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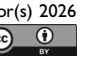
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Fractal paradigm of water-as-motion: Indeterminate being, decentred voluminosity, and orderly chaos

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Abstract

This article develops a fractal paradigm of water as an ontological and analytical framework for rethinking water beyond the modernist conception of H_2O as an atomistic and ontologically determinate substance. Drawing on the philosophy of movement and new materialist thought which critique ontological atomism and instead emphasise motion, change, and indeterminacy, the article proposes understanding water primarily through its fractal motion: *water-as-motion*. Building on the mathematical origins of fractals and their grounding in water-related forms (such as waves, turbulence, coastlines, and river meanders), the article expands the notion of the fractal into a broader conceptual paradigm for philosophies and geographies of water – one that arises from water's own materiality rather than being imposed upon it. The paper develops four "fractal curves" as conceptual openings. First, it argues that fractal water redirects analysis toward *decentered scalar voluminosity*, bridging debates on non-hierarchical scaling and decentered ontologies by showing how water emerges through intra-scalar, self-similar motion. Second, it conceptualises relationality as immanent to an ontology of motion and change: water-as-motion is relational to itself, but also to other matter and life forms, through continuous and collective transformation. Third, it rethinks order and efficiency through the notion of *orderly chaos*: a form of biophysical order that emerges not from linear causality but from indeterminate, yet metastable self-organisation. Finally, it frames fractal repetition as a source of vitality, suggesting that water's finite materiality becomes life-generative through the temporal and spatial cycles of fractal repetition.

Keywords

Water, fractal, motion, philosophy of movement

Introduction: Thinking of water differently

Scholarship on water has recently seen many attempts to think *water differently*. A consensus has emerged in critical studies on water that we must move away from modernist and anthropocentric

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ideas that frame water as a quantifiable, endlessly available resource that can be effectively managed and controlled through large-scale technical infrastructures for the benefit of humankind. The reason behind this shift is the argument that such anthropocentric and modernist *ontological* paradigms have contributed to *material* water crises on Earth – water scarcity, flooding, overuse, and pollution, which are thoroughly documented. Water has therefore been at the center of academic and political attention for several decades (Bunsen et al., 2021; Shulz and Gros, 2024), recognised as one of the essential planetary crises of our time (United Nations, n.d.).

Having recognised the crisis of modern, essentialized, and quantifiable water, scholars have attempted to conceptualise water differently (Linton, 2011). Most of these efforts address the problem of water's essentialization and alienation by rethinking water as *relational* – to planetary life-worlds, to human economic activities, and to cultural practices (De Wolff et al., 2022). There is a rise of Indigenous scholarship, where, in the critique of modernist water constitution, water is understood as a relational lifeforce (Lane, 2024; Sepulveda, 2018; Simpson, 2025; Wilson and Inkster, 2018). Other scholars have reinterpreted water through its gestational and corporeal roles, emphasising that water is an inherent part of human and nonhuman bodies (Chandler and Neimanis, 2013).

Another important opening to rethink the constitution of the modern water is the concept of the *hydrosocial cycle* (Boelens et al., 2016; Budds et al., 2014; Liao and Schmidt, 2023; Swyngedouw, 2009). Developed as a critique of the hegemonic hydrological cycle which abstracts water from human activities, the hydrosocial cycle draws attention to how water and society are always relational, dialectical, and co-emergent (Linton, 2011). Initially rooted in critical social science, the idea of the hydrosocial cycle has increasingly become a shared framework for collaboration between social scientists and hydrologists (Lane, 2014).

This article seeks to join these voices by attempting to think with and about water differently. This paper, however, aligns particularly with the project of new materialism. Instead of viewing water as an abstract, manageable entity subject to the logics of technical use, new materialist approaches emphasise water's materialities and encourage us to think *through* and *with* water (Chen et al., 2013). Increasingly, scholars engage with water's nonlinear movements and volumetric forms. For example, meandering – the curving paths taken by rivers – has been used not only to rethink how we understand water but also as a conceptual paradigm, challenging assumptions of linear efficiency and foregrounding uncertainty and relationality (Klaver, 2022). Similarly, Steinberg and Peters (2015), through their engagement with water's voluminosity, critique linear spatial ontologies and redirect attention to the emergent qualities of water's volumes.

Joining these conversations, I propose what I call the *fractal paradigm of water*. This paradigm defines water through the fractal patterns of its decentered, volumetric motion. More importantly, by bringing this approach into dialogue with the philosophy of movement, I seek to rethink water ontologically *primarily* through its motion. Focusing on water's movement allows us to challenge atomistic and reductionist ontologies and to highlight water's material emergence as something constituted through motion. Using water's fractal motion as the starting point of this intellectual exercise, I aim to broaden the concept of the fractal beyond its technical and mathematical usage and instead mobilise it as a conceptual paradigm that invites us to rethink water's material ontology, as well as dominant notions of efficiency and order.

Water-as-motion: Atomist ontologies, movements of modernity, and philosophy of motion

Before plunging to the fractal paradigm, I first outline the theoretical and ontological foundations from which it emerges, namely, the critique of ontological atomism developed by recent

philosophers of science and matter, together with the associated philosophy of movement. Focusing on the idea of movement and its primacy in the ontologization of water, I also examine how ontological atomism shaped the conceptualisation of material motion in modernity through infrastructures. This discussion will serve as a useful basis for approaching the fractal paradigm in the second half of the article.

Water has been defined ontologically in different ways across historical periods and cultural contexts. As mentioned above, in many Indigenous ontologies, water is understood as a lifeforce, deeply entangled with land, living beings, and planetary life more broadly. Across numerous ancient traditions, water was regarded as one of the primary elements composing the world (often alongside fire, earth, and air).

In Euro-Western thought, scientific methodologies that developed from the seventeenth century onward gradually came to dominate ontological understandings of water and became hegemonic (Linton, 2011). Standard descriptions and textbooks present water primarily as a chemical substance with the molecular structure H_2O (cf. Ball, 1999). This chemical identity is what *defines* water. Other properties – its physical behaviours, biological roles, or cultural meanings – are rendered secondary attributes of a universal and discrete chemical entity.

This chemical identity is significant not only because of what it does to water – how it abstracts water from its tangible, relational materialities, contributing to what Linton has called modern water – but also because it reflects how matter itself is understood. Water comes to be defined primarily by its atomistic composition rather than by change, motion, or relation.

This atomistic ontology of matter has recently been interrogated and challenged by philosophers working in the philosophy of science and the philosophy of matter (Barad, 2007; Nail, 2018, 2024; Stengers, 2010), and I believe these discussions would be of help of rethinking water as they stem beyond the modernity and identify a wider ontological apparatus of seeing matter. This ontology traces back to ancient Greek atomism and is carried forward into modern science, which in turn has shaped the material practices through which water is organised and controlled in modernity. Within this paradigm, matter is assumed to possess a *determinate* ontological essence, i.e., being qua being. The scientific ontologies characterising modern thought have been marked by atomism, or stasis. This stasis is not physical immobility but rather ontological staticity: matter is defined by a fixed and determinate constitution.

What, then, is motion in relation to matter within this ontological paradigm? The relationship between motion and matter has traditionally been understood through the model of discrete objects moving across a spatial and temporal plane. In this framework, motion is conceived as the displacement of such objects from one location to another, eventually returning to a state of rest (see also Ingold, 2007: 151). Every motion can thus be decomposed into a series of static snapshots that are thought to constitute it. Motion is further characterised by linear causality: a force is applied to matter at a specific point in space-time, initiating movement, which subsequently ceases and leaves the object at rest once again. In this conception, motion does not ontologically define matter. Matter is taken to be determinate, and motion is treated as a secondary attribute of material entities. Things may move, but their ontological identity is understood to reside in their determinate being-in-itself.

In this sense, water is no exception. Classified as one form of matter, it has primarily been understood through its determinacy. Prior to the emergence of chemical science, water was defined as a physical entity, yet still as a being-in-itself. With the advent of modern chemistry, water came to be understood as a substance defined by its chemical composition, H_2O. Although many of water's qualities may change (its physical state, spatial location, or its interactions through bonding and dissolution), its fixed chemical identity has come to anchor its ontological status within this dominant paradigm.

This chemical substance (H_2O) can, of course, move. Indeed, as Linton (2011) notes, the modern constitution of water is grounded in the concept of the hydrological cycle – a planetary circular

movement of water through various locations and states, independent of human activity. Yet within this ontology, motion does not define water itself. Movement is understood merely as a change of location, a transitory process through which water passes – a secondary characteristic of an otherwise ontologically determinate entity. Water's circulation across landscapes, its descent underground and return to the surface, its transitions between states, or its passage through living bodies are all attributed to the influence of external biophysical forces.

These are the forces that modernity sought to manipulate in order to subject water's movement to the demands of urban life and economic growth. Although humans have always managed water to some degree, it is arguably modernity that attempted not merely to work with water's biophysical movement but to alter and reshape that movement, assuming that water, as an ontological entity, remained the same and continued to perform the same biophysical function. Rivers were diverted and straightened, stripped of their meanders; water was channelled into pipes and transported across long distances; or, alternatively, halted and contained in dams (e.g., Hallward, 2010; Käkönen and Nygren, 2023). These interventions exemplify the modernist geographies of nature enabled by infrastructures: the application of force to redesign biophysical motion, either by containing matter or by directing it along straight, accelerated pathways for the sake of efficiency (cf. Cowen, 2025). This history is well documented, including the ways such practices have contributed to waterborne disasters, ecological degradation, and the broader contemporary water crisis. In imposing our own notions of efficiency through interventions in water's movement, it seems we overlooked something essential, both about water in general and about the nature of water's movement in particular. In other words, modernity *misunderstood* water.

The atomistic ontologies of matter, i.e., matter as being-in-itself, has been challenged by various relational approaches – assemblage theory, actor-network theory, and others – that refuse to essentialize or isolate beings, instead defining them through their relations. Yet these approaches still largely conceptualise change as arising *between* entities. What, then, if things can be defined through their *own* continuous motion and change? This is the proposition offered by the philosophy of motion.

Developed by Thomas Nail, the philosophy of motion centers on the idea that matter should be understood *primarily* through movement and change rather than through its determinate being (Nail, 2018, 2024). Nail argues that both the social world and recent developments in the sciences of matter (such as chaos theory and quantum mechanics) compel us to rethink ontologies rooted in being-in-itself and to approach the socio-material world through the primacy of motion and change. Such a shift, he suggests, may help us make better sense of things. Within this framework, matter is not separate from motion; rather, motion and change, not determinacy, define matter.

In this ontology, motion is not a line along which things move (as in the conventional image of an object travelling from point A to point B), nor can motion be broken down into a sequence of static snapshots. Instead, motion is a continuous metamorphosis of matter. Matter is never fully identical with what it has been, nor fully identical with what it will be. Accordingly, neither matter nor motion can be characterised by determinate causality; instead, they unfold through an indeterminacy that is always in flux. As Nail puts it, matter and motion are "two historical names for the same intermediate relational process" (Nail, 2024: 51).

This perspective invites us to attend more closely to how water moves and to consider what such movement implies, both conceptually and materially. Building on the philosophy of motion as the ontological foundation, I develop a fractal paradigm of water.

Introduction to the fractal paradigm

To develop the fractal paradigm in relation to water through the lens of the philosophy of motion, we must first consider the concept of the fractal itself. What is a fractal? Put simply, fractals are mathematical constructs that describe complex shapes or patterns exhibiting self-similarity across

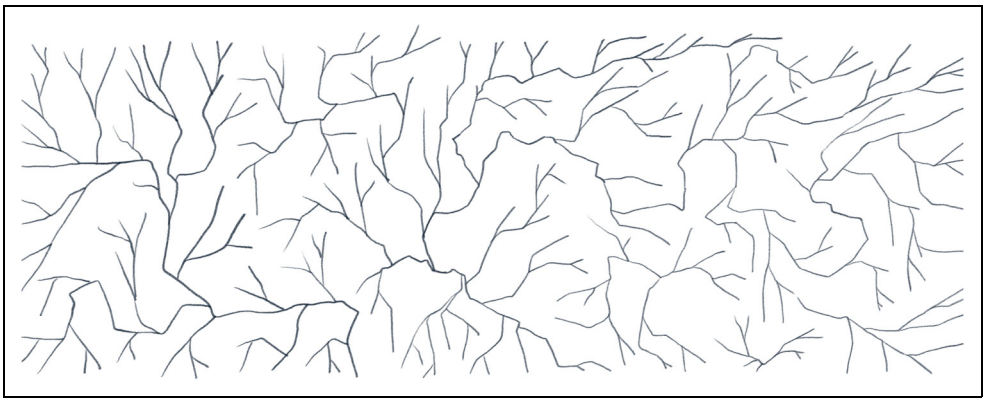

Figure 1. Fractals. Illustration by Natalia Batrakova.

scales. This means that, regardless of how far one zooms in or out, similar patterns continue to repeat, revealing structural resemblance at every level of magnification (Figure 1).

The term fractal was coined by the mathematician Benoît Mandelbrot in the 1960–1980s through a series of works that culminated in his magnum opus, "The Fractal Geometry of Nature" (Mandelbrot, 1983). Mandelbrot argued that contemporary mathematics focuses on linear, static, and easily measurable forms such as circles, lines, and planes, along with their locations, directions, and sizes, while dismissing many other shapes as "complex," "irregular," or even "monstrous." Yet, as Mandelbrot pointed out, these so-called "monstrous" shapes and forms actually constitute much of the geometry of the biophysical world around us.

Importantly, these shapes are not completely random or chaotic. Rather, Mandelbrot suggested that we fail to recognise their underlying patterns because classical mathematics is preoccupied with idealised forms that rarely occur in real life. There is order within this apparent chaos, and it is found *across* scales. Mandelbrot named these scale-dependent complex shapes as fractals.

Mandelbrot drew inspiration for fractals from many forms of matter and its movement found in natural environments, and water was one of the phenomena that particularly influenced his thinking. His early work on fractals actually began with his famous article in Science, "How Long Is the Coast of Britain?" (Mandelbrot, 1967). In this work, he noted that different attempts to measure a coastline always yield different results: coastlines are highly irregular, and no matter how far you zoom in, new intricate curves emerge at the boundary between water and land. Because this boundary is both complex and constantly shifting, any measurement becomes scale-dependent and ultimately approximate. Yet, despite this apparent complexity, the patterns of water–land interaction show similarities across different scales. Mandelbrot also examined the shapes of riverbeds, whose meandering paths likewise reveal fractal characteristics in their repeated, self-similar bends.

While the term fractal was coined in mathematics and geometry, i.e., the study of static forms, those fractal forms in natural environments are all result of the *movement* of matter. Fractal patterns have been argued to constitute one of the most efficient biophysical ways of transferring energy and matter precisely because they reuse the same structural logic across scales rather than generating entirely new forms each time (Lanza, 2019). That's why fractals express repetition across both spatial and temporal scales: although fractal shapes may appear "irregular", chaotic, or complex when seen statically in the three-dimensional Euclidean space, they are ordered and simple in a way that there is only one pattern of movement which repeats all the time across scales (Jiang and Brandt, 2016; Siu-Ngan Lam and De Cola, 1993). Because of this biophysical efficiency of matter-energy motion, fractal patterns are observed throughout both living organisms and physical environments,

from coastlines, mountains, and watersheds to blood vessels and lung structures. Thus, fractal patterns are generated by matter moving within and interacting with its environment, for example, a river gradually finding and curving its way through a landscape.

Fractals were not immediately embraced by the scientific community, particularly within mathematics, but over time they found their way into many fields of research and thought. Hydrology became one such field (Lanza, 2019; Rodriguez-Iturbe and Rinaldo, 1997), especially since water-related forms of motion originally inspired Mandelbrot's development of the fractal concept. Water's fractal behaviour is most clearly observed in its spatiotemporal movement. Water's turbulence, often described as "chaotic" motion, reveals fractal patterns through its flowforms: the shapes of waves, swirls, bubbles, and foam repeat across scales, where smaller vortices mirror the forms of larger ones, resulting in a voluminous movement-in-becoming.

These flowforms also generate fractal patterns through their sculpting of the Earth's surface. Fractal structures can be seen in riverbeds, where the meandering of water creates larger patterns that are self-similar to those observed when zooming in. The same is true of coastlines. Through these continuous interactions, water carries itself through and across environments, leaving behind fractal traces of its movement.

Knowledge about water's fractal movement has recently been taken up in hydrology through the emerging practice of *hydromimicry* (Marrin, 2011): an approach that seeks to study water's biophysical processes and properties more closely and to design water infrastructures in ways that correspond to water's fractal motion. Hydromimicry thus responds to the water-borne disasters that became increasingly common after modern engineering attempted to force water's movement into straightened and angular forms – solutions that channel, divert, or contain water in ways misaligned with its voluminous motion. In contrast, hydromimicry seeks to observe and work with water's own physical patterns, i.e., how it precipitates, evaporates, and moves in fractal motion.

However, it is important to recognise that fractals did not come into existence only when Mandelbrot identified them or developed a conceptual language to describe them. Fractal patterns have long been present in Indigenous design and thought, even if they were not articulated using the same terminology (Eglash, 1999). Through close observation of natural forms of motion and the patterns they inscribe in the environment, Indigenous communities have incorporated fractal principles into architecture, craftwork, social organisation, and cosmological storytelling. Many Indigenous knowledge systems likewise acknowledge that water itself is fractal (Simpson, 2025).

In this piece, I propose approaching fractals not merely as a mathematical concept or instrument, nor in the exact way they appear in the work of Mandelbrot or in hydrological research. These fields do not serve only as empirical data for my argument, nor do my propositions rely solely on their specific empirical investigations of fractality. Rather, by drawing simultaneously on the mathematical understanding of fractals and on Indigenous perspectives on the fractality of water, I take the concept of the fractal as a starting point in order to develop it further conceptually and theoretically, particularly in relation to debates in political and material geography as well as the philosophy of movement. In this sense, the concept of the fractal in this paper can be considered *post-mathematical*, in a manner similar to the way topology has been taken up and transformed in human geography (see Martin and Secor, 2014). Thus, fractal here is intended to function as a broader conceptual paradigm.

As a broader conceptual framework, the idea of fractals has already been taken up in the social sciences and humanities. Most notably, fractals have been used to reconceptualise scale, since scale is the central dimension through which fractals are actualised (Abraham, 1993; Jensen, 2007; Moussawi, 2020). More generally, fractals unsettle the conventional conceptual apparatus shaped by ontological atomism, linearity, binaries, hierarchies, and stratification. Similarly, in this article, the fractal paradigm becomes a conceptual framework to rethink water ontologically by aligning the idea of a fractal with the previous conceptual debates on water's relationality, vitality, and

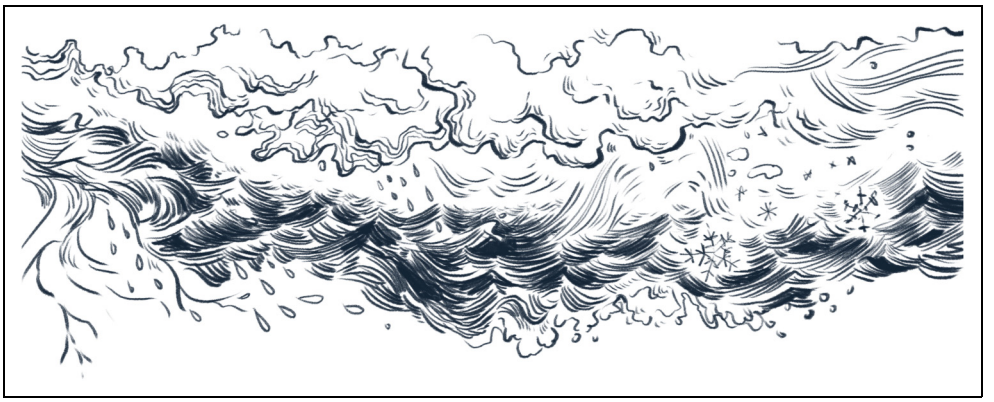

Figure 2. Decentred scalar voluminosity. Illustration by Natalia Batrakova.

voluminosity, as well as broader critiques of the reductionist, linear, and statist scientific ontologies through which matter has hegemonically been understood.

The fractal paradigm of water that I propose in this piece begins with the primacy of motion, both analytically and ontologically. Whenever we speak of the fractal behaviour of water's flow forms, we are inherently speaking of movement. Fractals draw our attention to the flow forms through which water comes into being. This movement, grounded in fractality, destabilises the notion of water as ontologically atomistic. Thus, fractals do more than describe the shapes of water's motion; they redirect our focus to movement as more foundational than water's atomistic characteristics, such as its chemical composition. In this sense, they invite us to speak not of *water-as-H_2O* but of *water-as-motion*. If water is ontologized primarily through its movement, how, then, do we conceptualise fractal motion?

Below, I present four openings of the fractal paradigm for rethinking water's materiality as *water-as-motion*. I refer to each as a *fractal curve*, in recognition of their inherently non-linear nature, even though they appear here in a numerically ordered sequence. Yet we should imagine them not as discrete points lined up one after another, but as voluminous forms that emerge out of one another.

Fractal curve 1: Of decentered scalar voluminosity

Because fractals are inherently about the shapes of water's movement – such as swirls, vortices, and other flow forms – they redirect our analytical attention into water itself, inside its indeterminate, decentered, and scalar materiality (Figure 2). To develop a fractal paradigm of *water-as-motion* and to elaborate what water's movement is and how we might conceptualise it, I draw on two strands of scholarly discussion, bringing them into conversation and extending them in the process: voluminous space and decentered (or flat) ontologies.

First, to engage with the idea of voluminous motion, let me make a brief detour into human and political geography. The concept of volume has recently permeated debates in these fields, offering a more nuanced conceptual apparatus for understanding space, power, and territory. Traditionally, human and political geography relied on two-dimensional notions of territory as a horizontal plane (along with people's movements across it or their enclosure within it) and on linear borders that cut across and divide this plane. Through several recent liminal interventions (see specifically Elden, 2013; Steinberg and Peters, 2015), however, the idea of three-dimensional volume as space which expands and proliferates in multiple directions has been introduced as a spatial concept through which power relations materialise.

For the fractal account developed here, it is especially important that one of these liminal works drew its inspiration directly from water: its voluminous material becoming served as a productive ground (or, as we may say here, watershed) through which the idea of voluminous space was articulated (Steinberg and Peters, 2015). The authors termed this contribution as *wet ontologies.*

While the authors' discussion was largely directed toward what voluminosity means for political geography and for our conceptualisation of (political) space, I would argue that their intervention just as much provides openings for our understanding of water, which served as their point of departure. Through wet ontologies, they conceptualise water as non-static, non-linear, and non-bounded; that is, as voluminous, immanent, ever-becoming, and always in motion. This perspective speaks directly and productively to the fractal paradigm of water (and, indeed, of other forms of matter as well).

Fractal water is inherently voluminous, inviting us to observe water in its emergence: from smaller flow-forms that, through repetition, expand exponentially into similar larger flow-forms across all dimensions. Rather than observing water only from its surfaces or from the structures that enclose it – riverbanks, canals, or pipelines, the places where water is presumed to "end" – a fractal view redirects us *inside* water's own movement. Water in its fractal motion does not begin or end as it does in the atomistic ontologies of linear causality. It moves through a kind of circularity, yet through a non-linear fractal circularity without a fixed beginning or end (cf. Cole, 2017).

For now, it is productive to return to debates on horizontal versus voluminous understandings of space in Steinberg and Peters (2015). In their contribution, water's ontological becoming has served as a starting point for conceptualising ever-emerging volumes rather than the linear and bordered forms of space that, the argument goes, we inherited from land-based horizontal ontologies. Yet I would suggest that the binary between horizontally bordered land and ever-becoming voluminous water is somewhat misleading. Land is arguably voluminous too – in its curves, depths, peaks, and elevations. What has flattened both land and water (and our thinking along with them) is not their materiality but Euclidean linear geometry, which has long subordinated matter to ideals of casual linearity, abstracted movement, and ontological determinacy. A fractal paradigm rooted in the ontology of motion instead invites us to zoom in and out of material processes of becoming – processes that spiral through similar patterns across scales. Matter, approached fractally, is indeterminate, unfixed, and always becoming.

This is therefore the right moment to turn to the issue of scale and to the conversation between fractal and decentered ontologies. Fractal movement is inherently movement *across* scales. In the case of water, this means that smaller flow-forms give rise to larger ones through self-similar repetition; through this emergent voluminosity, water comes into being. The self-similarity of these intra-scalar, voluminous patterns renders scales equal to one another: larger swirls, waves, and vortices are continuously generated from smaller ones without any ontological separation or hierarchy between them. This resonates directly with earlier discussions of decentered ontologies.

The conceptualisation of decentered – or flat – ontologies emerged as a critique of the hierarchical scaling that permeates modernist ontology and thereby shapes political thought about the world's ontological composition, whether concerning human societies, human–nonhuman relations, or the material environment. Fractal paradigm, I argue, speaks productively to these debates. In the self-similar scales of fractal water movement, scales are not hierarchical; each emerges from another. As water moves, it carries matter and energy through these self-similar flow-forms, with smaller forms giving rise to larger ones and vice versa, generating the full volume of water. Water's fluid movement is therefore decentered and of indeterminate topology (and I specifically use the term decentered rather than flat, because "flat," although not conceptually intended that way, still subconsciously suggests a two-dimensional spatiality that I seek to avoid here). Regardless of the scale, i.e., the point of entry into water's voluminous becoming, whether we zoom in or out, moving through its intra-scalar dimensions, we continue to

encounter water in its self-similarity. From any point within this voluminous scaling regardless of where one begins or ends self-similarity removes the need to treat any scale as primary (cf. Noxolo, 2016).

This decentered and non-hierarchical scaling in fractal thinking allows us to understand intra-scalar emergence as a voluminous *continuum*, rather than as a set of ontologically separate scales neatly nested one inside another. This discussion brings me back to the debates on decentered ontologies and non-hierarchical scaling. There have been many attempts to reconcile these two approaches, and Marston et al. (2005) argued that such efforts only further obscure the very idea of scale. According to this critique, it might be preferable to abandon the concept of scale altogether and focus instead on developing the notion of decentered ontologies (or volumes which appeared in the recent literature as another concept which defies hierarchical scaling).

Yet I argue that preserving the idea of scale, though in a non-hierarchical sense, is essential for fractal thinking. If we think of water solely in terms of decentered volumes, we risk losing sight of intra-scalar motion iterations and the ways they repeat from smaller to larger scales in self-similar patterns. A strictly voluminous view of motion tends to suggest homogeneous emergence, or at least renders the self-similar iterations of movement obscure within the idea of volume alone. Therefore, to conceptualise the fractal motion of water – *water-as-motion* – we must bring together the insights of decentered ontologies, voluminous motion, and non-hierarchical scaling.

This conceptualisation of fractal movement of water has some implications for rethinking atomistic ontologies of determinacy and modern material infrastructures which stops motions of water from its voluminous spreading (cf. Opperman et al., 2017). Water tends to be conceptualised as a chemical entity that conveniently takes on different shapes when contained by riverbanks, dam walls, or pipes. From this perspective, water's fluidity simply enables it to be held, channelled, or redirected. Engineered water solutions such as dams, levees, or channels attempt to render the motion of water through the linear straight infrastructures. Yet the fractal paradigm allows us to start seeing water primarily through its voluminous indeterminate motion.

We have recently seen both material and conceptual efforts to revitalise water in its movement. There is a growing movement to remove dams and allow rivers to flow freely again; new anti-flood engineering approaches that seek not to keep water separate or at a distance, but to work with it, becoming relational once more. There is also an expanding body of literature on water that challenges the logics of capture, containment, othering, and immobilisation (Shulz and Gros, 2024). The fractal paradigm, I hope, contributes to these ongoing attempts.

Fractal curve 2: Of material relationality

As we spiral further through fractal patterns, we arrive at a shorter iteration. The fractal paradigm, grounded in the philosophy of movement, allows us to think productively about relationality – an issue that has become central in recent discussions of water ontologies. How, then, do we conceptualise water as relational within the fractal paradigm?

If material reality, including water, is characterised by motion and change, then water is first and foremost relational to itself. It is self-relational through its movement: it is in constant transformation and remains unfixed not only through external forces or relations with other entities but through its own internal motion. Different iterations of fractal motion influence changes across the entire volume of water simultaneously. As Nail writes, "The patterns [of waves] are just different ways the water relates itself to itself through itself" (Nail, 2024: 44). Relationality, therefore, is the simultaneous transformation of the whole through the dynamic transformation of its parts; the entire body of water – whatever it may be at any given moment – is relationally constituted and moved indeterminately all at once (Nail, 2024: 45).

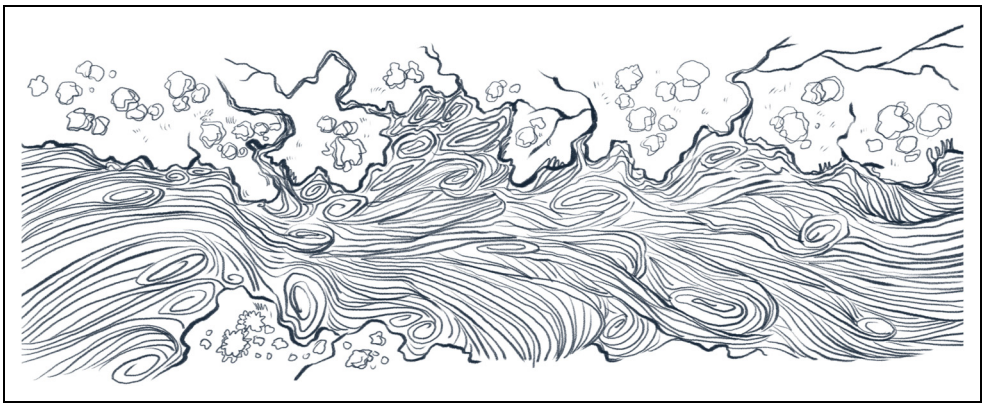

Figure 3. Material relationality and interaction-in-motion. Illustration by Natalia Batrakova.

This does not mean, however, that water (or any other matter) is self-enclosed through its own motion or relational only to itself. Water is in constant intra-action with other matter-as-motion – land, living bodies and cells, the atmosphere. These entities, too, are always moving and changing, and they relate to one another through their motion. Relationality is immanent to the collective, simultaneous transformation of matter through movement (Figure 3).

Whether along riverbeds or coastlines, the fractal patterns of water continually remind us of its intra-actions with other entities. Water's voluminous movement generates fractal patterns with land, drawing our attention to this dynamic zone of water–land interaction. The fractal line of these intra-actions – never a fixed boundary but a line perpetually in motion – shows how water and land curve into one another, how they become what they are through their mutual movement. Coastlines and riverbeds are, at their core, geological encounters between water and land. They are also cosmological encounters: in Nishnaabe Indigenous thought, as Simpson (2025) notes, a coastline or shore is understood as a meeting place between two worlds.

This reframes water away from its modernist, self-enclosed constitution as a chemical entity circulating through the hydrological cycle independent of humans and other biophysical forces, and toward an understanding of water as always relational through its motion. Klaver (2022), in "Radical Water," has already theorised water's relationality through meandering, i.e., water's nonlinear carving of landscapes, which signals a shift in mentality toward nonlinearity and uncertainty. Building on these accounts, I would add that water's relationality is not uncertain – it is fractal. And this brings me to the next iteration: that of uncertainty, or randomness, and order.

Fractal curve 3: Of orderly chaos

This leads us further: through the questions on certainty and uncertainty, linearity and chaos, structure and randomness, we arrive at a fractal ontological perspective on order and efficiency.

Modernity subjected water to regimes of mastery and control through a logic of linear ordering, equating straightness with "efficiency" (Ingold, 2007: 151). This meant eliminating fractal meandering and voluminous becoming, and instead forcing water into linear motion or staticity – through pipes, canals, and dams that immobilise or rigidly direct its movement. In contrast, contemporary efforts to liberate water from these imposed modernist categories of fixed, static, and measured linearity have often re-theorised water as fluid, uncertain, or boundary-defying. While these characterisations are true, and indeed powerful, I worry that they sometimes lack clarity and a careful

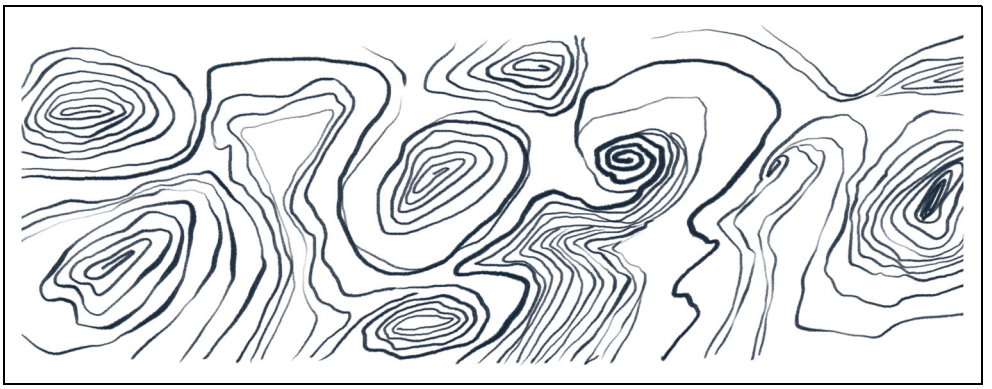

Figure 4. Orderly chaos and fractal efficiency. Illustration by Natalia Batrakova.

attention to water's materiality: they describe what water is *not* in relation to modernist constraints, rather than examining what water then *is*.

Fractal paradigm and the philosophy of movement provide an opening here, as it offers a way to contemplate order and efficiency differently, on water's own terms.

Fractal patterns have been recognised as among the most efficient ways to transfer energy and matter through space, as fractal patterns "occupy most of the available volume and connect the most locations on a surface [while] saving or dissipating energy" (Lanza, 2019: 1). This is why they are found across diverse biophysical processes, from the movement of water to the branching of blood vessels in living organisms. This form of biophysical efficiency differs sharply from the modernist conception of efficiency, which imposes hierarchical linearity on water through containment, redirection, and separation. Fractality allows us to attune to the planet's own modes of energetic and material organisation and reproduction, rather than persisting in linear impositions that, among other things, contribute to catastrophic water-borne events.

By resisting modernist orders of control and mastery, water's fractal movement gestures toward another kind of order – an order of indeterminate becoming. When observed through meandering or turbulence, water's movement is neither random nor uncertain. *Randomness* is only a relative term used to describe movements whose causes are unknown; we perceive randomness because such movements defy our linear causal logic, in which change begins at one identifiable point and ends at another (Nail, 2024: 49). Water-as-motion does not begin or end in this way. It is indeterminate – continuously in motion and continuously changing (Figure 4).

Yet the indeterminate fractal motion of water characterised by voluminous becoming and self-repeating iterations of movement is *metastable*, to use the vocabulary of the philosophy of movement, both at the planetary scale and in its biophysical functions. As Nail notes, "a metastable pattern is an ongoing process that restores and repeats itself slightly differently, like a whirlpool or eddy in a river" (Nail, 2024: 49). The finite amount of water on Earth continually moves through this metastable biophysical cycle. We know how water moves in metastable patterns through the oceans. We know how it circulates through the metastable planetary cycle. Through this ongoing, repeating-yet-changing biophysical motion, water gives rise to life again and again. The fractal order is thus fundamentally different from modernist ideas of linear causality and quantified predictability.

This feature of fractal patterning in water's movement resonates closely with insights from chaos theory. Although water moves through self-similar patterns and its behaviour is not entirely undetermined, the precise materialisation of its flow-forms – their shapes, velocities, and intra-active relations – cannot be predicted and often emerges contingently through fluvial relational processes. This is what the notion of *orderly chaos* conveys: an efficient order that does not rely on a fixed,

mechanistic universe subjected to anthropocentric mastery. And it is this understanding that brings us, finally, to the vital force of water's fractal composition as sustaining reproduction of planetary life.

Fractal curve 4: Of repetition and vitality

Water is a vital element that sustains the reproduction of life on this planet. It is in constant motion: swirling in oceanic masses, meandering through rivers, moving between its liquid and solid forms, dissolving minerals, and combining with other elements and compounds. It circulates through landscapes, the atmosphere, and the bodies of living beings. Yet despite these continual movements and transformations, (aside from minute amounts that escape into space, see Gronoff et al., 2020) water is finite in quantity on our planet. And while it has always been somewhere before, it is somehow always taken up into new iterations of life-forms.

Chandler and Neimanis (2013) draw on the Deleuzian conception of difference and repetition to conceptualise water as a vital life-force. While finite and materially constant, water nevertheless enables an unfathomable plurality of life-forms. This is possible because water is, "in both its inception and its ontogenetic manifestations, always already constituting and constituted by overlapping and interconnected cycles of repetition" (Chandler and Neimanis, 2013: 74). Water repeats itself in its finitude, yet always through new iterations – and it is this repetition that generates difference. Any given volume of water has been elsewhere before, sustaining other forms of life, yet returning again into circulation.

This resonates with Deleuze's account of difference and repetition, in which repetition does not signify sameness (Deleuze, 1997). Water does not repeat *forms*; it repeats *patterns of movement*. Repetition is not replication, analogy, or duplication of an original; rather, it is a creative process, continually producing new iterations. As water repeats its cyclical motions through its eternal movement across bodies, landscapes, atmospheres, and organisms, it becomes a vessel for ever-new biological life.

Thus, water cannot be essentialized or reduced to its chemical identity or to a stable structural blueprint. Although water is materially "the same," its motion exceeds its fixed chemical composition. As Chandler and Neimanis (2013) argue, this is how we encounter infinity within water's material finitude – through its immanence, its cycles of repetition, and its temporal passage from one life-vessel to another.

I would like to extend Chandler and Neimanis's (2013) argument here. The vitality that water possesses through its temporal cycles of repetition is intrinsically connected to the fractality of its movement. Fractals describe the temporal and spatial repetition of flow-forms across scales, giving slightly different iterations with each change of motion. Water moves through cycles of temporally repeating fractal patterns – self-similar to one another – across deep planetary time, continually giving rise to new life-forms and, thus, making biophysical cycle metastable despite constant change. This happens both through differentiated repetition (assembling new forms from the same elements) and through fractal repetition (repeating the same pattern across different scales) (Figure 5). And this is precisely what water will continue to do, as long as we do not attempt to constrain or oppose its fractal nature through linear forms of capture.

Fractal ontology as amodern

These four analytical openings, or what I have called fractal curves, constitute the fractal ontology of water. However, before moving to the conclusions, one further question deserves consideration. If the concept of fractals itself emerged from within the scientific apparatus, how, then, can it function as the foundation of an ontological proposition aimed at contesting the modern constitution of water as a statist, measurable, and controllable resource? In the body of the article, I have already begun to address this question by suggesting that fractals may be understood as post-mathematical. In this section, I extend that discussion.

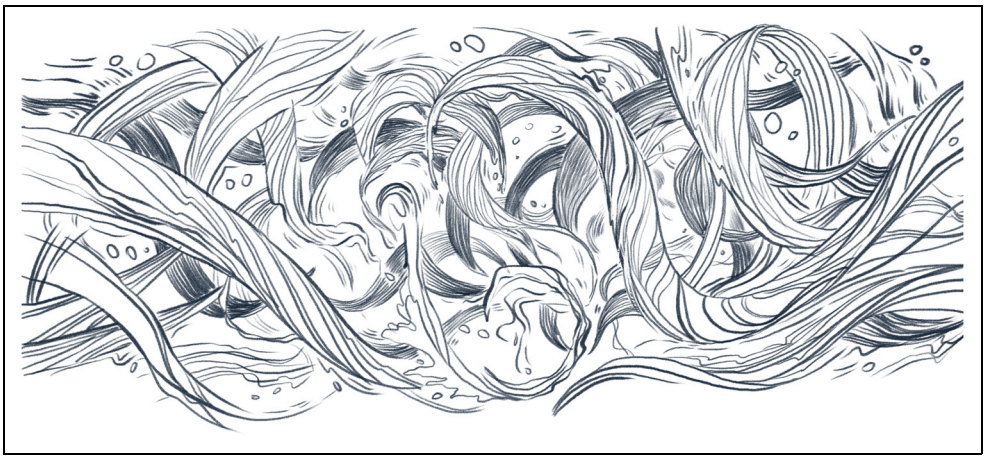

Figure 5. Repetition and vitality. Illustration by Natalia Batrakova.

I argue that the fractal paradigm remains promising in rethinking water ontologically because I believe that the scientific idea of fractals contains lines of flight that make it convergent with other onto-epistemologies, particularly those that have critiqued statist, linear, and reductionist paradigms of water. Science is not a homogeneous ontological apparatus. While reductionist, statist, and linear ontologies of mastery and control have become prevalent and hegemonic within modern science, scientific thought has always contained tendencies that destabilise these dominant orientations or, at the very least, point toward alternative openings and convergences with other cosmologies (cf. Latour, 1993).

In this sense, fractal ontology can be understood as one of these lines of flight. The idea of fractals entered scientific discourse through *observation*: the recognition of the multiscalar and seemingly chaotic, yet metastable, organisation of matter and energy, including water. The *observational* issue is important here. It signals an act of *noticing* and subsequently *acknowledging* the complexity of matter-energy-life cycles. The fractal paradigm also creates space for engaging with the unknown. In this sense, fractals challenge assumptions of total knowability and complete predictability through quantification. The fractal paradigm points instead toward the limits of human knowledge, inviting attentiveness to forces and processes that exceed human comprehension and control. As such, they resonate with cosmologies that foreground unknowability, humility before greater-than-human powers, and learning from the patterns and processes of the more-than-human world.

Such learning also often involved humility and even awe in the face of these processes, opening an ethical dimension within the fractal paradigm that challenges anthropocentric assumptions of mastery and control. It is therefore no coincidence that fractal forms have appeared in various Indigenous designs and cosmologies, nor that water has been conceptualised in fractal terms in works such as *Theory of Water* by the Mississauga Nishnaabeg thinker and writer Leanne Simpson (Simpson, 2025). In this reading, fractals become more than mathematical and scientific objects, but rather ontological propositions towards – if we use Latour's conceptual terminology – *amodern* water (Latour, 1993).

Conclusion: Summary of the fractal paradigm, its practical implications, and future directions

In this article, I have proposed a fractal paradigm of water as a way of rethinking water's material becoming beyond the modernist ontology that renders it a determinate chemical substance. By drawing from philosophy of movement and, thus, foregrounding movement rather than

determinacy as its ontological constitution, this paradigm reframes water not as H_2O-in-itself but as *water-as-motion*: an always-emerging materiality constituted through fractal, volumetric, intra-scalar, and ultimately indeterminate motion.

Thinking fractally shifts our analytical attention away from the ontological atomism, linear causality, and hierarchical scaling that have shaped modern ways of seeing water. Instead, it encourages us to perceive water from within its own self-similar yet indeterminate and ever-transforming flow-forms. Water is therefore relational to itself through its motion, but equally relational to other forms of matter and life, which are likewise characterised by motion and change rather than by fixed, determinate identities. Relationality is thus a constant and collective process of transformation.

The fractal paradigm also challenges prevailing ideas of order and efficiency that have justified the containment, straightening, and immobilisation of water in modernity. Fractality draws attention to the forms of biophysical order produced by indeterminate becoming: while matter is always in motion, it nevertheless exhibits the meta-stability of planetary circulation and biophysical functions. I call this state of an indeterminate yet meta-stable universe *orderly chaos*. Through this paradigm, water's capacity to sustain and reproduce life emerges not from its chemical sameness but from the indeterminate, yet self-similar and repeated patterns of its movement across time and space.

Since the article's primary contribution lies in the realm of theory and conceptual work through the development of a fractal paradigm of water, its practical contribution is the transformation of how we understand and relate to water. However, because the argument emerges from an actual political problem, namely the global water crisis and the ontological configurations that presumably contribute to it, it is important to provide some indication of what the fractal paradigm might mean for water management and governance.

With regard to water management, it is important to note that knowledge of the fractal organisation of water movement has already been used extensively, particularly within geoengineering. Indeed, these practical applications provided much of the initial inspiration and empirical grounding for this article and its subsequent theorisation. Applications of such knowledge range from water mixing and treatment to the design of water infrastructures that accommodate fractal patterns of movement rather than dividing and disrupting flows, which can contribute to water-borne disasters and ecological degradation. Attuning to fractality can thus inform more responsive and relational engagements with water – visible in contemporary shifts toward dam removal, hydromimetic design, and approaches that work with, rather than against, water's own dynamic patterns.

It is important to emphasise that the fractal paradigm, while questioning and reworking the modernist paradigm of water, does not seek to abolish the idea of water management altogether. Humans have always interacted with water and attempted to manage or utilise it; what matters is the ontology and cosmology upon which such practices are based. Rather than imposing anthropocentric ideological designs upon water and attempting to subordinate it to human intentions, the alternative is to cultivate humility and learn from water's movements, cycles, and processes, as well as those of other forms of matter and energy. It is this latter approach to which I hope the fractal paradigm can contribute. The shift is therefore not from management to non-management, but from *mastery* to *participation*: from attempts to stabilize, control, and redirect flows toward a mode of coexistence that engages with processes of water's movement.

With regard to water governance, the fractal paradigm first and foremost invites us to reconsider how we understand water and its materiality, rather than focusing exclusively on questions of distribution among human users. The intra-scalar fractal organisation of water movement resonates strongly with what has been termed nested governance: an approach that is organised less around geographically bounded units defined by linear, two-dimensional political and administrative borders and more around nested watershed units that correspond to the interconnected dynamics of hydrological systems (Rosso, 2025). Such arrangements are responsive to the fractal organisation of water itself. Nested governance also aligns with the concept of polycentric governance, in which

multiple scales and centers of decision-making coexist without being subordinated to a single centralised authority. These forms of governance appear particularly compatible with the material dynamics of water movement, although they undoubtedly require considerable coordination and institutional effort to function effectively (Huang et al., 2025).

Furthermore, because the fractal paradigm incorporates discussions of water's relationality and vitality, it resonates with recent developments in water governance that emphasise these principles. This includes ideas of geographical and temporal responsibility that arise from water's capacity to connect places, communities, and generations through its movements and cycles. In many Indigenous approaches, such responsibilities are enacted through practices of stewardship (Acharibasam et al., 2024; Castleden et al., 2017). Similarly, the fractal paradigm echoes recent rights-of-nature initiatives in which rivers, lakes, and other water bodies are recognised as legal entities possessing rights of their own, reflecting their constitutive role in sustaining broader ecological relations and forms of life.

As a final opening in this article, it is important to consider potential future intellectual engagements with fractal ontologies. With regard to the practical implications of this conceptual paradigm, important questions remain concerning what fractal understandings of water might mean for water management and governance, and how these insights could contribute to more ecologically attuned forms of collective coexistence with hydrological processes. However, fractal ontologies also invite further *theoretical* development. Fractals characterize not only the movements of water but also many constitutive processes of the material and living world. The fractal paradigm may therefore serve as a productive conceptual tool for reimagining material relationality, understandings of diverse forms of matter and biophysical forces, and human–nonhuman intra-actions more broadly.

Highlights

- Develops a fractal paradigm to reconceptualise water beyond atomistic ontologies.
- Theorises water-as-motion, integrating the fractal paradigm into the philosophy of movement.
- Conceptualises water as fractal motion characterised by decentered voluminosity.
- Introduces orderly chaos to describe water's indeterminate yet metastable nature.
- Argues that water's vital role in reproducing planetary life emerges from its changing yet self-similar temporal and spatial cycles of motion.

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Consent for publication

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