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ARTICLE

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Making the Sea Knowable: Ocean Literacies From a Sea-Centred Perspective

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Abstract

In this article, I focus on the wave buoy and how it expands the concept of ocean literacy. The Directional Waverider buoy, manufactured by Datawell, is used worldwide to measure waves to produce knowledge about oceans in the context of rising sea levels and storm surges. My ethnographic fieldwork took place on the German North Sea coast, where these ocean developments affect the low-lying coastline. Using buoys along the coast is one way of making the sea knowable through datafication and climate modelling. To understand how the buoy pushes the limits of the concept of ocean literacy and what this means for human–ocean relations, I focus on the knowledge production processes of scientists working with the buoy and its data, and how the established infrastructure territorialises the North Sea. I subsequently show how the wave buoy rides the waves and how this relates to my embodied knowledge of the sea, drawing on Ingersoll's concept of "seascape epistemology." I argue that these knowledge practices are based on a sea-centred perspective, and that in order to remain stable, this infrastructure needs to be as supple as the sea. I conclude by suggesting that it is important to understand ocean literacy as a plural concept, as ocean literacies, as demonstrated by these plural knowledges.

Keywords

climate change; datafication; embodied knowledge; knowledge production; maritime anthropology; ocean literacies; seascape epistemology; territorialisation

1. Introduction

The concept of ocean literacy aims to better understand human–ocean relationships (McKinley et al., 2023). It is mainly developed from a land-centred perspective, targeting people's behaviour towards the ocean. The concept emphasises different aspects of the management and governance of the ocean—of making it legible. Knowledge of the ocean is one of these aspects. In the context of climate change and my field case, knowledge of the sea is needed to help protect people from rising sea levels and storm surges by building and elevating dykes and other elements of infrastructure that are used to manage and govern the ocean. To produce this knowledge, wave buoys, among other things, are deployed worldwide to record the behaviour of waves along the coasts. This brings us to the central figure of my ethnographic work: the wave buoy (see Figure 1). In this article, I examine, from an ethnographic perspective inspired by science and technology studies (STS), how the wave buoy measures waves and contributes to the datafication, territorialisation, and management of the ocean. My work thus contributes to the field of maritime anthropology, which focuses on human–ocean relationships (Roszko, 2021). Roszko (2021) notes that, despite a focus on the ocean, anthropological research has for a long time been situated in a land-centred perspective. This article challenges this terrestrial bias by turning attention to how the buoy rides the waves and reflecting on what this means for how the sea is shaped in knowledge production. In addition, this perspective allows me to challenge the land-centred perspective that often underlies the concept of ocean literacy. I aim to show that there are plural ways of being ocean literate and how these ways can be more sea-centred.

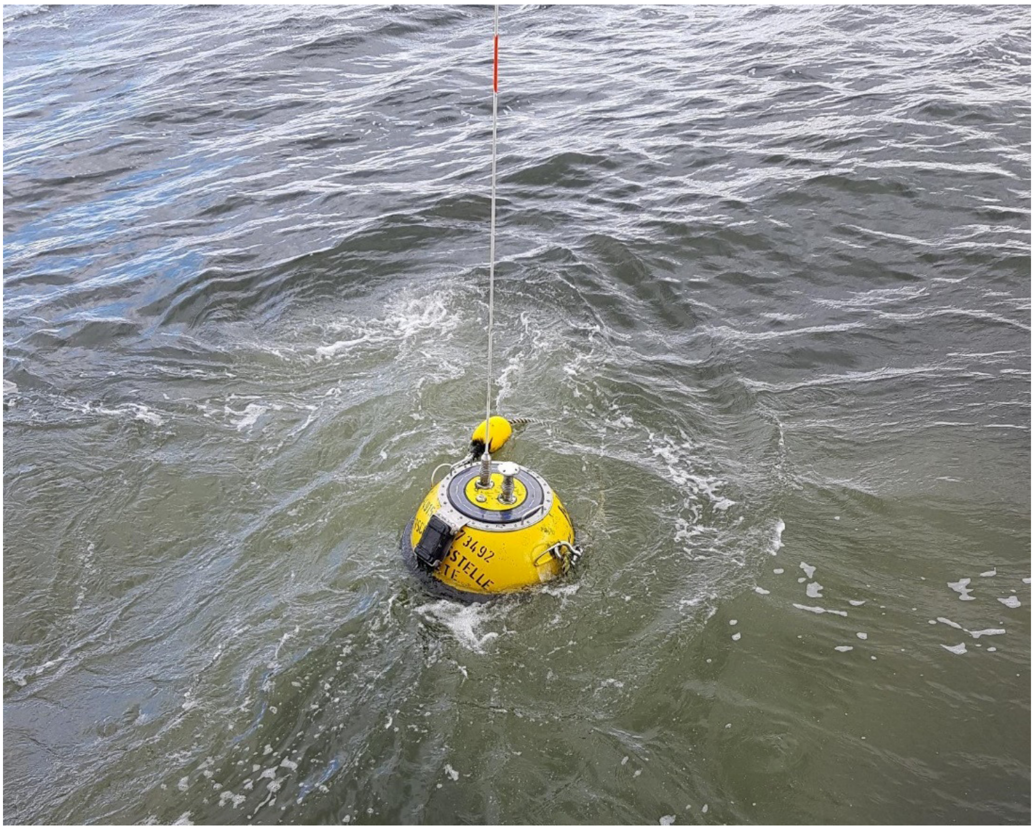

Figure 1. Wave buoy in the North Sea.

My interest in the wave buoy emerges from my experience surfing. From the beginning, I had noticed something of an obsession that surfers had with the surf forecast, which plays a major role in every conversation between them. After a few years of surfing, I wondered how the surf forecast, which I would use every day for surfing, is made. The answer from a friend was: with buoys that measure waves off the coast. My ethnographic curiosity was aroused. After some research, I soon found out that one of the most widely used wave buoys is the Directional Waverider from the Dutch company Datawell. It was developed following a severe storm surge in the Netherlands in 1953 to monitor the behaviour of waves a few kilometres off the coast. The aim was to prevent such serious disasters in the future (Joosten, 2013). Until today, knowledge about the waves is produced through these wave buoys to help ascertain the strength of the dyke infrastructure along the North Sea coast as well as to make better predictions about when and how strong the next storm surge will be. To predict storm surges, and create surf forecasts, climate models are used. Based on model data and observational data, they calculate how and when the next storm surge can be expected. The vision of ocean management is now so far-reaching that efforts are being made to develop a digital image of the Earth, or what is called a digital twin. The digital twin can be understood as an Earth system model in which all climate models that have had different orientations are combined into one. The digital twin is intended to provide an even more comprehensive overview of planetary developments and make them manageable (field note, October 5, 2023; Rothe, 2024). This project requires data from wave buoys.

As part of this research, I worked with scientists from three scientific and state institutions that work with the wave buoy or the data it generates on the German North Sea coast. These scientists maintain the buoys, look after the measurement network, and use the data from the wave buoys to research waves, storm surges, and storms—and thus produce knowledge about how waves behave. I see this knowledge production as one form of ocean literacy. The design and operation of the buoy and the knowledge practices around it play a crucial role in building infrastructures and therefore influence how people living on the German North Sea coast shape their relationship with the ocean. In this article, I will argue that there are other ways of understanding ocean literacy. Both the ways in which the buoy rides the waves, and my embodied surfing knowledge point to a plural understanding of ocean literacy. To argue this, I will draw on Ingersoll's concept of "seascape epistemology" (2016), which brings in an Indigenous perspective of being and moving with the sea in constant movement. In other words, I am interested in how the wave buoy expands the concept of ocean literacy, and in what it can teach us about human–ocean relationships.

To analyse this, I will begin by describing in the next section how the scientific practices and the wave buoy are connected and how the buoy acts as a mediator. The third section then focuses on how the infrastructure around the buoy territorialises the North Sea from a land-centred perspective. In the fourth section, I describe how by riding the waves the wave buoy is in excess of them and how this is connected to embodied surfing practices in order to argue that ocean infrastructure has to be as supple as the sea itself. Finally, I draw on Ingersoll's concept of "seascape epistemology" (2016) to develop a sea-centred perspective that acknowledges plural knowledges of the sea to then argue for a plural understanding of the concept of ocean literacy—ocean literacies.

2. The Wave Buoy as a Mediator: Scientific Practices

The wave buoy is yellow, waist-high, heavy, made of stainless steel, and reminds me of the Minions from the film *Despicable Me*. With a built-in accelerometer it can measure the wave spectrum, e.g., wave height and wave direction (Helmreich, 2019; Nielsen et al., 2023). It is deployed in the ocean near the coast, is regularly maintained, and sends data every half hour through a radio signal at a particular frequency to its receiver, which is often located on land or, if at sea, on offshore facilities. These data are then further processed by different kinds of scientists. I worked with meteorologists, oceanographers, hydrographers, and engineers of different research institutions, who use the data of the buoy in various ways and for different scientific tasks such as wave modelling or climate modelling. The climate models have a variety of purposes—one of which is to develop forecasts of oceanic futures, of what can be expected of them in the future.

By deploying the wave buoy in the ocean, collecting and processing the data that the buoy generates, scientists acquire technically mediated knowledge about the ocean. The buoy plays a mediating role in these practices. Wave buoys do not simply produce neutral data by measuring waves, but do this in a specific way. In his article "Reading a Wave Buoy," Helmreich (2019) focuses on the Directional Waverider buoy, which also plays a central role in my research. It is one of the most widely used wave buoys in the world: "The global gold standard in directional wave measurement" as the manufacturer, Datawell, states on its website (Datawell, 2022). Utilising the Directional Waverider, Helmreich (2019, p. 740) develops the argument that the buoy can be read in different ways: as a commodity, as a manifestation of territorial dominance, or as an embodiment of media ecologies. At the same time, the buoy reads waves itself through sensing practices (Gabrys & Pritchard, 2018). The buoy's sensory capacity—its ability to sense or read the waves—is conditioned by its specific materiality, the way it is built, and the technologies used, highlighting that technology is never objective (Benjamin, 2019). Therefore, the materiality of the buoy, and how it is built, shape what it senses, or what can be sensed (and thus known) in a particular way, or as Helmreich writes, "*what kinds of waves* are considered matters of concern by various anticipated users (e.g., storm surge waves that follow hurricanes, waves that batter oil platforms, waves that can be read as signs of sea level rise)" (2019, p. 741). Buoys are therefore "solid pieces of technology, but they matter within a comprehensive set of practical, social and political relations" (Hastrup, 2012, p. 18). The wave buoy is thus not a neutral but a socio-material artefact that is politically and socially powerful insofar as its inscriptions (Akrich, 1992) configure what is important by making specific characteristics of waves visible (while perhaps rendering other aspects invisible).

In *A Book of Waves*, Helmreich (2023) describes how waves off the coast of the Netherlands are "domesticated." A large-scale infrastructure had been built and is still maintained for this purpose. An important part of this infrastructure is the wave buoy, which has been integrated into it; however, its role goes beyond just measuring waves in the ocean—it also provides data for a "global information system" as described by Edwards (2010). To establish this global information system, various interlocking infrastructures have been maintained and further developed since the 19th century to record and make the phenomenon of global climate change comprehensible. This system consists of instruments that measure the Earth vertically and horizontally, such as weather stations, satellites, aeroplanes, and ships that make it possible to measure climatic conditions such as temperatures, or the use of water gauges that measure water levels and wave buoys that measure waves (Edwards, 2010, p. 4). The scientists I worked with contribute to this knowledge on the climate with wave buoys that measure waves which are then transformed into data and models. Lovis, one of the scientists, gives an overview of the process:

> I think it's quite good, we've talked about how you collect data, how you then process the data, and that the best thing to come out of it is an explanation of what you've seen and why....That actually describes the whole process, what we do [laughs]. (Lovis, interview)

As Lovis explains, the knowledge they acquire is produced through practices in which each step relies on the one before and after. The buoy is thus part of a data transformation chain in which knowledge that takes the form of scientific explanations is produced through “translation” processes (Latour, 1999). Following Callon, I understand these translation processes as (hierarchical) relations through “which the social and natural worlds progressively take form” (1984, p. 224). In these translation processes, scientists make decisions while speaking on behalf of the buoy and its data. But these processes also transform how the ocean is perceived, how data are produced and circulated, and thus contribute to a scientific form of ocean literacy.

The wave buoy primarily assumes the function of a “reference” in two respects in this transformation process. In relation to other sea state measurement methods (e.g., from a radar), it is regarded as “something like the ‘standard’ against which all other methods must be validated to be recognised” (Kay, interview). At the same time, its role in the climate modelling process is to validate the calculations. The buoys’ data are considered observational data, whereas the climate models are considered differently insofar as they primarily calculate with model data and are driven by these. The results of these calculations are compared with the observed data from the buoy. The “model world” is therefore constantly being compared with data collected in the water. In other words, the wave buoy mediates between the “model world” and the “observable world” or the sea; it builds the bridge and the reference that can validate what happens in the “model world.”

In this process of validating the “model world” by acting as a reference, the wave buoy does not just measure the waves and send these measurements to the “land” in the form of data, but it interprets the data themselves, as Lovis tells me in an interview (Lovis, interview). This interpretation already happens before the scientists deal with the data. The interpretation can be understood as a kind of correction. If something is implausible, which means measured values do not correspond to the physical laws that are programmed into the buoy, the buoy corrects this. The buoy therefore “knows” what waves should “look like.” When I ask how the wave buoy does this, Janne, another scientist, replies:

> [Measuring] direction is very exciting from a technical, metrological point of view, because it is always said that swell is frequency-direction spectrum, which is what such a buoy spits out. But this is actually an estimate. So, it is estimated from the movements of the buoy what the frequency-direction spectrum is most likely to be. It’s not a directly measured spectrum. (Janne, interview)

This estimation takes the form of equations that are based on statistical distributions and are programmed into the buoy. The equations assume a normal state of how waves should be depicted in the measurements. If the measurement of the buoy does not represent this, what Janne calls the “filters” in the buoy intervene in the measurement, “which ensure that what the buoy measures is as close to reality as possible” (Janne, interview). These filters are technical methods that involve “Elektrotechnik” (Janne, interview) and signal processing. Therefore, the filters clean up the buoy’s measurements whenever there are outliers and where what is measured is not understandable as “waves” to the scientists sitting at their desks looking at the data. However, Janne describes that these “filters…sometimes [do] funny things with the waves” (Janne, interview), for example when these do not correspond to the “normal conditions” to which the buoy is exposed in most cases. Then the filter “can suddenly do things that look like waves” (Janne, interview). When such cases occur, the scientists’ “hand tools” are required in the form of a plausibility check. These tools are based on an experiential knowledge that the scientists build over time to recognise and explain inconsistencies. But even here, says Janne, you may get something wrong (Janne, interview). In other words, "normal conditions" for sea conditions are defined so that outliers can be adjusted to this norm by the buoy itself and the scientists. This experiential knowledge shows that the scientific practices are based on several forms of knowledges. These scientific practices, or these scientific forms of knowing the sea, concerned with the measuring of the waves are part of what I call the laboratorisation of the North Sea. In laboratories, everything is standardised, extracted, and transformed. It is a place where the social and natural order are relationally reconfigured by all the actors—human and nonhuman—involved (Knorr-Cetina, 1992, p. 134). Therefore, the laboratorisation of the North Sea aims to make general claims about the ocean and make it legible.

For Lovis, dealing with these inconsistencies means above all that scientists must be aware that the buoy serves as a kind of "mediator." The surface deflection itself, i.e., the waves, cannot be recorded in themselves; instead, there is only what the buoy senses and conveys. As it has a large, heavy body, it cannot record every small wave: "Yes, the buoy itself interprets the data. So that's something you have to be aware of, that the buoy doesn't contain the truth, but only what it sees and what it interprets itself" (Lovis, interview). In addition to the aspects that the buoy selectively mediates—thus creating the basis for the scientists to grasp the ocean in a particular way—Lovis also describes an observation that certain waves cannot be interpreted by the buoy and are not adapted to the norm:

> What fascinates me is that you can do as much research [on extreme waves] as you like. In the end, they do what they want....You always try to approach things neutrally. But at some point, you have an idea of what it should be like based on experience. And then you look at the measured values, and it's different. And I think that's kind of great [laughs]. I always have the feeling that nature is winning against me, and that's how it should be [laughs]. (Lovis, interview)

This clearly shows that the strategies used by scientists to make waves comprehensible are only possible within a limited framework. The laboratorisation of the North Sea builds on the mediation by the buoy by inscribing assumptions in the form of reference values, in mathematical equations, and by providing already interpreted measurement data. Therefore, the ocean literacy that emerges here is based on the practices of the scientists around the wave buoy, its data, and the buoy itself, which makes it possible for the scientists to produce knowledge about the waves in the first place. At the same time, however, the waves in the form of measured values behave in an unpredictable way on a regular basis. "Nature," as Lovis notes, repeatedly eludes and "wins" the dance around the rules of physics that guide the expectations of the scientists, which have to be defined and revised again and again by scientists because the ocean behaves differently than expected. The scientists need to be limber and supple towards the sea as they produce knowledge on this flexile and mediated basis that is the sea. The laboratorisation of the North Sea, which aims to make the waves understandable through translation, is therefore built on a supple foundation, which I will explore in the next section.

3. The Wave Buoy as a Sentinel: Territorialising the Sea

The wave buoy watches over the waves off the coast; it is a "sentinel," a "guard of the bay" (Helmreich, 2019, p. 744). For the buoy to fulfil this task, the North Sea must be datafied and infrastructured. The infrastructure serves the purpose of enabling people to continue living on the coast in the face of rising sea levels and extreme weather events. Storm surges, especially those with serious consequences such as those in the Netherlands in 1953 or on the German North Sea coast in 1962, which caused dykes to break and many people to die ("Sturmflut 1962: Als Hamburg im Wasser versank," 2024), make it clear that the North Sea requires this attention. Knowledge is needed about the water's behaviours because water is always in motion and can become threatening. Sea state forecasts help to produce knowledge about the North Sea and to initiate measures to better prepare for and prevent such threatening and momentous events. This effort to infrastructure the North Sea, however, indicates that it is seen as land. Even the buoy, which is part of that infrastructure and is deployed by humans in the sea, is oriented towards the shore insofar as humans want to have knowledge about the sea to protect the land, namely, to turn it into a territory. I use the term "territory" derived from the Latin *terra*, which signifies earth or land, and is defined as "area, country, district; land" or the "territory of a state, domain" (Territorium, n.d.). On the one hand, this indicates that the North Sea is thought of here in terms of land, and, on the other hand, that territories are associated with an exercise of (state) power. One of the aims of this, what I call territorialisation, is to preserve the North Sea coast as a living space for people by dealing with the water, by turning it into a territory. To do this, threats and unpredictabilities like stronger storm surges, warmer water, and rising sea levels due to climate change need to be managed.

However, this motivation to "territorialise" the sea by making it an object of prediction and governance also extends to other areas, and has its own specific history. For instance, military interests continue to characterise the development and advancement of the precision of these wave and wind forecasts (Van Dorn, 1974). Wind farm operators in the North Sea also need this information to build appropriately robust wind farms (Janne, interview). Shipping companies, fisheries, and oil platform operators use the information to navigate (field note, April 24, 2024). The sea state forecast is based in part on the data measured by the buoy, which monitors the waves as a sentinel. Numerous users, who all need the knowledge to understand the forecast, use this information. This is another kind of ocean literacy that I call forecast literacy.

These processes of forecasting the sea have one goal: The ocean is to be datafied and thus made tangible, accessible, and navigable. Datafication refers to a knowledge-production process in which qualitative, perceptible aspects of life are transformed into quantitative data (Ruckenstein & Schüll, 2017, p. 261). However, to be able to measure waves at all, an infrastructure is required (cf. Larkin, 2013). To build this infrastructure, knowledge, data, "practices, materials, and settings of infrastructuring" (Blok et al., 2016, p. 3) are brought and held together in a constant process. Nadim (2021), for instance, describes this data infrastructure or data-mediated relational constellation of humans, materials, and places as "data formations." The buoy's data are thus related to a variety of different kinds of data, bodies, and materials. They continually form an infrastructure that sustains the existence and proliferation of data, while also ensuring that the sea can be used in a safe way as a "territory." Yet, it is important to note that the assumptions and decisions inscribed in the wave buoy are not neutral but follow certain knowledge hierarchies. In this way, hegemonic descriptions of the world prevail (Nadim, 2021, p. 68) through the hierarchies inscribed into the way these data describe the world because the datafication of the ocean serves particular interests of humans for managing the ocean.

The infrastructure for gathering these data is made up of several relational elements. There are the maintaining practices around the buoy itself, trips with the research vessel (which must be ready to sail and equipped accordingly), nautical charts, weather and sea state forecasts (which also come from the buoys), the expert and experiential knowledge of the scientists and technicians, the navigational buoys and other markers in the water, all the technical equipment on the ship that makes it possible to sail smoothly, the crane that lifts the buoys out of or into the water, GPS probes and data, the programmes with which the positions and data are checked beforehand, and the wave buoy itself. It is a large and complicated network of different elements, which are relationally intertwined: The buoy relies on the network and the processing of the North Sea as an infrastructure and the infrastructure of the North Sea relies upon the sea state predictions that the buoy provides. In other words, there is a mutual dependency between the maintenance of the infrastructure and the buoy. If errors or problems occur in this interdependent relationship, the buoy will not be able to fulfil its task of measuring the waves, which, in turn, makes the infrastructure "visible." This mutual dependency shows that there needs to be a constant process of adapting to the conditions of the sea. Like the knowledge practices of the scientists, this infrastructure also needs to be limber. It is the *excess* of the buoy that indicates this suppleness. Building on the work of Rheinberger (1994, p. 77), I refer to excess as a term that describes the unforeseen or unplanned events that happen in laboratories or "experimental systems." In order to deal with this excess, the scientists' handling of the buoy and the work around it follows structured procedures as part of the laboratorisation of the North Sea.

During maintenance trips, it becomes clear how much the employees on the ship have to work together and rely on the infrastructure. If this workflow is disrupted by various factors, e.g., a swell that is too rough, or if individual team members behave in unexpected ways, the situation can become dangerous and everyone is aware of this. The buoy monitors this potential danger because the ship will only sail when the forecast looks good enough. However, the suppleness of the infrastructure becomes visible when the excess of the buoy manifests in the buoy's behaviours, like when it is "dancing across the deck like a wrecking ball" (field note, April 24, 2024) while hanging from the crane, or when the buoy cannot be found in the water, or when the ship cannot approach the buoy due to excessive waves and unfavourable winds, making it inaccessible. The buoy therefore watches over the network; it indicates through its excess that the infrastructure needs to be flexible.

The constant processes of maintaining a limber infrastructure are necessary because the coast is a space of interaction (Janne, interview) in which a lot of movement takes place. People's attempts to understand this better with the help of the buoy, and to take measures to control these changes and movements as best they can, are, in turn, part of the process of territorialising the sea. This "maritime territorialization" (Roszko, 2021) is likewise visible in terms of the division of economic zones. The buoys are maintained by the respective institutions within these zones of responsibility. With the economic zones, concrete borders are defined for the space that is then called, e.g., the "North Sea" or the "German Bight."

But the ocean is a contradictory space. While it is a space that is constantly under processes of domestication and territorialisation by humans, to produce knowledge, generate data, and constitute territories, it is also, on the other hand, untamable or controllable, as Helmreich (2009) and Roszko (2021, p. 9) have described. In this tense relationship, the buoy is part of domestication, of making the ocean knowable, and of establishing it as a territory, as an extension of land, and yet it makes clear that the ocean cannot be domesticated when, for example, the buoy breaks free because the swell is too strong, that is, in its excess. In conclusion, the wave buoy indicates through its excess that the infrastructure needs to be supple like the sea, both in order to ensure its maintenance as an infrastructure, and also to provide forecasts and protection for people who live along the coast—in other words, to be able to constitute the sea as a territory.

4. Riding the Waves

In this section, I turn my attention towards the wave buoy in the sea. I will show how the buoy rides the waves and how this is intertwined with practices of surfing and the infrastructure that needs to adapt. The buoy, with its large, heavy metal body, moves freely in the waves thanks to a rubber rope but is simultaneously fixed to the seabed by a heavy iron weight, an anchor. The rubber rope keeps the buoy in check; it determines the radius in which the buoy is allowed to "dance"; it is flexible and at the same time firm—or, in other words, supple. The rules according to which the buoy dances are determined by the waves, but also by the people who built it, positioned it in a specific place, tied it down, and anchored it. However, the buoy regularly breaks out of these rules. Referring to this as excess (Rheinberger, 1994), the scientists' handling of the buoy is often geared towards managing the uncontrollability of both the buoy and the ocean. The excess of the buoy shows that the investigation of the waves is made possible only by an infrastructure that, too, is limber and in a constant adaption to the sea.

As one scientist told me, the word "buoy" is not really a suitable term for the wave buoy, but, instead, "waverider" is much more appropriate because that is what the wave buoys do: They ride the waves (field note, May 9, 2023). The word "buoy" is in itself a collective term that combines a variety of different floating bodies. Some serve as "red or green fairway marker buoys" (Janne, interview), others mark harbour entrances and swimming areas, or indicate where divers and swimmers are located. However, these buoys are rather passive: They are not supposed to move but remain in the same place or are passively pulled along to mark a specific point in the water. The wave buoy, in contrast, works differently. The rubber rope allows it to ride waves, to, as they say, "dance" in the waves. In fact, the rubber rope turned out to be very central to the scientists' ideas:

> Actually, I then only see this rope in front of me in a very scientific way. So then…I just see in front of me the diagram of how the buoy lies in there, like a cut through the water, where you can see that there is a heavy anchor chain at the bottom and then this rubber rope. And then I look at the rubber rope and hope that it will hold and that the buoy will really be able to dance there and that it will be held in place. (Lovis, interview)

Two aspects of this quote seem relevant to me here. Firstly, the rubber rope gives the wave buoy the room it needs to dance. At the same time, it limits the radius in which it is allowed to dance. This can be up to 20 meters (Janne, interview). The buoy is held in place and generally does not move anywhere else. However, Lovis already indicates here that they expect the buoy to break free. Another aspect is the imagination of the buoy in its environment. Lovis, for instance, speaks of a "scientific way" of looking at the buoy, through the idea of a schema, or diagram, a section through the water in which all the components that hold the buoy in place and make it dance at the same time are imagined in a two-dimensional view.

Janne describes the purpose of the wave buoy differently. It is supposed to measure the wave spectrum (Nielsen et al., 2023), i.e., the surface deflection of the water surface. The scientist describes the mobility made possible by the rubber rope as follows:

> The idea is that you want your buoy….So, it should stay at the place where it is supposed to measure the swell spectrum, so to speak, but at the same time it should be free, as free and unhindered as

possible to follow the circular paths that such a wave makes on the surface, on the surface deflection. (Janne, interview)

However, the buoy sometimes has difficulties following the waves on the surface. If the waves are too high, it "can be pulled through the crest" (Sanja, interview) and then measures inaccurately:

> And then it can also be when the waves are very high and then actually the most interesting thing for me is that the buoy goes with the wave, but then, before it reaches the crest of the wave, it slips a bit and slides past it. It's a well-known fact that buoys often don't hit the top of the wave at all [laughs]. (Lovis, interview)

This happens because the buoy can only reach a certain height with the waves due to it being anchored and the limited length of the rubber rope. The rubber rope often cannot withstand very high waves and breaks regularly (field note, April 25, 2024). Due to its relatively large and heavy body, the wave buoy also cannot perceive very small waves. Its dance therefore only takes place in a certain wave height spectrum.

This demonstrates that two contradictory requirements are placed on the buoy, namely, that it should remain at a fixed point while still moving freely with the waves to measure them accurately. The fixed point is important because the measurement data are aligned to this specific point and the measurements should be comparable. At the same time, waves are always in movement, and it is precisely this movement that the buoy should record by dancing. In the imagination of a physical model, the circular paths of waves always have the same effect. If one realises that the water surface is constantly changing due to various factors, such as wind, the circular paths may still be physically (explainably) the same, but waves can come from different directions, intersect, overlap (Lovis, interview), and get whipped up or flattened by the wind. These circular paths, the surface deflection, can therefore be very different. In addition to the peculiarities of the waves, the buoy also regularly defies the rules of dance due to its design and the material used, and, above all, the conditions of the sea.

I am told that some buoys regularly break loose. For example, one "sits" in a place where extreme waves often occur. A scientist shows me a graphic with the words: "We had a [buoy] that went on a journey, 900 kilometres in a week" (field note, April 24, 2024). The buoy ran aground on the island of Sylt and had to be collected there. One of the scientists then calculated the distance and the path that the buoy had travelled in the water. As the radio frequency was not sufficient on the way through the North Sea, the measurement times stored on the SD card could be used for tracking, as fortunately the buoy's battery level was sufficient. The tracking, which resulted in a graph, also shows the tide and the speed at which the buoy was travelling (see Figure 2). The graph of the measurement times provides information on how the buoy was moving. The scientist explained why the buoy made a long circle in the North Sea and finally landed again on an island just north of its actual location by comparing the wind directions of the respective days. The wind had influenced the drifting direction of the buoy. Another buoy was found in the middle of the dunes of an East Frisian Island (see Figure 3). Explaining this and translating it into a graphic followed a similar procedure. The buoy must have "wandered" across the island during high tide, and when the island was probably flooded.

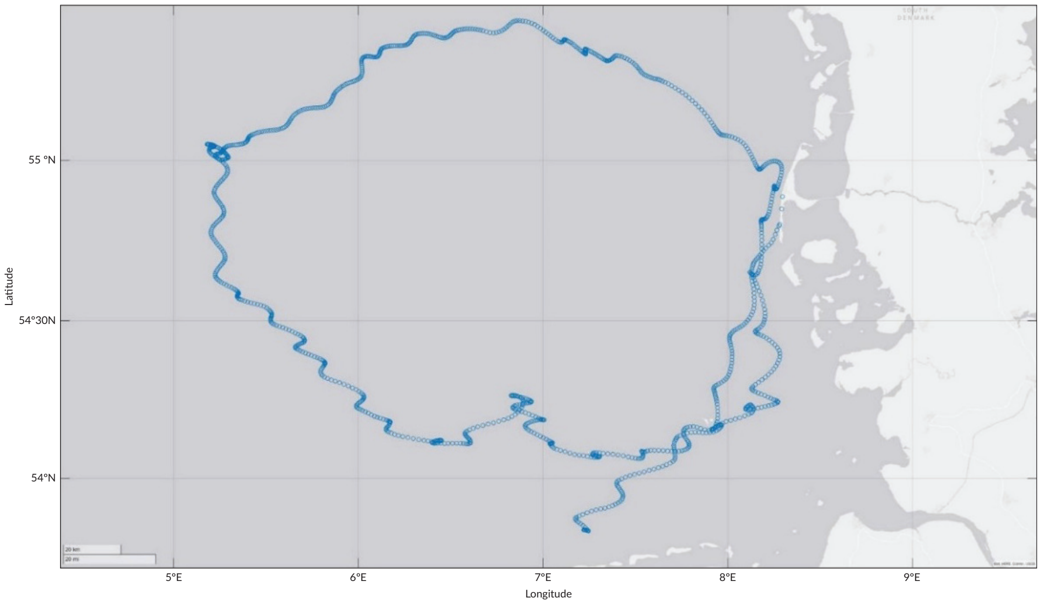

Figure 2. The travelling of a buoy in the North Sea. © Produced by members of Forschungsstelle Küste des Niedersächsischen Landesbetriebs für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN).

Figure 3. A buoy in the dunes. © Produced by members of Forschungsstelle Küste des Niedersächsischen Landesbetriebs für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN).

An additional factor in enabling the buoy to ride the waves is keeping it as undisturbed as possible: A special smooth yellow paint is used to prevent mussels and algae from settling on it; they are removed with a strong jet of water during maintenance trips if they are still able to latch onto it. This is done to preserve the ability of the buoy to move symmetrically with the waves. Zinc sacrificial anodes are used to prevent the metal of the wave buoy from corroding in salt water. Maintaining this standardised condition is an extensive undertaking in view of the numerous excessive "impairments" caused by the sea. All of this, from the rubber rope and the slack of the anchor to the removal of mussels, shows that the infrastructure which keeps the wave buoy riding the waves needs to be as flexible and supple as the sea itself. Hardening the infrastructure would make it impossible to withstand the conditions that the sea imposes on it.

On my surf longboard, I too want to dance on the waves. I too need to be as supple as the sea. Surfing is also known as "wave riding." Just like the buoy, I perceive the waves in which I move with my surfboard; I drift in them, but I also control my position so as not to be carried too far away from the shore by the current or the wind. As a surfer, I use the surf forecast which is based on the data from the buoy. The forecast informs me about the waves coming in on the coast. I know how to read the forecast and decipher the figures in it. I have forecast literacy.

When I go surfing, I check the wave forecast every day, either in the form of an app or a website. The surf forecast is based on the same principles as the forecasts that scientists use, for instance, to calculate storm surges. Gerrit, another scientist, describes what needs to be done with the model's prediction in their work:

> In other words, you trust that the models will be able to roughly calculate [predictions] into the future. And part of it is, of course, that you then look to see when this model has finished calculating, has made a prediction, and, at some point, this point in time will occur. And then you know what it really looks like. And then you look, did the model calculate roughly correctly or not? (Gerrit, interview)

Gerrit states that the more likely case is that the model did not calculate correctly. The comparison between what the prediction indicates and what is then found in the water (mediated by translation processes) can differ greatly. Gerrit describes that the wave buoy data have a very high temporal resolution (Gerrit, interview) and therefore cover shorter time periods better, whereas model data, for example, cover much more widely separated points in time. These high-resolution data are visible, for example, in the hourly wave forecast for surfing. On surf-forecast.com or surfline.com, like everyone else who wants to go surfing, I check which direction the waves are coming from, how high they are, what the swell period and wave energy are, which direction the wind is coming from, when it is high tide or low tide, and I use the map to decide where a surf is most likely to be suitable for my surfing level and preferences. That is step one. Step two, however, cannot be deduced from the data. For this, I need the experiential knowledge about the ground at the surf spot, the orientation of the bay, whether it is sheltered from the wind according to the wind direction, and the effect of the tide at the specific location. Step three is then the "spot check" or "wave check" to see whether the conditions correspond to the forecast. Step three also shows how many other people are already surfing in the water; people who have made the same comparison with the same knowledge. It is only after this final check that I put on my wetsuit and go surfing. Thus, in everyday practice, I compare the model forecast in the form of a surf forecast with the conditions I find on the spot. I become a mediator like the wave buoy. I too relate the forecast figures to the waves that I can observe and experience, a process that is not dissimilar to that of the scientists who check the accuracy of the model calculations with the observations of the wave buoy.

In addition to forecast literacy, I need this embodied knowledge to be able to read the waves that I can observe because I already know how they *feel*. When I am in the water I feel the tension between the ocean and myself: I can sense the energy in the waves, how I float with my board, and how small and insignificant I am in relation to the ocean. This knowledge makes clear to me that I cannot control the ocean and that I am at its mercy and its excess. Hence, I should behave according to what I know. This, in contrast to the scientific form of literacy, or forecast literacy, is an embodied form of ocean literacy. Since I cannot control the waves, I try to find a way to deal with them, and this may include not going into the water because I cannot and do not want to control the situation. These embodied and experiential knowledges help me navigate in the water. I know something about the bay where I want to go surfing: what the sandbanks are like, where I can best position myself, where the current is that will take me into the "line-up," and what the tide is like. These knowledges and practices connect me to the wave buoy as I move in the water in the same limber way, relying on the buoy's work in the form of the surf forecast, the supple infrastructure, and my embodied and experiential knowledges. It is this sea-centred perspective, becoming as supple as the sea, by riding the waves like a wave buoy, that challenges land-centred perspectives of ocean literacy.

In summary, it can be said that the wave buoy is riding the waves excessively. This shows that the infrastructure which territorialises the North Sea has to be as limber as the sea itself. Riding the waves as a wave buoy and also as a surfer, excessively and embodied, are practices pointing towards a flexible understanding of the sea which challenges land-centred perspectives.

5. Challenging Land-Centred Perspectives: A Seascape Epistemology

The efforts to understand the waves in a scientific way are based on an infrastructure that maintains the coast as a habitable space. The sea becomes, in this maintenance, territorialised through a form of ocean literacy that approaches the sea from a land-centred perspective. However, as I have shown in the previous sections, the infrastructure which is maintained to make the sea knowable is dependent on its suppleness. It needs to be as limber as the waves, flexible like the wave buoy. The buoy is not fixed in the sea, like a fixed territory, but rides the waves: It is with the water, with the wind, and with more-than-humans, like mussels or algae, and other living beings in the ocean. This connection to the water, as in my surfing, is also about feeling, sensing, and being *with* it. In this section, I am interested in how this sea-centred perspective of knowing the ocean can help us think about how the wave buoy expands the concept of ocean literacy, and what we can learn from it about human–ocean relationships.

Ingersoll (2016) turns away from land-centred perspectives to develop the concept of "seascape epistemology," which focuses on the ocean from an Indigenous perspective, as a relational place of being and knowing. This embodied approach to understanding the sea and the wind not as separate things, isolated from us, but as interconnected systems including humans is what I aim to highlight by theorising the buoy's experience as a form of ocean literacy. These systems are constantly in motion, just as I am, as a surfer, a part of them. As Ingersoll defines:

> [Seascape epistemology] is an approach to knowing presumed on a knowledge of the sea, which tells one how to move through it, how to approach life and knowing through the movements of the world.…As a philosophy of knowledge, seascape epistemology does not encompass a knowledge of "the ocean" and "the wind" as things. Seascape epistemology is not a knowledge of the sea. Instead, it

> is a knowledge about the ocean and the wind as an interconnected system that allows for successful navigation through them. It's an approach to life and knowing through passageways….Seascape epistemology organizes events and thoughts according to how they move and interact, while emphasizing the importance of knowing one's roots, one's center, and where one is located inside this constant movement. (Ingersoll, 2016, pp. 5–6)

Ingersoll develops this seascape epistemology through her embodied knowledge as a surfer and Native Hawaiian (Ingersoll, 2023, p. 37). In addition to my surfing experience, my embodied knowledge of the ocean is further based on my experiences underwater as a diver since my childhood, especially in the Aegean Sea. In addition, I grew up in northern Germany with its tides, dykes, and storm surges. I therefore have a specific embodied knowledge of water, the ocean, and the sea, and this immersed positionality in and with the water and the infrastructures around it allows me to grasp how the buoy rides the waves in a sensitive and intimate way.

Seascape epistemology also points out that colonial, military, and touristic aspects cannot be ignored in the way people interact with the ocean. These aspects are intertwined with the ocean and are therefore relevant to consider: "Despite our perceived identities as organic beings, surfers are neither innocent nor benign voyagers, and our experiences and our practices often escape our intentions and philosophies" (Ingersoll, 2016, p. 4). Surfing, for instance, can involve relying on touristic infrastructure that "colonises" areas to make them accessible to surfers, while at the same time being in the water, with the water, sensing and feeling it, riding the waves like a buoy. The infrastructure necessary to enable surfing and also to sustain life on the low-lying North Sea coast must be constantly adaptable and flexible to remain as such. Seascape epistemology allows us to understand the sea by thinking from the sea and approaching life as constant movement. The excess of the buoy as it rides the waves shows the sea as a limber and supple space that needs to be understood from the perspective of the sea. The wave buoy therefore expands the concept of ocean literacy. It embodies plural ways of understanding the ocean, forcing people to understand the ocean and their relationship to it in a supple way.

Scientists who study the waves too have to adapt their practices and the maintenance of the infrastructure they rely on to the conditions that the sea forces upon them. They produce knowledge about waves and make the ocean legible through physical explanations, data, and model calculations, but this is based on the excess of the buoy. They are aware of this uncertainty associated with the excess and the unplanned, and deal with it by maintaining an infrastructure that is constantly adapted to the conditions of the sea, as supple as the sea. The scientists' relationship with the sea is therefore aimed at understanding it in such a way that action can be taken to enable human life on the coast to be sustained. This relationship means understanding the sea from a land-centred perspective.

The supple infrastructure that is maintained also helps surfers expand their embodied and experiential knowledge when they use surf forecasts and touristic infrastructure. Surfers ride the waves, know, feel, and sense the ocean in an embodied way. In this way, they are connected to the wave buoy, which also rides the waves. My relationship with the sea as a surfer is embodied and experiential; it is intimate and sensitive to it.

Embodied Indigenous knowledges, inherent in the concept of seascape epistemology, understand the sea from a sea-centred perspective. Feeling connected to the ocean can be a refuge from colonial and capitalist structures for Indigenous colonised bodies (Ingersoll, 2016, p. 20). It can trigger and mediate reverent, unwavering peace by allowing one to drift and let one's mind wander. At the same time, the ocean can mean exactly the opposite: Even though the ocean can be seen as a refuge, a path to a better life, it becomes a grave for certain bodies through migration and border regimes. It is territorialised and militarised; it enables the transport of colonised bodies and goods. The human–ocean relationships that result from those plural knowledges are contradictory and full of tension. They are characterised by humans negotiating fear, respect, awe, humility, and strong feelings of connection, fascination, joy, and freedom. The tension is marked by a lack of knowledge and a sense of the power of the ocean, and at the same time knowing things partially and not being able to control them; it is about being in relation with what is an excess. When I go surfing, or when the conditions prevent me from doing so, I feel this tension of knowing partially and feeling the ocean, of being able to surf in partly domesticated conditions, and of the ocean's uncontrollability. Lovis also describes this tension when I ask how they think about the sea:

> I tend to have something wild in my head. I'm surprised myself, because the last time I was by the sea, the North Sea wasn't there at all [laughs]. There were only mudflats or the water was smooth. But actually, when I think of the sea, I think of something that foams and moves in all directions. And especially this thing with energy, that there is an incredible amount of energy in it and that we have already done a lot of research on it and still know very little. And we will probably still know very little in 100 years' time. So much is happening. That's why, in my opinion, we shouldn't intervene so much in all these things. We should leave nature alone for a bit....And have respect for it too. I think research also makes you respect it, because you try to explain things. But you realise that you can only explain a very small part of it. (Lovis, interview)

Lovis advocates for being a little more modest, doing less shipping, and exploiting the sea less (Lovis, interview). This would be an approach to not only manage the North Sea but to change the way we deal with it.

In summary, the buoy's excess, my embodied surfing knowledge, and the scientists' way of knowing show that different knowledges of the sea exist and that the contradictory characteristics of (not) knowing and (not) controlling reveal the plurality of ocean literacies because (human) endeavours to understand and be with the ocean vary greatly. Attempts to territorialise and domesticate the sea are linked to the management of the water, to make it accessible and usable for economic and military purposes. But for some, the ocean is also a refuge, a place of peace and tranquillity. It is a place that deserves respect, whether in a threatening or in a reassuring way. In other words, the sea needs to be understood as a supple place, and knowledges and practices need to be as limber as the sea itself, even when they are contradictory and full of tension. I have shown that land-centred perspectives are challenged by the wave buoy and that the different ways of having relationships with the sea lead to a plural understanding of ocean literacy.

6. Conclusion: Ocean Literacies

This article focused on the question of how the wave buoy expands the concept of "ocean literacy," and what we are able to learn from the buoy about human–ocean relationships. Through my focus on the wave buoy, fieldwork with different kinds of scientists, my positionality as a surfer, and the concept of "seascape epistemology" (Ingersoll, 2016), I argued for an expansion of the concept of ocean literacy, to turn it into a plural concept, that is, I argued that there are many ways to read the ocean, there are "ocean literacies."

I showed that all these different relationships with the sea are based on the suppleness of the sea, insofar as the sea requires one to always adapt; both the wave buoy and I as a surfer seek to align with the sea's suppleness, going with its flow, riding the waves. But also, in contrast to the solid and inflexible view of infrastructure, the infrastructure used and maintained to gain physical knowledge about the waves, to model possible outcomes, has to be as limber as the sea, as the wave buoy showed with its excess. The extension of the concept of ocean literacy to ocean literacies is based on my finding that there are plural knowledges of the sea and that some of these knowledges grasp the sea from a sea-centred—from the middle of it—rather than a land-centred perspective.

The wave buoy, through its excess, furthermore shows that understanding the sea as an expansion of the land, as a territory, does not grasp the suppleness or limberness of the sea and the need for constant adaptation of infrastructure to these characteristics. A sea-centred perspective allows for conceptual rethinking and includes embodied and Indigenous knowledges. Understanding ocean literacy as a plural concept, as ocean literacies, is a first step towards recognising and respecting plural forms of knowledge and thinking from a sea-centred perspective.

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