
The nature that capital can see: science, state, and market in the commodification of ecosystem services

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Abstract. The development of stable markets in ecosystem services is now a major neoliberal policy initiative in the United States and elsewhere. Such markets, however, require ecosystem scientists to play a new and challenging role in certifying the value of the commodities traded, which are defined using the holistic measures of ecology rather than the uncontroversial measures of weight, volume, or time. As ecosystem science increasingly serves as a metrical technology for the commodification of ecosystem services, its fine and fragile distinctions increasingly bear the weight of capital circulation. In this paper I report on fieldwork among ecosystem assessment technicians, and suggest that this new round of the commodification of nature may overwhelm the capacity of science to provide stable representations of commodity value. The methods and techniques of ecosystem assessment must describe a nature that capital can ‘see’—that has an uncontroversial measure—in order for trade to occur. However, these assessment methods currently produce unstable data that are rendered meaningful in economic terms only by dint of creative and ad hoc efforts at translation by field technicians. It is suggested that this may represent a practical limit or crisis point in the expansion of capital relations, or at least a complication in the streamlined neoliberal narratives about the commodification of ecosystem services.

The career of *Aster simplex*—a diminutive herbaceous plant in the sunflower family—as a stable object of knowledge over the past few decades has been something of a rough ride. Genus *Aster* has always been taxonomically difficult, and contains several groups of interbreeding species that separate poorly on the basis of morphological features alone. Attempts to classify this particular small, white-flowered aster, native to wetland habitats in temperate North America, have invoked the following partially overlapping set of formal botanical descriptions:

Aster interior Wiegand

Aster lanceolatus Willd. subsp. *interior* (Wiegand) A. G. Jones

Aster ontarionis Wiegand X *A. tradescantii* L.

Aster bellidiflorus Willd.

Aster lamarckianus Nees

Aster laxis Willd.

Aster tenuifolius sensu Torr. and A. Gray var. *ramosissimus* Torr. and A. Gray

Aster paniculatus Lam. var. *simplex* (Willd.) E. S. Burgess

Aster simplex Willd.

There is, in fact, no current consensus on the very existence of a coherent and discrete species called *Aster simplex*. To make things more complex, Guy Nesom (1994) has authoritatively revised the entire genus based on genetic-sequencing work, and declared that all North American *Aster* actually belong in genus *Symphiotrichum*. And even if the welter of taxonomic revisions were set aside and one were to turn to a simple technical identification manual that describes *A. simplex*, it is one of the more maddeningly difficult plants to identify definitively when standing in a field.

This may seem like a fascinating debate for botanists but for few other people. However, because of the increasingly close connections between scientific methods of ecosystem assessment and the creation of commodities in ecosystem services, scientific disputes over classification and measurement now figure prominently in the establishment and stabilization of new realms for the circulation of value. The physical similarities between, and taxonomic uncertainties among, a group of plants in the genus *Aster* are now important because the federal government has decided that only *some* of these plants serve as indicators of the presence of a functioning wetland ecosystem. Wetland ecosystems that fit the federal definition produce ecosystem services that can now be sold on a market. Correct and repeatable identification of these plants thus becomes a practice with repercussions far beyond botany.

The many functions performed by wetlands are explicitly protected by the Clean Water Act of 1977. With the rise of market-led environmental policies, the protection of these functions is increasingly being accomplished through the definition and trading of 'wetland credits' in regional markets (Robertson, 2004), where the credit commodity is defined in units of ecological function. The definition of such units requires the application of ecological assessment techniques that draw botanists, ecologists, and hydrogeologists into the world of capital circulation as never before—as integral parts of the entrepreneurial production of large acreages of wetland commodities that require certification for their subsequent sale. The very definition and measurement of the commodity is at stake in these assessment techniques: an accurate count of the diversity and density of plants at a wetland site provides the information required to certify a unit of production for sale. As ecosystem science increasingly serves as a metrical technology for the commodification of ecosystem services, the fine and fragile distinctions between *Aster simplex* and other similar asters begin to bear the weight of the commodification process: the validation or rejection of the commodity that a provider of wetland services brings to market may, in fact, rest on this shaky taxonomic distinction.

The nature that capital can see

This controversy over plant identification provides a window on the latest round of the commodification of nature, well described by such authors as Karl Polanyi (1944), James O'Connor (1994), and Noel Castree (2002). Although material elements of nature have been sold as commodities since the birth of markets, the most pedestrian of measurement technologies have typically been used in their measurement, abstraction, and classification as commodities. William Cronon's (1991) classic account of the commodification of grain in Chicago in the 1860s, although illuminating, demonstrates the reliance on uncontroversial measures such as weight and volume. By contrast, the new and rapidly developing markets in 'ecosystem services' are promoted by economists, scientists, and policymakers who insist that the commodity be measured in units of *ecosystem function* (Daily, 1997; Daily and Ellison, 2002; Heal, 2000). This is a fundamental but underappreciated change: the early markets in environmental goods and services were quantified in terms of tons of carbon dioxide or the concentration of a particular pollutant in water or air, which is easily measured in both cases. However, markets in wetland credits are quantified using complex algorithms that measure habitat value, contribution toward water quality, biodiversity, and a number of other difficult-to-quantify functions. The phrase 'units of ecosystem function' does not have a clear ecological meaning, and the task of creating stable metrical techniques for ecosystem service commodification has fallen largely to practitioners in a science-policy hybrid field known as 'rapid ecological assessment'. In the use of such assessments, scientific debates over the true nature of *Aster simplex*, for example, must be silenced so that ecological

information can be intelligible in the logic of capital. A stream of recent work in science studies suggests that capital is not necessarily (as is often thought) blind to ecology: it is not that ecology is excluded, rather it is *how* it is included that matters (Haraway, 1997; Hayden, 2003; McAfee, 1999; Parry, 2004; Sayre, 2002). The story of *Aster simplex* points to the distinction between the ecology that capital can ‘see’, and ecological distinctions that are hidden to the “one-eyed imperatives” of capital (Castree, 2002, page 138).

This idea that the state and capital may be able to ‘see’ only that ecological information which works inside their own logics calls for some elaboration here because it carries important implications for the study of human–environment relations. This is an argument against determinism, whether it is the determination of society by nature, the determination of nature by society, or the determination of one part of society by another: there remains some element of our scientific understanding of nature which is uncaptured by state and capital, and which may provide leverage for reshaping and resistance in these other social spheres.⁽¹⁾ Recently, authors in and beyond geography have focused on the notion of ‘articulation’ as a way of expressing the complexity and lack of determination between three spheres that are traditionally analyzed separately: the state, capitalism, and science. To avoid the determinism that plagues many discussions of nature and science, I have elsewhere argued (Robertson, 2004) that these interactions can be understood as articulations between structurally closed but operationally open (that is, autopoietic) logical realms, following the work of Bob Jessop (2001) and Niklas Luhmann (1989; 2002; see also Rasch, 2000). I have found it helpful to borrow Luhmann’s model of modern society as composed of *multiple* specialized knowledge systems, each with their own governing logic and standards of verity (that is, structurally closed). And yet these knowledge systems occasionally require that input from their outside be translated for circulation ‘inside’, as when scientists give testimony in legal cases (that is, operationally open).

Far from being a brand of cyberneticism (with which it shares the language of ‘systems’), the concept of knowledge realms invoked by Luhmann is actually sympathetic with some versions of poststructuralism and their attendant sophisticated notions of agency (see especially Callari and Ruccio, 1996). Luhmann is an observer of the contingent process of constructing a modernist crazy quilt of logics that, when sutured together, ostensibly provide panoptic knowledge; this quilt, however, is fully capable of coming apart at the seams. For all that modernity purports to be concerned with master narratives and totalizing knowledges, note that we do not go to the Supreme Court to discover the speed of light, just as we do not attempt price discovery in the laboratory. The presence of scientists in the courtroom, or of economists in the laboratory, is sometimes required to produce this suturing, but always also produces a particular epistemic anxiety.

Luhmann conceives of modernity as the ungrounded⁽²⁾ project of aligning multiple (and multiplying) arenas of expertise and systemic knowledge—the lacuna-ridden totality of it lacks both head and center, and the ‘alignment’ of these spheres is responsive to the need to constitute hegemony in Antonio Gramsci’s (1971) sense. He focuses on those points at which new knowledge systems and logics are created to shore up the inevitable paradoxes that can never be fully erased in the modernist project;

⁽¹⁾ This is not just to tilt at the ghosts of Ellen Churchill Semple and Ellsworth Huntington; geographers have recently suggested that some form of environmental determinism might be fruitfully revisited (Peet and Watts, 1996; Walker, 2001, page 178).

⁽²⁾ ‘Ungrounded’ in the sense that the epistemically ‘modern’ era can be understood to be characterized by the lack of a single source of truth, be it king or God, and by the proliferation of knowledges (science, economics, faith) that depend much more on the situatedness and qualities of the knower.

for example, the originary discontinuities that attend the establishment of colonial sovereignty, which has frequently drawn on science and economics to hide the uncomfortable origin and prehistory of a foundational notion such as 'legal'.⁽³⁾ Luhmann draws our attention to individuals whose work makes these sutures appear or disappear. In this he undermines the more dogmatic versions of structuralism while producing an undeniably structural schematic of how our interventions must stand both *within* particular knowledge systems (playing by their rules if we wish to change their dynamics) and *outside* particular knowledge systems (showing where they drop their epistemological anchors: not into ontological bedrock, but into *other* knowledge systems).⁽⁴⁾

Realms of knowledge interact through the contingent work of translation in places or institutions that Luhmann calls *forums of articulation*. Because each specialized knowledge system has established unique standards of proof and verity, ecological information can never enter into legal or capital logics qua ecological information. Instead it must be translated into speech and codes appropriate to law and capital by people who occupy forums of articulation. As an example think of the Federal Reserve, which translates between the languages and standards of law and economics. In these forums, which mediate between systems with very different operational codes, the terms by which one system will play a role in another are negotiated through the constant work of actors whose job it is to make scientific and economic data *mean something* politically, or vice versa. "Scientific descriptions of physical reality cannot dictate the content of the descriptions emanating from other domains", says William Rasch (2000, page 73); they may *appear* to do so, but rather than causing us to cry 'determination' this should instead draw our attention more closely to the forums of articulation in which the *appearance* of determination is forged.⁽⁵⁾

In the arena of neoliberal environmental policy this is close to the way that some writers have characterized the impossibility of a pure 'market triumphalism' which can subsume not only earlier iterations of capitalist and state strategy but also the realms of culture, law, and science (McCarthy and Prudham, 2004; Mansfield, 2004; Peck and Tickell, 2002). Luhmann has paid particular attention to the way that neoliberal

⁽³⁾ He therefore compellingly describes *postmodernism* as the simple recognition of these inevitable paradoxes or lacunae and the abandonment of the nostalgia of modernism for a master narrative which it never possessed.

⁽⁴⁾ The claim that Luhmann is essentially a poststructuralist theorist may seem unlikely given his predilection for structuralist terminology, but it finds a full and sophisticated defense in the work of his US elaborators (Luhmann, 2002; Rasch, 2000; Rasch and Knodt, 1994). My understanding of Luhmann's use of 'system' is as a way of *indicating*, rather than suppressing, the foundational paradoxes in an ostensibly totalizing modernity. All such systems, for Luhmann, are in practice grounded in *other* would-be totalizing systems of knowledge, an acknowledgment which draws our attention to the 'ordering of appearances' and unsettles a complacent acceptance of 'the appearance of order' (Mitchell, 1988; Willems-Braun, 1997, page 15). The systemic, architectonic impulse is analyzed as a symptom of anxiety, and of the inability to ever create the truly totalizing system, in the face of the *political necessity* of producing hegemony. This distinguishes Luhmann entirely, though subtly, from approaches that can comfortably be called 'structuralist' in the traditional sense. Luhmann's family resemblance to poststructuralism is essentially that "they each make the ground they stand on; each then must also show how we necessarily forget that we've made the ground we stand on. Poststructuralism tries to remind us [of this]; Luhmann shows what we do when we are so reminded" (that is, we create systems founded on the concealment of paradox) (Rasch, personal communication).

⁽⁵⁾ This comes close to the study of what Susan Star and James Griesemer (1999) call 'boundary objects'; but my concern with the boundary-objects literature is that it rarely pays sufficient attention to the power relations which are invested in any forum in which boundary objects are created or used to pass information.

economic strategy *requires* other systems of logic such as science and law to be independent enough to *resist* subsumption into economics:

“Within the conceptual framework of economic theory it is possible to determine that the marginal utility and marginal costs of the protection of the environment ought to balance out... *But enormous problems of measurement and practical problems of attribution remain.* Above all, one must realize that the decisions of the economic system never decide for the whole system... the [market] is prefiltered to such an extent that an all-encompassing economic decision rule directed at the environment would find no application” (Luhmann, 1989, page 59; emphasis added).

Neoliberal strategy, particularly regarding the environment, begins to look much more complicated than a fiat of globalizing capital or the hollowing of nation-states. The reward of analyzing environmental governance in this way lies in the appreciation that, although legal and capital logics have come to depend heavily on scientific information in maintaining certain aspects of neoliberalism, *getting hold* of this information in a useful form can be problematic—if not impossible. For example, neoliberal strategies require information from ‘outside’ economics—in the form of legal guarantees on property, or scientific techniques for the metrical evaluation of commodities—and a failure to acquire this information can create bottlenecks or even roadblocks to expanded capital accumulation. The achievement of stable arrangements between the spheres of logic, capital, and various arenas of culture (for example, education, religion) is, as I suggested above, one way of describing the project of hegemony.⁽⁶⁾ The coordination and provision of stable articulations between the state, the economy, and *natural science* is perhaps one way of describing the task of *environmental governance*. When such articulations are firmly made, Tim Luke observes, “ecological analysis emerges as one more productive power formation, disciplinary knowledge system, or strategic political technology” (1999, page 128).

Indeed, neoliberal economists charged with creating these new markets in ecosystem services have pursued such a role for ecological knowledge for some time. Consider the words of Len Shabman (see also Shabman, 1985; 1992), a giant of wetland economic valuation:

“It should be clear at this point that sound economic valuation depends upon sound biological assessment data and analysis.... Clearly, there can be significant gains from cooperative research between biologists and economists so that the development of environmental assessment methods may contribute to economic valuation techniques” (Batie and Shabman, 1982, page 261).

Shabman has been joined by a stream of work from environmental economists that has had a considerable impact on US environmental policy. A growing environmental consulting industry now employs thousands of trained ecologists, who on a daily basis face scientifically unsettled issues such as the identity of *Aster simplex*, reaching a settlement in the cause of commodification. The knowledge system of science is being put into new articulatory relationships with the standards of capital, and scientific data

⁽⁶⁾ For Gramsci, popular consent to hegemonic power turns on the question: “how will educative pressure be applied to single individuals so as to obtain their consent and their collaboration, turning necessity and coercion into ‘freedom’? [‘Law’] will have to be extended to include those activities which are at present classified as ‘legally neutral’, and which belong to the domain of civil society; the latter operates without ‘sanctions’ or compulsory ‘obligations’, but nevertheless exerts a collective pressure and obtains objective results in the form of an evolution of customs, ways of thinking and acting, morality, etc” (1971, page 242). Luhmann’s autopoiesis describes the interpenetration of ‘law’ and other social realms, which is a move toward obtaining just such ‘objective results’.

are doing important new work in expanding the circuits of capital. Drawing from my field experience as a botanist employed in environmental monitoring,⁽⁷⁾ I examine that moment in detail. It is a moment of contingency and potential instability in environmental governance that is crucial to understanding emerging neoliberal market-led environmentalism.

Wetland mitigation banking

Markets for wetland ecosystem services have been created in many regions of the United States since the early 1990s, given footing by the Clean Water Act—which requires that wetland functions be protected by the US Army Corps of Engineers. Anyone wishing to dredge or fill a wetland area must apply for a permit from the Corps. Although permits are usually granted, the court may require ‘compensatory mitigation’, meaning that the applicant must *create* at least as much wetland function as is destroyed through the permitted action. These constructed wetlands, or ‘wetland mitigation sites’, are now common features of new suburban residential and commercial subdivisions. By the early 1990s, however, there was widespread acknowledgment of the failure of these dispersed, project-by-project wetland creation sites to provide lost functions. In addition, land-development interests were becoming increasingly hostile to the long delays by the Corps in approving permits. These factors, plus the structural similarity between the Clean Water Act and the provisions in the Clean Air Act that had fostered a thriving market in air-pollution credits, produced the conditions for the emergence of a group of entrepreneurs creating large consolidated acreages of high-quality wetlands. The Corps certified these sites as containing a certain number of function-based ‘credits’, which could then be sold to developers who held Corps permits. Thus was born *wetland mitigation banking*: the first successful market in ecosystem services defined *as such*, rather than (as in the case of air-pollution credits) defined in conventional units of weight or volume—see Robertson (2004) for a more complete account of wetland banking. Though still a small industry it is experiencing geometrical growth in membership, and has captured the imagination of those who promote market-led environmental policy (Daily and Ellison, 2002; Environmental Law Institute, 1993; 2002).

For the purposes of this analysis I will focus narrowly on one aspect of the banking industry: the process by which wetland credits are certified as providing wetland functions, and the subsequent monitoring which ostensibly guarantees their continued provision. This monitoring is carried out both by private environmental consulting firms and by a team of federal regulators known as the Mitigation Bank Review Team (MBRT). This moment of evaluation is, of course, a moment common to all commodities: the moment at which a classificatory scheme is used to abstract the messy specificities of the object being modified into a set of categories intelligible in the market. Scientific knowledge has long played a part in this moment, testifying to the commodity’s purity, weight, or other relevant qualities of a community. I will argue here that classification is a moment of particular difficulty for ecosystem service commodities, because of its dependence on areas of scientific knowledge that are far less settled than the standard technologies used for the metrical evaluation of commodities.

⁽⁷⁾ During the field seasons of 2002 and 2003, I performed participant-observation research working as a consulting ecologist for a mid-sized environmental engineering firm, which serves clients primarily in the Chicago metropolitan area.

Rapid assessment methodologies and capitalized nature

“Thus, assessment is not a neutral technical exercise but is rather an activity closely tied to the process of redistributing the rights to use the environment, and will become part of the political acrimony accompanying that process.”

Shabman (1985, page 12)

The creation of an enormous legal and political infrastructure to respond to environmental crises in the United States has occasioned the equally massive project of generating ecological data that will allow for the assessment and regulation of environmental impacts. Largely because of the procedural mandates encoded in the National Environmental Policy Act, a great need has developed for methods of functional assessment that are simple, easy to learn, take only a short period of time, and yet can claim some basis in ecological science. Collectively, these methods are known as ‘rapid assessment methods’ (RAMs), and a body of professional and scientific practice has developed around their creation and utilization (Brinson, 1988; 1996; Karr, 1993; Sayre et al, 2000). RAMs function as instruments of translation between science, policy, and economics. Designed by ecologists to respond to logical criteria that come from outside ecological science, they create data that can circulate in each realm (Espeland, 1998; Miller, 2001; Rasch, 2000). Early in the development of wetland banking it was recognized that the commodity to be traded must be defined in a way that maintained a consistent identity across space and time, and was not subject to controversy among the market participants (Brumbaugh and Reppert, 1994). This task must be accomplished before any market can function, not just markets in ecosystem services. Ecosystem scientists are now called upon to create RAMs with a function parallel to that of metrological standards in the regulation of other markets (see Porter, 1995, pages 12–48), but there remains a fundamental debate about their scientific soundness (National Research Council, 2001; Shabman et al, 1994). Some ecologists feel that the use of progressively better RAMs, however imperfect, is the only way for ecological concerns to factor into economic decisions, whereas others feel that RAMs are irretrievably unscientific and therefore should not be relied upon. What is clear is that RAMs are crucial in performing one step in the process of reference abstraction that creates commodities, allowing the abstract ‘wetland service’ to escape from the messy physicality and uniqueness of the wetland itself. David Demeritt describes a similar maneuver in the creation of the commodity of timber out of forests:

“This abstraction of nature’s diverse physical qualities was a reduction, to be sure. It ignored everything about forests except the potential quantity of merchantable timber within them. But it was productive as well. Quantifying the forests in this way created a variety of new and apparently abstract entities, such as the normal forest, annual allowable cut, and the maximum sustainable yield” (2001, page 439).

RAMs are essentially algorithms that transmute easily observable data into some kind of score that stands for the functional value of the entire site. Because there is literally no end to the categories of ecological information that can be included, there is also no end to disputes over which RAMs are superior. Some RAMS, such as the US Fish and Wildlife Service’s habitat evaluation protocols, focus on the quality of habitat for one or a few given species, whereas others, such as the wetland evaluation technique (Adamus et al, 1991) (used by the Federal Highway Administration), cast a broad net and present scores for water quality, hydrologic storage, heritage, recreation, and many other functions. For commodification purposes a single score is more useful than many scores; summing the various scores solves this problem, but also

produces a number whose ecological significance is even less clear. The Index of Biological Integrity (IBI), for example, presents a final score that is the sum of many component evaluations, offering only an unsupported assertion (Karr, 1993, page 1526) that this does not produce arbitrary, unitless data.

In practice, the assessment of bank credits has tended to focus on the functions of hydrology and floristic biodiversity. By comparison, assessments of water quality require expensive laboratory work, and faunal habitat assessments usually are limited to evaluating the quality of the site for only a single species of animal. Hydrologic function is a relatively easy and uncontroversial measurement because of the authoritative power of hydrologic models (which can demonstrate the flood-storage capacity of the site given a minimum of topographic data, without even a site visit). However, as even a lifeless stormwater detention basin can provide 'hydrologic function', most assessors feel that biotic criteria must be included. The MBRT uses a simple list of vascular plants present at a site to assess the ability of a site to provide the function known as 'biodiversity provision'. *Animal* habitat is the primary mandate of the Fish and Wildlife Service (which is heavily involved in regulating the banking market), and attempting to monitor a mobile resource is much more difficult:

"Predictions of wildlife-use are always surrounded by huge levels of uncertainty, and so I don't think you could hold a banker to guarantee that a site'll be used by six pairs of yellow-headed blackbirds, I mean it's not going to work that way, ... Essentially, we all have a sense of what good, native plant communities look like, which end up supporting good, native wildlife populations, and so the plant community structure becomes the structure for wildlife function in a way" (Fish and Wildlife Service official, interview, 9 December 2002).

In fact, plant lists have become surrogates indicating the ability of a site to provide nearly *all* wetland functions. To help formalize this method, the Corps has provided, in the form of a federal rule no less, the *National List of Plant Species that Occur in Wetlands* (Reed, 1988). This is a list of every vascular plant that might be found in a wetland in the United States, sorted by region, each given a score reflecting the certainty with which it indicates the presence of a wetland environment. The RAM used in the Chicago wetlands banking market, known as the floristic quality assessment (FQA), attests to the function of wetlands solely through reference to the presence or absence of particular plants, which are ranked by their desirability in a system designed by eminent regional botanists Floyd Swink and Gerould Wilhelm (1979) to accompany their flora of the region. This method has the dual attributes of authoritativeness and speed, because, above all else, the wetland banking industry needed assessment to be based on

"things that were *quick* to measure: plants are the quickest things to look at. We happened to have in this region Swink and Wilhelm. Okay. No one could argue that Swink and Wilhelm wasn't a definitively expert piece of work, and that it covered exactly our region. So it wasn't a big stretch to say, let's use some of the numbers out of that stuff, which is a well-accepted tome of knowledge, well-regarded by anybody, as our process for measuring whether or not they're successful" (wetland banker, interview, 4 December 2002).

Though there is some regional variation across the United States, wetland banking markets have largely followed the Chicago consensus and based the value of their traded credits on metrics generated from a list of plants present at the bank site. Let us consider how these lists come to be.

Ad hoc logics of articulation

“More! Less! Not sufficiently! So far! Not altogether! What a way of determining one’s concepts!”

Karl Marx (1976, page 187)

“That’s *exactly* what it might be.”

monitoring-team member, identifying a plant (field notes, 17 June 2002)

In his meticulous study of soil scientists researching the savanna transition zone in Brazil, Bruno Latour (1999) discovers that he has not, in fact, left the laboratory behind. Instead, the lab has been transported into the field as the scientists lay out a numbered grid at the field site: “I thought that I was deep in the forest, but the implication of this sign, ‘234’, is that we are in a laboratory, albeit a minimalist one, traced by the grid of coordinates” (page 32). He watches carefully as scientists create stable chains of reference from the messy uniqueness of the physical site, by using representations that are progressively more transportable and abstract. The scientists finally produce a schematic diagram that is said to contain all the relevant information from the site, and yet which weighs no more than a piece of paper.

Latour, as is his habit, wonders more at the performance and construction of these chains of reference than at the forces they serve. In my participant-observation work with a team of monitoring technicians working for a private environmental consulting firm in the Chicago area, however, I was unable to forget that the way we constructed ‘laboratories in the field’, and abstracted the uniqueness of the physical site into a simple list of plants, was heavily enmeshed in the process of producing a commodity. Luhmann would say that Latour studies only the *internal* workings of the social knowledge system that produces ecological knowledge. But when the laboratory in the field is required to present results suitable for commodification, to produce data that can circulate in *other* logics, translations are necessary between the standards employed by the ecologist and other standards employed by capital and by law.

In the examples below I show that the monitoring team members, whose job is to produce ecological data that can circulate in the logics of capital and law, are continually forced to depart from the methodology and logic of ecological science. Ecological science speaks in falsifiable statements drawn from replicable experiments in the hypothetico-deductive knowledge paradigm; the data produced by these scientists, however, must be made to speak to the standard of legality and utility, rather than to that of falsifiability. In each example below, ecological workers produce data and statements that are, from a scientific perspective, flawed. What is significant is not that they are *wrong*, but that they are *scientifically incoherent* in ways that make them coherent legally or economically.

Officially, data submitted on wetland bank sites in the Chicago District should follow the guidelines laid out by the Corps (US Army Corps of Engineers, 1998). The following field procedures are prescribed:

(1) A list of plants must be generated twice a year, in May or June and in August or September.

(2) Permanent straight-line sampling transects must be established, within each different vegetational assemblage (wet meadow, sedge meadow, emergent marsh, etc).

(3) Sampling occurs within 0.25 square meter quadrats along each transect.

When the list has been assembled the FQA is applied and three numbers are extracted:

(1) native mean C: the mean of the desirability values assigned by Swink and Wilhelm;

(2) floristic quality index (FQI): a transformation of native mean C;

(3) native mean wetness coefficient: the mean of the ‘wetness values’ assigned to each officially recognized plant species by the Corps.

Private firms, such as the one I worked for, are contracted to perform the monitoring duties at bank sites and to present the regulatory agencies with the data. Armed with these three numbers, the federal agencies that regulate the wetland banking industry allow or disallow the sale of credits produced at a bank site. In the abstract it seems a perfectly reasonable way of substantiating the value of the commodity. But experience in the field quickly demonstrated moments of potential disruption in these ordinary looking metrical desiderata.

Chasing the vegetation

There is a constant tension between alternative methods of locating the sampling points, known as transects, each of which was established to assess the existence and health of a component of the entire site. At the sites we visited the method chosen depended largely on who was leading the team on a given day. One could sample within the vegetational community that the transect was *supposed* to represent—but, because of problems with the site hydrology or planting, this community might be in a different place than it was *supposed* to be. Alternatively, one could sample along a transect line described in the site plans submitted to the Corps—a letter-of-the-law approach that ignores any discrepancy between site design and the as-built conditions. For instance, if a given transect was established to inventory the ‘wet meadow’ vegetational community—but because the site received somewhat more water than was planned the transect now runs through an ‘emergent’ community—a practitioner of the former approach will simply move the transect to where the wet meadow actually is that season. The latter approach would sample in the emergent community, producing a survey that shows the site to be substantially out of compliance. Speaking personally, the temptation was enormous to move the line of sampling slightly to capture at least some of the vegetation that a given transect line was established to sample, and the practice of monitoring technicians tended to vary by how ‘purist’ the team leader was feeling that day. Another aspect of ‘chasing the vegetation’ was in the mechanics of how the sampling hoop (a hoop of one meter square which, when thrown down, encircled all the plants to be identified) was physically thrown at each monitoring point: far from the intended exercise in random sampling, it is evident that monitoring technicians (myself included) tended to skew the throw to make the hoop land on potentially more interesting or more valuable plants when we arrived at a sampling point. This was at least in part because of the extreme repetition of the task—we sometimes recorded seventy or eighty hoops per day—and the desire to break up the repetition with a botanically interesting or challenging find.

Conventions of identification

Because Corps guidelines mandate that monitoring information be taken in May or June, well before most plants have flowered, the monitoring team is required to assemble a list of plants that must be identified without reference to their flowering parts. As the flower is extremely useful, and often essential, in plant identification, the monitoring team was often unable to rely on floristic identification manuals. We fell back on what can only be described as a set of shared myths concerning the identity of regularly encountered plants. Sprouts in the difficult *Aster* genus, for example, were subjected to a kind of triage: if the stem had hairs decurrent from the leaf bases it was probably *Aster puniceus*; if the lateral buds were bolting it was probably *Aster lateriflorus*; and anything else was probably *Aster simplex*. We would repeat this typology to each other, believing it until someone found, for example, an *Aster* with both decurrent hairs *and* lateral buds: this would either be dismissed as ‘a mutant’, or the dogma would be revised on the spot, with no attempt to correct earlier errors.

We knew ourselves to be ‘wrong’ in the strict sense. Standing within botanical science it would have made sense to recognize that no identification could be made in such a situation; however, because the FQA system the Corps uses to analyze floristic lists *required* a species-level identification, we were compelled to provide one. The certification-driven needs of the industry had created a directive that was botanically incoherent: ‘Identify a nonflowering sprout at the species level.’ Thus, we referenced botanical information (‘*Aster puniceus* has decurrent hairs’), without standing fully within the constraints of scientific procedure and logic—which would have forbidden identification without flowering parts. Our own myths about the significance of various physical features, myths which were sometimes variable over the course of a single day, filled in as an ad hoc logic of articulation.

In discussing these and other irregularities (such as uncontrolled-for differences in stride length, or the unwillingness of shorter technicians to sample in deeper water), the welter of contingencies should not blind us to the point that such irregularities will plague *all* attempts to measure ecosystem function, be it in wetlands or in rainforests or on the tundra. This is because the primary directive for monitoring technicians is *not* to produce falsifiable results that can circulate within a hypothetico-deductive paradigm (as it would be in a scientific experiment such as the one Latour observes). It is instead to produce data that successfully circulate in the networks of law and economics. As workers in a forum of articulation between science and capital, we made use of scientific codings and principles, but, ultimately, scientific operational logic was rejected in favor of the ad hoc logics (our ‘shared myths’) that worked better to bridge the two systems.

Setting baselines

These elements of indeterminacy are at work wherever ecological science plays a role in the banking industry, and nowhere more tellingly than in the baseline survey that establishes the amount of ecological function already extant at the site prior to the restoration of a wetland. The ideal prospective bank site has low preexisting ecosystemic function; this allows bankers to add a good deal of ecosystem service value through relatively little effort. Thus, the initial survey is extremely important in determining the eventual productivity of the site. This is a question not of science but of the economics of differential rent, and it must be answered using RAMS: to strategize production, capital needs to know the comparative advantage presented by specific site conditions. Again, the production of a firm account of existing functional levels pushed the monitoring team to appeal to ad hoc logics, beyond the pale of routinized and replicable scientific activity.

This example considers a proposed wetland bank site in the western suburbs of Chicago. The official application for the bank in question had been submitted with an ‘existing vegetation’ map that had been traced by examining air photography, rather than from data gathered during a site visit. Examining air photographs, the bank applicant had apparently concluded that there was a degraded ‘sedge meadow’ community on the site that, if restored, could generate bank credit. When we arrived on the site it was clear that there actually was no sedge meadow community present, and that a transect installed to evaluate the function of this ostensibly preexisting community would have little meaning. Putting our heads together the team decided that, sedge meadow or no, a ‘sedge meadow transect’ would have to be laid. Failure to do so might result in the bank application being seriously delayed pending major revisions, or even abandoned. After a thorough search of the area a short transect was finally plotted through an area that could be called ‘sedge meadow’ only by a very imaginative and forgiving botanist. In sampling this transect, great care was taken—far more care than

is usually devoted—to ‘catch’ and record every last plant that might have belonged in, and could testify to the presence of, a sedge meadow community.

Again, the botanist might cry foul. By any ecological measure, no sedge meadow community was present. And yet the monitoring team knew that the presence of *some few* floristic components of this community would suffice—in the view of the federal regulatory team that oversees banking—to allow the delineation of a certain acreage of low-function sedge meadow community on the map of the new bank. Had there been no ‘sedge meadow’ plants present, no attempt would have been made to argue that a sedge meadow existed. The monitoring team knew, however, that, because the MBRT looks favorably upon proposals to restore relatively rare sedge meadow communities, the rehabilitation of this area as a sedge meadow would produce a certain amount of marketable credits for the banker. Thus, the paltry few sedge meadow species present at the site sufficed to trigger the MBRT’s bureaucratic mandate to encourage the restoration of degraded sedge meadows. The same data would have failed to trigger the use of the appellation ‘sedge meadow’ in strictly ecological terms.

Hierarchies of plant identification

The final example I will relate has to do with what *should* be the most replicable and most stable aspect of the scientific certification of ecological function at a bank site: the identification of plant specimens with the aid of experts and manuals. As related in the first example, a good deal of questionable identification occurs in the field when the monitoring technician is alone, hip deep in water, face-to-face with a nameless sprout. With plants that baffled our ad hoc field logics, however, we would commonly take samples, carefully labeled with information on their provenance. That night, in a suburban hotel lobby, under the surreptitious glances of traveling businesspeople, the team would convene around a table mounded with drooping vegetation, and stacked with the expert texts: Swink and Wilhelm’s *Flora of the Chicago Region* (1979), Norman Fassett’s *Spring Flora of Wisconsin* (1976), and Edward Voss’s epic *Michigan Flora* (1972; 1980; 1996). In this setting even the most inexperienced members of the team felt that answers, should they be known to science, would be found. After all, alongside the team members with only a few years of training in botany were also some quite eminent experts.

A hierarchy emerged early in the field season, by which the less-experienced members of the group would pass specimens to the next-more-experienced member for help, and these members, needing help, would turn to the next-more-experienced. The middle-range members of the group were often skilled at using botanical texts to identify a specimen, even if they were personally unfamiliar with many plants. Although mobility was possible within this hierarchy, as new members joined and skills were sharpened, there never seemed to be any doubt about the proper order at any given moment. The penultimate and ultimate seats in the hierarchy were occupied by two legitimate experts: Maya and Frank. To paraphrase the famous proclamation made by Justice Robert Jackson about the Supreme Court, Frank was not final because he was infallible; he was infallible because he was final.⁽⁸⁾ As the Supreme Court is to the system of law in the United States, so was Frank to our group’s application of scientific botany: no further authority existed, and so the definition of truth within our ad hoc logic rested with him.

What has to be remarked upon here is the highly intuitive, multisensory, indeed *gestalt* nature of this activity, which appears at first to be the most classically scientific moment in our monitoring activities. In Latourian terms the science we invoked in compiling plant lists which certify value at the bank sites should be at its *coldest*,

⁽⁸⁾ “We are not unaware that we are not final because we are infallible; we know that we are infallible only because we are final” *Brown v. Allen* 344 US 443 (1953), at 540 (J Jackson, concurring).

and *least* open to controversy, when we are consulting thirty-year-old taxonomic manuals and degree-laden experts. And, yet, Frank's and Maya's encounter with an unknown plant is typically a very sensual one: they will stroke the specimen, standing it upright and massaging out the kinks where it was stuffed into a collection bag, crushing or masticating a leaf to taste and smell it, and observing visible and sensible textures, before declaring an opinion. Only rarely will they consult a text. A typical encounter occurred when I handed Frank a flowering grass that I suspected was a desirable native species. Frank stroked it for a moment, blew through his mustache, and declared: "Looks like it might be a *Sphenopholis*." A quick check of the *Michigan Flora* confirmed his identification; eager to be able to identify it myself in the field in the future, I asked what specific traits had tipped him off. Frank frowned slightly, as if I had asked an unexpected question, and took a moment to think about his identification. Finally, he gave up and shrugged: "Oh... it's kinda wispy."

Given that there are over 2700 different species of vascular plants in the Chicago region, and that 'kinda wispy' legitimately describes more than a few of them, Frank's answer indicates the fragility of our passage between two logics. Beyond our little lamplit table lay not the laboratory, nor the marketplace, but an uncomfortable place in between; and Frank sensibly declined to stare too intently into that void. When asked to link his identification to our shared understandings of the principles of systematic botany, he did not. This is because systematic botany might produce the incoherent (to law) result 'no identification possible' far too often for the successful certification of legal mitigation sites—which is, after all, required by the Clean Water Act. Adhering to the cautious methodologies of scientific botanists, loath to rush to identification without sufficient plant material, would also require too high an investment of billable hours for the successful achievement of profit—which is required by entrepreneurial wetland bankers. To produce botanical information that worked for capital and law, and in good time, Frank had to use his intuition to draw a suture closing the space between science and capital that can only be called aporetic (Best, 1999, page 478). This is a phenomenon that all botanists are familiar with, and was confirmed in my discussions with the monitoring team: you give enough sensory inputs enough different kinds of data, and you go with the name that floats to the surface of your mind.

This gestalt, intuitive, idiosyncratic knowledge is the foundation of value in the wetland credit economy.

Submitting the data: science that works for law and capital

"Quantitative decision techniques are the province of weak elites who are accountable to powerful outsiders."

Wendy Espeland (1998, page 19)

As described above, the plant lists are abstracted to produce three numbers which are submitted (along with the lists) to the federal agency representatives, often ecologically trained themselves, for evaluation and approval. The way that the multiagency team of regulators (the MBRT) handles these duties should be a model of bureaucratic regularity.

The job of the MBRT, however, is just as much one of articulation as is that of the monitoring team. In fact, the MBRT could be said to make up the other half of the forum through which scientific knowledge comes to play a role in the legal and economic circuits of wetland banking. Rather than accepting the data submitted by the monitoring teams as a direct quantification of the functional value of the bank sites, the federal regulators tend to use the scores idiosyncratically, as no more than a *guide* to their ultimate judgment in certifying credits for sale:

“Some people maybe focus in on [the scores], but our big concern is really to make sure that they’re on a right trajectory and that you’ve got the heavy work on controlling invasives done. . . . And then to be truthful, the Mitigation Bank Review Team, before the final signoff, we go out and walk the site, and see what our gut reaction is to the site: does this look like the community we thought would be here?” (MBRT member, interview, 9 December 2002).

This tends to reinforce what both economists and bankers see as a fatal flaw within the system of credit valuation: it all seems to rest, as one banker put it, on “who it is and what kind of day they’re having”. MBRT members would argue that it is not quite as arbitrary as all that: each decision can be defended with reference to the numbers. Whenever a decision is contested the numbers are referenced immediately, much as a factory inspector’s reports might be referenced when the quality of a shipment of beef is questioned. MBRT members categorically claim that they do *not* make decisions that are unsupported by the RAM scores, as long as those decisions are *also* consistent with the institutional mandates of the agencies they work for. Thus, before becoming operational in the circuits of capital, the RAM assessments are transformed not only by the monitoring teams’ understanding of the banking regulations but also by the MBRT members’ understanding of their role in enforcing federal law.

The informality of this connection between the monitoring data and the credit certification is a source of both humor and anxiety for the regulators as well as for the banking industry. While the regulators defend their prerogative to make intuitive judgments about the quality of a site, they are also aware that the success of the market depends, above all else, on a *predictable* regulatory environment that they do not always provide. This tension is commonly expressed in humor during site inspections; the ad hoc logic used by both monitoring teams and the MBRT is exaggerated at certain moments *ad absurdum*. During bank inspections, bankers jump to point out desirable features of their site that had not been captured in the floristic assessment, knowing that these features cannot figure in any formal way into the valuation of their site but hoping to influence the ‘gut’ of the regulator nonetheless. To defuse this tension both regulators and bankers joked about the existence of a perfect scoring system, which could capture all such values:

MBRT member 1: “Got a cormorant checking out your wetland.”

Banker: “Hey, we get credit for that! If it flies over, we get credit for it.”

MBRT member 2: [rolling eyes, laughing] “You don’t get credit for that . . . we take away credit for that!”

MBRT member 1: “We gave you a point for an egret. . . if we give you a point for an egret, we’ll take away points for a cormorant.”

MBRT member 2: “Lot of people consider those a nuisance bird” (field notes, 24 June 2003, Lake County, IL).

Such humor serves to demonstrate the impossibility of a perfect articulation between scientific, legal, and capital logics. It deflects with a laugh what Frank deflected with a shrug: the anxiety-ridden resort to ad hoc logics that mimic the coherence of science. The absence of a point-based scoring system that converts from ecological observation to economic valuation is precisely the lacuna the MBRT (as a forum of articulation) is designed to cover up. But the forum participants gesture towards it nonetheless, nervously and even conspiratorily. At a different bank the observation of a somewhat-uncommon leopard frog led an MBRT member to joke: “Oh, well, that’s points, great! Find a cricket frog and we’ll give you a lot of credit. Oops, there’s carp in the ditch—minus 2—that cancels out your leopard frog credit” (fieldnotes, 24 June 2003, McHenry County, IL). This time it is the regulatory officials who were issued an ecologically incoherent directive: ‘Use three numbers to certify the

ecosystem function of the site.' They must perform this task with *reference* to ecosystem science, but cannot do so standing *within* that science.

The turn to humor is poignant in part because of the impossibility of the task economists have laid on the MBRT. The economists who have shepherded the emergence of the wetland banking market have made it clear that no market can emerge unless regulators provide stable and transparent definitions of what constitutes a marketable commodity.

"The available evidence suggests that having such rules established in advance may be necessary for the timely establishment of commercial credit ventures, particularly private ventures. Indeed, without such advance rules, the regulatory uncertainty maybe so great that the willingness to invest in credit production is dampened" (Scodari and Shabman, 1995, page 37).

In a market whose commodities are as hard to measure as ecosystem services, economists insist that apples must be compared with apples: "While credit valuation protocols and credit currency will vary from bank to bank, there must be consistency in the way credits are evaluated and defined across all uses of any particular mitigation bank" (Shabman et al, 1994, page 52).

Procedural consistency and transparency, in other words, are the highest priority concerning articulations. Bankers frequently testify that they do not actually care how stringent the rules are so long as they are transparent and do not change. One wetland banker in Chicago considering the purchase of land for a new bank in a neighboring Corps district (a district with a regulatory staff less experienced in banking) balked when it became clear that major issues of site evaluation had not even been considered by the staff of that district, much less systematized. The Corps district was pushing him to create a bank consisting of harder-to-restore forested wetlands:

"And I'll tell you the truth, I haven't done any forested projects, and I don't think I want to, because they're harder to manage, and I'm thinking '...how would you manage... deer damage, road damage, loss of individual trees, how often are you going to keep replacing those over the next twenty or thirty years? I mean, how are they going to break out your credits?' When I asked [the Corps official] questions like that, I didn't get a real strong feeling that he had figured all that out yet, and I thought, 'well, then, that's too risky'" (wetland banker, interview, 6 December 2002).

What this banker required was *not* that ecological principles on deer predation and tree mortality *directly* inform the estimation of ecological function at his bank site, but that *some stable articulation* exist between those principles and the way that Corps officials use a RAM to allocate his credits.

His unwillingness to take this entrepreneurial risk must also have been informed, however, by his experience in the Chicago District: after ten years the oldest functioning market in ecosystem service provision has not found a way to ground its valuation of the commodity in uncontroversial, transparent, replicable metrics. The ecological significance of the FQI (a measure used in the FQA) is not clear to some ecologists, and is still controversial among some environmental consultants:

"Yeah, this FQI is nonsense. ... [T]hat's an example of how botanists have dominated the wetland field, and have tended to lead the parade, and so we get things like FQI. And the FQI is area-dependent. If I have ten thousand acres, I'll have a very high FQI, if I have one acre, it's going to be low. And if I'm in a sedge meadow, my FQI may be not very good. So the FQI really isn't the measure. I think the measure in wetlands should simply be whether or not there's a wetland, and we have the three criteria" (environmental consultant, interview, 4 December 2002).

Unlike most commodities, the metrical technology of the wetland credit is still vulnerable, and is frequently attacked by those who wish to shift or disrupt the grounds of commodity assessment.

Science in the service of capital: why more science is not necessarily better

“Obviously, society as a whole neither wants to nor is in the position to assume the scientific world-picture....[O]ther function systems acquire the task of sorting out what is usable and what is not.”

Luhmann (1989, page 83)

Many ecologists have decried the proliferation of ‘bad science’ in the RAMs which populate the world of wetland mitigation assessment and other similar science–policy hybrids. But there is something decidedly more complex than ‘bad science’ going on here. I want to conclude by highlighting the differences between attempts to create and measure ecosystem service commodities, and other more standardized ways of creating and measuring commodities. All may involve an articulation between science and capital, but not all achieve stability.

As we have seen, the scientific techniques for the metrical evaluation of commodities in even the oldest ecosystem service market have not reached the level of stability expected in most commodity markets. The difference between selling ecosystem services and selling loaves of bread is that legal and capital logics require information about ecosystem services that scientists *cannot provide* in an uncontroversial way. It is an open question whether or not they will *ever* be able to provide such information without disrupting the fundamental mechanics of the market; but it is clear that they cannot do so today. Whereas the metrical evaluations involved in standard commodities are the products of a successful and stable articulation of science with capital, the metrical evaluation of wetland services is the product of a constantly shifting and unstable articulation, producing information that works within capital only by virtue of a set of ad hoc logics employed by those who populate the forums of articulation.

The current mainstream environmental policy literature firmly espouses the commodification of ecosystem services, seeing them as the latest new realm for the circulation of value, and is overflowing with confidence that the problems of assessment will soon be solved. Innovation beyond the basic production of ‘wetland credits’ is being contemplated, and some entrepreneurial ecosystem service providers are already pushing a new business model: selling individual, *segregable* ecosystem services rather than bundling them together in a way that ignores the niche markets for each particular service (Kieser, 2002; Sokolove, 2001; Waters, 2002). Thus, in theory, a single bank site could generate as many different kinds of commodities as there are functions that can be assessed: water quality, habitat for individual species, flood storage during particular seasons, etc. The list, as one ecologist has put it, is limited only by “the imaginations of ecologists and the shortcomings of language” (Goldstein, 1999, page 253).

My first point, therefore, is that, even without trying to measure individual ecosystem functions, we may be approaching the current limits of an articulation between science and capital. The word ‘limits’ is, as always, somewhat dangerous, which is why I have turned toward Luhmann’s concept of autopoiesis to describe limits that are imposed not by ahistorical relations of determination, but rather by the immaturity or inadequacy of the forums of articulation that join them. It is one thing to show that the reliance on noneconomic information by economics is a paradox; it is a somewhat more interesting thing to show how that reliance is nonetheless achieved, and then how that achievement is immediately obscured. The MBRT and other monitoring teams in the field vividly demonstrate the ability of capital to compel the production of ‘erroneous’ scientific data to support commodification, and the ability of law to compel the same data to fulfill the legal directives of the Clean Water Act. The MBRT also demonstrates a certain inadequacy in responding to these compulsions with the limited

scientific tools and concepts it has at hand. It is just barely able to decide how many leopard frogs are required to certify one unit of industrial production.

Second, lest we become dazzled by systems-heavy talk, I want to insist that these articulations and forums have histories, that they are staffed by agents who inhabit multiple subject positions, and that their efficacy changes over time. Sometimes these forums are stable and well staffed, sometimes they stand on shifting sands, and sometimes they are simply empty. It should be clear that capital cannot simply compel a successful articulation with science to generate required input: much depends on the *kind* of scientific knowledge that has to be coded for capital and on the ability of the agents who operate in forums of articulation to invent and propagate stable logics of coding. In this context the job for the critical analyst has to be understood as one of geography and close observation: as Gavin Bridge and Andrew Jonas (2002, page 761) put it in their study of the neoliberal rationalization of extractive industries: “the challenge is to show how differences within the emerging regulatory landscapes of resource provision are constructed through specific geographies of struggle. That is, how institutions and governance structures are fashioned through the concrete politics of differentially constrained agents in specific places.”

This process is only beginning in the wetland banking industry. Taking up Bridge and Jonas’s challenge, I have characterized the private and federal monitoring technicians who create and certify the data that undergird the value of the wetland service commodity as working close to the current practical limits of articulation. We could see the limits from where we stood at the bank sites: in the choice of an MBRT member to accept (or not) that the credit of a frog can cancel out the debit of a carp. These limits are not imposed by nature or society, but rather are contingent features, emergent from the agency of the people that perform necessary negotiations between elements of the differentiated epistemological structure of modernity.

Third, as capitalists seek ecological foundations for further niche trade in segregated individual ecosystem services, they begin to call upon science which is more and more complex and contestable to secure the identity of these goods, placing further stress on the people in forums of articulation. This creates a specifically geographic tension, as these efforts converge on a point where smaller and smaller ecological distinctions begin to *matter*: any market in the individual function of ‘turtle habitat’, for example, must grapple with the fact that terrestrial turtles tend to have small geographic habitat ranges and thus scientific assessors may stipulate that the ‘turtle habitat’ service should not be traded over large distances. Or they may not. Either way, the many uncertainties and debates concerning turtle ecology will become awkwardly consequential to capital. Although this appeal to further ecological precision is logical as part of the pursuit of new markets, it simultaneously retreats from the very spatial abstractions that make commodification work in the first place: the fundamental conceit that a loaf of bread in Newark does not change when you ship it to Tucson. A market in the generic, undifferentiated ‘wetland credit’ has successfully been erected at the cost of *ignoring* a good deal of ecological information. *Using* more ecological information may expand the circulation of capital, but at a serious cost to its spatial conceit (Robertson, 2004, page 369). In short, capital cannot indefinitely colonize science, ever widening its view of ‘the nature that capital can see’, because its own logical imperatives—which assure circulation by ignoring the too-particular or too-uncertain details about turtles—will be fundamentally disrupted.

Inasmuch as the banking industry is rendered unstable by the fragility of the articulation maintained by the monitoring technicians, the push into further realms of ecological distinction in search of further realms of accumulation may well result in a total failure of articulation. Such a scenario is vividly represented by Douglas Bruggeman et al (2005),

who propose a dauntingly complex set of equations for calculating the value of ecosystem service credits based on the genetic diversity ‘services’ provided by wildlife populations, incorporating advanced theoretical notions of metapopulation dynamics and discounting their production over time. Bruggeman et al’s proposed market in ‘average expected heterozygosity’ imposes such extraordinary data and translation demands that it is quite simply unrealizable at the current moment, and no forum of articulation will arise.⁽⁹⁾

I propose this as one way that capitalism and the project of producing hegemony encounter ecological crisis: in having created an articulation with the realm of scientific knowledge, both the state and capital begin to ask science to do things it cannot do in a stable way. As capitalists argue for ever-finer distinctions to be defined by ecologists, science thus helps to create a more and more differentiated realm for the circulation of capital; but ecosystem science is ever less able to offer stable metrics which measure those differentiations in a replicable way. The apparent systematicity and stability of scientific taxonomies and hierarchies looks extremely tempting to ecosystem service entrepreneurs, many of whom view the potential multiple markets in finely divided ecosystem services as a chance to multiply the value of their assets. But it is in attempting to capture the proliferation of ecological distinctions that capital is potentially destabilized.⁽¹⁰⁾ This is a somewhat startling role for scientific knowledge to play, as it is often theorized as complicit in the expansionary dynamics of state and capital.

To accompany such a dire warning it is important to say that the state has already demonstrated its ability to pull back from this brink. The current RAMs used in wetland banking are the descendants of much more complex RAMs developed in the early 1980s, when wetland banking was performed only noncommercially, by state agencies creating wetlands solely to mitigate for their own impacts. As there was no need to translate ecological information into the abstractions required by the commodification process, assessments developed by the US Fish and Wildlife Service (USFWS) to monitor these early banks were notoriously complex, involving pages of look-up tables and finely tuned multipliers. The system employed throughout the 1980s by the Minnesota Department of Transportation, for example, used an agonizingly precise method that calculated ‘habitat units’ from a complex algorithm involving acreage, habitat type, and ‘habitat value’ for several different species (each calculated using a different protocol). When a private, entrepreneurial banking system was initiated in Minnesota there was never any question of using this ‘habitat unit’ system for credit assessment: the complexity of it would have driven away any potential producers. Similarly, the first bank ever to sell wetland services on the market, Tenneco LaTerre in Louisiana, was allowed to do so only as an afterthought in its institutional design, and it used a typically convoluted USFWS-style RAM to define its credits. As LaTerre continues selling credits into the present, now joined by several other banks whose commodities are measured in simple plant lists or even in raw acreage, it is regarded as a dinosaur using a system of metrical evaluation that is considered impossibly precise. Of course, those who promote the selling of segregable ecosystem services will claim that the only problem is that the market rules have not been written to allow LaTerre to sell what it measures. I have argued that the problems run considerably deeper than that, but perhaps they are not eventually fatal to capitalist strategy: perhaps scientists

⁽⁹⁾ Discussing examples of articulatory failures is necessarily more difficult than discussing examples of success, because the former are logical nonevents and tend not to leave a trace to follow.

⁽¹⁰⁾ This parallels Neil Smith’s (1990) discussion of the instability inherent in the pursuit of spatial comparative advantage by capital.

and regulators will push back against the data demands of capital that might produce dangerously destabilizing problems of measurement. Again, we may not be at the limits, but they are in view.

Clearly, science can contribute to the expansion of capital and the securing of neoliberal hegemony. But here we return to the problems that *Aster simplex* poses for environmental governance. Its refusal to be fixed, taxonomically, and the considerable skill required to identify it in the field even when it is flowering, exemplify the problem of articulation. In short, success at making science work for law or capital depends on the skill of the people in intermediary forums creating, and rendering noncontroversial, routines of translation between mutually incoherent logics. Botanists in the field are on shaky ground in examining a sprout that, through our actions, may or may not naturalize the value of a commodity that has a unit price of \$55 000. If the capitalization of ecosystem services is just another instance of capital spinning profit out of difference then it will be the labor of those who staff the forums of articulation—who attempt to translate the essence of that difference between two systems of logic—which will determine the success of the project.

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References

- Adamus P R, Stockwell L T, Clairain E J Jr, Morrow M E, Rozas L P, Smith R D, 1991 *Wetland Evaluation Technique (WET); Volume 1: Literature Review and Evaluation Rationale* US Army Corps of Engineers Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS
- Batie S S, Shabman L A, 1982, "Estimating the economic value of wetlands: principles, methods, and limitations" *Coastal Zone Management Journal* **10** 255–278
- Best B, 1999, "Postcolonialism and the deconstructive scenario: representing Gayatri Spivak" *Environment and Planning D: Society and Space* **17** 475–494
- Bridge G, Jonas A E G, 2002, "Governing nature: the reregulation of resource access, production, and consumption" *Environment and Planning A* **34** 759–766
- Brinson M M, 1988, "Strategies for assessing the cumulative effects of wetland alteration on water quality" *Environmental Management* **12** 655–662
- Brinson M M, 1996, "Assessing wetland functions using HGM" *National Wetlands Newsletter* January–February, pp 10–21
- Bruggeman D J, Jones M L, Lupi F, Scribner K T, 2005, "Landscape equivalency analysis: methodology for estimating spatially explicit biodiversity credits" *Environmental Management* **36** 518–534
- Bumbaugh R W, Reppert R, 1994 *National Wetland Mitigation Banking Study: First Phase Report* US Army Corps of Engineers Institute for Water Resources, Alexandria, VA
- Callari A, Ruccio D F, 1996, "Introduction: postmodern materialism and the future of Marxist theory", in *Postmodern Materialism and the Future of Marxist Theory: Essays in the Althusserian Tradition* Eds A Callari, D F Ruccio (Wesleyan University Press, Hanover, MA) pp 1–48
- Castree N, 2002, "False antitheses? Marxism, nature and actor-networks" *Antipode* **34** 111–146
- Cronon W, 1991 *Nature's Metropolis: Chicago and the Great West* (W W Norton, New York)
- Daily G C, 1997, "Introduction: what are ecosystem services?", in *Nature's Services: Societal Dependence on Natural Ecosystems* Ed. G C Daily (Island Press, Washington, DC) pp 1–10
- Daily G C, Ellison K, 2002 *The New Economy of Nature: The Quest to Make Conservation Profitable* (Island Press, Washington, DC)
- Demeritt D, 2001, "Scientific forest conservation and the statistical picturing of nature's limits in the Progressive-era United States" *Environment and Planning D: Society and Space* **19** 431–459
- Environmental Law Institute, 1993 *Wetland Mitigation Banking* (Environmental Law Institute, Washington, DC)
- Environmental Law Institute, 2002 *Banks and Fees: The Status of Off-site Wetland Mitigation in the United States* (Island Press, Washington, DC)

- Espeland W N, 1998 *The Struggle for Water: Politics, Rationality, and Identity in the American Southwest* (University of Chicago Press, Chicago, IL)
- Fassett N C, 1976 *Spring Flora of Wisconsin: A Manual of Plants Growing Without Cultivation and Flowering Before June 15* 4th edition (University of Wisconsin Press, Madison, WI)
- Goldstein P Z, 1999, "Functional ecosystems and biodiversity buzzwords" *Conservation Biology* **13** 247–255
- Gramsci A, 1971 *Selections from the Prison Notebooks* translated by Q Hoare, G N Smith (International Publishers, New York)
- Haraway D J, 1997 *Modest_Witness@Second_Millennium. FemaleMan[®]_Meets_Oncomouse[™]: Feminism and Technoscience* (Routledge, New York)
- Hayden C, 2003 *When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico* (Princeton University Press, Princeton, NJ)
- Heal G, 2000 *Nature and the Marketplace: Capturing the Value of Ecosystem Services* (Island Press, Washington, DC)
- Jessop B, 2001, "Capitalism, the regulation approach, and critical realism", <http://www.lancs.ac.uk/fss/sociology/papers/jessop-capitalism-regulation-realism.pdf>
- Karr J R, 1993, "Defining and assessing ecological integrity: beyond water quality" *Environmental Toxicology and Chemistry* **12** 1521–1531
- Kieser M, 2002, "Developing markets to manage ecosystems", paper presented at the 5th National Mitigation Banking Conference, Washington, DC; copy available from the Terrene Institute, <http://www.terrene.org>
- Latour B, 1999 *Pandora's Hope: Essays on the Reality of Science Studies* (Harvard University Press Cambridge, MA)
- Luhmann N, 1989 *Ecological Communication* translated by J Bednarz Jr (University of Chicago Press, Chicago, IL)
- Luhmann N, 2002 *Theories of Distinction: Re-describing the Descriptions of Modernity* Ed. W Rasch (Stanford University Press, Stanford, CA)
- Luke T W, 1999 *Capitalism, Democracy, and Ecology: Departing from Marx* (University of Illinois Press, Chicago, IL)
- McAfee K, 1999, "Selling nature to save it? Biodiversity and green developmentalism" *Environment and Planning D: Society and Space* **17** 133–154
- McCarthy J, Prudham S, 2004, "Neoliberal nature and the nature of neoliberalism" *Geoforum* **35** 275–283
- Mansfield B, 2004, "Rules of privatization: contradictions in neoliberal regulation of North Pacific fisheries" *Annals of the Association of American Geographers* **94** 565–584
- Marx K, 1976 *Capital: A Critique of Political Economy, Volume 1* 4th edition, translated by B Fowkes (Penguin Books, New York)
- Miller C, 2001, "Hybrid management: boundary organizations, science policy, and environmental governance in the climate regime" *Science, Technology and Human Values* **26** 478–500
- Mitchell T, 1988 *Colonising Egypt* (University of California Press, Berkeley, CA)
- National Research Council, 2001 *Compensating for Wetland Losses under the Clean Water Act* (National Academy Press, Washington, DC)
- Nesom G L, 1994, "Review of the taxonomy of *Aster sensu lato* (Asteraceae: Astereae), emphasizing the New World species" *Phytologia* **77** 141–297
- O'Connor J, 1994, "Is sustainable capitalism possible?", in *Is Capitalism Sustainable?: Political Economy and the Politics of Ecology* Ed. M O'Connor (Guilford Press, New York) pp 152–175
- Parry B, 2004 *Trading the Genome: Investigating the Commodification of Bio-information* (Columbia University Press, New York)
- Peck J A, Tickell A, 2002, "Neoliberalizing space" *Antipode* **34** 380–404
- Peet R, Watts M, 1996, "Liberation ecology: development, sustainability, and environment in an age of market triumphalism", in *Liberation Ecologies: Environment, Development, Social Movements* Eds R Peet, M Watts (Routledge, New York) pp 1–45
- Polanyi K, 1944 *The Great Transformation: The Political and Economic Origins of Our Time* (Beacon Press, Boston, MA)
- Porter T M, 1995 *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton University Press, Princeton, NJ)
- Rasch W, 2000 *Niklas Luhmann's Modernity: The Paradoxes of Differentiation* (Stanford University Press, Stanford, CA)
- Rasch W, Knodt E, 1994, "Systems theory and the system of theory" *New German Critique* **61** 3–7

-
- Reed P B, 1988 *National List of Plant Species that Occur in Wetlands: National Summary Biological Report 88*, US Fish and Wildlife Service, Washington, DC
- Robertson M M, 2004, "The neoliberalization of ecosystem services: wetland mitigation banking and problems in environmental governance" *Geoforum* **35** 361 – 373
- Sayre N F, 2002 *Ranching, Endangered Species, and Urbanization in the Southwest: Species of Capital* (University of Arizona Press, Tucson, AZ)
- Sayre R, Roca E, Sedaghatkish G, Young B, Keel S, Roca R, Sheppard S, 2000 *Nature in Focus: Rapid Ecological Assessment* (Island Press, Washington, DC)
- Scodari P, Shabman L A, 1995 *National Wetland Mitigation Banking Study: Commercial Wetland Mitigation Credit Markets: Theory and Practice* US Army Corps of Engineers Institute for Water Resources, Alexandria, VA
- Shabman L A, 1985, "The contribution of economics to wetlands valuation and management", paper presented at National Wetlands Assessment Symposium, Portland, ME; copy available from Association of State Wetlands Managers, Box 269, Berne, NY 12023
- Shabman L A, 1992, "Beyond mitigation banking: fee-based permitting, wetlands credit markets and watershed restoration", paper presented at Effective Mitigation: Mitigation Banks and Joint Projects in the Context of Wetlands Management Plans, Palm Beach Gardens, FL; copy available from Association of State Wetlands Managers, Box 269, Berne, NY 12023
- Shabman L A, Scodari P, King D, 1994 *National Wetland Mitigation Banking Study: Expanding Opportunities for Successful Mitigation: The Private Credit Market Alternative* US Army Corps of Engineers Institute for Water Resources, Alexandria, VA
- Smith N, 1990, *Uneven Development: Nature, Capital and the Production of Space* (Blackwell, Malden, MA)
- Sokolove R D, 2001, "Multiple uses for wetland mitigation banks", paper presented at the 4th National Mitigation Banking Conference, Fort Lauderdale, FL; copy available from Terrene Institute, <http://.terrene.org>
- Star S L, Griesemer J R, 1999, "Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology 1907–39", in *The Science Studies Reader* Ed. M Biagioli (Routledge, New York) pp 503 – 524
- Swink F, Wilhelm G, 1979 *Plants of the Chicago Region: A Checklist of the Vascular Flora of the Chicago Region, with Keys, Notes on Local Distribution, Ecology, and Taxonomy, and a System for Evaluation of Plant Communities* Morton Arboretum, Lisle, IL
- US Army Corps of Engineers, 1998, "Chicago District mitigation requirements", US Army Corps of Engineers, Chicago District, <http://.lrc.usace.army.mil/co-r/mitgr.htm>
- Voss E G, 1972 *Michigan Flora—A Guide to the Identification and Occurrence of the Native and Naturalized Seed-plants of the State. Volume 1: Monocots and Gymnosperms* (Cranbrook Institute of Science, Bloomfield Hills, MI)
- Voss E G, 1980 *Michigan Flora—A Guide to the Identification and Occurrence of the Native and Naturalized Seed-plants of the State. Volume 2: Dicots* (Cranbrook Institute of Science, Bloomfield Hills, MI)
- Voss E G, 1996 *Michigan Flora—A Guide to the Identification and Occurrence of the Native and Naturalized Seed-plants of the State. Volume 3: Dicots Concluded* (Cranbrook Institute of Science, Bloomfield Hills, MI)
- Walker R A, 2001, "California's golden road to riches: natural resources and regional capitalism, 1848–1940" *Annals of the Association of American Geographers* **91** 167 – 199
- Waters S, 2002, "Issues in the economic appraisal of mitigation", paper presented at the 5th National Mitigation Banking Conference, Washington, DC; copy available from the Terrene Institute, <http://.terrene.org>
- Willems-Braun B, 1997, "Buried epistemologies: the politics of nature in (post)colonial British Columbia" *Annals of the Association of American Geographers* **87** 3 – 31

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