vide an objective way to decide on the degree of preservation of different environments of the world's coasts.

The results also suggest several fertile areas for further research. First, it is important to determine how general nonlinearities may be; in the Thai mangrove example, the value of coastal protection by wave attenuation was nonlinearly related to the area of mangrove loss, but yields of fishery and wood products were linearly related to habitat area. Second, scientists must establish whether the deviations from linearity are significant in both ecological and management terms to make sure that implementation of policies resulting from use of curved functions leads to detectable differences. Third, more solid evidence is needed that a service is actually being provided; for instance, there has been considerable debate about how much wave protection is provided by mangroves (*7*–*11*). Fourth, future studies should more comprehensively cover the suite of locally relevant factors influencing economic value. Barbier (*12*) made a good start toward addressing local issues by quantifying the net effects of economic costs and benefits resulting from conversion of mangrove forests to shrimp farming, but the valuation might benefit by addition of a few key terms. In Ecuador, for example, the shrimp industry came to a standstill not because of deficit income, but because the supply of juvenile shrimp in nearby waters (used as the "seed" for shrimp ponds) was depleted by overfishing. In Ecuador and elsewhere, the mangrove conversion rate may be accelerated by the need to abandon ponds that, as a result of high-yield culture methods, have become too chemically altered to be suitable for shrimp growth.

Finally, Barbier *et al.* point to the need to determine ecosystem-based management for coastal areas by weighing and incorporating the interests of several players: shrimp farmers, who will think about the price of shrimp, but are unlikely to consider long-term, regional benefits of coastal protection when deciding whether to dig another pond; outside investors, who might not know or care about mangrove services; and officials, who might be responsible for implementing regional environmental strategies that foster ecological services.

The report by Barbier *et al.* highlights the complexities involved in making the compromises needed for future coastal management. Research from the study areas pointed out above will show whether "bent" relationships make for compromises that are not only ecologically desirable, but also enable compromises for planned management of coastal wetlands that are acceptable to the diverse stakeholders.

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GEOLOGY

Dreams of Natural Streams

Human influences have fundamentally changed river morphologies in temperate regions around the world.

David R. Montgomery

What does a natural river look like? Centuries of human influence can mask historically distinctive river forms in and among regions around the world (see the figure). Results reported by Walter and Merritts on page 299 of this issue (*1*) suggest that human modification of riverscapes has been so extensive that even some fundamental ideas about how rivers work bear the stamp of human influence. The authors show how colonial mill dams and land use changed New England's streams from a marshy multichannel morphology to today's meandering single-channel form.

This transformation is obviously fascinating to students of regional environmental history, but it is not only of academic interest. Understanding how natural streams work is crucial for river restoration, an academically young discipline that is rapidly maturing into a billion-dollar-a-year industry. The classic sinuous form of meandering channels (*2*) has come to represent a natural ideal in channel-restoration design—even for rivers for which such an ideal is historical fiction.

Modern fluvial geomorphology—the study of rivers—evolved out of the studies of Luna Leopold, M. Gordon Wolman, and their colleagues in the 1950s. As the field developed, pioneering studies of streams in the eastern United States contributed to a standard model for how fluvial processes shape rivers and floodplain environments. This model has been elaborated upon and exported around the world. Indeed, these now classic studies provided the basis for the so-called natural channel design central to many river-restoration efforts across the United States (*3*).

Walter and Merritts now show that some of the rivers studied by Leopold, Wolman, and colleagues were not so natural after all. The new study does not challenge their fundamental insights into how the interplay of hydraulics and sediment transport shapes river and stream channels, but in light of the new findings, what constitutes a natural channel form requires reexamination.

The results parallel findings in Europe and the Pacific Northwest of how historical clearing of large wood and logjams altered river morphology. Before European rivers were cleared to promote waterborne commerce, large trees and logjams obstructed many rivers; local blockages split flow into multichannel networks of branching streams (*4*). Similarly, downed wood split channels into branching networks of small channels flowing across slough-rich valley bottoms in the forested floodplains of the Pacific Northwest (*5*, *6*).

Walter and Merritts now present compelling evidence for a similar change that radically altered rivers in the eastern United States. Thus, a comparable transition from

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Natural or not? A single-channel meandering form provides the template for many river engineering and restoration projects, but as Walter and Merritts show in this issue, it may not reflect forms that predated anthropogenic modifications.

multithread channels to meandering single-thread channels occurred in all three regions. This observation suggests that a common transformation accompanied human development of temperate forest rivers.

Walter and Merritts also help to resolve a long-standing geographical conundrum. Recent studies have confirmed the long-articulated idea that modern agriculture greatly accelerated rates of soil erosion (*7–9*), but at the same time, sediment delivery to oceans declined by half (*10*). Where is all the dirt thought to have been stripped from upland farms? Walter and Merritts show that tremendous amounts of floodplain sediment previously thought to date back thousands of years actually represents material impounded behind mill dams. Here may lie much of New England's precolonial topsoil.

The study by Walter and Merritts also has substantial implications for river restoration. The implicit mantra of such restoration programs—enough studying, let's just fix it—has been based on the idea of reengineering an archetypal meandering channel form. Given the compelling demonstrations of extensive human alteration of the fundamental morphology of river systems in New England (*1*), Europe (*4*), and the Pacific Northwest (*5*, *6*), the first step in a river-restoration program should instead be to develop a solid understanding of what the targeted rivers were actually like before the changes that restorationists seek to undo or mitigate.

Over recent decades, substantial progress has been made in deepening the understanding of how rivers work and addressing how different environmental contexts in different regions left their own mark on rivers. The report by Walter and Merritts shows that it pays to do the painstaking work of historical sleuthing—even in areas thought to define benchmarks in understanding.

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PHYSICS

Probing Quantum Magnetism with Cold Atoms

The interactions of atoms held in an optical trap reveal fundamental mechanisms of magnetism.

Maciej Lewenstein and Anna Sanpera

In 1995, ultracold atoms were experimentally locked together in a single quantum state known as a Bose-Einstein condensate (*1*). Since then, researchers keep broadening the scope of research with ultracold atoms. On page 295 of this issue, Trotzky *et al.* (*2*) report measurement of interactions between atoms trapped in an optical lattice that are analogous to the interactions between atomic spins in magnetic materials, a phenomenon called "superexchange." This is an essential step toward experimental realization of models for studying arrangements of quantum spins. These relatively simple models will help us study and understand the most fundamental physics associated with quantum magnetic ordering, quantum phase transitions, and a large zoo of exotic quantum phases.

Although spin models have been traditionally constructed as ideal approximations of real magnetic materials, many theorists have pointed out that ultracold atoms in optical lattices allow for an almost perfect realization of these systems [see review (*3*) and references therein]. An optical lattice is a spatially ordered array of potential wells or traps produced by the interference pattern of counterpropagating laser beams. In simpler terms, the optical lattice looks effectively like an egg carton, where the atoms, like eggs, can be arranged one per well to form crystals of quantum matter.

These quantum crystals can be controlled and manipulated by modifying the frequency, intensity, or polarization of the lasers forming the lattice. One can also superimpose a secondary optical lattice (or "superlattice") on top of the primary one to further modify the potential in which the atoms are trapped.

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