Wissenschaftliche Kommission Niedersachsen

Structural Analysis of Marine Research in Northern Germany

Niedersachsen

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Preface

The various German marine science institutions enjoy international recognition. Germany as a country, however, lacks a common and unifying strategic conception in marine science. At present, therefore, German marine science appears not to come up to its given potential. In this situation, the federal states of Northern Germany convened an international Expert Committee with the aim of undertaking a strategic evaluation. In addition to analyzing the present status of marine research in Germany the group was asked to draw conclusions thereof and to make recommendations for a new dimension of performance capability.

In a phase, when federal states and the government are about to reflect on the development of the German science policy system and its future funding, it was felt that this was an historic opportunity to critically look at the performance of marine sciences and to devise strategies to possibly enable the diverse parties involved to take more responsibility with regard to the global usage, protection, management and governance of the blue continent.

This report is the result of our work. We, in the Expert Committee, would like to express our deep gratitude to those who have helped to create this report. We are particularly grateful to the members of the "Wissenschaftliche Kommission Niedersachsen" (WKN) and its Secretary General Dr. Mathias Pätzold as well as Mrs. Saskia Gangl, Mrs. Sabrina Metzner and Dr. Daniel Wendler. Our special thanks go to Dr. Birgit Albowitz (WKN) and Dr. Jan Helmke (IASS, Potsdam) who compiled the first versions of this report and, always under time pressure, provided essential help in bringing it into its final form.

We also thank the group of marine scientists who so competently prepared the evaluation process. In addition, we warmly thank the delegates of State Ministries, who so openly discussed the issues of cross-border cooperation and competition. The reflections of the members of these groups have greatly enriched this report.

Berlin/Hanover, August 2013

For the Expert Committee

Prof. Dr. Dr. h.c. mult. Ernst Th. Rietschel
(chair)

1. Executive Summary

The conference of ministries of science and research of the five federal states of Northern Germany (NWMK) initiated a structural analysis of marine research. The purpose of this analysis was to identify organizational and structural initiatives which are suitable to strengthen and unify the international profile of German marine science as a whole.

Overall impression:

- The scientific performance and international competitiveness of German marine science is routinely evaluated in other contexts and is generally found to be good to excellent and in individual cases outstanding. Nevertheless, given the excellent infrastructure and the present funding situation, the Expert Committee believes that there is potential to further increase global impact and visibility of German marine science. To achieve this, a coordinated research approach, building on, but going beyond the existing tradition of individual cooperation, is needed.

Research Landscape:

- The institutional diversity of German marine science may be regarded as an asset and particular opportunity for creating synergies, provided that the often complementary profiles, strategies and objectives of the different institutions are combined in a better coordinated approach.
- Larger non-university institutions of the Helmholtz, Leibniz and Max Planck organizations as well as the Federal Research Agencies are major contributors to the quality and reputation of German marine science. During the last decade, universities have also played a major role in promoting German marine science. This is not only due to their innovative research potential, teaching and the recruitment and training of talented young researchers, but also to their disciplinary breadth as a basis for interdisciplinary marine research approaches. However, the relationship between universities and non-university institutions remains severely unbalanced, among other reasons as a result of legal funding restrictions, which are seriously threatening the continuity of research at the universities. Special efforts should be made to foster marine sciences at the university level, to enhance the established profiles in marine science and to assure reliable funding.
- Access to large infrastructure (e.g. ship time, expensive infrastructure, computing) must be made possible for all German marine research groups regardless of the type of institutional affiliation. Efficient mutual use should be enabled.

Thematic Foci:

- The Northern German marine scientific community drafted six scientific themes ("Grand Challenges") for a future collaborative research approach: "Ocean and Climate", "Changing Biogeochemical Cycles", "Marine Biodiversity, Ecosystem Research and Ecosystem Services", "Geological Resources from the Sea", "Earth Dynamics and Geological Risks" and "Coastal and Shelf Sea Research". Overall, the Expert Committee views these themes as a possible basis for future research.
- The Expert Committee acknowledges that the themes address globally important problems of ecological, economic and social relevance. However, the societal impact of the themes needs to be addressed more clearly and inter- and transdisciplinary research approaches need to be systematically implemented.
- In order for the themes to be addressed, they still need to be thoroughly revised and elaborated on, working programs need to be developed and the proper institutional partners identified. Also, teaching programs related to marine sciences have to be adapted to the requirements of the themes as the two go hand in hand.
- The Expert Committee recommends that the scientific themes to be organized in clusters that cross institutional and federal state boundaries.
- Furthermore, the themes should be coordinated regionally, such that each federal state holds responsibility for the coordination of at least one thematic cluster. This will be a challenging task but is the basis for creating synergisms.

Organization and Governance:

- In order to build up a unified and strong profile, German marine science will need to develop a strong coordinating organization with clear governance structures and decision-making authority. The German Marine Research Consortium (Konsortium Deutsche Meeresforschung, KDM) may be able to fulfill this task as an already established body. In its present form, however, it will hardly be capable of meeting this challenge. Therefore, the Expert Committee recommends that KDM is to be restructured and developed further.
- In the scenario of a reformed KDM, a governance structure would need to be established in which each major player (institution, university, etc.) in German marine research has a seat and a vote.
- An institutionalized relationship and an organized exchange need to be established between the Senate Commission for Oceanography (SCO) of the German Science Foundation (Deutsche Forschungsgemeinschaft, DFG) and KDM. At least the two chairpersons and the vice-chairpersons should be mutual (full) members of both the KDM board and the DFG Senate Commission.
- Coordination is not only needed among research partners of German marine science, but also at the political level of the state governments and the Ministry of Science and Education (Bundesministerium für Bildung und Forschung, BMBF). Thus, the German federal states engaged in marine research – in particular of Northern Germany – should form a forum for marine research ("Forum Deutsche Meeresforschung"). In this forum, the federal states should coordinate and balance their specific interests in marine sciences.
- Finally, it is strongly recommended, that the various bodies dealing with marine science (KDM, SCO-DFG, federal states and BMBF) establish an institutionalized high level council, the "German marine research council" ("Deutsche Meeresforschungsrat"), which cares for the present and future issues and interests of German marine science. The "Deutsche Meeresforschungsrat" should, based on the research themes and the specific needs of the present actions, develop a master plan for German marine science which covers not only present necessities, but also a research based vision for the coming decades taking budgetary issues into account as well.

Further Perspectives:

- In view of these recommendations a follow-up review procedure in three years is proposed to evaluate the progress of structural coordination of marine sciences in Northern Germany. Core of this follow-up review will be an in depth evaluation of the revised and elaborated concepts on thematically oriented research and of the governance structures established until then.

2. Introduction and Scope

The conference of ministries of science and research of the five federal states (Länder) of Northern Germany (Norddeutsche Wissenschaftsministerkonferenz, NWMK) intends to improve the coordination of research activities among their states, strengthen common research areas and enhance cooperation between universities and non-university organizations. In doing so, they wish to strengthen their performance in science and research and increase competitiveness on a national and international level.

To this end, the ministries initiated structural analyses in a number of areas of science and research and authorized the Scientific Commission of Lower Saxony (Wissenschaftliche Kommission Niedersachsen, WKN) to coordinate the evaluation process. The WKN is an independent body of experts that advises the state government and academic institutions of Lower Saxony in matters of policy regarding academia and research. It has been primarily active in the field of quality assurance, conducting assessments of research quality and research structures.

In October 2011 the WKN was authorized by the NWMK to organize a structural analysis of marine research performed by scientific institutions of the federal states of Northern Germany, including marine-related aspects of climate research. The structural analysis reported here takes into account a recent evaluation by the German Council of Science and Humanities (Wissenschaftsrat, WR), which focuses on renewal and strategic realignment of the German fleet of research vessels.[1]

German marine sciences cover the full range of open ocean and coastal (from continental shelf to the intertidal) and from tropical to polar seas. Moreover, all relevant disciplines are recognized for their international scientific competitiveness in marine research. Nevertheless, an unwieldy combination of institutional, financial and governance structures are constraining marine sciences and thereby preventing it from attaining its full potential. This is because marine research is conducted at a range of institutional types resulting in serious financial, administrative and scientific fragmentation. Research is performed in universities and non-university research institutions including the Helmholtz (HGF) and Leibniz (WGL) Association, the Max Planck Society (MPG) and certain Federal Research Agencies. These institutional affiliations are associated with different governance structures, research programs and funding systems. For example, whereas the HGF Centers are mainly supported by the federal government, the WGL and MPG are equally financed by both the federal

1 Wissenschaftsrat: „Empfehlungen zur zukünftigen Entwicklung der deutschen marinen Forschungsflotte“ (Lübeck 2010).

and the state governments. In contrast, universities receive their base funding exclusively from the federal state of their location.

Although institutional diversity allows for differentiated performance of tasks (a strength), the financial and structural fragmentation create governance problems for coordination of research (a weakness)[2]. The lack of a coordinated national research strategy for marine sciences makes it difficult for Germany to fully exploit its potential and to advance to a permanent position among globally leading nations performing marine research.

Thus, the main goals of the structural analysis were to analyze the fragmentation problem in its three facets (science, funding, governance [institutional, state, federal]) and to recommend an action plan that will lead to a better utilization of the research diversity offered by individual institutional types. Better coordination will lead to synergies that will allow the marine sciences community to address the grand challenge questions of relevance to science and society.

2 Forschungsförderung in Deutschland, Bericht der internationalen Kommission zur Systemevaluation der DFG und der MPG (Hannover 1999).

3. Approach to the Structural Analysis

The present structural analysis aimed to develop recommendations on the future prospects of marine sciences in Northern Germany and the development of a coordinated research strategy. It was not intended as an assessment of research quality. Scientific quality and originality of German marine science is regularly evaluated either through periodic national assessments of non-university research institutions or in the frame of grant application reviews, e.g. within the German national excellence initiative.

The present structural analysis was undertaken only after the scientific community itself had taken the initiative to discuss and to organize various options, a bottom-up process that lasted for about one year. This initiative was coordinated by a steering committee, comprising scientists from leading institutions in Northern German marine research as well as guest representatives of the Ministries of science of the Northern German federal states. The members and guests of the steering committee are listed in Appendix E 3.

Coordinated by this steering committee, marine scientists of Northern Germany authored a conceptual paper on the future prospects of marine research, which served as an important input for the present structural analysis (Chapter 4 and Appendix A: "The Prospects of Future Research Strategies from the Perspective of the Marine Science Community"). This paper contains a detailed analysis of the strengths, weaknesses, opportunities and threats of German marine research (SWOT analysis) and outlines six scientific themes for future collaborative research work.

In addition to the conceptual paper, each research institution provided a compact outline of its profile, personnel, funding, research output and infrastructure. The resulting "Fact Sheets" are provided in Appendix B.

The structural analysis was conducted by an external, international Expert Committee (for members, see Appendix E 1).

Finally, a conference and hearing took place at the International Maritime Museum in Hamburg April 11–13 2013. Participants were the members of the Expert Committee, marine scientists representing the most important marine research institutions in Northern Germany and representatives from the ministries of science of the Northern German federal states as well as a representative from the BMBF as a guest observer. The participants of the hearing are listed in Appendix E.

On the basis of the conceptual paper, the fact sheets and the conference, the Expert Committee was asked

- To assess the adequacy of the selected scientific themes;
- To evaluate the strategic alignment of German marine science with regard to the scientific themes;
- To discuss governance structures suited best for the strategic alignment of German marine science;
- To develop recommendations on the research foci, strategic alignment and governance structures of marine research in Northern Germany.

These recommendations will be directed to the ministries of science of the five federal states of Northern Germany.

4. Marine Research in Northern Germany – A Brief Overview

The majority of German marine research is concentrated in Northern Germany, i.e. the federal states (Länder) of Bremen, Hamburg, Mecklenburg-West Pomerania, Lower Saxony and Schleswig-Holstein. They share access to either the North or the Baltic Sea or both. These institutions are shown on the map in Figure 1 and further information can be found in the Fact Sheets in Appendix B. In other federal states of Germany, marine research plays a less prominent role and is performed in rather small research groups, mostly related to marine biology or geology. Together, these groups account for about 30%.[3] The remaining 70% of marine scientists are concentrating in institutions and universities in Northern Germany, a unique selling point for the states, a great source of regional pride and national responsibility for research on some of the most important marine-related global challenges.

Apart from universities, universities of applied sciences (Fachhochschulen), and non-university research institutions, significant marine research is conducted by federal agencies (Bundesbehörden), funded exclusively by federal ministries according to their objectives as well as by many smaller agencies and institutions of the federal states and by museums. Universities and the various non-university research organizations differ not only in their structural organization and funding but also in their scope. The Max Planck Society focuses on basic research, whereas the Leibniz Association focuses on strategic research that is centered on themes. The research centers of the Helmholtz Association concentrate on large-scale research, organized around programs. Federal agencies perform work that is directly related to the activities of federal ministries and in special cases (based on federal/federal state agreements) to the research activities of the states.

Among the many specific institutions involved in marine sciences in Northern Germany, only those with a major focus in this research area were involved in this structural analysis. They are depicted in Figure 1 and are characterized further by fact sheets (Appendix B). Other universities and research institutions in Northern Germany and outside this region may, to some extent, contribute to marine research, but will not explicitly be mentioned in this report.

In 2004, fifteen marine institutions established the German Marine Research Consortium (Konsortium Deutsche Meeresforschung, KDM), a bottom-up organization designed to coordinate the expertise of its member institutions. So far, it mainly acts

3 Wissenschaftsrat: „Empfehlungen zur zukünftigen Entwicklung der deutschen marinen Forschungsflotte“ (Lübeck 2010).

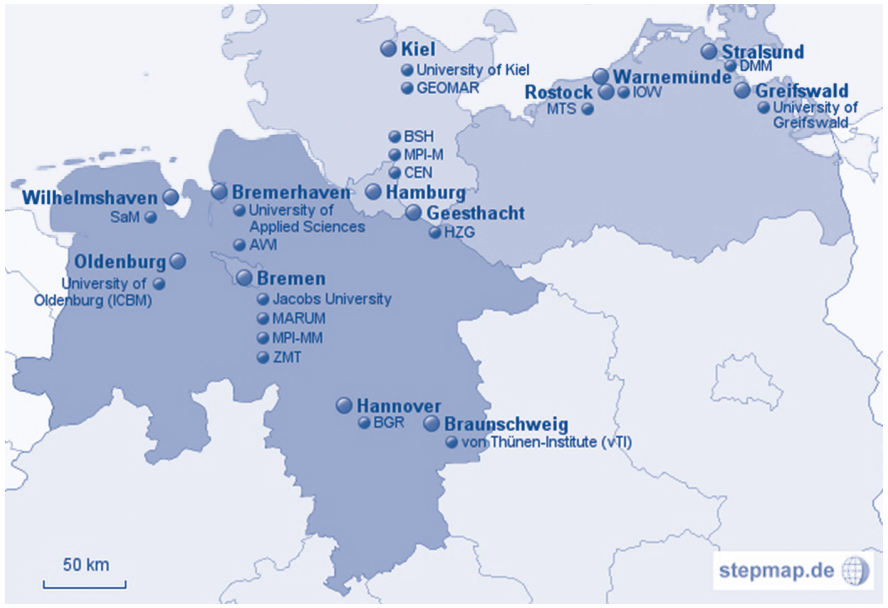


Fig. 1: Affiliations of marine research in Northern Germany Universities

Universities

- University of Bremen (MARUM): Center for Marine Environmental Sciences*
- Jacobs University Bremen gGmbH*
- Bremerhaven University of Applied Sciences
- University of Greifswald: Greifswald Center for Functional Genomics of Microbes (GC-FunGene) & Institute for Geography and Geology (IGG)
- University of Hamburg (CEN): Center for Earth Systems Research and Sustainability*
- University of Kiel: Kiel Marine Science (KMS), Center for Interdisciplinary Marine Sciences*
- University of Oldenburg (ICBM): Inst. for Chemistry and Biology of the Marine Environment*
- University of Rostock (MTS): Dept. Maritime Systems, Faculty of Interdisciplinary Research*

Helmholtz Association

- Alfred Wegener Institute Helmholtz Center for Polar and Marine Research (AWI, Bremerhaven)*
- Helmholtz Center Geesthacht (Zentrum für Material- und Küstenforschung) (HZG, Geesthacht)*
- GEOMAR Helmholtz Center for Ocean Research Kiel (Kiel)*

Max Planck Society

- Max Planck Institute for Marine Microbiology (MPI-MM, Bremen)*
- Max Planck Institute for Meteorology (MPI-M, Hamburg)*

Leibniz Association

- Leibniz Center for Tropical Marine Ecology (ZMT, Bremen)*
- Leibniz Institute for Baltic Marine Research Warnemünde (IOW)*
- Senckenberg am Meer (SaM, Wilhelmshaven)*

Federal Research Agencies

- Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI, Braunschweig)*
- Federal Maritime and Hydrographic Agency (BSH, Hamburg)
- Federal Institute for Geosciences and Natural Resources (BGR, Hannover)

Others

- German Oceanographic Museum Stralsund (DMM, Stralsund)*

* Members of KDM (German Marine Research Consortium)

as a lobbying organization to promote marine research issues and interests vis-à-vis funding agencies and stakeholders both at the national and international level. KDM is headed by a board consisting of five representatives (one chairperson, two co-chairpersons and a steering committee) and maintains two offices in Berlin and Brussels. Strategy Groups within KDM develop positions on relevant topics (e.g. Strategy Groups "Ocean and Climate System", "Coastal Research" and "Polar Oceans").

A further representative of marine science is the "Senate Commission on Oceanography" (SCO) within the German Research Foundation (DFG). This Senate Commission is responsible for coordinating the DFG's activities in marine research. Its primary function is to allocate ship time for the vessels METEOR and MARIA S. MERIAN. In addition, the Commission acts as Germany's "scientific voice" in the Scientific Committee on Oceanic Research (SCOR) of the International Council for Science.

With respect to infrastructure, German marine science is well equipped. The German fleet of research vessels consists of three globally operating vessels (POLARSTERN, METEOR and SONNE), two ocean-class vessels (MARIA S. MERIAN and POSEIDON), two regionally operating vessels (ALKOR and HEINCKE) as well as several smaller coastal vessels. The replacement of older vessels is planned, scheduled and already partly budgeted.[4] Procurement of ship time is coordinated through a harmonized procedure including a standardized application system and a peer review procedure according to transparent criteria.

Large sea-going instrumentation includes four remotely operated vehicles (ROVs), three autonomous underwater vehicles (AUVs), the manned underwater vehicle JAGO, a sea floor drilling rig and a benthic crawler. A hybrid ROV is under construction.

Observatory systems are available for monitoring long-term changes in environmental conditions such as the coastal observation system (COSYNA) at the Helmholtz Center Geesthacht (HZG) and observatories for Arctic and Antarctic waters at the Alfred Wegener Institute AWI (e.g. HAFOS, FRAM array and HAUSGARTEN).

Land-based infrastructure includes specialized laboratories, high-performance computing centers, genomic sequencing facilities and core libraries.

Furthermore, German marine scientists are enabled to participate in international top-notch marine research programs, e.g. within the international "Integrated Ocean Drilling Program" (IODP). The German contribution to this program is jointly financed by the BMBF and the DFG.

In general, major third-party funding sources for marine research are the BMBF and the DFG. During 2007–2011, the BMBF supported German marine research with

4 Wissenschaftsrat: „Empfehlungen zur zukünftigen Entwicklung der deutschen marinen Forschungsflotte" (Lübeck 2010).

about € 98.3 million (about € 192.8 million if infrastructure investments are included)[5]. DFG funding during the same period amounted to roughly € 258 million (collaborative research projects only). A list of collaborative research projects funded by the DFG and an overview of funding by the BMBF is provided in Appendix C.

Universities in Northern Germany offer a wide variety of Bachelor, Master and PhD study programs related to marine sciences (Appendix D). These programs are frequently taught in collaboration with non-university research institutions.

Further details on research profiles, funding, personnel, infrastructure and performance are provided in the "Fact Sheets" (Appendix B). The organization of marine research and its infrastructure are described in greater detail in the paper "The Prospects of Future Research Strategies from the Perspective of the Marine Science Community" (Appendix A).

5 Source: Projektträger Jülich, Geschäftsbereich Meeresforschung, Geowissenschaften, Schiffs- und Meerestechnik (MGS), Forschungszentrum Jülich GmbH, Rostock.

5. The Prospects of Future Research Strategies from the Perspective of the Marine Science Community

5.1 SWOT Analysis

The marine science community of Northern Germany performed its own SWOT analysis of German marine science and identified six research themes for future collaborative research work. The "SWOT Analysis of German Marine Research" as well as the "Scientific Themes and Future Prospects" are found in Appendix A. Key points from these analyses may be summarized as follows.

The marine science community views its major **Strengths** in its high research quality and state-of-the-art infrastructure. The establishment of KDM as a lobbying body and nascent platform for cooperative research work is also regarded as a strength of German marine science.

From the marine science community's point of view, budget constraints at universities and limited access to large sea-going infrastructure due to lack of funding are considered to be major **Weaknesses** of German marine science. A further weakness is seen in the performance of coastal marine science, which enjoys only limited national and international visibility. In addition, the linkage between marine sciences and the maritime economic sector as well as the collaboration with social sciences and engineering are presently weak.

Strengthening of interdisciplinary and transdisciplinary initiatives are regarded as **Opportunities** by the German marine science community. Other opportunities are seen in the development of innovative marine observation technologies, increased efficiency and collaboration in coastal research and also increased international collaboration. Finally, the recruitment of outstanding young scientists and the improvement of public outreach are considered to be opportunities.

From the marine science community's point of view, **Threats** for German marine science are seen in the low public interest in and recognition of marine sciences as well as the decreasing involvement in marine related topics at universities outside the federal states of Northern Germany. Difficulties in the recruitment of high-level scientists are considered to be a further threat. In addition, due to the uncertain position of the ESF Marine Board and Polar Board, the collaboration of European marine science is regarded as critical. Finally, upcoming budget constraints of the federal states and the government may represent a significant threat for the coming years.

5.2 Scientific Themes

The marine science community of Northern Germany has defined six scientific themes which will be jointly addressed by the researchers.

Ocean and Climate: The variability of ocean circulation is a key factor controlling global climate change and its regional manifestations. Reliable future projections of climate change thus require an advanced understanding of the physical processes and phenomena in the oceans which are critical to the ocean-sea ice-atmosphere system. In Germany, climate-oriented marine research has contributed to a better understanding of e.g. processes leading to deep-water formation, the role of the tropical oceans in climate change, the nature of large-scale ocean-atmosphere interactions, sea level changes and climate predictability. Future marine research in Germany will seek to investigate the variability of ocean circulation, changes of the sea-level, the role of mixing processes in large-scale ocean circulation, feedbacks between ocean circulation and marine ecosystem dynamics and biogeochemical cycles as well as the role of the ocean in affecting climate on land.

Changing Biogeochemical Cycles: Matter cycles in the ocean are controlled by a multitude of biogeochemical processes with specific adaptations to changing boundary conditions. Many of these biogeochemical processes represent key ecosystem functions and services to humanity. Therefore, monitoring of natural and manmade variations has become a societal challenge. German marine science has addressed material flux changes associated with changes in the Earth System. For the future study of material fluxes, it is planned to develop observation systems and environmental indicators. Further, it is intended to develop modelling systems in order to anticipate trajectories of matter fluxes and their consequences for ecosystems and societies. These models are to be used for hindcasts, projections and experiments. Finally, German marine science plans to integrate observations and modelling to develop management strategies for sustainable use of marine resources.

Marine Biodiversity, Ecosystem Function and Ecosystem Services: Biodiversity is of fundamental importance to ecosystem functioning and human well-being. At the same time biodiversity is threatened by overharvesting (fisheries), habitat loss, eutrophication, invasive species and the effects of climate change. We still know little about marine biodiversity, especially in the deep sea, yet marine biodiversity is being destroyed before it can even be discovered. Ecosystems have to be managed in order to counteract species and habitat loss. Furthermore, ocean biota has a high potential for valuable resources such as pharmaceuticals. German marine science has been actively involved in research on the evolution of life in the oceans, diversity and distribution of marine life, marine biology and physiology as well as geosphere-biosphere interactions and extreme environments. In the future, it is planned to explore marine biodiversity further and investigate the mechanisms leading to the observed patterns in biodiversity and to the monitored changes in the Anthropocene. Furthermore, marine science will investigate the effects of changing biogeochemical cycles on biodiversity and intend to provide information on the sustainable use of marine ecosystems.

Geological Resources from the Sea: As depletion of conventional resources on land continues, there will be growing pressure to exploit marine systems for energy, mineral and biological resources too. Germany has been particularly active in the discovery and assessment of manganese nodules, cobalt-rich crusts, massive sulfide resources and phosphorite nodules from the seafloor in different areas. In addition, gas hydrates have been intensively researched. German marine research institutions dispose of the methods and skills needed to identify technologically relevant resources. Future objectives are to provide tangible criteria for the selection of areas suitable for exploration of marine mineral resources in the oceans and to develop more successful strategies as well as technologies for exploration, mineral assessment and exploitation. Furthermore, German marine science engages in research to assess the potential for exploitable hydrocarbon resources located at great water depths, in deep geological formations and in remote Arctic regions.

Earth System Dynamics and Geological Risks: Continued growth of the world's population has resulted in expansion to new living spaces, making people more vulnerable to geo-hazards such as earthquakes, volcanic eruptions, tsunamis and submarine landslides. In order to respond more effectively to these hazards, the processes themselves have to be understood. The role of fluids and volatiles in subduction zones and consequences for earthquakes, volcanic eruptions and tsunami generation has been investigated by German marine sciences. They have performed research on the formation of mid-ocean ridges and oceanic intraplate volcanism and have investigated submarine landslides. Future objectives include large-scale mapping of the seafloor surface using modern multi-beam systems.

Coastal and Shelf Sea Research: Coastal research focuses on a particularly vulnerable region that includes both marine and terrestrial end members. Coastal research requires the integration of social, engineering and natural sciences not only in interdisciplinary cooperation but also in a transdisciplinary one involving stakeholders from industry and practice. Acknowledging the complexity arising from interactions of the natural and the human system, coastal research in Germany strives for a more integrative system view. For the future, the understanding of coastal ecosystems should be improved. It is planned to analyze the impacts of global and regional change on coastal systems in a modular coastal model system that is able to assess the vulnerability of coastal systems. Furthermore, the scientific basis for

innovative infrastructures in the coastal realm should be broadened. Research activities target implementation of an integrated marine policy.

6. Assessments and Recommendations

6.1 Overall Impression

Marine research, as compared to other scientific fields, is a specific strength of Northern Germany and, therefore, represents a unique selling point for the five northern federal states. This becomes particularly evident when looking at the outcome of the German national excellence initiative. Three clusters of excellence in Northern Germany, located in Bremen, Hamburg and Kiel, are devoted to marine research[6]. Marine sciences are of national importance and the Northern states assume national responsibility for marine sciences in general and for research on some of the most important global marine-related problems, in particular. Thus, marine sciences are to be regarded as a proudly cherished specialty of the Northern German federal states, with the potential to place German research in a leading position in areas of key importance to meet global challenges such as climate change, biodiversity, energy and resources.

Although a detailed assessment of the quality of research was neither intended nor possible during the process of this structural analysis, the Expert Committee views the overall performance of German marine research as good to excellent. This appraisal is based on the results of other review procedures, strategy papers[7] and the documents presented in this structural analysis.

The Expert Committee considers marine research of Germany to be well established on the national and international level. There are a number of large and well-known institutions and excellent scientists performing internationally recognized research related to marine sciences. Institutions are well equipped and have access to state-of-the-art infrastructure (seagoing, laboratory and computing). At present, marine sciences are comparatively well funded by national agencies like BMBF and DFG as well as by the state governments of Northern Germany.

Despite of the excellent performance and prerequisites, the global impact and international visibility of German marine science is, though undoubtedly present and strong, restricted to the activities of specific institutions and staff. Thus, international visibility is mostly due to individuals and individual cooperation rather than being

6 Bremen excellence cluster "The Ocean in the Earth System" (2007–2017); Hamburg excellence cluster "Integrated Climate System Analysis and Prediction" 2006–2017); Kiel excellence cluster "The Future Ocean – Sustainable Ocean Development" (2006–2017).

7 E.g. Wissenschaftsrat: „Empfehlungen zur zukünftigen Entwicklung der deutschen marinen Forschungsflotte" (Lübeck 2010).

associated with the German marine science system as a whole. In other words, the idea of a German international program of marine science is not yet apparent. However, the globalization of research requires such a strong and visible international presence. The Expert Committee feels, that German marine science possesses the potential to occupy an even more prominent international position, provided a number of system weaknesses are addressed and overcome.

The expert group applauds the fact that German marine science has chosen to present its future research in the form of thematic foci and not as programs of individual institutes or organizations. This collaborative spirit should be maintained as it represents a necessary prerequisite for the promotion of German marine science as an entity. This initiative for collaborative research and the development of common research programs will improve the visibility of German marine science as a whole and strengthen its competitiveness for national and international research grants. Thus, it will help to make the best use of institutional diversity and overcome its possible disadvantages.

The Expert Committee is in general agreement with the SWOT analysis performed by the marine science community but has a number of further observations which are reflected in its specific recommendations following.

The Expert Committee recommends performing a follow-up review in about three years in order to evaluate the further development of German marine science and its structural organization as well as the implementation of the recommendations presented in this report.

6.2 Thematic Foci

6.2.1 General Remarks

The marine scientific community identified six "Grand Challenges" (themes) of German marine science as a framework for future collaborative research: "Ocean and Climate", "Changing Biogeochemical Cycles", "Marine Biodiversity, Ecosystem Research and Ecosystem Services", "Geological Resources from the Sea", "Earth Dynamics and Geological Risks" and "Coastal and Shelf Sea Research" (Chapter 4 and Appendix A).

The selection of themes is in principle supported by the Expert Committee. While other thematic approaches might be appropriate as well, the themes chosen appear suitable for innovative scientific approaches and might serve as a good start. It is particularly appreciated that the themes are to address globally important overarching questions of ecological, economic and social relevance extending geographically defined problems such as "Polar Research" or "Deep Ocean Research". The research themes are seen to stand for Grand Challenges in marine research. However, the themes should not be considered to be "cast in stone". They might be developed and modified during the process of elaboration and need to be adapted to new challenges and research advances.

As presented in the concept paper, the scientific descriptions of some of the themes appear to be largely governed by the interest and expertise of specific institutions and scientists and do not outline and consider the full scientific potential being available in Northern Germany marine research. An important next (and immediate) step is to determine which institutions and lab groups (regardless of their size) have something to contribute to a chosen theme. In this way, hidden synergies can be discovered. The Expert Committee understands that it is neither intended nor possible to align all research activities within the framework of the identified themes; monodisciplinary research or specialized topics must also be maintained. Nevertheless, the themes should be tailored in such a way that all institutions of marine research can contribute in varying degrees as appropriate. Research work within the themes should not be governed by selected institutions but rather as cooperative, which considers both depth and breadth within a theme. Development of a governance structure for a theme will be a challenging task but an essential one.

The integration of socio-economic and policy dimensions to some of the themes is currently missing. Likewise, some of the themes are more defined by methodologies than by their global and societal impacts. The Expert Committee recognizes that this type of integration is new and difficult. In any case, the internal depth and breadth of the themes with respect to impact need further development.

Thus, the choice of themes has to be justified in more detail, both with respect to the impact of the themes and to the expertise available within German marine science. At present, the thematic scopes are rather broad and only few specific questions are addressed. A detailed working plan has to be established for each of the themes. Moreover, specific research partners for an effective interdisciplinary research approach have to be identified and included in the development of a working plan for each theme. The plan should indicate as to how the various universities and research institutions might contribute best to each of the themes and what benefits they expect from cooperative research.

The impact of the themes on teaching activities, on the one hand, and the need for teaching required by the themes, on the other, must be addressed by both university and non-university institutions. This applies to both undergraduate and graduate level teaching.

According to the Expert Committee, simulation tools and modelling should be taken into account much more intensively in all of the listed research themes. This may require development of additional platforms in a coordinated effort by the community. Likewise, data management and joint data information systems (data portals), as those in existence (e.g. PAN-GAEA – "Data Publisher for Earth & Environmental Science", hosted by AWI and MARUM), do not appear sufficiently developed for all future challenges (see below: "6.5 Infrastructure").

6.2.2 Interdisciplinary and Transdisciplinary Research Approaches

Since the themes selected are aligned to the needs and problems of society, interdisciplinary and transdisciplinary research approaches[8] should be more convincingly implemented in the respective working programs. To achieve this, social sciences, economics, law, engineering and humanities must be integrated with the natural sciences. Moreover, constant dialogue and interaction with stakeholders are of crucial importance for marine research so that researchers become aware of the problems and needs of society, and be included in the decision-making process. Transdisciplinarity starts from the assumption that scientists and practitioners are experts in different kind of knowledge, where both sides can benefit from a mutual learning process. Stakeholders may include local, national and international representatives and decision-makers from agencies, governments and industry. Due to the different and partly conflicting interests in coasts and oceans, arising from environmental issues, traffic, logistics, business (related to resources from the sea) and tourism, expertise from marine sciences becomes increasingly relevant for decision-makers.

The Expert Committee acknowledges that both interdisciplinary research approaches and transdisciplinary interactions are already partly established within the marine sciences of Northern Germany. However, in view of the immense importance of interdisciplinary and transdisciplinary research, the Expert Committee recommends that these approaches are to be developed further and put on a more robust basis. While this is true for almost all fields of marine sciences, it is of particular significance for coastal research. Since the coastal environment represents an interface between

8 In this context **interdisciplinarity** is defined as a research approach that integrates different scientific disciplines into a joint scientific question. An interdisciplinary approach requires an intensive dialog on methods, terminology and concepts.

Transdisciplinarity is defined as a research approach that goes beyond the scientific disci-plines. Transdisciplinary research approaches integrate scientific knowledge into knowledge gained outside the academic system. For instance, transdisciplinary research seeks to identify societal problems and apply results in order to solve these problems. It implies a strong interaction between researchers, practitioners, stakeholders and politicians. (Mittelstraß, J. 2002: Transdisciplinarity – New Structures in Science. In: Max-Planck-Gesellschaft (ed.): Innovative Structures in Basic Research [Ringberg-Symposium October 4–7, 2000]. München, pp. 43–54).

people and the sea, coastal research needs a link to social sciences and engineering and has to consider legal frameworks and international regulations. It is not sufficient to include scientists from different subjects as an "add-on" in the course of a project. Rather, it is necessary to develop research programs jointly right from the start.

The Expert Committee recommends the further integration of social sciences and other related scientific fields in decision-making bodies such as KDM, its Strategy Groups, etc. For example, the endorsement of a chair for socio-economic studies at the Leibniz Center of Marine Tropical Ecology is particularly applauded. Also, the Kiel excellence cluster ("The Future Ocean") may serve as a good model for successful implementation of neighboring sciences. In addition, the existing research activities on interdisciplinary and transdisciplinary approaches at the Helmholtz Centre Geesthacht are supported. These projects should be continued and implemented in other programs.

Public outreach that communicates the impact of the marine environment on society and explains research approaches would improve ocean literacy and facilitate greater interest and acceptance of marine sciences beyond Northern Germany. Thus, the committee is supportive of high-quality presentations and events like the successful exhibition "Tiefsee" that ran in Rosenheim (Bavaria) in 2012.

Marine sciences hold an enormous economic potential. The already existing contacts with the maritime industry should be extended beyond the present state. The Expert Committee recommends establishing the infrastructure required to foster applications of marine research.

6.2.3 Assessment of the Scientific Themes – Individual Recommendations

The Expert Committee submits the following more specific comments regarding the individual research themes:

"Ocean and Climate"

The Committee is highly supportive of this research theme and the strategy outlined. There is no doubt regarding the impact of the topic. For this research theme it is of particular importance that the relevant stakeholders in society and politics are reached and included in the design of research programs. Even though German research activities related to this thematic topic are already interconnected with different national and international organizations dealing with the assessment and impact of climate change, these activities should be strengthened and continuously developed further in order to heighten impact and increase global interaction.

German marine science is strong and is in the forefront of international research in the key fields of modern climate research and supporting disciplines, including both past, present and future climate change.

Data management and modelling are particularly important in this field of research. Up to now, climate models and their evolution into Earth System Models have been developed mostly in-house and at times ad hoc in the different institutions and not as a community effort. The Expert Committee recommends setting up joint projects for cooperative development of Earth System Models and would encourage developing of a joint process of model development, process studies and model analysis facilities to enable the community at large to make further progress.

"Changing Biogeochemical Cycles"

The Expert Committee is highly supportive of this research theme (e.g. the study of past and present changes in material cycles including those related to human activities) and the strategy outlined (e.g. long-term observation systems, development of predictive models). The Committee emphasizes the particular importance of interaction between scientists and users. Although the aim of enhancing the usability of science for societal needs and informing decision-makers of sustainable solutions has been presented to the Expert Committee, a strategic plan for an efficient dialogue is lacking. This deficiency needs to be addressed soon, including interaction with the private industry, for example, in relation to an operational system such as the Coastal Observing System for Northern and Arctic Seas (COSYNA). Because COSYNA provides real-time data that can help authorities and other stakeholders to manage routine tasks, emergency situations and evaluate trends, it may also represent a platform of opportunity for funding of research from extramural sources.

"Marine Biodiversity, Ecosystem Research and Ecosystem Services"

The Expert Committee is highly supportive of this research theme and the strategy outlined. This area of research is well supported by research groups at universities beyond Northern Germany. The Committee recommends establishing bioinformatics and "omics" technologies further. Experimental facilities should be used mutually in "modularized experimental networks". The experts encourage the scientific community to intensify investigation of deep sea and polar marine biodiversity. Particular care needs to be given to coastal studies (see also section "Coastal and Shelf Sea Researchs" below) involving ecosystem services in the context of anthropogenic pressures and coastal spatial planning. This extends into areas that have historically been viewed as coastal zone management (monitoring, long time series, pollution, habitat modification, local fisheries, aquaculture and risk assessment). The biodiversity constellations will be best poised to further initiate transdisciplinary research which should be actively encouraged through joint funding opportunities as is the case for German research in terrestrial biodiversity, which has an extremely strong international profile. Efforts to combine these research strengths should be actively encouraged.

Germany hosts the secretariat for the UN Platform for Biodiversity and Ecosystem Services (IPBES) established in 2012 and, given the strong scientific base within Germany, biodiversity research would be an obvious candidate for profiling German marine research internationally.

The Expert Committee was surprised that fisheries and fisheries research did not feature more prominently in this theme. Resource exploitation generally must be seen in a system context and fisheries, in particular, needs to be seen in an "ecosystem" context. The hearing did not make it clear to the Committee how and where interaction with the fisheries research and management community is coordinated.

"Geological Resources from the Sea"

Resources from the sea are of increasing economic and social value. The concept paper on this theme points to different types of resources, such as energy, mineral resources and biological resources, the latter including food supplies as well as marine substances as a basis for the biotechnological development of medication and other products. Apart from naming a variety of possible resources, the concept for this research theme seems to focus on specific sources of energy (gas hydrates) and mineral resources (manganese nodules, massive sulfides) only. It might be worthwhile, however, to analyze the potential for investigation of other marine energy sources and biological resources as well. If the marine science community decides to restrict this topic to geological resources, a combination with the theme "Earth Dynamics and Geological Risks" should be considered as an alternative approach.

The Expert Committee realizes that some work on mineral resources is conducted on licenses either granted under national regulations under the Exclusive Economic Zone (EEZ) or under the EEZ or under regulations of the International Seabed Authority setting a framework for research activities requiring also investigations concerning mining, metallurgy and economic assessments. However, the Committee recommends extension of the scientific approach beyond identification and harvesting of resources and performance of basic research, e.g. on the origin of mineral resources, their relation to environmental parameters or geo-physical detection methods.

As far as the economic value of mineral resources is concerned, the Expert Committee comments, that mineral processing of the resources is not resolved yet, such that the net value of the resources remains unclear. Nevertheless, since mineral resources do represent economic value, the Committee wonders whether the discovery of minerals might be patented, such that the patent's revenue might pay for future research. Also, a "payback" from mining industry in order to support research might be considered.

Pilot sites for a selection of production and exploitation of mineral and unconventional resources, coordinated with industry efforts and in cooperation with international research teams could lead to a breakthrough in environmental assessment, a necessary step towards full scale exploitation.

In pursuing this research theme, it is of utmost importance to consider the environmental impact of exploration and harvesting of resources, which always means a significant impact on the environment. This not only implies that environmental impacts are observed when dealing with marine resources, but also that research on environmental impacts continues and is performed in conjunction with the research on the resources themselves, i. e. long-term environmental observations with time series are required. In the Expert Committee's opinion, the scientific community is responsible for the environmental impact of utilization of the sea. Therefore, research on the environmental impact should become an integral part of this research theme and environmental, social and economic scientists should therefore be included in the research approaches.

"Earth Dynamics and Geological Risks"

There is no doubt that geological risks, particularly in the context of oceans and coasts, are highly relevant to society. While the geological work was well presented in the concept for this theme, the Expert Committee felt that a link to the social dimension of this subject is lacking and needs to be included, especially in relation to geohazards, early warning systems and risk assessments of natural hazards.

Both passive and active (shear zone) continental margins show signs of mass-movements that bring large volumes of sediments from the upper slope to the deep sea creating natural disasters. These events are difficult to predict and a relationship to earthquake activity remains to be proven.

European coasts and shelves are most vulnerable in regions of a dynamic earth where earthquakes and/or volcanoes may become active. Such geological risk areas combined with highly populated coastal zones are known to exist in the Mediterranean. Due to the high density of populated coastlines in the Mediterranean these areas are of particular interest for bringing research to the forefront in European research efforts.

"Coastal and Shelf Sea Research"

Coastal research is considered to be a challenging theme with particularly extensive socio-economic impact and interactions. The theme encompasses the entire breadth of opportunities and problems involved in the interaction of humans with the ocean. Conflicts of interests, e.g. between use and protection of natural resources, are prevalent in coastal research. The specific scope of coastal research requires substantial integration of social and economic sciences, engineering as well as national and international law and politics.

Moreover, a strong stakeholder interaction is essential for coastal sciences. On the one hand, science has to be aware of and recognize social and environmental problems, needs and conflicts related to coasts; on the other hand, the research activities must have an effective impact on decision-makers.

Social sciences are incorporated into some research activities (e.g. integrated approaches on tropical coastal systems) and stakeholder interactions are sought (e.g. within the framework of the workshops "Küsten 2021"). In the Expert Committee's view, however, interdisciplinary research approaches need to be far more developed and integrated. The same is true for the interaction with stakeholders and the public, which has to be substantiated and should be developed in a much more systematic and stringent manner, as the coastal area is where "Society meets Ocean" (this term might even be a better description of the theme).

Coastal sciences in Northern Germany are both fragmented and highly diversified. Numerous research institutions deal with different aspects (e.g. climate, risks, ecosystems and resources) of various coastal systems (e.g. North and Baltic Sea, Wadden Sea, tropics and polar regions). While the need for a stronger coordination is necessary for all research themes presented, this holds particularly true for the field of coastal research. To fulfill this task, suitable governance structures need to be developed (see below "Organization and Governance").

6.2.4 Management of Cooperative Research with Respect to Thematic Foci

The thematic foci, while principally being suited for a future collaborative research approach, have to be developed within the context of overall expertise that can be contributed by individual lab groups regardless of institution. In this manner, synergisms can be discovered. An in-depth evaluation of the revised thematic concepts and scenarios for the clustering of research groups contributing to the themes and subthemes is an essential and urgent task; and at the core of the follow-up review recommended by the Expert Committee.

The Expert Committee recommends the scientific themes to be managed and organized under regional coordination. This implies that each theme be coordinated by an institution harboring scientists with a specific research profile in terms of the respective theme. The regional coordinating responsibility should aim at creating first class research teams across the federal states of Northern Germany. Thus, universities and research institutions from all regions of Northern Germany (and possibly beyond) are invited to participate in the clusters on an equal footing. The research teams created are in charge of revising the respective research theme, of developing and managing suitable research programs and of agreeing on an efficient, mutual

use of infrastructure as a joint effort. Such coordination structures have to be kept flexible as regional research foci and scientific needs may change in the future.

The Expert Committee further recommends that each federal state and its respective research institutions should be in charge of coordinating at least one of the scientific themes. The Expert Committee recommends that a discussion be initiated to decide on the thematic coordination of clusters within KDM and the newly established German marine science forum.

The following propositions may serve as a basis for further discussions. Research on the theme "Ocean and Climate" could be coordinated by Hamburg, "Marine Biodiversity, Ecosystem Research and Ecosystem Services" by Lower Saxony, and "Coastal Research" by Mecklenburg-West Pomerania. Both Schleswig-Holstein and Bremen are well suited for coordination of the themes, "Geological Resources from the Sea", "Earth Dynamics and Geological Risks" and "Changing Biogeochemical Cycles". As the topics "Geological Resources from the Sea" and "Earth Dynamics and Geological Risks" share common aspects they might well be coordinated by the same geographical site, e.g., Schleswig-Holstein. In this case, Bremen would coordinate "Changing Biogeochemical Cycles".

The Expert Committee wishes to emphasize that the suggested regional responsibility of a federal state extends to its function as a coordinator and facilitator of a theme on the one hand engaging itself for the local clusters but supporting cross-border themes with expertise and infrastructure on the other.

6.3 Research Landscape and Funding Situation

The Expert Committee recognizes the diversity of organizations that perform marine research in Germany. Even though the diversity of affiliations involved complicates research cooperation, it also holds opportunities for a more creative and flexible use of resources for specific themes. Universities and the various non-university research associations, in particular the Helmholtz Association, the Leibniz Association and the Max Planck Society pursue different research strategies and objectives so that approaches in marine sciences may complement one another. For example, whereas the Max Planck Society is particularly strong in basic research, the Helmholtz Association is capable of carrying out large-scale projects, the Leibniz Association and the federal research agencies are particularly engaged in looking at urgent problems of society, the latter maintaining direct contact to stakeholders. Universities, on the other hand, are rather flexible in choosing their research topics so that new approaches and innovative ideas may quickly develop and flourish. In addition, universities while being organized largely in a disciplinary manner, do provide a broad range of disciplines and, thus, generate the necessary basis for interdisciplinary research approaches that are required in marine research. Finally, they are needed to ensure teaching and education of young scientists and, thus, guarantee excellent marine sciences in the future.

The Expert Committee acknowledges the present diversity of institutions and their different obligations. However, "diversity" should not be mistaken for "unevenness". In the German academic system, strong partners with great impact and adequate funding (like the Helmholtz Centers) operate alongside smaller, less well funded (in particular university-based) institutions. In order for the German marine science system to move forward, this disparity will need to be addressed and it must be guaranteed that all institutions involved are enabled to perform their tasks with reliable funding and have an equal impact on common research programs and decisions.

The Expert Committee is particularly concerned about the role and situation of the universities. In Northern Germany the universities of Oldenburg, Bremen, Hamburg, Kiel and Rostock have developed a major profile in marine sciences. At other universities in Northern Germany and in other regions smaller working groups in the geological or biological faculties are also making important contributions to marine sciences.

Thus, universities have and will continue to have a major impact on the development of German marine science. This impact is magnified by the educational tasks universities undertake in the science system. Because universities are the only institutions allowed to grant doctoral degrees, they are crucial for the sustainability of marine research. University graduate students frequently conduct research at neighboring non-university institutions and thereby help to maintain research performance at these sites. Therefore, it must be of the greatest interest for non-university institutions too, to support marine sciences at the university level. In this spirit, the larger non-university institutions, should seek closer collaborations with university units and explore all possible means to provide financial support in a manner, which respects the present legal situation. These collaborative efforts include joint projects provision of infrastructures, laboratory space and shared educational programs. Each local thematic focus could develop a unique profile cluster – specific cooperation programs, making use of the strengths of the various partners involved.

There are several developments which harbor the danger of weakening university-based marine sciences. First, financial support of universities is, in general, declining, a fact, which is particularly dangerous for those universities which have dedicated a large proportion of their budget to a particular domain such as marine sciences. This is to different extents the case for the Universities of Oldenburg, Bremen, Rostock, Kiel and Hamburg. If confronted with further budget cuts, these universities will have to shift parts of the budget allocated to marine sciences to other areas. Such

a development would inevitably result in replacement of marine science-oriented professorial chairs, a reduction in the number of student and finally, a weakening or even a loss of a university profile in marine sciences. In the long run, this development would also impose a danger to non-university research institutions, which would not be able to recruit the talents they need for the development of their research any more.

Marine sciences require research vessels and large expensive equipment with high running costs, long-term observation systems and a great deal of manpower. Accordingly, marine sciences are particularly costly. In view of this, the Expert Committee appreciates the previous enormous efforts of the government and the federal states to keep the overall funding of marine sciences on an adequate level. As a result, infrastructure at present is, in general, state-of-the-art.

However, there are still a number of major threats to the future of marine sciences, particularly at the university level. First, the federal states, which are exclusively responsible for the basic funding of their universities, cannot expect financial help from the government due to the "ban on cooperation" stated in the German constitution (§91b). The Expert Committee feels that the present funding system is not suitable for supporting sufficiently and assisting universities to successfully compete with marine research at non-university institutions, which receive substantial funding from the federal government.

Second, the excellence initiative – a major external financial source of marine sciences – will end by the end of 2017.

Third, in 2016 the "debt cap" comes into effect for the federal government and in 2020 for the federal states.

Fourth, the "Pakt für Forschung und Innovation" which ensures an annual budget increase of 5% for the Helmholtz and Leibniz Association as well as the Max Planck Society, will terminate by the end of 2015.

In anticipation of the second point above, the German Council of Science and Humanities is presently working on recommendations to procure continued funding of successful excellence clusters after the year 2017. The federal states involved are aware of these problems and the need for further development and have, independent from the possible recommendations of the German Council of Science and Humanities, taken first measures in securing marine science activities at the university level.

The Federal State of Hamburg will provide 20 million for an additional funding period of seven years in order to continue the excellence cluster initiative, also those concerning directly or indirectly marine sciences. Funding during this period will decrease so that the years following the excellence cluster might be used to compensate by

competing for other large-scale grants. The Expert Committee highly acknowledges this monetary commitment of the Federal State of Hamburg, expressing its prioritization of outstanding marine research.

Also, both the University of Bremen and the Federal State of Bremen have already shown their clear commitment to marine research by particularly supporting their high ranking marine research in the past. For the time beyond the excellence initiative, Bremen seeks a solution involving a joint structure of MARUM and AWI. The Expert Committee is supportive of this idea provided that MARUM remains within the context of the University of Bremen.

The Expert Committee strongly recommends that marine research at the University of Kiel be assured. Marine sciences at the University of Kiel, as represented by the interdisciplinary institution "Kiel Marine Science", gives the university a specific, unique and visible profile also in view of the partnership with the Helmholtz Center GEOMAR. Therefore, the federal state of Schleswig-Holstein is asked to promote marine sciences both at the university and non-university level, to support plans to pursue the cooperation with GEOMAR in the context of the "Kiel Academy for Interdisciplinary Marine Science (KAIMS)", and to develop strategies for sustainable funding of marine sciences in Schleswig-Holstein.

The other federal states having important marine research centers in or outside their universities, in particular Lower Saxony (University of Oldenburg) and Mecklenburg-West Pomerania (University of Rostock, IOW Warnemünde) are urged to develop strategies to guarantee structural and financial sustainability of their marine research.

Marine sciences are recognized as a key task of national and global relevance by both the state governments and the federal government. The Expert Committee is convinced that all levels are willing to further invest in marine research. The Expert Committee's analysis suggests that German marine science is well prepared when competition for funds intensifies. This is important as marine sciences have to come up with powerful joint programs and an overarching common strategy for their future research activities in order to be competitive. In this strategy priorities and posteriorities should be defined and justified.

With national funds becoming sparser, the marine science community should strive for even stronger participation in European research programs, e.g. the EU's eightth framework program for research "Horizon 2020" starting in January, 2014. The Expert Committee urges the German marine science community with the help of the federal states to combine strengths and develop a coordinated strategy to push for more European funds. KDM maintains an office in Brussels which already now plays a prominent role in communicating funding options, offering expertise in the European marine and research sectors and lobbying to enhance the international visibility

of German marine research. The Brussels office would unfold an even greater efficiency if the EU coordinators of KDM members would form a forum which discusses and precoordinates programs finally handled by the Brussels office.

6.4 Education

Teaching at the undergraduate and graduate level as well as training of young scientists is crucial for the sustainability of marine sciences. The universities in Northern Germany offer a wide variety of bachelor and master programs as well as graduate programs on different subjects within marine sciences (Appendix D). While the Expert Committee acknowledges that teaching and training are frequently a joint activity between universities and non-university research institutions, the major responsibility for teaching and the right to grant a degree remains with the universities. At present, teaching and training of young scientists meets the demands of German marine science. Also, German marine science appears to be attractive for many international graduate students.

The Expert Committee suggests, however, that the spectrum of courses and training opportunities should be reviewed and modified as appropriate with regard to the global themes chosen for collaborative research in a coordinated joint effort.

6.5 Infrastructure

Excellent infrastructure characterizes German marine science. The German marine research fleet is a key infrastructure for marine scientists and considered to be fundamental to secure the position of German marine science in the next decades. Hence, the Expert Committee acknowledges the current and scheduled activities of the government to timely replace RVs SONNE, POLARSTERN, METEOR AND POSEIDON before the current vessels are decommissioned due to the end of their operational lifetime. In addition, research infrastructure comprises state-of-the-art seagoing equipment (e.g. Remotely Operated Vehicles), laboratory equipment, computing facilities or large free-floating mesocosm platforms.

Whereas funding for large equipment appears to be adequate, high running costs are not covered adequately. This is a problem for smaller groups which should have equal access opportunities to both ships and large equipment and associated running costs. Whereas equipment and laboratory facilities will have to remain located at larger institutes rather than being centralized, all efforts should be made to enable efficient use among the partners of German marine science.

The procedure established for the application and allocation of vessel time is currently being restructured in such a way, that all applications are collected via the "Portal Deutsche Forschungsschiffe" and reviewed in a synchronous manner in line with transparent criteria. The Expert Committee approves the new procedure for the allocation of ship time and suggests developing a similar system for access to other large equipment.

In addition to research vessels and large equipment, the development of new sensors and new observing systems is necessary. The establishment of long-term multidisciplinary observatories, coordinated within international networks, is required for climate change monitoring. The Northern German marine research institutions have the talent and stature to lead by example here and start to forge effective international partnerships on observing, shared and interoperable research infrastructure, and ocean data sharing and management.

Further, the Expert Committee recommends joint efforts for establishing, developing and maintaining "soft infrastructure" platforms. Such efforts are considered to be of great importance for marine sciences. Thus, adequate tools for modelling and simulation are most important for many fields of marine sciences. At present, the development of models and simulation tools is concentrated in Hamburg at the CEN (Hamburg University) and the Max Planck Institute for Meteorology and takes place on a rather individual basis. The Expert Committee recommends strengthening modelling and simulation systems in order to meet future requirements and challenges.

Additional technologies important for marine sciences include long-term databases from cabled and non-cabled observatory systems, bioinformatics and "omics" technologies (e.g. metagenomics and proteomics) and core libraries. Such infrastructural needs will only be satisfied and successfully implemented if an overarching strategy is developed jointly by marine scientists.

Databases are of key importance for marine sciences. At present, the marine science community has access to several data centers located, for example, at the Federal Maritime and Hydrographic Agency or at MARUM and the Alfred Wegener Institute, that jointly support the Data Information Center PANGAEA ("Data Publisher for Earth & Environmental Science"). All other institutions maintain data bases (e.g. Bioinformatics at the University of Kiel). In an ongoing project, efforts are being made to coordinate the different data bases and to provide for all users a web-based portal for uniform access to the distributed data bank.

Despite these initiatives it is to be expected that they may not be sufficient for future development of data collection. In the long run, a national solution for data

management appears to be necessary. The Expert Committee recommends concentrating these challenges at centers of the Helmholtz Association, which are best prepared for large-scale tasks of national importance.

6.6 Organization and Governance

In order to increase international visibility and competitiveness in a global research world, German marine research needs better coordination in the future. The coordination and organization of German marine sciences concern both the scientific and political level. Clear governance structures, budget competence and decision-making authority need to be reviewed and modified to meet the new challenges (see chapter 6.6.2).

6.6.1 Role of Science and Scientific Institutions

The scientific organization should be in charge of various tasks including the following:

- Steering and monitoring the process of elaborating and focusing research themes as well as of developing specific research plans;
- Identification of cooperation partners available and needed for each theme (in Northern Germany and beyond);
- Implementation of interdisciplinary and transdisciplinary research approaches and partners;
- Creating platforms for interaction with stakeholders;
- Generating platforms for interaction with the maritime industry;
- Joint efforts to establish the required "soft infrastructure";
- Joint efforts in public outreach;
- Main contact point for EU funding and politics.

At present, an organization with the capability and empowerment to tackle these tasks is lacking and has to be developed. KDM represents a logical candidate to overtake this role and evolve from the present lobbying organization to a strong coordinating structure.

Today, KDM consists of 15 member institutions which include major players in German marine research. As a first step in creating a restructured KDM it should be ensured that all institutions involved in German marine research are enabled and invited to join KDM. This should also include the Federal Agencies, which could not become members in the past. Also, it should be ensured that all institutions, universities as well as non-university institutes are equally represented and will have a seat, vote and a voice within KDM. The specific needs of universities should be considered by KDM and universities should have the same impact on all KDM activities as non-university institutes. The role of universities within KDM is important because they can promote the inclusion of additional sciences for interdisciplinary research approaches. Relevant working groups, e.g. within the social sciences, engineering, economics or law, are mostly located at the universities and could be included in the design of specific research strategies and programs from the start.

KDM should develop into a forum for discussing ideas and identifying the participants required in joint scientific programs. At present, strategies and future concepts are mostly discussed within small groups that gather more or less by chance or via personal contacts. In the future, a more systematic approach will be needed. All players should get the chance to participate in such discussion and in the development of strategies so that smaller working groups have an impact as well.

From the Expert Committee's point of view, the "strategy groups" already established within KDM represent a suitable basis for the discussion and development of new positions and strategies. These strategy groups should strengthen their authority and impact. They should be in charge of coordination, identify the necessary participants and come up with specific working programs. KDM would be best suited to initiate a mapping of the marine science landscape followed by the appointment of clusters to regions by the elaboration of thematic foci.

KDM should become empowered to develop self-obligatory research strategies. KDM should communicate these and the needs of marine science to politics and develop into the voice of German marine science vis-à-vis society, governments and funding agencies (see chapter 6.6.2).

A powerful KDM needs a clear governance and steering structure, being guided by the principles of transparency, participation, openness and mutual respect. KDM is presently organized as a registered association ("eingetragener Verein"). Its future board could consist of five members, i.e. two representatives of the universities, one representative of each the Leibniz and Helmholtz Association and one of the federal research agencies. The Max Planck Society may decide whether a representative of their institutions should become a member of the board. The chairperson and the vice-chairperson of the board should have a term of not less than two years. As KDM develops into an accepted structure of German marine science, it must have a budget at its disposal, adequate to cover the running costs of the offices in Berlin and Brussels; as well s to finance KDM-initiated meetings, symposia, summer schools etc. and the relevant travelling and housing costs. The source of this budget should come from its members, the federal states and the federal government.

The "Senate Commission of Oceanography" (SCO) represents the second important organizational structure for German marine science. SCO fulfills important functions as it is e.g. responsible for the scientific coordination of the vessels METEOR and MERIAN and at the same time organizes the evaluation of the scientific use of vessels. The existence of the senate commission alongside KDM is, therefore, acknowledged although the Expert Committee feels that only one strong coordinating organization should represent scientific aspiration of German marine research. Under the precondition that both organizations exist, it will be essential that a far closer relationship and institutionalized exchange between the SCO and KDM be established in order to develop a powerful common strategy for German marine science. The Expert Committee strongly recommends that at least two marine scientists, i.e. the chairperson and vice-chairperson of each organization be full members of the other committee having a seat and vote.

6.6.2 Role of the State Governments and the Federal Government

The Expert Committee was impressed by the high esteem given by the federal states to marine research. Support and funding of marine research have a long tradition in Northern Germany, which is not only recognized as necessary, but also viewed with pride. The federal states are aware that marine sciences have special requirements regarding infrastructure. Marine sciences are regarded as very important for the research and economic profiles of the states themselves as well as on a global level.

Until now, each federal state has promoted "its own" marine science institutions in a competitive way against those in neighboring states. While this is understandable to a certain extent, the federal states themselves now realize that inter-institutional and inter-state collaboration (rather than competition) is the best way to develop German marine science into a unified and powerful force. In short, to make a global impact, German marine science will have to change its way of functioning also on the political level.

Thus, after scientists and scientific institutions have agreed on common and shared thematic foci, the federal states will need to develop a common cross-border strategy guided by the principle of cooperation. In view of these considerations, the expert group strongly recommends establishing a committee consisting of representatives of the federal states dealing with marine issues. The Expert Committee appreciates the openness of the five federal states of Northern Germany towards the creation of such a "German marine science forum". The federal state representatives of the "Forum Deutsche Meeresforschung" should take responsibility for the thematic cluster coordinated by their respective state and promote it. At the same time this Forum Deutsche Meeresforschung should be in a place to coordinate federal

state policies regarding marine sciences, enabling the federal states to speak with one voice in view of a common federal state policy for marine sciences. In addition, the Forum Deutsche Meeresforschung should serve as a single point of contact for the scientific marine community. The chairpersons of the Forum Deutsche Meeresforschung should act for a period of not less than 2 years. They and the chairpersons of the new KDM should come from two different federal states.

Finally, the chairperson and vice-chairperson of this forum should be part of an overarching council which comprises high representatives of KDM, SCO (DFG) and, in particular, of the government (BMBF). This "German marine research council" (Deutscher Meeresforschungsrat) could serve as the single point of contact of all members of the German marine scientific and political community acting as the essential interface between science, state governments and the federal government. It would represent the high level council for discussion and decision making in German marine science. The German marine research council could be charged with the task of developing a thematic and budgetary masterplan for German marine science for the upcoming decade. The establishment of the German marine science council, representing German marine science also internationally, could substantially contribute to the overall aim of the present structural analysis, i.e. to increase visibility and impact of German marine science at the global level.

Appendix

Appendix A

Concept Paper:

The Prospects of Future Research Strategies from the Perspective of the Marine Science Community

Compiled by Members of the German Marine Research Consortium (KDM)

A 1 Scope of the Structural Analysis

Marine research in Germany is organized in a decentralized manner, at university institutes and non-university research institutions of the Helmholtz Association, the Leibniz Association, the Max Planck Association as well as at institutes of the Federal States (Länder) and of the Federal Ministries. German marine research covers the full range of marine, coastal and polar research and all oceanographic and geoscientific disciplines. In marine science, and coastal marine science in particular, historical reasons have led to the establishment of a number research institutions in the German federal states. This diversity has proven an asset in view of the complex subject matter and adapted scientific profiles for North and Baltic seas as well as other shelf seas worldwide. At the same time, however, this diversity is in part responsible for a lack of coherent research planning and international visibility of German marine sciences.

Marine research institutions founded in 2004 the German Marine Research Consortium (Konsortium Deutsche Meeresforschung, KDM) in order to coordinate efforts with regard to research planning and development, international cooperation, dialogue with decision-makers, large marine science infrastructure management and for the provision of information to stakeholders and public outreach.

In 2011, the Science Commission of the State of Lower Saxony received the mandate from the Conference of Ministers of Science of the Northern German States of Bremen, Hamburg, Lower Saxony, Mecklenburg-West Pomerania, and Schleswig-Holstein to carry out a structural analysis of German Marine Research. This follows on from the recommendations of the German Council of Science and Humanities regarding the development of the German Research Fleet.

The goal of the recommended structural analysis, as addressed here, is to provide a basis for a coordinated strategy of all the North German Federal States in the field of marine research. To meet this task, a panel of representatives from German marine scientific institutions has been set up. It has identified strengths and weaknesses of marine sciences in Germany along with new opportunities and potential threats (SWOT analysis) and is summarized in this document. The Federal States have the intention to strengthen marine research with the aim of increasing national impact and international visibility. Traditionally, the German marine research institutions and universities with marine research programs are located in the afore-mentioned Federal States on Germanys´ marine borders of the North and the Baltic Seas. These institutions have already taken steps to better organize themselves in order to increase research effectivity and visibility.

An outline of the self-analysis (section 2), of common research foci of the German marine science community (section 3) and the self-organization of German marine research (section 4) are the basis for an outlook in section 5.

A 2 Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis of the Structure of German Marine Research

Strengths:
German marine science has a long and successful record of research in all oceans and seas ranging from coastal processes to the deep sea exploration. Science ranges from the sea surface into the ocean floor, and from tropical to polar systems. Today, the research activities embrace all disciplines of the marine natural sciences (physics, chemistry, geology and biology). More recently and importantly maritime-oriented social sciences have been established, especially in the field of coastal research.

Within the German "Excellence Initiative" marine science has been very successful with three Clusters of Excellence in Bremen (The Ocean in the Earth System), Hamburg (Integrated Climate System Analysis and Prediction) and Kiel (Future Ocean). This has catalyzed the further integration of marine science in northern Germany, specifically between universities and non-university institutions.

Due to the both, stable and targeted, support by the German Government (mainly the Federal Ministry of Education and Research – BMBF, and partly other Ministries involved in marine research) access to excellent infrastructure has been available on the long term. This ranges from well-equipped and well-maintained ships to a range of advanced sea-going infrastructures (ROV, AUV, MeBo, manned submersible, drifters, gliders, advanced moorings, underwater cables etc.). It also includes analytical

tools and computer support for modelling (Climate Computing Center Hamburg, main-frame computers in Kiel and Bremerhaven). Presently a joint portal for all marine data is set up to facilitate easy access to the data of different institutions. The German Government has developed a long-term strategy for the replacement of research vessels and, therefore, we are confident that this most important platform for marine science is secured for the next decades. Allocation of ship time on a competitive basis is organized in a transparent way by scientific advisory boards for the different ships (see section 4.3.1.).

Fifteen institutions involved in marine academic research (including university and non-university institutions, musea and a Federal Agency) constitute the German Marine Research Consortium (KDM). KDM serves as a key contact point for German Federal Ministries and for authorities in the coastal Federal States, the coordination of inputs to national and EU research programming and for organizing public events for decision makers as well as exhibitions and other outreach activities for the general public.

Scientists from different German institutions are actively involved or have a leading role in many international programs and boards (e.g. SCOR, SCAR, IOC, IOI, POGO, programs of IGBP and WCRP, IODP, ESF Marine Board, ESF Polar Board).

Strengths of German marine science:

- Interdisciplinary research programs in all oceans and seas and internationally competitive research in all major marine scientific fields
- State-of-the-art seagoing, laboratory and computing infrastructure
- Replacement of ageing research vessels planned and budgeted by the federal ministry
- Transparent competitive allocation of ship time and advisory council for large infrastructure (Senate Commission for Oceanography of the German Science Council)
- Development of joint data information systems for marine sciences
- KDM as membership organization of German marine science institutions for long-term strategic planning and as partner for federal and state ministries and EU Commission
- Long-standing cooperations between universities, non-university institutions (of Max-Planck-Association, Helmholtz Association, Leibniz Institutes) and federal agencies ("Ressortforschung")
- Active participation in international networks, programs and boards

Weaknesses:
Despite the quality of German marine science in the individual institutions and the complementing political interests, the administrative and financial regulations of the

five Federal States of Northern Germany are an obstacle for overarching collaboration. Therefore, this evaluation is seen as a great chance to improve the strategic joint development of marine science throughout northern Germany.

An effort is necessary to link more effectively the marine science and maritime economy sector that is presently only weakly connected. For instance, there is little cooperation between the academic research and coastal engineering or marine spatial planning. Especially with regard to such aspects as sea level rise and coastal engineering it is important to improve this link in shelf and coastal sciences. These and other new links to the maritime economy sector would strengthen efforts to protect the marine environment, safeguard sustainable use of its resources, develop risks assessment systems for coastal regions, aid communication with stakeholders, and advance integrated research programs.

While an asset in terms of scientific diversity, the spread of coastal marine science institutions across northern Germany makes it a challenge to effectively communicate existing and upcoming research strategies, both in a national and an international policy context.

The BMBF has in the past provided the marine science sector with sufficient financial support, especially for investments of large infrastructure and funding of non-university institutions. However, the operating costs for large sea-going equipment are the responsibility of the users and, hence, present an unresolved problem. Because they are not fully financed by institutional funds of the operating institutions, external users are charged the incurred costs. These are often far beyond the available means of the users, in particular those from smaller institutions and universities. Only in some cases can these costs be covered by project funding.

For universities, the increasing gap between level basic funding and growing costs for carrying out state-of-the-art marine research poses a severe limit for most university groups to engage in marine research.

The marine science community in Germany is starting to link the natural sciences with social sciences and engineering sciences (e.g. Clusters of Excellence in Bremen, Hamburg and Kiel) and only a few institutions have transdisciplinary research integrated into their portfolio (e.g. Leibniz Center for Tropical Marine Ecology, Leibniz Institute for Baltic Sea Research, Thünen-Institutes for Aquatic Resources). However, such transdisciplinary research is fundamental to meet the societal challenges and needs of the future.

Weaknesses of German marine science:

- Linkage between the marine science and maritime economic sector needs to be improved
- Only partial national and international visibility of coastal marine sciences
- Severe budget constraints at universities, which limit the long-term development of marine research at universities
- Access to large sea-going infrastructure limited by lack of funding of operations
- Insufficient collaboration with social sciences and engineering sciences

Opportunities:

We are confident that we will remain a leading nation of marine research based on the present scientific expertise and infrastructure. We see opportunities in further developing several research fields, particularly those addressing societal needs and stakeholder interests. These include concepts and tools for sustainable use of marine resources while maintaining or reaching good environmental status or valuing ecosystem services in the emerging field of 'Blue Economy'. Hazard and risk assessment tools for coastal regions have to be provided as protection measures against geo-risks. Development of innovative technologies, especially for a growing number of autonomous and interactive observatories, offers many opportunities for collaboration of marine science with engineering science and industry. This holds for the national as well as the international area whereby the implementation of innovative observation technologies, new data distribution and networking strategies are of high priority.

Coastal research in Germany is well developed albeit quite dispersed due to the distribution of research activities across institutions with specific regional or scientific foci. At the same time, the diversity of research in the different institutions allows the multifacetted approach required in the face of interdependent natural and anthropogenic changes and societal needs in coastal ecosystems. We see opportunities to increase effectiveness and visibility of this field and to create a blueprint for integration of natural sciences with social and engineering sciences.

A stronger integration of marine research, particularly in the area of coastal research, is timely and offers several very positive development opportunities. It brings together expertise from different institutions on the basis of research themes that cannot be addressed comprehensively by one institution alone. A modernized structure for networking between German marine science institutions with closer cooperation on the basis of research themes is seen as a way forward in the development of marine science in the North German Federal States. Such development needs support by the Federal States and the BMBF to underpin the thematic network and its regional nodes.

Most research is done in international collaboration and this is often on the basis of project collaborations. In order to address global challenges in a more comprehensive manner strategic partnerships within but also beyond Europe are required. Long-term institutionalized collaborations already exist, but we see further chances in the expansion of international alliances especially at the European level.

International capacity building by dedicated study and training programs is a chance to educate a new generation of scientists well equipped for the future challenges in marine science. We see great opportunities to promote young leading scientists by expanding the "Young Investigator Group" grant system. These grants enable young and excellent researchers to develop new fields of research and leadership skills. The already existing groups introduce new ideas, topics and methods. These promotion programs will alleviate the impending recruitment problems created by the imminent wave of retirements.

Last but not least, the large and growing interest of the public in the world's ocean subjects marine science to great visibility associated with new demands. Public outreach is an opportunity to bring marine scientific themes and their relevance for our future living to the understanding of people.

Opportunities of German marine science:

- Strengthening of inter- and transdisciplinary initiatives in all areas of ocean science that address societal needs
- Development of innovative marine observation technologies
- Increased efficiency and collaboration in coastal research
- Political support for coordinated thematic marine research
- Increased international collaboration
- Recruitment of outstanding young scientists via dedicated training programs and support of young investigator groups
- Public outreach to inform about the relevance of marine issues for our future

Threats:

The challenges and demands of marine research are well recognized in the Northern Federal States, but are of low priority in other German regions. This is aggravated by the fact that marine industries are of small importance in Germany in general and have low economic impact. These factors combine to give marine science a relatively marginal status in most of Germany. This also leads to a low priority of marine subjects for most German universities. In only five of more than 80 German universities do marine sciences constitute part of the curriculum of biological, physical, chemical or geological studies. In many universities only individual groups are involved in marine research and are in danger of being closed when the principal investigator retires. We see a threat in the fact that education and research in marine science is (with few exceptions) only found in the northern German Universities. It limits exchange of ideas with other fields of science and restricts recruitment of young researchers.

In higher positions (professorships) it is sometimes difficult to recruit excellent marine scientists. This is partly caused by comparatively low salaries in Germany and partly by still inadequate support of female scientists or families.

Fifty funding and research organizations from 23 countries have founded Science Europe, an organization replacing EuroHORCS (European Heads of Research Councils) and reducing the functions of the European Science Foundation (ESF). Potential risks of this structural change are a loss of representation and cooperation of marine research institutions in, for example, the ESF Marine Board and Polar Board. Furthermore, a loss of funding for cross-border basic research is also to be expected, which will directly affect international research collaboration. The process, however, is ongoing and ESF currently discusses the definition of future roles and activities with its member organizations and Science Europe.

Threats for marine science:

- Low interest in and recognition of marine science in Germany beyond the Federal States of Northern Germany
- Limited maritime-oriented industries in Germany
- Decreasing involvement in marine topics in universities beyond northern Germany
- Difficulties in recruiting high level scientists
- Critical phase for collaboration of European marine science due to uncertain position of ESF Marine Board and Polar Board

A 3 Scientific Themes and Future Prospects

The marine science community in Germany has identified the following overarching research themes as being of major importance for the strategic scientific development of German marine science. The themes underpin international research areas and are targeted to societal challenges related to the marine environment. All marine science institutions can collaborate under these thematic lines which may offer a means to structure the research landscape.

- Ocean and climate
- Changing biogeochemical cycles
- Marine biodiversity, ecosystem function and services
- Resources from the sea
- Earth system dynamics and geological risks

Because of the emerging importance of coastal science as a global research area it is presented in this document as an overarching theme, with links to social sciences and governance. Aspects of the above five themes are incorporated in the crosscutting coastal theme.

A 3.1 Ocean and Climate

A 3.1.1 Scope

The variability of the ocean circulation on a large range of spatial and temporal scales is a key factor controlling global climate change and its regional manifestations. It also influences biogeochemical cycling and marine ecosystems, and thus the food supply from the oceans. Reliable future projections of climate change thus require an advanced understanding of the physical processes and phenomena in the oceans which are critical to the ocean – sea ice – atmosphere system.

The ocean's horizontal and vertical circulations share with the atmosphere the role of transporting heat from low to high latitudes. The ocean's large thermal inertia and its ability to transport mass and other properties over long distances play a key role with respect to decadal and longer timescale climate variability. As documented during the last decades, ocean properties exhibited noticeable changes; for example we know from observations and models that nearly 90% of the excess heat over the past decades due to 'the enhanced greenhouse effect' was taken up by the upper 2 km of the oceans. However, because the observational database in the deep ocean remains to be very sparse both in time and space, only little is known about deep ocean heat uptake and its potential to affect surface climate evolution on decadal and longer timescales.

At the global scale, a key component of ocean transport results from the global overturning circulation which connects the warm upper ocean flow with the re-circulation in the cold deep ocean. The communication between these involves water mass formation in key regions such as the high-latitude North Atlantic and Southern Ocean, where dense surface waters sink to a depth of a few kilometres. Considerable progress has been achieved during the last years in understanding this process. However, new observations combined with historic data have revealed the complexity of the global overturning circulation involving intricate fluctuations on seasonal to centennial time scales and possibly beyond. Furthermore, the relative role of air-sea exchange of heat, freshwater and momentum in high and low latitudes as well as anomalous inputs of freshwater from the polar regions in driving the global overturning circulation remains unclear.

Recent observations and modelling results suggest that the larger scale circulation may be significantly influenced by the integrated effect of small-scale processes with spatial scales of tens of meters to a few kilometers and temporal scales of a few hours. These processes play an important role for the ocean energy cascade by transporting energy from the large-scale ocean circulation to turbulence and friction where it is removed.

The ocean affects coastal environments due to storm surges, tsunamis, waves, erosion, or the effects of global warming, such as sea level rise. The coastal zones are characterized by an interaction of oceanographic, atmospheric and terrestrial processes with implications for engineering as well as social, political, or economic interest. In particular, sea level rise – as predicted for the next hundred years and beyond – will be a large challenge for the population of nearly all nations. The current global average sea level rise amounts to about 3 mm per year. It partly results from thermal expansion of the oceans and partly from the addition of mass, e.g. in form of melt water from mountain glaciers and continental ice sheets. In the decades to come, the potential effect of melting ice sheets will become increasingly important not only for sea level rise but also for ocean circulation patterns. In turn, the melting of ice sheets will depend more strongly on the state of the surrounding ocean than previously considered. Furthermore, warmer ocean temperatures affect also the global hydrological cycle and thus the mass balance of all terrestrial glaciers and ice sheets. While estimates of future global-mean sea level rise have considerable error bars, the degree of uncertainty is much larger for local sea-level projections which are essential for planning processes. Sea level changes in the North Atlantic and along the German coast are intimately coupled to the North Atlantic circulation, which in turn is linked to the global overturning circulation on decadal and longer timescales.

The terrestrial environments beyond coasts are affected by global climate processes at time-scales of societal relevance. For instance, the upper North Atlantic circulation – represented by the Gulf Stream and its eastward extension, the North Atlantic Current – transports significant amounts of heat to the Northern latitudes, which in turn contributes to the warming of northern Europe. The tropical oceans also influence terrestrial climate. The monsoon system affecting the livelihood of 60% of the world population is an example and depends on the state of all three tropical oceans. However, our current level of understanding of the ocean's role in monsoon system dynamics together with biases in climate models make reliable predictions of the onset and the intensity of monsoonal rainfall challenging. Other examples of prominent model biases are the inability of ocean models to correctly simulate the path of the North Atlantic Current or the incorrect representation of subtropical low-level clouds in atmosphere models. Variations in tropical ocean temperatures can lead to severe disturbances of the hydrological cycle not only over tropical but also over extra-tropical land areas. Prominent examples include the Dust Bowl dry phase over much of the United States during the 1930s, a period which suffered enormous economic and social impacts, and similar trends in recent decades in the same region. Another well-known example is the dry phase of the Sahel region during the 1970s, claiming hundreds of thousands of casualties; a phenomenon which repeats itself quasi-periodically. From climate models there is evidence that such changes can be linked to variations in the global overturning circulation.

Besides the ocean's role in the physical part of the climate system, the oceans also exert a major control on biogeochemical cycles from small to the global scale. Most

importantly, the global ocean takes up part of the anthropogenic carbon dioxide (CO_2) emissions to the atmosphere. Without the oceanic uptake, the atmospheric CO_2 level would be much higher than the current level of about 0.039% – probably around 0.05–0.06%. Naturally, the deep ocean contains approximately 60 times more CO_2 than the atmosphere. On time scales of a century or longer, the efficiency of the oceanic uptake of anthropogenic CO_2 depends on changes in deep-ocean circulation and chemistry, both of which are not well understood. One of the greatest concerns in this context is that the ability of oceans to absorb CO_2 will decrease in response to climate change, thereby amplifying global warming.

Improved understanding of the ocean dynamics and the associated physical processes through regional and global observation, fundamental theory and their adequate representation in climate models is a requirement to assess ongoing ocean, coastal and climate change and to develop credible scenarios for the next decades and centuries. Large uncertainty still exists regarding the changes of the ocean circulation on regional and local scales under climate change conditions. This lack of knowledge to a large extent originates from the lack of long-term ocean observations. The relative shortness of instrumental records is particularly critical in the deep ocean, which has internal timescales of centuries and even millennia. This hampers the understanding of the role of the deep ocean in the climate system.

Paleoceanography offers a means to quantify the full range of natural variations of the oceanic environment on timescales beyond the instrumental record. The deep-sea floor constitutes the largest archive for climate data that are stored in sedimentary deposits. Paleoceanographic time series from deep-sea sediments enable the investigation of the role of the oceans in the Earth's climate system over a wide range of timescales and allows testing and improving the understanding of processes needed in predictive models. Paleoceanographic data can also be used to investigate whether the oceans exhibited rapid changes and possibly threshold behaviour. Other valuable climate archives allowing insight into the role of the ocean in the climate system are ice cores, corals and tree rings. In conjunction with numerical models, paleodata will enhance our knowledge about past ocean changes and their potential implications for future climate change. Paleoceanographic research has already led to a paradigm shift in climate research by acknowledging the key role of the ocean in abrupt climate changes.

A 3.1.2 Major Research Foci and International Impact

During the past decades, climate-oriented marine research in Germany has contributed significantly to a better understanding of the role of the ocean in the climate system. Based on a noticeable German contribution to oceanographic observations (sustained and process oriented) and coordinated model experiments in the framework of international projects such as WCRP/CLIVAR and GOOS, substantial progress has been achieved in understanding the role of the ocean in climate variability and predictability. Of particular importance in this context are German contributions to a better understanding of processes leading to deep-water formation, the role of the tropical oceans in climate change, the nature of large-scale ocean – atmosphere interactions, sea level changes and climate predictability on seasonal to decadal timescales. Towards the goals of the international IMBER and SOLAS programs, research activities have led to an improved understanding of the interactions between the physical ocean circulation and biogeochemical cycles. Under the umbrella of IODP and PAGES, German research continues to be at the forefront of paleoceanographic research, including a precise assessment of the state of the glacial ocean (as a major target for testing climate models) and climate-system dynamics during warm climates.

Coastal research in Germany has advanced due to the establishment of operational coastal observing systems such as COSYNA. Especially the development of data assimilating techniques has led to an improvement of the forecasts. Publically available real-time data products provide an essential tool for stakeholders in industry, search and rescue or agencies to aid in the planning of routine tasks and emergency situations.

A 3.1.3 Future Perspectives of the Field

Research over the past years has highlighted the important role of small-scale processes in the large-scale circulation of the ocean. This together with our limited understanding of the deep-ocean circulation is a hindrance to reduce significantly uncertainties in several areas that are of direct societal relevance: short-term predictions of the ocean's state, regional expression of sea-level rise during the 21st century, carrying capacity for anthropogenic perturbations (e.g. uptake of heat and CO_2), and interaction of the ocean with the other compartments of the climate system. New research questions arise, in particular concerning processes critical for climate state bifurcations, for the interaction between ocean subsystems (e.g., between the sea-floor and open ocean), for the interaction of the ocean circulation with the ecosystems, and for the interaction of all these with marine chemistry. Of growing interest is specifically the time evolution of key climate processes on interannual to multi-decadal time-scales, that is on timescales corresponding to the lifespan of humans during which anthropogenically forced climate change also leads to significant alterations.

Specific research topics for the German marine science over the next years encompass:

- Assessing and understanding the processes underlying external (i.e. forced) and internal (i.e. unforced) variability of the ocean circulation over a wide range of timescales:

- Investigation of the mechanisms of ocean circulation change on global and regional scales; separation of natural variations and anthropogenic changes. This includes:
  Investigation of the Atlantic Meridional Overturning Circulation (AMOC) and of the overturning circulation across the Antarctic Circumpolar Current (ACC).
  Quantification and origin of changes in subtropical-tropical ocean circulation, and their implication for regional sea level, sea surface temperatures, the nutrient supply and oxygen availability in the biologically highly productive tropical ocean regimes.
- Investigation of changes in the oceanic upwelling regimes and their role in the global climate system.
- The role of coupled feedbacks between the ocean, sea ice and atmosphere in producing internal climate variability on interannual to decadal timescales and in modulating the ocean's response to anthropogenic forcing
- Understanding the different modes of the ocean circulation and quantifying the level of natural variability from paleoceanographic records
- Using paleoceanographic information to assess the processes leading to abrupt changes in ocean circulation
- Understand the role of small-scale (submesoscale) physical dynamics for the ocean energy budget and biogeochemical and biological processes

• Assessment of sea-level changes from the global to regional and local scale
  - Investigating of future regional sea level variations and changes and underlying causes. This includes the impact of the changing atmospheric circulation and hydrological cycle on future regional sea level as well as the impact of Greenland's melt (fresh) water on the Atlantic circulation and sea level
  - Investigating ocean - ice shelf interaction as important mechanism for ice sheet melt
  - Assessment of the regional impact of sea level rise on coastal systems and communities.
  - Assessing the magnitudes and rates of sea-level change from geological archives in order to test ice-sheet models
  - Deciphering the temporal relationship between climate (e.g. orbital) forcing and ice-sheet response from paleoceanographic data
  - Extending the instrumental record of regional sea-level variations using paleoceanographic information
  - Assessing current sea level change and the effect on coastal societies
• Investigating the role of mixing processes in large-scale ocean circulation and their representation in climate models

  - Determine the mixing-induced vertical exchanges in tropical and subtropical shallow layers
  - Understand the regional variability of diapycnal mixing in the deep oceans and their variability
  - Improve the parameterisation of mesoscale ocean eddy-induced horizontal exchanges
  - Understand the role of submesoscale processes for mixing across fronts and the thermocline. Develop parameterizations for changing mixed layer depth due to region, seasonal or long-term changes
• Understanding feedbacks between ocean circulation and marine ecosystem dynamics and biogeochemical cycles:
  - Investigating the effect of circulation changes on regional biogeochemical processes (including CO_2-uptake and oxygen-minimum zones)
  - Employing the sedimentary record to analyse the response of marine biota and biogeochemical cycles to climate changes
  - Studying ongoing changes in upwelling systems, their impact on biological production and its effect on fisheries
  - Assessing the role of submesoscale processes for global biogeochemical and biological processes such as mixing, nutrient pathways and phytoplankton dynamics
• Investigating the role of the ocean in affecting land climate:
  - Disentangling the influence of a warmer ocean on major modes of atmospheric variability (e.g. the North Atlantic Oscillation), weather extremes (e.g. tropical storms) and terrestrial hydroclimate from observations and paleo-records.

A 3.1.4 Relevant Research Infrastructure (> 250.000 Euro)

Marine Sciences in the 21st century is generating an ever growing demand for ocean observations and ocean modelling. In situ observations are needed to track global properties in a sustained manner as outlined in international plans under GOOS (Global Ocean Observing System). Realistic ocean models are required to help to interpret the data, to understand past ocean changes and to enable ocean and climate prediction.

Research vessels will continue to be the key infrastructure for marine climate research. Globally operating ships are a prerequisite for installing the next generation of ocean-observing systems. Ship-based surveys can be extended in scope by launching autonomous underwater vehicles to map three dimensional environmental conditions in the upper ocean with highly energy efficient gliders and near the

sea floor with propeller driven miniature submarines that can carry a range of sensing systems including high resolution swath bathymetry.

Dramatic advances in sensor, platform and communication technology have opened up new possibilities for marine sciences. Drifting profiling floats within the international ARGO consortium are today sampling the upper global ocean down to 2000 m on a weekly basis. This network holds the potential to grow in scope from measuring temperature and salinity to include dissolved oxygen and other parameters. Furthermore, it is envisioned that ARGO floats go deeper to close the Earth's heat budget. In coastal and shelf regions the network needs to be augmented by gliders that can be recovered and have the ability of limited navigation.

To document the time evolving ocean, efforts are under ways to establish long-term multidisciplinary ocean observatories that contribute at one location to regional process understanding, and within the global network of OceanSites to the large-scale picture. The classical approaches are either bottom-mounted sensors (such as seismic recorders, temperature, pressure and inverted echo sounders) or moored systems, where a vertical array of instruments (such as current meters, temperature and salinity sensors) are deployed. In some regions it is now possible to connect these observing systems to sea floor communication cables. Alternatively, several options of transmitting data back to shore are emerging ranging from infrequently launched data shuttles, subsurface winch systems that will allow for daily communication to a permanent small surface expression with satellite data transmission.

Besides the continuation of international observing programs (e.g. drifters, moorings), long-term observatories in hot spots of ocean and climate change (e.g. AMOC, Labrador Sea, Denmark Overflow) is expected to result in significant progress in understanding the role of the ocean in the climate system. Specifically, long-term observations of mixing processes in the subsurface and in the deep ocean are of great importance for improving the predictive skill of ocean models. Observatories for climate research in the ocean should be flexible with regard to changing scientific demands. Mobile observatories are expected to be installed for several years at a given location.

Satellites have become an integral part of the ocean observing system. Today routine observations of sea surface height, sea surface temperature, sea surface currents, surface wind stress and primary productivity, among many other essential climate variables, are fundamental for capturing the full spectrum of ocean variability and for understanding underlying causes, for improving ocean circulation models and for initializing climate predictions. The need for continuous coverage by satellite observations will continue to exist, calling for a sustained satellite climate observing program as it is being discussed under GMES and as part of EUMETSAT's long-term strategic planning.

Paleoceanographic work will continue to rely on sampling sediments from the seafloor. Increasing demand on high-resolution records over long time span are expected to result in advanced piston coring technologies and drilling. For the latter, the next generation of the deep-sea drilling MeBo will provide new opportunities by an extended drill depth of up to 200m below the sea floor. Construction of high-resolution and continuous time series will increasingly employ multiple coring and make use of pole-equator-pole and other transect strategies. In addition, novel techniques are required for assimilating sparse paleoenvironmental data into climate models.

Marine-oriented climate research relies fundamentally on the availability of high-performance computing systems, which are designed for long integrations, intermediate level of parallel processing and very high storage demands for model output. Scientific interest in ocean modelling arises to a large extent from our need to better understand, quantify and eventually predict the ocean's role in the global energy, water and carbon cycles, and to provide projections of the future climate. Finally, data information structures are required that allow access to climate-related data from a wide range of sources through a joint entry point.

In order to observe and better understand the environmental state of coastal waters as well as to predict various parameters in real-time, integrated observing and data assimilating forecasting systems are needed. In particular the real-time access to forecasts and other products is essential to respond to the increasing environmental, economic and societal conflicts in the coastal zone. Long-term observatories are needed to detect trends and the human impact by climate change or the establishment of extensive wind farms on coastal dynamics and ecosystems.

A 3.2 Changing Biogeochemical Cycles in the Earth System

A 3.2.1 Scope

Past, present and future matter cycles in the ocean are controlled by a multitude of biogeochemical processes (e.g., productivity, export, sedimentation, remineralization, water-rock interactions, burial) with specific adaptations to changing boundary conditions (e.g., temperature, redox status). Unraveling the linkages between marine and terrestrial physical, chemical, and biological processes in the cycling of matter over a wide range of scales in space and time remains a challenge, although significant progress has been made and our analytical and conceptual power has significantly increased. Furthermore, many of the biogeochemical processes in the ocean represent key ecosystem functions and services to humanity and monitoring of the natural and man-made variations have become a societal challenge.

With the onset of the Anthropocene many material cycles have seen unprecedented perturbation and acceleration by additions from pools in the geosphere (or atmos-

phere, in the case of nitrogen), rearrangements of fluxes between compartments of matter, and introduction of chemicals unknown in nature and with adverse effects to organisms. Complex interactions between the flow of energy and the cycles of matter constitute the fabric that reacts to and accommodates perturbations in marine systems. The human footprint in marine biogeochemical cycles is prominent on global (such as CO_2-induced warming, ocean acidification and enhanced nutrient element transport via the atmosphere), and regional/local scales (eutrophication/ pollution from agriculture and industry in individual watersheds, altered nutrient ratios, coastal and open ocean hypoxia). In many regions, the ocean will become warmer, more acidic and more polluted. In the interest of a sustainable use of marine resources, research in coming years needs to further build the knowledge basis of marine biogeochemistry as a science, evaluate the consequences of enhanced and altered material cycles for the ocean and for regional subsystems, and anticipate the subsequent chances and risks for human society emerging from these changing marine biogeochemical cycles.

A 3.2.2 Major Research Foci and International Impact

German marine science institutions have taken prominent roles in international and national alliances and projects addressing material flux changes associated with changes in the Earth System within the corridor of natural variability, and those introduced by activities of humans. Biogeochemical research in KDM institutions has contributed substantially to international advances in

- analyses of paleoclimate from sedimentary, ice and other archives (development and use of proxies),
- investigations of hydrosphere – geosphere interactions, marine resources (geofluids and hydrothermal systems, gas hydrate occurrences and dynamics), and seafloor as source or sink of materials,
- understanding processes, causes and effects of ocean acidification and ocean de-oxygenation, closely linked to biological effects and to ecosystem shifts,
- estimation of exchanges of matter between the ocean and terrestrial environments, the cryosphere and the atmosphere, including dissolved organic matter, climate-relevant gases, nutrients, and pollutants,
- elucidation of the roles of microbial processes and biological diversity in matter fluxes, and their interactions,
- models of complex interactions in global oceans and regional seas, including the land-sea-atmosphere continuum,
- enhancement of biogeochemical data acquisition by automated systems,
- development of predictive models of the Earth System, where biogeochemical interactions are essential in order to quantify global and regional fluxes, detect and attribute change to plausible drivers, and identify uncertainties or unknowns,
- understanding of the effects of anthropogenic activities on these cycles, including downstream effects of land-use change and deforestation of coastal areas.

Contributions to many internationally coordinated projects, such as PAGES, IMBER, SOLAS, GEOTRACES, LOICZ under the auspices of ICSU and IGBP have positioned marine biogeochemical research in Germany as a partner, often in a coordinating role. Topical research on the effects of rising CO_2 concentrations has been jointly carried out in EU projects such as CarboOcean, EPOCA, CarboChange, COMBINE and ECO2; pollution issues are central in EU projects such as GMOS.

A 3.2.3 Future Perspectives for Research in Changing Biogeochemical Fluxes

The international and national science communities are in the process of supplementing disciplinary research – the basis for evolving scientific understanding of processes, functions, and consequences of global environmental change – with increasingly inter- and transdisciplinary efforts to enhance the usability of science for societal needs. For the study of material fluxes, this requires that specific capabilities be strengthened:

- Development of novel observation systems and environmental indicators to assess and quantify global and regional variations in element cycles, matter transformations and other types of ecosystem functions and services;
- Development of novel modelling systems coupling physical, biogeochemical, ecological, and socio-economic model components and assimilation of data to anticipate trajectories of matter fluxes and their consequences for ecosystems and societies; use of these enhanced models for hindcasts, projections and experiments;
- Integration of observations and modelling to develop management strategies for sustainable use of marine resources; evaluation of ecosystem services provided by natural biogeochemical processes.

These are the overarching goals that are common to all institutions in KDM engaged in research on material cycles. From the intermediate-term research plans, prominent specialisations and common threads emerge that link efforts in the institutions towards these overarching goals:

- Develop and use biogeochemical tools to decipher past states of the Earth System and interactions of its components (development and application of proxies);
- Detect the footprints of anthropogenic perturbations in global and regional marine systems over the last 200 years, quantify the corridor of natural variability in the geological and recent past; recognize deviations from that corridor;
- Explore the cascade of consequences of individual or concerted drivers of change on marine ecosystem functions and services, and for the Earth System as a

whole (e.g. ocean acidification and warming effects on marine productivity, hypoxia effects on greenhouse-gas emission);
- Clarify the roles and leverages of marine biogeochemical processes as fly wheels between physical and biological system components (biodiversity; processes acting in different environmental settings; controls on rates of microbial turnover);
- Explore the role of biogeochemical processes at the sea floor in providing services, such as resources (hydrothermal and geofluid systems; seafloor habitat), and mitigation of unwanted effects of changing biogeochemical cycles (sea floors as sinks of pollutants; denitrification);
- Analyze strategies to use or accelerate natural feedback mechanisms to mitigate threats to the global environment (assessment of environmental and climate engineering).

A 3.2.4 Relevant Research Infrastructure (> 250.000 Euro)

The basis for past and future success of German biogeochemical research is access to modern seagoing vessels and other large infrastructure designed for specific areas and types of operation. Increasingly sophisticated ship-based and autonomous sampling and in situ analysis tools continue to revolutionize the way and the detail (spatial and temporal), in which biogeochemical processes are being studied. Advances in technologies for analyzing important physical-chemical and biological parameters drive the development of in situ observation systems, of instrumentation on ships of opportunity, cabled and autonomous platforms that routinely monitor biogeochemical states of the sea. Long-term autonomous observation systems are relevant in monitoring and detecting the response of the ocean ecosystems to natural and man-made variations in climate, as well as to various types of disturbances and dynamic processes. They provide synchronous multidisciplinary data to detect and quantify links between driving factors and consequences for the hydro-, geo- and biospheres. Germany's marine institutions cooperate to provide biogeochemical observatories from the coasts (Baltic and North Sea) to the polar, temperate and tropical deep seas (focus on the Atlantic system).

All institutions engaged in the study of material transformations and fluxes rely on highly specialized laboratories with specialized instrumentation for elemental, isotopic and molecular studies. Sophisticated instruments (e.g. high resolution secondary ion mass spectrometer NanoSIMS, RAMAN spectroscope, confocal laser scanning microscope) are used to link between microbial community composition and biogeochemical cycling of matter. XRF core scanners and laser ablation multi-collector-ICP-MS allow investigations of signatures from past biogeochemical processes. Fourier-Transform ion cyclotron resonance mass Spectrometers (FT-ICR-MS) allow to extend detailed investigations of the carbon cycle to dissolved organic matter. Autonomous and remotely operated underwater platforms with biogeochemical sensors allow the in situ quantification of biogeochemical processes from coasts to deep seas.

A 3.3 Marine Biodiversity, Ecosystem Function and Ecosystem Services

A 3.3.1 Scope

The ocean is the cradle of life on our planet and most of the biosphere of Earth is in the sea. Marine and terrestrial biota drive key processes, such as oxygen production, carbon fixation, and the transfer of energy and recycling of matter in food webs resulting in a habitable environment on Earth. Today, about 250.000 species of marine plants and animals are known, with an estimated million, which remain to be discovered or have not yet been explored in their genetic, physiological, and ecological capacities. Molecular genetic research has revealed many new cryptic species with first estimations of the diversity of marine bacteria and archaea running at 10–100 million of unknown genotypes. New metabolic functions have been discovered with the potential for insights into undiscovered evolutionary pathways and valuable metabolites. The knowledge as to how marine communities are structured has also changed in that the simple "food chain" concept was substituted by a multidimensional, complex "food webs" concept. The introduction of the microbial loop concept including marine viruses, the knowledge as to how predation and mortality regulate food webs, the role of rare species proliferating under shifting environmental conditions, and symbiosis as a driving force in evolution are among these. New marine habitats and ecosystems have been discovered in the ocean. These include the biosphere in subsurface sediments and rocks, deep water corals and sponge gardens around continental margins, life in sea ice, and in other types of extreme environments such as hydrothermal vents, gas seeps and anoxic brines.

Biodiversity is widely considered to be of fundamental importance to human well-being. At the same time it is a major societal challenge to manage ecosystems in order to counteract species and habitat loss in the oceans. In addition to obvious human needs with regard to nutrition, energy and mineral resources, the potential for other valuable resources from ocean biota is not fully explored. Examples include pharmaceutical substances for protection and defence against predation and infections, biomechanical solutions for optimal bioconstructions (biomics), biochemical pathways for detoxification of harmful substances, or biogeochemical pathways to ensure the optimal use of rare chemical elements. The challenge for research in these fields is linked with the need for sustainable environmental management of marine ecosystems world-wide and with an emphasis on the rapidly changing coastal and shelf seas.

A 3.3.2 Major Research Foci and International Impact

Evolution of life in the oceans: Modern techniques as complementary tools to investigate species taxonomy, biology and physiology are a major component of Germany's marine biological research. As new species are described for many environments, the question arose how these species have evolved to fit into a particular habitat in a medium (ocean) that by nature is highly dynamic and ideal for mixing and dispersal between geographical locations.

The emerging fields of molecular genomics revealed afore unknown metabolic capacities, and presented clues as to how species interact with each other, and how they had adapted for better survival in hostile environments. The concept of an arms race in plankton for better protection against grazing versus advanced modes for capturing food has been established. The role of symbiosis and infections in the evolution of marine species is another highly relevant topic. Species performance is now, once again, seen in an evolutionary context.

Diversity and distribution of marine life: The role of biological entities – from viruses to vertebrates – in structuring and determining the functioning of marine ecosystems is a focus in many German research institutions and universities. Species-species relationships such as predator – prey interactions are investigated on every trophic level of the food web from the microbial loop to the top predator level.

Many marine ecosystems are constantly changing (e.g. temperature, pH, and nutrients). Along with these changes, newly introduced (alien) species potentially lead to a reorientation of ecosystem structure and functioning. The determination of consequences of such changes on biodiversity, resilience, and stability of marine ecosystems is a challenge to marine biodiversity research. In situ experimentation and mesocosm studies are used to unravel biological and physiological mechanisms related to change and to quantify the relevant biogeochemical processes involved.

Marine biology and physiology: Unravelling the biotic (functional groups, biodiversity) and abiotic (temperature, nutrients) drivers of ecosystems processes are a major research focus of ecology in general. Here, marine sciences contribute uniquely by integrated assessments of organism physiology, processes and biogeochemistry (see 3.2.3). This is fostered by well established close collaborations between disciplines in the marine institutions. Integration across scales of organisation from gene to ecosystem is enabled by modern high-resolution technology (e.g. NMR, NanoSims, Maldi-TOF, next generation sequencing, etc.) and accelerated understanding of the physiology of marine organisms. Substitution of essential elements in metabolic pathways under limiting conditions, discovery of new metabolic pathways (e.g. ANAMMOX), the use of inorganic energy sources such as hydrogen by animals with symbiotic bacteria, metabolic pathways for detoxification in anoxic-oxic boundary layers, regulation of metabolites via gene expression by different stressors, are just a few examples of recent advances by Germany's marine biological sciences enabled by innovative technologies. Therefore, we can assess intra- and interspecific effects in changing environments and build more realistic scenarios for potential consequences of ecosystem change.

Geosphere-biosphere interactions and extreme environments: The composition and function of life in the deep biosphere, microbial habitats formed by giant sulphur bacteria or hydrocarbon degrading microorganisms, the heterogeneity of biological provinces in the ocean are also examples where German research advanced international marine sciences. With the closer examination of the performance of the organisms within such "new" habitats, previously unknown metabolic performances have been discovered. This immediately leads to new questions: How can organisms survive geological time-scales under stagnant conditions in the deep biosphere, what are the minimum requirements for very low but still active metabolism, what allows single cells (bacteria) become macroscopically large without loosing their metabolic performance, is there something like job-sharing among organisms to maintain a habitable environment, and what do we learn from all this in general terms how organisms have evolved and will adapt to new situations?

Ecosystem services: In our society the awareness grows that services of all marine ecosystems for mankind are endangered. It has been almost generally accepted that natural resources are not invulnerable and infinitely available. Ecosystem services have been grouped into four broad categories: provisioning, such as the production of food; regulating, such as the control of climate and disease; supporting, such as nutrient cycles or marine productivity; and cultural, such as spiritual and recreational benefits. The environmental impacts of anthropogenic actions, which are processes or materials resulting from human activities, are on the increase. Air and water quality are compromised, oceans are overfished, and pests and harmful species are spreading. More than 60% of marine fisheries are either overexploited or at their limits, atmospheric CO_2 has increased more than 30% since the advent of industrialisation. Society is increasingly becoming aware that ecosystem services are threatened by human activities and that they are limited. Accordingly, national and international science programs have this topic high on their agenda and German marine research groups have dedicated their activities along those lines.

National and international programs: German contributions to and leadership in international programs related to marine biodiversity and marine ecosystem research are numerous and distributed among EU, BMBF, DFG and other funding sources. Major contributions were made to biodiversity exploration, long-term monitoring of environmental and biodiversity change, and functional biodiversity research relating biotic changes to ecosystems processes and services. A major trait characterizing

the success of the Northern German marine institutes in the field of biodiversity and ecosystem research is the strong connectivity between the partners. Research across institute boundaries is the norm, synergistically bundling the expertise available based on topical or regional aspects of biodiversity and ecosystem research. The need to coordinate this research has led to major new national and international initiatives. Nationally, this is reflected by the establishment of a DFG Senate Commission on Biodiversity Research (founded 2008), and by the founding of a German Centre for Integrative Biodiversity Research by the DFG. Internationally, the ongoing formation of an Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IP-BES) will strengthen especially the interdisciplinary links between aspects of biodiversity and ecosystem research and the human utilization of marine goods and services.

A 3.3.3 Future Perspectives for Research in Marine Ecosystem Research

Understanding the response of marine life to the pressures of global change and assessing its role for ecosystem functions requires integrative research across basic ecology. Evolutionary biology is embedded in ecosystem sciences. To ensure conservation and management of biodiversity a transdisciplinary approaches is followed. The grand challenges for marine biodiversity and ecosystem research can be divided into five hotspots of activity:

- **Marine Biodiversity Discovery**: Whereas many are aware of the degree of uncertainty about biodiversity in tropical forests, the gap in scientific knowledge about marine biodiversity is much less appreciated. Regarding the exploration of this biodiversity, the mid-tem goals are
  - uncovering the functional diversity of marine microbes (especially viruses and bacteria) using new molecular information to reveal genomic, proteomic and metabolomic diversity,
  - establishing cross links to bionic, medicine, pharmaceutical products,
  - understanding the diversity in interaction networks between species, e.g., linking symbioses and food webs,
  - describing the diversity in marine systems of low accessibility and in undersampled organism groups,
  - creating baseline observations to quantify and monitor ongoing shifts in marine systems,
  - spatially scaling marine communities and habitats towards conservation principles.
- **Mechanisms**: The mechanisms leading to the observed patterns in biodiversity and to the monitored changes in the Anthropocene need to be unravelled. This requires much greater integration of theory, ecology and evolutionary biology in the marine sciences. Research priorities comprise
  - integrating mechanisms organizing biodiversity patterns over temporal and spatial scales by linking the historic evolutionary contingency to spatial dynamics of species and local interactions that constrain biodiversity and ecosystem processes,
  - evaluating the adaptive scope of marine life and ecosystems under rapidly changing environmental conditions.
- **Functions**: Marine research has undergone a paradigm shift in recent decades, as biodiversity is no longer seen as a mere descriptor of life, but as a functional determinant of ecosystems. It has been shown that ecosystem processes and properties alter if biodiversity changes. Here, mid-term goals are
  - linking biodiversity and biogeochemical research is still a challenge; integration will inform biodiversity researchers as to how altered biogeochemical cycles affect biodiversity, and biogeochemists how matter flow and transformation is affected by various aspects of marine biodiversity (see also section 3.2),
  - understanding the traits connecting biodiversity at the genetic, species interaction and ecosystem level to processes and properties of marine ecosystems.
- **Services**: Many of the functions described above are relevant to humans, as they provide food (fisheries), goods (marine natural resources), or services (coastal protection). These questions require inter- and transdisciplinary approaches to marine research. Here, the marine institutions in Germany will have to cooperate with a broad array of disciplines, some of which are in-house groups, but others will require new collaborations, in order to
  - provide information on sustainable use of marine ecosystems, e.g. heavily used coastal systems or in mineral extraction sites including hydrothermal vents, seamounts and manganese nodules areas,
  - link these service to functional properties of species,
  - evaluate the economic value of marine biodiversity.

A 3.3.4 Relevant Research Infrastructure (> 250.000 Euro)

German marine ecological research operates world-wide and thus relies heavily on sea-going infrastructure. The basis for biological sampling and assessment of ocean life and its many functions is a modern research fleet (small, medium and large research vessels), underwater platforms (remotely operated and autonomous underwater vehicles with sensors and analytical instruments) including deep-sea research capacity (winches, mapping tools, video-guided instrumentation). To assess temporal dynamics of marine ecosystems, long-term ecological research platforms and marine observatories with the capacity to record biogeochemical and biological vari-

ables are a key infrastructure. Impact studies need specific infrastructures such as large-scale experimental facilities or mesocosms.

Marine ecological laboratories are equipped with state-of-the-art analytical technology such as single cell / NanoSims facilities located at Bremen and Warnemünde; the NMR´s available in Bremen and Bremerhaven, state of the art organic geochemical laboratories in Bremen, Bremerhaven, Warnemünde and Oldenburg, molecular sequencing centres in Kiel and Greifswald. Aquaria, seawater mesocosms and cultivation facilities to maintain living marine species under environmentally relevant conditions are maintained with continuous support in personnel, seawater from the original location, water control (temperature, oxygen, pH, etc.) in Kiel, Sylt, Helgoland and Wilhelmshaven. Comprehensive data sets are increasingly needed in ecological research, and modern sequencing techniques generate huge data sets that require intensive processing. Hence data management, distribution, storing and bio-informatics as well as bio-statistical data analysis have become important components of research infrastructures. Key competence dedicated to marine environmental bioinformatics is currently located at in Bremen (Bacteria, Archaea), Bremerhaven and Kiel (Eukaryotes). Computational facilities for ecological modelling linked to ocean and climate modelling and in the future also socioeconomic modelling are key infrastructures maintained in Kiel, Warnemünde, Bremerhaven and Oldenburg.

A 3.4 Resources from the Sea

A 3.4.1 Scope

With the continuous depletion of conventional resources on land, there will be growing pressure to exploit marine systems including the deep sea. Research on the sustainability of any future marine exploitation is critical to prevent loss of marine ecosystem services and values. Utilisation of marine energy (gas, oil, offshore renewables) and minerals (metal sulphides, nodules, crusts, phosphorites) will increase in response to the growing demands for these resources. From a geological point of view, there is no scarcity of energy or most raw materials on Earth, but many of these cannot yet be obtained at low-cost or in a sustainable way. Geological and geophysical investigations of the seafloor and sub-seafloor provide critical data for assessing mineral and hydrocarbon resources in the oceans and for options as to their sustainable management (e.g. exchanging gas hydrates with CO_2 as a means of carbon sequestration). Marine biology and chemistry provide the framework for sustained management of living resources such as fish, enzymes or other biomaterials of biotechnological relevance. The challenges for future resource development in the oceans underlie environmental considerations that vary between different countries and in international waters, and by different legislation and exploitation codes. Transdisciplinary research is needed to develop information for political and

economical options for the ecologically and economically sustainable use of marine resources, especially in sensitive environments such as the Arctic, Antarctic or the tropics. Marine sciences assess the effect of global change on marine resources (e.g. fisheries, biodiversity), the conflicts between conservation objectives and differences between short and long-term use options (e.g. fisheries vs. offshore wind energy generation; biodiversity vs. mineral mining). One of the important future tasks of applied marine sciences is to advance interdisciplinary approaches with environmental law and socio-economical sciences and make sure that intensive use of marine space and ecosystem services will be sustainable and in line with conservation aspects.

Research into biological and genetic resources is also currently being intensified in Germany and worldwide. Substances produced by marine organisms represent a potentially rich source for the treatment of human diseases such as cancer, microbial infections and inflammatory processes. The exploration of the molecular diversity of marine life for biotechnology including bionic materials, medical and pharmaceutical substances as well as enzymes for industrial purposes was recently revolutionized by new methods including rapid screening tools and geo-referenced bioinformatics databases. Food from the sea is a traditional resource and depletion of commercial fisheries continues to be a threat to society. In Europe, fishery science and technology have the capacity to provide independent information for economically and ecological sustainable marine fisheries. Although aquaculture has gained a tremendous importance as a profitable alternative to fisheries, expanding into marine aquaculture is not without risks for coastal ecosystems and its native fish stocks. In the mid- to long-term, sustainable fishing practises that would allow expanded catches after stock recovery are often a better alternative than aquaculture. Germany is far behind in the economic development of the marine aquaculture sector and its corresponding research policy.

A 3.4.2 Major Research Foci and International Impact

Marine mineral resources: Research on massive sulphide deposits and manganese nodules included some of the first major geological surveys of the world's mid-ocean ridges and submarine volcanic arcs, aimed at understanding the regional-scale geodynamic controls on seafloor mineralization. German marine research institutions have been instrumental in the discovery and assessment of seafloor massive sulphide resources in regions as diverse as the East Pacific Rise, the Juan de Fuca Ridge, Mid-Atlantic Ridge, Mediterranean, Iceland, New Zealand, Tonga, Antarctica, and Papua New Guinea, making some of the most important discoveries in marine minerals exploration of the deep sea. This research has produced one of the most comprehensive inventories of seafloor mineral deposits available, including the current classification scheme for seafloor massive sulphide (SMS) deposits and the first global

assessment of seafloor hydrothermal systems prepared for the U.N. International Seabed Authority. This assessment formed the basis for the current international regulations for seabed mineral exploration.

Energy resources (hydrocarbons incl. gas hydrate, renewables): Gas hydrates have been intensively researched by German marine scientists for many years. This research now focuses on developing new technologies for the exploration and exploitation of marine gas hydrates as a new unconventional resource of natural gas. One option could be to inject carbon dioxide (CO_2) captured at coal power plants and other industrial point sources into subseafloor submarine gas hydrate deposits to enhance methane gas production and sequester CO_2 as solid gas hydrate. New technologies for the environmental monitoring of conventional and deep-sea oil and gas production, pipelines and CO_2 storage in sub-seabed geological formations need to be developed. Hydroacoustic and chemical sensors for leakage detection at the seabed are augmented by cutting-edge geophysical techniques imaging the migration of fluids and gases in the sub-surface. New research fields include offshore wind energy, wave energy converters and coastal engineering measures including the advancement of knowledge in design, efficiency and reliability of offshore infrastructure and harvesting of marine energy.

Marine space: Applied research that focuses on issues related to spatial management of human activities at sea is gaining importance especially in coastal areas due to increased shipping, oil and gas exploration and offshore wind energy generation. The role of science is to provide a solid knowledge base to balance ecological sustainability against economic prosperity and growth of the various marine and maritime sectors. German research in the Baltic Sea and North Sea concentrated on method development to evaluate spatial management systems and has contributed significantly to mainly EU-funded projects (e.g., CO-EXIST, MESMA, KNOWSEAS, MASPNOSE, BaltSeaPlan, BALANCE). In the tropics, the governance of protected areas and the variety of protection schemes is being studied. Major achievements were the implementation of transdisciplinary research projects, e.g. to evaluate the effectiveness and acceptance of protected areas especially in relation to fisheries. The effects of multiple anthropogenic stressors including impacts of wind energy generation on marine ecosystems and living resources were assessed. Explicitly, the effects of building and operating windmills on sea birds, marine mammals and habitats were addressed.

Genetic resources: A first step in the exploration of genetic resources of ocean life is the discovery of biodiversity and its distribution and function. Research on extreme environments has provided insight into new types of metabolic pathways and adaptations of cold- or heat-adapted organisms, some of which led to the finding of industrially relevant enzymes (e.g. DNA polymerases, detergents). The ocean is

currently considered a key environment for much of the hidden potential in bionics, antimicrobial agents replacing conventional antibiotics, and new food or pharmaceutical supplements. Germany's marine research institutions have substantially advanced marine microbiology, environmental genomics and proteomics, bioinformatics and rapid biodiversity assessment as well as research on distribution, physiology, adaptation, biological interaction and evolution of organisms and function of their genes and enzymes, which are all key skills in the identification of technologically relevant genetic resources.

Natural substances: A major focus of marine natural products research is on the analysis of marine microorganisms and fungi as producers of bioactive substance for application in human health. A number of new substances with application potential were identified and characterized. Some with important biological activities have been patented and are promoted to the stage of preclinical studies with international consortia in EU-funded projects. The focus is on anti-tumoral and antibiotically active substances as well as on inhibitors of key enzymes playing a role in diabetes or neurological disorders (e.g. dementia) in order to meet the most urgent demands for new drug developments.

Food resources (incl. aquaculture): Fisheries and aquaculture research in Germany covers three broad aspects, (i) basic research into the physiological, genetic and ecological principles of ecosystem functioning and resource distribution and dynamics, (ii) dynamics of fishing and aquaculture activities including feedback mechanisms with the environment and ecosystems as well the economic and social dimension of these activities, and (iii) research into food processing, food quality and safety. Research into the socio-ecology and economics of fisheries and aquaculture, however, has mostly been addressed by federal research institutions with a focus on management aspects. Non-university research institutions have investigated these issues in specific geographic areas including the tropics. Only recently have these aspects been considered in integrated coastal management research.

Major international achievements with substantial contributions of German marine research institutions over the last five years provided a better mechanistic understanding of ecological processes in marine systems by developing new sampling and analytic techniques (e.g. genetics and microchemistry), as well as by improving sensors, the resolution of remote sensing plus modelling capabilities. New targeted fish farming methods have been developed (aquafarming) on land as well as in the sea, most significant in the area of offshore wind farms. Significant progress was also made in fish meal and fish oil substitution in fish feed to minimize the utilization of raw materials from fisheries using alternative plant and other raw materials from terrestrial and aquatic origin and development of innovative, resource efficient rearing systems. Further research activities concern the interaction of nutrition, im-

mune competence and immuno-genetics for rearing of juvenile fish. The integration of economics and social sciences into fisheries and aquaculture research enabled a much more realistic evaluation of the costs associated with alternative management approaches. In addition, innovative technical solutions for the maritime economy including ocean engineering, maritime logistics or fisheries and aquaculture are being developed.

A 3.4.3 Future Perspectives of the Field in Germany

Marine mineral resources: Mining of manganese nodules, cobalt-rich crusts and seafloor massive sulphide deposits on the deep seafloor has long been proposed as one option to supplement declining reserves of base metals (e.g. copper, zinc, lead), precious metals (gold, silver, platinum), rare earth elements, and special metals such as nickel, cobalt, selenium, tellurium, lithium, and indium that are currently mined on land. An important strategic research objective is to provide tangible criteria for the selection of areas suitable for discovery of these resources in the oceans, including their total amount, spatial distribution, and chemical composition. A prerequisite for risk reduction in the supply of raw materials is the development of more successful exploration strategies, informed by a better understanding of the geological processes responsible for the origin and location of the resources. The discovery of these resources needs to act in combination with innovative new technologies for exploration, mineral assessment and exploitation. Germany has the essential world-class marine science assets to conduct this research and the academic environment needed to promote these new discoveries. It has an established international presence in this field, with the essential sea-going experience in mineral exploration. This capacity ensures future collaborations with the marine minerals industry and in particular the new industrial sector that has emerged within the last decade that is focused on the evaluation of mineral occurrences on the seafloor.

Energy resources (renewables, hydrocarbons incl. gas hydrates): Wind power is presently the main renewable energy resource that is being developed at a large scale in shallow coastal seas. The large planned wind parks will leave an imprint on the marine ecosystem and require comprehensive environmental impact studies partly based on autonomous observation technology. Threats to the technical installations from hydrodynamics and sediment movement have to be considered. The ever-growing demand for energy resources will furthermore be met by the exploitation of hydrocarbon resources located at large water depths, in deep geological formations and remote Arctic regions. The extreme pressure and temperature conditions in these marine environments pose a significant risk and increase the likelihood of catastrophic failure. Moreover, large volumes of CO_2 captured at power plants and other industrial facilities could be stored below the seabed. Research will aim at improving technologies for the environmental monitoring of offshore production and storage sites, to assess the impacts on marine ecosystems, and to define best practice guidelines for operation and monitoring.

Marine space: The interest of various stakeholders in the oceans and coastal zone has increased constantly in recent years and led to a growing demand for marine and maritime space and ecosystem goods and services. In order to ensure sustainability of the multitude of human activities in the sea, we need to understand the synergistic and cumulative impacts of multiple anthropogenic pressures on marine ecosystems. The difference in temporal and spatial scales of relevance for ecological and habitat processes and the human activities to be managed need to be understood to identify conflict potential and possible synergies. Competition between sectors (e.g. traffic, coastal engineering, mineral resources, commercial and artisanal fisheries, local livelihoods in general) and the economic and social consequences of spatial planning scenarios need to be in focus when developing integrated management systems.

Genetic resources and natural substances: Research on genetic resources and marine natural products need to be embedded into knowledge on the functioning of compounds in their natural settings (i.e. chemical ecology). A combination of gene, cell and substance screening with methods of bioprospecting using high throughput genomic and molecular technologies is needed to increase findings of organisms with desirable functions and specific metabolic pathways. When combined with phylogenetic, environmental and biogeographical frameworks, such studies can also greatly contribute to characterize biodiversity in the oceans and its key functions. An area in need of development are advanced bioinformatics and information infrastructures together with archives of original environmental samples, DNA materials and reference organisms to preserve knowledge about the diversity of marine life. Also needed is the link to up-scaling technologies and to marketing strategies once substances with application potential have been identified.

Food resources (incl. aquaculture): In current and future decades major changes in economies, markets, resources and social conduct can be expected. Climate change impacts will bring increasing uncertainties in many food sectors, including capture fisheries and aquaculture. An incorporation of climate change adaptation scenarios in sustainable management programs is inevitable to ensure global food security. In this respect, a major focus for the next decade must be on ecosystem functioning and biodiversity in relation to global change drivers. For risk adverse management strategies ecosystem models have to be developed for making reliable forecasts of major ecological regime shifts. Coastal seas will be central areas of investigation in this respect as they are most relevant for fisheries and aquaculture, and at the same time these activities tend to conflict with conservation and natural coastal protection. A focus will be on implementation of low-impact/resource efficient pro-

duction technologies in commercial fish production. Creation of value from primary production by reducing postharvest loss and improving value chains for fish products is central in this respect. Research into sustainable fish feeds that make aquaculture efficient producers of safe, high-value food with low impact on wild forage fish populations is crucial for future development of the stagnant aquaculture sector in Germany and Europe. Advances in economics and social sciences are needed for understanding of markets for fish and fish products in order to satisfy consumer demand through local production and processing, which will be essential for German aquaculture development, as well. Rapid diagnosis tools for fish diseases in aquaculture settings are needed, and culturing conditions need to be improved in such a way that the natural immune competence is maximized. Behavioral assays will address fish welfare aspects, which will be linked to the immune response. We need to fully understand the ecosystem impacts of various fishing and aquaculture activities to develop technology and incentive based solutions for minimizing ecosystem impacts of fishing and aquaculture. Last but not least, analyzing and understanding the main issues of participation, legitimacy and responsibility and providing advice on suitable, acceptable and effective governance models (Institutional Arrangements) will be a challenge for German marine research, as economics and social sciences with a focus on marine and maritime issues is presently underdeveloped in Germany.

A 3.4.4 Relevant Research Infrastructure (> 250.000 Euro)

A prerequisite for research in the field of marine resources are research vessels ranging from local over regional to ocean class. Deep-sea technologies (submersibles, autonomous and remotely operated vehicles), ocean observation systems and geophysical instrumentation (Ocean Bottom Seismometer Pool, 2D and 3D seismic reflection systems, electromagnetic systems) are essential tools for mapping, detection, assessment and sampling of resources. Further sampling tools include specialized sampling devices (e.g. TV-guided grab) and drilling facilities (e.g. Sea-Floor Drill Rig MeBo). Fisheries research in the high seas is mainly carried out on the federal research vessels and to a limited extent on RV POLARSTERN. In addition, research on living organisms requires specialized culturing (e.g. the tropical temperature MAREE "Marine Experimental Ecology" mesocosm facility of ZMT) and aquaculture facilities (e.g. "Association for Marine Aquaculture" GMA in Büsum with land-based closed aquaculture farming basins with a total volume of appr. 170 m³). High-throughput molecular analytics and laboratory facility, a prerequisite for molecular and genetic investigations, are available at AWI, MPI, University Kiel and Hamburg. Furthermore, geo-referenced information infrastructures including genomic and taxonomic data bases, geospatial information systems, habitat maps and other types of knowledge platforms are important to ocean resource research (e.g. MPI, MARUM/AWI).

A 3.5 Earth System Dynamics and Geological Risks

A 3.5.1 Scope

New discoveries in recent decades reveal a fascinating picture of the dynamics of our planet. Processes at the core-mantle boundary at a depth of 2,900 km evidently drive hot spot phenomena at the Earth's surface, while volcanism at mid-ocean ridges and subduction zones makes up 90–95 % of volcanism on Earth. On the other hand, at some locations ocean lithosphere plunges to great depths into the lower mantle and may rise again to the surface in the form of mantle plumes. Subduction of oceanic lithosphere carries water into Earth's mantle and water returns to the surface through volcanism at convergent and divergent plate margins and at hotspots. Convection currents in the Earth's mantle can be detected directly and compared with numerical models. Our understanding of the Earth's magnetic field has reached the point at which numerical models can reproduce the spontaneous geomagnetic field reversals in the geological past.

Progress has been made in forecasting volcanic eruptions in recent decades, while earthquake prediction/forecasting is still in its infancy, although earthquake precursor phenomena have been described and earthquake foci and magnitude of the tremors anticipated can be calculated. Improved understanding of the system is indispensably linked to direct observations and sampling with long-term monitoring techniques and the application of mathematical methods and models based on such time series data. The dynamics of Earth's interior can be inferred by modelling the fluid dynamics of mantle convection.

Continued growth of the world's population has resulted in expansion to new living spaces, making people more vulnerable to the forces of nature. Especially high human casualties and severe levels of damage occur when events with a low probability of occurrence hit regions with high populations. Recent examples of this include the megathrust-earthquakes and subsequent tsunamis in Southeast Asia on Boxing Day 2004, and off Japan in March 2011.

To be able to respond more effectively to so-called geo-hazards, such as earthquakes, volcanic eruptions, tsunamis, submarine landslides, storms and floods, the processes themselves have to be understood. Among other things, early warning systems need to be installed for various geo-risks. GIS-based information and decision systems are important tools in the development of defense and response measures with respect to natural disasters. Over the last 100 years, increasing numbers of natural hazard events per year have been observed, including earthquakes, volcanic eruptions, floods and cyclones. Associating increasing impact of natural hazards on society with more vigorous climatic conditions (global change) should be treated

with caution, since the space occupied by urban areas, industries and infrastructures has dramatically raised the vulnerability of large sectors of our society.

A 3.5.2 Major Research Foci and International Impact

Convergent margins: Convergent plate margins are major sites for a number of natural hazards, including large earthquakes, volcanic eruptions, submarine landslides and tsunamis. These hazards are largely triggered by subduction fluids, derived from serpentinized lithospheric mantle of the incoming plate, seawater-altered igneous ocean crust and the overlying marine sediments. Dehydration of the subducting plate at depth and fluid infiltration into the mantle wedge leads to increased magma production, and subsequent formation of highly explosive volcanic eruptions that may also eject climate-relevant gases (such as CO_2, S, Cl, Br) into the stratosphere. Approximately 90% of the Earth's total seismic moment is released in potentially devastating subduction zone earthquakes, which are still an incompletely understood scientific phenomenon that poses an enormous societal threat. Gigantic tsunamis, inundating coastal communities with waves up to 30 meters in height and resulting in unforeseen casualties may result. Considerable progress in the understanding of these processes and the quantification of volatile transfer through the system has been achieved during the past eleven years. It is presently assumed that both frictional properties of the fault material and pore pressure transients play a deciding role in whether an earthquake is triggered and how extensive it is in magnitude and slip. Innovative experiments are thus necessary to shed light on the relationships between fluid release, pore pressure generation and seismicity. Experimental approaches have to be complemented and calibrated by in situ long-term measurements in key areas. One of the most challenging tasks is the identification of precursory processes before large earthquakes as well as their use in hazard mitigation and early warning scenarios. One of the most important aims of modern geosciences is the risk assessment of natural hazards, in order to better prepare for, respond to and recover from these hazards and thus prevent them from becoming disasters. This includes both the direct risk emerging from volcanic eruptions, earthquakes, tsunamis, etc., and the consequences of the longer-term global change induced e.g. by the climatic impact of volcanic eruptions.

Pioneering work at the international forefront has been carried out in Germany on the role of fluids and volatiles in subduction zones and consequences for megathrust earthquakes, explosive volcanic eruptions and tsunami generation along continental margins.

Divergent margins: The ocean crust is formed at mid-ocean and back-arc spreading ridges, and the circulation of seawater through young and fractured seafloor mediates global heat and elemental fluxes to a large extent. The consequences of these processes for crust – ocean (bio)geochemical budgets and microbial biodiversity are basically unknown. Plate tectonic forcing parameters play the predominant role in controlling the hot spring chemistry and the associated mass transfers, deposit types, and microbial ecosystems. In few other settings on Earth do processes driven by the interior dynamics of our planet affect the surface environment more directly. Divergent plate margins are therefore ideal places for studying the co-evolution of our planet and life.

In the oceans, the formation of Mid-Ocean Ridges and oceanic intraplate volcanism, providing a window into Earth's dynamic mantle, as well as into the initiation and evolution of deep mantle plumes, has been a major target of German research over the last decades. More recently these investigations also led to a focus on lithosphere – biosphere interactions at hydrothermal vents.

Cold seeps and continental margins: Although sometimes called passive because they are not active in a plate tectonic sense, continental margins on diverging plates host the majority of the Earth's petroleum resources and are highly dynamic systems. High rates of sediment deposition lead to compaction and mobilization of fluids which is the basis for the development of subsurface hydrocarbon reservoirs, and under certain conditions, even leads to hydrocarbon migration and focused emission of fluids, gases and muds at the seafloor. First estimates suggest that the magnitude of upward fluid flow through continental margins could be similar to hydrothermal venting. Associated with fluid outflow at such cold seeps are chemosynthetic communities that utilize the chemical energy of reduced components such as H_2, H_2S, CH_4, and other hydrocarbons. Associated with hydrocarbon pathways in passive margin settings is the formation of solid gas hydrates along all continental margins. While forming a probably underexplored huge extra hydrocarbon reservoir, decomposition of the gas hydrates as a result of global warming and exploitation techniques can cause slope instability and associated mass-wasting, with large submarine landslides triggering tsunamis. First studies hint at a cyclic behavior in growth and active fluid venting periods that can probably be linked to global climatically or tectonically controlled processes and are therefore a key to understand the behavior of entire slope systems at active and passive margins during human induced sea-level changes. Novel 3D seismic imaging tools provide unique insights into these processes and are crucial for safe management of industrial activities in order to prevent disasters such as the Deepwater Horizon accident in the Gulf of Mexico in 2011.

At passive continental margins, the distribution, timing and mechanisms of submarine landslides have become a major focus of German marine research, because of marine geohazards originating from such settings. All these scientific efforts incorporated new seagoing infrastructure, such as portable drilling technology and borehole testing or more sophisticated sampling techniques attached to deep-diving ROVs (e.g. KTB, ICDP, MeBo, high-resolution camera systems, or hot fluid sampling devices). More

recently the occurrence and formation of shallow gas hydrates in few selected areas, as well as the ecosystem structure of cold seeps and enhanced activities related to free gas ebullition has gained large attraction and importance in marine research.

A 3.5.3 Future Perspectives of the Field in Germany

Major objectives of future marine research in Germany with respect to earth system dynamics and resulting geological risks include large-scale mapping of the seafloor surface using modern multi-beam systems to delineate plate boundaries, identify outcrops of deep-seated structures, e.g., fault and fracture zones, seamounts and mud domes, and improve our understanding of seafloor dynamics. For this purpose high-resolution bathymetric surveys with decimeter resolution using AUV's are needed, as well as repeat surveys to recognize small seabed changes, e.g. to detect movements along slide planes, creeping slopes, mud volcano eruptions. The latter will guide the selection of representative locations for case studies to perform experiments and in situ measurements (e.g. Crimean and Kerch margin, West of Svalbard, Nice margin) and to develop strategies and implementation for in situ long-term measurements of seafloor deformation and scientific drilling including CORK systems.

For subsurface processes the intimately connected dynamics of solid plate tectonics and fluid flow as well as their consequences for the formation of non-living resources, marine ecosystems and geohazards will be investigated. In addition, models of the geodynamo need to be further developed to reliably predict the future of the Earth's magnetic field. Also, we need to gain a more comprehensive understanding of the evolution and chronology of subduction systems, to facilitate hazard assessment.

The study of subsurface processes will also include drilling of gas hydrates to understand the distribution and formation of methane hydrates deeper in the hydrate stability zone and to assess the potential of gas hydrates as a future energy source (see section 3.4.3.). The latter will be embedded in the more general objective to quantify hydrothermal and non-hydrothermal seepage mass and energy transfers, and to determine their impact on microbial life and deep-sea fauna and biogeochemical and inorganic cycling in the deep sea.

The study of the dynamic processes will have a direct impact on planned investigations of the stability of ocean margins, particularly related to areas of gas hydrates, volcanic flank collapse, enhanced fluid emission activity, and/or gravitational sliding along steep morphological gradients. Future challenges include long-term monitoring of hazard precursors, determination of trigger mechanisms and the use of smart technology (transducers, communication) to improve early warning for volcanic eruptions, earthquakes and tsunamis, especially those directly affecting Europe. Predicting the role of seafloor carbon emissions in long-term climate change, as well as the study of interactions between climate and volcanism through-out Earth history, will be major contributions of German marine research for the ongoing global change discussions.

Submarine volcanic activity is also a poorly known process, because eruptions at depth are strongly attenuated by seawater and reports on submarine volcanisms are largely restricted to those sites where erupted products reached the sea surface. Eruption rates and eruption dynamics are hence poorly studied processes. Several proposals strive for an enhanced understanding of submarine volcanism and assessing related geo-hazards like subaerial pyroclastic surges, flank collapses, resulting tsunami and to conclude on matter flux – biosphere interaction.

A 3.5.4 Relevant Research Infrastructure (> 250.000 Euro)

Key infrastructures are research vessels with high maneuverability (dynamic positioning system) and better underwater navigation systems, which are able to launch and recover several deep-sea vehicles and handle 3D seismic equipment. The vessels need to be equipped with improved high resolution mapping tools for imaging of the sea floor in great detail. Scientific demand requires the continuous development of remotely operated vehicles and autonomous underwater vehicles for specific missions. For geological sampling, mobile drilling systems, such as the MeBo system, and development of various borehole measurements are required. Ideal would be Logging-While-Drilling technologies (LWD) and development of borehole observatories. Mobile seafloor observatories will provide platforms which allow responding rapidly to new scientific challenges. Finally, research in this theme will be based on satellite-based remote sensing of solid earth structures and physical field properties (geo-magnetic, gravitational, surface height anomalies).

A 3.6 Cross-cutting Theme: Coastal and Shelf Sea Research

The coastal and shelf sea research theme encompasses aspects of the previous five themes but focuses on a particularly vulnerable region that includes both marine and terrestrial end members. In this field of research the large impact of human activities on the ecosystem requires a closer collaboration with to socio-economic sciences. Due to the special position of coastal and shelf research straddling several research themes it is considered here as a special cross-cutting theme.

A 3.6.1 Scope

Coasts are the interface between land and sea and are characterised by atmospheric, terrestrial and marine influence. Shelf seas are the interface between the coasts and

the ocean. Together the marine components of this continuum are coastal seas that bracket gradients of natural influence and human activities.

Coastal seas are particularly exposed to natural risks (tsunamis, storm surges, sea level rise) and are the active zone for matter fluxes between land and sea. They are of great relevance to humankind, which is obvious in their intense and multiple usage, the supply of specific ecosystem services, and the fact that they are attractive regions for humans to live. They are a matter of conflicting interest of economy, culture and governance. Concurrently, societal preferences and perception of coastal use differ between countries and vary over time. Coastal research thus requires the integration of social, engineering and natural sciences. Such a successful integration will be of fundamental significance in marine-oriented sustainability research over the next decade. This view is in line with national and international developments (for example, in the framework of the international Future Earth Initiative).

In the following we view these systems from a marine perspective.

A 3.6.2 Major Research Foci and International Impact

Coastal seas have regionally specific characteristics and their own particular challenges to research. They are exposed to various levels of natural and anthropogenic pressures. Very different examples constitute the pristine coasts in the Arctic, the heavily fortified North Sea coasts, the basins and coasts of the Baltic Sea, and mangrove or reef coasts in the subtropics and tropics. The combination of this natural diversity with significant societal, economic and political differences is locally reflected by substantially different research thrusts and infrastructure, whereas in a "global coast" context many natural processes and conflicts are shared. Thus, depending upon location a great degree of international coordination and exchange is required.

Currently, the main research foci are exploratory or process-oriented (what is there, and how does a particular system function). These approaches unravel ecosystem structures, consider eutrophication/pollution, the manifestation of global warming, the importance of alien species, or the effects of and best practise for coastal engineering. These and other disciplinary approaches advance our understanding of complex interactions in coastal seas.

Acknowledging complexity arising from interactions of the natural and the human system, coastal research in Germany has evolved towards more integrative systems views. These build on insights from detailed and long time-series observations of ecosystem and hydrographic properties and evolution, evaluation of past change and scenarios of future change, and societal and policy drivers. Operational issues linked to environmental monitoring and risk assessment as well as the evaluation of anthropogenic pressures and modifications in terms of resilience or sensitivity

are part of the remit. Coastal research in Germany interacts successfully with public institutions and authorities on local, regional and national authorities and stakeholders. Scientific support is needed for marine spatial planning and coastal management issues related to sustainable use of resources. Coastal research in Germany contributes to the EU marine strategy framework directive, ICES, HELCOM, OSPAR, UNESCO efforts by running monitoring programmes and process studies in the frame of the national and international research community. Major progress has been made in the training of a new generation of coastal scientists in a transdisciplinary environment ranging from natural through to social science.

International impact is best seen in coordinating roles that coastal research institutions had in major EU projects, such as BASYS and BONUS. Other examples are bilateral coordinated research projects such as SPLASH in China, SPICE in Indonesia, MADAM in Brazil and SPACES in Southern Africa. They contribute substantially to international initiatives such as EuroGOOS, MyOcean, EMODNet, ATKIM, Coastal Futures that aim to set new standards in safeguarding sustainable use of coastal seas.

A 3.6.3 Future Perspectives of the Field

Sustainable development of coasts and shelf seas needs to resolve the conflict between use and protection of natural resources. This requires research on a wide range of environmental, social (including economic) and legal problem sets that must be merged in a systems approach to management of marine resources. An emerging issue of high relevance is sea space use for renewable energy production in the German Exclusive Economic Zone (EEZ) of the North and Baltic Seas. At the same time the UN Convention on the Law of the Sea has put a large burden of responsibility on many less developed countries that causes a huge need for capacity building in these countries. The pervasive and global new societal demand on sea space will have impacts on the ecology and biogeochemistry of the coastal ocean, will compete for space and superiority with other uses, offer potential for development of coastal regions, and requires rigorous assessments of status, risks and chances to safe-guard an overall sustainable development in environmental, social and economic sectors.

Policy drivers, such as the EU Maritime Policy (IMP), the Marine Strategy Framework Directive (MSFD) or the recent revision of the EU Common Fisheries Policy (CFP) stipulate and prescribe interdisciplinary approaches to environmental management of European coastal seas. They require concepts that must be based on the best available science within the fields of physical oceanography, biogeochemistry, marine ecology and fisheries on the one hand, and social and economic, and engineering sciences on the other hand. A systems view will enable coastal research to iden-

tify potential solutions for the various conflicts that arise around the multiple uses of marine resources while recognising the inherent uncertainties in system behaviour.

The major challenges confounding the achievement of a system understanding and development of management strategies for coastal and shelf seas are to identify ongoing change, to assess the state and sensitivity of the coastal system to natural and human influences, and to develop robust methods of communication with stakeholders. The following represent some of the salient questions:

- What processes and functions of coastal seas are most sensitive to global or regional drivers?
- What are societal adaptations (including technical adaptions) to changing drivers?
- What are the relevant scales for natural and anthropogenic processes in the coastal ocean and shelf seas and how are they linked across disciplines?
- What are the appropriate techniques and strategies for their detection, observation and modelling, risk assessment and mitigation of unwanted effects?
- How can coastal science best interact with governance and management of conflicting interests?

A first initiative for integrative coastal seas research in Germany was the BMBF "Research Agenda in the North Sea and Baltic Sea". Reacting to the KDM Strategy Paper "Changing Coastal Seas", a new funding direction was opened for collaborative research efforts that merge coastal marine research with engineering sciences with an explicit focus on societal needs. It had the following objectives:

- To improve the understanding of coastal ecosystems and the knowledge base for a sustainable use of their services. A focus will be on the North Sea and Baltic Sea, considering increasing anthropogenic pressures and impacts of climate change that will affect many coastal areas in the world.
- To enhance abilities to analyse the impacts of global and regional change on coastal systems in a modular coastal model system with capabilities to assess vulnerability of coastal systems.
- To broaden the scientific basis for innovative infrastructures in the coastal realm.
- To target research supporting the implementation of an integrated marine policy (e.g. Framework Directives, Marine Spatial Planning).

A major impetus comes from the EU-Marine Strategy Framework Directive that initiated a renewed interest in optimal ways to detect and understand the impact of various anthropogenic pressures on good environmental status of the coastal seas.

Beyond national and EU arenas, German coastal zone research is proud of long-standing and mutually beneficial engagement with local and regional partners in e.g. Norway, Africa, China, Indonesia, Russia, Canada and North and South America. Dedicated to supporting capacity building with practical training and international study programmes, international networking with universities and research institutions worldwide will place emphasis on the development of international specialist and postgraduate programs that focus on advanced marine and coastal information systems.

National and international coastal sea science currently fits the vision of the Future Earth Programme which highlights trans-disciplinary projects as a key element for future research addressing societal needs. German coastal sea science has taken first steps in this direction and will deliver significant contributions. Further conceptual and structural development is urgently required unifying the available expertise in the natural, engineering and social sciences that are needed for society driven coastal science to unfold its full potential.

A 3.6.4 Relevant Infrastructure (> 250.000 Euro)

Because coastal seas research includes all marine disciplines it is dependent on research vessels designed for a large variety of operational, scientific, and educational demands. Currently the combined fleet of small to intermediate vessels available to the various institutions is sufficient. However, it is imperative that this fleet which is aging is also maintained in the future and continuous to complement the larger research platforms and airborne observations. Requirements for ship capabilities are dependent on the needs of the interdisciplinary groups of scientists and interested stakeholders. Increasingly sophisticated seagoing equipment is being deployed including platforms and fixed nodes for underwater observatories. As in the more disciplinary topics, autonomous devices and instrumentation integrated in ocean observatories are gaining importance. The specific environmental characteristics in the various coastal zones call for specialised instrumentation and infrastructure adapted e.g. to anoxic zones, tropical mangroves, intertidal areas and near-shore systems. German institutes are ideally placed to develop and test seagoing instrumentation and coastal seas are ideal for testing new instrumentation before their deployment in the open ocean. Closer cooperations with engineering sciences and stakeholders (e.g. wind power industry) should be fostered in order to provide innovative instrumentation.

A 4 Organization of Marine Research

A 4.1 Marine Research Funding

Basic Funding differs between institutions according to their affiliation.

- *Public Universities* receive basic funding to conduct their marine research exclusively from the German Federal States where they are located (applies to

Universities of Bremen, Hamburg, Kiel, Oldenburg, Rostock, but also to all other universities contributing to marine research projects).

- *Leibniz Institutes* are funded by the Federal Ministry of Education and Research (BMBF) (50%), the respective Federal State (37.5%), and by all other Federal States (12.5%) according to "Agreement of Königstein" (applies to Leibniz Center for Marine Tropical Ecology, Leibniz Institute for Baltic Sea Research).
- *Max Planck Institutes* are funded by BMBF (50%), respective Federal State (25%) and 25% all other Federal States according to "Agreement of Königstein" (applies to Max Planck Institute for Marine Microbiology in Bremen, Max Planck Institute for Meteorology in Hamburg).
- *Helmholtz Centres* are financed by BMBF and the respective Federal States on a 90:10% basis (applies to Alfred Wegner Institute Helmholtz Centre for Polar and Marine Research, GEOMAR Helmholtz Centre for Ocean Research Kiel, Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research).
- *Federal Agencies* receive funds for research activities from those Federal Ministries they are associated with (applies to Thünen Institutes, German Maritime and Hydrographic Agency, Federal Institute for Geosciences and Natural Resources).

Third Party Funding additional funding is obtained for projects through competitive application processes. Various sources exist; the most important ones for German institutions are the following:

- German Research Foundation (DFG) is the main funding source for projects of universities.
- Federal Ministry of Education and Research (BMBF) provides funding for large scale projects in specific fields of research (including infrastructure).
- EU Framework Programs support projects in international collaboration and large-scale infrastructure.
- Industry projects and projects from local authorities support contract work.
- Funds from German Federal States as well as different Federal Ministries are available for specific support actions (including research accompanying monitoring).

A 4.2 Governance of Marine Research

German Marine Research Consortium

German Marine Research Consortium (KDM) is a voluntary association of marine research institutes, founded in 2004. Fifteen major research institutions active in marine, polar and coastal research are members. These include university and non-university institutes, museum and a German federal authority. The consortium is led by a chair, two co-chairs and a steering committee. With offices in Berlin and Brussels, KDM is the recognized point of contact for the German Federal Government for marine research matters. KDM interacts with the EU Commission jointly with European partner institutions.

KDM coordinates the expertise of its member institutions in order to represent strategically important issues to research funding organizations and policy stakeholders at the national and international levels. KDM acts proactively for the German marine research community regarding the orientation of upcoming research programs especially on the EU level. KDM jointly with the Senate Commission for Oceanography of the DFG promotes strategic concepts for the renewal of existing infrastructure (e.g. research vessels) and the development of new technologies and infrastructures to meet future challenges (e.g. ocean observatories). For this purpose KDM has set up Strategy Groups and Working Groups with topical foci on current and upcoming marine science issues (e.g. Ocean and Climate, Coastal Research, Ocean Observatories, Marine Genomics).

The following institutions are members of KDM:

- Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven
- CEN Center for Earth System Research and Sustainability, University of Hamburg
- Department of Maritime Systems, Faculty of Interdisciplinary Research, Rostock University
- German Oceanographic Museum, Stralsund
- GEOMAR Helmholtz Centre for Ocean Research Kiel
- Helmholtz-Zentrum Geesthacht (HZG) Centre for Materials and Coastal Research, Geesthacht
- Institute for Chemistry and Biology of the Marine Environment (ICBM), University of Oldenburg
- Jacobs University, Bremen
- Leibniz Center for Marine Tropical Ecology (ZMT), University of Bremen
- Leibniz Institute for Baltic Sea Research (IOW), Warnemünde
- MARUM Center for Marine Environmental Sciences, Bremen
- Max Planck Institute for Marine Microbiology, Bremen
- Max Planck Institute for Meteorology, Hamburg
- Senckenberg Research Institute and Museum, Wilhelmshaven & Frankfurt
- Thünen Institute, Aquatic Resources, Hamburg & Rostock

Senate Commission for Oceanography of the German Research Foundation (DFG)

The Senate Commission for Oceanography is mandated by the DFG to evaluate and grant proposals for expeditions with RV METEOR und RV MARIA S. MERIAN and for large sea-going equipment (see below). It plans and coordinates the activities of DFG in the field of marine research. The Commission represents Germany in the

Scientific Committee on Oceanic Research (SCOR) of the International Council for Science (ICSU) and in other international science organizations (e.g. ESF Marine Board, ESF Polar Board). It is active in strategic planning of marine research programs and advises on the renewal of the research fleet and infrastructure.

A 4.3 Organization of Large Infrastructure

A 4.3.1 Research Vessel Organization and Planning of Expeditions

A harmonized procedure for the application and allocation of ship time on board research vessels is applied to RVs POLARSTERN, METEOR, SONNE, MARIA S. MERIAN, POSEIDON, ALKOR und HEINCKE. A joint portal offers guidance for the access to these ships which differ as to their main working areas, affiliation and organisational procedures. Coastal federal states and some federal ministries own research vessels to fulfil legal requirements. Accessibility of these vessels for academic research is very limited.

Senate Commission for Oceanography of the German Research Foundation (DFG)

The Senate Commission for Oceanography evaluates proposals for expeditions with RV METEOR und MARIA S. MERIAN and decides on the vessels' itineraries in co-operation with the Control Station German Research Vessels at Hamburg University.

Control Station German Research Vessels

The Control Station German Research Vessels, operated by the Center for Earth System Research and Sustainability (CEN) at Hamburg University, is responsible for the scientific, technical, logistical and financial planning, execution and support of RV METEOR and MARIA S. MERIAN. These large vessels perform open ocean research on a global scale and in international cooperation. The Control Station collaborates with the expedition coordinators and chief scientists, and works in partnership with the contract ship operators. Contractual obligations exist to the German Research Foundation (DFG) and the Federal Ministry of Education and Research (BMBF) as owners and funding agencies. In addition, there is a contract with the German Weather Service regarding the Weather Station METEOR.

Federal Ministry of Education and Research (BMBF)

BMBF provides ship time and funding for projects on board RV SONNE which primarily operates in the Pacific Ocean. An Advisory Board appointed by BMBF evaluates proposals for ship time. Based on their ranking and considering science-political priorities, the vessels schedule is organized by Project Management Jülich in behalf of BMBF.

Alfred Wegener Institute for Polar and Ocean Science

AWI operates the research ice-breaker RV POLARSTERN, two research airplanes, polar stations in the Arctic and in the Antarctic. Proposals for ship time on board POLARSTERN are evaluated by an Advisory Board, considering the scientific quality and feasibility of the implementation on board this ship. The vessels itinerary covers three to four years, with planning being completed one year prior to the first cruise. Access to the airplanes and polar stations is similarly organized via applications that are evaluated by advisory boards.

Control Group for the Medium-Sized Research Vessels

The Control Group for the Medium-Sized Research Vessels, located at the Leibniz Institute for Baltic Sea Research, Warnemünde, evaluates proposals and schedules expeditions with the regional vessels RV ALKOR, RV POSEIDON (operated by GEOMAR), RV HEINCKE (operated by AWI).

KG Schiff (Coordination Group – Research Vessels)

KG Schiff is the joint Coordination Group of the DFG Senate Commission on Oceanography and all ship operators and aims at optimizing the vessels itineraries in order to avoid long transfers. It coordinates the regional and ocean class research vessels RVs POLARSTERN, SONNE, METEOR, MARIA S. MERIAN und POSEIDON. It also organizes ship time exchange with the European Ocean Facility Exchange Group (see below). A Federal Navy rep-resentative is member of KG Schiff as well as a representative of the European Ocean Facility Exchange Group.

Ocean Facilities Exchange Group

OFEG represents Europe's leading oceanographic research organizations and provides a forum to consider barter exchange and cooperation opportunities for the Global and Ocean Class research fleets of its members. The presently six members are Natural Environment Research Council (UK), Institut Français de Recherche pour l'Exploitation de la Mer (France), German Federal Ministry of Education and Research (Germany), Royal Netherlands Institute for Sea Research (Netherlands), Consejo Superior de Investigaciones Científicas (Spain), and Institute of Marine Research (Norway). Within the agreement, 90% of the European Global Class and more than 50% of the Ocean Class academic research ships are currently represented.

A 4.3.2 Large Sea-going Equipment

German marine science is – in comparison with other European nations – well equipped with large sea-going infrastructure. The institutions operate and finance their specific sea-going equipment which demands considerable financial and personnel

investments. This equipment includes a range of observation and sampling equipment for coastal and open ocean research. Of major importance in this respect are the observation systems to assess long-term changes in environmental conditions (e.g., coastal observing systems COSYNA at HZG), observatories in Arctic and Antarctic waters (HAFOS, FRAM array, HAUSGARTEN at AWI, Central Irminger Sea Observatory at GEOMAR), low latitude observatories (Cape Verde Ocean Observatory CVOO at GEOMAR & international collaborators). Further information on the different equipments available at the institutions can be found in the Fact Sheets.

Some of the large sea-going equipment is made available for partner institutions upon application. This type of sea-going equipment comprises:

- Three work class Remotely Operated Vehicles (ROV): „Quest“ rated to 4,000 m depth (MARUM), „Kiel 6000“ rated to 6,000 m depth, „Phoca“ rated to 3,000 m depth (GEOMAR), a 1000-m ROV (“Cherokee”, MARUM).
- Three Autonomous Underwater Vehicles (AUV): „Abyss“ rated to 6,000 m depth (GEOMAR), „Seal” rated to 5,000 m depth (MARUM), Bluefin 21 rated to 3.000 m depth (AWI).
- One hybrid ROV (under construction at MARUM).
- One manned underwater vehicle „JAGO“ rated to 400 m depth (GEOMAR).
- One sea floor drilling rig MeBo for cores up to 70 m; a second device for a drill-depth of 200 m is under construction (both MARUM).
- One benthic crawler ‘C-MOVE’ rated to 6000 m (MARUM).

These instruments can be applied for and the external users have to pay the operational costs to the respective institution. It includes the technical personnel, consumables and maintenance. To a limited extend this can be covered by project funding. At present, applications for the use of these instruments can be submitted together with an application for ship time on RV METEOR or RV MARIA S. MERIAN to the DFG, and on RV SONNE to the BMBF. On other ships this possibility of funding does not exist. A fixed daily rate has been negotiated for the different types of instruments for scientific users, which is however not based on full cost analyses including depreciation. Only industrial users pay full costs. The annual cost of operation of the above listed sea-going equipment is presently at least equal to the operation of a regional research vessel and will increase in future.

However, existing budgets of DFG and BMBF for support of expeditions allow only financing a few expeditions per year. Also EU projects generally do not cover these expenses; at best a partial contribution is given. The home institutes themselves are not able to fully support the operation and technical improvement of these instruments. In conclusion, these restricttions limit the use of such advanced instruments.

The technological development in the last decades has brought about a change in the approach to observation, experimentation and sampling of the ocean. Also in

future this trend will continue and autonomous and tethered robotic instruments will take over more and more tasks at sea. The financial burden connected to this new development is at present not fully realized by the marine science institutions and funding authorities. A solution to this situation has to be found. Three ways are possible: a) creating a separate fund for applications to large-sea going equipment administered by a separate advisory board (e.g. DFG Senate Commission); b) increase of the budget for expeditions of all ships to include the deployment of this equipment in the ship time applications and evaluated by the present ship advisory boards; c) increase of the institutional budgets with the obligation to provide free of charge the equipment for external academic users if their project has been positively evaluated by the funding authority (e.g. DFG).

A 5 Outlook

The German marine science community has established two organizations to jointly manage its needs: the German Marine Research Consortium (KDM), and the DFG Senate Commission for Oceanography. We consider this self-organization as effective means for strategic research planning, granting proposal driven access to large infrastructure and to represent Germany in the context of international science programs. As a result of a consultative process the following procedures and processes are proposed for the further strategic development of German marine science:

- The five scientific themes and coastal crosscut should be developed further within KDM. We suggest implementing strategic groups with representative members from all involved institutions to jointly develop the themes together with funding agencies into a programmatic strategy.
- KDM is seen as an ideal platform to foster additional collaboration and synergies among coastal research institutions and to act as hub with regard to improved communication with governmental research institutions and European and international partners.
- The operation of the large sea-going equipment needs to be financially secured so that all users from universities or other national research institutions can have free access based on a peer-reviewed proposal driven process. A working group should be established to look at modalities for the use of such large infrastructure, with representative membership from funding agencies, federal states and infrastructure hosting institutions and users.

We anticipate that marine science will develop in a very dynamic way during the next decades. Society will have to use the seas and oceans increasingly as a resource and its knowledge base has to be expanded to facilitate sustainable use and the

safeguarding of the marine environment from irreversible changes. This will lead to development of new fields of marine sciences and collaborations between additional disciplines and new partners. KDM will continue to maintain and initiate strategic cooperation in new and emerging topics of scientific and societal relevance. The present review and strategic analysis by the Science Commission of the State of Lower Saxony will help the German marine research community to respond to these challenges.

Appendix B

Fact Sheets:

Universities
University of Bremen (MARUM): Center for Marine Environmental Sciences*
Jacobs University Bremen gGmbH*
Bremerhaven University of Applied Sciences
University of Greifswald: Greifswald Center for Functional Genomics of Microbes (GC-FunGene) & Institute for Geography and Geology (IGG)
University of Hamburg (CEN): Center for Earth Systems Research and Sustainability*
University of Kiel: Kiel Marine Science (KMS), Center for Interdisciplinary Marine Sciences*
University of Oldenburg (ICBM): Institute for Chemistry and Biology of the Marine Environment*
University of Rostock (MTS): Department Maritime Systems, Faculty of Interdisciplinary Research*
Helmholtz Association
Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI, Bremerhaven)*
Helmholtz Centre Geesthacht Zentrum für Material- und Küstenforschung (HZG, Geesthacht)*
GEOMAR Helmholtz-Centre for Ocean Research Kiel (Kiel)*
Max Planck Society
Max Planck Institute for Marine Microbiology (MPI-MM, Bremen)*
Max Planck Institute for Meteorology (MPI-M, Hamburg)*

Leibniz Association
Leibniz Center for Tropical Marine Ecology (ZMT, Bremen)*
Leibniz Institute for Baltic Marine Research Warnemünde (IOW)*
Senckenberg am Meer (SaM, Wilhelmshaven)*
Federal Research Agencies
Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI, Braunschweig)*
Federal Maritime and Hydrographic Agency (BSH, Hamburg)
Federal Institute for Geosciences and Natural Resources (BGR, Hannover)
Others
German Oceanographic Museum Stralsund (DMM, Stralsund)*

* Members of KDM (German Marine Research Consortium)

MARUM – Center for Marine Environmental Sciences at the University of Bremen

Leobener Str.
28359 Bremen

Research at MARUM has the overarching goal to achieve a better understanding of key processes in the marine environment in order to provide information for sustainable use of the ocean. The research themes are: Ocean and Climate, Geosphere-Biosphere Interactions and Sediment Dynamics. MARUM studies past and present environmental changes from the coast to the deep sea at a global scale. Processes at and below the seafloor are a special research focus. The second major goal of MARUM is the training of young scientists. Within the framework of the Graduate School GLOMAR (Bremen International Graduate School for Marine Sciences) interdisciplinary training of doctoral students in marine sciences (incl. social sciences and law) is achieved. A third goal is to develop and provide technology and infrastructure for marine research in cooperation with industry. MARUM operates underwater technologies, including two remotely operated vehicles, an underwater drill rig and an autonomous underwater vehicle. Through the development and operation of cutting-edge underwater instruments MARUM has established itself as a leading center of marine research technology. Furthermore, MARUM operates one of the three IODP core repositories in the world and, together with the AWI, the World Data Center for Marine Environmental Sciences (PANGAEA). The fourth goal is the communication of scientific topics to the general public, including special programs for schools.

MARUM has developed into an internationally recognized center for marine research with a focus on geosciences, anchored in the University of Bremen. MARUM's position within the University of Bremen has been considerably strengthened in 2011 when MARUM became the first research faculty of the university. Through MARUM, the University of Bremen closely collaborates with the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven (AWI), the Max Planck Institute for Marine Microbiology in Bremen (MPI), the Senckenberg Institute by the Sea in Wilhelmshaven (SGN), the Leibniz Center for Marine Tropical Ecology in Bremen (ZMT), the University of Oldenburg, and the private Jacobs University in Bremen.

MARUM has achieved a position at the forefront of science in several areas, including the sub-seafloor biosphere, processes underlying natural climate variations, the role of microbial processes in shaping biogeochemical cycles, formation and disintegration of gas hydrates, and submarine slope stability, as well as in integrating numerical modeling into Earth-system science.

With regard to underwater technology, a unique feature of MARUM in Germany is that large-scale equipment is not only operated but also developed. About 45% of the usage of the underwater technology is by external users (at the national and international levels). Further service facilities for working groups in Germany and at the international level include the World Data Center, the IODP core repository (200 scientific visitors per year), and lab infrastructure.

Affiliation
University of Bremen

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	10 Mio €/y
• third party funding	15 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	302
• permanent / third party funding	70 / 224
• professors	23
• senior scientists	53
• postdocs	86
• PhD students	61
• technical staff	79
(student helpers	98)

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	191/y
• in Nature & Science	7/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	19/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	87.3 / 79.9 Mio €
• BMBF	14.5 / 12.3 Mio €
• EU	86.1 / 5.6 Mio €
• industry	-
• other	30.7 / 2.3 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	53/y
• Master & Diploma	12/y
• PhD	27/y

Further Specifics

- Traveling exhibition „Experience the Sea" in shopping centres across Germany (2009-2014; 10,000-30,000 visitors per day, more than 5 million in total; international extension planned)
- MARUM UNISchool lab with regular course for schools, teachers and kindergarten children (c. 30,000 participants since 2001)

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Seafloor Drill Rig MARUM MeBo (second instrument under construction)
- Remotely Operated Vehicles MARUM QUEST (4000 m) and MARUM CHEROKEE (1000 m)
- Autonomous Underwater Vehicle MARUM SEAL (5000 m)
- Autonomous Benthic Crawler C-MOVE (2000 m)
- Electromagnetic Profiler (NEREDIS III)
- Geotechnical Seabed Tool (GOST)
- Hybrid-Remotely Operated Vehicle (under construction)

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- IODP (1300 m^2) and GeoB (440 m^2) Core Repositories
- Two technology halls (1050 m^2)
- 3 XRF scanners
- 15 mass spectrometers (incl. multi-collector ICPMS)
- Sediment-mechanics laboratory (incl. dynamic triaxial testing unit)

Jacobs University

Campusring 1-3
28759 Bremen

Jacobs University combines a broad spectrum of disciplines to follow a modern, integrated approach in education and research. 1300 students from more than 110 nations are engaged in the 19 Bachelor and 20 Graduate programs, receiving their training from 130 professors. At the university, students or researchers primarily working in one field can benefit greatly from the cross-disciplinary focus of the university. The majority of study areas are closely linked with another, examples including natural science with engineering science, environmental science with social science, electrical engineering with computer science, geosciences with astrophysics, and biochemistry with cell biology.

In the field of marine research, scientists from Jacobs University are active in the areas of geology, biological and chemical oceanography, marine molecular microbiology, geochemistry and geophysics. Work in the OceanLab focuses on improving our understanding of carbon and trace element cycles in the areas of the continental shelf and the deep sea, within hydrothermal vent ecosystems, and in surface waters. Work in the Molecular microbiology labs concentrate on cell-driven fluxes of particulate organic carbon. By understanding these systems better we can also develop new strategies for the sustainable utilization of marine resources such as biological resources and mineral deposits. Jacobs University's OceanLab has been successful in the field of underwater robotics development for internet monitored deep sea observatories, and continuing such development in the future will be a major foci of the groups work. Currently around 6o people (faculty including adjunct faculty and the robotics group, technicians, graduate and undergraduate students) are involved in ocean sciences at Jacobs University. 4 faculty from the Geosciences and Biosciences programs, who are mainly involved in marine sciences answered this questionnaire. OceanLab provides a 12 m seawater-flume, a large saltwater test basin, a 7 m research boat, a water column simulator, 1000 m^2 of microalgae production plant and access to two cabled online observatories (one in the NE Pacific, one in the Norwegian Skagerrak). Several internet operated vehicles (10Vs) can be used to study processes in the bottom waters and surface sediments of the oceans. There is full access to all molecular biology facilities via the MOLIFE Research Center and geochemistry facilities. A GIS-lab and expertise in WebGIS and related services can also be used for teaching. The group is heavily involved in EU and international basic and applied research. Additional industry projects allow a broad education and offer excellent career chances for students.

Affiliation

University (Jacobs University Bremen)

Financial Budget *(2010-2012 mean, marine research only)*

- basic funding 0.45 Mio €/y
- third party funding 1.34 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

- total 36
- permanent / third party funding 9 / 27

- professors 4
- senior scientists -
- postdocs 5
- PhD students 22
- technical staff 5

Number of Publications *(2010-2012 mean, marine research only)*

- peer reviewed (ISI) 18/y
- in Nature & Science 0.3/y

Expeditions *(2010-2012 mean, number involved in)*

- research cruises 4/y
- land-expeditions 0/y
- teaching cruises 1/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

- DFG -
- BMBF -
- EU 10 / 0.3 Mio €
- industry -
- other 15 / 0.5 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

- Bachelor 10/y
- Master & Diploma 3.5/y
- PhD 5/y

Further Specifics

Access to deep sea online observatory network and internet operated vehicles
Research boat for training and research
Outdoor algae farms for CO_2 mitigation
Geochemistry laboratory equipped for trace metal analytics, focus on marine mineral resources and geochemistry of seawater and hydrothermal fluids. Molecular microbiology with full access to all molecular biology facilities. Marine Geophysics equipment; GISlab. Expertise in WebGIS and related services. Large laboratory for experimental oceanography. Teaching and training as part of the undergraduate and PhD (ESSReS) curriculum. Involved in 4 inter-institutional graduate programs (marmic, POLMAR, GLOMAR, MoLife), strong international collaborations. Tight interactions with MPIMM, AWI, ZMT, Uni Bremen, and Uni Oldenburg.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Internet operated deep sea vehicles

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Microalgae farm 1000 m^2

University of Applied Sciences Bremerhaven
Maritime Technology

An der Karlstadt 8
D-27568 Bremerhaven

The University of Applied Sciences Bremerhaven was founded in 1975 as a successor of the Geestemünde Navigation College and the Municipal College. As “the university by the sea” it has a maritime profile with over one hundred years’ history in education. The University of Applied Sciences Bremerhaven consists of two faculties, each headed by a dean.

Currently, about 3 000 students are studying in 14 Bachelor (e.g. Maritime Technologies, Cruise Tourism Management, Ship Operation Engineering, Food Technology, Transport/Logistics) and 10 Master programs (e.g. Biotechnology, Wind Energy Technology, Logistics Engineering and Management; further details: www.hs-bremerhaven.de). As shown by the university ranking, the study programs have good reputation both nationally and internationally. Depending on their field of study, students receive degrees of Bachelor / Master of engineering, Bachelor / Master of Science or Bachelor / Master of Arts.

The maritime character is reflected in close cooperation in the field of teaching and research. For this purpose the university established an extensive network with leading research institutes in maritime topics such as Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research (AWI), Institute of Marine Resources (IMARE), Institute of Wind Energy (fk-wind) as well as the *Centre for Technology Transfer (TTZ) and the* Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Hence, students have access to practice-orientated education as well as contacts and input which are helpful for the completion of their internships and Bachelor / Master’s theses.

The marine profile of the University is emphasized by the Bachelor’s program Maritime Technology, which combines core maritime competences with modern technologies and requirements of the maritime industry, wind energy and maritime research. The study course is divided into the three specialist fields “Marine Biotechnology”, “Wind Energy Technology” and “Marine Energy Technology”.

The field “Marine Biotechnology” addresses the sustainable use of the resource ocean (key words: aquaculture, marine biology, bioanalytics). It focuses on production, processing, analysis and marketing of marine organisms and natural products such as algae, shellfishes and fishes. “Wind energy technology” covers development, construction and operation of on-shore and off-shore wind energy turbines and wind parks, whereas “Marine energy technology” deals with the generation of marine renewable energies whether it is from wave, tide or biomass.

In addition, the Master’s program “Biotechnology” has been developed focusing on Bioanalytics / Marine Bioresources. While bioanalytics specializes in the field of protein analysis and molecular biology, Marine Bioresources focuses on topics such as marine ecosystems, natural resources as well as marine aquaculture / marine biodiagnostics.

Affiliation
University of Applied Sciences

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	2.0 Mio €/y
• third party funding	0.6 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	23
• permanent / third party funding	13 / 10
• professors	10
• senior scientists	7
• postdocs	0
• PhD students	0
• technical staff	6

Number of Publications
(2010-2012 mean, marine research only)

• peer reviewed (ISI)	8/y
• in Nature & Science	0/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	0/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	-
• EU	4.9 / 0.23 Mio €
• industry	-
• other (BMU)	50.0 / 0.43 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	21/y
• Master & Diploma	12/y
• PhD	0/y

Further Specifics

The collaboration with the Alfred Wegener Institute, Helmholtz-Centre for Polar and Maritime Research (AWI) particularly enables access to sea going expeditions and marine research stations and infrastructure. Bachelor and Master students (especially in the field of Biotechnology) have the opportunity to participate in expeditions and research cruises especially during their internship and their thesis work at AWI.

Moreover, the research vessel “Heincke” is even used during the academic studies in several courses such as “Marine Environmental Studies”, “Biogeochemistry”, and “Marine Sensors”.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

not applicable

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

not applicable

Greifswald Center for Functional Genomics of Microbes (GC-FunGene)
& Institute for Geography and Geology (IGG)
Ernst-Moritz-Arndt-Universität Greifswald

Friedrich-Ludwig-Jahn-Straße 17a
17487 Greifswald

ERNST MORITZ ARNDT
UNIVERSITÄT GREIFSWALD
Wissen lockt. Seit 1456

During the last years an internationally recognized proteomics platform could be established at the University of Greifswald. Recently, the German Council of Science and Humanities ("Wissenschaftsrat") recommended the construction of a *Greifswald Center for Functional Genomics of Microbes* (GC-FunGene) at the University of Greifswald. One of the main research topics of the GC-FunGene is "Marine environmental proteomics". In the interdisciplinary GC-FunGene, different groups of the Department of Biology, the Institute of Biochemistry, the Institute of Pharmacy and the Institute of Mathematics and Informatics collaborate in order to address relevant ecological issues of marine microbial interactions in their natural environments. The participating groups from the Ernst-Moritz-Arndt University have close cooperation with nationally and internationally recognized marine research institutes (e.g. MPI für Marine Mikrobiologie, Bremen; AWI, Helmholtz-Zentrum für Polar- und Meeresforschung; WHOI, MA; SIO, CA; or IOW, Warnemünde) in the fields of marine (meta)proteomics and the physiological characterization of model bacteria. Groups of the University of Greifswald are closely involved in the national BMBF-competence networks for microbial genomics and the „MIMAS"network (Microbial Interactions in Marine Systems). Within the framework of the MIMAS group, in-depth functional characterizations of bacterial communities at model locations in the North Sea and the Baltic Sea are being performed by the integration of metagenome, metaproteome and environmental analyses.

The research field "Marine environmental proteomics" at the University of Greifswald is an important aspect of the newly established bachelor and master courses for Biology and Biochemistry students.

The *Institute for Geography and Geology (IGG)* holds a long-term tradition in marine science and in particular coastal marine research and the interaction with glacial processes of the northern hemisphere. In addition to coastal research and quaternary studies, we have established interests in geodynamics and marine geology, as well as expertise in marine mineralogy and geochemistry. New aspects include collaboration between mineralogy and microbiology in advancing new methods for marine bioremediating oil spills.

The IGG holds a good collaborative record with the marine research institutes, such as the IOW (*with the joint employment of 2 permanent professors in marine science*), IfM-Geomar in Kiel, the *Integrated Ocean Drilling Program* and JASTEC, Japan. We also work closely together with the University of Szczecin (Poland), the "Landesamt für Umwelt, Naturschutz und Geologie (LUNG) and the Federal Institute for Geosciences and Natural Resources (BGR). The IGG house state-of the art geochemistry and electron microscopic facilities for studies of water chemistry and mineral matter.

Our future quest is to strengthen our research activities in focused aspects of marine science at the University of Greifswald by improving our level of participation in larger scale research projects and to integrate these activities into our growing scientific programme on Baltic resources.

Affiliation
University of Greifswald

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	0.6 Mio €/y
• third party funding	1.4 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	36
• permanent / third party funding	20 / 16
• professors	7
• senior scientists	2
• postdocs	5
• PhD students	17
• technical staff	5

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	17/y
• in Nature & Science	1/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	4/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	3.0 / 1.6 Mio €
• EU	3.0 / 0.5 Mio €
• industry	-
• other (BMU)	1.4 / 0.3 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	28 /y
• Master & Diploma	15 /y
• PhD	4 /y

Further Specifics

IMaB Institut für Marine Biotechnologie e.V.

The CF-FunGene closely cooperates with the Institut für Marine Biotechnologie e.V. (Greifswald). The goal of this cooperation is the support of research and development in the field of marine biotechnology. Activities include the functional genome analysis of biotechnologically relevant marine bacteria and the identification and characterization of marine bioactive compounds.

Currently a new international level masters in Marine Sciences is been planned between the University of Szczecinski, Poland, the University of Greifswald and the IOW.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- 18m long research vessel (Bornhöft)

  (http://www.mnf.uni-greifswald.de/institute/geo/geographie/physische-geographie/ausstattung.html)

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Proteomics platform with more than 10 mass spectrometers
- NMR spectroscopy and GC-MS for metabolomics
- ICP-MS with laser ablation
- FIB-SEM microscope
- Transmission electron microscope

Centrum für Erdsystemforschung und Nachhaltigkeit (CEN)
Universität Hamburg

Bundesstraße 53
20146 Hamburg

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

The *Centrum für Erdsystemforschung und Nachhaltigkeit (**CEN**)* is a research centre at the University of Hamburg.

Since its foundation in 2011, CEN pools the expertise in climate, environment and earth system sciences at the University of Hamburg. The main objective of CEN is to promote research on the earth system and on sustainability and to expand its interdisciplinary cooperation in science by acquiring new funding for joint research projects. CEN is part of the KlimaCampus Hamburg, founded by the University Hamburg together with the Max Planck Institute for Meteorology (MPI-M), the Helmholtz-Zentrum Geesthacht (HZG) and the German Climate Computing Centre (DKRZ).

CEN research activities are dedicated to climate, ocean, atmosphere, cryosphere and land systems as well as their feedbacks and their interactions and with humans on all space and time scales. Together with the Centre for Globalization and Governance (CGG) at the School of Business, Economics and Social Sciences – CEN strengthens the trans-disciplinary research and educational structures which were created within the Cluster of Excellence „Integrated Climate System Analysis and Prediction“ (CliSAP). About 40% of the research performed within CEN is dedicated to marine sciences. CEN research is excellently networked on a national and international level, partly through consorted efforts.

CEN fosters excellent research-oriented graduate education. As a research center at the School of Mathematics, Informatics and Natural Sciences (MIN), CEN supports a cross-curricular education for undergraduates and graduates. Within CEN several B.Sc. and M.Sc. programs are firmly anchored through the philosophy that teaching and research are closely coupled so that students learn to work scientifically from the very beginning. M.Sc. and doctoral Students carry out experiments in modern laboratories, use the supercomputer of the German Climate Computing Center, participate in research cruises or operate equipment in research aircraft. The CEN institutes are excellently networked internationally so that students also have a chance to gain experience abroad.

As a member of the German Marine Research Consortium (KDM), CEN co-represents the interests of German marine, polar and coastal research and promotes international cooperation. CEN coordinates several major coordinated research efforts on national and international level. In the Control Station German Research Vessels, CEN organizes on national level for the German oceanographic community operations of the research vessels „METEOR“ and „Maria S. MERIAN“, with the new research vessel “Sonne” soon to be added as a third large research vessel. CEN, through the University of Hamburg is one of the shareholders of the DKRZ.

Affiliation
University of Hamburg

Financial Budget *(2010-2012 mean, marine research only)*

- basic funding 0.5 Mio €/y
- third party funding 13.0 Mio €/y

Staff total staff in CEN *(december 2012, head counts, excluding administration, marine research only)*

- total 562 (227)
- permanent / third party funding 90 (137)

- professors 45 (20)
- senior scientists 177 (70)
- postdocs 112 (45)
- PhD students 169 (68)
- technical staff 59 (24)

Number of Publications *(2010-2012 mean, marine research only)*

- peer reviewed (ISI) 68/y
- in Nature & Science 2/y

Expeditions *(2010-2012 mean, number involved in)*

- research cruises 9/y
- land-expeditions 2/y
  (e. g. to polar stations)

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

- DFG 34 /10 Mio €
- BMBF 11 / 5 Mio €
- EU 27 / 6 Mio €
- industry -
- other (BMU) -

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

- Bachelor 75/y
- Master & Diploma 30/y
- PhD 25/y

Further Specifics

CEN holds the ‚Leitstelle Deutsche Forschungsschiffe', which operates the German Research Vessels, *METEOR* and *MARIA. S. MERIAN*. The new RV *SONNE* will be the third global research vessel soon to be added to this organization. These research vessels are entrusted with German basic deep-sea research on a worldwide scale and in collaboration with other states.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- oceanographic CTD-sonde and rosette sampling systems
- lADCP
- underway CTD
- mooring equipment (releaser, ADCP, PIS, CTDs, Microcats, current meters)
- towed underwater video microscope system (video plankton recorder, VPR)
- towed multi-purpose platform TRIAXUS (phys. oceanographic param., trophic structure, fluorometer, Laser Optical Plankton Counter, hydroacoustics)
- epi-benthos sledge (sediment profiles, video cameras)
- complete underway Geophysical equipment (Seismic, Gravity and Magnetics)

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- large climate compute facilities (DKRZ).
- remote sensing technology and infrastructure
- wind-wave canal (for air-sea momentum and gas exchange)
- airborne scatterometer (soil classification, permafrost thawing, snow and sea ice param.)
- radar and lidar systems (atmospheric boundary layer and aerosol / cloud processes)
- rotating tank laboratory (fluid dynamics)
- Biological laboratories (wet labs) (plankton organisms; climate chambers for temperature-controlled experiments)
- Seawater recirculating systems (large fish and crustacea)
- analytical chemistry laboratories
- isotope ratio mass spectrometer facility workshop
- Geophysical instruments (Seismic, Gravity, Magnetics and Radar)

Kiel Marine Science (KMS)
Center for Interdisciplinary Marine Sciences
Christian-Albrechts Universität zu Kiel (CAU)

Christian-Albrechts-Platz 4
24118 Kiel, Germany

The CAU is a medium-sized university with eight faculties (Mathematics and Natural Sciences, Arts and Humanities, Business, Economics and Social Sciences, Engineering, Law, Medicine, Agricultural and Nutritional Sciences, and Theology), 380 professors, 1800 scientific staff and currently 23,000 students. The CAU strongly promotes interconnected and interactive academic cultures in research and education. This concept builds upon strength and proven excellence in interdisciplinary research within four research priority areas with increasing international relevance: “Kiel Marine Sciences”, “Kiel Life Sciences”, “Kiel Nanoscience”, and “Kiel Societal, Environmental, Cultural”. In 2012 the CAU implemented the new virtual institution ´Kiel Marine Science´ - Center for Interdisciplinary Marine Sciences, joining marine oriented research group leaders and their teams involved in larger interdisciplinary projects like the Cluster of Excellence *Future Ocean* DFG Collaborative Research Centres. About 25 research groups hosted at 17 different departments or institutes in 7 faculties contribute to the marine research and education profile of the CAU. A much longer outstanding tradition in marine research at the CAU is existing at the Institute of Geosciences covering the fields of marine geochemistry and petrology, paleoclimate research, marine geophysics and coastal zone research, the latter also executed at the CAU Research Centre for Coastal Research and Technology (FTZ) at Büsum. Promoted by *Future Ocean* the CAU has established an outstanding profile for investigation of past, present and future changes in ocean dynamics and biogeochemical cycles, to explore strategies for the sustainable and environmentally friendly use of marine resources, and to promote the integrated study of marine hazards. Major actual research themes address questions on how the ocean is increasingly affected by human action including anthropogenic CO_2 emission, non-sustainable fisheries, large-scale waste disposal and other pollution, as well as better forecasting potential hazards originating from ocean warming and acidification, destabilisation of gas hydrates and submarine land slides, sealevel rise and future coastal zone management. Expertise from natural sciences is combined with arts, political, socio-economic, legal, and life sciences as well as ethics adresssing the ocean in a broad integrative and multidisciplinary approach in close dialog with society, politics and other stakeholders. This approach strongly benefits from the tight network between KMS, the Helmholtz Centre for Ocean Research (GEOMAR), the Kiel Institute for the World Economy (IfW), as well as with members of the Muthesius Academy of Fine Arts and Design. Marine Science education is carried out in the Integrated School of Ocean Science (ISOS) for 120 PhD students and by 3 international MSc study programs.

Affiliation
University of Kiel

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	6.5 Mio €/y
• third party funding	12.5 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	150
• permanent / third party funding	50/100
• professors	15
• senior scientists	15
• postdocs	45
• PhD students	50
• technical staff	25

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	55/y
• in Nature & Science	2/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	3/y
• land-expeditions	1/y
• Cruise leadership: SO-217 (2011), SO-220 (2012)	

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	48.0 / 24.5 Mio €
• BMBF	-
• EU	3.7 / 0.4 Mio €
• industry	2.5 / 0.9 Mio €
• other (BMU)	6.3 / 0.8 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	15/y
• Master & Diploma	30/y
• PhD	40/y

Further Specifics
The broad multidisciplinary spectrum of KMS is mainly based on the expertise of about 25 research groups from 7 faculties at the CAU.
Research and education of mainly marine oriented research groups cover the fields of Geology/Palaeontology, Geophysics, Coastal Zone Management and Climate Research, Physical Chemistry, Marine Ecology, Informatics, Economic and Social Sciences, Law of the Sea, as well as Environmental Ethics. This spectrum is com-plemented by additional contributions from Geochemistry/Mineralogy, Geo-graphy, International Law, Life Sciences, Microbiology, Evolutionary Biology and Cell Physiology, Biomechanics, Botany and Zoology, as well as Aquaculture and Pharmacy. All these disciplines contribute to marine research projects through principle investigators organised in KMS.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*
The CAU is not hosting large infrastructure in terms of individual instruments or vehicles except for common sediment coring devices and various towed hydroacoustic systems for the shallow and deep sea. The FTZ Büsum operates a small-size research vessel for the coastal seas.

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*
Through KMS and Future Ocean the CAU has established joint research plattforms providing access to large technical facilities. The plattform concept comprises the “Center of Molecular Biology” (Genomics), the “Interdisciplinary Centre for Numerical Simulation (Modeling)”, the “Kiel Nanolab” for Material Sciences, and “Tracer Analysis” which is a consortium mainly providing state-of-the art mass spectroscopy and spectrometry facilities in Geosciences, Physics, and Physical Chemistry, including the Leibniz Laboratory for Radiometric Dating and Isotope Research. Herefore, more recently installed large equipment comprises

- Laser Ablation MC-ICP-MS systems
- an ICR-Mass Spectrometer
- 2 Gas Mass Spectrometer
- a XRF core scanner
- high throughput gene sequencing and high performance computing add-on equipment.

Institute for Chemistry and Biology of the Marine Environment
Carl von Ossietzky University of Oldenburg

Carl-von-Ossietzky-Straße 9-11
D-26111 Oldenburg

ICBM studies the significance of shelf seas and coastal regions in the System Earth through an interdisciplinary research approach, bringing together the fields of geochemistry, microbial ecology, biodiversity research, marine physics, and numerical modeling. In addition it carries out a variety of marine science studies in the world's oceans in the understanding that processes in the coastal regions cannot be readily separated from those in the open sea.

Besides contributions to national and international joint programs, research activities in microbial ecology, e.g., are focused in a Transregional Collaborative Research Centre (CRC, Transregio-SFB) on the ecology, physiology and molecular biology of the marine Roseobacter clade. Coastal research for more than 8 years was concentrated in the DFG-funded research group on BioGeoChemistry of Tidal Flats (completed in 2010), is presently continued in the interinstitutional Jade Bay, COSYNA and WIMO research projects, and in future will focus on coastal high-energy systems and subterranean estuaries.

The research groups of ICBM can be attributed to three divisions but without any formal structures to them hampering interdisciplinary cooperation:

- Geochemistry and Analytics
- Geobiology and Ecology
- Physics and Modeling

ICBM in addition to its presence at the Wechloy Campus of the University of Oldenburg has facilities in Wilhelmshaven (ICBM-Terramare building and rented laboratory and office space) as well as on Spiekeroog Island (shared laboratory and accommodation facilities at the Environmental Centre/National Park House Wittbülten). The overall research activities were considerably extended since 2008 when the former Terramare Research Centre was merged into ICBM, two new research groups on Marine Geochemistry and Marine Isotopic Geochemistry were established as a joint venture of the Max Planck Institute of Marine Microbiology in Bremen and the University of Oldenburg, and when additional funding by the State of Lower Saxony allowed ICBM to enter the field of marine technology with two new groups on marine sensor systems and marine biosensors, strengthened by a close cooperation with the University of Applied Sciences in Wilhelmshaven (Jade Hochschule) in the field of marine engineering.

Study programs offered by ICBM educate experts in marine and environmental sciences.

(i) Bachelor in Environmental Sciences,

(ii) Bachelor in Marine Engineering together with the University of Applied Sciences in Wilhelmshaven (Jade Hochschule),

(iii) Master in Marine Environmental Sciences,

(iv) Master in Microbiology (in English),

(v) Master in Environmental Modeling,

(vi) Master in Marine Sensors (to start in summer 2014) together with the University of Applied Sciences in Wilhelmshaven (Jade Hochschule),

(vii) PhD program in "Environmental Sciences and Biodiversity" as part of the Graduate School on "Science and Technology",

(viii) Integrated Research Training Group of the CRC Roseobacter.

Affiliation
University of Oldenburg

Financial Budget
(2010-2012 mean, marine research only)

• basic funding	7.2 Mio € /y
• third party funding	3.6 Mio € /y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	150
• permanent / third party funding	97 / 53
• professors	17
• senior scientists	5
• postdocs	30
• PhD students	54
• technical staff	44

Number of Publications
(2010-2012 mean, marine research only)

• peer reviewed (ISI)	105 /y
• in Nature & Science	2 /y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	13 /y
• land-expeditions (coastal) (e. g. to polar stations)	150 /y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG (CRC Roseobacter, Tidal Flat Research Group)	15.9 / 10.1 Mio €
• BMBF	-
• EU	4.7 / 0.5 Mio €
• industry	-
• other (VW-Vorab: Scientific Monitoring North Sea (WIMO), Helmholtz Foundation: COSYNA)	14.3 / 0.9 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	16 /y
• Master & Diploma	19 /y
• PhD	11 /y

Further Specifics

Sea-going Infrastructure and Large Equipment
(>400.000 €, marine research only)

-

Land-based Infrastructure and Large Equipment
(> 400.000 €, marine research only)

- Fourier-Transform Ion Cyclotron Resonance Mass Spectrometer (FT-ICR-MS, Bruker)
- Multicollector-ICP-Mass Spectrometer (Thermo Scientific, Neptune)
- High-Resolution-ICP-Mass Spectrometer (Thermo Scientific, Element II)
- MALDI-TOF-MS/MS instrument (Bruker)
- GC-High Resolution Double Sector Field Mass Spectrometer (MAT 97)
- GC/Elemental Analyzer-Isotope Ratio Mass Spectrometer (MAT 252)
- GC-Isotope Ratio Mass Spectrometer (MAT 253)
- Q-TOF micro LC-MS-MS instrument (Waters/Micromass)
- Flow Cytometer (FACS Aria III)
- Transmission Electron Microscope (Jeol JEM 2100F)

Department Maritime Systems
Faculty of Interdisciplinary Research
University of Rostock
Wismarsche Straße 8
18051 Rostock

Universität Rostock Traditio et Innovatio

The Department *Maritime Systems* is one of four thematic departments within the Faculty of Interdisciplinary Research founded in 2007. It concentrates the **maritime research** at the University of Rostock and functions as **institutionalized basis.**
At the moment **41 professorships** / **chairholder** / **researchers** from the University of Rostock (approx. 10 % of the university's professorships) or associated research institutions are allied in the department covering various disciplines e.g., **marine biology** / **oceanography, engineering, agriculture social sciences, economy and law**.
Since the members administratively stay in their traditional faculties / institutions, the Department MTS forms a **horizontal structure**, offering an **exceptional possibility of interdisciplinary exchange**, **exploration of complex scientific issues** and **development of new perspectives and technologies**. The advantage is the **investigation of maritime issues under all relevant aspects**, e.g., beside the basic marine scientific background we can simultaneously **investigate socio-economic** and **juridical implications**, look for **improved technical solutions** and thus can build teams of experts who **develop suggestions for better governance** and moreover are **potential partners for companies** acting in the coastal area. Most relevant issues for the near future will be offshore wind farms and other power plants, ship transport, aquaculture, nature conservation, and tourism.

Research focuses on **coastal zones (land and sea based)**. Research is organized in three main research topics (A, B, C).
Coastal Zones in Global and Regional Change (A) concentrates on important ecosystem and socioeconomic trends e.g., changes in sediment dynamics, in element cycles, in biodiversity or socio-culture and socio-economy. Causes and effects of these trends are determined to derive prognoses for prospective scenarios or developments.
Utilization of Maritime Systems (B) focuses on the development of innovative technical solutions for the maritime economy including ocean engineering, maritime logistics, fisheries & aquaculture and agriculture in coastal zones.
Sustainable Development and Management (C) combines the interests of stakeholders in an ecological, economical, political and societal context to develop strategies for ecologically intact and economically profitable coastal regions.

Besides the marine study programmes ‚Marine Biology' (M.Sc.), 'Aquaculture' (M.Sc.) and Shipbuilding / Ocean engineering' (B.Sc. and M.Sc.) **education and research on maritime topics are well established in almost all faculties** at the University of Rostock.

Affiliation
University of Rostock

(+ members from external research instutitions e.g., Leibniz Instutite for Baltic Sea Research Warnemünde, Technical University Hamburg Harburg, Johann-Heinrich von Thünen Institute Hamburg; IGD - Fraunhofer – Institute for applied research in Visual Computing Rostock, Jade - University of Applied Sciences, Wilhelmshaven-Oldenburg-Elsfleth)

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	Mio €/y *
• third party funding	9.5 Mio €/y

* NOTE: salary / infrastructure is provided by the research institutions

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	41
• permanent / third party funding	41
• professors	39*
• senior scientists	2
• postdocs	-
• PhD students	-
• technical staff	-

* NOTE: 25 professors + 2 senior scientists from the University of Rostock; 14 professors from other research institutions

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	58/y
• in Nature & Science	1/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	1/y
• land-expeditions	1/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-*
• BMBF	-*
• EU	-*
• industry	-*
• other (BMU)	-*

NOTE: approx. **55 projects** are accomplished on external funding per year (20% DFG; 26% National Ministries; 8% EU; 16 % regional funds; 30% others)

Further Specifics

- the **Scientific Diving Centre:** training and qualification of scientific divers according to the European Scientific Divers Committee (ESCD); **included as module** in the Master Programme 'Marine Biology'
- Project **‚Reefs in the Baltic Sea'** (EFF + national funding): investigation of two large-scale artificial underwater reefs

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- GADUS research vessel

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Marine Science Centre (Mammal Res.)
- Biological Station Zingst (laboratory + research boat NAUPLIUS)
- Artificial dike
- Flumes in various sizes e.g., wind flume, trailing flume, cavitation flume; compression chamber)
- Hydro-acoustic and laser-optical instruments e.g., Time Resolved Stereo PIV

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	-/y	(B.Sc. Biology; approx. 1/3 of the students accomplish a thesis towards a marine topic)
• Master & Diploma	5/y	(Marine Biology)
• PhD	5/y	(only for Marine Biology, Aquatic Ecology, Applied Ecology)

NOTE: Since the University provides a **broad spectrum in maritime research** within almost all faculties and in cooperation with associated research institutes, the number of graduates is much higher, but difficult to define. Further the Department itself finances 18 PhD students by a scholarship.

Alfred Wegener Institute
Helmholtz Centre for Polar and Marine Research
Am Handelshafen 12
27570 Bremerhaven

The Alfred-Wegener-Institute Helmholtz-Centre for Polar and Marine Research (AWI) is one of the internationally leading institutions for research in polar regions and oceans of temperate and high latitudes. The institute works bipolar and fosters interdisciplinary research in three divisions (Climate Science, Geoscience and Bioscience). It coordinates and provides infrastructure for polar research for all German scientists and international cooperation. The institute is based in Bremerhaven, Potsdam, Helgoland and Sylt, and operates polar stations in Antarctica and Spitsbergen. AWI is a Foundation of Public Law.

The main focus of research is to understand the changes and driving forces of the Arctic and Antarctic system with particular emphasis on climate change issues. It considers the impact of a warming world on the polar regions and feedbacks to the global climate. In the North Sea climatic and anthropogenic impacts are studied as driving force for ecosystem change. About three quarter of AWI research is related to marine aspects; the remainder concerns polar terrestrial and atmospheric research. We study the paleoclimate from ice and sediment cores and focus on the present climatic impact on the sea ice cover and its effect on the physical, biogeochemical and biological processes in the polar ocean. Polar marine systems are also severely impacted by melting of glaciers, ice shelves and thawing permafrost. Investigation of the physiological adaptation of marine organisms to changing environmental conditions, alterations of food webs and biodiversity due to climatic or anthropogenic impacts in coastal systems is another main point of AWI research. Strength of AWI is the excellent infrastructure for observing the ocean including ships, moorings, floats, AUV and airplanes. Advanced laboratory equipment is available for high precision analysis of ice cores, sediment cores and biological samples Long term observations (up to 50 years) of the marine ecosystem are maintained at the AWI stations at Helgoland and Sylt; long term observation are also maintained in the Fram Strait (oceanography and biology) and Weddell Sea (oceanography). The AWI high-performance mainframe computers provide excellent facilities for coupled ocean-atmosphere models, climate and biogeochemical models.

AWI employs over 1000 staff (head counts) and has a total budget of 109 Mio €; this includes funds for operating the ships, airplanes and polar stations. Third party funding is around 20 million € per year, thereof on average over the last three years 8.7 Mio € from BMBF, 4.6 Mio € from DFG, 2.5 Mio € from the EU, 2.0 Mio € from HGF and 3.7 Mio € from industry and others. The AWI as a Helmholtz Centre can only apply with restrictions and in connection with universities for DFG funding.

AWI research is embedded in many international cooperations with main partners being France, Norway, Russia and Australia. AWI scientists are involved in leading functions in national and international scientific organizations for polar, marine and climate research.

The AWI offers excellent training and research conditions for Master and PhD students in connection with several German universities at which senior AWI scientists hold professorships. The Earth System Science Research School (ESSReS) and the Helmholtz Graduate School for Polar and Marine Research (POLMAR) provide a framework for education of PhD students and give support for career development.

Affiliation
Helmholtz Association

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	109.8 Mio €/y
• third party funding	20.7 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	633
• marine only	480
thereof:	
• professors	17
• senior scientists	211
• postdocs	25
• PhD students	110
• technical staff	117

Number of Publications *(2010-2012 mean, marine research only)*

• total	472/y
• marine only	354/y
• in Nature & Science	5 & 7/y

Expeditions *(2010-2012 mean, number involved in)*

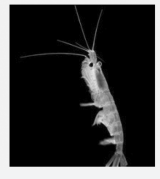
• research cruises total	46/y
thereof with RV Polarstern and RV Heincke:	34/y
• land-expeditions (e. g. to polar stations) total	41/y
thereof at AWI-stations:	28/y
• air-based campaigns	2/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	9.9 / 9.8 Mio €
• EU	17.2 / 14.8 Mio €
• industry	-
• others (=HGF)	18.6 / 2.7 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	26/y
• Master & Diploma	46/y
• PhD	29/y



Further Specifics

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

Ships/boats:
- RV Polarstern
- RV Heincke
- RC Uthörn
- RC Mya
- MB Aade
- MB Diker

- DEPAS (German Instrument Pool for Amphibian Seismology)
- Deep-sea long-term observatory HAUSGARTEN
- HAFOS (Hybrid Arctic and Antarctic Float Observation System)
- COSYNA (with HZG)
- ROV (Ocean Modules V8 Sii)
- AUV (Bluefin robotics)

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*
- Research Base AWIPEV (Marine Lab associated, Underwater observatory)
- Neumayer Station (Marine Acoustics)
- Dallmann Laboratory
- Samojlov Station
- Research Aircrafts Polar 5 and 6 (Sea ice thickness)
- AWI-Center for Scientific Diving
- XRF Core Scanner (Geochemical element compositions and concentration)
- BRUKER 400 WB spectrometer for NMR-measurements

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung GmbH
Max-Planck-Strasse 1
21502 Geesthacht

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

The 850 employees (among them 600 scientists, engineers and technicians) of the Helmholtz Zentrum Geesthacht - Zentrum für Material- und Küstenforschung GmbH (HZG) conduct materials and coastal research. Coastal research is embedded in HGF research field “Earth and Environment” under the programme “Polar Regions and Coasts in a changing Earth System” (PACES), a joint effort with AWI. The 180 staff of the Institute for Coastal Research (IfK) are organised in 3 sections: "System Analysis and Modelling", "Development of Operational Systems" and "Biogeochemistry in Coastal Seas". As a means to identify the potential for change, sustainability, and adaptation in coastal zones, IfK is conducting research to provide tools, assessments, and scenarios for managing this vulnerable landscape. Research activities span both the natural and human dimensions of coastal dynamics, analysing the coastal system in global and regional contexts, conducting assessments of the state and sensitivity of the coastal system to natural and human influences, and developing scenarios of future coastal options. The approach is exemplified by three groups of products:

The Coastal Observation System for Northern and Arctic Seas (COSYNA) develops and tests analysis systems for the operational synoptic description of the environmental status of the North Sea. COSYNA provides knowledge tools that can help authorities and other stakeholders to manage routine tasks, emergency situations and evaluate trends. It designs the next generation of observing systems, including hardware, software, quality assurance and sampling strategies.

coastDat is a model data set of long-term, high-resolution reconstructions (60 years) of present and recent developments of weather related phenomena in coastal regions, as well as of scenarios of future developments (100 years) in the Northeast Atlantic and northern Europe. It is widely used, also by the private sector, for risk assessment for present operations and management (such as wind energy) but also for deriving perspectives for future conditions, in particular with respect to coastal defense.

coastMap is being developed as a digital inventory of biogeochemical seafloor characteristics in the German Bight, including physical boundary conditions and their natural corridor of variability. The data base and WebGIS will publish data on properties, functions and spatial/temporal variability of sea floors in the Wadden Sea and North Sea merged from observational data and numerical models. They are the basis for ecosystem models, sensitivity and risk assessments, and ecosystem service evaluation.

IfK of HZG introduces a strong component of regional and shelf sea systems science into the Center of Excellence CLISAP (Climate Science and Prediction) at Hamburg University and maintains strong links with several universities (Kiel, Hamburg, Oldenburg, Lüneburg, Hannover) and national and international institutions engaged in coastal and shelf sea research. Furthermore, IfK hosts the North German Climate Office, the International BALTEX Secretariat, which brings together climate research in the Baltic Sea Basin, and the International IGBP - LOICZ project office, that coordinates coastal research on a global scale.

Affiliation
Helmholtz Association

Financial Budget *(2010-2012 mean, marine research only)*

- basic funding: 18.1 Mio €/y
- third party funding: 3.0 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

- total 183
- third party funding 49

- professors 8
- scientists 76
- postdocs 19
- PhD students 42
- technical staff 28

Number of Publications *(2010-2012 mean, marine research only)*

- peer reviewed (ISI) 98/y
- in Nature & Science 2/y

Expeditions *(2010-2012 mean, number involved in)*

- research cruises 30/y
- land-expeditions 12/y
  (e. g. to polar stations)

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

- DFG 0.6 Mio €
  (CLISAP)
- BMBF 2.0 Mio €
  (GENUS, ENMAP, CALIPSO, MADURA, PACE, SOPRAN)
- EU 2.3 Mio €
  (GMOS, JERICHO, MyOCEAN, GROOM, SAIL, PROTOOL, EPOCA)
- industry 1.6 Mio €
  (Env. Monitoring)
- other 1.5 Mio €
  (WiMo, KLIFF, MaNIDA)

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

- Bachelor 4 /y
- Master & Diploma 5 /y
- PhD 8 /y

Further Specifics

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Research vessels „Ludwig Prandtl“ and „Storch“

COSYNA – Coastal Observatorium System for Northern and Arctic Seas:

- FerryBox mounted on “ships of opportunity” (3)
- Gliders and Scanfish
- Underwater node
- Landers for measurement at the sediment/water interface

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- FerryBox mounted on shore based installations (2)
- Ground based Radar (HF-band and X-band)
- High Performance Computing Cluster with High Performance and High Capacity Storage
- Chemical laboratories for the investigation of current and emerging contaminants as well as proteinaceous compounds equipped with tandem mass spectrometry coupled to gas and liquid chromatography among others
- Shareholder of the DKRZ GmbH (Deutsches KIlimarechenzentrum)

GEOMAR | Helmholtz-Zentrum für Ozeanforschung Kiel

Wischhofstr. 1-3
24148 Kiel

GEOMAR
Helmholtz Centre for Ocean Research Kiel

GEOMAR Helmholtz Centre for Ocean Research Kiel is one of the world's leading institutions in the field of marine sciences. The mission of GEOMAR is to investigate the physical, chemical, biological, and geological processes in the oceans and their interaction with the seafloor and the atmosphere. With this spectrum, ranging from the deep sea to the atmosphere, GEOMAR is unique in Germany. In a number of research areas, GEOMAR is bridging the gap between basic and applied science. Currently, GEOMAR has a staff of about 800, including up to 40 university professors, 160 Ph.D students, 300 research scientists, and 300 engineers, technicians and service personnel.

The state-of-the-art infrastructure of GEOMAR includes two mid-size (60m+) research vessels (R/V Alkor, R/V Poseidon), two smaller research vessels, three remotely operated underwater vehicles (6.000m), an autonomous underwater vehicle (6.000m), the only manned research submersible in Germany (400m), as well as a large number of specialized instruments and technologies for ocean and deep-sea research. GEOMAR is one of the main users of the globally operating German research fleet consisting of R/V Sonne, R/V Meteor and R/V Merian.

The overarching research topics of GEOMAR include: (1) the role of the ocean in climate change, (2) human impact on marine ecosystems, (3) biological, mineral and energy resources as well as (4) plate tectonics and natural hazards. GEOMAR works world-wide in all oceans within an international network of scientific and industry partners.

GEOMAR has four major research divisions:

- Ocean Circulation and Climate Dynamics
- Marine Biogeochemistry
- Marine Ecology
- Dynamics of the Ocean Floor.

In cooperation with Kiel University, GEOMAR is a leading partner in the Cluster of Excellence "The Future Ocean" (10 year program) and the collaborative research centre "Climate-Biogeochemistry Interactions in the Tropical Ocean", funded up to 12 years by the German Research Foundation (DFG).

GEOMAR also closely cooperates with the University of Kiel in education and training of the next generation of marine scientists. Curricula include a B.Sc. course on "Physics of the Earth System" and two internationally oriented M.Sc. courses "Climate Physics" and "Biological Oceanography." Contributions to other curricula such as Geology and Geophysics are also part of GEOMAR's cooperation with the University of Kiel. GEOMAR also has cooperative programs with other universities around the world. Special programs for pupils and teachers aim to stimulate interest in marine sciences at an early stage. GEOMAR puts a strong emphasis on public outreach in all media.

Affiliation
Helmholtz Association

Financial Budget *(2010-2012 mean, marine research only)*

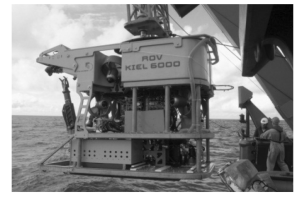
- basic funding 32.3 Mio €
- (third party) project funding 27.5 Mio €

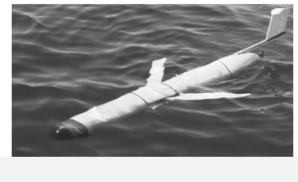
Staff *(december 2012, head counts, excluding administration, marine research only)*

- total 800
- permanent / third party funding -
- professors 40
- senior scientists -
- research scientists 300
- postdocs -
- PhD students 160
- technical staff (engineers, service personnel) 300

Number of Publications *(2010-2012 mean, marine research only)*

- peer reviewed (ISI) 355/y
- in Nature & Science 10/y
- Journal Impact Factor (mean) 291





Further Specifics

Expeditions *(2010-2012 mean, number involved in)*

- ALKOR (regional class)
- POSEIDON (ocean-class)

212 days / year

- SONNE (ocean-class)
- MERIAN (ocean-class)
- METEOR (ocean-class)

276 days / year

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- ROV Kiel 6000 (6.000m)
- ROV HYBIS (6.000m)
- ROV PHOCA (3.000m)
- AUV ABYSS (6.000m)
- Sub JAGO (400m)
- Modular Multi-disciplinary Seafloor Laboratory (MoLab)
- 10 offshore Mesocosms (65 m³ each)
- 100 ocean bottom seismometers
- 2D and 3D reflection seismic systems
- Autonomous seafloor monitoring system
- Marine electromagnetic systems
- Glider fleet (10)
- 5 deep-sea lander observatories
- TV-guided deep-sea grab

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Technology and Logistics Centre
- Trace element and isotope analytical laboratory
- Central molecular laboratory
- Centre for marine natural products research
- Aquaculture facility

Max Planck Institute for Marine Microbiology

Celsiusstraße 1
D-28359 Bremen

Max Planck Institute for Marine Microbiology

Research at the Max Planck Institute for Marine Microbiology (MPIMM) is dedicated to the exploration of the microbial potential and activity in aquatic systems. Founded in 1992, the MPIMM is one of currently 80 institutes of the Max Planck Society. The MPIMM is divided into three departments and seven research groups, in which researchers work in the fields of microbiology, molecular ecology and biogeochemistry.
The scientists at the MPIMM investigate the role of microbes in the marine realm, their diversity and their interaction with their environment both on community level as on the scale of single cells. Microbial activity impacts the global cycles of the elements carbon, sulfur, nitrogen, and iron. By their sheer number they influence not only the chemistry of the oceans but ultimately also our climate.
One of the foci of research at the MPIMM is microbial activity in areas that are low in oxygen or completely oxygen-free. These conditions can be found in sediment underneath the ocean floor and in several regions in the water body. The microbial communities that live in these areas and their metabolism are yet poorly known. Another key aspect of research at the MPIMM are symbioses either among bacteria or between bacteria and animals or algae. Deep-Sea research and in-situ-technology development is performed in cooperation with the Alfred Wegener Institute for Polar and Marine Research. The MPIMM owns and operates a secondary mass spectrometer and a Raman spectroscope. The database projects Silva and Megx provide access to ribosomal RNA data, and environmental and metagenomic data, respectively.

The scientists of the Max Planck Institute for Marine Microbiology collaborate closely with the universities of Bremen at which the heads of the departments are appointed as professors. They also cooperate with other marine research facilities both in northern Germany and worldwide. To meet the high demand of the scientists and to facilitate their research the technical and engineering staff constantly develops new technologies and instruments in the institute's own workshops for sampling and analysis either on research cruises or in laboratory experimental setups. The interdisciplinary International Max Planck Research School for Marine Microbiology Marmic provides an excellent training for junior researchers. Within a four years period the students can obtain their Master's and PhD degree. Besides lectures and practices in a variety of disciplines like marine geology, microbiology of prokaryotes, and bioinformatics the curriculum comprises hands-on training at a German field research station, introduction to state-of-the-art technologies, and soft skills courses.

Affiliation
Max Planck Society

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	10.1 Mio €/y
• third party funding	4.2 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	167
• permanent / third party funding	30 / 37
• professors	7
• senior scientists	2
• postdocs	74
• PhD students	34
• technical staff	50

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	313/y
• in Nature & Science	6/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	18/y
• land-expeditions (e. g. to polar stations)	10/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	77.9 / 4.2 Mio €
• BMBF	17.0 / 0.8 Mio €
• EU	64.3 / 5.5 Mio €
• industry	-
• other	-

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	4/y
• Master & Diploma	14/y
• PhD	12/y

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Modular Benthic Lander System

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- NanoSIMS
- CLS Microscope
- RAMAN

Max Planck Institute for Meteorology

Bundesstraße 53
20146 Hamburg

Max-Planck-Institut für Meteorologie

Overview and Mission

The Max Planck Institute for Meteorology (MPI-M) is an internationally renowned institute for climate research. Its mission is to understand Earth's changing climate.

The MPI-M comprises three departments: *The Atmosphere in the Earth System* (Prof. Dr. Björn Stevens), *The Land in the Earth System* (Prof. Dr. Martin Claußen), *The Ocean in the Earth System* (Prof. Jochem Marotzke) and four independent research groups: *Fire in the Earth System* (Dr. Silvia Kloster), *Forest Management in the Earth System* (Dr. Julia Pongratz), *Sea Ice in the Earth System* (Dr. Dirk Notz), and *Turbulent Mixing Processes in the Earth System* (Dr. Juan Pedro Mellado).

Scientists at the MPI-M investigate what determines the sensitivity of the Earth system to perturbations such as the changing composition of its atmosphere, and work toward establishing the sources and limits of predictability within the Earth system. MPI-M develops and analyses sophisticated models of the Earth system, which simulate the processes within atmosphere, land and ocean. Such models have developed into important tools for understanding the behaviour of our climate, and they form the basis for international assessments of climate change. Targeted in-situ measurements and satellite observations complement the model simulations.

Together with several other non-university research institutions the MPI-M and the University of Hamburg constitute the KlimaCampus, a centre of excellence for climate research and education in Hamburg, Germany.

IMPRS-ESM International Max Planck Research School on Earth System Modelling

The International Max Planck Research School on Earth System Modelling (IMPRS-ESM) is the structured PhD programme at the Max Planck Institute for Meteorology (MPI-M). It is in operation since 2001. With the IMPRS-ESM, the MPI-M and the University of Hamburg (UHH) offer particularly qualified young scientists of all nations a custom-designed PhD programme for the newly developed discipline Earth System Sciences. The three departments of the MPI-M as well as the thematically related institutes of the UHH (Meteorology and Oceanography), the UHH's Faculty of Economics and the Research Unit Sustainability and Global Change (FNU) are participating in the IMPRS-ESM.

The IMPRS-ESM works closely together with the „School of Integrated Climate System Science" (SICSS), the UHH graduate school which has been founded in October 2009 within the framework of excellence initiative UHH. The research orientation of SICSS is complementary to IMPRS-ESM. Both schools are similarly structured and organized. English is the working language for both schools.

Affiliation
Max Planck Society

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	2.0 Mio €/y
• third party funding	1.4 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	62
• permanent / third party funding	12 / 17
• professors	1
• senior scientists	29
• postdocs	28
• PhD students	9
• technical staff	5

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	33/y
• in Nature & Science	1/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	0/y
• land-expeditions (e. g. to polar stations)	0/y

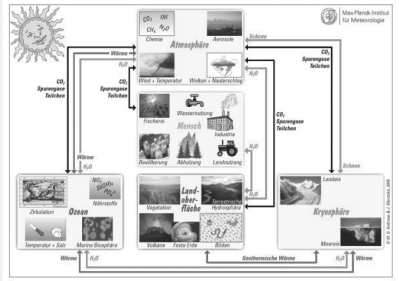
Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	5.1 Mio €
• EU	3.0 Mio €
• industry	-
• other	-

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	0/y
• Master & Diploma	0/y
• PhD	4/y

Further Specifics



Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

not applicable

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

not applicable

Leibniz Center for Tropical Marine Ecology (ZMT)

Fahrenheitstraße 6
28359 Bremen

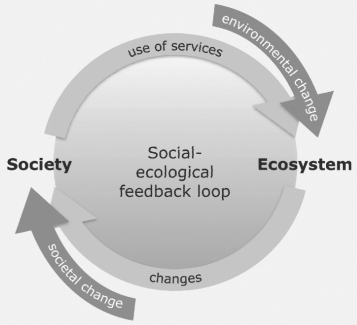
Gaming in the context of social-ecological studies to question fishing methods in Spermonde Archipelago, Sulawesi, Indonesia.

Photo: H. Reuter, ZMT

ZMT's profile

ZMT's research contributes to the scientific basis for the protection and sustainable use of tropical coastal ecosystems and their resources. The research topics are addressed in an integrated approach combining natural and social sciences – one of the outstanding features of the institute. Moreover, the ZMT puts a high value on working in a partnership of equals with its tropical counterparts. This is achieved through joint interdisciplinary projects, initiated and led by the ZMT, and joint education of scientists. Education, as well as capacity building, is provided for students and young scientists from all over the world, and ZMT also provides educational and governmental institutions with expert knowledge in tropical aquatic ecosystem research. ZMT's staff teaches at both local universities and abroad, and supervises a large number of Ph.D. students, mostly with international background.

ZMT's focus is exclusively on marine research tropical coastal areas, which is a unique feature for a marine research institute in Germany. ZMT addresses its research topics in a holistic way, integrating social and natural sciences. The drivers of and the adaptations to environmental change in the social-ecological and socio-economical context are investigated (*see graphic*). This includes social-ecological feedback cycles, and the impact of societal use and environmental changes on ecosystems (among others eutrophication, acidification, and pollution). Today's approaches are based on time-series and large-scale geographical comparisons of different tropical regions (with research foci on Southeast Asia, the Eastern Pacific Ocean and Sub-Saharan Africa).



The addressed key questions include the response of key organisms to environmental changes (e.g. CO_2 concentration, temperature) and anthropogenic factors (e.g. overfishing, aquaculture). Moreover, the consequences of these factors for element cycles, biodiversity and ecosystem functioning are analysed. This is complemented by the study of governance structures and how these can be amended to achieve a sustainable use of resources.

After becoming a member of the Leibniz Association in 2009, the ZMT underwent a continued phase of expansion and reorganisation, which included a strengthening of all scientific disciplines of the institute. A departmental structure with four scientific departments (Biogeochemistry & Geology, Ecological Modelling, Ecology, and Social Sciences) and currently 16 workgroups was established in 2011. In addition, an infrastructural department bundles laboratories, library, IT service, facility management, and administration.

Affiliation
Leibniz Association

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	6.2 Mio €/y
• third-party funding	1.2 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	103
• permanent / third-party funding	21 / 45
• professors	6
• workgroup leaders	9
• scientists	14
• PhD students	64
• technical staff	10

Number of Publications *(2010-2012 mean, marine research only)*

• Total	87/y

thereof:

• peer reviewed (ISI)	57/y
• in Nature & Science	0/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	4/y
• land-expeditions (e. g. to polar stations)	27/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF:	
○ SPICE II (2007-2010)	5.5 / 1.9 Mio €
○ SPICE III (2012-2015)	5.7 / 2.4 Mio €
○ GENUS I+II (2009-2012)	5.3 / 0.9 Mio €
• EU	
○ FORCE (2010-2014)	6.5 / 0.4 Mio €
• Industry	-
• other	-

* SPICE: Science for the protection of Indonesian coastal marine ecosystems; GENUS: Geochemistry and ecology of the Namibia upwelling system; FORCE: Future of reefs in a changing environment

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	3/y
• Master & Diploma	24/y
• PhD	7/y

Further Specifics

The ZMT also functions as a coordinator for collaborative projects in tropical coastal areas, e.g. the BMBF-funded programme SPICE* (2004-2015) in Indonesia.

The institute maintains about 80 national and international partnership agreements with universities and research institutions and holds teaching and specialty courses at home and abroad.

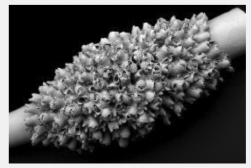
In 1999, the ZMT developed the first English Master programme at the University of Bremen, ISATEC (International Studies in Aquatic Tropical Ecology, DAAD-supported), and contributes significantly to its lecture programme.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*
-

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

ZMT's Marine Experimental Ecology MAREE is the largest tropical marine laboratory in Germany with aquaria of different size for ecophysiological experiments, to complement ecological field studies, and to breed and reproduce key species.

Thin section laboratory and high-end scanning electron microscopy (SEM) enables detailed ultra-structural studies of e.g. carbonate skeletons and sediment.



In cooperation with partner universities in the tropics, the ZMT installed field stations in Purwokerto (Java, Indonesia) and Bragança Peninsula (Northern Brazil) to provide the basis for long-term studies.

Leibniz Institute for Baltic Sea Research Warnemünde

Seestrasse 15
18119 Rostock

The IOW´s mission is to conduct **interdisciplinary marine research in coastal seas, with special emphasis on the Baltic Sea**. It has four departments representing the disciplines of physical oceanography, marine chemistry, biological oceanography and marine geology. An instrumentation group is affiliated with the department Physical Oceanography. The departments work jointly on a long-term research programme with the research foci “Small and mesoscale processes”, “Basin-scale Ecosystem Dynamics”, “Changing Ecosystems” and “Coastal Sea and Society”.

Research at the IOW focuses on observations and modelling of ecosystem changes and their underlying processes in marginal seas and shelf regions. The research programme strives for an in-depth understanding of the functions of the ecosystem with the overall objective to differentiate between natural variability and anthropogenically triggered changes. Past ecosystem states are reconstructed from sediment archives.

Long-term observation data from the Baltic Sea, collected and hosted at the IOW and its predecessor since the 1950s, are a valuable treasure for the entire coastal sea research community, both nationally and internationally. These time series ensure high-quality data support for hydrodynamic and ecosystem models and enable the institute to analyse trends. In addition, the data are used to support "what-if“ model scenarios as future projections.

The IOW contributes significantly to the sound scientific knowledge that is needed to implement the marine strategy for the Baltic Sea. Therefore, the institute cooperates with ministries, agencies and authorities, at both the federal and state level. The Federal Maritime and Hydrographic Agency (BSH) has entrusted the IOW with the Baltic Sea Monitoring Programme, to which Germany and the other countries bordering the Baltic Sea committed themselves in the Helsinki Convention. Besides, the IOW runs for the BSH three autonomous measuring stations in the western Baltic Sea (at Darss Sill, in the Arkona Basin and Odra Bight) which deliver oceanographic data from different water levels around the clock.

The nine IOW professors are simultaneously members of the universities in Rostock and Greifswald. In Rostock, they are also members of the department “Maritime Systems” of the Interdisciplinary Faculty (INF).

The IOW scientists have r/v Elisabeth Mann Borgese (length o.a.: 56.50 m) and r/v Maria S. Merian (length o. a.: 94.80 m) at their disposal.

Affiliation

Leibniz Association

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	11.0 Mio €/y
• third party funding	9.8 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	157
• permanent / third party funding	89/68
• professors	9
• senior scientists	47
• postdocs	16
• PhD students	22
• technical staff	62

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	95.0/y
• in Nature publ. group & Science	1.6/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	30/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	25.0 / 2.3 Mio €
• EU	44.0 / 1.0 Mio €
• industry	-
• other	28.7 / 6.3 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	9/y
• Master & Diploma	21/y
• PhD	7/y

Further Specifics

IOW was entitled by the Federal Maritime and Hydrographic Agency (BSH) to carry out a monitoring programme in the Baltic Sea according to Germany´s obligations in the frame of the Helsinki Convention. This observation programme is accompanied by the operation and maintenance of three autonomous measuring stations installed at key positions in the Western Baltic Sea, continuously measuring with different sensors in certain water depths.

Together with the University of Rostock, the IOW offers experimental learning modules (“Ocean acidify-cation” and “Eutrophication”) for school classes under the umbrella of the pupils´lab “MariSchool”. Up to 300 school students visited MariSchool per year.

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- In situ pump CTD system
- Profiling mooring system GODDESS

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- NanoSIMS
- Flow cytometer FACS Aria III
- GC isotope ration combustion MS Calibration laboratory
- Molecular biology laboratory
- Certified analytical laboratory for organic trace elements
- Scanning electrons microscope /
- microanalyses laboratory

Senckenberg am Meer
Marine Research Department
German Centre for Marine Biodiversity Research
Südstrand 40
26382 Wilhelmshaven

SENCKENBERG
world of biodiversity

The institute **Senckenberg am Meer** (SaM) deals with basic and applied research in several disciplines of marine geology and biology and houses a national sorting center and archive for biological samples from deep-sea expeditions in Wilhelmshaven. We also provide expedition equipment and technical support on demand for external working groups and manage the coastal research vessel SENCKENBERG.

The **Marine Research Department** (MRD) consists of four sections. Thematic topics are processes and fluxes of sedimentation and erosion in the Wadden Sea and in the German Bight to better understand the complex interplay of sea-level change, hydrodynamics, sediment transport and coastal protection. The analysis of geological and ecological consequences of phytal and faunal bioinvasions affecting North Sea ecosystems forms another major objective that strongly interferes with legal, social and economic spheres. Complementary to the Helgoland long-term study on plankton organisms, our marine biology holds a long-lasting time series which documents the faunal shifts of epi- end endobenthic communities in the entire German Bight including several sampling programs within the UNESCO Wadden Sea World Heritage. Biosedimentary systems both in shallow and deep waters are another speciality. We investigate the growth and biological degradation of bathyal cold-water coral mounds on continental margins of all oceans. These deep coral systems are hotspots of biodiversity and harbor numerous economical important species. We analyse biological interactions of coral-associated communities under contrasting trophic regimes and in modern and Neogene examples.
The main scientific objective of the **German Centre for Marine Biodiversity** (GCMB) currently is to understand drivers of biodiversity change along gradients in the seas. The focus during past years has been the deep-sea, with the coordination of the international project Census of the Diversity of Abyssal Marine Life as a part of the Census of Marine Life, researching the large abyssal plains in depths between 2000 and 5000 meters. The GCMB, heading an international team of experts, aims to determine how many species live in these plains, how large the geographical area of their distribution is, and how much these vast areas contribute to the species richness of the world's oceans. Current large projects involve the study of the biodiversity at the manganese nodules sites in the Pacific, and a whole biodiversity assessment around Iceland including the production of predictive models for marine species distributions. The overarching research disciplines present at the GCMB include taxonomy, both morphology-based and molecular genetic-based, and the systematic treatment of marine organisms. GCMB scientists work in two locations. The majority is based in Wilhelmshaven and a smaller group is located at the Biocenter Grindel at the University of Hamburg.

The permanent staff at SaM has teaching obligations with Oldenburg University (biology) and Bremen University (geology). We have a professional guesthouse and teaching facility on the estate and provide service about 300-400 students from German, Austrian, Polish and Swiss universities per annum.

Affiliation
Leibniz-Association

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	1.25 Mio €/y
• third party funding	1.25 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	73
• permanent / third party funding	33 / 40
• professors	2
• senior scientists	10
• postdocs	6
• PhD students	28
• technical staff	21

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	70/y
• in Nature & Science	1/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	50*/y
• land-expeditions(e. g. to polar stations)	5/y

*40 with own research vessel

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	5.0 / 0.2 Mio €
• EU	20.0 / 0.8 Mio €
• industry	-
• other	1.0 / 0.1 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	20/y
• Master & Diploma	15/y
• PhD	4/y

Further Specifics

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Research vessel
- Reson Multibeam Systems

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- µCT-EDX-CL-Scaning Electron Microscope
- confocal laser microscope
- Skyscan µCT

Johann Heinrich von Thünen Institute
Federal Research Institute for Rural Areas,
Forestry and Fisheries
Aquatic Resources
Palmaille 9
22767 Hamburg

The Johann Heinrich von Thünen-Institute (TI), Federal Research Institute for Rural Areas, Forestry and Fisheries is a governmental research institution and higher federal authority. The fisheries unit comprises three institutes conducting applied research on the effects of fisheries and aquaculture on fish stocks and aquatic ecosystems and its interactions with other forms of marine use.

Our main goal is to create a scientific basis for environmentally friendly, sustainable fisheries and aquaculture and to anchor the principle of ecologically and economically sustainable use of living marine resources in national and international management bodies. Harmonizing exploitation of living resources with the general goal to protect the marine environment is central to our work.

We cooperate with universities and domestic and national marine research institutes and are member of the Association of the European Fisheries and Aquaculture Research Organisations (EFARO). We contribute to international conventions and bodies, such as the International Council for the Exploration of the Sea (ICES), the North-Atlantic Fisheries Organization (NAFO), and we are working with the Food and Agricultural Organization of the United Nations (FAO), the Oslo-Paris Commission (OSPAR) and the Helsinki Commission (HELCOM), the Commission for the Conservation of Antarctic Marine Living Resources (CCMLAR) and nationally with the Federal-State Monitoring Program for the Marine Environment in the North and Baltic Seas (BLMP). We provide essential contributions to internationally coordinated and long term scientific monitoring programmes of living aquatic resources and their ecosystems in the North Atlantic region and the Antarctic.

The results of our research feed into scientific policy advice for a sustainable use of living aquatic resources and ecosystems and form a basis for risk adverse regulatory and environmental policy measures to achieve the goals of integrated marine policy and the Common Fishery Policy of the European Union (CFP).

With the latest reform of the CFP at the heart of the new, integrated EU marine policy, the political demands for future fishery and aquaculture research have changed substantially. Assessment and prediction of marine ecosystem status rather than only target species of the fisheries are in focus of modern fisheries research. Central to our work is the economic and social dimension of fisheries and aquaculture and how these activities interact with other marine and maritime sectors. To understand the major drivers of change in marine systems is central for advising management. By integrating research on ecology, economy and societal and political priority setting the work of the Thünen-Institute is interdisciplinary at its core.

Affiliation
Federal Agency
Ministry of Food, Agriculture and Consumer Protection

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	≈ 5.3 Mio €/y
• third party funding	≈ 3.5 Mio €/y
•	

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	159
• permanent / third party funding	111 / 48
• professors (incl. PD)	5
• scientists	65
• postdocs	-
• PhD students	16 (9 Ext.)
• technical staff	82

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	59/y
• in Nature & Science	0.3/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	35/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	-
• EU	
○ "COEXIST"	3.8 / 0.4 Mio €
○ "MESMA"	8.5 / 0.1 Mio €
○ "VECTORS"	16.5 / 0.7 Mio €
○ "SOCIOEC"	3.8 / 0.4 Mio €
○ “MYFISH”	6.5 / 0.3 Mio €
○ “CHEMSEA”	4.5 / 0.4 Mio €
○ “UNCOVER”	5.7 / 0.5 Mio €
○ “DCF”*	73.0 / 5.4 Mio €
• industry	3.0 / 1.5 Mio €
• other	-

(* annual average 2010-2012, 80% implementation rate assumed)

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	1/y
• Master & Diploma	6/y
• PhD	2/y

Further Specifics

- Advisor of the German Government and the European Commission on fishing quotas and fisheries management measures
- Federal coordination centre for radioactivity monitoring of the marine environment
- Long-term monitoring and measurement programs in the Baltic Sea, North Sea, North Atlantic and Antarctic (Biology, Phys. Oc.)
- Coordination of Germany’s EU data collection framework program for the fishing sector

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- Three seagoing fishery research vessels ranging from 65m to 29m (WALTHER HERWIG III, SOLEA, CLUPEA)
- TRIAXUS ROTV

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Large scale fresh water and salt water Aquaculture facility
- Facility for determination of environmental radioactivity
- Facility for analysis of hazardous substances in marine biota
- Library specialized in fisheries, aquaculture and fish processing

Bundesamt für Seeschifffahrt und Hydrographie – BSH
Federal Maritime and Hydrographic Agency

Bernhard-Nocht-Straße 78
20359 Hamburg

Neptunallee 5
18057 Rostock

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

The BSH is a higher federal authority in Germany with responsibility for maritime matters. It is under the authority of the Federal Ministry of Transport, Building and Urban Development. As a partner to maritime shipping and a supporter of environmental conservation efforts and maritime uses, we

support maritime shipping and the maritime industry,
promote sustainable use of the oceans,
ensure the continuity of measurements,
provide competent information about the status of the North and Baltic Seas.

Our tasks as an important provider of maritime services in Germany include:

Environmental protection in maritime shipping (MARPOL, civil liability for oil pollution, Ballast Water Convention, oil identification)
Maritime security
Hydrographic surveying, wreck search
Nautical information systems
Services to shipping (flag documents, Certificates of Competency for mariners, promotion of shipping)
Warning services (water level foreasts and tide predictions, storm surge warning service, sea ice service)
Monitoring of the sea (with regard to climate and environmental changes)
Maritime geospatial data centre
Maritime spatial planning in the German Exclusive Economic Zone (EEZ)
Planning approval procedures for offshore wind farms and pipelines

The BSH is represented not only in national state and federal bodies but co-operates with more than 20 international organisations.

The BSH is intensively engaged in the field of operational oceanography. Research is highly practice-oriented, with a focus on continually upgrading and updating its services. The objectives and research focus of the BSH are:

Ensuring reliable maritime services
Continuity of measurements
Professionally competent advice to political bodies and society
Economic efficiency

Bringing new scientific developments (knowledge, methods, measuring devices, etc.) into operational use is a very important issue. Research projects are being performed in close co-operation with research institutes, universities, agencies and companies on national and international level.

Affiliation

Federal Agency, Federal Ministry of Transport, Building and Urban Development (BMVBS)

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	15.6 Mio €/y
• third party funding	5.4 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	115
• permanent / third party funding	80 / 35
• professors	0
• scientists	49
• postdocs	0
• PhD students	4
• technical staff	62

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	3/y
• in Nature & Science	0/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	7/y
• land-expeditions (e. g. to polar stations)	0/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	-
• EU	
“MyOcean1 (2009-2011)”	33.8 / 0.7 Mio €
“MyOcean2 (2011-2014)”	27.9 / 0.6 Mio €
“SeaDataNet1 (2006-2011)”	8.7 / 0.3 Mio €
“SeaDataNet2 (2011-2015)”	6.0 / 0.3 Mio €
“GeoSeas (2009-2013)”	4.9 / 0.1 Mio €
• industry	-
• other BMU (total amount = institutes share)	
“FINO (2011-2014)”	3.0 Mio €
“alpha ventus (2012-2014)”	7.7 Mio €
“RAVE (2011-2014)”	3.0 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

is not applicable for BSH

• Bachelor	/y
• Master & Diploma	/y
• PhD	/y

Further Specifics

Long term measurement programmes in North and Baltic Seas (oc, biogeochem)

Operational modeling of North and Baltic Seas

Forecast and warning services (tides, sea level and storm surges, sea ice, drift)

Marine scientific data centre

Budget for awarding extramural R&D contracts

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

Three 52m survey, wreck-search and research vessels (ATAIR, DENEB, WEGA)

Marine Environmental Monitoring Network in the North Sea and Baltic Sea (MARNET) which presently comprises eleven automated measuring stations.

Operating ARGO Germany within the framework of the international ARGO-programme, consisting of 150-180 active floats, 30 new floats per year

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

Special library
Computer centre plus backup
Marine chemistry laboratories
Calibration laboratory
Workshop for scientific equipment

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) / Federal Institute for Geosciences and Natural Resources

Geozentrum Hannover
Stilleweg 2
30655 Hannover

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

The Federal Institute for Geosciences and Natural Resources (BGR) was founded in 1958. BGR is a sovereign centre of competence in geosciences and Germany's national Geological Survey. We are partnering (a) with the regional Geological Surveys of Germany, (b) the national Geological Surveys of Europe, and (c) numerous university and non-university research institutes in Germany and abroad.

Based on own research and inquests, BGR advises the Federal Government and the German industry in all issues concerning the availability of fossil energy and mineral resources world-wide. We are engaged in investigations into the sustainable use of groundwater and soil resources and the application of geothermal energy. We also examine the suitability of potential geological sites for the long-term disposal of radioactive wastes and look into options of geological storage of CO2 to reduce its release in the atmosphere.

International activities include collaboration with countries suffering from geological hazards, cooperation in the administration of geoscientific databases, and capacity building in a wide range of matters of geological concern. Herein, BGR is often mandated by the Federal Ministry for Economic Cooperation and Development (BMZ). We run the national seismological data centre and monitor world-wide seismic activities in compliance with the international nuclear test-ban treaty.

BGR is also involved in various multinational research projects in marine areas and in the two polar regions. Marine research activities comprise exploration of passive and active continental margins, in particular sedimentary basins located in shelf areas. Investigations are focused on frontier regions with potential resources in hydrocarbons including gas hydrates (frozen natural gas) that are accumulated in many marine sedimentary formations and regarded as a possible energy source of the future. Active participation in the international Ocean Drilling Program (ODP), now named Integrated Ocean Drilling Program (IODP), is an important module of the marine research sector of BGR.

In addition, BGR explores the occurrence of mineral resources in the deep sea that might be minable in the near future. They comprise polymetallic nodules, cobalt-rich ferromanganese crusts, and polymetallic sulphides of hydrothermal origin. Like other countries, Germany has obtained an exploration license from the International Seabed Authority (ISA) for research on manganese nodules. The license could be transferred into an exploitation license at a later stage. In providing corresponding advice to the International Seabed Authority, BGR looks into the technical and environmental concerns of deep-sea-mining and the Law of the Sea.

Some 750 scientific, technical and administrative employees and civil servants are working at BGR. They are supported by a modern scientific-technical infrastructure, laboratories, geological collections, equipment, and one of the world's largest geoscientific libraries. New technical expertise is being permanently developed and provided for specific missions. Central technical service such as public relations work and information technology guarantee documentation and target-group oriented provision of data, information and publications.

Affiliation

Federal Agency
Ministry of Economics and Technology (BMWi)

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	6.0 Mio €/y
• third party funding	1.5 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	48
• permanent / third party funding	28 / 20
• professors	0
• senior scientists	18
• post-docs	10
• PhD students	6
• technical staff	14

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	10/y
• in Nature & Science	0/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	8/y
• land-expeditions (e. g. to polar stations)	1/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	10.5 / 0.6 Mio €
• EU	3.0 / 0.2 Mio €
• Industry	3.5 / 0.3 Mio €
• Other (BMWi)	5.5 / 0.3 Mio €

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	2/y
• Master & Diploma	2/y
• PhD	1/y

Further Specifics

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

- 2D Seismic
- 3D Seismic
- Ocean-Bottom-Seismometers (13)
- Magnetometer array
- Sea-Air Gravitymeter
- Deep tow SideScan
- Deep tow Video
- TV guided grab

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

- Seismic processing facility

Deutsches Meeresmuseum
Museum für Meereskunde und Fischerei • Aquarium
Stiftung bürgerlichen Rechts
Katharinenberg 14-20
18439 Stralsund

The **German Oceanographic Museum** (**DMM**) is the major museum for natural history along Germany's coastline. Visited by more than 1 million people per year on its four locations (MEERESMUSEUM, OZEANEUM, NAUTINEUM & NATUREUM) it is one of the five most visited museums in Germany
Exhibitions in all four locations extend over 10,000 sqm with further 20,000 sqm of outdoor presentations. Traditional museum exhibitions are combined with marine aquariums holding a total of approximately 7 million liters of seawater in 70 subsystems of about 100 display tanks. Further quarantine and experimental research systems are present.
In 2010 the OZEANEUM was awarded the "European Museum of the Year 2010" due to its modern exhibition concept and design, its close cooperation with partner institutions in German marine research and its proactive visitor-focused engagement of museum staff.

Research within the DMM is aiming mainly on marine mammals, ichthyology, ornithology, invertebrate zoology, marine ecology, environmental and museum education, and under-water-archaeology. All tenure scientists are responsible for developing exhibition concepts and visitor programs, managing collections and performing research at the same time. Marine research in a strict sense thus amounts to only about 15 % working time of permanent scientific staff. In addition a varying number of non-permanent research-staff is working on the topic of marine mammals, concentrating on the Baltic populations of harbor porpoise and Grey seal.
All parts of the DMM's science department regularly facilitate internships and studies of students, like Bachelor-, Master-, Diploma- or PhD-theses. Co-operations are established with universities all over Germany.

Collections mainly focus on marine organisms, marine research and fisheries. Besides storage for vouchers and source of exhibition material, the collections of the DMM provide a huge base for a variety of research studies. Outstanding collections exist in the fields of Baltic marine mammals, ichthyology, coelenterates, and local fishing boats.

Exhibitions display marine biology and oceanography augmented by general natural history topics. Our institution is outstanding in communicating marine research to the public, including not only general topics, but also detailed displays on current marine research, best seen in the exhibition "Research and Utilization of the Sea". This exhibition opened in 2011 was developed in close cooperation with the German Marine Research Consortium (KDM) and is presenting some of the present major research topics within the field of German marine research.

The DMM is combining exhibitions, collections and research in one institution. National and international awards and high number of visitors have proven this concept to be successful. The DMM is holding a German key-position in knowledge-transfer of marine research topics to the general public.

Affiliation
Foundation (Stiftung bürgerlichen Rechts)

Financial Budget *(2010-2012 mean, marine research only)*

• basic funding	1.0 Mio €/y
• third party funding	0.4 Mio €/y

Staff *(december 2012, head counts, excluding administration, marine research only)*

• total	16
• permanent / third party funding	9 / 7
• professors	0
• senior scientists	5
• postdocs	0
• PhD students	0
• technical staff	4

Number of Publications *(2010-2012 mean, marine research only)*

• peer reviewed (ISI)	3.7/y
• in Nature & Science	0/y

Expeditions *(2010-2012 mean, number involved in)*

• research cruises	1/y
• land-expeditions (e. g. to polar stations)	2/y

Large-Scale Collaborative Research Projects
(>3.000.000 € total project volume, marine research only, projects running at any time 2010-2012 only, total amount / institutes share)

• DFG	-
• BMBF	-
• EU	-
• industry	-
• other	-

University Education *(no. of graduates, 2010-2012 mean, marine research only)*

• Bachelor	2.0/y
• Master & Diploma	1.3/y
• PhD	0.3/y

Further Specifics

Four museums: MEERESMUSEUM, OZEANEUM, NATUREUM & NAUTINEUM

Sea-going Infrastructure and Large Equipment *(>400.000 €, marine research only)*

not applicable

Land-based Infrastructure and Large Equipment *(> 400.000 €, marine research only)*

not applicable

**** Other special infrastructure**

- Museum collections of marine organisms
- Network of acoustic harbor porpoise detectors along the coast of the German Baltic Sea.
- Large facilities for keeping marine organisms
- more than 1 million visitors per year

Appendix C

Funding

C 1 Funding of Marine Research – DFG
(collaborative research projects only)

Title	Speaker	Period of Funding	DFG Verfahren
Global Change in the Marine Realm - Bremen International Graduate School for Marine Sciences (GLOMAR)	Prof. Dr. Dierk Hebbeln Universität Bremen MARUM	Since 2006	Graduate School GSC 119
The Future Ocean	Prof. Dr. Martin Visbeck GEOMAR	Since 2006	Cluster of Excellence, EXC 80
Intergrated Climate System Analysis and Prediction (CliSAP)	Prof. Dr. Martin Claußen Universität Hamburg MPI für Meteorologie	Since 2007	Cluster of Excellence, EXC 177
The Ocean in the Earth System	Prof. Dr. Gerold Wefer Universität Bremen MARUM	Since 2007	Cluster of Excellence, EXC 309
Tiefdruckgebiet und Klima-system des Nordatlantiks	Prof. Dr. Burghard Brümmer Universität Hamburg	1998–2009	SFB 512
Volatiles and Fluids in Subduction Zones: Climate Feedback and the Causes of Natural Disasters	Prof. Dr. Kaj A. Hoernle GEOMAR	2001–2012	SFB 574
Climate-Biogeochemistry Interactions in the Tropical Ocean	Prof. Dr. Andreas Oschlies GEOMAR	Since 2008	SFB 754
Ökologie, Physiologie und Molekularbiologie der Roseobacter-Gruppe	Prof. Dr. Meinhard Simon Universität Oldenburg, ICBM	Since 2010	SFB: Transregio, TRR 51

Ocean Margins – Research Topics in Marine Geosciences for the 21st Century	Prof. Dr. Gerold Wefer Universität Bremen MARUM	Since 2001	DFG-Forschungszentrum, FZT 15
Bereich Infrastruktur – Integrated Ocean Drilling Program/Ocean Drilling Program (IODP/ODP)/Ocean Drilling Program/Deep Sea Drilling Project	Dr. Jochen Erbacher Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) Hannover	1979–2013	Schwerpunktprogramm, SPP 527
Durchführung von Meteor/Merian-Expeditionen Auswertung von Meteor-Expeditionen		Since 1964 Since 1970	Schwerpunktprogramm, SPP 511 SPP 516
Antarctic Research with Comparable Investigations in Artic Sea Ice Areas	Prof. Dr. Martin Melles Universität zu Köln Institut für Geologie und Mineralogie	Since 2003	Schwerpunktprogramm, SPP 1158
The Impact of Climate Variability on Aquatic Ecosystems (AQUASHIFT)	Prof. Dr. Ulrich Sommer GEOMAR	2004–2010	Schwerpunktprogramm, SPP 1162
Integrated Analysis of Interglacial Climate Dynamics (INTERDYNAMIC)	Prof. Dr. Michael Schulz Universität Bremen MARUM	Since 2007	Schwerpunktprogramm, SPP 1266
SAMPLE: South Atlantic Margin Processes and Links with Onshore Evolution	Prof. Dr. Hans-Peter Bunge Universität München	Since 2008	Schwerpunktprogramm, SPP 1375
Vom Mantel zum Ozean: Energie-, Stoff- und Lebenszyklen an Spreizungsachsen	Prof. Dr. Colin W. Devey GEOMAR	2003–2009	Schwerpunktprogramm, SPP 1144
BioGeoChemie des Watts	Prof. Dr. Jürgen Rullkötter Universität Oldenburg, ICBM	2001–2009	Forschergruppe FOR 432
Impact of Gateways on Ocean Circulation, Climate, and Evolution	Prof. Dr. Michael Sarnthein CAU zu Kiel	2001–2009	Forschergruppe FOR 451

Sinking Coasts: Geosphere, Ecosphere and Anthroposphere of the Holocene Southern Baltic Sea (SINCOS)	Prof. Dr. Jan Harff Leibniz-Institut für Ostseeforschung Warnemünde, Universität Rostock	2002–2009	Forschergruppe FOR 488
Proxies in Earth History	Prof. Dr. Helmut Willems Universität Bremen	Since 2002	Graduiertenkolleg GRK 717
Erhaltungsprinzipien in der Modellierung und Simulation mariner, atmosphärischer und technischer Systeme	Prof. Dr. Jens Struckmeier	Since 1999	Graduiertenkolleg GRK 431
INTERCOAST – Integrated Coastal Zone and Shelf-Sea Research	Prof. Dr. Katrin Huhn Universität Bremen MARUM	Since 2009	Internationales Graduiertenkolleg 1598

C 2 Funding of Marine Research – BMBF 2007–2011

	2007	2008	2009	2010	2011	
Klimaforschung	4.344.333	5.016.191	6.607.037	8.445.106	5.624.304	
Klimafaktor Ozean/Polargebiete	303.492	102.782	1.280.699	4.353.149	4.100.030	
Marine und polare Ökosysteme	2.968.015	3.460.084	4.261.154	6.185.953	3.508.767	
Marine Ressourcen	1.561.929	246.973	240.044	258.752	31.881	
Meeresforschungstechnik	907.053	2.324.525	1.133.172	3.296.570	578.236	
Integriertes Küstenzonenmanagement	1.637.770	7.127.397	713.409	424.285	91.718	
Küsteningenieurwesen	1.661.528	1.489.410	1.295.973	1.614.316	2.509.479	
Geowissenschaftliche Untersuchungen	1.675.421	1.038.017	870.373	1.229.957	1.225.392	
Sonderprogramm Geotechnologien (marine Vorhaben)	2.249.250	294.284	38.194	6.422	0,00	
subtotal	**17.308.791**	**21.099.663**	**16.440.055**	**25.814.510**	**17.669.807**	**98.332.826**
Infrastruktur (inkl. Charter und Neubau Forschungsschiffe)	12.749.158	14.903.065	16.069.025	20.300.306	30.425.896	
total	**30.057.949**	**36.002.728**	**32.509.080**	**46.114.816**	**48.095.703**	**192.780.276**

Source: Projektträger Jülich, Geschäftsbereich Meeresforschung, Geowissenschaften, Schiffs- und Meerestechnik (MGS), Forschungszentrum Jülich GmbH, Rostock

Appendix D

Teaching

D 1 Bachelor and Master Courses Related to Marine Science at Northern German Universities

University	Bachelor	Master
University of Bremen MARUM – Center for Marine Environmental Sciences	Geosciences	Marine Geosciences
Bremerhaven University of Applied Sciences Institute for marine resources	Food Technology/Food Economics (Seafood) Maritime Technologies Transport and Logistics Ship Operation Engineering	Biotechnology Logistics Engineering and Management
Jacobs University Bremen gGmbH	Biochemistry and Cell Biology[1]	
University of Hamburg Center for Earth Systems Research and Sustainability CEN	Meteorology Geophysics/Oceano-graphy Geosciences	Meteorology Geophysics Oceanography Geosciences MARSYS[1] (Marine Ecosystem and Fisheries Science) Integrated Climate System Sciences
Ernst Moritz Arndt University of Greifswald	Module Marine Geology Marine Geochemistry	Module Oceanography and Continental Margin Systems Module Sedimentology and Quaternary Geology

University of Rostock Department Maritime Systems	Shipbuilding/Ocean engineering	Shipbuilding/Ocean engineering Marine Biology Aquaculture[2]
Carl von Ossietzky University of Oldenburg Institute for Chemistry and Biology of the Marine Environment (ICBM)	Environmental Sciences	Marine Environmental Sciences Microbiology (in English) Environmental Modelling Water and Coastal Management Marine Sensoring[3]
Christian Albrechts-University of Kiel	Geosciences PEMOG (Physik des Erdsystems: Meteorologie – Ozeanographie – Geophysik)[4]	Marine Geosciences Biological Oceanography[5, 6] Climate Physics: Meteorology and Physical Oceanography[5] Coastal Geology and Engineering[7]

1 Thünen-SF and FOE contributes to the University of Hamburg M.Sc.-curriculum MARSYS.
2 Thünen-OSF takes part in this M.Sc.-course.
3 Application pending, expected to start in summer 2014. Offered by ICBM, this curriculum will comprise contributions from the University of Applied Sciences in Wilhelmshaven (Jade Hochschule).
4 In cooperation with GEOMAR.
5 Directed and executed by professors and lecturers from GEOMAR.
6 Thünen-FOE participates in this M.Sc.-course.
7 The formerly existing M.Sc.-program on Coastal Geology and Engineering run at the FTZ Büsum with contributions from the Institute of Geosciences, is currently developed into a new full 4 semester M.Sc. study program and should be offered at the begin of 2014 again.

D 2 PhD-Programs

While only universities are allowed to grant doctoral degrees, most PhD-programs related to marine sciences are being jointly conducted by universities and non-university research institutions. Some of them are:

- GLOMAR (Global Change in the Marine Realm): Bremen International Graduate School of Marine Sciences within the excellence cluster "The Ocean in the Earth System", University of Bremen (MARUM) with ZMT.
- INTERCOAST (Integrated Coastal and Shelf Sea Research): DFG International Research Training Group, University of Bremen (MARUM) with University of Waikato, New Zealand.
- EUROPROX (European Graduate College Proxies in Earth History), DFG International Training Group, University of Bremen.
- POLMAR (Helmholtz Graduate School for Polar and Marine Research), the Helmholtz Graduate School POLMAR is based on a network connecting the AWI with the universities of Bremen and Potsdam, Jacobs University Bremen, Max Planck Institute for Marine Microbiology (Bremen), Bremerhaven University of Applied Sciences, and Institute for Marine Resources (IMARE). These partners already cooperate within the Bremen International Graduate School for Marine Sciences (GLOMAR), International Max Planck Research School of Marine Microbiology (MarMic), and the Helmholtz Research School on Earth System Sciences (ESSReS).
- SICSS (School of Integrated Climate System Sciences), University of Hamburg with MPI of Meteorology.
- IMPRS-ESM (International Max Planck Research School for Earth System Modelling), University of Hamburg with MPI of Meteorology.
- IMPRS-MA7,8 (International Max Planck Research School for Maritime Affairs), University of Hamburg with MPI of Meteorology.
- Integrated Research Training Group of the CRC Roseobacter, University of Oldenburg.
- ISOS (Integrated School of Ocean Science), University of Kiel with GEOMAR within the excellence cluster "The Future Ocean".

Appendix E

Participants

E 1 Members of the Expert Committee

Prof. Dr. Dr. h.c. mult. Ernst. Th. Rietschel	Past President of the Leibniz Association, Germany, Chair
Prof. Dr. Eystein Jansen	Bjerknes Centre for Climate Research Bergen, Norway, Polar Research
Prof. Dr. Carina Lange	University of Concepción, Chile, Marine Geology
Prof. Dr. Jack J. Middelburg	Utrecht University, Netherlands, Coastal Research
Prof. Dr. Jürgen Mienert	University of Tromsø, Norway, Marine Geology
Prof. Dr. Jeanine Olsen	University of Groningen, Netherlands, Microbiology
Prof. Dr. Katherine Richardson	University of Aarhus, Denmark Christensen, Biology and Biological Oceanography
Prof. Dr. Tron Frede Thingstadt	Universitetet i Bergen, Norway, Microbiology
Prof. Dr. Anne-Marie Treguier	Laboratoire de Physique des Océans, Plouzané, France, Physical Oceanography
Dr. Robert Weller	Woods Hole Oceanographic Institution, USA, Physical Oceanography
Prof. Dr. Friedrich W. Wellmer	Past President of the Federal Institute for Geosciences and Resources, Hannover, Germany, Structures of Science

E 2 Representatives of the Federal State Governments

Frau Ingrid Malecki Frau Kirstin Piper Dr. Gustav Sauer	Ministerium für Bildung und Wissenschaft Schleswig-Holstein
Dr. Stefan Grötzschel	Senatorin für Bildung und Wissenschaft der Freien Hansestadt Bremen
Dr. Silke Bertram Frau Heike von der Heide	Ministerium für Wissenschaft und Kultur Niedersachsen
Dr. Birgit Gruner	Behörde für Wissenschaft und Forschung Hamburg
Herr Holger Wandsleb	Ministerium für Bildung, Wissenschaft und Kultur Mecklenburg-Vorpommern

E 3 Members of the Steering Committee

Prof. Dr. Rudolf Amann	Max Planck Institute for Marine Microbiology Bremen
Prof. Dr. Ulrich Bathmann	Leibniz Institute for Baltic Marine Research Warnemünde (IOW)
Prof. Dr. Kay Emeis	Helmholtz-Centre Geesthacht (HZG)
Prof. Dr. Peter Herzig Dr. Nicole Schmidt	GEOMAR Helmholtz-Centre for Ocean Research Kiel
Prof. Dr. Jürgen Rullkötter Prof. Dr. Helmut Hillebrand	Institute for Chemistry and Biology of the Marine Environment (ICBM) University of Oldenburg

Dr. Gerd Kraus	Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI), Braunschweig
Prof. Dr. Karin Lochte	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven
Dr. Rolf Peinert	German Marine Research Consortium (KDM)
Prof. Dr. Ralph Schneider	Kiel Marine Sciences (KMS), Center for Interdisciplinary Marine Sciences, Christian-Albrechts University Kiel
Prof. Dr. Michael Schulz Prof. Dr. Gerold Wefer	Center for Amrine Environmental Sciences (MARUM), University of Bremen
Prof. Dr. Detlef Stammer	Center for Earth Systems Research and Sustainability (CEN), University of Hamburg
Prof. Dr. Hildegard Westphal	Leibniz Center fro Tropical Marine Ecology (ZMT), Bremen

E 4 Participants in the Hearing April 11 – April 13 in Hamburg

Expert Committee	
Prof. Dr. Dr. h.c. mult. Ernst Th. Rietschel	Past President of the Leibniz Association, Germany (Chair)
Dr. Jan Helmke	Institute for Advanced Sustainability Studies, Germany

Prof. Dr. Eystein Jansen	Bjerknes Centre for Climate Research Bergen, Norway
Prof. Dr. Carina Lange	University of Concepción, Chile
Prof. Dr. Jack J. Middelburg	Utrecht University, Netherlands
Prof. Dr. Jürgen Mienert	University of Tromsø, Norway
Prof. Dr. Jeanine Olsen	University of Groningen, Netherlands
Prof. Dr. Katherine Richardson	University of Aarhus, Denmark Christensen
Prof. Dr. Tron Frede Thingstadt	Universitetet i Bergen, Norway
Prof. Dr. Anne-Marie Treguier	Laboratoire de Physique des Océans, Plouzané, France
Prof. Dr. F. W. Wellmer	Past President of the Federal Institute for Geosciences

Marine Scientists of Northern Germany	
Prof. Dr. Rudolf Amann	Max Planck Institute for Marine Microbiology, Bremen
Prof. Dr. Ulrich Bathmann	Leibniz Institute for Baltic Marine Research, Warnemünde (IOW)
Prof. Dr. Kay Emeis Prof. Dr. Wolfgang Kaysser	Helmholtz-Centre Geesthacht (HZG)
Prof. Dr. Peter Herzig Dr. Nicole Schmidt	GEOMAR Helmholtz-Centre for Ocean Research, Kiel

Prof. Dr. Helmut Hillebrand Prof. Dr. Meinhard Simon	Institute for Chemistry and Biology of the Marine Environment (ICBM), University of Oldenburg
Dr. Gerd Kraus	Johann Heinrich von Thünen-Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI), Braunschweig
Prof. Dr. Karin Lochte Prof Dr. Dieter Wolf-Gladrow Prof. Dr. Karen Wiltshire	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven
Dr. Rolf Peinert	German Marine Research Consortium (KDM)
Prof. Dr. Ralph Schneider Prof. Dr. Roberto Mayerle	Kiel Marine Sciences (KMS), Center for Interdisciplinary Marine Sciences, Christian-Albrechts University Kiel
Prof. Dr. Michael Schulz Prof. Dr. Gerold Wefer Prof. Dr. Antje Boetius	Center for Amrine Environmental Sciences (MARUM), University of Bremen
Prof. Dr. Detlef Stammer Prof. Dr. Detlef Quadfasel	Center for Earth Systems Research and Sustainability (CEN), University of Hamburg
Prof. Dr. Bela Buck Prof. Dr. Boris Koch	Bremerhaven University of Applied Sciences
Prof. Dr. Thomas Schweder Prof. Dr. Martin Meschede	University of Greifswald
Prof. Dr. Gerhard Graf	University of Rostock, Department “Maritime Systems”
Dr. Jing-Song von Storch	Max Planck Institute for Meteorology, Hamburg

Prof. André Freiwald Dr. Achim Wehrmann	Senckenberg am Meer, Wilhelmshaven
Dr. Bernd Brügge	Federal Maritime and Hydrographic Agency (BSH), Hamburg
Dr. Christian Reichert	Federal Institute for Geoscience and Natural Resources (BGR), Hannover
Dr. Götz B. Reinicke	Deutsches Meeresmuseum, Stralsund
Prof. Dr. Hildegard Westphal Prof. Dr. Matthias Wolff Dr. Helen Pfuhl	Leibniz Center fro Tropical Marine Ecology (ZMT), Bremen
Ministries	
Dr. Heide Ahrens	Ministerium für Bildung und Wissenschaft Schleswig-Holstein
Dr. Christian Alecke	Federal Ministry of Education and Research (BMBF)
Dr. Walter Dörhage	Senatorin für Bildung und Wissenschaft der Freien Hansestadt Bremen
Herr Rüdiger Eichel Dr. Marcus Beiner	Ministerium für Wissenschaft und Kultur Niedersachsen
Dr. Birgit Gruner	Behörde für Wissenschaft und Forschung Hamburg
Herr Holger Wandsleb	Ministerium für Bildung, Wissenschaft und Kultur Mecklenburg-Vorpommern

Appendix F

Stellungnahme der Wissenschaftlichen Kommission Niedersachsen (WKN) zum Bericht “Structural Analysis of Marine Research in Northern Germany”

Die Wissenschaftliche Kommission Niedersachsen hat den Ergebnisbericht zur Strukturanalyse der Meeresforschung zur Kenntnis genommen, beraten und verabschiedet. Die WKN dankt den Mitgliedern der Expertengruppe und insbesondere dem Vorsitzenden, Herrn Prof. Dr. Dr. h. c. Ernst Th. Rietschel, für das außerordentliche Engagement in diesem komplexen, zeitintensiven Verfahren und für die wertvollen Analysen und Empfehlungen. Die WKN schließt sich den Empfehlungen der Expertengruppe nachdrücklich und vollständig an.

Die WKN begrüßt insbesondere die geplante Fokussierung auf eine gemeinsame, koordinierte Bearbeitung von Themen, wobei eine inhaltliche Weiterentwicklung und Flexibilität in der Themenauswahl gewährleistet sein sollte. Allerdings muss auf Grundlage der vorhanden disziplinären Expertise der für die Bearbeitung globaler und gesellschaftlich relevanter Herausforderungen notwendige interdisziplinäre Forschungsansatz noch viel stärker herausgearbeitet werden.

Die WKN stimmt darüber hinaus mit der Expertengruppe überein, dass eine Neustrukturierung der Koordinations- und Entscheidungsstruktur der deutschen Meeresforschung zukünftig unabdingbar sein wird, vorausgesetzt, man will sich jenseits der bestehenden Leistungsfähigkeit zu einem „Global Player“ weiterentwickeln. Die neuen Koordinations- und Entscheidungsstrukturen müssen von Partizipation und Transparenz gekennzeichnet sein. Zusätzlich zu den ausgeprägten individuellen wie einzelnen institutionellen Vernetzungen bestärkt die WKN die Einschätzung des Vorsitzenden der Expertengruppe, dass die deutsche Meeresforschung im Ergebnis einer neuen Governancestruktur mit einer Stimme sprechen sollte, um ihre Belange und Leistungen wirksam gegenüber den Fördermittelgebern und weiteren gesellschaftlichen Akteuren vermitteln zu können. Die Beschlüsse sollten zunächst gemeinsam aus der Wissenschaft heraus entwickelt werden, um sodann in die politischen Gremien eingebracht zu werden. Nach der Koordination in der Wissenschaft ist auf der nächsten Stufe dann auch die Koordination auf Länderebene unabdingbar, um gegenüber dem und mit dem Bund gemeinsam agieren zu können.

Bei der Neustrukturierung der Koordinations- und Entscheidungsstruktur sollte aus Sicht der WKN geprüft werden, ob für spezifische Problemfelder weitere Akteure be-

rücksichtigt werden müssten. So sind für die Belange der Meeresforschung neben dem BMBF z. B. auch das BMELV und andere Ressorts zuständig.

Aus Sicht der WKN sind neben den im Bericht hierfür vorgeschlagenen Organisationsformen ggf. auch andere Möglichkeiten denkbar. So könnte das im Laufe der Strukturanalyse verworfene Modell einer Stärkung des „Konsortiums Deutsche Meeresforschung" (KDM) und dessen Ausstattung mit einem relevanten Budget zur Finanzierung gemeinsamer For-schungsvorhaben der Einrichtungen in den Augen der WKN eine denkbare Alternative darstellen. Dies wäre jedoch beim Aufbau neuer Governancestrukturen nur bei gleichzeitiger Etablierung effektiver Kontrollmechanismen denkbar.

Die WKN bekräftigt die Empfehlung der Expertengruppe, in ca. drei Jahren eine Folgeevaluation durchzuführen, bei der zum einen die ausgearbeiteten Konzepte hinsichtlich ihrer wissenschaftlichen Qualität evaluiert und zum anderen die Leistungsfähigkeit der geschaffenen Organisationsformen überprüft werden sollten. Diese Reevaluation ist nach Einschätzung der WKN unbedingt erforderlich, um einerseits dem schwierigen Koordinationsprozess genügend Zeit einzuräumen und andererseits der Notwendigkeit einer Neustrukturierung Nachdruck zu verleihen.

Die WKN hebt hervor, dass die von der Expertengruppe für die Meeresforschung herausgearbeiteten Probleme der Fragmentierung und Heterogenität auf Ebene der institutionellen Anbindungen, Förderstrukturen und Länderinteressen symptomatisch für die deutsche Wissenschaft im Allgemeinen sind. Eine neue Organisationsform der Meeresforschung, die eine Erhöhung der Struktureffizienz und bessere Nutzung der institutionellen, methodischen und thematischen Vielfalt erzielt, könnte daher als Modell für weitere Wissenschaftsgebiete mit einer ähnlichen Problematik gelten. Mit dem KDM hat die Meeresforschung bereits jetzt beste Voraussetzungen diesen neuen Weg konsequent einzuschlagen.

Appendix G

Abbreviations

BAW	Federal Waterways Engineering and Research Institute / Bundesanstalt für Wasserbau; Hamburg
BGR	Federal Institute for Geosciences and Natural Resources / Bundesamt für Geologie und Rohstoffe; Hannover
BMBF	Federal Ministry of Education and Research / Bundesministerium für Bildung und Forschung; Bonn and Berlin
BSH	Federal Hydrographic and Maritime Agency / Bundesamt für Seeschifffahrt und Hydrographie; Hamburg
CEN	Center for Earth Systems Research and Sustainability / Zentrum für Erdsystemforschung und Nachhaltigkeit; Hamburg
CIRM	Interministerial Commission for Ocean Resources
CliSAP	Integrated Climate System Analysis and Prediction (Clusters of Excellence)
CMAR	CSIRO Marine and Atmospheric Research
CSC	Climate Service Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Department MTS	Department Maritime Systems (Rostock University)
DFG	German Research Foundation / Deutsche Forschungsgemeinschaft; Bonn
DIVERSITAS	International Programme on Biodiversity
DKK	German Climate Consortium / Deutsches Klima-Konsortium e.V.; Berlin
DKRZ	German Climate Computing Centre

DMM Stralsund	Deutsches Meeresmuseum Stralsund
DSMZ	German Collection of Microorganisms and Cell Cultures (Leibniz Institute)/Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH; Braunschweig
DZMB	German Center for Marine Biodiversity Research (SaM)
EFRE	European Fund for Regional Development
ESSReS	Helmholtz Research School on Earth System Sciences
EUROPROX	European Graduate College Proxies in Earth History
FOE	Thünen Institute of Fisheries Ecology
FSK	Forschungsstelle Küste
FZ Jülich	Forschungszentrum Jülich GmbH
FZK	Coastal Research Centre/Forschungszentrum Küste
GCMB	German Centre for Marine Biodiversity
GEOMAR	Helmholtz-Centre for Ocean Research Kiel
GFZ	German Research Centre for Geosciences / Deutsches Geoforschungszentrum; Potsdam
GLOMAR	Global Change in the Marine Realm
HELCOM	Helsinki Commission – Baltic Marine Environment Protection Commission
HGF	Helmholtz Association/Helmholtz-Gemeinschaft
HZG	Helmholtz Centre Geesthacht
HZI	Helmholtz Centre for Infection Research
IFREMER	Institut français de recherche pour l'exploitation de la mer

ifw-Kiel	Kiel Institute for the World Economy / Institut für Weltwirtschaft an der Universität Kiel; Kiel
IMaB	Institute of Marine Biotechnology e. V.
IMARE	Institute for Marine Resources GmbH; Bremerhaven
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research
IMMH	International Maritime Museum Hamburg/Internationales Martimes Museum Hamburg; Hamburg
IMPRS MarMic	International Max Planck Research School for Marine Microbiology
IMPRS-ESM	International Max Planck Research School for Earth System Modeling
IMPRS-MA	International Max Planck Research School for Maritime Affairs
INTERCOAST	Integrated Coastal and Shelf Sea Research
IOC	Intergovernmental Oceanographic Commission of UNESCO
IODP	Integrated Ocean Drilling Program
IOW	Leibniz Institute for Baltic Marine Research Warnemünde
IPCC	Intergovernmental Panel on Climate Change / Zwischenstaatlicher Ausschuss für Klimaänderungen (Weltklimarat); Genf, Switzerland
ISOS	Integrated School of Ocean Science
KDM	German Marine Research Consortium/Konsortium Deutsche Meeresforschung; Berlin
LIAG	Leibniz Institute for Applied Geophysics/Leibniz Institut für angewandte Geologie; Hannover
LWI	Leichtweiß-Institut für Wasserbau/Leichtweiß-Institute for Hydraulic Engineering and Water Resources
MARUM	Center for Marine Environmental Sciences

MPI-M	Max Planck Institute for Meteorology
MPI-MarMic	Max Planck Institute for Marine Microbiology
NIhK	Lower Saxony Institute for Historical Coastal Research
POLMAR	Helmholtz Graduate School for Polar and Marine Research
PTB	Physikalisch-Technische Bundesanstalt; Braunschweig
PTJ	Projektträger Jülich
SaM	Senckenberg am Meer
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
UFZ	Helmholtz Centre for Environmental Research / Helmholtz-Zentrum für Umweltforschungszentrum; Leipzig
ZMT	Leibniz Center for Tropical Marine Ecology