



# Trilateral Research Agenda

for the Wadden Sea Region  
and its World Heritage Site



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# Colophon

Trilateral Research Agenda developed by the trilateral scientific community on the invitation of the Trilateral Wadden Sea Cooperation

## CONTACT PERSON

Klaas Deen, executive secretary Waddenacademie

[klaas.deen@waddenacademie.nl](mailto:klaas.deen@waddenacademie.nl)

Tel. +31 (0)6 144 013 74

## GRAPHICAL DESIGN

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# Content

<b>0.</b>	<b>Outline</b>	4
<b>1.</b>	<b>Introduction</b>	9
<b>2.</b>	<b>Brief history of the Trilateral Research Agenda</b>	11
<b>3.</b>	<b>Challenges and opportunities</b>	13
3.1	The Wadden Sea Region as living lab for human-nature interactions	14
3.2	The Wadden Sea Region coping with climate change and relative sea level rise	15
3.3	The Wadden Sea Region towards a sustainable maritime region	17
<b>4.</b>	<b>Thematic lines</b>	19
4.1	Climate, water, sediments and subsurface	19
4.2	Ecology, biodiversity and spatial processes	21
4.3	Cultural heritage, identity and historical embedding	23
4.4	Economy, society and sustainable development	25
<b>5.</b>	<b>Mapping and Monitoring</b>	28
5.1	TMAP	28
5.2	Future mapping and monitoring needs	29
5.3	Innovation in mapping and monitoring	29
<b>6.</b>	<b>Funding, outreach, communication and education</b>	32
6.1	Funding and organization	32
6.2	Outreach, communication and education	35

## 0. Outline

The Wadden Sea forms the largest coherent belt of intertidal mud and sand in the world and has become a World Heritage Site for its Outstanding Universal Value. The entire Wadden Sea extends over three countries. Since forty years, Denmark, the Netherlands and Germany have actively cooperated in the management and protection of the Wadden Sea with the goal to “[...] achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way“ (Guiding Principle, Joint Declaration, 2010).

Realizing this aim and safeguarding the Outstanding Universal Value of the World Heritage Site in the long term, however, requires very carefully balancing natural, societal and economic needs in the region. This complex task must be underpinned by a good, scientific understanding of underlying ecological and socio-economic processes. This knowledge base will inform future policies to support the protection of the Wadden Sea and sustainable developments in the region.

The basis of a Trilateral Research Agenda for the Wadden Sea Region originates from the declarations following the Trilateral Ministers meetings in 2010 and 2014.

In 2015 the Wadden Sea Board appointed Prof. Dr. Jouke van Dijk (the Netherlands), Dr. Mette Guldborg, later replaced by Prof. Dr. Jesper Bartholdy (Denmark) and Prof. Dr. Karsten Reise (Germany), to take the lead in developing this Trilateral Research Agenda for the Wadden Sea Region and its World Heritage Site.

The Trilateral Research Agenda was developed by the scientific community from the Netherlands, Germany and Denmark in a joint effort for identifying common future challenges and for developing and implementing comprehensive approaches to trilateral research. Inter-disciplinary, multi-faceted research combined with committed interactions between scientists, policy makers, regional managers, educators and the civil society will be required to inform future measures for safeguarding the Outstanding Universal Value of the World Heritage Site while promoting the sustainable use of the Wadden Sea Region and the wellbeing of its inhabitants.

The joint scientific community of the three Wadden Sea countries proposes a coherent Trilateral Research Agenda for the whole Wadden Sea Region, with the aim to maintain natural and cultural values and to find a sustainable course for natural, societal and economic development. The agenda focuses on three

major, broadly inter-disciplinary, challenges for the future which have been identified by the research community. All of them are complex by nature and call for multi-, inter- and transdisciplinary approaches. Evidently, answers to those challenges require a sound disciplinary basis as well as continued monitoring of relevant natural and socio-economic variables.

### **Challenge 1. The Wadden Sea Region as living lab for human-nature interactions**

Preserving the values of the Wadden Sea Region for future generations requires surpassing the traditional divide between nature and culture because decisions and actions to preserve natural values must be placed in socio-economic context. Likewise, social, cultural and economic initiatives and developments in the Wadden Sea Region should explicitly consider impacts on natural systems.

Historically, large parts of the marshlands of the Wadden Sea Region have been a laboratory for engineering and water management throughout many centuries, giving rise to a rich cultural heritage comprising both tangible and intangible elements. As far as visible aspects are concerned, the remaining artifacts of human-nature interactions provide us with indispensable information about the evolution of the cultural landscape and the capabilities of people that allowed natural hazards and threats to be dealt with.

Risks emerging in the wake of climate change and sea level rise can be supported by a better understanding of former adaptive capacities and forms of resilience, thereby yielding important lessons for the future. A more comprehensive approach to the questions of identity is called for, encompassing the entire Wadden Sea Region beyond national, linguistic and cultural borders.

### **Challenge 2. Coping with climate change and relative sea level rise**

Global warming with gradual changes in weather patterns, extreme storm events and rising sea levels will probably proceed over the coming decades and centuries. Simultaneously subsiding land may further enhance the rate of relative sea level rise. This slow but pervasive process forms one of the main challenges for the Wadden Sea Region with strong long-term repercussions, not only for natural but also for social, economic and cultural structures and processes.

Coping with climate change and relative sea level rise requires integrated efforts from all parties. We urgently need to improve our understanding of the coastal sediment and freshwater balance for the entire Wadden Sea Region under elevated temperatures, higher relative sea levels, more extreme storm surge levels, higher tidal ranges and stronger wave action. This will be essential for developing successful climate adaptation strategies, for purposes of nature conservation and coastal defense and also for interrelated economic sectors such as agriculture, fisheries, tourism, shipping and harbor activities.

The ongoing rise in temperature causes biological species in all habitats to shift their geographical ranges or seasonal population dynamics, thereby invading new territories and altering ecosystem functions and services at an accelerating pace. We do not understand the consequences of this pervasive process in a wider perspective of food-chains, predator-prey and parasite-host interactions, ecosystem resilience and potential species loss. This is also essential to protect the natural values of the Wadden Sea Region.

### Challenge 3. Towards a sustainable coastal region

The Wadden Sea Region has entered a phase of major transition owing to a complex interplay between processes such as climate change, energy transition and demographic changes. Safeguarding the Outstanding Universal Value of the Wadden Sea World Heritage Site and, at the same time, offering residents attractive social and economic opportunities poses demanding future challenges. We need evidence-based policies, measures and incentives to allow both the ecosystem and the socio-economic structures to develop throughout the transformation process.

An economically sustainable Wadden Sea Region has to make use of regional assets, services and products embedded in attractive, healthy ecosystems. In addition, economic activities in the service sector can be stimulated, especially those with little or no impact on the Wadden Sea ecosystem, driven by residential amenities, human well-being and ageing in healthy environments. Scientists, policy makers, entrepreneurs, NGO's and the residents of the area will need to collaborate to provide the appropriate knowledge base for facilitating evidence-based decisions to manage this complex transition.

The Wadden Sea Region is an economically peripheral, predominantly rural region with few interspersed urban centers. The population in the entire Wadden Sea Region is shrinking and the age-structure of residents is biased towards elderly people. These



trends present severe challenges such as avoiding social decline which must be counter-acted by offering education opportunities and by providing innovative high-quality jobs and preserving low and medium skilled job opportunities in the region. Radically new, creative concepts with respect to nature conservation, active aging, sustainable tourism, agriculture and fisheries with local products should be stimulated in order to make the Wadden Sea Region a true 'living lab' for socio-economic transitions.

### Thematic lines

Evidently, answers to those challenges require a sound interdisciplinary basis as well as continued monitoring of relevant natural and socio-economic variables. Addressing the challenges requires collaborations between scientists across disciplinary borders and beyond academic schools and between researchers of different generations. These collaborations will have to be fueled by individuals, groups and institutions with profound knowledge and experience in different subject areas. A programmatic and multidisciplinary approach as described in the challenges may lead to rather abstract formulations of the research questions. To be more concrete in the Trilateral Research Agenda four thematic lines are distinguished:

- Climate, water, sediments and subsurface
- Ecology, biodiversity and spatial processes
- Cultural heritage, identity and historical embedding
- Economy, society and sustainable development

For each thematic line some concrete research topics are proposed that reflect urgent knowledge gaps that are relevant for the appropriate management of the Wadden Sea Region.

Good research strongly depends on the availability of coherent long-term data sets. Therefore, **Monitoring** represents an integral part of the Trilateral Research Agenda. Denmark, Germany and the Netherlands also jointly developed and implemented a trilateral Monitoring and Assessment Program (TMAP), which is one of the cornerstones of the trilateral cooperation and covers the entire Wadden Sea. Monitoring needs are likely to increase in the future. Newly developing technologies may significantly enhance current monitoring capacities in various fields, and technological advance may offer the opportunity to monitor new variables in a feasible way. Citizen science is already used in several programs and is likely to be extended in future as it can significantly foster public support and engagement, thereby helping to build robust links between science and society.

**Organization and funding.** Implementing the Trilateral Research Agenda requires a dedicated committee that represents the three countries and their main stakeholders and that oversees and coordinates the necessary activities. The members of the committee should consist of a balanced mix of representatives of various scientific disciplines and policy makers to guarantee a fair award procedure to carry out high quality multi-, inter- and transdisciplinary research projects. Ideally, the joint research agenda presented here should lead to a coherent Trilateral Research & Monitoring Program with a funding period of at least five years (2019-2024), and including natural sciences, socio-economic, cultural and historic, demographic and policy-related research, as well as monitoring and mapping. The program should consist of three equally relevant, strongly interconnected and partially overlapping areas of activities, namely:

- a) Frontier academic research aimed at enhancing our basic understanding of natural, societal and cultural processes and systems of importance to the Wadden Sea Region;
- b) Applied research, mapping and monitoring with the main aim of applying existing knowledge to concrete situations and gathering long-term data series through comprehensive monitoring of natural and societal systems. The mapping and monitoring activities stem at least partly from national and European policy obligations;
- c) Regional studies, dissemination and local implementation aiming at a strong embedding of this program and its outcomes in local and regional structures, institutions and people. The Trilateral Research Agenda must be deeply rooted in the Wadden Sea Region, its inhabitants, schools and other educational institutions, regional businesses, NGO's, natural park administrations and other public and private bodies active in the area.

**Outreach, communication and education.** The planned Wadden Sea World Heritage Partnership Hub including its network is envisaged to play an important role in outreach, communication and education activities by providing a platform and a network for interactions between researchers, policy makers, regional organizations including schools, and the public at large.

# 1. Introduction

From Blåvands Huk in Denmark via the German coast to Den Helder in the Netherlands, the tides and waves of the North Sea have built up a 500 km long unique coastal wetland and a string of barrier islands with dunes. This system forms the largest coherent belt of intertidal mud and sand in the world. Geographically, the Wadden Sea Region comprises the transition zone from the North Sea to the mainland, including adjacent coastal provinces and municipalities with extensive marshlands, rivers and a few seaports.

The entire Wadden Sea Region extends over three countries: about 60% of the Wadden Sea Region belongs to Germany, 30% to the Netherlands and 10% to Denmark. Since 1978 the three Wadden Sea countries Denmark, the Netherlands and Germany actively cooperate in the management and protection of the Wadden Sea Region as a natural entity and they have agreed to “achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way” (Stade-declaration, 1982). This trilateral approach extends to the entire region with 3.5 million inhabitants on islands and in low-lying coastal marshlands. Since 2009, the marine and coastal part of the Wadden Sea Region is listed as a World Heritage Site because of its Outstanding Universal Value.

The Wadden Sea Region has always been an area of intensive human-nature interactions. Even though the Wadden Sea has become a World Heritage Site for its natural values, their long-term protection adequate management can only be ensured by carefully balancing economic, societal and natural values in the region. This requires a good, scientific understanding of underlying processes as well as effective translation of insights into policies and measures to support sustainable developments in the region.

In an era of human-driven global warming and with the prospect of significant sea level rise, the question arises how to maintain this low-lying coastal region for future generations. Even though tidal flats and salt marshes grow with the sea by means of sedimentation, this process may not be sufficient to compensate for accelerating levels of sea level rise. In addition, complex demographic and socio-economic changes lead to a shrinking population and a decrease in economic activity, while societal trends such as a renewed quest for livable environments and authentic regional products may provide new incentives for future economic and social developments.

For many decades the Wadden Sea Region and in particular its unique ecosystems have been subject to extensive scientific research by many individuals and institutions, enabled by considerable financial support from a diverse range of sources in the three

Wadden Sea countries. Notwithstanding all these efforts, research in and about the Wadden Sea Region still suffers from a relatively high degree of fragmentation and sub-optimal coherence in terms of content and standardization, but also in terms of funding. The Trilateral Research Agenda represents a joint effort by Germany, the Netherlands and Denmark to develop and implement a more comprehensive approach to trilateral research and research funding, not least that available within the EU-system, with the aim of fostering integrated multi-disciplinary research approaches, and to make efficient use of available funds.

How can the long-term, overarching challenges to the Wadden Sea Region and the Outstanding Universal Value of the World Heritage Site be sustained through proper precaution and adaptive management?

The three involved countries join forces to stimulate and support research for addressing the main challenges of the region by presenting the Trilateral Research Agenda for the Wadden Sea Region and its World Heritage Site. **Inter-disciplinary, multi-faceted research approaches** combined with committed interactions between scientists, policy makers, regional managers, educators and the civil society will be required to provide new knowledge that can help safeguard the unique values of the region while promoting the sustainable use of the Wadden Sea.

The aim of this research agenda is not to list topics for abstract academic research. Rather, science should be viewed as a means to provide the necessary understanding and insights for informed decisions by policy makers and regional managers, thereby facilitating and improving the protection and management of the Wadden Sea Region. Obtaining the appropriate knowledge require collaborations within the scientific community between scientists of different generations across disciplinary borders and beyond academic schools and research institutes to create added value derived from effective interaction and communication of the scientific community with stakeholders and concerned citizens. The planned Wadden Sea World Heritage Partnership Hub is envisaged to play a central role in this endeavor by providing a platform for interactions between researchers, policy makers, regional organizations including schools, and the public at large.

In this document the scientific community of the three Wadden Sea countries proposes a coherent trilateral research agenda with the aim to maintain natural and cultural values, to find a sustainable course for natural, societal and economic development, and to advance the entire Wadden Sea Region as example for engaging future challenges.

## 2. Brief history of the Trilateral Research Agenda

The basis of a Trilateral Research Agenda for the Wadden Sea Region originates from the declarations following the Trilateral Ministers meetings in 2010 and 2014, stating the following:

*“Support the establishment of a trilateral research platform directly connected with existing national networks. The platform will elaborate a trilateral agenda for policy-relevant research in consultation with the Board...” (Sylt-declaration 2010).*

*“Encourage discussions by the scientific community and policy makers on the major policy issues and related knowledge as a basis for further developing a trilateral research agenda and a trilateral research platform” (Tønder-declaration 2014).*

These goals have been included in the priorities of the Dutch presidency of the Trilateral Wadden Sea Cooperation in June 2015 by in the following way.

*Scientific agenda for the Wadden Sea World Heritage Site: The Wadden Sea has long been a site of much and diverse scientific research. For good management of the World Heritage Site there are plenty of questions that will require common and better coordinated research.*

*Objective: A coherent scientific agenda, relevant to the World Heritage Site which supports decision-making on current and future issues, captures the interest of young scientists and promotes scientific cooperation between institutions.*

In 2015 the Wadden Sea Board appointed Prof. Dr. Jouke van Dijk (the Netherlands), Dr. Mette Guldborg, later replaced by Prof. Dr. Jesper Bartholdy (Denmark) and Prof. Dr. Karsten Reise (Germany), to take the lead in developing this research agenda with coordinating support by Dr. Folkert de Jong of the Common Wadden Sea Secretariat (CWSS) and Drs. Klaas Deen of the Waddenacademie. Dr. Josef Stuefer NWO (Netherlands Organization for Scientific Research) has acted as executive secretary.

In a series of preparatory workshops experts from the three countries provided input on major scientific achievements so far, on persisting gaps of knowledge, and on policy-relevant topics and themes for transdisciplinary research. Based on this and other relevant information the trilateral research agenda starts with giving special attention to three overarching challenges (Chapter 3) and is further developed along four broad thematic lines (Chapter 4).

A draft version of the trilateral research agenda was presented and extensively discussed at the 14th International Scientific Wadden Sea Region Symposium in Tønder, Denmark (9-11 May 2017), and delegates and their home institutions were invited to provide written input after the meeting. The current version includes these comments. The final draft shall be presented to and discussed by the Wadden Sea Board in autumn 2017. The intention is to have the final document formally adopted and approved during the Trilateral Governmental Conference to be held in May 2018 in Leeuwarden (the Netherlands).

### 3. Challenges and opportunities

The Wadden Sea Region and its World Heritage Site must be seen as an integral socio-ecological system with specific, and sometimes complex challenges, and opportunities. The ultimate challenge is to understand the functioning of this complex system in order to foster effective management and sustainable development. This requires an inter- and transdisciplinary approach. Science and research can make a significant contribution to understanding, safeguarding and developing the region in a sustainable manner by providing impartial, rigorous and robust knowledge for informed decision-making. However, the most pressing questions for the future of the Wadden Sea Region can only be understood and successfully tackled by true interaction between different fields of science, including various disciplines and types of science (fundamental research, monitoring, applied and citizen sciences), and between science and diverse players in society such as regional and national authorities, private companies, NGO's and concerned citizens.

The preservation of the Outstanding Universal Value of the Wadden Sea as a UNESCO world heritage nature area is the prime objective for future management decisions. Notwithstanding, the safety and well-being of people living and working in the region are of utmost importance and require due attention from all stakeholders, including policy makers and scientists. For centuries the Wadden Sea region has been, and still is, a 'living lab' for human-nature interactions. Natural values are embedded in cultural understanding, and vice versa. Global climate change in combination with subsiding land is expected to have inevitable impacts on the region via sea level rise and warming, potential intrusion of seawater into arable land and drowning of natural resources and cultural heritage sites. At the same time we enter a phase of energy transition leading towards increased sustainability which may alter regional balances. Finally, dealing with the demographic change already now seen in the Wadden Sea Region will be a central issue in the transition towards sustainable coastal development. These transformations carry risks and uncertainties but also bear new opportunities. Science-informed policy decisions are needed to find a balanced way forward.

The following sections attempt to identify three major themes that bear challenges as well as opportunities for the Wadden Sea Region, and which must be dealt with in the decades to come. All of them are complex by nature and call for multi-, inter- and transdisciplinary approaches.

### 3.1 The Wadden Sea Region as *living lab* for human-nature interactions

The unique cultural landscape of the Wadden Sea Region is the product of a fundamental transformation from a smooth and highly dynamic sea-to-land transition toward a rigidly divided coastal landscape with an amphibious natural side and a defended drained marshland and stabilized barrier islands. Over the last 2500 years, large wetland areas has been converted from bogs and pastures into arable land behind dikes, which has led to a common maritime culture. More recently, the islands and to a lesser extent also the mainland coast, developed into a recreational region with a considerable number of guests. The Wadden Sea region can only be understood and properly valued by acknowledging the long-standing, and still on-going, close interaction between nature and mankind. The Wadden Sea Region can best be seen as a “living lab”, where key functions such as coastal safety, natural values, industry and demography co-exist within the overarching themes of economy, society and environment. This offers unique opportunities to study interactions between human beings and their environment from diverse viewpoints in a historic and socio-economic context. Such studies require several academic disciplines and types of research to closely cooperate, exchange data and ideas, and to explicitly involve the main actors of this living lab: people and nature.

Historically, the Wadden Sea Region has been a laboratory for engineering and water management throughout many centuries, giving rise to a rich cultural heritage comprising both tangible and intangible elements. As far as visible aspects are concerned, the remaining artifacts of human-nature interactions provide us with indispensable information about the evolution of the cultural landscape and the engineering capabilities that allowed natural hazards and threats to be dealt with. Risks emerging in the wake of climate change and sea level rise can be supported by a better understanding of former adaptive capacities and forms of resilience, thereby yielding important lessons for the future.

The Wadden Sea is recognized as a UNESCO World Heritage Site because of its Outstanding Universal Value. Preserving this for future generations requires surpassing of the traditional divide between nature and culture because decisions and actions to preserve natural values must be placed in a historical and socio-economic context. Likewise, social, cultural and economic initiatives and developments in the Wadden Sea Region should explicitly consider impacts on natural systems.



The Wadden Sea Region faces urgent challenges linked to multiple human pressures such as fisheries, shipping, tourism, energy transition and stabilized islands, all of which can be seen as modern manifestations of human-nature interactions. Informed decisions, based on solid empirical and inter-disciplinary research, are required to balance different human uses against each other in the attempt to safeguard the outstanding universal values of the Wadden Sea. Awareness of the historic cultural dimension of the region, not only from a political and administrative perspective but also among social and natural scientists, professionals, citizen scientists and the regional public, is a prerequisite for the successful protection and sustainable development of the special qualities of the Wadden Sea. The contentious history of the Wadden Sea Region in all its variation requires detailed empirical research in order to be presented as a coherent, comprehensive narrative with the existing sense of place and appreciation of the region as home for the people and to cope with the challenges of globalization and climate change.

### 3.2 The Wadden Sea Region coping with climate change and relative sea level rise

Global warming with gradual changes in weather patterns, extreme storm events and rising sea levels will probably proceed in an unprecedented way over the coming decades and centuries, thereby threatening coastal flatlands world-wide, including the Wadden Sea Region. Simultaneously subsiding land is likely to further enhance the rate of relative sea level rise. This slow but pervasive process forms one of the main challenges for the area with strong long-term repercussions, not only for natural but also for social, economic and cultural structures and processes.

Climate change and relative sea level rise directly threaten the outstanding universal values of the region, implying that they deserve close attention by and high priority for researchers, policy-makers and regional entities in order to jointly develop and implement long-term sustainable solutions. Coping with climate change and relative sea level rise requires integrated and truly transdisciplinary efforts from science and society as a whole, including timely public participation in problem identification, analysis and solutions. To achieve enhanced understanding of global processes and regional responses will without doubt require significant amounts of public funding.

Major impacts can be expected on ecosystems (e.g. by species invasions and changes in species diversity, progressive salinization and inundation), regional economies (e.g. maritime industry,

agriculture and fisheries, tourism), and societies (e.g. flood safety, demography). All of these impacts are by nature complex, and are strongly interlinked with each other, giving rise to intricate networks of causes and consequences on different organizational, spatial and temporal levels. Understanding of these processes and searching for adequate solutions will require multidisciplinary studies based on reliable data. It should be emphasized that dedicated and sustained monitoring activities are of paramount importance for tracing subtle changes in natural and socio-economic systems such as those to be expected from climate change and relative sea level rise.

One of the most pressing issues relates to the unanswered question of whether natural sedimentation in the Wadden Sea and on the islands and marsh-lands can keep pace with the anticipated acceleration in relative sea level rise. And if not, what should and could be done to safeguard the natural, societal and cultural values of the region. Research from various disciplines is needed to help coastal societies design and implement appropriate and feasible adaptation measures with high urgency in order to mitigate the diverse consequences of global change. A scientific understanding of the drivers and processes of change, combined with substantial stakeholder involvement and civic participation should form the basis for informed political decisions on how to deal with climate change and relative sea level rise in the longer term.

No quick and easy solution is at hand to tackle the complex issues of flooding, erosion and salinization. The historic interventions in the water and sediment system of the Wadden Sea Region have provided economic wealth in the past. However, the combination of subsiding land and a rising sea will force us to reconsider earlier approaches. To start with we urgently need to improve our understanding of the coastal sediment and freshwater balance for the entire Wadden Sea Region under elevated temperatures, higher relative sea levels, more extreme storm surge levels, higher tidal ranges and stronger wave action. This will be essential for developing successful coastal defense strategies, both for nature conservation purposes and for economic sectors such as agriculture, fisheries, tourism, shipping and harbor activities. Based on this knowledge we can develop strategies and scenarios for coastal defense and adaptation. Measures that can be envisaged today would entail cascades of adaptations in natural systems, economics, society and life styles in the entire Wadden Sea Region.

### 3.3 The Wadden Sea Region towards a sustainable maritime region

Due to a complex interplay between global and local processes such as climate change, long term morphodynamic effects energy transition and demographic changes the Wadden Sea Region has entered a phase of major transition. Supporting the long-term sustainability of the Outstanding Universal Value of the UNESCO World Heritage Site and, at the same time, offering residents attractive social and economic opportunities poses demanding challenges to science and society as a whole. We need to develop balanced policies, measures and incentives to allow both the ecosystem and the socio-economic structures to develop in a balanced way throughout the transformation process. In other words: the big challenge is to guide the Wadden Sea Region towards a sustainable, economically thriving maritime region.

An economically sustainable Wadden Sea Region has to make use of local and regional assets, services and products embedded in attractive, healthy ecosystems. Several of the services originally provided by the Wadden Sea Region (e.g., food, water quality, coastal protection, recreation) are in transition and many economic opportunities for coastal people have been lost. However, deliberate and informed choices for new and sustainable economic activities offer new opportunities for creating jobs and for building sustainable livelihoods through tourism and producing high-quality regional products (e.g. foods) in the agricultural and fisheries sector that match with the locational characteristics and the skill of the people in the Wadden Sea Region. In addition to that economic activities in the service sector with no impact on the Wadden ecosystem driven by residential amenities, human well-being and ageing in serene environments can be stimulated. These developments, however, require paradigm shifts concerning traditional and new economic endeavors. Scientists, policy makers, entrepreneurs, NGO's and the residents of the area will need to collaborate to successfully engage in order to provide the appropriate scientific knowledge to facilitate evidence based decision to manage this complex major transitions.

The quest for sustainable coastal development of the Wadden Sea Region will have to identify and to stimulate viable transformation processes creating educational and economic opportunities for residents. Innovative approaches including radically new and creative concepts with respect to nature conservation, active aging, sustainable tourism development, agriculture and fisheries with local products and innovative developments such as saline agriculture as adaptation to climate

change and sea level rise should be stimulated and supported in order to make the Wadden Sea Region a true 'living lab' for socio-economic transitions and thereby set a positive example for other coastal regions in Europe and the rest of the world, challenged by climate change and economic fluctuations.

The Wadden Sea Region is an economically peripheral, predominantly rural region with unequally distributed, interspersed urban centers like Hamburg and easily accessible, densely populated areas like the Dutch Randstad, the Ruhr area and the Øresund region. Various areas in the world with similar basic characteristics undergo demographic changes arising from declining birth rates, longer life expectancies and migration. The population in the entire Wadden Sea Region is shrinking and the age-structure of residents is becoming gradually biased towards elderly people. At the same time, the relative level of education among residents tends to decrease due to selective migration of young people out of the Wadden Sea Region. These trends present severe challenges such as avoiding social decline by offering education opportunities and providing innovative high-quality jobs and preserving low and medium skilled job opportunities in the region. Population decline, however, can also provide new opportunities for natural values and tourism, and it can contribute to the positive image of the region as tranquil, attractive destination for visitors and residents alike.

## 4. Thematic lines

Addressing the challenges and opportunities described in section 3 requires collaborations between scientists across disciplinary borders and beyond academic schools and between researchers of different generations. These collaborations will have to be fueled by individuals, groups and institutions with profound knowledge and experience in different subject areas. The following sections aim at describing four thematic lines which seem especially important for advancing research in the Wadden Sea Region. For more detailed relevant information, it is advised to read the above mentioned five reports. A programmatic and multidisciplinary approach as described in comprehensive research agenda may lead to a rather abstract formulation of the research questions. To be more concrete below for each thematic line some (unprioritized) research topics are formulated that reflect urgent knowledge gaps that are relevant for the appropriate management of the Wadden Sea Region. However, the programmatic approach will only work if there is a continuous reflection on the knowledge needed and has to avoid money driven research. This requires an open mind for new approaches and problems that need to be addressed by an independent programming board.

### 4.1 Climate, water, sediments and subsurface

Given the prospects of accelerating relative sea level rise, the primary goals of preserving the natural dynamics in the Wadden Sea and protecting the inhabited islands and the mainland against erosion and inundation are not easily combined. Existing experience with the application of nature-based solutions (e.g., 'Building with Nature') and soft interventions like beach and foreshore nourishments may form the basis for adaptation. Facing the prospect of major transitions induced by climate change and relative sea level rise we need to better understand how the restoration and protection of coastal ecosystems can be reconciled with the socio-economic functions of the coastal areas, thereby safeguarding natural and cultural values.

Regional climate change is expected to trigger a chain of hydrologic and geo-morphologic impacts and processes which will affect the Wadden Sea Region comprehensively. Pressing questions relate to possible changes in tidal regimes, storm surge levels, the spatio-temporal distribution of sand and mud including possible tipping points and whole-system sediment budgets. Equally important are issues linked to progressive salinization and its impact on soils and ground water, a possible deterioration of fresh water quality and the provision of drinking water under altered

hydrological conditions. These questions should be studied for the Wadden Sea Region as a whole, yielding a scientific understanding of ongoing and expected processes as well as climate change scenarios, options for interventions and other adaptation strategies. This knowledge will also be instrumental for the attempt to mitigate the impact of climate change and relative sea level rise on the conditions for deploying economic activities and for safeguarding agreeable residential conditions.

The Netherland's part of the Wadden Sea Region includes subsurface reservoirs for natural gas which have been exploited in the past. Gas extraction led to increases in the frequency and intensity of regional earthquakes and additional subsidence, directly threatening cultural values and the livelihood of people in the region. Furthermore, there is growing public concern on oil drilling, maintaining and renewing coal power plants, dredging shipping lanes for ever larger vessels, and mining sand for sand nourishments in the Wadden Sea Region. Transdisciplinary studies into these aspects can underpin and stimulate policy processes directed towards guaranteeing the safety of citizens, protecting the environment, and rebuilding mutual trust between residents, state authorities, private companies and concerned citizens.

Some (unprioritized) research questions are formulated below. These reflect urgent knowledge gaps that are most relevant for the appropriate management of the Wadden Sea Region for this thematic line:

- Formulating a combined sedimentary/morphological model of the development of the Wadden Sea in the Holocene. This is essential for our understanding of the continued development of the area, and invite to transdisciplinary projects between geology, geomorphology and archeology.
- Building up a modern database containing all relevant geo-parameters including frequent mapping of the combined Wadden Sea. Such an easy accessible database would serve all types of interdisciplinary investigations and management.
- Investigating how the tidal regime in the southern North Sea change in response to sea level rise and climate-driven changes, and describing possible trends towards higher storm surge levels.
- Achieving a better understanding of the sediment/geomorphological response of the Wadden Sea to the previous point, i.e. how the Wadden Sea sediment system reacts in terms of spatial distribution and path ways of sand and mud, sediment budget and morphologic changes, natural upward growth of tidal flats and salt marshes. Of special interest in this context is also to investigate the reaction of the ebb tidal deltas, as they are vital for the coastal stability of the Wadden Sea islands,

the overall impact on reservoirs of fresh groundwater in the systems and the risk of living in this coastal zone.

- Achieving a better understanding of reactions in the subsurface in relation to e.g. the post glacial rebound and reactions related to the utilization of oil and gas.

#### 4.2 Ecology, biodiversity and spatial processes

The Wadden Sea Region is characterized by high rates of ecological change. Current insight suggests that these changes are mainly driven by four factors, namely (1) gradual temperature rise, (2) bio-invasions on land and in water, (3) relative sea level rise including concomitant salinization of habitats, and (4) regional human impacts. Since most of these factors operate on a large geographical scale, regional studies as well as future management decisions will have to be linked more closely to processes at a wider spatial scale to meet the ecological challenges in the Wadden Sea Region. The values of the Region can only be preserved if we acknowledge that the Wadden Sea is embedded in, and tightly linked to ecological processes on a larger scale. Special attention is required for feedback cycles and exchange processes between the North Sea, the Wadden Sea Region and the mainland, including rivers and the long-distance migration routes of fish, sea-mammals and birds (such as studies in the Flyway and Swimway initiatives). It is time for adopting a more integral systems approach to ecological studies in the Wadden Sea Region and to take connectivity and mutual impacts between processes at different spatial and temporal scales into explicit consideration.

Biological invasions play a central role in shaping patterns of biodiversity and ecosystem change in the Wadden Sea Region. New plant and animal species, parasites and pathogens become introduced, establish and gain dominance in dunes, salt marshes and shallow waters of the Wadden Sea Region. In the wake of the ongoing rise in temperature, species shift their geographical ranges or seasonal population dynamics, thereby invading new territories and altering ecosystem functions and services at an accelerating pace. Nevertheless, we do not understand the consequences of this pervasive process in a wider perspective of food-chains, predator-prey and parasite-host interactions, ecosystem resilience and potential species loss. This also hinders the deployment of appropriate nature management measures to protect the natural values of the Wadden Sea. Basic research efforts should be combined with target-oriented studies to enable adaptive and timely management measures for a rapidly changing environment.

Transforming the Wadden Sea Region to climate neutrality and adapting the coastal zone to increasing sea levels will require measures with the potential for altering ecological processes on both sides of the dikes. Novel interdisciplinary research is needed to explore possibilities for adaptation measures based on natural structures and processes. Nature-inspired solutions, such as “building with nature”, hold big promise for integrating natural processes into transformation strategies to cope with relative sea level rise and climate change. Close collaboration between natural, social and technical scientists are needed to develop a basis for these innovative approaches.

Diverse human pressures are simultaneously at work in the Wadden Sea Region, as the area provides people with various benefits ranging from fisheries, agriculture and mining to recreational opportunities and maritime trade. Balancing these socio-economic benefits and functions with ecological values through policy measures and management efforts is far from trivial and will require a careful and inclusive process of coastal spatial planning. Incompatible functions and uses should be separated in space. The envisaged process brings together scientists, authorities and multiple users of coastal areas to make informed and coordinated decisions about how to use coastal resources sustainably. A future framework for coastal spatial planning in the Wadden Sea Region needs to include not only the Wadden Sea but also the North Sea coastal zones, river catchment areas, estuaries, rural marshes on the mainland and on the islands.

For this thematic line the concrete (unprioritized) research topics questions that reflect urgent knowledge gaps that are most relevant for the appropriate management of the Wadden Sea Region are:

- How will climate change affect populations and communities and how fast can marine species adapt to the actual and projected rates of environmental changes?
- How are main habitats including migratory pathways and areas of primary production distributed over the trilateral Wadden Sea, which abiotic and biotic factors determine this distribution and its dynamics, and how sensitive are these to climate change and other human activities for ecosystem integrity?
- How strong is the influence of the exchange of dead (e.g. sediments, organic matter, plastics) and living matter between the Wadden Sea and the surrounding to which it is connected (North Sea, rivers, hinterland, terrestrial Wadden habitats) on species and communities and how is this affected by climate change?



- What are the consequences of means and extremes of climate change and sea level rise for the nature and rates of biogeochemical processes, and how does this affect the species, communities and ecosystem of the Wadden Sea?
- What would be a good framework for Coastal Spatial Planning of the Wadden Sea area (including North Sea coastal zones, river catchment areas, estuaries and land), what scientific information is needed and how could this be implemented?

All these questions are suited to be answered in cross-disciplinary projects where especially the third and the fourth bullet of the previous section 4.1 seem obvious.

#### 4.3 Cultural heritage, identity and historical embedding

Based on the historical development, the question arises whether there is something like a regional identity of the Wadden Sea Region and how it is constructed or sustained based on a common cultural heritage and challenged by current existing interdependencies, diversities and dynamics as well as the complex and fragmented geographical structure. Recent developments call for an investigation of the driving forces and mechanisms enabling and hindering greater regional integration. Strong political interests are at stake on multiple political and administrative levels – from local to global levels – and a better understanding of the policy processes and the existing governance structures is therefore needed, including the effects of the recent designation as UNESCO World Heritage. Moreover, an increased economic focus on regional products and services related to local and regional assets and amenities can help enhance innovative capacity and fuel interests in informed historical embedding of present-day structures, goods and activities.

Heritage is the tangible and intangible expression of historical development. Some of it is subject to preservation, other parts are unnoticed or unknown. Intangible heritage includes phenomena such as language, music, food, dressing habits, festivities, place names, and others. Both tangible and intangible heritage elements deserve mapping and analysis. History, heritage and traditions are considered to be important factors in shaping the identity of the population of the Wadden Sea Region. However, it is unclear what constitutes identity, whether there is a common (emerging) Wadden identity, how this relates to other, parallel identities, and whose identity this might be or might have been in the past, considering the enormous population dynamics, historic flows of migration and trade relations in the Wadden Sea Region.

Cultural elements and sites in the Wadden Sea Region have been mapped through an extensive trilateral program, called 'Lancewad'. Many scenic and archaeological relics have been preserved, but to be able to interpret these traces, it is important to know how, when and why they originally appeared. Mainly national investigations have been made in the area and unanswered questions relate to regional identity, values, imaginaries, gender issues and frustrations, as well as how these sentiments have been influenced by power structures and discourses. A more comprehensive approach to the questions of heritage and identity is called for, encompassing the entire Wadden Sea Region beyond national, linguistic and cultural borders.

The 'Lancewad' inventory should progressively be expanded to encompass the historical landscape of the Wadden Sea Region as a whole and its constituting natural and cultural values. Constructive inter- and transdisciplinary research in the trilateral Wadden Sea Region should focus on the interaction between natural characteristics and past, current as well as future settlement in the region, on coastal management informed by a historical perspective, studies on biodiversity from a historical viewpoint, and traditional economic activities such as agriculture, shipping, fisheries, trade, handicraft, tourism including pathways of socio-economic development.

It is vital that the trilateral 'Lancewad' inventory is made accessible and progressively expanded to encompass the historical landscape of the Wadden Sea Region as a whole and its natural and cultural values.

Important research questions raised under this theme that reflect urgent knowledge gaps can be summarized (unprioritized) as:

- Is there a Wadden Sea identity and why does identity matter? Region-wide cultural traditions could be seen as constituting elements of a wider Wadden society which should be analyzed. There are various connecting elements (e.g. churches, organs, architectural structures, shipwrecks, nautical signaling, dwelling mounds, sluices canals, dikes and ditches etc.), but also many regional rather than circum-regional traditions and routines such as drinking tea in East Frisia, *boseln*, Frisian skating and *kaatsen*, *skûtsjesilen* or Danish cake boards and many others. Continued modernization processes increasingly threaten the existence of these traditions and routines but at the same time they experience resurgences also in the context of tourism.
- For centuries, trade has been a major factor in constituting 'Wadden society' especially along the Wadden Sea coast. These mutual connections are forming the basis for the development

of the area as a coherent cultural forum, and are vital for the understanding of the reason for the cultural situation in the Wadden Sea today. These matters include detailed investigations of activities like agriculture, shipping, fisheries, and handicraft. To this comes truism starting in the 20th century.

- The need for studies of factors enabling and hindering greater regional integration including the effects of the recent designation as UNESCO World Heritage.

#### 4.4 Economy, society and sustainable development

The Wadden Sea Region is economically very heterogeneous. Apart from belonging to three different countries, the area is characterized by strong regional differences between the islands and on the mainland between remote coastal marshlands and estuarine marshes near large urban centers, between natural shorelines, agro-industrial landscapes and large port facilities at dredged shipping lanes. These locational aspects interact with sectoral dynamics in tourism, agriculture, maritime industries and external trends as well as with employment, education and population development. The rural areas are suffering from population decline and aging due to selective out-migration of especially young people moving to urban areas with institutes of higher education. On top of that due to automation and robotization a lot of medium skilled jobs disappear in the agriculture and industrial sector, but in recent years also in the service sector. How can policies help to mitigate this heterogeneity in economic and societal outcomes towards sustainable development in the face of global warming, relative sea level rise, economic transitions and demographic change? Which activities can best be stimulated to foster sustainable economic and inclusive societal development while maintaining environmental integrity? Which type of governmental structures and institutions are needed to stimulate and facilitate (bottom up) initiatives to mobilize the economic assets and the stock of human and social capital?

Answering these and closely related questions requires careful identification and analyses of latent or new opportunities for the sustainable development of different socio-economic activities in the various parts of the Wadden Sea Region. Such efforts should be based on qualitative as well as quantitative data and models which permit the evaluation of investments in nature and coastal protection, sustainable use of natural resources, support the energy transition and pending changes towards climate change transitions on various scales in time and space. Identification of innovative potentials for small and medium sized enterprises in

tourism, food production, and related value chains, which may sustain the quality of life and integrity in the Wadden Sea Region will be of utmost importance. Such socio-economic systems analyses require a solid scientific data base for monitoring the economic, social and demographic developments for delivering robust and meaningful outcomes that can underpin relevant policy initiatives.

Aspects relating to jobs, education, housing and human capital and the quality of governance are all important factors to consider when co-designing future socio-economic pathways for the Wadden Sea Region. The principle of 'place based smart specialization' that takes into account the economic and social variety in characteristics in the different parts of the Wadden Sea Region is a logical starting point for policies aiming for resilient and inclusive regional development. This needs to be complemented by an integral, trans-national approach, as this will allow for the use of synergies and mutual strengths in building, using and preserving of assets in the whole Wadden Sea Region. Dedicated measures such as investments in digital communication technology may significantly increase the attractiveness in terms of people and businesses staying or moving into the Wadden Sea Region, especially the rural areas. An increasing number of activities can be carried out on-line providing potentially large groups of people with the opportunity to live outside urban centers making use of self-driving (electric) cars while engaging in high-end jobs. In this respect clean air, serene landscapes and quality of life are fundamental. Socio-economic studies are needed to support the development of a proper trilateral branding and marketing strategy for the inhabitants and visitors of the Wadden Sea Region which is based on regional natural and societal values.

A scientific comprehension of natural and socio-economic processes in the Wadden Sea Region will be of vital importance to support policy and management decisions in an attempt to strike a good balance between people, planet and profit. The Wadden Sea holds substantial values in the form of outstanding nature, cultural heritage, free and open access and considerable possibilities for active engagement. Advanced spatial planning efforts will be needed to help assign different functions to different areas, thereby avoiding overuse of sparse space and minimizing conflicts between separate functions. Responsible innovation strategies should be laid out to interact with the public and with civic organizations in order to gain societal acceptance for adaptation strategies and their potential for economic use in the Wadden Sea Region.

The most urgent (unprioritized) research questions for this thematic line that reflect knowledge gaps can be summarized (unprioritized) as:

- Developing of a monitoring system for the entire Wadden Sea Region with a trilateral set of consistent and coherent indicators at a detailed spatial scale (municipalities) over a longer time period (panel data) that permits the combined longitudinal and cross-section analyses of the socio-economic and demographic trends over time and space in terms of the development of jobs by sector and skill level, technical and social innovation potential, human capital, firm dynamics, including self-employment, unemployment, level of education, income, capital assets, home ownership; population development (births, deaths, migration, aging), well-being, quality of life, life expectancy, perceived health, etc.
- Which type of economic activities, supply chains, business models and governmental and social structures and institutions are needed to identify economic opportunities for a place based smart specialization strategy to create jobs that fit with the skill characteristics of the people? Compare the opportunities of sectors directly interacting with the location and ecosystem, like tourism, agriculture and fishing, energy, harbor activities, with residence related footloose economic activities that hardly have an impact on the ecosystem and are less sensitive for job losses due to automation and robotization?
- Developing of models that permit the evaluation of investments in nature protection, coastline protection, exploitation of natural resources, etc. in terms of monetary values but also in terms of economic potential, well-being and livability for the population and impact on the natural values and ecosystem of the UNESCO World Heritage Wadden Sea?

## 5. Mapping and Monitoring

### 5.1 TMAP

Monitoring represents an integral part of the Trilateral Research Agenda, because good research strongly depends on the availability of coherent long-term data sets. Based on a decision at the Ministerial Conference in Stade (1997) Denmark, Germany and The Netherlands jointly developed and implemented a common monitoring program, called “The Trilateral Monitoring and Assessment Program” (TMAP). TMAP is a harmonized monitoring and assessment program, based on sound scientific evidence. TMAP supports the management of the Wadden Sea as an ecological entity, and this program is one of the cornerstones of the trilateral cooperation and covers the entire Wadden Sea Region including islands and offshore areas, spanning a broad thematic range from physiological processes and population development to changes in landscape and morphology.

Over the years the TMAP common monitoring package was further developed to fulfill the needs of various national and international reporting obligations, in particular those from the EU Frame-work Directives on habitats, birds and water. This reflects a development, where the monitoring (also) in the Wadden Sea largely is/has been guided by development in monitoring obligations based on EU-regulation and international Conventions, latest in the field of climate change and alien/invasive species as it is expressed in the EU Invasive Species Regulation and the Ballast Water Convention. The set of indicators monitored may still have its limitation in scope and geographical detail in specific fields. To serve the needs of future policy making at all levels, the commitments ensuing from relevant directives and conventions and from the World Heritage status and data for scientific research, trilateral monitoring is needed with a larger coherent set of longitudinal indicators and with a broader scope and a greater level of detail. The most recent trilateral Quality Status Report and the prototype trilateral Sustainability Monitor 2016 based on Sustainability Balance Sheets for ecological-, economic- and social-capital are first attempts in this direction and prove that this is possible. This, however, also stresses the need for a platform for transverse regional access to Wadden Sea relevant data and for exhibiting and communicating monitoring and research results.

Monitoring serves the collection of coherent, long-term data sets focusing on critical variables that can provide a better understanding of the functioning and the dynamics of natural and socio-economic systems. Coherence, consistency and

continuity are of paramount importance for the quality of data sets obtained from monitoring. For this reason the design of the monitoring programs should to an even greater extent be carefully designed and coordinated at the trilateral level and guaranteed for longer periods of time, e.g. 10-15 years and longer. Shorter time frames, as well as disrupted or inconsistent time series, inevitably lead to a sharp decline in the relevance and usability of monitoring data and should therefore be avoided.

## 5.2 Future mapping and monitoring needs

Several preparatory workshops for the trilateral research agenda have identified monitoring needs for the future. These suggestions span a wide thematic and disciplinary range as can be seen from the list below.

- Easily accessible geodatabase/-portal for the entire trilateral Wadden Sea Region, to be established and maintained by scientists from all three countries including representatives from the national geological surveys and coastal authorities.
- Digital Terrain Models for the whole Wadden Sea Region to be carried out with a frequency of a few years and made available for research and monitoring purposes.
- Dedicated monitoring program permitting the analyses and impact of socio-economic and demographic trends (see also section 5.4) in the entire Wadden Sea Region at the micro level of individuals/households and at a detailed spatial scale (municipalities) over a longer time period (panel data) that permits the combined longitudinal and cross-section analyses.
- The Lancewad-inventory (see also section 5.1) of cultural heritage sites and objects should be developed into a true monitor.
- Novel mapping approaches are needed to support coastal spatial planning processes, allowing stakeholders and policymakers to measure impacts and reduce risks to the ecosystem, refine zones of human use and enhance delivery of multiple benefits.
- It is of great importance to continue and further harmonize long-term field observations within the Wadden Sea Region and to advocate the importance of observations and models covering the entire Wadden Sea Region.

## 5.3 Innovation in mapping and monitoring

Monitoring needs are likely to increase in the future as a result of more and broader reporting obligations and as a consequence of scientific interests and societal needs for a better understanding of the Wadden Sea ecosystem and the interaction with socio-

economic and demographic trends. Monitoring simply means keeping track of relevant changes over time and space which is a very powerful means for measuring intrinsic change, for evaluating the effects of policy measures, and for predicting future change based on past observations and measurements. The expected growth in the number of variables to be monitored, the increasing demand for higher monitoring frequencies and a better geographical data resolution will put pressure on the current monitoring capacities. New ways of monitoring and combining data sources will therefore have to be considered in order to meet the increasing demands for long-term data series.

Fortunately, new and developing technologies may significantly enhance current monitoring capacities in various fields, and technological advance may offer the opportunity to monitor new variables in a feasible way. To meet future mapping and monitoring requirements for the trilateral Wadden Sea Region it seems imperative to explore techniques derived from satellite imaging, remote sampling by drones, big-data applications, (environmental) DNA-techniques and others. Implementing novel techniques into the monitoring program will require initial investments into research and new facilities. In this context though, it is foreseen that EU – and Convention-based monitoring as well as the general development within the scientific world will push this development, which will urge the Wadden Sea scientific community to adapt this development best possible in a Wadden Sea context. Thus, on the medium to long term the use of novel approaches will contribute to reducing the costs of mapping and monitoring while enhancing data quality and usability.

Citizen science is still in its infancy but is expected to develop rapidly over the years to come. Trilateral citizen science is already used for counting coastal birds but could (and should) be used much more frequently and intensively in future. It may be developed into a strong pillar for certain mapping and monitoring exercises in the Wadden Sea Region. Citizens science refers to the participation of non-scientists in the process of gathering data according to scientific protocols and in the process of using and interpreting that data. Involving citizens can strongly improve the efficiency and breadth of monitoring activities owing to the “many hands” or “many eyes” that can be used in such approaches. Equally important, citizen science can significantly foster public support and engagement, thereby helping to build social capital fostering a robust link between science and society.



With the above as well as the deliberations in paragraphs 5.1 and 5.2 in mind it is imperative that overall attention must be given to the accessibility of data, which in the future can/will differ more both in type, origin as well as quality. In this context attention must also be given to the fact that structuring accessibility to large amounts of data from different sources does not longer mean the creation of centralized databases, but rather knowing the location of data by the responsible data owner and linking to these data by means of general and/or specialized web-portals.

## 6. Funding, outreach, communication and education

In line with the goals formulated in the priorities of the Dutch presidency of the Trilateral Wadden Sea Cooperation in June 2015 (see chapter 3.1) in the chapters 3 and 4, gaps in cross-domain knowledge and research questions are identified resulting in a coherent scientific agenda which captures the interest of young scientists and promotes scientific cooperation between institutions. Chapter 5 describes the future mapping and monitoring needs. This leads to insights to supports decision-making on current and future issues in the Wadden Sea Region in order to enhance sustainable development and the proper management of the World Heritage Site. To obtain the answers to these questions a coherent research program at regional, national and international level requires common and better coordinated research and funding from existing – e.g. scientific and regional EU-programs but also from new financial sources. Another crucial aspect formulated in this process is promoting information supply and knowledge exchange between research institutes, government, industry and social organizations. This requires that strategies need to be developed for funding, outreach, communication and education.

In the remainder of this chapter a first attempt is made to describe opportunities and dilemma's for these strategies. These are only first ideas that need to be developed further in the process towards the Trilateral Government Conference in May 2018.

### 6.1 Funding and organization

Based on this background we propose a comprehensive and truly multi-disciplinary, Trilateral Research Agenda & Monitoring Program with funding periods suggested to be of five years (2019 - 2024), which includes natural sciences, socio-economic, cultural and historic, demographic and policy-related research, as well as monitoring and mapping. The program can roughly be subdivided into three equally relevant, strongly interconnected and partially overlapping areas of activities: (1) academic research, (2) applied research and monitoring, and (3) regional studies and dissemination.

1. *Frontier academic research* aimed at enhancing our basic understanding of natural, societal and cultural processes and systems of importance to the Wadden Sea Region. Commonly, this type of research is publicly funded by research councils or research ministries and primarily carried out by universities and specialized academic research institutions.

2. *Applied research, mapping and monitoring* with the main aim of applying relevant, existing knowledge to concrete situations and of gathering long-term data series through comprehensive monitoring of natural and societal systems. The mapping and monitoring activities stem mainly from international and European policy obligations (e.g., European Framework Directives). In addition they can be used as a very valuable basis for scientific research in different areas. Applied research, mapping and monitoring is typically conducted at (semi-) publicly funded, applied research institutions financially linked to specialist departments.
3. *Regional studies, dissemination and local implementation* aiming at a strong embedding of this program and its outcomes in local and regional structures, institutions and people. The Trilateral Research Agenda must be deeply rooted in the Wadden Sea Region, its inhabitants, schools and other educational institutions, regional businesses, NGO's, natural park organizations and other public and private bodies active in the area. A considerable part of the research program shall therefore be devoted to regional studies, outreach, education and dissemination, and to the implementation of research outcomes on a regional and local scale. These types of activities are typically funded by regional authorities and funds. In-kind contributions of relevant organizations may form a very substantial and for the regional anchorage important part of the funding.

The new program should be jointly funded on a project by project basis, from national and regional existing and new sources from the three Wadden Sea countries Germany, Denmark and The Netherlands and be coordinated with potential EU funding instruments. This section attempts to provide some first ideas for a possible funding strategy for implementing the Trilateral Research Agenda. If the three areas of activities are equally relevant, they may also contribute equally in terms of funding to reach a balanced research and monitoring program if this is permitted by the different characteristics of the funding systems and institutions in the three participating countries. Given that the Netherlands are responsible for about thirty percent of the trilateral Wadden Sea Region, Germany for about sixty percent and Denmark for the remaining ten percent, this could serve as an indication for the expected contribution from each of the three countries.

A relevant question is of course also how much funding is needed for the implementation of the multi-disciplinary Trilateral Research Agenda. This question is not easy to answer, but an indication can be derived from previous Dutch/German experience. Over the last decade, the Dutch National Science

Foundation (NWO) developed and implemented a broad research program (National Program Sea and Coastal Research) with a thematic focus on the Wadden Sea Region. The program was funded by different Dutch Ministries, private partners and NWO and had a funding period of five years. The Wadden-related part of the research program had a budget of about M€ 10, focusing mainly on marine ecology, sedimentology and on the improvement of monitoring schemes. At the same time the program aimed at fostering institutional integration and collaboration between different research organizations, funding partners and disciplines also in the form of international cooperation. To achieve this goal the bilateral German-Dutch Wadden Sea call on 'bio-risks' and 'geo-risks' in which NWO in collaborated with the German Federal Ministry for Education and Research (BMBF) was part of this program. An international audit committee evaluated the research program and characterized it as a game changer in Dutch Wadden Sea research. The committee strongly advised to place future Wadden Sea research in an international, whenever possible trilateral context, and emphasized the importance if not necessity of a holistic approach to research and monitoring in the entire Wadden Sea Region.

Based on the German-Dutch experiences mentioned above and on the aim and ambition for a broad disciplinary scope the funding requirements for the Dutch part of the new program is can be estimated at approximately M€ 15. Adopting that The Netherlands are responsible for about thirty percent of the trilateral Wadden Sea Region, Germany for about sixty percent and Denmark for the remaining ten percent of the Wadden Sea region, the expected contribution from Germany would amount to roughly M€ 30 and for Denmark M€ 5. This results in a tentative overall budget of M€ 50 for the implementation of the Trilateral Research Agenda for the first five years. Clearly, the Trilateral Research Agenda needs to be developed with more detailed research questions, including setting priorities, in order to obtain a more robust underpinning for the necessary funding. This also requires taking into account the very different characteristics and opportunities of the funding systems in the three participating countries and the expected synergy that can be obtained from better coordinated research using a mix of funding by existing and new financial sources. In this respect the establishment of the Wadden Sea World Heritage Foundation (WSWHF) can also play a role as a potential source for providing trilateral funding. For the effective and efficient management of the implementation of the Trilateral Research Agenda it might also be helpful to establish a trilateral programming board with the task to formulate calls for proposals and evaluate the submissions based on the general framework developed in this Trilateral Research Agenda.

However, further elaboration of the funding and the organisation of the implementation of the Trilateral Research Agenda falls beyond the scope of this document.

## 6.2 Outreach, communication and education

From the goals formulated in chapter 2 it is clear that in addition to the elaboration of the Trilateral Research Agenda which supports decision-making on current and future issues, the aim is also the establishment of a trilateral research platform directly connected with existing national networks, to encourage discussions by the scientific community and policy makers, promotes scientific cooperation between institutions and captures the interest of young scientists. Therefore, the activities to be developed and implemented from the Trilateral Research Agenda need not only be targeted towards the academic scientific community and their research institutions but needs also to include partners and stakeholders such as governmental bodies from national to local levels, applied research and educational institutions, NGO's with an interest in the region, relevant private partners, and citizens.

With the construction of the Trilateral Wadden Sea World Heritage Centre at “Banter See Park” in Wilhelmshaven, institutions of the Trilateral Wadden Sea Cooperation will get a new home. The development of the Wadden Sea World Heritage Partnership Hub can fulfil an important role in this and can among others facilitate to capture the interest of young scientists and promote scientific cooperation between institutions. The hub could e.g. be the base for a Data Centre with TMAP that can serve as a coordinator and platform for the dissemination of and easy access to the broad variety of monitoring data that are gathered in the trilateral Wadden Region. To foster the networking of young scientists the hub can facilitate initiatives for e.g. the organization of multi-disciplinary workshops and Summer schools for master, PhD-students and post-docs. There are already initiatives for a Wadden Summerschool for PhD's and for a number of years there is an annual student/staff seminar workshop organized by the Universities of Groningen, Oldenburg and Hamburg. PhD courses with about 3-4 years interval have been carried out by University of Copenhagen. At the universities in the Wadden Region are several masters on Tourism (e.g. RUG/Leeuwarden and USD/Esbjerg), Coastal Zone Management (Groningen/Oldenburg), Logistics and Harbour Studies (Groningen/Hamburg) and probably there are many more. Efforts to appoint a Flyway Coordination Officer of the Arctic Migratory Bird Initiative (AMBI) can also contribute to the exchange of ideas and

collaboration between research institutes. Most likely are many more of this kind of initiatives that can be promoted are newly developed. The Trilateral Wadden Sea World Heritage Centre can serve as the new physical home in Wilhelmshaven as a meeting place for interaction between researchers and policy makers and the hub can coordinate and facilitate in making data available, the dissemination of research outcomes and stimulate the exchange of staff and students of institutes of education. Without doubt outreach, communication and education are important complements for the successful implementation of the Trilateral Research Agenda to disseminate to results to support decision-making on current and future issues in the Wadden Sea Region in order to enhance sustainable development and the proper management of the World Heritage Site, to capture the interest of young scientists and to promote scientific cooperation between institutions.



