ABSTRACTS

Research Alumni Meeting:

Sustainable Ocean Development –

A Perspective from Former, Current and Future Kiel Marine Scientists

September 28-30, 2015, New York City

(Location: Union Theological Seminary, 3041 Broadway, New York)

organized by the Cluster of Excellence 'The Future Ocean' at Kiel University, Kiel, and the Earth Institute at Columbia University, New York
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Context

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Session 1 – Valued Ocean

KEY NOTE

1. Vast, unknown, and critical: Ecosystem function and services provided by the deep sea

A. Thurber
(College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA)

The deep sea is often viewed as a vast, dark, remote, and inhospitable environment, yet the deep ocean and seafloor are crucial to our lives through the services that they provide. Our understanding of how the deep sea functions remains limited, but when treated synoptically, a diversity of supporting, provisioning, regulating and cultural services becomes apparent. For example, the waters and seafloor below 200m are one of the largest sinks of carbon dioxide on the globe and have already absorbed more than a quarter of human released atmospheric CO_2. Concurrently, the degradation of sinking particles by life of all sizes releases nutrients that, when upwelled, fuel productive and harvestable shallow-water fish stocks. In addition to the role the deep sea plays in global biogeochemical cycles, it also hosts a diversity of extractable resources. Oil and gas resources are mined from deep sea localities around the globe. Fisheries are expanding deeper yearly with certain fisheries harvesting stocks bellow 2000m. And yet the big unknown for the trajectory of the deep sea is if and how the mineral resources that it contains will be harvested. Crusts and sediments that contain rare earth element deposits, manganese nodules, metals trapped in hydrothermal vent chimneys, and the expansive methane hydrate reservoirs all are vast resources whose mining may define the future of the deep-sea ecosystem. While these resources have yet to be harvested the likelihood of their extraction range from distant possibilities to soon realities with the scale of impact being as large as thousands of square kilometers. In addition, deep-sea habitats are and will continue to be impacted by climate change due to a variety of stressors including warming, expanding oxygen minimum zones, reduced food input, and altered pH. The question remains as to how we can conserve the services provided by the deep sea when confronted with global (climate change) and local (resource extraction) pressures when always faced with the incredible “unknown” that typify the habitat. As a first step, we can identify how this habitat is both beneficial to society, what makes it unique and uniquely vulnerable, and how society can and will be impacted by a shift in an ecosystem that covers over 63% of the globe.

ORAL PRESENTATIONS

2. Ecosystem services and sustainable development of coastal regions – Conceptualizing "coastal sustainability"

B. Neumann[1], B. Burkhard[2], S. Kühnle[1], K. Ruhberg[2]
([1]Institute of Geography and [2]Institute for Natural Resource Conservation, Kiel University, Germany)

The appreciation of the ecosystem services concept is growing in policy making and environmental governance. Yet, the question of what methods to use and how to consider ecosystem services, which are also an expression of the close linkages and interactions between the human system and the natural system, is not only debated between disciplines but also often a matter of resource availability, desired outcomes or information/knowledge. Qualitative mapping methods offer a pragmatic approach to gain an overview over the potential supply or actual flow of ecosystem services and give first-hand insights into a region's potential for sustainable development.
On the example of two coastal regions in Germany (Kiel Fjord region, Schleswig-Holstein) and Australia (Illawarra region, New South Wales), we will discuss methodological aspects of expert-based qualitative mapping of ecosystem services, also with regard to specific characteristics of coastal regions or the validity of expert and local knowledge. The results from these mapping exercises will be brought together with insights gained through semi-structured expert interviews on chances and challenges of the regions to conceptualize a "coastal sustainability" and develop a sustainability assessment framework for coastal regions.

3. LCA based ecological footprinting of aquaculture and fisheries

B. Samuel-Fitwi[1], A. Hock[2], C. Schulz[1]
([1]Institute of Animal Breeding and Husbandry, Marine Aquaculture, *Kiel University, Germany and [2]Sustainable Food, Büsum, Germany)*

Fisheries production has stagnated for the past two decades. On the other hand, aquaculture production has doubled every decade for the past fifty years, representing the fastest growing food sector. The environmental impact of fishing and aquaculture is of increasing concern for sustainable seafood production. Recent studies on impact assessment of seafood production have utilized life cycle assessment (LCA) method. The LCA method represents a holistic approach with advanced methodological framework used for quantitative assessment of materials used, energy flows and environmental impacts of products. Two case studies using this method are presented to evaluate the environmental impact of brown shrimp fisheries and trout farming in Germany and to identify hotspots for improvement. However, the usually chosen seafood impact categories in LCA (global warming, eutrophication, acidification and ozone depletion) have been adopted from the manufacturing industry that lacked some of the vital specific impacts associated with seafood production. The major specific environmental concerns in fishery are overfishing and the destruction and/or disturbance of natural habitats, namely discards, by-catch, undersize catch, idle and ghost fishing gear, marine pollution and seafloor disturbance impacts. On the other hand, impacts specific to aquaculture include spread of disease, overexploitation of wild fish, escapees and use of aquatic medicines. These traditionally recognized impacts of fisheries and aquaculture have not yet been characterized and included in LCAs, and hence incorporate limitations that impair their use in decision-making. Therefore, the development of tailored environmental assessment tool incorporating impacts distinctive to aquaculture is necessary. By reviewing recent methodologies used in aquaculture and fisheries, their limitations are identified and future research needs are highlighted that may provide the basis to support sustainable policy formulation.

4. Integrating different user groups into fishery management

E. Regnier and M. Quaas
(Department of Economics, Kiel University, Germany)

Different user groups have different stakes in fisheries. The societal challenge is that, exploiting the same fish stock, or ecologically interacting stocks, recreational and customary fishermen compete with a continuum of commercial fishermen, ranging from very small-scale and part-time artisanal fishermen to large-scale fishing firms. Not accounting for externalities in fisheries, management schemes will fail to maximize the net economic benefit withdrawn by society from this natural resource, and are likely to result in the over-exploitation of natural resources.
In this paper we develop a theoretical framework of fisheries management that integrate different user groups and internalize externalities between them. Tackling the conservation, social equity, and economic efficiency challenges inherent to resource allocation, we derive the socially optimal harvesting strategy in the two steps of (i) determining the joint total allowable catch (TAC) for all user groups at an optimal level and (ii) computing the optimal allocation of quotas among the different user groups. User groups differ in their production technology and objective functions. In our modelling approach, we capture these differences by different parameterizations of a common functional forms. Fishermen can target a same species stock, or species interacting with each other. The regulator maximizes the aggregate surplus of all actors w.r.t. harvesting technology, while social constraints impose a minimum participation level for each sector. The technical challenge is then to identify fishing paths consistent with conservation constraints, social goals, and ecosystem dynamics. We put forward the viability theory (Aubin, 1991) as a powerful method to address dynamic control problems under constraints. Finally, we conduct a numerical application of the viability analysis and experiment the operational scope of our theoretical framework.

5. The 'nature' of sustainability in ocean affairs from a poststructuralist perspective

U. Kronfeld-Goharani
(Institute of Social Sciences, Kiel University, Germany)

The ocean and coasts play a key role for human wealth and well-being. The free access to the high seas and the availability of ocean resources have put strong pressure on maritime spaces that are increasingly threatened by climate change, unsustainable fishing practices, pollution and waste. The conservation and protection of marine ecosystems demand a more careful use of marine resources and dealing with marine pollution. In this context, the concept of sustainability is assumed to provide a conceptual basis for integrating these requirements. Since its classical definition provided by the Brundtland Commission (WCED 1987) the concept has received much international attention and has become a dominating leitmotif for shaping international environmental and developmental relations. However, though numerous multilateral environmental agreements have been concluded, many conferences are held every year and significant human resources are spent to produce flagship reports on the efforts undertaken to achieve more sustainability ecosystem decline, global warming and unsustainable practices are going on. Thus the question arises how this contradictory behavior and the paradox of institutional success and environmental degradation at the same time can be explained.
Drawing on a poststructuralist approach this study presents some first results on the analysis of the social construction of the concept of sustainability in maritime affairs. It will be shown, how the ambiguity of meaning can be explained and how it is possible, that institutions can rephrase existing objectives and activities in compliance with sustainability without really changing their business as usual. It will conclude with an estimate whether it should be useful to adhere to the concept in ocean affairs especially in view of the complexity, uncertainty and continuous change of marine ecosystems.

6. Evidence for bottom-up and top-down controls on planktonic microbes near natural hydrocarbon seeps in the Gulf of Mexico.

N.A. D'souza[1,3], A. Juhl[1], A. Subramaniam[1], M. Hafez[1], A. Chekalyuk[1], S. Phan[1], B. Yan, K. Ziervogel[4], K. Bullock[1], I. MacDonald[2]; J. Montoya[3]
([1]Lamont-Doherty Earth Observatory of Columbia University, NY; [2]Florida State University, Tallahassee, FL; [3]Georgia Institute of Technology, Atlanta, GA; [4]University of North Carolina, Chapel Hill, NC)

The Gulf of Mexico has a large number of deep (>1000 m) natural hydrocarbon seeps, that release up to 1.1×10^{8} L oil $year^{-1}$, and while their impact on benthic productivity is well documented, less is known about their impact on surface water organisms. Evidence from ocean-color satellites, as well as shipboard flow-through, and in-situ autonomous-profiler-based fluorescence measurements revealed elevated chlorophyll concentration in surface waters near natural hydrocarbon seeps. We found evidence for the upwelling of nutrient-rich water from depth at these seep sites that could potentially facilitate phytoplankton growth (bottom up control). However, shipboard experiments with surface water samples collected in the vicinity of natural seeps indicated a more complex process. While addition of oil and nutrients (N, P, trace metals), independently increased chlorophyll concentrations, biological oxygen demand (BOD), bacterial cell counts, and enzymatic activities involved in oil degradation, lowered predation (top-down control) also synergistically contributed to these rate processes. The nature of interactions between oil-degrading heterotrophic bacteria, phytoplankton, and their micropredators in these assemblages remains unanswered. Current approaches to investigating the impacts of hydrocarbons on microbial communities tend to focus primarily on the bottom-up controls, and often overlook the top-down controls and complex food-web interactions that influence these processes. We emphasize this knowledge gap, and highlight the need to consider both, top-down and bottom-up controls in assessing the impact of hydrocarbons on planktonic microbial communities.

7. Undergraduate research in the marine sciences

T.-M. Anders
(Mt. San Antonio Community College, CA, USA)

Conducting research with students at the undergraduate level offers the unique opportunity to develop long-term monitoring projects and to build an extensive database spanning many years. In addition, due to diverse student interest, projects can be geared towards inclusion of all marine science disciplines.
For students, the opportunity to participate in genuine research, while taking introductory courses can have far-reaching consequences. They build knowledge, confidence and their resumes, as well as prepare for potential careers in research.
At Mt. San Antonio Community College we are in the first phase of developing such a long-term research project. In Fall 2015, student groups will explore and formulate long-term monitoring research projects. Overarching theme will be "Our changing Ocean and Coast". They will then pilot their projects at various locations along the southern California Coast. The second phase (Spring 2016) will focus on redefining the research topics and locations with the goal to focus the research efforts on one location.
During the meeting I hope to develop collaboration opportunities. These could include: comparison studies of W-coast to E-coast sites (or beyond), use of research lab space to run samples (or have them run), international exchange, and/or participation of our students in research cruises.

POSTERS

8. Conoidean peptides - Novel ion channel-targeted peptides from the ocean

J. Song
(Institute of Physiology, Kiel University, Germany)

Ocean as an invaluable resource contains a large amount of biological active substances. In the ocean there are different species of predatory marine snails of the superfamily conoidea. The conoideans (cone snails, terebrids and turrids) are a hyperdiverse group of marine gastropods. During the evolution conoideans have obtained capability to produce high effective and specific peptide-rich venoms and use these venoms to capture their prey. It is known, that most of these peptides are targeted selectively to ion channels. However, only a very small part of these peptides is identified so far and most of the peptides are still uncharacterized. The ion channels are membrane proteins and present in all kingdoms of life, demonstrating their central role in maintaining physiological functions. Ion channels are regarded as important therapeutic targets for treating a number of different pathophysiologies such as neurological diseases, cardiac disorder and diabetes mellitus. Through the investigation of these conoidean peptides which have evolutionarily optimized for the native ion channel compositions, their function mechanisms can be elucidate. Especially their potential pharmaceutical applications in in vitro systems will be focused.

9. Fisheries productivity in the Peruvian upwelling ecosystem: Lessons from the sedimentary record to understand the impact of global warming

R. Salvatteci[1], D. Gutierrez[2], D. Field[3], L. Ortlieb[4], A. Sifeddine[4], A. Bertrand[5], T. Baumgartner[6], R. Schneider[1]
([1]Institute for Geosciences, Kiel University, Germany; [2]Peruvian Sea Institute, Peru; [3]Hawaii Pacific University; USA, [4]IRD-Sorbonne Universités-CNRS-MHNH-LOCEAN Laboratory, France; [5]IRD, UMR EME, IRD/IFREMER/UM2, France; [6]CICESE, Mexico)

The Peruvian Upwelling Ecosystem (PUE) sustains high marine productivity and the world's largest fisheries due to the upwelling of nutrient-rich waters from the oxygen minimum zone (OMZ). In the PUE, OMZ intensity, marine productivity, and fish biomass show strong temporal variability indicating a high sensitivity to climate variability. However the response of the fish populations to global warming remains largely unknown, although the potential adverse social and economic impacts may be severe. The reconstructed PUE response to contrasting climatic conditions in the past two millennia provides an insight about the driving environmental factors controlling fish abundance. To reveal the mechanisms that control OMZ intensity, marine productivity, and fish population fluctuations in the PUE at sub-decadal to centennial timescales, we used a multi-proxy approach including paleontological, organic, and inorganic proxies in laminated sediments retrieved off Peru. During the last 100 years and during Northern Hemisphere (NH) warm periods (e.g. Medieval Climate Anomaly), the PUE exhibited a La Niña-like mean state characterized by an intense OMZ, high marine productivity and anchovy biomass. By contrast, during the NH cool periods (i.e. Dark Ages Cold Period and the Little Ice Age), the PUE exhibited an El Niño-like mean state, characterized by a weak OMZ, low marine productivity and fish biomass. During the last 150 years, there were two multidecadal periods favorable to sardines, and a centennial-scale increase in productivity and anchovy biomass since ~1900, supported by an increase in upwelling intensity. The Tropical Pacific main state seems to be a driver of multidecadal to centennial-scale fluctuations in the PUE. We expect for the next decades that sardine will displace anchovy when Pacific trade winds weaken and the Tropical Pacific sea surface temperatures shift again to a warmer state, a scenario that needs to be taken into account for future fishery management.

10. Measuring sustainable oceanic development

W. Rickels[1], M. Quaas[2], J. Schmidt[2], M. Visbeck[3]
([1]Institute for the World Economy, Kiel; [2]Department of Economics, Kiel University; [3]GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

The Sustainable Development Goals will be an integral part of the post-2015 UN development agenda. Goal 14 is specifically devoted to the protection and conservation of the ocean. However, achieving sustainable ocean and coastal development requires also an adequate set of indicators to comprehensively monitor and assess progress over and against both the overall goal and the specific targets. A major concern in the current discussion about the monitoring process is that clear policy guidance towards achieving an SDG is blurred by the number of targets and indicators, which might lead to an overall process of arbitrary application of management measures, focusing only on less critical or easy to achieve targets. Here, we show in how far different concepts of sustainable development are already implicitly embedded in the proposed framework and discuss how application of established guidelines for sustainable development assessment and inclusion of meaningful composite indicators can improve the meaning, validity, and policy relevance of the current SDG measurement framework. Additional inclusion of scientifically sound composite indicators could not only help in visualizing and assessing the overall development, but would also support selecting appropriate management measures regarding the inherent trade-offs in the human interaction with the ocean. By quantitative application of the currently proposed indicators for the ocean SDG we show how different assemblies of selected indicators reflect sustainable oceanic development and how policy recommendations are correspondingly affected. We argue that significant attention should be devoted to the proper aggregation of data in assessing the health of the ocean, and demonstrate that otherwise a) countries are certified a healthy human-ocean system that in reality neglect important aspects of ocean health and b) development trajectories are identified as being sustainable although this is actually not the case.

11. Microbial diversity within the *Trichodesmium* consortia

M. Rouco, S. Haley, S. Dyhrman
(Department of Earth and Environmental Sciences and Lamont Doherty Earth Observatory of Columbia University, NY, USA)

Populations of the cyanobacteria *Trichodesmium* are a key component of the phytoplankton community in the tropical and subtropical oceans. They provide an important source of new nitrogen to these oligotrophic waters, playing an important role in the global cycling of carbon and nitrogen. *Trichodesmium* cells are found both as free filaments or colonies, and colonies can have different morphologies depending on the arrangement of filaments within the colony. *Trichodesmium* colonies sustain a complex microbial consortium where heterotrophic bacterial epibionts are typically present at high concentrations. Despite *Trichodesmium* ecological importance, little is known about the structural and functional role of these epibionts and their interaction with each other and *Trichodesmium*. Some research studies have suggested that these interactions can play a role in the nutrient cycling within the colony. My research focuses on understanding the environmental factors driving the abundance and distribution of *Trichodesmium* clades in the ocean, as well as the effect of regional geochemistry or *Trichodesmium* colony morphology on epibiont diversity and physiology. A better understanding of the physiology and ecology of the *Trichodesmium* consortia will help us better predict its response to climate change as well as its future contribution to the global cycles of carbon and nitrogen.

12. Mapping the oceans: A global assessment of the deep sea

I. Yeo
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Only around 15% of the ocean floor has been mapped by ships and less than 0.05% at a resolution high enough to detect features smaller than about a hundred metres, for example a hydrothermal field or a lost aircraft. To map the unexplored 85% of the oceans at around 50m resolution would take a single ship, operating a modern multibeam system 24 hours a day, approximately 175 years, while mapping the entire ocean floor at a resolution better than around 20m would take 100 typical autonomous underwater vehicles (AUVs) around 75 years (not including maintenance). The cost, logistics and environmental consequences of such an operation render it impossible, yet having a map of the ocean floor is essential both for understanding the history of our oceans as well as for assessing the locations and extents of marine resources and hazards. Without a comprehensive knowledge of ocean resource stock, for example sulphide deposits in the oceanic crust which contain many metals that are in high demand, it is impossible to assess the future availability of such deposits. In order to produce such maps it is necessary to carry out targeted mapping expeditions alongside historical data to develop predictive models for the locations and extents of ocean floor hosted resources such as minerals and oil, as well as to locate sites suitable for other purposes, for example carbon sequestration. These models get better the more data you put into them, requiring a global cooperation between science institutes, both in terms of sharing data, as well as making small changes to collect information that otherwise would be wasted or lost.

13. Inferring microbial ecosystem function from community structure

J. S. Bowman and H. W. Ducklow
(Lamont Doherty Earth Observatory of Columbia University, NY, USA)

Bacteria and Archaea perform an array of critical ecosystem functions including carbon and nutrient remineralization, nitrogen fixation, and pollutant degradation. The composition of these communities is easily and frequently explored through the analysis of taxonomic marker genes, such as the 16S rRNA gene. While taxonomic marker gene studies are useful for describing how microbial communities are structured within the environment, they provide little information on the ecosystem functions provided by these communities. This information can be more directly developed from ‘omics’ technologies, such as metagenomics and metatranscriptomics, however, these methods are expensive and low throughput, making them suboptimal for long term monitoring projects or very high resolution surveys. We have developed a novel framework to infer the metabolic structure of a microbial community – analogous to its ecosystem functions – from its taxonomic structure. In an initial analysis we applied our framework to 16S rRNA gene libraries collected from the Palmer Long Term Ecological Research site, located on the ecologically vulnerable West Antarctic Peninsula, and validated our metabolic inference against whole genome shotgun metagenomics. We propose that using a metabolic inference technique in combination with metagenomics is an effective and economical way to explore and monitor microbial community function at a high spatial and temporal resolution. Our framework has the additional advantage that it organizes predicted functions in a manner that is amenable to both gene expression analysis and metabolic modeling, which we are pursuing in ongoing work.

14. Low-temperature hydrothermal systems as potential source of renewable energy. Where to find them on the seafloor?

D. Pałgan
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Hydrothermal activity in the world's oceans was originally thought to dominantly occur as high-temperature venting confined to neotectonic zone (extending ~15km on each side of the axis) along Mid–Ocean Ridges. However, extensive exploration and discoveries of new hydrothermal fields in off–axis regions (e.g. Lost City, Mid-Atlantic Ridge) show that a large proportion of hydrothermal fluids exiting the crust are low-temperature (<100°C) and located off–axis. For instance, on Iceland, (only subaerial section of the Reykjanes Ridge and analogous to submarine hydrothermal systems), it has been observed that 95% of the hydrothermal activity occurs as low-temperature venting. These low-temperature systems may transport up to 90% of the total hydrothermal heat to the oceans. These systems have the potential to be significant sources of renewable energy. To date, the technology to detect these systems is rudimentary. We need to develop an inexpensive and precise method for detecting low-temperature venting that will have little impact on the environment but help us assess the potential of specific systems. Observations of Icelandic systems helped me to develop a predictive model for locating venting on the Reykjanes Ridge (south of Iceland) based on interpretation of existing bathymetry maps. This method could potentially be applied to other mid-ocean ridges worldwide.
Comparability of Iceland and Reykjanes Ridge let us use high resolution maps to focus investigations to targeted areas of interest. Additionally, biological observations can significantly improve this method since detecting signals created by low-temperature fluids is difficult with only geological, acoustic and optic measurements. Visual observations of bacteria mats or mussels (e.g. Bathymodiolus) can help directly locate sites of fluids discharge. With growing demand of energy, renewable sources are crucial, and assessing all potential resources is the first step in making a powerful and long-term change.

15. Microbial role in the marine phosphorus cycle

K. Popendorf, S. Duhamel
(Lamont Doherty Earth Observatory of Columbia University, NY, USA)

Phosphorus is a limiting macronutrient for biological productivity in many areas of the ocean, making its utilization an important lever in controlling the role of microbes in global biogeochemical cycles. Of particular interest is the relative activity of carbon-fixing primary producers (phytoplankton) and dissolved organic carbon recyclers (heterotrophic bacteria). We investigated the variation in phosphorus uptake rates across different microbial groups (heterotrophic bacteria and the phytoplankton groups *Synechococcus*, *Prochloroccus*, and picoeukaryotic phytoplankton) in the phosphorus-depleted Gulf of Mexico using radioisotope labeling coupled with cell sorting flow cytometry. We found that heterotrophic bacteria were the dominant consumers of phosphorus on both a per cell biomass basis and a population basis--heteretrophic bacteria phosphorus uptake per biovolume was roughly an order of magnitude greater than phytoplankton uptake rates, and heterotrophic bacteria were responsible for generally greater than 50% of total picoplankton phosphorus uptake. We suggest this variation in uptake rates reflects variation in cellular phosphorus allocation strategies, and found that, indeed, the fraction of cellular phosphorus uptake allocated to phospholipid production was significantly higher in heterotrophic bacteria compared to phytoplankton. These findings indicate that heterotrophic bacteria may be uniquely adapted to outcompete phytoplankton for phosphorus acquisition in low-phosphorus environments, and play a dominant role in cycling dissolved phosphorus.

Session 2 – The Ocean in 2100

KEY NOTE

1. Sea level rise: Wide-ranging estimates, disaster planning, and the need to decide

M. Oppenheimer
(Woodrow Wilson School and Department of Geosciences, Princeton University, NJ, USA)

Highly divergent estimates of future sea level rise present policy makers worldwide with a difficult and unusual dilemma. Coastal management to reduce risk can be very expensive and projects can require long lead times between initial planning, decisions to implement, and completion. First I review recent projections of increases in coastal flood frequency due to sea level and storm frequency changes to illustrate both the large magnitude and large uncertainty of the future hazard. Then, drawing on experience in the US, Europe, and Asia, including the political and institutional obstacles to timely action, I discuss the prospects for effectively managing the risk via both emissions mitigation and adaptation.

ORAL PRESENTATIONS

2. Combined effects of ocean acidification and its co-stressors on marine organisms

H. Baumann
(University of Connecticut, Storrs, CT, USA)

A suite of parallel anthropogenic changes affects contemporary marine ecosystems. Excessive carbon dioxide (CO_2) pollution results in warmer, more acidic oceans with lower dissolved oxygen (DO) levels, meanwhile the emission of reactive nitrogen/phosphorus results in eutrophication, excessive microbial degradation and thus metabolic hypoxia and acidification. Despite decades of empirical research how each individual stressor of the 'climate-change syndrome' (i.e., temperature, CO_2, DO) affects the fitness of marine organisms, we still know little about the combined effects of these stressors. This lecture gives an overview over the nascent field of multi-stressor approaches evaluating the climate sensitivity of marine organisms across taxa. In most studied cases, combined effects of these stressors exceed those observed individually. Effects of combined warming, acidification, and deoxygenation have mostly been additive (no stressor interaction) or synergistically negative (stressor interaction). The occurrence and strength of synergistic stressor interactions in some species, life history stages, and traits comprises a vexing challenge but also hints at potentially greater sensitivities of organisms to marine climate change than previously recognized. This lecture intends to inform a broad audience from researcher to the general public, providing them with illustrated examples from the most resent literature, while aiding in communicating the urgent need for empirical data from multi-stressor approaches.

3. Coastal erosion and sea level changes on North Eastern Brazil

H. Vital[1], K. Stattegger[2], K. Schwarzer[2], W. Tabosa[1], M. Gomes[1], A.G. Aquino da Silva[2], P. Eichler[1]
([1]UFRN, Natal, Brazil, and [2]Institute for Geosciences, Kiel University, Germany)

The problem of natural and human impacts to the coastal ocean has been addressed on a global scale. We observe that a large and growing impact from anthropogenic impoundment worldwide, and the risks to the ocean and ecosystems it supports have been underestimated. This abstract presents a brief overview of the major results of the research developed by the Brazilian-Germany cooperation between UFRN (Natal, Brazil) and CAU (Kiel, Germany) related to environmental impacts occurring on the northeastern Brazilian coastal zone; in particular, problems of a rising sea level and their consequences for coastal environments. Coastal erosion has both natural causes and causes related to human activities. Gradual coastal erosion results naturally from the very slow rise of sea-level. Like other areas on the coast around the world, the Brazilian NE beaches are essential to tourism, and growing numbers of permanent and seasonal residents choose to live at or near the ocean. Moreover this area needs to address risks associated to very shallow-sea oil exploration, shrimps-farm, salt industry, pollution and biodiversity loss. Coastal erosion is a cause for concern along many NE Brazilian beaches, and several erosion hot spots were already recognized. Our studies identify the most common indicators of coastal erosional processes, as well as the most important factors and their causes on the Brazilian NE coast. Our next step is to organize networks and address scientific results to improve governance, build capacities, and support new and emerging issues.

4. Isolating the impact of Agulhas leakage in the South Atlantic

J. V. Durgadoo[1], A. Biastoch[1], J.F. Luebbecke[1], A.K. Morrison[2], S.M. Griffies[2], E. van Sebille[3]
([1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany; [2]Atmospheric and Oceanic Sciences Program, Princeton University, NJ, USA; [3]Grantham Institute & Department of Physics, Imperial College London, United Kingdom)

Changes in the South Atlantic have local and remote origins. This presents some challenges in understanding the compounding effects forcing components have since they each exhibit different changes and trends. The South Atlantic receives warm salty surface and intermediate water from the Indian Ocean - Agulhas leakage. A time-series of Agulhas leakage is reconstructed using sea surface temperature observation for the period 1870-2014. Multi-decadal variability in leakage follows that of the Southern Annular Mode, adding support to the hypothesized link to the Southern Hemisphere westerlies. Overall, the reconstructed time-series shows a trend with leakage values increased by about 20 % in the last century. Furthermore, the upper oceanic temperatures of the tropical South Atlantic exhibit an upward trend since the 1960s. Local forcing, such as heat exchange with the atmosphere or wind driven upwelling, cannot explain this observed increase, suggesting that it is possibly of remote origin. Since leakage also shows a sharp increase since the 1960s, we investigate whether a link exists. We present an attempt to isolate changes in the South Atlantic that are induced by an increase in Agulhas leakage. Using a Lagrangian framework, we show that a significant portion of the heat content increase in the upper 1000m of the tropical South Atlantic is due to the increase in leakage.

5. Predicting phytoplankton sensitivity to climate change requires cross-disciplinary synthesis

M. Gutowska
(Monterey Bay Aquarium Research Institute, Moss Landing, CA, USA)

Future changes in ocean carbon cycling and sequestration are closely tied to the responses of marine phytoplankton to climate change. However, intra-group variation in phytoplankton communities, and complexity of inter-group interactions, make it challenging to confidently predict future shifts. I will discuss calcifying haptophytes, coccolithophores, as a case study. Sufficient information is available for this group to offer a unique perspective on the advantages of synthesis across physiological, ecological and temporal scales. Looking into the past, we are able to trace changes in the biogeography and abundance of different species during periods of climate change. In understanding the present, we define physiological mechanisms that determine sensitivity of different species. This enables us to move away from repeat, individual observations. With the goal of looking into the future, we can then use these physiological traits to parameterize modeling efforts of coccolithophore responses. Continued reference back to the geological record enables us to ground truth our predictions against data from, what can be thought of as, global scale evolutionary experiments during periods of past climate change.

6. Impact of ocean acidification on N_2 fixation

A. Singh and U. Riebesell
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Nitrogen is a limiting nutrient for ocean productivity. N_2 fixation is the major process via which ocean receives bio-available nitrogen. As a consequence of increase in the atmospheric carbon dioxide, ocean pH has decreased significantly in the last century which might affect ocean N cycling. There have been numerous studies to access the role the decreased pH (ocean acidification) on ocean N_2 fixation but most of these studies were short-term (days to a few weeks) small scale (a couple of liters of samples) laboratory based and involved isolated single species, hence provided some contradictory results. We have done a long-term (60 days) experiment to assess the impact of ocean acidification on N_2 fixation by manipulating pCO_2 from 400-2000 µatm in nine different large scale (75000 L) mesocosms in the oligotrophic waters of the North Atlantic Ocean (in Gran Canaria) during September-December 2014. Our preliminary analysis of data does not show any significant impact of ocean acidification on N_2 fixation. I shall share results obtained from this study in the conference.

POSTERS

7. Explaining variability observed in calcification during the PeECE-I experiment

S. Krishna and M. Schartau
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

During the past two decades a series of studies were conducted with large tanks or bags of enclosed volumes of water that comprised a plankton community called mesocosms. Typically, these mesocosms are perturbed by changes in environmental variables and the response in plankton dynamics could be investigated under controlled conditions. Some mesocosm experiments focused on ocean acidification (OA) effects on marine calcifying algae (coccolithophores) captured in enclosed water volumes and exposed to different CO_2 concentrations, e.g. Pelagic Ecosystem CO_2-Enrichment Studies PeECE-I, II, III (Riebesell et al., 2008, Biogeosciences).
In our study we apply a plankton ecosystem model to understand and explain most of the variability observed during PeECE-I between the enclosures with similar CO_2 treatments, with a major focus on the large variations observed in Particulate Inorganic Carbon (PIC). We first defined a cost function that considers covariances between observations and model results. Then, we performed an identical twin experiment and model sensitivity analysis, which helped us to exclude those parameters from optimization that have little to no effect on our cost function. This analysis was followed by a parameter optimization that included initial conditions as additional parameters. Finally, a Markov Chain Monte-Carlo method was applied to come up with an a posteriori distribution of parameter values, including collinearities. The procedure, of optimization followed by MCMC, was repeated with respect to the initial conditions to disentangle high-, mean-, and low calcification model solutions that can explain the large differences in the observed precipitation of PIC. According to the results of our data-model synthesis study we conclude that the variability observed in total alkalinity and calcification during the PeECE-1 experiment could be well explained by small differences in the initial plankton composition while mesocosms were filled.

8. Impact of orbital forcing on marine productivity during last two interglacials

Y. He, B. Schneider, V. Khon
(Institute of Geosciences, Kiel University)

The marine productivity due to the orbital forcing has been analyzed in transit simulations by using an ocean biogeochemical model (PISCES), which were forced by two transient simulations of the Eemian (126 - 116 kyr BP) and the Holocene (9 - 0 kyr BP), obtained from the Kiel Climate Model (KCM). Both climate periods underwent similar transient changes in the orbital parameters, nevertheless, there are regional and latitudinal shifts, which impact marine productivity. Interestingly, although the climate forcing is weaker in the Holocene simulations, there are larger changes in global mean net primary production (NPP, decreased 10%), while NPP in the Eemian simulation is relative constant. The simulation results showed that the thermocline mixing and surface current driven by atmospheric forcing and the storage nutrients at subsurface in the tropical oceans, played an important role in the change of NPP in last two interglacials.

9. Computer vision and marine science - Towards efficient handling of big data on the example of 3D reconstruction

A. Jordt
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

In the marine sciences, growing amounts of digital data need to be processed in order to gain information about the ocean floor. Towards the year 2100, the amount of data will continue to grow at a staggering rate. However, when combining marine science with computer science, interesting possibilities arise for both sides. For example in the area of computer vision, which is concerned with automated information extraction from visual data, interesting solutions for working with video or still images are being researched. The marine sciences offer interesting applications that include automated detection, counting, measuring, and categorization of various objects of interest, e.g., fish, gas bubbles, or Manganese nodules.
Another interesting example, where both disciplines profit from interdisciplinary research, is the reconstruction of 3D information based on video data. Considering the example of an underwater volcano, it is very difficult and tiresome for Geologists to gain an overview due to the limited range of visibility. A digital 3D model of the scene however, can be examined interactively allowing to detect fault lines or joints. In addition, such models allow to efficiently document and quantify underwater findings and even monitor them over time.
On the side of computer vision, applications in marine science pose interesting problems caused by the use cameras under water, due to refraction at the underwater housing and limited visibility caused by light absorption and scattering, which need to be considered explicitly.
An interesting opportunity for future research is the fusion of data streams of optical and acoustic devices. This will allow to increase the resolution of the acoustic data and make the optics-based 3D reconstruction more accurate. In addition, color information and backscatter information in combination will allow to draw conclusions about the kind of material, e.g. detect gas bubbles or Manganese nodules.

10. New nitrogen supply in a future acidified ocean

A. Paul, L. T. Bach, U. Riebesell
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Numerous single-strain cultures studies on nitrogen-fixing organisms (diazotrophs) have indicated that changing ocean carbonate chemistry speciation affects diazotroph activity, and hence new, bioavailable nitrogen inputs under future ocean acidification. As phytoplankton in large regions of the ocean are limited by fixed nitrogen availability, this may have implications for marine primary productivity, carbon sequestration, secondary production and energy transfer to higher trophic levels.
Our aim was to assess CO_2-related differences in diazotroph growth and activity in a nitrogen limited plankton assemblage in the Baltic Sea, and the interaction with plankton community biomass and structure. In the Baltic Sea, diazotrophic fixed nitrogen is estimated to sustain between 20 - 45% of new production annually (Gustafsson et al. 2013). We enclosed nitrogen-limited natural plankton communities, including diazotrophs, and manipulated the CO_2 levels to simulate future ocean conditions over the range projected by the IPCC by 2100. Our results suggest that while there was limited impact of elevated CO_2 on diazotrophic organisms in this particular plankton community, small phytoplankton (< 2 µm) appeared to have the strongest response to higher CO_2 and despite nitrogen limitation were more capable of sustaining higher biomass under ocean acidification.

11. Impact of North Atlantic surface salinity bias on the ocean circulation and Atlantic multidecadal variability in the Kiel Climate Model

T. Park, W. Park, M. Latif
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

A long-standing problem in climate models is the large sea surface salinity (SSS) biases in the North Atlantic. We describe the influences of these biases on the North Atlantic ocean circulation, and North Atlantic sector mean climate and climate variability by control integrations of the Kiel Climate Model (KCM) with and without freshwater flux correction in the North Atlantic. The quality in simulating ocean circulation, mean climate and decadal variability is greatly enhanced in the freshwater flux-corrected integration that, by definition, depicts realistic SSS. Improvements comprise a more realistic representation of deep convection sites, sea ice, gyre circulation and Atlantic Meridional Overturning Circulation (AMOC). In response, a large reduction of the North Atlantic cold sea surface temperature (SST) bias and a more realistic pattern of the Atlantic Multidecadal Variability (AMV) are simulated. The results suggest that climate model simulation of North Atlantic sector mean climate and climate variability could strongly benefit from alleviating SSS biases.

12. Climate change and marine phytoplankton

S. Sett, K. G. Schulz, L. T. Bach, U. Riebesell
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Climate change driven by anthropogenic activities is leading to ongoing changes in sea surface temperature (ocean warming) and seawater carbonate chemistry speciation (ocean acidification) at an unprecedented pace. Both of these stressors are expected to significantly impact marine ecosystem in the near future. Despite their invisibility to the naked eye, marine phytoplankton are responsible for ~50% of global primary production and thus investigating their response to changing environmental conditions is of great importance. I will present results from controlled laboratory experiments, as well as natural communities of key phytoplankton groups investigated under the individual and combined effects of ocean acidification and warming. The laboratory results provide valuable information on physiological capabilities, metabolic thresholds and sensitivities of organisms under controlled experimental conditions. On the other hand, studies with natural communities show more complex, but also more realistic responses, to the potential effects of climate change.

LUNCH LECTURE

Ocean conservation in focus: Meeting the sustainability challenges of the new Blue Economy

C. McClennen
(Wildlife Conservation Society, NY, USA)

The century of the Blue Economy is upon us, having mainstreamed sustainable development of our oceans in the soon to be agreed upon UN Sustainable Development Goals (SDGs), become a formal policy of the European Commission in its efforts to spur “Blue Growth”, and a buzzword for the private sector as realized in the recent Economist sponsored World Ocean Summit. What makes this “new” approach to managing our oceans across the spectrum from exploitation to conservation different than the past? What opportunities are presented by the new sweet of policies and economic perspectives brought on by the emergence of this new paradigm? First this keynote will analyze the degree to which the “Blue Economy” does in fact represent a paradigm shift in ocean exploitation and management. Second, we will explore how the ocean conservation sector will or will not need to adapt to the changing human uses and impacts on the world’s oceans of the next century. Will the tools developed in the last century, such as protected areas, work in seas exploited in a manner never before imagined? Or, are we in need of conservation and management innovation at the same pace as the technological development that is making the ocean economy an increasingly important component of the global economy. A particular focus will be the impact of a rapidly changing ocean and global economy on the waters of emerging economies where change is most dramatic, but effective policy solution lag. Are new policies and approaches developed to manage the waters of developed economies immediately transferable? Do these solutions provide opportunities to leapfrog progress in ocean conservation? Or do the conservation challenges of the Blue Economy require the innovation of grassroots local solutions? The keynote will conclude with a proposed blueprint for accelerating bottom up innovation and scaling solutions for sustainable management globally to both embrace, and meet the challenges presented by the new Blue Economy.

Session 3 – Ocean Conservation

KEY NOTE

1. BBNJ, process and prospects for the marine biodiversity beyond national jurisdiction negotiations in the United Nations

L. Lijnzaad
(Department of International and European Law, Maastricht University, The Netherlands)

The UN General Assembly established a working group on marine biodiversity beyond national jurisdiction (BBNJ), which began its work in February 2006 and concluded in January 2015. The conclusion of the work of this working group with the proposal to develop an internationally legally-binding instrument on the conservation and sustainable use of marine biodiversity means that the debate at the United Nations has entered a new phase, with the establishment of a so-called preparatory committee that will make substantive recommendations towards the formulation of a treaty on marine biodiversity.
The address will be a reflection on this next step in the BBNJ negotiations, and will identify prospects and risks in terms of the process. A comparison with the development of the UN Fish Stocks agreement may be useful, and more in general the dynamics of this discussion in terms of the diplomatic reality and the legal dimensions will be addressed.

ORAL PRESENTATIONS

2. Marine mammal monitoring using hydrophone streamers during seismic reflection surveys – *Presentation at End of Session 2 Orals*

Shima H. Abadi[1], Maya Tolstoy[1], William S. D. Wilcock[2]
([1]Columbia University, NY and [2]University of Washington, Seattle, WA, USA)

Seismic reflection surveys use acoustic energy to image the structure beneath the seafloor, but concern has been raised about their potential impact on marine animals. Most of the energy from seismic surveys is low frequency, so the concern about their impact is focused on Baleen whales that communicate in the same frequency range. To better mitigate against this impact, safety radii are established based on the criteria defined by the National Marine Fisheries Service. Marine mammal observers use visual and acoustic techniques to monitor safety radii during each experiment. However, additional acoustic monitoring, in particular locating marine mammals, could demonstrate the effectiveness of the observations, and help us understand animal responses to seismic experiments. A novel sound source localization technique using seismic streamers has been developed. Data from seismic reflection surveys conducted with the R/V Langseth are being analyzed with this method to locate baleen whales. Data from the marine mammal observers on the R/V Langseth is used to verify the analysis.

3. Sharing the benefits of fisheries' common heritage: A proposal based on the natural capital approach

E. v. Doorn[1], M. Quaas[2], J. Schmidt[2]
([1]Walther-Schücking-Institute for International Law and [2]Department of Economics, Kiel University, Germany)

The current status of the world's fisheries is deplorable. Most proposed solutions use individual rights as a basis. This paper takes a reverse approach and develops a normative framework that is based on the idea of a common heritage. The main question to answer is consequently to what extent the notion of common heritage of humankind could provide enhanced protection for highly migratory fish stocks. Realising both the aims of utilisation and preservation at the same time, however, appears to be difficult. The 1982 United Nations Law of the Sea Convention offers a solution by theoretically splitting a fish stock in a part that shall not be touched and a part that can be fished. We propose to use the maximum sustainable yield (MSY) principle to delineate the boundary between these two parts. Incorporating a precautionary approach might shift this boundary.
A quintessential characteristic of common heritage is that benefits that arise from its exploitation should be shared among humankind. Contrary to the freedom of the high seas, access to a common heritage is restricted. Humankind consequently needs to regulate the access and benefit sharing. One a fraction consistent with the MSY approach should be allowed to catch in each year. The benefit to be shared is the natural capital value of this allowed catch. One way of collecting the monetary value is to annually auction off licenses to catch up to that given total allowable catch (TAC), to be determined by fisheries biologists. We show that if the TAC is set at a level according to the MSY principle, the auction price of a license equals the corresponding shadow price of the fish stock, i.e. the foregone marginal natural capital value. We discuss how our proposal can be extended to a multi-species setting where the standard MSY concept is of limited use.

4. Invasive species in an era of globalization

E. Briski
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

The world's ecosystems are undergoing rapid changes, with the introduction and spread of non-indigenous species (invasive species) being one of the greatest threats to biodiversity. Many species fail to establish after arrival to a new environment but those that succeed may have negative consequences on local community composition, ecosystem functioning and/or services to human society. The shipping industry has played a major role in the spread of aquatic non-indigenous species globally, so the International Maritime Organization suggested and several countries implemented mid-ocean ballast water exchange (MOE) as a regulation to prevent new biological invasions. Furthermore, after ratifying a numeric performance standard which is supposed to be achieved by ballast water treatment technologies (BWT), MOE will be phased out of use. Combining the results of my work in the last eight years on transport patterns and survival of taxa in ships' ballast tanks with work of other scientist in this area, I am going to determine the current status of protection of marine habitats from biological invasions. In addition, by testing BWT systems and determining taxa that survive the treatments, I am going to estimate future protection scenarios.

5. Oxygen minimum zones: Past, present, future

P. Grasse[1], M. Frank[2], L. Stramma[2]
([1]University of California Santa Barbara, CA, USA and [2]GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

The tropical Oxygen Minimum Zones (OMZs) are regions of very low oxygen in today's ocean and are covering approximately 30 Mio km² (8%) of the world's ocean. The distribution of oxygen in the ocean interior is controlled by an intimate interplay of water mass mixing, primary productivity, and bacterial respiration of organic matter. Recent investigations have shown that the oxygen content of the global ocean is decreasing and OMZs are expanding and model results reveal that the magnitude of the observed change is consistent with CO_2–induced climate change. As oxygen is essential for marine life, changes will have a major influence on the marine ecosystems. Furthermore, changing oxygen concentrations in the future ocean may also experience major shifts in nutrient cycling, strongly effecting the biological productivity in surface waters. A change in nutrient availability (e.g. phosphate, silicate, and nitrate) induced by changing oxygen concentrations and/or circulation can either enhance or diminish the primary productivity. How strongly changes in ocean circulation can affect primary productivity is documented during strong El Niño events, when weak upwelling ultimately leads to very diminished fish populations. Studies investigating the last 20,000 yrs show that times of high El Niño-Southern Oscillation (ENSO) with periodically strong upwelling (e.g. the late Holocene) caused high nutrient supply and intense diatom blooms. During studies in the Peruvian Upwelling area the overall linkage between nutrients, especially silicate and nitrate with oxygen concentration and the extent of the OMZs in the past and the present ocean was investigated to understand what we have to expect in the future. Considering global warming and anthropogenic climate change that most likely will exert major influence on ocean circulation, it is of great importance to investigate low oxygen areas and the mechanisms controlling their nutrient cycles.

6. Oxygen minimum zone induced fluctuations in cod genetic diversity – and what the Baltic Sea may tell us about the global future ocean

J. Dierking, B. von Dewitz, H.-H. Hinrichsen, T. Reusch
(GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Oxygen minimum zones are increasing worldwide, and particularly so in the Baltic Sea, as one consequence of global change, with important ecological repercussions. However, the effects of these zones on the genetic composition of marine animals – which is essential for their potential to adapt to future, more extreme conditions – has been neglected to date. Recent work suggests that the genetic diversity of marine fishes is affected by population declines due to overfishing. Here, we took a step further and assessed the combined effects of stock size and structure and the prevailing oxygen situation on Baltic cod genetic diversity, using an integrative long-term sample and data series. Genetic diversity showed surprisingly strong year-to-year fluctuations and was correlated with the number of cod females with surviving eggs in a given year. This finding highlighted that environmental pressure can cause rapid alterations in exploited fish stock genetic composition, and pointed to the importance of large females for Baltic cod reproduction. Considering the correlation of standing genetic variation and evolutionary potential, this is relevant for projections of the future state of cod stocks under global change.
In a second step, we scale up from this case study to community ecology, evolutionary adaptations, and resource management under the extreme environmental conditions of the Baltic Sea in general, and ask the question what the Baltic can tell us about the global future ocean. Here, the severity of oxygen minimum conditions and elevated pH frequently surpass values expected for 2100 in the open ocean, overfishing has been rampant, and eutrophication and impacts of invasive species are severe – mirroring the situation expected for the future global ocean. We use the integrative framework applied in the case study above to highlight the potential roles of natural resilience, evolutionary adaptations and sensible management actions in preparing for the future.

POSTERS

7. Assessing marine biodiversity – Pteropods as indicator species for climate change

N. Keul[1] and N. Bednarsek[2]
([1]Institute for Geosciences, Kiel University, Germany and [2]NOAA, Washington DC, USA)

How do we assess marine biodiversity? Ecosystems depend on a complex combination of factors and are not easily defined. As defined in 1992 biodiversity is the variability among living organisms from all sources, this includes diversity within species and ecosystems. The range of ecosystems found in each of the marine realms can vary greatly within a small geographic area, or remain more or less constant across vast areas of ocean. The interaction of different biological and physical factors leads to a complexity of ecosystems, the distribution and extent of which are poorly understood. Marine biodiversity is currently threatened by a variety of factors, including anthropogenic climate change, namely Ocean Warming and Ocean Acidification. This raises the question on how we can assess the state of marine biodiversity. When is the ecosystem healthy? What is "good" biodiversity? Due to the vast size of the ocean and restriction of resources, assessing this is a difficult task. We therefor propose indicator species that can serve as sentinels for biodiversity.
Pteropods are ubiquitous pelagic snails that are currently threatened by ocean acidification. It has been found that around 50% of pteropods in coastal regions are already affected by dissolution, which will amount to ca. 70% by 2050. Due to their extreme vulnerability and quick response to ocean acidification we propose to use pteropods as indicators of ocean acidification. They are the ideal candidates- globally distributed, relatively easy to catch and signs of dissolution can be easily detected.

8. Cnidarian microbiome: Impact of microbial communities for acclimation

S. Fraune
(Zoological Institute, Kiel University, Germany)

Marine ecosystems are threatened by global environmental changes such as ocean acidification and global warming. The basis of animal responses to different environmental conditions is only just beginning to be revealed. Genes, regulatory regions of the genome and epigenetics can be rapidly modified by environmental cues, and may thus represent mechanisms for rapid acclimation of individuals to a changing climate. However, the “hologenome theory of evolution” hypothesizes that the host-associated microbiota provides an additional toolkit for rapid acclimatization to environmental changes by changes in the microbial associations.
The starlet sea anemone *Nematostella vectensis* serves as a cnidarian model organism due to the availability of field samples, laboratory cultures and transgenesis. Through a combination of field and lab studies, the aim of my research is to determine the interactions of genomic polymorphisms, epigenetic regulations, and microbial communities to holobiont thermal acclimation by utilizing *Nematostella vectensis*.
Here, I show that the anemone’s epithelia are colonized by diverse bacterial communities and that the composition of its microbiota is tightly coupled to host development. Environmental variations led to robust adjustments in the microbial composition while still maintaining the ontogenetic core signature. In addition, analysis of bacterial communities of *Nematostella* polyps from different populations revealed a strong correlation between host biogeography and bacterial diversity. These observed variations could represent the microbiome’s contribution to host acclimation and thereby contribute to the maintenance of homeostasis due to environmental changes.
In future we will perform experiments with long-term acclimated animals to investigate the impact of changing temperatures on host transcription, bacterial colonization, epigenetic and their contribution to holobiont acclimation.