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COUPLING COMPLEXITY

Ecological Cybernetics as a Resource for Nonrepresentational Moves to Action

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We live in an era of ecological crisis. Climate change, plastic pollution, radiation drift—our most pressing environmental concerns are on a planetary scale. They are experienced everywhere and yet they are difficult, if not impossible, to see. An extraordinary amount of resources devoted to addressing ecological crises are spent simply trying to depict these crises and trying to teach people how to properly interpret the representations. The hope is that if only the general public and policy makers could *see* what is happening, they would better understand, and this understanding would lead to action. Scientists, activists, and policy makers advocate for *higher* resolution climate models and *more complete* descriptions of the locations and effects of ocean plastics, or radiation drift from Fukushima, or extreme weather. Bigger, better, clearer pictures are the key to informed action. They account for more variables, simulate more mechanisms, and inform the construction of better models that reflect our total understanding.

This pursuit of representational fidelity aligns with the long-standing technocractic legacy of what historian Paul Edwards calls "the closed world," or "global surveillance and control through high-technology military power."[1] With the detonation of atomic bombs at the end of World War II and subsequent threats of planetary nuclear annihilation during the Cold War, it became increasingly possible to imagine that humans could act at planetary scale. Such action required global infrastructures like computing networks for gathering information about everywhere. It also required new kinds of whole world sciences that would provide knowledge paradigms for reasoning about the state of the entire earth.[2] When both the planet and its knowledge systems are imaged as global and enacted as such, ecological crisis also becomes understood through the computational infrastructures undergirding military action.[3]

In this chapter we revisit the legacy of two of the most "whole world" of the whole world sciences: ecology and cybernetics. Both imprinted the popular imagination with ideas about holism, systems, balance, and equilibrium. Their legacies are entangled in the development of global knowledge infrastructures. They are remembered as intellectual disciplines that helped gather, license, represent, and finally act upon global knowledge. What failed to endure was their more radical critique of the technocratic genre of ecological knowledge. By looking back at mid-century cybernetics and ecology, we'll show that in their efforts to describe complex systems these sciences rejected reductive, linearly causal concepts of the world. As they encountered the limits of representation implicit in the knowledge structures of traditional disciplinary sciences,[4] they created ways of describing "systems" and "loops" where many different kinds of entities interacted to maintain stability. Ecology coined the "ecosystem" concept and cybernetics turned to models of self-regulation to find mechanisms like "feedback" by which systems maintained "homeostasis" in spite of environmental change.

We follow a strand of ecological cybernetic thought in which practitioners' ambitions to address massively complex, dynamic, and contingent circumstances led them away from the hallmarks of representational knowledge: translation, prediction, accuracy, resolution, and the accumulation of data. Instead, they articulated a knowledge regime that skipped representation in favor of getting complex systems to talk to one another directly. They offered a vision of complexity managing complexity through co-regulation, or coupling. By attempting to pair ponds with factories or children with algorithms, cyberneticists modeled systems speaking to one another to accomplish action without an interpretive middleman vetting facts and knowledge beforehand. This break with dominant modes of knowing and acting offers resources for critical media scholars and environmental activists interested in addressing ecological crisis without relying on bigger, better, clearer pictures.

How Ecology Got Its System

Ecology developed at the beginning of the twentieth century at the intersection of biology, natural history, and botany. Traditionally, life sciences were concerned with documenting species living in particular areas, and then asking why these species were present. Scientists focused on generating lists of vegetation *or* animals. In the rare cases where both were recorded these lists excluded living and nonliving variables like soil or climate that were key to ecological change.[5] As scientists became interested in changes in species and vegetation occurring over time, methodologies that relied on listing no longer sufficed. In 1935 Arthur Tansley coined the term "ecosystem" as a universal concept to address methodological problems emerging within ecology:[6]

> The whole webs of life adjusted to particular complexes of environmental factors, are real "wholes," often highly integrated wholes, which are the living nuclei of systems in the sense of the physicist [. . .] including not only the organism-complex, but also the whole complex of physical factors

> forming what we call the environment of the biome—the habitat factors in the widest sense. Though the organisms may claim our primary interest, when we are trying to think fundamentally we cannot separate them from their special environment, with which they form one physical system. It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth.[7]

By the 1940s ecologists treated the environment and its parts as a holistic system.[8] Ecologists generally agreed that living systems changed over time even as they remained relatively stable, but they disagreed about the nature of these seemingly contradictory dynamics. Ecologists like Henry Gleason argued that ecological interactions are uneven, even coincidental, and probabilistic rather than deterministic.[9] Living systems are so complex and indeterminate that accounting for all interactions within them is impossible. Tansley believed "ecosystem" captured this sense of complexity while making the study of interrelations feasible. Ecosystems were "systems we isolate mentally . . . the isolation is partly artificial, but is the only possible way in which we can proceed" with research.[10] Part theory, part thing-in-the-world (constructed as they may be), ecosystems "form one category of the multitudinous physical systems of the universe, which range from the universe as a whole down to the atom."[11] An ecologist could study a small system, or part of a system, and extrapolate discoveries to other scales, but an exhaustive description of the system was never a possibility.[12]

During the late 1930s and early 1940s, Raymond Lindeman became the first ecologist to study an entire ecosystem as an ecosystem.[13] By organizing a lake ecosystem into a food chain (also called trophic levels), he measured energy transfers between species.[14] This method let Lindeman trace the ecosystem's behavior at a minute level, allowing previously invisible and unknown relationships to emerge. Most famously, he discovered "the ten percent law," describing the efficiency of energy transfer between trophic levels. When predators eat herbivores, ten percent of the matter consumed becomes flesh. The rest is lost to respiration and other processes, a shockingly inefficient outcome given assumptions at that time.

Lindeman's models were at the cutting edge of ecology and yet he never purported that they represented the whole system. His calculations allowed him to map ecosystem *relations* and he considered his diagrams approximations.[15] Precision was not required. Imprecise data was fine for building low-resolution models since even low-resolution models proved that energy moved in an ecosystemic fashion. More than forty years later, ecologists still agreed that "an ecosystem model, no matter how sophisticated or difficult to produce, is but a shadow of its prototype."[16] Early ecologists never aspired to completeness. Metaphor, analogy, and approximation sufficed because their goal was to describe the general shapes of systems in terms of their basic mechanics. Lindeman's work demonstrated that even low-resolution models revealed previously unsuspected relationships. Thus, ecological "maps" of complex relationships—node and arrow models that give the "gist" of relations rather than precise descriptions—became the hallmark of the ecological imagination (Figure 14.1).

Historian of science Lorraine Daston distinguishes between precise and accurate scientific representations: precision is "the clarity, distinctness, and intelligibility of concepts; accuracy refers to the fit of numbers to some part of the world, to be ascertained by measurement."[17] Daston argues that early modern scientists often employed precise rather than accurate definitions of novel phenomena. For example, Van Leeuwenhoek's claim "that there 'were no less than 8 or 10,000' living creatures teeming in a drop of water . . . spoke to this penchant for precision without accuracy."[18] Likewise, early ecology was precise, rather than accurate. It pointed to processes discernable within a new perspective and showed the general shape of complexity in an overall system.

Today, ecology and ecosystem are floating signifiers that usually mean whatever interpreters want them to mean, including different and often contradictory concepts in different fields and discourses. In their earliest deployments, however, these terms designated living systems composed of many moving parts that were capable of sustaining themselves in dynamic conditions. Even though early

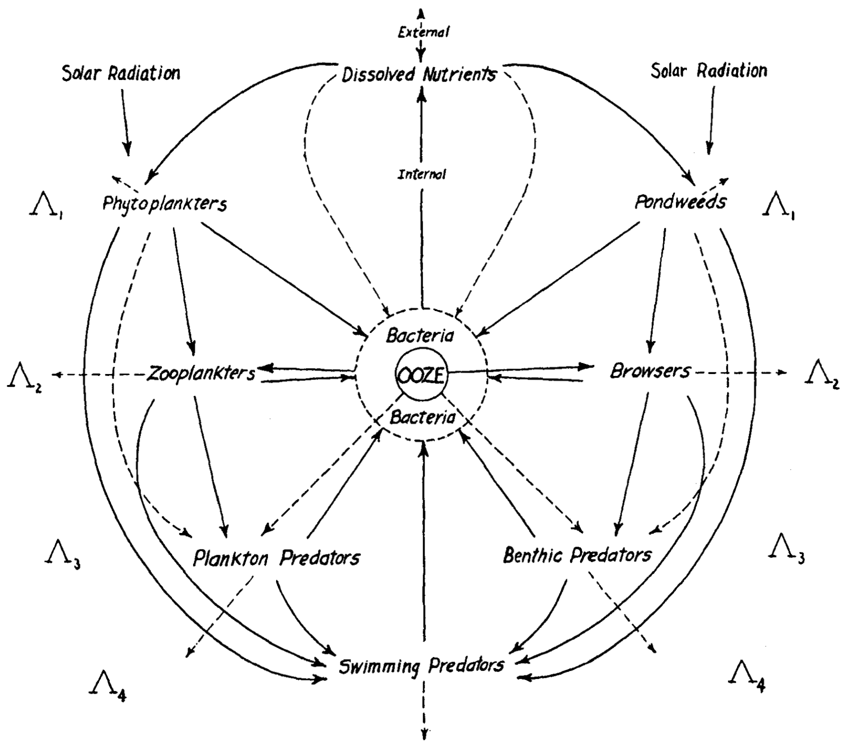

FIGURE 14.1 Lindeman's food web diagram of relationships between soil, microorganisms, animals, plants, and chemicals.

cyberneticists did not collaborate with ecologists for nearly a decade, they were already engaged in ecological thinking because they were working on analogous questions.

How Cybernetics Got Its Loop

Cybernetics, or "the entire field of control and communication theory, whether in the machine or in the animal," coalesced into a research paradigm during World War II.[19] In 1941, Norbert Wiener, one of the field's progenitors, joined the Radiation Laboratory at Massachusetts Institute of Technology (MIT) as part of a project funded by the National Defense Research Committee. There, he collaborated with control engineer Julian Bigelow and physiologist Arturo Rosenblueth to develop an anti-aircraft artillery system that would become emblematic of the cybernetic paradigm. The chief difficulty in building an anti-aircraft system was not the physics. After all, projectiles in flight are mainstay examples of classical Newtonian physics. The problem was the "machine in the middle," or the human being. How could an automatic system accurately predict the behavior of the pilot in the plane? How could a machine forecast the actions of a system that is simultaneously mechanical, electrical, and psychological, whose parts are both human and machine?

In 1943, Rosenblueth, Wiener, and Bigelow published a seminal paper entitled "Behavior, Purpose, and Teleology," arguing that systems could be studied in terms of their relationship to their environment.[20] Environments provided *inputs*, external events that modified the system, and systems generated *outputs*, or changes in the surroundings. Their framework focused on behavioral loops that bound systems to their environments. Thus, cybernetics adopted a *black box ontology*, bypassing any ambitions towards complete descriptions of the system's inner workings to focus instead on how parts interacted to produce sustainable wholes.[21]

Like early ecology, early cybernetics concerned itself with the mechanisms by which systems sustained themselves in changing conditions. The trick was in understanding self-regulation without recourse to the inner workings of the entity in view. Rosenblueth, Wiener, and Bigelow accounted for the self-regulatory process in terms of *feedback* and *homeostasis*, concepts borrowed from control engineering and physiology, respectively. Feedback names the capacity for a system to take past performances as inputs, thus monitoring actual rather than expected performance to adjust future conduct. Homeostasis refers to the processes by which systems self-regulate to maintain stable conditions in shifting external environments. The classic example is temperature regulation in warm-blooded animals.[22]

These concepts let cyberneticists go forward with unknown elements in their systems; the inner workings of the machine in the middle did not matter so long as feedback loops could be constructed. The anti-aircraft system could consider the plane's position (input), then fire (output), and then consider the plane's new position (input) before firing again (output). From recursive loops of inputs

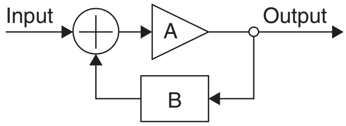

FIGURE 14.2 Cybernetic loop.

Source: Wikimedia Commons.

and outputs, homeostasis emerged. Cybernetic systems were stable despite—and because of—change.

Cybernetics offered a behavioral rather than functional framework for scientific inquiry. What mattered were whole-systems performances rather than complete models of the inner workings of parts. Practitioners could black box parts of systems and focus instead on effects, or outputs, and control by communication, or inputs. Abstracting away inner workings opened the door to a radical inclusion of different entities that could be studied within a common domain. This accounts, at least in part, for the diverse phenomena studied by early cyberneticists: anti-aircraft guns, ataxia, purpose tremors, wave filters, heart flutters, neuronal nets, and rather macabre experiments that involved splicing cats to engineer feline-mechanical circuits.

Second Wave Cybernetics: What Cybernetic Ecology Looks Performs Like

In the Cold War climate of the 1950s, political and environmental threats to the cessation of life on a planetary scale gave ecological and cybernetic projects a sense of urgency. The watchword for both was *entropy*. As social, environmental, and political systems seemed to become more disorganized and precarious, scientists in both disciplines wondered how life—order and organization—was maintained despite the second law of thermodynamics, the tendency towards disorganization.[23] Bernard C. Patten and E.P. Odum, prominent ecologists and staunch cybernetics advocates, wrote that "the balance of nature" is an organizational design that "creates order where there could be chaos."[24] In "An Introduction to the Cybernetics of the Ecosystem: The Trophic-Dynamic Aspect," Patten borrowed concepts from cybernetics to analyze the life-sustaining organization of ecosystems:

> A general theory of ecosystem dynamics is developed from basic considerations of order and disorder as elucidated by modern information theory. Disorder is proportional to entropy; order to information, which is negative entropy. . . . This is in opposition to the second law of thermodynamics which militates that ultimate absolute disarray of all energy matter.[25]

Likewise, Norbert Wiener's *The Human Use of Human Beings* (1950), which introduced the general public to cybernetics, cautioned that "life is an island here and now in a dying world. The process by which we living beings resist the general stream of corruption and decay is known as *homeostasis*."[26] Scientists turned to homeostatic systems to understand how to resist entropy at the level of the organism, machine, civilization, and ecosystem.

These concerns intensified as cybernetics entered its second wave in tandem with popular environmentalism. A growing catalogue of the disastrous effects of pesticides, radiation, and industrial chemicals entered public discourse through works like Rachel Carson's 1962 *Silent Spring*. These accounts made clear that humans had inadequate means for thinking about and controlling their relationship to the environment. Left unchecked, our behaviors risked the survival of humankind. The idea that humans were runaway elements of a larger system that we would eventually crash crystalized in the 1972 book *The Limits to Growth*, which used computer modeling to predict an exponential increase in human population and subsequent depletion of the earth's food supplies.[27]

In 1968 cyberneticist Gregory Bateson convened a conference aimed at addressing the problem of balancing runaway human-ecological systems. The conference entitled "Effect of Conscious Purpose on Human Adaptation" opened with a paper on environmental crisis delivered by Barry Commoner, a founder of the modern environmental movement. Commoner used the example of nitrate pollution to explain how human actions affected larger ecosystems. His call to action dovetailed with Bateson's goal of expanding cybernetics to three kinds of homeostatic systems: the individual human organism, the human society, and the larger ecosystem.[28] At each scale, consciousness was considered "an important component of *coupling* of these systems."[29]

> This concept of *coupling*—hooking systems together to constitute each other's environment—brought self-regulating systems into a more complex version of a steady state. Each system remained a black box to the other system while regulating its neighboring system just the same. The trick was getting them to recognize each other's inputs and outputs, or communicate. Bateson described the problem through an analogy to Lewis Carroll's description from *Alice in Wonderland* of Alice playing croquet:
>
>> Alice is coupled with a flamingo, and the "ball" is a hedgehog. The "purposes" (if we may use that term) of these contrasting biological systems are so discrepant that the randomness of play can no longer be [. . .] known to the players. Alice's difficulty arises from the fact that she does not "understand" the flamingo, i.e., she does not have systemic information about the "system" which confronts her. Similarly, the flamingo does not understand Alice. They are at "cross purposes." The problem of coupling [humans] through consciousness with [their] biological

> environment is comparable. If consciousness lacks information about the nature of [humans] and the environment, or if the information is distorted and inappropriately selected, then the coupling is likely to generate meta-random sequences of events [or chaos].[30]

Clarifying the rules of croquet will not make the game more playable. The real stakes of this game, and by analogy this model of science, were communicative, not representational. Alice cannot understand the inner workings of hedgehogs any more than hedgehogs understand the inner workings of little girls. What Alice needed was neither more precision nor greater fidelity, but rather a means of coupling in the hedgehog's terms in a way that allowed her to win the game. The emphasis on regulation through coupling and communication was a hallmark of second wave cybernetics.

Stafford Beer, perhaps the most prolific second-wave cyberneticist, spent much of his career concerned with what he called "exceedingly complex systems." These systems were so indeterminate and unknowable that they could never be accounted for through the traditional paradigms of determinate science and linear causality. Instead, Beer advocated the regulatory paradigm common to both cybernetics and ecology. He drew upon the holistic visions of ecologists like James Lovelock and Jan Smuts to urge a shift towards systems thinking:

> The image of life crawling around in its multiplicity of species, looking for a "biological niche" to which it can somehow adapt, is replaced by the creation of an environment that implies such life. It is an environment in which tiny changes in the salinity of the oceans, the composition of the atmosphere, and indeed all other major variables make life impossible.[31]

In the 1950s Beer began experimenting with what he called "fabrics" for regulating exceedingly complex systems. His hope was that these fabrics might proffer a more robust means of regulating firms, factories, or even nations.[32] Rather than try to blueprint, say, an ideal factory, he treated the factory as a system built of recursive parts that worked in the looping fashion of input and output to respond to a changing world. The trick was to enroll some other already homeostatic system into the position of regulation: to couple Alice to the hedgehog.

Beer surveyed a range of chemical and biological candidates (computing was still too primitive to be considered) such as chemical systems, lipid membranes, human, and other vertebrates. He invented a game where children solved simultaneous linear equations without understanding any of the underlying mathematics. The game demonstrated that systems relations amplified the intelligence of their constituent parts thereby proving animals like mice, rats, and pigeons should also suffice. Beer investigated social insects like bees, ants, termites, and smaller organisms like the larva of yellow fever mosquitoes and *Daphnia*, a freshwater crustacean.

The inner circuitry of these fabrics never needed to be (and never could be) designed in detail. Otherwise, Beer argued, "What virtue is there in self-organizing capacity?"[33] In fact, fixed circuitry was a liability. Unable to adapt or respond to new situations, fixed systems are not stable over the long term. Beer argued that what is needed is "not blueprints, but high-variety undifferentiated fabric which we can *constrain*. We do not want lots of bits and pieces which we have to put together."[34] It was better if fabrics were "constrained by their own experience, an 'epigenetic landscape,'" since no designer could possibly know what the future required.[35] Comfortable with—even celebratory of—radical indeterminacy and not-knowing, Beer thought about how specific systems characteristics might be compatible with humans. Knowledge was gained through trial and error, coupling different things together over and over. Hence the bull in a tea cup with Beer looking on (Figure 14.3); his job was not to know, but to introduce and to prod.

In a series of experiments on *Daphnia*, dead leaves and iron filings were added to their tanks in the hope that if the crustaceans ingested sufficient filings they would respond to magnetic fields. Inputs could then be transmitted to colonies via electromagnets. Outputs would be the colony's adaptive behaviors, as embodied iron filings changed the electrical characteristics of their space. In theory, the system would retain sufficient freedom to continue evolving through processes of self-perpetuation and regulation. Beer's experiments never succeeded because the colony kept collapsing due to a steadily increasing suspension of tiny magnets in the water. His next move was to enroll an even more complex system, an entire

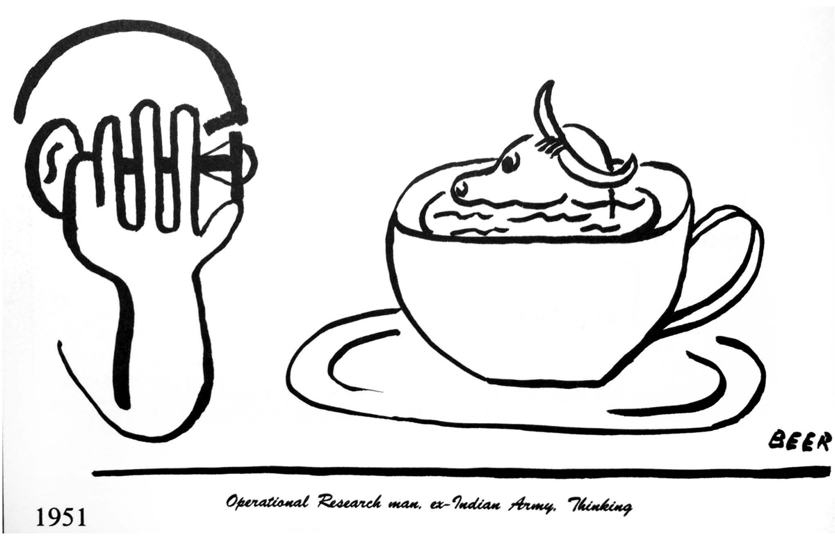

FIGURE 14.3 The difficulty of coupling complex systems.

Source: Beer, 1951.

pond. Beer filled tanks with water samples collected from Derbyshire and Surrey. The samples contained the usual suspects: hydra, *Daphnia*, a leech, microorganisms, other biota. Such a system should self-stabilize so long as enough trophic levels were in the sample. Still, the problem of enlisting the system into the position of a controller in some recognizable manner remained.

Historian of science Andrew Pickering writes that the

> sheer oddity of trying to use a pond to manage a factory dramatizes the point that ontology makes a difference. If one imagines the world as populated by a multiplicity of interacting exceedingly complex systems . . . then one just might come up with this idea.[36]

Pickering characterizes cybernetics projects as "non-modern ontological theater," where emblematic projects demonstrate how departing from the traditional technoscientific vantage produces radically different knowledge structures, practices, and entities.[37] Beer's work inverted the traditional hierarchy between designers and raw materials. Rather than treating materials as "inert lumps of matter that have to be assembled to make a meaningful system," his work treats the world as a place already filled with lively, vibrant matter just waiting to be enrolled.[38] For Pickering (following Heidegger) cybernetic materiality emphasizes relationships of *revealing* rather than *enframing* between humans, machines, nature, and the world. For Heidegger, technology enframed nature as a *standing reserve* of resources for human tasks.[39] Knowledge preceded action. Here, knowledge *is* action. It is revealed in performance rather than mapped in advance.

A concern with coupling moved cybernetics further from the stakes involved in knowledge accumulation models that trade upon representational completeness and towards more performative interests. The science of control grew, at least in part, into a framework for articulating the ethics of communication. Complex systems interacted only when systems were addressed in a language that their structure understood. Control became communication and communication was the emergent property of open, coupled systems interacting in recursive loops. Conversation was the mode of both self-regulation and entropic resistance, and without it life in the contingent universe would not persevere.

Coupling Complexity and the Case of Ocean Plastics

By the 1960s cybernetic thinking was disappearing from computer science.[40] High formalism and an emphasis on symbolic processing, precisely the kinds of cognitivist, determinist modes of knowledge that cybernetics and ecology pushed against, came to dominate the field. Today, a resurgence in cybernetic thinking is underway. Detectable in areas like robotics, biological computing, and machine learning, scientists and engineers are increasingly incorporating feedback loops between complex systems as a means of achieving systems performance in the

world. Thus, revisiting ecological strands of cybernetics enlarges our imagination by showing how performative approaches change the stakes of critique and action, particularly in the face of twenty-first-century environmental crises. We ground this contribution by closing with an example of environmental change in order to illustrate what an eco-cybernetic approach to the problem might look
AuQ34 perform like.

Every ocean in the world contains plastics. Ocean plastics are tiny (usually less than 5 millimeters), unevenly distributed in the water column, and spread across the oceans like a liquid smog.[41] In 2011, plastics outweighed plankton, and thus food stock, in the middle of the Pacific Ocean by six to one.[42] On beaches in Kauai, Hawaii, plastic washes ashore at a rate of 484 pieces a day.[43] Two-thirds of marine animals ingest ocean plastics; the chemicals associated with plastics become concentrated in their bodies and then through food chains.[44] In other words, we *know* that ocean plastics constitute an ecological crisis because they are changing how ecological systems work.

Yet ocean plastics are not legible as a single global phenomenon. There is no island of plastic to point to, let alone measure. Attempts to quantify plastic and paint a big picture have faced acute challenges. For example, a 2010 scientific report synthesizing all plastic collection studies conducted in the North Atlantic from 1986 to 2008 and based on more than sixty-four thousand pieces of plastic provided one of the most complete representations to date.[45] Yet the model did not indicate a stable progression of pollution over time. Rather, ocean plastics seemed to disappear and reappear. Thus, "despite a strong increase in discarded plastic, no trend was observed in plastic marine debris in the twenty-two-year data set . . . it is impossible to estimate the size of this sink."[46] Another recent report found that although we *know* (based on models and empirical data) that there are millions of tons of plastics, "[w]e can't account for 99% of the plastic that we have in the ocean."[47] Scientists hypothesize that fish are ingesting the plastic and that these plastics are then sinking, but "the pathway and ultimate fate of the missing plastic are as yet unknown."[48] For many scientists, policy makers and industry representatives, these results trigger calls for more data, more studies, and better models. In short, they call for bigger, better, clearer representations. But what call to action might result from an eco-cybernetic imagination?

DISCUSSANT: Do you really have anything in the nature of a meaningful measure of the environment in question?

BEER: I do not suppose I have to, and I do not care. You see, the things is, if we preoccupy ourselves with transfer functions, and being able to define things, and the getting of meaningful measures, we are constructing a descriptive science—not a control science. [. . .] It seems to me that our conditions for the real control system are very, very simple. You take a line from a control box into the world, where there must be some effect, any effect; and you take a line out of the world and into the control box, where there must be some effect. And this system will run to stability . . . we do not need to know what those transfer functions are.[49]

Following Beer, we could assume that the amount, location, and movement patterns of plastics in the ocean are unknown and perhaps even unknowable. They can remain black boxed. We can instead look at the inputs to and outputs from the ocean. We know from industry reporting that plastics production is increasing exponentially.[50] We also know that most ocean plastics come from land.[51] Thus, we can identify an input.

The ocean has long been regarded as the "ultimate sink," an "ecosystem service" that absorbs the detritus of production, allowing more to occur.[52] It is an infrastructure that allows for disposability, a way of making waste go away. This property is feedback. It fundamentally connects land-based economies to oceans such that together they constitute the oceanic environment. Many scientists and activists are calling for a *de*coupling of land and ocean. They argue that rather than build a scientific infrastructure for adequately representing the state of ocean plastics pollution, we should act to reduce the flow of plastics.[53] Interrupt the loop rather than open the black box. Many ocean plastic researchers are involved in banning microbeads in personal care products, plastic bag bans, and other legislation to reduce disposable plastics.[54]

Another example of eco-cybernetic thinking in marine plastics is the 2015 publication, "Plastic Waste Inputs from Land into the Ocean." In it, a group of American scientists estimates the amount of plastic entering oceans by "linking worldwide data on solid waste, population density, and economic status."[55] They argue that the "small size [of ocean plastics] renders this debris untraceable to its source and extremely difficult to remove from open ocean environments, suggesting that the most effective mitigation strategies must reduce inputs."[56] They stacked estimates of "mismanaged" waste that could easily escape into oceans from 192 coastal countries. Of course their numbers are estimates and approximations, because like ocean plastics, land-based waste and populations in developing countries are notoriously difficult to measure. Yet they generated a precise, rather than accurate, model that showed the countries with the highest impacts on ocean plastics. The authors conclude that, "industrialized countries can take immediate action by reducing waste and curbing the growth of single-use plastics."[57] This low-resolution model of inputs and outputs shows that plastics move in an ecosystemic fashion. The entire system cannot be defined in detail, nor should it be, as such an approach will miss inputs and possible outputs. The argument for action is to decouple industrial and oceanic systems that are reaching towards a plastic equilibrium.

Tapping back into a cybernetic imagination of ecological action can shift our strategies. Currently, most scholars and activists focus on problems of resolution, or how to understand and represent the mechanisms of ecological crisis. Thus, environmental and scientific disputes often revolve around questions of uncertainty:

How can we get a better picture, a clearer view, or bigger data? Exactly how much plastic is in the ocean? How can we become more certain that what we are seeing closely approximates what is actually happening in the world? Reframing the world as a contingent place filled with complex, interacting systems makes these concerns rather moot. We won't know and so uncertainty is no longer at stake. A cybernetic imagination of ecology might provide resources for worrying less about fidelity and resolution—the hallmarks of certainty—and moving towards comfort with not knowing and yet acting at the level of systems anyhow. We could turn to questions of what should and should not be coupled and whether there might be other kinds of regulating systems better equipped than either humans or computers to manage exceedingly complex problems.

Notes

1 Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996), 1.
2 This model predates computers. See, for example, Thomas Richards, *The Imperial Archive: Knowledge and the Fantasy of Empire* (London: Verso, 1993).
3 Paul Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010).
4 We note that humanities approaches to representation, on the other hand, are characterized by thoroughgoing critique of knowledge transparency and profound recognition of textual polysemy, the play of meaning, and the role of subjectivity in textual formation. In the field of film studies, much of this debate unfolded in the 1970s in the pages of the British journal *Screen*.
5 Kurt Jax, "Holocoen and Ecosystem: On the Origin and Historical Consequences of Two Concepts," *Journal of the History of Biology*, 31, no. 1 (March 1, 1998): 113–142.
6 A.G. Tansley, "The Use and Abuse of Vegetational Concepts and Terms," *Ecology*, 16, no. 3 (July 1935): 284–307.
7 Ibid., 297, 299.
8 Frank Benjamin Golley, *A History of the Ecosystem Concept in Ecology: More Than the Sum of the Parts* (New Haven, CT: Yale University Press, 1993), 72. Note that most of these discussions were happening in the English-speaking worlds of the UK and the US at the time, while other parts of Europe were occupied with slightly different issues.
9 H.A. Gleason, "The Individualistic Concept of the Plant Association," *Bulletin of the Torrey Botanical Club*, 53, no. 1 (January 1926): 7–26.
10 Tansley, "The Use and Abuse of Vegetational Concepts and Terms," 300.
11 Ibid., 299.
12 See for example, Stephen Alfred Forbes, "The Lake as a Microcosm," *NHS Bulletin*, 15, no. 9 (November 1925), https://www.ideals.illinois.edu/handle/2142/45976.
13 Raymond L. Lindeman, "The Developmental History of Cedar Creek Bog, Minnesota," *American Midland Naturalist*, 25, no. 1 (January 1941): 101.
14 Lindeman, "The Trophic-Dynamic Aspect of Ecology," *Ecology*, 23, no. 4 (October 1, 1942): 399–417.
15 Ibid.
16 Bernard Patten and Eugene P. Odum, "The Cybernetic Nature of Ecosystems," *American Naturalist*, 118, no. 6 (December 1981): 890.
17 Lorraine Daston, "The Language of Strange Facts in Early Modern Science," in *Inscribing Science: Scientific Texts and the Materiality of Communication*, edited by Timothy Lenoir (Stanford, CA: Stanford University Press, 1998), 35.
18 Ibid., 35–36.

19 Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine* (New York, NY: John Wiley & Sons, 1948).
20 Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow, "Behavior, Purpose, & Teleology," *Philosophy of Science*, 10 (1943): 18–24.
21 "Black box" is a term from Maxwell on thermodynamics that was annexed to cybernetics by Walter Ashby in his *Introduction to Cybernetics* to allow practitioners to construct systems descriptions without specifying their inner mechanisms.
22 Wiener was introduced to the term "homeostasis" by Walter Cannon, whose book *Wisdom of the Body* described how organisms self-regulate despite environmental fluctuations. In the late 1930s Wiener participated in a series of conversations organized by Cannon and Rosenblueth on the question of scientific method.
23 See Leon Brillouin, "Life, Thermodynamics, and Cybernetics," *American Scientist*, 37 (1949): 554–568.
24 Patten and Odum, "The Cybernetic Nature of Ecosystems," 894.
25 Bernard Patten, "An Introduction to the Cybernetics of the Ecosystem: The Trophic-Dynamic Aspect," *Ecology*, 40, no. 2 (1959): 221–231.
26 Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (New York, NY: Doubleday, 1950), 95.
27 Club of Rome, *The Limits to Growth. A Report for the Club of Rome's Project on the Predicament of Mankind*, edited by Donella H. Meadows (New York, NY: Universe Books, 1972).
28 Bateson characterized these systems as cybernetic because they had subsystems that were potentially regenerative, governing loops, and tendencies towards homeostasis. See Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (San Francisco, CA: Chandler, 1972), 446–453.
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