Integrating spatial processes into ecosystem models for sustainable utilization of fish resources

INSPIRE

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INSPIRE Overview

Process-based understanding of changes in commercial fish spatial distributions, and to disentangle the role of natural drivers and various anthropogenic impacts, is a challenging research topic with high relevance to resource management. The four-years BONUS INSPIRE project will fill in the most persistent gaps in knowledge of the spatial ecology of the major commercial fish and thereby support the effectiveness of the relevant policies and ecosystem-based management of the Baltic Sea. The project would serve as a *„framework axis project“* which other Baltic Sea research could be related to.

INSPIRE is designed to substantially advance our knowledge on the major commercial fish species – cod, herring, sprat and flounder, which represent key elements of the Baltic Sea ecosystems. The specific objectives of INSPIRE are to:

i. Quantify processes generating heterogeneity in spatial distributions of fish;
ii. Quantify and map potential hazards to the connectivity between identified key habitats, and assess the impact of anthropogenic and climatic environmental changes on habitat connectivity;
iii. Quantify the population dynamics and interactions of the fish species in a spatially explicit context;
iv. Develop spatially explicit advice for ecosystem-based fisheries management.

INSPIRE proposes pilot ecosystem integrated surveys to resolve the habitat requirements of different life-stages of fish species by combined use of traditional methods and application of modern advanced analysis techniques. The surveys are conducted in close collaboration with local fishermen.

www.bonus-inspire.org

Project partners:

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1. Executive summary

WP1 Spatial Distributions

We have found that at high stock sizes, adult cod is distributed over a wider area, whereas at low stock sizes the population contracts into the most favorable areas in terms of hydrological conditions. These results provided further evidence of the existence of density-dependent habitat selection for the adult Baltic cod. In additon, analyses of vertical distribution of cod revealed a clear day/night pattern, confirming the overall migration of adult cod to the pelagic habitat during night.

The main outcome of the overlap analyses show a temporal drop in the occurrence of cod in the distribution area of sprat and herring, and a similar drop in the occurrence of large cod in the distribution area of small cod. Conversely, prey occurrence in the areas occupied by cod did not change as much during the past 35 years, likely evidencing that cod feeding opportunities on fish prey have not changed substantially. Sprat occurrence in the rectangles occupied by herring increased in the period 1985-2014 indicating a potential increased competition by sprat on herring.

The spatial dynamics in the taxonomic composition of clupeid stomachs broadly resembled that of the availability of prey. Sprat and herring diet overlapped more in the eastern Gulf of Finland than in the Baltic Proper. The diet similarity appeared to be the highest between large sprat and large herring, large sprat and small herring, and small and large herring. The least similar diet was observed for small and large sprat.

WP2 Passive movements, active migrations, and habitat connectivity Information about species interactions at a spatial scale comparable to the perceptive abilities of the involved species is crucial for the establishment of predictive, food consumption models at the population level. We studied the diel, vertical dynamics of species interactions between Atlantic cod *Gadus morhua* and its major clupeid prey sprat *Sprattus sprattus* at a location in the Bornholm Basin of the Central Baltic Sea during late winter. This was accomplished by combining acoustic information on diel vertical fish distribution, time of ingestion of individual sprat estimated from cod stomach content data and observed vertical profiles of salinity, temperature and oxygen content. Cod predation took place primarily at dusk and dawn during ascent and descent of sprat associated with school dissolution and formation. Cod resided close to the bottom outside these temporal predation windows. Sprat schools were located at the same depth or deeper than cod during light hours, whereas dispersed sprat at night were situated higher in the water column. These vertical dynamics could be explained by fitness optimization using bioenergetics and trade-offs between temperature, oxygen saturation of the water, and predation risk. The study thus forms the first step to providing a mechanistic background for the aggregate functional response of cod at basin scale and beyond.

WP3 Scaling from individuals to populations For the first time, a drift study has been performed in which fertilized cod eggs have been released in historically important Baltic cod spawning grounds. These eggs drifted at levels of neutral buoyancy until they entered the first feeding state. The initial result on final distribution of cod eggs at the end of the embryonic phase were then used as starting points to subsequently model the drift of early stage larvae until their metamorphosis to the juvenile stage (90 days). In the case the drift transported the particles into non-suitable habitats, the particles were not assumed to resemble successfully recruiting juveniles. The results revealed that a limited proportion of juveniles, hatched in the Arkona Basin and in the Gotland Basin successfully settled in suitable areas. In general, the study confirmed the importance of habitat availability and its effect on density dependence as a process relevant for recruitment success.

Herring reproduction and recruitment was studied for the western Baltic and Gulf of Riga populations. For the western Baltic population, there are indications for active habitat selection which is larval stage specific. Elemental fingerprinting from otoliths of young-of-the-year herring revealed specific signatures of the particular nursery areas. Local stressors, such as egg mortality caused by storm induced wave action might be important drives for the year class variability. Concerning the Gulf of Riga spring herring population, substantial progress was achieved in understanding the drivers of recruitment variability: hydroclimate (linearly combined effects of annual sum of sunshine hours and water temperatures in January-March) significantly affected inter-annual recruitment variability during 1957-2012. However, during the distinct periods of low and high spawner biomass, winter water temperature and the Baltic Sea Index in December-March were the best predictors of recruitment, respectively.

WP4 Stock Assessments Cod assessment models using natural mortality (M) related to growth performed much better than the standard assessment models in which M is assumed constant; these assessments are better both in diagnostics of the model quality and consistency with the trends in survey indices of stock size. The effects of parasitic infection of cod on its condition and possibly mortality suggest that natural mortality of heavily infected cod increased. This is consistent with behaviour of assessment models with increasing M, and coupled together indicate that natural mortality of eastern Baltic cod has probably increased markedly in recent years.

Conducted assessments of herring show similar trends in biomass development in former assessment units (AUs) and similar are trends in fishing mortality. The biomass of herring in SDs 25-27 is about two times higher than in SDs 28-29+32. Opposite is estimated for fishing mortality. The sum of biomasses by AUs is very similar to biomass of Central Baltic Herring (CBH) estimated by ICES. Trial assessments indicate that the AU of herring in SDs 28-29+32 should rather not be decomposed into smaller units. The merging of two AUs (SDs 25-27 and 28-29+32) into one AU of CBH is justified from assessment point of view. However, spatial management of the stocks could be recommended, then assessment and data by former AUs would be needed.

In general, assessments of sprat show trends in stock biomass and fishing mortality developments similar in the considered AUs (in 22-25, 26+28 and

27,29-32) and sum of biomasses by AUs is close to ICES estimates of sprat biomass. The biomass in SDs 26+28 is the biggest; in most years it was close to the sum of biomasses of other sprat stocks. Fishing mortality of this stock has been the highest in recent years. Merging of three AUs into one AU is justified from assessment point of view. However, differences in intensity of exploitation of the stocks is substantial and spatial management could be considered. Such management would require assessment and data by former AUs.

WP5 Ecosystem based assessment Implications of merging smaller fish stock assessment units into larger ones was evaluated from both assessment and management point of view. The project has developed estimates of biomass and fishing mortality of clupeids by former assessment units (which were smaller) and compared those with the assessment units used in nowadays. The process to estimate biological reference points for former assessment units has also started. In addition, the method of estimating maximum sustainable yield parameters when growth and natural mortality are density dependent, was developed and applied to Baltic sprat. It appeared that density dependence has huge impact on the MSY and related fishing mortality estimates.

Predator-prey interactions and intra-specific density-dependence are essential to explain temporal variation in the food-web indicators. When accounting for these interactions, the indicators overall respond to multiple pressures acting simultaneously rather than to single pressures. The manageable pressures fishing and eutrophication, as well as the prevailing hydrological conditions influenced by climate, were all needed to reproduce the inter-annual changes in the food-web indicators combined. Our indicator-testing framework can therefore be used to identify responses of food-web indicators to manageable pressures while accounting for the biotic interactions in food-webs linking such indicators.

The quantitative analyses of stock mixing were an important contribution to facilitate the transition from area-based to stock-based assessments of cod in the Baltic Sea. Information on the annual proportions of eastern and western cod found in the western Baltic management area allowed allocating fisheries catch to the populations of origin, and performing stock assessments for the two biological populations separately. This change provides a more realistic picture of the dynamics of western Baltic cod population that were masked in the earlier area-based assessments by increasing proportions of the eastern Baltic cod in the area.

WP6 Dissemination has facilitated, by the close contact to various ICES expert groups and Baltic Sea Advisory Council, that project results have been made available to stakeholders and interested public almost in a real time. The overall goal in dissemination work has been to show and apply the importance of spatial heterogeneity in the different activities. During the third year of the project, these activities continued substantially supporting the Eastern Baltic cod initiatives, and contributing to diverse ICES working groups with special focus on the ICES Workshop on Spatial Processes in the Baltic

(WKSPATIAL). Main achievements of the INSPIRE work in relation to Baltic cod include the development of a new model for cod growth and mortality that has been presented at ICES WKBEBCA (Workshop on Biological Input to Eastern Baltic Cod Assessment).

Two joint events with other BONUS projects include: BONUS BIO-C3/INSPIRE /COCOA/BAMBI 2016 Summer School: Modelling Biodiversity for Sustainable Use of Baltic Sea Living Resources and start planning the BONUS symposium on ’Science delivery for sustainable use of the Baltic Sea living resources’ in 2017. INSPIRE web-site has been continuously updated, linking now publications (36), project reports with ‘public’ status (8), meta-databases (24) and affiliated projects (8). During the third project year, one PhD and two MSc theses, all supervised by INSPIRE scientists, were successfully defended

WP7 Management has ensured timely science delivery according to the project workplan via efficient internal communication, systematic contacts with the BONUS Secretariat and continuous monitoring of the progress by the project coordination unit.

2. Scientific and/or technological results achieved

WP 1 Spatial Distributions

Lead: Michele Casini, P5 (SLU)

1. Scientific highlights

At high stock sizes, the adult cod population is distributed over a wider area of the Baltic Sea, whereas at low stock sizes the cod population contracts in the most favorable areas (in terms of hydrology), i.e. the southwestern Baltic Sea (Fig. 1). These analyses, along with the spatio-temporal patterns in commercial catches, provide indications of the existence of density-dependent habitat selection for the adult Baltic cod.

Analyses of cod vertical distribution revealed a clear day/night pattern in the catches, with catches in the pelagic habitat being higher at night-time and lower during the day-time, demonstrating the overall migration of adult cod to the pelagic habitat during night.

The main results of the overlap analyses show a temporal drop in the occurrence of cod in the distribution area of sprat and herring, and a similar drop in the occurrence of large cod in the distribution area of small cod. This put in evidence a potential decrease in predation pressure by cod on its prey (including cannibalism) due to spatial mismatch. Conversely, prey occurrence in the areas occupied by cod did not change as much during the past 35 years, likely evidencing that cod feeding opportunities on fish prey have not changed substantially. Moreover, sprat occurrence in the rectangles occupied by herring increased in the period 1985-2014 indicating a potential increased competition by sprat on herring stock.

The main results of the study on the feeding habits of sprat and herring showed that the spatial dynamics in the taxonomic composition of clupeid stomachs broadly resembled that of the availability of prey. Sprat and herring diet overlapped more in the eastern Gulf of Finland than in the Baltic Proper. The diet similarity appeared to be the highest between large sprat and large herring, large sprat and small herring, and small and large herring. The least similar diet was observed for small and large sprat.

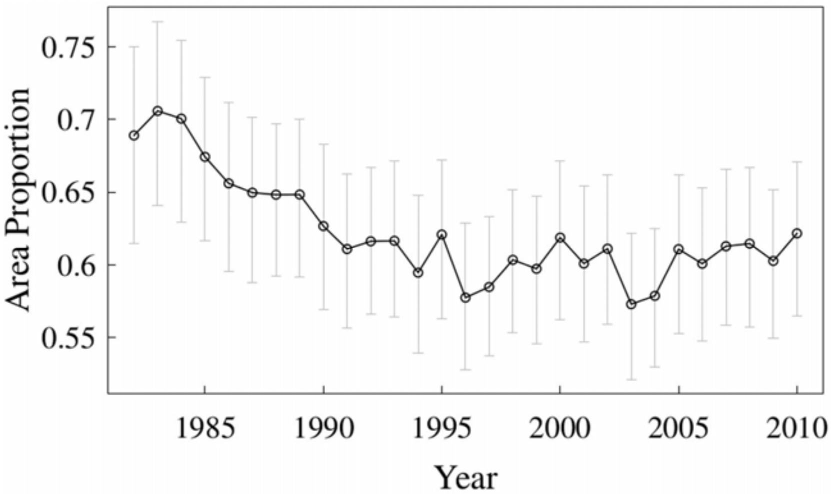

Fig.1. Habitat occupancy index. Minimum area containing 95% of the estimated cod abundance by year. From Bartolino V, Tian H, Bergström U, Jounela, P, Aro E, Dieterich C, et al. (2017) Spatio-temporal dynamics of a fish predator: Density-dependent and hydrographic effects on Baltic Sea cod population. PLoS ONE 12(2): e0172004.

2. Summary by task

Task 1.1. Data collection and assembly in common databases

Completed during the 2nd Project Year.

Task 1.2. Mapping the spatial distribution of fish: linking existing data, new sampling and statistical analyses

Annual and seasonal maps of fish distribution in demersal and pelagic habitats from 1978 onwards are produced using advanced spatial statistics, using the data from existing international monitoring programs. Maps of the spatial distribution of sprat eggs and larvae, and their condition, are also produced using the INSPIRE pelagic field surveys. Indices of spatial overlap between predator/prey and competing species are produced to evaluate the potential predator-prey and competitive relationships in the Baltic Sea. The importance of distribution and overlapping for the diet composition of cod are examined as well as dietary habits of herring and sprat will be investigated.

Statistical habitat modeling were employed to relate the spatial distribution of different life stages of the target fish species to biotic (predators, preys, competitors) and abiotic (temperature, salinity, oxygen) factors, using both existing surveys (BITS, BIAS, BASS databases and newly compiled historical data) and the data from the INSPIRE field surveys (gillnets and ichtyoplankton/acoustic surveys) collected under Task 1.1.

The abundance indices from the gillnets samplings were used to design a reliable recruitment index for cod (integrating BITS data) and flounder, applicable in stock assessment. Otoliths of the captured cod juveniles are used for studies on growth and survival in particular habitats. Habitat characterization of nursery areas was done for settling flounder using the data gathered during the beach seine sampling under Task 1.1.

Distribution maps for different life-stages

We have created distribution maps for different life-stages of fish, using BITS and BIAS international databases and INSPIRE sampling (gillnets and beach seines, as well as acoustic and ichthyoplankton surveys, the latter exemplified in Fig. 2). Maps have been produced separately for eggs, larvae, juveniles and adults of cod, flounder, sprat and herring. Information on data and maps available is presented in a metadata table. Finalized map predictions based on statistical modelling have been produced, together with maps depicting field data that has been collected within Inspire and that is currently used for spatial modelling.

Spatio-temporal analyses of cod from the Baltic International Acoustic Surveys (BIAS)

The pelagic control catches from autumn acoustic surveys (BIAS) were used by SLU to study the spatio-temporal dynamics of the cod population in the pelagic waters. The survey covers the whole potential area of Eastern Baltic cod distribution (SDs 25-32), in this way constituting a very useful tool in spatial modeling that can be used together with the data from the ordinary bottom trawl surveys (BITS). The data were analysed with GAMs (Generalized Additive Models) to simulate the spatial distribution (i.e. estimate the CPUE, catch per unit of effort, in Kg/h) of cod in the pelagic water in each ICES statistical rectangle and Subdivision, between 1979-2014. The analyses have been so far made using Swedish, Polish, Latvian and Lithuanian data. The submission of a manuscript is planned for March 2017.

Standardization of bottom trawl surveys and analyses of stock trends

The standardization of the trawl catches from the DATRAS database (available at ICES website) and previously conducted surveys (Swedish and Latvia) has been made by SLU. This allows following with survey data the spatio-temporal historical development and the length distribution of different stocks of cod and flounder in the Baltic Sea. Reconstruction of population trends of cod and flounder stocks using the standardized data from bottom trawl surveys was published in January 2017.

Source: Orio, A., Florin, A.-B., Bergström, U., Sics, I., Baranova, T., and Casini, M. (2017). Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data. ICES Journal of Marine Science. doi:10.1093/icesjms/fsx005.

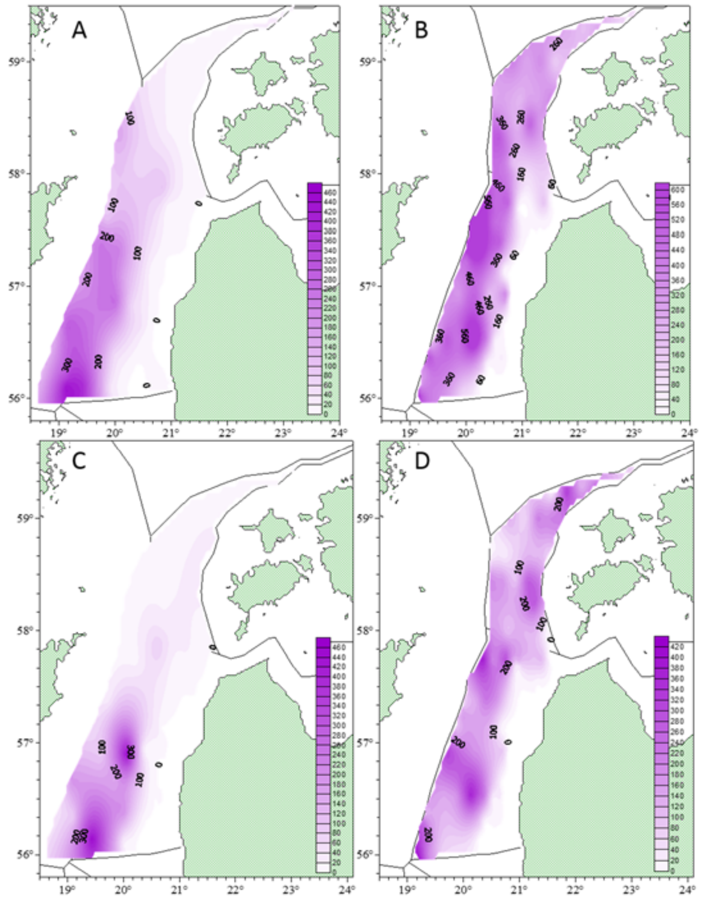

Fig. 2. Interpolated number of sprat eggs per m^2. F/V "Dzintari". Panel A shows results for the period 15-25 May 2014, B the period 17-22 June 2014, C the period 15-25 May 2015 and D 15-22 June 2015.

Spatio-temporal analyses of cod from bottom trawl surveys (BITS and historical data)

Standardized bottom trawl CPUEs (Kg/h) were used by SLU and FGFRI to simulate the fine-scale spatial distribution of cod in the Central Baltic Sea (SDs 25-29) between 1982-2010 using GAMs (Generalized Additive Models). The analyses revealed that the spatial distribution of adult cod is affected by salinity and oxygen, but also by the cod stock size. At high stock sizes, the adult cod population is distributed over a wider area of the Baltic Sea, whereas at low stock sizes the cod population contracts in the most favorable areas (in terms of hydrology), i.e. the southwestern Baltic Sea (Fig. 3). These analyses, along with the spatio-temporal patterns in commercial catches, provide indications of the existence of density-dependent habitat selection for the adult Baltic cod. A paper was published in February 2017.

Source: Valerio Bartolino, Huidong Tian, Ulf Bergström, Pekka Jounela, Eero Aro, Christian Dieterich, H. E. Markus Meier, Massimiliano Cardinale, Barbara Bland and Michele Casini (2017). Spatio-temporal dynamics of a fish predator: density-dependent and hydrographic effects on Baltic Sea cod population. PLoS ONE, 12(2): e0172004.

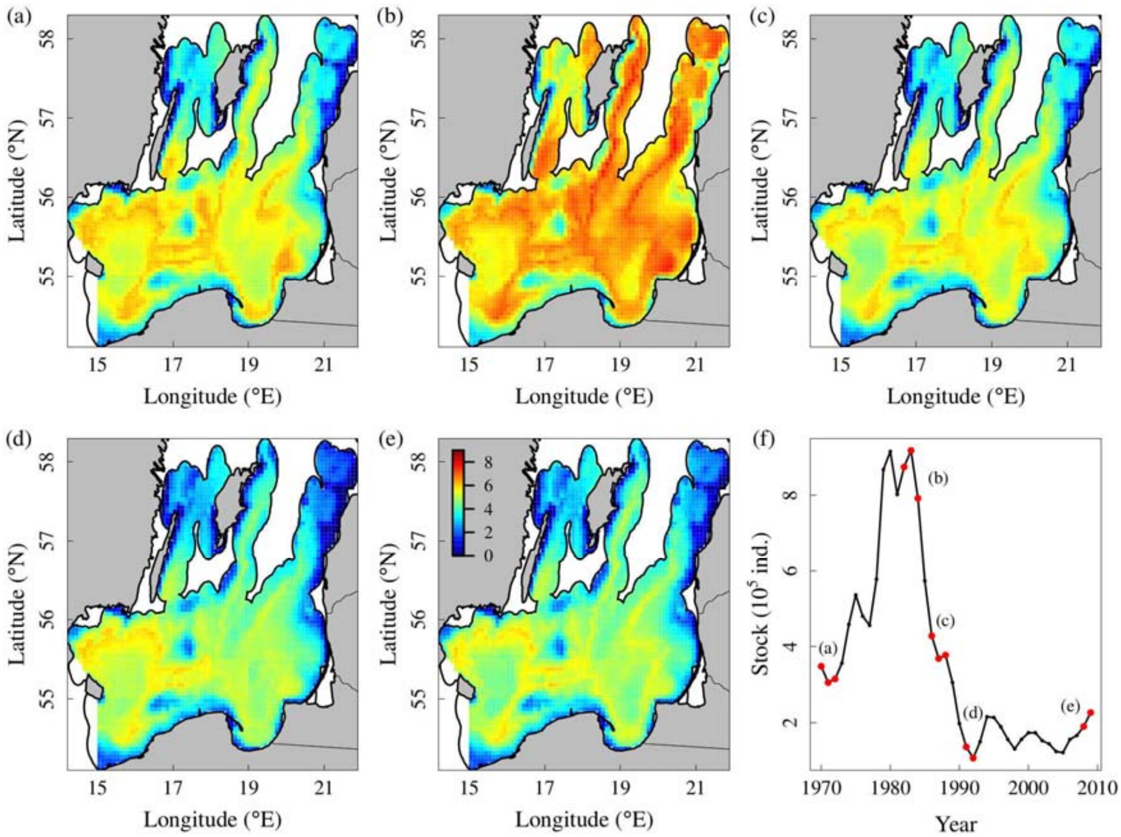

Fig 3. Predictions of cod spatio-temporal population distribution at different population levels. (a) 1970-1972 (hindcast), (b) 1982-1984, (c) 1986-1988, (d) 1991-1992, (e) 2006-2007. (f) Baltic cod population size (ages 3+). Red and blue colors indicate high and low predicted CPUEs, respectively.

Spatial overlap between predator-prey and competing species

The spatial overlap between predator/prey and competing species was quantified. For this purpose, data from ICES currently coordinated surveys and historical data newly compiled and standardized within INSPIRE, were used to produce maps of spatial distribution from which simple estimations of spatial overlap were performed. To better characterize the actual competition between the herring and sprat, dietary habits and diet overlap of herring and sprat were also investigated. The main results of the overlap analyses show a temporal drop in the occurrence of cod in the distribution area of sprat and herring, and a similar drop in the occurrence of large cod in the distribution area of small cod. Conversely, prey occurrence in the areas occupied by cod did not change as much during the past 35 years (Figs. 4-6). Moreover, sprat occurrence in the rectangles occupied by herring increased in the period 1985-2014. The main results of the feeding habits of sprat and herring showed that the spatial dynamics in the taxonomic composition of clupeid stomachs broadly resembled that of the availability of prey. Sprat and herring diet overlapped more in the eastern Gulf of Finland than in the Baltic Proper. The diet similarity appeared to be the highest between large sprat and large herring, large sprat and small herring, and small and large herring. The least similar diet was observed for small and large sprat.

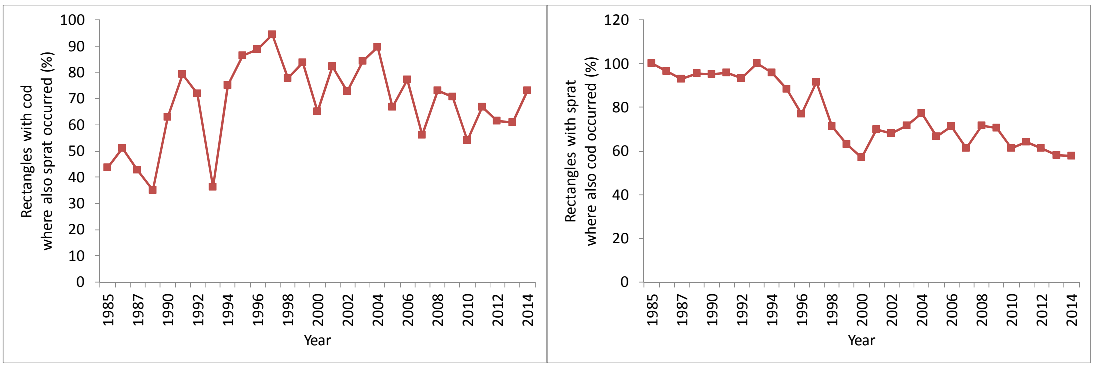

Fig.4. Time-series of spatial overlap between cod and sprat. Left panel: rectangles occupied by cod in which also sprat occurred. Right panel: rectangles occupied by sprat in which also cod occurred

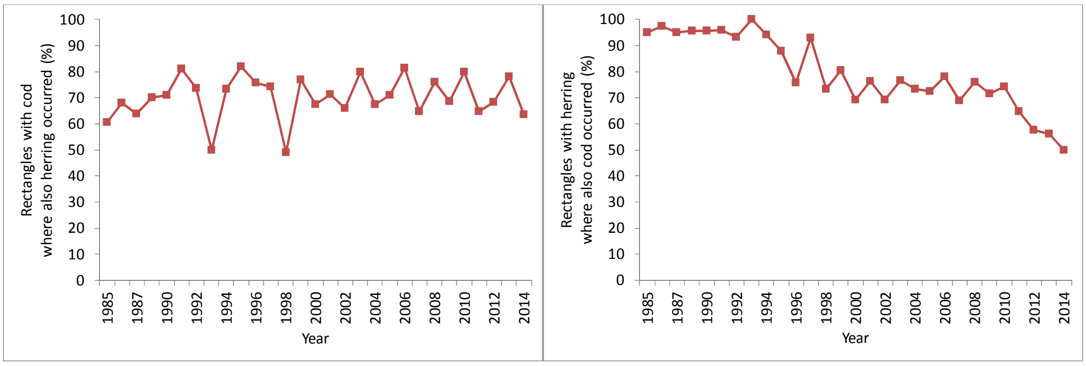

Fig.5. Time-series of spatial overlap between cod and herring. Left panel: rectangles occupied by cod in which also herring occurred. Right panel: rectangles occupied by herring in which also cod occurred

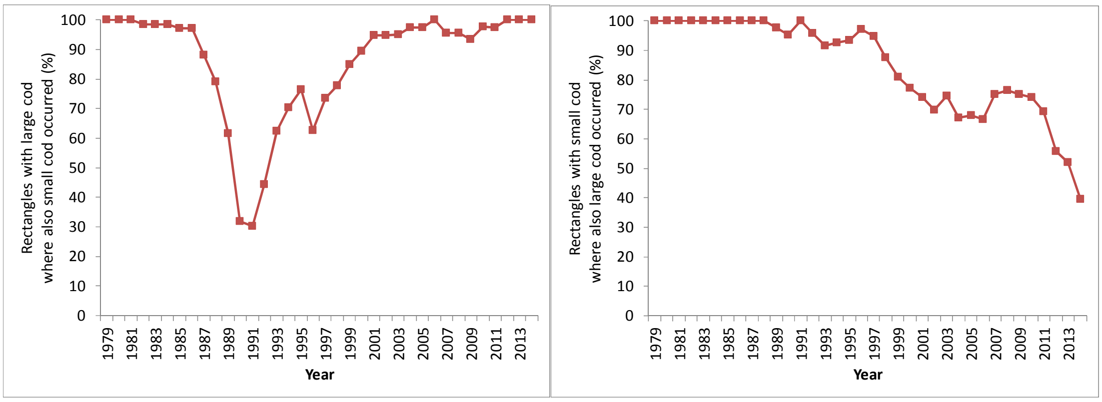

Fig.6. Time-series of spatial overlap between large cod (≥ 45 cm) and small cod (≤25 cm). Left panel: rectangles occupied by large cod in which also small cod occurred. Right panel: rectangles occupied by small cod in which also large cod occurred.

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

In this study we have addressed three main research questions: 1) What environmental conditions characterize the spatial distribution and abundance of adult flounder during the spawning season? 2) What are the main factors defining the habitats of the two flounder ecotypes during the spawning season? 3) Where are the potential spawning areas of flounder? We modelled catch per unit of effort of flounder from gillnet surveys conducted over the southern and central Baltic Sea in the spring of 2014 and 2015 using generalized additive models. The general model captured distinct ecotype-specific signals as it identified dual salinity and water depth responses. The model for the demersal spawning flounder revealed a negative relation with the abundance of round goby and a positive relation with Secchi depth and cod abundance. Vegetation and substrate did not play an important role in the choice of habitat for the demersal ecotype. The model for the pelagic spawning flounder showed a negative relation with temperature and bottom current and a positive relation with salinity. Spatial predictions of potential spawning areas of flounder showed a decrease in habitat availability for the pelagic spawning flounder over the last 20 years in the central part of the Baltic Sea. A paper was submitted for publication on M36.

Spatial egology of feeding of small pelagics in the Gulf of Riga

We investigated the feeding of the dominant small pelagic fish – herring *Clupea harengus membras* and three-spined stickleback *Gasterosteus aculeatus* – in the Gulf of Riga (Baltic Sea) in the summers of 1999–2014. The share of empty stomachs, stomach fullness and taxonomic composition of fish diet was analysed. On average, large herring had the highest (19%) and small herring the lowest (6%) share of empty stomachs. Small cladoceran *Bosmina* spp. was the most important prey for threespined stickleback; preying on small copepod *Eurytemora affinis* was the most efficient for small herring, while *Bosmina* spp. and *E. affinis* were equally important for the large herring. Feeding conditions for small herring, as revealed by the proportion of empty stomachs and stomach fullness, were relatively uniform across the GoR with the highest stomach fullness observed in the western part of the GoR. Small herring also had the lowest proportion of empty stomachs of the three fish groups studied. In contrast, large herring feeding conditions improved in the northeastern part of the basin where the proportion of empty stomachs is the lowest, while the wider east coast of the basin seems to support higher stomach fullness index. The lowest share of empty stomachs of three-spined stickleback was recorded in the southern part of the basin adjacent to plume of River Daugava, and the best feeding conditions in terms of stomach fullness index are concentrated to the southwestern GoR (Fig. 7). However, the R^2 of the GAMs of spatial patterns was low (0.03–0.11); hence, the spatial patterns are quite weak and interannual variation dominates

Source: Ojaveer, H., Lankov, A., Teder, M., Simm, M., Klais, R. 2016. Feeding patterns of dominating small pelagic fish in the Gulf of Riga, Baltic Sea. Hydrobiologia, DOI 10.1007/s10750-016-3071-5.

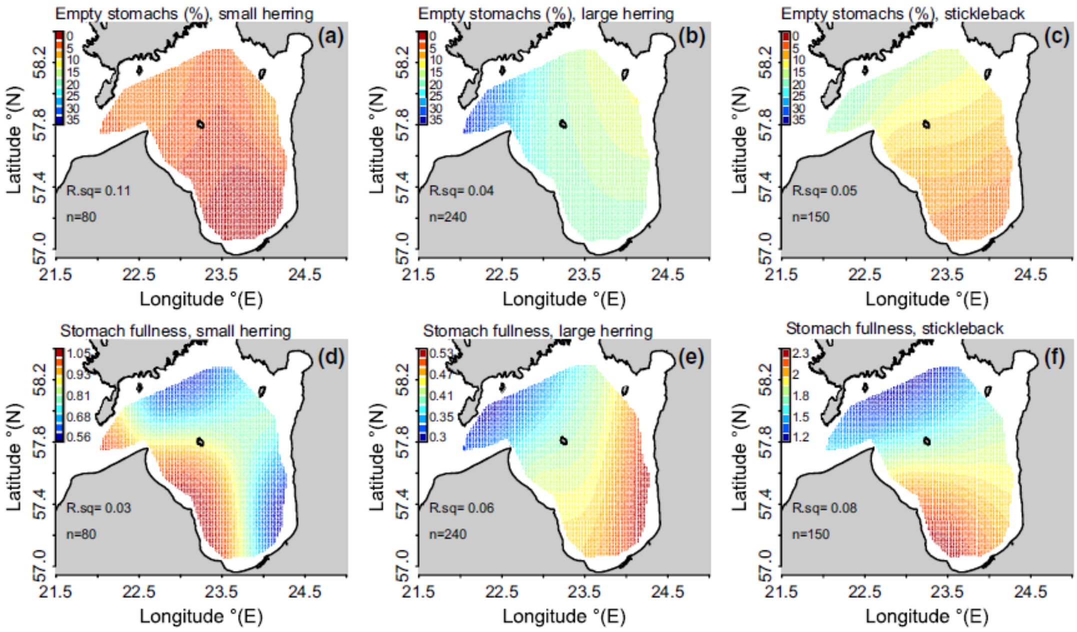

Fig. 7. Spatial patterns of the empty stomachs (a–c) and mean fullness of the non-empty stomachs (d–f) of small and large herring *Clupea harengus membras*, and three-spined stickleback *Gasterosteus aculeatus*. In a–c, same colour scale has been used (Ojaveer et al. 2016).

<u>Spatial ecology of clupeid feeding in the NE Baltic Sea</u>

Data collected during the INSPIRE clupeid feeding survey in July 2015 were further analysed and new evidences of the clupeid feeding ecology were obtained. The share of empty stomachs, stomach fullness and taxonomic composition of fish diet was analysed. We have found that:

i. Stomach fullness index of small sprat tended to be higher than that of large sprat. Mean stomach fullness index of small and large sprat tended to be positively influenced by total zooplankton biomass, but negatively by zooplankton evenness. For herring, these links were either less clear or lacking.
ii. The three dominating taxa in stomachs of juvenile and adult sprat and herring were copepods *Temora longicornis*, *Eurytemora affinis* and *Acartia* spp. Diet spectrum of sprat was wider than that of herring. Taxonomic composition of clupeid stomach content was consistently and positively linked to Shannon index of the ‘edible part’ of the zooplankton sample (Fig. 8) with stomach species richness being higher for sprat tan for herring.
iii. Mean dietary overlap of clupeids was negatively related to Shannon index of the ‘edible part’ of the zooplankton sample, but positively to mean stomach fullness. The latter was mostly due to small and large sprat, while no clear pattern was observed for small and large herring.

Source: Ojaveer, H., Lankov, A., Raid, T., Põllumäe, A. Klais, R. Selecting for the dominance – feeding of sprat and herring in the Baltic Sea (in prep.).

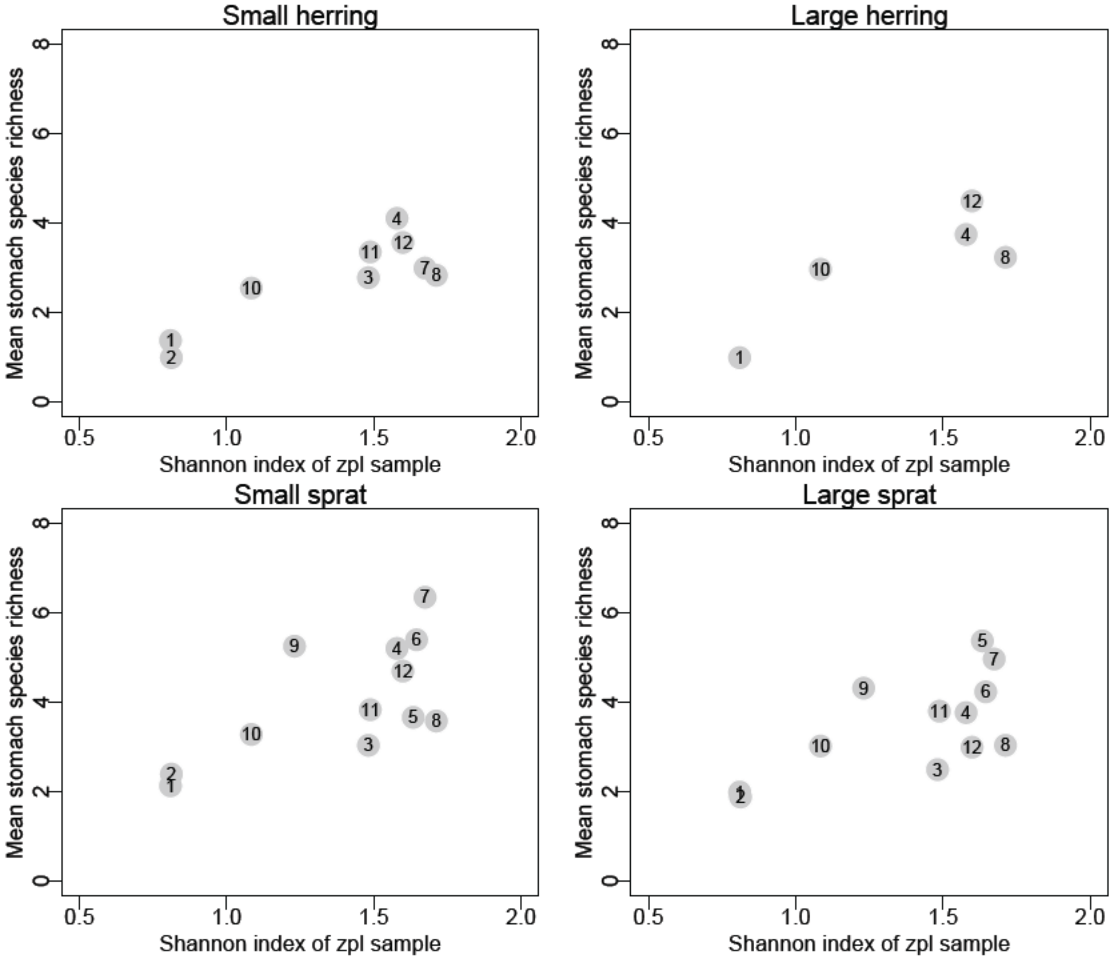

Fig. 8. Mean stomach species richness of juvenile and adult sprat and herring as a function of Shannon index of zooplankton sample. Numbers in gray filled circles indicate the number of trawl (Ojaveer et al. in prep).

Relation to Deliverables and Milestones

D1.2 (Report on distribution maps for different life-stages), D1.3 (Manuscript on simulating spatial distributions of key exploited stocks), D1.4 (Report on spatial overlap between predator-prey and competing species) and D1.5 (Manuscript on habitat preferences of different life-stages of fish) have been fulfilled.

Task 1.3. Population dynamic consequences of spatio-temporal shifts in predator-prey interactions and implementation into stock assessment

INSPIRE applies and further developed the spatial SMS (stochastic multispecies model) using the information gained under Tasks 1.1 and 1.2. SMS describes stock dynamics of interacting stocks linked together by predation. An extended SMS model with area-dependent predation mortality for cod, herring and sprat has been developed and is applied in INSPIRE. ICES Sub-division based values for predation mortalities of herring and sprat were derived in the hindcast SMS by accounting for the distributions of cod, herring and sprat when estimating the prey-specific consumption rates of cod.

The consequences of recently limited spatial overlap between cod, herring and sprat populations are evaluated and incorporated into current population models (e.g. SMS) for later use in stock assessment (WP4).

Furthermore, a historical reconstruction of the food-web is performed to understand spatial distributions in response to factors different from those observed during the past few decades. Especially, cod-flatfishes interaction is reconstructed back in time under oligotrophic conditions and low fishing pressure.

Spatially explicit population and food-web modelling – state of the art and where to go from here in INSPIRE

Management of fisheries for cod can have an impact on fishing opportunities for sprat and herring, and vice versa. Cod are predatory, and their main prey is sprat and, to a lesser extent, herring and also juvenile cod (cannibalism). Growth of herring and sprat has been density-dependent. The relative distributions of predator (cod) and prey (herring and sprat, juvenile cod) have changed substantially during the last years, and for the time being much herring and sprat are outside the predatory reach of cod.

Preliminary model runs have indicated that the present distribution patterns of cod, herring and sprat imply that an increase in fishing mortality (F) on cod not necessarily will result in increasing Baltic wide clupeid stock sizes. Conversely a decrease in F on cod will not necessarily result in a decrease of the Baltic clupeid stock size if it will not be accompanied by a cod expansion to northern areas. Higher sustainable fishing mortalities for herring and sprat are also obtained when density dependent growth is assumed for the two species, as the stocks compensate by a higher growth at lower stock densities due to either higher fishing mortalities or predation.

A basic model has been developed that is purely length based and couples population dynamcis, foraging behavior and predator (cod) growth. The model will be expanded to account for different spatial units and apply the knowledge gathered in INSPIRE.

Updates on spatial food web modelling for the Baltic

Understanding the dynamics across the established regime shift observed in the late 1980s requires novel research into the spatial heterogeneity of the key processes. In INSPIRE, the emphasis will be to develop more sophisticated models, based on enhanced field data, that help explore the spatial and temporal relationships. Using a similar set of collected and modeled environmental and ecological data (describing the trophic structure and environmental status) we will develop 2 model approaches in synchrony. The first model described as the size structured mechanistic model is based on mathematically describing the relationships (often based on metabolic theory) across the trophic web. The second model is the development of a spatially explicit Bayesian Belief Network. The first step currently underway is the collection of data spanning many years and relevant to a suite of factors deemed most influential in the dynamics. The next step will be the use of the data to generate conditional probabilities such that a fully working model is constructed. This model will encompass spatial structure, not through isolated instances of the model but through a process of identifying the key spatial drivers of the population interaction. At the moment the model is ready for testing both spatially and temporally. A manuscript will be prepared collectively with the experts in spring 2017 and the results will be presented at the international Baltic Sea Science Conference in June 2017

Relation to Deliverables and Milestones

No Deliverables or Milestones for the Task 1.3 were due during the 3rd Project Year.

3. Deviations from the work plan

D1.5, originally planned for M34, was postponed to M36 due to delays in the data quality-check and delivery from the INSPIRE gillnet sampling.

WP 2 Passive movements, active migrations, and habitat connectivity

Lead: Christian Möllmann, P8 (UHAM)

1. Scientific highlights

Information about species interactions at a spatial scale comparable to the perceptive abilities of the involved species is crucial for the establishment of predictive, food consumption models at the population level. Nevertheless, such information is sparse due to methodological constraints. We studied the diel, vertical dynamics of species interactions between Atlantic cod *Gadus morhua* and its major clupeid prey sprat *Sprattus sprattus* at a location in the Bornholm Basin of the Central Baltic Sea during late winter. This was accomplished by combining acoustic information on diel vertical fish distribution, time of ingestion of individual sprat estimated from cod stomach content data and observed vertical profiles of salinity, temperature and oxygen content. Cod predation took place primarily at dusk and dawn during ascent and descent of sprat associated with school dissolution and formation. Cod resided close to the bottom outside these temporal predation windows. Sprat schools were located at the same depth or deeper than cod during light hours, whereas dispersed sprat at night were situated higher in the water column. These vertical dynamics could be explained by fitness optimization using bioenergetics and trade-offs between temperature, oxygen saturation of the water, and predation risk. The study thus forms the first step to providing a mechanistic background for the aggregate functional response of cod at basin scale and beyond.

2. Summary

Work-package 2 contains statistical and process-based analyses of movements of the focal species at different temporal and spatial scales and in different life-stages. Besides quantifying these movements, emphasis is put on the characterization of obstacles for the transport or movement between nursery and feeding habitats, between feeding and spawning habitat, and (closing the life cycle) between early life stages habitats and nursery grounds. This includes the assessment-relevant movements between ICES sub-divisions.

Work-package 2 is separated into 3 Tasks and the work of Task 2.1 and 2.2 has been completed during the second reporting period. During the recent reporting period work has been conducted only in Task 2.3 (see *Scientific Highlight* and below).

Task 2.3 Small scale movements relevant for species interactions

In this task small-scale movements of cod, herring and sprat, such as school formation, evasive reaction, distance between schools, reactions to the presence of predators (including fishers) have been analysed using existing acoustic and data storage tag data. The small scale movements knowledge will be used (i) to test hypotheses on density dependent emigration on a sub-basin scale and (ii) to understand if the exchange between ICES sub-divisions has other reasons than reproductive success or fishery, that is availability of prey or predation risk, or a combination of different factors. Drivers of species distribution will be also investigated at the small temporal and spatial scale using high resolving acoustic, video and plankton net (prey field) data, generated in a dedicated survey activity (pilot study).

Small-scale movements: sprat schooling

In March/April 2015, a 10 km acoustic transect in the central Bornholm Basin of the Baltic Sea has been sampled constantly sailing back and forth during a 48 hour period. Sprat schools (Fig. 9) were identified and their height, width and acoustic backscatter as approximation for the fish density in each school were recorded using the Echoview software (Myriax) with the school detection module. School height, length and backscatter (nautical area backscattering coefficient) were all clearly log-normally distributed (Fig. 10).

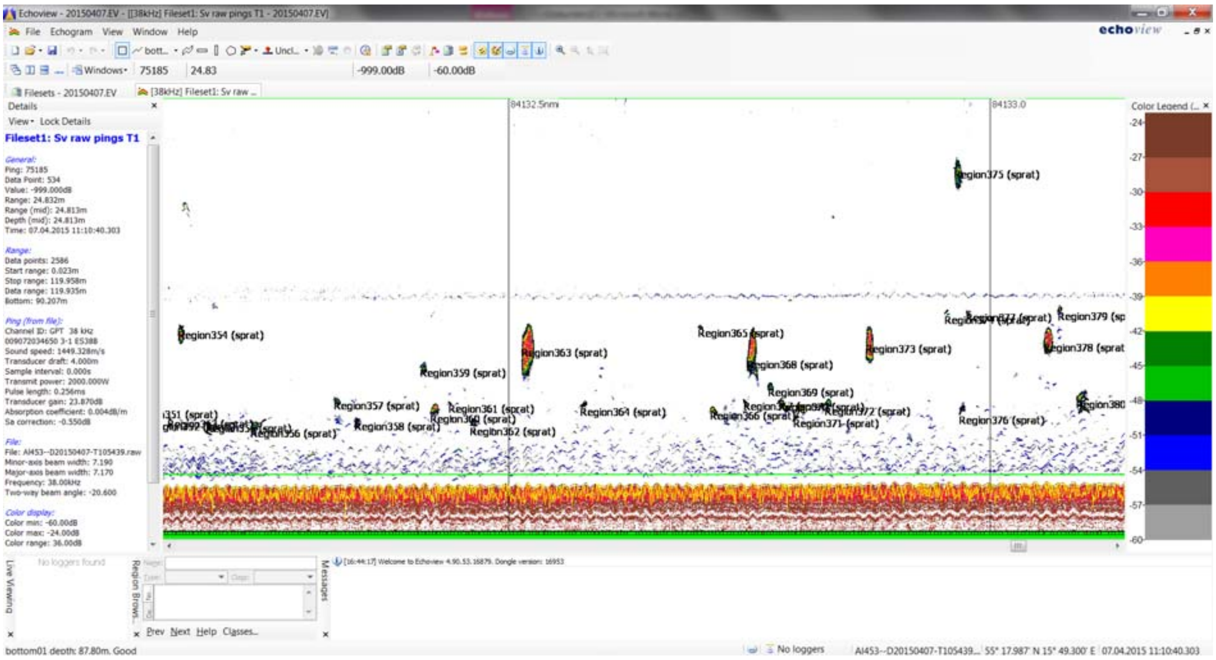

Fig. 9. Sprat schools identified using the school-ideintification software included in the Echoview package. Species was identifed conducting fishery hauls over the acoustic transect. This picture shows a typical daylight situation in the Bornholm basin.

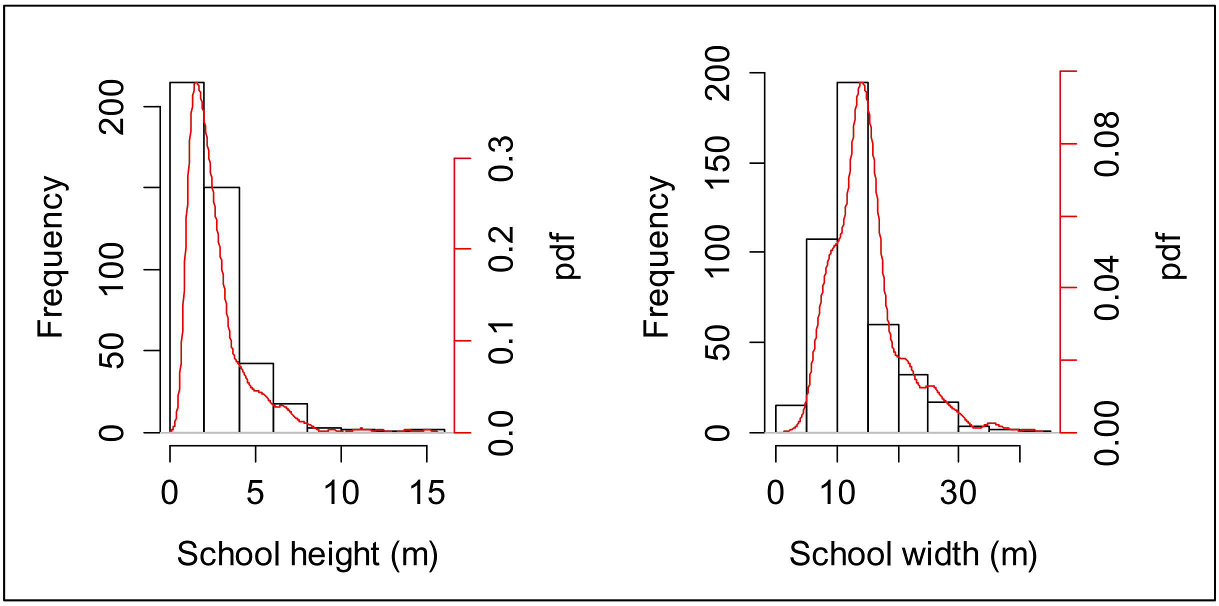

Fig. 10. Histograms and probability density functions (pdf) of school height and width combining all schools detected during the pilot study.

A simple mechanisms was proposed, leading to the log-normal distributions, based on Gibrat's law of proportional growth. There are alternative causes for the observed apparent universality in the size distributions of the sprat schools, which have to analysed further in relation to the processes involved in foraging of cod on the school-forming sprat (see below). The observed aggregation pattern gives rise to several testable hypotheses on the school formation process and related species interactions during dusk and dawn which are currently developed as continuation of the work conducted in Deliverable 2.6.

The acoustic data, as well as allother acoustic data collected during INSPIRE and selected survey data reflecting small scale spatial distributions of clupied fish were collected in the acoustic database in INSPIRE Deliverable 2.5. This database will form the basis for further investigations of spatial structure and school formaiton beyond the lifetime of INSPIRE.

Small-scale movements: drivers of species distributions

The predator-prey interactions between piscivorous and forage fishes are structuring elements in the dynamics of the ecosystem through trophic cascading effects (Paine 1980, Frank et al. 2005). A basic understanding of these interactions is therefore a prerequisite for studying ecosystem functioning in general and an essential part of ecosystem-based fisheries management (Link 2010) to predict the indirect effects of removing targeted key predators or prey.

Neuenfeldt & Beyer (2009) suggest that the aggregate diet of cod in the Bornholm Basin is determined by the vertical habitat overlap dynamics of cod and its clupeid prey. They developed conceptual models for the effects of the spatial overlaps of predator and prey on the aggregate diet of the predator population and used field data on densities and spatial distribution of the fishes together with information about diet composition obtained from sampled cod stomachs in March 1958–2004. Associated with a prolonged stagnation the predation on clupeids decreased due to the reduced cod stock in the 1980s. At the same time the ratio of herring to sprat consumed by cod decreased more slowly than did the abundance ratio. This relationship, which might have contributed to the drastic increase in sprat abundance during the late 1980s, could be derived by use of conceptual modelling of the effect of one part of the cod habitat containing both clupeids and another part only sprat. If the cod-clupeid overlaps were disregarded then the observed diet composition dynamics could be misinterpreted as a situation of negative switching.

The model of Neuenfeldt & Beyer (2009) only considered the vertical distribution during day time and disregarded the diel vertical migration (DVM) of clupeids in the Bornholm Basin (Cardinale et al. 2003, Nilsson et al. 2003). Using hydroacoustics and examining the contents of sampled clupeid stomachs in the feeding season, Cardinale et al. (2003) found that the clupeids performed DVM with schooling close to the bottom during day time, ascending and dispersing at dusk, and descending and aggregating again at dawn. This behaviour was related to DVM of their zooplankton prey as a response to optimal feeding conditions and further linked to predation avoidance (light conditions) and bioenergetics optimization (temperature). However cod predation on the clupeids was just inferred from a more generalised phenomenon for pelagic forage fish, and not observed.

INSPIRE Deliverable 2.6 aimed to examine how the stratified water column together with the diel light conditions influence the behaviour and interaction of cod and sprat at a scale comparable to the perceptive ability of the species involved (Fig.11). This was accomplished by combining (i) information on the diel vertical distribution dynamics of the fishes obtained from hydroacoustic data, (ii) profiles of salinity, temperature and oxygen content of the water, (iii) cod predation rates, ingestion times of individual sprat and energy balance estimated from contents of sampled cod stomachs and (iv) the energy balance of sprat as inferred from contents of sampled sprat stomachs. The observed behavioural dynamics and interactions of predator and prey were interpreted in terms of simple fitness optimization considerations using bioenergetics and trade-offs between temperature, oxygen saturation of the water and risk of predation.

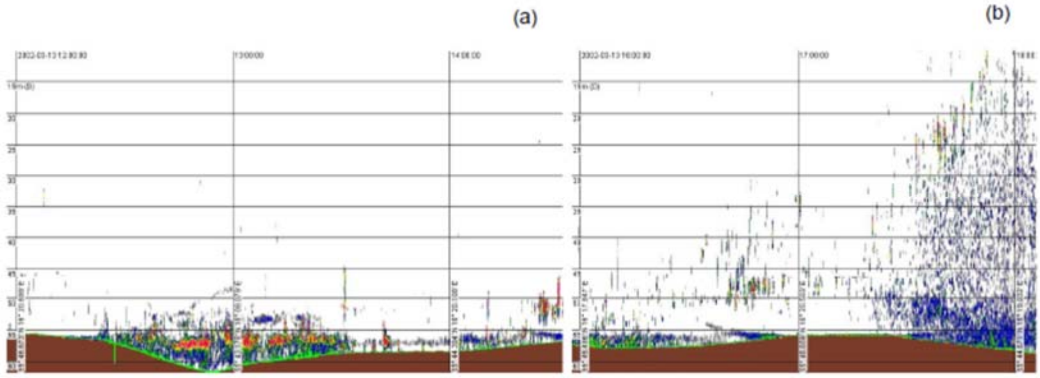

Fig. 11. Echograms produced by the Echoview software in 20 log R display mode for (a) day and (b) dusk situations.

The diel feeding pattern obtained from the estimated ingestion times of sprat (n = 194) showed a distinct pattern with peaks at dusk and dawn (Fig. 12). Using 95 % CIs of the estimated ingestion times, 12.4 % of the sprat were ingested during night and only 1 sprat at day time, whereas it could not be excluded that 87.1 % were ingested at dusk (39.7 %) or dawn (47.4 %).

Different energy balances of the two species partly explained their respective temperature preference and vertical distribution. Also, there appeared to be a trade-off between temperature and oxygen saturation for cod profiting from the availability of plenty of sprat prey by staying in combination of temperature and oxygen that maximizes the food processing rate. Schooling of sprat at the level of – or below – cod in the day time appeared to be an effective way of protection against predation as cod did not seem successful in capturing the sprat during this period. Reduction of metabolic costs of the starving sprat at low temperature may be the adaptive background for the ascents to and descents from the upper water layers of lower temperature at dusk and dawn where predation risk is reduced. Hence, a trade-off between predation and winter starvation mortality may explain the DVM behaviour of sprat under these environmental conditions.

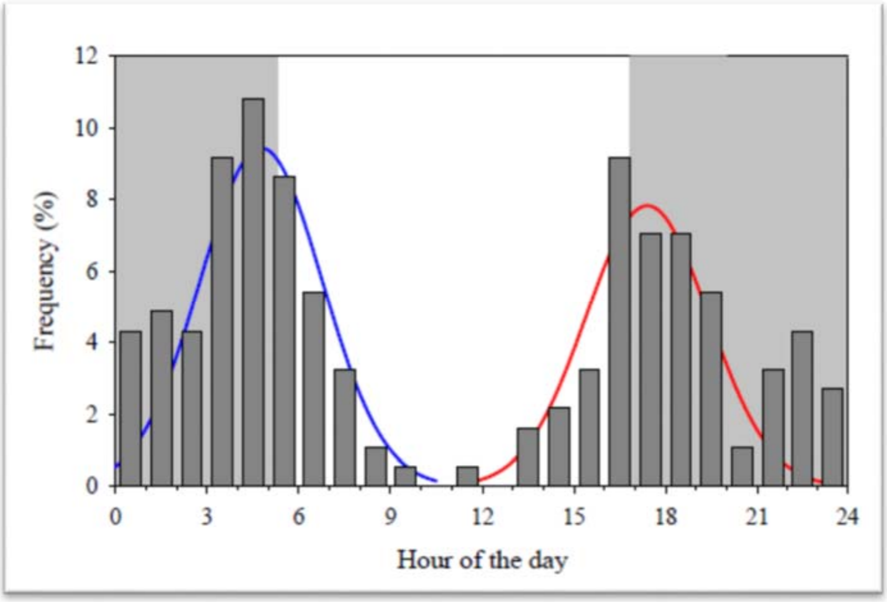

Fig. 12. Diel dynamics of Atlantic cod *Gadus morhua* feeding on sprat Sprattus sprattus. The columns represent the distribution of all estimated ingestion times (n =194) within a period of 24 h prior to sampling of the individual cod. The blue curve displays the normal distribution of all dawn-related estimates (for which ingestion within the dawn period could not be excluded), (i) assuming that the actual ingestion take place in the middle of the dawn period, (ii) using the mean S.D. of the estimates and (iii) scaling to the proportion of all estimates made up by the dawn-related estimates (n = 92). The red curve shows the same for the dusk-related estimates (n = 77). Sunrise and sunset are indicated by the transitions between white and grey background (Andersen et al., submitted).

Through estimation of diel pattern of cod food consumption coupled to the other information, Deliverable 2.6 presented an avenue for estimating the relative predation risk of pelagic forage fish at different times of the day. The present, empirical case study only represents the daily cycle in a winter situation at a limited location in the most important basin in the central Baltic Sea. Scaled to different seasons as well as to entire basin and beyond through dedicated field surveys, information obtained from the used methodologies in concert should ultimately enable establishment of aggregate functional response of the predator as well as quantification of trade-offs between for example winter starvation mortality/foraging opportunities/growth rate and predation risk for fitness optimization in life history models. The latter should moreover prove useful for forecasts of the upper trophic dynamics in scenarios enforced by global warming.

Source: Andersen NG, Lundgren B, Neuenfeldt S and Beyer JE. Vertical predator-prey interactions between Atlantic cod Gadus morhua and sprat Sprattus sprattus in the Baltic Sea. Marine Ecology Progress Series (submitted), INSPIRE deliverable 2.6.

3. Deviations from the workplan

There were no deviations from the workplan.

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Nilsson LAF, Thygesen UH, Lundgren B, Nielsen BF, Nielsen JR, Beyer J (2003) Vertical migration and dispersion of sprat (Sprattus sprattus) and herring (Clupea harengus) schools at dusk in the Baltic Sea. Aquat Living Resour 16:317–324

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WP 3 Scaling from individuals to populations

Lead: Patrick Polte, P7 (TI-OF)

1. Scientific highlights

Drift of eastern Baltic cod larvae and juveniles spawned in eastern Baltic cod spawning grounds was investigated using a Langrangian particle tracking model. The analysis was based on detailed drift model simulations for the years 1971-2010. For the first time, a drift study has been performed in which fertilized cod eggs have been released in historically important Baltic cod spawning grounds. These eggs drifted at levels of neutral buoyancy until they entered the first feeding state. The initial result on final distribution of cod eggs at the end of the embryonic phase were then used as starting points to subsequently model the drift of early stage larvae until their metamorphosis to the juvenile stage (90 days). In the case the drift transported the particles into non-suitable habitats, the particles were not assumed to resemble successfully recruiting juveniles. The results revealed that a limited proportion of juveniles, hatched in the Arkona Basin and in the Gotland Basin successfully settled in suitable areas. In general, the study confirmed the importance of habitat availability and its effect on density dependence as a process relevant for recruitment success.

Multiple studies adressed life stage specific distribution of early Baltic herring life stages and the regional factors affecting their survival. In a major spawning- and larvae retention area in the western Baltic Sea, results revealed indications for active habitat selection which differed between larval herring stages. Additionally, elemental fingerprinting from otoliths of young-of-the- year herring revealed specific signatures of the particular nursery areas for the population of western Baltic spring spawning herring. Otolith elemental fingerprinting is a novel approach and the results will be immensely valuable for investigating the numerical contribution of different juvenile habitats to the adult population. Local stressors, such as egg mortality caused by storm induced wave action might be important drives for western Baltic herring year class variability. Concerning the Gulf of Riga spring herring population, substantial progress was achieved in understanding the drivers of recruitment variability: hydroclimate (linearly combined effects of annual sum of sunshine hours and water temperatures in January-March) significantly affected inter-annual recruitment variability during 1957-2012. However, during the distinct periods of low and high SSB, winter water temperature and the Baltic Sea Index in December-March were the best predictors of recruitment, respectively.

2. Summary

The scope of this WP is to quantify the impact of small and meso-scale ecosystem drivers and stressors on population scale, spatial distributions and species recruitment dynamics. Especially for fish species with a high degree of habitat fidelity according to spawning grounds or nursery areas, impacts of local hazards might be transported to larger spatial scales and affect entire stock dynamics. The focus of the WP is on the contribution of certain spawning grounds/juvenile habitats to adult populations and effects of local scale mortality, for example hazards due to hot spot fisheries, predation on aggregations of juveniles, or regional climatic extremes such as severe storm events.

The question to be addressed is whether local hazards might shape large scale population abundance and recruitment strength and thus spatial distribution patterns.

WP 3 includes two major objectives:
1. To develop methods to scale individual movements of cod, herring, sprat and flounder (early life stages) to population distributions.
2. To perform process-studies collecting basic knowledge on regional hazards for population dynamics of Baltic herring and cod

Task 3.1 Scaling individual movements to populations' spatial distributions
Observed distribution patterns of early life stages have been put in relation to individual movement and migration analysis. The Kiel Baltic Sea ice-ocean model (BSIOM) and a Lagrangian particle-tracking technique have been used to evaluate drift patterns of cod and flounder eggs and larvae. The hydrodynamic model is coupled with an oxygen sub-model which describes the dissolved oxygen distribution in the water column with its seasonal and quasi-permanent extended areas of oxygen deficiency. This allows the consideration of oxygen concentration as the major contributor to egg-mortality and habitat suitability for the eastern Baltic Cod stock. The basis of the drift model study are realistic 4-dimensional temperature, salinity, oxygen and current velocity data provided by BSIOM. Drift simulations were performed to quantify processes generating

heterogeneity in spatial distribution of cod early life stages. The environmental conditions were tested in the different spawning grounds for suitability of spawning and egg survival probability. Furthermore, the population connectivity of eastern Baltic cod eggs and yolk-sac larvae was estimated. The study has shown that also particles representing eastern Baltic cod juveniles settled to a relatively large extent in the western Baltic cod management area, and may significantly contribute to western Baltic cod recruitment. Therefore, it could be suggested that not only immigration but also larval and juvenile transport could contribute to recruitment in the western Baltic Sea. However, it is also evident that the stock component in the Gotland Basin only to a minor degree contributed particles to nursery grounds in other ICES subdivisons (Hinrichsen et al. 2016a; Hinrichsen et al., submitted).

The development of the tracking model and according model simulations are in progress for flounder (Hinrichsen et al. 2016b). The aim is to provide temporally and spatially resolved distribution and settlement probability maps focusing on relative densities of juveniles within the different nursery areas. Results are submitted within the manuscript on the impact of active migrations in the observed distributional changes of cod (D3.1).

Task 3.2 Quantifying effects of regional hazards on larger scale productivity and spatial distributions

<u>Cod net displacement rates and time at large</u>

Process-based understanding of changes in commercial fish spatial distributions, and to disentangle the role of natural drivers and various anthropogenic impacts, is a challenging research topic with high relevance to resource management.
Especially in time of locally high recruitment, it is important to understand beforehand how the local recruitment is translated to stock recovery over the whole assessment area. In case of Baltic cod, there has been an increase in abundance in one of the Baltic basin (ICES Sub-division 25), resulting in density-dependent decrease of weight at length (Svedäng and Holmborg 2014). However, the specimen did apparently not migrate eastwards out of the basin in search for better feeding conditions.

Based on this more anecdotal though a bit surprising observation, we collected a database of historical tagging experiments on Baltic cod in order to investigate the hypothesis, that only a very small proportion of the tagged population actually undertakes ‘off-standard migrations’. The term ‘off-standard migrations’ includes those migrations which obviously are not related to either the ‘standard’ feeding and spawning migrations, which are with the exception of exchange between the Bornholm (ICES Sub-div. 25) and Arkona Basins (ICES Sub-div. 24), limited to within-basin migrations, but long-distance migrations typically longer than 100 km.

Data from 1236 cod recaptures from traditional tagging programs and 602 records from data storage tags, comprising depth, temperature and salinity every 10 minutes while at large, have been collected in the INSPIRE tagging database. Recapture rate represents <10 % of the actually tagged cod. Hence, to recapture the total of 1236 cod, more than 12 000 specimen had to be tagged.

A preliminary analysis of the traditional tagging data is presented here. 565 tag-recapture data-points indicate that cod in general do not perform long-distance migrations, but that only a small fraction (<10%) of the tagged population is conducting trans-basin migrations (Fig. 13A). Furthermore, the net displacement is independent of the time at large (Fig. 13B). There is hence no diffusion-like process at work. This means that adult cod migrations probably do not contribute to whole Baltic scale re-distributions of this species. Furthermore, it implies that regional stock recovery might not lead to recovery of cod in the whole Baltic Sea, but rather to regional regulation of stock size due to density-dependent processes.

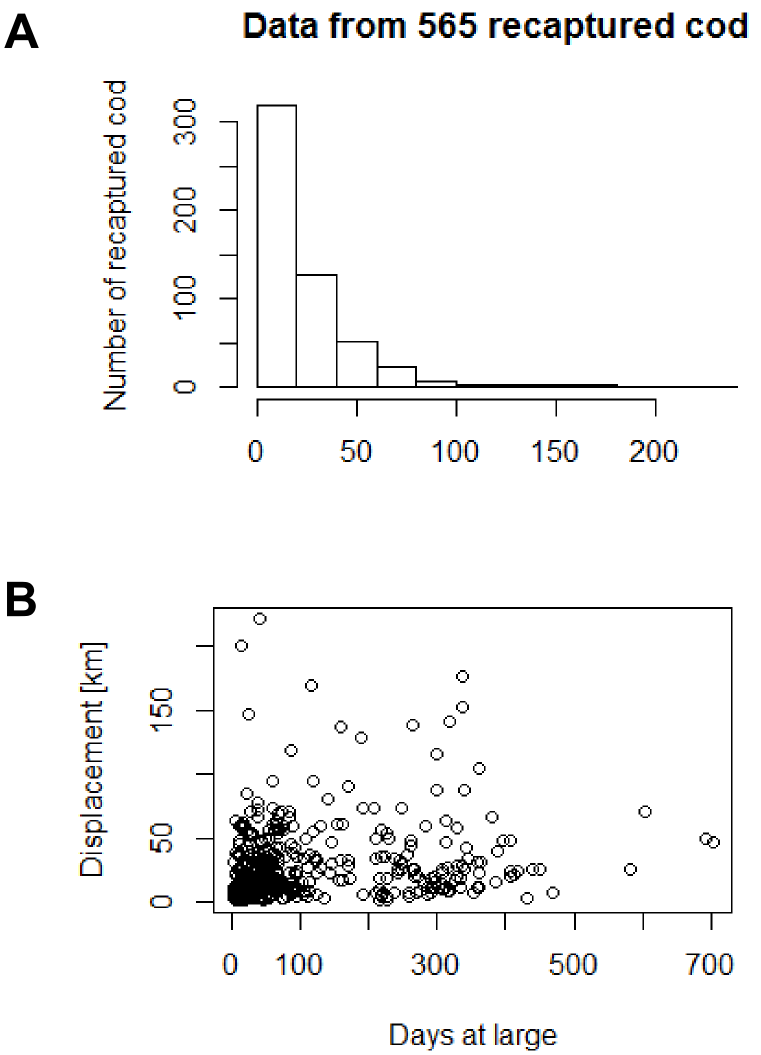

Fig. 13: Net displacement data from a sub-set of 565 recapture (Panel A); Net displacement verus days at large (Panel B)

This work was conducted in the ICES Study Group on Spatial Processes in the Baltic Sea that has been initiated to make INSPIRE results available for the ICES advice giving domain.

<u>Impact of active migrations on fish distribution</u>

General concepts of larval fish ecology in temperate oceans predominantly associate dispersal and survival to exogenous mechanisms such as passive drift along ocean currents. However, behavioural aspects of habitat selection are potentially important components of dispersal. This study is focused on larval Atlantic herring (*Clupea harengus*) distribution in a Baltic Sea retention area, free of lunar tides and directed current regimes, considered as a natural mesocosm.

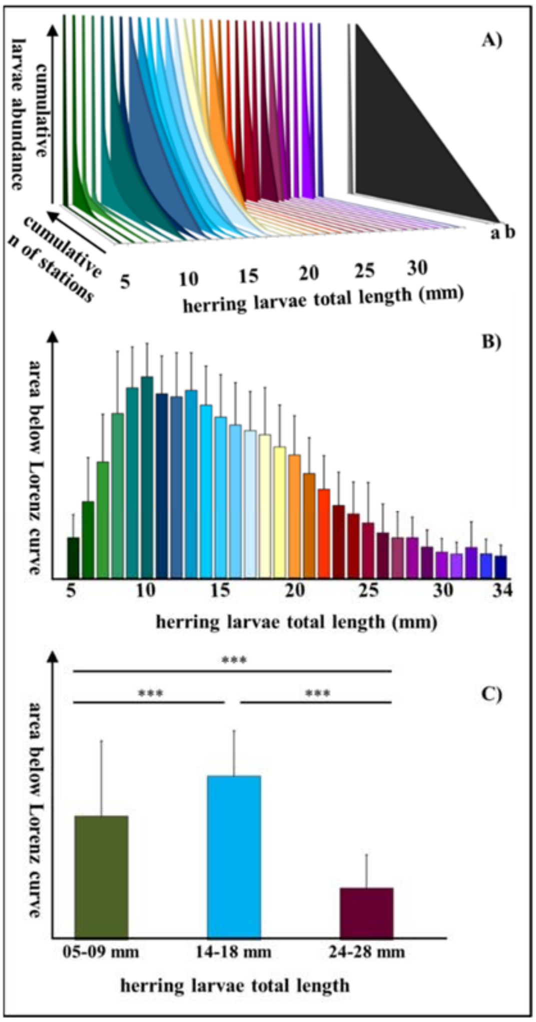

Fig. 14: Size-specific homogeneity of spatial distribution of herring larvae. A) Spatial homogeneity of herring larvae of different size classes (5-34 mm) plotted in a Lorenz curve design (exemplarily shown for 2011): a and b represent theoretical curves for maximum heterogeneity and homogeneity, respectively. B) Mean Homogeneity of larval distribution for each 1 mm length class aggregated for the years 1992-2014. Bars represent arithmetic means, error bars represent standard deviations. C) Mean area (and standard deviations) below Lorenz curve for selected length groups. Horizontal bars with asterisks indicate significant differences (*** represents a significance level of $p \leq 0.001$).

A Lorenz curve originally applied in socio-economics to describe demographic income distribution was adapted to a 20-year time-series of weekly larval herring distribution, revealing size-dependent spatial homogeneity. Additional quantitative sampling of distinct larval development stages across pelagic and littoral areas uncovered a loop in habitat use during larval ontogeny, revealing a key role of shallow littoral waters (Fig. 15). With increasing rates of coastal change, our findings emphasize the importance of the littoral zone when considering reproduction of pelagic, ocean-going fish species; highlighting a need for more sensitive management of regional coastal zones

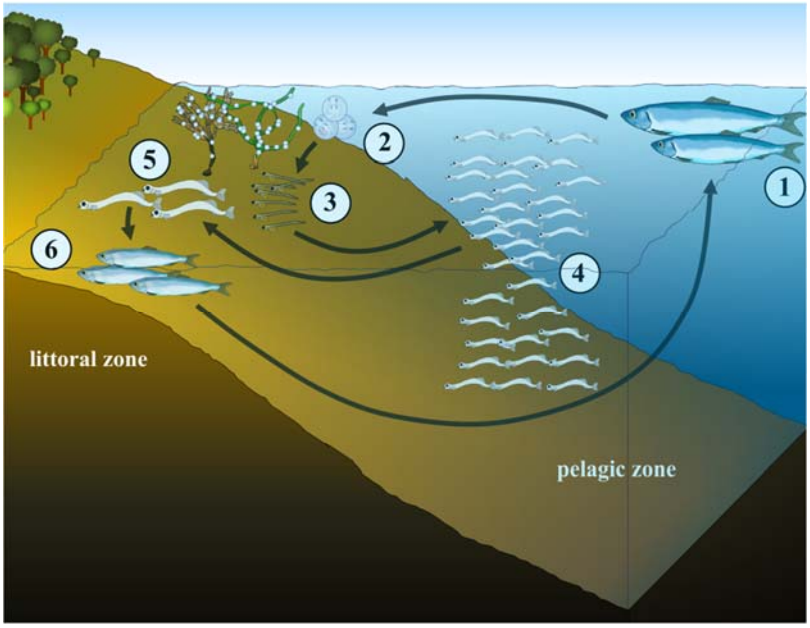

Fig. 15. Ontogenetic habitat loop of herring in the Baltic Sea. Adult herring (1) migrate from the offshore pelagial into inshore waters to spawn their adhesive eggs on littoral substrates such as macrophytes (2). Yolk-bearing hatchlings (3) appear concentrated in the vicinity of the spawning beds, while medium sized larvae (4) are rather horizontally well distributed in the pelagic area of the bay; however, their vertical distribution in the water column is significantly heterogeneous. Large larvae (5) return to shallow littoral areas where they remain even after their metamorphosis to juvenile fish (6). Growing juveniles migrate to offshore areas along their development and usually recruit to the spawning group after 2-3 years.

Source: Polte P., Kotterba P., Moll D., von Nordheim L. (2017) Ontogenetic loops in habitat use highlight the importance of littoral habitats for early-life stages of oceanic fishes in temperate waters. Scientific Reports 7:42709, DOI: 10.1038/srep42709

Identifying of nursery areas

Western Baltic populations of Atlantic herring (*Clupea harengus*) show a distinct homing behavior returning to particular spawning grounds every year during spring. Attributed to early life stage mortality, herring recruitment decreased in the western Baltic Sea during the past two decades. Since major drivers and stressors for herring reproduction are potentially introduced on the local scale of spawning and nursery grounds, the knowledge of the contribution of different nurseries to population dynamics is essential but challenging to investigate. We have used elemental fingerprinting in herring otoliths to detect differences in the chemical composition based on varying water chemistry in particular spawning areas along the German coast (Fig. 16). Cluster analysis revealed a distinct chemical separation between juvenile herring caught in the vicinity of the Island of Rügen (south-western Baltic Sea) and other potential nursery areas further west in the Baltic Sea. Element concentrations differed significantly among areas, indicating that otolith means to identify the origin of herring offspring and therefore the contribution chemistry is a suitable of particular nursery areas.

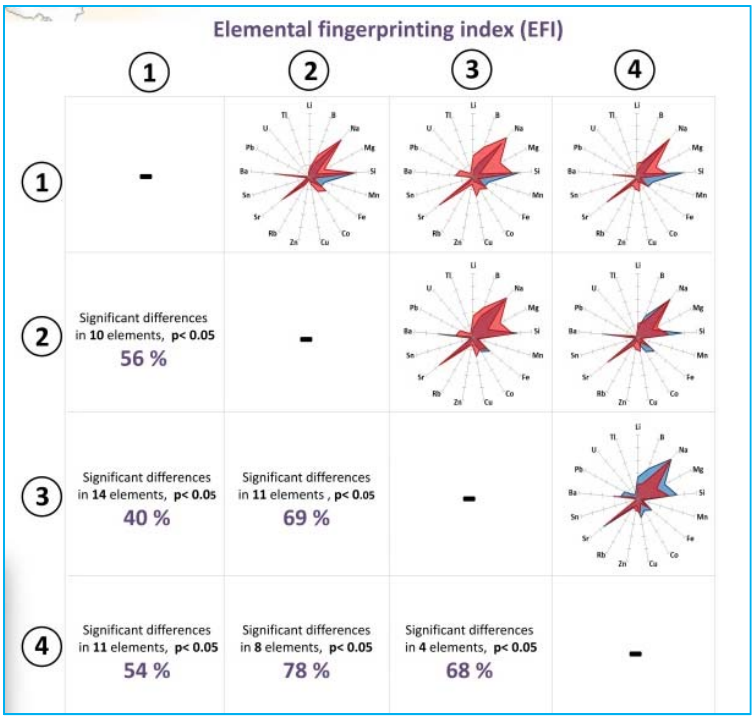

Fig. 16. The elemental fingerpinting index (EFI) is a measure of similarity of elemental composition in herring otoliths between spawning areas. In a defined order of elements, mean standardized element concentrations of 17 elements for each spawning area were visualized by radar plots. The index is derived by the congruence of areas resulting from specific element concentrations. Number of significant different elements (with significant level $p < 0.05$) are given for each spawning area comparison.

Further analyses of trace elements in otoliths from a random sample of adult herring will prove the ratio of individuals that originated in a certain nursery area. Otolith chemistry is considered a valuable tool for evaluating the contribution of different spawning areas to the adult population which could lead towards a more directed management of important spawning grounds and nursery areas.

Source: Moll et al. Using elemental fingerprinting in early life stages of Western Baltic herring (Clupea harengus) otoliths to distinguish different nursery areas (in prep.)

The role of small- and meso-scale drivers and stressors for overall Baltic herring recruitment

During their spring migration, Atlantic herring (*Clupea harengus*) populations in the Baltic Sea rely on shallow transitional waters, such as estuaries, bays and lagoons for spawning. Those inshore spawning grounds are ecologically important by providing suitable substrates for demersal egg deposition. However, these habitats are often highly impacted by multiple anthropogenic threats. Decades of eutrophication caused a decline in depth distribution of submerged aquatic vegetation, the main herring spawning substrate of *C. harengus* in the Baltic Sea. Nowadays spawning beds are often limited to shallow shore zones. Accordingly, macrophytes are increasingly exposed to mechanic forcing due to storm induced wave action.

Generally, reproductive success and year class strength of the Western Baltic herring population is strongly determined by the survival of early life stages such as eggs and larvae in local nursery areas. However, the explicit mechanisms by which local stressors might affect overall recruitment are currently not well understood.

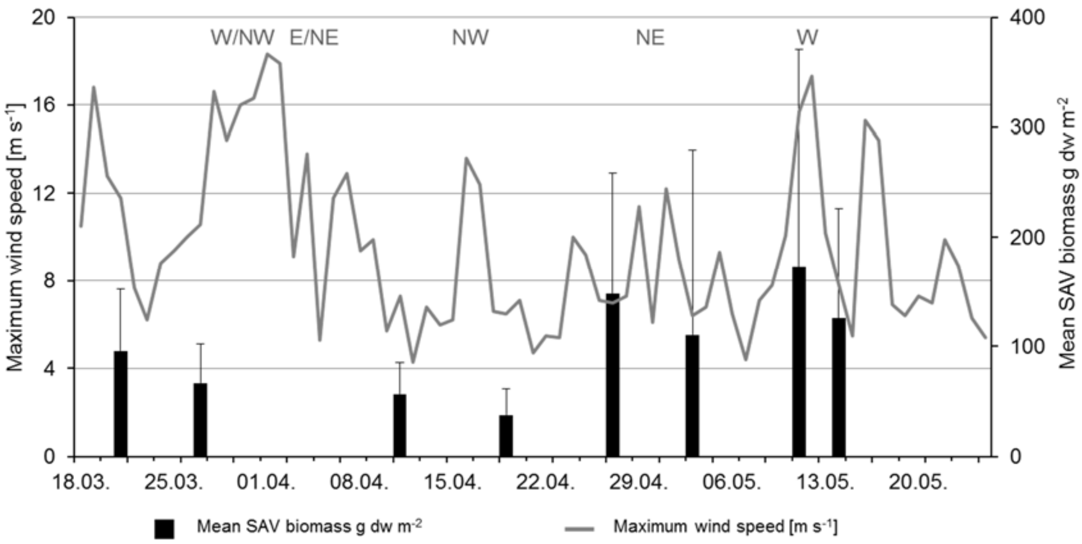

Fig. 17 Mean SAV biomass g DW m^{-2} (bars) with standard deviation along the spawning season 2012. The grey line represents the daily maximum wind speed [m s^{-1}].

Hypothesizing that a water depth limit of vegetation causes increased herring egg mortality due to high exposure to storm induced hydrodynamics, we performed a combination of field studies investigating the impact of storm events on herring egg loss. Results of egg loss experiments and - quantification of eggs attached to wrack on the shoreline revealed a total egg loss of 29% in one single spawning bed during a storm event within the spawning season. Our results emphasize the potential of regional weather extremes such as storm events to act as influential stressors for herring reproduction.

Source: Moll et al. Storm-induced Atlantic herring (Clupea harengus) egg mortality in Baltic Sea inshore spawning areas (submitted)

Impact of local temperature on herring recruitment

Processes occurring during early life-history stages influence the year-class abundance of marine fish. We found that the abundance of 1-year old spring spawning herring obtained from hydroacoustic estimates is statistically significantly (non-linear regression: n = 9, r^2 = 0.63, P<0.01) determined by the number of post-flexion herring larvae in the Gulf of Riga (Fig. 18) during 2005-2013. The abundance of consecutive developmental stages of larvae: yolk-sac, pre-flexion, flexion and post-flexion strongly correlated with each other, indicating that factors which already influence the yolk-sac stage are important in determining the abundance of postflexion herring larvae. Winter air temperature before spawning determined the timing of maximum abundance of pre-flexion herring larvae, but not their main prey: copepod nauplii, implying that different mechanisms governing major preconditions for the formation of year-class strength. The abundance of postflexion larvae displayed a potential dome-shaped relationship with sea surface temperature experienced after hatching. We suggest that increased summer temperatures, which exceed the physiological optimum, negatively affect the survival of post-flexion herring larvae. Overall, future climate warming poses an additional risk to larval herring survival and this may lead to a reduction in those herring stock which rely on recruitment from shallow coastal areas.

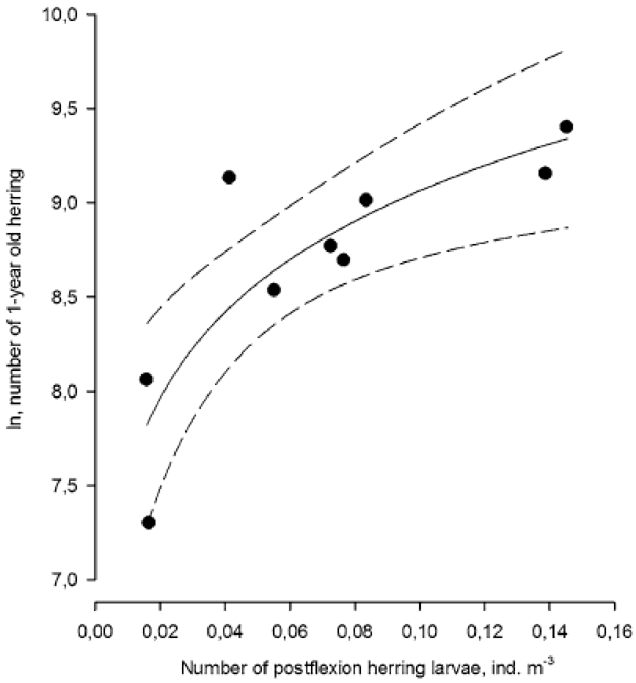

Fig. 18. Relationship between the number of post-flexion herring larvae and 1-year-old herring abundance (logarithmic scale) derived from hydroacoustic indices in the Gulf of Riga during 2004–2013. Non-linear regression with CI ± 95% (Arula et al. 2016).

Source: Arula, T., Raid, T., Simm, M., Ojaveer, H. 2016. Temperature-driven changes in early life-history stages influence the Gulf of Riga spring spawning herring (Clupea harengus m.) recruitment abundance. Hydrobiologia 767: 125-135.

Long-term dynamics of herring recruitment

Scientific interest in the dynamics of fish recruitment dates back to the beginning of the 20th century, when it was first understood that variations in catch could be related to variations in year-class strength. Since then, several studies have shown that the environment may have stronger effect on recruitment (R) than the spawning biomass (SSB), and that models including environmental variables significantly improved the predictions of recruitment. We have investigated the individual and combined effects of several abiotic and biotic variables on the inter-annual variability of the Gulf of Riga (Baltic Sea) spring herring R during 1957-2012. The linearly combined effects of annual sum of sunshine hours (SH_A) and water temperature in January-March (T_{JFM}) resulted in highest explanatory power of R over the entire time series (Fig. 19), while T_{JFM} and the Baltic Sea Index in December-March were the best predictors of R during the periods of low and high SSB. Although significant, the SSB as predictor was inferior compared to abiotic drivers. Non-stationary and non-linear functional relationships between R and its controlling factors were detected in more detailed modelling, with the effects of abiotic drivers depending on the mean level of SSB. In the same analyses, SSB was shown to have a notable effect on R during periods of relatively low water temperature, suggesting threshold-like transient links between R, SSB, and environmental forcing.

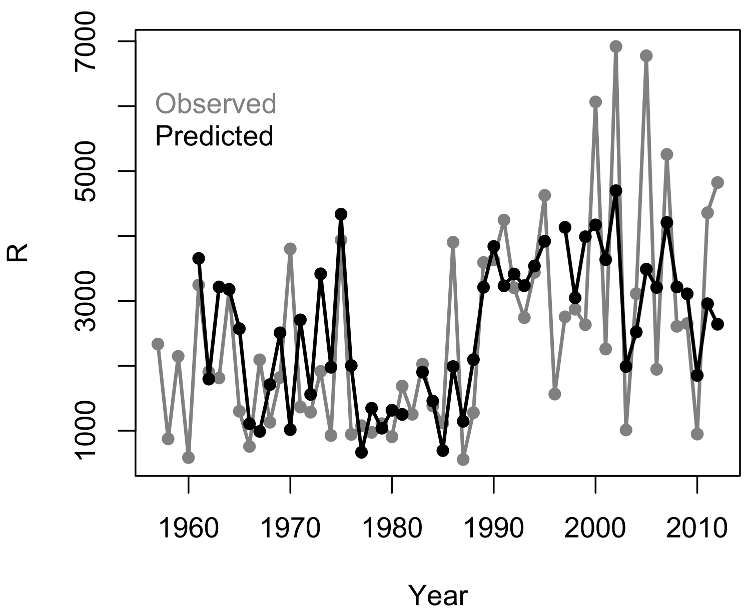

Fig. 19. Observed vs. predicted Gulf of Riga spring herring recruitment abundance dynamics. R = -6400 + 4.55*sun hours + 648* winter water temperature (R^2 = 0.45, p < 0.0001). 'Observed' data from Ojaveer et al. 2001 and ICES, 2015.

Source: Ojaveer, H., MacKenzie, B.R., Raid, T., Kornilovs, G. and Klais, R. Long-term transient recruitment dynamics of a herring population (submitted to ICES JMS)

3. Deviations from the workplan

There were no deviations from the workplan.

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WP 4 Stock Assessments
Lead: Jan Horbovy, P3 (MIR-PIB)

1. Scientific highlights
Cod assessment models using natural mortality (M) related to growth (and generally increasing in recent years) performed much better than the standard assessment models in which M is assumed constant; these assessments are better both in diagnostics of the model quality and consistency with the trends in survey indices of stock size. Statistical analyses of the effects of parasitic infection of cod on its condition and possibly mortality were made available to INSPIRE, and they suggest that natural mortality of heavy infected cod increased. This is consistent with behaviour of assessment models with increasing M, and coupled together indicate that natural mortality of eastern Baltic cod has probably increased markedly in recent years.

Conducted assessments of herring show similar trends in biomass development in former assessment units (AUs) and similar are trends in fishing mortality. The biomass of herring in sub-divisions 25-27 is about two times higher than the biomass of herring in sub-divisions 28-29+32. Opposite is estimated for fishing mortality. The sum of biomasses by AUs is very similar to biomass of Central Baltic Herring (CBH) estimated by ICES. Trial assessments indicate that the AU of herring in sub-divisions 28-29+32 should rather not be decomposed into smaller units. The merging of two AUs (herring in sub-divisions 25-27 and herring in sub-division 28-29+ 32) into one AU of CBH seems to be justified from assessment point of view. However, spatial management of the stocks could be recommended, then assessment and data by former AUs would be needed.

In general, assessments of sprat show trends in stock biomass and fishing mortality developments similar in the considered AUs (sprat in sub-divisions 22-25, sprat in sub-divisions 26+28, and sprat in sub-divisions 27,29-32) and sum of biomasses by AUs is close to ICES estimates of sprat biomass in the Baltic. The biomass of sprat in sub-divisions 26+28 is the biggest; in most years it was close to the sum of biomasses of other sprat stocks. Fishing mortality of this stock has been the highest in recent years. Merging of three AUs of sprat into one AU of sprat in the Baltic seems to be justified from assessment point of view. However, differences in intensity of exploitation (fishing mortality) of the stocks is substantial (fishing mortality being higher in the north-eastern areas) and spatial management could be considered. Such management would require assessment and data by former AUs.

The genetic data processed for flounder succeeded in discriminating between demersal and pelagic spawning ecotype and revealed a significant mix of the two ecotypes in assessment unit SD26+28. A database with the genotypes have been constructed. Morphometric analysis revealed that a combination of 11 landmarks could be used to discriminate among ecotypes with 71% accuracy.

2. Summary

The WP4 has two major objectives:

1. to include and quantify the effects of migrations and spatial and temporal changes in exploited fish distribution (cod, herring, and sprat) on stock assessment,
2. to provide assessment of the status of flatfish in the Baltic, as a basis for quantitative management of these stocks.

First deliverable for that WP was scheduled for month 36; it was D4.1. Report on assessments of herring, sprat and cod, including spatial effects (biomass distribution, natural populations). The deliverable was uploaded and provided to BONUS following time schedule (by 31 January, 2017).
The second deliverable is D4.2. Database for flounder assessment or stock evaluation by stock and is due in month 38, i.e. by end of March, 2017. Preparation of the deliverable is in progress.

Task 4.1 Assessment of fish stocks with inclusion of migration, spatial and temporal effects and taking into account impact of cod predation

Standard stock assessment approaches used by ICES do not take into account differences in spatial distribution of fish within assessment units/stocks, while decreasing overlap between cod and clupeids has been observed for several years. The aim of this task is to include differences in spatial distribution of fish stocks and fish migrations into the assessment models. Following this aim, the assessment of herring and sprat in the present assessment units (herring in the Central Baltic (sub-div. 25-29,32) and sprat in the whole Baltic) was verified by applying assessment models to stocks identified earlier on biological grounds in these units, 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.

In addition, failure of ICES standard assessment of Baltic cod required some work on this topic. In 2014 - 2016, International Council for the Exploration of the Sea (ICES) unexpectedly was unable to provide an analytical assessment of eastern Baltic cod stock, and factors such as data issues, assessment methodology, and the ecological situation of cod were indicated as the reasons for this failure (ICES, 2015). In light of these difficulties, some effort was put to perform assessment of the eastern Baltic cod stock as such assessment (or stock evaluation) is necessary to include cod effects on clupeids through cod predation and extend of overlap between cod and clupeids stocks.

<u>Cod stock assessments</u>

The work conducted in previous year on Baltic cod assessment was continued and resulted in published paper on the effects of varying natural mortality and selectivity on the assessment of eastern Baltic cod (Horbowy, 2016). In the paper it was shown that assessment models with increasing since 2007 natural mortality of cod perform much better than models with constant natural mortality in terms of the distribution of catch residuals and retrospective estimates of biomass and fishing mortality. The models with size-dependent selectivity did not perform better than other standard assessments. The assessment of generated stock (where the natural mortality was increasing) with constant natural mortality in the assessment model showed a poor distribution of residuals and strong retrospective patterns, similarly to the ICES eastern cod assessment with constant M. Results of the analyses provide strong suggestion that one of the important difficulties in present analytical assessment of eastern Baltic cod results from probable increase in natural mortality not accounted for in the recently applied models in ICES assessment. The performed analyses suggest increase of mean natural mortality (mean of estimates by age weighted by biomass of age groups) from 0.3-0.4 in 2007 to 0.6-0.7 in 2013.

In addition, statistical analyses of cod infection with nematodes was made available to INSPIRE, revealing significant negative effects of the parasitic infection on cod condition and probably negative effects on cod natural mortality. Data from the southern Baltic from 2011 – 2014 were inspected and the analyses showed that both prevalence and intensity of infection were increasing with length (which was expected) but next peaked up and declined for bigger cods (Horbowy et. al., 2016). However, following the model of des Clers (1989) and Horbowy and Podolska (2001) the intensity of infection should increase due to accumulation of parasites during the host life. At least part of the discrepancy between the Horbowy and Podolska (2001) model and the model fitted basing on observations may be related to increasing mortality of older and heavily infected cods

Analyses presented in both papers suggest that natural mortality of cod underwent marked changes in recent years, showing generally increasing trend.

<u>Herring and sprat stock assessments</u>

Details of the analyses aimed at stock assessments have been provided in Deliverable 4.1. Below mainly summary of obtained results is presented.
Compilation of the data for assessment of herring and sprat stocks by assessment units (AUs) used up to early 1990s (initialised in previous year) was finished and the data were used for assessment of the stocks. These includes data for separate assessment of herring in sub-divisions 25-27 and 28.2-29+32 and sprat in sub-divisions 22-25, 26+28, and 27+29-32. Compiled data include catch and weight at age by sub-division, tuning data at age by fleet and sub-division, and natural mortality estimates (including mortality component due to predation) by assessment unit.

The basic mathematical models applied for the stock assessments of herring and sprat were XSA (Shepherd, 1999) and SAM (Nielsen and Berg, 2014). These models are routinely used by ICES when performing quantitative analysis of development of stock biomass and intensity of fisheries (ICES, 2016a). However, when performing stock assessments by former assessment units it was observed that estimated by assessment model survey catchabilities were different by AUs. This was rather unexpected result as all surveys were coordinated by Working Group on Baltic International Fish Survey (WGBIFS) and followed the same methodology (ICES, 2016b). Thus, in addition to assessments with XSA and SAM, a cohort analysis model in which catchability was external parameter to the model was developed. Such cohort analysis (referred to as CohAnalQ) with the same catchability for AUs (taken as average of catchabilities estimated for AUs by XSA) was used for comparative assessments.

The script in R was developed to perform with XSA several assessments in a row with sets of different parameters, which facilitated assessments and selection of optimal parameterisation.

Herring

The basic aim of the herring assessment by former stock assessment units, *i.e.* herring in sub-divisions 25-27 and herring in sub-divisions 28-29+32, was to check if the dynamics of herring in these units is similar, so that the merging in 1990s of AUs into one stock of Central Baltic Herring is still justified.
In Figure 20, the biomasses and fishing mortalities from XSA, SAM, and CohAnalQ by former AUs are presented and their sums or average are compared to SSB and fishing mortality estimated for CBH stock. It appears that sums of herring SSB's in both former AUs estimated with XSA and CohAnalQ are very similar to the SSB estimated by ICES (2016a) for CBH. Similarly, average fishing mortality by AUs is similar to the F estimated for CBH. However, the XSA estimates of fishing mortality of herring in sub-divisions 25-27 are unexpectedly low in recent years and the share of biomass of herring in sub-divisions 25-27 to herring biomass in CBH area is in recent years higher than such share estimated in acoustic surveys (Fig. 21). On the other hand, the biomass estimates from SAM assessment indicate too low share of southern herring biomass (sub-divisions 25-27) in biomasses in CBH area, compared to survey results.

As already indicated the catchabilities obtained in XSA analyses were quite different in AUs and that was the reason for conducting additional assessments, using cohort analysis with the same catchability for both AUs. The catchability applied was an average of catchabilities estimated for both AUs in XSA. For such assessment sum of biomasses estimated for AUs is also very similar to biomass of CBH estimated by ICES, and similarly close to ICES estimates of fishing mortality is average of F estimates by AUs. However, now the share of biomasses in both assessment units is much closer to the share of these biomasses resulting from survey (Figs. 20 and 21).

The conducted assessments do not provide clear indication on absolute level of biomass by assessment units in recent years; the biomass estimates for given AU differ in recent years by about +/- 30% depending on the assessment approach applied. However, performed assessments show very similar trends in biomass development of herring in both AUs and similar are trends in fishing mortality. The biomass of herring in sub-divisions 25-27 is about two times higher than the biomass of herring in sub-divisions 28-29+32. Opposite is estimated for fishing mortality. The growth of herring in the northern areas is lower than that in the south, the biomass of herring in sub-divisions 25-27 in investigated years was higher than biomass of herring in sub-division 28-29+ 32 and fishing mortality of that stock was lower.

The merging of two AUs (herring in sub-divisions 25-27 and herring in sub-division 28-29+ 32) into one AU of CBH seems to be justified from assessment point of view. However, spatial management of the stocks requires assessments and data by former AU.

In addition, to above analyses of herring dynamics, the following assessment units of herring were considered in trial assessments in north-eastern Baltic: herring in sub-division 28.2, herring in sub-division 29, herring in sub-division 32, herring in sub-divisions 29+32, herring in sub-divisions 28.2+29+32 (Raid et. al., 2016). The most reliable results were obtained for the assessment unit covering sub-divisions 28.2, 29 and 32 and this area may also be the most inclusive concerning the whole distribution area of the herring that occur in the Gulf of Finland. The results also suggest that the assessment results of smaller assessment areas may be substantially influenced by unknown rate of migration and mixing of herring from smaller stock units (Raid et. al., 2016).

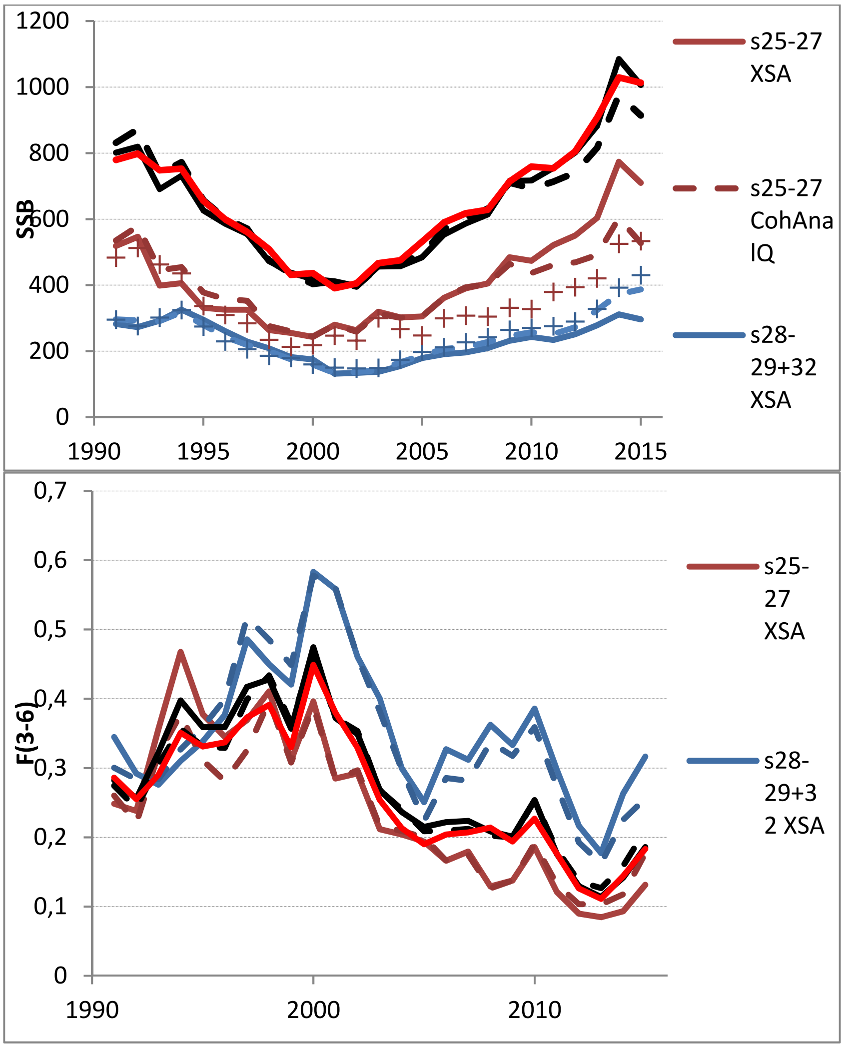

Fig. 20. Comparison of biomass and fishing mortality estimates by former assessment units (AU) with ICES assessment of central Baltic herring (CBH) stock.

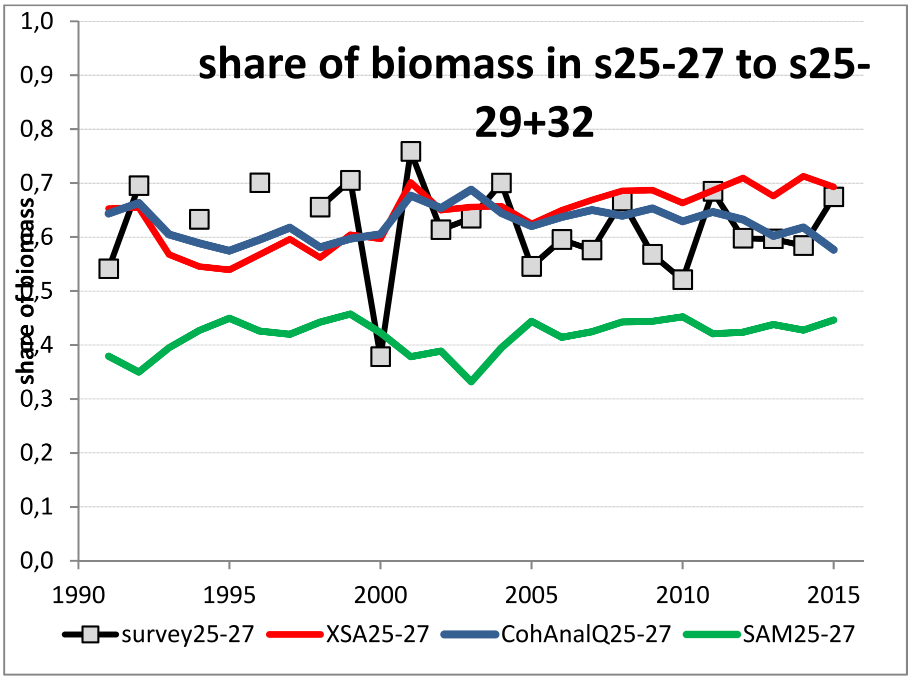

Fig. 21. Share of biomass estimates of herring in sub-divisions 25-27 to biomass in CBH area (sub-divisions 25-29+32) derived from acoustic surveys, XSA, cohort analysis with assumed catchability (CohAnalQ), and SAM.

Sprat

The basic aim of the sprat assessments by former stock assessment units, *i.e.* sprat in sub-divisions 22-25, sprat in sub-divisions 26+28, and sprat in sub-divisions 27,29-32, was to check if the dynamics of sprat in these units is similar, so that the merging in 1990s of former assessment units into one stock of sprat in the Baltic (sub-divisions 22-32) is still justified. In Figure 22 the biomasses and fishing mortalities by former AUs are presented and their sums or averages are compared with SSB and fishing mortality estimated for sprat stock in the whole Baltic Sea.

It appears that sum of sprat SSB's by former AUs estimated with XSA is very similar to the SSB estimated by ICES (2016a) in present assessment of sprat in the Baltic. Similarly, average fishing mortality by AUs is very close to F estimated by ICES for Baltic sprat (Fig. 22). Estimates from SAM model are not presented in the figure as they are similar to the XSA values.

As already indicated the catchabilities obtained in XSA analyses were quite different in AUs and that was the reason for conducting additional assessments, using cohort analysis with the same catchability for all AUs (CohAnalQ). The catchability applied was the average of catchabilities estimated for three AUs in XSA. For such assessments sum of biomasses estimated for AUs is also very similar to biomass of sprat in the whole Baltic estimated by ICES, and similarly close to ICES estimates of fishing mortality is average of F estimates by AUs (Fig. 22). However, the assessments assuming the same catchabilities better reflect the survey derived share of biomasses in assessment units. Share of biomass in AU in the total biomass is now somewhat closer to the respective share of biomass from the October survey but differences for sprat in sub-divisions 22-25 and sprat in sub-divisions 27,29-32 are still quite large. Better consistency in this respect is observed for the May survey – applying CohAnalQ model made share of sprat biomass in sub-divisions 26+28 closer to share of respective survey biomass than in case of XSA estimates (Fig. 23).

The conducted assessments provide rather consistent estimates of biomass and fishing mortality by AUs. However, some differences between assessments obtained in biomass estimates for recent years for sprat in sub-divisions 22-25 and sprat in sub-divisions 27,29-32 made these two assessments uncertain. On the other hand, quite large differences in recent years biomass estimates for these stock between XSA or SAM and CohAnalQ is not surprising as the differences between catchabilities for sprat AUs are big (at a level of 2-4), much bigger than in the case of herring assessment. In general, trends in stock biomasses and fishing mortality development are similar for all three stocks. The biomass of sprat in sub-divisions 26+28 is the biggest; in most years it was close to sum of biomasses of other sprat stocks. Fishing mortality of this stock has been the highest in recent years, and the lowest was exploitation rate of sprat stock in sub-divisions 22-25.

The assessment of sprat in sub-divisions 27,29-32 was performed with natural mortality of 0.2 (residual natural mortality) as there is almost no overlap with cod in this area. The question arises if this level of natural mortality is not too low. The trial assessment with M of 0.3 produced stock size about 30% higher and fishing mortality almost 25% lower than in the assessment with M=0.2.

The merging of three AUs (sprat in sub-divisions 22-25, sprat in sub-divisions 26+28, and sprat in sub-divisions 27,29-32) into one AU of sprat in the Baltic seems to be justified from assessment point of view. However, possible spatial management of sprat resources requires assessments and data by former AUs.

Task 4.2 Stock identification of flounder in the Baltic Sea

The aim of this task is to develop tools to be used for identification of different flounder stocks to enable allocation of catch to different spawning types of flounder in different fisheries in the Baltic Sea.

In year 3 all genotyping was finished, in total 1053 adults and 388 juvenile flounder from several places around the Baltic Sea have been genotyped for 16 microsatellite markers. Analysis of the genetic data showed a clear structure of two clusters which, according to our reference material with known ecotype, corresponded to the flounders with pelagic and demersal eggs respectively. There was no strong differentiation within clusters. Looking at current management units these results suggest that SD 24-25 is dominated by pelagic ecotype, while SD 27,29-32 is dominated by demersal flounder but in management unit SD 26+28 there could be equally much of the ecotypes.

Additionally, analysis of morphometric data, with 11 landmarks and 18 associated morphometric distances coupled with genetic data revealed that there was a significant difference between spawning types but also between sampling areas and the largest difference was between sexes. Nevertheless, a discriminant function based on morphometrics was able to successfully classify 71% of fishes to correct spawning type.

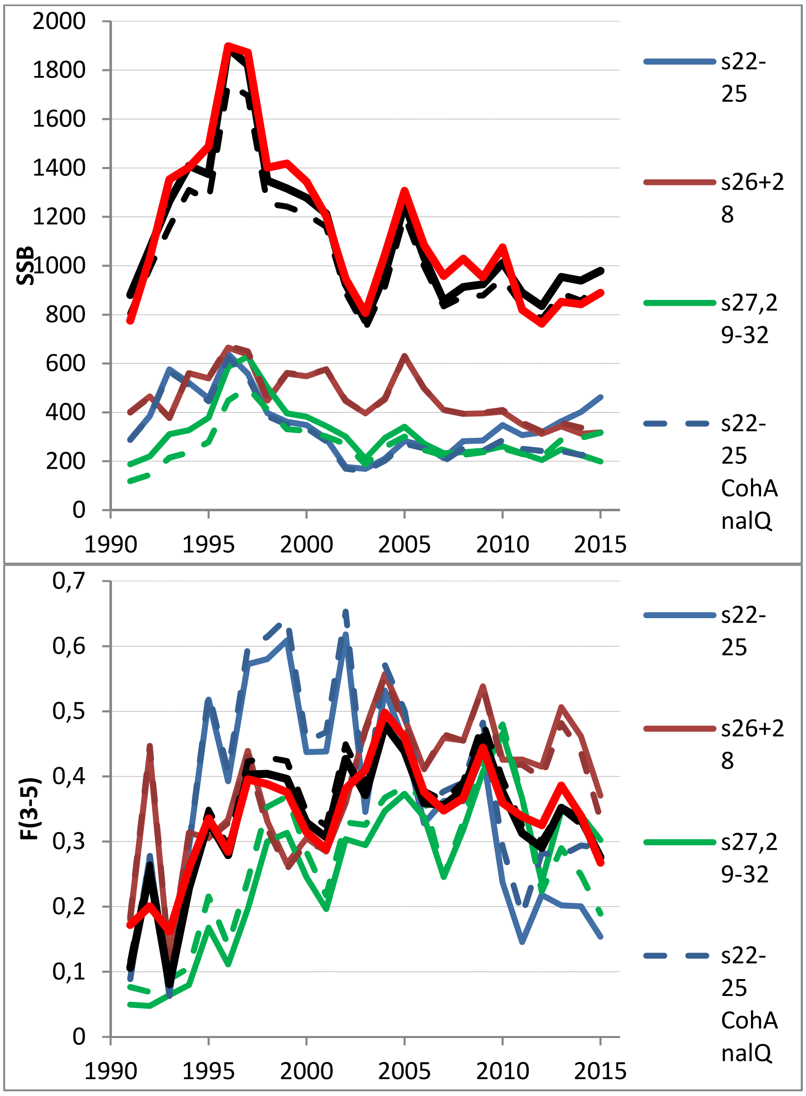

Fig. 22. Comparison of biomass and fishing mortality estimates by former assessment units (AU) with ICES assessment of sprat in the whole Baltic.

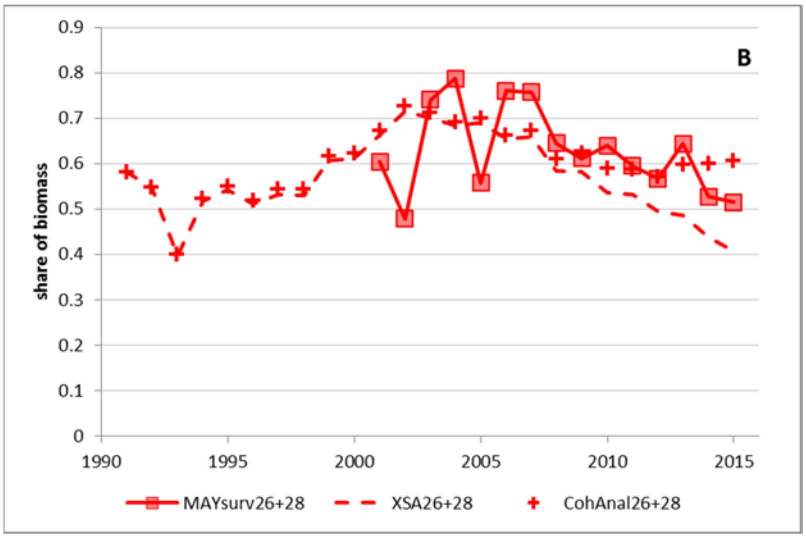

Fig. 23. Share of biomass estimates of sprat in sub-divisions 26+28 to biomass of sprat in whole Baltic (sub-divisions 22-32) derived from acoustic surveys, XSA, cohort analysis with assumed catchability (CohAnalQ). B=May survey.

Task 4.3. Data analysis and analytical assessment or evaluation of flatfish stocks

So far there is no accepted analytical assessment of flatfish stocks in the Baltic and ICES provides management advice on the basis of survey indices of stock size. Such advice is only approximate. The aim of this task is to provide analytical assessment or evaluation of the Baltic flatfish stocks, taking into account differentiation into populations (e.g. demersal and pelagic flounder) determined within Task 4.2. Depending on availability of data different approaches will be attempted for different stocks (e.g. catch curve analysis, stock-production models, length based models, age-structured models, random effect or Bayesian approaches). In addition, some standard approaches like ASPIC and/or Collie & Sisenwine (1983) will be tested.

Development of two specific stock-production models in spreadsheet has finished. One model is a difference model of Horbowy (1992) and the other is difference Schafer model in which demographic method to get estimate of intrinsic rate of increase (r) is used (McAllister et al., 2001). In addition, length structured model of stock assessment is under development and will be tested on flounder stock that year.

The compilation of data and preparation of data base for evaluation or assessment of flounder stocks is in progress. This includes age-structured data (catches and survey results), length distributions of catches and surveyed biomass, fishing effort and/or catch per unit of effort (CPUE), results of national surveys. The workshop on flatfish assessment will be organised in early June to facilitate preparation of deliverable 4.3, i.e. report on the assessment of flatfish stocks.

3. Deviations from the workplan

There were no major deviations from the workplan.
The deadline for Deliverable 4.2 was postponed by 2 months (from month 36 to month 38, approved by BONUS Secretariat) due to unexpected complexity of various sources and types of information, and additional time needed for validating and harmonizing data.

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WP 5 Ecosystem based management

Lead Jari Raitaniemi, P9 (LUKE)

1. Scientific highlights

Implications of merging smaller fish stock assessment units into larger ones was evaluated from both assessment and management point of view. The project has developed estimates of biomass and fishing mortality of clupeids by former assessment units (which were smaller) and compared those with the assessment units used in nowadays. The process to estimate biological reference points for former assessment units has also started. In addition, the method of estimating maximum sustainable yield (MSY) parameters when growth and natural mortality are density dependent, was developed and applied to Baltic sprat. It appeared that density dependence has huge impact on the MSY and related fishing mortality estimates.

Predator-prey interactions and intra-specific density-dependence are essential to explain temporal variation in the food-web indicators. When accounting for these interactions, the indicators overall respond to multiple pressures acting simultaneously rather than to single pressures. The manageable pressures fishing and eutrophication, as well as the prevailing hydrological conditions influenced by climate, were all needed to reproduce the inter-annual changes in the food-web indicators combined. Our indicator-testing framework can therefore be used to identify responses of food-web indicators to manageable pressures while accounting for the biotic interactions in food-webs linking such indicators.

Dynamics of different stock components over time has huge implications to both assessment and management of fishery resources. Reasons behind the drastic decrease and almost disappearance of autumn herring in the Gulf of Riga were invesrtigated. Initial results indicate that catches were higher in the 1920s and 1930s than in the late 1940s and the early 1950s and peaked again in the turn of the 1950s and the 1960s. Since then the catches have declined and remained low. Fishing mortality was very high, and the exploitation was probably too high to ensure long-term sustainability ($F > F_{msy}$).

The quantitative analyses of stock mixing presented with contributions from INSPIRE scientitst were an important contribution to facilitate the transition from area-based to stock-based assessments of cod in the Baltic Sea in 2015. Information on the annual proportions of eastern and western cod found in the western Baltic management area allowed allocating fisheries catch to the populations of origin, and performing stock assessments for the two biological populations separately. This change provides a more realistic picture of the dynamics of western Baltic cod population that were masked in the earlier area-based assessments by increasing proportions of the eastern Baltic cod in the area.

Several INSPIRE scientists have been involved in the Baltic implementation of the Ocean Health Index by invitation in order to ensure a high quality in the data assessment.

2. Summary

Research carried out in WP5 was attempted to answer the question if the merging of smaller assessment units in the 1990s into bigger ones is still justified from both assessment and management point of view, especially in the light of changed species distribution and changed overlap between cod and clupeids. The methodology for the estimation of MSY parameters (maximum yield, Fmsy, B at Fmsy), when growth rate and predation mortality are density dependent, was developed and applied to the Baltic sprat stock.
By using multivariate autoregressive time series models, we have identified how fish indicators in an exploited food-web relate to fishing, climate and eutrophication, while accounting for the linkages between indicators caused by species interactions. Food-web indicators for marine management are required to describe the functioning and structure of marine food-webs. In Europe, the Marine Strategy Framework Directive (MSFD), intended to lead to a ‘good environmental status’ of the marine waters, requires indicators of the status of the marine environment that also respond to manageable anthropogenic pressures.

The history of the Gulf of Riga autumn-spawning herring was studied to reconstruct the century-scale development of landings and investigate the reasons behind the drastic decrease and almost disappearance of autumn herring in the Gulf of Riga. In general, our results show that exploitation occurred both on juveniles and adults and was probably too high to ensure long-term sustainability (i.e. $F > F_{msy}$). These findings provide a quantified perspective to the historical dynamics and potential management targets for the future.

In addition, mixing of cod between ICES sub-divisions 24 and 25 was thoroughly investigated and ecosystem state of the Baltic Sea has in addition ot the work programme been assessed by participation in implementing the Baltic Health Index (BHI).

Task 5.1. Importance of including spatio-temporal heterogeneity into stock assessments for ecosystem-based management

<u>Relevance of spatial scale in cod assessment and management</u>

In the Baltic Sea, two genetically distinct cod populations occur, the eastern and the western Baltic cod. Since 2006, cod abundance has increased substantially in the Arkona Basin (SD 24), the potential mixing area between the two stocks management areas, presumably due to spill-over from the eastern stock. The spatio-temporal dynamics of stock mixing were analysed using shape analysis of archived otoliths. Further, the impact of eastern cod immigration on recruitment in the western Baltic Sea was investigated using hydrographic drift modelling. The percentage of eastern Baltic cod in the Arkona Basin increased from ca. 30% before 2005 to >80% in recent years. Geographic patterns in stock mixing with a pronounced east–west trend suggest that immigration occurs north of Bornholm, but propagates throughout the Arkona Basin. The immigration cannot be attributed to spawning migration, as no seasonal trend in stock mixing was observed. Based on environmental threshold levels for egg survival and time-series of hydrography data, the habitat suitable for successful spawning of eastern cod was estimated to range between 20 and 50% of the maximum possible habitat size, limited by primarily low salinity. Best conditions occurred irregularly in May–end June, interspersed with years where successful spawning was virtually impossible. Using a coupled hydrodynamic modelling and particle-tracking approach, the drift and survival of drifters representing eastern cod eggs was estimated. On average, 19% of the drifters in the Arkona Basin survive to the end of the yolk-sac stage, with mortality primarily after bottom contact due to low salinity. The general drift direction of the surviving larvae was towards the east. Therefore, it is the immigration of eastern cod, rather than larval transport, that contributes to cod recruitment in the western Baltic Sea.

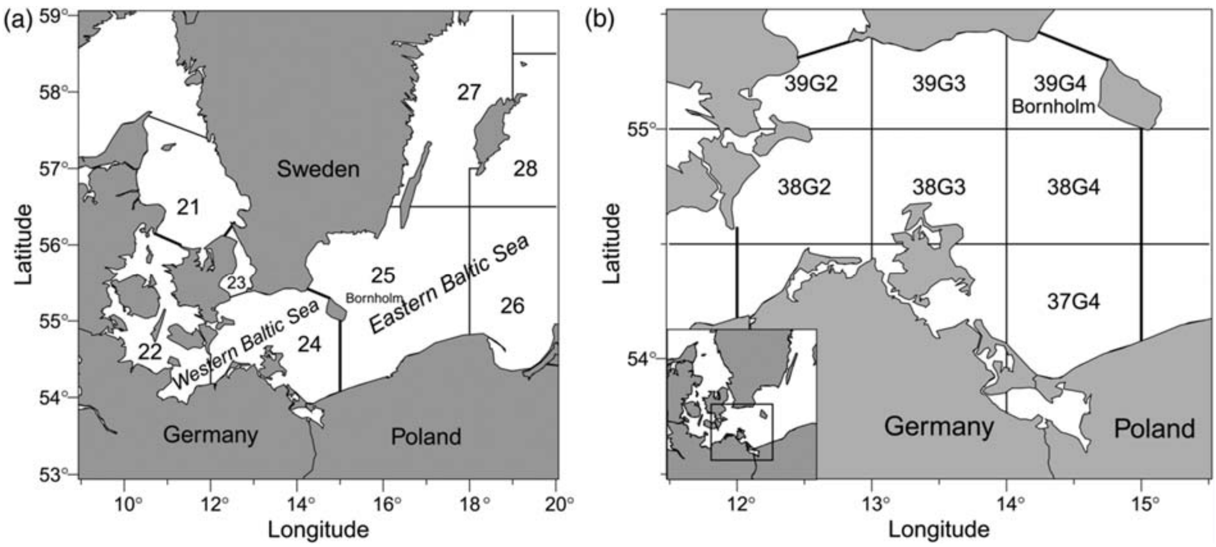

Fig. 24. (a) Map of the southern Baltic Sea. Numbers indicate ICES SD, thin lines indicate SD boundaries, and solid lines the boundaries between the Kattegat, western and eastern Baltic Sea management areas. (b) Map of the Arkona Basin (SD24) in the western Baltic Sea. Lines indicate the statistical rectangles with rectangle names; bold lines mark the boundaries of SD 24. The inset shows the location of SD 24 in the Baltic Sea.

The quantitative analyses of stock mixing presented with contributions from INSPIRE scientists were an important contribution to facilitate the transition from area-based to stock-based assessments of cod in the Baltic Sea in 2015. Information on the annual proportions of eastern and western cod found in the western Baltic management area allowed allocating fisheries catch to the populations of origin, and performing stock assessments for the two biological populations separately. This change provides a more realistic picture of the dynamics of western Baltic cod population that were masked in the earlier area-based assessments by increasing proportions of the eastern Baltic cod in the area. Continued monitoring of the proportions of eastern and western cod populations within the western Baltic Sea is needed for long-term sustainable management of the two stocks.

Methodology to estimate MSY parameters

Within task 4.1, the Deliverable 4.1, ‘Report on assessments of herring, sprat and cod, including spatial effects (biomass distribution, natural populations)’, was produced and provided to BONUS. As part of this deliverable, the assessments of fish stocks by former assessment units (AUs) (which were smaller) and using predation mortality from cod, estimated for given area, were performed. The overlap between clupeids and predator (and resulting from this overlap predation mortality) is in such assessments taken into account much more realistically than in standard ICES assessments, in which estimates of predation mortality are assumed to be valid over larger assessment units.
In this deliverable, it was attempted to answer the question if the merging of the smaller assessment units in 1990s into bigger ones is still justified from both assessment and management point of view, especially in the light of changed species distribution and changed overlap between cod and clupeids. However, important effects of deliverable 4.1 are the estimates of dynamics of clupeids stocks (in terms of biomass, fishing mortality and recruitment), that take into account cod-clupeids overlap in a much more realistic way than standard ICES assessment. These estimates provide data for derivation of stock-recruitment relationships for former AUs. Such stock-recruitment relationships with the biological parameters referring to AUs will be used for estimation of biological reference points (BRP) for previously defined stocks. Both BRP referring to MSY and to precautionary approach will be considered. Next, comparing the estimated BRP with obtained within task 4.1 stock dynamics will enable the evaluation of stock management with respect to BRP and advice on eventual changes in management of clupeids.

As a part of the activity within task 5.1, the methodology for the estimation of MSY parameters (maximum yield, Fmsy, B at Fmsy), when growth rate and predation mortality are density dependent, was developed and applied to the Baltic sprat stock. In addition, the effects of cod biomass on the estimates were analysed. The study was based on long-term deterministic and stochastic simulations, in which sprat density-dependent growth and predation mortality were considered. The resultant model is a relatively simple tool that allows for streamlined analyses of problems typically approached using complex multispecies models.

The analysis indicates that estimates of the MSY parameters and equilibrium biomass differ significantly between approaches that hold growth and natural mortality constant, and those that allow for density-dependent growth and natural mortality (Fig. 25). Based on the cod biomass observed in the 1980s, the MSY parameters estimated by a model that accounts for density-dependent growth and by a model assuming constant growth may differ by a factor of 2. As such, the MSY parameters decline (approximately linearly) with the size of the cod stock (Horbowy & Luzenczyk 2016).

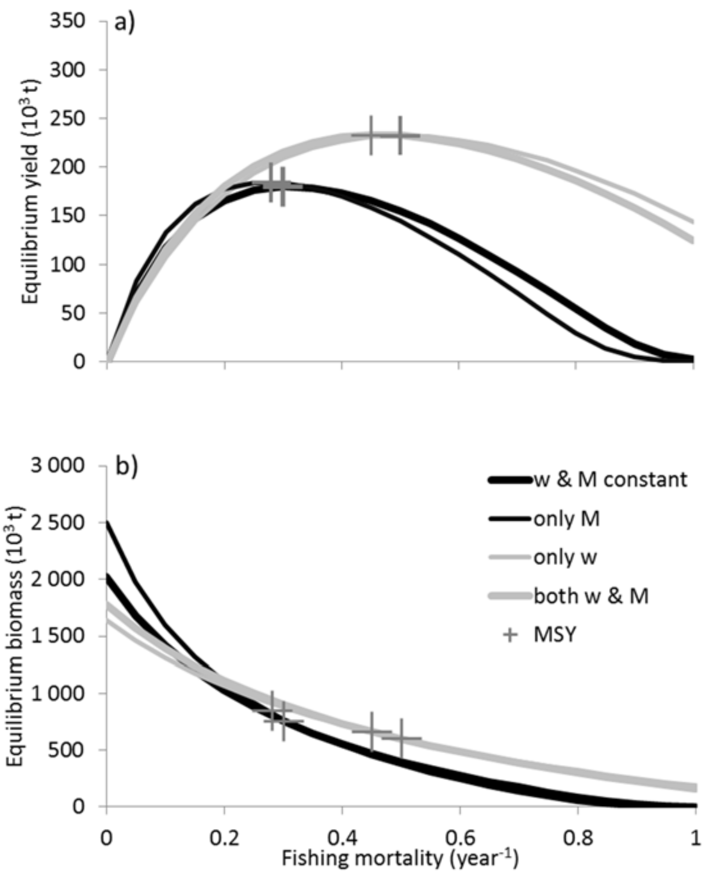

Fig. 25. Equilibrium yield (a) and biomass (b) of sprat relative to fishing mortality for the four combinations of density-dependent and constant growth and natural mortality: density-dependent weight and natural mortality (both w and M), density-dependent w (only w), density-dependent M (only M), and constant w and M (w and M constant). Cod biomass assumed at 200 thousand tons.

Source: Horbowy, J., Luzenczyk, A. 2016. Effects of multispecies and density dependent factors on MSY reference points: Example of the Baltic Sea sprat. Can. J. Fish. Aquat. Sci. DOI: 10.1139/cjfas-2016-0220 (accepted).

Task 5.2. Importance of spatial heterogeneity in defining Baltic-specific MSFD indicators

Impact of external stressors on fish indicators

Food-web indicators for marine management are required to describe the functioning and structure of marine food-webs. In Europe, the Marine Strategy Framework Directive (MSFD), intended to lead to a 'good environmental status' of the marine waters, requires indicators of the status of the marine environment that also respond to manageable anthropogenic pressures. Identifying such relationships to pressures is particularly challenging for food-web indicators, as they need to be disentangled from linkages between indicators of different functional groups, caused by species interactions. Still, such linkages have not been handled in the indicator development.

We used multivariate autoregressive time series models to identify how fish indicators in an exploited food-web relate to fishing, climate and eutrophication, while accounting for the linkages between indicators caused by species interactions. We assembled 31-year long time series of indicators of key functional groups of fish in the Central Baltic Sea pelagic food-web, which is characterized by strong trophic links between cod (*Gadus morhua*) and its main fish prey sprat (*Sprattus sprattus*) and herring (*Clupea harengus*). These food-web indicators were either abundance-based indicators of key piscivores (cod) and zooplanktivores (sprat and herring) or size-based indicators of the corresponding trophic groups (biomass of large predatory fish (cod ≥ 38 cm) and biomass of small prey fish (sprat and herring <10 cm)).

Comparative analyses of models with and without linkages among indicators showed that for both types of indicators, linkages corresponding to predator-prey feedbacks and intra-specific density-dependence were essential to explain temporal variation in the indicators. Thus, no indicator-pressure relationships could be found that explained the indicators' variation unless such linkages were accounted for. When accounting for these, we found that the indicators overall respond to multiple pressures acting simultaneously rather than to single pressures, as no pressure alone could explain how the indicators developed over time. The manageable pressures fishing and eutrophication, as well as the prevailing hydrological conditions influenced by climate, were all needed to reproduce the inter-annual changes in these food-web indicators combined, although individual relationships differed between the indicators (Torres et al. 2017). We conclude that our innovative indicator-testing framework can therefore be used to identify responses of food-web indicators to manageable pressures while accounting for the biotic interactions in food-webs linking such indicators.

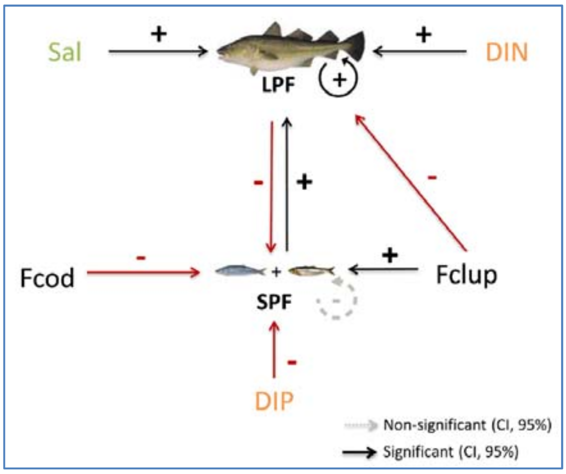

Fig. 26. Diagram of the final model of the size-based indicators represented by the biomass of large predatory fish (LPF) and biomass of small prey fish (SPF). Circles show intra-specific interactions and arrows interactions between indicators and their relationships to the pressures. DIN=dissolved inorganic nitrogen; Sal=deep-water salinity; DIP=dissolved inorganic phosphorous; Fcod= fishing mortality on cod; Fclup= fishing mortality on sprat and herring combined.

Source: Torres, M.A., Casini, M., Huss, M., Otto, S.A., Kadin, M. and Gårdmark, A. 2017. Food-web indicators accounting for species interactions respond to multiple pressures. Ecological Indicators, 77: 67-79.

Assessment of ecosystem health

The Ocean Health Index is a global assessment of ocean health, which is the comprehensive framework used to measure ocean health from global to local scales (http://www.oceanhealthindex.org/). The Index establishes reference points for achieving ten social-ecological goals and measures how well each country meets these goals in their exclusive economic zones in the ocean. Initially published in the journal *Nature* (Halpern et al. 2012), the Ocean Health Index (OHI) is the first comprehensive ocean assessment that also includes humans as a part of the marine ecosystems. The Baltic Health Index (BHI) is a project led by Stockholm Resilience Centre (Stockholm University), together with the Ocean Health Index team http://www.stockholmresilience.org/research/research-themes/marine/baltic-health-index.html). Several researchers from INSPIRE are involved in this project to ensure a high quality in the data assessment. In the following, the preliminary results of the fisheries goal are presented. The fisheries sub-goal of the BHI describes the amount of wild-caught seafood harvested and its sustainability for human consumption. The model generally compares landings with Maximum Sustainable Yield (MSY). A score of 100 means the country or region is harvesting seafood to the ecosystem's production potential in a sustainable manner. In the Baltic Sea, the calculation of the status of the fisheries is based on spatial and temporal data from the ICES assessment, using spatial resolved cod and herring stocks from the entire Baltic together. The status was based on B/B_{MSY} for each landed stock and fishing mortality that can deliver maximum sustainable yield (F/FMSY). Estimates were extracted for each species and then assigned to each region based on the contribution of each species in each region to the overall catch in that region. The preliminary results are shown below. Except for the very low status of the western Baltic cod stock, the combined (herring and cod together) fish stocks show an overall healthy status (high values), i.e. the species are fished at a sustainable level.

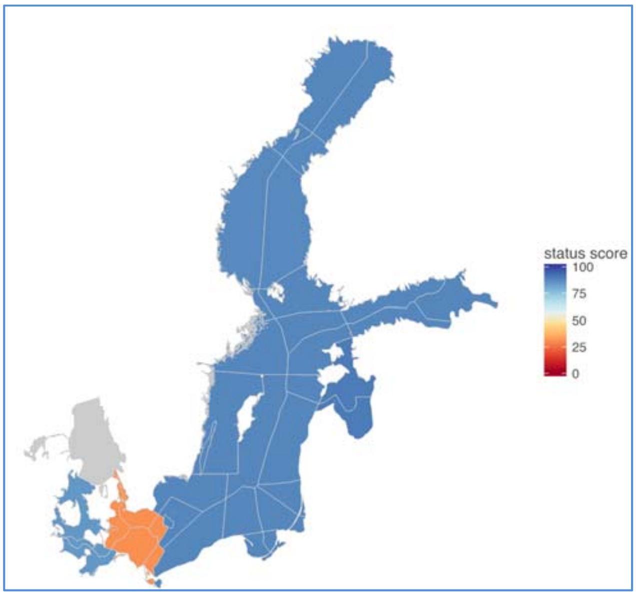

Fig. 27. Preliminary results of the status of the BHI fisheries goal. A score of 100 means the country or region is harvesting seafood to the ecosystem's production potential in a sustainable manner.

Task 5.3 Regional management considerations

Gulf of Riga autumn-spawning herring

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. To reconstruct the century-scale development of landings and investigate the reasons behind the drastic decrease and almost disappearance of autumn herring in the Gulf of Riga, we have extracted information from the multiple national sources since the 1920s, incl. landings statistics by different gears and the number of spawners caught by age-cohorts. The collected data was used for estimation of instantaneous total and fishing mortality, performed by a catch curve analysis method. Also, we have estimated the spawner biomass and conducted simulations of population dynamics, using a standard single-species age-structured model of fish population dynamics to investigate the potential role of fishing on the decline of autumn spawning herring in the Gulf of Riga.

Our inital results indicate that: i) Landings peaked at the turn of the 1950/1960, followed by a steep and gradual decline afterwards. The period from the early 1980s to 2005 was characterized by a deep depression of the stock (Fig. 28); ii) The percentage of immature fish (calculated by year-class cohorts) in catches was on average over 40%; iii) Fishing mortality, calculated by year-class cohorts, exceeded a value of 0.6; and iv) The estimated mean SSB during the peak period of catches (1957–1961) was ca. 25 thousand tons. In general, our results show that exploitation occurred both on juveniles and adults and was probably too high to ensure long-term sustainability (i.e. $F > F_{msy}$). These findings provide a quantified perspective to the historical dynamics and potential management targets for the future (MacKenzie and Ojaveer, in prep.).

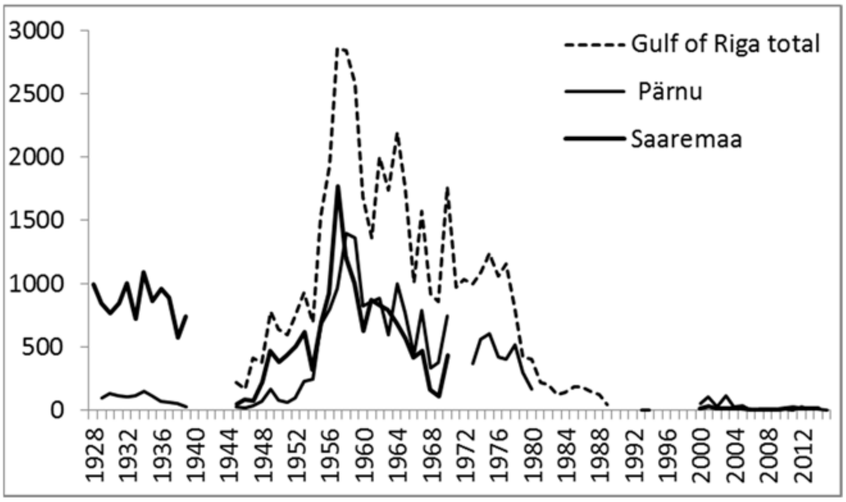

Fig. 28. Autumn herring landings (in tons) in coastal fishery in the Gulf of Riga and in Pärnu Bay area during 1928-2014 (MacKenzie and Ojaveer, in prep.).

Source: MacKenzie, B.R. and Ojaveer, H. Uncovering the past dynamics of a collapsed fish stock: Gulf of Riga autumn spawning herring (in prep.).

Early warning indicators

During the 4th integrating INSPIRE workshop, potential early warning indicators were discussed and the remaining work in WP5 was planned (Table 1).

Table 1. Early warning indicators of the Baltic eastern cod stock development.

Indicator (time-period)	Notes / reference levels	Responsibility	Comments
Recruitment environment	Thresholds for envir. variables	C. Möllmann	Analysis done
Condition **(1976-2014)**	< 0.8 is critical, what proportion of the stock to choose?	M. Casini/S. Neuenfeldt	Early warning analysis
Stock Abundance (1966-2012)	Last accepted assessment	A. Orio	Early warning analysis
Consumption/feeding level (1965-2014)	<0.4 is critical, what prop?	S. Neuenfeldt	Early warning analysis
Recruitment **(1966-2012)**	Last accepted assessment time series	S. Neuenfeldt	Early warning analysis
Size distribution **(1991-2015)**	Reference level?	A. Luzenczyk	Early warning analysis
L(max) (1978-2014)	Reference level?	Alessandro	Early warning analysis
.95 length percentile **(1991-2015)**	Reference level?	A. Luzenczyk	
90% of the stock total area occupied **(1982-2011)**	Reference level – proportion of the max	M. Casini/ S. Neuenfeldt (WKSPATIAL)	Early warning analysis
Hypoxic benthic areas – trend **(1965-2015)**		S. Neuenfeldt /M. Casini (WKSPATIAL)	Early warning analysis

3. Deviations from the workplan

There were no deviations from the workplan.

Submission of D5.3 and D5.4 was shifted from M46 to M48, to be able to capture the symposium outputs into these deliverables. This request was approved by the BONUS Secretariat.

References:

Horbowy, J., Luzenczyk, A. 2016. Effects of multispecies and density dependent factors on MSY reference points: Example of the Baltic Sea sprat. Can. J. Fish. Aquat. Sci. DOI: 10.1139/cjfas-2016-0220 (accepted, October 2016).

MacKenzie, B.R. and Ojaveer, H. Uncovering the past dynamics of a collapsed fish stock: Gulf of Riga autumn spawning herring (in prep.).

Torres, M.A., Casini, M., Huss, M., Otto, S.A., Kadin, M. and Gårdmark, A. 2017. Food-web indicators accounting for species interactions respond to multiple pressures. Ecological Indicators, 77: 67-79.

WP 6 Dissemination

Lead: Stefan Neuenfeldt, P2 (DTU-Aqua)

1. Highlights

By the close contact to various ICES expert groups and Baltic Sea Advisory Council, INSPIRE results have also during the third project year been made available to the stakeholders and interested public almost in real time. During the third year of the project, these activities continued substantially supporting the Eastern Baltic cod initiatives, and contributing to diverse ICES working groups with special focus on the ICES Workshop on Spatial Processes in the Baltic (WKSPATIAL) which has been continued in close collaboration to INSPIRE. Main achievements of the INSPIRE work in relation to Baltic cod include the development of a new model for cod growth and mortality that has been presented at ICES WKBEBCA (Workshop on Biological Input to Eastern Baltic Cod Assessment) and the ongoing development of alternatives for estimating predation pressure exerted by cod on herring and sprat in a spatially explicit context.

Two joint events with other BONUS projects include: BONUS BIO-C3/INSPIRE /COCOA/BAMBI 2016 Summer School: Modelling Biodiversity for Sustainable Use of Baltic Sea Living Resources (Holbæk, Denmark, 21-26 August 2016) and start planning the BONUS symposium on 'Science delivery for sustainable use of the Baltic Sea living resources' (Tallinn, Estonia, 17-19. October 2017).

INSPIRE co-chaired a theme session on 'The emerging science of ecological multi-model inference for informing fisheries management' at the ICES Annual Science conference 2016 in Riga, together with experts from NOAA, Seattle, USA.

As during the first two project years, INSPIRE has been represented at several workshops and meetings outside ICES community. The overall goal in dissemination work here has been to show and apply the importance of spatial heterogeneity in the different activities.

The INSPIRE web-site has been continuously updated, linking now publications (36), project reports with 'public' status (8), meta-databases (24) and affiliated projects (8).

During the third project year, one PhD and two MSc theses, all supervised by INSPIRE scientists, were successfully defended.

2. Summary

The WP aims to engage key target audiences downstream of the RTD core of the project, using a broad variety of engagement approaches:

1. Policy makers, by putting the latest research in policy-relevant context;
2. Non-specialist audiences, through effective use of press and medias;
3. Society at large, by providing full Open Access to projects' research publications.

Scientists are criticized for poor communication of research to a non-scientific audience. The formats for communication that are respected in the scientific community (peer-reviewed publications and conference talks), are not appropriate to disseminate research to policy and decision makers. WP 6 will use a variety of proven non-technical communication means and methods to adapt the project's knowledge output to the evolving needs of the high-level end users through regular interaction with decision makers and to connect with the public through media, open access to research. This multi-faceted approach allows each target audience to be addressed in the most effective manner in order to best engage, exchange and inform.

Task 6.1 Participation at expert groups coordinates the consortium capacity to transfer the latest research into the "policy informing" domain, via consortium partners' participation in the relevant ICES expert groups, consultations via HELCOM and interaction with the relevant environmental stakeholders for the Baltic Sea Region and beyoned (e.g., EU). In total, INSPIRE scientists have 100 participations at various stakeholder committees (Annex 2).

Like in previous project years, Eastern Baltic cod stock has been in strong focus, due to difficulties with providing analytical assessment and the fact that the stock is now classified as a 'data-poor' stock.

This work was continued during the ICES Working Group on Baltic Fish Stock Assessments held in Copenhagen, Denmark, April 2016, the ICES Working Group on Integrated Stock Assessments held in Helsinki, Finland, 2016, and the ICES Workshop on Spatial Processes in the Baltic, held in Riga November 2016.

INSPIRE work was presented at several ICES expert groups, such as Working Group on History of Fish and Fisheries (WGHIST), Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES), Working Group on Integrated Assessments in the Baltic Sea (WGIAB), Workshop on DEveloping Integrated AdviCE for Baltic Sea ecosystem-based fisheries management (WKDEICE), Workshop on Biological Input to Eastern Baltic Cod Assessment (WKBEBCA)

Besides these 'hands-on' activities, the INSPIRE project and the BONUS framework were presented at two international science events with ICES involvement:

1. ICES/PICES 6th zooplankton production symposium Bergen, Norway 9-13 May, 2016
2. ICES Annual Science Conference Riga, Latvia, 26-30 September 2016.

INSPIRE scientists contributed to a Theme Session at the ICES Annual Science Conference 2016 in Riga. S. Neuenfeldt (DTU-Aqua) co-chaired a theme session on 'The emerging science of ecological multi-model inference for informing fisheries management' at the ICES Annual Science conference 2016 in Riga, together with experts from NOAA, Seattle, USA. This session explored the practical use of multi-model approaches in solving pressing management and policy issues, identify challenges in ecological multi-model inference, and aims to bring together marine scientists from different disciplines to discuss the development and application of multi-model inference in marine ecological and fisheries contexts.

In addition, INSPIRE scientists presente their work also at the following international events:

1. Baltic Health Index workshop (Stockholm, Sweden, January 2016);
2. 5th EcoSummit Conference: Ecological Sustainability, Montpellier (France), 29 August-1 September 2016;
3. Fisheries Society of the British Isles Symposium on 'Fish Genes and genomes: Contributions to Ecology, Evolution and Management', Bangor, UK, 18-22 July 2016;
4. 51 th European Marine Biology Symposium (EMBS), Rhodes, Greece, 26-30 September 2016;
5. 3rd International Conference on maritime technology and Engineering (Martech), Portugal, 4-6 July 2016;
6. European Geoscience Union General Assembly, Vienna, Austria, 17-22 April 2016;

7. 1st Baltic Earth Conference, Nida, Lithuania, 13-17 June, 2016;
8. 4th International Maritime Congress, Szczecin, Poland, 8-10. June 2016;
9. Baltic – a small sea with big management problems“, Gdynia, Poland, 5. October 2016

Task 6.2 Public awareness collaborates with the project research authors and ensure that 100% of the postprint versions of the projects` peer-reviewed manuscripts are accessible free of charge via EC FP7 Infrastructures OpenAIRE research repository (www.openaire.eu), boosting access to policy-relevant research, and increasing the visibility of the project and its publications authors.

Several advisory-related activites started previously, were continued during the third project year. These include, for instance:

1. review of the ICES management options on Baltic Sea fish stocks in order to advice the European Commission implementing the EU Common Fisheries Policy; analysis of effort allocation in European fisheries in the Baltic Sea in order to advice the European Commission implementing the EU Common Fisheries Policy; advisory servicies for the Estonian Ministry of Environment on fisheries management options in the Baltic Sea (EU Common Fisheries Policy), and contribution to the national process of MSFD to propose monitoring scheme and developing program of measures (UT-EMI);
2. Advisory services for the Danish Ministry of Environment, Agriculture and Fisheries on fisheries options in the Blatic Sea with special focus on cod fisheries and the Common Fisheries Policy (DTU-Aqua);
3. Providing advice services to Polish Ministry responsible for fisheries on stock management (MIR-PIB);
4. Advisory service to Swedish Agency for Marine and Water Management on fisheries management options in the Baltic Sea with special focus on cod fisheries and the Common Fisheries Policy; Contribution to HELCOM for the development of indicators of the state of offshore fish community (SLU);
5. Participation in national and international (BaltFish) meetings on fishing possibilities in the Baltic Sea; participating in national discussions on the fishing possibilities in 2017, with distribution of the fishing effort in pelagic fisheries (BIOR).

In addition, the following activities related to updates of the existing databases were continued during the reporting periood with involvement of several INSPIRE partner institutes:

1. Contribution of BIAS and BAS data to BAD database;
2. Entry of data into Baltic International Fish Survey (BIFS) and Baltic International Trawl Survey (BITS) databases;
3. Entry of Baltic International Trawl Survey (BITS) data to DATRAS database;
4. Entry of data to the ICES Acoustic database from the Baltic International Acoustic survey (BIAS) and Baltic Acoustic Spring Survey (BASS)
5. Entry of data into Intercatch, Entry of data to Fishframe
6. Entry of stomach content data in the ICES database

7. Entry of data to pan-Baltic zooplantkon database

The following previously started international scietific collaborations were continued in the reporting period: partnership within the global research network ‘Oceans Past Initiative’ (OPI, www.oceanspast.net); partnership with the EU COST Action ‘Oceans Past Platform’ (OPP), and participation in the global science initiative ’Indicators for the Seas (IndiSeas) (H. Ojaveer, UT-EMI); pan-Baltic regional study on the Baltic Health Index (BHI), by involving cooperation from outside the Baltic Sea - Ben Halpern and the Ocean Helth Index team (T. Blenckner SU, S. Neuenfeldt DTU-Aqua, C. Möllmann UHAM, H. Ojaveer UT-EMI); membership of the LENFEST Fishery Ecosystem Task Force, led by Tim Essington and Phil Levin, to develop Ecosystem Management Plans for the US (C. Möllmann UHAM).

Blogs from INSPIRE young scientist can be found at:
http://www.bonusprojects.org/bonusprojects/blogs/inspire_me
and
http://www.bonusprojects.org/bonusprojects/blogs/data_cruncher/delicate_business_of_sharing_the_data.2586.blog
and
http://www.bonusprojects.org/bonusprojects/blogs/inspire(d)

In addition, INSPIRE has performed several other national public outreach activites. These are:

1. National BONUS BAMBI/BIO-C3/INSPIRE seminar on ’The new challenges in management of the Baltic Sea’ (Tallinn, Estonia, 27. April 2016)
2. Forum of Baltic Fisheries (Gdynia, Poland, 25. October 2016)
3. In total of 14 interviews to national radio and TV (in Estonia, Denmark, Latvia, Sweden and Poland)
4. In total four popular science papers in national fishery journals (H. Ojaveer, T. Raid (TU-EMI), J. Raitaniemi (LUKE))

And finally, INSPIRE has made available 24 metadata sheets at the project website (http://www.bonus-inspire.org/metadata). These provide information on the data used in all relevant peer-reviewed papers published so far.

Work on the popular science book for children has started. The idea is to explain how spatial pattern is generated in nature, and what spatial structure mean for understanding ‘how many fishes there are’. As a model, the successful children’s book ‘The world of Hopfs’ (http://heuschele.com/worldofhopfs/) has been chosen, and its author Jan Heuschele has agreed to collaborate with INSPIRE to create a simple story explaining the basic ingredients and consequences of spatial heterogeneity (Fig. 29).

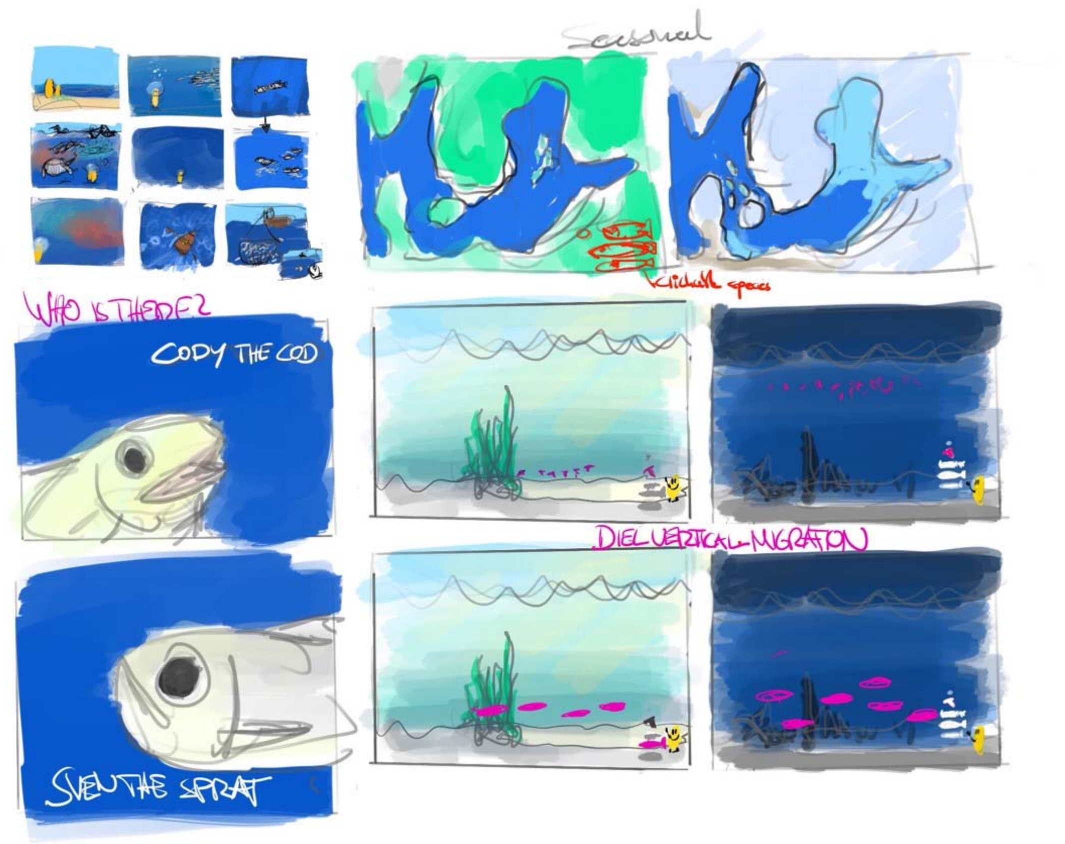

Fig. 29. Example drawing of INSPIRE popular book (© Jan Heuschele).

Task 6.3 Training school and concluding symposium conducts a summer school and a concluding symposium together with other, close related BONUS projects.

As well as in 2016, INSPIRE participated also in 2016 actively in a summer school in close collaboration with other BONUS projects. The focus of the BONUS BIO-C3/INSPIRE/COCOA/BAMBI 2016 Summer School was 'Modelling Biodiversity for Sustainable Use of Baltic Sea Living Resources'. The summer school ran from August 22-26 at Søminestation, near Holbæk, Denmark. One of the main purposes of the summer school was to educate and train a new generation of young scientists on the challenges and opportunities that face biodiversity in the Baltic Sea and provide them with new knowledge and quantitative tools on how to model its variations and their consequences. The course consisted of a mix of lectures, hands-on statistical analyses/ modelling exercises and discussions addressing both functional and taxonomic aspects of marine biodiversity, with emphasis on estuarine systems, using the Baltic Sea as a case study. Students learned new modelling approaches and softwares which they could take home and apply to their own research projects. And thanks to the participation of 23 students (16 women, 7 men) and 10 lecturers (4 women, 6 men), they now have expanded and developed a network of colleagues that they can interact and collaborate with in future. The students came from both Baltic and non-Baltic countries, were mostly Ph.D students (18), with some postdoctoral scientists (4) and Masters graduates (1).

From INSPIRE, lectures were given by Henn Ojaveer, Riina Klais (UT-EMI), Thorsten Blenckner, Susa Niraanen (SU) and Stefan Neuenfeldt (DTU AQUA), while, Alessandro Orio and Natalia Kulatska (SLU), Sieme Bossier and Nicolas Azaña Schnedler-Meyer (DTU Aqua), Romain Frelat (UH), Katarzyna Nadolna-Ałtyn and Katarzyna Spich (MIR-PIB) attended the summer school as PhD students.

The title of the concluding symposium is 'BONUS SYMPOSIUM: Science delivery for sustainable use of the Baltic Sea living resources' and it will be held in Tallinn, 17-19. October. 2017. All the organising committees (science committee, co-conveners and local organisng committee) are in place and conference website contains all required information (conference venue, registration, accommodation, submission of abstracts and manuscripts to ICES JMS special volume) http://www.bonus-inspire.org/symposium. The symposium was also endrosed by ICES and included into the science events of the Estonian Presidency in EU.

3. Deviations from the worklan

There were no deviations from the workplan.

WP7 Management

Lead: Henn Ojaveer, P1 (UT-EMI)

1. Highlights

Efficient internal communication, systematic contacts with the BONUS Secretariat and continuous monitoring of the progress by the project coordination unit has secured timely science delivery according to the project workplan.

2. Summary

This WP has five generic objectives:
1. Ensuring that project objectives are achieved on time and within the costs estimated;
2. Co-ordinating all work conducted in the project,
3. Overseeing the task and work-packages,
4. Ensuring the development and production of deliverables, as well as reporting.
5. Ensuring that appropriate levels of communications are maintained among partners in order to achieve expected levels of scientific outputs.

The coordinator will carry out the day to day monitoring and management of the project, ensure co-ordination between the project partners and the circulation of project documents and data, and organize meetings and discussions. Work package leaders will keep the coordinator informed of the ongoing status of work packages. The co-ordinator will be responsible for communications with BONUS. The co-ordinator will organize the kick-off meeting, annual project meetings (report of the project second annual meeting can be found in Annex 1). The coordinator will administer a budget for travel and subsistence costs for members of the Advisory Board to attend the project meetings and participate in the project. The co-ordinator will be responsible for financial and management reporting, as required by BONUS and defined in the workplan. The co-ordinator is also responsible for finalising all the reports, with input from work-package leaders. The final report will have broader dissemination and will circulate among partners prior to dissemination outside the consortium. The co-ordinator will make sure that the final report reflects a consensus of all partners. The co-ordinator will also take responsibility for ensuring that the project results are appropriately disseminated.

The co-ordinator will be responsible for the organisation of a concluding symposium. The symposium title is 'BONYS SYMPOSIUM: Science delivery for sustainable use of the Baltic Sea living resources' and it will be held in Tallinn, 17-19. October. 2017. All the organising committees (science committee, co-conveners and local organisng committee) are in place and conference website contains all required information (conference venue, registration, accommodation, submission of abstracts and manuscripts to ICES JMS special volume) http://www.bonus-inspire.org/symposium. The symposium was also endrosed by ICES and included into the science events of the Estonian Presidency in EU.

3. Promoting an effective science-policy interface to ensure optimal take up of research results

INSPIRE strategy is to ensure efficient and timely two-directional communication with stakeholders. In this regard, communication and cooperation with Baltic Sea Advisory Commission (BSAC) and International Council for the Exploration of the Sea (ICES) is our priority. BSAC representative (Pehr Eriksson) is involved in scientific discussions in INSPIRE and is regularly attending project annual meetings and integrating workshops. In total, INSPIRE scientists had 100 participations in local, national and international stakeholder committees (Annex 2) with the dominating role in fisheries and ecosystem-oriented groups in ICES. In addition, several scientists are performing advisory role at national and international levels (incl. in relation to EU Common Fisheries Policy, EU Marine Strategy Framework Directive and Multiannual management of Baltic fish stocks), which has recently expanded beyond fisheries management (e.g., advisory role on the subject of Maritime Spatial Planning).

4. Collaboration with relevant research programmes and the science communities in the other European sea basins and on international level

Several project partners are involved in international collaboration beyond the Baltic Sea. The nature and framework of the collaboration is varying and spanning from formal long-standing global international reserach networks (such as ‘Oceans Past Initiative’ and ’Indicators for the Seas’) to more regional and narrower activities (US LENFEST Fishery Ecosystem Task Force) and attendances of workshops focussing on modeling of ecological systems and performing ecosystem assessments. Strong collaboration in several ICES expert groups has been established and it forms backbone for some of the ecosystem-related research in INSPIRE. During the reporting period, three new collaborations were established (see performance statistic #5 below).

5. Progress in comparison with the original research and financial plan, and the schedule of deliverables

The project is progressing according to the research plan without any deviations affecting achieving its aims and goals. Ten deliverables sceduled to year #3 (D1.2, D1.3, D1.4, D1.5; D2.5, D2.6, D3.1, D4.1, D6.2, D7.5) were submitted according to SoD. Minor modifications in the original financial plan have occurred in several partner institutes without implications to the workplan and science delivery.

6. Amendments to the description of work and schedule of deliverables

No changes to the description of work has neither occurred nor expected in coming years. However, there are few changes (please see details below) in milestone/deliverables, which all were approved by the BONUS secretariat. These changes were driven from the motivation to increase efficiency of the science in the project in altered external conditions, will not affect planned science delivery, but will increase visibility and impact of the project results.

i) Arrange the 4th Integrating workshop (originally scheduled to M18) on M20 (to allow INSPIRE scientists to present their work at the BONUS theme session during the ICES ASC). This request was approved by the BONUS Secretariat;

ii) Timing of the third annual meeting was shifted from M27 (April 2016) to M32 (September 2016), to be held it in conjunction with ICES ASC (Riga, Latvia), to be able to reflect on the first iteration of assessment work. This request was approved by the BONUS Secretariat.

iii) Timing of INSPIRE Training school was shifted from 2017 to 2016, and to held it together with other relevant BONUS projects (Denmark, August 2016). This request was approved by the BONUS Secretariat.

iv) Shift the timing of the concluding symposium, 4th annual meeting and final SC meeting from M48 to M45. This request was approved by the BONUS Secretariat.

7. Performance statistics

The information below is given by project partners for the first project years by using institional short names as indicated on page 4 above.

1. **Number of times the project has contributed significantly to the development and implementation of 'fit-to-purpose' regulations, policies and management practices on international, European, the Baltic Sea region or national level aimed at safeguarding the sustainable use of ecosystem's goods and services.**

2014
UT-EMI
Review of the ICES management options on Baltic Sea fish stocks for 2015 in order to advice the European Commission implementing the EU Common Fisheries Policy (2014-06_STECF 14-10 - BALTIC ADVICE for 2015_JRC90504.pdf)
Analysis of effort allocation in European fisheries in the Baltic Sea in order to advice the European Commission implementing the EU Common Fisheries Policy (STECF 2014-12 Evaluation of Fishing Effort Regimes - p2_JRC93183.pdf)

Advisory services for the Estonian Ministry of Environment on fisheries management options in the Baltic Sea (EU Common Fisheries Policy).

Contribution to the national process of MSFD to propose monitoring scheme and start to develop program of measures.

BIOR
Participation in national and international (BaltFish) meetings on fishing possibilities in the Baltic Sea. Important component of these meeting have been proposing management options of fishing effort distribution in the Baltic Sea in pelagic fisheries that is closely connected with the INSPIRE objective to elaborate a spatially explicit advice for ecosystem-based fisheries management.

MIR-PIB
Attendance of the meeting at EC discussing the Multiannual plan for the Baltic Sea fisheries (by Jan Horbowy).

2015
DTU-Aqua
Advisory services for the Danish Ministry of Environment, Agriculture and Fisheries on fisheries options in the Blatic Sea with spoecial focus on cod fisheries and the Common Fisheries Policy.

MIR-PIB
Formulating management advice of the Baltic fish stocks to ICES, and providing evidences of increasing natural mortality of cod.

Providing advice services to Polish Ministry responsible for fisheries on stock management, incl. reporting on indicators of balance between fishing capacity and fishing opportunities.

SLU
Contribution to HELCOM for the development of indicators of the state of offshore fish community and for the HOLAS II project.

Advisory servicies for the Swedish Agency for Marine and Water Management on fisheries management options in the Baltic Sea with special focus on cod fisheries and the Common Fisheries Policy.

2016
UT-EMI
Proposals of methodology and data requirements for EU Member States for reporting on the EU Landing Obligation Proposed types of information, metrics and indicators that would be useful in reporting on the elements defined in the legislation (Omnibus Article 9 additions as applied to Article 15 of the CFP) (STECF EWG 16-13).

SLU
Advisory service to Swedish Agency for Marine and Water Management on maritime spatial planning

2. **Number of suggestions for designing, implementing and evaluating the efficacy of relevant public policies and governance on international, European, the Baltic Sea region or national level originating from the work of the project.**

2014
BIOR
National discussion on the fishing possibilities in 2015, distribution of the fishing effort in pelagic fisheries.

2015
DTU-Aqua
National discussions and suggestions on limiting sprat fisheries in ICES SD 25 in order to increase living conditions for cod.

MIR-PIB
National discussions at the Department of Fisheries on developing measures to improve cod stock and fisheries in the Baltic Sea.

3. **Number of times the scientists working in the project have served as members or observers in stakeholder committees.**

INSPIRE scientists have in total 100 participations in stakeholder committees during the third project year (for details, please see Annex 2).

4. **Number of international, national and regional stakeholder events organised by the project** (include information about number of participants and kinds of sectors represented)

2014
None

2015
LUKE

Open doors at survey vessel RV Aranda 09/2015. The scientists from Luke presented fisheries research and stock assessment work to media and public. 900 participants.

2016
UT-EMI

National BONUS BAMBI/BIO-C3/INSPIRE seminar on ’The new challenges in management of the Baltic Sea’, Tallinn, Estonia, 27 April 2016. Attended by about 30 participants from Ministry of Environment, Ministry of Rural Affairs and Ministry of Education and Research.

5. **Number of joint events/co-operation activities/partnerships of the project with non-Baltic research actors and other European marine basins**.

2014

UT-EMI

Partnership within the global research network ‘Oceans Past Initiative’ (OPI, www.oceanspast.net) and the EU COST Action ‘Oceans Past Platform’ (OPP).

Participation in the global science initiative ’Indicators for the Seas, (IndiSeas).

DTU-AQUA

Participation in the the 3rd NMFS National Ecosystem Modeling Workshop held by NOAA in Seattle, WA, USA. The workshop was focused on ensemble modelling of ecological systems, and Stefan Neuenfeldt was invited to present some of the INSPIRE concepts to NOAA scientists.

Particiaption in Knowledge Based Bio-Economy (KBBE) workshop on MICE models, multispecies models, and harvest strategies for lowinformation stocks in Wellington, NZ. The workshop was focused on Models of Intermediate Complexity for Ecosystem assessments, and Stefan Neuenfeldt was invited to present the modelling strategy in INSPIRE in relation to identification of potential target levels for Central Baltic Sea fishing mortalities taking species interactions and spatial overlap into account.

SU

Pan-Baltic regional study on the Baltic Health Index (BHI), scientifically led by Thorsten Blenckner was initiated, where INSPIRE is also expected to contribute. It involves also cooperation from outside the Baltic Sea - Ben Halpern and the Ocean Helth Index team.

UHAM

Christian Möllmann is member of and has participated in 2 meetings of the LENFEST Fishery Ecosystem Task Force lead by Tim Essington and Phil Levin. The Task Force develops Ecosystem Management Plans for the US. Christian Möllmann is the selected European expert.

UU

Co-operation with Pedro Morais, Portugal in a planned pan-European project „Causes and mechanisms explaining fish life history plasticity“ focusing on flounder. Otoliths (for trace element analysis) and tissue samples (genetical analysis) from flounder from the Baltic will be included in the comparison.

2015

TI-OF

Workshop on larval herring ecology in Greifswald Bay to establish cooperation with Canadian scientists (Université Laval Département de biologie). Thuenen-Institute of Baltic Sea Fisheries 20-24. August 2015 (12 participants).

UU

Incolved in a U.S. National Science Fundation project concerning effects of hypoxia on growth in fish; including fish from the Gulf of Mexico, Great Lakes and the Baltic Sea. From the Baltic, microchemistry analysis of otoliths from cod and flounder are used to identify whether indivuduals have been subjected to low oxygen concentration or not.

2016

DTU Aqua

Contributing to the Seanors initiative with the aim to develop an integarted view on the so-called ’Seas of Norden’. Particiaptionin a workshop held by Oslo University and resutling manuscript in Nature Climate Change.

SU

Cooperation with Benjamin Halpern and the global Ocean Health Index team to develop Baltic Health Index. Two days meeting organised at SU in January 2017.

UU

Cooperation with Karin Limburg and Melvin Samson from State University of New York College of Environmental Science and Forestry US on flounder otolith microchemistry research.

6. **Number of persons (1) and working days (2) spent by foreign scientists on research vessels** participating in the cruises arranged by the project.

2014
None

2015
DTU-Aqua
At the combined INSPIRE/BIO-C3 research cruise in the Bornholm Basin (ICES SD 25), DTU-Aqua hosted 1 research scientist from GEOMAR (PhD Cornelia Jaspers, and one from IOW (PhD Jörg Dutz), Warnemünde. The 15 days cruise took place in September 2015

UHAM
Research cruise on RV Alkor in the Bornholm Basin in April 2015. UHAM hosted 1 research scientist from DTU-Aqua (Stefan Neuenfeldt) for two days cruise.

2016
None

7. **Number of persons and working days spent by foreign scientists using other major research facilities involved in the project**.

2014
None

2015
LU
Post-doc Mikael van Deurs from DTU-AQUA Denmark has used laboratory facilities at LU, working on cod biology 365 days.

UU
PhD Melvin Samson, SUNY-ESF U.S. stayed at the Ar Research Station, Uppsala university for preparation of flounder otoliths within the U.S. National Science Fundation project concerning effects of hypoxi on growth in fish 12 days.

2016
None

8. **Number of peer-reviewed publications arising from the project research with authors from, at least, two different participating states**.

2014
None

2015
UT-EMI
Ojaveer, H., Tomkiewicz, J., Arula, T., Klais., R. (2015). Female ovarian abnormalities and reproductive failure of autumn-spawning herring (*Clupea harengus membras*) in the Baltic Sea. ICES Journal of Marine Science. 72(8), 2332–2340

DTU-AQUA
Eero, M., Hjelm, J., Behrens, J., Buchmann, K., Cardinale, M., Casini, M., Gasyukov, P., Holmgren, N., Horbowy, J., Hüssy, K., Kirkegaard, E., Kornilovs, G., Krumme, U., Köster, F. W., Oeberst, R., Plikshs, M., Radtke, K., Raid, T., Schmidt, J., Tomczak, M. T., Vinther, M., Zimmermann, C., Storr-Paulsen, M. 2015. Eastern Baltic cod in distress: biological changes and challenges for stock assessment. ICES Journal of Marine Science, http://icesjms.oxfordjournals.org/content/72/8/2180

Hüssy, K., Hinrichsen, H. H., Eero, M., Mosegaard, H., Hemmer-Hansen, J., Lehmann, A. and Lundgaard, L. S. (2015) Spatio-temporal trends in stock mixing of eastern and western Baltic cod in the Arkona Basin and the implications for recruitment ICES Journal of Marine Science . fsv227. DOI 10.1093/icesjms/fsv227.

Hüssy, K., Gröger, J., Heidemann, F., Hinrichsen, H.-H., and Marohn, L. 2015. Slave to the rhythm: seasonal signals in otolith microchemistry reveal age of eastern Baltic cod (*Gadus morhua*). ICES Journal of Marine Science, http://icesjms.oxfordjournals.org/content/early/2015/12/18/icesjms.fsv247

BIOR
Ustups, D., Bergström, U., Florin, A.B., Kruze, E., Zilniece, D., Elferts, D., Knospina, E. & Uzars, D. 2016. Diet overlap between juvenile flatfish and the invasive round goby in the central Baltic Sea. J. Sea Res. 107, pp. 121-129

GEOMAR
H.-H. Hinrichsen, A. Lehmann, C. Petereit, A. Nissling, D. Ustups, U. Bergström, K. Hüssy. 2016. Spawning areas of eastern Baltic cod revisited: Using hydrodynamic modelling to reveal spawning habitat suitability, egg survival probability, and connectivity patterns. Progress in Oceanography. http://dx.doi.org/10.1016/j.pocean.2016.02.004

Hinrichsen H.-H, von Dewitz B, Dierking J, Haslob H, Makarchouk A, Petereit C, Voss R. 2016 Oxygen depletion in coastal seas and the effective spawning stock biomass of an exploited fish species. R. Soc. open sci. 3: 150338. http://dx.doi.org/10.1098/rsos.150338

2016

UT-EMI
Bekkevold, D.; Gross, R.; Arula, T.; Helyar, S.J.; Ojaveer, H. 2016. Outlier loci detect intraspecific biodiversity amongst spring and autumn spawning herring across local scales. PLoS ONE 11(4): e0148499

Klais, R., Lehtiniemi, M., Rubene, G., Semenova, A., Margonski, P., Ikauniece, A., Simm, M., Põllumäe, A., Griniene, E., Mäkinen, K., Ojaveer, H. (2016). Spatial and temporal variability of zooplankton in a temperate semi-enclosed sea: implications for monitoring design and long-term studies. Journal of Plankton Research 38: 652−661

DTU-Aqua
Casini, M., Käll, F., Hansson, M., Plikshs, M., Baranova, T., Karlsson, O., Lundström, K., Neuenfeldt, S., Gardmark, A. and Hjelm, J. 2016. **Hypoxic areas, density-dependence and food limitation drive the body condition of a heavily exploited marine fish predator.** Royal Society Open Science 3: 160416
http://rsos.royalsocietypublishing.org/content/3/10/160416

Huwer, B., Hinrichsen, H.-H., Hüssy, K., and Eero, M. **Connectivity of larval cod in the transition area between North Sea and Baltic Sea and potential implications for fisheries management.** ICES Journal of Marine Science, doi: 10.1093/icesjms/fsw043
http://icesjms.oxfordjournals.org/content/early/2016/03/28/icesjms.fsw043

SU
Griffiths, J.R., Kadin, M., Nascimento, F.J.A, Tamelander, T., Törnroos, A., Bonaglia, S., Bonsdorff, E., Brüchert, V., Gårdmark, A., Järnström, M., Kotta, J., Lindegren, M., Nordström, M.C., Norkko, A., Olsson, J., Weigel, B., Žydelis, R., Blenckner, T., Niiranen, S. and Winder, M. 2017. **The importance of benthic-pelagic coupling for marine ecosystem functioning in a changing world.** Global Change Biology,
http://onlinelibrary.wiley.com/doi/10.1111/gcb.13642/full

SLU
Bartolino V, Tian H, Bergström U, Jounela P, Aro E, Dieterich C, Meier H. E. M., Cardinale C, Bland B, Casini M (2017). Spatio-temporal dynamics of a fish predator: density-dependent and hydrographic effects on Baltic Sea cod population. PLoS ONE, 12(2): e0172004.

Torres, M.A., Casini, M., Huss, M., Otto, S.A., Kadin, M. and Gårdmark, A. (2017). Food-web indicators accounting for species interactions respond to multiple pressures. Ecological Indicators, 77: 67-79.

BIOR
Orio, A., Florin, A.-B., Bergström, U., Sics, I., Baranova, T., and Casini, M. (2017). Modelling indices of abundance and size-based indicators of cod and

flounder stocks in the Baltic Sea using newly standardized trawl survey data. ICES Journal of Marine Science. doi:10.1093/icesjms/fsx005.

LUKE

Raid, T., Järv, L., Pönni, J., Raitaniemi, J. and Kornilovs, G. 2016. Central Baltic herring stock: What does the assessment of combined stock say about the status of its components? In: Guedes Soares,C. & Santos, T.A. (Eds). Maritime Technology and Engineering. Taylor & Francis Group, London: 961-966. ISBN 978-1-138-03000-8

GEOMAR

Lehmann, A., Hinrichsen, H-H., Getzlaff, K. and Myrberg, K. 2014. Quantifying the heterogeneity of hypoxic and anoxic areas in the Baltic Sea by a simplified coupled hydrodynamic-oxygen consumption model approach. Journal of Marine Systems 134: 20-28.

Hinrichsen, H. H., Petereit, C., Nissling, A., Wallin, I., Ustups, D., and Florin, A. B. (2016). Survival and dispersal variability of pelagic eggs and yolk-sac larvae of central and eastern baltic flounder (Platichthys flesus): application of biophysical models. ICES Journal of Marine Science: Journal du Conseil, fsw163.

Lehmann, A., Höflich, K., Post, P., Myrberg, K., 2017. Pathways of deep cyclones associated with large volume changes (LVCs) and major Baltic inflows (MBIs). Journal of Marine Systems, 167, 11-18. http://dx.doi.org/10.1016/j.jmarsys.2016.10.014

LU

van Deurs, M., Persson, A., Lindegren, M., Jacobsen, C., Neuenfeldt, S., Jørgensen, C. and Nilsson, A.P. 2016. **Marine ecosystem connectivity mediated by migrant–resident interactions and the concomitant cross-system flux of lipids.** Ecology and Evolution, doi: 10.1002/ece3.2167 http://onlinelibrary.wiley.com/doi/10.1002/ece3.2167/full

9. **Number of entries to existing openly accessible common databases, storing original data from the entire Baltic Sea system or larger geographical area.**

2014
UT-EMI

Entry of the Gulf of Riga larval herring data (2004-2013) into ICES ichtyoplankton database.

Assembling pan-Baltic zooplantkon database (joint activity with BIO-C3; see http://kodu.ut.ee/~riina82/index.html). The metadatabase is under preparation and will be uploaded to the website as soon as ready.

MIR-PIB
Multiple data entries to BITS database.
Multiple data entries to INTERCATCH database.

LUKE
Entry of data into Baltic International Fish Survey (BIFS) and BITS databases.

2015
UT-EMI
Entry of data to pan-Baltic zooplantkon database (together with BIOR and MIR-PIB; this is a joint activity with BONUS BIO-C3; http://kodu.ut.ee/~riina82/index.html).

DTU-Aqua
Entry of stomach content data in the ICES database (together with SLU).

MIR-PIB
Entry of BITS data to DATRAS database (together with BIOR, SLU, DTU-Aqua, UT-EMI and LUKE).

SLU
Contribution of BIAS and BAS data to BAD database (together with DTU-Aqua, BIOR, MIR-PIB, UT-EMI and LUKE).

TI-OF
Entry of the Rügen larval herring data (1992-2015) into the ICES ichtyoplankton database.

LUKE
Entry of data to ICES INTERCATCH database (together with BIOR, DTU-Aqua, SLU, MIR-PIB and UT-EMI).

2016
SLU
Entry of data in the Swedish national database on coastal fish (KUL)

LUKE
Entry of data into the Finnish national database (Suomu 2)

10. Number of popular science papers produced by the project.

2014
None

2015
UT-EMI
Ojaveer, H. 2015. Sprat. In: Kalastaja, pg. 112 (national fishery journal).

LUKE

Jari Raitaniemi and Jukka Pönni 2015. Torsken återhämtar sig. Fiskarposten no 9, pp. 4. (in Swedish; popular article in Finnish national fisheries newspaper 'Fiskarposten' about Baltic fish stocks).

2016

UT-EMI

Ojaveer, H. 2016. Changing relations between the man and the sea. Sirp (newsletter on Estonian culture), 17. June.

Ojaveer, H. 2016. Investigations on pelagic fish feeding: what and why? Kalastaja (national fishers journal), 81: 115-117

Raid, T. 2016. On the status, fishery and catch outlook of herring, sprat and cod stocks on the Baltic. Eesti Kalamajandus 2014-2015: 38-50 (in Estonian).

LUKE

Raitaniemi, J., Pönni, J., Lilja, J. & Leskelä, A. Still high density of sprat in the Baltic Sea close to Finland (in Swedish) 2016. Fiskarposten no 9: 4.

11. **Number of interviews to media** given by the members of the project's consortium.

2014

MIR-PIB

Interview to Polish TV by Jan Horbovy (September 2014).

SLU

Michele Casini, phone interview, 16-09-2014. Radio Germany: Current Research, "Fishery-induced changes in fish population structure, with Baltic Sea focus".

Ann-Britt Florin, 10-05-2014, Gotlands Allehanda – local Swedish newspaper, "Fiskar efter svar om östersjöns arter" (Fishing after answers about Baltic species).

UU

Anders Nissling, local radio (Radio Gotland), Sweden, January 2015 (topic: saline water inflow & potential effects on fish stocks).

2015

SLU

Michele Casini, radio interview, 22-01-2016. Sveriges Radio, P4 Blekinge: "Miljonsatsning ska kartlägga torsken i Östersjön" ("Million effort to map cod in the Baltic Sea").

UU

Anders Nissling, local radio (Radio Gotland), Sweden, April 2015 (topic: flounder ecology; life-history strategy of the respective flounder ecotype).

2016

UT-EMI

Interview to national TV (H. Ojaveer) on climate impacts to the Baltic Sea (25 October 2016)

Interview to national radio (H. Ojaveer) on various marine and maritime issues (17 June 2016)

Interview to national radio (R. Klais) about the interactions between climate and biological processes in the Baltic Sea (14 April 2016)

DTU-Aqua

Interview (Stefan Neuenfeldt) to a journalist from regional TV on the impact of the February flood on the Baltic cod stock (4 January 2017)

MIR-PIB

Interview to Polish TV TVN on management of Baltic stocks (J. Horbovy)

SLU

Michele Casini, radio interview, 30-01-2017. *P4 Gotland*: "Artontusen torskar i Östersjön registreras" ("18000 cod in the Baltic Sea are registered").

Michele Casini, radio interview, 17-06-2016. *Vetenskapsradion* and *Dagens eko*: "Östersjön strömmingar allt magrare" ("Baltic herring increasingly thinner").

Michele Casini, TV interview, 23-05-2016. *SVT Nyheter*: "18000 torskar märks med telefonnummer" ("18000 cods will be tagged with phone number").

Michele Casini, newspaper interview, 15-11-2016. *Skärgården*: "*Syrebristen orsak till mager torsk*" ("Lack of oxygen the cause of thin cod").

Michele Casini, newspaper interview, 27-10-2016. *Sydsvenskan: "Brist på syre och föda hotar torsken"* ("Lack of oxygen and food threaten the cod").

Michele Casini, newspaper interview, 03-08-2016. *Svenska Dagbladet SvD: "Många fiskarter trivs i Östersjön-men inte torsken"* ("Many fish species thrive in the Baltic Sea - but not the cod").

Michele Casini, newspaper interview, 03-08-2016. *Svenska Dagbladet SvD: "Nya kemikalier hotar Östersjön-upptäcks inte"* ("New chemicals threat the Baltic Sea – but they are difficult to detect").

BIOR

Interview to national radio (D. Ustups) on various marine and maritime issues (20 September 2016)

Interview to national TV (G. Kornilovs) on various marine and maritime issues and ICES Annual Science Conference (24 September 2016)

12. **Number of multi-media products and TV episodes produced by the project with dissemination purpose**.

2014
None

2015
None

2016

UT-EMI
Riina Klais: Blog "Data cruncher" in the BONUS blogspace (4 entries in 2016). http://www.bonusprojects.org/bonusprojects/blogs/data_cruncher

TI-OF
Dorothee Moll: "INSPIRE(D) Blog – BONUS INSPIRE" in the BONUS blogspace (1 entry);
https://www.bonusprojects.org/bonusprojects/blogs/inspire(d)

13. **Number of other international, national and regional communication, dissemination and public outreach initiatives to disseminate the project's research results.**

2014

UT-EMI
Ojaveer, H. 2014. BONUS INSPIRE: Integrating spatial processes into ecosystem models for sustainable utilization of fish resources. Written communication to HELCOM FISH-ENV 10-2014.

Ojaveer, H. et al. 2014. Integrating spatial processes into ecosystem models for sustainable utilization of fish resources. Poster presentation at ICES ASC.
Ojaveer, H. 2014. Integrating spatial processes into ecosystem models for sustainable utilisation of fish resources. Baltic Maritime Spatial Planning Forum. 17-18. June 2014, Riga, Latvia.

Arula, T., Ojaveer, H. 2014. Can we predict Baltic spring spawning herring *Clupea harengus membras* recruitment form larval abundance? EU FP7 project VECTORS Final Meeting in La Grande Motte (France) in 17-21 November 2014. Poster presentation.

2015

UT-EMI

Arula, T., Laur, K., Simm, M. and Ojaveer, H. 2015. Dual impact of temperature on growth and mortality of marine fish larvae in a shallow estuarine habitat. Estuarine, Coastal and Shelf Science, http://dx.doi.org/10.1016/j.ecss.2015.10.004

Arula, T., Raid, T., Simm, M., Ojaveer, H. 2015. Temperature-driven changes in early life-history stages influence the Gulf of Riga spring spawning herring (*Clupea harengus* m.) recruitment abundance. Hydrobiologia. doi:10.1007/s10750-015-2486-8.

Raid, T., Arula, T., Kaljuste, O., Sepp, E., Järv, L., Hallang, A., Shpilev, H., Lankov, A. 2015. Dynamics of the commercial fishery in the Baltic Sea: What are the driving forces? In: Towards Green Marine Technology and Transport – Guedes Soares, Dejhalla & Pavleti (Eds). Taylor & Francis Group, London

Arula, T., Ojaveer, H., Raid, T. Mortality and growth at larval stage: advancing the understanding of stock dynamics processes in the Gulf of Riga spring spawning herring (Clupea harengus membras). 10th Baltic Sea Science Congress, 15-19 June 2015, Riga, Latvia.

Arula, T., Raid, T., Simm, M. and Ojaveer, H. Factors affecting the abundance of spring spawning herring (*Clupea harengus membras*) larvae in the Gulf of Riga. ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Arula, T., Raid, T., Simm, M., Ojaveer, H. Importance of plankton seasonality on larval herring and year-class abundance of the Gulf of Riga spring spawning herring (Clupea harengus m.). 39th Annual Larval Fish Conference. Vienna, Austria; 12-17. July 2015.

Klais, R., Lehtiniemi, M., Teder, M., Rubene, G., Semenova, A., Margonski, P., Ikauniece, A., Simm, M., Põllumäe, A., Griniene, E., Mäkinen, K. and Ojaveer, H. 2015 Spatiotemporal variability of the Baltic Sea mesozooplankton. ICES WKSPATIAL (Rome, Italy, 3-6. Nov. 2105).

Klais, R., Lehtiniemi, M., Teder, M., Rubene, G., Semenova, A., Margonski, P., Ikauniece, A., Simm, M., Põllumäe, A., and Ojaveer, H. 2015 Spatial and temporal variability of mesozooplankton in the Baltic Sea. ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Ojaveer, H. Moderating panel discussion exploring how the BONUS, PRIMA and JPI Oceans initiatives can cooperate and contribute to the Horizon 2020 marine research priorities in the areas of Blue Economy and Resource Efficiency. Cooperation in Marine Science around the Baltic Sea and beyond: a contribution to Europe's Societal Challenges. Event organised by Estoanian Research Council. Brussels, Belgium, 22. April 2015.

Ojaveer, H. What kind of shift your project will bring to scientific basis of fisheries management? BONUS projects' kick-off meeting, triple meeting and a BONUS information event for the European community, Brussels, 1-2 December 2015.

Ojaveer, H. 2015. Representing INSPIRE project at a panel session discussion on 'Science and knowledge' of the Annual Forum of the EU Strategy for the Baltic Sea Region, 16 June 2015, Jurmala.

Ojaveer, H. BONUS projects INSPIRE and BIO-C3. Conference about international cooperation. Tallinn, Estonia, 3. December 2015.

Ojaveer, H., Teder, M., Simm, M., Raid, T. and Klais, R. 2015. Feeding ecology of pelagic fish in the Gulf of Riga. ICES WKSPATIAL (Rome, Italy, 3-6. Nov. 2105).

Raid, T., Arula, T., Kaljuste, O., Sepp, E., Järv, L., Hallang, A., Shpilev, H., Lankov, A. Dynamics of the commercial fishery in the Baltic Sea: What are the driving forces? 16th Congress of the Maritime Association of the Mediterranean, IMAM, 21-24 September 2015, Pula, Croatia.

DTU-Aqua

Bekkevold, D., Gross, R., Arula, T. and Ojaveer, H. 2015. Spring and autumn spawning herring in the Gulf of Riga: intraspecific biodiversity across small local scales. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Karin Hüssy, Henrik Mosegaard, Christoffer, Moesgaard Albertsen, Jakob Hemmer-Hansen, Margit Eero. 2015. Stock mixing of eastern and western Baltic cod in SD 24. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Margit Eero, Helén Andersson, Elin Almroth Rosell, Brian R. MacKenzie. 2015. Has human-induced eutrophication promoted fish production in the Baltic Sea? Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Ojaveer, H., Tomkiewicz, J., Arula, T. and Klais, R. Female ovarian abnormalities and reproductive failure of autumn spawning herring (*Clupea harengus membras*) in the Baltic Sea. ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Stefan Neuenfeldt, Christian Möllmann 2015. Net displacement and time at large: Adult migrations probably do not contribute to whole Baltic scale redistribution of cod (Gadus morhua L.). Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Stefan Neuenfeldt, 2015. Eastern Baltic cod consumption and energy uptake decreased. Presentation at ICES WGSAM (Woods Hole, USA, via skype, September 2015).

Stefan Neuenfeldt, 2015. Eastern Baltic cod prey dependent growth. Presentation and ICES WKSPATIAL (Rome, USA, Italy, September 2015).

MIR-PIB

Horbowy, J., Podolska, M. 2015. Does parasitic infection effect natural mortality of cod? Working document for ICES WKBALCOD [in: ICES. 2015. Report of the Benchmark Workshop on Baltic Cod Stocks, 2–6 March 2015, Rostock, Germany. ICES CM 2015/ACOM:35].

Horbowy, J., Luzeńczyk, A. 2015. Cod in the eastern Baltic - assessment with stock-production models. Working document for ICES WKBALCOD [in: ICES. 2015. Report of the Benchmark Workshop on Baltic Cod Stocks, 2–6 March 2015, Rostock, Germany. ICES CM 2015/ACOM:35].

Horbowy, J., Podolska, M., Nadolna-Ałtyn, K. 2016. Increasing occurrence of anisakid nematodes in the liver of cod (Gadusmorhua) from the Baltic Sea: Does infection affect the condition andmortality of fish? Fisheries Research 179: 98–103. http://dx.doi.org/10.1016/j.fishres.2016.02.011

SU

Thorsten Blenckner, Viktorsson, L., Schewenius, M., Elwing, T. Rockström, J., Halpern, B. 2015. Assessing the ocean health of the Baltic Sea. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Meeting with Her Royal Highness Crown Princess Victoria from Sweden to present the ongoing work on the Baltic Sea ecology and management (23. Sepember 2015).

SLU

Casini, M., Käll, F., Hjelm, J. 2015. Changes in the body condition of the Eastern Baltic cod - potential explanations. Working document for ICES WKBALTCOD [in: ICES. 2015. Report of the Benchmark Workshop on Baltic Cod Stocks, 2–6 March 2015, Rostock, Germany. ICES CM 2015/ACOM:35]

Orio, A. 2105. Understanding the spatio-temporal dynamics of demersal fish species in the Baltic Sea. Aqua Introductory Research Essay 2015:1 Department of Aquatic Resources. Swedish University of Agricultural Sciences, Drottningholm Lysekil Öregrund. 29 p. http://pub.epsilon.slu.se/12864/7/orio_a_151126.pdf.

Casini, M. Käll, F., Hansson, M. And Hjelm, J. 2015. Dead zones relate to the body condition of the Baltic Sea cod. Oral presentation at the “ICES Annual Science Conference”, Copenhagen (Denmark), 21-25 September 2015.

Alerssandro Orio and Michele Casini 2015. Modelling the spatio-temporal dynamics of cod and flounder in the Baltic Sea using bottom trawl surveys data. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Casini, M. “Spatio-temporal changes in exploited fish populations in the Baltic Sea: patterns, causes and consequences”. Oral presentation at the Annual Congress of the Swedish Society of Marine Sciences, Lund (Sweden), 18-20 November 2015. Key-note speaker.

Organising workshop on Essential Coastal Habitats (SLU, Öregrund, Sweden, 2-4 June 2015).

BIOR

Makarchouk, A. and Arula, T. 2015. Changes in spation-temporal distribution of eggs and larvae of sprat (Sprattus sprattus) in the Gotland Basin (Baltic Sea) in 2004-2014. ICES CM 2015/Q:16. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Briekmane L., Ustups D., Berzins V. and Pliksh M. 2015. Changes in fish communities in the coastal area of Baltic Sea and Gulf of Riga during last decade. ICES CM 2015/Q:32 Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

TI-OF

Moll Dorothee; Kotterba Paul; Polte Patrick 2015. Spawning bed selection of Atlantic herring (*Clupea harengus*) in coastal waters of the Western Baltic Sea. Presentation at 39th Annual Larval Fish Conference. Vienna, Austria, 12-17. July 2015.

Moll Dorothee; Kotterba Paul; Polte Patrick 2015. Spawning bed selection of Atlantic herring in coastal waters of the Western Baltic Sea. Presentation at European Marine Biology Symposium, 21.-25. September 2015. Helgoland, Germany.

Polte, Patrick, Paul Kotterba, Julia Heiler, Sarah Beyer, Dorothee Moll, Lena v. Nordheim 2015. Loops of near shore habitat use by early herring (*Clupea harengus*) life stages in the Western Baltic Sea. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Polte, Patrick, Paul Kotterba, Dorothee Moll, Lena v. Nordheim 2015 Drivers and stressors of Atlantic herring (*Clupea harengus*) recruitment in inshore Baltic Sea spawning areas. Presentation at CERF 2015, Grand Challenges in Coastal & Estuarine Science: Securing Our Future, Portland, Oregon, USA, 8.-12- November.

Paulsen Matthias; Clemmesen Catriona; Hammer Cornelius; Malzahn Arne; Patrick Polte; Peck Myron. 2015. Investigating nutritional effects on growth rates of larval herring in the vestern Baltic Sea. Presentation at 39th Annual Larval Fish Conference. Vienna, Austria; 12-17. July 2015.

LUKE

STOCK DIVERSITY OF HERRING IN THE NORTHERN BALTIC: IS THE SEPARATE ASSESSMENT OF THE HERRING IN THE GULF OF FINLAND POSSIBLE? Tiit Raid Jukka Pönni and Jari Raitaniemi Gulf of Finland

Trilateral Co-operation Scientific Forum, 17-18 November 2015, Tallinn, Estonia.

PELAGIC FISH STOCKS IN THE GULF OF FINLAND - LIFE ON THE EDGE OF THE SEA Heikki Peltonen, Tiit Raid and Jukka Pönni Gulf of Finland Trilateral Co-operation Scientific Forum, 17-18 November 2015, Tallinn, Estonia.

Participating at international/regional communication: trilateral cooperation Finland-Estonia-Russia / Gulf of Finland studies.

GEOMAR
Andreas Lehmann, Hans-Harald Hinrichsen, Katharina Höflich. 2015. Spawning areas of eastern Baltic cod revisited: Using hydrodynamic modeling to identify hotspots. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

Katharina Höflich, Andreas Lehmann, Piia Post, Klaus Getzlaff and Kai Myrberg. 2015. On the atmospheric and oceanic conditions associated with large volume changes (LVCs) and major inflows (MBIs) to the Baltic Sea. Presentations at BSSC (Riga, Latv15-19 June 2015).

LU
Anders Persson, Peter Ljungberg, Anders Nilsson. 2015. Predicting spatial and temporal use of coastal habitats by Atlantic cod using foraging theory. Presentation at ICES ASC (Copenhagen, Denmark 21-25. September 2015).

UU
Wallin, Isa 2016. Opportunities for hybridization between two sympatric flounder (*Platichtys flesus*) ecotypes in the Baltic Sea. Master thesis in biology, Biology Education Centre, Uppsala university (supervisor Anders Nissling).

Nyberg, Sofia 2015. Egg buoyancy and survival probabilities of the Baltic flounder (*Platichtys flesus*); differences between spawning areas and interannual variation in conditions for reproduction. Bachelor thesis in biology, Biology Education Centre, Uppsala university (supervisor Anders Nissling; assistant supervisor Christoph Petereit).

2016
UT-EMI
Publication:
Ojaveer, H., Lankov, A., Teder, M., Simm, M., Klais, R. (2016). Feeding patterns of dominating small pelagic fish in the Gulf of Riga, Baltic Sea. Hydrobiologia, DOI 10.1007/s10750-016-3071-5

Presentations:
Klais, R., Otto, A.S., Teder, M., Simm, M., Ojaveer, H. Climate effects on small copepods [Oral presentation]. ICES/PICES 6th zooplankton production symposium Bergen, Norway 9-13 May, 2016

Klais, R., Otto, S., Teder, M., Simm, M. and Ojaveer, H. 2016. Long-term dynamics of small copepods in a coastal area of the Baltic Sea. [Oral presentation]. ICES ASC Riga, Latvia, 26-30 September 2016

MacKenzie, B., Ojaveer, H. 2016. Uncovering the past dynamics of a collapsed fish stock: Gulf of Riga autumn-spawning herring [Oral presentation]. ICES WGHIST, Copenhagen, Denmark, 6-9 September 2016

Ojaveer, H. and Klais, R. 2016. The spatial dynamics in quantitative and qualitative feeding of sprat and herring and their dietary overlap [Oral presentation]. ICES WKSPATIAL, Riga, Latvia, 8-10 October 2016

Ojaveer, H. and Klais, R. 2016. Dynamics of pelagic fish, their feeding and prey. National BONUS BAMBI/BIO-C3/INSPIRE seminar on The new challenges in management of the Baltic Sea. Tallinn, Estonia, 27 April 2016

Raid, T. 2016. Herring stocks in the open Baltic Sea and Gulf of Finland. National BONUS BAMBI/BIO-C3/INSPIRE seminar on The new challenges in management of the Baltic Sea. Tallinn, Estonia, 27 April 2016

DTU-Aqua

Publications:

Andersen, N.G., Chabot, D. and Couturier C.S. 2016 Modelling gastric evacuation in gadoids feeding on crustaceans. Journal of Fish Biology 88, 1886–1903

Ross, S.D., Andreasen, H., Andersen, N.G. 2016. An important step towards accurate estimation of diet composition and consumption rates for the harbor porpoise (*Phocoena phocoena*). Marine mammal science 32: 1491-1500.

Presentations:

Neuenfeldt, S. Et al. (2016) Feeding and growth potential of Atlantic cod in the Baltic Sea in the wake of climate change. ICES ASC Riga, Latvia, 26-30 September 2016

Neuenfeldt, S. (2016) Further analyses of the stomach content database for the Baltic Sea ICES WKSPATIAL, Riga, Latvia, 8-10 October 2016

MIR-PIB

Publications:

Horbowy, J., Luzenczyk, A. 2016. Effects of multispecies and density dependent factors on MSY reference points: Example of the Baltic Sea sprat. Can. J. Fish. Aquat. Sci. DOI: 10.1139/cjfas-2016-0220 (accepted, October 2016)

Horbowy, J. 2016. Effects of varying natural mortality and selectivity on the assessment of eastern Baltic cod (*Gadus morhua* Linnaeus, 1758) stock. Journal of Applied Ichthyology, 32: 1032-1040. doi:10.1111/jai.13202

Presentations:

Horbowy, J. 2016. Presentation for „Forum of Baltic Fisheries“ (national meeting) on Baltic fishery management plan. Gdynia, Poland, 25. October 2016.

Horbowy, J. 2016. Presentation on the dynamics of cod stock. 4th International Maritime Congress, Szczecin, Poland, 8-10 June 2016.

Podolska, M., Horbowy, J., Nadolna-Ałtyn, K. 2016. Perils of the sea - parasites transmitted by seals. Presentation and abstract at Conference „Baltic – a small sea with big management problems“, Gdynia, Poland, 5. October 2016

SLU

Publications:

Casini, M., Käll, F., Sorais M. and Larson N. (2016). Mapping the ecological status of the fish community in the pelagic habitat: spatio-temporal trends of size-based indicators in the Baltic Sea. ICES CM 2016/J:573.

Otto, S. A., Kadin, M., Torres, M. A., Casini, M., Huss, M., Blenckner, T. and Gårdmark, A. (2016). Ecosystem-based approach for developing pelagic food-web indicators. Project final report. Naturvårdsverket, 30 pp.

Erlandsson, M. (2016) Ensemble modelling of the habitat of turbot based on video analyses and fish survey data (in Swedish), Master thesis, Uppsala University & Swedish University of Agricultural Sciences.

Presentations:

Casini, M. et al. “Mapping the ecological status of the pelagic fish community: spatio-temporal trends in size-based indicators in the Baltic Sea”. Oral presentation at the “5th EcoSummit Conference: Ecological Sustainability”, Montpellier (France), 29 August-1 September 2016.

Casini, M. Käll F, Sorais M. Larson N. “Mapping the ecological status of the fish community in the pelagic habitat: spatio-temporal trends of size-based indicators in the Baltic Sea”. Oral presentation at the “ICES Annual Science Conference”, Riga (Latvia), 19-23 September 2016.

Florin, A.-B., Palm, S., Ustups, D., Hüssy, K., Casini, M., Nissling, A., Limburg, K., & Schade, F. “Using genetics to identify management units of European flounder in the Baltic Sea“. Oral presentation at the Fisheries Society of the British Isles Symposium on ’Fish Genes and genomes: Contributions to Ecology, Evolution and Management’, Bangor, UK, 18-22 July 2016.

BIOR

Publication:

Svecovs F., Ozernaja O., Fettere F., Strods G., Vingovatova A. 2016. Baltic sprat fishery, stock assessment and prediction. Maritime Technology and Engineering III: Proceedings of the 3rd International Conference on Maritime Technology and Engineering (MARTECH 2016, Lisbon, Portugal, 4-6 July

2016). June 21, 2016 by CRC Press. II: 973-978 pp. ISBN 9781138030008 – CAT# K30346.

Presentations:
Ustups, D., Samson, M.A., Florin, A.-B., Zilniece, D. and Limburg, K. 2016. Otolith microchemistry: A tool to solve a mystery of the Baltic Sea flounder (*Platichys flesus*) Oral presentation at the "ICES Annual Science Conference", Riga (Latvia), 19-23 September 2016.

Plikss, M. 2016. Eastern Baltic cod cannibalism: stock dependent or occasional effects. Oral presentation at ICES WKSPATIAL, Riga, Latvia, 8-10 October 2016.

TI-OF
Publications:
Polte, P., Kotterba, P., Moll, D. and von Nordheim, L. 2017. Ontogenetic loops in habitat use highlight the importance of littoral habitats for early life-stages of oceanic fishes in temperate waters. Scientific Reports 4: 42709 http://www.nature.com/articles/srep42709

Polte P., Knecht N., Nordheim L.v., Oeberst R., Kotterba P. 2016. Potential effects of climate change on herring recruitment phenology in a Baltic Sea retention area. Report to ICES Working Group on Atlantic Fish Larvae and Eggs Surveys (WGALES), Thessaloniki, 17-21 October 2016.

Presentations:
Moll, D., Kotterba, P., von Nordheim, L., Polte, P. 2016. Estimating the contribution of single nursery areas to the overall herring (*Clupea harengus*) population in the western Baltic Sea by otolith chemistry. Presentation at the 51 th European Marine Biology Symposium (EMBS), September 26 -30 2016, Rhodes, Greece

von Nordheim, L., Polte, P., Kotterba, P., Moll, D. 2016. Effects of benthic substrate complexity on egg mortality of Atlantic herring (*Clupea harengus)* in the Baltic Sea. Presentation at the 51 the European Marine Biology Symposium (EMBS), September 26 -30 2016, Rhodes, Greece

Kotterba, P., Moll, D., von Nordheim, L., Hammer, C., Peck, M.A., Oesterwind, D., Polte, P. (2016) Predator impacts on inshore Baltic herring (*Clupea harengus*) larvae: Lions, tigers and bears – but where? Best-poster-award at the 51 the European Marine Biology Symposium (EMBS), September 26 -30 2016, Rhodes, Greece

LUKE
Presentation:
Raid, T., Pönni, J. & Raitaniemi, J. Central Baltic herring stock – What does the assessment of combined stock say about the status of its components?

Oral presentation in 3rd International Conference on maritime technology and Engineering (Martech), Portugal, 4-6 July 2016**.**

GEOMAR

Presentations:

Lehmann, A., Höflich, K., Post, P. and Myrberg, K. 2016. Pathways of deep cyclones associated with large volume changes (LVCs) and major Baltic inflows (MBIs). European Geoscience Union General Assembly, Vienna, Austria, 17-22 April 2016.

Höflich, K., Lehmann, A., and Myrberg, K.. 2016. Disentangling the role of atmospheric and oceanic conditions in the occurrence of major Baltic inflows: The importance of haline stratification in the Belt Sea. European Geoscience Union General Assembly, Vienna, Austria, 17-22 April 2016.

Lehmann, A., Höflich, K., Post, P. and Myrberg, K. 2016. Pathways of deep cyclones associated with large volume changes (LVCs) and Major Baltic Inflows (MBIs).1st Baltic Earth Conference, Nida, Lithuania, 13-17 June, 2016.

Höflich, K., Lehmann, A. and K. Myrberg. 2016. On the role of the haline conditions in the Belt Sea in the formation of highly saline barotropic inflows to the Baltic Sea. 1st Baltic Earth Conference, Nida, Lithuania, 13-17 June, 2016.

LU

Publication:

Berndt, K. 2016 Fishing the gene pool: Genetic structure, admixture and behavioural complexity in fisheries management (Supervisors Anders Persson, Rosa Figueroa and Johan Hollander). PhD Thesis. Lund University.

UU

Publication:

Wallin, I. 2016. Opportunities for hybridization between two sympatric flounder (*Platichtys flesus*) ecotypes in the Baltic Sea Supervisor Anders Nissling). MSc thesis. Uppsala University.

14. Number of post graduate courses organised by the project (1) and persons participating (2).

2014

None

2015

None

2016

DTU-Aqua

BONUS BIO-C3/INSPIRE/COCOA/BAMBI 2016 Summer School: Modelling Biodiversity for Sustainable Use of Baltic Sea Living Resources; August 21–

27, 2016, Søminnestationen, Holbæk, Denmark. 23 student participants and 7 lecturers.

15. Number of mobility activities – persons (1), visit days (2) – From the project to the other BONUS projects.

2014

UT-EMI

Participation in BONUS BIO-C3 work: meetings and initiation of joint activities: Baltic Sea zooplankton study (http://kodu.ut.ee/~riina82/) and BONUS Theme Session at ICES ASC 2015 (http://www.ices.dk/news-and-events/asc/ASC2015/Pages/Theme-Sessions.aspx).

MIR-PIB

Participation (A. Luzeńczyk) at BIO-C3 kick-off meeting.

UU

Anders Nissling participated on a survey with R/V Alkor & provided Jan Dierking (BIO-C3) with flounder samples for isotope analysis.

2015

UT-EMI

Attendance (H. Ojaveer) at BONUS BIO-C3 annual meeting in Kiel, Germany; 30. June – 3. July 2015 (4 days).

Working visit (7 days) of H. Ojaveer to DTU-AQUA for collaboration with BONUS BIO-C3.

DTU-Aqua

S. Neuenfeldt visited UHAM 2 times á 2 days to coordinate with BONUS BIO-C3 participants.

UU

Sofia Nyberg participated on a survey with R/V Alkor (BIO-C3) (time spent 15 days) sampling flounder for determination of ecotype & performed measurements of egg specific gravity.

2016

UT-EMI

Attendance (H. Ojaveer) at BONUS BIO-C3 annual meeting in Tallinn, Estonia; 28-30 June 2016 (3 days)

Attendance and hosting (H. Ojaveer) BONUS BIO-C3 Baltic Sea round goby workshop in Tallinn, Estonia; 27. June 2016 (1 day)

Attendance (H. Ojaveer) at BONUS GOHERR fieldwork near Pärnu (Estonia); 14. May (1 day)

LUKE
Attendance (J. Raitaniemi) at BONUS GOHERR workshop in Copenhagen, Denmark; 16-17 February 2016 (2 days)

16. **Number of PhD students (1) and the number of post-docs (2) funded by the project** as well as the number of **doctoral thesis defended (3)**.

2014
SU
One post doc (Susa Niiranen) started in SU in 2014**.**

SLU
One PhD student (Alessandro Orio) started in SLU in 2014.

BIOR
One PhD student (Ivars Putnis) is a part-time participant and one Post doc (Didzis Ustups) started in INSPIRE project.

TI-OF
One PhD student (Dorothee Moll) started in TI-OF in 2014.

UHAM
One Post doc (Klas Ove Möller) and one PhD student (Muriel Kroll) started in UHAM in 2014.

GEOMAR
One PhD student (Katharina Höflich) started in GEOMAR in 2014

2015
MIR-PIB
Two PhD students (Anna Luzeńczyk and Szymon Smoliński) and one Post doc (Krzysztof Radtke) started in INSPIRE project.

LU
PhD student (Kim Berndt) is working for INSPIRE project in 2015.

2016
SU
Post doc (Stuart Kininmonth) started in INSPIRE in 2016**.**

BIOR
Post doc (Maris Plikss) started in INSPIRE project in 2016.

GEOMAR
Two post docs (Klaus Getzlaff and Hans-Harald Hinrichsen) started in INSPIRE in 2016.

LU
PhD thesis defended: Berndt, K. 2016 Fishing the gene pool: Genetic structure, admixture and behavioural complexity in fisheries management. Shared supervision together with Anders Persson, assistant supervisors Rosa Figueroa and Johan Hollander. Defended 18. May 2016.

8. Distribution of the project 's research staff and research organisations involved by age class, seniority and gender

Age group	PhD students		Post-docs		Assistants, lecturers, instructors and eq		Associate professors and eq		Professors and eq	
	F	M	F	M	F	M	F	M	F	M
<= 24	0	0	0	0	1	0	0	0	0	0
25 - 49	4	6	1	6	16	14	9	11	0	5
50 - 64	0	0	0	2	5	9	2	12	0	5
>= 65	0	0	0	0	1	3	0	2	0	0

Annex 1

Integrating spatial processes into ecosystem models for sustainable utilization of fish resources (INSPIRE)

Report

Second Annual Meeting

21, 23 September 2016

Riga, Latvia

Agenda item #1: Arrival and registration

Second annual meeting of INSPIRE was held in Riga, Latvia on 21 and 23. September 2016, in conjunction of ICES Annual Science Conference. The meeting was hosted by BIOR and held in Radisson Blu Hotel Latvia. The meeting agenda can be found in Annex 1. The meeting was attended by 22 participants (Annex 2).

Agenda item #2: Welcome and housekeeping

The meeting host Georgs Kornilovs welcomed participants and introduced houskeeping rules.

Agenda item #3: Project coordination and reporting update

The project coordinator described and explained the requirements and needs for the project annual reporting. Reports of work package leads and project partner institute PI's according to the required format is due 10. March. This will allow sufficient time for the coordinating partner to assemble all input and finalise the report to BONUS (due 31. March 2017).

Agenda item #4: Workpackage and champions overviews

WP1 Spatial distributions (Lead Michele Casini, SLU)

Work package 1 focuses on understanding the spatial distribution and habitat preferences of the focus species, cod, flounder, herring and sprat.

The status of the Deliverables was presented by the WP1 lead. A summary of the status of the Deliverables, together with the data envisaged to be used to tackle them, is presented below.

D1.1 Database from first surveys to initiate habitat modelling and spatial distribution analyses (M14, SLU)

The Deliverable has been submitted, approved by the Coordinator and accepted by BONUS.

The databases of INSPIRE gillnet and beach seines samples and Ichthyoplankton samples are now finalized. The data are quality-checked and ready to perform the analyses to tackle future deliverables and additional analyses.

D1.2 Report on distribution maps for different life-stages (M28, SLU)

The Deliverable has been submitted and approved by the Coordinator.

- ✓ An existing hydrodynamic model (BSIOM) was combined with a Lagrangian particle-tracking technique to resolve drift patterns of cod and flounder eggs and larvae and predict their abundances in the Baltic seascape. These maps represent a significant step forward in the knowledge on essential reproduction habitats for Baltic cod, and will be of use in both fisheries management and marine spatial planning.
- ✓ Using an extensive dataset of trawl survey data that has been collated from different national sources around the Baltic and then standardized to account for different gear types, the spatial distribution of different life-stages of cod and flounder was statistically related to hydrographic, bathymetric and geographic predictor variables, taking year-by-year variation into account. The resulting statistical models were then used to produce spatial predictions of abundance of cod and flounder across the Baltic Proper every year from 1979 to 2014. The resulting map predictions of juvenile cod (15-30 cm) show a contraction and an increase in abundance of small cod individuals in the southern SDs of the Baltic Sea. The maps of adult cod (> 30 cm) show that the cod was distributed in high abundances in the whole area of study in 1985 and then started contracting in SDs 24-26 in the 90s and 2000s. The maps of flounder show that in 1985 the highest abundances were in SD 24 and on the eastern coast of the Baltic. In 1995 the abundance of flounder generally increased in the whole area and in 2005 it is possible to see particularly high abundances of flounder in the coastal areas of SD 28. In 2014 the high abundances in SD 28 are still present but a great increase in abundance of flounder can be seen in SDs 24 and 25.
- ✓ Data from the Baltic International Acoustic Survey (BIAS) was used for producing distribution maps of herring and sprat biomass. These maps are then used to study the spatial overlap over time between cod (D1.4), sprat and herring which is used to evaluate the potential predator-prey and competitive relationships in the Baltic Sea.
- ✓ The data from the ichtyoplankton survey were used to map and analyze the spatial distribution of sprat eggs and larvae and its changes, to detect correlations between

spatial patterns and the hydrographic situation, and also the correlation between spatial distribution of eggs and larvae and success of recruitment of sprat in the area. In May sprat eggs were abundant only in the southern and central parts of the Gotland Basin. In June sprat eggs appeared in big numbers also in the northern regions. The amount of sprat larvae was rather low in both years.

- ✓ The habitat use of herring larvae have been mapped in a major spawning area in the southwestern Baltic Sea, in the Greifswald Bay. The weekly survey on this detailed station grid provides a rather high resolution of larval herring distribution patterns throughout early life stage retention in the sheltered lagoon. From a total length (TL) of 11 mm on, larvae were found to be increasingly dispersed throughout the pelagic zone of the bay. However, all size classes were found in high concentrations in the connecting sound (Strelasund) at the western entrance to the bay. It is currently unclear if this is due to increased migration through this pass way or due to an increased likelihood of sampling larvae because the limited extension of the water body potentially increases larval densities (Polte et al. 2016).

D1.3 Manuscript on simulating spatial distributions of key exploited stocks (M28, SLU).

The Deliverable has been submitted and approved by the Coordinator.

Generalized Additive Models were used to investigate the spatio-temporal dynamics of the Eastern Baltic cod stock during the past 35 years in view of density-dependence and hydrographic variability. The results showed that adult cod distribution was mainly affected by cod population size, and to a minor degree by small-scale hydrological factors and the extent of suitable reproductive areas. As population size decreases, cod population concentrates to the southern part of the Baltic Sea, where the preferred more marine environment conditions are encountered. Using the fitted models, we predicted the Baltic cod distribution back to 1970s and a temporal index of cod spatial occupation was developed. Our study will contribute to the management and conservation and of this important resource and of the ecosystem where it occurs, by showing the forces shaping its spatial distribution and therefore the potential response of the population to future exploitations and environmental changes (Casini et al. 2016).

D1.4 Report on spatial overlap between predator-prey and competing species (M28, SLU)

The Deliverable has been submitted and approved by the coordinator.

- ✓ Data from ICES currently coordinated surveys and historical data newly compiled and standardized within INSPIRE were used to produce maps of spatial distribution from which simple estimations of spatial overlap were performed. The main results show a temporal drop in the occurrence of cod in the distribution area of sprat and herring, and a similar drop in the occurrence of large cod in the distribution area of small cod. This put in evidence a potential decrease in predation pressure by cod on its prey (including cannibalism) due to spatial mismatch. On the other hand, prey occurrence in the areas occupied by cod did not change as much during the past 35 years, likely evidencing that cod feeding opportunities on fish prey have not changed substantially. Moreover, sprat occurrence in the rectangles occupied by herring increased in the period 1985-2014 indicating a potential increased competition by sprat on herring stock.
- ✓ To better characterize the actual competition between the herring and sprat, dietary habits and diet overlap of herring and sprat were also investigated. The analyses showed that the spatial dynamics in the taxonomic composition of clupeid stomachs broadly resembled that of the availability of prey. Sprat and herring diet overlapped more in the eastern Gulf of Finland than in the Baltic Proper. The diet similarity appeared to be the highest between large sprat and large herring, large sprat and small herring, and small and large herring. The least similar diet was observed for small and large sprat.

D1.5 Manuscript on habitat preferences of different life-stages of fish (M34, SLU).

The amount of data collected during the INSPIRE field surveys allows for tackling the Deliverable from different angles and using different approaches. A list of potential studies was discussed and produced.

- ✓ Habitat characterization of cod and flounder, related to abiotic circumstances and interactions with other species (INSPIRE gillnet surveys) (Alessandro Orio, SLU).

- ✓ Gradient offshore-inshore in cod condition related to abiotic circumstances and the abundance of other species (INSPIRE gillnet surveys) (Karin Hüssy, DTU-Aqua).
- ✓ Habitat preferences for early life stages of flounder (INSPIRE beach seines sampling) (Ulf Bergström, SLU).
- ✓ Habitat characterization of sprat eggs and larvae and relation to the distribution of the spawning biomass (INSPIRE ichtyoplankton surveys) (Georgs Kornilovs, BIOR).

It was suggested to ask permission from BONUS to postpone submission of D1.5 from M34 to M36.

D1.6 Manuscript on spatially explicit population and foodweb modeling (M40, DTU-Aqua)

- ✓ A spatially explicit Bayesian Belief Network is under development for the Baltic Sea. Spatially-resolved biological and hydrological data will be used to generate conditional probabilities such that a fully working model is constructed. This model will encompass spatial structure, not through isolated instances of the model but through a process of identifying the key spatial drivers of the population interaction. A paper is in preparation with the preliminary title "Non-Stationary modeling of a fishery in flux: The structural, environmental and trophic influences of the Baltic Sea system" (Kininmonth et al. 2016) (Thorsten Blenckner, SU).
- ✓ The spatially explicit SMS model will be updated and ran for recent years. Despite the problems in cod age-reading, the model will be applied to illustrate relative trends in the ICES sub-divisions 25, 26 and 28. Sub-division specific stock-recruitment relationships will be analysed and the sensitivity for all-Eastern Baltic stock-recruitment relationships to sub-division specific recruitment relationships will be investigated (Stefan Neuenfeldt, DTU-Aqua).

D1.7 Design protocol for future surveys for flatfish and juvenile cod M44 (SLU).

The original plan of INSPIRE for this Deliverable was that the data and analyses from the gillnet samplings would be used to design a reliable recruitment index for cod (integrating BITS data) and flounder, applicable in stock assessment. However, too few juvenile cods were caught during the gillnet surveys to be able design a reliable index for this species. On the other hand, for flounder this is still considered feasible.

References

Casini M, Tian H, Bergström U, Jounela P, Aro E, Dieterich C, Meier M, Cardinale M, Bland B, Bartolino V. (2016). Spatio-temporal dynamics of a fish predator: density-dependent and hydrographic effects on Baltic Sea cod population. Under revision, PLoS ONE.

Hinrichsen et al. (2016). Spawning areas of eastern Baltic cod revisited: Using hydrodynamic modelling to reveal spawning habitat suitability, egg survival probability, and connectivity patterns. Progress in Oceanography 143: 13-25.

Polte P, Kotterba P, Heiler J, Beyer S, Moll D, v. Nordheim L. (2016). Loops of near shore habitat use by early herring (*Clupea harengus*, L.) life stages in the Western Baltic Sea. ICES CM 2015/ Q:05.

WP2 on passive movements, active migrations and habitat connectivity (Lead Christian Möllmann, UHAM)

Objectives of WP2 are:

1. Develop and test estimates of drift pattern for early life stages of cod and flounder.
2. Estimate net migration rates of adult cod, herring and sprat between ICES sub-divisions.
3. Develop a mechanistic test for importance of migrations compared to fishing, predation and reproduction in relation to changes in the spatial distributions of cod, herring and sprat.

Deliverables 2.1-2.5 have already been submitted and approved.

D2.6 Manuscript on small scale movements M36 (UHAM)

The deliverable work is proceeding according to the plan. Information about species movements and the resulting interactions at a spatial scale comparable to the perceptive abilities of the involved species is crucial for establishment of predictive, functional response models at the population level. Nevertheless, such information is sparse due to methodological constraints. We studied the diel, vertical dynamics of species interactions between Atlantic cod *Gadus morhua* and its major clupeid prey sprat *Sprattus sprattus* at a location in the Bornholm Basin of the central Baltic Sea during late winter. Bioacoustics information on diel vertical fish movements, time of ingestion of individual sprat estimated from cod stomach content data and vertical profiles of salinity, temperature and oxygen content were combined. Cod predation took place primarily at dusk and dawn during ascent and descent of sprat associated with school dissolution and formation. Cod resided close to the bottom outside these temporal predation windows. Sprat schools were located at the same depth or deeper than cod in the light hours, whereas dispersed sprat at night were situated higher in the water column. These dynamics could be explained by simple fitness optimization considerations using bioenergetics and trade-offs between temperature, oxygen saturation of the water, and predation risk. This study thus forms the first step to providing a mechanistic background for the aggregative function response of cod at basin scale and beyond.

Progress on hydrodynamic modeling Sea (Andreas Lehmann, GEOMAR):

1. The Kiel Baltic Sea model has been run for the period 1979-2015, 2016 will be calculated as soon as the atmospheric forcing is available.

2. The horizontal resolution of the model is about 2.5 km and in the vertical 3 m levels are prescribed. The model comprises the entire Baltic Sea including Kattegat and Skagerrak. Three-dimensional fields of temperature, salinity, density, oxygen and current fields as well as two-dimensional fields of sea level, sea ice, sea ice drift are stored as daily averages. The atmospheric forcing to run the models is also available on the Baltic Sea model grid with a temporal resolution of 3 hours. The data are available for further analysis and studies. We use the data also for drift studies and reconstruction of abiotic conditions of the Baltic Sea.

3. In cooperation with Karin and Margit we started to calculate the habitat size for cod for the period 1979-2015. Also benthic oxygen conditions and reproductive volumes could be calculated. This work is in an initial state and will hopefully be continued and intensified until the end of the year.

4. Model development with respect to oxygen: Recent observations confirm that oxygen depletion rates in the deep basins of the Baltic Sea have increased since the last 10-20 years. There is a need for the detailed analysis of increased oxygen consumption rates, and as a next step, to implement this effect into the Baltic Sea model, because it directly affects habitat sizes. This work should be coupled to the calculations of habitats.

5. BSIOM coupled to a wave model: The hydrodynamic model has been coupled to a simple wave model. The coupling affects exchange processes between atmosphere and ocean, the vertical mixing in the Baltic Sea and surface drift.

6. Planned publications:

Lehmann A., Höflich K., Post P., Myrberg K. Pathways of deep cyclones associated with large volume changes (LVCs) and major Baltic inflows (MBIs). (First revision under review).

Hinrichsen H.-H., von Dewitz B., Lehmann A., Bergström U., Hüssy K. Spatio-temporal dynamics of juvenile cod's nursery areas in the Baltic Sea (draft).

Höflich K., Lehmann A., Myrberg K. Disentangling the role of atmospheric and oceanic conditions in the occurrence of major Baltic inflows: the importance of haline stratification in the Belt Sea (draft).

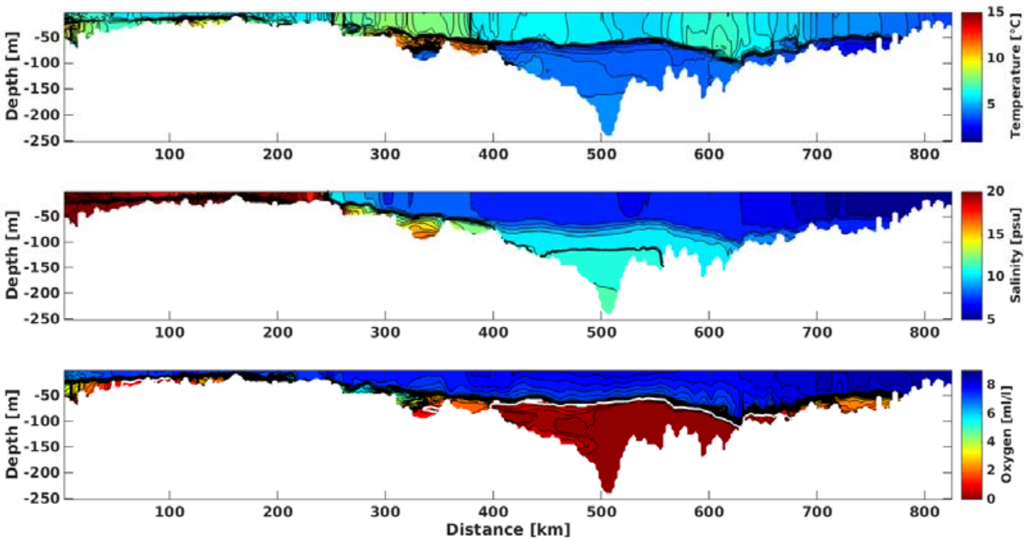

Fig. 1a. Section through the Baltic Sea on 12 December 2014 (based on Kiel Baltic Sea model BSIOM).

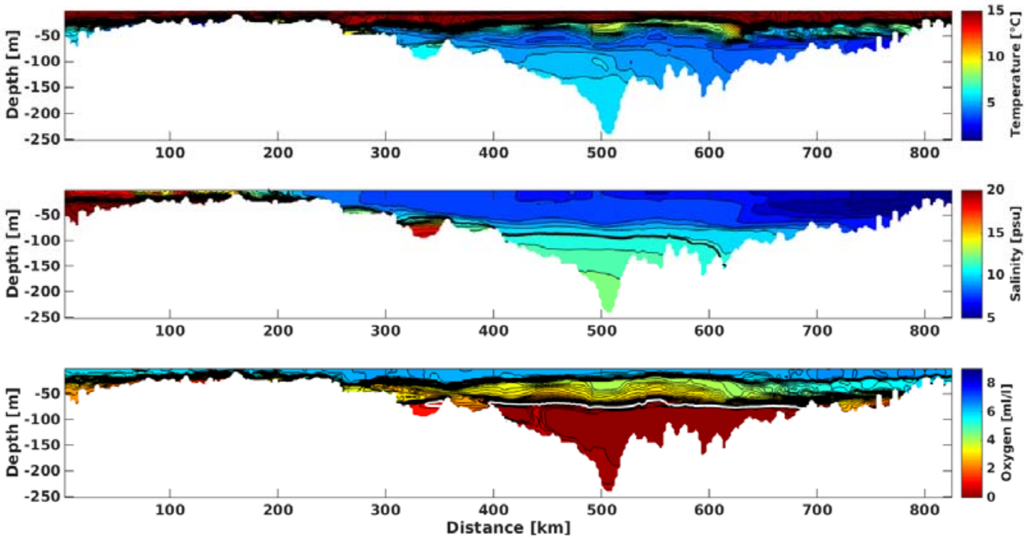

Figure 1b. Section through the Baltic Sea on 4th August 2015 (based on Kiel Baltic Sea model BSIOM).

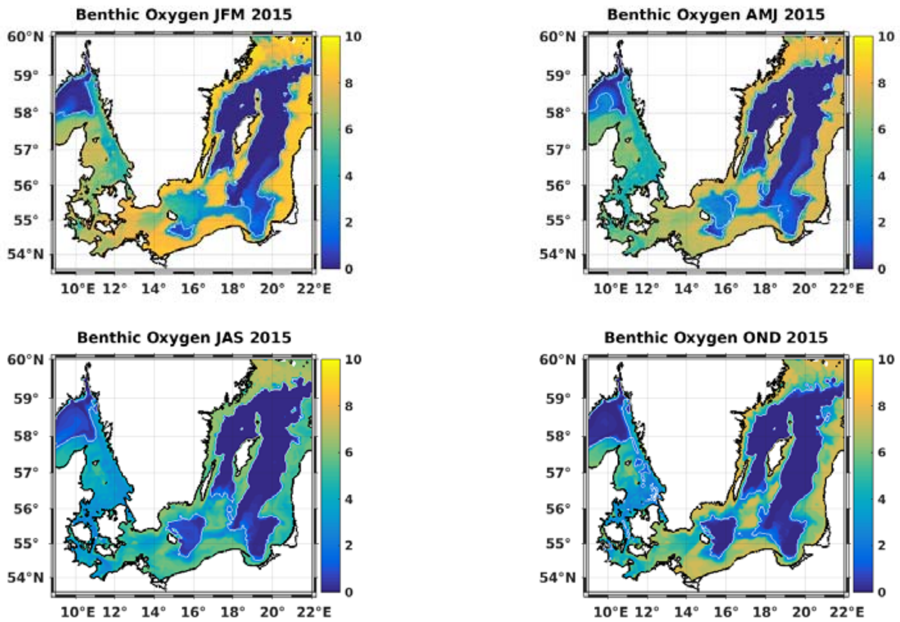

Figure 2a. Seasonal benthic oxygen distribution for the year 2015, 2 ml/l is marked by white isoline (based on Kiel Baltic Sea model BSIOM).

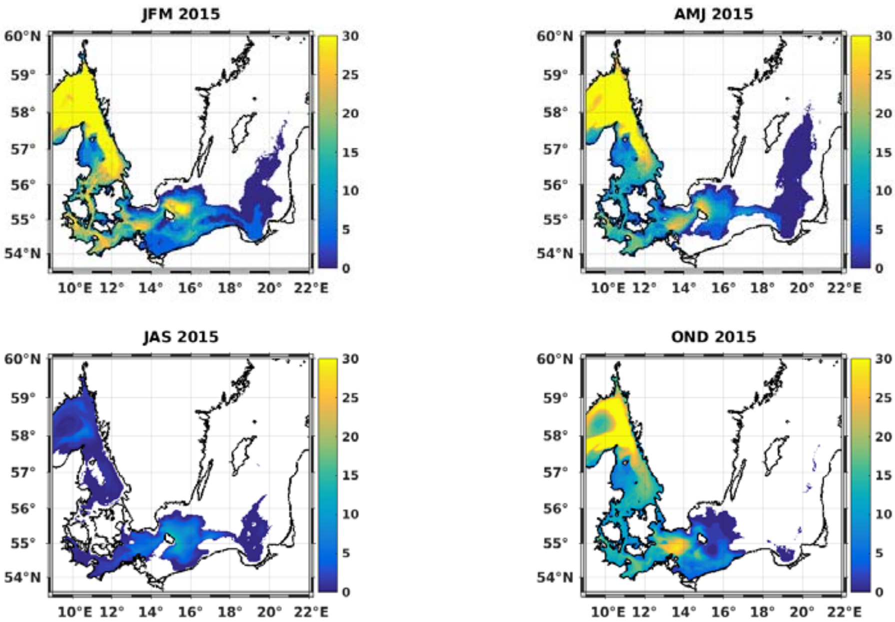

Figure 2b. Seasonal cod pelagic habitat thickness [m] for the year 2015 (based on Kiel Baltic Sea model BSIOM).

WP 3 Scaling from individuals to populations (Lead: Patrick Polte, TI-OF)

Task 3.1 Scaling individual movements to populations' spatial distributions

D3.1 Manuscript on distribution probability maps for juvenile cod and flounder (M36)

Hinrichsen H.-H., von Dewitz B., Lehmann A., Bergström U., Hüssy K. Spatio-temporal dynamics of juvenile cod's nursery areas in the Baltic Sea (draft).

The transport of eastern Baltic cod larvae and juveniles spawned within the historical eastern Baltic cod spawning grounds was investigated by detailed drift model simulations for the years 1971 to 2010. In this study, the spatio-temporal dynamics of environmental suitability in the nursery areas of juvenile cod settlement areas were examined. The results of the long-term model scenario runs, where juvenile cod were treated as simulated passively drifting particles, enabled us to find strong indications for the effect of long-term variability of the location of eastern Baltic cod nursery grounds. Generally, only a low number of juveniles which hatched in the Arkona Basin and in the Gotland Basin were able to settle. Juveniles hatched in the Bornholm Basin were most widely dispersed and showed the highest settlement probability, while the second highest settlement probability and horizontal extension was obtained for juveniles originating in the Gdansk Deep. On a long-term perspective wind-driven juvenile transport patterns were dominated by settlement in the Bornholm Basin and in the Gdansk Deep, i.e. the Bornholm Basin contributed on average more than 54 % and the Gdansk Deep around 11% to the overall production of juveniles. Furthermore, transport of successfully settled juveniles with origin in the Bornholm Basin contributed on average 13 and 11% to Arkona Basin and the Gdansk Deep, respectively. A manuscript on probability maps based on flounder larvae drift is in preparation. Most of the calculations have been already done, but there is still analysis and writing work to do.

D3.2 Manuscript on the impact of active migrations in the observed distributional changes of cod, herring and sprat (M40)

Moll D., Kotterba P., v.Nordheim L., Polte P. Estimating the contribution of single areas to the overall herring (*Clupea harengus*) population in the western Baltic Sea by otolith chemistry (in prep.).

Task 3.2 Quantifying effects of regional hazards on larger scale productivity and spatial distributions

D3.3 Manuscript on the role of small- and meso-scale drivers and stressors for overall Baltic herring recruitment M40

Moll D., Kotterba P., v. Nordheim L., Polte P. Storm-induced Atlantic herring (*Clupea harengus*) egg mortality in Baltic Sea inshore spawning areas (draft).

During spring migration Atlantic herring (*Clupea harengus*) populations in the Baltic Sea rely on shallow transitional waters, such as estuaries, bays and lagoons for spawning. Those inshore spawning grounds provide suitable substrates for benthic egg deposition and important retention areas for hatching larvae. Strong correlations between larval and 0 group abundances suggest that egg and early larval survival is critical in determining reproductive success of the Western Baltic herring population. The mechanisms by which local stressors might affect overall recruitment on population level are currently not well understood. Decades of eutrophication caused a decline in depth distribution of submerged aquatic vegetation, the main herring spawning substrate of in the Baltic Sea. Hypothesizing that water depth limit of vegetation exposes herring eggs to high mortality by storm induced hydrodynamics, we combined field studies and model approaches to investigate the impact of storm events on herring egg loss.

Results of a pre-impact/post-impact experiment shows a 94 % egg loss on herring spawning beds. Since this amount potentially includes an unknown loss due to larval hatching the study was complemented by an egg loss model based on the observed storm induced loss of spawning substrate revealing a minimum egg loss of 30 %. Impact analysis on population level resulted in a reproductive capacity loss of 2.7×10^6 (min.) and 12.7×10^6 (max.) individuals in one single spawning bed during multiple storm events. The results underline the function of vegetated littoral zone for herring reproduction and conclude that overall population dynamics can be affected by regional weather extremes.

Publications under task 3.2

Published

Arula T., Laur K., Simm M., Henn Ojaveer. 2015. Dual impact of temperature on growth and mortality of marine fish larvae in a shallow estuarine habitat. Estuarine and Coastal Shelf Science, 168: 326-335

Arula T., Raid T., Simm M, Ojaveer H. 2016. Temperature-driven changes in early life-history stages influence the Gulf of Riga spring spawning herring (*Clupea harengus m.*) recruitment abundance. Hydrobiologia, 767:125-137.

Submitted

Kotterba P., Moll D., Hammer C., Peck M.A., Oesterwind D., Polte P. Evil residents? - Predation on Atlantic herring *Clupea harengus* eggs in vegetated spawning beds in a Baltic Sea lagoon (under review, Limnology & Oceanography)

In preparation

Ojaveer, H. et al. What determines of Gulf of Riga spring spawning herring recruitment abundance

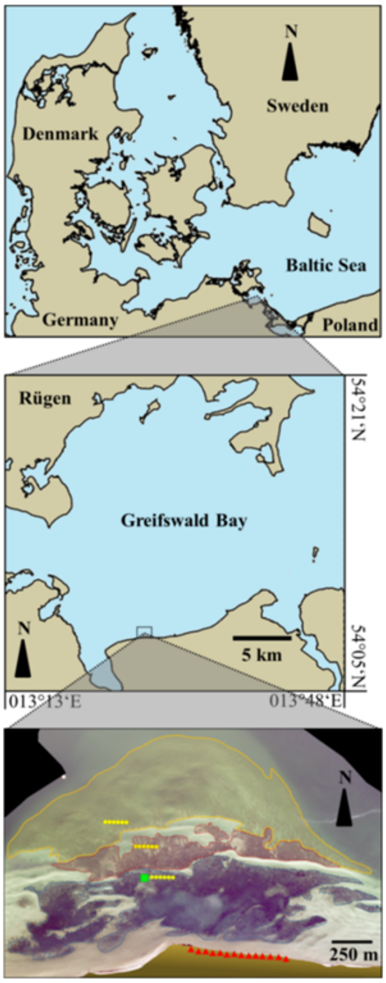

Figure 3. The investigated herring spawning site in Greifswald Bay and its location within the Western Baltic Sea. Dots in the aerial image of the spawning bed (lower map) indicate the location of fixed transects used for the monitoring of depth-dependent spawning intensity. The square represents the area used for the storm impact experiment while the triangles on the beach indicate the sampling points for the examination of storm induced SAV litter. The broken line defines the area that represents spawning zone "A", the dotted line limits the spawning zone "B" while spawning zone "C" is indicated by the solid line. Black areas on the higher corner of the aerial image indicate submerged aquatic vegetation (SAV)-free zones with water depth of more than 5 meters

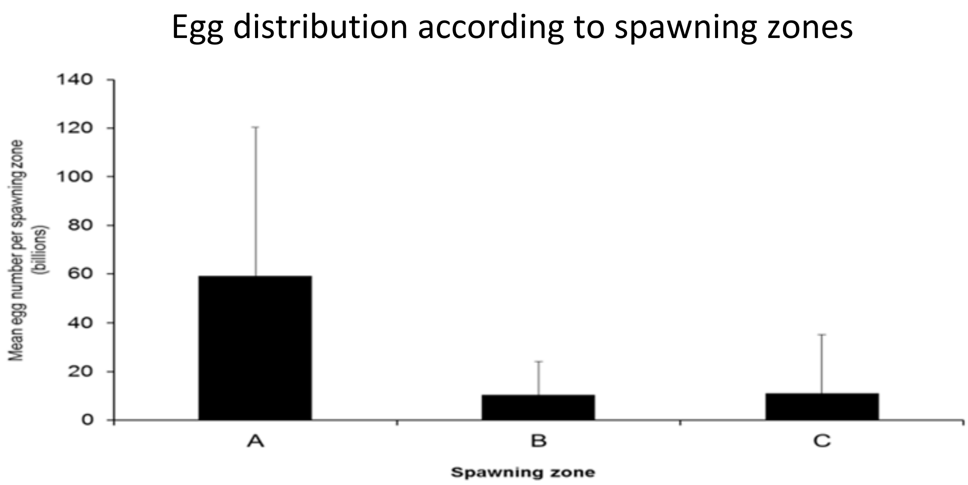

Figure 4. Herring egg distribution on three different spawning zones prior to the storm, based on calculated mean eggs numbers per spawning zone (n = 6). Standard deviations are indicated by error bars.

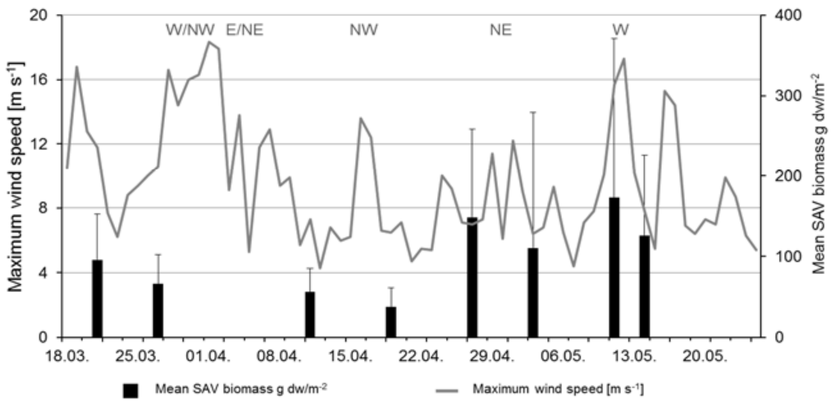

Figure 5 Mean submerged aquatic vegetation (SAV) biomass g DW m^{-2} (bars) with standard deviation along the spawning season 2012. The grey line represents the daily maximum wind speed [m s^{-1}] prevailing wind directions during selected storm events are given in abbreviation

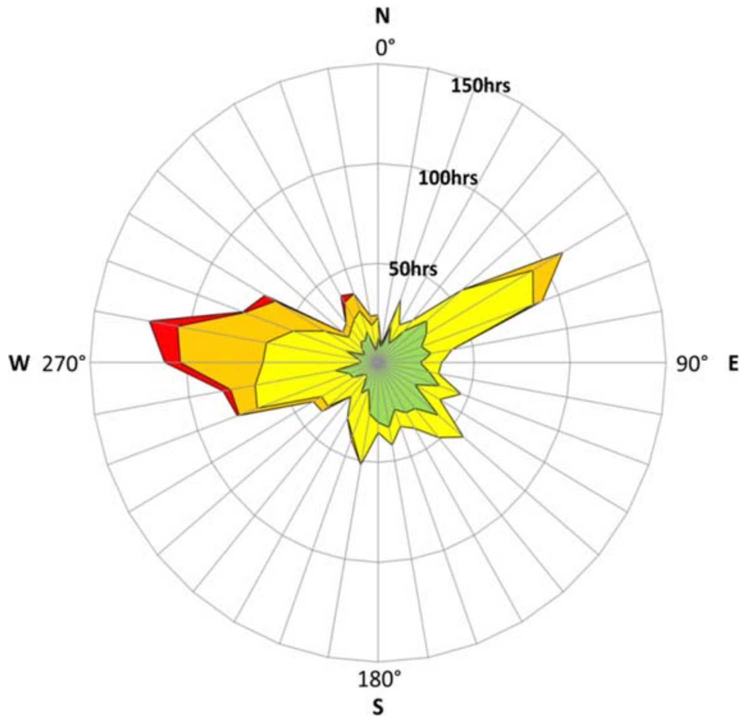

Figure 6 Dominant wind directions and wind speeds for Greifswald Bay between March 15th and May 25th 2012 based on hourly measurements provided by Germany's National Meteorological Service (DWD). Wind speeds are given in distinct categories (green indicates hours with a measured wind speed of ≤ 5 m s^{-1}; yellow indicates hours with a wind speed between 5 and 10 m s^{-1}, orange indicates a wind speed between 10 and 15 m s^{-1} and red a wind speed of > 15 m s^{-1}).

WP4 on Stock assessments (Jan Horbowy, MIR-PIB)

Objectives of WP4 are:

1. to include and quantify the effects of migrations and spatial and temporal changes in exploited fish distribution (cod, herring, and sprat) on stock assessment,
2. to provide assessment of the status of flatfish in the Baltic, as a basis for quantitative management of these stocks.

The work-package is composed of three tasks:

Task 4.1. Assessment of fish stocks with inclusion of migration, spatial and temporal effects, and taking into account impact of cod predation

Task 4.2. Stock identification of flounder in the Baltic Sea

Task 4.3. Data analysis and analytical assessment or evaluation of flatfish stocks.

First two deliverables were originally scheduled on month 36:

D4.1. Report on assessments of herring, sprat and cod, including spatial effects (biomass distribution, natural populations)

D4.2. Database for flounder assessment or stock evaluation by stock.

D4.3. Manuscript on model and methods of assessment and evaluation of flounder stocks status is scheduled on month 44. It was suggested at the meeting to ask permission from BONUS to postpone submission of D4.2 from M36 to M38 and D4.3 from M44 to M46.

Status of the work: cod

As it was indicated in 1st year report, ICES had (and still has) severe difficulties with providing analytical assessment of eastern Baltic cod stock, while such assessment is important for fulfilling Task 4.1. So, as it was suggested in 1st year report, some additional work has been undertaken in relation to eastern cod assessment, as without such assessment it may be difficult to correctly determine the dynamics of clupeids stocks.

The eastern Baltic cod stock was assessed with two models, in which natural mortality in recent years was allowed to increase (or be dependent on weight of cod, which drastically declined in recent years). The applied models were the age-structured CAGEAN and difference stock-production model, as it was relatively easy to implement into these models varying natural mortality and estimate this mortality within the models. It was shown that the assessment models with natural mortality showing increasing trend perform much better that the standard assessment models in which M is assumed constant; they are better both in quality of the model diagnostics and in consistency with the trends in survey indices of stock size. In addition, a stock similar to eastern cod with natural mortality increasing in recent years was generated. It was shown that the assessment of such stock using constant natural mortality performs similarly badly as recent ICES assessments in terms of model diagnostics. On the other hand, when natural mortality is allowed to increase, the model performance is almost perfect.

Obtained results strongly suggest that natural mortality of cod in recent years markedly increased. This work has been published as: Horbowy, J. 2016. Effects of varying natural mortality and selectivity on the assessment of eastern Baltic cod (*Gadus morhua* Linnaeus, 1758) stock. Journal of Applied Ichthyology, DOI 10.1111/jai.13202)

Status of the work: herring

The data has been compiled for separate assessment of herring stocks in sub-div. 25-27 vs 28-29,32, i.e. for assessment units used by early 1990s.

The software was developed to perform several parameterisations of the XSA in one run and plot and compare some results; the software was developed in R and it uses Fisheries Libraries in R (FLR).

A few assessments of herring in Gulf of Finland (sub-division 32) and sub-divisions 28.2, 29, and 32 were performed. The methods used were XSA and SAM models. The assessments showed that fishing mortality in these stocks (assessment units) may be significantly higher than the F for presently used assessment unit of Central Baltic herring (CBH). The development of biomass and F in Gulf of Finland showed highest differences when compared to CBH dynamics. The persistent spatial and temporal differences in stock structure and in mean weights in particular can have a significant influence on the effects of the fishery in central Baltic waters (regulated as for CBH) on sub-stocks forming Central Baltic herring stock. It is suggested to perform periodic local stock assessments to reduce uncertainties related to management of herring in the Central Baltic Sea.

Assessment of Central and Western Baltic herring taking into account migrations between the stocks has started. In the model it is assumed that in first half of year part of Western stock migrates to Central area and returns by mid of year while in second half of year part of Central stock migrates to Western area and returns by end of the year. The software to run the model has been updated to include new data (up to 2015). First runs of the model in „No migration" mode has been performed (SSB & Fs similar to ICES assessments). Now, estimates of the migration rates will be needed, and possible sources are the following:

- Estimates basing on growth function (paper by Gröhsler et. al. (2016))
- Evaluation basing on parasitic infection
- Estimation within the model

Next, the assessment model incorporating migration rates between western and central Baltic herring stocks will be run and the consequences of inclusion of migration into assessment on biomass estimates and catch projections will be evaluated.

MIR-PIB will perform:

- herring assessments by former assessment units
- herring assessments taking into account migrations between the western and Central Baltic herring stocks

Status of the work: sprat

The data has been compiled for separate assessment of sprat by assessment units used by early 1990s, i.e. sprat in sub-div. 22-25, sprat in sub-div. 26+28, and sprat in sub-div. 27, 29-32. Predation mortality of sprat has been obtained from area disaggregated multispecies model (SMS). Practically there is no cod in areas 27,29-32, so in these areas lower natural mortality was assumed for sprat than in first two assessment units. Next, assessment of sprat stocks in each of the above assessment units was performed using XSA model, i.e. model applied by ICES so far. Preliminary results indicate good correspondence of biomass estimates in present ICES assessments covering whole sprat in the Baltic and sum of biomass estimates by smaller assessment units (Fig. 1). However F_{MSY} estimated for separate assessment units may differ by a factor of 2, suggesting consideration of different management strategies in analysed assessment units of sprat.

MIR-PIB will perform:

- sprat assessments by former assessment units

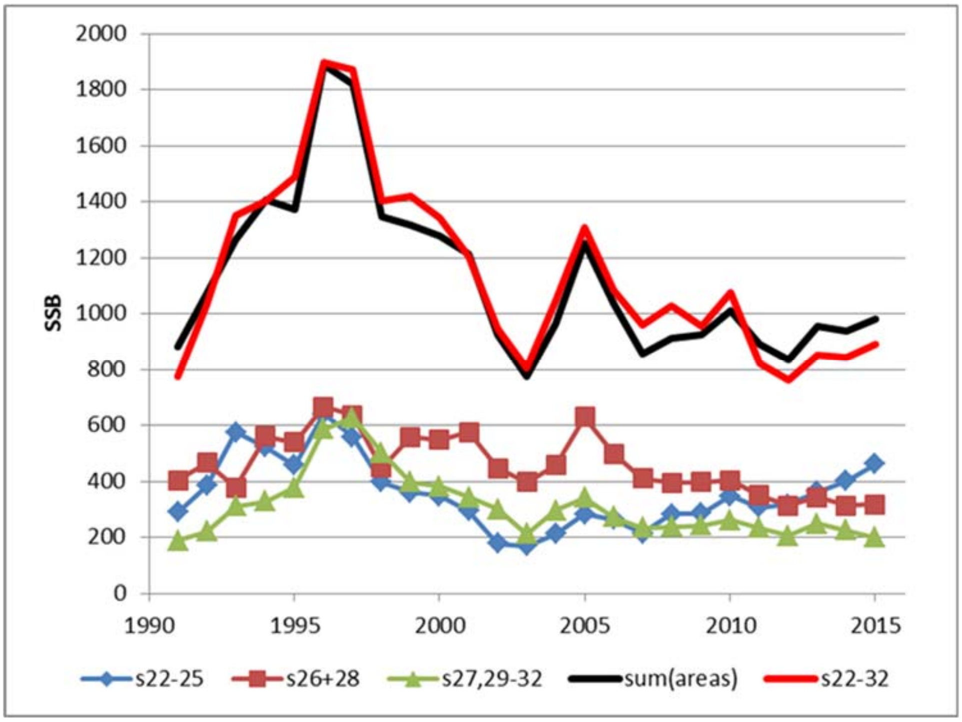

Figure 7 Comparison of sprat biomass estimates by former assessment units and in present ICES assessment.

Status of the work: Multispecies assessment considering spatial effects and predator-prey overlap

Some work using are disaggregated SMS was performed by DTU-Aqua and DTU-Aqua is responsible for that work.

Assessments of herring and sprat by former assessment units to some extent also cover that topic as natural mortality in the units is adopted to take into account the co-occurrence (lack of co-occurrence) of sprat and cod in the units.

Status of the work: flatfishes

Identification of management units of flounder in the Baltic is in progress. Adult and juvenile flounder have been genotyped (1000 and 388 individuals, respectively). Results showed that we can distinguish the ecotypes and that there is a mix of the ecotypes in our sampling (manuscript on that will be prepared). Some results were presented by Ann-Britt Florin on the Fisheries Societies of the British Isles Symposium in Bangor, Wales in June 2016 (Fish, genes and genomes; contribution to ecology, evolution and management).

Work on evaluating the morphometry as a tool for distinguishing flounder ecotypes is in progress (unfortunately it seems not to work very well).

Recently results on otolith chemistry have been obtained (from Karin Limburg and her student Melvin Samson); interpretation of these results is in progress.

Conclusion from the work conducted so far:

- both flounder types mix in current management units
- No strong genetic differentiation within clusters

These results will contribute to the development of data base for flounder assessment or evaluation by stocks. As soon as management units of flounder are identified the existing data will be compiled by management units and new data made available to the project to perform the assessment or evaluation of stock status.

National data needed to perform assessments of flounder will be provided by project participants. MIR-PIB will perform compilation of these information into data base to be used for flounder assessments.

WP5 on Ecosystem-base management (Lead Meri Kallasvuo, LUKE)

The main aim of WP5 is to critically revise the existing management for Baltic cod, herring and sprat by taking into account possible modifications and extensions when spatial heterogeneity is accounted for. Furthermore, the implementation of the Marine Strategy framework Directive will be supported by linking MSFD indicators in a spatially explicit context. The WP5 consists of three tasks that were briefly discussed in the Annual Meeting:

Task 5.1. Importance of including spatio-temporal heterogeneity into stock assessments for ecosystem-based management

Here the results of assessments conducted in WP1-4, which take account of spatial effects, migrations, and stock structure or are provided with standard approaches will be compared and their influence on stock management will be analyzed and evaluated. The progress so far includes preparation of an R script and planning of analyses where two former assessment units of herring in the central Baltic and the presently used one unit will be compared (MIR-PIB). The work is still ongoing, since WP4 assessments must be finalized first. Similar comparisons have been conducted for the northern Baltic herring (UT-EMI, LUKE), which indicate that the fishing mortality can be significantly higher and relative stock biomass lower in local stocks compared to estimates from the assessment of the combined stock (Raid et al. 2016). While performing sub-regional annual assessments is unfeasible due to several reasons, it was suggested that periodic local stock assessments would be required to reduce uncertainties related to management of herring. Also work for sprat has been started and one publication is under review (Horbowy et al. in prep).

Autumn herring reproduction failure and their link to spatial herring assessment and management has been studied. Firstly, it has been demonstrated the frequency of fish with abnormal ovaries varied annually between 10 and 15% among all females sampled. Specific sampling events showed up to 90% of females with abnormal gonads. The specific cause of this abnormality remains unknown. However, prevalence was associated with unfavourable environmental conditions encountered before spawning: ovarian abnormality was positively related to water temperatures, with the highest level found at ≥15 °C and negatively related to the frequency of strong winds. The frequency of occurrence of abnormal gonads decreased with the progression of spawning from August to October. The observed abnormality and associated spawning failure will negatively affect the realized fecundity of autumn herring in the Baltic Sea and may act as a limiting factor for recovery of the stock, which has experienced profound depression during the last three decades (Ojaveer et al. 2015). Secondly, temporally replicated analyses revealed that there are clear genetic differences between spring and autumn herring ecotypes (Figure 1) and, hence, reproductive isolation of spring and autumn spawners. The abundance and exploitation of the two ecotypes have varied strongly over space and time in the Baltic Sea, where autumn spawners have faced strong depression for decades. The results therefore have practical implications by highlighting the need for specific management of these co-occurring ecotypes to meet requirements for sustainable exploitation and ensure optimal livelihood for coastal communities (Bekkevold et al. 2016).

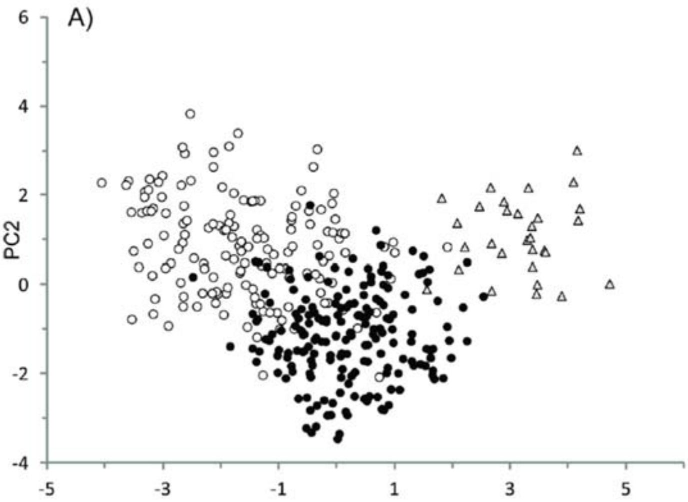

Figure 8. Genotypes form three ecotype associated clusters strongly driven by outlier loci. DAPC clustering for the first two principal components (PCs) explaining 98% of the variation. Filled black dots: Baltic Sea autumn spawners; open circles: Baltic Sea spring spawners; grey triangles: North Sea autumn spawners (Bekkevold et al. 2016).

Thirdly, the driving forces behind the collapse of autumn herring have been studied. Catch data time-series were established in the autumn herring fishery on spawning grounds in the Gulf of Riga and Saaremaa island since the late 1920's. By using historical information on autumn herring fishery and fish performance at the stock and individual level from the 1950's-1970's, and by also applying population dynamics modeling, fishing (historical mean F (for the age groups 3-8) 0.58 with substantial fishing mortality of immature fish) as the primary reason for the collapse of autumn herring in the Gulf of Riga is currently being investigated. Manuscript will be likely submitted by end of year 2016 (UT-Emi and DTU-Aqua). Fourthly, fish feeding ecology studies on spatial management issues have been conducted. They reveal that spatial signal on herring feeding is relatively weak. Therefore, specific conservation areas relative to feeding success cannot be designated (Ojaveer et al. in prep). These four case studies will form the scientific basis for suggestions on how to consider the currently commercially lost and data-limited autumn herring in the management context of herring in the Baltic Sea. The aim is also to suggest candidate indicators for management considerations.

Evaluations of spatial food-web dynamics affecting fish stocks in SDs 25-29 and 32 using spatial food web model has been started and may lead to alternative assessment approaches and assessment units. A spatially explicit Bayesian Belief Network (BBN) model has been built to study the potential causes in spatial and temporal fish distributions (SU). Manuscript is being prepared by Kininmonth et al. Also another manuscript of the food web size structure is being prepared, presenting a simple mechanistic model that performs better than the Ecospace modelling approach (Niiranen et al. in prep).

Deliverable D5.1 Report on the early warning indicators of cod stock development is due to M40. Work concerning this deliverable has been started.

Task 5.2. Importance of spatial heterogeneity in defining Baltic-specific MSFD indicators

Here the results from WP1-WP4 will be synthesized to MSFD indicators addressing descriptors, such as biodiversity (species distributions), commercial species, food webs etc., and the developed indicators will be evaluated. Further, the information across assessed stocks could be aggregated in different MSFD regions and used to determine whether or not GES is achieved.

The progress so far includes research on spatial and temporal variations in food web indicators (Large fish indicator LFI, maximum length and mean length in fish community in the pelagic waters), based on Swedish data from acoustic surveys (SLU). The results have been published by Casini et al. in HELCOM core indicator report. Basically, the indicator reflects environmental status based on size structure of offshore fish communities. The higher the proportion of large fish, the better the status of fish community.

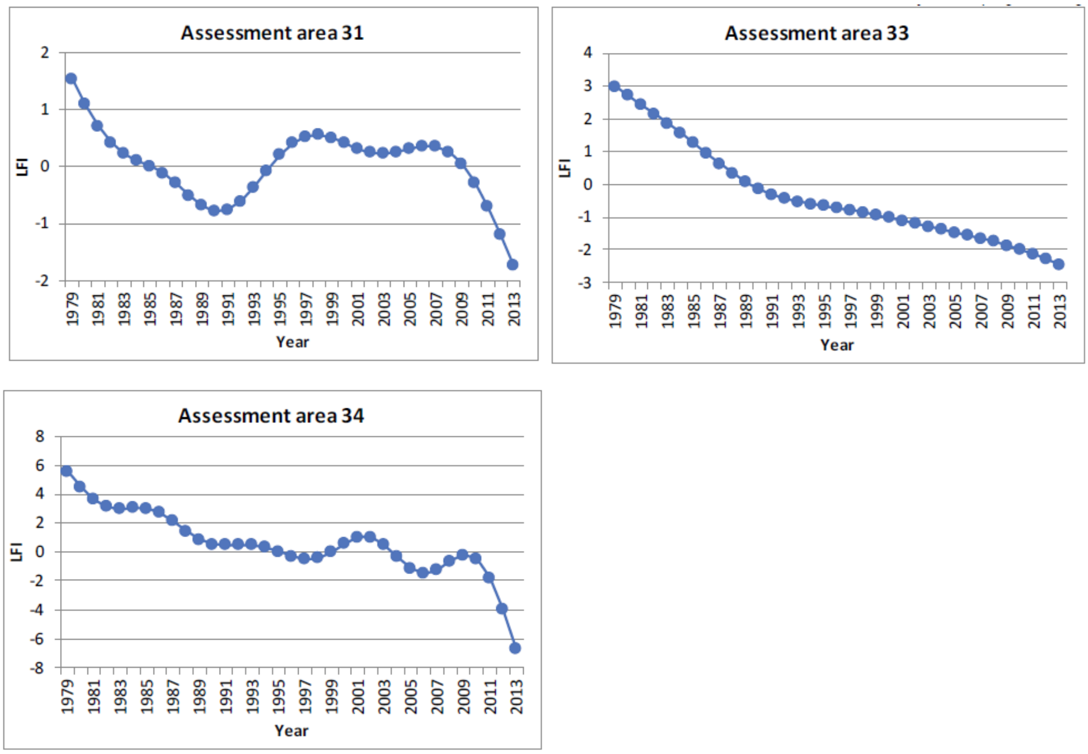

Figure 9. Standardized LFI for the off-shore pelagic community in three HELCOM assessment units (31: Bornholm Basin, 33. ICES SD27 and 34: eastern Gotland Basin).

In Figure 9, it can be seen that the overall trend in the Large fish indicator has been descending in the past decades (HELCOM core indicator report). The preliminary evaluation of the whole Baltic Proper states that currently the environmental status is in sub-GES.

Deliverable D5.2 Report on spatially explicit MSFD indicators is due to M40. Work concerning this deliverable has been started.

Deliverable D5.3 Manuscript on the role of spatial heterogeneity in Baltic ecosystem-based management is due to M48. The content of this deliverable will be further discussed in the next integrated workshop in the early 2017.

Task 5.3 Regional management considerations

Here it will be evaluated how to include the new knowledge gathered in INSPIRE into the current SD-based assessment and management routines and suggest modifications for improvement in management. This task will be discussed further in the fourth integrated workshop in 2017.

Deliverable D5.4 Manuscript on regionalisation of Baltic Sea ecosystem-based management due to M48. This deliverable is strongly linked to the high-profile paper that will disseminate the main results of INSPIRE. UHAM has started to draft the outline of the paper, but the results from WP1-5 must be finalized before it can be promoted further. This deliverable will be discussed further in the next integrated workshop in 2017.

Publications:

Bekkevold, D., Gross, R., Arula, T., Helyar, S.J. and Ojaveer, H. 2015. Outlier Loci Detect Intraspecific Biodiversity amongst Spring and Autumn Spawning Herring across Local Scales. PLoS ONE 11(4): e0148499. doi:10.1371/journal.pone.0148499

HELCOM 2015. Large Fish Indicator. HELCOM core indicator report. Online: https://portal.helcom.fi/meetings/FISH%20IND%20WS%202016-345/MeetingDocuments/Proportion%20of%20large%20fish%20in%20the%20community%20(LFI%20off-shore)-HELCOM%20core%20indicator%20report%20DRAFT.pdf

Horbowy et al. (in prep). Effects of multispecies and density dependent factors on MSY reference points: Example of the Baltic Sea sprat (in review)

Kininmonth, S., Blenckner, T., Niiranen, S., Orio, A., Casini, M., (in prep). Non-Stationary modeling of a fishery in flux: The structural, environmental and trophic influences of the Baltic Sea system. (manuscript, plan is to submit to Fish and Fisheries)

Niiranen S., Gårdmark A., Kadin M., Kotta J., Lindegren M., Nordström M., Törnroos A., Weigel B. and Blenckner T. (in prep). How does species body size distribution affect the benthic-pelagic coupling in the Baltic Sea? (manuscript)

Ojaveer, H., Tomkiewicz, J., Arula, T., and Klais, R. 2015. Female ovarian abnormalities and reproductive failure of autumn-spawning herring (Clupea harengus membras) in the Baltic Sea. ICES Journal of Marine Science, 72: 2332–2340.

Ojaveer, H., Lankov, A., Teder, M. and Klais, R. (in prep). Feeding patterns of dominating small pelagic fish in the Gulf of Riga, Baltic Sea (in review).

Raid, T.; Järv, L.; Pönni, J.; Raitaniemi, J.; Kornilovs, G. 2016. Central Baltic herring stock: What does the assessment of combined stock say about the status of its components? In: Guedes Soares,C. & Santos, T.A. (Eds). Maritime Technology and Engineering. Taylor & Francis Group, London: 961-966. ISBN 978-1-138-03000-8

WP6 on Dissemination (Stefan Neuenfeldt, DTU-Aqua)

Dissemination has continued to facilitate, by the close contact to various ICES expert groups and Baltic Sea Advisory Council, that project results have been made available to stakeholders and interested public almost in a real time.

Deliverable 6.1 (Website, M3)

The project web-site has been constantly updated by adding information on new publications, metadatabases and affiliated projects.

Deliverable 6.2 (Training school M47)

The major joint activity with other relevant BONUS projects included participating in BONUS Summer school on 'Modelling Biodiversity for Sustainable Use of Baltic Sea Living Resources'. The training school was moved from initially planned year #4 to 2017. The deliverable report has been submitted (M33).

Deliverable 6.3 (Symposium M48)

The symposium will be held at Tallinn University Conference Center, 17.-19. October 2017. It will summarise and synthesise the recent scientific findings by providing: i) new evidences on the spatiotemporal dynamics of Baltic Sea biodiversity at various levels of organisation, and its relationship with changing environmental conditions, ii) new basic knowledge on the ecology of the main commercial species – cod, herring, sprat and flounder, incl. habitat requirements, connectivity, migrations, species interactions and impact of external drivers, and iii) improved assessment methods and tools for the management of marine living resources, thereby assisting to address several regional (HELCOM) and EU legislative frameworks. <u>To be able to involve BONUS BIO-C3 project, the symposium will be held three months before the originally planned time (i.e., in M46 instead of planned M48).</u>

Deliverable 6.4 (Popular science book M48)

The activity has not stated, yet. However, at the meeting it has been decided to focus on a children's book, that can easily be translated into all languages represented in INSPIRE.

Agenda item #5 Planning for the integrating workshop 4

It was decided that during the workshop,

1. Workpackage leads to give short overview about the progress of the work;
2. Discuss any outstanding issues related to flatfish assessments
3. Devote much of the time to discuss achieving WP5 deliverables

There was also a suggestion to have the meeting early in 2017 and to move the workshop from initially planned M39 to M36. Christian Möllmann and Stefan Neuenfeld were asked to organize/co-chair the workshop.

Fish overviews

1. Baltic cod highlights (Karin Hüssy)

Western Baltic cod stock

Background: Eastern and western Baltic cod have historically been managed as separate stocks. In the mid 2000's, trends in biological data suggested that a considerable migration of eastern Baltic cod into SD 24 of the western Baltic management area was occurring. A national Danish EMFF project funded the development of a stock identification method based on otolith shape and genetics. For this method to be implemented into stock assessment, a time series was necessary, which was only achieved for the years 1996-2011.

INSPIRE contribution: Within INSPIRE two issues were addressed, the mixing of adult cod in SD 24 and the impact of these adults on recruitment of the western Baltic cod stock. For the adult cod, the time series of stock mixing based on otolith shape of the two stocks was extended to include all years from 2012 onwards. This time series shows that the proportion of eastern Baltic cod in SD 24 increased considerably during the years 2005-2011, from ca. 25% to 80%. Since then the proportion of

eastern Baltic cod has stabilized at ca. 66%. This work is contributing to INSPIRE D2.3.
The impact of the eastern Baltic cod immigrating into SD 24 on the recruitment of the western Baltic cod stock was analyzed using hydrodynamic modeling to 1) test the suitability of this area as spawning habitat for the eastern stock, 2) estimate the survival success of eggs and larvae, and 2) estimate how many of these survivors remain in SD 24. Only about 30% of the habitat in SD 24 is suitable for eastern Baltic cod spawning, predominantly because of low salinity at the bottom. Of the spawned eggs, only 10-20 % expected to survive, the majority of which seem to remain in SD 24. This work is contributing to INSPIRE D3.2.

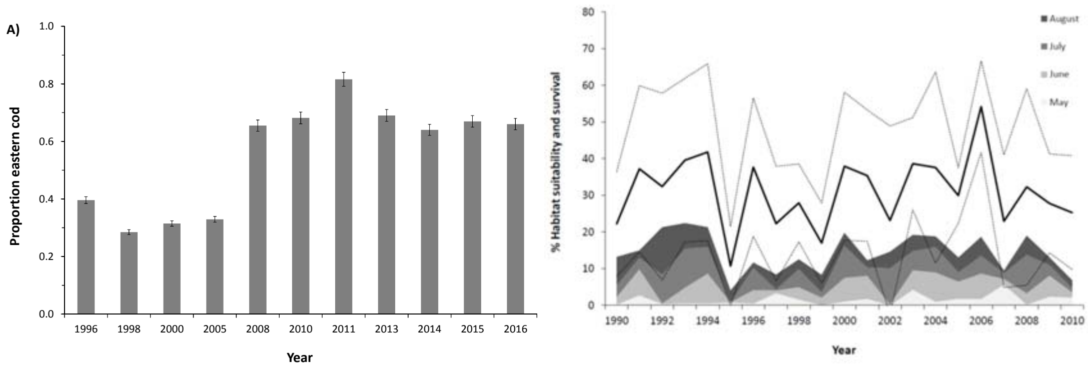

Figure 10. Left panel: Proportion of eastern Baltic cod in SD 24 from 1996 to 2015. Right panel: Proportion of habitat in SD 24 suitable for eastern Baltic cod spawning (line) and proportion of egg survival in different months (shaded areas)

Conclusions: The stock mixing has been implemented in the stock assessment of the Baltic cod stocks. Catches in SD 24 are being split according to the annually established splitting key, and assigned to either eastern or western Baltic cod stock.

Publications: This work has been published as a single publication which addresses both migration dynamics and recruitment and hence to both D2.3 and D3.2
Hüssy, K., Hinrichsen, H.-H., Eero, M., Mosegaard, H., Hemmer-Hansen, J., Lehmann, A., Lundgaard, L.S. (2016) Spatio-temporal trends in stock mixing of eastern and western Baltic cod in the Arkona Basin and the implications for recruitment DOI: 10.1093/icesjms/fsv227

Eastern Baltic cod stock

Background: Survival of eastern Baltic cod early life stages is generally believed to be a function of egg size coupled with environmental salinity and oxygen conditions. However, also processes during the late pelagic stage and the juvenile stage in the demersal nursery areas have come into focus as potential bottlenecks limiting recruitment. The objectives of INSPIRE were to 1) evaluate to what extent the shallow nearshore areas serve as nursery areas, 2) to test size-selective survival in these areas and 3) to test the spatio-temporal dynamics of the environmental suitability of nursery areas, and 4) estimate the connectivity between spawning areas. Shortly after the start of INSPIRE, the stock assessment working group for Baltic Fisheries (WGBFAS) were no longer able to conduct an analytical assessment. Historically known difficulties in age reading of this stock had increased to a degree where stock indices were heavily influenced. The current advice is given based on a survey index of the stock. This also impacts on some of the INSPIRE deliverables, where particularly the implementation of a recruitment are no longer is feasible, and the stock abundances data series has been discontinued. This has lead to the eastern Baltic cod stock now being categorized as "Data Limited Stock", where automatic technical measures are initiated for quota reduction. As a consequence of these problems, the MSC certification of the stock was suspended in December 2015.

Initiatives within INSPIRE: Objectives 1) and 2) were to be examined based on a new series of coastal gillnet surveys (WP1). However, recruitment in the two years covered by these surveys showed exceptionally back recruitment across the entire Baltic Sea. As only 44 juvenile cod were caught altogether in the gillnet surveys (2 years with a total of 4 surveys and 8 transects covered Baltic wide), it was not possible to examine objectives 1 and 2.

However, using hydrographical modeling and data from the routine Baltic International Trawl Survey (BITS), the spatio-temporal dynamics of the environmental suitability in the nursery areas and the connectivity between spawning areas (objectives 3 and 4) were successfully analyzed. This work showed that there are strong area-specific differences in spawning habitat quality, where the Bornholm Basin is the primary spawning area, with intern-annually varying degrees of good environmental conditions for spawning in the Gdansk Deep as well. Connectivity of areas is highly dependent on meteorological forcing, with a predominantly eastward trend in transport of early life stages. The area of the eastern Baltic Sea which is suitable as nursery areas has decreased somewhat over the time period evaluation (1975 – 2010). However, in recent years drift patterns of early life stages has apparently changed, leading to a decrease in the degree of the suitable habitat actually occupied by juvenile cod. Concurrently, the somatic conditions of juveniles in the nursery areas has decreased, particularly in SD 26, but also to some degree in SD 25, while condition has remained unchanged in SD 24. This work is contributing to INSPIRE D3.2.

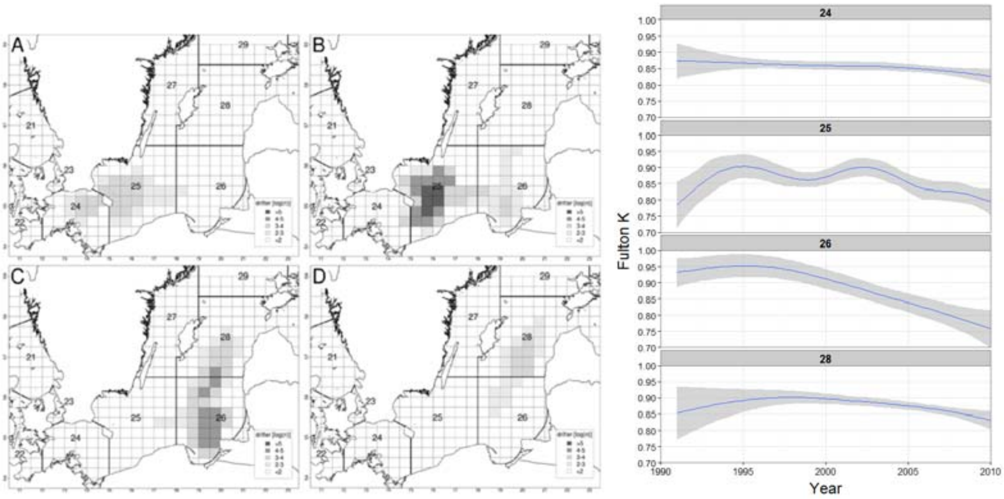

Figure 11. Left panel: Distribution of eastern Baltic cod at the end of the larval stage, showing eastward connectivity of spawning areas. Right panel: Somatic condition of juvenile cod in the nursery areas by SD.

Conclusions: This suggests that eastern Baltic cod are experiencing negative environmental impact during their juvenile stage in the nursery areas.

Publications: Two publications, one published, one in preparation contribute to D3.2
Hinrichsen, H.-H., Lehmann, A., Petereit, C., Nissling, A., Ustups, D., Bergström, U., Hüssy, K. (2016) Spawning areas of eastern Baltic cod revisited: Using hydrodynamic modelling to reveal spawning habitat suitability, egg survival probability, and connectivity patterns. Progress in Oceanography, DOI: 10.1016/j.pocean.2016.02.004
Hinrichsen, H.-H., von Dewitz, B., Lehmann, A., Bergström, U., Hüssy, K. Spatio-temporal dynamics of juvenile cod's nursery areas in the Baltic Sea. Progress in Oceanography (*in prep*)

2. Herring: ICES view on herring stocks and management advice for 2017 (Tiit Raid)

The following assessment units are considered by the ICES at present.

- Central Baltic herring (SD 25-28.2,29,32)
- Gulf of Riga Herring (28.1)
- Bothnian Sea herring (SD 30)
- Herring in the Bothnian Bay (SD 31)

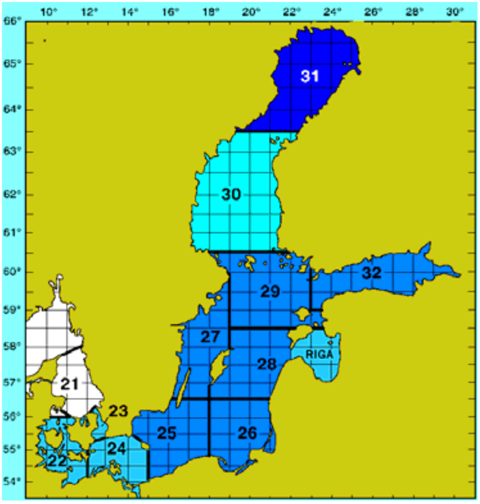

Figure 12. Assessment units of the Baltic herring.

Central Baltic herring (Sub-divisions 25-28.2, 29&32)

Since 1974 The Baltic herring landings have fluctuated from 200,000 to 440,000 tons annually with Poland, Finland and Sweden being as leading countries.

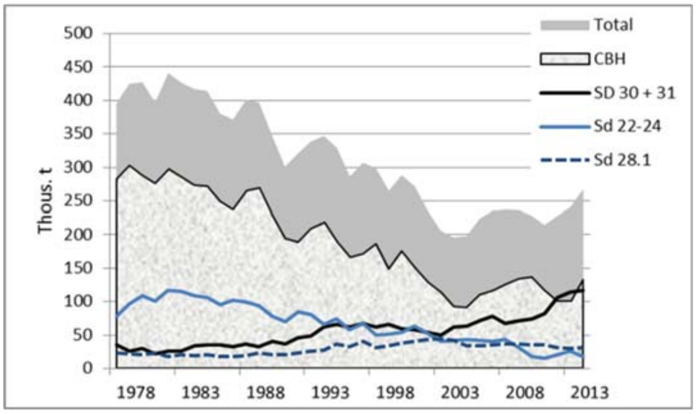

Figure 13. Total landings of the Baltic herring in 1978-1985

The majority of herring landings (100,000 - 300,000 tons annually) are from the Central Baltic herring (CBH) stock. Despite the scientific and administrative effort, the dynamics of the spawning stock biomass (SSB) of the Central Baltic herring has shown a declining trend during most of its management history.

Spawning-stock biomass (SSB) decreased until 2001 and then increased, and has been above MSY $B_{trigger}$ since 2006. Fishing mortality increased until 2000 and then decreased, remaining below F_{MSY} since 2011. The 2014 year class is estimated to be the fourth highest of the whole time-series.

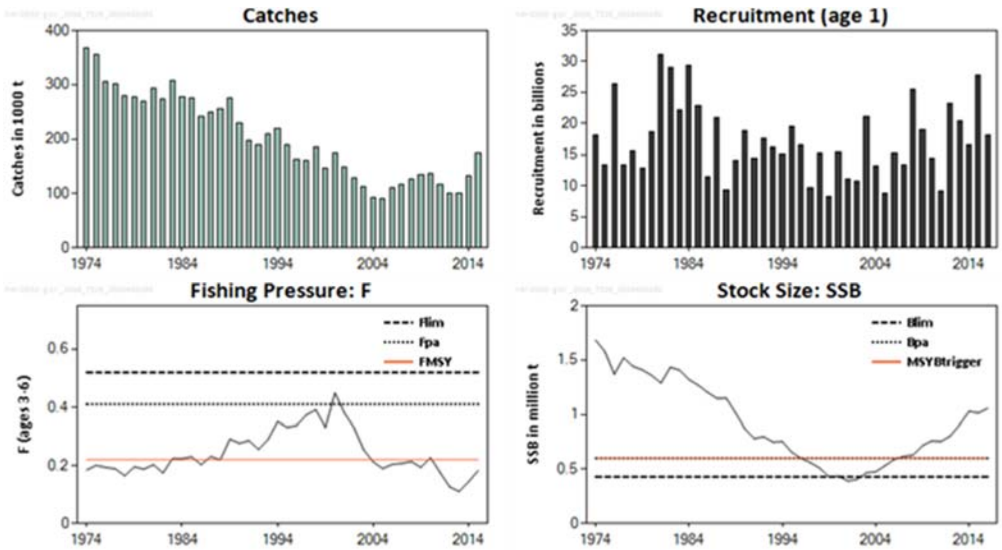

Figure 14. Central Baltic herring: dynamics of main stock parameters since 1974.

The substantial decrease of mean weight at age has been observed of the CBH since the end of 1980s. The present weights make up 40-60% of the level of 1980s (Figure 15). The feeding competition with abundant sprat stock and changes in zooplankton composition due to worsened salinity conditions are believed to be the main reason for such a decrease in herring growth.

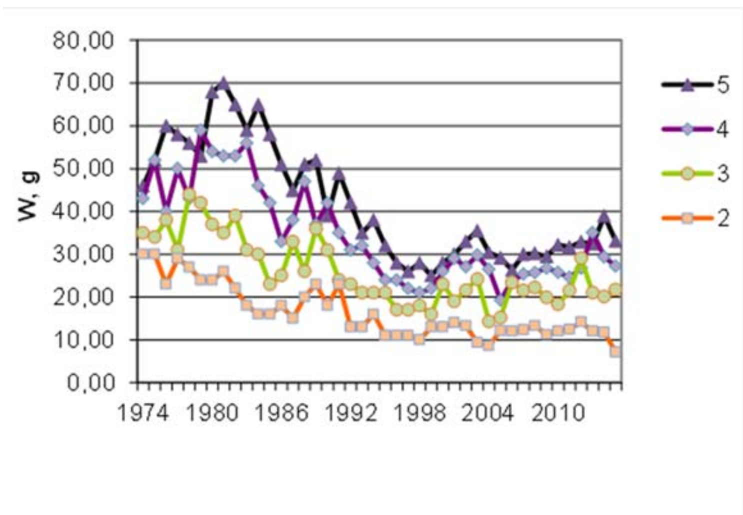

Figure 15. Mean weight of Central Baltic herring in age groups 2-5 in 1974-2015.

ICES advises that when the MSY approach is applied, catches in 2017 should be no more than 216 kt. This applies to all catches from the stock, including those taken in Subdivision 28.1.

A mixture of central Baltic herring (subdivisions 25–27, 28.2, 29, and 32) and the Gulf of Riga (Subdivision 28.1) herring is caught in the central Baltic Sea. The assessment and the advice consider that the central Baltic herring stock is caught both in and outside the central Baltic Sea. The TAC (sum of the EU and Russia autonomous quotas) is set for herring caught in the central Baltic management area, which includes also a small amount of Gulf of Riga herring caught in the central Baltic Sea but excludes central Baltic herring caught outside the central Baltic Sea.

The TAC value proposed for the central Baltic area is based on the advised catch for the central Baltic herring stock, plus the assumed catch of the Gulf of Riga herring taken in the central Baltic, minus the assumed catch of herring from the central Baltic stock taken in the Gulf of Riga. The values of the two latter are given by the average over the last five years.

- Central Baltic herring assumed to be taken in the Gulf of Riga in 2017 (Subdivision 28.1) is 4574 t (average 2011–2015);
- Gulf of Riga herring assumed to be taken in Subdivision 28.2 in 2017 is 223 t (average 2011–2015).

Following the ICES MSY approach catches in 2017 should be no more than 216 kt. The corresponding TAC in the central Baltic management area for 2017 would be calculated as 216 kt + 0.223 kt – 4.574 kt = 211.649 kt.

Gulf of Riga herring

Herring fishery in the Gulf of Riga is performed by Estonia and Latvia, using both trawls and trap-nets. Herring catches in the Gulf of Riga include the local Gulf herring and the open-sea herring, entering the Gulf of Riga for spawning. Discrimination between the two stocks is based on the different otolith structure due to different feeding conditions and growth of herring in the Gulf of Riga and the Baltic Proper. The Latvian fleet also takes gulf herring outside the Gulf of Riga in Subdivision 28.2. In 2015 these catches were 316 t, while the average catches in the last five years were 200 t.

Following high recruitment, spawning-stock biomass (SSB) increased in the late 1980s and is estimated to have been above the MSY $B_{trigger}$ since then. The 2011 and 2012 year classes are well above average, the 2013 year-class is poor, and the 2014 year-class is below average. Fishing mortality (F) has been close to F_{MSY} since 2008 but generally above F_{MSY} (Figure 16).

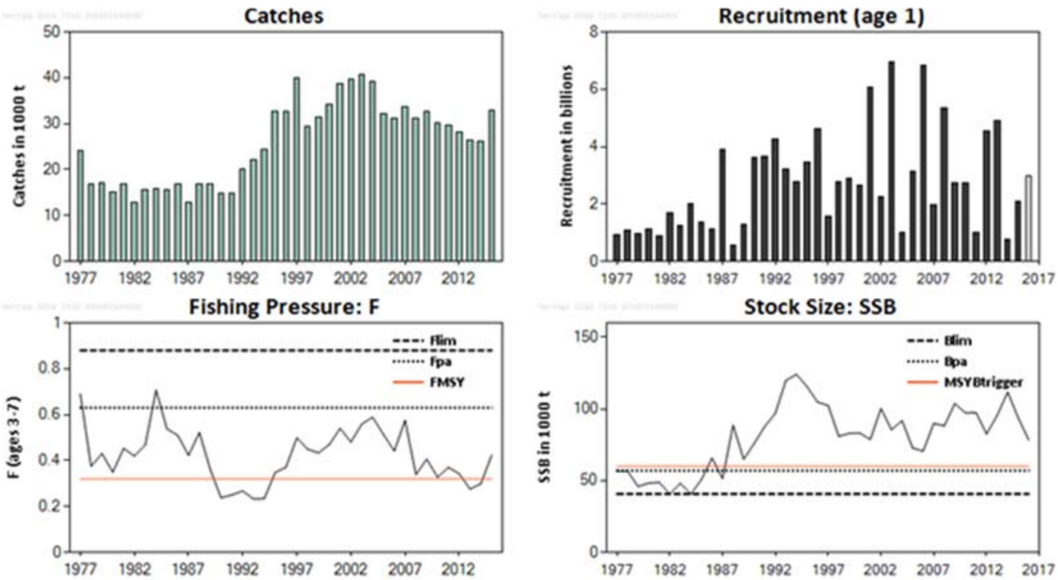

Figure 16. Gulf of Riga herring: dynamics of main stock parameters since 1977.

Like in the Central Baltic herring, the decrease in mean weights at age occurred also in the Gulf of Riga herring stock, to a lesser extent, however. The present weights are of 40-70% of the level of 1980s indicating the worsening growth conditions in the recent decades (Figure 17).

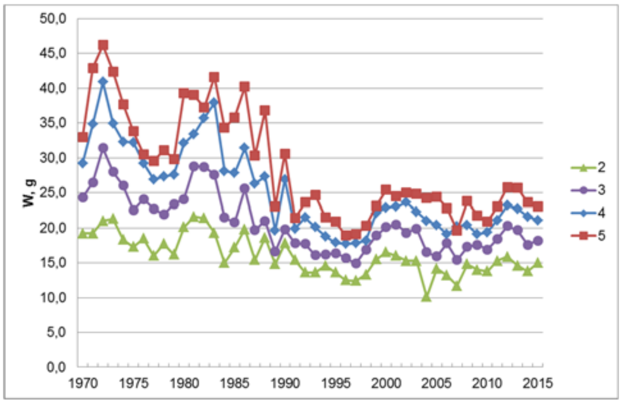

Figure 17. Mean weight of the Gulf of Riga herring in age groups 2-5 in 1970-2015.

ICES advises that when the MSY approach is applied, catches in 2017 should be no more than 23 078 tonnes. This applies to all catches from the stock in subdivisions 28.1 and 28.2.

The assessment and the advice consider the Gulf of Riga herring stock taken both in and outside the Gulf of Riga. The TAC is set for herring caught in the Gulf of Riga, which also includes a certain amount of central Baltic herring caught in the Gulf of Riga, but does not include Gulf of Riga herring taken outside the Gulf of Riga.

The TAC value proposed for the Gulf of Riga area is based on the advised catch for the Gulf of Riga herring stock, plus the assumed catch of herring from the central Baltic stock taken in the Gulf of Riga, minus the assumed catch of the Gulf of Riga herring taken outside the Gulf of Riga. The values of the two latter are given by the average over the last five years:

- Central Baltic herring assumed to be taken in the Gulf of Riga in 2017 (Subdivision 28.1) is 4574 t (average 2011–2015);
- Gulf of Riga herring assumed to be taken in Subdivision 28.2 in 2017 is 223 t (average 2011–2015).

Following the ICES MSY approach catches in 2017 should be no more than 23 078 t. The corresponding TAC in the Gulf of Riga management area for 2017 would be calculated as 23 078 t − 223 t + 4574 t = 27 429 t.

Bothnian Sea herring (Sub-division 30)

The total catch in SD 30 decreased by 119 tonnes (0,1%) from 2014 to 110,415 tonnes in 2015 of which 87 % (96414 tonnes) was Finnish catch and 13 % (14001 tonnes) was Swedish catch The Finnish catch decreased by 1 % (1365 tonnes) and the Swedish catch increased by 10 % (1246 tonnes) compared to 2014.

The spawning-stock biomass (SSB) has been above MSY $B_{trigger}$ since 1987 and has been increasing since 1999. Fishing mortality (F) has been mostly below F_{MSY} although it was slightly above in 2012–2014. Recruitment has increased over time (Figure 18).

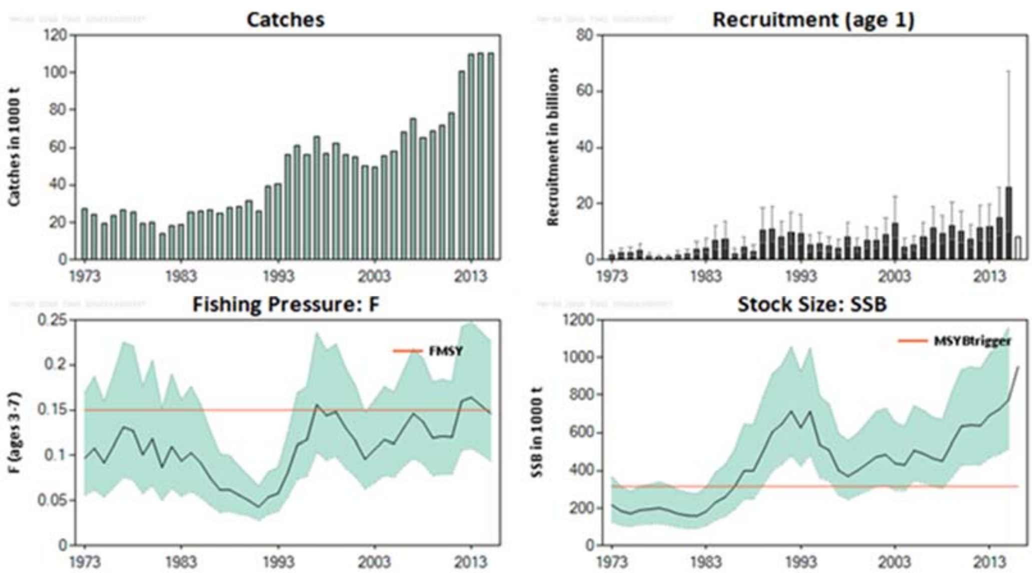

Figure 18. Bothnian Sea herring: dynamics of main stock parameters since 1973.

There has also been a decrease of mean weights at age in the Bothnian Sea herring, but clearly in smaller scale that in CBH and the Gulf of Riga herring. The present weights are of 75-80% of the level of 1980s indicating that herring growth conditions have been relatively good in the Bothnian Sea, possibly due to the low numbers of sprat in most of the area (Figure 19).

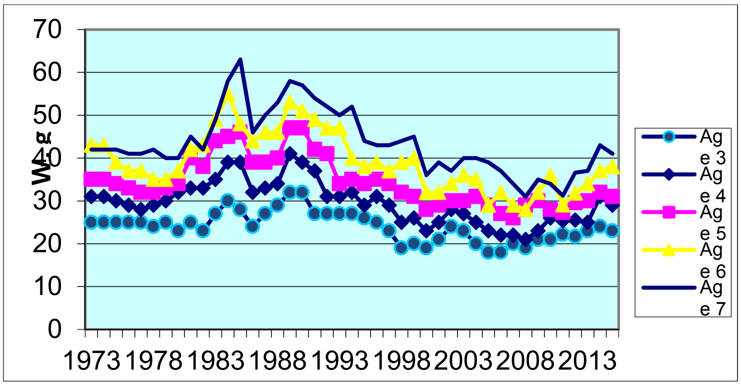

Figure 19. Mean weight of the Bothnian Sea herring in age groups 3-7 in 1973-2015.

ICES advises that when the MSY approach is applied, catches in 2017 should be no more than 134 556 tonnes.

Bothnian Bay herring (Sub-division 31)

The total catch of herring in the Bothnian Bay in 2015 (4526 t) is comprised of Finnish (4370 t) and Swedish (156 t) catches (97% and 3%, respectively).

Generally, catches were decreasing from the change of the 1980s and 1990s to the half of the 1990s, after which they have varied at lower levels. In recent decades, there has been a decline in the number of fishermen due to decreased profitability of fishing: low prices and high fuel costs.

An exploratory assessment shows that the spawning-stock biomass (SSB) has increased since 2008. The fishing mortality (F) has had an overall increasing trend since 2010. Recruitment since 2010 has been above average, except for 2013 (Figure 20).

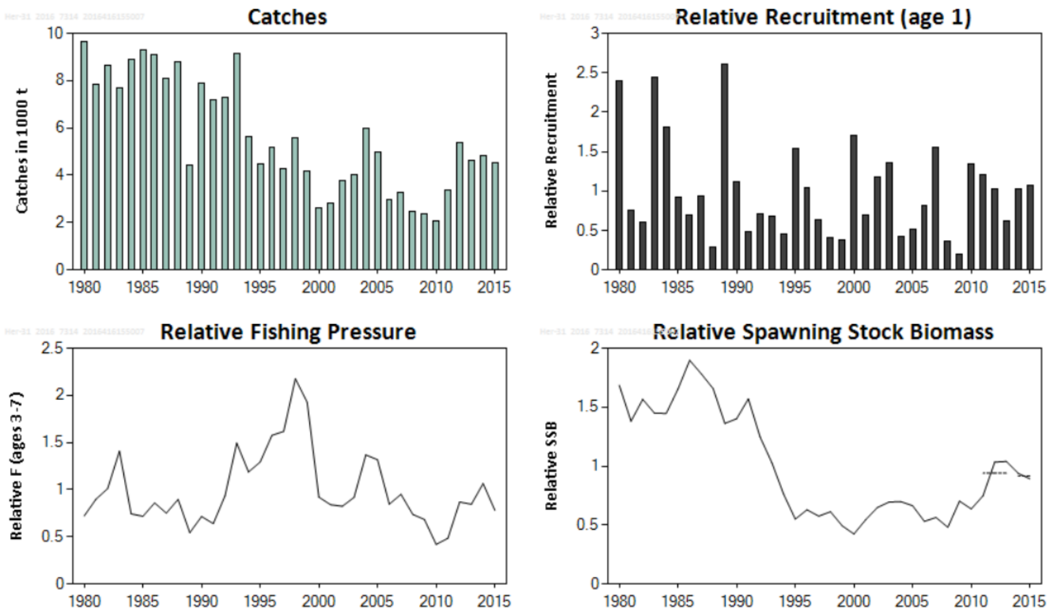

Figure 20. Bothnian Bay herring: dynamics of catches and relative stock parameters since 1980.

The ICES framework for category 3 stocks was applied for this stock. The SSB trend from the exploratory stock assessment is used as the index of stock development. The advice is based on a comparison of the two latest index values (index A) with the three preceding values (index B), multiplied by the recent advised catch.

The index is estimated to have decreased by less than 20% and thus the uncertainty cap was not applied when calculating the catch advice. The stock status relative to candidate reference points is unknown. Considering that the fishing effort has been decreasing since the 1980s and is considered to be low (Figure 9) no additional precautionary buffer was applied.

ICES advises that when the precautionary approach is applied, catches in 2017 should be no more than 6442 tons. The herring stocks in subdivisions 30 and 31 are currently assessed separately, but they are managed by a common TAC. Adding up the catch advice for the two stocks in 2017 results in a total herring catch of 134 556 t + 6 442 t = 140 998 t in subdivisions 30 and 31 in 2017.

Annex 1. Meeting Agenda

Agenda

INSPIRE 2016 Annual Meeting

Riga, Latvia (Radisson Blu Hotel, room Sigma 1)

Wednesday 21. September

15:00-15:15	**Agenda item #1**: Arrival and registration
15:15-15:30	**Agenda item #2:** Welcome and housekeeping
15:30-16:00	**Agenda item #3:** Project coordination and reporting update
16:00-16:15	Coffee/Tea
16:15-18:00	**Agenda item #4:** Workpackage and fish champions overviews
16:15	WP1 – Michele Casini
17:00	Cod – Karin Hüssy
17:30	WP2 – Christian Möllmann

Friday, 23 September

09:00-10:30	**Agenda item #4** continues
9:00	Updates from BONUS – Andris Andrushaitis
9:30	WP3 – Patrick Polte
10:30-11.00	*Coffee/Tea*
11:00-13:00	**Agenda item #4:** continues
11:00	WP4 – Jan Horbowy
12:20	Herring – Tiit Raid
12:40	Sprat – Georgs Kornilovs
13:00-14:00	*Lunch*
14:00	Hydrodynamic modeling - Andreas Lehmann
14:20	WP5 – Meri Kallasvuo
14:40	**Agenda item #5**: Planning for the integrating workshop 4
14.55	AOB
15:00	**Closure**

Annex 2. List of participants

	Name	Partner
1	Andris Andrusaitis	BONUS
2	Henn Ojaveer	UT-EMI
3	Tiit Raid	UT-EMI
4	Christian Möllmann	UHAM
5	Georgs Kornilovs	BIOR
6	Didzis Ustups	BIOR
7	Maris Plikss	BIOR
8	Michele Casini	SLU
9	Ulf Bergström	SLU
10	Alessandro Orio	SLU
11	Stefan Neuenfeldt	DTU-AQUA
12	Karin Hüssy	DTU-AQUA
13	Margit Eero	DTU-AQUA
14	Andreas Lehmann	GEOMAR
15	Meri Kallasvuo	LUKE
16	Jari Raitaniemi	LUKE
17	Jan Horbowy	MIR-PIB
18	Anna Luzenczyk	MIR-PIB
19	Patrick Polte	TI-OF
20	Susa Niiranen	SU
21	Anders Nissling	UU
22	Pehr Eriksson	BSAC

Annex 2

Participation in stakeholder committees

No	Last name	First name	Affiliation short	Committee
1	Klais	Riina	UT-EMI	ICES WKSPATIAL
2	Ojaveer	Henn	UT-EMI	ICES WGHIST
3	Ojaveer	Henn	UT-EMI	ICES WKSPATIAL
4	Ojaveer	Henn	UT-EMI	Executive committee of the global network on Oceans Past Initiative
5	Ojaveer	Henn	UT-EMI	ICES SSGEPI
6	Ojaveer	Henn	UT-EMI	ICES SCICOM
7	Ojaveer	Henn	UT-EMI	ICES WGBOSV
8	Ojaveer	Henn	UT-EMI	ICES WGIAB
9	Ojaveer	Henn	UT-EMI	ICES WGITMO
10	Ojaveer	Henn	UT-EMI	ICES Awards Committee
11	Ojaveer	Henn	UT-EMI	EU JPI Oceans (management board member)
12	Ojaveer	Henn	UT-EMI	HELCOM MARITIME
13	Põllumäe	Arno	UT-EMI	ICES WGZE
14	Raid	Tiit	UT-EMI	ICES WGBFAS
15	Raid	Tiit	UT-EMI	ICESWGBIFS
16	Raid	Tiit	UT-EMI	ICES Baltic Sea Advice Drafting Group
17	Raid	Tiit	UT-EMI	ICES North Sea Advice Drafting Group
18	Raid	Tiit	UT-EMI	EC STECF EWG 1604 Landinging obligation
19	Raid	Tiit	UT-EMI	EC STECF EWG 1606 Landinging obligation
20	Raid	Tiit	UT-EMI	EC STECF EWG 11610 Fisheries - dependent Information
21	Raid	Tiit	UT-EMI	EC STECF EWG 11616 Procedure for Evaluation of DCF Workplans
22	Raid	Tiit	UT-EMI	ICES WGBIOP
23	Raid	Tiit	UT-EMI	ICES PGDATA
24	Raid	Tiit	UT-EMI	ICES ACOM
25	Raid	Tiit	UT-EMI	EC STECF Plenary meetings
26	Neuenfeldt	Stefan	DTU Aqua	ICES WGIAB
27	Neuenfeldt	Stefan	DTU Aqua	ICES WKSPATIAL
28	Neuenfeldt	Stefan	DTU Aqua	ICES WGSAM
29	Neuenfeldt	Stefan	DTU Aqua	ICES WKBEBCA
30	Neuenfeldt	Stefan	DTU Aqua	ICES WKDEICE
31	Eero	Margit	DTU Aqua	ICES WGIAB
32	Eero	Margit	DTU Aqua	ICES WGBFAS
33	Eero	Margit	DTU Aqua	ICES WKBEBCA
34	Hüssy	Karin	DTU Aqua	ICES WKBEBCA
35	Horbowy	Jan	MIR-PIB	ICES WGBFAS
36	Horbowy	Jan	MIR-PIB	ICES ACOM
37	Horbowy	Jan	MIR-PIB	ICES ADGBS
38	Horbowy	Jan	MIR-PIB	ICES IBP Arctic Cod

39	Horbowy	Jan	MIR-PIB	ICES WKPELA
40	Luzeńczyk	Anna	MIR-PIB	ICES WGBFAS
41	Luzeńczyk	Anna	MIR-PIB	ICES/HELCOM WGIAB
42	Radtke	Krzysztof	MIR-PIB	ICES WGBIFS
43	Radtke	Krzysztof	MIR-PIB	ICES WGRFS
44	Luzeńczyk	Anna	MIR-PIB	ICES WKGMSFDD3-II
45	Luzeńczyk	Anna	MIR-PIB	ICES ADGNS
46	Luzeńczyk	Anna	MIR-PIB	ICES ADGCS
47	Smoliński	Szymon	MIR-PIB	ICES WGBIOP
48	Smoliński	Szymon	MIR-PIB	HELCOM FISH-PRO II
49	Smoliński	Szymon	MIR-PIB	ICES WGBFAS
50	Blenckner	Thorsten	SU	ICES WGIAB
51	Niiranen	Susa	SU	ICES WKSICCME
52	Casini	Michele	SLU	ICES WKSPATIAL
53	Casini	Michele	SLU	ICES WGBFAS
54	Casini	Michele	SLU	ICES ADGBS
55	Casini	Michele	SLU	HELCOM Workshop on Fish Indicators
56	Casini	Michele	SLU	HELCOM HOLAS
57	Bergström	Ulf	SLU	Swedish national working group on marine spatial planning
58	Bergström	Ulf	SLU	Swedish national working group on fisheries regulations in marine protected areas
59	Bergström	Ulf	SLU	Swedish national reference group on marine green infrastructure
60	Bergström	Ulf	SLU	ICES WGVHES
61	Bergström	Ulf	SLU	Nordic council workshop on Essential coastal habitats for fish in the Baltic Sea
62	Bergström	Ulf	SLU	HELCOM TAPAS
63	Florin	Ann-Britt	SLU	ICES WGITMO
64	Florin	Ann-Britt	SLU	ICES WGBFAS
65	Bartolino	Valerio	SLU	ICES WKSPATIAL
66	Bartolino	Valerio	SLU	ICES HAWG
67	Bartolino	Valerio	SLU	ICES WGSAM
68	Bartolino	Valerio	SLU	Workshop Towards Ecosystem Based Fisheries Management in the Baltic Sea
69	Bartolino	Valerio	SLU	Workshop on the Ecosystem Approach to Fisheries Advice in the European Union: scoping and regionalization processes
70	Bartolino	Valerio	SLU	Workshop on Elicitation of stakeholders preferences and presentation for the MareFrame DSTv1
71	Orio	Alessandro	SLU	ICES WKSPATIAL
72	Kornilovs	Georgs	BIOR	ICES WGBFAS
73	Kornilovs	Georgs	BIOR	ICES SCICOM
74	Ustups	Didzis	BIOR	ICES WGBFAS

75	Ustups	Didzis	BIOR	ICES SGSPATIAL
76	Plikss	Maris	BIOR	ICES WGBFAS
77	Plikss	Maris	BIOR	ICES SGSPATIAL
78	Makarcuks	Andrejs	BIOR	ICES WGALES
79	Svecovs	Fausts	BIOR	ICES WGBIFS
80	Strods	Guntars	BIOR	ICES WGBIFS
81	Polte	Patrick	TI-OF	ICES WGALES
82	Polte	Patrick	TI-OF	ICES WGIPS
83	Möllmann	Christian	UHAM	Baltic Health Index
84	Möllmann	Christian	UHAM	WKDEICE
85	Möllmann	Christian	UHAM	ICES/HELCOM WGIAB
86	Otto	Saskia	UHAM	ICES/HELCOM WGIAB
87	Möllmann	Christian	UHAM	WGCOMEDA
88	Möllmann	Christian	UHAM	ICES MSEAS
89	Pönni	Jukka	Luke	ICES WGBFAS
90	Pönni	Jukka	Luke	ICES WGBIFS
91	Pönni	Jukka	Luke	ICES WGBIOP
92	Pönni	Jukka	Luke	ICES WKBALT
93	Pönni	Jukka	Luke	RCM Baltic, Rostock
94	Raitaniemi	Jari	Luke	ICES ADGNS
95	Raitaniemi	Jari	Luke	ICES WGBIOP
96	Raitaniemi	Jari	Luke	ICES WGBFAS
97	Raitaniemi	Jari	Luke	ICES WKGESFISH
98	Raitaniemi	Jari	Luke	ICES WKIND 3.3
99	Raitaniemi	Jari	Luke	ASCOBANS Bycatch WG
100	Lehmann	Andreas	GEOMAR	Baltic Earth Scientific Steering Group