IMPULSE PAPER

Nature and society in marine research

Perspectives for interdisciplinary cooperation in the Anthropocene

An impulse paper of the Working Group Inter- and Transdisciplinary Ocean Science of the Future Ocean Forum

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Summary

The human-induced environmental crises are becoming increasingly clear and visible; in the oceans just as on land. The natural and technical sciences in particular have contributed to raising public awareness of the threatened state of the oceans and coasts through large-scale research initiatives. However, the results and recommendations to date have not yet led to effective societal action. This requires a better understanding of the interactions between social and ecological processes. In order to capture these interactions, cooperation between the major disciplinary groups of the natural and technical sciences on the one hand, and the social and cultural sciences on the other must be significantly intensified and professionalized. This cooperation requires structural support and strategically viable implementation in research and training. Against the background of the ongoing UN-Decade of

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KDM Konsortium Deutsche Meeresforschung German Marine Research Consortium

2021 2030 Vereinte Nationen Dekade der Meeresforschung für nachhaltige Entwicklung

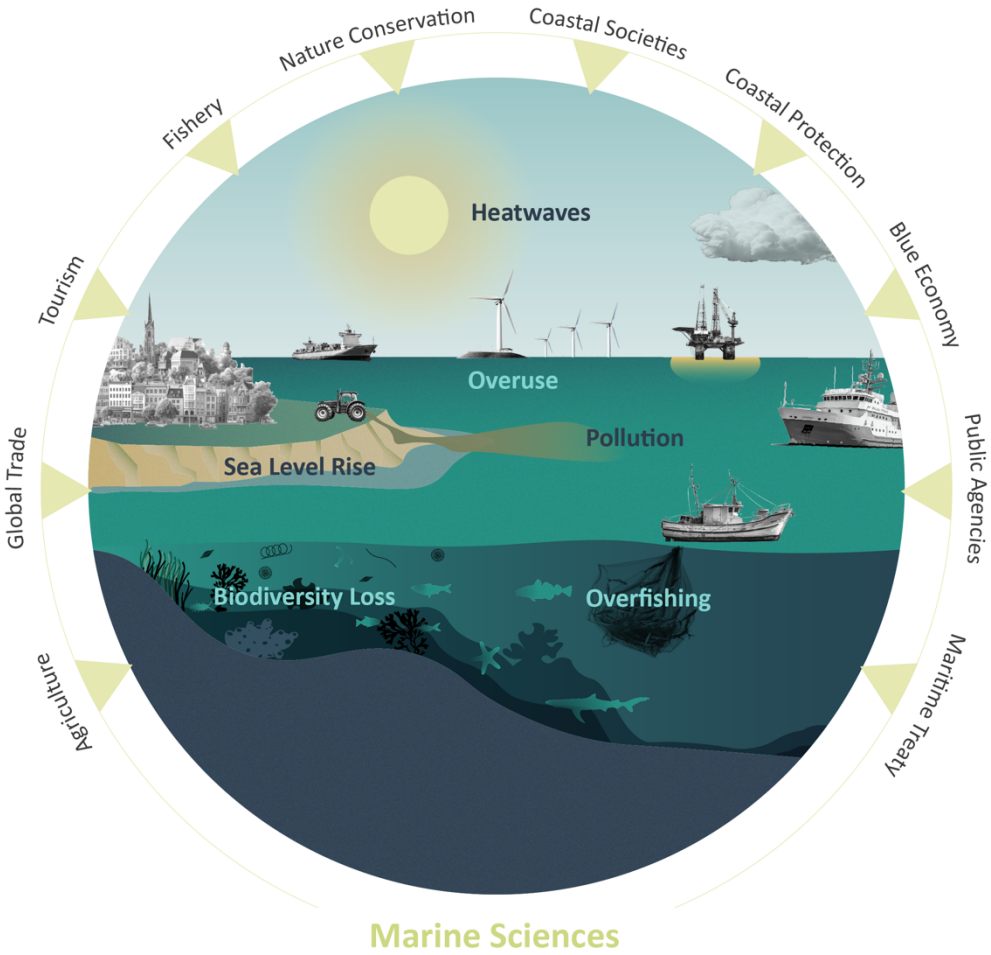

Figure 1: Complex challenges for interdisciplinary marine research

Ocean Science for Sustainable Development (2021-2030), this position paper presents five areas of development for future interdisciplinary marine research and puts them up for discussion: 1. Establishing connectivity between academic scientific cultures; 2. Reforms in training to professionalize interdisciplinary research and teaching; 3. Reforms of marine research organisations; 4. Adaptation of project funding and project organisation and 5. Structural opening into society.

In summary, we conclude that interdisciplinary research requires not only the expertise of the individual disciplines but also a reflection on the different scientific cultures in order to identify the conditions and potential for collaboration. Interdisciplinary collaboration then arises from a solution-oriented view of jointly defined problems, so that solutions can be based on both natural and social knowledge. This can be promoted by aligning funding objectives with action knowledge and by taking interdisciplinary needs into account at the operational level (networking and determining phases for the recruitment of potential partners). The development of interdisciplinary excellence, however, also requires a development path for interdisciplinary scientific training, providing the basis for both transdisciplinary and non-academic careers. The establishment of interdisciplinary assessment mechanisms in the various evaluation committees is also important, and these should be multidisciplinary and equipped with interdisciplinary expertise. At the same time, there is a need to expand interdisciplinary competence in the individual research institutions, in turn contributing to the structured expansion of transdisciplinary

cooperation with non-academic actors.

1 Introduction

German marine research needs better incentives and research structures in order to adequately comprehend the interactions between anthropogenic changes in the sea and societal processes, and to derive action-oriented conclusions for the sustainable protection of the oceans. The rapid loss of species, climate change and the spread of pollutants are man-made. The loss of nature, in turn, changes and threatens the material foundations of society and the peaceful negotiation processes within society that are linked to them. These interactions appear to be in crisis because they are too complex to be managed by

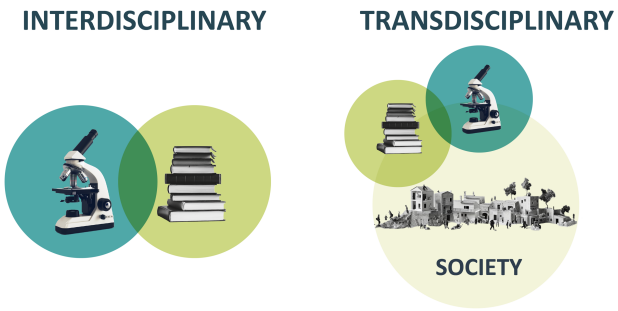

Figure 2: 'Interdisciplinary' here refers to cooperation between the major disciplinary groups of the natural and technical sciences on the one hand, and the social and cultural sciences on the other. We use the term 'transdisciplinary' for cooperation with non-academic actors in society.

individual sectors of society (science, politics, business), and they appear difficult to control as we usually perceive and analyse nature and society separately. Overcoming environmental crises requires a form of science in which nature and society are understood as integrated research objects and coordinated with one another in relation to specific problems.

Concrete fields of action for interdisciplinary marine research in the German context range from the societal preparation and implementation of protected areas at the coast (e.g. Baltic Sea National Park) and in international waters (e.g. UN Treaty on Biodiversity Beyond National Jurisdiction) on sustainable marine use (e.g. fishing, aquaculture, tourism) and maritime spatial planning (e.g. wind farms and multi-use concepts), as well as adaptation measures to deal with increasing risks from extreme events and natural hazards (e.g. general coastal plan, flood protection), through to research, management and, if necessary, certification of marine carbon sinks and technical CO_2 storage (e.g. Blue Carbon, CCS). The UN Ocean Decade and the numerous publications of the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) also emphasize the urgency of cooperation between the natural and social sciences. However, its implementation is a difficult process, because a separation that has existed for more than a century between the natural and engineering sciences on the one hand, and the social and cultural sciences on the other cannot simply be eliminated.

Until now, marine research has been largely shaped by the natural and engineering sciences. With the internationally visible establishment of marine social sciences (MSS), the social and cultural sciences are now expanding marine research by examining relationships between people and the sea using social science methods and analytical approaches. However, the complexity of these relationships has so far only been partially investigated in an interdisciplinary manner. Beyond the academic division of labor, common methodological, analytical and research strategy intersections still need to be developed.

This commentary presents strategies and development paths for interdisciplinary marine research. Since there is already a wide range of interdisciplinary work and initiatives in German marine research, we do not claim to reinvent interdisciplinary cooperation. However, we do

note that interdisciplinary cooperation is consolidating too slowly and is falling far short of demand. What conditions hinder interdisciplinary marine research and how can it be promoted? To answer this question, we have developed five areas of development: academic knowledge cultures (2), training (3), research organization (4), project organization (5), and societal integration (6). In the summary (7) we formulate targeted approaches to improving inter- and transdisciplinary cooperation in German marine research. It should be noted that we are not taking stock of existing interdisciplinary approaches and structures and that all references to them are therefore selective and exemplary. This position paper reflects our roles primarily as scientists who are institutionally and organizationally located in the context of the German Marine Research Consortium - knowing full well that not only does our subject have planetary dimensions but that most of us are also active internationally. However, the focus on German marine research allows us to formulate transformation needs for interdisciplinary marine research more concretely and purposefully.

In terms of content, we begin with a reflection on the epistemological prerequisites for successful interdisciplinary marine research. Where do we come from - historically, academically and epistemologically? We believe that by becoming clear about our different academic knowledge cultures, we not only develop a more systematic basic understanding of our differences but can also better work out our potential similarities and use them effectively.

2. Academic science cultures

Until now, marine research was mainly the preserve of the natural and technical sciences. However, as a result of man-made climate change, rapid biodiversity loss, intensified economic use of the oceans and increased public awareness of anthropogenic influences on the seas and coastal regions, the field has expanded. In the context of the internationally flourishing marine social sciences, the Marine Social and Cultural Sciences Strategy Group has successfully established itself in the German Marine Research Consortium (KDM). This means that German marine research has more interdisciplinary potential than ever before. The work of international scientific bodies such as IMBeR, the Ocean Decade and Future Earth Coast reflects the global relevance of this change. However, there is still a long way to go to achieve a research practice, suited to the times we are living in. We see one shortcoming in the lack of engagement with the scientific cultures that have developed across disciplines and the methodologies associated with them.

Nature – society: the ontological separation

"Nature" and "society" are only weakly integrated in German marine research. The difficulty of systematically relating them to one another as research objects highlights the cumbersomeness of a system that has been able to generate enormous scientific productivity from their separation, but has now clearly reached its limits. In order to better understand the current need for interdisciplinary cooperation, it is worth taking a look at the history of science and scientific research.

Our respective scientific families have historically developed against the backdrop of the Enlightenment, itself based on the postulate of a fundamental separation between "nature" on the one hand and "society" on the other. In the 18th Century, the natural and technical sciences took the spirit of the Enlightenment as their starting point, according to which rationality and objectivity in the examination of natural phenomena can only be achieved through a methodology in which social and cultural elements are systematically excluded. Methodologically,

they were based on the hypothetical-deductive paradigm, which is based primarily on causal knowledge acquisition. In contrast, large parts of the social sciences and humanities emerged as interpretive sciences in the context of hermeneutic-inductive reflection. The social and cultural sciences therefore did not see themselves as natural sciences and based their independent profile on this demarcation. As a result, modern universities and research institutions view nature and society as two separate entities. This difference is still virulent today. It is reflected in the academic organisation of faculties in which natural and social sciences (with the exception of geography) mostly belong to different institutions and have neither professional-organisational nor everyday-world contact points.

Scientific cultures

Long before the social sciences and humanities became established at universities and research institutions at the beginning of the twentieth century, the natural and technical sciences had agreed on their methodological standards: causal relationships were mainly determined by deductive processes; the experiment with its open-ended forms of exploration was geared towards falsifying reduction, methodologies were thought of in terms of causal relationships rather than constructivist-relational ones. This development, which is only roughly outlined here, can be broadly observed for the natural and technical sciences from their beginnings to the molecular genetic revolution, despite diverse differentiations in sub-disciplines (e.g. ecology, human geography) and the widespread practice of field research or technology assessment. While the natural and technical sciences build their methods based on their respective applicability to complex problems through exclusion processes and thus participate in a jointly developed epistemology, the social sciences and humanities are characterized by paradigmatic diversity and methodological pluralism (Table 1). This is also related to the fact that the object of investigation, "society," has an abstract and self-referential dimension, so that the inherent logic of the actors being investigated, which is embedded in complex socio-cultural and socio-economic contexts, must always be considered. The hypothetical-deductive approach is thus contrasted with a critical-reflexive understanding of knowledge production, and this is also currently

Figure 3: Discipline-specific perspectives

reflected in the proposed solutions to current environmental crises: the natural and technical sciences rely on a discipline-typical "solutionism ", in which society is reduced to a (disturbance) factor in the causal chains being investigated - according to the motto: the (scientific-technical) knowledge is there, now society only has to apply it (Figure 3). For social and cultural scientists, such an understanding of society appears one-sided and under-complex. They insist on a reflection of the complex social structures typical of the

discipline and on the negotiation processes necessary for achieving socio-ecological transformation. This "society first" approach appears to natural scientists and engineers to be too one-sided and too simplistic since they consider the scope for negotiation with nature to be non-existent. It is, therefore, hardly surprising that both approaches - which are being pointed out here - not only lack a shared perspective on human-ocean relationships but also that it is difficult to develop a shared practical approach to dealing with today's environmental crises.

After all, what use is the most exciting case study if it does not have systematic parameters of comparability or is not highly scalable - some natural scientists ask themselves? What is the point of climate scenarios if we do not have a realistic picture of the everyday concerns of the coastal population, some sociologists ask themselves? The different scientific cultures also include different forms of knowledge production. Natural and technical sciences work in larger collectives than the social sciences and humanities, which is reflected in the different presentation of their results and corresponding gratification systems: While for the maritime historian "the second book" is still considered indispensable, documenting the studies of a (usually) single person, for the marine biogeochemist the specialist article with a high impact and citation factor, in which specific partial expertise of many colleagues is combined into a larger whole, is evidence of scientific excellence.

All of these differences are habitually practiced through academic research traditions. They follow complex and powerful logics within the respective scientific field and form central criteria for research organization, evaluation, training and careers. They continue to support and promote different characteristics of disciplinary knowledge cultures, which often belong to corresponding families of disciplines:

Table 1:
Ideal-typical characteristics of dichotomously structured epistemic cultures

SoSc Epistemic Cultures	NaSc Epistemic Cultures
Individual studies	Consortia
Schools of thought / methodological pluralism	Cumulative Knowledge
Understand / Explain / Describe	Derive / Measure
Particularity	Universality
Contextualization	Determination
Increasing complexity	Reduction of complexity
holistic	specific
Experience	Evidence
Relativism / Constructivism	Positivism

Thinking about relationships between people and the sea in an integrative way: from difference to collaboration

Interdisciplinary marine research must emancipate itself from the dichotomous ontologies of established disciplinary solutions and develop integrative procedures. It is becoming increasingly clear that an integrative research approach is needed in view of the apparent increase in socio-marine target-conflicts of interests and values on the coasts and at sea. The situation for new interdisciplinary approaches in marine research is more favorable than ever. Corresponding conceptual thinking has already begun. In terms of science policy, interdisciplinary cooperation is currently being called for and, in some cases, formally supported by relevant consortia - from IPBES and IPCC, the Ocean Decade to calls for research missions by the German Alliance for Marine Research (DAM). In 2021, the German federal government appointed a marine commissioner with a political science background, thereby also sending a signal towards interdisciplinarity. In many places, we are also observing a high level of motivation for collaboration and the need to overcome existing barriers. Beyond tactical cooperation, many colleagues - especially younger ones - emphasize the added value of interdisciplinary work. But good will in crisis mode alone is not enough - we need appropriate framework conditions, organizational structures and experimental fields to make marine research fit for the challenges of the 21st century. We do not see interdisciplinary cooperation as a replacement for existing disciplinary research, but as a necessary complement to it.

Marine nature-society relationships have a broad spectrum of problem areas, the joint treatment of which can be locally specific, but is often transferable to comparable cases. Whether overfishing, eutrophication, pollutant input, sea level rise, tourism, or environmental policy measures for marine protection - these and similar challenges can be seen on German coasts and worldwide. In general, the common focus on the respective problem areas and an objective in the direction of action knowledge and social impact serve as integrative brackets that counteract the tendency towards a monodisciplinary focus. At the same time, the concrete design of interdisciplinary research is very case-dependent. Therefore, we discuss interdisciplinary cooperation below using two modes as examples: a) a complementary research approach and b) a collaborative research approach.

The choice of approach cannot be defined in the abstract, but should already be part of the interdisciplinary collaboration. It depends on the research question and, therefore, also on whether, within interdisciplinary teams, a group of disciplines takes lead responsibility and thus tends to follow its inherent disciplinary solution logic or whether the collaboration follows a more integrative approach. The first approach promotes a complementary logic of collaboration, while the second relies on a collaborative logic. Both can be useful depending on the problem area, although we consider the collaborative logic to be better suited to the required transformation of marine research in order to overcome the unproductive effects of established scientific cultures in situ. When setting up interdisciplinary consortia, it is therefore important to clarify at an early stage whether the problem areas and the resulting research questions are already being developed jointly (integrative-collaborative approach) or whether the research questions (currently mostly defined by the natural and technical sciences) are being "commissioned" cooperatively as work packages in the sense of complementary division of labour. Complementary approaches are probably more suitable in fields in which a family of disciplines already has strong expertise or a problem (e.g. conflict of objectives)

has already manifested itself as a political conflict, for example.

In collaboration, on the other hand, the specific question is worked out together (not set by a family of disciplines) that arises from current or predicted challenges - e.g. rising sea levels with expected effects on the economy and coastal and urban populations, or the development of criteria for establishing a marine protection zone. The collaborative approach is, therefore, more suitable for anticipating and exploring the foreseeable consequences of environmental crises, while the cooperative approach enables a more pragmatic approach to existing tensions and problem areas - e.g. the organization of ad hoc round tables to resolve a socio-ecological conflict with local scientific organizations and stakeholders. Regardless of the approach, however, the fact that cooperation between widely divergent specialist cultures means that time resources for the integration of research methods are more important than in monodisciplinary contexts in which much can be assumed. Investment of time in the exchange of knowledge regarding various methods, as well as their selection and integration and learning new approaches is therefore already part of the research process.

various epistemological prerequisites of the methods must be taken into account so that the potential of the respective non-disciplinary methods can be recognized and integrated into the research phases. Co-design phases are generally helpful; they should be systematically recorded and taken into account centrally in the overall approach developed (see Figure 7: interdisciplinary project progression in the Project Organization section). The collaborative approach, in particular, enables integrative method reflection and the discovery of any similar methodologies,

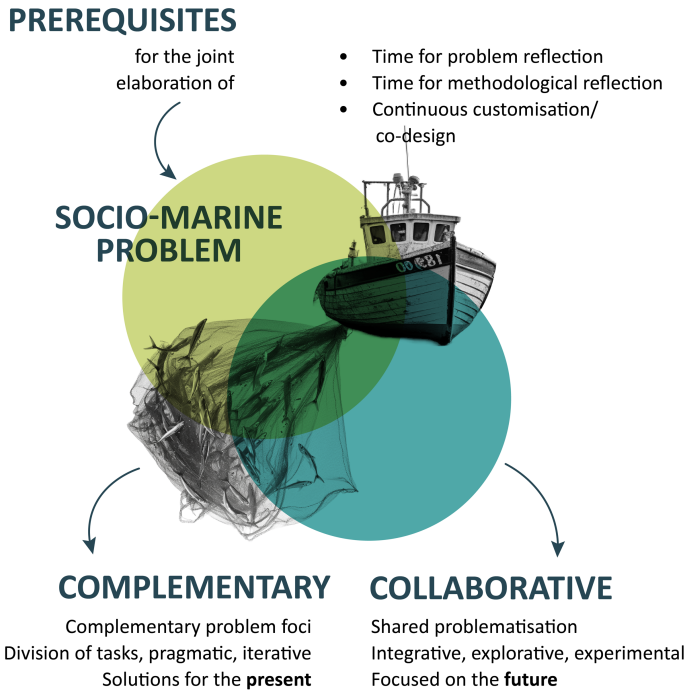

Figure 4: Two modes of interdisciplinary cooperation: complementary - collaborative

Challenge of choice of method

When clarifying the choice of method for a specific problem, many questions arise: Inductive or deductive methods? Exploration or hypothesis testing? Understanding or explaining? These arise in the natural and engineering sciences as well as in the social and cultural sciences. The joint reflection and clarification of method integration takes place at the various levels of data collection, processing, evaluation and interpretation. The

which are often used without explicit reference to one another, however: e.g. interdisciplinary organized coastal observations and field research (planning and using together) or natural and social science network analyses. In collaborative mode, those involved see themselves as a community of practice that is constantly learning. Their approach is exploratory and experimental and, depending on the topic, also allows the inclusion of

innovative methods, e.g. learning cabinets (members of one discipline family bring members of the other discipline family into the field); sharing cabinets (interdisciplinary exploration and discussion of data, e.g. in coastal areas where protective measures are expected to be implemented in the foreseeable future), the creation of common typologies or ocean accounting (collection of ocean-related data on social, ecological and economic processes that enables a holistic analysis of the oceans). However, targeted adjustments to the training system are also required for the sustainable establishment and broad anchoring of the integrative knowledge culture described above.

3. Training

There are already institutions and program lines in Germany that have made interdisciplinary marine research their mission. These include the Center for Interdisciplinary Marine Sciences (KMS) at the Christian-Albrechts University (CAU) in Kiel, individual interdisciplinary degree programs at the University of Oldenburg and the University of Bremen, or the interdisciplinary faculty at the University of Rostock. Non-university institutions include the Helmholtz Institute for Functional Marine Biodiversity (HIFMB) in Oldenburg, the Research Institute for Sustainability Helmholtz Center Potsdam (RIFS), the Leibniz Center for Tropical Marine Research (ZMT) and the Thünen Institutes. The interdisciplinary collaboration associated with the above is largely at graduate level, i.e. between already established scientists who are mostly trained in one discipline - the typical format for this is complementary research projects (see Figure 4).

However, we believe that the foundations for effective and more promising interdisciplinary cooperation between natural, technical, social and cultural scientists must be laid much earlier for four reasons: in order to (a) break down the ontological difference between the established academic knowledge cultures described above in a professional and everyday way and thus (b) avoid many of the start-up and communication difficulties in later joint projects, and (c) develop methodological expertise and mutual analytical connectivity between the discipline families at an early stage and thus also (d) generate early expertise on which form of cooperation (complementary or collaborative) is suitable for which problem.

In contrast, these needs are not taken into account in the vast majority of all degree programs, or only partially so. The lack of interdisciplinary skills is correspondingly great, and this becomes apparent in later research. Even if young scientists strive for a new orientation in interdisciplinary subject areas out of their own interest and motivation or in response to the changing demands on science, this is made difficult by the existing structures of scientific training (as well as the research and funding landscape). Some of these obstacles are:

- Interdisciplinary work requires a lot of self-study and time, as integrated teaching options are lacking. Slow progress through trial and error is not rewarded in the current scientific system, as excellence and, thus, opportunities for continued employment and advancement are measured by the number of scientific publications that can be clearly assigned to one of the two discipline families (or a single discipline). There is therefore a lack of career-related incentives for young scientists to participate in interdisciplinary projects.
- In graduate programs, due to the lack of interdisciplinary events, offerings and platforms, horizontal networking between disciplines rarely or never occurs. Above all, course offerings from the other disciplinary areas (social and cultural sciences for natural and technical scientists; natural and technical sciences for social and cultural scientists) in

theory and methodology would be necessary in order to gain a better understanding of the different approaches, as well as their possible complementarity and collaborative potential. Interdisciplinary dissertations under review from both discipline groups are also only possible in a few exceptional cases.

- Publishing interdisciplinary studies remains less attractive and less successful than publishing with a focus on just one discipline. Although there are increasingly interdisciplinary journals in marine research, these are only just beginning to establish themselves and build up corresponding impact factors. On the other hand, the review of interdisciplinary work is difficult because there are not enough reviewers available who can evaluate work in an interdisciplinary manner beyond their disciplinary expertise. This means that the requirement that interdisciplinary work in all disciplines involved must meet the same high level of scientific excellence and be reviewed on an equal footing can hardly be met. This often leads to inadequate evaluations of interdisciplinary studies. The same applies to theses and research proposals.

The attractiveness of interdisciplinary training and career paths within the established academic system is therefore relatively limited, although interdisciplinary trained graduates are also urgently needed outside of academia (NGOs, authorities and industry). Universities should, therefore, more effectively fulfil their training obligations to students who will pursue a career outside of academia after graduation while at the same time promoting the expansion of interdisciplinary career paths within the academic system.

There are various ways to promote interdisciplinary thinking and collaboration, particularly during the training phase. These include additional offers for acquiring the relevant key competencies, as well as structural reforms of the academic training system. Key competencies are already extensively integrated into the curricula at German universities and are awarded credits. Successful interdisciplinary collaboration across the boundaries of natural and social sciences requires communication skills (active listening, avoiding technical terms, reflexivity, identifying commonalities), thinking in larger contexts and the formulation of appropriate overarching objectives (systemic approach; bigger picture), an interdisciplinary understanding of methods, and translation skills in relation to technical terminology. Marine study projects with a practical focus offer a good opportunity to bring scientists

Figure 5: Early interaction between students from different disciplines through projects with practical relevance

together on the basis of a concrete task specified by the stakeholders in order to jointly develop holistic solutions and thus promote exchange between the disciplines at an early stage. The focus is on the following core aspects as learning objectives: (1) the interdisciplinary formulation of the problem, i.e. everyone works towards a jointly formulated goal, (2) a joint development and linking of suitable methodological approaches, and (3) a joint development of interdisciplinary solution proposals, taking into account the feedback of the stakeholders. Appropriate courses are required as a fixed, complementary component of disciplinary training.

However, such supplementary offers can only partially meet the needs for effective interdisciplinary cooperation outlined above (a-d). The increasing international demand for a stronger integration of social and natural science courses among school leavers has long been documented by many studies. With the establishment of Liberal Arts and Sciences (LAS) or Anthropocene Studies courses at many European and international universities, an educational paradigm has been established that addresses the needs of the younger generation for a stronger and practice-oriented integration of nature and society. While the Netherlands and Scandinavia, in particular, are leading the way here - for example, by establishing corresponding courses ("Interdepartmental Majors", e.g. in Amsterdam or Utrecht), German faculties have so far been much more sluggish with regard to this integration. Courses and graduate programs in marine sciences confirm this overall picture. In international comparison, German universities still have a lot of catching up to do here. Firstly, the vast majority of all "interdisciplinary" study programs in the marine sector actually only involve the collaboration of several scientific disciplines. Secondly, even the few interdisciplinary (in the sense of natural /engineering and social/cultural sciences) study programs are usually located in just one scientific department.

Here, too, there are exceptions at the institute level, such as the interdisciplinary Master School of Marine Sciences at the CAU Kiel or the Center for Environmental and Sustainability Research at the University of Oldenburg (COAST), within which students can freely put together their courses with a certain proportion of natural, technical and social sciences. Another example would be the Marine Ecosystem and Fisheries Sciences degree program at the University of Hamburg, which combines purely scientific elements with aspects of management and politics. In the vast majority of cases, however, teaching in Germany is still conceived and practiced within the individual faculties in line with the historical separation of natural and social sciences discussed above and the resulting established structures (see Table 1).

The marine sciences are not alone in facing this challenge. For almost ten years now, supplementary courses have been offered in general environmental research and training. In Germany, for example, these courses are known as the "Studium Oecologicum " (based on the classic Studium Generale) or as certificates in the field of sustainability. However, in order to train young marine scientists for effective and promising interdisciplinary collaboration (referred to under ad), a systematic revision of the existing study organization and the respective curricula is required. This should not replace disciplinary training, but update it and supplement it with further options. Establishing personal interdisciplinary relationships and networks as early as possible through collaboration during the training phase enables trust and mutual appreciation to be built. Universities and colleges with a marine training focus in particular are called upon to develop appropriate concepts that contribute to the existing marine science profile and that incorporate local research contexts and

expertise.

We see a key prerequisite for this in a more general reform of faculty organizations, as well as chair and subject structures, which can be broken up by department structures, as have long been common in the international context. The latter enable knowledge organization and policy that is less oriented towards people and more towards subject areas. There is sometimes understandable resistance from the teaching staff here, as the care of "non-specialist" students currently represents an uncompensated additional effort. Counting interdisciplinary training towards the teaching load, on the other hand, would provide an incentive for teachers to make a contribution to interdisciplinary training. Joint courses by natural /engineering and social/ cultural scientists also require more intensive preparation and didactic mediation work and should be flanked by teacher training, which are also counted towards the load, the supervision ratio, or the working hours. Cross-university marine science certificates, international mobility programs and the financing of cooperation initiatives for research projects create further incentives for students as well as for teachers to use topic-specific interdisciplinary institutions and to promote their networking.

At the graduate and postdoctoral level, interdisciplinary graduate schools with appropriate course offerings could then build on cohorts that have completed such interdisciplinary training. The focus is on raising awareness of the fact that the methodological approaches and thought patterns of different scientific disciplines complement each other and promote the finding of solutions to overarching socially relevant issues. It should be borne in mind that not all graduates remain in science, but strive for careers and leadership positions in non-university professions related to the sea. In order to prepare this group specifically for such fields of activity, the establishment of a marine post-graduate academy would be sensible and timely. Current role models for this are the Postdoc Academy for Transformational Leadership (IRI THESys / Humboldt University of Berlin) or the DRIFT Institute (Rotterdam, Netherlands), which focuses on transformative processes. Such institutions respond to the broad demand among young people for the linking of environmental sciences with concrete fields of practice. All this will also benefit interdisciplinary marine research in the long term.

4. Research institutions

Many of the structural obstacles mentioned in the section on scientific cultures, which are reflected in the training system, can also be found in our research institutions. The majority of German marine science institutions limit themselves to scientific research. There are historical reasons for this. Today, however, this one-sided focus is hindering interdisciplinary cooperation between marine natural, technical, social and cultural sciences that is appropriate to the challenges and is effective. Research institutions thus need to adapt, and this adaptation process has already begun in some places - through the establishment of social science research departments or the filling of (transfer) positions by marine social and cultural scientists . Beyond transfer tasks, however, in view of the imperative for socio-ecological transformation, this expertise must be accessed much more systematically where it lies: in the analysis of socio-ecological, socio-economic and socio-cultural social dynamics in coastal societies, as well as the analysis and sometimes also the provision of cooperation formats between different sectors.

Examples of this can be found at the Thünen Institutes with a marine focus, which conduct research and policy advice with a social science (including economic) orientation, or at the ZMT and HIFMB. Here, the importance of people for the sustainability of the seas and coasts and thus

for marine sciences is already considered in the diversity of disciplines. The newly founded Center for Ocean and Society (CeOS) at the CAU Kiel also combines marine social and natural sciences. An increase in interdisciplinarity along topic lines, but also in management structures, is an important prerequisite for being able to coordinate and link the research subjects of nature and society in a problem-related manner when researching environmental crises.

Today, scientific organizations and research institutions are shaped centrally by regular evaluations. This cyclical review procedure offers good opportunities to align research with current needs. Evaluations are often carried out by experienced scientists who usually have strong disciplinary expertise. Similar to what was already explained in the "Training" section, the promotion of interdisciplinarity makes it necessary to pay attention not only to the multidisciplinary composition of the evaluation committees when filling them, but also to the interdisciplinary, i.e. integration, competence of their members, since it is not the diversity of disciplines that should be evaluated, but especially their productive interaction.

Therefore, the evaluation criteria often set by the science system also need to be adapted. The problem here is again that excellence is often measured by discipline-oriented specialist journals that have a higher reputation in the relevant scientific community. The traditional academic incentive system does not reward a research organization if it makes greater efforts in terms of an interdisciplinary orientation. Therefore, a fundamental expansion of the evaluation criteria is needed, for example, to include the social impact of research contributions. Work is already underway in various places to revise the research assessments, for example, at the " Coalition fo r Advancing Research Assessment" (CoARA), which is also supported by numerous German organizations and institutions.

Interdisciplinary competence is not only important for evaluation. Due to the pronounced disciplinary-oriented training and research structures in Germany, people are also needed who can advance research at the interfaces of the traditional disciplines at an operational level and who feel at home in the different knowledge cultures. The research organization, therefore, needs interdisciplinary translators, communicative bridge builders, and experienced process coordinators who are able to lead the different disciplines and scientific cultures into a

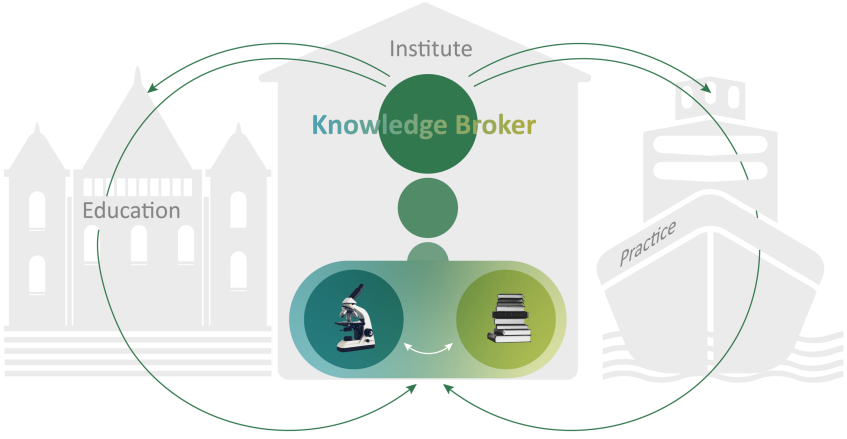

Figure 6: Knowledge Broker as mediators in training and practice.

constructive dialogue in order to maintain the focus on the complex problems in research practice. However, there is a lack of appropriately trained "knowledge brokers" due to the gaps in university training programs outlined above. In the postgraduate phase, there is also a lack of interdisciplinary career and permanent employment options in the research institutions themselves. Careers that involve switching between the major disciplines or between scientific and non-scientific activities are rare since the lack of evaluation criteria for inter- and transdisciplinarity means that proof of excellence must be provided in a monodisciplinary manner. In principle, however, with the increasing number of environmental crises, there is also a growing need among researchers to place their scientific work in a broader context that is geared towards overcoming the crises holistically and not (only) focused on aspects of their own specialization. In many cases, this leads to knowledge transfer activities or socially and politically relevant activities (public relations work or involvement with Scientists for Future, for example). This action orientation indicates a high potential for interdisciplinary problem-oriented research that exists in the research institutes and could be tapped through appropriate (in-house) programs. It should be noted that the development and implementation of interdisciplinarity requires more time and resources than disciplinary research. Understanding other knowledge bases and recognizing synergy potential requires extensive communication and long-term cooperation.

Another important structural prerequisite for improving interdisciplinary cooperation concerns the expansion of complementary or collaborative marine data exploration and data analysis by research organizations. This would require considering the varying availability of long-term data both within and in comparison, with, discipline families. However, the lack of long-term observations and measurements is particularly glaring in the marine social and cultural sciences. A stronger involvement of social and cultural scientists, for example, at marine stations, could help here, as these are also suitable for long-term social observations due to their geographical location (at the coast) between the sea and society and their dual function as research institutions and observatories. These and other forms of integration result in specific requirements for project-related marine research itself, which we will discuss below.

5. Project organization

What circumstances promote or hinder interdisciplinary research at project level? It should be emphasized again that scientific careers currently take place predominantly within individual disciplines since the visibility and evaluation of individual work is guided by disciplinary questions that aim to deepen previous knowledge. This development is not without reason. The motto "a new insight simultaneously raises ten new questions" illustrates the intrinsic urge for in-depth inquiry, which also includes one's own peer group and thus creates the environment in which one's own work becomes visible and comparable. Up to now, it has often only been possible to cast a curious glance to the side when one's own position within a discipline is secure.

But now it is becoming increasingly important to look beyond the individual disciplines. Science funding in recent decades has focused on complex environmental crises with the task of identifying sustainable solutions. Successfully acquiring project funding now generally involves convincingly combining an inter- and transdisciplinary problem with one's own monodisciplinary perspective. Within marine research in the natural sciences, large multidisciplinary consortia can be formed in this way, grouped around the various facets of a

complex topic, in order to then be able to deepen one's own disciplinary expertise - because in view of the academic differentiation described above, this expertise primarily serves to consolidate one's personal scientific profile and corresponding career path. This motivation is reflected quite openly in the self-critical description of such consortia as a "predatory community", constantly under pressure to seek for high funding-amounts. Funding programs that target interdisciplinary projects must deal with this motivation. In order to cushion this, it would make sense for the relevant funding institutions to be able to provide and evaluate interdisciplinary skills themselves.

In addition to producing descriptive knowledge on the respective topic, the funding objectives should be equally focused on practical knowledge and applied concepts. Starting from a complex understanding of the problem, the expertise of those involved can thus be grouped along solution-oriented collaborative research (see Figure 2), in which interdisciplinarity becomes a necessity for the success of the project rather than a mere funding requirement. The recent German-Dutch funding of Wadden Sea research may serve as an interesting example. The application form asks about the problems from the perspective of society, the social impacts that the consortium wants to achieve, and the concrete contribution that the consortium will make to achieving the desired impacts (NWO). Something similar can be found in the calls from biodiversa + and t he GIZ's MeerWissen initiative. It is clear that the social perspective on action requested with regard to complex environmental issues makes interdisciplinary cooperation a prerequisite.

In addition to the content-related focus of the funding objectives, structural conditions that can promote or hinder interdisciplinary research are important. Interdisciplinary research begins with a cross-disciplinary problem (Figure 7). This requires two things: calls for proposals should describe a topic area, but give applicants enough space to formulate an interdisciplinary problem. In contrast to monodisciplinary applications, it takes considerably more time and effort to set up the

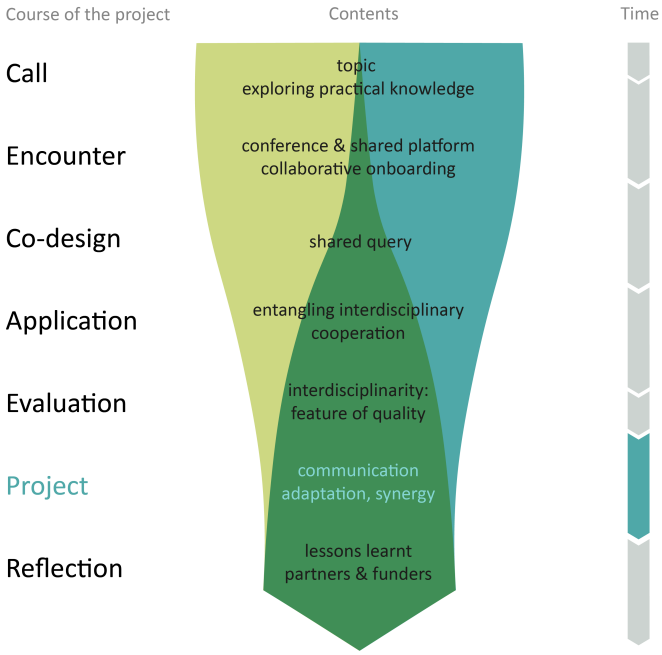

Figure 7: Interdisciplinary project process

consortium and carry out a joint problem analysis. Two-stage project funding with a financed discovery phase (co-design phase) would be one way of taking these special features into account. The only obligation: the discussion must be documented in order to reflect on this process and share experiences, as well as the actual problem analysis and the associated research approach as a result.

Furthermore, the formation of interdisciplinary consortia requires spaces for meetings and exchanges. Naturally, the number of possible partners is much more confusing than in one's own discipline, so holding regular interdisciplinary conferences and workshops for open exchange along content-related, problem-oriented and methodological topics is an important prerequisite for establishing interdisciplinary research. In addition to the formation and design of interdisciplinary consortia, questions and project ideas, appropriate interdisciplinary expertise is also required for their assessment. Accordingly, an adjustment of the selection of reviewers and an independent assessment of interdisciplinarity would also be necessary here, since a monodisciplinary understanding of excellence distorts an assessment in terms of interdisciplinary funding objectives.

When organizing and implementing interdisciplinary projects, it is sensible, due to the breadth of expertise, to establish interdisciplinary content-related project management with the appropriate know-how in addition to organizational project management ("knowledge broker", see section 4), because in the course of a project, the interdisciplinary added value depends on the timely recognition of synergies and productive interfaces between the disciplines. This requires staff with broad interdisciplinary knowledge and good communication skills. When designing the projects themselves, care should be taken to ensure that the design of work packages, project tasks and -services promotes possible interfaces and practical collaboration between the disciplines. This enables and promotes exchange between the disciplines along a common question and solution perspective and avoids an incoherent coexistence of research due to the monodisciplinary dynamics described above.

6. Social integration (transdisciplinarity)

The best scientific survey of the state of the oceans and coasts is of little help if the practical consequences resulting from it cannot be implemented by society. Interdisciplinary cooperation between the sciences must therefore take into account the conditions for transdisciplinary cooperation with parts of society and social integration. This concerns the use and protection of the oceans, adaptation to the effects of climate change, and fundamentally changes in understanding of the relationship between the sea and humans in a phase of sociopolitical polarization.

There is a tension between the role of non-academic contributors in transdisciplinary collaboration as contributors of expert knowledge (including local and traditional knowledge) on the one hand and as representatives of the interests of their own institution or group, on the other hand. Both are valuable for generating actionable knowledge, but the interests should be handled transparently. Expert knowledge is usually contributed by institutions that themselves collect and present knowledge: authorities, companies, associations (e.g. fishing, tourism), NGOs, coastal communities, consulting institutes (think tanks) and international organizations. Cooperation with offices and authorities, for example, can contribute to the joint design of political processes. The involvement of NGOs and cultural institutions (such as natural history or maritime museums) can play a central role, for example, in the exchange of knowledge, in the representation

of society's ideas about nature and needs, and in the application of scientific findings for public purposes. In a transdisciplinary environment, the role of academic actors often has an advisory or moderating function in addition to the production and integration of knowledge, depending on how closely the knowledge generated is linked to decision-making processes, for example, when it comes to the establishment of marine protection zones. The participation of social actors is essential in order to integrate local experiences, expertise and needs, which are particularly relevant in research projects in which the social acceptance of marine transformation projects is put to the test (e.g. with co-design and co-production approaches, participatory research or real-world laboratories). The key condition for the success of any transdisciplinary collaboration is joint reflection on the analytical standards in the production of knowledge, on the basis of which action corridors and decision-making processes can then be discussed.

Transdisciplinary collaboration and research benefit from the measures of interdisciplinary collaboration proposed above, as culture and society are already integrated as research subjects and potential contributors to possible solutions. At the same time, it inspires interdisciplinary thinking because it invites people to leave established disciplinary paths and make their own scientific expertise compatible with societal needs. This, in turn, can lead to a better understanding of the potential complementarity of expertise in different sectors, for example, when authorities, conservationists, scientists and coastal residents exchange their knowledge and experience about the condition and sustainable use of a specific area and transfer it into " communities of practice".

Transdisciplinary cooperation is currently being called for in many places – but the corresponding structural integration and resources are lacking here too. As a rule, the existing institutional interfaces serve to transfer knowledge from research to other parts of society and (still) too little to reciprocate the involvement of non-academic people in the planning and implementation of research. Such interfaces exist at both the local and intergovernmental levels – to name just a few: the North Sea Office and the German Arctic Office of the Alfred Wegener

Figure 8:
Integrating the transdisciplinary perspective

Institute Helmholtz Centre for Polar and Marine Research (AWI), or the "Round Table for Marine Research" initiated by the CeOS at the CAU Kiel , the Arctic Governance Group of the RIFS, the MeerWissen initiative of the GIZ (supported by the BMZ), or the partnership strategy and the Office for Knowledge Exchange of the ZMT. However, as with training, there is still no coherent strategy for the permanent implementation and consolidation of transdisciplinary structures in German marine research.

The question already discussed under 3 and 4 as to what training and organization interdisciplinary marine research requires also includes the professionalization of selection competencies with regard to the choice of specific transdisciplinary partners and methodologies. This not only builds bridges between science and other important

knowledge carriers, but also promotes complementary or collaborative cooperation between the natural, technical, social and cultural sciences. As mentioned under point 5, this integration can be built more systematically into transdisciplinary project funding by asking the concrete contribution that a consortium will make to achieving the desired project goals from the perspective of the non-academic participants. They would thus have a "participating" (e.g. co-design and participation) and also an evaluating (checking for practical suitability) role (if necessary supplemented by participation in the implementation).

Even if the form and extent of transdisciplinary involvement differ between individual projects, it is always important for successful collaborative marine research. Trustful contact is central here. What is needed is temporal, spatial and financial (flexibility) space for exchange on an equal footing, spaces that can be easily accessible, open to any topic or topic-related, spaces for involvement before, during and after research projects as a constitutive part of the "actual" research process.

Trust is a commodity that is becoming increasingly valuable in marine environmental policy in view of the current increasing socio-cultural disparities and political polarization. Building it takes time, i.e. repeated meetings and exchange opportunities, clear responsibilities and respect, in addition to people who can carry out professional work across the boundaries of science and society on a long-term basis. German marine research therefore needs a systematic overview of complementary competencies and reliable networks, particularly in northern Germany, but also internationally, which can be drawn upon for many years to come. We see a first pragmatic step in collecting relevant and possibly not yet identified partners in (northern) German marine research (stakeholder mapping), as well as in collecting existing transdisciplinary initiatives and experiences (e.g. stakeholder working groups). This would contribute to:

- identify established local practitioners and communities of practice and to embed them in topic-specific networks and to secure them in the long term;
- gain an overview of different formats of transdisciplinary research in order to transfer successful models where appropriate or to define desiderata, for example to overcome marine conflicting objectives;
- enable comparisons with successful transdisciplinary practices abroad (e.g. with the "dike communities" in the Netherlands, or the pro-active marine conservation management practices in Denmark);
- to create a basis for identifying thematic intersections and related research areas in order to encourage positive spin-offs in interdisciplinary collaboration.

The complementary or collaborative research approach that we outlined above for interdisciplinary cooperation (2-5) forms the prerequisite for transdisciplinary marine research. This in turn expands and intensifies the interdisciplinary cooperation between the major discipline families and shows in many ways the added value to society of our knowledge production.

7. Our recommendations to science and science policy

The prerequisites for successful interdisciplinary research, which we have presented along the five development areas (scientific cultures, training, research institutions, project organization and social involvement / transdisciplinarity), cannot be viewed independently of one another. It became

clear that they are partly mutually interdependent and/or build on one another. Below we summarize them and formulate recommendations for scientists and decision-makers within German marine research.

Interdisciplinary research requires reflection on scientific cultures. The different research subjects and scientific traditions of the discipline families establish powerful logics of their own, from which criteria for research organization, evaluations, training and careers within the respective scientific field emerge. Reflecting on these different knowledge cultures in the context of a common practice is the first prerequisite for successful interdisciplinary collaboration.

Interdisciplinary collaboration arises from problem focus. The solution-oriented view of a jointly defined problem acts as an integrative bracket that counteracts the tendency towards monodisciplinary focus. This enables collaborative specialization along problem areas. Approaches to solutions are then based on both natural and social science knowledge and link various forms of knowledge in relation to the issue in question.

The development of interdisciplinary excellence requires structure and experimentation. Interdisciplinary expertise is created through interdisciplinary structures and vice versa. Individual support, exchange spaces and structural adjustments are equally necessary to build up the interdisciplinary research field. A willingness to experiment in the design of the measures is also necessary as there are no blueprints. Depending on the problem, a variety of possible interdisciplinary constellations are possible.

Existing reward systems must be adapted. Visibility, evaluation and consolidation of individual research, as well as the assessment of research associations and institutes, are mainly carried out according to monodisciplinary criteria and thus often hinder interdisciplinary research. Interdisciplinary evaluation criteria must be established, as well as evaluation committees with multidisciplinary composition and interdisciplinary expertise of the individual members.

Scientific education requires an interdisciplinary development path. This is also an important basis for transdisciplinary and non-academic careers, e.g. in NGOs, public authorities and business. Possible measures include the establishment of subject-related divisions or departments (instead of person-based chair structures), interdisciplinary course offerings, degree programs and graduate programs, the promotion of key competencies necessary for interdisciplinarity and early interdisciplinary practical relevance.

Expanding interdisciplinary competence in the institutions. Many German marine research institutions have employees who are interested in interdisciplinary research. Building on this, in-house programs, strategic partnerships with social science institutes, and even the establishment of social science research departments can promote interdisciplinary competence in the marine research institutions in a targeted manner.

Alignment of the funding objectives with process and action knowledge. In addition to descriptive knowledge, the development of process and action knowledge results in problem-focused and solution-oriented collaboration between disciplines. Social processes in the marine sector must be reflected and accompanied by long-term studies in order to avoid impending social polarization and to strengthen socio-marine cohesion.

Adapt project organization to interdisciplinary needs. Collaborative research formats should

begin with a discovery phase to jointly define the problem. Resources must be available for this. Possible targeted measures include two-stage project financing, opportunities for networking at interdisciplinary workshops/conferences, and interdisciplinary content-based project management.

Transdisciplinary cooperation promotes interdisciplinary knowledge. And vice versa. Transdisciplinarity makes one's own scientific expertise compatible with societal needs. At the same time, transdisciplinary work benefits from an interdisciplinary knowledge base and a systematic understanding of the complementarity of diverse expertise. It would be helpful to record, categorize and systematize previous transdisciplinary subject areas and participation formats in German marine research. In this way, interdisciplinarity becomes a condition for success, rather than a requirement, in order to recognize the societal prerequisites for the desired transformation needs and to provide targeted support.

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Glossary

AWI	Alfred Wegener Institute for Polar and Marine Sciences
BMZ	Federal Ministry for Economic Cooperation and Development
CAU	Christian-Albrechts University of Kiel
CCS	Carbon Capture and Storage
CeOs	Center for Ocean and Society, CAU
CoARA	Coalition for Advancing Research Assessment
COAST	Center for Environmental and Sustainability Research at the University of Oldenburg
DAM	German Alliance for Marine Research
DRIFT	Research Institute for Transformative Processes Rotterdam
GIZ	German Society for International Cooperation
HIFMB	Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg
IMBeR	Integrated Marine Biosphere Research
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRI THESys	Integrative Research Institute on Transformations of Human-Environment Systems Berlin
KMS	Kiel Marine Science, CAU
LAS	Liberal Arts and Sciences
NWO	Research Council of the Netherlands
RIFS	Research Institute for Sustainability Helmholtz-Zentrum Potsdam
ZMT	Leibniz Centre for Tropical Marine Research Bremen

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