Maritime Studies (2025) 24:13
https://doi.org/10.1007/s40152-025-00401-8

COMMENTARY

Five commentaries on 'Waves Dangerous, Domesticated and Diagnostic' plus Stefan Helmreich's response

Darryl Colenbrander[1] · Clemens Driessen[2] · Michael Fisch[3] · Jun Mizukawa[4] · Philip Steinberg[5] · Renzo Taddei[6] · Stefan Helmreich[7]

Received: 1 June 2024 / Accepted: 1 August 2024

Abstract
This review article engages with Stefan Helmreich's paper 'Waves dangerous, domesticated, and diagnostic' as well as his 'A Book of Waves'. It offers a set of critical commentaries on key themes raised in these works unpacking the role of wave science, technology and power in various contexts: On treating waves as an outside enemy to be fought by hard barriers between land and water, or as objects of commodification when models functions as ways to claim and export knowledge thereby overriding other forms of knowing waves and protecting coasts; On the role of the state in coastal governance in the Global South and on transdisciplinary approaches dealing with the systemic nature of coastal risks and resilience; On comparison and integration of modern wave science with indigenous knowledges; On the importance of social besides physical oceanography; On practices of attuning not only to the daily tidal schedule and coastal weather, but also to the oceanic rhythms, tempos, and shifts that materialize the ocean's potentials and risks, and on waves as carriers of meaning. The review paper ends with a response by Helmreich.

Keywords Wave science · Flood risk · Coastal engineering · Coastal resilience

Commentary 1: Knowing the waterwolf inside

Clemens Driessen

The Dutch have a remarkable self-confidence when it comes to water. Water professionals in this highly secularized country somehow eagerly embrace the phrase 'God created the earth, but the Dutch created the Netherlands', often attributed to an enlightenment authority such as Voltaire or Descartes. This confidence seems primarily based on a half-century window of success in keeping sea water at bay, with no expenses spared. The peculiar condition of happily dwelling 'below sea level' has been marketed by Dutch water experts for selling their approach globally, drawing on the country as an experimental site, a testing ground for hydrological solutions, and a living proof of a population trusting in these. Stefan Helmreich, in the paper published here as well as in his 'Book on Waves', takes us on a journey to a variety of sites where waves are made and studied. Domesticated perhaps, or at least represented and simplified. We meet Dutch water experts, their models and their particular blend of modesty and pride.

✉ Darryl Colenbrander
Darryl.Colenbrander@capetown.gov.za

✉ Clemens Driessen
Clemens.driessen@wur.nl

✉ Michael Fisch
mfisch@uchicago.edu

✉ Philip Steinberg
Philip.steinberg@durham.ac.uk

✉ Renzo Taddei
renzo.taddei@unifesp.br

✉ Stefan Helmreich
sgh2@mit.edu

Jun Mizukawa
jm2063@columbia.edu

[1] City of Cape Town, Cape Town, South Africa

[2] Wageningen University, Wageningen, The Netherlands

[3] University of Chicago, Chicago, IL, USA

[4] Lake Forest College, Lake Forest, IL, USA

[5] Durham University, Durham, UK

[6] Federal University of Sao Paulo, Sao Paulo, Brazil

[7] Massachussets Institute of Technology, Cambridge, MA, USA

Published online: 13 February 2025

We attend the 'Waterwolf' flood preparedness exercise: an enactment of a disaster, described as a B-movie situated in a town harbouring a dark secret. The historical Waterwolf, threatening to engulf the fragile lowlands, was a zoomorphic creature representing the arch-enemy of the nation. Early-modern water managers were keen to portray the water as a wild force, an outside threat that needs to be tamed and domesticated. Meanwhile, this threat of flooding was as much a homegrown problem of ever-expanding inland waterbodies resulting from peat extraction. Not spectacular waves emerging from the sea, but burning the land as fossil fuel to heat Dutch homes and industry triggered the forces that engulfed villages and roads and that required increasingly ambitious engineering schemes to counter.

Helmreich takes us to another key site of Dutch water sciences: the Waterloopbos, a former outdoor laboratory with scaled-down hydrological models of harbours and other waterworks across the globe, now abandoned and overgrown. The physical structures that once assured coastal engineers of the soundness of their planned taming of waves offer a lush reminder of the materiality and situatedness of models: how these emerge at a particular time and place which unavoidably shape the reductionism inherent to modelling; how a particular community develops around these models; how shortcuts and decisions may be made in the context of events such as the model being frozen over; how key sites are scaled down, and knowledge is scaled up again, and how that knowledge is made to travel; where the peculiarities of one place get erased and implemented elsewhere, where the resulting solutions need to make new sense.

The trees and shrubs growing out of the miniature port models of Lagos, Abidjan, Karachi and Rotterdam produce a vibrant sense of the ways in which uncontrolled processes overwrite the realities produced in models. The Waterloopbos helps drive home the truisms of Science and Technology Studies: how we have never been fully modern in the sense of working rationally under ideal conditions; how these experts and their models, even, or especially when largely replaced by computer models, are not situated in universal mathematical space, but will hold very particular assumptions about what water is, how it poses dangers, what it means to protect land from water, and who has relevant knowledge to do so.

With Helmreich we follow the efforts of Dutch hydrologists in successfully exporting their approach to places which had much more fluid, adaptive and sensible ways of living with the ebb and flow of water. Places such as Bangladesh (Hasan 2022) where water/polder engineering has wreaked havoc while attempting to do good. The Netherlands in general - as my own institution (Wageningen University) also exemplifies - has over the past decades become a hotbed of state-funded, neoliberal knowledge production, with few hesitations about closely integrating governmental, corporate, scientific and engineering logics and institutions. Exemplifying the Dutch 'polder model' that draws on a collectivist spirit that assumes we-are-all-in-this-together, with flood protection - and export success - as a common goal. Not rocking the boat of this expertise appears a strong norm in wave land (Hasan 2022). Meanwhile, wave domestication is not merely a matter of exporting knowledge as development aid. In the wake of hydrological expertise, the globally dominant Dutch dredging sector is eager to deepen shipping access to ports and to realize artificial islands and storm barriers.

The political ecology of this form of water knowledge and its export –supported by government insurance and world bank financing- can now draw on the unpacking by Helmreich, exposing the limitations of transposing knowledge that is inherently situated and potentially riven with interests and assumptions. Especially as we learn how waves produced in wave tanks to calibrate the digital models can be proprietary: "Someone owns this wave" (Helmreich 2023, 51), making for exclusive access for corporate partners to generate proven ways of taming waves.

What the Dutch/Global North could learn from Bangladesh is how transposing, or translating, knowledge can best be understood in a more symmetrical, dialogic way of adjusting to political realities and cultural practices of living with water in the face of a range of challenges and possible answers (Hasan et al. 2022). In the process, opening up what amounts to water knowledge and who is considered to be a water expert. We can learn from these experiences, as well as from a large body of work in hydro-feminism (Neimanis 2017), how imagining coastal protection as fighting an external enemy while maintaining a hard boundary between land and water may create the illusion of safety but also sets land on a course to become ocean in a disastrous way.

While Dutch water engineers may heroically style themselves as battling an outside enemy, the 'wave' to come may not be a spectacular tsunami-style disaster, but a slow seeping under the dikes until they become unstable. Increased flood risks in a place such as the Netherlands will emerge in the form of ripples, when insurance companies retreat from securitizing polder-based real estate as infrastructural maintenance costs are weighed against the speculative prospects produced in combined financial and climate models.

Apart from learning about building-with-nature and living-with-water from other places and cultures which do not frame their experience via hard barriers between land and water, nor imagine separating engineering from the political ecologies of land and water use, there may be other potential models of learning emerging from these sites. After being reintroduced in the Netherlands in the late 1980s, beavers have been slowly but steadily making their way to becoming a driving force in Dutch water systems, and a growing nuisance to human water managers. Their claims of control

and incessant sensibility to flowing water; their mental models of keeping their environments wet, containing water in place rather than channelling it off to sea as soon as possible, may be a more sensible ethos of living with water. It is probably a matter of time until beavers will start using the Waterloopbos. Their water management logic could be a timely input to new forms of modest, careful experimentation, – their work acknowledged as modelling. Rather than fighting or taming the imagined Waterwolf coming from the outside, could a beaver-managed Waterloopbos function as a more-than-human model for knowing how to manage water? Perhaps that would help the Dutch, and other hard-headed modernist water managers, realize the Waterwolf may be the product of overly ambitious and self-assured ways of knowing waves?

REFERENCES

Hasan, S., Evers, J., & Zwarteveen, M. (2022). The Work That Goes Into Policy Transfer: Making the Dutch Delta Approach Travel. *Water Alternatives*, *15*(1), 56–72.

Hasan, S. (2021). *Making waves: Reimagining policy transfer in the context of development cooperation*. PhD thesis, University of Amsterdam https://dare.uva.nl/search?identifier=0ba394a7-ab96-42e5-8144-e0f20d965822

Helmreich, S. (2023). *A Book of Waves*. Durham: Duke University Press.

Neimanis, A. (2017). *Bodies of water: Posthuman feminist phenomenology*. London: Bloomsbury Academic.

Commentary 2: Modes of enquiry and the role of the state in building coastal resilience

Darryl Colenbrander

Helmreich's paper entitled *Waves Dangerous, Domesticated, and Diagnostic* examines – in the main—how waves are studied within the broader domain of coastal risk governance. In response to Helmreich's paper this commentary focuses on two themes provided from a local level government perspective in the Global South. Firstly the manner in which knowledge is produced, how it is used, and what this means within the broader domain of coastal risk governance is considered. Secondly, and with a focus on South Africa as a developing nation state, this commentary provides a reflection on differences in the role and capacity of the *state* as it relates to building coastal resilience.

Traditional modes of knowledge production (referred to as 'Mode 1'—see Klein 2014) are founded on positivistic enquiry. Within the discipline of oceanography and coastal engineering such forms of enquiry are ubiquitous and primarily manifests through mathematical simulations and modelling. As detailed by Helmreich, such forms of enquiry are central to informing responses to reduce or eliminate the risks posed by waves and/or coastal flooding. In the context of contemporary pressures arising from climate change induced risks such as coastal flooding that are inherently systemic in nature, the exclusive reliance on 'Mode 1' knowledge production is considered to be too narrowly conceived for the formulation of adequate responses (Schön 1995; Harris 2002; Cartwright 2012). The 'awkward fit' and associated mal-adaptive impacts that Helmreich refers to due to engineering interventions (founded on positivistic enquiry) in the Bangladeshi example is perhaps a consequence – at least in part—of the exclusive reliance on ' Mode 1' knowledge in responding to coastal risks.

A case study in South Africa reveals the same problematic of relying exclusively on 'Mode 1' forms of knowledge production. The formulation of socio-institutional responses (in this case coastal setback lines used to spatially demarcate coastal risk areas) based exclusively on 'Mode 1' orientated knowledge led to the failure in the adoption of the setback line. The setback line, in itself, was crucial to protect, and promote, a resilient and risk averse coastal community. The failure in the adoption of the setback line was because the process of delineating the setback line discounted, and underestimated, the socio-political, economic and temporal dimensions that are inherent constituents of planning for coastal risk (Colenbrander and Sowman 2015). Insofar as the temporal element is concerned, it was not related to the science of downscaling wave models and the temporal mismatch that results between real storm surge events and scaled down simulations as presented by Helmreich, but more to do with ensuring sufficient time for *engagement* between various governance actors. Sufficient time is required to facilitate iterative dialogue between communities at risk, consulting engineers and oceanographers in the formulation of risk reduction strategies. In South Africa this remains a challenge: often referred to as the consulting state – the South African government is heavily reliant upon the private consulting sector in developing sustainability orientated strategies (Oelofse et al. 2006), which includes coastal risk reduction strategies. Contractual appointments of the private sector however cannot accommodate the decadal timescales that may be required to formulate, and successfully implement, risk reduction strategies (Colenbrander and Sowman 2015). These findings align with Helmreich's assertion that understanding risks posed by waves and formulating appropriate responses requires an expansion beyond mathematical simulations and which interrogates broader environmental, political and governance considerations, and also pays heed to temporal elements. Achieving this underscores the imperative of 'Mode 2' forms of knowledge production. This form of knowledge production requires a process that brings together different knowledge orientations i.e. tacit, community, practitioner, expert and academic through trans-disciplinary engagement and over meaningful periods of time. This form of knowledge production is, as a result, more sensitised to socio-political and temporal considerations and is ultimately more socially robust (Gibbons et al. 1994; Nowotny et al. 2003). Indeed the critique

of relying exclusively on 'Mode 1″ knowledge production is fuelling shifts to a process whereby knowledge is 'co-produced' (Klein et al. 2001; Kasemir et al. 2003; Cundill et al. 2005; Hadorn et al. 2006).

The imperative of considering broader socio-political aspects in the domain of wave science and risk reduction also requires theoretical considerations of governance. Interactive governance, for example, proposes that governance in itself becomes "…a function of the interactions between government, the markets and civil society (Kooiman et al. 2005; Kooiman and Bavinck 2013). Whilst not explicitly examined, the Dutch and American case studies presented by Helmreich locate the state as a central and key governance actor that provides an enabling role in building coastal resilience for entire nation states.

Conversely, and acknowledging the differing contexts and risk profiles unique to each country, the demonstrative capacity of "reflexive modernity" (Beck 1992) as enabled by the Dutch and American state and which is critical to building coastal resilience, is less evident in South Africa. As a developing nation state, South Africa has neither the resources nor the capacity for such "reflexive modernity" to protect its citizens currently vulnerable from climate change induced coastal risks at scale. Whilst state led interventions are evident in the domain of coastal adaptation and planning which are geared towards the future, strategies and plans that provide solutions and responses to coastal communities currently exposed to coastal hazards are by-and-large absent. Indeed there is national legislation that *absolves* the state from protecting communities and individual citizens at risk from the erosive forces of waves along South Africa's 3000 km of coastline . The inability of the state to provide this support effectively leaves coastal communities as standalone entities to 'fend for themselves' and to navigate the process of responding to coastal erosion as a 'wicked problem' (Colenbrander 2018). This introduces a layer of complexity that, in itself, can provide fertile grounds for a range of both direct and indirect mal-adaptive impacts and where such impacts may be felt across the broader community. In the absence of the state, communities that defend their properties—and their livelihoods—against the erosive forces of the sea inevitably opt for the most economical interventions that are also oftentimes ill-informed. The direct consequence is either the pre-mature failure of such protective structures – and the resultant exposure of properties to coastal risk—or the deflection of erosive forces caused by wave energy to a wider area, thereby transferring, and expanding, the ambit of coastal risk and vulnerability. The indirect consequence is the gradual deterioration and loss of beaches – and livelihoods of which communities from broader geographic areas also depend, and that such impacts may be irreversible and 'locked in' across multiple generations. Indeed, the temporal, multi-scalar and socio-economic dimensions evident in these case studies supports Helmerich's assertion that wave science, and understanding coastal risk, is in every sense about "…time, about orientations toward the future – coastal, environmental, national, political, planetary" (Helmreich 2023).

REFERENCES

Beck, U. 1992. *Risk society: Towards a new modernity*, London: Sage.

Cartwright, A., S. Parnell, G. Oelofse and S.Ward. 2012. *Climate Change at the City Scale: Impacts, Mitigation and Adaptation in Cape Town*. Cape Town: Routledge.

Colenbrander, D. 2019. Dissonant discourses: revealing South Africa's policy-to-praxis challenges in the governance of coastal risk and vulnerability. *Journal of Environmental Planning and Management*, 62(10), 1782–1801.

Colenbrander, D. R. and M. R. Sowman. 2015. Merging socioeconomic imperatives with geospatial data: a non-negotiable for coastal risk management in South Africa. *Coastal Management*. 43 (3), 270–300.

Cundill, G.N., C. Fabricius and N. Marti. 2005. Foghorns to the future: using knowledge and transdisciplinarity to navigate complex systems. *Ecology and Society*, 10(2).

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, and M. Trow. 1994. *The new production of knowledge: The dynamics of science and research in contemporary societies*. London:Sage.

Harris, J. 2002. The case for cross-disciplinary approaches in international development. *World development*, 30(3), 487–496.

Hadorn, G. H., D. Bradley, C. Pohl, S. Rist, and U. Wiesmann. 2006. Implications of transdisciplinarity for sustainability research. *Ecological Economics*, 60(1), 119–128.

Helmreich, S. 2023. *A book of waves*. Durham: Duke University Press.

Kasemir, B., J. Jäger, C. C. Jaeger, and M. T. Gardner (Eds.). (2003). *Public Participation in Sustainability Science*. Cambridge, UK: Cambridge University Press.

Klein, J. T., W. Grossenbacher-Mansuy, R. Häberli, A. Bill, R.W. Scholz, and M. Welti. 2001. Transdisciplinarity: *Joint Problem Solving among Science. Technology, and Society. An Effective Way for Managing Complexity*. Basel: Birkhauser.

Klein, J.T. 2014. Discourses of transdisciplinarity: looking back to the future. *Futures*, 63, 68–74.

Kooiman, J. and M. Bavinck. 2013. Theorising Governability – The Interactive Governance Perspective. In M. Bavinck, R. Chuenpagdee and S. Jentoft, (Eds.), *Governability of fisheries and aquaculture: Theory and applications*. Netherlands: Springer.

Kooiman, J., M. Bavinck, S. Jentoft and R. Pullin. 2005: *Fish for life: interactive governance for fisheries*, Amsterdam: Amsterdam University Press.

Nowotny, H., P. Scott and M. Gibbons. 2003. Introduction: Mode 2 revisited: The New Production of Knowledge. *Minerva*, 41(3), 179–194.

Oelofse, C., D. Scott, G. Oelofse and J. Houghton. 2006. Shifts within ecological modernization in South Africa: Deliberation, innovation and institutional opportunities. *Local Environment*, *11*(1), 61–78.

Schön, D. A. 1995. Knowing-in-action: The new scholarship requires a new epistemology. *Change: The Magazine of Higher Learning*, 27(6), 27–34.

Commentary 3: Beyond the Blue Fear

Michael Fisch and Jun Mizukawa

Stefan Helmreich's article, "Waves Dangerous, Domesticated and Diagnostic" explores three sites of expertise where ocean waves are rendered objects of scientific inquiry, monitoring, and modeling as part of ongoing efforts to transform the unpredictable and often destructive natural force - the "Blue Fear" - into a manageable phenomenon. In so doing, Helmreich asks us to consider the kinds of epistemic and material challenges that the modulations of matter and form (water and sine wave) in motion present for future-invested practices such as national politics, infrastructure planning, and coastal management. Waves, in Helmreich's argument (and even more so in the book) are not simply an oceanic and maritime problem. Rather, waves embody the central problematic of our age - how do we live with the rapidly transforming and increasingly unpredictable forces born at the intersection of human activity and a dynamic, lively earth?

The weight of Helmreich's discussion tracks the translation of waves into meaning and knowledge. That which escapes the transductive practices of knowledge and meaning production resurfaces in the shape of uncertainty that drives fear of the oceans' destructive potential - the Blue Fear. At the same time, Helmreich gestures (particularly in the book[1]) at points to where that which escapes translation is treated not merely as a remainder irreducible to the signifying structures of epistemology, but rather as a force that animates different ways of living with the dynamism of the waves. The notion of an oceanic force that resists knowledge practices while simultaneously being transformed - if not intensified - by human practices resonates with what Christopher Görg, drawing from Theodore Adorno, calls the "non-identity of nature" (Görg 2011, 45–56, Saitō 2022, 109). As Saito Kohei cogently suggests in his reading of Görg, the "non-identity of nature" presents us with the matter of a nature that is irreducible to thought and "escape[s] comprehensive organization and control" (Saitō 2022, 109). It can only be lived as something that is deeply entangled with human society and yet not subject to the human conceit and aspiration to master nature. It is the effect of this force and the different way of living with the matter, form, and movement embodied in the wave that we want to explore briefly here by asking how waves ask us to think and to live. In so doing, we draw inspiration from another of Helmreich's articles to think transductively in the sense of exploring how waves elicit transformation by animating relationships between different ecological orders, by which we mean, for example, marine and coastal ecologies.

To understand what it means to live with the transformative force of waves we can look to the residents of Japan's northeast coast, the *tohoku* region. For aquaculture famers of Kesennuma, the ocean is an unbounded living field of potentials and risks. This relation is manifest in their annual *Wakame* (kelp) cultivation, which demands attunement not only to the daily tidal schedule and coastal weather, but also to the oceanic rhythms, tempos, and shifts that materialize those potentials and risks. Once the kelp farming season begins and the plants begin growing on ropes hung offshore, farmers must continuously remain alert to even the most minute changes in the ocean environment. Kelp thrives in the mercurial zone between open ocean and cove –between the global oceanic flow of nutrients and oxygen, and specific marine qualities of the shallow coastline. Wind, human industry, gravitational pulls, and seismic activity are among the many forces that animate the waves. But this particular field of interactions is further animated by the waves themselves. Kelp farmers understand that kelp does not grow merely in the ocean but rather in the provisionally stable zone between these varying ecological orders of magnitude. The zone is an opening, a space of potentials and risks. The long stalks of kelp with their broad brownish green leaves undulate in the ocean currents, becoming ephemeral forests that hold those heterogeneous orders together. Kelp famers do not need to master this field. Indeed, they cannot. They need only to 'borrow' a moment within it while cultivating awareness to its rhythms, tempos, and shifts. When the kelp is finally harvested, it becomes the catalyst for an entirely different set of relations and attunements. It gathers coastal residents into other forms of collective action. Each dawn, they work an industrial size cauldron to flash boil and sort *wakame* into different sizes and parts before straining. Once properly salted, women (and some men) come together to sit at a long rectangle table day after day to disentangle and further divide the *wakame* into parts with skilled incisions to prepare it for final packaging. Without a written manual, these men and women astutely observe every detail, including the size, the thickness, and the color of the *wakame*. Such attention and practice

[1] Helmreich, S. *A Book of Waves*. Durham, NC: Duke University Press, 2023.

demands subtle, but continuous recalibration of the ways in which the processing transpires.

The seawalls that have arisen along the northeast coast since the Great East Japan Earthquake and Tsunami of March 11, 2011, are the antithesis to the intricate ecological orders animated in matter, form, and movement of waves. Insofar as these structures are designed to hold the ocean and its unpredictable waves at bay, they embody the Blue Fear. Like giant grey concrete monsters, the seawalls straddle the once generative ecotone between ocean and coast. They are monuments to the science of rational design and the corollary desire to domesticate the uncertain rhythms, tempos, and shifts of the ocean. In the years since their construction was concluded, coastal residents, aquaculture farmers, and fishermen have become increasingly alarmed by the phenomenon of the dying ocean at their feet. For instance, a number of ecologists point to a direct correlation between the seawall construction and increasing cases of eutrophication and sea desertification (Abe 2022). Concurrently, aquaculture (wakame) farmers have noted a significant decline in the quality and quantity of their annual harvest. Waves interrupted become life interrupted. Matter and form without movement fails to produce those generative interstices from which generations of coastal residents have drawn and cultivated life. Although silent and grey, the concrete seawalls elicit a question: Can we think of a term, expression, or orientation toward ocean waves that is not about knowing, fearing, or instrumentalizing?

REFERENCES

Abe, Takuzo. 2022. Welcome to the ocean forest ~ The world renown biodiversity of the Miyagi ocean. Biodiversity Forum, Miyagi, Japan, January 29, 2022. https://www.pref.miyagi.jp/documents/41214/koenroku.pdf.

Görg, Christopher. 2011. Societal Relationships with Nature: A Dialectical Approach to Environmental Politics. In *Critical Ecologies: The Frankfurt School and Contemporary Environmental Crises*, edited by Andrew Biro, 43-72. Toronto: University of Toronto Press.

Saitō, Kōhei. 2022. *Marx in the anthropocene : towards the idea of degrowth communism*. Cambridge ; New York, NY: Cambridge University Press.

Commentary 4: A world without waves?

Philip Steinberg

In Stefan Helmreich's "Waves Dangerous, Domesticated, and Diagnostic," waves are understood as "avatars of an oceanic nature at once periodic and irreversible, wild and pacific, ephemeral and eternal." From Helmreich's travels in Oregon, Bangladesh (virtually), and The Netherlands, we learn how waves have been alternately feared and modelled, fought and harnessed, associated with the embedded specificities of a place and then used (not always successfully) to construct connections to distant lands across the ocean's expanse. Always, though, whether as metaphor, memory, or model, there is the wave.

But what if there were no waves? This question is not as preposterous as it sounds. Navigators and cartographers, at least in the Western tradition, typically imagine a flat, non-undulating surface across which a vessel can plot its passage. In ocean general circulation models based on Eulerian understandings of flow, the movement of the ocean is plotted against a static environment, suggesting that, as for the Western navigator, at some conceptual level there exists a static world without waves against which their forces can be measured. Perhaps most strikingly, in the 320-article United Nations Convention on the Law of the Sea, totalling over 200 pages, the word 'wave' does not appear once. The legal ocean is a space without waves.

Of course, lawyers, navigators, and (especially, as Helmreich would point out) oceanographers and climate modellers are all well aware that the ocean is in fact a dynamic volume, with periodicities, forcings, atmospheric interactions, gravitational pull, and a host of other factors that, inevitably, produce waves. The conceptualisation of a waveless ocean is an *abstraction*. However, like every abstraction, it has an effect. The idealisation of the ocean as being without essential geophysical character (i.e. without distinct features that can be bounded, possessed, preserved, improved, traded, etc.) facilitates its designation as being without essential geopolitical character (Schmitt 2003). This idealisation has underpinned a spatial imaginary that has supported mercantilist expansion and overseas colonisation. Today, it serves as the spatial foundation, both economically and politically, for our world of sovereign land-based territories that engage in long-distance commodity trade (Steinberg 2001).

In short, it would not be an exaggeration to state that the spatial patternings and temporal rhythms of our contemporary world are dependent on imaging an ocean *without* waves. The converse is also true: Once the ocean becomes saturated with features – not just waves, but also the memories of oceanic traumas that haunt the African diaspora (e.g. Sharpe 2016), the subsurface features mediated by Google Earth (e.g. Helmreich 2011), or even the technologically infused universe of drifting floats and remotely operated vehicles (e.g. Lehman 2017) – the ocean becomes less a sublime environment of danger or escape and more an arena for understanding histories and generating alternative spatiotemporalities.

As the ICE LAW Project has discovered in its attempts to design a law that might limit the right of icebreakers to destroy the structural integrity of sea ice, the barriers to thinking differently about the ocean – and to using the ocean to think differently about land – are not so much legal as they are ontological (Steinberg et al. 2022; see also Peters 2020). The challenge, first and foremost, is to change our thinking about what the ocean *is*, to undermine the conceptualisation

of the ocean as a space whose geophysical properties lack ontological being and, therefore, are immune from legal protection. This is as true for waves as it is for ice floes. To think about the ocean differently we need to think about its constituent parts – its features, its physical states, its places – differently. All too often, in law, science, policy, and cultural expressions, the ocean's features (or, as Schmitt would say, it's character) are overlooked in favour of an ocean perceived as a geometric abstraction across which (or sometimes within which) social and physical forces interact. The alternative requires us to perceive the ocean not as an arena that *hosts* mobilities, places, and processes but rather as a space that *is* mobilities, places, and processes.

In this respect, Helmreich's work is particularly provocative. Although his article could be read as a story of scientists and how they measure, model, manipulate, and memorialise waves, I prefer to read it as a meditation on the wave *itself*, as a thing, a force, a carrier of meaning. Like the decaying port models in the Waterloopbos, the ocean's waves connect across space and time, constituting an ocean that likewise connects across space and time.

Helmreich ends by suggesting that we think of the ocean as a book of waves. Perhaps, but what if instead we reverse his provocation and think of the wave as a book: as an object that, even with stable ontological definition, takes on new meaning in the processes of creation and encounter. Seen from this perspective, every wave, like every book, is both like, and not at all like, every other one, differentiating, and connecting, as it travels through, and constitutes, the oceans of the world.

REFERENCES

Helmreich, S. 2011. From spaceship Earth to Google ocean: Planetary icons, indexes, and infrastructures. *Social Research* 78(4): 1211–1242.

Lehman, J. 2018. From ships to robots: The social relations of sensing the world ocean. *Social Studies of Science* 48(1): 57–79.

Peters, K. 2020. The territories of governance: Unpacking the ontologies and geophilosophies of fixed to flexible ocean management, and beyond. *Philosophical Transactions of the Royal Society B* 375(1814): 20,190,458.

Schmitt, C. 2003 [1950]. *The* Nomos *of the Earth in the International Law of the* Jus Publicum Europaeum. E Ullman, trans. Brooklyn: Telos Press.

Sharpe, C. 2016. *In the Wake: On Blackness and Being*. Durham, NC: Duke University Press.

Steinberg, P. 2001. *The Social Construction of the Ocean*. Cambridge: Cambridge University Press.

Steinberg, P., G. Ferloni, C. Aporta, G. Bridge, A. Chircop, K. Coddington, S. Elden, S. C. Kane, T. Koivurova, J. Shadian, and A. Stammler-Gossmann. 2022. "Navigating the structural coherence of sea ice." In: *Laws of the Sea* (Irus Braverman, ed.). London: Routledge, pp. 165–184.

Commentary 5: Waves invented, in nature and beyond

Renzo Taddei

Helmreich's text synthesizes issues he explores in more detail in his book "A Book of Waves" (2023). His narrative provides an account of oceanographic science in the making, particularly within certain authoritative branches. Helmreich achieves this by incorporating the voices of those immersed in the complex task of crafting a scientific practice. The effectiveness of the text lies in how the author artfully manipulates frames and reference points, offering visibility, contrast, and salience to specific elements.

A key point is that through wave science, certain regimes of imagination materialize, reflecting and interacting with how modern polities engage with time and space through modeling and prediction. These regimes provide orientation to collectivities. The text delves into the political dimension of imagined futures, where some actors unleash worldmaking forces, often with unpredicted negative results. Simultaneously, this all exists in an arena of hyperobjects (such as the ocean, see Morton 2013) that elude full comprehension by any mind or technology, especially within a context where planetary biophysical systems are not just in crisis but undergoing transformations that challenge the reliability of many historical databases crucial to science (Taddei et al. 2022).

The text made me reflect on the extent to which waves, when occupying a position of alterity, are invented in ways that reflect their inventors. Drawing on Roy Wagner's argument in his magistral book "The Invention of Culture" (1981), I ask whether framing oceanographers' work with waves as analogous to how anthropologists deal with cultural differences is a productive way forward. The idea is that our experience of the world clashes with reality, and the perception derived from it is affected by our own contours and dichotomic semiotic tendencies. This is why difference often replicates the views of the observer. This has historically resulted in constructions like supposed primitives defined by lacking what the supposed civilized prize most in themselves, or the construction of a modern perception of nature (and waves) shaped by its resistance to the control of modern agents. If we add to that the tremendous material worldmaking powers of Western modernity, it is no coincidence that moderns live in a paranoid world full of concrete walls. Helmreich's description of the Bangladesh case illustrates how this can go wrong.

The text also guides us through intricate technocultural devices, allowing the construction of a nation on watery ideologies while making coloniality invisible but still effective. Referencing the overlap between the Netherlands' participation in colonial and science history, the text subtly connects the two roles. Particularly telling is the description of scale models of water and water worlds as ideological state mechanisms for transforming children into citizens imbued

with an appropriate hydrological ideology. This setup assists in maintaining the infrastructure required to keep the Netherlands safe and Dutch science as a major global force in shaping hydrological futures.

The Dutch example also indicates that water experimentation at the reported level demands unified state sovereignty – not a minor detail. Added to that, in the narrative, money is never a problem. Ideas seamlessly become material infrastructures, and suffering transforms into learning, infrastructure, and national pride. It is remarkable how wealth is taken for granted in certain technological imaginaries. Developing nations such as Bangladesh suffer from severe infrastructural gridlocks because, among other things, financial resources often arrive in waves. The temporal distance between two sets of funding waves may be significantly extended, exposing entire populations to infrastructural malfunction and violence. Anthropological work like the one discussed here is crucial for intervening in the construction and circulation of dominant forms of technical imagination and ideologies exported as technological solutions.

Some text elements converse with the ongoing debate about oceanography's standing as a discipline. The text focuses on physical oceanography, a subdiscipline of the larger field. However, the points it brings are relevant to the discussions about what has been called *social oceanography* in places like Mexico and France and *socioenvironmental oceanography* in Brazil (see Narchi et al. 2018). One of the central aspects of the debate is whether the incorporation of social elements and variables into oceanography should occur through the creation of a new subdiscipline or whether it should involve a radical reorientation of the discipline that cuts across all its subfields. Physical oceanography may intuitively seem to many people the most distant from social variables of all the subfields. Helmreich's text is a vivid demonstration that this is an erroneous perspective.

I find it fascinating how Helmreich's treatment of time connects different aspects of the issue and points to productive ways forward. In the account, blue fear serves as a motive to scale things and a thing being scaled up. One way this is achieved is by scaling down all that is possible through mathematical and material models. Time, however, cannot be properly scaled down due to the molecular structure of water and gravity. As a result, time is out of sync in the models, leading to analytically interesting observations. The text shows that timing is everything when it comes to hydro-ideology. A different time frame changes the genre of interpretation for the public observing a model of a tsunami devastating a coastal city. The wrong timing turns tragedy into comedy, as exemplified in the text. This ethnographic insight has profound implications for various fields, from risk perception to science communication.

Finally, a note on the presence of the so-called Global South. Here, Helmreich remains faithful to the ethnographic contexts in which he worked, which may seem excessively reticent to someone like me who works with traditional environmental knowledge in Brazil. I want to highlight a few aspects that could enrich the panorama and potentially inspire dialogue with other fields of inquiry.

The first concerns the idea of domestication. The text denaturalizes waves but keeps the concept of domestication naturalized. Recent ethnological work produced in the lowlands of South America, where agriculture is taking place in the absence of domestication as often understood, brought new and interesting ways of problematizing the concept (Carneiro da Cunha 2019). What would be an existential choreography of humans and waves in the absence of the dominant ideology of domestication?

The second is about animated waves and the presence of Indigenous peoples. Indigenous stories appeared in Oregon, but to confirm, with oral history, what science documents about past tsunamis. There's nothing in Helmreich's text about how waves feature in local Indigenous ways of relating to and understanding the world. In the text, blue fear animates mythologies in the Netherlands, like the Waterwolf; in Oregon, the ocean is perceived as *daemonic* because it is impossible to domesticate. What happens when the oceanic supernatural is not exceptional but part of local cultural backgrounds? I am thinking about how the figure of the Yoruba orixá (divinity) Yemojá, mythically associated with the oceans in the Americas, became part of the popular imagination in so many countries. Called Iemanjá in Brazil and Yemanjá in Cuba, the divinity is associated with maritime elementals that control the movements of the ocean and give humans the capacity to connect with specific spiritual forces and with the symbolism associated with the orixá (Vieira Andrade 2017). When the supernatural is an everyday practice, nature is something else. Exploring how waves play a part in this would be a fascinating task.

REFERENCES

Carneiro da Cunha, M. 2019. Antidomestication in the Amazon: Swidden and its foes. *HAU: Journal of Ethnographic Theory*, 9 (1): 126-136

Helmreich, S. A Book of Waves. Durham, NC: Duke University Press, 2023

Morton, T. Hyperobjects: Philosophy and Ecology after the End of the World. Minneapolis: University of Minnesota Press, 2013

Narchi, N. E. et al. El CoLaboratorio de Oceanografía Social: espacio plural para la conservación integral de los mares y las sociedades costeras. *Sociedad y Ambiente*, 18 (7): 285-301

Taddei, R., K. Shiratori, and R. C. Bulamah. Decolonizing the Anthropocene. The International Encyclopedia of Anthropology. Wiley, 2022.

Vieira Andrade, R. Como Fazer Santas e Sereias: imaginária de Umbanda, Design e Sociedade. Master Thesis. São Paulo: Universidade Anhembi Morumbi, 2017.

Wagner, R. The Invention of Culture. Chicago: The University of Chicago Press, 1981

Response to the commentaries on 'Waves Dangerous, Domesticated, and Diagnostic

Stefan Helmreich

I am grateful for these five considered responses to my keynote text. Each offers a welcome new angle on waves and wave knowledge.

Clemens Driessen digs into my examples from the Netherlands, offering that the weedy Waterloopbos might be understood as itself a scale model of how unanticipated processes often overgrow coastal and harbor planning. He also points out that the Waterwolf is a figure that visits not only from the sea, but from the land, as peat burning in order to heat homes has historically eroded the integrity of soils, leading to subsidence and inundation from within. Thinking about more literal mammals, he wonders what the recent re-introduction of beavers into Dutch waterways might betoken for non-human forms of hydrological planning. As it happens, when I was last in Amsterdam, I visited a nature-art site called "Otterdam," aimed at modeling a welcoming ecology for these semi-aquatic mammals as they were being slowly reintroduced into the city's waterways. The effort seemed apiece with recent "building with nature" strategies, scripting the previously wild into the possibly domesticatable.

Drawing on examples from South Africa, Darryl Colenbrander centers attention on the frequent absence, even retreat, of the state in planning for coastal resilience. Local communities are left in the thrall of economic and private logics that operate too schematically as well as too shortsightedly to enlist the kind of reflexive and pluralistic social scientific planning that might lead to long-term shorings up of coastal integrity. If coastal resilience is to have any chance of realization, Colenbarder argues, Mode 1 knowledge claims — positivistic claims coming from single, often engineering disciplines — must be met with reflexive Mode 2 knowledge — about social forces and interests. Particularly necessary, here, is the provision of adequate time — planning on the scale of decades — for such reflexively modern interventions, which must not be led by the often abbreviated time-scales of private industries and cash-strapped local communities. If wave action can be understood by physics and its short, looping time scales, wave histories and futures require a wider time horizon — the horizon of expectations demanded by thinking of long-term human habitation.

Michael Fisch and Jun Mizukawa offer examples from Japan, both to do with the hard infrastructure of seawalls and the more delicate worlds summoned up in harbor-bound kelp farming, which sees people working with waves to steward this aquaculture crop. Fisch and Mizukawa are interested in what happens at sites and moments of natural excess, or in the dynamics of what Christopher Görg, calls the "non-identity of nature," those instances (which are unfolding pretty much all the time) when wave formations exceed the human tools crafted to represent or corral them. They join my interest in the wave break — the moment of suspense, of a lack of full predictability — with an interest in the many scales that waves bring together: wind, gravity, currents. They write, "Kelp farmers do not need to master this field. Indeed, they cannot. They need only to 'borrow' a moment within it while cultivating awareness to its rhythms, tempos, and shifts." The giant concrete seawalls that have appeared since the 2011 tsunami offer an antithetical approach to waves, seeking to contain and control them — though with results that, as the kelp farmers can see, lead to a less dynamic and less healthy ocean, with wavescapes stilled in ways that generate stillness and eutrophication. The seawalls, thinking at only one scale — the scale of fear and disaster that comes with tsunamis — block engagement with the many scales of action that produce waves in the first place.

Philip Steinberg returns us to a time when ocean waves were not treated as landmarks (seamarks?) on the sea but were rather elided in the blankness of maritime maps. And he points out that this blank sea survives even today, as the Law of the Sea and other official bureaucratic documents hold no mention at all of waves, construing the sea as a simple space to traverse. The counter to this kind of thinking — some of which comes from oceanography itself, he argues — is to see the sea not as a space that hosts mobilities, but as a space that IS mobilities. Waves are not, then, surface features that simply texture the ocean, but ontologically part of the ocean itself. If the ocean is a book of waves — and each wave, as Steinberg suggests, has the complexity of a book, amenable to multiple interpretations — then it is a volume ever being written and read, never blank.

Renzo Taddei asks a couple of key questions. One provocative one is to "ask whether framing oceanographers' work with waves as analogous to how anthropologists deal with cultural differences is a productive way forward." Answering this question might demand that we ask which anthropologists, for many oceanographers approach waves in the way old fashioned anthropologists approached subject peoples — as entities to be measured, compared, objectified. Oceanographers, to highlight one aspect of this approach and to bring it into comparison with positivistic social sciences, do not generally ask for the consent of the ocean to be measured. Waves are simply to be known and controlled. Things could be otherwise — and, as Taddei points out, indigenous epistemologies might be one way to think in an alternative register. The new Center for Indigenous Futures at the University of California at San Diego, for example, has lately seen the local indigenous community, the Kumeyaay, build traditional reed boats, whose use requires asking

the sea permission to traverse it. This would be a kind of explicit social oceanography.

Of course, all oceanography is in some sense social oceanography as these commentaries have helped me see. Wave science is, in many ways, anthropology by other means.

Declarations

Competing Interests The authors indicated no conflicts of interest.