SHEBA NEWS

// Dear Reader ...

Welcome to the 5th BONUS SHEBA newsletter, which aims to inform project collaborators, stakeholders affected by Baltic shipping and interested scientists on the content and development of BONUS SHEBA.

BONUS SHEBA started in April 2015 and is now nearing completion. The work packages concentrate their efforts on finalising and consolidating the research programmes. In October 2017 SHEBA co-organised an international conference on "Shipping and the Environment". Read more on the conference in this newsletter. The featured topic this time is devoted to modelling air quality in harbour cities.

We hope you enjoy reading this issue, and welcome any feedback via the contact information given on the last page,

Jana Moldanova (IVL) and Markus Quante (HZG)

// Shipping in the Baltic Sea

Assessing costs to the environment and human health

By Ben Boteler, Ecologic Institute, Jenny Tröltzsch, Ecologic Institute, and Eva Roth, SDU

Work Package 5 of BONUS SHEBA aims to provide an overview of the pressures created by shipping, how this leads to changes to the state of environment and human health, and ultimately how this could impact human well-being. For that, a framework for the integrated assessment of shipping in the Baltic Sea was developed in order to link the social and ecological system. The framework was developed to assess the linkages from the drivers of shipping in the Baltic Sea to its effects on ecosystem services and human well-being. The framework was then applied in an effort to identify potential changes to ecosystem services and the resulting socio-economic costs this may create. The analytical framework for the integrated assessment was based on the DPSIR (Driver-Pressure-State-Impact-Response) framework, which was adapted to the Baltic Sea and shipping in the BONUS SHEBA project, see Figure 1.

In a next step, two methods were applied to assess the costs of degradation: an analysis of ecosystem services and an estimation of abatement costs. The ecosystem services approach is used to assess potential future changes **to** essential services to human well-being. This also includes an assessment of human health as it is impacted through air emissions from shipping. In addition, a costs based approach focusing on the costs of technologies and Measures to avoid or reduce environmental pressures leading to degradation is used. Results from the two methods are provided monetarily when possible, otherwise provided quantitatively or qualitatively.

The ecosystem services assessment shows that, compared to other activities, shipping is as an important driver for the increase of non-indigenous species and physical impacts. NOX, PM, and underwater noise are also important pressures from shipping compared to other land and sea-based drivers. These pressures lead to changes in the state of the environment and have the potential to lead to significant impacts on ecosystem services and human well being and respectively on costs of degradation.

Impacts to tourism and recreation as well as recreational fishing are expected, mainly due to eutrophication and oil spills. Genetic resources can be especially influenced by invasive species. Human health is influenced by a broad variety of drivers but is most likely influenced in local settings, e.g. especially where large harbours are close to or in big cities.

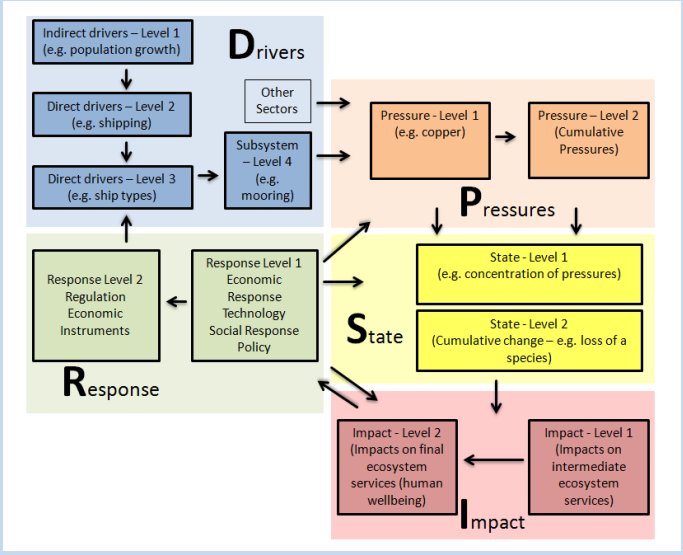

Figure 1. The DPSIR framework for shipping in the Baltic Sea region.

Source: adapted from Hassellöv et al. 2016.

The evaluation of abatement costs suggests the average total costs of air and water pollution caused by shipping in the Baltic Sea to be €5.12 billion in 2014, €3.20 billion in 2030, and €2.5 billion in 2040. RoPax ships, container ships, chemical tankers, general cargo ships and bulk cargo ships are the main contributors of pollution in terms of environmental costs. The reduction of the costs is completely due to the improvement in air pollution. The average abatement costs linked to air emissions are predicted to be €4.24 billion in 2014, €2.19 billion in 2030, and €1.40 billion in 2040.

The results of the assessment show that the environmental externalities and impacts on human well being by shipping could be reduced. A first step will be done based on the technological improvements and adjusted regulations, which have already been assumed in a Business As Usual case which would reduce the air emissions and their effects significantly. In a next step, management options and technologies to reduce pressures and impacts from shipping and harbours in the Baltic Sea will be assessed to identify suggestions for policy.

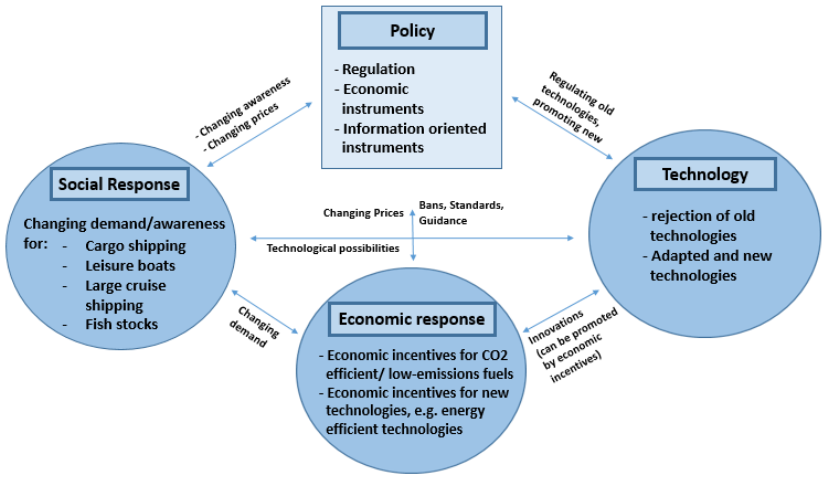

Figure 2. Responses and their interlinkages. *Source: Author*

The abatement costs of air emissions are decreasing between 2014 and 2040 in the BAU almost by 75%. In 2014, the abatement costs of only NOx emissions accounted for 60% of total abatement costs. The share of abatement costs of water emissions (17 % in 2014) is by far lower than costs of air emissions (83 %, 2014) and estimated to amount to €878 million in 2014, €1,014 million in 2030 and €1,095 million in 2040. It is increasing by 25 % between 2014 and 2040. In terms of environmental costs, copper contaminants from shipping make up a large proportion of impacts on the ecosystem. This metal's share is over 85% of the total abatement costs of water pollution from shipping.

Figure 2 shows an overview about potential responses, which will be further analysed in the BONUS SHEBA project.

// Impacts of shipping induced underwater noise on marine life

By Heikki Peltonen, SYKE

Underwater noise is currently identified as a major problem for marine animals and the noise levels are increasing along with the industrialisation of seas.

In particular, noise from marine traffic has become a part of the underwater soundscape in wide marine areas. Loud underwater sounds can induce mortality and physical damages in marine animals. Even lower level noise can be harmful when inducing stress and masking biologically important sounds especially as marine animals depend on sound e.g. for communication, for seeking prey, for avoiding predators and for echolocation. However, at present, why and how noise affects marine organisms is still poorly understood, with only some aspects and a small proportion of the marine organisms having been investigated.

Within the project SHEBA, we are conducting impact assessment of noise on marine fish, seals and the harbour porpoise. Spatial data on marine traffic are compared to the existing information on the location of biologically sensitive areas. This work relies on Baltic Sea wide marine traffic noise emissions modelling and on noise propagation modelling on selected ecologically important areas – both of these materials were produced within SHEBA using e.g. information from marine traffic tracking (AIS).

To support the impacts assessment we conducted experiments with Baltic Sea fish to learn about hearing abilities of species and study the behavioural responses of the fish on underwater noise. The experimental setup consisted of a net enclosure for holding the fish and it was equipped with underwater loudspeakers, hydrophones and equipment for monitoring fish movements. The experiments were made at the Tvärminne Zoological Station in southwestern Finland (Figure 3).

Species with different salinity tolerances were selected for these experiments because the fish fauna in the Baltic Sea constitutes of a mixture of marine and freshwater species. The sound materials applied in the playback included recorded underwater shipping noise, and also tonal single

frequency sounds. The behaviour of the fish schools in a net enclosure were monitored with hydro-acoustics using a multi beam imaging sonar, which is a device providing video-resembling data of underwater objects (Figure 4).

Figure 3. Installing the experimental setup. The area around the research station at the coastal sea at southwestern Finland constitutes a diverse mosaic of islands and sea. *Source: Author*

As suitable software was not available, custom-made analysis tools were programmed to analyse the video-type data, i.e. to extract in-formation on the movements and on the dimensions of fish schools within the enclosure. Additionally, new Bayesian modelling methods are being developed for tracking of the fish schools and for identification of their behavioural responses.

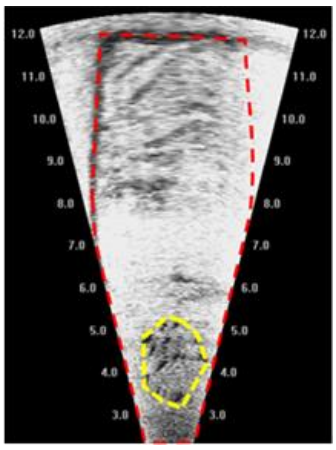

Figure 4. A frame captured from the video-type data recorded with the Multibeam echosounder. The dashed red line indicates the dimensions of the net enclosure, and the dimensions of the fish school are shown with the yellow line. *Source: Author*

// "Featured Topic"

Modelling Air-Quality in Harbor Cities

By Matthias Karl and Martin Ramacher, HZG

Air pollution in harbor cities

Marine ports in the Baltic Sea are major hubs of economic activity but also major sources of air pollution. Harbor cities also receive pollution from sea, because ships release 70 % of their emissions within 400 kilometers of land with the wind carrying them shoreward. Ships spend a large proportion of time moored in harbors and ports.

Merchant vessels, for example, spend around 100 days a year at berth. In order to keep the electrical systems - such as lightning, air conditioning and sanitation - running during the time at berth, the ship's auxiliary engines are constantly in operation. They are therefore producing emissions to air the whole time. In addition to the ship activity at berth, there are hundreds of diesel trucks visits per day for the loading and unloading of ships, and cargo-handling operations in the port.

The growth of international trade has resulted in corresponding rapid growth in the amount of goods that are shipped on sea. Despite the enormous growth within the marine shipping sector, most pollution prevention efforts at the local level have focused on other pollution sources, such as industries or road traffic, while the environmental impacts of ports have received less attention. An exception is the European Parliament Directive 2005/33/EC regulating the sulfur content of marine fuels in ports of the European Union. The EU Port Directive came into force on 1st January 2010, reinforcing the limits of sulfur for ships operating in the sulfur emission control area (SECA), and limiting the sulfur content of fuels used ashore in the EU. It also introduced legislation governing the maximum sulfur content of fuels used by inland waterway vessels and ships at berth in ports. The limit placed is 0.1 % sulfur, which is the maximum sulfur content of marine gas oil (MGO). Marine vessels must arrive at the port with supplies of the 0.1 % sulfur fuel on board. They cannot arrive and then take on the fuel.

The diesel engines at ports, which power ships, trucks, trains, and cargo-handling equipment, create vast amounts of air pollution that affect the health of harbor workers and the health of people living in proximity of the port. More than 30 human epidemiological studies have found that diesel exhaust increases cancer risks.

More recent studies have linked diesel exhaust with asthma. The health effects of pollution from ports may include asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature death. In children, these pollutants have been linked with asthma and bronchitis, and high levels of the pollutants have been associated with increases in school absenteeism and emergency room visits.

Hong Kong considers emissions from berthed cruise and cargo ships to be the biggest cause of its air pollution. According to figures from the Los Angeles Air Quality Management District, emissions from berthed ships account for 700 premature deaths every year. In the European Union, international shipping pollution is expected to outstrip land-based sources by 2020.

EU recommendation 2006/336/EC describes shore power as the optimal solution in terms of both cost savings and pollution control. Other measures for marine vessels in harbours include:

- ➔ Clean up harbour craft, such as tugboats, through engine repower and retrofit programs.

- ➔ Limit idling of oceangoing vessels and tugboats by providing electric power at docks and requiring ships and tugboats to “plug in” to shore side power while at berth.
- ➔ Require ships, including oceangoing vessels, to use the cleanest grade of diesel fuel possible. Provide liquefied natural gas (LNG) tanks to refuel LNG ships.
- ➔ Retrofit existing cargo-handling equipment with emission control technology, including diesel particulate filters, with lean NO_X catalysts and, if not feasible, with diesel oxidation catalysts.
- ➔ Where possible, create incentives for, or otherwise promote the use of, emission controls on oceangoing vessels.

City-scale Modelling

Modelling the air quality in harbor cities is a complicated task. Many activities like road traffic, domestic heating, commercial and industrial combustion, electricity production and last not least harbor activities contribute to air pollution in the city (Figure 5). The chemistry that takes place in the atmosphere above the city is complicated because of the manifold input from anthropogenic emissions in the urban area.

Emissions of nitrogen oxides from traffic and combustion processes together with emission of volatile organic compounds for example from the industrial usage of solvents mixing in the air. The mixture reacts with sunlight in a photochemical reaction cycle that produces ozone. Breathing in ground-level ozone can be harmful for health. People most likely to experience health effects caused by ozone include people with asthma or other lung diseases, elderly people, people of all ages who exercise or work hard outside, children and babies.

City-scale chemistry transport models (CTMs) take into account the different emission sources of air pollutants, their chemical processing, as well as their dispersion in the urban atmosphere and deposition to the ground. These models calculate the concentration of air pollutants in three dimensions of space and their change with time. Air pollutant concentrations at the ground, i.e. at the height where we breathe, are of the greatest interest. Methods have been developed to calculate the exposure of the citizens and to estimate the impact on human health in the city, based on the model-calculated pollutant concentration.

Meteorological conditions and chemical boundary conditions are also important components to consider in air quality modeling (Figure 6).

A good description of the meteorological conditions is important since the meteorology influences the dispersion and the chemistry of the pollutants and contributes to variations in polluted air arriving to in the harbor city from other regions and/or countries. The prognostic meteorological model TAPM is used in the BONUS SHEBA to compute the meteorological conditions for the area of the harbor city with high accuracy.

Chemical boundary conditions define the concentrations of air pollutants that are transported with the wind to the city, often coming from long distances, such as the Saharan dust that arrives from time to time in Northern Europe. In the BONUS SHEBA project the concentrations of pollutants in the atmosphere over the Baltic Sea is calculated with regional-scale CTM systems. The chemical boundary conditions for the simulation of the city atmosphere are provided from the regional-scale CTM system (Figure 7).

The exhaust emissions from shipping is modelled by combining ship movements based on the automatic identification system (AIS);with the most up-to-date load dependent emission factors for all important pollutants. Ship emissions for the selected harbor cities have been created in the BONUS SHEBA for moving ships and ships at berth with a grid resolution of 250 x 250 m^2.

Figure 5. Illustration of the activities in a harbour city connected with emissions to air.
Source: NILU Products AG (with modifications)

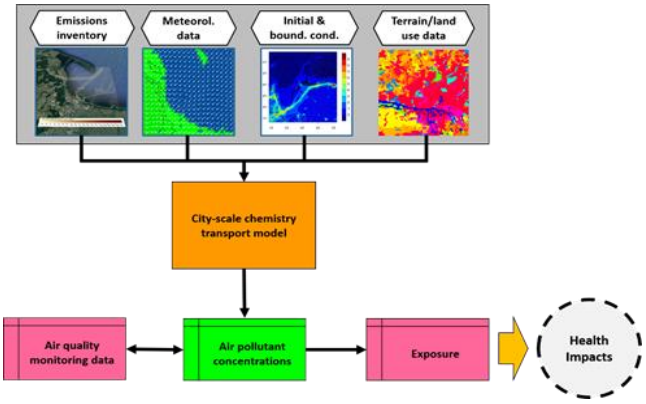

Figure 6. Scheme for input and output of the city-scale chemistry-transport models. *Source: Mathias Karl*

Emissions from the other inner-city activities have been estimated based on data that was made available from the harbor city municipality, from universities or from air quality monitoring networks.

With the help of city-scale models, the impact of emissions from ships in the port on the city's air quality will be investigated in the BONUS SHEBA project. The city-scale models (TAPM and CityChem) will simulate contributions of the emissions from harbor activities to the air pollution and to the exposure of people to air pollutants in the harbour cities.

The model simulation are performed on a 1 x 1 km² scale or even finer and resolve the individual emission sources inside the territory of the harbor city in space and time. In order to evaluate the fitness of the model for the purpose of policy decision support and the plausibility of the model results, the modelled concentration of pollutants are compared against measurements of the concentrations from the air quality monitoring network of the respective harbor city.

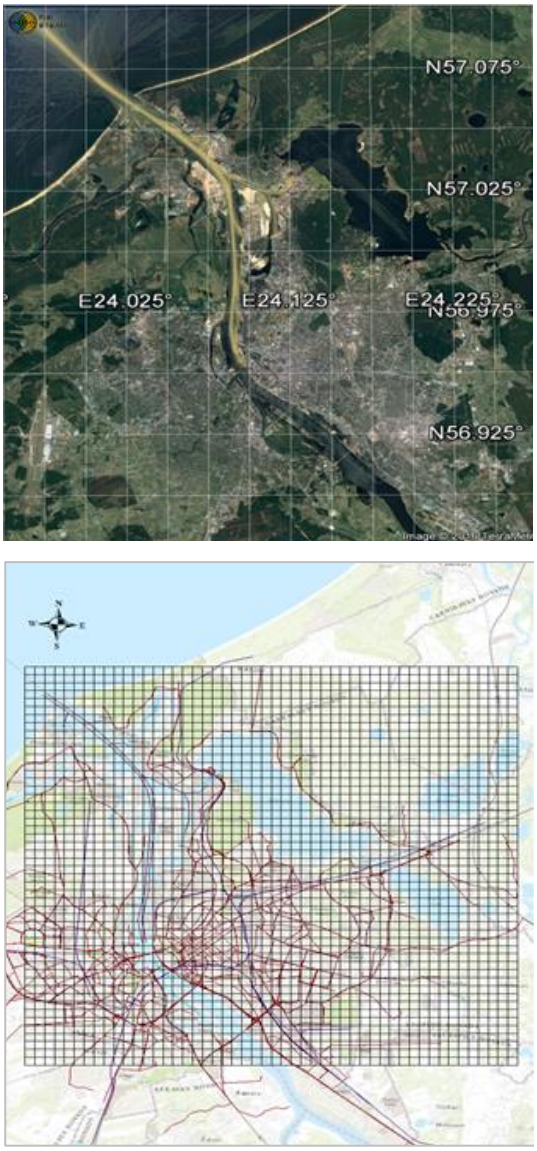

Figure 7. Shipping emissions and the traffic line sources (streets and railway) used in the modelling of air quality in Riga.

Source: FMI – Lasse Johansson (using GoogleEarth), Matthias Karl (using Esri ArcGIS)

// "Inside SHEBA"

This rubric will briefly introduce over the set of newsletters the partners of SHEBA as well as key personnel. Last time we introduced the Tallinn University of Technology and the Ecologic Institute – now we continue with Finnish Environment Institute and Maritime Institute in Gdansk.

Finnish Environment Institute (SYKE)

The Finnish Environment Institute (SYKE) is the research and development centre of Finnish environmental administration with a staff of c. 600 employees. SYKE is both a research institute and a centre for environmental expertise.

SYKE's expertise covers marine and freshwater, biodiversity and ecosystem services, climate change mitigation, sustainable production systems, environmental policies and environmental monitoring. SYKE serves as the national centre for environmental data, and it has a long tradition in supporting, developing, assessing and studying the interface between research and decision-making.

SYKE's Marine Research Centre (MRC) makes multidisciplinary research on the functioning of marine ecosystems and on the impacts of the anthropogenic perturbations and exploitation of marine resources by analysing data coming from multiple platforms, with experimental work and with modelling. SYKE MRC acts as an expert on marine resource management planning, and on implementation of EU's maritime legislation and the Baltic Sea environmental protection convention. SYKE MRC works closely together with European universities, research institutes and enterprises, and operates also in the Arctic region and in developing countries.

SYKE MRC hosts marine research infrastructures including the research vessel Aranda which is currently being extensively rebuilt and modernized. Special emphasis is put on silencing the vessel, to support marine ecology research with hydroacoustics and studies on underwater soundscapes.

Within BONUS SHEBA the personnel from SYKE is mainly involved in the assessment of the effects of noise from marine traffic on the marine animals. Further, it contributes to the assessment of ecosystem services, to the development of the noise fingerprint library of individual ships, and to establishing the Baltic Sea shipping noise source maps based on the knowledge about marine traffic in the Baltic Sea area.

The persons from SYKE involved in the BONUS SHEBA project are (*with affiliation and research tasks*):

Jukka Pajala,

Naval Architect, Research vessel manager, underwater radiated noise and soundscapes

Heikki Peltonen,

PhD, Senior Research Scientist, sustainable use of marine living resources

Riitta Autio,

Head of Unit, Project manager

Riikka Puntila,

PhD, Researcher, experimental marine ecology

Eeva Sairanen,

PhD student, Researcher, ecological impacts of underwater noise

Maritime Institute in Gdansk (MIG)

Maritime Institute in Gdansk (MIG) is the R&D organization under Polish Ministry of Maritime Economy and Inland navigation with 67 years of experience and over 200 employees.

The scope of work performed by six research departments and additional laboratories covers transport management and logistics, operational oceanography (with the use of MIG's own research vessel), maritime hydrotechnics, protection and shaping of the environment (chemical and biological analysis), seaports development, inland waterway shipping, maritime tourism, database construction, monitoring of maritime processes and activities.

Maritime Institute in Gdansk co-operates with the key international maritime institutions, ports and universities and has long history of comprehensive data collection (summarized in the annual publication "*Statistical Review of Maritime Economy*") and marine safety research and studies.

Maritime Institute in Gdansk participated in several EU co-financed and national research projects, both as Lead Partner, or Project Partner. Apart of BONUS SHEBA, the Institute has been involved in such environmental protection initiatives as *INTERREG BSR Baltic Master* II - *Maritime Safety and the Environment in the South Baltic Sea Region, BSR Baltic Master* (project awarded by EU), *Efficiensea, BRISK* and *BSR CleanShip - Clean Baltic Sea Shipping* and *EcosHaz*.

The Institute also conducts several official reports for the Polish government related to the ICZM, implementation of BWMC and port waste management facilities.

Rich professional knowledge, resources of the Institute, long record of research and implementation of projects, mainly in the field of maritime transport, safety, environment and logistics, wide international cooperation - all these elements place the Institute as one of the leading European R&D organizations in the maritime field.

Tasks on SHEBA project are conducted by MIG's Economics and Law Department, managed by Marcin Kalinowski. The notable MIG members involved in the SHEBA project are Mrs. Urszula Kowalczyk – coordinator of "*Statistical Review of Maritime Economy*", expert in shipping market analysis, multimodal transport plus maritime economics and Jakub Piotrowicz – Manager of SHEBA tasks responsible for socio-economic aspects of maritime economy.

Marcin Kalinowski

Urszula Kowalczyk

Jakub Piotrowicz

// SHIPPING & the ENVIRONMENT -

from regional to global perspectives, Gothenburg 24-25th October

2nd BONUS symposium

by Sara Jutterström and Jana Moldanová, IVL

The BONUS SHEBA project co-organized together with the project SOLAS (International Surface Ocean - Lower Atmosphere Study) a conference, addressing a wide range of aspects regarding the impact of shipping on the environment. The conference was held in Wallenberg's conference center of the University of Gothenburg. The head-organizers Dr. Jana Moldanova of BONUS SHEBA and Professor David Turner of SOLAS welcomed over a hundred participants representing nearly sixty organizations and 15 countries. Dr. Andris Andrusaitis opened on behalf of the BONUS Secretariat the conference (Figure 8), which also was affiliated as 2nd BONUS symposium.

Figure 8. Opening address by Dr. Andris Andrusaitis, programme manager from the BONUS secretariat. *Photo: M. Quante*

Participants of the conference included researchers and students from a wide range of research areas corresponding to the 5 major themes of the conference: Atmospheric processes, Assessments of integrated effects on environment and climate, Marine processes, Noise and Socio-economic aspects and policies.

There were also representatives of environmental and transport agencies as well as environmental managers representing organizations on local, regional and governmental levels.

A keynote presentation was given at the start of each of the two conference days. Professor James Corbett (University of Delaware, USA) held the first keynote presentation on the theme "Shipping and Environment: Four Steps Forward", where he outlined the 4 key steps defining progress in role of shipping in the global economy, including economic demand, natural conditions, innovating technologies and natural consequences of social value. The second day opened with a keynote from Professor Kate Mackey (University of California Irvine, USA) on "From sky to sea: How atmospheric deposition influences marine microbial." The sessions also included invited talks from 4 experts of the different themes of the sessions: Peter Louie from the Hong Kong Environmental Protection Department, who presented initiatives taken by the Government of Hong Kong to reduce emissions from shipping; Shen Yin from Shanghai Environmental Monitoring Centre, who gave a presentation about shipping emissions in Shanghai and their impact on air quality in the city; Dr. Mar Viana from IDAEA–CSIC, Spain, assessed in her presentation the impact of maritime transport emissions on coastal air quality in Europe; Dr. Dietrich Wittekind from DW-ShipConsult GmbH gave a presentation on the generation of underwater noise by commercial ships.

The conference also included 2 poster sessions (Figure 9) with much appreciated "flash-talks" as introduction, and a panel discussion concerning the question "How can we bridge the gap between science, management and industry to insure sustainable shipping in the future?" (Figure 10).

Figure 9. Lively discussions took place during posters sessions. *Photo: M. Quante*

Figure 10. Members of the panel discussion debate on how to bridge the gap between the diverse interests related to shipping. *Photo: M. Quante*

In the panel, moderated by Jessica Hjerpe Olausson (Senior Maritime Expert from Västra Götaland Region Administration), some of the leading experts participating in the conference, representing both shipping related environmental research, relevant authorities and shipping industry, discussed what is necessary to achieve sustainable shipping.

At the closing of the conference it was clear that the environmental impact of shipping and its importance within policy, marine spatial planning and the maritime transport sectors is an issue engaging a great number of people and organizations and is of significant societal importance. It is therefore important to continue building and expanding the community. A follow-up conference within the next two years is under consideration.

The abstracts and many of the presentations are available on the conference website: http://shipping-and-the-environment-2017.ivl.se/

6th BONUS SHEBA consortium meeting

The 6th general consortium meeting of BONUS SHEBA project took place on the 23rd October at Wallenberg conference centre in Gothenburg. In course of the meeting the progress of the project has been discussed as well as the work that is needed to finalize the project outputs within the months left before SHEBA. During the 2.5 years passed the project has produced many new, interesting and important research results in all its workpackages and has organised several outreach activities to communicate the environmental impacts of shipping with stakeholders from authorities and industry. The project has experienced some minor delays in the time plan and, especially recognising a need for time for synthesis and publication of BONUS SHEBA's numerous results, the General Assembly of the project decided to apply for an extension of the project by 4 months, until July 31st 2018. This application has been submitted and was granted by the BONUS secretariat.

SOLAS Shipping workshop 26 October 2017

In conjunction with the "Shipping & the Environment" conference in Gothenburg the International Surface Ocean - Lower Atmosphere Study (SOLAS) project conducted a workshop on shipping (Figure 11). The goal of the gathering was to develop an active international research effort on "Shipping and the Environment". The Gothenburg workshop therefore focused on forming the basis for a joint international proposal. David Turner, who is member of the SHEBA advisory board, was a member of the workshop organizing committee. The SHEBA consortium was represented by Ida-Maja Hassellöv, Jana Moldanova, Volker Matthias and Markus Quante.

Figure 11. Participants of the SOLAS meeting on shipping in Gothenburg. *Photo: SHEBA*

Upcoming:

SHEBA results will be presented at international conferences

The effects of shipping emissions on air quality in the Baltic Sea region have been investigated in SHEBA. Model results for the entire Baltic Sea as well as for selected harbour cities will now be presented at two international conferences. From 12 – 16 March Jana Moldanova (IVL), Armin Aulinger (HZG) and Matthias Karl (HZG) will participate in the Air Quality Conference in Barcelona. They will give two oral and one poster presentation on SHEBA findings. From 14-18 May 2018, more of the outcomes will be shown at the International Technical Meeting on Air Pollution Modelling and its Application (ITM) in Ottawa, Canada. During this meeting, Martin Ramacher (HZG) will give a presentation on air quality modelling results for the Port of Hamburg and Volker Matthias (HZG) will give an overview of emission modelling techniques for three dimensional air quality models. Shipping emissions based on individual ship movements and detailed emissions factors as they are prepared in SHEBA will be one example for state of the art emission modelling techniques.

Final SHEBA Consortium and Stakeholder Meeting in May/June 2018

The final BONUS SHEBA project meeting will take place from the 30th of May to the 1st of October 2018 in Berlin, Germany. The meeting will be hosted by Ecologic Institute. Besides the entire project consortium the BONUS secretariat and our advisory board members are invited.

2nd Baltic Earth Conference

BONUS SHEBA is an affiliated project in Baltic Earth. The second Baltic Earth conference is scheduled for 11 to 15 June 2018, it will take place in Helsingør, Denmark. The overarching topic is "The Baltic Sea Region in Transition". SHEBA themes would fit under the subtopic "Multiple drivers of regional Earth system changes". Deadline for abstract submissions is the 18th of February. Markus Quante (HZG) and Jana Moldanova (IVL) with co-authors will submit an overview on achievements of SHEBA. Conference homepage:

http://www.baltic-earth.eu/helsingor2018/index.html

BONUS
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

SHEBA

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