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Table of contents

Overview

All scientific work in BIO-C3 is currently advancing in line with the project document of work. Scientific output from the project has multiplied, and resulted in >20 accepted or published peer-review publication in 2015 alone, as well as close to 100 presentations of results, addressing amongst others the quantification of environmental drivers, the distribution, spread, impacts and management of invasive species, the better quantification of top-down control and predator-prey mismatch, and the dynamics of Baltic key species in response to environmental drivers. This progress was also mirrored by the acceptance of the first two scientific deliverables of BIO-C3, D1.1 "Review of environmental factors influencing distributions of selected Baltic species", and D2.1 "Report on effects of changing drivers on pelagic and benthic speices composition and production" by the BONUS secretariat. The three Deliverables D1.2, D2.2 and D3.1 were also completed and submitted at the same time as this report. All BIO-C3 output is accessible on our website under the link www.bio-c3.eu/publications.

All scientific work packages of BIO-C3 are now running, and an increasing focus of the project has been on the establishment and strengthening of pipelines of new scientific results becoming available from WPs 1-3 to the modeling, synthesis, and resource management framework approaches in work packages WP 4 and 5. In addition, collaborations of oceanographers from WP3 and biologists from WP1 and 2 have led to integrative studies and first publications. The integration efforts between work packages will remain a focus for the next reporting period.

We have made strong efforts to pass on the expertise of BIO-C3 project personnel, and to use the project scientific output, to inform stakeholders and policy makers in the Baltic realm and beyond. This included contributions to the implementation of the MSFD and the design of the Ballast Water Management Convention and EU marine fisheries research priorities, as well as advice to national policy makers and stakeholders on several occasions. The role of BIO-C3 in the science-policy interface was reflected in the membership and participation of project personnel in a total of 102 committees and working groups in 2015, including ICES, HELCOM, EC, MSFD, UN, and OSPAR. We will continue these efforts in the next reporting period.

2015 highlights from our consortium included the highly successful special BONUS theme session *From genes to ecosystems: spatial heterogeneity and temporal dynamics of the Baltic Sea* at the ICES Annual Science Conference 2015 in Copenhagen in Sept 2015, which we convened jointly with BONUS INSPIRE and BAMBI. It brought together more than 80 scientists from both within and outside the BONUS community, as well as stakeholders and policy makers. The session also resulted in an invited guest column in the BONUS in Brief December newsletter on "Finding bridges between biodiversity research and ecosystem–

based management", thus mirroring the central approach and interest of BIO-C3. A second key event in 2015 was the very well received BONUS BIO-C3/BAMBI/INSPIRE Summer school "*The Baltic Sea: a model for the global future ocean?*" that took place in July in Glücksburg, Germany, with 32 participating PhD students and postdocs and 13 lecturers from 8 nations (see event summary under the link: www.bio-c3/links). The seed planted at this school will continue to grow with a cross BONUS project concept paper writing workshop in fall 2016 on the same topic as part of the BONUS Clustering activities.

Another WP overarching benefit of BIO-C3 is the continuously improving coordination of large-scale scientific activities in the Baltic Sea. This includes the optimization of the temporal and thematic coverage of research cruises of the consortium in the Baltic (9 in total in 2015), and the continuation of collaborative activities. The latter include the data harmonization and collaborative use of long-term data series on meso-zooplankton, which has grown into a large international effort resulting in first publications (see http://kodu.ut.ee/~riina82/), and continued sampling initiatives of invasive combjelly *Mnemiopsis leidyi*, and invasive round goby *Neogobius melanostomus*. 2015 has also seen the continuation and strengthening of the close interactions between BIO-C3 and the thematically related BONUS projects BAMBI and INSPIRE, and now also COCOA. This includes research collaborations as well as the successful summer school and ICES ASC session, and joint outreach efforts. We are planning to continue along the same lines with the planned second BIO-C3/BAMBI/INSPIRE/COCOA summer school in September 2016 in Denmark, this time focusing on modeling approaches.

Overall, we thus look back to a successful year 2015, and are excited about the perspectives for the next reporting period. In the following, the scientific activities and progress in each of the project WPs during this reporting period is summarized (Scientific report, pages 6-83). This is followed by the summary of BIO-C3 output and statistics for 2015 (Performance statistics report, pages 87-118).

I. Scientific report

1. Scientific results during the reporting period (by work package)

WP1 – Genetic adaptation and ecophysiology

Lead: Dorte Bekkevold, P2 DTU Aqua

Overview:

WP 1, "Genetic adaptation and eco-physiology", investigates physiological tolerances and adaptive variation of key Baltic Sea species. The goal is to provide a general understanding of principal determinants of the distribution of species and populations, which ultimately determine the functional diversity and resilience of Baltic Sea ecosystems in response to environmental drivers. WP1 output feeds into WP3 and 4, and is therefore crucial for the incorporation of evolutionary processes into future projections of the Baltic Sea.

Work in tasks 1.1 and 1.2 in this WP is going according to plan. Task 1.1 has been completed. The resulting Deliverable 1.1 - "Review of environmental factors influencing distributions of selected Baltic species", submitted in project month 22, was accepted by BONUS and is now available on the BIO-C3 website, www.bio-c3.eu/publications. Task 1.2 is nearing completion, and the resulting Deliverable 1.2 – "Documentation of key drivers and physiological tolerance limits for selected resident and invasive species" was submitted in February 2016 and has now been accepted by BONUS. Regarding Task 1.3, most work lines are going according to plan, however, due to the need to re-establish some of the copepod cultures following a crash, we have applied for and received a shift in the deliverable D1.3 deadline to Month 36. This delay was discussed with partners in WP 3 and 4, and we do not anticipate any downstream problems.

Task 1.1: Environmental conditions, eco-physiology and species distribution

Lead: P3 UHH (Axel Temming), participation of Partners P1-8 and P11.

Deliverable 1.1. *Review of environmental factors influencing distributions of selected Baltic species*. **Month 22**. Accepted by BONUS, accessible at www.bio-c3.eu/publications.[1]

The objective of this task was to supply an up to date overview of environmental factors influencing Baltic Sea biodiversity as well as data which can be adopted in the BIO-C3

[1] Since the full deliverable is available open access online, we focus on an overview of key results from this work here.

modeling work (WP3). The delivered work first presents a brief overview of ecologically and economically important species for different habitats and trophic levels in the Baltic Sea. With its extreme hydrographic conditions, the Baltic is an area of low species diversity with only about 70 species forming self-sustained populations. Out of these 70 species, almost 50% were then selected for a review of their physiological tolerances and limits. The species, nine benthic, 13 planktonic and eight fishes, were chosen either because of their abundance in and importance for the ecosystem, or because they were considered as potentially important species under future condition, e.g., because of expected increasing biomass trends. Specific emphasis was given to species that are to be included in subsequent modelling exercises. One of the key applications of this rather unique compilation of information is the application of envelope modelling of their potential habitats using hydrodynamic models, both in hind cast and for future scenarios derived from down-scaled climate model predictions. This task in effect supplies the BIO-C3 modeling work (WP3) with species-specific information on environmental tolerances and preferences and identifies some gaps in knowledge. Gaining all necessary information for this task was possible only due to the consequent cooperation of all partners within BIO-C3. Task 1.1 was accomplished within the planned time. The resulting deliverable was accepted and is available at the BIO-C3 webpage (www.bio-c3.eu/publications). The underlying data set is available online (see https://docs.google.com/spreadsheets/d/11zBNylWvdaQ8fEZ0JRgF6Ac5p75NbFWZcnecnkum8Hc/edit?pli=1#gid=2117449428).

Task 1.2.: Physiological tolerance, preference and phenotypic plasticity

Lead: Catriona Clemmesen, P1 GEOMAR, participation of partners P2-P8.

Deliverable 1.2: *Documentation of key drivers and physiological tolerance limits for selected resident and invasive species*. (**Month 26**, Accepted by BONUS, accessible at www.bio-c3.eu/publications)

Milestone 1.2: *Assessment of physiological tolerances* (**Month 22**, completed)

Work has gone according to plan. The output of this task, together constituting deliverable D1.2, has been accepted by BONUS and is freely accessible online under www.bio-c3.eu/publications. Specifically, the evaluation of physiological tolerance, preference and phenotypic plasticity in relation to environmental factors for a range of different species has been performed. The Milestone 1.2 associated with this task was met, and output of Task 1.2 as basis for downstream analyses was discussed and will be further pursued with WP3 (Task 3.2, 3.3 and 3.4). Specific lines of work are listed in the following. A number of scientific papers reporting on individual results are in various states of preparation or publication and we refer to these below.

Community level responses and invasive zooplankton species performance along gradients (P08 – KU)

Two field surveys were conducted, representing 17 locations along a salinity gradient from the Nemunas river mouth to the Curonian lagoon to the western edge of the Lithuanian EEZ. Zooplankton and phytoplankton samples were collected within vertically stratified water columns above and below the halocline. The results show that zooplankton biomass increased from the Nemunas River delta towards the Baltic Sea. A community shift from cladocerans in the Curonian Lagoon to rotifers in the Baltic Sea was observed. The most significant factors determining shifts in zooplankton community structure were salinity and chlorophyl-a concentration (Griniene et al., in preparation).

Zooplankton biodiversity within the Lithuanian coastal zone was assessed from the samples applying novel molecular techniques. High-Throughput Sequencing (HTS) metabarcoding for the surveillance of plankton communities within the SE Baltic Sea coastal zone was applied. Results were compared to those from routine monitoring surveys and morphological analyses. Four of five non-indigenous species (NIS) found in the samples were identified exclusively by metabarcoding. All of them are considered as invasive in the Baltic Sea with reported impacts on ecosystems and biodiversity. The proportion of identified NIS was significantly higher in metabarcoding results than using traditional surveys. Most NIS were detected in the transitional zone between the Curonian Lagoon and the Baltic Sea, which also has the most variable salinity levels. In all three sampling locations there were sequences attributed with high confidence to the invasive polychaete *Marenzelleria viridis*. Based on the results of the earlier molecular identification and areal distribution assessment of three sibling *Marenzelleria* species within the Baltic Sea, only *M. neglecta* was unambiguously reported from the eastern and south-eastern regions (which include the Lithuanian cost). These findings contribute to the update of the current distributional maps of the species as well as national inventories of the non-indigenous organisms. However, further ground-truthing studies are required to verify the particular distribution of these two species in the benthic habitats. The work is currently in preparation for publication (Zaiko *et al*., in preparation).

Physiological tolerance to temperature and salinity change of a key copepod species in the Baltic Sea - *Eurytemora affinis* (P04 – SU)

Populations of the calanoid copepod *Eurytemora affinis* from locations across the Baltic Sea (Bothnian Bay, Gulf of Riga, Askö) were collected and exposed to different salinities and temperatures in common garden experiments to investigate their fitness response. Lowering the salinity from 6 to 2 PSU increased mortality, delayed development time and reduced egg hatching success in several populations. The combined effect of increased temperature and low salinity increased mortality even further. Increased temperature appears to be especially stressful in the most northern populations, as they are at their outmost

temperature range. This suggests that some copepod populations likely have low tolerance levels to future climate change. The project was performed within a master and PhD thesis and is currently being prepared for publication (Winder *et al*., in preparation).

Physiological tolerance: *Temora longicornis* – *Acartia longiremis* (P02 – DTU Aqua)

Laboratory experiments were conducted to determine metabolic and reproductive responses of two populations of the calanoid copepod *Temora longicornis* from the Bornholm- and the Gotland Basin. Ingestion, respiration, egestion, egg production and egg hatching success were compared at salinities ranging from 10 to 5. Both populations showed a decreasing ingestion and egg production with decreasing salinity, down to a critical salinity of 6, below which mortality increased to 100%. However, hatching success of eggs was high and respiration was generally constant at all salinities. Our results suggest that energy partitioning of *T. longicornis* is significantly changed due to decreased salinity.

In contrast to *T. longicornis*, cultures of the calanoid copepod *Acartia longiremis* could not be established in the laboratory. The salinity tolerance was, therefore, investigated during a cruise to the Arkona and Bornholm Basin in September 2015 on R/V Dana. Feeding, fecundity and instantaneous survival to lowered salinity was compared in two populations originating from a salinity of 16 and 7.8. Females of both populations displayed a broad salinity tolerance to lowered salinity. The lower lethal salinity, however, depended strongly on the population origin indicating local acclimation/adaption to salinity. Metabolic and reproductive rates were strongly related to salinity and decreased with lowered salinity. Similar to *T. longicornis*, a salinity of 5 is critical to the population with regard to the species vital rates. Below 5, decreased feeding rates were not sufficient to sustain reproduction and high survival of the species. The results are in preparation for publication (Dutz et al., in preparation).

***Mnemiopsis* - range expansion - salinity and temperature limits** (P02 – DTU Aqua and P01 - GEOMAR)

The NIS *Mnemiopsis leidyi* was present in the Baltic Sea from 2006 to the winter of 2010/2011. However, thereafter reports became sporadic and there were strong indications that the species was not able to establish a permanent population in the low saline Baltic Sea region. On the other hand, areas with higher salinity and higher winter temperatures, like the Dutch Wadden Sea and German Bight, support year-round populations and animals have been present consistently since the first sightings. Here, we assessed the effects of temperature on the observed spatio-temporal patterns and distribution ranges throughout Europe, and were able to demonstrate a strong role of temperature in particular in the Baltic. The results are in preparation for publication (Jaspers *et al*., in preparation).

Effects of natural environmental conditions and shipping on the distribution of the invasive round goby (P06 – UT-EMI)

Introductions of NIS are considered a major threat to aquatic ecosystems worldwide. While it is valuable to know the distributions and ranges of NIS, predictive spatial models along different environmental gradients are more useful for management of these species. In this study we modelled how external drivers and local environmental conditions contribute to the spatial distribution of an invasive species using the distribution of the round goby *Neogobius melanostomus* in the Baltic Sea as an example. Using the collected distribution data, an updated map on the species distribution and its invasion progress in the Baltic Sea was produced. The current range of the round goby observations is extensive, covering all major sub-basins of the Baltic Sea. The most recent observations appeared in the northern regions (Northern Baltic Proper, the Gulf of Bothnia and the Gulf of Finland) and on the eastern and western coasts of southern Sweden. Modeling results show that the distribution of round goby is primarily related to local abiotic hydrological conditions (wave exposure). Furthermore, the probability of round goby occurrence was very high in areas in close proximity to large cargo ports. This links patterns of round goby distribution in the Baltic Sea to shipping traffic and suggests that human factors together with natural environmental conditions are responsible for the spread of NIS at a regional sea scale. Results are reported in Kotta *et al.* (2016).

Salinity tolerance of round goby (P02 – DTU Aqua)

NIS can have strong impacts on marine biodiversity and ecosystem structure and function, including their services. Once introduced into a new region, secondary dispersal of NIS depends on a suite of ecological factors such as presence of predators, competitors, and parasites, yet with the most fundamental constraints on the distribution arising from the organism's physiological limitations in relation to the ambient environment. Predicting dispersal however remains a challenge. Here, it was possible to show that physiological traits, namely aerobic scope and osmoregulation, can be used to predict performance and dispersal potential of an aquatic invasive species in novel environments. It was shown that round goby *N. melanostomus*, one of the most wide-ranging invasive fish species in Europe and North America, has the capacity to occupy full oceanic environments. Currently, round goby thrives in brackish and fresh waters, while it hitherto has remained unclear if the species will endure high salinity waters. Our results demonstrate that key physiological traits provide a tool to predict dispersal and hence 'area of impact' at an early state. Early predictions are a great asset in relation to taking appropriate management actions. While eradication of round goby is unrealistic, population control that leads to minimizing the risk of further secondary dispersal is feasible **(**Behrens *et al*., submitted**)**.

Juvenile sprat–functional feeding response (P03 – UHH-IHF)

Laboratory experiments were conducted to study the effects of temperature and body size on the functional response of sprat (*Sprattus sprattus*) using *Artemia salina* nauplii as prey to determine the maximum feeding rates. Functional response curves help to understand and quantify the impact of sprat on zooplankton communities in the Baltic Sea and serve also as a basis for the estimation of food densities required for optimal growth of early juveniles. The present results indicated a strong influence of temperature on feeding success, with lower numbers of sprat feeding at low temperatures. Feeding rates increased with both temperature and fish body size. The relation between snatching rate and prey concentration, temperature and body weight was then summarized in a mathematical model. Smaller fish had higher Q10 values than larger conspecifics, suggesting that larger fish reached maximum feeding rates at even lower temperatures. This may be reflected in the habitat utilization in summer, with small juveniles living near the coasts in warmer water, whereas larger individuals occupied deeper areas with lower temperatures.

The feeding rate equation was then combined with experimental data on the relationship between metabolic rate and temperature and body size in juvenile sprat (Meskendahl *et al.* 2010) to simulate the food requirements of different seasonal cohorts of juvenile sprat. For this, the growth rates at different combinations of temperature and body size were deduced from increment analysis of field caught juvenile sprat. The results indicate that early season cohorts reach large body sizes at the time of the year with maximum temperatures, which then require high prey concentrations due to the increased metabolic demands. Later born seasonal cohorts experience these maximum temperatures at smaller sizes and can utilize lower prey concentrations for maximum growth. The results are in preparation for publication (Temming *et al*., in preparation).

Fish egg - buoyancy– experimental and field approach (P01 – GEOMAR, P02 – DTU Aqua)

Data from a 6-year time series (data analysis from up to four different stations) confirm a positive relation between egg size and egg buoyancy for sprat (*Sprattus sprattus*) during April spawning. Large eggs float higher in the water column compared to small eggs. The inter-annual variation in the specific density layer was lowest for the largest diameter sprat eggs, thus reflecting rather stable density conditions. Egg density increased in 2014 and 2015 compared to previous years, although with large variation in 2014. In 2015, the highest significant mean value in the egg density time series for sprat could be measured. The years 2012 and 2013 were characterized by low April temperature in general, and 2014 and 2015 by significantly higher temperatures. The oxygen conditions also changed during years on the analyzed density layers – however, if considering the threshold level of 2mg/l oxygen (Nissling et al., 2003), all egg diameter classes in all years and stations experienced values above that condition.

The general characteristics of the pelagic flounder eggs (*Platichthys flesus*) in relation to environmental and depth related variables showed statistically significant differences between the Bornholm Basin and the Gdansk Deep/Gotland Basin areas. Accordingly, the cumulative survival probabilities of egg batches might have changed in those areas. The results showed greatly enhanced survival probabilities in Bornholm basin in 2015, as egg survival increased from 47% in 2014 to 100%. In Gdansk Deep the situation was similar, and survival probability increased from 13% to 100%. In the Gotland Basin no difference in survival probability was identified over time, although the dominant cause of mortality shifted from sedimentation due to low salinity conditions in 2014 to oxygen deficiency in 2015 (Nyberg 2015, Bachelor Thesis; Nissling, Nyberg and Petereit, in preparation).

Hinrichsen *et al.* (2016) used field-derived cod egg diameter data in combination with buoyancy data, and linked this information with stock characteristics to improve the current estimation method of spawning stock biomass. The newly established relationship between egg diameter and buoyancy (floating depth) allowed the quantification of the "number of effective spawners", i.e., the spawners which were able to successfully reproduce under ambient and hydrographic conditions. This study used eastern Baltic cod (*Gadus morhua*) eggs sampled during 8 years in the central Bornholm Basin. For the time period 1993-2010, the results revealed large variations in the horizontal extent of spawning habitat (1000-20000 km²) and oxygen-dependent egg-survival (10-80%) (Petereit *et al*., in preparation).

Cod larvae – climate stressor experiments (P01 – GEOMAR)

In collaboration with researchers from the Heinrich Heine University and NOFIMA AS, Norway, a trans-generational experiment was performed in order to assess the potential of trans-generational mediation on deleterious effects of ocean acidification in cod. Adult cod (*G. morhua*) from the Barents Sea stock were kept at either 1) current or 2) projected end-of-century pCO_2 condition for 20 weeks and allowed to spawn. The resulting eggs were incubated at both the parental and the opposite treatment. After hatching the larvae were reared for 36 days with a large variety of samples and analyses being taken and performed. These included measurements of growth, mortality, family specific mortality, carbon chemistry and respiration. Samples were also used for assessing bone development, feeding rates and histology. Further samples were collected for gene expression analysis, gut microbiota analysis and epigenetic investigations. Since the conclusion of the experiment, the analysis of the growth and mortality data has been completed, while the transcriptomic and epigenetic analysis are still ongoing. This experiment will yield further data on the long term effects of ocean acidification on adult cod (Clemmesen *et al*., in preparation).

Task 1.3. ***Adaptive evolution of resident versus invasive species***

Lead: Thorsten Reusch, P1 GEOMAR participation of partners P2-5, P7, P11

Deliverable 1.3: *Report on adaptive evolution linking trait and functional genetic variance for selected species*. (**Month 36**[2])

In 2015, the population genetic analysis of selected key native and invasive taxa was continued, focussing on zooplankton species (copepods and invasive comb jelly *M. leidyi*) and on a key fish species, Atlantic cod (*G. morhua*). In addition, a large spatial sampling programme on the invasive round goby (*N. melanostomus)* was finished, while the development of genetic markers to track invasion pathways and possible rapid adaptation to the new environment is currently in progress. In focal copepod species a first series of common-garden experiments have been performed for different populations to determine local tolerance and adaptation potential. The Milestone 1.3 associated with this task was met, as inference from analyses conducted under this task has been brought forward to WP3 (Task 3.2, 3.3 and 3.4).

Experimentation with copepod species (contributors Anette Christensen, Jörg Dutz, P02 – DTU Aqua and IOW; Monika Winder, P04 - SU)

In parallel to the experiments aiming at the characterization of the physiological tolerance of *T. longicornis* to decreasing salinity (task 1.2), work was started to determine local adaptation of the populations isolated along the salinity gradient. For this purpose, populations established in the laboratory from the Kattegat (salinity 25), the Bornholm Sea (salinity 7.7) and the Gotland Sea (salinity 7.1) were grown at a common salinity of 15 in order to determine reaction norms with regard to reproductive success and offspring survival. Unfortunately, these cultures as well as the original stock cultures from the Baltic Proper ceased growth in autumn 2015 and were lost. Cessation of the reproductive activity of females was identified as the cause for the failure. Similar culturing problems with the Baltic cultures occurred already in autumn 2014 and may point to within species differences in the life cycle strategies among these populations. Whether this reflects an adaptation to the conditions in the Baltic needs to be addressed in future studies. The common garden experiments will be continued after re-establishment of new cultures in spring 2016.

Besides the experimental studies, samples allowing the study of the populating genetics of *T. longicornis*, *Centropages hamatus* and *Acartia longiremis* were taken from the Arkona, Bornholm and the Gotland Basin during a cruise with RV Elisabeth Mann Borghese in May 2015. These samples were taken shortly after a Major Baltic Inflow in February 2015, which brought a large amount of saline water to the Gotland Basin. A repetition of the sampling in

[2] Shifted from Month 32 to re-establish the crashed copepod cultures and complete copepod experiments as planned.

2016 offers the opportunity to study the effect of inflow events on the genetic structure of populations and the connectivity between major Baltic Basins.

Another series of experiments were conducted at Stockholm University to estimate the adaptive capacity of the copepod *E. affinis* to changing temperature and salinity. The Stockholm group led by Monica Winder established populations from different sites that experience differences in temperature and salinity: the Bothnian Bay, the Northern Baltic Proper and the Gulf of Riga, and asked: how much genetic variation is maintained by natural differences in temperature conditions *among* populations? Siblings were placed in different environments to estimate genetic and environmental effects on traits. We found large variation in survival between populations across temperatures and independent to temperature in two sites, but different survival sensitivity at the third site across temperatures. In addition, we also identified morphological differences between populations. The large variation in survival suggests genetic differentiation between populations. Data are being analysed and summarised in a manuscript; further experiments with changing salinity and temperature are planned for 2016.

Population biology and adaptation of invasive comb jellies *M. leidyi* (contributors Conny Jaspers, P02 – DTU Aqua, Thorsten Reusch, P01 - GEOMAR)

Why the invasive comb jelly species *M. leidyi* is so successful in its new habitat is still elusive. A MSc Thesis, successfully defended in January 2016 by Sarah Kaehlert (GEOMAR), investigated the contribution of a primitive trait, larval reproduction, to the invasion success of *M. leidyi* in northern and southern Europe, respectively. The work has shown that *M. leidyi* larvae from both southern and northern invasions do reproduce as larvae. However, the new and exciting result is that animals do not stop reproduction during metamorphosis, as has been described for the native population. This might indicate that invasive populations select for maturation at an early age to increase the per capita population growth rate, explaining their invasion success in northern and southern Europe. A manuscript will be submitted by spring 2016. The tolerance of the invasive comb jelly *M. leidyi* to currently limiting environmental parameters will be assessed in a large common garden experiment in Kiel during summer 2016. We aim to investigate the genetic basis of performance differences using RAD and RNA sequencing techniques.

Adaptation and migration in different cod (*G. morhua*) stocks (contributors Jakob Hemmer-Hansen, Karin Hüssy, P02 – DTU Aqua)

Genetic analyses of contemporary tissue samples have shown that western and eastern Baltic cod populations mix in SD24, and that there is an east-west gradient in mixing proportions within the area. Time series of salinity data from SD24 were analysed to identify periods of major salinity shifts in the region (Figure 1.3.1). These were related to recorded

Major Baltic Inflow (MBIs; Morholz *et al.* 2015) events, which may affect population dynamics and distributional patterns cod populations in the area.

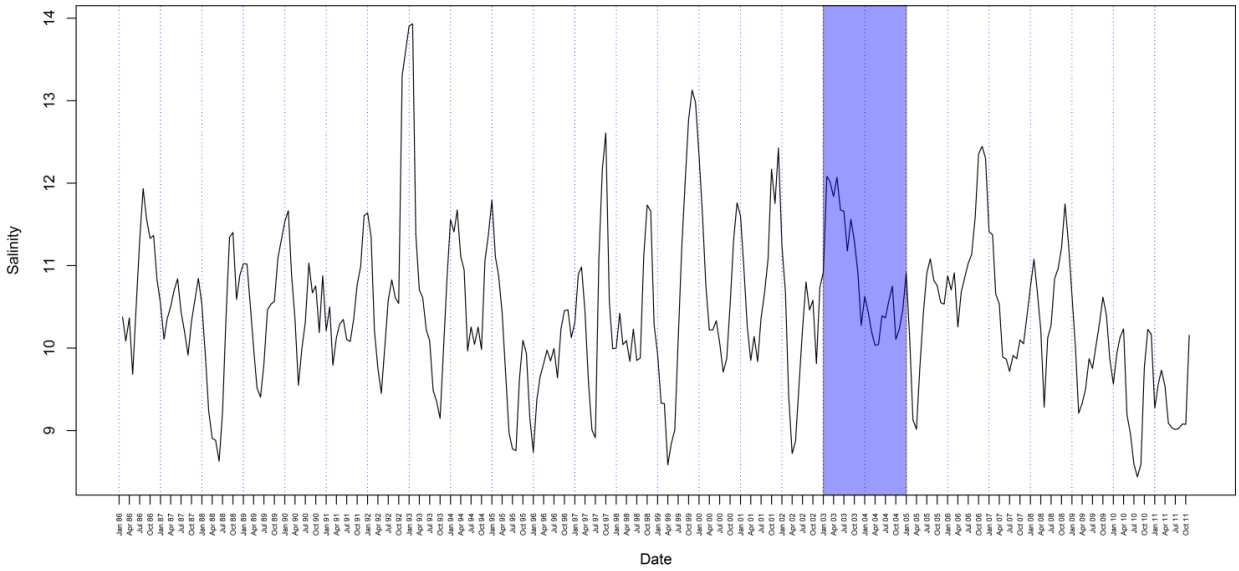

Figure 1.3.1 Monthly average of salinity in SD24 (averaged across all depths). Selected period for historical genetic analyses is shown in blue. Data provided by Hans-Harald Hinrichsen, P01 -GEOMAR.

Subsequently, hydrographical data were related to an inventory of available otolith collections to identify time points and geographical areas where different environmental regimes could be contrasted through genetic analyses. Here, 2003 and 2004 were selected to represent inflow and stagnation years, respectively, as reasonable sample sizes of otoliths were available for these years (Figure 1.3.2) and 2003 was identified as a moderate MBI year.

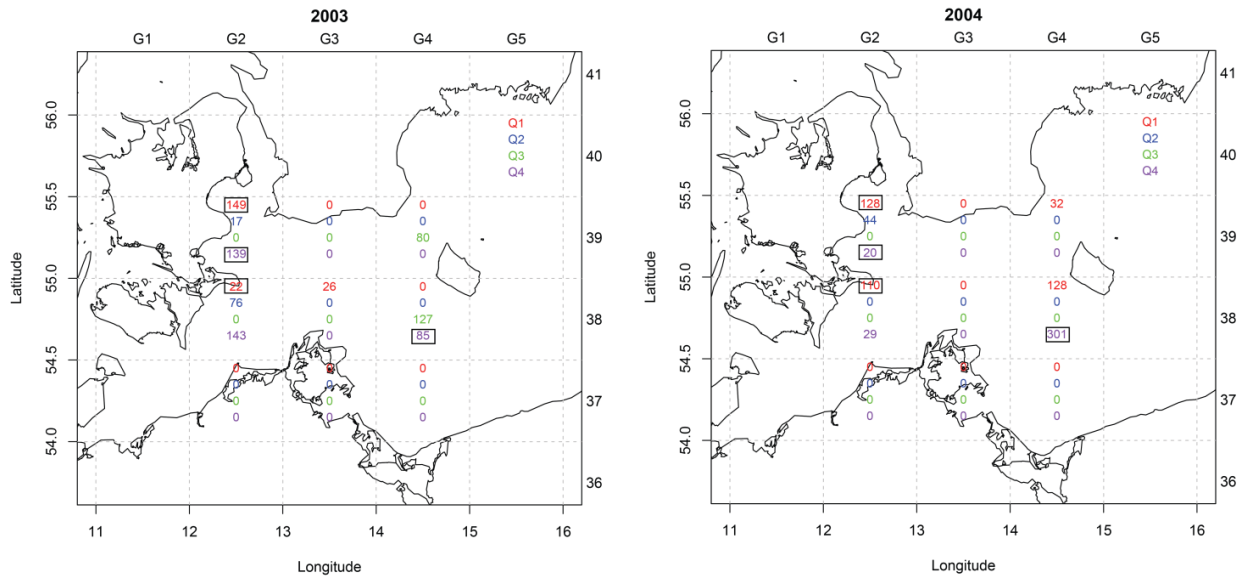

Figure 1.3.2 Overview of otolith collections in SD24 by ICES squares and quarters. Areas and time points selected for analysis are indicated by squares.

A very strong MBI was observed in December 2014 (Morholz *et al.* 2015). Consequently, sampling of additional tissue samples from 2015 was coordinated to facilitate a contrast between samples from this inflow year and the baseline data collected in 2014. In summary, the available samples will allow the effect of high saline water inflows to be tracked in two different years by comparing 2003 vs. 2004 and 2014 vs. 2015, respectively. These genetic analyses are currently on-going.

Time series on cod genetic diversity in Bornholm basin (contributors Jan Dierking, Thorsten Reusch, Burkhard von Dewitz, P01 - GEOMAR)

A second line of work focuses on time series of cod genetic diversity in response to environmental drivers and changes in stock structure in the Bornholm Basin (ICES SD25). This study integrates datasets on oceanographic parameters, cod biology and neutral and selective genetic markers. The assembly of the individual datasets needed for this integrative analysis was completed. In particular, genetic datasets (microsatellite and single nucleotide polymorphism, SNP, data) of archived Bornholm Basin cod samples spanning the years 1996 – 2015, and of a spatial reference dataset including locations to the East (Gotland Basin, Gdansk Deep) and West (Arkona Basin, Kiel Bight, Oeresund, North Sea/North Atlantic) were obtained using historic cod otoliths from sample archives, as well as cod finclips from recent years. Secondly, time series of environmental condition and cod stock structure for the period 1991-2015 were obtained from public databases and own datasets.

The analysis of the microsatellite dataset is completed. It confirms the genetic differences between the North Atlantic, Western Baltic, and Eastern Baltic that were already reported in the past (Nielsen et al. 2003). It also reveals for the first time high temporal genetic integrity of the Bornholm Basin cod population, i.e., very limited mixing with Western Baltic cod genotypes, as well as little no observable genetic structure among locations to the East of Bornholm Basin (Figure 1.3.2).

While spatial stability was high, genetic diversity (measured as mean allelic richness) over time in cod cohorts from Bornholm Basin showed inter-annual fluctuations. Moreover, recent own results show that bottlenecks in the number of cod contributing to reproduction may be induced by the lack of large females, and by environmental fluctuations (in particular oxygen and salinity) that put a prime on large females due to the better survival of their eggs in years with bad conditions (Hinrichsen et al. 2016). Combining these results, we investigated whether year to year differences in genetic diversity of cod cohorts was correlated with a hypothetical driver comprising stock structure and environmental condition (“n F” =, the number of females with surviving eggs in a given year). The correlation was indeed significant, but with a temporal lag of 1.5 years (Figure 1.3.4), potentially related to artifacts due to ageing problems in Eastern Baltic cod.

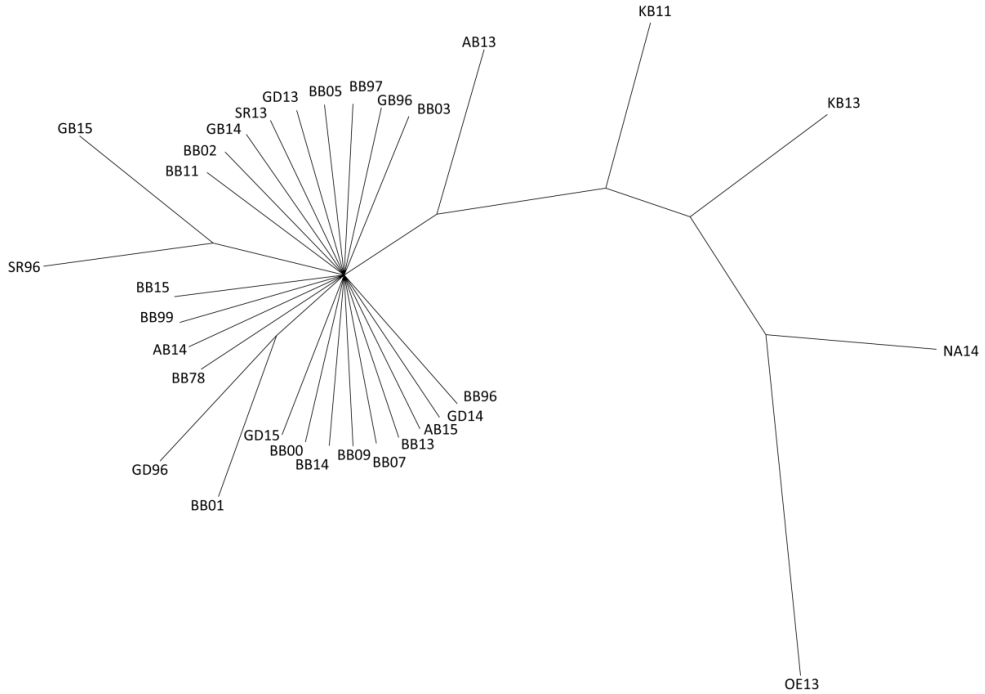

Figure 1.3.3 Spatial genetic structure in cod populations along an East to West gradient from the North Atlantic (NA) and Oeresund (OE), via Kiel Bight (KB), Arkona Basin (AB) to the Eastern Baltic cod populations Bornholm Basin (BB), Gotland Basin (GB), Gdansk Deep (GD) and Stolpe Trench (SR), obtained using microsatellite data, and analyzed and graphed using the program Phylip. Two digit number represent sampling years.

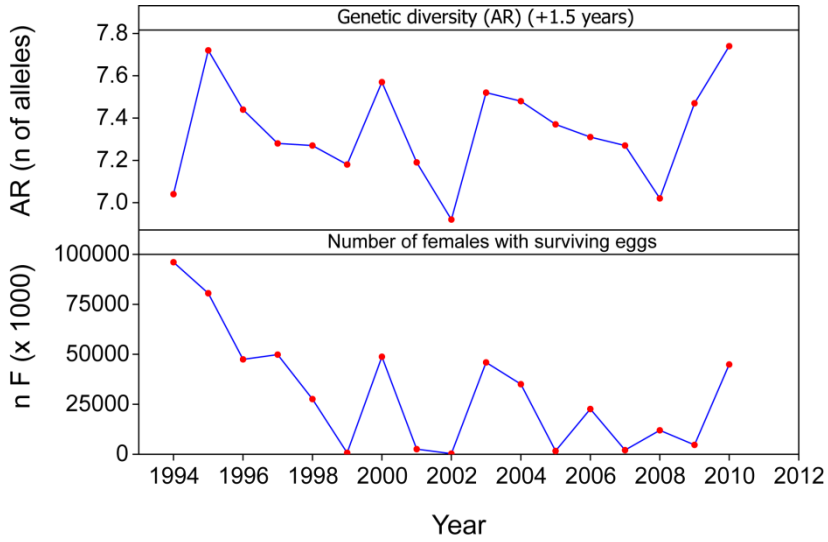

Figure 1.3.4 Time-series in genetic diversity, measured as mean allelic richness AR (top panel) and of the number of females with surviving eggs in a given year as measure of potential bottlenecks (bottom panel). The upper time-series was shifted by 1.5 years to the right in this figure, as statistical analysis showed a significant correlation between the two series ($p = 0.037$, $r^2 = 27.5\%$), but with a lag time of 1.5 years.

As last step, we are currently using the completed SNP dataset to gain a complementary, higher resolution, look at temporal integrity and migrations, and an alternative estimate of genetic diversity.

The cross-cutting interaction with oceanographers from WP3 was essential for the interpretation of genetic results shown here. Results from this line of work on SD25 will be compared with the spatio-temporal results for SD24 above, and will jointly feed into WP4 and 5 considerations on improved stock discrimination and modeling, as well as a discussion on the use of genetic markers as novel indicators. To conclude, all analyses are going according to plan, and we expect to deliver all results within the task timeline.

Sampling programme of round goby and genetic marker development (contributors Dorte Bekkevold, Jane Behrens, P02; Henn Ojaveer, P06; Felix Mittermayer, P01; Anastasija Zaiko, P08; Riika Puntila, P07; and partners from the NORDEN round goby network)

The sampling initiative on the invasive round goby *N. melanostomus* is continuing successfully. To date, BIO-C3 partners (including P1, P2, P3, P6, P7, P8, P11, and P13) have succeeded in obtaining tissue samples of 50-100 fish each from 15 locations in seven countries spanning large parts of the Baltic Sea and its entrance to the Kattegat. This sample set is now curated by DTU Aqua (P2). DNA extraction is on-going and the development of genetic markers to track invasion pathways and possible rapid adaptation to the newly invaded environments is ongoing, according to plan.

To link genetic patterns to demography and population functioning, a web-based workshop on round goby ageing techniques was held in August 2015, organized by Dr. Ann-Britt Florin from the Swedish University of Agricultural Sciences, who is part of the BIO-C3/Norden round goby network. Participants were round goby researchers from six Baltic countries, including representatives of BIO-C3 P2, P7 and P11. An internal report was produced.

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WP2 – Food webs under changing biodiversity

Lead: Axel Temming, P3 UHH-IHF

Overview:

Biodiversity influences food web structure, ecosystem functioning, and stability. Recently, changes in community composition on nearly all trophic levels, including planktonic and benthic foodwebs and fishes were described in the Baltic Sea, but the underlying processes by which these changes impact coastal and pelagic systems are only partly understood. WP2 investigates the consequences of changing biodiversity including non-indigenous species on Baltic food web configurations, transfer of energy and essential compounds, and productivity of the system using a combination of existing information, field work, experiments, and modelling, and considering different trophic levels, functional groups and habitats.

The work in all three tasks of this WP has progressed as planned, and no major problems are anticipated. The Deliverable 2.1 - "Report on effects of changing drivers on pelagic and benthic species composition and production", containing completed output of Task 2.1, was submitted to and accepted by BONUS in project month 24. It is now available online on our BIO-C3 website www.bio-c3.eu/publications. The lipid analyses within Task 2.1 are ongoing, following delays due to technical reasons and the maternal leave of a project scientist. The delays were discussed with downstream data users in WP3 and 4, and we do not expect negative impacts on the project work flow. Results will become available within the run time of the project.Task 2.2 is nearing completion, and the resulting Deliverable 2.2 – "Report on effects of changing predation pressure on benthic and pelagic species" was submitted to BONUS at the same time as this report. The downstream use of available results from WP2 in WP3 and WP4, as well as the joint work on collaborative datasets including biological and environmental data, will remain a strong focus in the coming reporting period.

Task 2.1: Bottom up control

Lead: Monika Winder, P4 SU, participation of P1, P2, P3, P5, P9, P11.

Deliverable 2.1: *Report on effects of changing drivers on pelagic and benthic species composition and production*. **(Month 24)** Accepted by BONUS, accessible at www.bio-c3.eu/publications.[3]

[3] Since the full deliverable is available open access online, we here focus on an overview of key results from this task.

The goal of Task 2.1 is to investigate bottom-up controlling mechanisms due to drivers of climate and eutrophication, and consequences for transfer efficiency and food quality for higher trophic levels and biodiversity. Within this task we investigated how shifts in species composition at the base of the benthic and pelagic food web as well as temporal and spatial mismatches between critical trophic linkages influence energy flow and limit overall productivity. In addition, fine-scale benthic ecosystem models (3-D MIKE3 FM) quantify effects of oligo- and eutrophication in relation to the conservation targets of key fish and waterbird species. For the pelagic system, the focus was on food quantity and nutritional prey quality using field observations, experiments, compound-specific stable isotopes, quantitative fatty and amino acid analyses. The taxonomic diversity and the functional role of largely understudied but diverse microzooplankton in 'trophic upgrading' was investigated. These studies are feeding into bioenergetic models in WP4. All work has gone according to plan, with specific progress described below. D2.1 was submitted and is accepted, but some of the work lines will still continue over the next project year. Detailed results of the studies below are accessible in the D2.1 report:

- To predict and quantify the bottom-up effects of oligo- and eutrophication and climate, and the interaction between these on benthic habitats and in relation to top predators such as fish and water birds, fine-scale benthic ecosystem models (ECO Lab/3-D MIKE3 FM) and bioenergetics models have been developed. The models aim at describing effects of eutrophication on selected benthic habitats (mussels, clams, eelgrass, macroalgae (e.g., *Fucus vesiculosus, Furcellaria*) and fish species (round goby) and selected benthivorous water birds (e.g. velvet scoter and long-tailed duck). Modeling runs will continue until mid 2016, and final results will reported in the 2016 annual report. (P9)

- A quantitative comparison of key food quality parameters (fatty acids, amino acids and C:N:P ratios) across four major groups of pelagic primary producers (diatoms, cyanobacteria, green algae and haptophytes) were conducted. Results indicate that major taxonomic groups differ in the concentrations of important biochemical compounds. Differences in compound concentrations explain why a more diverse nutrition leads to higher production rates of consumers than mono-specific diets. Data analysis is currently ongoing and a manuscript will be finalized in 2016. (P4)

- Compound-specific stable isotopes analysis (CSIA) of amino acids (AA) and fatty acids (FA) are proposed to be promising biomarkers to trace energy flow in aquatic food webs. We investigated the differentiation of algae groups using CSIA. A premise for tracing food web processes at a high resolution in aquatic ecosystems is the ability to differentiate base-line source groups, especially major algae groups. The implications of these biomarkers for tracing energy sources are currently being analyzed. Data analysis is currently ongoing and a manuscript will be finalized in 2016. (P4)

- Laboratory experiments were conducted to investigate whether microzooplankton maintains homeostasis. This is important because microzooplankton is a major component in marine food webs and in comparison to mesozooplankton, less is known about the ability of microzooplankton to maintain stoichiometric balance. Our study implies that microzooplankton growth can be constrained by imbalanced resource supply and indicates that these key primary consumers have the potential to trophically upgrade poor stoichiometric autotrophic food quality for higher trophic levels. This study is completed and published. (P4)

- We used CSIA to assess energy transfer from phytoplankton to a widespread key copepod species (*Acartia* spp.) in the northern Baltic proper with complimentary approach of bulk $\delta^{13}C$ and $\delta^{15}N$ values, and $\delta^{13}C$ values of essential amino acids. Results indicate that *Acartia* preferentially utilized specific dietary resources that comprised only parts of the total phytoplankton composition (i.e. varying from 19.7% to 81.4 % throughout the season). Analysis of $\delta^{13}C$ values in essential amino acids showed to be a promising tool to accurately trace consumer resource use in natural systems. This study is completed and published. (P4)

- The zooplankton mean size and total abundance (MSTS) indicator was tested on the Polish monitoring data. MSTS is a core HELCOM indicator indicating whether the investigated pelagic food web structure is or is not optimal for energy transfer from primary producers (phytoplankton) to fish. The MSTS, a two-dimensional, multi-metric indicator representing a synthetic descriptor of zooplankton community structure is a promising tool to test the temporal dynamics and the present state of the pelagic food web. Further work will focus on preparing a manuscript for publication. (P5)

- The effects of zooplankton biomass vs. temperature were analysed on the growth rate of larval and early-juvenile sprat. The goal of the present work was to describe growth rate of larval sprat in years 2006-2010 and to evaluate the effect of temperature and zooplankton biomass on both the differences among years and the differences between geographical areas (Bornholm Basin and Gdansk Basin). The growth rate of larval sprat in the southern Baltic is higher in May-June than in July-August as a result of higher zooplankton biomass, despite much higher temperature in the latest period. The importance of temperature is however observed when geographical differences in growth rate are analyzed within the same time period. Further work will focus on cod larval size group and the preparation of a manuscript for publication. (P5)

- The phenology in appearance of larval fish and zooplankton as well as the nutritional condition of larval fish over the spawning season and changes in the condition of adult fish were analysed. Aim of the analyses was to relate larval fish condition to zooplankton prey fields for an evaluation of match/mismatch scenarios and potential consequences for recruitment and to understand the observed changes in adult fish condition. The

proportions of cod larvae with positive growth rates varied between years and months analysed. A positive correlation between cod larvae nutritional condition and abundance of the most important food item copepodid C1 stages of *Pseudocalanus spp.* was found. Correlations between larval cod growth rates based on biochemically derived estimates (RNA/DNA ratios) and zooplankton abundance as well as numbers of recruits could be shown, providing support for the "Match-Mismatch" and "Bigger is better" recruitment hypotheses. (P1, P3, P2)

- Data on individual cod sampled during the Danish part of the Baltic International Bottom Trawl Survey (BITS) ICES Sub-division 25 from 1995-2014 were analysed. Results show a significant decline in nutritional condition over time. (P1, P3, P2)

- Data and samples from six surveys in Sub-division 25 were collected as part of BIO-C3. It follows the cod reproduction cycle from onset of maturation until end of the main spawning season, with emphasis on spawning period. The histological analysis of samples has been performed and provides the basis for sub-sampling of cod for total lipid and fatty acid analysis to be performed in 2016. Also the lipid and fatty analyses will indicate if cod is limited in specific polyunsaturated fatty acids at present, and data will be compared with previous data, where similar analyses were performed for females at specific times of the year, including also information about prey quality. Data analysis is ongoing and a manuscript about first results will be prepared in spring 2016. (P1, P3, P2)

- The onset of the inflow stagnation period since 1983 is reflected in the consumption, and condition of cod <40 cm. Most probably, the absence of sufficient benthic food forces relatively small cod to forage on sprat with relatively low success. This development is still ongoing, and is aggravated by decreasing sprat abundance in the central area of the cod distribution (additional decrease in the mid 90s). Cod >40 cm can compensate by feeding on herring, small cod, and benthic fishes. (P1, P3, P2)

- Research cruises in the Bornholm Basin were performed to support partners with data and samples, including ichthyoplankton, zooplankton and fish stomach samples, as well as adult fish and CTD data. (P11)

Task 2.2: Top down control

Lead: Monika Winder, P4 SU, participation of P1, P2, P3, P5, P11.

Deliverable 2.2: *Report on effects of changing predation pressure on benthic and pelagic species.* **(Month 26**, submitted to BONUS at same time as this report)

Milestone 2.2: *End of analysis of consequences for biodiversity of changing selective predation (top-down control).* **(Month 12**, completed**)**

This task aims at understanding consequences of changing selective predation pressures on biodiversity in the Baltic Sea, using a combination of historical data series, monitoring data, new field studies and laboratory analyses, and modelling. Progress has been made on all of these aspects, including the collection of data needed to assess effects of different predators, and the implementation of several models to assess top-down control. Work is progressing according to plan, and most dataset are completed. The resulting Delilverable D2.2 was submitted to BONUS at the same time as this report, and will be accessible open access online on our website www.bio-c3.eu/publications, once it has been accepted. Assessment of the available datasets, and downstream applications, with partners in WP4 and 5 will be a focus of the next reporting period. Key results from Task 2.2 are summarized below.

Cod, herring and sprat spatio-temporal overlap and cod condition (P02 – DTU Aqua)

- Cod, herring and sprat abundances, predation mortality rate and resulting biomasses were estimated for the time period 1974-2010. The estimation was conducted both for the Eastern Baltic Sea stocks (named 'Southern Baltic' in the DOW) and separately for ICES sub-divisions 25, 26 and 28 in order to allow for basin-scale analyses of the strength of trophic interactions between cod, herring and sprat.

  Accounting for spatial predator-prey overlap in a selected basin, ICES Sub-division 25 which is the only basin with a relatively constant occurrence of the top predator cod, implied that spatial overlap in connection to the type of functional response probably decreased the trophic pressure on sprat over-proportionally at decreasing cod and slightly increasing sprat abundances.

  As part of an EU financed tender, the cod stomach database for Eastern Baltic cod has been substantially expanded backwards in time and updated to include recent years. Analyses indicate a bottom up control of benthos, especially *Saduria entomon*, decreasing after the stagnation of inflow events in the early 1980s. However, the control is dampened by cod utilizing sprat as food earlier in their life history. The cod initiate predation on sprat already at length around 20 cm, whereas in the earlier periods before 1980 cod started to prey on sprat at 30 cm total length. However, cod cannot compensate totally for the lack of benthic food, and a decrease in cod condition can be observed since the mid-1980s.

  In contrast to previous reports based on large scale sampling and time series of sprat and zooplankton, first analyses based on the BIO-C3 zooplankton sampling revealed that on

the relevant, smaller spatial scale, there is a trophic decoupling between clinoid copepods and sprat. Here, the analyses are still ongoing.

Increased process understanding gained from this work will be implemented in the food web models in Task 4.2 in order to summarize and simulate food web responses and interactions to changes in biodiversity and community species composition.

Cod, herring and sprat interaction – new insights from stable isotope analysis (P01 – GEOMAR, contributiors by Jan Dierking and Clarissa Mohm)

- Understanding the feeding ecology of commercial fish species is an essential component of multi-species stock assessments and food web models, and is consequently assessed as part of monitoring programs. This is particularly true for top predators such as Baltic cod (*Gadus morhua* L.), which may exert top-down control on lower trophic levels. Yet even with large investments in studies based on stomach content analysis (SCA), the spatio-temporal resolution that is logistically feasible to obtain is frequently coarse. This is particularly problematic in the environmentally highly dynamic Baltic Sea, as illustrated by recent strong declines in condition in the top predator Baltic cod, that were not predicted by existing models (*"the starving cod problem"*).

  Stable isotope analysis may be a tool to improve the spatio-temporal resolution of such estimates and to complement existing SCA-based information. Here, we provided the first systematic assessment of Baltic commercial fishes including cod, herring (*Clupea hargengus* L.) and sprat (*Sprattus sprattus* L.), as well as six other fish species with carbon, nitrogen and sulphur stable isotope analysis (SIA). This method is now irreplaceable in feeding ecology studies but applied surprisingly little in assessments of commercial fishes.

  Key results obtained based on a highly resolved spatial sampling design (19 sites covering Kiel Bight – ICES SD22, Arkona Basin - SD24, Bornholm Basin - SD25, and Gdansk Deep – SD26 and Southern Gotland Basin – SD26/28) during a cruise with RV Alkor in April 2014 revealed the presence of systematic within and between basin differences in isotopic baselines, indicating spatial sub-structure in fish populations even within basins (e.g., for cod). Secondly, the presence of isotopic outliers in several fish populations better reflecting values of neighbouring populations pointed to between basin migrations, e.g., for herring. Three different case studies then highlighted (1) spatial differences in cod feeding ecology, with different patterns in ontogenetic shift observed between basins of the Baltic Sea; (2) spatially consistent patterns of competitive interaction in herring and sprat that can help to identify size classes most likely to compete; (3) a surprising degree of intraspecific plasticity in several species, including flounder in SD 22 consistent with the presence of different feeding strategies of individuals in the same population. The

interpretation of results benefited from discussions with BIO-C3 P02 and 03, exploiting the available expertise on feeding ecology and stomach content analyses in our consortium.This study demonstrates how SIA can serve to obtain long-term feeding estimates for multiple species and with a spatial resolution that would be logistically challenging to obtain with SCA, and represents a baseline dataset for future studies of temporal variation (e.g., pre- and post inflow situations). The work has so far resulted in a Bachelor thesis (Mohm 2014), available via the BIO-C3 website. A manuscript is in the advanced stages of preparation.

- A second feeding ecology study based on stable isotopes on temporal patterns in the jellyfish species *Aurelia aurita* and *Cyanea capillata* over their period of occurrence in Kiel Fjord in 2012 showed the presence of a rapid dietary shift in *A. aurita* within just a few months, and the potential importance of benthic material at the base of Kiel Fjord foodwebs during part of the year. A manuscript based on this work has been accepted for publication in the journal Marine Biology.

  Both completed lines of work highlighted the potential for stable isotope studies in obtaining high resolution (temporal or spatial) feeding ecology datasets that can improve the knowledge base for foodweb modeling (including in BIO-C3 WP 4) and ultimately, resource management frameworks (WP 5). Applications in these contexts will be pursued during the coming reporting period.

  Resulting manuscripts:

  Mohm, C. (2014) Feeding ecology of Baltic cod assessed by stable isotope analysis (Bachelor thesis), Christian-Albrechts-Universität Kiel, Kiel, Germany, 42 pp.

  Mohm, C. and Dierking, J. Cod & Co. feeding ecology revisited: Baltic Sea commercial fish species assessed by stable isotope analysis. in preparation

  Javidpour, J. Cipriano-Maack, Mittermayr, A., Dierking, J. Temporal dietary shift in jellyfish revealed by stable isotope analysis. Marine Biology, in press

Zooplankton and sprat interaction (P03 – UHH)

- Existing data with bi-weekly to monthly time resolution of zooplankton abundance and production and simultaneous measurements of sprat abundance and predation in the Bornholm Basin (SD25) were analyzed with a focus on the quantification of consumption/predation and consumption biomass ratios. A key result is that most of the production is not consumed at all, mainly due to the limited vertical overlap of feeding sprat at daytime and the key copepods (*Acartia spp., Temora longicornis and Pseudocalanus acuspes*). The largest overlap exists between older stages of

Pseudocalanus and sprat, and this species suffers the highest C/P ratios, however restricted mainly to the month May (P3).

The above findings triggered specific studies into the fine scale vertical overlap between predator and prey. Earlier results based on Video Plankton Recorder (VPR) data indicated that *Pseudocalanus* actively avoids its preferred depths layers during day, when sprat feed in the same layer (Möller 2013). The species can be identified in the images due to their egg sacs; hence the study is referring only to the females. During night, when sprat migrates to the surface, the majority of *Pseudocalanus* in 2002 and 2009 returned to the preferred depth layer in the halocline. However, since a series of summer cruises indicated a trend of decreasing sprat abundances in the Bornholm Basin, this lead to idea of testing if *Pseudocalanus* continues its daytime vertical migration into deeper oxygen poor layers also in the absence of sprat. In 2012, sprat abundances where notably lower than in 2009, when copepod DVM patterns where investigated by Möller and colleagues based on VPR data. Our study draws the comparison of copepod behavior between those periods, and comes to the conclusion that no DVM pattern can be observed for ovigerous *P. acuspes* females in the central Baltic Sea in years with low sprat abundances. This suggests that the observed daily vertical migration aims at reducing the predation risk (P3).

A separate study was conducted as to why the prey (*Temora longicornis*) is actually dominating the stomach content of sprat, although the vertical overlap is also fairly limited. Here the hypothesis was tested that sprat actually feed on the morning descent to deeper waters in the regions with maximum concentrations. The evidence so far confirms the hypothesis, however, the quantitative analysis of this process is not completed. The expected outcome is an estimate of the share of the daily ration that is actually consumed on the descent (or ascent) (P3).

References:

Möller, K.O., 2013. Impacts of trophodynamics and climate-induced habitat changes on zooplankton distribution and behaviour: An optical sampling approach. PhD Dissertation, Department of Biology; Faculty of Mathematics, Informatics and Natural Sciences. Hamburg, Germany: University of Hamburg.

Top-down control (P04, 05, 07, 08, 11)

- Historical data of benthic species and cod abundance were compiled from the Bornholm basin to investigate the role of cod on top-down control on benthos, as well as cod consumption on benthos. The data are being summarized in a master thesis project. (P4)

- A study was conducted to estimate the magnitude and uncertainty of seal prey consumption using bioenergetics modeling, population and diet data. By comparing the prey consumption to fish catches, a first assessment of potential resource competition between seals and fisheries was received. For the most important commercial species (cod, herring and sprat), catches generally exceeded the seal consumption in the entire Baltic Sea but regionally, seal consumption could be more important. The length distributions of seal prey and commercial catch of herring and common whitefish overlapped, strengthening the concerns for competition, while the cod consumed by seals were generally smaller than in fishery catches. The uncertainty in prey consumption is substantial for many prey species. Except for the most common prey, herring, this is mainly explained by uncertain diet data rather than population and bioenergetics data. The consumption model used constitutes a starting point for further assessments of the predatory role of Baltic grey seals. This study is in review. (P4)

- The effect of increasing seal populations on fisheries are investigated using the Ecopath and Ecosim modelling framework. Model parameterizing and input data were improved. This study is in progress. (P4)

- A workshop was organized to synthesis benthic-pelagic coupling processes in the Baltic Sea. Two workshops were organized; including partners from other BONUS project. A synthesis paper focusing on the effects of climate change, eutrophication and fishing on benthic-pelagic coupling was compiled and will be submitted early 2016. This addresses the top-down control of fish on benthic species composition and processes and how this coupling is affected by environmental change. (P4)

- A study was conducted to estimate the impact of fish larvae on zooplankton in the Vistula Lagoon to estimate feeding selectivity of larvae and potential predation effects on the zooplankton community. Based on data collected in the Vistula Lagoon in 2004 – 2005 (three cruises each year, between hatching and metamorphosis of herring), a noticeable difference in herring larvae abundance was observed in the two successive spring seasons. The high, initial survival of larvae in 2004 potentially caused a considerable “top-down” pressure of older larvae on preferred organisms in May and June. Food composition and food selectivity investigations showed that copepod *Eurytemora affinis* (adults and copepodits IV-V) was the most important food component and it was highly selected even when significantly decreased in abundance. In contrast, the abundance and biomass of zooplankton in 2005, when much lower predatory

pressure of fish larvae was observed, did not present as dramatic changes during the comparable, spring and early summer season. High survival of early larvae in 2004 could be explained by coupling of the hatching period with abundance peak of copepod nauplii (match), while in April 2005 the abundance of this preferred food component was ca. tenfold lower (mismatch).

Different larvae abundance triggered density dependent mechanisms, i. e. growth rate and condition differed significantly between both sampling seasons: in 2004, high survival of early larvae resulted in a slower growth rate and lower condition factors of survivors due to food limitation; in 2005, lower survival of early larvae resulted in a faster growth rate and better condition factors of surviving individuals due to the favorable feeding conditions. (P5)

- The role of microzooplankton on algal community structure was evaluated by experimental studies on microzooplankton grazing (dilution experiments) from Lithuanian coastal waters. The data are analyzed and a manuscript is submitted to Oceanologia: Griniene E, Sulcius S & Kuosa H, Size-selective microzooplankton grazing on the phytoplankton in the Curonian Lagoon (SE Baltic Sea). This is a BIO-C3 publication if accepted. (P7, P8)

- Allochtonous matter contribution to food webs via bacteria: A review has been completed: Hoikkala L, Kortelainen P, Soinne H & Kuosa H 2015, Dissolved organic matter in the Baltic Sea, J Mar Systems 142: 47- 61. This is not a BIO-C3 contribution, but the primary material is collected to tables covering all Baltic Sea areas. This material can be provided for the use of BIO-C3 WPs by us (preferred way of action as the data may require modification) or given to a common database. (P7, P8)

- In 2015, TI-OF continued the investigation of herring spawning intensities (egg concentrations per area) during the spring reproductive season in Greifswald Bay (conducted in close collaboration with the herring recruitment research group and the BONUS-INSPIRE working group at TI-OF). In parallel, weekly beach seine samples were taken during the spring spawning season (and monthly thereafter) to investigate the seasonal succession of the resident small-fish fauna including potential herring spawn predators. Stomach content analyses were performed (and are still being conducted) to quantify the amount of herring spawn that is consumed by the local piscine predator community. A manuscript is currently being prepared focusing the predation impact of dominant small fish species on the survival of herring eggs. (P11)

- Additionally, samples taken in previous years and further existing data sets were used to estimate the predation mortality of early herring larvae. Although a clear spatio-temporal overlap was found for larvae and there potential predators (such as threespine stickleback *Gasterosteus aculeatus*), no significant predation on herring larvae was

observed. Gelatinous plankton (e.g. *Aurelia aurita*) - known to be a major clupeid larvae predator within Baltic Sea waters as well as in other marine systems worldwide - are subject to a temporal mismatch with the herring larvae in Greifswald Bay and thus being of no importance for larval herring survival. These analyses of trophic interactions of the small fish fauna within Greifswald Bay resulted in the successful completion of the dissertation of P. Kotterba at the Thünen-Institute, Rostock / University of Hamburg. (P11)

Task 2.3 Changes in food web function and diversity due to non-indigenous species

Lead: Harri Kuosa, P07 – SYKE, participantion of P2, P3, P5, P6, P8, P11, P13

Deliverable 2.3: *Report assessing the effects of key NIS on ecosystem functioning.* **(Month 38)**

This task focuses on direct and indirect food-web effects resulting from the increasing abundance and expanding ranges of invasive / non-indigenous species (NIS), as well as habitat engineering through these effects on native populations. Work to date is going according to plan, and progress is described in more detail below:

<u>P2 (DTU Aqua)</u>

- During BIO-C3 cruises conducted in 2014 and 2015, abundance and biomass data of the invasive comb jelly *Mnemiopsis leidyi* were collected collaboratively by the following partners: P1, P2, P3, P5. The data were entered into a database and are part of a MSc thesis which is supervised jointly by P1 and P2.

- The *Mnemiopsis* invasion front moves back and forth due to environmental parameters – here drift modeling is used to show Limfjorden as potential seed region, representing a successful example of the integration of WP3 and WP2 expertise and datasets. The work has advanced and is running as planned. We are currently in the process of developing a SNP chip to target the source population in N EUR after the extinction of *M. leidyi* in the Baltic Sea following 2011. We are planning to analyze how the genetic diversity is changing within sub-populations in northern Europe over time to investigate how different populations are interconnected. High saline regions can at times host huge abundances of *M. leidyi* that are 1 to 2 orders of magnitude higher than observed in the Baltic Sea. This means that eutrophic, disturbed regions have a high potential to act as seed region of non-natives for the Baltic Sea. Results from this work have been presented at an international meeting in 2015 (partner P1, P2 - see below) and will be written up as a manuscript in 2016.

- The synthesis about the invasive comb jelly distribution throughout western Eurasian waters has been completed (Figure 2.3.1). A manuscript will be submitted in 2016. This work is linked to analyses undertaken in Task 1.2 (P1, P2, P5, P7).

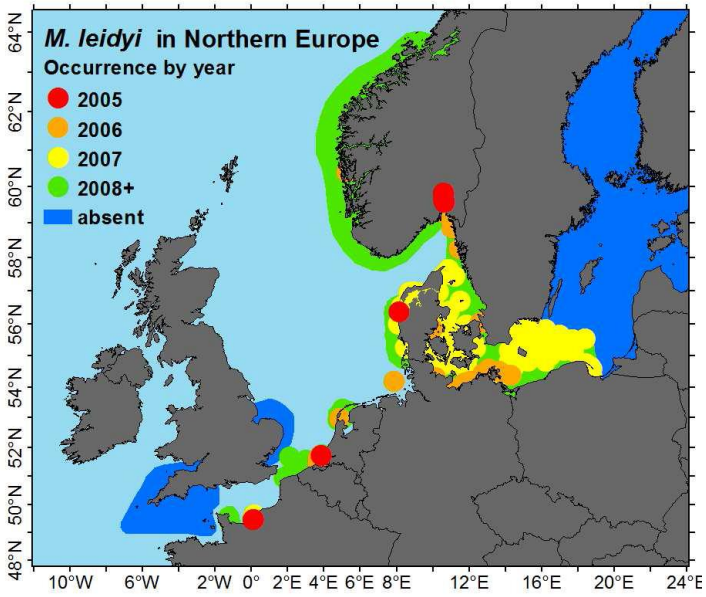

Figure 2.3.1 Range expansion of *M. leidyi* following the first 3 years after recognition of this invasive comb jelly in northern Europe (part of Jaspers et al. in preparation, with P1, P2, P5, P7).

P3 (UHH-IHF)

- During hand line surveys in the Western Baltic Sea, stomachs were collected from the two dominant goby species, the resident black goby and the invasive round goby. Diet analyses revealed that round gobies at the northern German Baltic coast specialized either on barnacles or molluscs, while black gobies had a broader prey spectrum including crustaceans, annelids and molluscs (Figure 2.3.2). Furthermore some black goby individuals were specialized on fish. A low dietary overlap was calculated for the two goby species, which suggests that other factors such as competition for habitat and nesting sites have caused the disappearance of black gobies inTravemünde.

- A coordinated sampling of round gobies was initiated covering the regions Travemünde (P3), Helsinki (P7), and Gdynia (P5). These data will be used to compare population structure, sex ratios, growth and condition from different regions.

- Cod stomachs were sampled at the German Baltic coast, to investigate to which extent round goby *Neogobius melanostomus* is used for prey. About 20 cod stomachs were provided by a local fisherman in Lübeck Travemünde. Further cod stomachs were available due to a cooperation with the INSPIRE project, that established a gillnet survey. We analyzed to date 97 cod stomachs provided by the Thünen Institute- Institute of

Baltic Sea Fisheries. In addition stomach content data acquired within the EU-Tender No MARE/2012/02 will be analyzed concerning the same question. (P3)

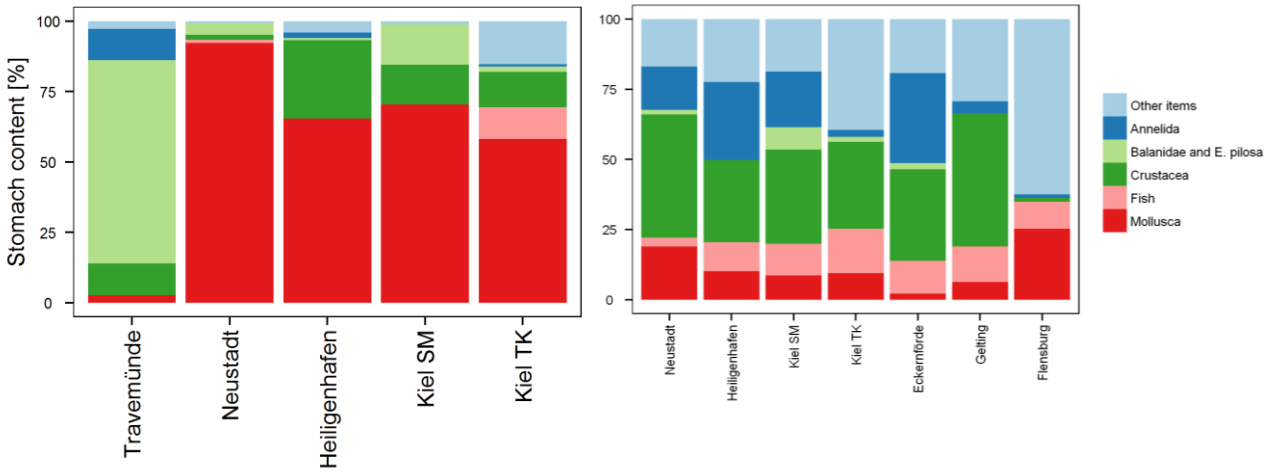

Figure 2.3.2 Stomachs contents of round goby (left panel) and black goby (right panel)

P5 (NMFRI)

- Our contribution to Task 2.3 is focused on the preparation of the manuscript with the tentative title: Synthesis on the *M. leidyi* distribution throughout western Eurasian waters coordinated by P2.

P6 (UT-EMI)

- **Feeding ecology of the native gammarid amphipod *Palaemon adspersus* and the invasive palaemonid prawn *Palaemon elegans*.**

  Macroalgae are an important habitat for small mobile invertebrates such as gammarid amphipods and palaemonid prawns. Gammarid amphipods are important grazers of micro- and macroalgae whereas palaemonid prawns are feeding on macroalgae and small aquatic invertebrates including gammarids. As *P. elegans* occurs within the same habitats as the native *P. adspersus*, it is expected that this invasion modifies the existing trophic interactions. To address this question, we experimentally investigated the feeding of the native *P. adspersus* and the invasive *P. elegans* on the benthic macroalga *Cladophora glomerata* and on the invasive gammarid amphipod *Gammarus tigrinus*. The results showed that the alien prawn does not add an extra function to the trophic system of the coastal ecosystem of the Baltic Sea. Nevertheless, due to its progressively increasing densities and wide habitat range, *P. elegans* is expected to exert stronger predation pressure on gammarid amphipods as compared to *P. adspersus* alone.

Manuscript published: Kuprijanov, I., Kotta, J., Lauringson, V., & Herkül, K. (2015). Trophic interactions between native and alien palaemonid prawns and an alien gammarid in a brackish water ecosystem. Proceedings of the Estonian Academy of Sciences, 64(4), 518-524.

- **Feeding behavior of the round goby in north-eastern Baltic Sea.**

The round goby *Neogobius melanostomus* has successfully achieved almost pan-Baltic distribution. However, very little is known about the feeding habits of the species in this newly invaded environment, thus, an evaluation of the ecological consequences of such invasion is required. A laboratory experiment showed that the round goby is able to effectively consume a diverse variety of prey when given a choice between dominant benthic invertebrates. However, this species did not select for any of the prey taxa provided. The predation by the round goby was size- and species-specific towards prey and density-dependent with elevated consumption rates at higher prey densities. We can conclude that shifting densities of benthic invertebrate prey has little implications for further dispersal of the round goby in the Baltic Sea as the species is potentially able to switch between several native invertebrate taxa. This opportunistic feeding behavior has likely favored this invasion and ensured success of the species in the invaded ecosystem.

Manuscript submitted to Hydrobiologia: Nurkse, K., Kotta, J., Orav-Kotta, H., Ojaveer, H. A successful non-native predator, round goby, in the Baltic Sea: generalist feeding strategy, diverse diet and high prey consumption.

- **Role of two pelagic cladocerans (*Cercopagis pengoi, Evadne anonyx*) in pelagic fish diet in the Gulf of Riga (since 2000).**

In total of over 9600 stomachs of the two dominating pelagic fish, herring and three-spined stickleback, collected in the Gulf of Riga during 1999-2014, were investigated. Altogether 20 different prey items were identified in fish stomachs. The non-indigenous predatory cladoceran *Cercopagis pengoi* qualified as third in terms of the presence of frequency with 21%. However, in terms of biomass the species was consumed significantly (around 80% in adult herring and ca. 60% in three-spined stickleback). Consumption of *C. pengoi* by juvenile herring (TL≤10cm) remains relatively low (less then 10%), but increases almost exponentially between TL 8 to 14cm. Thus, large herring mostly consumes *C. pengoi*, which, however, might not satisfy the required energy needs due to indigestible spines. The share of another non-native cladoceran *Evadne anonyx* in fish stomachs remains insignificant and does not exceed the level of 1%.

Data: UT-EMI internal database (non-BONUS and non-monitoring)

Manuscript in preparation: Ojaveer, H., Lankov, A., Teder, M. and Klais, R. Individual and spatial patterns in the feeding of small pelagic fishes in the Baltic Sea.

P7 (SYKE)

- Contribution to the preparation of the manuscript with the tentative title: Synthesis on the *M. leidyi* distribution throughout western Eurasian waters coordinated by P2.

- The food web role of the invasive Harris mud crab was studied in the Archipelago Sea, Finland. Changes induced by NIS are potentially more pronounced with functionally novel invaders, such as the omnivorous Harris mud crab (*Rhithropanopeus harrisii*) in the Northern Baltic Sea. The species was first introduced to the western and southern parts of the Baltic Sea already in late 19th century, most likely via ballast originating from the eastern US. In the 2000s the species begun to spread again and in 2009 it was found in the Archipelago Sea in Finland, where it has since established and steadily increased its range. The area lacks any native crab species, providing an excellent opportunity to observe how invasion of a functionally novel species establishes to the food web. Based on various mesocosm experiments and a series of field studies, the Harris mud crab has adapted to the local food web: they appear more predatory than in the native areas and have themselves become a prey item to many native fish species. Apparent prey naïvety may explain why the Harris mud crab consumes more mobile prey than in other areas. Results also indicate that mud crabs appear to predate preferentially on isopod *Idotea baltica*, which is one of the key species in the ecosystem. Based on fishermen reports and field studies mud crabs are found in the stomachs of several fish species (perch, pikeperch, four-horned sculpin, burbot and roach). Based on sampling of local fish communities, four-horned sculpin appears to be the most effective predator in the area. Of fish caught, 85% four-horned sculpins had consumed mud crabs. Also perch, ruffe and some cyprinids (mostly roach) were recorded consuming mud crabs. Despite of the predation, mud crabs continue to spread further and populations increase. (P7)

  Manuscripts in preparation:

  Puntila R, Fowler A, Riipinen K, Vesakoski O ja Lehtiniemi M: Invasive Harris mud crab (*Rhithropanopeus harrisii*) prefers isopod prey in the Northern Baltic Sea

  Riikka Puntila, Olli Loisa, Amy Fowler, Katariina Riipinen: A taste for aliens? Incorporation of a novel prey item into native fishes diet

- The diet of the invasive round goby (*Neogobius melanostomus*) was studied in different locations in the Baltic Sea representing different invasion stages (old vs recent). Based on the findings, round goby diet is determined largely by what is available in the area and they show little preference on certain prey species. Furthermore, round gobies caught in

Mariehamn (Åland islands, Finland) appear to forage in higher trophic level than in Hel (Poland), where populations have been detected since 1990's. This is explained by presence of sticklebacks in the diet of gobies caught in Mariehamn.

Manuscript in preparation:
Diet of the invasive round goby (*Neogobius melanostomus*) varies in different parts of the Baltic Sea. Heidi Herlevi, Riikka Puntila, Katri Aarnio et al.

- Parasite prevalence and diversity in the invasive round goby (*Neogobius melanostomus*) was studied in different parts of the Baltic Sea. Samples were collected from Denmark, Lithuania, Estonia and Finland. The fish were frozen prior to analyses (due to transport) and therefore inspected mainly for endoparasites. Based on the results, parasite assemblage in the round gobies is very dissimilar between the sites, reflecting the importance of local conditions and local parasites in determining the assemblage. Prevalence of parasitized fish is similar throughout the Baltic Sea, except in Lithuania, where fewer fish had parasites. (P7, P06, P02, P13)

  Manuscript in preparation:

  Heidi Herlevi, Riikka Puntila, Harri Kuosa et al.: Infection rates and prevalence of metazoan parasites of the non-native round goby (*Neogobius melanostomus*) in the Baltic Sea:

P8 (KUCORPI)

- **Effect of invasive species on community trophic structure, exploring new trophic links and native species niche shifts due to invader effects: the model species - grass prawn Palaemon elegans. 2015** (Jūratė Lesutienė)

  2015 progress:

  The seasonal dynamic of the abundance of *Palaemon elegans* were investigated (continuation of the work started in 2014) in the shallow exposed littoral area. The population abundance peaked in July along with the hatch of first generation of juveniles. By the end of September shrimps were absent from the shallow areas.

  In addition, 202 fish were dissected in 2015 to estimate the importance of *P. elegans* in the diet. In summer, 21 % of shorthorn sculpins and 40 % of perch contained shrimps in their guts. In October-November, shrimps were found in 22% stomachs of cod caught in the coastal areas.

  Preliminary results show that *P. elegans* became a key component in the coastal food web, contributing significantly to the diet of commercial fish. Work will continue throughout the next reporting period.

- **Impact of round goby on local populations and food web (also partly contributing to Task 4.2 Food web responses and interactions to changes in biodiversity and community species /trait composition)** (Artūras Skabeikis)

  2015 progress:

  Retrospective data analysis of the dynamics of the round goby population in the Lithuanian coastal zone (since species establishment, until present). Feeding patterns of the round goby were determined at the peak of population abundance in 2012 and in 2015, when population passed from expansion to adjustment phase.

  First individuals of the round goby in the Lithuanian coastal waters of the SE Baltic Sea were captured in 2002. The population remained relatively sparse for next 8 years (2003-2010), it rapidly exploded during 2011-2012 and since 2013 abundance of the species began to decline slightly (Figure 2.3.3).

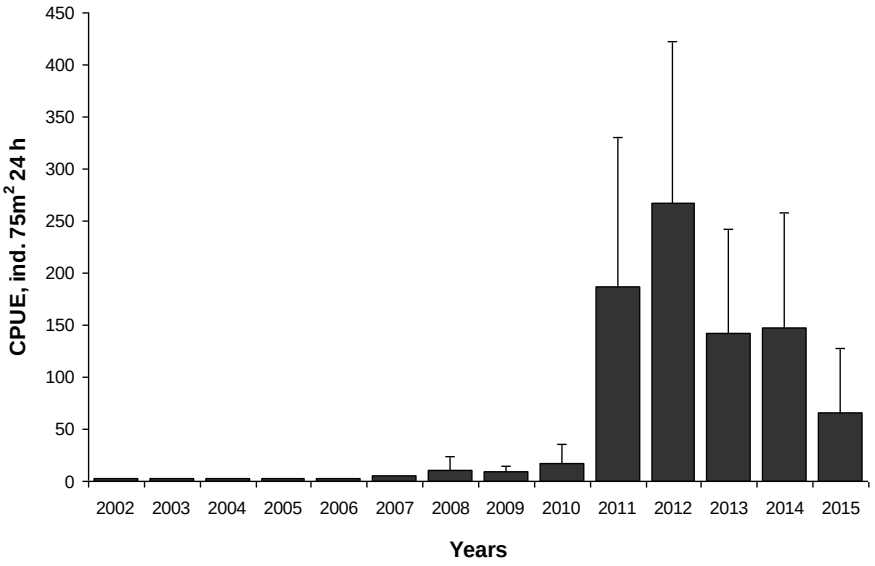

Figure 2.3.3 Abundance dynamics (mean ± st. dev.) of round goby in the Lithuanian coastal waters of the Baltic Sea during 2002-2015. Monitoring data of the Fisheries Service under the Ministry of Agriculture of the Republic of Lithuania.

Work in 2015 focused on the determination of the diet composition and feeding activity of round goby in relation to body size, sex and reproductive cycle (Skabeikis and Lesutienė, 2015). Specific dietary analyses showed that benthic fauna, particularly newly settled generation of epibenthic mollusks in autumn, is likely under strong predatory pressure of the round goby, and recruitment success of the blue mussel may be considerably affected by intense round goby consumption of newly settled juveniles. This can explain dramatic reduction of *M. trossulus* abundance and biomass in the Lithuanian coastal waters in the recent past. Round goby predation also has a great potential directly

and indirectly affect diversity and abundance of many other benthic invertebrate species living in association with colonies of the blue mussel. The response of the round goby in the upper trophic levels will be analysed in the next year.

Highlights:

The results of the study were presented at several international workshops/conferences, and are published in the Oceanological and Hydrobiological Studies Journal:

Artūras Skabeikis and Jūratė Lesutienė, 2015. Feeding activity and diet composition of round goby (*Neogobius melanostomus*) in the coastal waters of SE Baltic Sea. Oceanological and Hydrobiological Studies 44(4): 508-519.

- **Contribution of the invasive polychaete Marenzelleria neglecta to fish diet and the quality of benthophagous fish feeding grounds (empirical modelling, fish feeding grounds mapping)** (Andrius Šiaulys)

  2015 progress:

  Species distribution modelling of *Marenzelleria* complex was performed for the spatial information on the biomass in Lithuanian marine area (contribution from Task 4.1). Also, the share of *Marenzelleria sp.* in local benthic communities was estimated. Data on the occurrence and importance in the fish diet were collected for Baltic cod, flounder and eelpout.

  The model showed that areas of the highest biomass is located in shallow and exposed sandy bottoms (3-10 m depth), where species richness is relatively low (3-5 species). In these habitats spionid polychaetes can comprise up to 50 % of biomass in the zoobenthic community. It is yet to be confirmed whether *Marenzelleria sp*. outcompeted local species, such as other polychaete *Hediste diversicolor* or occupied empty niche thus increasing total biomass of zoobenthos. If the latter is true, this would suggest that the invasion of this species could have positive impact on mobile sand habitat, known as nursery areas of several fish species.

  In deeper areas the biomass share of *Marenzelleria* sp. in benthic community becomes relatively low, thus despite being a prey item for cod, flounder and eelpout, the importance for the diet of these fish species is low. The highest biomass of a non-indigenous spionid Marenzelleria sp. was observed in the shallow coastal areas, where local species richness is the lowest due to natural roughness of mobile sand habitat

  The results of the study were presented at the Baltic Sea Science Congress, Riga, 2015:

  Šiaulys A., Jun 9-12, 2015 - 10th Baltic Sea Science Congress, Riga, Latvia – poster presentation “Ecological niche modelling of non-indigenous spionid *Marenzelleria sp*. in the SE Baltic Sea”

P11 (TI-OF)

- Two Master theses (C. Henseler & C. Bock) focussing on the trophic interaction between invasive round goby *Neogobius melanostomus* and the resident fauna were completed at TI-OF in spring 2015 (in collaboration with the University of Rostock). The results indicated a size-dependent feeding behaviour of the gobies comparable with the feeding ecology observed within their native range. While the amount of ingested crustaceans decreased for growing juveniles, they become more and more molluscivorous. Furthermore, comparative catches between vegetated and unvegetated sites within the study area Greifswald Bay have demonstrated a clear preference towards complex and structured habitats. However, the vegetated areas were primarily used by juvenile individuals while adults are rare at these sites. We hypothesise that distinct life stages of round goby utilize different habitats in Greifswald Bay; while juveniles use the vegetated areas as nursery grounds, adults might aggregate in other areas which offer more appropriate spawning substrate such as stone fields.

- Another Master thesis supervised by University of Rostock and TI-OF focused on the percentage of *N. melanostomus* within the prey of cormorants during the last years. Therefore cormorant pellets were sampled at two different colonies in the Pomeranian Bay between 2010 and 2015. After sampling, the pellets were watered to trigger the maceration of the contents (which improves the identification of prey items). All items were identified to the lowest taxon. Length and biomass of prey individuals were recalculated via regressions. The results showed that the proportion of *Neogobius melanostomus* in the cormorant diet has significantly increased.

- Another Master thesis supervised in the framework of collaboration between the University of Rostock and TI-OF focused on the prey of different piscivorous fish species. While stomachs from *Aspius aspius* were empty, stomachs from *Scophthalamus maximus* and *Gymnocephalus cernuus* contained prey items, but no *N. melanostomus* was detected. However, stomachs from *Perca fluviatilis* and *Sander lucioperca* contained items from *N. melanostomus* beside other prey species. Estimates of the *Index of Relative Importance* (IRI) showed that *N. melanostomus* became an important prey for *S. lucioperca* and *P. fluviatilis* within the last years. At the moment we are integrating results from the different master theses and prepare a manuscript.

- In summer 2015, we tested different passive fishery approaches such as fish traps, fykes and eel pots at distinct sites for their capability to catch round goby. Due to a mass development of filamentous green and brown algae in Greifswald Bay during the summer month, the catch efficiency of the fykes and fish traps was very low. Furthermore, those passive devices are rather inappropriate to investigate trophic interactions of the target species, primarily due to the long time, caught individuals might spend trapped before they are analysed and the biases caused by applying baited

traps. In 2016, TI-OF will therefore conduct more trials with different catching devices considering the issues raised above.

- TI-OF analysed existing data generated during the *Rügen herring larvae survey* (RHLS) and distinct case studies related to the herring larvae distribution in Greifswald bay to analyse the effect of potential predators such as *Mnemiopsis leidyi* on the survival and recruitment of herring larvae. Although *M. leidyi* is a known predator of clupeoid larvae and can actually be observed in Greifswald Bay during some summers, we found a significant temporal mismatch with the herring larvae in the lagoon which have already grown to an inappropriate size for the comb jellies when these predators appear within the bay.

- Hypothesising round goby to be a predator of herring spawn in spring we sampled the small fish fauna on vegetated spawning beds at the southern coast of Greifswald Bay. Although high numbers of juvenile round gobies can be found in late summer and autumn, they appear to be absent during the spring spawning of herring between March and May. Further investigations will include more rocky spawning beds in Greifswald Bay as well as nocturnal catches in the vegetated areas sampled only during daylight so far.

- In addition a survey with FRV Solea (SB699) was performed. The first part of the survey focused on acoustic transects for task 3.3, whereas the second leg focused on biodiversity inventories close to the Island of Rügen, and on the distribution of *N. melanostomus*.

P13 (AAU)

- Work on invasive species, including round goby, mud crab and *Marenzelleria* spp., is going according to plan, and has resulted in the following completed studies and accepted publications in the reporting period:

    - Weigel, B., H. C. Andersson, H. E. M. Meier, T. Blenckner, M. Snickars & E. Bonsdorff, 2015: Long-term progression and drivers of coastal zoobenthos in a changing system. - Mar. Ecol. Progr. Ser. 528: 141-159. doi: 10.3354/meps11279

    - Maximov, A., E. Bonsdorff, T. Eremina, L. Kauppi, A. Norkko & J. Norkko, 2015: Context-dependent consequences of *Marenzelleria* spp. (Spionidae: Polychaeta) invasion fornutrient cycling in the Northern Baltic Sea. - Oceanologia 57: 342-348, doi: 10.1016/j.oceano.2015.06.002

    - Aarnio, K., A. Törnroos, C. Björklund & E. Bonsdorff, 2015: Food web positioning of a recent coloniser: the North American Harris mud crab *Rhithropanopeus harrisii* (Gould, 1841) in the northern Baltic Sea. - Aquatic Invasions 10: 399-413. doi.org/10.3391/ai.2015.10.4.04

WP3: Natural and anthropogenic drivers of biodiversity

Lead: Helén Andersson, P12 - SMHI

Overview:

WP3 is concerned with the examination of historical and contemporary data and development of models for future scenarios of the spatio-temporal variation of drivers. The ultimate goal is to thus improve the understanding of environmental change in the Baltic Sea ecosystem. A highlight from the second reporting period is the review of existing knowledge of patterns and dynamics of drivers of biodiversity (species, communities, habitats) across Baltic Sea ecosystems in space and time. This constitutes Deliverable 3.1, "Report on patterns and dynamics of drivers of biodiversity (species, communities, habitats) across Baltic Sea ecosystems in space and time including socio-economy" (submitted to BONUS in February 2016 and now accepted). This work combined a review of important drivers and pressures, including socio-economic factors, and model runs to hind-cast and analyse different pressures. It also highlights the imprecise use of the wording 'Driver' and 'Pressure' and give a possible definition in line with the Driver-Pressure-State-Impact-Response (DPSIR) approach (Oesterwind et al, in press). With the help of the entire BIO-C3 consortium, a general table of potential important drivers and pressures of the Baltic Sea was produced, which will be used as foundation for Task 5.1.

All work in WP3 is progressing without major deviations from the original work plan. Two milestones, "Meta-database on drivers affecting biodiversity completed" (M 3.1) and "Framework for evaluating dynamics of habitats under driver forcing established" (M 3.2), as well as the Deliverable D3.1 were completed during the reporting period 2015.

Task 3.1: Dynamics of drivers including socio-economy (Month 1-24)

Lead: Daniel Oesterwind, P11 TI-OF, participation of P1, P2, P6, P8, P9.

Deliverable 3.1: *Report on patterns and dynamic of drivers of biodiversity (species, communities, habitats) across Baltic Sea ecosystems in space and time including socio-economy.* (**Month 26**, Accepted by BONUS, accessible at www.bio-c3.eu/publications).

Milestone 3.1: *Meta-database on drivers affecting biodiversity.* **(Month 18**, completed**)**

Task 3.1 and the resulting Deliverable 3.1 entailed a comprehensive review of drivers of biodiversity in the Baltic Sea, including the assessment of their spatial heterogeneity. The review was delivered according to plan, and is summarized in the following highlight report. The complete D3.1 report is available on the BIO-C3 website, www.bio-c3.eu/publications .

Task 3.1 Highlight report and summary of BIO-C3 deliverable 3.1

Compiled by Daniel Oesterwind (lead), Burkhard von Dewitz, Ralf Döring, Margit Eero, Leyre Goti, Jonne Kotta, Kristiina Nurske, Henn Ojaveer, Andrea Rau, Henrik Skov, Daniel Stepputtis, Anastasija Zaiko

Abstract

The catchment area of the Baltic includes 14 countries, about 85 million people and around 200 rivers. Therefore it is not surprising that different drivers and pressures induced by human activity impact the Baltic ecosystem. The task 3.1 comprises a review of important drivers and pressures, and model runs to hind-cast and analyse different pressures.

At the beginning we present a review about the imprecise use of the wording 'Driver' and 'Pressure' and give a possible definition in line with the Driver-Pressure-State-Impact-Response (DPSIR) approach (Oesterwind et al, submitted). With the help of the entire BIO-C3 consortium we produced a general table of potentially important drivers and pressures of the Baltic Sea which will be used as a basis in task 5.1 (table is already discussed with task leader) as well. In the following sections information about main pressures were reviewed concerning status, impact and outlook, and model results were presented if available.

Introduction of non-Indigenous Species (NIS) is an important Baltic pressure. We found out that observation of 132 NIS and cryptogenic species, with in total of 440 introduction events have been documented in the Baltic Sea mainly caused by maritime transport (Ojaveer et al. in prep.). So far, all documented impacts are ecosystem and species-specific and have been and remain one of the major concerns associated with bioinvasions. Unfortunately, our current knowledge on bioinvasion impacts is very limited and insufficient for management actions (Ojaveer and Kotta 2015).

In the Baltic Sea, fishing has been documented to have affected both the dynamics of target species as well the entire ecosystem structure and functioning (Casini et al. 2009; Möllmann et al. 2009). The present fishing impact and exploitation status of the main pelagic fisheries for sprat and herring are generally close to being in line with management targets while fishing mortality for western Baltic cod is presently above the defined targets for maximum sustainable yield (ICES 2015a) (Figure 3.1.1). For eastern Baltic cod the present exploitation status of the stock is unknown (ICES 2015b). The stock size of plaice in the Baltic Sea including the Kattegat has substantially increased in later years under stable or declining fishing pressure. Similarly, the stock size of flounders in the south-western Baltic Sea is increasing while the fishing pressure is estimated to be stable. However, an increasing fishing pressure and a declining stock size are identified for flounders in the eastern Baltic Sea. The harvest rate of salmon has decreased considerably since the beginning of the 1990s.

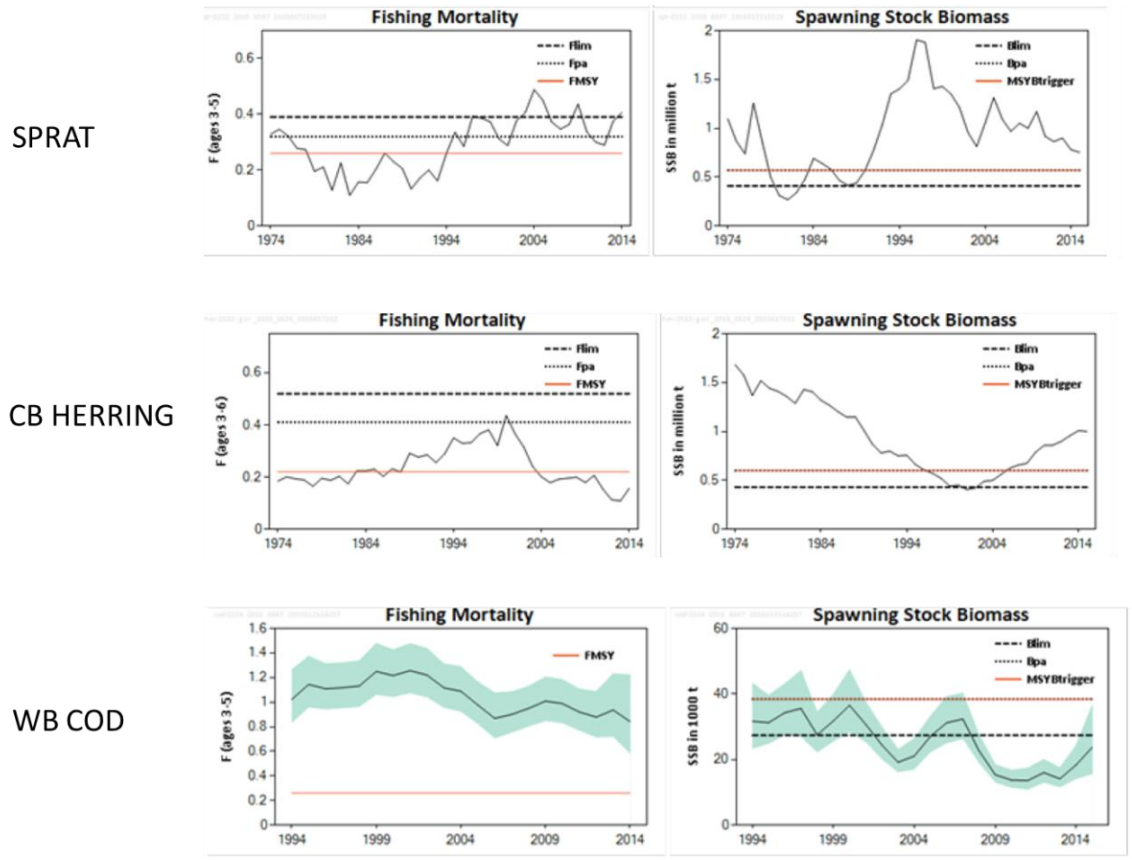

Figure 3.1.1 Developments in fishing mortality and spawning stock biomass of some major fish stocks in the Baltic Sea, sprat, central Baltic herring and western Baltic cod (ICES 2015a).

Climate change and oceanographic variables are important pressures in the Baltic as well. Beside the summary of current information we investigated the variability and dynamics of the abiotic parameters of temperature, salinity, oxygen and pH in two lines of work. One was aggregating and completing in vivo measurements from the ICES Oceanographic data base. The other was producing hydrodynamic model run output of the Ice Ocean model BSIOM (Figure 3.1.2).

In addition, nutrients were modeled as well. The bio-geochemical models show that nutrient concentrations have undergone major changes, involving significant enrichment followed by decreasing nutrient levels in some regions and habitats during 1970 – 2010. Nutrient concentrations increased up to the 1980s except for the Gulf of Finland, and nitrogen concentrations have declined in some areas, showing a high degree of spatial heterogeneity in the trends within the different regions of the Baltic Sea. In general, declining trends in nitrogen concentrations are seen in coastal waters shallower than 20 m. Within the more open waters and especially for the deeper basins trends are more variable. The declining trends in coastal areas are related to lower nutrient loads from land, while changes in the open waters are driven by changing volumes of hypoxia in the Baltic Proper which affect nutrient concentrations in bottom waters, and, subsequently in surface waters.

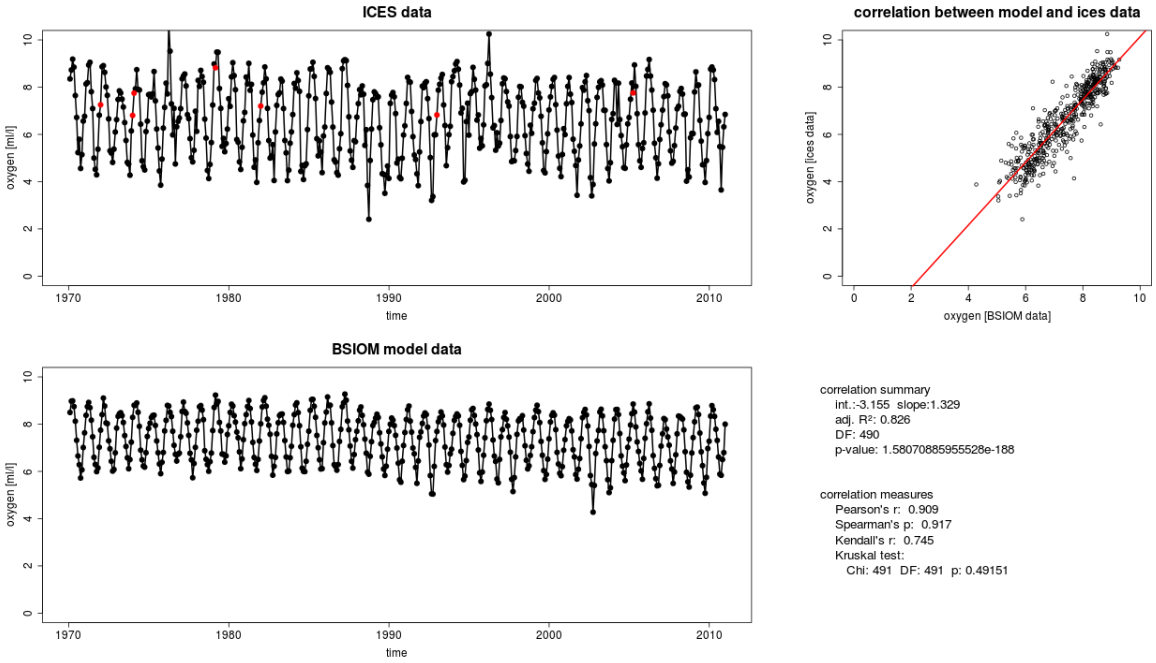

Figure 3.1.2 Time Series comparison between ICES Oceanographic db and BSIOM model data. Time series for the water layer above the halocline in the Arkona Basin. Upper left panel: time series aggregated from ICES data base data. Reconstructed data points indicated in red. Lower left panel: time series aggregated from BSIOM model data. Upper right panel: correlation graph between the two time series. Lower right panel: correlation parameters.

Beside those aspects we conducted a socio-economic analysis of different drivers and pressures and could show as example that although maritime transport in the Baltic was expected to increase greatly, it was affected by the economic crisis and consequent decline in international trade that reduced maritime transport globally. Nevertheless, maritime traffic in the Baltic has recovered to values around a ten percent higher to those of 2005 (Eurostat), with big differences between countries. However, in the same period oil spills in the Baltic reduced in around 40% (HELCOM, 2015).

Figure 3.1.3 Maritime transportation vs. oil spills in the Baltic (2005-2013). The graph shows the fall and recovery of maritime transportation together with the reduction of oil spills.

References

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Task 3.2 Driver interactions (Month 1-32)

Lead: Jonne Kotta, P6 UT-EMI, participation of P1, P2, P9, P12.

Deliverable 3.2: *Report on the nature and types of driver interactions including their potential future.* **(Month 32)**

Milestone 3.2: *Framework for evaluating dynamics of habitats under driver forcing established* **(Month 24**, completed**)**

This task investigates a set of key interactions of selected natural and anthropogenic drivers in space and time. Model runs of different drivers relevant to the key species-functions-communities of BIO/C3 project are conducted in order to provide both spatial and temporal variability of selected drivers and their interactions. Progress during the reporting period includes the following activities:

- A review of data and reports was conducted to summarize data on shipping, fishing effort and introduction of non-indigenous species (NIS). Search for and analysis of the information in the relevant literature contributes to the understanding of the synergistic, additive and cumulative impacts of climate and multiple anthropogenic stressors on biodiversity components in marine ecosystems generally. The contribution was provided to the ICES WGBIODIV 2015 report and is available under the link http://www.ices.dk/community/groups/Pages/WGBIODIV.aspx. The completion of invasion event entries to the Baltic Sea module of AquaNIS http://www.corpi.ku.lt/databases/index.php/aquanis could thereby also be achieved for all Baltic Sea countries (including those not involved in BIO-C3). Some of the initial results indicate that countries hosting more variable environment (Germany, Sweden and Poland; by including high-saline conditions as well as nearly fresh water habitat) are invaded with higher number of non-indigenous and cryptogenic species (>50) while countries having relatively more uniform marine environment (Denmark, Latvia, Lithuania, Estonia) are invaded with substantially lower number of species (≤40).

  A manuscript is in preparation: Ojaveer, H., Olenin, S., Narščius, A., Florin, A-B., Ezhova, E., Jensen, K.R., Lehtiniemi, M., Minchin, D., Normant-Saremba, M. and Strāke, S.: Dynamics of biological invasions and pathways over time: case study of a temperate coastal sea (P6).

- In order to provide data on the introduction of non-indigenous species two case studies to investigate interaction of selected natural and human-induced stressors were performed. One related to the spatial distribution of the invasive non-native round goby (*Neogobius melanostomus*), and modeling was performed in order to show how external drivers and local environmental conditions contribute to the spatial distribution of an invasive species. Using the collected distribution data, an updated map on the species distribution and its invasion progress in the Baltic Sea was produced. The current range of the round goby observations is extensive, covering all major sub-basins of the Baltic Sea. The most recent observations appeared in the northern regions (Northern Baltic Proper, the Gulf of Bothnia and the Gulf of Finland) and on the eastern and western coasts of southern Sweden. Modelling results show that the distribution of the round goby is primarily related to local abiotic hydrological conditions (wave exposure). Furthermore, the probability of round goby occurrence was very high in areas in close proximity to large cargo ports. This links patterns of the round goby distribution in the Baltic Sea to shipping traffic and suggests that human factors together with natural environmental conditions are responsible for the spread of NIS at a regional sea scale.

  A manuscript describing this was published: Kotta, J., Nurkse, K., Punttila, R. and Ojaveer, H. 2016. Shipping and natural environmental conditions determine the distribution of the invasive non-indigenous round goby *Neogobius melanostomus* in a regional sea.

Estuarine, Coastal and Shelf Science 169: 15-24.

Further, the temporal distribution of the dominating small-sized copepods *Eurytemora affinis* and *Acartia* spp. was studied. The interaction between sea surface temperature and potential predation effect by the invasive non-indigenous predatory cladoceran *Cercopagis pengoi* (invaded in 1992) for late summer abundances of these two copepod taxa in the shallow area of the Gulf of Riga, from 1992 to 2013 has been evaluated. This area is very important spawning and nursery area of herring. For the analysis, we have applied a non-additive threshold formulation (TGAM) by using *C. pengoi* abundances as threshold variable. It appears that the summer dynamics of all three *E. affinis* life-history stages (copepodites I-III, IV-V and adults) were explainable by a combination of positive SST effect and negative effect of *C. pengoi* abundances. While these effects were for the younger stages independent of each other, we found for *E. affinis* adults indications of a control change. The TGAM suggested that under higher abundance levels of *C. pengoi*, reproductive processes governed by SST cannot counteract the predation pressure. In contrast, dynamics of *Acartia* spp. was neither related to SST nor to *C. pengoi* abundances, at least statistically.

A manuscript is in preparation: Klais, R., Otto, S., Teder, M., Simm, M. and Ojaveer, H. Long-term (1957-2013) dynamics of dominating small calanoid copepods in the shallow temperate bay (P6).

- Work on assessing oxygen depletion and effective spawning stock biomass of Baltic Cod. Oxygen minimum zones (OMZ) may have previously underappreciated effects on the reproductive processes of commercially exploited fish populations, for example Eastern Baltic cod that is living at the physiological limits of their distribution. To identify potential driver interactions we quantified the stock-structure effect on the number of effective spawners, which are able to reproduce under ambient hydrographic conditions. Our results revealed large changes in the horizontal extent of spawning habitat and oxygen-dependent egg survival. Due to egg buoyancy mediated exposure to different oxygen conditions, large OMZs in the Baltic Sea may only allow large female fish to successfully contribute to recruitment. The novel concept of an effective spawning stock biomass takes into account offspring that survive depending on the spawning stock age/size structure if reproductive success is related to egg buoyancy and the extent of OMZs. This novel concept reflected the role of environmental conditions for Baltic cod recruitment better than the spawning stock biomass alone. This highlights the potential usefulness of similar approaches in other OMZs worldwide. This study represents an example for insights that can be gained from linking biological information, including from BIO-C3 WPs 1 and 2, and environmental information synthesized in WP3.

  A manuscript on the findings was published: 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. Royal Society Open Science 3: 150338. http://dx.doi.org/10.1098/rsos.150338 (P1).

- The habitat sensitivity of pelagic Baltic Sea species to eutrophication was studied through different approaches. Firstly, high resolution hydrodynamic model runs for the whole Baltic Sea were conducted. The resulting data base of hydrological data of the period between 1971 and 2014 provides a comprehensive foundation for the analysis of environmentally driven habitat dynamics. These runs include three scenarios in which the eutrophication of the Baltic Sea either increases, stagnates or decreases after 1989. This will enable us to explore the sensitivity of oxygen depending habitats. The model runs have been completed and the data is ready to be analysed. Further, model data for investigations of the frequency and magnitude of deep-water inflow events were compiled and the analysis is ongoing. Also, analysis of habitat dynamics of early life stages of cod is ongoing. Investigations on sensibility of the reproductive volume of Baltic cod to eutrophication started with horizontal expansion maps. Modeling of flounder and *Pseudocalanus* spawning environment will be started shortly. To proceed with additional species we are pending results of threshold testing experiments of other work packages and tasks (P1).

- Investigations on the impact on increased eutrophication from 1950s to 1980s on production of forage fish were completed. The analyses were based on long time series of monitoring data including reconstructions of historical fish biomasses, supplemented by nutrient concentrations from a 3D coupled physical-biogeochemical ocean model. The results showed that nutrient enrichment from the 1950s to 1980s modified fish biomasses by up to 50% in some years due to increased body weight of fish. Nevertheless, major fluctuations in fish biomasses were decoupled from changes in nutrient concentrations. The study provides useful insights to whether reduced fish production can be expected if historical trophic status of the sea is restored, and can contribute to defining good environmental status in a wider ecosystem context.

  A manuscript of the findings has been submitted to Ambio: Eero M, Andersson, H.C., Almroth-Rosell, E., MacKenzie, B.R.: Has eutrophication historically promoted forage fish production in the Baltic Sea?

  Findes were also presented at conferences:

  ICES ASC 2015: Eero M, Andersson, H.C., Almroth-Rosell, E., MacKenzie, B.R.: Has human-induced eutrophication promoted fish production in the Baltic Sea?

  The Swedish Society for Marine Sciences annual Swedish Marine Science conference, 2015: Elin Almroth-Rosell, Margit Eero, Helén Andersson, Brian R. MacKenzie: Eutrophication no major driver of forage fish production in the Baltic Sea (P2) and (P12).

- Local ecological model complexes have been set up for the two case study areas in the Gulf of Riga and Pomeranian Bay, including quantification of hydrodynamic and eutrophication dynamics calibrated with regional and local run offs and data on nutrient concentrations. Calibration and test runs were initially planned to be finalized by December 2015, but further refinements have made it necessary to delay final model runs into January 2016. Based on the model runs and measurements for the period 1980-2010 trends in eutrophication and sea temperature will be described along coastal gradients (lagoon-littoral-sublittoral) in the two regions. Additionally, trends in eutrophication and sea temperature along coastal gradients in other parts of the Baltic Sea will be assessed based on available measurements (P9).

- Work is conducted on regional downscaling of SRES and RCP scenarios for Baltic Sea region. Analyzes of the projected changes in sea surface temperature, wind and heat fluxes with respect to upwelling in the Baltic Sea are performed, with indications of intensified and more frequent upwelling in coastal areas of the Baltic. Upwelling zones can enhance vertical nutrient fluxes that can promote biological production. Further, as the saltwater inflows from the North Sea and associated ventilation of the deep exert crucial control on the entire Baltic Sea ecosystem a study on the impact of anticipated sea level changes on the dynamics of those inflows was performed, using a numerical oceanic general circulation model covering both the Baltic and the North Sea. The model successfully retraces the essential ventilation dynamics throughout the period 1961–2007. A suite of idealized experiments suggests that rising sea level is associated with intensified ventilation as saltwater inflows become stronger, longer, and more frequent. Expressed quantitatively as a salinity increase in the deep central Baltic Sea, we find that a sea level rise of 1 m triggers a saltening of more than 1 PSU. This substantial increase in ventilation is the consequence of the increasing cross section in the Danish Straits amplified by a reduction of vertical mixing.

  The findings were published in Journal of Geophysical Research Oceans: Hordoir et al (2015): Influence of sea level rise on the dynamics of salt inflows in the Baltic Sea (P12).

Task 3.3: Connectivity (Month 8-32)

Lead: Per Jonsson, P10 UGOT, participation of P1, P6, P10, P11, P13.

Deliverable 3.3: *Report on the importance of connectivity as a driver of biodiversity (populations, species, communities, habitats).* **(Month 32)**

Milestone 3.3: *Set of models to evaluate importance of connectivity ready.* **(Month 30)**

This task aims to understand the connectivity patterns of key species in shallow coastal and offshore areas, and the effects of predicted changes in environmental forcing on transport and connectivity within coastal meta-populations. Dispersal and connectivity is estimated with hydrodynamic models combined with habitat mapping and modeling, and also through studies of field populations. Connectivity is analysed on multiple scales from local models to the whole Baltic Sea, and selected species include foundation species, commercial species and examples of invasive species. Results from Task 3.3 will be passed on to WP 5 in the analysis of tools for adaptive management. During the reporting period, the following work has taken place:

- At the local scale, models were set up to analyse fine-scale (100-1000 m) connectivity patterns in one-two areas (now Gulf of Riga) in the Baltic Sea, with the overall aim to assess the importance of small-scale patterns of retention/dispersal for connectivity between MPAs. An agent-based model (ABM in ECO Lab) has been implemented, being able to simulate planktonic larval dispersal of two key benthic species: *Mytilus* spp. and *Macoma balthica*. The model will allow the combination of physical input (flow, salinity, temperature, habitat characteristics) and biological inputs (biomasses, spawning etc.) from WP2.1 to synchronize ABM model and WP2. Mechanisms have been developed to make it possible to identify from which MPA larvae are spawned and to track their path and settling location, results that will be passed on to WP5 (P9).

- Connectivity analyses on basin scale or the whole Baltic Sea have produced dispersal information for several key species. These analyses are based on Lagrangian trajectories driven by regional oceanographic models. Focus has been on the southern Baltic Sea with dispersal modeling of cod, *Mytilus* spp. and the invasive comb jelly *Mnemiopsis leidyi* with the main aim to understand population dynamics and stock structure, partly in collaboration with BONUS INSPIRE (P1). Results indicate that eastward transport of egg and early cod larvae may be limited between spawning areas, that the population genetic structure of the *Mytilus* spp. hybrid zone is likely not an effect of founder events through long-distance dispersal, and that Limfjorden may seed the Baltic Sea with the invasive comb-jelly *M. leidyi*. A regional model covering the whole HELCOM area was used to estimate large-scale connectivity patterns and dispersal barriers for selected key species, including the foundation species *Fucus* spp. and *Mytilus* spp, partly in collaboration with BONUS BAMBI (P10). Modeling of future connectivity based on velocity fields from climate scenario models was also started. Results such as sources and sinks of drifting *Fucus* spp. will be passed on to WP 5.2 for analyses of, e.g. optimal MPA networks (P10).

- The transport and connectivity between the shallow coastal areas and offshore areas is investigated in detail for herring populations. In collaboration with BONUS INSPIRE an analysis of the extensive data set of the Rügen herring larvae survey is used to test for a habitat utilization loop during the very early life stages of herring in Greifswald bay. One

interesting result is the remarkable prey switch in autumn of adult herring which intensively fed on macroinvertebrates and gobies (*Pomatoschistus* spp.) although parallel plankton samples demonstrated that this behaviour was not triggered by a lack of usual prey items (such as copepods). In addition, three acoustic surveys were conducted to produce new insights concerning general herring migration (P11).

- Habitat models are used within BIO-C3 to test if the knowledge obtained from dispersal models improves spatial predictive models (P6). Firstly, it is tested if prior knowledge on species distribution can be used to improve connectivity estimates and secondly we test if knowledge on dispersal can improve spatial predictive models. In collaboration with P10, two benthic keystone species are included, *Fucus vesiculosus* and *Mytilus* spp. in the Gulf of Riga study area. All environmental data and biological measurements have now been integrated into a database together with connectivity information, and once the climate change scenarios are defined, the final runs of the models will be carried out. Initial runs suggest that the first approach seems to be more appropriate in order to get higher synergy when combining species distribution and connectivity data.

- In collaboration with the Swedish University of Agricultural Sciences, University of Oslo, the Technical University of Denmark, and the Norwegian Institute of Marine Research, we have studied egg and larval dispersal of cod larvae in the eastern North Sea, Skagerrak and Kattegat with the Interreg program "CodS – restoration and management of cod in Kattegat/Skagerrak (P10).

Task 3.4 Dynamics of habitats in space and time under driver forcing (Month 14-38)

Lead: Helén Andersson, P12 SMHI, participation of P2, P6, P8, P9, P11

Deliverable 3.4: *Report on dynamics of benthic and pelagic habitats in space and time under different driver forcing, including identification of vulnerable habitats.* **(Month 38)**

This task investigates spatial patterns and temporal dynamics of benthic and pelagic habitat based on empirical data ecosystem models. Area and volume of vulnerable habitats will be identified. We will investigate climate-related changes of in order to relate environmental pressures to habitat impacts. Progress during the reporting period includes:

- Investigation on how hyperspectral remote sensing by airplane can be used in order to get fine-scale information on bottom topography and benthic habitats (bottom substrates and habitat forming species). We seek if and how hyperspectral variability relates to species richness/diversity in various benthic habitats at landscape scale. As a test area the Estonian coastal sea area is used due to large amounts of existing fine-scale

data for background information. The activity gave input to ecological modeling of species and benthic habitats as sediment layer information (P6).

- In late 2014 there was a Major Baltic Inflow (MBI) that led to natural re-oxygenation of the earlier long term anoxic Baltic proper. Measurements from the summer 2015, when the bottom water in deeper parts of the Baltic proper was oxygenated from the MBI were complemented by measurements from 2008-201 including the deep part of the Baltic proper when these bottoms were covered with anoxic bottom water. The effects of the natural oxygenation of previously anoxic bottoms of the Baltic proper on benthic fluxes of phosphorus, nitrogen, silicon and carbon were studied. The preliminary results show that the phosphate fluxes are lower, and in some cases there is an uptake of phosphorus by the sediments, during the summer 2015 when there is oxygen present in the bottom water compared to earlier years.

  The work was presented at the Swedish Marine Science Conference 2015 with a poster titled “Influence of natural oxygenation of Baltic proper deep water on benthic recycling and removal of P, N, Si and C, by Per Hall, Elin Almroth Rosell, Stefano Bonaglia, Astrid Hylén, Mikhail Kononets and Lena Viktorsson (P12).

- The dataset on blue mussel biomass, coverage and size structure in the Lithuanian coastal zone was compiled for the period before the establishment of round goby population and after. The invasive species impact on mussel populations has been analyzed. The compiled dataset consists of 260 samples collected from the hard bottom habitats by SCUBA divers (biomass and size structure) and 173 video transects (coverage). A major decline in blue mussel population was observed after the establishment of the round goby population in Lithuanian coastal area in 2003-2006. The mean mussel biomass decreased from 2 313 ± 1 513 g m^{-2} to 62 ± 46 g m^{-2}, the coverage decreased by more than 80 % from nearly complete overgrowth of boulders to single individuals or none at all (Figures 3.4.1 and 3.4.2). The shift in size structure was also observed: mussels of 1-2 cm were not found at all after the round goby establishment, only individuals of first year cohort and few large individuals (> 2 cm) suggesting that the decline was due to increased pressure of predators and not due to changes in environmental conditions.

  The results were presented in Baltic Sea Science Congress (Riga, 2015): Stulpelytė A., Šiaulys A. 2015. Major decline of blue mussel *Mytilus sp.* Population in coastal Lithuanian Baltic Sea. Poster presentation, BSSC, Riga, Latvia and a manuscript is in preparation (P8).

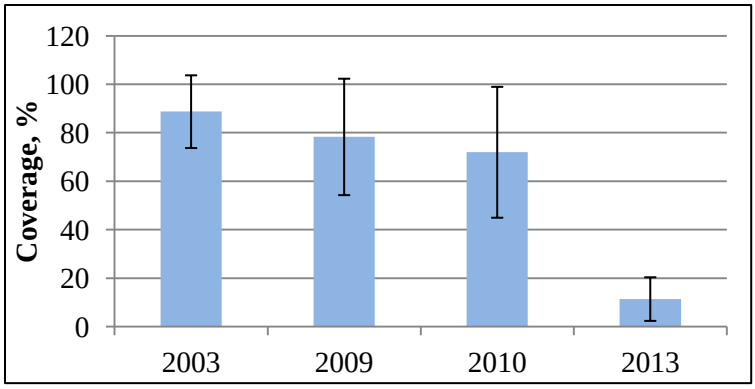

Figure 3.4.1. The coverage of *Mytilus edulis trossulus* on boulders in Lithuanian coastal area during 2003-2013.

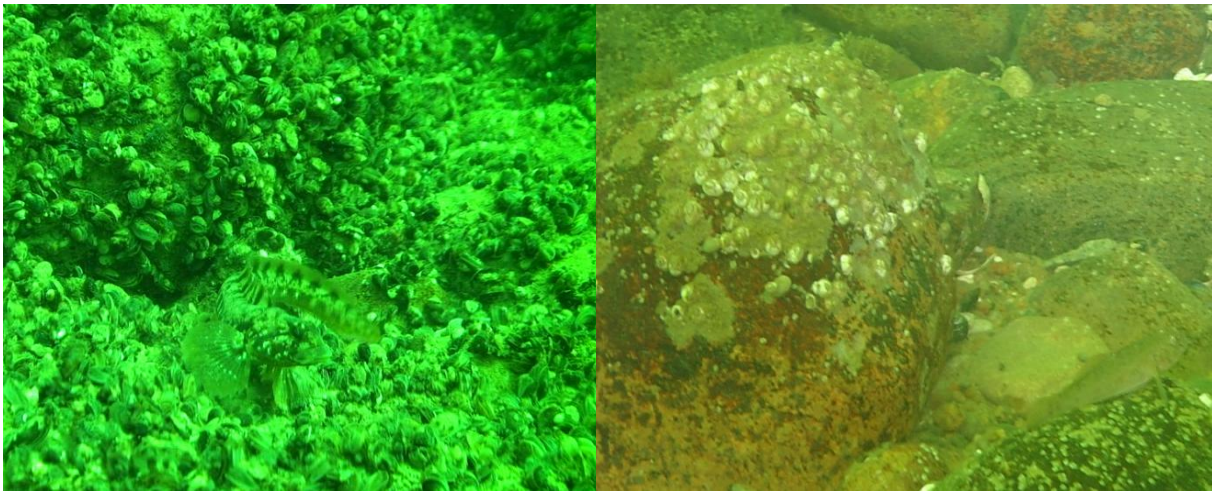

Figure 3.4.2. Typical coastal hard bottom reefs before (left) and after (right) the expansion of the round goby population.

References:

Eero M, Andersson, H.C., Almroth-Rosell, E., MacKenzie, B.R.: Has eutrophication historically promoted forage fish production in the Baltic Sea? submitted to Ambio

Hordoir, R, Axell, L., Löptien, U., Dietze, H., and Kusnetzov, I. 2015. Influence of sea level rise on the dynamics of salt inflows in the Baltic Sea. J. Geophys. Res. Oceans. doi 10.1002/2014JC010642

Kotta, J., Nurkse, K., Punttila, R. and Ojaveer, H. 2016. Shipping and natural environmental conditions determine the distribution of the invasive non-indigenous round goby *Neogobius melanostomus* in a regional sea. Estuarine, Coastal and Shelf Science 169: 15-24.

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. Royal Society Open Science 3: 150338. http://dx.doi.org/10.1098/rsos.150338

Presentations:

Almroth-Rosell,E., Eero, M., Andersson, H., and MacKenzie, B.R.: Eutrophication no major driver of forage fish production in the Baltic Sea, The Swedish Society for Marine Sciences annual Swedish Marine Science conference, 2015

Eero M, Andersson, H.C., Almroth-Rosell, E., MacKenzie, B.R.: Has human-induced eutrophication promoted fish production in the Baltic Sea? ICES ASC 2015

Hall, P., Almroth Rosell, E., Bonaglia, S., Hylén, A., Kononets, M., and Viktorsson, L. Influence of natural oxygenation of Baltic proper deep water on benthic recycling and removal of P, N, Si and C, Swedish Marine Science Conference 2015

Stulpelytė A., Šiaulys A. 2015, Major decline of blue mussel *Mytilus sp.* Population in coastal Lithuanian Baltic Sea..in Baltic Sea Science Congress, Riga, Latvia

WP4 – Impacts of changing biodiversity on ecosystem functioning

Lead: Brian MacKenzie, P2 DTU Aqua
Co-Lead: Erik Bonsdorff, P13 AAU

Overview:

This work package draws on large amounts of data in various national and international repositories. These data need to be assembled and compiled in ways that facilitate later analysis and modeling. Since the official start of the WP in project month 8, most of the activity has occurred in sub-task 4.1 and focused on identifying where the data are located, contacting the relevant colleagues and institutes, and starting data assembly and compilation. Partner activities are detailed below. The work is due to be completed during Year 3, so progress will continue in the coming years.

Task 4.1: Retrospective analyses of biodiversity and ecosystem functioning

Lead: Erik Bonsdorff, P13 AAU, participation of P2, P4, P5, P6, P7, P8.

Deliverable 4.1: *Report summarizing statistical analyses of (i) how biodiversity indicators (species, communities, traits) respond to past abiotic variables and (ii) relationships between biodiversity and ecosystem functioning in the Baltic Sea*. **(Month 32)**

Milestone 4.1: *Data identified and compiled, preliminary models parameterized, initial results available.* **(Month 26**, completed**)**

This task is progressing well and in accordance to plan. The aim is to conduct statistical analyses of the spatio-temporal variation of biodiversity indicators and selected species with major functional roles in Baltic Sea food webs (e.g., species with strong interactions with other species; species that modify habitats).

This work package draws on large amounts of data in various national and international repositories, as well as data that are increasingly becoming available from WP1 and WP2. The assembly and compilation of these dataset in ways that facilitate systematic analysis and modeling has continued from project year 1. At the same time, progression in analysis and outputs have already at this stage been great (total number of papers published/accepted: 5, manuscripts in preparation: 6). Detailed progress in the reporting period includes:

- A 50 yrs time series of Eastern Baltic cod stomach content data has been analyzed with focus on understanding how cod conditions depends on prey biodiversity. Cod >40 cm,

mainly foraging on benthic food suffered from the absence of inflows since the mid-1980s. This is visible in less benthic food, change n the composition of benthic food, an earlier usage of pelagic fishes as alternative food source during the cod life history, and concomitantly decreasing rates of energy intake. The knowledge will be implemented in a sub-model for prey-dependent growth in Task 4.2 (P2). Understanding and modelling prey-dependent growth is an important stepping stone to overcome the problems in cod assessment due to problems in age reading.

- A study was conducted to understand environmental effects on spring bloom dynamics for predicting future climate responses and for managing aquatic systems. We analyzed long-term phytoplankton data from one coastal and one offshore station in the northwestern Baltic Proper to uncover trends in timing, composition and size of the spring bloom and its correlations to environmental variables. There was a general trend of earlier blooms by 1-2 weeks over the last 20 years, correlated to more sunshine and less windy conditions. High water temperatures were correlated to earlier blooms of diatoms and dinoflagellates that dominate the spring bloom. Overall bloom timing, however, was buffered by a temperature and ice related shift in composition from early blooming diatoms to later blooming dinoflagellates and *Mesodinium rubrum.* Such counteracting responses to climate change highlight the importance of both general and taxon-specific investigations. The study is under reviewing process. (P4)

- Phytoplankton long-term time series from monitoring programs were compiled across the Baltic Sea gradient to investigate if there are shared trends in summer biomass and community properties. We assessed three alternative hypotheses for phytoplankton biomass patterns by evaluating the support for shared trends and variances among time series for four phytoplankton classes and 17 monitoring stations. We also investigated the ability of local and regional environmental variables to explain either shared trends or variability within individual time series. Data are being analyzed and manuscript prepared. (P4)

- Analyses of long-term data on the distribution and biomass of a key species *Saduria entomon* in Polish EEZ continued. The aim of the work was to identify and compile all available, unpublished and published data, from the entire area of the Polish EEZ. The first quantitative analyses of macrobenthic samples from the period of 1948-1951, including weight of *S. entomon* specimens, were performed for the area that corresponds to the present Polish EEZ. However, due to differences in methodology, the data from the period 1948-1977 cannot be used for long-term comparisons. The developed database includes 434 records on *S. entomon* distribution and biomass (wet weight). Additionally, all the available data on water depth, salinity, temperature and oxygen content, as well as on the type of sediment and grain size structure (complementary as much as possible to biological data) since 2000 were also extracted. (P5)

- Development of a Baltic-wide database of occurrence, abundance and biomass of *Saduria entomon* has continued. This database is being developed from existing databases around the Baltic, including those reported by P5 above, and those held by HELCOM/ICES and IOW. These databases have different coverage in space and time and are not structured in ways that allow abundance estimation (i.e., no zero-abundance records). The new database being developed will be spatially-temporally resolved to facilitate distribution and abundance/biomass modelling, and will include bathymetric and locational information to facilitate data analyses and interpretation. Main work during this reporting period included database merging, checking/elimination of duplicates, inclusion of zero abundance data (i.e., samples collected but no *Saduria* observed) and inclusion of the bathymetric and locational information (e. g., ICES subdivision). The data preparation work is still ongoing but expected to be completed in first half of 2016. Preliminary analyses show that there is a large material available when aggregated across all years, areas and depth in the Baltic Sea for analyzing spatial and temporal distributions and potentially also for abundances. Two manuscripts are in preparation (MacKenzie et al. a,b) (P2)

- Retrospective analyses of spatio-temporal variation in key fish species was initialized and statistical analyses are currently performed. (P5)

- Mesozooplankton is a key element in marine food web. In the southern Baltic Sea conditions it is extremely vulnerable to environmental forcing - observed changes in temperature and salinity have an impact on zooplankton community structure. Differences in abundance and biomass of key species at open-waters as well as coastal stations located in the Polish EEZ were analyzed and their response to the environmental factors was tested. Data used were the Polish contribution to the HELCOM COMBINE Programme. The longest data series (since 1979) were collected at deep-water stations whereas those taken at more coastal ones started within the last twenty years. In most of the cases, samples were taken 5 times per year using the WP-2 net. Profound changes in zooplankton community were recorded at the deep water stations of the southern Baltic Sea. This is mostly caused by a decrease in abundance of *Pseudocalanus* copepods. This species is correlated with salinity and, thus, positively responding to each of the inflows from the North Sea. Similar changes were not observed in more shallow-water stations. There were no clear long-term patterns detected for *Acartia* and *Temora* copepods. (P5)

- Study on the use of functional traits to predict macroalgal primary production. Macroalgal primary production forms the backbone of aquatic food webs, regulates benthic and pelagic ecosystems and forms a key aspect in the global carbon cycle. Benthic primary production was assessed based on the oxygen production of the whole macroalgal community. Boosted regression tree modeling (BRT) was used to evaluate

how community traits can be used to estimate macroalgal primary production. Results showed that biological traits derived from macroalgal community data explained most of the variation in community photosynthesis without the need to incorporate environmental data on the habitats. The study also showed the existence of trait clustering as the studied trait categories were not fully independent and strong interlinkages between and within trait categories emerged. This suggests that functional trait analysis captures different aspects of ecosystem functioning and thereby enables assessing macroalgal community photosynthesis over geographically distinct areas, including the Baltic Sea, without extensive taxonomic knowledge. This could result in a novel framework through which a simplification of the general procedure of production estimations and comparisons across environmental gradients is achieved. Manuscript in preparation (Jänes et al. 2015). (P6)

- Study on establishing functional relationships between abiotic environment, macrophyte coverage, resource gradients and the distribution of *Mytilus trossulus* in a brackish non-tidal environment. In this study data of various mapping technologies spanning from traditional field sampling (benthic, grab, diving, underwater video observation) to more modern methods (hyperspectral remote sensing, retrospective spatial modelling) were combined. Boosted regression tree modeling (BRT) was used in order to explain the distribution and biomass of the suspension feeding mussel *Mytilus trossulus* in the non-tidal Baltic Sea. The models suggested that (1) distribution patterns of *M. trossulus* are largely driven by separate effects of direct environmental gradients and partly by interactive effects of resource gradients with direct environmental gradients. (2) Within its suitable habitat range, however, resource gradients had an important role in shaping the biomass distribution of M. trossulus. (3) Contrary to tidal areas, mussels were not competitively superior over macrophytes with patterns indicating either facilitative interactions between mussels and macrophytes or co-variance due to common stressor. To conclude, direct environmental gradients seem to define the distribution pattern of *M. trossulus*, and within the favorable distribution range, resource gradients in interaction with direct environmental gradients are expected to set the biomass level of mussels.
  Manuscript published (Kotta et al. 2015, PloS one 10(8), e0136949). (P6)

- Study on specialization among amphipods: the invasive *Gammarus tigrinus* has narrower niche space compared to native gammarids. We applied the species marginality index (OMI) and species distribution modeling (SDM) in the northern Baltic Proper to determine (a) if environmental niche spaces at habitat scale differ between taxonomically and functionally closely related invasive and native gammarid species, and (b) whether the observed pattern relates to the species distribution overlap. Both methods agreed in notably narrower and more segregated realized niche of invasive *Gammarus tigrinus* compared to the studied native gammarids. Among native species, the distribution of *G. zaddachi* overlapped the most with *G. tigrinus*. Our results confirm

that widespread colonization does not require a wide niche of the colonizer, but may rather be a function of other biological traits and/or the saturation of the recipient ecosystem. The niche divergence and wider environmental niche space of native species are likely to safeguard their existence in habitats less suitable for *G. tigrinus*. (P6)
Manuscript accepted (Herkül, Lauringson, Kotta, Ecosphere, in press).

- Study on geographic patterns of biodiversity in European coastal marine benthos. The degree and variation of the diversity and densities of soft-bottom communities from the lower intertidal or the shallow subtidal was measured at twenty-eight marine sites along the European coastline (Baltic, Atlantic, Mediterranean) using jointly-agreed and harmonised protocols, tools and indicators. The hypothesis tested was that the diversity for all taxonomic groups would decrease with increasing latitude. In contrast to general biogeographic theory, species diversity showed no linear relationship with latitude, yet a bell-shaped relation was found. The diversity and densities of benthos were mostly positively related with environmental factors such as temperature, salinity, mud and organic matter content in sediment, or wave height. We conclude that latitudinal trends and regional differences in diversity and densities are strongly influenced by specific sets and ranges of environmental factors, like in the Baltic salinity clines favour insects and in the Mediterranean higher temperatures favour crustaceans. Therefore, eventual trends with latitude are primarily indirect and so can be overcome by local variation of environmental factors. (P6)
  Manuscript submitted (Hummel et al. 2015).

- Study on long-term dynamics of copepods – *Eurytemora affinis* and *Acartia* spp. in relation to local hydroclimate variables in the NE Gulf of Riga (1957-2013). The small-sized copepods *Eurytemora affinis* and *Acartia* spp. dominate in mesozooplankton communities in coastal areas and form an important food resource for planktivorous fish (incl. commercially exploited sprat and herring) and also larval/juvenile fish. Therefore, advanced understanding on their spatio-temporal dynamics and factors responsible is of essential importance. Assessment of long-term dynamics showed that early summer abundances of both copepods were positively linked to milder winters, and in both taxa, strongest correlations were with winter air temperatures. All final models of *E. affinis* included the interaction between continuous explanatory variable (i.e. winter air severity measure – winter air temperature, BSI or ice break off day) and the month – strong positive association in May, still positive but weaker in June, and negative association in July. In models of *Acartia* spp., we found significant three-way interaction between month, stage and continuous explanatory variable: no effect on the youngest stage in contrast to positive effect on the copepodite stage IV-V and adults only in May and June. The correlation with ambient SST was similar for both taxa with the strength of the positive association increasing with stage, irrespective of the month. Data: UT-EMI data, contains monitoring and non-monitoring data as part of the Baltic Sea zooplankton dataset (http://kodu.ut.ee/~riina82/policy.html). (P6)

Manuscript in preparation (Klais et al. 2015).

- Study on trophic interactions between zooplanktonic prey and pelagic fish (herring *Clupea harengus membras* and the three-spined stickleback *Gasterosteus aculeatus*) in the Gulf of Riga. Investigations on individual and spatial patterns of feeding of the two pelagic fish, herring and three-spined stickleback, in the Gulf of Riga were carried out using data originated from pelagic fish hydroacoustic surveys carried out in summer during 1999-2014. Both species dominate in the pelagic system of the basin and therefore exert strong influence on the food-web processes. In terms of prey species consumed, *Bosmina* sp. (present in >50% of all stomachs), followed by *Eurytemora affinis* (36.7%), *Cercopagis pengoi* (21.0%), *Acartia* spp. (16.7%) and *Pleopis/Podon* spp. (8.7%) were consumed most. The Baltic herring exhibited size-specific predation, with increasing proportions of *C. pengoi* in diet with increase in fish length (4cm ≥ TL ≤17cm), while consumption of *E. affinis* and *Pleopis/Podon* spp. exhibited dome-shaped pattern. Taxonomic diversity of the diet was low for both species. Overall, adult herring had the highest (19%) and juvenile herring the lowest (6%) share of empty stomachs. At the same time, the stomach fullness of adult herring was the lowest (0.38) while that of the three-spined stickleback the highest (1.58). The north-western part of the basin (Irbe Strait and southern coast of Saaremaa) offers to both adult herring and three-spined stickleback the worst feeding environment. Adult herring finds the best feeding conditions in the north-eastern part of the basin where the proportion of empty stomachs is the lowest, while the wider east coast of the basin seems to support the highest stomach fullness index. The lowest share of empty stomachs of three-spined sticklebacks was recorded in the southern part of the basin adjacent to plume of River Daugava. The best feeding conditions in term so stomach fullness index is concentrated to the south-western Gulf of Riga. Data: UT-EMI internal database (non-BONUS and non-monitoring). (P6)
  Manuscript in preparation (Ojaveer, H. et al. 2015).

- A 35 year time series on hydrography, chemistry, phyto- and zooplankton, benthos and fish stocks for the Gulf of Bothnia: available data compiled, statistical analysis on responds to abiotic variables completed and manuscript finished. The work was done to explain the role of hydrography, eutrophication and top predator shifts (e.g. cod) to food web structure. Whole communities of phyto- and zooplankton and benthos were analyzed, but in fish Baltic herring was the focal species due to its high commercial value and major role as pelagic predator. The data is open to all partners. (P7)
  Manuscript submitted (Kuosa, H et al. 2015).

- Data collection on Gulf of Finland and northern Baltic Proper phyto- and zooplankton from 1970s is progressing. The aim is to find out how much retrospective data reveals about major changes in food webs, and their abiotic and biotic connections. Biodiversity is taken into account by using all available data sets with species information. Data to be open to all partners. (P7)

- A retrospective analysis of the Benthic Quality Index (BQI) response to eutrophication and physical disturbance in the SE Baltic Sea. Based on the results, it could be concluded, that over the analyzed period BQI exhibited fair response to both eutrophication and sediment dumping pressure. However, the assessment (particularly, set-up of the sensitivity values) should be adjusted for an ecosystem and be habitat-specific. More specifically, a responsiveness test applying Signal Detection Theory (SDT) approach was used. For the assessment of the BQI response to eturophicaiton, macrozoobenthos abundance data from national monitoring surveys (2005-2011) were used and chlorophyll-*a* concentrations (summer average) were extracted from MERIS full resolution satellite images for the same period and the same area where macrozoobenthos samples were collected. Total phosphorus and nitrogen sediment concentrations (summer averages) from the same monitoring stations were also considered. The calculated BQI values varied and five water quality classes (bad, poor, moderate, good and high) were distinguished. The regression analysis between BQI values and chl-*a* concentrations and nitrogen concentration (with one-year lag) revealed statistical significant correlations. For the SDT analysis, the BQI "gold standard" (cutpoint) was set at 2.6, and the estimated area under the curve (AUC) indicated a fair response of BQI (with one-year lag) to the chl-*a* concentrations. For the BQI response to physical disturbance (sediment dumping), macrozoobenthos abundance data (2004-2012) from two monitoring stations within a dumping area and one control station was used. The SDT analysis revealed a fair response of BQI to P concentrations at the dumping stations, compared to a poor response at remote control station. There was also fair response of BQI to the suspended matter concentration and petroleum pollutants concentration at the dumping stations. In trials with heavy metals, a poor response was detected for Pb and Cd, but fair – for Hg. (P8)
  Results published in two manuscripts (Chuseve R. et al. 2016, Ecological Indicators and Zaiko A., Daunys D. 2015, Ecological Indicators).

- An empirical model of the non-native polychaete *Marenzelleria* spp. distribution (importance of distribution shaping environmental factors). Species distribution modelling of *Marenzellria* sp. complex was performed for the spatial information on the abundance and biomass in Lithuanian marine area. A random forests regression model was used to model the biomass and abundance of *Marenzelleria sp.* in the Lithuanian marine area. The dataset on *Marenzelleria sp.* consisted of 205 sampling sites during 1998-2014. Environmental predictors were depth, sediment types, near bottom orbital velocity, current velocity, salinity, oxygen concentration, Secchi depth, temperature, and topographic features. Most important predictors for the abundance were: sediments, salinity, oxygen concentration, orbital velocity, and for biomass: salinity, sediments, orbital velocity. The results of this study have contributed to work within Task 2.3 (assessment of contribution of *M. neglecta* to fish diet and the quality of benthophagous fish feeding grounds) and will contribute to Task 4.2 (food web responses and

interactions to changes in biodiversity and community species /trait composition in relation to NIS). (P8)

- A validation of the *Marenzelleria* genus benthic distribution in Lithuanian coastal waters (continuation of the study above). Since the presence of two species from the *Marenzelleria* genus (*M. neglecta* and *M. viridis*) in Lithuanian coastal area was identified from environmental plankton samples (Zaiko et al. 2015*) using molecular methods, the validation of their benthic distribution and distribution model update was initiated. For that, 335 *Marenzelleria* specimens were collected from 17 sampling sites, covering depth range from 4 to 60 meters for molecular analysis, than will allow to split the model for both species and to estimate the spatial overlap level of *M. viridis* and *M. neglecta* populations. For precise species identification, a molecular method based on the PCR/RLFP protocol applied. This work is in progress and completion anticipated within 2016. (P8)

- Study on long-term functional trends of Baltic Sea coastal macrofauna and fish. Here we explore the long-term temporal (~ 40 years) pattern in functional structure of fish and benthic macrofauna in three Baltic Sea coastal areas with different environmental conditions located in Kattegat (Vendelsö area), the Baltic Proper (Kvädöfjärden area) and the Bothnian Sea (Forsmark area). The data consists of Swedish monitoring data while trait information was assembled for six traits spanning morphology, life history and behaviour for over 200 macrofaunal taxa and six traits describing diet, habitat and productivity for over 52 fish taxa. To assess functional changes we analysed three key measures of diversity: functional richness, evenness and dispersion, as well as a community weighted mean per trait in each area. Functional community trends were also related to environmental variables measured on a local and regional scale (water temperature and salinity). Here we highlight the coupling of these two ecosystem components (benthos and fish) in terms of their functional properties and their importance for coastal functioning (e.g. secondary production). In addition, we discuss the applicability of functional indices for the understanding of long-term community changes. This work will contribute to Task 4.3 (future change of biodiversity and ecosystem functioning of the Baltic Sea under combinations of drivers). (P13)
  Manuscript in preparation (Törnroos et al. 2015).

- Study on patterns and drivers of fish community assembly and functional (trait) diversity of demersal fish in the Baltic Sea. This collaborative study between P2 (BIO-C3 associated colleagues) and P13 provides a first assessment and understanding of patterns and drivers of fish community composition in terms of taxonomic and functional measures along the Baltic Sea environmental gradients. By using trait-based indices that summarise the species' niches in a community, we pinpoint the assembly rules shaping the fish community composition spatially. The results showed a marked decline in

taxonomic- and functional richness explained by a decrease in salinity when entering the Baltic Sea. The trait composition of the fish community in the western Baltic Sea indicated that environmental filtering is the dominant mechanism, while in the eastern part community assembly was also affected by biotic interactions. The results provide insight into the abiotic drivers of fish communities in the area and their vulnerability to environmental changes. Data was extracted from the Baltic International Trawl Survey Database (DATRAS, ICES) and spanned an 11-year period from 2003-2014. Trait information was gathered from FishBase and literature (provided as supplementary material in the paper and thereby open to all partners in the project). (P13)
Manuscript accepted for publication (Pechuchet, L., Törnroos, A., Lindegren, M., 2015, MEPS).

- Evaluation of biogeographic changes in fish diversity driven by changes in climate and exploitation in the Kattegat-Belt Sea. Fish communities are influenced both by climate-hydrographic impacts on habitats and by exploitation of selected species within foodwebs. The response of fish communities to these impacts are complex and usually difficult to resolve. In this study, we investigate using demersal survey data how climate variability and exploitation have influenced the dynamics of the fish community (biodiversity and biomass) in the Kattegat, Belt Sea and Øresund during 1994-2013. During this time period, temperatures have increased and overall exploitation levels in most of the region have declined. We found that biodiversity (overall species richness, scaled for sampling effort) of the fish community has increased both in spring and fall, and that these increases were partly explained by local bottom temperatures as estimated by a regional oceanographic model. We also observed that species richness increased as indicators of fishing effort declined. The increase in species richness is mainly due to an increase in the number and presence of species from southern regions, as detected by examining interannual changes in the biogeographic origins of all species in the fish assemblage. These results show that climate variability and fishing interact to affect the assemblage of fish species in the region, probably by altering the number and strength of interactions among species during a period when environmental conditions were becoming warmer. (P2)
  Manuscript in preparation (Bryndum et al.)

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Bryndum, K. M., Christensen, A., She, J., Richardson, K., MacKenzie, B. R. Biogeographic changes in fish diversity driven by changes in climate and exploitation. In prep.

Jänes, H., Kotta, J., Pärnoja, M., Crowe, T.P., Rindi, F., Orav-Kotta, H. (2015): Use of functional traits to predict macroalgal primary production. In prep.

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Task 4.2 Dynamics of populations, traits and ecosystems

Lead: Stefan Neuenfeldt, P2 – DTU Aqua; participants: P1, 5, 4, 9, 3

This task will synthesize and scale the process knowledge generated in WPs 1-3 using (i) existing population and ecosystem models and (ii) food web models developed in task 2.1 (P1, 2, 3, 4, 8, 9). The processes comprise climate and hydrographic variability, genetic adaptation, physiological acclimatization, food quality influences on reproductive potential, pathways of energy flow, as well as feeding in hot spots and their importance. The models will include quantitative genetics, mass-balance, trait-based, stochastic multispecies, coupled biophysical oceanographic and ecosystem models. These models are applied for case study regions and subsequently applied for projections (Task 4.3) and to derive MSFD indicators. The outputs are used in WP5 analyses of indicator sensitivities to external forcing, and quantification of impacts for marine protected areas. The ensemble of models is used to test concepts for management evaluation frameworks (P1, 2, 3, 4, 8, 9).

Deliverable 4.2: *Report summarising food web responses and interactions to changes in biodiversity and community species / trait composition*. **(Month 38)**

Milestone 4.2: *Model outputs of how biodiversity may respond to future scenarios of multiple drivers* **(Month 32)**

- The high resolution ice ocean model BSIOM for the whole Baltic Sea was used to reconstruct property fields of salinity, temperature and oxygen in a monthly resolution for the time period between 1979 and 2015. This data base will be used for modelling habitat extensions of various taxa in WP3 task 3.2 and 3.4. The resulting time series and BSIOM model data are available for approaches coupling these with biological data from WP1 and 2. Here input from other tasks is needed to identify possible biological processes to be investigated by this approach. Requests should be made in a timely

fashion to be able to produce results in the given time frame. Hydrographic measurements from the ICES data base and age resolved stock data for Eastern Baltic Cod was coupled to be used as a hypothetical driver for cod genetic diversity. The core concept for this driver comprises known relationships between mean weight and mean length at age to fecundity, egg buoyancy and oxygen depending egg mortality. Results feed into Task 1.3 where the genetic analyses and results are being reported (P1).

- Prey-dependent growth, including a bioenergetics sub-model and predator-prey-overlap, is currently implemented in a multispecies model for Eastern Baltic cod, herring, sprat and benthic species. Besides predation rates on sprat, herring and small cod, the model can be used to assess the effects of changing benthic biodiversity on cod growth, but also secondary effects on compensatory feeding. The model is purely length based and circumnavigates the problem with age reading of Eastern Baltic cod. With the accumulation of historical growth rates (from the BONUS INSPIRE project) and monitoring cod growth in the future (currently initiated in a Baltic wide programme), the model will hopefully also be applicable in stock assessment. (P2)

- A study on phytoplankton community interactions and environmental sensitivity in one coastal and offshore habitat in the Northern Baltic Proper has been published using multivariate autoregressive (MAR) models. The results showed that coastal phytoplankton responded more strongly to environmental variation than offshore phytoplankton, although the specific environmental driver changed with time scale. A trend indicating a state shift annual biovolume anomalies occurred at both sites and the shift's timing at the coastal site closely tracked other long-term Baltic Sea ecosystem shifts. Cyanobacteria and Mesodinium rubrum were more strongly related than other classes to this trend with opposing relationships that were consistent across sites. (P4)

Manuscripts in review, submitted or in preparation:

Neuenfeldt, S., Casini, M., Bartolino, V., Orio, A., Andersen, K.H. Spatio-temporal changes in prey-dependent growth of Baltic cod. In prep.

Task 4.3 Projection of impacts of changed drivers on future biodiversity

Task leader: Monika Winder, P4 SU, participation of P2, P5, P6, P7, P8, P9, P12, P13

D4.3 *Report summarizing scenarios of future change of biodiversity and ecosystem functioning of the Baltic Sea under combinations of drivers*. **Month 40.**

Milestone 4.2: *Model outputs of how biodiversity may respond to future scenarios of multiple drivers*. **Month 32.**

This task will investigate how distributions and abundances of species and populations that are important for food web functioning, as well as entire species assemblages in the Baltic Sea, might change under different scenarios of anticipated changes of major drivers.

This task started at recently (Month 20) and there are no final results or highlights available yet. Activities so far have involved development and configuration of models, and discussions of how to use results and outputs from previous subtasks in the future scenarios. Some examples illustrating the ongoing activities are presented below:

- *Saduria entomon* distributions under future climate change scenarios: Discussions between P4 - SU and P12 - SMHI have addressed the climate model runs, scenarios and data delivery formats for inputs to habitat distribution models for *S. entomon*. The necessary habitat distribution models are being developed in Task 4.1. (P4, P12.)

- Effects of climate change on functional trait composition of coastal fish and benthos communities: Building on from ongoing work in Task 4.1, plans are being finalised on how to progress with evaluating future scenarios based on novel insights from the retrospective analysis on long-term functional (trait) changes in coastal fish and benthos communities. Additional data are being collected (phyto- and zooplankton). (P13).

- Effects of seal populations on fish stocks: ECOSIM models are being constructed to investigate effects of changing seal populations on fish stock. Scenarios are built for different seal population sizes on fish stock impact for cod, herring and sprat populations. Work is in progress (P4).

- In addition to these examples, there are plans to include additional species, processes and functional groups during the coming reporting period (e. g., effects of climate change on potential abiotic habitat sizes for non-indigenous species, and on species interactions among fish stocks and their pelagic and benthic prey).

WP5 – Biodiversity indicators and tools for adaptive management

Lead: Piotr Margonski, P5 NMFRI

Overview:

The overall objective of this WP is to synthesize the knowledge developed within the other BIO-C3 work packages and to provide a science based evaluation framework and progress towards adaptive management of biodiversity in the Baltic Sea. This WP will develop guidelines on relevant data and monitoring needs, recommend biodiversity indicators and candidates for targets and threshold values, as well as contribute to relevant modelling and assessment tools.

Task 5.1: Response of MSFD indicators to various management measures to achieve Good Environmental Status

Lead: Anastasija Zaiko, P8 KU-CORPI, participation of P2, P4, P5, P6, P7, P11.

Deliverable 5.1: *Report on response of biodiversity indicators to management measures (test of indicators).* **(Month 42)**

Milestone 5.1: *Data identified and compiled, preliminary models parameterized, initial results available.* **(Month 20**, completed**)**

This task aims to identify and quantify the pressure-state links of biodiversity indicators by producing pressure and impact matrices based on analysis of environmental conditions and anthropogenic activities at coastal and offshore study sites. Relevant indicators will be selected and tested for their performance (incl. stability and sensitivity).

The first Milestone of this task was passed; specifically, a draft of pressure and impact matrices was created, distributed in the BIO-C3 consortium and discussed with partners, and a set of indicators for testing against the existing pressures was compiled. A discussion regarding the framework of assessment was initiated among the WP5 contributors. All work is going according to the plan, with the specific progress described below:

- In collaboration with WP3, a review paper on development of consistent definitions of “Drivers”, “Pressures”, “Impacts” and “State” in order to facilitate the communication between science and policy and to enhance the application of the ecosystem-based management approach, was completed and submitted for publication. The pressure-state links were identified for the non-indigenous species (P8, P11)

- In collaboration with the DEVOTES project, an assessment of the indicators targeting MSFD 2.2.1 and 6.2.2 criteria – Abundance and Distribution Range of non-indigenous

species (ADR) and Benthic Quality Index (BQI) was performed. Applicability, policy relevance, possibility to set GES boundary or target values and overall quality evaluation were part of the assessment. We concluded that the ADR indicator can be operational if comprehensive information on marine biological communities is available and can be derived in a consistent way for different habitats within MSFD sub-regions. The further development of novel surveillance methods (application of remotely operated monitoring devices, remote sensing, molecular barcoding) is expected to enhance the resolution of data on species distribution and community composition (Ardura et al. 2015; Zaiko et al. 2015). However there is still an issue with the possible subjectivity when assigning the ADR class, so before considering it as an "out-of-the-shelf" method, the overall assessment method should be thoroughly revised and adjusted for every particular area/habitat and invasive species under consideration. It is necessary to determine precisely the relevant communities and available habitats in relation to which the abundance and distribution of an invasive species is assessed (P8).

- In regards to the BQI, the indicator provides robust estimates of ecosystem health related to eutrophication and physical disturbance (Chuševė et al 2016). However, if there are invasive species in the ecosystem, affecting the benthic habitats and macrofauna communities, the BQI evaluation should be refined with appropriate corrections (Zaiko and Daunys 2015, also see highlight report at the end of the 5.1 section). It is essential to ensure the taxonomic consistency and the best possible resolution in the benthic biodiversity data used for the BQI calculation. Potentially, with the further development of the novel molecular techniques (eDNA metabarcoding), the BQI assessment could be refined and adjusted to such molecular data utilization, thus enhancing its sensitivity and accuracy. Before routine exploitation of the BQI, a comprehensive analysis and fine tuning of the calculation procedure should be undertaken for each particular geographical area/ecosystem/habitat. The assignment of sensitivities and target values should be also carefully revised and validated by the qualified experts (P8).

- A list of selected MSFD indicators referring to fish was specified, addressing D1, D3, and D within MSFD. An assessment of indicators' performance was conducted applying scoring system, following the evaluation methodology of the ICES Working Groups on Biodiversity Science (WGBIODIV) and on Ecosystem Effects of Fishing Activities (WGECO) who specifically developed a set of criteria to assess performance of indicators to support implementation of the MSFD (ICES 2013). Accordingly indicator performance was evaluated considering three aspects: (I) Overall evaluation, taking into account all criteria; (II) applicability, and (III) evaluation of the theoretical basis. The experts from the Thünen-Institutes of Sea Fisheries and Baltic Sea Fisheries in Germany were involved in the assessment. In order to ensure consistency between their ratings, guidelines were used for assessing each indicator against each criterion. Both pressure and state indicators were assessed. The results indicated that overall performance of assessed

indicators ranged from 55 to 95%. The best performing indicators were identified and included: distributional range and pattern; population abundance and/or biomass; fishing mortality (F); spawning stock biomass (SSB); biomass indices (CPUE); proportion of fish larger than the mean size of first sexual maturation (L_{MAT}); 95% percentile of the fish length distribution observed in research vessel surveys (L95); large fish by weight (LFI) (P11).

- The approach and the current state of the zooplankton Mean Size and Total Stock (MSTS) indicator tests based on the Polish national monitoring data was presented and discussed in the BIO-C3 Deliverable 2.1, which has been accepted by BONUS and is available on the BIO-C3 website at www.bio-c3.eu/publications. The pivotal position of zooplankton organisms in the pelagic food web is indicative of both fish feeding conditions (and to some extent the predatory pressure of small pelagic fish on zooplankton) as well as grazing pressure of zooplankton on phytoplankton. MSTS is strongly linked to two anthropogenic pressures listed in the MSFD Annex III, Table 2: selective extraction of species and nutrient and organic matter enrichment. At the current stage of analysis, data from the deep-water station located at the southern slope of the Gotland Basin (P140), were selected. MSTS has a status of HELCOM core indicator, thus, the concept and the rationale is already sufficiently well developed. Further development will focus on technical issues as (i) the unification of the biomass calculation methods over the entire Baltic Sea area, (ii) estimating of the reference periods for chlorophyll a EQR and sprat condition that should be identified based on the sub-regional (i.e. regionally disaggregated) data to reflect the spatial dynamics at the local scale, (iii) coastal vs. offshore areas comparison, (iv) testing methods on how to combine results derived from several data series located in the same assessment unit, and (v) different aspects of confidence variability (P5).

- Two indicators, based on the macrozoobentos, were selected for analysis: (i) Benthic Quality Index (BQI) and (ii) population structure of long-lived macrozoobenthic species. The calculation of the indicators was based on the data of NMFRI, collected since 1978 from the entire Polish EEZ. In case of BQI, the calculated values reflected patterns in distribution of species in relation to natural environmental conditions in the Polish zone, also within the same range of salinity. The heterogeneous distribution of sediment types, was proposed to be an important factor affecting benthic diversity, especially at the dynamic sandy bottom in the open sea area. The observed effect of natural environmental factors on the BQI values, suggests the necessity to analyse the index in correspondence with both natural and anthropogenic habitat parameters. The primary task before calculations for indicator “Population structure of long lived macrobenthic species”, was to indentify all available historical data from the entire area of the Polish EEZ. The first measurements of the size of individuals of bivalves *Macoma balthica, Mya arenaria, Astarte spp., Mytilus edulis* and *Cerastoderma lamarcki* were performed in 1951-1952. Due to low accuracy of the classes, data from the 1950s were difficult to use.

This also concerns the scarce available data until 1970. More precise, although still relatively large classes (< 5mm, 5-10 mm, 10-15 mm, 15-20 mm, 20-25mm) were introduced in the years 1978-1979. Our analyses suggest that available historical data since 1980 (1mm size classes), can be used as reference values. The preliminary analyses showed that from among bivalves, only the number of specimens of *Macoma balthica* from three replicates/grabs, and only at muddy bottom, can be sufficient to determine the size distribution. Thus, a further task is to develop methods of obtaining a sufficiently abundant sample for the determination of a representative size structure of other bivalves. All the analyses of size structure of *M. balthica* were performed in correspondence with data on abundance and biomass and - if present- with data on environmental factors. A preliminary hypothesis that oxygen deficit is the primary factor causing observed long - term changes in the size structure was formulated. However, there are not many historical data on oxygen content, which can be directly related to the changes in the size structure of *M. balthica* in the Polish EEZ (P5).

- Research presented in Smoliński and Całkiewicz (2015) aims to develop a fish-based Multimetric Index and assessment system for an evaluation of the ecological status of Polish transitional waters that would meet the requirements of the Water Framework Directive and could be applied to coastal areas. The index was developed based on how fish communities respond to anthropogenic pressures. Fish data were collected along the Polish coast in the years 2011, 2013 and 2014 using different types of gear. Redundancy analysis showed that the most important environmental factor affecting fish community was salinity. Responses to anthropogenic disturbances of 20 candidate metrics were tested by different generalized linear models, taking into account salinity, sampling protocol and the proxy of human pressures described by the Baltic Sea Impact Index (BSII). Five selected metrics (Shannon Weaver Index, abundance of piscivorous fish greater than 20 cm, number of species, number of freshwater species, abundance of alien species) were combined in a Multimetric Index, which showed negative significant correlation with BSII. Writing of the paper was supported by the national project but the analyses were performed by the BIO-C3 team and achieved results have a very high relevance to the further BIO-C3 work (P5).

- Being a major predator fish species in the open Baltic ecosystem and closely connected to lower trophic levels via predator prey relations, as well as to higher trophic levels (i.e., seals) and abiotic conditions, cod can be considered a useful indicator species picking up signals of changes in various abiotic and biotic indicators that are affecting overall biodiversity status of the Baltic Sea. Major changes have been observed in recent years in average size and nutritional condition of cod likely affecting also its reproductive capacity, which is presumably linked to various ecosystem and environmental indicators shaping the Baltic ecosystem and its functional biodiversity. The work conducted under this task involved identification of indicators that best reflect the observed changes in cod and their links to human and ecosystem pressures will be evaluated, involving the

results from WP2 on improved understanding of related processes. The analyses are based on long time series of monitoring data on relevant indicators and drivers. Compilation of the datasets is currently ongoing (P2).

- Datasets for the development and assessment of the NIS-related and zooplankton indicators has been compiled and populated in the on-line databases AquaNIS (http://www.corpi.ku.lt/databases/index.php/aquanis) and Baltic Sea zooplankton dataset (http://kodu.ut.ee/~riina82/policy.html) (P6, P7, P8).

- An activity, aimed at NIS-related indicator development has been initiated. The considered indicator is a Number of new NIS invaded through primary invasion (addresses both EU MSFD revised D2 as well as HELCOM NIS indicator). Country-level approach was adopted for this. Activity just started and will be carried out in cooperation with ICES WGITMO (P6, P7, P8).

- Development of NIS environmental impact evaluation framework. This activity addresses explicitly EU MSFD revised D2. Activity started and will be carried out at pan-European scale. In total, Publisher evidence on the environmental impact of 11 wide-spread invasive non-indigenous taxa covering different trophic levels / organism groups (phyto/zoobenthos, phyto/zooplantkon, fish) will be assembled/synthesised. Based on the collected information, the impact evaluation framework will be suggested (P6).

- This section closes with one **highlight report** from Task 5.1:

"Invasive ecosystem engineers and biotic indices" – Summary of the BIO-C3 publication:

Zaiko A., Daunys D. 2015. Invasive ecosystem engineers and biotic indices: giving a wrong impression of water quality improvement? Ecological Indicators 52: 292-299. doi:10.1016/j.ecolind.2014.12.023

Abstract

Benthic component of an ecosystem is considered in ecological status assessment of the key European Directives. Most of the metrics proposed for the benthic quality assessment are biodiversity based. Their robustness and applicability are widely discussed in many recent studies. However an impact of invasive alien species on biotic indices and environmental quality assessments has been largely overlooked by researchers so far.

In this study, the performance of the Benthic Quality Index (BQI) was assessed in a coastal ecosystem highly affected by the invasive zebra mussel *Dreissena polymorpha*. Zebra mussel is able of modifying benthic habitats and enhancing local biodiversity. In the analyzed ecosystem it affected benthic species richness, abundance and community structure. As a result, the BQI values in samples with zebra mussels were significantly greater (W=2548,

p<0.001) comparing to those devoid of zebra mussels, with no apparent temporal trend. There were some species recorded only in the presence of zebra mussel. Additionally, analysis of samples with zebra mussels demonstrated an evident effect of *D. polymorpha* abundance on the total macrofauna abundance, significantly correlating with a number of common soft-bottom species in the ecosystem. When verifying the results on 1999 data, using organic carbon concentration as a proxy of eutrophication-related benthic quality, ANCOVA revealed statistically significant effect of zebra mussel presence (F=5.67; p=0.02) on the BQI values, while statistical significance was marginal in case of effect on organic carbon (F=3.63, p=0.07). Moreover, there was a shift from negative to positive regression in the samples with zebra mussels (Figure 5.1.1).

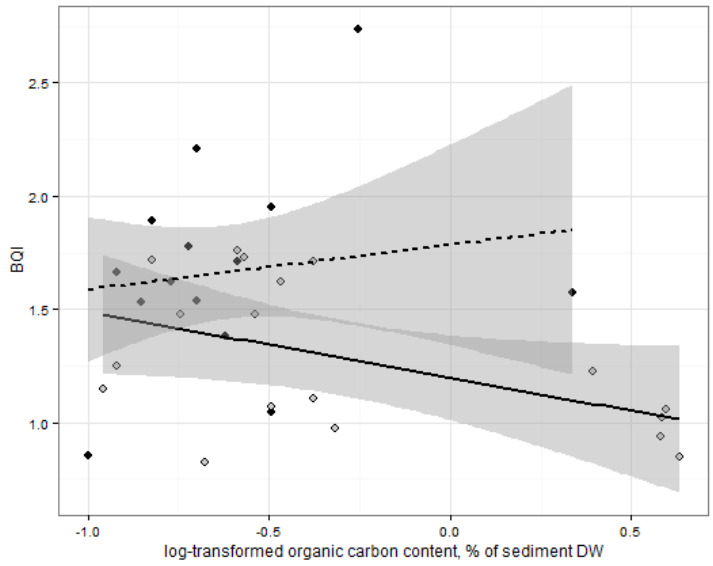


Figure 5.1.1 BQI values calculated for 1999 dataset based on the pre-assigned species sensitivity values (Table 1). Grey dots – samples without zebra mussel: solid regression line (t=12; p<0.001; BQI= 1.19-0.29x[log(C_org)]); black dots – samples with zebra mussel: dashed regression line (t=3; p= 0.006; BQI=1.89+0.36[log(C_org)])

Based on the results presented, we suggested a data correction framework that has been tested on the current dataset and proved to be effective in minimizing zebra mussel impact on BQI assessment. Our experience could be applied for other coastal ecosystems invaded by the zebra mussel or any other aquatic invasive species with resembling biological traits and bioinvasion impacts.

Presentations:

The outcomes of the task have been presented at international symposiums and seminars (e.g. Baltic Sea Science Congress, ICES Annual Scientific Conference).

References :

Ardura A., Zaiko A., Martinez J.L., Samuiloviene A., Borrell Y., Garcia-Vazquez E. 2015. Environmental DNA evidence of transfer of North Sea molluscs across tropical waters through ballast water. Journal of Molluscan Studies, 1-7, doi:10.1093/mollus/eyv022

Chuseve R., Nygard H., Vaiciute D., Daunys D., Zaiko A. 2016. Application of Signal Detection Theory approach for setting thresholds in benthic quality assessments. Ecological Indicators, 60: 420-427.

Smoliński, S., Całkiewicz, J., 2015. A fish-based index for assessing the ecological status of Polish transitional and coastal waters. Mar. Pollut. Bull. (in press) doi:10.1016/j.marpolbul.2015.10.065 (*this paper is highly relevant to BIO-C3 work but it was financed by the national project*)

Zaiko A., Daunys D. 2015. Invasive ecosystem engineers and biotic indices: giving a wrong impression of water quality improvement? Ecological Indicators 52: 292-299

Zaiko A., Samulioviene A., Ardura A., Garcia-Vazquez E. 2015. Metabarcoding approach for non-indigenous species surveillance in marine coastal waters. Marine Pollution Bulletin, 100:53-59.

Task 5.2: MPA implications

Lead: Anne Lise Middleboe, P9 DHI, participation of P1, P5, P8, P10.

Deliverable 5.2: *Report on MPA tool - Development of methods to describe connectivity and importance of the MPAs network and MPA tool testing in two selected case studies.* **(Month 42)**

Milestone 5.2: *End of evaluation of methods to test the importance of MPA networks & connectivity to protect biodiversity. Models provided to user group for validation.* **(Month 34)**

Progress: The work is progressing as planned.

Marine protected areas (MPAs, in EU Natura 2000 network) are core elements in efforts to protect biodiversity, as it is realized that protection of habitats is vital for protecting species. Designation of MPAs is at present based on assessment of species and habitats within the individual potential MPAs and primarily seen from a national perspective. This also applies to monitoring and assessment of their status. The importance of MPA networks for long term viability and protection of key habitats and species, vital for the Baltic Sea biodiversity and ecosystem function, will be assessed.

In this task, work carried out as a part of other WPs is synthesized to assess the importance of MPA networks. The assessment will be done for selected species and habitats based on

carrying capacity analyses (Task 2.1), connectivity analyses (Task 3.3), analyses of importance of biological diversity for ecosystem functioning (Task 4.2), and the expected results of climate changes (Task 4.3). During the reporting period, the following work has taken place:

- In order to assess the importance of MPA networks, positions of important dispersal corridors and connectivity hot-spots, spatially and temporally resolved long-term averages of dispersal distances were calculated for the whole Baltic Sea (input also from Task 3.3). These patterns are based on the long-term wind driven and thermohaline circulation calculated by using a coupled sea ice-ocean model of the Baltic Sea (BSIOM) for the time period 2001-2010. From the model runs there is a clear evidence of persistent dispersal patterns which comprise mostly the sub-basins of the Baltic Sea with less transport between the basins. However, averaged dispersal distances provide no information about their variability. Thus, for a more complete representation regarding the variance of dispersal we have calculated the stability (P1).

- Update of database of the present network of marine protected areas within the HELCOM area, with a focus on Natura 2000 areas and HELCOM protected areas in the Baltic Sea. For the Natura 2000 SAC network only areas characterized by marine habitat codes have now been included (P10).

- Implementation of the updated MPA database as a GIS resource (P10).

- Developed and published a new theory for identification of optimal MPA networks based on multiple species with different dispersal strategies (Jonsson et al. 2015). This work shows how it is possible to find a consensus network of MPAs that can simultaneously protect several species, e.g. a community, with a diversity of dispersal strategies. The theory is applied to a real situation in the Kattegat-Skagerrak (P10).

- Developed new theory for optimal addition of new areas to present MPA networks (Technical report: Moksnes et al. 2015). We have here developed a new algorithm applied to connectivity data that can find the optimal way to extend present networks of MPAs to improve over-all connectivity and the effect of protection (P10).

- Preparing data for an analysis of the MPA coherence within the HELCOM area using input from connectivity modeling within WP 3.3 (P10).

- Preparing for Species Distribution Modelling (SDM) of changes in distribution of selected key species as a consequence of the predicted change in temperature and salinity caused by climate change. We will here use the SDM platform BioVeL (www.biovel.eu). Key species that will be modelled are yet not decided but foundation species like *Mytilus trossylus/edulis*, *Fucus vesiculosus/radicans* and *Zostera marina* are priority. For the

SDM we have here received environmental fields produced in climate scenario models from P12 (P10).

- To address fine-scale connectivity patterns, a MPA connectivity model has been set-up for the Riga Gulf area. Mechanisms has been developed to make it possible to identify from what MPA the larvae (*Mytilus* and *Macoma*) are spawned and to track their path and settling location. The model basis is the connectivity models developed in Task 3.3 that use results of the hydrodynamic (physical input i.e. flow, salinity, temperature, habitat characteristics) and ecosystem modeling (biological inputs as biomasses, spawning etc.) model results of WP2.1 (P9).

- At a similar fine-scale, an individual-based model (IBM) for major bivalve predators in the Gulf of Riga has been setup focusing on two most abundant sea ducks species, Long-tailed Duck and Velvet Scoter, and round goby. The model is set-up to assess the carrying capacity of MPAs in the study area Gulf of Riga. The overall purpose of the individual-based model is to predict how environmental change might affect carrying capacity of the study area for the analyzed predators when looking at their survival and body condition (P9).

- In analysis of MPA impact on surrounding coastal ecosystems, their vulnerability to NIS, resilience and potential role in restoration of the native key-habitats, focus is on connectivity analysis of MPA and other habitats within the Lithuanian Baltic Sea area. Genetic connectivity analysis (population differentiation and gene flow analysis) will be based on population genetics of blue mussel (*Mytilus* sp.) (P8).

- Samples of blue mussel were collected from different habitats within and outside Lithuanian MPA, Figure 5.2.1, covering depth ranges of 8-10m; 18-30m and 41-45m (P8).

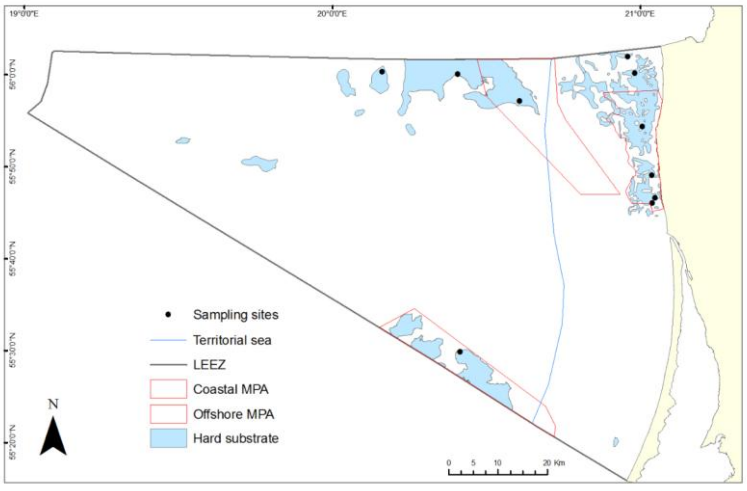


Figure 5.2.1 Locations of sampling sites for blue mussel population study within the Lithuanian EEZ.

- Population genetic indices essential for the genetic connectivity analysis will be estimated based on microsatellite DNA variation. Therefore, a panel of 9 microsatellite loci was prepared for genotyping and analysis of genetic variation (P8).

- In collaboration with P10 validation of the MPA network model with the outcome of the genetic connectivity analysis will be carried out. Two different approaches (modelling and population genetics) will help to analyze connectivity between coastal and offshore mussel populations and to predict possibilities of recovery after crucial impact of invasive species (Round goby) (P8).

- This section closes scientifically with one **highlight report** from Task 5.2:

"How to select networks of marine protected areas for multiple species with different dispersal strategies" – Summary of the BIO-C3 publication:

Jonsson PR, Nilsson Jacobi M, Moksnes P-O (2016) How to select networks of marine protected areas for multiple species with different dispersal strategies. Diversity and Distributions 22:161-173. DOI: 10.1111/ddi.12394 (first published online in 2015)

Abstract

This paper shows how eigenvalue perturbation theory (e.g., used in Google's search engine) can be used to identify an optimal network of Marine Protected Areas (MPAs) with connectivity that maximizes the global metapopulation growth rate (Figure 5.2.2). Specifically, this work extends our previous theory for the protection of single species (Nilsson Jacobi & Jonsson 2011) to the protection of communities including different dispersal strategies. With a new application of the eigenvalue theory we show how an optimal consensus network of MPAs can be identified from connectivity data, e.g. dispersal estimated with biophysical models. Verification with a simple metapopulation model shows that the eigenvalue-based selection of MPA networks significantly improves the simultaneous protection of multiple species with different dispersal strategies. This framework may be particularly valuable when assessing a range of alternative MPA designs.

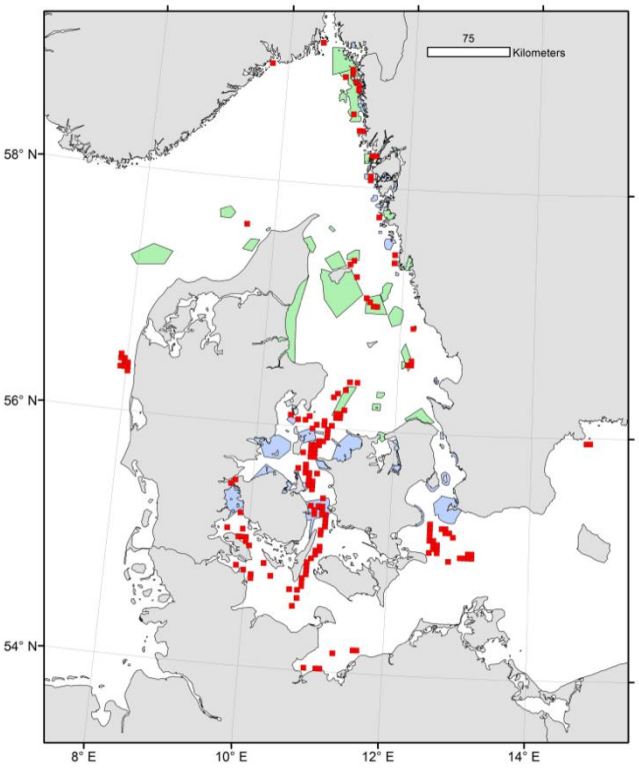


Figure 5.2.2 The figure shows the consensus network based on eigenvalue perturbation theory (red squares) for five different dispersal strategies with different spawning times, pelagic larval duration, and larval drift depths. Also shown is the present MPA network as blue (Natura 2000) or green (OSPAR MPAs) polygons.

Literature cited

Nilsson Jacobi M, Jonsson PR. 2011. Optimal networks of nature reserves can be found through eigenvalue perturbation theory of the connectivity matrix. Ecological Applications 21: 1861-1870

To inform MPA authorities about BIO-C3 Task 5.1 results and to initiate collaborations, the following initiatives have been taken:

- UGOT arranged a meeting (Nov 17, 2015) with the Swedish Agency for Marine and Water Management (SwAM) and the Regional Administrative Board of Västra Götaland to inform about work, e.g. within BIO-C3, in particular about new methods to extend present networks of MPAs and identification of optimal networks with respect to enhance connectivity. We also published a technical report for SwAM about guidelines how to extend MPA networks to improve connectivity and coherence of MPAs in the Kattegat area (Moksnes et al. 2015) (P10).

- DHI arranged a meeting with the Danish Nature Agency (May 13, 2015) to inform about BIO-C3 work and the methods that are being developed to support management and for decision support in relation to MPA management (P9).

References :

Jonsson PR, Nilsson Jacobi M, Moksnes P-O (2016) How to select networks of marine protected areas for multiple species with different dispersal strategies. Diversity and Distributions 22:161-173. DOI: 10.1111/ddi.12394

Moksnes PO, Nilsson Jacobi M, Jonsson PR. 2015. Identifying optimal areas for larval connectivity to add to existing networks of marine protected areas (MPAs): Case study of the Kattegat-Skagerrak region. Swedish Agency for Marine and Water Management, Technical Report (*this work will also be published as a scientific report*).

<u>Task 5.3: Evaluation framework for holistic management</u>

Lead: Piotr Margonski, P5 NMFRI, participation of P2, P4, P6, P8.

Deliverable 5.3: *Report on evaluation framework for holistic management – summary of the concept, requirements and management implications.* **(Month 44)**

The role of this task is to synthesize the existing and newly developed knowledge on relevant biodiversity indicators and their response to management measures, with specific focus on MPAs and considering potential adaptations under the expected ecosystem change. A

comprehensive framework in terms of monitoring design to collect appropriate data, using recommended biodiversity indicators as well as modelling, assessment and decision support tools will be presented. All the work to date is going according to the original plan, with specific progress described below:

- Management evaluation framework for integrated management of biodiversity in the Baltic Sea should consider the complexity of the effects of natural and human pressures. Attempts to modify the status of biodiversity indicators by management measures require the links between the state indicators and manageable pressures to be known. In this task we conduct a review of existing evidence-based knowledge of the links between selected biodiversity indicators and pressures at different spatial and temporal scales, including identifying important knowledge gaps. Planning and designing this review is currently ongoing. (P2, P5 and P6)

- Developing the exemptions framework to be applied under the IMO Ballast Water Management Convention (this work contributes primarily to Task 5.3 as is an explicit management measure/suggestion for new NIS invasions via ship ballast transfers, but in future perspective also contributes to Task 5.1 as enables to evaluate management measures). The IMO Ballast Water Management Convention (BWMC) is a powerful instrument aimed to reduce spread of harmful aquatic organisms and pathogens (HAOPs). As BWMC is expected to enter into force soon, shipping companies will start seeking exemptions for ballast water management in accordance with BWMC Regulation A-4. However, without scientifically robust risk assessment (RA) and consistent rules, the exemptions may introduce a new form of risk within BWMC generally designed to reduce invasion risks. The Olenin et al. (in press) paper describes an adaptive system for granting exemptions, consisting of six major components: target species selection procedure, port-to-port RA, monitoring, information support, administration decision and review process. The system is based on key principles defined in the IMO guidelines for RA and is designed to constantly accumulate evolving experience on granting exemptions. The ultimate goal is to contribute to the control of the spread of HAOPs, without placing an unnecessary burden on the shipping industry. (P6)

- Spatio-temporal patterns of zooplankton at the pan-Baltic scale (contributes to both variability/sensitivity as zooplankton abundance as an indicator (Task 5.1) as well as monitoring/assessment requirements (Task 5.3). Spatiotemporal patchiness of plankton and appropriate sampling strategy are crucial considerations for the studies of long term plankton dynamics, determining the confidence with which statistically significant ecological changes can be detected and attributed to the drivers. Klais et al. (submitted) paper analyzes the spatiotemporal variability of the Baltic Sea zooplankton using monitoring data from various sources. It indicates dominant patterns in the variability emerging at scales below 100 km and 90 days, in different hydrological regions – small lagoons, larger gulfs, Baltic Proper, and by differently sized zooplankton groups – large

and small copepods and cladocerans. In most cases, temporal variability in one place exceeds the synoptic spatial variability, and that smaller fast reproducing cladocerans vary more in abundance than larger slow reproducing copepods. The average abundance differences systematically increased with increasing time and space between samplings. For copepods, dominant temporal cycle of 60-70 days emerged, implying the need of sampling after every 20-23 days. For cladocerans authors suggest the two weeks as minimum sampling frequency, the time during which the abundance difference between samples doubled. Caution should be given to calculate long term trends of copepods and cladocerans when sampling frequency has been less than 3 or 2 weeks. This work is a common effort of BONUS INSPIRE and BIO-C3 projects (P6, P5, P7, P8)

- To provide essential information for evaluation framework for holistic management, inventory started on the current legal framework, existing (or suggested) indicators and measures with special emphasis on work and findings of the relevant projects as e.g. MARMONI, DEVOTES, COST-EMBOS, and HELCOM CORESET & CORESET II (P5)

- In collaboration with DEVOTES project, a framework for selecting indicators and setting their target ranges to assess sustainable use of marine ecosystems was developed. The collaborative paper was submitted to Ecological Indicators (Rossberg et al.).

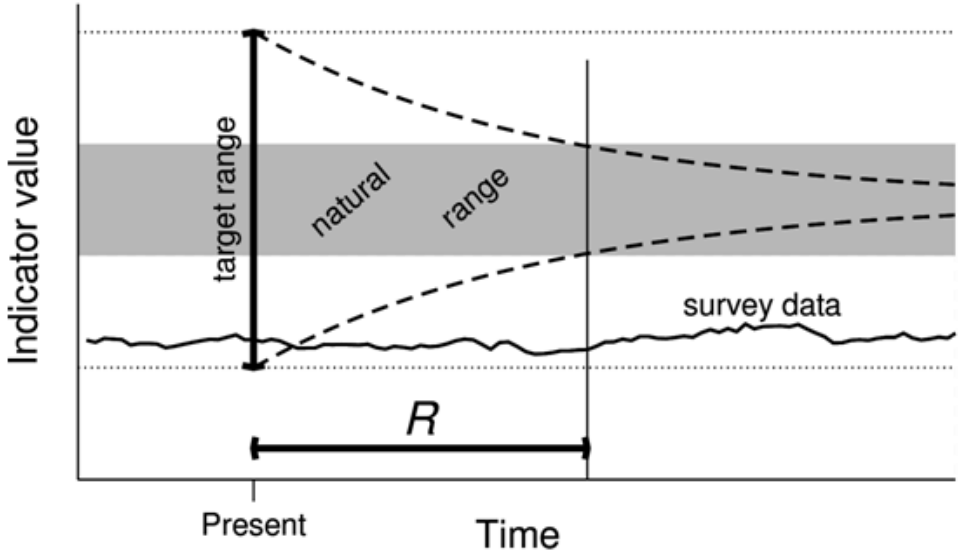


Figure 5.3.1 Illustration of proposed approach for choosing target ranges. The target range of an indicator is determined as the range of values from which it takes, on average, at most a time R to reach the natural range in a hypothetical situation without anthropogenic pressures. Dotted lines indicate the width of the target range, dashed lines hypothetical average relaxation trajectories, the grey area the natural range, and the ragged solid line a conceivable trajectory of the indicator for an ecosystem in strongly sustainable use. In practice, the target range may need to be narrowed to take measurement uncertainty and model uncertainty into account.

- Wide-ranging, indicator-based assessments of large, complex ecosystems are playing an increasing role in guiding environmental policy and management. An example is the EU's Marine Strategy Framework Directive, which requires Member States to take measures to reach "good environmental status" (GES) in European marine waters. However, formulation of indicator targets consistent with the Directive's high-level policy goal of sustainable use of the marine environment has proven challenging. In collaboration with the EU DEVOTES project, a specific, quantitative interpretation of the concepts of GES and sustainable use in terms of indicators and associated targets was developed, by sharply distinguishing between current uses to satisfy current societal needs and preferences, and unknown future uses. Within the proposed framework, it was suggested, that consistent targets to safeguard future uses derive from a requirement that any environmental state indicator should recover within a defined time (e.g. 30 years) to its pressure-free range of variation when all pressures are hypothetically removed (Figure 5.3.1).

In this account, routes to implementation of this proposal for indicators of fish-community size structure, population size of selected species, eutrophication, impacts of non-indigenous species, and genetic diversity are discussed, examples of applications and policy implications presented.

The output of this work has been presented at a seminar "Mission Impossible: measure unmeasurable and compare uncomparable", Cawthron Institute, Nelson, New Zealand, Oct. 7 2015 (P8).

References:

Olenin, S., Ojaveer, H., Minchin, D. And Boelens, R. Assessing exemptions under the Ballast Water Management Convention, preclude the Trojan horse. Marine Pollution Bulletin (*in press*).

Klais R., Lehtiniemi M., Rubene G., Semenova A., Margonski P., Ikauniece A., Simm M., Põllumäe A., Grinienė E., Makinen K., Ojaveer H.. Comparison of spatial and temporal variability of zooplankton in a temperate semi-enclosed sea: implications for monitoring design and long-term studies. Journal of Plankton Research (*submitted*).

Rossberg A.G.; Uusitalo L.; Berg T.; Zaiko A.; Chenuil A.; Uyarra M.C.; Borja A.; Lynam C.P. Choosing targets and indicators for sustainable use of marine ecosystems. Ecological Indicators (*submitted*).

WP6 – Project management and dissemination

Lead: Thorsten Reusch, P1 GEOMAR

Task 6.1 Dissemination and communication strategy (lead: P1; participants: P2-13)

Deliverable 6.1: *Homepage and leaflet produced and publicised.* **(Month 8,** completed**)**

Milestone 6.2: *Communication and dissemination strategy developed.* **(Month 14**, completed/ongoing**)**

During the second reporting period, we have continued to pursue the BIO-C3 dissemination and communication strategy established in 2014 (Deliverable 6.1 approved by BONUS in 2014). Importantly, this entailed the maintenance and expansion of the BIO-C3 website (www.bio-c3.eu) (Appendix 1). This site consists of public pages, **including a section giving access to all BIO-C3 output produced to date**, including public deliverables, publications, reports, and presentations (www.bio-c3.eu/publications). Moreover, the site has an internal section used for document exchanges within the consortium. We have continued to contribute BIO-C3 content including the blog "Baltic biodiversity notes" by Anna Törnroos (P13) (http://www.bonusprojects.org/bonusprojects/blogs/baltic_diversity_notes) to the BONUS website (www.bonusportal.org). We also continue to distribute the project flyer produced in 2014 at outreach events and conferences.

The BIO-C3 mailing lists ("All project personnel", "Young scientists", "Steering committee", "Work package and Task leaders") that were established in 2014 are in regular use for discussions, posting of initiatives and job offers, and scientific coordination within the project.

We have continued to make significant efforts to present BIO-C3 results at international and national conferences, the highlight of the reporting period certainly being the special BONUS theme session "*From genes to ecosystems: spatial heterogeneity and temporal dynamics of the Baltic Sea*" at the 2015 ICES ASC in Copenhagen that was organized and convened by BIO-C3 and partners from BONUS INSPIRE and BAMBI, and that saw a large number of >80 participants both from within and outside the BONUS community. The number of peer-reviewed and popular publications, BIO-C3 related interviews, and stakeholder interactions has increased drastically in 2015, mirroring the strong efforts of the coordinators and all partner institutes to disseminate the new knowledge in BIO-C3 to the scientific community, stakeholders and the public (see Statistics report).

Our close ties to the thematically linked BONUS projects BAMBI and INSPIRE and now also COCOA have continued and evolved further, and reach from scientific collaborations and

joint sampling initiatives, to joint organization of the ICES ASC theme session and the highly successful 2015 BONUS BIO-C3/BAMBI/INSPIRE summer school *"The Baltic Sea: a model for the global future ocean?"*, to planning for the 2016 BONUS clustering activity "Drafting workshop for an integrative concept paper along the lines of the 2015 summer school topic", planned for November 2016 near Kiel, Germany.

Task 6.2 Project organisation and milestone-trend analysis (lead: P1; participants: P2-13)

Milestone 6.1: *Kick-off meeting executed.* **(Month 4,** completed**)**

Milestone 6.3: *Annual project meetings* **(Month 18,** completed**)**

Project organisation has been advanced both via large-scale meetings and smaller scale exchanges between coordinators and WPs/Tasks, within and between WPs, between the steering committee members, and the BIO-C3 advisory board. In 2015, we held our first BIO-C3 annual meeting from June 30 – July 3 in Kiel, Germany (Milestone 6.3). Participants (ca. 40 in total) included the large majority of BIO-C3 institute PIs, WP and Task leaders and fulltime project scientists, our adivisory board members Carol E. Lee and Herman Hummel, and BONUS secretariat representative Andris Andrusaitis. The meeting included a meeting of the steering committee and the advisory board, and an advisory board report with constructive feedback on the discussions during the annual meeting and on project progress was made available to the consortium in September 2015. Further SC meetings with all partner institute PIs took place in March and November 2015 via web conference. Our 2016 annual meeting of BIO-C3 is planned for June 27-30 in Tallinn, Estonia, and additional SC meetings are planned in April and November 2016.

Task 6.3 Financial administration and reporting to the Commission (lead: P1; participants: P2-13)

Deliverable 6.2: *First periodic report to the BONUS Secretariat, including reporting to meta database.* **(Month 14,** completed)

Deliverable 6.3: *Second periodic report to the BONUS Secretariat, including reporting to meta database.* **(Month 26** – this report**)**

The administration of the project coordinator GEOMAR has facilitated the distribution of funds to participants, and the relevant financial information for all participants for the second reporting period are submitted with this report. The steering committee has agreed to enforce the submission of data underlying publications resulting from BIO-C3 to public databases for all partner institutes, and this is resulting in an increasing number of submissions of datasets to public repositories such as Dryad (http://datadryad.org/) and Pangaea (http://www.pangaea.de/), as well as the ICES database

(http://www.ices.dk/marine-data/data-portals/Pages/ocean.aspx). Data and metadata on BIO-C3 cruises are available via the GEOMAR data portal (https://www.bio-c3.eu/de/osis). The present report constitutes Deliverable 6.3.

2. Promoting an effective science-policy interface to ensure optimal take up of research results (performance statistics 1-4)

From the onset, BIO-C3 has made strong efforts to pass on the expertise of project personnel, and to use the scientific output resulting from BIO-C3 to inform stakeholders and policy makers in the Baltic realm and beyond. This includes contributions to the implementation of the MSFD by several of our partners, and the design of the Ballast Water Management Convention and EU marine fisheries research priorities (Statistic 1), as well as advice to national policy makers and stakeholders (Statistic 2). The strength of the BIO-C3 consortium and the role that project participants play in the science-policy interface is reflected in the continued strong membership and participation in a total of **102** committees or working groups in 2015, including those of ICES, HELCOM, EC, MSFD, UN, and OSPAR (Statistic 3). Important for the visibility of the BONUS program and of BIO-C3 results, BIO-C3 co-convened the ICES Annual Science Conference 2015 Theme session Q *From genes to ecosystems: spatial heterogeneity and temporal dynamics of the Baltic Sea*, Copenhagen, Denmark, Sept. 24 2015, 21 oral and 15 poster presentations, ca. 80 participants from BONUS BIO-C3, INSPIRE, BAMBI, as well as scientists and stakeholders from outside the BONUS community. (http://www.ices.dk/news-and-events/asc/ASC2015/Pages/Theme-Sessions.aspx).

This session also resulted in an invited guest column in the BONUS in Brief newsletter (J. Dierking, K. Hüssy, L. Laikre, L. 2015. Finding bridges between biodiversity research and ecosystem–based management. BONUS in Brief December 2015:2. Available at http://www.bonusportal.org/files/4481/BONUSInBriefDecember2015.pdf

Finally, the BIO-C3 coordinators participated in the in the stakeholder conference / information event for the European community organized by BONUS in Brussels, Belgium, on December 2 2015. These activities will continue and further expand, as scientific output from BIO-C3 continues to grow (Statistic 4). All of these activities combined ensure that new results from BIO-C3 during the reporting period have become visible to stakeholders and policy makers, and can be applied in informed decision-making benefiting the Baltic region.

3. Collaboration with research programmes and the science communities in other European sea basins and on an international level (performance statistic 5)

BIO-C3 scientists have continued to collaborate with a range of different research programmes and individual scientists from beyond the Baltic region (16 activities listed

under stastic 5 in 2015), including most European countries, the US, and global networks, and focusing on seas including the North Sea, Atlantic, Mediterranean and the US Great Lakes. These exchanges are highly relevant for the project, since scientifically and for management purposes, they serve to place the Baltic Sea results in a larger context. Pan-Baltic approaches will benefit for example the research foci on bio-invasions, environmental/global change, and connectivity, amongst others. We consequently expect pan-regional comparative or integrative output/publications in addition to the products focusing more strongly on the Baltic Sea per se over the lifetime of the project (Statistic 5).

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

Scientifically, BIO-C3 has taken large strides in 2015, as evidenced by the large output of publications and other project output (see Statistics section below). In addition, all WPs and Tasks are generally advancing well, and no major problems are anticipated in reaching all original project objectives and deliverables.

At the same time, to fully exploit the project potential, we contacted the BONUS secretariat with a first informal request for cost neutral extension of the project until the end of December 2017, instead of the current end date end of June 2017. The reasons for this are three-fold:

(1) BIO-C3 started 2 months later than planned due to the late signing of the consortium agreement by several partners, which was in turn due to the problem that several national budgets were reduced. Consequently, hires of personnel and the start of worklines was also delayed. The deliverable deadlines were in fact all shifted backwards by 2 months compared to the initial proposal to account for the delayed project start in agreement with the BONUS secretariat, but the overall project was not extended at the same time. This leads to a situation where the end date of BIO-C3 is M42, but several deliverable deadlines, and the submission of the final report and of final outreach products in part would take place later than that, which is not ideal since there will not officially be any personnel left in BIO-C3. Along the same line, some funds that were not used in 2014 (see section I.4. in our first periodic report) due to the late start of the project may not be used up if work lines are not extended.

(2) Adding a total of 6 months until the end of 2017 will give us the opportunity to strengthen the synthesis tasks in work packages 4 and 5 of BIO-C. Since these tasks require input from our work packages 1, 2 and 3, this also provides a buffer against potential small delays in the lower work packages.

(3) The added time would benefit the communication of our end results to stakeholders and would thus strengthen our project outreach and knowledge transfer components.

Following an initial informal OK from BONUS to pursue these plans, we are planning to contact all national funding agencies in March 2016 with requests for cost neutral extension. If the national partners agree, BONUS has indicated that it will support the extension.

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

There have been no changes to the original description of work. Deliverable 1.1 was postponed by 2 months to Month 22, and was submitted last October in line with this amended due date. D2.1 was postponed by four months from month 20 to month 24, and has also been submitted. Both deliverables have already been accepted by BONUS. The D3.1 due date was shifted from Month 32 to Month 36 to account for some problems with copepod cultures. We do not expect any negative consequences or delays for other lines of work or work packages from this change.

6. Other relevant information

BIO-C3 has offered the unique opportunity to continue to strengthen collaborations and to improve coordination of sampling and research initiatives in the Baltic region. This has had clear benefits for the scientific output of the consortium and beyond. Initiatives include:

- **The improved coordination of research cruises in the Baltic region:**

  During the initial phase of the project, the timing of research cruises by project partners was adjusted to avoid previous overlaps in survey coverage, and regular exchange of survey staff between the institutes was initiated. This close cooperation and coordination of field activities was continued during 2015, and just as in 2014, five institutes (DTU Aqua, GEOMAR, NMFRI, UHH-IHF and TI-OF) contributed to these research cruises (Figure I.6.1). During 2015, a total of 9 research cruises was conducted to the BIO-C3 focus area in the Bornholm Basin as well as partly to adjacent areas in the Arkona Basin, Gdansk Deep and Gotland Basin. Owing to three cruises specifically dedicated to BIO-C3 (two cruises in August conducted by UHH-IHF and one cruise in September conducted by DTU AQUA), an even better temporal coverage than in 2014 was achieved, resulting in a very intensive coverage of the summer months and an almost monthly survey coverage from March to November, with the exception of October. In particular the September cruise conducted by DTU AQUA provided a unique opportunity for collection of samples and onboard experiments during a period of the year which has seldom been investigated in the past. Furthermore, the continued collaboration with the IOW, Germany, has again enabled additional sampling during periods not covered by the aforementioned cruises. During 2016, a similar coverage as in 2015 is anticipated.

Januar		Februar		März		April		Mai		Juni		Juli		August		September		Oktober		November		Dezember	
1		1		1		1		1		1		1		1	IHF	1		1		1		1	
2		2		2		2		2		2		2	TI-OSF	2	BIO-C3	2		2		2		2	
3		3		3		3		3		3		3	Stepputtis	3		3		3		3	DANA	3	
4		4		4		4		4		4		4	Österwind	4	Herrmann	4		4		4		4	
5		5		5		5		5		5		5		5		5		5		5	DTU Aqua	5	
6		6		6		6		6		6		6		6		6		6		6		6	
7		7		7		7		7		7		7		7		7		7		7	Storr-	7	
8		8		8		8		8		8		8		8		8		8		8	Paulsen	8	
9		9		9		9		9		9		9	Fishery until	9		9		9		9	Huwer	9	
10		10		10	DANA	10		10		10		10	10.07.	10		10		10		10		10	
11		11		11		11		11		11		11		11		11		11		11	03.-20.11.	11	
12		12		12	DTU Aqua	12		12		12		12	Bongo grid	12		12		12		12		12	
13		13		13		13		13		13		13	& plankton	13		13		13		13		13	
14		14		14		14		14		14		14	from 12.07.	14		14		14		14		14	
15		15		15	Storr-Paulsen	15	AL 454	15		15		15	Kotterba	15		15		15		15		15	
16		16		16	Huwer	16	GEOMAR	16	AL 457	16		16	Levinsky	16	AL 462	16	DANA	16		16		16	
17		17		17		17		17	GEOMAR	17		17		17	16.-31.08.	17		17		17		17	
18		18		18		18		18		18		18		18		18	DTU Aqua	18		18		18	
19		19		19	10.-28.03.	19	Dierking	19		19	Baltica	19		19	IHF	19	BIO-C3	19		19		19	
20		20		20		20		20	v. Dewitz	20	NMFRI	20		20	BIO-C3	20		20		20		20	
21		21		21		21	15.-30.04.	21		21	DTUAqua	21		21		21	Huwer	21		21		21	
22		22		22		22		22	16.-31.05.	22	(joint)	22		22	Herrmann	22		22		22		22	
23		23		23		23		23		23		23		23		23		23		23		23	
24		24		24		24		24		24	19.-30.06.	24		24		24	16.-30.09.	24		24		24	
25		25		25		25		25		25		25		25		25		25		25		25	
26		26		26		26		26		26	Drgas	26		26		26		26		26		26	
27		27		27		27		27		27	Huwer	27		27		27		27		27		27	
28		28		28		28		28		28		28		28		28		28		28		28	
29				29		29		29		29		29		29		29		29		29		29	
30				30		30		30		30	CLUPEA 291	30	AL 461	30		30		30		30		30	
31				31				31				31	30.07.-12.08.	31				31				31	

Figure I.6.1 Baltic cruises with BIO-C3 context in 2015.

- The Baltic Sea mesozooplankton initiative that was started 2014 grew rapidly into a large dataset, involving by the end of 2015 the contributions from 9 institutions and 7 countries (full list can be found at http://kodu.ut.ee/~riina82/providers.html). A total of 25,074 samples have been harmonized to date. To avoid any data misuse issues, and to protect the data providers, firm data use policy was set in place, describing the principles of collaboration (http://kodu.ut.ee/~riina82/policy.html).

  A first publication based on this data initiative was accepted for publication in Journal of Plankton Research, analyzing the spatial and temporal variability of zooplankton abundance: Klais, R., Lehtiniemi, M., Rubene, G., Semenova, A., Margonski, P., Ikauniece, A., Simm, M., Põllumäe, A., Grinienė, 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. DOI: 10.1093/plankt/fbw022.

- The sampling initiative on the invasive round goby *N. melanostomus* is continuing successfully. To date, BIO-C3 partners (including P1, P2, P3, P6, P7, P8, P11, and P13) have succeeded in obtaining tissue samples of 50-100 fish each from 15 locations in seven countries spanning large parts of the Baltic Sea and its entrance to the Kattegat. This sample set is now curated by DTU Aqua (P2), and is prepared for genetic analyses planned in the context of BIO-C3.

- The large-scale sampling initiative of the invasive combjelly *Mnemiopsis leidyi* in the context of BIO-C3 WP1 has continued, with contributions of P01, 02, 03, 05, 11, as well as collaborators outside of BIO-C3. This sample set provides the foundation for analyses now running in BIO-C3.

II. Report on BIO-C3 performance statistics 2015[4]

1. Number of times the project has contributed significantly to the development and implementation of 'fit-to-purpose' regulations, policies and management practices (5/8)[5]

P06 – UT-EMI:

- Contribution to the MSFD D2 process: complementing the review manual for D2, further support the review process, feed the drafting of the revised Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters, and define the way forward on further technical and scientific needs.

P07 – SYKE:

- Contribution to the Finnish Program of measures in the Marine Strategy Framework Directive: participation in Finnish governmental working groups 2014-2015, lead Ministry of Environment; Plan accepted by Finnish Government in 2015.

- Contribution to the development of national law on non-indigenous species to implement the EU regulation on invasive species: Participation in the Finnish governmental working group 2015, lead Ministry of Transport and Commerce; Legislation under preparation.

- Contribution to the Finnish ratification of the Ballast Water Management Convention; Participation in Finnish Governmental working group 2014-2015, lead Ministry of Transport and Commerce; IMO convention confirmed signing by Finland in 2015.

P08 – KU:

- Contribution to the national process of MSFD (D2 and D6) to adjust the proposed NIS and benthic integrity indicators for the Lithuanian coastal zone area and review the set of measures required for GES achievement. The activity has taken place throughout the year.

[4]For details on 2014 contributions, please refer to the 2014 BIO-C3 periodic report.
[5]Numbers represent the 2015 totals (left), and the cumulative totals since project start (right).

2. Number of suggestions for designing, implementing and evaluating the efficacy of relevant public policies and governance (8/11)

P01 – GEOMAR

- T. Reusch. Election into German National Academy of Sciences Working group "Environment", developing recommendations in all fields of environmental science to decision makers/politics.

P02 - DTU Aqua:

- Storr-Paulsen, R & Eero, M. 2015: ICES Advice on Baltic Fish Stocks. Information to the Baltic Sea Advisory Council. Information to Danish Fishing Industry.
- Storr-Paulsen, R & Eero, M. 2015: Briefs to Danish Ministry of Food and Environment on fish stock status and fisheries management advice.

P07 – SYKE

- Contribution to the Finnish government alien species legislation action; Lead Ministry of Transport and Commerce ad hoc working group meetings in 2015.
- Contribution to the Finnish Ministry of Transport Sulfur emission (IMO MARPOL ANNEX VI) control; Lead Ministry of Transport and Commerce; expert evaluation of marine ecosystem effects of planned control measures in 2014-2015 for the Finnish Government.

P08 – KU:

- Participation of two project scientists as experts advising the Lithuanian Environmental Agency regarding the implementation of the EU MSFD.

P09 - DHI

- DHI arranged a meeting with the Danish Nature Agency (May 13, 2015) to inform about BIO-C3 work and the methods that are being developed to support management and for decision support in relation to MPA management.

P10 - UGOT:

- UGOT arranged a meeting (Nov 17, 2015) with the Swedish Agency for Marine and Water Management (SwAM) and the Regional Administrative Board of Västra Götaland to inform about work within BIO-C3, in particular about new methods to extend present networks of MPAs and identification of optimal networks with respect to connectivity. We also published a technical report for SwAM about guidelines how to extend MPA networks to improve connectivity and coherence of MPAs in the Kattegat (see 13. below).

3. **Number of times the scientists working in the project have served as members or observers in stakeholder committees** (102/201)

See Appendix 2 for the list of all WG and stakeholder committee memberships and observer functions of BIO-C3 personnel in 2015.

4. **Number of international, national and regional stakeholder events organized by the project** (1/3)

P01 – GEOMAR (with partners from BONUS INSPIRE and BAMBI)

- Organization of the ICES Annual Science Conference 2015 Theme session Q *From genes to ecosystems: spatial heterogeneity and temporal dynamics of the Baltic Sea*, Copenhagen, Denmark, Sept. 24 2015, 21 oral and 15 poster presentations, ca. 80 participants from BONUS BIO-C3, INSPIRE, BAMBI, as well as scientists and stakeholders from outside the BONUS community. Co-conveners J. Dierking (GEOMAR, BIO-C3), K. Hüssy (DTU Aqua, INSPIRE), Linda Laikre (Stockholm University, BAMBI).
  (http://www.ices.dk/news-and-events/asc/ASC2015/Pages/Theme-Sessions.aspx

5. **Number of joint events/co-operation activities/partnerships of the project with non-Baltic research actors & other European marine basins**. (11/24)

P01 – GEOMAR:

- Cooperation activities: (C. Clemmesen /F. Mittermayer) participation in a joint project at the national Cod Breeding center of NOFIMA Tromsö, Norway from middle of March to early June 2015 to assess the potential of transgenerational adaptation to mediate adverse effects of future climate change on early life stages of cod.

P03 – UHH:

- Cooperation activities: (A.Temming) Participation in German research project on Net selectivity and management on Crangon fishery in the North Sea region. Several meetings in Hamburg in 2015.
- Joint event: A. Temming Participation in 23. Coastal Ecology Workshop with special emphasis on salt marsh ecology, with a focus on the North Sea, Atlantic and Baltic regions. 1.-5. Nov 2015 in Westerhever, Germany

P04 – SU:

- Collaboration with James Cloern (US-Geological Survey, USA) on large-scale phytoplankton analysis in coastal-estuarine systems.

P05 – NMFRI

- Jan Warzocha contribution to the work of the Development and implementation of a pan-European Marine Biodiversity Observatory System (COST-EMBOS) project including participation in April 2015 workshop in the Hellenic Center for Marine Research (HCMR) on Crete

P06 – UT-EMI:

- Joint co-operation with Italian, Finnish and Irish researchers to develop life-form based approach for tracking changes in the status of the ecosystem:
    - Fabio Rindi: Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Italy
    - Tasman P. Crowe: Earth Institute and School of Biology and Environmental Science, University College Dublin, Ireland
    - Markku Viitasalo: Finnish Environment institute, Finland

P07 – SYKE:

- Participation in the EU Pan-European Cost Action: Alien Challenge Action WG3: Trends and analyses on impacts of priority species, Lead Emili García-Berthou, University of Girona, Spain

P08 – KU:

- Close collaboration with researchers from University of Oviedo on development and application of molecular techniques for non-indigenous species surveillance in coastal ecosystems worldwide. Two joint papers have been recently published in Marine Environmental Research and Marine Pollution Bulletin journals.

- Contribution to the development of new approach for the mapping of water turbidity and suspended matter over environmental gradients, applicable to ecosystems worldwide, lead by researchers from Stockholm University. One manuscript entitled “Retrieval of suspended particulate matter from turbidity– model development, validation, and application to MERIS data over the Baltic Sea” is under the preparation.

P13- AAU

- Collaboration with the EU Marie Curie Horizon2020 Network MARmaED
- Cooperation with NATO. Participation in working group meeting (the NATO Specialist Team on bio-Databases (ST-bioDB) 3rd meeting) 14-16.9. 2015. Member.

6. Number of persons and time spent by foreign scientists on research vessels participating in the cruises arranged by the project. Persons: (13/16); Days: (160/199)

P01 – GEOMAR:

- 1 person for 8 working days: Maria Krüger-Johnsen, P02 – DTU Aqua, on BIO-C3 Alkor cruise AL457, 23.5.-31.5.2015.
- 1 person for 8 working days: Julie Josias Nielsen, P02 – DTU Aqua, on BIO-C3 Alkor cruise AL457, 16.5.-24.5.2015.
- 1 person for 16 days : Alondra Rodriguez Buelna, P02 – DTU Aqua, on BIO-C3 Alkor cruise AL457, 16.5.-24.5.2015.
- 1 person for 15 working days: Sophia Nyberg, Uppsala University, Sweden, on BIO-C3 Alkor cruise AL454, 15.04.-29.04.2015.
- 1 person for 10 working days: Rebecca Eliasson, Göteborg University, Sweden, 1 leg on BIO-C3 Alkor cruise AL454, 15.04.-24.04.2015.

P02 - DTU Aqua:

2015: BIO-C3 cruise on RV DANA, September 2015:

- Jörg Dutz, IOW, Germany: 15 working days
- Sebastian Utermann, IOW, Germany: 15 working days
- Isabel Keller, P01 - GEOMAR, Germany: 15 working days
- Sarah Kaehlert, P01 - GEOMAR, Germany: 8 working days

P03 – UHH:

- 1 person for 13 working days: Dr. Bastian Huwer, DTU Aqua, participated in the RV Alkor cruise August in 2015 organized by IHF in the context of BIO-C3.
- 1 person for 13 working days: Kristin Öhman, SLU, Sweden, participated in the RV Alkor cruise August in 2015 organized by IHF in the context of BIO-C3.

P05 – NMFRI:

- 2 persons for 12 working days each: Bastian Huwer and Svend-Erik Levinsky (both DTU Aqua) participated in the RV Baltica cruise in June 2015 organized in the context of BIO-C3.

7. Number of persons and working days spent by foreign scientists using other major research facilities involved in the project. (0/1); (0/52)

None in 2015.

8. Number of peer-reviewed publications arising from the project research with authors from, at least, two different participating states[6] (8/11)

Note: Peer-reviewed publications with authors from a single state listed under 13..

P02–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., and Storr-Paulsen, M. Eastern Baltic cod in distress: biological changes and challenges for stock assessment. ICES Journal of Marine Science, 72: 2180-2186. doi: 10.1093/icesjms/fsv109. (with P11 – TI-OF)

P06 – UT-EMI:

- Kotta, J., Nurkse, K., Puntila, R., Ojaveer., H. (2015). Shipping and natural environmental conditions determine the distribution of the invasive non-indigenous round goby *Neogobius melanostomus* in a regional sea. Estuarine, Coastal and Shelf Science. doi:10.1016/j.ecss.2015.11.029 (with P07-SYKE)

- Kotta, J., Kotta, I., Bick, A., Bastrop, R., Väinölä, R. (2015). Modelling habitat range and seasonality of a new, non-indigenous polychaete *Laonome* sp. (Sabellida, Sabellidae) in Pärnu Bay, the north-eastern Baltic Sea. Aquatic Invasions, 3, 275−285.

- Ojaveer, H., Galil, B.S., Lehtiniemi, M., Christoffersen, M., Clink, S., Florin, A., Gruszka, P., Puntila, R., Behrens, J.W. (2015). Twenty five years of invasion: management of the round

[6]**Note regarding Statistics 8. – 13.:** All BIO-C3 output (interviews, reports, popular and peer-reviewed publications) is continuously updated on the BIO-C3 website:
https://www.bio-c3.eu/publications

goby *Neogobius melanostomus* in the Baltic Sea. Management of Biological Invasions, 6: 329-339. (with P02-DTU-AQUA, P07-SYKE)

- 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 (with P02-DTU-AQUA)

- Ojaveer, H, Lehtiniemi M, Christoffersen M, Clink S, Florin A-B, Galil BS, Gruszka P, Puntila R, Behrens JW (2015) Risk-averse: post-invasion management of the round goby *Neogobius melanostomus* in the Baltic Sea. Management of Biological Invasions Vol 6 in press (with P02 – DTU-Aqua)

P07-SYKE:

- Maiju Lehtiniemi, H Ojaveer, M David, B Galil, S Gollasch, C McKenzie, D Minchin, A Occhipinti-Ambrogi, S Olenin, J Pederson (2015): Dose of truth—Monitoring marine non-indigenous species to serve legislative requirements. Marine Policy. Volume 54, 26–35 (with P02 – DTU-Aqua, P06 – UT-EMI)

P12 – SMHI:

- Hordoir, R, Axell, L., Löptien, U., Dietze, H., and Kusnetzov, I. 2015. Influence of sea level rise on the dynamics of salt inflows in the Baltic Sea. J. Geophys. Res. Oceans. doi 10.1002/2014JC010642 (with P01 - GEOMAR)

9. Number of entries to existing openly accessible common databases, storing original data from the entire Baltic Sea system or larger geographical area. (11/18)

P01 – GEOMAR:

- Biological information from Alkor cruise AL454 in April 2015. Available at the GEOMAR data portal. https://portal.geomar.de/metadata/leg/show/329864
- Hydrographical data from Alkor cruise AL454 in April 2015 was added to the Oceanographic data base of the ICES council. Available to the public through the ICES webpage, http://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes
- Biological information from Alkor cruise AL457 in May 2015. Available at the GEOMAR data portal. https://portal.geomar.de/metadata/leg/show/329874
- Hydrographical data from Alkor cruise AL457 in May 2015 was added to the Oceanographic data base of the ICES council. Available to the public through the ICES webpage, http://ocean.ices.dk/HydChem/HydChem.aspx?plot=yes

P02 – DTU Aqua:

- Hydrography and single fish data on cod growth and nutrition from March and November surveys 2015 in the central Baltic Sea submitted to ICES regional database (i.e., 2 entries in total for DTU)

P06 – UT-EMI:

- Multiple entries throughout the year to 'Information system of aquatic alien and cryptogenic species in Europe' (AquaNIS; http://www.corpi.ku.lt/databases/index.php/aquanis) to update the Baltic non-native species invasion events (first record by country, source region, pathway/vector responsible, species status, population status). Information of the invasion events module of the Baltic Sea is freely accessible.

P07 – SYKE:

- Entries for Finnish observations added to the European marine alien species database AquaNIS (http://www.corpi.ku.lt/databases/index.php/aquanis).

P08 – KU:

- Multiple entries throughout the year to 'Information system of aquatic alien and cryptogenic species in Europe' (AquaNIS; http://www.corpi.ku.lt/databases/index.php/aquanis) to update the biological traits information of the Baltic non-indigenous species. Information is freely accessible on-line.

- DNA sequences of 6 mollusk species from the SE Baltic Sea (corresponding to *Cerastoderma glaucum*, *Dreissena polymorpha*, four different haplotypes of *Macoma balthica*, *Mya arenaria, Mytilus trossulus* and three different haplotypes of *Rangia cuneate*) were submitted to GenBank and are available with the accession numbers KP052743-KP052753:
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052743
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052744
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052745
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052746
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052747
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052748
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052749
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052750
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052751
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052752
    - https://www.ncbi.nlm.nih.gov/nuccore/KP052753

- Raw data, underlying the publication Zaiko A., Samulioviene A., Ardura A., Garcia-Vazquez E. 2015. Metabarcoding approach for non-indigenous species surveillance in marine coastal waters. Marine Pollution Bulletin, 100:53-59, were submitted to PANGAEA repository and are available at: http://doi.pangaea.de/10.1594/PANGAEA.853664

10. Number of popular science papers produced by the project. (19/23)

P01 – GEOMAR:

- Reusch, T. B. H. und Jaspers, C. (2015) *Schwarzmundgrundel und Meerwalnuss: Neubürger in Nord- und Ostsee: Die Globalisierung macht vor der Meeresumwelt nicht halt: Auf lange Sicht wird die Artenvielfalt darunter leiden*, newspaper: shz.de , 12.5.2015. (with P02 – DTU Aqua)

P02 – DTU Aqua:

- Gesa Seidel, Mark Lenz, Cornelia Jaspers (2015) *Forschen in der Ostsee - von großen Forschungsschiffen und kleinen Rippenquallen. Magazin snipp Dez. 2015*
- Jane Behrens og Peter Rask Møller (2015) Sortmundet kutling spreder sig hastigt i Danmark ? og truer din rejemad. Videnskab.dk 31. August 2015

P07-SYKE:

- Lehtiniemi, M.: EU:n vieraslajiasetus tuli voimaan. Ympäristö 2015, ISSN 1238-4674; 1:18-21

P12 – SMHI:

- On-line debate article in Swedish National Newspaper "Svenska Dagblandet" *There is no medicine of miracle for the Baltic Sea" (*In Swedish: *Det finns ingen mirakelmedicin för Östersjön)* by Gustafsson, B., Humborg, C., Elfwing, T., Bonsdorff, E., Norkko, A., Carstensen, J., Conley, D., Gladh, L., Andersson, H. Published 1st of September, 2015. http://www.svd.se/det-finns-ingen-mirakelmedicin-for-ostersjon

- Web article: http://www.smhi.se/en/research/research-news/summer-school-increases-knowledge-of-the-baltic-sea-region-s-future-climate-1.90758

P13 – AAU:

- 13 monthly columns in the daily newspaper Åbo Underrättelser/Erik Bonsdorff (Topic: primarily marine and environmental policy making in the light of science)

11. Number of interviews to media given by the members of the project's consortium. (35/47)

P01 – GEOMAR:

- J. Dierking. Live radio-Interview about impacts of climate change on marine fish populations, for the German radio station HR2 report “Der Tag”, topic “How El Nino is changing our world“. 12 November 2015.

P02 – DTU Aqua:

BIO-C3 September cruise on RV DANA:

- Interview to P1 by B. Huwer (live radio interview directly from RV DANA) about the BIO-C3 cruise on RV DANA, Baltic cod, Major Baltic inflows, Mnemiopsis leidyi and the BIO-C3 project in general
- Interview to Weekendavisen by B. Huwer about the BIO-C3 cruise on RV DANA, Baltic cod, Major Baltic inflows, Mnemiopsis leidyi and the BIO-C3 project in general
- Interview to DR.dk by B. Huwer about the BIO-C3 cruise on RV DANA, Baltic cod, Major Baltic inflows, Mnemiopsis leidyi and the BIO-C3 project in general
- Interview to Bornholmstidende by B. Huwer about the BIO-C3 cruise on RV DANA, Baltic cod, Mnemiopsis leidyi, herring larvae and the BIO-C3 project in general (resulting in total of 3 newspaper articles and 1 online article)
- Press release in connection with the “BIO-C3” cruise on RV DANA (16.-30.09.2015), resulting in a total coverage of >20 contributions (radio, newspaper, e-newspaper/online) about the BIO-C3 cruise on RV DANA in various national and international media.

November cruise on RV DANA:

- Interview to TV2 Bornholm by B. Huwer & M. Storr-Paulsen about Baltic cod, Major Baltic inflows, Mnemiopsis leidyi and the BIO-C3 project in general
- Interview to P4 Bornholm by B. Huwer, M. Storr-Paulsen & S.-E. Levinsky about Baltic cod, Major Baltic inflows, Mnemiopsis leidyi and the BIO-C3 project in general

Other:

- Interview to RTL (television) by Cornelia Jaspers about bio invasions in the Baltic Sea 4.11.2015
- Interview to NDR (radio) by Elizabetha Briski, Cornelia Jaspers in relation to bio invasions in the Baltic Sea 25.5.2015
- Interview to NDR (television) by Cornelia Jaspers about adaptation potential of invasive species 17.4.2015, NDR//Das! 18:45 "Quallenalarm"

- Interview to NDR (television) by Cornelia Jaspers 17.4.2015, NDR//Aktuell 21:45 Uhr, "Neue Quallenart in der Ostsee entdeckt“.

P06 – UT-EMI:

- Nurkse, K. New predators threat benthic communities in the Baltic Sea. 27th March 2015. In: novaator.err.ee (in Estonian).
- Nurkse, K., Ojaveer, H., Kotta, J. New predatory crab’s mass reproduction in Pärnu Bay. 18th June 2015. In: Maaleht 25 (1445) (in Estonian).
- Nurkse, K., Kotta., J. (2015) Ümarmudil Eesti vetes. [video] In: Aktuaalne Kaamera (Estonian National News) 09.08.2015. http://etv.err.ee/v/9cab52c6-ce6a-40a3-825a-e18f369363d8

P07 – SYKE:

- Finnish national radio broadcast (7 interviews): Alien species (2 interviews) Maiju Lehtiniemi, round goby (1) Riikka Puntila, state of Baltic Sea (4) Harri Kuosa
- Finnish national TV (2): Alien species (1) Maiju Lehtiniemi, state of the Baltic Sea (1) Harri Kuosa
- Finnish newspapers (6): State of Baltic Sea (Helsingin Sanomat (3) Harri Kuosa, Salon Seudun Sanomat (1) Harri Kuosa, Aamulehti (1) Harri Kuosa, Huvudstadsbladet (1) Harri Kuosa

P08 – KU:

- October 26, 2015. Live interview with A. Šiaulys (about ongoing environmental research within the Lithuanian coastal zone): (http://www.lrt.lt/mediateka/irasas/86423/laba_diena_lietuva#wowzaplaystart=1433000&wowzaplayduration=388000) and commentary in evening news (http://www.lrt.lt/mediateka/irasas/86443/panorama#wowzaplaystart=1070000&wowzaplayduration=118000) on National television (in Lithuanian).
- December 17, 2015. Interview (D. Vaičiūtė) for the local radio station (Radijo GAMA). The talk was about the ecological problems of the Baltic Sea, ongoing eutrophication, bio-pollution, problems and consequences. The ongoing international projects in Klaipėda University (including Bio-C3) and Lithuania were presented.

P12 – SMHI:

- Interview for Swedish Radion P4 Kalmar about BONUS BIO-C3 Summer School, July 6 http://sverigesradio.se/sida/avsnitt/567648?programid=4301 (1.20 hours into program).

P13 – AAU:

- Interview to Radio Vega Åboland, February & September 2015/EB (Nominee for a Baltic Sea environmental Prize; EU H2020-funding for marine habitat and food web research)
- Interview to newspaper Åbo Underrättelser, February & September 2015/EB (Nominee for a Baltic Sea environmental Prize; EU H2020-funding for marine habitat and food web research)

12. Number of multi-media products and TV episodes produced by the project with dissemination purpose. (8/8)

P01 – GEOMAR:

- Online blog „Integrative Baltic time series analysis with RV Alkor" on the long-term data series of Baltic pelagic systems, and on events during the BIO-C3 Alkor cruises AL454 and AL457 in April and May 2015. (Jan Dierking, Burkhard von Dewitz - 2 series of blog posts). http://www.oceanblogs.org/baltic-rvalkor/

- T. Reusch: Production of Massive Open online course (lead Future Ocean Kiel, Dr. Avan Antia), two 10 min episode on nutrient management and on coastal sea management that heavily rely on recent BONUS results

P13 – AAU:

- Anna Törnroos: Blog "Baltic Biodiversity Notes" in the BONUS blogspace (5 entries in 2015). http://www.bonusprojects.org/bonusprojects/blogs/baltic_diversity_notes

13. Number of other international, national and regional communication, dissemination and public outreach initiatives to disseminate the project's research results. (115/156)

P01 – GEOMAR:

Publications (not peer reviewed):

- J. Dierking, K. Hüssy, L. Laikre, L. 2015. Finding bridges between biodiversity research and ecosystem–based management. BONUS in Brief December 2015:2. (invited guest column) http://www.bonusportal.org/files/4481/BONUSInBriefDecember2015.pdf
- K. Hüssy, Dierking, J., Laikre, L. 2015. From genes to ecosystems: spatial heterogeneity and temporal dynamics of the Baltic Sea. ICES Annual Science Conference Theme session Q report. http://www.ices.dk/news-and-events/asc/ASC2015/Pages/Theme-Session-Q.aspx

- J. Dierking, von Dewitz, B., Elsbernd, L., Schulz, H., Bracamonte, S., Hüssy, K., Hemmer-Hansen, J., Krumme, U., Oeberst, R. Hinrichsen, H.-H., Reusch, T. 2015. Oxygen minimum hone induced rapid temporal fluctuations of Eastern Baltic cod genetic diversity. Extended abstract, ICES ASC 2015.

Presentations of project results:

- Clemmesen C., Listmann L., Sswat M., Stiasny M., Maneja R., Frommel A., Geffen A. and Reusch T.: Physiological response on a new level – gene expression analysis in herring larvae in relation to temperature and CO_2. Larval Fish Conference, Vienna, Austria, 15.06.2015
- C. Clemmesen: Effects of Ocean Acidification on Atlantic cod (*Gadus morhua*). FRAM Science Days, Tromsö, Norway, 10 – 11 November 2015
- J. Dierking, B. v. Dewitz, L. Elsbernd, S. Bracamonte, H. Schulz, K. Hüssy, H.-H. Hinrichsen, T. Reusch. Baltic cod genetic diversity in SD 25 predicted by stock structure and oxygen situation: A different perspective on the cod ageing problem? Presentation at the ICES Benchmark for the Baltic cod stocks (WKBALCOD), Rostock, Germany, 3 March 2015.
- J. Dierking, B. v. Dewitz, L. Elsbernd, H. Schulz, S. Bracamonte, K. Hüssy, J. Hemmer-Hansen, U. Krumme, R. Oeberst, H.-H. Hinrichsen, T. Reusch. Oxygen minimum zone induced rapid temporal fluctuations of Eastern Baltic cod genetic diversity. ICES Annual Science Conference, Copenhagen, Denmark, 21-24 September 2015.
- J. Dierking, B. v. Dewitz, H.-H. Hinrichsen, T. Reusch. Oxygen minimum zone induced fluctuations in cod genetic diversity – and what the Baltic Sea may tell us about the global future ocean. Sustainable Ocean Development Symposium, New York City, USA, 27-29 September 2015.
- Petereit, C. Density columns and the principle of egg buoyancy measurements. Lecture and practical demonstration during the BIO-C3 Summer school July 5th-11th 2015, Glücksburg, Germany (BIO-C3)
- T. Reusch. Ocean Ecosystems in the Face of Global Change. Keynote lecture at Marine Symposium Univ Gothenburg 16.-17.2.2015. Talk with many examples from Baltic and emerging results from BIO-C3
- T. Reusch. Adaptation of Marine Ecosystems in the Face of Global Change. Invited lecture at Station Biologique de Roscoff 13.11.2015. Talk with many examples from Baltic and emerging results from BIO-C3
- Martina H. Stiasny, Felix H. Mittermayer, Michael Sswat, Rüdiger Voss, Fredrik Jutfelt, Melissa Chierici , Velmurugu Puvanendran, Atle Mortensen, Thorsten B.H.Reusch, Catriona Clemmesen: Effects of end-of-the-century ocean acidification on Atlantic cod larvae of different populations in terms of survival, growth and recruitment to the fished stocks. ICES Annual Science Conference Copenhagen, September 2015

Posters:

- Mittermayer, F. 2015. Poster presentation “Can Cod cope?” at BONUS BIO-C3/Bambi/Inspire summer school 5-11 July 2015, Glückstadt, Germany
- Mittermayer, F. 2015 Poster presenation “Can Cod cope” at CeMEB 14th assembly 6-8. October 2015, Tjärnö, Sweden
- MIttermayer, F. 2015. Poster presentation „Is Transgenerational Adaptation to OA Mediated by Epigenetic Effects in Cod”, FRAM Science Days 10-11 November 2015 Tromsø, Norway
- Martina Stiasny, Felix Mittermayer, Rüdiger Voss, Catriona Clemmesen: Recruitment collapse of Atlantic cod under end-of-century ocean acidification. Moscow Summer Academy, 20.07.15 – 01.08.2015
- Martina Stiasny, Felix Mittermayer, Michael Sswat, Rüdiger Voss, Fredrik Jutfelt, Melissa Chierici, Velmurugu Puvanendran, Atle Mortensen, Thorsten Reusch, Catriona Clemmesen: Effects of end-of-the-century ocean acidification on Atlantic cod larvae of different populations in terms of survival and recruitment to the fished stocks. FRAM Science Days, Tromsö, Norway, 10 – 11 November 2015

P02 – DTU:

Presentations of project results:

- Behrens JW & Flindt E (2015) Take it with a grain of salt; salinity tolerance and correlated physiology of the invasive round goby *Neogobius melanostomus*. Society of Experimental Biology Main Annual Conference, Prague
- Behrens JW & Flindt E. Ny invasiv art truer Danmark. National Aquarium Denmark, August 2015
- Bekkevold, D., Gross R., Arula T., Ojaveer, H. 2015. Spring and autumn spawning herring in the Gulf of Riga: intraspecific biodiversity across small local scales. Oral presentation. ICES ASC, 21-25 Sept. 2015, Copenhagen, Denmark.
- Colin, S. P., MacPherson, R., Gemmel, B., Costello, J. H., Sutherland, K. und Jaspers, C. (2015) Elevating the predatory effect: sensory-scanning foraging strategy by the lobate ctenophore *Mnemiopsis Leidyi* [presentation] In: ASLO Aquatic Sciences Meeting 2015, 22.-27.02.2015, Granada, Spain.
- Eero, M., Andersson, H.., Rosell, E.A., MacKenzie, B.R. 2015. Has human-induced eutrophication promoted fish production in the Baltic Sea? Oceans Past V, Multidisciplinary perspectives on the history of human interactions with life in the ocean 18-20 May 2015, Tallinn, Estonia
- Eero, M., Andersson, H.., Rosell, E.A., MacKenzie, B.R. 2015. Has human-induced eutrophication promoted fish production in the Baltic Sea? ICES ASC, 21-25 Sept., 2015, Copenhagen, Denmark

- Hüssy, K., Mosegaard, H., Albertsen, C.M., Hemmer-Hansen, J., Eero, M. 2015. Stock mixing of eastern and western Baltic cod in SD 24: Baltic cod, stock discrimination, migration, otolith shape analysis [Presentation]. ICES ASC, 21-25 Sept., 2015, Copenhagen, Denmark
- Jaspers, C., Hinrichsen, H. H. und Möller, F. (2015) The invasive comb jelly Mnemiopsis Leidyi in northern Europe: transport, origin and local extinction and re-invasions of subpopulations [presentation] In: ASLO Aquatic Sciences Meeting 2015, 22.-27.02.2015, Granada, Spain.
- Jaspers, C., Weiland-Bräuer, N. und Reusch, T. B. H. (2015) The role of hybridization and microbial associations for invasion success in a comb jelly [presentation] In: Future Ocean: Cluster Retreat 2015, 14.-15.10.2015, Schleswig, Germany
- Köster, F.W.; Huwer, B.; Hinrichsen, H.-H.; Neumann, V.; Makarchouk, A.; Eero, M.; Hüssy, K.; Plikshs, M. 2015. Processes controlling recruitment in Baltic cod. ICES ASC, 21-25 Sept. 2015, Copenhagen, Denmark.

Posters:

- Behrens, J., Flindt, E., van Deurs, M. 2015. Round goby, physiology, salinity tolerance, invasive species, Baltic Sea. Salinity tolerance and correlated physiology of the invasive round goby *Neogobius melanostomus* [Poster]. ICES ASC, 21-25 Sept., 2015, Copenhagen, Denmark
- Bucholtz. R.H., Nyengaard, J., R., Andersen, J.B., Tomkiewicz. 2015. Fecundity regulation, maturation progression and spawning fidelity in relation to size, condition and age of Baltic herring (*Clupea harengus* L.). (Poster) ICES ASC, 21-25 Sept., 2015, Copenhagen, Denmark
- Jaspers, C. (2015) Invasion success - looking at a key trait [poster] In: Future Ocean: Cluster Retreat 2015, 14.-15.10.2015, Schleswig, Germany

P03 – UHH:

Presentations of project results:

- Claudia C. Günther, Jens-Peter Herrmann, Marc Hufnagl and Axel Temming Temperature effects on growth of spring and summer cohorts and implications for survival in young sprat (*Sprattus sprattus* L.) of the Western Baltic Sea. Poster. ICES ASC, 21-25 Sept. 2015, Copenhagen, Denmark.
- Kristin Hänselmann, Jens-Peter Herrmann, Rini Kulke, Klas Ove Möller, Axel Temming. Small-scale heterogeneity of zooplankton patches in the Baltic Sea. Poster. ICES ASC, 21-25 Sept. 2015, Copenhagen, Denmark.

P04 – SU:

Publications (peer-reviewed)

- Nielsen J.M. and Winder M. (2015) Seasonal dynamics of zooplankton resource use revealed by carbon amino acid stable isotope values. *Marine Ecology-Progress Series* 531, 143–154. doi: 10.3354/meps11319
- Angeler DG, Allen CR, Garmestani, AS, Gunderson LH, Hjerne O, Winder M (2015) Quantifying the adaptive cycle. PlosOne. DOI: 10.1371/journal.pone.0146053

Presentations of project results:

- Griffiths J et al. Coastal and offshore phytoplankton community interactions and environmental sensitivity differ in the northern Baltic Sea. ASLO. Granada, Feb. 2015.
- Griffiths J et al. Coastal and offshore phytoplankton community interactions and environmental sensitivity differ in the northern Baltic Sea. Invited Speaker, University of Hamburg, Germany. January 2015.
- Karlsson K et al. Adaptive Capactity to climate change of zooplankton in the Baltic Sea. ASLO, Baltic Sea Bonus session. Granada, Feb 2015.
- Winder M. Adaptive capacity to climate change of Baltic Sea copepods. ICES, Copenhagen, Sept 2015.

Posters:

- Karlsson K et al. Effect of temperature on different populations of a common Baltic Sea zooplankton. BONUS BIO-C3/BAMBI/INSPIRE 2015 Summer School, Kiel, Germany

P05 – NMFRI

Presentations of project results:

- Margonski P. and Całkiewicz J. 2015. Changes in zooplankton community and its response to various environmental stressors – the case of the southern Baltic Sea. 10th Baltic Sea Science Congress, Riga, Latvia, 15-19 June 2015 (poster no P13)
- Fey D.P. and Szymanek L. 2015. Temperature and zooplankton effects on the growth rate of larval and early-juvenile sprat (*Sprattus sprattus*) in the South Baltic Sea. Symposium on "Growth – survival paradigm in early life stages of fish: controversy, synthesis, and multidisciplinary approach", Yokohama, Japan, 9–11 November 2015 (poster)

P06 – UT-EMI:

Publications (peer-reviewed):

- 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.
- Kotta, J., Oganjan, K., Lauringson, V., Pärnoja, M., Kaasik, A., Rohtla, L., Kotta, I., Orav-Kotta, H. 2015. Establishing functional relationships between abiotic environment, macrophyte coverage, resource gradients and the distribution of *Mytilus trossulus* in a brackish non-tidal environment. PLoS ONE 08/2015; 10(8):e0136949. DOI:10.1371/journal.pone.0136949
- Kuprijanov, I., Kotta, J., Lauringson, V., Herkül, K. 2015. Trophic interactions between native and alien palaemonid prawns and an alien gammarid in a brackish water ecosystem. Proceedings of the Estonian Academy of Sciences, 64, In press.
- Lokko, K., Kotta, J., Orav-Kotta, H., Nurkse, K., Pärnoja, M. 2015. Introduction of a functionally novel consumer to a low diversity system: Effects of the mud crab *Rhithropanopeus harrisii* on meiobenthos. Estuarine, Coastal and Shelf Science. doi:10.1016/j.ecss.2015.11.017

Publications (not peer-reviewed):

- Ojaveer, H., Olenin, S., Minchin, D. and Boelens, R. 2015. Proposal for IMO Ballast Water Management Convention A-4 Target Species selection criteria. Document submitted to HELCOM Workshop on IMO BWMC target species, criteria and revision process (Tallinn, Estonia; 26 August 2015).

Presentations of project results:

- Arula, T., Ojaveer, H., Raid, T. (2015). 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).
- 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).

- Kotta, J., Kotta, I., Bick, A., Bastrop., R., Väinölä, R. (2015). Description, habitat range and seasonality of a new non-indigenous polychaete Laonome sp. (Sabellida, Sabellidae) the north-eastern Baltic Sea. 10th Baltic Sea Science Congress, 15-19 June 2015, Riga, Latvia.
- Nurkse, K. (2015). Highlights of the recent round goby research in Estonia. Gobies as a model for invasion biology, evolutionary ecology, and reproductive strategies". A Marcus Wallenberg symposium held in Sweden, Umea 24-27. February 2015.
- Nurkse, K. (2015). Round goby (*Neogobius melanostomus*). XVII Marine biology winter seminar. 4-5. February 2015 in Estonia, Kiviõli. (in Estonian)
- Nurkse, K., Kotta, J., Orav-Kotta, H., Kotta, I., Pärnoja, M., Ojaveer, H. (2015). Invasive epibenthic predators' impact on benthic communities functioning. 10th Baltic Sea Science Congress, 15-19 June 2015, Riga, Latvia.
- Ojaveer, H. BONUS projects INSPIRE and BIO-C3. Conference about international cooperation. Tallinn, Estonia, 3. December 2015.
- Ojaveer, H., Olenin, S., Minchin, D. and Boelens, R. 2015. Proposal for IMO Ballast Water Management Convention A-4 Target Species selection criteria. HELCOM Workshop on IMO BWMC target species, criteria and revision process (Tallinn, Estonia; 26 August 2015).
- Ojaveer, H., Teder, M., Simm, M., Raid, T. and Klais, R. 2015. Feeding eceology of pelagic fish in the Gulf of Riga. ICES WKSPATIAL (Rome, Italy, 3-6. Nov. 2105).
- Ojaveer, H., Tomkiewicz, J., Aryual, 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).
- Ojaveer, H. Non-indigenous species. Open lecture in Pärnu bibliotheca. 30. March 2015. Estonia, Pärnu. (in Estonian)
- Ojaveer, H. Non-indigenous species. Lecture at workshop organised by Koidula Gymnasium. 15. April 2015. Estonia, Pärnu. (in Estonian)
- Ojaveer, H. 2015. AquaNIS in action: comprehensive overview on the non-indigenous species invasions and the vectors responsible in the Baltic Sea. 10th Baltic Sea Science Congress, 15-19 June 2015, Riga, Latvia.
- Puntila, R., Granhag, L., Normant, M., Ojaveer, H., Strake, S. and Lehtiniemi, M. 2015. Baseline surveys of non-indigenous species in the Baltic Sea ports - Testing and evaluating the HELCOM-OSPAR Port Survey Protocol. ICES ASC (Copenhagen, Denmark 21-25. September 2015).

P07 – SYKE:

Presentations of project results:

- Puntila, R., Forsström, T.; Vesakoski, O., Riipinen, K.; Fowler, A.; Lehtiniemi, M.: The role of the invasive Harris mud crab (Rhithropanopeus harrisii) in the coastal food web of the Northern Baltic Sea. Oral presentation in the CERF meeting 08. – 12.11.2015 in Portland, Oregon.

- Puntila, R., Loisa, O., Fowler, S.and Riipinen, K. 2015. A taste for aliens? Incorporation of a novel prey item into native fishes diet. Oral presentation at the Benthic Ecology Meeting 04.-08.03.2015 in Quebec City, Canada.
- Kuosa, Harri: Alien species in Finland, Rauma high school 11.03.2015
- Kuosa, Harri: State of the Baltic Sea, Laajasalo preliminary school and high school 21.04.2015
- Kuosa, Harri: Winter biology of the Baltic Sea, Archipelago Sea Conference, Kemiönsaari 05.03.3015
- Kuosa, Harri: Future Baltic Sea biodiversity, Baltic Sea Days, St. Petersburg 19.03.2015
- Kuosa, Harri: State of the Baltic Sea, John Nurminen Foundation Seminar 18.08.2015, Helsinki

P08 – KU:

Publications (peer-reviewed):

- Zaiko A., Samulioviene A., Ardura A., Garcia-Vazquez E. 2015. Metabarcoding approach for non-indigenous species surveillance in marine coastal waters. Marine Pollution Bulletin, 100:53-59.
- Ardura A., Zaiko A., Martinez J.L., Samuiloviene A., Semenova A., Garcia-Vazquez E. 2015. eDNA and specific primers for early detection of invasive species- a case study on the bivalve *Rangia cuneata*, currently spreading in Europe. Marine Environmental Research, 112(B): 48-55.
- Skabeikis A., Lesutienė J. 2015. Feeding activity and diet composition of round goby (*Neogobius melanostomus*) in the coastal waters of SE Baltic Sea. Oceanological and Hydrobiological Studies 44(4): 508-519.

Presentations of project results:

- Oct 7, 2015 – Seminar at the Cawthron Institute, New Zealand – “Mission Impossible: measure unmeasurable and compare uncomparable”, presented by A. Zaiko
- Sep 29 - Oct 1, 2015 - Course for PhD students "Fish and Fisheries Evolutionary Ecology", Kristineberg, Sweden - oral presentation ''Resource competition between round goby (*Neogobius melanostomus*) and eelpout (*Zoarces viviparus*)'', presented by A. Skabeikis.
- Sep 21-25, 2015 - ICES Annual Science Conference, Copenhagen, Denmark – oral presentation “Assessing biofouling community succession using a metabarcoding approach”, presented by A. Zaiko.
- Sep 21-25, 2015 - ICES Annual Science Conference, Copenhagen, Denmark – poster presentation “Abundance and composition of zooplankton communities in the continuum of the Nemunas river, Curonian Lagoon and Baltic Sea”, presented by E. Grinienė.
- Sep 17, 2015 – Seminar at the Klaipeda University, Lithuania - “Studies of marine biofilm communities – early succession patterns and implications for marine bioinvasions” (in Lithuanian), presented by A. Zaiko.

- Sept 7-11, 2015 - XV European Congress of Ichthyology - oral presentation ''Feeding activity and diet composition of round goby (*Neogobius melanostomus*, Pallas 1814) in the coastal waters of SE Baltic Sea'', presented by A. Skabeikis.
- Aug 31- Sep 4, 2015 - 1st Hjort Summer School "Fishing and physics as drivers of marine ecosystem dynamics", Bergen, Norway - oral presentation ''Feeding ecology of round goby (*Neogobius melanostomus*) in the coastal waters of SE Baltic Sea'', presented by A. Skabeikis.
- Jul 5-11, 2015 - BONUS BIO-C3/BAMBI/INSPIRE 2015 Summer School "The Baltic Sea: a model for the global future ocean?", Glücksburg, Germany - poster presentation ''Role of the round goby (*Neogobius melanostomus*) in the food web of the Baltic Sea exposed coastal waters'', presented by A.Skabeikis.
- Jun 15-19, 2015 - 10th Baltic Sea Science Congress, Riga, Latvia – oral presentation “Molecular approaches for non-indigenous species surveillance – from introduction pathways to established populations”, presented by A. Zaiko.
- Jun 15-19, 2015 - 10th Baltic Sea Science Congress, Riga, Latvia – poster presentation “Major decline of blue mussel *Mytilus spp.* population in coastal Lithuanian Baltic sea”, presented by A. Stulpelytė.
- Jun 9-12, 2015 - 10th Baltic Sea Science Congress, Riga, Latvia – poster presentation “Ecological niche modelling of non-indigenous spionid *Marenzelleria sp*. in the SE Baltic Sea”, presented by A. Šiaulys
- Jun 9-12, 2015 – 10th Baltic Sea Science Congress, Riga, Latvia – poster presentation “Abundance and composition of zooplankton communities in the continuum of the Nemunas river, Curonian Lagoon and Baltic Sea”, presented by M. Juodeikytė.
- May 5, 2015 - Marine Biosecurity Annual Forum on Marine Biosecurity Research, Wellington, New Zealand – oral presentation "Enhancing Marine Biosecurity Using Next-Generation Molecular Tools", presented by X. Pochon (co-authored by A.Zaiko).
- April 24, 2015 – national student science conference “Environmental research and protection – towards development of sustainable society”, Grūšlaukė, Lithuania – opening presentation “Marine environmental protection in Lithuania” (in Lithuanian), presented by A. Šiaulys.

P09 – DHI:

Presentations of project results:

- Rasmussen EK, Uhrenholdt T, Middelboe AL, Skov H, Hansen FT Ecological model of the Riga Bay area: a contribution to the BONUS project BIO-C3. 10th Baltic Sea Science Conference, 15-19 June 2015

P10 – UGOT:

Technical reports

- Technical report for the Swedish Agency for Marine and Water Management (SwAM) about guidelines how to extend MPA networks to improve connectivity and coherence of MPAs in the Kattegat area.

Presentations of project results:

- Regular communication with the County Administrative Board in Västra Götaland, Sweden.
- Skype meeting (March 13, 2015) with HELCOM secretariat (Janica Borg) about MPA inventory for BIO-C3.
  P11 – TI-OF

Publications (not peer-reviewed)

- Kotterba, P.: Atlantic herring (*Clupea harengus*) within the estuarine food web of a southern Baltic Sea lagoon. 2015. PhD thesis, 173pp. Hamburg University.
- Henseler, C., Bock, C., Kotterba, P., Winkler, H., Oesterwind, D. 2015. Biology, abundance and feeding ecology of the round goby (*Neogobius melanostomus*) in the eastern German Baltic. Extended Abstract, ICES Annual Science Conference, Copenhagen 21. – 25 September 2015.

Presentations

- Kotterba, P.: Atlantic herring *Clupea harengus* within the estuarine food web of southern Baltic lagoons. 2015. Talk. Disputation at the Institute for Hydrobiology and Fisheries Science of the University of Hamburg, Germany.
- Moll, D., Kotterba, P., v. Nordheim, L., and P. Polte: Spawning bed selection of Atlantic herring in the waters of the Western Baltic Sea. Talk. 2015. 39th Annual Larval Fish Conference, Vienna, Austria.
- Polte, P., Kotterba, P., Heiler, J., Beyer, S., Moll, D., and L. v. Nordheim: Loops of near-shore habitat use by early herring (*Clupea harengus*) life stages in the Western Baltic Sea. Talk. 2015. ICES Annual Science Conference, Copenhagen, Denmark.
- Kotterba, P., Moll, D., Hammer, C., and P. Polte: Estuarine stickleback predation on the eggs of inshore-spawning Atlantic herring in the Baltic Sea. Talk. 2015. 23rd biennial CERF conference, Portland, Oregon, USA.
- Polte, P., Kotterba, P., Moll, D., and L. v. Nordheim: Drivers and stressors of Atlantic herring (*Clupea harengus*) recruitment in inshore Baltic Sea spawning areas. Talk. 2015. 23rd biennial CERF conference, Portland, Oregon, USA.
- Kotterba, P., Beyer, S., Heiler, S., Moll, D., and P. Polte: Habitat utilization of herring larvae in an inshore retention area in the Western Baltic Sea. Talk. 2015. 50th European Marine Biology Symposium, Helgoland, Germany.

- Moll, D., Kotterba, P., and P. Polte: Spawning bed selection of Atlantic herring in coastal waters of the Western Baltic Sea. Talk. 2015. 50th European Marine Biology Symposium, Helgoland, Germany.
- Henseler, C., Bock, C., Kotterba, P., Winkler, H., Oesterwind, D. 2015. Biology, abundance and feeding ecology of the roundgoby (*Neogobius melanostomus*) in the eastern German Baltic. ICES Annual Science Conference, Copenhagen 21. – 25 September 2015.
- Kotterba, P.: Atlantic herring *Clupea harengus* within the estuarine food web of southern Baltic lagoons. 2015. Talk. Herring Recruitment workshop, Rostock, Germany.
- Moll, D., Kotterba, P., and P. Polte. Otolith chemistry – An opportunity to estimate the importance of single spawning grounds to the overall population of the WBSSH. 2015. Talk. Herring Recruitment workshop, Rostock, Germany.
- Moll, D., Kotterba, P., v. Nordheim, L., and P. Polte. Spawning bed selection of Atlantic herring in the waters of the Western Baltic Sea. 2015. Talk. Herring Recruitment workshop, Rostock, Germany.
- Polte, P., Beyer, S., Heiler, J., and P. Kotterba. Loops of near shore habitat use by early herring (*Clupea harengus*) life stages in the Western Baltic Sea. 2015. Talk. Herring Recruitment workshop, Rostock, Germany.
- Oesterwind, D. Distribution of adult herring at Rügen Island – Metadata. 2015, Herring Recruitment workshop, Rostock, Germany

Posters

- Winkler, H., Kotterba, P., Oesterwind, D. 2015. Round Goby: A story of invasive success in the Baltic. ICES Annual Science Conference, Copenhagen 21. – 25 September 2015.

P12 – SMHI:

Presentations of project results:

- Almroth-Rosell,E., Eero, M., Andersson, H., and MacKenzie, B.R.: Eutrophication no major driver of forage fish production in the Baltic Sea, The Swedish Society for Marine Sciences annual Swedish Marine Science conference, 2015
- Eero M, Andersson, H.C., Almroth-Rosell, E., MacKenzie, B.R.: Has human-induced eutrophication promoted fish production in the Baltic Sea? ICES ASC 2015

P13 – AAU:

Publications (peer-reviewed)

- Törnroos, A., E. Bonsdorff, J. Bremner, M. Blomqvist, A. B. Josefson, C. Garcia & J. Warzocha, 2015: Marine benthic ecological functioning over decreasing taxonomic richness. - J. Sea Res. 98: 49-56. doi: 10.1016/j.seares.2014.04.010
- Aarnio, K., A. Törnroos, C. Björklund & E. Bonsdorff, 2015: Food web positioning of a recent coloniser: the North American Harris mud crab *Rhithropanopeus harrisii* (Gould, 1841) in the northern Baltic Sea. - Aquatic Invasions 10: 399-413. doi.org/10.3391/ai.2015.10.4.04
- Törnroos, A., M. C. Nordström, K. Aarnio & E. Bonsdorff, 2015: Environmental context and trophic trait plasticity in a key species, the tellinid clam *Macoma balthica* L. - J. Exp. Mar. Biol. Ecol. 472: 32-40. doi:10.1016/j.jembe.2015.06.015

Presentations of project results:

- BSSC, Riga, Latvia, June 2015/EB, AT; oral presentation: "Interpreting ecological functioning in coastal waters: spatial and temporal trait patterns across the Baltic Sea"
- ICES, Copenhagen, Denmark, September 2015/AT; oral presentation Q10:" Long-term functional trends in Baltic Sea coastal macrofauna and fish"
- The Royal Swedish Academy of Sciences (275 y anniversary conference; invited presentation), Gothenburg, Sweden, February 2015/EB: "The ecology of the coastal filter in the Baltic Sea – structure, function, and adaptation"

14. Number of post graduate courses organized by the project and persons participating. (2/2); (60/60)

P01 – GEOMAR (with contributions of lecturers from P01, 03, 05, 12, as well as BONUS INSPIRE and BAMBI):

- Organization of the BONUS BIO-C3/BAMBI/INSPIRE Summer school *The Baltic Sea: a model for the global future ocean?*, Glücksburg, Germany, July 5-11 2015, organizers J. Dierking, T. Reusch. 32 participating PhD students and postdocs and 13 lecturers from 8 nations. (www.bio-c3/links).

P09 – DHI

- ECOlab - A framework for bio-geochemical modelling. Course in ecological modelling. 25-26 August 2015 at DHI, Hørsholm, Denmark; 15 course participants.

15. Number of mobility activities (persons, visit days) from the project to the other BONUS projects. (14/21); (39/72)

P01 – GEOMAR:

- Participation Thorsten Reusch in BONUS BAMBI annual project meeting in Estonia, 25.-26. August (2 days)

P03 – UHH:

- 3 persons (Jens-Peter Herrmann, Jan Niemax, Kristin Hänselmann) one day each coordinating field sampling of round goby with INSPIRE , on the 14th August in Gdynia, Poland.

P05 – NMFRI:

- Dariusz Fey and Piotr Margoński participated in the BONUS INSPIRE project workshop organized by DTU AQUA in Charlottenlund (September 25th, 2015): 2 persons, 1 day visit each

P06 – UT-EMI:

- Participation in BONUS BAMBI project meeting (Tallinn 24.08.2015-26.08.2015): Jonne Kotta, 3 days.
- Participating in INSPIRE project meetings, Henn Ojaveer, 2 activities, 5 days:
    - Annual meeting and the second integrating workshop, 10-13.02.2015
    - Third integrating workshop, 25.09.2015
- Henn Ojaveer was hosted by Brian MacKenzie (P02 – DTU-Aqua), for 7 days to work on autumn Riga herring stock, collaboration INSPIRE and BIO-C3.

P07 – SYKE:

- Riikka Puntila, 4 days, BONUS INSPIRE round goby sampling in Lithuania.

P10 – UGOT:

- Per Jonsson and Hanna Corell (post.doc) visited Tallinn (hosted by University of Tartu) within the Bonus-BAMBI project for 5 days in August 2015.

P13 – AAU:

- Representation of BIO-C3 at COCOA-meeting, (Erik Bonsdorff) (3 days)

16. Number of PhD students and the number of post-docs funded by the project, number of doctoral thesis defended. (6/15) ; (4/14) ; (1/1)

P01 – GEOMAR:

2 PhD students: Burkhard von Dewitz, Felix Mittermayer; 1 postdoc: Jan Dierking, scientific coordination of BIO-C3

P02 – DTU Aqua:

1 PhD student: Anette Maria Christensen (shared with IOW Warnemünde)

P03 – UHH:
1 PhD student, Jan Niemax, 1 Postdoc, Claudia Günther

P04 – SU:
1 PhD student, Konrad Karlsson, 1 Postdoc Olle Hjerne

P07 – SYKE:
1 PhD student: Riikka Puntila (partly funded)

P08 – KU:
1 PhD student: Arturas Skabeikis (partly funded, Klaipeda University); 3
Post-docs: Diana Vaičiūtė, Aurelija Samuilovienė and Andrius Šialulys (all partly funded).

P11 – TI-OF:
1 postdoc: Paul Kotterba (full funding); 1 PhD: Leyre Goti (partial funding); 1 PhD thesis defended (Kotterba, P.: Atlantic herring (*Clupea harengus*) within the estuarine food web of a southern Baltic Sea lagoon. 2015. PhD thesis, 173pp. Hamburg University)

P12 – SMHI:
1 Postdoc partly funded: Elin Almroth Rosell

P13 – AAU:
1 Postdoc: Anna Törnroos

17. Table of distribution of the project's research staff involved (copied from EPSS)

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	2	0	0	1	0	0	0	0	0
25 - 49	11	7	12	5	7	3	13	15	1	5
50 - 64	0	0	0	0	0	1	3	6	0	8
>= 65	0	0	0	0	0	0	0	0	0	0

18. List of other significant in kind, free of charge research infrastructures

Contributions are summarized in the EPSS system.

19. List of other than infrastructure in kind contributions

Contributions are summarized in the EPSS system.

20. Other contributions

P01 – GEOMAR:

During 2015, preparations for two activities that will take place in 2016 were initiated: the BIO-C3 highschool teacher training workshop on Baltic biodiversity and ecosystem functioning from September 9.-10. 2016 at Schloss Noer, Eckernfoerde Fjord, Germany (25-30 participants expected), and the 3-day cross BONUS project concept paper writing workshop "The Baltic Sea: a model for the global future ocean?" planned for Nov./Dec. 2015. The latter event will be funded by BONUS clustering activity funds.

P02 – DTU Aqua:

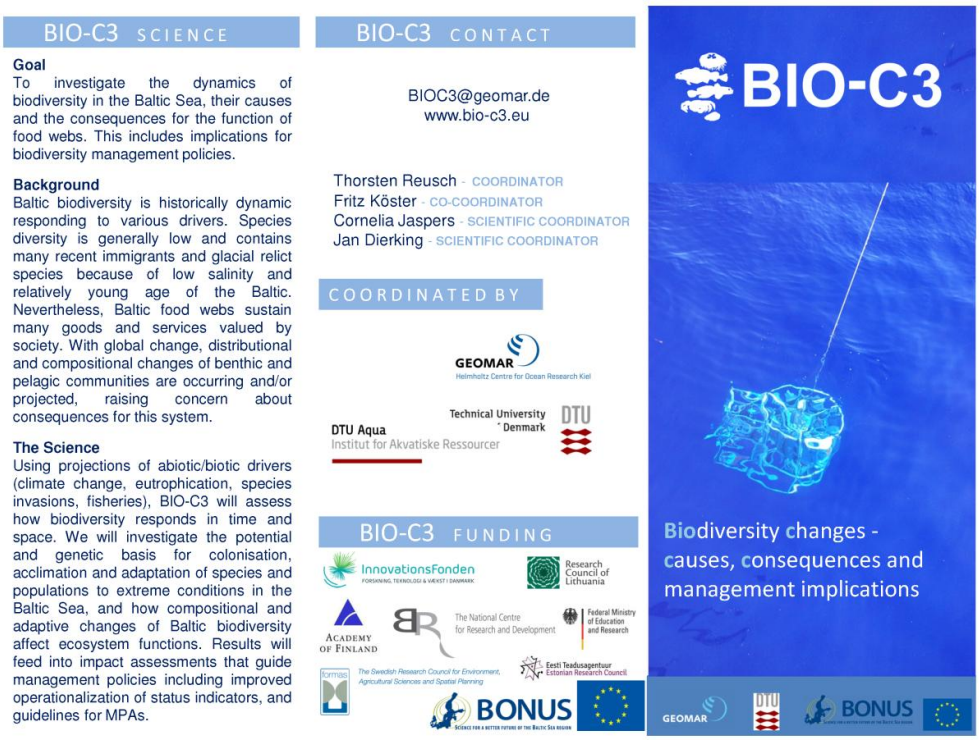
During 2015, planning for the BIO-C3/BAMBI/INSPIRE/COCOA summer school on "Modelling biodiversity for sustainable use of Baltic Sea living resources" took place. The course will take place in Denmark during August 2016, and announcement and call for registration is expected to be circulated in March-April 2016. The course is intended for Phd students and postdoctoral scientists.

21. List of PhD, MSc and BSc theses defended in 2015

Partner	Student	Title	Year
PhD theses			
P03 – UHH, P11 – TI-OF	Paul Kotterba	Atlantic herring (*Clupea harengus*) within the estuarine food web of a southern Baltic Sea lagoon. 173pp. Hamburg University	2015
Msc theses			
P01 – GEOMAR	Ramona Beckmann	Effects of microzooplankton on the planktonic food web. Kiel University	2015
P01 – GEOMAR	Lea Kraienhemke	Stable isotope fractionation rate in the carnivorous jellyfish *Mnemiopsis leidyi.* Kiel University.	2015
P02 – DTU Aqua	Katharina Bading	Healing & regeneration assessments on the ctenophore *Mnemiopsis leidyi* in its larval life cycle stage with observations on larval reproduction. DTU Aqua	2015
P04 – SU	Lia Simona Puiac	Effects of salinity and temperature on the development of *Eurytemora affinis* from the Baltic Sea. Stockholm University	2015
P11 – TI-OF	V. Siebert	The Spatial and Temporal Distribution of Cod (*Gadus morhua*), Herring (*Clupea harengus*) and Sprat (*Sprattus sprattus*) in the Bornholm Basin as resolved by hydroacoustics. Rostock University	2015
P11 – TI-OF	M. Gabel	Rolle der Schwarzmundgrundel (*Neogobius melanostomus*) in der Ernährung des Kormorans (*Phalacrocorax carbo sinensis*) an der Vorpommerschen Küste. Universität Rostock	2015
P11 – TI-OF	C. Bock	Seasonal habitat utilization and feeding ecology of round goby (*Neogobius melanostomus*) within the Pomeranian Bight. Universität Rostock,	2015
P11 – TI-OF	C. Henseler	Habitat specific feeding ecology of the round goby (*Neogobius melanostomus*) in the Greifswald Bay. Universität Rostock	2015
BSc theses			
Co-supervision INSPIRE and BIO-C3 P01 – GEOMAR	Sophia Nyberg	Egg buoyancy and survival probabilities of Baltic Flounder (*Platichthys flesus*) – Differences between spawning areas and inter-annual variation in conditions for reproduction	2015

Appendix 1: BIO-C3 project flyer and website

1. Front page of the BIO-C3 flyer distributed at numerous occasions in 2015



BIO-C3 SCIENCE

Goal
To investigate the dynamics of biodiversity in the Baltic Sea, their causes and the consequences for the function of food webs. This includes implications for biodiversity management policies.

Background
Baltic biodiversity is historically dynamic responding to various drivers. Species diversity is generally low and contains many recent immigrants and glacial relict species because of low salinity and relatively young age of the Baltic. Nevertheless, Baltic food webs sustain many goods and services valued by society. With global change, distributional and compositional changes of benthic and pelagic communities are occurring and/or projected, raising concern about consequences for this system.

The Science
Using projections of abiotic/biotic drivers (climate change, eutrophication, species invasions, fisheries), BIO-C3 will assess how biodiversity responds in time and space. We will investigate the potential and genetic basis for colonisation, acclimation and adaptation of species and populations to extreme conditions in the Baltic Sea, and how compositional and adaptive changes of Baltic biodiversity affect ecosystem functions. Results will feed into impact assessments that guide management policies including improved operationalization of status indicators, and guidelines for MPAs.

BIO-C3 CONTACT

BIOC3@geomar.de
www.bio-c3.eu

Thorsten Reusch - COORDINATOR
Fritz Köster - CO-COORDINATOR
Cornelia Jaspers - SCIENTIFIC COORDINATOR
Jan Dierking - SCIENTIFIC COORDINATOR

COORDINATED BY

GEOMAR Helmholtz Centre for Ocean Research Kiel
DTU Aqua Institut for Akvatiske Ressourcer
Technical University of Denmark

BIO-C3 FUNDING

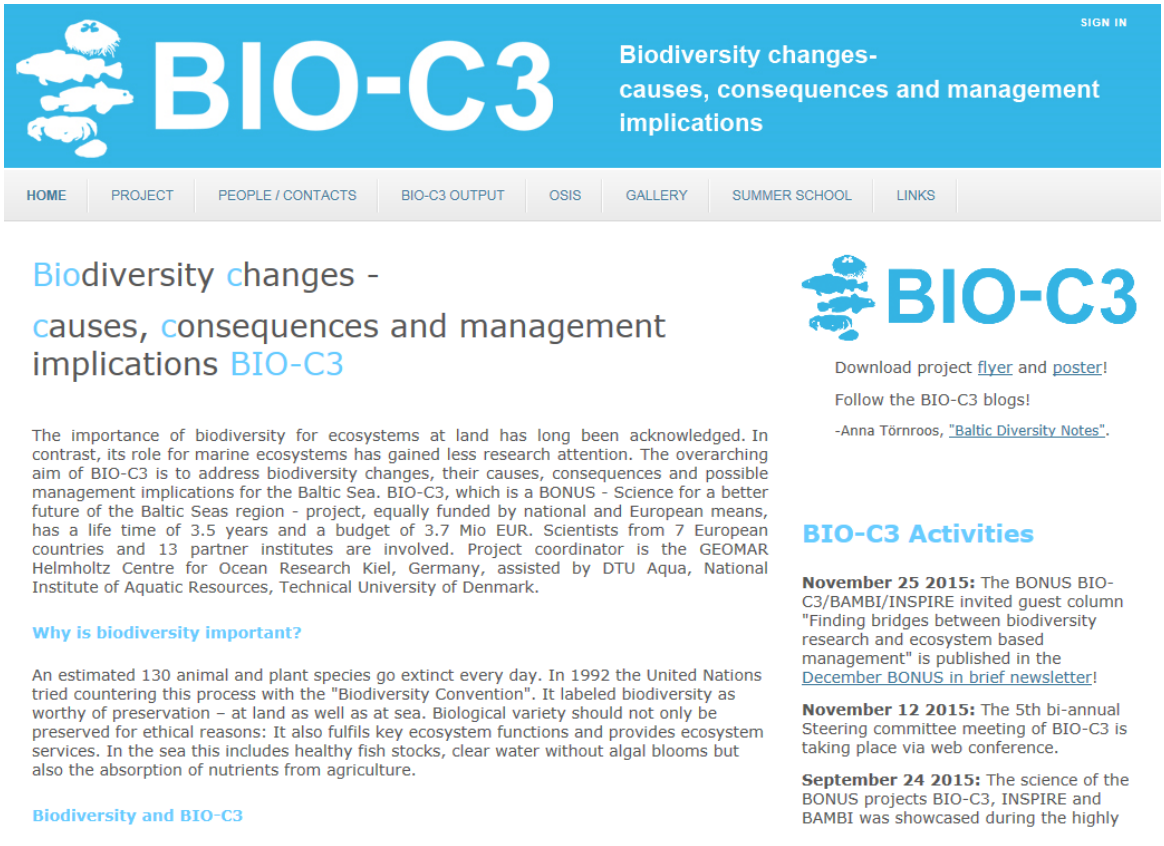
InnovationsFonden
Research Council of Lithuania
Academy of Finland
The National Centre for Research and Development
Federal Ministry of Education and Research
Formas
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
Eesti Teadusagentuur Estonian Research Council
BONUS

BIO-C3

Biodiversity changes - causes, consequences and management implications

GEOMAR DTU BONUS

2. Start page of the public website of BIO-C3 (www.bio-c3.eu, accessed 24.02.2016)



SIGN IN

BIO-C3

Biodiversity changes- causes, consequences and management implications

HOME | PROJECT | PEOPLE / CONTACTS | BIO-C3 OUTPUT | OSIS | GALLERY | SUMMER SCHOOL | LINKS

Biodiversity changes -
causes, consequences and management implications BIO-C3

The importance of biodiversity for ecosystems at land has long been acknowledged. In contrast, its role for marine ecosystems has gained less research attention. The overarching aim of BIO-C3 is to address biodiversity changes, their causes, consequences and possible management implications for the Baltic Sea. BIO-C3, which is a BONUS - Science for a better future of the Baltic Seas region - project, equally funded by national and European means, has a life time of 3.5 years and a budget of 3.7 Mio EUR. Scientists from 7 European countries and 13 partner institutes are involved. Project coordinator is the GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, assisted by DTU Aqua, National Institute of Aquatic Resources, Technical University of Denmark.

Why is biodiversity important?

An estimated 130 animal and plant species go extinct every day. In 1992 the United Nations tried countering this process with the "Biodiversity Convention". It labeled biodiversity as worthy of preservation – at land as well as at sea. Biological variety should not only be preserved for ethical reasons: It also fulfils key ecosystem functions and provides ecosystem services. In the sea this includes healthy fish stocks, clear water without algal blooms but also the absorption of nutrients from agriculture.

Biodiversity and BIO-C3

BIO-C3

Download project flyer and poster!

Follow the BIO-C3 blogs!

-Anna Törnroos, "Baltic Diversity Notes".

BIO-C3 Activities

November 25 2015: The BONUS BIO-C3/BAMBI/INSPIRE invited guest column "Finding bridges between biodiversity research and ecosystem based management" is published in the December BONUS in brief newsletter!

November 12 2015: The 5th bi-annual Steering committee meeting of BIO-C3 is taking place via web conference.

September 24 2015: The science of the BONUS projects BIO-C3, INSPIRE and BAMBI was showcased during the highly

Appendix 2: BIO-C3 scientist memberships and participations in stakeholder committees in 2015 (n = 102 in total)

Last name	First name	Affiliation	Working group (ICES, HELCOM, OSPAR etc.)
Clemmesen-Bockelmann	Catriona	GEOMAR	ICES WGRP (Working Group on Recruitment Processes)
Dewitz	Burkhard	GEOMAR	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Dierking	Jan	GEOMAR	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Hinrichsen	H.-H.	GEOMAR	DEMO (DEMOnstration exercise for Integrated Ecosystem Assessment and Advice of Baltic Sea fish stocks)
Hinrichsen	H.-H.	GEOMAR	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Petereit	Christoph	GEOMAR	ICES WGBAST
Andersen	Ken Haste	DTU Aqua	ICES WKSPATIAL
Behrens	Jane	DTU Aqua	ICES WKSIBCA
Behrens	Jane	DTU Aqua	HELCOM 'Abundance and distribution of round goby (*Neogobius melanostomus)*'
Bekkevold	Dorte	DTU Aqua	ICES WGAGFM
Bekkevold	Dorte	DTU Aqua	ICES WGIMT
Dutz	Jörg	DTU Aqua/IOW	ICES WGZE
Eero	Margit	DTU Aqua	ICES WGSPATIAL
Eero	Margit	DTU Aqua	ICES WGBFAS
Eero	Margit	DTU Aqua	ICES WGHIST
Eero	Margit	DTU Aqua	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Hemmer Hansen	Jakob	DTU Aqua	ICES WGAGFM
Hemmer Hansen	Jakob	DTU Aqua	ICES WGNSSK
Huwer	Bastian	DTU Aqua	ICES WGALES
Huwer	Bastian	DTU Aqua	ICES WGBIFS
Jaspers	Cornelia	DTU Aqua	ICES JWMS (Joint workshop on Mnemiopsis science)
Köster	Fritz	DTU Aqua	ICES Bureau
Köster	Fritz	DTU Aqua	ICES Council
Köster	Fritz	DTU Aqua	ICES CWGMTC
Köster	Fritz	DTU Aqua	ICES CSIMTC
Köster	Fritz	DTU Aqua	ICES CWGIBM
Köster	Fritz	DTU Aqua	ICES WKBALCOD

Lindegren	Martin	DTU Aqua	ICES WGCOMEDA
Lindegren	Martin	DTU Aqua	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
MacKenzie	Brian	DTU Aqua	ICES SCCIME (Strategic Initiative on Climate Change Effects on Marine Ecosystems)
MacKenzie	Brian	DTU Aqua	ICES WGHIST
MacKenzie	Brian	DTU Aqua	ICES WGRFE
MacKenzie	Brian	DTU Aqua	ICES WKSPATIAL
Neuenfeldt	Stefan	DTU Aqua	ICES WKSPATIAL
Neuenfeldt	Stefan	DTU Aqua	ICES WGBFAS
Neuenfeldt	Stefan	DTU Aqua	ICES WGBIODIV
Neuenfeldt	Stefan	DTU Aqua	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Neuenfeldt	Stefan	DTU Aqua	ICES WGIPEM
Neuenfeldt	Stefan	DTU Aqua	ICES WGSAM
Neuenfeldt	Stefan	DTU Aqua	ICES WKBREF
Tomkiewicz	Jonna	DTU Aqua	ICES WKMSGAD
Pecuchet	Laurene	DTU Aqua	ICES WGCOMEDA
Pecuchet	Laurene	DTU Aqua	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Temming	Axel	UHH-IHF	ICES WGCRAN
Horbowy	Jan	NMFRI	ICES WGBFAS (Baltic Fisheries Assessment Working Group)
Luzenczyk	Anna	NMFRI	ICES WGBFAS (Baltic Fisheries Assessment Working Group)
Margonski	Piotr	NMFRI	ICES WGZE (Working Group on Zooplankton Ecology)
Margonski	Piotr	NMFRI	ICES/HELCOM WGIAB (Working Group on Integrated Assessments of the Baltic Sea)
Radtke	Krzysztof	NMFRI	ICES WGBFAS (Baltic Fisheries Assessment Working Group)
Radtke	Krzysztof	NMFRI	ICES WGBIFS (Baltic International Fish Survey Working Group)
Radtke	Krzysztof	NMFRI	ICES WGRFS (Working Group on Recreational Fisheries Surveys)
Smolinski	Szymon	NMFRI	ICES WGBIOP (Working Group on Biological Parameters)
Warzocha	Jan	NMFRI	ICES BEWG (Benthos Ecology Working Group)
Woźniczka	Adam	NMFRI	ICES WGBYC (Working Group on Bycatch of Protected Species)
Kalaus	Marilyn	UT-EMI	ICES WGITMO (Working Group on Introductions and Transfers of Marine Organisms, member)
Klais	Riina	UT-EMI	SCOR WG137 (Global Phytoplankton Group)
Klais	Riina	UT-EMI	ICES WKSPATIAL (Workshop on Spatial Analyses for the Baltic Sea, member)

Ojaveer	Henn	UT-EMI	ICES WKSPATIAL (Workshop on Spatial Analyses for the Baltic Sea, member)
Ojaveer	Henn	UT-EMI	ICES CSWGIS (The Council SCICOM Working Group on ICES Science)
Ojaveer	Henn	UT-EMI	OPI (Global network on Oceans Past Initiative, executive committee member)
Ojaveer	Henn	UT-EMI	ICES SSGEPI (Steering Group on Ecosystem Pressures and Impacts, chair)
Ojaveer	Henn	UT-EMI	ICES SCICOM (Science Committee, member)
Ojaveer	Henn	UT-EMI	ICES WGBOSV (Working Group on Ballast and Other Ship Vectors, member)
Ojaveer	Henn	UT-EMI	ICES WGIAB (Working Group on Integrated Assessments of the Batic Sea, member)
Ojaveer	Henn	UT-EMI	ICES WGITMO (Working Group on Introductions and Transfers of Marine Organisms, chair)
Ojaveer	Henn	UT-EMI	ICES Awards Committee, member
Ojaveer	Henn	UT-EMI	EU JPI Oceans (management board member)
Ojaveer	Henn	UT-EMI	UN Regular Process for Global Reporting and Assessment of the State of the Marine Environment (nominated expert)
Ojaveer	Henn	UT-EMI	Joint HELCOM/OSPAR Task Group on Ballast Water Management Convention Exemptions, member
Ojaveer	Henn	UT-EMI	HELCOM MARITIME ad hoc Correspondence Group on Ballast Water Management, member
Orav-Kotta	Helen	UT-EMI	BMB member
Kuosa	Harri	SYKE	HELCOM CORESET II
Kuosa	Harri	SYKE	HELCOM PEG
Kuosa	Harri	SYKE	UN Regular Process (State of marine environment)
Lehtiniemi	Maiju	SYKE	HELCOM MONAS
Lehtiniemi	Maiju	SYKE	HELCOM CORESET II
Lehtiniemi	Maiju	SYKE	HELCOM MORE
Lehtiniemi	Maiju	SYKE	HELCOM/Ospar TG Ballast
Lehtiniemi	Maiju	SYKE	ICES/IOC/IMO WGBOSV (Working Group on Ballast and Other Ship Vectors)
Lehtiniemi	Maiju	SYKE	ICES WGITMO (Working Group on Introductions and Transfers of Marine Organisms)
Lehtiniemi	Maiju	SYKE	ICES WGZE (Working Group on Zooplankton Ecology, member)
Lehtiniemi	Maiju	SYKE	National committee to implement the EU regulation on invasive species
Lehtiniemi	Maiju	SYKE	National committee to implement the Finnish alien species strategy
Lehtiniemi	Maiju	SYKE	National committee on Ballast Water Convention led by Traffic and Safety Agency
Puntila	Riikka	SYKE	National Ad hoc committee on Alien species invasions (TraFin)
Skov	Henrik	DHI	Advisory Committee for Baltic Conservation Foundation
Skov	Henrik	DHI	JWGBird

Törnroos	Anna	AAU	ICES WGCOMEDA
Törnroos	Anna	AAU	ICES WGIAB
Andersson	Helen	SMHI	ICES WGIPEM (Working Group on Integrated Physical-biogeochemical and Ecosystem Modelling)
Andersson	Helen	SMHI	OSPAR ICG-EMO
Meier	Markus	SMHI	OSPAR ICG-EMO
Rau	Andrea	TI-OF	ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB)
Rau	Andrea	TI-OF	MSRL Fach-AG Fisch und Fischerei
Rau	Andrea	TI-OF	Workshop on guidance for the review of MSFD decision descriptor 3 – commercial fish and shellfish II (WKGMSFDD3-II)
Oesterwind	Daniel	TI-OF	ICES Working Group on Cephalopod Fisheries and Life History, 8-11 June 2015, at the IEO in Tenerife, Spain
Oesterwind	Daniel	TI-OF	ICES Review Group on Bycatch of cetaceans and other protected species
Oesterwind	Daniel	TI-OF	ICES Advice Drafting Group on Bycatch of cetaceans and other protected species
Stepputtis	Daniel	TI-OF	ICES Working Group on Fishing Technology and Fish Behaviour
Döring	Ralf	TI-OF	STECF (EU Scientific, Technical and Economic Committee for Fisheries) WG on implementation of the landing obligation
Döring	Ralf	TI-OF	STECF Working group on balance between fishing capacity and fishing opportunities
Goti	Leyre	TI-OF	STECF Working group on balance between fishing capacity and fishing opportunities