Lands, Water, Wildlife, and Climate Change: Intersections of Science, Policy and Management[1]

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Yogi Berra, baseball catcher and populist philosopher, once quipped: "The future ain't what it used to be." Yogi's witticism seems apt in the context of a changing climate. Yes, resource managers face many familiar challenges. For water systems, continuing threats include high levels of water extraction, pollution, wetland drainage and river channelization, deforestation leading to sedimentation, introduced invasive species, and over-harvesting of fish. These challenges are familiar, yet their resolution often eludes us in the midst of complexities, competing values, institutional limits, and financial constraints. At the same time, with a changing climate, the future may unfold with dramatic impacts on lands, water and wildlife.

The effects of a changing climate cut a broad swathe across our lands and waters. Those effects include increased storm intensity, altered amounts and timing of water flows, changed evapotranspiration rates, sea level rise, thawing permafrost, water temperature elevation, altered incidence and impacts of disease, and so on. I will examine some decision making puzzles and efforts to inform policy and management decisions with science.

Resource managers and policy makers must make decisions on a daily basis, often with incomplete and ambiguous information. Fundamental limits on our ability to predict future conditions, whether as a consequence of the nonlinearities and other circumstances described in chaos theory or, simply, from the inevitable vagaries of human action mean the resource manager inevitably operates in a realm of uncertainty.

Complexities that accompany resource management spring from the context of lands, waters, and wildlife. That context is one of multiple variables, temporal considerations, management constraints, values tensions, and a constant flux of circumstances.

Consider the matter of variables. At Klamath Basin, for example, is it water flows, water quality, something else, or all of the above, that causes fish die offs? For dying corals, is it changing temperatures, changing sediments, contaminants, disease, or all of the above and more that lie behind current trends?

Complexities also spring from ambiguities in the temporal framework of decisions and goals. In restoration, what is the goal? And how do climate considerations bear on these

[1] Portions of this talk were derived from a presentation in May 2009 to the North American Benthological Society in Grand Rapids, Michigan.

choices? For the Everglades, for example, is the restoration goal to achieve conditions that prevailed in the pre-drainage 1800s, or the 1930s, or some other point in time? How is that restoration choice affected by other circumstances such as the dramatic alteration of the landscape, with only a portion of the original landscape available for restoration? Time, too, does not stand still. Conditions continue to change. How might sea level rise affect restoration outcomes in different scenarios?

Complexities also have a utilitarian dimension. Often, what information resource managers need depends on how they want to use it. On the one hand, many scientists engage in deepening our knowledge of details, providing what some economists have referred to as knowledge "richness." On the other hand, other scientists look broadly across interdisciplinary knowledge to understand general ecological systems, providing what is sometimes referred to as knowledge "reach." In a resource management setting, "richness" may be imperative when examining whether to list a species as threatened or endangered. Yet "reach" may be more relevant when developing indicators resource managers can use to assess the effectiveness of their actions and ongoing, broad, landscape-scale trends.

All of these complexities mean choices about which information and data to generate, which measures and what analysis to use, and what research to undertake are not self-evident. Policy and management challenges do not present themselves as pre-defined problem sets. Defining the scope and scale of the relevant problem can, itself, raise both scientific and social questions. Is the relevant boundary for accumulating and applying information a backyard, a stream, a watershed, a continent, or a world? Through what processes might we draw appropriate boundaries for a problem set and decision focus? Answering these questions demands scientific insights. But these are as much questions of human communities, values, and social constructs as they are matters of scientific distinctions and categories.

A changing climate amplifies the context of complexity for resource managers. As I turn to the matter of climate change, let me preface my comments with an affirmation of the need for action to reduce greenhouse gases. At same time, as we are already experiencing the effects of changing climate, we need to think about management in that context.

Let us, for a moment, consider that context. Perhaps no restoration effort is as rich with scientific underpinnings as the Everglades. Scientists have accumulated a wealth of research—on the paleoecology of this unique system, on multiple species, on mangroves and sediment accretion, on tree islands, water flows and quality. Yet tying this research to Everglades restoration decisions presents all the issues outlined earlier. Debates over water quality metrics turn, in many ways, not on science, but on interpretations of law. Complexities underpin decisions about how to meet the needs of the Cape Sable seaside sparrow while, at the same time, restoring water flows that might inundate its nesting sites. Complexities underpin questions of how much water should flow in a much-altered topography with significant peat subsidence so that flows could cause pooling rather than traditional sheet flows. Are current governance mechanisms adequate to assure that science informs decisions and that key science issues are explored?

With this decision making backdrop, let us peer for a moment into the world of climate science. Global climate models are improving our ability to project future conditions. But our ability to project at scales less than 50 kilometers with any certainty is extremely limited. Yet that scale is essential for land managers. The effects of changing climate at local and regional levels are highly complex and varied. One Colorado River study shows decreases in summer precipitation and increases in winter precipitation. For water managers, what does this mean? One study estimates a 20 percent increase in water shortages and their duration. Other projections are much less austere.

I'd like, for a moment, to amplify this science saga with a few brief vignettes. We know so much—and yet so little. But consider one modeling effort. That effort looked at two scenarios from the Intergovernmental Panel on Climate Change to cover possible climate change outcomes. The study combined these scenarios with global hydrological modeling to estimate possible losses in river water availability due to climate change and trends in water consumption. The study linked results to known relationships between fish species and changes in water availability and investigated riverine fish richness over the next 70 years in more than 300 worldwide basins. The calculations showed that by 2070, water availability would decrease up to 80 percent in more than 130 investigated rivers with available fish data. About half were predicted to lose more than 10% of their fish species when climate change and water consumption impacts were considered.

We do know something about climate impacts on freshwater systems. But often what we know is at a coarse scale. So, what's a manager to do? An agenda for action requires contemplating the problem set.

Let me highlight the nature of that problem set with a few tales. Consider stream macroinvertebrates in Alaska. I reviewed one study of ecological adaptations of aquatic macroinvertebrates in sub-arctic streams. The study concludes that the presence of unfrozen stream bottoms is critical for the normal functioning of northern stream ecosystems. The maintenance of unfrozen stream bottoms depends on groundwater inputs and, to a lesser extent, air temperature. Changes in precipitation and temperature are likely under a scenario of global climate warming. Yet these changes and their effects are not straightforward. Reduction in groundwater due to reduced late-summer and fall rain and winter snow, according to authors of the study, might cause extreme freezing of stream beds. Even with warmer air temperatures, the authors note that economically important fisheries may depend on the presence of unfrozen refuges for the successful overwintering of their food species. But scientists don't have good data on overwintering mortality in different habitats. The authors conclude—and I quote: "Knowledge concerning overwintering of aquatic invertebrates is a major gap in stream ecosystem theory."

Or let us consider vernal pools in California. One study looked at the sensitivity of these pools to changes in temperature and precipitation associated with climate projections. The study observed that the ensemble of global climate models provided projections for California in the year 2100 that differed in both magnitude and sign for temperature and precipitation. One projected warmer temperatures and more precipitation; the other projected cooler temperatures and drier conditions. As the authors looked at sensitivities of branchiopods to changes in vernal pools that might result from climate change, they observed that ecological outcomes will hinge on a balancing of two factors: more extensive colonization by slower developing predators that will benefit from longer vernal pool periods of inundation; and increases in the fraction of pools within the landscape that are suitable for reproduction of branchiopods. The authors conclude that the relationship of vernal pools, reproductivity, and species diversity, abundance, and persistence is highly complex.

Their findings highlight the difficulty of predicting ecological responses in complex ecosystems and communities across a range of spatial and organizations scales. I could tell many more tales, but I want to tease out some lessons from these several tales.

These lessons are important as we think about the nexus of climate change, wildlife, and land management. The first lesson is that changes underway are incredibly complex, with variability over time, space, and species of the changes unfolding. Some places are becoming drier, some wetter; some places are becoming warmer, some not. A second condition is the ever-presence of change. We live in a very dynamic world. But changes appear to be especially rapid in northern latitudes such as the Arctic.

These characteristics of complexity and rapid change imply that we face tremendous uncertainties. Adaptation strategies are imperative as scientists tell us that currently accumulated levels of greenhouse gases will result in a changing climate out many decades, even if we completely turned off the greenhouse gas switch tomorrow. As we think about management responses to the landscape effects of a changing climate, this backdrop sets the stage.

But have I painted a hopeless picture? What adaptation options are available to us?

Long-standing conservation tools that improve resource health will remain important. Those tools include land conservation and protection of interconnecting wildlife corridors; mitigation of invasive species; and addressing risks of catastrophic fires through hazardous fuels reduction. We need to manage and conserve diverse conditions and habitats. We need to protect coastal wetlands and sea marshes to build resilience to storm intensity and storm surge. We also need to maintain ongoing pollution reduction strategies since climate change could result in releases of phosphorous from sediments, which amplifies the importance of existing pollution reduction strategies. Wetlands restoration strategies—as in the Everglades Restoration—have increased importance as these efforts can build resilience to sea level rises and saltwater intrusion into freshwater supplies.

But we also need to broaden our management horizons. We need to recognize the effects of a changing climate on landscapes and water management. We cannot simply look at historic data as we plan our land management. We need to peer into the future and that can be difficult. Already the Bureau of Reclamation is re-evaluating its water models to take into account changed timing of snow melt and altered precipitation patterns as it develops its annual operating plans.

The Nation needs a much more concentrated focus on freshwater systems, water consumption, and instream flows. Even without climate change, water use patterns are careening toward persistent shortages under current management patterns. A major threat to freshwater ecosystems now *and* with climate change is human-generated changes in water flows.

Key to providing for human water needs is sustaining healthy, functioning freshwater ecosystems that tolerate changes in river flows and are resilient to drought, floods, and rising temperatures. Natural freshwater habitats such as floodplains and wetlands temporarily store flood waters and help reduce downstream damages. Thus, conservation of freshwater ecosystems and floodplains is a central element of climate change adaptation strategies. The Nature Conservancy and the Army Corps of Engineers are partnering in a Sustainable Rivers Project. Through the project, the Corps is altering water management regimes to restore more natural flow patterns. They commenced with 9 river basins—the first of which was Green River Dam.

Especially ambitious are efforts to rethink flood control infrastructure and move from structural to nonstructural approaches. Consider Hamilton City, California, where managers replaced an old levee with a new one, but set the new one far back from the river to recreate a partial floodplain of 1,500 acres. Though these pioneering nonstructural efforts are occurring, Army Corps of Engineers decision processes are not currently well suited to evaluating total ecosystem cost-benefits and the potential benefits of nonstructural floodplain, coastal, and river management regimes.

Climate-induced changes must be assessed in the context of changes in water quantity and quality resulting from altered patterns of land use, water withdrawal, and species invasions. Some authors conclude that these changes may even dwarf or exacerbate climate-induced changes. Yet competition for water will likely increase as a consequence of climate change.

The good news is that integrated strategies are emerging. The Fish and Wildlife Service is looking at a new reservoir strategy. Over 600 dams have flood control operations. Could flood storage behind dams be reallocated to other purposes: water supply, environmental flow restoration? That reallocation may be possible with downstream floodplain restoration. Elsewhere, Portland's Comprehensive Planning integrates "greening" into all aspects of infrastructure development.

Climate changes may generate warmer water temperatures that alter lake mixing regimes and availability of habitat. Climate changes may also alter the magnitude and seasonality of runoff regimes that alter nutrient loading and limit habitat availability at low flow. Furthermore, many changes in aquatic ecosystems are a consequence of climatic effects on terrestrial ecosystems, with shifts in riparian vegetation and hydrology especially critical, underscoring ecologist Barry Commoner's admonition about the "interconnectedness of everything."

With climate changes driving the relocation of some species, we face a significant policy challenge: are currently protected lands and waters sufficiently diverse and interconnected to maintain genetically diverse populations across multiple locations? Do we have wildlife corridors along north-south dimensions to facilitate relocation as animals migrate to more northerly latitudes and interconnected waterways?

The importance of interconnections also underscores the continued relevance of partnerships and cooperative conservation, bringing a mounting importance to cross-boundary governance—and some pioneering successes. In Walla Walla, Washington multiple water users, agencies, landowners, and others are partnering to jointly manage decisions about water flows and timing. In Wisconsin, the Southeastern Wisconsin Watersheds Trust now combines 28 separate jurisdictions into a single water management partnership. In Long Island Sound, a basin wide plan to reduce nitrogen loadings includes New York, Connecticut, and the Environmental Protection Agency in a partnership.

We also need some broad policy reflection. What are our goals? In conservation, we have tended to use retrospective benchmarks, defining success as a return to some past condition. Yet retrospection in a rapidly changing environment may not be a relevant target.

We also need creative use of existing tools. The Clean Water Act and Safe Drinking Water Act grant provisions support land acquisition and water management greening, but these grants are seldom used for these purposes. The Ohio Water Restoration Sponsorship Program, in a pioneering effort, uses low interest loans if "savings" from the lower interest loans are used for watershed protection and restoration. In New Jersey, its Green Acres Program gives a threefold weighted advantage to projects with water supply protection benefits through land acquisitions in allocating funds.

Other tools, too, are emerging to affirm protections of ecosystems, including riparian areas. Oregon's SB 513 is the first state ecosystem services law. In Florida, its Ranchlands Environmental Services Project is paying landowners to conserve wetlands and reduce pollution.

Climate change for resource managers puts a premium on resilience and nimbleness. It also puts a premium on monitoring, course corrections, and adaptive management. We have seen major efforts in adaptive management unfold, such as the effort at Glen Canyon Dam, though that effort has moved forward in fits and starts.

The climate change context reinforces the importance of what author Gretchen Daily has called "Nature's Capital," the use of management strategies premised on bioengineering and investment in protecting and restoring natural ecosystems. Can we enhance landscape resilience through maintaining permeable surfaces in the built environment? This sort of greening is efflorescing in urban environments. Consider the Tualatin Basin, where managers developed a clustered permit and trading regime. Can we restore natural hydrology along the coasts we manage to enhance sediment deposition where feasible? The State of Louisiana is looking at whether wetlands restoration could qualify as potential carbon offset projects. Reality, of course, is tricky, to borrow a phrase from economist Thomas Sowell. Carbon dioxide, methane and nitrous oxides interplay in wetlands such that achieving net greenhouse gas sequestration presents a challenging balancing act. How can we use natural wetland systems to purify water and maintain buffers against coastal flooding?

I offer several concluding observations about the interface of science, policy and management in a climate context.

First, managers need a more holistic decision framework—holistic in terms of geography, issue focus, and time. This broader focus does not necessarily require agency reorganization and consolidation. It does require better mechanisms for coordination. The good news is that we have emerging models that provide a platform for multiple agencies, with multiple jurisdictions to coordinate decisions and action. This coordinated decision making also requires multi-agency, integrated budgets for conservation and restoration projects in which they share responsibility—and this funding should be designated for multiple years rather than year-by-year.

Second, managers need more monitoring and multi-variable metrics. TZ1 is an emerging ecosystem registry tool that provides a common platform to incorporate multiple-benefit metrics, for example. The Willamette Partnership in Oregon is using the tool to develop a multi-credit, regional program for ecosystem services. Their composite metrics focus on water quality, salmon habitat, prairie habitat, and water quantity.

Third, resource managers need policy foundations that support environmental performance. For example, U.S. Department of Agriculture conservation grants to landowners, traditionally offered on a first-come, first-served basis or on a formula basis need to reorient with a conservation performance focus. The Forest Service, with its State Forestry grants, has begun this shift toward awarding grants on a competitive basis to landscape-scale initiatives. Beyond grant programs, the Nation's basic environmental planning tools, such as environmental reviews under the National Environmental Policy Act, need to accommodate climate considerations into project evaluation and planning. The laundry-list of possible policy enhancements is long, including modifications, perhaps, of the Coastal Zone Management Act or its implementation and Clean Water Act implementation regarding structural versus nonstructural infrastructure.

While the tools vary, the necessary policy characteristics are straightforward. These policies need to accommodate holistic and integrated evaluation and planning; they need to provide a performance focus; they must be sufficiently flexible to allow adaptation and resilience; they must have a forward orientation to anticipate change; they must be anchored in science; and all action must be accompanied by monitoring and evaluation.

I conclude, as I began, with words of wisdom from Yogi Berra: “ When you come to a fork in the road, take it.”