Title
Turbulent Strait - Materializing Seawater Practices in the Strait of Gibraltar

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Turbulent Strait – Materializing Seawater Practices in the Strait of Gibraltar

By

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Abstract:

This dissertation centers the Strait of Gibraltar as a space of “material imagination” (Bachelard 1983) through which to examine the political ecologies and oceanographic science of the region. Rather than depict the Strait as a setting in which politics and economy occur, this dissertation asks how the particular seawater of the Strait and of the Mediterranean informs the Strait’s political and scientific importance. To make sure that the specific seawaters of the Strait and Mediterranean “matter,” I draw on the concepts, histories, and images of oceanographic science. This dissertation is based on a year of multi-sited and remote fieldwork that followed alongside the waters of the Strait, including research from such sites as Gibraltar, Cádiz, and Málaga. Throughout the chapters in this dissertation, I ask not only how the Strait functions as an important site of scientific knowledge about oceans and seas, but also how this knowledge about seas and oceans can form a kind of “seawater thinking” that can be used to think through ocean sensing, Mediterranean migration, the role of oceans and seas in climate change, and the political and environmental effects of living alongside seawater.

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Introduction:

Crossing over through Spanish and Gibraltar customs, I made my way past the buses that will carry groups over the isthmus air strip and into Gibraltar. Some days, the passage through customs is marked by clear slow-downs on the Spanish side, with a single customs agent ushering in a constant stream of border crossers. Some are there to visit the Rock, which in itself rises 400 meters above the landscape below, and others are part of the thousands that cross the border each day to work in Gibraltar. I walked across the black tarmac that forms the airstrip separating Gibraltar customs from the rest of the city. Often the departure or arrival of aircraft shuts down the runway crossing, forcing pedestrians, cars, bicycles, and motorbikes to chafe against gates and roadblocks in anticipation until the signal is given to resume crossing. Moving past gas stations and residential buildings, I began to see some of the stone walls and fortifications that mark the beginning of the city center. This border zone separating the Spanish town of La Linea de la Concepción and Gibraltar, once a neutral ground "Littered with rotting seaweed and other detritus…" (Pack 2019: 23), is now clearly defined by fences and customs offices.

Though the land border between Gibraltar and Spain features so prominently in the depiction of relations between the two, I was at once struck by the ways in which Gibraltar is joined all around by the sea. Gibraltar's sea connections are apparent in the moorings on its western shore, where hulking ships exchange crew or refuel. Its military importance is apparent in the gun batteries overlooking the placid beaches of such inlets as Rosia Bay. On Europa Point, at the very tip of Gibraltar, I could look out on the Mediterranean, tracing the movement of distant ships in the Strait or raising my eyes on a clear day to see Morocco across it. Many of the daily concerns of those that I spoke to in Gibraltar were essentially sea-based. My first visits had been during the buildup to the changes that would come with Brexit, and several potential exit strategies focused on the sea. Local officials planned how Gibraltar might rid itself of its refuse or how groceries would be resupplied. Some of the more precarious problems that came with Brexit were those that involved Gibraltar becoming increasingly sea-reliant, as services across the land border with Spain could be withheld or slowed down.

Despite these anxieties, Gibraltar was also deeply tied to the connections made possible by the Strait. Its port and refueling economies are central to its identity as a port state, and it has been heralded as a key passage point in the Western Mediterranean, with "ten to fifteen percent" of "...the seventy or eighty thousand ships that pass through the Strait of Gibraltar annually" making call in Gibraltar's port, according to Port Captain Manuel Tirado. It was the "passing through" the Strait of Gibraltar that caught my attention and drew it to the Strait and the sea. While the Strait's surface is central to economies of shipping and exchange, I wondered what it might mean to consider the Strait in its material depth and particularity, rather than only as a pass-through.

This dissertation centers the Strait of Gibraltar as a space of "material imagination" (Bachelard 1983) through which to examine the political ecologies and oceanographic science of the region. Rather than depict the Strait as a background against which politics and economy occur, then, this dissertation asks how the particular seawater of the Strait and of the Mediterranean informs the Strait's political and scientific importance. To make sure that the specific seawaters of the Strait and Mediterranean "matter," I draw on the concepts and images of oceanography. This dissertation is based on a year of multi-sited fieldwork that followed alongside the waters of the Strait, including research from such sites as Gibraltar, Cádiz, and Málaga. Throughout the chapters that follow, I ask not only how the Strait functions as an important site of scientific knowledge about oceans and seas, but also how this knowledge about seas and oceans can form a kind of "seawater thinking" that can be used to think through ocean sensing, Mediterranean migration, the role of oceans and seas in climate change, and the political and environmental effects of living alongside seawater.

Throughout the dissertation, I center the material seawater that connects, disrupts, and potentiates relations between my interlocutors and the Strait. Alongside the oceanographers that have spent their careers thinking with the Strait and with bodies of water, I believe that the material capacities of seawater – not just their symbolic capacities – offer new ways of thinking of the political ecology of the Strait. I, however, stretch the specificity that oceanographers use when they talk about the many component seawaters that make up the Mediterranean (by depth/density/salinity), arguing throughout these chapters that these waters make up the *many seas* and *many oceans* through which our relation with seawater must be thought.

Seawater Thinking:

My dissertation draws on a wide range of scholars who have sought to understand water as a key element of their fieldsites or have centered water, sea, and oceans in their research. One of the approaches to including water as a central figure in research has been to acknowledge that natural systems like rivers and reservoirs can be powerful actors in a political ecology (Kortelainen 1999, Kropp 2005). In this approach, the politics of water resource management is incomplete without a consideration of natural systems or of the water landscapes that are the object of politics. Others draw on the symbolic affordances of water as a purifying, life giving, or death giving substance (Alley 2008, Boomgaard 2007). These thinkers consider how these valences of water dictate cultural and political valuation of water landscapes. Still others consider water as a key actor and element within state infrastructures, acting as part of the ecology of an infrastructure and contributing to ideas of what it means to maintain and to grant access to water services (Anand 2018, Carse 2012). All of these approaches begin to admit water to the realm of politics (Latour 2005), acknowledging water as an actor.

Other scholars not only include water in the array of actors that they consider in their research, but begin to admit water into their analysis. Hastrup and Hastrup (2016) and Krause and Strang (2016) find that, while water has been acknowledged as a connective element in politics and culture, it must also be treated as something that co-configures social worlds alongside humans. Astrida Neimanis and Miele Chandler (2013) argue that water facilitates existence and becoming – via capacities such as the gestational – in a way that moves beyond the settled nature of the bounded entity to include both active and passive potentials. Neimanis (2017, 2019) argues that the "hydro-logics" of water allow for openings to a posthuman feminist phenomenology in which nature/culture and male/female are eroded by the connective/turbulent potential of water and its movement across boundaries. Melody Jue (2020) is also attentive to water's capacities as more than just passive medium, and she calls for an increased attention to water's medial effects and to the phenomenological engagements that are possible with water as a medium. An important distinction made by these thinkers is that water is not merely one among many symbolic objects in a fieldsite or in a political ecology – its material capacities inform the relations that exist between bodies of water, whether human or not.

Seawater, too, has a distinct potential for the concept-making work of anthropology. Stefan Helmreich (2016) argues that seawater might allow anthropologists to operate "athwart" theory – its material logics do not allow for an easy separation of the theoretical and the empirical but instead call for us to allow our theories to be submerged in material waters. I noticed this capacity of seawater to shift theory in most of the interactions that I had with oceanographers. An idea of the way that water flowed across the Strait and generated a gyre within the Western Mediterranean, for example, was suspended when models generated a previously unexpected, smaller gyre in a different location. These small noticings did not dismantle the models or the theories that were being applied to seawater, but they offered a pause in which the seawater of the Strait began to overflow into even the models – why is water behaving that way? Similarly, water's connective and turbulent capacities greatly inform the concepts that I have chosen to deploy in this dissertation. Whenever I sought the unexpected or a line of flight that could take me away from my easy thinking, I looked to water's upheavals and intermixing.

Throughout my engagement with water, I asked myself how it shifted and dismantled terrestrial logics. Steinberg and Peters (2015) argue that water can challenge "flat," terrestrial ontologies when thinking about territory and the state. They acknowledge moves in the field of geography toward a more "volumetric" thinking, in which water as territory has a volume and a depth. However, they argue that this idea of volume is not enough if we are to be attentive to the material capacities of seawater and its constant movement. Steinberg and Peters instead argue that, "...it is the chaotic movement and reformation of matter, which is seen most clearly in the churnings of the ocean, that both enables and disrupts (or reterritorialises and deterritorialises) earthly striations…" (ibid: 255). Thus, it is not enough to attend to seawater as a new medium that adds the dimension of depth. Instead, the specific movements and materialities of seawater must be part of the analysis of its intervention into concepts like "territory." In this dissertation, I think of the seawaters forming the Mediterranean in both their connective *and* disconnective capacities, seeing the multiple strata of seawaters as forming *many seas* (in their potential) instead of reducing seawater's novelty to its volume.

Methodology:

The fieldwork for this dissertation took place in several phases between the summer of 2018 and the fall of 2021. For the first phase of research, I conducted participant observation in Gibraltar and at the oceanography departments of the University of Málaga and the University of Cádiz. In Gibraltar, I observed and interviewed citizens who were concerned with environmental remediation, the health of the Strait and Gibraltar's coastal bays, and the booming shipping and "bunkering" (refueling) economy. These interlocutors came from organizations including Gibraltar's Environmental Safety Group, the Gibraltar Department of the Environment, the Gibraltar Maritime Administration, and the Port of Gibraltar. I spent the initial months of my fieldwork living in La Linea de la Concepción, the border town in Spain across from Gibraltar. Because of this, I was able to observe both cross-border politics and the coming and going of the thousands of workers that cross the border to Gibraltar each day. In Gibraltar, my focus began with the bunkering industry. At that time, Gibraltar offered refueling services for ships along the "detached mole," a breakwater located on the Western side of Gibraltar. Hearing the concerns of interlocutors at the Environmental Safety Group and the Department of the Environment, I expanded my interests beyond bunkering to include Gibraltar's Strait ecosystems. This concern further transformed into a Strait-based ethnographic methodology.

Tackling the Strait as an object of analysis required that I conduct further research in locations along the coast. As I was interested in the Strait's role both for the region and in thinking of seawater circulation between the Atlantic and Mediterranean, I spent time interviewing (mostly physical) oceanographers at the departments of oceanographic science of the University of Málaga and the University of Cádiz. I am deeply indebted to these oceanographers for the context that they gave me regarding the Strait's role in the Mediterranean and for the style of oceanographic thinking that they imparted to me. Alongside my multi-sited fieldwork in the Strait, I performed archival research regarding early surveys of the Strait, the Gibraltar Experiment (a large-scale oceanographic project that sought to understand the flow regime at the Strait and its topography), and involvement of Spanish, British, American, and Moroccan oceanographers in research expeditions through the Strait. My expanding focus on the Strait as part of a sea-wide and oceans-wide field site was further developed when the COVID-19 pandemic interrupted my second phase of research.

With the start of the COVID-19 pandemic and limitations on making physical contact with my interlocutors in the Strait, I adopted a remote fieldwork protocol. Many of the oceanographers that I collaborated with in Spain were working from home, and so interviews with them fit into their new schedule well. Additionally, my curiosity about the wider-reaching networks of oceanography and my desire to learn more about some of the oceanographic phenomena that the "model sea" of the Mediterranean could help to understand spurred a wider network of remote fieldwork sites. I conducted several interviews with oceanographers at the Woods Hole Oceanographic Institute, some of whom were conducting research regarding the Strait and some of whom could speak to wider oceanographic phenomena that could help me to think with the Strait. I also participated in a remote introductory oceanography course hosted by the University of Barcelona that was focused on the Mediterranean as a means for understanding some of the core principles of oceanography. This opportunity allowed me to think like an oceanographer and gave me new sea-based concepts through which to think the politics and ecology of the Strait.

Reframing the Syn-optic:

In descriptive physical oceanography[1], the term "synoptic" is used to describe the practice by which a synopsis or simple statement is produced to characterize an oceanographic feature or its connection to others (Pickard and Emery 1990: 2). Here, the practice begins with observations of an oceanographic feature and culminates in an analysis which yields an overall synopsis. While this is one of the ways in which the "synoptic" is deployed by oceanographers, the term takes on a more embodied (or disembodied) character when used in the term "synoptic data." When an oceanographer or many oceanographers make observations of key oceanographic variables like salinity, temperature, or flow velocity over a desired area of seawater, they face the challenge of seawater's circulatory nature. They are confronted by the fact that upon making an observation or gathering data in one place, the flow of their object of analysis has shifted the data readings along the other points in their field of study. Unless they are fortunate enough to have multiple observation vessels, oceanographers must collect a series of observations across the area of seawater that interests them, keeping in mind that seawater's flow slowly erodes at the stability of the links between their measurements. Gathering synoptic data is a practice that attempts to smooth the temporal variation between sequential observations of a body of water. To gather synoptic data, an oceanographer takes their measurements across a body of water as quickly as possible, trying their best to eliminate the effects of flowing water through time. In this practice, the oceanographer acts *as if* they were reading or seeing all of the data across a body of water from a single point in time or a single place.

The meaning of the synoptic embedded in synoptic data closely matches its originary etymology. The synoptic designates 'a seeing altogether, a seeing all at once,' bridging the

[1] While *descriptive* physical oceanography develops a synopsis based on the observations of a body of water, *dynamical* physical oceanography begins with the physical laws that act on a body of water, often simulating these with models (Pickard and Emery 1990).

‘together’ of ‘syn-’ and the ‘sight, appearance’ of ‘opsis’ (Online Etymology Dictionary 2014). While the collection of synoptic data is a valuable tool for an oceanographer faced with the constant circulation of their object of study, the use of the “synoptic” concept in this work and its extension to the practices that I describe could be fraught with the unacknowledged situation of power. Donna Haraway (1988), in her call for an attention to *situated* rather than *disembodied* knowledges, critiques the overwhelming metaphor of vision that is present in notions of objectivity. While the term “synoptic” in oceanography designates a process or a trial by which embodied observations are pulled together, resisting the intense forces of coursing seawater, its extension to ideas outside of oceanography threatens to disembody or de-situate practice. Because of the synoptic’s potential complicity with regimes of power, I instead pull apart oceanography’s term and move away from totalizing vision.

While the visual affordances of the synoptic may be too compromised, the promise of “syn-” (together) remains intact. Throughout my research, I was constantly reminded of how much seawater holds together. On the chemical and biological front, it is both a solution of a range of salts (which oceanographers attempt to measure with salinity, itself a complex and historically formed variable) and suspends nutrients and organic matter, the circulation of which is responsible for the nutrient cycle of the seas and oceans. On the physical front, seawater forms multiple strata based on density, holding together seawater with particular qualities. This holding together is of enough note that oceanographers are keenly attentive to the formation of water strata, tracking which layers move between and within seas and how they circulate. Throughout many of the processes of seawater’s mattering, I had to treat it as a material holding together of chemical substance that self-articulated in a holding together of circulation and flow. Because of this, I see “syn-” (together) as a means to allowing the holding together of seawater and of seas and oceans to permeate the concepts throughout this dissertation. For that reason, each of the chapters adopts a syn- togetherness that informs its potential.

Dissertation Structure:

In Chapter 1: Synclinal, I examine how oceanographers' thinking about the circulation and co-formation of different strata of water in the Mediterranean contribute to an understanding of the possible impacts of climate change and, more broadly, how seawater's circulatory logics exceed currently available terrestrial logics for thinking of the environment. I use the accounts of oceanographers who understand the Mediterranean in terms of multiple, shifting layers to consider the future possibility of a collapse of Mediterranean deep water formation. A larger system of deep water formation known as Atlantic Meridional Overturning Circulation (AMOC) has been of interest to oceanographers and climatologists who wish to understand the tipping points of certain circulatory systems in the ocean with increases in sea temperature and the melting of arctic sea ice. Deep water formation in the Mediterranean may provide, according to oceanographers, a scale model by which to understand the potential collapse of the larger Atlantic system. More than simply point to the crisis of a collapse in ocean circulation systems, I inquire as to the underlying logics of water formation in the Mediterranean, asking what it means for a system in motion to collapse. To do this, I describe the way in which the Mediterranean becomes "many seas" in its complex stratification and self-regeneration. This means that the collapse of deep water formation is not a collapse of the Mediterranean Sea, but a stagnation of the circulation of the many seas that form it.

In Chapter 2: Sympatry, I elaborate Gibraltar's ties to its turbulent seascape, uniting topics in species ecology, marine industry, and (non)colonial migration to show that Gibraltar's stalwart foundations are as much tied to the turbulent Strait along which they sit as to the walls and borders that have defined it as a seaside fortress. To do this, I examine how seawater intervenes in many of the central concerns that Gibraltar has about its position in a Strait ecology. These concerns cross between the human and nonhuman, covering the increasing threat of invasive species (and the concomitant "tropicalization" of the Mediterranean) as well as the ecologies of shipping ballast water and the networks that designate Gibraltar as a "non-colonial" entity (Ballantine Perera 2021). I argue that seawater, rather than being the background to Gibraltar's political ecology, participates in Gibraltarian politics and identity. To do this, I move beyond Gibraltar's association with the backdrop of the Strait in its formation as a port, coastal, and flag state, instead asking how the mattering of its surrounding seawater positions its environment, economy, and sovereignty.

In Chapter 3: Synallagmatic, I outline several versions of the "operational" in oceanography to better understand both oceanography's link to civilian/military interests and its self-defined role as a science of seas and oceans. To do this, I dive into some of the history of Spanish and Mediterranean oceanography, using the work of pioneer Spanish oceanographer Odón de Buen to understand how multiple sciences contributed to oceanography and how a founder of an oceanographic program saw the science's relationship with its object of analysis. In the chapter, I argue that, while oceanography has several important historical and foundational ties to military interests, as argued by Naomi Oreskes (2021), the identification of the "operational" can confound the practicing ecologies of the military and of oceanography. To this end, I follow a different trajectory of the operational in oceanography, examining a shift toward a notion of "operational oceanography" that ramped up in the early 2000s. I find that the foundational notions of operational oceanography (the potential to remotely sense and forecast the state of multiple oceans and seas and to report real-time data to public partners) are fundamentally linked to both originary notions of the field of oceanography and to important shifts in the increasing quantification of the subfield of physical oceanography.

In Chapter 4: Synchrony, I hold together works of experimental art on the oceans and the experimental praxis of oceanographers. I consider both an eddy sculpture by Anastasia Azure and the HoverDive performance by the Okeanos collective as forms of "aquatic expression," wherein ocean images are embodied or fabricated with a keen attention to the material rhythms of turbulent ocean eddies and deep circulation. Rather than draw a divide between these works of expression and the experimental praxis of oceanographers who have studied "Meddies," or Mediterranean eddies, I argue that the attunement of oceanographers to the specific becomings of these Meddies (both individualized and fluctuating between Mediterranean and Atlantic) requires an attention that is also a form of aquatic expression. In holding these forms of seawater thinking together, I call on the testimony of oceanographer Larry Pratt, who sees art and dance as being modes of knowing oceans and seas that can be useful even for students of physics and of physical oceanography. I argue that all of these oceanic practitioners operate in a mode that exceeds the purely phenomenological, instead allowing the material traces of seawater to leak into practices.

In Chapter 5: Synesthesia, I perform a technography (Fisch 2018) of a specific series of ocean floats, sensor arrays that are housed within a casing and sunk into the depths of the ocean to report on key oceanographic variables. I examine how this series of "isopycnal" (of the same density) floats developed historically and how the changing designs and affordances of each float corresponded to ideas within oceanography of how to meaningfully measure the nature of the seas and oceans. I argue that within the telos of the design of these floats can be seen an oceanographic imagining of the surfaces that bring sense to the organization of seawater and to its circulatory links throughout the globe. Along these lines, I link the movements from single floats to float networks and arrays to an oceanographic desire to extend the density surfaces within bodies of water to mappings that could correspond to the world ocean. Thus, I argue that float design and the history of float maintenance are a window into how floats began to "make" the oceans that are studied by oceanographers.

In Chapter 6: Synecdoche, I reframe the temporality of migration discourse within the Western Mediterranean, asking how the oceanographic concept of "memory" can be used to think of the long durée of the bodies of migrants that are captured by the turbulent waters of the Mediterranean. Rather than contribute to the temporality of crisis surrounding the historical shift of Mediterranean migratory paths to the Western Mediterranean, I follow the oceanographic time of the memory of the sea and the ways in which migrant bodies become wrapped up in this temporal logic. Drawing on the idea that a parcel of deep water can have a "memory" and practices of care whereby Algeciras mortician Martín Zamora connects the bodies of migrants to their families via material traces, I extend the work of forensic oceanography (Heller and Pezzani 2020) to include the specific mattering of seawater that impact migration. I suggest a "thallasontology" that extends the binaries of living/nonliving to include the ways in which the dead become subject to the circulations and rhythms of seawater in the Mediterranean. I argue that this mode of understanding the dead alongside seawater makes room for ethical engagement with those who have died en route to the EU.

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1. Synclinal[2]: Deep Water and the Hydrological Churn

When, then, these substances had been withdrawn,

Amain the earth, where now extend the vast

Cerulean zones of all the level seas,

Caved in, and down along the hollows poured

The whirlpools of her brine; and day by day

The more the tides of ether and rays of sun

On every side constrained into one mass

The earth by lashing it again, again,

Upon its outer edges (so that then,

Being thus beat upon, 'twas all condensed

About its proper centre), ever the more

The salty sweat, from out its body squeezed,

Augmented ocean and the fields of foam

By seeping through its frame, and all the more

Those many particles of heat and air

Escaping, began to fly aloft, and form,

By condensation there afar from earth,

The high refulgent circuits of the heavens

- Lucretius (*De rerum natura*, Book V)

Introduction:

[2] “Sloping downward on both sides”...from *syn-* “together”...+ *klinein* “to slope” (Online Etymology Dictionary 2017). In geology, a syncline is a structural fold where layers fold downward and the sides of the fold dip toward a common plane. What would it mean to think of the fold of a syncline hydrologically rather than terrestrially, where folds are always in circulation?

Speaking of the two-way flow in the Strait of Gibraltar, oceanographer Larry Pratt told me that, “ancient mariners knew about the inflow, but…there were a lot of weird theories and conjectures about where that water actually went” (Interview). Pratt, an oceanographer at the Woods Hole Institute for Oceanography, has been interested in the flow within oceanic straits since his graduate thesis, and he is fascinated by the explanations for strait flow that came from early mariners. Pratt and his colleague, John Whitehead (2007: 16-17), draw on early observations presented in 1684 by Captain Thomas Smith before the Royal Society of London to describe some of the early theories. Smith details how speculation on the destination of waters flowing into the Strait of Gibraltar was extensive – some mariners guessed that ‘subterraneous vents, cavities, and indraughts…” could explain how water flowing into the strait could be stored or could exit the basin, resolving the problem of waters with an origin and without destination. Otherwise, these mariners could only suspect that the waters flowing into the Mediterranean were entering in on the “Christian side” (ibid) of the strait and were flooding the shores of the African side. This could explain how to account for surplus inflow, but had no empirical backing. Smith proposed a new hypothesis: an undercurrent existed beneath the inflow that carried water out of the Mediterranean.

In 1675, ship captain Richard Bolland had formulated a similar hypothesis, stating “...it seems most reasonable, that as the straight’s mouth of Gibraltar has its continual indraught aloft, so the superficial part thereof may have its recourse back again below” (Bolland 1675: 779). Along with his hypothesis, Bolland provided an experiment that could be conducted by ship to sound the undercurrents of the Strait (Figure 1.1).

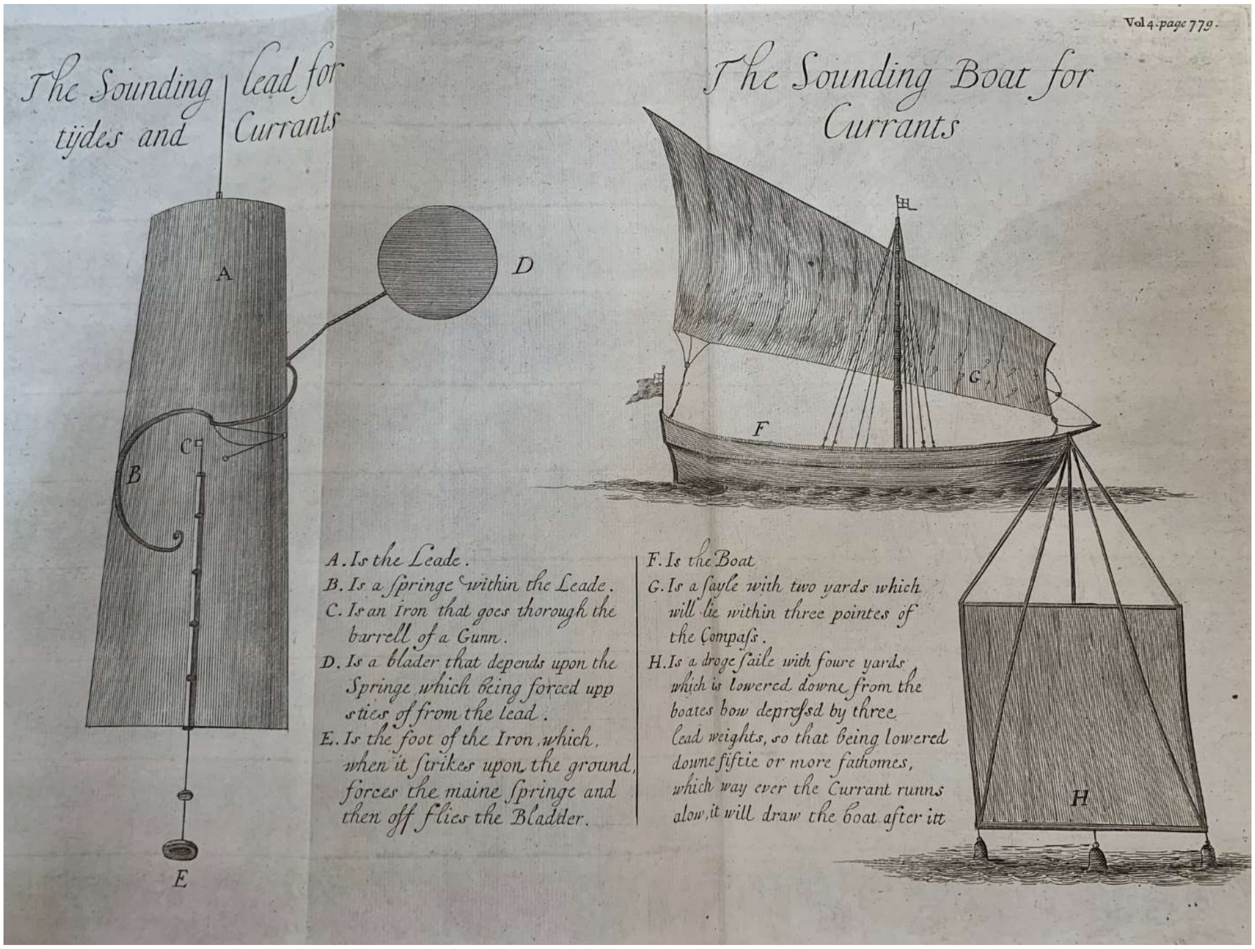

Figure 1.1: Experiments designed by Richard Bolland to detect the direction of deep currents in the Strait of Gibraltar (Bolland 1675)

In his experiment, a ship would carry a weight to which a bladder was tied and from which a weight was suspended. When the weight struck the seafloor, a spring would trigger that would send the bladder flying in the direction of the prevailing deep current. Depending on the side of the ship on which the bladder emerged to the surface, the surveyors could discern the direction of the submerged current. Bolland further suggested the use of a ship carrying a submerged, weighted sail. This sail, upon dragging the ship in a certain direction, could further confirm the direction of the subcurrent at the strait and could give an idea of the force of this current. Such experiments dispelled notions that the waters entering the Strait of Gibraltar crept into underwater caves or flooded the African shore, but they only began to hint at the layered notions of seawater that oceanographers deploy today.

Speaking with Jesús García-Lafuente, an oceanographer at the University of Málaga, I was quickly disabused of the notion that establishing a two-way flow at the Strait was the end of the story. While he confirmed that water entering from the Atlantic did flow in on the surface and water exiting from the Mediterranean did flow at depths of around 1000-1200 meters, he also complicated my idea of the way that seawater flows. The water exiting from the Strait was far from the same water that had entered, and understanding its process of transformation throughout the Mediterranean would require thinking of multiple points of origin and multiple flowing strata. Different waters in the Mediterranean were classified based on density (and thus associated with different temperatures and salinities, variables that affect the density of seawater), and there was a variable cycle of exchange of identities between the Atlantic water that came in, the Levantine Intermediate water that it turned into, and the various deep waters and outflow waters that made up the rest of the vast Mediterranean. Where before I was pushed to think of two-way flows, I was soon pushed to consider a multi-origin, temporally dependent, interwoven system of the multiple waters that made up the sea. Each of these waters had its own domain and depended on the others for circulation and renewal. Beneath the surface of the Mediterranean Sea, then, were *many seas*.

That these many seas circulate is essential to their formation, and the stakes of this formation extend to the consequences of warming seas. The waters of the strait, according to oceanographer Alfredo Izquierdo at the University of Cádiz, are local indicators of phenomena unfolding within the Mediterranean. As a bellwether of the changes to waters moving throughout the Mediterranean, the Strait reflects the impacts of climate-scale warming on this sea. Alfredo and his colleagues have recently examined the impact of warming under the RCP 8.5 (Representative Concentration Pathway of greenhouse gasses with high emissions, business-as-usual) climate change scenario (Parras-Berrocal et al. 2021). Over the next 100 years, under this scenario, oceanographers expect to see an increase in upper sea temperature of 2.6 degrees Celsius that brings with it a higher temperature and salinity of the water flowing out of the Mediterranean. While overall warming and the change of these variables in Mediterranean outflow may be worrisome for oceanographers, they also indicate a potential shutdown within the Mediterranean of the formation of deep water, a complex mixing process that aids in the transportation of heat throughout the basin and speaks to the global worries of how ocean warming may alter both oceans and atmosphere in a shift of weather patterns. According to Alfredo, the collapse of deep water formation in the Mediterranean could be a "preamble" of changes to come to larger bodies of water like the Atlantic, where some of the driving forces that circulate water throughout the globe originate. These forces include AMOC (Atlantic Mediterranean Overturning Circulation), which is one of the driving forces of deep water formation and circulation in the Northern Atlantic.

In this chapter, I argue that the oceanographic study of the formation of *many seas* in the Strait of Gibraltar produces an understanding of relation that challenges terrestrial logics of fixity and stratification. These turbulent relations also challenge earlier ideas of circulation in oceanography that privileged a predictable pathway for water around the globe. Thinking with seawaters in the Mediterranean that are always flowing and co-forming, variables such as density, temperature, and salinity (determiners of water's tendency to rise, sink, or maintain depth) become as much markers of relation as they are markers of identity. I contend that if we are to understand the consequences that climate change has in store for oceans and seas, we must attend to the interrelatedness of their many constitutive seawaters. I propose the term "turbulent relation" to account for the ways in which the waters of the Mediterranean mix and co-create one another, bridging relations to include nonhuman entities as wide as seas. In a Mediterranean seawater exchange based on flow and turbulence, the threats of stratification and stagnation posed by warming seawater can be thought of as the dwindling of turbulent relation.

A Note on the Concept of Oceanographic Variables:

In his exploration of the co-creation of the measurement of temperature and the development of the thermometer, Hasok Chang (2004: 47) argues that measurement standards developed via "epistemic iteration." Observers of temperature started from the senses available to them, relying on sensation to provide empirical knowledge. With the development of patterns in sensation came the creation of the thermoscope, a device meant to measure relative temperature. Chang observes that it was only once the thermoscope was used to detect sufficiently fixed points in temperature (at that time, markers like the temperature of the human body) that the numerical temperature scale and the creation of the thermometer were possible. This idea of "fixed points" that make measurement possible carries with it the idea of the variable, or the measure that can move up and down relative to these fixed points. Variables, then, are hardly separable from the conditions of interest that generate their importance. Just as the variable of temperature developed as a way to more accurately measure heat and cold relative to fixed points of interest, the variables used in oceanography are immersed in the history of the science. Variables like temperature, salinity, and density represent both a means of understanding the qualities of seawater and a means of securing the standards of oceanographic science.

The AMOC and the Conveyor Belt

One of the most studied systems of circulation in the Northern Atlantic is the Atlantic Overturning Meridional Circulation (AMOC), which plays a key role in circulating waters in the

Northern Hemisphere. Though this system of circulation is thought alongside the formation of deepwater in the Mediterranean (a process the cessation of which could harken wider, oceanic changes), the logics of circulation taking place are of a vast scale and correspond to a major key oceanic imaginary: the great ocean conveyor belt. Though this model elegantly imagines the circulation of water throughout the globe, it excludes the turbulent processes of mixing that drive the formation of seawaters.

Unlike the kind of circulation of water that an observer is used to seeing from shore, such as waves and the movement of water in whipping winds or against a rock face, the AMOC is governed by the mixing of waters with different salinity and temperature below the surface of the ocean. Describing this process, Renee Cho (2021) states, "Cold salty water, which is dense and heavy, sinks deep into the ocean in the North Atlantic, and moves along the bottom until it rises to the surface near the equator, usually in the Pacific and Indian Oceans. Heat from the sun then warms the water, and evaporation then leaves the water saltier. The warm salty water travels up the coast via the Gulf Stream, warming the U.S. East Coast and Western Europe." Cho warns that a slow down or shut down of the AMOC could alter rainfall patterns, make sea levels rise, cause drying, reduce agriculture, and perhaps set off other tipping points. The far-reaching influence of the AMOC represents the impact of oceanic systems in the effects of climate change.

The system of circulation in which the AMOC is embedded is most commonly represented by the global ocean conveyor belt, or the circulation of warm and cold water throughout the ocean basins of the world. In describing this picture of ocean circulation (Figure 1.2), first created by Walter Broecker, Jessica Lehman (2021: 10) states, "The diagram, still produced in oceanography textbooks and popular science media, conveys a picture of ocean

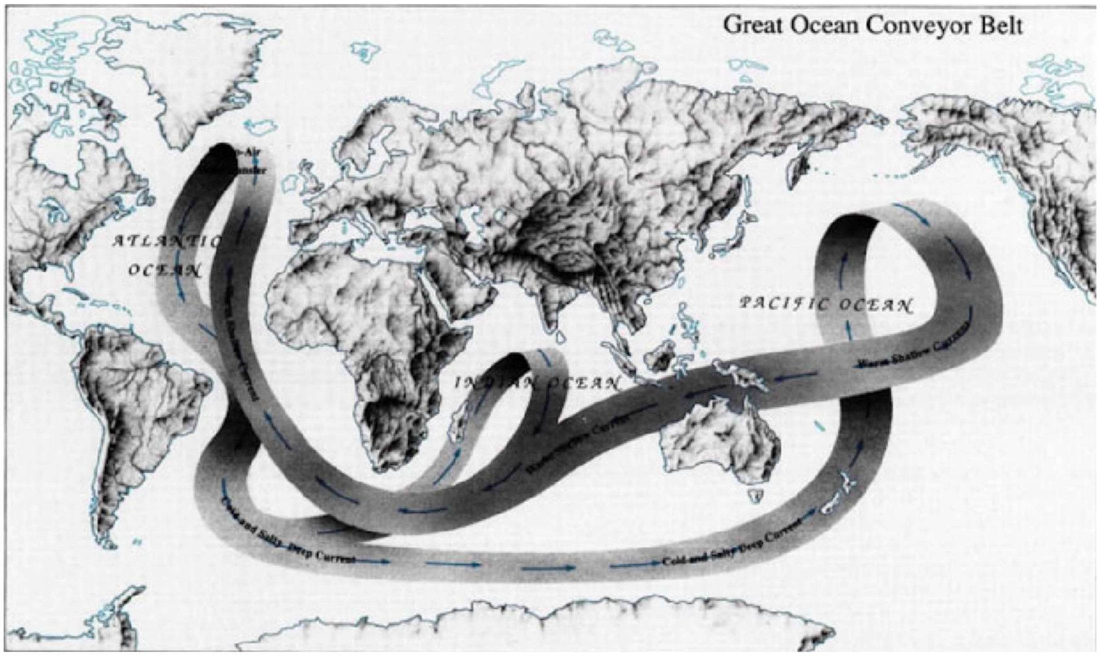

Figure 1.2: The Great Ocean Conveyor Belt

circulation as moving sinuously around the globe, cyclical with regard both to deep-shallow current patterns and to global surface extent; the diagram 'implies that if one were to inject a tracer substance into one of the conveyor's segments it would travel around the loop as a neat package eventually returning to its starting point' (Broecker 1991: 79)." While Broecker understood that the conveyor-belt image was lacking in its representation of the ocean as a simple circulation system, the conveyor belt reflected contemporary assumptions that the oceans of the world were 'slow-moving and passive in a sense' (ibid: 11). The ribbon of the conveyor-belt diagram is captivating in its expanse and connects the different waters of the world ocean, but its simplicity belies the chaotic processes that drive ocean circulation.

Conveyor-belt diagrams of ocean circulation typically have arrows indicating direction of circulation and include spots where warm surface waters overlap with deeper waters. Some do not include spots of overlap or areas where increasingly cool and salty waters dive from the surface to form deep water – such as in the AMOC. Overall, ribbon or conveyor diagrams lend to a surface understanding of the way that water circulates throughout the globe, their flat sections resembling the large-scale road works of a major city. The processes driving the conveyor and the systems like AMOC that generate its movement are anything but surface. Along the surface, winds and waves dictate the movement of the seas, but below the surface layer and into the unlit depths, “there is another ocean” (Flos, Universitat de Barcelona). Beyond the reach of solar illumination and the shoreside observer is an ocean where temperature and salinity difference govern the movement and mixture of seawater. While current strength still plays a role in circulation at these depths, the sheer masses of water (the circulation of which is measured in Sverdrups, or 106 m^3/s) at these depths move via convective processes driven by temperature and salinity differences. Waters that are cooler and saltier sink, while those that are warmer and fresher tend to rise to find the density at which they belong. It is not so much the laminar flows of the conveyor-belt diagram that best characterize this movement, as these flows do not capture the volume of this second ocean.

The volumes of water churning in the oceans are a complex weave of waters of different density, rising to the surface and plunging to the deepest depths. The conveyor-belt’s ribbon lacks both the depth of oceanic volumes and the idea that the waters of the ocean could possibly be different (other than those diagrams which provide simplistic markers of different ocean temperature only via red, warm waters and blue, cold waters, presented as a binary of only two types of water). This view of the movement of waters in oceans and seas is reminiscent of the flattened understandings of an only-terrestrial knowledge. Steinberg and Peters (2015) argue that even at the surface, the sea must be conceived of via its volume instead of its flatness. They invoke several others in saying, “In the sea multiple mobilities engage each other in reciprocity (Adey, 2010), opening attention to unrecognized *volumes* of hydrospace (see Elden, 2013a); a mosaic of vertical, horizontal, and angular shapes that provisionally coalesce into a spherical voluminous realm of matter (Sloterdijk, 2011)" (ibid: 250). Nowhere is this clearer than at sites of deep water formation, where the density difference of vast masses of waters contributes to the pitching of shallow waters all the way to the deepest reaches of the ocean, driving the circulation of waters that will reach across the globe. While Steinberg and Peters meditate on the way that volumetric thought can change even our perception of waves and surface, it is in the depths of the ocean that churning volumes of water become most salient.

Jessica Lehman describes how oceanographers working on the World Ocean Circulation Experiment (WOCE), which collected data to better understand the detail of global ocean circulation, were faced with data that challenged even those who were critics of a simple diagram of the conveyor belt. She tells of how "…ocean circulation is characterized less by the steady flows of the conveyor-belt heuristic and more by swirling, fluctuating, meandering features that follow the laws of chaos and complexity rather than linear calculation" (Lehman 2020: 11). The turbulent mixing and churning of the oceans, which was taken to be the background to the overarching systems that drove the flow of water across the earth, was far more formative to this flow that previously thought. Scientists on the WOCE project were "…forced to grapple with this newly complex view of ocean circulation, as the first and largest attempt to understand the ocean in dynamical terms on a global scale" (ibid). This newly dynamical model could assume the conveyor belt diagram only as a useful approximation of the actual processes of turbulence that were playing in water formation and movement. One of the challenges to understanding this complexity comes from the overwhelming scope of even circulation in the North Atlantic. Oceanographers studying the AMOC must contend with watery relations that reach into all of the worlds oceans. It is in this sense that the Mediterranean becomes useful as a means for thinking about the churning processes of deep water formation and circulation.

The Mediterranean Strata

In the Mediterranean, the alteration of deep water formation under the effects of climate change has been recently studied (Parras-Berrocal et al., 2021). Under the RCP (Representative Concentration Pathways) 8.5 scenario, or the business-as-usual with no policy mitigation scenario, for the effects of carbon emissions on the environment, oceanographers in this recent study say that the collapse of deep water formation in the Western Mediterranean could come by the middle of the 21st century. This collapse would be driven by a change in the temperature and salinity of the constituent waters of the Mediterranean participating in deep water formation in the Gulf of Lion. The effects of climate change on deep water formation can then be measured in the Strait of Gibraltar, where the signal of the Mediterranean outflow waters tells oceanographers about changes happening in the basin. In the Strait, incoming Atlantic waters of lower density rush over the higher density Mediterranean waters exiting the basin.

Thinking through deep water formation in the Mediterranean requires thinking with its multiple seas. Because evaporation exceeds precipitation in the Mediterranean (ibid), the sea relies on inflow from the Atlantic to replenish its waters (See Figure 3). Water flowing into the Mediterranean from the Atlantic is known at first as Atlantic Water (AW), but soon becomes warmer and saltier as it is exposed to the evaporation in the basin and the warmer waters of the Mediterranean. This leads to its designation as Modified Atlantic Water (MAW). Once MAW reaches the Eastern basin of the Mediterranean, winter ocean and atmosphere conditions cool the water, causing it to sink and become Levantine Intermediate Water (LIW). Levantine Intermediate Water flows westward at depths of 150-600 meters, through the Strait of Sicily and into the Gulf of Lion. It is in the Gulf of Lion where the deep water formation of the Western Mediterranean takes place.

During the summer and spring months, Atlantic Water and Levantine Intermediate Water remain distinct, mixing intermittently but maintaining a clear zone of separation in the thermocline (the intermediate depths where temperatures drop and which form the boundary between waters). In the winter months, however, waters in the Gulf of Lion are exposed to intense winds and winter storms. Their cooling forms an instability in the thermocline as upper waters become denser than those below them, and there is a period of intense mixing. For this period of time, waters interpenetrate without the former clarity of the distinct thermocline. Cold surface waters plunge down, taking on some of the salinity and warmth of the Levantine Intermediate Waters as they dive. Now still cold and even saltier yet, these surface waters plummet to the depths of the Mediterranean, forming Western Mediterranean Deep Water (WMDW).

In most of the diagrams of the different waters of the Mediterranean, they appear almost as watery strata (Figure 1.3). They recall the geological strata of the terrestrial world, which are

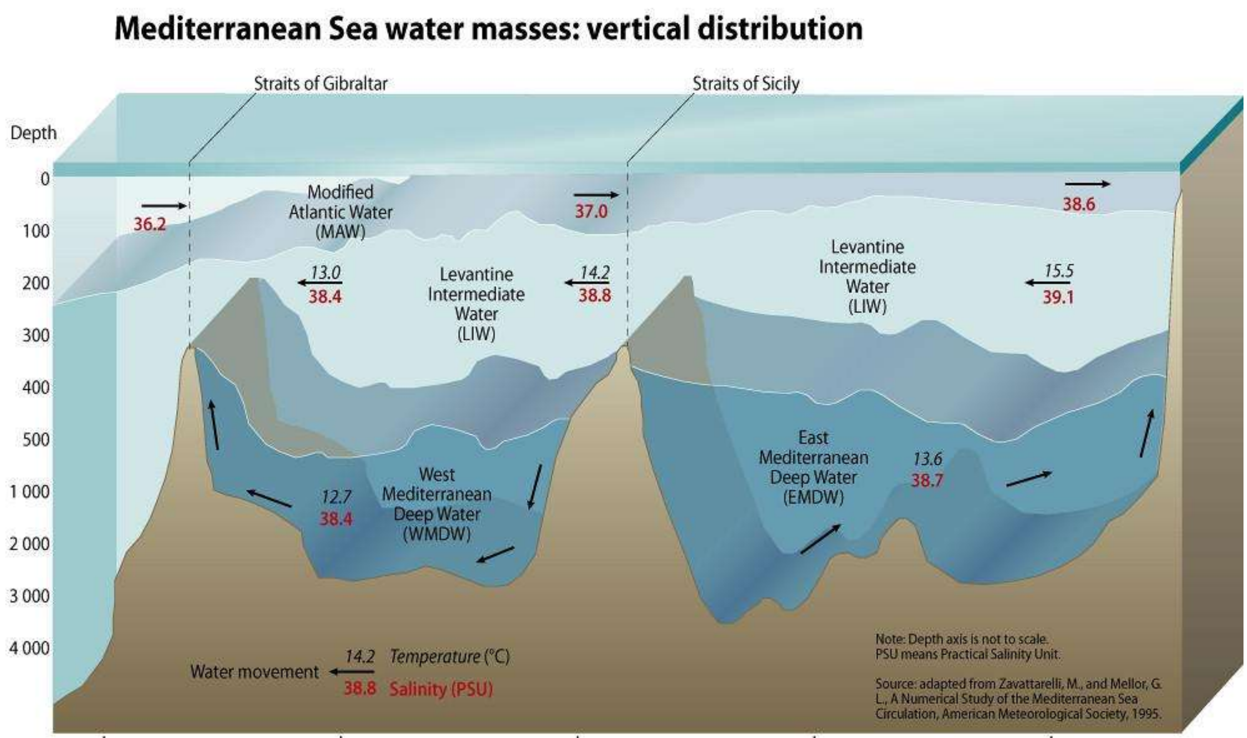

Figure 1.3: The many waters of the Mediterranean Sea, vertical distribution (GRID-Arendal)

formed according to two articulations. The first "…deposits units of cyclic sediment according to a statistical order: flysch, with its succession of sandstone and schist. The second articulation is the 'folding' that sets up a stable functional structure and effects the passage from sediment to sedimentary rock" (Deleuze and Guattari, 1987: 41). Thinking of watery strata alongside their terrestrial complement has distinct advantages. While the time scale for deposition of terrestrial strata is far longer than that of the shifting ways of oceanic strata, Levantine Intermediate Water generated out of the cooling and salting of Modified Atlantic Water in the Eastern Mediterranean may still take more than ten years to make its way to the Western basin. Similarly, effects on deep water formation may take an equivalent amount of time to appear as signals in the Strait of Gibraltar. Additionally, terrestrial stratification deposits layers that have a unitary quality when imagined as being slices of a particular time. The generation of watery strata likewise distributes the many waters of the Mediterranean, but according to their temperature and salinity.

In his meditations on the ground where atmosphere meets earth, Tim Ingold (2021) considers how we imagine this interface. The earthly ground is assumed to be a kind of boundary which cordons off the atmosphere and the earth, providing an almost paper-thin interface which virtually disappears when one must identify the media that it separates. It is clear that the atmosphere is there with all of its concomitant flows and processes, and it is clear that the earth subtends it with its processes of sedimentation and concentration. Ingold describes, "The ground surface, however, has depth but no thickness. Should we attempt to measure it, we would find that starting from the lower, atmospheric horizon, there is no limit to how far up we could go and that, conversely, starting from the upper, earthly one, we could keep on going down without ever reaching rock bottom" (ibid: 90). While the figure of the ground provides a useful boundary point for thinking of where atmosphere and earth meet, attempts to measure it or to delimit where it ends or begins are met with a distinct challenge. The co-constitution of earth and atmosphere make the ground anything but a solid boundary or divider. Instead, Ingold suggests that the ground is "…the zone of their interpenetration" (ibid). The paper-thin ground becomes instead a zone, where the limits drawn depend on the atmospheric and earthly processes at hand.

This idea of a ground that is always also a zone of interpenetration troubles any easy comparison that could be made between Mediterranean waters and terrestrial strata. Waters in the Mediterranean gain much of their identity through transport and through relations of churning and turbulence with other waters in the basin. Atlantic Water may face the atmosphere, where processes of evaporation and forcing are still essential to understanding how the waters flow, but the formation of waters at depth is a relation of mixing. Waters that lose enough temperature or gain enough salinity to have a density lower than the waters above them will plummet (all else equal), just as those that gain temperature and/or lose salinity will rise toward the surface. There is no easy separation of strata of water such as could be accomplished with a paper thin ground, but instead only interpenetration and churning.

Unlike most terrestrial strata, the waters of the Mediterranean also take part in processes that displace even the deepest strata. For example, fierce storms during the winters of 2004-2006 contributed to the dramatic cooling of surface and runoff waters in the Gulf of Lions. These waters mixed downward via convection and slid from the coast down underwater canyons until they were able to displace even the deepest Mediterranean waters in their density. Although warmer than the old Western Mediterranean Deep Water, they had acquired enough salinity to supplant them, resulting in "…an anomalous stratification of the deep water column due to the superposition of newly formed warmer and saltier deep waters (Schroeder et al. 2016)" (Tintoré et al., 2019: 4). This climatic anomaly became known as the Western Mediterranean Transition, and signatures of this new deep water were detectable in the Strait of Gibraltar a decade later (ibid). While the second articulation of terrestrial stratification imbues those strata with a kind of historical sequence in order of deposition, aquatic strata disrupt the stability of the ordering of vertical volumes.

Thinking of the water as strata is a practice that is eminently useful to oceanographers. Waters of a common temperature and salinity range can be tracked throughout the Mediterranean, giving an idea of how waters circulate and where they wash up. Waters can also be tracked as they leave the Mediterranean and enter the Atlantic. Leaving the Strait of Gibraltar and passing westward over the Espartel Sill, waters leaving the Mediterranean can be identified by their warm and salty nature, being described as a salty "tongue" that reaches into the Atlantic at intermediate depths. Similarly, the identification of waters allows oceanographers to determine when new waters have been formed or when there has been a general change in the average temperature or salinity of a certain water – a practice that is increasingly important under general warming trends. While it is clear that the separation of water into strata is a boon to oceanographers, it is necessary to think of the qualities imparted to a strata via its aquatic nature. Thinking with terrestrial strata limits the way in which we can imagine how waters in the Mediterranean are constantly churning and mixing, potentially displacing the most dense and deepest of waters.

The relation between churning waters in the Mediterranean exceeds the qualities that allow seawater to be sorted into such layers as Modified Atlantic Water or Levantine Intermediate Water. These waters are not only separate bodies that maintain relations of similarity based on temperature, salinity, and density. Their mixing also makes them the conditions of their co-becoming, where Atlantic Water that reaches the Eastern Mediterranean is

Levantine Intermediate Water in potentia (Wu and Haines 1996). It is the turbulent and circulatory capacities of seawater that give them what I call a "turbulent relation." This relation, imagined as the co-constitution of waters that nevertheless maintain the qualities of their strata, can be imagined as the material flooding of what it means to think of relation. In a passage aptly titled "Flow and Overflow," Marilyn Strathern (2020: 91-92) examines the kind of comparative kinship relation that can be called "analogical." She compares the thoughts of Roy Wagner and Philippe Descola, who differ greatly on the notion of analogical relation. She finds that, for Descola, the sorting of beings into 'essences, forms, and substances…' that is needed to form the web of analogies that endow each being with its intrinsic qualities requires that each of these beings be initially distinct. Thus, similarities are only detected once key differences have been established. Wagner (1977: 623), instead, puts forth the notion of analogic "flow," where the work of differentiation allows for a "flow" of similarity to wash over kin relations without being perceived as contagion or moral degeneracy. Strathern states that, for Wagner, 'analogic flow' "lies in the potential of relating to spill over the actualization of specific analogies formed through selection and differentiation." This image of relation appears as if submerged, subject to the same logics that both set Mediterranean waters apart and make them the conditions of their co-formation. Thus, my exploration of a "turbulent relation" proper to seawater is not only material or Mediterranean, but strikes at the ways in which water has always already flooded the concept of relation.

Relation and Collapse

Nowhere is the churning and mixing relation of Mediterranean waters clearer than in the potential collapse of deep water formation in the Western Mediterranean. As the sea warms under the RCP 8.5 scenario, the generation of warmer and saltier waters contributes to a temperature and salinity increase for the Levantine Intermediate Waters. Increase "…in LIW temperature (0.3°C) and salinity (0.08) limits the winter mixing, blocking the export of heat and salt to deeper layers" (Parras-Berrocal et al., 2021: 3)." As heat concentrates in the Levantine Intermediate Water, the zone of mixing between it and the Modified Atlantic Waters becomes shallower and shallower. Where before the winter mixing in the Gulf of Lions would have taken place at a maximum depth of 2043 meters, warming trends would cause the mixed layer depth to rise by 1821 meters toward the surface. Where before the turbulent mixing of Levantine Intermediate Waters and Modified Atlantic Waters would engender newly formed Western Mediterranean Deep Water, the rise of the mixing layer and warming of the LIW would prevent waters from reaching the depths where they could form these deep waters (ibid). Warming of the Mediterranean outflow measured at the Strait of Gibraltar would not be anomalous prior to the collapse of deep water formation, but warming after the collapse could accelerate to 0.034°C/year (ibid).

The churning relations that make up the formation of deep water in the Western Mediterranean defy any idea of strata or stratification that would fix the relations between these strata. Waters in the Mediterranean require not only that the interface between them be a zone of interpenetration, but that this zone be constitutive of the formation and becoming of future waters. In fact, the formation of deep water in the Mediterranean requires that the dissolution of strata be the identifying move for new waters to be formed. The warming of waters in the Mediterranean would "…increase the vertical density gradient between the Modified Atlantic Water and Levantine Intermediate Water, strongly reducing the vertical mixing between these water masses" (ibid: 10). The qualities of waters in the Mediterranean that enable their sorting into strata also play into regimes of mixing that, when too heavily stratified or separated, hinder the generation of new deep waters in this sea. Instead, waters with a high density gradient between them fail to be involved in the same churning relations. Simone Sammartino, an oceanographer at the University of Málaga, described to me how Atlantic and Mediterranean waters in the Strait of Gibraltar accommodate a high density gradient, saying that the more the disparity, the quicker the currents in the Strait must be to compensate.

The potential collapse of deep water formation in the Mediterranean suggests that, for oceans and seas, tipping points such as these may be more associated with a suspension of turbulence and chaos rather than a departure from the static. Rather than solidifying the processes that drive circulation in the Mediterranean, stratification is a force that limits the becoming of its waters. Terrestrial stratification encodes new layers of sediment that solidify into sedimentary rock, but aquatic strata are as much a product of turbulent relation as they are of concentration – their generation requires their own dissolution in processes of mixing that constitute such stable bodies as Modified Atlantic Water, Levantine Intermediate water, and Western Mediterranean Deep Water. That increased stratification of waters in the Mediterranean resulting from the world's warming could contribute to the collapse of a major system of circulation in that sea suggests that thinking of ocean tipping points also means thinking through turbulent relations.

Oceanographers are faced with the requirement to think of waters in their dynamical state. Lehman emphasizes that oceanographers in the WOCE project puzzled over "…complex mixing between vertical layers of water, which has profound influence on how the ocean interacts with the atmosphere (Wunsch 1999)" (Lehman 2020: 11). The simple conveyor belt model with its lack of dimensionality and its simplicity of expressing circulation fails to capture the turbulent mixing that drives the worlds oceans. The picture of waters in the Mediterranean is both more elaborate in its variation (whether MAW, LIW, WMDW, or one of several other waters present in the sea) and more striking in its interrelatedness. Watery strata are separable by their density, but they are constituted by the churn of turbulent mixing. Formation, dissolution, and interpenetration are key features of a Mediterranean that could continue to circulate and form new deep waters. The co-constitution of waters suggests that thinking of seawater means thinking of churning as much as volume.

The Churn and Turbulent Relation

Thinking alongside oceanographers, I see the interpenetration of waters in the Mediterranean Sea as indicative of a frame of thought that is opposed to strata as stable and is built upon the heterogeneity of waters. In their discussion of a "nomad" or "minor" science that is set against a linear notion of science, Gilles Deleuze and Félix Guattari (1987) draw on the work of Michel Serres (1980). They point out how Serres recuperates the physics of such thinkers as Archimedes to establish an inheritance of physics that is fluid and dynamical, more akin to Lucretius than to Aristotle. They say, "One no longer goes from the straight line to its parallels, in a lamellar or laminar flow, but from a curvilinear declination to the formation of spirals or vortices…The model is a vortical one; it operates in an open space throughout which thing-flows are distributed, rather than plotting out a closed space for linear and solid things" (Deleuze and Guattari, 1987: 361). This idea of matter is watery at its roots, echoing the anxieties of the oceanographers that Lehman described as having to confront the turbulence and variability of oceanographic phenomenon like global circulation. This model also evokes the many waters of the Mediterranean which, rather than being settled into a static basin, are circulating, generating new deep waters, and involved in a regime of exchange with the Atlantic.

The generation of deep water in the Mediterranean is built upon the way that heterogeneous waters come to constitute new waters in their interpenetration. For the nomad science of Serres, this means that "The model in question is one of becoming and heterogeneity, as opposed to the stable, the eternal, the identical, the constant" (ibid). While waters such as the Levantine Intermediate Water may be identified via their temperature and salinity, their constitution relies on the mixing and exchange of these qualities with other waters in the Mediterranean. This model is not one with stability at the core and with each of the waters of the Mediterranean finally constituted for good, but one that is premised on the generation and becoming of multiple waters in the churn – a generation that instead faces danger in equilibration in the form of stratification. The breakdown of easily separated waters is what allows for periods of winter mixing to establish new deep waters in the western Mediterranean. Turbulence is generative of new waters rather than being a detriment to the equilibrium. "The cataract, the torrent, the flux of collapse, is the core of being, the fabric of the core…" (Serres 1980: 75).

Each of the waters in the Mediterranean is important not only in its particular qualities, but in the way that its generation is premised on an unstable individuation. The waters of the Mediterranean are not only themselves, but also potentially other in their capacity to churn and mix. For example, in the regime of intense mixing that takes place in the Gulf of Lions in the Western Mediterranean during the winter, the Modified Atlantic Water there is said to be "pre-conditioned" to become part of the Levantine Intermediate Water or newly formed Western Mediterranean Deep Water. This echoes Wagner's idea of analogic flow, but it is cast in the materiality of seawater. Kinship differences for Wagner are worked through and made to make the flow of similarity possible. Waters in the Mediterranean may be pre-conditioned to become other waters, a quality tied to temperature and salinity that is actualized in the process of mixing and churning that takes place in sites like the Gulf of Lions.[3] Waters in the Mediterranean that are involved in processes of formation are always both themselves and potentially other waters, and the generation of watery identity iterated through labels like Levantine Intermediate Water is actualized only with the churn at the center of individuation.

What might this way of thinking mean for the wider context of the ocean's flows and of the ways of thinking of tipping points? Steinberg and Peters draw on Andrew Barry by saying that "…the linear calculative logic of Anthropocene scholars, which divides time into strata, is itself a function of the anthropocenic age, not the means of its diagnosis. We therefore argue for an alternative perspective in which time, as expressed through *assembled* matter, is nonlinear and fluctuating, and matter is mutable and leaky – part of a process of ongoing reformation" (Steinberg and Peters 2015: 256). The understanding of how waters are formed both in the flows that establish the Atlantic Meridional Overturning Circulation and in those that establish the Western Mediterranean Deep Waters speaks to an ethics attentive to churning and turbulence. At stake is not only the models that could be used to conceive of water's particular forms of movement and generation, but also the way that these models reorient notions of equilibrium and individual. Waters of the Mediterranean are never just individual, but are generative of both new waters and of different means of imagining circulation and becoming.

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[3] Interestingly, processes of mixing may highlight the relational capacities of variables like temperature and salinity. Though they measure the qualities of a mass of seawater, they also refer to the fixed points at which the mass might sink or rise and become another seawater. This highlights the relational valence of the variable that Chang (2004) emphasizes when describing the movement from sensory perception to the quantitative determination of fixed points (see note on variables).

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2. Sym/Allopatry[4]: Gibraltar's Turbulent Territorial

Gibraltar stands, a fortress as solid as the rock that provides its foundation, but there is something more in its foundations than the terrestrial. Peter Sloterdijk, in his meditation on the formation of cities and settlements, emphasizes the immunological function of enclosure (Sloterdijk 2014). He cites the figurative model of the Greek "oikumene," or the depiction of the civilized world, as the icon of the immunological model of civilization. In this model, the immunological boundary is provided by the flowing ocean, which insulates the polity in a secure membrane. Thinking of Gibraltar as overseas territory and as fortress on the rock, I seek to particularize the turbulent waters of the Strait of Gibraltar that encapsulate it. Rather than thinking of the terrestrial foundation of Gibraltar as the fortress and as the sovereign territory, I move to extend this space into the immunological membrane of its surrounding seawaters. Here, the particular flows of the strait make thinking with the untethered "ocean" of the oikumene *impossible*. The strait's seawater is not just a watery backdrop, but is also the oil, the ecology, and the mobility (of shipping and of settlement) for Gibraltar. Focusing on the immune system of Sloterdijks immunological model, it is also the context for deciding what counts as invasive (species, territorial claims, pollution) and what counts as gestational/formative (settlement, preservation, heritage). Gibraltar as fortress may be stalwart, but it is not unmoving. The Strait of Gibraltar provides an ecology which locates the overseas territory, all while making it subject to organic and inorganic flows that are specific to the strait's ecology.

Introduction:

[4] Sympatric: from assimilated form of syn- "together with" + Greek *patra* "fatherland," +ic Opposite of *allopatric* (other than) (Online Etymology Dictionary). Here, I want to refigure the "landing" of fatherland, instead thinking of what is held together in Gibraltar as fortress when one includes the sea as an integral part of the fortress and of the landscape. I am holding together the opposites of sympatric and allopatric in this chapter, analyzing how turbulent seawater circulation and ecologies both congeal and disperse the boundaries of habitat and territory.

Spending time in Gibraltar, the land border between Spain and Gibraltar was the most discussed boundary, finding its way into daily conversations alongside the weather. The border's 20th century history as bellwether of the relations between Gibraltar and Spain belies its origins. Sasha Pack (2019: 34) describes how the isthmus separating Spain and Gibraltar, once a neutral ground, became more concrete with the means taken to contain the 1853 cholera outbreak. With support from Gibraltar Governor Sir Robert Gardiner, medical envoy William Baly set up sick houses and a permanent lazaretto in the neutral ground. This outpost was soon fortified, and even after the sick houses disappeared, "…the sentry boxes remained." The border zone separating the Spanish town of La Linea de la Concepción and Gibraltar, once a neutral ground "Littered with rotting seaweed and other detritus…" (Pack 2019: 23), is now more clearly defined, and it would become delineated by fences and customs offices.

The mobility of border crossers has long indicated the relational state of the two sides that it separates. Closed by Franco in 1969 (Ballantine and Canessa 2016, Orsini et al. 2019, Pack 2019), the border became a disruption of the family ties that spanned the entire Campo de Gibraltar, which includes both Gibraltar and the Spanish coastline surrounded by mountainous terrain. Families thus separated could be seen at the border communicating the latest news from their side, even informing each other of the passing of loved ones. Even after the blockade ended in 1982, Gibraltar had established new ties with commercial interests abroad and across the strait (Pack 2019), diminishing some of the connection that it had with the wider Campo. This decoupling came also with an increased sense of Britishness that was established with refuge of many Gibraltarians in Britain during WWII (Ballantine and Canessa 2016, Canessa 2019). According to historians Chris Grocott and Gareth Stockey (2012: 13), the ceding of Gibraltar to

British interests by the 1713 Treaty of Utrecht made clear that cut-off between Gibraltar and it's campo, calling for ownership "'without any open communication by land with the country round about'." Gibraltar was designated as a fortress garrison meant to be defended, though its positioning on the Strait of Gibraltar would open unique trade opportunities.

Though the land border between Gibraltar and Spain features so prominently in the depiction of relations between the two, I was at once struck by the ways in which "fortress" Gibraltar was enacted on its sea front. Gun batteries overlook the placid beaches of such inlets as Rosia Bay, and the traffic in the Strait is marked by both shipping vessels and patrol boats that monitor Gibraltar's territorial waters. The Rock is remembered as a defensive point for the 1805 Battle of Trafalgar and the place to which Vice Admiral Horatio Nelson's body was taken after that battle. Gibraltar's purpose as a fortress, with its responsibility in "protecting overseas trade routes and securing the lines of imperial communication," brought with it a civilian population that took advantage of the opportunities of the shipping lanes (Grocott and Stockey 2012). This civilian population, while deeply connected to the fortress nature of Gibraltar's past, has also seen marked gains in self-determination, most recently with their 2006 constitution (Ballantine Perera 2021).

Gibraltar, named as Jabal Ţāriq, or the Mountain of Tarik, after Berber Umayyad general Ţāriq ibn Ziyād, who conquered the peninsula in 711, is wrapped up in the multinational history of the Strait. Pack argues that the Strait of Gibraltar, at first a "shatter zone" in the mid-1800s, when the mobile phenomena of "epidemic disease, trade, and banditry" challenged the sovereign borders of Spain, British Gibraltar, and Morocco, could eventually be conceived of as a "trans-Gibraltar zone" in which the emergent borderland became a site of relations between the empires of the Strait (2019: 14). Pack emphasizes the medial nature of the Strait as a zone of interest, pointing out that the remoteness from imperial centers of nodes like Tangier, Gibraltar, Melilla, and Oran often forced cooperation across the trans-Gibraltar zone. Gibraltar's territoriality, then, must be thought alongside history of the networked relations of the Strait.

The integrity of Gibraltar as sea-side territory also comes to matter for the protection of flows of species in the strait and of ecological niches along the rock. Stephen Warr of Gibraltar's Department of Environment described to me how Gibraltar features as an ecological "stronghold" in its positioning on the strait. Waters that flow through the strait and that are propelled by the Atlantic Jet (a surface-flowing current that is propelled from the Atlantic through the strait) both bring nutrients through the Bay of Algeciras and concentrate populations of species like the Mediterranean limpet (*Patella ferruginea*). Gibraltar's capacity to become fortress or stronghold depends on the capacities of the strait to accrete species or to provide shipping lanes to the Rock. These same capacities of accretion can also concentrate invasive seaweeds such as *Rugulopteryx okamurae*, a consequence that could build with the so-called "tropicalization" of the Mediterranean due to climate change (Carlo Nike Bianchi and Carla Morri 2003). When featured in a straitside view, Gibraltar's fortress nature seems to move with the flows and circulation of the strait itself. These flows encompass Gibraltar's civilian interests, its non/post/colonial relations with Britain and Spain (Ballantine 2021), and the ships and species that concentrate and disperse according to their rhythms.

The circulation of seawater carries a more dispersed story of Gibraltar's place in the Strait, crashing into and dissolving some of the boundedness of its territory. Rachael Squire (2015) argues that an inclusion of elemental agencies in a study of Gibraltar can open up the politics of the region. She shares the story, told by a local official, of storms that sent waves rebounding off of the land reclamation in Spain's port at Algeciras, crashing into Gibraltar's reclamation. Another local official, recounting the same story to me, mentioned that the Spanish reclamation was not designed to include gaps to break the waves, and water during the storm flooded parts of the western side of Gibraltar. Nor is the turbulent incursion of seawater limited to the bay – the impacts of sea surface warming from climate change may include the intensification and multiplication of “Medicanes,” or tropical-like cyclonic storms in the Mediterranean (Koseki et al. 2021). Consequences of a tropicalizing Mediterranean pervade notions of ecologies, territory, and economy in the region.

In this chapter, I consider how the making-fortress of Gibraltar and the determination of ideas such as the non-colonial, native, and invasive are wrapped up in the hydro-logics of the strait itself. The Strait of Gibraltar is not just a background or environment upon which these concepts are built (Steinberg 2013), but is instead a key aspect of the rhythms, shifts, and accretions that make up Gibraltar’s roles as fortress and ecological stronghold. I hold together the geological, the ecological, and the colonial by imagining the flow of the Strait as bringing about the concentrations and dispersions of sovereignty and species. For this reason, the chapter’s title, both sympatric and allopatric (fatherland-together and fatherland-other), maintains the turbulence created by seawater as it circulates. I examine accounts of Gibraltar’s shipping industry, of the strait’s marine ecology, and Jennifer Ballantine’s investigation of Gibraltar as “non-colonial” (Ballantine 2021), refiguring each as wrapped up in the hydro-logics of the waters in the strait. I use these accounts to develop an idea of the fortress of Gibraltar as an aquatic accretion and dispersal that is particular to the ecology of the seawaters of the strait.

Pieces of Gibraltar, Patches of Oil

“Of the seventy or eighty thousand ships that pass through the Strait of Gibraltar annually, ten to fifteen percent of them will call in Gibraltar,” explains Manuel Tirado, captain of the Gibraltar Port Authority. Tirado showed me through the facilities of the port, bringing extra attention to a wide room that overlooks the strait. This room is host to several radio and computer systems occupied by busy port workers. They both watch from their strategically positioned vista and tap into the Vessel Tracking System (VTS) that monitors the ships passing through the strait and through Gibraltar's waters. This system allows the port authority to advise ship captains passing through their waters of routing advisories, sea conditions, and of fueling priority at Gibraltar's fueling station. VTS is coordinated with the systems of other ports in the area, such as Spain's port of Algeciras across the bay. Tirado is quick to point out the state-of-the-art capabilities of VTS, noting the automatic identification of commercial vessels passing through, as well as the CCTV and thermal imaging to track a vessel's passage and any kind of waste that it may discharge.

Shipping and bunkering (the fueling of commercial ships) are key industries in Gibraltar, but port officials must contend with heavy traffic passing through a narrow strait. Coming in from the Atlantic or Mediterranean at different trajectories, traffic flows rely on consistent communication between ports. The strait itself and the flows that constitute it provide both the lifeblood of Gibraltar's economy and the turbulence that necessitates the work of the port authority. The authority uses hydrographic information provided by the UK Hydrographic Office to manage the traffic passing through Gibraltar waters, negotiating the rhythms of the Strait to maintain a steady flow whilst avoiding collisions and spills. The consequences of being overcome by the forces of the Strait were seen in the 2008 grounding of the MV Fedra on the east side of Gibraltar. Severe winter weather conditions, including the cold and winds that drive the circulation of water in the strait, also cast the Fedra onto the Rock, provoking a search and rescue for the crew onboard.

Gibraltar's capacity as a port has long been deeply tied to its fortress capacity. Queen Anne declared in 1706 "…that Gibraltar would henceforth become a 'free port'", where "…vessels of any nationality, including those at war with Gibraltar's sovereign, were free to trade with the Rock without duties being paid on their cargo, providing that they brought with them supplies for the garrison" (Grocott and Stockey 2012: 13). Gibraltar's port status drew a civilian population that could service the garrison, rendering the Rock more than a stark fortress upon which a flag was planted. The echoes of this original dedication to Gibraltar's status as both free port and garrison are clear in the management of Gibraltar's waters. Officials at the port authority must balance between the direction of a flow of trade that supports Gibraltar and the potential violations and incursions that could put Gibraltar's waters under threat. Throughout this endeavor, they are attuned to the circulation of the Strait itself, which intervenes in the passage of ships instead of just providing a background on which the economy of Gibraltar is staged. If Gibraltar's capacity as fortress is to be considered as deeply linked with its port capacity and place along the strait, then this situation must not reduce the strait to a mere background for these activities. Instead, the strait intervenes in and shapes the port and fortress capacities of Gibraltar.

The separation of the physical fortress Gibraltar is not entirely distinctive from the gathering and dispersing capacities of the strait. Richard Montado, while serving as head of the Gibraltar Maritime Administration, told me of Gibraltar's many responsibilities as a coastal state, port state, and flag state, all designations outlined under the United Nations Convention on the Law of the Sea (UNCLOS 1982). In its capacity as a flag state, Gibraltar maintains a registry of ships that form part of Gibraltar's charter. These ships fly the flag of Gibraltar, which itself is one of the subregistries of the UK. The idea of a flag state and the fleet that it is associated with carry their own, seabound representative logics. Ships gain representation and the power to adopt or refuse regulation by their association with registries of greater ship tonnage (Leeuwen 2010). For Gibraltar, this means abiding by the regulations of the International Maritime Organization (IMO). More than simply associating with the flag of Gibraltar or the regulations to which it is beholden, ships in the Gibraltar registry become seabound representatives of Gibraltar's interests. Montado described the ships in the Gibraltar registry as being "little pieces of Gibraltar." Fortress Gibraltar is wrapped up not only in the circulation of its port trade in the Strait, but also in the dispersal of aquatic representatives which, cast to the seas and oceans, form a kind of national particulate.

Ships passing through the strait also bring threats of oil spills and pollution to the coast. In early September of 2022, the bulk carrier OS 35 (Figure 2.1) collided with a liquefied natural gas tanker and began to leak both diesel and heavy fuel oil (Kirby 2022). While booms were deployed to contain most of the spill, not all of it was containable. Luis Stagnetto, marine biologist with Gibraltar's Nautilus Project, warned that much of the unseen diesel could be in the seawater in a viscous state, harming local wildlife. The quickly moving waters of the strait make it a fraught space for dealing with the spread of oil pollution. Even aside from larger spills like that of the OS 35, bunkering activities throughout the region and shipping activity contribute to micro-spills that may flow into Gibraltar's waters.

Figure 2.1: Bulk Carrier OS-35 Surrounded by Oil Boom (Picture by Riccardo Igieni)

Gibraltar's Environmental Safety Group, led by Janet Howitt, has long tracked wastes and spills that accumulate in key sites along the Rock, aware of the complicity of bunkering and shipping in local pollution. She led me through several of Gibraltar's key ecological niches and tourism spots, with a noted focus on the bays (such as Camp Bay, Little Bay, and Rosia Bay). She constantly pointed out how Gibraltar's environmental and ecological fate was tied to its relation to its waters.[5] Her organization works steadfastly to clean up the areas around the rock, bringing attention to the situatedness of Gibraltar and the ecological biodiversity of the waters of the strait.

[5] As well as to the air, where a key local environmental interest was the movement of migratory birds and where Howitt's group worked to bring attention to airborne particulate matter.

Port Captain Manuel Tirado, while maintaining vigilance of the waste that can be tracked coming from vessels in Gibraltar's territorial waters, mentioned that spills may also come from farther afield in the strait, flowing into the area. These spills defy attribution, whether to a ship or to an associated state. They challenge Gibraltar's management of a circulatory regime that would see ships and spills follow an orderly regimen. In her work on the landmark case between Chevron and the people of Lago Agrio, Ecuador, Suzana Sawyer points to the unique interactions of water and hydrocarbons (Sawyer 2022: 193-194). While most accounts stop at classifying hydrocarbons as hydrophobic (splitting from and being pushed away by water), Sawyer delves into the chemistry of hydrocarbons and water. She states, "…when drops of oil come in contact with water, hydrophobia is not what is at issue…Because water molecules are so drawn to each other by virtue of their polar forces, they inadvertently move the oil drops out of the way and squeeze them together…At play is not water's essence or oil's phobia, but the dynamic relations whereby polar aquatic fluids importantly partake in evincing oil." Sawyer highlights the fact that oil contamination, rather than being as clear as an experiment in a Petri dish, consists of several hydrocarbons that may volatilize and degrade, as well as others that lodge themselves in the matrix in which they are found. These concerns are of vital importance in the strait, where constant shipping traffic and the flow of the many waters of the strait may disperse and accrete oil through the air, on the surface, and below.

The circulation of oil and of emissions in the strait works upon hydrocarbon logics and on the relations between water and oil. While certain hydrocarbons may be evinced on the surface, separated off by boons, and cleaned up, others may be entrained in the driving flow of the strait. González et al. (2019) demonstrate that the movement of surface currents and the link between surface currents and the many water masses of the strait are essential to understanding how oil slicks might spread around the strait. Stratification between the strait's many water masses drives surface flows in a manner which may complicate the tracking of oil spills in areas such as the Bay of Algeciras. In the bay, periodic water transport inversions can provoke the re-entrance and persistence of pollutants. In the strait, internal waves generated by tides may cause local distortions in the surface flows dictating the path of spills (ibid). Frustrations with unexpected movements of water could be seen in the management of the OS 35 spill, where unruly winds pushed many of the booms that were meant to contain the spill, driving oil and water out of their containment zone (Cañas 2022).

Looking on from the port's strategic vista, I found it hard to imagine that the waters of the strait could be considered as separate from the Rock or as a background on which the Rock's interests play out. Nor was it feasible for me to imagine the waters as a kind of surface on which ships and spills might move. Instead, the dynamic flows of the strait, seen in a panorama of Gibraltar's waters, seem to encompass both Gibraltar and its industries. Montado's description of ships as being "pieces" of their national registries and the movement of wily oil slicks in the churning waters of the strait call for a more immersed and turbulent understanding of Gibraltar's relation to its waters. If the waters of the strait are a part of the making-fortress of Gibraltar, this is not just true for its politics and economy, but also carries over to its ecologies. Holding oil spills together with the shipping industry is one way to imagine this, and the strait's force can be seen in how it drives both slick and ship. The management of ballast water and of species flow within the strait expand an idea of the Rock as stronghold to its ecological niches.

Ecological Strongholds, Invasive Water

Stephen Warr, Environment Officer at Gibraltar's Department of the Environment, is quite passionate about one particular species in the strait: the Mediterranean ribbed limpet

(*Patella ferruginea*). He has spent time modeling and documenting the spread of limpet larvae in the strait, using predictive hydrodynamic models that have also been used to track oil and to understand the meteorological conditions of the strait. He describes the strait, the Chafarinas Islands, and Ceuta as "ecological strongholds" in the Western Alboran for the limpet. These strongholds represent the locations of the highest number of these limpets, and they are potentially the areas of the greatest genetic resilience. Warr explains that the Bay of Algeciras has the potential to act like a "funnel" for the limpet larvae that are passing through. The shape of the bay, its prevailing currents, and the strong Atlantic jet that flows into the Mediterranean from the Atlantic have the tendency to push larvae into the bay, maintaining their presence in the Western Mediterranean while preventing many of the larvae from drifting out to the Atlantic. Key to the circulation of larvae are the depth and tides of the bay, which also allow for biological productivity as nutrients are circulated from the depths to the surface.

The Alboran Sea, which makes up the first subbasin encountered by water entering the Strait of Gibraltar from the Atlantic and includes the bay neighboring Gibraltar and Algeciras, "…is one of the most productive sub-basins of the Mediterranean" (Sánchez-Garrido et al. 2015: 7329). The Atlantic jet, which flows along the surface of the sea and is driven by inflow from the Atlantic, is responsible for much of this productivity, driving the circulation of phytoplankton. In this circulation, tides in the Alboran Sea drive the "…pumping of nutrient-rich water from depth to the sunlit surface layers" (ibid: 7341). Movement within the waters of the Strait of Gibraltar, aside from dispersing oil and driving shipping, establishes the ecological strongholds of which Warr spoke. These strongholds, then, are not so much static positions in which species like the limpet can be found, but are concentrations driven by the circulation of the wider Alboran sub-basin. Limpets, which potentially become female as they grow (with females starting to appear at a size of 60mm), benefit from the concentration of larger individuals for the fecundity of the species (Espinosa et al. 2006). Maintaining the limpet population relies on both the circulation of limpet larvae and the maintenance of havens for larger individuals of the species. Gibraltar's capacity as a stronghold for these kinds of organisms comes from the accretion of flowing larvae funneled into the bay.

Mateo-Ramírez et al. (2021) point out that the Alboran Sea is a region marked by the proliferation of Marine Protected Areas (MPAs) (Figure 2.2). Gibraltar falls within the Southern Waters of Gibraltar Special Area Conservation (SAC) as of 2006, which extends to 800 meters depth and overlaps with parts of Spain's Estrecho Oriental SAC. SACs, a type of Marine Protected Area, protect one or more species' habitats under the European Union's Habitats Directive. Mateo-Ramírez et al. note that Gibraltar, with its departure from the EU under Brexit, could face administrative challenges to its SAC, as that designation belongs to the EU directive. Another kind of Marine Protected Area, Morocco's Sites of Biological and Ecological Interest seem to echo the call by Warr for ecologically driven protections. These sites identify sensitive areas in relation to ecological functions like feeding and breeding (Mateo-Ramírez et al. 2021: 826).

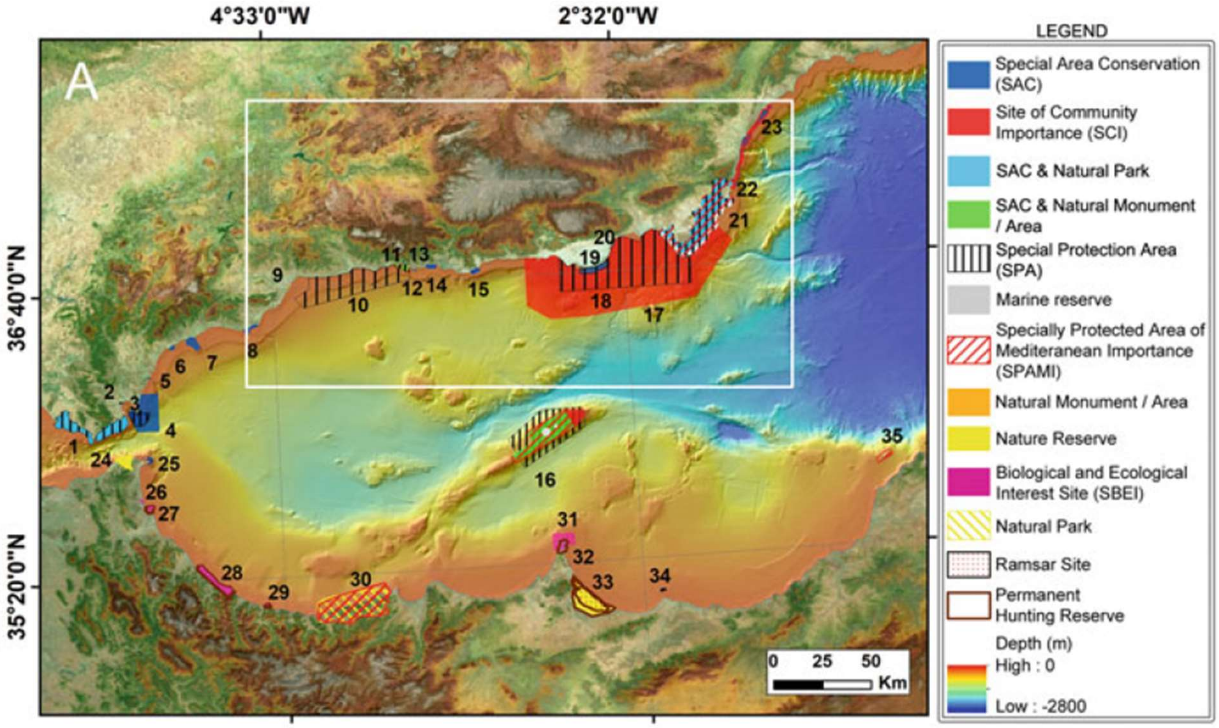

Figure 2.2: Marine Protected Areas of the Alboran Sea (Mateo-Ramírez et al. 2021)

While the limpets are recognized by environmentalists and marine biologists as a key indicator of marine health and conservation, another species has come to the fore as one smothers many of the ecological strongholds of the area. *Rugulopteryx okamurae*, a seaweed with origins in the Western Pacific, covers much of the seabed in sunlit areas surrounding Gibraltar. When I first heard of this seaweed, it was in the context of large amounts of it drying on the same tarmac that connects Spain with Gibraltar. The brown seaweed had begun to appear in the strait in 2015, covering patches of the seafloor and choking out native seagrasses (Figure 2.3). García-Gómez et al. (2020, 2021) examined the coverage of *Rugulopteryx* on the Ceuta side of the strait, finding that there was 80-90% coverage in the illuminated habitats between ten and twenty meters. Though the seaweed threatens native biodiversity and modifies the structure of native habitats, removing it is hardly simple. Warr pointed out that the seaweed, while cleaned up when it began to grow into the swimming areas of the beaches around Gibraltar, covered too much of the seabed and did so too densely to make possible total removal. Populations of seahorses could be spotted making a home in the dense patches of brown seaweed, but other species have not fared as well. *Rugulopteryx* has been noticed affecting populations of sea urchins, local sea grass, and the entire intertidal environment where it is present. The same connectivity that promotes the spread of limpet larvae also intensifies the spread of species like *Rugulopteryx*.

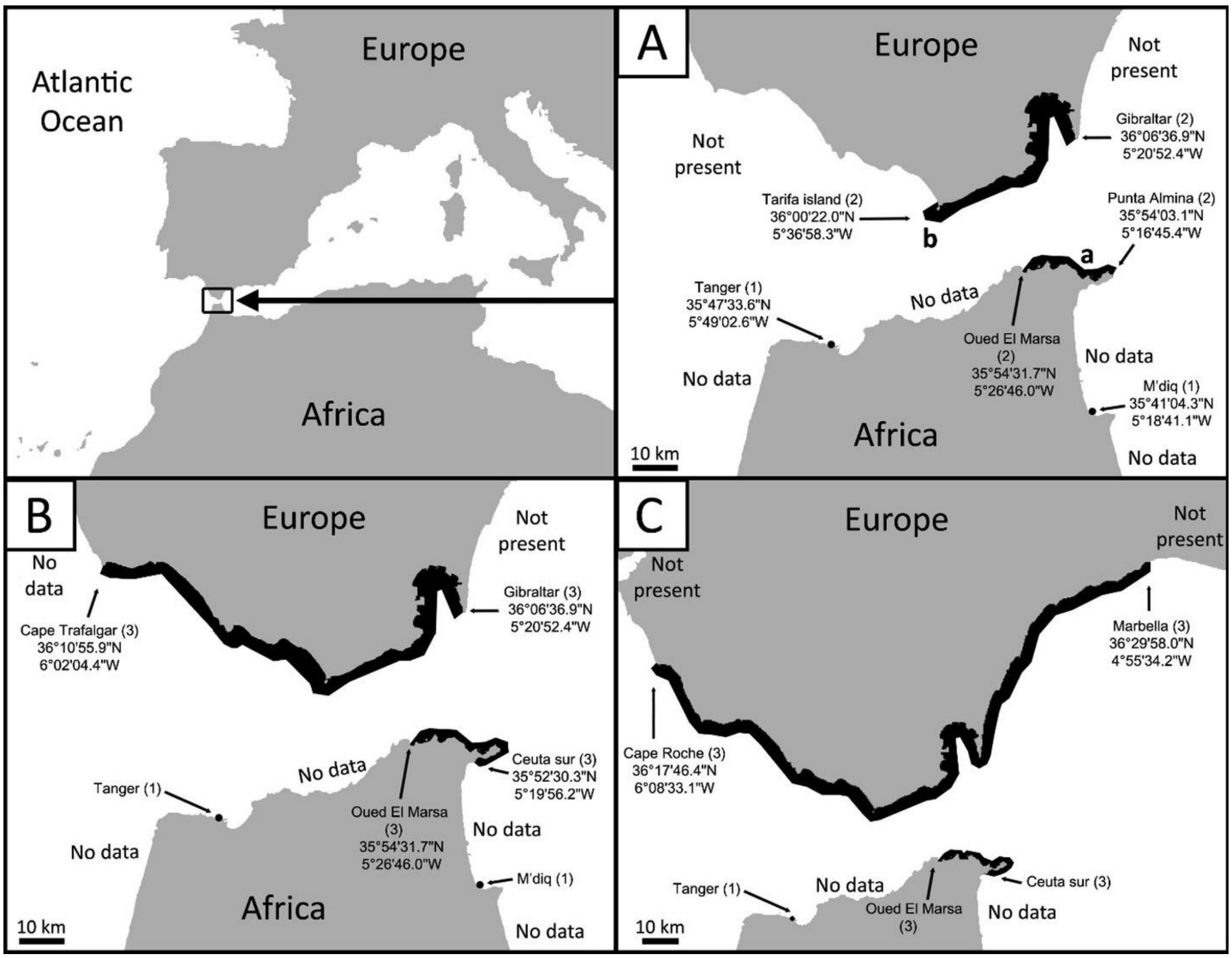

Figure 2.3: Distribution of R. okamurae in the Strait of Gibraltar and nearby areas (Garcia-Gomez et al. 2020)

Stefan Helmreich (2005: 124), in observing the way that terms such as “native,” “alien,” and “invasive” are used in regard to certain species in Hawaii, highlights that “terms of debate about nativeness transform when transported into water." Seawater troubles a stable concept of nativeness and invasiveness, forcing the terms to become mobile. This is especially true in the Strait of Gibraltar, where shipping lanes overlap with multiple territorial waters. Invasiveness of species is linked not only to these species disruption of native species, but to their circulation within and occupation of marine environments. The conditions that engendered the spread of *Rugulopteryx* speak to the complexity of dealing with the Strait's flows. While this seaweed has been introduced up the coast at French mollusc farms, a more likely explanation for its spread in the Strait is the flushing of ballast water by passing ships. Once ejected in ballast water, spores of *Rugulopteryx* do not simply thrive by virtue of being in a new place. One must also consider the environ-ing of the location in which spores are introduced. Increased temperatures leading up to 2015 have coincided with the peak introduction time of *Rugulopteryx*, with a warmer Mediterranean providing an environment in which the invasive can spread natively (García-Gomez et al. 2020, 2021). Thus the invasiveness of the seaweed, when understood as part of the flow of the strait, must be considered alongside both the strait's circulation (of water and ships) and its seawater conditions (becoming tropical).

Ballast water is carried in the ballast tanks of cargo ships to make the ship more stable and maneuverable, and it is cyclically discharged and exchanged. This water carries with it its own aquatic ecology. The first suspicion of shipping as a carrier of non-indigenous organisms came about in a 1908 report on Asian phytoplankton in the North Sea, but it wasn't until 70 years later that ballast water samples were formally tested (Gollasch et al. 2007). While the risk of carrying and spreading non-indigenous species in ballast water was acknowledged at this point, early guidelines on the organism concentrations in ballast water made clear that the transport of non-indigenous organisms could not be completely avoided. To mitigate the potential for the spread of non-indigenous species, a philosophy of mitigation was established that set distance from land as a metric for risk. Gollasch et al. (2007: 588) write, "The philosophy behind BWE [Ballast Water Exchange] is that coastal organisms when discharged at sea are unlikely to survive and that high sea organisms when pumped onboard during the water exchange will not likely survive when released in coastal regions." In this idea, there are several overlapping ideas of the ecologies that must be managed by ships that would exchange ballast water.

First the differentiation of ballast water and seawater draws a distinction between the ship's watery ecology (which carries its own potential organisms and is temporarily contained) and the general ecology of the water through which the ship moves. Here is where the categories of indigenous and non-indigenous seem to be staked. Further, the description of best exchange practices plays upon specific ecologies within the native ecology, drawing a division between the "high seas" and coastal ecologies. Here, it is implicitly recognized that coastal ecologies, in their inclusion of human activity, are the nexus of potential risk. The high seas, separated from the coastal ecology by an ideal exchange distance of 200 nautical miles away from shore, acts as a buffer and as a hostile ecology for whatever nascent organisms are carried onboard a ship. While the density of non-indigenous organisms is shown to be less in these high seas exchange areas, ideas of ecological exchange and the flow of water appear to be not entirely present. What might it mean to think of the barriers between high seas and coastal ecologies in the strait, where the Atlantic jet drives waters into areas like the Bay of Algeciras, disrupting the even distinction between ecological zones. Furthermore, Gollasch et al. mention that in some scenarios, repeated exchange locations may become spots in which certain non-indigenous species flourish, as they are able to establish a foothold.

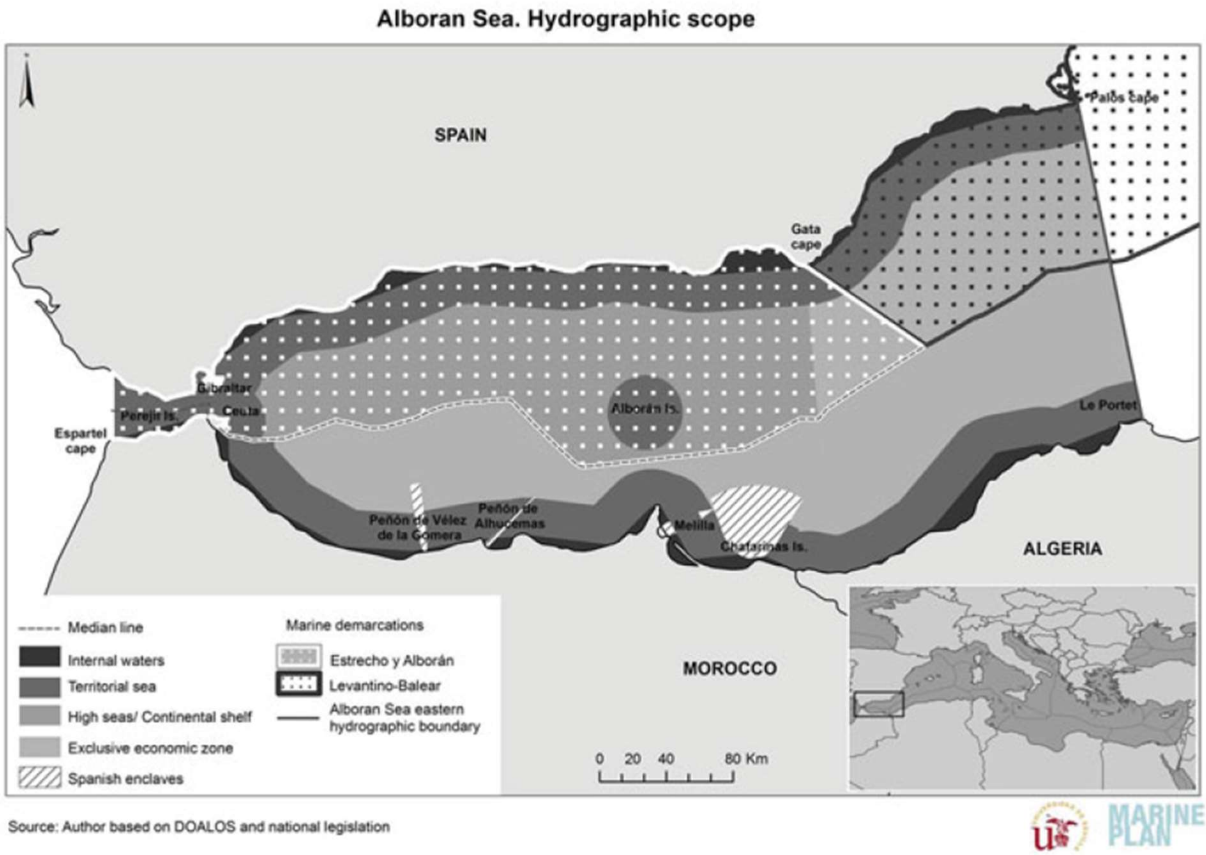

Figure 2.4: Demarcations of different classifications of seas under UNCLOS. Gibraltar and Ceuta are shown toward the left-hand side. (Suárez-de Vivero et al. 2021)

In the Strait waters between Gibraltar and Ceuta, the idea of "high seas" is further complicated by the narrowness of the gap. Territorial seas extend up to 12 nautical miles (3 nautical miles for Gibraltar) under the United Nations Convention on the Law of the Sea, and the entirety of the Strait is occupied by territorial seas (Figure 2.4). High seas in the legal sense begin appearing only once the Strait opens up into the Alboran Sea (Suárez-de Vivero et al. 2021). Thus, the Strait presents a bottleneck, where ships may not even be able to meet the less stringent ballast water ejection zone distance of 50 nautical miles from land and may instead have to eject ballast water in closer locations.

For shipping areas in which cargo ships may not be able to exchange ballast too far from the coast, ballast water exchange zones can be designated. These manage the depth (aiming for deep) and the currents (aiming for offshore directing currents) to preserve the integral nature of the coastal ecology. Certain ships like oil tankers must make use of onshore treatment facilities, as their oily ballast requires a system attuned to their specific ballast ecology. Testing of ballast water may try to trace the viable and non-viable organisms within the ballast tank, but Gollasch et al. (ibid: 596) highlight that the specific maturation stages of certain species may dictate the need for an expert well-versed in whether those species are viable. Organisms that form colonies may not have the same units of fertility or of individuals as those that do not, challenging the metrics for the size and count of viable organisms within a ship's ballast water.

The Strait of Gibraltar, in its conjunction of multiple coastal ecologies and its circulation of water and nutrients, provides an ideal location for the spread of *Rugulopteryx*. Gárcia-Gómez et al. (2020) warn that the strait forms a convergence of Lusitanian, Mauritanian, and Mediterranean provinces with the Atlantic-Mediterranean subregion, providing both a spot for biodiversity and, consequently, an intensified version of the "coastal" ecology that is most protected by ballast water measures. While the Gibraltar Maritime Administration performs regular testing of ballast water and closely follows the IMO (International Maritime Organization) regulations on it, Gibraltar cannot track all of the ballast water exchange that goes on out in the Strait. When spores or larvae are the units at stake, it is difficult to prevent ships passing through the strait from contributing to the spread of non-indigenous species in coastal regions.

In addition to the strait's provision of a circulatory regime that brings both biodiversity and the potential spread of invasive species, the increased temperatures of the strait may be creating an ecology that is not limited to the division of coastal and high seas. Due in part to warming trends within the Mediterranean, the sea is said to be undergoing a process of "tropicalization" (Bianchi and Morri 2003, Bianchi 2007). Tropicalization as a process denotes both general warming trends (the increased presence of warm marine biological niches) and an increased introduction of tropical species, whether from aquaculture, ballast water, or migration from the Red Sea. *Rugulopteryx*, rather than only taking advantage of strait temperatures that rarely drop below 15ºC, could be seen as part of a general trend of the becoming-tropical of the Mediterranean. With this, the invasiveness of *Rugulopteryx* becomes more than the introduction of an out-of-place species – the potential tropicalization of the Mediterranean troubles what it means for the seaweed to be invasive. If the ecological strongholds of native species within the strait are seen to be subject to potential processes of tropicalization, the species unit must be considered alongside the way that warming trends alter the foundations of flows, of "high seas," and of coastal environments. Shipping, in its introduction of non-indigenous species, may diminish the security of the ecological stronghold as it bolsters the economic and political capacity of the sovereign one. Tensions between the non-indigenous and the native, when submerged in the connections of the strait, also play into notions of nationhood and self-determination for Gibraltar.

Seawater Connections and the Non-colonial:

In her work on Gibraltar's colonial history, Jennifer Ballantine-Perera (2021) tracks Gibraltar's growing sense of self-determination since the 1969 constitution. This document centered the self-determination of the people of Gibraltar, rather than its national self-determination, transitioning Gibraltar from colony to the City of Gibraltar. Later, the British Overseas Act of 2002 would further push Gibraltar and Britain's colonial relation to the background, setting the stage for an economically motivated partnership. Ballantine-Perera asks, however, how one might discuss the nature of the relation between Gibraltar and Britain without erasing the colonial. She opts for the term "non-colonial," which holds Gibraltar in a state of tension between its colonial past and the independence of the postcolonial, all while acknowledging its increased self-determination (which was further cemented with the drafting of its 2006 Constitution). While the nexus of determination of the colonial or non-colonial status of Gibraltar appears to be the connection between it and the UK, Ballantine-Perera argues that Gibraltar's relation with Spain constitutes a further point of tension in which Gibraltar's colonial nature is determined. It is not enough to describe Gibraltar's self-determination vis-à-vis the UK, even in the context of the increasing cultural connection of Gibraltar's "Britishness" (Canessa 2019). Instead, Gibraltar's identity is deeply tied to its relation with Spain, one which touches on the 1713 Treaty of Utrecht and on the contentious relations of Gibraltar and Spain in the strait.

While Gibraltar has been described as 'effectively decolonised' by former Prime Minister Peter Caruana (Ballantine-Perera 2021: 335), decolonization is still not formalized under UN measures. This is because a full independence of Gibraltar and formal decolonization would invoke a "…revisionary clause in the Treaty of Utrecht which would see Gibraltar revert to Spain should Britain ever renounce its rights over the territory" (ibid: 336). Rather than experiencing the state of the "non-colonial" only as an incomplete or incremental step toward the post-colonial, Gibraltar is in a perpetual state of denying the post-colonial and, with it, the claims of Spain. Ballantine-Perera describes the non-colonial as a 'Faustian pact' and a 'balancing act' which is actively negotiating what it might mean to achieve self-determination and to reframe the colonial. Spain, by being included in Gibraltar's colonial relations, takes on the adversarial role of the colonizer-colonized relation, becoming a potential colonizer against which Britain provides a defense.

I propose that the tension underlying Gibraltar's "non-colonial" status can be found also within the link between Gibraltar and its waters. While the British Overseas Act of 2002 named Gibraltar a Dependent Territory (later an Overseas Territory), Ballantine-Perera argues that Gibraltar is hardly as much of an offshoot as these terms would suggest, instead being a strategic point at the link between Atlantic and Mediterranean. Ballantine-Perera (2021b) points out the importance of Gibraltar's geography and of the liminal space of the strait between Atlantic and Mediterranean when she ponders whether Shakespeare's *The Tempest* could be told as a Gibraltarian story. Here, she experiments with the ideas of the colonial and non-colonial, concluding that Gibraltar's status as a specifically Western Mediterranean territory troubles the "out there" notion of the exploitable colony. Gibraltar is not just sandwiched between Atlantic and Mediterranean – it is close to the centers of European colonial empire. It is the flows between the Atlantic and the Mediterranean and Gibraltar's position astride them that allows for Gibraltarians to stand as a self-determining people while maintaining import for the UK. Gibraltar's territorial waters, too, gain special importance via the tense relations of colonialism that exist between Gibraltar, the UK, and Spain. The Treaty of Utrecht recognizes Gibraltar as having a dry shore, and Spain's refusal to formally recognize Gibraltar territorial waters indexes both past tensions between Spain and Gibraltar and the looming threat of Spain's claim were Gibraltar to become formally decolonized.

A Turbulent Fortress:

Gibraltar's status as fortress is buttressed by the sheer magnitude of the rock, but its ecological and political fate is wrapped up with turbulent connections through seawater that link it to global shipping lanes (and the "exotic" and potentially harmful seawaters that they transport) and to a notion of self-determination torn between the UK and Spain. Gibraltar's ecological niches themselves may appear as 'strongholds' that particularize the smallest of zones in a hyper-localization of the global call for the protection of biodiversity. Making Gibraltar's fortress nature into one that is linked to the Strait of Gibraltar is not just about including the strait as a background for politics and economy. The circulation of the strait and its turbulent connections pervade the notion of a sovereign Gibraltar, flooding over territorial politics into affective ties to territorial waters and to local species. As Rachael Squire (2015) argues about the Strait of Gibraltar, seawater as a natural element is not limited to the 'whole earth' scale of climate change discourse. This discourse remains important in Gibraltar – especially in concerns of 'tropicalizing' waters and industrial pollution – but it does not determine the particular becoming of Gibraltar's micro-strongholds and the passage of its waters into its idea's of self-determination and the non-colonial.

In this chapter, I argued that the strait is neither a backdrop for the state and environmental politics of Gibraltar nor merely a generic connection to wider oceans and wider discourses. Instead, it reshapes ocean-wide and global thinking by turning international shipping into the meeting of heterogeneous seawaters and species, turning ecological preservation into an attention to micro-level strongholds of biodiversity, and links notions of the colonial and non-colonial to a seawater connections (of territory and of national identity).

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3. Synallagmatic[6]: Operational Ecology

Introduction:

A year after the turn of the 21st millennium, oceanographer Gregorio Parrilla and oceanographer-ecologist Carlos M. Duarte (Duarte and Parrilla 2001) called attention to oceanography's burgeoning role in understanding the ocean and its connections. They lamented a lack of knowledge on the complex mechanisms tying biodiversity, climate, and fishing stocks together across thousands of kilometers. These challenges, tied up in the difficulty of generating large amounts of data on oceans, a medium that they said makes sampling "difficult and scarce." Looking forward to the potential futures of oceanography, Duarte and Parrilla underscored two specific characteristics of the field that could help to address their worries. They emphasized the "inherent interdisciplinary character" of oceanography, recognizing that systems of observation would have to be coordinated across disciplines. They also pointed to a new opportunity (and challenge) in the field: the advent of operational oceanography. Operational oceanography coordinates the reporting of real-time oceanographic data across seas and oceans, making that data available for use to public institutions such as fisheries and ports. The "operational" of operational oceanography pertains to its mission to address the practical needs of multiple sectors and nations (providing data in a way that is often compared to the forecasts of

[6] "'expressing reciprocal obligations,' from Greek *synallagmatikos*, from *synallagma* 'a covenant, contract,' from *syn-* 'together with'…+ *allagma* 'thing taken in exchange…'" (Online Etymology Dictionary). In a legal sense (used by Roman jurists M. Antistius and Titius Aristo, the synallagmatic contract (or synallagma) refers to "agreements that resulted in obligations for both parties" (Schiemann 2006). For Gilbert Simondon (2020: 661), "Allagmatics is the theory of operations. In the order of the sciences, it is symmetrical with the theory of structures…" To set apart operations and structures, Simondon uses the example of the geometer, who engages with structure in designating two lines as parallel, but who engages with operation in the act of tracing them. Both structure and operation inhere in the geometer's act. Rather than define relations as being between different structures, Simondon designates allagmatics as a study of the operations that dynamize structures and of the rapport between multiple operations or between operations and structures. Simondon designates cybernetics as the beginning of a *general allagmatics*, in the sense that allagmatic theory deals with the organization of the individual, whether through its energy/operations or through its structures.

meteorology). Though the field of operational oceanography is formally quite young, its objectives are not. Parrilla and other oceanographic scientists (Yánez et al. 2011: 65) argue that though operational oceanography is a modern field, its aspirations in systematic observation and sensing networks extend to the roots of the Spanish Institutes of Oceanography (IEOs). They cite networks of systematic oceanographic observation that have been built into these institutes since 1943. Their idea of operational oceanography is not limited to the "operations" of a single branch of oceanography, but is instead "multidisciplinary and multipurposed" (ibid) in its systems of observation, providing data on seas that can be distributed to a "plethora of users," each with diverse ends. For these oceanographers, then, the operational is tied to a history of Spanish oceanography and to a community of practices.

In its relation to other practices, oceanography has long been linked to military projects (Oreskes 2021). Naomi Oreskes outlines an implicated history in which oceanographic lines of questioning were tied to the practical or "operational" concerns of military branches like the US Navy. For Oreskes, the idea of the operational stems from a difference between "basic" and "applied" science (ibid: 12). She argues that, in the historical case of the studies of the thermocline by Henry Stommel and Arnold Arons, "…basic science did not lead to application…;rather, an operational problem led to a fundamental scientific insight" (ibid). Oreskes' "operational" is tied up in the applied work that funded and shaped the field of oceanography, as it related to military operations. Within this idea of operational is the interface of two practices – military and oceanographic – that converge at several important historical points. This operational, however, does not fully determine the practice-defining ideas of "operational oceanography," and a reduction of the latter to military interests has the potential to obscure an understanding of the relations between oceanography, its ecologies (both of practice and environmental), and its publics.

In this chapter, I explore the tension within the idea of the "operational" when it is considered either as an aspiration to map the world ocean and to provide data (i.e. operational oceanography) or as a subsumption of oceanography's interests into the force majeure of military interests. I follow a thread of Spanish oceanography, beginning in the early 20th century with the career of oceanographer Odón de Buen, that traces a transnational, transdisciplinary, and engaged notion of oceanography as a science. I then use Oreskes' (2021) insightful look into the links between oceanography and military interests, and I explore how these links manifest in the Strait via the 1985-1986 Gibraltar Experiment (Kinder and Bryden 1985, Camprubí and Robinson 2016) to question what it might mean to think of the "operationalization" of oceanographic science when it refers to militarization. I argue that oceanography, rather than having a deterministic relation with military interests, developed a rapport between its increasing focus on dynamic oceanography and military interest in the study of sound propagation at sea. Oceanography, which has itself taken on a shift toward the operational demands of government and civilian interests (Parrilla 2001) in the form of the burgeoning field of "operational oceanography," has also witnessed a transformation in its relation with seas and oceans since the early work of de Buen. Throughout this chapter, I experiment with the notion of the "operational," examining shifts in both oceanography's ecology of practices (Stengers 2005) and its practicing of ecologies (in its operative notions of oceans and seas).

Odón de Buen and the Collaborative Beginnings of Spanish Oceanography:

Odón de Buen, first exposed to the study of the sea on an 1885 expedition aboard the *Blanca* as a naturalist, soon became a key innovator for Spain of the nascent field of oceanography. On his first expedition, he "'felt an insatiable eagerness to know the hidden secrets below the waves and the causes of the origin and life of the oceans…'" (Parrilla-Barrera 2005: 130, de Buen 2003). From the start, de Buen's interest in oceanography was collaboratively oriented. He made frequent visits to French marine biologist Henri de Lacaze-Duthiers' seaside lab in Banyuls sur Mer, Laboratory Aragó. There, he would develop a sense for oceanography that was founded on the observation of the seas rather than on the museum studies that had informed his past work as a naturalist. With the help of Lacaze-Duthiers and Prince Albert I of Monaco, he established a marine laboratory in Mallorca and one in Málaga (Pelegrí 2012). These laboratories merged with a station in Santander that was founded by Augusto González de Linares, becoming the Spanish Institute of Oceanography (Instituto Español de Oceanografía, IEO). Laboratories were planned in Vigo and the Canary Islands (See Figure 3.1) and would expand to several Spanish cities over time (Parrilla-Barrera 2005: 132).

Figure 3.1: IEO locations as of 2005 (Parrilla-Barrera 2005: 135)[7]

De Buen, in founding the IEO, had a clear idea of how they would define the operations of oceanography. His institutes would enable scientists to observe ocean variables, which de Buen hypothesized would obey laws and cycles that demanded long-term measurement (ibid). These variables, rather than being simply for the benefit of the record of oceanographers, could also be used by seafarers and farmers, as well as for the forecasting of weather over land and at sea. Writing on the objectives of oceanography, de Buen states, "Study our seas to establish a solid basis for the fishing industry; it was my most determined effort to rationalize fishing and to put in the hands of fishermen the most secure means of obtaining the maximum return with the least effort and risk" (de Buen 2003: 389, translation). Thus, oceanography's operative mission, other than the establishment of the trends of ocean variables for the purpose of good oceanographic science, included an application of these variables to local interests. Indeed, de

[7] Blue dots are research laboratories ("centros oceanográficos"), black dots are facilities dedicated to marine research, and red dots are faculties of marine sciences (Parrilla-Barrera 2005)

Buen stated, in an address at the Central Institute of Marine Biology, that concerns such as communication between Europe and Africa across the Strait of Gibraltar, submarine navigation, and exploitation of living resources were included in the directives of oceanographic science (ibid). This commitment was reflected in the practices of oceanographic research expeditions, which could include both water column hydrology (for the measurement of oceanic variables) and fishing (for the purposes of biological collection and monitoring). Nor did de Buen limit the interests of oceanography to his own nation – he saw Spain host the Commission for the Scientific Exploration of the Mediterranean Sea (CIESM) and become a member of the International Council for the Exploration of the Seas (ICES) (Pelegrí 2012).

Beyond the international status of oceanography, de Buen saw the science as one that is intensely interdisciplinary. Speaking of biological oceanography, he described it as "'a science of meticulous analysis but also of relation with many factors and of synthesis as wide as the sea…Is not the separation of two branches of a same science prone to make impossible the solving of the wider problems because of excessive specialization?'" (Parrilla-Barrera 2005: 132, de Buen 2003). De Buen's description of oceanography is rich in its use of both more common metaphors of branches within the sciences and of the drawing of an important relation between the operations of oceanographers and their medium of study. Oceanographers are not just tasked with understanding a wide sea or the world oceans, but with synthesizing interdisciplinary relations that are themselves as wide as the sea. De Buen's object of study leaks into his appeals to a collaborative ethos in oceanography. De Buen's vision extends the field of oceanography topographically, comparing the science's will to knowledge to the conceits of empire. He states, "I dream of that empire of oceanography, since oceans have been everything in the past of the earth and they still dominate. As the oceans belong to everybody and nobody owns them, they belong to the most daring thoughts, to the most enterprising scientific spirits, to the harder human work and the best organized, to the most civilized peoples and the most powerful ones; it will constitute the general field of all the efforts of science and its exploration should be collective and its exploitation rationalized by common agreements" (Parrilla-Barrera 2005: 135, De Buen 2003). De Buen's vision of the work of oceanography does not separate the scientific and social ends of the field, instead blending together questions of territory, economy, and knowledge. Though his use of empire may suggest a conquering of the seas, his language regarding the capacity of oceans to "dominate" the past and present of the Earth draws a link between the scientific imperative of oceanography and the ancient, pervading nature of the ecology that interests them. De Buen's imagination of an "empire" of oceanography also extends to a connection between the vastness and primacy of oceans and oceanography's interdisciplinary potential. He describes oceanography as the "…science that completes and agglutinates all the conclusions of Geodesy and Geophysics" (ibid), recognizing both the potential for oceanography to contribute to understanding the unknown aspects of oceans and its seawatery potential to draw the work of terrestrial sciences into the interdisciplinary pull of the new discipline.

Within de Buen's foundational understanding of Spanish oceanography are ideas not only of the frontiers that might be understood by the science (ocean variables and the state of seas), but also of what operational ethos might best do this. He extended the rapport of Geodesy and Geophysics with the terrestrial to oceans, pushing to adhere to a multidisciplinary practice that could match the vast, global syntheses that would need to be performed. Oceanographic data collection would also have to include a rapport between nations and between laboratories, as attested to by the formation and gathering of organizations like ICES. Additionally, the operations of oceanography were understood by de Buen not as transcending the concerns of industries like fisheries, but as potentially including the benefits that could come from understanding ocean variables, fish populations, and the relation of oceans to weather. Gregorio-Parrilla (2005: 134) points out that de Buen was keen to pay attention to oil spills, suggesting that CIESM be mindful of their effects on the oceans. He also supervised the IEO's efforts to acclimatize the gambusia, a fish that feeds on malaria-carrying mosquito larvae.

The potential social impacts of de Buen's new science were soon smothered by the onset of the Spanish Civil War (Gregorio-Parrilla 2005, Pelegrí et al. 2012, Gomis 2020). De Buen, self-described as having "freethinking ideas" and as having lived "away from any religious community," recognized that his ideas of oceanography did not exist outside of the realm of the political. Later in his life, he wrote that "the audacity to have created in my country a new branch of science created much dislike" (Pelegrí et al. 2012, translation), pointing out the envious and petty adversaries of his that existed both within the academy and in public office. De Buen fled Spain, and awareness of his personage and ideas was largely erased until the 1970s. With his censure came also a dearth in new oceanographic research and knowledge, and work at the IEO took a back seat to the creation of the Navy Hydrographic Institute and the Fisheries Research Institute. De Buen's vision of an oceanography that would operate based on international cooperation and interdisciplinary work was later revived, though it would be inflected by the designs of military funding and a shift in the disciplinary makeup of the field.

Military-Funded Oceanography and Its "Operational" Value

Before the start of the Spanish Civil War, Odón de Buen had proposed the idea of an Ibero-American oceanographic commission. While this proposal never received the approval of all participants (Pelegrí et al. 2012), its legacy was revived by Spanish oceanographer Gregorio

Parrilla in the 1970s. According to Jesús García Lafuente, oceanographer at the University of Málaga and former student of Parrilla's, Parrilla was an innovator in the field where collaborative projects were concerned. Parrilla, whose testimonies on de Buen (Parrilla-Barrera 2005) show the inspirational role of that founding Spanish oceanographer, oversaw a treaty between Spain and the United States that would revitalize Spanish oceanography after its period of obscurity. This cooperative treaty, signed in 1976, included the exchange of scientists and of instrument funding between Spain and the US (Committee on Science and Technology 1984, Pelegrí et al. 2012). This treaty motivated projects in the Strait of Gibraltar that included the Donde Va? Project (Donde Va Group 1984).

Donde Va, a project that included participation of the IEO, the Navy Hydrographic Institute of Spain, and American and European colleagues at other research centers, was designed to study the structure of water flow between the Mediterranean and the Atlantic. Among their objectives, they included research on the flow of intermediate and deep water out of the Mediterranean; the biological and chemical influences of the Alboran Gyre, a large gyre of water in the Alboran Sea; the atmosphere-ocean boundary; and the signatures of and atmospheric forcing of the gyre. The Alboran Gyre was found to play a significant role in the circulation of nutrients in the Alboran Sea, and the effects of Atlantic flow on the makeup of the gyre were studied with methods including remote observation of the chlorophyll concentrations in the Alboran (Figure 3.2). Chlorophyll concentrations indicate populations of phytoplankton, and the swirls in Figure 1 show the swirls of the Alboran Gyre. Lafuente, when speaking of Parrilla's work on the Donde Va? Project, clarified that the background of the project was clearly military. Military interest in the effects of ocean fronts and the thermocline (the main boundary between warm surface waters and cold deeper waters) on the propagation of sound was high. Blind spots or “shadow zones” in the propagation of sound could mean the failure to detect enemy submarines, and a detailed understanding of the division of water masses and of the temperature,

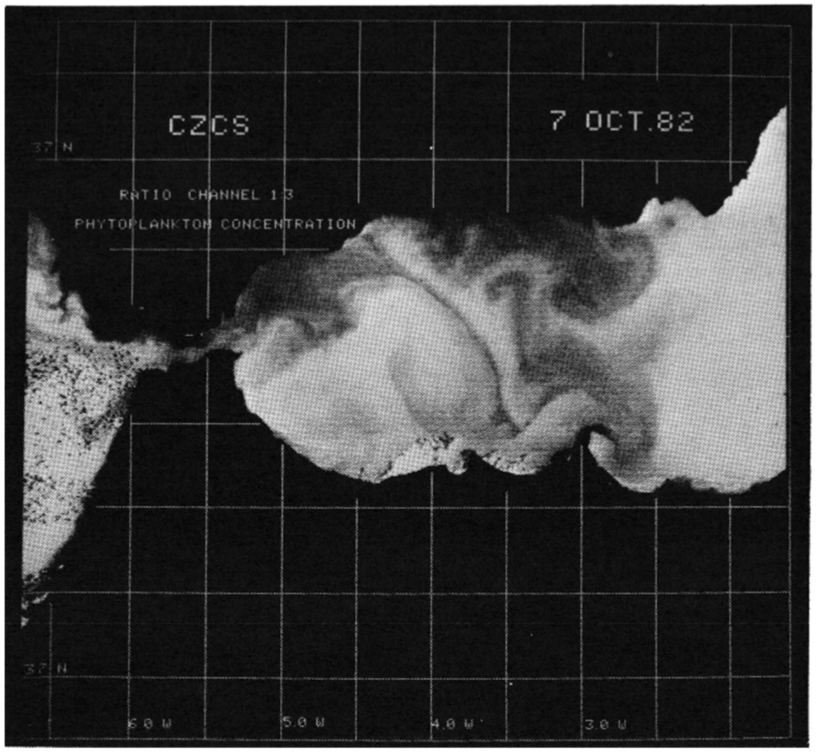

Figure 3.2: Chlorophyll Concentrations in the Alboran Sea (Donde Va Group 1984)

pressure, salinity, and density characteristics of waters on either side of the Strait of Gibraltar was necessary to best understand potential gaps in surveillance.

In her expansive and detailed study of the effects of military projects and funding on the field of oceanography, Naomi Oreskes (2021) contends that military funding did not just support “pure” scientific questions for the field – military concerns directed the focus of oceanographers by forming the questions that they might ask about the ocean. In one of her case studies, Oreskes describes the ways in which Henry Stommel, pioneering oceanographer at the Woods Hole Institute, came to his conclusions about deep ocean circulation by paying attention to phenomena that were of military interest. Before Stommel, oceanographers had attempted to understand deep ocean circulation by attending to the fact that the deep ocean was the zone of the coldest temperatures. This caused them to focus on the mechanism by which colder waters could sink to these depths. Stommel, however, paid more attention to the thermocline, the zone that separated cold and warm strata of seawater. He found that, for there to be a thermocline at all, there also had to be circulation *from* the deep ocean toward the surface, such that the warm surface layer and deep cold layer met at the boundary of the thermocline. These ideas contributed to the Stommel-Arons model of deep ocean circulation. Oreskes argues that Stommel, rather than having been drawn to the thermocline naturally, was interested in it because of a military directive at Woods Hole to understand the impacts of density on sound propagation.[8] As an important feature in the density makeup of the ocean, the thermocline was of great interest to the military, and Stommel's line of questioning was directed by this interest.

Describing the relationship between the military and oceanographic knowledge, Oreskes (2021: 74) states,

"The Navy wanted to increase oceanographic knowledge and so did oceanographers. It seemed natural, and even obvious, that the relationship forged in war should be continued in peace to mutual benefit. If Woods Hole would change as a result, those changes would be for the better, as the institution would be able to pursue oceanographic investigations with a vigor and consistency that was previously impossible."

Thus, funding arrangements with the Navy were both convenient for oceanography and promised the continued success of the field. According to Oreskes, it also changed the ways in which oceanographers thought about theoretical problems. She states that, for Stommel and his colleagues, "The operational problem was the effect of the thermocline on sonar; the

[8] Oreskes discusses how this military directive, called "military defense oceanography," was called the "basic task" by staff at Woods Hole

breakthrough was the understanding of deep-ocean circulation" (Oreskes 2021: 58). Oreskes draws a clear split between the "operational" as attached to the concerns of military operations and the theoretical breakthroughs that make up the science of oceanography. For Oreskes, this split is useful in delineating and showing the intersections of the interests of oceanography and the military, where the operational becomes a way to talk about the practical challenges faced by military interests. These same military concerns were present in the Donde Va? Project and within its successor, the Gibraltar Experiment.

The Gibraltar Experiment (Bryden and Kinder 1985), like the Donde Va? Project, sought to understand the flow of seawater in the Strait of Gibraltar. Unlike Donde Va?, the Gibraltar Experiment focused mainly on the dynamics of the two way flow between the Atlantic and the Mediterranean. The experiment included work by American, Spanish, Moroccan, Canadian, and French oceanographers, and it sought to study the dynamics of the strait as an exemplar of two way flow within a strait. Oceanographers working on the Gibraltar Experiment examined whether friction, mixing, rotation, or nonlinear processes were responsible for regulating the strait's flow. Other projects included the work of chemical and biological oceanography to understand the concentrations of nutrients and trace metals in the strait, as well as the work of physical oceanographers to study the formation of standing waves at the Mediterranean entrance of the Strait. Researchers were interested in generalizing the oceanography of straits in a way that wasn't purely descriptive and could attend to the dynamism of these passages, and the Strait of Gibraltar was of interest due to its strong internal motions and influence on the Alboran Sea (Bryden and Kinder 1985). According to Camprubí and Robinson (2016), the Gibraltar Experiment was also directly linked to the military's desire to fully understand sound propagation in the strait. Decades before the experiment, he oceanographer Harald Sverdrup found that the location of the thermocline was influenced by daily tides and by topological features such as the Camarinal Sill, a sill extruding from the ocean floor between Spain and Morocco (ibid: 436). Changes in temperature, salinity, and depth at the thermocline provided pockets in which submarines could potentially hide from sonar devices, forming a security threat that could only be alleviated by a greater understanding of the oceanographic properties of the Strait and its multiple tides and layers. The Gibraltar Experiment, in addition to providing more information on the effect of the thermocline and of topography on sound propagation, provided an idea of the Mediterranean Sea as a "model ocean" that could be understood at the strait.

Belgian oceanographer and NATO program participant Jacques C. Nihoul "stated in 1982 that the conception of the Mediterranean as a 'reduced scale model of the world ocean' had taken hold only in the previous decade (Camprubí and Robinson 2016: 456). The idea of the Mediterranean as a model or scale ocean concentrated in the Strait of Gibraltar, as the waters in the strait were indicative of the processes occurring in the Mediterranean. Indeed, the iconography of the Gibraltar Experiment echoes the idea of the strait as a gateway to the model ocean of the Mediterranean, where waters in that sea could be read at the interface between Mediterranean and Atlantic (this is a double reduction that moves from global ocean to model ocean to gateway of the model ocean)[9]. The emblem of the experiment (Figure 3.3) is reminiscent of a traditional O-T (orbis terrarum) map. In many medieval O-T maps (Figure 3.4), the world was depicted as split between the known land masses of Europe, Africa, and Asia (Williams 1997). Rivers, seas, and oceans bordered the land masses that dominated the circle of the world. In the Gibraltar Experiment emblem, however, the Strait of Gibraltar dominates the

[9] Indeed, the connection between the Atlantic and Mediterranean seems to engender many levels of model ocean or sea. Báez et al. (2021: 2-3) argue that the Alboran Sea itself could also be a miniature ocean, owing to its biodiversity and biological productivity.

frame. Arrows map out the exchange of waters between the Atlantic and the Mediterranean, and unlabeled land masses serve only to border the strait. A moon and sun signify the importance of the atmosphere and tides in the strait's flow regime. This emblem represents the strait as a world in itself, echoing the notions of the strait as the nexus of the Atlantic and of the Mediterranean "model ocean." Additionally, it centers the exchange of water as the dominating force, drastically changing the peripheral nature of waters in medieval O-T maps.

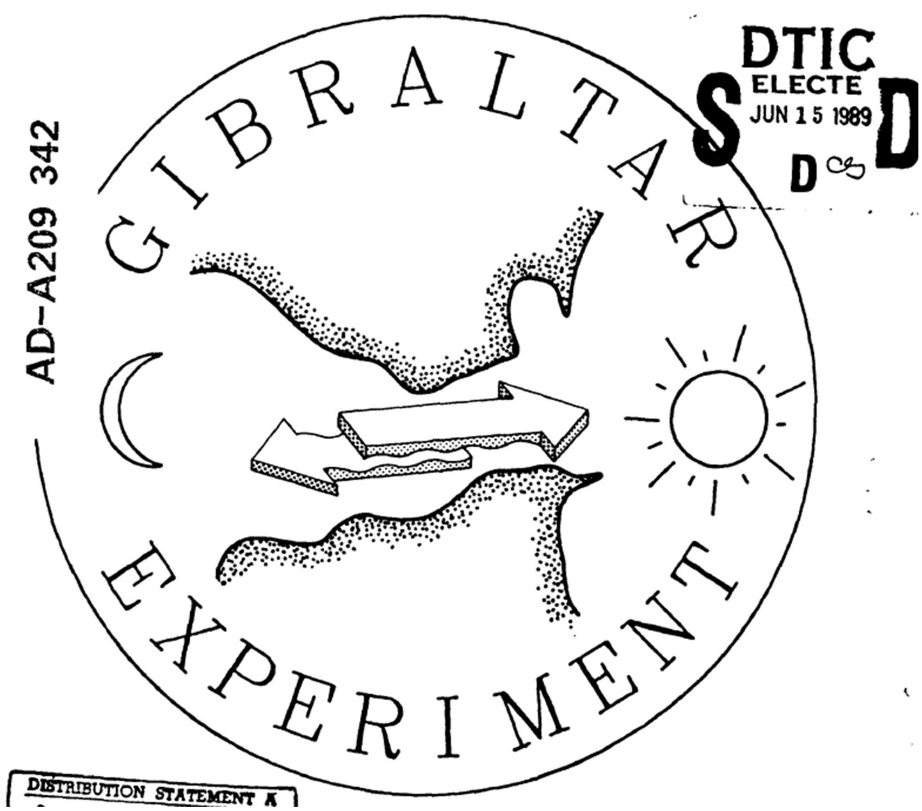

Figure 3.3: Seal of the Gibraltar Experiment

While Oreskes' use of the "operational" effects of the oceanographic program centers on its usefulness for military operations, it also elides military and oceanographic ecologies. While naval concerns did have a significant effect on the kinds of questions that were asked by oceanographers (consistent with Oreskes' line of reasoning), the split between "operational" guiding principles (the "basic task" of military intelligence orienting oceanography toward the thermocline) and the breakthroughs of oceanography (discovery of abyssal circulation and, in the strait, understanding of two-way flow) creates a structural hierarchy in which the operations of oceanography are partially erased. The influence of naval intelligence on oceanographic concerns aside, there are also ideas of the "operational" in oceanographic practice itself that support a growing interest in the thermocline. These ideas are not entirely separable from the line of inquiry followed by Oreskes – oceanography cannot be entirely cleansed of its military history – but they may be informative of where the operational for military interests and for oceanography experience an overlap.[10] An operational sense in oceanography that moved the science toward the study of the thermocline can be identified in the shift away from descriptive

[10] Here, I mean to suggest that military interests and oceanographic interests are divergent practices that converge on the thermocline without equating military and oceanographic structures.

Figure 3.4: Traditional Orbis Terrarum (O-T) Diagram

and toward dynamic oceanography. This history is tied up with both that of military interest in oceanography and oceanography's own movements toward modeling and mathematicization.

Oreskes describes dynamic oceanography as having been founded based on "...an analogy between the atmosphere and the ocean" (Oreskes 2021: 68). Oceanographer Harald Sverdrup had been informed by the work of his mentor, Vilhelm Bjerknes, who demonstrated that air masses move under the effects of differences in pressure (which itself is tied to temperature and to Coriolis forces from the Earth's rotation). Sverdrup understood that the same might be said about oceans, though pressure differences were tied to both temperature and salinity. The Scandinavian "Bergen school" of oceanography developed dynamic oceanography as concerned with the equations for calculating ocean dynamics. These concerns tied oceanography's future to the possibility of density driven circulation, a path that would include a study of the thermocline. Jacob Hamblin (2014) contends that the shift to dynamic oceanography, though, was not agnostic to previous practices in the field. The Bergen school of dynamic oceanography intervened in the more localized practices of descriptive oceanography. Descriptive oceanography, which drew on the data-collection ethos inherent in the -graphy of oceanography, tracked ocean variables in specific locations, monitoring changes in these variables over time. Dynamic oceanography, on the other hand, emphasized the roles of mathematics and predictive modeling, drawing together the available data to forecast ocean dynamics.

Dynamic and descriptive oceanography, according to Hamblin, were not without associations of values for oceanographers. He states, "Dynamic oceanographers were not just advocating mathematics; they were redefining what deserved to be called oceanography" (2014: 354). Climatologists and descriptive oceanographers could be lumped in with the "...old, the halt, and the infirm," while "...the able-bodied men were expected to be forecasters, which was man's work" (ibid: 355). This was because these scientists used probabilistic calculations based on seasonal data rather than plugging data into the latest equations. Dynamic oceanography's embrace of mathematical methods was, in the opinion of historian Eric Mills (2009), the foundation for the models of circulation that would be the domain of oceanographers like Henry Stommel. As dynamic oceanography privileged the work of physical oceanography in determining the interaction of water masses in ocean circulation, it diminished the ecological network described by de Buen. Where de Buen saw biological, chemical, and physical oceanography as making up a science that could accommodate the many phenomena of wide oceans, Bergen-style dynamic oceanography often subordinated fields such as marine biology to physical oceanography (Hamblin 2014: 356). Marine biology could be seen as using the models and results of physical oceanography, which was then positioned as the independent science driving oceanography as a whole.

Thus, the operations behind the study of the thermocline and the mapping of the Strait of Gibraltar were not just the "operational" of military interest – they were also the transforming practices of the field of oceanography. While the transition to dynamic oceanography should, as argued by Oreskes, be seen as having clear ties to the concerns of the military about sound propagation and the thermocline, it was also connected to a changing ecology of oceanographic operations themselves. Descriptive studies were giving way to efforts to understand and predict large-scale ocean dynamics, and the mathematical models of physical oceanography provided that sub-field of oceanography with an ascendant role in the network of biological, physical, and chemical oceanographies. Dynamic oceanography also came paired with a cosmology of ocean-as-atmosphere. The oceans could be understood as driven by density layers and as analogically connected to the layers of the atmosphere. These aspects of dynamic oceanography clarify the founding logics of the Gibraltar Experiment, where density layer exchanges at the Strait of Gibraltar could be seen as having far reaching implications for global and "model" oceans.

Operational Oceanography:

Dynamic oceanography, in its mission to model the dynamics of the global ocean, also demanded the wide scale collection of oceanographic data. One of the early drivers of data collection was the International Geophysical Year, which aligned oceanography's need for data with military and political interest in these data (Hamblin 2014: 360). Oceanography after 1980 witnessed an explosion in methods of sampling, observation and analysis that included the use of satellite and float data. According to Gregorio Parrilla (2001), it wasn't only oceanography that yearned for new data, but also governments, industry, and the general public. The data generated by projects such as WOCE (World Ocean Circulation Experiment) and CLIVAR (Climate Variability and Predictability) contributed to the birth of what is now called "operational oceanography." Parrilla describes operational oceanography as:

"All of that activity which seeks to understand the methods and sampling performed in the oceans, seas and atmosphere, their diffusion and interpretation, all of which is performed routinely, with the goal of: 1. supplying a continuous prediction of the future conditions of the sea with as much advance notice as possible; 2. giving the most precise description, from a perspective of usefulness, of the state of the sea, including living resources; and 3. contributing to large scale climatological data that supply the necessary information to describe past states to formulate time series that show trends and changes" (Parrilla 2001: 171, translation).

While Odón de Buen already realized how useful the operations of oceanography could be for ports and for the fishing industry, his extension of the operational benefits of oceanography to these groups differs from the context of operational oceanography as a discipline. Without a steady supply of data provided by new satellite and float technology, there was little possibility of predicting large scale trends in the ocean. Parrilla points out that this lack of data also informed general assumptions about the nature of the ocean – it was assumed that variables in the ocean were of a steady state. WOCE demonstrated that the ocean was more dynamic and variable than suspected, and the ocean's variability necessitated a kind of monitoring that would span large networks of information. The operations of oceanography changed from the descriptive efforts of de Buen to the dynamic oceanography of projects like the Gibraltar Experiment, and the sea-spanning disciplinary diversification of the former became the predictive power of models that could describe the mean state of the entire world ocean. Parrilla mentions that operational oceanography, above all else, is novel in its provision of a service based on oceanographic data, which requires a readjustment of the ways in which oceanographers apply their scientific understanding.

Like the joint nature of sea and atmosphere in the originary metaphors of dynamic oceanography, operational oceanography aspired to the success of meteorology. Parrilla argues that, for meteorology, variables are fewer, data easier to obtain, and the benefits more obvious. For oceanography, the needs of marine sciences may not be fully articulated. Operational oceanography already provides local data for the velocity and direction of wind, surface currents, tides, and sea surface temperature. For example, oceanographers at the University of Málaga provided high resolution local forecasts for the Port of Algeciras using multiple versions of a program called SAMPA (Sistema Autónomo de Monitorización y Previsión en Algeciras [Autonomous Monitoring and Forecast System in Algeciras]) (Fanjul et al. 2018). This system has been more widely incorporated into a multi-port initiative titled SAMOA (Sistema de Apoyo Meteorológico y Oceanográfico a las Autoridades portuarias). Both Lafuente and another oceanographer at the university, Jose Carlos Sánchez Garrido, described to me the collaborative project between the oceanography department and the port of Algeciras. The forecasts provided by SAMPA are not just the fare of the descriptive efforts that de Buen saw being extended to local industries. Instead, the affordances of dynamic oceanography are built into operational oceanography. High resolution local models are nested within larger, regional models, like the Copernicus Marine Environment Monitoring Service (CMEMS) model for the Iberian region. This nesting of models furthers the atmosphere-ocean connection and operational oceanography's aspirations to emulate meteorology's relation to the needs of the public.

Nested modeling furthers de Buen's image of a science of oceanography that could be as wide as the ocean that it studies, but it is firmly redirected by the predictive ethos of the Bergen school. De Buen's inclusion of multiple disciplinary operations (biology, chemistry, physics, etc.) into oceanography imagined the oceans as phenomena that could only be captured by a multidisciplinary approach. This approach is resonant, too, with the historic increase in methods of observation (satellites, autonomous floats, moorings) to produce more data on the seas. The predictive bent of modeling, however, reshapes not just the amount of possible ways to observe the wide reaches of the oceans, but also the form of data that are collected. In *A Vast Machine,* Paul Edwards (2010: 283), using the history of meteorology and climatology, draws the difference between *making global data* and *making data global*. The former concerns itself with the expansion of new instrumentation to capture a wider array of data about the oceans or atmosphere. The latter, however, concerns the use of predictive models to create a "data image" of the world that is complete, "...even though the observations are not." In other words, the stakes of operational oceanography include both the expansion of coverage and the modeling techniques to allow already collected data to fill in the gaps where data are not entirely present. With operational oceanography's capture of real-time data and its integration of wide scale predictive modeling, it expands de Buen's disciplinary commitment to seeing oceanography "fill" the oceans by including the predictive modeling techniques of dynamic oceanography.

The scope of operational oceanography embeds, too, a political premise. Parrilla states that operational oceanography falls into the category of a "megascience" that requires both planning and decisions at a national and planetary level. In its aspirations for global, real-time monitoring of the oceans, operational oceanography expands both its ecology of interest and its political ecology. With de Buen's vision of oceanographic sciences that could span the seas comes a mandate for international cooperation. The collaborative projects that he saw as essential to the operations of oceanography (the spirit of which is seen in the Gibraltar

Experiment) are also present in the "making global data" that define operational oceanography and that coordinate international and regional ocean/atmosphere models.

Practicing Ecologies and the Operational:

With the notion of operational oceanography in mind, what are the stakes of distinguishing between oceanography's political obligation to the operations of military interests and the operations that define the science's multidisciplinary and sea-spanning praxis? The former idea of operational entails a capture of oceanography's worlding apparatus, where the fundamental questions of oceanographers (e.g. Is there abyssal circulation, and how does it relate to knowledge of the thermocline?) are merely reflections of the driving military interests embedded in science funding (understanding the thermocline and other types of circulation to better understand sound propagation and submarine warfare). Here, the ecology of oceanography is completely redefined – oceanographers describe or predict the oceans, but only insofar as these oceans are the oceans of military interests. On the other hand, oceanography's operations, when examined through the founding tenets of oceanographers like de Buen and the driving questions of projects like the Gibraltar Experiment, expand beyond a capture by military interests, instead including foundational notions of what studying the oceans must mean for oceanographic practice.

I am not interested here, in denying the involvement or influence of military interests in oceanographic practice – it is clear from the Gibraltar Experiment and the Donde Va? project that an understanding of phenomena within the Strait of Gibraltar and in the Alboran Gyre were wrapped up in the military's goal of understanding sound propagation and the influence of the thermocline. I do, however, want to make room for a messy interaction between oceanographic practice and military interests that does not see oceanography's operations limited to the military operational, understood as a state application of oceanographic knowledge. As demonstrated by Oreskes, funding of key institutions such as Woods Hole and the Scripps Institution of Oceanography by naval interests caused many of the questions of oceanographers to become entangled with specific objects of analysis – namely the thermocline. However, the split between scientific analysis of oceanography and military interests supplants the operational as it functions for operational oceanography. This relates both to an ecology of practices (Stengers 2005) between oceanography and the military and to an oceanographic practicing of ocean ecologies.

In her "Introductory Notes on an Ecology of Practices," Isabelle Stengers (2005: 195) argues that, if one is to understand the milieu in which a practice unfolds, the practice should not be viewed in terms of its weakness, but rather its force. She states, "The problem for each practice is how to foster its own force, make present what causes practitioners to think and feel and act. But it is a problem which may also produce an experimental togetherness among practices, a dynamics of pragmatic learning of what works and how." While military interests in the thermocline may produce this togetherness with oceanography, where the questions of oceanography are shaped by the funding of the science, these interests do not override the force of oceanography for its practitioners. Rather than treat the historical relations of military funding and oceanography as only a complex of capture, I suggest, along with Stengers, that they be viewed as intersecting practices in an ecology. However, I want to contextualize this insight by attending to the way in which oceans themselves become part of the ecology of oceanographic practice – where ecology also means the vast reaches of oceans that compel oceanographers to expand their scientific techniques and knowledge. It is clear from the work of Oreskes that part of the ecology of practices faced by oceanography is the question of survival via funding. This may be a motivating relation that forms between military interests and oceanography, but it need not erase the existing operations of oceanography. What then, are some of the intersections between oceanography and military interest that could be seen as resonances rather than captures, and how do they also form the idea of the practitioner of oceanography?

Military interests in the operational of ocean surveillance and operational oceanography intersect in how they imagine the scope of science, but operational oceanography extends into the ethos of international and interdisciplinary collaboration. In the cases of the Gibraltar Experiment and the Donde Va? Project, the strait is instrumental to understanding the role of the thermocline in sound propagation, where understanding on this topic can be widely applied. For operational oceanography, though, the aspiration to an oceans-wide, real-time monitoring system ties into the material ecology studied by oceanographers. They must, as de Buen argues, be able to extend the surface of oceanography as seawater extends across the globe. This ecological relation within oceanography has a history, as demonstrated by the development of dynamic oceanography and the attachment of prestige to Bergen values and to predictive power. It is also a connected ecology that further roots oceanography to other material milieux and to other practices. This is clear in the connection between the aspirations of operational oceanography and those of meteorology, where the physical interface of the sea and atmosphere pour into the general circulation models that promise both a global and local understanding of sea and air conditions. Under operational oceanography and de Buen's vision, the oceanography of oceanographic scientists is also the knowledge contributing to fisheries, ports, and a real-time understanding of a sea's biological resources.

Oceanography as a discipline practices an ocean ecology, extending its analysis into the connections between regional basins and the connections between oceans. The O-T diagram of the Gibraltar Experiment can be read both as emblematic of the object of analysis of the experiment and as forming connections between the strait and the global ocean. The Mediterranean as "model ocean" is not just made up of the variables being studied in the Gibraltar Experiment or the Donde Va? Project, but circulates into understandings of ocean-scale phenomena that may not be easily understood at a large scale and over geological time. In their description of what they call a "more-than-wet ontology," Steinberg and Peters (2019: 295) explain that the materiality of oceans is more than the oceans themselves, saying, "The ocean is not an entity then; it is an *extension*." In applying de Buen's maxim that oceanography must move as the ocean does, oceanographers extend the sea's materiality to include connections between strait and ocean. The sea's extension leaks, too, into their models, where data flows between nested regional and local models to provide operational data to ports and industries.

The extensive capacities of oceans form a part of how oceanographers practice the ecology that confronts them, and this forcing of thought is erased when oceanography is made self-same to its military funding. Instead, oceanography should be seen as both part of an ecology of practices (that intersects at points with military interests) and as attending to the material ecologies of ocean-as-extension. This does not mean that oceanographic practices are not political in and of themselves – even the extension of oceanography's operations to real-time observation and prediction opens questions of the political infrastructures that inform regional and global models and that shape how data are made global. It does mean, however, that oceanography can be seen as both informed by its military history and driven by an obligation to think with the sea's extension as de Buen did.

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4. Synchrony[11]: Water's Dance of Forms

Figure 4.1: Eddy Sculpture by Anastasia Azure

"So imagine shrinking yourself down to the size of a teardrop, and then being dropped into the ocean, and just being swept around by the ocean currents. And imagine the path that you would take." Larry Pratt, an oceanographer at the Woods Hole Oceanographic Institute, describes a tumultuous journey of water in an ocean eddy, captured in the three-dimensional artwork of artist Anastasia Azure at the Boston Museum of Science. The sculpture, part of a 2013 exhibition titled "Synergy: Ocean Stories," is a medley of forms. Nylon string, dip-dyed

[11] "Occurrence or existence at the same time" (Online Etymology Dictionary 2014). What might it mean to think of the movement or timing of bodies of water alongside oceanography and dance? Oceanographers do not only observe the timings of water, but also attune their instruments and practices to water's timing. Dancers may time their own bodies and the bodies of other dancers as they time the movements of water – the same time does not need to produce sameness of body and water.

and variegated, makes up bands and laminar pathways, follows single streams, and ends abruptly where lines are cut. Various colors interpenetrate each other, even in the same bands, and loose bundles of string bunch up and work their way through more regular structures. Even in the loose bundles, there are distinct trajectories and a following of boundary and structure. The weave of this sculpture isn't meant to evoke just any watery pathway, but is instead designed to capture the routes that water might follow in the swirl of an eddy.[12]

While an ocean eddy is a system emerging out of the turbulence of the ocean, Pratt and Azure were careful to isolate the coherent and structured geometric forms of eddies so that metastable parts of them could be captured in this work of sculpture. Pratt described the scientific grounding of the shapes and threads, distinguishing the particular pathways of the sculpture as Lagrangian in nature. Unlike a Eulerian frame of reference, which would consider the temperature and velocity of water passing all around a single, stable point of reference (imagine that you are sitting at a single point and mapping all of the waters that are passing you by), the Lagrangian frame of reference follows single parcels of water, tracking them as they are caught up in the structures of the eddy or as they dip and dive through the eddy before making an offshoot. Azure's artistic interest in the project was built on the concept of the geometric forms and structures that can be isolated in something as turbulent as an eddy, and her collaboration with Pratt highlighted some of the paradoxical relation of order and chaos that is manifest in the world's oceans.

Pratt was careful to underscore the importance of the Lagrangian frame. Viewers of the eddy sculpture could identify several distinct pathways that a parcel of water would follow, whether it were part of a layer of a torus shape, part of a semi-stable pathway, or part of a more

[12] An eddy is formed when currents in the ocean "pinch off" in sections and create circular currents of water (NOAA 2021)

chaotic pathway. Attendees at the exhibition were not only meant to understand that there is turbulence in the ocean or that an eddy is turbulent – they were able to establish an experiential register of turbulence that had a structured substrate. Viewers were drawn to the piece, but there were limits to the fictions or abstractions that could be present in the sculpture. Pratt insisted that certain physical behaviors of an eddy be maintained, and the sculpture was guided by 3D models rendering the ordered chaos of these turbulent phenomena. These models distinguished some of the regular and irregular pathways that water follows as it moves within and through an eddy. Physical realities of the eddies would not be completely sacrificed for the sculpture, but there had to be room for a particular kind of embodied experience of an eddy that could elicit its various internal forms and that could appear in a fixed sculptural format.

While I am curious about the experience elicited for those seeing the eddy sculpture, I am principally interested in the work of artists and scientists to elicit this experience and to link it with experimentation. Natasha Myers and Joe Dumit (2011) argue that scientists themselves become entangled kinesthetically and affectively in the process of experiment, engaging in a form of "haptic creativity" which troubles the separation between the scientist and their instruments/objects. They follow scientists who use visualization technologies in their day-to-day work, pointing out moments where the habits and bodies of scientists are at stake just as much as their data and results. While attendees at the exhibition of Azure's eddy sculpture were able to experience some of the structures that make up an eddy, the sculpture's creation also provides insights into the intersection of scientific and artistic abstraction, where the process of creating a didactic tool for capturing part of the ocean was itself a window into some of the embodied and theoretical assumptions behind oceanography, water, and art. The translation of geometric models to three-dimensional form in the sculpture gives one example of the way in which ocean water becomes a means of thinking through form and relation.

One facet of this sculpture's move to capture oceanic phenomena is its imagination of the movement or experience that might come from being part of something not typically accessed directly by human senses. Eliciting the form of the meddy may be linked to phenomenological experience (i.e. the idea of haptic creativity), but it is not only about phenomenological experience, enlisting also scientific instruments and models.[13] While a diver might be able to find themselves caught up in an eddy or a careful observer might see the small eddies forming in a river around bends and obstacles, many of the eddies that play a large part in ocean circulation are not observed directly by oceanographers. Oceanographers take advantage of technical prostheses like satellites and floats to capture the information about eddies that becomes part of a model. As argued by Jue (2020), those studying the ocean as a particular milieu must be attentive to the conditions of mediation that go on in observation, whether it be via satellites, submersibles, or sonar. Jue troubles the notion that it is enough to stop at the idea that the ocean itself is a medium, asking what the conditions of perception are for our mediation of the ocean. As the ocean "...offers an epistemological check on human knowledge formation" (Jue 2020: 10) via its perturbation of our typical terrestrial sensing, it is essential to find out what form thought might take within water. As bodies of water ourselves (Neimanis 2019), thinking through the mediations of oceanic phenomena is never fully separated from our own watery forms, and attempts to access the experiential register of watery forms in the ocean may alleviate some of alienating aspects of thinking of ocean as primordial other (Helmreich 2009). Following Astrida Neimanis (2019), I resist either the temptation to render the ocean an alien other or the

[13] Which, I will argue in a further chapter, extends phenomenological experience to the "sense" that can be elicited by the technical objects of oceanographers.

temptation to come up with a master viewpoint from which to "know" water. Instead, I seek to map some of the connections between watery and human bodies that emerge out of oceanography and dance.

In this chapter, I follow various experiences of oceanographers working with a particular kind of eddy, the "Meddy," and I examine HoverDive, a collaborative project that joins oceanography and dance. Meddies, or specific types of eddies that form off the coast of Portugal and are made up of Mediterranean water, evoke many of the analytical challenges of ocean observation in that they are submerged, becoming difficult for oceanographers to find and measure via direct observations or satellite surface readings. Likewise, the HoverDive project asked dancers to capture some of the bodily translations of deep oceanic phenomena that are not typically accessible to terrestrial bodies. Like Myers and Dumit, I wish less to point out the difference between oceanographers' work with meddies and dancers' experience of oceanic phenomena, and more to point out the "affinities" between these practices that shed insight on ways of thinking through watery forms. Through both the mediated attempts of oceanographers to capture the nature of a Meddy and the negotiation of watery forms with dance, seawater's forms become ways to think of movement (whether of the body of a practitioner or of an eddy) as foundational to emergent identity. Oceanographers and dancers, however, are separated from direct access to oceanic phenomena like eddies or deep ocean circulation. Their creative activities trouble a typical phenomenological approach, and so my analysis moves more with Tarek Elhaik's (2022) concept of "marine cogitation," in which oceanographers and dancers create as if distant phenomena were present. Though oceanography and dance do not render the existence of human bodies and nonhuman water commensurable, they do offer a means of relation that allows one to both individuate watery forms like meddies and to make watery/displace the subjectivities of those dancers and scientists who join their bodies to oceanic phenomena. I call "aquatic expression" the more-than-phenomenological relation of oceanographers and dancers with oceanic phenomena.[14] Oceanic phenomena like meddies are reframed not just as objects to be understood by oceanographers, but also as distinguishable identities that must be attuned to and elicited by scientists. Similarly, the attunement of scientists and dancers to the watery forms of the deep ocean provides an embodied gateway through which one might understand what oceans and water mean for these practitioners and their concepts.

Uncovering the Meddy:

Sailing off the Bahamas in 1976, Scott McDowell and Thomas Rossby (2000) "knew that they had found something phenomenal when their instruments measured temperature and salinity values much higher than were normally found at this depth." Temperature and salinity values, which are typically used to identify the source of masses of water in the ocean, distinguished a source that could not have been local. The nature of the measured water matched much more closely with that of the Mediterranean, and it was caught up in the swirl of an eddy. McDowell and Rossby posited a Mediterranean origin for the water and designated the structure as a "Meddy" that would have originated just outside of the Strait of Gibraltar and made its way west across the Atlantic. They deployed SOFAR (Sound Fixing and Ranging) floats that would move within the center of the eddy for a ten-day period. They confirmed the existence of this Meddy (McDowell and Rossby 1978), but later found out that it would have to have been five years old

[14] For my concept of aquatic expression, I draw heavily on Whitehead's notion of expression (Whitehead 1968), whereby the 'mood' of the finite conditions the environment. I interpret this as a reframing of an empiricist approach in which oceanographers would gain knowledge only through direct observation and a phenomenological approach in which dancers would gain knowledge based only on bodily attention. Instead, the sensibilities of these practitioners inflect the phenomena that are meant to be observed. Expression 'diffuses' the work of practitioners into notions of the environment in a way that defies the privileging of direct experience of phenomena. The work of dancers and oceanographers expresses the aquatic by bringing the "here" of their techniques to the "there" of the phenomena meant to be observed, collapsing distance.

to have made its way across the Atlantic, and that it would have to have crossed the mid-Atlantic ridge to get to where they detected the eddy in the Bahamas. Though they confirmed that the eddy that they had found did not originate in the Mediterranean, their research launched further surveys which did distinguish submerged Meddies being formed outside of the Strait of Gibraltar.[15]

The formation of Meddies outside of the Strait of Gibraltar is tied to the turbulence present in ocean systems. "When you have water exiting the Strait, it has to turn," explained oceanographer Jesús García-Lafuente of the University of Málaga (Interview). Coriolis forces, large scale forces found within rotating fluid systems like the Earth's bodies of water, tend to push water in the Northern Atmosphere toward the right of whatever its flow trajectory is. Thus much of the water exiting the Strait of Gibraltar turns to the north, following Portugal and moving toward Galicia and the Bay of Biscay. The outflow from the Mediterranean is not always this predictable. During the high tides of full and new moons in the Strait, the velocity of water exiting into the Atlantic has the potential to do something far different than turn smoothly to the North. Instead, the water pulses and achieves a velocity at which flow begins to destabilize. Packets of water are shorn off of the "tongue" of Mediterranean water by turbulence and physical landscape features as it leaves the Strait, spinning off instead to the South and rotating clockwise. These are the vortices that come to be known as Meddies.

Meddies, however, are distinct from a typical eddy in their depth. Unlike the eddies that can be seen swirling along a coast or forming behind rocks in a rapid, Meddies form at the depth of the Mediterranean outflow waters. These waters, which form a "tongue" that flows out of the Strait and over rough sea bottom terrain like the Camarinal Sill and Espartel Sill, lie around a

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[15] McDowell and Rossby (2000) called this the "double irony" of the Meddy, in that they found something anomalous and that the misattribution of this anomaly to the Mediterranean led to the discovery of actual Meddies.

depth of 1000 meters. They snake out from under the Atlantic waters, flowing westward into the intermediate depths of the Atlantic. Meddies form at these subsurface depths and lurk there throughout their existence. The scale of Meddies is vast, pushing the comprehension of eddies that might arise from observing the turbulent swirls in a river from the riverbank. Meddies can be up to 100 kilometers in radius, having a lifespan of 2-3 years (Armi et al. 1988, Filyushkin et al. 2017). While they cover such a wide swath of water, their existence at depths of around 700-1300 meters mean that they are not easily identifiable from the surface.

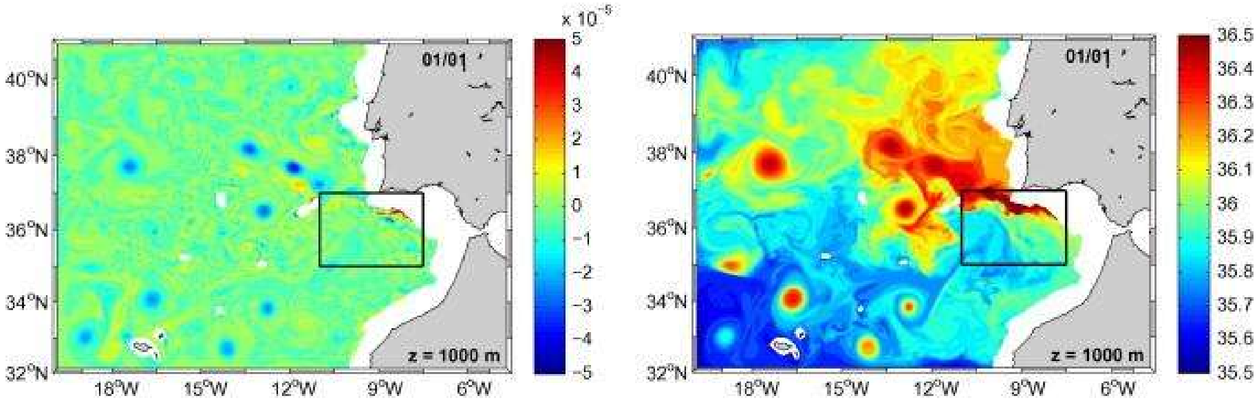

Figure 4.2: Vorticity and Salinity readings showing multiple Meddies (the distinguishable vortices in the figure) (Aguiar et al. 2013)

For oceanographers, this means that finding a Meddy can be far more difficult than locating its typical eddy counterpart. Surface eddies can be identified by satellite networks, which track measures such as sea surface temperature and altitude, catching any anomalous temperature pockets that may be classified as eddies. Finding Meddies, according to Garcia-Lafuente, requires a bit more luck. One must hope that autonomous subsurface floats (like those of the ARGO network, which includes thousands of programmed floats which report to data centers via satellite antennae) can detect the specific regions where temperature and salinity anomalies are present and might constitute a Meddy. ARGO floats often take measurements only at depths past where a Meddy may reside, and it may be up to the oceanographer to set out and plumb the depths with different devices, trawling for the possible signatures of the elusive Meddy.

Oceanographer Amy Bower at the Woods Hole Oceanographic Institute described similar challenges in her expeditions to uncover the source and propagation of Meddies. Her and her colleagues had to find an atypical research vessel, a privately chartered sailing ship, to accommodate the extended period of time that they'd have to be out at sea. While most chartered research vessels can help oceanographers to accomplish their tasks over the span of a few weeks to a month, the tracking of eddies defied this short timeframe. "We decided that the best sampling strategy would be to deploy these floats...sequentially over time. In the end it was a period of eight months...Every week we'd put floats in, we'd put them into the undercurrent, the outflow from the Mediterranean, and we put them in there and they swept downstream, and that's sort of one realization or one picture. But we don't know how often the Meddies form" (Interview). Bower and her colleagues spent eight months deploying floats and sinking measurement devices from their ship to try to locate the formation of Meddies and the frequency with which they were formed. They tested several depths with the floats, and their careful deployment did not eliminate the expedition's struggles to find the Meddies. Several floats took on water and sank below the desired pressure level, rising to the surface to report when they sank below 1400 decibars [unit of pressure] (Bower et al. 1997). Other floats were ballasted to a lower pressure than intended, sinking only to 800 meters instead of 1000, but they happened to encounter the upper boundary of the core waters coming out of the Mediterranean. Finding Meddies was not simply a matter of taking a reading or launching an instrument – oceanographers were faced with the task of sensing the contours of Mediterranean outflow and possible eddy formation via the careful calibration and deployment of their floats. Bower and her colleagues found consistency once they were able to find spots that were both deep enough to launch the floats and were along the strands of water coming out of the Mediterranean. “Water likes to follow isobaths” [horizontal line of water at the same depth], Bower said, so her and her colleagues worked to find the deep-enough areas where Mediterranean water moved about.

Throughout the early history of Meddies and the studies of eddies, they emerge not only as regular oceanic phenomena, but also as wily bodies of water that demand attention and a certain particularization of individual identity. One of the landmark cruises in the understanding of Meddies saw the main watery object of study receive the name “Sharon,” after the person on the cruise who had come closest to guessing the time at which a Meddy would finally reveal itself to instruments (Armi et al. 1989, McDowell and Rossby 2000). Far from being a novelty in the understanding of eddies, this naming practice is resonant with the singular identification of eddies as systems particular in and of themselves. While many ocean phenomena have not been distinguished as such, the irregularity and singularity of eddy properties has led to them being individuated. Earlier descriptions of the motley assortment of different kinds of eddies in the ocean, says Jessica Lehman (2020) resulted with them being described as “beasts in the eddy zoo.” While this idea of an eddy “zoo” lends itself to the collection or naming of different species fitting under the general phenomenon of “eddy,” it is also limiting in its diminution of the individualizing qualities of the eddy. These were not just species to be tagged and collected, but accomplishments in distinguishing particular entities from the general flow of ocean currents. Eddies were set aside in their particularity more so than other oceanic phenomena because of certain qualities that both established their identity and distinguished them from other members of the eddy group.

This individuated quality of these bodies of water also comes from the ways in which their abstraction or particularity links with their core waters. Meddies are distinct from the Atlantic waters around them because of the qualities of the waters that reside in their core. Armi et al. (1988) describe this as "Meddy Core Water," or the water that most closely rotates about the central axis of the Meddy and which has temperature and salinity attributes closest to Mediterranean Intermediate Water exiting the Strait of Gibraltar. The interface between this core water and the Atlantic Water in which the Meddies reside is described as "Meddy Mixed Water," waters that have taken on some of the qualities of the outside Atlantic water and that slowly come to make up the entire Meddy as it decays throughout its lifespan. While Meddies spin through the Atlantic, they maintain a "coherent, vortical structure" which contributes to their being given a "life history" (Armi et al. 1988: 651). Oceanographers like Bower, who must attune their instruments and attention to the depths, are not just tracking constant currents of water, but are instead looking for the signs of lively, persistent, phenomena.[16] They must track at the right depth and align the rhythms of their testing to the potential propagation of the Meddies.

The attunement of oceanographers to the finding of Meddies and the individualization of turbulent phenomena of the many possible eddies points not only to a quirk in the habits of oceanographers in the field, but also to a general picture of the way that one can imagine global ocean circulation. With regard to the water coming out of the Mediterranean in a salty "tongue," Meddies played a key role in explaining the contribution of Mediterranean waters to the Atlantic. Prior to the discovery of Meddies, the measurement of the mean flow of the water coming out of the Mediterranean suggested that not nearly as much transmission of saline waters was

[16] Here, I extend the idea of forms of life to the level of ecologies, where the principles of the individuation of a Meddy depend not on organismic homeostasis, but on vortical homeorhesis, or the idea of an equilibrium flow. This troubles the separation of form and movement by capturing the Meddy as both.

accounted for as was expected (McDowell and Rossby 2000). Meddies and their coherent core waters would explain how salty water from the Mediterranean could transmit throughout the Atlantic, as these vortices ambled throughout the Atlantic up to the mid-Atlantic ridge. With regard to the larger picture of global ocean circulation, Meddies contribute to the prevailing oceanographic sentiment that variability is far more important to circulation than suspected when pictures of the global ocean conveyor belt had first emerged (Lehman 2020).

Bower points out that her attunement to the formation of eddies and Meddies has driven a commitment to transmitting this important aspect of oceanographic understanding. She insists that continuous ocean conveyor belt pictures miss the importance of eddies in determining ocean circulation. The global ocean conveyor belt image "contrasts enormously against eddy pictures that we have. The ocean is really very turbulent" (Interview). Eddies generally and Meddies specifically bring forth a contrasting image at the core of the turbulent picture of oceanography, which is that the identity of these phenomena can emerge out of chaos and turbulence. Identity is not only attributed to mean flows of water or stable bodies of water like oceans or rivers, but is also attached to the lifespan of a Meddy. Attending to stable forms that arise out of turbulence, oceanographers do much of the work that was embedded in the earlier-described translation of three-dimensional computer models to the sculptural depiction of the eddy. Oceanographers discern eddy and Meddy forms that, while more turbulent than a smooth picture of an ocean conveyor belt, also maintain regular vorticity and characteristics throughout their life span. It is at this juncture, where oceanographers plumb the depths of the ocean to capture the unique character of a Meddy, that I want to consider the ideas of form that might emerge from oceanographic thought. What might it entail to take Meddies and eddies seriously as "bodies of water" with an emergent identity, and how does this contribute to the oceanographer's commitment to thinking of global mean circulation through rupture and turbulence?

In his consideration of the forms found in the Amazon forest, Eduardo Kohn (2013) argues that Peircian semiotics can be used to imagine the forest as a constellation of entities that themselves participate in symbolic meaning-making. One of the examples that he uses is that of whirlpools, which "...possess novel properties with respect to the river in which they appear; namely, they come to exhibit a coordinated circular pattern of moving water" (ibid: 166). He posits that a whirlpool, while requiring the continuous flow of a river, is "something other" and "something less" than the flow of the river. Water in a whirlpool is "less free" than the water that flows in the river, but the pattern forming the whirlpool "...accounts for its form" and, Kohn argues, makes the formation of whirlpools an example of "symbolic reference." The whirlpool, while continuous with the form of the river, displays emergent properties that set up a difference with the continuous flow of the river. Meddies, which distinguish themselves from the form of water coming out of the Mediterranean, also display emergent properties that contribute to the oceanographer's sense that there is "something phenomenal" (McDowell and Rossby 2000) or something different about their existence or form. The continuous flow of Mediterranean water out of the Strait of Gibraltar, which forms a salt tongue that branches as it enters the Atlantic, is both the means of identifying the Meddy/its "Core Water" and that form with which the Meddy draws a difference. Pulses of water exiting the Strait and making a turn that encounters turbulence are ripped from the outflow and contribute to a different form of Mediterranean Water.

This semiotic method of thinking of the water's forms may also help in thinking about the identification and singularization of Meddies. As emergent phenomena in the order of symbolic reference, Meddies take on the qualities that would allow them to be part of the "eddy zoo" or allow for their unique lifespans to be named. While the naming of Meddies and the picture of the eddy zoo were also driven largely by the oceanographic novelty of discovering discontinuous forms where before there had been a focus on continuity, the practice still deserves to be connected to oceanographers' way of thinking through watery bodies and their articulations. Meddies are continuous with an overall picture of the spread of Mediterranean water into the Atlantic, but the practical implications of observing them demand that oceanographers be attuned to discontinuities. Meddies as both practically discontinuous and conceptually continuous with Mediterranean Water suggest that for oceanographers, attending to these watery bodies that emerge from turbulence means holding together discontinuity and continuity in a way that is grounded by movement (outflow) rather than substance (stagnancy). In other words, distinguishing a Meddy from the flows that constitute it is done with an attention to moving bodies of water, where the Meddy is not already constituted as a stable object. The conditions for the generation of Meddies are turbulent ones, but this turbulence engenders Meddies as singular phenomena.

While the semiotic register for thinking of the split between Mediterranean outflow and Meddies can be useful for thinking of them as particular symbolic forms, oceanographic understandings of the Meddy exceed Kohn's efforts to bring life to natural phenomena. The particular materiality of a Meddy's formation defies a totalizing, symbolic frame of thought. Kohn argues that "The whirlpool's circular form emerges from the river's water, and this is a phenomenon that cannot be reduced to the contingent histories that give that water its specific characteristics" (Kohn 2013: 166). It is only physical conditions that determine whether a whirlpool will spawn, not the particular river that the water came from or the chemical conditions that it has built as it swept across soil and minerals. For the Meddy, the story is similar and yet more complicated. While the conditions of turbulence and shearing that give rise to the Meddy could pass with any water reaching the same threshold, the Meddy's identity is more closely linked to watery history and characteristics than the whirlpool that Kohn describes. He identifies water moving through the river as a continuous flow, but the Meddy is also important in the difference that it draws between Mediterranean/Atlantic water, not just the difference drawn between continuous Mediterranean water and discontinuous Mediterranean water. Meddies help oceanographers to think of how the qualities (temperature/salinity) of the Mediterranean might be transmitted to the Atlantic, and it is only the Mediterranean qualities of the Meddy and its distinction from Atlantic water that grants it its lifespan, differentiation, and importance. In other words, oceanographic concepts like the "Core Water" of a Meddy make the Meddy's lifespan contingent on its systematic holding-on-to or diffusion of Mediterranean water. The scale of the Mediterranean and Atlantic is such that contingent histories of multiple waters are what drive movement and diffusion, where waters move along layers of similar density and exchange attributes like temperature and salinity.

Meddies exceed Kohn's semiotic distinction between a river and a generalized, emergent whirlpool. Bruno Latour (2014: 6) anticipates the potential shortcomings of applying Peircian semiotics to multiple phenomena in a similar way, comparing Kohn's approach to his own ANT approach. He says, "Any attempt at choosing a homogeneous concept to establish connections among all entities (association for ANT, semiosis for Kohn) has a powerful but short lived effect. Powerful because it allows *not* to make artificial distinctions (human and nonhuman for ANT, language and world for Kohn), but short lived because inevitably the differences that had been recorded slowly fade, turning out to be the *same way* for everything to be different." While

Kohn's use of semiosis and the symbolic register may be generative for thinking about how the form of eddies and Meddies emerges out of the turbulence of the flows exiting the Mediterranean, the limitations of such an approach are a side effect of Kohn's semiosis being dedicated to more than just the semiotic differences being drawn in whirlpools and water. What is a specific example (the whirlpool/water) of a larger framework (semiosis and the capability to think of forests/nonhumans as being part of the symbolic order) is for oceanographers a specific obligation[17] to think through water and ocean. Oceanographers face a different task than Kohn in that they must account for the specific order of watery bodies that make up the possible phenomena in the world ocean. For Meddies, this means that oceanographers distinguish not only the singular quality of a Meddy which has split off of the Mediterranean outflow, but also the distinct kinds of water which make up the Meddy and which separate it from and allow it to contribute to the qualities of Atlantic water.

Rather than start from semiotics and move to the specific case of watery turbulence and form, Michel Serres (2000) uses thinkers including Lucretius and Archimedes to reframe the history of physics as one of hydraulics. Serres finds within ancient descriptions of the behaviors of water a kind of form or identity that is founded on movement and turbulence rather than stability and substance. Using Lucretius' *De rerum natura*, he draws attention to the slight difference between *turba* and *turbo* (ibid: 28). "The first designates a multitude, a large population, confusion and tumult...But the second is a round form in movement like a spinning top, a turning cone or vortical spiral." He compares the distance between these terms with the distance between *turbulence* and vortex in French, finding that "The first is simply disorder and

[17] Here I use "obligation" as deployed by Isabelle Stengers (2010: 50) to speak about experimental fact and the positioning of the scientist as part of a community. She says that facts which are experimental "...have value only if they can be recognized as being able to obligate practitioners to agree about their interpretation." Scientific practitioners are not free to assign meaning, but rather face the obligation of soliciting agreement.

the second is a particular form in movement." In their separation from and emergence out of the turbulent forces acting on Mediterranean water as it moves into the Atlantic, Meddies become distinct in form, taking on qualities that identify them as both a certain class of phenomena (vortices, eddy-like in nature) and as particular (submerged, nameable, of a particular rotation and lifespan). Serres' considerations of how the hydraulics of Lucretius and Archimedes might reorient the nature of physics find more resonance with the obligations of oceanographers who study Meddies than do Kohn's considerations, if only because the physical movement of water is the foundation of the Serres' order (rather than just an example of a more general semiotics).

What then, is the importance for oceanographers of thinking of how watery forms like a Meddy emerge from turbulence? Jessica Lehman (2020) asserts that, for the field of oceanography, the picture of global circulation after the early 1990s has shifted from one based on continuity and flow to one based on turbulence and phenomena like eddies. This is consistent with the lesson that Bower has wished to impart in any of her community-engaged talks, which is that a global conveyor belt picture can only tell us so much about the physical reality of global circulation. If the global conveyor belt picture can be thought of as relatively uninterrupted and smooth flow-form(s), the eddy picture of global circulation is determined by vortex-forms like eddies or Meddies that are constantly mixing and distributing waters throughout the world's oceans. Jake Gebbie of the Woods Hole Oceanographic Institute suggests that the global conveyor belt picture allows us to imagine that we might drop a bit of water into one part of the conveyor and watch as it makes its way around the globe (Interview). Under this assumption, the same parcel of water that we had deposited in one place would be unaltered, except that it had risen and sunk with temperature/density/salinity changes and that it had made its way through several different oceans. Turbulence-based circulation, however, suggests that a parcel of water would not be identifiable as the same at the end of its journey, even if it were tracked in full circulation. A parcel of water is mixed intensely within processes like eddies, and even anomalous signals (like a particularly salty or warm outflow) are dampened by the mixing of the ocean's turbulent processes. Thus, even the most distinct of water parcels (that might, in their temperature or salinity, document a weather event) are submerged in the turbulent processes of global circulation, their differences muted by mixing.

Thus the figure of the Meddy is not only as a phenomenon that is being measured as it exits the Mediterranean, but is also part of a turbulence-based image within oceanography of the nature of circulation. It is because of this centrality of eddies and Meddies to the oceanographic image of circulation that I want to imagine the nature of their forms. Oceanographers may be taking readings of Meddies via their instruments to analyze variables including temperature and salinity, but they are also drawing a difference between flows and Meddies. This process of distinction outlines the watery body of a Meddy, and the qualities of such a body (as carrying signals of the Mediterranean, as not-Atlantic, as becoming-Atlantic, as having a lifespan, as making possible a name) take on importance for oceanographers in thinking of both the Mediterranean-Atlantic interface and the way that waters across the global ocean are linked. By looking at the ideas of Meddies as they have developed since the Meddy's first detection, I want to show how oceanographers attend to watery bodies and how the distinction of these watery forms is one set against a foundation of movement and turbulence. Meddies, with the additional quality of being submerged and demanding a specific kind of detection, make manifest the techniques of attention that oceanographers must bring to relate with their oceanic objects of study. It is also worth asking, though, how the making-manifest of watery bodies via specific techniques of attention is complicated by the explicit inclusion of one's own (watery) body.

HoverDive:

Figure 4.3: Frame from HoverDive performance (Okeanos Collective 2014)

The two dancers turn in unison, standing diagonal from each other as their turns inch them back and forth on the stage. Their arms cast a sweeping arc above their heads before their forms double over, the arc of their arms now compressed to a tracing of the stage below them. A third dancer, bowing to the same pressure as their body bends, splits the original two as they cross the stage. Though they sink low with the others, their path is marked by a clear trajectory, devoid of the gentle drift of the original pair. Their slow turns contrast with the synchronized turns of the pair, and the new dancer marks the end of the stage and end of their cross with a single leap, exiting the stage thereafter. Another dancer, caught in the same crosswise journey through the synchronized pair, is quickly drawn into the hypnotizing gyre of the pair. The fourth dancer's quick turns adjust to match the rhythm of the pair, with arms once again arcing above before being cast low by an unseen force. Now a trio of dancers, the group turns together back and forth across the stage. Each of them wears a loose, lightly colored garment splashed by discoloration. They sway to a mix of orchestration and hydrophone recordings.

These dancers take part in a multimedia dance work titled “HoverDive” (Okeanos Collective 2014). Inspired by the work of oceanographer Larry Pratt on wave dynamics, turbulence, and ocean science, their bodies evoke the signals, turbulence, and watery movement of the ocean. Their stained garments call forth the process of ocean acidification, as the presentation is designed to call attention to the threats of climate change and sea level rise. HoverDive’s dancers bring forth images of both chaos and structure, as dancers shoot through the established, synchronized structures of the dance or are enveloped in their regularity. The composer for the performance, Amber Vistein, “reimagined the ocean as a site of complex interaction and highly codified systems of communication similar to a royal court” (ibid). Dancers, in articulating the eddy forms and current forms of deep water, thus bring bodily interaction and synchronization/communication to an imagination of how water flows and how it breaks with itself. Though Pratt provided the oceanographic material and recordings to allow the performance to evoke aspects of the ocean and its movements, he did not desire that the performance be totally determined by oceanographic thought as a scientist would carry it out. At stake in this performance were not just the bodies of water that are the subjects of oceanographic understanding, but the embodiments of watery dynamics that could translate the movement of oceans into such complex rhythms as that of courtly movement. Like the depiction of the eddy sculpted by Azure, the HoverDive dance maintains an embodied, affective register that carries traces of oceanographic science as joined to human bodies. There is a distinct shift in the notion of obligation to watery bodies held by oceanographers, as the movements of HoverDive now must oblige the sensibilities of choreography and fleshy movements. Seawater, however, offers a link between oceanographic and dance practices in their distinction of particular watery forms (whether sensed by instruments or articulated in dance).

Recently, Pratt has continued this extension of oceanographic science into choreographed performance via a collaboration with Boston Dance Theater. He says that they "discuss various aspects of ocean physics using embodied movement" (Interview). He mentions that, for example, "...we took the students on an embodied journey from the ocean surface, in and out of eddies, down into the abyssal circulation, around the globe, and finally into the deep Northern Pacific Ocean." This journey, which he says can take more than 1000 years, sees dancers carried by abyssal circulation, caught up in deep internal waves, and thrust into turbulence and great pressure. One important aspect of this journey is that it is performed before students are shown any diagrams or maps of the circulation in which they are meant to be participating. Their dancing is a translation of the descriptions of ocean circulation, without any of the guiding images like a conveyor belt. In other words, there is an emergent experience of seawater that is tied to intuitive ideas of water without being determined by a firm oceanographic image of what water should do.

While these students do not have the same scientific obligations as oceanographers, their embodied imagination of the currents and chaos of the ocean creates a new register for imagining theater. Dancing-as-ocean or thinking of the ocean-as-dancing become ways of thinking that are enacted through acts of synchronization, rupture, and movement that appear on the stage. The experience, however, is not limited to those outside of the field of oceanography. Pratt says that he performs some of the same exercises with physics students, who may develop "...a different sort of intuition and also a new kind of memory" from the performances. Physics students who participate develop a more varied relation with what might become their object of studies, adding a density of connection to the ocean that does not allow embodied experience to be subsumed within a detached view of scientific objectivity, but that embraces the materiality of water. While it is clear that the obligations of physics students and dancers are quite different when it comes to performing the ocean, both of their endeavors subvert notions of mastery or total enlightenment when it comes to understanding different aquatic milieux. Dancers are not expected to "capture" the reality of the ocean in their dance and through their bodies, and the prior institutional knowledge of the physics students does not give them some edge in finally mastering oceans as objects of knowledge. Instead, both see a multiplication of the possibilities of relating with aquatic environments, and the differing obligations of dancers and physics students inflect the ways in which embodied knowledge of ocean-as-dancing intervene in their current ways of knowing or understanding.

Astrida Neimanis (2019: 22) calls for a rethinking of water and relation to water as "never 'just' metaphoric." She points to a notion of fluidity in poststructuralist and anti-atomistic thinking that emphasize the continuities of water's flow and the possibilities for thinking of connection in a similar way to the flow of water. Neimanis wants to move beyond water's capacity for continuity by attending to water's other capabilities (mixing, turbulence, state) and by focusing on "actual waters" and the waters that actually exist in our watery bodies. Neimanis makes this move as part of a call for a posthuman, feminist phenomenology that can provide "...the theoretical scaffold for articulating what it means to be a body of water – to be always only precariously contained in a skin sac, and instead profoundly distributed, inherited, gestational, differentiated" (ibid: 40-41). She joins Elizabeth Grosz in imagining thinking and the concepts that we make as always embodied acts, and she asks how our positioning as watery bodies. Much of this positioning, Neimanis contends, is in excess of the humanist conception of the body or the I (“a bounded materiality that houses an individual subject”) and distributed throughout the bodies of water in the world that constitute our own (and all of their chemistry and contamination). Neimanis sees phenomenology as a way of approaching the connection of watery bodies that is principally sensory rather than abstract[18].

For the dancers and physics students involved in HoverDive and in the bodily evocation of movement in the deep ocean, a posthumanist phenomenology such as Neimanis’ draws connections between human bodies and watery bodies that are more than mechanistic and decidedly experiential for those involved. Dancers do not literally become the parcels of water in different parts of the ocean that might be caught up in specific turbulences and flows, but are instead capable of being affected by some of these turbulences and flows in a way that is necessarily linked to their positionality. The “different sort of intuition and...new kind of memory” that Pratt sees as being possible for physics students who participate in oceanic dancing distinguish the pedagogical capabilities of dance as separate from the descriptions and mechanics that students would traditionally learn throughout their physics/oceanography curriculum. The positionality of dancing as bodies of water disallows the bifurcation between water as either something “out there” with physical properties or something “in here” with subjective qualities. The potential for mastery of being-as-water is displaced by human otherness from the actual depths of the ocean and by the necessity for those dancing to be “caught” or “captured” by the movements of water. This is especially noticeable in portions of the HoverDive performance where dancers weave through groups or become caught up in the

[18] In the sense of monolithic scientific abstraction, not of the generalized, daily process of abstraction taken up by all. This is to say that “abstraction” as a process is not only scientific abstraction, but also everyday movements between concrete and abstract.

rotations and rhythms of these groups. Those who quickly pass through the groups and have their own speed and rotation are not simply agentive, but are affected by the turbulence that tears at water's continuity. Those dancers that become caught up in regular rotation, as in an eddy, are both themselves as dancers trained in a choreography and as-water in manifesting the tendencies of circulation.

Myers and Dumit (2011: 246) cite Deleuze's (1988) interpretation of Spinoza ("we still don't know what a body can do") to clarify that embodiment of knowledge is hardly self-evident or mastered. Just as they follow scientists in the midst of using embodied visualizations to acquire the knowledge and practices of their discipline, I highlight HoverDive and other deep ocean dance practices as being "in the midst" of the making of subjects and objects. The objective of dancers is not to capture the behavior of water as such, once and for all, but to imagine and to be affected by the physics and chemistry of bodies of water. Additionally, dancers who work collectively to embody ocean water's potential do not precipitate a kind of being-as-water that is the same for all who are part of the performance. Neimanis, in detailing differential exposure to contaminated water and the different chemistry and experience of bodily waters like breast milk, cautions that the hydrocommons is not a place for the erasure of differences (2019: 143). She states, "In acknowledging our commonality, we risk succumbing to the idea that our embodied debts are fully knowable. Surely, if we are all bodies of water then your water is also, somehow, mine." Similarly, Neimanis is careful in treading the distance between her "ontological assertion" that water connects us and the "epistemological limit" of knowing water and knowing watery connections, warning that being a body of water is not about narrowing this gap until we master knowledge of water and its connections (ibid).

HoverDive and dance performances of deep ocean circulation, while not enabling some kind of mastery of knowing embodied water, also have the restorative quality of allowing one to wonder how distant and typically unembodied processes can be felt or can allow our watery bodies to be affected. Unlike notions of the deep ocean which Helmreich (2009) characterizes as alien and other, dances which evoke the movement of the world's oceans change the requirements to engage with the deep. The depths at which Meddies are formed or at which internal waves move along the sea floor are beyond the terrestrial toolkits of humans, both in the sense that they are outside of the photic zone and in the sense that they represent areas of immense pressure. However, this does not mean that the bodies of dancers are too separate or too unaffected by direct contact with the deep ocean or with eddies to develop any meaningful knowledge of water or watery bodies. Azure's eddy sculpture, while not physically located in the ocean or made up of the same chemistry of the ocean's waters, was contingent upon the preservation of certain tendencies or habit's of water's form. To be a joint venture between oceanography and art, the sculpture was constrained by the balance of chaos and order that could be found in eddy models, even when the concrete expression of these models was enacted via woven nylon. Dancers, too, preserve some of the formal qualities of water in eddies or in the deep ocean as they evoke phenomena like turbulence, continuity, and ocean acidification. Though the concrete expression of these phenomena is carried out in a way that is clearly by positioned/specific bodies and not submerged in the physical medium of the ocean, there are parallels between watery and bodily forms that force physical realities and bodily movement to be held in tension.

Theodor Schwenk (1976), in his exploration of the forms that water takes in oceans/rivers and in the bodies, draws a direct, metonymic link between these systems. He states, "Together earth, plant world and atmosphere form a *single* great organism, in which water streams like living blood. What is here spread out over a large space, animal and man have within themselves" (ibid: 14). This description trades in vitalisms not only at the level of water-as-human, but also for watery systems outside of the human. Schwenk clarifies, "When we study...we get a picture of water everywhere vitally active, combining and uniting in creative continuity as it carries out its varied tasks. Not only is it 'body,' subject to gravity; it is also an *active* element and the foundation of life" (ibid: 15). Rather than take this metonymic relation between watery bodies and human bodies as water at face value, I want to focus on the formal resonance between oceanic phenomena and dances that evoke them. That is to say, Schwenk's language is permeated with organismic thinking that is contrary to the analytic distance between oceans and bodies, but can be shifted to talk about forms of life without needing to have the same kinds of vital energy in oceans and in bodies.[19]

For example, Schwenk argues that, for water, "'*The resting state originates in movement*'" (ibid: 58). This means that the forms distinguishable in water (of eddies, the wake of a moving object, of waves) do not exist but for the movement and turbulence of water. Eddies and Meddies achieve a certain stability which originates in the relations of movement of different layers or temperatures/densities of water. The HoverDive performance inhabits this formal quality of water, as even dancers who are stationary in one plane (not moving back and forth across the stage) are in motion in another (folding or stretching vertically in place). Regular and sporadic movement are both present, as identifiable patterns emerge and are interrupted or broken apart by other dancers. While single dancers may stand in for entire flows of water,

[19] Here, I mean to stay closer to Helmreich (2009) and Myers and Dumit (2011) when they talk of aquatic or experimental forms of life. That is, I want to draw parallels between processes and forms that avoid organismic/vitalistic qualities that would make oceans and bodies the same. I focus less on "life forms" and more on forms of life.

crashing through the patterns established by others, regularity of form such as that in an eddy is seen in the coordination and synchronization of multiple bodies. The bodies of dancers are expressly not bodies in the same way as oceanic bodies of water, but they utilize the affordances of water's form, and this is how the choreography seems to have a "watery" quality or to be evocative of water.

HoverDive and other choreographed performances of the ocean's movements inquire not only into how we might experience phenomena that are typically beyond our reach, but also how we might think of forms/bodies of water through our own bodies of water. Doing so means restoring the formal resonance between ocean and body (such as identity in movement) while maintaining the care and attention that disallow a total sameness to be drawn between their ontologies. Here, dance offers a way to move bodies through water and the capability to build an alternative intuition to oceanography's or physics' understanding of water. Yet, the accounts of oceanographers studying Meddies are not only instrumental – oceanographers also attune themselves to distinguishing watery forms, gauging their practices to make manifest the boundaries and core of a Meddy phenomenon.

Aquatic Expression:

In accounting for oceanographers' practices of distinguishing Meddies and dancers' evocation of deep ocean forms, I seek to draw a connection that is neither wholly instrumental nor wholly phenomenological. I call these practitioners' attention to and production of seawatery forms "aquatic expressions." Drawing on Whitehead's notion of expression, I call these practices expressive both because of their appeal to the finite occasion (the "there it is" of the oceanographer identifying the Meddy and the affective experience of the dancer synchronizing with others in a courtly dance of water) and because of their extension into general environmental phenomena regarding seawater. The oceanographer does not just instrumentally monitor the Meddy – they attune their practice to its turbulent, mobile nature and ascribe these qualities to the way that water may be turbulent on a global scale. The dancer from HoverDive may tap into the phenomenological register of bodily expressing the movement of water, but this act begins to attach qualities to the water that they are meant to enact – seawater becomes a courtly dance in which turbulence or flow is both "out there" and in the synchronization of bodies. This kind of expression is necessarily aquatic, as it must tune into the capacities of water as its conditions of possibility (that its qualities are iterated through movement). My notion of aquatic expression maintains a family resemblance to Tarek Elhaik's (2022) Averroan concept of "marine cogitation," in which experimental oceanic practitioners cogitate by rendering present all of the images of the possibilities of that which they are considering. For both Elhaik and I, those involved in oceanic practices are doing more than making the oceanic a result of instrumental readings and less than joining practitioners to an aquatic "sublime." Instead, "the cogitative soul at work in oceanic practices relies on fiction and fabulation, rather than restoration" (ibid: 109). Similarly, aquatic expression describes how oceanographers and dancers might extend certain images of their object of study (Meddies or deep circulation) as if those images told a larger story about bodies of water – that they are multiple (in the Meddy as Atlantic/Mediterranean) or that they are ordered in their turbulence (in the courtly dance of circulation).

For Meddies and for HoverDive, it is not enough to wonder "...what a body can do" (Deleuze 1988) in the manner of Spinoza, and both oceanographers and dancers instead ask "What can a body of water do?" The idea of a "body of water" as it is imagined in this chapter is one that marks a tension between the oceanographer's identification of singular tendencies within oceanic phenomena and the dancer or physics student's capability to align with the formal qualities of ocean water. A body of water holds formal properties characterized by an origination of identity in movement – both the evocation of eddies in dance and the making of Meddy Core Water in separation of Atlantic and Mediterranean flow. While Myers and Dumit (2011) characterize "mid-embodiments" (249) as processes that scientists participate in as they come to distinguish their experimental praxis and scientific data and which defy easy notions of objectivity, the notion of "aquatic expression" explored in this chapter is bivalent and multidisciplinary. In one sense of bodies of water, oceanographers use naming conventions and the distinction between different types and flows of water to identify Meddies. These Meddies demand a particular kind of remote sensing and align with a turbulent picture of circulation in the world's oceans. In another sense of bodies of water, dancers draw the metonymic link between oceanic and human bodies, testing the resonances between them and developing notions of water which are learned through choreographed movement. While these are different kinds of situated knowledges of water and ocean, I argue that they both engage in experimentation with water's formal qualities.

In his call for a more "terrestrial" engagement with the Earth and its phenomena, Bruno Latour (2018) draws a distinction between "nature-as-universe" and "nature as process." The former imagines nature in a view from nowhere, where nature is encompassing, apolitical, and indifferent. The latter introduces politics into nature and imagines Earth as singular and mobilizing. Latour associates nature-as-process with a viewpoint that he terms "Lovelockian" (ibid: 71), in that Lovelock "*...stopped denying* that living beings were active participants in biochemical and geochemical phenomena." A viewpoint in which living beings are active participants is one that is "terrestrial," in the sense that it is grounded in the Earth's processes rather than viewing the phenomena on Earth as like any other planet and as including politics only as an addition.

Latour focuses in on the sciences which examine the "*Critical Zone(s)*" (ibid: 73), or "a miniscule zone a few kilometers thick between the atmosphere and bedrock. A biofilm, a varnish, a skin, a few infinitely folded layers." While it is clear that his call for a grounded, "terrestrial" mode of thinking and the critical zones include the world's oceans (where terrestrial seems to be more associated with Earth than land), the distinction of a "terrestrial" point of view is potentially at odds with the conceptual work that oceanographers and dancers do to imagine water's form as flows, eddies, and turbulence. Latour importantly reverses the bifurcation of nature that occurs when nature-as-universe is allowed to exist outside of the embodied, involved politics of living agents, but, as Cecilia Chen (2013: 275) argues, water transforms notions of events and place that are typically terrestrial. She states that "Thinking with watery places asks us to recognize places as always permeable and permeated with water..." (ibid). The idea of critical zones and of a terrestrial grounding may miss out on the relational capacities of the watery and oceanic that are present in both Meddies and HoverDive.

I have argued that while the investigation of Meddies and the HoverDive performance are characterized by different disciplinary obligations, both are involved in the imagination of water's forms. Meddies and the bodies of dancers are very different bodies of water, yet experimentation with both contributes to the notion that water's forms are movement-based and that the subjectivation of bodies in an aquatic context (whether they be named bodies or twirling dancers) is turbulent and multivalent in its articulation.

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5. Synesthesia[20]: Surfacing the Depths – Following Floats

Introduction:

Sometimes, when I truly pay attention to the sea, its surface extends and multiplies. The waters crashing and sloshing against the bridge leading to the Castillo de San Sebastian in Cádiz proliferate in their activity. Foamy waters, white and glacial green, strike the stone sides of the bridge, where the conversations of fishers tail off into the strong breeze. Their sound is a hum of white noise punctuated by changes in frequency, as if coasting through radio stations. The hum is often broken by claps as they make landfall. Every few impacts, some of the foamy water breaks the plane of the path, skating along in rivulets of the broken surface and deepening the habits of water in stone. This water pools in the cracks, clear and tinted by the deep brown and beige of the bridge. On a particularly strong strike, the waters become a misty spray, lightly coating and cooling my skin on the humid day. Still other waters undulate alongside the bridge, perturbed by the activity of wave fronts but ensconced in havens askew of their forces. Unlike the quickly moving surf, these waters are deep brown and blue. Their foam is spread across the surface in webbed networks of bubbles and froth that connect and disconnect as they are jostled by the waves. Their sound is a burbling that only becomes apparent with focus, becoming a texture or fabric of sound on which the more apparent movements are overlaid.

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[20] "'sensation in one part of the body produced by stimulus in another'...from Greek *syn-* 'together'...+ *aesthēsis* 'feeling'..." (Online Etymology Dictionary). Synesthesia disrupts the notion of what is sensible in its reorganization of the topology of sensation. In the most cited instances, numbers or musical notes come with a perception of color. Synesthesia, in attaching qualities or sensations to new nodes, stretches the points forming the topology of sensation, perhaps allowing sight to inhere in sound and surfacing intensities like color that were formerly omitted or elided. Synesthesia is also hard to pin down, existing more in reference to a normative topology, such that its reorganization calls attention to what makes a topology of sense normative (should numbers or notes bring colors with them?). Synesthesia reorients habits of sense, bringing contingency to what is sensible. Sense may also be productive of place, as Cecilia Chen (2013: 289-290) argues for watery places that emerge out of what Brian Massumi calls a '*synesthetic* system of cross-referencing' wherein spatial and proprioceptive dimensions are laid bare by place-making.

All of these water forms become my experience of the surface of the sea on a bridge extending into the Bay of Cádiz. Though some of them, like the insistent breaks of seawater against stone, break up the time of water's course against the bridge, distinguishing waves from each other and setting a swirling beat on stone, the other forms persist or inhere in the noticeable moments, forming a bubbling baseline. For me, the sea becomes sensible as a "surfacing" that includes multiple water forms that proliferate with careful attention. Nor are water forms the only participants in this surfacing – winds buffet the waves and howl between the sides of the bridge, and all manner of silt and particulate wells up at the side of the bridge and leaches from its mortar. Whereas my typical notion of surface is a non-extensive flat sheet that makes up the top part of the sea, the surfacing that comes from attention to the sea extends as a topos to include the limit potential of air, depths, and stone. This means that, in my sensible moment of noticing, distance collapses between sea as waves, sea as spray, sea as rivulets-in-stone, sea as foam, and sea as frothing webs. All of these seawaters form what is sensible for me as the surface of the ocean near the Castillo de San Sebastian.

These seawater forms and others that might have emerged with continued attention to the sea could also form a lay or experiential understanding of the seawater properties that gain importance for oceanography. From the waves that crashed against the bridge I could read tides, and an extended stay (such as that of the fishers) could likely mark the moments of day when tides lapped frustratedly against the base of the bridge or when they threatened the footfalls of passers-by. The colors of the sea in different places on the extensive surface could tell me something of the seawaters' turbidity, or the amount of particulate matter suspended in them. I could see the pressure of winds on the water, forming ripples and altering the course of spray. I could perhaps even notice some of the surface tension distributed across the surface of the sea, broken by the punctuation of waves but maintaining its sticky grips on the webs of foam in the less perturbed depths. These webs pulled and stretched, but were more often than not restored in their undulating movement.

While these impressions "surface" the sea for me and lend themselves to possible inquiries into oceanographic variables, they are limited in descriptive capacity when addressing the movements of the deep sea. My phenomenological approach, though able to pick up on many of the qualities of sensible water at the surface, did not exceed the observations that I could make for another, perhaps terrestrial, landscape. Melody Jue (2020: 3) describes the disconnect between the capacity to sense from land and to perceive the depth, stating "By offering entirely different conditions than land – increased pressure, three-dimensional movement, light refraction and magnification, and the inability to tell the direction of sounds, to name a few – the ocean is a material and imaginative space for the conditions of perception that we have taken for granted." While I could gain a phenomenological understanding of these depths were I to follow Jue's practice of diving, I would still only just breach into the conditions that inform the variables of oceanographers (and likely not even a hint were I attempting depths inhospitable to divers). Jue's analysis strikes at the gap between our terrestrial phenomenology and a potential aquatic phenomenology, but this paper is drawn more toward the practices of oceanography. Rather than maintain a phenomenological approach, oceanographers supplement their knowledge with a milieu-specific analysis. By milieu-specific analysis, I mean an analysis suited to the depth, circulation, and turbulence of seawater. Limited by human sensory capacities, oceanographers deploy sensing apparatuses that include "drifters," or floats that follow along with deep seawater and report on key variables. That these mechanical apparatuses are so essential to crossing between the phenomenological and the milieu-specific, I argue, makes them important points at which to understand the knowledge-making practices of oceanography.[21]

In this chapter, I follow the evolution of various oceanographic floats that could be termed "Lagrangian drifters," or floats that aim to follow a particular parcel of water in order to report on such things as the temperature, density, or average current along the parcel's path. I argue that, in their construction as Lagrangian drifters, these floats not only sense the depths of the ocean, but are designed to make sensible certain aspects of the deep sea. I extend what Jue calls a *milieu-specific analysis* to include the sensory and proprioceptive apparatus of floats, tuning into what Stefan Helmreich (2019) calls the "operational impressions" of oceanographic devices. I contend that, while Lagrangian drifters are operating at depth, they "surface" certain parts of the deep ocean, attuning themselves to topographies of pressure and density (isobars and isopycnals) to make sensible the variables that most interest oceanographers. By following a select series of Lagrangian float designs, I examine the junctures of float and depths, float and surface, float-as-water, and floats-as-ocean(s) that are maintained and tempered by the designs of oceanographers.

Lagrangian Method and the Swallow Float

A Lagrangian approach, which follows a particle or parcel of water in its course, enables oceanographers to track how fluids might carry things such as salt, nutrients, heat, or particulate matter throughout the ocean (Van Sebille et al. 2018). For example, an oceanographer on board a ship might suspend a current meter from the ship, detecting the current reading of water at a desired depth. They would find difficulty, however, in measuring the average current across a

[21] My focus on the technological as constituting a shift from what counts as phenomenological and what counts as milieu-specific oceanographic analysis is indebted to Gilbert Simondon, who emphasized the poverty of understanding of technical objects and their roles.

region, as they would not be able to stick to a particle of water from their shipboard observation post (though they might draw estimates with repeated observation across multiple stations). To reach a direct measurement of current at depth, it would be necessary to create a situated observer that could be as a parcel or particle of water, moving along the same paths and shifts as seawater. To this end, British oceanographer John Swallow designed a "neutral-buoyancy" float that could reach a desired depth and follow the seawater there (Swallow 1955, Rossby et al. 1985). This float, appropriately named the Swallow float, moved toward becoming a particle of water in its design.

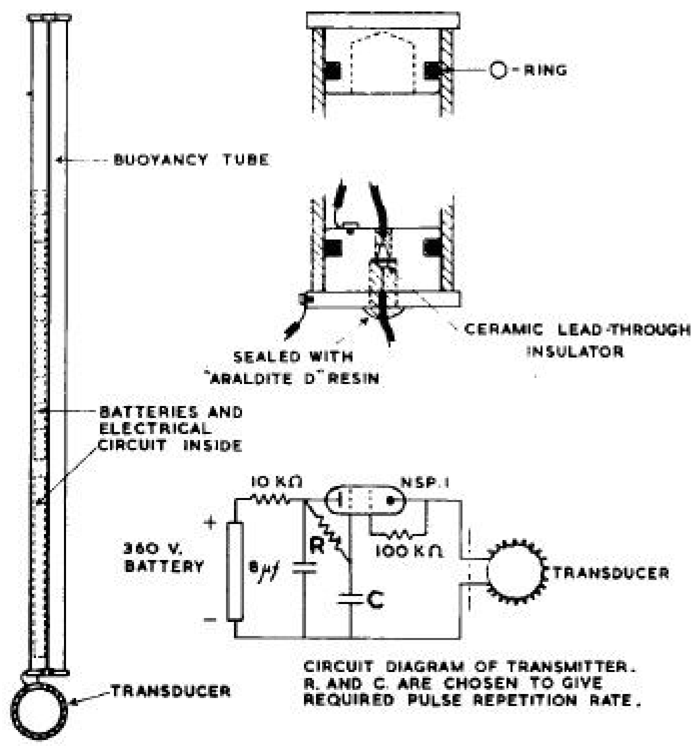

Figure 5.1: Early Swallow Float - The housing is shown on the left and components on the right. Notice the simplicity of the form of the device.

While the compressibility of many fluids, including water, is often treated as virtually zero – these fluids will be displaced rather than compressed – seawater has a nonzero compressibility that oceanographers take into account when talking about different density layers in the ocean. Water that is denser than its surroundings will tend to sink, whereas water that is less dense than its surroundings will be comparatively more buoyant and will rise to a layer of its own density. Oceanographers designing a float that could follow a particle of water would have to keep this relation in mind, designing a device that could sink to a certain depth but that would not sink past that depth. The Swallow float takes advantage of this relation, being designed as less compressible than seawater. Swallow explains, "...if its excess weight at the surface is small, it may at some depth gain enough [buoyancy] to become neutrally buoyant, when no further sinking will occur" (Swallow 1955: 74). In the Swallow float's design (Figure 5.1), the outside tube is pluri-functional, both containing the sensing and power equipment inside and also tuning to the compressibility of the surrounding seawater. The float's aluminum alloy scaffold tubing has a rigidity that, at a certain depth, will allow it to resist the pressure that would compress seawater, instead being displaced upwards by its buoyancy. "The density can be altered to any desired value by adding or subtracting weights, in proportion to the total weight of the float" (ibid: 75). Weights are added internally such that the volume of the float is not changed. Upon viewing the diagram of the Swallow float, I was at once struck by its simplicity – I wondered how such a simple tube might achieve the design of following water.

Rather than acting only as a device that resists the whims of the deep ocean, the Swallow float carries along the surface of its aluminum container the conditions that allow it to become a particle of water.[22] The alterability of its weights allow oceanographers to tune the float for a specific density of water, allowing for a particular surface or particle of water to emerge which is not just the undifferentiated depths of the sea. In reckoning the surface of the float and the

[22] In the technical thinking of Gilbert Simondon, this could be described of as a process of individuation of the float whereby its external milieu is integrated into its functioning (Simondon 2017, de Boever et al. 2012). The process of individuation proceeds as the float's potential to relate to its external milieu in certain ways (in this case, matching the pressure of water with the float's housing) comes into being.

objectives of Lagrangian method, oceanographers not only measure the depths of the sea – they condition them in favor of the particles and paths that might be useful for determining oceanographic variables. In other words, floats do not generally become water – they become a particular notion of water as particle or path that has power for oceanographers. While other monitoring devices, such as a wave buoy (Helmreich 2019) may try to resist the outside milieu of the ocean, overcoming the forces of waves and turbulence, the Swallow float integrates the oceanic milieu into its design. The Swallow float forms a sensing surface in which the seawater of interest and the inner functioning of float reach a limit threshold.

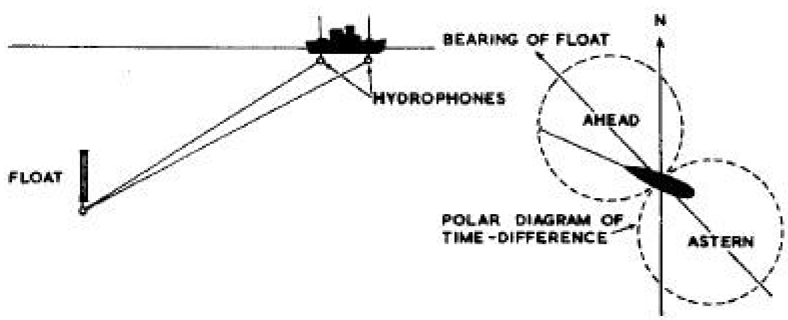

Figure 5.2: Diagram of the tracking of a Swallow Float, where a ship equipped with hydrophones may locate the submerged float.

While the Swallow float lends a new sensory apparatus to oceanographers limited by shipboard measurement, its tracking is still tied to an oceanographic vessel. A transducer attached to the bottom of the float sends out pulses that are received by hydrophones on a vessel (Figure 5.2). This allows the ship to track the position of the float, adjusting its bearings until the hydrophones receive the pulses of the transmitter. While on the cruise of the "Discovery II," Swallow reports that two floats disappeared within hours of being released (Swallow 1955: 77). These floats may have failed to condition their surface to the particles and paths desired by oceanographers, experiencing faults in compressibility that caused them to sink out of the range of detection. While these earlier floats made use of seawater's relations of pressure and compressibility, it is important to emphasize that the early Swallow floats were not *as* compressible as seawater, rather being less compressible to avoid sinking past the desired depths. This not-quite-seawater status would have consequences for designing floats according to Lagrangian principles.

Isopycnal Attunement – Later Swallow and SOFAR

Swallow floats, while able to follow particular particles and paths, were "...not Lagrangian followers of water parcels in a strict sense" (Rossby et al. 1985). In the static nature of their design, these floats relied on their casing to be less compressible than seawater, tuning into a specific depth in a rigid manner. They were close followers of certain surfaces and paths, approximating the water traveling along isobars (zones of constant pressure), but they missed elements that would make them true Lagrangian followers. While a particle or parcel of water would respond to pressures in the ocean, truly following this particle or parcel would mean attuning to the *density* changes in seawater. Early Swallow floats could draw lines of constant pressure, but their fixedness elided the mobility of seawater. Seawater's density could change according to temperature and salinity, and the early Swallow floats would be left behind this dynamic seawater, bound to a pressure-based milieu and with designs that made their other-than-seawater qualities inherent to their design (their compressibility being set apart from that of the waters around them). "For the standard (**isobaric**) float, the compressibility is typically 30-50% less than seawater; so if a float is depressed from its equilibrium depth, it compresses less than the surrounding seawater, gains buoyancy, and thus has a relatively larger restoring force than an equivalent parcel of water" (Rossby et al. 1985). To bring Swallow floats closer to being

Lagrangian followers, Rossby, Levine, and Connors (1985) would add a more dynamic design to a new Swallow float that could follow **isopycnals**[23], or lines of constant density.

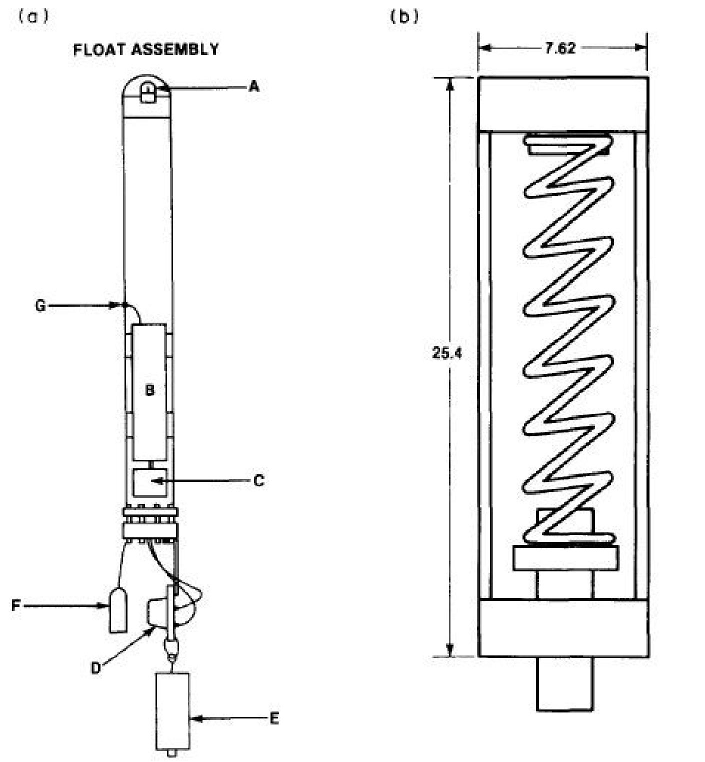

FIG. 1(a). Schematic diagram of the cylindrical isopycnal follower: (A) Flasher; (B) Electronics; (C) Batteries; (D) Transducer; (E) Compressee; (F) Expendable Ballast; (G) Thermistor. FIG. 1(b). Schematic diagram of compressee. The diameter of the piston and the spring constant are adjusted so that the compressibility of the float assembly matches that of seawater.

Figure 5.3: Later Swallow Float Diagram. Unlike the earlier Swallow Float, there is more of a focus on the compressee suspended from the float and its design (right side). Now, it is no longer just the housing that makes the float water.

In their later version of the Swallow float, Rossby, Levine, and Connors would add a compressee (Figure 5.3, component E and schematic b) that could adjust the volume of the float to match that of the surrounding seawater. Unlike the early Swallow floats, this later Swallow float possessed a glass enclosure instead of an aluminum one. Following a parcel of water by

[23] The power of isopycnals and their attractiveness to oceanographers comes from the fact that they mark lines of constant density. If a parcel of water is more dense than the water around it, then it tends to sink to a place where the surrounding density matches its own. This means that isopycnals can suggest the surfaces or boundaries along which a typical parcel of water might move.

matching the compressibility of the surrounding seawater, a later Swallow float would be steered astray were its volume to be affected by temperature changes (with volume impacting the density of the float). The later Swallow float's glass tube housing, with its low coefficient of thermal expansion, prevented this version of the later Swallow float from deviating from its course. Like the earlier Swallow float, the late Swallow float design draws paths or surfaces of interest to the oceanographer. Its design, rather than manifesting waters of constant pressure (seawater-as-isobar), matches the compressibility of seawater and follows water along lines of density (seawater-as-isopycnal). Thus, the sensing surface in which the float's technical milieu meets at the seawater milieu responds to the demands of maintaining density (sensing temperature without allowing it to affect the surface, matching the compressibility of seawater).

While the later Swallow float maintained much of the same detection apparatus as the earlier one, another float developed alongside it that incorporated sounds in its surface and in its method of tracking and detection. This float was called the SOFAR (Sound Fixing and Ranging) float.

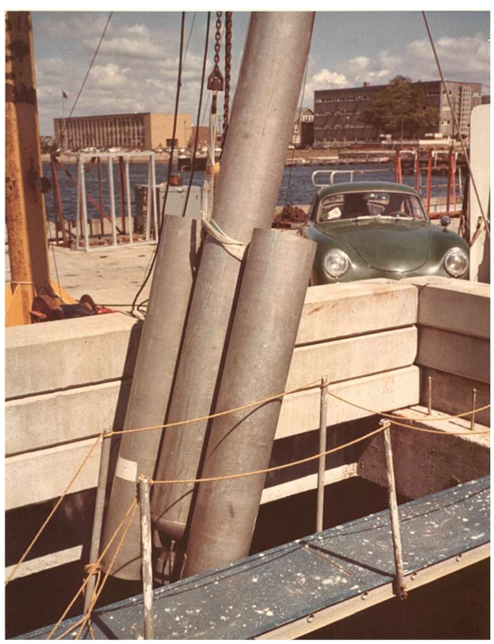

Figure 5.4: The bulky housing of the SOFAR Float

The SOFAR float (Figure 5.5, URI) would incorporate topologies of sound in its design to further separate the operations of the float from shipboard observation. The SOFAR design in Figure 4 shows two resonator tubes on the sides of the main body of the float. These resonator tubes, excited by a piezoelectric bender plate, would incorporate the earlier role of the transducer into the body of the float, resonating at a frequency that would be picked up by mooring stations that had been used to detect the splashdown of missiles. An upgraded, autonomous listening system that could be attached to moorings was soon deployed to be able to monitor the oceans away from monitoring stations (Fig. 5.5).

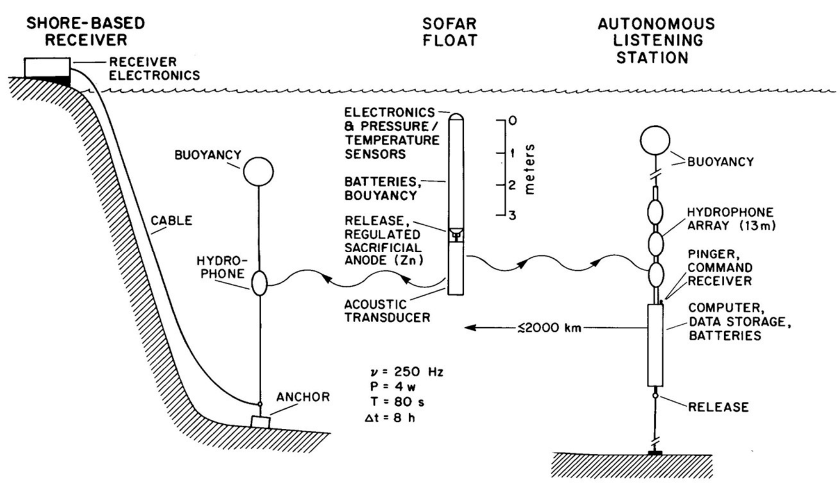

Figure 5.5: The network of communication for the SOFAR Float. Shipboard hydrophones have been replaced by listening stations.

The SOFAR float, rather than only drawing out the surfaces of water, incorporated surfaces of sound into its design. The frequency of sound emitted by the float would be captured by the SOFAR channel, an acoustic waveguide (a physical structure governing sound waves) discovered by the Woods Hole Oceanographic Institute during World War II (URI, Ewing and

Worzel 1948).[24] This channel, located at around 1000-1300 meters depth, would trap sound due to sound waves reaching their minimum velocity in this channel (Figure 5.6).[25] The SOFAR float, with its incorporation of an acoustic waveguide into its signaling apparatus, surfaced sound as part of the becoming-seawater of Lagrangian floats. Whereas the Swallow float used a transducer and was detected by shipboard hydrophones, the SOFAR float followed parcels of water that glided along surfaces of potentially suspended sound. The presence of sound was no longer artificial or wholly engineered, but instead was inherent in the surfaces sensed by the float. The descendant of the SOFAR float, the RAFOS float, would be so named because it emphasized the sound surfacing feature of the float, reversing the roles such that the float did the listening and greatly reducing the size of the float.

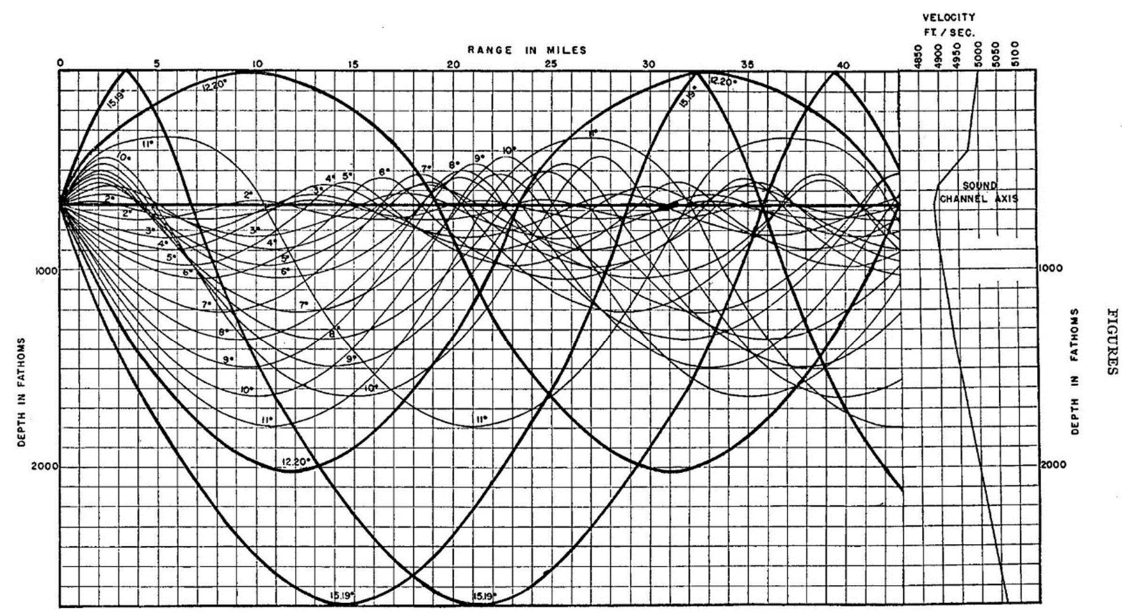

FIGURE 5.—*Ray diagram for typical Atlantic Ocean sound channel—sound channel and refracted surface-reflected rays*

Figure 5.6: Waveguide model showing the distribution of sound waves at different depths. The SOFAR waveguide takes advantage of the entrapment of certain sound waves at a specific depth.

[24] This project was part of the host of experiments during the period dedicated to the detection of submarines.
[25] Up to this channel, the speed of sound decreases due to decreasing temperature, but the speed of sound begins to increase again deeper down as pressure dominates rather than temperature.

ALACE, SOLO, and the Becoming-Ocean of Floats

The Scripps Institution of Oceanography designed a different float, motivated by the designs of both the Swallow and SOFAR/RAFOS floats but with key differences in operation that would change the surfaces drawn by Lagrangian drifters (Davis et al. 1992, Davis et al. 2001). The autonomous Lagrangian circulation explorer, "ALACE, pronounced as Carroll's Wonderland explorer…" (Davis et al. 1992: 265), replaced both the means of becoming-isopycnal of the SOFAR floats and their method of data transmission. Like the SOFAR floats, ALACE deploys a design that matches the density of a water parcel, but with several changes. "Buoyancy changes are accomplished by moving hydraulic fluid from the internal reservoir [Figure 5.7] to inflate an external bladder, thereby increasing float volume and buoyancy, or allowing fluid to flow from the bladder back into the internal reservoir" (ibid). SOFAR's compressee is replaced by a dynamic bladder system that must be carefully designed to prevent folds in the bladder and air bubbles in the system. Improper adjustment of these systems could mean that the float, like earlier Swallow floats, fails to be a good follower of the desired water parcel.

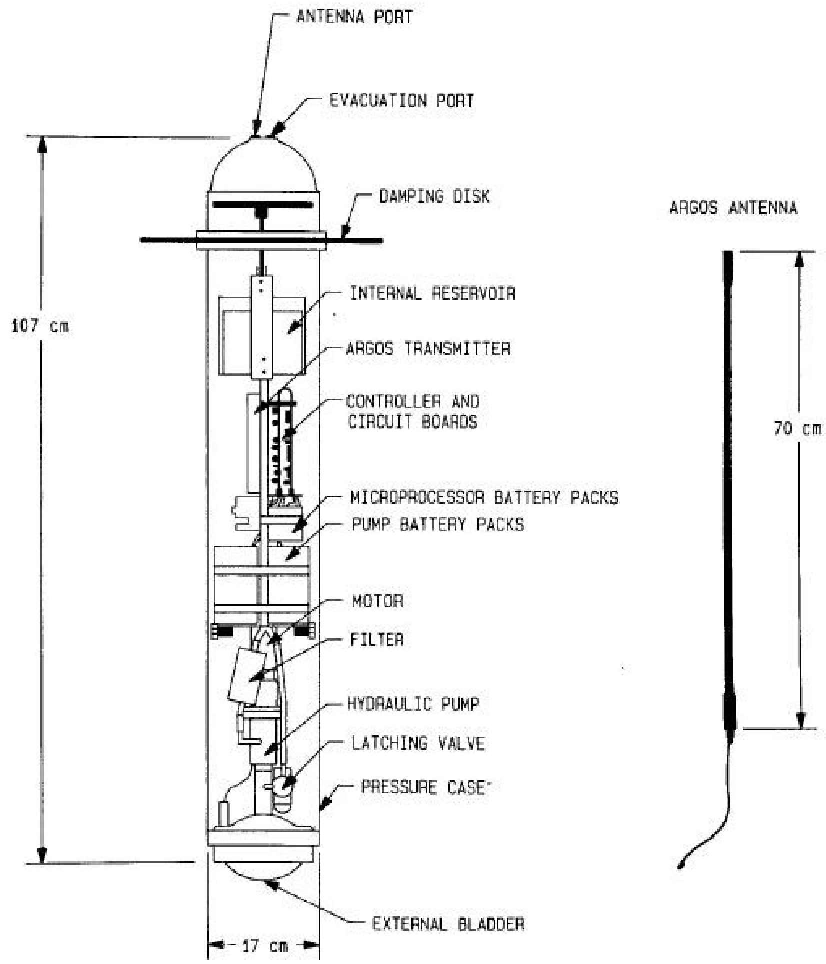

FIG. 1a. Schematic of an ALACE. To ascend, the hydraulic pump moves oil from internal reservoir to external bladder. To descend, the latching valve is opened allowing oil to flow back into internal reservoir. Antenna shown to right is mounted on the top hemispherical endcap.

Figure 5.7: Diagram of the ALACE Float. Note the complexity of the bladder system (bottom) that allows the float to become like water of a certain density and the signaling apparatus (top) that integrates the float into the Argos satellite system.

While SOFAR floats made use of an acoustic waveguide to transmit their positions to listening stations, the design of ALACE aspires to a wider network of communication via a new means of data transmission. Notable in the design of ALACE are the protruding antenna, meant to transmit the data from the float to the Argos satellite network, and the damping disk, meant to keep the float stable on the surface as it transmits. ALACE's design links the deep surfaces measured by the float to the sensible interface of sea and air, and the float is manufactured to incorporate both of these surfaces. "To ascend, hydraulic fluid flows from the internal reservoir through a 25-μm filter to a small motor-driven hydraulic pump; this pumps high pressure fluid through a one-way check valve and into the external bladder" (Davis et al. 1992: 265). The float may spend years and many cycles in the sea, and it shuffles between one and several hundred atmospheres of pressure.

ALACE's difficulty of incorporating the sea's surface in its regime of deep sensing is shown by design changes that were made in the move to the SOLO (Sounding Oceanographic Lagrangian Observer). While ALACE was quite adept at following water parcels in its their high pressure and density pathways, it also had to draw together surface communication and deep movement. According to Davis et al. (2001: 983), "...a significant fraction of the ALACE energy budget is associated with pumping a relatively large volume of oil at the surface where its high-pressure pump is quite inefficient." Additionally, the ALACE had a difficult time adjusting to become less buoyant once it was at high pressures – it would have to return to the surface and restart its dive if it were to make adjustments to its desired depth. The SOLO replaced these with a single-stroke hydraulic pump that allows for full control, ballasting or sinking.

Separating the reporting regime of the ALACE and SOLO from that of SOFAR, satellite communication embeds a different seawater topology in the design of the later floats. While "acoustically tracked floats [like SOFAR] are more logistically efficient when used in dense localized arrays," "widespread low-concentration arrays [are] most appropriate for mapping low-frequency flow" (Davis et al. 1992: 265). This means that ALACE and SOLO floats, less densely distributed than SOFAR and communicating with satellites, are better at compiling long-term observations to establish mean flow in a region. The shift from SOFAR to ALACE/SOLO is also a scaling of the topology of sensed surfaces – ALACE and SOLO represent the becoming-region and becoming-ocean of Lagrangian float sensing, establishing a technological ensemble[26] that draws together particle/parcel surfaces into entire bodies of seawater.

The oceanographic aspiration of scaling the observations of Lagrangian floats into entire regions and oceans is embodied in the Argo program (Roemmich et al. 2009). This program "...began with regional arrays in 1999, scaled up to global deployments by 2004, and achieved its target of 3000 active instruments in 2007" (ibid: 35). This program, named for its integration with the Jason satellite altimeter, has been sustained by multinational participation and the deployment of thousands of floats by ships including "...commercial ships, Antarctic supply vessels, research vessels, and others…" (ibid: 37). Jessica Lehman (2017: 61) describes the shift to Argo as one that is not just about sensing, stating "Distributed sensors differ from remote sensing, as they make *in situ* measurements of ocean properties and provide comparatively high-resolution temporal and spatial monitoring data." Additionally, the Argo network has been part of a wide-scale increase in the availability of data for oceanographers. Whereas oceanography had previously held on tightly to any bit of available data, the discipline is now faced by an unprecedented increase in these data (Lehman 2017: 63). SOLO floats, along with others including SOLO II, APEX, PROVOR, NAVIS and ALTO have become part of an Argo surface that covers the world's oceans (Figure 5.8) and scales up the paths and parcels drawn by individual floats (NOAA 2022).

[26] Here I use Simondon's (2017) notion of ensemble to suggest that this move from float to float network emphasizes the relations of multiple floats, in that successful sensing is no longer just about detecting a single surface – it is about a distribution of floats that allow these surfaces to scale into regions and oceans.

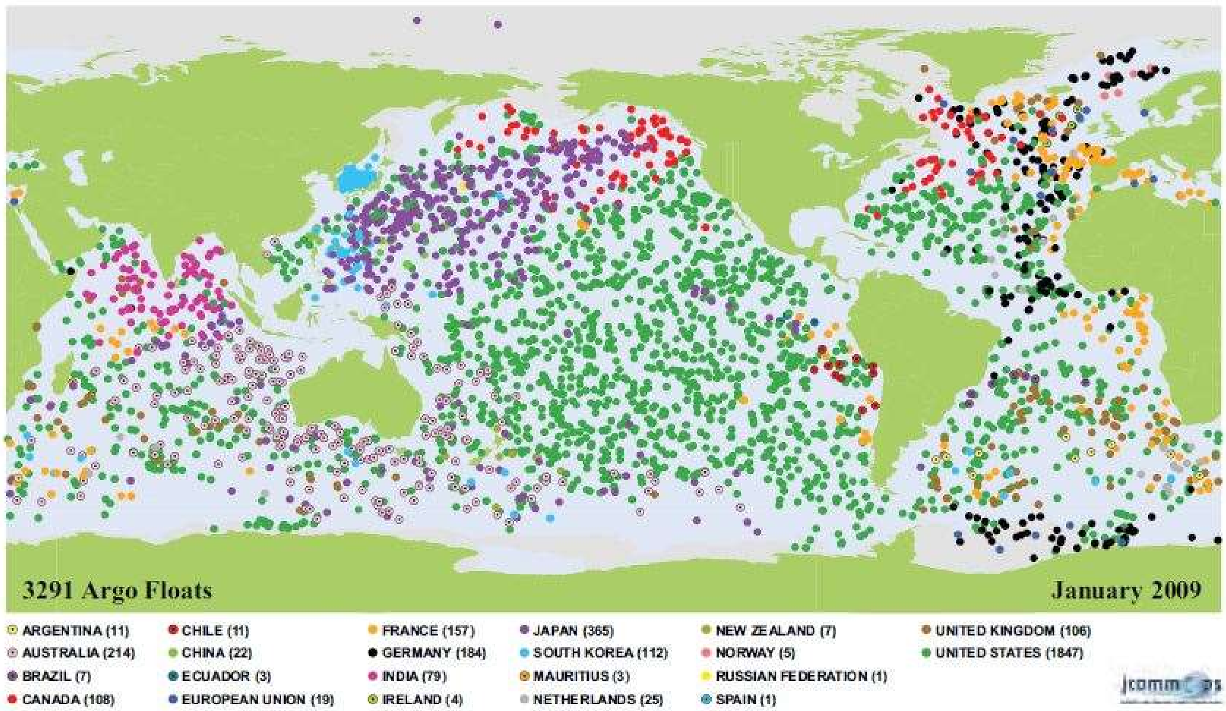

Figure 5.8: Distribution of Argo Floats throughout the oceans

Surfacing the Depths

The view conjured by float systems such as Argo also merits criticism when separated from the conditions of its production. Lehman (2017: 64) cites Helmreich when contextualizing the critique that "...technologies such as satellites, drifting floats, ROVs [remotely operated vehicles] and AUVs [autonomous underwater vehicles] can effectively obscure the fact that they are situated in particular social and geographical contexts." This critique is especially relevant for oceanography's relation with data and the production of these data by networks like Argo. Argo represents one part of a shift from scarce, physically collected data to abundant, automatically collected data. Jennifer Gabrys (2016: 146) points out that, in this frame, "The becoming environment of computing sensors in oceanic spaces involves the instrumentation of oceans with extensive sensing networks as well as the reworking of the environments in which sensing takes place (from underwater to living rooms). It is entirely possible, departing from the point at which the Argo network is already constituted, to construct a "view from nowhere" that sees the ocean as a product of disembodied data.

This critique is not only limited to float networks as already constituted but may extend to specific devices designed for ocean sensing. In *Reading a Wave Buoy*, Stefan Helmreich (2019) studies the design of a wave buoy, contending that it misses the sea's materiality – it is constantly trying to overcome and survive the sea. Its mission is to deliver clean, mathematical lines, and the sea's materiality serves only to impede this mission. The wave buoy's design reflects this purpose, and it is equipped with the proprioceptive and dampening capacities to resist the materiality of the ocean and to effectively deliver its data. Helmreich, however, points to an opening in the critique of the disembodiment of ocean sensing. He distinguishes between "operational images" of data which give a representation of the waves being captured by floats, and "operational impressions," which result less from the data product of the buoy and more from the buoy's necessarily tactile and proprioceptive capacities. Operational impressions take into account the means of sensing incorporated in these pieces of ocean equipment, and the distinction between the desired end product (clean data) and the means of actually sensing the indices of these data (the drifting and onboard sensors of the buoy). Gabrys (2016: 146) also opens up a view of ocean sensing that limits floats to only clean data, stating that "As sensors fill…spaces and provide monitoring data, they also generate other sensor tales, including observations about the likely drift of marine debris through ocean currents." Indeed, there is potential danger in limiting the analysis of ocean floats to a critique of their production of clean data. Lehman (2017: 65) states, "If we fail to consider the specific mechanisms of these new practices and associated technologies, then we risk falling into the trap of abstracting them ourselves, or evaluating them absent their social, political, and environmental situatedness.

Rather than limit the analysis of Lagrangian drifters to a critique of their final data product, I instead propose an approach more akin to what Michael Fisch (2018: 6) calls a "technography" in his analysis of Tokyo's commuter train network. He states, "Technography, I insist, must…move beyond anthropology's representational mode of knowledge production. Merely describing a technological condition or in situ processes whereby people adapt technologies to realize a specific outcome does not suffice. Not only does such a descriptive approach risk reifying a binary structural ontology of human versus machine, it is also burdened with a problematic, twentieth-century anthropological conceit for producing knowledge of another."

A technographic view of Lagrangian drifters follows these devices as they follow parcels of water, highlighting the processes by which floats integrate a certain kind of water that they are themselves mapping (or fail to do so). Floats embody a specific design protocol created by oceanographers, but their operation encounters an oceanic milieu that often disrupts or intervenes in this design. It is not enough to accept the float as a complete unit – the movement from Swallow floats toward later floats like SOLO reflects a careful association of elements within the float that may trouble design forms.[27] A float may be a good water follower, but only along isobars, and it may even run into issues, as ALACE did, when trying to adapt high pressure components to the surface of the sea.

Moving to a technographic analysis of Lagrangian floats does not mean leaving behind the social or historical context of these devices. Indeed, Fisch (2018: 7) states that in his

[27] The movement between floats more closely resembles what Simondon terms "transduction," borrowing from Jean Piaget (de Boever et al. 2012: 230). Transduction, rather than fitting into deductive or inductive operations, sees a technological device as propagating within a specific milieu without being ruled only by milieu or by design. Individual elements within the device may also move in this fashion, becoming more complex as they themselves are tailored to a specific technological milieu.

technographic approach inspired by Simondon, "...machines are more than tools external to an ontologically stable human subject; rather, they are integral to the processes of human thinking and social becoming." Lagrangian floats aren't simply means by which the material ocean can become disembodied – they iterate what it means to follow a water parcel and extend the sensory apparatus of oceanographers, who are called to enact upon the float's interface ideas of which threads or topologies of the oceanic milieu are most worth sensing. Indeed, I see the Lagrangian float's packaging of oceanographic ocean-making views in its design as similar to Marianne de Laet's and Annemarie Mol's (2000) location of such domains as disease control and national standards within the design of the Zimbabwe bush pump type B. Like de Laet and Mol, I follow floats not just as complete machines, but as ensembles of technical elements, each of which interfaces with a geographical and social milieu. If de Laet's and Mol's bush pump is useful because it is fluid, Lagrangian floats are useful because they inform what it means to be fluid (whether seawater as isobaric, seawater as isopycnal, seawater at depth, or seawater at the surface).

In carefully following the technical development of floats from the early Swallow float to SOLO floats, I have stated that these floats, in following specific seawaters, "surface" these topologies for oceanographers. This idea plays with both the human sensory disparity between surface and depth for oceanographers (oceanographers must rely on the float as a sensory apparatus at high pressures) and the "surface" as a locus of sense wherein the limits of the float's technological milieu and the oceanic milieu with which it is in contact converge. Here, I draw on Deleuze's (1990:104) notion of the surface, about which he states, "...the surface is the locus of *sense*: signs remain deprived of sense as long as they do not enter into the surface organization which assures the resonance of two series." The limit of the relations between the technological float and the oceanic milieu in which it is submerged is the locus of sense, and this surface is far from stable. Deleuze draws on Simondon's ideas of the membrane as a place where "...life exists in an essential manner, as an aspect of a dynamic topology which itself maintains the metastability by which it exists" (ibid). The interface of the Lagrangian float and the oceanic milieu is not a guarantee, but is instead metastable. For example, the surface at which the Swallow float was meant to be a good Lagrangian follower was broken down in its response to pressure and asymmetry with the compressibility of seawater. Once it became too buoyant, it could still be a sensor of the deep ocean, but it ceased in making sensible the surface that most interested oceanographers.

Key to this idea of surfacing is Deleuze's distinction between truth/falsity and sense/nonsense (Smith 2022). While the surface of the float may have been designed to follow a particular surface – an isopycnal – this surface does not necessarily precede the float's observation. Rather than viewing the float as producing a surface that already existed, turning the noise or intensity of the deep ocean into the truth of an isopycnal or the falsity of a bad observation (perhaps only an isobar), I would argue that the float makes a distinction between the sense of a particular surface and the nonsense of a vast, undifferentiated ocean. This situates both the objectives of oceanographers, who in their design of floats are responding to gaps between that which they desire to sense and that which they find to be less useful, and the actual operation of floats, where failure to produce surfaces such as isopycnals can still leave Helmreich's "operational impressions" and Gabrys's "sensor tales" (without rendering them "false"). In bridging the oceanographer's surface-limited sensory apparatus and the limit between float and ocean the Lagrangian float still leaves open alternate surfaces that exceed its design.

Thus, Lagrangian floats, from the Swallow float to SOLO, participate in a "surfacing of the depths" that enacts the seawaters and oceans of oceanographers (such as water-as-isopycnal) in the smallest elements of the float. By focusing in on several floats and on the elements therein, I avoid the problems of a float or sensory network already made. Rather than elide the sensory apparatus of the float by suggesting that new oceanographic data is only disembodied or is now in the 'living room' of oceanographers, I propose that oceanographic floats and data not be fully abstracted from the surfacing practices of sensing devices. With this approach in hand, it is possible to attend both to Jue's call for a *milieu-specific analysis* (2020) and to incorporate technical devices such as floats in the meaning-making practices of the oceanographic sciences.

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6. Synecdoche[28]: Migration and Memory - Residence Time and the Ocean

Introduction:

Martín Zamora, a mortician in the southern coastal city of Algeciras, works to collect the bodies of migrants that wash up on Spain's shores (Casey and Sarasketa 2021). Ravaged by the turbulent waters of the Strait of Gibraltar and the Western Mediterranean, these bodies are often hard to recognize, even for family members. In his efforts to reunite the bodies of migrants with their families, he must often rely on traces of clothing or belongings to identify who these people were. Shoes, shirts, and other belongings come with stories, linked to the last time that the person was seen alive or to their line of work. This was the case for Achraf Ameer, a mechanic from Tangier. Achraf was identified by his sister, Soukaina, who stated, "The paint on his clothes was the paint he has on his clothes at work" (ibid). By that time, Achraf's body had been drifting for most of the month of April, and it was subsequently kept without being frozen for the rest of Spring and part of the Summer. Zamora continues his forensic work, often bringing clothing and belongings to markets with the hope that they will be identified by relatives.

According to the UN Refugee Agency (UNHCR 2022), Spain has seen 28,595 sea arrivals through the course of 2022. Arrivals in Spain spiked in 2017 and 2018 with the growing use of the Western Mediterranean Route, especially in the Spanish overseas territories of Ceuta and Melilla. Ruben Andersson (2016) argues that migration routes in the Western Mediterranean have been subject to a movement between physical border fences (surrounding colonies like

[28] "'Figure of speech in which a part is taken for the whole or vice versa'…from Greek *synekdokhe* 'the putting of a whole for a part; an understanding one with another,' literally 'a receiving together or jointly'" (Online Etymology Dictionary). Like metonymy, synecdoche is an relation of association, but synecdoche specifically expresses the part being taken as the whole or together with the whole. Separation and taking together of part and whole bring attention to the material conditions of association. What material conditions force a piece of clothing to stand in for a person or the chemical nature of water to stand in for age-old weather patterns? How can a water molecule have a history? These questions may come together in the material of oceans and seas.

Melilla) and technologies of surveillance that coordinate multiple EU nations (such as Eurosur, or the European Border Surveillance System). Technologies of surveillance, according to Andersson, join security-centered concerns of intercepting migrants with humanitarian concerns, but they do so with the illusion that the border can be mastered. Technologies and networks of surveillance, purportedly uniting EU interests, also obscure the factionalist imbalances that occur when member nations direct migration elsewhere. This can be seen in the shift between Italian and Spanish migration routes. Spain's rescue operation, Salvamento Marítimo, observed that, "With the increase in disembarkments spurred on by Italy's closure of its ports," civilian rescue moved from a non-policing measure under the Ministry of Public Works to a multi-ministry effort aimed at efficient rescue (Fine and Torreblanca 2019: 5). In 2019, several rescue ships were withdrawn from the Alboran Sea to other areas, sparking claims that designed inefficiencies were occurring to enforce a tough migration policy (ibid). While the Western Mediterranean Route remains a key political topic for the EU and for Spain, I choose to focus instead on the necropolitics (Heller and Pezzani 2020, drawing on Achille Mbembe) of migrant bodies. A focus on the discourses of security and humanitarianism that govern migration policy along the Western Mediterranean route may have a tendency to reify a temporality of crisis. Heath Cabot (2019) argues that anthropological intervention in refugee crisis may reinforce the border regimes that police migrants. My focus on the traces of memories and materials that connect migrant bodies to their relatives and that submerge migrant bodies into the circulation of the Strait of Gibraltar moves along an entirely different temporality. The temporality of this chapter is one that moves with seawater, flowing with the long durée of circulation rather than being caught up in a moment.

In this chapter, I connect forensic projects that track the paths and identities of submerged bodies (Mateus et al. 2015, Heller and Pezzani 2020, Palazzo et al. 2021) to the notion of "memory" as it emerges in paleoceanography (Gebbie 2019, Gebbie and Huybers 2019, Gebbie 2020). I examine how the time scales of death at sea begin to resonate with concepts of age and "residence time" (Woods 1985, Monsen et al. 2002) that are used to describe the temporality and fate of water. I argue that the bodies of migrants, in being engulfed by and circulated within the waters of the Mediterranean, take part in the dissolution of identity that comes with the hydro-logics of water (Chandler and Neimanis 2013), their clothing standing forth as "informed materials" (Barry 2005) in a way similar to the tracking of the age of water. As a space beneath the typical politics of migration, the politics of submerged bodies demands an ethics that stays with the "wake" (Sharpe 2016) of the long-durée of aquatic exposure. Because migrant bodies at sea become wrapped up in its circulation, they are subject to a kind of blurring of subjectivity that moves beyond the notion of "bare life" (Agamben 1998) and into the notion of geontopower (Povinelli 2016). As the processes that bind bodies to the fate of water and the logics of circulation that hold them are so specific to the scale of seas, I call the form of being in which bodies and water meld a "thalassontology."

Ocean Memory:

At the surface, seawater receives a constant influx of information from the atmosphere in the form of heat, cold, wind, and rain, but this information is distilled and attenuated as one moves past the noise of the surface and into the depths. Past 200 or 300 feet, Woods Hole oceanographer Jake Gebbie tells me, warming and cooling from the atmosphere or rain and evaporation altering the salts of seawater start to slow down and to become fixed values. Past a certain depth, things like temperature become conservative, tending to preserve the values that they had at the surface. Gebbie studies the impacts of centuries-ago events like the Medieval Warming Period and Little Ice Age on the ocean, tracking whether the deep Atlantic might have a register of the warming of the former or the cooling of the latter (Gebbie 2019). Gebbie contends that deep water may contain traces of these historical moments in its material composition. He is challenged by the availability of oceanographic data – the first major oceanographic expedition to collect data on the scale to which it would be useful to his endeavors is the HMS Challenger expedition of 1872-1876. This is a far cry from the stretches of time reaching back to the year 900 that interest Gebbie, and so he must draw on the paleoceanographic records – sediment cores that are radiocarbon dated and assumed to fix certain variables of deep ocean water from the past. Nor are the temperature changes that Gebbie is monitoring stark and distinct. Small temperature changes in deep water can indicate massive shifts in thermodynamic energy when calculated across the entire Atlantic basin.

To describe the changes in deep ocean temperatures and the preservation of values within deep seawater, Gebbie deploys the term "memory." He told me, "...waters that are in the deep actually can have the same properties that they had hundreds or thousands of years ago, and that's what I'm colloquially calling…memory here. To measure the temperature and the salinity and to relate it to things in the atmosphere a long time ago…" (Interview 2021). Thus, for Gebbie, the memory of ocean water is a crystallization of the ocean-atmosphere interface, where the exchange of temperature, salinity, and certain gasses like oxygen and carbon dioxide leave an imprint on seawater before it sinks and is circulated to the depths of the ocean. This complicates spatial notions of circulation with originary, temporal notions of seawater. Rather than just coming from different parts of the ocean, seawater in the depths has different time origins. Gebbie cleverly calls these time origins "vintages," drawing on viticultural metaphors of preservation. Unlike fixed volumes of wine, however, seawater is still subject to the turbulent forces of circulation. While a certain volume of water may be tied to a memory of the surface, establishing its age, this age-identity is not indicative of a sameness throughout the volume. A simple ocean conveyor belt model, Gebbie explains, might give one the idea that water at the surface could simply hop on at one point and be sampled in the depths at another point, unchanged other than spatial displacement. Because of the turbulent nature of ocean circulation, however, mixing leaves an indelible impression on any single volume of water. Reaching for a water's memory as a signature of its former interaction with the atmosphere is an exercise in statistical distribution – talking about the age of a parcel or volume of water is actually talking about the mean age of the heterogeneous waters of that parcel.

For seawater, then, time is attenuation. The long-term circulation of water that takes place before the water is retrieved in the depths performs a "temporal smoothing" of certain signals that were registered at the surface (Gebbie and Huybers 2019). This means that the mark of an anomaly, like a spike or drop in temperatures at the surface, once preserved in the past of a volume of seawater, may be blurred by the time the seawater's properties are studied in the deep ocean. Comparatively, then, the longer journey of Pacific deep waters attenuates the signal of surface anomalies even more than does the shorter journey of Atlantic deep waters. This is part of why the records of deep sea temperature and salinity must be understood from a distributive perspective – Gebbie considers the memories of water, perhaps themselves dilute and blurred, across the entirety of a basin. Gebbie, then, is performing memory work, establishing an historical narrative and filling in the gaps in the memory of the deep Atlantic. He describes his process as the opposite of the techniques of numerical weather prediction. While numerical weather prediction uses available data to do the best to see what weather looks like in the future, Gebbie's inverse methods try to puzzle together the story of what has happened in the past. Thus, he follows the traces and signatures of past warming and cooling, establishing the fragments of seawater's memory that may be worn smooth at the edges, more of a messy palimpsest than a distinct series.

For oceanographers like Gebbie, the memories of seawater turn it from a collection of water, salts, and organic matter into volumes of water that have a history. Water, then, is not just a collection of identical, molecular materials, but instead consists of what Andrew Barry calls "informed materials" (Barry 2005). Barry draws on Alfred North Whitehead's description of the way that matter works for chemists. Whitehead argues that, for chemists, molecules are historical rather than physical entities. Molecules may endure, but they are not identical, instead carrying with them a register of relations and associations that gives them a history. Barry argues that, for a molecule to be an informed material, it "embodies information" (ibid: 58). Information is built into the structure of the molecule, but this view does not work if molecules are treated as distinct, self-contained objects (i.e. as transcendental units defined by their chemical composition only). Instead, Barry argues along with Whitehead, the informational and material environment of the molecule enters into its constitution, where the environment cannot be taken as external to the molecule. Molecules, then, may have similar structures and very different histories.

Barry's concept of informed materials inheres in seawater's capability of having a memory. Water in the deep ocean may have a certain temperature, salinity, organic matter, or gas content that is similar to other volumes of water around it or water across the world ocean, but it embodies information of when that water was last at the surface. Seawater's status as an informed material, though, is mediated by the material processes of circulation that dampen its relation with its past, surface-self. Seawater may be an informed material, but this information comes as a statistical mean across a volume of seawater or across a basin. Signals of temperature anomalies or of other atmospheric events are eroded and processed by the forces of mixing that make up global ocean circulation. Because this often leaves a parcel of seawater with only a trace of the surface and its events, its history is consigned to memory. Seawater memories are not just a transportation of the capacities of a human mind to the material of seawater – they swell with the circulatory capacity of seas and oceans and create a history may only be understood as distributive. While seawater may be agnostic to its contents, it is still important to capture concepts such as its "memory" as having eventuating capacities. When the material traces of seawater converge into the account of an event, memory becomes a capacity of interest. This capacity for memory is all the more clear when seas and their circulation carry with them the bodies of migrants.

Terrain Violence and Liquid Violence:

In *The Land of Open Graves: Living and Dying on the Migrant Trail* (2015), Jason de León examines the ways in which the killing capacities of the environment itself become means of executing a migration deterrence strategy. He follows the stories of migrants along the Mexico-US border as they make their way through the Sonoran Desert, facing harsh temperatures and terrain along their journey. De León argues that the "natural" processes of the Sonoran Desert are, rather than being separate from human endeavors at migration deterrence, a killing machine that renders invisible the discourse of security and enforcement along the border. He insists that the encounters that migrants have with animals, terrain, and temperatures in the Sonoran Desert are part of the federal policies of deterrence that prevent them from reaching the United States safely. Environment and humans form a hybrid (de León draws on Callon and Law here) that should be taken together so as to make visible the in-between of the journey and the violence that migrants face as they travel. The landscape itself intervenes in what can be taken as policy and allows for the tools of power to be obscured.

In his argument about the connection between the violence of the Sonoran Desert and the policies of deterrence that use it as a proxy of their power, de León draws on Giorgio Agamben's notion of "bare life" (Agamben 1998). While bare life designates the undifferentiated mass of life in which life itself is given priority over quality of life, De León's ethnographic descriptions call for an approach that can cross the line into the deaths of migrants in the Sonoran Desert. Thus, he deploys Achille Mbembe's concept of "necropolitics," arguing that discourses of war or security are used to kill in the name of sovereignty. The killing of migrants by the Sonoran Desert is not just about the undifferentiated lives of migrants under a regime of deterrence – it is also about discourses of security that allow the desert to act on behalf of sovereignty. Migrants are put in a 'state of exception' (Agamben 1998) in which they are made killable, and their death is also rendered invisible by the inhuman processes of the Sonoran Desert.

De León, however, does not stop with the killing of migrants in the desert. The necropolitics that he describes include, too, the violence done upon the corpses of migrants as they are exposed to the elements and to scavenging wildlife. To this end, he draws upon the science of taphonomy to describe the interactions of migrant bodies, microbes, scavenging animals, and weather. The extent of his depiction is macabre – he places the corpse of a pig in the desert to better understand the process of decay and the involvement of environmental factors. While the corpses of migrants may have already been deemed killable under discourses of war and security, de León still seeks to render the processes of decomposition visible, linking them to the invisible violence being carried out against migrants. While his focus on the geography of the Sonoran Desert calls attention to the ways in which the landscape can become part of a violent discourse of deterrence and sovereignty, there is a depth and volume to the Mediterranean that defies the particularities of the desert.

Heller and Pezzani (2020), in their work on "Forensic Oceanography," bring many of de León's concerns to the Mediterranean. They also see the landscape as part and parcel of the tools of power within the region, describing a 'liquid violence' that is carried out on migrants. They argue, "Most migrants' deaths across the Mediterranean frontier have not only occurred *at* sea, but *through* the sea, which has been turned into a deadly liquid as a result of the EU's exclusionary policies which precaritize their crossings" (ibid: 95). Similar to those crossing in the Sonoran Desert, the migrants in the Mediterranean are subject to policies of non-assistance that allow their deaths to be carried out by the sea itself. Here, Heller and Pezzani draw on the case of the Left-to-Die-Boat, which in 2011 carried 72 migrants from Libya who, despite pleas for help, were tragically ignored, only nine passengers left alive. The practices of bordering that happen at sea create further precarity for migrants, as nations decide who is responsible for certain crossing routes and for how long.

Like De León, Heller and Pezzani recognize the "geopower" that is enrolled by sovereign authorities to allow the Sonoran Desert or the Mediterranean Sea to carry out violence upon the bodies of migrants. I contend, however, that the distinction between life and death which De León points out in his use of taphonomy is subject to a further distinction between life and non-life. Here, I draw on Elizabeth Povinelli's concepts of "geontologies" and "geontopower" (Povinelli 2015). While the lives of migrants are very much at stake in their crossing of desert and sea, there is a separation of life and non-life that appears in the material geography which sees the bodies of migrants becoming subject to geological processes. For Povinelli, geontology is meant to both highlight "the biontological enclosure of existence" and to find a critical language to talk about settler late-liberalism's prioritizing of life over non-life (ibid: 17). Povinelli is careful to point out that geontology, as well as its corresponding form of power, geontopower, are not meant to replace the workings of biopower, but instead to make visible the workings of power when one passes from the lively to the inert. It is Povinelli's focus on the ontological level of operations and her move to include it in notions of power that I find most compelling in thinking through the case of migrant bodies at sea. Where Heller and Pezzani's use of geopower accurately captures the way in which seas can become part of the discourses of security and humanitarianism that surround migrants in the Mediterranean, they do not venture beyond treating seawater as a medium. There are traces in their work of the volume and depth of seawater, but the logics of seawater like "memory" are not connected to the fate of migrant bodies. It is for this reason that I propose the concept *thalassontology* (drawing on the thalassa- of seas) to discuss the fate of migrant bodies in a way that is attentive to the circulation of seawater and to the fate of the dead. Where Povinelli's stakes in designating geopower rather than some other sort of climate power are in the fundamental distinction between life and non-life, my stakes move with the flow of seawater in the Mediterranean.

A Body's Fate and Circulation:

Determining the fate of a body circulated by the seas is often a difficult task. In their case study of a pair of beach-goers lost at sea off of Portugal, Mateus et al. (2015) resort to comparing the movement of a body to the movement of seawater itself. They describe how, after rescue operations succeeded only in retrieving one of the bodies, the location of the other body was not known for days. To find whether hydrodynamic models may have helped to predict the location of the body, they apply several layers of analysis. Firstly, they account for the general trends in the region – a large-scale model from the Portuguese Coastal Operational Monitoring System provided information on the generally southward tides in the region. Where the bounds of the larger model ended, the researchers deployed a Lagrangian drifter model. Lagrangian drifter models manipulate hypothetical parcels of water along their course through the sea, predicting based on governing physical parameters where these parcels of water might travel. In this case, the body of the drowning victim was visualized as tied up in the sweeping circulation of seawater as if it were a parcel of that water.

While the experiment by Mateus et al. was successful in predicting the general trends in movement of a submerged body, it did not account for the relations between a body and seawater. Here, the cause of death was a determining factor. Where the first body was found to be the result of a possible heart attack, the body found adrift was a victim of drowning. Mateus et al. state, “the floatability of the human body changes as a result of drowning. Water aspiration and ingestion increases the specific gravity of the body, thus decreasing its floatability” (ibid: 329). Where a parcel of water may have maintained its course along a constant layer of density, moving laterally with a body of seawater, the changes in buoyancy of a decaying body produce upward and downward movements in the water column, both following and defying the movements of seawater. Thus, bodies at sea hold a trace of their death while becoming part of the hydro-logics of seawater circulation.

Alongside the consideration of what it means for migrant bodies to dwell at sea are notions of memory and of “residence time.” Where memory is a register of the age of water that carries a trace of water’s memory of the surface and that deals with a probabilistic multiplicity in a parcel of water, residence time is the in-between of the journey. Memory may record the last impression that water had of its interaction with the atmosphere, but residence time draws boundaries to explain a duration. In hydrology, residence time is the amount of time that a parcel of water spends in a particular body of water before exiting. Monsen et al. (2002) argue that residence time, while apparently clear in its cuts of when a parcel enters or exits, is made complex by non-steady flow and by irregularity in bathymetry and circulation. Staying with a parcel of water as it resides means attending to the specifics of the regional landscape and circulation.

Like the marks of temperature and salinity that water may carry as a register of its memory, bodies themselves may become informed materials. The time spent in the sea is not the only important variable in understanding how a body might move with circulation – decomposition is altered by states of temperature. Forensic scientists deploy the metric of "Accumulated Degree Days" (Megyesi et al. 2005, Mateus et al. 2015) to describe how temperature impacts the fate of a body cast away at sea. Here, temperature speeds up or slows down decomposition time, and accumulated degree days account for a kind of temperature-time in which days spent above a certain temperature speed up the process of decomposition. Aside from the traces of clothing and belongings that tie drowned migrants to jobs, to departures, and to families, the bodies of the drowned carry temperature, further breaking down the barriers between contained self and environment that separate life and the non-life.

The separation between life and non-life in a seawater environment elicits certain qualities of circulation that make a thalassontology specific. Information is an immanent quality that is also spread throughout the circulatory system of seawater, where variables like temperature denote both the qualities of a parcel of water or body and the relations that these have to density layers of water and to basins. The bodies of migrants attended to by Martín Zamora may carry a trace of memory via stories and clothing, and these join the journey of seawaters that carry variable traces of the surfaces with which they last met. To this end, thalassontology points to both the separation of life and non-life (and all of the exercise of settler late-liberalism that it entails) and to the conditions of distribution and circulation that tie submerged materials to memory. It highlights the importance of the milieu in which migrants are left to die – maintaining a link to the critiques of De León and of Heller and Pezzani – but it is also specific about the hydro-logics of circulation that envelop migrant bodies.

Thalassontological Ethics

In her critique of certain modalities of attending to migration, Heath Cabot (2019) points out that anthropology may itself reproduce the epistemic violence of a strictly humanitarian approach to topics in migration. Here, she attends specifically to the temporality of migration studies, cautioning against viewing them in the "crisis" model of thought (ibid: 265). By attending to migration as a crisis rather than treating it with the same care that other anthropological topics receive, anthropologists risk losing ethnographic nuance and acceding to the demand for quickly-published information, becoming complicit in an intervention style mode of action that is tied to humanitarianism. Cabot urges that scholars attend to the protracted impacts of migration and the long-term violence of the exercise of state power. I find it worth questioning, then, what the epistemic and ethical stakes are of an approach to migration that can account for the care of those like Martín Zamora or can follow the circulation of water and of bodies. A thalassontological ethics calls for an attention both to the violence carried out upon migrant bodies and to the ethical affordances of (sea)water.

Peter Boomgaard (2007) argues that water has multiple valences, operating as both a life-giving force and a deadly one. While these multiple valences open up the possibility of encountering water outside of the typical circuits of state violence that characterize migration as crisis, they do not maintain enough of a connection to seawater's materiality to fully encapsulate what might be possible with a thalassontology. In searching for water's ethical capacities, Miele Chandler and Astrida Neimanis (2013) disrupt the substantialist and transcendent judgment of traditional ethics. They make water more than the outside environment, questioning what it might mean to outline an ethics of water as a gestational force. They argue "Water, in its gestational and facilitative capacity is not *beyond*; it is not a divine creator itself unfettered by corporeal existence. Water is rather *beneath*, the very material precondition of infinite biological life" (ibid: 68). Thus, water as gestational participates in a kind of proto-ethics that blurs the conscious actions of a contained subject. Instead, water dissolves the boundedness of subjects, flowing "beneath subjectivity," facilitating the potential for new subjectivities while dissolving others.

Inherent in this view of water as proto-ethical is the notion of its virtuality. Drawing on Deleuze, Chandler and Neimanis point out that water, while in circulation, is turbulent and indeterminate, both actuating certain currents while potentiating others, fulfilling roles as both material and virtual. Seawater's turbulent circulation and constant mixing dissolve the boundedness of water and of subjects, churning them in a flux that stretches out their material and temporal relations. Thus, seawater's memory is not the bounded fate of a parcel of water that can enter a global conveyor belt at one part of the world and step off at another – it is distributed across self-different waters that may still tell a story across a basin or have a history. Nor are the materiality and virtuality of thalassontology's seawater hydro-logics limited to what we typically conceive of as the boundaries of oceans – they flow into the stories of deceased migrants, leaving the traces of submersion and of temperature that make identification as task in gathering together traces.[29] Thalassontology calls for a proto-ethics that can attend to water's material and virtual capacities, staying with the distributed temporalities of a body or basin of water.

In her work *In the Wake: On Blackness and Being*, Christina Sharpe (2016) develops a temporality of black experience that is deeply thassontological. She wonders how best to capture the modern black experience of slavery in a way that can stay with the journey of the slave ship, marking a temporality that is both "now" and "then." To this end, she develops the idea of the "wake," or the experience in which the history of the slave trade can be both now and then in an immanent connection. She speaks of her discussion with a colleague, Anne Gardulski, who describes the residence time of water, saying, "Human blood is salty, and sodium, Gardulski tells me, has a residence time of 260 million years. And what happens to the energy that is produced in the waters? It continues cycling like atoms in residence time. We, Black people, exist in the residence time of the wake…" (Sharpe 2016: 36). Even removed from the physical materiality of a seawater passage, the wake is pervaded by the long-durée of residence time, the circulation of energies that float beneath and can come crashing back into conscious experience.

The wake and the work of noticing it also extend into the uncovering of the remains of the Transatlantic slave trade. Diving With a Purpose (DWP), a group of mostly African-American divers, orients marine archaeology toward the uncovering of cultural artifacts tied to the slave trade (Roberts 2022). Lonnie Bunch III, secretary of the Smithsonian Institution, argues that this practice of uncovering underwater artifacts pays homage to those who didn't make it, and he says that the uncovered ships "'…allow us to sort of almost touch sacred spaces that are

[29] Indeed, Steinberg and Peters (2019), in their argument that watery ontologies extend outside of the "wet" realm of water, draw on the work of Mark and Diana McMenamin (1993). These scholars conceive of a biophysical "Hypersea" connection between land and marine organisms, arguing that the comparative diversity of land biota can be thought of as a result of their ability to direct the transfer of fluids (whether through eukaryotic or mycorrhizal relations), where marine biota rely on wind and mixing to replenish nutrients.

not just spaces of death, but spaces of memory'" (ibid). Diving with a Purpose's mission fits firmly in the watery temporality of circulation, and its exploration into seawater's memory speaks to the ethical engagements of the thalassontological. The circulation of seawater does not only eventuate the stories that water can tell about climate or about watery paths of travel – it informs the recovery of cultural memories in the wake.

Thalassontology, then, is part of the passage of migrants in the Mediterranean, but it does not belong to the temporality of crisis. It belongs to the circulation of seawaters over centuries, but also to the recuperative work of Zamora. It ties up memory in the swirling traces of temperature, clothing, and ocean chemistry that may tell both a story of the climate a millennium ago and the story of a person who was last seen in clothes covered in paint. Thalassontology is not meant to replace or to supersede notions of biopower and of bare life that reveal discourses of security and state power – it is instead a tool for thinking with the connective and displacing capacities of seawater and to submerge the ethics of migration in the ocean material. Submerged ethics need not be forgotten ethics, as the work of Zamora and of groups like Diving With a Purpose show.

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