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SWAMP SWAPS: THE "SECOND NATURE" OF WETLANDS

BY

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Traditionally, American wetlands had market value only after being dredged or filled. Gradually, however, alternative markets are being provided in which wetlands may obtain market value while remaining wet. As these markets grow they will raise new issues for U.S. wetlands policy, which today provides little guidance for the management of wetlands that remain wet.

Mitigation banking provides one of these markets, and has been given new stature by recent federal regulations. Water quality banking is being used to create wetlands to treat nitrogen and other pollutants. Markets for conserving wetlands that harbor rare species are attracting increasing interest both here and abroad. Markets for greenhouse gas diminution are producing interesting opportunities for wetland management, and traditional commodity markets are beginning to become interested in wetland plants and algae grown for biofuels.

Market-oriented environmental regulation has been a priority for federal policy for two decades. Such regulation can encourage innovative new approaches to reach environmental goals, and wetlands offer promise as sites for new management techniques. Among the issues that will need to be resolved, however, are the size of the geographic area to be addressed, the identification of the biogeochemical processes in wetlands that need to be considered, the translation of the policy objectives into commodities that can be monetized, and the choice of management technologies to achieve these objectives.

The most serious issue is whether newly-formed markets can acquire the same reputation for integrity that our well-established markets have worked hard over generations to obtain. Recent experience with companies like Enron, various Ponzi imitators, and subprime indenture marketers have given heartburn to even the strongest proponents of free markets. Whether traditional or behavioral economists can restore market integrity is an issue that resonates far beyond this narrow application of the problem.

However, even if that problem is resolved, there remains the issue of "naturalness." Our existing wetland policy is underlain by a powerful assumption that preserving wetlands in their natural state is desirable. Should future laws embody that policy, or do irreversible trends require

us to concede that intensive ecosystem management is required? I suggest a compromise based on reading Thoreau. He would have recognized the need for ecosystem management, but only as long as large areas of natural wetlands remained—places in which people who love wild nature could continue to make the kind of serendipitous discoveries from which so much of our scientific knowledge has grown.

I. INTRODUCTION AND SUMMARY

> Bison and pine trees had once been members of ecosystems defined mainly by flows of energy and nutrients and by relations among neighboring organisms. Rearrayed within the second nature of the market, they became commodities: things priced, bought, and sold within a system of human exchange.[1]

Until recently, the wetland preservation movement has relied primarily on public and nonprofit entities that recognized the important nonmarket functions that wetlands may perform.[2] These entities used public or donated funds to manage wetlands in ways that would further the desired functions.[3] Wetlands were generally believed to have no market value except as opportunities to be destroyed for development.[4]

Today, we are at the early stages of wetland management for market values. These opportunities arise in a growing number of trading systems in which components of managed wetlands can be traded for rights having cash value. The first half of the Article will describe five markets, in varying stages of maturation, that offer the prospect of managing wetlands for profit.

Mitigation banking has been employed sporadically for some years, but it has been given a big boost by 2008 federal regulations adopted by the

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1 WILLIAM CRONON, NATURE'S METROPOLIS: CHICAGO AND THE GREAT WEST 266 (1991).

2 *See* MARK S. DENNISON & JAMES F. BERRY, WETLANDS: GUIDE TO SCIENCE, LAW, AND TECHNOLOGY 71–73 (1993) (discussing the history of wetlands preservation by public and nonprofit entities).

3 *See id.*

4 *See id.* at vii.

United States Army Corps of Engineers (COE) and the United States Environmental Protection Agency (EPA).[5] These new rules make the purchase of shares in a wetland mitigation bank the preferred option for land developers who plan to eliminate existing wetlands. The new guidelines for the creation of mitigation banks have created an outpouring of interest.[6]

Water quality trading is also a favorite of EPA, though it has developed more slowly than its proponents have wished.[7] Municipal and industrial wastewater dischargers, who require federal permits that force them to reduce pollutant loads, may find it cheaper to reduce an equivalent amount of pollution from nonpoint sources, such as agriculture, for which permits are not required.[8] The restoration or creation of wetlands to reduce nonpoint source pollution is often more efficient than end-of-pipe treatment of point sources.[9] The use of wetlands to reduce toxic pollutants also offers trading possibilities. Federal legislation clarifying the rules for water quality trading could spur renewed interest in the program.

Species conservation banking is at a relatively early stage of development, but it has aroused growing interest as the concern for biodiversity has increased.[10] California has an ongoing conservation banking program through which vernal pool wetlands have been restored as a tradeoff for take of certain declining species that rely on such pools.[11] Habitat conservation plans under the Endangered Species Act[12] have also included such tradeoffs, as have many informal state and local transactions.[13] International organizations are now promoting large-scale conservation banks.[14]

The big gorilla in the tradeoff tent is greenhouse gas offsets. Many developed countries have adopted regulations that mandate reductions in the emission of greenhouse gases (GHGs) such as carbon dioxide, methane, and nitrous oxide.[15] These countries often allow their local sources of GHGs to reduce emissions by crediting reductions in other countries rather than at home.[16] This has spurred a rapidly growing phalanx of entrepreneurs who design projects in the developing countries that will reduce GHGs.[17] In the United States, some states and regions have adopted such legislation, and

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5 *See infra* Part II.A.

6 *See infra* Part II.A–B.

7 *See infra* Part III.

8 *See infra* Part III.

9 *See infra* Part III.

10 *See infra* Part IV.

11 *See infra* Part IV.

12 Endangered Species Act of 1973, 16 U.S.C. §§ 1531–1544 (2000).

13 *See infra* Part IV.

14 *See infra* Part IV.

15 *See infra* Part V.A (noting that all Kyoto signatory nations must adopt regulations that mandate greenhouse gas reductions).

16 *See infra* Part V.A.

17 *See infra* Part V.A.

the Obama administration supports a national bill.[18] Because wetlands can serve as both sources and sinks for the three most important GHGs, these opportunities have spawned extensive research and development of ways to manage wetlands for GHG credit.[19]

Farthest from actual development, but the object of substantial venture capital investment, is the use of wetlands to produce biofuels.[20] Potential wetland crops include algae and genetically modified varieties of wetland plants.[21] While the technology is at an early stage, investment is triggered by federal legislation that mandates steadily increased use of this type of biofuel.[22] Other countries are also exploring wetland biofuel options to produce commodities tradable on world markets.[23]

Each of these five marketing opportunities has a similar advantage. They may modify wetlands, but they will leave them wet. Federal wetland law has been aimed primarily at the dredging and filling of wetlands, not their management.[24] The national policy of "no net loss" has made wetness the objective and acreage the standard. Concern about wetland function has been more rhetorical than prescriptive. Consequently, the management of wetlands for profit may escape some of the legal complications that now attend the destruction of wetness.

The second half of the Article steps back to look at the broader issues raised by this potential wonderland of wetland windfalls. Managing wetlands to achieve the goals of these programs requires at least five stages, each of which poses both risks and opportunities for both the manager and the public. First, a wetland needs to be identified, selected, and defined as the locus of management. No two wetlands are exactly alike, nor is the landscape in which they are situated. How much information about the location of a project is needed before a project begins? To what extent must the area surrounding the wetland be managed as part of the project?

Second, within every wetland, a host of biogeochemical processes are constantly emerging, changing, evolving, and disappearing, often in ways difficult to predict. Some of these processes provide utilitarian benefits to people and can be characterized as services. Others, like emission of methane, methylation of mercury, and production of disease-vectoring organisms, are disservices. Which processes will need to be managed and monitored to achieve the objectives of the applicable market?

Third, once one or more wetland processes have been identified as objectives, the processes need to be monetized for trading. Some processes are much easier to value than others. The valuation methodology must be

18 *See* Regional Greenhouse Gas Initiative, About RGGI, http://www.rggi.org/about (last visited July 19, 2009); John M. Broder, *Obama's Greenhouse Gas Gamble*, N.Y. TIMES, Feb. 28, 2009, at A15.

19 *See generally infra* Parts V–VI.

20 *See infra* Part VI.

21 *See infra* Part VI.B–D.

22 *See infra* Part VI.A.

23 *See infra* Part VI.

24 *See generally infra* Part II.

simple enough to encourage trading but not so unscientific that it will foster gaming the system. Additionally, if trading will produce benefits for managers, their responsibilities for maintaining baseline standards without compensation must be clearly identified.

Fourth, a market should produce important byproducts. It should foster entrepreneurship and imagination rather than the mechanical check off of regulatory lists. It should encourage research and development of new and enhanced wetland science. It should encourage creative, adaptive management that monitors and adjusts projects throughout their lifetime. But abuse of creativity can result in demands for more restrictive controls, which in turn may reduce marketability.

Fifth, credibility is essential for a market to achieve its goals. Recent history may make this the most difficult objective to achieve. For some time, market supervision has been generally minimized for philosophical reasons. The resulting abuse of markets has bred a growing suspicion of markets in the United States and throughout the world. Better oversight of these new markets is essential, but providing adequate supervision without increasing transaction costs to self-defeating levels is a challenge.

Finally, in the brief concluding section of the Article, the basic question suggested by the subtitle is addressed. What do we lose by converting the components of natural wetlands into tradable commodities—that is, into a second nature? Ecosystem management is essential if we are to deal with the problems that human impacts on the planet create. Management of wetlands could be an important component of ecosystem management to achieve benefits to humanity. But neither science nor economics can recreate the psychological value of nature appreciation.

While we undertake to manage wetlands, we should be sure that plenty of unmanaged wetlands remain available, not just to provide controls against which our management can be compared, but as opportunities for future generations to understand and wonder at the complex ways in which nature operates without human management. We should not let our descendants forget that although individual wetland components may have value as commodities, they all originated within the "first nature" of natural wetlands.

II. WETLAND MITIGATION BANKING

Under section 404 of the Clean Water Act (CWA), developers must obtain a permit from the United States Army Corps of Engineers (COE) to dredge or fill certain types of wetland.[25] COE's preferred alternative is for the developer to redesign the project so it will not affect wetlands,[26] but many project

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[25] Federal Water Pollution Control Act, 33 U.S.C. § 1344 (2006).

[26] A permit applicant must take all appropriate and practicable steps to avoid and minimize wetland impacts, but "practicable" is defined as "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes." 33 C.F.R. § 332.1(c)(2) (2008); *see also* Royal C. Gardner et al., *Compensating for*

developers have proposed to create new wetlands either onsite or in some other location to "mitigate" for wetlands being destroyed.[27]

By the 1990s, COE's acceptance of such mitigation had become so routine[28] that many scientists doubted mitigation's usefulness.[29] EPA, which shares some wetland responsibilities with COE, responded to the criticism by asking the National Research Council (NRC) of the National Academies of Science and Engineering to study the effectiveness of wetland mitigation.[30]

NRC found that the existing mitigation procedures needed to pay more attention to the long-term management of mitigation projects: "The presumption that once mitigation sites meet their permit criteria they will be self-sustaining in the absence of any management or care is flawed."[31] NRC recommended that where project redesign was not feasible, the developer should be encouraged to buy shares in a large, created or restored wetland that would be professionally managed to maintain wetland values over the long-term.[32]

A. The 2008 Regulations

In 2008, COE issued new regulations endorsing many of NRC's recommendations.[33] Wetland mitigation banks, which have been functioning in some areas for twenty years,[34] now get preferred status under the new regulations.[35] COE encourages development of wetland mitigation banks in

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Wetland Losses Under the Clean Water Act (Redux): Evaluating the Federal Compensatory Mitigation Regulation, NAT'L WETLANDS NEWSL., Mar.–Apr. 2009, at 1, 3–4.

27 *See* WILLIAM L. WANT, LAW OF WETLAND REGULATION § 6.41 (2008); *see also* Palmer Hough & Morgan Robertson, *Mitigation Under Section 404 of the Clean Water Act: Where It Comes From, What It Means*, 17 WETLANDS ECOLOGY & MGMT. 15, 24 (2009).

28 Ad hoc mitigation has become a common feature of many types of American land development law. *See* Fred Bosselman, *Planning for a Bull Market in Wetlands*, PLAN. & ENVTL. L., Feb. 2009, at 3, 10.

29 *See, e.g.*, Samuel D. Brody et al., *A Spatial-Temporal Analysis of Section 404 Wetland Permitting in Texas and Florida: Thirteen Years of Impact Along the Coast*, 28 WETLANDS 107, 108 (2008); Rebecca L. Kihslinger, *Success of Wetland Mitigation Projects*, NAT'L WETLANDS NEWSL., Mar.–Apr. 2008, at 14, 16 (2008); Robert P. Brooks et al., *Are We Purveyors of Wetland Homogeneity? A Model of Degradation and Restoration to Improve Wetland Mitigation Performance*, 24 ECOLOGICAL ENGINEERING 331, 337–38 (2005) (stating that mitigation projects result in wetlands that are "moderate to low condition").

30 *See* NAT'L RESEARCH COUNCIL, COMPENSATING FOR WETLAND LOSSES UNDER THE CLEAN WATER ACT 2 (2001).

31 *Id.* at 152.

32 *See id.* at 160–64 (discussing institutional reforms for enhancing compensatory mitigation).

33 *See* 33 C.F.R. § 332.1 (2008). EPA coauthored the regulations and adopted equivalent regulations under its own authority. *See* 40 C.F.R. § 230.91 (2008); *see also* Gardner et al., *supra* note 26, at 1.

34 *See* MARK LANDRY ET AL., APPLYING LESSONS LEARNED FROM WETLANDS MITIGATION BANKING TO WATER QUALITY TRADING 5 (2005), *available at* http://www.abtassociates.com/reports/WQT_Lessons_from_Wetlands_Mitigation_Banking.pdf.

35 33 C.F.R. § 332.1 (2008); *see also* Gardner et al., *supra* note 26, at 6–7.

order to produce larger wetlands systems[36] that will perform more functions more reliably,[37] and because a mitigation bank can sell shares to developers before they destroy other wetlands,[38] thereby reducing the time lag between destruction of a wetland and its replacement.[39]

One contentious issue addressed in the regulations is whether mitigation banks must always involve newly created or restored wetlands.[40] The idea of no net loss implies that mitigation should involve a gain in acreage, but if wetland functions become the key, then acreage may be less important. Restoration can reverse some functional degradation, but many types of damage are not reversible, even with newer restoration techniques.[41]

The regulations compromise by allowing a mitigation bank to protect the permanence of existing wetlands, but only if a watershed study has identified such preservation as a high priority.[42] NRC emphasized that "the mitigation program would achieve greater short- and long-term results by looking at each permitting decision over a broader space and longer time period."[43] When a plan is "viewed from a watershed perspective over a long period, the purpose is to secure a desired matrix of wetland types and locations to achieve the goals of the CWA in the watershed."[44]

Standards for mitigation banks as set forth in the 2008 regulations now apply broadly to all permits affecting "aquatic resources," which include rivers, lakes, and other water bodies, as well as wetlands; the mitigation must be "practicable and capable of compensating for the aquatic resource functions that will be lost as a result of the permitted activity."[45] The regulations state that the bank should be located in the same watershed, at a place where it can "*successfully replace lost functions and services*, taking

36 33 C.F.R. § 332.3(b)(2) (2008) ("Mitigation banks typically involve larger, more ecologically valuable parcels, and more rigorous scientific and technical analysis, planning and implementation than permittee-responsible mitigation.").

37 *See* David T. Urban, Rule Offers Philosophy Change to Mitigation, NAT'L WETLANDS NEWSL., July–Aug. 2008, at 5, 5.

38 U.S. Envtl. Prot. Agency, Mitigation Banking Factsheet, www.epa.gov/owow/wetlands/facts/fact16.html (last visited July 19, 2009). Mitigation Bank managers have formed a trade association and are working on a clearinghouse for mitigation bank information. *See* Nat'l Mitigation Banking Ass'n, Who We Are, http://www.mitigationbanking.org/about/index.html (last visited July 19, 2009).

39 Amos Esty, *Banking on Mitigation*, 95 AM. SCIENTIST 122, 122 (2007).

40 *Id.*

41 Joy B. Zedler & Suzanne Kercher, *Wetland Resources: Status, Trends, Ecosystem Services, and Restorability*, 30 ANN. REV. ENV'T & RESOURCES 39, 57 (2005).

42 *See* Robin Mann & Jan Goldman-Carter, *Avoidance: Still the Best Solution to the Compensatory Mitigation Challenge*, NAT'L WETLANDS NEWSL., July–Aug. 2008, at 8. For an example of such a study, see Jos T. A. Verhoeven et al., *An Operational Landscape Unit Approach for Identifying Key Landscape Connections in Wetland Restoration*, 45 J. APPLIED ECOLOGY 1496 (2008).

43 NAT'L RESEARCH COUNCIL, *supra* note 30, at 142.

44 *Id.* at 143; *see also* Gardner et al., *supra* note 26, at 1, 3; Jonathan Z. Cannon, Commentary, *Sustainable Watersheds*, 107 MICH. L. REV. FIRST IMPRESSIONS 74, 76–77 (2008), *available at* http://www.michiganlawreview.org/firstimpressions/vol107/cannon.pdf.

45 33 C.F.R. § 332.3(a)(1) (2008).

into account . . . watershed scale features."[46] Unresolved is the issue of whether emphasis should be on large, remote wetlands[47] or on smaller wetlands closer to urbanized areas.[48]

The regulations define "services" as the "benefits that human populations receive from functions that occur in ecosystems."[49] The regulations also indicate "functions" are "the physical, chemical, and biological processes that occur in ecosystems,"[50] and that "functional capacity" is "the degree to which an area of aquatic resource performs a specific function."[51] The regulations do not describe the "lost functions and services" to be replaced, and could hardly be expected to do so by rules that relate to all aquatic resources, not just wetlands.[52] The result for now is to give the sponsor and the district engineer wide discretion in deciding the objectives of a mitigation bank.

What are the "physical, chemical and biological processes that occur in" wetlands? "Biogeochemistry" is the term that encompasses all of these processes:

> Wetland biogeochemistry involves processes by which an element or a compound is transformed within wetlands, including means by which various forms are interchanged between the solid, liquid, and gaseous phases. Thus, the broader ecosystem biogeochemistry definition is also applied to wetland biogeochemistry, which focuses on surface and near-surface processes in wetlands that govern biogeochemical cycles, plant production, microbial transformations, nutrient availability, pollutant removal, heavy metal chemistry, atmospheric exchange, and sediment transport.[53]

Some of these processes have been more extensively studied than others.[54]

Evolution is continually reshaping ecological patterns and modifying biogeochemical processes.[55] As Princeton ecologist Simon Levin puts it, "[t]he

46 *Id.* § 332.3(b)(1) (emphasis added). The district engineer is to use a watershed approach in determining the appropriate type and amount of mitigation. *See id.* Watershed-scale features include "aquatic habitat diversity, habitat connectivity, relationships to hydrologic sources (including the availability of water rights), trends in land use, ecological benefits, and compatibility with adjacent land uses." *Id.*

47 Paul A. Keddy et al., *Wet and Wonderful: The World's Largest Wetlands are Conservation Priorities*, 59 BIOSCIENCE 39, 40–41 (2009).

48 J.B. Ruhl & James Salzman, *The Effects of Wetland Mitigation Banking on People*, NAT'L WETLANDS NEWSL., Mar.–Apr. 2006, at 1, 9.

49 33 C.F.R. § 332.2 (2008).

50 *Id.*

51 *Id.*

52 *See* J.B. Ruhl et al., *Bank Failure*, ENVTL. FORUM, Jan.–Feb. 2009, at 22, 26.

53 K. RAMESH REDDY & RONALD D. DELAUNE, BIOGEOCHEMISTRY OF WETLANDS: SCIENCE AND APPLICATIONS 3 (2008).

54 *See, e.g.*, Eric Struyf & Daniel J. Conley, *Silica: An Essential Nutrient in Wetland Biogeochemistry*, 7 FRONTIERS ECOLOGY & ENV'T 88, 88 (2009) (silica transport in wetlands needs further study).

55 "The physical and chemical environment of a wetland affects all biological processes. In turn, many wetland biological processes modify this physical/chemical environment." Jae Seong

biosphere is a complex adaptive system in which the never-ending generation of local variation creates an environment of continual exploration, selection, and replacement."[56] As each organism adapts to its environment, it also modifies its environment, sometimes in minute ways and sometimes more dramatically.[57] Meanwhile, the environment is continually changing as a result of landscape processes, such as soil erosion, storm damage, or subsidence.[58] Analysis of landscape factors, such as soil type, hydrology, or weather, assume increasing importance as spatial and temporal scales increase.[59]

B. Qualifying as a Bank

The COE regulations give mitigation banks preference because they typically involve large, ecologically valuable parcels, rigorous scientific and technical analysis, planning, implementation, and significant investment of financial resources.[60] The procedures for obtaining approval of a mitigation bank certainly appear to require all of those things as well as a high degree of patience. Stages of the process include preliminary review of a prospectus,[61] extended review of a draft instrument, and final approval of an instrument that includes approved mitigation plans for each separate mitigation site.[62] Mitigation plans must include 1) work plans for construction, maintenance, and monitoring,[63] and 2) ecologically-based performance standards "based on variables or measures of functional capacity" that will be used to determine the extent to which the project is meeting its objectives at various stages.[64]

Once approved, a bank may sell credits that may be released according to performance-based milestones established in the plan, but a "significant share" of the credits must be retained until all of the performance standards

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Rhee et al., *Phytoremediation Processes for Water and Air Pollution Control in the Aspects of Nutrient and Carbon Dioxide Removals*, *in* WETLANDS: ECOLOGY, CONSERVATION AND RESTORATION 325, 338 (Raymundo E. Russo ed., 2008).

56 SIMON A. LEVIN, FRAGILE DOMINION: COMPLEXITY AND THE COMMONS 23 (1999).

57 *See* EDWARD O. WILSON, THE FUTURE OF LIFE 109–11 (2002); James G. Sanderson & Larry D. Harris, *The Rest of the Story: Linking Top-Down Effects to Organisms*, *in* LANDSCAPE ECOLOGY AND RESOURCE MANAGEMENT: LINKING THEORY WITH PRACTICE 55, 62–67 (John A. Bissonette & Ilse Storch eds., 2003).

58 *See, e.g.*, Sanderson & Harris, *supra* note 57, at 55–56.

59 *See* GUY R. MCPHERSON & STEPHEN DESTEFANO, APPLIED ECOLOGY AND NATURAL RESOURCE MANAGEMENT 17 (2003).

60 *See* 33 C.F.R. § 332.3(b)(2) (2008).

61 The regulations direct the sponsor of a mitigation bank to specify "[t]he objectives of the proposed mitigation bank" and "[t]he ecological suitability of the site to achieve the objectives" in a prospectus to be submitted to the COE. *Id.* § 332.8(d)(2)(i), (vii)(A). The district engineer then makes an initial evaluation to determine whether the proposed bank "has potential for providing appropriate compensatory mitigation for activities authorized by [COE] permits." *Id.* § 332.8(d)(5)(ii).

62 *See id.* § 332.8(d)(7), (6)(ii)(A).

63 *See id.* § 332.4(c)(7)–(8), (10); *see also* Gardner et al., *supra* note 26, at 4–5.

64 33 C.F.R. § 332.5(b) (2008).

have been met.[65] The plan must also describe a process for long-term adaptive management and provide assurances that financing will be available for all stages.[66]

The new rules have provided a great deal of encouragement to the developers of wetland mitigation banks.[67] The regulations seem likely to encourage the type of large-scale projects that can afford the time and expense the procedures require.[68] Prospective bank developers have formed an active association seeking to develop a national exchange of information on all types of mitigation banks.[69]

III. WATER QUALITY TRADING

Wetlands can sometimes be managed with the objective of improving the quality of the water downstream, especially where pollution from rivers has been causing severe oxygen deficiencies.[70] The CWA does not require nonpoint sources to control their pollution-causing runoff.[71] Point sources, such as industries and sewage treatment plants, do have such requirements, and in some cases might find it cheaper to pay a nonpoint source to reduce pollution than to reduce it themselves.[72]

Both EPA and the United States Department of Agriculture (DOA) have been encouraging states to develop programs for water quality trading.[73] Seven states have programs to allow statewide trading of water quality credits.[74] In some instances, constructed wetlands may serve as a source for

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65 *See id.* § 332.8(o)(8).

66 *See id.* § 332.4(c)(12)–(13); *see also* Gardner et al., *supra* note 26, at 5–7.

67 *See* David Cusick, *Wetlands: Entrepreneurs See Opportunity as U.S. Promotes 'Third Party' Restorations*, LAND LETTER, May 19, 2008, http://www.eenews.net/public/Greenwire/2008/05/19/1 (last visited July 19, 2009).

68 *See, e.g.*, Morgan Robertson, *The Work of Wetland Credit Markets: Two Cases in Entrepreneurial Wetland Banking*, 17 WETLANDS ECOLOGY & MGMT. 35, 35 (2009).

69 *See* Nat'l Mitigation Banking Ass'n, *supra* note 38. A recent book on species conservation banks describes the nascent effort to use mitigation banks for the protection of rare species. *See* Ricardo Bayon et al., *Introduction*, *in* CONSERVATION AND BIODIVERSITY BANKING: A GUIDE TO SETTING UP AND RUNNING BIODIVERSITY CREDIT TRADING SYSTEMS 4–8 (Nathaniel Carroll et al. eds., 2008).

70 Robert J. Diaz & Rutger Rosenberg, *Spreading Dead Zones and Consequences for Marine Ecosystems*, 321 SCI. 926, 928 (2008).

71 *See* WANT, *supra* note 27, at § 4:32. In some cases, wetlands created to serve as holding ponds for mining or cattle wastes may be treated as point sources. *See* Katy Bartelma et al., *Environmental Crimes*, 44 AM. CRIM. L. REV. 409, 443 n.231 (2007).

72 U.S. ENVTL. PROT. AGENCY, WATER QUALITY TRADING TOOLKIT FOR PERMIT WRITERS 17 (2007), *available at* http://www.epa.gov/npdes/pubs/wqtradingtoolkit_fundamentals.pdf.

73 *See id.* at 1; CONSERVATION TECH. INFO. CTR., GETTING PAID FOR STEWARDSHIP: AN AGRICULTURAL COMMUNITY WATER QUALITY TRADING GUIDE 5 (2006), *available at* http://www.conservationinformation.org/images/GPfS_FINAL.pdf [hereinafter CTIF REPORT].

74 *See* U.S. Envtl. Prot. Agency, Water Quality Trading: State and Individual Trading Programs, www.epa.gov/owow/watershed/trading/tradingmap.html (last visited July 19, 2009).

tradable water quality credits.[75] The opportunity to manage existing wetlands to reduce downstream pollution should be a natural opportunity for water quality trading.

Effluent that is discharged directly into rivers from sewage treatment plants or factories carries heavy loads of nitrogen and phosphorous downstream. Fertilizers add these same elements to water bodies through runoff.[76] If certain treatment methods can reduce nutrient inputs more cheaply than others, a trading program can be used to promote use of the most efficient methods.[77] One example of trading is one in which a regulated factory obtains credits for paying an unregulated agribusiness to establish buffer zones along the riverbank to reduce agricultural runoff.[78]

The problem of nutrient pollution is a serious one. In the Mississippi Valley, for example, such high quantities of nutrients remain when the river reaches the gulf that oxygen content is lost and large areas can no longer support most marine life.[79] Similar "dead zones" are found in the Baltic Sea and other water bodies around the world.[80] To alleviate this type of problem, efforts are underway throughout the world to restore riparian wetlands[81] and to construct treatment wetlands[82] to absorb more of these nutrients.[83] Nutrient pollution from nonpoint sources cannot be easily monitored, however, and water quality trading programs tend to rely heavily on modeling. Models "are uniformly based on pollution loads that are predicted based on

75 *See* Matthew T. Heberling et al., *Incorporating Wetlands in Water Quality Trading: Economic Considerations*, NAT'L WETLANDS NEWSL., Jan.–Feb. 2007, at 6, 7.

76 *See, e.g.*, James A. Montgomery & J. Marshall Eames, *Prairie Wolf Slough Wetlands Demonstration Project: A Case Study Illustrating the Need for Incorporating Soil and Water Quality Assessment in Wetland Restoration Planning, Design and Monitoring*, 16 RESTORATION ECOLOGY 618, 625–26 (2008).

77 *See* PAUL FAETH, FERTILE GROUND: NUTRIENT TRADING'S POTENTIAL TO COST-EFFECTIVELY IMPROVE WATER QUALITY 2 (2000), *available at* http://pdf.wri.org/fertile_ground.pdf.

78 *See generally* S.L. McGinnis, *Watershed-Based Pollution Trading Development and Current Trading Programs*, 2 ENVTL. ENGINEERING & POL'Y 161, 167 (2001) (describing various trading programs for pollution).

79 *See* Nancy N. Rabalais, *Hypoxia in the Gulf of Mexico*, 12 TUL. ENVTL. L.J. 321, 321–22 (1999); *see also* Simon D. Donner & Christopher J. Kucharik, *Corn-Based Ethanol Production Compromises Goal of Reducing Nitrogen Export by the Mississippi River*, 105 PROCEEDINGS NAT'L ACAD. SCI. 4513, 4513 (2008).

80 Diaz & Rosenberg, *supra* note 70, at 926; Thomas W. Simpson et al., *Impact of Ethanol Production on Nutrient Cycles and Water Quality: The United States and Brazil as Case Studies*, *in* BIOFUELS: ENVIRONMENTAL CONSEQUENCES AND INTERACTIONS WITH CHANGING LAND USE 153, 156 fig.9.2 (R.W. Howarth & S. Bringezu eds., 2008), *available at* http://cip.cornell.edu/biofuels/files/SCOPE09.pdf.

81 *See, e.g.*, Fu-Liu Xu et al., *The Restoration of Riparian Wetlands and Macrophytes in Lake Chao*, 405 J. AQUATIC ECOSYSTEM STRESS & RECOVERY 169, 169–70 (1999).

82 ROBERT H. KADLEC & SCOTT D. WALLACE, TREATMENT WETLANDS 13–20 (2d ed. 2009).

83 ENVTL. LAW INST., NATIONAL FORUM ON SYNERGIES BETWEEN WATER QUALITY TRADING AND WETLAND MITIGATION BANKING FORUM REPORT 55 (2005) (summarizing presentation by Donald Hey, The Wetlands Initiative, entitled "Stimulating Creation of a Point/Nonpoint Source Trading System on a Watershed Scale"); FAETH, *supra* note 77, at 26–30.

changes in land use practices."[84] Large wetland mitigation banks may be better able to monitor nutrient outflows and provide reliable predictions.[85]

Coordinating the timing of credit issuance also becomes an issue in water quality trading. Because the new mitigation banking regulations provide for staged payments and adaptive management,[86] they can provide better long-term assurances that water quality will be maintained.[87] Stephanie Stern has shown how staged payments can better instill a lasting motivation for conservation. She cites decades of psychology experiments to show why upfront payment of incentives for conservation rarely promotes lasting conservation behavior; staggered or intermittent incentives are more effective.[88]

Many of the existing trading programs are loosely organized and depend largely on bilateral negotiations.[89] Because there is no specific federal statutory authority for the program, the states have a wide variety of approaches, and the overall effectiveness of the programs is hard to determine.[90] In some cases, trading programs have been instituted, but very little trading occurs.[91] However, many of the problems with water quality trading might be overcome if the program had a stronger legal foundation.

Trading in toxic pollutants also offers possibilities that are not yet widely used. "Because wetlands can be sinks for almost any chemical, applications of treatment wetlands are quite varied, with thousands of applications worldwide to treat domestic wastewater, mine drainage, non-point source pollution, storm water runoff, landfill leachate, and confined livestock operations."[92] Treatment wetlands are being used in many places to help clean up sites having high heavy metal concentrations.[93] For example, cattail marshes have been used to reduce acid mine drainage, which is a major problem in many coal mining areas.[94] Some wetland plant varieties

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84 Richard T. Woodward et al., *The Structure and Practice of Water Quality Trading Markets*, 38 J. AM. WATER RESOURCES ASS'N 967, 970 (2002). *See, e.g.*, FAETH, *supra* note 77, at 26–30.

85 ENVTL. LAW INST., *supra* note 83, at 53 (summarizing presentation by Donald Hey, The Wetlands Initiative).

86 *See id.* at 31 (summarizing presentation by Cyrus Jones, Washington Suburban Sanitary Commission). Earlier mitigation banks typically sold credits on a one-time basis. *Id.* at 42 (summarizing presentation by David Urban, Land and Water Resources, Inc.).

87 *Id.* at 33 (summarizing presentation by Craig Denisoff, Wildlands, Inc.).

88 Stephanie Stern, *Encouraging Conservation on Private Lands: A Behavioral Analysis of Financial Incentives*, 48 ARIZ. L. REV. 541, 567–72 (2006).

89 Woodward et al, *supra* note 84, at 973.

90 Cannon, *supra* note 44, at 77–78; Thomas K. Ruppert, *Water Quality Trading and Agricultural Nonpoint Source Pollution: An Analysis of the Effectiveness and Fairness of EPA's Policy on Water Quality Trading*, 15 VILL. ENVTL. L.J. 1, 4–7 (2004).

91 ENVTL. LAW INST., *supra* note 83, at 12 (summarizing presentation by Dennis King, University of Maryland). J.B. Ruhl and his co-authors conclude that water quality trading has largely failed because of "regulatory inequity, compromised fungibility, and geographic specificity of pollution impacts." J.B. RUHL ET AL., THE LAW AND POLICY OF ECOSYSTEM SERVICES 230 (2007).

92 WILLIAM J. MITSCH & JAMES G. GOSSELINK, WETLANDS 425 (4th ed. 2007).

93 Rhee et al., *supra* note 55, at 330–35.

94 MITSCH & GOSSELINK, *supra* note 92, at 431–34.

have been shown to be particularly good at uptake of heavy metals,[95] and genetic modification of these plants might increase their uptake capacity and reduce invasive tendencies.[96]

In particular, mercury may provide valuable opportunities for wetland managers to earn credits through water quality trading.[97] Mercury causes serious health problems that have proven difficult to contain.[98] The primary source of mercury is airborne, but its health impacts begin after it reaches water, becomes methylated, and is absorbed up the food chain to fish and wildlife. These issues do not fit neatly within our existing regulatory systems in which air and water are treated separately.[99]

Some biogeochemical processes that occur in wetlands appear to play a key role in the conversion of atmospheric mercury to the methylmercury (MeHg) that becomes bioaccumulated in fish and other wildlife.[100] A review of the literature in 2002 commented that "it is ironic that wetlands, landscape elements that both regulation and legislation have attempted to protect from disturbance, are the single most identifiable source of MeHg in terrestrial systems."[101] Measurements taken at a number of wetland sites have shown that wetlands export more MeHg than they receive.[102] Sulfate-reducing anaerobic bacteria, which appear to be causing much of the methylation, thrive in wetlands—particularly in wetlands where organic carbon and sulfate are common, such as those impacted by acid rain.[103]

Biotechnologists are working on methods of wetland management that use genetically modified plants to treat toxic substances,[104] including plants that could counteract or limit the methylation process.[105] Scientists have engineered wetland plants with bacterial genes that can convert MeHg back to

95 Zhenhua Zhang et al., *Nutrition and Toxicity of Inorganic Substances from Wastewater in Constructed Wetlands*, *in* WETLANDS: ECOLOGY, CONSERVATION AND RESTORATION, *supra* note 55, at 253–54; Laura Fay & Mae Sexauer Gustin, *Investigation of Mercury Accumulation in Cattails Growing in Constructed Wetland Ecosystems*, 27 WETLANDS 1056, 1063 (2007).

96 Jack Gallagher, *Improving Wetland Plants: A Good, Bad, or an "It Depends" Idea?*, NAT'L WETLANDS NEWSL., Jan.–Feb. 2009, at 10, 11.

97 Jeffrey K. King et al., *Mercury Removal, Methylmercury Formation, and Sulfate-Reducing Bacteria Profiles in Wetland Mesocosms*, 46 CHEMOSPHERE 859, 860 (2002).

98 *See, e.g.*, Wendy Jastremsky, *Cracking Down on Coal*, 16 PENN ST. ENVTL. L. REV. 431, 436 (2008).

99 Susan E. Cowell, *Law at the Air/Water Interface*, 8 WIS. ENVTL. L.J. 51, 62–63 (2002).

100 JERRY JENKINS ET AL., ACID RAIN IN THE ADIRONDACKS: AN ENVIRONMENTAL HISTORY 164–76 (2007).

101 D.F. Grigal, *Inputs and Outputs of Mercury from Terrestrial Watersheds*, 10 ENVTL. REV. 1, 29 (2002); *see also* J.M. Benoit et al., *Geochemical and Biological Controls over Methylmercury Production and Degradation in Aquatic Ecosystems*, *in* BIOGEOCHEMISTRY OF ENVIRONMENTALLY IMPORTANT TRACE ELEMENTS 262, 263 (Yong Cai & Olin C. Braids eds., 2003).

102 Carl P.J. Mitchell & Cynthia C. Gilmour, *The Role of Wetlands in Methylmercury Production*, NAT'L WETLANDS NEWSL., Sept.–Oct. 2008, at 1, 7.

103 JENKINS ET AL, *supra* note 100, at 171–72.

104 Gallagher, *supra* note 96, at 10.

105 Susan Eapen & S.F. D'Souza, *Prospects of Genetic Engineering of Plants for Phytoremediation of Toxic Metals*, 23 BIOTECHNOLOGY ADVANCES 97, 109 (2005); Ute Krämer, *Phytoremediation: Novel Approaches to Cleaning Up Polluted Soils*, 16 CURRENT OPINION BIOTECHNOLOGY 133, 133 (2005).

its volatile form; for example, experiments found that both transgenic rice[106] and transgenic cottonwoods[107] appeared to be able to convert MeHg to its less toxic form. Such research might eventually lead to regulations that would provide valuable credit for management of wetlands for MeHg removal.

IV. SPECIES CONSERVATION BANKS

Species conservation banks have attracted considerable interest recently. Wetland managers have had over a century's experience in managing wetlands for the benefit of waterfowl and fish; the U.S. Fish and Wildlife Service (USFWS), various state agencies, and nongovernmental organizations (NGOs), such as Ducks Unlimited, have shown that active management can improve wetland habitat for wildlife.[108] Although much of the management has been financed by duck hunters,[109] the managers have also learned how to provide habitat for species other than ducks, including those in need of special protection.[110]

The idea of using banking systems to help finance wetland biodiversity is more recent and grew in recognition of the need to protect large wetland areas in certain places.[111] Some species suffer when their habitat is fragmented; their chances of survival improve if they can occupy a larger habitat in which changing conditions may cause less stress.[112] Amphibians, for example, often need both wetlands and some adjacent protected uplands in order to maintain stable populations.[113] Birds that migrate long distances may require large protected areas at key points on their migratory routes.[114]

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106 Sharon Lafferty Doty, *Enhancing Phytoremediation Through the Use of Transgenics and Endophytes*, 179 NEW PHYTOLOGIST 318, 325 (2008).

107 Satu Lyyra et al., *Coupling Two Mercury Resistance Genes in Eastern Cottonwood Enhances the Processing of Organomercury*, 5 PLANT BIOTECHNOLOGY J. 254, 254 (2007).

108 Robert L. Fischman, *The National Wildlife Refuge System and the Hallmarks of Modern Organic Legislation*, 29 ECOLOGY L.Q. 457, 465 (2002); Matt Young, *Rescuing the Duck Factory*, DUCKS UNLIMITED MAG., Nov.–Dec. 2008, http://www.ducks.org/DU_Magazine/DUMagazineNovDec2008/4105/RescuingtheDuckFactory.html (last visited July 19, 2009).

109 Ned H. Euliss Jr., et al., *Linking Ecosystem Processes to Sustainable Wetland Management*, NAT'L WETLANDS NEWSL., Jan.–Feb. 2009, at 1, 3.

110 *See, e.g.*, Nancy Shepherdson, *Wetland Birds Demand Change*, CHI. WILDERNESS MAG., Summer 2008, at 15, 15–17.

111 *See, e.g.*, ENVTL. DEF. FUND, MITIGATION BANKING AS AN ENDANGERED SPECIES CONSERVATION TOOL 2 (1999), *available at* http://www.edf.org/documents/146_mb.pdf.

112 ANDREW P. DOBSON, CONSERVATION AND BIODIVERSITY 34–35 (1996). For a general discussion of fragmentation and habitat loss, see *id.* at 33–57.

113 Gentile Francesco Ficetola et al., *Influence of Landscape Elements in Riparian Buffers on the Conservation of Semiaquatic Amphibians*, 23 CONSERVATION BIOLOGY 114, 115 (2009); Tracy A.G. Rittenhouse & Raymond D. Semlitsch, *Distribution of Amphibians in Terrestrial Habitat Surrounding Wetlands*, 27 WETLANDS 153, 153 (2007), *available at* http://www.leap.missouri.edu/MOLEAP/pubs/Rittenhouse&Semlitsch2007.pdf.

114 For example, the Red Knot makes one of the longest yearly migrations of any bird, traveling 9300 miles from Tierra del Fuego at the southern tip of South America to its Arctic breeding grounds, and relies on a specific area of Delaware Bay to fuel its spring migration.

The state of California has operated a program for over a decade that encourages the development of reserves for the protection of rare species by allowing the managers of the reserve to sell shares in it to people who need the credits to mitigate for habitat destruction.[115] Some forty conservation banks have been created, many of which are devoted to the protection of wetlands, including rare vernal pools and wetland-upland interfaces needed by rare amphibians such as the California red-legged frog (*Rana aurora draytonii*).[116] The program differs from earlier wetland banking by emphasizing the quality of the habitat protected rather than just the acreage.[117] The USFWS supports California's program, and has encouraged the development of similar programs in other states.[118]

The informal legal status of conservation banks outside California has made it difficult to collect comprehensive information about their existence and operations.[119] A study in 2003 found 76 places that were designated as conservation banks, not all of which were associated with state or federal programs.[120] Congress has not specifically addressed conservation banking for the protection of species, so the rules are set forth in guidance documents issued by the USFWS rather than in statutes or regulations, which creates a risk that future statutes could change the rules retroactively.[121] However, many of the conservation bank transactions are included in habitat conservation plans endorsed by the USFWS,[122] and such plans have been accepted by the courts as binding contracts.[123]

The World Bank has promoted the use of conservation banks at the international level.[124] The United Nations Convention on Biological Diversity has encouraged the development of guidelines for "biodiversity offsets" and a

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Cornell Lab of Ornithology, All About Birds: Red Knot, http://www.birds.cornell.edu/AllAbout Birds/BirdGuide/Red_Knot_dtl.html (last visited July 19, 2009).

115 Cal. Dep't of Fish & Game, Conservation and Mitigation Banking, http://www.dfg.ca.gov/ habcon/conplan/mitbank (last visited July 19, 2009).

116 Cal. Dep't of Fish & Game, Habitat Conservation: Conservation and Mitigation Banks in California Approved by the Department of Fish and Game, www.dfg.ca.gov/habcon/conplan/ mitbank/catalogue/catalogue.html (last visited July 19, 2009).

117 Raymond D. Semlitsch, *Moving Wetland Banking Towards Conservation Banking*, NAT'L WETLANDS NEWSL., Sept.–Oct. 2008, at 15, 15.

118 U.S. FISH & WILDLIFE SERV., CONSERVATION BANKING: INCENTIVES FOR STEWARDSHIP 1 (2006), *available at* http://www.fws.gov/endangered/factsheets/banking_7_05.pdf [hereinafter INCENTIVES FOR STEWARDSHIP].

119 For an overview of the legal issues concerning conservation banks, see Royal C. Gardner, *Legal Considerations*, *in* CONSERVATION AND BIODIVERSITY BANKING: A GUIDE TO SETTING UP AND RUNNING BIODIVERSITY CREDIT TRADING SYSTEMS, *supra* note 69, at 9, 71–73.

120 Jessica Fox & Anamaria Nino-Murcia, *Status of Species Conservation Banking in the United States*, 19 CONSERVATION BIOLOGY 996, 998 (2005). For an "off-the-books" example, see Juliet Eilperin, *Pentagon Issues "Credits" to Offset Harm to Wildlife*, WASH. POST, Feb. 9, 2009, at A2.

121 *See* Gardner, *supra* note 119, at 72–73.

122 INCENTIVES FOR STEWARDSHIP, *supra* note 118.

123 Gardner, *supra* note 119, at 73–76 (explaining the legal status of conservation easements).

124 INT'L FIN. CORP., BIODIVERSITY OFFSETS AND OPPORTUNITIES 1, *available at* http://www.ifc.org/ ifcext/sustainability.nsf/AttachmentsByTitle/BiodivGuide_Offsets/$FILE/Offsets.pdf.

number of countries have begun work on such programs.[125] A new NGO has been created specifically to work on this subject.[126]

Scientists are paying specific attention to the possibility of designing biodiversity banks that might receive carbon credits under the Kyoto Protocol's Clean Development Mechanism (CDM) system.[127] Two Australian analysts suggest that the "convergence of schemes to sequester carbon and conserve biodiversity present an opportunity to revolutionize environmental management. If correctly harnessed, the power of carbon initiatives could fuel a major biodiversity renaissance."[128]

V. GREENHOUSE GAS TRADING

Interest in stabilizing climate by reducing emissions of GHGs has stimulated the creation of markets in which reductions of such emissions are traded. Because wetlands have a unique relationship with three of the most important GHGs, the idea of managing wetlands to reduce GHG emissions seems opportune. However, the complexity of the biogeochemistry makes grasping the opportunity a challenge.

A. Carbon Markets

Markets in which GHG credits are traded are referred to as "carbon markets," although they typically trade all the major GHGs.[129] Nations that are bound by Kyoto protocol commitments already participate in a well-established United Nations carbon market, and many companies engage in the carbon market created by the European Union.[130] Many businesses expect that the United States will adopt some form of carbon trading law within a few years,[131] and individual states and groups of states are already working on their own carbon trading programs.[132] "We see enormous opportunities for the financial industry," said the vice chairman of

125 Kerry Ten Kate & Mira Inbar, *Biodiversity Offsets*, *in* CONSERVATION AND BIODIVERSITY BANKING: A GUIDE TO SETTING UP AND RUNNING BIODIVERSITY CREDIT TRADING SYSTEMS, *supra* note 69, at 189, 201–02.

126 Forest Trends, Business and Biodiversity Offset Program, http://www.forest-trends.org/biodiversityoffsetprogram/index.php (last visited July 19, 2009).

127 *See* discussion *infra* Part V.B.

128 Sarah A. Bekessy & Brendan A. Wintle, *Using Carbon Investment to Grow the Biodiversity Bank*, 22 CONSERVATION BIOLOGY 510, 512 (2008).

129 RICARDO BAYON ET AL., VOLUNTARY CARBON MARKETS: AN INTERNATIONAL BUSINESS GUIDE TO WHAT THEY ARE AND HOW THEY WORK 4 (2007).

130 Dennis Hirsch et al., *Emissions Trading—Practical Aspects*, *in* GLOBAL CLIMATE CHANGE AND U.S. LAW 627, 635–57 (Michael B. Gerrard ed., 2007).

131 U.S. CLIMATE ACTION P'SHIP, A BLUEPRINT FOR LEGISLATIVE ACTION 5 (2009), *available at* http:// www.us-cap.org/pdf/USCAP_Blueprint.pdf.

132 *See, e.g.*, W. CLIMATE INITIATIVE, DRAFT DESIGN OF THE REGIONAL CAP-AND-TRADE PROGRAM (2008). The Western Climate Initiative also includes some Canadian provinces. *See* W. Climate Initiative, WCI Provincial and State Partner Contacts, http://www.westernclimateinitiative.org/wci-partners (last visited July 19, 2009).

Deutsche Bank; "If leadership is there to create a Kyoto successor that is based on cap-and-trade, then it creates a global carbon market—and then we are in business."[133]

Carbon markets try to make it possible to find the cheapest way to reduce GHG emissions. If Able Company wants to continue to emit GHGs, it can pay Baker Company to reduce a comparable amount of emissions instead.[134] Because the emitted substances mix in the global atmosphere, a reduction in any part of the world is as effective as an equivalent reduction at any other part.[135]

When the reduction is accomplished by some party that has no legal obligation to reduce GHGs itself, it is known as an "offset."[136] Because the cost of reducing emissions can vary widely, offsets encourage economic efficiency by encouraging entrepreneurs to undertake projects that will reduce emissions at the lowest cost per unit of GHG and then sell the credit generated by the project to a company that would find reducing its own emissions more costly.[137] For example, a chemical company could continue its GHG emissions in France by installing equipment to reduce emissions on a plant in Korea.[138]

The geographic irrelevance of the project site is based on the widely accepted scientific principle that greenhouse gases mix globally during their lifetimes in the atmosphere.[139] Therefore, reducing emissions any place in the world is as good as any other—or, as the traders like to say, a ton is a ton is a ton.[140]

In addition, an offset project need not reduce the same gas as the gas that produces the emissions it is offsetting. To facilitate these calculations, trading systems translate the global warming potential of each greenhouse gas to the number of tons of carbon dioxide that would have an equivalent global warming

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133 Richard Black, *Business Chiefs Urge Carbon Curbs*, BBC NEWS, June 20, 2008, http://news.bbc.co.uk/2/hi/science/nature/7464517.stm (last visited July 19, 2009).

134 Michael B. Gerrard, *Introduction and Overview*, *in* GLOBAL CLIMATE CHANGE AND U.S. LAW, *supra* note 130, at 1, 18.

135 Goddard Inst. for Space Studies, Nat'l Aeronautics & Space Administration, Forcings in GISS Climate Model: Well-Mixed Anthropogenic Greenhouse Gases, http://data.giss.nasa.gov/modelforce/ghgases (last visited July 19, 2009).

136 KATHERINE HAMILTON ET AL., STATE OF THE VOLUNTARY CARBON MARKETS 2007: PICKING UP STEAM 15 (2007).

137 LYDIA P. OLANDER & BRIAN C. MURRAY, OFFSETS: AN IMPORTANT PIECE OF THE CLIMATE POLICY PUZZLE 1–2 (2008), *available at* http://www.nicholas.duke.edu/institute/offsetseries1.pdf; *see also* PEW CTR. ON GLOBAL CLIMATE CHANGE, GREENHOUSE GAS OFFSETS IN A DOMESTIC CAP-AND-TRADE PROGRAM 1–2 (2008).

138 Charles Forelle, *French Firm Cashes in Under U.N. Warming Program*, WALL ST. J., July 23, 2008, at A1.

139 Jonathan Baert Wiener, *Protecting the Global Environment*, *in* RISK VERSUS RISK: TRADEOFFS IN PROTECTING HEALTH AND THE ENVIRONMENT 193, 213 (John D. Graham & Jonathan Baert Wiener eds., 1995).

140 PEW CTR. ON GLOBAL CLIMATE CHANGE, *supra* note 137, at 5 (2008).

potential. For wetlands, the United Nations assigns methane and nitrous oxide the values of 23 and 296 carbon dioxide (CO_2) equivalents, respectively.[141]

The system in the United Nations for verifying compliance with Kyoto offset reductions "has undergone significant growing pains."[142] Although the controversies involved in offset reduction monitoring are beyond the scope of this Article, some of the problems include the following:

> (1) [P]rojects that cause huge reductions of the more potent greenhouse gases at chemical plants by installing cheap equipment that other plants use in the normal course of business; (2) projects that would probably have been undertaken anyway because they are economically profitable, such as some landfill methane capture and utilization projects; or (3) projects that will produce benefits only if one assumes that conditions will remain unchanged for decades, such as restoration of forests.[143]

Although reforms are likely, the disappearance of offsets is not.

B. Wetlands and Greenhouse Gases

Traders are likely to view the creation, management, or destruction of wetlands as tempting targets with high potential value.[144] The actual global warming potential (GWP) of any particular wetland is site-specific and scientists believe the emissions of a wetland fluctuate with temperatures and precipitation quantities; specifically, models show "[e]missions increase . . . where an increase in temperature is associated with increases in precipitation and [net ecosystem production (NEP)], but emissions decrease if elevated temperature results in either reduced precipitation or reduced NEP."[145]

Under federal law, a wetland owner can manage the wetland in a wide variety of ways while ensuring that it remains categorized as a wetland.[146] Federal law does not prohibit management alterations as long as they do not involve dredging or filling and they leave the land wet.[147] Some types of wetland management may be found to create very significant reductions in

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141 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS 38 (2001). These equivalent numbers have a certain degree of artificiality because the gases react in the atmosphere in different ways and over different time periods, *see* REDDY & DELAUNE, *supra* note 53, at 600, but the Intergovernmental Panel on Climate Change has agreed on these values to facilitate trading among the various gases.

142 Bosselman, *supra* note 28, at 5; *see also* Robert N. Stavins, *A Meaningful U.S. Cap-and-Trade System to Address Climate Change*, 32 HARV. ENVTL. L. REV. 293, 366–67 (2008).

143 Bosselman, *supra* note 28, at 5.

144 GABRIELLE WALKER & SIR DAVID KING, THE HOT TOPIC: WHAT WE CAN DO ABOUT GLOBAL WARMING 164 (2008).

145 *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 541–46 (Susan Solomon et al. eds., 2007) [hereinafter IPCC 2007].

146 Several states have their own wetland laws that have their own jurisdictional rules that would need to be taken into account. *See* ENVTL. LAW INST., STATE WETLAND PERMITTING PROGRAMS: AVOIDANCE AND MINIMIZATION REQUIREMENTS 4–10 (2008).

147 *See, e.g.*, Rapanos v. United States, 547 U.S. 715, 719–25 (2006).

the net balance of GHGs they emit, which would qualify them as valuable offset projects, but since the value will be determined solely by the net effect on GHGs, the other social and environmental impacts of the projects on wetland functions are likely to be swept aside, just as has happened with the law's current concentration on the wetness acreage.[148]

Another aspect of the scientific basis for offsets is particularly important when thinking about wetlands. Although the arguments about climate change have focused on the issue of whether and how humans are changing the climate by emitting GHGs, it is well known that natural sources also emit large amounts of GHGs.[149] If too many GHGs are the problem, then reducing natural GHG emissions could be as beneficial as reducing emissions from human-caused sources.[150]

Why are wetlands logical opportunities? First, some kinds of wetlands can store enormous amounts of carbon in the form of submerged organic material and might be managed in a way that stores more.[151] Second, the 2007 Intergovernmental Panel on Climate Change (IPCC) report emphasized that some wetlands are significant sources of methane, an even more potent GHG.[152] The prevailing scientific opinion is that natural wetlands cause roughly 25% of methane emissions.[153]

In addition, IPCC estimates that climate change already underway will significantly increase the total area of wetlands worldwide, and that a doubling of carbon dioxide emissions would cause wetland methane emissions to increase by 78%.[154] So if a particular wetland could be managed to increase carbon storage, while reducing methane and nitrous oxide emissions, it could be an alchemist's tempting pot of gold: $C - NH_4 - N_2O = Au$. How much gold? Any project that might be planned today would need to speculate on the price that volatile carbon credits would bring when the project was completed.

But is this alchemy possible? Given the wide-ranging research going on all over the world, it appears that many scientists think the pot of gold is within reach, but because of the complex interrelationship of the three gases no one yet seems to have come up with a universal solution to which everyone agrees.[155]

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148 *See* Zedler & Kercher, *supra* note 41, at 45–46.

149 MARQUITA K. HILL, UNDERSTANDING ENVIRONMENTAL POLLUTION 165–69 (2d ed. 2004).

150 Nigel T. Roulet, *Peatlands, Carbon Storage, Greenhouse Gases, and the Kyoto Protocol: Prospects and Significance for Canada*, 20 WETLANDS 605, 606–09 (2000).

151 MITSCH & GOSSELINK, *supra* note 92, at 318.

152 *See* IPCC 2007, *supra* note 145, at 542–47.

153 *See id.* at 541, 542 tbl.7.6 (2007).

154 *Id.* at 543.

155 *See, e.g.*, Jack Parker, *Turning Manure into Gold: The Potential of Methane-Producing Bacteria to Meet Future Energy Needs*, 3 EMBO REP. 1114, 1115 (2002), *available at* http://www.nature.com/embor/journal/v3/n12/pdf/embor005.pdf (describing research).

C. Carbon Dioxide

Carbon sinks play an important role in climate because they store carbon that might otherwise be emitted to the atmosphere in the form of carbon dioxide. Wetlands constitute one of the world's most important carbon sinks.[156]

1. Carbon in Soil

Soils contain three times as much carbon as live vegetation, but different types of soils vary greatly in their ability to store carbon.[157] Wetland soils contain enormous amounts of carbon in the form of decomposed vegetation.[158] While the amount of aboveground biomass may be easy to estimate, the ratio of belowground to aboveground storage may vary from 0.2 to 2.5 according to various studies.[159] Although the data is limited and estimates vary, there is no argument that some wetlands can store a lot of carbon that would otherwise contribute to climate change.[160]

The processes by which wetlands store carbon are affected by many factors. For example, the extent to which the wetland's organic matter contains lignin reduces the rate of its decomposition; the amount and type of soil microbes regulate the transformation and storage of nutrients; hydrological fluctuations that increase the presence of oxygen can speed up decomposition; and decomposition can be slowed by extremes of temperature either above or below the ideal range.[161]

2. Peatlands

Carbon storage is particularly extensive in "peatlands," a category of wetlands in which continuous inundation has turned vegetative material into peat.[162] Peatlands are found extensively in both tropical regions and in the northern parts of the northern hemisphere.[163] In northern wetlands much of

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156 MITSCH & GOSSELINK, *supra* note 92, at 317–18.

157 REDDY & DELAUNE, *supra* note 53, at 615–16.

158 Various estimates include 1) wetlands store 33% of soil organic matter on only 4% of the global land surface, 2) wetlands store 14.5% of soil carbon on only 2% to 6% of land area, and 3) of carbon stored in soil, 20% to 30% is stored in wetlands. Ned Euliss, Jr., et al., *North American Prairie Wetlands are Important Nonforested Land-Based Carbon Storage Sites*, 361 SCI. TOTAL ENV'T 179, 186 (2006); REDDY & DELAUNE, *supra* note 53, at 615; MITSCH & GOSSELINK, *supra* note 92, at 317.

159 Virginie Bouchard & Matthew Cochran, *Wetland and Carbon Sequestration*, *in* 2 ENCYCLOPEDIA OF SOIL SCIENCE 1887, 1887 (Rattan Lal ed., 2d ed. 2006).

160 For an assessment of various estimates of global wetland area, see Sudip Mitra et al., *An Appraisal of Global Wetland Area and its Organic Carbon Stock*, 88 CURRENT SCI. 25, 30–32 (2005).

161 For a review of these factors, see REDDY & DELAUNE, *supra* note 53, at 157–73.

162 *See* J. Limpens et al., *Peatlands and the Carbon Cycle: From Local Processes to Global Implications—A Synthesis*, 5 BIOGEOSCIENCES 1475, 1476 (2008) (discussing the importance of the water table).

163 INT'L PEAT SOC'Y, PEATLANDS AND CLIMATE CHANGE 9 (Maria Strack ed., 2008), *available at* http://www.peatsociety.org/user_files/files/PeatlandsandClimateChangeBookIPS2008.pdf.

the peat is formed by sphagnum moss, while in the tropics it may consist of the decomposed roots of plants grown in aerobic conditions.[164]

Estimating the total global amount of carbon stored in peat is difficult because peatlands are most prevalent in subarctic and tropical areas rather than the temperate zones where most data has been collected.[165] Satellite images can provide assessments of peatland area, but because the depth of peat can vary from a foot or so to many yards and because there are variations in peat density, the volume of carbon is difficult to determine without adequate site-specific information.[166] Nevertheless, a recent United Nations Environment Programme (UNEP) supported report says that peatlands contain as much carbon as all terrestrial biomass and twice as much as all forest biomass.[167] Peatlands also outlast forests and can continue to store carbon for many thousands of years.[168]

The opposite side of the coin is that draining and burning of peatlands can produce extremely high volumes of carbon dioxide emissions.[169] Peat bog fires, which can occur from lightning strikes or human activities, may instantly convert a carbon sink into a huge source of carbon emissions.[170] However, restored peatlands appear to only accumulate carbon very gradually.[171]

Attention has recently been focused on the extensive conversion of peatlands in Southeast Asia to oil palm plantations.[172] The UNEP-supported

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164 Rodney A. Chimner & Katherine C. Ewel, *A Tropical Freshwater Wetland: II. Production, Decomposition and Peat Formation*, 13 WETLANDS ECOLOGY & MGMT. 671, 672 (2005).

165 *See* PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM AND WORKSHOP ON TROPICAL PEATLAND: CARBON-CLIMATE-HUMAN INTERACTIONS ON TROPICAL PEATLAND 19, 22 (J.O. Rieley et al. eds., 2007), *available at* http://www.geog.le.ac.uk/carbopeat/media/pdf/yogyapapers/yogyaproceedings.pdf (abstract of presentation by Susan E. Page et al. entitled Tropical Peatlands: Distribution, Extent and Carbon Storage—Uncertainties and Knowledge Gaps, which highlighted the lack of accurate, up-to-date data on tropical peatlands).

166 *See, e.g.*, DANIEL CHARMAN, PEATLANDS AND ENVIRONMENTAL CHANGE 32 (2002) (discussing the use of satellite imagery to determine peatland areas); E. PAAVILAINEN & J. PÄIVÄNEN, PEATLAND FORESTRY: ECOLOGY AND PRINCIPLES 13–14 (1995) (noting that variations in depths and densities contribute to uncertainties in carbon storage estimates for peatlands). *See generally* MITSCH & GOSSELINK, *supra* note 92, at 317–18 (describing peat storage issues).

167 GLOBAL ENV'T CTR. & WETLANDS INT'L, ASSESSMENT ON PEATLANDS, BIODIVERSITY AND CLIMATE CHANGE 102 (2008), *available at* http://www.imcg.net/docum/pcb/assessment_peatland.pdf (noting that estimates of "global peat carbon stocks generally suffer from a lack of adequate inventories in large parts of the world, especially with respect to the depth and dry bulk densities of global peat deposits," but still concluding peatland carbon content is "equal to all terrestrial biomass, and twice the carbon stock in the forest biomass of the world").

168 Bouchard & Cochran, *supra* note 159, at 1888. A forested swamp can store carbon both in the soil and vegetation. *Id.* at 1889.

169 *See* GLOBAL ENV'T CTR. & WETLANDS INT'L, *supra* note 167, at 3 ("The annual carbon dioxide emission from peatlands in Southeast Asia by drainage alone is at least 650 million tonnes, with an average of 1.4 billion tonnes released by peatland fires.").

170 Stephen W. Running, *Ecosystem Disturbance, Carbon, and Climate*, 321 SCI. 652, 653 (2008); *see also* David Schimel & David Baker, *The Wildfire Factor*, 420 NATURE 29, 29 (2002) (describing the carbon impacts of a peat fire in Indonesia).

171 Zedler & Kercher, *supra* note 41, at 55.

172 *See, e.g.*, Lian Pin Koh & David S. Wilcove, *Cashing in Palm Oil for Conservation*, 448 NATURE 993, 993–94 (2007); Nicola Colbran & Asbjørn Eide, *Biofuel, the Environment, and Food*

report also noted that the burning of forested peat bogs in Indonesia in 1997 emitted some 2.6 billion tons of carbon, "equivalent to 40% of global emissions from burning fossil fuels that year," and identified such conversion "as one of the largest sources affecting the levels of CO_2 in the atmosphere."[173]

3. Estimating Carbon Storage

A number of different factors determine the extent of organic matter decomposition in any specific wetland, including 1) the amount and type of organic matter that reaches the wetland, especially the amount of lignin, 2) the availability of high temperatures to speed up decomposition, 3) the availability of nitrogen or phosphorous to increase decomposition, 4) the presence of certain types of microbes, and 5) the depth and stability of water levels.[174]

Agreement on a protocol for estimating future carbon storage will facilitate the trading of wetland offsets.[175] Carbon storage research is underway throughout the world, including places as widely dispersed as Korea,[176] Micronesia,[177] Spitsbergen,[178] and Ohio.[179] A recent evaluation of Chinese wetlands found the highest carbon sequestration rates in mangrove swamps and coastal salt marshes.[180]

Security: A Global Problem Explored Through a Case Study of Indonesia, 9 SUSTAINABLE DEV. L. & POL'Y 4, 4 (2008).

173 GLOBAL ENV'T CTR. & WETLANDS INT'L, *supra* note 167, at 132. Similar problems can also occur in subarctic regions. *See* Tomoko Nakano et al., *Temporal Variations in Soil-Atmosphere Methane Exchange After Fire in a Peat Swamp Forest in West Siberia*, 52 SOIL SCI. & PLANT NUTRITION 77, 77 (2006) (noting fire is common in boreal forests). Wetland fires can also increase other forms of air pollution. *See* UNITED NATIONS ENV'T PROGRAMME, ATMOSPHERIC BROWN CLOUDS: REGIONAL ASSESSMENT REPORT WITH FOCUS ON ASIA SUMMARY 10 (2008), *available at* http://www.unep.org/pdf/ABCSummaryFinal.pdf (listing the air pollutants in atmospheric brown clouds).

174 *See* REDDY & DELAUNE, *supra* note 53, at 157–73 (discussing these factors). If climate change produces more extreme periods of drought and flooding, the ability of wetlands to store carbon is likely to be affected. *See* Scott D. Bridgham et al., *Rapid Carbon Response of Peatlands to Climate Change*, 89 ECOLOGY 3041, 3046 (2008) ("[P]eatlands can gain or lose large amounts of soil carbon within a few years in a homeostatic response from small-scale feedbacks to climate change . . . ."). Methane emissions may also be reduced. *See infra* Part V.D.

175 *See* INT'L INST. FOR SUSTAINABLE DEV., PRAIRIE WETLANDS AND CARBON SEQUESTRATION: ASSESSING SINKS UNDER THE KYOTO PROTOCOL 19 (David Wylynko ed., 1999), *available at* http://www.iisd.org/wetlands/wrkshp_summ.pdf (advocating a need for scientific evidence showing carbon-storage potential of wetlands in order to fit into a Kyoto Protocol-type system).

176 Rhee et al., *supra* note 55, at 343.

177 Chimner & Ewel, *supra* note 164, at 671.

178 Sofie Sjögersten et al., *Habitat Type Determines Herbivory Controls Over CO_2 Fluxes in a Warmer Arctic*, 89 ECOLOGY 2103, 2105 (2008).

179 Christopher J. Anderson et al., *Temporal and Spatial Development of Surface Soil Conditions at Two Created Riverene Marshes*, 34 J. ENVTL. QUALITY 2072, 2072 (2005).

180 Duan Xiaonan et al., *Primary Evaluation of Carbon Sequestration Potential of Wetlands in China*, 28 ACTA ECOLOGICA SINICA 463, 463 (2008). These categories of wetland also emitted less methane. *Id.*

D. Methane

The literature on wetland methane emissions is proliferating rapidly, reflecting the complexity of the factors that apparently affect the emission rates as well as the many variations among wetland types.[181] Scientists interested in analyzing the GWP of wetlands must contend with two notable ironies; first, in general, the constant high water levels that promote carbon storage cause increased methane emissions,[182] and second, the sulfates brought by acid rain, which harm plants and animals, appear to reduce methane emissions.[183]

1. Oxygen Deprivation

Bacteria that generate methane thrive in anaerobic conditions, so that continuous water over wetland soils can increase methane emissions.[184] In some cases, the methane from the wetland may cause it to be a net source of GHGs despite the carbon storage that takes place.[185] Natural periodic variations in water levels may substantially reduce methane emissions,[186] so periodic draining of wetlands can reduce such emissions, even to the point of creating a methane sink,[187] but such drainage may increase carbon dioxide emissions.[188]

2. Sulfates

A number of studies have shown that even small amounts of sulfates can reduce the production of methane in wetlands.[189] Studies that simulated the effects of acid rain on inland wetlands concluded that the components of typical acid rain reduced methane emissions.[190] Sulfates, but not nitrates,

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181 *See generally* Mitra et al., *supra* note 160, at 25.

182 *Id.*

183 Nancy B. Dise & Elon S. Verry, *Suppression of Peatland Methane Emission by Cumulative Sulfate Deposition in Simulated Acid Rain*, 53 BIOGEOCHEMISTRY 143, 143–44 (2001).

184 Lena Ström et al., *Greenhouse Gas Emissions from a Constructed Wetland in Southern Sweden*, 15 WETLANDS ECOLOGY & MGMT. 43, 44 (2007).

185 Kewei Yu et al., *Effect of Hydrological Conditions on Nitrous Oxide, Methane, and Carbon Dioxide Dynamics in a Bottomland Hardwood Forest and Its Implication for Soil Carbon Sequestration*, 14 GLOBAL CHANGE BIOLOGY 798, 806 (2008).

186 Anne E. Altor & William J. Mitsch, *Methane Flux from Created Riparian Marshes: Relationship to Intermittent Versus Continuous Inundation and Emergent Macrophytes*, 28 ECOLOGICAL ENGINEERING 224, 224 (2006).

187 Anne E. Altor & William J. Mitsch, *Methane and Carbon Dioxide Dynamics in Wetland Mesocosms: Effects of Hydrology and Soils*, 18 ECOLOGICAL APPLICATIONS 1307, 1307 (2008).

188 Mitra et al., *supra* note 160, at 31.

189 *See, e.g.*, MITSCH & GOSSELINK, *supra* note 92, at 193 (noting that "methane is emitted at low concentrations in reduced soils when sulfate concentrations are high").

190 Vincent Gauci et al., *Suppression of Rice Methane Emission by Sulfate Deposition in Simulated Acid Rain*, 113 J. OF GEOPHYSICAL RES., at G00A07 (2008); Vincent Gauci et al., *Sulfate Deposition and Temperature Controls on Methane Emission and Sulfur Forms in Peat*, 71 BIOGEOCHEMISTRY 141, 141 (2004).

seemed to have the effect of reducing methane emissions.[191] Similar results were found in a Russian study.[192]

Much of the research on methane emission has involved peatlands in the far north. Wetlands in the Arctic tend to be moderate methane sources under current conditions,[193] perhaps because of the limited amount of tundra vegetation.[194] However, increasing Arctic temperatures in recent decades have caused more emissions of methane from northern wetlands,[195] as vegetation increases with the warming conditions.[196]

Large volumes of methane have been locked in permanently frozen ground (permafrost), and some of this methane is being released as warmer temperatures cause the ground to melt in the summers.[197] One study estimates that increasing Arctic precipitation and temperature could increase methane emissions 80 to 300%.[198] Growing populations of geese have also had dramatic impacts on Arctic wetlands, affecting the wetlands' GHG balance unfavorably.[199]

Subarctic peat wetlands are also affected by temperature. Some models predict that warming temperatures may increase methane emissions from such wetlands.[200] In parts of Europe, agriculture on drained peatlands is being phased out and the water level is being raised, resulting in renewed

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191 S.C. Whalen, *Biogeochemistry of Methane Exchange Between Natural Wetlands and the Atmosphere*, 22 ENVTL. ENGINEERING SCI. 86 (2005).

192 I.K. Kravchenko & A.A. Sirin, *Activity and Metabolic Regulation of Methane Production in Deep Peat Profiles of Boreal Bogs*, 76 MICROBIOLOGY 791, 791 (2007).

193 Christian Wille et al., *Methane Emission from Siberian Arctic Polygonal Tundra: Eddy Covariance Measurements and Modeling*, 14 GLOBAL CHANGE BIOLOGY 1395, 1404–06 (2008).

194 Mark E. Hines et al., *Uncoupling of Acetate Degradation from Methane Formation in Alaskan Wetlands: Connections to Vegetation Distribution*, 22 GLOBAL BIOGEOCHEMICAL CYCLES, at GB2017 (2008).

195 Torbjörn Johansson et al., *Decadal Vegetation Changes in a Northern Peatland, Greenhouse Gas Fluxes and Net Radiative Forcing*, 12 GLOBAL CHANGE BIOLOGY 2352, 2352–53, 2366 (2006).

196 Mark Brinson, *Consequences for Wetlands of a Changing Global Environment*, *in* ECOLOGY OF FRESHWATER AND ESTUARINE WETLANDS 436, 459 (Darold P. Batzer & Rebecca R. Sharitz eds., 2006); Hines et al., *supra* note 194, at 1402 ("Plant-mediated transport of methane from soil layers or lake sediments to the atmosphere plays an important role in the gas exchange of wet tundra.").

197 K.M. Walter et al., *Methane Bubbling from Siberian Thaw Lakes as a Positive Feedback to Climate Warming*, 443 NATURE 71, 71 (2006).

198 M.R. Turetsky et al., *Short-Term Response of Methane Fluxes and Methanogen Activity to Water Table and Soil Warming Manipulations in an Alaskan Peatland*, 113 J. GEOPHYSICAL RES., at G00A10 (2008).

199 Sjögersten et al., *supra* note 178, at 2103. On the other hand, one study found that swans reduce wetland methane emissions because their foraging causes bioturbidity. Paul L.E. Bodelier et al., *Animal-Plant-Microbe Interactions: Direct and Indirect Effects of Swan Foraging Behaviour Modulate Methane Cycling in Temperate Shallow Wetlands*, 149 OECOLOGIA 233, 233 (2006).

200 P.M. Crill et al., *Methane Flux from Minnesota Peatlands*, 2 GLOBAL BIOGEOCHEMICAL CYCLES 371, 379 (1988).

carbon storage, but short-term methane emissions at extremely high levels.[201] A recent review of the literature on European wetlands concluded that the factors affecting methane production included not only temperature and water depth but also the rate of primary production and the concentration of alternate electron acceptors (such as iron, magnesium, nitrogen, and sulfur).[202] In China, research indicates that certain types of soils seem to emit more methane than others.[203]

3. Plant Varieties

The effect of different species of wetland plants on methane emissions varies.[204] Some studies suggest that a greater diversity of wetland vegetation reduces methane output,[205] but other studies found that some species of plants differ substantially from other nearby species in their GWP impact. For example, in an Irish bog, buckbean plants seemed to produce methane hotspots.[206] In an Ohio wetland, common rush was more effective in lowering methane emissions than black willow.[207] Sedges have been found to increase methane emissions in wet periods, but reduce them in dry periods.[208] Another study concluded that deep-rooted plants may contribute to higher methane emissions.[209]

Tropical and subtropical wetlands have also been studied extensively, although data on total emissions from tropical wetlands are sketchy.[210] A study of a forested freshwater wetland in Louisiana found that the methane emissions created a net GWP increase.[211] Atmospheric measurements

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201 Jürgen Augustin & Hans Joosten, *Peatland Rewetting and the Greenhouse Effect*, INT'L MIRE CONSERVATION GROUP NEWSL., Aug. 2007, at 29, *available at* http://www.imcg.net/imcgnl/pdf/nl0703.pdf.

202 Sanna Saarnio et al., *Methane Release from Wetlands and Watercourses in Europe*, 43 ATMOSPHERIC ENV'T 1421, 1422 (2008).

203 Zxeng-Qin Xiong et al., *Nitrous Oxide and Methane Emissions as Affected by Water, Soil and Nitrogen*, 17 PEDOSPHERE 146, 160–62 (2007) (noting clay emits more methane than loess).

204 REDDY & DELAUNE, *supra* note 53, at 244–45 (describing that different species of plants vary in their capacity to transport methane).

205 Bouchard & Cochran, *supra* note 159, at 1889.

206 Anna Laine et al., *Methane Flux Dynamics in an Irish Lowland Blanket Bog*, 299 PLANT SOIL 181, 186 (2007).

207 Jamie Smialek et al., *Effect of a Woody (*salix nigra*) and an Herbaceous (*juncus effusus*) Macrophyte Species on Methane Dynamics and Denitrification*, 26 WETLANDS 509, 514 (2006).

208 M. Strack et al., *Sedge Succession and Peatland Methane Dynamics: A Potential Feedback to Climate Change*, 9 ECOSYSTEMS 278, 278 (2006).

209 Anna Ekberg & Torbe Christensen, *Wetlands and Methane Emission*, *in* 2 ENCYCLOPEDIA OF SOIL SCIENCE, *supra* note 159, at 1905, 1907.

210 Peter Bergamaschi & Philippe Bousquet, *Estimating Sources and Sinks of Methane: An Atmospheric View*, *in* THE CONTINENTAL-SCALE GREENHOUSE GAS BALANCE OF EUROPE 113, 119–20 (A. Johannes Dolman et al. eds., 2008).

211 Yu et al., *supra* note 185, at 798, 808. *But see* BRIAN MURRAY ET AL., VALUING ECOSYSTEM SERVICES FROM WETLANDS RESTORATION IN THE MISSISSIPPI ALLUVIAL VALLEY 20–21 (2009), *available at* http://www.nicholas.duke.edu/institute/msvalley.pdf.

suggest that recent dry years in the tropics significantly reduced methane emissions from tropical wetlands.[212]

Mangrove wetlands, in their natural condition, may have only a modest adverse impact on GWP.[213] Many tropical coastal wetlands have acid sulfate soils.[214] Coastal wetlands may receive enough sulfate from seawater to neutralize methane production,[215] but seasonal rainfall may sometimes reduce the effectiveness of sulfates.[216] A study in coastal wetlands on the Bay of Bengal found high rates of methane emissions in the November to January period and low rates in other months.[217]

In many parts of the world, wetlands are subject to fires.[218] For example, a fire in a forested wetland in West Siberia turned it from a methane sink into a methane source.[219] The fires in forested peatlands in Southeast Asia not only released carbon dioxide, but may convert some peatlands into net methane sources by reducing carbon stocks.[220]

E. Nitrous Oxide

Nitrous oxide is a very powerful greenhouse gas that ranks fourth in total global warming impact; annual emissions have increased by 40 to 50% since preindustrial times.[221] Most of the increase has come from the use of agricultural fertilizers, although over 20% may be the result of natural terrestrial emissions.[222] The good news is that most wetlands in their natural state emit only small amounts of nitrous oxide; the bad news is that many wetlands are not in their natural state.[223]

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212 Bergamaschi & Bousquet, *supra* note 210, at 128.

213 Diane E. Allen et al., *Spatial and Temporal Variation of Nitrous Oxide and Methane Flux Between Subtropical Mangrove Sediments and the Atmosphere*, 39 SOIL BIOLOGY & BIOCHEMISTRY 622, 623 (2007) ("It has been suggested that trace gas emissions from coastal mangroves are negligible compared to trace gas emissions originating from wetlands.").

214 W. Andriesse & M.E.F. van Mensvoort, *Acid Sulfate Soils: Distribution and Extent*, *in* 1 ENCYCLOPEDIA OF SOIL SCIENCE, *supra* note 159, at 14, 14.

215 Antje Strangmann et al., *Methane in Pristine and Impaired Mangrove Soils and its Possible Effect on Establishment of Mangrove Seedlings*, 44 BIOLOGY & FERTILITY SOILS 511, 512 (2008) (explaining that sulfate reduction prevents methanogenesis in sulfate-rich environments such as salt marshes and mangroves).

216 Allen et al., *supra* note 213, at 627–28.

217 Strangmann et al., *supra* note 215.

218 WETLANDS INT'L, FACT BOOK FOR UN-FCCC POLICIES ON PEAT CARBON EMISSIONS 12 (2008), *available at* http://www.wetlands.org/LinkClick.aspx?fileticket=Dg7X8aI83q4%3d&tabid=56.

219 Nakano et al., *supra* note 173, at 85.

220 GLOBAL ENV'T CTR. & WETLANDS INT'L, *supra* note 167, at 157.

221 IPCC 2007, *supra* note 145, at 544.

222 REDDY & DELAUNE, *supra* note 53, at 609; *see also Biofools*, ECONOMIST, Apr. 11, 2009, at 81.

223 *See, e.g.*, GLOBAL ENV'T CTR. & WETLANDS INT'L, *supra* note 167, at ix; Junbao Yu et al., *Nitrous Oxide Emission from* Deyeuxia angustifolia *Freshwater Marsh in Northeast China*, 40 ENVTL. MGMT. 613 (2007) (concluding that annual average nitrous oxide emissions from a freshwater marsh were 4.45 $\mu g\ m^{-2}\ h^{-1}$ in 2002 and that it was thus not a major source of nitrous oxide); Deborah Zabarenko, *Wetlands Could Release "Carbon Bomb*,*"* REUTERS, http://www.reuters.com/article/environmentNews/idUSN17459051200807 20?pageNumber=1&

Nitrous oxide tends to be an important issue in at least three kinds of wetlands: 1) wetlands converted for crops, particularly rice; 2) wetlands created for treating wastewater containing nitrates; and 3) natural wetlands that are receiving runoff from fertilized agriculture.

1. Rice Paddies

Scientists in rice-growing areas are studying ways to manage rice farming to reduce GHG emissions.[224] Under continuously flooded conditions little nitrous oxide should be produced.[225] However, experiments conducted in tropical rice fields seem to confirm that periodic drainage increases nitrous oxide emissions.[226] The type of rice may also make a difference; a study of a Chinese wetland found that Manchurian wild rice stimulated nitrous oxide emissions more than other varieties.[227] Some of this research is stimulated by the future potential of carbon credits for rice production methods.[228]

2. Treatment Wetlands

The creation of wetlands for treatment of wastewater sometimes provides a significant source of nitrous oxide emissions.[229] Hernandez and Mitsch concluded that permanent flooding of treatment wetlands will deter nitrous oxide emissions only if plants are absent.[230] Similar conclusions were reached in a study of wastewater wetlands in the Netherlands.[231] However,

virtualBrandChannel=0 (last visited July 19, 2009) (noting that "60 percent of wetlands worldwide have been destroyed in the past century").

224 *See e.g.*, Jianwen Zou et al., *A 3-Year Field Measurement of Methane and Nitrous Oxide Emissions From Rice Paddies in China: Effects of Water Regime, Crop Residue, and Fertilizer Application*, 19 GLOBAL BIOGEOCHEMICAL CYCLES, at GB 2021, GB 2021 (2005); William Salas et al., *Mapping and Modeling of Greenhouse Gas Emissions From Rice Paddies with Satellite Radar Observations and the DNDC Biogeochemical Model*, 17 AQUATIC CONSERVATION: MARINE & FRESHWATER ECOSYSTEMS 319, 321 (2007) (describing a study mapping and modeling greenhouse gas emissions from rice paddies).

225 REDDY & DELAUNE, *supra* note 53, at 611.

226 Shuhui Huang et al., *Effects of Water Regimes on Nitrous Oxide Emission from Soils*, 31 ECOLOGICAL ENGINEERING 9, 9 (2007); J.R. Freney, *Nitrous Oxide Emissions: Agricultural Soils*, *in* 2 ENCYCLOPEDIA OF SOIL SCIENCE, *supra* note 159, at 1129, 1130.

227 Yanhua Wang et al., *Nitrous Oxide Emissions from Polyculture Constructed Wetlands: Effect of Plant Species*, 152 ENVTL. POLLUTION 351, 357 (2008).

228 Lauren Etter, *Power Plant: In China, a Plan to Turn Rice into Carbon Credits*, WALL ST. J., Oct. 9, 2007, at A1.

229 Lena Ström et al., *supra* note 184, at 44. *See generally* A.K. Søvik & B. Kløve, *Emission of N_2O and CH_4 from a Constructed Wetland in Southeastern Norway*, 380 SCI. TOTAL ENV'T 28, 29 (2007) (linking the construction of wetland to emission of nitrous oxide).

230 Maria E. Hernandez & William J. Mitsch, *Influence of Hydrologic Pulses, Flooding Frequency, and Vegetation on Nitrous Oxide Emissions from Created Riparian Marshes*, 26 WETLANDS 862, 875 (2006) ("[W]etland plants did increase nitrous oxide emissions when sites were flooded but not when soils were exposed."); MITSCH & GOSSELINK, *supra* note 92, at 181.

231 Jos T.A. Verhoeven et al., *Regional and Global Concerns over Wetlands and Water Quality*, 21 TRENDS ECOLOGY & EVOLUTION 96, 101 (2006) (concluding in Netherlands study that

it is hard to determine whether nitrous oxide emitted from treatment wetlands merely replaces emissions that otherwise would come from downstream waters.[232]

3. Upland Runoff

The reason that most natural wetlands produce little nitrous oxide is potentially because they have low nitrate concentrations.[233] However, human activities are increasingly directing runoff from fertilized agriculture or urban uses into wetlands, substantially increasing nitrate volumes.[234] One study found that wetland soils appear to convert a high proportion of fertilizer runoff to nitrous oxide rather than other nitrogen forms.[235] A study of Brazilian wetlands that absorbed runoff from sugar cane fields suggested that the nitrous oxide emissions from the wetland cancelled out the savings from carbon storage.[236] Unfortunately, such effects are likely to become more and more common throughout the world.[237]

Nitrous oxide emissions also vary with different species of wetland vegetation.[238] In India, the pneumatophores of grey mangroves (*Avicennia marina*) were found to be conduits of increased emissions of both methane and nitrous oxide.[239] In Malaysia, conversion of wetlands to sago farming seems to create more nitrous oxide emissions than when oil palms or other trees are grown.[240] In Sweden, land formerly used for agriculture, which was then drained and converted to forestry, continued to emit large amounts of nitrous oxide.[241]

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high nitrate loads lead to high nitrous oxide emissions and advocating for restoring plants to wetlands and increasing biodiversity).

232 Hernandez & Mitsch, *supra* note 230, at 876.

233 *See, e.g.*, Yu et al., *supra* note 185, at 808; Anu Liikanen et al., *Temporal and Seasonal Changes in Greenhouse Gas Emissions from a Constructed Wetland Purifying Peat Mining Runoff Waters*, 26 ECOLOGICAL ENGINEERING 241, 242 (2006).

234 *See* Oswald Van Cleemput & Pascal Boeckx, *Nitrogen and Its Transformations*, *in* 2 ENCYCLOPEDIA OF SOIL SCIENCE, *supra* note 159, at 1125, 1125.

235 *See id.* at 1127–28; H. Biswas, *Spatial and Temporal Patterns of Methane Dynamics in the Tropical Mangrove Dominated Estuary, NE Coast of Bay of Bengal, India*, 68 J. MARINE SYSTEMS 55, 62 (2007) ("Further decrease of emission rate in the mangrove water and soil suggested intense oxidation of methane or out competition of methanogenic bacteria by sulfate and nitrate reducing bacteria.").

236 Bosselman, *supra* note 28, at 7.

237 *See, e.g.*, *id.*; *see also* P.J. Crutzen, *N_2O Release from Agro-Biofuel Production Negates Global Warming Reduction by Replacing Fossil Fuels*, 8 ATMOSPHERIC CHEMISTRY & PHYSICS 389, 393 (2008) (noting "the replacement of fossil fuels by biofuels may not bring the intended climate cooling due to the accompanying emissions of N_2O").

238 Wang et al., *supra* note 227, at 355–56.

239 K. Krithika et al., *Fluxes of Methane and Nitrous Oxide from an Indian Mangrove*, 94 CURRENT SCI. 218, 223 (2008).

240 Lulie Melling et al., *Nitrous Oxide Emissions from Three Ecosystems in Tropical Peatland of Sarawak, Malaysia*, 53 SOIL SCI. & PLANT NUTRITION 792, 802 (2007).

241 Maria Ernfors et al., *Nitrous Oxide Emissions from Drained Organic Forest Soils—An Up-Scaling Based on C:N Ratios*, 89 BIOGEOCHEMISTRY 29, 29–30 (2008).

VI. WETLAND BIOFUELS

A. Peak Oil?

Projects to grow biofuels are receiving significant government support not only in the United States but throughout the world.[242] The projected high prices of fossil fuels have made many renewable energy projects appealing economically on their own merits.[243] Such projects are also stimulated by a widespread interest in achieving a greater degree of energy independence.[244] Biofuel projects are particularly attractive if they can also be designed to get carbon credits.[245]

Biofuels have attracted big investments. Producers make lots of ethanol from corn, and biodiesel from soybeans or rapeseed.[246] But by using crops of agricultural value, biofuel producers have been accused of increasing food prices. For example, Lester Brown, head of the Earth Policy Institute, says: "We are witnessing the beginning of one of the great tragedies of history. The United States, in a misguided effort to reduce its oil insecurity by converting grain into fuel for cars, is generating global food insecurity on a scale never seen before."[247]

In addition, some scientists argue that because farmers worldwide are responding to higher prices and converting forest and grassland to new cropland, "corn-based ethanol, instead of producing a 20% savings, will nearly double GHG emissions over 30 years."[248] This has led to a search for biofuel products on lands that would not replace existing agriculture,[249] but would be capable of high productivity.[250] Congress has mandated increasingly high targets for nonfood-based biofuels in future years.[251]

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242 Ralph E.H. Sims et al., *Energy Crops: Current Status and Future Prospects*, 12 GLOBAL CHANGE BIOLOGY 2054, 2054–55 (2006).

243 *Id.* at 2055.

244 *Id.* at 2054.

245 *Id.* at 2065 tbl.6.

246 *Id.* at 2054–55, 2066.

247 Lester R. Brown, *Why Ethanol Production Will Drive World Food Prices Even Higher in 2008*, ECO-ECON. UPDATES, Jan. 24, 2008, http://www.earth-policy.org/Updates/2008/Update69.htm (last visited July 19, 2009).

248 Timothy Searchinger et al., *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change*, 319 SCI. 1238, 1238 (2008). Conversion of prairie potholes to corn cropland is also a concern. *See* Jim Ringelman et al., *Biofuels: Impacts on Prairie Pothole Wetlands*, NAT'L WETLANDS NEWSL., Mar.–Apr. 2008, at 1, 1, 3 (2008).

249 Richard Hamilton, *Biotechnology for Biofuels Production*, *in* A HIGH GROWTH STRATEGY FOR ETHANOL: THE REPORT OF AN ASPEN INSTITUTE POLICY DIALOGUE 55, 58 (Aspen Inst. ed., 2006), *available at* http://www.aspeninstitute.org/sites/default/files/content/docs/energy%20and%20environment%20program/FINALEthanolText.pdf; *see also* Russell Gold, *BP Jumps into Next-Generation Biofuels With Plans to Build Florida Refinery*, WALL ST. J., Feb. 19, 2009, at B1.

250 Monique Hoogwijk et al., *Potential of Biomass Energy Out to 2100, for Four IPCC SRES Land-Use Scenarios*, 29 BIOMASS & BIOENERGY 225, 252 (2005).

251 *See* Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 202, 121 Stat. 1492, 1522 (2007) (to be codified at 42 U.S.C. § 7545).

B. Biofuel from Algae

Scientists are undertaking wide-ranging research into the development of new types of algae as a source for biodiesel. "The use of algae has potential due to their easy adaptability to growth conditions, the possibility of growing in either fresh or marine waters and avoiding the use of land."[252] Both microalgae and macroalgae, such as seaweed, are being tested for biofuel production.[253] Some pilot projects grow algae in enclosed photobioreactors, but photobioreactors cost about ten times as much as open ponds, so many projects grow the algae in the reactor and then inoculate open ponds with the desired species.[254] When the pond eventually becomes contaminated with competing species the pond is drained and sterilized before being reinoculated.[255]

Scientists are still searching thousands of algae species for one "to continually dominate an open pond and have desirable biofuel properties."[256] Algae can often be harvested repeatedly at intervals of ten days or less, and are reported to produce up to three hundred times more oil for biodiesel production than traditional crops on an area basis.[257] Even so, biotechnologists are "working to improve the productivity of microalgae in order to meet the demands of a rapidly growing market."[258] Metabolic engineering can directly control the cellular machinery of the algae through the introduction of transgenes or by mutagenesis.[259]

Potential inputs to algae production include such diverse sources as CO_2 from power plants[260] and municipal sewage wastes.[261] Anticipated

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252 Vishwanath Patil et al., *Towards Sustainable Production of Biofuels from Microalgae*, 9 INT'L J. MOLECULAR SCI. 1188, 1189 (2008).

253 *See* Yusuf Chisti, *Biodiesel from Microalgae Beats Bioethanol*, 26 TRENDS BIOTECHNOLOGY 126, 126 (2008); A.B.M. Sharif Hossain et al., *Biodiesel Fuel Production from Algae as Renewable Energy*, 4 AMER. J. BIOCHEMISTRY & BIOTECHNOLOGY 250, 251 (2008), *available at* http://www.scipub.org/fulltext/ajbb/ajbb43250-254.pdf.

254 Palligarnai T. Vasudevan & Michael Briggs, *Biodiesel Production—Current State of the Art and Challenges*, 35 J. INDUS. MICROBIOLOGY TECH. 421, 428 (2008); Qiang Hu et al., *Microalgal Triacylglycerols as Feedstocks for Biofuel Production: Perspectives and Advances*, 54 PLANT J. 621, 635 (2008).

255 *See generally* Mark E. Huntley & Donald G. Redalje, *CO_2 Mitigation and Renewable Oil from Photosynthetic Microbes: A New Appraisal*, 12 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 573, 582 (2007).

256 Peer M. Schenk et al., *Second Generation Biofuels: High-Efficiency Microalgae for Biodiesel Production*, 1 BIOENERGY RES. 20, 29–30 (2008); *see also* Russel Gold, *Pond Scum Gets Its Moment in the Limelight*, WALL ST. J., Apr. 11, 2009, http://online.wsj.com/article/SB123940976513610235.html (last visited July 19, 2009).

257 Schenk, *supra* note 256, at 24.

258 Julian N. Rosenberg et al., *A Green Light for Engineered Algae: Redirecting Metabolism to Fuel a Biotechnology Revolution*, 19 CURRENT OPINION BIOTECHNOLOGY 430, 430 (2008), *available at* http://www.orau.gov/algae2008/breakouts/rosenberg2008algaereview.pdf.

259 *Id.* at 432.

260 *From CO_2 to Algae to Biofuel? Missouri Partners to Send Coal-Plant Gases into Ponds*, MSNBC.COM, Sept. 10, 2008, http://www.msnbc.msn.com/id/26625884 (last visited July 19, 2009).

261 Scott Harper, *ODU Experiment on Turning Sewage into Algae-Based Biodiesel Is Flourishing*, HAMPTONROADS.COM, Jan. 19, 2008, http://hamptonroads.com/node/450771 (last visited July 19, 2009).

outputs include jet fuel, biodiesel, or hydrogen.[262] Significant amounts of venture capital have gone into a variety of algae production ventures,[263] including money from Shell,[264] Chevron,[265] and Bill Gates,[266] as well as limited amounts of government funding from various federal agencies.[267] The European Union countries have also provided funding; the Carbon Trust, an independent company backed by the British government, anticipates contributing up to sixteen million British pounds in funding for its Algae Biofuels Challenge.[268]

One well-financed American venture, Sapphire Energy, talks about millions of barrels a day from tens of thousands of acres devoted to algae farms dotted all over the Gulf Coast and the Pacific Southwest.[269] Nevertheless, not only are there awesome challenges involved in the basic research on the 40,000 plus species of algae that have already been identified,[270] but there are also complications in genetically engineering new varieties, and anyone pursuing permits for any sizable facility would need to deal with a host of government agencies.[271]

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262 Donghui Song et al., *Exploitation of Oil-Bearing Microalgae for Biodiesel*, 24 CHINESE J. BIOTECHNOLOGY 341, 343 (2008); Prachi Patel, *Hydrogen from Algae: Genetically Modified Algae Could Be Efficient Producers of Hydrogen and Biofuels*, TECH. REV., Sept. 27, 2007, http://www.technologyreview.com/Energy/19438 (last visited July 19, 2009); Peter Pae, *Continental Airlines Uses Biofuel on Test Flight*, L.A. TIMES, Jan. 8, 2009, http://articles.latimes.com/2009/jan/08/business/fi-biofuel8 (last visited July 19, 2009).

263 Brady Huggett, *Investors Temper Interest in Grain Biofuels, Focus on Alternatives*, 26 NATURE BIOTECHNOLOGY 1208, 1208 (2008).

264 Lewis Page, *Shell in Hawaiian Algae Biofuel Pilot: Sees Big Future in Green Scum*, REGISTER, Dec. 12, 2007, http://www.theregister.co.uk/2007/12/12/shell_algae_biofuel_green_scum_plan (last visited July 19, 2009).

265 *Chevron Partners with Solazyme on Developing Biofuel from Algae*, E. BAY BUS. TIMES, Jan. 22, 2008, http://www.bizjournals.com/eastbay/stories/2008/01/21/daily22.html (last visited July 19, 2009).

266 E. Shailaja Nair, *Algae—Biofuel of the Future or Pipedream?*, INSIGHT, Oct. 2008, http://www.platts.com/Magazines/Insight/2008/oct/20081d0iz07Kh16dW552K9_1.xml (last visited July 19, 2009).

267 *Id.*

268 Carbon Trust, Algae Biofuels Challenge, http://www.carbontrust.co.uk/technology/directedresearch/algae.htm (last visited July 19, 2009); Carbon Trust, Home, http://www.carbontrust.co.uk (last visited July 19, 2009) ("The Carbon Trust was set up by Government in 2001 as an independent company, to accelerate the move to a low carbon economy.").

269 *Algae Biofuels Offer Enormous Promise, Face Tough Production and Cost Challenges to Scale*, GREEN CAR CONGRESS, Oct. 24, 2008, http://www.greencarcongress.com/2008/10/algae-biofuels.html (last visited July 19, 2009); *see also* Bradley J. Fikes, *Biotech: Sapphire Energy Says Algae Can Relieve Our Dependence on Foreign Oil*, N. COUNTY TIMES, Nov. 13, 2008, http://www.nctimes.com/articles/2008/11/12/business/zf74a32010fde78a4882574ff006bbd3f.txt (last visited July 19, 2009).

270 Hu et al., *supra* note 254, at 621.

271 *See* Rachel G. Lattimore, Bloomin' Government! Environmental Laws and Regulations That May Impact Algae Production, Presentation to the AFOSR-NREL Microalgal Lipid to Biofuels Workshop (Feb. 20, 2008), *available at* http://www.nrel.gov/biomass/pdfs/lattimore.pdf.

C. Paludiculture

"Paludiculture" is the cultivation on wet peatlands of macrophytic plants that can be harvested for biofuel while still contributing to increased carbon storage through peat formation.[272] In a number of European countries, scientists are testing the possibility of using plants such as reeds, cattails, and reed canary grass for biofuels.[273]

In the United States, the search for biofuels that might replace petroleum has included studies involving the harvesting of wetland vegetation. Developers have proposed a plantation of Asian giant reed (*Arundo donax*) near the Everglades[274] over the strong objection of conservation groups who point to the plant's history of invasiveness.[275] Reed canary grass (*Phalaris arundinacea*) is also being tested for biofuel production in the United States, despite its reputation as an invasive wetland species.[276] Other wetland species with invasive histories that are being tested for biofuel production include Chinese tallow (*Triadica sebifera*) and castor bean (*Ricinus communis*), a native to Africa.[277] Some native American wetland species are being tested for biofuels elsewhere in the world, such as elderberry (*Sambucus canadensis*) and persimmon (*Diospyros virginiana*), even though they have become invasive in some other countries.[278]

Scientists differ on the extent to which any nonnative plant should be used for biofuel production or GHG reduction. Some argue that the inevitable climate change that will occur over the next decades will make use of nonnative species necessary,[279] but many other scientists find this prospect alarming[280] and urge the development of tests to determine invasive potential[281] or the use of sterile triploid clones of nonnative species.[282]

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272 Wendelin Wichtmann & Hans Joosten, *Paludiculture: Peat Formation and Renewable Resources from Rewetted Peatlands*, INT'L MIRE CONSERVATION GROUP NEWSL., Aug. 2007, at 24, *available at* http://www.imcg.net/imcgnl/pdf/nl0703.pdf.

273 *Id.*

274 Elisabeth Rosenthal, *New Trend in Biofuels Has New Risks*, N.Y. TIMES, May 21, 2008, at A6.

275 Allison Fox, *A Giant Reed Conundrum*, WILDLAND WEEDS, Spring 2007, at 4, *available at* http://www.fleppc.org/ww/WWW08.pdf.

276 S. Raghu et al., *Adding Biofuels to the Invasive Species Fire?*, 313 SCI. 1742, 1742 (2006).

277 GLOBAL INVASIVE SPECIES PROGRAMME, ASSESSING THE RISK OF INVASIVE ALIEN SPECIES PROMOTED FOR BIOFUELS 5 (2008), *available at* http://www.gisp.org/whatsnew/docs/biofuels.pdf.

278 *Id.* at 4–5; *see also* CONFERENCE OF THE PARTIES TO THE CONVENTION ON BIOLOGICAL DIVERSITY, THE POTENTIAL IMPACTS OF BIOFUELS ON BIODIVERSITY 6 (2008), *available at* http://www.cbd.int/doc/meetings/cop/cop-09/official/cop-09-26-en.pdf.

279 Carl Hershner & Kirk J. Havens, *Managing Invasive Aquatic Plants in a Changing System: Strategic Consideration of Ecosystem Service*, 22 CONSERVATION BIOLOGY 544, 546 (2008).

280 *See, e.g.*, Martha Groom et al., *Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production*, 22 CONSERVATION BIOLOGY 602, 603 (2008); Laura J. Martin & Bernd Blossey, *A Framework for Ecosystem Valuation*, 23 CONSERVATION BIOLOGY 494, 494 (2009). *But see* Carl Hershner & Kirk Havens, *Ecosystem Services and Management of Invasive Species in a Changing System: Response to Martin and Blossey*, 23 CONSERVATION BIOLOGY 497, 497 (2009).

281 Jacob N. Barney & Joseph M. DiTomaso, *Nonnative Species and Bioenergy: Are We Cultivating the Next Invader?*, 58 BIOSCIENCE 64, 65–68 (2008).

In Southeast Asia, extensive oil palm plantations are being created by clearing and burning forested peatland swamps.[283] Palm oil converted to biodiesel fuel reduces carbon emissions from vehicles[284] but the GHG emissions produced by the peatland conversion significantly outweigh the reduction at the consumption end of the chain,[285] and the loss of biodiversity is irreplaceable.[286] A recent analysis found "that replacing high-carbon and high-biodiversity forest or peatland with oil-palm monocultures in an effort to reduce the use of fossil fuels will accelerate both climate change and biodiversity loss."[287]

Global Seawater Incorporated wants to channel seawater through canals into created wetlands and aquaculture ponds in Sonora, Mexico.[288] Global Seawater Incorporated claims that salt-tolerant plants such as salicornia could be converted to biofuels, and that the creation of more acreage for seawater would mitigate sea level rise.[289] Although many scientists fear the project's implications for groundwater, it appears to be moving forward.[290] Some countries provide subsidies for this kind of research and development project.[291]

One project to grow sugar cane in Kenya's Tana River Delta, a major wetland area north of Mombasa, has attracted widespread opposition. Proposed sugar plantation developments would convert an area of more than 270,000 acres into sugarcane plantations.[292] The projects received

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282 Emily A. Heaton et al., *Meeting US Biofuel Goals with Less Land: The Potential of Miscanthus*, 14 GLOBAL CHANGE BIOLOGY 2000, 2001–02 (2008).

283 Rudolf M. Smaling, *Environmental Barriers to Widespread Implementation of Biofuels*, 2 ENVTL. & ENERGY L. & POL'Y J. 287, 299 (2008).

284 *See* Mauricio Rojas, *Assessing the Engine Performance of Palm Oil Biodiesel*, BIODIESEL MAG., Aug. 2007, http://www.biodieselmagazine.com/article.jsp?article_id=1755&q=&page=all (last visited July 19, 2009).

285 Finn Danielsen et al., *Biofuel Plantations on Forested Lands: Double Jeopardy for Biodiversity and Climate*, 23 CONSERVATION BIOLOGY 348, 348 (2009) (estimating that it takes more than 600 years for carbon emissions avoided by the use of palm oil biofuel to balance the emissions from the peatland conversion); *see also* Aljosja Hooijer et al., PEAT-CO2: ASSESSMENT OF CO_2 EMISSIONS FROM DRAINED PEATLANDS IN SE ASIA 29 (2006), *available at* http://www.wetlands.org/Portals/0/publications/General/Peat%20CO2%20report.pdf; WETLANDS INT'L, PEATLAND LOSS FUELS CLIMATE CHANGE 2 (2006), *available at* http://www.wetlands.org/Portals/0/publications/Policy%20document/Policy%20brief%20delegations%20to%20Poznan_20nov08.pdf.

286 Thomas Lovejoy, *The Threat from Trees: Global Warming Isn't Just a Problem of Cars and Smokestacks but of the Chain Saw, Too*, NEWSWEEK, July 7, 2008, http://www.newsweek.com/id/143691/output/print (last visited July 19, 2009).

287 Danielsen et al., *supra* note 285, at 356.

288 Global Seawater, Inc., What We Do, http://globalseawater.com/whatwedo.html (last visited July 19, 2009); Atl. Greenfuels, Mexico Seawater Project, http://atlanticgreenfuels.com/html/body_mexico.html (last visited July 19, 2009).

289 *See* Atl. Greenfuels, *supra* note 288; Jelte Rozema & Timothy Flowers, *Crops for a Salinized World*, 322 SCI. 1478, 1478–79 (2008).

290 Marla Dickerson, *The Old Man Who Farms with the Sea*, L.A. TIMES, July 10, 2008, http://articles.latimes.com/2008/jul/10/business/fi-seafarm10?pg=1 (last visited July 19, 2009).

291 Eli Kintisch, *Sowing the Seeds for High-Energy Plants*, 320 SCI. 478, 478 (2008).

292 Tana River Delta Campaign, Proposed Sugar Projects for the Delta, http://www.tanariverdelta.org/sugar.html (last visited July 19, 2009).

government permits, but litigation is pending.[293] Sugarcane is a renewable and relatively inexpensive source of ethanol, but many local and international groups say the plantations and an accompanying ethanol production facility will have very detrimental effects on wetland functions.[294]

D. Transgenic Plants

Scientists are developing new plant cultivars that will be more tolerant of salinity and wet soils.[295] One of the plants seen as a potential target for genetic modification is the willow, which is already quite tolerant of wet conditions.[296] An Aspen Institute report, *Biotechnology for Biofuels*, concludes that "[t]he next horizon for biotechnology will be its impact on the development of improved biomass feedstocks for biofuels production." The ideal crop will grow on land not suitable for agriculture and have a high yield in tons per acre. "Preliminary results indicate that biomass yield increases of greater than 300 percent in some grass species can be achieved via genetic engineering."[297] Scientists have sequenced the genomes of a wide range of plants and microorganisms, including plants, bacteria, and algae that grow in wetlands, as a predicate for developing cellulosic biofuels.[298]

These examples are merely illustrative of the creative ingenuity that is being attracted to biofuels and other renewable energy projects.[299] If wetland biofuels can be developed that will reduce reliance on petroleum without destroying other important wetland functions, they would create important

293 Tana River Delta Campaign, Welcome, http://www.tanariverdelta.org (last visited July 19, 2009).

294 *See, e.g.*, Xan Rice, *Wildlife and Livelihoods at Risk in Kenyan Wetlands Biofuel Project*, GUARDIAN, June 24, 2008, at 17.

295 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, TECHNICAL PAPER VI: CLIMATE CHANGE AND WATER 65 (Bryson Bates et al. eds., 2008), *available at* http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf.

296 *See generally* Sims et al., *supra* note 242, at 2056.

297 Hamilton, *supra* note 249, at 55–58.

298 *See generally* Edward M. Rubin, *Genomics of Cellulosic Biofuels*, 454 NATURE 841 (2008) (discussing the idea that genomic information will improve cellulosic biofuel production).

299 It should also be noted that other types of renewable energy projects may impact wetlands. For example, in Britain, the government is studying a project to dam the estuary of the Severn River in Wales, an area that has a range of almost 50 feet between high and low tide. The dam would store water that flows in with the high tide and release it to produce hydroelectric power as the tide goes out. The project will produce intermittent flooding of some intertidal wetlands. *See* James S. Paterson et al., *Mitigation, Adaptation and the Threat to Biodiversity*, 22 CONSERVATION BIOLOGY 1352, 1353 (2008). In the great plains of the United States, fears have been raised about the impact of wind farms and associated power lines on wetland birds, *see* Playa Lakes Joint Venture, Wind Energy and Birds, http://www.pljv.org/cms/wind-energy (last visited July 19, 2009), and on the whooping crane's (*Grus americana*) migration routes to its wintering grounds in the Texas wetlands, Patrick Reis, *Wind Power Could Doom Treasured American Bird*, LAND LETTER, Oct. 2, 2008, http://www.eenews.net/ll/2008/10/02 (last visited July 19, 2009). On the Atlantic coast of Europe, peatlands are being drained to build windfarms. *See* Richard Lindsay, *Windfarms and Peat: Conflicts from a Confluence of Conditions*, INT'L MIRE CONSERVATION GROUP NEWSL., Dec. 2007, at 17, *available at* http://www.imcg.net/imcgnl/pdf/nl0704.pdf.

benefits, but it is hard to foresee all of the potential risks that these projects may create.[300]

At the 2008 meeting of the Conference of Parties to the Convention on Wetlands, many participants expressed concern about the potential impact of biofuels on wetlands.[301] The conference resolved that:

> Decisions on land use change must integrate adequate knowledge of the range of benefits, and their values, that wetlands provide for people and biodiversity.
>
> Decision-making should, wherever possible, give priority to safeguarding naturally-functioning wetlands and the benefits they provide, especially through ensuring the sustainability of ecosystem services, while recognizing that human-made wetland systems can also make a significant contribution to water and food security objectives.[302]

The opportunity to combine income from biofuels, carbon credits, and wetland mitigation credits will pay for some real scientific creativity—but can and will this be done consistently with other important ecological processes in which wetlands play a key role?

VII. WETLAND MANAGEMENT LAW

A wetland owner can manage the wetland in a wide variety of ways while ensuring that it remains categorized as a wetland.[303] Federal law does not prohibit management alterations as long as they do not involve dredging or filling and they leave the land wet. Some types of wetland management may be found to create very significant reductions in the net balance of GHGs they emit, which would qualify them as valuable offset projects.

To understand why carbon banks provide valuable opportunities for wetland managers, it is necessary to summarize the convoluted way in which federal wetlands law has evolved: 1) federal jurisdiction depends on land's wetness, not its function;[304] 2) a policy of "no net loss" of wetlands has also focused on the area of land that is wet, regardless of the functions the land performs;[305] and 3) the regulations treat all wetland

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300 Past experience with the loss of wetlands to aquaculture projects should engender a degree of caution about the effects of biofuel projects. Although rice farmers have long grown crayfish or ducks as an ancillary use without serious harm, most modern aquaculture projects are intense monocultures that effectively destroy other wetland functions. *See generally* MITSCH & GOSSELINK, *supra* note 92, at 309–12.

301 Conference of Parties to the Convention on Wetlands, *Wetlands and "Biofuels"*, Res. X.25 (Nov. 4, 2008), *available at* http://www.ramsar.org/res/key_res_x_25_e.pdf.

302 Conference of Parties to the Convention on Wetlands, *The Changwon Declaration on Human Well-Being and Wetlands*, Res. X.3 (Nov. 4, 2008), *available at* http://www.ramsar.org/res/key_res_x_03_e.pdf.

303 *See infra* Part VII.A.

304 *See infra* Part VII.A.

305 *See infra* Part VII.B.

ecological processes as functions, regardless ofwhether or not they are beneficial to people.[306]

A. The Law of Wetness

The primary federal law relating to wetlands, section 404 of the Clean Water Act, has been interpreted as establishing the law of wetness.[307] That is, the law categorizes land as either wet or dry, and any piece of land that meets the wetness tests deserves the same degree of protection as any other piece of land that meets those tests; these tests, which were developed by the United StatesArmy Corps of Engineers, deal with soils, vegetation, and hydrology, and are intended to assist individuals in determining the boundaries of a wetland.[308] The federal jurisdiction over wetlands is unrelated to the functions that wetlands perform.[309]

The activities that require federal permits are also circumscribed in a manner having no relation to wetland function: "[M]any activities that can decrease the functional capacity of a jurisdictional wetland are not regulated. These activities include diversion of water from a wetland, flooding, diversion of sediment, shading, change of nutrient concentrations, indirect introduction of toxic substances, grazing, disruption of natural populations, and alteration of adjacent uplands."[310]

So under federal law, a wetland is a jurisdictional wetland only if it is wet.[311] Why is this important? Because this means a project to manage wetlands in which the land will remain wet does not need a federal permit regardless of its impact on wetland functions. In some places, state or local wetland laws may be on the books, but even then the management may be covered by an agricultural exemption.

B. No Net Loss

The lack of a permit requirement is consistent with our national wetlands policy, which provides that there should be "no net loss" of wetlands.[312] Under that policy, the target is measured by the total area of

306 NAT'L RESEARCH COUNCIL, WETLANDS: CHARACTERISTICS AND BOUNDARIES 223 (1995).

307 33 U.S.C. § 1344 (2006).

308 *See generally* MITSCH & GOSSELINK, *supra* note 92, at 477–86 (describing the process of delineating wetlands in the United States).

309 NAT'L RESEARCH COUNCIL, *supra* note 306, at 223.

310 *Id.*

311 The jurisdictional requirement of "wetness" is also reflected in the COE guidelines; the guidelines define wetlands as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." 33 C.F.R. § 328.3(b) (2008).

312 *See* DENNISON & BERRY, *supra* note 2, at 8–10.

wetlands, regardless of wetland processes or functions.[313] As long as the land remains wet, it complies with national policy.[314]

The first Bush administration promoted a policy "to achieve no overall net loss of the nation's remaining wetland base,"[315] as recommended by the National Wetlands Policy Forum, a blue-ribbon task force organized by the Conservation Foundation.[316] Abbreviated to "no net loss," this concept "became a cornerstone of wetland conservation in the United States and remains so to this day."[317] Because federal law downplays wetland function in favor of wetness, the practical effect of the no net loss policy has been to encourage the preservation, creation, or rehabilitation of any amount of wetland area equal to the amount that development projects or natural processes will destroy.

The relationship between wetlands and GHGs suggests that management to reduce net GHG emissions would not necessarily require activities that would require federal permits. Raising and lowering water levels, regulating upland runoff, changing wetland vegetation, and even growing algae can all be done while the land remains wet.[318] Thus, modification of wetland functions, even if defined as biogeochemical processes, does not by itself trigger federal jurisdiction.

Mitigation bankers are exploring the possibilities of managing their bank in a way that will give them credits for performing a number of valuable functions.[319] Although the appropriateness of getting multiple benefits needs to be examined on a case-by-case basis,[320] examples of projects that should be entitled to multiple credits are easy to imagine.[321]

VIII. MANAGING WETLANDS IN A WONDERLAND OF WINDFALLS

So what is really going on in this wonderland of wetland windfalls? Is this a prototype of the more beneficially organized landscape of the future, or is it a precursor of the abyss into which utilitarian reductionism will take us?

Complying with the rules of these various markets will require the use of at least five analytical processes, each of which involves making certain

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313 *See, e.g.*, S. Scott Burkhalter, *Oversimplification: Value and Function: Wetland Mitigation Banking*, 2 CHAP. L. REV. 261, 280–82 (1999) (describing four methods of compensatory mitigation measuring "no net loss" by total area of wetlands without referring to wetland functions).

314 *See supra* Part VII.A.

315 *See* DENNISON & BERRY, *supra* note 2, at 8–10.

316 CONSERVATION FOUND., PROTECTING AMERICA'S WETLANDS: AN ACTION AGENDA, FINAL REPORT OF THE WETLANDS POLICY FORUM 18 (1988).

317 MITSCH & GOSSELINK, *supra* note 92, at 473.

318 *See infra* Part VI (discussing wetland biofuels).

319 G. Tracy Mehan III, *Establishing Markets for Ecological Services: Beyond Water Quality to a Complete Portfolio*, 17 N.Y.U. ENVTL. L.J. 638, 644–45 (2008). On the relationship between wetland function and mitigation, see generally Urban, *supra* note 37, at 5.

320 Bosselman, *supra* note 28, at 9–10.

321 *See* Jessica Fox, *Getting Two for One: Opportunities and Challenges in Credit Stacking*, *in* CONSERVATION AND BIODIVERSITY BANKING: A GUIDE TO SETTING UP AND RUNNING BIODIVERSITY CREDIT TRADING SYSTEMS, *supra* note 69, at 171, 173–74.

generalized assumptions. First, we must isolate and bound the pattern on the landscape that we label a wetland. Second, we must identify and categorize some of the many ecological processes affecting this wetland. Third, we must decide which of these processes we believe are providing services or disservices to humans of sufficient significance that we can attach monetized property rights or responsibilities to them. Fourth, we must design management proposals that we think will favorably affect the balance of services and disservices. Fifth, we must assure the creditability of the market in which these rights and obligations will be verified, traded, and monitored.

A. Identifying Wetland Patterns

Ecology originated as an attempt to classify and study the interrelationship of various biotic organisms and their relationship to abiotic landscape patterns, focusing on apparently discrete entities such as bogs, dunes, or prairies.[322] Some early ecologists thought that wetlands were an intermediate stage in the transformation of ponds into terrestrial environments, but scientists today recognize that wetlands are evolving in much more complex ways.[323]

Some of these early ecologists hoped to identify ecological patterns that had fixed natural boundaries, but today's ecologists recognize that all ecological systems are somewhat flexible artifacts that we define for the purpose of facilitating the study and management of natural areas.[324] These systems must be defined in terms of their "scale," that is, their location both in space and time, because what may appear as a relatively discrete boundary at one scale may look more like a continuous gradient at different levels of resolution.[325]

Landscape ecologists study the interrelationships between the biotic structure of an ecological system, its physical environment, and its setting within the landscape.[326] What we call a wetland "consists of an abiotic and biotic community that are linked together by the flow of energy through the sub-entities and the cycling of resources such as water and nutrients."[327]

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322 *See* DONALD WORSTER, NATURE'S ECONOMY: A HISTORY OF ECOLOGICAL IDEAS 192–94 (2d ed. 1994).

323 *See* MITSCH & GOSSELINK, *supra* note 92, at 232–34.

324 *See* LAWRENCE B. SLOBODKIN, A CITIZEN'S GUIDE TO ECOLOGY 82–83 (2003); Robert V. O'Neill, *Is It Time to Bury the Ecosystem Concept? (With Full Military Honors, of Course!)*, 82 ECOLOGY 3275, 3275–76 (2001).

325 *See* R.V. O'Neill, *Theory in Landscape Ecology*, *in* ISSUES AND PERSPECTIVES IN LANDSCAPE ECOLOGY 23, 23 (John A. Wiens & Michael R. Moss eds., 2005); David L. Peterson & V. Thomas Parker, *Dimensions of Scale in Ecology, Resource Management and Society*, *in* ECOLOGICAL SCALE: THEORY AND APPLICATIONS 499, 503–07 (David L. Peterson & V. Thomas Parker eds., 1998).

326 *See* John A. Bissonette, *Linking Landscape Patterns to Biological Reality*, *in* LANDSCAPE ECOLOGY AND RESOURCE MANAGEMENT, *supra* note 57, at 15, 16–17.

327 Jim Sanderson & Larry D. Harris, *An Epistemology of Landscape Ecology*, *in* LANDSCAPE ECOLOGY: A TOP-DOWN APPROACH 19, 23 (Jim Sanderson & Larry D. Harris eds., 2000).

From that vantage point, the description of the boundaries of a particular ecological system may seem quite arbitrary since it is apparent that many of the biogeochemical processes are interrelated.[328]

So we know that whatever we define as a wetland is actually an inseparable component of the landscape. Nevertheless, if we are to develop a concept of wetland trading that avoids endless arguments over applicable definitions, we need to agree that each wetland has boundaries for our purposes. Any system for managing natural resources needs to compromise between accuracy and simplicity.[329] Rather than reinvent the wheel, people will probably continue to use the three-factor analysis that has become traditional in the federal permitting process.[330]

B. Choosing Among Processes

Today's ecologists study the biogeochemistry of wetlands to identify ecological processes that affect many ecological patterns.[331] Ecological processes can be defined by aggregation and subdivision in various ways. Processes that are largely internal to the wetland can be distinguished from landscape-level processes such as hurricanes, floods, wildfire, drought, and the whole range of human impacts on the landscape, such as habitat modification and pollution.[332]

The evolving interactions of the organisms in an ecological system are the internal ecological processes of the system. Ecologists study how ecological systems become adapted to new environmental conditions through the pursuit of continuing fitness by the various animals, plants, and microbes that comprise the system.[333] As the organisms adapt, they cause changes in the landscape; beaver, for example, build dams that enlarge areas of open water

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328 LEVIN, *supra* note 56, at 71 ("[W]hat we call a community or ecosystem is often a fiction, an arbitrary restriction of spatial boundaries rather than a reflection of real thresholds of species change."); *see also* RUHL ET AL, *supra* note 91, at 20–22.

329 *See generally* Fred P. Bosselman, *The Statutory and Constitutional Mandate for a No Surprises Policy*, 24 ECOLOGY L.Q. 707, 708–10 (1997) (discussing the benefits of assurances agreements policies, which necessarily require compromise between adequate conservation measures and efficient administration).

330 *See* NAT'L RESEARCH COUNCIL, *supra* note 306, at 71–74 (discussing various federal agencies' analyses of hydrology, soils, and vegetation as the three parameters relevant to a wetland delineation determination).

331 The goal should be "the restoration of natural ecological processes across the landscape" rather than the maintenance of "certain landscape patterns." Sanderson & Harris, *supra* note 327, at 16. For a discussion of ethical issues in ecological restoration, see Alyson C. Flournoy, *Restoration Rx: An Evaluation and Prescription*, 42 ARIZ. L. REV. 187, 187–88 (2000); C. Mark Cowell, *Ecological Restoration and Environmental Ethics*, 15 ENVTL. ETHICS 19, 19 (1993).

332 *See* Ying-zi Wang, *Application of Landscape Ecology to the Research on Wetlands*, 19 J. FORESTRY RES. 164, 164 (2008); Larry D. Harris et al., *Landscape Processes and Their Significance to Biodiversity Conservation*, *in* POPULATION DYNAMICS IN ECOLOGICAL SPACE AND TIME 319, 328–39 (Olin E. Rhodes, Jr. et al. eds., 1996).

333 *See* Simon A. Levin, *Ecosystems and the Biosphere as Complex Adaptive Systems*, 1 ECOSYSTEMS 431, 431 (1998). *See generally* SCOTT CAMAZINE ET AL., SELF-ORGANIZATION IN BIOLOGICAL SYSTEMS (2001) (exploring the biological structures of ecological systems).

and may protect against drought.[334] These add to the changes caused by landscape-level processes, such as soil erosion, storm damage, or subsidence. "The result is a coupled, complex, dynamic system of organism and environment, wherein natural selection optimizes the fitness of populations amid a continually changing, biotically driven environment."[335]

The internal ecological processes of an area must operate within the ranges set by the landscape level processes. Thus, for example, the biological productivity of an area is limited by soil conditions, water availability, and climate.[336] These landscape-level processes, including both the natural changes in the landscape resulting from fire and storms, and the changes resulting from human activities, must be studied along with changes internal to the systems themselves if ecological processes are to be fully understood.[337]

Science also tells us that nature did not create ecological processes with the intent of helping or hurting humans. In medieval times, people may have believed that the people who lived by the wetlands were being punished by disease-causing mists that pervaded these areas,[338] and the early New England colonists may have attached some teleological implications to their belief that wetlands harbored wolves,[339] but today we accept ecological processes as neutral "acts of God."[340]

1. Wetland Services

The 2008 mitigation regulations have now defined a wetland "service" as a biogeochemical process that occurs in a wetland ecosystem and benefits human populations.[341] Wetlands are the locus of many processes, some of which may aggregate to provide significant beneficial functions for humans, such as purification of air and water, flood abatement, and soil nutrient cycling, and for the last decade such functions have often been characterized as "ecosystem services."[342]

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334 Glynnis A. Hood & Suzanne E. Bayley, *Beaver (*castor canadensis*) Mitigate the Effects of Climate on the Area of Open Water in Boreal Wetlands in Western Canada*, 141 BIOLOGICAL CONSERVATION 556, 565 (2008).

335 John N. Thompson et al., *Frontiers of Ecology*, 51 BIOSCIENCE 15, 20 (2001).

336 *See* John J. Ewel, *Ecosystem Processes and the New Conservation Theory*, *in* THE ECOLOGICAL BASIS OF CONSERVATION: HETEROGENEITY, ECOSYSTEMS, AND BIODIVERSITY 252, 259 (S.T.A. Pickett et al. eds., 1997).

337 *See* Monica G. Turner et al., *Ecological Dynamics at Broad Scales: Ecosystems and Landscapes*, 45 BIOSCIENCE S-29, S-34 (1995).

338 *See* Fred P. Bosselman, *Limitations Inherent in the Title to Wetlands at Common Law*, 15 STAN. ENVTL. L.J. 247, 270–73 (1996).

339 WILLIAM CRONON, CHANGES IN THE LAND: INDIANS, COLONISTS, AND THE ECOLOGY OF NEW ENGLAND 133 (1983).

340 *E.g.*, Zygmunt J.B. Plater, *Law, Media and Environmental Policy: A Fundamental Linkage in Sustainable Democratic Governance*, 33 B.C. ENVTL. AFF. L. REV. 511, 534 (2006).

341 *See* 33 C.F.R. § 332.2 (2008).

342 Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 253, 254 tbl.1 (1997).

The trading mechanisms discussed in this Article illustrate how certain processes can be identified as a service that people will be willing to pay for.[343] But even the most experienced proponents of ecosystem service analysis agree that "turning the valuation of ecosystem services into effective policy and finance mechanisms [is] a problem that, as yet, no one has solved on a large scale."[344]

The way particular wetland services are defined in the various trading programs varies greatly in both simplicity and precision. First, for wetland mitigation, the credits have traditionally been measured in acres of wetness, despite criticism of the imprecision of this criterion.[345] Whether the 2008 regulations will bring a closer correlation between mitigation and services remains to be seen.[346]

Second, wetlands' role in reducing potential emissions of carbon dioxide depends on the extent of carbon buildup in each particular wetland.[347] The existing trading systems measure sequestration of carbon by the tons of carbon dioxide that would have been emitted to the atmosphere in the absence of the sequestration.[348] Estimating this requires a number of assumptions, but the renewed interest in the issue has stimulated extensive research.[349]

Third, water quality trading could theoretically involve trades of a mix of many water pollutants, but in practice the medium of trade is usually a single pollutant, either a nutrient such as phosphorus, or a heavy metal such as mercury.[350] Limiting nutrients can help reduce eutrophication and anoxia downstream, making the waters more valuable for human use, while limits on toxic metals have a direct relationship to human health.[351]

Fourth, the so-called "biodiversity trading" markets are not monetizing the abstract concept of biodiversity—an impossible task in the absence of some very complex definition of the term.[352] The trades have usually been designed to help one or a few species of plants or animals that are either seen as at risk of extinction or as keystone species for the survival of a suite

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343 Gretchen C. Daily et al., *Ecosystem Services in Decision Making: Time to Deliver*, 7 FRONTIERS ECOLOGY & ENV'T 21, 26 (2009).

344 *Id.* at 21. EPA's scientists say that research is needed to clearly understand the ecosystem services provided by wetlands such as a safe water supply, fish and fiber, wildlife habitat, and flood regulation. U.S. ENVTL. PROT. AGENCY, RESEARCH TO SUSTAIN ECOSYSTEM SERVICES BROCHURE (2009), *available at* http://www.epa.gov/ecology/pdfs/EcoSystemsResearchBrochFINAL1-20-09.pdf.

345 *See generally* James Salzman & J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 648–57 (2000).

346 *See, e.g.*, Joseph M. Kiesecker et al., *A Framework for Implementing Biodiversity Offsets: Selecting Sites and Determining Scale*, 59 BIOSCIENCE 77, 77 (2009); Ruhl et al., *supra* note 52, at 22–24.

347 Ruhl et al., *supra* note 52, at 22–24.

348 *Id.*

349 For an example of this type of research, see Mitra et al., *supra* note 160, at 25.

350 *See, e.g.*, Mehan, *supra* note 319, at 642.

351 *See generally id.* at 640–42.

352 Fred Bosselman, *A Dozen Biodiversity Puzzles*, 12 N.Y.U. ENVTL. L.J. 364, 366 (2004).

of organisms.[353] Measurement may involve either the number of individual organisms or the size of suitable habitats.[354]

Like wetland boundaries, precise computation of ecosystem services requires us to maneuver among hazy boundaries of imperfect proxies.[355] Carol Rose says that the "proxy or nonfungibility problem" permeates wetland and habitat trading:

> As a consequence, wetlands and habitat trade proposals are hedged with numerous restrictions and conditions. The more ex post conditions affect these trades, of course, the thinner the trading market and the more cumbersome the trade itself. At the far end of the spectrum, conditions can become so numerous that the rights themselves are untradeable—inalienable, as it were.[356]

However, any system of wetland trading will need to fix upon a few services and search for the most reasonably available proxy.[357]

The rhetoric of ecosystem services may accomplish environmental goals better than attempts at quantification. Monetization of the utilitarian valuation of an ecosystem service creates a serious risk: won't there frequently be a more "efficient" way to provide the same service?[358] The rhetoric of ecosystem services may educate the public to the importance of natural processes, but quantification of ecosystem services may turn out to have been a "Faustian bargain."[359]

2. Wetland Disservices

Wetlands are also the locus of natural biogeochemical processes that harm the human race, such as emission of methane and nitrous oxide and the conversion of organic mercury to toxic methylmercury.[360] Another well-known disservice is the spread of diseases transmitted by mosquitoes that

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353 *See, e.g.*, Dawn M. Scott et al., *The Influence of Habitat and Landscape on Small Mammals in Estonian Coastal Wetlands*, 57 EST. J. ECOLOGY 279, 280 (2008).

354 *See, e.g.*, *id.*

355 *See* A. Dan Tarlock, *Ecosystem Services in the Klamath Basin: Battlefield Casualties or the Future*, 22 J. LAND USE & ENVTL. L. 207, 216 (2007).

356 Carol M. Rose, *From H_2O to CO_2: Lessons of Water Rights for Carbon Trading*, 50 ARIZ. L. REV. 91, 106 (2008).

357 Other wetland processes have been treated as ecosystem services without being quantified with the degree of precision that would facilitate trading. Ever since James Watt tried to equate the value of wetland waterfowl to the value of ducks in the supermarket, attempts to monetize each and every wetland value have been the cause of embarrassment. *See, e.g.*, Ohio v. U.S. Dep't of the Interior, 880 F.2d 432, 456 (D.C. Cir. 1989). For a more recent example, see R. KERRY TURNER ET AL., VALUING ECOSYSTEM SERVICES: THE CASE OF MULTI-FUNCTIONAL WETLANDS 98–102 (2008).

358 Dale D. Goble, *What* Are *Slugs Good for? Ecosystem Services and the Conservation of Biodiversity*, 22 J. LAND USE & ENVTL. L. 411, 429–30 (2007).

359 MITSCH & GOSSELINK, *supra* note 92, at 374.

360 *See supra* Parts III, V.D–E.

breed in wetlands.[361] The literature on ecosystem services has paid little attention to disservices, but if a utilitarian concept of value is being used, the concept should be consistent with utilitarian theory and take disservices into consideration.

From a utilitarian perspective, the alleviation of a disservice has a value equivalent to the performance of a service. Bentham said that because the goodness of a law can be measured "according to the tendency which it appears to have to augment or diminish the happiness of the party whose interest is in question," then the alleviation of pain is equivalent to the creation of pleasure.[362] So, for example, if natural wetlands are responsible for 20% of emissions of methane, as the scientists estimate, than any reduction of those emissions should deserve the same amount of credit as any other service that is based on the value of GHGs.

3. Naturalness

The utilitarian perspective runs counter to a key assumption motivating much of the ecosystem services movement—that the quantification of ecosystem services will facilitate the preservation and restoration of natural ecological systems[363] rather than promoting ecosystem management.[364] The 2008 regulations relating to wetland mitigation illustrate this assumption;[365] the regulations define a mitigation bank as "a site, or suite of sites, where resources (e.g., wetlands, streams, riparian areas) are *restored, established, enhanced, and/or preserved* for the purpose of providing compensatory mitigation for impacts authorized by [Department of Army] permits."[366] Restoration[367] involves "returning natural/historic functions to" aquatic

361 Paul I. Boon, *Biochemistry and Bacterial Ecology of Hydrologically Dynamic Wetlands*, *in* ECOLOGY OF FRESHWATER AND ESTUARINE WETLANDS, *supra* note 196, at 115, 127.

362 JEREMY BENTHAM, PRINCIPLES OF MORALS AND LEGISLATION 2, 24 (Hafner Press 1948) (1780).

363 On the difficulty of deciding what natural means, see K.J. Willis & H.J.B. Birks, *What Is Natural? The Need for a Long-Term Perspective in Biodiversity Conservation*, 314 SCI. 1261, 1261 (2006).

364 *See, e.g.*, Zedler & Kercher, *supra* note 41, at 53–55.

365 *See* discussion *supra* Part II.A.

366 Compensatory Mitigation for Losses of Aquatic Resources, 33 C.F.R. § 332.2 (2008) (emphasis added).

367 The definition of "restoration" refers to two categories of restoration that are to be applied for the purpose of tracking net gains in aquatic resource area:

> *Re-establishment* means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. Re-establishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions.
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> . . . .
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> *Rehabilitation* means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.

Id.

resources, and preservation involves "removal of a threat to, or preventing the decline of" aquatic resources.[368]

"Enhancement" is defined as "the manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s). Enhancement results in the gain of selected aquatic resource function(s), but may also lead to a decline in other aquatic resource function(s)."[369] Again, the text seems to assume that the selected function is beneficial, and that the decline of other functions would be some adverse tradeoff that is justified by the gain in the selected function.

The desire to preserve things is a natural reaction: "The impulse to preserve is partly a reaction against the increasing evanescence of things and the speed with which we pass them by. In the face of massive change we cling to the remaining familiar vestiges."[370] But we should be careful about the extent to which we enact this preservation impulse into a legal system that is largely based on utilitarian reasoning.[371] Science now views wetlands as dynamic systems that respond to changes over time, not as systems to be walled off to conserve their inherent stability.[372] One can imagine a biotechnologist creating a plant (perhaps a sterile variety of a nonnative species) that would reduce both methane emissions and the methylation of organic mercury. If this plant were to replace existing wetland vegetation, and the replacement had only minimal adverse impact on other wetland functions, why wouldn't it qualify as providing beneficial services?

C. Monetization

Once particular processes have been selected to be traded, the next step is to determine how each such process should be measured for purposes of determining its value. Successful monetization for trading purposes depends on the reduction of variables that affect value so that buyers can confidently value the product.[373]

1. Valuation Methodologies

If we could identify every wetland service and disservice would we know how much value people would attach to a wetland? No; a seemingly insuperable problem stems from 1) the law's definition of a service as a process that has value to humans, and 2) the difficulty of quantifying some human

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368 *Id.* The definition of "establishment" makes no mention of services, but indicates that "[e]stablishment results in a gain in aquatic resource area and functions." *See id.*

369 *Id.*

370 DAVID LOWENTHAL, THE PAST IS A FOREIGN COUNTRY 399 (12th prtg. 2005).

371 *See, e.g.*, Emily T. Yeh, *From Wasteland to Wetland? Nature and Nation in China's Tibet*, 14 ENVTL. HIST. 103, 122 (2009).

372 Tarlock, *supra* note 355.

373 Rose, *supra* note 356, at 104.

values.[374] The things that humans value about wetlands are not the "abstruse ecological processes that occur in wetlands," few of which they are likely to understand, but their perceptions of the totality of the place in the context of the surrounding landscape, a value for which no proxy exists.[375] Each swamp is idiosyncratic.[376]

It is true that complex computer models of many quantified processes may lend an artificial assurance of scientific integrity to the monetization process, but only if people are content to leave the black box unopened. As William Cronon put it, "The market fosters exchange relationships of almost unimaginable complexity, and then hides them from us at the very instant they are created, in that last moment when cash and commodity exchange hands and we finally consume the thing we have purchased."[377] The monetization of services could push policy makers to redistribute environmental effort toward easily quantified objectives at the expense of more nuanced goals such as biodiversity.[378]

2. Rights and Responsibilities

In the complex and overlapping trading regimes discussed earlier, the rules address a wide range of rights and responsibilities relating to all relevant aspects of the affected ecological systems. Where rules assign certain people or groups rights without responsibilities, or responsibilities without rights, their willingness to negotiate modifications in the rules is likely to be limited. Elinor Ostrom has cautioned against the use of privatization of rights without careful consideration of the responsibility for managing those parts of the system that cannot be privatized.[379] In groundwater resource management, for example, the flow of water can be privatized, but the basin itself must be managed jointly.[380]

Increasingly, analysts of natural resource management systems argue that the creation of partial property rights in resources may overemphasize the part of the system that is given property status at the expense of the rest of the ecosystem.[381] In forest, fishery, and wildlife management, crises have driven home the point that individual resources cannot be successfully

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374 *See* 33 C.F.R. § 333.2 (2008).

375 MITSCH & GOSSELINK, *supra* note 92, at 334.

376 Kenneth Arrow et al., *Managing Ecosystem Resources*, 34 ENVTL. SCI. & TECH. 1401, 1403 (2000).

377 CRONON, *supra* note 1, at 384.

378 Barton H. Thompson, Jr., *Ecosystem Services & Natural Capital: Reconceiving Environmental Management*, 17 N.Y.U. ENVTL. L.J. 460, 474 (2008). "By conceding that nature can be valued, conservationists put themselves in an untenable position." Matthew F. Child, *The Thoreau Ideal as a Unifying Thread in the Conservation Movement*, 23 CONSERVATION BIOLOGY 241, 241 (2009).

379 C. Dustin Becker & Elinor Ostrom, *Human Ecology and Resource Sustainability: The Importance of Institutional Diversity*, 26 ANN. REV. ECOLOGY & SYSTEMATICS 113, 122 (1995).

380 *Id.*

381 Hal Salwasser, *Ecosystem Management: A New Perspective for National Forests and Grasslands*, *in* ECOSYSTEM MANAGEMENT: ADAPTIVE STRATEGIES FOR NATURAL RESOURCES ORGANIZATIONS IN THE TWENTY-FIRST CENTURY 85, 91 (Jennifer Aley et al. eds., 1999).

managed except in the context of the full array of ecosystem components and processes.[382] For example, where only large fish have value in the marketplace, fishermen may simply toss out all but the biggest fish of the most desirable species.[383]

Like monetization, the awarding of property rights only in specific components of an ecosystem, without creating correlative duties to maintain the whole underlying ecosystem, can lead to distorted investment in the propertized resource, so that "conservation of *that* resource may be disproportionately great, while the use of non-propertized resources is simply spendthrift—an imbalance that can threaten a larger and intricately interrelated ecosystem."[384] The owners of fish farms treat their own stock with care, but often harvest wild marine life indiscriminately as feed for their stock.[385]

Any market must evaluate ecosystem management proposals in light of certain baseline standards of appropriate behavior rather than continually relying on external funding.[386] Should a landowner have a responsibility to alleviate a natural ecological process that is causing public harm? American laws have long given landowners certain responsibilities to take actions designed to avoid the spread of wildfire and to reduce the flow of floodwaters onto neighboring property.[387] If we are to award financial benefit for managing wetlands in appropriate ways, should we not set baseline standards for wetland management for which no compensation would be required?[388] We do not want a system in which an operator could effectively degrade a wetland in order to get paid for cleaning it up.[389]

Getting outside observers involved in wetland management can also help. If the general public can manage itself and prevent wasteful overuse of a resource, it "can tame and moderate the dread rule of capture that

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382 Norman L. Christensen et al., *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management*, 6 ECOLOGICAL APPLICATIONS 665, 669 (1996).

383 CARL SAFINA, SONG FOR THE BLUE OCEAN 30 (1998).

384 Carol M. Rose, *The Several Futures of Property: Of Cyberspace and Folk Tales, Emission Trades and Ecosystems*, 83 MINN. L. REV. 129, 170–73 (1998). Contrast this with Judge Posner's observation that before the financial crisis the profits of the "free wheeling banks and hedge funds and private equity funds and all the rest" were enormous, "but undoubtedly contained a large amount of economic rent." RICHARD A. POSNER, A FAILURE OF CAPITALISM: THE CRISIS OF '08 AND THE DESCENT INTO DEPRESSION 295 (2009).

385 Carol M. Rose, *Expanding the Choices for the Global Commons: Comparing Newfangled Tradable Allowance Schemes to Old-Fashioned Common Property Regimes*, 10 DUKE ENVTL L. & POL'Y F. 45, 61 (1999).

386 *Observations on the Potential Role of Carbon Offsets in Climate Change Legislation: Testimony Before the Subcomm. on Energy & Environment of the H.R. Comm. on Energy and Commerce*, 116th Cong. 14–15 (2009) (statement of John Stephenson, Director, Natural Resources & Environment, Government Accountability Office) [hereinafter Stephenson Testimony].

387 ERNST FREUND, THE POLICE POWER: PUBLIC POLICY AND CONSTITUTIONAL RIGHTS 110–14 (1904).

388 OFFSET QUALITY INITIATIVE, ENSURING OFFSET QUALITY: INTEGRATING HIGH QUALITY GREENHOUSE GAS OFFSETS INTO NORTH AMERICAN CAP-AND-TRADE POLICY 3–4 (2008), *available at* http://www.offsetqualityinitiative.org/documents/WhitePaper.pdf.

389 Cannon, *supra* note 44, at 77–78; Thompson, *supra* note 378, at 482–83. *But see* PEW CTR. ON GLOBAL CLIMATE CHANGE, *supra* note 137, at 7.

supposedly tends to turn every common into a waste."[390] Ecosystem management can benefit from a large number of independent participants who can monitor each others' activities and feed back information into the system.[391]

Baseline management responsibilities need not necessarily require heavy-handed, top-down regulation. We expect "a minimum level of environmental protection without compensation from the beneficiaries of that protection."[392] We should be able to condition use of the wetland markets on certain broad standards that will prevent people from creating harm in order to alleviate it.[393] As Stephanie Stern explains, "Regulation can provide a context for incentives, define the parameters of market-based strategies, and complement incentive programs."[394] The state of the science regarding such processes as carbon storage, nutrient removal, methanogenesis, and so forth probably gives us enough information to design simple baseline trading rules that can provide adequate market infrastructure.

D. Designing Management Projects

The government has increasingly tried to use market-related incentives as a way of encouraging new entrepreneurs to explore projects that will improve on traditional ways of doing things—the famous "creative destruction" that markets provide.[395] This atmosphere of innovation stimulates applied scientific research to support new projects, and the necessity of keeping up with a changing environment encourages managers of both new and existing projects to use adaptive management techniques to prevent their projects from sliding into obsolescence. What kind of wetland projects will this group of markets be likely to stimulate?

1. Entrepreneurship

The relatively limited experience with national market-based incentives in the United States provides a few examples of incentive programs that significantly enlarged the number of entities operating in a particular market.[396] The Public Utilities Regulatory Policies Act of 1978[397] created

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390 CAROL M. ROSE, PROPERTY AND PERSUASION: ESSAYS ON THE HISTORY, THEORY, AND RHETORIC OF OWNERSHIP 125–27 (1994).

391 Allison Rieser, *Property Rights and Ecosystem Management in U.S. Fisheries: Contracting for the Commons?*, 24 ECOLOGY L.Q. 813, 827–29 (1997).

392 Thompson, *supra* note 378, at 482.

393 For discussion of similar issues that have arisen in the United Nations GHG offset program, see Michael Wara, *Measuring the Clean Development Mechanism's Performance and Potential*, 55 UCLA L. REV. 1759, 1802 (2008); Stavins, *supra* note 142, at 304.

394 Stern, *supra* note 88, at 583.

395 JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY 83 (3d ed. 1942).

396 *See id.* at 81 (describing "creative destruction"). I do not pretend to have made a survey of all national market-based incentive programs and am only citing a few examples with which I am familiar.

397 16 U.S.C. § 824a-3(a) (2006).

incentives for building owners that install cogeneration systems—equipment that would both generate electricity and provide other useful outputs, such as heat.[398] The incentive was the opportunity to require the local electric utility to buy the power on a long-term, fixed-rate contract at a rate favorable to the seller.[399] The design and manufacture of a wide variety of cogeneration equipment by firms new to the electric generation market produced significant savings in energy efficiency, and produced major technological advances.[400]

Another incentive program was featured in the Energy Policy Act of 1992.[401] The statute provided new encouragement for independent power producers to enter the market for power plant construction by allowing independent generators of electricity to negotiate sales to electric utilities at market rates.[402] Again, a large number of new players entered the business and succeeded in capturing a significant share of the market, but the program contributed little in the way of new ideas and did not produce the energy efficiency gains that had been anticipated.[403]

The adoption of a cap-and-trade system for the control of sulfur dioxide emissions by coal-burning power plants was a prominent element of the Clean Air Act Amendments of 1990.[404] Power plant operators in the eastern half of the country were required to acquire allowances each year to emit sulfur dioxide, and paid penalties if their emissions did not comply with a gradually decreasing national cap on total emissions.[405] The entrepreneurs that captured a huge share of the market were coal companies, only a few of which were new to the industry, who used advanced surface mining technology and unit trains to mine and ship Wyoming coal to power plants in the east.[406]

The experience with the actual trading programs affecting wetlands is even more limited.[407] Water quality trading has produced few trades, most of which have simply involved use of existing "best management practices" for

398 For a discussion of the early history of cogeneration, see THOMAS R. CASTEN, TURNING OFF THE HEAT: WHY AMERICA MUST DOUBLE ENERGY EFFICIENCY TO SAVE MONEY AND REDUCE GLOBAL WARMING (1998).

399 "Utilities which had over-expanded their facilities had to buy a competitor's electricity not at the prevailing market value, but at the utility's own higher cost of producing electricity." JOSEPH P. TOMAIN & RICHARD D. CUDAHY, ENERGY LAW IN A NUTSHELL 272 (2004).

400 "PURPA, unintentionally, discovered a new generation market." *Id.*

401 Pub. L. No. 102-486, 106 Stat. 2776 (1992).

402 FRED BOSSELMAN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT: CASES AND MATERIALS 832–33 (2d ed. 2006).

403 "Since 1997, natural gas-fired additions in effect offset net retirements across all fuel types, with the cumulative net increase in capacity equal to 14,760 MW of nonhydroelectric, renewable capacity and 3,111 MW of other gases, hydroelectric and other capacity." ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ELECTRIC POWER ANNUAL 2007, at 4 (2009), *available at* http://www.eia.doe.gov/cneaf/electricity/epa/epa.pdf.

404 42 U.S.C. § 7651 (2006).

405 *Id.*

406 ENERGY INFO. ADMIN., *supra* note 403, at 204.

407 Robertson, *supra* note 68, at 35.

handling runoff from farms.[408] Wetland mitigation banking is bringing a significant number of new entrepreneurs into the business of wetland management, but it is still too early to find reliable surveys of their effect on long-term management.[409]

Greenhouse gas trading has been developing in Europe and Asia for a few years, but even its strongest supporters agree that the early years of the program showed need for significant improvement.[410] Rapid decline in overall market conditions during 2008 makes it difficult to separate internal program performance from the overall market in terms of cause and effect.[411] The number and kind of entrepreneurs that have been attracted to the program can be seen by looking at the membership list of the International Energy Trading Association, where bankers, brokers, law firms, and multinationals are prominently featured.[412]

Past experience shows that market incentives can sometimes stimulate new competition, and that sometimes that competition fosters development of significant new science and technology.[413] Because many people believe that the issues posed by wetlands involve several unsolved scientific issues,[414] a key question is whether market-related incentives will help resolve these scientific issues.

2. Scientific Progress

The scientific literature cited in earlier parts of this Article is a small part of a rapidly growing effort to look at the relationship of wetlands to some of the key policy issues of our time. Some of this research appears to be at a quite basic level, such as the understanding of methylmercury formation or the impact of increased ethanol production on wetlands.[415] Other research is at

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408 RALPH E. HEIMLICH ET AL., WETLANDS AND AGRICULTURE: PRIVATE INTERESTS AND PUBLIC BENEFITS 43 (1998), *available at* http://www.ers.usda.gov/publications/aer765/aer765.pdf.

409 *Id.* at 43, 46.

410 *See, e.g.*, Christopher Carr & Flavia Rosembuj, *Flexible Mechanisms for Climate Change Compliance: Emission Offset Purchases Under the Clean Development Mechanism*, 16 N.Y.U. ENVTL. L.J. 44, 60–62 (2008) (describing lessons learned during initial years of program).

411 Ellen Simon, *Business Year in Review: At Least You've Got Your Health*, ATLANTA J. CONST., Dec. 26, 2008, http://www.ajc.com/business/content/printedition/2008/12/26/topstories.html?cxntlid=inform_artr (last visited July 19, 2009).

412 Int'l Energy Trading Ass'n, IETA Member List, http://ieta.org/ieta/www/pages/index.php?IdSiteTree=1249 (last visited July 19, 2009).

413 *See, e.g.*, YORAM BAUMAN, FREE-MARKET INCENTIVES FOR INNOVATION: A CLOSER LOOK AT THE CASE OF POLLUTION CONTROL (2004), *available at* http://www.smallparty.org/yoram/research/maxincent.pdf ("In [the field of pollution control], . . . the superiority of market-based instruments over direct controls in providing incentives for innovation have appeared steadily for almost 30 years and are supported by an extensive theoretical literature that examines incentives for innovation in competitive market settings." (citation omitted)).

414 *See, e.g.*, Barbara Cosens, *Resolving Conflict in Non-Ideal, Complex Systems: Solutions for the Law-Science Breakdown in Environmental and Natural Resource Law*, 48 NAT. RES. J. 257, 270–72 (2008) (describing scientific debates).

415 *See, e.g.*, King et al., *supra* note 97 (methylmercury formation); Ringelman et al., *supra* note 248, at 1, 3–5 (discussing the impact of biofuel-driven agriculture on wetlands).

the applied level, such as the use of treatment wetlands to reduce nutrient outflow or to remediate heavy metals.[416]

Will wetland trading programs foster needed scientific progress? Here the working example that deserves close study is the United Nations program known as the Clean Development Mechanism, or CDM.[417] Under this program, projects to reduce GHG emissions in developing countries can produce credits that can be sold to GHG-emitting entities in those developed nations that have ratified the Kyoto Protocol, and these entities can use these credits as "offsets" against their obligation to reduce their emissions.[418]

Numerous analysts have studied the performance of the CDM, although the program has only been in operation for a few years.[419] While criticisms of the program abound, and operational changes are underway,[420] insofar as the issue of scientific progress is concerned, the early years tell us some interesting things.

Examples of technology transfer to the reduction of GHGs are easy to find in the projects that have applied for CDM approval, though they may not be the majority.[421] In some cases the new ideas have been technological, but in other cases novel applications of social and psychological research have been employed in promoting the use of GHG reduction methods.[422] Whether the initial applications of these ideas have been successfully implemented or are economically efficient remains to be seen,[423] but the CDM program has been a stimulus for the dissemination of new scientific ideas.[424]

Whether such success will continue is a different question. When the management of a program has been highly criticized, the managers who value job security would probably tend to restrict the program to its safest and most well-established elements.[425] Evidence of this is already accumulating in the

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416 *See, e.g.*, ENVTL. LAW INST., *supra* note 83, at 53 (nutrient outflow); Zhang et al., *supra* note 95, at 256–58 (heavy metals).

417 *See* U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 143, at 2–3.

418 *Id.*

419 *See, e.g.*, OFFSET QUALITY INITIATIVE, *supra* note 388, at 11 (studying offsets in context of possible North American cap and trade program); OLANDER & MURRAY, *supra* note 137, at 2 (analyzing positive and negative aspects of offsets, including in the CDM context).

420 U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 417, at 42.

421 *See generally* Rob Youngman et al., *Evaluating Technology Transfer in the Clean Development Mechanism and Joint Implementation*, 7 CLIMATE POL'Y 488, 495 (2007).

422 A. Flamos et al., *EU and Asian Countries Policies and Programmes for the Diffusion of Sustainable Energy Technologies*, 6 ASIA EUR. J. 261, 267–72 (2008); ORGANISATION FOR ECON. CO-OPERATION & DEV. ENV'T DIRECTORATE & INT'L ENERGY AGENCY, TECHNOLOGY INNOVATION, DEVELOPMENT AND DIFFUSION 29–30 (2003), *available at* http://www.oecd.org/dataoecd/23/52/2956490.pdf.

423 U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 417, at 55–56.

424 *Id.* at 37–38.

425 *See* Wara, *supra* note 393, at 1790–97; David M. Driesen, *Sustainable Development and Market Liberalism's Shotgun Wedding: Emissions Trading Under the Kyoto Protocol*, 83 IND. L.J. 21, 53–54 (2008) (arguing performance standards create more superior incentives for innovation than trading programs).

CDM program, where models of existing technologies are given a faster track for approval under the complex CDM permitting process.[426]

Direct grants or loan guarantees for applied science projects are not immune from this type of administrative caution. A large pot of money appropriated for advanced energy efficiency projects by the Energy Policy Act of 2005 remains unspent as of February 2009 despite general agreement on the need for more such projects.[427] Perhaps projects that are designed to be managed adaptively could give administrators additional assurance.

3. Adaptive Management

The 2008 COE regulations require mitigation bank operators to employ a system of adaptive management.[428] In essence, adaptive management simply means that managers should be prepared to modify their original plans if they are not working.[429]

Broad dissatisfaction with inflexible "end-state" planning grew out of the economic turmoil of the 1970s and 1980s, when floating exchange rates, high inflation, and increasing international competition made such plans seem increasingly irrelevant.[430] In 1972, Ira Michael Heyman wrote a seminal article in which he compared end-state planning unfavorably with a "planning process" approach that would recognize the ever changing nature of the human and natural environment.[431] At the same time, ecologist C.S. Holling was also advocating the need for plans to be flexible to accommodate the resilience of natural systems: "A management approach based on resilience . . . would emphasize the need to keep options open, the need to view events in a regional rather than a local context, and the need to emphasize heterogeneity."[432] By the 1990s, many federal agencies were also advocating adaptive planning and management.[433]

In his book, *Adaptive Management of Renewable Resources*, Carl Walters argued that we need to embrace uncertainty and admit that "many key management decisions are essentially *gambles*, no matter how nicely we may try to package the justification for these decisions by presenting reams of data and elaborate calculations."[434] Adaptive management has been called

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426 PEW CTR. ON GLOBAL CLIMATE CHANGE, *supra* note 137, at 8–9.

427 *See* U.S. Dep't of Energy, Loan Guarantee Program, http://www.lgprogram.energy.gov (last visited July 19, 2009).

428 *See* 33 C.F.R. §§ 332.4(c)(12), 332.7(c) (2008).

429 Fred Bosselman, *A Role for State Planning: Intergenerational Equity and Adaptive Management*, 12 U. FLA. J.L. & PUB. POL'Y 311, 311 (2001).

430 Richard P. Rumelt et al., *Fundamental Issues in Strategy*, *in* FUNDAMENTAL ISSUES IN STRATEGY: A RESEARCH AGENDA 9, 20 (Richard P. Rumelt et al. eds., 1994).

431 Ira Michael Heyman, *Innovative Land Regulation and Comprehensive Planning*, 13 SANTA CLARA LAW. 183, 234 (1972).

432 C. S. Holling, *Resilience and Stability of Ecological Systems*, 4 ANN. REV. ECOLOGY & SYSTEMATICS 1, 21 (1973).

433 THE KEYSTONE CTR., THE KEYSTONE NATIONAL POLICY DIALOGUE ON ECOSYSTEM MANAGEMENT: FINAL REPORT 15–16 (1996).

434 CARL WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES 159 (1986).

a "learning-led strategy" that is "responsive to the variations, rhythms, and cycles of change natural in [the ecosystem] and are able to react quickly with appropriate management techniques."[435]

Wetlands are a good example of ecosystems that should be managed adaptively because their biogeochemical processes are strongly affected by the surrounding landscape.[436] Implementing wetland management in phases can identify the most effective methods while work is ongoing[437] and reduce the risk of massive mistakes.[438]

Legal scholars such as Dan Tarlock have pointed to a number of legal issues that need to be addressed if resource management systems are to be managed adaptively. He emphasizes that "adaptive management . . . is premised on the assumption that management strategies should change in response to new scientific information. All resource management is an ongoing experiment."[439] On the other hand, he notes that:

> The idea that all management is an on-going experiment poses a profound challenge to our legal system because it undermines a core principle of procedural and substantive fairness—finality. . . . Once a decision is rendered, we expect parties to abide permanently by the outcome. . . . For example, the premise behind an environmental impact statement is that once environmental damage has been fully disclosed, a one-time decision on the merits of the activity is legitimate and final.[440]

It may be necessary to reduce the law's traditional demand for predictability and certainty in favor of more flexible concepts of property such as found in oil or wildlife, because these kinds of property are more fluid; they recognize the need to adapt to changes in the environment, while property rights in land have typically emphasized the value of finality.[441] The differing systems of water rights illustrate the problems posed by inflexibility.[442]

J.B. Ruhl notes that we are still trying to make too many permanent decisions about environmental policy even though we recognize that our old

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435 Frances Westley, *Governing Design: The Management of Social Systems and Ecosystem Management*, *in* BARRIERS AND BRIDGES TO THE RENEWAL OF ECOSYSTEMS AND INSTITUTIONS 391, 394 (Lance H. Gunderson et al. eds., 1995).

436 Euliss et al., *supra* note 109, at 3–4.

437 Zedler & Kercher, *supra* note 41, at 65–66.

438 Joy B. Zedler, *Wetland Restoration*, *in* ECOLOGY OF FRESHWATER AND ESTUARINE WETLANDS, *supra* note 196, at 348, 370, 402–06.

439 A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOYOLA L.A. L. REV. 1121, 1139 (1994).

440 A. Dan Tarlock, *Environmental Law: Ethics or Science?*, 7 DUKE ENVTL. L. & POL'Y F. 193, 206 (1996).

441 DANIEL A. FARBER, ECO-PRAGMATISM: MAKING SENSIBLE DECISIONS IN AN UNCERTAIN WORLD 178–79 (1999); Robert J. Goldstein, *Green Wood in the Bundle of Sticks: Fitting Environmental Ethics and Ecology into Real Property Law*, 25 B.C. ENVTL. AFF. L. REV. 347, 347–48 (1998); William H. Rodgers, Jr., *Adaptation of Environmental Law to the Ecologists' Discovery of Disequilibria*, 69 CHI.-KENT L. REV. 887, 887 (1994).

442 Rose, *supra* note 356, at 107–09.

decisions are based on outmoded science.[443] Robert Keiter argues that all resource management proposals should be evaluated using an ecologically-derived time scale.[444] Wetlands have changed greatly over ecological time, and climate change will only speed up the changes.[445]In doing so, however, managers must avoid using the legitimacy of change as an excuse to speed up processes of change beyond the limits of the ecological system to absorb such changes without collapsing.[446] For example, ever since Aldo Leopold's pioneering works, we have been aware that the attempt to "wipe out" a predator or pestilence is likely to have a much more unpredictable impact than mere management measures.[447] Yet predator control, using traps and poisons, remains a federally-funded program intended to "wipe out" species such as the prairie dog and the coyote, while ignoring the adverse impact on ecological systems.[448]

Ecological systems like wetlands are well-suited for adaptive management because all ecosystems have the dynamic character of works in progress and every "ecosystem is always in an emergent state, whose participants and constituent features may be roughly known but not completely specifiable in advance."[449] Wetland management should advance the goal of intergenerational sustainability.[450] On the other hand, our recognition of the need for flexibility puts great pressure on the designers of the system to find an appropriate balance between the variability needed to promote adaptive management and the concreteness sought by market participants.

E. Creating Markets

I am reasonably sanguine about the prospect of using ecosystem management to bring about beneficial changes in some of America's wetlands. The rate of change predicted for our future environment means that maintenance of the status quo seems hopeless. In concept, I see no reason why some wetlands cannot be managed in ways that will make them more valuable to humans while maintaining their role in the ecological landscape. Whether this can be done through markets, however, is a much more difficult question.

Perhaps my suspicion of markets is unduly influenced by an incident from my childhood. When I was about nine years old, one of my relatives

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443 J. B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933, 996–1000 (1997).

444 Robert B. Keiter, *Beyond the Boundary Line: Constructing a Law of Ecosystem Management*, 65 U. COLO. L. REV. 293, 302 (1994).

445 Willis & Birks, *supra* note 363, at 1261–62.

446 WALTERS, *supra* note 434, at 17.

447 *See* CURT MEINE, ALDO LEOPOLD: HIS LIFE AND WORK 468–69 (1988).

448 Coby C. Dolan, *The National Grasslands and Disappearing Biodiversity: Can the Prairie Dog Save Us from an Ecological Desert?*, 29 ENVTL. L. 213, 226–27 (1999).

449 Rose, *supra* note 384, at 180.

450 Euliss et al., *supra* note 109, at 5.

became convinced that he had discovered a way to make money by gambling on horse racing. He would sit down with me and the racing form and try to explain his complex system for beating the odds. I was impressed at the time, but he died drunk and broke. I became a non-gambler and a very cautious investor.

America has many well-established markets on which I and millions of other people rely. Chicago, where I work, has hosted important markets for a century and a half.[451] Americans rely on New York and Chicago markets to assign value to our assets, to provide hedging opportunities, and to create fluctuations from which we may hope to divine future prices.[452] Because most of these markets have evolved over long periods of time with only occasional lapses of integrity, they inspire a great deal of investor confidence.[453]

New markets, however, don't inherit that confidence—they must earn it. Investors must not only believe that the rules of the market are fair and being observed by the traders,[454] but they must think that the government agencies that oversee the market are trustworthy.[455] Will the various venues for swamp swaps meet those tests? I hope so, but our experience with recent new markets gives me pause.

1. Enron and the California Electricity Market

In the 1990s, the Enron Corporation gained wide accolades as the world's leading trader in a wide variety of new markets.[456] "It streaked across the last decade of the twentieth century like a newly discovered comet, burning bright as it flew, only to flame out suddenly with a blinding flash."[457] That flash helped to destroy a market for electricity in California that had been created with great hopes in the middle of the decade.[458]

Enron built its reputation by making trades with blinding speed and by blinding investors with its lack of transparency.[459] It purported to have proprietary trading methods that could not be revealed, and thereby convinced people to trust the proverbial black box because of the continuing

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451 CRONON, *supra* note 1, at 114–119.

452 *See generally* New York Stock Exchange, http://www.nyse.com (last visited July 19, 2009); Chicago Stock Exchange, Inc., http://www.chx.com (last visited July 19, 2009).

453 *See, e.g.*, Chicago Stock Exchange, Inc., History, http://www.chx.com./content/Inside_CHX/Gen_History.html (last visited July 19, 2009).

454 *See, e.g.*, Jacqueline Lang Weaver, *Can Energy Markets Be Trusted? The Effect of the Rise and Fall of Enron on Energy Markets*, 4 HOUS. BUS. & TAX L.J. 1, 27 (2004) (explaining that major power plant developers were reluctant to invest in California without "rules of the game").

455 *Id.* at 29.

456 *Id.* at 17.

457 Richard D. Cudahy & William D. Henderson, *From Insull to Enron: Corporate (Re)Regulation After the Rise and Fall of Two Energy Icons*, 26 ENERGY L.J. 35, 83 (2005).

458 Weaver, *supra* note 454, at 44, 47.

459 LOREN FOX, ENRON: THE RISE AND FALL 2 (2003).

rise in the company's reported earnings and the corresponding rise in the value of Enron stock.[460]

California's creation of a market for electricity has been critiqued in many books and articles.[461] In essence, the various interest groups each sought to obtain an advantage, and the legislature gave each one what it wanted, heedless of the fact that these advantages were mutually inconsistent.[462] In the 1990s, California electricity was pricey, and electric generating capacity was plentiful, so the utilities agreed to a rate reduction and rate freeze to avoid the prospect of new proceedings before the Public Utility Commission.[463] The legislature enacted a statute, the Federal Energy Regulatory Commission (FERC) granted the market preliminary approval, and the game was underway.[464]

A key element of the new market was a requirement that the major electric utilities, which controlled most of the demand for electricity, had to buy all of their power in an open market on a day-to-day basis; long-term contracts were prohibited.[465] This meant that new government agencies needed to be created to administer this market, but there were few examples of a working electricity spot market[466] on which to base a program.[467]

Electricity poses some inherent difficulties for market regulators. Unlike most commodities, the demand for electricity must be satisfied almost instantaneously because electricity cannot be stored in large quantities.[468] The physical principles of electricity transmission meant that any individual transaction would have certain unique characteristics, which made it difficult to specify uniform parameters for the commodity that would facilitate trading.[469]

To work around these problems, California created a series of trading rules. For example, 1) trades were to be made on a next-day basis based on predicted demand and supply, but an exception was made for immediate trades at unregulated prices when the previous day's forecasts proved to be

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460 Enron "seem[ed] to have produced profits out of fictional trades in sometimes nonexistent products." Geraldine Szott Moohr, *An Enron Lesson: The Modest Role of Criminal Law in Preventing Corporate Crime*, 55 FLA. L. REV. 937, 965 (2003).

461 *See, e.g.*, KEVIN STARR, COAST OF DREAMS: CALIFORNIA ON THE EDGE, 1990–2003, at 588–603 (2004).

462 *Id.* at 591.

463 *See generally* Richard J. Pierce, Jr., *How Will the California Debacle Affect Energy Deregulation?*, 54 ADMIN. L. REV. 389, 393–95 (2002) (describing the events leading up to the deregulation of energy markets in California and the resulting crisis).

464 *See* Pac. Gas & Elec. Co., 77 F.E.R.C. 61,204 (1996), *available at* http://elibrary.ferc.gov/idmws/common/OpenNat.asp?fileID=10759961.

465 Pierce, *supra* note 463, at 399.

466 David B. Spence, *Can Law Manage Competitive Energy Markets?*, 93 CORNELL L. REV. 765, 808 (2008).

467 A few critics warned that the experience in other countries had not been smooth, but little heed was paid. *See* Weaver, *supra* note 454, at 35 (citing SEVERIN BORENSTEIN & JAMES BUSHNELL, UNIV. OF CAL. ENERGY INST., ELECTRICITY RESTRUCTURING: DEREGULATION OR REREGULATION? 2 (2000)), *available at* http://www.ucei.berkeley.edu/PDF/pwp074.pdf.

468 STARR, *supra* note 461, at 594; Weaver, *supra* note 454, at 27.

469 Weaver, *supra* note 454, at 27–28.

inaccurate; 2) purchases of electricity from other states could be made at higher prices than in-state purchases; 3) where transmission lines were congested, companies who agreed not to take electricity that would flow through those lines could receive compensation; and 4) if a generator said it needed to shut a plant down temporarily for safety reasons, that assertion was accepted as valid on its face.[470]

To Enron, these complex rules were seen as "open invitations for gaming the system."[471] Fake trades, made on a real-time basis, established artificially high prices while avoiding detection.[472] Electricity generated in California was sold to out-of-state traders, who sold it back to California utilities at the higher out-of-state price.[473] Enron collaborated with other traders to submit bids to transmit electricity over congested lines for the sole purpose of being able to withdraw those bids and obtain compensation for relieving the line congestion.[474] Generating companies took turns claiming that plants were shut down for safety reasons, thereby reducing supply and forcing prices up.[475]

Enron hid its manipulation of the California market much like it hid the rest of its activities, using off-the-books entities to hide the suspiciously high trading profits it was making in California.[476] It steamrollered its own lawyers and auditors to approve accounting practices of highly dubious validity.[477] It bought an electric company in Oregon with a view to disguising some of its trades as legitimate hedging.[478]

The manipulation of the market by Enron and others greatly increased the price that California utilities had to pay for electricity.[479] But the utilities had agreed to a freeze of the prices they could charge residential and small business customers, and this freeze was embodied in state law.[480] The utilities soon found themselves insolvent because of the great difference between the price they had to pay for electricity and the price at which they

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470 *See infra* notes 472–75 and accompanying text; *see also* Pierce, *supra* note 463, at 394–400; CHRISTOPHER WEARE, THE CALIFORNIA ELECTRICITY CRISIS: CAUSES AND POLICY OPTIONS 47–48 (2003).

471 KURT EICHENWALD, CONSPIRACY OF FOOLS: A TRUE STORY 342 (2005).

472 Moohr, *supra* note 460; Jerry W. Markham & Daniel J. Harty, *For Whom the Bell Tolls: The Demise of Exchange Trading Floors and the Growth of ECNs*, 33 J. CORP. L. 865, 918–19 (2008).

473 Weaver, *supra* note 454, at 42–43.

474 David B. Spence, *The Politics of Electricity Restructuring: Theory vs. Practice*, 40 WAKE FOREST L. REV. 417, 443 (2005).

475 Weaver, *supra* note 454, at 49, 70.

476 *Id.* at 39. The electricity trading schemes that eventually exposed Enron and other traders were carried out in a market in which demand for power must be satisfied instantly, and in which suppliers had no legally enforceable requirement to provide accurate information about their product, so neither regulators nor the public had the resources to determine whether trading was fair. Spence, *supra* note 466, at 779–81.

477 EICHENWALD, *supra* note 471, at 521–27.

478 Cudahy & Henderson, *supra* note 457, at 86.

479 The price of wholesale electricity increased almost 1000% between April and December 2000. Pierce, *supra* note 463, at 395.

480 STARR, *supra* note 461, at 591.

had to sell it.[481] Power shortages caused frequent rolling blackouts and forced consumers to conserve energy.[482]

In December 2000, Governor Davis went to Washington to try to persuade the lame-duck Clinton administration and the Federal Reserve Board to provide assistance, but Chairman Allan Greenspan and Treasury Secretary Larry Summers both said the state should just allow consumers' electricity prices to rise to market levels.[483] Later negotiations with the new Bush administration proved equally futile until the summer of 2001, when FERC was persuaded to impose caps on wholesale prices throughout the western states and the crisis ended.[484] Afterwards, California abolished its system of deregulation, and many other states followed suit.[485]

To acquire the cash needed to back up its trading, Enron borrowed large amounts of money on loans secured by Enron stock. Ironically, one of the first and largest of these transactions was an Enron off-books partnership financed by the California Public Employees' Retirement System (CalPERS), the huge California state pension fund, which got a twenty percent annual return on its investment with Enron.[486] All of Enron's leverage seemed secure as long as its stock collateral remained highly valuable, but as suspicions about the company's activities began to grow, the stock started dropping.[487]

Enron's eventual bankruptcy and the criminal convictions of its officers were caused by a wide range of activities beyond the company's manipulation of the electricity markets.[488] The company used off-balance sheet partnerships backed by Enron stock to obscure its highly leveraged capital structure, but "once the investing public began to grasp the true risk that lurked within Enron's obscure financial statements, the company's stock price plummeted, triggering loan commitments that the company had no reasonable ability to pay."[489]

In the subsequent bankruptcy of Enron, and in the criminal trials of its executives, it became clear that the company never had a superior trading system.[490] Its profitability was the result of crooked bookkeeping.[491] But the most surprising thing about these widely publicized events is that they seemingly did not make the American public suspicious of black box trading

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481 WEARE, *supra* note 470, at 86.

482 STARR, *supra* note 461, at 594, 599. In June 2000, "California experienced blackouts on a scale unknown since World War II." *Id.* at 594.

483 EICHENWALD, *supra* note 471, at 402–03.

484 *Id.* at 464.

485 Lori A. Burkhart, *Restructuring Rollback: State-Policy Turmoil Reshapes Utility Markets*, PUB. UTIL. FORT., Nov. 2007, at 34, 35.

486 EICHENWALD, *supra* note 471, at 66, 146.

487 *Id.* at 507.

488 *See id.* at 664–75.

489 Cudahy & Henderson, *supra* note 457, at 91.

490 *See* EICHENWALD, *supra* note 471, at 664–75.

491 *See id.*

schemes that produced unbelievable results.[492] Instead, the public embraced what George Akerlof and Robert Shiller call "new era stories"—that is, claims that the current boom somehow made the old rules irrelevant.[493]

2. Secrecy, Leverage, and Gambling

Why have Americans become believers in the ability of secret trading systems to beat the odds, despite mounting evidence of market manipulation? (Americans now refer to manipulation as "gaming the system," as if it were just a sport.) Three factors that may have influenced this trend are 1) investors' willingness to buy into nondisclosure, 2) Government's willingness to allow unlimited leverage by nonregulated investment vehicles, and 3) wide income disparities that make gambling seem the only hope of many people with high economic aspirations.

Since the 1930s, the central principle of investor protection has been disclosure. The securities laws set up complex requirements by which entities seeking to attract investors must provide information about what the entity will do with the investor's money.[494] In 1998, an ironically named hedge fund, Long Term Capital Management, told investors that it would use a widely publicized trading system devised by respected economists.[495] The fund used what amounted to a variation on what gamblers call the Martingale system: Whenever you lose, you double your bet, because the odds against an infinite string of losses are so slim that they aren't even worth considering.[496] But when the economies of many Asian countries encountered serious problems, the impossible became real and the highly leveraged fund collapsed and required an emergency government bailout.[497]

After 1998, proposals to regulate hedge funds were made, but never succeeded. The funds argued that their high minimum investment levels assured that their investors were sophisticated people who could take care of themselves.[498] Corporate and public pension funds became big investors in hedge funds that were paying out high levels of current income without giving investors much information.[499] So the lesson that hedge funds apparently took from the failure of LTCM was to never reveal your

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492 *But see* Alexia Brunet & Meredith Shafe, *Beyond Enron: Regulation in Energy Derivatives Trading*, 27 NW. J. INT'L L. & BUS. 665, 668 (2007) ("The collapse incited a public outcry against the wild free market of trading, viewed by most casual observers as speculative and manipulative.").

493 GEORGE A. AKERLOF & ROBERT J. SHILLER, ANIMAL SPIRITS: HOW HUMAN PSYCHOLOGY DRIVES THE ECONOMY AND WHY IT MATTERS FOR GLOBAL CAPITALISM 54–56 (2009).

494 JIM BARTOS, UNITED STATES SECURITIES LAW: A PRACTICAL GUIDE 1–3 (3d ed. 2006).

495 POSNER, *supra* note 384, at 126 ("The biggest warning sign of all had appeared much earlier—when Long-Term Capital Management faltered in 1998, was taken over by its creditors in a deal arranged by the Federal Reserve, and then expired.").

496 William N. Thompson et al., *Remedying the Lose-Lose Game of Compulsive Gambling: Voluntary Exclusions, Mandatory Exclusions, or an Alternative Method?*, 40 J. MARSHALL L. REV. 1221, 1243 (2007).

497 AKERLOF & SHILLER, *supra* note 493, at 82–85.

498 Steven L. Schwarcz, *Systemic Risk*, 97 GEO. L.J. 193, 203 (2008).

499 POSNER, *supra* note 384, at 244–45.

investment or trading strategy, but rely on the investors' trust that high current returns from a secret strategy promised a secure future.

Pyramid schemes flourished in this atmosphere. Many of them were not exposed until the decline in real estate, stock, and commodity values in 2008. Suddenly, a number of investment programs collapsed that had attracted investors with Enron-like secrecy.[500] They had been paying steady returns at levels significantly higher than found elsewhere in the market, and by refusing to disclose information about their strategy they convinced investors that they must know something about trading that no one else did.[501]

Seventy years of experience with legally mandated disclosure was abandoned, and the door was opened to fraudulent "snake oil merchants."[502] The government's ideological commitment to the free-market was "carried to new heights by the Bush Administration and is typified by the [Securities and Exchange Commission's] failure to detect the Madoff swindle."[503] A New York attorney, Marc Dreier, pled guilty to peddling millions of dollars worth of forged securities.[504] A Texan who operated offshore banks, Allen Stanford, was charged with defrauding investors throughout the United States and the Caribbean.[505]

Americans are not the only ones who have continued to be duped by these so-called pyramid programs. In 2008, in Colombia, a pyramid scheme managed by Daniel M. Guzman is said to have ensnared some 500,000 people and caused significant civil unrest.[506] In the 1990s, five million Russians lost their money through a pyramid scheme run by the MMM Investment Company.[507] During this same decade, hedge funds and other bank-substitutes provided equally secretive vehicles for investors who did not want to know how their money was being made. They claim to take very little risk, but "it has yet to be seen whether their strategies work only in normal times and then fail in times of crisis, when asset markets are unusually unpredictable."[508]

Americans seem to be particularly willing to believe that the law of averages can be beat. Do they really believe that traders are acting legitimately, or do they simply not care? Has deregulation fostered

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500 *See, e.g.*, Alec Wilkinson, *Not Quite Cricket*, NEW YORKER, Mar. 9, 2009, at 24.

501 *Id.* at 27.

502 AKERLOF & SHILLER, *supra* note 493, at 37.

503 POSNER, *supra* note 384, at 243; *see also* Weaver, *supra* note 454, at 30 (quoting Pat Wood III, FERC Chairman, in June 2001 as saying "[d]eregulation always benefits people" and "[i]f it doesn't, you have to rework it until it does").

504 Benjamin Weiser, *Lawyer Pleads Guilty in $400 Million Fraud*, N.Y. TIMES, May 12, 2009, at A23.

505 Jenny Booth & Hannah Strange, *Allen Stanford Fraud Charges Trigger Panic and Run on His Banks*, TIMES ONLINE, Feb. 18, 2009, http://www.timesonline.co.uk/tol/news/world/us_and_americas/article5760612.ece (last visited July 19, 2009).

506 *See generally* Helen Murphy & Andrea Jaramillo, *Columbia Bank Keeps Interest Rate at 10% on Inflation*, BLOOMBERG, Nov. 21, 2008, http://www.bloomberg.com/apps/news?pid=20601086&sid=aKkXs_PxnOgM&refer=news (last visited July 19, 2009) (describing a pyramid scheme in Columbia).

507 Barbara Rudolph, *Poof Go the Profits*, TIME, Aug. 8, 1994, at 44.

508 AKERLOF & SHILLER, *supra* note 493, at 38.

acceptance of corruption, as some economists believe, so that investors do not want to ask questions about how their money is being made?[509]

Meanwhile, the failure to effectively provide disclosure in the mortgage market led to an even greater eruption in the market place. Daniel Kaufmann of the World Bank points out that the subprime mortgage debacle had many elements of a pyramid scheme:

> Figure what consumers were told (including on their prospective house value appreciation) and promised by mortgage lenders when the massive rush to acquire a house with zero (or less. . .) down-payments. Then figure the role of mortgage bankers in selling such mortgages in the secondary market, then the role of other financial intermediaries, and of the risk rating agencies, in selling 'securitized' (hmmm) paper, and how they were supposedly 'guaranteed' through insurance schemes.[510]

A number of these new mortgage institutions "became corrupt at the core," and others simply closed their eyes to the risks their clients unknowingly assumed.[511] Even where the law required disclosure, the laws were rendered ineffective by the use of hundred-page indentures describing complex derivatives and by the use of salesmen who knew that first-time homebuyers could not understand intricate legal terminology.[512]

The scale of all of these deceptive practices was dramatically enlarged by removal of the most effective regulation of financial institutions—limits on leverage. Commercial banks had always been subject to inspection to ensure that the extent of their lending stayed within safe limits, but beginning in 1999, with the passage of the Gramm-Leach-Bliley Act,[513] a wide range of "non-banks" took over financial markets, including commercial bank holding companies that created their own separate entities to bypass leverage restrictions.[514]

The purpose of leverage limits was to forestall the kind of systemic risk that took place in the 1929 depression, when a buyer of stock was allowed to borrow the great majority of the price of the stock. When the market suddenly fell, these stockholders were often subject to margin calls that eliminated their entire investment. As the limits came off, leverage increased exponentially, creating the conditions that eventually devastated the financial markets in 2008.[515]

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509 *Id.* at 26; *see also Gluttons for Punishment? Investors in Hedge Funds Remain Unexpectedly Enthusiastic*, ECONOMIST, May 14, 2009, at 82.

510 Dani Kaufmann, *Ponzi Schemes in Russia, Colombia and the US: From Mavrodi to Murcia to Madoff (MMM)*, GOVERNANCE MATTERS, Dec. 18, 2008, http://governanceblog.worldbank.org/ponzi-schemes-russia-colombia-and-us-mavrodi-murcia-madoff-mmm (last visited July 19, 2009).

511 AKERLOF & SHILLER, *supra* note 493, at 155.

512 For a useful and amusing summary of the subprime mortgage situation, see Subprime Primer, http://www.slideshare.net/guesta9d12e/subprime-primer-277484 (last visited July 19, 2009).

513 Pub. L. No. 106-102, 113 Stat. 1338 (codified in scattered sections of titles 12 and 15 of U.S.C.).

514 *See generally* David Leonhardt, *Washington's Invisible Hand*, N.Y. TIMES, Sept. 28, 2008, at MM32 (describing the financial crisis and the problems created by the Gramm-Leach-Bliley Act).

515 JOHN KENNETH GALBRAITH, THE GREAT CRASH 18–22, 36–37 (1979).

Why were both investors and politicians willing to give leverage free rein in the last decade? Economists will probably spend the next decade debating this question, but to me the correlation with Americans' personal expenditures on gambling seems relevant. Arizona State University sociology professor Jeffrey Sallaz, whose book *The Labor of Luck* is due out in October 2009,[516] notes that recent data show that 25% of Americans' personal expenditures on recreation consist of gambling losses, up from 5% in 1990.[517]

In their 1995 book *Winner-Take-All Society*,[518] Robert Frank and Philip Cook posited that Americans' willingness to gamble so heavily against long odds for very large payoffs reflected wide income disparities and the decline of the century-old dream epitomized by Horatio Alger—the dream that even the poorest individual could become reasonably well off through honest work.[519] The new dream is fostered by the public's obsession with people such as television celebrities, sports figures, and billionaires.[520] This creates a strong desire to be at the very top of the heap, rather than being satisfied to be somewhere in the middle.[521]

This desire seems to have grown stronger as income disparities have grown during the past decade.[522] Ironically, of course, gambling just increases income disparity, which seems to lead to more desperate gambling, not just by people at the bottom of the income levels, but by relatively wealthy people such as those who invested in the now-defunct pyramid schemes. Where corruption is rampant, as it was in horse racing a century ago, people rely on tips from touts rather than their own analysis.[523]

3. Law and Economics Reevaluated

The views of economists about the events of 2008 are just beginning to be heard. As might be expected, many of the followers of neoclassical economic philosophy have reacted with attitudes ranging from puzzlement to despair.

Gregory Mankiw, Chairman of the Council of Economic Advisors from 2003 to 2006 and now a professor at Harvard, wrote an amusing article, *That Freshman Course Won't be Quite the Same*, in which he said "[e]conomists have yet to figure out what combination of mass delusion and perverse incentives led banks to undertake so much leverage."[524]

516 E-mail from Jeffrey Sallaz, Assistant Professor, University of Arizona Sociology, to Fred Bosselman, Professor of Law Emeritus, Chicago-Kent College of Law (May 5, 2009, 1:03 EST) (on file with author) (discussing Jeffrey Sallaz's forthcoming book, JEFFREY J. SALLAZ, THE LABOR OF LUCK: CASINO CAPITALISM IN THE UNITED STATES AND SOUTH AFRICA, at xiv (forthcoming 2009)).

517 *See* DALTON CONLEY, ELSEWHERE, U.S.A. 34 (2009) (citing JEFFREY J. SALLAZ, THE LABOR OF LUCK: CASINO CAPITALISM IN THE UNITED STATES AND SOUTH AFRICA (forthcoming 2009)).

518 ROBERT H. FRANK & PHILIP J. COOK, THE WINNER-TAKE-ALL SOCIETY (1995).

519 *Id.* at 14–16.

520 *Id.* at 203–06.

521 *Id.* at 32–36.

522 *See generally* NATHAN J. KELLY, THE POLITICS OF INCOME INEQUALITY IN THE UNITED STATES 9 (2009).

523 STEVE DAVIDOWITZ, THE BEST AND WORST OF THOROUGHBRED RACING 246–60 (2006).

524 N. Gregory Mankiw, *That Freshman Course Won't Be Quite the Same*, N.Y. TIMES, May 24, 2009, at BU5.

Financial institutions, he said, will need to become more prominent in the economics classroom.[525]

Judge Richard A. Posner, a distinguished student of private markets, takes a more dire approach: "The depression has hit economic libertarians in their solar plexus, because it is largely a consequence . . . of innate limitations of the free market."[526] The present depression appears to be the result of the normal operation of economic markets in a laissez-faire regime. The financial crisis is a failure of capitalism rather than a failure of government.[527]

Unlike the followers of behavioral theory, Posner argues that although emotion plays a role in the behavior of businessmen and consumers, as with all human beings, emotion it is not necessarily or even typically irrational. Risky behavior was individually rational during the bubble, but it was collectively irrational.[528] "A depression is too remote an event to influence business behavior."[529] Indeed, "[t]he most daring, aggressive players in the financial sandbox would ramp up the riskiness of their lending or other investing . . . [and] timid competitors would be forced to match the daring ones' strategy or drop out of the competition."[530]

No one had responsibility for systemic risk—the risk of failure of the entire financial system. Posner argues that all of the participants were merely acting out the roles that evolution allotted them: "[A]lthough the financiers bear the primary *responsibility* for the depression, I do not think they can be *blamed* for it—implying moral censure—any more than one can blame a lion for eating a zebra. Capitalism is Darwinian."[531]

Are bad faith and corruption truly "second nature" to practitioners of capitalism? Duke University's Steven Schwarcz reaches a similar conclusion from behavioral psychology. Because the costs of systemic risk extend to a wide group, while the benefits of gaming the system go to the individual manipulators, the manipulators will discount the likelihood of systemic risk because it seems so unlikely. "No firm . . . has sufficient incentive to limit its risk taking in order to reduce the risk of systemic contagion for other firms."[532]

Hedge funds did not endanger systemic risk as long as they were not operating as strategic financial intermediaries, Schwarcz suggests. He says there is little inherently unique about hedge funds "[o]ther than their lack of transparency," but that in today's market, where hedge funds are adopting aggressive investment strategies that may converge, the larger funds may have greater potential to create systemic risk.[533] However, one might wonder

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525 *Id.*

526 POSNER, *supra* note 384, at 306.

527 *Id.* at 235.

528 *Id.* at 106.

529 *Id.* at 28.

530 *Id.* at 323–24.

531 *Id.* at 284.

532 Schwarcz, *supra* note 498, at 206, 232.

533 *Id. at* 202–03.

whether the hedge funds' complete lack of transparency might not have been the proximate cause of systemic risk from the beginning.[534]

George Akerlof and Robert Shiller, in their book *Animal Spirits*, present a more detailed analysis of the behavioral factors that influenced recent market behavior.[535] Unlike Posner, they do not equate emotion and rationality. Markets function well only as long as people have confidence in them, and confidence is determined not only by a rational weighing of costs and benefits but by an irrational reliance on "stories." Economists have been wary of stories, they note. "But what if the stories themselves move markets? . . . What if [the stories] themselves are a real part of how the economy functions?"[536]

"New era stories," which purport to describe historic changes that will propel the economy into a brand new era, did not die with the end of the dot com boom. Investor confidence continued to snowball as stories about people getting rich by flipping real estate circulated.[537] "High confidence tends to be associated with inspirational stories, stories about new business initiatives, tales of how others are getting rich."[538] Stories about the inevitability of rising home prices and the success of people who flipped homes abounded during the run up to 2008.[539] Such naive beliefs about real estate were not rational, but they spread by word of mouth, feeding the boom.[540]

But confidence can be lost by new perceptions of corruption, bad faith, or unfairness, and these perceptions are not the result of rational analysis, but of stories of individual misbehavior and its impact on people like the Madoff investors. Lack of confidence can be contagious when such stories dominate public thinking, and "epidemics of pessimism may arise mysteriously simply because there was a change in the contagion rate of certain modes of thinking."[541]

4. Voluntary Carbon Offset Market

To what extent are the recent market difficulties likely to weigh on the various markets for "swamp swaps" discussed in this Article? Probably the closest existing American analogy to the kind of markets that might benefit wetlands is the so-called "voluntary carbon offset market" in which

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534 As long as the "new era story" of the magic hedge fund prevails, I fear that the beneficial attributes of markets will not be achieved because markets today move at time and space scales that severely strain the capacity for oversight even when trading rules are well established. *See* Weaver, *supra* note 454, at 31–32.

535 AKERLOF & SHILLER, *supra* note 493.

536 *Id.* at 54.

537 I suspect that the gaming of markets has also been fostered by the declining reliance on carefully edited journalism. Blogs make floating rumors much easier than it used to be. Who could find out if I were to adopt a strategy of sell short, spread stories, and clean up? And if they did discover my strategy, how could they prove it when cyberspace makes identity so easy to conceal?

538 AKERLOF & SHILLER, *supra* note 493, at 55.

539 *Id.* at 153–55.

540 *Id.* at 151.

541 *Id.* at 56.

American companies can participate. Companies use this market to be able to say that they have offset their emissions of greenhouse gases and are therefore "carbon neutral."[542]

In 2007, members of Congress asked the Government Accountability Office (GAO) to describe the scope and analyze the credibility of the voluntary carbon offset market.[543] It produced a report in August 2008.[544] The GAO found that over 600 organizations are developing, marketing, or selling carbon offsets in the United States in a market with no significant government oversight:

> Project developers implement individual projects and may sell offsets directly to consumers or to intermediaries. Intermediaries are further subdivided into retailers, aggregators, and brokers, among other categories. Retailers generally sell smaller quantities of offsets to individuals or organizations. Aggregators, also known as wholesalers, sell in bulk and often own a portfolio of offsets. Brokers facilitate transactions between sellers and buyers.[545]

Consumers motivated by corporate responsibility or public relations may purchase offsets to compensate for emissions that result from a variety of activities including flying, driving, and purchasing consumer products.[546] The GAO found that about half of the offsets came from projects that claimed to "capture and destroy methane from coal mines, agricultural operations, or landfills"—projects that were likely to be profitable without the offsets.[547] Another nineteen percent was produced from projects that "capture emissions from industrial and energy-related emissions sources and then store these emissions in geologic formations."[548] An additional seventeen percent was produced from "biological sequestration projects, including agricultural soil projects such as no-till farming and forestry projects."[549]

The GAO purchased offsets anonymously from thirty-three retail providers. Few retailers identified specific projects associated with the transaction. Only two explained how their project met the test of "additionality."[550] The GAO found that general information provided on web sites "could not be linked to particular transactions," and "found it difficult, in

542 *See* U.S. GOV'T ACCOUNTABILITY OFFICE, HIGHLIGHTS OF GAO-08-1048: CARBON OFFSETS 1 (2008), *available at* http://www.gao.gov/highlights/d081048high.pdf.

543 *Id.*

544 *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFFICE, CARBON OFFSETS: THE U.S. VOLUNTARY MARKET IS GROWING, BUT QUALITY ASSURANCE POSES CHALLENGES FOR MARKET PARTICIPANTS (2008), *available at* http://www.gao.gov/new.items/d081048.pdf.

545 *Id.* at 10.

546 *See* David A. Farenhold, *There's a Gold Mine in Environmental Guilt*, WASH. POST, Oct. 6, 2008, http://www.washingtonpost.com/wp-dyn/content/article/2008/10/05/AR2008100502518.html (last visited July 19, 2009); *see also* U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 544, at 10.

547 U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 544, at 14.

548 *Id.*

549 *Id.*

550 *Id.* at 30.

many cases, to determine exactly what we had purchased," so it concluded that "consumers in the offset market may face similar challenges."[551]

David Greising, the chief business correspondent for the *Chicago Tribune*, says that voluntary credits "exist in an unregulated and sometimes opaque netherworld, where the demands of 'greenwashing' and public relations can trump the need to protect the atmosphere and mitigate global warming."[552] Jeffrey Ball, writing for the *Wall Street Journal*, found many questionable examples of landfills getting credits for profitable things they were doing anyway:

> The Federal Trade Commission also is examining whether the marketing is deceptive—in particular, whether credits really represent emission cuts that wouldn't otherwise have happened. With a tangible product, say, an apple, a buyer can easily judge a seller's claims that it's "crisp and juicy and red," says James Kohm, associate director of the FTC's enforcement division. Intangible products, such as pollution credits, "have a greater potential for deception."[553]

Offsets for no-till farming are frequently permitted,[554] although recent research suggests that this farming method does not necessarily increase carbon storage.[555]

A recent study of both regulated and unregulated carbon markets noted that most markets utilize a potentially problematic system for auditors: "[M]ost standards require third-part [sic] auditors to verify the emissions reductions. Yet auditors are chosen and paid by a project's developer. There is thus pressure on the auditors to approve projects in order to preserve their business relationships with the project developers. This compromises the auditors' independence and neutrality."[556] The study found that no voluntary market had "specific procedures in place to review the approved auditors nor to allow for sanctions against or the discrediting of an underperforming auditor."[557]

Much of the public has become more amused than impressed by the claims of carbon neutrality,[558] but it is traders and dealers who continue to

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551 *Id.*

552 David Greising, *The Carbon Frontier*, BULL. ATOM. SCIENTISTS, July–Aug. 2008, at 35, *available at* http://metapress.com/content/00143k749w7p8307/fulltext.pdf.

553 Jeffrey Ball, *Pollution Credits Let Dumps Double Dip*, WALL ST. J., Oct. 20, 2008, at A14. The FTC held a workshop on carbon credits in January 2008, but as of this writing has taken no further action. *See* Fed. Trade Comm'n, FTC Reviews Environmental Marketing Guides, Announces Public Meetings, http://www.ftc.gov/opa/2007/11/enviro.shtm (last visited July 19, 2009).

554 *See e.g.*, Greising, *supra* note 552, at 32.

555 Vincent Poirier et al., *Interactive Effects of Tillage and Mineral Fertilization on Soil Carbon Profiles*, 73 SOIL SCI. SOC'Y AM. J. 255, 255 (2009).

556 ANJA KOLLMUSS ET AL., WORLD WILDLIFE FUND, MAKING SENSE OF THE VOLUNTARY CARBON MARKET: A COMPARISON OF CARBON OFFSET STANDARDS 90 (2008), *available at* http://assets.panda.org/downloads/vcm_report_final.pdf.

557 *Id.* at 91.

558 For an amusing send up of the voluntary carbon market, see Cheatneutral, http://cheatneutral.com (last visited July 19, 2009).

push market-based regulatory systems.[559] The prospect of stacking credits for different benefits is particularly mouth watering,[560] and energy traders are concerned that new regulations of derivatives may hamper the creation of securities based on carbon-related derivatives.[561]

5. Integrity v. Innovation

Markets undeniably perform important functions. By providing liquidity they encourage investment. By offering a theoretically unlimited up-side they encourage creative risk-taking. By encouraging competition they discourage satisfaction with the status quo. But they perform these functions only as long as they are perceived as institutions with integrity.[562]

It is possible to imagine systems of regulating markets for wetland functions that would provide a reasonable degree of confidence in the integrity of the process. But could this be done without limiting projects to a few well-accepted types for which demonstration of integrity was economically feasible?[563] Such a limitation might be acceptable in a field that has been thoroughly studied over a long time, but wetlands research is at an earlier stage, and more applied research is needed.

The U.S, Congress actually recognized the need for this type of applied research, but hardly anyone seems to have noticed. Section 712 of the Energy Independence and Security Act of 2007 directs the Secretary of the Interior to develop a land use and management strategy that can be used to increase the sequestration capabilities of carbon dioxide, methane, and nitrous oxide of any ecosystem, or to reduce the emissions of such gases from any ecosystem.[564]

Under section 712, the Secretary is directed to 1) "determine the processes that control the flux of greenhouse gases in and out of each ecosystem," 2) "estimate the potential for increasing carbon sequestration in natural and managed ecosystems through management activities or restoration activities in each ecosystem," 3) "develop near-term and long-term strategies" to "enhance the sequestration of carbon" and "reduce emissions of greenhouse gases from ecosystems," and 4) "estimate the

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[559] *See* Leila Abboud, *Carbon King: Economist Strikes Gold in Climate-Change Fight*, WALL ST. J., Mar. 13, 2008, at A1.

[560] Roger Feldman, EBA Climate Change Primer: Financing a Renewable Energy Project, Panel Presentation at Energy Bar Association (Nov. 30, 2007), *in* 29 ENERGY L.J. 195, 201 (2008).

[561] Brian Baskin & Gregory Meyer, *Crackdown Worries Energy Markets: Observers Say Proposed Regulations on Derivatives Complicate Trading*, WALL ST. J., May 19, 2009, http://online.wsj.com/article/SB124260335094228561.html (last visited July 19, 2009).

[562] *See, e.g.*, Stephenson Testimony, *supra* note 386, at 3–8.

[563] Driesen, *supra* note 425; Wara, *supra* note 393, at 1780.

[564] *See* Energy Independence and Security Act of 2007, 42 U.S.C. § 17,272 (West Supp. 2008) "The term 'ecosystem'' means any terrestrial, freshwater aquatic, or coastal ecosystem, including an estuary." *Id.* § 17,272(a)(4).

annual carbon sequestration capacity of ecosystems" under a range of management policies.[565]

No funds appear to have been appropriated by Congress to carry out this work, nor have I found any subsequent reference to section 712. However, someone obviously thought enough about these issues to have recognized that the interplay of various greenhouse gases in systems such as wetlands deserves further study. Whether the current state of the science would allow the Secretary to reach such an assessment is a question that I cannot answer.

IX. THE "FIRST NATURE" OF WETLANDS

Is it possible to understand and appreciate the creativity and technology that allow us to create a "second nature" in wetlands while we still cherish their "first nature"? Henry David Thoreau, often viewed as a precursor of the John Muir school of nature preservation, was actually a more complex person who valued both the protection and management of nature.[566]

In the journals in which Thoreau recorded his daily walks he often commented on his frequent visits to what we now call wetlands. Thoreau absorbed the wetlands through all of his senses. He searched for the skunk cabbage that marked the end of winter,[567] listened for the arrival of the swamp sparrow in the spring,[568] smelled the sweet fern that perfumed the marsh,[569] enjoyed the berries that grew on the edge of the swamps,[570] and liked the feel of the wriggling turtle's shell.[571]

Thoreau loved the wetlands at all seasons. In January he wrote, "I love to wade and flounder through the swamp now, these bitter cold days when the snow lies deep on the ground, and I need travel but little way from the town to get to a Nova Zembla solitude."[572] In June he wrote, "Would it not be

565 *Id.* § 17,272(c).

566 South African zoologist Matthew Child says that each new conservation graduate should take a "Thoreauvian oath": Nature should be preserved because it makes the world a better place. Matthew F. Child, *The Thoreau Ideal as a Unifying Thread in the Conservation Movement*, 23 CONSERVATION BIOLOGY 241 (2009).

567 Henry David Thoreau, Journal (Apr. 2, 1856), http://www.walden.org/Institute/thoreau/writings/Writings1906/14Journal08/Chapter%206.pdf (last visited July 19, 2009).

568 Henry David Thoreau, Journal (May 29, 1855), http://www.walden.org/Institute/thoreau/writings/Writings1906/13Journal07/Chapter%209.pdf (last visited July 19, 2009).

569 HENRY DAVID THOREAU, *Journal of June 16, 1840*, *in* 1 THE WRITINGS OF HENRY DAVID THOREAU: JOURNAL 141 (Bradford Torrey ed., Houghton Mifflin & Co. 1906), *available at* http://www.walden.org/Institute/thoreau/writings/Writings1906/07Journal01/Chapter%204.pdf.

570 HENRY DAVID THOREAU, *Journal of August 6, 1860*, *in* 14 THE WRITINGS OF HENRY DAVID THOREAU: JOURNAL, *supra* note 569, at 18, *available at* http://www.walden.org/Institute/thoreau/writings/Writings1906/20Journal14/Chapter%201.pdf.

571 HENRY DAVID THOREAU, *Journal of August 28, 1856*, *in* 9 THE WRITINGS OF HENRY DAVID THOREAU: JOURNAL, *supra* note 569, at 31–32, *available at* http://www.walden.org/Institute/thoreau/writings/Writings1906/15Journal09/Chapter%201.pdf.

572 HENRY DAVID THOREAU, *Journal of January 10, 1856*, *in* 8 THE WRITINGS OF HENRY DAVID THOREAU: JOURNAL, *supra* note 569, at 99, *available at* http://www.walden.org/Institute/thoreau/writings/Writings1906/14Journal08/Chapter%203.pdf.

a luxury to stand up to one's chin in some retired swamp for a whole summer's day, scenting the sweet-fern and bilberry blows, and lulled by the minstrelsy of gnats and mosquitoes?"[573]

Why was Thoreau so attracted to the bogs and marshes and fens and swamps? Perhaps because each particular wetland was made up of its own special collection of organisms living on the edge of the more solid or liquid habitats that humans preferred. Maybe a man who liked to live along the edge of ordinary human society felt a natural kinship with these evanescent grounds. "Thoreau savored opposites, that the muddied swamp waters are as interesting to him as the pond waters that are crystal clear."[574]

His journals record the daily impressions of a man who not only loved every component of nature, but saw a swamp as a metaphor for the interrelationship of nature and humanity. Thoreau knew that the wetlands were "ecotones" even though the word did not yet exist. In the swamp there is a thin line between dry and wet ground. There is a thin line, too, between appreciation of nature and understanding of scientific knowledge. "Henry David Thoreau appreciated, loved, revered, and took joy in both nature *and* civilization."[575]

Thoreau was also a gardener, and sometimes engaged in what we now call ecosystem management. "As an observer and a naturalist, Thoreau consistently refuses to make 'invidious distinctions' between different orders of nature; sworn enemy of hierarchy, the man boasts of the fact that he loves swamps more than gardens."[576] But his primary source of income was his family's pencil factory, and Thoreau used his engineering skills to develop a model that became known as the best pencil in the world.[577]

Daniel Botkin concludes,

> The swamp on the edge of town provides the mixture that leads to the best in human life, and that was Thoreau's desire. Nature and civilization need each other. Perhaps if we learn to "think like a swamp," we might find a way to sustain both the organic soils and the organic innovation of humanity.[578]

Smithsonian anthropologist Rick Potts posits that the creative talent to manage our environment is the result of an evolutionary process that has allowed humans to survive so successfully. He suggests that the human species may have survived for millions of years, during which time it faced

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573 HENRY DAVID THOREAU, *Journal of June 16, 1840*, *in* 1 THE WRITINGS OF HENRY DAVID THOREAU: JOURNAL, *supra* note 569, at 141, *available at* http://www.walden.org/Institute/thoreau/writings/Writings1906/07Journal01/Chapter%204.pdf.

574 ROBERT SULLIVAN, THE THOREAU YOU DON'T KNOW 13 (2009).

575 DANIEL B. BOTKIN, NO MAN'S GARDEN: THOREAU AND A NEW VISION FOR CIVILIZATION AND NATURE, at xxi–xxii (2001).

576 MICHAEL POLLAN, SECOND NATURE: A GARDNER'S EDUCATION 108 (1991).

577 SULLIVAN, *supra* note 574, at 140–42.

578 BOTKIN, *supra* note 575, at 44.

wide differences in survival conditions.[579] Evolution would have favored retention of those mutations that might help the species to adapt to ongoing environmental change, which has probably contributed to our ability to adapt to so many different environments.[580]

I recognize the value of ecosystem management, and its necessity if we are to cohabit with nature in a world in which we are making such a formidable impact, but I hope that we will not try to manage every single place. In his book *Nature's Metropolis*, William Cronin related how the tall grass prairies and white pine forests of the Midwest were converted to "second nature" commodities.[581] The process has continued unabated; farmers plant monocultures of a few varieties of corn and soybeans from fence to fence.[582] Now, only isolated remnants of the prairie remain, and great effort is required to reimagine and reconstruct their historic condition.[583] Any stand of really old white pine is hard to find.[584]

Of course, we can justify saving some unmanaged wetlands from a utilitarian perspective. Scientists can watch how human and natural modifications of the environment change these wetlands, and perhaps learn better ways of improving managed wetlands for our own benefit. "[M]an occasionally creates new ecosystems much richer than the ones they replaced . . . [such as] the tall-grass prairies of the Midwest, [or] England's hedgerow landscape . . . . Most of us would be happy to call such places 'nature,' but that does not do them (or us) justice; they are really a kind of garden, a second nature."[585]

But I would hope that the idea of unmanaged nature would lure a new generation of Thoreaus to smell, hear, watch, taste, and feel the wetlands with a sense of awe toward nature's complexity that will provide a counterweight against a gardener's untempered admiration of the wonders of horticulture. Sauntering through nature while observing it closely, as Thoreau did, may seem like an educational process far removed from standardized tests and computer drills, but for trailblazers like Darwin and Mendel it created a desire to learn more. "The seamless, unforced play of a concert pianist starts with a kid picking out tunes on the piano, right? His fingers didn't always know what to do. . . . Only much later does it become second nature."[586]

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579 *See* RICK POTTS, HUMANITY'S DESCENT: THE CONSEQUENCES OF ECOLOGICAL INSTABILITY 243–47 (1996).

580 *Id.* at 232, 243–47.

581 CRONON, *supra* note 1, at 151–52.

582 *See, e.g.*, POLLAN, *supra* note 576, at 220.

583 Dan L. Flores, *A Long Love Affair with an Uncommon Country: Environmental History and the Great Plains*, *in* PRAIRIE CONSERVATION: PRESERVING NORTH AMERICA'S MOST ENDANGERED ECOSYSTEM 6–9 (Fred B. Samson & Fritz L. Knopf eds., 1996) (discussing the changing landscape of the Great Plains over time and the cultural difficulties in re-imagining that landscape).

584 *See* CRONON, *supra* note 1, at 200–03 (describing the late 19th century wholesale destruction of the White Pine forests in the Midwest).

585 POLLAN, *supra* note 576, at 194.

586 *Id.* at 120.