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# Addressing Crises More Effectively:

# The Other Answers to Rising Sea Levels, Storms, Floods, Desertification, Earthquakes and More Environmental Crises in the Sacramento Delta

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*Abstract*:

Consensus is that California's strategically important Sacramento Delta is headed for all manner of environmental disasters, not least of which are earthquakes and the storms, floods and dry periods associated with global and regional climate change. Added to this list are the environmental problems associated with urbanization, chemical agriculture and declining fish species in the Delta. In the prevailing view, there are so many crises that if one does not happen, others will. Therefore, the probability and consequences of something failing are extremely high, whatever way you look at it.

But there is no "therefore" there. The chief feature of complexity is surprise, not inevitability. Ecosystems are very complex as are the infrastructure systems mandated to reliably manage ecosystem services, including water, hydropower and renewable energy. Surprises are happening all the time in these systems, raising the questions this paper answers: Who manages these surprises systemwide in real time? What are the answers this management provides and how do they differ from current approaches to climate change, earthquakes and other environmental crisis scenarios for the Delta?

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*Introduction*[1]

Consensus is that climate change in California's Sacramento Delta (hereafter, "Delta"), an area already prone to earthquakes and environmental hazards, poses considerable new threats to the region.

The *Delta Vision* report (Delta Vision Blue Ribbon Task Force 2008, 3) concludes: "Climate change may increase the severity of winter storms and floods that could damage levees and threaten people and other infrastructure. The sea level may rise 28 to 55 inches by 2100—more if large ice sheets melt." Elevated sea levels, storms and flooding would have substantial impacts on Delta islands already 20 feet or more below sea level behind their aging levees.

Increased precipitation is not the only environmental threat. Another report suggests that global climate change will also bring to the state and region more intense heat waves and drought episodes (Cayan et al 2009). As for earthquakes, the Delta risk management assessment (DRMS 2009) found: "A major earthquake of magnitude 6.7 or greater in the vicinity of the Delta Region has a 62 percent probability of occurring sometime between 2003 and 2032. This could cause multiple levee failures, fatalities, extensive property destruction and adverse economic impacts of $15 billion or more."[2]

One could easily add to this list of crisis scenarios other environmental threats such as intensified urbanization and chemicalized agriculture in the region. Once one considers

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[2] Wider regional considerations are also at work. A staff report for the San Francisco Bay Conservation and Development Commission (2009, 1) summarized:

> The economic value of Bay Area shoreline development (buildings and their contents) at risk from a 55-inch rise in sea level is estimated at $62 billion—nearly double the estimated value of development vulnerable to sea level rise along California's Pacific Ocean coastline. An estimated 270,000 people in the Bay Area are at risk of flooding, 98 percent more than are currently at risk from flooding. In those areas where lives and property are not directly vulnerable, the secondary and cumulative impacts of sea level rise will affect public health, economic security and quality of life.

all scenarios as a package, it is difficult not to conclude that something major and disastrous in the region is inevitable by 2100, and all but a dead certainty within the next several decades.

Consequently, acceptance is growing that the status quo has to change, but little consensus exists over what those changes must be, save that big problems are said to require big solutions. Proposals range from huge public works (e.g., “Fortress Delta) to abandoning the region (e.g., “Getting out of Dodge”). Various proposals exist in between and include options for new water conveyance structures, governance arrangements and region-wide conservation plans, all and more to be managed adaptively.

This paper suggests that the preceding five paragraphs represent a seriously misleading conventional wisdom of what is happening in the Delta. Because the Delta crisis scenarios are misformulated, so too are our regional approaches and preferred solutions. We are not seeing the other answers to the serious problems there that could be and are in fact being managed.

The rest of the paper is divided into several parts. First, I outline my approach to recasting crisis scenarios. I focus on global climate change and population and only refer to the Delta and California in passing. Because my approach is unconventional, I spend considerable time on it and the ways it directs us to other answers. Once the approach has been set out, it is an easy matter to conclude with an extended discussion of its implications for the Delta.

## *Recasting Crisis Scenarios*

### I

There is a curious discrepancy in current scenarios about global climate change—and we know that discrepancies in crisis storylines can lead to useful insights when pursued (Roe 1994, 2007).

The most significant feature of global climate change (GCC) is surely the urgency it poses. It is very much a matter of time—and therein rests the discrepancy. We are accustomed to talk about the history of climate change in terms of anthropogenic causes of warming since the industrialized 19th century. Others go further back and talk about periods of global warming and cooling in the geologic record.

But then and there the GCC narrative suddenly stops. The telling of the historical record does not go all the way down, as the anthropologist, Clifford Geertz, might have put it. For while GCC is about urgency and having to do something now, it is also taking place in time and as part of a long history of crises people have talked about in similar ways.

What crisis scenario do I have in mind? The earth releases gases into the atmosphere that are then triggered by sunlight into storms, droughts and other natural disasters. No, not global climate change, but Aristotle's theory of comets (see Tinniswood 2002, 108). I read in the newspaper that a new advance in science and technology threatens to set abroad grey goo. But which grey goo? The one predicted from recombinant DNA experiments at Harvard in the 1970s, the genetically engineered "ice-minus" bacterium for strawberry fields in the 1980s, the genetically engineered crops of the 1990s, or the nanotechnology of the 2000s? While differing in their merits, our crisis narratives can and frequently do share similar structures.

Once you take the unit of analysis to be the history of crisis scenarios for the climate, you immediately start seeing discrepancies. If we were no further in the historical record than the 1970s when nuclear winters and global cooling were the pre-eminent dangers identified by experts, would global warming as we experience it in the 2000s have then been the better alternative? If not, then we were wrong in the 1970s; if yes, how do we know our views in the 2000s are not wrong in the same or different way?

Nothing in what I just wrote or in what follows is intended to relativize, diminish or otherwise dismiss GCC. I am assuming for the purposes of this paper and in my own life that GCC is real. What I show here, however, is that were we to address the record of such crisis narratives without stopping prematurely and pursue the emerging discrepancies, we end up with a neglected perspective on the other answers to GCC above and beyond those currently discussed for mitigation and adaptation.

II

First we were told by experts to get the politics right. How can you have the society you want without the right politics in place? Then we were told the economics had to be right. You can't repeal the business cycle; get the right economics in place and the politics will follow. When that too didn't work as planned, we are now told to get the science right. Dummy, it's the politics and economics that accelerated global climate change and our only hope is to take science seriously. And yet through all this, farmers have been subsidized because politics required it, then world food economics required it, and now carbon sequestration requires it. Whatever the gauge of the tracks on which we place our engine, we seem to have little choice in the direction taken.

So too when it comes to science and GCC. We are told that GCC leaves us no option but to act, and what options we have are few, clear and sobering. Environmentalism, writes the critic, Christopher Caldwell (2007, 7), "used to be about how we want to live, now it is about how we have to live." James Howard Kunstler (2006, 176), another critics, adds,

> It is necessary to insert right there that, contrary to a lot of wishful thinking and techngnostic wool-gathering rampant these days, no combination of alternative fuels or systems for using them will allow us to run American the way we currently run it, or even a substantial fraction of it. . .The stark truth of the situation is that we are simply going to have to make other arrangements—and I'm sorry to have to repeat that this will be the case whether we like it or not.

"Above all," the *Guardian Weekly*'s Timothy Garton Ash (2007, 5) opines, "there is the inescapable dilemma that this planet cannot sustain 6.5 billon people living like today's middle-class consumers in its rich North". Note that "inescapable." From the other side of the political spectrum, a senior fellow at the Hoover Institution agrees: "The climate for the next several decades is set in concrete. If sea levels rise, greater storms occur and relief needs to be supplied. . .there is nothing now to prevent those disastrous events" (Moore 2008, 10). Just when saving the environment caught on, it turns to be too late.

Pause for a moment, though, and ask yourself: Where have we heard this inevitability talk before? Why is the drumbeat of grim scientific and historical necessity so utterly familiar?

III

The crisis narratives of historical, material and scientific determinism share a long history, and most are fueled by appeal to the natural sciences. "The ideal of all natural sciences," writes Isaiah Berlin (1996, 21),

> is a system of propositions so general, so clear, so comprehensive connected with each other by logical links so unambiguous and direct that the result resembles as closely as possible a deductive system, where one can travel along wholly reliable, logical routes from any point on the system…

The problem for natural scientists, Berlin adds, is that "nature is full of surprises, and as little as possible must be taken for granted" (Berlin 1981, 140). A historian of ideas, Berlin had no patience with scenarios of historical determinism (e.g. Berlin 1998, 119-190) and I doubt he would have a good word for crisis scenarios grounded in any scientific inevitability, whatever the merits being claimed. For Berlin (1996, 22), the historian's gift—we could call it the gift of any well-informed analyst—

> may well entail logical processes not altogether unlike those of the natural sciences, with their tendency to generality and abstraction, and the use of idealised models, but [more often this gift entails] something at the opposite end of the scale, namely an eye for what is unique and unrepeated, for the particular concatenation of circumstances, unique combination of attributes, which give a person, a situation, a culture , an age its peculiar character. . .

From such a perspective, what is missing in most reports on global climate change is any admission that surprise, accident, luck and contingency will majorly alter the course of that change.

To see how, keep with science for the moment. The globe is the world's most complex ecosystem, and the principal feature of complexity is surprise, as many remind us (Demchak 1991). Yet there is no room for surprise in inevitability scenarios. "Climate change is best viewed as threat multiplier which exacerbates existing trends, tensions and instabilities" (quoted in the *Guardian*, March 12-20, 2008, 2). Always a threat? If yes, then how do we know that, given the global complexity at issue? You tell me we already have proof-positive that globalization has harmed the environment: Look only at the muck our sea and air have become. Wouldn't it be better, however, to object to globalization precisely because we do *not* know whether its effects on the most complex system around are irreversible?

We can choose from a number of powerful examples of this paradox of talking certainly about that which is surprising. "No one could have predicted the coincidence [of high oil prices, poor harvests, rising food demand and high biofuel production] that has caused the food price rise," said the Director of Friends of the Earth, an organization that had a few years before urged governments to encourage biofuel production (Harvey 2008, 2).

But a perfect storm is the exemplary surprise. How then can the same organizations confidently predict, as it has done, devastation decades ahead if GCC is not addressed now? More to the point, why would we ever believe that these people and organizations are the ones to manage us out of global climate change, if they can't see most—some, a few, hey just one—perfect storm ahead?

From this perspective, the silliest thing government could do would be to act as if it can legislate against surprise in the environment. Yet just that is sought in stipulating "no surprise clauses" in settlements and agreements, such as habitat conservation plans. Here binding restrictions are to be put into place for extended periods (say, 50 to 100 years) that would leave the landowner or developer immune from further regulation should a threatened or endangered species or habitat be unexpectedly found on the property in question. But the unexpected surely has to be expected, notwithstanding all the no surprise clauses to the contrary.

To act as if surprise can be eliminated can itself cause other major surprises in the form of unintended consequences associated with our policy designs. Water security, food security, agricultural price stability, carbon neutrality, stability of financial and credit markets—all and more promise a steady-state, homeostasis, or equilibrium in a world where sustainability is at best seen as an effort to increase human opportunities to respond to persistent and unavoidable surprise without killing ourselves in the process (e.g., see Sayer and Campbell 2004, 57). To act as if the globe consisted of predictably coupled and interactive relationships, when coupling and interactivity make for unpredictability, is to invite the rudest of surprises.

IV

Related to surprise but different for our purposes is uncertainty. It is true that GCC scenarios have always recognized the importance of uncertainty, as in the roles of clouds and the sea with respect to greenhouse interactions. Less recognized is how what was taken to be fairly certain when it comes to addressing GCC is now uncertain. Again many examples exist. Consider only those cap-and-trade schemes grounded in economic theory and touted with such early promise here and abroad.

Following on the Kyoto Protocol, January 1 2005 rolls around and so does the EU's mandatory greenhouse gas emissions trading scheme, the European Emissions Trading Scheme (ETS). "The cap on emissions will start relatively high but will be reduced over time," Europeans were told (Harvey 2005). What actually happened was that first the permit price shot up, then it fell largely as a result of having issued too many permits relative to the lower-than-expected levels of carbon produced through industrial facilities (*Economist* 2006). Volatility turned out to also be unexpectedly high (Morrison 2006):

> The price of EU carbon permits dropped from more than €30 per tonne to about €8.5 within three weeks from the end of April to mid-May [2006], although it has since partially recovered to about €11…Trading volumes have also dropped sharply. Having grown from an average of about 2m tones a day at the end of last year to about 20m a day at the end of April [2006], volumes are currently running at about 1m a day.

By 2007, most everyone conceded that "too many emission permits were issued and the low prices have defeated the scheme's original purpose; moreover [as a result], coal imports into Europe have been rising" (Morrison 2007). In other words, emissions *increased* as a result of the ETS.

Still, transactions in the ETS nearly doubled between 2006 and 2007, from 1.1 billion permits to 2.1 billion (Harvey 2008). In fact, 2008 started with the EU proclaiming the need for further cuts in greenhouse emissions, with "the lion's share of the proposed cuts

[to] come through the European Union’s emission trading scheme (Bounds and Barber 2008). But unexpected problems persisted, and by end of 2009 the ETS remained highly troubled:

> Critics complain that difficulties in administering the system, price volatility and the market’s exposure to political risk mean carbon trading simply cannot be relied on as a means to make companies invest in emissions reduction....Another concern is that the carbon market exists only because of political fiat, and politics can change. That was shown up with cruel clarity in 2006, when the EU market collapsed just a year after its start. Traders discovered that companies had been issued with far more permits than they needed, a full-blown panic ensued and the carbon price fell through the floor....Though confidence has since been restored, by imposing a tighter cap on quotas, permit prices remain volatile. This year the recession felled prices from 2008 highs of about €30 (US$45) a tonne of CO2 to only €8. They now hover around €13, a level companies say is too low to stimulate investment in cutting carbon emissions (Harvey and Crooks 2009)

Just as problems of  the ETS first phase were to be worked out in its second phase (2008-2012), by 2010 people were having to hope these and all the other problems—the effect of the recession and financial crisis as well as computer hacking and permit fraud—will “abate in the third phase of the scheme” (Harvey 2010, 23). To summarize, event though improvements had been made, what started out as an assured ideal—using economic theory to price CO2 and thereby reduce its emission—unexpectedly increased emissions for a time and encountered a host of unexpected problems(for problems with other Kyoto-induced carbon reduction and offset schemes, see Schapiro 2010 and Harvey and Fidler 2007).

Fair enough to criticize a plan because of poor design, but you ask, can I say anything useful about the surprises and major uncertainties ahead, other than they are by definition unpredictable?

V

In answer, first, ask yourself: What would be our biggest surprise in the GCC controversy?

For some, the starting point in answering is thinking through what is possible. British economist, G.L.S. Shackle (e.g., 1955), argued that economics for its part is much better grounded in possibilities than probabilities, given pervasive uncertainty and ignorance of the world. For Shackle, possibility is the inverse of surprise, i.e., the larger one's surprise or disbelief that something will happen, the less possible it is from the perspective of the person concerned. To ask what would be the biggest surprise in GCC is then to ask ourselves what would be the most counter-expected or unexpected event we can imagine with respect to global climate change.

My choice of that most-surprising event would be: Either global climate change does not lead to the collapses predicted or most everyone most everywhere prospers as a result of GCC. Note this is saying more than that some countries will benefit from climate change while many others won't. For those on the right, left and in the middle of the political spectrum who take GCC seriously, surely the pre-eminent surprise would be that what we are doing by way of "business as usual" in intervening in climate change actually makes things better for far more people than currently supposed. In other words, the biggest surprise would be if we were able to manage our way through global climate change with no more than the counter-measures already underway or planned.

Rude surprises are those unexpectedly overwhelming events that alter things, sometimes for the better, sometimes for the worse, by delivering punishing blows to the status quo (LaPorte 2007). For example, 9/11 was a rude surprise; is it also surprising that the FAA landed without incident 4500 aircraft that day? If it is, then the answer to a rude surprise may be—can only be?—another momentous surprise. The question is, How do we manage in the face of such surprises?

To answer the latter question means we have to understand that surprise and uncertainty are not the only features of complexity. Complexity also produces resources (options and strategies) with which to handle surprise, albeit in ways that are themselves uncertain.

Complex systems—not just ecosystems—are complex by virtue of their three components: the number of elements in the system, the functional differentiation of each element, and the interdependence among these functionally different elements (e.g., Roe 1998). A system is more complex when it has more elements, each element serves different functions or roles, and more of the elements are interrelated. That is why the earth is a very complex system indeed: If we focus only on people, there are over 6.5 billion of us, each with a number of different roles (parent, child, worker, etc), and all interconnected by virtue of the resource scarcity of having only so much air, food and other resources on the planet.

In brief, the earth's complexity lays in its elements being more or less tightly coupled and more or less complexly interactive. While that condition produces surprise, it also produces options to respond to surprises. In contrast, crisis scenarios insist that tight coupling and high complex interactivity predispose their respective systems to cascade uncontrollably into crises. This is the prospect presented by GCC as a crisis scenario leading to all manner of irreversible declines in species, habitat, and biological diversity.

Our research (Roe and Schulman 2008) has found that large critical infrastructures responsible for the provision of ecosystem services, such as water and power, can use their system's tight coupling and complex interactivity as a resource. The complexity of multiple generators, lines and switching systems in electricity transmission enable operators frequently to improvise remedies on a case-by-case basis for real-time grid management. Control operators are able to assemble a variety of solutions to many real-time grid management problems, using one part of the system to compensate for a shortfall in another. What is possible one day may not be possible or even probable another day that is otherwise like it. [3] To repeat, nothing in this is inevitable.

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[3] I was in the control room of the California grid manager (CAISO) during the firestorms affecting San Diego at the end of October 2007. Engineers and support staff were gathered around the conference phone as the shift manager talked to his counterparts in San Diego and elsewhere. At one point, a San Diego control room operator said, "The two lines relayed [out of service] this morning and that could happen again this afternoon." This immediately sent the engineers and staff to their grid maps to see what these relays would mean in terms of shifting the load later that day.

What is important is that the two lines going out of service the way they had that morning had not been seen before, as far as I could determine. While fires are a feature of the San Diego region, the operators hadn't seen this kind of effect, in that way and under the circumstances then pertaining. One instance of relaying, however, was enough to prove the truth of the statement, "It could happen again." For professionals, one instance is always enough to take that statement seriously. This statement was not a conditional probability, i.e., what was likely to happen in the afternoon, given what had happened in the morning. Probability in this sense requires a run of cases, yet the defining feature of the episode was that the professionals involved had not been in that San Diego context in which they found themselves that October. Rather, something had to be done, because harm to the electricity supply was *possible*.

Rather than finding a system always on the edge of being out of control because of tight coupling and complex interactivity, we found operators using those conditions not only to produce many ways to achieve a given end (namely, load and generation should be in balance) but also to ensure those solutions could be implemented just in time. None of this is to say that tight coupling and complex interactivity are not a major problem for any critical infrastructure reliant on already complex ecosystems for their service provision, but it is to insist that such interconnectivity is not everywhere and all the time the negative driving so many of today's crisis scenarios.[4]

None of this is to say that tight coupling and complex interactivity are not a major problem for any critical infrastructure reliant on already complex ecosystems for their service provision, but it is to insist that such conditions are not everywhere and all the time the negatives behind many of today's and yesterday's crisis scenarios.

Where then are the resources produced by global climate change that can address the surprises that are coming our way but which by definition we cannot predict? If we are in a bad mess, where are the good messes to be pulled out of it?

VI

I argue that our primary resources are the discrepancies themselves in environmental crisis scenarios, including those for global climate change. The discrepancies are everywhere once one looks for them.

First, longstanding adages make those discrepancies explicit: The best is the enemy of the good; the opposite of good is good intentions; perfectionism is a kind of idleness gone bad. Do we really believe that a cadre of managers required to ensure a prescribed standard of no more than 450 parts per million of $CO_2$ emissions in the atmosphere—no,

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We expect the professionals who provide critical services—and not just in control rooms—to move beyond pattern recognition of risk and manage in the face of the inevitable surprises that context-dependent contingencies bring—as by definition there are no surprises in a continuous probability distribution.

[4] So too for other systems. Friedrich von Hayek, the Nobel economist, was fond of pointing out what he saw as the great virtue of competitive markets: Their prices coordinate the behavior of innumerable individuals fairly automatically. But the more people in the market, the greater its complexity, and market complexity means prices are resources to some but not for others. It is no wonder then that markets are the engine of that other even older commonplace: One person's profit is another's loss.

make that 350 ppm (McKibben 2007, 39; Hansen et al 2008; Revkin 2009, 6)—exists, let alone would achieve such a ideal without disastrous consequences to life as we know it on this planet? The resource here is the realism that comes with recognizing there are no-go areas for policymaking, namely, those areas for which there are no competent managers whatsoever.

Resources are to be found in analogies that render discrepancies visible. Clearing a forest for slash-and-burn agriculture destroys an ecosystem only in the same way as burning a Home Depot destroys houses. It's what happens to ecosystem services and ecosystem functions as a result of the burning that is the issue, and that is an empirical question, case by case.

So too are there all those other empirical discrepancies, which when recognized enable rather than disable. If we should protect the rainforests because they could hold the cure for cancer, where then is all that research to find those cures there? Much planning in California's Central Valley or Holland's Randstad views urban sprawl as a threat to adjacent agriculture. But couldn't the problem also be the opposite—one of agricultural sprawl with its subsidized water for subsidized crops?

Indeed, it need not be agricultural *versus* urban *versus* environmental when you take an ecosystem services and functions approach. As ecologists insist, it depends on where system boundaries are drawn. From one perspective, it looks like three separate systems in competition with each other: a forest next to grazing land next to arable plots, no one of which can expand without loss to the other. From a perspective that treats them as subsystems to one larger ecosystem, the grazing land serves as a firebreak between the forest and arable holdings. The Delta can be seen not just as its own system but also as a buffer against encroaching urbanization from the east (Sacramento and Stockton) and west (San Francisco Bay Area), much as agriculture in South Florida and Western Netherlands stop urbanization moving into the "green" areas of those regions (see Van Eeten and Roe 2002).

In fact, the current view of the Sacramento Delta—a longstanding zero-sum stalemate between agricultural, urban and environmental interests, where to help one must harm the others—is too narrow. For ecosystem services and functions, the issue instead is where that extra investment would produce the greatest positive impact on those functions and services together: planting trees in Sacramento or Stockton (the urban ecosystem), reducing chemical agriculture on Delta islands (the agricultural ecosystem), or constructing more wetlands around the islands (the environmental ecosystem). There is more than one way to help "the environment."

Note the general point is not only making the best of a bad environment or recasting an environmental problem as an opportunity for change. The issue is that the best and worst can be in the policy mess at the same time:

- Crisis: It is said that up to two-thirds of the world's population live in regions without adequate water supplies or environmental sanitation (e.g., WHO 2007). Good Mess: Now three to four billion is a very, very large number, right? They form a distribution of people without adequate supplies ranging from those much better off to those much worse off. That means then there must be tens of millions, maybe hundreds of millions, of people who have something useful to say about how to survive without adequate supplies to those millions more who are trying to survive in inadequate environments as well.

- Crisis: The world is way overpopulated. Crisis: But then again there are too few people with ideas on how to substantially mitigate and adapt to GCC. Which is it then? Are there too many or too few people when it comes to mitigation and adaptation—or is wanting it both ways the real crisis?

Stay with the overpopulation crisis narrative for the moment, since it is intimately tied to GCC scenarios. Here too all manner of discrepancies are evident when you look for them.

If the world is overpopulated, then which global carrying capacity figure do we use for stabilizing numbers—a recent count had 69 different estimates (see Roe 2007). If the world is overpopulated, then why are we not focusing on the handful of countries producing the greatest net increase, including China, India, Bangladesh, and Nigeria—and by the way, what are those countries' "optimal" carrying capacities?

If overpopulation causes most all our environmental crises, including global climate change, wouldn't we want first to know what strategies enable the citizenry of densely populated countries to accommodate their human population numbers? Wouldn't it better to say a country or region is overcrowded and overpopulated when there are few if any ways to manage to keep people residing, employed and productive there?

VII

My message here is that to want to do something positive about GCC—or any environmental problem for that matter—requires you to be the partisan of what my colleague, Paul Schulman, calls the neglected perspective in our major science and technology debates—that is, the perspective of the managers who are and will be mandated to pull the good messes out of the bad ones we have gotten ourselves in, or stop the bad ones from getting worse.

From this neglected perspective, you'd know the global climate change mess was being better managed if you heard a great deal more about control room operators in our electricity infrastructures making real-time decisions over using this versus that generator to reduce greenhouse gas emissions.[5] Some of this is going on (e.g., "environmental dispatching" of generators in Austin Texas to meet specific emission standards) and much more should be, but you would never know this was a central issue from current GCC scenarios and their preferred mitigations and adaptations.

It will scarcely do to counter by claiming real-time interventions do not substitute for long-term perspectives, which infrastructure managers cannot be expected to generate on their own. The operators we have studied know better than anyone that operating just-in-time or just-for-now when trying to bounce back from a surprise does not constitute the long term—and they to a person want to operate with the long term in mind.

However, operators would also be the first to ask: How can infrastructures manage, let alone operate reliably over that long-run environment, if they can't manage critical ecosystem services and functions reliably right now? In this view, managing for reliable services and functions is a "no-regrets" strategy. No engineer can build a bridge to withstand the loads it must take once operational, if that bridge could not first take the

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[5] Such a priority means much more emphasis needs to be put on developing regional climate change models, including ones for the Sacramento Delta.

loads placed on it when actually being built (where many times, the loads while it is being built are greater).[6] In other words, whether the long run can be guaranteed or not, it is best to manage reliably now, whatever stage you are at.

Yet where are the ecologists in the control room making the real-time decisions on whether to open the gate now and save the manatee or shut it and put the other aquatic habitat at risk? Where are the atmospheric scientists in the control room making the real-time decisions about whether to use this generator or that generator in order to meet prevailing ozone standards on this day and this hour? Where are the fish biologists in the control room making the real-time decisions that generator temperatures can be adjusted within this or that bandwidth without jeopardizing adjacent spawning populations, now?

Not only are many not there or even near the control rooms, but such professionals are acculturated to believe they can make plans for saving the manatee, habitat, air and fish without ever having management competence to ensure such plans are actually revised in real time so as to improve the ecosystem services and functions at risk.

*Recasting Crisis Scenarios in the Delta*

With the above in mind, where then do we start in the Delta? The first place to begin is by taking off the "inevitability" blinders of the crisis scenarios currently on the radar screen for the Delta. Surprises are happening all the time in the Delta, not least of which was the sudden and unexpected 1990s decline of pelagic fish species that led to the current Delta smelt crisis. Since the decline came so unexpectedly to the experts, of what use to real-time management then are the surprise-free expectations of experts who predict all manner of extinctions and worse across the Delta?

To take surprises seriously means focusing on those professionals in and around the Delta who are still surprised and who, in managing their surprises, are managing to improve ecosystem services and functions in the process.

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[6] My thanks to Ian Mitroff for this point.

Who and where specifically are these managers? Paul Schulman and I call them reliability professionals. They are the managers, operators and support staff, whose supervision, networks (formal and informal) and skills (measurable and immeasurable) ensure what society considers critical services do not fail as often as they could. They are often found in the control rooms, dispatch centers, and operations units of our large technical systems that are to ensure the safe and continuous provision of those critical services even during turbulent times and across a set of legal and regulatory reliability mandates, including those related to the environment.

These professionals are the ones preventing technical and system accidents waiting to happen, albeit sometimes at the last minute with close calls and near misses. Their networks include engineers, agency scientists, IT specialists, line operators, or middle level managers of operations units. The professionals can include the Chief Operations Officer, regulatory staffer, legislative analyst, or inspector and auditor, among many others, who ensure the reliable (i.e., safe and continuous) provision of a critical service under severe time pressures. In California, you find these networks in infrastructures mandated to ensure their ecosystem-based services are reliably provided without harm to the environment. These include, but are not limited to the control rooms of the generation, transmission and distribution facilities for our electric grid, as well as the control rooms of the State Water Project (SWP) and the Central Valley Project (CVP).

Are reliability professionals always there? No. Do they always ensuring ecosystem-based services are provided in ways that do not undermine ecosystem functions? No. Are they doing enough to save the environment? No.

What they are doing—and uniquely so—is learning to operationally revise or recalibrate poorly conceived macro-designs, laws and regulations based on crisis scenarios so neutered of surprise and so predicated on an impossible foresight as to render them a clear and present danger to all concerned.

People who take surprise seriously are those who learn from setbacks inevitably induced by those surprises (Roe 2009). The control rooms of the SWP and CVP, along with their real-time interagency operating arrangements (the Data Assessment Team [DAT] and the

Water Operations Management Team [WOMT]), have had repeated setbacks in managing the Delta smelt, an endangered fish species.[7] That however begs the larger question about what they have learned from these setbacks. In particular, what other fish or habitat, if any, have prospered under their management at the same time? The WOMT agencies have limited water flows on the Stanislaus River to certain levels and the threadfin shad, a pelagic fish species of concern to State agencies, has from time to time been caught in large numbers ("entrained") at the Project pumps, just as the Delta smelt have. What has happened with respect to these other species because of current management? The record is not as clear on this as it is for the more studied Delta smelt.

Some setbacks have the positive function of serving as a test-bed for developing strategies for better anticipation and resilience in the organization or infrastructure. A great deal of learning went on in and around the Environmental Water Account, which provided some flexibility that conventional standards approach did not.[8] That the EWA had problems and faltered does not mean it failed, at least when the unanticipated is taken seriously. One has to expect setbacks in such interventions in a Delta that is ecologically so dynamic that reverting to "normal values" in the foreseeable future is simply not possible (Healey et al 2008).[9] As conditions change, so too does the need for new management interventions that express a better understanding of the system, its tradeoffs, and priorities (Roe and Van Eeten 2002; Weinstein et al 2007).

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[7] To be clear, co-management of California's two major water projects, the CVP and SWP, has been exercised through the multi-agency Water Operations Management Team (WOMT). There are many instances of this. In addition to the examples in the text, a 2007 agreement of the WOMT agencies implemented a combined reduction in SWP/CVP exports from 1,500 cfs (cubic feet per second) to 1,200 cfs (850 cfs at the CVP and 350 cfs at the SWP). For more on the importance of interagency management of control rooms in meeting multiple reliability mandates, see Roe and Van Eeten (2002).

[8] For information on the Environmental Water Account, see http://science.calwater.ca.gov/events/reviews/review_ewa.html (accessed online on March 10, 2010).

[9] "Dynamic" means highly uncertain as well. The federal judge in charge of a major Delta smelt court case found: "All parties agree that there is no firm and reliable population estimate for the Delta smelt and there never has been. . . .No scientist was able to explain how, despite the marshaling of federal, state and private resources, over ten testifying experts presented in this case, and over ten years of study, what is necessary and how long it will take to produce a reliable total population estimate for the Delta smelt" (Judge Oliver Wanger [December 14, 2007]. *Findings of Fact and Conclusions of Law Re: Interim Remedies Re: Delta Smelt ESA Remand and Reconsultation*.)

Another cluster of positive setbacks are design probes as to whether that organization is broadly in the "right direction," even when no obvious pathway exists ahead. For example, U.S. District Judge Oliver Wanger, responsible for California's long-standing Delta smelt cases, issued rulings imposing real-time operational requirements on federal and state water supplies in the Delta. While no one in the Judge's chambers monitored compliance directly, it appears the government agencies did (Lisa Coffman, staff to Judge Oliver W. Wanger, personal communication). If so, his opinions serve as design probes into those government agencies, even if it has not yet been possible to determine how the Delta smelt responded to those operational changes.

In other instances, the setbacks serve to remind managers that other things matter for what they are doing. Here setbacks unsettle what had been settled knowledge, yet in a way that does not question the operating premise that managers still have to manage in the face of the unpredictable (see Hillman and Phillips 2007). One great but unheralded benefit of the Delta smelt crisis has been to remind managers that other things than water flows out of the Delta must be going on affecting fish populations (and by implication, their habitats). But isn't that the crisis? Not if the real and present danger is posed by all those who believe that complex systems, including ecosystems, can be macro-designed and micro-managed.

*Conclusion: Which Adaptive Management?*

Some readers will find the last point a strawman. They would argue instead: Yes, surprise is inevitable and, yes, we will have to manage adaptively by learning along the way. No command and control in this! In this view, what is really needed is adaptive management, which the Bay Delta Conservation Plan defines as "Using results of new information to adjust the implementation of conservation measures." That should do the needful, right? Indeed, one of the BDCP's planning principles is to "Address scientific uncertainty through adaptive management." The problem, however, is that word, "scientific."

Adaptive management appeals to ecologists and other field scientists because of its systematic focus on reducing scientific uncertainty through hypothesis testing, experimentation, formal trial and error learning, falsification, or some mix of such strategies. As a 2008 peer review panel of experts funded by the US Fish and Wildlife Service to examine proposed action plans affecting endangered fish in the Delta puts it: "Adaptive management includes a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of the actions, a formal process for assessment evaluation (i.e., learning), and a program of periodic peer review" (Peer Review Panel 2008, 12). The difficulty is that learning this way conflicts with the high reliability mandates and complexities of the large technical systems in which adaptive management is meant to improve associated ecosystem functions and services.[10]

No one in a critical infrastructure's control room wants to risk system reliability where the first error means the last trial. Experimental learning does occur in large technical systems, but this is ideally done outside primary operations, through advanced modeling, simulations, and in other ways that avoid testing the boundary between system continuance and collapse. *The crux of the problem is that conventional adaptive management is to be undertaken precisely on the same system level for which reliability is mandated.* "Basically," conclude two prominent Delta scientists, adaptive management "means developing a coordinated, system-wide vision and plan for ecosystem rebuilding…with management decisions guided by large-scale experimentation and modeling" (Moyle and Bennett 2008, 21). No large critical infrastructure obligated by law and regulation to be reliable all the time could ever manage that way. For what happens were the experiment to fail and the lights go off and the water cease to come out of the tap, just when all were needed the most?

How then do institutions respond to the cognitive dissonance in saying they manage adaptively, but cannot do so if they are to manage reliably? Critical infrastructures responsible for water and power generation resisted adaptive management in the form of large-scale experiments in one of two ways: Either they undertook experimental designs for adaptive management on a small scale or they gave up the experimental design when

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[10] The starting point for reliability management and complexity in large technical systems is the work of Todd R. LaPorte (e.g., 1975, 1996).

undertaking adaptive management on the large scale (Roe and Van Eeten 2002). In either event, they ensured that the results of adaptive management (and by implication environmental restoration and rehabilitation) would not jeopardize the reliability operations of their large-scale water and hydropower systems.

Today, the Sacramento Delta represents a third way to deal with the tension between managing adaptively and managing reliably: The former has been redefined as a variety of the latter. In declarations and statements to Judge Wanger's court on the Delta smelt cases, federal agencies claim they are managing adaptively by managing to stay within upper and lower ranges of water flows, a strategy very similar (but with one very important reservation) to what we have termed bandwidth management for high reliability (Roe and Schulman 2008).

Here is how the operations of the federal Fish and Wildlife Service (hereafter "Service") and the Bureau of Reclamation (hereafter "Reclamation") are described with respect to regulating water flows (in cfs—cubic feet per second) on the Delta's Old and Middle Rivers for the Delta smelt. I quote at length to underscore how "adaptive management" and "bandwidth management" have become virtually synonymous:[11]

> When the level of diversion at the pumps is high, flows on the Old and Middle Rivers may become "negative," that is, they flow in the opposite direction than they would under natural hydrological conditions and toward the CVP and SWP pumps [for pumping water from the Delta to the south]. Negative OMR flows draw delta smelt in the central and south Delta toward the pumps, and high negative flows increase the risk that they will be entrained at the pumps. As OMR flows become more negative, the zone of influence of the pumps expands and levels of entrainment increase. Unlike larger fish species, entrainment is lethal for delta smelt. . . .
>
> The Service also found that high negative OMR flows reduce the extent of available rearing and foraging habitat, and draw larval and juvenile smelt into the central and south Delta, where there is less suitable habitat, and they are more susceptible to high water temperatures, predation, entrainment at the facilities, and potential adverse contaminant effects.
>
> The Service based the OMR flow ranges…on data trends identified in the best available scientific and commercial data, such as "break points" and "change points" in entrainment metrics that occur at certain OMR flow levels. . .[E]ntrainment risk

[11] The quoted material has silently excised legal citations and footnotes in the interests of readability.

> grows exponentially as OMR flows become increasingly more negative than -2000 cfs." Similarly, the Service based the ceiling of -2,000 cfs …upon an inflection point or "change point" found by Dr. Michael Johnson where entrainment begins to increase with more negative OMR flows.
>
> Within the specified OMR flow ranges, the [Service] uses "adaptive management" to set specific OMR flow targets that are updated in real-time based on actual conditions in the Delta and the distribution of the delta smelt population. The process begins with the Smelt Working Group ("SWG"), a technical team, which meets often to develop frequently- adjusted flow target recommendations based on real-time data, using their best professional judgment. The Service then determines the OMR flow necessary to protect the delta smelt and presents that information to the Water Operations Management Team ("WOMT"). The WOMT either concurs or provides a written alternative within one calendar day. The Service then makes the final decision and sets an appropriate OMR flow target within the range prescribed. . .
>
> The SWG and the Service review "physical and biological real-time monitoring data" weekly, including the levels of salvage occurring at the CVP and SWP facilities. . . They also review the results of "particle tracking" models to help determine where larval and juvenile delta smelt may be transported based on hydrodynamics in the Delta. As the [Biological Opinion] explains, when there is no evidence of delta smelt in the south and central Delta, the risk of entrainment is low, and the OMR flow target may be set as negative as -5,000 cfs. Under most conditions, the OMR flow target will be set between -2,000 and -3,500 cfs (but, as set out in the [Biological Opinion], could be as low as -1,250 cfs or as high as -5,000 cfs). This adaptive management process "provides necessary protections while resulting in the minimum regulatory constraints on [pumping] as demonstrated in Water Year 2009 when the Service did not call for a flow restriction until February 27, 2009.". . .
>
> Rather than imposing inflexible restrictions, it relies heavily on adaptive management, through the SWG and WOMT, a described above [and in the Biological Opinion]. This adaptive process "promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood." Adaptive management allows Reclamation to protect the delta smelt, while "reduc[ing] operational constraints when the risk of delta smelt entrainment is low . . . .". This strategy provides "necessary protections while utilizing the minimum possible regulatory constraints on the project."

While the above is not "true adaptive management" in the view of the 2008 peer review panel (Peer Review Panel 2008, 13), the description has the makings of high reliability management, including operations within bandwidths, co-management of control rooms for overlapping reliability mandates, avoidance of invariant performance standards, and adjustments made in light of real-time information.

What the description does NOT reflect are bandwidths that have been established and confirmed through past experience and better practices along the lines, say, of the bandwidths around the 60 Hertz frequency for U.S. electrical grids, which if breached for a prescribed period lead to reliability violations, among other penalties. As Judge Wanger underscored: “There are significant scientific disputes regarding the relationship between OMR flows and entrainment and between entrainment and smelt population abundance.”[12] Nor is this the conclusion only of a judge. A science committee of the National Research Council set up to assess options for reducing water management effects on listed fish species in the Delta concludes (NRC 2010, 3 and 39):

> There clearly is a relationship between negative OMR flows and mortality of smelt at the pumps, but the data do not permit a confident identification of the threshold values to use in the action [to regulate flows within the OMR flow ranges], and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses that permit regular review and adjustment of strategies as knowledge improves.
>
> The choice of the limit to negative flows. . .gives the benefit of the doubt to the species. But there are important uncertainties in the choice. The different trigger points suggested by the different analyses have important implications for water users. The committee concludes that until better monitoring data and comprehensive life-cycle and fish-movement models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt.

In short, the level of certainty or confidence in bandwidths within which to manage the Delta smelt comparable to bandwidths in other infrastructures does not currently exist, though whether this is a firm conclusion or a temporary setback has yet to be determined. For its part, NRC science committee considers it is too soon to say.[13]

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[12] Judge Oliver Wanger (February 12 2010). *Memorandum Decision Denying Without Prejudice Renewed Application for Temporary Restraining Order (Doc. 562).*

[13] “The committee heard several times at the public sessions that the…actions for delta smelt are not working as there has been no response in the standard annual abundance indices during the last 3 years when action-related restrictions have been imposed. Such comments are appropriate, but only if realistic expectations are used to judge effectiveness. In this case, it is unrealistic to expect immediate and proportional responses to actions in annual indices of delta smelt, especially within the first few years of implementation” (NRC 2010, 48-49).

That said, one cannot sufficiently emphasize the real-time flux within which those in the control rooms and their agency support staff manage and for which adaptive management has little to offer when it is most needed. I was privileged to sit in on the conference calls of the Data Assessment Team for an extended period and receive summaries of the DAT discussions. The real-time deliberations I heard were often caught between the need to recommend water flows for the week ahead and the lack of "incontrovertible evidence" (the federal judge's term) with respect to then-prevailing system patterns and site specificity that served as the context for any such recommendations. Here is an example from the DAT call of August 3 2007:

> Water temperature in the south Delta, based on the three stations used in the DSWG temperature criterion, remains below 25C at 23.7C. Jim Snow [Westlands Water District] asked if the temperatures would exceed 25C with the expected heat wave later this week. Peter Johnsen (FWS) noted that the water temperature could exceed 25C but that the DSWG will continue to monitor other factors such as salvage. He explained that while 25C was considered the "lethal" temperature, delta smelt could still remain in the south Delta using temperature refugias, areas with lower temperatures than what is measured at the stations, or tolerate high day temperatures if water temperatures cool off during the night. In addition, Tina Swanson [Bay Institute] noted that smelt that are acclimated to warm temperatures, as the fish in the south Delta are, can survive temperatures greater than 25C.

It is difficult to imagine how conventional adaptive management, especially trial and error learning through falsification, could *ever* solve or adequately address all the choices that matter practically, let alone when and at the time required.

In contrast to conventional adaptive management, one principal feature of high reliability management is the ability to flex standards, such as the 25C threshold. Why? Because managing invariantly—"Never exceed 25C"—would introduce more modeling instability—in this case the model on which the 25C standard was derived—into a situation already fraught with uncertain patterns and diverse site specifics. Then why take any decision? Because the mandate remains one of having to manage, regardless. For example, the Service is not only permitted to use its expertise in forming a reasoned estimate based on the best available data in such cases, it is *required* to do so where it is unable to quantify all impacts on a species with specificity (Tepper et al 2010, 7-8).

The WOMT, SWG and others have also disagreed over whether OMR flows be averaged on a 5-day, 7-day or 14-day period, so which is it to be for when and where it needs to be?[14] Such are the questions of managers and the real-time scientists that support them—yet by the time conventional adaptive management would have answers, ecologists recognize that the Delta ecosystem could have altered substantially (Healey et al 2008). Yet, to repeat, the multiple reliability mandates remain.

Thus, it bears repeating the importance of determining what other species (not just fish), if any, are managed reliably and in real time in the Delta, including but not limited to those related to OMR flows.[15] As for better managing the Delta smelt in the absence of established bandwidths, it may be advisable to redirect research and attention to those chokepoints where important other critical infrastructures intersect with Delta smelt habitat. We already know much about the bandwidth management of electrical systems and reliability management of telecommunications (e.g., De Bruijne 2006), and smelt studies could be focused where multiple important infrastructures are spatially adjacent. Instead of setting out to know everything about the smelt and its lifecycle, the option here

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[14] See the Smelt Working Group notes for April 2 2007 accessed on line on March 25, 2010 at http://www.fws.gov/sacramento/es/OCAP_BO_actions.htm). The SWG, the technical team, and WOMT, the operations team, have at times disagreed, e.g.,

> Citing their continued high concern due to declining abundance indices, increasing Delta water temperatures, seasonal adult salvage totals, the presence of a spent female delta smelt in salvage on February 17 [2008], and the distribution of adult delta smelt based on Spring Kodiak Trawl data from February 4-7, the Smelt Working Group recommended that the [CVP and SWP] Projects operate to a 7-day running average Old & Middle River upstream flow of no greater than 2,000 cfs. However, because no adult smelt had been reported at the exports since February 29, and no larval smelt had been reported at the exports in the last week, and recognizing the current OMR flows, WOMT proposed that the Projects continue to operate to a 7-day OMR upstream flow between -2,500 and -3,000 cfs (and not to exceed -3,000 cfs) for another week. (WOMT Summary for 3/4/2008 accessed online on March 25, 2010 at http://www.water.ca.gov/swp/operationscontrol/calfed/calfedwomt.cfm)

Some point to such inter-team differences as examples of disregard of science (e.g., Judge Oliver Wanger December 14 2007 *Findings of Fact and Conclusions of Law Re: Interim Remedies Re: Delta Smelt ESA Remand and Reconsultation*, p.24), though it is difficult to determine what qualifies as "incontrovertible evidence" when it comes to the uncertain fish biology of the Sacramento Delta.

[15] There are other problems with the OMR flow limits, not least of which were, I am told, pressures to keep flows at the top of their range rather than moving across a range set by the lower limit. The extended quote is taken from *Federal Defendants' Opposition to Plaintiff's Motion for Interim Relief/Preliminary Injunction*, filed January 20 2010, Case No. 1:09-cv-00407-OWW-DLB in the Delta Smelt Consolidated Cases heard before the United States District Court, Eastern District of California (Fresno Division): pp. 16-18, 21-22.

would be first to know as much as one can about the smelt where its threatened habitat is adjacent to other priority infrastructures, like high voltage transmission lines and telecom satellite towers which are already managed more reliably in real time.

That said, an adaptive management whose bandwidths are not based in repeated findings and improved practice is certain only of uncovering one thing: the repeated rude surprise of finding more complexity challenges to manage more uncertainly.

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