Basin with the horizontal distribution of daily production of its eggs on the 1st stage. This was possible for May in years from 1981 to 1989 and from 2004 to 2014, when both hydro-acoustic and ichthyoplankton surveys had been made. Distribution of spawning stock was determined from the results of hydro-acoustic recording and trawling. The daily production of 1st stage of sprat eggs has been calculated using model for the vertical distribution of sprat eggs that helped to obtain an ambient water temperature and thus the duration of the stages of development. After the comparison of these two distribution maps the degree of match or mismatch was assessed. We also looked at the patterns of distribution, like patchiness and gradient. The degree of match altered between the years, but in general it was closer to mismatch. The correlation of the match with the survival index was slightly negative.

Fine-scale connectivity patterns in Gulf of Riga

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The dispersal patterns of planktonic phases creates the fundamental properties of connectivity between benthic communities that affect the risk of local extinctions, genetic diversity and evolution of local adaptations. We applied a combination of hydrodynamic, ecosystem- and agent-based (ABM) modelling to analyze fines-scale dispersal patterns of *Mytilus* larvae in the Gulf of Riga area during 38 years (1971-2007). An ABM-model was developed for larvae dispersal based on spawning conditions, hydrodynamics, temperature- and food-dependent growth and mortality rates as well as substrate dependent settlement. The average importance of the areas as source and sink areas was spatial variability within the study area. The mean (±SD) dispersal distance of *Mytilus* larvae was 34.3 (±6.0) km, with most larvae traveling 5-35 km and few traveling long distances (240 km). The year-to-year variability in average dispersal distance was 30 - 50 km. The mean dispersal time was 30 days, and most larvae travelled 23-34 days. The number of settled larvae was related to food availability (r=0.61-0.81), suggesting that high food availability ensure survival of the larvae to competent size. The results can be used as basis for recommendations for management of the large number of sites protected by the EU habitat and bird directives.

Cod & Co. feeding ecology revisited: Baltic Sea commercial fish community assessed by stable isotope analysis

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Understanding the feeding ecology of commercial fish species is an essential component of multi-species stock assessments and food web models. However, the necessary spatio-temporal resolution is often difficult to obtain with studies based on stomach content analysis (SCA) due to logistical constraints. Here, we used carbon, nitrogen and sulfur stable isotope analysis (SIA), to obtain a complementary dataset to SCA for the key commercial species in the Baltic Sea, cod (*Gadus morhua*), herring (*Clupea hargengus*) and sprat (*Sprattus sprattus*), three flatfishes, and three other fish species including whiting. Highly resolved spatial sampling in April 2014 revealed the overall trophic structuring of fish communities and the presence of systematic inter-basin differences in isotopic baselines. Three different case studies then highlighted (1) spatial differences in ontogenetic shift patterns in cod between basins, and potential for competition with whiting; (2) spatially consistent patterns of competitive interaction in herring and sprat that can help to identify size classes most likely to compete; (3) a surprising degree of intraspecific plasticity in several species. This study demonstrates the potential of SIA to obtain long-term feeding estimates for multiple species and represents a baseline dataset for future studies of temporal variation (e.g., pre- and post inflow situations).

Trophic interactions in the Baltic Sea: Clupeid predation on cod early life stages

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Predation pressure by planktivore clupeids sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) on cod (*Gadus morhua*) eggs is an important factor affecting cod recruitment and has been considered as a main driver preventing recovery of the stock in the 1990s. During the early 2000s, improved recruitment led to distinct signs of cod stock recovery, which environmental conditions enhancing reproductive success of cod could not explain alone. Clupeid stomach contents sampled during 2004-2008 were analysed to investigate possible changes in predation pressure on cod eggs leading to increased reproductive success. Additionally, new methodological approaches were followed to yield improved consumption estimates of cod eggs in the main cod spawning area, the Bornholm Basin. Results were compared with updated data from a 1990s time series resulting in more realistic overall estimates. To investigate whether predation pressure differs between development stages, whether eggs of other fish species are subject to predation to a similar extent as cod eggs, and to assess whether the presence of other eggs triggers predation on cod eggs, stage- and species-specific selection indices for clupeids were derived. Combined results clearly show that overall changes in predation pressure are likely to have contributed to improved cod recruitment.

Predator–prey size relationships in a low diversity marine system: The Eastern Baltic cod case study

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How predators choose their prey largely defines ecosystem trophic structure and food web dynamics. In aquatic systems organism body size is an important trait explaining predator-prey interactions, such that a positive relationship is often observed between the size of predators and of their prey. This relationship is particularly pronounced between predator size and the maximum size of prey consumed. Here, we use a unique cod stomach content dataset with diet information collected from the Baltic Sea in 1963-2014 to explore prey size distribution in the diet of Eastern Baltic cod. The results show that the predator-prey size ratio increases with increasing predator size, as in other marine systems. Overall the Eastern Baltic cod, however, preys on smaller prey than other North Atlantic cod populations. The cod prey size spectrum reflects the low species

diversity of the Baltic Sea, such that some prey size classes contain only a few prey types. Particularly, the small cod is potentially vulnerable to changes in individual invertebrate prey species. We suggest that further study of the relationship between Eastern Baltic cod and the size-distribution of its prey can provide valuable insights into changes in body condition, growth, vulnerability and food web dynamics.

Changes in horizontal and vertical distribution of Baltic cod and flounder as analysed using standardised fishery-independent data

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Understanding the spatiotemporal dynamics of marine species is essential for an ecosystem-based management. The distribution of marine species is the result of the connections between the intrinsic characteristics of the populations, trophic interactions, climate and anthropogenic factors. Because of all these interdependencies, the distribution of a species in a determined area is likely changing over time. In the Baltic Sea, cod (*Gadus morhua*) and flounder (*Platichthys flesus*) are commercially important species dominating the demersal community. Furthermore the Baltic Sea has experienced throughout the years relevant changes in salinity, temperature and oxygen conditions. Here we analysed the changes in spatial distribution of cod and flounder in the Baltic Sea between 1979 and 2016 using standardised trawl surveys and hydrographic data and employing Delta-Generalized Additive Models. We also analysed the changes in the depth distribution of the two species. Our results show a contraction of distribution areas and changes in depth distribution of both cod and flounder, likely due to the increased hypoxia that have made extensive areas of the Baltic seafloor unsuitable for the two species. This new knowledge improves our understanding on the spatial dynamics of cod and flounder, thus promoting a long-term sustainable management of these marine resources.

Drivers and stressors of herring (*Clupea harengus*) early life stage mortality in inshore spawning areas of the Western Baltic Sea

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“Ruegen herring” is considered a significant component of the spring spawning herring stock in the Western Baltic Sea. As herring reproduction and development of early life stages takes place in particular bays and lagoons, local hazards can potentially introduce survival bottlenecks transported to higher spatial scales and affect entire population dynamics. To increase mechanistic understanding on the contribution of inshore nursery areas to herring reproduction, habitat use of differing early life stages was investigated on the scale of i) a major larval retention area and ii) multiple inshore systems along the southern Baltic Sea coast. Additionally, local stressors such as storm effects, predation and regional climate response to herring phenology were quantified by their impact on early life stage mortality. Results indicate that larval stages actively select differing near shore habitats. 0-group juveniles can be assigned to certain coastal nurseries by

elemental "fingerprints" in their otolith. Major survival bottlenecks were identified in the egg and early larval phase. Strong egg predation by sticklebacks as well as storm induced turbulence can cause drastic losses of herring eggs on vegetated spawning beds. Additionally, changes in herring phenology can lead to record lows in coastal production of larvae, resulting in decreased population productivity.

Some evident particularities of sprat – *Sprattus sprattus balticus* (Schneider) spatial distribution over the Gotland Deep in the Baltic sea

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Since 1981 Latvia performs regular hydro-acoustic surveys of sprat stock In the Eastern Baltic Sea (ICES Subdivisions 26 and 28.) Oceanographic surveys are carried out simultaneously with hydro-acoustic surveys. Within the framework of the BONUS EEIG INSPIRE project the database of historic Latvian acoustic surveys was created and data from database was the basis for analysis of long-term sprat distributional changes. The peculiarities of sprat distribution were analysed in relation to season, size of the stock, size of the recruitment, and some environmental conditions like severity of winter, inflows of saline waters from the North Sea, water temperature and content of oxygen in the water. The analysis showed that seasonal vertical distributional pattern is rather steady while the horizontal distribution could have differences between years although main concentrations of sprat are over big depth in cold part of the year and closer to the coast in summer-fall period. There are also differences between distribution of younger and older age groups of sprat. A hypothesis is put forward that Gotland Deep basin is the centre of distribution of sprat stock in the Baltic Sea.

Hidden variables in a Dynamic Bayesian Network identify ecosystem level change

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Marine ecosystems' complexity is a major challenge for models, particularly as ecological data are often scarce, and ecosystems are known to sometimes undergo relatively fast structural changes that have a major effect on the ecosystem dynamics. These changes may be driven by unobserved variables, i.e. ecosystem components that we do not have data on. This talk presents a set of Dynamic Bayesian Network (DBN) models fitted to the Gotland Basin food web data. The models include different setups of hidden variables that were used to capture the ecosystem dynamics that are not directly observed through the data. The hidden variables were able to find similar patterns and links to observed variables regardless of their exact setup. These patterns were also in line with other research, and can be used to increase understanding of the ecosystem change. The next step will be to evaluate the predictive capacity of the models and the factors that affect it.

Session 2, poster presentations

Lack of top down control of sprat (*Sprattus sprattus* L.) and herring (*Clupea harengus* L.) on zooplankton in the Central Baltic Sea

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In 2002 and 2003 we conducted a temporally resolved comprehensive investigation on the plankton production and diet of sprat (*Sprattus sprattus* L.) and herring (*Clupea harengus* L.) in Bornholm Basin.
Herring and sprat were mainly zooplanktivorous, largely feeding on the calanoid copepods *Temora longicornis* and *Pseudocalanus acuspes* and additionally on the cladocerans *Bosmina* spp. and *Podon* spp. The daily food intake was estimated for herring (2.2-2.9% *BM* in summer and 0.5% *BM* in winter) and sprat (2.6% *BM* and 0.4% *BM*, respectively). In April and May considerably more than the production of these two copepod species was consumed. Furthermore, almost the entire copepodite standing stock (C1-6) of *T. longicornis* was consumed (consumption/biomass (C/B) = 0.94) by sprat and herring in April 2002, indicating a high predation pressure on these stages in spring. However, the impact on the population dynamics of both copepods was negligible. Likewise, the impact on *Acartia* spp. was considered negligible (C/P < 0.1). If integrated over the year, the utilization of the copepod production by both clupeids was low with only 18% of the annual production of *T. longicornis* (all stages). 36% of the annual production of *P. acuspes* was consumed by both clupeids together, while the production of *Acartia* species (1.4%) and cladocerans (2.3%) was almost completely unused by fish predators. The utilization of only 9% of the combined production of copepods and cladocerans indicates an overall poor trophic coupling between mesozooplankton and pelagic planktivores in the Central Baltic Sea.

Baltic Sea mesozooplankton network and database

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Baltic Sea zooplankton network is a joint and voluntary effort by number of researchers from institutes that conduct or have conducted zooplankton monitoring on the Baltic Sea. The network was initiated some years ago, and gained notable impetus in 2014-2016. Data harmonization was partly funded by BONUS INSPIRE and BIO-C3 projects.
Aim of the joint effort was to expand the range of research questions that can be studied by pooling the available and scattered data from all parties that have conducted sampling and have interest in the Baltic Sea mesozooplankton ecology. In the pooled and harmonized dataset, value of every single sample increases, when it becomes part of the big picture.
This poster will give the updated overview of the activities of mesozooplankton network and current status of the dataset.

Consumption rates of sprat (*Sprattus sprattus*). A new look on an old story

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The daily food consumption of sprat is commonly estimated using an average stomach content weight from day time and a model of gastric evacuation. Our study provides a new approach using a temperature- and body length-dependent functional response model (per capita feeding rate as a function of prey concentration) and vertically resolved prey density data from the field. Our method allows for different feeding rates in different plankton concentrations and ambient temperatures within the day accounting for diel vertical migration. For our purpose we collected stomach content weights of sprat (n = 5970) and zooplankton data on 8 different 24h stations from June 2001 to August 2015 in different basins of the Baltic Sea. The distribution of sprat during the day was assessed by hydroacoustic data. In contrast to the estimates of the gastric evacuation method, our new feeding estimates led to completely different diel patterns and quantitative results. The main outcome is that feeding at day time in the deep represents only between 13%

and 35% of the daily consumption. More than 65% of the daily consumption is taken at the dusk and dawn vertical migration. This has mayor implications not only for daily ration estimates but also on prey selectivity estimates, as different prey species are fed at different day times and depths.

Changes in the horizontal distribution of mortality of sprat eggs

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Baltic sprat has strongly variable year-class strength. Different environmental factors have been used to explain this high variability however it still not clear which are the most important stages of development at which the year-class strength is determined. Regular ichthyoplankton surveys in the Central Eastern Baltic have started since 1970s. Daily mortality rates and then total mortality of sprat eggs in the Gotland Basin during the whole incubation period have been calculated for the number of years starting from 1973. The daily mortality rates of sprat eggs have been calculated using model for the vertical distribution of sprat eggs that helped to obtain an ambient water temperature and thus the duration of the stages of development. Maximum of survival of eggs in most of the cases was in the centre of the Gotland basin and it was rather close to the geographical centre of abundance of sprat eggs that was very stable and moved less than 10 nm to the East from April to July. The attempts were made to link the success of spawning of sprat to the patterns of the horizontal distribution of total mortality of eggs. Good survival indices were observed in years when the centre of survival of eggs had more eastwards position.

Selecting for the dominance – feeding of sprat and herring in the Baltic Sea

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Feeding habits of herring and sprat were investigated in the north-eastern Baltic Sea in five transects from the Gulf of Finland to north-eastern Baltic Proper). In total, stomachs of 970 sprat and 556 herring were inspected for quantitative (proportion of empty stomachs, stomach fullness index) and qualitative (taxonomic composition) aspects of feeding.
The analysis of stomach content revealed that the feeding success (share of empty stomachs) and stomach fullness tended to be higher for smaller than larger fish (by species), but stomach fullness of herring also depended on the time of sampling, being highest in the noon, and decreasing towards the evening. This is in line with the feeding behaviour of the species, but complicated to some extent the diet comparison between sprat and herring. From zooplankton, *Temora longicornis*, *Eurytemora affinis* and *Acartia* spp. were the three most important prey taxa in stomach for both small and large herring and sprat. Overall, sprat was consuming more variable prey than herring. The dietary overlap within groups (small sprat, large sprat, small herring, large herring) was similar

to the between-group dietary overlap, and both were linked to the evenness of the zooplankton community in the sea. The overall diet overlap decreased when the zooplankton community was more diverse in terms of biomass evenness. This implies that both taxa prey on what they see, selecting for the dominance.

Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data

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Long time-series of standardized indices of abundance and size-based indicators are important for monitoring fish population status. This study's objectives were to (i) combine and standardize recently performed trawl survey with historical ones, (ii) discuss the trends in abundance, and (iii) in maximum length (L_{max}) for cod (*Gadus morhua*) and flounder (*Platichthys flesus*) stocks in the Baltic Sea. Standardization of catch per unit of effort (CPUE) from trawl surveys from 1978 to 2014 to swept area per unit of time was conducted using information on trawling speed and horizontal opening of the trawls. CPUE and L_{max} data for cod and flounder stocks were modelled using generalized additive models (GAMs). The CPUE time series of the Eastern Baltic cod stock closely resembles the spawning stock biomass trend from analytical stock assessment. The results obtained furnish evidence of the cod spill-over from Subdivisions (SD) 25–28 to SD 24. The CPUE trends of flounder show phases of the stocks' dynamics that were poorly known because of the short time-series available before. A drop of L_{max} in the past thirty years was evident for both species in all the stocks analysed indicating that the demersal fish community has become dominated by small individuals.

Characterising and predicting the distribution of Baltic Sea flounder during the spawning season

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Two sympatric flounder (*Platichthys flesus*) ecotypes are present in the Baltic Sea, pelagic and demersal spawning flounder. Here we address two main research questions: 1) what environmental and habitat conditions characterize the spatial distribution and abundance of adult flounder during the spawning season? 2) Where are the potential spawning areas of flounder? To this end, we modelled catch per unit of effort from gillnet surveys conducted in 2014 and 2015 using generalized additive models. A general model included all the stations fished while two other models, one for the demersal and one for the pelagic spawning flounder, included only the stations where each flounder ecotype dominates. The general model captured distinct ecotype-specific signals in salinity and depth. The model for the demersal flounder revealed a negative relation with the abundance of round goby (*Neogobius melanostomus*) and suggested that vegetation and substrate play a marginal role in the habitat choice. The model for the pelagic flounder showed a negative relation with temperature and bottom current and a positive with salinity. Spatial predictions of potential spawning areas of flounder showed a decrease in habitat availability for the pelagic flounder over the last 20 years in the central part of the Baltic Sea.

Seagrass *Zostera marina* habitat restoration in the Estonian coastal waters

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Seagrass meadows are globally important marine habitats for diverse epiflora and fauna. Although, their communities are globally in serious decline mainly due to eutrophication, habitat destruction and climate change. There has been increasing interest in restoration of shallow soft bottoms seagrass habitats in many coastal ecosystems. However, far too little attention has been paid to the interactions between plant and animal engineers in ecosystem restoration context. The main aim of this study is to develop new restoration technique for seagrass *Zostera marina* in a brackish water environment. In addition, to investigate ecological interactions between ecosystem engineers (bivalves, seagrasses) and key mechanisms that influencing the restoration success. The field experiments are conducted in West Estonian Archipelago Sea, northern Baltic Sea in two different sites (exposed and sheltered). Considering that seagrass *Z. marina* reproduces vegetatively in

the study area, the restoration can be done via transplanting only. The transplantation experiments started in spring 2017. To evaluate the success of the transplant experiments the monitoring and sampling from experimental site will be conducted during three growing seasons 2017-2019.

ECOMAP - Baltic Sea environmental assessments by innovative opto-acoustic remote sensing, mapping, and monitoring

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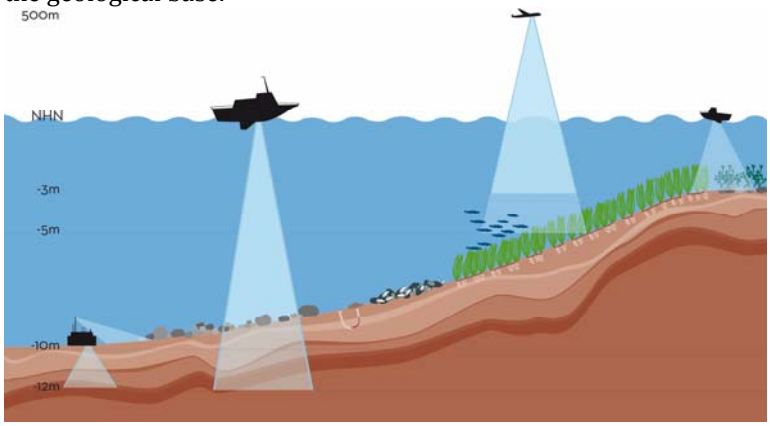
In this presentation we want to highlight the anticipated work and expected results of the new BONUS project ECOMAP. A fundamental goal of ECOMAP is to develop and test optimized remote sensors and classification of the seafloor especially in regard to benthic life assessments. Today the state-of-the art marine remote sensing focuses on characterization of the physical properties of the seabed surface. However, we believe that a more holistic remote sensing view on the seabed is imperative for a comprehensive examination of macrobenthic life. We suggest to extend the view on the near seabed with innovative multi-frequency and multi-angular opto-acoustic methods and full waveform analyses to better remotely sense (1) the seafloor surface itself (2) the macrobenthic life and vegetation thereon, as well as (3) associated sub-surface pattern as indicators for flora and fauna. Hereafter, we term this compound the near seabed domain hosting the macrobenthic facies. We aim to investigate in detail the signal response of opto-acoustic waves to improve remote sensing of specific key environments in the Baltic Sea taking into account spatial geodiversity and the geological base.



Overview of the acoustic and laser remote sensors and habitats to be investigated in ECOMAP. Carrier platforms are ship vessels, in situ monitoring devices on the seabed, and aircrafts.

Finally, a catalogue will be developed in close co-operation with authorities to meet their requirements and will allow stakeholders with different interests to quickly judge which

remote sensing method is ideally suited for respective monitoring tasks of specific habitats.

A comparative analysis of performing and data processing methods of hydro-acoustic surveys in the Baltic Sea

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Baltic international hydro-acoustic survey is the only fisheries independent survey for tuning the assessment of sprat stock in the Baltic Sea. Although this survey is performed since 1970s there are still uncertainties and differences between institutes in performing control trawling during the survey as well as on the interpretation of the data. In frames of BONUS INSPIRE project two experimental hydro-acoustic surveys were carried out. These surveys included performance of daily stations on concentrations of the sprat, execution of control trawling during day and night, separately at different water layers and stepwise trawling. The trawl catches were compared with the acoustic records using different methods. The calculation of the abundance of pelagic fishes has been performed using currently used methodology and with changes that are based on the performed surveys. The comparison of the obtained results is shown.

Length-at-age based calculations of sprat stock structure determined by the hydroacoustic surveys in the Baltic Sea

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Baltic international hydro-acoustic survey is the only fisheries independent survey for tuning the assessment of sprat and herring stocks in the Baltic Sea. Although this survey is performed since 1970s there are still uncertainties and differences between institutes in interpretation of the data. Based on the data taken from historic and recent acoustic survey database created during the BONUS INSPIRE project we elaborated and proposed a method for calculation of size-age structure of the sprat and herring stocks that differs from the currently used method in the Baltic Sea. The main difference of the proposed method is that takes into account the size of the catch in the control trawls calculating the average size-age structure of both stocks per area unit. The paper shows differences in the obtained values for species proportion and size-age structure of both stocks obtained by two methods.

Session 3: Ecosystem internal and external drivers of change affecting biodiversity

Oral presentations

Effects of underwater habitat quality on the top predator Baltic cod and its food web interactions

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Coastal states around the Baltic Sea engage in continued management efforts with the aim to restore underwater habitats and ecosystem health. In this study, we investigated potential effects of nutrient management efforts on the key predator cod (*Gadus morhua*). We use a spatial ecosystem model (Ecospace), forced by a coupled physical-biogeochemical model (RCO-SCOBI), to explore the potential future developments of the fish community under three different nutrient load scenarios: increased (BAU), current (REF) and decreased (BSAP). The distribution range and the center of gravity of cod distribution were similar in the BAU and REF scenarios. However, the model predicted an increased distribution range, as well as a northward shift of the center of gravity, of both adult and juvenile cod, within 20 years from present under BSAP. This suggests an increased spatial overlap between cod and its main fish prey groups, sprat (*Sprattus sprattus*) and herring (*Clupea harengus*), implying potential for stronger top-down control. Our study provides evidence that nutrient load and eutrophication reductions may be effective in decreasing the current predator-prey spatial mismatch and thereby contribute to restoring ecosystem functioning in the Baltic Sea.

Biogeographic changes in fish diversity in the Kattegat-Belt Sea driven by changes in climate and exploitation

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Fish communities are influenced both by climate-hydrographic impacts on habitats and by exploitation of selected species within foodwebs. The response of fish communities to

these impacts are complex and often interactive. In this study, we investigate using demersal survey data how climate variability and exploitation have influenced the dynamics of the fish community (biodiversity and biomass) in the Kattegat, Belt Sea and Øresund during 1994-2013. During this time period, temperatures have increased and overall exploitation levels in most of the region have declined. We found that biodiversity (overall species richness, scaled for sampling effort) of the fish community has increased in spring and fall, and that these increases were partly explained by local sea temperatures. In addition, species richness increased as indicators of fishing effort declined. The increase in species richness is mainly due to an increase in the number and presence of species from southern regions, as detected by examining interannual changes in the biogeographic origins of all species in the fish assemblage. These results show that climate variability and fishing interact to affect the assemblage of fish species in the region, probably by altering number and strength of interactions among species while environmental conditions were becoming warmer.

Dissecting the spatio-temporal dynamics of Baltic fish communities and its relation to environment.

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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 multi-species community dynamics in heavily exploited large marine ecosystems over time and space is difficult and requires specialized multivariate statistical approaches. We here applied STATICO, a mathematical framework that allows the simultaneous analysis of a sequence of paired ecological tables (in our case species abundances and environmental variables). We used this comprehensive approach to investigate the link between the spatio-temporal dynamics of 31 fish species and 13 environmental variables, including hydro-climatic conditions and primary production. The study was performed on information collected by more than 3000 hauls over seven subareas of the Baltic Sea for the period of 2003 to 2014. The fish community is structured along a strong and temporally stable gradient from the South-West to the North-East determined by environmental conditions, specifically salinity, temperature and oxygen content. We found the temporal dynamics of the fish community to be heterogeneous and not significantly linked with the temporal dynamics of the environmental variables. Finally, we identified 4 sub-communities of fish species, favored 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.

Size-dependent prey availability explains salmon (*Salmo salar*) diet and condition at sea

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In aquatic environments, predator-prey interactions are highly size-dependent, which in combination with food-dependent processes govern individual level performance of predators. Still, the combination of size- and food-dependencies is commonly not accounted for in studies of predator-prey interactions in large open systems. Here, we investigate the size-dependency between Baltic salmon and its prey and test whether this dependency affects the diet and performance of salmon. Using extensive stomach content data combined with long-term monitoring data of their main prey species, we derive size-specific prey availability estimates for salmon in different years and parts of the Baltic Sea. The size-specific prey availability estimates explained the diet composition of Baltic salmon better than estimates not accounting for prey or predator body size. Furthermore, we show that individual salmon body condition depends on the size-specific prey availability, especially at low resource levels. Thus, our results emphasize the importance of accounting for size-dependent predator-prey interactions for resolving what governs diet and performance of salmon feeding out at sea. As body condition governs individual survival and reproduction success, we argue that the influence of size-dependent prey availability at sea is important to account for to understand salmon population dynamics and transfer of matter in aquatic food-webs.

The round goby *Neogobius melanostomus* colonisation and potential impact on the coastal food web in Latvia

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The round goby (*Neogobius melanostomus*) is a demersal benthivorous invasive fish species and since introduction via ship ballast water discharge in the early 1990`s it has successfully spread in the coastal waters of the Central Baltic Sea. In Latvian waters, it was first recorded in year 2004 and currently is found in the entire coastal zone and frequently in offshore areas as well. A sharp increase in the population size occurred in the last years. We have selected Latvian coastal site Jurmalciems, characterised with one of the highest densities of round gobies to analyse the abundance the feeding patterns of round goby in different depth zones and habitats in 2015 and 2016. During summer the highest abundance of round goby was observed at rocky and mixed substrate habitats in depths ranging from 5 to 10 meters. The round goby diet was influenced by fish size and habitat. Bivalves *Macoma balthica* and *Mytilus* spp. were identified as the main prey items for round goby in all habitats. Decreasing abundance of bivalves suggests that round goby potentially can exert significant predation pressure and cause structural and functional changes in coastal benthic food webs.

Climate variability of hydrographic conditions of the Baltic Sea and their impact on cod nursery areas

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The Baltic Sea deep waters suffer from extended areas of hypoxia and anoxia. Their intra- and inter-annual variability is mainly determined by saline inflows which transport oxygenated water to deeper layers. During the last decades, oxygen conditions in the Baltic Sea have generally worsened and thus, the extent of hypoxic as well as anoxic bottom water has increased considerably. Climate change may further increase hypoxia due to changes in the atmospheric forcing conditions resulting in less effective Baltic inflows, decreased oxygen solubility and increased respiration rates. A decline in oxygen conditions has generally a negative impact on marine life in the Baltic Sea. Thus, a detailed description of the evolution of oxygenated, hypoxic and anoxic areas is particularly required when studying oxygen-related processes such as habitat utilization of spawning fish, survival rates of their eggs as well as settlement probability of juveniles. The detailed spatial and temporal evolution of the oxygen concentrations in the entire Baltic Sea have been simulated for the period 1979–2016 by utilizing a hydrodynamic Baltic Sea model coupled to a simple pelagic and benthic oxygen consumption model. The model proved to be a useful tool to describe the detailed evolution including trends of oxygenated, hypoxic and anoxic areas in the entire Baltic Sea and their impact on cod nursery areas.

The elemental composition, respiration and ammonium excretion of *Cercopagis pengoi* (Ostroumov, 1891) in the Baltic Sea

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The non-indigenous cladoceran *Cercopagis pengoi* is presently a permanent member of pelagic zooplankton community in the Baltic Sea. Its annual abundance varies mostly due to temperature fluctuations, but it can be considered as one of the key components in the Baltic Sea food webs during summer. We studied the variability in basic elemental characteristics and weight of *C. pengoi* from the Gulf of Bothnia, the Archipelago Sea, the Gulf of Finland and the Baltic Proper. The data covers 5 years of measurements of mature parthenogenetic and gametogenetic females, males and juveniles. The dry to wet weight ratio is high, close to 50%. The carbon content was about twice higher in gametogenetic than in parthenogenetic females, but the C:N –ratios were rather stable, generally between 4 and 5 (w/w). The total lipid content of females varied considerably from relatively low (5%) to high (26%) with one year (2005) having significantly lower total lipid content. We also present data oxygen consumption and apparently high ammonium excretion. The results show considerable differences between life stages and geographic locations. Data can be utilized in evaluating the quality of *C. pengoi* as a food source, and its role in nutrient cycling in the food web.

Phytoplankton functional diversity during spring-summer succession in the Baltic Sea

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The dynamics in plankton biodiversity that are often masked by difficulties in species identification when using light microscopy only can have a different pattern when using the molecular approach. In spring and summer 2012 spatial and temporal variability of cyanobacteria and phytoplankton were analysed from samples taken along cross-section between Estonia and Finland in the Gulf of Finland at 5 m depth. We used massively parallel tag sequencing of 18S rRNA gene V4 region on Illumina MiniSeq platform. Light microscopy was used to perform the phytoplankton sample analysis in a "traditional way" and flow cytometry data was used to determine seasonal changes in abundance of unicellular cyanobacteria (Synechococcus populations). From environmental parameters, changes in temperature, salinity and inorganic nutrient concentration were measured. The aim of the study was to characterise the seasonal succession of plankton (cyanobacteria and phytoplankton) from spring to summer in the changing physicochemical environment and to have deep insight to the overall biodiversity of surface layer phytoplankton in the study area. The used approach also helped us to identify and quantify the members of heterotrophic eukaryotes (very often neglected during phytoplankton analysis) and to follow the changes between autotrophic, heterotrophic and mixotrophic compartments.

The interaction of perch and round goby involves characteristics of physical environment and macrophyte habitat

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The Baltic Sea is impacted by multiple stressors with invasive species currently being responsible for the major reorganization of its coastal ecosystems. Here we model how the novel epibenthic predator, round goby (*Neogobius melanostomus*), has been incorporated into the diet of the native perch (*Perca fluviatilis*). Analyses of stomach content suggested that round goby comprised a large proportion of all prey items. Predation pressure increases with elevated water temperature and visibility. The round goby is mostly preyed by 15–30cm sized perch but other size-classes may also consume large amounts of the novel fish. Macrophytes provide a refuge from predation for the round goby, and in areas with over 60% macroalgae coverage, the round goby was practically not consumed. Surprisingly, the density of round goby only marginally affected the feeding of perch. Overall, the round goby is well incorporated into the coastal food webs of the Baltic Sea and provides a significant source of nutrient for native predatory fish. A lack of density-dependence in the perch-goby interaction suggests that the numbers of round goby are far beyond control by predators, and perch have little role in controlling the density of round goby in Baltic Sea coastal ecosystems.

Uncovering the Past Dynamics of a Collapsed Fish Stock: Gulf of Riga Autumn-Spawning Herring

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Fishery resilience to perturbations is promoted by a diverse assemblage of stocks and species to support fishing yields. Reductions in the diversity of the resource base on which fisheries depend can make fishery-dependent societies more vulnerable to future natural and human-induced perturbations. Here we describe and quantify the loss of the fall spawning component of herring from the Gulf of Riga ecosystem of the Baltic Sea in the 1960s-1970s. The reasons for the decline are unknown and there are no biomass targets that can guide potential recovery actions. We compile and analyse existing fishery and biological data to investigate hypotheses regarding the reason for the decline (e. g., role of overexploitation, changes in productivity) and to derive a new baseline of stock biomass. Our results show that exploitation occurred both on juveniles and adults and was probably too high to ensure long-term sustainability (i. e., F > F-msy). This result is also consistent with simulations of an age – structured population dynamics model representing the stock and forced with exploitation rates similar to the observed historical levels. These findings provide a quantified perspective to the historical dynamics and potential targets for recovery actions.

Estimating the abundance and biomass of round goby in the Baltic Sea

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In recent decades, the invasive round goby has rapidly increased its range and abundance in the Baltic Sea and is becoming an important component of the coastal ecosystem. The species has dramatically intensified benthic predation and at the same time is consumed by many native predatory fish. Therefore, it is important to quantify round goby populations in its current range to assess its role in Baltic Sea ecosystems. Here we tested baited trap, drop video and scuba diving methodologies to evaluate the density of round goby in the NE Baltic Sea. Among the studied methods, scuba diving observations gave the most accurate density estimates. These density estimates were used to model relationships between environmental variables and densities of round goby, and then the established relationships were used to predict densities of round goby in the entire study area. The presence of round goby was largely defined by the physical environment such as exposure to waves, salinity, water depth and sediment type, whereas its abundance and biomass were also a function of the structure of macrophyte habitats. It is likely, however, that round goby biomass has not yet reached the carrying capacity allowed by the environment, and the growth is partly uncoupled from ambient environmental conditions because it reflects the current early stage of invasion.

Integration of the invasive round goby (*Neogobius melanostomus*) into the coastal ecosystem of the western Baltic Sea

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The round goby (*Neogobius melanostomus*) is considered to be one of the most successful piscine invaders in the Baltic Sea. Combining several case studies on habitat preferences, feeding ecology and their appropriateness as prey organism for higher trophic levels we examined the biological and ecological causes and consequences of the establishment of this particular species in the ecosystems of western Baltic coastal waters. Classical stomach content analysis of round goby stomachs sampled in different habitats were conducted and resulted in a quantitative and qualitative species list of preyed organisms. While a direct predation effect on native fish species appears rather unlikely, indirect competition effects cannot be excluded yet and an ontogenetic diet shift was observable. Analysis of predatory fish and cormorant pellets show the importance of round goby as prey for different native predators. In the study area the abundance and size of round goby differed between habitats assuming a preference of more complex habitats.

Food webs, the missing link in investigating biodiversity effects on ecosystem functioning

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Biodiversity is decreasing at an unprecedented rate and it is vital to understand how this change impacts ecosystems and their ability to maintain functioning. A food web topology describes the diversity of species and of their trophic interactions, i.e. who eats whom. We know that species interactions play a crucial role in how species contribute to ecosystem functions. However, little is known about how the food web structure and the functional diversity of species influence each other. Traits constitute a link between food webs and ecosystem processes, as: (i) trophic interactions are only possible when traits of the prey match with traits of the predator; (ii) functional traits influence species contributions to ecosystem functions. We developed a trait web which shows links between traits based on species interactions. This dual food web-trait web approach helps us understand which species are important for the stability of the ecosystem and which of their traits are most likely to influence ecosystem functions. In the Baltic Sea, we investigate how environmental drivers (e.g. environmental gradients) alter the food web structure by removing or allowing interactions (i.e. extinction or invasion) and how these changes may affect the relationship between food webs and ecosystem functions.

Mapping benthic biodiversity using predictive modeling

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Biodiversity is critical for maintaining and stabilizing ecosystem processes in changing environments. There is a need for high resolution biodiversity maps that cover large sea areas in order to address ecological questions related to biodiversity-ecosystem functioning relationships and also to provide data for marine environmental protection and management decisions. Spatial predictive modelling using biodiversity data form sampling points and georeferenced environmental data layers covering the whole study area is a potential way to create biodiversity maps for large spatial extents. Random forest (RF), generalized additive models (GAM) and boosted regression trees (BRT) were used in this study to produce biodiversity maps for the whole Estonian sea area. Different georeferenced environmental raster layers (wave exposure, salinity, temperature etc.) were used as independent variables in the models to predict the spatial distribution of species richness. All three models proved to have high predictive ability. RF and BRT predictions had higher correlations with validation data and lower mean absolute error than those of GAM, but GAM showed less overfitting artifacts compared to RF and BRT based on visual assessment. Depth, wave exposure, temperature and sediments were the most influential abiotic variables in predicting biodiversity.

Eutrophication and oil spills make a quantifiable impact on herring stock dynamics

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The Baltic Sea is one of the world's most stressed sea areas. A major problem is eutrophication caused by excessive nutrient loads. In chorus, potential oil spills pose a threat to the ecosystem. The progression of anthropogenic nutrient enrichment is lengthy and gradual while oil spills are causing rapid changes in the system with varying impact and recovery times. We quantify the impact of eutrophication and key environmental covariates on the population dynamics of the Baltic herring in the Gulf of Finland. Moreover, we analyze the influence of the oil spill from M/T Antonio Gramsci on herring mortality in 1987. Credible quantification of the impacts is achieved by using prior knowledge of herring biology in the Bayesian modeling framework. The Gramsci oil spill caused additional mortality of herring, especially at early life-stages. Currently, the optimal July-August chlorophyll-a concentration for herring reproduction has been exceeded in the Gulf of Finland, suggesting herring recruitment is impaired due to eutrophication. The herring stock was also recruitment overfished, implying that spawning biomass was depleted to a level where the population no longer had the reproductive capacity to replenish itself.

Possible impact of size selective gillnet fishery on the cod stock in the Eastern Baltic Sea

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Since early 1950s in the Baltic Sea traditional cod fishery gear is the trawl. Gillnet fishery of cod in the eastern Baltic strongly developed after the beginning of 1990s when cod stock was the lowest on record. In the Eastern Baltic, the dominating are stony bottoms that are not suitable for trawling and that promoted the gillnet fishery. Over 20 years the gillnet fishery was catching more than 50% of cod landings. Expansion of gillnet fishery also led to situation that cod had no natural refuge areas. However, in recent two years the direct gillnet fishery in Eastern Baltic has strongly decreased. It is widely accepted that passively operated gears preferentially catch bold, aggressive, explorative and active individuals. A few generations under the size selective harvesting may alter life history and behavior. Under the present low stock size in the Baltic these effects may be even more pronounced.
Our main aim is to analyze the gillnet fishery size selective peculiarities in comparison with trawl fishery and evaluate the possible effects on life history trait changes of cod under the present environmental regime.

Effects of diazotrophic cyanobacteria on concurrent plankton communities in the Baltic Sea

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Blooms of cyanobacteria are and will be a recurrent phenomenon in the northern Baltic Sea. Their maximum abundance coincides with the productive period of zooplankton and pelagic fish. Based on experimental studies and analysis of field data, the immediate effects of diazotrophic blooms on other phytoplankton or pelagic grazers vary depending on the target group considered. We used multidecadal monitoring data from one coastal station (Seili; covering the period 1992-2013) and ten open sea stations (1979-2013) in the northern Baltic Sea, to explore the potential effect of diazotrophic cyanobacteria on the non-diazotrophic phytoplankton and on zooplankton. The association of cyanobacteria to phytoplankton evenness and biomass, and zooplankton evenness, mean size, and copepod nauplius:female ratio was analyzed using linear regression. Redundancy analysis was used to reveal possible differences between the effects of diazotrophic and non-diazotrophic cyanobacteria on the plankton communities. Less negative effects than expected were found: an increase in diazotrophic cyanobacterial biomass was connected with an increased class-level evenness and total biomass of the concurrent phytoplankton community, and with a decrease in the mean size of zooplankton, which may be due to a simultaneous increase in the copepod nauplius:female ratio.

Bottom-Up limitation of sprat (*Sprattus sprattus*) in the Bornholm Basin

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During 2002 and 2003 seasonally resolved samples of sprat were taken with pelagic trawls to analyse abundance, stomach contents and length- and age structure. The field sampling was supplemented with laboratory experiments investigating sprat gastric evacuation and metabolic rates, both as a function of temperature and body size. With these data it was possible to calculate seasonal sprat consumption independently with two approaches: from the bioenergetics approach and from the gastric evacuation method. The main finding was a mismatch of the two results, with bioenergetic estimates being substantially higher than the gastric evacuation based estimates. The discrepancy is explained with seasonal migration of sprat out of the basin directly after spawning into areas with better food supply, leading hypothetically to higher stomach contents in these feeding areas. This interpretation could be confirmed with stomach content data from a potential summer feeding area in the Arkona Basin. The conclusion is, that feeding in the Bornholm Basin is insufficient to explain the observed growth of sprat. This study resolves the debate about the most appropriate method for the estimation of sprat consumption rates.

Changes in reproductive life history and resource allocation impacting population dynamics of Baltic cod

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During recent decades, the population dynamics of Eastern Baltic cod has changed with significant alterations in life history parameters. We analysed time trends in cod maturation pattern and nutritional condition in the Bornholm Basin of the Baltic Sea over the last 20 years using Danish research surveys in Subdivision 25 during 1995–2016. Here, we evidenced that size at sexual maturation in Eastern Baltic cod has significantly decreased for both sexes. While it is common that male fishes reach sexual maturation earlier in life than females, the observed trend towards maturation at smaller size is extraordinary. The prominent reduction in size at sexual maturation was histologically validated through sampling during five Danish, German and Polish cruises in 2014-15 distributed over the annual reproductive cycle. Overall, female L50 has changed from 43 to 24cm and for males from 35 to 19cm over the 20 year period. This decline is correlated with reduced nutritional condition and changes in environmental parameters. Earlier maturation and increased reproductive investment is commonly associated with shorter life span, which matches the observed changes in the stock demography with fewer large-sized specimens and decreasing male:female ratio with increasing size. What does this imply for the Baltic Sea ecosystem?

Inter-annual and spatial regulation of an invasive species' (*Cercopagis pengoi*) range expansion: a laboratory and field investigation

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The prediction of regional geographic range expansion requires knowledge on both life-history and ecophysiological properties of a species. Cercopagis pengoi, a predatory zooplankton, was introduced in 1992 and since then spread and now exhibits high variation in abundance and inter-annual occurrence. With the help of laboratory experiments and field investigations spatial and temporal regulation in response to salinity and temperature was investigated in the northern Baltic Sea (2000-2007). C. pengoi was found to have an optimum salinity range between 4.5 and 6. We predict that C. pengoi is unlikely to expand its range to areas in the Baltic Sea region with surface seawater salinity >6, provided other physio-chemical properties remain unchanged. Temporally we found seasonal population development to be limited by inter-annual variation in temperature, occurring once surface seawater temperature was above 16°C over 52 days. Maximum abundances were reached once 65 days and 17.5°C was exceeded. We hypothesize that its inter-annual variation in occurrence and diffuse range expansion front can be explained by its inter-annual life-history strategy interacting in both space and time. The species in the region warrants monitoring with lower detection threshold than present if we wish to detect its response to climate change.

Assessing impact of bottom trawling and hypoxia on seafloor status of the Baltic Sea

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Bottom fishing disturbance and hypoxia have widespread impacts on marine benthic habitats and the structure and function of benthic communities. Quantifying the impact of these regional pressures is required for assessing the state of marine habitats and to understand their cumulative effects (e.g. MSFD D6/D1). Here, we present a quantitative approach to predict effects of fishing disturbance and hypoxia on benthic communities across the Baltic Sea. For both pressures, impact is estimated from the longevity composition of the benthic community and from depletion and recovery rates of benthic biota following these disturbances. The method assesses the relative state of the benthic community (the amount of biomass relative to its carrying capacity) and is calculated for the entire community and for specific functional groups (suspension feeders,

bioturbators). The work provides a mechanistic linkage between both pressures and benthic habitat state and is used to derive an overall prediction of the environmental status of the habitat at the regional scale that can be assessed over time. This can support the development of management plans for setting good environmental status thresholds and to account for the effects of human disturbances to the seafloor.

Session 3, poster presentations

Coastal habitats and their link to the biodiversity of faunal communities

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Coastal ecosystems are productive areas with a high habitat diversity hosting rich faunal communities including fish and invertebrates. The characteristics of these species assemblages such as composition, abundance and their functional diversity, i.e. the composition and richness of different biological traits, provide information on the functioning and services of an ecosystem.
This project focuses on fish and invertebrate communities in different coastal habitats in the Baltic Sea evaluating the link between the organism assemblages themselves, but also between the species communities and their environment. In particular, the impact of fish on the structural and functional biodiversity of invertebrates is investigated taking into account the consequences of this connection for the functioning of the ecosystem. Additionally, the impact of current environmental stressors, such as climate change, eutrophication and the invasion of non-native species, on faunal communities within their habitats is assessed. Coastal ecosystems in the Baltic have shown significant rates of change over recent decades, and further climate change-related alterations are expected for the future. Therefore, understanding the link between organisms and their environment is crucial for predicting consequences for the functioning of coastal ecosystems.

The food web positioning of the non-indigenous round goby in two introduced populations in the Baltic Sea

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The food web positioning of the non-native round goby (*Neogobius melanostomus*, Pallas 1814) was studied in a new invasive population in Mariehamn, Åland Islands (northern Baltic Sea). The trophic position, trophic niche space and ontogenetic changes in the isotopic signatures of the invasive round goby were compared between the new population and an established invasive population in Hel, Gulf of Gdansk (southern Baltic

Sea). The trophic position (TP) was estimated based on stable isotope analysis of carbon (^{13}C:^{12}C) and nitrogen (^{15}N:^{14}N) ratios. Ontogenetic changes in isotope ratios were evaluated with a regression analysis as well as comparison of trophic niche space between small and large round gobies. Interspecific competition with other benthic-feeding fish species was estimated using Bayesian Standard Ellipse analysis. The results show the round goby positioned as a second order consumer among other predatory benthic-feeding fish. The round goby experiences significant intraspecific competition as well as competition with other predatory fish in the new invasive area. The trophic position of round gobies in Mariehamn is significantly higher than in Hel, likely due to different prey items in these areas. Furthermore, the ontogenetic patterns differ between the two invasive populations, suggesting more intraspecific competition in Hel.

Infection rates and prevalence of metazoan parasites of the non-native round goby (*Neogobius melanostomus*) in the Baltic Sea

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Studies in the Baltic Sea have identified over 30 parasite taxa infecting the invasive round goby (Neogobius melanostomus (Pallas, 1814). In this study, we aimed at comparing parasite assemblages and infection rates (prevalence and intensity) in different populations across the invasive range in the Baltic Sea (Denmark, Lithuania, Estonia and Finland). Infection rates were 56–60% across all locations except Lithuania (28%). However, the parasite assemblages in the sampled populations were dissimilar, each location having unique parasites. In addition, many of the parasites were generalists commonly infecting native fish species. Based on the results of this study and those previously conducted in the Baltic Sea, the round goby has not retained parasites from its area of origin, but instead has been successively colonized by native generalist parasites. Although variable, overall parasite richness is still quite low around the Baltic compared to the native areas (34 vs 71 taxa, respectively). Also, prevalence and mean infection intensities in the Baltic Sea are significantly lower than in the native areas. Therefore, the invasion success of the round goby in the Baltic Sea can at least partly be attributed to enemy release, in this case shedding a significant proportion of their native parasite load.

Curionian lagoon fish stocks model: ECOPATH/ECOSIM approach

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The impact of fisheries in the Curonian lagoon is intense. Decrease in commercially important fish stocks and shift in fish community have proven that traditional assessment and management of fish stocks is outdated and incapable to fully evaluate fishing impact

to whole ecosystem, therefore application of ecosystem based fishery management models is necessary. Measure and predict the response of fish stocks to exploitation it is necessary to understand how the direct and indirect effects of fishing interact. We used an ECOPATH with ECOSIM approach to describe the relationship between the main species and overall fishing mortality and to try to understand how fishery affects fish stocks communities and entire ecosystem. ECOPATH model includes key and most important fish species in the Curonian lagoon: six fish species, piscivore birds, bivalve, zoo benthos, phytoplankton, zooplankton and detritus. Because fishing and predation are size-selective processes, we use multi-stanza approach for commercial fish species in the lagoon, splitting each fish species to three different age groups: juveniles, pre-commercial and commercial size. The structure of the model is discussed and mixed trophic impact analysis was undertaken to determine the direct and indirect effects of biomass changes within and between groups in the system, due to effects of fishery.

Parasite infestation of the round goby in two localities in the NE Baltic Sea

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Parasite infestation of the non-indigenous round goby was investigated based on spatially and seasonally replicated sampling in the NE Baltic Sea (Muuga Bay in the Gulf of Finland and Pärnu Bay in the Gulf of Riga) from May to December 2016. These sites represent two different invasion history situations: an established population in Muuga Bay and the beginning of colonisation in Pärnu Bay. Infection rate of the fish was very high in both localities (86% in Pärnu Bay and 95% in Muuga Bay) with in total of 21 parasite taxa identified. 71% of parasite taxa were found to occur in both bays. The eye fluke *Diplostomum spathaceum* showed by far the highest infection and prevalence rates (65% and 6.1, respectively), followed by a group of four species (*Cryptocotyle concavum, Cucullanus heterocrous, Cucullanellus minutus and Pomphorhynchus laevis)* with much lower and broadly similar infestations and prevalence (15-21% and 3.5-4.6, respectively). Infection rate of all other parasites remained below 10%. Our study suggests relatively high local infestation rates, which are independent from invasion history. In addition, the study confirms low prevalence rate, the latter being likely one of the reasons behind the spatial expansion and establishing of vital populations in the newly colonised environments.

Investigation of the relationships between the size and production characteristics of phyto- and zooplankton in the Vistula and Curonian lagoons of the Baltic Sea

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In the study the statistical relationships between the size and production characteristics of phytoplankton and zooplankton of the Vistula and Curonian lagoons, the Baltic Sea,

were investigated. Research phytoplankton and zooplankton within the Russian part of the area of the Vistula and the Curonian lagoon was carried out on the monthly basis within the framework of long-term monitoring program on evaluating of ecological status of the lagoons. It was shown that the size structure of plankton is the basis for understanding of the development of production processes, mechanisms of formation of the plankton species diversity and functioning of the lagoon ecosystems. It was found that the maximum rate of photosynthesis and the integral value of the primary production with a change in cell volume of phytoplankton are changed according to a power law. It is shown that the formation of plankton species diversity in ecosystems of lagoons is closely linked with the size structure of plankton communities and with features of development of the production processes. It is proposed the structure of a spatially homogenous mathematical model of the plankton food chain for the lagoon ecosystems taking into account the size spectrum and the characteristics of phytoplankton and zooplankton.

The role of the invasive Harris mud crab (*Rhithropanopeus harrisii*) in the coastal food web of the Northern Baltic Sea.

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Non-indigenous species are known to induce a variety of changes to the food webs in their new environments. Changes are potentially more pronounced with novel invaders, such as the Harris mud crab (*Rhithropanopeus harrisii*) in the Northern Baltic Sea. Originating from the eastern US, it was first introduced to the southern parts of the Baltic Sea already in late 19th century. In 2009 it was found in the Archipelago Sea, Finland, where it has since established and steadily increased its range and abundance. The area lacks native crab species, providing an excellent opportunity to observe how a novel species establishes into the food web. Based on mesocosm experiments and field studies, the crab has been able to establish and adapt to the local food web: they feed effectively on native prey and have become a prey to native fishes. Results indicate that mud crabs prefer isopod (*Idotea baltica*), a key species in the system as prey. Furthermore, in the field samples gastropods decline in areas where the crab is numerous. Based on fishermen reports and field studies the crabs are prey for several fish (perch, pikeperch, four-horned sculpin, burbot and roach) of which four-horned sculpin appears to be the most effective.

Spatial prediction of demersal fish diversity in the Baltic Sea: comparison of machine learners and regression-based techniques

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Predictive modelling may be applied in marine spatial planning to obtain spatially explicit information about biodiversity patterns. In the presented study we evaluated performance of selected machine learners and regression-based methods which were applied for modelling fish community metrics. We hypothesized, that habitat features can influence fish assemblages structure and investigated effect of environmental gradients on demersal fish diversity (species richness and Shannon-Weaver Index). We used fish data from Baltic International Trawl Surveys (2001-2014) and six potential predictors mapped by HELCOM: bottom salinity, depth, seabed slope, growth season bottom temperature, seabed sediments and annual mean bottom current velocity. Then we compared performance of six alternative modelling approaches: generalized linear models, generalized additive models, multivariate adaptive regression splines, support vector machines, boosted regression trees and random forests with repeated 10-fold cross-validation using accuracy as the measure of models quality. Finally, we selected random forest, as the best performing algorithm, and implemented it for spatial prediction of fish diversity in the broad range of the Baltic Sea. We showed how state-of-the-art predictive techniques, based on easily available data and simple tools of Geographic Information System, can be used to obtain reliable spatial information about fish diversity.

Effect of non-indigenous round goby (Neogobius melanostomus) on the native European flounder (Platichthys flesus) biomass density in the southern Baltic Sea

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Invasive round goby (*Neogobius melanostomus*) may change structure and functioning of native fish communities in the Baltic Sea. The aim of this study was to test effects of round goby occurrence on the biomass densities of the flounder (*Platichthys flesus*). Catch information from the Baltic International Trawl Surveys (years 2003-2017; 1st and 4th quarter) were used with data on first occurrence of round goby, which was interpolated for the study area to simulate effect of this species invasion. Additionally, hydrological conditions measured *in situ* (depth, bottom temperature and salinity) and modelled data (slope of seabed, mean annual current velocity, type of sediments) were incorporated in the generalized additive models (GAMs) developed for each quarter. Year effect and effect of round goby occurrence were added as additional factors. According to obtained predictions flounder biomass was driven mainly by depth. Significant differences ($p<0.001$) were found between hauls conducted before and after simulated first occurrence of round goby, suggesting negative effects of round goby presence on flounder biomass. These results may have importance for ecosystem-based management of the flatfish resources in the Baltic Sea and risk assessments for invasive species.

BONUS BLUEWEBS: Blue growth boundaries in novel Baltic food webs

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Novel food webs, compositionally unlike any found today, are increasingly likely due to climate change and the multiple anthropogenic impacts marine ecosystems face. Not anticipating them will significantly hamper the success of future ecosystem-based management (EBM) and provision of ecosystem services (ESS). BONUS BLUEWEBS will investigate the development and consequences of novel food webs using innovative data analyses such as big data analytics, cutting edge trait-based ecology and ecological network analysis. A 3D coupled physical-biogeochemical modelling system will project large-scale scenarios of changes in external and internal drivers and inform case study models that specifically account for thresholds between different ecosystem states, allowing assessments of the effects of environmental degradation on the capability of food webs to cycle and transform nutrients and hazardous substances. An outstanding characteristic of BONUS BLUEWEBS is the application of modern bio-economic and social science approaches to evaluate the consequences of novel food webs for ESS provision, and inclusion of stakeholders in a transdisciplinary exercise. BONUS BLUEWEBS will directly provide tools for EBM, such as indicators for MSFD descriptors and Bayesian Network based decision support systems. Overall, BLUEWEBS will have as its major outcome an assessment of the consequences of achieving a Good Environmental Status on the capability of Baltic Sea food webs to sustainably produce Blue Growth.

Trophic interactions of invasive round goby (*Neogobius melanostomus*) and Baltic herring eggs

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The round goby (Neogobius melanostomus) is considered to be one of the most successful piscine invaders in the Baltic Sea. Based on stomach content analysis, current studies reveal a negligible direct effect of round goby on native fish species, while spatial and temporal overlap between spawning grounds were largely ignored. Therefore, we conducted a case study on the predatory effect of round goby on native fish eggs combining prey preference experiments from the laboratory with field observations in one of the most prominent spawning areas of the Western Baltic spring spawning herring (Clupea harengus). During the first year we observed a clear spatio-temporal mismatch between round goby and herring egg occurrence in the field. However, the study site was characterized by an extended sandy littoral densely covered with submerged aquatic vegetation. To complete the study, we actually extended our field observations to more rocky areas offering both; optimum habitats for round goby and appropriate spawning substrate for herring. The synthesis of the field and laboratory experiments will give new insights of the trophic interactions of the invasive round goby and Baltic herring eggs.

Session 4: Temporal dynamics in biodiversity

Oral presentations

Long-term changes in the annual reproductive cycle of Eastern Baltic cod in the Gotland Basin

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Ecosystem regime shifts in the Baltic Sea over recent 45 years have resulted in significant fluctuations in cod abundance, population structure and vital rates accompanied by phenological changes and alteration of life history patterns. Although, the environmental conditions of the Gotland Basin during the recent two decades have been less suited for cod, affecting its distribution and reproduction.
Here, we evidence phenological changes and alteration of life history patterns of cod in the Gotland Basin that have appeared since the mid-1990s. Firstly, the spawning time has shifted from March-April towards summer with mature fishes in different maturity stages prevailing in catches from spring to late autumn since 2002. Secondly, size at maturation has steadily declined and the proportion of males in the stock has decreased likely due to the earlier maturation. Furthermore, cod condition significantly deteriorated during this period.
Main factors considered are decrease of growth and biological condition of cod in the Eastern Baltic due to long-term reduction of oxygen in the Gotland deep, warming of water, low benthic food availability and fishery pressure during last two decades.
The study is based on long-term meta-data analyses of physical environment and cod maturity data collected during research surveys from 1974 to 2015.

End-to-end modelling of fish community changes in the Baltic Proper

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The newly developed end-to-end Baltic Atlantis ecosystem model was used to investigate the main dynamics in the Baltic Sea ecosystem. Special focus was put upon the observed significant fluctuations in its fish community structure during the last 30 years. The predominant change in the Baltic Proper was the system shift from piscivorous cod (*Gadus morhua*) to planktivorous sprat (*Sprattus sprattus*) dominance. Previous research indicates cascading effects, probably due to this shift, downwards the foodchain. However, these studies focused only on a few key species and environmental data, as time series data were not available for most other species. Lately, a detailed view on interactions of the Baltic cod and changes in its diet composition was provided by stomach content data covering the last five decades. Results from the Atlantis ecosystem model, including this information, were compared with historical observations. The application of an end-to-end model allowed to investigate related fluctuations of species, difficult to be measured regularly. Hence, with the development of this holistic approach,

such components of the ecosystem can be assessed in relation to environmental or biological fluctuations. This, in turn, is a building stone towards a more effective ecosystem based fisheries management approach for the Baltic Sea.

Spatio-temporal dynamics and behavioural ecology of a "demersal" fish population as detected using acoustic survey pelagic trawl catches: the Eastern Baltic Sea cod (*Gadus morhua*)

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Cod is usually monitored for scientific purposes using bottom trawl surveys, although its pelagic regular occurrence is well documented. Here we analysed, using GAMs, the spatio-temporal changes in the Eastern Baltic cod population based on pelagic catches from an acoustic survey targeting small pelagics and covering 35 years. Our analysis shows that, considering the whole study area, cod catch per unit effort (CPUE, kg h^{-1}) was high in the 1970s-1980s whereas beginning from the early 1990s the CPUE decreased and remained very low thereafter. This pattern was common for the northern areas of the Baltic Sea, whereas in the southernmost area CPUE largely oscillated after the early 1990s. The partial effects of our models, moreover, were able to capture key ecological features of the Baltic cod, such as preferred depth of occurrence and response to hypoxic conditions. The model also revealed a clear daily cycle of CPUEs, which demonstrates the occurrence of diel vertical migrations of cod at the population level. Temporal comparisons with the CPUEs from ordinary bottom trawl surveys were performed. Our results point to the great potential of the acoustic survey trawl catches to investigate the spatio-temporal population dynamics and ecology of the Baltic cod.

Faster or slower: Has growth of juvenile eastern Baltic cod changed?

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In eastern Baltic cod, growth rates and mortality are currently unknown owing to extensive age estimation problems. In this study, temporal patterns of growth and condition in relation to maturation were analysed using "known-age" samples of 15 – 35 cm long cod, where annual growth zones were identified with daily otolith growth patterns and size at previous age back-calculated. Over the years examined (2001, 2004 and 2013), neither growth rates nor somatic condition (Fulton's *K*) changed significantly. By the first winter, juvenile cod had attained a size of 4-10 cm, growing by approximately

10, 8 and 5 cm · year^{-1} over the subsequent years of their life. Immature individuals had throughout all sampling years experienced significantly lower growth rates and were in lower somatic condition at sampling than mature individuals. Growth rate (estimated as growth in length in the year prior to sampling) was significantly related with somatic condition at catch. Overall, it does not appear that neither growth nor condition has changed in the smaller size classes of eastern Baltic cod, but it is important to note that it is not possible to extrapolate these results to the entire size range of the population.

Detecting non-linear and non-stationary effects in marine time-series – methods and some examples

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It is generally accepted, that the effect of external drivers on marine life is usually non-linear, and temporally varying, but there is still very little evidence available on such effects globally. In this talk I will discuss and present some of the methods and possibilities to detect non-linear, non-stationary and additive effects in biological marine time series. I will show the results from three case studies – i) the long-term abundance of *Limnocalanus macrurus* in Gulf of Riga ii) abundance of small-sized copepods in Pärnu Bay, and iii) Gulf of Riga herring recruitment, to demonstrate the merits and limitations of two approaches for detecting the non-linear and dynamic links in marine ecosystems – empirical dynamic modeling, and sliding window correlation analysis.

The past and future habitats of a key benthic animal, *Saduria entomon*, in the Baltic Sea – combined impacts of climate change and nutrient loading scenarios.

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The isopod, *Saduria entomon*, is a glacial relict species and plays an important role in benthic foodwebs in the Baltic Sea, both as a prey for higher trophic level species such as cod, and as a predator of other benthic animals. Its spatial distribution and abundance has been measured frequently as part of ecosystem monitoring programmes and dedicated studies of Baltic Sea food webs and benthos. However the environmental factors that control its large-scale spatial distribution in the Baltic Sea have not been quantified. As a result it is presently unclear how environmental perturbations such as climate change might affect the habitat and food web role of this species in future. Here we construct new habitat distribution (realized niche) models for this species in the Baltic Sea and estimate the relative importance of different variables that affects its spatial distribution. We then use regionally-downscaled coupled climate-ocean biogeochemistry models to investigate

the combined impacts of future climate change and nutrient loading scenarios on its spatial distribution. Results showing the changes in distribution under different combinations of climate change and nutrient loading scenarios will be presented and interpreted in context of *S. entomon*'s role in the food web.

Phytoplankton community trends in cross-ecosystem comparison.

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Phytoplankton has a central role in the nutrient and carbon cycling, and biogeochemistry of the oceans. Yet cross-ecosystem comparisons are rare due to the scattered nature of regional data sets. In the Baltic Sea environmental monitoring reveals long term changes in phytoplankton community structure, species richness, and ecosystem functions. The diversity patterns indicate that the phytoplankton community in the Baltic Sea is not in a steady state. This contrasts with some other intensively studies coastal ecosystems of the world ocean, like the Chesapeake Bay and the San-Francisco Bay.
A cross-ecosystem comparison suggests that the global microbial species pool of the world ocean does not have instantaneously access to the Baltic Sea. However, the dispersal limitation is gradually eroded by the current environmental changes. This causes an ongoing invasion, which exceeds the local extinctions, leading to changes in species richness and related ecosystem functions.

Has climate change affected the body condition of Baltic cod *Gadus morhua* L. in the eastern Baltic Sea?

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Cod in the Baltic Sea live in an estuarine environment whose variable salinity and oxygen conditions, dependent on the intermittent water inflows from the North Sea, impose physiological stresses to the marine organisms. The body condition of cod during the past twenty years has significantly decreased with implication for reproductive potential, growth and also fisheries. Changes in fish condition might also influence natural mortality and thus provide insight on the fish general health over time. The reduced frequency of water inflows from the North Sea increased euthrophication symptoms and resulted in

increased extension of hypoxic areas. This consequently influenced the availability of cod benthic food resources.
Data from Latvian, Lithuanian and Russian ecosystem monitoring indicate that the decrease in the condition of cod during last decades coincided with a period of stagnation development in the Baltic Sea. Here we analysed the changes in Baltic cod condition in the Eastern Baltic Sea (Gdansk and Gotland Basins) over the past 40 years in relation to the local oceanography, density dependence, and abundance of the main pelagic and demersal prey. The analyses were supported by stomach content data sampled in the same areas and time period.

Benthic ecosystem dynamics in the coastal parts of the Baltic Sea

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A detailed ecological model study in the Gulf of Riga and Pommeranian Bay has been undertaken aiming at reconstructing the food web dynamics in two coastal ecosystems between 1970 and 2007 using coupled high-resolution bio-geochemical and ecosystem models. The model complex covered all major biological components and ecosystem indicators of benthic food web including predators. By examining coupled spatio-temporal trends in nutrient loads and modelled phytoplankton growth, bivalve biomass and waterbird abundance we examine quantify changes in the coastal ecosystems driven by reduction in the load of nutrients supplied to coastal areas since 1990. Based on the patchiness observed in both areas we identify small-scale spatial gradients in the response of ecosystem components to the reduced nutrient supply. Corresponding spatio-temporal trends in weekly biomass estimates of three phytoplankton groups and two bivalve species (*Macoma baltica* and *Mytilus edulis*), as well as trends in energetics of bivalve-feeding waterbirds were analysed. Periods showing similar trends were analysed separately in order to identify parallel changes in nutrient loads, phytoplankton, bivalve biomass and waterbird fitness. Trend analysis of spatially discrete zones revealed considerable covariance between the analysed groups of ecosystem indicators indicating fine-scale and heterogeneous responses to recent reductions in nutrient supply.

40yrs of functional change in Baltic Sea coastal macrofauna and fish

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Broadening our understanding of temporal biodiversity changes from taxonomical assessments on single trophic levels to functional multitrophic analysis is key for implementing appropriate management measures. We explored long-term (1971-2013) patterns in functional trait structure of fish and macrofauna in three coastal areas located

in Kattegat, Baltic Proper and Bothnian Sea. Using trait information on six traits related to habitat, life history, diet and behaviour, we assessed functional trait development and timing of potential shifts with three functional diversity indices as well as trait composition over time. To quantify temporal dynamics, we assessed trait turnover, accumulation as well as rate and direction of community change in each area. Functional indices and composition showed gradual changes over time rather than abrupt shifts, pinpointing 1980s and late 2000s as periods of change. Interestingly, taxonomical changes were not always manifested functionally. Compositional changes in trophic groups paralleled each other, e.g. demersal fish benthivores co-increased with macrofaunal epibenthic scavengers, although areas showed contrasting trends. Rate of change was higher for macrofauna than fish, and in Kattegat compared to the other areas. Results highlight discrepancy in type of change between coast and open sea and importance of multiple measures across trophic levels for understanding functional dynamics.

Potential habitat change in the Baltic Sea – implications of climate change and nutrient-load scenarios on the future marine environment

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An investigation of the combined impacts of future climate change and nutrient load on benthic and pelagic habitats for organisms in different parts of the Baltic Sea by the end of the 21st century has been performed, with a specific focus on the cod reproductive volume. This was done by utilizing a three- dimensional coupled physical-biogeochemical ocean model. The results suggest fresher and warmer water masses by the end of the 21st century and two out of three socio-economic scenarios point towards lower oxygen concentrations. These changes can drastically affect the ability of marine species to survive and reproduce in a future Baltic Sea, as illustrated by the results for cod reproductive habitat, whose volume decreased in all three socio-economic scenarios by the end of 21st century. Estimations of the future development of two HELCOM eutrophication core indicators show that in two out of three socio- economic scenarios there are possibilities of a development towards an even more eutrophic Baltic Sea than at present. However, implementing the nutrient load mitigation scheme of the BSAP appears to improve the environment with lower concentrations of *Chl* a in the surface water in several basins and decreased oxygen debt, also in a changed climate.

Session 4, poster presentations

Inter-annual and spatial variability in the abundance and distribution of a benthic trophic connector species, *Saduria entomon*, in the Baltic Sea

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The isopod *Saduria entomon* has a key functional role in Baltic food webs because it is both a predator of other benthic animals and is a prey for higher trophic level species including cod *Gadus morhua*. *S. entomon* is relatively widely distributed and common in large areas of the Baltic Sea. Consequently, it has an important connective role in Baltic food webs because it mediates the flow of carbon and energy from primarily detritivores, scavengers and smaller predators in the benthos back into higher, larger-sized trophic levels where it can contribute to increased production of biomass. Knowledge of the magnitude of variations in its abundance and spatial distribution over time is therefore needed in order to understand and predict how food webs might react when *S. entomon* abundance changes. We have compiled a large database of abundance and distributional data from monitoring and dedicated field studies to estimate the time-space variations at inter- annual and regional scales. The results help define new baselines of abundance and range that can be used in Baltic food web models, and compared with impacts of future climate and nutrient loading changes.

Session 5: Ecosystem-based adaptive management in the context of new understanding in spatio-temporal heterogeneity

Oral presentations

Towards ecosystem-based adaptive maritime spatial planning in the Gulf of Finland (Baltic Sea)

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The EU Maritime Spatial Planning (MSP) Directive establishes a framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The marine environment is heavily impacted by human activities especially in intensively used sea areas such as the Baltic Sea where the assessments of environmental vulnerabilities and cumulative risks are increasingly demanded in environmental

decision and policymaking. The Gulf of Finland marine environmental vulnerability profile as a spatial data layer that incorporates the distribution of nature values and their sensitivities to disturbances is developed by the INTERREG CB Plan4Blue project. The HELCOM Baltic Sea Pressure Index as a measure of cumulative spatial human pressures and the Gulf of Finland marine environmental vulnerability profile are used to identify the likelihood and magnitude of potential environmental effects under multiple human pressures and to develop the Gulf of Finland marine environmental cumulative risk profile to be used in the ecosystem-based adaptive MSP processes in Estonia and Finland. The advanced Bow-tie analysis conceptual framework is used to evaluate the appropriate risk management options for achieving ecosystem objectives within MSP context.

Health benefit-risk assessment of human consumption of Baltic salmon and herring in four Baltic Sea countries

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Baltic Sea is a significant basin for dioxins and PCBs that are persistent and bioaccumulative environmental toxins affecting development, reproduction and immune functions. Consequently dioxin levels are high in aged herring and other fatty Baltic fish. Overall dioxin intake by citizens of Baltic Sea countries has decreased because dioxin levels in Baltic fish as well as their consumption have decreased, although variations still exist between population groups. Health benefits and risks caused by eating Baltic herring and salmon in four Baltic Sea countries (Denmark, Estonia, Finland and Sweden) were studied as part of the BONUS project GOHERR. The purpose was to evaluate the level of health risks due to dioxin exposure and health benefits due to intake of omega-3 fatty acids and vitamin D. An open access on-line model utilizing probabilistic and Bayesian methodologies was developed. Modelling results indicate that health risks and benefits caused by human consumption of Baltic salmon and herring varies between the four countries. Health risks are higher in Finland and Sweden, and lowest in Denmark. In Estonia consumption of Baltic herring is the highest, but the consumed fish is mainly small herring with lower levels of dioxins. Overall, benefits outweigh risks in all countries studied.

No-take areas to strengthen fish populations and recover ecosystem functions

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No-take areas, where no fishing is allowed, are often promoted as a tool for ecosystem-based management, but experience from the Baltic Sea region is scarce. We present results from a recent evaluation of the ecological effects of Swedish no-take areas, targeting fish species with different life histories from both coastal and offshore areas. The areas evaluated varied in size, and together corresponded to two thirds of the total areal extent of no-take zones in Europe. The results showed that the abundance and body size of targeted species increased in most of the no-take areas, causing an increase in the overall reproduction potential of the populations. Where evaluated, effects on fish

communities and benthic fauna were also observed, probably due to both direct effects of excluding fisheries on target and bycatch species, and indirect effects of increases in large predatory fish, re-establishing important ecosystem functions. It is concluded that no-take areas can be an important tool for management, especially of mixed fisheries and fisheries on local coastal fish populations, as well as for counteracting adverse ecosystem effects of fishing. Marine protected areas where the protection of both fish and their habitats is combined may be an important instrument for ecosystem-based management.

Title: Do spatio-temporal spawning closures promote the recovery of cod in the Baltic Sea?

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Spatio-temporal measures such as closed areas and seasons are frequently applied in fisheries and ecosystem management, with a wider aim of preserving biodiversity and meeting various nature conservation objectives. Spawning closures usually have a more specific focus of protecting spawning fish of a specific stock or a group of species. Although the general aim of spawning closures is recognized as being related to improving the stock status, it is not always clear through which mechanism is this expected to be achieved. Knowledge of spatio-temporal scale and variability of the biological processes affecting the organisms of concern is essentially important in this respect, to ensure an appropriate design of the spatio-temporal management measures implemented. In this study, we review the evidence for biological effects of the established spawning closures for eastern and western Baltic cod. This includes synthesizing available knowledge of spatio-temporal heterogeneity in distribution of spawning activities and survival of early life stages, as well as the effects of closures on population structure and overall fishing pressure. The example of Baltic cod is used to outline data, monitoring and knowledge requirements for an adequate implementation and evaluation of spatio-temporal management measures such as spawning closures, in future.

The potential use of mussel farms in German coastal waters as an option to improve water quality

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Many German coastal waters like Szczecin (Oder) Lagoon or Bay of Greifswald are strongly used, heavily polluted by nutrients and at the same time a crucial supplier of ecosystem services. Although, nutrient loads have been decreased over the last decade,

water quality of most coastal waters remained bad characterized by low macrophytes coverage and secchi depth caused by high phytoplankton densities and strong resuspension of sediments. Hence the Good Environmental Status claimed by EU`s Water Framework Directive will not be achieved in most coastal waters. Introducing mussel farming techniques is seen as an option to reduce the phytoplankton densities and to improve water transparency, e.g. in Kiel Bay a first farm using *Mytilus edulis* is running. Unfortunately, most German coastal waters have only low salinities causing a limited growth of *Mytilus* spp. or make it even impossible – like in Szczecin Lagoon, where an alternative species like *Dreissena polymorpha* could be used. Knowing central parameters like filtration rates or the release of dissolved nutrients from field experiments, allowed us to include mussel farms in our ecosystem models, which were then used to calculate different scenarios ranging from a very local scale to a full coverage of the German part of Szczecin Lagoon to estimate possible impacts on water quality but also on selected ecosystem services.

The method for estimating MSY reference points incorporating density dependence in growth and predation mortality

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The method is based on the long-term deterministic and stochastic simulations including selected determinants of fish growth and predation mortality in the estimation of equilibrium yield, biomass, and MSY reference points. The resultant model is a relatively simple tool that allows for streamlined analyses of problems typically approached using complex multispecies models. It was used to estimate MSY parameters (i.e., MSY and F_{MSY}) for the Baltic Sea sprat in relation to pressure from cod predation and taking into account the influence of density dependence on sprat growth and predation mortality.
The analysis indicates that estimates of the F_{MSY} and equilibrium yield and biomass differ markedly between approaches in which growth and predation mortality are constant, and those that allow for density-dependence in these variables. For sprat the results showed that omitting density-dependent growth, when it exists, leads to underestimation of F_{MSY} and MSY, whereas not taking into account the density-dependent predation mortality can caused overestimation of F_{MSY} and MSY.

Bioaccumulation of dioxin in Baltic Sea fish under contrasting harvesting regimes: integrating from individual physiology to size-dependent species interactions

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High levels of dioxins in Baltic Sea fish is of great concern. The concentrations of dioxin differ between areas in the Baltic Sea, with the highest concentrations in herring and salmon from the Bothnian Sea. These regional differences may be linked not only to variation in concentrations in sediments, but also to variation in herring growth rates, with dioxin level being strongly correlated with both age and size of herring. Still, the

combination of size-dependent interactions and food-dependent body growth has been overlooked in studies trying to link prey selection to dioxin content in fish. Here we develop a size-structured population model, explicitly taking size- and food-dependencies into account, to simulate dioxin content in Baltic herring. We specifically study implications of varying the intensity and size-selectivity in herring trawl fisheries for herring body growth, and for herring and salmon bioaccumulation of dioxins in the Bothnian Sea. We evaluate the effect of these management actions under alternative scenarios of nutrient load reductions and of reduced dioxin in lower trophic levels. We show how accounting for the size-dependency between salmon, herring and their prey has great potential to increase our understanding of how dioxin is transferred up the food web to fish.

Socio-cultural values as a dimension of fisheries management: the cases of Baltic salmon and herring

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The way fish resources are utilised and managed reflects the socio-cultural values associated with the fish. Different values may, however, be represented in an unbalanced way in current fisheries management systems, thereby potentially reducing the legitimacy of management schemes. We suggest that addressing the whole range of values in policy processes could reinforce the knowledge base of management, facilitate trade-offs between objectives, and enhance successful implementation of decisions. We analysed values that stakeholders in Finland and Estonia associate with Baltic salmon and herring, based on interviews. In the case of salmon, fair management, species conservation, and recreational values were often emphasized both in Finland and Estonia. The Finns also highlighted the economic importance of salmon for the coastal fishery and fishing tourism, traditions, and symbolic values. Efficient and sustainable use of the herring resource and its economic value were regarded important in both countries. In Finland also environmental values relating to herring fishing, and in Estonia traditions were emphasised. The analysis demonstrates the multivalued nature of fish resources. The next steps will be to reflect how these values materialize in management, and to discuss how they could be systematically engaged in policy processes and how this might influence management performance.

Disentangling environmental and trophic volatility for a fishery in flux: Non-Stationary modeling of the Baltic Sea system

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Fishery management has historically focused on population elasticity of target fish based primarily on demographic modeling with the key assumptions of stability in environmental conditions and static trophic relationships. The predictive capacity of this fishery framework is poor especially in closed systems where the benthic and boundary effects are important. Here we present a probabilistic model that couples key fish populations to a complex suite of trophic, environmental and geomorphological factors. Using 41 years of observations we model the changes in Baltic Cod, Herring and Sprat (*Gadus morhua*, *Clupea harengus* & *Sprattus sprattus balticus*. respectively) for the Baltic Sea within a Bayesian Belief Network. The model predictions are spatially explicit and show the transfer of the central Baltic Sea from Cod to Sprat dominated ecology during the 41 years. This also highlights that the 2004 to 2014 years deviate in the typical Cod-Environment relationship with environmental factors being less influential on Cod population abundances than in previous periods. Indications are that a decoupling of the Baltic Cod growth from environmental conditions which, combined with a trophic alteration in the prime fish growth regions, resulted in a regime shift to Sprat dominated environments in the central Baltic Sea. Fisheries management that is able to accommodate shifting ecological and environmental conditions relevant to habitats will be more effective and realistic. In particular each homogeneous habitat region has a specific ecology that is relevant to understanding the fish population behavior.

The impact of material and institutional infrastructures on sustainable maintenance practice – exploring the case of leisure boat maintenance practices in the Baltic Sea

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This paper seeks to illustrate the role of infrastructure in shaping sustainable consumer practices by exploring the case of leisure boat maintenance. Boat maintenance practices contribute to polluting the marine environment as hazardous substances like copper and zinc from antifouling paints are released when boaters maintain their boat, such as scraping the boat hull. Existing guidelines and regulations regarding boat maintenance vary between countries as well as their enforcement. To describe how infrastructure shapes boat maintenance practices in a sustainable or unsustainable way we conducted case studies of five different boatyards around Baltic Sea. On the one hand material infrastructures such as wash water collection and recycling areas were studied. On the other hand we also explored institutional infrastructures, such as rules and regulations on boatyards as well as their enforcement through different institutions like municipalities or police.
Our findings show that a relationship exists between infrastructure and sustainable boat maintenance practices. In order to keep the Baltic Sea an attractive area for tourism, the

material and institutional infrastructures in marinas all over the Baltic Sea must be improved to reduce the pollution from boat maintenance practices.

Safeguarding adaptive potential of Baltic Sea marine biodiversity: ways forward to address identified shortcomings in MPA governance

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Genetic biodiversity provides key equipment for species' adaptation and for ecosystem resilience in rapidly changing environments such as the Baltic Sea. In a three-stage rocket approach we first explored concerns regarding genetic variation in international and national biodiversity policies and evaluated if and how such policy is put into practice in management plans governing Baltic Marine Protected Areas (MPAs). We found that international and national policies express goals for conserving genetic biodiversity but these goals are not reflected in MPA management plans. Second, in-depth interviews with Baltic Sea managers confirmed that genetic biodiversity is largely ignored in MPA management. Reasons for this include lack of knowledge and the managers' own policy beliefs. Our third stage included assessing the impact on managers´ policy beliefs of communicating knowledge on genetic biodiversity to managers through lectures/discussions. We documented a significant impact on the managers' policy beliefs but monitoring the effect after a three month period showed that the impact is perishable. We provide recommendations for how to improve meeting internationally policy goals for Baltic Sea genetic diversity building on input from managers. Increased knowledge-transfer between managers and researchers is a key aspect; ongoing efforts within the BONUS BAMBI project are presented.

Optimizing environment, safety and business – a planning tool for sustainable development of small ports

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Water tourism is highly dependent on recreational ecosystem services, making a healthy ecosystem and clean environment an important objective to small port business as well. If the port and boating activities are not carried out in a sustainable manner, the resort will soon lose its attractiveness, which leads to loss of visitors. On the other hand the visitors also appreciate good service and safety levels of the port. A novel planning tool to support the sustainable development of the water tourism is under construction in the Central Baltic Interreg project 30MILES. The tool is based on a decision model, where the sustainability is measured through the aspects of environment, safety and financial profitability. We collect and compile information concerning preferences of divergent client groups, costs of alternative investments in the ports, feasibility of investments in different ports, and the level and types of environmental pressures caused by the

business. Based on this data, an optimization model is built and used for the planning of future investments. As a method we use Bayesian networks, which are visual and transparent analytic tools, where divergent uncertainties as well as the variability in the clients' answers can be taken into account and further analyzed.

Sustainable Development of the Recreational Ports in the Eastern Gulf of Finland from the Stakeholders' Perspective

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Recreational boating is an important cultural ecosystem service, gaining more and more popularity in the Gulf of Finland. Its attractiveness being highly dependent on the healthy ecosystem, it is significant to pay attention to the sustainability of the related activities, such as the port business. In this paper, we study how stakeholders communicate and think about the concept of sustainability in the context of recreational boating, especially the development of recreational ports. Involving stakeholders in the decision making is important to utilize the ecosystem services in a sustainable and justice way. Based on interviews and following content analysis, concept maps were created and compared between two groups: boaters and port actors. The concept of sustainable development is theoretically seen to consist of three main pillars: environmental, economic and social perspectives, which should be acknowledged in a balanced manner. According to our results, stakeholders agree on the existence and importance of these three pillars, but they often emphasize one over the others. Many port actors stress the importance of sustainable economy and especially boaters seem to underline the safety. Environment is also seen to be important and to protect it the importance of increasing the environmental consciousness is emphasized too.

After the Baltic Sea regime shift – spatial differences and stable states

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Regime shifts are ubiquitous in the world´s marine ecosystems. The often sudden and catastrophic transitions have strongly altered the services these ecosystems provide to humanity, especially when it comes to fisheries. Internal mechanisms and external drivers are generally well investigated, however, whether post-shift configurations are stable is less investigated. The Central Baltic Sea displayed a prime example of an ecosystem regime shift with the collapse of the Eastern Baltic cod stock and subsequent trophic cascasding. However, the stability of the new system state in space and time is unclear yet. Here we investigate the post-shift ecosystem dynamics in the Central Baltic Sea separately for the Bornholm and Gotland Basins. Indicators of ecosystem states were derived by Principal Component Analysis and Boosted Regression Trees were used to evaluate the importance of abiotic drivers. We furthermore applied Stochastic Cusp Modelling developed from catastrophy theory to separate discontinuous from linear

ecosystem changes. Our results show limited evidence of a recovery of Baltic ecosystems to historical configurations but major spatial separation due to the proliferation of hypoxic and anoxic areas. We eventually discuss the importance of post-shift dynamics for fisheries management, especially the recovery of the Eastern Baltic cod stock.

Food limitation and growth potential of a heavily exploited marine fish predator under environmental change – are all places the same?

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Understanding long-term changes in the spatial distribution of trophic interactions under environmental change is crucial in ecosystem ecology. Spatial differences in the structuring impacts of predators might well result in spatially varying system stability. Furthermore, spatially differentiated predation pressure is probably not adequately described by large-scale averaging. Massive environmental changes have occurred in the Baltic Sea during the past 40 years. These changes were followed by decreased benthic productivity and large variations in the population abundances of Atlantic cod (*Gadus morhua* L.) and sprat (*Sprattus sprattus* L.). Sprat is the main fish prey for cod and also an exploited fish population. Locally, the observed environmental and population changes differed in timing and amplitude. Focusing on the three major basins of the Baltic Proper, five decades of stomach content data allowed detailed insight into long-term changes in diet composition and energy uptake of cod separately for the Bornholm Basin, the Gdansk Deep and the Gotland Basin. We estimated prey-specific energy consumption rates and trends in feeding level and compared them together with the cod diet composition between the basins. While cod consumption rates decreased, with few exceptions, equally between basins, cod compensated differently for the decrease in benthic food availability and hence caused spatial differences in their structuring impact on the ecosystem.

Baltic Sea herring for food: Shades of grey in how backcasting recommendations work across exploratory scenarios

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Scenario methods can be useful to create alternative strategies to enhance sustainability of social-ecological systems. However, the methods often explore futures without normative dimension, or develop normative recommendations without considering whether such recommendations work across different futures. Therefore, there is a need to combine different scenario methodologies. We will do this in the context of Baltic

herring fisheries, which provide significant potential for sustainable food production. The objective of this paper is to combine exploratory scenarios and normative backcasting scenarios to identify recommendations on how to increase the use of Baltic herring as food and to assess how these normative recommendations work under four plausible futures. The empirical value is to explore how the use of sustainable protein sources, such as Baltic herring, can be increased having positive environmental and health impacts. The theoretical value is to advance the integration of exploratory and backcasting scenarios and to identify assumptions on "HOW" specific recommendations work across alternative futures instead of simply assessing "WHETHER" they work or not in different exploratory scenarios. We conclude that combining and further developing scenario methodologies is needed to better understand what kind of social-ecological contexts are plausible and how to cope with future changes.

Central Baltic herring: does the assessment of combined stock complex describe adequately the trends in its components?

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The local stocks of Baltic herring (*Clupea harengus* L.) show remarkable geographical variability in morphology and other characteristics. In order to advice the Total Allowable Catch (TAC), most of the open sea stocks were combined into one single Central Baltic Herring (CBH) stock in 1990 and assessed together in the management process since then.

Our study introduces the results from separate exploratory assessments of herring in three assessment units within CBH: the Gulf of Finland herring (ICES Sub-division 32), herring in the SD29 & 32 and in SD 28.2, 29 &32. The results indicate that the fishing mortality can be significantly higher and relative stock biomass lower in local stocks compared to values from the assessment of combined stock. Though the re-implementation of local assessment and management units on permanent status may not be feasible, at least occasional assessment exercises with the local stocks may give valuable information on the whole Central Baltic herring stock complex.

The Baltic Sea: a time machine for the future coastal ocean

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Protecting the ecological integrity of marine waters is a prime objective that has recently been explicitly acknowledged by the United Nations with the sustainable development goal SDG14, but that is challenged by the mounting pressures on marine systems. We here argue that the Baltic Sea can serve as marine time machine to study the causes and consequences of major environmental perturbations, but also the successful implementation of management via an international governance system. Specifically, many perturbations have already reached levels in the Baltic predicted for the future elsewhere, with consequences including fish stock collapses, increased algal blooms, and the expansion of oxygen-minimum zones. To mitigate these alarming trends, environmental management via international treaties of the Baltic Sea region started relatively early. Here, we highlight failures and successes of science-based management in a coastal sea that has been intensely studied since the early 1900s, and discuss possible lessons for future global coastal areas. For several regionally manageable perturbations we find measurable improvements, in particular the return of top-predators and the reduction of nutrient inputs and harmful substances. At the same time notable problems arise from the inertia of the ecosystem to react to improvements, the complex interaction of pressures, and the management of perturbations when significant economic trade-offs come into play.

Evaluating Baltic Sea fisheries governance in the context of open policy practice

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Open policy practice (OPP) is a decision support method that is based on open co-creation of materials describing scientific evidence and stakeholder values related to a given policy. In the BONUS GOHERR project, we assess the current Baltic Sea fisheries and environmental management procedures using the normative principles of OPP as criteria. Three main principles of OPP are openness (of information and participation), criticism (based on scientific evidence, local experience-based knowledge or stakeholder values), and shared information objects (permanent, structured online pages for managing, updating, and distributing information).
The current regional governance structures fulfil these principles poorly, and there are organizational reasons for this. Information flows through closed channels (e.g. email) between groups that have narrow tasks such as to recommend or determine total allowable catch. Stakeholders are heard, but there is no standardized procedure to incorporate emerging critique. With current structures, it would be difficult to achieve integrated governance between e.g. species or sectors based on shared information base. During the latter part of the project, we will apply OPP principles in a stakeholder meeting about Baltic Sea fisheries and environmental governance and collect feedback about what hindrances participants see in their implementation in actual policy-making.

Monitoring biofouling on settlement panels in the Baltic Sea – a management tool for reducing impact of toxic antifouling practice?

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Biofouling is a major problem for leisure boating worldwide, causing increased costs for fuel and maintenance and affecting maneuverability of vessels. Some 3 million leisure boats use the coastal areas of the Baltic Sea for recreational boating. A great majority of these boats use toxic paints, predominantly containing copper and zinc oxide to prevent fouling. However, these paints release biocides into the shallow coastal ecosystems leading to negative impact on non-target organisms. Although the Baltic Sea is classified as a particularly sensitive sea area (PSSA) under the IMO, regulations concerning the use of antifouling paints differ dramatically between countries bordering the Baltic Sea, despite of similar environmental conditions. This highlights the need for better information about sustainable antifouling methods, to harmonize regulations between countries and reduce the negative impact of unsustainable antifouling practices. In the Bonus CHANGE project we have collected data on natural fouling pressure throughout the Baltic Sea area during four consecutive boating seasons (2013-2016). Furthermore, we

have evaluated performance of five different commercial antifouling paints with variable copper content. Our studies show that paints containing low concentrations of copper, i.e., (7-8% (w/w)), are highly effective against fouling in most parts of the region, spanning from the Kattegat to the northern Baltic, and that several paints are efficient during two seasons without re-painting. Monitoring programs using field panels is a convincing tool to support policy recommendations and adaptive management strategies towards more sustainable and environmentally friendly antifouling practices in the Baltic Sea.

Session 5, poster presentations

Human consumption of Baltic salmon and herring in four Baltic Sea countries

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As part of the BONUS project GOHERR a consumer survey was done in Denmark, Finland, Estonia and Sweden on October 2016. The purpose of the questionnaire was to investigate how Baltic herring and salmon are used as human food in Baltic Sea countries and which determinants affect people's eating habits of these fish species. Around 500 answers were collected in each country with an internet panel organized by a professional survey company Taloustutkimus Oy. Based on the survey data, modelled average consumption in the study population for Baltic salmon varied from 0.6 g/day (Finland) to 2.9 g/day (Denmark) and for Baltic herring from 2.5 g/day (Denmark) to 7.1 g/day (Estonia). In addition analysis of the survey data indicates that Baltic salmon is eaten because it tastes good and is considered healthy, except in Sweden, but the availability and price limits the consumption of it. Baltic herring is eaten because it tastes good; in Denmark herring is also considered to be healthy. Less chemicals and better availability would increase consumption of Baltic herring. Survey results show clear differences in the consumed amount of Baltic salmon and herring between these four countries and between age and gender groups within the countries.

Different nursery habitat requirements of two nearby cod populations – implications for management

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The cod stocks of the Baltic Sea and the Kattegat are in a precarious state, and measures beyond fisheries restrictions need to be considered for improving stock status. Since fish in their juvenile stages are often critically dependent on specific habitat types, one such action may be to protect or restore nursery habitats. Efficient protection, however, requires good knowledge of the spatial distribution of these essential fish habitats. To characterize and map the nursery habitats of Baltic Sea and Kattegat cod populations, statistical modelling based on field surveys of juvenile cod were conducted. The field surveys were performed using multimesh gillnets in the Baltic Sea and fyke nets in the Kattegat, covering the major environmental gradients of the areas. In the statistical GAM

models, the abundance of juvenile cod was explained by variables relating mainly to bathymetry and hydrography. The results of the models revealed striking differences in the habitat choice of juvenile cod in the Baltic Sea compared to Kattegat. These divergences suggest that the threats to cod nursery habitats differ between the stocks, which has implications for their protection. The results demonstrate the importance of detailed knowledge on essential fish habitats for ecosystem-based management and spatial planning.

Application of Cooperating Smart Spaces technology for efficient collaboration in oil spill response management (Gulf of Finland, Baltic Sea)

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In general, the concept of Cooperating Smart Spaces (CSSs) has been introduced to extend pervasive systems beyond the individual to dynamic communities of users and to enable the merging of pervasive and social computing. The oil spill response management is seen as a highly relevant application domain where the CSSs technology can support the rapid and accurate collection of data, Common Situational Awareness, individual guidance and the efficient decision-making. This paper outlines the CSSs concept based structure and functionalities of the New Generation SmartResponse Web (NG SRW) under development by the BONUS STORMWINDS project and discusses the applicability and potential of NG SRW in the oil spill response management realm. NG-SRW as an online information management and exchange platform provides operational access to web services related to Accident Damage and Spill Assessment Model (ADSAM), Post-Accident Ship Condition Assessment Model (PASCAM), and the spilled oil drift model (Seatrack Web). Operational environmental risk assessment is based on the Regional Environmental Sensitivity Index (RESI) web services: a) shoreline classification, ranked according to sensitivity, natural persistence of oil, and ease of clean-up, b) biological resources sensitive to oil spills – environmental vulnerability profile, and c) human-use resources (beaches, parks, marine protected areas, historic/cultural sites).

Integrated governance to manage the dioxin problem of Baltic salmon and herring: potential and challenges

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The ecosystem approach to fisheries and marine management entails a shift from single-species and single-sector management to a holistic one that addresses interactions within the ecosystem and between the ecosystem and society, and strives for integrated and adaptive management, involving stakeholders. In the BONUS GOHERR project, we explore the potential of integrated management and governance in solving the dioxin problem of Baltic salmon and herring. An expert workshop will be arranged for creating shared understanding of the salmon-herring-dioxin problem and its solution possibilities, and for identifying the main challenges of the existing governance system to support the management of the problem in an integrated way. The workshop focuses on analyzing 1) the potential of a systematic cross-talk between the fisheries sector and dioxin experts in managing the problem, and 2) the challenges of breaking down the sector-based "silo thinking" in order to share knowledge, interests and awareness between sectors. The results of the study will inform the current discussion relating to the implementation of ecosystem based and integrated approaches to fisheries and marine management.

To eat or not to eat? A socioecological decision model to evaluate the sustainable use of the dioxin-rich Baltic herring and salmon

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Ecosystem-based fisheries management aims to achieve sustainable use of fish stocks in a socioecologically balanced manner, paying attention to human-environment interconnections. This requires systemic perspective to management: interactions between species, environmental conditions and human pressures determine the productivity and health of the ecosystem. These further on define the limits of the sustainable use, where both environmental, social, and economic aspects are considered. In the BONUS project GOHERR we analyze alternative ways to reduce the dioxins accumulating to humans via eating Baltic herring and salmon. Dioxin compounds accumulate to fatty tissues, thus the concentrations in the organisms increase cumulatively along the food chain. On the other hand, fatty fish as part of human diet form an excellent source of healthy Omega-3 fatty acids and vitamin-D. We study the impact of different fishing regulations and fish eating recommendations to find ecologically and socially sustainable ways to use Baltic herring and salmon, acknowledging the risks and utilities to different sectors. A probabilistic influence diagram is presented, based on modular model coupling, where the output of an ecosystem model serves as an input to a

human health risk–benefit model. The management options are evaluated acknowledging all the three aspects of sustainability.

From climate changes to vanishing fishes – warmer surface waters in prolonged periods may keep cod away from the coasts in the western Baltic Sea

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Recent studies in Kattegat and south-western Baltic Sea have suggested that Baltic cod changed their spatial distribution with declining abundance in shallow, coastal areas. In this context it is important to be able to distinguish between regionally manageable processes, such as fishing, and regionally unmanageable processes following climate change. Here, we used data storage tag (DST) data to measure the thermal tolerance and temperature envelope for Baltic cod, and a hydrodynamic model to assess extent, temperature and duration of the warm upper water layer, forming in the Baltic between May and October. The DST data suggest that the cod avoid this warm surface layer when they return to shallow water after spawning. The hydrodynamic model suggests that the area of coastal zone, where the upper water layer has bottom contact increased, and that the warm surface layer persists longer. Avoidance of this warm surface layer is hence probably a mechanism that contributed to the declining cod abundance in shallow, coastal areas. We discuss the magnitude of its impact in relation to regional fishing pressure.

COMPLETE - Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping

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Modern ships are getting faster, more economically efficient and environmentally friendly, but still the involvement of shipping in uncontrolled introduction of harmful aquatic organisms and pathogens (HAOP) continues to have both environmental and economic consequences. The management of both ballast water and biofouling of ships is

a complex task. COMPLETE is tackling several gaps: the need to take into account rights and obligations of involved stakeholders; to review and develop operational risk assessment procedures for ballast water management exemptions; to strengthen regional cooperation and information exchange on findings of potential HAOP, including developing the integrated regional NIS monitoring system and surveillance for compliance control with ballast water management standards. There is a need to establish a stakeholder network in order to develop a harmonized biofouling management strategy in the Baltic Sea Region. Such strategy will help to reduce risk of NIS introductions at the same time preventing chemical pollution by antifouling paints, and decreasing fuel consumption and emissions. COMPLETE is addressing one of the key challenges of the BSR with the ultimate goal to develop operational frameworks and provide user-oriented tools to make shipping more environmentally friendly and, whenever possible, without placing an unnecessary burden on the shipping industry.

Catching the future: Using Bayesian belief networks to visualise and examine the sustainability of Baltic herring and salmon fisheries under alternative exploratory scenarios

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Exploratory scenario method is often used in planning for long-term sustainable use of environmental resources. The method is deterministic, which means that the scenario-forming factors are fixed within each storyline, although in practice uncertainties are inherent to them. Combining probabilistic methods such as Bayesian belief networks (BBN) with exploratory scenario analysis can be useful to account for these uncertainties. Another advantage of combining the two methods is that the BBN expands the analysis beyond the fixed storylines to cover all possible combinations of the states of the scenario-forming factors. The aim of this paper is to combine the two methods to examine the future sustainability of Baltic herring and salmon fisheries. We built four exploratory scenarios following the matrix logic approach and formulated them into a BBN to visualise the assumed causalities. We also used the BBN to examine quantitatively how changes in the societal drivers affect the social-ecological system and ultimately the fisheries management objectives, including achieving good environmental status and increasing fisheries contribution to food security and safety. The empirical findings enhance our understanding of the probabilities of different storylines and their implications to long-term sustainability of Baltic herring and salmon fisheries.

Dioxin flux in the Baltic Sea – soft system approach

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Dioxins are very persistent and lipophilic congeners, which accumulate to fatty tissues. Thus, the concentrations in the organisms increase cumulatively when shifting upwards from a trophic level to another. Dioxins have proven causing different types of chronic symptoms to vertebrates. Systems analysis is used as a tool to qualitatively study the dioxin flux in different basins in the Baltic Sea, and ways to reduce the dioxin accumulating into humans via eating fatty fish, Baltic herring and salmon. Graphical networks are used to conceptualize the causalities of different biotic and abiotic factors, the underlying uncertainty, as well as potential management options affecting the dioxin flux in the ecosystem. We aim to focus on the mechanisms how dioxin is brought to the system, which factors affect on the dioxin cycle in the food-web, and how the individual species behavior and interspecies interactions affect on accumulation. Management options are selected on the spatial characteristics basis: in addition to ecological differences, anthropogenic pressures such as fishing and eutrophication, and social drivers, such as national fatty fish-eating habits vary between basins, which all have profound impacts on the amount of dioxin accumulating to humans.