

**Time to turn the tide:
A praxeological exploration of marine sciences**

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Summary

Marine carbon observations (MCOs) are crucial for understanding the ocean's role in the global carbon cycle. The ocean is one of the largest natural sinks for anthropogenic carbon dioxide (CO₂), buffering climate change, while facing profound biogeochemical transformations. MCOs are not only a matter of science but also of global climate governance, as they feed into key scientific and policy processes, such as the Global Carbon Budget or the Intergovernmental Panel on Climate Change (IPCC) assessments.

Despite their importance, the socio-material dimensions of MCOs remain vastly underexplored. While natural sciences focus on biogeochemical and modelling challenges, less attention has been paid to how MCOs are produced, and which internal and external factors influence these knowledge production processes, which is the main research question of the dissertation. To address this gap, the dissertation uses an inductive, praxeological, and multi-sited ethnographic approach, inspired by approaches of the Sociology of Knowledge (SoK), Science and Technology Studies (STS), New Materialism, and marine social sciences to examine not just data, but the social, material, epistemic, and affective practices in marine knowledge production.

Through rich and in-depth empirical observations of knowledge production processes in marine sciences in diverse research localities ranging from laboratories to merchant and research vessels, to virtual meetings, to marine science institutes in Brazil and Germany from 2021 to 2024, four linked empirical studies were conducted: an ethnographic study of following a deep-sea channel aboard a research vessel, an analysis of transnational intersectionality in research and work at sea, an investigation of socio-material (de-)stabilising processes in knowledge production processes in MCOs, and an autoethnographic account from a seven-week marine expedition.

The key findings show repeating patterns across the empirical studies: First, MCOs are not simply measured, they are enacted and co-produced by human and more-than-human forces, such as sensors or seawater. Interpersonal connections, human and more-than-human communication, and data availability stabilise MCOs, whereas funding shortages, national borders, and climate change impacts destabilise these observations. Second, scientists', technicians', and crewmembers' sensory landscape and experiential knowledge are factors that influence science-making. Prior experiences,

senses, intuition, and emotions are used in everyday routines and generate scientific insights. Third, knowledge production processes in marine sciences are influenced by transnational intersectional hierarchies, positionalities, and micropolitics. Especially the intersection of gender, age, class, ethnicity, and physical appearance mediates access, credibility, and safety at sea.

The dissertation concludes by highlighting the relational and socio-material account of MCOs by showing how they are enacted, stabilised and rendered policy-relevant through human and more-than-human forces rather than linear technical processes. Empirically, the dissertation provides fine-grained insights into sensory and embodied practices, intersectional dynamics at sea, more-than-human entanglements, and the researcher's own positionality. Conceptually, it advances debates in the SoK, STS, feminist and postcolonial theory by foregrounding embodiment, affect, inequality, and more-than-human forces, and by developing the Intra-active Observation Assemblages (IOA) framework as a mid-range concept that links situated practices with broader theoretical debates. Methodologically, it expands multi-sited ethnography through mobile, transnational, and more-than-human field sites, and by integrating autoethnographic approaches. Socio-politically, the findings highlight how borders, funding, and institutional hierarchies shape access and cooperation, and provide recommendations for more transparent, diverse, and inclusive science-making at sea.

Zusammenfassung

Marine Kohlenstoffbeobachtungen sind zentral für das Verständnis der Rolle des Ozeans im globalen Kohlenstoffkreislauf. Der Ozean zählt zu den größten natürlichen Senken für anthropogenes Kohlenstoffdioxid und wirkt als Puffer gegen den Klimawandel, während er zugleich tiefgreifende biogeochemische Veränderungen durchläuft. Marine Kohlenstoffbeobachtungen sind daher nicht nur ein wissenschaftliches Thema, sondern auch ein wesentlicher Bestandteil globaler Klimapolitik, da sie in zentrale wissenschaftliche und politische Prozesse wie dem *Global Carbon Budget* oder in die Berichte des *Intergovernmental Panel on Climate Change* (IPCC) einfließen.

Trotz dieser Bedeutung sind die sozio-materiellen Dimensionen von marinen Kohlenstoffbeobachtungen bislang kaum erforscht. Während sich die Naturwissenschaften auf biogeochemische und modellierungsbezogene Herausforderungen konzentrieren, ist wenig darüber bekannt, wie marine Kohlenstoffbeobachtungen tatsächlich produziert werden und welche internen und externen Faktoren diese Wissensprozesse beeinflussen – was auch die Forschungsfrage der Dissertation darstellt. Um diese Lücke zu adressieren, nutzt die Dissertation einen induktiven, praxeologischen und *multi-sited* ethnografischen Ansatz, inspiriert von der Wissenssoziologie, den Science and Technology Studies (STS), des Neuen Materialismus sowie marinen Sozialwissenschaften. Untersucht werden nicht nur Daten, sondern die sozialen, materiellen, epistemischen und affektiven Praktiken mariner Wissensproduktion.

Auf Grundlage umfassender empirischer Beobachtungen mariner Wissensprozesse in verschiedenen Forschungskontexten – von Laboren über Handels- und Forschungsschiffen bis hin zu virtuellen Meetings und meereswissenschaftlichen Instituten in Brasilien und Deutschland zwischen 2021 und 2024 – wurden vier miteinander verknüpfte empirische Studien durchgeführt: eine Ethnographie der Kartierung eines Tiefseegrabens an Bord eines Forschungsschiffs, eine Analyse transnationaler Intersektionalität in marinen Forschungs- und Arbeitskontexten, eine Untersuchung sozio-materieller (De-)Stabilisierungsprozesse in der Wissensproduktionen von marinen Kohlenstoffbeobachtungen sowie eine autoethnografische Analyse über eine siebenwöchige Expedition.

Die zentralen Ergebnisse zeigen wiederkehrende Muster über alle Studien hinweg: Erstens werden marine Kohlenstoffbeobachtungen nicht einfach gemessen, sondern in *more-than-human* Verflechtungen hervorgebracht und ko-produziert - etwa durch Sensoren, Meerwasser und situierte Entscheidungen. Persönliche Beziehungen, Kommunikation zwischen Menschen und *more-than-humans* und Datenverfügbarkeiten stabilisieren MCOs, während Finanzierungslücken, nationale Grenzen und Klimawandelfolgen sie destabilisieren. Zweitens prägen sensorisches Wissen sowie Erfahrungswissen von Wissenschaftler:innen, Technike:rinnen und Crewmitgliedern die Wissensproduktion. Erfahrungen, Sinne, Intuitionen und Emotionen fließen in alltägliche Routinen ein und generieren wissenschaftliche Erkenntnisse. Drittens zeigen sich transnationale intersektionale Hierarchien, Positionalitäten und Mikropolitiken als zentrale Einflussfaktoren. Insbesondere die Verschränkung von Geschlecht, Alter, sozialer Herkunft, Ethnizität und äußerem Erscheinungsbild bestimmt Zugang, Glaubwürdigkeit und Sicherheit in verschiedenen Orten der marinen Wissensproduktion.

Die Dissertation schließt mit einem relationalen und sozio-materiellen Verständnis von marinen Kohlenstoffbeobachtungen ab, das zeigt, wie diese Beobachtungen durch menschliche und *more-than-human* Kräfte hervorgebracht, stabilisiert und politisch wirksam werden – statt durch linear-technische Abläufe. Empirisch liefert sie detaillierte Einblicke in verkörperte und sensorische Praktiken, intersektionale Dynamiken an Bord, *more-than-human* Verflechtungen sowie die eigene Positionalität der Forschenden. Konzeptionell erweitert sie Debatten in der Wissenssoziologie, STS, feministischer und postkolonialer Theorie, indem sie Verkörperung, Affekt, Ungleichheit und *more-than-human* Kräfte in den Mittelpunkt rückt und mit den *Intra-active Observation Assemblages* (IOA) ein Konzept mittlerer Reichweite entwickelt, das situierte Praktiken mit breiteren theoretischen Diskussionen verbindet. Methodologisch erweitert die Arbeit *multi-sited* Ethnografie um mobile, transnationale und *more-than-human* Forschungsorte und integriert autoethnografische Zugänge. Sozialpolitisch verdeutlichen die Ergebnisse, wie Grenzen, Finanzierung und institutionelle Hierarchien Zugang und Kooperation beeinflussen, und bieten Empfehlungen für transparentere, diversere und inklusivere Wissensproduktion auf See.

Resumo

Observações do carbono marinho (Marine Carbon Observations – MCOs) são fundamentais para compreender o papel do oceano no ciclo global do carbono. O oceano é um dos maiores sumidouros naturais de dióxido de carbono (CO₂) de origem antropogênica e atua como um amortecedor das mudanças climáticas, ao mesmo tempo em que passa por transformações biogeoquímicas profundas. Assim, as MCOs não são apenas uma questão científica, mas também um elemento central da governança climática global, pois abastecem processos científicos e políticos chave, como o *Global Carbon Budget* e os relatórios do Painel Intergovernamental sobre Mudanças Climáticas (IPCC).

Apesar dessa importância, as dimensões socio-materiais das MCOs permanecem amplamente pouco exploradas. Enquanto as ciências naturais se concentram em desafios biogeoquímicos e de modelagem, há pouca atenção dedicada a como as MCOs são produzidas e quais fatores internos e externos moldam esses processos de produção de conhecimento – a questão central desta dissertação. Para preencher essa lacuna, a pesquisa adota uma abordagem indutiva, praxeológica e etnográfica multi-situada, inspirada pela Sociologia do Conhecimento (SoK), pelos Estudos de Ciência e Tecnologia (STS), pelo Novo Materialismo e pelas ciências sociais marinhas, para examinar não apenas dados, mas também as práticas sociais, materiais, epistêmicas e afetivas da produção de conhecimento marinho. Com base em ricas e extensivas observações empíricas realizadas entre 2021 e 2024 em diferentes contextos de pesquisa e produção de conhecimento – i.e. laboratórios, navios mercantes e de pesquisa, reuniões virtuais e instituições científicas no Brasil e na Alemanha –, foram desenvolvidos quatro estudos empíricos interligados: uma etnografia acompanhando o mapeamento de um canal profundo durante uma expedição marítima a bordo de um navio científico, uma análise da interseccionalidade transnacional no trabalho e na pesquisa no mar, uma investigação dos processos socio-materiais de estabilização e desestabilização na produção de conhecimento sobre MCOs e um relato autoetnográfico de uma expedição de sete semanas.

Os principais resultados revelam padrões recorrentes entre os estudos: primeiro, as MCOs não são simplesmente medidas, mas sim produzidas e co-produzidas por forças

humanas e mais-que-humanas, como sensores e a água do mar. Conexões interpessoais, formas de comunicação entre humanos e não humanos e a disponibilidade de dados contribuem para estabilizar as MCOs, enquanto a falta de financiamento, fronteiras nacionais e impactos das mudanças climáticas podem desestabilizá-las. Segundo, as paisagens sensoriais e o conhecimento experiencial de cientistas, técnicos e tripulações influenciam fortemente a produção científica. Experiências prévias, sentidos, intuições e emoções são mobilizados nas rotinas diárias e geram *insights* científicos. Terceiro, hierarquias interseccionais transnacionais, posicionalidades e micropolíticas moldam o acesso, a credibilidade e a segurança no trabalho de campo marinho. Em especial, interações entre gênero, idade, classe, etnia e aparência física influenciam profundamente quem participa, quem é ouvido e cujos saberes são reconhecidos.

Como conclusão, a dissertação ressalta a compreensão relacional e socio-material das MCOs, mostrando como essas observações são produzidas, estabilizadas e tornadas politicamente relevantes por meio de interações humanas e mais-que-humanas, e não por procedimentos técnicos lineares. Empiricamente, o trabalho oferece uma visão detalhada de práticas corporificadas e sensoriais, dinâmicas interseccionais no mar, interações mais-que-humanas e da própria posicionalidade da pesquisadora. Conceitualmente, contribui para debates na SoK, nos STS e nas teorias feministas e pós-coloniais ao destacar corporalidade, afeto, desigualdade e forças mais-que-humanas, além de propor o conceito de *Intra-active Observation Assemblages* (IOA) como um conceito de médio alcance que conecta práticas situadas a discussões teóricas mais amplas. Metodologicamente, amplia a etnografia multi-situada ao incluir contextos móveis, transnacionais e mais-que-humanos e ao integrar abordagens autoetnográficas. No âmbito sociopolítico, os resultados mostram como fronteiras, financiamento e hierarquias institucionais moldam acesso e cooperação e oferecem recomendações para práticas científicas mais transparentes, diversas e inclusivas no mar.

Declaration of authorship

I hereby declare that I have written this cumulative dissertation independently and that I have not used any sources other than those indicated. All passages that are taken verbatim or in substance from published or unpublished texts are identified as such.

The included articles were written by me as the main author. In the case of the co-authored publication (chapter 5), I have made a substantial contribution to the conception, data collection, analysis, and interpretation, as well as to the writing of the manuscript. These contributions are described in detail in annex 6 of this dissertation.

This dissertation, in its entirety or in parts, has not been submitted to any other university for the purpose of obtaining a doctoral degree.

Eidesstattliche Erklärung

Hiermit versichere ich, dass ich die vorliegende kumulative Dissertation selbstständig angefertigt habe und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten oder unveröffentlichten Schriften entnommen sind, habe ich als solche kenntlich gemacht.

Die in dieser Dissertation enthaltenen Kapitel wurden von mir als Hauptautorin verfasst. Bei der gemeinschaftlich verfassten Publikation (Kapitel 5) habe ich einen wesentlichen Beitrag zur Konzeption, Datenerhebung, Analyse und Interpretation sowie zur Abfassung des Manuskriptes geleistet. Diese Beiträge sind in Annex 6 der Dissertation erläutert.

Die Arbeit wurde weder in gleicher noch in ähnlicher Form einer anderen Hochschule zur Erlangung eines Doktorgrades vorgelegt.

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Ramona Haegele

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List of abbreviations¹

ANT	Actor-Network-Theory
BGC-Argo	Biogeochemical-Argo program
BIPOC	Black, Indigenous and People of Colour
BSH	Federal Maritime and Hydrographic Agency of Germany, German: Bundesamt für Seeschifffahrt und Hydrographie
C-SCOPE	Towards Marine Carbon Observations 2.0: Socializing, COnnecting, Perfecting and Expanding (a BMBF funded research project)
CO ₂	Carbon dioxide
CRM	Certified reference material
EEZ	Exclusive Economic Zones
EU-Argo	European contribution to the international Argo programme
FGV	Getulio Vargas Foundation, Portuguese: Fundação Getulio Vargas
GEOMAR	Helmholtz Centre for Ocean Research Kiel
ICOS	Integrated Carbon Observation System
IOA	Intra-Active Observation Assemblages
IOC	Intergovernmental Oceanographic Commission
IOW	The Leibniz Institute for Baltic Sea Research Warnemünde
IPCC	Intergovernmental Panel on Climate Change
MCOs	Marine carbon observations
MSM	Maria S. Merian (German research vessel)
NAMOC	Northwest Atlantic Mid-Ocean Channel
SOCAT	Surface Ocean CO ₂ Atlas
SOCONET	Surface Ocean CO ₂ NETwork
SoK	Sociology of Knowledge
SOOP	Ship of opportunity
STS	Science and Technology Studies
UERJ	Rio de Janeiro State University, Portuguese: Universidade do Estado do Rio de Janeiro
UNESCO	United Nations Educational, Scientific and Cultural Organisation

¹ Each abbreviation is written out in full at the beginning of every section to ensure reader-friendliness. After that, the abbreviation is used.

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Back to matter

Back to matter

Covered by the ocean
surrounded by seawater
we become less human,
as if we go back to become matter.
where we came from
what we are made of.
waves on my thighs
grief comes in waves
we are breathing in waves
shell rings and tree rings
counting our age
going back to matter
when the last ring is counted.

Ramona Hägele²

² Writing eco poetry or blue poems – how I call them – became part of my PhD journey. Every time I immersed myself in the ocean, academically or bodily, I took a step back to acknowledge how deeply we relate to the ocean and how we intra-act with aquatic life every day. We are made of water. It keeps us alive. But what are we as humans doing to keep the ocean alive?

Chapter 1

Following marine carbon observations: An introduction



Picture 1: View from the bridge of the German research vessel Maria S. Merian (MSM) in the North Atlantic in 2021. Source: Author.

1. Following marine carbon observations: An introduction

The ocean is not only a resource or a backdrop, but also a vital part of the planet, covering more than 70 percent of the earth's surface (Visbeck 2018). All humans and more-than-humans, such as animals, plants, microorganisms, and technologies depend directly or indirectly on the ocean. It provides important services to people such as food and water supply, trade routes, renewable energy, cultural and spiritual values, climatic regulation, and livelihoods.

Yet, in public and scientific discourses, the term 'the ocean' is rarely used, though there is one world ocean that connects every region on this planet with each other. 'The ocean' is rather used in plural demonstrating human dominance and state-centric thinking, grouping the ocean into geographical constructs ranging from the Arctic to the Southern Ocean, adding to the human disconnection from the ocean despite its inherent connectedness to us. Beneath the surface we are all connected by water and the ocean.

The ocean faces radical changes due to anthropogenic ocean acidification leading to an unstable climate. Although the expected profound impacts on humanity and ecosystems are the scientific consensus, marine realms have attracted little attention in politics and climate change negotiations. The ocean as a carbon sink constitutes one of the last planetary boundaries that regulates the stability of the earth (Richardson et al. 2023). Therefore, data on marine carbon dioxide (CO₂) are required to provide for knowledge-based governance of the ocean and its protection. However, there exist material and immaterial path dependencies in knowledge production in marine sciences, further consolidating the powerful influence of countries of the Minority World³ (Hornidge, Partelow, and Knopf 2023; Partelow et al. 2020). Moreover, little is known on knowledge production processes in marine carbon observations (MCOs) and how humans and more-than-humans approach marine CO₂ as they cannot see, touch, feel, hear, taste, or smell it. MCOs provide important information on how CO₂ is stored, exchanged, and

³ Today's global configurations are highly fragmented, and so are the terms used to describe them. I use 'Global South' and 'Global North' to indicate historically produced geopolitical asymmetries shaped by colonialism (Dados and Connell 2012; Mignolo 2011). When referring to the distribution of lived experiences and demographic proportions, I draw on the framing of 'Majority World' and 'Minority World' (Alam 2008; Wagner and Hornidge 2025). I acknowledge that these terms remain contested and analytically imperfect, but I employ them here as heuristic categories rather than homogenous entities. Whenever the data allows, I refer to the specific countries.

transformed in the ocean, which is crucial to understand the ocean's role in regulating the global carbon cycle and mitigating climate change. Despite this socio-environmental importance, a sociological understanding of how MCOs are produced, legitimatised, and integrated into global climate governance remains limited. Thus, this dissertation researches interdisciplinary and transcultural knowledge production processes in MCOs, as well as underlying social realities, diverse ways of knowing, and intersectional power asymmetries.

The dissertation uses an inductive research design to allow the conceptual framework to emerge from the data and starts with an explorative research question rather than a theory: How are MCOs produced, and which internal and external factors influence these knowledge production processes?

This praxeological approach aims at understanding the socio-material construction of scientific facts in different physical social and cultural working environments. The dissertation is rooted in approaches of Sociology of Knowledge (SoK) (Berger and Luckmann 1966; Hornidge 2007, 2011, 2012), Science and Technology Studies (STS) (Knorr-Cetina 1988; Latour 1987), New Materialism (Barad 2007; Braidotti 2013), and marine social sciences (Bogusz 2018; Hornidge 2018, 2020; Helmreich 2021). Methodologically, it uses an inductive explorative approach and qualitative ethnographic methods, such as field notes, participant observation, thick description, and semi-structured and informal interviews (Marcus 1995; Geertz 1973). The dissertation's findings show that knowledge on MCOs is not simply produced by scientists and instruments, but it emerges through intra-action of entangled practices involving humans, more-than-humans like autonomous diving robots, software, or weather conditions, sensory, experiential, and embodied types of knowledge, intersectional identities, positionalities, and micropolitics. The term intra-action thereby emphasises that entities do not pre-exist their relations but emerge through them (Barad 2007). Through case studies within knowledge production processes in MCOs, I have gathered rich empirical data in diverse research localities and show that embodied, sensory, and intersectional types of knowledge, but also boundary infrastructures and geopolitics influence science-making in MCOs. Moreover, the findings are synthesised into the Intra-Active Observation Assemblages (IOA) framework as a mobile and context sensitive mid-range concept,

which bridges approaches of SoK, STS, New Materialism, and marine social sciences as a conceptual contribution of the dissertation. Methodologically, the dissertation extends and advances multi-sited ethnography with the mobility turn (Mielke and Hornidge 2017; Marcus 1995) to take different sites of meaning-making, such as virtual and in-person research localities, into account. Socio-politically, the dissertation contributes to a better understanding of MCOs through transparent, accessible, and open data, and provides recommendations for more just climate knowledge infrastructure as well as inclusive and diverse working environments at sea.

The following sections will explain the embeddedness of the dissertation into a research project, briefly introduce the research design, to then provide a more detailed outline of the dissertation.

1.1 Situating the dissertation: The research project

The Intergovernmental Panel on Climate Change (IPCC) Special Report (2019) on the *Ocean and Cryosphere in a Changing Climate* evidenced that at an increasing rate human activities are continuously changing the earth's climate and the ocean's capability to absorb and redistribute natural and anthropogenic carbon dioxide (CO₂). Marine heatwaves are increasing in frequency and intensity while rising CO₂ absorptions lead to surface acidification. Sea level rise caused by ice loss and cryospheric changes impact and threaten terrestrial species and ecosystems (IPCC 2019).

Despite strong scientific evidence for these profound impacts and while climate models heavily depend on marine measurements and data, the ocean remains peripheral in policy discussions (Riebesell, Körtzinger, and Oschlies 2009; Gruber 2011; Richardson et al. 2023). Therefore, knowledge-based governance of the ocean system and its protection are urgently required. However, the necessary knowledge is difficult to generate since the ocean's spatial and temporal scales of variability are a challenge to observe. This especially applies to marine carbon observations (MCOs), which need innovative and interconnected networks of autonomous observing platforms to overcome the above-mentioned challenges. Despite the importance of MCOs for global climate governance, they are still rarely studied in marine sciences (Steinhoff et al. 2019; Aricò et al. 2021).

This research gap can partly be explained by MCOs materiality, as problems are merging while measuring marine carbon in-situ. The diverse layers of the ocean ranging from the surface to the deep sea, currents, or weather conditions can influence MCOs (Roemmich, Boebel, and Desaubies 2001; Haegele 2025; Talling et al. 2015).

To address this unsolved problem of under-sampling, an interdisciplinary research project – in which the dissertation is embedded – aims to improve data quality, fill observation gaps, and improve knowledge production on marine CO₂ across multiple observation networks and stakeholders, focusing on three key regions: the North Atlantic thermohaline circulation system, the Baltic Sea and the Amazon rainforest system in South America. Starting in 2021, the research team ‘Towards Marine Carbon Observations 2.0: Socializing, COnnecting, Perfecting and Expanding’ (C-SCOPE) worked and continues to work on these tasks from oceanographic, mainly biogeochemical, and sociological perspectives. The embeddedness of this dissertation within the C-SCOPE project also explains the case selection of Brazil and Germany, among other rationales (see section 3.1).

Besides the above-mentioned problem of under-sampling, there exists a research gap of studying knowledge production in marine sciences – the practices and processes of knowledge production themselves – and especially in MCOs, which usually remain unseen. Mahoney (2000) and Partelow et al. (2020) found existing material and immaterial path dependencies in knowledge production in (marine) sciences. Through the predominant influence as well as financial, technological and linguistic supremacy of North America, Australia and Europe in marine sciences, structural inequalities and path-dependencies in knowledge production exist (ibid.; Hornidge, Partelow, and Knopf 2023). Yet, processes of knowledge production within marine sciences as well as the underlying varying social realities and potential power asymmetries influencing the latter remain unexplored. Moreover, the rare empirical research on ocean observations remains thus far grounded in geography (Lehman 2016, 2018), economics (Boettcher, Schenuit, and Geden 2023; Sovacool, Baum, and Low 2023) and political sciences (Vadrot and Wanneau 2024) and do not include holistic analyses of human and more-than-human forces in science-making in diverse research localities. Thus, the dissertation aims to

address this gap with a sociological understanding of knowledge production processes in MCOs.

1.2 Inductive explorations: Research design

The research follows an explorative, inductive, and praxeological design (Charmaz 2014; Glaser and Strauss 1998; Reckwitz 2002; Stebbins 2001). While discussions in Science and Technology Studies (STS), the Sociology of Knowledge (SoK), and the marine social sciences inspired me, the empirical focus on practices of marine carbon observations (MCOs) has guided me throughout the research process. The conceptual framework developed in dialogue with these observations through empirical depth. This allowed me to refine and alter conceptual perspectives as fieldwork progressed and culminated in the mid-range concept developed in section 8.2 (Houben 2017; Hornidge 2017; Keller 2011; Merton 1949; Schwachula 2019).

I conducted multi-sited ethnography (Marcus 1995) throughout three years (February 2021 – February 2024). During fieldwork, I extended multi-sited ethnography informed by the mobility turn (Mielke and Hornidge 2017; Urry 2016), thereby following diverse research localities in which MCOs are enacted, e.g. virtual discussions while being on a research vessel at sea. Such an ethnographic approach allows researching knowledge production processes in geographically fixed localities, but also virtual sites of science-making. Through episodic patchwork ethnography (Günel and Watanabe 2024; Tsing 2015; Tsing, Mathews, and Bubandt 2019) I was able to conduct fieldwork across sites, such as on research and merchant vessels, in laboratories, in online meetings, and in marine science institutes, over repeated in-person and virtual field stays in Brazil and Germany.

Given the inductive and explorative approach within a praxeological framing, the following main research question and sub-research questions (see figure 1) emerged: How are MCOs produced, and which internal and external factors influence these interdisciplinary and transcultural knowledge production processes?

The research questions emerged around ‘the how’ of producing, negotiating, analysing, and transferring knowledge on MCOs. In line with Keller (2011, 61), the aim of the study is

not to find the “ultimate truth”, but rather to understand the underlying factors influencing knowledge production processes, while simultaneously aiming to develop a mobile and context sensitive mid-range concept (Houben 2017; Hornidge 2017).

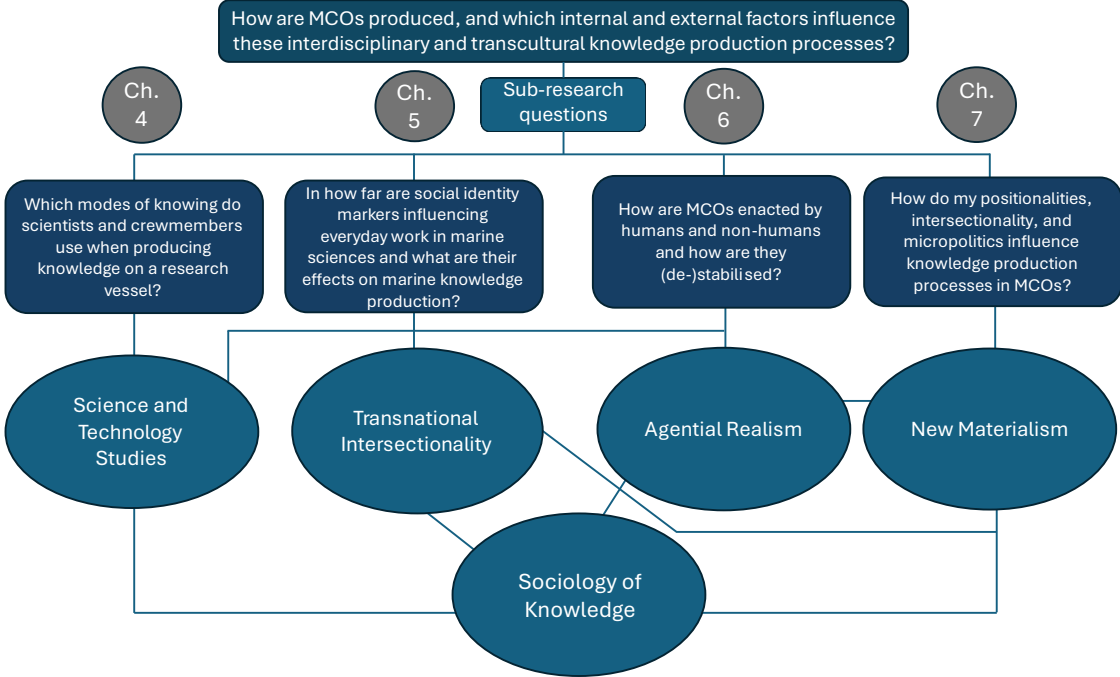


Figure 1: Main and sub-research questions and their analytical lenses. The chapter number indicates in which chapter of the dissertation the sub-research questions will be answered. Chapter 4 uses approaches of STS, SoK, and New Materialism. Chapter 5 employs transnational intersectionality and SoK. Chapter 6 applies agential realism, New Materialism, STS, and SoK approaches. Chapter 7 uses a transnational intersectional, new materialistic, and SoK lens. Source: Own elaboration.

The selected research design and subsequent research questions require qualitative data collection as only observations on everyday practices, routines, and negotiation processes across diverse research localities will contribute to the research aim. Methods include participant observation, semi-structured interviews, go-alongs, autoethnography, thick description, visual anthropology, and field notes. While chapter 3 provides a more detailed explanation of the methods, its application, and the analysis of the data collected, as well as its limitations, the following section sketches the outline of the dissertation.

1.3 Charting the course: Outline and analytical structure

The cumulative dissertation is organised into eight chapters, starting with the conceptual foundations, toward the methodological framework and empirical analyses to the conclusion including the contributions.

While chapter 1 introduces the field of marine carbon observations (MCOs), outlines the research project, and situates the dissertation within its institutional and scientific context, chapter 2 presents the conceptual foundations of the research. The approaches of the Sociology of Knowledge (SoK), Science and Technology Studies (STS), and marine social sciences guided my thinking throughout the data collection and analysis. The chapter provides a holistic overview of existing concepts and case studies, but it also points to their limitations and addresses the research gap of including socio-material practices and the more-than-human forces in marine science-making.

Chapter 3 details the methodological framework including the research design, multi-sited ethnography, and the methods used, such as participant observations, field notes, thick description, autoethnography, interviews, go-alongs, visual anthropology, and literature reviews. It moreover describes how I adapted the research methods to the COVID-19 pandemic, provides an overview of the in-depth empirical observations and analytical tools, and discusses my positionalities, ethical considerations, and limitations of the research.

Building on the conceptual foundations and the rich empirical data, chapters 4 to 7 provide the main empirical analyses. Starting with an ethnography on a seven-week expedition on a German research vessel, chapter 4 finds sensory and experiential types of knowledge used by scientists and crewmembers as two modes of following, researching, and knowing a deep-sea channel in the Labrador Sea. Chapter 5 relies on participant observations, field notes, and 82 interviews with scientists, technicians, and crewmembers working at sea. The analysis identifies that social identity markers including gender, age, ethnicity, and physical appearance influence knowledge production processes in marine sciences. Sexual harassment and discrimination occur independent of research localities and lead either to emancipation processes or to withdrawal. Moreover, tensions between scientists and non-scientists arise, which broadens the gap between these knowledge systems and delays urgently needed marine

research for climate change policies. Chapter 6 examines the complexities of knowledge production in MCOs by exploring how humans, such as scientists and technicians, and the more-than-human, including floats, software, and GPS, mutually co-produce knowledge. By using the concept of agential realism (Barad 2007), the analysis identifies diverse forces that stabilise and de-stabilise MCOs ranging from two-way communication between scientists and an autonomous diving buoy to geopolitical practices. To account for my intersectional positionalities and micropolitics in the field, chapter 7 brings together concepts of positionality, intersectionality, and micropolitics. Through reflections on my shifting emotions, my access to the field, and entanglements with scientists and the more-than-human throughout my fieldwork on a research vessel, the findings shed light on the usually unseen in science-making, including a researcher’s emotions.

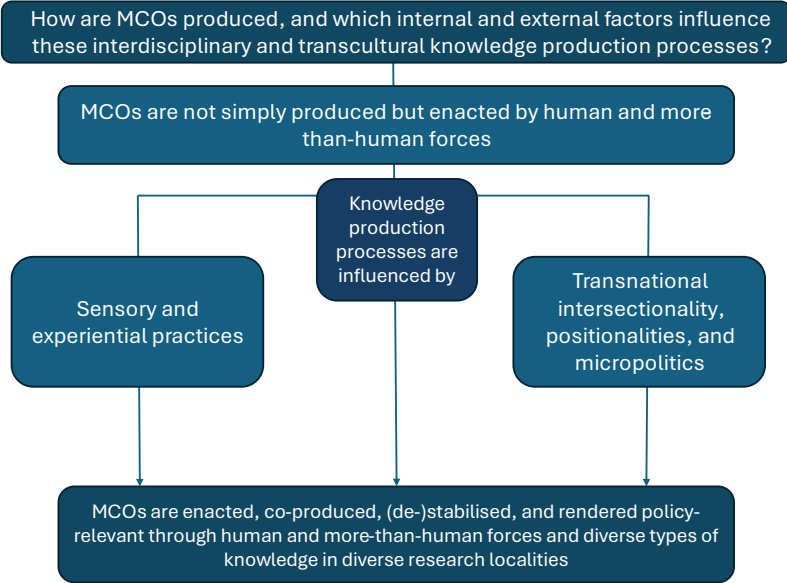


Figure 2: Main research question and the key findings. Source: Own elaboration.

The dissertation concludes by synthesising the findings from the empirical chapters (see figure 2). Several patterns identified in one chapter appeared across the others. The recurrence of these findings across the four chapters indicates cross-cutting patterns within the marine sciences, such as sensory landscapes and intersectional inequalities. In continuation, chapter 8 also highlights the empirical, conceptual, methodological, and socio-political contributions of the dissertation. The chapter concludes with a reflection on the research process and outlines future research needs.

Chapter 2

Opening and cleaning a sediment core: Conceptual foundations



Picture 2: Two halves of an opened sediment core, which is being cleaned by a marine scientist during an expedition on a German research vessel in the Labrador Sea in 2021. The sediment core is a sample extracted from the seafloor and its texture, composition, and layering provide insights into climatic conditions. Source: Author.

2. Opening and cleaning a sediment core: Conceptual foundations

This chapter will provide an introduction to the three main conceptual approaches which largely inspired the research: 1) Sociology of Knowledge (SoK), 2) Science and Technology Studies (STS) and New Materialism, and 3) Marine Social Sciences. These conceptual foundations guided my thinking throughout the data collection and analysis. In seeking to weave together a broad and heterogeneous body of literature, I want to note that my synthesis is selective and situated, shaped by the empirical observations throughout my research.

A sediment core is a sample extracted from the seafloor, which preserves layers of deposited material over time. These layers reveal changes in composition, colour, texture and grain size (see picture 2) and point to shifts in climate, human influence, or biological activity. They can tell us about past environmental and climatic conditions, such as glacial cycles, pollution events, or volcanic activity, but also about the future, such as carbon storage and climate change. Just like opening and cleaning a sediment core, providing an overview of the sediment's surface, the following sections present the conceptual foundations of the dissertation and embeds it into past and current literature⁴. Although the concepts, interdisciplinary fields, and areas of study are presented in sections, they cannot be completely separated as they built on and fall back into each other.

2.1 Sociology of Knowledge

Sociology of Knowledge (SoK) as a subfield within sociology looks at how social structures, routines, and practices determine what counts as knowledge, how and by whom knowledge is legitimised, and how knowledge circulates. Thinking with Berger and Luckmann (1966) and Hornidge (2007, 2011, 2012), all knowledge production processes, no matter if scientific or non-scientific involve a social element, shaping how humans make sense of the world.

⁴ For a more detailed account of literature and conceptual framings, please see chapters 4 to 7. Each chapter has its own in-depth literature review and conceptual approach.

Social history represents an important indicator affecting knowledge production. Durkheim (2013 [1982]) understands time, space, and causality as result of (social) history and thereby integrates historical influences on knowledge production. Similarly, Berger and Luckmann's (1966) influential work on the social construction of reality concludes by emphasising the importance of history when asking sociological questions. Their account of reality as social construction looked at everyday practices of knowledge production and its institutionalisation and legitimation. Social constructivism understands knowledge as built upon sets of beliefs humans use to interpret certain phenomena (ibid.). It thereby considers the diversity of worldviews and realities constructed within social groups over time. Each individual uses frameworks constructed through processes of internalisation (absorption of knowledge by a recipient), habituation (creation of knowledge through routines) and transformations (new ideas) to interpret the world and other people. Hence, knowledge is externalised into the physical world, objectivised through shared constructs and legitimised through acceptance followed by reification, a process in which concepts are no longer challenged. Institutionalisation provides stability through routines, thereby establishing certain roles that are socially accepted. Roles are linked to schemes that define interactions and the co-creation of knowledge, which develops through verbal and non-verbal communication. Thereby, socio-cultural backgrounds, status, uncertainties and individual biases influence knowledge production and realities (ibid.). This also includes knowledge production in scientific settings, which is embedded in social environments, institutional structures, norms, and values and as such in a normative structure (Merton 1973).

Drawing on Berger and Luckmann (1966), Haraway (1988), and Hornidge (2012), I define knowledge as socio-materially influenced and situated understandings that guide the practice of science- and meaning-making. I observed the socio-material and situated influence in working routines of humans, like scientists, and the more-than-human, such as software or sensors, as dynamic and varying depending on the research locality (see chapters 4 and 6; Haegele 2024, 2025). Moreover, I understand knowledge as a plural form of sense-making, referring to scientific knowledge, local knowledge, and tacit, experiential knowledge, bringing together diverse types of knowledge from scientists, technicians, and crewmembers. Framings and conceptualisations of knowledge are “constructed in and through discourse while at the same time [...] communicated as an

action guiding construct itself” (Hornidge 2012, 40). Studying the construction of knowledge is important in order to assess who decides which types of knowledge are produced, negotiated, shared, and considered important. Moreover, close linkages between knowledge governance and power or rather the legitimacy of existing power asymmetries should be questioned (ibid.). Knowledge and power are inseparable “and there is no point in dreaming of a time when knowledge will cease to be dependent on power [...]. It is not possible for power to be exercised without knowledge, it is impossible for knowledge not to engender power” (Foucault 1977, 15).

While I was working with the Sociology of Knowledge Approach to Discourse (SKAD) by Keller (2011) in the beginning of this dissertation, I soon realised that it cannot holistically grasp my observations in the field. Although SKAD offers a framework for analysing how knowledge and meaning are socially produced through discourse, it offers limited tools to include the material, affective, and more-than-human forces in science-making. Moreover, it predominantly focuses on terrestrial cases and is mainly used in the German-speaking context (Keller 2018; Schünemann 2018; Truschkat and Muche 2018), which also shapes its epistemological orientation, renders it largely Eurocentric in scope and limits its engagement with decolonial perspectives. The discourse focus turned out to be too narrow as my observations in the field needed a more praxeological lens for analysis, while also including legitimacy, inequalities, and power in meaning-making processes.

The field of SoK also studies these power dynamics within knowledge production (Bourdieu 2004; Foucault 1977). Authority and symbolic capital are driving scientific autonomy (Bourdieu 2004), while constructions of boundaries between science and other types of knowledge have been observed by Gieryn (1983), which contributes to a favourable public image of science compared to non-scientific or technical knowledge. Fricker (2007) and Dotson (2014) analysed such epistemic authority and oppression and its influential advantage to structure the social world. Bailey (2014) took up Fricker’s and Dotson’s thoughts on epistemic advantages, conceptualising epistemic oppression of socially dominant groups leading to social injustice. The SoK moreover looks at feminist, postcolonial, and reflexive epistemologies. Our view of the world is not free from the consequences and traces of colonialism (Said 1978; Spivak 1999; Ziai 2017). This also applies to science-making and proved to be an important lens during my fieldwork (see

chapter 5 – 7; Haegele and Hornidge 2025; Haegele 2025). The Eurocentric worldview of researching problems in the Global South world while providing solutions by the Global North still dominates current knowledge production processes (Ziai 2017). Watson-Verran and Turnbull (1995) analysed cross-cultural knowledge and technology systems and argue where knowledge systems overlap, there exist cultural contradictions. In a later study, Verran (2002) looked at science from a post-colonial perspective and explored how Aboriginal people and scientists carry collective memories that shape how they engage with knowledge. Moreover, feminist epistemologies argue that the researcher's own standpoint, situatedness, and partial perspectives can make power more visible (Harding 2009, 2013, 2008; Haraway 1988). Black feminist scholars extended these thoughts by including intersectionality as a dominant force in knowledge production (Crenshaw 1991, 1989; Collins 2022) – a force I also observed in marine science-making (see chapter 5; Haegele and Hornidge 2025).

This combination of postcolonial theory, feminist epistemologies, reflexivity, and knowledge production in the SoK research, both on the local and global level, is essential to reveal the influence of the Minority World on the global intellectual agenda and its construction of the “other” (Watson-Verran and Turnbull 1995). Other scholars studied path dependencies of knowledge production in tropical marine sciences (Partelow et al. 2020) or in historical sociology (Mahoney 2000). Their findings reveal asymmetries in the global science systems. Partelow et al. (2020) indicated path dependencies relating to technological infrastructure, e.g. laboratory equipment, access to funding, language, or access to national, transregional and international research networks. These path dependencies carry implications for the modalities of current research practices and create an imbalance in access to research policy processes such as agenda setting and the outcomes of (maritime) research. Thus, benefits of such research are unevenly distributed internationally. Similar to scholarship on epistemic authority, Knorr-Cetina Knorr-Cetina (1991) developed the concept of epistemic cultures, which questions the unity of science by showing how different scientific fields assemble knowledge differently. My empirical data strengthen these findings (see chapter 6; Haegele 2025), however, a theoretical understanding of how these inequalities and path dependencies materialise in a praxeological sense, remained lacking and thus I turned to research that included the more-than-human.

Callon (1984) for example offers a framework to understand how human and non-human actors build networks and influence despite controversial or conflicting opinions by using the case of a network of fishers, scientists, and scallops. This Actor-Network-Theory (ANT), mainly developed by Callon (1986), Latour (2007), and Law (1992), advances the SoK by empirically showing how socio-material processes influence knowledge production. By including humans and non-humans it adds to STS approaches as the following section will explain.

2.2 Science and Technology Studies and New Materialism

Science and Technology Studies (STS) as an interdisciplinary field deepened the field of the Sociology of Knowledge (SoK) by looking at knowledge production as a socio-technical practice rather than a mainly cognitive process. STS look at how science, technology and society shape and influence each other.

The field emerged in the 1970s in the United States, Europe, and Great Britain and focused on how technology influences scientific knowledge and vice versa in societies (Beck, Niewöhner, and Sörensen 2014). The previously mentioned Actor-Network-Theory (ANT) showed that technological instruments conflate knowledge in collaboration with researchers thereby constituting an important theory for STS research (Latour 1987). The influential studies of Latour and Woolgar (1986), Knorr-Cetina (1983) and Collins and Yearley (1992) demonstrated that practices, routines, and negotiations are part of science-making. STS is also guided by social constructivism, assuming that scientific knowledge is socially constructed.

Since the 1980s, the intersection of anthropology and STS increased. Looking through a STS lens, ethnography serves as a common research approach to assess research practices and practitioners and its socio-cultural and material leverages (Niewöhner, Sörensen, and Beck 2012). The writings and empirical cases of Niewöhner, Sörensen, and Beck (2012) influenced my thinking as it went beyond discourses and emphasised that rationality in science-making should be studied as empirical, materialised, and situated practices, not as something normative or abstract (see chapter 7). Knowledge is generated and negotiated in interactions within and between researchers and influenced

by diverse research settings such as laboratories or research vessels (Hornidge 2018, 2020; Knorr-Cetina 1988). Latour and Woolgar (1986), for example, argue that chemical substances in laboratories are socially constructed, proposing knowledge is produced through negotiation processes of scientists within a laboratory. The production of knowledge is further shaped through interactions of researchers and non-scientists, such as policy makers, economic actors, or lay people (Wynne 1992). Yet, these important studies did not include the more-than-humans. Coined by Donna Haraway (Haraway 2003), the term *natureculture* supported my thinking in the field of marine knowledge practices, as it rejects the idea of a strict separation between human-made culture and nature, but rather emphasises their mutual co-production (see chapter 6; Haegele 2025). Gesing et al. (2018) support Haraway's thinking in situating the relationship between humans and the more-than-humans within political ecologies to address environmental, technological, political and material issues. They provide examples of ecological injustices, multi-species entanglements, and global to local connections, such as community coastal protection in New Zealand, mosquito net policies in Ghana, or global capitalistic supply chains of mushrooms and their socio-technical and ecological interaction (ibid.).

Another important concept of STS constitutes the boundary object by Star and Griesemer (1989), which are artifacts, concepts, or practices different groups use to enable collaboration. These boundary objects are “both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (ibid., 393). Examples of boundary objects are maps or museum species but also shared ideas on sustainable transitions or resilience (Franco-Torres, Rogers, and Ugarelli 2020). In the beginning of my fieldwork, I thought of the instruments and infrastructures of MCOs as a boundary object. However, existing approaches of STS fall short in explaining the affective, sensory, and emotional dimensions of human-instrument entanglements, e.g. scientist-observation platform co-becoming, in knowledge production processes (see chapters 4 and 6; Haegele 2024, 2025). Thus, conceptual approaches of New Materialism expanded my thinking.

New Materialism as an approach extends STS by emphasising matter, more-than-human agency, affection and emotions in science-making, thereby building on posthumanism

(Barad 2007, 1998; Bennett 2020; Braidotti 2013; Coole and Frost 2010). Rather than understanding materiality as passive, New Materialism foregrounds onto-epistemology and intra-action (Barad 2007). According to Barad (2007) ontology and epistemology are inseparable and objects only emerge through intra-action rather than simple interaction. Knowledge is understood as co-constituted and enacted in practice of diverse entities, so that humans are understood as becoming with technologies and other species (Haraway 2023, 2003, 2013; Bennett 2020). Thereby the body plays a central role. Bodies are processual and situated in knowledge production. Mol (2002) shows how different medical practices enact bodies in distinct ways by using the example of kidney patients in Dutch hospitals, highlighting that reality is multiple and practice dependent. Haraway (1989) acknowledges embodied and situated knowledges through her studies of primatology laboratories in which scientist's understandings of chimpanzee behaviour is shaped by their own bodily experiences. Braidotti (2013) decentres the human autonomy by treating the body as affective and relational, considering how humans intra-act with technologies and animals in urban or ecological contexts. Similarly, assemblage theory understands a relational emergence of entities in an open-ended process through constant reconfiguration (Murray Li 2007; Deleuze and Guattari 1987; DeLanda 2006). Assemblage theory allows to bring attention to autonomous elements, such as humans or objects that – in relation – function as a whole, while they maintain their identity. For example, people, institutions, rivers, trees, and technologies are intra-acting in an open-ended process of resource governance in a community forestry (Murray Li 2007). Assemblages are dynamic, co-constituted and constantly shifting (DeLanda 2006).

I use the term 'more-than-human' (Abram 2010; Bennett 2020; Tsing 2015; Whatmore 2006) as it decentres the human and includes living beings, infrastructures, and materialities, which are all forming part of knowledge production processes in MCOs. I use the term non-human when technical precision is needed (especially in chapter 6). The agency of more-than-humans has been captured by cases of flora, fauna, and soils (Whatmore 2006), mushrooms (Tsing 2015), and things, such as metals, plastics, and electrical systems (Bennett 2020) among others, and highlight the inseparability of *naturecultures*.

Although STS and New Materialism try to decentre the human by including the more-than-human and agency that only emerges through intra-action and co-constitution, I realised throughout my research that it falls short in including power and the political economy (see chapter 6; Haegele 2025). Yet, they are crucial to understand environmental and marine worlds in which socio-material entanglements of humans and the more-than-human are actively involved in science-making as the subsequent section will show.

2.3 Marine social sciences and marine carbon observations

Marine social sciences are not a concept or theoretical framing but an applied and interdisciplinary area of study. As a problem-focused area it draws from diverse disciplines such as sociology, anthropology, political science, law, and geography. Marine social sciences are increasingly institutionalized and play a crucial role in global marine governance (Bavinck and Verrips 2020; McKinley et al. 2022; Spalding and McKinley 2025; McKinley, Acott, and Yates 2020).

The area of study examines how knowledge on the ocean, its governance, related livelihoods, culture, and economy are influenced by institutional, technological, economic, environmental, societal, and more-than-human relations. Interdisciplinary in nature, it aims to bridge gaps between ecology and humans contributing to a better management and sustainable use of the ocean (Bennett 2019). With the UN Decade of Ocean Science for Sustainable Development (2021-2030) increased efforts on local, regional, national and international levels have brought attention to inter- and transdisciplinary research, local and Indigenous knowledge, and science-policy interfaces (Spalding and McKinley 2025).

Yet, currently, marine social science's publications represent less than four percent of the marine science literature published since 1990, and natural sciences dominate the debate on marine realms (Partelow et al. 2023; IOC-UNESCO 2020). However, since the last decade human-ocean research is increasing (Pelke and Simonn 2023) "to identify solutions to global environmental problems" (Spalding and McKinley 2025, 146). Core strands of this research are ocean governance (Hornidge, Partelow, and Knopf 2023; Blythe et al. 2021), fisheries and aquaculture (Arthur et al. 2022; Lasner and Gimpel

2024), political economy of the ocean (Armstrong 2022; Campling and Colás 2021; Carse and Lewis 2017; Midlen 2024; Steinberg 2001), marine conservation (Cochrane et al. 2024; Ison et al. 2024), ocean justice (Gissi, Portman, and Hornidge 2018; Hein, Klepp, and Bercht 2024), and ocean literacy (McRuer et al. 2025; Shellock et al. 2024).

Empirically grounded research within marine social sciences is rich, yet compared to terrestrial research, marine and coastal realms have received less attention (Liquete et al. 2013; Bennett 2019; Spalding and McKinley 2025). Social science studies on marine knowledge production have predominantly focused on ship-based research, such as Sorrenson (1996), Bogusz (2018) or Hornidge (2018, 2020). Helmreich (2009a) for example, empirically studied knowledge production in laboratories and on vessels through a STS and social constructivist lens. He explored how knowledge travels as it moves from data collection to public knowledge by actively researching marine biology knowledge production. Hornidge (2018, 2020) took a further step by combining social constructivist STS and discursive knowledge sociology (Keller 2019, 2011) approaches in marine science by researching knowledge production on a research vessel. It thereby became evident that “[t]he research vessel acts as a boundary place between field and lab, between different disciplines, nationalities and social groups that in everyday life have little in common” (Hornidge, 2018, 439). Although a team spirit emerged, the study revealed epistemic authority, hierarchies, high degrees of masculinity and sexualised behaviour on the research vessel (ibid.)⁵.

Partelow et al. (2020) highlight further structural path dependencies and inequalities by using the field of tropical marine sciences. Their findings demonstrate the predominance of the Global North in shaping knowledge production globally through material and immaterial science infrastructures, access to funding, English as dominant publishing language, and contact to science networks (cf. Reardon 2021). Non-tropical countries such as North America, Australia and Europe are mainly researching tropical countries and their marine and coastal systems continuing historical disparities by maintaining their superior research capacities, infrastructures and funding (Partelow et al. 2020). These inequalities in funding and access to infrastructures, but also national boundaries appeared in my empirical research in Germany and Brazil multiple times pointing to

⁵ For a detailed literature review on social science research on research vessels, see section 4.3.

historical power asymmetries that still persist (see chapters 4 – 7; Haegele 2024, 2025; Haegele and Hornidge 2025; Schoderer et al. 2025). Rutherford’s (1990) interview with Homi Bhaba revealed the contradiction of Western modernity and its progressive development with its simultaneous despotic colonialism. This contradiction does not only hold true for terrestrial spaces, but also for the ocean, since colonial voyages connected different countries resulting in power (a)symmetries (Glissant 1997). Colonialisation has led to pluriversal knowledge systems via cultural and epistemic intersections, however, dominated by a hierarchical system (Varela, Dhawan, and Randeria 2016). Thus, it illustrates the privileged role individual countries, such as North America, Europe, and Australia possess in scientific agenda setting (Partelow et al. 2020). Since all of these countries have a colonial past, it is important to study and understand knowledge production through its history. “[A] transcultural and postcolonial lens is a useful analytical perspective” (Partelow et al., 2020, 2) for researching the path dependencies that guide research practices and knowledge production. During my empirical research, these postcolonial dimensions become visible through institutional and geopolitical hierarchies that shape co-production of knowledge and epistemic authority. While such dynamics are rarely made explicit in scientific practices, I observed these manifested in subtle exclusions and asymmetries, but also in intersectional discrimination. Although I did not think of a transnational intersectional lens for my research, it emerged from my data as a necessary frame to capture inequalities, harassment, and discrimination, which are rooted in colonial pasts and epistemic authority (see chapters 6 and 7; Haegele and Hornidge 2024). Also in marine sciences, there exists a “lack of inclusion of minority groups” (Belhabib 2021, 709), since “[r]ealities of people, communities and political dynamics are often disregarded” (ibid.). Colonial pasts shape public discourses, social norms, and political agendas, as well as epistemological and ontological trajectories that continue to resonate today (Escobar 2019; Spivak 1999; Ziai 2012; Bhabha 1994). Moreover, further inequalities exist within marine sciences and marine knowledge production, such as gender inequality (Kitada 2022; Johannesen et al. 2023), misogynistic behaviour at sea (Grasmeier 2022), or racial discrimination and prejudice (Shellock et al. 2022)⁶.

⁶ For a detailed literature review on gender inequality and transnational intersectionality at sea, see section 5.4.

Looking at marine carbon observations (MCOs), natural sciences, especially biogeochemistry, dominate scientific literature on these ocean observations. Relevant publications focus in particular on the effects of anthropogenic ocean acidification, ocean deoxygenation and rising temperatures, which will affect organisms and biogeochemical cycles (Gruber 2011; Gulev et al. 2009). Moreover, studies have shown that the ocean's carbon cycle feedback and its magnitude to climate change remains unknown (Riebesell, Körtzinger, and Oschlies 2009). Monteiro (2009) added the importance of knowledge exchange between the CO₂ community and the global carbon budget assessment activities of the Global Carbon project and its essential inputs to the IPCC assessments. They further call for strengthening international coordination of the carbon observations, data quality control, and data archiving. Steinhoff et al. (2019) took a further step and argued for building and extending an ocean component of the Integrated Carbon Observation System (ICOS). A network of researching the marine carbon cycle and the anthropogenic carbon sink was established, allowing monthly estimates of CO₂ air-sea exchange for European waters. They conclude by stressing the importance of collaboration with marine industries and thus of transdisciplinary research, since half of the ICOS stations are located on commercial ships. However, they are highlighting spatial gaps and insufficient funding constitute the main drawbacks (ibid.). Social science research on knowledge production on MCOs across multiple observation networks and stakeholders to better understand the need and urgency of such observations pose another research gap, which the dissertation aimed to address (cf. Schoderer et al. 2024).

Social science approaches on ocean observations⁷ in general, and MCOs specifically are very limited. Empirical research on ocean observations mainly focuses on the global governance of the ocean, such as the creation of a digital twin of the sea (Lehman 2016) or by using marine biodiversity monitoring as part of ocean observations that captures the politics and multidisciplinary practices of monitoring (Vadrot and Wanneau 2024). Further research on ocean observations includes the change in data collection from ship-based to remote and associated opportunities and challenges, such as increased equitable scientific practices but also loss of time at sea (Lehman 2018; Helmreich 2009).

⁷ For a detailed literature review on ocean observations generally, but not on MCOs specifically, see section 6.3.

Some limited studies analysed more-than-human's role in ocean observations, such as eels in marine pollution monitoring (Gramaglia and Mélard 2019), wave buoys in ocean monitoring (Helmreich 2019), or data visualisation tools like Google Ocean (Jue 2014). Yet, social science studies concretely researching and analysing marine carbon observations remain lacking. Even in the latest Global Ocean Science Report IOC-UNESCO (2020) and the IOC-UNESCO State of the Ocean Report (2024), MCOs are not mentioned. Only ocean observations as generic term including large scale infrastructures, such as research vessels or tsunami early warning systems are referred to in both reports.

Most social science research on MCOs has been published through the project 'C-SCOPE' the dissertation is embedded in. Schoderer et al. (2024) use a social network analysis to trace the marine carbon value chain from in-situ MCO measurements on the local level to global governance. They identify key information providers and brokers who maintain the MCO data translation and communication across networks. Due to the rather small MCO community, members of this community have well-established relationships with each other, such as scientists, representatives in international organisations and their counterparts in ministries. The knowledge system within such a small community is very vulnerable to changes in funding or personnel. In another study by Schoderer et al. (2025), the authors argue for open science reforms to strengthen equity in accessibility, participation, funding, and infrastructure of MCOs, as path dependencies in funding MCOs, data collection and processing, and geographical gaps in the observation network exist.

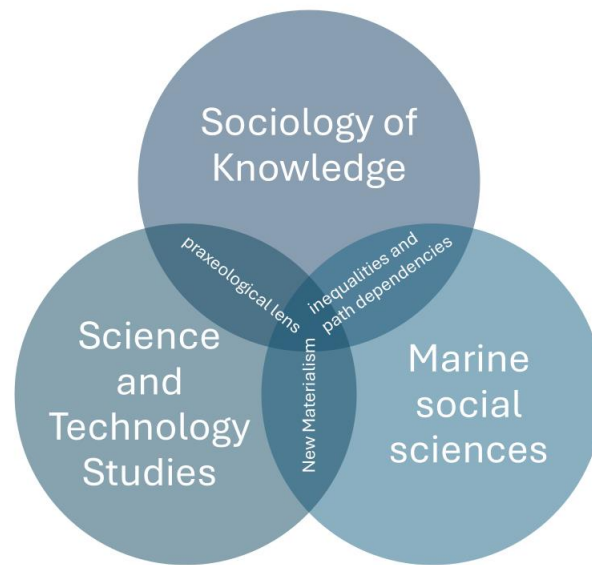


Figure 3: Bringing together the Sociology of Knowledge, Science and Technology Studies and marine social sciences as conceptual foundations. Source: Own elaboration.

To conclude, despite the importance of MCOs for global climate governance, there exist very little studies on MCOs through a social science lens. Despite the rich and valuable marine research within the Sociology of Knowledge (SoK), Science and Technology Studies (STS), and New Materialism, a multi-sited, empirically grounded account of MCOs which holistically includes socio-material practices, such as emotions, positionality, and uncertainty in science-making remains lacking. Analyses that follow knowledge production on MCOs from funding of instruments to deployment, to data, to syntheses, to climate governance and the micropolitics surrounding these processes do not yet exist. To address these gaps the cumulative dissertation provides a comprehensive analysis of human and more-than-human forces in science-making in diverse research localities with a sociological understanding of knowledge production processes in MCOs. I thereby follow posthuman and critical constructivist approaches (Barad 1998; Haraway 2023, 2003), which understands knowledge as situated and practice-based, including more-than-human forces in knowledge co-production, and adds a focus on inequalities, power, and political conditions under which knowledge is produced (see figure 3).

Similarly to cleaning a sediment core, such a holistic analysis requires in-depth empirical data to examine all layers of knowledge production processes in MCOs. When cleaning a sediment core, the responsible scientist must proceed very carefully. The top layer of the sediment core needs to be removed so that each section of the core can be examined in detail. Only through this careful process can scientists identify the grain sizes of the core revealing evidence of its geomorphic past, its carbon capture, and its responses to climate change.

The next chapter introduces the methodological framework including the chosen research design and methods, the empirical cases, reflections on positionalities and micropolitics, analytical tools, and limitations of the research.

Chapter 3

Sampling a sediment core: Methodology and empirical depth



Picture 3: A sediment core is being sampled by removing material from different depths and layers with plastic syringes during a research cruise in the Labrador Sea in 2021. Source: Author.

3. Sampling a sediment core: Methodology and empirical depth

After the sediment core is opened and cleaned (see chapter 2), the deeper layers of the sediment core are explored. For this step of the analysis, scientists use a plastic syringe to extract smaller samples from the sediment and to gain a profounder understanding of its structures (see picture 3). Likewise, this chapter presents my research design and approach of how I sampled or rather collected my data, which methods, empirical cases, and analytical tools I used.

As I started to approach the field of knowledge production in marine carbon observations (MCOs) and re-read Geertz' (1973) influential work on the concept of thick description, I came across his argument of "if you want to understand what a science is, you should look in the first instance not at its theories or its findings, and certainly not at what its apologists say about it; you should look at what the practitioners of it do" (ibid., 5). This is what I did and what enabled me to approach the field of MCOs and to understand the field through diverse lenses: the one of natural scientists, crewmembers on vessels, technicians in laboratories, engineers and software programmers in offices, and myself – a social scientist – a set of diverse types of knowledge. Throughout my research, I noticed that more-than-human forces and the localities of where this knowledge is produced is crucial as a lens too and quite diverse as well: sensors, satellites, winches, weather conditions, online meetings and workshops, universities, (marine) science institutes, conferences, laboratories, research and merchant vessels, or spaces in-between like joint walks to the harbour or conversations over lunch.

As the following sections will show, such an explorative, inductive, and multi-sited research design and approach extended by the mobility turn allowed me to holistically map knowledge production processes in MCOs in diverse localities and in empirical depth. By using (auto-)ethnography, I moreover built-in micropolitics and intersectional positionalities influencing data collection and analysis. The chapter also includes tools for analysis and shows the limitations of the research.

3.1 Research design

The research follows an inductive, explorative, and multi-sited qualitative design to understand how MCOs are produced, and which internal and external factors influence these knowledge production processes in an interdisciplinary and transcultural setting⁸. The inductive design allows to follow the observations during fieldwork and to note patterns that extend existing conceptual framings and thoughts through the observed practices aiming to develop a mobile and context sensitive mid-range concept (Charmaz 2014; Houben 2017; Hornidge 2017; Schwachula 2019; Stebbins 2001). The selected design suits well for research on MCOs, as it is an heterogenous, dynamic, diverse field which is characterized by uncertainty due to weather conditions, technological dependence, geopolitics, and funding shortages (see chapter 6; Haegele 2025).

From an epistemological perspective, the dissertation treats knowledge as situated by using an interpretive and praxeological approach rather than aiming to proof a theory or pre-given facts (Hammersley and Atkinson 2019; Knorr-Cetina 1991). It thereby follows feminist and decolonial critiques of universalism and integrates intersectional reflexivity (Collins 2022; Crenshaw 1991; Haraway 1988; Harding 2013).

The research was embedded in the project C-SCOPE (see section 1.1) that focused on MCOs in Brazil and Germany including the Baltic Sea, the North Atlantic thermohaline circulation system, and the Amazon rainforest system in South America. Brazil and Germany were selected as case studies for several empirical and conceptual reasons: 1) They have different oceanic contexts ranging from a temperate and highly industrialized Baltic Sea to the tropical large-scale Brazilian coastline, which serves as an interesting case to study how observations can be carried out in diverse environmental conditions; 2) The Brazilian scientific infrastructure operates with different funding resources and constraints, whereas Germany has a long-standing funding for marine sciences despite its limited coastline; 3) Both countries represent different positions in global environmental and climate governance hierarchies and partnerships, suitable to examine how knowledge is (co-)produced, shared, and translated across institutional, cultural, and (inter-)national boundaries and which role geopolitical and epistemic hierarchies are

⁸ For details on the research questions, please see section 1.2.

at play (Hornidge, Partelow and Knopf 2023; IOC-UNESCO 2020, 2024; Schoderer et al. 2025).

The main unit of analysis were the scientists, laboratory assistants, and technicians around the C-SCOPE project team in Brazil and Germany, as well as associated crewmembers of merchant and research vessels used for MCOs. I extended the data collection and analysis to the C-SCOPE team's collaborators and its internal and external intra-actions with other humans and the more-than-human. Throughout three years, I conducted an ethnographic study of the knowledge practices of these transnational, interdisciplinary composed research networks, as the following sections will explain.

3.2 Multi-sited ethnography: Methods

In generating empirical data, the dissertation mainly relies on ethnographic methods for primary data collection including participant observation, field notes, visual material collection (photography and video), informal and semi-structured interviews, go-alongs, and thick description. The selection of methods aims at gaining in-depth data to understand everyday knowledge production in MCOs involving human and more-than-human forces.

Although the research usually took place in one research location, e.g. on a research vessel or in a laboratory and counts as a “strategically situated (single-site) ethnography” (Marcus 1995, 110), it was always guided by external factors and diverse types of knowledge from outside of this locality, such as virtual meetings during a research cruise or GPS data received in German offices from satellites above the North Atlantic. The empirical research also included different physical parts of the ocean, such as diverse water depths and multiple research and sampling stations. Thus, I combined multi-sited ethnography (Marcus 1995) with the mobility turn (Mielke and Hornidge 2017; Sheller 2017; Sheller and Urry 2006; Urry 2016), as the data collection made dynamic boundaries between geographically fixed and virtual knowledge production spaces visible and shed light on multiple sites of meaning-making and its dynamisms. Such an approach also allows to include sites of knowledge production processes I cannot physically visit (cf. McAdam-Otto and Nimführ 2021).

Throughout the ethnographic data collection, the multi-sited approach extended by the mobility turn allowed me to follow and observe continuous knowledge flows of and between the human and more-than-human, e.g. crewmembers on a merchant vessel calling scientists on land about a malfunctioning sensor or scientists on a research vessel who explored the ocean's surface, deep-sea, and seabed through technologies that enable them to study many ecosystems and biogeochemical parameters at the same time.

By following humans, such as scientists, technicians, and crewmembers and more-than-humans including sensors (on measuring instruments, e.g. Argo floats), research and merchant vessels, technologies in the laboratory (e.g. calibration tools), offices (e.g. laptops, software), the research aims to overcome anthropocentrism and take socio-material entanglements seriously, especially the role of materialities in knowledge production processes (Gesing 2019).

Qualitative methods including participant observations, thick description and field notes, semi-structured interviews, go-alongs, and tools of visual anthropology capture the diverse and complex knowledge production processes of MCOs (see figure 4). In the following, I will briefly explain the applied methods and the adaptation of these during research in 2021 and 2022, as COVID-19 pandemic measures of (social) distancing affected ethnographic research. In a further step, I will introduce the empirical data collection, reflect on my positionalities and micropolitics in the field, explain the analytical tools I used, and display ethical considerations and limitations of the research.

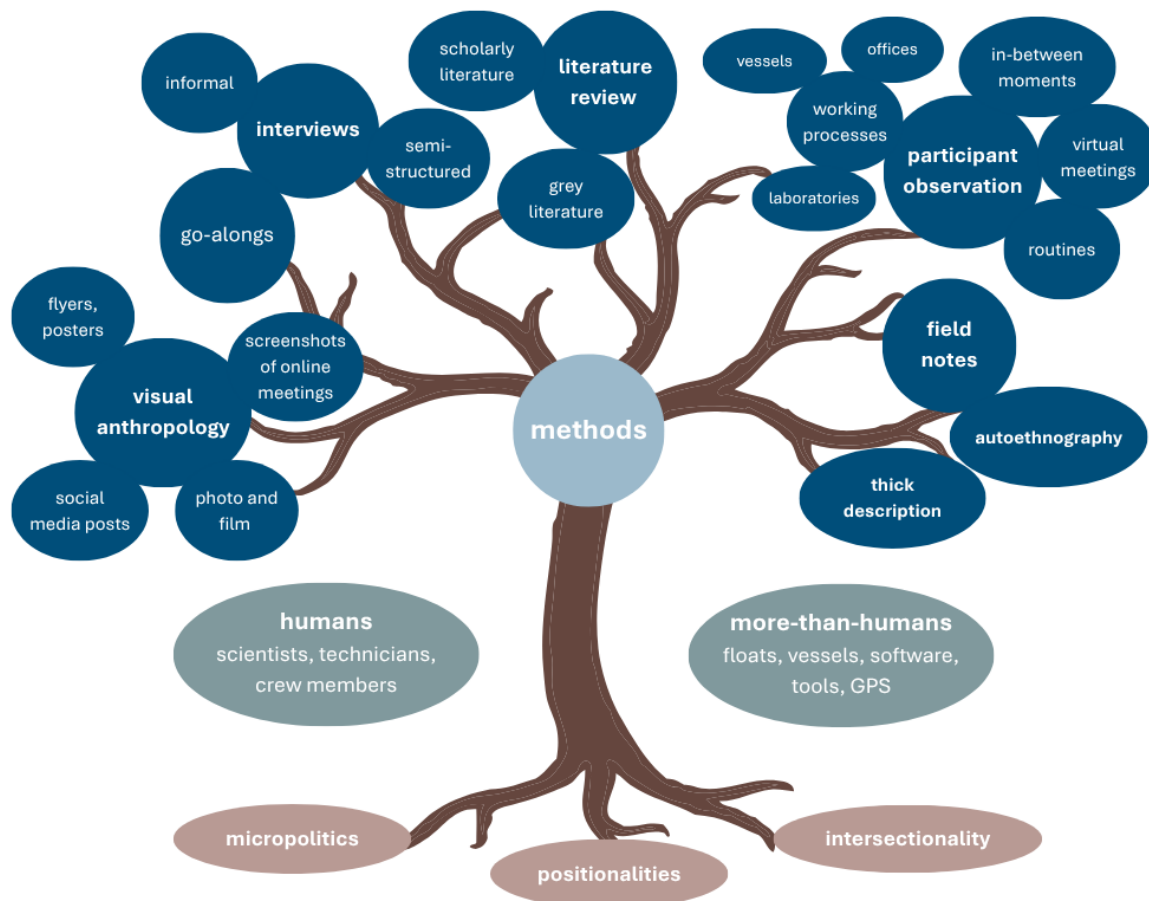


Figure 4: Method tree displaying the methods, research participants, and its rootedness in micropolitics and intersectional positionalities. Source: Own elaboration.

3.2.1 Participant observation

Participant observation is a traditional ethnographic method aiming at collecting qualitative data on everyday practices, experiences and strategies of actors in the field and to document them descriptively (Adler and Adler 1998; Hammersley and Atkinson 2019; DeWalt and DeWalt 2011). Initial observation is primarily descriptive, unfocused and generally oriented so that the researcher gets a first basic orientation of the field. Once one is more familiar with the field, focused observation follows to better understand certain phenomena. Participant observation then sets in to gain a deeper understanding of the observed research unit (Adler and Adler 1998).

Such a procedure in participant observation helped me to understand and assess everyday practices of knowledge production and underlying social, cultural, technological, and cognitive factors of the C-SCOPE team and associated more-than-human forces. While being in the field, my basic assumptions changed, and new

understandings of the field emerged. Through observing the work processes of the natural scientists, I did not only gain new knowledge on marine carbon observations (MCOs), its measurement, associated difficulties, its importance for the earth's climate, but also about the usually unseen processes in science-making, such as technology dependence, intuitive decision-making, or time pressure.

Moreover, the work processes in diverse research localities were ethnographically documented, such as the processes of collecting, processing, and analysing data, negotiations involved in these processes, the technology dependence and human-technology entanglements (cf. Hornidge, 2018). In order to produce reliable data out of participant observation, a prolonged or repetitive episodic stay in the field – patchwork ethnography – was necessary (see section 3.3), combined with systematic field notes as well as visual material (Clifford and Marcus 1986; Geertz 1987), as the following sections will explain.

3.2.2 Field notes

Field notes served as an additional method. They contain information, descriptions and statements of the everyday observations (DeWalt and DeWalt 2011). Moreover, they record first analytical memos with conceptual links (Charmaz 2014). Field notes also include intimate information about the ethnographer's state of mind, fears, wishes, and hopes (Clifford 1990; Sanjek 1990). They retrospectively make one's own presuppositions clear by describing what one experiences as new and surprising. From an analytical point of view, this made (implicit) expectations and possibly unconscious basic assumptions as well as one's own categories and evaluation schemes clear (Clifford 1990). I used a field notes template (see annex 1) to assess which memos emerge as patterns and potentially turn into codes and categories during analysis (see chapter 3.5). The template also included a section on my own positionality and the micropolitics surrounding me to autoethnographically take note and reflect on my role in the field including my emotions and power. The field notes proved an important method and key source for my analysis. Besides everyday descriptions of participant observations, work processes, conversations, observed socio-material encounters, I also wrote down key take-aways of

interviews, but also drew sketches of work processes or sensors, and noted down first analytical thoughts, which added to the thick description explained in the next section.

3.2.3 Thick description and autoethnography

Geertz (1987, 1973) was the influential founder of symbolic and interpretive anthropology, which was responsible for a shift away from generalising statements to the thick description of individual cases aiming to explain with as much detail as possible the reason behind human actions. Thick description does not only describe physical behaviour but also the context of behaviour explained by the observed actor. The method fits perfectly for observing knowledge production in marine carbon observations (MCOs) as it can easily be extended to more-than-human actors.

Thick description adds an analytical approach to participant observation. According to Geertz (1973) each culture is a system of meanings that the anthropologist can unlock through decoding and interpretation. He compares ethnographic analysis to the interpretation of literature, full of meanings that the researcher can interpret rather than conclusively explain. Each system (here: knowledge production within MCOs) has to be understood as an assemblage of different texts: 1) interpretations of the studied persons' environment in time and space (first order interpretations), 2) interpretations of the informants about phenomena of their environment in time and space (first or second order interpretations), and 3) the ethnographers' interpretations of environment phenomena guided by their intellectual background in time and space (second or third order interpretations). The amalgamation and superimposition of these individual interpretations is what Geertz calls thick description.

First-order interpretations represented the observation of the C-SCOPE team's everyday research practices and its socio-material entanglements with e.g. colleagues, policy makers, technicians, sensors, or software. First or second order interpretations were the C-SCOPE team's interpretations of their everyday practices through e.g. informal and semi-structured interviews and go-alongs (see section 3.2.4). Second or third order interpretations entail my interpretation of the observed phenomena including my positionalities and micropolitics. Thereby autoethnography (Anderson 2006) represented

a useful method, as I combined it with thick description in my field notes through reflexive entries to address the role of my intersectional positionalities and power dynamics in the field (see sections 3.4 and 7).

3.2.4 Interviews and go-alongs

During field research, informal and semi-structured interviews were conducted. Informal interviews usually take place spontaneously during ethnographic field research and the interlocutors do not always perceive the situation as a research situation (Bernard 2002). Go-alongs are a method to accompany research participants during their everyday tasks, which can also reduce hierarchies or mistrust (Kusenbach 2003). They proved especially helpful when following scientists or technicians in everyday work processes in the laboratory or during seismology and hydroacoustic. As a mobile method, go-alongs allowed me to access embodied, sensory, and experiential knowledge in-situ (ibid.). In contrast to the conducted ten informal interviews and eight go-alongs, semi-structured interviews using an interview guide with specific questions were conducted with 82 research participants. Semi-structured interviews aim to answer predetermined questions (see annexes 2 and 3 for interview guideline; Bernard, 2002). This type of interview mostly aims at the scientists to cover core topics which enable comparison but simultaneously allow flexibility in asking questions. Semi-structured interviews especially helped me to clarify comprehension questions, but also more personal questions, as these types of interviews were mostly conducted in a more private and calmer environment, whereas the informal interviews and go-alongs allowed more spontaneity to come up with new questions that emerged from the situation. The interviews are labelled as Int-number throughout the dissertation to ensure anonymity, while selected identity markers such as gender and professional role are included to situate statements within their broader contextual setting.

3.2.5 Visual anthropology⁹

Photo and film documentation of work processes, research surroundings, human-human, human-more-than-human, and more-than-human-more-than-human entanglements complemented the mentioned methods by documenting the embodied, material, and socio-material organisation of knowledge production on MCOs. Visual anthropology tools, such as photography and video material of the field, make a repetitive representation of sense-making processes visible (Banks and Zeitlyn 2015; Pink 2020). Further visual materials include screenshots of virtual presentations, social media posts, photos of posters or whiteboards at conferences or workshops, and flyers. Such visual data captured the tacit dimensions of knowledge production in MCOs, including mimics and gestures, affective atmospheres, and socio-material entanglements, which are difficult to describe verbally but shape meaning-making processes. The visuals also supported me to communicate complexity, such as abstract working processes. Combining visual and textual data deepened my qualitative analysis and offered a multi-sensory understanding of how knowledge in marine sciences is produced, negotiated, shared, and (de-)stabilised (see chapter 6).

3.2.6 Literature reviews

Scientific peer-reviewed publications, policy reports, and technical standards were treated as an empirical field for data collection and are sites where knowledge, credibility, and authority are produced and negotiated. Using literature added to the inductive and explorative research design as it supported observations in the field, concept development, and methodology questions (Booth et al. 2021). Throughout my empirical research, I always came back to the literature to situate my empirical findings within existing research, conceptual discussions, and methodological debates. Conducting literature reviews moreover supported my conceptual situatedness in Science and Technology Studies (STS), New Materialism and post humanism, as it sharpened my

⁹ Some material of the photo and film documentation was used for science communication and can be found on YouTube: https://www.youtube.com/results?search_query=%22Ramona+H%C3%A4gele%22 Other visual material was disseminated via the social media platform formerly known as Twitter (now X). Following the deletion of the associated account for political reasons, these materials are unfortunately no longer publicly available.

analytical focus and provided me with tools to interpret my collected data, recognise patterns, contradictions, and blind spots.

The searches for literature were conducted across diverse databases, such as Web of Science, Google Scholar, or PANGAEA – a digital data library for earth system sciences – by using Boolean operators and an open-ended time window to iteratively find documents on MCOs. As reference managers, Endnote was used to store full texts and metadata. Together with the ethnographically collected data, literature was coded and analysed (see section 3.5).

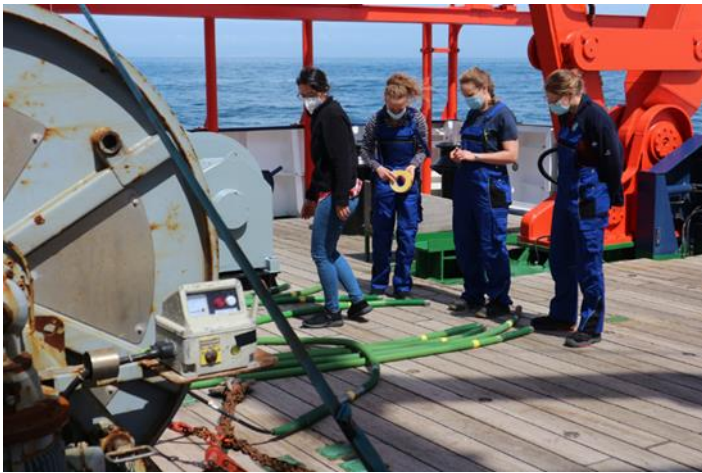
3.2.7 Adapting the research methods to the COVID-19 pandemic

The COVID pandemic had a large effect on the function of the science system. It influenced everyday research practices and especially fieldwork. Research on MCOs constituted no exception. Despite the pandemic's restrictions, the conduct of ethnographic methods remained indispensable in order to assess everyday research practices. Berger and Luckmann (1966) argue that language is constructing shared social realities through daily conversations. Thereby knowledge is realised through interactions and legitimised afterwards supported by diverse forms of social organisation. Through the permanent use of language or non-verbal communication, knowledge transforms and reproduces itself (*ibid.*). Thus, participant observation of everyday practices of the C-SCOPE team was necessary to understand their reality constructions.

Yet, for the first and partly the second year of research (2021 – 2022), conventional ethnographic fieldwork was impossible due to COVID-19 restrictions and presented a challenge for the chosen methodology. “Anthropologists are used to living with their interlocutors and to move with them through time and space. This is currently simply not possible” (Kuiper 2020, 301).

To maintain continuity while preserving safety, health, and data quality, methodological adaptations were a solution for the first months of research as digital ethnography has a promising potential for STS studies (Bychkova 2020). Thus, I also observed digital and virtual discourses of the C-SCOPE team and beyond, e.g. on social media, in virtual conferences, and meetings, respective institute's homepages and scientific publications.

After seven months, I received the opportunity to participate in a German research cruise, which was the first one to be allowed during the 2021 pandemic wave. Vaccination status, prior testing and quarantine enabled the boarding of the vessel. For the first week, everyone had to wear masks on the vessel and were tested daily. After one week PCR tests allowed COVID-19-free research for the following six weeks aboard. Similarly, during research at the marine science institutes and universities in Brazil and Germany, masks in laboratories were a requirement during 2022, which influenced parts of the research (see pictures 4 and 5, and section 3.6). Yet, despite the pandemic's influence on fieldwork, I was able to gather rich and in-depth empirical observations, as the next section will describe.



Picture 5: Working in a pandemic setting on a German research vessel in the North Atlantic in 2021. Source: Sebastian Krastel.



Picture 4: Working in a pandemic setting in a Brazilian laboratory in Rio de Janeiro in 2022. Source: Author.

3.3 Studying diverse research localities and knowledge systems: Empirical depth

As mentioned earlier, the research project C-SCOPE in which the dissertation was embedded in, determined the empirical setting and case selection of knowledge production localities in Brazil and Germany. Through episodic patchwork and multi-sited ethnography (Günel and Watanabe 2024; Marcus 1995) fieldwork across sites and virtual field stays in Brazil and Germany was conducted throughout three years (February 2021 – February 2024, see table 1).

Throughout these years, fieldwork was conducted in diverse spaces. In episodic fieldwork, I stayed nine months at a university, a laboratory, and a research institute in Brazil, more than two months at marine science institutes and a federal agency including laboratories in Germany, seven weeks on a German research vessel, four days on Brazilian and German merchant vessels, and approximately one month in virtual workshops and meetings on MCOs. I conducted participant observations, wrote three notebooks of field notes and thick descriptions (approximately 380 pages), conducted 82 semi-structured interviews, go-alongs, and informal interviews with scientists, technicians, crewmembers, and laboratory assistants, and photographed and filmed work processes on the vessels and in laboratories.

The seven-week geomorphic expedition on a German research vessel in the North Atlantic and the Labrador Sea between Canada and Greenland gave in-depth insights into everyday working routines. It made the work at sea visible, ranging from working in shifts, detailed work processes in hydroacoustic sedimentology, and socio-material entanglements, hierarchies between crewmembers and scientists but also within these social groups, and related negotiation processes (see chapters 4 and 7). I observed the use of sensory landscapes and experiential knowledge on the research vessel, during my stays on merchant vessels and in all the laboratories (see chapters 4 – 7).

Participant observation in these localities also made the usually invisible infrastructural and socio-material entanglements of MCOs seen, such as the co-constitution of humans, sensors, cables, calibration tools, GPS, floats, vessels, data, and types of knowledge that travel from the deep-sea to the data centres (see chapter 6). Moreover, technology dependence, emotions and affect in everyday knowledge production processes became apparent, as well as hierarchies, authority, and emotions in science-making during workshops, meetings, or bilateral conversations in offices. These power dynamics and hierarchies at sea became especially visible on vessels between crewmembers and scientists but also at universities and in laboratories between technicians, laboratory assistants and scientists, and between humans and non-humans, e.g. scientists delegate some of their work to technologies like winches, mobile transmitters, or software. The ethnographic research also showed inequalities in funding,

accessibility, and negotiation authority in the diverse knowledge systems of Brazil and Germany (see chapter 6).

These empirical insights added to the conceptual foundations (see chapter 2) and the developed mid-range concept (see section 8.2) and allowed to ask system questions of inequalities in science-making. Inequality, discrimination and (sexual) harassment especially became apparent after having collected and analysed all 82 interviews, in which more than one third of the interviewees reported having experienced discrimination and (sexual) harassment due to their intersectional identity markers (see chapter 5).

Table 1: Fieldwork between 2021 and 2024 by research locality, participants, and time. More-than-humans, such as software, instruments, and sensors were always part of the research participants. Source: Own elaboration.

Research localities	Research participants	Time in the field
Virtual German MCOs meetings	Scientists, policy makers	5 days, 2021 – 22
Virtual European MCOs workshops	Scientists, policy makers	3 days, 2021 – 22
Virtual international MCOs workshops	Scientists, policy makers	5 days, 2021 – 22
Virtual UN Decade events	Scientists, policy makers, artists	5 days, 2021 – 23
Research vessel, Germany, Canada, North Atlantic, Labrador Sea	Crewmembers, scientists	7 weeks, 2021
Merchant vessel Hamburg, Germany	Crewmembers, scientists	2 days, 2022
Merchant vessel, Santos, Brazil	Crewmembers, scientists	2 days, 2022
ICOS Germany workshop, Germany	Scientists	3 days, 2022
EU-Argo workshop, Germany	Scientists, technicians	3 days, 2022
UERJ and laboratory and FGV guest research, Rio de Janeiro, Brazil	Scientists, technicians, and laboratory assistants	9 months, 2022 – 24
GEOMAR and laboratories, Kiel, Germany	Scientists, technicians, and laboratory assistants	3 weeks, 2022 – 23
IOW and laboratory, Warnemünde, Germany	Scientists, technicians, and laboratory assistants	2 weeks, 2022
BSH and laboratory, Hamburg, Germany	Scientists, technicians, law makers, and laboratory assistants	3 weeks, 2022 – 23
Total time in the field	Scientists, technicians, crewmembers, law makers, and laboratory assistants	14 months, 2021 – 24

Abbreviations within the table: ICOS (Integrated Carbon Observation System); EU-Argo (European contribution to the international Argo programme); UERJ (Rio de Janeiro State University); FGV (Getulio Vargas Foundation); GEOMAR (Helmholtz Centre for Ocean Research Kiel); IOW (The Leibniz Institute for Baltic Sea Research Warnemünde); BSH (Federal Maritime and Hydrographic Agency of Germany).

By conducting this patchwork and multi-sited ethnography, I was not only traveling through diverse virtual, physical, and socio-material spaces, but also became aware of my intersectional identity markers, multiple positionalities, and micropolitics influencing the research. Thus, the following section provides a reflection of my role as a researcher within these spaces, particularly the merchant vessels, laboratories, marine science institutes and universities in Germany and Brazil, while chapter 7 provides a detailed literature review on intersectional positionalities and micropolitics and focuses on my experience during the seven-week expedition on a German research vessel.

3.4 Relational waves of assembled intersectional positionalities and micropolitics

Usually, there is not enough space in academic journals in the methodology section to holistically reflect on how a researcher influences their own work and that of others. Thus, this chapter provides a more detailed account and reflections of my intersectional positionalities and micropolitics during my PhD journey and especially throughout ethnographic data collection. These are not footnotes. They are part of the data set.

I am building on Haraway's (1988) situated knowledges, intersectionality (Crenshaw 1989), and micropolitics and assemblage thinking (Deleuze and Guattari 1987; Fox and Alldred 2017). In line with these authors, I argue that positionality is not static, but dynamic as it is shifting depending on my environments, emotions, and socio-material entanglements with humans and more-than-humans. "Everything is data", my PhD supervisor once said to me during a conversation on difficulties during fieldwork. In scientific papers, the of what I call 'in-between moments' are often missing. There is a gap between the data collection and the findings. What happens in this in-between state? The in-between moments are manifold and range from walking with natural scientists I observed the whole morning in the laboratory to lunch, the silence of waiting for a sediment core to arrive back on deck, or WhatsApp messages explaining how to deploy a float for measuring marine carbon while standing on a vessel's rail. These moments materialise micropolitics and translate events of co-production in science-making.

Methodologically, I relied on autoethnography, thick description, and field notes and propose attending to the in-between moments of fieldwork. Theoretically, my reflections are embedded in situated knowledges, and I acknowledge that there is always only a partial perspective in aiming for objective research (Haraway 1988). As a white female researcher funded and trained within German institutes, I was privileged to be able to conduct fieldwork in Brazil and Germany and my positionality emerged of these heterogenous entanglements, rather than being a fixed property of myself as an individual (Farías and Bender 2012). Intersectionality treats social identity markers, such as gender, age, class, nationality as co-constituted and analyses how these produce specific exposures to the individual and their environments (Cañada and Valdivielso 2025; Crenshaw 1989). In line with New Materialism and assemblage thinking, affect, materiality, and ethics organise research practices (Deleuze and Guattari 1987; Fox and Alldred 2016)¹⁰.

Throughout my research, I continuously questioned my situated vision and “partial perspective” (Haraway 1988, 583), reminding me that my socialisation, both academically and personally influences how I see and analyse observations in the field. Haraway’s work on situated knowledges (1988) is important as it reminds researchers to transparently disclose where they come from, what they see and in which ways they are seeing it. My intersectional identity markers of being white, female, rather young and able-bodied, German, with a German institutional setting and education of the Minority World influences how I do research. I was born and raised in a conservative 1000 inhabitants’ village in Southern Germany, close to the Swiss border. I grew up in a working-class family, in which my father was the only one who finished high school. My decision to visit a high school after finalising middle school was met with reluctance by my parents and broader family, as they were expecting I would start an apprenticeship and stay in the village. After I finished high school and decided to move away to do a voluntary year of social service and then go to university, the mutual misunderstanding grew. In the academic world I did not feel at home either, as I was lacking basic general knowledge, even more so when I as a social scientist started to work on MCOs, a topic I have never heard of before. As an early career researcher, I sometimes feel helplessness of where to locate myself,

¹⁰ For a detailed literature review on intersectionality, positionality, and micropolitics, as well as the conceptual application on empirical cases in marine settings, see chapter 7.

straddling between different social classes. Although this class mobility feels like a burden, it is also a gate opener to other social classes in the field. Thus, I learnt how to switch my positionalities oscillating between being an academic to gain access to the scientist's work and being a working-class member to gain the trust of the crewmembers on vessels and technicians in laboratories (see chapter 7).

I am aware that researching other researcher's scientific knowledge production is a delicate topic, especially by taking into account the underlying historical and power-related path dependencies of knowledge production in marine sciences (Partelow et al., 2020). While conducting social scientific accompanying research, I as a researcher and the researched are in an asymmetry of power, which affects the social reality of both sides. I as a social scientist hold power when choosing which observations or events I record, translate, or analyse. When conducting interviews in German or Brazilian Portuguese, it is in my authority to decide what to paraphrase, where to leave the original language or where to shorten. These are micropolitical acts and decide who is being heard or silenced.

The more-than-human forces also play a key role as they hold power, too (Rafliana 2025; Schutter et al. 2025). Instruments might not work on an important day of sampling or weather conditions might postpone research practices or lead to seasickness. These conditions can also decide on my mental and physical capabilities during fieldwork. During one of my research stays in Brazil, I fell sick with a virus for several weeks. On the research vessel, I fell seasick quite often which made me feel very exhausted and delayed my work. It also led to pressure, as I couldn't work well during the assigned shifts. During the first few weeks, I also experienced difficulties in gaining access to the field as I was seen as an outsider for being the only social scientist on board, which was vocalised in jokes and comments that I am standing in the way. My intersectional identity markers of gender, age, and occupation also led to unsolicited comments by the crewmembers about my body and my marriage status. Yet slowly I started to adapt, participated in the after-work activities, stayed up late and shared drinks. The risk of "going native" (Spittler 2014, 213) increased, but I took countermeasures by writing my field notes every evening, no matter how late it was and how tired I was, and reflected about these micropolitical

encounters. I collected fragments of diverse realities in in-between moments to analyse who owns authority, who is being heard, who speaks for the data, and who remains silent.

Back on land and throughout my fieldwork in Germany, I felt more at home and confident, as the access to the field went smoothly due to the involved project colleagues. I conducted ethnographies in three institutes in Hamburg, Kiel, and Warnemünde but the distance of going to the office in the morning and back home in the evening did not lead to 'going native'. At the same time, an in-depth immersion was not possible in each research institute. However, due to shared language and familiar institutional settings, I could quite easily read the micropolitics surrounding the everyday knowledge production processes.

During my episodic fieldwork in Brazil, I barely spoke Brazilian Portuguese, which was a burden in the beginning but significantly improved. After arriving in Rio de Janeiro, a city in a country I have never been before, I was overwhelmed by the humidity, heat, the mould in my hostel room, and the carefulness one should have when leaving the house. After a week, I rented a small apartment in Flamengo, the Southern zone of the city, which is relatively wealthy and safer. As I was financially backed by German and EU funding and a social security system, my micropolitical embeddedness became apparent.

Due to my physical appearance, I was not considered as particularly German. Often, I was approached by Brazilians talking in Brazilian Portuguese in the grocery store, in restaurants or at the university, which made my access to the field straightforward. After an initial familiarisation, I felt at home in Rio. I felt much more at home than in Germany although I didn't speak the language. Suddenly, my emotional intelligence and my directness, which was often treated as an affront in German settings, was generally accepted and even desired.

As I was seen as a white Brazilian with an institutional privilege to conduct research in Rio de Janeiro, I navigated open doors at universities, research institutes and the private sector. Yet, throughout my studies, I met Black, Indigenous and People of Colour (BIPOC) colleagues and new friends with different life realities highlighting inequalities of the science system and the still prevalent postcolonial past of Brazil.

Although I cannot change my intersectional identity markers, I can reflect about the micropolitics surrounding me and use my dynamic positionalities. These are ever changing and flexible depending on the environment, language, institutional roles, and localities, as well as the humans and more-than-human actors surrounding and engaging with me. The relational waves foreground motion as the positionalities function in specific settings, then break, and reassemble across sites, while at the same time are always co-constituted in relation with other humans and more-than-humans. According to the Writing Culture Debate's representatives, such as Edward Said and James Clifford, no ethnologist can guarantee neutrality and objective truth cannot be reached (Clifford and Marcus 1986). My reflexivity does not excuse biases, and it can also lead to narcissism by centring myself (Amoureux and Steele 2015; Gani and Khan 2024). Yet, I hope my reflections and disclosure of emotions are not self-absorbent but can be used to tie them to mechanisms of accessibility, inequality, and power. I reflected on my insider and outsider position continuously while simultaneously knew that my position in the field is important but not the central element of inquiry (cf. Haraway 1988; Mol 2002).

The next chapter will transparently present the analytical tools, such as coding software, for analysing collected data.

3.5 Analytical tools

For analysing the collected data, I first transcribed the audio-recorded interviews and go-alongs with the software *F4*, which supports to slow down the voices so that I can simultaneously type the spoken words. For content in German and Portuguese, I – partly and only for non-sensitive content – used the machine learning translation tool *deepL*. After an initial automatic translation, I reviewed the content to verify if the translation does not neglect or modify the spoken words.

Once all the data was transcribed, I used the *Atlas.ti* software, an extensive tool facilitating the analysis of qualitative data. I coded the data including literature, transcripts, field notes, and visual material, inductively, starting with open coding and then developed code groups and sub-codes (Charmaz 2014; Glaser and Strauss 1998). In an ethnographic (see chapters 4 and 7) or theme based (see chapter 5 and 6) coding

scheme, I identified patterns of themes throughout coding. A pattern is a frequent reoccurrence of a theme (Hatch 2002), and a theme is a statement of meaning that runs through most data or carries a factual impact (Ely et al. 2003). *Atlas.ti* provided additional tools, such as memo linkages, timestamps, and colour-coding, which improved the analysis. Moreover, visualisation of codes in diagrams or co-occurrence graphs were used to enhance the analysis.

After data processing, I conducted a thematic analysis (Miles and Huberman 1994; Braun and Clarke 2006) to answer the research questions, which provides inductive categories, which can constantly be compared across thick description's first, second and third order interpretations. By developing the Intra-Active Observation Assemblages (IOA) framework as a mid-range concept (see section 8.2), I iterated between the data material and the concepts, allowing the patterns to consolidate (Charmaz 2014; Glaser and Strauss 1998; Houben 2017; Hornidge 2017).

Conducting ethnographic research requires researchers to do no harm, obtain informed consent and protect the informants (American Anthropological Association 2012), as the following chapter will explain. Moreover, every study has its limitations (Hammersley and Atkinson 2019), which I will shed light on.

3.6 Ethical considerations and limitations

In line with polyphonic ethnology, I aimed to break down the hierarchy between ethnologist and informant (Clifford and Marcus 1986). I disclosed the research project and the objectives of participant observation to the participants, who were aware of the research process. Moreover, in each interview and during ethnographic fieldwork, I ensured anonymity to the participants and maintained the integrity of informants. Thus, the research participants were aware of my research endeavour and were asked prior and during the interview for their consent, which was audio-recorded. Given the relatively small community of people working on marine carbon observations (MCOs), all interviewees and research participants were anonymized, and sensitive content was paraphrased rather than quoted directly to avoid potential re-identification of my interlocutors (cf. American Anthropological Association 2012). As the research on the

seven-week expedition was rather intimate, I sent chapter 4 to the Chief Scientist before the publication for approval. Throughout the research in Brazil and Germany, I tried to include diverse opinions into the different stages of research, e.g. in literature review or during empirical research by making the voices and perspective and voices of women and early-career researchers of the Majority World and non-scientific knowledge holders heard.

I displayed openly and transparently my intersection identity markers (gender, age, class, nationality, race, institutional, financial, and disciplinary locations), and my positionalities and micropolitics, so that readers can evaluate how these shape the research process and analysis. Ethics extend beyond the human and include the more-than-human. Whenever financially possible, I offset my flights to Brazil to at least support projects that reduce greenhouse gas emissions. Throughout my research, I tried to incorporate the voice of the more-than-human (Barad 2007), such as infrastructures or marine species and environments (see chapters 4, 6, 7).

The collected data including audio records are stored on a password protected cloud only I have access to. I also acknowledged the work and knowledge of non-scientists, such as technicians, data managers, or translators as part of knowledge co-creation in MCOs. I consider their contributions and that of co-authors or reviewers in transparent acknowledgements to make the shared work and efforts visible.

Ethnographic research is partial and situated and influenced by access, time, and context of the field (Hammersly and Aktinson 2019). As already explained, the selection of the cases – knowledge production processes in Brazil and Germany – were determined by the project the research was embedded in. Thus, most of the interviewees' selection was also based on the project and extended by humans who were in proximity to the projects, as interviewed people working on and with MCOs. This could lead to an exclusion of some and an overrepresentation of others (Palinkas et al. 2015).

Because of institutional, visa-related reasons, the fieldwork was conducted in episodic returns (Günel, Varma and Watanabe 2020), which can be a limitation, but it allowed me to follow-up iteratively and to observe the in-between moments influenced by time, movement, and constant coordination.

The regulations of the COVID-19 pandemic have led to limitations, too. Wearing masks in the laboratories and during the first week on the research vessel, as well as during the first project meetings hindered the analysis of human mimic, which is very important as a form of bodily communication, as it sometimes speaks more than words (Mehrabian 2017).

I also want to emphasise that I inadvertently contribute to the overrepresentation of perspectives of the Minority World in scientific knowledge production (Collyer 2018). My embeddedness in German and EU research funding allowed me to conduct multi-sited fieldwork, participate in (inter-)national conferences, and covered publication fees in international journals. By reflecting on my intersectional positionalities and micropolitics, I am aware that I cannot be neutral and that my presence in the field might have altered some of the observations in the field. With my micropolitical power of deciding which and how data is analysed, I contribute to a certain degree to selectivity (Tracy 2010). Similarly, as German is my mother-tongue, and most interviews were conducted in English and some in Portuguese, technical vocabulary or humour might have been misunderstood or missed. Yet, careful back-translation and triangulation improved this limitation.

Triangulation across field notes, thick description, interviews, literature reviews, visual documentation, and autoethnography across research sites, support the robustness of the findings. The developed concept of Intra-Active Observation Assemblages (IOA) as a mid-range concept (see section 8.2) offers analytical lenses and patterns, but it does not provide universal claims, which is also a goal the research never aimed at, as in line with Keller (2011, 61) an “ultimate truth” cannot be found, but rather an understanding of the underlying factors influencing knowledge production processes.

Further limitations and ethical considerations are also reflected in each of the following finding’s chapters (see chapters 4 – 7) as there are dependent on the research context and diverse localities, as well as the human and more-than-human research participants.

Chapter 4

Following a deep-sea channel: Sensory landscape and experiential knowledge in science-making on a research vessel



Picture 6: The German research vessel Maria S. Merian (MSM) in the North Atlantic in 2021. Source: Author.

4. Following a deep-sea channel: Sensory landscape and experiential knowledge in science-making on a research vessel¹¹

4.1 Chapter summary

Little is known of deep-sea channels and their role as an effective carbon sink. How do scientists approach the deep sea, and which are their strategies to generate knowledge? To answer these questions, my research focuses on knowledge production processes along the Northwest Atlantic Mid-Ocean Channel (NAMOC) during a research expedition in the Labrador Sea. The research is conceptually guided by approaches of Science and Technology Studies (STS) and New Materialism. Methodologically, the study employs multi-sited ethnography and uses multi-modal materials including participant observation and semi-structured interviews with representatives of the research vessel's crew and scientists. The findings shed light on the usually unseen practices of science-making. Sensory landscapes as well as experiential knowledge were identified as two modes of following, researching, and knowing the NAMOC.

4.2 An epistemology of a deep-sea channel

Underwater canyons and their diverse channel systems constitute landscapes in the deep sea. Similar to the shape of rivers, valleys and mountains on land, these submarine channels are part of the earth's biogeochemical cycle by transporting and redistributing carbon and nutrients to the deep sea. This is done by so-called turbidity currents, gravity-driven avalanches, which deliver sediment and carbon through these submarine canyons from shallow to deep water. In their effective role as carbon sink, they sink in carbon into the ocean's seabed. Thus, the morphology and sedimentology of deep-sea channels can provide insights into their effectiveness as a carbon sink of the past and create a basis for the analysis of possible future scenarios on global warming (Krastel and Mosher 2022). Yet, little is known of the deep sea and its channels, due to difficulties in measuring these

¹¹ This chapter has been published in the *Berghahn journal Nature and Culture*. Citation: Haegele, R. (2024). Following a Deep-Sea Channel: Sensory Landscape and Experiential Knowledge in Science-Making on a Research Vessel. *Nature and Culture*, 19(2), 209-235. <https://doi.org/10.3167/nc.2024.190205>. This article is available open access under a CC BY 4.0 license.

in-situ (Talling et al. 2015). Mapping narrow channels like the Northwest Atlantic Mid-Ocean Channel (NAMOC) especially constitutes a challenge (Krastel and Mosher 2022).

The NAMOC is one of the longest submarine channels in the world with a length of more than 3,800 kilometres, between four and five kilometres wide and one hundred meters deep, unfolding from Hudson Strait through the Labrador Sea to Newfoundland Ridge in the North Atlantic. Besides the gap of knowing the NAMOC's morphological details, a gap in understanding how scientists map, document and analyse the channel they cannot see with their own eyes exists. This includes the exact processing and practices of researching the channel itself. These observations led me to ask: How do scientists approach the deep sea and its channels, which are the strategies to produce knowledge during the expedition?

To answer these questions, I examine knowledge production processes along the NAMOC during a seven-week research expedition I participated in (see figure 5). The expedition mapped previously undiscovered large parts of the NAMOC by following the channel for approximately two thousand kilometres and taking sediment samples up to 4526 meters deep. The research is rooted in discussions within the Sociology of Knowledge (SoK) as well as conceptually guided by approaches of Science and Technology Studies (STS) and New Materialism as lenses, as well as socio-material entanglements in knowledge production processes. Methodologically, the study employs ethnographic fieldwork including participant observation, field notes, photo and film documentation of work processes and practices, and semi-structured interviews with representatives of the research vessel's crew and scientists, as well as autoethnography.

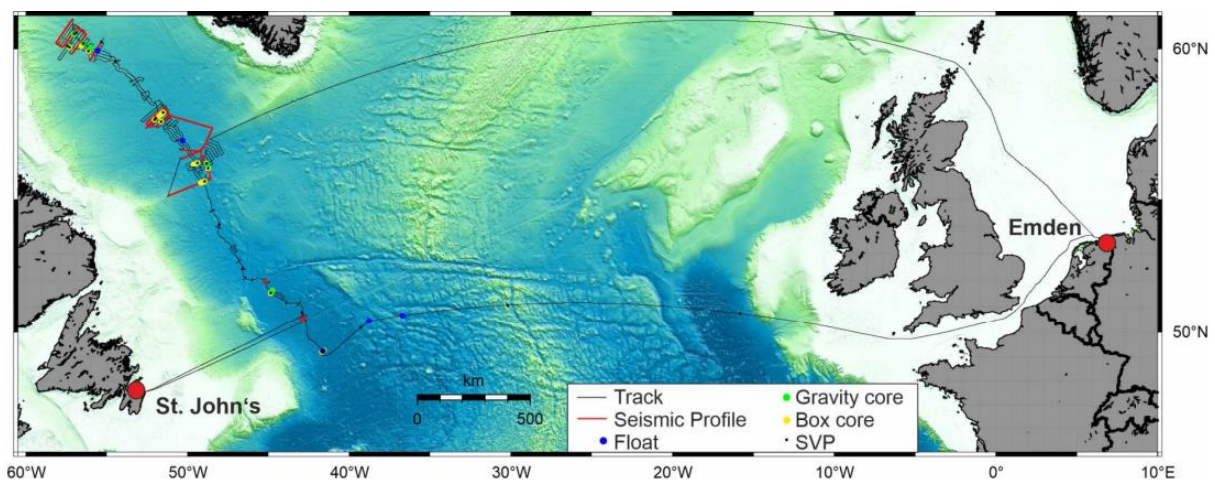


Figure 5: Track of the research cruise I participated in including detailed track of the working area (NAMOC) between Newfoundland, Canada in the West and Greenland in the East. Source: Krastel et al. (2021, 8).

Earlier studies by Knorr-Cetina (1983), Star (1985), and Latour (1987) already emphasised the importance of following scientific practices to grasp and understand the lived reality of science and its practitioners, such as negotiation processes or hierarchies in science-making. There is power involved as the way in which a problem is framed determines its solutions. Therefore, my examination of everyday practices of knowledge production on a research vessel aims to shed light on the behind-the-scenes practices of science-making. By following the NAMOC at multiple stations and water depths and across physical boundaries, the study moreover employs multi-sited ethnography (Marcus 1995) in an innovative fashion by conducting fieldwork at different places, for instance on land and at sea. It moreover aims to incorporate multiple sites of meaning-making and its dynamism in line with the mobility turn (Mielke and Hornidge 2017; Sheller 2017; Urry 2016). Instead of following solely human actors, following the NAMOC and the research vessel's technologies as non-human actors, the study aims to overcome anthropocentrism and takes greater account of the role of materialities in knowledge production processes (cf. Gesing 2019; Latour 1992)

The findings shed light on the strategies researchers are using to generate knowledge by closely observing how scientists define what a deep-sea channel actually constitutes. Moreover, the study aims to contribute to recent STS and New Materialism literature by both integrating the material methodologically and considering the constant flux between nature, technology, and society rather than outsourcing them ontologically (Bogusz 2018; Spence 2014).

4.3 From research vessels and following things: Literature review

Among scholars researching expeditions, Sorrenson analysed the ship as a scientific instrument by taking into account its physical form and its prime task: “probing the unknown” (Sorrenson 1996, 226). His work focused on the history of marine expeditions of the eighteenth century (ibid.). Adler (2014) continued Sorrenson's work by looking at the development of a “ship as instrument” to a “ship as laboratory” to a “ship as invisible technician” in the nineteenth and twentieth centuries. He noted that research vessels nowadays predominately deploy remote sensing techniques, which leads to data being analysed on land and no longer on board of a vessel (ibid.). Similarly, Laloë

(2012) analysed the ship from an historiographic point of view as an active space, ascribing agency to the vessel in knowledge production processes.

Ethnographic research on research vessels and marine sciences generally is still rather rare. An early example constitutes Bernard and Killworth's (1973) work, who conducted an ethnographic and mathematical analysis on a vessel by using social network analysis. They found the social network on a vessel guided by structured hierarchies on board, which influences the organization of work at sea (please see Hasty and Peters 2012; Sampson and Schroeder 2006 for further analyses of vessels through a geo-political lens). Helmreich (2008, 2009b, 2021) conducted ethnographic research on submersible and research vessels showing how soundscapes (2008), spaces (2009a), and perspectival shifts (2021) influence research on the deep sea, microbes and waves, thereby taking into account marine biodiversity. More recent studies by Hornidge (2020) deal with knowledge production processes on a German research vessel and the pluriverse of epistemes shaping the latter. Hornidge looks into bodily communication on the research vessel and describes the vessel as a socially constructed science island (ibid.). Bogusz (2018) accompanied a large-scale expedition in Papua New Guinea and followed researchers in a laboratory, along the coast and on a research vessel. She found that heterogeneous cooperation and transdisciplinary co-laboratories were only partly achieved, mainly caused by the missed opportunity of a mutual problem definition before the expedition (ibid.).

The aforementioned studies predominately focused on social and human-human interactions in meaning-making at sea, rarely considering non-humans, materiality or human and non-human interactions comprehensively. STS scholars such as Knorr-Cetina (1988) and Latour (1987, 1992) followed scientists in the laboratory and in the field, or in sampling soil in the Amazon forest, to demonstrate the social construction of scientific facts (cf. Berger and Luckmann 1966; Latour and Woolgar 1986). Siriwardane-de Zoysa and Hornidge (2016) go beyond human entanglements by un-humanising the concept of lifeworlds in marine sciences. Moreover, further STS and new materialist literature that looks into human and non-human interactions in science-making do not focus on marine spaces, such as Vertesi (2012) who researches embodiment on a Mars

exploration rover mission or Harris (2005) who considers embodied skills of fisher people in the Amazon forest.

Despite the findings of these few studies and their contribution to (marine) ethnographies and STS, there are still plenty unknowns regarding epistemic processes of researching the deep sea, which takes into account scientist's approaches and strategies to conduct their research, as well as their interactions with non-human actors. Moreover, an empirically based understanding of the micro levels in knowledge production processes, such as on board a research vessel while including multiple sites of meaning-making, within marine sciences has received very little attention.

Due to globalization and associated changes in social orders, ethnography moved from its traditional single-site observations to the tracing of people, things, metaphors, plots, lives, or conflicts (Marcus 1995). The mobility turn (Urry 2000) reinforced this trend by moving from researching geographically fixed spaces to more connectivity and fluidity in science-making (Mielke and Hornidge 2017; Urry 2016). This tracing of things gained high popularity in ethnography and was applied, adapted and interpreted differently in multiple studies. Multi-sited ethnography was taken up by STS (Latour 1987; Haraway 2006), media studies (Escobar et al. 1994), and more specifically environmentalism linked to commodities (Cook 2004), biotechnology, and modes of digital communication (Marcus 1996; Beaudry and Kananian 2013). Even though Marcus' work on the emergence of multi-sited ethnography (Marcus 1995) was published nearly three decades ago, it is still considered as a relevant and necessary approach (Gagnon 2017). Following the research vessel exploring the NAMOC in different parts of the ocean, such as the surface and different water depths, as well as diverse research stations of the scientists and the fluidity between geographically fixed and virtual knowledge production sites, provides an opportunity to construe Marcus' approach innovatively. This study rather employs multi-sited ethnography in a way that enables the consideration of multiple sites of meaning-making and its dynamism in line with the mobility turn by incorporating the agency of people, places and the more-than-human (Mielke and Hornidge 2017; Sheller 2017; Urry 2016).

The presented research initially focused on the scientists. However, once in the field, an inductive approach allowed me to follow "objects of interest," other people and things,

mainly the crewmembers, but especially non-human actors, such as the vessel, its (marine) infrastructure, and the NAMOC itself. Thus, the study contributes to Marcus' "strategically situated (single-site) ethnography" (Marcus 1995) because the ethnography takes place on a single-site – the research vessel – yet it is guided by the external factors and types of knowledge from the outside world shedding light on the fluidity of knowledge production processes contributing to discussions on the mobility turn (Hornidge et al. 2020; Mielke and Hornidge 2017; Sheller 2017; Urry 2016). My understanding of a multi-sited ethnography was informed by McAdam-Otto and Nimführ's (2021) conception of a multi-sited ethnography within one locality, which enables the inclusion of sites researchers are not able to physically visit. Though the research vessel itself, the data it receives and sends through internet and satellite, the crossing of international borders and even international waters and thus is prone to (inter-)national law, I argue that a multi-sited ethnography does not necessarily need to take place transnationally. It rather needs to map the complexities and potential contradictions of a single-site and its multi-sited entanglements.

In conclusion, there is manifold research on historic expeditions, but analyses on expeditions through an ethnographic sociological lens remain limited. The "follow the" debate is highly contested in social sciences. Although Marcus' multi-sited approach is criticized for being inapplicable in today's globalized world (Hulme 2017), I claim that globalisation and especially technologisation enable the tracking of things at first without being physically present at all sites, while simultaneously being able to investigate how non-human actors help to shape human understandings of the world.

4.4 An ethnography: Methodological and conceptual framework

My research is rooted in social constructivism, discussions in knowledge sociology, conceptually guided by approaches of Science and Technology Studies (STS) and New Materialism and inspired by laboratory studies (Barad 2007; Berger and Luckmann 1966; Fox and Alldred 2017; Latour and Woolgar 1986). Social constructivism understands knowledge as built upon sets of beliefs humans use to interpret certain phenomena. It thereby considers the diversity of worldviews and realities constructed within social groups over time (Berger and Luckmann 1966).

Geertz (1973, 5) argued that “if you want to understand what a science is, you should look in the first instance not at its theories or its findings, and certainly not at what its apologists say about it; you should look at what the practitioners of it do.” Therefore, the scientists on board the research vessel and their approaching of the NAMOC, as well as their interacting with non-human actors serve as both the main unit of analysis and the field. Diverse research settings, such as laboratories or research vessels, influence the generation and negotiation of knowledge in interactions within and between researchers. The production of knowledge is further shaped by interactions of researchers and non-scientists, for instance policy makers or lay people, as well as through technology dependence. My study therefore adds STS approaches that analyse how science, technology and society shape and influence each other (Harding 2008). New materialist approaches emphasise the materiality of the social and natural world, which are in constant flux. Moreover, these approaches take into account emotions, desires, affect and meanings as forces in producing the social world (Barad 2007; Fox and Alldred 2017), a lens this article is using as well. STS and New Materialism approaches no longer look at explanations or mechanisms of social structures, but at “events” that explain “the continuities, fluxes and “becomings” that produce the world around us” (Fox and Alldred 2017, 7). As such, the knowledge production processes observed and the coding patterns that emerged while analysing the data are events (Hertz and Mancilla García 2019), both singularities and pluralities, which are continuously reoccurring and shape the knowing of the NAMOC.

Only everyday observation of research practices and knowledge production will show what constitutes the underlying factors that influence science-making. The aim of the study is not the “ultimate truth” (Keller 2011, 61), but rather an understanding of the “how” of knowledge production processes. Thus, I follow an explorative and descriptive approach while simultaneously aiming for a comprehensive reflexive and analytical interpretation of collected data (ibid.).

To follow the NAMOC and to observe the approaches and strategies of the scientists, I joined a seven-week geomorphological expedition on a German research vessel in the North Atlantic and Labrador Sea. Specifically, I 1) assisted in hydroacoustics and sedimentology aiming to map the NAMOC and gain insights into its morphology; 2)

deployed nine so-called BGC-Argo floats, which are biogeochemical autonomous diving buoys measuring the ocean's salinity and temperature in the upper 2000m, thereby providing essential inputs for climate change scenarios; and 3) (auto-)ethnographically documented everyday life and (research) practices on the vessel from an epistemic perspective.

During the seven-week expedition, I conducted 37 audio-recorded semi-structured interviews with 20 out of 24 crewmembers and 15 out of 16 scientists (including myself) on board ranging from 20 minutes to two hours, providing almost 38 hours of audio material. I interviewed two senior scientists twice, at the beginning and during the final days of the research to reflect on the experienced cruise. Questions ranged from everyday life on a research vessel including the scientist's and crewmember's social interactions as well as the technology dependence that both influence data collection, processing, and analysis (see annexes 2 and 3). Further questions referred to perceptions and emotions of crewmembers and scientists during the cruise. Findings from interviews are referenced throughout the text with "Int-number." Besides, participant observation including field notes allowed documenting working routines, the processes of data and sample collection, in-team negotiations, and the interaction between scientists and crewmembers, as well as between humans and non-humans.

All interviews were transcribed. Field notes of 55 pages serve as an additional corpus of material. For interpreting collected data, I used the *Atlas.ti* software, an extensive tool facilitating the analysis of qualitative data by coding the data both deductively and inductively, starting with a set of created codes while simultaneously adding additional codes. I used an ethnographic coding scheme to search and discover patterns of themes in the data. Ely et al. (2003, 150) define a theme as "a statement of meaning that 1) runs through all or most of the pertinent data, or 2) one in the minority that carries heavy emotional or factual impact". The frequent reoccurrence of a theme makes it a pattern. Thereby, the co-occurrence of the same pattern in multiple interviews makes it a regularity in the data (Hatch 2002).

Besides, I want to note that in line with Haraway (1988), I am aware of my own positionality, and I cannot master "the god trick" (ibid., 582) of being fully objective. I experienced the first two weeks on the vessel as very challenging, since I was neither part

of the crewmember's in-group, nor a full member of the natural scientist's group. Some scientists, especially the younger students, perceived me as an alien element and as someone who supplants one of the very limited spots for scientists on a research vessel. One student referred to social sciences as “no real science” (field notes 04.08.2021). Moreover, my research endeavour received only second-rate importance, since it was not part of the main goal of the expedition: mapping the NAMOC's morphology. Thus, I felt very insecure, solitary and excluded. Yet, after I started conducting the interviews, I felt increasingly accepted by both social groups. Some crewmembers called me a “psychologist” or a “social worker” (field notes, 16./19.08.2021) and advertised my interviews among their colleagues. Consequently, interviewees trusted and confided in me. They shared their personal life stories, such as the difficulties of living between land and sea (Int-12; Int-20; Int-26, all male crewmembers), failed relationships (Int-15; Int-18; Int-21, all male crewmembers), and extreme loneliness (Int-7; Int-29; Int-36, all male crewmembers). The chief scientist conceded that he never thought I could conduct so many interviews, particularly with crewmembers since they usually stay in their comfort zone (field notes, 07.09.2021). As a result of this newly gained trust among crewmembers, the scientists were impressed and increasingly shared their emotions with me, such as anger and sadness, for example a scientist started to cry during the interview due to homesickness (Int-10; junior female marine scientist). I also want to share that during the time on the vessel, I slowly had the feeling of ‘going native’ by participating in everyday shifts and spending my limited leisure time with crewmembers and scientists. Yet, every evening I wrote field notes, trying to make note of the daily processes as seeing and experiencing them for the first time. In line with Boyer (2008) and by taking into account my own positionality, I treat the natural scientists observed as human subjects and not solely as rationalists.

4.5 Knowing the NAMOC through sensory landscape and experiential knowledge: Findings

The aim of the expedition was to map large parts of the so far undiscovered NAMOC to understand its turbidity currents and its effectiveness as a carbon sink. These findings create a basis for the analysis of possible future scenarios on global warming. The

ethnography of science-making on the research vessel allowed disclosing usually unseen research practices, such as the use of researcher's senses and experiential knowledge, and enabled me to sketch out the sensory landscape of knowing the deep-sea channel. For example, one interviewee reflected:

“You try to pick out based on all the data that's available [...] the places that seem to you the most relevant, where you can learn the most, and that's just [...], that's really experience and also feeling and sometimes a little bit of luck as well” (Int-35, senior male marine scientist).

The following sections show examples of scientist's and crewmember's use of senses and experiences in knowing the deep-sea channel. Researchers frequently used their “gut feeling” (Int-13, female junior marine scientist) in hydro acoustic data collection, their senses of sight, taste, smell, sound, and touch in determining sediment grains and deploying an autonomous diving buoy. Experiences, such as former maps of the channel helped scientists map the NAMOC, fix technologies, and decide on sediment coring stations, as section 4.5.2 will demonstrate.

4.5.1 Sensory landscape

“At the beginning [of software based first-level data processing], because I never done it before, I was rather cautious and didn't delete so many points [laughs], and now I'm more careful about that [laughs]. Because you do it more often and then you have the feeling that, no, you can take away even more [...]. And I proceed [hesitates] no idea, so by learning, no idea, so intuitively.” (Int-10, female junior marine scientist)

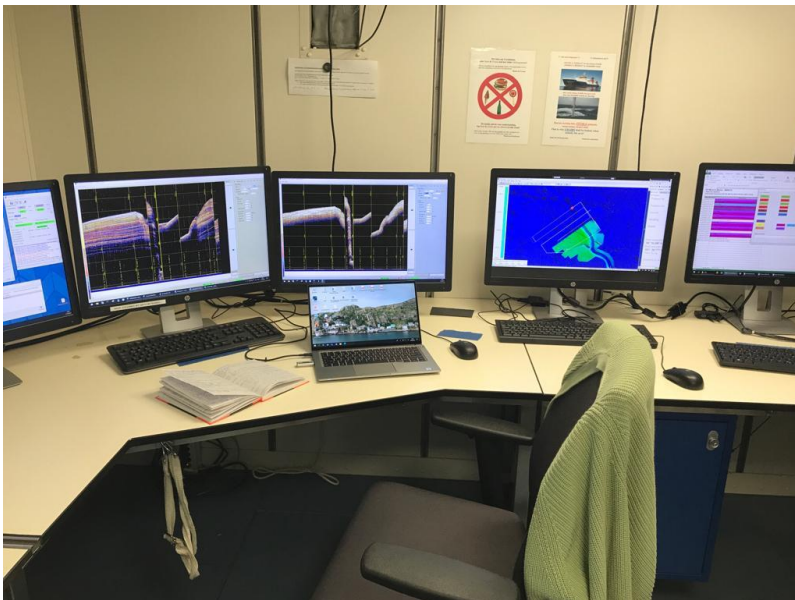
One of the identified unseen research practices scientists use in knowledge production processes constitute their sensory landscape. In the following, I will provide three examples of knowledge production processes, which were guided by scientist's and crewmember's sensory landscape.

Following “your gut feeling” means knowing the NAMOC

The expedition followed the NAMOC for approximately 2000km. Mapping the NAMOC was a crucial part of the everyday knowledge production processes onboard. Mapping the NAMOC requires the hydroacoustic systems and high-resolution-reflection seismic, as well as sub-bottom profile data for crossing the NAMOC at several locations. Emotions of uncertainty emerged in team meetings and negotiations discussing on how and where to follow the NAMOC exactly. This corresponds with the uncertainty of the formation of the NAMOC itself, its shape and multiple side channels and the fact that researchers themselves cannot experience, see, and touch the physically inaccessible channel. So far, limited data exists on the NAMOC and its characteristics, so that natural scientists need to use imprecise language for describing the formation of the deep-sea channel, such as “it is believed that the most profound influences on the basin's modern geomorphology resulted from high sediment fluxes” (Krastel and Mosher 2022). Yet, “to believe is not to know” (Weingartner 2018, 113). As such, scientists and crewmembers have to deal with uncertainty in researching and following the NAMOC. They also have to rely on remote technologies to map the channel, since it is out of human reach and thus makes it another site of meaning-making (cf. Sheller and Urry 2006; Siriwardane-de Zoysa and Hornidge 2016).

The hydro acoustic data collection is digital and recorded with a software, but the scientists need to follow and observe the moving seabed on seven computer screens using their senses (see picture 7). Every time the seabed moves, the scientists manually click up or down an arrow within a software to not lose track of the NAMOC. They need to rely on their sensory landscape, especially seeing and their “gut feeling” as one interlocutor puts it (Int-13, female junior marine scientist). I worked in the hydro acoustic shift as well. In the beginning, I felt insecure and was afraid to lose the moving seabed on the computer screen, but with each shift my insecurity vanished. During 24/7 watches, the scientists were trying to follow the NAMOC by using previously mentioned hydro acoustic systems. Usually, one scientist sat in front of seven computer screens following a set of diverse software on the ground floor laboratory of the vessel, while another scientist sat on the bridge together with an officer trying to follow NAMOC physically. The scientist on the bridge had the tough job of indicating how many degrees starboard or

larboard the officer should navigate the vessel. There was no concrete procedure, and scientists had to decide the degrees intuitively (field notes, 04./06./09./14./25./28.08.2021). For making decisions, “you need to work a lot with your gut feeling” (Int-13, female junior marine scientist; cf. Int-35, male senior marine scientist) during the process of following the seabed and navigating accordingly, since you do not know for a fact toward which direction the channel extends. In moments of insecurities, the scientist on the bridge and the scientist in the laboratory communicated via mobile transmitter to find an agreement in which direction the officer should direct the vessel. Sometimes, diverse types of knowledge are interacting (Hornidge et al. 2020; Mielke and Hornidge 2017) when the officer in charge shares his intuition of how many degrees to navigate the vessel to follow the channel (field notes 04./09./14.08.2021). Afterward, the scientists had to first-level process the data of the results to receive a readable map of the seabed (see figure 6). Again, deciding on which pixels of the map to keep and which ones to remove represents a process based on “intuition,” “feeling,” and sensory knowledge (Int-10; Int-13; Int-16; Int-25, all female junior marine scientists; Int-24, male junior marine scientist).



Picture 7: Observing the moving seabed during a nightshift in the laboratory on the vessel, 17.08.2021. Source: Author.

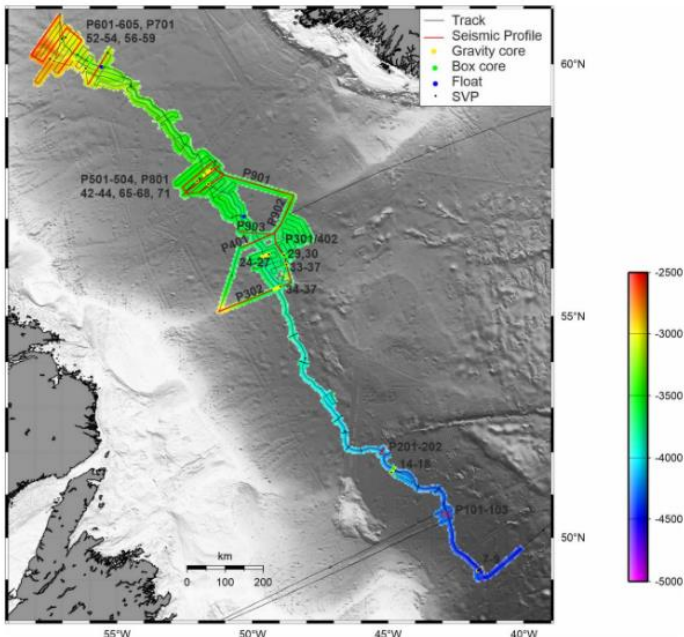
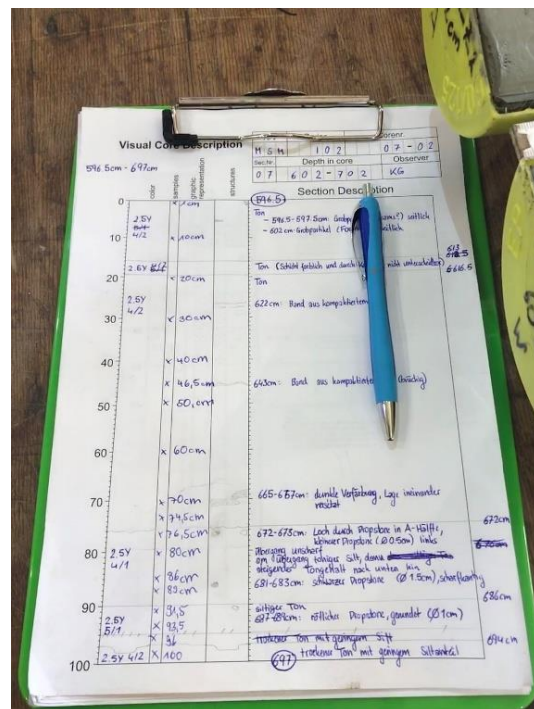


Figure 6: Detailed track chart of the working area of the cruise. Source: Krastel et al. (2021, 9).

Sensing sediment: Tasting, smelling, seeing, and touching grains

After having collected the data for an underwater map of parts of the NAMOC, the scientists come together for a meeting and mutually decide where to take sediment samples (see section 4.5.2). Sediment cores at 24 stations were taken throughout the cruise. Once decided where exactly along the NAMOC sediment cores or samples should be extracted, constant remote communication between scientists, bridge and deck crewmembers via mobile transmitter enables the correct positioning of the station. Thus, multiple sites of meaning-making intersect during these procedures. Right before the extraction of the sediment cores with the instruments of a standard gravity corer and a giant box corer, the scientists always estimate how many meters will reach the deck based on their intuition (field notes 30.07./05./07.–13./24./28.08.2021). The post-doc responsible for the sedimentology always feels nervous and excited in those moments (Int-1, senior female marine scientist). The uncertainty and nervousness increase until the gravity corer or giant box corer reaches the surface again, which can sometimes take up to two hours depending on the water's depth (field notes 07.08.2021).

Once on deck, the up to 10m long sample and the gravity corer are cleaned. The team then carries the heavy pipes filled with sediment to the respective station where they measure them and cut them into 1m long pieces. Afterward, the 1m pieces are marked with 1) the cruise number and position, 2) the date, 3) length in cm, 4) a line where the core will be cut, and 5) “A” for archive and “W” for working. One part of the cut cores will be refrigerated and archived for analysis back in Germany, and the other part will be examined during the cruise (see picture 8). During this procedure, scientists exchange on the smell, heaviness, and colours of the sediment by using their sensory landscape of touching, seeing and smelling (field notes 30.07.2021). I followed this process multiple times and experienced it as sculptural work in an almost artistic way.



Picture 8: First-level analysis of a sediment core, 02.08.2021. Source: Author.

Picture 9: Visual core description, 02.08.2021. Source: Author.

After cleaning the cut cores, each section receives a handwritten description; the scientists photograph them and determine the grain sizes within each core: clay, silt, sand, gravel, and stones. Each scientist works on one sediment core, takes little samples out of the cleaned cores, and smears them between their fingers or on the backs of their hands to define the grain size based on feeling of softness, roughness, or creaminess. I observed two students who even tasted the sediment to feel if it crunched between the teeth to differentiate between silt and clay. This is why geoscientists are named *Steinelecker*, which literally translates into stone lickers, especially by

geophysicists, as one student discloses (Int-3, junior female marine scientist). Afterwards, the scientists use coloured templates to define the sediment's colours. All information is documented manually and digitally. The scientists fill out a document (see picture 9) indicating visual core description, colour (using a handbook with colour schemes), graphic representation (cm), structure (painted on document), and section description (how do transitions look, are there pebbles, different layers, etc.). When asking the scientists how they decide where exactly to take the grain samples with a plastic syringe, they answer they take the samples depending on the transition, on particularities, and on each new layer they find “interesting” (Int-3; Int-33, both junior female marine scientists). Yet, when asking the researchers how this intuitive decision is reflected in legitimising their scientific findings, they negate the use of sensory landscape (ibid.). Afterwards, they seal resulting holes with Styrofoam. Finally, the scientists wrap the cores in cling film, then in d-tubes and seal them with waterproof tape (field notes 10./12./13./24.08.2021).

I experienced the geomorphological work similar to qualitative data analysis. The core cleaning has craft-like, almost artistic traits. The initial analysis consists of purely descriptive and visual data, such as the description of the layers and the reliance on sensory landscape, especially the touching, seeing, smelling and even tasting of the sediment (field notes 12.08.2021).



Picture 10: Preparing a BGC-Argo float for deployment (see next section), 29.07.2021. Source: Author.

Vibrating senses: Deploying a float

Throughout the expedition, we deployed nine BGC-Argo floats (see picture 10), which are biogeochemical autonomous diving buoys measuring the ocean's salinity and temperature, as well as other chemical elements depending on the sensors, such as nitrate or oxygen, thereby providing essential information for climate change scenarios. Their data contributes to the Global Carbon Project and the Intergovernmental Panel on Climate Change Report (IPCC), crucial in providing assessments of climate change and its future impacts as well as policy advice. Moreover, the data could be compared with the findings of the NAMOC, which can provide insights into the effectiveness of deep-sea channels as a carbon sink of the past and future (Krastel and Mosher 2022).

As the sole person responsible for deploying floats during the cruise, I employed an autoethnographic approach, relying on my own senses and emotions. Despite being a social scientist with no prior experience in float deployment, I felt a constant sense of insecurity (field notes 29./30.07./15./19.08.2021). Access to the research cruise was granted through a colleague's personal connection with the chief scientist, highlighting power asymmetries in the German science system. I was not involved in the negotiation process, but gaining access to such a research expedition that has limited space and capacities requires personal connections, which was confirmed during my interviews (Int-3; Int-10; Int-13; Int-16; Int-25; Int-33, all junior female marine scientists; Int-5 Int-24 Int-32, all junior male marine scientists).

The deployment of the first floats did not work out as planned. Once on deck, the floats need to be activated. This is usually done by removing a heavy magnet and waiting for a continuous beeping sound. Yet, no sound appeared after thirty minutes. After continuous exchange via (satellite) telephone, voice messages, and pictures via text messengers with colleagues in Germany, we figured out that the float's manufacturer had changed the procedure of activation (field notes 29.07.2021). Instead of a beeping sound, the float starts to vibrate and to sprinkle water caused by the internal activated hydraulic pump thereby signalling it is ready for drifting. Without the vessel's internet connection and telephone, a deployment would not have been feasible. Including these multiple sites of meaning-making on land enabled the knowledge travel, which led to a successful float

deployment at sea, and demonstrates the movement of objects, people, and ideas (Cresswell 2011; Hornidge et al. 2020; Marcus 1995).

Due to the foggy weather conditions, the noisy environments caused by the vessel itself, the waves and crew's rust removing in the hangar, it was extremely difficult to hear and feel the vibrating float. Hence, I had to trust my remaining senses, emotions and gut feelings hugging the float, feeling and hearing its vibrations and its spattering water (field notes 29.07.2021). With each new float deployment, my insecurity vanished. Interviewees confirmed the intersection of sound and feeling: “Yes, it [the vessel] is always loud (laughs). [...] It has many different sounds. In the meantime, you can feel whether the ship feels comfortable or not. [...] You have one foot on the ground, and you know: there is something wrong” (Int-18, senior male crewmember). Another interviewee referred to sound and smell as an indication that something is wrong on the vessel (Int-22; junior male crewmember). These statements show that scientists and crewmembers do not only rely on their senses but already internalized the sounds and movements of the technologies and the vessel, which touch their bodies and thus only enables knowledge production processes. The quotes moreover show that the combination of diverse types of knowledge, by crewmembers and researchers, facilitates science-making.

4.5.2 Experiential knowledge

“Well, I've been doing what I'm doing for quite a long time, and I've seen a hell of a lot and had a hell of a lot of technology in my hands. And it's always the case that we don't have that many technicians, and as a doctoral student we also did a lot of the technology ourselves. So, I can operate everything we do here technically and also disassemble and reassemble it technically. So if something doesn't work, I think I have a relatively large wealth of experience and can say that it's because of that.” (Int-2, senior male marine scientist)

Besides sensory landscapes, experiential knowledge of scientists and crewmembers in science-making and experiences with non-human actors, such as technologies, represent another mode of knowing the NAMOC.

Follow former NAMOC maps and previous experiences

Due to the NAMOC's large-scale and uncertain pathway, including multiple side channels, researchers have to rely on previously collected data and experiences from other expeditions. This especially applies to the southern part of NAMOC, for which “transit data from other expeditions that crossed portions of it” (Krastel and Mosher 2022) were used.

Previous experience and data gained by other natural scientists with different research questions contribute indirectly to the research. This also applies to previous experiences of data collection, which was hindered by error-prone technology (Int-2, senior male marine scientist), weather conditions (Int-31, senior male crewmember), or ineffective leadership (Int-9, senior female marine scientist). Experiential knowledge and potential problem solutions are shared and sustained. Following experiential knowledge facilitates future research (Int-23, senior male marine scientist) scientifically but also individually. The travel of types of knowledge between different hierarchical levels of scientists and between crewmembers and scientists enables following the NAMOC. One interviewee explains her gained experience by the chief scientist: “So if I'm kind of going off track or getting anxious or nervous about something, he [the chief scientist] can just really bring me back onto track [...]. I think a lot of that is experience, but a lot of it is also who he is” (Int-9, senior female marine scientist).

Flows of ideas and experiences with colleagues not being physically present on the vessel adding their experiential knowledge, but virtually, highlight the mobility turn in knowledge production processes away from geographically fixed spaces of science-making (Marcus 1995; Mielke and Hornidge 2017; Sheller and Urry 2006). The different experiential types of knowledge of physically present and absent scientists and crewmembers on board are taken into account in decision-making processes, for example in recovering sediment samples. Thereby, the bosun advises the scientists on safety measures, while recovering the giant box corer. Yet, the people in more powerful positions, such as the chief scientist, the master, bosun or chief officer always need to make the final decision after mutual negotiation processes, which points to power dynamics on board but also to the required hierarchy for the sake of security (field notes 07.-10./18./19./22./27./30.08.2021).

Knowing technology, knowing how to fix it

The crewmembers and the scientists have delegated non-humans (cf. Latour 1992) some of their work. On the vessel are diverse winches that help deploy heavy instruments, mobile transmitters to communicate from bridge to deck, or the dynamic positioning program that helps the vessel to hold its position during sampling. Without these instruments data collection at sea would not be possible, which shows technology dependence. Yet, this reliance does not account to the streamer (field notes 18.08.2021).

Mapping the NAMOC involves deploying a seismic streamer, a process that demands precision. Despite routine deployment, the streamer often required recovery due to malfunctions in its sections, causing delays and significant effort. The intricate procedure involves careful handling of sensitive connectors, secured with tape, foam, and cable ties to prevent air bubbles (see pictures 11 and 12). Experienced scientists and crewmembers are crucial for testing, replacing, modifying, and retesting. Work at sea follows a hierarchical organization, with senior researchers guiding students in correctly handling the streamer sections, and crewmembers instructing scientists on operating the winch (field notes 24./28./31.07./03./12.–14./25.08.2021). The organization of work at sea is thus characterized by clear instructions and a diversity of (routine) knowledge.

One interviewee also referred to the extreme environmental conditions that impede the data collection with the streamer:

“So with all kinds of devices, when we take equipment with us, we try to prepare it as well as possible and keep it in good working order, but testing under real conditions is not possible. We can set it up at our home, then it all works, but it is not in moving salt water and not in wind [...]. Anything that is highly engineered is also susceptible actually” (Int-2, senior male marine scientist).

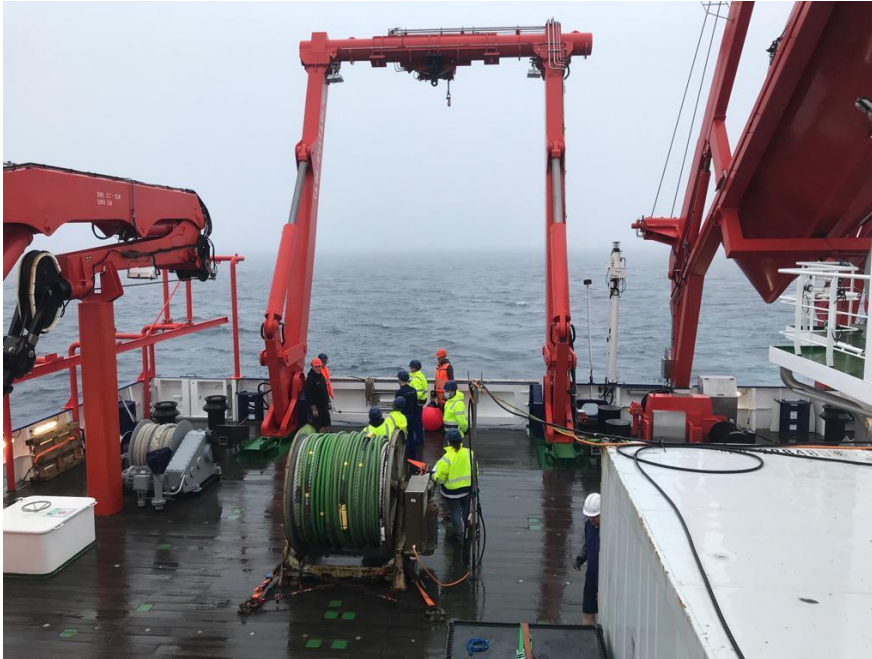
Thus, although scientists test the streamer beforehand, their experiential and routine types of knowledge show that external influences, such as changing weather conditions, might interfere with data collection. Simultaneously, due to their experiential knowledge, they know how to solve such complications.



Picture 11: Repairing a defective part of the streamer, 31.07.2021. Source: Author.

Experiential knowledge and “gambling:” Where to take sediment samples

When determining sediment-sampling locations, scientists engage in negotiation processes. Prior to sample collection, senior scientists meet to discuss the next research station, with students invited to join voluntarily. Using processed NAMOC data, they identify intriguing sediment extraction locations. The chief scientist, drawing on experience, suggests a location and seeks agreement through negotiation. When questioned about the basis for this decision, the chief scientist cites experience and “a little bit of gambling,” emphasizing the confidence gained through experience in making core extraction decisions (field notes 09.08.23).



Picture 12: Recover the defective streamer from the ocean, 28.07.2021. Source: Author.

Knowledge production on board involves various types of knowledge. When deciding on sediment-sampling locations, the chief scientist consults colleagues first and then collaborates with the master and officers to plan workforce and steps. The bosun allocates tasks among the crew, establishing a hierarchy. The crew, scientists, Officers, and crane operator engage in constant negotiation via wireless transmitter or body language to complete the sampling. This ongoing negotiation process among humans and non-humans, facilitated by the vessel as research infrastructure, is crucial for knowledge production and shared understanding (field notes 30.07./05./07. – 13./24./28.08.2021).

Hierarchies and experiential knowledge from previous expeditions intersect. One interviewee notes:

“In a certain way, there is a hierarchy, simply because this hierarchy [...] is related to experience. There are people who have more experience, who [...] from my experience, speak louder in meetings [...] when things are decided [...]. Of course, the structures on board, the fact that in principle the chief scientist is ultimately responsible for everything, means that there is at least one veto somewhere” (Int-4, junior male marine scientist).

The chief scientist, with significant experience, holds a pivotal role, but the ultimate decision-making authority lies with the captain, emphasising the highest hierarchical level on board (Int-4, junior male marine scientist; Int-14, senior male crewmember).

4.6 Sensory and experiential knowledge – a mélange: Conclusion

“I find it difficult to separate senses and experience, because they are fully conditional on each other. So, I only get a sense for it when I have also gained the experience.” (Int-25, junior female marine scientist)

The ethnography aimed to uncover scientists’ approaches to the deep sea and their strategies for generating knowledge during expeditions. The analysis showed that bodily communication and the researchers’ senses, emotions, and experiences played a crucial role in understanding the NAMOC. Sensory landscapes and experiential knowledge emerged as primary modes of approaching and defining the morphology and sedimentology of the deep-sea channel, particularly its role as a potential carbon sink. Navigating the NAMOC requires a blend of data on sediment, coordinates, positions, and bearing, coupled with individual estimations based on intuition and senses like touch, smell, taste, sight, and hearing. These strategies form an integral part of a larger sensory landscape and knowledge system, highlighting the importance of both scientific study and experiential knowledge in comprehending the deep-sea channel.

Emotions and affection are a result of sensing and link human bodies to their environments, both socially and physically (cf. Fox and Alldred 2017) and as such contribute to the production of knowledge. Unexpected events, like surprising features in sediment cores or unprecedented strong currents, trigger emotions, particularly for first-time experiences. Malfunctions in technologies and hardware evoke frustration, creating a semipermeable membrane between emotions and experiences. The role of non-humans and materialities thereby reflect the constant flux between nature, technology and society. They cannot be analysed independently. Multi-sited ethnography and the mobility turn shed light on multiple sites of meaning-making including virtual knowledge sharing beyond the vessel. These transcend boundaries between human and non-

human, nature and society, land and sea illustrate the diverse more-than-sea relations (cf. Cresswell 2011; Spence 2014).

The STS perspective illustrates that social dynamics, from decision-making to daily routines, shape science-making on a research vessel. Sensory landscapes, emotions, and experiential knowledge form a *mélange* guiding understanding of the NAMOC, with (senior) experiential knowledge playing a decisive role.

Usually, we only see the final product of science-making and not the process that brought researchers to their findings. Yet, the ethnography demonstrates that scientists do not use their sensory landscape and experiential knowledge to legitimise their findings although they are part of the science-making processes.

In conclusion, our reliance on senses and prior experiences is inherent as humans. The interplay of sensory landscapes and experiential knowledge is integral to science-making, shaping our understanding of the world. The ethnography demonstrates that researchers, both social and natural scientists, utilise (socially) constructed experiences, senses, and embodied knowledge in their scientific endeavours. This does not mean that new knowledge guided by sensory landscapes, including emotions, and experiential knowledge is not scientific *enough*, but it should be normalised and considered. Emphasising the importance of constant reflection on one's positionality during fieldwork, it highlights the need for transparency, trust, and (to some extent) objectivity in knowledge production processes across social and natural sciences. Recognising and normalising the influence of sensory landscapes and experiential knowledge in generating scientific insights is crucial.

Chapter 5

Transnational intersectionality at sea: Gender, appearance, ethnicity, age, and marine knowledge production



Picture 13: Two female marine scientists working on calibrating a sensor for MCOs in a Brazilian laboratory in Rio de Janeiro in 2023. Source: Author.

5. Transnational intersectionality at sea: Gender, appearance, ethnicity, age, and marine knowledge production¹²

5.1 Chapter summary

Knowledge production is inherently social, as humans interpret their environment. Scientific knowledge production differs from non-scientific production in its systematic data collection for validation, yet both involve a social element shaping our understanding of the world. This article investigates social contestation processes as part of knowledge production processes on a German research vessel and in German and Brazilian marine science institutes, with a particular focus on the social identity markers of gender, ethnicity, and age and how they affect team-based sense-making processes. Methodologically, our research draws on participant observation of marine scientists and associated non-scientists in their daily working routines as well as semi-structured interviews. This took place on a research vessel in 2021 and in marine science institutes from 2022 to 2024. Conceptually, the research follows approaches of the Sociology of Knowledge (SoK) and intersectional approaches that integrate transnational experiences across national borders and other (physical) boundaries. Based on this empirical research, we assess transnational intersectional sense-making practices at sea. Our findings show that (sexual) harassment in marine knowledge production processes occurs independent of localities, intersectional discrimination at sea leads either to emancipation processes or to withdrawal, and tensions arise in particular between scientists and non-scientists, which broadens the gap between these social groups and knowledge systems. We conclude by providing recommendations for a more diverse workforce at sea and in marine sciences so that the conduct of research and work at sea can be more inclusive, equal, and safe.

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5.2 Introduction

Among the “transformative ocean science solutions” in the mission of the UN Decade of Ocean Science for Sustainable Development is the aimed-for outcome of “open and equitable access to data, information and technology and innovation” during and after the decade ending in 2030 (IOC-UNESCO 2021, 8). Empowering women in marine sciences, science policy, and other marine occupations represents a crucial component of these goals (ibid.). Although the *Global Ocean Science Report* (IOC-UNESCO 2020) states that 39% of marine scientists globally are women, women remain underrepresented in decision-making and leadership roles (Shellock et al. 2022; Shellock et al. 2023; Sun et al. 2023). Only 1.28% of seafarers globally are women and these mainly work in stereotypical roles in catering and hotel sections of vessels (Kitada 2022). The maritime industry sector and marine sciences still represent homogenous work environments dominated by men (Giakoumi et al. 2021; Johannesen et al. 2023). Yet, women’s contributions are often overlooked, including their socio-ecological linkages to fisheries, maritime industries and blue economy, sustainable development, and marine conservation (Gissi, Portman, and Hornidge 2018). Besides gender imbalances in marine (science) institutes and organisations such as the International Council for the Exploration of the Sea, and a female gender gap at senior-levels (Johannesen et al. 2023; Shellock et al. 2022), barriers exist to the collection of gender-related data in marine sciences (Kitada et al. 2023). Therefore, collecting disaggregated data on gender in marine sciences on the micro-level (cf. Elliker 2017) beyond armchair analyses remains crucial and constitutes a research gap we aim to fill. We even take a further step by mapping thus far neglected intersectionality in marine knowledge production processes and analysing the effects of intersectional discrimination in working at sea.

5.3 Following seafarers, marine scientists, and technicians: An ethnography of work at sea

Our analysis is based on in-depth ethnographic fieldwork conducted on land and at sea between April 2021 and January 2024. Methods used include participant observation and go-along (Kusenbach 2003) on a German research vessel and two merchant vessels, as

well as in laboratories, meetings, workshops, conferences, and everyday work at offices in five Brazilian and German marine science institutes and universities. The country and interlocutor selections are based on an interdisciplinary joint project of Brazilian and German research institutes that aims to expand marine carbon observations (for more details see section 3.1). Our primary research interest was the analysis of knowledge production processes in marine carbon observations (MCOs). We approached the field in an explorative and inductive way and realised that topics of gender, transcultural, and epistemic (in)equalities, as well as (sexual) verbal or physical harassment and discrimination, emerged repeatedly throughout the research. As part of the research, 82 semi-structured interviews with marine scientists and (laboratory) technicians in science institutes, and with seafarers of the German research vessel *Maria S. Merian* were conducted during a seven-week expedition (for the interview questions, see annexes 2 and 3). We guaranteed the anonymity of the interviewees and audio-recorded and transcribed the interviews. Of the interviews, 30 were conducted in English and 52 in German; 35 interviewees identified as women and 47 as men. No interviewee identified as non-binary. Only one woman, compared to 25 men, worked as a non-scientist, e.g., as a crewmember of the research vessel or as a (laboratory) technician. Out of the 24 crewmembers on the research vessel *Maria S. Merian*, two were women (one of whom declined the interview request), reflecting the low proportion of female seafarers (cf. Kitada 2022). Of the interviewees, 34 females and 22 males worked as (marine) scientists.

We aggregated the information on the interviewees through the creation of categories, which makes it easier to put the referenced 82 interviewees into the context of age, gender, and ethnicity (see table 2). The term ‘ethnicity’ includes nationality as both concepts shape social identities, belonging, and group memberships. In our interviews, these concepts were used interchangeably by the interviewees and reflected their origin, culture, collective identity, and language – both applicable to nationality and ethnicity. Moreover, field notes of everyday working processes and team negotiations, as well as scientific and secondary literature, contributed to the empirical data. Besides the quantification of the categories in table 2 and the numbers in section 5.5, we want to note that we only collected qualitative data and did not aim for a quantification of intersectionality at sea. The number of interviewees ($n = 82$) and the interview questions support our claim not necessarily to reduce gender inequality, intersectional harassment,

and discrimination to quantification (cf. Morley 2011), but rather to give voice to the affected people through interview quotes.

Table 2: Interviewees (scientists and non-scientists) categorised by gender, age group, ethnicity, highest degree, country of work, and interview group. Source: Own elaboration.

Gender	Age group	Ethnicity	Highest degree	Country of work	Referred to as	No. of interviewees
Scientists						
female	19–37	Brazilian (5) Colombian (1)	BA (1) MA (3) PhD (2)	Brazil (4) UK(1) Germany (1)	Interview group 1	6
male	19–37	Brazilian (2)	MA (2)	Brazil (1) Germany (1)	Interview group 2	2
female	19–37	German (11) Sweden (1) New Zealander (1)	A-level (3) BA (3) MA (2) PhD (5)	Germany (13)	Interview group 3	13
male	19–37	German (7)	A-level (1) BA (4) MA (1) State examination (1)	Germany (7)	Interview group 4	7
female	38–62	Brazilian (10) Brazilian-German (1) Brazilian-UK (1) Mexican (1)	Post-Doc (3) Professorship (10)	Brazil (12) Germany (1)	Interview group 5	13
male	38–62	Brazilian (5)	Post-Doc (1) Professorship (2) Director (1) Vice Director (1)	Brazil (5)	Interview group 6	5
female	38–62	German (2)	Post-Doc (2)	Germany (2)	Interview group 7	2
male	38–62	German (7) Canadian (1)	Post-Doc (4) Professorship (4)	Germany (7) Canada (1)	Interview group 8	8
Non-scientists						
female	28	German (1)	BA (1)	Germany (1)	Interview 8	1
male	19–37	German (25)	Apprenticeship (5) BA (4)	Germany (25)	Interview group 9	9
	38–65		Apprenticeship (7) medicine (1)* MA (5)** PhD (3)**		Interview group 10	16
Notes: * Ship's doctor; ** Five interviewees hold an MA degree and three a PhD, but they work as (laboratory) technicians, which does not require such a degree.						Total: 82

5.4 Transnational intersectionality at sea: A research gap and a conceptual framework

Research on diversity, inequality, and discrimination in marine sciences and industry predominately focuses on gender (in)equality and thus on female scientists or seafarers. Kitada (2022, 240) researched women working in the maritime sector, where they face (sexual) harassment in their workplace or during their training. She moreover revealed that shipping companies tend to avoid employing women since their bodies are “considered as possible risks at work.” Similarly, Grasmeier (2022) reports misogynistic behaviour and masculine work culture in the cargo shipping industry. The male-dominated working culture and (sexual) harassment on a marine research vessel were also observed and documented by Hornidge (2018, 2020). Moreover, studies of early-career researchers found that junior female scientists were more likely to be downgraded from a paper to a poster presentation than male or more senior scientists at an international marine science conference (Johannesen et al., 2023). Giakoumi et al. (2021), Johannesen et al. (2022), and Shellock et al. (2022) pointed to a relative gender balance in early-career stages of ocean-going science, but to a growing gap between the number of women and men represented in senior positions, leadership, funding, and publishing. In European marine science institutes only 13% to 24% of women occupy senior positions in marine sciences and female marine scientists are less likely to be first authors on publications (Giakoumi et al. 2021). Johannesen et al. (2022) cite social norms at sea, gender-insensitive design of marine facilities, lack of security at sea, and imbalances in responsibility for family care duties as some of the reasons. Legg et al. (2023) add further reasons, such as former bans on female involvement in sea-going research, restrictions on women’s employment in oceanography, and harassment at sea. Other studies provide solutions or interventions for more equal (work) opportunities in maritime careers. McLaughlin and Fearon (2022) propose to increase female participation in seafaring by introducing policies on discrimination, raising the awareness of girls and young women of job opportunities in the sector, and promoting career counselling and female role models. Van Stavel et al. (2021) provide suggested solutions for advancing diversity and inclusion in ocean observation through self-assessment by, for example, continuously reassessing our own biases. Giakoumi et al. (2021) argue for

mechanisms that promote a more transparent hiring process and shared family responsibilities. Shellock et al. (2023) propose strategies for the empowerment of early-career female marine scientists, such as equitable access to funding, a more inclusive culture, and mentoring opportunities. Hendry et al. (2020), moreover, mention increased awareness of, and training for, chief scientists to support team members during expeditions, the provision of sanitary bins on research vessels for those menstruating, and more inclusive sizes of personal protective equipment for women and smaller people, as well as further measures to create a more inclusive environment for sea-going scientists.

So far, research on issues relating to gender, social class, age, ethnicity, or sexual orientation at sea is fairly limited, and on the issue of intersectionality even more so. Bourabain (2021), for example, studies the intersection of female early-career researchers and their ethnicity in social sciences and humanities. Shellock et al. (2022) found that 28% of interviewed female ocean researchers ($n = 34$) mention experiencing, in addition to gendered discrimination, racial discrimination and prejudice. Eaton et al. (2020) used an experimental design that showed a gender and racial bias towards the selection of post-Docs in biology and physics. Hornidge, Partelow, and Knopf (2023) look at inequalities in the marine science system, especially at the intersection of neglected knowledge systems, such as indigenous and feminist types of knowledge, and their influence on ocean governance. Yet, a research focus on intersectionality in marine sciences is so far lacking, as is research on the potential effects of intersectional discrimination and (sexual) harassment at sea.

The term intersectionality was first introduced by Crenshaw (1989, 139) “to develop a Black feminist criticism because it sets forth a problematic consequence of the tendency to treat race and gender as mutually exclusive categories of experience and analysis.” In her framework, she emphasises the multidimensional discrimination women experience due to heritage, social class, sex, race, gender, and ethnicity. In the later work of Crenshaw (1991), she introduces three different forms of intersectionality: 1) structural intersectionality, which highlights the complexity of intersectional marginalisation; 2) political intersectionality, in which intersectionally marginalised individuals experience different treatments from that experienced by white women; and 3) representational

intersectionality, which emphasises the non-visibility of intersectional identities in the media.

Although Crenshaw's framework is still influential and valid, we use the term transnational intersectionality coined by Grabe and Else-Quest (2012), which incorporates postcolonial and transboundary experiences of individuals, as well as social hierarchies. We want to note that sexism, racism, white supremacy, socially constructed gender norms, and heteronormativity are still manifested in contemporary societies (cf. Kessel 2022; Phipps et al. 2018) and that they influence power dynamics and inequalities in marine sciences. Traditional gender norms and stereotypes, historical exclusion of women in marine sciences, opposing cultural narratives, and male-dominated homogenous working environments (Hendry et al. 2020; Legg et al. 2023) still contribute to gender inequality at sea. We, as "WEIRD" (Western, educated, industrialised, rich, democratic; Henrich, Heine, and Norenzayan 2010), female researchers share the critique on mainstream and Western feminist approaches, as well as so-called Third World feminisms as overly essentialist and neo-colonial (Butler 2002; Mohanty 2003). By considering an individual's experienced discrimination along diverse intersections, such as gender, sex, ethnicity, social class, social hierarchy, and age, as well as continued cross-border dynamics (cf. Patil 2013), transnational processes, epistemic inequalities caused by (post-)colonialism, and diverse (national) science systems that may enable or continue path dependencies of, e.g., racism, rape culture, and Western sexism and misogyny (cf. Mercer 2018), we aim for a comprehensive conceptualisation of transnational intersectionality at sea.

Marine sciences and related sectors, such as shipping companies, still operate in (neo-)colonial and territorial spaces, yet the ocean remains inherently transboundary and transcultural and thus requires transnational marine governance. In line with Tacheva (2022), we argue for a transnational feminist approach, which we aim to extend to a transnational intersectionality approach in marine sciences. In our understanding, such an approach is dynamic, culturally diverse, heterogeneous, and includes different types of knowledge. We are aware of our positionality and embedded micropolitics as Western female social scientists, which can limit the scope of our research. Yet, by having collected the aforementioned qualitative data on marine knowledge production

processes, and by including the voices of, for example, women of colour, diverse age groups, and non-scientific marine staff, we aim to make intersectionality at sea and its effects on structural change in the organisation of work at sea, the blue economy, and marine knowledge production processes visible.

In doing so, we look at the micro-level of knowledge production processes through a sociological lens (Elliker, 2017). By following the scientists and non-scientists in their everyday working routines, and by conducting fieldwork in diverse places and multiple sites of meaning-making on land and at sea, we contribute to an innovative application of Marcus's (1995) multi-sited ethnography (cf. Haegele, 2024). With the help of software-based coding (*Atlas.ti*), we qualitatively analysed our collected data. During the coding, two groups ("harassment and discrimination" and "intersectionality") each with five sub-codes, evolved, as seen in figure 7. Patterns emerged as part of the analysis, which we present in section 5.5.

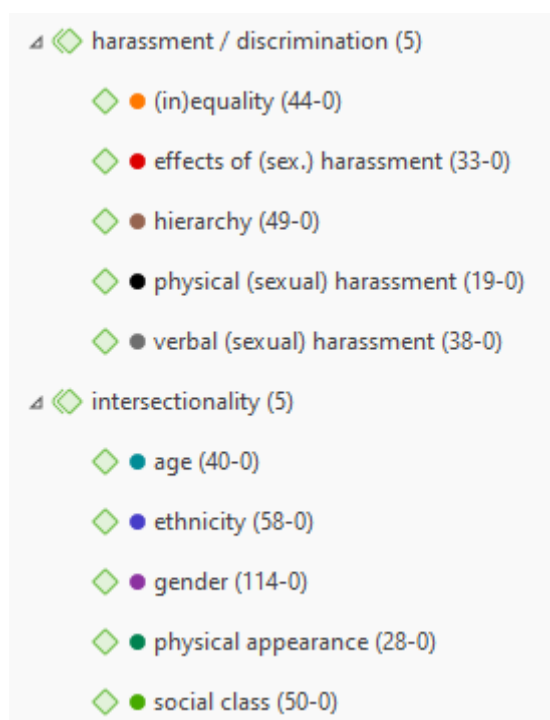


Figure 7: Coding groups and sub-codes in Atlas.ti. Note: The numbers in brackets refer to the number of sub-codes below the coding group and the frequency of the used sub-codes. Source: Own elaboration using Atlas.ti.

5.5 From diverse localities, emancipation, and withdrawal to conflicts in marine knowledge production

Our findings are structured in terms of four outcomes. First, we mapped intersectionality at sea within our empirical sample. Second, we found that (sexual) harassment in marine knowledge production processes occurred independently of the exact locality. Third, the discrimination at sea led either to emancipation processes or to withdrawal and heightened insecurities of the victims. Fourth, tensions between scientists and non-scientists broadened the gap between these knowledge systems, leading to an intersectional dilemma and thus to a potential problem of transferring and implementing marine types of knowledge and science, as we explain in more depth in the following sections.

5.5.1 Mapping intersectionality in marine knowledge production processes

During the interviews, 26 out of 35 women reported having experienced (sexual) verbal harassment. Nine women out of these 26 had also been victims of physical sexual harassment. The harassment took place on vessels, in the university, especially in laboratories, or at conferences and was always performed by older men such as senior scientists, colleagues, or crewmembers. As one interviewee said:

“We could probably be the daughters of most of them. Someone touched my buttocks; I’ve been pulled up by the waist...and I don’t think that’s appropriate... We are the guests here. We’re the ones who think five times about whether we really want to go up to the bridge and tell them off because we’d like to come here again. I don’t think that’s okay...I think that’s taking advantage of something: this division of roles between regular crew/guests, younger/older, and those in non-permanent/permanent positions.” (Int-33, German junior female marine scientist, on older male crewmembers employed by a German company)

Verbal remarks and bullying were of a sexual nature and mostly directed at the physical appearance of women, including their gender, ethnicity, and age. For example, one interviewee reported:

“And this guy, that was the boss of everyone. He said like: “[Her name], you think that you are in the United States, you are not in the United States. We are here [in Germany on a research vessel], we can talk about whatever we want, the way we want. And if you don’t want it, you don’t have to be here. Hear this, you must be grateful that you haven’t been raped – raped in this country.” And I just went out, sorry... [interviewee starts to cry].” (Int-51, junior international female marine scientist, employed by a German marine science institute)

The nine physical assaults included unwanted touching of hips, waist, buttocks, hair, and face, or undesired close physical contact, such as hugs, massages, kisses, or the exposure of genitals and masturbating in front of female scientists (interviewee groups 1, 3, and 5). As seen in figure 8, harassment predominately occurred along the intersection of gender, social class, physical appearance, ethnicity, and age. Other social identity markers, such as disability or religion, were not mentioned by interviewees or observed in the field. Interview group 5 was mainly affected by (sexual) harassment and discrimination; Brazilian female senior scientists between the ages of 38 and 62, mostly based in Brazil, pointed to postcolonial gender norms and Western sexism and misogyny.

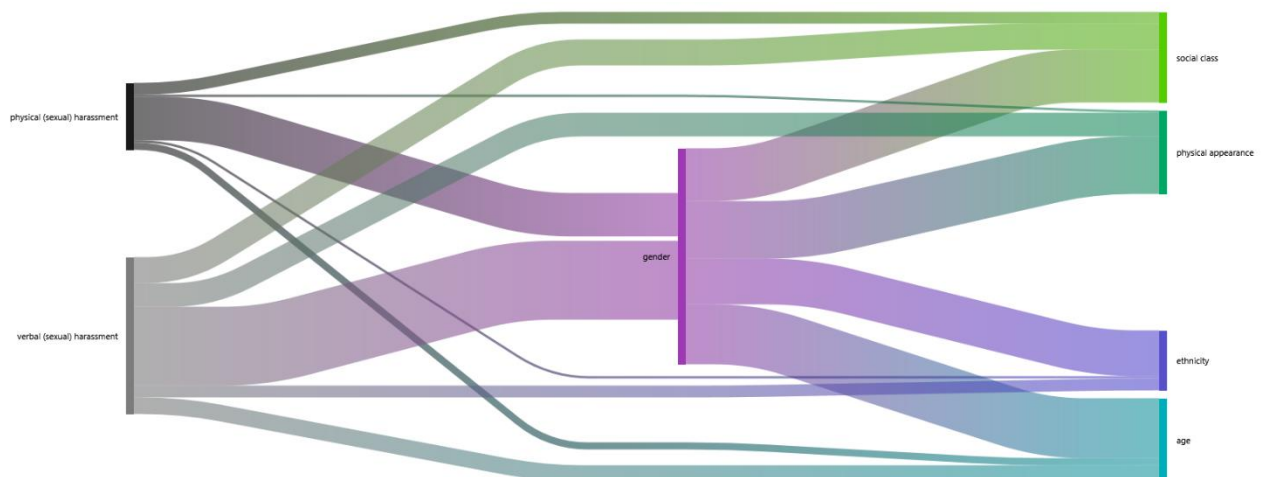


Figure 8: (Sexual) physical and verbal harassment caused by gender, social class, physical appearance, ethnicity, and age displayed in a code-co-occurrence Sankey diagram. Note: The thickness of the lines refers to the frequency of occurrence of the codes, e.g., the highest co-occurrence of codes appeared at the intersection of verbal harassment, gender, and age. Source: Own elaboration using Atlas.ti.

Three men out of 47, two junior scientists (interviewee group 4) and one crewmember (interviewee group 9) reported verbal (sexual) harassment due to their gender, age, and physical appearance. The crewmember’s harassment was perpetrated by a female senior

marine scientist on a research vessel. He remembers his feeling of discomfort: “When the scientists [came] on board and one of the women pointed to one of the sailors and said, ‘all right, you’re mine for the next six weeks’” (Int-7, German junior male crewmember). The two junior male marine scientists were discriminated against by senior male crewmembers along the intersection of their age and physical appearance, as one of them reports, “sometimes I hear someone say that I’m too weak...for a man” (Int-32, German junior male marine scientist).

5.5.2 No boundaries in transnational intersectional harassment at sea: The politics of localities

Intersectional discrimination appeared in all marine scientific knowledge production sites – on vessels, at the university, in the laboratory, and at workshops and conferences. Thus, marine sciences, and its adjacent localities and workplaces of marine knowledge production, seem to enable an operation of power in the enclosed vicinity of a ship or a laboratory, as well as a spatial structuring of inequality (cf. Certomà, Clewer, and Elsey 2012). In our analysis, we refer to these localities as physical spaces, although we are well aware that spaces can also be a form of mobility or a distance (see the discussions in political geography on the multidimensionality of space, cf. Delaney and Leitner 1997; Jessop, Brenner, and Jones 2008; Jones and Jessop 2010). To illustrate this, one of our interviewees said:

“There’s a nice saying: What happens on the ship stays on the ship, and there’s a reason for that. And we are, I think, at a critical mark of seven weeks. These are really periods of time where perhaps the desire for closeness...continues to grow” (Int-6, German senior male technician).

The data collection on a vessel or in a laboratory requires the collaboration of scientists and non-scientists in very compact and narrow rooms and for a long period, which has led to multiple cases of intersectional discrimination in marine knowledge production processes (interviewee groups 1, 3, 4, 5, 7, and 9). One female interviewee discloses a case:

“He [head of the laboratory] started love bombing, like ‘oh, you are important. Come to my laboratory. You’re perfect, we need you.’ And then when things didn’t feel OK, he started to undermine my qualities and work... It took me a few years to understand there was a lot of moral harassment” (Int-79, Brazilian junior female marine scientist).

In an earlier study by Hornidge (2020), she documents the use of the saying “what happens on the ship stays on the ship” on a different German research vessel. She assesses it as a discursive practice, contributing to the construction of an in-group, as opposed to the out-group who are not sharing the experience. Our data collected beyond the vessel show that (sexual) harassment in marine knowledge production does not stop on land. While 20 cases of (sexual) harassment occurred on vessels, nine happened on land during coastal fieldwork and conferences, as well as at universities and laboratories. Three men were harassed at sea, while 20 women experienced harassment on vessels and six on land. Interviewees reported verbal (sexual) harassment, bullying, and discrimination due to their gender, ethnicity, and age among colleagues at university or (international) meetings or scientific conferences. As one interviewee reports, “as a female expert, I was pushed by a male expert who said he was now more of an expert than me” (Int-59, German senior female marine scientist).

5.5.3 Building a wall or joining intersectional forces: Effects of intersectional discrimination

The effects of intersectional discrimination and harassment have led to two different outcomes or adaptation strategies: withdrawal and heightened insecurities, or emancipation. Similar to these observed strategies, Hornidge (2020) finds authoritarian, hierarchical, and repressive censorship in a remote Uzbek field station, and open resistance and emancipation against (sexual) harassment on a German research vessel. In the research presented here, 20 of the 29 interviewees who experienced harassment, reacted with withdrawal and heightened insecurities and nine with emancipation as a coping strategy. Yet, it is important to note that these coping strategies do not always follow a linear process. The often lengthy and difficult process can be dynamic and might involve both liberation and withdrawal. For example, an initial emancipation through

reporting the (sexual) harassment may be followed by withdrawal and a departure from the marine job sector (cf. Int-51, junior international female marine scientist). This simultaneity of emancipation and withdrawal was also found in earlier research by Ford, Ivancic, and Scarduzio (2021). The authors concluded that the resilience of victims decreases after reporting their experiences and when victims decide to leave their employer (Ford, Ivancic, and Scarduzio 2021):

“Because of that, I built a wall and ‘No, I’m here for work, I don’t interact.’ Like I would talk and everything, but I would not give any space for misinterpretation or anything. But still, if I can, I prefer not to participate in those cruises anymore” (Int-57, junior international female scientist, based in Germany).

Female scientists, especially of interviewee groups 1, 3, and 5, used adaptation strategies, such as changing the way they talk in meetings or presentations (Int-59, senior female marine scientist and 76, senior international female scientist), the way they dress (Int-1 and 3, both German female marine scientists), especially during fieldwork (Int-37, German senior female marine scientist and 72, Brazilian senior female marine scientist), pointing to the intersection of gender and physical appearance – or they felt ashamed and did not report the (sexual) harassment and discrimination (Int-1, German female marine scientists; 8, German female crewmember; 24, 32, both German junior male marine scientists; 39, German senior female scientist; 51, junior international female marine scientist; 59, German senior female scientist; 69, 70, 73, all Brazilian senior female marine scientists; 79, 80, both Brazilian junior female marine scientists). Female marine scientists with a different ethnicity from that of the country they worked in were especially likely to have experienced harassment and to have reacted with withdrawal and heightened insecurities. One senior international female scientist based in Germany said, “I learned that I have to step back” (Int-60). Another interviewee changed her behaviour on subsequent research cruises after having experienced harassment, resulting in a disadvantage to herself:

“Even when I was the person that had the most expertise on the thing that they were doing, I was never involved....I don’t think that has to do with being a woman, but it has to do to [with being] a foreigner....When I was on a vessel again, I was super rude with everyone in the crew, all the time, because I didn’t want them to

be near to me...because otherwise...you know this self-blaming when things happen, so you are at least sure that you did everything to prevent this to happen". (Int-51, junior international female scientist, based in Germany).

Another female scientist changed her physical appearance while on board:

"I'm a woman [laughs] so, I don't know, I make sure that my neckline doesn't go all the way down, and I also pay attention to what pants I wear, and I've noticed that people here have already said, yes, 'do you have to wear leggings so tight that you can see all the details?'" (Int-37, German junior female scientist)

In some cases, female researchers decided not to finalise their PhD or to leave academia and their employment (Int-39, German senior female scientist; 51, junior international female marine scientist; 59, German senior female scientist; 79, and 80, both Brazilian junior female marine scientists) due to (sexual) harassment, which can be analysed as the ultimate form of withdrawal. As one interviewee stated, "there are a lot of women, who say 'I can't cope with it anymore' and then leave and I think that's an incredible waste of know-how, of knowledge....I think that's super unfortunate" (Int-59, German senior female scientist, who herself changed from being a marine scientist to a science communicator).

Other female scientists employed similar withdrawal mechanisms, as the following interview quotes show:

"There have been cases of sexual harassment and that's [a] difficult path to walk for everyone and makes it difficult to even want to be there [in academia]" (Int-70, Brazilian senior female scientist).

"She was a professor at the faculty of Geology at [a Brazilian University], then she had to leave this university because she could not collaborate with the other professors of her own faculty. Really. They refused to cooperate since she was a woman" (Int-73, Brazilian senior female scientist).

"It was the worst onboard experience of my life because I felt like, if someone hit on me, it will be my fault. It was awful. It's not only people that are on board but also people that are on land and determined. It's awful, so I left the job" (Int-79, Brazilian junior female scientist).

Another female scientist reported the assaults she experienced, trying to achieve justice and emancipate herself, but then left her job:

“I told my boss; he didn’t do anything. And I know that the equal opportunities officer is a marionette. She interrupts speakers to say to us: ‘Oh, you are a woman. We are trying to succeed in a male-dominated place, we must act like a man’ ... To be honest it took me like maybe six months to process this and to start to talk about it... After getting depression, I just quit” (Int-51, junior international female scientist, based in Germany).

The minority of victims of transnational intersectional discrimination at sea made a stand against their harassers and emancipated themselves. We refer to emancipation as an active resistance by the victim towards his/her/them oppressor and/or employer. During the German research cruise in which 37 of the 82 interviews were conducted, multiple (sexual) verbal and physical harassments were perpetuated by a male crewmember. Six junior female researchers joined forces, collected the incidents in written form and reported them to the chief scientist, who then went to the captain. The crewmember received a formal warning as a result (interviewee group 3). On a Brazilian navy vessel, which is commonly used for marine research, a female researcher experienced sexual harassment. She “went to the police when the ship arrived back and it was a military guy and there was a complaint” (Int-62, Brazilian senior female scientist). During a marine field trip, a male crewmember physically harassed a female scientist, who reported the incident (Int-81, Brazilian junior female marine scientist). Afterwards, many other female researchers reported the same, and the crewmember was finally fired (Int-81). Another Brazilian female researcher reported using the following protective device: “A knife inside my boots, it was normal because we are working the field, and I sleep with my knife [under the] cushion” (Int-72, Brazilian senior female scientist). To be able to stay in academia, one female professor explains the following:

“I balance my feminine side because I’m pretty much facing stereotypes all the time, so, if I can, I present myself just like a man and look like a man and identify myself with men and being very masculine and being very aggressive and talking with my voice more in a male way. But if they know that I have a vagina, it changes everything... We face a lot of stereotypes...a Brazilian woman comes with a burden

because people associate Brazil many times with sex. A lot. Regardless of where you are, regardless of what you do, regardless of everything... And then I start the class, and everything changes because I'm not aggressive, but I am very assertive. I'm being more male. I have to do that, otherwise they going to question me. So, my voice, that helps me...because I don't have like a female voice" (Int-76, Brazilian senior female scientist).

As shown in the previous example, Brazilian female marine scientists who experienced (sexual) harassment specifically pointed to their ethnicity as a major reason for discrimination. In Brazil, the prevalence of the machismo culture, gender-based violence, silencing, and victim blaming are still predominant (Rodrigues 2024). Yet, in Brazil, a group of female marine scientists joined forces and founded the Women's League for the Oceans (Liga das Mulheres pelo Oceano 2022), as well as a blog to write about their experiences (Int-79, 80, 81, and 82, all Brazilian marine scientists). The group has now more than 2,500 members from marine sciences, politics, and the non-profit and maritime private sectors.

5.5.4 Beyond boundaries: Intersectional discrimination broadens the gap between knowledge systems

As the previous section has shown, a pattern of harassment that has also been found by Hornidge (2020) regarding research sites of proximity (a research vessel and an isolated research station), led the victims to join forces and take action against their harassers. In most cases of our research, though, it did lead to further forms of withdrawal and heightened insecurities. Besides gender as a social identity marker, our analysis shows that discrimination mostly occurred due to the intersection of gender, ethnicity, physical appearance, and age, as well as between knowledge systems, for example between scientists and non-scientists. This accumulation of discrimination and (social class) conflicts further increase distrust between science systems and disrupts work at sea:

"Sometimes it really clashes, and then there's...also bullying approaches where you almost think "holy cow! What's going on here?" But you've also noticed that many people try to counteract it, but you can't get a grip on it because nobody can

take a weekend at home to...reset....At some point, you see them during the day and that's a completely different kind of psychological stress" (Int-39, German junior female scientist about conflicts on research vessels).

We observed a recurring pattern of conflicts that arose from the contact between scientific and non-scientific types of knowledge by conducting fieldwork on the micro-level (cf. Elliker 2017). On the vessel, but also in the laboratories and universities, authoritarian expert knowledge clashes with the non-scientific knowledge of technicians and crewmembers. As one interviewee put it: "There are many stories about harassment, especially onboard navy ships, and it is a clash of cultures, so that is not that easy" (Int-79, Brazilian junior female scientist). Fifty-six of our interviewees were scientists (see table 2), from which 26 female scientists experienced (sexual) harassment and discrimination during marine knowledge production processes. These incidences were perpetrated by both male scientists and non-scientists fairly evenly (47% by scientists and 53% by non-scientists). Twenty-six of our interviewees were non-scientists, such as crewmembers or technicians. Two out of 26 non-scientists experienced (sexual) harassment in contributing to marine science-making. One interviewee was verbally harassed by a scientist and the other by both – a scientist and a non-scientist in two different situations.

As Tessnow-von Wysocki and Vadrot (2022) already pointed out by using the example of intergovernmental negotiations, tensions exist between opposing views on which types of knowledge are considered relevant to the addressing of climate and environmental issues. Our research observed these tensions between scientists and non-scientists, such as technicians in laboratories (Int-43, 52, 53, and 54) or crewmembers on the vessels (Int-21, 29, and 31), in everyday knowledge production processes and adjacent negotiations. This clash of knowledge and belief systems results in an intersectional dilemma (cf. Bauman 2012; Giddens 1991) in which intersectional discrimination occurs while, simultaneously, diverse types of knowledge are seen as superior. This power is also reflected in the Brazilian cooperation of the navy and marine sciences:

"They have the power because they are [the] navy. I think you must separate things from the marine and things from science. I don't like this system, that you go to the navy. I don't like my students going there... [The navy] are a Machismo... They think

that they are there to get women or boys” (Int-69, Brazilian senior female scientist, who decided to no longer send her students on research cruises, pointing to withdrawal).

Societal power structures, misogyny, and (racial) inequalities are a global phenomenon, which is also reflected in marine sciences and echoes these societal path dependencies. The clash of scientific and non-scientific types of knowledge mirrors a social class conflict, which condenses along the intersection of hierarchy, gender, and age (cf. Grabe & Else-Quest 2012):

“When there is a pretty girl...you’re very careful, and then you prefer not to go into detail or something. So, if you’re sitting in the bar having a drink, and somehow you talk to a scientist, hit on her...and you have a nice evening, and the next day she thinks ‘what an asshole’, she goes to the captain, then you’re fired” (Int-29, male crewmember, about interaction with female scientists).

“It’s still the case, many of the doctoral students I’ve accompanied here, for whom I’ve also built devices, have unfortunately lost their grounding. They don’t say ‘hello’ anymore. I then say “boy, we built this together” and then they don’t see you anymore. No, they just look past you and then I just think ‘what an asshole’” (Int-54, senior male laboratory technician at a German marine science institute, about male scientists).

Thus, in line with Grabe and Else-Quest (2012) and Patil (2013), we argue that the social class conflict of diverse marine types of knowledge and knowledge production processes at sea manifest a continuation or even expansion of transnational intersectionality rooted in transboundary social hierarchies, (post-)colonial epistemic inequalities, and science systems that continue path dependencies (see figure 9).

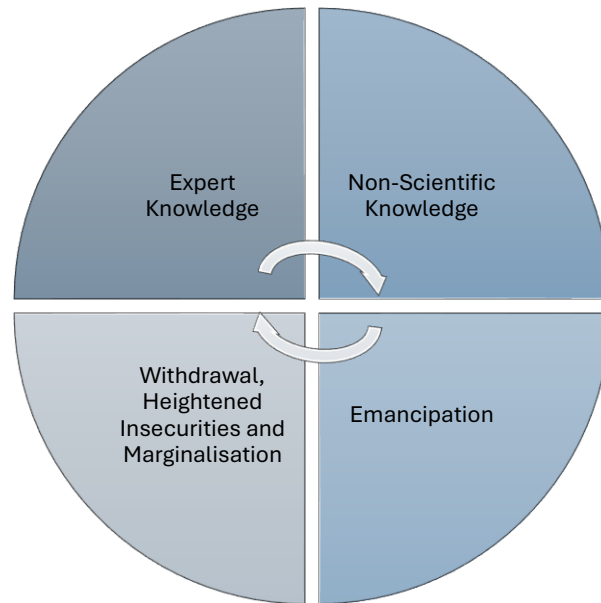


Figure 9: An intersectional dilemma through emancipation and withdrawal and heightened insecurities strategies and the (social class) conflict of scientific and non-scientific types of knowledge. Source: Own elaboration.

Our findings, moreover, point to the diversity of science systems and distrust between them. The observed and reported intersectional discriminations in the marine work sector continue to solidify and narrow expert knowledge. Without the non-scientific knowledge of technicians and crewmembers, experts can neither operationalise nor implement their knowledge. Who has the power and authority? Who remains marginalised? An intersectional dilemma between those with expert scientific knowledge and those with non-scientific knowledge emerges and disrupts urgently needed marine sciences for climate change scenarios and mitigation strategies. Moreover, through transnational intersectional harassment, the knowledge system loses diverse types of knowledge, emotional intelligence, and socio-cultural competencies through disempowerment and marginalisation.

5.6 Conclusion

Our research showed a pattern of intersectional discrimination, bullying, and (sexual) harassment that occurred in particular along the lines of gender, age, social class, ethnicity, and physical appearance. Young female scientists with a different ethnicity from that predominant in their working environment were most likely to experience

intersectional discrimination. The majority of perpetrators were male crewmembers and white male scientists, usually in a hierarchically more senior work relationship with the victim. Nine out of 29 intersectional incidents were physical, while the remainder were verbal.

The harassment occurred independently of the precise localities or spatial characteristics of where they took place and led to either emancipation or withdrawal, heightened insecurities, and further marginalisation of the victim. Through these strategies and the conflict of scientific and non-scientific types of knowledge, an intersectional dilemma emerges in which distrust of gained knowledge develops and even disrupts urgently needed marine scientific work.

A shift towards intersectionally shared knowledge is needed. Diverse types of knowledge must become part of the collective identity in marine science projects, regardless of the localities in which knowledge production takes place. Scientific knowledge and non-scientific knowledge are of the same value, and only through the combination of both will research for climate change scenarios be successful. (Scientific) employers and shipping companies need to develop training and proactive institutional responses to increase diversity among their employees, especially at the senior-levels, and mitigate and prosecute racist, sexual, and homophobic misconduct.

We do recognise that we still live in a society in which internalised gender norms, misogyny, patriarchal power structures, and rape culture are unfortunately predominant, which also characterises the specific case-study context. Nevertheless, we argue that intersectional and transnational (sexual) harassment and discrimination in marine sciences and the blue economy require increased awareness by (national) science and knowledge systems and by marine employers and employees. The building of an intersectionally equal working environment and the establishment of an institutional framework for a sustainable blue and gender-sensitive future are urgently needed.

Moreover, future research on intersectionality at sea is required. Our qualitative research approach to the micro-level of knowledge production processes in marine sciences gave voice to people who have experienced or are experiencing intersectional discrimination, and our analysis points to the as-yet unrecognised impact of intersectional discrimination on scientific efforts to combat climate change while working at sea. Yet,

both contributions need further expansion. A mixed-method approach of a global quantitative survey and qualitative interviews on experienced discrimination and harassment of marine scientists and seafarers would ascertain at which intersections discrimination and harassment occur at an international-level. Thus, an analysis of these findings would allow further and more concrete (policy) recommendations for blue justice and intersectional equality within the blue economy.

Chapter 6

The stabilisation and destabilisation of marine carbon observations: Co-producing knowledge in murky waters



Picture 14: The deployment of an Argo float for MCOs from a German research vessel during an expedition in the North Atlantic in 2021. Source: Author.

6. The stabilisation and destabilisation of marine carbon observations: Co-producing knowledge in murky waters¹³

6.1 Chapter summary

This article examines the complexities of marine carbon observations by exploring how non-humans and humans, including: scientists, floats, and geopolitics, (de-)stabilise these processes. Drawing on ethnographic fieldwork in Brazil and Germany, the study uses Karen Barad's (2007) concept of agential realism to understand how these diverse actors are mutually co-producing knowledge on marine carbon. Instead of viewing entities as separate, intra-action emphasises their co-constitution. Through theme-based coding, the analysis identifies both stabilising and destabilising forces in marine carbon observations. Stabilising forces include the dedication of scientists, two-way communication between floats and humans, and the global accessibility of data on marine carbon observations. In contrast, destabilising forces involve climate change's impact on data collection and quality, funding shortages, and national borders. The research highlights how geopolitical and scientific practices are deeply dynamic and often overlooked in discussions of marine carbon observations. By following non-humans and humans, and incorporating diverse perspectives from the sea and land, the study provides new insights into the (un-)becoming of marine carbon observations, emphasising the importance of the more-than-human in shaping knowledge production practices. This work underscores the value of thinking with Science and Technology Studies (STS) and New Materialism about marine environments.

¹³ This chapter has been published in the *Springer Nature* journal *Maritime Studies*. Citation: Haegele, R. The stabilization and destabilization of marine carbon observations: Co-producing knowledge in murky waters. *Maritime Studies* 24, 48 (2025). <https://doi.org/10.1007/s40152-025-00435-y>. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

6.2 Autonomous diving buoys: An introduction to marine carbon observations

Imagine four thousand Argo floats¹⁴ moving up and down the ocean while you are reading this. Standard Argo floats (see picture 14) measure hydrographic properties in the water, especially temperature and salinity at different water depths and thus provide observations on climate change in the areas of global warming, sea levels, and water cycle. These floats are autonomous diving buoys (see figure 10) and are a more recent means in measuring marine carbon, by slowly adding biogeochemical sensors thereby providing data on ocean acidification and carbon fluxes¹⁵. Marine carbon observations (MCOs) are crucial to understanding the ocean's health, and its current, past, and future condition. These global observations feed into calculations for climate change scenarios and provide answers to a future ocean in a changing climate.

When I¹⁶, as a social scientist, started to research knowledge production processes in MCOs within an interdisciplinary Brazilian and German joint research project in early 2021, I thought that marine carbon would be easy to determine. I imagined that a simple sensor for its measurement would exist. During research, however, I learned that it was not that easy, as there is no existing sensor which simply provides data on carbon levels in the ocean. Scientists, like oceanographers or biogeochemists, who are interested in determining marine carbon, must proceed by measuring four different parameters in a specific layer and space of the ocean, namely dissolved inorganic carbon, alkalinity, partial pressure of carbon dioxide, and pH-level. If one can determine two of these four

¹⁴ Most of these floats are standard Argo floats measuring temperature and salinity. Currently, only 397 BGC (biogeochemical)-Argo floats with pH sensors are active. The low number of BGC-Argo floats can be explained by their expensive acquisition (OceanOPS 2024). Depending on the equipped sensors of the float, the costs for a float range approximately between \$20,000 and \$150,000. A standard float with temperature and salinity sensors is much cheaper than a sensor with more advanced tools for measurements, such as pH, nitrate or oxygen sensors.

¹⁵ (BGC-) Argo floats are not the only instruments to measure marine carbon, biogeochemical elements and hydrographic properties. Other instruments include drifters, gliders (Byrne et al. 2010), or autonomous marine carbon observation systems on so-called Ship of Opportunity Lines (SOOPs). SOOPs are merchant vessels that voluntarily carry the observation system, allowing marine scientists to collect data every time the SOOP returns to its port of registry. These carbon observation systems measure the ocean surface's salinity, pCO₂, temperature, alkalinity and pH value (Steinhoff et al. 2019; Int (Interviewee)-4, Int-5, German male senior marine scientists; Int-17, German male senior technician). Due to the limited number of SOOP lines globally and respective interlocutors for these types of marine carbon measurements, this study focuses on marine carbon observations via (BGC-) Argo floats.

¹⁶ Fieldwork was conducted by the author in an interdisciplinary research project funded by a German ministry and carried out jointly by Brazilian and German (marine) science institutes.

parameters, the other two can be calculated afterwards (Byrne et al. 2010; Dickson, Sabine, and Christian 2007; Steinhoff et al. 2019).

Argo floats are usually deployed in the open ocean from a vessel (see picture 15). After deployment, they move up and down different water columns measuring the temperature and salinity of the upper 2,000 meters. To extend temperature and salinity measurements, Biogeochemical (BGC-) Argo floats have been developed. They measure, depending on the sensors they are equipped with, six additional properties, i.e. nitrate, oxygen, chlorophyll fluorescence, optical backscattering, downwelling light, and pH, and they can dive to a depth of 2,000 meters (Bittig et al. 2019; Bundesamt fuer Seeschiffahrt und Hydrographie (BSH) 2024). While MCOs were predominantly conducted from ships in the past, advances in the miniaturisation of sensors, significant improvements in data storage, and highly durable batteries have enabled remote and autonomous sensing (Lehman 2018). Currently, approximately four thousands floats are actively involved in measuring marine carbon, sending their data usually after a ten day drift via satellite to respective data centres (Bundesamt fuer Seeschiffahrt und Hydrographie (BSH) 2024).

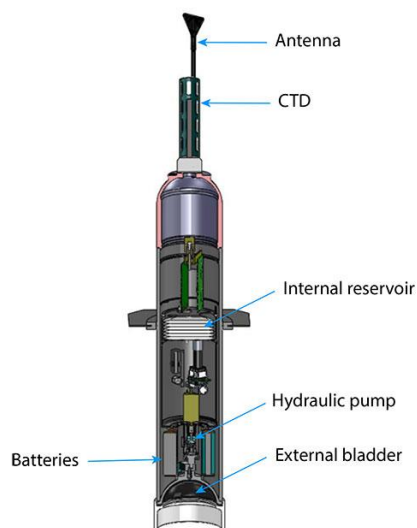
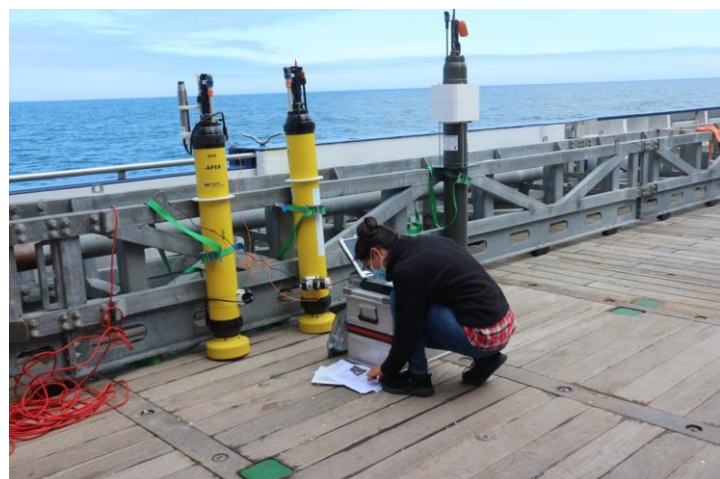


Figure 10: Argo float schematic.
Source: Argo (2023).



Picture 15: Author prepares the deployment of three (BGC-) Argo floats on a research vessel. Source: Sebastian Krastel.

Scientists use this data to calculate and predict essential information for climate change scenarios, including those outlined in reports by the Intergovernmental Panel on Climate Change (IPCC) and the Global Carbon Budget (Friedlingstein et al. 2023; Pörtner et al. 2019). These measurements play a vital role in global climate negotiations and policymaking (Haegeler and Schoderer 2021). Despite their importance and complexity,

MCOs are still considered a niche topic in marine natural sciences (Aricò et al. 2021; Riebesell, Körtzinger, and Oschlies 2009; Steinhoff et al. 2019). This is even more so in marine social sciences, where economic, geographical, or political science perspectives, for example, to assess the effectiveness of carbon dioxide removal, its social considerations and best practices (Boettcher, Schenuit, and Geden 2023; Satterfield, Nawaz, and Boettcher 2023; Sovacool, Baum, and Low 2023), are the dominant topics in research.

Having spent over a year in the field between 2021 and 2023, including time on a research vessel, two merchant vessels, in laboratories, in marine science departments, and at conferences all focusing on MCOs, I am intrigued by the knowledge production processes within MCOs. As a social scientist interested in these practices within knowledge production, the following dynamic forces caught my attention: non-humans and humans. Non-humans include climate change forces, technologies, floats, satellites for data transmission, and software for data translation, funding of associated technologies and the deployment of floats in exclusive economic zones (EEZs), and humans, such as the scientists and technicians who can (not) measure marine carbon. I often wonder: How do scientists responsible for determining marine carbon navigate the methodological and technological challenges and uncertainties they encounter? How do they collect, interpret, and share data, or, in other words, how is knowledge about marine carbon (socially) produced? And how are the forces of non-humans, humans, and geo-politics implicated in (de-)stabilising MCOs? In short, and this is the main question this article seeks to answer, how are MCOs (de-)stabilised?

So far, little is known about what (de-)stabilises the knowledge production processes within MCOs. To address this gap in research, I propose approaching this topic by understanding non-humans and humans as intra-acting forces (Barad 2007) in stabilising and destabilising them. By examining the practices within MCOs through ethnographic fieldwork and by using the example of Argo floats, I explore non-human and human forces at play. I render Barad's concept of intra-actions valuable for this article and, thus, my research contributes to approaches of marine Science and Technology Studies (STS) and oceanic New Materialism (Fox and Alldred 2017; Harris 2021; Jensen 2017; Latour 1987).

MCOs exemplify key characteristics of current climate science: they function through automation, operate at a distance, are distributed across various sites, and are embedded in political contexts. While they play a growing role in observing the ocean, an analysis of their socio-material embeddedness remains widely unexplored. This paper approaches MCOs not as passive data-gathering tools, but as components actively involved in shaping knowledge and practice. Building on Karen Barad's agential realism, I suggest that MCOs participate in producing specific understandings of marine environments, which have tangible effects, such as legitimising conservation strategies, guiding financial allocations, or underpinning territorial claims. MCOs emerge at critical junctions where marine monitoring, ocean governance, and climate futures intersect. A Barad-inspired social science lens highlights how oceanic knowledge and control are co-constituted through entanglements of human and non-human forces.

The analysis builds on ethnographic fieldwork, including semi-structured interviews, participant observation (Bernard 2002), and go-alongs (Kusenbach 2003). Ethnography enabled me to follow (Marcus 1995) scientists in their daily work routines, following floats and humans to their diverse (geographical) stations on land and at sea, keeping abreast of the geopolitics involved in these processes, and helping to include multiple sites of meaning-making (cf. Haegele 2024; Mielke and Hornidge 2017; McAdam-Otto and Nimführ 2021).

To answer the main research question of how MCOs are (de-)stabilised, the article is structured as follows: The subsequent literature review discusses the STS and New Materialism approaches which inspired my analysis. I present the conceptual framework, which proposes that MCOs can be perceived as intra-actions informed by Barad's concept of agential realism (1998, 2007). Section 6.4 discusses the methods used for data collection and analysis of the empirical data. Section 6.5 presents the findings of MCOs as intra-actions and their (de-)stabilisation through non-human and human forces. The conclusion demonstrates the dynamism of these forces and highlights the complexity of knowledge production processes within MCOs, which demonstrate that clear boundaries cannot be drawn to separate these forces.

6.3 Conceptualising marine carbon observations through a Baradian lens

More recently, the world's ocean has become increasingly relevant as an object of study in the social sciences, often critically reconceptualising the universal understanding of the ocean as static and usually associated with land, justice issues, and its *more-than-wet* materiality (Anderson and Peters 2016; Hein, Klepp, and Bercht 2024; Peters and Steinberg 2019; Tafon et al. 2023). Instead, more nuanced understandings of the ocean and the knowledge produced on the latter have been discussed, such as predominantly ship-based historiographic studies by Sorrenson (1996) or Laloë (2012), sociological research focusing on marine knowledge production processes by Hornidge (2020, 2018) or Bogusz (2018), or social network analysis on vessels pointing to the hierarchies at sea (Bernard and Killworth 1973).

Ocean observations have recently become an area of interest within the research on oceans in the social sciences. One research strand focuses on the global governance of oceans, with, for example Lehman (2016) referring to the Global Ocean Observation System (GOOS) to demonstrate how ocean observations create a digital twin of the sea, by conceptualising the ocean as a space of potential for geopolitics and capitalism. Vadrot and Wanneau (2024) use an international relations perspective to analyse the politics of marine biodiversity, keeping track of the politics and practices of monitoring marine life, shedding light on inequalities in governing the ocean. Miloslavich et al. (2019) point to the need of expanding human capacity for ocean observations beyond scientists from financially well-resourced countries, including the global community through funding models, partnerships, and marine technology transfer.

A second research trend focuses on how scientists generate and manage data from ocean observations. Lehman (2018), sheds light on the challenges and opportunities of shifting from ship-based oceanography to partly autonomous remote data collection. This shift not only provides opportunities for more equitable scientific practices, such as access to data, but also comes with the loss of time at sea for scientists and widespread nostalgia about a bygone era of ship-based observations among oceanographers. Similarly, Helmreich (2009b, 149) refers to scientists having access to data on the deep sea through robotic vehicles while being physically at home as “intimate sensing”. By following scientists’ knowledge production processes in mapping a deep-sea channel

and its important role in storing carbon, Haegele (2024) identifies two modes of knowing the ocean – sensory landscapes, and experiential knowledge, as scientists rely on their own senses and experiences in science-making.

A third trend, which is also propounded by Helmreich (2023), addresses the agencies of non-human actors in the field of marine social sciences. Gramaglia and Mélard (2019) include more-than-humans, such as eels as a sensor for monitoring marine pollution to detect environmental change and toxicity. Jue (2014) considers the different scales of seawater through the agency of *Google Ocean* and *ATLAS in silico*, two data visualisations on ocean observations. In another study, Helmreich (2019) analyses a wave buoy as part of ocean observations, its ability to monitor waves and its contribution to inequality between state organisations, militaries, multinational corporations, and citizens. Apostle and Gazit (2016) point to the dominance of political economies in tracking and observing marine species at risk.

This article builds and expands on these works. Barad's framework of agential realism offers a crucial extension to these debates by emphasising the relational and discursive dimensions of knowledge production. It shifts the focus from representation to the socio-material practices through which MCOs bring certain ocean and climate futures into being. This perspective enables an analysis of the (de-)stabilisations involved in making marine carbon comprehensible. By attending to the entanglements of non-human and human forces, a Baradian analysis highlights the dynamic processes through which MCOs contribute to shaping the ocean's role in climate governance. In so doing, the article also expands on existing and highly relevant literature on the governance of ocean observations within the social sciences (e.g. Lehman 2016, 2018) by suggesting conceptualising MCOs as intra-actions, hence strengthening New Materialism approaches in the research field (Brennan 2018). The aim of approaches within this research agenda is to consider non-human and human forces in science-making through a relational approach. The article offers ethnographic depth of socio-material entanglements in the knowledge production processes on MCOs. The perspective I rendered valuable for the analysis is rooted within the framework of agential realism, which serves as a lens to include the indivisibility between the ethical and (geo-)political in which open-ended forces act dynamically. Barad (2007) does not separate

epistemology from ontology or the human from the non-human, and in this understanding, materiality is not separate from, but entangled with the human world. Barad (2007) and other scholars from within New Materialism, such as Braidotti (2013), describe a continuous nature of matter and meaning. Barad introduces the idea of the “dynamism of forces” (Barad 2007, 141), to argue that reality is not composed of separate, individual entities that simply interact, but Barad views the becoming of reality as a dynamic process (Barad 2007; cf. Law 2008).

Barad’s agential realism consists of 1) apparatuses, 2) intra-actions, 3) phenomena, 4) agential cuts, and 5) diffractions. First, apparatuses are not mere instruments, but they “iteratively reconfigure space-time-matter as part of the ongoing dynamism of becoming” (Barad 2007, 141). Barad emphasises that matter is already entangled with discourse in the enactment of phenomena. Thus, the apparatus of marine knowledge production is material-discursive, producing phenomena in an open-ended process through intra-actions of diverse forces, e.g. scientists and technologies.

Second, within intra-actions, non-humans and humans gain agency. In this line of thought, agency is emergent and not something an individual or an object possesses (Barad 2007), which differentiates this approach from a human-centric and linear thinking about agency (see table 3). I found thinking about MCOs as intra-actions (Barad 2007) helpful, as I discovered that they are enacted by entangled non-human (predominantly floats) and human (mostly scientists and technicians) forces.

Table 3: Concepts of interactions and intra-actions. Source: Own elaboration based on Barad (2007, 2012), Bozalek and Fullagar (2021) and McAdam-Otto (2023).

Concept of	Interactions	Intra-actions
Actors	Preexisting and pre-established bodies or entities	Agency is not an inherent, determinate property of an actor but a “dynamism of forces”
Action	Entities meet, exchange and interact	Non-humans/humans do not gain agency; agency emerges in intra-actions of non-humans and humans
Process	Humans and non-humans interact, thereby modifying and changing with each other	Non-humans/humans permanently co-constitute and coproduce each other in an open-ended process

Third, a phenomenon produced by the apparatus “is a specific intra-action of an ‘object’; and the ‘measuring agencies’; the object and the measuring agencies emerge from, rather than precede, the intra-action that produces them” (Barad 2007, 128). MCOs thus constantly emerge through the dynamic forces of non-humans and humans at play which simultaneously produce these. This constant process of becoming is accompanied with the fusion of ontology, epistemology, and axiology – Barad’s ethico-onto-epistemological approach, highlighting the co-becoming of phenomena at play and the inseparability of intra-acting forces.

Fourth, agential cuts within the apparatuses draw boundaries between the subject (observers) and object (observed). My role as a researcher becomes central as I practice boundary-making in my doings, and in so doing diffract different types of agencies. Fifth, diffraction also serves as a methodology to cross the boundaries between disciplines aiming to rethink the old anew, potentially achieving unexpected outcomes, and becoming aware of diverse knowledge making processes (Barad 2007; Barla 2023).

With the argument that knowledge is not merely a reflection of a pre-existing world but part of the world’s becoming, I am well aware that I, the author of the article, am part of the apparatus and so is my methodology, the objects I observe, and the social and political situatedness of the research. I also contribute to the enactment of MCOs, as I am part of the becoming of the world (cf. Callon 1984; Fox and Alldred 2017; Haraway 1988). Thus, I want to note that my doings as a social scientist can lead to agential cuts as an act of observation of what is included and excluded (cf. Barad, 2007). To be able to analyse the forces at play in enacting MCOs, I rely on collected qualitative data by using a multi-sited ethnographic approach, as outlined in the following chapter.

6.4 Diving deep: An ethnographic approach towards marine carbon research

Marine carbon observations (MCOs) play a crucial role in our understanding of ocean acidification and climate change, yet they present unique challenges in implementation and interpretation. Scientists grapple with the inherent complexities of measuring carbon in dynamic marine environments, balancing the need for data availability with the limitations of current technologies and funding. Both the collection of data about marine

carbon and its interpretation involves navigating uncertainties and variabilities across different temporal and spatial scales. Ethnographic research in this field can illuminate how non-humans and humans (de-)stabilise MCOs. Ethnographic case studies can reveal the socio-technical entanglements within the apparatus of marine knowledge production that enact MCOs and how they shape our understanding of oceanic processes and their role in the global carbon cycle.

Between April 2021 and March 2023, I conducted ethnographic fieldwork in Germany, Brazil, and in the Labrador Sea, the North Atlantic, the Baltic Sea, and along the Brazilian Coast¹⁷ for a period of one year. As common in STS research, it quickly became apparent that conducting research on knowledge production processes on MCOs has its own challenges, such as power-laden negotiations within research teams, epistemic authority, and depending on the research locality, “working and living outside of everyone’s comfort zone” (Hornidge 2018, 436). Hornidge’s (2018, 2020) foundational work and the idea of combining interviews with natural scientists, photo and video documentation of everyday routines in the field, and participant observation during work processes served as an inspiration for data collection on the production of scientific knowledge.

Informed by Marcus (1995) multi-sited ethnography approach, I followed (BGC-) Argo floats while they were brought to life (birth) in German marine science institutes¹⁸; I followed them during their lifetime from their deployment on a ship to their data delivery via online tools, and sometimes until their death when they were no longer sending any data via GPS (see figure 11). Go-alongs (Kusenbach 2003) and participant observation (Spittler 2001) in laboratories, at workshops and in offices in Brazilian and German marine science institutes and universities were crucial to better understand the dynamic forces of non-humans and humans in the (de-)stabilisation of MCOs. By using go-alongs, I was able to accompany researchers and technicians in their daily routines including

¹⁷ The interviewee’s geographical location and predominant nationalities of interviewees being German and Brazilian can be explained by the research project’s structure the research is rooted in (see section 3.1). The case selection was predetermined and could not be changed.

¹⁸ Usually, German marine science institutes, such as the Helmholtz Centre for Ocean Research Kiel (GEOMAR), the Federal Maritime and Hydrographic Agency (BSH) in Hamburg, and the Leibniz Institute for Baltic Sea Research Warnemünde (IOW) negotiate with funding agencies, mainly ministries, such as the German Federal Ministry for Digital and Transport, for the procurement of floats.

translating data or tracking the floats in the open ocean via software. I accompanied them from the subway station to the university, to meetings with colleagues, lunch and coffee breaks, into the laboratory and workshops, while at the same time asking them questions based on my interview guideline. While doing so, some natural scientists confided their entanglements, sometimes emotions for *their* floats and lived experiences with the latter. Participant observation allowed me to dive into the working routines of researchers and technicians, such as testing sensors in the laboratory in salt and fresh water, deploying floats, or using software to track the floats in the vast ocean. To collect data on MCOs beyond Brazil and Germany, which cases were predetermined by the research project's structure this research was embedded in, and to include the global dimension of MCOs, I participated in (inter-)national (BGC-) Argo meetings¹⁹. During these meetings the European and global Argo teams discussed data, memberships, and new float deployments based on the current options to deploy them, for example, which research cruises can deploy floats in which geographical part of the ocean. Moreover, I followed negotiations between scientists and *Sea-Bird*, the latter is a float and sensor manufacturer based in the US and learnt from the difficulties and uncertainties which the scientists experienced with this manufacturer, as the company enjoys a monopoly in this area due to the nature of their highly specialised and miniaturised sensors. Other floats I followed online through their GPS signal and their raw data which was transmitted via satellite and can be accessible to everyone using the *OceanOPS* platform (OceanOPS 2024). I followed nine floats during their activation and deployment on a German research vessel in the North Atlantic and Labrador Sea and witnessed difficulties in activating them which involved either removing a heavy magnet or connecting them to software, while simultaneously balancing the vessels movements and noisy environment. Finally, I followed some floats until their death, meaning the end of their battery life which lasts approximately 150 cycles, or three to five years depending on the depth to which they profile and the surface water density in which the float is operating. After this, they remain on the seabed. Only a very limited number of floats are recovered, maintained, and

¹⁹ These meetings included the EU Argo Workshop in April 2021, the Global BGC-Argo Fleet Workshops from May to June 2021, DArgo2025 Meeting in May 2021, G7 Resource Strategy Group Workshop in March 2022, Euro-Argo Management Board Meeting and the Argo Germany User Meeting in June 2022, ICOS (Integrated Carbon Observation System) Germany Annual Meeting in December 2022.

redeployed; and this is dependent on their location and recovery options by a vessel close-by.

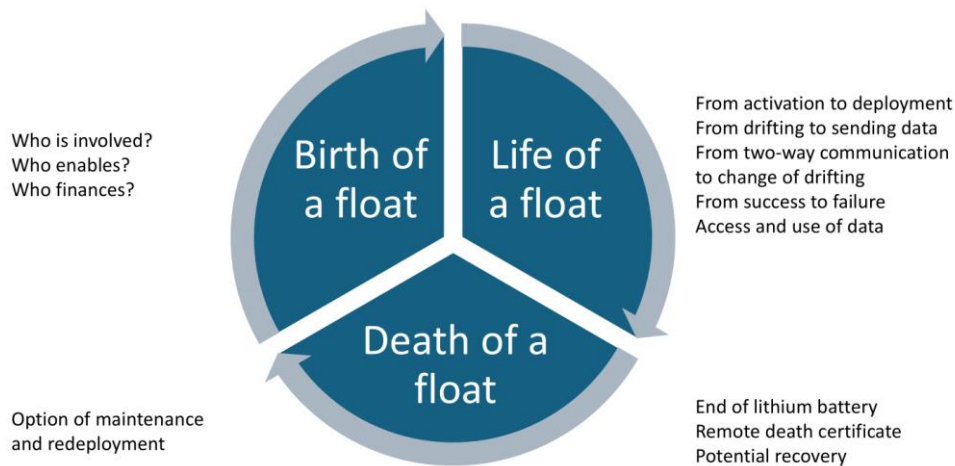


Figure 11: Life cycle of a float. Source: Own elaboration.

In addition to participant observation and go-alongs, I also conducted 38 interviews with scientists and technicians. The interviews enabled me to learn about the complexities of geopolitics entangled in MCOs, the scientist's and technician's challenges with technologies, such as sensors or software, and the reasons for their personal involvement and motivation in and for marine science-making. Findings from interviews are referenced throughout the article with "Int-number" to maintain the anonymity of my interviewees.

The interviewees provided verbal informed consent to conduct the interview and publish the findings. After the data collection, field notes, photos, videos, and interviews, were transcribed and coded with *Atlas.ti*, a software for qualitative data analysis. The exploratory approach of the research allowed me to start with a set of created codes and enabled further codes to be added throughout the coding process. In line with Miles and Huberman (1994), I followed a thematic analysis and used a theme based coding scheme, which allows themes identified in the data to be transformed into codes both deductively and inductively, subsequently discovering patterns of themes in the data.

The identified patterns helped me analyse these themes against the backdrop of Barad's concept of agential realism. Thinking with Barad's (2007) agential realism, MCOs are not

separated from their social or political contexts, as the following section illustrates. The findings shed light on how MCOs as intra-actions are (de-)stabilised through the dynamism of non-human and human forces.

6.5 (De-)stabilising marine carbon observations: Findings

The purpose of this study is to understand the actors involved in knowledge production processes of marine carbon observations (MCOs) and how they manage associated challenges and uncertainties. Having conceptualised MCOs as intra-actions within the apparatus of marine knowledge production processes, I will take a further step by providing an analysis of the (de-)stabilisations of MCOs through the inseparable forces of non-humans and humans. Unfolding the dynamism of these forces is critical, as they provide new insights into the events situated within social and political contexts (de-)stabilising urgently required MCOs for climate change scenarios.

6.5.1 Stabilising MCOs through communication, dedication, and accessibility

The core research aim was to identify the main (de-)stabilisations of MCOs. The emerging patterns through thematic analysis which stabilise MCOs are communication between the float and scientists or technicians, the dedication of scientists to translate the raw data outside their working hours, and the global accessibility of data. Only through these dynamic forces of non-humans and humans, are MCOs stabilised as the following sections will explain.

A human speaks to a float and the float replies: Stabilising MCOs through two-way communication

In the past, it was not possible to communicate with the float after its deployment in the open ocean. Now through technological improvements, such as GPS, humans and floats can exchange via two-way communication. This marks a notable transformation in the apparatus of marine knowledge production. The floats are now integrated into a continuous cycle of communication and adjustment, whereas they were fully solitary

sensing units. Approximately every ten days, they surface to transmit collected data and receive updated instructions via satellite, as one technician reported:

“Then I call them and say, ‘what are you doing?’ So, it always depends [on the error], it's [...] often things like, [the float] really didn't send data or is under the ice. [...] these are often things that I can change through this two-way communication, then I can send commands to the float, and there's a lot possible, because these are often little things like something with the hydraulics, these are limit values that you change or mission parameters” (Int-3, German male junior technician).

By asking the float about its feelings, the affective and communicative entanglements of the dynamic float-human forces become visible.

Moreover, the float can send error codes to the scientist, who can then correct these. The scientist can also send commands to the float to change the depth and days of drifting, e.g., from 2000m to 4000m depth or surfacing every five days instead of ten (Int-3, German male junior technician; Int-29, Brazilian male senior marine scientist). Scientists or technicians involved in data collection and analysis of MCOs, usually observe the deployed floats via an online tool (field notes 10.06.2022). The float's activities are saved in the online tool every time they surface. One technician said:

“I observe all the floats we have, I view them regularly, and I also have a fixed rotation for it. [...] I write down when something seems strange, but I also write down when everything seems ok. So, every time I look at a float, there is a kind of continuous checklist for this float” (Int-11, German male junior technician).

The technician showed me the software tool on his computer and explained that he is using a colour code indicating green for “the float is fine”, orange for “task”, and red for “inoperative” (field notes 17.06.2022). He added, “[red] basically means that there is no data at all. So, then you can just look, can I do something about it or not for the time being, or is there perhaps something that I can pass on to the manufacturer or [...] is it simply the final opponent, in the sense of not providing any data and that is the worst thing that can basically happen” (Int-11, German male junior technician). In the red and orange cases, the two-way communication can potentially solve errors, such as failed data transfers or wrong drifting times (Int-11, German male junior technician). Here, an agential cut of what

information is included and excluded is enacted within the apparatus of marine knowledge production. The status of the float's functioning is a material-discursive entanglement of oceanic matter, sensor, software, and technician.

The communication between floats and humans mediated by GPS and satellite stabilises MCOs. Through the two-way communication, scientists and technicians can reach the floats although they are out of human reach and sight, since the float solitarily drifts through the ocean measuring biogeochemical elements. In return, the floats can communicate with the scientists or technicians by sending them error-codes. Yet, much of the float's operation remains outside of the human eye. These unseen episodes are an agential cut in which neither the natural scientists and technicians, nor I as ethnographer can observe the whole material-discursive apparatus. Thus, the two-way communication does not represent simple interaction between technicians or scientists and the floats but mirrors the dynamic intra-active becoming of MCOs from a Baradian perspective. Only through the dynamic forces of oceanic matter, floats, sensors, communication, software, and humans, MCOs are enacted and stabilised. Yet, this stabilisation does not signify the elimination of failure, but rather a provisional configuration of entanglements within the murky waters of ocean sensing.

Volunteering and dedication for stabilised MCOs

During a float deployment in the North Atlantic which I was part of, I observed a moment of silence, of sadness, of togetherness, when everyone who participated in the deployment, both scientists and crewmembers, witnessed the float disappearing into the vast ocean. These moments allowed me to discover how humans are connected to the technologies they work with on a daily basis (field notes 19.08.2021) and how these entanglements are affective and relational. My observations at sea spurred me to also discuss the entanglements my interlocutors had with their technology on land. A scientist who I interviewed in his office mentioned that he named his floats before deployment (Int-18, German male senior marine scientist). Another scientist always marked the float before deployment with a sticker of the respective cruise to leave a physical trace of where and in which context the float has been deployed (Int-37, Brazilian male junior marine scientist). The floats all have a series number and can be tracked via an online tool

and GPS. Another scientist told me that she “stalks” the floats online to see “what they are up to” (Int-1, German female senior marine scientist). These observations of care e.g., naming and stalking the floats, enact a constant co-becoming of new phenomena as the scientists are trying to be part of MCOs through these material-discursive entanglements. Thus, scientists are constantly in touch with their floats. They also invest a significant amount of (over)time and effort in procuring funding for the floats, related technologies, data storage, translation, and analysis (field notes 14.06.2022). Due to the lack of funding for MCOs as a whole, but especially for staff for data translation, the marine science community has mobilised themselves into working groups to enable national, European, and even global MCOs by working voluntarily on data translation (Int-1, German female senior marine scientist; Int-3, German male junior technician; Int-4 and Int-5, both German male senior marine scientists, and Int-18, all German male senior marine scientists; Int-25, Brazilian female senior marine scientist). Since the float sends its data in the form of electronic signals via satellite, only raw data arrives at the data centres and this needs decoding into physical units (Int-1, German female senior marine scientist), as one scientist explained:

“[...] we have very confusing data formats that can’t be read at all. These are binary formats, you first need software to decode them and then you get physical units that you can read, but of course that’s not the whole story, depending on what kind of sensor you have, you have to make different corrections” (Int-2, German female junior marine scientist).

These corrections are already a minor refinement, as they involve a second review ensuring data quality and adequate metadata, which facilitates further use of the dataset (Int-4, German male senior marine scientist). Through the scientist’s voluntary work and dedication to transform the data into usable knowledge, MCOs are enacted. Only through dynamic processes of non-human and human forces high-quality data is made available to the public (Int-3, German male junior technician), which mirrors Barad’s becoming of reality as a dynamic process. Without scientist’s work, the float’s data would be “useless” (Int-2, German female junior marine scientist). Scientists are not being paid to translate the raw data. Instead, the Surface Ocean CO₂ Atlas (SOCAT) brings together a group of scientists who voluntarily translate and check the submitted raw data of MCOs. One

scientist explained that “the data records are increasing. There is also more and more data that is poorly measured and gets suspended [...], that’s a kick in the ass for every volunteer, because they all do it in their free time on the side” (Int-4, German male senior marine scientist), emphasising the scientists’ firm conviction to their work on MCOs. What these interview quotes moreover show are the Baradian diffraction enacted across disciplinary boundaries. In the joint effort of the scientists, the knowledge production processes become only visible and together they achieve the outcome of making the data understandable and usable.

Besides the decoding of data, scientists write their own software, often in *MATLAB*, which is a programming platform (Int-1, German female senior marine scientist; Int-19, German male senior technician). They voluntarily program these software applications and make them freely available to anyone interested in using it. These applications are particularly necessary if marine forces, such as boundary currents, interfere:

“[If the floats] are traveling in the Gulf Stream, where the velocity is very high, then the movement of the floats, which drift with the current, is much more violent and they don’t stay as long in areas where you actually want to collect data. If you want to have just as much data in boundary currents as in the interior of the ocean, we are now writing software [...], in which you can virtually predict these” (Int-1, German female senior marine scientist).

By providing this voluntary work, such as decoding data, programming software, and making these publicly available, MCOs can be stabilised to a better extent. But more importantly, by developing the software, the scientists want to avoid an agential cut, meaning the software serves as an intra-acting force aiming to not lose track of the float and thus the data. The careful approach of the scientists, which targets the float’s continuous operation, highlights the material-discursive and dynamic becoming of MCOs.

Stabilisation through globally available and accessible MCOs

So far, little is known about nation states’ practices and reasoning of observing marine carbon and of providing the required financial, technological, and human resources to do

so. Thus, the sole focus on humans and floats overlooks the important processes of geopolitics as part of MCOs, and as both non-human and human intra-acting forces, which are inseparable. These include the availability and accessibility of MCOs, entanglements with the exclusive economic zone (EEZ) or a nation state's financial contribution to the Argo program. To join the European Argo program, a nation state is required to have a long-term engagement with Argo at the country level and should have developed a national Argo program with the deployment of a minimum of three floats each year, and contribute €30000 for the central coordination management, often paid at the Ministry level (field notes 08.04.2021). This potentially leads to the exclusion of some countries due to the high monetary investment required (see the following section).

Besides the accessibility to the Argo program, the available contributions of MCOs to the Global Carbon Budget and the IPCC were frequently emphasised in the interviews conducted and seen as a crucial basis for climate change negotiations (Int-4; Int-5; Int-12 and Int-18, all German male senior marine scientists; Int-14, Colombian female junior marine scientist). These global climate governance mechanisms are not simply an outlet for climate data or a pre-existing reality, but they are part of the mutual constitution of MCOs. MCOs are a material-discursive mediator between global climate governance, climate forecasting, carbon budgeting, and marine environments. All data from Argo floats is available online and “[...] anyone could actually use them” (Int-1, German female senior marine scientists). As such, MCOs and the public access to its virtual data can constitute mediation and sharing of knowledge on climate change and the ocean's health. In practice, any person with access to the internet can use the data on MCOs. The global availability and accessibility of data enact the material-discursive field of climate governance and co-constitutes the open-ended process of knowledge production on the ocean and climate change. Scientists, technicians, floats, sensors, software, data, the translation of data, and climate governance mechanisms are all part of the apparatus constantly enacting MCOs.

Although the floats for MCOs are geographically unevenly distributed among nation states and the ocean (see the next section), the open access, availability, accessibility, and sharing of data and knowledge constitutes an enacted agential cut in form of an inclusion. The translation and standardisation of data support and mediates epistemic equity as

even countries who are not part of the Argo program can use the data. The active role of MCOs in its mode of knowledge mediation, for example climate change scenarios and respective global policies can be described as, “matter comes to matter” in a Baradian sense (1998) and stabilises MCOs.

6.5.2 Destabilising MCOs through climate change, lost knowledge, and (national) boundaries

Having identified the main forces stabilising MCOs, the subsequent sections examine the destabilising forces of the latter. Climate change forces, such as strong currents or marine life, lost knowledge caused by the retirement of scientists or technicians, and inequalities in funding, science systems, and along national boundaries are inseparable forces destabilising MCOs.

An antithesis: The forces of climate change destabilise MCOs for climate change scenarios

Paradoxically, climate change forces themselves can lead to a destabilisation of MCOs. One scientist explained that climate change has caused mild winters, which has led to different diving depths of the float, ergo to a variation from 500m to 4000m water depth leading to distorted observations (Int-1, German female senior marine scientist). Moreover, ocean currents and eddies, which are fast-swirling water columns, can sometimes lead to a permanent loss of the float’s GPS signal for a certain amount of time and consequently to an agential cut (Int-7, German male senior marine scientist), because the float can no longer send its data and humans can no longer identify the location of the float leading to periodical loss of data and communication. Again, an agential cut in the form of an exclusion emerges, in which the boundaries between observer and observed become visible. Neither humans nor non-humans within the apparatus can reach each other, highlighting the constant uncertainty and destabilisations in knowledge production processes of MCOs.

Sometimes, floats also diffract (inter-)national boundaries as they drift into the exclusive economic zones (EEZ) of countries, which usually require prior authorisation of MCOs

through the Argo program (Int-1, German female senior scientist). Although these drifts are caused by uncontrollable ocean currents, the responsible scientists in Germany must inform the countries which prohibit foreign floats in their EEZ, such as Brazil and Russia (field notes 09.06.2022). Similar observations have been reported for the South China Sea where multiple countries have competing territorial interest, and the presence of foreign floats could be viewed as a potential challenge to sovereignty, leading to restrictions (field notes 17.08.2022) and a destabilisation of MCOs through these agential cuts of prohibiting or confiscating floats.

The floats themselves and especially their sensors are likewise affected by marine life, such as molluscs, which can colonise the surface and the sensors of the floats, especially in the upper layers of the ocean, where light permeates. This can lead to gradual inaccuracies in the salinity sensors of Argo floats, requiring corrections with data obtained from SOOP measurements and laboratory-prepared standards (Int-11, German male junior technician; cf. Lehman 2018; Roemmich, Boebel, and Desaubies 2001), resulting in destabilised MCOs. Similarly, some interviewees mentioned “flawed data” (Int-1, German female senior scientist; Int-4, German male senior marine scientist) mostly caused by climate change effects as a challenge for MCOs. These are caused by sensor malfunctions and technical issues and can lead to periodic or constant agential cuts within MCOs, because the data is unreliable. Scientists then need to review the data closely and decide if it can be published or needs to be erased:

“And if you do that, then you want to do it fairly, that means you have to look at this data set, you don’t just say no and say ‘suspended, we won’t take it’, but you have to at least write something about why [the data is] suspended” (Int-4, German male senior marine scientist; cf. Int-20, Brazilian female senior marine scientist),

which increases the scientist’s workload drastically. These agential cuts diffract the knowledge production process of MCOs as unexpected outcomes, such as overtime or unusable data are enacted, highlighting the dynamic becoming of reality. Thus, the ocean’s geographic features itself, climate change forces and resulting “flawed data” and their material entanglements can destabilise MCOs.

MCOs are constantly (de-)stabilised through diverse forces at play in open-ended processes. In this case these forces are both human and non-human and predominately

caused by climate change and physical characteristics of the sea pointing to the ocean's relational ontology of responding, resisting and fluctuating. Looking at these dynamics through a Baradian lens makes sense in better understanding the complexity of MCOs and to take agencies beyond the human seriously. MCOs are constantly becoming, they are not fixed truth as they are in constant intra-action with marine life, humans, and technologies.

Lost knowledge and an engineered death as destabilisation

As a result of limited permanent funding in academia, the attrition rate of staff in MCO research teams is high. With these changes in personnel, much of the crucial knowledge to fund, implement, and analyse MCOs disappears. One oceanographer reported:

“There will simply be fewer and fewer people who can evaluate this. Of course, there will certainly be autonomous systems that will be able to evaluate this themselves at some point in the future. But as long as that doesn't happen, there will be problems at some point. Data is always collected, but there is no one who can evaluate it because there are no jobs. Or there are no jobs created, and I think that's the problem, that you're really tied to these funds [...]” (Int-8, German female senior marine scientist),

highlighting the loss of knowledge and limited funding in MCOs. This diffraction is not only a loss or rupture, but it is rendered as productive in a Baradian sense, as it leaves space to think the old anew. The absence of this knowledge continues to intra-act with what remains. In this case it uses the diffraction to question the science system and enacting epistemic consequences and constant becomings. The scientist continued:

“And that's what I think should change in the future, that this scientific system should be reconsidered at some point, that we really need to create permanent positions for people who can continue to do this and not always just through third-party funding” (Int-8, German female senior marine scientist),

referring not only to the intersection of the German academic system and the knowledge of analysing data, but also to the constant (un)becoming of scientists and technicians in the apparatus of marine knowledge production.

Retirement constitutes another agential cut through which essential knowledge disappears. One technician at a German research institute put it like this: “When I leave, this place will probably be closed. There will be no successor. Retrenchments are being made everywhere” (Int-17, German male senior technician). A researcher added: “Then they just say, now the data is there, and nobody takes care of it and at some point, nobody knows how to handle this data and how to process it anymore” (Int-8, German female senior marine scientist). Thus, the complex and often long-standing knowledge production processes and knowledge transfer of MCOs will be lost. At the same time the diffraction of lost knowledge and epistemic discontinuities can cause misalignments in ongoing MCOs, e.g. incorrect float maintenance or deployments. The exclusion of this knowledge and practices also represent agential cuts, which are ethically charged in Barad’s ethico-onto-epistemology as the material-discursive shift leads to reconfigurations of what reality is becoming.

Besides frequent job changes, limited funding, and retirement as destabilising factors for MCOs, there is also a lack of technicians to stabilise MCOs through the calibration of sensors, and maintenance and deployment of floats, as one junior marine scientist explained:

“We actually have a shortage of technicians and you notice that, sometimes there are a lot of tasks that could easily be delegated to technicians [...], but which you then have to do yourself [...] and that of course costs a lot of time, which you then can’t spend on your actual research” (Int-11, German male junior marine scientist).

The lack of technicians to support the scientists in their research was reported in all four marine science institutes that the research was conducted in, both in Germany and Brazil, pointing to a common phenomenon and the inseparability of intra-acting forces within the apparatus that is constantly reconfigured.

Another destabilisation of MCOs constitutes the actual death of a float, meaning their human-engineered lithium battery, after which, they remain on the seabed (Int-18, German male senior marine scientist). Argo floats are made from plastics, lead, aluminium, copper, zinc, metals, and lithium battery. After the depletion of the battery, a float sinks to the seabed, introducing pollutants to marine life (Riser and Wijffels 2020).

During fieldwork, I was puzzled by how such a human engineered float could simply remain on the seabed in times of climate change, ocean pollution, and limited resources. The large number of floats on the seabed raises concerns in the scientific and non-scientific community about their environmental impact, as some interviewees reported (Int-3, German male junior technician; Int-4, German male senior marine scientist). Isn't there another solution to avoid the floats becoming a sinking relic? Yet, Argo argues that "presently there is no method of observing the subsurface global ocean that is less environmentally damaging and more cost effective than Argo" (Euro Argo 2024). A study by Riser and Wijffels (2020, 9) found that "the chemical species injected into the abyssal waters during this process represent generally infinitesimal amounts in comparison to the natural and anthropogenic fluxes of these substances". Thus, despite the environmental impact and the missing human engineered solution, Argo floats are currently the most effective instrument for urgently needed MCOs. However, the death of a float always contributes to the destabilisation of MCOs, emerging out of the material-discursive forces of non-humans and humans. Simultaneously, the application of Barad's agential realism to MCOs underscores the inseparability of non-human and human forces. Especially MCOs as scientific practice aiming for climate change mitigation cannot be separated from the environmental and socio-economic entanglements and its ethical implication highlighting Barad's ethico-onto-epistemology.

Funding, (national) boundaries and inequalities as destabilisation of MCOs

MCOs are situated in a contested vacuum of epistemic inequalities (cf. Dotson 2014; Fricker 2007), data accessibility, demand for modelling, climate change scenarios and a complex bond between non-human and human forces. The Argo program consists of diverse national contributions of floats aiming to provide data to understand the ocean's role in the earth's climate. Yet, looking at the global distribution and contribution of different nations to the Argo program (see figure 12), countries in Africa, Latin America, or Southeast Asia, are highly underrepresented and if represented, only with a very limited number of floats, e.g., Peru currently has only one active float compared to the US which operates more than 2000 floats. The map also displays a very limited number of floats in coastal areas, pointing to a prohibition or restricted permission of deployments in EEZs.

Questions emerge on the geopolitical interests of nation states (cf. Melvin, Acton, and Campbell 2023), (epistemic) inequalities (cf. Fricker 2007) of MCOs and knowledge on climate change.

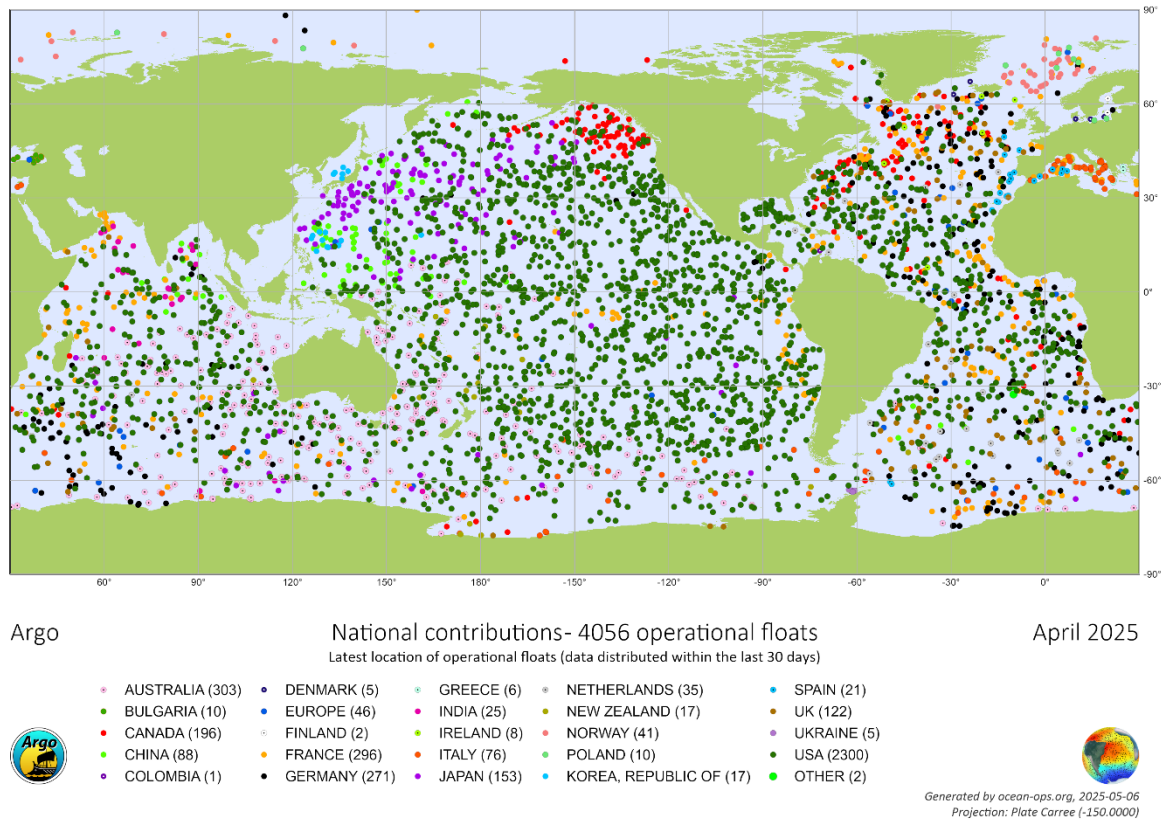


Figure 12: National contributions to the global Argo monitoring network with about 4,000 active Argo floats. Source: Argo (2025).

As figure 12 shows, many nations are not part of the Argo program and thus, not part of the apparatus of marine knowledge production. The inclusion and exclusion of nations and respective scientists point to inequalities in the international science system and can be explained by the lack of funding of MCOs (Int-10, Brazilian male junior marine scientists; Int-12, German male senior marine scientist; Int-14, Colombian female junior marine scientist; Int-20, Brazilian female senior marine scientist). Interviewees mentioned a lack of funding, staff, and time as limitations for observing marine carbon (Int-1, German female senior marine scientist; Int-3, German male junior technician; Int-4; Int-5 and Int-18, all German male senior marine scientists). Funding as part of the apparatus enacts MCOs. Thus, limitations in funding for staff and material are agential cuts that decide which nations, regions, and parts of the ocean matter in the constant (co-)becoming of MCO and global knowledge on the ocean and climate change. In

Germany, the Federal Ministry for Digital and Transport funds the atmospheric carbon measurements, which the state also needs for its national carbon budget calculations. There are fixed stations on land where measurements are taken, but there is no continuous funding for oceanographic measurements to date (Int-1, German female senior marine scientist; Int-4 and Int-5, both German male senior marine scientists; Int-6, German male senior technician). Float procurement, for example, is therefore always subject to third party funding and needs constant renegotiation. Such obstacles impede long-term and sustainable MCOs (Int-1, German female senior marine scientist; Int-5, German male senior marine scientist).

“You also must have contacts to the budget department, the procurement department, so that you can comply with the relevant rules. Even if I know I have money next year, I can only order next year and I have to make sure that I spent all the money by the end of the year, because otherwise the money has to be returned to the Ministry of Finance” (Int-1, German female senior marine scientist),

explained one oceanographer.

Moreover, (national) boundaries and EEZs can produce constant or periodical agential cuts of MCOs enacted through geopolitics. National borders and EEZs play a central role in enacting MCOs. Some countries, such as Russia have asked for bilateral communications if an Argo float enters their EEZ. In such a case the national program focal point (BSH for Germany) acts on an automated alert system installed at *OceanOPS* and contacts the national Argo focal point in the respective country and informs them accordingly (Int-1, German female senior marine scientist). This boundary-drawing practice in territorial terms translates into an epistemological one as it defines who observes, defines, and shares knowledge on MCOs. MCOs in the Arctic are of crucial importance for climate change scenarios. Yet, so far, only limited observations are possible, because the Argo community does not

“know whether we will be allowed to do anything in the Arctic in the next few years. Because the European part is almost all territory of Russia. [...] we cannot deploy floats directly in a foreign EEZ without authorization but have to rely on the float drifting into the right area. In the Arctic, where we would like to have measurements from the Russian shelves, we can currently only deploy just off the Russian border

in Norwegian waters and hope that the currents will do the rest.” (Int-1, German female senior marine scientist).

Some countries prevent globally required MCOs for geopolitical reasons, such as security concerns, thereby reconfiguring the apparatus of marine knowledge production intentionally.

The current distribution of floats and data centres also points to a financial and geopolitical inequality globally. France manages the data centre for all European Argo data, while the US has its own centre (Int-1, German female senior marine scientist). This distribution points to a hegemony of the US, as one scientist reported:

“Argo was an American project, it’s dominated by American floats, and the American community also dominates the technology, and the companies around it. The Americans would never buy from others, they have a much different attitude to us, they wouldn’t buy French or Japanese floats, it’s out of the question, they’re certainly not allowed to with NSF [National Science Foundation] and NOAA [National Oceanic and Atmospheric Administration] funding” (Int-5, German male senior marine scientist).

Similarly Lehman (2018, 74) found that the US is the largest funder of Argo. In particular, the navy is interested in areas of the sea “where it has marine interests, not just off the US coast but also [...] in the South China Sea”. The interest of one country and the non-participation in the Argo program by other countries as an agential cut highlight that MCOs are not neutral but enacted by historically uneven power dynamics. Due to the highly specialised nature of manufacturing sensors for floats, the US-owned company *Sea-Bird* has the monopoly. In recent years, however, the manufacturer prioritised orders from North America, delaying dispatches to other countries (Int-5, German senior marine scientist). Hence, this domination of the US in MCOs can potentially lead to their destabilisation in (and from) other nations, which do not have the respective knowledge, funding nor human resources. Barad’s ethico-onto-epistemology furthermore makes these inequalities visible. Science is not detached from the material practices and the power asymmetries of global MCOs – a site of contested and constant (un-)becoming of reality. Both, the paradox of contributing to climate change and marine pollution while simultaneously trying to solve these with MCOs and the financial, political, and

geographical dominance of certain nations in MCOs can be analysed as technological fixes (Harvey 2003) and may reinforce geopolitical, capitalist hierarchies, and ecological risks rather than solve these.

Table 4: (De-)stabilisations of marine carbon observations. Source: Own elaboration based on Barad (2007) and own data collection (Int-1 – Int-38; field notes).

Stabilisation	Destabilisation
Volunteering of scientists in making data understandable and accessible	Climate change effects and flawed data
Two-way communication between float and human	Lost knowledge and death of floats
Mediation role of MCOs on climate change and policies	Funding of MCOs
Global data accessibility free of charge	National borders including EEZs

As the previous sections have shown, a dynamism of inseparable intra-acting forces is part of destabilising MCOs (see table 4). The final section will summarise these findings and provide an outlook for further research needed.

6.6 Dynamic (de-)stabilisations of MCOs: Concluding remarks

The article took qualitative data from fieldwork on a research vessel and in Brazilian and German marine science institutes which produce knowledge on marine carbon as a vantage point for this article, to ask these questions: How do scientists responsible for determining marine carbon navigate the methodological and technological challenges and uncertainties they encounter? How do they collect, interpret, and share data, or, in other words, how is knowledge about marine carbon (socially) produced? And how are the forces of non-humans and humans implicated in (de-)stabilising MCOs? In short, how are MCOs (de-)stabilised?

By following floats, extending observations from land to sea, and incorporating usually inaccessible locations such as the deep sea and satellites, the research was able to provide valuable insights into the complexity of MCOs, highlighting the co-constituting nature of non-human and human forces in shaping our understanding of oceanic carbon

processes and its entangled material-discursive practices. I argue that Karen Barad's (2007) concept of agential realism provides a useful framework for understanding MCOs. Rather than viewing different components or actors involved in MCOs as separate entities interacting, intra-action emphasises their mutual co-constitution.

In my understanding of Barad's apparatus as a semi-permeable membrane, the non-human and human forces at play cannot be separated. The dynamism of inseparable forces is ever-present. Apart from shedding light on (de-)stabilisations of MCOs, the analysis also identifies diverse (un-)becomings, doings, and diffractions within the apparatus of marine knowledge production processes. The becoming of (marine) scientists and technicians, but also their doings by co-enacting knowledge on climate change, as well as their unbecoming through retirement or budget cuts is apparent when thinking with Barad's concept of agential realism.

The study furthermore examines the material-discursive, mainly geopolitical forces (de-)stabilising MCOs, which have previously rarely been studied. This highlights how political and geographical forces are essential in enacting MCOs, as they are co-constituting scientific practices and technological systems. Yet, the research highlighted global inequalities and raised questions about decision-making, access to funding, and exclusion. The (de-)stabilisation of MCOs appears to be shaped by power relations, funding structures, and governance mechanisms. These dynamics may also obscure environmental or political harms. Science-making in MCOs is more than just data collection as it is always entangled with materiality, emotions, ethics, and responsibility. Producing knowledge on MCOs is a material-discursive practice in which MCOs serve as mediator of what the ocean is and becomes in the context of global climate science-making and governance. Moreover, Barad's lens of agential realism made the usually unseen labour of scientists and technicians, the hidden hierarchies of national, financial, and oceanic boundaries, and the loss of diverse types of knowledge visible.

Moreover, my doings as a researcher show the material practice of knowledge production and its ethical and political implications, adding to Barad's ethico-onto-epistem-ology. With a diffracted understanding of me as a social scientist conducting research on natural scientists' knowledge production, I am contesting positivist understandings of subjectivity and objectivity, but I also enact agential cuts within the apparatus of

knowledge production by observing and including certain phenomena, while others remain excluded.

I invite you once more to imagine 4000 Argo floats moving up and down the ocean. Perhaps you thought, much like I did, that measuring marine carbon would be straightforward before reading this. But measuring marine carbon is by no means straightforward; they, to various degrees, take place in murky waters. The paper identified challenges and often-times overlooked dynamics within MCOs, clarified some of these and highlighted the intricate co-constitutions among various forces entangled in MCOs, yet it may have inadvertently revealed even more challenges than anticipated. Especially the material afterlife of floats and the environmental, labour, and ethical costs of MCOs, requires further research. Ultimately, navigating these murky waters by both floats and scientists underscores the ongoing need for a deeper understanding of how marine carbon research does (not) work.

Chapter 7

Mapping myself: An autoethnography of multiple positionalities, intersectionality, and micropolitics during a marine expedition



Picture 16: A reflection of myself while participating in the maintenance of an autonomous marine carbon observation system on a merchant vessel (a so-called Ship of opportunity (SOOP)) harbouring in Hamburg, Germany in 2022. Source: Mirja Schoderer.

7. Mapping myself: An autoethnography of multiple positionalities, intersectionality, and micropolitics during a marine expedition²⁰

7.1 Chapter summary

During the summer of 2021, I accompanied a seven-week expedition on a German research vessel, which aimed to map large parts of the Northwest Atlantic Mid-Ocean Channel (NAMOC) in the Labrador Sea. As the only social scientist on board, I followed a group of natural scientists and crewmembers in their everyday working routines to understand the knowledge production processes aboard.

How did my positionality including my intersectional identity markers, such as gender, age, and class, but also my socialisation, and social, economic, and political background guide and influence my research? How did it contribute to mapping the deep-sea channel on a moving research vessel? To answer these questions, this analysis brings together concepts of positionality, intersectionality, and micropolitics and includes the role of emotions in science-making processes.

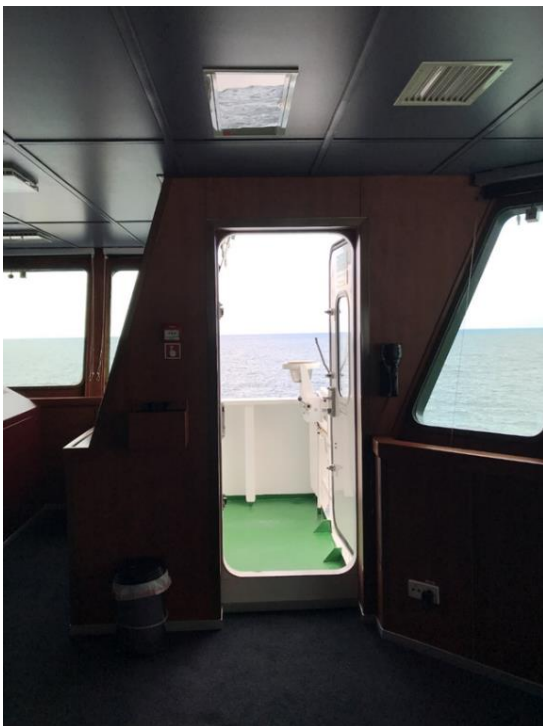
Approaches of Sociology of Knowledge (SoK), Science and Technology Studies (STS), and New Materialism guide my research. Methodologically, I rely on a rich corpus of daily field notes throughout the seven-week journey, interviews with scientists and crewmembers, participant observation, photo and film documentation, and autoethnography.

While the combination of positionalities, intersectionality, and micropolitics provides a conceptual contribution, my analysis includes reflections on my shifting and hidden emotions during the expedition, my access to the field, my entanglements with the scientists, the technology, the deep-sea, the vessel, and the effects of my research on the natural scientist's attempt to map a deep-sea channel. Thus, while contributing to mapping the material as blue infrastructures, my findings shed light on mapping the usually unseen in science-making – a researcher's positionalities, intersectionality, and micropolitics.

²⁰ This chapter has been submitted to the Royal Geographical Society's journal *Geo: Geography and Environment* for the special issue on *Blue Infrastructures: Mapping the visual while unpacking the unseen*. It is currently being amended after having received major revisions.

7.2 Introduction

During summer 2021, I participated in a German research cruise starting in Emden, Germany, crossing the North Atlantic with a quick bunker stop for fuel and comestible goods in St. Johns, Newfoundland, Canada, to then head to the research area in the Labrador Sea between Greenland and Canada aiming to map a deep-sea channel. I was the only social scientist on an ever-moving research vessel for seven weeks, surrounded by the vast ocean, not seeing land, other vessels, or human traces, such as oil platforms for more than five weeks (see pictures 17 and 18). My task was to assist a group of natural scientists, predominantly geoscientists, in mapping a deep-sea channel in the Labrador Sea, while simultaneously co-producing insights on everyday life and working routines of natural scientists and crewmembers through a knowledge sociology lens. I was trying to gain access to the field and in-group, while avoiding ‘going native’²¹ (Menziés 2001; Tresch 2001) and maintaining healthy boundaries to reflect on my own research, positionality, intersectionality, and micropolitics. Throughout but especially after the expedition, I kept wondering how these internal and external factors affect my research and that of others aboard.



Picture 18: View from the research vessel's bridge. Source: Author.



Picture 17: View from the upper deck. Both pictures demonstrate the social seclusion of being surrounded by the vast ocean. Source: Author.

²¹ The term ‘going native’ is employed here solely for illustrative purposes, as it is originally stemming from the 19th century British imperialist discourse and thus carries devaluing implications (Menziés, 2001).

Scientific research, no matter if carried out in the social sciences, the arts, humanities or natural sciences, is never conducted in a vacuum. As researchers, we are embedded in complex social, cultural, and institutional structures that shape our work, our entanglements, and the knowledge we produce (Cañada and Valdivielso 2025; Borgdorff 2012; Knorr-Cetina 1983; Latour and Woolgar 1986).

Haraway (2016, 12) argued that “[i]t matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knots knot knots, what thoughts think thoughts, what descriptions describe descriptions, what ties tie ties. It matters what stories make worlds, what worlds make stories.” Similarly, Hall (2007, 271) said, “all thought is shaped by where it comes from, that knowledge is always to some degree ‘positional’”. One can never escape the way in which one’s formation lays a kind of imprint on or template over what one is interested in, what kind of take one would have on any topic, what linkages one wants to make, and so on.” In line with these thoughts, I argue for the need to always think with and rethink our situatedness, intersectionality, positionality and the micropolitics constantly surrounding us and influencing our thoughts and behaviour as researchers, both in and after the field and during the analysis. The dwindling public trust in science (Oreskes 2019) and calls for a “return to truth” (Cain et al. 2019) reinforces this need for increased transparency and reflexivity in science-making.

To date, positionality is more prominent in the social sciences and humanities than in the natural sciences (Murray et al. 2025). Usually, we only see the analysis and findings of most natural science research, not a holistic interpretation of the access to the field, potential challenges or limitations, details on the data collection processes, and data processing. A positivist approach to science urges scientists to aim for objectivity and universality (ibid.). In the social sciences there is usually space for more detailed research methodologies and reflections on the scientist’s positionality, although it is still not *en vogue* and journals still prioritise an impersonal tone discouraging reflexive writing (Holmes 2020; Zembylas 2025). Yet, researchers are prone to their socialisation, intersectionality, values, belief systems, micropolitics, and biases that influence how they make sense of the world and hence of their research objects (Haraway 1988; Cañada and Valdivielso 2025).

Researching and mapping marine environments and lifeworlds are especially dynamic and complex, as boundaries are usually not fixed, social contestation processes appear in dense spaces such as vessels or laboratories, and sensory landscapes influence marine knowledge production processes (Haegele 2024; Hornidge 2018; Peters and Steinberg 2019). Moreover, what often remains overlooked, are the humans and non-humans involved in the production of marine knowledge and the ones who experience implications through the science-making processes, e.g., coastal and urban communities or marine ecosystems (Rafliana 2025; Schutter et al. 2025; Wheaton and Olive 2023).

Thus, to make the usual unseen visible, such as emotions, potential inequalities, vested interests, political entanglements of research including exclusions and inclusions of certain aspects of the research subjects and research processes, hidden blue infrastructures, and the more-than-human as part of the knowledge production processes, this paper provides a conceptual framing and analysis of positionality, intersectionality, and the micropolitics. This concept is then applied to the empirical example of mapping a deep-sea channel on a research vessel.

In the following sections, I will provide an overview of approaches on positionality, intersectionality, and micropolitics and my methodological framing including an inductive, explorative, and qualitative research design. In the analysis, I will reflect on my research aboard the research vessel, everyday routines, human and more-than-human entanglements, emic and etic perspectives, the research participants, and the traces I am leaving in the field. By exemplifying the challenges of following natural scientist's work in mapping a deep-sea channel on a research vessel as a social scientist, the analysis moreover stimulates thinking about inter-and transdisciplinary research and unequal power relations inherent in diverse forms of marine knowledge production and mapping. The conclusion will assess how a New Materialism lens including an ethnographer's emotions, positionality, micropolitics, and intersectional identity markers proves helpful in reflecting and disclosing the interwoven challenges in (marine) fieldwork and which future research is deemed necessary.

7.3 Assembling positionality, intersectionality, and micropolitics while mapping blue infrastructures

Science and Technology Studies (STS) look at scientific knowledge production processes as an object of investigation. Thereby, knowledge practices are situated and performative, meaning all knowledge is partial, located, and situated depending on the researcher's social, political, cultural, historical, and embodied context (Haraway 1988; Klein et al. 2024; Mol 2002). Approaches of New Materialism add to this thinking by shifting more attention to matter, affect, and emotions in science-making. These approaches furthermore argue that knowledge production in itself enacts knowledge and thereby produces diverse realities while including non-human matter and a researcher's positionality entangled with the phenomena they study (Barad 2007; Bennett 2020; Braidotti 2019).

Positionality is rooted in feminist (Haraway 1988; Harding 1991), postcolonial (Fanon 1963; Spivak 1994), and critical epistemologies (Calhoun 1995; Hamati-Ataya 2012). It emphasises reflexivity, requiring researchers to acknowledge how their identities, backgrounds, and power dynamics influence the research process. The fundamental and seminal works of Haraway (1988) and Harding (1991) laid the foundation for a researcher's reflection and positionality within knowledge production processes, including a researcher's socio-cultural background and epistemic position.

A researcher's cultural identity and biases influence their work and thus power dynamics along the 'insider/ outsider' status can emerge. Either researchers can be too consumed by their own culture, or they can be unaware of certain traditions and cultural taboos (Merriam et al. 2001). Yet, this black and white thinking does not take into account the intersectionality of social identities, past experiences, and socially constructed worldviews that can influence both – the researcher and the research participants (Cañada & Valdivielso 2025; Haegele and Hornidge 2025; Berger and Luckmann 1966).

An objective positivist "view from nowhere" (Haraway, 1988, 589) is questionable since it would require researchers to fully detach from their positionality. Positionality also foregrounds the researcher-participant relationship, recognising asymmetries in

knowledge production. Hamati-Ataya (2012) called the reflexive methodology of researchers to situate themselves within their field of study as the “reflexive turn”.

While the positionality of a researcher plays a crucial role in conducting research, co-producing knowledge and analysis, reflections of it usually only touch gendered dynamics (Traweek 2009; Soedirgo and Glas 2020). Using an intersectional lens by including how identity markers such as gender, class, and (trans)nationality, and everything we use to know the world can influence research, remains so far limited (Barad 2007; Grabe and Else-Quest 2012; TallBear 2013). These intersecting social identity markers influence how we “understand and perceive reality, but they also impact the way we interact with other beings and shape power dynamics and imbalances” (Murray et al. 2025, 69).

Other studies are providing reflections on their methodologies while studying a different epistemic culture, thereby highlighting power asymmetries between observer and observed (Traweek 2009). Latour and Woolgar (1979) and Traweek (2009) pointed to the challenges ethnographers face when studying in laboratories because they must navigate between insider and outsider position which can generate tensions between researchers and researched.

Another layer of integrating the researcher’s positionality are emotional and embodied factors influencing fieldwork. By taking into account discomfort but also alignment or ‘going native’ during research (Davies 2012; Menzies 2001; Tresch 2001). Haraway (1988) emphasises the embodiment of all participant objects and subjects in knowledge production processes, both human and non-human. Similarly, Latour (2004, 205) who argues that having a body means to be “moved, put into motion by other entities, humans or non-humans.” Thus, emotions and embodied factors as part of a researcher’s positionality influences – but is also influenced by – other humans and non-humans. Similarly, Myers (2015) finds that scientific knowledge is rooted in embodied sensory interactions of scientists vice versa their research objects, which are in Myer’s case molecules. She adds an affective dimension of researcher’s engagement with molecules, such as hand gestures that mimic the molecule’s movements or manipulations of models to see how the molecules behave.

Enloe (2016) adds that a researcher’s reflection on positionality in the field is usually done belatedly. She moreover argues that “[e]xercising genuine reflexivity, nevertheless, should

not be easy. It should not be comfortable” (ibid., 259). There exists a thin line between reflexivity and narcissism, as other scholars highlight (Amoureux and Steele 2015; Gani and Khan 2024). Researchers risk centring themselves to the detriment of the research subject, which can lead or enhance unequal power relations between researchers and research subjects (England 1994). This especially holds true when conducting fieldwork in international and postcolonial settings in which researchers should be cautious to not reproduce colonial patterns (Davis and Walsh 2020; Evans 2023; Gani and Khan 2024).

Such affective dimensions also add to micropolitics, which are influencing researchers and (ethnographic) fieldwork. Micropolitics especially refer to potential power dynamics in the field and the everyday life of researchers. These power dynamics include access to the field, the funding of research, recognition in the field, and questions of representation. Micropolitics moreover move away from an anthropocentric point of view and try to include the material and non-humans. Drawing from Lancione (2017), micropolitics shift the focus toward the assemblages and affective intensities shaping research. It moves beyond positionality and explores how multiple forces – human and non-human, institutional and material – continuously shape the research process (ibid.; DeLanda 2019). To avoid reinforcing potential power imbalances, researchers should reflect on their doings. Assemblage thinking allows to comprise the concepts of positionality, intersectionality, and micropolitics together and to provide a holistic conceptual framing. In assemblage theory, everything we observe – humans, ideas, environments, the more-than-human – are entangled in complex and dynamic relational networks (DeLanda 2019; Fox and Alldred 2017; Feely 2020; Lancione 2017; Rafliana 2025).

Bringing together the concepts of positionality, intersectionality, and micropolitics in an assemblage map (see figure 13), enables a visualisation of the non-linear, relational, and dynamic entanglements within a researcher’s (field)work. The dashed and curved lines around the concepts illustrate their semi-permeability and entanglements, not separations and silo-thinking. The smaller spheres around the four overlapping larger spheres show fieldwork dynamics, such as insider-outsider status, social hierarchies, power dynamics, epistemic inequalities, voice and access, emotions and affect.

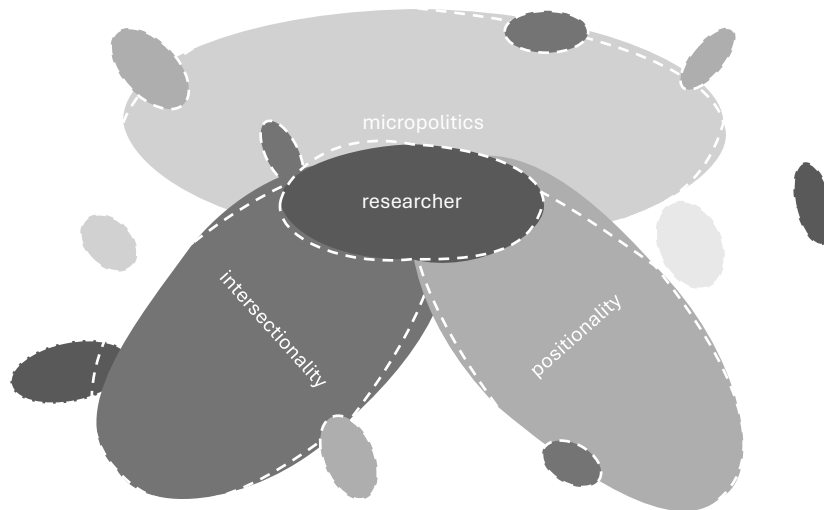


Figure 13: Assemblage map of positionality, intersectionality, and micropolitics. Source: Author based on Calhoun, 1995; Collins 1990; Delanda 2019; Fox and Alldred 2015; Freely 2020; Grabe and Else-Quest 2012; Hamati-Ataya, 2012; Haraway 1988; Spivak, 2004).

I moreover want to highlight that such a visualisation (see figure 13) cannot demonstrate the complexities of such assemblage, so it serves for an heuristic illustration, while acknowledging the Black feminist origin and praxis and the lived experience and resistance of (transnational) intersectionality (Collins 1990: Crenshaw 1991), as well as the feminist, critical, and postcolonial theoretical basis of positionality (Mohanty 2003; Spivak 2004).

Studying up, sideways, or down can come with challenges in being taken seriously and point to micropolitics. Studying up refers to researching actors owning (epistemic) authority such as government officials (Hannerz 2010). In science studies, scholars such as Knorr-Cetina (1988, 1991) and Latour and Woolgar (1986) have documented their access to science communities, for example to scientists working in laboratories. Explaining social science methods and theories to natural scientists while navigating expected objectivity can be challenging (Molyneux and Geissler 2008). Especially if the own research might have institutional or financial implications for the interlocutors through, e.g. critique, a dilemma between ethics and analytical distance may emerge (Marcus 1998). Hamati-Ataya (2012) encouraged social scientists to locate themselves vice versa their research subject, especially in science studies and when studying up. Similarly, Nader (1972), Bowman (2009), and Hannerz (2010) pointed to the challenges that emerge when studying up, but also sideways, e.g. studying within your own epistemic

group, and down, e.g. studying Indigenous communities as a white academic, such as difficulties in accessing the field or tensions in representation.

Having provided an overview of previous research on positionality and micropolitics including intersectionality, I will now zoom into empirical cases in marine contexts and mapping blue infrastructures. Rafliana (2025) calls for seeing research in itself as an assemblage alongside analysing the assemblage of her research subjects by using the case of human and non-human entanglements in tsunami early warning systems. Assemblage theory is particularly helpful to understand blue infrastructures as they are entangled with humans, more-than-humans, such as technologies and marine ecosystems, and allows researchers to explore their relational forces and fluidity (ibid.). Parmiggiani and Monteiro (2016) identified mechanisms scientists use to transform raw data into knowledge on environmental risk in the Arctic, such as sensing subsea ecosystems. They identified so-called infrastructure strategies the scientists use, highlighting the researcher's entanglements with technology and pointing to micropolitical dynamics and the ways that power is embedded in technical infrastructures. Bogusz (2023) provides a sociological reflection of marine natural sciences fieldwork on a methodological level. She provides an analytical framework for interdisciplinary marine fieldwork. Drawing on transdisciplinary artistic research Austen (2024) proposes that humans enact a "watery identity", entangled with marine environments. This destabilises rigid notions of self vs. sea and invites a sense of mutual becoming. Klein et al. (2024) make the situatedness of (marine) simulation modelling tangible through relational approaches in social-ecological dynamics. They found that modelling choices are entangled with discourse, institutional contexts, gender and values. These choices are always socio-materially and intersectionally embedded.

Further marine social science studies, such as Murray et al. (2025) explore positionality in relation to ocean literacy. They link positionality to epistemology aiming to guide the readers how their positionalities shape their views of and relation to the ocean. Although they include intersectionality, they do not incorporate micropolitics to their so-called 'toolkit' on ocean literacy. Shellock et al. (2023) provide recommendations for early career marine researchers to include their positionality throughout their research. Spalding and McKinley (2024) review the current state of marine social sciences including the history

of the field and current research themes but do not mention the importance of positionality, micropolitics, and intersectionality within the growing field. Hornidge et al. (2023) point to the overall Western and masculine theories that dominate marine sciences, marine data collection, and funding, which in turn leads to epistemic inequalities prioritising certain types of knowledge. These findings add to intersectional discrimination in marine sciences (Haegele and Hornidge, 2025) but still miss the incorporation of researcher's positionalities and micropolitics.

These important studies have contributed to providing insights into the usually unseen in blue infrastructures and marine environments, but researchers do not holistically reflect on their own positionalities, intersectionality, and micropolitics influencing their ethnographic or their interlocutor's – predominantly natural science – research. Moreover, only few studies engage with positionality when studying up or sideways including interrogations of micropolitics such as authority and access of social scientists researching e.g. politicians, experts, or natural scientist.

Although there exists a rich literature on a researcher's positionality, intersectionality, and micropolitics as outlined above, an integrated and combined framework and application of all concepts remains missing. This also includes reflections of the researcher's own institutional background, funding and perceived legitimacy in the field and how these might influence the objects or subjects of study. Moreover, an empirical analysis of how these unfold in practice during marine fieldwork remains missing. Thus, in line with New Materialism approaches and assemblage theory (Barad 2007; Bennett 2020; Braidotti 2019; Myers 2015; Delanda 2019; Lancione 2017), this research aims to apply these concepts by using the empirical example of mapping a deep-sea channel.

7.4 Mapping positionalities, intersectionality, and micropolitics in ethnographic research

This study employs an inductive, explorative research design informed by feminist epistemologies, approaches of STS, and New Materialism particularly focusing on the situatedness of knowledge production and the micropolitics of science-making.

Throughout the seven weeks on the research vessel, ethnographic fieldwork was conducted through a qualitative, multi-method approach combining semi-structured interviews, participant observation, film and photo documentation, autoethnography, and extensive field notes. These methods were chosen to trace how researchers, crewmembers, myself, but also non-humans, practices, and technologies co-produce meaning in mapping a deep-sea channel, while also mapping the embodied and affective dimensions of knowledge-making.

The research was embedded in an interdisciplinary research project aiming to expand marine carbon observations by combining different observation systems. As a social scientist, my aim was to understand how knowledge in marine carbon observations is produced, negotiated, and influenced by internal and external factors, such as research environments, socio-technological entanglements, or funding and time limitations.

The 37 semi-structured interviews were extremely important to gain insights into the crewmembers' and scientist's access to the research vessel, their personal life stories and careers. Throughout conducting interviews with experts, e.g. scientists, the way I – as social scientist – perceive them influences my research. As such it is important to critically reflect on these assumptions and find a balance between positionality and the research object or subject (Mason-Bish 2019).

Participant observation and field notes served as data triangulation to identify human and non-human entanglements, potential power dynamics, and hierarchies. Visual material, such as photos and films of routines, work processes, and the marine environment added to the material and embodied understanding of constant doings and co-becomings. Everyday field notes and autoethnography helped me to acknowledge my positionality and my embeddedness in the research process. Reflexive autoethnographic writing was used not only to document encounters but also to examine how my situatedness shaped by disciplinary training, institutional affiliation, and intersecting identity markers, mediated access, interpretation, and relations in the field. Autoethnography hence provides a reflexive tool to constantly reflect on a researcher's own emotional, socio-cultural, epistemic and political entanglements shaping their access to the field, knowledge co-production and analysis (Dumit 2021). Thus, every evening, no matter how late it was or how tired I was, I sat down and reflected on the day, my encounters with both

crewmembers and scientists, and non-humans, such as blue infrastructures, e.g. the vessel, the software, technologies, sediment, or the ocean itself. Yet months and even years after the expedition and the opportunity to exchange with other peers about its micropolitical entanglements, I realised that time and distance are crucial to provide holistic reflections about my situated, intersectional, and micropolitical assemblages during and after the fieldwork.

As this research aims to shed light on my thoughts, challenges, and biases in the field analysed through the lens of positionality, intersectionality, and micropolitics, my field notes including my observations, and emotions serve as primary source for this study. As the interviews and go-alongs are predominately based on questions of knowledge production processes of mapping the deep-sea channel as part of the research project mentioned earlier, they rarely added to questions of positionality and micropolitics. In fact, by the time the research was carried out, I did not plan to write on the latter. Yet, whenever the data allows, I reference the quoted interviews with Int-number to guarantee anonymity.

During coding and analysis of the co-produced insights through thematic analysis (Braun and Clarke 2006), a focus on micropolitics enabled attention to the subtle power relations and negotiations embedded in everyday scientific practices, such as work distribution, data processing, or field site selection. In line with intersectionality, the study resists reducing positionality to fixed categories, instead tracing how identities and power relations are performed and reconfigured within specific socio-material and epistemic settings.

In line with Haraway (1988, 579), I want to emphasise that although I cannot master the “god trick” of having a “view from nowhere”, I want to provide a feminist objectivity that is partial, situated, and contextual by including my positionalities, intersectionality, and micropolitics, such as power relations and the non-human. I use the plural of positionalities because they are multiple, dynamic, and fluid and constantly changing depending on the research localities, my surroundings, and my vis-à-vis. This is what makes us human. We cannot simply cut off our positionalities when entering the field, moving through diverse spaces with our interlocutors, conducting interviews, or when analysing our co-produced knowledge. I call these relational waves of assembled

positionalities which are always surrounding us. I am speaking of positionalities in plural, even though in academic literature it is used in singular, but I argue for the semantic use of multiple positionalities influenced by micropolitics in the plural form.

7.5 Relational positionalities, intersectionality, and micropolitics while following a deep-sea channel: Findings

Imagine the ocean: for seven weeks, I was surrounded by the vast ocean. For more than five weeks, I did not see land, another vessel, oil platforms or other human traces. Seasickness, sleep deprivation, a feeling of anxiety and extreme loneliness alternating with a feeling of freedom and of being far away from responsibilities accompanied me throughout the cruise.

Imagine my days that were structured by 24/7 shift operation working along natural scientists, strict mealtimes and my own ethnographic research. I was balancing between understanding seismology and hydro acoustics, meeting the expectations of the natural scientists, while experiencing everyday life on a research vessel and co-producing insights for my PhD through a knowledge sociology lens.

Imagine the sound and smell: A research vessel is noisy and accompanies a strong odour. Imagine the crew always removing rust, painting the ship's rail afterwards, the engine room buzzing 24/7, the Diesel smell always up in the air. Did you know that you cannot smell the ocean in the high seas? Its scent only reappears moving closer to shore when human matter becomes predominant again.

Imagine the people: 24 crewmembers, 22 male, 2 female, 16 scientists, 8 male, 8 female. Everyone is wearing blue working trousers, yellow jacket, security shoes, and helmets when working on deck. I kept wondering if this outfit similar to a uniform contributes to an in-group feeling. I observed diverse social dynamics during these seven weeks on the research vessel ranging from verbal arguments, new friendships, romantic relationships to sexual harassment. But today, I want to look into my very own every-day routines, behaviour, and its influence on human and non-human entanglements during my research on the vessel and the challenges of fieldwork on such a 100m long confined and constantly moving space.

Bringing together my reflexive and situated knowledge as a social scientist in a marine science setting and the micropolitics of access, trust, and emotional labour during fieldwork, my findings shed light on mapping the usually unseen in science-making – a researcher’s dynamic positionalities, intersectionality, and micropolitics.

7.5.1 Mapping myself while mapping a deep-sea channel: Intersectional forces

My own intersectional identity as a rather young, female, able-bodied, German, and white social scientist with a working-class background played a significant role in shaping my research aboard. During the first two weeks of the expedition, I was met with scepticism by the natural scientists due to the intersection of my age and discipline. As the only social scientist onboard, my role and the importance of a social science lens was rather perceived as useless and the question if I am not taking away the highly competitive spot of a natural scientist came up more than once including stereotypical statements by predominantly junior researchers claiming “I thought all social scientists are taxi drivers” (male junior researcher, Int-5, field notes). Natural scientists exhibited concerns about my potential critical approach as a social scientist and the implications for their funding pointing to micropolitics (field notes). Thus, intersectionality and micropolitics intersect, as I - as a social scientist who is observing natural scientists and crewmembers – can be perceived as invasive. It moreover emphasises that I have power, too, while at the same time I am actively involved in the micropolitics of my own research.

Moreover, the intersection of my gender, body and appearance and that I am “a very good catch” (male senior crewmember, Int-21) and the fact that I am “not yet married” was brought up several times by male crewmembers in their early to late fifties when I was working on deck (field notes). Work at sea is gendered and they mirror patriarchal gender relations and misogyny on land, which still structure society (Ekstedt et al. 2024; Haegele and Hornidge 2025).

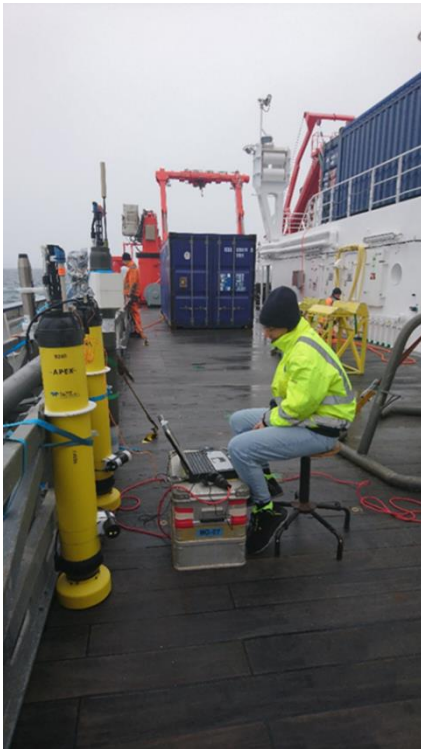
Yet, being a young women enabled me to gain the trust of female scientists and crewmembers. The intersection of gender, age, and physical appearance played a significant role: junior female marine scientists on the vessel shared their experiences of sexual harassment and emotions (Int-3, 9, 10, 13, 16, 25, 33) and they trusted me because

of my age and gender in ways they might not have with older and/ or male researchers. The confined and small space of the vessel, limited privacy and the fact that you cannot exit the vessel for seven weeks added to the search for close allies and someone you can trust.

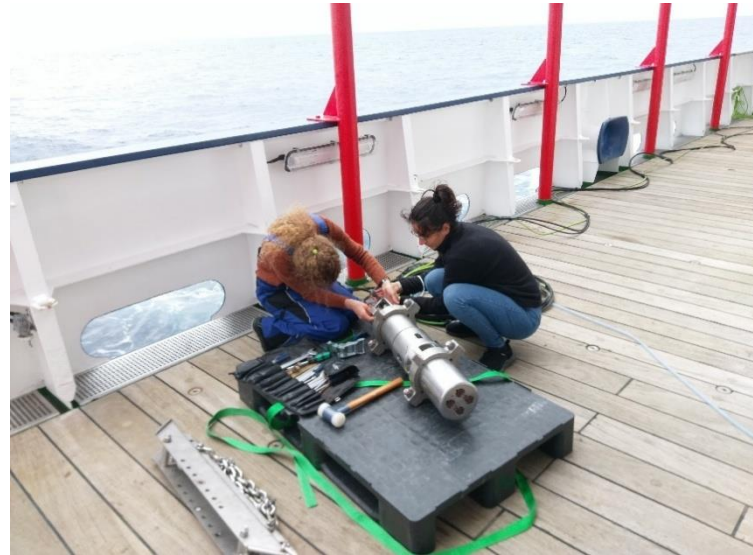
Coming from a working-class background with an unconventional academic trajectory, I often felt a sense of a so-called *Klassenreisende*, a German term which translates into someone straddling and oscillating between different social classes. At the same time, the intersection of my class and discipline, my limited prior knowledge of marine sciences and its methods added layers of both insecurity and openness in my entanglements with natural scientists. Interestingly, my relations with the crewmembers onboard revealed another layer of identity negotiation. As a daughter of an electrician and a receptionist, my access to the crewmembers was rather fast and much easier compared to the natural scientists, fostering a sense of class familiarity and comfort that contrasted with my experiences in German academia. Thus, my class, discipline, and my nationality enabled me to gain access to and win the confidence of the crewmembers more easily.

Uncertainty and insecurity played a key role co-producing knowledge, both in contributing to map the deep-sea channel but also in my own ethnographic research on knowledge production processes. Bodily work on deck was an everyday procedure, e.g. during seismology, while deploying autonomous diving buoys for marine carbon observations (see picture 19) or while assembling technology (see picture 20). Through my upbringing in a working-class environment in which I was used to physical work including using machinery and tools, such as tree felling work or house renovations, I was not afraid to engage with these technologies, but rather curious which supported my approaching of these new tasks. Yet, insecurities of mapping the deep-sea channel and deploying floats remained as I was trained as a social not as a marine scientist. While I was contributing to map the deep-sea channel, I was also intervening in the natural scientist's knowledge production processes. Such interventions differ from the routines I observed. To follow the deep-sea channel for example, I sometimes had to sit next to an officer on the bridge telling him in which direction to navigate the vessel to not lose track of the channel. This was not at all a routine for me, and I felt very insecure and afraid to lose sight of the

channel and to hinder or delay the mapping and thus the research aim of the natural scientist (field notes).



Picture 19: The author deploys floats for marine carbon observations. Source: Anina-Kaja Hinz.



Picture 20: A junior female marine scientist and the author assemble the air gun for bathymetry to map the deep-sea channel. Source: Alexander Schmitz.

7.5.2 Access, trust, and ‘going native’

While positionality emphasises identity, micropolitics urges us to examine broader relational forces at play. The intersection of institutional privileges, funding access, and Western theoretical frameworks shaped my research trajectory in ways I could not fully control. Ethnography itself carries a colonial legacy, and as a researcher trained in Germany, I was aware of the potential for epistemic dominance in my work.

Before acceptance to join the research vessel, I learnt that the spaces on such an expedition are extremely rare, expensive, competitive, and popular. As I was employed in an interdisciplinary research project, a natural scientist acted as a gate keeper to provide me with access to the cruise. Thus, my way in was based on privilege of knowing someone who knew the Chief Scientist. Many of the interviewees, but especially junior marine scientists (Int-10, 13, 16, 24, 25, 32, 33) confirmed that they received access to work on the research vessel through personal connections with the Chief Scientist, e.g. attended

seminars of the Chief Scientist at the university and asked for the possibility of participation on such an expedition.

The first weeks were characterised by extreme loneliness, bullying, and homesickness I experienced for the first time in my adulthood. After approximately three weeks, I felt socially accepted and part of the in-group. I followed everyday routines, worked in the 8 to 12 shift in hydro acoustics and sedimentology. It was expected from me to work in the eight-hour shift everyday while I conducted my interviews, field notes, and autoethnography in my work-free time. While I felt suspicion, mistrust and disempowerment by the two other junior marine scientists in my shift, especially during the first three weeks, time, informal talks, and the inception of my interviews improved their scepticism vis-a-vis myself and my research endeavour (field notes).

The information that the interviews I conducted with both scientists and crewmembers are “not that bad and actually quite fun” (male senior crewmember, Int-26) circulated like the waves surrounding us, which led to even more male crewmembers opening up, perceiving me as someone who quote “finally listens” (Int-15), “a social worker” (Int-11) or “a psychologist” (Int-21). The crewmembers surprisingly turned into gate keepers, they were curious about my work, and their openness provided unique insights into the usually unseen of ship life. An access I gained through the intersection of my class, discipline, and language, as mentioned earlier.

Despite extreme fatigue from working 24/7 and seasickness, I tried to participate in informal gatherings as much as possible. Especially during the evenings, both scientists and crewmembers met for drinks or board games. The acceptance in the field, the creeping in of the daily routines, and the constant monotonous sound and sight of the ocean and the vessel made me immerse myself into the field even more, so that I potentially turned a blind eye on some things. Were there things I no longer noticed because it had become routine for me as well, e.g. mapping the deep-sea channel by routinised sediment sampling, software checks, and patrols to see if the airgun still works properly. Moreover, did I merge into the becoming of the everyday life onboard, including insider jokes, afternoon coffee, and evening gatherings in which I might have overseen a social dynamic, another routine, hidden emotions, or hierarchies. There were some moments in which I have to confess that I couldn't differentiate between my diverse

embodied roles as a scientist and myself anymore. Did I ever stop working during these seven weeks?

Situating myself, my multitude of positionalities were in constant flux, dynamic, ever changing, and flexible, shaped by the moving physical environments and interactions surrounding me. As a social scientist in a predominantly natural science setting, my presence often raised questions about disciplinary boundaries and epistemological differences. During seismology I often felt I was getting in the way of natural scientists. During the crewmembers' after-work meetings I was frequently invited as special guest to their common room on deck – a space only very few scientists were invited to – switching my positionality from a scientist to a working-class member. Every time, I changed a research location, e.g. from sediment sampling to navigating, from an interview with a scientist to an interview with a crewmember, I negotiated my positionality anew. Throughout the cruise I also turned among others into a friend, an emotional supporter, a barkeeper, a navigator, and an autonomous buoy deployer. A multitude of *selves* or an assemblage of diverse roles. These entanglements underscore the relationality of my positionalities and the (in-)visibilities of my social identity markers and micropolitics - at times, I was an outsider; at others, I was an accepted person of trust.

7.5.3 Hidden emotions and the non-human

Power is tied to the researcher's social position. Power is relational and distributed through affect, materiality, and diffraction. These affective and material forces such as my emotions also played a significant role. My emotional labour, driven by a desire for climate justice and inclusivity, sometimes compromised my authority. On the vessel, I oscillated between outsider status and adaptation, and even 'going native' as I integrated into ship culture which ranged from joint movie nights to many beers after work. Experiences of verbal sexual harassment, shaped by intersections of age, gender, and occupation, further underscored the micropolitical tensions inherent in fieldwork.

Time is a central non-human actor within the assemblage of mapping a deep-sea channel and understanding knowledge production processes on a research vessel. It took some time for me to reflect about my intersectionality and positionalities during the fieldwork

but especially after. This is why micropolitics are central too. Only through time and distance to the field, I realised I was verbally (sexually) harassed and discriminated by senior male crewmembers and junior marine scientists due to my gender, age, physical appearance, discipline, and marital status (field notes). Only through time I realised that in the field, I ignored a lot of my emotions, such as homesickness, loneliness and insecurity. I focused on the research and avoided most of my negative emotions. Thus, research is always political while being in the field, but also after. This also includes my decisions of how to code and analyse my field notes and interview transcripts. There is power involved in how my intersectionality, positionalities, and micropolitics play out in and after the field and it takes time to reflect upon these assemblages.

During the interviews with the natural scientists, I felt I must prove that my research is important, too. Their epistemic authority and hierarchy implicitly shaped my behaviour during the interviews, in which I always try to be as neutral as possible, but given the limited space surrounding us, I had the feeling of performing neutrality and competence even more (Int-1, 2, 9, 23, 36, 37). During interviews with male crewmembers, I sometimes had to hide my emotions, values, and political views when they were making sexist, homophobic, conservative, or right-wing comments (Int-14, 17, 26, 29).

Looking at the ocean as non-human actor itself, the research object of the cruise and simultaneously the only landscape surrounding us for five weeks, the sentiment towards the sea differed among the people aboard. While some of my interlocutors experienced the life at sea as “being far away from responsibilities” (Int-2, senior male marine scientists) and as “freedom” (Int-37, senior female marine scientist), I observed a slow transformation of my own feelings towards the ocean throughout the expedition. In the beginning and particularly during the first two weeks, I felt seasick, scared of the weeks ahead, and uncomfortable of knowing that I cannot leave the vessel any time soon. On the last day of the cruise, I took a moment in solitude watching the ocean and waves passing by standing at deck, holding myself on the ship’s rail. I felt sadness of arriving back on land, being back to ‘real life’, being back to responsibilities and roles I was not having on the vessel. Similarly, the alienation and homesickness I experienced had disappeared.

The fieldwork also changed how I knew and related to the ocean (cf. Murray et al. 2025). While being only surrounded by the vast ocean for several weeks and far away from shore

(around 2000km), I gained much more respect of the ocean's force, the cycles, the rhythms, the waves. At the same time, I felt much more connected to the sea and its infrastructure. I knew the shapes of the deep-sea channel below us and it did not appear as something alien, but rather as a tunnel below the sea – a landscape similar to mountains on land (see figures 14 and 15).

The expedition on a research vessel is of course a special field site, as both the ethnographer and the natural scientist voluntarily displace themselves. As humans we are watery beings as we consist of water, and we need water to survive but we cannot live in the deep-sea. I kept wondering if this threatening of our existence and the fact that you give up control once you are trying to reach the deep-sea, makes us less empathetic towards it. Being human means being vulnerable to such harsh nature. If you don't want to become a cyborg anthropologist (cf. Haraway 2013) using technology to get a glimpse of the deep-sea, the only option to take part in the mapping of the deep-sea, is via blue infrastructures that bring the deep-sea up to you in the form of maps or sediment samples. Maybe this is also one of the reasons why there is so much more research on terrestrial spaces compared to the marine world, which is mostly unknown, alien, and uninhabitable.

Thus, not only my emotions towards specific humans on the vessel but also towards non-humans, such as the vessel, my cabin, the deep-sea channel, and the ocean itself shifted from something alien, uncomfortable, even dangerous, to something familiar, safe, and calm. The vessel itself as non-human actor structured the research, the spaces of where to work, eat, meet, and sleep. There was not much privacy nor diversity of what to see since we were only surrounded by the ocean. Rarely, we saw animals, such as pilot whales and Arctic fulmars, which were highlights for both scientists and crewmembers. During these happenings, everyone who was not working under deck, briefly stopped their work and ran on deck to observe the animals. In contrast to these encounters, I did not observe any emotions regarding the non-humans found in sediment samples. One time, a sample with two starfishes arrived. I had the feeling I was the only one caring for these more-than-humans since everyone ignored them and continued their work. I asked the working group leader if I may take them out of the sample and return them to sea, hoping they could survive, which was granted (field notes, see picture 21). Much later I did some

research and found that the species I returned to their habitat are *Astrodia abyssicola*, deep sea brittle stars and unfortunately, like all echinoderms, they rely on water for respiration, and they would quickly dehydrate and suffocate on land. Thus, when returning them to sea, they like many other microbes and more-than-humans in the sediment samples, probably must have been dead already, which saddened me.

In line with Barad (2007), Bennett (2020), and Braidotti (2019), I realised I am entangled with the humans and more-than-humans I study. My reflexions are sensory, material, and affective and entangled with the material agency of the vessel, ocean currents, sensors, animals, plants, and molecules and shape my knowledge production processes but also the ones of the natural scientists as I am part of the doings and becomings on the vessel.



Picture 21: Deep-sea brittle stars which the author tried to rescue out of a sediment sample. Source: Author.

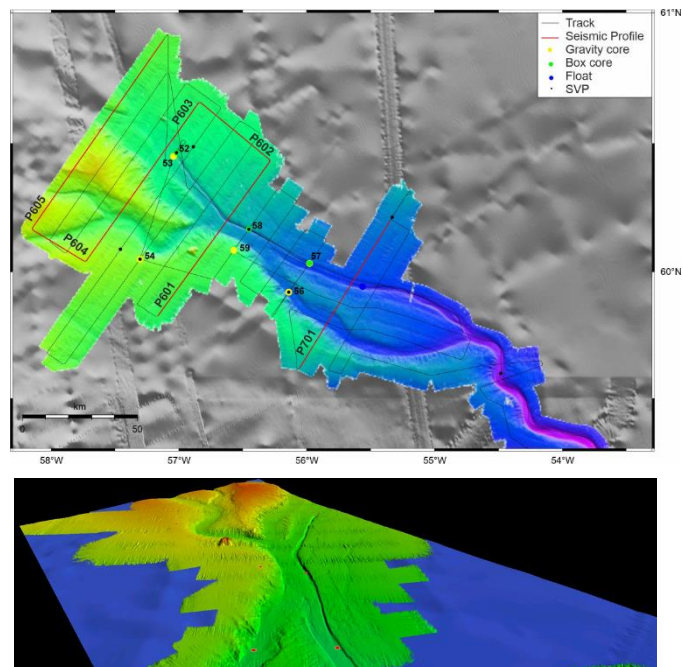


Figure 15: Map of the deep-sea channel. Source: Gitta von Rönn.

Figure 14: Track of the seismic profile of the deep-sea channel including workstations. Source: Gitta von Rönn.

7.6 Conclusion

Micropolitics, positionalities, and intersectionality cannot be separated. The concepts are all connected thinking with assemblage theory. As humans and especially as scientists, we want to map, box, and order things we find in the field. We are aiming to create order. Yet, in assemblage thinking, finding the ultimate truth is impossible.

Relational positionalities and micropolitics challenge traditional notions of objectivity. The knowledge I produce is inevitably shaped by my situatedness, intersectionality, biases, and experiences. Acknowledging this does not weaken research but instead strengthens it by fostering transparency and reflexivity. Recognising the entanglement of power, affect, materiality, and identity allows for a more nuanced understanding of scientific practice, especially within natural sciences that often operate under assumptions of neutrality. An integrated and combined application of positionalities, intersectionality, and micropolitics in every research to reflect on the interwoven challenges in the field ranging from access to authority to ethics could increase transparency, improve inter- and transdisciplinary collaboration in (marine) sciences, and regain public trust in science.

Further research should also explore the role of positionalities and micropolitics in post-fieldwork stages, including analysis, writing, and representation in publications. Questions should also include how an ethnographer chose the events which translate their research into findings and the power of such decision-making.

To conclude and to think with Haraway again, we cannot master the god trick of 'seeing everything from nowhere'. Even as scientists aiming for objectivity, we are prone to our emotions, to the unseen and to matter surrounding us. This is what makes us human. We cannot simply cut off our intersectionality, positionalities, and micropolitics when entering the field, conducting interviews, or when analysing our co-produced knowledge. Relational waves of assembled positionalities, intersectionality, and micropolitics are always surrounding us even if they often remain hidden, and acknowledging this complexity strengthens, not weakens, our knowledge production.

Chapter 8

Sealing a sediment core and reopening it:

Concluding remarks



Picture 22: Sealed sediment cores waiting to be transported from the research vessel to the laboratories on land for further analysis. Source: Author.

8. Sealing a sediment core and reopening it: Concluding remarks

Once the sediment cores have been cut, cleaned, and first-level processed, they are sealed with Styrofoam and cling-film and will only be reopened back on land to continue the analysis in the laboratory (see picture 22). As such this conclusion is not the end of social science research on marine carbon observations (MCOs); it can only be the beginning. I want to repeat Keller's (2011, 61) words of the "ultimate truth" that is usually not the end goal of research. There is always more to study, to navigate, to observe, to make visible. Like the sealed sediment core that will be reopened, the research should be continued, as there are more layers that need exploration, understanding, and translation.

The following sections will summarise the findings by restating the research gap and highlighting the research's contributions to empirical, conceptual, methodological, and socio-political discussions, but they will also reopen the discussion and point to future research needs (see section 8.5).

8.1 Summary of findings and empirical contributions

The dissertation started with an explorative and inductive approach, guided by two contextual observations: 1) marine social sciences as an area of study remains comparatively underexplored relative to terrestrial social science case studies. This gap widens if we turn to marine carbon observations (MCOs) and knowledge production processes. 2) a holistic, multi-sited, and empirically grounded analysis of the socio-material enactment of MCOs remains lacking thus far. This knowledge is crucial as it contributes to climate-relevant research and governance. Similarly to calculating marine carbon, for which no single sensor exists, and multiple parameters need to be measured (see chapter 6), to answer the main research question of how MCOs are produced, and which internal and external factors influence these knowledge production processes, diverse humans, more-than-humans and research localities have been analysed.

But what do we understand now that we did not understand before? Or how Knorr-Cetina (1999, 1) would put it "how [do] we know what we know"? MCOs are enacted, they are not simply measured or recorded. They are the result of complex socio-material practices.

Through sensory, embodied, experiential modes of knowledge practices in uncertain research settings, MCOs are co-constituted by humans and the more-than human and are central in producing stable and credible knowledge. These practices are embedded and shaped by (geo-)politics and historical legacies, which can shift MCOs into fragile observations despite their urgency for climate governance. Agential cuts (de-)stabilise MCOs and involve humans and the more-than-human, such as scientists who care deeply about their work and voluntarily translate and share data or gatekeepers who bring diverse types of knowledge together and navigate uncertainty. Moreover, the identified intersectional social identity markers and integrated positionalities and micropolitics do not only influence the knowledge production of MCOs in diverse localities but also delay science-making through lost types of knowledge from both scientists and non-scientists and an increasing gap between these knowledge systems rooted in transnational social hierarchies, epistemic inequalities, and science systems that continue path dependencies. These findings replace a thus-far linear thinking with a relational, socio-material, and affective account of how MCOs are enacted, become credible, transferred, and feed into policy (see figure 16).

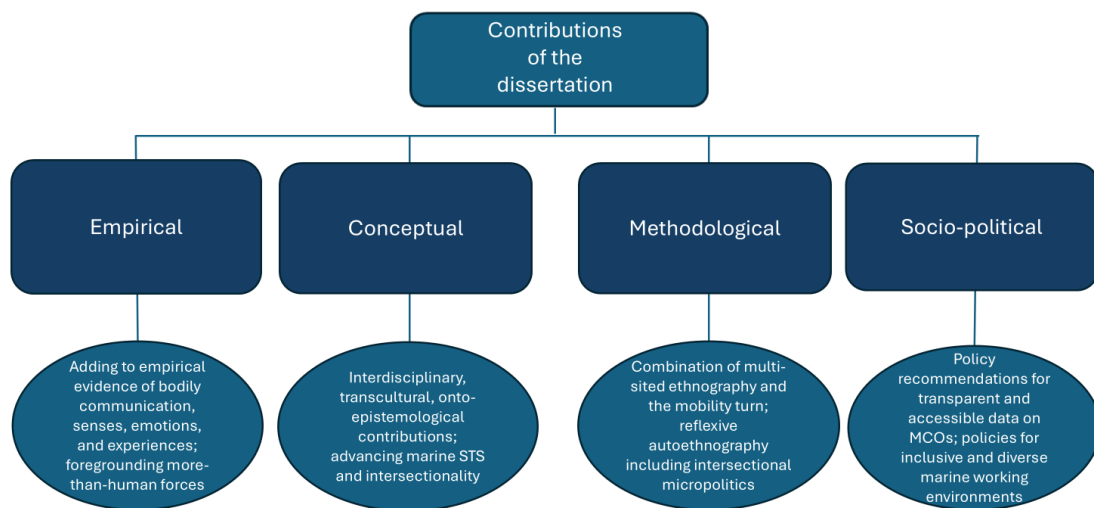


Figure 16: Empirical, conceptual, methodological, and socio-political contributions of the dissertation. Source: Own elaboration.

Empirically, the dissertation provided fine-grained observations and rich empirical insights into everyday life, routines, and research processes on the knowledge production processes of MCOs. MCOs are still a niche topic in science, but especially in social

sciences. In chapter 4, I provided close observations and documentation of on-board practices during a seven-week marine expedition on a German research vessel. I analysed how scientists and crewmembers deal with uncertainty in mapping a deep-sea channel, a river below the sea they cannot see or sense as it remains an inaccessible environment for humans. The findings especially shed light on the crucial role of sensing in science-making, which enable and sometimes limit marine knowledge production. These observations add to empirical evidence of bodily communication and senses, emotions, and experiences. Emotions and affection result in sensing, thereby linking the body socially and physically to the environment. Moreover, these embodied practices co-produce valid data and thus demonstrate that sensory landscapes are central to the quality of research. The observed experiential knowledge and sensory landscapes make diverse data collection processes visible, which are not fully represented in textual datasets.

Chapter 5 provided empirically rich data of observations in the form of field notes, virtual documentations, and thick description, visual material, literature, and 82 interviews, which demonstrated how specific intersectional identity markers, such as appearance, ethnicity, and age, shape social dynamics and increase (sexual) harassment in marine sciences extending the thus far solely gender-focused research. Patterns of (sexual) discrimination and harassment were documented and empirically demonstrated that intersectional dynamics operate transnationally at sea. In a further step, coping strategies of victims of discrimination and harassment – withdrawal or emancipation – and how these influence the knowledge production processes negatively were analysed. These dynamics affect who participates, who speaks, and whose knowledge is heard in marine sciences. The research moreover demonstrates how epistemic practices are constantly reshaped in sea-going working environments.

In chapter 6, I zoom into MCOs by taking the example of Argo floats, which are autonomous diving buoys moving through diverse water depths. During ethnographic fieldwork in Brazil and Germany, I trace how human and non-human forces including scientists, technicians, floats, climate change, funding regimes and national borders co-produce MCOs. Through scientist's dedication in voluntary data translation, human-float communication, and global data sharing, MCOs are stabilized, whereas climate change

impacts, funding insecurity, and geopolitical constraints destabilize urgently needed MCOs. The empirically grounded findings foreground the more-than-human forces and how they are constantly co-becoming or become fragile – a basis for rethinking governance in MCOs networks.

In chapter 7, I presented an autoethnographic account of the seven-week research expedition aboard the research vessel. I examine how my intersectional positionality including gender, age, class, and socialisation, shaped my access, socio-material interactions and interpretations during fieldwork. Empirically, I demonstrate how relational positionalities and micropolitics influence knowledge production processes and how I as a social scientist co-produce knowledge but also hold power in the way my presence altered routines and how I decide to analyse the data and make humans and the more-than-human visible or unseen. Writing this chapter was important to me because publications rarely allow space to reflect on such dynamics. Acknowledging my embodied, emotional, and political situatedness enhances rather than undermines scientific accountability.

The dissertation moreover empirically mapped the enactment of MCOs holistically from funding to more-than-human entanglements in chapter 6, to their integration into the IPCC and the Global Carbon Budget (Schoderer et al. 2024, 2025) and thus provided policy recommendations (see section 8.4).

To conclude, the dissertation contributed to an understanding of marine knowledge production as a socio-material process. By integrating approaches of Sociology of Knowledge (SoK), Science and Technology Studies (STS), New Materialism, and intersectional analysis, the complexities, dynamics, and dependencies of such processes became apparent. Past boundaries between nature and culture, human and non-human, objective and subjective types of knowledge no longer hold true in marine research contexts but rather understand science-making in the Anthropocene as dynamic, non-linear, and assembled processes. The chosen language used in the finding's chapters, such as “mélange” (see chapter 4), “semipermeable membrane” (see chapters 4 and 6), or “murky waters” (see chapter 6) demonstrate these processes and dynamic forces at work in knowledge production processes on MCOs and the constant flux between nature, technology, and society. In times of democratic backsliding,

increasing inequalities, and climate change denial and pressures, the dissertation's findings are timely to strengthen attention to marine environments and the need for more inclusive, just, affective, and effective approaches to marine science, policy, and governance.

8.2 Conceptual contributions

This dissertation contributes conceptually to debates in the Sociology of Knowledge (SoK), Science and Technology Studies (STS), and feminist and postcolonial theory by critically engaging with and extending existing analytical frameworks. Initially, I approached my material through the Sociology of Knowledge Approach to Discourse (SKAD) (Keller 2011), which offers valuable tools for analysing how knowledge and meaning are socially produced. However, as my fieldwork progressed, I recognised the framework's limitations in addressing the material, affective, and more-than-human dimensions of science-making. SKAD's strong focus on language and discourse, its primary use in terrestrial contexts, and its epistemological roots in the German-speaking academic sphere (Keller 2018; Schünemann 2018; Truschkat and Muche 2018) render it largely Eurocentric and insufficiently responsive to decolonial and post-humanist concerns.

In response, my research moves beyond discourse analysis toward a praxeological and relational understanding of knowledge production. Building on Knorr-Cetina's (1999) concept of epistemic cultures, I empirically confirm that scientific fields assemble knowledge in diverse ways, but I further demonstrate how inequalities, hierarchies, and affective relations materialise within these epistemic practices. My observations reveal that these dynamics are not merely organisational but embodied and sensory, emerging in daily intra-actions between scientists, instruments, and environments (see chapters 4 and 6; Haegele 2024, 2025). The identified embodied, sensory, and experiential ways of producing knowledge constitute an extension of STS and challenge positivist views of objective scientific rationality, as sensory landscapes and experiential knowledge have been found recognised as legitimate components of science-making.

Initially I thought of interpreting marine carbon observation (MCO) infrastructures as boundary objects (Star and Griesemer 1989), but I found that established STS approaches underplay the affective and sensory co-becomings between scientists and instruments (see chapters 4 and 6; Haegele 2024, 2025). Drawing on new materialist perspectives, I re-conceptualised these entanglements as active agents in knowledge production, enabling a more holistic understanding of how matter, emotion, and human intention intertwine in the field. My findings especially enhance the application of agential realism (Barad 2007) as the theory was applied to marine sciences (see chapter 6) and thereby shows how humans and non-humans mutually co-constitute MCOs, rather than seeing them as separate entities adding to post-humanist and critical constructivist approaches.

Moreover, my empirical research demonstrates how institutional and geopolitical hierarchies, which are rooted in colonial legacies, continue to shape transnational collaborations and epistemic authority in marine science. Through this, I developed a transnational intersectional lens (cf. Grabe and Else-Quest 2012) that captures inequalities, harassment, and exclusions within diverse research localities, thus adding to the predominantly only gender focused research. It advances intersectional theory by applying it to transnational marine sciences and shows that intersectional identity markers operate across national and institutional boundaries. By conceptually and empirically combining intersectional positionalities and micropolitics, the dissertation moreover holistically maps a researcher's internal and external influences on the research, making power and vulnerabilities visible that usually remains unseen (see chapters 5 and 7; Haegele and Hornidge 2024). These findings expand on feminist and decolonial STS approaches by empirically grounding how global power relations manifest within the micropolitics of everyday science-making.

Finally, by bringing together my empirical observations with my conceptual contributions and because I found existing conceptual discussions too fragmented, I developed the – of what I call – intra-active observation assemblages (IOA) framework as a mid-range concept (cf. Houben 2017; Hornidge 2017; Merton 1949). Thereby, I offer an analytical tool, which can translate other situated and empirical cases into broader theoretical debates without aiming to claim universality or deductive authority. The IOA framework

operates as a flexible, context-sensitive means of connecting practice, materiality, and affect in meaning-making processes, modestly contributing to a more plural and reflexive Sociology of Knowledge (SoK).

Mid-range concepts are concerned “with the analytical problem of identifying the social mechanisms which produce a greater degree of order” (Merton 1949, 452). More recent scholarship within the New Area Studies (Houben 2017; Hornidge 2017) understand mid-range concepts as contextually grounded analytical tool, which connects empirical observations with broader theoretical debates on knowledge production. Thus, I understand a mid-range concept development as a process of translation – of situating my empirical insights within a wider analytical conversation (cf. Houben 2017). In line with Hornidge (2017), who comprehends mid-range concepts as “lego bricks of meaning-making”, I want to note that the developed IOA is flexible and mobile and sensitive to context.

I consolidated the findings in this IOA concept only ex-post fieldwork and analysis. It integrates approaches of the SoK, STS, and New Materialism and contributes to empirically grounded theorisation without claiming universal validity. The IOA consists of 1) analytical elements, 2) patterns, and 3) heuristic claims, which I will explain in the following paragraphs.

Throughout my fieldwork, I repeatedly observed elements that I tracked across sites and now think of them as 1) analytical elements, which can be adapted to diverse contexts, namely enactment, sensory landscapes, micropolitics and intersectional positionalities, boundary infrastructure, governance, uncertainty, phenomena, and synthesis. Enactment is the active process of producing phenomena through human and more-than-human intra-actions, such as MCOs, protocols, or software. Sensory landscapes describe knowledge production processes in which human senses like touch, smell, or sight are involved. An example is identifying the grain sizes of a sediment sample by smearing it between scientist’s fingers. Micropolitics and intersectional positionalities involve external and internal influences on knowledge production that usually remain unseen, such as institutional settings, career stage, gender, ethnicity, or access. Gatekeepers, such as crewmembers on vessels or a technician in laboratories, but also standards that translate local practices to larger contexts count as boundary

infrastructures. The core construct of governance includes geopolitics, funding, regulations, institutional norms that condition what knowledge can be produced. In a marine context, these include funding for sensors, time on a vessel granted or marine exclusive economic zones (EEZ). Decisions about who, where, and when knowledge is produced and legitimated, negotiations, weather conditions, or socio-technical failures count as uncertainty. Phenomena are enacted data sets, models, or indicators and as such objects of knowledge. Finally, synthesis comprises the transformation of the phenomena through formalisation of knowledge into broader contexts, such as their integration into the IPCC or climate policies.

Typical processes through which these elements intra-act are the following patterns that re-occurred: intra-active calibration, micropolitical mediation, boundary translation, and contextual uncertainty. My empirical observations showed these patterns across diverse research localities: 1) Intra-active calibration is a socio-material pattern in which humans and more-than-humans mutually co-constitute each other, for example when a scientist adjusts a sensor based on embodied senses and on the sensor's digital readout. Thus, the calibration is an intra-action, which produces criteria for valid data. 2) Micropolitical mediation describes negotiation processes between humans whose authority is never neutral. A chief scientist can overrule a junior scientist due to their intersectional positionalities and the micropolitics attached. 3) Boundary translation allows local practices and knowledge to travel through gate keepers, such as a data manager who translates results into international standards. 4) The pattern of contextual uncertainty includes adaptation and care practices when needed, e.g. changing a sensor or maintaining a measuring system, and uncertainty due to funding cycles, governance, or geopolitics.

In order to guide comparative inquiry, I developed of what I call heuristic claims, which are claims that other researchers can use heuristically:

H1: Knowledge production processes are influenced by the enacting human and more-than-human forces and by contextual uncertainty.

H2: The inclusion and constant reflexion on micropolitics and intersectional positionalities can make inequalities visible and reduce them in the long term.

H3: Embodied sensory landscapes, experiential knowledge and boundary infrastructures improve knowledge production and enables translation and synthesis.

H4: Contextual uncertainty through governance, funding cycles, and geopolitics explain gaps and discontinuities more than technical failure.

These heuristic claims can be adapted to local conditions and contexts, so that it can facilitate translation between situated cases and wider debates in SoK and STS. Table 5 provides a flexible guide to apply the IOA to other contexts and cases.

Table 5: Application guide of IOA. Source: Own elaboration.

Step	Procedure for applying IOA
1	Specify context and access conditions
2	Gather rich ethnographic material
3	Use the analytical elements as lenses to map practices and relations
4	Trace the patterns where they appear in your data
5	Assess the heuristic claims against your evidence, sensitise analysis
6	Translate and adapt the IOA's elements to local conditions

8.3 Methodological contributions

The diverse ethnographic methods in diverse research localities and in multilingual settings by following both humans and more-than-humans extend and innovate Marcus' (1995) multi-sited ethnography with the mobility turn (Urry 2016; Mielke and Hornidge 2017). It includes multiple sites of meaning-making but also holistically maps external sites of knowledge production without being physically present, such as the inclusion of knowledge shared from outside the research vessel via zoom or GPS data send from the North Atlantic to a German office at the Baltic Coast. While much of the fieldwork was anchored in single-site locations, e.g. a laboratory, it was consistently shaped by knowledge originating elsewhere, such as GPS data or virtual communication. The novel approach of multi-sited ethnography moreover offers to study marine knowledge production processes in situ but also transnationally and beyond national boundaries. Thus, it adds a geopolitical and more-than-human lens (see chapters 4 – 6). Integrating

the material methodologically and consider the more-than-human as part of each research process, the usually unseen diverse infrastructures, such as the research vessel, the sensors, GPS signals, the deep-sea channel become visible in co-producing knowledge. The research further spanned multiple physical segments of the ocean, including various depths and sampling station, underscoring the heterogeneity of the field localities itself. The inclusion of mobile sites of meaning-making enables to incorporate research localities, which are usually inaccessible for physical observation.

The autoethnographic contribution (see chapter 7) provides insights into scientific practices while simultaneously maintaining critical reflexivity about the researcher's intersectional identity markers, positionalities, and the micropolitics surrounding the researcher. A combination of these three concepts demonstrates a novelty and allows a holistic and critical reflection on the researcher's influence in and beyond the field. It also adds to discussions on research ethics and reflexive validity and treats care not only as an empirical variable but also as a research practice.

Method triangulation of interviews, go-alongs, field notes, thick description, document analysis, participant observation, autoethnography, and visual and virtual ethnography allow a thick and practice-level triangulation. Moreover, the development of the Intra-active Observation Assemblages (IOA) framework as a mid-range concept allows a methodological operationalisation through an application guide (table xx), thereby enabling a mobile and context sensitive application beyond MCOs.

8.4 Socio-political contributions

The findings of the dissertation contribute to bridging the gap between natural and social sciences and hence between science, society, and policy to understand, predict, and prevent future impacts of marine carbon dioxide (CO₂). Studying knowledge production in an international, transcultural, inter- and transdisciplinary team, such as the C-SCOPE team, provides a great opportunity to consider the internationalisation of knowledge and accompanying challenges. Increasingly, science-policy and science-public relations are changing rapidly due to the fact that research activities and results are being internationally contested (Markus et al. 2018). Knowledge and data on marine carbon

observations (MCOs) should be transparent and accessible for both politics and society. The dissertation therefore observed who has and who does not have access to MCOs. The findings shed light on transnational cooperation in science and how this is hindered or facilitated through borders, funding, institutions, authority, and capacity building (see chapter 6).

Recommendations for a transparent and accessible procedure of marine CO₂ data incorporation in international databases and science-policy platforms were provided in two external publications (see Schoderer et al. 2024, 2025)²². By tracing the marine carbon value chain from in-situ MCO measurements on the local level to global governance, a social network analysis provided insights into the global MCO community, its vulnerabilities through funding shortages and its gate keepers (Schoderer et al. 2024). In another study by Schoderer et al. (2025), we argue for open science reforms through transparency, equality of opportunities, responsibility, collaboration, inclusion, flexibility and sustainability in MCOs knowledge production processes.

Another important contribution emerged throughout the analysis on intersectionality at sea. By tracing how intersectional identity markers influence marine knowledge production but also the wider science system to understand on which intersection and in which localities (sexual) harassment and discrimination appear, several socio-political recommendations emerged (see chapter 5). In cases of (sexual) harassment and discrimination during work on and with the ocean, immediate institutional responses by scientific institutes and shipping companies are required. In addition, anti-discrimination trainings should be obligatory for all participating persons, such as scientists and crewmembers. The research furthermore supports policies for inclusive, multilingual, and diverse marine working environments.

Moreover, pointing to uncertainty, sensory knowledge, emotions, and affect in science-making, the dissertation translates embodied experiences in knowledge production processes into an actual science-making practice with valid and valuable output (see chapters 4 and 7), which shifts solely instrument-based models to a collective, auditable

²² I also contributed my collected data and parts of the analysis to the two publications by Schoderer et al. (2024, 2025). To gain an understanding of the marine CO₂ value chain and associated coordination efforts (2024) and to learn more on the open science principles applied to MCOs (2025), please have a look at the two open-access publications.

practice. It can improve public trust while advancing epistemic justice, policy relevance, and institutional accountability.

8.5 Reflexional afterword and outlook

This research unfolded over more than four years within entanglements of humans and the more-than-human. It crossed borders and boundaries – both seen and hidden, it enacted relationships of collaboration, trust, but also of asymmetry. My access, identity, positionalities, and micropolitics shaped what I observed, whom I interviewed, how people engaged with me, which data I analysed, and how I transformed this data into findings and scientific outputs. The in-between moments of frustration, stress, joyful encounters, learning, seasickness, successful deployments, and ocean immersions were not noise that needed to be erased from the data but part of studying knowledge production processes of marine carbon observations (MCOs).

The research started on the surface, slowly removing layer after layer, reaching the centre of the sediment core to understand the travel of types of knowledge, of humans and more-than-humans, of carbon to the deep-sea, of the past, the present, and the future of the climate and the ocean. The findings contribute to calls for more reflexive, inclusive, creative, diverse, and socially engaged approaches in marine sciences and beyond that can better address contemporary marine, environmental, climate, and social challenges.

I – once more – want to come back to the statement of my supervisor “everything is data”. Her advice was an important one for me and I carried it throughout my PhD journey. But I keep questioning where do we start and when do we know we should end collecting data, and start analysing and writing? Apart from obvious observations and conversations, there exist countless in-between moments which hold valuable information and context for every research. There exists a thin line between observing the obvious and smoothing away uncertainty or technical failures while turning a blind eye on routines. We as researchers need to focus on both – the obvious but also the in-between to make these commitments visible.

There is much more to research in the murky waters of marine carbon observations, marine sciences, and natural sciences. Cosmological research including Indigenous

knowledge should be taken more fully into account in scientific practices. In Indigenous cosmologies, land and water are not separated but co-constitute relational grounds (Jones and Wanhalla 2022). Thus, the human and more-than-human are not seen as separated. Co-designing future research with local and Indigenous knowledge holders could add to equality and justice in (marine) science-making and beyond.

Future research could moreover apply the Intra-active Observation Assemblages (IOA) framework as a mid-range concept in diverse settings of interest for the Sociology of Knowledge (SoK), Science and Technology Studies (STS), and New Materialism, such as AI, digitalisation, climate technologies, and in under-represented (marine) regions. Additionally, extended research on how policies, funding cycles, and political changes influences epistemic cultures and their science-making over shifting governance conditions is needed. Some observations need longer and continuous tracking than a grant cycle allows, as some only unfold over timescales.

In closing, the research has taught me that what science calls evidence is always situated. Knowledge is kept afloat by humans and the more-than-humans, by their entanglements, their constant co-becoming, open-ended assemblages, and by relations of care. The dissertation is incomplete by necessity because observing systems are themselves always unfinished. The natural cycle does not know funding or institutional cycles; it continues. Knowing this, our responsibility is not only to continue research but to make the processes more just, inclusive, and equal for both – the human and the more-than-human.

Water

Home is many people and places and languages, some separated by the ocean.

Where is the place your body is anchored?

Which body of water is yours?

Is it that I've anchored myself in too many places at once, or nowhere at all?

The answer lies somewhere in between.

Over time, springing up from the in-between space, new islands form as some small proof that although my pieces of home are scattered, I will always find my way to them.

Adapted from Nina Mingya Powles, 2021, *Small Bodies of Water*

No water,

no life.

No blue,

no green.

Dr. Sylvia Earle, 2009, TED Talk, "My wish: Protect our oceans"

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Annexes

Annex 1: Field notes template

Field notes

Day and date of expedition/ laboratory / office / workshop / fieldwork: XX

Summary of the day:

(Epistemic) routines including knowledge production processes:

Processes of sample collection/ negotiation processes:

Social interactions/ processes/dynamics:

Physicality (space, communication):

Technology/gear/infrastructure interactions/ dependence:

Potential power (a)symmetries including intersectionality and (colonial trajectories) of k-production:

Own positionality (in-group/out-group thinking):

Annex 2: Semi-structured interview guideline for German speakers

Semi-strukturierter Interviewleitfaden

Einstieg

- Einverständniserklärung zu Teilnahme und Aufzeichnung
- Hinweis auf Vertraulichkeit/Anonymisierung der Daten
- Hinweise zum Ablauf

Informationen

- Datum
- Funktion am Institut und Abteilung
- Gruppe (Wissenschaftler:in/ Techniker:in, etc., Disziplin, höchster Abschluss)
- Muttersprache
- Nationalität
- Geschlecht
- Alter

Zugang

Wie kamst du an das Institut/ Bundesamt / Universität? (Berufsweg, Zugang, Motivation)

Alltag / Routinen

Du bist ja hierfür zuständig am Institut, ich stelle mir vor, das umfasst.... Erzähl mir doch was über deinen Alltag/ deine Routinen hier am Institut/ Institut/ Universität.

Gibt es Arbeitsschritte, die du jeden Tag machst?

Was ist eigentlich „Wissen“ für Dich? Und wie unterscheidet es sich von Daten oder Information?

Wissensproduktion alleine und im Team

Was sind deine konkreten Aufgaben? Was sind deine Forschungsfragen/ Methoden?

Wer ist dein/e Hauptansprechpartner:in?

Wie gestaltet sich der Prozess der Datenerhebungen/ Methodendiskussionen/ Aufbereitungen in C-SCOPE/ im Team am Institut/ Bundesamt/ Universität?

Wie gestaltet sich deine Interaktion mit anderen Kolleg:innen am Institut/ Bundesamt/ Universität / Partner:innen in C-SCOPE?

Ich welchen Sprachen arbeitest Du?

Wie gestaltet sich die Interaktion mit Teammitgliedern anderer Herkunft, Kultur und Geschlecht?

Könntest du mir einmal „den Weg“ einer marinen Kohlenstoffbeobachtung von Anfang bis Ende erklären? Wie ist die Vorgehensweise im deutschsprachigen/ europäischen Raum?

Technologie

Wie gestaltet sich deine Interaktion mit Technologie im Arbeitsalltag?

Wie hat sich deine Arbeit durch die Technologie über die Jahre hinweg verändert?

Welche Forschungsfragen fragst Du, weil die Technik es möglich macht? Welche gehen im Nichtwissen unter?

Was sehen wir, weil wir das Lineal zum Messen haben, was sehen wir aber genau deswegen nicht?

Empfindungen am Arbeitsplatz (Büro, Labor, Schiff, etc.)

Wie geht es dir mit Arbeitsortwechseln? Stellst du dabei Unterschiede in deiner Arbeit fest?

Gibt es äußere Faktoren, die Einfluss auf deine Arbeit/sroutinen haben? (finanzieller und zeitlicher Druck, ggf. Schichtdienst, etc.)

Was ist für dich eine besondere Herausforderung oder gar Belastung bei der Arbeit?

Abschluss

Was ist deine Perspektive auf das Wissenssystem mariner Forschung/ mariner Kohlenstoffbeobachtungen? Was würdest du dir für die Zukunft wünschen (z.B. Verbesserung)?

Annex 3: Semi-structured interview guideline for English speakers

Semi-structured interview questions

Prior to the interview

- Declaration of consent to participation and recording
- Note on confidentiality/anonymisation of data
- Procedure

Information

- Date
- Profession (including Department)
- Group (scientist, technician, etc.), discipline, highest degree
- Mother tongue
- Nationality
- Gender
- Age

Introduction

How did you come to be here (at the institute, agency, university) (career path, access, motivation)?

Everyday life at work

You are responsible for xxxx at the agency, university. I imagine that includes xxxx. Could you tell me something about your everyday life at work?

Are there tasks you do every day (routines)?

Knowledge production process

What are your concrete tasks at work? (What are your research questions/methods?)

Who is your main contact person?

Could you tell me something about the process of data collection / discussion of methods within the team?

How do you interact with other scientists/non-scientists?

In which languages do you work?

How do you interact with colleagues from different nations (languages), cultures and genders? (e.g. international team members/observers/women/men/others).

Technology

How do you interact with technology at your everyday work?

Has technology changed your work over the years and if so in how far?

Imagine the main technology you are working with most (e.g. a float, a laptop, etc.) as a human being. How would you assess your relationship with each other?

Could you explain to me "the journey" of a marine carbon observation from beginning to end? How does it feel about deploying a float/ taking a water sample/ deploying a system?

Perceptions

How do you perceive the German/ Brazilian (marine) science system (including funding)?

What means knowledge to you (despite data or information)?

What do you find particularly challenging or even stressful about your work?

How do you feel about changing work locations? Do you notice any differences in your work when you do so?

Are there external and internal factors (we have not yet talked about) that influence your work/routines? (Financial and time pressures, shift work if applicable, etc.).

Conclusion

What is your perspective on the knowledge system of marine research? What would you like to see in the future (e.g. improvement)?

Annex 4: List of semi-structured interviews

4.1 List of semi-structured interviews with scientists on a research vessel

position	function on board	discipline/ department	highest degree	mother tongue	nationality	gender	age
Post-Doc	Head of sedimentology	Geo sciences	PhD	German	German	female	33
Professor	Chief Scientist	Marine geo sciences	PhD	German	German	male	54
Student	Shift supervisor 8-12	Geophysics	Bachelor	German	German	female	28
PhD	Laboratory manager	Geo sciences	Master	German	German	male	26
Student	Student assistant	Geophysics	Bachelor	German	German	male	23
Technician & Self employed	Technician	Biology	Diploma	German	German	male	59

Post-Doc	Scientist, shift supervisor 4-12	Geophysics	PhD	English	South African, Great Britian, New Zealand	female	27
Student	Student assistant	Geophysics	A-Level	German	German	female	22
intern	Intern	Geophysics	A-Level	German	German	female	19
Student	Student assistant	Geo sciences	Bachelor	German	German	female	22
Professor	2nd Scientist	Geophysics	PhD	English	Canadian	male	61
Student	Student assistant	Geophysics	Bachelor	German	German	male	26
Student	Shift supervisor 0-4	Geophysics	Bachelor	German	German	female	22
Student	Student assistant	Geo sciences	A-Level	German	German	male	20
Student	Student assistant	Geo sciences	A-Level	German	German	female	23

Professor	Chief Scientist	Geo sciences	PhD	German	German	male	54
Post-Doc	Head of sedimentology	Geo sciences	PhD	German	German	female	33

4.2 List of semi-structured interviews with crewmembers on vessels

position	department	discipline if applicable	highest degree	mother tongue	nationality	gender	age
3rd Engineer	Engine room	Marine engineering	Bachelor	German	German	male	34
1st Officer	Bridge	Nautic	Bachelor	German	German	female	28
2nd Engineer	Engine room	Marine engineering	Patent	German	German	male	32
Chief Officer	Bridge	Nautic	Patent	German	German	male	34
Ship's Doctor	N/A	Medicine	Dr. med	German	German	male	60

System Operator	WTD (Wissenschaftlich-technische Dienstleistungen)	Geology	Diploma	German	German/ Italian	male	60
2nd Officer	Bridge	Nautic	Patent	German	German	male	36
Electrician	WTD (Wissenschaftlich-technische Dienstleistungen)	Engineering	Diploma	German	German	male	60
ship mechanic	Deck	N/A	Apprenticeship	German	German	male	31
Bosun	Deck	Nautic	Patent	German	German	male	36
ship mechanic	Deck	N/A	Apprenticeship	German	German	male	63
ship mechanic	Deck	N/A	Apprenticeship	German	German/ Albanian	male	20
ship mechanic	Deck	N/A	Apprenticeship	German	German	male	59
captain/ master	Bridge	Nautic	Patent	German	German	male	41

1st cook	Galley	N/A	Apprenticeship	German	German	male	52
Electrician	Engine room	N/A	Apprenticeship	German	German	male	55
2nd cook	Galley	N/A	Apprenticeship	German	German	male	33
locksmith	Deck	N/A	Apprenticeship	German	German	male	60
ship mechanic	Deck	N/A	Apprenticeship	German	German	male	20
oiler	Engine room	N/A	Apprenticeship	German	German	male	60

4.3 List of semi-structured interviews with scientists and technicians in Germany

position	department	discipline	highest degree	mother tongue	nationality	gender	age
Scientist	Oceanographic assessments	Physical oceanography	PhD	German	German	female	62
Scientist	Oceanographic assessments	Physical oceanography	Master	German	German	female	36
Technician	Oceanographic assessments	Maritime technologies	Bachelor	German	German	male	31
Scientist	Marine biogeochemistry	Chemical oceanography	PhD	German	German	male	48
Head	Marine biogeochemistry	Chemical oceanography	Prof.	German	German	male	59
Engineer/TLZ	Physical oceanography	Physical oceanography	Dipl.	German	German	male	65
Scientist	Physical oceanography	Physical oceanography	PhD	German	German	male	56
Scientist	Marine biogeochemistry	Chemistry	PhD	German	German	female	33
Scientist	Marine biogeochemistry	Chemical oceanography	PhD	French	France	female	28

Scientist	Marine biogeochemistry	Chemical oceanography	Master	Portuguese	Brazilian	male	28
Scientist	Marine biogeochemistry	Chemistry	Bachelor	German	German	male	32
Scientist	Marine biogeochemistry	Chemical oceanography	PhD	German	German	male	40
administrator	Science management and communication	Law	state examination	German	German	male	37
Scientist	Oceanographic assessments	Physical oceanography	Master	Spanish	Colombian	female	37
Technician	Working group Trace Gas Biogeochemistry	Chemistry	PhD	German	German	male	40
Technician	Working group Trace Gas Biogeochemistry	Ecology	Dipl.	German	German	male	50
Technician	Working group Trace Gas Biogeochemistry	Locksmith	apprenticeship	German	German	male	61
Scientist	Working group Trace Gas Biogeochemistry	Chemistry	PhD	German	German	male	38
Technician	Working group Trace Gas Biogeochemistry	Engineering	PhD	German	German	male	42
Scientist	Working group Trace Gas Biogeochemistry	Marine sciences	PhD	Portuguese	Brazilian	female	36

Scientist	Working group Trace Gas Biogeochemistry	Marine sciences	Master	Swedish	Swedish	female	26
Scientist/ Coordinator	Working group Trace Gas Biogeochemistry	Marine chemistry	PhD	German	German	female	39
Scientist	Oceanography	Environmental science	PhD	Spanish	Mexican	female	44

4.4 List of semi-structured interviews with scientists and technicians in Brazil

position	department	discipline	highest degree	mother tongue	nationality	gender	age
PhD Student	Department for Oceanography	Remote sensing	Master	Portuguese	Brazilian	female	33
Prof.	Department for Oceanography	Chemical Oceanography	PhD	Portuguese	Brazilian	female	50
Prof. Associate at the ICO	Department for Oceanography International Cooperation Office (ICO)	Biological Oceanography	PhD	Portuguese	Brazilian	female	49
Post Doc	Department for Oceanography	Physical Oceanography	PhD	Portuguese	Brazilian	male	37
PhD Student	Department for Oceanography	Oceanography	Master	Portuguese	Brazilian	female	31
Prof.	Department for Oceanography	Physical Oceanography	PhD	Portuguese	Brazilian	male	47
Vice Director	Department for Oceanography	Physical Oceanography	PhD	Portuguese	Brazilian	male	59
Director	Department for Oceanography	Biological Oceanography	PhD	Portuguese	Brazilian	male	61

Prof.	Department for Oceanography	Chemical Oceanography	PhD	Portuguese	Brazilian and German	female	56
Prof.	Department for Oceanography	Analytical Chemistry	PhD	Portuguese	Brazilian	female	51
Prof.	Department for Oceanography	Geology	PhD	Portuguese	Brazilian	female	46
Prof.	Department for Oceanography	Ecology	PhD	Portuguese	Brazilian	female	41
Prof.	Department for Oceanography	Geophysics	PhD	Portuguese	Brazilian and British	female	48
PhD Student	Department for Oceanography	Chemical Oceanography	Master	Portuguese	Brazilian	male	26
Prof.	Department for Oceanography	Physical geology	PhD	Portuguese	Brazilian	female	60
Prof.	Organizational behaviour	Psychology	PhD	Portuguese	Brazilian	female	39
Prof.	Innovation	Production engineering	PhD	Portuguese	Brazilian	female	40
Prof.	Public administration	Public administration	PhD	Portuguese	Brazilian	male	57
Researcher	Director's secretary	Oceanography	Bachelor	Portuguese	Brazilian	female	37
Researcher	Ocean voices and Liga das Mulheres pelo Oceano	Oceanography	PhD	Portuguese	Brazilian	female	33

Researcher	Private sector and Liga das Mulheres pelo Oceano	Oceanography	PhD	Portuguese	Brazilian	female	40
Researcher	Liga das Mulheres pelo Oceano	Oceanography	PhD	Portuguese	Brazilian	female	44

Annex 5: List of virtual participant observations

Euro-Argo Workshop Country Updates

Euro-Argo Workshop Baltic Sea Session

Global Biogeochemical-Argo Fleet: Knowledge to Action: Argo Introduction, Agency Perspectives

Global Biogeochemical-Argo Fleet: Knowledge to Action: Fisheries and Fisheries Management

Global Biogeochemical-Argo Fleet: Knowledge to Action: Carbon Budget Verification

Global Biogeochemical-Argo Fleet: Knowledge to Action: Modelling, Data Assimilation, and Forecasting

Global Biogeochemical-Argo Fleet: Knowledge to Action: Summary Panel Discussion

DArgo2025 Project Meeting

Euro-Argo Management Board Meetings

High-Level Launch of the Ocean Decade First International Ocean Decade Conference

Ocean laboratories of the UN Decade of Ocean Science for Sustainable Development (2021-2030)

Satellite activities of the UN Decade of Ocean Science for Sustainable Development (2021-2030)

G7 Future of the Seas and Oceans (G7 FSOI) Resource Strategy Group for the global Biogeochemical Argo Array 2030

Euro-Argo Science Meetings

Annex 6: Doctoral candidate's statement on her contribution to the joint publication

Erklärung der Doktorandin zum Eigenanteil an der gemeinsamen Publikation

“Haegele, R., & Hornidge, A. K. (2025). Transnational intersectionality at sea: Gender, appearance, ethnicity, age, and marine knowledge production. *Ocean and Society*, 2.“

Hiermit erkläre ich, Ramona Haegele, dass mein Beitrag zur Publikation „Transnational intersectionality at sea: Gender, appearance, ethnicity, age, and marine knowledge production“, verfasst gemeinsam mit Prof. Dr. Anna-Katharina Hornidge, die alleinige Datenerhebung, den wesentlichen Anteil der empirischen Analyse, der theoretischen Ausarbeitung sowie der schriftlichen Ausformulierung umfasst. Die Konzeption des Forschungsdesigns, die Erhebung und Auswertung des qualitativen Materials sowie die zentrale Argumentationslinie stammen von mir. Beiträge der Mitautorin beziehen sich auf fachliche Beratung, theoretische Rückbindung und redaktionelle Überarbeitung. Die wissenschaftliche Verantwortung für die genannten Inhalte liegt bei mir.

Bonn, 18.11.2025

Ort, Datum



Unterschrift Doktorandin

Bestätigung der Betreuerin

Hiermit bestätige ich, Prof. Dr. Anna-Katharina Hornidge, dass die von Ramona Haegele gemachten Angaben zum Eigenanteil an der gemeinsamen Publikation „Transnational intersectionality at sea: Gender, appearance, ethnicity, age, and marine knowledge production“ zutreffen. Der wissenschaftliche Hauptbeitrag, wie in der obigen Erklärung dargestellt, wurde von ihr erbracht.

Bonn, 18.11.2025

Ort, Datum


Unterschrift Betreuerin, Universität Bonn, Institut für Soziologie, German Institute for Development and Sustainability (IDOS)