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Technology Can Wear a White Hat

New technologies have dramatically increased human prosperity and welfare, but they have also had many insidious consequences for coastal ecosystems. The moldboard plow allowed productive harvests from the land, but caused sediments to wash into and fill bays and estuaries. Steam-powered vessels permitted industrial-scale removal of oyster reefs that took thousands of years to build. Mechanized power allowed humans to channel and even redirect rivers, and dredge and fill wetlands, spelling disaster for Louisiana's coastal wetlands, for example. The internal combustion engine afforded wonderful mobility, but spawned sprawl, pavement and flashy runoff, and the deposition of exhaust pollutants. The invention of the Haber-Bosch process for synthesizing ammonia allowed the agricultural revolution that feeds the world's six billion people, but ultimately caused eutrophication of many of the world's coastal waters, with resulting dead zones, disappearing seagrass meadows and harmful algal blooms. Chemists created useful new compounds such as pesticides, PCBs and flame retardants, some of which are persistent organic pollutants that are even finding their way to Arctic ecosystems. Acoustic fish finders and GPS allow fishers to efficiently harvest already depleted resources.

As our society moves from trying to manage impacts to actually restoring degraded coastal ecosystems, however, there are substantial opportunities in this more enlightened age for technology to become the ally of healthy coastal ecosystems rather than their foe. Technology can wear a white hat for a change.

Massive efforts are underway, or on the drawing boards, for the restoration of some of the nation's largest coastal ecosystems. The estimated costs are substantial—$8 billion authorized for the Everglades, $13 billion estimated to achieve Chesapeake Bay commitments, $0.4 billion already spent for the CALFED program for the San Francisco Bay-Delta and $14 billion forecast for coastal Louisiana. These involve reductions in pollutant loadings, re-introduction and management of flows of fresh water and sediments, and re-establishment of important habitats such as wetlands, seagrass beds and oyster reefs.

Since it will not be possible to restore these ecosystems to their original states, choices have to be made in selecting feasible restoration goals, incorporating the needed trade-offs with human activities and changing conditions such as population growth and climate change. Ultimately, these solutions must be sustainable so that they restore some level of the ecosystem's lost resilience to the periodic upsets of nature and human use.

New technologies that reduce pollution levels and conserve resources must play an important part of coastal ecosystem restoration. These technologies include advanced waste treatment for nutrient removal from sewage, precision agriculture to manage fertilization and ultra-low or ultimately zero-emission (fuel cell-powered) vehicles. Enhanced technologies can, for example, reduce nitrogen concentrations in sewage effluents from eight milligrams per liter, achievable though conventional biological nutrient removal, to three milligrams per liter. Other technological changes embraced by society have the potential of positive environmental benefits. For example, telecommunications and telecommuting could slow the growth of vehicular miles driven and sprawl development.

However, the greatest gains as well as the greatest challenges may be with the "softer" environmental technologies to restore biological habitats and resources. Although these technologies may involve "hard" engineering structures of flow gates and conveyance channels, they must be designed and operated to enhance the regenerative power of natural processes rather than to overpower or defeat nature. Examples include the management of water levels and flow through the Everglades to Florida Bay, wetland nourishment and building through diversions of the lower Mississippi River, and maintenance of salinity conditions optimum for fisheries production in the San Francisco Bay-Delta. These approaches involve what might be called "ecological engineering," in which the energy supplied by humans is small, relative to the natural sources, but sufficient to produce large effects.

Because these ecological engineering approaches depend to a significant degree on the self-design of the ecosystem, there is invariably uncertainty in the outcome. Therefore, they have to be executed adaptively, assessing progress and making adjustments as one goes along.

There are tremendous opportunities for technology to play a key role in adaptive management as embraced in most of these coastal ecosystem restoration strategies. Adaptive management involves learning by doing. It depends fundamentally on making careful observations of outcomes, comparing these outcomes to the expectations of design models and appropriately modifying the models and management approaches.

Adaptive coastal ecosystem restoration offers a real job for the Integrated Ocean Observing System (IOOS) being promoted and planned. This important use of information resulting from IOOS should be a key design criterion for its coastal module. Adaptive restoration also presents new requirements for environmental sensors, providing direction and purpose for developing and testing new sensor technology, such as through NOAA's Alliance for Coastal Technologies. Adaptive restoration will also depend on new tools for storage, access and manipulation of the vast quantities of data developed through automated monitoring. Finally, technologies are required to analyze the data, assimilate information into self-correcting models, and visualize and display results in a revealing and compelling manner.

In these and many other ways, there are exciting opportunities for technology to put on a white hat and ride to the rescue of our degraded coastal ecosystems. */st/*