Banking on Mitigation

New regulations might change the landscape of national wetlands policy

Although the Clean Water Act protects U.S. wetlands, every year thousands of acres of swamps and marshes are legally destroyed and converted into golf courses, shopping malls and other forms of dry, lucrative ground. Since 1989, the goal of wetlands policy has been to achieve "no net loss," but that remains an elusive target. Under current guidelines, developers whose projects will impinge on natural wetlands can receive permits allowing construction in return for agreeing to offset the damage through a process known as compensatory mitigation. The two most common forms of this practice are individual mitigation, in which developers build compensatory wetlands themselves, and mitigation banking, in which developers purchase credits from companies (mitigation banks) that have restored or created wetlands nearby.

In theory, it's a pretty straightforward system—for each acre of natural wetland lost there should be at least one acre created or restored. But a 2001 study by the National Research Council concluded that despite mitigation efforts the country was losing about 60,000 acres of wetlands annually. Last spring, in an attempt to improve the process, the U.S. Army Corps of Engineers proposed new regulations that would force developers to meet stricter—that is, more expensive—standards for individual mitigation sites, which might make mitigation banks seem like a bargain in comparison.

According to the Corps, increased use of mitigation banking will address many of the problems that have kept "no net loss" from being realized. But a number of studies, and quite a few scientists, dispute the benefits of mitigation banks—and question whether it's even possible to engineer successful wetlands.

"How do you re-create something that took nature a thousand years to develop?" asks Joy B. Zedler, an ecologist at the University of Wisconsin-Madison and one of the authors of the NRC report. "You don't." At least not, she says, within the timescale imposed by the Corps. Most mitigation sites are subject to no more than five years of oversight, but some wetlands, particularly forested areas, might take decades to replace adequately the land lost to development.

At a mitigation-banking site in North Carolina, workers convert former agricultural land to wetlands. (Photograph courtesy of George Howard, Restoration Systems.)

According to Zedler, the primary obstacle is that although scientists know that welands help regulate water cycles, serve as water filters and provide habitat for diverse flora and fauna, even specialists don't always know how they do it. William M. Lewis, Jr., an ecologist at the University of Colorado at Boulder, believes that for now "we don't have any reliable way of replicating functions and values."

A study published last year by Ohio's Environmental Protection Agency supports these concerns. The agency studied 12 mitigation-banking sites across the state to determine how well they mimicked natural conditions. The results weren't particularly promising. Twenty-eight percent of the area surveyed consisted of shallow ponds lacking rooted vegetation and could not be considered functioning wetlands. Most of this acreage, however, had either already been sold as credits or approved for sale.

The Ohio EPA also found that plant communities were generally of lower quality than natural wetlands and more likely to be home to invasive species. The banking sites scored even worse when judged by the presence of amphibians. None provided habitat for either wood frogs or spotted salamanders, which the report called indicative of successful sites, and all were dominated by just a few species of frogs.

Of course, individual mitigation sites face all of these same difficulties. But two factors add to the risks of banks. First, if one small individual mitigation site fails, the effects on the surrounding landscape should be minimal. The collapse of a large bank site is a much more costly mistake. Second, whereas developers who create their own mitigation sites are usually required to do so in the immediate vicinity of the destroyed wetlands, mitigation banks tend to be located farther from the impact sites.

At the same time, mitigation banking has a number of points in its favor. For one thing, purchasing credits from a bank that has already restored or created wetlands can reduce or eliminate the time lag between the impact of development and the construction of new wetlands. According to George Howard, co-founder of Restoration Systems, a mitigation-banking company based in North Carolina, there's another advantage to mitigation banks: "Unsuccessful projects could bankrupt me personally," he says, "and that's a great incentive to succeed."

Perhaps the biggest problem with individual mitigation is that no one knows just how well it works. In 2005, the Government Accountability Office issued a report showing that the Corps rarely visited sites to ensure that required mitigation was being completed. And in most cases, annual monitoring reports from the permit recipients (usually a condition of approval) were never filed. "Until the Corps takes its oversight responsibilities more seriously," the report concluded, "it will not know if thousands of acres of compensatory mitigation have been performed."

So although many wetlands ecologists don't share Howard's enthusiasm for banking, there is agreement that, as he puts it, "the alternatives are a sad, sad story." According to the Corps, the drafted regulations are unlikely to change significantly before being finalized later this year, which means that mitigation banks will soon become an increasingly important part of national wetlands policy. Whether that's a step toward "no net loss" remains to be seen. As Zedler says, "there's a lot of promise in mitigation banking, but it all depends on how it's done."—*Amos Esty*

Sensitive Cells

Stem cells take their cue from their physical surroundings

Our choice of careers as adults isn't determined by whether we slept on a cot or a feather mattress as a child. But then, we're not stem cells (at least, not any more). A pair of recent reports shows that when scientists grow stem cells in the laboratory, the physical properties of the cells' culture-dish homes influence when they will adopt a distinct path in life and what that path will be.

At the 2006 annual meeting of the American Society for Cell Biology in San Diego last December, Christopher J. Murphy of the University of Wisconsin-Madison presented data showing that embryonic stem cells are more likely to keep their *pluripotency*—their ability to become any type of cell—when they are grown on a surface stamped with a pattern of tiny ridges. The effect was independent of the scale of the ridges, which ranged from nanometers to micrometers in width. Traditionally, cultured cells are grown on smooth glass or plastic surfaces.

This finding challenges the ingrained culture of cell culture, which has long assumed that the molecules dissolved in the liquid medium that bathes cells, including growth factors and other chemical signals, had the last word in determining cell physiology. Murphy disagrees, citing work in his laboratory that shows physical properties of the surface to be "as fundamental an element [in determining cell behavior] as having growth factors in the media."

So what exactly does the physical topography do to the cell? "What doesn't it do?" asks Murphy. "It changes everything—adhesion, migration, proliferation, differentiation." From his systems-engineering perspective, the research offers potential benefits for the large-scale production of embryonic stem cells, which have the theoretical ability to divide indefinitely but often lose pluripotency for reasons that are poorly understood.

The Wisconsin team's findings echo previous work by scientists at the University of Pennsylvania. In the August 25, 2006, issue of the journal *Cell*, the Penn group showed that the fate of mesenchymal stem cells could be directed by the stiffness of the substrate on which they were grown. Mesenchymal stem cells come from adult bone marrow.

A research team led by Dennis E. Discher found that stem cells grown on the stiffest matrix became bone precursors. Those grown on the softest surface became nerve cells, and those grown on a medium-stiff substrate assumed the characteristics of muscle cells. The shapes of the cells and the suite of active genes contained within confirmed their new identities. Previous studies had shown that chemical cues could effect this kind of differentiation, but Discher's paper was the first to demonstrate that cell lineage could be controlled in the absence of soluble stimuli.

This property makes sense, Discher says, given the role of such cells in tissue regeneration and repair. "These [mesenchymal stem] cells leave the bone marrow and end up in different places—muscle, bone, fat." But to repair muscle, or become a neuron in the brain or cartilage at the end of a bone, the stem cell must become anchored and "physically engage the microenvironment" before becoming one of the gang.

Such differences in the relative stiffness of animal tissues are easy to appreciate, according to Discher. "You can feel it. You know brains, calf's brains, how soft they are? I take you to the supermarket, you can feel the difference between steak and bone, or between fat and calf's brains."

But groceries aside, how exactly does a cell "feel" the surface it grows on? "It starts with attachment and contraction," explains Discher. Cells create what are called *focal adhesions*—points of attachment on the substrate—that provide a foundation for the cytoskeleton. A type of motor protein known as nonmuscle myosin II applies tension to the actin filaments of the cytoskeleton. At the end of the line, a complex of proteins near the focal adhesion appears to act as a "mechano-transducer," translating physical forces into intracellular signals. In the *Cell* paper, Discher and his colleagues showed that inhibiting myosin prevented the substrate-based differentiation.

The strong effect of physical properties on cell behavior in these experiments doesn't mean that scientists were wrong before about soluble signals. On the contrary, the two types of stimuli seem to work together. But Discher states—using language similar to Murphy's—that "physical cues are just as influential [on cell fate] as chemical cues. It's a balance." In his mesenchymal stem cells, differentiation was more complete when chemical and physical cues pointed in the same direction.

The potential implications of this work for cell biologists are profound, given that everything scientists know about the way cells behave in culture comes from experiments on hard, smooth surfaces. For this reason, Discher cautions that biologists need to "take those data [from rigid substrates] with a grain of salt." Given the tens of thousands of research papers that include such methods, that's a lot of salt.—*Chris Brodie*