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Building Bridges at the Science-Stakeholder Interface

Towards Knowledge Exchange in Earth System Science

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Building Bridges at the Science-Stakeholder Interface

Towards Knowledge Exchange in Earth System Science

Springer

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ISSN 2191-589X ISSN 2191-5903 (electronic)
SpringerBriefs in Earth System Sciences
ISBN 978-3-319-75918-0 ISBN 978-3-319-75919-7 (eBook)
https://doi.org/10.1007/978-3-319-75919-7

Library of Congress Control Number: 2018932518

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

The role of societal relevance of Earth system science at the onset of the Anthropocene

Global change presents an enormous challenge for the future stability of societies and also for the work of science. In this respect, important tasks for science are the assessment of potential risks and discussions with stakeholders on how to mitigate, avoid or respond to negative developments. Hence, it requires a change of scientific approaches in many ways. This does not imply that all of science has to serve in a direct manner to societal needs, but that an increasing awareness and contribution to the challenges of the Anthropocene are necessary.

What does this mean for Earth system science? First of all, it means that there needs to be a more intense exchange with different actors of society. Relevant issues have to be defined both from the side of the society and from science, and by this interaction, the research should reflect a joint approach. Earth system research questions cannot be resolved by natural science alone, but require close collaboration with other fields, such as social sciences, law, politics, economics, technology and many others. Finally, effective communication of scientific knowledge to stakeholders is essential to raise awareness, establish meaningful dialogues and develop solutions. Scientists recognize this need of communication, but despite many efforts it is still felt to be insufficient.

This book gives an overview of different activities of the Earth System Knowledge Platform (ESKP) at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research to enhance knowledge transfer and dialogues with various societal actors. It spans data products and modelling with relevance for society, as well as different forms of exchange with stakeholders. It shows how natural science research is making an effort to address societal challenges in Earth system science. I hope that these examples stimulate many people from science and society to expand and to develop new approaches to societal relevant research, to knowledge transfer activities, and to improve scientific advice in the Anthropocene.

Karin Lochte

Acknowledgements

First, we gratefully acknowledge the funding from the Helmholtz Association Portfolio Topic ESKP, which has acted as the central pillar and driver for moving towards explorative knowledge transfer processes.

The staff in the ESKP Coordination Office at the Helmholtz Centre Potsdam (GFZ), German Research Centre for Geosciences, is thanked for their commitment to the development of an overarching platform under which the knowledge of all HGF Institutes in the Research Field Earth and Environment are collated. Our collaborators at the other research centres, at the German Aerospace Centre (DLR), at the Research Centre Jülich (FZJ), at the GEOMAR Helmholtz Centre for Ocean Research Kiel, at the Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research (HZG), at the Karlsruhe Institute of Technology (KIT) and at the Helmholtz-Centre for Environmental Research (UFZ) are thanked for fruitful engagements and a very collegial working atmosphere.

Without the willingness of our various stakeholders to embark on this journey with us, the topics and successive research efforts would not have taken place to this extent. There have been numerous exchanges, ranging from fisherfolk along the North Sea coast, multiple authorities and governmental institutions, NGOs as well as private sector representatives, to name but a few. Without their curiosity, energy and motivation to share their knowledge and perspectives outside their direct realm of everyday work, knowledge dialogues between science and society would not be possible.

On a more personal note, this book would not have been possible without the tremendous support of all colleagues of the Alfred Wegener Institute (AWI), but also by the various stakeholders that all have supported in one way or another, our effort to bridge science and society in the meaningful exchange and transfer of knowledge.

We take this opportunity to also acknowledge the support and involvement of some people very central to this initiative. First and foremost we thank the former director of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Prof. Dr. Karin Lochte, for her wonderful continuous support and trust in our knowledge transfer efforts! Without her positive and supportive attitude, utilizing the available funding to conduct exploratory projects on knowledge transfer in this somewhat unique way would not have been possible. We acknowledge also the continuation of this positive support by the AWI's new director, Prof. Dr. Antje Boetius, and we look forward to her ongoing engagement with this initiative.

Warm thanks also go out to Dr. Heike Wolke and Dr. Karsten Wurr, the former and current administrative directors of the Alfred Wegener Institute for their ongoing support and for making the rather unusual project setups possible. In this regard, also a special "thank you" to Carlo Ungermann and Astrid Feuster from the finances division who supported us with always good spirits and a cheerful smile whilst tackling the everyday handling and challenges of the ESKP@AWI projects. Dr. Angelika Dummermuth is thanked for her willingness to readily share her expertise and insights into the particularities of Helmholtz administration whenever it was needed.

Prof. Dr. Thomas Jung is greatly acknowledged twofold for his support—first, in his role of being the head of the Climate Dynamics section and his openness to link ESKP@AWI to his research team, but also secondly, and more importantly, providing his continuous support as responsible spokesperson for the research programme PACES II (Polar Regions and Coasts in the Changing Earth System) of the AWI.

We record also our appreciation for conversations with Stefanie Klebe, whose thoughtful and creative insights into knowledge transfer were especially valuable. Without these discussions, a lot of activities of ESKP@AWI would not have moved forward in this way. This also holds true for Maximilian Schupp, whose ideas and efforts in addressing the issue of how to capture knowledge transfer are gratefully acknowledged.

Dr. Annette Breckwoldt is wholeheartedly thanked for her great efforts in pulling the necessary strings to finalize this book and being a great reviewer to all of the chapter contributions. Without her energy and mindful comments, this book would not present itself in this state. Paul Waite is thanked for his swift and thoughtful revisions of several chapter contributions of this book to "tidy" the language.

Last but certainly not least, we gratefully acknowledge the courage of our fellow researchers at the AWI, who were willing to embark on untested knowledge transfer waters! Without their trust, courage, curiosity and collegiality, our work and this book would not have been possible!

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Setting the Scene

The Anthropocene—What Does It Entail for Science?

Gesche Krause

1 Introduction

Science permeates almost every aspect of modern life, sometimes in obvious and sometimes less obvious ways. Societies largely trust and expect science to inform debate, advance the standard of living and solve problems as they emerge. The Paris Climate Agreement (UN 2016) is an epitome of this *Zeitgeist* as policy makers, distinguished members acting as an extension of society, demonstrated their trust in the consensus of the scientific community and shaped future policies to tackle the predicted effects of climate change accordingly.

Humans interact with their environment in manifold ways; changing it and in turn, are themselves changed by it. However, these human-nature relationships are increasingly becoming more complex. This is reflected in the emergence of the term "Anthropocene" (Crutzen 2002), which has seen ever-increasing attention since the beginning of the new millennium. While the term is most often used in the realm of geology to discuss human impact on the Earth's geology and ecosystems, there is now a growing breadth in the discourse within Earth System Sciences (IGBP 2015). For the latter, focus has shifted away from the rather stringent search for criteria that distinguish the various geological epochs of the Earth's history, towards the identification of changes in the earth system, as voiced through the 'planetary boundary' discourse (Hamilton et al. 2015; Görg 2016). Taking account of the planetary-level thresholds, beyond which mainly anthropogenic environmental change endangers the "safe operating space" for humanity (Rockström et al. 2009), several biophysical components of the Earth System have reached a point of transition beyond threshold levels. Changes in climate, hydrological cycles, food systems, sea level, biodiversity, ecosystem services and other factors depend on the

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sensitivities of different components of the system. So far, these component changes are vastly outpacing our response capacities to mitigate drivers of global change. Furthermore, the "Anthropocene"entails a political aim: to motivate action and foster new efforts to combat climate change.

From a scientific standpoint, the "Anthropocene" discourse thus highlights the emerging agreement that current societal challenges require new ways of knowledge production and decision-making. One key aspect of science, therefore, is the involvement of actors from outside academia into the research process (i.e., transdisciplinary research), in order to integrate the best available knowledge, reconcile values and preferences, as well as to create ownership of problems and solution options (Lang et al. 2012).

Indeed, the growing interdependence of nature and society is a historical *fait accompli,* and conclusions about e.g., interdisciplinary and applied social-ecological research are drawn on this basis (Glaeser et al. 2009). That said, over the course of time, the formats of science-policy-public communication have undergone massive transformations. In the 1980s, communication was determined by "Public Understanding of Sciences" (PUS), by which emphasis was placed on advertisement for science among young academics as well as promoting a higher acceptance for science and technology at large. The basic assumption was that by improved education and information, the acceptance of science (predominately of natural sciences) would automatically increase. Over the course of time, this somewhat paternalistic view has proven wrong: better knowledge does not readily lead to better acceptance (Amel et al. 2017). This has resulted in a remarkable shift to a more two-way dialogue format between the academic knowledge realms of science and other knowledge realms of various stakeholders from the private and public sectors. The current efforts towards co-framing science present a case in point.

These widespread efforts are however, still in nascent stages in the sense of how relevant processes at this interface can be captured and evaluated. Thus the efforts of research on the necessary criteria and indicators of good (i.e. successful) knowledge exchange can be viewed as a first step toward a meaningful engagement between the different realms of knowledge. These efforts follow the plea of the ground-breaking article on sustainability science by Kates et al. (2001), which states that "participatory procedures involving scientists, stakeholders, advocates, active citizens, and users of knowledge are critically needed" (p. 641). Key arguments for this new type of research collaboration are that today's societal challenges require the constructive input from various communities of knowledge to ensure that all knowledge essentially related to the problem is incorporated. Additionally, research on solution options requires knowledge production beyond problem analysis, as goals, norms, and visions need to provide guidance for transition and intervention strategies. Fostering collaborative efforts between and among researchers and non-academic stakeholders alike promises to increase legitimacy, ownership, and accountability for the specific challenges, as well as for the solution options (Funtowicz and Ravetz 1993; Hirsch Hadorn et al. 2006; Lang et al. 2012).

In this book, we employ the recently developed definition of knowledge exchange by the German Helmholtz Association of German Research Centres (HGF 2016). This definition was developed through a series of workshops across the various Helmholtz Research Centres by representatives of the working group on knowledge transfer. Hereby the terms knowledge transfer and knowledge exchange are used interchangeably. In addition to the formulation of this joint definition, a concept paper was developed that outlined strategic steps to foster knowledge exchange/transfer throughout the association. During these deliberations, a strong connection between knowledge and technology transfer was recognized, in that they can both address economic stakeholders. Yet, while technology transfer possesses an inherent focus on fostering innovation and creating immediate economic value, knowledge transfer in this definition refers foremost to the processes acting between science and society.

These processes include:

- The transfer of/or the exchange of knowledge with members and societal institutions, as well as political representatives;
- The capability of the addressed target groups to make decisions on the basis of the best available scientific evidence;
- Embracing an own, target-oriented translation effort;
- The utilization of different formats, channels or instruments, which reflect the specific needs of the target audience;
- The unidirectional or increasingly dialogic nature of knowledge transfer; and
- The development and implementation of joint research projects as a result of the dialogue.

Target groups are manifold and can range from scientific communities, to policy makers, to NGOs, to the economy, to the media or simply to interested public stakeholders. Drawing on this definition, a dialogue with society and policy-makers is one precondition for the orientation of the German Helmholtz Association's dedication to pursue its long-term research goals. One such goal is to contribute substantially to solving the grand challenges of science, society and industry, which is reflected in the Helmholtz Mission Statement (HGF 2017).

In this light, this core role of science, coupled with the increased awareness of pressing societal issues in the information age, has given rise to a call for a new social contract between science and society. Science is called to arms to help meet society's "grand challenges" as reflected by the Sustainable Development Goals of the United Nations in 2015, in exchange for continued endorsement.

In traditional research activities in natural sciences, scientific publications remain the output of the research process and constitute one central measure in the evaluation process of research institutes or centres. In contrast to this, the output, outcome and especially the impacts of knowledge transfer activities are much less tangible. The ongoing considerations on how to find ways of assessing and evaluating knowledge transfer activities and dialogue processes are crucially important, yet complex. This is especially due to the wide diversity and variety of knowledge transfer in terms of, e.g., aims, content, stakeholders addressed and the timeline of the activities. This makes it almost impossible to capture and access knowledge transfer and dialogue processes by using traditional metrics and indicators, which in itself limits the existing potential strengths knowledge transfer processes possibly inherit.

To this end, this book contributes to the ongoing discourse by highlighting the potential pathways of knowledge exchange to fill some of the gaps in our understanding of how to capture, measure and evaluate these efforts at the science-stakeholder nexus.

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The Role of Knowledge Exchange in Earth System Science—The Earth System Knowledge Platform (ESKP)

Gesche Krause, Ute Münch, Jana Kandarr, Oliver Jorzik and Pia Klinghammer

In 2015, the UN 2030 Agenda for Sustainable Development expressed the commitment to protect the planet from degradation and take urgent action on climate change. These goals stress the need (for everyone) to act in order to combat climate change and its impacts, as well as to conserve and sustainably use the land and oceans of our planet. These grand challenges are mirrored in the research field "Earth and Environment" of the Helmholtz Association of German Research Centres (HGF). Central research efforts encompass the following four areas: "Earth system dynamics and risks", "Climate variability and climate change", "Ecosystem dynamics and biodiversity", and "Sustainable use of resources".

However, whether societies are able to achieve the required changes rather sooner than later, will largely depend on how effectively scientific knowledge is

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G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs
in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_2

exchanged and embraced, thus linking research efforts in a meaningful way to societal concerns and priorities. The HGF has taken up this challenge and entered this societal contract by promoting knowledge transfer and translation, and showcasing societal relevance throughout its centres. On this basis, the "Earth System Knowledge Platform" (ESKP) concept was initiated in 2012 and its successive steps towards a web-based online platform were undertaken in May 2014.

ESKP bundles the information and knowledge of eight institutes of the HGF within the research field "Earth and Environment" (see also www.eskp.de). ESKP was established as a platform in which the expertise of centres that conduct research on earth system issues can be combined and synthesized, thus acting as an integrative platform of knowledge. From the outset, ESKP focussed on combining knowledge on the various aspects of climate change, providing insights into various aspects of pollution, as well as showcasing research insights of natural earth system hazards, such as earthquakes, volcanoes and tsunamis. By offering scientifically grounded knowledge, ESKP aims to develop topic-specific translation and contextualization of knowledge. Highly reliable information is presented throughout the ESKP-Platform, rendering it a valuable feature in present times. Every single scientific contribution is thoroughly checked by Helmholtz scientists. Other important tools to convey knowledge are professionally designed infographics, all of which can be used openly under the creative commons license.

One example for such infographics is the simplified representation how micro-wave sensors differentiate between sea-ice types in the Arctic (Fig. 1).

In 2016, the knowledge platform was amplified by the topic, "Energy transition and environment". It was included on the ESKP platform to respond to the increasing societal requests to the German *Energiewende*. To further integrate

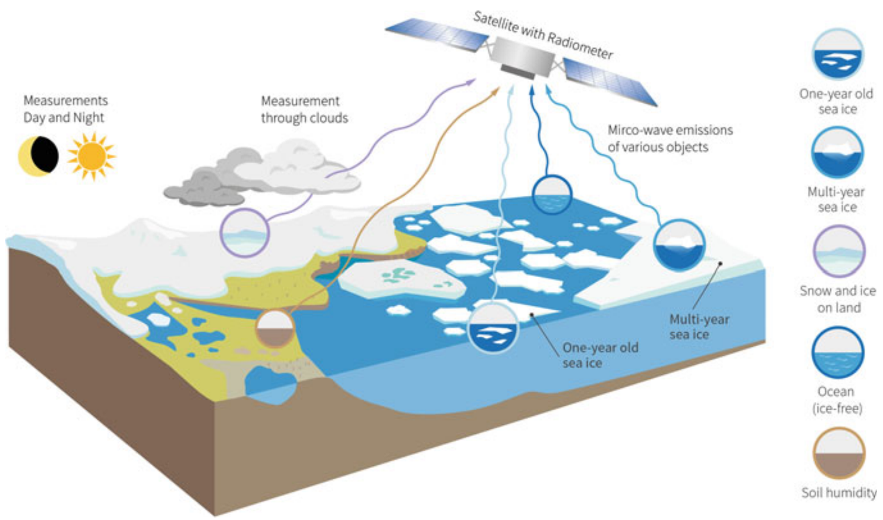

Fig. 1 Simplified representation of how micro-wave sensors capture different sea-ice types in the Arctic Region (cc-by4.0)

research conducted at various research institutes, and to raise awareness for the interdependency of seemingly independent topics, ESKP is creating another platform called *Themenspezial* (focus topics). It will especially highlight scientifically-based options for actions in order to enable society and decision-makers to tackle the "Grand Challenges".

So far, the web-platform has seen continuously increasing interest, as indicated by the positive trend of number of visits to the web-platform (via click numbers) and the download statistics of the various data products offered by the ESKP platform. This is a very encouraging outcome, bearing in mind that this platform is still in rather nascent stages. In 2016, new formats were introduced, e.g., an "Interview of the month", "Policy papers", or "Science-GIFs", in order to diversify the potential outlets for knowledge exchange. Furthermore, ESKP hosts its own social media channels to further promote relevant Helmholtz research topics.

Indeed, ESKP is developing into a synthesis platform for the entire research branch of "Earth and Environment" of the HGF. In the near future, the objective is to channel the efforts to develop scientifically sound and shared positions on socially relevant topics under the joint umbrella of an "Earth System Alliance". This is extremely timely, as present social and ecological developments demand different scientific expertise concerning the environment than they did half a century ago (Markus et al. 2017). For instance, a growing world population, technological advances, and globalising markets increasing demand for raw materials have led to "the industrialisation of the oceans" (Smith 2000). Consequentially, competition over watercourses, fisheries, mineral and biological resources have escalated and led to environmental, distributional, and geostrategic conflicts—a trend which is likely to continue into the future (German Advisory Council on Global Change (WBGU) 2013).

In conclusion, as the global political environment is changing, the relationship between science and policy-making is rapidly changing too, leading to a paradigm shift from output to outcome of research findings. Via the instrument of ESKP, it is hoped to initiate and facilitate dialogues and continuous exchange with policy makers, the private sector industries, as well as NGOs and the general public—via the preparation of recommendations, outlining potential courses of action and providing scientifically supported advice to inform policy deliberations.

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The AWI Approach at the Science-Stakeholder Interface

Gesche Krause, Klaus Grosfeld and Wolfgang Hiller

1 Introduction

Over recent years, the importance of knowledge transfer and dialogue processes in the field of earth system sciences has received increased attention. As the fundamental basis for discussion in areas ranging from climate change to the sustainable use of resources, the task of transferring earth system science knowledge into decision making processes and to society whilst acknowledging their respective priorities is both a vital and urgent challenge. The Alfred Wegener Institute for Polar and Marine Research (AWI), as part of the Helmholtz Association (HGF), is responding to this challenge, having established knowledge transfer as a specific research unit within its broader research program. This unit addresses the research topic "Bridging science and society—products, tools and climate services" and examines the exchange of knowledge between science and society (including representatives of politics, administration, business, industry, civil society, education and media). In addition to providing scientifically-based knowledge, the various research workpackages of the AWI focus on target-specific translation and the contextualization of knowledge. Utilizing this research approach, continuous and meaningful interactions between science and stakeholders on various levels are promoted. These interactions help to structure the research agenda and validate pivotal findings in response to stakeholder needs and their priorities.

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This increasing demand for knowledge transfer in the Helmholtz Association's research field 'Earth and Environment' also led to the HGF Initiative 'Earth System Knowledge Platform' (ESKP) in 2012. The initiative was welcomed as an opportunity for AWI to develop a unique, tailored ESKP@AWI strategy as part of the program-oriented research structure. A central focus for the strategy was to strengthen knowledge transfer capacities in the institute whilst acting as an explorative tool for science-stakeholder interactions. AWI's view is that meaningful engagements at the science-stakeholder nexus can only be achieved by creating and facilitating an environment and processes that acknowledge and support the necessary research and activities therein. To this end, fostering a culture that promotes and recognizes knowledge transfer as a critical activity has been identified as a necessary central focus within the institute and as a consequence, a coherent strategy to develop that cultural element was developed. A series of workshops at multiple levels were conducted across AWI to articulate the visions of what knowledge transfer at AWI entails and what would be regarded as successful knowledge transfer outcomes for the institute in the context of its mission statement.

2 ESKP@AWI—Visions-Workshop

As one activity to establish a reflectional framework of ESKP@AWI, a 3-day workshop was conducted in 2013 with 19 scientists of various AWI scientific backgrounds and from different structural units. Participants were asked to identify what visions they had, how knowledge transfer should take place, and what steps should be taken to achieve a unified knowledge transfer notion.

A central focus was placed on the joint identification of scientific topics that were also of economic and social relevance. Additional selection criteria for the identification of central topics pertained to their unique feature and linkages within the Helmholtz Association, their product achievement and feasibility, their solid and long-term sustainable roots within the scientific research program of AWI as well as their potential development to create topic clusters.

As already existing central pillars with cross-section functionality suitable for ESKP, the workshop identified the North Sea Office, Climate Office for Polar Regions and Sea Level Rise, the Helmholtz Climate Initiative "Regional Climate Change" (RECLIM) as well as the Arctic-Dialogue, as drivers which have already served for a long time as an interface between science and society.

Workshop participants also agreed on the following thematic clusters as a first point of condensation: Permafrost, Biodiversity, Coastal Ecosystems, Sea Ice, Coastal Hazards and Pollutants. Several knowledge transfer projects emerged over the course of time in these research themes and are described in this book.

Through deliberations at the 'Visions workshop', potential avenues for the coordination, planning and determination of further steps within the ESKP process were identified. A central component of the workshop was a discussion of the specific ESKP@AWI planning questions, which were adapted for each topic cluster:

- **WHAT?** (Topic, Product, Idea …)
- **FOR WHOM?** (audience, "customers" …)
- **WHY/WHAT FOR?** (relevance for audience, social relevance, risks/chances for AWI, etc.)
- **HOW?** (arrangements, activities, development needs to create a demand-driven "product" for targeted audience)
  - **Context** of use (as App; discussion forum; Science Slam; Web Data portal; newsletter, etc.)
- **BY WHICH MEANS?** (demand of resources—persons, finance, equipment, etc.)
  - **how** is it implemented?
- **WHO** attends to each identified topic **UNTIL WHEN and** by **WHAT** (nomination of experts and responsibilities, development of milestones and products…)
- **WITH WHOM** (strategic partners—other Helmholtz Institutes, external partners…)

It surfaced during the workshop that such an integration towards knowledge transfer processes within the AWI could be described as a "journey" which entails a high level of "transaction costs". The latter indicates that knowledge exchange requires long-term intrinsic and continued motivation by all participants involved in such processes. In addition, it was recognized that capacities for closer integrative approaches needed to be gradually built-up. However, it was also identified that disciplinary expertise is a crucial structural element in this integrative research process, since these set the framework and the methodical approaches on a case-to-case basis for each topic.

One central outcome of the ESKP@AWI "Visions workshop" is the establishment of an internal "ESKP@AWI *Call for Tender*", which invites explorative and integrative project proposals, actively working at the science-stakeholder nexus and with a clear focus on stakeholders and knowledge transfer. These proposals cover ideas specifically addressing new and emerging topics of interest to science and society alike in an explorative manner and for which the attraction of third party funding is difficult. For all ESKP@AWI projects, it is mandatory to develop products for the central ESKP website as well as to participate in the accompanying research survey, thereby fostering the learning about knowledge transfer processes in a more streamlined fashion.

To highlight this tailored approach, the term "ESKP@AWI" was developed as a way to identify related activities and establish a context for knowledge transfer efforts at the AWI, as well as providing an identifiable "trademark" for AWI's approach. Several activities fostering new approaches and methods for tailored science-stakeholder interactions were subsequently initiated and these are presented in the next chapters. The ESKP@AWI *Call for Tender* both reflected and framed the institutional learning capacities, and provided a better understanding of the opportunities, internal workings and potential pitfalls of knowledge transfer activities and dialogues.

3 Embedding ESKP@AWI in an Institutional Enabling Framework

As noted earlier, we at AWI believe that meaningful engagements at the science-stakeholder nexus can only be achieved by creating and facilitating an environment and processes that acknowledge and support the necessary research and activities therein. We also recognize the importance of an organizational culture that promotes and acknowledges knowledge transfer effort. With that said, we also acknowledge that knowledge transfer at the AWI is not solely restricted to activity within the ESKP@AWI program. The development of a reflectional, enabling framework of science-stakeholder interactions and knowledge transfer requires support and activity by individual scientists. However, these individual activities need to be consistent with the strategy of the institute. Over the course of time, this principle has been firmly established and integrated in the many components at AWI that contribute to knowledge transfer and exchange processes in varying degrees. In this respect, efforts within the compiling and endorsing processes that are ongoing in the AWI research topic “Bridging science and society—products, tools and climate services” are central. Thus, a discourse on how to position the ESKP@AWI research topic on various levels within the institute was considered an essential first step. To this end, in September 2015 a ‘World Café’ exercise was conducted with 60 participants during the annual 2-day retreat of AWI’s senior management, including representatives of both the science and administration leadership, aimed at fostering a common understanding of knowledge transfer at AWI and the ESKP@AWI initiative.

Central to this exercise was the joint deliberations across all science disciplines represented within the institute about how knowledge transfer is defined, how it functions at the AWI and how it relates to the overall research programme of the institute. An adapted version of the World Café method was employed for this exercise. The World Café is a large group method, which contains a sequence of discussions at tables with 4–7 people seated at each table (Brown and Isaacs 2005). Each group addressed in a sequence of 20–30 min the same questions. The results of the discussions and new ideas were collected for later presentation and discussion.

One central finding of the World Café exercise was that knowledge transfer not only involves the provision of scientifically-grounded knowledge, but also the translation and contextualization of that knowledge in a manner appropriate to a targeted audience. This fosters stronger ownership of the knowledge generation process and results in a higher degree of acceptance amongst potential stakeholders, e.g. decision-makers.

Complementary to this finding, an internal continuous knowledge transfer working group of those colleagues working at interfaces to society was launched. The new group developed a common strategic and structural framework of knowledge transfer at AWI in respect to the research program and worked in close alignment with the overall developments related to knowledge transfer in the Helmholtz Association. The latter defined three main knowledge transfer fields of activity: (1) Information and advice, (2) Exchange of knowledge, (3) Capacity building as a guiding structure. The proposed framework was echoed in the ESKP@AWI efforts, thus generating a streamlined institutional approach from the individual scientist, the different research divisions up to the institute leadership and across the Helmholtz Association.

In addition, to further amplify the AWI knowledge transfer culture, a first 'Bridging science and society' knowledge transfer day was conducted in 2015 for all AWI colleagues. This event provided a forum for the demonstration and discussion of 'good practice' knowledge transfer examples, as well as the examination of challenges and barriers to effective knowledge transfer. This exchange process stimulated AWI colleagues to internalize knowledge transfer as an important part of their work. The outputs were fed back into the knowledge transfer culture working group and subsequently to the ESKP@AWI activities.

4 Visions-Revisited Workshop

Three years after the initial "Visions-workshop" on knowledge transfer, a AWI-internal ESKP@AWI 2.5-day retreat was conducted in autumn of 2016. In this workshop, dubbed the "Visions-revisited workshop", all colleagues engaged in ESKP@AWI activities and working at interfaces to society over the course of the years, exchanged and shared their experiences. Being a novel strategy in the AWI research program to actively connect all research areas in respect to knowledge transfer, it was felt that the ESKP@AWI approach enhances AWI science's position as an integral part of society and strengthens awareness and visibility of AWI's activities in this field.

In order to achieve a summarized overview of the diverse and manifold activities under the umbrella of ESKP@AWI, these were clustered according to their primary methodological focus into to three major groups, (a) dialogue formats, (b) data-products and (c) modelling. However, it needs to be emphasized that most ESKP@AWI projects did not utilize one of these methods, but more often, a suite of different methods was applied.

In addition, the experiences of ESKP@AWI at the interface to the administrative department were presented and discussed. This pertained to the views of the financial administration, as well as the research management administration. This discussion highlighted the need for a closer connection and collaboration between these two administrative bodies in order to meet the specific demands of ESKP in knowledge transfer, particularly in terms of reporting and accounting in general.

Overall lessons learned were synthesized and discussed jointly. Furthermore, potential next steps towards "ESKP@AWI 2.0" were outlined and central focus areas were identified, such as fostering novel structural elements by developing a stakeholder management system and a tailored reporting system for knowledge transfer projects, among others.

5 Outlook

The transfer of scientific knowledge into society in a dialogic manner is only possible if enabling and appropriate method competencies exist. This comprises the development of enhanced and tailored data products as well as data portals, and building capacities for co-development. In addition, an affirming environment that acknowledges and supports the necessary research and activities is indispensable for successful knowledge exchange. This ongoing support is reflected in the 14 ESKP@AWI projects, which have been funded since 2014, each covering a period of up to 24 months. Most of these are presented in the following chapters. From the onset, each knowledge transfer project was concomitantly investigated using a project process assessment framework as, in contrast to the traditional scientific processes, outcomes of knowledge transfer are less tangible. Based on these activities, a first set of criteria and related indicators could be developed internally, which may act as reflectional framework to support the assessment and evaluation of knowledge transfer processes at a natural science institute in the future.

Therefore, these accompanying research activities were exploring new grounds of how to capture knowledge transfer processes (Krause and Schupp 2018 submitted). This approach mirrored the understanding that processes that frame and drive knowledge transfer must be viewed as products themselves. The central goal was to increase our understanding on what type of processes are needed to support knowledge transfer projects of a fundamental natural science driven research institute, and how to assess and evaluate these in a consistent manner. The ESKP@AWI *Call for Tender* allowed a safe navigation space for interested scientists at the AWI who worked at the science-stakeholder interface to test, in an explorative format, new approaches and tools to engage in topical knowledge transfer activities. The current EU-level deliberations on Open Science—where strategy development and decision-making based on scientific evidence are exposed to feedback from key stakeholders—are well reflected by this approach and are a case in point. Thus, the enabling ESKP@AWI framework supports socially accountable policies and practices whilst maintaining interpretational sovereignty.

In the following sub-chapters, the central topics, processes and initial findings of the ESKP@AWI projects are summarized.

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Part II
Dialogue Approaches of ESKP Contributions to AWI Knowledge Transfer

Regional Awareness on Sea Level Rise Effects—What Do We Know About the South-Eastern North Sea Coast?

Nina Eschweiler, Tobias Dolch and Christian Buschbaum

1 Background

During the 20th century climate change proceeded fast, especially accelerated by industrialization. Burning of fossil fuels, deforestation, agriculture and ranching increased the amount of emitted greenhouse gases such as CO_2, which accumulate in the atmosphere and hamper the heat emission from surface of the Earth into the universe. This anthropogenic greenhouse effect leads to rising mean temperatures of the atmosphere and oceans and also results in accelerated melting of ice sheets and glaciers. This means primarily a surplus of freshwater input and together with thermal expansion of the ocean water bodies, this inevitably leads to sea level rise (SLR) on a global scale (Church et al. 2011, Rahmstorf et al. 2012, IPCC 2013).

So far, no consistent nor permanent solution exists to significantly reduce the emission of greenhouse gases, which would mitigate global warming. But even if a stabilization of greenhouse gas concentrations and emissions would be achieved, it is unavoidable that SLR will continue and increase unabated for a considerable time, conditioned by the thermal inertia of the climate system (Wigley 2005, Rohling et al. 2009, Meehl et al. 2012, Yin 2012).

Especially for coastal zones the consequences will be immense if some predicted scenarios will come true. The latest IPCC report (2013) gives new projections about sea-level changes and about which factors are likely to contribute most to increasing sea level and extreme event frequencies. Newly calculated estimates within different scenarios indicate a global mean SLR of about 26–97 cm until the end of the century. High-end scenarios (Vermeer and Rahmstorf 2009) forecast even up to 190 cm. In this regard it has to be noted that SLR is not spatially homogeneous (IPCC 2007a, 2013, Stammer et al. 2012), as its dimension is

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G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_4

affected by a multitude of different factors, which depend on morphological, physical or climatic conditions that can strongly vary locally and regionally.

Nevertheless, SLR will directly influence future development of the coastal regions. Human settlements and economically relevant areas at the coast are of particular human interest and rising water levels will affect the costs for their protection. This includes not only the costs to protect industry, agriculture and tourism but also to protect the coastal population itself. Furthermore, coastal areas accommodate a high diversity of plant and animal species living in a diversity of important habitats.

The North Sea with a mean depth of 93 m is a relatively shallow marine environment. Especially its sedimentary and flat south-eastern coast will be strongly affected by an elevated sea level. Increased water depths as well as high exposure are likely to entail enhanced hydrodynamics (waves, tidal energy), which can result in an increased intensity of extreme events. The southern coastline of the North Sea is also densely populated. For example, about 1000 inhabitants/km^2 are living in near-shore urban areas in The Netherlands and Belgium. As tourism and industry play a prominent role along the mainland and the islands, the coastline is protected by many different coastal defence strategies.

The Wadden Sea as the south-eastern coastal region of the North Sea is a shallow sedimentary coastal region comprising an area of about 9000 km^2 and exhibiting the largest connected tidal flat area of the world. Due to its unique ecological global value it was appointed as UNESCO world natural heritage site in 2009. The area is characterized by specific habitats and a unique biodiversity. Each year millions of migratory and endemic birds use the habitats of the Wadden Sea for breeding, feeding and resting. The shallow waters of the area function as an important nursery ground for shrimp and fish. Mammals like grey and harbour seals use high sands and intertidal sand banks to rest and nurse their juveniles. Tidal flats are home to ecologically important seagrass beds, and they provide habitat to many invertebrates such as annelids, molluscs, echinoderms and crustaceans, which live above and below the sediment surface. Salt marshes as supratidal habitats are spaciously distributed along the coastline between dikes and tidal flats. Despite of exhibiting extreme living conditions they offer habitat for a variety of plants and animals with special adaptation strategies. For example, about 800 species are restricted in their occurrence to this area.

The Wadden Sea and its ecological functions can be strongly influenced by a continuing SLR. For instance, salt marshes as well as intertidal areas might become permanently drowned. Due to hard coastal defence structures, the shoreline is artificially fixed and, thus, natural dynamics of sediments and species are interrupted. With a rising water level, intertidal habitats and their associated communities become squeezed between the sea and coastal protection structures.

Therefore, it is important to know what kind of changes might be accompanied by SLR and what consequences for the ecosystem might be possible, including impacts on species diversity, habitats as well as ecological functions. An improved understanding of the development of SLR itself and its effects on coastal zones of the North Sea are required to provide sustainable adaptation and mitigation measures that will be able to combine the protection of both socio-economic and ecological systems.

2 Scope and Motivation

In contrast to global SLR, regional sea-level changes are more difficult to predict and may differ by more than 100% from the global average. The predictions for a rising sea level along the North Sea coast are variable and range from 20–80 cm at the English and from 40–80 cm at the German North Sea coast until 2100. While uncertainties exist, and the expected rise is not uniform along the North Sea coast, these predictions provide the magnitude of the expected SLR for the entire North Sea region.

The impact of SLR on coastal zones strongly depends on the ecological sensitivity of the specific areas, the influence of socio-economic developments on coastal landscapes, as well as the coastal population awareness of potential risk and related preparatory measures. For example, it is assumed that about 60% of the human population inhabiting coastal lowlands of the neighbouring countries of the North Sea did not even know that they are living in an area strongly endangered by flooding. One reason could be that the coastal inhabitants totally rely on the coastal protection measures such as dikes and hard defence structures, which were built, improved and renewed since about 1000 years. This went along with a strong modification of the once natural transition zone from land to sea, which is today a product of human coastal protection activities in the south-eastern North Sea region.

A heavily modified coast is especially relevant with respect to SLR. Naturally, plants and animals are able to adapt to a moderately changing sea level, with the entire coastal system shifting landwards with rising water levels. This is nowadays often inhibited by man-made hard defence structures, such as dikes. They also prevent other land-sea interactions such as natural sediment fluxes, resulting in missing sediment transport to the hinterland. This is accompanied by a change and loss of natural habitats and has consequences for associated species communities. For example, increased hydrodynamics can cause an extensive loss of muddy tidal flats as the fine-grained sediments are getting re-suspended in the water column and do not accumulate on the sea floor anymore. Species adapted to the specific conditions of muddy flats are in danger of disappearing. Saltmarshes are also highly endangered by increased erosion and the same is true for seagrass beds in the higher intertidal zone, which are additionally threatened by increased hydrodynamics (Fig. 1).

Thus, a lot of potentially far-reaching ecological consequences of SLR exist for the North Sea region. However, when comparing the number of scientific studies dealing with the effects of SLR on a global scale as well as in the North Sea area, it is quite surprising that only a few studies investigate such ecological consequences (Fig. 2). Most publications are focused on causes, economic effects and projections, modelling and adaptations to SLR. This imbalance was the motivation to bring experts from different disciplines together by organizing a multidisciplinary workshop at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Wadden Sea Station Sylt, in November 2013.

Fig. 1 Eroding salt marsh in front of a dike on the island of Sylt in the northern Wadden Sea

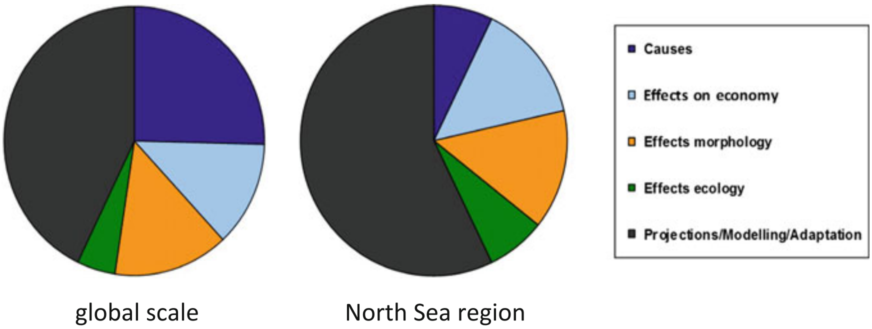

Fig. 2 Share of publications dealing with the categories: 1. causes of sea level rise 2. effects on economy 3. effects on morphology 4. effects on ecology and 5. projections, modelling and adaptations on the global scale (left) and the North Sea region (right). *Source* Web of Science by using above mentioned search criteria from 2007–2013

3 Materials and Methods

Often, natural scientists discuss their research activities primarily among colleagues of the same or similar field. SLR, however, is an issue with overarching implications. Cumulative as well as interacting effects are very likely. Thus, for a comprehensive assessment of SLR effects, it is essential to combine scientific knowledge of different disciplines. This is also the basis for the recognition and revelation of impacts that have not been previously known or considered. Therefore, one major aim of the workshop at the Wadden Sea Station Sylt was to detect the so far neglected consequences of SLR, such as changes in the ecology of the North Sea region and to raise awareness for the ongoing habitat loss of coastal and marine habitats among the stakeholders.

Workshop participants came from the south-eastern North Sea coastal states, namely the Netherlands, Germany and Denmark and consisted of experts in adaptation and mitigation strategies, SLR projections, sediment dynamics, coastal morphology and coastal ecology. Additionally, representatives from nature conservation associations, such as the World Wide Fund For Nature (WWF), presented their focus and perspectives. Current state-of-the-art research results were introduced in oral presentations and the outcome of each talk was intensively discussed among all participants.

4 Results

The presentations given in the course of the workshop identified several issues dealing directly and indirectly with global change and SLR in the North Sea region. A focus crystalized around the impacts on the coastal region with respect to current multidisciplinary scientific knowledge as well as adaptation strategies. The presentations were covering the following topics:

1. Global and regional SLR data, observed and projected, indicate that SLR is going along with climate change. SLR has many contributors, and not all are of anthropogenic origin. Next to thermal expansion and ocean mass changes there is still a notable amount of unknown components and, therefore, a number of remaining uncertainties exist. For example, glacial isostatic adjustment (GIA) and gravity processes are not sufficiently considered in SLR projections and predictions. GIA is the adjustment process of the earth when loaded with ice sheets. Heavy ice masses may cause subsidence of the earth crust and uplifting happens with decreasing pressure after the melting of ice sheets. In formerly glaciated regions this may cause a relative fall in SLR, as the rate of uplift is higher than the rate of SLR. These models require more details than available from current climate models.

2. The relative mean sea level (MSL) along the North Sea coast has been ascertained by tide gauge records since 1900. Due to the multitude and longevity of these records, the North Sea is worldwide one of the best regions to measure mean sea level projections (Dangendorf et al. 2014). Atmospheric forcing, due to shallow water levels of the North Sea was found to influence MSL even stronger than wind (especially in the southern and south-eastern region). Numerical models suggest that SLR will probably cause higher high tide water levels, faster tidal speeds and increasing erosion rates, including strong coastal morphological changes.

3. To understand sea level changes, it is necessary to understand the local variations of the Earth's surface. Relatively large-scale changes occur for example in the salt-dome provinces of northern Germany and northwest Denmark. Heavy deposits of plastic salt rise under high pressure, caused by tectonic movement and lift overlying sediment layers. A plausible geological explanation might be isostatic level changes (not just caused by GIA). Subsidence of the North Sea is assumed to occur due to strongly increased Quaternary sediment load of the North Sea and German Bight. If the modelled GIA-rates are reliable, the late Cenozoic isostatic system may account for about 70% of the present subsidence. Frequently unrecognized but normal geological "background noise" may account for inaccuracy of applied isostatic rates. In contrast to global absolute sea level (ASL) -rise and GIA, which usually and gradually decreased after the last glaciation, geological processes such as sediment compaction and tectonic movements can emerge at any time (Hansen et al. 2012).

4. Although there is an increased rate of SLR globally, a steady state seems possible, when SLR is balanced by vertical growth of a sedimentary coast. However, the availability of sand is crucial for this process. The Wadden Sea retrieves sand from the bottom of the open North Sea, which is transported by the tidal currents to the shallow areas and enables the coastal system to grow with the rising sea level. However, there is a so-called morphological tipping point, meaning that with a SLR of up to 5 mm/year, the system might be able to keep up with increasing water levels; but when the SLR is exceeding this rate, tidal flats will presumably drown. It has to be kept in mind that this threshold value is generalised for the entire Wadden Sea. As each tidal basin shows unique characteristics, they all have individual morphologic tipping points and the rate of SLR that can be balanced varies from one tidal basin to another.

5. As sedimentation is a key process for salt marsh existence in terms of SLR, they also depend on a continuous sediment supply. Various parameters may impact the accretion rate such as tidal inundation regimes, coastal vegetation structure and management, distance to sediment source and the structure of the tidal creek system. All these factors are strongly site-dependent. Data from Denmark, Germany and the Netherlands reveal that mainland marshes can better cope with a rising sea level than marshes on islands or holms. Although it could be ascertained that accretion rates are the same in sheep-grazed and ungrazed marshes, it is recommended not to keep grazers seaside in order to reduce soil compaction, which lowers the surface (Stock 2011).

6. Coastal habitats are essential for breeding and migrating birds. A continuous topographic model of the Danish Limfjord, which has been used as a pilot study, indicates substantial declines of mud flats, salt marshes and shallow-water macrophytes in the future due to coastal squeeze (Clausen et al. 2013). As a consequence of drowned coasts and an attended loss of feeding area, birds lose weight and the population of ground-breeding birds declines. An improved management of these areas at an early stage should improve the situation.

7. One major problem of adaptation to SLR is to integrate human safety and nature conservation. All over the world the development of coastal defence

structures temporarily protect humans, but in the long run, they neither serve as a permanent solution nor do they preserve natural habitats. Natural processes, such as coastal growth due to sedimentation, need to be maintained and (ideally) facilitated. One option is to open dikes and let tidal water and sediment reach areas in the hinterland where the sediment can accumulate. As many former tidal wetlands are embanked, one idea is to develop flexible inlets in the stone walls at the edge of a dike to enable sediments to drift inside with high water levels during winter times. The inlets should be closed during summer times to allow grazers in the areas. Thus, coasts may need to get reconstructed and human lifestyles need adaptations to cope with rising water levels.

8. About 59% of the area of The Netherlands is highly endangered by flooding (IPCC 2007b). In order to protect the dense human population, multiple strategies are carried out. To maintain the hinterland, the water system is strongly regulated by hundreds of locks, sluices and pumping stations. Even if the threat is not acute, measures to improve flood risk management and water supply should be prepared. The Dutch Delta Program is a national program, in which the central government, provinces, municipal councils and water boards work together, also involving social organisations and the business community. The main goal is to implement basic safety for coastal cities and communities and to prevent large scale economic damage. In this regard, five Delta decisions had been made for 2015 such as the discharge of water from the lake Ijssel into the Wadden Sea.

5 Reflections and Lessons Learned

Global climate change and associated effects such as rising water levels are of growing concern and relevance to the human population from the local to the regional and global scale. This is especially true for people directly affected by SLR and other effects of climate change. However, a lot of uncertainties exist how impacts of SLR affect specific regional coastal areas, such as the North Sea region. Coastal communities and other stakeholders regularly ask the scientific community for sea-level predictions and scenarios as well as their respective impacts. Adequate answers can often not be given, especially where information on ecological consequences are required. This is partly a consequence of the relatively low number of scientific studies dealing with the impacts of SLR on biota and habitats (Fig. 2). This gap of knowledge was invariably identified at the workshop at AWI. Additionally, all participants realized that conventional adaptation and protection measures (e.g., hard coastal protection measures such as dikes) are often not the best options for a sustainable, nature-compatible and cost-effective handling of the North Sea coast under SLR. Thus, innovative ways of thinking and strategies are essential to achieve an integration of human- and nature-oriented coastal protection. New ideas were intensively discussed in the course of the workshop (see results section) but it remained difficult to assess, whether identified alternative methods can also be implemented and find consideration by both stakeholders and policy makers.

Two important reports were published in 2015, both dealing with scenarios for a nature-compatible adaptation to SLR in the European Wadden Sea. The report *Strategie für das Wattenmeer 2100* (engl. Strategy for the Wadden Sea 2100, Fig. 3) was published by the Ministry of Environment of Schleswig-Holstein and contains several biological projections next to future scenarios of the development of climate, hydrology and coastal morphology (MELUR 2015). The effects of SLR on biota and habitats are intensively considered in this report. Furthermore, it contains new strategies for coastal protection measures. For example, the authors strongly recommend using sand replenishment at the coast instead of hard defence structures, which is much more nature-compatible. Sand is taken from the sea floor and flushed on the shore in order to replace sand losses caused by storm events. Sand is a natural material of the shores environment, which allows flexible adaptation of the shoreline to SLR and sandy shores provide a natural habitat for plants and animals. Similar conclusions are also given in the report *Klimaanpassung an weichen Küsten* (engl. Climate adaptation on soft-sediment shores), published by the World Wide Fund For Nature Germany (Fröhlich and Rösner 2015). It contains recommendations for alternative adaptation strategies that were gained by considering and carefully analysing several case studies conducted in Europe and the United States. The majority of authors and contributors of both studies were also participants of the AWI workshop in 2013.

Fig. 3 Key publications dealing with adaptation strategies on a rising sea level at the German North Sea coast. Strategy for the Wadden Sea 2100 published by the Ministry of Environment of Schleswig-Holstein (left) and Climate adaptation on sedimentary shores published by the World Wildlife Fund Germany (Fröhlich and Rösner 2015, MELUR 2015). Both reports were published in 2015 and contain new ideas for coastal and nature protection, which were intensively discussed at the multidisciplinary workshop on sea level rise held at AWI on Sylt in 2013

6 Summary and Outlook

Sea level rise (SLR) is one of the main risks caused by climate change. Even though public and scientific awareness and knowledge of these topics have strongly increased since the 1990s, there are still a lot of uncertainties and unanswered questions, especially related to predictions and scenario-building. Variety and variability of the factors responsible for changes in sea level are immense and fast changing. Therefore, modelling SLR on a regional scale is an interminable process. Nevertheless, recent predictions of SLR until the end of the century unambiguously reveal that the coastal population has to be prepared. Some of the North Sea neighbouring countries will be or are already affected by rising water levels. This includes economically important regions but also areas of high ecological value and rich biodiversity. The interacting effects of conventional coastal protection and rising water levels cause coastal squeeze, which results in additional losses of ecologically and societally valuable territories.

Scientists of different disciplines and transnational working groups are developing strategies and measures for adaptation, mitigation and protection, including withdrawal of population and industry from coastal areas. These new measures in combination with SLR scenarios and effects are presented at specific information centres at the south-eastern North Sea coast and knowledge platforms. A promising example for such an international multidisciplinary approach is the Trilateral Wadden Sea Cooperation, which exists since 1978 and consists of the countries Denmark, Germany and the Netherlands. The collaboration comprises the protection and conservation of the ecology of the Wadden Sea by means of different Task Groups. Within the Task Group 'Climate', coastal and nature protection specialists as well as spatial planning experts work on strategies for more adequate adaptation to climate change impacts. Their main goal is to maintain natural functions and structures, the scenic qualities of the landscape and the conservation of the characteristic biodiversity.

An example for knowledge transfer is the Earth System Knowledge Platform (ESKP) of the German Helmholtz Association. This virtual platform is an overarching information centre and provides details on global and regional environmental changes including details on SLR and its consequences. In the northern Wadden Sea on the island of Sylt an exhibition centre (Erlebniszentrum Naturgewalten Sylt) informs the public specifically on the causes, effects and future scenarios related to global change and SLR.

These are exemplary efforts pointing to the important task of informing the society and increasing public awareness on the effects of SLR for both economy and ecology. Economies such as tourism and fishery also strongly depend on the preservation of ecological values. A broad public support and acceptance of new strategies for coastal and nature protection are the basis for sustainably mitigating the effects of a rising sea level, which will be a critical task for current and future generations.

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Climate Change and Biodiversity—Implications for the Local Fisheries Sector

Christina Hörterer, Maximilian Schupp, Andreas Benkens and Bela H. Buck

1 Background

1.1 Context AWI

The North Sea has been and still is one of the most intensely used marine areas worldwide. Shipping (trade and private), the exploration/exploitation of energy resources (oil, gas and wind), fisheries and tourism compete for the scarce space (Holm et al. 2017). Especially, in German waters, resource-use conflicts rise between stakeholders. The construction of wind farms and the expansion of nature reservation areas and other marine and coastal protected areas are leading to the closure of areas for other activities, such as fishing and aquaculture. In order to solve these conflicts and to better manage the interests of stakeholders of such densely populated and intensely used marine areas, multi-disciplinary approaches are needed to reach a sustainable, economic and environmentally friendly development.

The working group *Marine Aquaculture, Maritime Technologies and ICZM* at AWI Bremerhaven is focusing its research for several years on a sustainable use of marine resources and has developed strategies and concepts for the multi-use of offshore structures of wind turbines for aquaculture (Buck et al. 2008; Buck et al. 2004; Buck and Buchholz 2004) and passive fisheries (Stelzenmuller et al. 2016; Pogoda et al. 2016), to solve some of the interest-conflicts occurring in the German Bight.

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in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_5

2 Scope and Motivation

2.1 Background Setting

Since our oceans and seas are under the above mentioned continuous anthropogenic pressure, additional effects of climate change, such as increasing temperatures and/or sea level rise add even more pressures on marine ecosystems. Changing temperatures have induced shifts in the composition of marine flora and fauna worldwide (Doney et al. 2012; Cheung et al. 2009), and we can observe those changes right at our doorstep, in the North Sea (Philippart et al. 2011; Beaugrand 2004; Franke and Gutow 2004). The North Sea is naturally susceptible for environmental changes due to its topographic, geological and geographical settings. From a geologic history perspective the North Sea is a young, shallow and enclosed shelf sea and is affected by changing climate and a diversity of anthropogenic activities. Its high biodiversity of habitats provide many essential ecosystem goods and services, such as productive fishing grounds or the Wadden Sea National Park (WSNP). The latter declared as UNESCO world heritage due to its high protection status, it also attracts millions of visitors per year.

Yet, especially in these southern reaches of the North Sea, water temperatures and sea level have and are predicted to increase faster than in other regions (Emeis et al. 2015). In the waters around Helgoland the annual mean temperature rose by 1.7 °C since 1962 (Wiltshire et al. 2010). These data are alarming as these changing parameters have tremendous effects on the abiotic and biotic environments and indirectly on the connected and reliant economy and society along the densely populated North Sea coast.

The increasing water temperature already triggered a northward shift of fisheries-relevant species in the north-east Atlantic, native species like cod and plaice migrate to colder and deeper waters, whereas Lusitanian species like anchovy and horse mackerel have become more abundant in the North Sea (Rijnsdorp et al. 2009). This will affect the North Sea fisheries as the fishing vessels have to go further north to catch their target species and catch quota have to be adapted to new species (Cheung et al. 2012). For North Sea aquaculture, temperature will likewise have effects, both positive and negative, on cultured organisms like salmon and blue mussel. Growth, feed intake and oxygen demand will change, and diseases and parasites as well as non-native species and harmful algal blooms will become bigger threats to the aquaculture production (Callaway et al. 2012).

2.2 Target Audience

At the German North Sea coast, the fisheries and aquaculture sector includes small-scale coastal (flat fish and brown shrimp) and high-sea fisheries as well as production of blue mussel (*Mytilus edulis*). Associated with the fisheries and aquaculture production is the further fish processing industry, which is located and since 1885 traditionally operating in the fisheries harbour in the City of Bremerhaven (Northern Germany). Since the coastal fisheries and blue mussel production is conducted in the vicinity of the protected WSNP, stakeholders involved in nature conservation (e.g. NGOs and public authorities) and tourism have to be considered. Furthermore, the academic community from biology, physics, chemistry, economy and social science departments detect and monitor the effects of climate change on the North Sea environment.

In order to identify potential threats and opportunities of climate change on local communities, the project "Climate change and biodiversity: Threats and Opportunities for local actors of the North Sea" took a transdisciplinary approach. Key stakeholders were identified and addressed as well as further involved by drawing from and integrating their knowledge to find solutions and strategies for the mitigation of future environmental changes and challenges.

3 Materials and Methods

The project was set-up and divided into three subsequent phases in which knowledge was gathered and curated (1), direct stakeholder engagement took place (2) and the results and gathered knowledge was used to stimulate joint efforts (3) (Fig. 1). All three phases only represent parts of a process of continuous and simultaneous knowledge gathering and transfer, as there were no hard borders between them.

Phase 1: At the beginning of the project, data on the recent and future effects of climate change on the biotic and abiotic environment of the North Sea were collected from various sources, such as reports published from the VECTORS project (www.marine-vectors.eu), publications from peer-reviewed journals as well as from proceedings from ICES (International Council for the Exploration of the Sea Data Centre), from the EC (e.g. EU Habitat Directive) and from national authorities (e.g. German Federal Agency for Nature Conservation [Bundesamt für Naturschutz—BFN]). Additionally, expertise from scientists (AWI) and other stakeholders in the fields of climate change, biodiversity, local ecosystems and socio-economics were gathered. Based on this information, key stakeholders affected by climate change and the associated changes in biodiversity, located at the German North Sea coast, were identified.

Phase 2: In this phase, stakeholders were engaged through participation in workshops, which served not only as tool to gather information from the

Fig. 1 Project setup: on the basis of gathered and curated knowledge, stakeholders were identified and engaged to facilitate knowledge transfer and to stimulate joint efforts

stakeholders, but also facilitated bidirectional communication and knowledge transfer between the participants themselves. Two workshops were held in order to assess the stakeholders' perceptions towards and discuss the impacts of climate change on their respective fields of expertise. In both workshops the topic of climate change and its effects on biodiversity, fisheries, aquaculture, invasive species, species communities and pollution was shortly introduced prior to further discussions. The first workshop, hosted at the AWI Bremerhaven, was directed towards a broad audience of local stakeholders from fisheries, science, and fish processing industry, NGOs and the local authorities. Due to the broad nature of the stakeholders' backgrounds, this workshop was prefaced with talks by three invited experts from the scientific community to help all participants starting with the same knowledge baseline and facilitate discussion in the later parts of the workshop. In the second workshop, hosted at the *YouMaRes 7* conference in Hamburg, young scientists (Bachelor, Master, Ph.D. students and early post-docs) from different research fields (biology, chemistry and social science) discussed the impacts of climate change and the future of climate change related research. In addition to these two workshops, meetings by local fisheries associations (mussel farming, German Fisheries Association [Deutscher Fischerei-Verband]) were attended to approach more stakeholders.

Phase 3: In the final phase of the project the information and outcomes of the first and second phase and its resulting discussions were evaluated and the gathered knowledge distributed through different channels and types of communication. Different types of media, such as the internet websites of the Earth System Knowledge Platform (ESKP 2017) as well as AWI (2017), electronic newsletters and print media (brochures, other publications), were used to communicate the results and outputs of the project to a wider, mainly non-scientific, audience. Furthermore, the data gathered in the workshops are planned to also be published in a peer-reviewed journal.

4 Results

4.1 What Was Done Directly (Activities)?

The stakeholder engagement in the workshops is the major part of the project as the participants successfully provided very important information about the stakeholders' perceptions on various aspects of climate change. By categorizing the impacts of climate change according to the four dimensions environment, society, economy and policy, the workshop participants suggested an order according to their personal sensation and importance. Most of the climate-related impacts were viewed as closely interlinked, since changes in the environment, e.g. weather extremes, affect not only the economic feasibility of the fisheries sector, but also those people living at or in the vicinity of the coast. The modern fishery above all needs vessels that are adapted to severe conditions, such as storms or high waves.

The coastline needs reinforced protective measures, which in turn alter the local landscape and can heavily influence biodiversity-rich coastal habitats by destruction and permanent flooding. Even though the composition and distribution of native species populations change, new species in turn migrate from warmer water origins (e.g. anchovy) or are introduced through human activities. These "new" species may have the potential to replace their former counterparts in their ecological and economical role or open up new niches.

These interlinkages between the environmental, economic and social processes highlight the importance of climate-adapted strategies in the management and governance of the southern North Sea region. In fisheries management, it will be important to act flexible in adapting catch quota to changing species distribution and abundances. Science thereby plays a key role by integrating social and environmental dimensions, providing data and communicating the results not only to the governmental authorities, but also directly to all affected stakeholders.

4.2 Outputs Directly of the Project (What Was Achieved?)

The workshops were the first step of bringing together the different stakeholder groups, facilitating a dialogue and creating a network of relevant stakeholders for future communication and cooperation on aspects of climate change and biodiversity.

In order to reach a wider audience a brochure was created by translating findings and expert knowledge into a 'common stakeholder language'. Gathered knowledge from both literature research and the two workshops was incorporated in this publication (available printed and online in German and English, via the ESKP website and the AWI hosted project website), to inform a non-academic audience, such as local fishermen, representatives from the political arena, and those people who live at or visit the German North Sea coast.

For the academic and science-interested audience, intermediate and final outcomes were communicated via the ESKP (Dzuba et al. 2016; Buck and Hörterer 2017) and AWI web site. A biannual newsletter will be released to inform the network of stakeholders about recent and future activities and projects.

5 Reflection and Lessons Learned

5.1 What Can We Draw from the Activity

One of the most important lessons learned is the importance of facilitating direct communication between stakeholders by bringing them together in personal dialogues. Workshops focusing on a diverse group of stakeholders, often with opposing perspectives, benefit from direct communication and from the knowledge and perception of different stances.

Furthermore, in comparing the results of both workshops, we noticed that the perception within the stakeholder groups can differ with age. Especially in science, young scientists have a different focus and thus identify different problems and different strategies to counter them. Additionally, they are aware that inter- and transdisciplinary approaches are needed in climate change research and management. They also possess an inherent drive to talk about and spread their scientific findings to the wider public and have a clear understanding of the importance of science education and communication.

5.2 What Can We Learn for Knowledge Transfer?

In both workshops we experienced that a direct and clear transfer of knowledge between the different stakeholders groups, especially but not solely between science and fisheries, is crucial to increase the wide understanding of the processes and impacts of climate change (Fig. 2).

Traditionally, knowledge is transferred unidirectional, as in fisheries management, when scientists propose catch quota, based on scientific data, to governmental bodies (EU), these implementing the suggestions and the fisheries industry following those. Unidirectional communication, containing a translation component, is helpful to give information to a wider audience. But, even more important is to acknowledge necessity to meet in person and communicate with each other directly to keep up the transfer processes. This bidirectional communication can help to prevent misunderstandings and to promote positive outcomes.

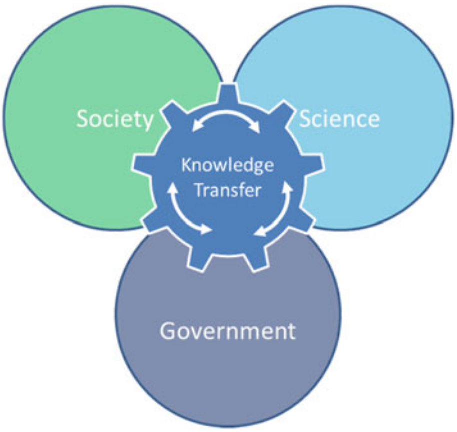

Fig. 2 Role of Knowledge Transfer in stakeholder communication: all groups involved have to communicate with each other to increase understanding of the processes and impacts of climate change

6 Outlook

The next steps in the project are the further development of a close network of stakeholders in order to facilitate direct communication in the future. Based on the findings of this project, we want to publish a research agenda to show a way for future research concerning climate change and its impacts on the North Sea system, its biodiversity and stakeholders. The research topics are based on the outcomes of both workshops and will be verified through interviews with representatives of the relevant stakeholder groups. The main conclusion from the multi-stakeholder workshop was that future cooperation between scientists, fisheries, local authorities and others is needed to develop a climate adaptation strategy for the southern North Sea region including Bremerhaven, the coastline of Lower Saxony and the WSNP with focus on ecology, research and governance.

Acknowledgements This project is a contribution to the Earth System Knowledge Platform (ESKP) and was funded by the Helmholtz Association (Berlin, Germany). The first workshop was part of the "Events in Europe" of the European Maritime Day 2016 in Turku and endorsed with information material and publicity.

We would like to thank all workshop participants for sharing their opinion, expertise and profound knowledge, and for bringing up new starting points for future cooperation, research on and strategies for climate adaptation. Furthermore, we are grateful to the invited speakers sharing their research results.

Special thanks go to Dr Gesche Krause for assisting in organizing and moderating the first workshop as well as being a good source of information and guidance on all aspects of the this knowledge transfer project.

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Linking Biodiversity Research Communities

Sonja Knapp, Alexandra Kraberg, Stephan Frickenhaus, Stefan Klotz, Oliver Schweiger and Gesche Krause

1 Background

The ecology of terrestrial and marine ecosystems has been studied for over a hundred years and human utilization of both realms has been documented going back hundreds or even thousands of years. Nevertheless, mainstream ecology is dominated by terrestrial research (Raffaelli et al. 2005), joint studies are rare (Rotjan and Idjadi 2013) and different research communities have developed (Stergiou and Browman 2005). Marine and terrestrial ecologists even tend to ignore each other's work, with especially terrestrial ecologists hardly citing marine research (Menge et al. 2009). Marine and terrestrial ecosystems however, are not disconnected but they are linked with each other, and some functional principles may be similar. A disconnection of marine and terrestrial research can therefore hamper our understanding of the response of biodiversity to global change and consequently our efforts to protect and manage ecosystems and their biodiversity (Ruttenberg and Granek 2011).

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2 Scope and Motivation

2.1 Context of Project Within the AWI/Background Setting

The point-of-departure to our motivation was the initiation of the Earth System Knowledge Platform (ESKP) of the German Helmholtz-Association in 2012. Both, the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research and the Helmholtz Centre for Environmental Research—UFZ were asked to intensify their knowledge exchange under the umbrella of ESKP. This resulted in a series of workshops where we identified common grounds in the marine versus terrestrial research domain. Despite focusing on different realms and despite our background in different research communities, we identified shared views but also divergences on the effects of global change on biodiversity. Therefore, we decided to gain a better overview on the knowledge of anthropogenic drivers of biodiversity change in the marine and terrestrial research community respectively and thus to bridge the persisting gap among these communities.

3 Approach and Methods

We met for two-day discussions at quarterly workshops of marine and terrestrial biodiversity researchers from AWI and UFZ in 2014/2015, all funded by ESKP. One workshop was held at AWI, one at UFZ, and others on common grounds (in Berlin and Hamburg). When meeting for the first time, we decided to perform a literature review, combined with an assessment of expert knowledge to identify the relevance of different drivers of global change for marine and terrestrial biodiversity. To do so, we applied a Delphi-assessment (Dalkey and Helmer 1963). In this kind of assessment, an expression of expert knowledge is used to achieve convergence of opinion among experts on a specified question. According to Hsu and Sandford (2007) it can be used to.

1. Explore individual assumptions or knowledge leading to different judgments;
2. Seek out information that may generate a consensus within the respondent group;
3. Correlate informed judgments on a topic spanning a wide range of disciplines;
4. Educate the respondent group as to the diverse and interrelated aspects of a topic.

We asked a group of 90 marine and 90 terrestrial senior ecologists ("experts") to rank the impact of selected anthropogenic drivers of change for marine or terrestrial biodiversity, respectively. The drivers were (i) land use/sea use, (ii) chemical inputs, (iii) climate change (with a focus on changing temperatures), (iv) increasing atmospheric concentration of CO_2, and (v) biological invasions. "Land/sea use" and "chemical inputs" were further divided into (ia) habitat loss, (ib) habitat degradation, (ic) habitat fragmentation, (id) hunting and fishing; and (iia) nutrients and (iib) pollutants. We asked all experts to give a maximum score of 100 to the driver they considered most important and to rank all other drivers accordingly between 0 (no impact) and 100.

In a second round (a crucial part in the Delphi process), experts who had taken part in the first round (21 terrestrial and 18 marine experts) were provided with the median and range of scores from the first round and an aggregated version of the arguments for high or low scoring. Based on the anonymised arguments, the experts then had the possibility to adjust their own scoring. This aimed at reducing uncertainty in an unbiased way. We compared the final judgements together with explanations and key references to our literature review on the effects of global change on terrestrial and marine biodiversity.

4 Results

We found asymmetries in the experts' perceptions of the importance of different anthropogenic drivers of biodiversity change in marine versus terrestrial systems (Figs. 1, 2 and 3). Based on our literature review, we conclude that this asymmetry roots in the differences of (i) how and how intensely humans use land and sea, (ii) the possibilities to investigate the biodiversity in marine versus terrestrial ecosystems and (iii) in time-lags of the response of biodiversity to global changes. However, differences in time lags as well as human uses are diminishing. On the one hand, the degree and scope of human exploitation of the sea is increasing drastically; on the other hand, human-induced environmental changes today have global and cross-system impacts rather than "just" regional ones.

Our joint work across ecological disciplines led to the conclusion that we are currently facing a major change in the use of the sea, reflecting the historic transition from hunters/gatherers to farmers on land. This, together with the other drivers of global change, will cause problems for marine ecosystems that will likely be similar to those experienced in terrestrial ecosystems. Still, we have the chance not to repeat mistakes but to focus on sustainability in a combination of both fishery and aquaculture well before all the huntable marine organisms have been reduced to levels below commercial efficiency or they already went extinct. Bridging the gap between marine and terrestrial research will allow us to better meet these challenges.

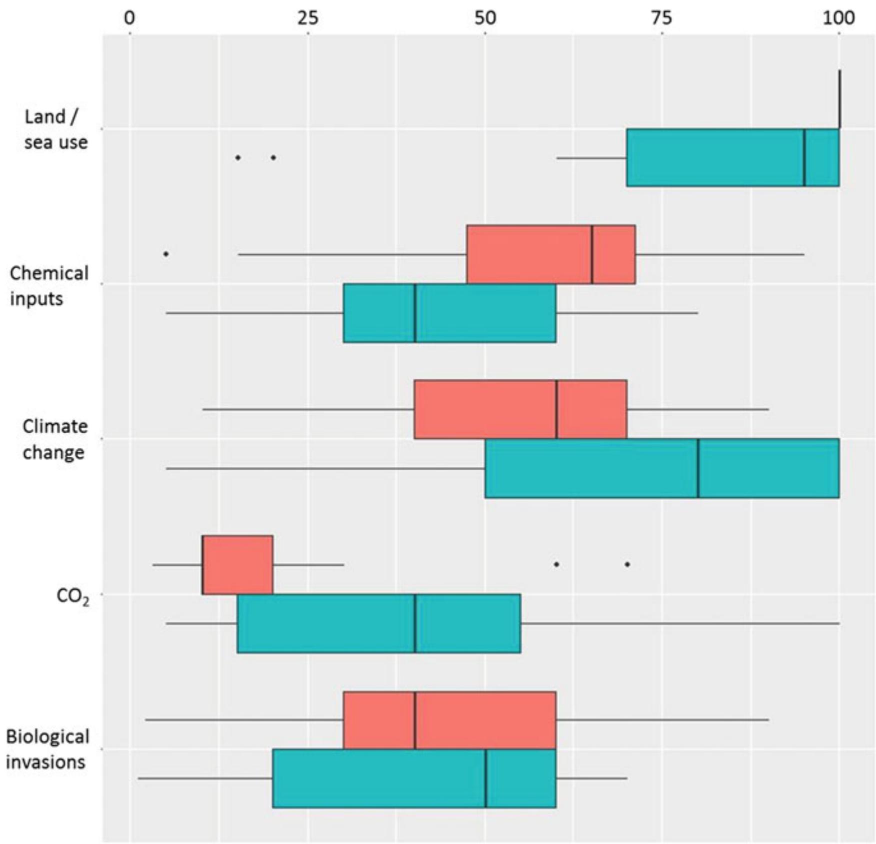

Fig. 1 Comparison of the relative impact of the main drivers of global change on biodiversity in terrestrial (red) and marine (blue) ecosystems covering the last 100 years (based on experts' perceptions provided in the frame of a Delphi assessment). Experts rated the most important impact = 100; all other impacts were rated relative to the most important one. Boxplots represent median (line) and 25–75% quartiles (boxes); upper/lower whiskers extend from the box to the highest/lowest value that is within 1.5 $*$ the interquartile range; outliers are represented by circles

5 Reflection and Lessons Learned

From a systems perspective, terrestrial and marine biodiversity changes follow similar principles. Cross-system synthesis (e.g. surveys, in situ experiments and analytical as well as predictive models) is the only way to understand differences and similarities between marine and terrestrial biodiversity change and whether these are driven by the history of human use or are inherent to the respective system.

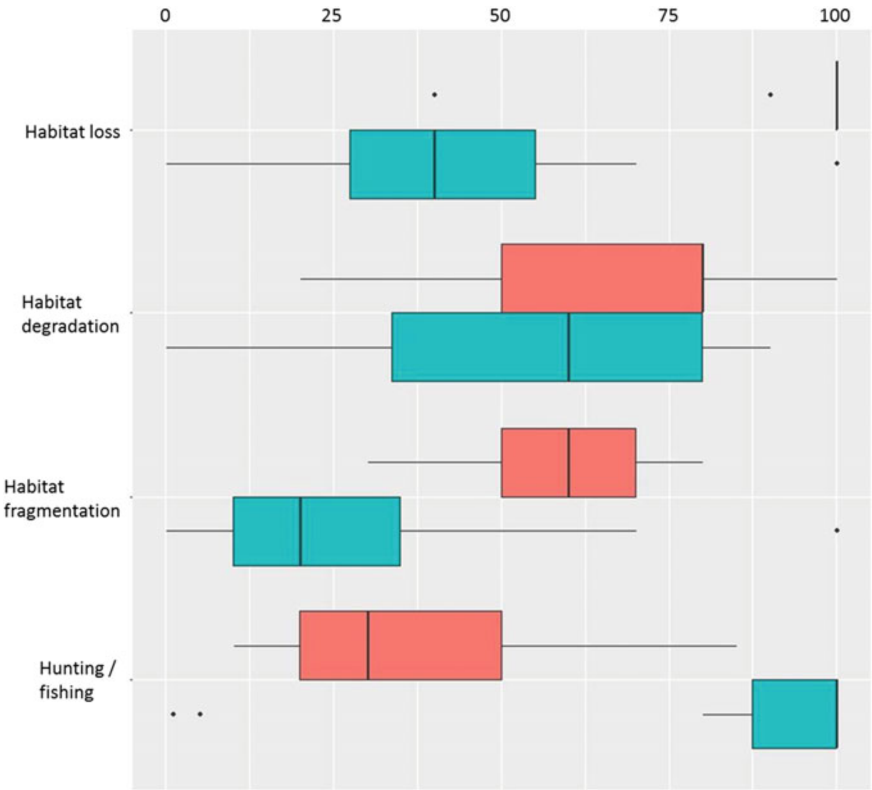

Fig. 2 Comparison of the relative impact of subcategories of anthropogenic use of land (red) and sea (blue) on biodiversity covering the last 100 years. For details, cf. Fig. 1

The personal exchange, the intensive scientific discussions combined with shared leisure time in the evenings as well as the opportunity to visit each other's working place and surroundings largely facilitated the interdisciplinary exchange and understanding as well as the subsequent joint publication process (the full publication is Knapp et al. (2017)).

6 Outlook

We aim at extending the cooperation among marine and terrestrial researchers within the Helmholtz Association, with the focus on biodiversity and how we can safeguard it in the light of global change.

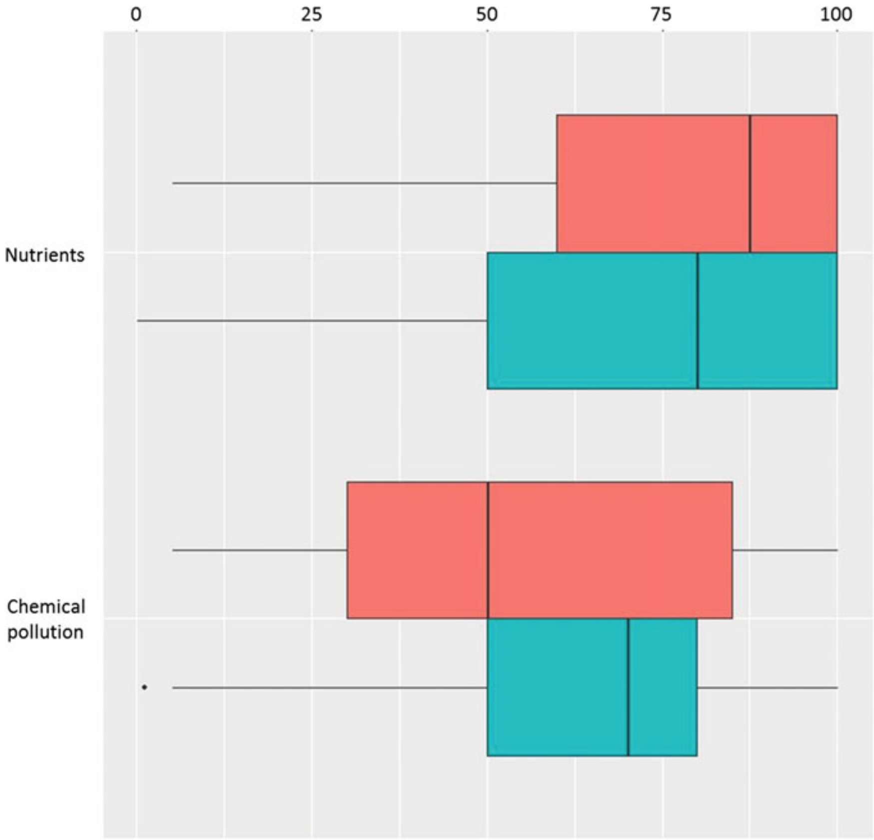

Fig. 3 Comparison of the relative impact of subcategories of chemical inputs on biodiversity in terrestrial (red) and marine (blue) ecosystems covering the last 100 years. For details, cf. Fig. 1

Acknowledgements We gratefully thank all experts at AWI and UFZ who participated in the Delphi-assessment and shared their views and insights. We acknowledge financial support by the ESKP initiative. This work is part of the PACES II Research Program at AWI, and of the Topic "Land Use, Biodiversity and Ecosystem Services" at UFZ. Furthermore, the Helmholtz Office in Berlin, the Climate Service Centre in Hamburg as well as AWI and UFZ are acknowledged for hosting our meetings.

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Engaging Forecast Users During the Year of Polar Prediction

Winfried Hoke, Kirstin Werner, Helge Goessling and Thomas Jung

1 Background

1.1 The Year of Polar Prediction

Triggered by global climate change, the rapidly changing polar environments increasingly capture public awareness. In the north, Arctic sea-ice opening comes with many opportunities for economic development, transport and tourism but also bears substantial changes and high risks for humans and nature. As the sea-ice cover will still be present during non-summer months but under more dynamic and less predictable conditions, accurate weather and environmental information is increasingly needed in order to facilitate risk reduction and safety management. Moreover, lower latitude weather and climate are significantly affected by what happens at the poles (Jung et al. 2016).

In 2013, the World Meteorological Organisation (WMO) initiated the Polar Prediction Project (PPP) with the overall goal to "improve weather and environmental prediction services for the polar regions, on time scales from hours to seasonal" (PPP-SG et al. 2013). A key activity of this initiative is the Year of Polar Prediction (YOPP; www.polarprediction.net) that integrates international research with activities of operating weather and sea-ice forecasting centres. During the Core Phase of YOPP from mid-2017 to mid-2019, observations of the atmosphere/sea ice/ocean system in the Arctic and Antarctic will be strongly enhanced to enable an optimisation of the observing system and the development of improved polar environmental forecasts.

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The YOPP community aims to develop forecasting capabilities responding to particular needs of stakeholders relying on polar forecasting products (e.g., sea-ice thickness). To this end, aside from a comprehensive international network of research institutes and operational forecasting centres, YOPP strives to engage a wide range of additional stakeholder groups, including social scientists, indigenous communities, funding agencies, as well as the transport, maritime, and tourist sectors.

In October 2015, the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research and WMO signed a Memorandum of Understanding to host the International Coordination Office (ICO) for Polar Prediction at the Alfred Wegener Institute in Bremerhaven, Germany. The ICO coordinates efforts of PPP and YOPP and serves as a focal point for the communication among internal and external stakeholders. It is supported by the Helmholtz Association's Earth System Knowledge Platform (ESKP), which provides funding to advance stakeholder involvement in YOPP.

1.2 The Socio-Economic Dimension of the Year of Polar Prediction

In order to address the above-stated aspects, the socio-economic dimension of human activities in the polar regions and their relationship with environmental forecasting need to be considered. In particular, the PPP subcommittee 'Societal and Economic Research and Applications' (PPP-SERA) fosters activities "to ensure that stakeholders' needs and their potential contributions to YOPP will be addressed appropriately" (PPP-SG et al. 2016). PPP-SERA applies multi- and trans-disciplinary social research methods to investigate "how end-users obtain, perceive, comprehend and use weather and sea-ice (and related risk) information to facilitate decision-making in the polar regions" (Hoke et al. 2016). The research within PPP-SERA relates to the needs and utilization of environmental prediction information, including impacts on decision-making processes, by a diverse range of users of polar environmental information. The work by PPP-SERA is supported and complemented by activities of the ICO.

2 Scope and Motivation

2.1 Stakeholder Groups

Two main groups of actors—providers and users of environmental forecasting products—are involved in PPP. Here, we use the term provider in a broad sense, including both the forecasters delivering environmental prediction services at operational centres as well as academic researchers working on improved polar predictions. The latter cover various research aspects, including polar observations, weather and climate modelling, data handling and assimilation (i.e., techniques to feed recent observations into models to start a forecast) as well as forecast verification (i.e., methods to evaluate how skilful forecasts are). Scientists and operators at forecasting centres translate enhanced process understanding and model improvements into better forecasting systems, thus providing improved forecasting services to the public.

Users of polar environmental forecasting services rely on high-quality polar prediction information in order to ensure safe operations during their work and daily life routines. A key user group is the marine transportation sector. Operators of local transport and long-distance journeys need to be informed by the current and near-future state of sea ice, wind, precipitation, waves, and other environmental factors. Fishery, tourism, cargo and other vessels, as well as local actors including indigenous communities, both at sea and on land, have individual requirements. However, the behaviour and needs of users with respect to environmental services are not well known. As a result, "this information gap has led to a culture of blind investments into the development of newer or higher resolution weather and climate data development that, while offered with the best of intentions, is often, and perhaps unknowingly, disconnected from actual end-user needs" (Thoman et al. 2016).

2.2 Goals of the Project—Communication Beyond Academia

The socio-economic component of YOPP addresses this gap by trying to better understand forecast use and needs of indigenous and other polar stakeholders. User requirements may substantially differ regarding forecast data, in terms of parameter (sea-ice concentration, thickness or pressure, cloudiness, winds, etc.), type (visual or descriptive), quality, temporal resolution and lead time (hours, days, seasons, etc.) as well as update frequency. Ideally, a forecast should be fully tailored to a user's needs. The potential requirements as exemplarily listed above should thus feed back into the development of forecasts at an early stage. Fostering the communication from users to providers (upper branch in Fig. 1) is key to ensure that resources invested into refining and developing new forecasting products pay off.

To address the above-mentioned gaps in communication and knowledge transfer, a better understanding of the interaction between the providers and the diverse range of users is essential. Notably, many of the providers of polar weather and climate information are also users of the same information (Thoman et al. 2016) which extends the complexity in investigating user requirements, and how providers integrate this information into their predictive skills developments.

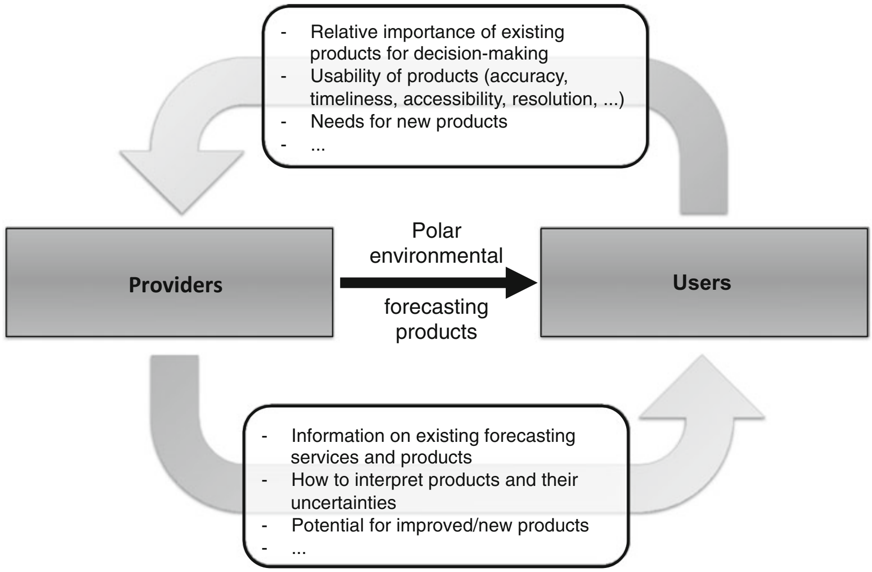

Fig. 1 The information flows between polar forecast providers (forecasters and academic researchers) and users who base decisions on forecasts. The basic process is the mere delivery of forecast products from providers to users (central arrow). However, this central element needs to be supplemented with additional communication in both directions—a dialogue: The requirements of various users need to be communicated to, and understood by, the providers (upper branch) so forecast systems and products can be designed to meet actual user needs. In reverse, polar forecast users need to be instructed on what forecast products exist, how a forecast product must be interpreted, what the associated uncertainties are, and what the potential for improvements and/or new forecast products are (lower branch)

3 Approach

3.1 The Social-Science Perspective

The social-science perspective carried into YOPP by PPP-SERA adds an otherwise often-missing dimension to PPP which is initially rooted in the natural sciences. PPP-SERA is currently represented in the international PPP Steering Group by two members. Involvement of PPP-SERA provides PPP with the required expertise to actively engage with stakeholder groups, for example through specific research projects that are to be carried out within PPP-SERA (involving, e.g., the tourism sector and indigenous people). The transpolar scope of PPP and close collaboration between PPP-SERA and the ICO bears the potential to significantly raise the level of communication between forecast providers and users. By integrating actual socio-economic needs, the YOPP initiative aims to make the most out of enhanced polar predictive skills, for the benefit of both society and nature.

The PPP-SERA committee convenes annually in order to make progress in their plans and activities. At the group's 2016 meeting PPP-SERA invited representatives from different stakeholder groups (e.g., fishing industry, tourism sector, maritime logistics) to learn about their perspectives and needs regarding polar forecasting. These perspectives also feeded into a comprehensive report (PPP-SERA 2017), including an overview of providers and users of forecasts, which will set the scope of PPP-SERA plans and projects during YOPP and beyond.

3.2 *The ESKP Contribution: Stakeholder Engagement by the International Coordination Office*

The International Coordination Office (ICO) for Polar Prediction has been established in order to support the PPP Steering Group, to manage everyday activities, and to coordinate, plan, and prepare details of the various flagship activities of PPP. Supported by ESKP, the ICO also fosters communication to and between different groups of stakeholders. Additionally, YOPP Task Teams led by members of the Steering Group and YOPP partners have been established in order to promote and coordinate specific activities during YOPP, which has been launched officially in May 2017.

As the coordinating focal point, the ICO maintains an overview on PPP and YOPP activities. The chair members of the PPP-SERA group are in regular exchange with the ICO. Besides active engagement in PPP-SERA activities, the ICO contributes to the provider-user dialogue with complementary activities, such as the preparation of YOPP-related scientific materials for non-academic audiences —including forecast users—and the establishment of a user feedback forum, details of which are sketched in the following section.

4 Ongoing Activities and Outlook

In order to maintain an overview of activities relevant to the aims of YOPP, an endorsement process has been established in 2015 (Goessling et al. 2016). Projects, programmes and initiatives that plan to contribute to YOPP can request endorsement (see also www.polarprediction.net for more information). After passing a rigorous review process handled by the ICO, endorsed research projects benefit from better visibility and likely increased chances of getting funded. In turn, endorsement allows the ICO and YOPP network to coordinate activities and enhance networking and communication amongst the various activities during YOPP. More than fifty activities have been endorsed by early 2017, and it is expected that significantly more activities will request endorsement over the course of the project.

In consultation with the PPP Steering Group (PPP-SG) and PPP-SERA, the ICO has extended the YOPP endorsement process by a socio-economic dimension: Since mid-2016, societal and economic activities can request endorsement and thereby become part of the YOPP network. Prior to endorsement, the initiatives are reviewed both by natural-scientific members of the PPP-SG and a social-science representative of PPP-SERA.

Moreover, the ICO has compiled a comprehensive list of YOPP stakeholders, revealing an abundance of private and public stakeholders with various roles and interests. This list has been further filled in cooperation with relevant partner projects (EU-PolarNet and GRASP/Alfred Wegener Institute), and is being continuously updated. It will be used for the planned user feedback forum (see below) and YOPP outreach activities. Also, the ICO analysed and summarised seven surveys on the needs of forecasting users, conducted by various research projects and institutions in the last 15 years. The outcomes are included in the above-mentioned report (PPP-SERA 2017).

One of the major projects planned and developed by the ICO in close consultation with PPP-SERA is the implementation of a "user feedback forum" with the aim to connect users of polar forecasts with forecast providers and establish a sustained information flow on a regular basis. Over the two-year course of the YOPP Core Phase, various users of polar forecasts will be invited to report on specific needs and requirements during their operations in the Arctic or Antarctic. In order to allow for lively discussions, contributors will be able to post comments and questions to a blog-like online format entitled "Polar Prediction Matters". The user perspectives will be complemented with selected contributions by social scientists and polar forecast providers (operational forecasters as well as natural scientists). All articles and discussions will be made publicly available, potentially also in the form of a book, so that provided insights will remain accessible to anyone also at any later stage. Collaboration with YOPP-affiliated (in particular YOPP-endorsed) projects is envisaged to enlarge the potential user base and to feature a sufficient number of stakeholder contributions. The EU-funded project APPLICATE (www.applicate.eu) is a particularly important partner with strong ties to a large number of forecast users. We invite any other relevant projects to join the initiative.

The YOPP Implementation Plan by PPP-SG et al. (2016) highlights the need to "promote interactions and communication between research and stakeholders". With the formation of the PPP-SERA subcommittee and the support of the ICO through ESKP, a solid groundwork for the involvement of stakeholders in YOPP beyond academia has been laid. The envisaged activities will contribute to an improved understanding of polar forecast needs from a socioeconomic perspective that will feed into the enhancement of environmental prediction capabilities, tailored to the users' needs, eventually leading to both safer living conditions and operations in polar regions.

Acknowledgements The contents of this article have significantly benefited from discussions and collaboration with the PPP-SERA group. In particular, we thank the PPP-SERA co-chairs Daniela Liggett, Jackie Dawson, and Machiel Lamers who provided very helpful comments to an earlier version of this article.

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Governance of Resources for Arctic Sustainable Policy and Practice (GRASP)—Stakeholder Mapping

Sebastian Knecht, Andreas Herber and Kathrin Stephen

1 Background

GRASP(*Governance of Resources for Arctic Sustainable Policy and Practice*) is an inter- and transdisciplinary research project jointly developed in 2014 by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), the Institute for Advanced Sustainability Studies (IASS) and the Jade University of Applied Sciences. The project seeks to contribute to building a more detailed picture of current and possible future developments of Arctic regions due to increasing human activity. Its central ambition is to analyse potential consequences of these developments from climatic, environmental, legal, social, political and economic perspectives, including processes and feedback loops of complex systems within the Arctic and beyond.

The changing Arctic ice regime has paved the way for many speculations as to the increasing accessibility of the region especially for economic activities in the resource and transport sectors (e.g. oil and gas exploration, fishing and shipping) and the respective consequences for Arctic communities and the fragile environment in the region. Such opportunities and their associated risks and challenges are usually exemplified in

- Tapping vast oil and gas resource bases predominantly offshore on the continental shelves of the Arctic coastal states, which are thus far subject to significant speculation and uncertainty and remain largely unexplored;

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G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_8

- Using new transport, trade and tourism routes through Arctic waters—especially along the Northeast Passage along Russia's and Norway's northern shores, as well as potentially through Canada's Northwest Passage or even using a Transpolar Route through the central Arctic Ocean;
- Increasing fishing opportunities in exclusive economic zones and in the high Arctic Ocean; as well as
- Increasing mining efforts in onshore Arctic regions.

Changing atmospheric, oceanographic and ice conditions will strongly determine the prospects and consequences of these activities for the people, their living conditions, the environment and the climate in the Arctic as well as beyond. The same holds true for the changing political, legal and economic as well as general societal priorities and related decision-making processes. While increasing economic activities can bring economic and social improvements to Arctic communities and their inhabitants (if conducted sustainably in the sense of environmental, economic and social considerations), negative consequences (whether unintended or through negligence) cannot be ruled out, both within the region and beyond. A prime example is the possibility of increasing marine and air pollution through discharges from energy and shipping activities, for instance due to increasing trace gas (NOx, SO_2, O_3, CO_2) and black carbon emissions. The latter could accelerate sea-ice reduction and thus exacerbate the consequences of rapid climate change in the Arctic and beyond.

There is thus a need to analyse the many processes, systems and interdependencies between Arctic and non-Arctic regions that determine the feasibility, likelihood and especially the desirability—especially from the perspective of the people living in the region—of Arctic economic activities with the entire range of consequences and risks. This includes many factors within the Arctic region, but also goes well beyond the Arctic Circle to include various rights- and stakeholders, systems, and processes that affect or are affected by the transformations occurring in the Arctic. The term 'stakeholder' is used here to refer broadly speaking to 'any group of people, organised or unorganised, who share a common interest or stake in a particular issue or system' (Grimble and Wellard 1997, p. 175), whether or not they reside within the Arctic region itself.

With the help of this wider picture, GRASP aims at improving decision-making for governance of resources for sustainable Arctic policy and practice. This will be achieved by building a set of scenarios for future Arctic transformations, including environmental changes, economic activities, technology and infrastructure developments, development of governance structures, and societal influences and effects. Scenarios will include different time and spatial scales and outline possible consequences for different stakeholder groups. Added to this are estimations of social and environmental costs (for example in relation to living conditions and environmental hazards) of decisions that might be taken in regard to Arctic ecosystems and Arctic communities. These scenarios then aim to support decision-making processes to prevent harmful or unintended development and to promote sustainable policies from environmental, social and economic perspectives.

GRASP is organised in different Work Packages, which range from stakeholder mapping and characterisation (Work Package A) to a set of scenario outputs (Work

Package B). These in turn (1) provide input for the modeling of global socio-economic costs and benefits (Work Package C), and (2) in combinations appropriate to the stakeholder-defined priority issues, allow more informed consideration of options and consequences for decisions through workshops and dialogue with stakeholders (Work Package D1). The *Earth System Knowledge Platform* (ESKP) of AWI has provided funding for the period from February 2016 until January 2017 to elaborate and refine Work Package A—Rights- and Stakeholder Groups. Work Package A is a crucial cross-sectional element of GRASP and thus has consequences for the scientific conduct and stakeholder dialogue in all other Work Packages and throughout the entire research process.

2 Scope and Motivation

By grounding the scenario approach in a fully collaborative design, development process, usage and evaluation with various stakeholder groups, GRASP will contribute to strengthening science-policy interactions. The main vehicle for this contribution is to provide scientific approaches and findings that are useful for governance processes and decision-making on multiple scales and governance levels. GRASP's *transdisciplinary* approach involves Arctic stakeholders throughout the entire research and knowledge transfer process and strives to make research results readily understandable, accessible, meaningful and thus useful for them. This approach enables GRASP to support a more effective and better-informed search for innovations and sustainable futures in the Arctic (see Reed 2008).

The inter- and transdisciplinary approach taken by GRASP builds on and augments, but explicitly does not replace, more traditional scientific research and outreach approaches. Rather, it adds a strong interaction and utilisation of synergies between natural and social science researchers to the research process. It also enables the organisation and facilitation of strategic dialogues for mutual learning and goal-oriented problem-solving with stakeholders from science, politics, civil society groups, non-governmental organisations (NGOs), business representatives and local communities, all of whom play a significant role in defining and building sustainable Arctic futures. With such an approach and a shared understanding of researchers and stakeholders involved in the project, GRASP helps building common ground between hitherto little connected groups dealing with Arctic development to find sustainable pathways for Arctic futures.

The crucial aspect of this process is eliciting information and ideas from diverse sources of knowledge, including local and traditional ecological knowledge (TEK), which is needed to co-construct meaning among interdependent stakeholders in a dialogue and to create a shared knowledge base and vision for sustainable Arctic futures. This process of knowledge sharing and co-construction among researchers from different fields and practitioners is meant to enable more informed and effective responses to challenges related to ongoing and future Arctic transformations. Such an approach requires the tapping of new sources of knowledge and creativity, which will be enhanced through the engagement of a wide range of stakeholders.

3 Materials and Methods

The number of research projects that seek to involve such Arctic stakeholders has drastically increased over the past few years as Arctic change has been more and more in the spotlight of academic interest, both in the natural and social sciences. Other research projects such as *EU-PolarNet* (www.eu-polarnet.eu), *Year of Polar Prediction* (YOPP) (www.polarprediction.net/yopp/), the *Arctic Futures Initiative* (AFI) (www.iiasa.ac.at/web/home/research/afi/arctic-futures.html), *Arctic Options —Holistic Integration for Arctic Coastal-Marine Sustainability* (www.arcticoptions.org), *Arctic Climate Change, Economy and Society* (ACCESS) (www.access-eu.org), *Ice, Climate, Economics—Arctic Research on Change* (ICE-ARC) (www.ice-arc.eu) or *Mistra Arctic Sustainable Development* (MASD) (www.mistraarctic.se) also closely interact with Arctic stakeholders, though at different degrees. In general, however, this puts a lot of pressure on each individual research project to decide which stakeholders to involve and how to involve them to make the engagement process as efficient, effective and sustainable as possible.

GRASP responds to these challenges by putting more focus on a qualitative selection of suitable stakeholders to engage with, instead of adopting a 'the more the merrier' approach. The choice of involved stakeholders nevertheless is a balanced one and represents the full spectrum of affected stakeholders as outlined above. To this end, GRASP pursues a three-point strategy to make the stakeholder engagement process as productive and mutually beneficial as possible:

(a) Initial screening of relevant stakeholders by GRASP project partners,
(b) An iterative 'engagement process' combining online tools and on-site stakeholder workshops, and
(c) High external harmonisation with other research projects in the field of Arctic sustainable policy and practice.

4 Results

To achieve internal coordination, GRASP conducted an online survey among project partners in the Work Packages B, C and D (see Fig. 1 above). Project partners were asked to identify needs and informational resources they require from stakeholders to pursue their research more effectively. They were further called upon to name a limited number of stakeholders from across the different stakeholder groups (business, politics, civil society, science and local residents) that they consider relevant in their respective field and whose input and expertise can complement other forms of knowledge already available to the project partners.

We then started to systematically map and collect contact details from stakeholders identified as critical by the project partners. The stakeholder mapping exercise has resulted in 103 individual rights- and stakeholder contacts from across

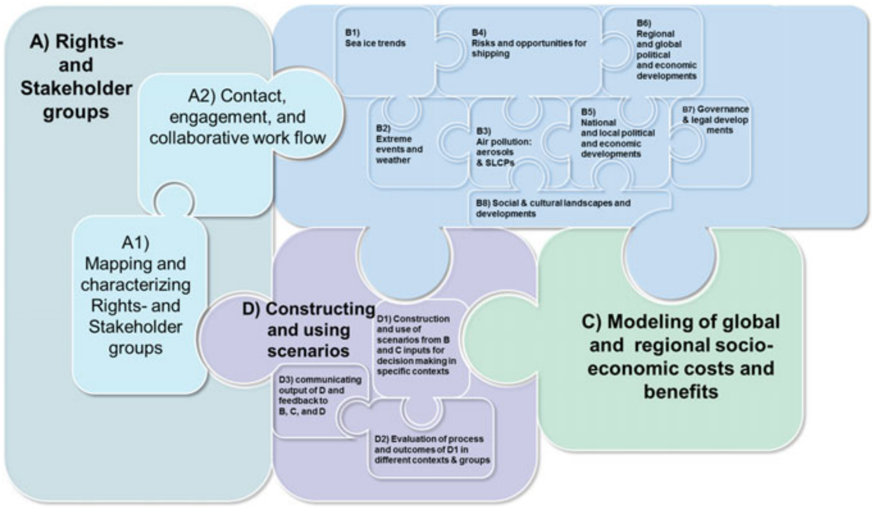

Fig. 1 The GRASP jigsaw puzzle (© Silke Niehoff, IASS Potsdam)

business, politics, civil society and science actors, as well as Arctic permanent residents. GRASP is interested in securing a constant and lasting relationship with these interested stakeholders and is well aware of the limited financial and organisational capacities that many stakeholders have at their disposal, and which puts severe constraints on their capability to actively and repeatedly participate in one or even several research projects. GRASP hence uses a combined approach of on-site events where stakeholders and project partners can interact face-to-face and online consultation tools that are less time- and cost-intensive to use.

A first stakeholder workshop was held in May 2015 at the Institute for Advanced Sustainability Studies (IASS) in Potsdam, Germany. The workshop had a strong interactive format to give participants an opportunity to actively engage in and shape the project and possibly establish collaborations with the existing project team. Participants included academic experts with various backgrounds from the natural and social sciences, as well as practitioners from industry, government agencies and NGOs. The workshop format involved:

- An opening brainstorming to develop a mutual problem understanding,
- Short plenary sessions providing insights in the key topics “Arctic Transformations” and “Trends and Needs in Arctic research” supported by two key-note presentations,
- Working group discussions of four key-problem clusters (Arctic as a global region—global-local interactions; costs/benefits, risks/opportunities; Governance; Data) that were identified with the help of a pre-workshop questionnaire, and
- In-depth working group discussions on the overall GRASP project idea and the three selected Work Packages.

Instead of competing for the best available stakeholders and their resources, research projects have to coordinate their engagement efforts in order to make use of available stakeholder expertise in the best possible manner. Some key research projects of which AWI is a key partner, namely YOPP, EU-PolarNet and GRASP, have thus agreed to establish a joint stakeholder database to better coordinate and update stakeholder contacts and avoid duplication of work.

5 Reflections and Lessons Learned

GRASP's stakeholder mapping exercise and engagement process (Fig. 2) allow for some initial lessons to be learned for how to build a meaningful and constructive dialogue with affected stakeholders in a dynamic region such as the Arctic. For one, research projects should take into account the needs and desires of the stakeholders they wish to address and engage with throughout the entire research process. A true and constructive dialogue that advances mutual learning between researchers and stakeholders is a reciprocal process at eye level.

Moreover, if the stakeholder communication process shall be a steady and fruitful one, it should be beneficial to both sides. In line with research on stakeholder engagement (Garnett et al. 2009), participants at the stakeholder workshop (in May 2015 at IASS) expressed more willingness to participate actively in a research project if they can help shape the research agenda and core research

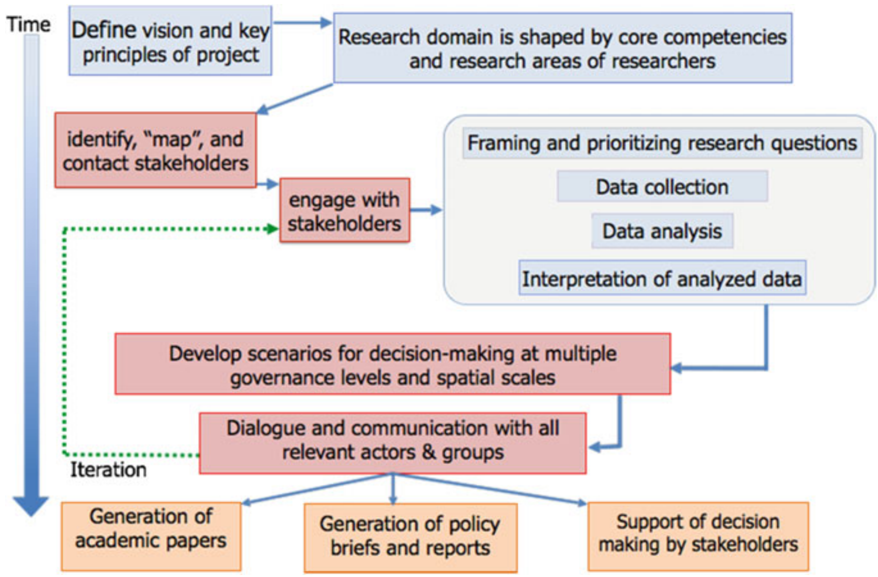

Fig. 2 Stakeholder engagement process (© Ilan Chabay, IASS Potsdam)

questions from the very beginning. This might ultimately turn out to further increase effective implementation of project results. Throughout the research period, research projects will have to secure direct, easy-to-use and innovative channels for communication in the light of limited financial and organisational resources on the part of many stakeholders.

Finally, GRASP's stakeholder engagement exercise shows that it may make sense to rely on a limited number of well-known, trustworthy and dedicated stakeholders instead of opening up the research process to as many actors as possible. In any case, sustained stakeholder dialogue and commitment to research projects necessitates close coordination between the involved research projects.

6 Outlook

Based on the output from Work Package A—Rights- and Stakeholder Groups, once sufficient funding is secured the GRASP project will continue in the different subgroups of Work Package B. The intention here is to incorporate different rights- and stakeholders in the research process.

Acknowledgements Funding is gratefully acknowledged of "Work Package A—Rights- and Stakeholder Groups" by the *Earth System Knowledge Platform* (ESKP) of Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), granted between February 2016 and January 2017.

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Building Bridges at the Arctic Science-Policy Interface

Volker Rachold

1 Background, Scope and Motivation

The Arctic is rapidly changing and increased atmospheric temperatures are resulting in the loss of sea ice cover, glacier retreat and changing snow and permafrost conditions. These transformations are not only affecting people and ecosystems in the Arctic but the entire Earth system. In particular, due to the loss of sea ice, the region becomes more accessible and economic and geopolitical interests have made the Arctic a larger player within the global context.

Though not an Arctic nation, Germany operates one of the world's largest Arctic research programs, mainly through the national polar institute, the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), but also through a number of universities and various other national institutes and authorities. Germany´s strategic approach to Arctic research—"Rapid Climate Change in the Arctic—Polar Research as a Global Responsibility" (2015)—was published in 2015 by the Federal Ministry of Education and Research. Germany is an observer in the Arctic Council, the leading intergovernmental forum for the Arctic that particularly addresses issues of sustainable development and environmental protection (http://arctic-council.org/index.php/en). In 2013, the Federal Foreign Office, representing Germany in this political forum, published the "Guidelines of the German Arctic Policy" (2013), which emphasize the role of science and environment in Germany´s approach to engaging with Arctic nations. Other federal ministries are attentively monitoring the developments in the Arctic, including the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Federal Ministry for Economic Affairs and Energy (BMWi), the Federal Ministry

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G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_9

for Transport and Digital Infrastructure (BMVI), the Federal Ministry for Food and Agriculture (BMEL), and the Federal Ministry for Defense (BMVg).

In light of the growing political interest in the Arctic and referring to its mission "…to perform knowledge-based consulting services for the political, economic and social arena…" (https://www.awi.de/en/about-us/organisation/profile/leitbild.html), the AWI initiated the "Arctic Dialogue" in 2013, a forum to discuss Arctic issues among German stakeholders from science and politics.

2 Methods and Results

The Arctic Dialogue is arranged twice per year as a half-day meeting of invited representatives of the abovementioned federal ministries, the AWI and other research institutes and Think Tanks. The meetings are hosted by one of the participating ministries or research institutes and a specific theme that is relevant for the host of the meeting is defined for each meeting. Additionally, each participating body provides a short update on its recent Arctic-related activities. Internal meeting documents and other background material are made available on the password protected area of the website of the German Arctic Office (http://www.arctic-office.de/en/). Up to now, nine meetings were held:

Date	Host	Theme
February 2013	AWI Potsdam	Structure and priorities of German Arctic Research
June 2013	BMUB	German environmental policy for the Arctic
October 2013	Federal Foreign Office	Guidelines of the German Arctic policy
May 2014	BMWi	Arctic resources and opportunities for sustainable development
February 2015	Institute for Advanced Sustainability Studies	Arctic governance
September 2015	BMBF	Arctic research and societal relevance
April 2016	Federal Foreign Office	Germany´s foreign policy with respect to the Arctic
September 2016	AWI Potsdam	Germany´s engagement in the Arctic Council
May 2017	Finnish Embassy, Berlin	Finnish Priorities for the Arctic Council Chairmanship

A feedback session to analyze the merit of the Arctic Dialogue and to identify ways to improve the usefulness of the meetings was organized at the September 2015 meeting. Participants were asked to comment on both the content and the format of the meetings. All 38 attendees who participated in the survey noted that the dialogue is very useful and should be continued. A number of additional themes that should be addressed at future meetings were mentioned. Participants also positively responded with regard to the frequency and format of the meetings, but pointed out that more time should be reserved for discussions.

3 Reflection and Lessons Learned

The Arctic is the region of the Earth where climate change is occurring more obviously and more rapidly than elsewhere and there is a rapidly growing need to provide scientific knowledge for political decision-making. The Arctic Dialogue facilitates the communication between science and politics that is needed for future-oriented and sustainable Arctic decision-making. Six federal ministries are participating on a regular basis and the feedback session not only confirmed the interest in continuing the dialogue but also in intensifying it with more and longer discussions.

The Arctic Nations are very interested not only in German scientific expertise but also in German technologies to support sustainable economic development as well as climate and environmental protection. This opens up important opportunities for German industry partners, who so far were not yet included in the Arctic Dialogue.

Finally, the dialogue between research and stakeholders must be fostered and maintained in both directions. Arctic science has to be communicated to decision-makers and to business and industry partners; at the same time, the questions that are asked by the stakeholders have to be brought back to the scientific community for the further development of meaningful research projects and outcomes.

4 Outlook

Responding to the requests to maintain and expend the Arctic Dialogue, the AWI set up an office for Arctic affairs at its research department in Potsdam beginning of 2017 (https://www.awi.de/nc/en/about-us/service/press/press-release/german-arctic-office-to-act-as-consultant-to-politics-and-industry.html). In addition to fostering the dialogue between research and the diverse range of stakeholders, this German Arctic Office serves as an information and cooperation platform between German Arctic science, politics and industry and offers direct scientific advice to decision-makers. More specifically, the office

- Supports the federal ministries interested in Arctic matters;
- Plans and implements Arctic events and projects with partners from science, politics and industry;

- Supports the Federal Foreign Office with coordinating Germany´s involvement in and input to the Arctic Council;
- Arranges presentations of Germany´s Arctic science and policy at related international conferences and
- Communicates international policies and research priorities to German stakeholders.

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Part III
Data-Products of ESKP Contributions to AWI Knowledge Transfer

The Web Portal 'meereisportal.de' in Context of ESKP

Klaus Grosfeld, Renate Treffeisen, Jölund Asseng and Georg Heygster

1 Background

The new knowledge and data portal 'meereisportal.de' is a contribution to the cross-linking of scientifically qualified information on climate change. It focuses deliberately on the theme 'sea ice in both Polar Regions'. With the establishment of 'meereisportal.de', science adapts to changing societal demands and embarks on new ways of communication between science and society. The website 'meereisportal.de' is the first comprehensive German-speaking knowledge platform focusing on sea ice and went first online in 2013. It was developed in the framework of the Helmholtz Climate Initiative, Regional Climate Change (REKLIM) as a joint project of the Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research (AWI) and the University of Bremen (Institute of Environmental Physics, IUP), and underlies the management of the Helmholtz Regional Climate Office for Polar Regions and Sea Level Change (Grosfeld et al. 2016; Trade Winds 2016; Treffeisen et al. 2017).

The website contains a wide range of information on sea ice, written and processed for the general public in Germany, as well as scientific data and results primarily targeting expert readers. It also provides various permanent tools that allow online feedback mechanisms.

The web portal provides comprehensive, high-quality and up-to-date information and data on sea-ice concentration, sea-ice thickness of thin and thick (multiyear-) ice,

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ice-tethered buoy-data, etc. The portal aims to offer users specified and individually tailored information and services. Through the multilevel structure (breadth and depth) and custom-made products tailored to user-specific needs, ‘meereisportal.de’ responds to increasing information-demands of various user groups.

The visibility and use of ‘meereisportal.de’ has increased since its launch in 2013 and is now well-established. Besides the overall project management, the team is also responsible for the development and the content of the portal.

2 Scope and Motivation

The site and project ‘meereisportal.de’ has its own specific objectives and framing, outstanding in the larger project-oriented research at AWI. By means of tangible deliverables, it is integrated into the research topic 4 ‘Bridging science and society: products, tools and climate services’ of the current AWI research program (https://www.awi.de/en/science/research-program.html). Within the context of ‘meereisportal.de’, two time-limited subprojects with clearly defined outputs have been supported in the early phase of ESKP. The provided funding was used to take forward basic programming on one hand and on the other structuring of necessary routine data flows of the portal as well as harmonising the maps’ online presentation. In case of ‘meereisportal.de’, the ESKP funding was used to accelerate processes in an already existing project and, thus, contributed to the timely professionalization of the portal.

3 Materials and Methods

Since a project frame and clear outline of objectives already existed for ‘meereisportal.de’, the outcomes within the two subprojects were planned and realised under the overall project aims. The core data needed for producing the outcomes as well as the structure and fundamental programming codes for data visualisation were already available and were provided by the project partner IUP. The ESKP funding was critical in accelerating the working process and shifting particular outcomes to an earlier stage on the project agenda.

4 Results

The ESKP funding was used for the following:

- Realisation of the programming environment for a routine incorporation of sea-ice concentration data for both Polar Regions into the portal by the University of Bremen;

- Creation of a specific portal layout that fits the available maps of the different partners’ expectations;
- Operationalisation of data transfer and map production in an adequate format in order to ensure the functionality on the web portal;
- Development of a secure processing chain;
- Data provision of daily data products of sea-ice concentration;
- Development of additional data products for sea-ice thickness on thin sea ice from satellite data;
- Processing the existing data for regional maps in high resolution.

Figure 1 (see below) shows a working example of a hemispheric map on Arctic sea-ice concentration (Fig. 1a) (Spreen et al. 2008) in a standardised layout of ‘meereisportal.de’, and an associated map of thin sea ice (<50 cm; Fig. 1b) derived from SMOS (Soil Moisture and Ocean Salinity) satellite data (Huntemann et al. 2014). Thin sea ice occurs during the freezing season. In the melting season the thickness of sea ice is highly variable. In addition, the emissivity properties change due to surface wetness and the occurrence of melt ponds in the Arctic. During the melting season the procedure does not yield meaningful results. Therefore, thickness data is calculated only during the freezing season, which lasts from October to April in the Arctic and from March to September in the Antarctic. The thickness of thin sea ice is retrieved daily from observations of the L-band microwave sensor SMOS in the incidence angle range of 40°–50°, in horizontal and vertical polarisation.

The ice thickness map indicates regions of newly formed sea ice. These are predominantly located at the sea-ice edge and show low sea-ice concentrations. Both services are generated in an automatic processing chain. The data from the producer IUP is transferred, formatted and stored (in raw and processed form) for

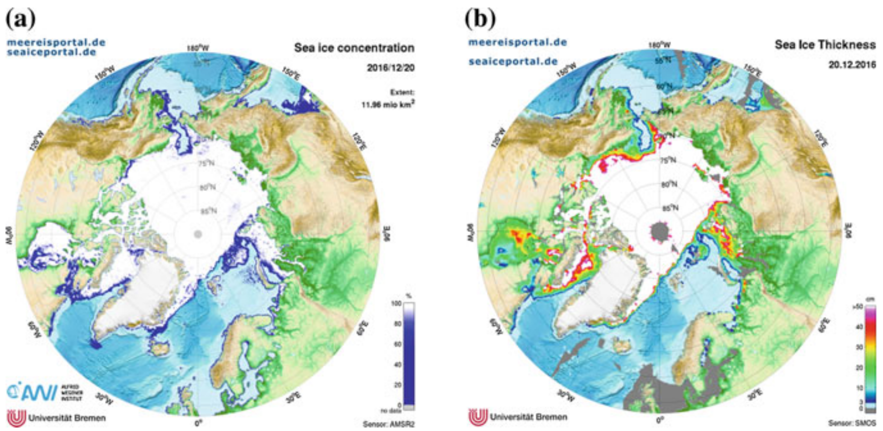

Fig. 1 Maps of (**a**) sea-ice concentration (regions with sea ice of higher than 15% areal coverage) from December 20, 2016 in the commonly developed portal design, and (**b**) of the data product thin sea ice from SMOS satellite data, indicating regions where the sea-ice thickness is less than 50 cm. Both maps are produced and provided as service on a daily basis on ‘meereisportal.de’

long-term archiving. Finally, maps in common formats (jpg and hdf) are produced for further use. The maps underlie the creative common licence 3.0, enabling their public use under citation of the respective reference. With this service, 'meereisportal.de' offers sea-ice data for different purposes in a high quality and printable form. Moreover, the service comprises regional maps in high quality as well as the production of special maps on user demand.

5 Reflections and Lessons Learned

Overall, ESKP funds were used to advance 'meereisportal.de' as an existing project with clear aims and defined deliverables, and to accelerate the use of these outputs on the science-stakeholder interface. The crucial role of ESKP support lies in this acceleration of the project's processes and earlier achievements of already defined outcomes. While certain realisation aspects of 'meereisportal.de' were therefore accelerated, their specific content did not originate from ESKP funded research. The funding structure (being treated like other funding sources) nevertheless enabled ESKP to have partly impact on the project's developments.

6 Acknowledgements

The project 'meereisportal.de' is funded by the Federal Ministry of Education and Research through the Helmholtz Climate Initiative Regional Climate Change REKLIM (grant: REKLIM-2013-04). Specific funding for special purpose through ESKP as described in this chapter is gratefully acknowledged.

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Knowledge Transfer by the Global Terrestrial Network for Permafrost (GTN-P)

Boris K. Biskaborn and Hugues Lantuit

1 Background

Permafrost ecosystems occupy a quarter of the land surface in the Northern Hemisphere. Ongoing rapid temperature change in these areas causes permafrost warming in the Arctic and thawing in the Subarctic regions (Romanovsky et al. 2010). Permafrost degradation associated with rising air temperatures are considered to amplify warming of the atmosphere through the conversion of soil organic carbonthat has been frozen for thousands of years, into greenhouse gases (Schuur et al. 2015). The GTN-P scientific community provides assessments of the impacts of warming permafrost to the global climate system. In this way, GTN-P data products are highly relevant for a broad range of stakeholders from scientific, public and economical sectors .

The Global Terrestrial Network for Permafrost (GTN-P, gtnp.org) is part of the Global Climate Observing System (GCOS) and the World Meteorological Organization (WMO). It was established in 1999 by the International Permafrost Association (IPA) aiming for systematic and long-term documentation of the distribution, variability and trends of permafrost. Permafrost has been identified as an Essential Climate Variable (ECV) by GCOS; GTN-P defined permafrost temperature and active layer thickness as main indicators and developed a Data Management System (DMS) for these two variables. Coordinated by AWI and funded by the EU project PAGE21 and ESKP, the GTN-P Database was launched in September 2015. The database currently includes about 1300 permafrost temperature boreholes and 250 active layer sites from the terrestrial Arctic, Antarctic and mountain areas (Figs. 1 and 2).

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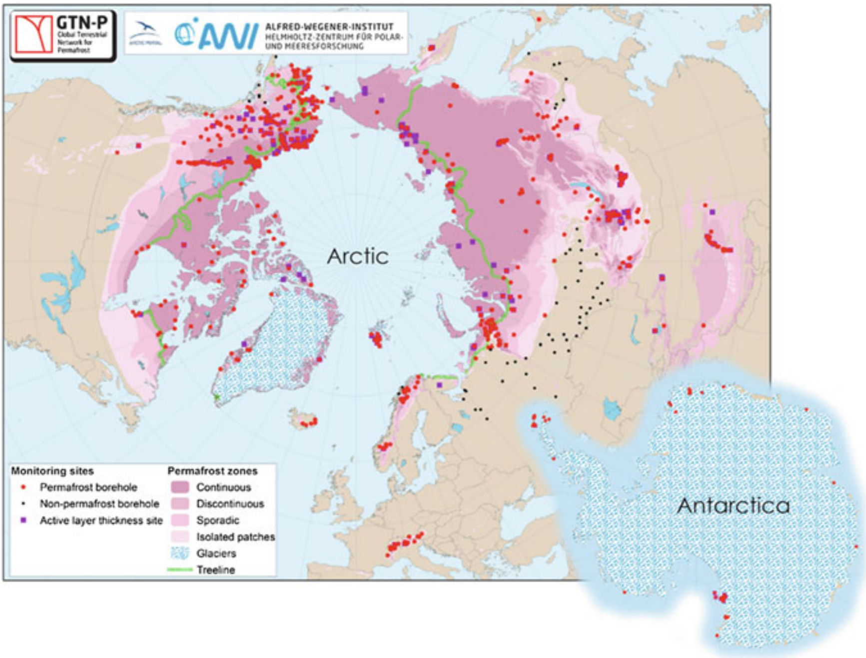

Fig. 1 Distribution of boreholes and active layer thickness sites in the GTN-P Database. Permafrost zones adopted from IPA.

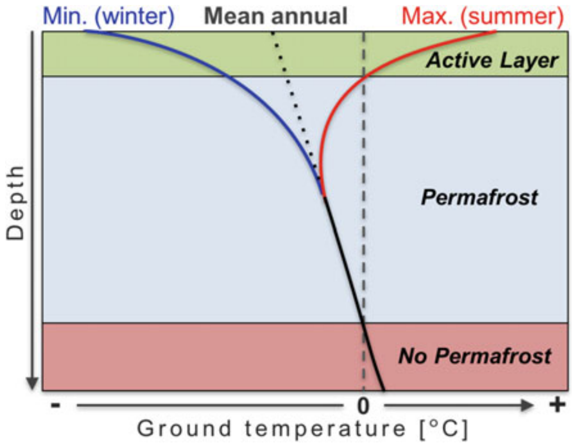

Fig. 2 Two main variables in GTN-P, temperature and active layer thickness, describing the ground thermal regime in permafrost

2 Scope and Motivation

Over the last decades, the Periglacial Research section in Potsdam established AWI as one of the leading institutes in international permafrost research. With increasing attention on environmental science on hemispheric to global scale, the AWI established international data management that is strongly coupled with knowledge transfer. Via ESKP, AWI developed and organized regular transfers of permafrost science highlights to the public, including political and economic sectors.

Co-hosted by the Arctic Portal (http://arcticportal.org/) and the Alfred Wegener Institute, the GTN-P Database and its data management systemprovide a critical link between the researchers involved in field data collection and a variety of end-users, from expert climate modelers, to policy makers, to the general public interested in aspects related to permafrost. Main stakeholders are scientists, public audience, universities, schools and environmental agencies. For this purpose, the DMS was developed with an easy-to-use interface, with extraordinary capacities in automated data visualization, based on user requirement questionnaires and various test phases.

3 Materials and Methods

The GTN-P Database (GTN-P 2015, Biskaborn et al. 2015) was developed in close collaboration between the AWI and the Arctic Portal(http://arcticportal.org/) and is accessible online at http://gtnpdatabase.orgor through the GTN-P website at http://gtnp.org. The general framework of the GTN-P Database is based on open source technologies following an object-oriented data model (Fig. 3) implemented with CakePHP and the spatial version of PostgreSQL. The database structure distinguishes between permafrost temperatures and annual thaw depths. The DMS is constantly improving, allowing for user-friendly data submission, processing and standardization of field data, and the provision of necessary tools for data-queries, visualization, and the ability to download data in various formats. To ensure interoperability and enable inter-database search, metadata field names are based on a controlled vocabulary registry (gtnp.org, ISSN 2410-2385). GTN-P follows an open-access policy in line with the IPY (International Polar Year) data policy and the GEO (Group on Earth Observations) data sharing principles.

Knowledge transfer from the AWI Periglacial Research Section, feeding in the ESKP Permafrost topic, is coordinated by an AWI scientist following (a) proactive and (b) reactive strategies. Proactive: transfer of main relevant outcomes of high-impact papers or expeditions from the section. Reactive: transfer of knowledge as reaction to geo-events that receive attention in the news, e.g. the crater holes in the Arctic (http://www.eskp.de/warnung-vor-weiteren-kratern-in-sibirien/).

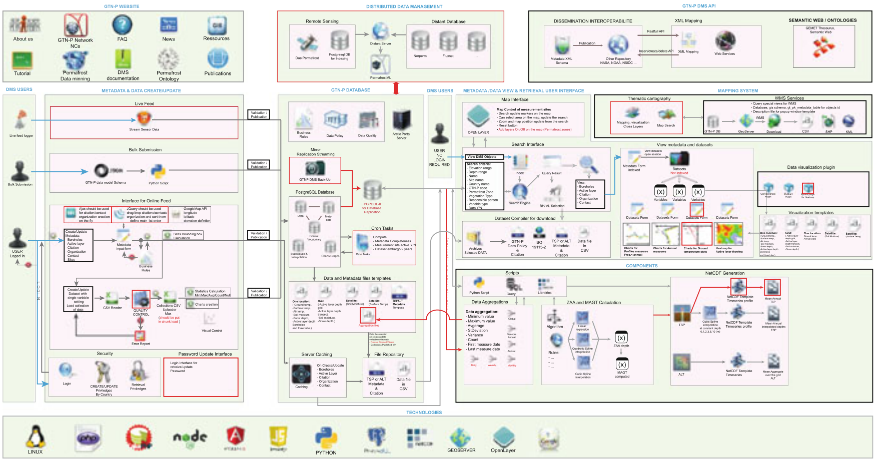

Fig. 3 Object oriented model of the GTN-P data management system

GTN-P Database products are freely available in harmonized formats (CSV, XML, KML, GIS shapefiles) as well as in network Common Data Form (NetCDF) to facilitate implementation in global models.

4 Results

Within the period funded by ESKP, the 2nd GTN-P National Correspondents Workshop, supported by AWI,IASC (International Arctic Science Committee) and IPA (International Permafrost Association), took place in Quebec, Canada. It was visited by 30 participants representing 16 countries, involved either in the GTN-P Steering Committee, the Secretariat, Advisory Board, as National Correspondent or as invited external collaborator (e.g. IASC, IPA, NSIDC (the National Snow and Ice Data Center) and NORDICANA-D). During the workshop the new database governance structure and terms of reference were approved. Several keynote talks were given on GTN-P in the modern scientific society. National Correspondents (NC) gave short talks on the state and availability of boreholes and active layer sites in their countries,and the needs to facilitate data management for data flow toward GTN-P were identified. The Permafrost Young Research Network (PYRN) was involved to establish “Young National Correspondents” of GTN-P, who actively support data management and participate in scientific reports, meetings, workshops and publications. GTN-P Database and metadata statistics were published in the journal ESSD (Biskaborn et al. 2015). The policy for the report on permafrost temperature development was also planned during this workshop. It was decided to establish a mirror of the GTN-P database at research institutes, e.g. in Russia, to facilitate data transfer on a national level. The next major GTN-P meeting was organized by AWI right before the ICOP2016 in Potsdam and brought together 50 participants from 20 countries. The participants discussed specifically the contribution of the GTN-P community to the GCOS Implementation Plan, and the development of a GTN-P Strategy and Implementation Plan 2020 (Streletskiy et al. 2017), a document that outlines network milestones and priorities for the next four years. The conference session "Results from GTN-P: TSP, CALM, and related environmental datasets and models" was the largest at the conference (with 60 abstracts), highlighting the important role of GTN-P within the international permafrost community.

In 2014, six articles on permafrost research highlights were published on the ESKP website, and since then the project output for ESKP is in average five articles per year (17 articles in August 2017 in total). Three ESKP articles described the development and the products of the GTN-P Database. At the moment, the main publication of the global thermal development of permafrost is in preparation and has already been shown on international conferences. The main product is conceived as a map showing the temperature differences (anomalies) of the last 10 years in the Arctic, the Antarctic and Mountain permafrost.

5 Reflection and Lessons Learned

As shown by ranking in clicks on ESKP articles, the topic permafrost receives exceptional attention from the ESKP readership. Since development of GTN-P data visualization, funded by ESKP, requests from public, scientific stakeholders and journalists to GTN-P Database products such as maps and datasets on permafrost temperature and active layer thickness increased significantly.

Knowledge transfer is facilitated by outreach activities based on data visualization provided in quality- proven graphics and maps.

6 Outlook

GTN-P is preparing the first report on global permafrost temperature change (Fig. 4). The report will be transferred to an ESKP article in both German and English. The dataset will be provided in standardized and quality-checked format to the modeling community. GTN-P is drafting the new GTN-P Strategy and Implementation Plan (2016–2020), including a funding concept to involve stationary data on climate observation, and to establish additional mirrors of the database at selected research institutes, e.g. in Germany and in Russia for facilitating data management and data input on national level.

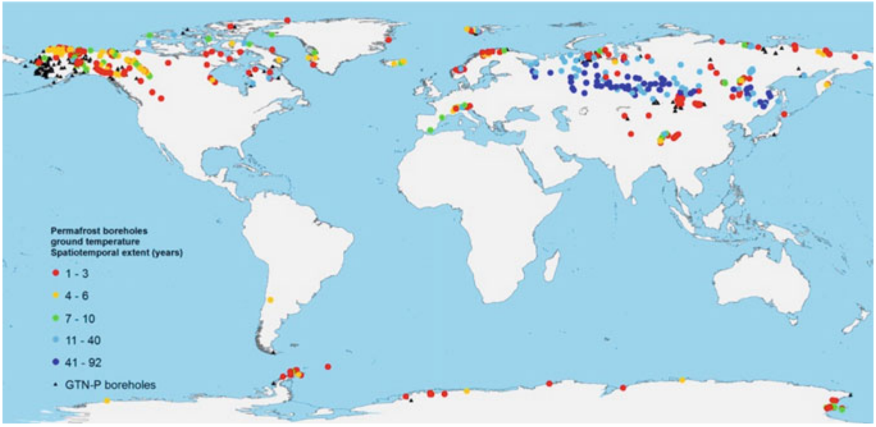

Fig. 4 Visualization of the temporal extend of data sets with mean annual ground temperature values in the GTN-P Database. This data set is currently being quality-checked and processed to report on the global temperature change in permafrost

Acknowledgements We thank ESKP for providing one year financial support to develop the visualization products of GTN-P Database. We thank Karl Dzuba for assisting with proof-reading the ESKP articles on permafrost research highlights. We also thank Jean-Pierre Lanckman, Malek Kaderi and Anseok Joo (Arctic Portal), and Almut Dressler and Saskia Bacher (AWI) for data management.

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A Web-Based Information System for Macrobenthic Biodiversity in the German North Sea

Jan M. Holstein

1 Background

Public authorities and corporations rely on biodiversity information for the assessment of nature conservation aspects within the legal scope of spatial planning and approval procedures of offshore structures. While large amounts of data are collected during planning and monitoring, these stakeholders or prospective data-users often do not have the opportunity to make full use of the data for their respective purposes. In this respect, the Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research (AWI) as a trusted third party can provide the expertise required to turn data into meaningful information and new knowledge where it is needed.

2 Scope and Motivation

A large part of the sense-making processes working with large data sets revolves around data tidying, modelling, visualization, and exploration. One main objective is therefore to further develop some of these methods into tools and expert systems

The original version of this chapter was revised: For detailed information please see Erratum. The erratum to this chapter is available at https://doi.org/10.1007/978-3-319-75919-7_19

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that can be operationalized and employed without obstacles by non-expert users. A tangible incentive exists to (i) free researchers from mundane filtering and visualization tasks, (ii) eliminate circumstances for inadvertent mistakes, (iii) increase the granularity of request specifics, (iv) increase the potential throughput, and (v) widen the target audience, i.e., broaden the service.

Against this backdrop, the aim was to construct a system that conveys biodiversity information of relevance for spatial decision-making pertaining to offshore constructions without influencing existing rights of data ownership claimants.

The development of this ESKP-project was based on the previous fruitful collaboration with the Bundesamt für Seeschifffahrt und Hydrographie (BSH—Federal Maritime and Hydrographic Agency) in Hamburg, which generously provided its benthic biodiversity data for research but also has specific information requirements regarding data to fulfil its public administrative and regulatory duties. Along those lines, relevant questions were developed that our information system should be able to answer. The most affected target groups, however, are often private sector planners and consultants; standing at the beginning of the entire process of realizing offshore structures, the 'costs of not knowing' are highest here.

3 Materials and Methods

The term 'information system' has a connotation heavily encumbered with features and functionality. In contrast, we aimed for a lightweight visualizer of the information in question. The only non-functional requirement was the use of the R Shiny framework (https://shiny.rstudio.com/), which provides a very efficient way to make web-based data exploration and visualization tools.

The basic components of the system were

- A relational database containing the biodiversity data, processed to fit the data model to be developed;
- The user interface;
- The business logic—all the computer code required to translate user input into SQL queries and to retrieve and process the answers;
- The mapping, which will facilitate the visualisation of JSON (Java Script Object Notation), Shape and Raster data via the Leaflet technology; and
- The export, enabling the download of data in generic geo-formats.

A number on functional requirements were put up reflecting the type of data most often requested. In the interest of user-friendliness of the final application, only one or two of the following requirements were actually to be realized:

1. Biomass and abundance maps of species aggregated on a grid;
2. Predictions of species distributions using statistical and machine learning methods;
3. Ecologically relevant indices aggregated on a grid, e.g. diversity measures;
4. Neobiota; and
5. Endangered species listed in the relevant Red-List catalogue;

The mode of knowledge transfer in this project was mainly the provision of data exploration and visualization tools for large data sets and providing these data in an accessible and flexible way for further analyses. Formats are generic geo-data file formats.

4 Results

The technical obstacles to the system's implementation could be overcome, and functionalities 1.−3. were actually realized (Fig. 1). The goal of an already operational information system, however, could not be achieved in the framework of this project. Two possible reasons can be brought forward, the first being critical concerns over data policy aspects (e.g., who owns the data, who analyses and interprets the data, and who links the data to the users). This also included aspects related to a clear distribution of responsibilities for such data-related services.

These are not surprising but critical considerations to keep in mind for future project planning involving research results with stakeholders from various governmental and business realms. Therefore, while there was consensus from the onset that the service as such would be useful, challenges existed on using various kinds of data-dissemination-channels.

The second reason is one where the challenges faced by the project also embody development opportunities. During the development of the information system it became obvious that the biodiversity data management in place was largely insufficient to carry out the project in its present approach, and inefficient for many other research approaches, potentially threatening the integrity of the data. While it is becoming more and more visible that this is a common problem, found in all kinds of disciplines (Wickham 2014; Vines et al. 2013; Gibney and Van Noorden 2013), our discovery and emphasis of this problem led the enactment to remedy and shed light on this pressing situation within the institute. A project is now underway to develop a fitting data model and to restore data integrity. Thus, as one central result, the awareness for much-needed data management plans has been raised by this project.

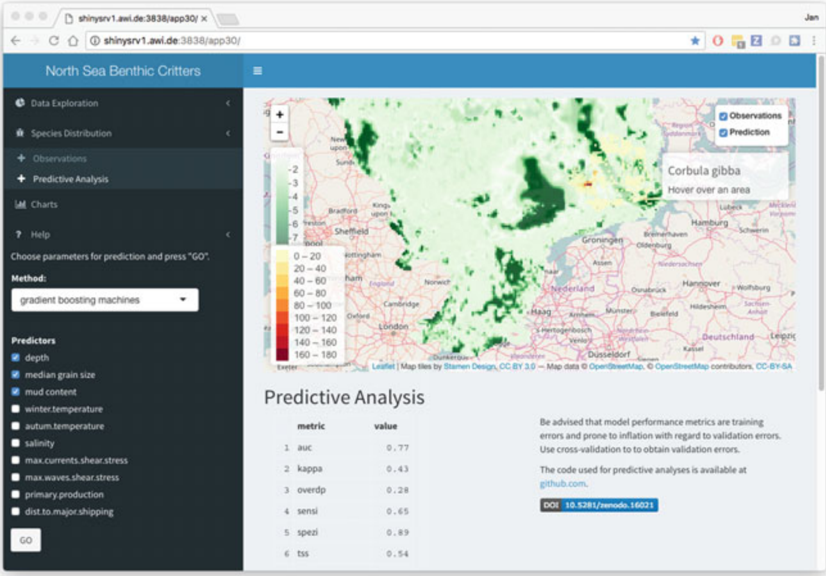

Fig. 1 Screenshot of the web application showing the module that performs a predictive analysis according to user set parameters and visualizes the result

Once this database becomes operational, the existing solution can hopefully be revived and put to its initially intended use.

5 Reflection and Lessons Learned

It is critical to reflect on when it is best to get the stakeholder on board of a project. To minimize obstacles on the stakeholder side it is good to be as prepared as possible, having done all the necessary research and a being able to present the fully laid-out project. On the other side, this holds the risk to alienate stakeholders or even lead to outright objection to a project objective.

However, insufficiently curated data makes research inept, future accessibility questionable, and good services impossible. At least in some areas of science, large amounts of the data will be lost if action is not taken to devise data models and enact data management plans quickly.

6 Outlook

A culture of separation of science and societal actors, in which conventional knowledge transfer is used by mostly narrating scientific results of a completed project, is inefficient in many ways. More often than not, public demands and specific tools are missing that could make scientific data more readily available to a broader target audience. However, limited integrated data management solutions at institutional levels necessitates that information systems are built on datasets that are at the end-point of elaborate cleaning, preparation, and study. They are hence often disconnected from any update mechanism by which new data could be poured into the system. Through the mostly project-oriented context in which many scientists work, in which the individual scientist needs to move on to new projects once the science is done and published, data sets and information systems are at high risk to become abandoned.

In conclusion, data management should be better integrated in the way that requirements of both science in progress as well as appropriate knowledge transfer tools are met by the same warehouse or information system. That way, tacit knowledge that resides in organizational members, tasks and networks stays connected to the tools and knowledge transfer draws closer to researchers and the actual research front, which can increase the responsiveness and potential of science to contribute to problem solving.

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Tackling Marine Litter—LITTERBASE

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1 Background

Anthropogenic litter contamination of the oceans is a global problem of growing concern and currently receives strongly increasing attention by policy makers, public authorities, media and the general public. Unlike many other pollutants, marine litter on beaches and its deleterious effects on marine mammals, birds and turtles have attracted much attention as they can be directly observed by stakeholders. 'Blue environments' provide a sense of connectedness with nature to humans, which is, however, significantly compromised by the presence of anthropogenic litter (Wyles et al. 2015). This explains its importance in public perception, and it also shows that the issue lends itself well to showcasing both the importance of our oceans to humankind and at the same time the global extent of anthropogenic impacts on marine ecosystems.

Marine litter consists primarily of plastics, which does not come as a surprise given the durability of the material and that 8,300 million tons of plastics have been produced to date (Geyer et al. 2017). The recent discovery of the great oceanic garbage patches and of microplastic, a degradation product ($\leq$ 5 mm) of larger items, has spurred new interest in this field of research, which is currently taking a

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G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_13

large leap forward. Great efforts are being made to assess the impacts of this form of pollution on marine biota. This has disclosed an unexpected complexity of a seemingly simple environmental problem (Kühn et al. 2015; Lusher 2015). The number of records on the abundance and distribution of litter in more and more aquatic ecosystems and all oceanic regions is growing rapidly in the scientific literature, highlighting its ubiquity (Galgani et al. 2015). Between the late 1960s and 2016, scientific research on marine litter has yielded some 250 publications. But although this figure rose to 200 papers just between 2010 and 2013 (Ryan 2015), studies currently lack standardisation of methodology, which hampers comparison, qualification and quantification of the impacts on a global level (Galgani et al. 2015). The temporal and spatial coverage of studies mostly focuses on local areas or specific time periods, which does not improve our understanding of possible sources and transport mechanisms at a global scale. Accordingly, we currently only know where 1% of the total amount of plastic assumed to enter the oceans from land ends up (van Sebille et al. 2015). Considering the vastness of marine environments and the complex interactions between different ocean biomes, we urgently need baselines to extrapolate data and thus allow global assessments.

In a survey among 3,876 stakeholders, including representatives of industries, management, education, environmental organisations, and the general public from 16 European countries, most respondents were concerned about marine litter (87%) and conceived it as a severe threat to marine environments (80%) (Hartley et al. 2015). However, survey respondents beleived most litter to be near urban coastal areas and underestimated the proportion of marine litter items composed of plastic by 30%. In another, smaller, survey (n = 68), the majority of respondents' mistakenly believed that microplastics were primarily found on beaches and at the sea surface (S. Pahl cited in GESAMP (2015)). These examples highlight that, despite the topic's societal relevance, the rapidly growing scientific knowledge is currently poorly fed back to and used by society. Effective environmental policy and management, however, require sound scientific advice as well as effective processes that enable information uptake and feedback within and from societal stakeholders.

Here, we developed a tool with two main goals: (1) compile existing scientific knowledge to enable meta-analyses, which allow us to deduce global patterns of marine litter abundance, composition, distribution and ecological effects; (2) increase public understanding of marine litter by channelling scientific knowledge into accessible and understandable information products.

2 Scope and Motivation

Scientists from five different research groups at AWI currently focus on different facets of this environmental problem, i.e. on the impact of litter and microplastics on marine life, the distribution of litter and microplastics in different biomes and geographic regions and on methodological harmonisation. At a national level, the AWI is therefore currently conceived at the forefront of marine litter research such that AWI scientists are frequently consulted by the media and public authorities for advice and information. For example, the institute's annual media resonance analysis showed that the press releases pertaining to this topic resulted in 686 citations in the press, reaching more than 37 million people in 2014 alone, a figure that does not even include enquiries independent of press releases. Queries of scholars or other interested parties refer primarily to basic but overarching issues such as current figures on global quantities, composition and distribution of marine litter, the number and kinds of biota affected, or the effects on marine life and human health. However, the rapid progress in marine litter research scattered all over the Globe has made information on this topic increasingly intangible and inaccessible to interested stakeholders who cannot extract the requested information. To overcome this, Bergmann et al. (2015) channelled the current state of research in the text book 'Marine Anthropogenic Litter' and then became aware that the compiled knowledge became outdated as the book was written because of the rapidly growing number of new research publications. To provide easily accessible, understandable and continuously updated statistics and information products on marine litter and microplastic, the online portal '*LITTERBASE*' was devised. Stakeholders using this portal include public authorities, policy makers, NGOs, media, scholars, education sector, fishing industry, the general public and plastic manufacturing industry. For the purpose of this text, a reference to litter hereafter refers to both microplastic and larger-sized items.

3 Materials and Methods

A scientific database was designed to allow standardisation and analysis of marine litter data. The need for the instant display of the latest data along with older entries and many-to-many relationships of study locations and findings precluded the use of simple data management and storage tools. Therefore, the database was implemented on PostgreSQL 9.5. The publications were grouped according to their focus on either litter distribution, or interaction between litter and biota, or on both. The position of each study location was stored separately so that as many details as possible could be displayed in the front-end maps. Information such as litter type, size, litter quantity unit, aquatic system, biome, interaction type and effect were defined as metadata categories and extracted. Taxonomic information of the species affected by litter was also included. Where possible, litter quantities were standardised during data entry. Interactive web-based data management forms were devised to facilitate a user-friendly entry of multidimensional information to LITTERBASE. The data management and front-end applications were implemented with open-source Java Exercise Evaluation Framework (JEEE) technologies (Spring framework, Hibernate, Tyhmeleaf) and deployed to Apache Tomcat 8.0.33 on the institute's server. Google chart API was used to produce graphs in the front-end to display the output of data analyses. Two geo-referenced maps (litter distribution and biota interaction) were implemented with ArcGIS 10.4.1 as part of the front-end application. The AWI GIS Viewer 0.3.3 extension was used to publish ArcGIS projects as Web Map Services. Data were assembled as feature classes via database views to enable an instantaneous display of new entries and updates in maps. The most common metadata categories were used as selection criteria in the front-end application to allow stakeholders to filter and display scientific data in an understandable and user-friendly manner.

4 Results

LITTERBASE comprises two main components and its extensions:

(1) **Data entry** (**back end**). Most peer-reviewed publications on the distribution of aquatic litter and its impacts were selected from previous review articles and new content alerts of scientific journals. Information extracted from 1,593 publications providing records of the distribution and/or interactions from more than 7000 locations were entered into the scientific database (status February 2018). Bibliometric data of all publications were entered, as were metadata pertaining to litter type (e.g. plastic, glass, metal, fishing gear), litter size (i.e. nano, micro, macro), litter quantity unit (e.g. items km^{-2}, items km^{-1}, items m^{3}), aquatic system (e.g. marine, freshwater, estuary), biome (e.g. beach, sea surface, water column, benthic) and total litter quantity. Litter quantities were standardised to the same units to achieve comparability. However, the use of many different sampling and analysis methods in different studies precluded a categorisation of all litter densities into one uniform set of units. Therefore, all analysis methods and units were kept in the database for further scientific analysis, while only three unit systems (items km^{-1}, items km^{-2} and items m^{-3}), comprising 42% of all records, were provided as selection and display criteria in geo-referenced maps.

Data on biological interactions with litter were also extracted: location of field records, number of species affected, percentage of individuals affected, type of interaction incurred (e.g. entanglement, ingestion, coverage, rafting), effects on biota (e.g. injury, mortality, growth, behaviour), litter type, litter size, aquatic system and biome.

(2) **Online data portal LITTERBASE** (**frontend**). Stakeholders can view the data entered in continuously updated information products. The distribution of global litter quantities and of interactions between litter and marine life is, for example, displayed in interactive maps (Figs. 1 and 2). Using tick boxes, stakeholders can restrict the display to records from certain aquatic systems, biomes or litter sizes. Pie charts show the contribution of different materials to the litter records. Differences in the quantities of litter from different areas are reflected in the size of the mapped pie charts. Upon click on a pie chart, further information as well as bibliographic data pops up in a text box.

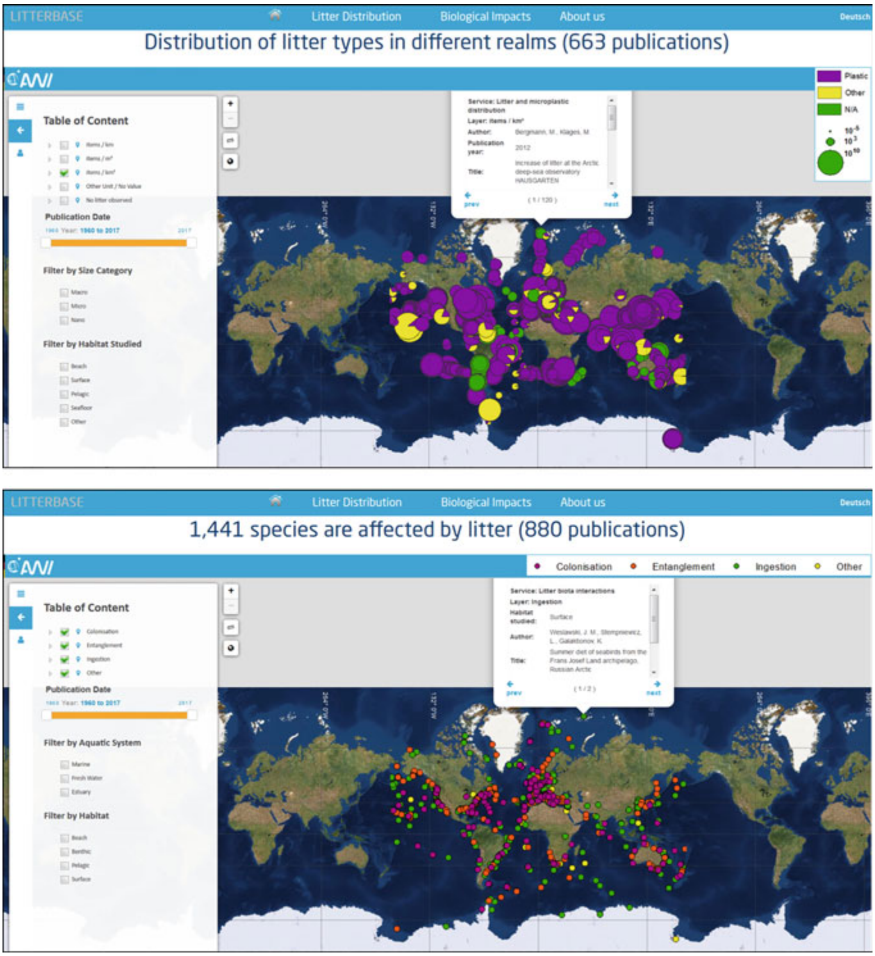

Fig. 1 Screenshots from LITTERBASE: (Top) Quantity and composition of litter and microplastic recorded from different locations worldwide. (Bottom) Field records of interactions between marine biota and litter from different locations worldwide (status 27/09/2017). Insert text box with information on record opens when clicking on points

In addition, information on the number and kinds of marine species affected by different types of litter can be viewed in pie charts. Data from laboratory experiments are also included in these information products but not shown in maps to preclude bias due to the position of laboratories.

Achievements of LITTERBASE during the first quarter after the launch
During the first year after the launch, the portal was visited about 77,284 times in 29,517 sessions Fig. 2. Maximum sessions per day were between 984 and 3,474 in the first month, probably as a result of a broadcast in the local TV news (Buten and

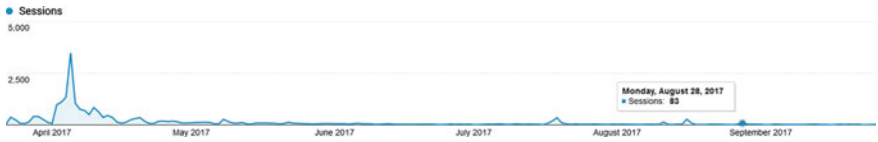

Fig. 2 Page visits per day (22/04-26/09/2017) from Google Analytics tool

Binnen). Mention of LITTERBASE in the News section of SCIENCE and in German newspapers instigated also increased page visits as did a communication about LITTERBASE in the high-ranking scientific journal NATURE (Bergmann et al. 2017).

Information from LITTERBASE was used in headlines of various Indian Newspapers and homepages stating "*Mumbai's sea-water most polluted globally*" or "*Vembanad Lake among most polluted in the world*". This is important as it highlights that the portal is being used by individual local stakeholders themselves to extract the information that they need. Additionally, both requests to use and offers to share further litter data were directed to the LITTERBASE team. These were put forward by scientists, regulators, scholars and teachers as well as citizens. LITTERBASE information graphics were also used in a geography text book for high school.

Currently, the homepage is visited on average by some 2,132 users per month. Twenty-one percent of the page visits are currently from German sites, followed by The Netherlands (14%), US (12%), France (9%) and others. Returning visitors account for 24%, new use for 76%. A Google Analytics survey returned 39,259 linkages (status February 2018), many of which were from German sites but also from US American, Asian, Russian, Italian, French, Dutch, Chilean and sites from other nations.

5 Reflection and Lessons Learned

The implementation of an online portal to aggregate and present scientific results goes beyond the usual activities of natural scientists and requires substantial support and close collaboration with contributors from other disciplines, primarily computing specialists. The development and implementation of LITTERBASE greatly benefited from the employment of an IT specialist with a strong environmental background and extensive experience in the topic of marine litter. Human resources with a broad expertise from multiple disciplines were essential for a successful implementation of the portal. However, such profiles clearly contrast the conventional development of specializations in academia. If online portals are to become an integral part of the knowledge transfer strategy of an institute, a prominent institutionalisation of this branch in the infrastructure and curriculum of the computing and other departments will be imperative to guarantee successful future developments and the sustainable long-term maintenance of the implemented technology.

6 Outlook

LITTERBASE is only one player in a concert of various online portals on marine litter, set up by other institutions. However, depending on the scientists and institutes involved, the various portals will have different *foci* and will hence provide different views on the same issue. A diverse supply of information from different sources will allow for a broad understanding of the marine litter problem in various stakeholder groups. Whether these diverse knowledge transfer activities actually contribute to the development of sustainable solutions to this eminent environmental problem is still difficult to assess and will have to be subject to dedicated social-science as well larger-scale interdisciplinary projects.

LITTERBASE will be subject to constant further development. Possible future extensions include geo-referenced litter observations made by citizens. Citizen science campaigns have the potential to substantially expand the spatial extent of investigations. The identification and quantification of anthropogenic litter in the environment and its multiple effects on the marine wildlife can easily be assessed by persons without specific scientific background, such as tourists, rangers, divers, fishers or members of the general public. Once added to the database, the results of citizen science campaigns can be viewed in combination with scientific data in the online portal thereby potentially enhancing connectedness of non-scientists with the specific research field.

Acknowledgements The authors thank the AWI IT and GIS departments for their support in developing and launching LITTERBASE. T. Busch, F. van Heeckeren, I. Kittel, C. Peter, B. Staufenbiel and N. Steiner extracted and fed information from publications into LITTERBASE. This publication is Eprint 43257of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research.

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Part IV
Modelling Approaches of ESKP Contributions to AWI Knowledge Transfer

Arctic Sea Ice Change, Large-Scale Atmospheric Circulation Patterns and Extreme Climate and Weather in Europe

Ralf Jaiser and Dörthe Handorf

1 Background

1.1 Context at AWI

Research at AWI is based on expertise in observing, modelling and analysing data from polar latitudes. This fosters the overarching aim to identify and quantify natural and anthropogenic changes in polar systems and to explore their unique system properties. AWI research covers the full range of time scales from paleo-climatology to future projections. This involves an interdisciplinary approach covering all aspects of the earth system bringing together atmosphere, biosphere, cryosphere, lithosphere and the oceans. All these subsystems are affected by amplified climate change in high latitudes. This emphasises the importance of exploring and understanding the environment of polar regions.

Moreover, polar regions are embedded in the global climate system. Changes in one region do not stay there, but interact with the entire globe. A better understanding of high latitude climate helps to better understand and better predict changes in other regions especially in mid-latitudes. Polar research at AWI is thus embedded in climate research for the entire earth system.

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1.2 Scientific Basis

Europe witnessed two extreme cold winters in 2009/10 and 2010/11. They were characterized by an anomalously negative phase of the Arctic Oscillation (AO) teleconnection pattern. This pattern describes the interrelated variability between the climatological low pressure over the Arctic and the high pressure belt over southern mid-latitudes. A positive phase describes a large difference in pressure and thus strong forcing of the jet stream and a generally intensified westerly circulation. A negative phase describes reduced pressure gradients and relates to a reduced forcing of westerly winds and a more meandering jet stream. The latter allows more direct transports of air masses between polar and mid-latitude regions. In fact, the record negative value for the AO pattern was determined for the winter 2009/10. This happened at times when a wide-ranged story was that because of global warming, winters in Europe will soon be warm and snow-free. But climate is non-linear. Statistical analysis showed that sea-ice retreat, amplified Arctic warming and the changed temperature gradient between polar and mid-latitudes have the potential to change the large-scale atmospheric circulation (Jaiser et al.2012, 2013). The forcing of large scale westerlies is reduced leading to observed negative phases of the AO. This effect is strongest in winter. The reduced westerlies lead to less warm air that is transported over the continents. Now cold spells from the north and eastern continental areas can reach Europe more easily as observed in these extremes as well as the following winters.

1.3 Previous Activities

The proposed relation between Arctic changes and mid-latitude weather proved to be popular. In the media they delivered a good catchline related to cold spells in February 2012 and March 2013. From a more general perspective it showed that global climate change means more than warming only. Moreover, it is one of the rare instances when a basic science topic leads to a large public interest. Many interviews in print, radio and TV were given during the weeks of these events. An ongoing demand for public talks and articles remained after these hype-like events.

The idea of the ESKP project was to use, keep and further develop this momentum of information demand and knowledge transfer in one of the hot topics of polar climate sciences. It was one of the first ESKP projects, and its explorative journey was still somewhat unknown at the time and needed to find its frame.

1.4 Relevant Stakeholders

The above mentioned high potential for news stories has been incorporated into the project from the onset, based on the previous experiences. The information demand depends largely on weather events and the corresponding media response. Nevertheless, the media response in these winters indicated a large potential and general interest by the public in general. This defines a complementary potential for interactions with a public audience in terms of talks at information events. The topic is related to people's everyday experience of weather and climate in general. There is a chance to make scientific results more visible and explain them better in this context. Climate is complex. There are separations between 'simple facts', their simple global implications like global warming, and more complex mechanisms that imprint anomalies on regional and seasonal scales. The latter potentially and apparently contradict the simple global fact, which is a story that needs to be told, to other scientists as well as the public.

The topic is clearly related to mid-term weather predictions and climate projections. In this area many stakeholders have an interest. The economy and especially the energy and insurance sector need to know how winters in mid-latitudes develop in the short term but also in future scenarios. Any future activities and investments in the Arctic region but also in mid-latitudes depend on good forecasts and projections. This further extends the potential to the provision of facts for political decision-making.

One problem is that—for real collaborations—these stakeholders are interested in "what will happen" but less in "what could happen". Therefore, any uncertainties stand in the way of these applications. The general opportunities had been identified at the ESKP vision workshop in 2013. Most of it was postponed as a future perspective, since more research was needed to build on.

2 Project Establishment and Progress

At the beginning of this project in 2013, the general topic of linkages between Arctic and mid-latitudes was still at its early stages. While empirical and statistical evidence was promising, there was a lack of process studies and a detailed understanding of the involved mechanisms. Uncertainties were (and still are) large, with studies showing contradicting results. Therefore, a major part was to perform and further develop research to gain more understanding of processes and mechanisms and to reduce uncertainties. Existing CMIP5 model simulations with ECHAM6 were analyzed (Handorf et al. 2015), additional project proposals were submitted for the "AWI strategy fund" and "DFG SPP Antarktisforschung". There was a close collaboration with the ERA.Net-Rus project ACPCA (Wegmann et al. 2015), and the follow-up proposal SWEXA was prepared. One of the ideas of these proposals was to further reduce the uncertainties through additional research and to enable successive knowledge transfer. Therefore, they included collaborations with different academic groups, including from the social sciences. This was supposed to build the foundation for future intensified stakeholder interaction opportunities also outside academia.

The project further enabled participations at mostly scientific workshops with invited talks between 2013 and 2015. While most of them were related to the research topic, there were also broader workshops for example at the IASS in Potsdam, where the natural science perspective was presented to an audience that included a broader academic community including social sciences and humanities.

Further outreach activities were first and foremost performed in terms of public relations. There is an interesting story to tell about a potential explanation (based on a fascinating mechanism) for a particular extreme event or a potential climate regime shift. This shows the complexity of weather and climate. On the one hand it shows great potential, on the other there are uncertainties that reduce the general applicability for forecasts and projections, thus further motivating additional research. This is bridging basic science directly to a general public audience. Catchphrases were “Things that happen in the Arctic must not stay in the Arctic” as well as “Global warming can imply regional and seasonal cooling”. Talks were given at public events (“Lange Nacht der Wissenschaften”, “Potsdamer Tag der Wissenschaften”) and at summer schools. Furthermore, articles for the ESKP website and the Meereisportal were prepared.

Summarizing, the project had a clear scientific background that was pursued despite some more complex obstacles. Unfortunately, all above-mentioned proposals for funding were rejected. Nevertheless, wide-spread outreach activities were successfully performed within the ESKP-funded period. On several occasions, the topic was presented to a wider public and scientific audience with lots of feedback from interested listeners. Therefore, knowledge from state-of-the-art basic science was indeed transferred to a wide range of other stakeholder communities.

3 Reflections and Lessons Learned

The outcome of this project has to be seen in relation to the early stages of ESKP at AWI at that time. The first vision workshop was not yet held and the Call for Tender program was still months away. Thus, AWI experience with these kinds of projects was accordingly low. Nevertheless, this was an important topic at AWI with a clear outreach perspective that has been already proven and needed to be further pursued. The share of scientific work in this project was rather large compared to future ESKP projects. This development might be considered as a lesson learned: future projects in the ESKP framework increasingly focus on how to get hold of stakeholders, and their interactions with scientists and scientific results.

One of the lessons learned was hence related to the foundation of this project. The topic is based on basic science. Basic science is by its self-definition hard to communicate to knowledge recipients outside the specific science community. The usual way has to go from basic sciences to applied sciences. This implies a major step of translation and intensive dialogue. There is a distinct need to develop actual applications and to transfer knowledge to stakeholders outside the specific science topic more easily. Therefore, the focus of this project was less to directly transfer the knowledge to stakeholders but more to develop the applied science part. The direct way was almost impossible to achieve at this stage due to uncertainties and a lack of understanding on both, the science and stakeholder part. Since it became clear very quickly that these issues could not be overcome within the ESKP project, a clear focus was set on the acquisition of additional funding, which was unfortunately not granted. Nevertheless, it has to be repeated that there was a good portion of knowledge transfer from this project to other scientific audiences and to the general public. The outcome here is that ESKP has the potential to act as a platform to support these kinds of projects not directly transferring knowledge yet, but trying to initiate follow-up projects that have a stronger perspective on knowledge transfer and stakeholder interactions.

A more general problem is that scientists and overall science is primarily evaluated by scientific output. Although this changes step by step in recent times, most scientists still need to follow primarily the consequential pathway. Publications in recognized peer-reviewed scientific journals are the top priority. Following this, it is very important to ensure enough funding to be able to continue the research. These primary criteria apply to internal and external evaluation of the whole research center, the research section and the individual researcher, respectively. In this environment, especially early career scientists are more encouraged to follow their scientific path, which means they are pushed to write manuscripts and proposals rather than to translate their science and develop their results and outputs for non-scientific audiences. Not only are they urged to do so, but also most support and funding is given in these areas. It is important to say that the resulting specialists are needed for a good science foundation. Still, it leads to scientists that clearly prefer their science. This is what they have been educated for, this is where their skills are. The complicated task is to develop an environment where we have great scientists that do state-of-the-art science on the one side and high quality knowledge transfer on the other side. This should not be arranged by forcing scientists to perform this transfer. They have not been educated to perform this task and their daily business is to far away from stakeholder needs. Performing both tasks at the same time would lead to worse science and insufficient knowledge transfer. Moreover, the knowledge transfer has to be anchored inside every research section. Otherwise, there is a risk of short-lived projects to end up in a 'lone-wolf-setup' tilting at windmills. Only with an altered foundation can these projects have a substantial impact and the potential to develop sustainably, and not 'just stop' at some point.

4 Outlook

Public interest in linkages between polar regions and mid-latitudes is still high and will most likely remain high. This is addressed with ongoing talks in different occasions. This includes events with teachers, students and school classes in addition to the events mentioned before. On the scientific side, the potential of these linkages to improve forecasts and projections has been shown, but applications are not yet there. Models have to be properly designed to cover processes and mechanisms of linkages between polar regions and mid-latitudes, and it seems that not all models are capable of this. Processes with difficulties include the interactions between troposphere and stratosphere, corresponding wave propagation on different scales and the interaction between waves and the mean flow. With our research we have a benchmark to check model performance and an incentive to improve it. Of course, this is in parallel to the general task of further improving our understanding and knowledge. These improvements will enable us to apply the knowledge leading to improved weather forecasts and climate predictions. Finally, this extends the potential for stakeholder interactions and more advanced knowledge transfer.

Acknowledgements The author appreciates the opportunity to be supported by this early ESKP project. In this regard, many thanks go to the coordinators Gesche Krause and Wolfgang Hiller. Additional very helpful support for articles on the ESKP website came from Karl Dzuba and Ute Münch as well as from Renate Treffeisen considering the Meereisportal. Public relations activities in Potsdam are only possible through the endless efforts of Marion Maturilli and Bernhard Diekmann. And finally the author wants to thank Klaus Dethloff and Dörthe Handorf for enabling and supporting his scientific work.

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Extending and Visualizing the TsunAWI Simulation Database of the Indonesia Tsunami Early Warning System (InaTEWS)

Antonia Immerz, Sven Harig and Natalja Rakowsky

1 Background

After the devastating Indian Ocean Tsunami 2004, the BMBF-project "**G**erman-**I**ndonesia **T**sunami **E**arly **W**arning **S**ystem" GITEWS (www.gitews.de) was part of the German contribution to reconstruction and development in the affected regions in Indonesia. As there had been no system for early tsunami warnings in the entire Indian Ocean, the project partners—with the German Research Centre for Geosciences (GFZ) as leading institute—designed and built this state-of-the-art warning system step by step. With AWI's expertise in ocean modelling, the Tsunami Modelling Group at AWI developed the tsunami simulation code TsunAWI, set up a database of precomputed scenarios, and implemented the interface SIM (SIMulation system) to administrate the database and to select and provide scenarios to the decision-support system (Rakowsky et al. 2013). In 2008, the Indonesia Tsunami Early Warning System (InaTEWS) was inaugurated at the Indonesian Agency for Meteorology, Climatology and Geophysics (Badan Meteorologi, Klimatologi dan Geofisika, BMKG, www.bmkg.go.id) (Fig. 1) and has since been operational. In 2011, it was fully handed over to Indonesia.

In the sustainability phase 2011–2014 of the BMBF-funded "**PRO**ject for **T**raining, **E**ducation and **C**onsulting for **T**sunami Early Warning **S**ystems" (PROTECTS), training was provided to the technical and scientific staff in

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Fig. 1 Tsunami Early Warning Center, Jakarta/Indonesia

Indonesia in order to successfully and permanently maintain InaTEWS. Twelve workshops were held at AWI on tsunami modelling and maintenance of SIM.

Since 2011, AWI provides maintenance and support for the software components TsunAWI and SIM for BMKG on a yearly basis. In a project supported by the Australian Government through the DMInnovation project (dfat.gov.au/geo/indonesia/development-assistance/Pages/development-assistance-in-indonesia.aspx), AWI assiststed BMKG to extend the area that is covered by pre-computed scenarios to the North-East of the Indonesian Archipelago.

2 Scope and Motivation

2.1 Project Goals

The tsunami project in ESKP aimed at implementing a versatile interface to TsunAWI scenario data. The overall goal was to facilitate access to wave propagation information, which until then was only possible with in-depth knowledge of the tsunami model and corresponding programs. In particular, tsunami scenario data had to be formatted in such a way that it could easily be used by several software components: the current decision support system in Indonesia (TOAST—Tsunami

Observation And Simulation Terminal) on the one hand and web accessible applications on the other hand. Furthermore, an interface was required for managing and distributing the data to the respective systems.

The second task was to enable Indonesian staff of BMKG (a) to independently calculate TsunAWI scenarios, (b) to then create, validate as well as interpret resulting data products, and (c) to import them into the tsunami early warning system (TEWS).

2.2 Relevant Stakeholders and Target Audience

The objective of visualising TsunAWI scenario data was to address a public audience including other tsunami researchers, media, politicians as well as editing the information for educational purposes e.g. for schools.

Certainly, the main stakeholder is the Indonesian staff at BMKG operating the InaTEWS. Warning centre operators are interested in obtaining an accurate tsunami forecast in case of an earthquake event, and in comparing scenarios with varying earthquake parameters for training purposes. System administrators and modelling staff benefit from a tsunami scenario database, which can be extended easily and independently as desired.

3 Materials and Methods

3.1 Project Set-up

The tsunami project in ESKP was built on the strong basis of GITEWS and PROTECTS. While the BMBF projects were focussed on the TEWS itself, the ESKP framework enabled us to add value to the tsunami simulation tools and products that were tailored to the use in InaTEWS, scientifically sound, but missing versatility. Of course, suggestions from BMKG staff were important input for the improvements, and the planned workshops contained phases to validate, discuss, suggest new changes.

Furthermore, ESKP offered a platform for outreach to the general public, and for networking inside AWI as well as, to a smaller degree, in the Helmholtz Foundation.

3.2 Knowledge Transfer Methods and Formats

The GIS web application is intended to enable stakeholders to obtain a quick overview of the consequences of a tsunamigenic earthquake events and to facilitate the understanding of tsunamis. Lectures, presentations and articles about tsunami modelling and tsunamis in general via various platforms should strengthen the knowledge and awareness of this topic.

Workshops were the most important component to transfer expertise in tsunami modelling. Furthermore, the improvements in the interface to the scenario database made it easier to use for us and, first of all, for the Indonesian staff. This puts them in a far better position to take over responsibility. Subsequent independent modelling with occasional remote support reinforced the knowledge at BMKG. Discussions between all parties enhanced the overall understanding for all participants, scientists, administrators and operators alike.

4 Results

4.1 Activities

For the visualisation of tsunami scenarios to a public audience, the existing GIS-infrastructure maps@awi (maps.awi.de) at AWI was extended to support an interactive GIS web application Fig. 2. Raster and vector data was extracted from existing tsunami scenarios, imported and edited appropriately. The application displays information of tsunami scenarios which are also used in InaTEWS. Users are able to choose simulated earthquake events for which maximum wave heights and estimated arrival times of a theoretically resulting tsunami will be displayed.

In exchange of requirements with colleagues from gempa GmbH (www.gempa.de), an interface managing and providing tsunami scenario information to TOAST was developed. Scenario data relevant for deciding upon a tsunami warning was transferred into an appropriate data format.

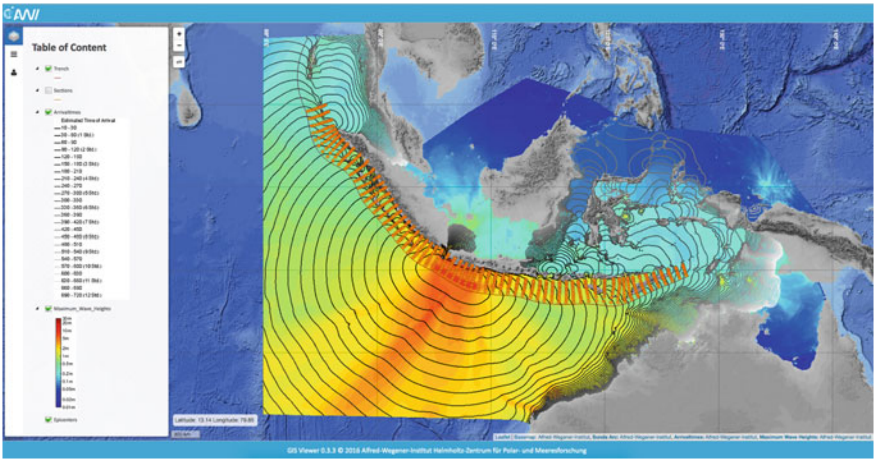

Fig. 2 Screenshot of the Tsunami-WebGIS available at maps.awi.de

Fig. 3 Workshop members at kick-off meeting in Jakarta, 2015

A number of workshops (Fig. 3) were conducted on site at the warning centre in Jakarta to train Indonesian staff to calculate scenarios with TsunAWI and import them into the TEWS. In active exchange during these workshops, the requirements were analysed to achieve the desired coverage in the resulting database. Independent calculations were performed by BMKG-staff between workshops. Remote support was given when needed. The source model was provided by GeoScience Australia, who also funded travels and part of the work through the DMInnovation project.

4.2 Outputs

The GIS web application maps.awi.de/map/map.html?cu=Tsunami_Simulations_in_Indonesia is online for AWI internal use since September 2016, and opened in March 2017 for the general public.

BMKG staff now has the knowledge to autonomously calculate tsunami scenarios and to employ the improved set of tools to generate and visualize data products.

Approximately 17,000 scenarios have been calculated and imported into the TEWS so far and are already in productive use.

Outreach: Three articles on the extension of the Indonesian database and on the Chilean tsunami 16th Sep 2015 published on eskp.de (Rakowsky et al. 2012, 2015a, 2015b); Radio interviews; Talks at Potsdam Summer School 2015 (Harig et al. 2015), in a school class and for teachers (MNU—Mathematisch-Naturwissenschaftlicher Unterricht) (Rakowsky et al. 2016), for interested lay people at *Haus der Wissenschaft* in Bremen (Rakowsky et al. 2014a, 2014b) and on the research vessel Sonne during an OpenShip Event (Harig et al. 2014); Presentation of achievements at the UNESCO IOC symposium (Harig et al. 2018); Internships and seminars for students and pupils.

5 Reflection and Lessons Learned

5.1 What Can We Draw from the Activity?

Never underestimate the complexity of a project. Heterogeneous infrastructure and dispersed responsibilities cost more time than expected. Furthermore technical aspects such as handling large amounts of data and performance tuning amongst others were an important issue during the course of the project.

5.2 What Can We Learn for Knowledge Transfer?

Never underestimate the human component in communication. We experienced various misunderstandings between all parties although the overall goal was the same for everyone. Since the main focus and expertise of every party was different, different institutes, different points of view (client vs. provider), different terminologies and different knowledge for arising topics, miscommunication was bound to occur. Furthermore, differences in culture between Indonesian and German staff sometimes caused confusion on both sides. Different organisational structures posed the biggest challenge regarding the cultural aspect, as confusion was also frequently observed between German colleagues. Having the possibility to cover topics from face-to-face alleviated work very much and arising misunderstandings could be discovered and solved quickly.

Afore mentioned points deepened the awareness for the necessity to listen closely when different parties are involved. In all cases clarifications led to increased knowledge on all sides resulting in a greater understanding for all. Questions and discussions therefor resulted in a higher overall quality of the project.

During the course of the project the quality of workshops improved, resulting from the experience on both sides: trainees and trainers. Not only did the understanding of trainees grow, also the teaching skills and teaching material improved through the exchange.

6 Outlook

The efforts performed in this project may result in further projects in Indonesia such as providing inundation maps for risk assessment purposes, or in new regions like South America's Pacific coast.

The Tsunami-WebGIS is to be extended in the future covering also the North-East of Indonesia. Furthermore, it is intended to display historic and recent tsunamis in the application.

Acknowledgements Involved student assistants and interns (Franziska Hoppe, Saghi Yousefi, Matthias Hardner and Felix Freiberger), BMKG, the Australian Government through the DMInnovation project, gempa GmbH, Gesche Krause, Wolfgang Hiller, Antonie Haas, Andreas Walter Jörg Matthes, Christian Schäfer-Neth and Angelo Steinbach.

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Streamflow Forecasting and Biodiversity

Monica Ionita, Madlene Pfeiffer and Stephan Frickenhaus

1 Background

"Streamflow forecasting and biodiversity" is a 1 year project developed at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven. The focus of this research project is to determine the degree of alteration of different river-based hydrological regimes, induced by climate change and human intervention, and how these alterations could influence biodiversity of stream ecosystems and beyond. The results of this project should serve as a guide for water managers to adopt a more sensitive and holistic approach in order to keep the distribution of annual values as close to the pre-impact distributions as possible.

Globally, ecologists are being asked to forecast ecological outcomes of alternative resource use and management options, typically in the context of changing climate and land. Population growth and expanding agricultural irrigation are increasing the demands to divert, transfer, and store water from stream and river ecosystems. At the same time, the declining capacity of river systems to support native biota, including imperiled species and fisheries, is a primary concern for natural resource managers and conservationists worldwide (Freeman et al. 2013). Both problems, increasing water demands relative to availability and declining viability of aquatic species, will likely be exacerbated by future changes in land use, such as urbanization (Paul and Meyer 2001) and climate change (Palmer et al. 2008; Nelson et al. 2009).

The streamflow regime is regarded by many aquatic ecologists to be the key driver of river and floodplain wetland ecosystems (Bunn and Arthington 2002).

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in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_16

The impacts of flow change are manifested across broad taxonomic groups, including riverine plants, invertebrates, and fish. Despite growing recognition of these relationships, ecologists still struggle to predict and quantify biotic responses to altered flow regimes (Bunn and Arthington 2002). One obvious difficulty is the ability to distinguish the direct effects of modified flow regimes from impacts associated with land-use change that often accompanies water resource development. The hydrologic regime is vital to the composition, structure, and functioning of stream ecosystems. Quantifying streamflow variables that define the hydrologic regime is important to stream ecosystem management and restoration.

2 Scope and Motivation

The major goal of this work is to develop models for the prediction of a broader class of flow regime variables chosen for their relevance in standard biological assessments of stream ecosystems. We selected to predict streamflow variables that are useful to characterize the hydrologic regime of a stream relevant to its biota. The methodology for the streamflow prediction has already been developed at AWI (Ionita et al. 2008, 2014) and is currently being evaluated by the German National Hydrological Institute (BfG Koblenz).

Throughout this project, we tried to find the potential applicability of the streamflow prediction in relation to biodiversity. Moreover, stakeholders that are dealing with coastal hazards, especially floods and storm surges (e.g. Bundesamt für Seeschifffahrt und Hydrographie*)*, can also use the streamflow prediction system. The main purpose of the project was (a) to develop methods to identify where tradeoffs or co-benefits (win-wins) within biological communities exist, and (b) to explore ways to effectively visualize and promote information exchange between scientists and stakeholders on local knowledge and management requirements.

3 Materials and Methods

Streamflow and water levels at hydrological stations located along two German rivers are analyzed, in terms of forecasting and hydrologic alteration. The two German rivers considered in this study, Rhine and Elbe, are two of the most important rivers of Europe. The German Federal Institute of Hydrology (BfG Koblenz) provided the streamflow data.

The forecast scheme for the monthly/seasonal prediction of Rhine streamflow and water levels using climate information from previous months (e.g. precipitation, temperature, geopotential height at 700 mb, and sea surface temperature), is based on a methodology similar to that used for the seasonal prediction of Danube streamflow (Rimbu et al. 2005) and Elbe streamflow (Ionita et al. 2008, 2014). The basic idea of this procedure is to identify regions with stable teleconnections between the predictors (e.g. sea level pressure, sea surface temperature, precipitation) and the predictand (streamflow, water levels) (Lohmann et al. 2005; Rimbu et al. 2005).

The hydrologic alteration (HA) at the gauging stations along the two German rivers was determined using the Indicators of Hydrologic Alteration (IHA) software developed by Richter et al. (1996). The IHA software determines how affected hydrologic regimes are by human-induced disturbances. Richter et al. (1997) proposed the 'range of variability approach' (RVA), which uses the pre-impact natural variation of IHA parameter values as a reference for determining the degree of alteration of natural flow regimes. In the last decades, the changing climate has affected the water regimes of German rivers. Bormann (2010) determined the hydrologic alteration of German rivers caused by climate change since middle of the 20th century and showed that climate change has an impact on the hydrological behaviour of rivers and their mean seasonal variability. In our study, we are also interested in the effects of climate change on the water regimes and thus choose the impact year as 1950. In the last decades, the changing climate has affected the water regimes of German rivers. Bormann (2010) determined that the hydrologic alteration of German rivers caused by climate change started in middle of the 20th century and showed that climate change has an impact on the hydrological behavior of rivers and their mean seasonal variability.

4 Results

The development of the statistical forecast system for the German waterways was made for the German Hydrological Institute (BfG), which was one of the main stakeholders of our project. The forecast methodology was successfully applied for the Rhine, Elbe and Danube rivers, respectively, at monthly and seasonal scale. Overall, the statistical model has revealed the existence of a very high predictive skill ($r > 0.9$) of the water levels and streamflow at monthly and seasonal time scales, a result that may be useful to water resources management and shipping companies.

Figure 1a displays a forecast example produced with the aforementioned forecast method: the observed and predicted November water level at Kaub (Rhine) between 1970 and 2015. The observed and predicted November water levels are significantly correlated ($r = 0.99$). Such a highly significant correlation ($r = 0.99$) is found also between the observed and predicted 7-day minimum low flow (NM7Q) for August streamflow at Neu Darchau (Elbe) between 1950 and 2015 (Fig. 1b).

In Fig. 2, an example of analyzing hydrologic alteration is given. For the Rhine river, the most affected hydrological station is Ems, which indicates high alterations for 12 IHA factors, namely: monthly flow for January, February, and March, 3-, 30-, and 90-day minimum discharge, base flow index, low pulse count, low pulse duration, rise rate, fall rate, and number of reversals (Richter et al. 1996) (Fig. 2a).

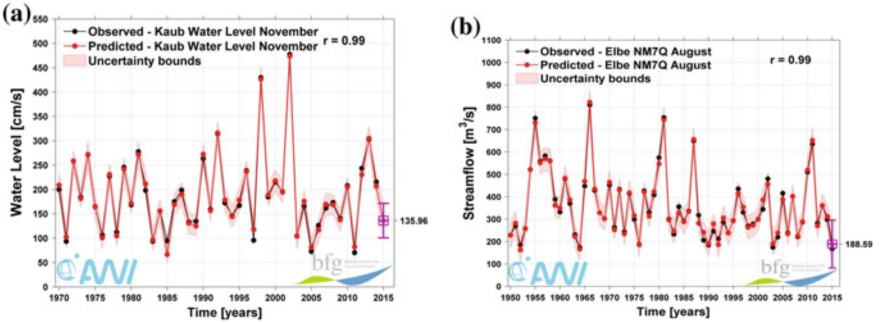

Fig. 1 **a** Comparison between the observed and predicted water level values for November at Kaub station (Rhine): Observed (black) and Predicted (red) November water levels values for the period 1970–2015. The light red shaded area represents the 95% uncertainty bounds. **b** Comparison between the observed and predicted NM7Q values for August at Neu Darchau (Elbe) station: Observed (black) and Predicted (red) November water levels values for the period 1948–2015. The light red shaded area represents the 95% uncertainty bounds

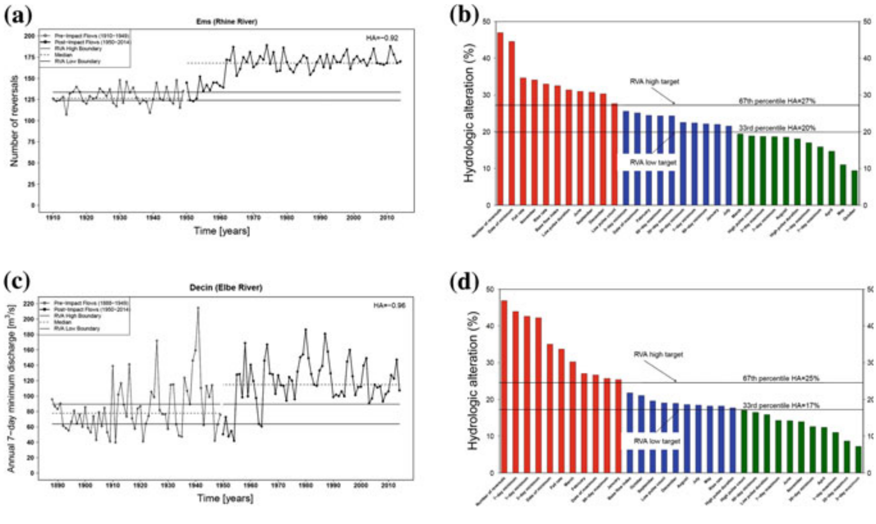

Fig. 2 **a** Example of changes in the hydrological regime at Ems hydrological station on the Rhine river: Number of reversals. **b** Ranked mean of absolute degrees of 32 indicators of hydrologic alteration (HA) for seven hydrological stations on the Rhine river and the 67th and 33rd percentile values. Red indicates mean HAs higher than the 67th percentile, blue indicates mean HAs between 33rd and 67th percentiles, and green indicates mean HAs lower than 33rd percentile. **c** Example of changes in the hydrological regime at Decin hydrological station on Elbe river. Annual 7-day minimum discharge. **d** Ranked mean of absolute degrees of 32 indicators of HA for five hydrological stations on Elbe river and the 67th and 33rd percentile values. Red indicates mean HAs higher than the 67th percentile, blue indicates mean HAs between 33rd and 67th percentiles, and green indicates mean HAs lower than 33rd percentile

Except for low pulse duration and fall rates, all the other altered IHA factors indicate higher values in the post-impact period compared to the pre-impact period.

Figure 2b shows the ranked mean of 32 indicators of hydrologic alteration for the 7 hydrological stations on the Rhine river. The factors for which the means exceed the 67th percentile are considered the factors with the highest impact. These parameters were considered in the calculation of the overall degrees of HA, which indicates that the most affected hydrologic regime is found at Ems station, followed by Neuhausen, Basel-Rheinhalle, Köln, Reckingen, Lobith, and Kaub being the least affected station. The order of the affected stations follows the downstream course of the Rhine River, except for the Reckingen and Kaub stations.

For Elbe River, high alterations are found at Decin hydrological station, where 3 IHA parameters indicate alterations higher than 90%, namely the annual 1-, 3-, and 7-day minimum discharge, with discharge values mostly higher in the post-impact period than the pre-impact period (Fig. 2c). High hydrologic alterations are found also at Dresden hydrological station, for the date of minimum alteration and number of reversals (the number of times that flow switches from one type of period (e.g. rising period) to another (e.g. falling period)). The Julian date of 1-day minimum discharge falls within the target range more often than expected, indicating a preference for summer and early autumn. The annual number of reversals in the post-impact period present a significant increase, indicating a larger annual variability.

Figure 2d presents the ranked mean of absolute degrees of 32 indicators of hydrologic alteration for the 5 hydrological stations on Elbe river. The factors for which the means exceed the 67th percentile are considered the factors with the highest impact. These parameters were considered in the calculation of the overall degrees of HA, which indicate that the most affected hydrologic regime is found at Decin station, followed by Dresden, Wittenberge, Neu Darchau, and Barby being the least affected station. The order of affected stations follows the downstream course of the Elbe river, except for the Barby station, indicating that the strongest effects on the hydrological regime occur mostly upstream rather than downstream. A change in the flow regime could have high impact on the German inland waterway system. Moreover, these hydrologic alterations can lead to undesirable ecological effects on local biota.

5 Reflection and Lessons Learned

Water resources management is an important and delicate subject on all levels from the local to the global, especially for the regions characterized by intense irrigation, hydropower systems, and navigational systems. The concern of the effects of climate variability and change on water resources makes management problems extremely challenging, and water managers are looking for ways to improve their management decisions. A key element of water management is to find out how much water will be available in the underlying water resources systems during the following months, seasons, and year. This study focuses on water levels and streamflow forecasting on monthly and seasonal time scales for the Rhine and Elbe rivers. We investigated the streamflow and water levels predictability, based on a statistical multi-model approach that uses predictors such as precipitation, temperature, soil moisture, geopotential height at 700 mb, mean sea level pressure, zonal and meridional wind, ground temperature, and sea surface temperature from the previous months.

Furthermore, we have determined the potential effects of climate change on these two German rivers. We have found alterations in different water regimes with respect to magnitude, timing, frequency, duration, and number of reversals. Such alterations have consequences on the ecosystem, such as (Richter et al. 1998):

- Habitat availability for aquatic organisms;
- Soil moisture availability for plants;
- Availability of water for terrestrial animals, influence on water temperatures, oxygen levels, and photosynthesis in the water column;
- Balance of competitive, ruderal, and stress-tolerant organisms;
- Structuring of aquatic ecosystems by abiotic versus biotic factors, structuring of river channel, morphology, and physical habitat conditions;
- Volume of nutrient exchanges between rivers and floodplains, and compatibility with life cycles of organisms.

6 Outlook

Overall, the analysis reveals the existence of a valuable predictability of the water levels and streamflow at monthly and seasonal time scales, a result that may be useful to water resources management. Although the analysis is restricted to particular gauging stations, the conceptual basis and lessons learned could be transferable to other catchment areas, which might have different climatological and/or hydrological backgrounds. For example, due to the high skill of the statistical model, since April 2016 the same model is used to give informative forecasts to the Hamburg Port Authority, which is in charge of managing the port for the city-state of Hamburg and it is responsible for development and maintenance of the port infrastructure and shipping traffic safety.

The current study based on the analysis of hydrologic alteration of river regimes has shown the degree of the climate-change-related impact on the river runoff since the middle of the 20th century. Other factors such as land use or water management may have additionally affected the water regimes and thus further studies on the influence of such factors on local catchment areas are needed.

Motivated by the results obtained throughout the ESKP project, the same methodology has been tested for the prediction of September sea-ice extent minimum, both for the Arctic as well as for the Antarctic regions, where it contributes, in the frame of meereisportal.de, to the international “Sea Ice Prediction Network project (SIPN)". The results obtained were extremely valuable and hence the ESKP project can be seen as a starting point of a long-term platform for the sea-ice prediction at AWI (with meereisportal.de; Grosfeld et al. 2017; see Sect. 2.2.1).

Acknowledgements This research was funded by Earth System Knowledge Platform (ESKP) as part of the "Streamflow forecasting and biodiversity" project. We thank the German Federal Institute of Hydrology (BfG) in Koblenz Germany for providing the streamflow data. Furthermore, we thank the developers of the IHA software for making it available to the public.

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Part V
Pathways to Formalizing Knowledge Transfer

Accompanying ESKP Projects—Development of a Process Assessment Strategy Within ESKP@AWI

Gesche Krause and Maximilian Felix Schupp

1 Background

Simply put, science is the pursuit of knowledge about ourselves and the world around us. This pursuit of knowledge and the application of knowledge shapes the way we view the world. However, the uses of science and technology are not shaped by science and scientists alone. They depend on an interplay of cultural, social, economic and political factors. We therefore need to advance our understanding of how such knowledge transfer processes work, and our understanding of the possible impacts of knowledge transfer activities on science and society. In contrast to conventional research activities in the natural sciences—where scientific publications are a principal output of the research process and generally form part of the evaluation procedure of research institutes, universities or centres—the output, outcome and especially the impacts of knowledge transfer activities between science and society are often less readily discerned.

To this end, new relevant tools to evaluate knowledge transfer efforts need to be established. Deliberation on ways to effectively assess and evaluate knowledge transfer activities is reflected in international efforts, such as the UK Research Excellence Framework 2014 excercise. This was the first major attempt to assess the impact of research outside of academia. Impact was defined as 'an effect on, change or benefit to the economy, society, culture, public policy or services,

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health, the environment or quality of life, beyond academia' (Wilsdon et al. 2015). Among other things, the assessment found that across different research communities, the description, production and implementation of 'metrics' remains contested and open to misunderstandings. Therefore, Wilsdon et al. (2015) concluded that for capturing the impact component of knowledge transfer, it is not currently feasible to use quantitative indicators in place of narrative impact case studies. This observation was also drawn by Wolf et al. (2013), whose research on knowledge transfer indicated the necessity for a broad and adaptable set of criteria, the identification and rating of core issues for evaluation criteria, the suggestion of criteria for productive interactions, and the impact of research on practice and society. For the latter, development of systems that link scientific publications via the project to research outputs for audiences outside academia, and to the interactions and impacts of this research as an indication of their societal relevance and applicability, is a promising opportunity (Wolf et al. 2015). Such an increase in the visibility of knowledge tailored towards specific target groups can increase the real-world impact of research and record that impact via feedback functions.

So far however, stakeholder engagement activities are commonly captured by application of the 'logical model' approach in respect to evaluation practices, as described by the concept of the European Commission in the 'Development and Conceptual Results Framework' (2008). Thereby it is possible to deliberate on the linkages between the inputs, processes, outputs, outcomes (from immediate to long-term), and the potential impacts of knowledge transfer activities. However, the logic model approach has limitations, as it does not indicate well, what specific processes have generated which specific outputs, outcomes, and impacts. To gain better insights, additional accompanying research into the knowledge transfer processes is mandated. In the following chapter, a framework for capturing the very nature of science-stakeholder interactions at AWI by the ESKP@AWI projects is described and first lessons outlined.

2 Scope and Motivation

In order to deepen our understanding of the contextual nature of ESKP@AWI, a process evaluation framework was developed and implemented as an accompanying measure from the onset of each of the knowledge transfer activities. By this, the understanding of central processes of knowledge transfer was deepened, thus helping the team to assess whether these processes could be captured at a later stage by regular institutionalized monitoring activities. Also, the framework enabled better insights into the questions of how to evaluate knowledge transfer and how to assess whether it was successful.

3 Materials and Methods

The development and testing of the process assessment framework took place between 2014 and 2017 by applying it to the ongoing activities of ESKP@AWI. In total, 14 initiated ESKP@AWI projects had to complete a three-stage survey of ex-ante, ex-itinere, and ex-post assessments. The selected knowledge transfer projects all had a duration of 1–1.5 years and included funding for staff capacities (one full time researcher) as well as for additional outreach or transfer activities during the projects' course. In most cases, the ESKP@AWI projects focussed predominately on societal stakeholders, regulators, special interests groups like NGOs, industry representatives, the broader public and even other researchers. The investigations of the knowledge transfer processes were conducted by a suite of both qualitative and quantitative methods that were effected within the aforementioned tailored knowledge transfer assessment framework. Under its umbrella, semi-structured interviews, questionnaires with indicators and metrics, as well as Likert-scale rankings were employed.

4 Project Setup

The developed knowledge transfer assessment framework consisted of three core pillars and two auxiliary stages (see Fig. 1). The central pillars were specific appraisal steps within the life-cycle of the respective project in which, by the application of the different methods, knowledge transfer elements were captured and investigated. These different stages and appraisal steps are described in more detail below.

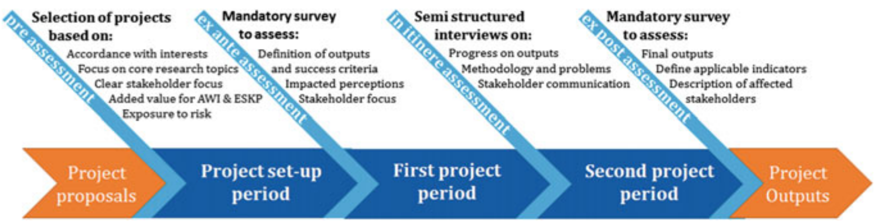

Fig. 1 Timeline and central appraisal steps of project process assessment framework

5 Results

5.1 Pre-assessment

Out of an array of diverse knowledge transfer project proposals, which were submitted after both the first ESKP@AWI Call for Tender in 2014 and the successive call in 2015, an internal pre-assessment and selection process was initiated. It aimed to identify those proposals that were assumed to have the most meaningful knowledge transfer approach for a specific research topic. The *pre-assessment* and selection was conducted by a group of representatives from multiple levels within AWI, ranging from the board of directors, senior scientists and head of research sections, as well as representatives from different natural science disciplines.

The project *pre-assessment* phase (Fig. 1) took place 4 months before the official project start and served to evaluate the proposed knowledge transfer projects on the basis of multiple criteria. These preliminary criteria were based on not (yet) explicitly defined institutional ideas on what constitutes a good knowledge transfer process and included:

- Accordance with institute interests,
- Conformance with core research topics,
- Stakeholder focus,
- Added value for AWI and ESKP, and
- Exposure and Visibility.

5.2 Ex Ante

The ex ante phase of the assessment was conducted within the first eight weeks of the projects' starting date (see Fig. 1) and was one of the core pillars of the knowledge transfer framework. It consisted of a mandatory survey to be completed by the researchers of each of the respective knowledge transfer projects. This survey asked researchers to predefine the planned outputs of the project, identify applicable success criteria as well as key stakeholders of the project. Six different types of outputs of knowledge transfer projects were offered as a starting point with the option of defining additional types for each project (Table 1). These served to showcase possible outputs for other knowledge transfer projects to encourage the respective project leaders to consider these new types in their project planning. The second part of the assessment tried to gain an overview of the plurality of impacted dimensions while also encouraging self-reflection and topical orientation of the projects. On a Likert-scale, ranging from 0 (lowest) to 5 (highest), researchers were asked to rate the expected impact of their research in ten dimensions, loosely based on the dimensions of scientific impact as defined by Godin and Doré (2005). The third and last section asked for detailed information on key stakeholders that were

Table 1 Overview of output types offered to researchers during ex ante stage of the assessment framework

Output type	Description
1	Peer-reviewed article
2	Keynote or plenary presentation
3	New or improved product, process or service
4	Free advice to Stakeholders (name Stakeholder)
5	Interview
6	Other (please specify)

going to be addressed or contacted during the course of the project. This list did not need to be exhaustive or complete but rather forced an early definition of each project's key stakeholders and target groups.

5.3 In Itinere

The in itinere phase was conducted about seven months into the project, shortly after the halfway point for all projects (Fig. 1), thus being the second core pillar of the assessment framework. This phase consisted of a semi-structured interview between the scientists engaged in the project and the evaluators, and also included a test of the previously self-defined success criteria for the individual outputs. The interview assessed the status quo of the project, whether all actions and pre-defined outputs were progressing on time, if new outputs were discovered, with resulting new or more applicable success criteria, as well as any occurring challenges

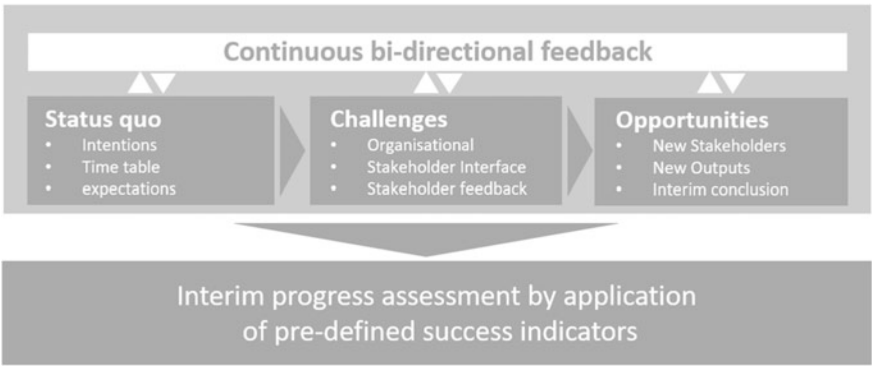

Fig. 2 Topical interview structure of the in itinere interview

(Fig. 2). These problems were then addressed to help the transfer projects in their further development. Answers to interview questions were collected and later collated according to McLellan et al. (2003).

The last part of the in itinere phase was a short survey that gave the researchers the opportunity to evaluate their progress on the previously planned outputs, using their self-defined success criteria and rating their progress on a scale towards reaching those criteria. This offered the opportunity to revisit those success criteria and test their soundness. Finally, this phase also contained a first feedback loop from the project participants back into the ongoing appraisal process.

5.4 Ex Post

The third pillar, the ex post stage of the assessment was conducted approximately one month after projects' completion (Fig. 1). A mix of the previous methods was applied to gather information on all final outputs as well as final suggestions for success criteria. It also asked researchers to revisit their perceived dimensions of impact (which they first stated during the ex ante phase) and to apply all changes. Additionally, researchers were asked to provide concrete examples of their stakeholder interactions and their direct outcomes, in order to be able to showcase their achievements. While it was often too early to identify central findings and impacts of the activities, this ex post questionnaire nonetheless helped to reflect in more detail on the initial outputs and potential outcomes, and to generate some first lessons learned that could be employed directly into the every-day research activities at AWI. Similarly to the in itinere phase, this last assessment also contained a feedback loop into the project management process and the option to state personal lessons learned about knowledge transfer processes.

6 Reflections and Lessons Learned

First results show that the criteria of success need to be somewhat flexible, as the scope of projects may change over the course of the life-span of the knowledge transfer activity, depending on the input and feedback from all involved project participants. Furthermore, outputs of knowledge transfer were often not considered as such and thus overlooked and not attributed as successful results by all project members. This is partly because contemporary output types do not match well with the plurality that knowledge transfer processes entail. Furthermore, this points out to the necessary skill-set of personal experience of the project participants, to be able to identify knowledge transfer outputs when they emerge. For the latter, the explorative ESKP@AWI projects highlighted that through comparatively small investments from AWI, positive institutional as well as individual learning effects can be initiated. Based on the successive surveys during the life-cyle of the

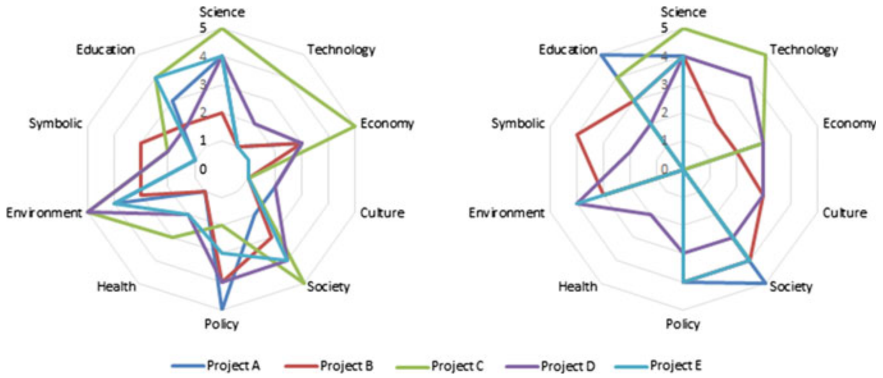

Fig. 3 Perceptions of impacted dimensions during ex ante (left) and ex post (right) surveys. Dimensions have been adapted from Godin and Doré (2005)

individual ESKP@AWI projects, Fig. 3 displays a clear shift in self-perception of the participating researchers over the projects' period. Initially, researchers almost unanimously perceived a very broad potential impact of their work towards the dimensions "environment", "science" and "policy" during the ex ante stage, which was shifted to more diverse dimensions in the ex post assessment that were previously not considered to be of high importance (e.g. "symbolic" or "culture").

Thus, it is safe to conclude that explorative knowledge transfer projects can offer added-value not only to society as a whole but also to science and scientists, as interaction with stakeholders can steer science into new areas. Yet, the knowledge transfer process in its entirety, ranging from basic research to research with multiple stakeholders and their contributions, is still only understood in somewhat nascent stages.

It can be demonstrated from our case-based analysis that hard metrics of "success" which effectively measure and demonstrate the impact of science for society on an evidence-based manner are difficult to develop. Indeed, transformation of knowledge, established technologies, regulations, practices, cultural preferences, and the respective legislative framing conditions must be taken into account (Pohl and Hadorn 2007). This calls for more research on how to capture and acknowledge these highly contextual driving forces, all of which influence knowledge transfer processes. Furthermore, projects differ substantially from one another, and significant discontinuities in flows of staff, materials and information are created; in a way where it becomes difficult to develop steady state routines that maximise and maintain the flow of knowledge and the capture of learning from the processes of one knowledge transfer project to the next (Bresnen et al. 2005). Therefore, much scope for optimisation is needed to explore the engagement and transfer process in more detail and how these play out over the course of time. Especially in basic research, conventional funding schemes do not support well possibilities for knowledge transfer. Therefore, new tools are still to be developed in order to better enable knowledge transfer processes in the future.

Indeed, from our case studies ESKP@AWI perspective, every knowledge transfer project and associated processes was different, e.g. ranging from projects with strong focus on dialogue approaches that differed in their set-up, approaches and outputs, to projects that focussed strongly on information database or modelling tools. However, by accompanying these with a central set of knowledge transfer criteria, it was possible to discern in an initial manner gaps in the processes, and to identify how these may possibly be addressed during the life-cylce of the respective project.

By this, our framework can be viewed as a preliminary operational tool on how to guide and evaluate knowledge transfer processes in a replicable and transparent manner, using partly quantitative metrics. It can be employed to capture knowledge transfer processes on our institute specific priorities, goal-orientation and background. However, this is yet not conclusively done, as more test applications to other knowledge transfer settings and other involved institutions need to be investigated.

7 Outlook

As captured by the process assessment framework, there is a lack of recognition of the importance and added-value of knowledge transfer processes which often pass unnoticed as intangible values. That said, there is an urgent need to foster the recognition and appreciation of scientists working at this interface of science and society.

We hope that by this process assessment framework of knowledge transfer, this current gap in recognition can be bridged. This would also reflect and strengthen the institutional capacity of learning within the research realm, vis á vis opening scope for new synergies and links with society and its research priorities. In this sense, the processes within knowledge transfer become somewhat more important than the actual outcome.

There remains, however, a dearth of reliable information on how society wishes to see research develop, and which perceived benefits of knowledge transfer are most important to them. The inclusion of an increasing number of surveys and workshops in knowledge transfer related projects may help improve this general perception, however, these have often limited scope outside a particular set of stakeholders. In future, more diverse ranges of opinion must be gathered and effectively analyzed to influence science and science policy towards meaningful knowledge transfer process developments.

Acknowledgements We gratefully acknowledge the openness and courage of our fellow researchers that were willing to embark on untested knowledge transfer waters and their wonderful support in the entire evaluation and reflection process!

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Science and Society—The Time to Interact

Gesche Krause, Klaus Grosfeld and Annette Breckwoldt

"Engaging in meaningful science-stakeholder dialogues in polar and marine research". This presentation given by three AWI colleagues in December 2016 at the 2nd International Marine Science Communication Conference in Bruges, Belgium (Bär et al. 2016 pers. comm.) has also been one of the guiding principles for the development of knowledge transfer and exchange at AWI. The timeliness of these efforts was mirrored at a recent high-level meeting of the EU under the SAPEA framework (Science Advice for Policy by European Academies), in which it was stressed that at present, no institutions are yet in place that capture knowledge transfer in a systematic manner. The research topic "Bridging science and society—products, tools and climate services" and subsequently ESKP within AWI, are the institute's reflections and efforts to tackle this task.

The challenge AWI and other research institutes face—to create relevant and reliable knowledge transfer processes—has led to the development of new tools, such as ESKP@AWI, which has rapidly evolved since its initiation in 2013. Based on the results and experiences of those ESKP-supported projects presented in this book, the new ESKP@AWI *Call for Tender* (2017) looks for projects which develop new formats to facilitate dialogue in knowledge transfer, with special consideration for the 'public expectation' of the institute's research and researchers (HGF concept paper 2016). What expectations and perceived benefits exist on both the research and the societal sides of a given knowledge transfer process? Can

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overarching generic patterns and good practices be found, once more knowledge transfer projects have been conducted with more diverse stakeholders and more diverse ranges of opinion? Experiences show that strategic alliances are needed, which in turn need competent individuals—on the science as well as on the societal side. These alliances can then eventually lead or contribute to 'knowledge infrastructures', which have been defined by Edwards (Edwards 2010) as "robust networks of people, artefacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds." Under this definition, knowledge infrastructures also include individuals with their respective knowledge, roles and organisational activities, but also with their respective norms and values. One of the major benefits such knowledge infrastructures can have for knowledge transfer and exchange is that the individual expert (whether from science or from society) becomes more visible and their individual knowledge more applicable.

All of the ESKP projects presented in this book have stories that in principle contain high societal relevance with a clear relation to the stakeholders involved, but are just beginning to develop communication and interaction processes to actually bring this relevance to life. These interactions—captured by the process assessment framework introduced in Chap. 4—help to foster recognition and accessibility of knowledge transfer processes and their merits to all sides. This in turn will also enable better recognition and appreciation of scientists and societal stakeholders working on, in and with these processes. Almost more importantly, the learning capacities of both research and societal stakeholders can be strengthened. Many of the ESKP projects and project participants engaged for the first time in specific stakeholder dialogues and witnessed a huge and sometimes almost overwhelming knowledge production process. These were then tackled to be sharpened, focused and tailored to the projects' objectives and aims. However, this sometimes included failures and unusual learning pathways. For all involved scientists, a more societal-focused confrontation and analysis with their own research topic took place. Quite often, an unexpected learning set in (on the science and scientists' side), about the existing societal knowledge and data gaps on one side and the sheer need and necessity of good science and good science dialogues on the other.

More specifically, the importance of facilitating direct communication between stakeholders and scientists by bringing them together in various forms of (personal) dialogues, clearly ranks high in the lessons learned of the individual contributions presented in this book. These dialogue forms were, for example, workshops that focused on a diverse group of stakeholders (with opposing perspectives), benefiting from direct communication and from multi-facetted knowledge and perceptions. Or it was the rare opportunity to visit each other's working place. The requirements of both research and informed decision-making profited from this personal exchange at eye-level and from active partnership in knowledge transfer and research itself. Ideally, the same knowledge transfer process is capable of meeting these requirements. In this way, knowledge that resides in process participants, tasks and networks has the chance to stay connected in intra- and inter-institutional ways.

In the following, we highlight some central issues that reappeared throughout the journey of bridging science and society. Most prominently, and somewhat simply put, ahead of a meaningful knowledge transfer process lies **the simple act of**

communicating. This is indeed not simple at all, given that basic natural science is by its self-definition already ‘hard to communicate to knowledge recipients outside the specific science community’ (cf. Jaiser, Chap. 14). Lessons to be learned for how to build a meaningful, intensive and constructive dialogue include stakeholder engagement exercises (‘who to talk to’) and major translation efforts, which requires a dynamic dialogue platform that not many scientists currently have at their disposal. Communication becomes even more challenging when it involves persons with such diverse knowledge backgrounds, priorities, norms, terminologies and cultures as the participating stakeholders in the contributions of this book. While a research plan can be as clear-cut as possible—misunderstandings can and will happen. Yet, while disturbing, this is exactly where the process of understanding and mutual learning starts, eventually resulting in a higher overall quality and relevance of the project, and leading to novel insights and innovation—for decision-making as well as for the feedback loop of informing future research agendas.

Meaningful dialogic communication can be further enhanced by **developing different forms of knowledge exchange tools.** These can surface as comprehensive and transparent data management, development of online portals or other forms of data access and visualization. The latter, while still very consuming of time and money, can be a great tool for knowledge transfer to encourage, set off, inform, steer, re-ignite, guide or facilitate dialogues at the science-stakeholder nexus. The required skills however, often go far beyond the capacities and capabilities of the involved researchers themselves and require a team of specialists from multiple disciplines (e.g., IT).

Knowledge transfer therefore requires teams—the lone-wolf principle usually does not work here, as too much time would have to be allocated at the science-stakeholder interface of the individual projects, which scientists may eventually perceive as too big distraction from their core research tasks. Some working groups may thus still perceive knowledge exchange as a ‘burden with uncertain future benefit’ and distracting from daily research chores, while—not least due to ESKP@AWI—all projects presented here have moved beyond perceiving stakeholder engagement as pure ‘outreach and dissemination’ activity. On the contrary, some projects and researchers in fact received a veritable boost to their (previously less visible) research activity, as well as to their research perspectives and ideas. One showcase example is the application of statistical multi-model approach that acted as backbone for the river streamflow forecasting tools developed, currently implemented at the Hamburg Port Authority (cf. Ionita, Chap. 16). Motivated by the results obtained in this ESKP project, the same methodology is currently tested for its suitability for the forecast of September sea ice extent minimum, thus contributing to the sea ice prediction research at AWI.

With ESKP@AWI, the institute thus has developed a tool that enables for the first time **exploratory research into the meaning and effect of AWI research** outside of the institutional science arena. By accompanying efforts towards impact assessment, the surprising **weight of dialogues and different forms of narratives** (‘which are only stories that we cannot measure at all’; AWI scientist, pers. comm.) could be made visible. This exploratory character enables AWI scientists to find and trace new ways of interaction with stakeholders, not least for joint identification of new research areas of societal relevance. These efforts however, could only be implemented and effected due to the initiation of an entire research topic on science-stakeholder interactions in 2014, as an innovative research unit within the AWI research programme. This clearly has demonstrated its equal importance and place alongside the institute's more conventional research activities. On the upper institutional level, relevant next steps have been identified by the HGF-knowledge transfer working group to further advance knowledge exchange. Central to the ongoing discourse on this level is how to align the work performed with the societal priorities defined by the Helmholtz 'Grand Challenges', vis à vis the UN Sustainability Goals, and also on the EU level by the current Open Science initiative.

Knowledge transfer is thus characterized by a wide range of diverse activities on multiple levels and acts on very different time scales, depending on the scope and the stakeholder group being addressed. This **requires a clear strategy**, in which activities can be prioritized, scaled and harmonized within AWI's long-term research effort. The success of these activities can only be maintained if personnel and financial support are allocated on a long-term yet flexible basis. Flexibility is key to the initiation and contribution of new ideas (e.g., realized by ESKP@AWI) but it is also important to guarantee reliable and sustainable knowledge transfer activities. ESKP@AWI reflects the learning ability of the AWI in that it has shown itself to be an important transformative element of the knowledge exchange culture. Currently, possibilities are being investigated to both couple and support integrative science, knowledge transfer and technology transfer activities at AWI by developing further institutional support and incentives, e.g., by establishing a suite of complementary *Calls for Tender* that target science excellence (AWI strategy fund), short-term science-stakeholder interactions (ESKP@AWI fund) and science innovation (Innovation fund).

These developments can be seen as AWI's nascent steps towards developing its own culture and infrastructure in knowledge transfer and exchange. And just as it can be expected that AWI's **data products will continue to grow in both volume and complexity**, so too will the collective knowledge that qualifies them broaden and deepen, requiring a flexible and accessible knowledge infrastructure. Therefore, while the inclusion of qualitative data will clearly remain a challenge and a lower priority for this natural science institute, the contributions in this book have all shown that there is no alternative to a professional integration and validation of qualitative data. This book therefore highlights the **importance of the different forms of dialogue and creative combinations of qualitative and quantitative interdisciplinary research**, which in the end also has to be captured and analysed in a visible, transparent, academically anchored and targeted manner. In this way, ESKP@AWI continues to make knowledge transfer more attractive for researchers, and to foster the existing projects within and outside of AWI.

In essence, it is time to interact for scientists of all disciplines and all stakeholders—supported by good dialogues and enabling knowledge transfer processes. Or, to finish with a quote from the same presentation cited in the beginning of this chapter (Bär et al. 2016 pers. comm.): "Keep in mind that societal relevance and impact of research are not achieved by ever-broader dissemination of results but rather by opening up conventional academic structures to allow non-academic stakeholders to become equal partners in a research project and thereby to promote meaningful outcomes while not losing touch with scientific curiosity."

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Erratum to: A Web-Based Information System for Macrobenthic Biodiversity in the German North Sea

Jan M. Holstein

Erratum to:
Chapter "A Web-Based Information System for Macrobenthic Biodiversity in the German North Sea" in: G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_12

An error in the production process unfortunately led to publication of this chapter prematurely, before incorporation of the final corrections. The version supplied here has been corrected and approved by the author.

As part of this update, the authorship of the chapter was changed and mistakes in the Results section were corrected as follows:

Authorship: Jennifer Dannheim was mistakenly included as author of the chapter in the original version. This author has been removed in the final version supplied here.
Results section: The information on the data policy aspects was updated and corrected.

The updated online version of this chapter can be found at
https://doi.org/10.1007/978-3-319-75919-7_12

G. Krause (ed.), *Building Bridges at the Science-Stakeholder Interface*, SpringerBriefs in Earth System Sciences, https://doi.org/10.1007/978-3-319-75919-7_19