California Bay-Delta – Photo Credit: Paul Hames, Courtesy of the California Department of Water Resources

The Science Enterprise Workshop: Supporting and Implementing Collaborative Science

Proceedings Report

Scientists, science-policy experts, and stakeholders gathered for a two-day workshop on November 1-2, 2016 at UC Davis to better understand how collaborative science is being managed, funded, and communicated in several high-profile ecosystems around the country. The program was designed to identify common themes and differences in the approaches being used in the California Bay-Delta, Chesapeake Bay and Watershed, Coastal Louisiana, Great Lakes, Greater Everglades Ecosystem, and Puget Sound.

This Proceedings Report combines information found in the Science Enterprise Workshop Advance Briefing Paper, including an overview of each system, with abridged transcripts of the presentations, panel discussions, and audience questions and answers. The report is organized according to the workshop agenda and integrates slides and graphics used during the program. The contents of this report, including individual sections, can also be viewed online at (www.mavensnotebook.com) and videos from the workshop can be viewed online at (www.deltacouncil.ca.gov/youtube-page).

Co-hosted by U.S. Geological Survey and the Delta Stewardship Council

USGS science for a changing world

Delta Stewardship Council

Introduction

The Science Enterprise Workshop, held on **November 1- 2, 2016,** at **Davis, California**, brought together scientists and science-policy experts from across the country to share information about how collaborative science is funded, managed, and communicated in several high-profile and complex ecosystems – the California Bay-Delta, Chesapeake Bay and Watershed, Coastal Louisiana, Great Lakes, Greater Everglades Ecosystem, and Puget Sound.

The workshop was conducted at a critical time for the California Bay-Delta. In the Delta, "every decision becomes unimaginably complex," because virtually any change intended to improve a public value is perceived to degrade some other value.[1] The Delta is not unique in this regard. At the Science Enterprise Workshop, participants had the opportunity to hear from a wide-range of experts highlighting how different regions have developed science management mechanisms to support managers who are working on improving long-term health and viability of the nation's high-profile ecosystems.

The Delta management and policy community is looking for a path forward marked by better coordination, collaboration, and innovation – guided by the vision of **"One Delta, One Science."**[2] This workshop provides a way for California's Bay-Delta to identify possible ways to improve science management and funding. Feedback and lessons learned from the workshop were given to the Delta Stewardship Council's (Council) Delta Plan Interagency Implementation Committee (DPIIC) within two weeks of the workshop. The discussion at the DPIIC meeting in late November 2017, focused on how best to improve funding, management, and communication for science enterprise in the Delta.

Purpose and Expected Outcomes

The Science Enterprise Workshop was designed to orient participants to how science is being conducted in several high-profile ecosystems and identify common themes and variations in the approaches across key points of comparison. This workshop offers an opportunity to draw lessons from other systems, including a few with more highly-integrated science programs than the California Bay-Delta's. As a first step, this workshop was designed as a comparative review that may reveal important lessons from other systems, helping managers and policymakers to:

- Avoid mistakes or "reinventing the wheel" in efforts to better coordinate and integrate science, including integrative approaches to deal with social, biological, chemical, and physical aspects of complexity;
- Better understand governance and management systems that have been set up in other high-profile systems to jointly manage resources and conduct science;
- Identify practical means by which science programs manage financial and intellectual resources and ensure the relevance of ongoing lines of research and monitoring;
- Hear expert's perspectives on what makes science "legitimate" to stakeholders and the public, and on the limitations of traditional approaches to applied science; and
- Enhance networking among programs and experts, and contribute to the body of knowledge on natural resource management of major regional systems.

[1] Luoma SN, Dahm CN, Healey M, and Moore JN. 2015. Challenges Facing the Sacramento-San Joaquin Delta: Complex, Chaotic or Simply Cantankerous? San Francisco Estuary and Watershed Science, Volume 13, Issue 3. http://dx.doi.org/10.15447/sfews.2015v13iss3art7

[2] "One Delta, One Science" means - an open Delta science community that works collaboratively to build a shared body of scientific knowledge with the capacity to adapt and inform future water and environmental decisions. Delta Science Plan. 2013. Delta Stewardship Council. http://deltacouncil.ca.gov/science-program/delta-science-plan-0

Working Definitions

Science refers to information gathered in a rational, systematic, testable, and reproducible manner (Lackey 2009).[3] Although there is no definition specific to the California Bay-Delta, the 2013 Delta Science Plan encompasses all of the following activities:

- Research
- Data collection and monitoring
- Data management and accessibility
- Modeling
- Analysis and synthesis
- Independent scientific peer review and advice
- Science communication

Science Enterprise is not interchangeable with "science program." Instead, it refers to the collection of science programs and activities that exist to serve managers and stakeholders in a regional system. The elements of an enterprise range from in-house programs within individual agencies or other organizations to large-scale collaborative science programs funded by governments. Included in this definition is academic research, recognizing that academic researchers often operate independently of management and stakeholder entities. Science enterprises can vary greatly in the degree to which resources are concentrated in collaborative programs and produce publicly-available results. The differences among regional systems can reflect historical factors, depth and persistence of conflict regarding resource issues, governmental guidance and engagement, the range of agencies and interests involved, and other factors.

Science-Policy Interface is the methods by which scientists and policymakers communicate with one another. A science-policy interface (SPI) may be entirely informal, somewhat formal, or highly formalized, depending on the circumstances. The Intergovernmental Panel on Climate Change (IPCC) is an example of a highly formalized SPI. Building and maintaining an effective SPI is an important aspect of science program management.

Cooperation, Coordination, Collaboration are often used interchangeably, but with recognizable differences, in order of increasing joint commitment:

- Cooperation –involves sharing information and sometimes resources while each party pursues its own goals;
- Coordination –involves sharing information and resources, with the parties pursuing a common interest or objective. The interest or objective, however, is defined independently by each party; and
- Collaboration –involves sharing information and resources with the parties pursuing a common interest or objective that they jointly define.

Co-production denotes the participation of managers or stakeholders in the design, execution, and interpretation of scientific studies. The term has come into use as the practice of integrating science consumers into the process of science production. Co-production may be implemented as a transparency measure or as a form of actual collaboration (see above).

[3] Lackey, R. 2009. Is Science Biased Toward Natural? Northwest Science 83(3):291-293. 2009 doi: http://dx.doi.org/10.3955/046.083.0312

Useful versus Useable Science distinguishes between the perceptions of scientists who conduct research to answer questions important to resource managers and the perceptions of the managers. While all useable science is useful, the converse is not true. Useable science "directly reflects expressed constituent needs, should be understandable to users, should be available at the times and places it is needed, and should be accessible through the media available to the user community" (Lemos and Morehouse 2005).[4] One purpose of an effective science-policy interface is to increase useable science as a fraction of all science produced within a science enterprise. Of course, management and policy processes sometimes have difficulty assimilating science to make it used.

Enabling Guidance is the combined set of laws, treaties, executive orders, agency policies, regulations, court rulings, and other authorities that provide a framework under which science programs are developed and implemented.

Relevance, credibility, and legitimacy are three features commonly thought to be essential for science to play a role in policy and management decisions (Sarkki et al 2013;[5] Heink et al 2015[6]). Legitimacy is the belief that the scientific process is being applied impartially and without partisan bias or prejudice and can be the most difficult, and important, of the three factors to foster in situations where science is being used to inform contentious resource management decisions. An effective science-policy interface generally acts in part to increase legitimacy (Posner et al 2016).[7]

Workshop Agenda and Proceedings Report Layout

The format for each panel included presentations from experts representing each region organized by common points of comparison or specific topics and concluded with an open question and answer session.

Day 1: Comparison of Science Enterprises – Regional Programs

The workshop started with presentations by science leaders on the structure and organization of the science programs in several major systems: California Bay-Delta, Chesapeake Bay and Watershed, Coastal Louisiana, Great Lakes, Greater Everglades Ecosystem, and Puget Sound. Common points of comparison included:

- History of regional program development;
- Major resource management issues;
- Current science enterprise structure;
- Funding for science;
- Important tools for implementing science; and
- Communications and co-production.

[4] M.C. Lemos, B. Morehouse. The co-production of science and policy in integrated climate assessments Global Environ. Change, 15 (2005), pp. 57–68. http://www.sip.ucar.edu/thorpex/pdf/Lankao.pdf

[5] Sarkki,S., et al. (2013)Balancing credibility, relevance and legitimacy: A critical assessment of trade-offs in science–policy interfaces. Science and Public Policy first published online August 28, 2013 doi:10.1093/scipol/sct046. http://spp.oxfordjournals.org/content/early/2013/08/28/scipol.sct046.short

[6] Heink, U., et al. (2015). Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science–policy interfaces: Challenges and opportunities. Science and Public Policy 2015 42: 676-689. http://spp.oxfordjournals.org/content/42/5/676.abstract

[7] Posner, S. M., et al. (2016). "Policy impacts of ecosystem services knowledge." Proceedings of the National Academy of Sciences 113(7): 1760-1765. http://www.pnas.org/content/113/7/1760.abstract

Following presentations from experts representing each system, outcomes from the 2013 Puget Sound Science Enterprise Workshop was presented. Lastly, a panel discussion presented additional data and allowed questions from the audience. Panelists also discussed practical and field-tested examples of how to achieve greater science integration, and how networking among programs and experts can contribute to the body of knowledge on natural resource management of major regional systems.

Day 2: Collaborative Science Management, Governance, and Funding

The second day featured comparative discussions on common challenges and opportunities that often arise in the management of science enterprises. Regional experts were joined by social scientists, legal experts, and economists on panel presentations to discuss decision-making and key topics related to:

- Science strategies in large programs;
- Governance and adaptive management;
- Funding and resource allocation; and
- Legitimacy, co-production, and communication.

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Regional Comparisons

Science enterprises in major systems are large and complex. The following pages include short descriptions of each of the six systems represented at the workshop, followed by the presentations that the system experts provided at the workshop addressing system characteristics, major challenges, and how restoration and scientific research is organized and funded.

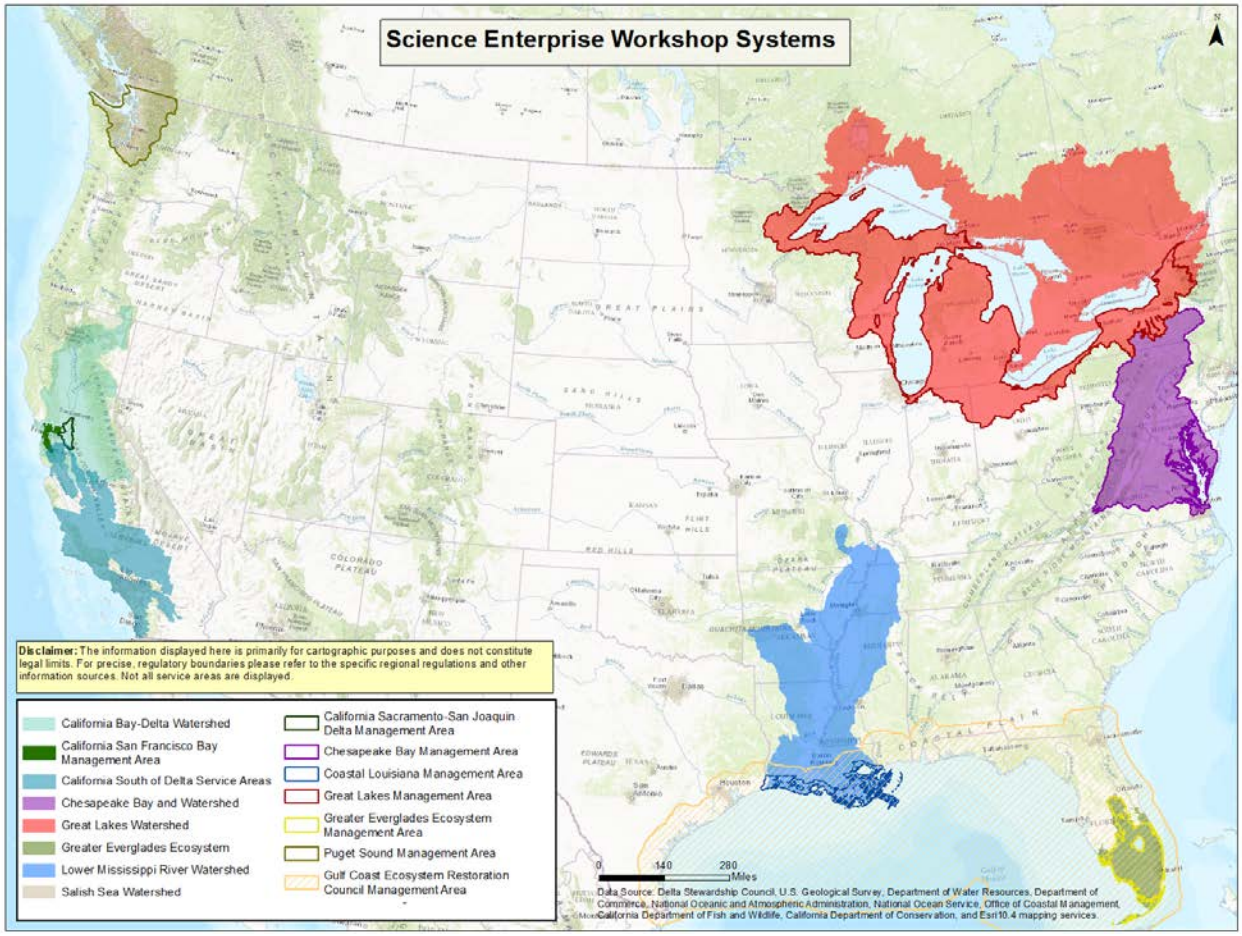
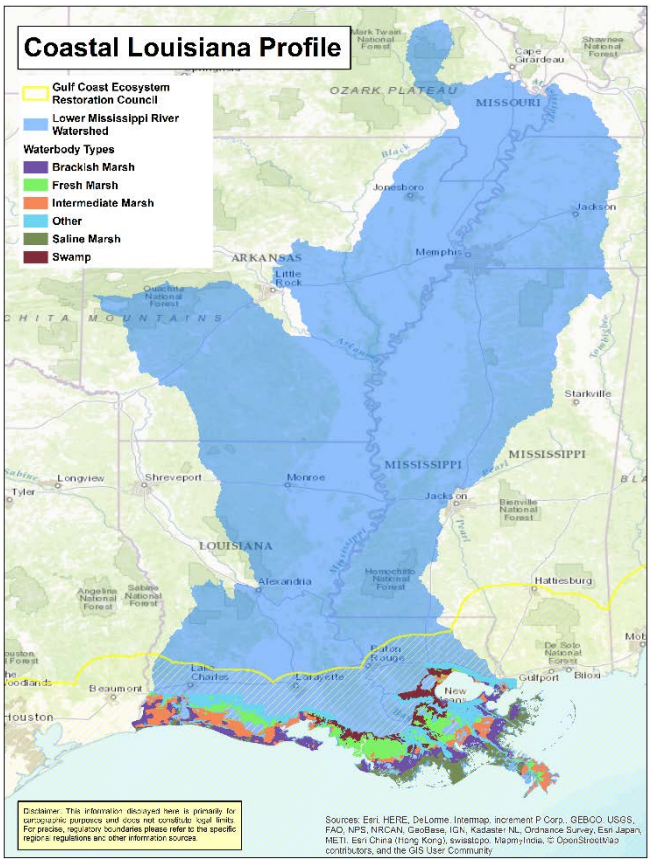


Table 1, Regional Informational Highlights: Sources for all data below provided in respective regional profiles

Watershed	Size (mi²)	States & Provinces	Human Population Reliant on Water System (million)	Dependent Economic Output ($B) (please note that reported figures may employ different methods and may not capture economic output in the same fashion)
California Bay-Delta	45,600	CA	27	$2,200
Chesapeake Bay & Watershed	64,000	DE, MD, NY, PA, VA, WV, DC	18	$107
Coastal Louisiana	8,277	LA	2	$36
Great Lakes	295,000	IL, IN, MI, MN, NY, OH, PA, WI, ON, QC	30	$4,600
Greater Everglades Ecosystem	18,000	FL	8	$394
Puget Sound	13,700	WA, BC	4.8 (U.S. only)	$194

Coastal Louisiana



Background

Coastal Louisiana is the drainage gateway to the Gulf of Mexico for the Lower Mississippi River Watershed. Southern Louisiana contains approximately 40 percent of the coastal wetlands found in the contiguous 48 states. The coastal system is comprised of the Mississippi Deltaic Plain in the east and the Chenier Plain in the west.

Why is this system important?

The wetlands of the Louisiana coast provide habitat for a variety of land and aquatic life and are the breeding ground and nurseries for thousands of species of wildlife including the bald eagle. The ecosystem provides migratory habitat for millions of waterfowl Map each year. Threatened and endangered species that rely on Coastal Louisiana include sturgeon, sea turtles, the West Indian manatee, and the piping plover. The coastal zone is over 8,277 square miles[8] and inhabited by roughly half of Louisiana's population – over 2 million people.[9] The coast is home to unique cultures made up of people whose way of life is directly connected to the bayous and wetlands. Louisiana's economy is dependent on the industries that rely on the coast, including oil and gas production, shipping, seafood, hunting, fur harvesting, and tourism; accounting for up to 1.7 million jobs and approximately $35.7 billion in economic output.[10] For example, Louisiana accounts for roughly 75 percent of fish and shellfish from the Gulf of Mexico and 28 percent of total volume of United States fisheries with a value of about $1 billion annually.[11] Louisiana ranks among the top in the United States in crude oil and natural gas production and the Port of South Louisiana is one of the ten busiest ports in the world by cargo volume.

What are major challenges?

Coastal Louisiana has experienced dramatic land loss since at least the 1930's. A combination of natural processes and human activities has resulted in loss of over 1,880 square miles since the 1930's, and a current land loss rate of 16.6 square miles per year. Not only has this land loss resulted in increased environmental, economic, and social vulnerability, but these vulnerabilities have been compounded by multiple disasters, including hurricanes, river floods, and the 2010 Deepwater Horizon oil spill, all of which have had a significant impact on the coastal communities in Louisiana and other Gulf coast states.

[8] Louisiana Watershed Management. Southern Region Water Quality Planning Committee (SRWQPC). http://srwqis.tamu.edu/louisiana/program-information/louisiana-target-themes/watershed-management/
[9] Louisiana Coastal Facts. Coastal Protection and Restoration Authority of Louisiana. http://www.americaswetland.com/photos/article/Coastal_facts_sheet_03_27_2012.pdf
[10] Answering 10 Fundamental Questions About the Mississippi River Delta. 2012. http://www.mississippiriverdelta.org/files/2012/04/MississippiRiverDeltaReport.pdf
[11] Coastal Wetland Planning, Protection and Restoration Act. NOAA. http://www.habitat.noaa.gov/restoration/programs/cwppra.html

Another challenge includes excess nutrients from the upper Mississippi River watershed that contribute to the "dead zone", or a low-oxygen hypoxic area along the coast that is toxic to marine life. In 2016, the area reached about 5,898 square miles, an area about the size of Connecticut.[12] Global warming will also bring more extreme weather events, and exacerbate land loss from sea level rise.

How is restoration and scientific research organized?

Several State and federal restoration programs are currently in place. The Coastal Wetlands Planning, Protection, and Restoration Act[13] of 1990 is federal legislation designed to identify, plan, and fund coastal wetlands restoration projects to provide for long-term conservation. The U.S. Army Corps of Engineers (USACE) and the State of Louisiana initiated the Louisiana Coastal Area (LCA) Comprehensive Coastwide Ecosystem Restoration Study in 2003. Following hurricanes Katrina and Rita in 2005, the Louisiana Legislature created the Coastal Protection and Restoration Authority (CPRA) and tasked it with coordinating the local, State, and federal efforts to achieve comprehensive coastal protection and restoration. To accomplish these goals, the CPRA was charged with developing a Coastal Master Plan to guide work toward a sustainable coast. Scientific research on coastal Louisiana has been funded by Louisiana Sea Grant and others. The Mississippi River Hydrodynamic and Delta Management Study under the LCA program included research and model development to better understand the dynamics of the lower Mississippi River and the estuarine basins. The CPRA Applied Research Program ran for several years and funded research projects in support of implementation of the Coastal Master Plan. CPRA also sponsors a Coastal Science Assistantship Program (CSAP) which funds graduate student research. Many other government, non-government, academic, and private institutions participate in research and restoration efforts. The Water Institute of the Gulf, named the Louisiana Center of Excellence under the RESTORE Act, is a nonprofit institute that conducts research and links academic, public, and private research to increase the understanding of human influences to the coastal water systems and develops tools to assist in ecosystem restoration planning.

How is scientific research funded?

Broadly, a range of agencies and organizations provide funding for scientific research in Coastal Louisiana and, like the other systems, it is very difficult to find funding information in general for total research, restoration, and protection efforts. A legislative audit found for FY2008 – 2015, federal agencies provided $10.276 billion in funding for protection and restoration projects to CPRA; average annual funding has been $1.285 billion.[14] State agencies for FY2008 – 2015 provided in total $1.615 billion for CPRA protection and restoration projects, and on average $202 million.[15] Of note, these figures do not include funds from the oil spill settlement, which were reported separately. Scientific research is often leveraged as part of restoration project development and refinement. CPRA's three-year protected budget through FY2019 is $1.5 billion, with over $96 million identified as part of adaptive management. This includes, for example, $325,000 per year for the CSAP and $6.4 million for Data Management. Under the RESTORE Act, Centers of Excellence across the Gulf coast will receive 2.5 percent of Trust Fund principal; 0.5 percent goes to Louisiana or about $4 million from the Transocean and about $0.6 million from the Anadarko settlements. It is expected that the gross allocation to Louisiana for the Center of Excellence will amount to $26.6 million through 2031. Scientific research will be funded across several different organizations including the Gulf Coast Ecosystem Restoration Council,

[12] NOAA and partners cancel Gulf Dead Zone summer cruise. NOAA. 2016. http://www.noaa.gov/media-release/noaa-and-partners-cancel-gulf-dead-zone-summer-cruise

[13] About CWPPRA. Coastal Wetlands Planning, Protection and Restoration Act. http://lacoast.gov/new/About/

[14] Oversight of Project Funding and Outcomes Coastal Protection and Restoration Authority. Louisiana Legislative Auditor. 2016. http://app.lla.state.la.us/PublicReports.nsf/0/EAF432D2895F6F4A86257F40007DE11E/$FILE/0000C38F.pdf

[15] *Id*

the National Academy of Sciences, and the National Oceanic and Atmospheric Administration (NOAA) RESTORE Science Program.[16]

Restore the Gulf
Following the Deepwater Horizon spill in 2010, many investigation and restoration efforts took place, including the establishment of the Gulf Coast Ecosystem Restoration Council (GCERC[17]) in 2012 by the RESTORE Act (Act). The Act dedicates 80 percent of civil and administrative penalties paid under the Clean Water Act, to the Gulf Coast Restoration Trust Fund (Trust Fund) for ecosystem restoration, economic recovery, tourism promotion, and science to benefit the Gulf Coast Region—defined as land within the coastal zones (CZMA 1972), adjacent land, water, and watersheds within 25 miles of the coastal zone, and all federal waters in the Gulf of Mexico. The GCERC will oversee approximately $3.2 billion over the next 15 years, which is 60 percent of the Trust Fund. The Act requires the GCERC to "undertake projects and programs, using the best available science that would restore and protect the natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches, coastal wetlands, and economy of the Gulf Coast." In addition, the GCERC is committed to science-based decision-making, delivering results, and measuring impacts.

Coastal Louisiana Presentation

Presenter

Dr. Denise Reed, Chief Scientist, The Water Institute of the Gulf

Presentation

Coastal Louisiana and the delta of the Mississippi River are a very young landscape that was built by the Mississippi River over the last 6,000-7,000 years through the process of delta evolution. It extends from the border with Texas on the west to the border of the Mississippi to the east. It's largely still a natural ecosystem, and has not been altered the same way the California Bay-Delta has. There are swamps, marshes, and millions of acres of wetlands; some in good shape, others in not-so-good shape. There are low-lying barrier beaches and islands around the Gulf's shore line which are threatened by hurricanes and other events.

The Louisiana coast is a place where people live and work. It's known as a sportsman's paradise for recreational fishing, as well for its culture and environment. People live in communities stretched out along the Bayou ridges and along the higher land and have lived there for centuries. Some of those communities have moved over the years in response to hurricane impacts and many of them now survive behind levees and structures to protect them. It's also a working coast with the oil and gas industry being a key player in coastal issues for the last 80 years. Commercial fishing is also a very important part of the ecosystem.

The main issue facing the Louisiana coast is land loss; wetlands and barrier islands are being lost to open water – nearly 2000 square miles since 1932. "So something that was a wetland, a barrier island, or a natural land form has been converted to open water," said Dr. Reed. "This is not land lost to golf courses and Walmarts. This is land lost to open water."

[16] About the DWH Funding Programs. DWH Project Tracker. http://www.dwhprojecttracker.org/about/about-the-funders/
[17] GCERC's effort is in addition to the restoration of natural resources injured by the spill that is being accomplished through a separate Natural Resource Damage Assessment under the Oil Pollution Act. A third and related Gulf restoration effort is administered by the National Fish and Wildlife Foundation using settlement funds from criminal charges against BP and Transocean Deepwater, Inc.

Dr. Reed presented a map showing the land loss, noting that the areas in red represent the land that has changed to open water, and green are the areas where land has been gained.

There is also the underlying issue of people and economy on the coast and the threat of hurricane storm surges. Dr. Reed presented a map showing the prediction of how deep the water would be for the hundred-year coastal flood event – not from riverine flooding but from storm surge flooding coming in from the Gulf of Mexico anywhere from 5-25 feet. Economic damages could be $7.7 to $23.4 billion by 2061.

One of the key contributions that science has been able to make to the discourse around Coastal Louisiana is to use the science and knowledge about the system not to describe its current status or how it's changed from the past; but to think about what it's going to look in the future, said Dr. Reed. “This idea of predicting and thinking ahead in order that policy and management decisions can be appropriately laid out in advance, as opposed to being reactive, which is very much the kind of Hurricane Katrina story of New Orleans, is I think one of the key roles of science in Louisiana and one of the key roles in large scale ecosystem management across the country.”

Dr. Reed then presented a draft map from the 2017 Coastal Master Plan[18] that shows the prediction of what will happen in Coastal Louisiana in 50 years with sea level rise if no action is taken. “This is the context for planning,” Dr. Reed said. “All of the red on here would be lost. That means the Gulf of Mexico is at the door of Lake Charles. There is very little out port around New Orleans left.”

Another role of science besides communicating what could happen is to also help think scientifically about what the options are. Is there anything we can do about this? How can we use our science and our understanding of how the system works to prevent this happening? Can we prevent it happening and to what degree and where? “The policy decisions are going to be about investments and choices, but the science can really be about what can or could be done,” said Dr. Reed.

This issue of land loss is not new; they’ve been working on it for a while. When Dr. Reed began working in Louisiana in 1986, there was recognition of the issue and a grassroots effort to try to mobilize some investments and make some policy decisions to take some action. In 1990, the Coastal Wetlands Planning Protection and Restoration Act[19] was passed; it was a federal statute which provides about $40-50 million a year for coastal restoration in Louisiana from the Small Engine Gas Tax and therefore it is independent of federal appropriations. The Act focused on vegetative wetlands on a project by project basis. It began as a comprehensive approach, but was scaled down to individual projects. It focused on protection and multi-criteria decision analysis.

That led to a comprehensive plan in 1993, which Dr. Reed described as ‘a wish list of projects.’ “A realization came out of that process in the early '90s where we realized that $40-50 million a year was just not making any difference in this problem at all,” she said. “In the mid '90s, there was an effort to do more of a strategic planning process to really think about what the coast needed and start to play offense rather than defense in trying to hold back the sea. Let's see what we can do to actually get this system functioning again.”

[18] 2017 Coastal Master Plan. Coastal Protection and Restoration Authority (CPRA). http://coastal.la.gov/2017-coastal-master-plan/
[19] Coastal Wetlands Planning Protection and Restoration Act. https://lacoast.gov/new/About/

In 1998, Louisiana's Comprehensive Plan for a Sustainable Coast was developed in 18 months using existing information. The plan recognized the challenges and tradeoffs and was much more solidly scientifically based in general understanding; it brought decades of research on the coast to bear in terms of the underlying thinking about what needed to be done. It was very much strategic, but it wasn't a plan that could be readily implemented. "We did a back of the envelope price tag for the things we were discussing and it came to $14 billion," Dr. Reed said.

In 2004, the Louisiana Coastal Area Plan articulated projects in a little bit more detail at a cost of $11 to $20 billion. "That draft documentation was sent to Washington, but frankly nobody in the administration in Washington had the stomach for that kind of program to be authorized at that point," Dr. Reed said. "It was very much a scaled down program by the time it was authorized, down to $2 billion, and again, really a selection of projects."

Post-Katrina, efforts by the USACE were focused more on protection rather than restoration of the ecosystem. The state combined the program that was working on restoration of the ecosystem and coastal land loss with the program that was designed to protect people from storm surge flooding. The state also called for a comprehensive master plan to be developed, which was to be updated by statute every five years. The first plan was developed in 2007, about a year after Katrina. "It was very strategic," she said. "It was kind of a chicken in every pot, everybody's got something in that plan and again, it wasn't a plan that could be implemented."

The governor then laid out a challenge to the scientific community. "He said, 'Everybody is coming to my door saying I want this project, I want that project… Which one should we do? Are they all good? How do we work out what are the keepers, which ones to do first?'" Dr. Reed said. "This challenge was presented to several of us who had been involved in these plans over the years to think about how to do it."

The 2012 Coastal Master Plan[20] was built on science and engineering; it evaluated hundreds of project concepts and identified the investments that would pay off in the long run. They are currently working on the 2017 update. The plan had specific objectives. "It's not just any old knowledge - it's about tuning what we know about the system to evaluate different ideas about what can be done relative to some very specific objectives," Dr. Reed said. "I think one of the things that had confounded some of those earlier planning efforts was a lack of sufficiently specific objectives. We had gone through a long planning effort on where an objective was improved fish and wildlife habitat. Who's going to object to that?"

"But you can't actually improve brown shrimp and alligators in the same place; you have to choose," she continued. "We actually had to think about how we could use our scientific knowledge about the system in a way that would enable the decision makers to make that kind of choice. Am I going to do an action that promotes alligators or am I going to do an action that promotes brown shrimp with their eyes wide open. I think that's the role of science."

The objectives of the 2012 plan were to reduce economic losses from storm-based flooding, to promote a sustainable coastal ecosystem by harnessing the processes of the natural system, to provide habitats

[20] 2012 Coastal Master Plan. Coastal Protection and Restoration Authority (CPRA). http://coastal.la.gov/a-common-vision/2012-coastal-master-plan/

suitable to support an array of commercial and recreational activities coast-wide; to sustain Louisiana's unique heritage and culture; and to provide a working coast to support industry.

A group of scientists were assembled to evaluate the projects, and what came out at the end were a series of projects all along the coast that if they were all to be implemented, the costs would be $50 billion in 2010 dollars. "One of the other pieces of this was this gradual recognition over a period of 20 years or so, was that the devil was really in the details; understanding the details and the scientific understanding of the system and its dynamics and how those need to be changed in order to get a more optimistic future," Dr. Reed said. "That then comes with a substantially increasing price tag."

Dr. Reed then turned to the question of their science infrastructure. "How do we organize ourselves to do this? Well, not very well is probably the answer," she acknowledged. "In an ad hoc manner, we've been lucky in the way in which we as a scientific community have been able to contribute."

Science is conducted by universities, agencies such as the U.S. Geological Survey (USGS), research institutes, and non-governmental organizations (NGOs); a lot of cutting-edge science research is being done in the private sector as well. "Even though I can see all of these people making a contribution, it's not obvious that there is any real coordination except around any one specific issue," she said. "There isn't one way we come together."

Dr. Reed said they are fortunate to have decades of research; being on the delta of the sixth largest river in the world really has made it a scientific point of interest for decades. They were able to leverage all of the previous research, understanding, and knowledge base. "I think we're actually able to leverage the knowledge base from university research better than we are able to leverage the current skills of the university research community," she said. "This is really not about me or any of my colleagues as much as it is about the work that has come before."

The very first act, the 1990 Coastal Wetlands Planning Protection and Restoration Act that was focused on vegetative wetlands, called for a scientific evaluation to be conducted every three years. It established the Coastwide Reference Monitoring System (CRMS)[21], an extensive coastal monitoring system focused on vegetative wetlands. There were 390 monitoring stations across the coastal wetlands of Louisiana, founded by for the most part by Act, which continues to do work after 20 years and continues to provide tens of millions of dollars for restoration every year.

They are now thinking about moving beyond just a vegetative wetlands monitoring system and establishing a system-wide assessment and monitoring program. "The need to think about all different aspects of our coastal system is now something that is very much on the radar screen of the agencies," said Dr. Reed. "We've actually have some initiatives within the agency teams working on coastal Louisiana that are focused on providing a really important baseline of information."

With regards to funding, even though they are not well organized, they do quite well taking advantage of different funding sources. Funding for university research is thin and there are no dedicated funds; the Sea Grant program has done a valiant effort over the years with fairly limited resources of about $2 million a year. In those early years, some of the early work on the Mississippi delta was funded by the Office of Naval Research who wanted to understand delta processes; a lot of it was funded by oil and gas

[21]Coastwide Reference Monitoring System (CRMS). U.S. Geological Survey. https://gom.usgs.gov/v1/web/Projects/View/2

companies who wanted to understand deltas, reservoirs and sedimentary dynamics. Those resources are not ongoing or necessarily currently available.

The programmatic monitoring is important for providing a solid baseline; those 390 stations now have produced a very rich and available pool of data across the coast. “We now actually have opportunities to develop and apply science, not within the context of a science program or a specifically science labeled entity or activity, but within the context of actually moving the restoration forward in project specific opportunities,” Dr. Reed said.

The 2017 Coastal Master Plan has three basic elements: Projects to be evaluated, predictive modeling, and a planning tool, which is an optimization or an applied math scheme. So far, it has cost about $10 million over the last three to four years, Dr. Reed said. A lot of the funding goes through the Water Institute and 14 different subcontractors. The Water Institute has an advisory panel and includes expert review on key reports.

Dr. Reed explained when a project is included in the Master Plan, it's a concept that’s risen to the top of the pile; it then has to go through detailed planning and engineering and design before any kind of dirt is moved. There is modeling, permits, and a decision to advance. “What you see in here is an awful lot of analysis being done that is really an opportunity for the scientific community and for science to come together to inform the decision,” said Dr. Reed. “A lot of funding is associated with that.”

Another source of significant funding for building projects and for science has come as a result of the Deepwater Horizon incident in 2010 in the form of civil penalties, criminal penalties, and natural resource damages. The funding is split between five states on the Gulf Coast; each state has a Center of Excellence that receives $133 million over 15 years. The NOAA has a science program for research relative to Gulf restoration that also has $133 million which is to be distributed over 15 years through a competitive grant process. The project money to develop and apply science within the context of projects is $1.3 billion from the National Fish and Wildlife Foundation. Louisiana is also receiving some of the natural resource damage assessments.

Dr. Reed noted that most of the available resources are to build projects. The Louisiana Center of Excellence is about to issue a request for proposals for $3 million. “That's the biggest RFP for research from coastal Louisiana that I ever remember in 30 years,” she said. “It's not enough but hopefully we'll be able to make a dent in this. This is research to support the implementation of the Coastal Master Plan.”

In terms of making science helpful and making a difference to a decision maker, modeling has been what has enabled them to come together and to think about the future. “In the Master Plan, we had to evaluate hundreds of different projects and we did that specifically by developing models,” she said. “We had specific things we had to analyze, too. We had to analyze about land. We had to analyze about expected annual damages. We needed to really develop a set of tools and apply information to a very specific end that the Coastal Production Restoration Authority was looking for.”
They built a specific modeling approach to evaluate the projects having learned from earlier efforts to use existing models in the early 2000s that were not successful because the research models that were being used at the time weren't necessarily applicable to the application at hand.

The modeling approach they built was a simplified coastal model that covers the whole coast and a lot of process interactions within the natural environment, such as open water processes, barrier island

processes, wetland processes, exchanges of salt or fluctuations in water level, and movements of sediment. The physics is simplified; it is essentially mass balance approach. “This is not our best, most sophisticated model,” said Dr. Reed. “It is one that is tailored to this very specific purpose that we had in mind. It's only been possible because we have data from those 390 monitoring stations across the coast of wetlands off the coast.”

Dr. Reed acknowledged there were a lot of issues with how they resolved different spatial scales of resolution. “There are a lot of assumptions in here. I probably know where all the challenges are in it but it certainly seems to meet the purpose. It was really a key thing underlying the 2012 Coastal Master Plan and will be the key thing underlying the 2017 Master Plan. We have been able to continue to develop it because it has been so useful. That $10 million for the 2017 plan would not have been invested in the team unless we had actually shown that we could provide evaluations for the 2012 plan.”

A lot of research has been done on deltas, so the job was to leverage that information into the kind of detailed level analysis needed for engineering design. “These opportunities have forced us or allowed us to work across disciplines very closely,” said Dr. Reed. “It has been uncomfortable, but it has been the secret to success.”

They were asked questions, such as ‘Are these projects effective? ‘Can they build land?’ "We know conceptually they can; we know a lot about deltas and how they work,” said Dr. Reed. “But how much land would you actually build with 75,000 CFS at this location versus that location? We can predict what would happen if we don't do the project. Then, if we do four of these diversions, what do we get? If we only do two of them, what do we get? We're talking about billion dollars of investments to build these things, and so the investment in this kind of team building and modeling for this kind of science and application here is really a very minor part of the overall project cost. I think it's gone a long way to moving these things forward in the decision-making framework.”

Dr. Reed said that being asked questions that are of that scope and having resources being made available and at a kind of scale of magnitude that is reasonable. The model was built with a large team of people in about 18 months for around $3-5 million. “It was doable,” she said.

In terms of communication, Dr. Reed said there are few specific mechanisms; it's very top down. There are many people working on the master plan: federal agencies, state agencies, universities, and the private sector. “The boards are held pretty narrowly by the state,” Dr. Reed said. “It says on here that the CPRA and the Water Institute of the Gulf directs and coordinates model improvements and analysis, but I'd say CPRA directs and we coordinate.”

One of the challenges and the opportunities is with all the knowledge they already have about the system, making sure they can still be innovative and creative. For funds associated with projects and planning, innovation and risk can be constrained. “Having opportunities for science and scientists to advance, expand, and increase thinking in addition to really applying it in a very exciting way is something that we don't really have,” she said. “Perhaps because I am in the middle of this, it feels very top-down sometimes.”

They have a successful biennial science conference modeled after the Bay-Delta’s and the Everglades which is a great venue for sharing. There are a few occasions where there is public engagement on science, but Dr. Reed acknowledged there weren’t very many of them. They have started to do webinars and give presentations to stakeholder groups.

In terms of coproduction, Dr. Reed said working in the context of moving projects from idea to plan to eventually moving dirt on the ground and to actually move 75,000 cfs of water requires they work very closely with the private sector. "We are not doing the engineering," she said. "There were engineers working on this project on the science side and on the analytical side, but they're not really doing engineering, so we're working very closely with the private sector design firms that are doing this. Therefore, we're answering pretty specific questions. This is a good collaboration."

Dr. Reed said they do a lot of external expert engagement, reports, and reviews. One approach they have found really useful is the 'over-the-shoulder review.' "You don't wait until the end to get people in; you actually have people looking at what you're doing on a regular basis and providing advice and guidance along the way," she said. "That's pretty helpful."

Dr. Reed said the Coastal Protection and Restoration Authority (CPRA)[22] does a fantastic job at with the Coastal Information Management System (CIMS)[23] which makes the monitoring data available.

Dr. Reed then gave her closing thoughts. There are no formal mechanisms. "We've tried a lot over the years to get university collaboration and coordination," she said. "A lot of the university scientists have recognized that this is the research opportunity of our lifetime, of multiple generations, to work on this. How can we as a university community come together and provide a collective platform for those federal and state agencies who are trying to address this problem? We have not been successful at that. We have tried several times. That lack of success is one of the reasons why the Water Institute was established, as a kind of convening body as much as anything else."

There are few opportunities to synthesize, Dr. Reed said. "Here in the Bay-Delta, the kind of state of knowledge synthesis work that you've been able to do on a regular basis - we have not been able to do that. That is something which would be very valuable and would really help with communication. I think a lot of the folks who are very concerned about the problems in coastal Louisiana don't really understand how much we know about it and what we don't know about it."

The community of scientists and researchers in coastal Louisiana are very active in going after standard things like National Science Foundation reviews. "If you've been on a review panel for the National Science Foundation, or you've been subject to review by the National Science Foundation, you know that the reviewers are not always interested in the kind of things that it takes to actually move a restoration forward," Dr. Reed said. "It's challenging."

"The thing we have yet to realize and that we are finally getting serious about is program level adaptive management," she said. "Come back in three years and I would be happy to have that discussion about whether or not we've actually really managed to use that as a unifying concept for the science enterprise. I think there is a lot of promise in that, depending on how we think about it. That for me will be the real test, of how that really plays out as we move forward."

"We've got billions of dollars to spend on this coast. We have a responsibility as a society to use that wisely, and to have those decisions informed by science and to have that as a continuing process, and so, that is going to be a watch-this-space for coastal Louisiana," concluded Dr. Reed.

[22] Coastal Protection and Restoration Authority (CPRA). http://coastal.la.gov/
[23] Coastal Information Management System (CIMS). Coastal Protection and Restoration Authority (CPRA). http://cims.coastal.la.gov/

Question and Answer

Question: Could you tell us a little more about that integrated compartment model, how it was started, who funded it and how long it lasted?

Dr. Reed: One of the reasons I stepped through all those previous plans was that there were a number of us in the university community coastal researchers who had been trying over the years to engage in these processes and try to help. Certainly, in the Louisiana coastal area study in 2004, they really tried to apply what research models were available.

When this challenge came up of how to work out which of the best projects to do, I can distinctly remember having a conversation with one of my colleagues at the University of Louisiana, Lafayette, saying if we're going to do this, we can't do it the way we've done it before. We have to simplify. … It's not quite as fulfilling as doing that really well defined, very detailed, very process based research type modeling. It's not as fulfilling as that, but are you interested in doing it?

There were enough folks that were interested in doing it, and the state at that time, the folks in the governor's office were sufficiently motivated that for the 2012 coastal master plan, the modeling probably was similarly of the order of $10 million but we were building these things from scratch at that point. The money came from the state. Everybody who worked on it, including the federal agencies, was paid to work on it. … It was the same money that could otherwise have gone to building our project, went to doing this. It was money in the state trust fund.

Question: Are those outcomes, those recommended projects that points to diversion and volumes, are those generally accepted in the region or is it highly controversial? It seems like it was pretty much, 'here's what we're going to do; here's what makes sense.' I'm just curious if other people were saying no. Is it really a contentious issue for the region?"

Dr. Reed: The story with the diversions is that the idea had been in all the previous plans. The idea had been in the 2012 plan; the simple compartment model analysis identified that four or five of them were worth doing. They weren't the only things in the plan, but they rose to the top. There's another, more detailed set of analysis… At one point, it was kind of complex slide with all these decision boxes on, which was really the state trying to move to a decision on what they were going to do with these. The current thinking of the state government, as articulated very clearly by the governor's coastal lead was we are going to do these diversions. We are going to work though some of these issues, but we are going to do the diversions.

This is also a story of evolving sides. When you do a simple model, you can't get into all of the details; you have a generalized picture of what's going to happen. As we get more and more into the details of these things, we apply more sophisticated tools and can look at things in more detail. We explore actually how you operate a diversion like this to maximize land building. We are now looking at optimizing the operation to maximize sediment delivery and minimize freshwater input and how you can do that at different times of year. There is this continuing role for the analysis. It's not like, okay it's in the master plan, now the engineers are going to go on and build it. As you get into all of these further issues, then there is more and more analysis needed.

I was saying earlier that sometimes I felt like the boards were little constrained. That scientists and expert panels - these external people were making very good suggestions and they were being ignored.

That kind of social impact analysis side of this, which is what is going to happen to commercial fishery and the people whose livelihoods depend on it, has not yet been analyzed in a lot of detail. The EIS for those projects is just going out and being competed. The idea is that the social impact assessment part of the EIS will be quite thorough, but that has yet to be proven.

I didn't spend a lot of time talking about whether the social science came into this. There is a large part of the master plan which is about hurricane storm damage risk reduction, and things like that where there is economic analysis of storm damages done. That's not quite the same as livelihoods and displaced fisheries.

Question: Are these being designed as explicit adaptive management experiments? I was also curious who the decision makers are. That's an issue we have in adaptive management around here; who are the decision makers, anyway?

Denise: There's only one Mississippi River and there's only one basin, so this is not going to be an adaptive management experiment. We are not going to experiment with a billion dollars of valuable resources. That is not the terminology that will be used. I think these are great opportunities for us, because there is a knob, right? You can turn it on and you can turn it off. You can have it half-open or you can have it full-open.

I think there is a great opportunity with the development of the operational plans, and the master manual or whatever there will be for these, to ensure that the decision making is nimble in response to changing system conditions. One thing we have developed at the institute... is we've developed a real-time forecasting system for those basins… We have enough real time streams of data coming from some of these stations across the coast that we can get it operational so that we can look at what the water level and salinity conditions, at least in those basins, will be for the next week if you do this, or for the next week if you do that.

This is something where if people want to be able to make real-time adaptive management decisions, the science is there. We can do that. We haven't actually got funding to do that, yet, to actually make that operational but I do think that we are starting to move. Perhaps there's controversy and discussion about how are these things going to be operated, and that may actually be the thing that stimulates the resources being made available for the scientific community to respond.

We would really like to move that into nutrients and harmful algal blooms. At the minute, we're a bit limited by real-time data streams… those should be coming online soon. We have a little bit of foundation money from a private foundation to try and add that piece on. Some of this is like entrepreneurial science; you're doing it because you think it's going to be really useful and then you're hoping somebody's going to pick it up and carry it on. As yet, they haven't done that.

There are no experiments. I am not going to say that they are experiments. I shouldn't have even said the word, because, that's just not an appropriate way of framing it within our system. This is not the time for experimentation; this is the time to build on our decades of science and knowledge about how the system works, and to actually implement a solution with the resources we happen to have available from Deepwater Horizon. It's just an impossible discourse, to talk about it in that kind of theoretical scientific way.

Puget Sound

Background

Puget Sound is the second largest estuary in the western United States, and largest by volume. It is a complex system of connected waterways and deep basins, fed by thousands of seasonal rivers and streams from the Olympic and Cascade mountains. Puget Sound is part of a larger marine ecosystem called the Salish Sea, which also includes the Georgia Basin in Canada and the Strait of Juan de Fuca, which is the major connection to the Pacific Ocean. Puget Sound generally refers to the marine areas south of the United States-Canada border and east of the Strait of Juan de Fuca. Settlement in the area began in 1833, as a fur trading post. Population soon expanded due to hunting, logging, trading, shipbuilding, and seafood industries.

Why is this system important?

The Puget Sound Estuary and surrounding lands are made up of wetlands, salt marshes, bays, beaches, and rivers. Thousands of species of invertebrates, fish, birds, mammals, and vegetation rely on the system. Endangered and threatened species impacted by the health of the Puget Sound area include orcas, the gray wolf, Chinook salmon, and the marbled murrelet. Aquatic vegetation is a key component of the ecosystem, including 26 species of kelp,[24] which make Puget Sound one of the highest sites of kelp diversity in the world. The Puget Sound water area covers over 1,016 square miles, and the watershed covers over 13,700 square miles.[25] About 4.8 million people live in the 12 counties around Puget Sound, many of which depend on the watershed for drinking water.[26] Puget Sound's natural resources are directly tied to the area's economy through industries including seafood, lumber, recreation, shipping, aerospace, and recreation, which generate up to 194.2 billion[27] of annual dependent economic activity and hundreds of thousands of jobs for the State of Washington.

What are major challenges?

Urbanization and industrial development have led to numerous environmental challenges in and around Puget Sound. Historical poor management of dangerous chemicals, as well as numerous oil spills and stormwater and wastewater discharges have led to contamination. Another challenge is hypoxia (low-oxygen) in some marine waters, caused by natural and human-made sources, which can lead to wildlife "kills" either locally or over a wide area. Excess nutrients, which originate from wastewater discharge, storm water runoff, agriculture, and other sources, lead to algal blooms that consume oxygen and exacerbate hypoxia. Combined sewage overflow (CSO) occurs when runoff in combination with raw sewage overflows the pipes. CSO carries pollutants, pathogens, and excess nutrients into Puget Sound, threatening wildlife. Other challenges include sharp declines in aquatic vegetation, including eelgrass, a

[24] Puget Sound. National Wildlife Federation. https://www.nwf.org/Wildlife/Wild-Places/Puget-Sound.aspx
[25] 2015 Puget Sound Fact Book. Encyclopedia of Puget Sound. https://www.eopugetsound.org/articles/2015-puget-sound-fact-book
[26] *Id*
[27] *Id*

keystone species; shoreline modifications that contribute to degradation and loss of important habitat; invasive species that threaten biodiversity, natural habitats, and irrigation systems; and sea-level rise, which is predicted to threaten critical wildlife habitats and make habitats and infrastructure more susceptible to damage from storms.

How is restoration and scientific research organized?

Multiple overlapping efforts to advance Puget Sound recovery and long-term protection are managed by federal and State agencies. The Puget Sound Partnership, a State agency formed in 2007, leads a broad restoration and protection effort, responding to assignments from Washington State statute for Puget Sound ecosystem recovery and recovery of threatened and endangered salmon and related species in the Puget Sound region. The state's approach to Puget Sound ecosystem recovery dovetails with the designation of Puget Sound as an estuary of national significance and its inclusion in the U.S. Environmental Protection Agency (USEPA) National Estuary Program (NEP). The Puget Sound Partnership (and other regional entities elsewhere in the State) implements Washington State's innovative, watershed-based approach to recovery of threatened and endangered salmonid stocks, which is overseen by NOAA Fisheries.

To develop a restoration program for nearshore habitats, federal, State, tribal, and local governments, non-governmental organizations, universities, and private industry created the Puget Sound Nearshore Ecosystem Restoration Project in 2001. This effort generated a State-funded restoration program – the Estuary and Salmon Restoration Program – and may lead to authorization of a Puget Sound nearshore restoration program by the USACE.

In its work to connect the hundreds of partners to further the collective effort to restore and protect Puget Sound, the Puget Sound Partnership has described (but not fully developed) a strategic science program and prepares (but is not able to fully implement) biennial science work plans.

In 2011, a Puget Sound ecosystem monitoring program was launched to coordinate monitoring and assessment activities in the region. This program is managed independently of the Puget Sound Partnership but is supported by staff and other resources provided by the Partnership.

The USGS Coastal Habitats in Puget Sound project provides scientific support for ecosystem recovery activities. Other important contributions to scientific research that supports Puget Sound recovery and protection include programs and studies at a variety of federal, State, and local organizations.

How is scientific research funded?

The overall spending on Puget Sound recovery and long-term protection, and on scientific research, has not been calculated. One available data source, which emphasizes capital investments in restoration and acquisition projects, demonstrates a majority of project funding from State sources (55 percent) with significant contributions from local (34 percent) and federal (11 percent) sources. As there is no Federal Crosscut Budget for Puget Sound, it is somewhat more difficult to obtain funding information in general for Puget Sound program activities, and like the other systems, scientific-specific funding information is not available.

- For reported years 2003-2018, average annual federal funding for the Puget Sound Partnership recovery projects has been $6.4 million and federal project funding totaled $102.5 million.[28]
- For reported years 2003-2018, total State project funding for the Puget Sound Partnership has been $508 million, with an annual average of $31.7 million in funding for Puget Sound restoration and protection projects.[29]

Over 11 years (2006-2016), a total of $198 million of Puget Sound NEP funds has been invested in projects; $50 million of this total supported research and monitoring projects.[30] This is the primary Puget Sound-identified source of federal funding to support scientific investigation. Investments in Puget Sound-relevant studies through other federal programs (i.e., those identified above) have not been summarized.

Puget Sound Presentation

Presenters

Dr. Bill Labiosa, Regional Science Coordinator, USGS Northwest Regional Office
Dr. Scott Redman, Program Manager, Puget Sound Action Team

Presentation

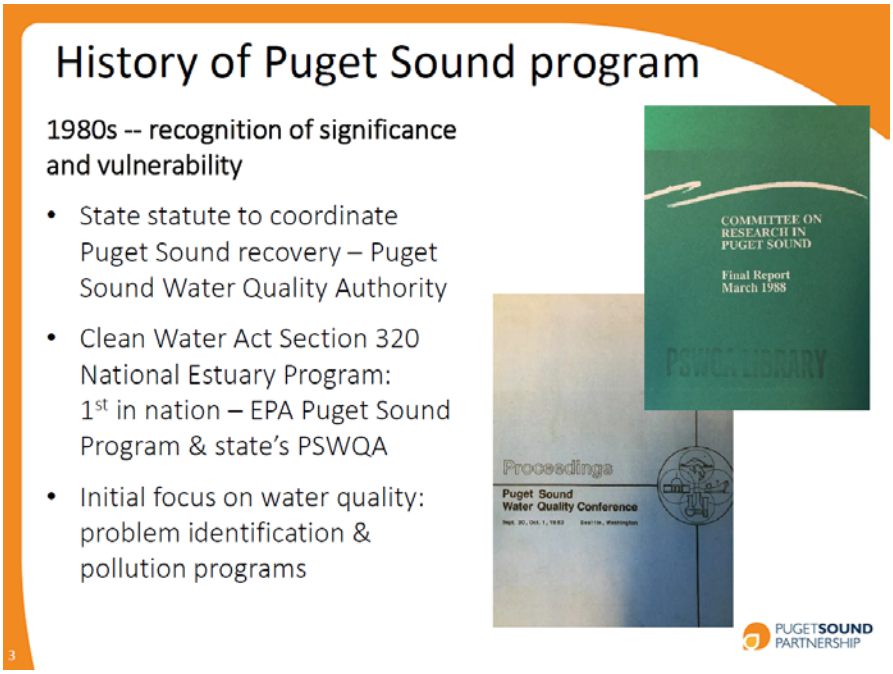


Figure 1, Slide 3

In the 1980s, the significance and vulnerability of Puget Sound was recognized. In response to water quality issues, the state of Washington passed legislation that created some institutional arrangements, including the first of many state agencies to come that was called the Puget Sound Water Quality Authority. It was started with a real expectation that it would be a science-informed process; there were conferences and research committees that were brought together to outline what needed to be done. "There was a vision that was never quite brought to reality back in that point," said Dr. Redman.

In the late 1980s - early 1990s, Puget Sound was named an Estuary of National Significance. "The story we tell there is we were the first of the 28 programs," said Dr. Redman. "I'm not sure if that's true… I think the other programs that are here today don't really have these national estuary programs; this is a

[28] Puget Sound Partnership. http://gismanager.rco.wa.gov/projectatlas/?summaryArea[areaName]=Puget+Sound&summaryArea[areaType]=PSP+Boundary&summaryArea[areaShapeId]=NA
[29] *Id*
[30] Puget Sound Partnership. http://psp.wa.gov/gis/NEPAtlas/NEPActivities

key feature that I will talk about. What this means is that one of our key federal partners is the EPA. It also means that we started very much with the Clean Water Act and the water quality standards and the contaminated sediments as a focus. That's where we began."

Figure 2, Slide 4

In the 1990s, the focus began to shift to habitat concerns, specifically wetlands which were close to the Clean Water Act. Then in the late 1990s, the Puget Sound chinook salmon were listed as threatened under the Endangered Species Act. They started to think about habitat for Chinook and other salmon as part of the National Estuary Program problem and as part of the state's interest in the future of Puget Sound. The Puget Sound National Estuary Program transitioned into the governor's office from being an independent agency and a monitoring program established; a biennial conference was also part of the science program.

At the time, there was an emphasis on monitoring more so than other topics which broadened through the years into monitoring water quality and habitat. "We took the unique approach in Washington State of having the local effective community build the recovery plan for Puget Sound Chinook," Dr. Redman said. "It was done at the scale of these 22 populations and 16 watersheds; it was called 'the Washington way.'"

Figure 3, Slide 5

It's important for science to work at the appropriate units of analysis, and for salmon, that was clear because of the watersheds, said Dr. Redman. That unit of analysis work was brought forward in the Puget Sound Nearshore Ecosystem Restoration Partnership (PSNERP)[31] which was a federal-state effort to understand, restore and preserve

[31] Puget Sound Nearshore Ecosystem Restoration Partnership. http://www.pugetsoundnearshore.org/

critical features of nearshore habitats; it began in 2001 and is focused on a process-based approach to restoration of Puget Sound's shorelines. The units of analysis are drift cells[32], which similar to watersheds, provide a meaningful way of physically organizing a complex landscape and its ecosystems. The Puget Sound consists of more than 800 independent drift cells, each with their own sources and sinks of sediment and an established direction of net sediment transport. "I think that was really instrumental to learn what the focus of analysis should be, and to do some good science to articulate the problem, and then the potential solutions," said Dr. Redman.

Concurrent with that, the National Estuary Program version of work in Puget Sound morphed yet again in 2007 into the Puget Sound Partnership[33]. that integrates ecosystem recovery and salmon recovery under the Endangered Species Act around a shared strategy and the prior work on water quality.

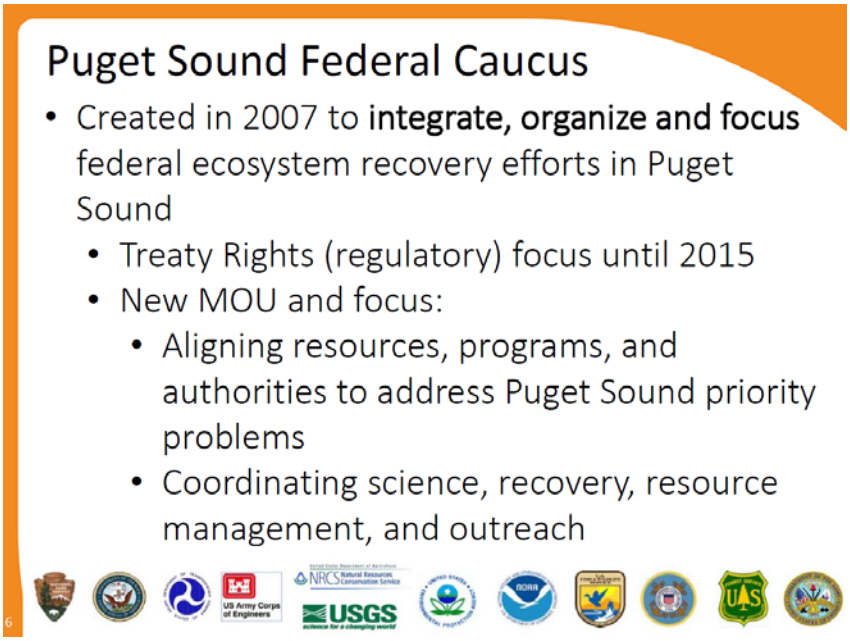


Figure 4, Slide 6

On the heels of the creation of the Puget Sound Partnership, the Puget Sound Federal Caucus was formed with the initial purpose of bringing federal capabilities and resources into play to help support the state-led recovery of Puget Sound. However, right away, things became sidelined as concerns for tribal rights and issues emerged when the Northwest Indian Fisheries Commission,[34] published a white paper in 2011, Treaty Rights at Risk,[35] documenting the continued habitat loss and its impact on salmon recovery in spite of the Endangered Species Act-related recovery efforts to date.

"It was a very powerful paper and it had a very big impact," Dr. Labiosa said. "You could tell that their legal case was very strong because the Department of Justice and the White House Council on Environmental Quality immediately asked the Puget Sound Federal Caucus to focus entirely on developing a response to the treaty rights at risk issue, and in particular to develop an inter-agency work plan to address the issue."

Tribal issues really dominated the agenda entirely from around 2011 to 2015; there's a good and a bad side to that, Dr. Labiosa said. "On the good side, there's the argument that what's good for tribal treaty rights is good for Puget Sound ecosystem recovery; it's a very strong argument," he said. "On the other

[32] Puget Sound Feeder Bluffs. Washington Department of Ecology. http://www.ecy.wa.gov/programs/sea/shorelines/FeederBluffs/BeachesAndDriftCells.html
[33] Puget Sound Partnership – National Estuary Program. U.S. Environmental Protection Agency. https://www.epa.gov/nep/local-estuary-programs
[34] Northwest Indian Fisheries Commission. http://nwifc.org/
[35] Treaty Rights at Risk. Northwest Indian Fisheries Commission. http://treatyrightsatrisk.org/

hand, science and monitoring went completely to the backseat on the federal side, because the tribes didn't want to talk about science and monitoring in the work plan; they wanted to talk about what the federal government was going to do to stop continued habitat loss."

Figure 5, Slide 7

The challenge is that habitat loss involves land use decision making and other things at the local government level, which is outside of federal jurisdiction. "We were really trying to uncrack that nut in this work plan," Dr. Labiosa said. "It's a very complicated set of issues that we were trying to get on top of. Last week, Christy Goldfuss, the CEQ director, came to Washington State and with Governor Inslee and the regional directors of the federal agencies and tribal leaders, announced a new memorandum of understanding between federal agencies to really revamp our support of Puget Sound ecosystem recovery in general and tribal treaty rights will be a part of that." On September 30, 2016, nine federal agencies and cabinet departments signed a Memorandum of Understanding (MOU) creating the Puget Sound Federal Task Force[36]. The MOU will help align collective efforts to protect and restore Puget Sound.

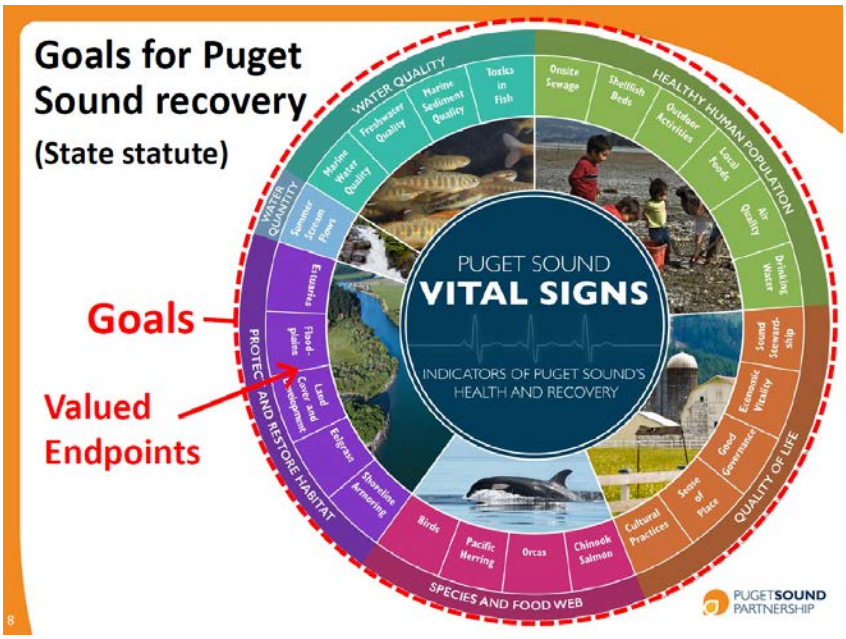


Figure 6, Slide 8

The MOU has explicit language on science and monitoring and establishes a science and monitoring work group to try to help marshal federal efforts in supporting Puget Sound ecosystem recovery through science and monitoring as well as on the action side.

[36] Puget Sound Federal Task Force. U.S. Environmental Protection Agency. https://www.epa.gov/puget-sound/puget-sound-federal-task-force

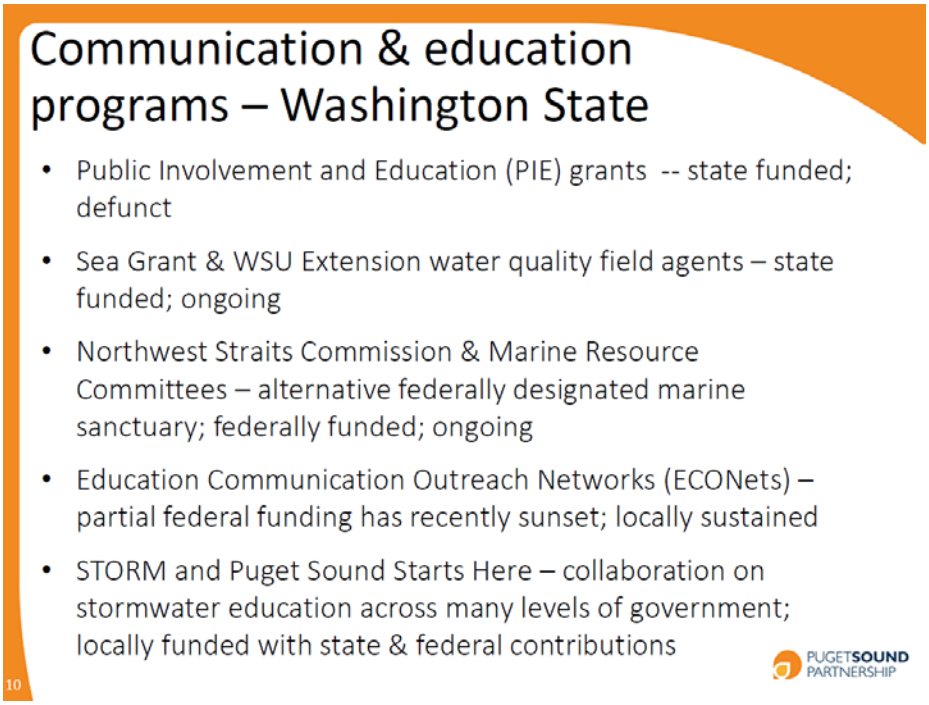


Figure 7, Slide 10

Dr. Redman then presented a graphic used to help convey the diversity of the concerns, noting that the goals are on the outside of the circle, and the inner circle represents the valued endpoints. "One thing you'll see here is we're treating the Puget Sound ecosystem as a social ecological system," he said. "Both human health and human quality of life are critical elements of the future that we're aiming at, as are species, habitats, water quality, and water quantity."

In the 1980s, the focus was more on water quality, but the approach has broadened into these other dimensions, and it's been a challenge to grow the scientific engagement into those. "One of the important aspects of science engagement for us has just been knowing what we mean when we say a healthy, recovered, and protected Puget Sound? Articulating from those fairly general goals, what do we mean?" Dr. Redman said.

In state statute, the science panel was given an assignment to identify indicators for Puget Sound, and in 2010, a suite of indicators was adopted which are now referred to as the Vital Signs[37]. "We've articulated desired future conditions and set targets with the planning horizon of 2020," he said. "That was really a co-production issue of agreeing that that was a place to start - from the goals and then to get more specific and get science advice about desired future conditions, but to have the articulation of desired future condition be a policy statement. Our leadership council, seven people appointed by the Governor, adopted targets for these Vital Signs."

The statute further articulates how they should be meeting these goals; it gives some direction to focus on species of concern and imperiled species. The statue calls out the Puget Sound Nearshore Ecosystem Restoration Program (PSNERP) protecting and restoring habitat; stormwater management and certain kinds of pollution control. A program was then built from those indicators the needed to be articulated. "I'd say we're in the midst of producing the science-based plans for accomplishing the targets that we've established," Dr. Redman said.

[37] Vital Signs. Puget Sound Partnership. http://www.psp.wa.gov/vitalsigns/

In terms of communication and education programs, Dr. Redman said that they have connected science into the decisions that are being made about the path forward, but somewhat independent of that work, a variety of education and communication efforts have been spawned. He acknowledged that the science program is poorly connected to those programs. "We don't know what these communication outlets could be used for and we're not focused on who their audiences are or what they need from us, but both the Washington Sea Grant[38] and our land-grant university's extension program have some key tools there, in terms of water quality field agents. That's a really nice connection between getting extension-type services out to the communities and in the same organization where we get the Sea Grant research done, so there's an opportunity for interaction there."

The Education Communication Outreach Networks, or ECO Nets[39], was a recent effort to provide a service to get groups together so that they build from each other's capacities, but what was missed was what to bring to those ECO Nets so that they can distribute out to the broader community, said Dr. Redman. With respect to stormwater management, there are 120 local governments around Puget Sound who play a role in stormwater management, and part of that assignment is to maintain what goes into the storm water system and therefore to educate the people who own the property in their area. There's a lot of work around managing things correctly and a connection to the local governments and the science that they do with behavior management. "There's a good connection to social science on that last part," Dr. Redman said.

Figure 8, Slide 11

On the federal side, there are substantial communication and education programs, but they are related to individual agency missions, such as the USDA Natural Resources Conservation Service (NRCS) providing training and technical assistance to farmers. The Department of the Interior has a number of tribal education grants and projects; the tribal trustee responsibility of the Department of the Interior is very important, so those programs are funded and exist, but they aren't necessarily connected to Puget Sound ecosystem recovery directly. NOAA also has a number of programs, such as the Western Fishery Science Camp to teach young people about issues that are related to salmon recovery among other things. The EPA's National Estuary Program provides funding to support state and local efforts.

[38] Sea Grant. University of Washington. https://wsg.washington.edu/
[39] Education Communication Outreach Networks (ECO Nets). Puget Sound Partnership. http://www.psp.wa.gov/econet.php

"I think individual efforts are important, but there's just a lack of coordination among these programs," Dr. Labiosa said. "Again, it's not in service of Puget Sound ecosystem recovery per se, but I think it could greatly benefit from that, taking it to that next level of being coordinated in service of Puget Sound ecosystem recovery."

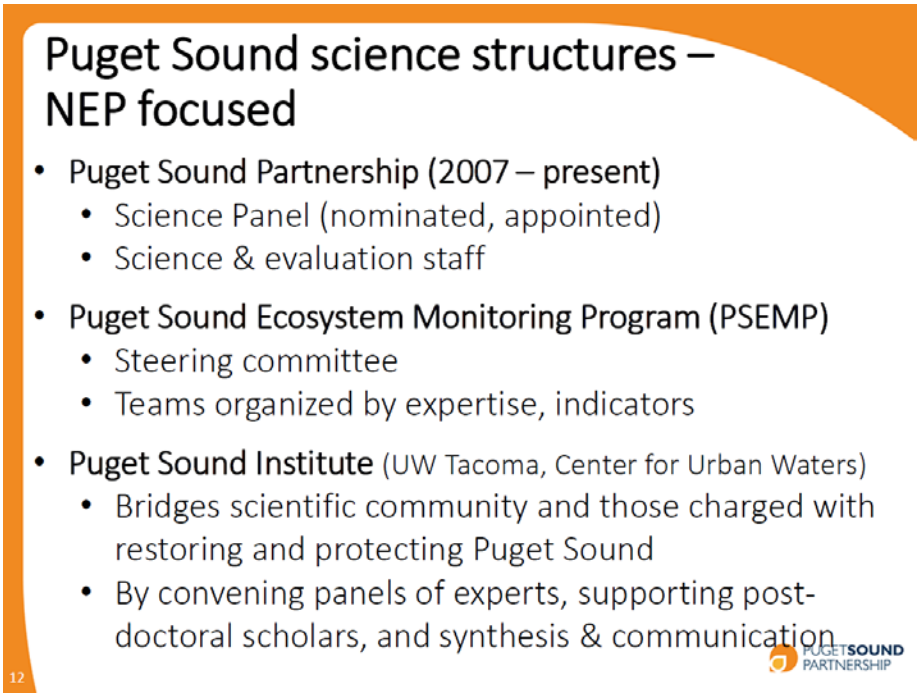


Figure 9, Slide 12

With respect to the multi-part science infrastructure, there are science programs that build from the National Estuary Program focus. "The Puget Sound Partnership is authorized to have a scientific research account, but we have never been appropriated for that," acknowledged Dr. Redman. "We have a volunteer panel and some staff that largely that work on the Puget Sound ecosystem monitoring program, but we don't have funds. It's zero."

"I think the theory of the Puget Sound Partnership and the ecosystem monitoring program is that it's wise to invest in the backbone of the collaborative effort," continued Dr. Redman. "Where we have quite limited resources, we provide a small number of staff to convene work groups and a steering committee around ecosystem monitoring. The ecosystem monitoring program addresses both stats and trends questions. We ask them to be our source for the material about those Vital Signs and their indicators and we also expect that they'll tell us about other signals from monitoring the system."

A marine water workgroup puts out an annual rain waters year in review which is a nice collaboration. "It comes about because the work group, for which we fund a small fraction of a FTE to staff that work group, has routine meetings, a workshop in the spring, and is able to bring up a synthesis report about it was that year. "It's frustrating that that's just a year at a time, but there's a synthesis provided there by that structure," Dr. Redman said. "We have work groups to deal with a variety of topics, such as toxic contaminants, forage fish, and birds, so we cover our interests through people's finding time and willingness to join colleagues in routine meetings."

About five years ago, the Puget Sound Institute[40] at the University of Washington was established, which provides another bridge to connect the scientific community into the management concerns. "This is

[40] Puget Sound Institute. University of Washington. http://www.pugetsoundinstitute.org/

another intent towards co-production," Dr. Redman said. "I think this is also a design that's not fully executed yet and not well funded."
He noted that there have been relatively few instances of convening panels of experts, and post-doctoral scholars have gotten scarce in recent years. Synthesis and communication is something that the Institute works on, but needs better support, Dr. Redman said.

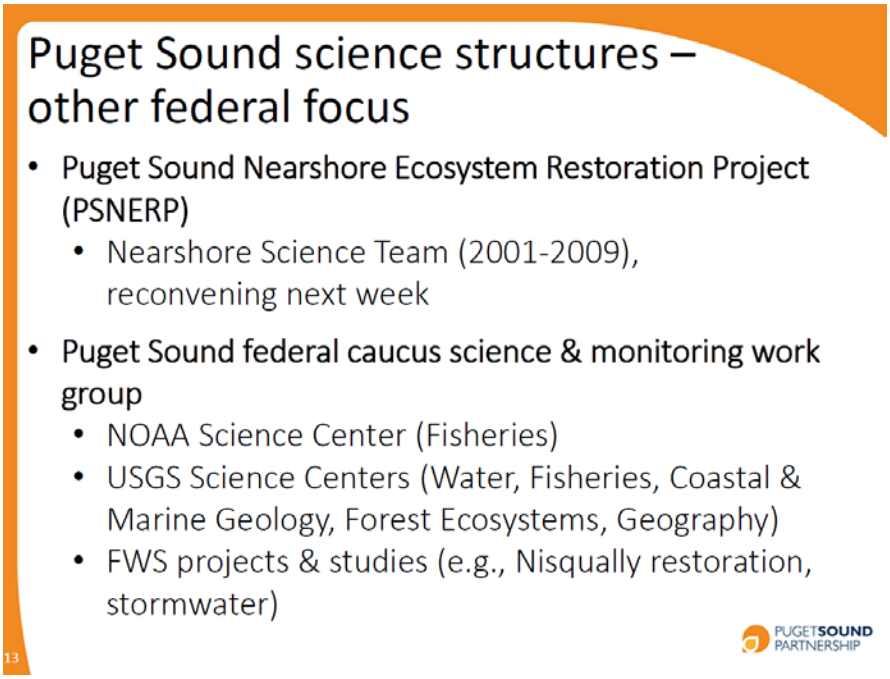


Figure 10, Slide 13

On the federal side, Puget Sound Nearshore Ecosystem Restoration Project's Nearshore Science Team was active from 2001 to 2009. They developed a very substantial body of work on the recovery of nearshore ecosystems. They developed the frameworks for thinking about how Puget Sound has changed in the past, for understanding how stressors impact it, and how the projects that are being proposed might help recover shorelines. They went in hiatus in 2009, reflecting the fact that the project had then moved into the USACE's process for getting funded; it's just now coming out of hibernation.

"It's great news, because it looks like the PSNERP will be in the next Water Resources Development Act reauthorization, and it will be funded at the level of $450 million for three substantial projects that are part of a larger grouping," said Dr. Labiosa. Those projects include the removal of roughly 30,000 linear feet of shoreline barriers, moving and raising a highway, and some ecosystem recovery in the Nooksack River delta. "The anticipated benefits of that are roughly a quarter of the Puget Sound Action Plan's restoration goals for estuary habitat recovery," Dr. Labiosa said.

The North Fork Skagit River delta project will restore some of the floodplain and tidal connectivity in the estuary that was diked off largely for agricultural purposes. "Reclaiming a lot of that lost connectivity is very important from a salmon recovery point of view," he said.

The memorandum of understanding that was announced last week included a federal science and monitoring work group that will be run under the auspices of the federal caucus. "The idea there is to do a much better job bringing together federal capabilities in the region," Dr. Labiosa said. "We do a lot of important work right now, but it's not really marshaled to support Puget Sound recovery in fully-integrated manner. It's largely in support of our own individual missions and organized around individual issues at the present."

The Puget Sound Partnership was created to cut across that problem of individual missions not achieving regional ecosystem recovery; the idea was for the feds to do a better job of helping with that problem,

bringing to bear their resources. Dr. Labiosa said there are some short-term steps that can be done, such as listing the high-priority activities that need help on the collaboration side or the funding side and trying to find funding for them; they can do a better job of integrating with the Puget Sound Partnership science panel so that the science planning is coordinated with federal science planning.

"We're going to use this as an opportunity to lay out the vision of what a federal science program would look like in Puget Sound," Dr. Labiosa said. "It will require resources, and it will require program building, and a real budget that directly supports this program. I want to make sure you really take in the importance of that. We have the opportunity to help lay out what that thing could look like. Building on what we hear at this workshop, for example, and also getting input from the state side and other interested parties so that we can really gin up something that'll work."

Dr. Labiosa noted that they've been stuck with a lack of a budget process for the last eight years. "One of the reasons why the Feds haven't really moved on Puget Sound is we haven't had a budget that allows new things to be created," he said. "On the other hand, we're now at the point where we really can have a lot of flexibility in this vision that we put together. We really hope that with the little volunteer army that we have right now, that we're going to be able to do that in a meaningful way."

There are a number of key activities going on, a lot of small successes, and a lot of important work focused around particular issues and particular places. These include efforts such as the NOAA's Integrated Ecosystem Assessments (IEA) for the California Current and Puget Sound[41] as part of their mission work. The USGS has some funding for a coastal and habitats in Puget Sound landscape project, but it's not funded at the level where it can make the envisioned impact. The Salish Sea Marine Survival Project[42] is an important project to try to determine the cause of salmon mortality in the Sea. Ocean acidification related work is really coming to the fore.

On the co-production side, the Salish Sea Ecosystem Conference[43] is held every two years which brings people together to talk across science areas and also to policy makers. The Vital Signs monitoring work that tries to answer if they are making progress towards recovery is very under-resourced, but it's there and it's something to build upon, Dr. Labiosa said. A big driver now is effectiveness assessments of recovery projects to see if they are performing as expected, and if not, why not. There are yearly science policy forums; they are working to make those more effective, he said.

"On the biennial science work plan, we look at and recommend priority actions and recommendations every two years, but again, we don't have a funding mechanism to fund that work, so we're trying to influence others with that process," Dr. Labiosa said. "I think that's where a federal science program could fit in; to try to help make that more of a 'what should we fund?' kind of question, rather than 'what should other people fund, because we say so' kind of situation. Of course, we have the advice and review roles as well."

A key missing piece has been work plan alignment across federal agencies, but there is some work underway. Dr. Redman said they suffer from decision makers who don't understand that they need the decision making model such as the model Coastal Louisiana uses; they need decision-maker's commitment to science-based advice and scientists that are committed to delivering science in a useful

[41] Ecosystem Assessments (IEA) of the California Current and Puget Sound. NOAA. https://www.nwfsc.noaa.gov/research/divisions/cb/ecosystem/nearshore/iea.cfm
[42] Salish Sea Marine Survival Project. http://marinesurvivalproject.com/
[43] Salish Sea Ecosystem Conference. http://cedar.wwu.edu/ssec/

form. “The people aren't understanding the value that would have, and how that would be worth the cost,” he said. “I think, to Dr. Reed’s point [Coastal Louisiana], do follow the lead of others, but be willing to simplify the model so it's useful.”

They also need attention to traditional ecological knowledge and the full transboundary system. “Frankly every time someone looks at our system, and when you look at our map you'll say the same thing, is "you're only dealing with one side of the border,” Dr. Redman said.

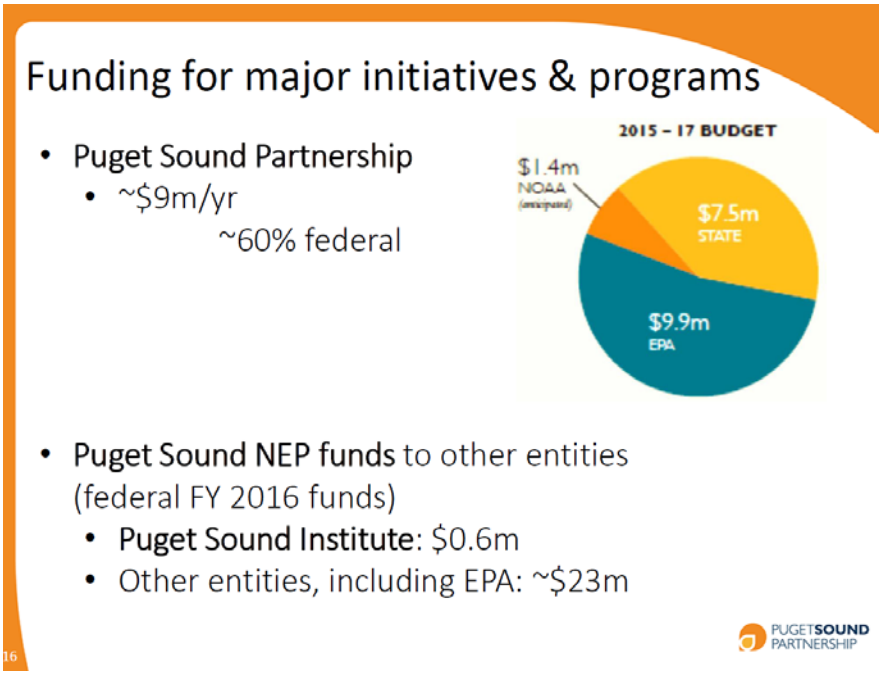


Figure 11, Slide 16

With respect to funding, Dr. Redman said there isn’t a separate science element for funding the program. “We don't have any set aside with the allocation of the National Estuary Program that so much will go to research and monitoring,” he said. “We really borrow from these implementation funds, which helps with the co-production side of things, but really doesn't allow us to build the science horsepower that we've imagined would really serve the system well.”

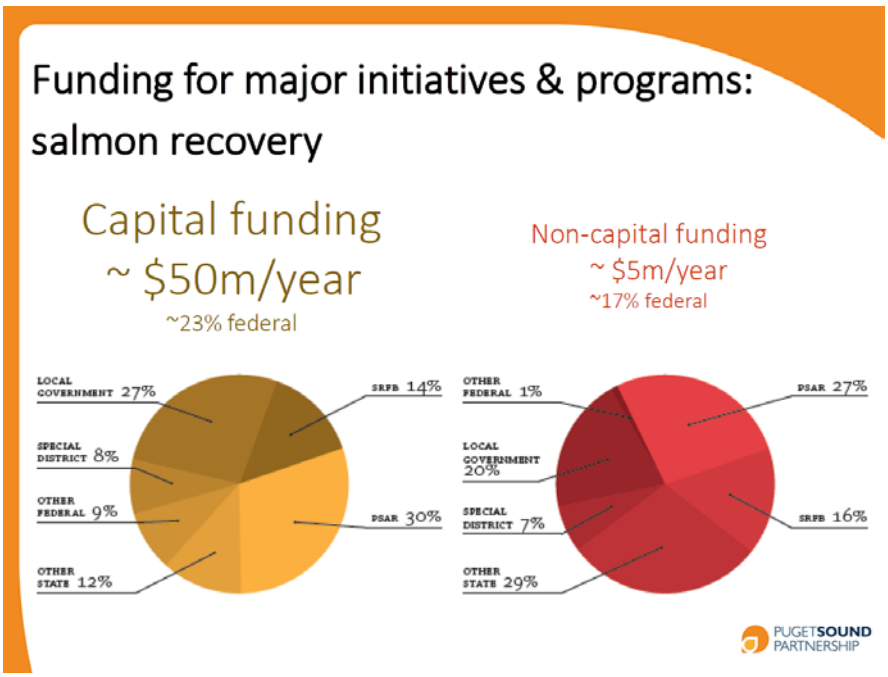


Figure 12, Slide 17

That’s also true for salmon recovery. “We do see a really nice blend of federal, state, local, even private investment,” Dr. Redman said. “We have seen some better articulation of what percent of the effort should be devoted to science, but even that is a bit spotty, so I think our answer to "what's the funding for science?" It kind of depends on people's willingness in a program to invest in science.”

Dr. Labiosa said that although they’ve been delivering the message that they’re not coordinated

enough, there are some things they've done pretty well. "One is that we take social science very seriously in Puget Sound," he said. "That doesn't necessarily mean we fund it well, but that's not a reflection of its perceived importance; it's a reflection of our funding realities. A group that spun from the Puget Sound Partnership science panel to include researchers from the University of Washington and other places has been meeting over the years, and they have really put together an impressive body of work supporting the human well-being indicator side. For example, the PSP recovery goals, really bringing that in. We've been looking at how to use structured decision making in a way to support recovery planning and implementation."

There is an integrated ecosystem model for Puget Sound being spearheaded by NOAA; it's a marine food web model that is being linked to biogeochemical cycling. "It's very cutting edge, very impressive stuff, but that's NOAA's mission so it's on the marine side, it's not the landward side," Dr. Labiosa said. "We want to try to think about what an integrated ecosystem model that includes the land side might look like, and put that together in the future."

There is good work going on at the Climate Impacts Group[44] at the University of Washington and elsewhere, summarizing information on climate change and ocean acidification in the state of knowledge report that came out last year. The USGS is working on the implications of sea-level rise. There are very large implications for habitats, floodplain recovery, and estuary recovery; USGS is attempting to secure a million dollars a year for five years to support this work. "Our claim is that you have to think about the importance of sea-level rise within the context of co-incident winter storm surges, high tides, and river floods," he said. "The big floods occur under that very unlikely event of a big storm with a very high tide and sea-level rise at the same time with high river flooding, that's when things really happen."

They are working with eDNA so they can think about salmon patterns with limited resources. They are now at the point where they're looking at using eDNA to think about numbers of fish and not just their presence or absence.

Question and Answer

Question: I'm one of the social scientists scattered in the crowd here, so I have a particular bias. I want to challenge you a little bit on this idea that you're treating the system as an integrated socio-ecological system. When you presented your water quality goals separate from your socio-economic goals, I have to immediately wonder, when you set water quality goals, you're implicitly asking people to change their behavior, to make trade-offs? It's how the Clean Water regs are written; it's scientists who decide what the water quality goals are. Trust me, when you eventually get to paying for this, people start asking very difficult questions about those water quality goals. The economists are trying to suggest that those kinds of decisions are really socio-political goals, right from the get-go, and that a truly integrated system would be looking at what are the trade-offs of setting those water quality goals?

Dr. Redman: As soon as we set targets, which we were so very proud of, our science panel including social scientists, said, the real story is how do these fit together, and if so, what gives? You're right. That's the space we're in. We're glad to have those up there in front of us, but we're unsure really how to crack that problem. One thing we are encouraged about is that a member of our leadership council is very keen that as we adopt those Vital Signs, we don't just use them as part of our monitoring system, to record and to track progress, but that we also do impact analysis about those Vital Signs. What's the

[44] Climate Impacts Group. University of Washington. https://cig.uw.edu/

effect of a proposed action on culture, on sense of place, on outdoor recreation? We intend to infuse the dialogue about actions, whether they are focused on species recovery outcome or something else a little more broadly. That's probably only part of the answer.

Dr. Labiosa: The one thing I would add to that is there's another bite at that apple. The way that we're trying to organize implementing ecosystem recovery on top of all this other work is through the development of implementation strategies, picking off a large part of the problem, such as a shoreline recovery implementation strategy, or a storm water related implementation strategy. Within that implementation strategy process, we can think about questions that aren't so neatly addressed within the framework of the goals as we've laid them out. We can roll up our sleeves and go into the real world as we do that. We view a good bit of how to do that from the adaptive challenge point of view, where we're not giving folks a road map on how to solve the problem; we're working with them to define and constrain the problem so that they can help figure out how to solve the problem. I think you can get into the real-world issues you referenced when you're involving the people on the ground, to try to help do that. I say we're doing that, but we're still trying to get people to understand better what that means, the nature of adaptive challenges versus technical challenges.

Question: The Puget Sound and Great Lakes are somewhat unique in that they're trans-national. You already acknowledged that you're addressing one half of the ecosystem; that might be hard enough. I was curious on more details and if there's been an effort to coordinate and leverage funding for important research with Canada as well.

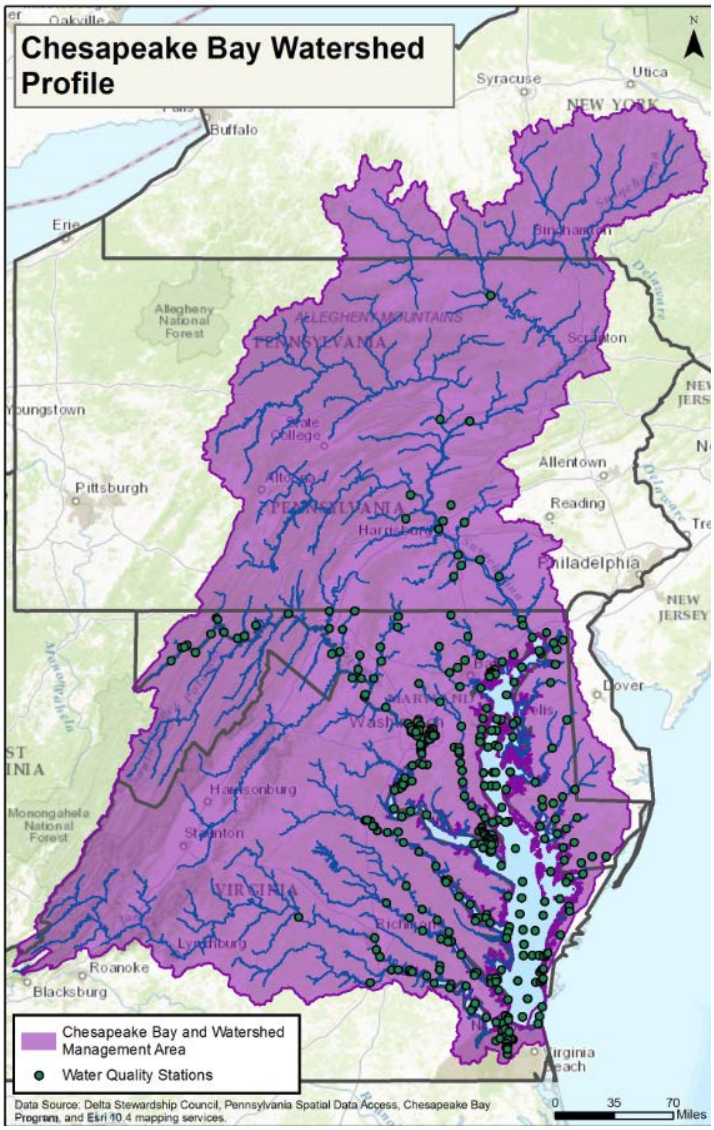
Dr. Redman: There's been a history of attempting to coordinate, and it benefited in the early 1990s from the governor and the Premier signing an environmental cooperation agreement. We formed trans-boundary task forces, including some on science and monitoring. What almost immediately happened is that we fell back to the US side of the work group got together, and the BC side, the Canadian side, of the work group got together. It's just a really hard culture to break through. Not to say that we have stable politics or political leadership here, but it's really been hard to break through because the Canadian federal governments come in and out of that system. The province has been agreeable or not to working with us. It continues to be a big challenge. We're pretty hopeful that the energy around the trans-boundary conference and some simple indicators reporting leads us in that direction, but we're most hopeful that it will be about shared discussion about what the problems are, and that the solution space is in most cases not going to be trans-boundary.

Question: Here in the Sacramento San Joaquin river Delta, it appears to some that there's a myopic focus on a few of the stressors as a result of species being listed and those few stressors having a federal nexus and as a result, having greater attention because of a consultation under the Endangered Species Act. In your presentation, you touch on species that are listed, but quickly turn to the efforts being focused on watershed or ecosystem. I'm wondering if in your experience on Puget Sound, you have focused on particular stressors or if you've been able to avoid that?

Dr. Labiosa: What I would say is, we have enough issues that it's not as bad as a myopic focus on one little thing, it's more like a myopic focus on 26 different “little” things. But because we do have so many little things to worry about, it does give you a fairly broad look across the larger ecosystem and I really do think that we do need to think bigger and to think at that higher level about how to bring these diverse elements together in a more intentional way. It's a very complicated set of issues that we're wrestling with, so that's both good and bad. It does divide our forces a lot, but we certainly don't get wrapped around one axle.

Dr. Redman: Maybe to the detriment of what the tribes and NOAA fisheries have pointed out about our inability to protect existing habitat, it might be that we've swung the pendulum too far away from what you're describing here.

Chesapeake Bay and Watershed



Background

The Chesapeake Bay (Bay) is the largest estuary in the United States and connects the Atlantic Ocean with the over 150 major rivers in the surrounding watershed. The Bay is within Virginia and Maryland, while the watershed extends to New York, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, and the District of Columbia. The extremely productive Bay and surrounding lands encouraged numerous early settlements in the area along with rapid growth in agriculture, industry, and population starting in the 1700s thought the 1800s. After WWII extensive urban development accelerated, along with increased use of fertilizers on agricultural lands, leading to degraded water quality, loss of habitat and over fishing.

Why is this system important?

The Bay and watershed covers about 64,000 square miles.[45] The ecosystem is complex and supports over 3,600 species of plants and animals. Threatened and endangered species that rely on the Bay ecosystem include the atlantic sturgeon, the puritan tiger beetle, and the loggerhead sea turtle. Almost 18 million people live within the Chesapeake Bay watershed, most of which rely on the system for drinking water.[46] The Chesapeake Bay system heavily bolsters the region's economy by supporting commercial fishing. Each year, 500 million pounds of seafood are harvested, yet productivity used to be much greater. Oyster harvests have fallen to less than 1 percent of historic levels.[47] Other industries reliant on the Bay include tourism and recreation, agriculture, real estate, and shipping. In

[45] Facts & Figures. Chesapeake Bay Program. http://www.chesapeakebay.net/discover/bay101/facts
[46] Chesapeake Bay. National Wildlife Federation. https://www.nwf.org/Wildlife/Wild-Places/Chesapeake-Bay.aspx
[47] The Economic Importance of the Bay. Chesapeake Bay Foundation. http://www.cbf.org/about-the-bay/issues/cost-of-clean-water/economic-importance-of-the-bay

2009, the lands and water of the Bay region provided an estimated $107.2 billion[48] annually in general economic benefits. It is projected that by restoring the Bay, rivers, and streams, the economic activity driven by the Bay will increase by $22.5 billion a year.[49]

What are major challenges?

The major threats to the Chesapeake Bay are population growth and associated effects of land-use change, pollution, and resource consumption.. Forests and wetlands provide critical wildlife habitat, protect clean water and air, and support recreation and the economy. By the late 1800s, 40-50 percent of the watershed's forest had been harvested for timber and to make space for agriculture and urban development. Between 1990 and 2005, about 100 acres of forest habitat were lost each day to urban and agricultural development. Increases in impervious surfaces have also results from development. The major pollution input to the Bay is excess nutrients, which come from agriculture and urban runoff, wastewater treatment plants, and air pollution. Excess nutrients fuel harmful algal blooms, which deplete the water of oxygen and suffocate aquatic life. Two other major sources of pollution are chemical contaminants (including pesticides) and sediment. Some resource management actions have led to over harvesting of fisheries and introduction of invasive species (like the blue catfish and zebra mussel),). These challenges are compounded by climate change, which causes warming temperatures and more frequent occurrences of extreme weather.

How is restoration and scientific research organized?

The Chesapeake Bay Program was formed in 1983 to guide restoration efforts. The program is a regional partnership that includes dozens of federal and State agencies, local governments, non-profit organizations, and academic institutions. The partners work together through voluntary agreements that are implemented by the Bay Program's goal teams, workgroups, and committees. . In 2009, President Obama issued Executive Order 13508 for Chesapeake Bay Protection and Restoration, directing the enhanced federal involvement by over 10 different agencies. In 2014, the Chesapeake Bay Watershed Agreement was signed by representatives from each of the watershed's six states and the Federal Government, containing ten goals aimed at advancing restoration and protection. Data and information related to restoration and pollution prevention efforts are communicated, tracked, and shared via ChesapeakeStat and the Chesapeake Bay Program Data Hub.

How is scientific research funded?

Broadly, a range of agencies and organizations conduct coordinated science activities to support the Chesapeake Bay Program's goals. Funding comes from numerous federal agencies, State and local governments, non-governmental organizations, and private interests.[50] Currently, there is only a rough estimate of funding that is directed toward science, with is $40-60 million. Like the other systems, science research funding is rarely separated out as a budget line item. Of note, the recently passed Chesapeake Bay Accountability and Recovery Act will require an annual Federal-State Cross-Cut Budget starting in fall of 2016.[51] The funding reported under this Act was the States contributing about $1.2 billion with the Federal Government providing about $500 million.

[48] The Economic Benefits of Cleaning up the Chesapeake. Chesapeake Bay Foundation. http://www.cbf.org/news-media/features-publications/reports/economic-benefits-of-cleaning-up-the-chesapeake-bay

[49] *Id*

[50] Chesapeake Bay Accountability Act report to Congress, 2016

[51] Chesapeake Bay Accountability and Recovery Act Implementation (CBARA). Chesapeake Bay Program. http://www.chesapeakebay.net/channel_files/23868/cbara.pdf

Funding information reported related to the Executive Order for FY2016, shows federal agencies provided an estimated $487 million in funding for the Chesapeake Bay Program. For reported years 2011-2016, average annual funding was $473.3 million and totaled $2.8 billion.[52]

Chesapeake Bay and Watershed Presentation

Presenter:

Scott Phillips, USGS Chesapeake Coordinator

Presentation

Figure 13, Slide 3

Science and restoration activities at Chesapeake Bay are focused on restoring fish and wildlife populations while simultaneously trying to provide benefits to the 18 million people who live there. There are almost 3,600 different species of plants and animals. Some of the most followed species are striped bass (with about 90 percent of striped bass in the Atlantic Ocean spawning in the Bay), blue crabs, and migrating waterfowl, since the Bay is part of the Atlantic Flyway.

"All of this provides a lot of economic benefit for the mid-Atlantic area, but we've had problems over the past century," he said. "With the amount of people came into the watershed, we started seeing declines of fish and wildlife species for two main reasons: poor water quality and loss of habitat. That was all caused by the population growth we had in the area, as well as some climate variability and over harvesting."

Mr. Phillips then presented a graph showing female striped bass population. "Back in the seventies, they had really been decimated by over harvesting," he said. "So when the Bay Program first started, one of the big decisions made was to put a moratorium on striped bass harvesting. It was very controversial through both Maryland and Virginia, but as you can see from the graph, we had a pretty remarkable recovery of the striped bass populations after that moratorium. In fact, now they're at levels between the thresholds that we try to manage them of our fishing and mineral populations as shown by the two lines on the graph."

[52] Funding. Chesapeake Progress. http://www.chesapeakeprogress.com/funding

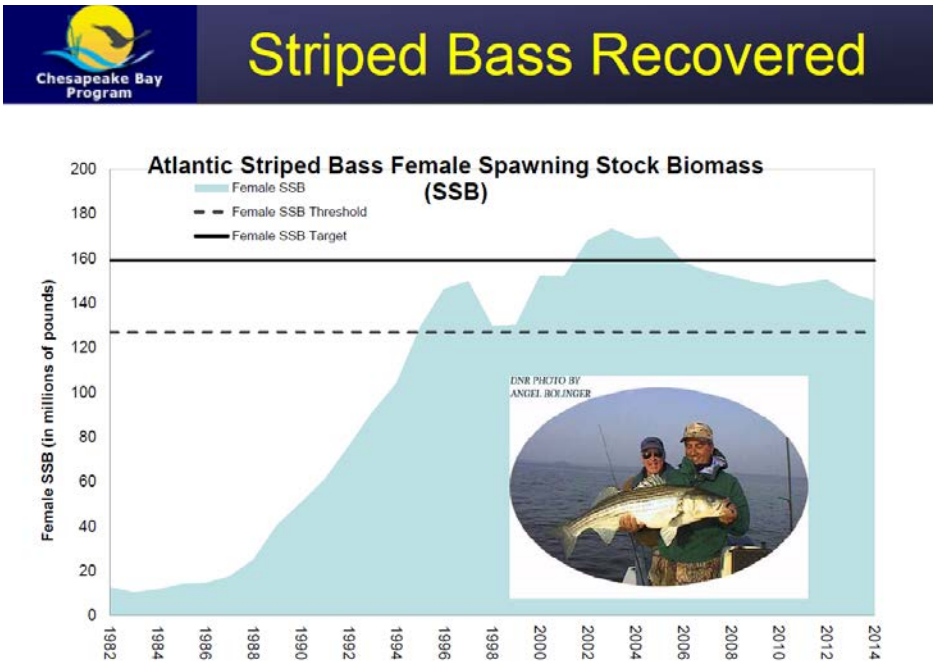


Figure 14, Slide 4

Blue crabs are another important species and one of the delicacies in the area. Mr. Phillips presented a graph showing their population from 1993 to present, noting that the population has been near the lower part of the threshold for much of the record due to overharvesting, poor water quality, and other environmental factors that affect the life cycle. Harvest limits were established and efforts made to improve the water quality to support fish and shellfish such as the blue crabs.

There are two main issues with water quality: low dissolved oxygen as each summer, there are fish kills due to anoxic conditions in the bay, and poor water clarity which has caused loss of submerged aquatic vegetation. Mr. Phillips noted the submerged aquatic vegetation is important for putting oxygen into the bay, for providing spawning habitat for a lot of the fish and shellfish, and as food for the waterfowl.

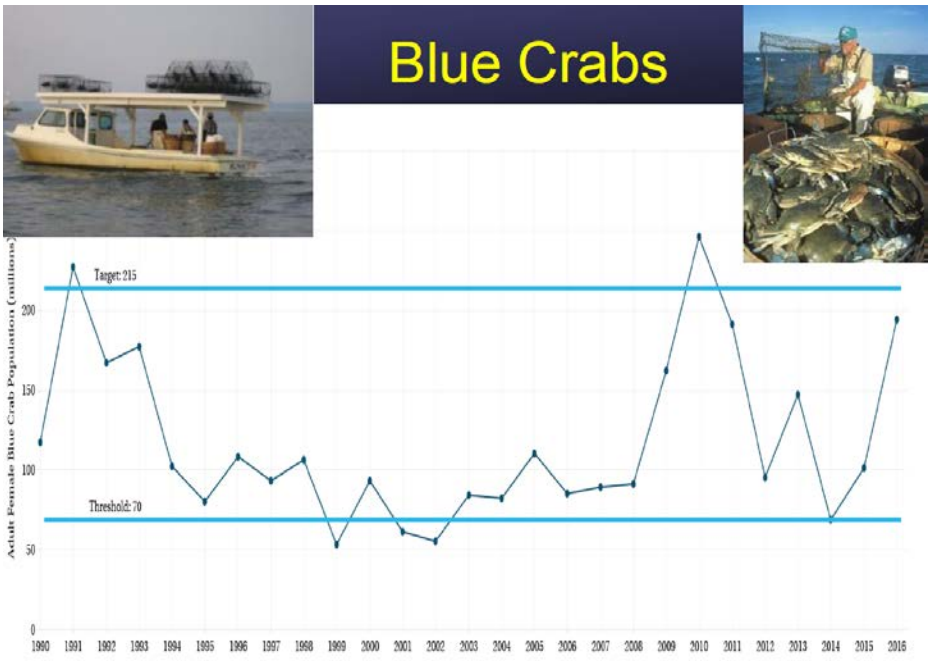


Figure 15, Slide 5

An initial part of the Chesapeake Bay Program was to try to improve water quality conditions; however, since the standards were set, they have only been able to achieve about 30 – 40 percent of attainment. “A big focus of the Bay was trying to reduce nutrients and sediment that come into the tidal waters that cause these water quality declines,” he said. “When the Bay Program started, we had some improvement in conditions; most of that

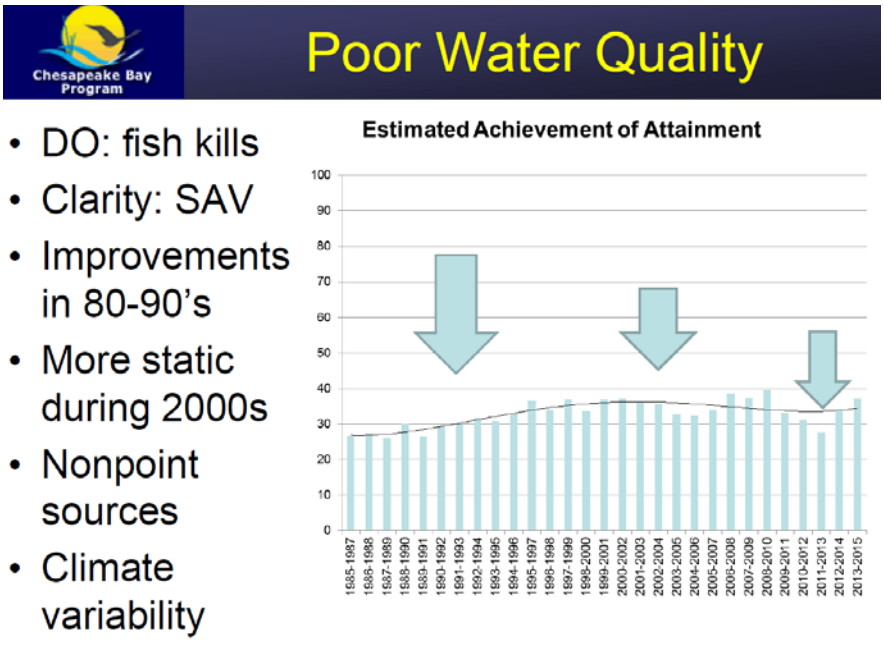


Figure 16, Slide 6

was due to point source upgrades as the EPA put a lot of money into reducing nutrients coming from waste water treatment plants."

Conditions have been more static since about 2000, and due to the lack of improvement, they have been working to address non-point sources of pollution, especially agriculture and urban-suburban runoff. This led the Bay Program to move from a voluntary program to reduce nutrients and sediment to a more regulatory program in 2010 when Total Daily Maximum Loads (TMDLs)[53] were established for the entire watershed. "It's the biggest one in the nation," Mr. Phillips said. "But while it has led to more focused efforts to reduce nutrients and sediments, it has almost fractured some of the partnerships that we've had in the Bay Program."

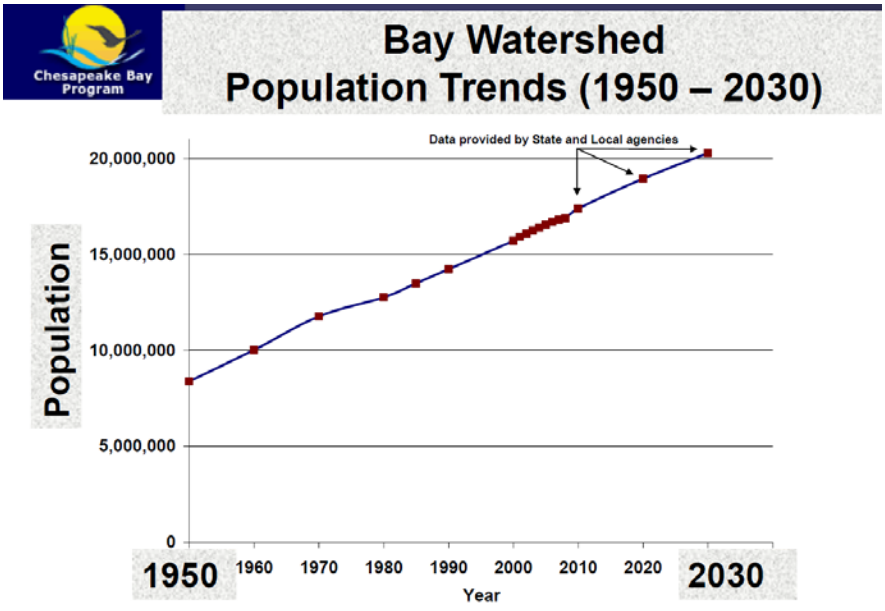


Figure 17, Slide 7

They have also been experiencing increased variability due to climate change. "Big storms in some places will have large amounts of nutrients and sediment washing into the bay causing some of the degradation that we have, especially in the summer months," he said.

A lot of these issues are driven by the number of people in the watershed, Mr. Phillips acknowledged. "We've doubled the amount of people in the watershed over the past fifty years from about 8 million in 1950 to about 18 million at present and we're expecting that to continue to grow. This is a situation where, even though we're trying to restore the system and in some places

[53] Chesapeake Bay Total Maximum Daily Load (TMDL). US Environmental Protection Agency. https://www.epa.gov/chesapeake-bay-tmdl

conserve other parts of our ecosystem, we're up against continued population growth, so that's why we're trying to bring in more of socioeconomic decision making into the Bay Program."

The Chesapeake Bay Program[54] was established in 1983 under the Clean Water Act, and because of that, it did have a big water quality focus when it began. The federal lead agency for the program is the U.S. Environmental Protection Agency (US EPA). They also partner closely with the six states in the watershed as well as Washington, DC; local governments, and a large number of academic institutions that help provide the science.

"The way we work is really topically based, where we have goal teams for fisheries, habitat, water quality, and land conservation," he said. "That's where we have a nexus of scientists and resource managers working together to try to say, 'How are we going to restore or recover those different topic areas?' So a lot of co-production right there. That goes up the food chain, where you have higher level policy managers trying to take that science and recommendations and put it into policy decisions, and then finally, once a year, the governors of those six states and the EPA administrator meet to talk about what has been accomplished and what are some of the directions we need to set out in the future. Science factors in in two ways: we have an assigned coordination group and an advisory group."

In the beginning, it was mostly a voluntary partnership worked through a series of agreements, the first in 1983 through 2000; the agreements had a water quality focus on nutrient and sediment reduction. By 2000, the agreements broadened things out to look at fisheries and habitat, as well as water quality.

In the early years of the Obama Administration, President Obama put out Executive Order 13508 - Chesapeake Bay Protection and Restoration[55]. "This came from Tim Kaine, who at that time was governor of Virginia, and he wanted to get more federal involvement within the Bay watershed," said Mr. Phillips. "So at first, the executive order did not focus on science at all. We were negotiating what should be in this order and we were able for them to move out from just recovery of habitat, fisheries, and water quality to also consider climate change and the strength in science as part of that executive order. It took some work, but we got it in there, and the administration has been pretty supportive of providing funding to back that executive order up, but not all of those requests from the administration actually make it through Congress."

About the same time as the Executive Order, the TMDL program was established. Mr. Phillips said this formed a real chasm in the Bay Program, because the states now were being told what to do under a regulatory framework versus voluntary agreements. "We had the executive order come out in 2009 and the TMDL in 2010. It took about four years for us to recover into a voluntary partnership again where we finally signed what we called the Chesapeake Bay Watershed Agreement[56] and the states and the federal government agreed to what they were going to work on through 2025."

The agreement has 10 goals and 31 outcomes, which are too many to be able to do effectively, so they are working through a prioritization exercise.

[54] Chesapeake Bay Program. https://www.chesapeakebay.net/
[55] Chesapeake Bay Executive Order. http://executiveorder.chesapeakebay.net/page/About-the-Executive-Order.aspx
[56] Chesapeake Bay Watershed Agreement. Chesapeake Bay Program. http://www.chesapeakebay.net/chesapeakebaywatershedagreement/page

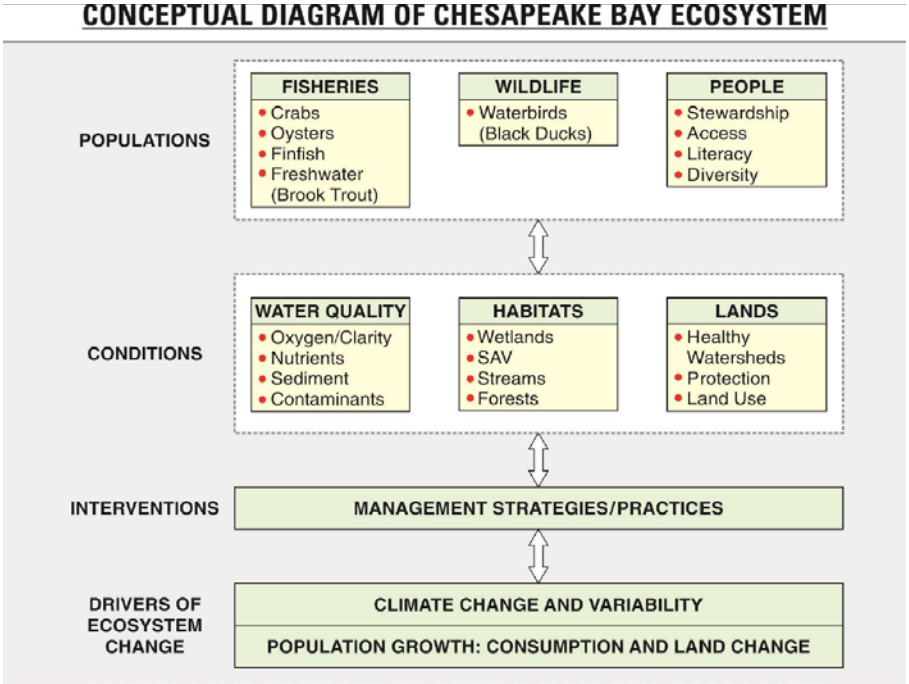


Figure 18, Slide 10

"Let me visualize what this looks like for you," Mr. Phillips said. "The big overall goal is to restore and sustain populations of fish and wildlife for the benefit of the people and the watershed and beyond, through bringing back their conditions, water quality, and habitat, and while also conserving the lands they depend on through different management interventions," he said. "These can be practices and policies, while trying to take into concern what the future conditions could be, both from population growth and associated consumption and land change, as well as climate change variability."

Each of the 10 goals has an outcome that is measurable. "We went through a long process with the Office of Management and Budget to say, 'We will restore crabs, oysters, and rock fish to these target levels by 2025,'" he said. "All these outcomes have a decade target that we need to address. One big issue here is trying to make sure groups aren't focused just on their outcomes; we have an interconnection between these outcomes, so we have more of an ecosystems approach. That's one of our big challenges."

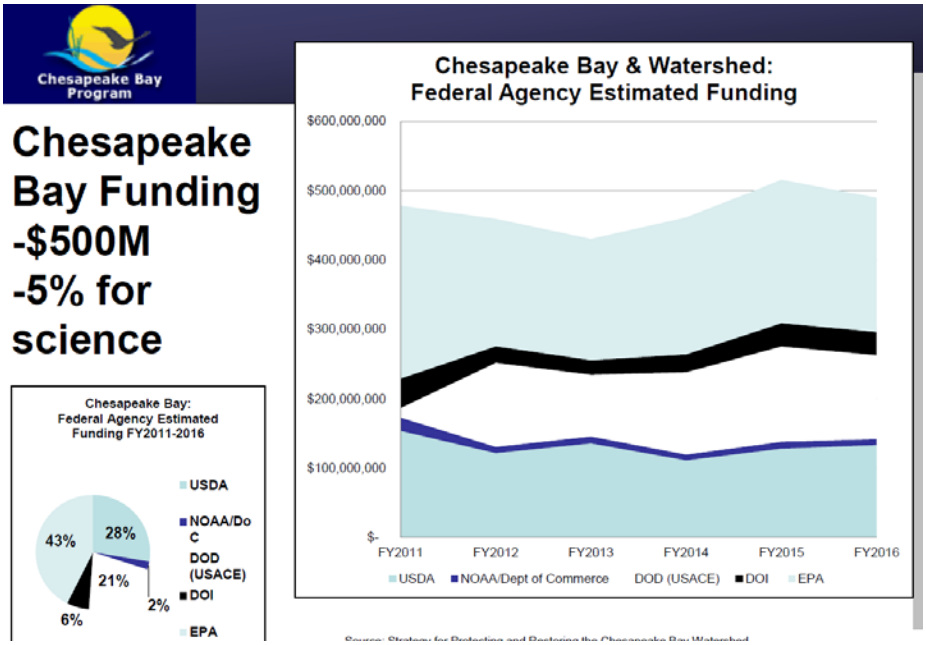


Figure 19, Slide 11

Federal funding is about $500 million; over time it's waned, but since the Executive Order, funding has increased and has sustained well over time. The majority of that funding goes for water quality improvements; much less of the funding goes towards fisheries, management, or habitat restoration, which is mostly supported by NOAA and the Department of Interior at the federal level. The

states put in a similar amount of money - about $600 million dollars, mostly focused on water quality restoration.

"This is one of our big challenges," Mr. Phillips said. "We have an unbalanced approach for the 10 goals we're trying to meet. I would say 80 percent of the effort is just for water quality. Of that, I would say 5 percent goes maybe goes for science if we're lucky."

Mr. Phillips then turned to how science is organized in the program. "We have a very closely linked science decision framework where we work with the resource managers on a daily basis on decision making," he said. "Where science informs is in setting up the ten goals and the factors influencing those goals to help inform what the management approach is to be. Then we have monitoring in place to assess, 'Are we getting the environmental benefits we had hoped for?' Then, we synthesize information so resource managers can make adjustments to their strategies, or we can make adjustments to our science."

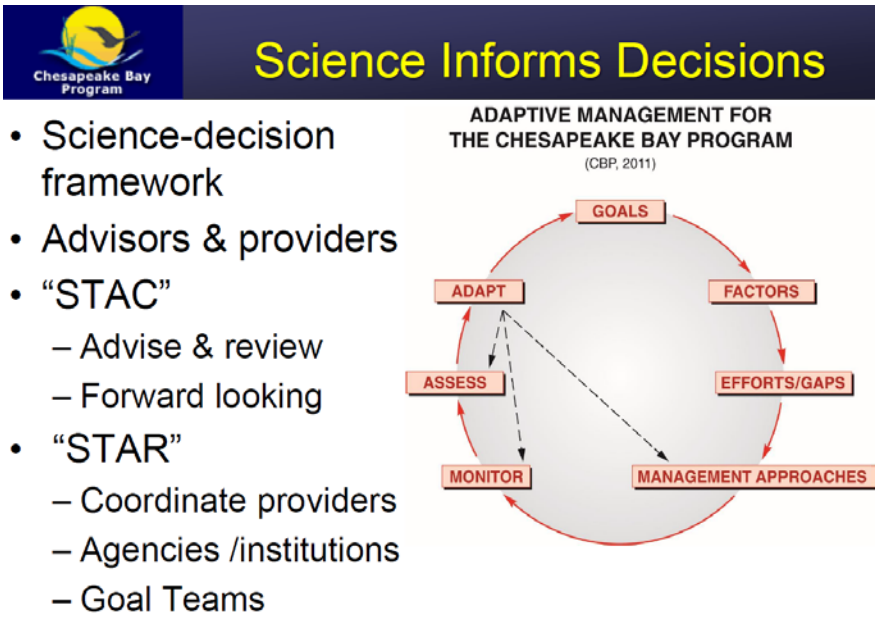


Figure 20, Slide 13

There are two main science groups: an advisory group and a science provider group. The advisors are the Scientific and Technical Advisor Committee (STAC)[57], which is comprised of 38 different representatives, mostly from academic institutions who review and provide guidance. "They are more forward-looking," he said. "They say, 'ten years from now, you need to be worried about climate change, because if you look at projected increases of relative sea level rise, Chesapeake Bay has the highest increase of the whole east coast.'"

On the other hand, the Scientific, Technical Assessment and Reporting (STAR)[58] team is where they try to coordinate the science for the topical areas. This group is comprised of the different agencies and academic institutions, and they support the management needs of the goal teams.

Mr. Phillips then presented an organizational chart for the science enterprise. At the top are the goal teams which focus on fisheries, habitat, water quality, healthy watershed, stewardship, and leadership. Then there is the STAC and the STAR team who tries to coordinate the science from all of the providers

[57] Scientific and Technical Advisor Committee (STAC). Chesapeake Bay Program. http://www.chesapeake.org/stac/
[58] Scientific, Technical Assessment and Reporting (STAR). Chesapeake Bay Program. http://www.chesapeakebay.net/groups/group/scientific_and_technical_analysis_and_reporting

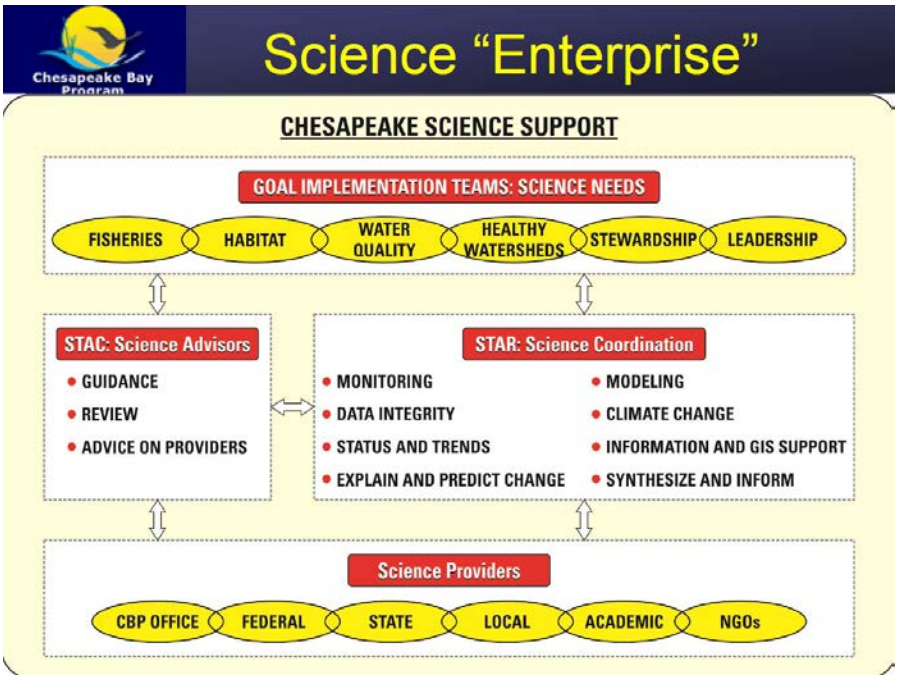


Figure 21, Slide 14

which include the Bay Program office, the GIS team, the federal partners, state agencies, local governments, academic, and NGOs.

Mr. Phillips said that they work directly to prioritize the science needs of the goal teams. "We have 29 outcomes and we can't meet them all, so we usually go through a bi-annual prioritization process that asks, 'What do you need the most for monitoring or modeling, or other aspects of your science?'" he said. "Then we will look for the providers. Usually these different folks have a certain area of expertise, and they are lined up to try to work with these teams. For instance, there's an oyster work group and a crab work group with NOAA members on those, and there are academic institutions helping to support those."

With a lot of different people with different areas of expertise, one way they work is directly under work groups with the teams. "But we don't want them stove-piped. This is where the science coordination comes in where we have a bigger group of functions that we're trying to carry out."

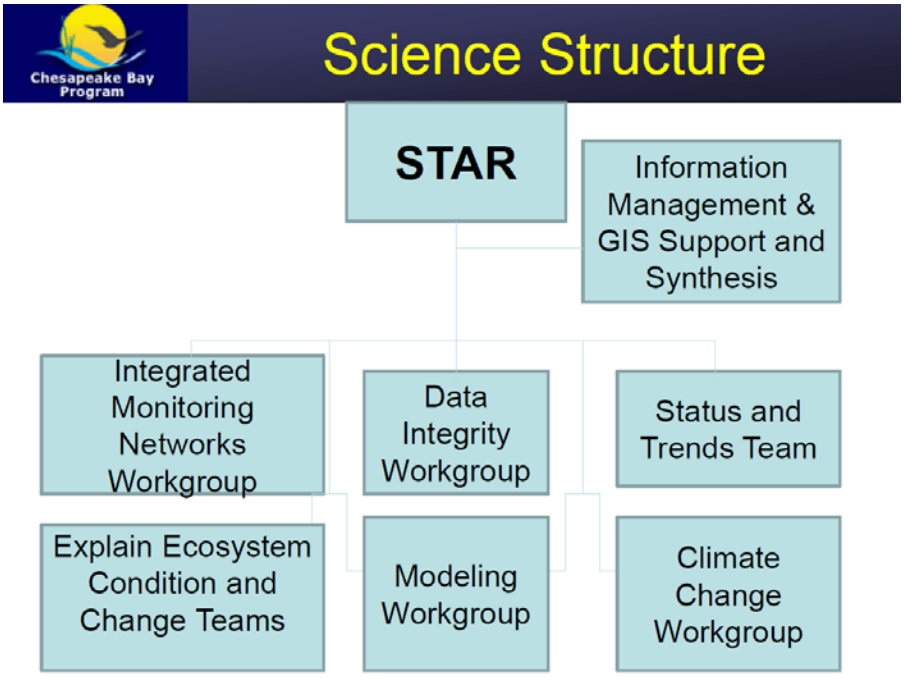


Figure 22, Slide 16

Major functions include monitoring - integrated monitoring, data integrity, status and trends which are the indicators for the 29 outcomes; ecosystem change; modeling, which is mostly water quality based; potential impacts of climate change, information management and GIS, and science synthesis to inform decision making. STAR has established workgroups for these functions which meet monthly and have a full-time coordinator to help them carry out their duties.

There are federal agencies (the USGS, EPA, NOAA, FWS), state agencies, and more than a dozen universities that focused and coordinated through the Chesapeake research consortium as well as STAC and different NGO's. “The way they interact with the resource managers is either through these topical work groups or through STAR,” he said.

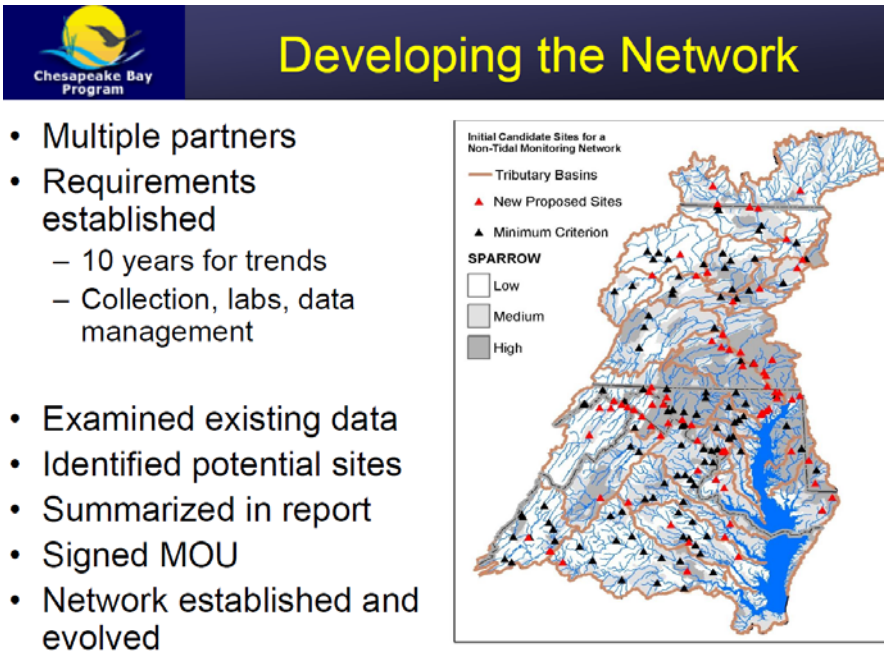


Figure 23, Slide 20

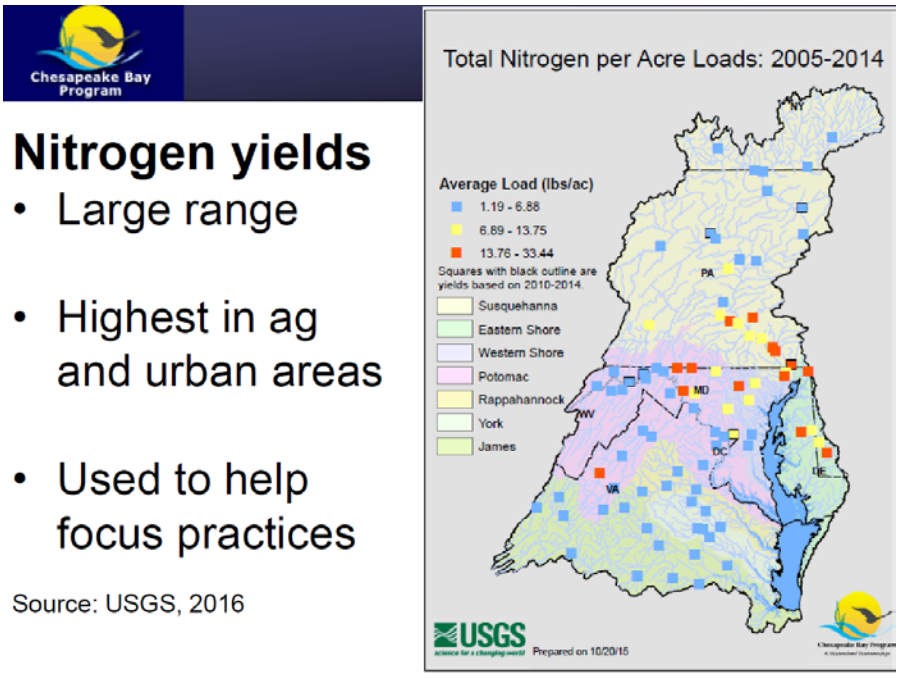


Figure 24, Slide 22

that evolution to occur.”

Mr. Phillips said there’s no magical approach to funding. “We use any way we can think of - multiple approaches,” he said. “A lot of times the federal and state folks bring their own resources. We have certain expertise within USGS, so we have our own science plan. Of those thirty outcomes, there's about ten of them we think we can help with. We work within our internal programs and line those up, so we have about $11 million dollars to put towards the effort. NOAA and U.S. Fish and Wildlife have similar approaches.”

In order to guard against redundancy, there is a federal coordination group that ensures the work plans are aligned. “At the beginning when we had this executive order, there were a lot of turf battles,” he said. “We had to really get beyond that and take what we call an abundance mentality of saying, 'Look, guys, these are complicated issues. There's something in here for everybody if you get beyond your turf war and start working together.' That took a couple years for

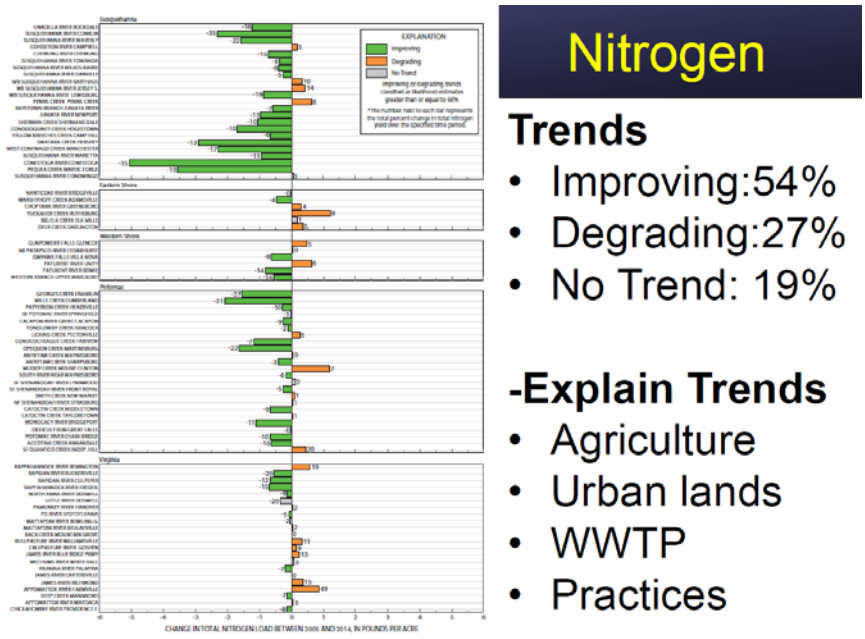


Figure 25, Slide 23

EPA is the lead federal agency that provides resources that can go out through inter-agency agreements, and they've set up RFPs for particular topics that are open for academic institutions and consultants to put forward proposals for. The academic institutions are somewhat coordinated through the Chesapeake Resource Consortium[59], but most of it is individual researchers who already have some funding from their university for a particular topic, but they will try to look for grants from other entities to try to help with that work.

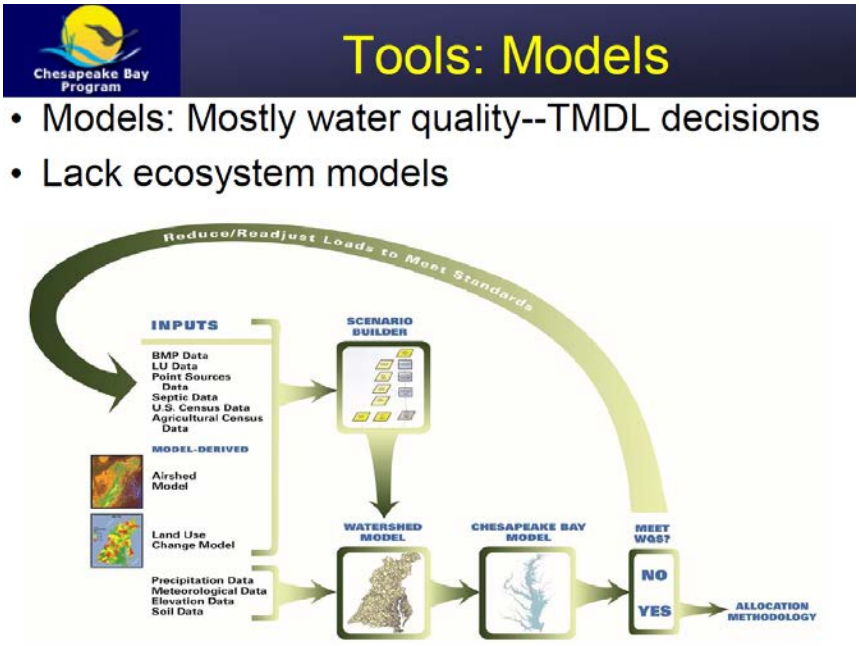


Figure 26, Slide 26

"I think some of the biggest challenges here are that we have more needs than we have resources for, so we have to go through this prioritization process," Mr. Phillips said. "Trying to align what the different groups are doing is very difficult, and we'll have to move on from some of those challenges."

Mr. Phillips then gave an example of how some groups are working with water quality monitoring. "We needed to set up monitoring throughout the bay watershed to look at how these nutrient-sediment practices are working," he said. "What we found was that all the states had different ways to do that. We took two years and we worked with all the partners, we said, 'What are we want to try to do?' We said, 'we want to try and look at trends which will take ten-year investment, and we also need to look at compatible data.' We examined the data, essentially came up with a report of how to approach it and signed an MOU to move

[59] Chesapeake Resource Consortium. http://www.chesapeake.org/

Figure 27, Slide 27

practices," he said.

forward together on it. Now there are monitoring stations, about a hundred and twenty of them across the watershed; not all of those have the ten years of data we need yet, but they will finally."

The program costs about $6 million dollars. It provides information on the watershed that show where the highest yields in red and the lowest in blue, so people can target where they put practices in. The data is accessible through a website. They can also look at trends. "This is what's used to help inform some of the TMDL

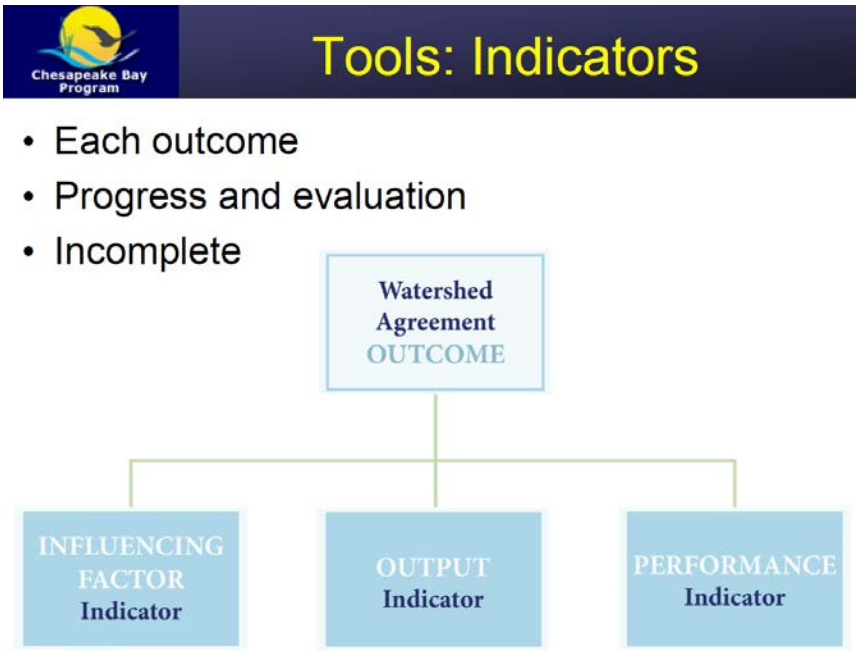


Figure 28, Slide 29

Mr. Phillips turned to his final topic, tools and communication. They work with three major tools: models, monitoring, and mapping. Most of the tools are focused on water quality; they lack a lot of the ecosystem tools.

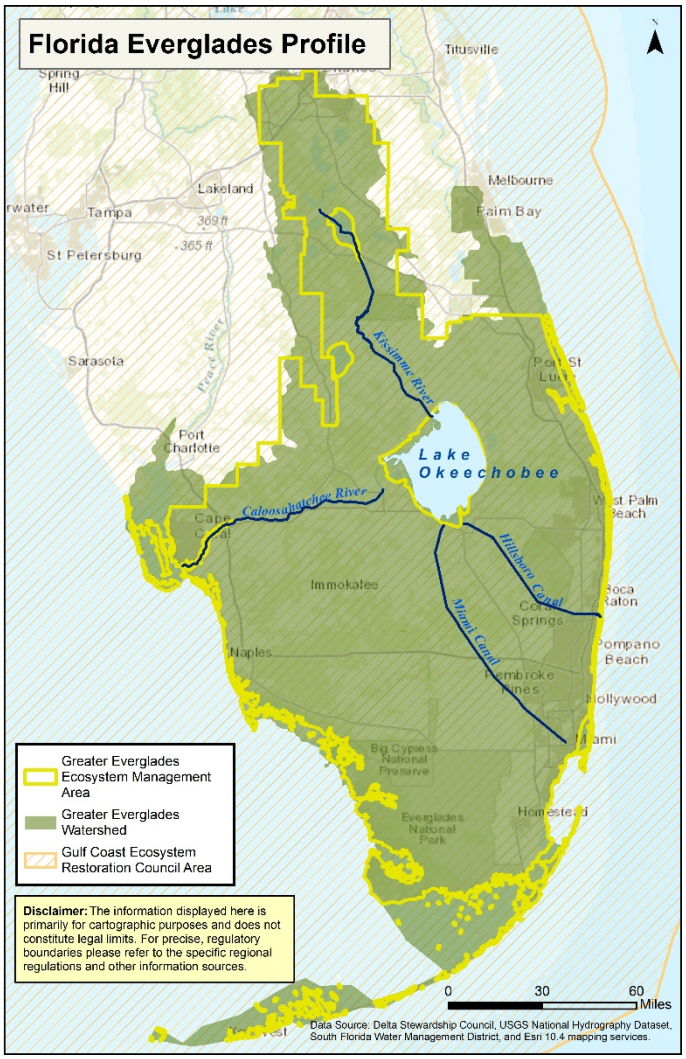
In terms of mapping, they are looking at how outcomes are interrelated rather than looking specifically at each of the outcomes. "Where are the healthy watersheds in the sixty-four thousand square mile area that can support brook trout, that have adequate stream health and that we can put land conservation practices to work in. We try to do mapping exercises to say, 'In these darker areas, that's where all those coalesce, so this is where we should focus our efforts to benefit multiple outcomes by aligning partner activities,'" he said.

Each of the 29 outcomes has an indicator and they try to look at the influencing factor that might affect achieving that outcome. "For the 29 outcomes, maybe half of those have an indicator, so we're really incomplete, given all the monitoring we have to do. This is a big challenge, trying to get the monitoring to set up these different indicators."

In terms of communication, there are multiple audiences that range from policy makers to implementers to the interested public. Mr. Phillips acknowledged that trying to translate to different levels of understanding can be really challenging. “When we try to synthesize, we take the mantra of 'Less is more,'” he said. “The resource managers trying to make decisions can't use all the data and science we put out, so we need to be able to work the scientists to get their findings, interpretations, and sound scientific footing, but that needs to be refined when you start to talk about the implications for decision makers. Then you need to refine and distill it more when you're giving them policy options.”

“Just to summarize, we really depend on the science decision interface,” he said. “Groups of both providers and advisors try to emphasize long term investments and modeling and monitoring, and then use that to evaluate and adapt in this decision framework. This takes a lot of perseverance and passion.”

Greater Everglades Ecosystem



Background

The Greater Everglades Ecosystem is a region of tropical wetlands beginning at the headwaters of the Kissimmee River. The Kissimmee drains into Lake Okeechobee, which would historically spill over its southern banks during the wet season and replenish the Everglades with fresh water. The Everglades was once a free-flowing, vast, and shallow river of grass. Watershed alteration began on a small scale in the late 1800s, and reached a peak with the Central and Southern Florida Flood Control Project authorized in 1948. Hundreds of water control structures and thousands of miles of canals and levees were constructed over the ensuing five decades to provide flood protection and water supply. This large civil works project and the millions of residents reliant on the water it supplies have resulted in significant environmental damage.

Why is this system important?

The Florida Everglades is currently the largest wetland ecosystem in the United States covering over 18,000 square miles.[60] The Everglades supports an extraordinarily rich and unique wildlife population consisting of nearly 70 threatened and endangered species, including the manatee, American alligator, sea turtle, Florida panther, and a variety of birds. About one third of the state’s population (8

[60] What is Everglades Restoration? Everglades Restoration. http://www.evergladesrestoration.gov/

million people) rely on the Everglades for their water supply.[61] The Everglades National Park is a World Heritage Site, an International Biosphere Reserve, and a Wetland of International Importance. The economic influence of a healthy Everglades ecosystem is substantial. Recreational fishing alone generates approximately $1.2 billion a year in economic activity in the 13-county Everglades Region.[62] It is projected that investing $11.5 billion in Everglades restoration will result in $46.5 billion in gains to the economy, and create more than 440,000 jobs over 50 years.[63] Major industries impacted by the Everglades include freshwater supply, fishing, hunting, real estate, and tourism/visitation - all contributing to up to $394.1 billion in dependent economic output in 2008.[64]

What are major challenges?

Meeting the water supply and flood protection needs of population growth, urbanization, and the agricultural sector required severe land-use alterations and water flow control. This effort has reduced the area of the Everglades to about half of its original area. Decreases in habitat, combined with a widespread invasion of non-native plants and animals such as the brazilian peppertree and the burmese python, have resulted in severe ecosystem degradation. Water quality within the Everglades suffers from extreme variations in salinity, pollutants from agricultural/urban runoff and other sources (especially excess phosphorus), harmful algal blooms, and high levels of dissolved organic matter and methyl mercury. Water quality challenges have led to deteriorated habitat and stressed native wildlife. Another challenge includes water management and the complications that go with it, including groundwater overdraft and saltwater intrusion. Development pressure is threatening the remaining Everglades landscape on many of the urban/agriculture and Everglades borders. Climate change, especially more variable precipitation events, temperature increases, and sea-level rise are additional challenges to the Everglades and restoration efforts.

How is restoration and scientific research organized?

In 2000, the United States Congress enacted the Comprehensive Everglades Restoration Plan, the most substantial ecosystem restoration ever attempted. In support, the USGS initiated the Greater Everglades Priority Ecosystem Science program to inform and monitor the results of restoration decision-making. To assist ongoing South Florida restoration efforts, the USDOI and its bureaus, the USFWS, the NPS, and the USGS, developed a science plan to identify the science needed to support natural resources in South Florida. In addition, many agencies, consortia, academic institutions, non-profit organizations, and water districts (including the South Florida Water Management District) are involved in research and restoration efforts. The South Florida Ecosystem Restoration Task Force[65] brings together and coordinates federal, State, tribal, and local agencies involved in restoring and protecting the Everglades.

How is scientific research funded?

While the South Florida Ecosystem Restoration Program Federal Crosscut budget is perhaps one of the more detailed fiscal reports, and funding for scientific research is identified throughout the budget narrative, it is generally integrated within projects or programs and not separated as a budget line item. Like the other system reports, given the nature of estimated budgets, it should be considered as

[61] Quick Facts. The Everglades Foundation. http://www.evergladesfoundation.org/the-everglades/facts/
[62] Reports. The Everglades Foundation. http://www.evergladesfoundation.org/what-we-do/reports/
[63] Economic Benefit of Restoring America's Everglades. Clean Water Fund. http://www.cleanwateraction.org/files/publications/fl/Economic_Benefits_of_Restoration.pdf
[64] The Economics of the Everglades Watershed and Estuaries. Center for Urban and Environmental Solutions at Florida Atlantic University. 2009. http://www.drivecms.com/uploads/riverofgrasscoalition.com/1022369245Thepercent20Economicspercent20ofpercent20thepercent20Evergladespercent20FINALpercent20REPORT.pdf
[65] South Florida Ecosystem Restoration Program: Cross-Cut Budget 2017. Everglades Restoration. http://www.evergladesrestoration.gov/content/cross-cut_budget.html

providing a "directional" estimate that can be compared with other Federal Crosscut budgets in other systems.

For FY2017, federal agencies requested $174.6 million in funding for Everglades restoration. For reported years 1993-2017, average annual enacted and requested funding has been $231 million and totaled $5.8 billion.[66]

For FY1993 – 2017, State agencies enacted and requested in total, $17.095 billion and on average, $712 million in annual funding for Everglades wetland restoration.[67]

Florida Everglades Presentation

Presenter

Dr. Nick Aumen, Regional Science Advisor, South East Region, USGS

Presentation

Figure 29, Slide 2

The Greater Everglades Ecosystem spans all the way up from headwaters north of the Everglades near Orlando, through the upper chain of lakes down through the Kissimmee River watershed and Lake Okeechobee, down through the agricultural areas and Everglades National Park. It includes the conservation areas, the east and west coast estuaries, and Florida Bay all the way out to the reef tracks.

"We have a very expansive definition of what we call the Everglades," said Dr. Nick Aumen. "I think that's important because everything we work on is linked as we know ecosystems function. The area that's shaded represents about 18,000 square miles."

[66] *Id*
[67] *Id*

He noted that there are some special features to South Florida that can be challenging. It's a very, very flat landscape; the span from Lake Okeechobee to Florida Bay is about 100 miles, but the drop in elevation is only about 20 feet. "In the Everglades National Park, when you're driving the main park road, there's a sign noting where the two main watersheds divide, the Taylor river watershed and the Shark river watershed," he said. "The sign says, 'You're now crossing Rock Reef Pass, elevation one meter.' That's the way we work."

That certainly gives us a lot of problems that turn to managing water, he said. "When it rains a lot, the water stays in one place; it's like pouring water on this table top. That's always given water control people and flood control people headaches in how to manage this system but it's still something we have to deal with."

He also noted that the southeast coast of Florida is densely populated, and huge population increases are expected to occur in the areas around Orlando and to the south.

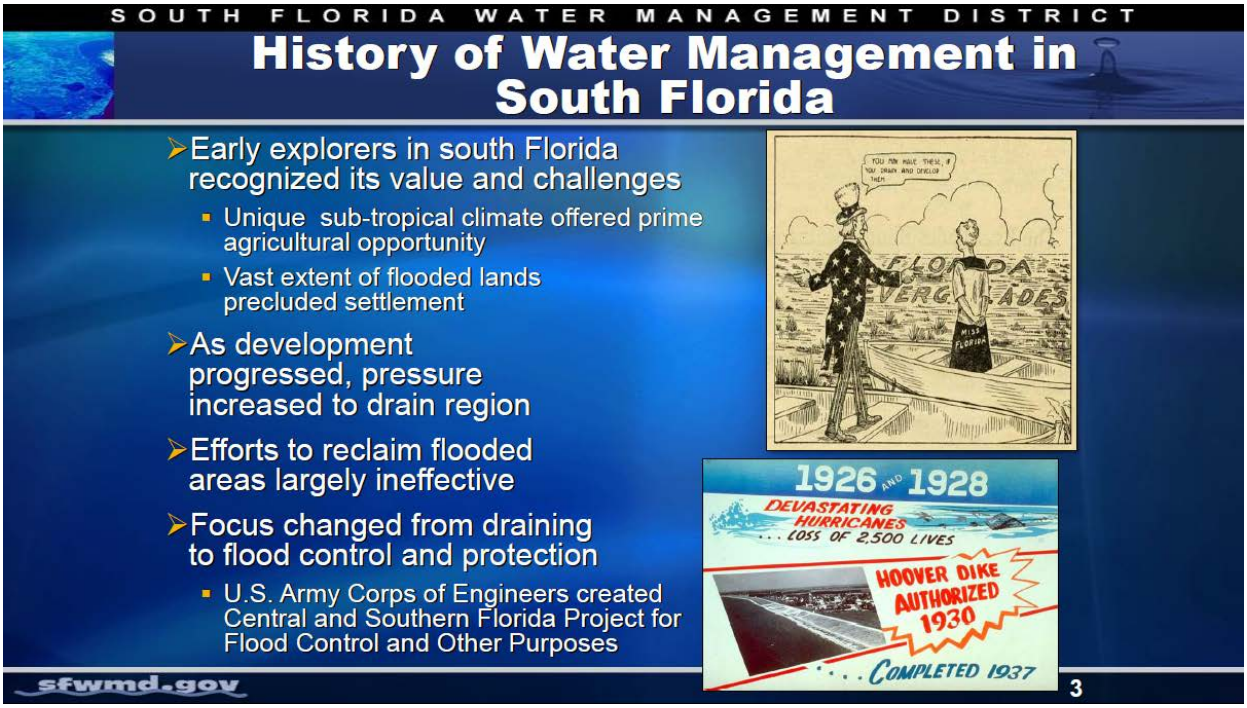


Figure 30, Slide 4

South Florida also suffers from the history of having very sensitive natural areas jammed up against urban and agricultural ecosystems. "We have some very sensitive ecosystems," Dr. Aumen said. "Very small increases in nutrient content can have big implications on Everglades ecology and unfortunately most of our natural areas are downstream of the ag areas and urban areas. That also gives us a little bit of a challenge to deal with."

As far as history of water management, Florida is a fairly young state in terms of its human development and change. Most of those changes to the watershed began about 1890. Early explorers recognized the potential for agriculture in Florida with its subtropical climate. "Our two seasons are wet and dry," he said. "There was a vast extent of flooded lands during the wet season that precluded development. It

made it difficult to put in ag development and urban places. As development progressed, there was an increasing pressure to drain the 'worthless swamp' and an effort to reclaim these areas and make them useful for agriculture."

By 1928, there was already quite a bit of agricultural development south of Lake of Okeechobee; small levees were built around the edge of the lake to create the farmland. Then a hurricane came across Florida which created a large storm surge which overtopped the small levees. "About 3,000 people died," he said. "We'll never know the exact number because most were unrecorded, undocumented migrant workers in farm fields. There are mass graves in West Palm Beach. It was a huge event in terms of a natural disaster and still counts as a third costliest US natural disaster in terms of loss of human life. That got everybody's attention."

In 1947, there were back-to-back hurricanes about three weeks apart that didn't result in the loss of human life but did result in most of south Florida being flooded for about three months. Finally, the people of Florida said, 'We've had enough. We have to do something.' So in 1948, Congress authorized the Central and Southern Florida Flood Control Project, a massive civil works project intended to both provide flood control and water supply. Over the next three decades, the system was put into place that really changed the face of south Florida.

The flood control project was designed primary for flood control and water supply. During the design phase, engineers had estimated that by the year 2000, two million people would be living in South Florida. "They were off by a factor of three but the system still works remarkably well," Dr. Aumen said. "Unfortunately at the same time, it created some environmental problems that began to be recognized just as some of the components were being constructed and put into place. When it was authorized in

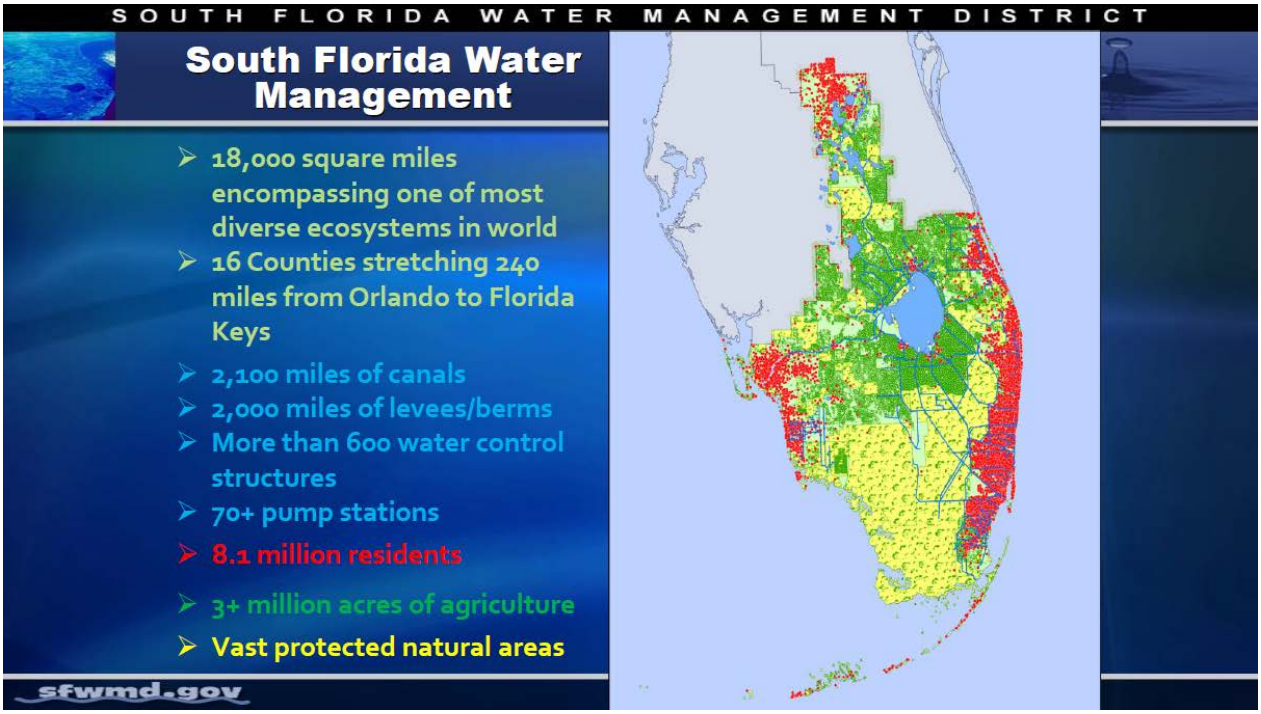


Figure 31, Slide 5

1948, most of our field of ecology was in its infancy. What we know now is vastly different from what we knew then."

The system covers 18,000 square miles and sixteen counties from Orlando to Florida Keys. There are 2,100 miles of canals, 2,000 miles of levees and berms, more than 600 water control structures and over 70 pump stations. "We do a lot of pumping of massive quantities of water up short heads with relatively small differences in elevation," said Dr. Aumen. "We have these big pumps that move a lot of water. Even though there is less topographic relief to deal with, it still ends up being a lot of expense." He also noted that the pumping stations are all diesel-powered because they have to be operational during hurricanes.

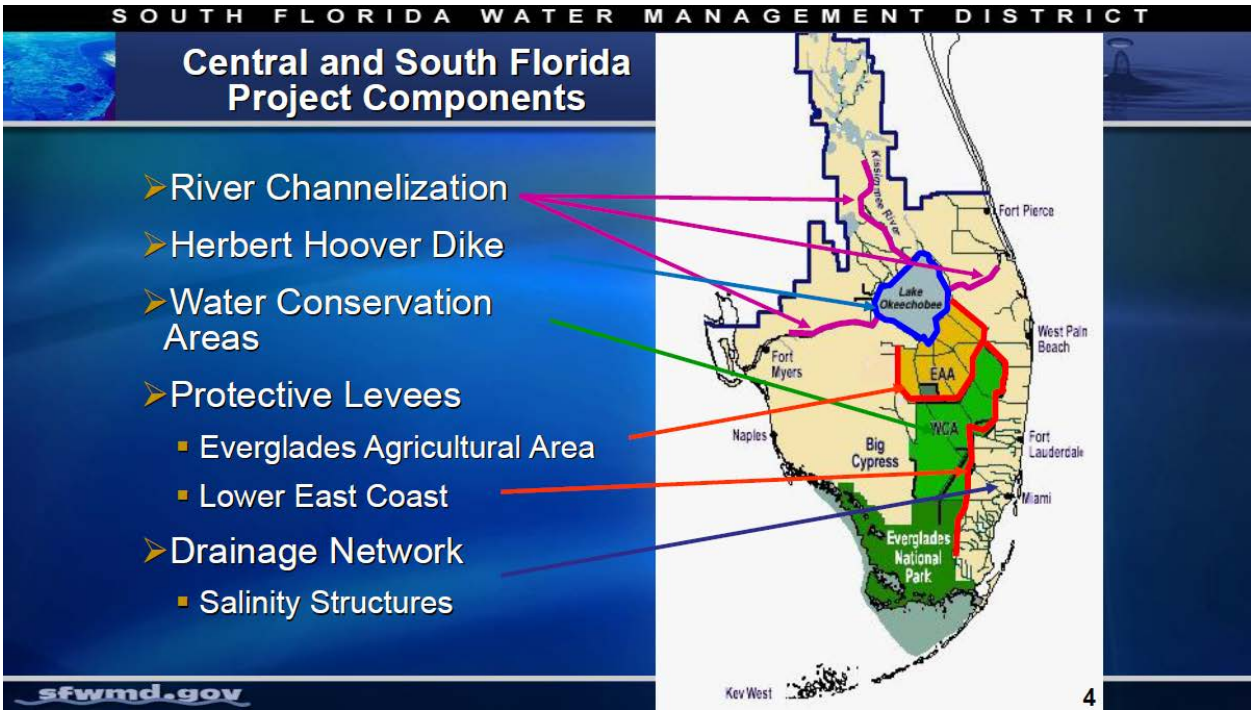


Figure 32, Slide 6

Currently, there are 8.1 million residents in the area; that number is projected to double in 30 years. Most of the development is expected on the coasts, around Orlando, and in the area between Orlando and Lake Okeechobee. Along with a growing urban population, there is a lot of agriculture interspersed in the area that includes a large beef cattle industry, sugar cane, winter vegetables, and tropical fruits.

In the midst of all the urban development and agriculture, there are large protected areas interspersed and downstream from these vast agricultural enterprises and urban development. For example, the Everglades agricultural area just south of Lake Okeechobee is about 700,000 acres of agricultural development, mostly sugar cane but also vegetables, rice, and other crops.

There are a lot of components to the Central and South Florida Project. The Kissimmee River was channelized in the early 1970s; the 15-year project was completed in the early 1970s at a cost of $10-$11 million. "Now we're undergoing a massive project to undo a third of that and fill in that channelization and re-flood the river flood plains," Dr. Aumen said. "That's just about to be completed

after about 20 years and the expenditure is probably pushing $800 million to undo the third of what we did."

As part of the project, a levee was built around Lake Okeechobee. The project also created Water Conservation Areas, which are large swathes of former Everglades that are used for water storage. Since Florida gets most of its drinking water from subsurface aquifers, the water conservation areas are designed to store water when it's wet and keep it to recharge the shallow aquifer during the dry season. The northern-most Water Conservation Area is the Loxahatchee National Wildlife Refuge which encompasses about 140,000 acres of what's left of Northern Everglades.

"The Water Conservation Areas are still Everglades but they've been impounded," Dr. Aumen said. "Just the impoundment of one part of this free flowing system also has had its ecosystem impacts."

There are protective levees around the agricultural and urban areas, and a vast network of drainage structures to provide the flood control and water supply that the project was designed to do; it includes salinity structures on the coast in order to keep seawater at bay.

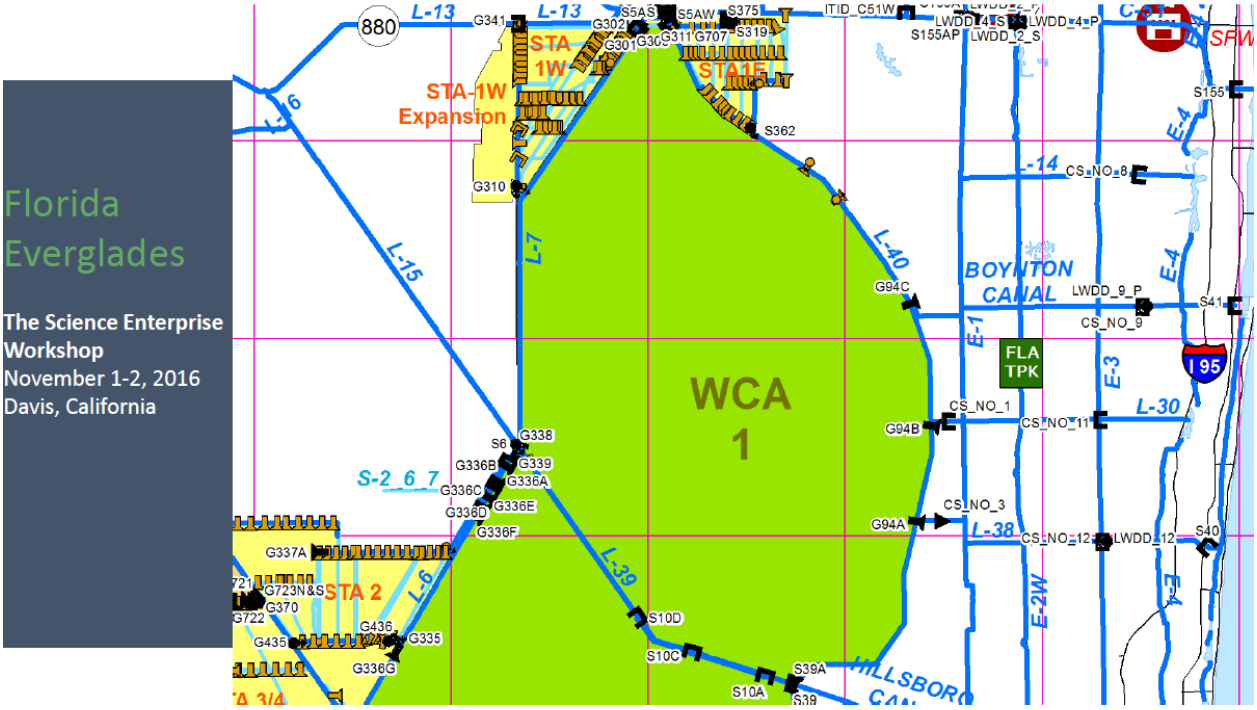


Figure 33, Slide 8

Dr. Aumen presented a detailed map of a portion of Water Conservation Area 1 (or Loxahatchee National Wildlife Refuge) and pointed out that the symbols are either control structures or sampling stations. There are constructed wetlands put in place to reduce the nutrients coming in to the Everglades. It's a very vast and complex system to manage, he said.

To illustrate the complexity, Dr. Aumen noted that in this area, the Water Management District controls the inflows - the gates and the pumps that feed water in, but the USACE control the outflow. "There has to be a lot of good communication and coordination between those entities to manage this area," he said. "Even though it's now an impoundment, it's still part of the remaining Everglades. We've lost about

half of this spatial extent of the Everglades to agriculture and urban development so a lot of the work now is designed to protect the remaining half."

Dr. Aumen said that in the early 70s, water management districts were created. "One of the advantages was it divided Florida into five water management districts," he said. "The cool thing was each of those were roughly delineated by natural drainage boundaries. You have a single entity that can control a lot of things in the natural watershed. That's really important, rather than having multiple entities having to make all those decisions across agency sea boundaries and stakeholder boundaries. It is a good system."

Major resource management issues are:

- **Altered hydro-patterns:** The water management system has really cut across and interrupted what was the natural flow of water from Lake Okeechobee in north from the upper chain of lakes all the way down. The lake was much larger than its current boundaries; the natural boundaries of the lake flow down through what are now the Water Conservation Areas through the Everglades. The water is shallow and relatively slow moving because of the lack of topographic relief. "The Everglades is still, and always was, a water base system and we've made some big changes with that with this drainage network," he said. "It's a very successful drainage network for its flood control and water supply purposes that's created a lot of environmental problems including alteration of the distribution timing and flow of water. That's one of our major efforts; when we talk about the focus of restoration, we use the term, 'just get the water right.' If we get the water right, then a lot of other things we hope will follow and there's a lot of good science behind that."
- **Degraded water quality:** The Everglades are very sensitive to small changes in nutrient content, particularly phosphorus. "It's a phosphorus limited ecosystem; that's all forms of phosphorus: dissolved, particulate, organic, inorganic," Dr. Aumen said. "What I mean by sensitive, I mean that going from 10 micrograms per liter of total phosphorus to 15 could cause a change that may take decades to undo. Those levels are unheard of mostly in any other natural system. It's just a unique future of the Everglades - the subtropical setting and the underlying limestone which absorbs phosphorus." "We have an additional hurdle of not just dealing with nutrients but dealing with them at such a level that management opportunities are really limited," he said. "In water quality, phosphorus is certainly not the only thing; there is nitrogen and all the other nutrients. We have a big mercury problem and we've had a major mercury research program going on for decades. We now know that the methylation of mercury is closely tied to carbon and sulfur cycles which bring in all kinds of other management implications, particularly with sulfur."
- **Nonnative plant and animals:** There are dozens of invasive plants and animals that have outcompeted our native species in many ways and are causing major problems, he said. "You know about the Burmese pythons," Dr. Aumen said. "One thing you may not know is that in Everglades National Park, the pythons have almost completely eliminated the medium and small mammal populations in 1.4 million acres. They are completely eliminated. In the park, you cannot find in marsh rabbits, raccoons, otters, even bobcats. Anything that's in that small to medium mammal category is gone. We still don't know yet even what implications that has on the ecosystem of the park. The food web has been altered permanently and there's still a lot of science to be done to show the outcome of that in the long run."
- **Development pressures:** Every day, Florida adds about 1000 new residents; a lot of people want to retire Florida because of the climate and that there isn't a state income tax.

"Everything is done to encourage that as well as our tourist industry which brings in a lot of people every year, so development pressure is a big issue."

- **Climate change:** Sea level rise will have a big impact; 60 percent of the Everglades National Park is at three feet or less of sea-level, so even a modest range of sea level rise have impacts, he said. Another impact of climate change will be changes in precipitation, projected to be a 10 percent decrease to a 10 percent increase. "For a long time I didn't think that was much of a difference until some modeling that we did," he said. "What came out of that exercise was that a 10 percent decrease in long term rainfall coupled with a 1.5-degree centigrade increase in temperature would result in some really drastic problems. There would be multiple years when Lake Okeechobee would be below five feet. We have never experienced anything below 10 feet."

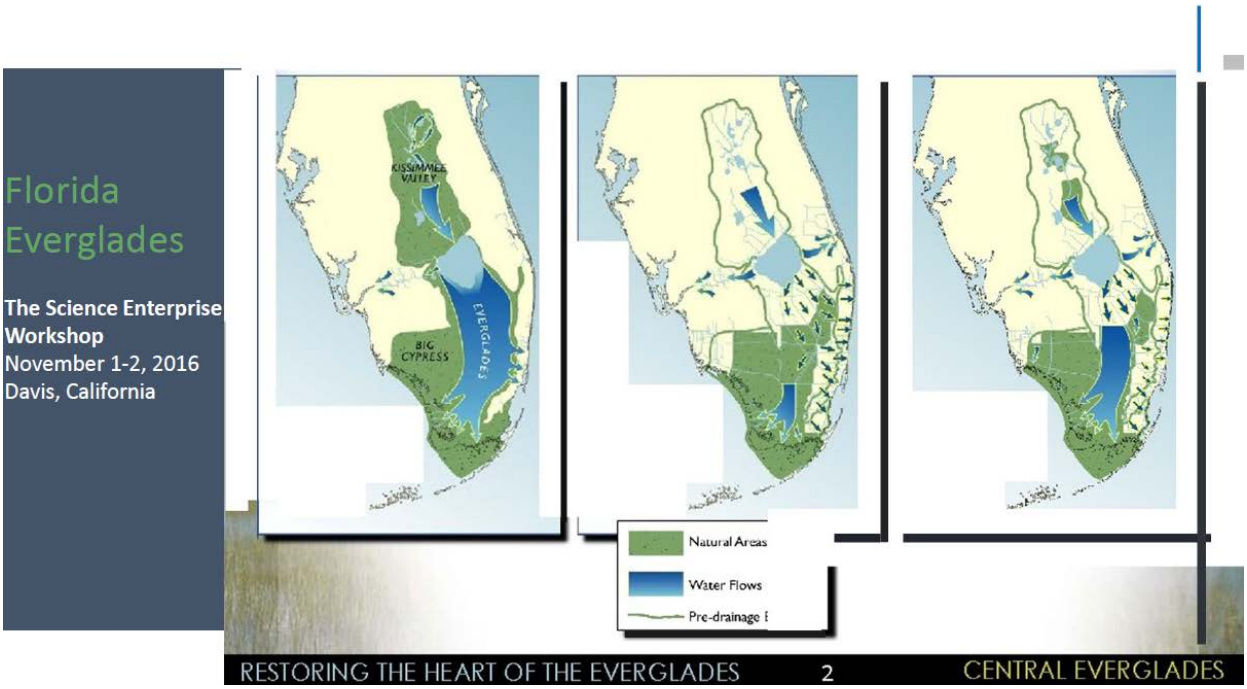


Figure 34, Slide 10

The major restoration programs are focused around restoring the original flow of water through the Kissimmee River floodplain, Lake Okeechobee, and down through the Everglades. "With this complicated drainage system we put in place, whenever the lake gets high during our wet season or we get a tropical storm or two, we're releasing vast amounts of water to the east and west coast estuaries that did not have a natural connection with Lake Okeechobee. Those massive discharges are causing all sorts of problems in those estuaries - wiping out sea grass beds and oyster beds with the nutrients that come in. We had a big incidence of harmful algal blooms occurring on both coast, but especially on the eastern coast."

Restoration is focused on de-compartmentalizing and restoring that natural flow of water in the parts of the Everglades that remain. "That's really the gist of the restoration," Dr. Aumen said. "In order to restore that flow, we have to do it with clean water. There's also been a big effort over many years in making sure that water that we're putting back into the system is clean enough not to cause changes and damages itself."

In terms of challenges, there is a lot of work done on climate change impacts. The science is increasing in terms of predictions on the amount of sea level rise and the impacts on precipitation. Extreme events are also predicted to become more frequent which presents challenges as the flat terrain makes draining floodwaters difficult.

Dr. Aumen then turned to the science enterprise efforts. "I think that compared to some of the systems, I'll say it's a mature and well developed effort," he said. "Please don't interpret that to mean it's a perfect or well running effort all the time, but it's mature and well developed and it's been in place for a long time. We've had a long history of working in a collaborative interagency context. We've made a lot of mistakes and we've learned a lot of things."

Dr. Aumen said they work really well together across state and federal agency lines. "We really function in a lot of ways like one group down there; we don't see those divisions," he said. "I co-fund projects with the National Park Service. We have scientists working together on joint projects. That's one of the good things that we've developed through actual necessity of a need to pool our efforts and work together well."

Science entities working to produce science in South Florida include the USGS, the National Park Service, the Environmental Protection Agency, the Environmental Protection Agency, the US Fish and Wildlife Service on the federal side; state agencies include the South Florida Water Management District[68], the Florida Fish and Wildlife Conservation Commission, and the Florida Department of Environmental Protection, as well as several non-governmental organizations and the tribes.

There are several large science programs in place that include the USGS's Greater Everglades Priority Ecosystem Sciences Program[69], the RECOVER (REstoration COordination & VERification) Program[70], Critical Ecosystems Studies Initiative (CESI),[71] and the Restoration Monitoring and Assessment Program as well as several hydrologic and water quality monitoring programs. "There's a lot of monitoring going on," Dr. Aumen said. "Everybody is involved in that both with hydrologic and water quality. At the center of it is the Water Management District[72] with a vast monitoring network that spans the entire state. I fund some monitoring; the Everglades National Park has monitoring. Everybody has all of that information and we try to make that all available in one place."

[68] South Florida Water Management District. https://www.sfwmd.gov/
[69] Greater Everglades Priority Ecosystem Sciences Program. U.S. Geological Survey. https://sofia.usgs.gov/
[70] RECOVER:(Restoration Coordination & Verification). South Florida Ecosystem Restoration Task Force. http://141.232.10.32/pm/recover/recover.aspx
[71] Critical Ecosystems Studies Initiative (CESI). National Park Service. https://www.nps.gov/ever/learn/nature/cesi.htm
[72] Water Management Districts. Florida Department of Environmental Protection. http://www.dep.state.fl.us/secretary/watman/

There are a lot of players, Dr. Aumen noted, "One thing we have in common with other major ecosystem programs and enterprises is that there are a lot of moving parts and a lot of agencies and entities involved - water utilities, agriculture, environment, civic groups, and recreational interests," he said. "There is a lot of involvement by USDA and Florida Department of Agriculture and Consumer Services, the Department of Justice… One of our big partners now is Florida Department of Transportation. We've been working with the Department of Homeland Security on invasive species; they're at the frontlines of preventing things from coming in at our ports."

Figure 35, Slide 13

"We have some fairly new collaborations and partnerships that are going there that are really important," he continued. "We have two major tribes in south Florida, the Seminole tribe of Florida and the Miccosukee Tribe of Indians of Florida, who are very active in all aspects of restoration. There are also local governments and of course the academic sector."

Dr. Aumen noted that the four southern Florida counties - Monroe County which encompasses the Florida Keys, Miami-Dade County, Broward County, and Palm Beach County are taking an absolute leadership role in responding to the threat of rising sea level because they're already experiencing it. "We had an event downtown Fort Lauderdale during a recent king tide with a local congressman which was scheduled," he said. "We were in a real estate office that focused on high end properties in downtown Fort Lauderdale. We were there at nine in the morning. The doors were barricaded with sandbags and there are barriers on the street. Everything was completely dry. By high tide which occurred at 11:30, that street was under a foot and a half of water. Seawater was gushing up out of storm drains like little fountains and that if not for sandbags in front of the door, there would have been water coming into the building."

The king tides are seasonal tides that have always happened, but clearly they are getting more severe, he said. "The local governments recognize they're going to have to start doing things now," he said. "Each county has a climate change coordinator in place. Even the smaller municipalities - some of them

have sustainability and climate change people in place. Some of the leadership is really happening first at the grassroots from the government standpoint."

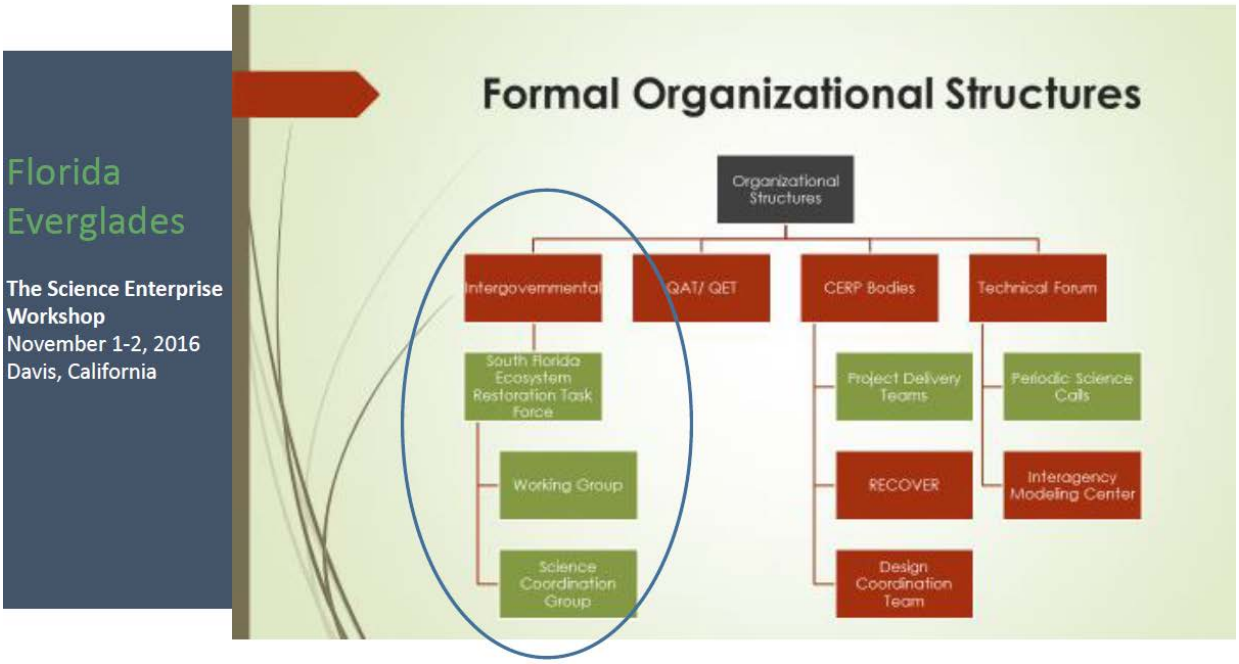


Figure 36, Slide 15

Dr. Aumen then turned to how they are organized to deal with stakeholder involvement. "When the big restoration project was authorized in the year 2000, it created the South Florida Ecosystem Restoration Task Force[73]," he said. "That is a cabinet level federal entity as it started out with cabinet level people at the top. It's chaired by the Department of Interior with the Secretary of Interior at the chair position which is normally delegated down to assistant secretary level. Then the other members like the Water Management District would be the executive director or chair of the governing board and so on. That body meets about twice a year."

The South Florida Ecosystem Restoration Working Group[74] meets every three months, which is about 50 members that cross all the boundaries; there are representatives from the federal, state, and local governments, plus tribes, academia, NGOs, and private citizens. "That's where the rubber hits the road - that's where the coordination goes on for the overall restoration," Dr. Aumen said.

As part of the working group, there's the Science Coordination Group[75] which is tasked with being the communication and the coordination between the science and the managers. "The Science Coordination Group has been in place for a long time but it has some challenges," Dr. Aumen acknowledged. "I think we do very well at communicating the science to each other but we still have some of the same challenges of actually pooling resources and coordinating. Each one of the member agencies that have science activities have their own charges and reasons to do their science. That's been a major hurdle. Some of those are things they're required to do are required under lawsuit settlements or under

[73] South Florida Ecosystem Restoration Task Force. https://evergladesrestoration.gov/
[74] South Florida Ecosystem Restoration Working Group. https://evergladesrestoration.gov/content/wg.html
[75] Science Coordination Group (SCG). South Florida Ecosystem Restoration Task Force. https://evergladesrestoration.gov/content/scg.html

legislation. It's still is a challenge to take our science dollars and put them together and use them in an effective way."

There are a number of websites to access the data that is collected. The South Florida Water Management District has the website called DBHYDRO[76] that is makes all their hydrologic and water quality data accessible to the public and free of charge. There are federal websites as well. They have common models that are used across these entities which are very important.

"We have a lot of collaborative approaches," he said. "We have an interagency modeling center that's housed at the water management district where we actually put monitors from different agencies in one place. We have a strong peer review component including the National Academy of Sciences (NAS)[77] and we use adaptive management."

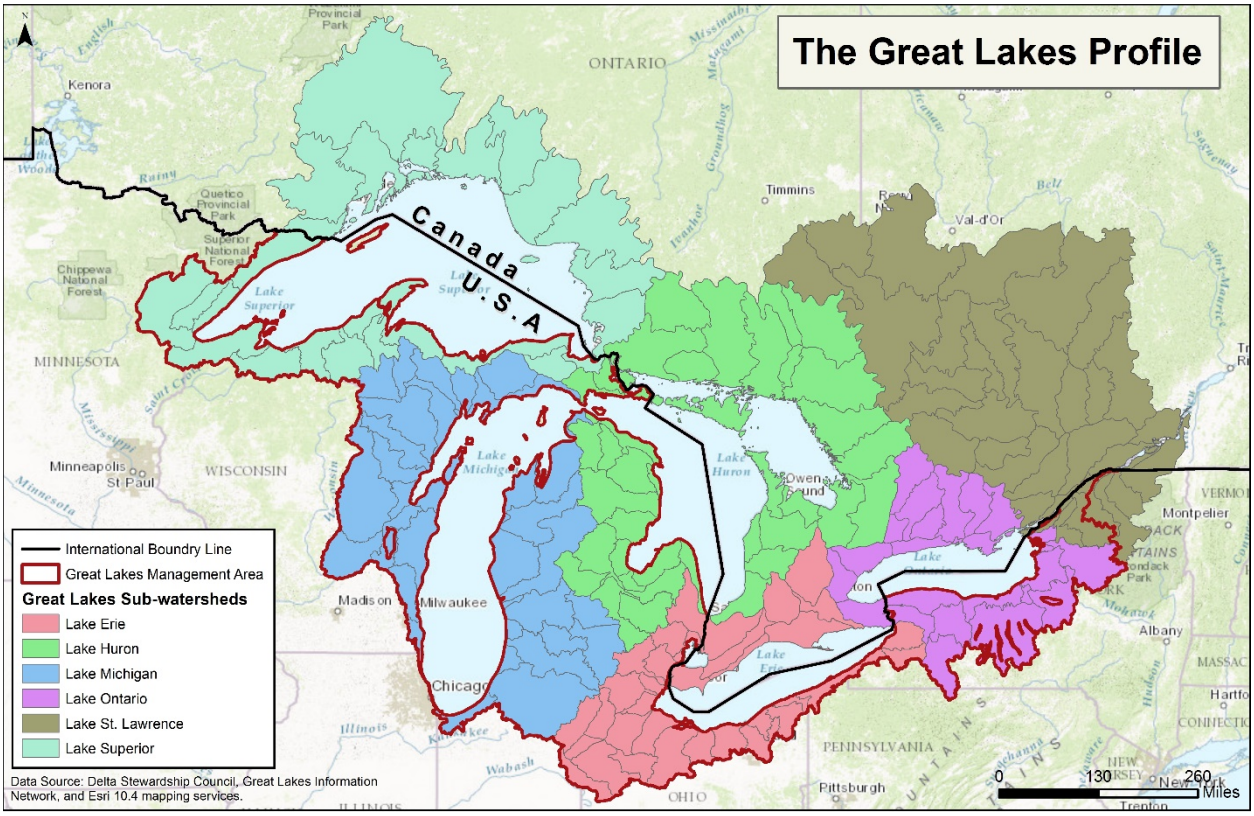
Dr. Aumen then concluded his presentation with his comments on co-production. He attributed their success in this area to the fact that they have a Federal Advisory Committee Act (FACA)[78] exemption which allows for a higher degree of interaction between the agencies and the stakeholders. "Starting in 2009 with one of our restoration initiatives through the water management district, we held a workshop for developing restoration alternatives where literally this number of people in this room would come in for two days, sit at tables in smaller groups and develop restoration alternatives, drawing them out on maps. Circling in the room, there were engineers and scientists from all the agencies being resource supplier. If you have one restoration alternative, you could pull over an engineer and say, 'I want to put this here. Is that doable?'"

"You had this real time interaction that go on for several days and in the end you might have a dozen restoration alternatives drawn up," he continued. "The agencies would take those and then work them up, run them through the models and then come back in two or three weeks and have another one where the outcome from the modeling and the technical analysis was now put back to all the stakeholders and this would go on iteratively. In one case it went on for about nine months."

Dr. Aumen acknowledged that it was resource intensive and hard to do. "It takes everybody at every agency all of their time for that timespan to be responding to that, but it paid really big dividends in that all of the stakeholders truly felt that they were at the table and in fact some of their ideas were incorporated into restoration alternatives. I think that's something that we've done well and it's worth looking at."

[76] DBHYDRO (Environmental Data). South Florida Water Management District. https://www.sfwmd.gov/science-data/dbhydro
[77] National Academy of Sciences (NAS). http://www.nasonline.org/?referrer=https://www.google.com/
[78] Federal Advisory Committee Act (FACA). U.S. General Services Administration. https://www.gsa.gov/portal/category/21242

Great Lakes



Background

The Great Lakes consist of lakes Superior, Michigan, Huron, Erie, and Ontario. Some water enters Lake Superior from the Hudson Bay drainage system. Between 65-85 percent of the precipitation evaporates, while some water drains out of Lake Michigan. The Great Lakes and surrounding lands, once covered by forests, grasslands, and interspersed wetlands, are heavily impacted by urbanization, agriculture, and industry.

Why is this system important?

The Great Lakes cover a surface area of over 94,294 square miles, and drain about 201,460 square miles of land.[79] They contain 84 percent of the surface fresh water in the United States, and about 21 percent of the world's supply of fresh water.[80] The Great Lakes contain over 150 species of fish, including lake sturgeon, which are endangered due to extensive commercial fishing. Hundreds of other diverse plants and animals are dependent on the Great Lakes ecosystem, including many threatened or endangered species like the gray wolf and piping plover. Over 30 million people live in the Great Lakes basin – in 8 states and 2 Canadian provinces.[81] The land surrounding the Great Lakes supports nearly 25 percent of Canadian agricultural production, and 7 percent of American farm production.[82] The Great Lakes support over 1.5 million United States jobs in numerous sectors including shipping, manufacturing,

[79] Physical Features of the Great Lakes. EPA. https://www.epa.gov/greatlakes/physical-features-great-lakes
[80] Great Lakes. US Environmental Protection Agency. https://www.epa.gov/nutrient-policy-data/great-lakes
[81] Great Lakes Facts and Figures. US Environmental Protection Agency.https://www.epa.gov/greatlakes/great-lakes-facts-and-figures
[82] *Id*

agriculture, science and engineering, utilities, commercial fishing, mining, recreation, and tourism - and in 2008, the region generated more than $4.6 trillion in economic output.[83]

What are major challenges?

Invasion of non-native species and nonpoint source pollution (nutrients) resulting in increased occurrences of harmful algal blooms (HABs) are two of the major challenges in the Great Lakes system. The introduction of zebra mussels has decimated the amount of *diporeia* (zooplankton), an important food source for fish in Lake Michigan. In addition, changes in the amount, composition (particulate vs. soluble), and timing of nutrient loads, most notably phosphorus, is likely a major cause of increased HABs over the past few years. Other major challenges include the existence of legacy contaminants in ports and harbors (Areas of Concern) and the degradation and/or loss of wetlands and other fish and wildlife habitats across the Basin. Finally, potential climate change impacts related to air and water temperatures, water quality, and habitat are compounding the challenges that affect the Great Lakes ecosystem.

How is restoration and scientific research organized?

Restoration and research efforts are coordinated and executed by government agencies, academic institutions, non-governmental organizations (NGOs), and private industries. The U.S. Environmental Protection Agency's Great Lakes National Program Office (GLNPO) coordinates U.S. efforts with Canada to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem according to the guidelines set in the Great Lakes Water Quality Agreement (1972, 1978, 1983, 1987, and 2012). The U.S. Geological Survey Great Lakes Science Center was established in 1927 with the mission of providing scientific information for restoring, enhancing, managing, and protecting living resources and their habitats in the Great Lakes basin ecosystem. NGOs such as the Alliance for the Great Lakes, the Healing our Waters-Great Lakes Coalition, and the Great Lakes and St. Lawrence Cities Initiative also play important roles in coordinating Great Lakes activities. The Conference of Great Lakes and St. Lawrence Governors and Premiers, the Great Lakes Commission, the Great Lakes Fisheries Commission, and the International Joint Commission all provide bi-national direction and governance as directed and authorized by the U.S. and Canadian governments. The development and use of data management systems has greatly improved how science is used in the Great Lakes. Primarily, project data and/or metadata are organized and served using the Great Lakes Observing System (GLOS), the USGS Science in the Great Lakes Mapper (SIGL), and the USEAP Great Lakes Monitoring website. GLOS is a binational nonprofit organization funded by dues that are scaled based in type and size of organization. The other two systems were developed using GLRI funds and are now operational and publically available.

How is scientific research funded?

Like the other systems, funding for scientific research in the Great Lakes comes from numerous sources, including government (federal, State, and local), non-government organizations, and private interests. Like the other systems, it is difficult to obtain funding information for scientific research specifically. The publically available funding estimates from the Federal Crosscut Budget for the Great Lakes are provisional and final allocations may differ. It is useful, however, in providing a "directional" estimate in general terms that can be compared with other Federal Crosscut budgets in other systems.

[83] Annual Report of the Great Lakes Regional Water Use Database Representing 2012 Water Use Data. 2012. http://projects.glc.org/waterusedata/pdf/wateruserpt2012.pdf

For FY2016, federal agencies budgeted $785 million for Great Lakes related activities, including $300 million specifically for restoration (GLRI[84]); for reported years 2011-2016, average annual funding has been $932 million and totaled $5.6 billion.[85] Of note, the USEPA administers the GLRI, which funds a variety of activities including grants and implementation of the Great Lakes Legacy Act projects.[86]

Great Lakes Presentation

Presenter

Jon Hortness, Supervisory Hydrologist, U.S. Geological Survey

Presentation

Jon Hortness began by saying that the Great Lakes is different than the other systems; it's much larger, there is a bi-national component with Canada, and it covers a large, vast area that is very different, even from one end of the Lakes to the other. There are major urban centers, such as Chicago, Cleveland, and Detroit, as well as vast undeveloped areas. All the lakes do have a connection that is important to be aware of. "There is a vast range of ecosystems and a vast range of issues, but yet they are all interconnected," he said.

There is 10,000 miles of coastline and a 200,000 square mile drainage area that includes eight states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin) and two Canadian provinces (Ontario and Quebec). The Great Lakes hold 20 percent of the world's fresh water; it is a source of drinking water for 42 million people. The Great Lakes are also economically important; $62 billion in wages are tied directly to the lakes.

There's a long history of bi-national cooperation, beginning with the Boundary Waters Treaty of 1909[87], which wasn't specifically related to the Great Lakes, but just Canada and U.S. in general. Subsequent to that was the development of the Great Lakes Fisheries Commission[88] in 1954 and the Great Lakes Basin Compact[89] in 1955 which set the stage for collaboration in the Great Lakes, not only with Canada but also amongst the state and federal agencies. Then in 1972, the development of the Great Lakes Water Quality Agreement[90] which set the stage for the science and the restoration that's currently ongoing.

[84] Great Lakes Restoration Initiative. https://www.glri.us//
[85] Great Lakes Restoration Crosscut: Report to Congress. Office of Management and Budget. Jan 2016. https://www.whitehouse.gov/sites/default/files/omb/assets/legislative_reports/great_lakes_crosscut_2016_final_a.pdf
[86] Great Lakes Funding. EPA. https://www.epa.gov/great-lakes-funding
[87] Boundary Waters Treaty. International Joint Commission (IJC). http://www.ijc.org/en_/bwt
[88] Great Lakes Fisheries Commission. http://www.glfc.org/aboutus/brief.php
[89] Great Lakes Basin Compact. http://glc.org/about/
[90] Great Lakes Water Quality Agreement. https://www.epa.gov/glwqa

Figure 37, Slide 5

The Fisheries Commission was established in 1954. The Commission is a federal agency comprised of the Canadian and U.S. federal governments; there isn't a state or local component to it. Even back in 1954, science was included as it was recognized early on that in order to manage the fishery at a regional level, they needed to make sure they had the science background to support that. “Their main focus when they first started was the sea lamprey control,” Mr. Hortness said. “The early goals were to get rid of the sea lamprey and get back to some kind of a natural state. Now they've basically gotten to a point where they can live with the sea lamprey and we can function together.”

Figure 38, Slide 6

The Great Lakes Commission is similar to the Fisheries Commission; it was developed as part of the Great Lakes Compact with Canada. However, this is only a state and provincial organization, so federal governments are not involved other than to be observers.

Figure 39, Slide 7

With the development of the Water Quality Agreement in 1972, there were several additional agreements in 1978, 1987, and 2012. The agreement was spurred by a fire in 1969 on the Cuyahoga River, a river in northeast Ohio that feeds into Lake Erie, along with other chronic pollution problems facing the lakes. An article in Time Magazine in 1969 said, 'Lake Erie is in danger of dying by suffocation.' "That was what really increased public awareness, especially in the Great Lakes region, that something had to be done," he said.

However, although there were formalized agreements, there wasn't a lot of funding to go along with the agreements that were in place. "Anything that was happening was done basically under current authorities," he said. "There wasn't really any coordinated structure or any coordinated effort, and there was no money to drive any of that."

In 2004, President Bush signed the Executive Order 13340 — Establishment of Great Lakes Interagency Task Force and Promotion of a Regional Collaboration of National Significance[91] for the Great Lakes that created a federal interagency Task Force for the Great Lakes that was charged with establishing a regional collaboration of national significance. The task force included governors, mayors of the Great Lakes' major cities, federal leaders from cabinet-level departments, tribal leaders, congressional delegations, and also industrial and environmental advocates - the entire breadth of folks interested and willing to work on Great Lakes issues. Out of that, they developed a regional collaboration strategy.

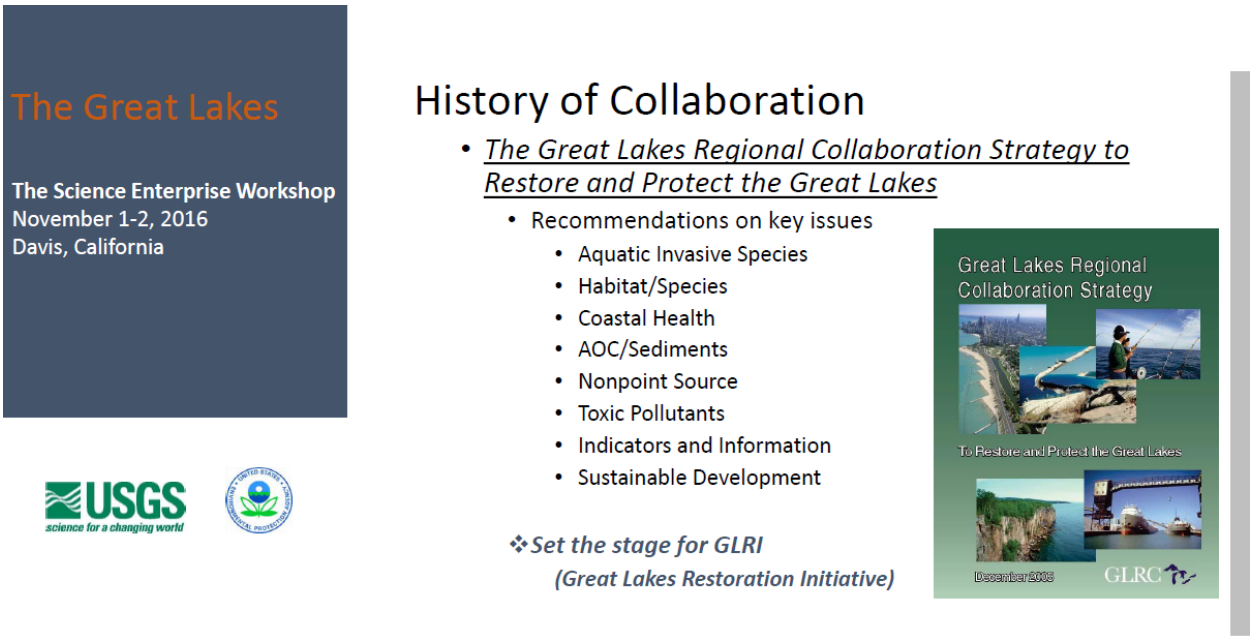


Figure 40, Slide 9

The strategy was released in December of 2005, and it was a high-level plan listing everything that needs to be done to address issues in the Great Lakes along with cost estimates in the billions of dollars. "It set the stage for where we are now with Great Lakes Restoration Initiative," Mr. Hortness said. "This was

[91] Executive Order 13340—Establishment of Great Lakes Interagency Task Force and Promotion of a Regional Collaboration of National Significance for the Great Lakes. Federal Register. http://www.cglslgp.org/media/1842/executive-order-13340.pdf

kind of that high, overarching, 'this is where we really want to be,' but nothing was in place until the funding came in 2010 for the Great Lakes Restoration Initiative (GLRI)[92]."

Based on the regional collaboration strategy, an action plan was developed; no longer just a strategy, there was now an action plan. "It was now in writing that these are the most important issues that need to be addressed and here is how we are going to address them. That's the way these action plans have been written," he said.

Figure 41, Slide 10

The first action plan was developed in 2010 and went through 2014; currently they are in Action Plan 2.[93] The action plan focused on five components: toxic substances and areas of concern; invasive species; non-point source pollution; habitats and species; and foundations for future restoration actions.

"In Action Plan 1, science was not recognized as important to the process per se," Mr. Hortness said. "Part of it was maybe a little bit of a payback; we had all of these people that are a part of that regional collaboration and all these people that had participated in all these efforts, so when the money finally came, it was kind of, 'All right, everybody get your piece of the pie because you've been with us the whole time.' That's kind of the way funding worked under Action Plan 1 for the first four or five years."

With Action Plan 2, there was a definite change in structure; there were outcomes with metrics on the things they wanted to achieve, such as pounds of phosphorous reduction, or number of invasive species prevented. This made science much more important to the process as they now needed to start tracking and monitoring the metrics, and consider what the best methods were to achieve those metrics. "The agencies, like the USACE, would build something or would want to take something out and started to look to the science agencies and ask, 'We need help to determine what's the best way to do

[92] Great Lakes Restoration Initiative. https://www.glri.us/index.html
[93] GLRI Action Plan II. Great Lakes Restoration Initiative. https://www.glri.us/actionplan/index.html

this; what's the most efficient way to do this?'" he said. "So we've evolved over those years where now science has become a much greater piece of what we're doing as far as the restoration. … It's evolved over time as the needs have arisen, and people start to understand where all those niches fall."

Mr. Hortness then turned to the specific issues they are dealing with, noting the issues that they are dealing with aren't so different from a lot of the other places.

The 1987 Water Quality Agreement identified 'areas of concern,' which included toxics (legacy contaminants and 'new chemicals of mutual concern'), invasive species (Dreissenid mussels, Asian Carp, sea lamprey, and phragmites), nutrients (ag and urban sources, harmful algal blooms), and habitat and species (loss/degradation of wetlands, collapsing food webs, native species declines). These issues were identified both in the Water Quality Agreement as well as the action plan under the Great Lakes Restoration Initiative.

The big question mark is climate change and how climate change will impact all of these issues, Mr. Hortness said. "That definitely still remains to be seen," he said. "We're trying to determine what the best approach to take is, and we haven't gotten to the point of even making that decision or coming up with a potential decision."

He then turned to the science structure. "There are a lot of people doing a lot of different things," he said. "It's difficult to coordinate; it's difficult to try to keep everybody pointed in the same direction. We have to grab stakeholders from northern Minnesota all the way to New York, and try to get all those folks together at the same time and the same place. It's a struggle, but there are certain things that we've done to try to get together."

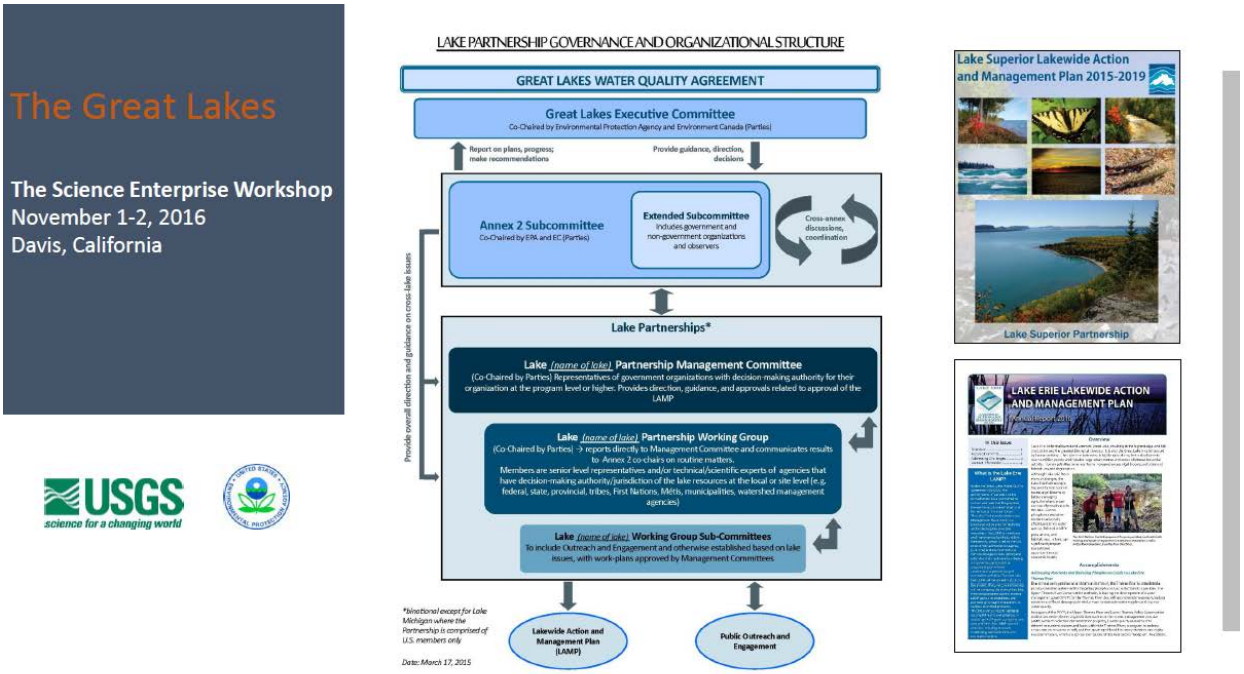


Figure 42, Slide 16

With the Water Quality Agreement, it is a bi-national approach with both the U.S. and Canada; it is co-chaired by both the US EPA and Environment and Climate Change Canada. The Great Lakes Executive Committee[94] is comprised of cabinet-level representatives on the U.S. side and similar type folks on the Canadian side. Under that are the annexes (or issues) that they want to address. Each annex has a subcommittee, which has a regional representative from the federal agencies as well as state representatives and subject matter experts.

Below that, each lake has a partnership which is another place where collaboration and co-production occurs. Each partnership is comprised of a management committee and a working group. The working groups are where the scientists, the subject matter experts, the management agencies, the locals, the watershed groups, the citizen groups, and stakeholders come together to talk about the issues on that lake. Every five years, each lake develops a Lake Action and Management Plan, which is a detailed and more focused version of the action plan under Great Lakes Restoration Initiative (GLRI) that identifies the major issues and the tools and methods for addressing them. On an annual basis, a summary is produced of the work that was done and how they are progressing on the plan.

"All the stakeholders are part of that process," Mr. Hortness said. "We want everybody in the room; we want everybody to be part of that mechanism to develop that Action and Management Plan. That is where the social science comes in. That is where we talk about, what can we live with? What can we afford? What can the public handle? All those types of questions are brought up and, hopefully, laid out in the action plan."

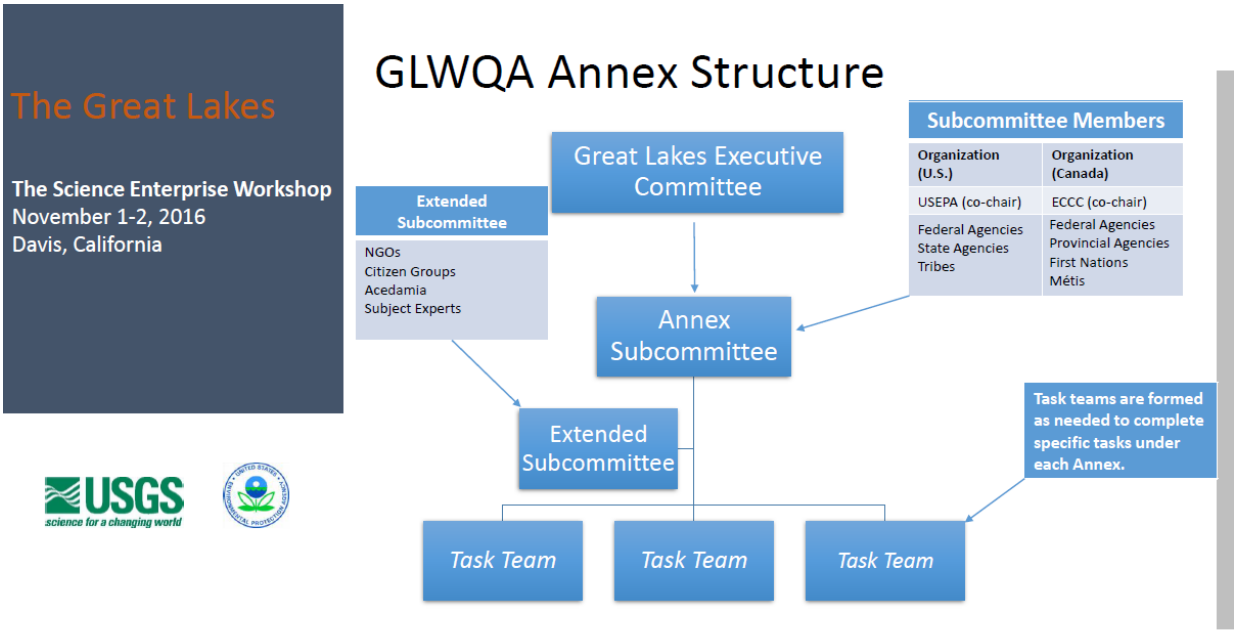


Figure 43, Slide 17

The Great Lakes Water Quality Annexes[95] are the opposite of the partnerships; they are only on the federal side. Under the executive committee, there are 'annex sub-committees,' which are basically the

[94] Great Lakes Executive Committee Members. https://binational.net/glec-cegl/mem/
[95] Great Lakes Water Quality Annexes. U.S. Environmental Protection Agency. https://www.epa.gov/glwqa/glwqa-annexes

management agencies at the federal and state level. It includes the EPA, federal, state, and tribes on the U.S. side, and on the Canadian side, Environment and Climate Change Canada, federal, provincial, and first nations. There are also extended sub-committees which includes NGOs and citizen groups. "They don't have any responsibility per se, but they can provide input and comments throughout this entire process," he said.

Under the annex process, they form task themes as needed to complete a specific task. For example, one of the big goals has been to reduce harmful algal blooms on Lake Erie. "A team was developed with university experts, federal scientists, state folks, and representatives who basically came up with the recommendation over about an 18-month period including modeling and social science conversations," Mr. Hortness said. "What would it take to reduce the occurrence of harmful algal blooms in western Lake Erie? And what could the public live with? What would we have to do to reduce the phosphorus inputs to make those harmful algal blooms drop down? So that team came up with a recommendation of a 40 percent reduction in phosphorus by 2025 to reduce the occurrence of harmful algal blooms in western Lake Erie."

"That was the recommendation that came out of the Water Quality Agreement annex," continued Mr. Hortness. "Then the states have bought into that and have basically signed on to support that agreement or that resolution. That's where they are now in the state process - trying to achieve those standards or figure out how they're going to achieve those standards. It started at the federal level on both sides of the border, but now the states and the provinces are brought into that, and now we're pushing forward to try to achieve those reduction recommendations."

Outside of GLRI Water Quality Agreement, there are other federal-agency-based programs which have ongoing work under each agency's mission that may or may not fit into that overarching goal of the Water Quality Agreement and/or GLRI, but in a lot of cases, they do, he said.

Figure 44, Slide 18

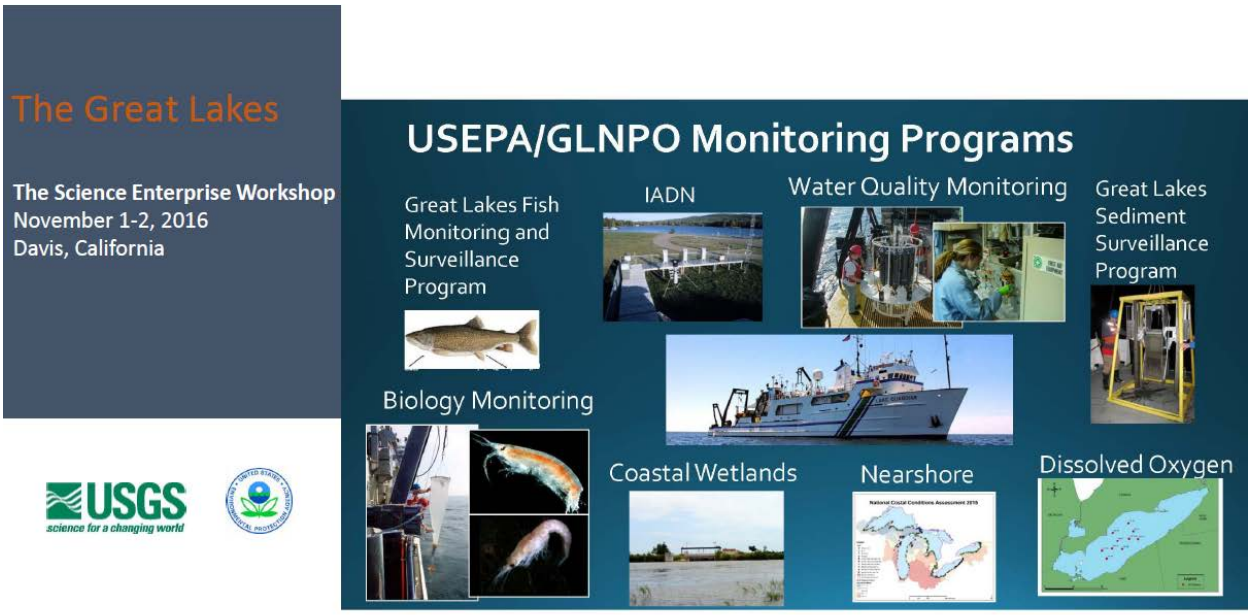


Figure 45, Slide 19

The USEPA has the Great Lakes National Program Office which has a long-term monitoring program, where they have a large vessel that rotates from lake to lake every year; on a five-year cycle, it collects major open-water data on things like dissolved oxygen, sediment, water quality, biology, and fisheries.

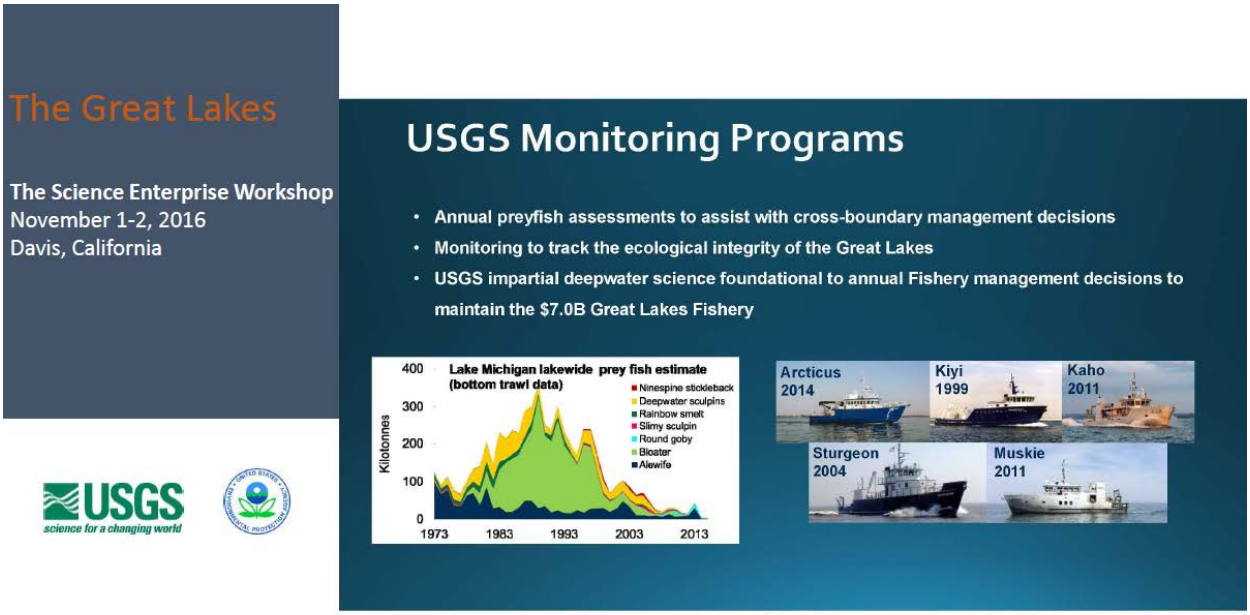


Figure 46, Slide 20

As part as the federal agency support of the Great Lakes Fishery Commission, the USGS monitors the prey fish in all of the lakes to help make fishery management decisions. There is a vessel on each of the five lakes that does annual open-water fisheries assessments to support the Fishery Commission with the fisheries management of the Great Lakes.

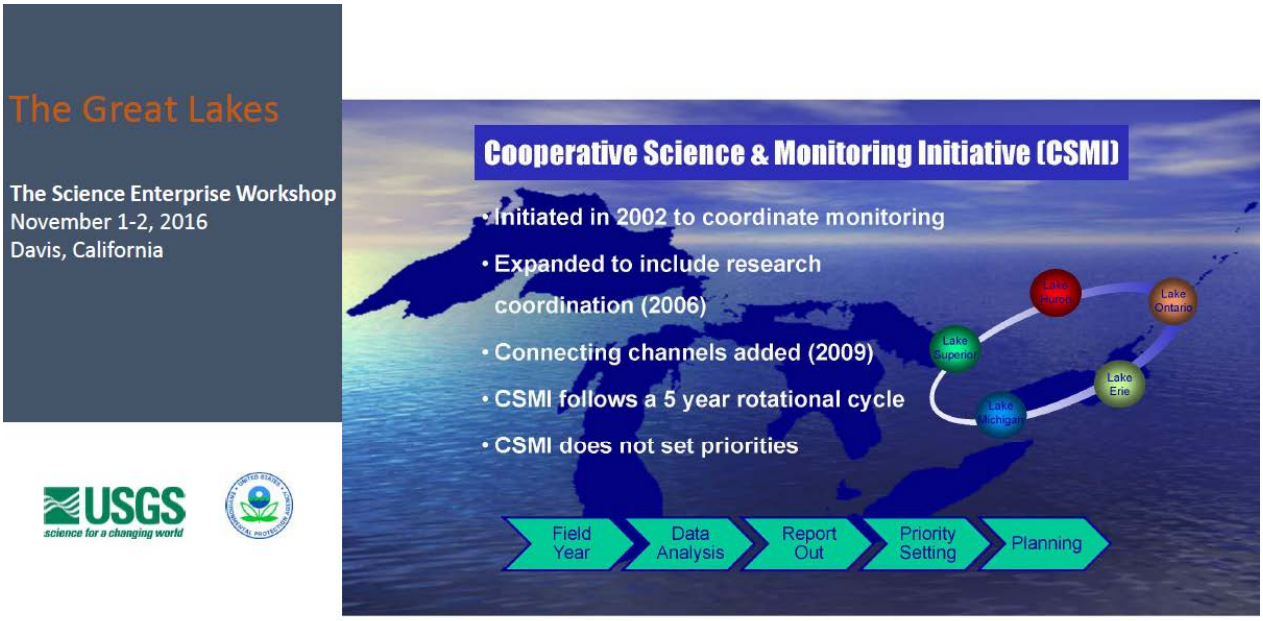


Figure 47, Slide 21

There is a lot of monitoring being performed by federal programs, state programs, municipalities, universities and others, so the Cooperative Science and Monitoring Initiative was developed with the goal to coordinate all of the monitoring that's ongoing. On a regular basis, they bring all the monitoring entities together to discuss who is collecting what and what their goals are for the next year to be sure there are no overlaps and to identify any gaps where data is not collected. This group doesn't set priorities; it is basically a data coordination effort.

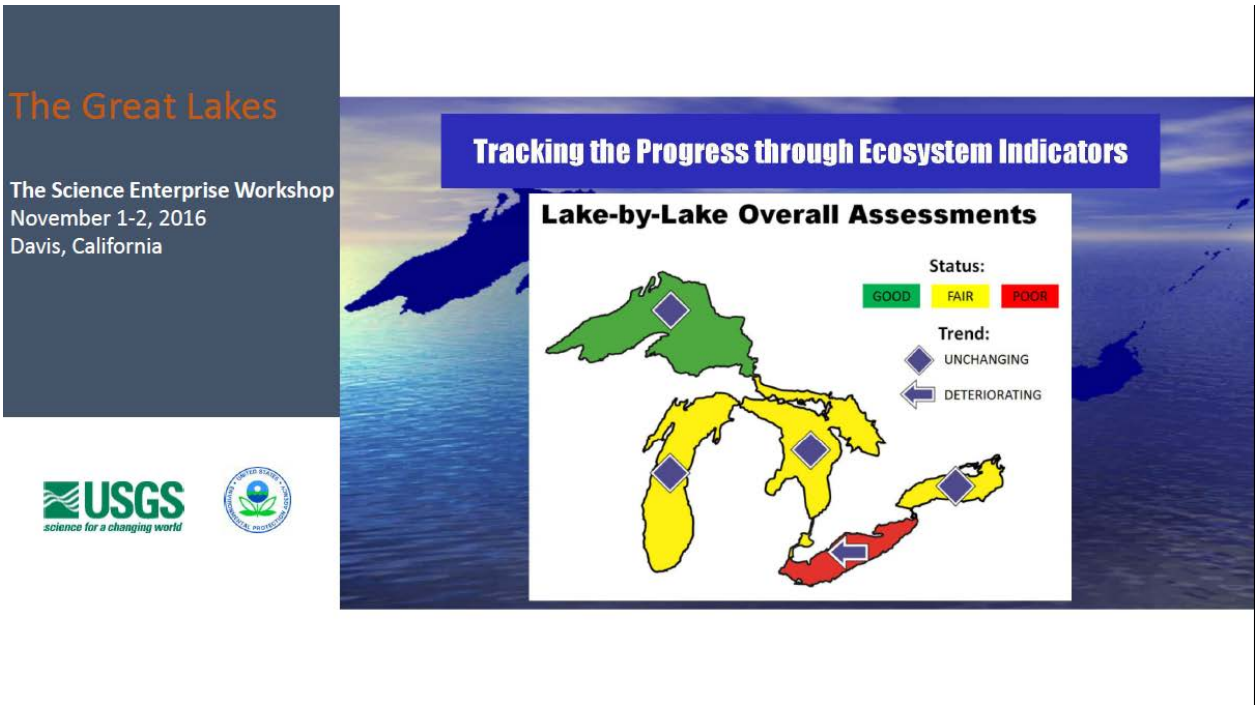


Figure 48, Slide 22

Mr. Hortness then presented a slide from a recent meeting, noting that it was a little 'dangerous'. "It's a 30-thousand-foot view of how is each lake doing," he said. "There's a lot of data behind the scenes in something like this. This is basically summarizing all of the different indicators in each of the lakes into one answer, which is very dangerous. Sometimes it's good just to lay that out … it could be something that's very simplified to explain to the public, 'Here's the big picture, here's where we are,' or it can tell a very dangerous story that somebody might look at this and say, 'Lake Erie is in bad shape and it's getting worse.' It doesn't mean all of Lake Erie is that way; just because Lake Superior's in good shape and it seems to be holding pretty well doesn't mean that all of Lake Superior is in great shape. It's a really high-level view."

The Great Lakes Restoration Initiative is the major funding source of work on the U.S. side. The Interagency Task Force heads the initiative; it is a cabinet-level group. Under that is the Regional Working Group. "Basically that's the federal agencies that work on the Great Lakes and are working under GLRI," he said. "That's where most of the decisions are made on what needs to be done and where the money will go. But as part of their process, we do have a lot of check-ins with state and tribal partners, talking about priorities. … We then take that all into account, so we're trying not to do this in a vacuum."

There is also the Great Lakes Advisory Board which is where the Regional Working Group can go to and ask for advice. "For example, one of the questions might be, how should adaptive management be used under GLRI to achieve the best benefits and be mostly efficient?" he said. "That's a big, overarching question that could have lots of little arms and little fingers coming out of that. It's difficult, but the advisory board is there to provide advice on and support the Working Group."

Under the Working Group, there are five focus areas. Each has an EPA lead and federal agency representatives that sit on each of those focus area teams and under those, there are sub-groups. "This

is where we kind of evolved into," Mr. Hortness said. "Instead of each agency taking their money and supplementing their existing programs and doing what they would normally do, we've really evolved into these sub-groups under the focus areas. This is where a lot of the science starts to play a huge role in determining what work gets done and how it gets done."

For example, there's a multi-agency team on Asian carp; another on priority watersheds, and a native fishery team. "A lot more collaboration, a lot more science involved in the planning and the work, and I think we've evolved over time to make that happen," he said. "It's worked out really well."

Then Mr. Hortness turned to the issue of funding. He said there are basically the congressional appropriations on the U.S. side that may or may not fit really well within the lines of GLRI and/or the Water Quality Agreement, but there are some that do fit well; GLRI is obviously the major funding source on the U.S. side. Other agencies performing on-the-ground activities include the Corps, the Forest Service, and the National Park Service. There's also the USGS, NOAA, and the EPA, and other agencies with large grant programs, such as the NRCS.

"Canada was kind of lagging behind, and even prior to GLRI, they were not putting as much money into Great Lakes as we were," Mr. Hortness said. "After GLRI came about, I think they kind of felt the peer pressure, and so after the last couple three years, there's been a pretty major focus from the Environmental and Climate Change Canada side and the provinces to try to come up with a little more support to support the Great Lakes activities."

In terms of funding restoration versus monitoring and research, in the first year there was $450 million, with only a small percentage for research and monitoring. Over time, it's been stable at the $400 million level. "If I think of the USGS and NOAA budgets, which is where a lot of the science goes on, there's a good $30-40 million going to those agencies, and most of that's going to be science-related so it's definitely on the upswing, Mr. Hortness said. "I think the agencies are seeing the importance of building science into the program."

In terms of implementation tools, there are a number of websites. GreatLakesMonitoring.org[96] is a data clearing house, a single location for data online. There is the Great Lake's Mapper and a metadata tool where anyone collecting data can lay out the metadata, even if it's not going to be on the web. There's also the Great Lakes Observing System (GLOS)[97], one of several across the country.

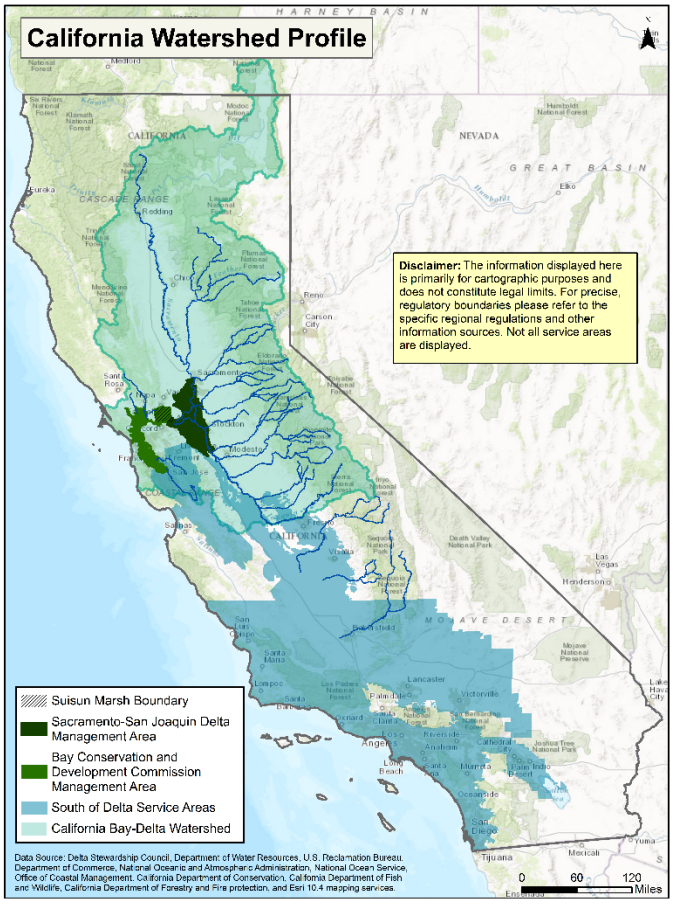
For monitoring, there is the USGS and the buoy network which is part of GLOS, as well as some emerging tools, especially in the area of invasive species. For communications, there are several websites for that. One is the Great Lakes Information Network[98], which is a news service run by the Great Lakes Commission. There are agency press releases, publications, and journal articles. There are annual meetings for each lake each year, an annual conference that focuses on restoration, and a major science meeting focusing on science in the Great Lakes that alternates between the U.S. and Canada each year. There are also a lot of communication with the state and tribal partners.

Lastly, they have developed collaborative: one for phragmites, one for mussels, and one for harmful algal blooms. It's an information sharing mechanism where all the stakeholders come together and share information, whether through a website or a webinar. Mr. Hortness said the collaborative and the

[96] GreatLakesMonitoring.org. https://greatlakesmonitoring.org/
[97] Great Lakes Observing System (GLOS). https://www.glos.us/
[98] Great Lakes Information Network. Great Lakes Commission. http://www.great-lakes.net/

webinars seem to be going over well with the public. “Folks like to have that quick information and they've seemed to have taken to that pretty well.”

California Bay-Delta



Background

The California Bay-Delta is where the Sacramento and San Joaquin rivers meet as they flow out of the Sierra and Cascade mountains– spreading out into 1,160 square miles of islands, canals, and shallow waterways before flowing into the San Francisco Bay. Before it was diked, drained, and developed, the Delta was a vast wetland complex of low islands, shifting channels, woody debris accumulations, and tule marshes. Today, the Delta is a patchwork of largely agricultural islands separated by deep channels and protected by 1,100 miles of levees. It hosts farms, fisheries, water projects, recreational areas, and neighbors the State capitol of Sacramento. Geographically, it is the largest delta on the Pacific coast.

Why is this system important?

The Bay-Delta is a complex ecosystem made up of interconnected tributaries, rivers, bays, wetlands, marshes, floodplains, and islands. It contains areas of rich biodiversity, supporting hundreds of species of birds (migratory and resident), fish, and other plant and animal species. Endangered and threatened species include the delta smelt,[99] Chinook salmon, and ridgway’s rail. The Delta and Suisun Bay/Marsh together cover about 1,300 square miles (land and water) spanning 6 counties, hold 400,600 acres of high quality farmland,[100] and are home to more than 550,000 people. The Bay’s watershed covers over 45,600 square miles and drains 40 percent of California.[101] The Bay’s surrounding lands are home to over 7.5 million residents.[102] The Bay-Delta is the hub of the nation’s largest water delivery system. Two-thirds of the state’s population, about 27 million people, depends on the Delta watershed for some portion of their water supply, as do more than 3 million acres of irrigated farmland.[103] Water from the California Bay-Delta provides a critical base for most of the State’s economic output of $2.2 trillion in 2015.[104] In addition to water supply and agriculture, the Bay-Delta supports other industries including tourism and recreation, technology, entertainment, and fisheries.

[99] Please note for consistency purposes, all species names throughout the report are lower case
[100] The Delta Plan: Chapter 5. http://deltacouncil.ca.gov/sites/default/files/documents/files/CH_05_2013.pdf
[101] The Delta Plan: Chapter 1. The Delta Plan. http://deltacouncil.ca.gov/delta-plan-0
[102] The San Francisco Bay Estuary. San Francisco Estuary Partnership. http://www.sfestuary.org/about-the-estuary/
[103] *Id*
[104] Luoma SN, Dahm CN, Healey M, and Moore JN. 2015. Challenges Facing the Sacramento-San Joaquin Delta: Complex, Chaotic or Simply Cantankerous? San Francisco Estuary and Watershed Science, Volume 13, Issue 3. http://dx.doi.org/10.15447/sfews.2015v13iss3art7

What are major challenges?

The Bay-Delta is confronted with many challenges due to extreme habitat alterations and its central role in California's water supply. Water diversions impair natural flow regimes, migratory cues, and water quality, and entrain fish into water delivery systems. More than a century ago, Delta residents began to build an intricate levee system to channel water and dry out land, which converted hundreds of thousands of acres of seasonally and tidally flooded wetlands into fertile agricultural fields. As a result of continued land use change and urbanization, 95 percent of the historical tidal marsh in the Delta has been lost and has led to major declines in native species. Other Delta challenges include land subsidence, nutrients (which affect plankton communities and aquatic plants), toxins/pollutants (which affect species survival and human food safety), invasive and introduced species (which lead to competition with native species, predation, and habitat alteration), and a boom and bust hydrologic cycle of floods and prolonged droughts. The Delta and Bay are interconnected, and stressors affect the health of both. Water management decisions have significant financial implications for the economic interests of the State, and by extension, represents one of the most politically charged subjects in California. Additional complications arise from the differences in governance and science organization between the Delta and the Bay, which have their own unique, but interrelated management needs. Each of these challenges will be compounded by climate change.

How is restoration and scientific research organized?

Hundreds of government, non-government, academic, and private institutions are involved with Bay-Delta research, restoration, and science management. Several interagency science groups organize new studies, review study plans and proposals, write scientific papers and reports, and promote collaboration, including the Interagency Ecological Program, San Francisco Estuary Partnership, San Francisco Estuary Institute, Collaborative Adaptive Management Team, Delta and Bay Regional Monitoring Programs, and the California Department of Fish and Wildlife's (DFW) Watershed Restoration Grants Branch. A host of State and federal government agencies play roles in Delta science or management, including the U.S. Geological Survey (USGS), U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service (USFWS), DFW, California Department of Water Resources (DWR), and the State Water Resources Control Board. The Council, created as part of the 2009 Delta Reform Act, is the State agency charged with creating the Delta Plan, a blueprint for how to connect the many stakeholders to further achieve the coequal goals of a reliable water supply and a healthy ecosystem. The Delta Plan includes a recommendation for better organizing science, which led to the creation of the Delta Science Plan in 2013. The Council's Delta Science Program is charged with developing scientific information and synthesizing the state of scientific knowledge on issues critical for managing the Bay-Delta system. That body of knowledge must be unbiased, relevant, authoritative, integrated across State and federal agencies, and communicated to Bay-Delta decision-makers, agency managers, stakeholders, the scientific community, and the public.[105] Numerous academic institutes also play major roles in Bay-Delta research, including the UC Davis Center for Watershed Sciences and the UC Davis Coastal Marine Sciences Institute.

How is scientific research funded?

Funding for scientific research in the Delta comes from numerous sources, including government (federal, State, and local), non-government organizations, and private interests. In general, it is difficult to obtain funding information on all scientific research as it is rarely separated out as a budget line item. It is also challenging to find funding information on restoration and other system-wide investments. For

[105] About the Science Program. Delta Stewardship Council. http://deltacouncil.ca.gov/science-program/about-science-program

example, public sources like the Federal Crosscut Budget are not revised over time to reflect actual spending; however, it is useful in providing an estimate that can be compared with other Federal Crosscut budgets in other systems.

For FY2016, federal agencies budgeted $372 million for the Bay-Delta Program. For reported years 1998-2017, average annual budgeted funding has been $314.7 million and totaled $6.294 billion.[106] For FY2000-2012, State agencies provided, in total $3.258 billion and on average $250 million in funding for the Bay-Delta Program.[107] Public water agencies and the State and Federal Water Contractors Agency also play major roles in funding and implementing restoration and scientific research, as well as quasi-private organizations like water districts.

The Council has recently launched DeltaView (http://deltaview.deltacouncil.ca.gov/), a new database that will capture and track State and federal spending on programs, plans and projects in the Delta, as well as project goals and project descriptions, cost and funding sources, key dates, responsible agency, and relevant performance measures. DeltaView will provide implementing agency users the opportunity to update their records on an ongoing basis, and allow the broader public the ability to track progress toward Delta Plan implementation.

California Bay-Delta Presentation

Presenters:

Dr. Ted Sommer, Lead Scientist, California Department of Water Resources
Dr. Josh Collins, Chief Scientist, San Francisco Estuary Institute (SFEI)

Presentation

“The Delta is a tough nut to kind of crack,” began Dr. Ted Sommer. “We can talk about the basic geography and where it is but to be honest, a lot of folks that live right next to the Delta don't even realize they're right next to the Delta. We can talk about the statistics. It drains almost half of the state, it has 1000 miles of levees, it has 60,000 acres of open water habitat, but even that really doesn't get you to the kind of sense of place. One of the best ways to come to grips with the Delta and how science is constructed around it is really to go straight to the extremes.”

[106] California Bay-Delta Federal Budget Crosscut. Fiscal Year 2017. Released March 2016. Executive Office of the President. https://www.whitehouse.gov/sites/default/files/omb/assets/legislative_reports/bay-delta_fy17_budget_crosscut_-_alexander.pdf
[107] CALFED Projects by Agency. CPPIS. http://cppis.deltacouncil.ca.gov/drilldown.aspx?view=agency&obj=1&year=8&element=8

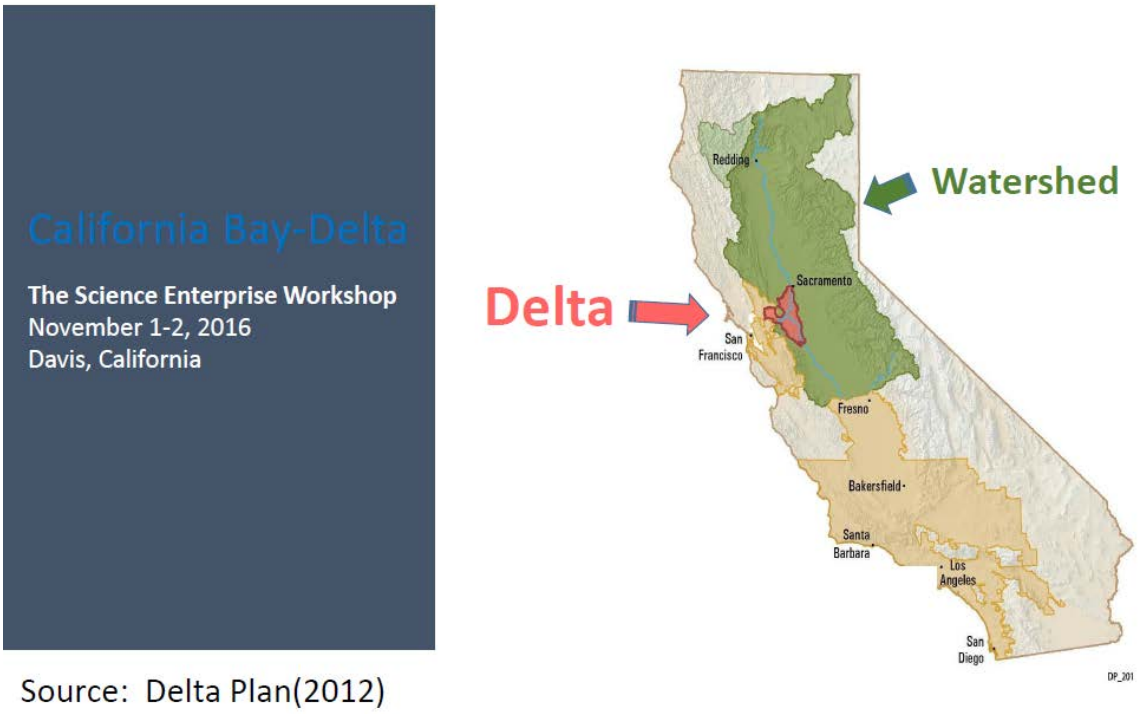


Figure 49, Slide 2

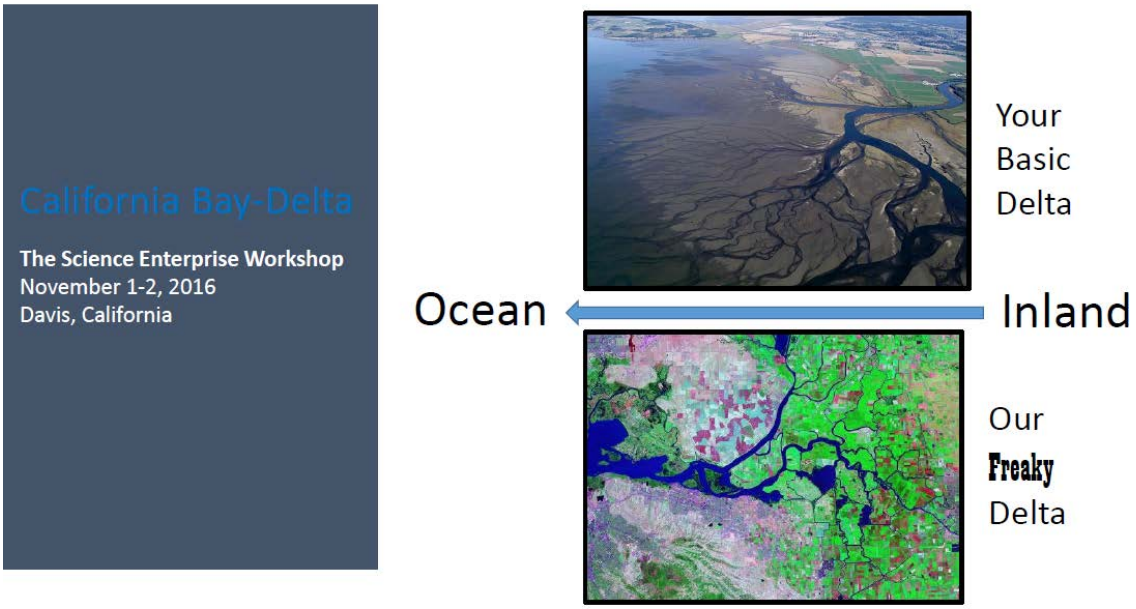
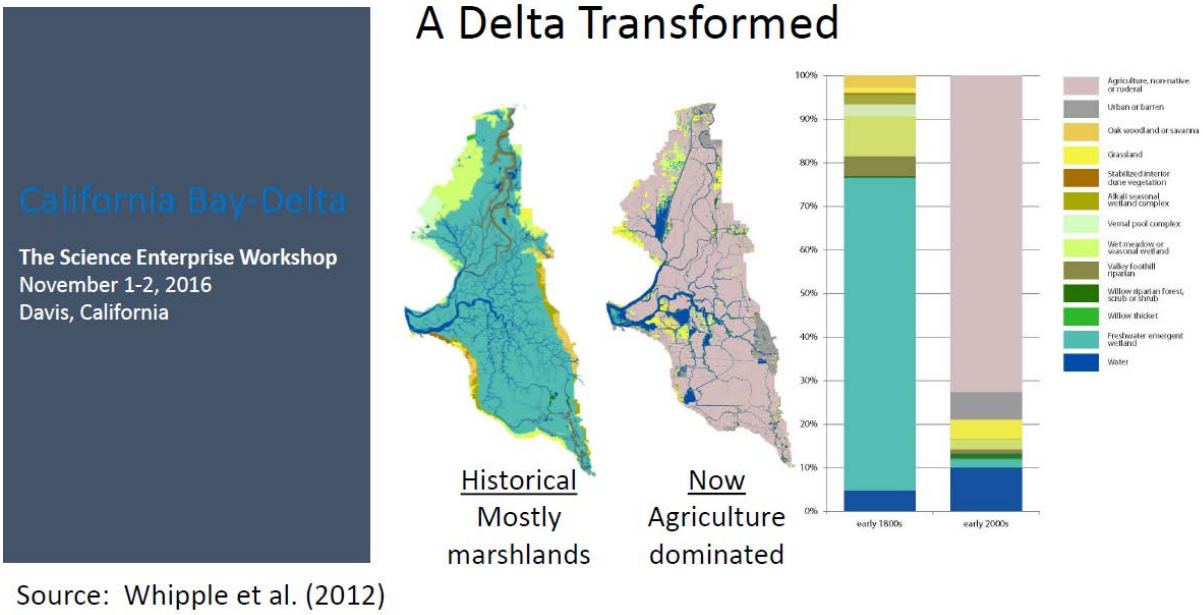


Figure 50, Slide 3

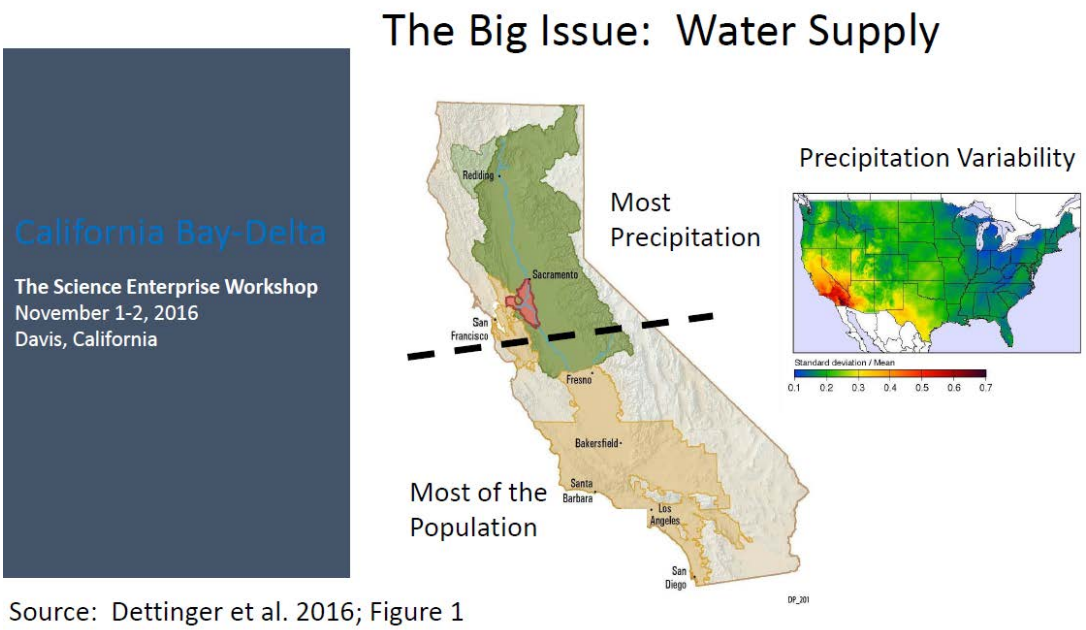
Most deltas have a river that drains from inland and fans out into the ocean. “The gods were clearly drunk when they did our Delta,” he said. “They put the Delta facing the wrong way and that has all kinds of consequences for hydrodynamics and management.”

"When we do landscape alteration here, we do not mess around," said Dr. Sommer, presenting a graphic from the San Francisco Estuary Institute comparing the historical Delta to the modern Delta. The historical Delta was dominated by tidal wetlands with complex small channels; in contrast, the modern Delta is dominated by agriculture.



Source: Whipple et al. (2012)

Figure 51, Slide 4

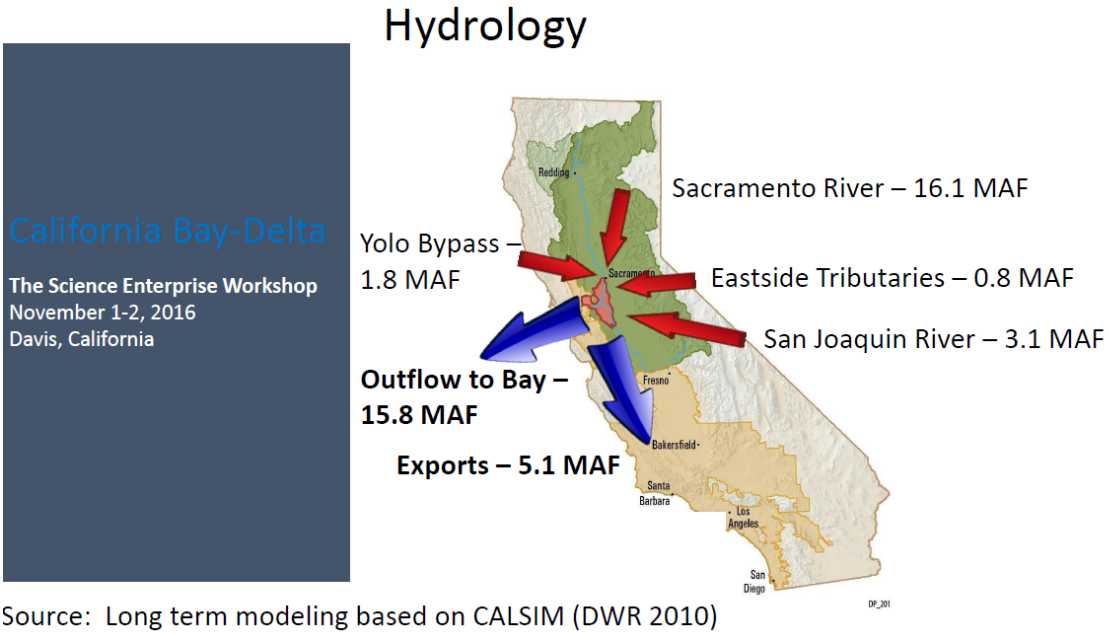


Source: Dettinger et al. 2016; Figure 1

Figure 52, Slide 5

In California, most of the precipitation falls in the northern part of the state, while most of the population lives in the southern part of the state. California has the sixth-largest economy in the world. This is all driven by hydrology, said Dr. Sommer. Most of the inflow into the Bay Delta comes from the

Sacramento River, although there is inflow from some of the other tributaries as well; some of it actually makes it out to the San Francisco Bay; most of it is redistributed to other areas where a lot of the population sits. All or a portion of the water supply for 25 million people comes from the Delta.



Source: Long term modeling based on CALSIM (DWR 2010)

Figure 53, Slide 6

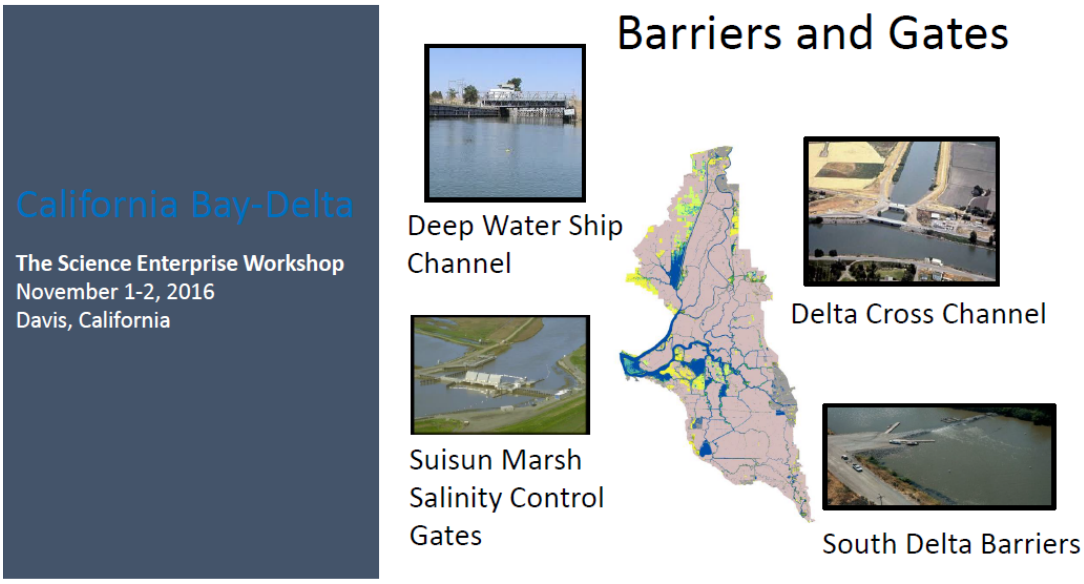


Figure 54, Slide 7

Dr. Sommer said the Delta has a lot of barriers and gates, with some unusual uses of the different barriers. One example are the Suisun Marsh salinity control gates, which are operated to tidally pump fresh water into the Suisun Marsh, one of the largest contiguous marshes. The Delta Cross Channel is a large channelized corridor in the central Delta; the Cross Channel gates help control when fresh water

and fish get into the central Delta. In the south Delta, there is a network of barriers because of the elevation changes from all the diversions; the gates there are needed to maintain elevations.
Fresh water diversions are the one thing that is different than any of the other systems presented at the workshop. There are large diversions from the state and federal water projects as well as a couple thousand smaller agricultural diversions which play a large role.

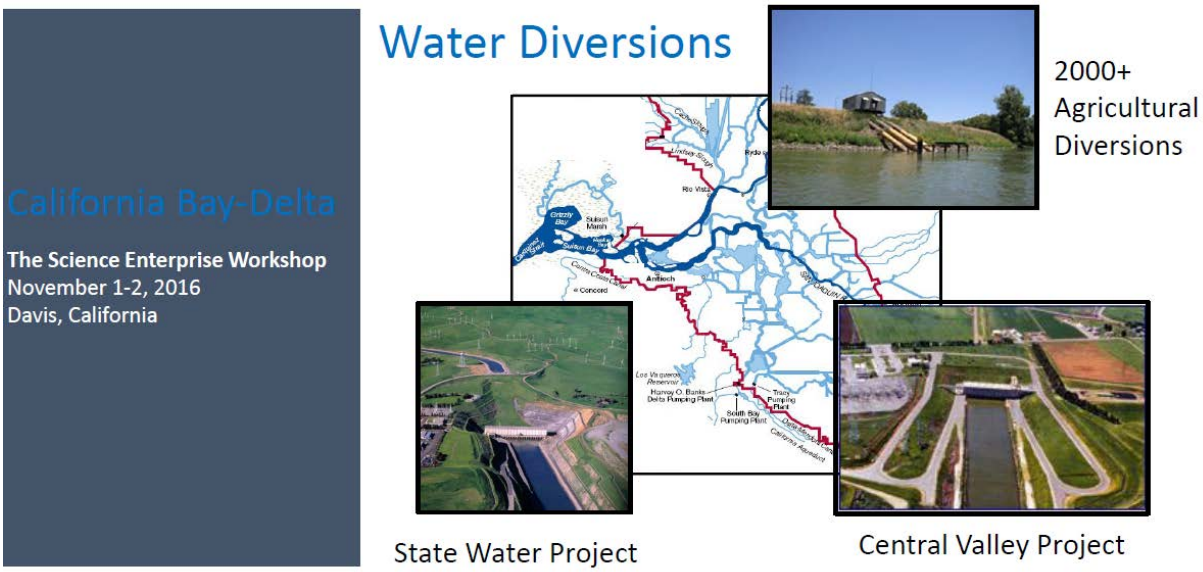


Figure 55, Slide 8

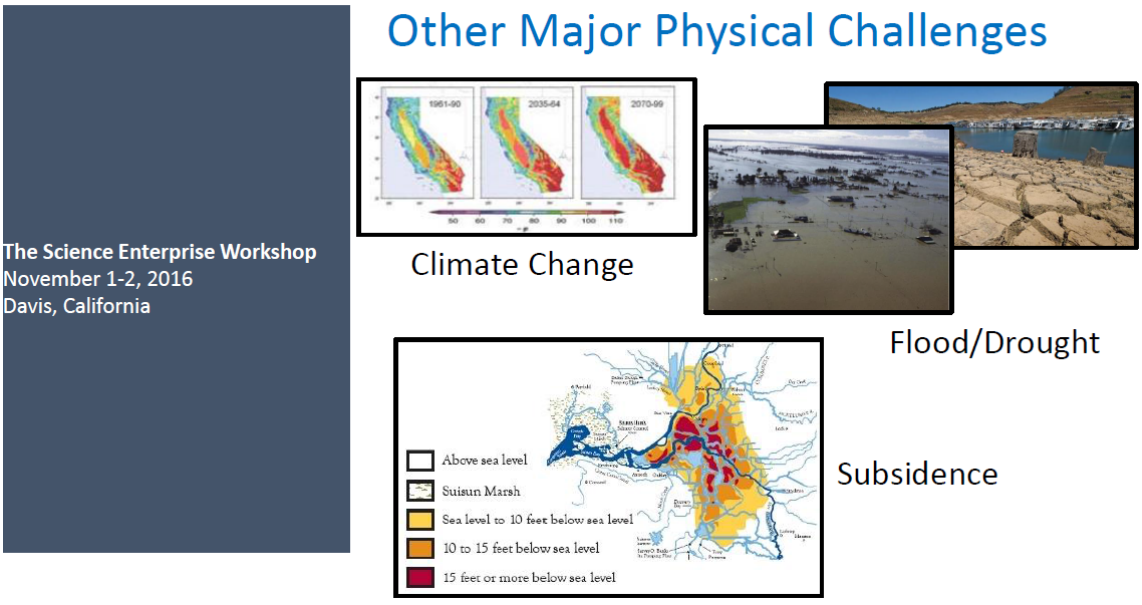


Figure 56, Slide 9

However, the big challenges don't stop there, noted Dr. Sommer. Climate change is an emerging issue. Because of the state's climate variability, the hydrology alternates between flood and drought. On top of that, the landscape is gradually subsiding with parts of the Delta 25 foot below sea level, just waiting for a big earthquake or flood.

Given the amount of changes that have occurred and the challenges facing the Delta, there are a whole suite of native species that are in trouble: spring run and winter run chinook salmon, the delta smelt, the longfin smelt, steelhead trout, and green sturgeon. “Collectively, the status of these species is a really big deal in both the science and management,” said Dr. Sommer. “I would characterize, given how important water is in the state and the effect these species have on management, these are the most economically important fish species we have in the United States.”

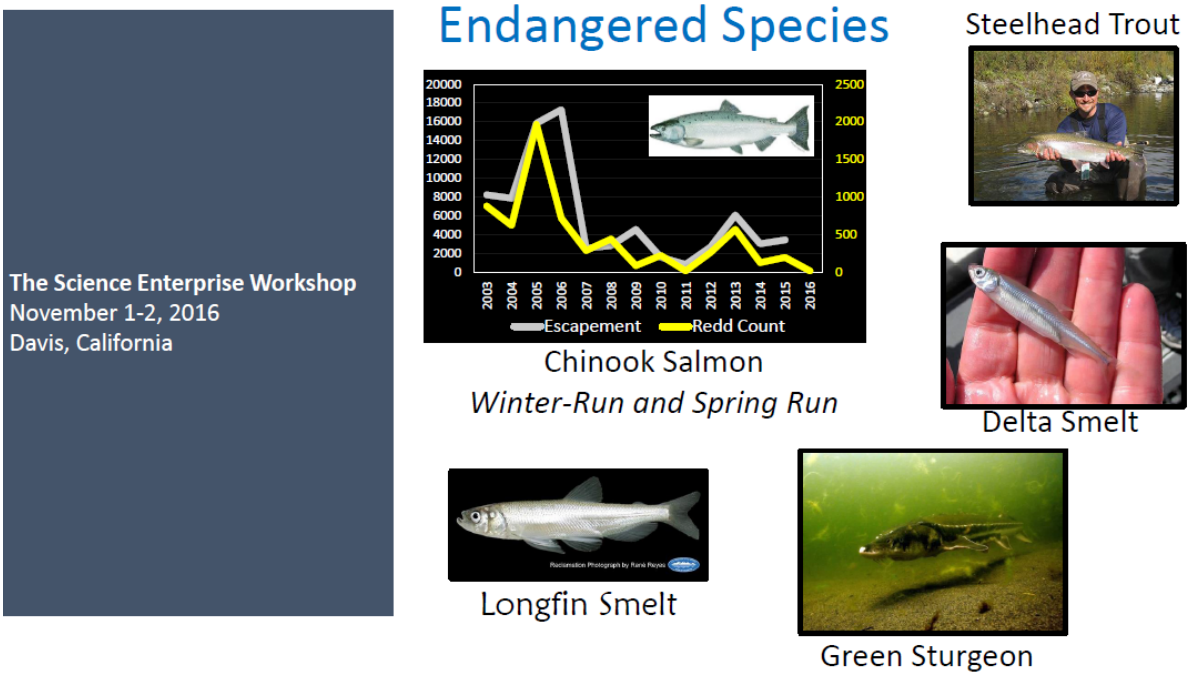


Figure 57, Slide 10

There are also problems with invasive species. Recent estimates from UC Davis are that 30 percent of the open water in the Delta has aquatic weeds. There have been major benthic invasions that have transformed the food web so the fish communities are shifting rapidly. “We're seeing a move away from pelagic communities towards more benthic and inshore communities, and a lot of those are driven by invasive species,” said Dr. Sommer.

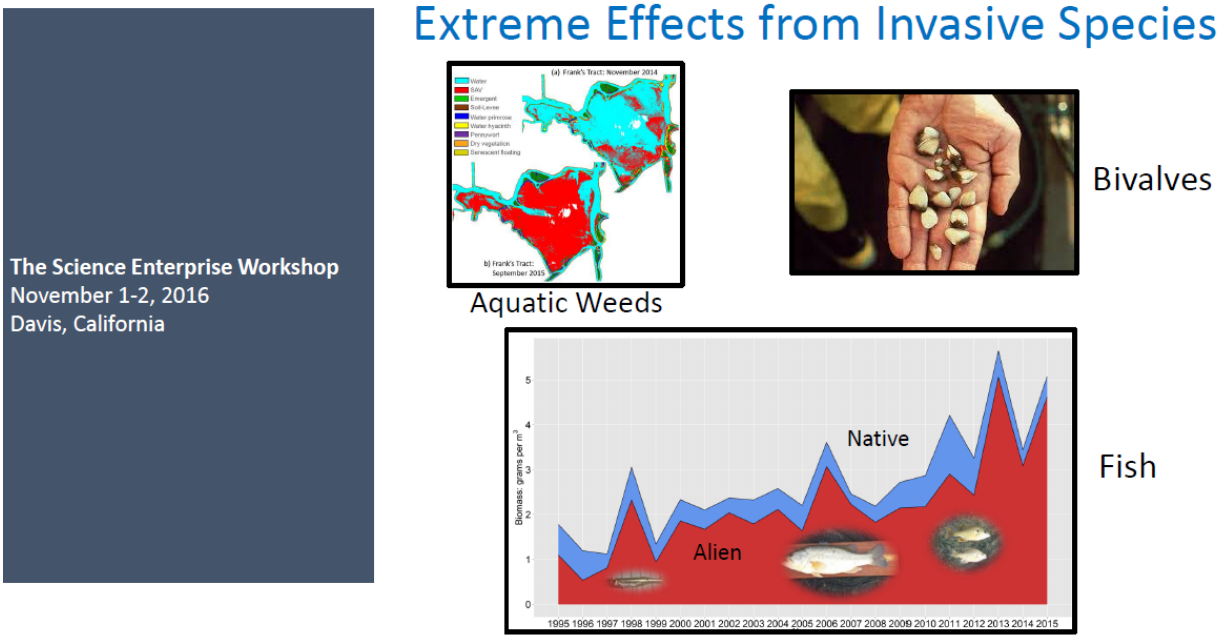


Figure 58, Slide 11

Water quality is another major science and management issue. With the agricultural economy, there is an ever-shifting array of different contaminants that are coming in the system. There are issues with nutrients, and harmful algal blooms have become a serious issue. “This year in particular, we've seen some of the most striking harmful algal bloom issues in the South Delta, but also statewide in places where we're redistributing the water,” said Dr. Sommer.

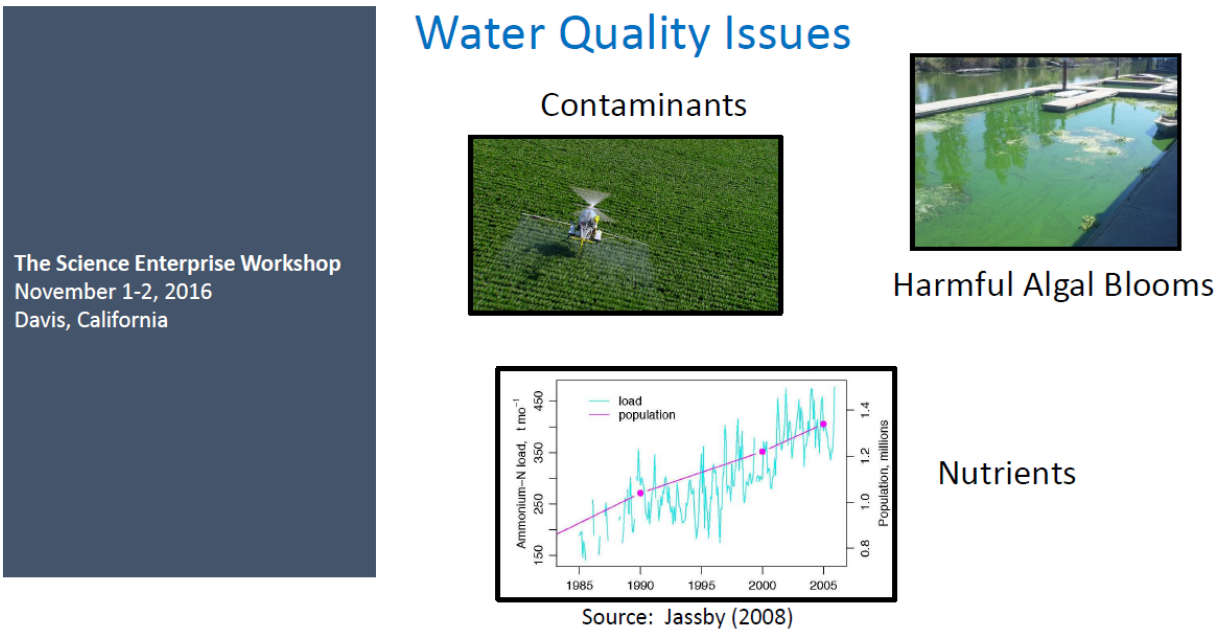


Figure 59, Slide 12

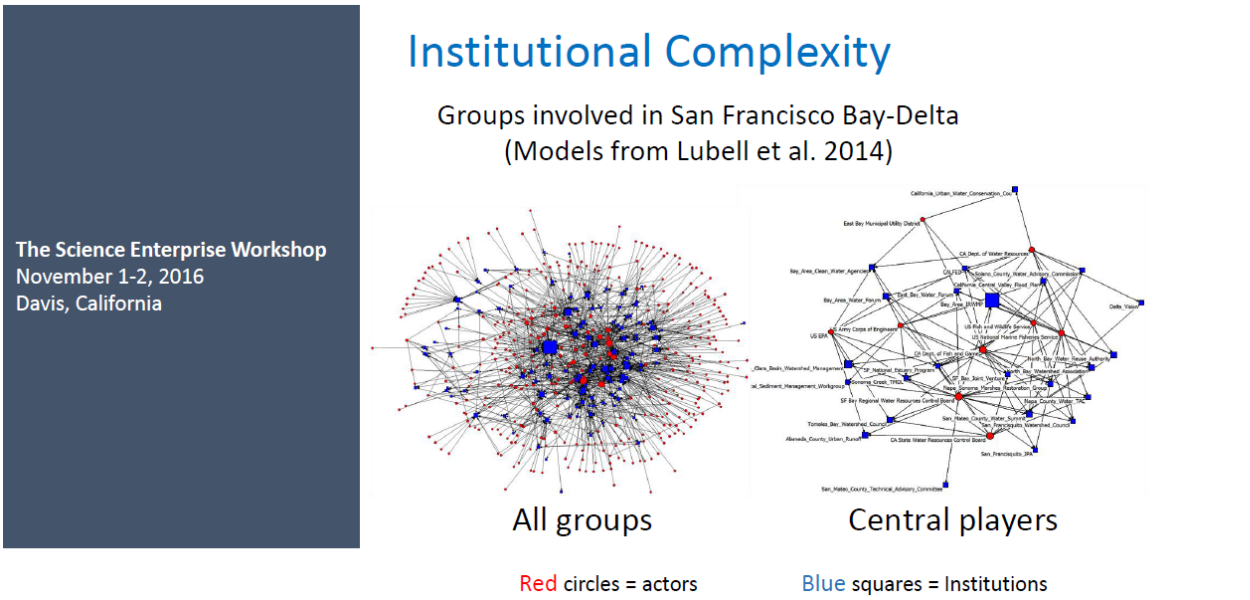


Figure 60, Slide 13

The institutional complexity is also extreme. It may not appear to have any structure, but it's somewhat clearer when you look at the central players. "We do have some organization, but it just does give folks a sense of all of the challenges we have in balancing both the resource management and the science," said Dr. Sommer.

There are a lot of groups involved in science in the Delta. There are universities, such as UC Davis, San Francisco State, UC Berkeley, and UC Santa Cruz who are involved heavily in the research. The agencies play a huge role in the monitoring, so there is a broad collection of both state and federal agencies involved. There are also a number of NGOs, consultants, and public water agencies who are also contributing to the science.

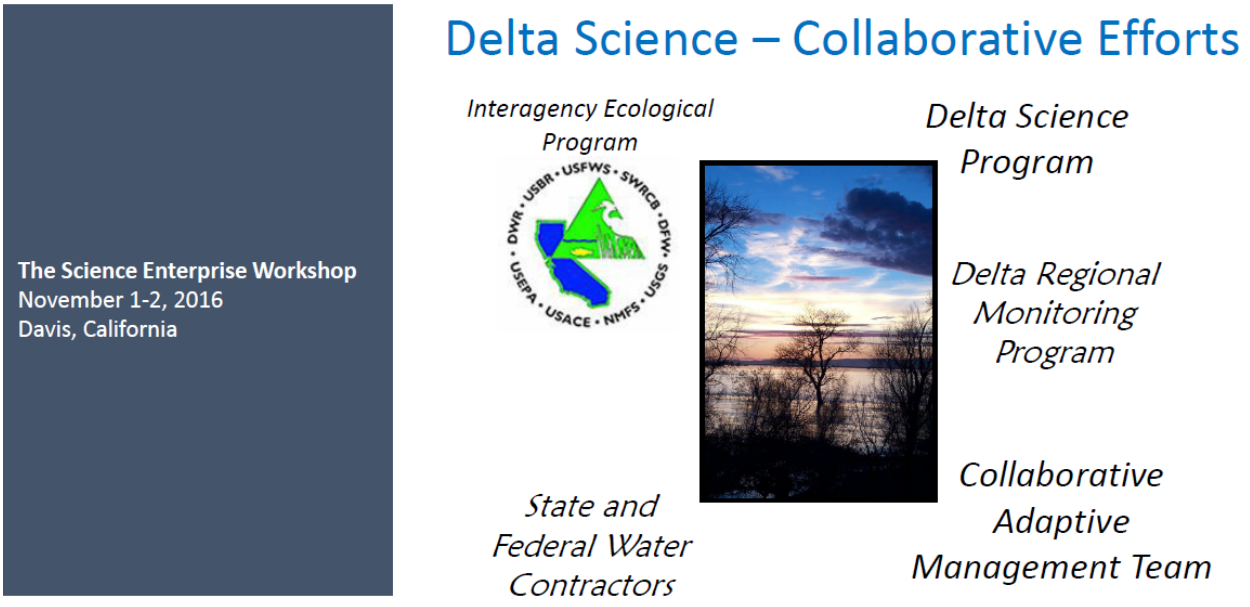


Figure 61, Slide 15

With so many issues and so many different agencies and organizations involved, Dr. Sommer acknowledged that it is a struggle to collaborate and work together. There are individual efforts like the Delta Science Program[108] that provide some overall vision; the Delta Regional Monitoring Program[109] tries to provide cohesiveness to some of the key water quality issues; and the Collaborative Adaptive Management Team (CAMT)[110], which is an effort to keep some of the key parties that have been warring over water issues out of the courts.

The state and federal water contractors do their best to pool resources. The Interagency Ecological Program (IEP)[111] is the most cohesive effort, bringing together a suite of state and federal agencies with a nexus by which the public and stakeholders can participate, but also a series of agency layers that allow managers and directors to provide input as well.

Dr. Sommer noted that none of the efforts include co-location. "Personally, one of the things I believe is that co-location is a big deal for science - getting a critical mass of scientists together that can work together," he said. "We're working towards building a new IEP field station where we can at least co-locate a lot of the monitoring efforts that we're doing right now, and hopefully build some synergies, but again, co-location is not currently a part of the program."

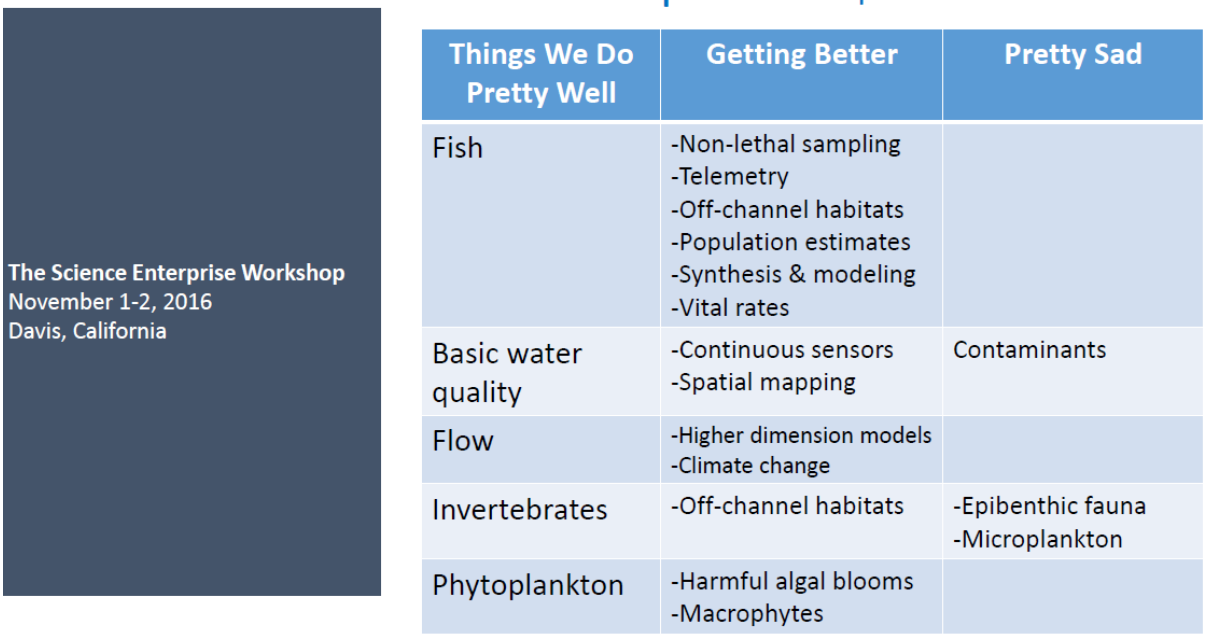


Figure 62, Slide 16

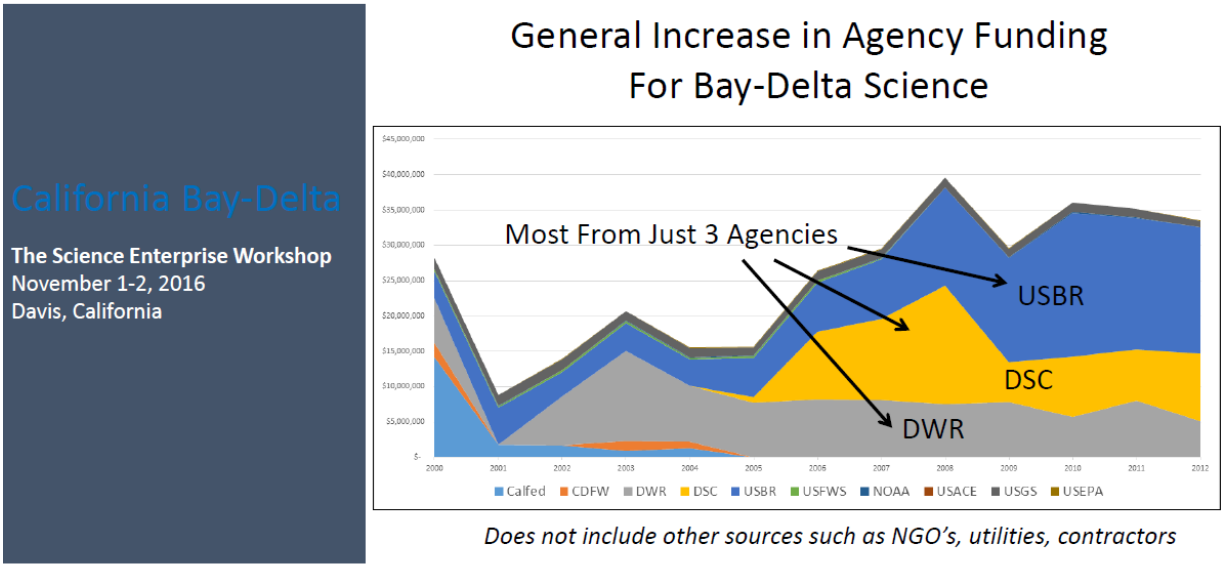
Dr. Sommer then presented a list of science topics, sorted into things that are done well, things that are done terribly, and things that are rapidly improving. "In the terrible column, I think most folks would agree we're pretty bad at doing things like contaminants, and some of the small invertebrates," he said.

[108] Delta Science Program. Delta Stewardship Council. http://deltacouncil.ca.gov/science-program
[109] Delta Regional Monitoring Program. Central Valley Regional Water Quality Control Board. http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/delta_regional_monitoring/index.shtml
[110] Collaborative Adaptive Management Team. State and Federal Contractors Water Agency. http://www.sfcwa.org/category/projects/camt-projects/
[111] Interagency Ecological Program. California Department Water Resources. http://www.water.ca.gov/iep/

"We actually do a pretty good job on relative measurements of some of the fish species and distribution. We're really good at some of the basic water quality functions. We're really good at flow, and kind of okay at invertebrates and phytoplankton."

Much of the innovation in monitoring includes non-lethal sampling as there are so many different listed species to deal with and looking at off-channel habitats as much of the program is designed around channel habitats. Our capabilities on synthesis are improving. There is increased use of continuous sensors. "In the phytoplankton area, I wanted to emphasize new efforts to look at harmful algal blooms and macrophytes," Dr. Sommer said. "That's the most vibrant area of science right now in my opinion."

Dr. Sommer presented a graph showing funding for science activities in the Delta, noting that it's an estimate and does not include NGOs, utilities, and contractors. "There are other sources, but this is a reasonable, relative approximation," he said. "Since 2000, there's been a general increase in funding. Also the funding sources aren't particularly diversified. In the Delta, it's mostly coming from three different agencies: the Bureau of Reclamation, the Delta Stewardship Council, and the Department of Water Resources."



Source: DSC CALFED Project Performance Information System

Figure 63, Slide 17

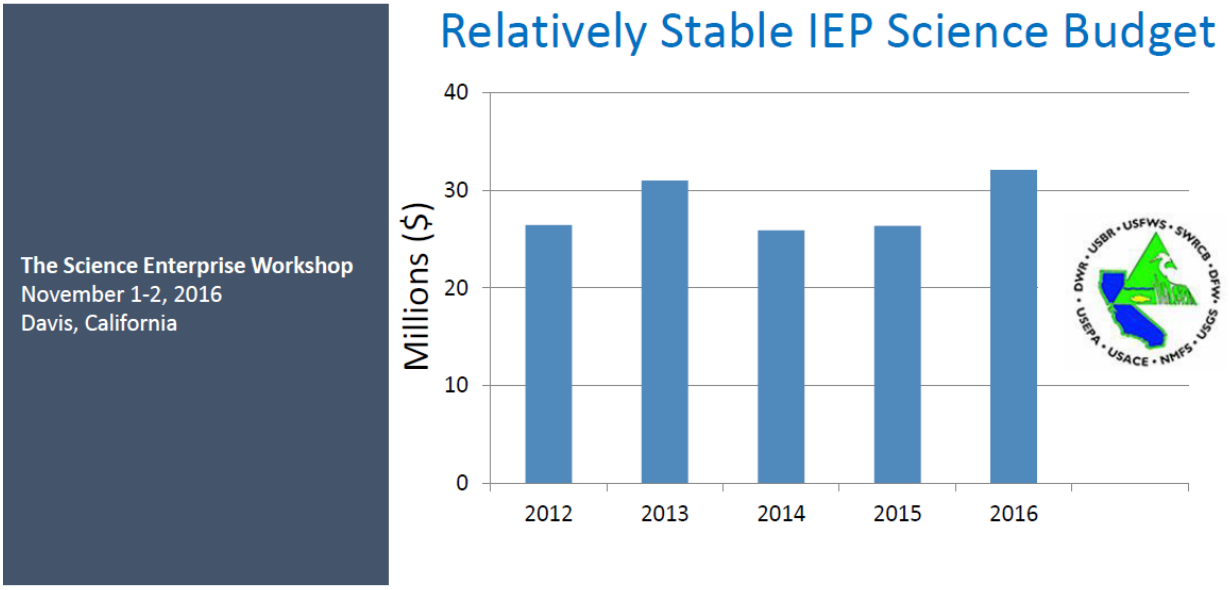


Figure 64, Slide 18

The budget for the Interagency Ecological Program has been relatively stable, but the number of issues has increased steadily, Dr. Sommer said.

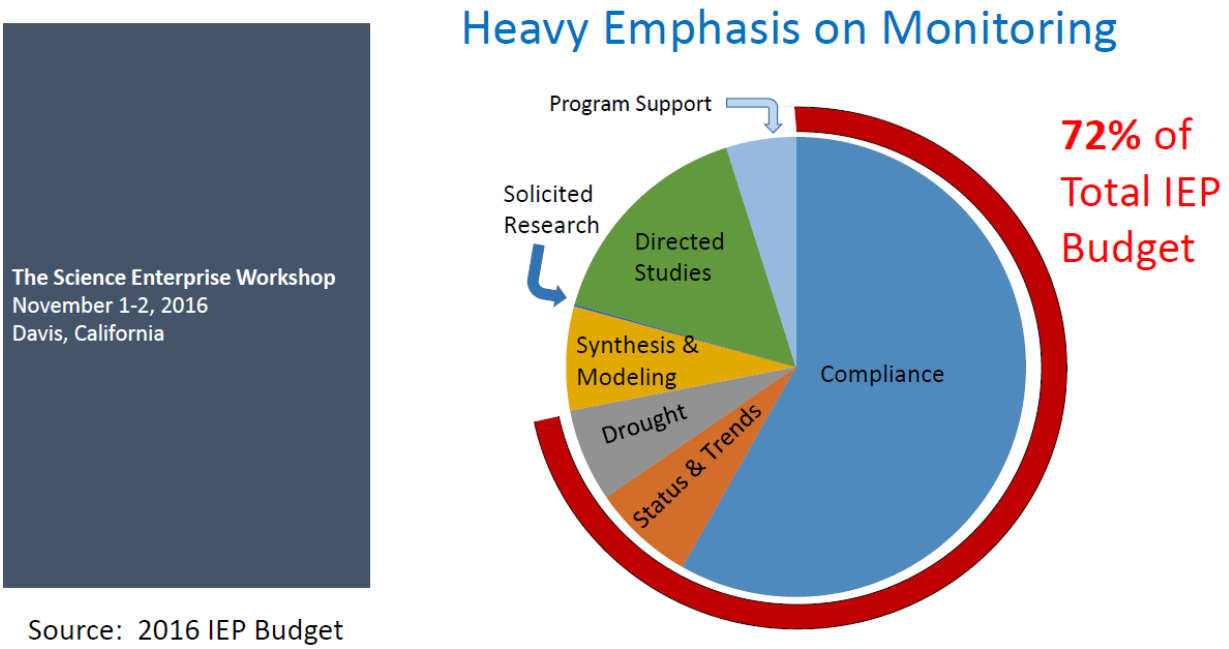
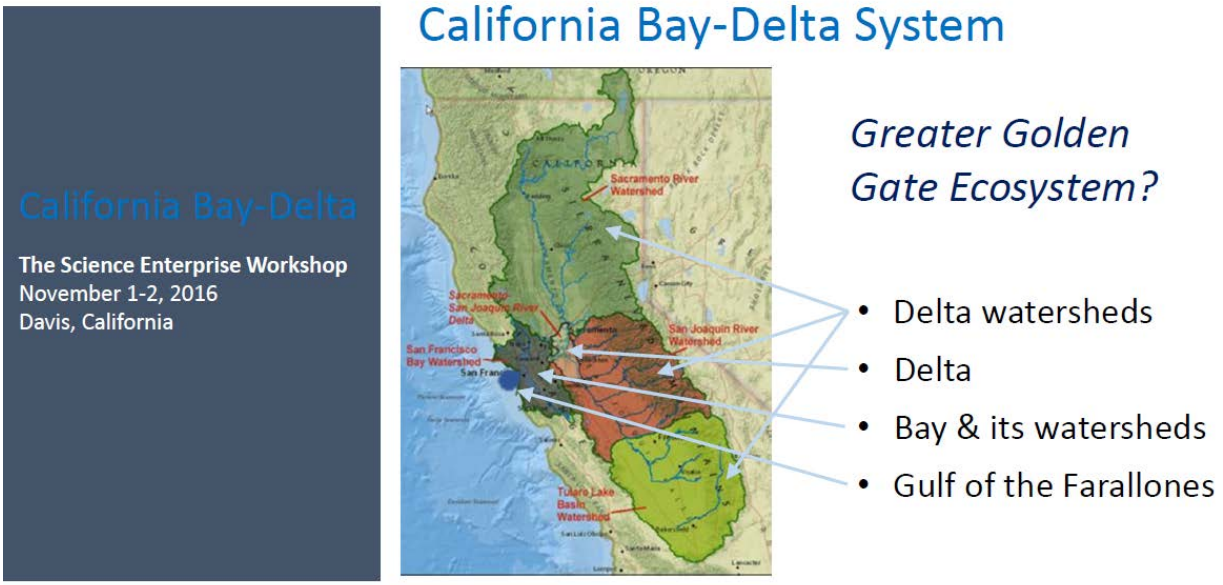


Figure 65, Slide 19

Dr. Sommer noted that there's an imbalance in the way a lot of the science is being done in the Delta. "This is my opinion, but if you break down the budget for the Interagency Ecological Program into compliance, directed studies, synthesis, and modeling, more than 70 percent of our budget is just going into compliance and monitoring of standard things. We are making improvements on synthesis, and we still have some directed studies, but there's a sliver you can't even really see, which is solicited research. We're not doing much in the way of solicited research. That was not the case historically; we did

historically have funds available for that. Our compliance costs have gone up and up, our budget has been flat, and the net effect is the compliance and monitoring takes a larger piece of the puzzle."

Dr. Josh Collins then took over the presentation, noting that he's going to look downstream and then look upstream. "We've taken this system and found some way to carve it up, and we are working to put it back together again," he said. "Those of you who are from outside the region, this is a call for help. Most of you look as though you've done a better job for a longer period of time of trying to put your systems back together again and we're on that trajectory, but we have some ways to go."



Josh Collins, San Francisco Estuary Institute
Figure 66, Slide 20

He presented a map of the Bay Delta system, noting that he sometimes calls it the Greater Golden Gate Ecosystem, but the name hasn't caught on. There are three principal Delta watersheds, the Delta itself, and the San Francisco Bay and its watersheds. "We also have the Gulf of the Farallones that never gets talked about, but if you've ever had the pleasure of going in or out the Golden Gate, you'd know that it's a long way out from the Golden Gate before you get away from the estuary. It's a long way before the water turns color, before you feel as though you're actually away from the influences of that Greater Golden Gate Ecosystem. Arguably, the Gulf is part of it."

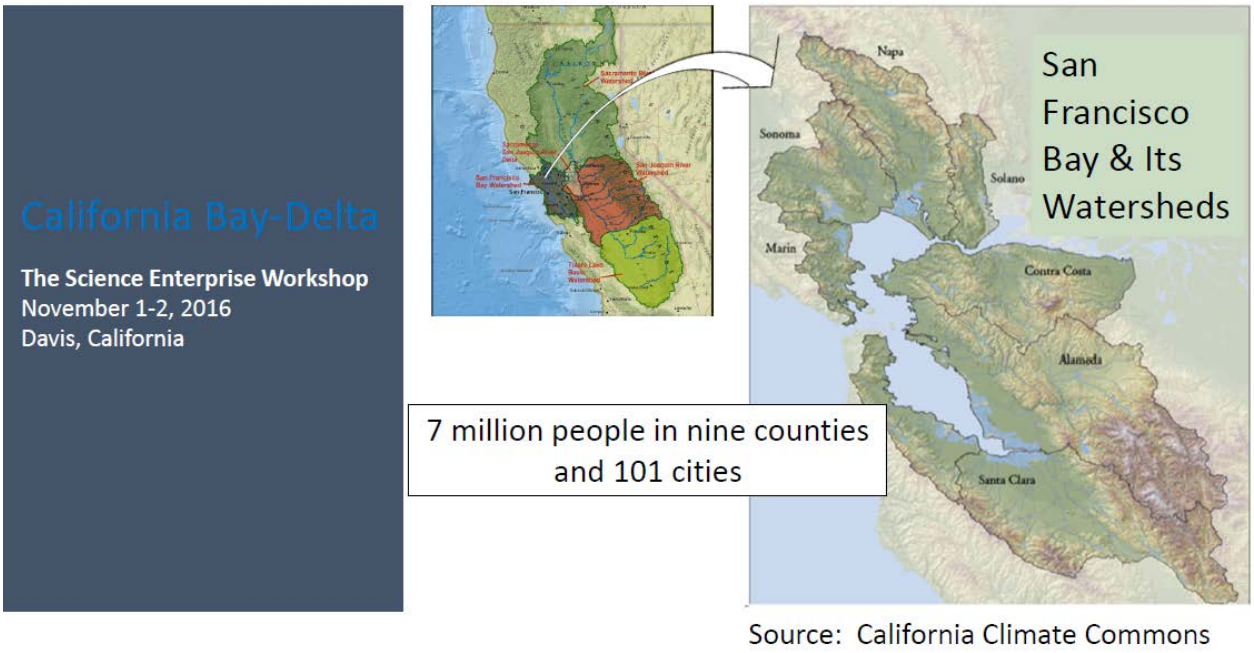


Figure 67, Slide 21

The San Francisco Bay Area is a big place in terms of the number of people and in terms of an economic engine. It's also a big place ecologically, in terms of number of rare and endangered species. It's only been around for five or seven thousand years and there's been endemism in that amount of time. The modern environmental movement was based, in part, on the Bay Area; it's all part of the legacy.

"There's always enough money in this magical place for so many bright people to get something started that then peters out," Dr. Collins said. "It's very hard to get a consistent and coherent focus that lasts more than two or three one-off something-or-others, so part of what we're dealing here was just too much money, too much intelligence, not enough time, and everybody trying to do the best they can. That's an underlying theme in the Bay Area: entrepreneurial endeavors though horizontal organizational structures, both public and private. The idea of disruptive boundary organizations with flat organizational structures was invented here. Why? Because nobody here wants to work for anyone else. And we're proud of it."

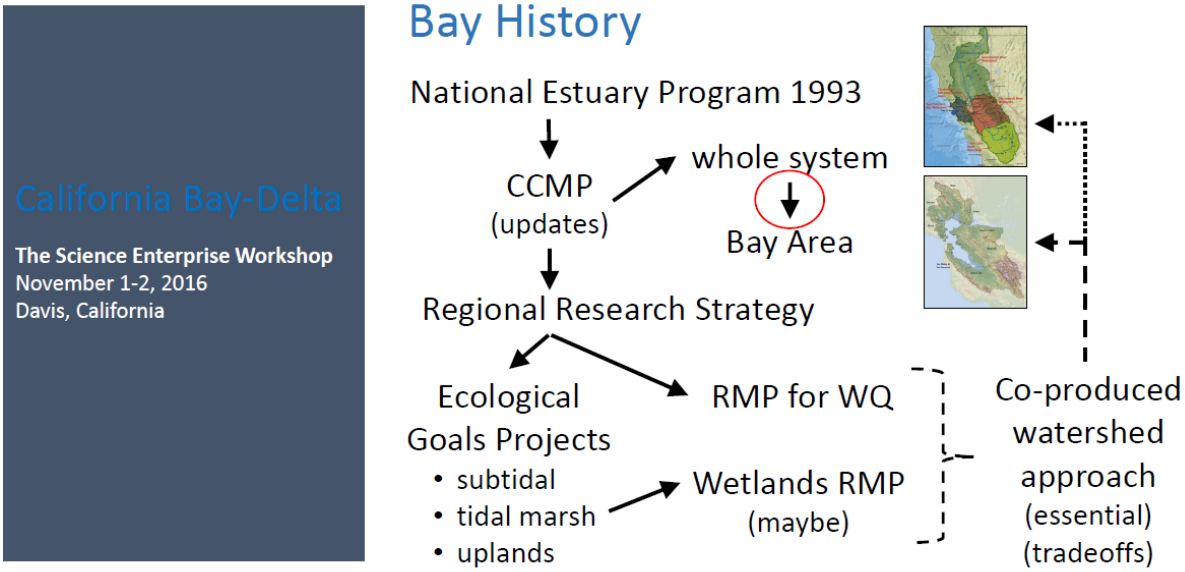


Figure 68, Slide 22

Dr. Collins then turned to the history of the Bay, noting that it's his version of the history of the Bay Area; other people could tell a different story. "One of the things that happened was the EPA walked into the San Francisco Bay and said, 'This is a national estuary.' People said, 'I beg your pardon? What is the national estuary?' 'Well, you qualify for the National Estuary Program (NEP)[112]. We'll dump some money on you to figure out how it doesn't work, and then how to fix it, and you'll keep getting some money until you have the capacity to carry on by yourselves. If you agree to that and you manage to produce a Comprehensive Conservation and Management Plan (CCMP),[113] and if the governor signs, and it then goes to the EPA, and if the EPA Secretary signs it, it then becomes an instrument of the Clean Water Act. Then you have something you can use to hold yourselves accountable to each other." All of that happened, and we've been trying to live up to it ever since.

The CCMP, sponsored by the EPA, began big. It encompassed the Delta and its watersheds. And it hit political walls, and then the focus fell back to the Bay Area. "That decision to scale back to the Bay, however it was made, just perpetuated the problem that we're trying to overcome now," he said. "We have a legal instrument still on the books. The CCMP gets updated, most recently this year. It always talks about the whole system; but always gets applied mainly to the Bay Area." While the San Francisco Estuary Partnership is recognized as a National Estuary[114], it does not include the Delta.

In 1993, a regional research strategy was prepared as part of the CCMP that supported creation of the SF Bay Regional Monitoring Program (Bay RMP)[115]. It focuses on ambient monitoring around San Francisco Bay and Suisun Marsh for the purposes of determining whether the National Pollutant Discharge Elimination System (NPDES) permits for sewage treatment plants and storm drain systems are actually working. "Are those individual, end-of-pipe permits adding up to something better for the bay?

[112] National Estuary Program. US Environmental Protection Agency. https://www.epa.gov/nep
[113] Comprehensive Conservation and Management Plans. US Environmental Protection Agency. https://www.epa.gov/nep/local-estuary-programs#tab-2
[114] Individual Estuary Program Homepages. US Environmental Protection Agency. https://www.epa.gov/nep/local-estuary-programs#tab-1
[115] Bay Regional Monitoring Program. San Francisco Estuary Institute Aquatic Science Center (SFEI-ASC). http://www.sfei.org/programs/bay-regional-monitoring-program

The RMP decides whether it is," said Dr. Collins. "It's a very important program, but it's driven by the US Clean Water Act and therefore emphasizes pollution monitoring."

Dr. Collins said the community has been trying to integrate ecological considerations into the monitoring program by emphasizing the need to monitor the beneficial uses of the waters, which includes wildlife support, and not just the chemical stressors. The community has also set regional goals for subtidal and intertidal habitat and has called for a program to monitor progress toward the goals. "We're on the verge of maybe having a regional wetland monitoring program, after 25 years of trying," he said. "It was called for in the original CCMP; maybe now we get it. Those of us involved with this initiative have said, 'Let's do the Delta, too' and the agencies' answer has been, 'No, not yet.' We're still trying to create a wetland monitoring program in either the Delta or Bay that can be expanded across the entire system, but we continue have trouble with funding. The need is clearer than ever, given the large amount of funded wetland restoration, so perhaps the monitoring will follow."

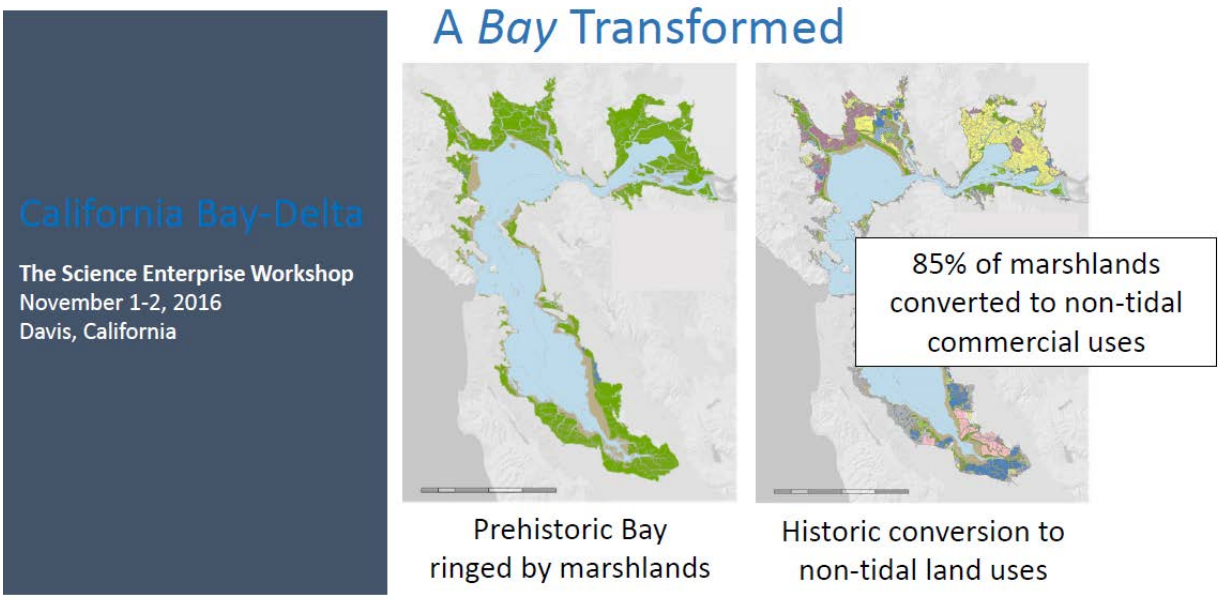
Dr. Collins said if they can get more regional monitoring programs going, which is what they are aiming for, they will likely be designed to support coordinated environmental review and permitting at regional and landscape scales. "If we can get rid of the ridiculous balkanization of the system we might be able to coordinate restoration planning and management of the system as a whole, as intended through the CCMP. We can get all the way back to caring for the whole system again," he said. "But the real charge now, the frontier of both environmental science and monitoring in the Bay, is the regional approach to watershed-based coordinated environmental review and permitting across water quality, flood management, and wildlife conservation. There is a growing need to better coordinate regulatory procedures across the Clean Water Act and Endangered Species Act at ecologically meaningful scales, as necessary to adapt regulation to shifting baseline conditions due to climate change and population growth."

"Climate change, sea level rise, drought, and deluge are creating a climate of change where regulators and managers are saying, 'How are we going to deal with this?', and they say 'Not by ourselves. Not individually,'" said Dr. Collins. "At what scale do we coordinate permitting? You can't get rid of permits; they protect the relationship between people and the environment. And you can't integrate them. That's against the law. So, they have to be coordinated. At what scale do we coordinate environmental review and permitting, so that we can get ahead of these issues, and not be slowing down our restoration work with necessary but slow and inefficient environmental review and regulation?"

Dr. Collins said that in the Bay Area, they think in threes: such as past, present, and future; or federal, state, and local. "It doesn't do any good for science to reach across to only one level of government, because in this country, you have to integrate vertically," he said. "Environmental laws are implemented mostly by local agencies. That's where land use happens, and land use controls the environment, so you have to integrate vertically through government from federal agencies to local jurisdictions. We're aware of that in the Bay Area - not that we do it well, but we tend to think federal, state, local when we envision policies, their implementation, and science support."

Another set of three perspectives is near-term, midterm, and long-term. "We try to keep the big thought out there in front of the immediate thinking, to know where we need to be in 5, 10, 20 years or beyond. Then we try to take the baby steps in that direction," he said. "There are no home-runs in government. There's a lot of singles. It's important to know when the bases are loaded. There are other triplets as you can imagine: the three laws of thermodynamics; me, you, the other guy; w, y, and z. This

is the practical way we organize everything we do. On the science side, on the policy side, and on the public side, we really seem to think in threes."



Sources: Goals Project, 1999 & 2015
Figure 69, Slide 24

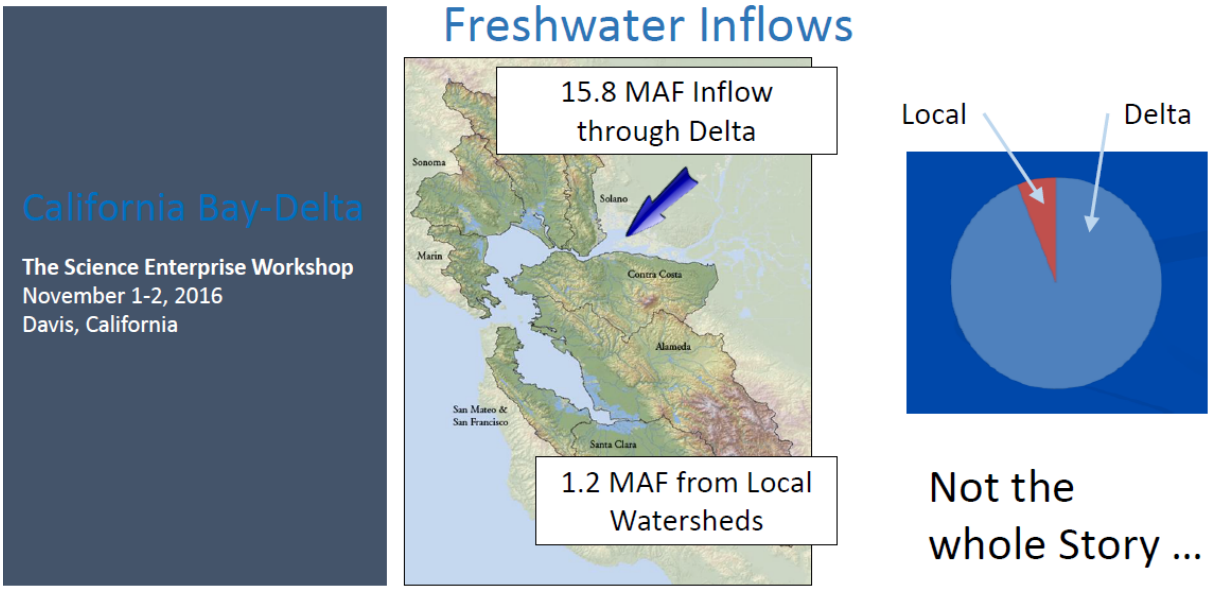
"Like the other regions represented here today, including the Delta, the San Francisco Bay has also been transformed: 85 percent of marshlands around the Bay have been converted to non-tidal commercial uses. The historical ecology report referenced earlier came about because there were a lot of people fighting over what this or that piece of land should be next; they couldn't agree, so a program was created to reconstruct the past in compelling detail in a geographic information system. It lives on with additional information because everybody loves the historical past," Dr. Collins said. "Everybody shares the history of family and place, and they hold no guilt about the past. We have found, quite surprisingly but wonderfully, that people who are fighting tooth and nail over what should be done with some piece of land will work together to learn its natural and human history, to literally map their discoveries, or re-discoveries, become associates or even friends, and start envisioning the future together."

Dr. Collins noted that the past isn't something you can reach; ecosystems don't run backwards. "When you do the historical ecology, you can see what you used to have, and you understand how things have changed," he said. "You know what you can manage and what you can't manage, and you can aim for things that you can really do. The past matters, not because you can reach it, not because you can reproduce it, but because it informs your thinking about what the future could and should be."

"Why are we focusing so much on wetlands?" Dr. Collins asked. "Wetlands matter for lots of scientific reasons. For one thing, everybody meets there," Dr. Collins said. "Lots of environmental policies, both terrestrial and aquatic, meet or collide in the wetlands. They really are transitional areas, not just in ecological terms, but in political terms. They're very sensitive to surrounding environmental change, both intentional and otherwise. So, they can be difficult to fully restore. They're good indicators of environmental conditions and problems. They're also important unto themselves, for many celebrated reasons. If you can bring the wetlands back, you can do other things."

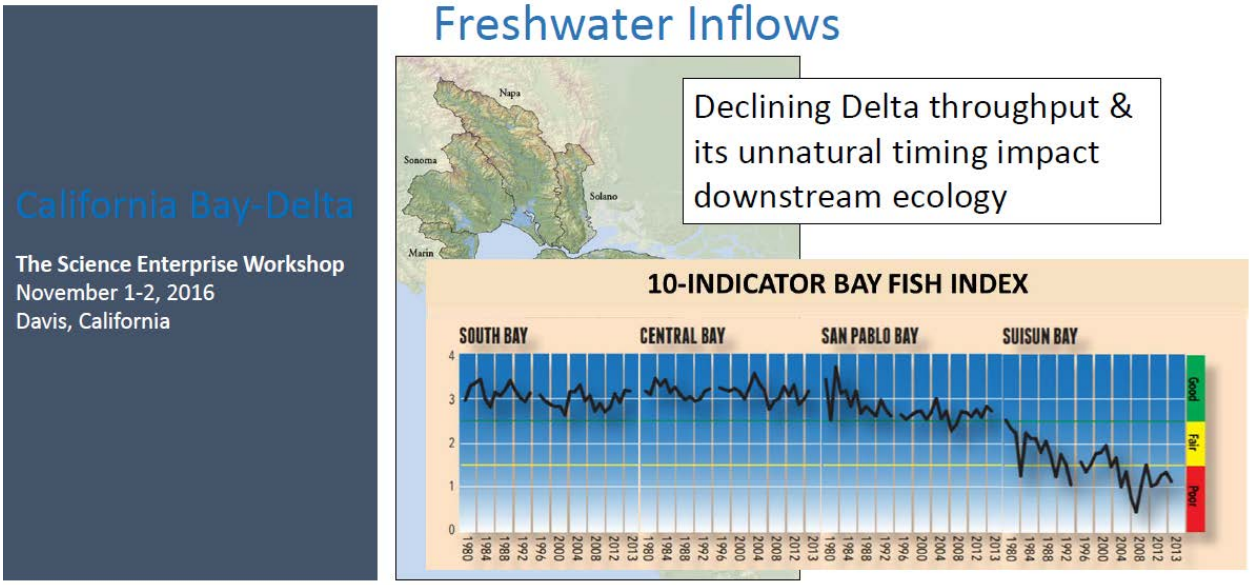
In the Bay Area, the community of wetland interests is quite literally following the Clean Water Act and Endangered Species Act from the bay waters to the wetlands and into watersheds. “We're just following the flow upstream, and slowly, maybe too slowly, we’re understanding the need for a watershed approach to wetland protection, and therefore a watershed approach to coordinated regulation,” Dr. Collins said.

The key science topics in the Bay Area are fresh water supply, sediment supply, water quality, population growth, sea level rise, and many of the related topics. For the Bay as a whole, most of the freshwater flows and coming through the Delta, but that’s not the whole story. “It's the unnatural timing and lack of variability in Delta outflows to the Bay as well as their volumes that are impacting downstream ecology,” Dr. Collins said.



Source: McKee et al 2010, DWR 2010.

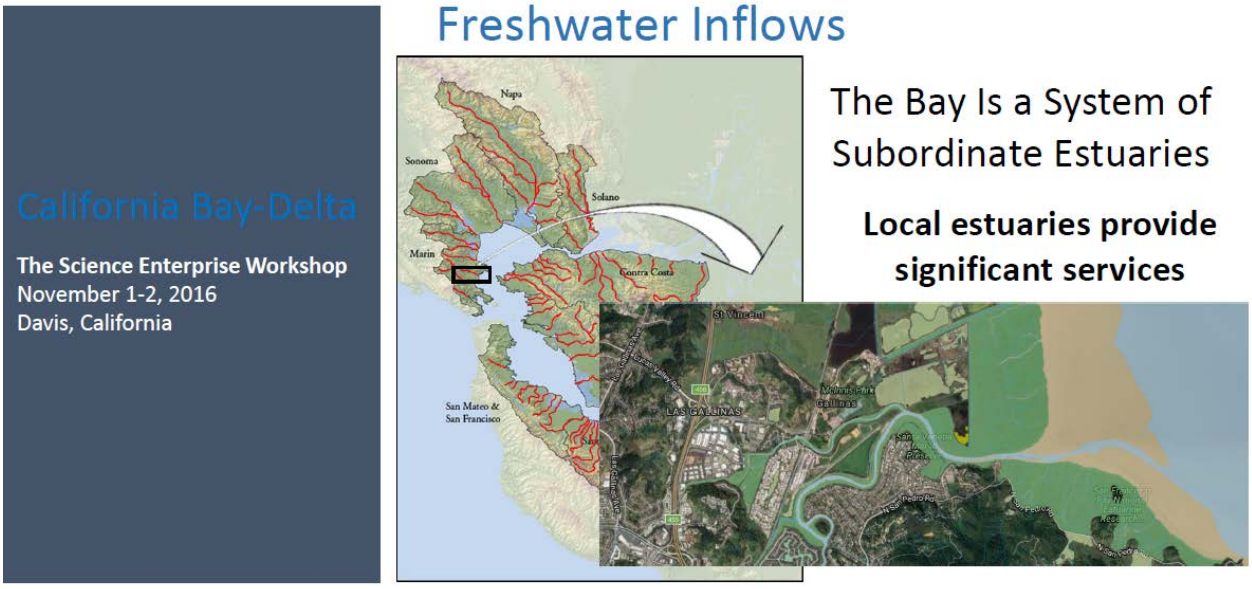
Figure 70, Slide 26



Source: Christina Swanson, State of the Estuary Report, 2015, The Bay Institute 2016

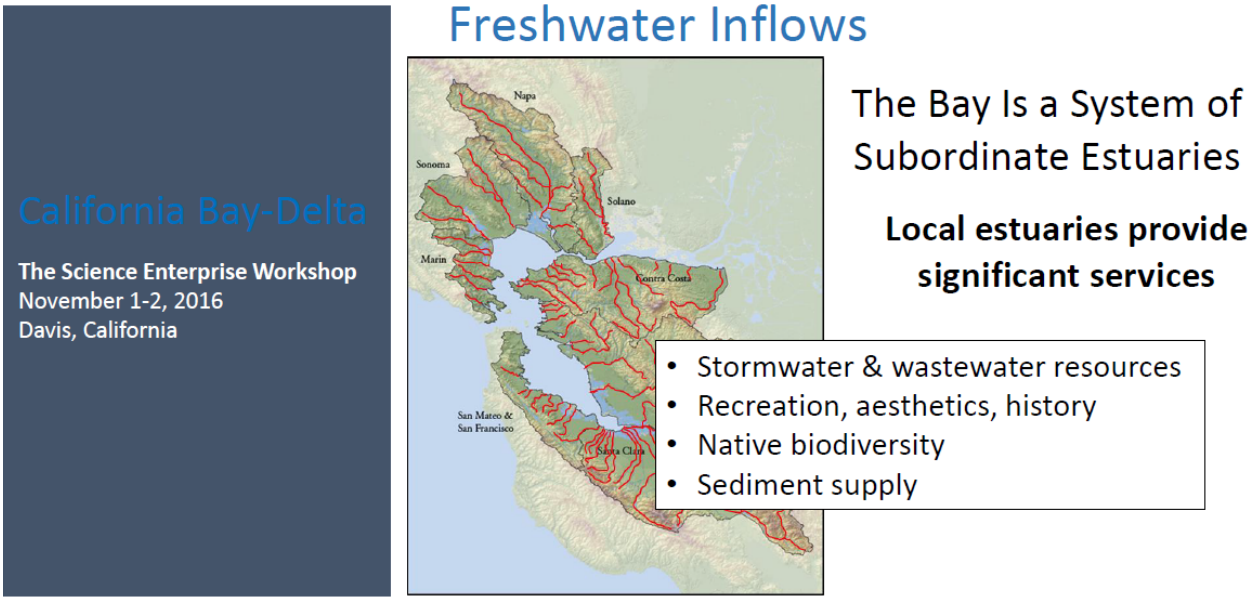
Figure 71, Slide 27

He presented a 10 indicator bay fish index as an example of the kind of synthesis done to assess Bay conditions. "Bay scientists put together an 'uber' index of fish health based upon numerous species that shows the declining condition upstream in the estuary and over time," he said. "But there's still much more to the story," he said. "The Bay is fed by numerous local streams and each one has its own little estuary. They matter a lot in terms of their ecological services and cultural resources," Dr. Collins said. "We see the Bay as a complex of many small estuaries, each belonging to a local watershed, and each providing sets of services that contribute to the Bay's environmental wealth."



Source: EcoAtlas 2016.

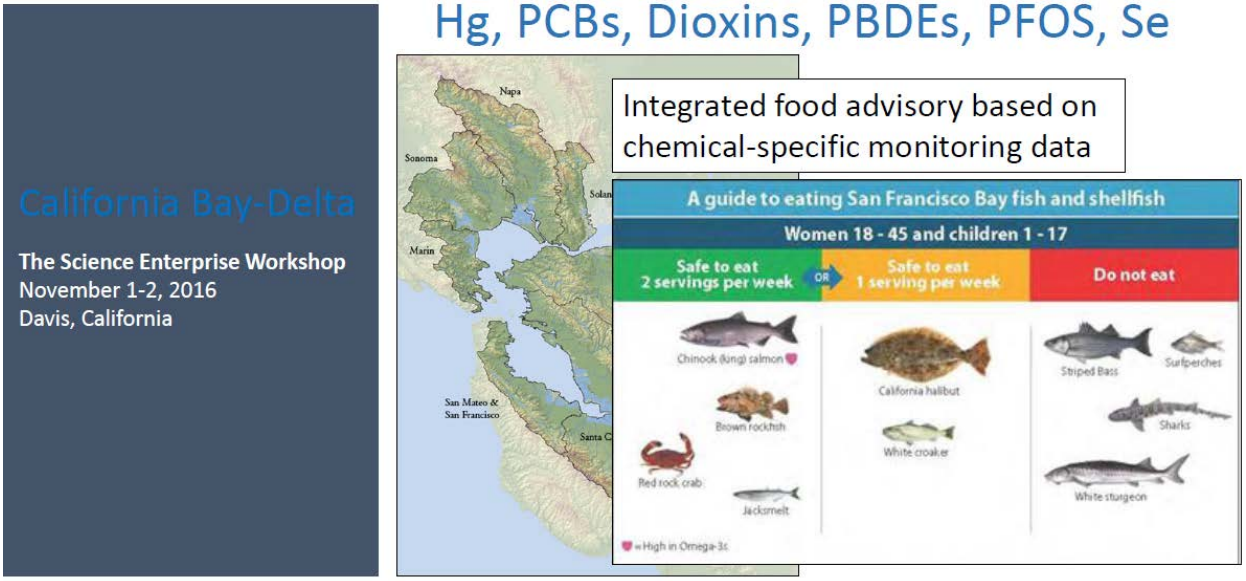
Figure 72, Slide 28



Source: EcoAtlas 2016.

Figure 73, Slide 29

The sediment supply is mainly coming from local watersheds rather than the Delta, but that wasn't always the case, Dr. Collins said. The throughput of sediment from the Delta used to be the largest supply, but that's been turned off by upstream dams retaining a lot of sediment and a reduction in erosion off of land surfaces. "In the meantime, we still have erosion in watersheds around the Bay, so the local watersheds are now becoming the dominant source of fine sediment that we need for building marshes," he said. "At the same time, we have TMDL (Total Maximum Daily Load) limits on fine sediment being imposed on local watersheds, telling people to turn off the supply of fine sediment from the watersheds. So, we continue to disconnected the Bay from its local watersheds through public policy and regulation. We've disconnected the Bay from the Delta, and we've disconnected the watersheds from the Bay though policy and practices, despite scientific consensus that the Gulf, the Bay, the Delta, and their watersheds comprise one integral system with clear, physical, ecological, and economic connections."

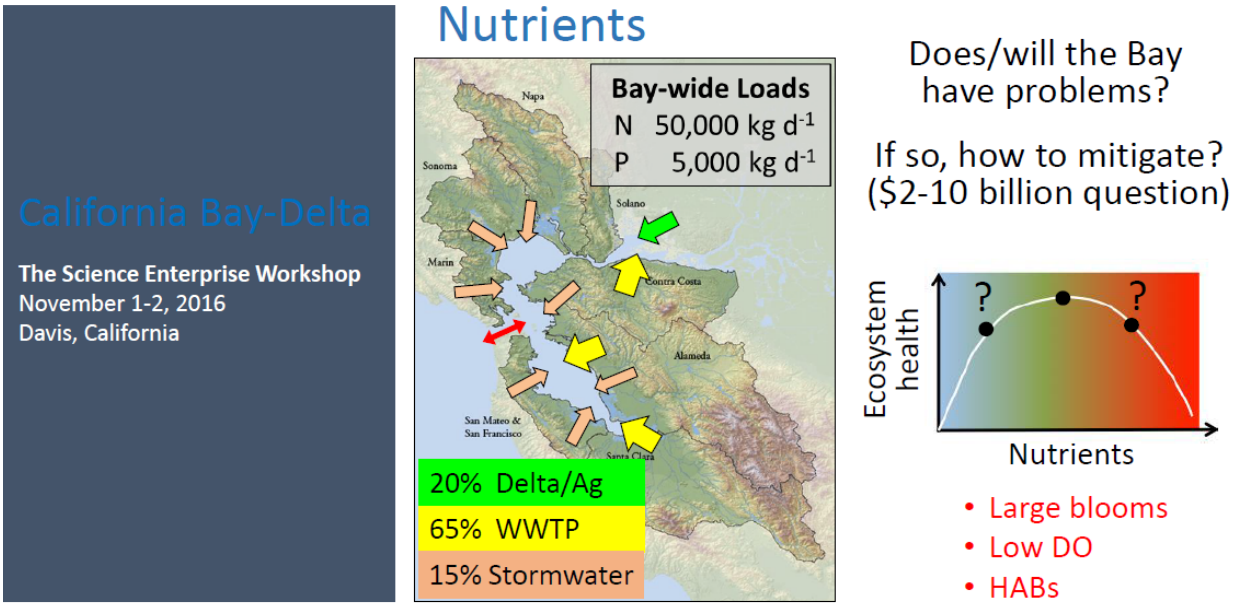


Source: Water Quality Regional Monitoring Program 2016

Figure 74, Slide 32

There are numerous chemical contaminants and other related water quality issues in the Bay. Through the Bay RMP, the monitoring data on contaminated species of estuarine wildlife eaten by people are converted into consumption advisories for the public. Microplastics are also a big deal; baseline measures of their concentrations in Bay waters were recently completed for the first time and the results show a greater abundance than in other estuaries.

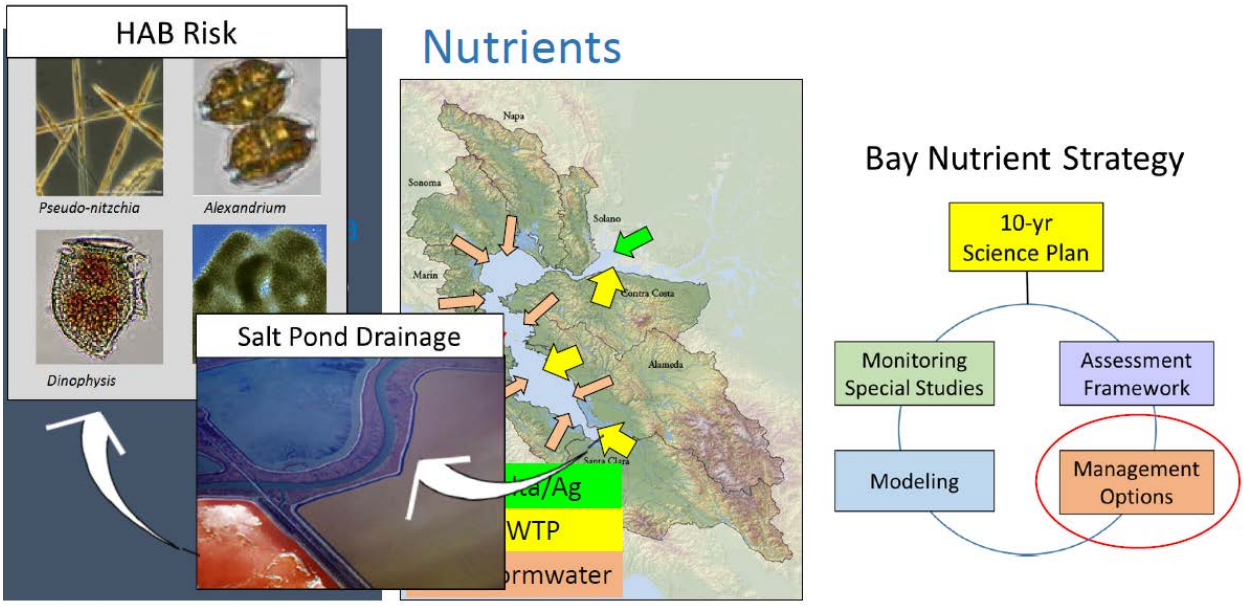
The Bay monitoring and research efforts have increased their focus on assessing the effectiveness of regulatory and management actions. “We are increasingly focused on the beneficial uses and services of the environment,” said Dr. Collins. For example, with regard to contaminants, what we're really caring about is not the contaminants themselves, but their level of impact on living resources. So, we monitor those resources. If they're okay, we see no automatic need for research. If they're not okay, we have to use research to understand the pathways of contamination and its manageable causes. We see targeted research as an essential aspect of a mature monitoring program, with the research being driven by the monitoring results.”



Source: Cloern et al 2007, 2012; SFEI 2014

Figure 75, Slide 34

The nutrient story in the Bay is complex. There are nutrients coming out of the Delta, from local watersheds, and from wastewater treatment plants. There are a lot of storm water systems around the Bay. “We have a lot of nitrogen coming into this system,” Dr. Collins said. “The Bay is not as transparent as it used to be, before the advent of modern land uses that greatly increased the inputs of fine sediment. As we reduce these inputs, through entrapment of sediment behind dams and erosion control, the transparency of the bay will increase. Light penetration will also increase, and algae and phytoplankton will be able to make use of the nutrient stores. The whole bay could turn green. Is that a problem? If so, how do we solve it? Do we retool all these public treatment plants and storm drains? That's billions of dollars in retooling. So, we're asking the question, is green bad? Probably green is not good, because there are harmful algal blooms involved with green. So, we can revise our question: ‘Where do we need to be on the system’s response curve to increased water transparency?’ We're moving toward classifying conditions as poor, fair, good, based on what color the bay should be, and based on what color means in terms of environmental risk and management costs.”



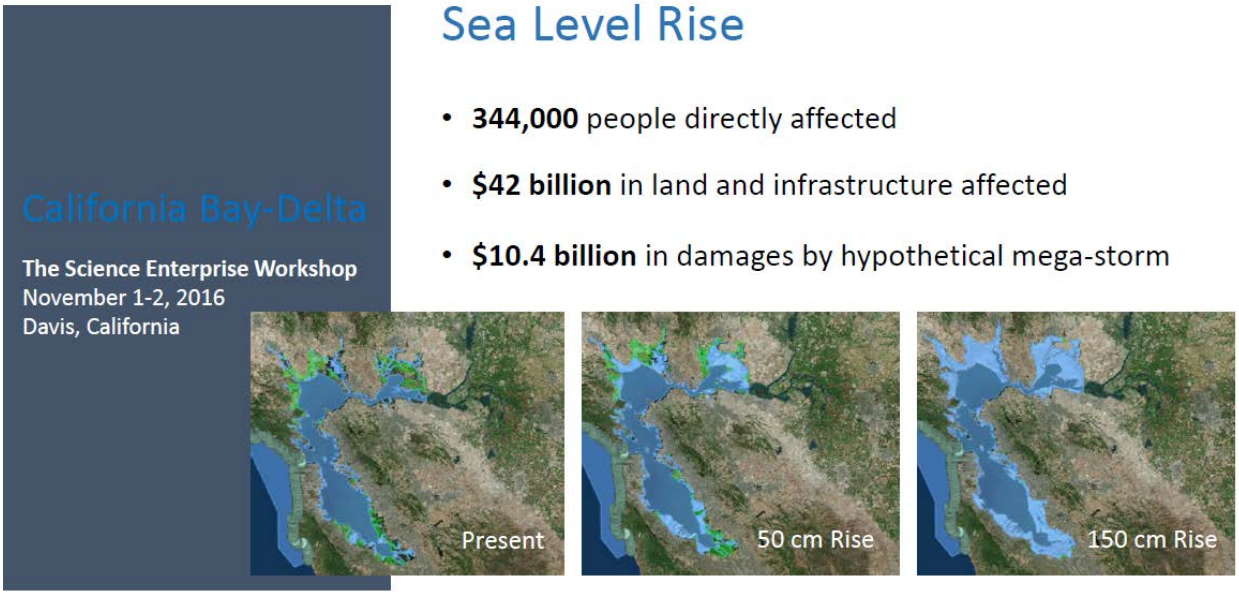
Source: Cloern et al 2007, 2012; SFEI 2014

Figure 76, Slide 35

Dr. Collins noted that the wastewater treatment plants are paying into a research program to see how much wastewater plants need to reduce their nutrient outputs to solve the emerging nutrient problem. There are management options, he noted. In the south part of the San Francisco Bay, salt ponds are being restored to tidal marsh, but they can bleed chlorophyll and nitrogen out into the Bay system, so they need to be managed so they won't augment the outputs from the wastewater treatment plants. "We're realizing there are some options at the landscape scale for managing different parts of the system to help solve a problem," Dr. Collins said.

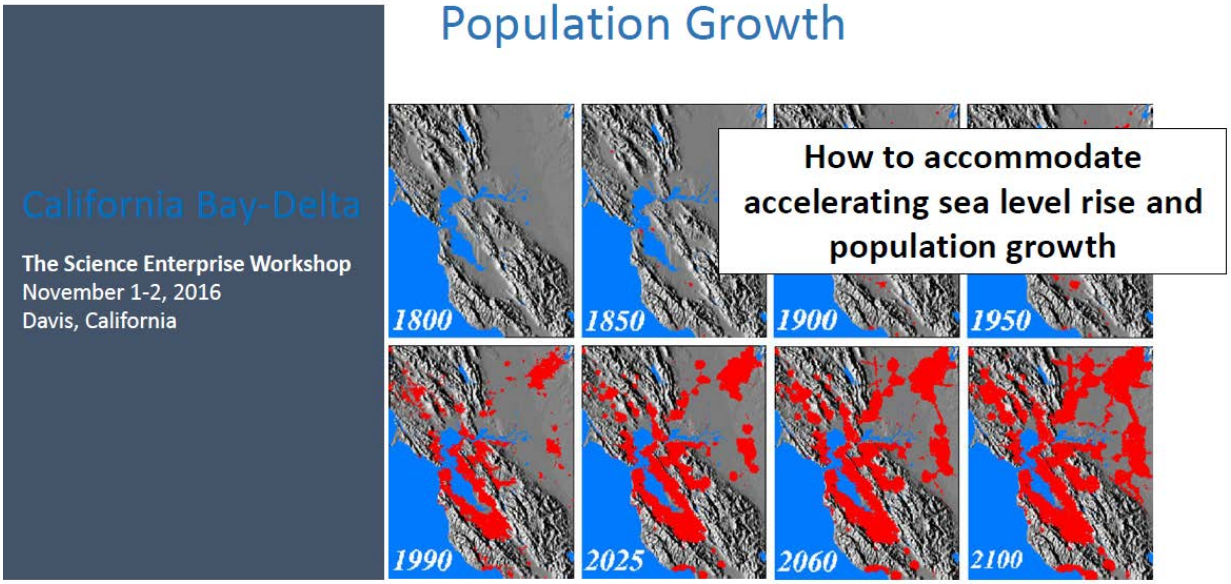
With respect to sea level rise, a local consortium involving Point Blue Conservation Science[116] is working with NOAA and USGS to produce models that integrate tidal flooding and river flooding at the margins lf the Bay. There are lots of people who are going to be affected by this flooding. "We know that the sea level rise estimates are going to be revised upwards, not downwards," Dr. Collins said. "We know that the forecasts we're dealing with now are probably low and the planning timeframe needs to extend further into the future. Sea level rise will not stop in 2100. We need to plan for higher waters over a longer period."

[116] Point Blue Conservation Science. http://www.pointblue.org/about-pointblue



Sources: Our Coast Our Future 2016; Bay Area Council, Surviving the Storm 2015

Figure 77, Slide 36



Source: Jantz et al. 2010, Project Gigalopolis

Figure 78, Slide 37

The human population in the region is expected to continue to grow. “Sea level rise will squeeze the growing population between the Bay and the higher ground that's steeper. The resulting socio-ecological issues are likely to intensify,” Dr. Collins said. “We wonder how we're going to marry social planning to ecological planning. How do you marry transportation planning with housing planning, with environment planning? The CCMP I spoke about is kind of a blueprint for the bay, but it's not looked upon with the same authority or importance as the regional transportation planning, or the regional economic or housing planning, even though it probably needs to be on the same footing.”

Sea level rise in the Bay Area is mostly about the transition zone. That is the area of ecological interaction between the bay and its surroundings. There is very little natural transition zone left; most of it is urbanized. Only about 23 percent of the area that is projected to be impacted by sea level rise is actually undeveloped and protected at this time. “That means we have to move people, or somehow build a lot of levees around them, and the levees will have to be built over and over again,” said Dr. Collins. “and what about the railroads and freeways surrounding the Bay? Do we move them or elevate them or put them in tunnels or underground? Major changes in infrastructure are going to happen and they could be planned in concert with t-zone restoration.”

In terms of Institutional changes, we need to regard the estuary as a single system with many administrative divisions. “There are different water quality boards that are regulatory agencies of considerable importance. At every level of government there are multiple agencies for land planning, flood management, water supply, pollution control, and wildlife protection. There are essential environmental NGOs operating at local, regional, statewide, and national scales. But everyone seems to recognize two parts to the estuary, magically meeting at a place called Broad Slough. “If you're on east side of that slough, you probably read the Sacramento Bee. If you're on the west side, you probably read the San Francisco Chronicle or San Jose Mercury News. People of the Delta and Bay see themselves differently. The politics are managed differently. The cultures are different. That may not change. The challenge is to coordinate environmental science across the boundary, to the degree necessary to protect the whole system. The challenge is to create a Bay-Delta science enterprise.”

Figure 79, Slide 39

Figure 80, Slide 40

Dr. Collins said that the Bay does not have a science enterprise yet, but one is possible. It's also possible to create an enterprise for the Delta. There is a danger that two separate enterprises might be created, with inadequate coordination between them. "Why does it matter?" asked Dr. Collins. "Obviously there are some large estuarine processes and functions that cross the boundary between the Bay and Delta. Estuarine transgression doesn't care where that boundary is. Fresh water supply doesn't care, nutrient loadings don't care, sediment transport doesn't care, anadromous fishes don't care, maritime shipping doesn't necessarily care. As scientists we're aware of this, and we're trying to understand the processes linking the bay and delta together, to explain the tonal nature of their transitions into each other, and better define their shared boundary or dissolve it."

Dr. Collins said bay scientific community enjoys many partnerships, including the private sector. "Increasingly, we're reaching out to the major businesses and industries that are at risk because of these environmental problems, especially sea level rise, and we're saying, 'This is your issue, too.' We don't want Silicon Valley to move to Utah just because it can. Why are those CEOs here? Because of the aesthetic and environmental amenities. We garner their support; we have to protect the Bay as the aesthetic centerpiece of the region. We have to consider the emotional impetus for protecting the bay. Or we risk losing the progressive economic engines that help define the region. So, anti-up Google and anti-up wine country. You have a stake in the ecological health of the region, too."

The Bay science community enjoys numerous internal partnerships and collaborations. Academia is a vital part of that community. Stanford, Cal, UC Davis, UC Santa Cruz, multiple State Colleges and some community colleges are increasingly involved regional and local environmental science issues. But the Bay doesn't have a bona fide science enterprise, it doesn't have an established a science forum. It doesn't have something like the Delta Science Program. The Bay has a number of enterprising groups, mostly centered on sea level rise, and they are starting to work together, and it's really very important that an enterprise of science grows from these beginnings with a clear purpose that is either consistent or complimentary to that of the delta," he said.

On the water quality side, it is clear that there is a need to integrate across management actions. “Water quality is the result of many things going on individually, and subject to varying levels of control. Point sources and non-point sources are large and complex categories of water pollution subject to varying controls that are inadequately coordinated. The focus on receiving waters almost always leads to upstream explorations that reveal multiple sources that must ultimately be addressed through politically challenging changes in land use,” Dr. Collins said. “With regard to habitat, we occasionally do ambient surveys of threatened and endangered species, just not very often and not always very well. The data tend to be variable and for most species we lack long enough or consistent time series to accurately depict trends. For most species, we lack understanding of thresholds for habitat distribution, abundance, patch size, and inter-patch distance. The majority of the endangered species in the region depend on wetlands. We need a wetland RMP that fills in the gaps in our understanding about the population status and trends in these species. Since many of them will be tracking spatial shifts in habitat due to sea level rise and upstream salt water intrusion, the wetland RMP should extend between the Bay and the Delta.”

“In terms of sea level rise, we need to map and evaluate the “T zone,” and we need to get that started in the Delta,” Dr. Collins said. “All the fundamental work by NASA and NOAA that enables us to identify the T zone hasn't been done in the Delta yet. We cannot rectify tidal datums with geodetic datums in the Delta. We can't run the tides over the land with sufficient accuracy to inform local sea level rise planning and response. That needs to be fixed.”

With regard to sediment supply and tidal marsh restoration, the Bay science community has begun studying ways to augment natural sedimentation with various applications of dredged sediment. But, there also needs to be a comprehensive survey of all sources of sediment and a plan to efficiently exploit them. “Sediment is becoming a valuable commodity,” Dr. Collins said.

Overall, the Bay community of environmental scientists is moving into the social-ecological framework for integrating the natural and social sciences at large spatial scales. Public polling is becoming a more common tool to understand priorities, and there are growing efforts to involve disadvantaged communities in environmental plans. There is always a need to get more people directly involved in the plans that will affect their lives. Sea level rise provides a large opportunity to shorten the distance between environmental science, policies, and the people they affect. Consistent research and ambient monitoring is needed between the Gulf and the Delta for key concerns, such as wildlife conservation and water quality, with ample communication of resulting information to the public,” he said.

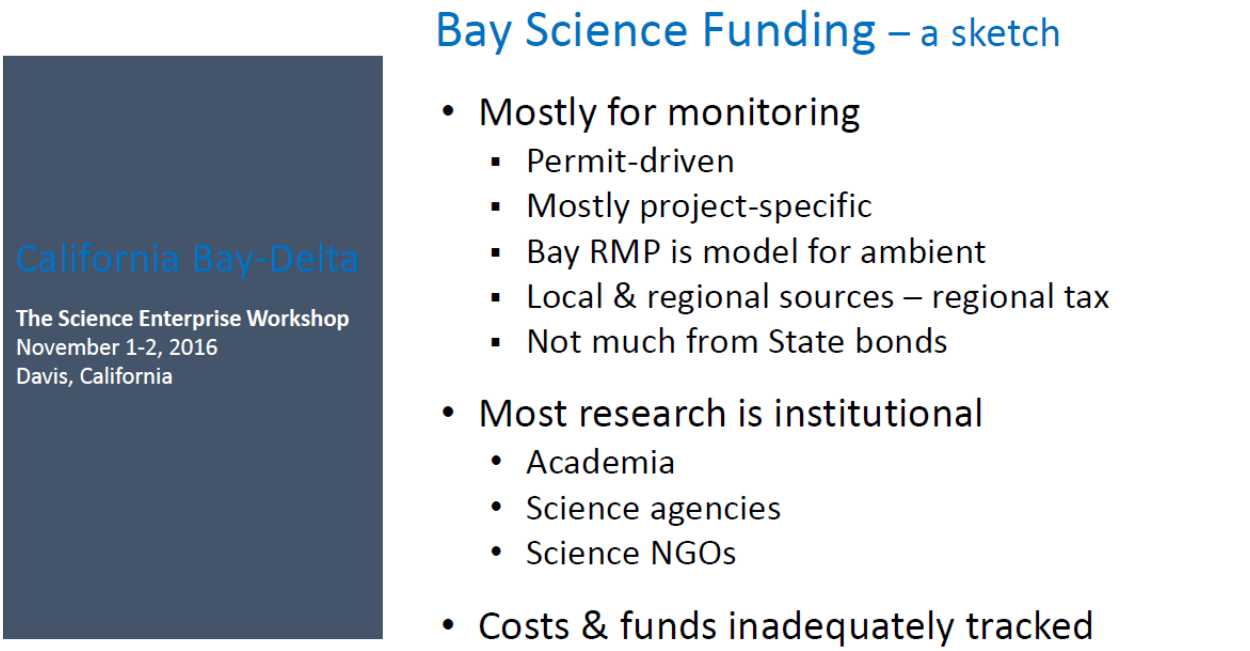


Figure 81, Slide 44

Funding for monitoring and related applied research is mostly driven by regulatory permits and is therefore project-based. Even the existing Bay RMP for water quality is permit-based. Funding for basic research comes through its own avenues, such as various programs of the National Science Foundation, US EPA, DOI, and in some cases state grants programs. Academic institutions have access to funds that are not available to regional monitoring programs except through partnerships with academicians. The basic research of our major academic institutions can inform monitoring programs in many ways, from the collection and analyses of data to their interpretation and visualization. "We can do a better job of aligning basic research with applied research," Dr. Collins said.

Dr. Collins concluded by noting that the Bay-Delta community already has some great ways of communicating environmental science to the public. There are regular conferences and reports for individual programs, the San Francisco Estuary Magazine[117], the Pulse of the Bay[118], Bay Nature[119], lots of symposia and synthesis, and new online data aggregation delivery systems are forthcoming.

Outcomes from 2013 Puget Sound Workshop on Role of Science in Ecosystem Recovery

Presenter:

Dr. Joel Baker, Port of Tacoma Chair in Environmental Science, University of Washington Tacoma, Science Director of the Center for Urban Waters in Tacoma

Dr. Joel Baker discussed the outcomes from the 2013 Puget Sound Science Enterprise Workshop on the role of science in ecosystem recovery, but before he started his presentation, he threw out a couple of thoughts and ideas about ecosystem restoration programs.

[117] San Francisco Estuary Magazine. San Francisco Estuary Partnership. http://www.sfestuary.org/estuary-news/
[118] The Pulse of the Bay. San Francisco Estuary Institute. http://www.sfei.org/programs/pulse-bay#sthash.tBUl4rUT.dpbs
[119] Bay Nature Magazine. The Bay Nature Institute. https://baynature.org/product-category/issues/

"The first question I would put to you is recognizing there's this dynamic tension between those who think we know what the problems are and what the solutions are and it's just a matter of effort - so do we really know what it takes and we're just not doing enough of it? That's one camp," said Dr. Baker. "The other camp is, we have no idea how to fix the problem, so we need to do the research, we need to do adaptive management, and we need to figure this out. At least in Puget Sound and the other systems I've worked in, there's always that tension. There's oftentimes, 'We don't need to study this. We just need to fix it,' versus the, 'We don't quite know which of these problems is most important.' That's something to think about."

"The other question I would throw out is, are we really trying to fix ecosystems or are we trying to fix institutions and people because the ecosystem could be degraded?" continued Dr. Baker. "I've been fortunate in my career to work in three of these large ecosystems. I started in the Great Lakes quite a while ago when Lake Erie had a phosphorus problem; now, apparently Lake Erie has a phosphorus problem. Not much has changed there. Then I spent 20 years working in the Chesapeake Bay system, so I was glad to see that we've recovered the striped bass in the Chesapeake. For the last seven or eight years, I've been working in the Puget Sound system, so I have a big of perspective on how these ecosystems work."

A few years ago when they were working through planning with the Puget Sound Partnership, they brought together the science directors of large aquatic ecosystems for a workshop. Dr. Baker said that although the ecosystems are radically different, the similarities and approaches are remarkably the same. "There's a lot of commonality among the people in this room, and I think it's fantastic that organizations get people from different ecosystems together to talk about this, because there's certainly more that binds us together than separates us," said Dr. Baker.

Seven years ago, the University of Washington Puget Sound Institute[120] was created from a cooperative agreement with the EPA. This came about because Dr. Baker recognized that in the 25+ years he has been working in large ecosystems, he recognized that the interface between science and policy doesn't just happen organically. "You have to have a very deliberate structure to make sure that this kind of interaction happens," he said.

The core mission of the Puget Sound Institute is to support targeted research, to address the uncertainties, but more importantly, to synthesize and integrate research findings into policy-relevant guidance. "I think most ecosystems probably have far more science laying around in reports, databases, theses, dissertations and in published papers that hasn't been pulled together than you'd care to admit, so we spend a lot of time not doing new research, but just digging up old reports and trying to make some sense of them," he said. "Then we spend a lot of time in communication."

The goals of the workshop were to cross calibrate among large aquatic ecosystem science programs; to discover and discuss what's working and what's not across systems with an eye towards best practices; to explore how much science is needed to adequately support ecosystem restoration and protection, and to build a peer network of large aquatic ecosystem program science leaders. "We were largely trying to not make the same stupid mistakes that each ecosystem was going around and around," Dr. Baker said.

[120] Puget Sound Institute. University of Washington. http://www.pugetsoundinstitute.org/

Dr. Baker acknowledged that they 'dropped the ball' on building a peer network. "I think it would be fantastic if we established a peer network of the scientists and the science program leaders in the large ecosystems that get together every year or so, have a beer, kabbitz about what's going on, and have these kinds of conversations," he said. "Some sort of enduring structure would be nice coming out of this."

The topics in the workshop were very similar to the topics here at the Science Enterprise Workshop: How do we set the priorities in the face of uncertainty? How do we use adaptive management or how do we make management adaptive? What's the most effective institutional structure for recovery? How should social sciences advance recovery? How do we effectively communicate science to decision makers? The workshop participants were other systems that were part of EPA's Large Aquatic Ecosystem Program[121]: The Chesapeake Bay Program, The Great Lakes, The Gulf of Mexico Program, The Long Island Sound Study, The South Florida Geographic Initiative, The Lake Champlain Basin Program, The Puget Sound – Georgia Basin, The Columbia River Basin, The San Francisco Bay Delta Estuary, and The Pacific Islands Program Office.

Dr. Baker than discussed his interpretation of the findings from the workshop.

Target setting is common to all systems, but the number of targets varies widely. There are two extremes: A few (or one) 'influential' targets, or a portfolio of diverse targets.

All systems have goals, targets, and benchmarks, although they might be called different things, said Dr. Baker. "There's always this sense of, 'We need to find a few things and work towards them,'" he said. "One of the interesting things that came out is this dichotomy or different strategies. Do you have one or two goals and really laser focus in on that? When I was working in the Chesapeake, it was just nitrogen, nitrogen, nitrogen. If you could fix the nitrogen problem, everything else would just take care of itself."

On the Louisiana coast, they went through the exercise of generating a lot of different goals. "I think they had a fairly nice handful of goals, and it became difficult to communicate," Dr. Baker said. "It seemed pretty complicated. We need to prioritize our goals. Finally, through some modeling work, they were able to show, if we recover land or at best, keep the land from eroding away, a lot of this other stuff is going to come along for that ride. In terms of communicating, let's just talk about, let's not lose land or let's solve the erosion problem and that covers a lot of other things."

Dr. Baker said noted that there are advantages of having a narrow set of targets, but the downside is that you can give the perception that you are leaving some people behind; some people may not want to participate because their issue isn't included in the selected targets.

The flip side is to have a diverse portfolio of targets, such as they do in the Puget Sound where they have identified 25 Vital Signs[122] that cover water quality, habitat, species and food web, as well as human

[121] https://nepis.epa.gov/Exe/ZyNET.exe/P100658J.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=Dpercent3Apercent5Czyfilespercent5CIndexpercent20Datapercent5C06thru10percent5CTxtpercent5C00000013percent5CP100658J.txt&User=ANONYMOUS&Password=anonymous&SortMethod=hpercent7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Resultspercent20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

[122] Puget Sound. Vital Signs. http://www.psp.wa.gov/vitalsigns/

well-being and quality of life. There is a downside to that, Dr. Baker said. “Then the policy makers come look at it and say, ‘Which one of these should we work on?’ You say, ‘Well kind of all of them.’ They don't like that answer,” he said. “We spent a fair bit of time talking about target setting, and I was impressed looking across the ecosystems, how variable the result was to the approach of target setting.”

Models are indispensable recovery tools, but the extent of development and degree of utility and acceptance varies widely across systems.

Another common theme that came out was that models, broadly defined, are really indispensable recovery tools. “If you have the models, it provides you with a way to contextualize the information that you're gathering, identify data gaps, and all the things that you know about,” said Dr. Baker. “It’s a great way to communicate causal relationships between stressors and responses.”

One of the advantages of modeling that came out of the workshop came from the program manager of the Chesapeake program. “He made the point that models for him as a program manager were really valuable as a programmatic tool,” he said. “It allowed him to evaluate and communicate when new science information would be needed and when it would be ingested by this big machine. You could say, ‘I have a graduate student that really wants to work in this one process.’ He could say, ‘Well, we ran the model, and that process might be interesting to you, but it doesn't look like it has much impact, so we can down-weight that.’ Or, ‘Wow. Our model is real sensitive of that, so it's an important piece to get to.’”

“Updating the model in the Chesapeake, they said, also helped them programmatically think about staging different science aspects. They might say that this year, they were going to work on fixing hydrology; and next year, it will be the food web. “So you've kind of keyed up when different parts of the program could then spin up,” said Dr. Baker.

Adaptive management is widely accepted in principle, commonly used in specific restoration projects, but rarely (never) effective at the ecosystem scale and perceived as slow and expensive.

Adaptive management is commonly used at the project scale, but it hasn’t happened at the ecosystem scale, or the big-scale projects. “We like to draw this circulative diagram where we act and monitor and all that kind of stuff,” Dr. Baker said. “It's a good description of what you would like to do, but no one has really ever actually done one, so I'll leave that as a challenge to you for your discussion.”

Large potential for social sciences, but it has been neglected to date. Social sciences are not a silver bullet, but can offer critical, valuable insight. In addition, social sciences are at least as diverse as natural sciences, and should be involved early on in the science enterprise development. Building the “human capital” or functional relationships between natural and social scientists takes time and investment.

Social science has been neglected to date. “I was fortunate in the Puget Sound program,” Dr. Baker said. “I had an excellent social scientist walk into my office one day and say, "Can I work for you? I have National Science Foundation (NSF) funding. I'm completely supporting. Can I work for you? I'm a social scientist." My answer was, ‘Yes.’ She's now on faculty at Oregon State. She brought to us this really rich understanding of what social sciences can do for you as an ecosystem restoration program.”

Social sciences can help you market and change hearts and minds, Dr. Baker said. “Once the natural sciences figure out how to fix the problem, the social scientist can help you convince people that the natural sciences have figured out the problem; that's one way to view social sciences in restoration,” said Dr. Baker, noting that it’s not the best way to think of social scientists and you can really tick them off if you do that.

First of all, social scientists are not a monolithic group of people any more than natural scientists are a monolithic group of people, Dr. Baker said. “When we say social sciences, it's everything from sociology, political science, economics - it's a very broad swath of stuff, so a lot of diversity there to think about,” he said. “Social sciences are not outreach. Another way to tick them off is to say, "Oh, you run an outreach program. You're a social scientist.’”

“What do social scientists really do? Social scientists study us. They study institutions. They study how people work together as organizations, as individuals,” Dr. Baker said. “All of the organizational charts that were shown today, those would drive institutional analysis folks nuts… Institutional analysis and social scientists can look at how your organization is built and tell you whether it's optimal to what you're trying to do. We hardly ever do this in restoration forums, so something for you to think about that came out of our workshop. I was thinking social scientists were going to help us market our great ideas. They're actually much smarter than that and you should involve the social scientists early on in the process.”

Effectively communicating science to policy and decision makers often results from trusted science ‘champions’ engaged with influential elected.

Broadly, enterprises must balance between conducting further research to address uncertainty, or taking action. Within the policy realm, enterprises must clearly communicate to politicians how there is enough information to move forward, how uncertainties will be addressed, and acknowledge the slow pace of ecosystem response.

“One of the things that came out of our workshop and is often we ask the question, ‘When does this really work well? When do you feel like there's a great communication path between the science community and the elected officials or politicians?” said Dr. Baker. “It's almost always because of individual people. Either a scientist or two that are super good communicators, or a legislator who's either trained as a scientist or not turned off by science to begin with and is willing to make that connection, so it's really a person-to-person, or small group-to-small group interaction where it works well. It’s hard to build that into your system, but you should recognize it and encourage it when it happens.”

Dr. Baker said that they spent a lot of time discussing managing the expectations. “This problem of, how do you communicate uncertainty - the science community needs to be able to say to the policy makers, ‘You have enough information to act on, but we need to learn from it. We're going to do an experiment,’” he said. “Never say to a politician you're going to be doing an experiment with their money. We know exactly what we're doing. Learning while doing is a tough concept for politicians to deal with.”

Then there is the issue of the pace of ecosystem response. “We have to be able to communicate that we want you to do a heavy-lift politically and make it an action,” Dr. Baker said. “It's going to take a decade to see a change in the environment. This is another tough message for communicating policy.”

Final thoughts …

"The different systems have different origins, structures, histories, cultures, but despite that, the commonalities among the restoration programs far exceed these differences, so we should really embrace that and take advantage of it," said Dr. Baker. "In fact, almost a demand. We're not going to get this right unless we really, seriously engage social sciences in a smart way, so hopefully when we have this meeting a few years from now, when we raise hands, half the people in this room will be social scientists."

Dr. Baker acknowledged that it's not necessarily easy. "You need to walk into the social science departments and start talking them about this stuff, and it turns out, they're not that good at it, either," he said. "It's a long slog to build social sciences who are smart about participating in ecosystem restoration projects, so that's a bit of an infrastructure, human capital thing to work on."

"The final thing I'll leave you with is to think about the programs that are successful, they have long-term continuity in people, programs, and approaches at the ecosystem scale that are really important to the success of programs," he said. "Earlier we saw photographs of people who have been working in Louisiana for decades. That is such a valuable resource. We need to find ways to encourage that. They are usually underappreciated and therefore under-resourced. Keeping monitoring in programs - playing the long game here is really a challenge."

Question and Answer

Question: How did you use the information you got from this workshop going forward with the Puget Sound program?

Dr. Baker: It helped us inform how we were structuring some of the programs that were evolving within the Puget Sound Partnership. Since the agency was growing up at the same time, we were able, based on what came out of the workshop, to encourage the creation of the social science work group, so it's hardwired within the Puget Sound Partnership as a thing. We got them in the tent, but the social scientists are all down there in their own little work group and they meet and talk about their stuff, so we're not quite there yet. That's one example of it. I would say that we didn't make a lot of progress on figuring out how big your program should be or what the best organization structure is, which is what you're wrestling with here. We had a good conversation, but I can't say that it really actually changed our program, because it was pretty much already started.

Question: I was surprised that there was no mention of these social ecological systems as being complex. When do we start talking about these things as being complex systems as opposed to complicated systems? This still looks like we're trying to model and study our way out of the problem.

Dr. Baker: That's a really good point, because we do confuse complicated with complex. Part of that is communication, because I think that policy makers understand complexity, because they deal with things that are far more complex than ecosystems. There's this tension between needing to boil it down to something fairly simple, versus embracing the complexity that it is... The best way I've seen this handled are where you capture all of the fine detail and you really do get down in the weeds and you build super-complex models that cover everything, but you got to do that to get it right. Then you build a front end that looks really simple for the policy makers. I'm not quite sure I'm ready to go to coloring the lakes red, green, and yellow. I don't know if I'm there yet.

Dr. Baker (continued): "The front-end of the model can have a very simple output. That doesn't mean you have a simple model or a simple description of the system, but it does mean that you vary that complexity so you don't turn off the people you're trying to talk to, but I think we all know that the complexity of the system is what makes the system what it is. I'm afraid we have too much of an engineering approach of deconstructing everything down to individual pieces and figuring those out, and then hoping we can put it back together again, which has failed. It failed medical science. It'll fail ecosystems sciences as well."

Panel on Regional Programs

Panelists:

Dr. Nick Aumen, USGS Regional Science Advisor, Southeast Region (Florida Everglades)
Dr. Josh Collins, Chief Scientist, San Francisco Estuary Institute (Bay Delta)
Jon Hortness, USGS Coordinator for Great Lakes Restoration Initiative (Great Lakes)
Dr. Bill Labiosa, USGS Regional Science Coordinator, Northwest Region (Puget Sound)
Scott Phillips, USGS, Chesapeake Bay Coordinator (Chesapeake Bay)
Dr. Scott Redman, Program Manager, Puget Sound Action Team Partnership (Puget Sound)
Dr. Denise Reed, Chief Scientist, Water Institute of the Gulf (Coastal Louisiana)
Dr. Ted Sommer, California Department Water Resources Lead Scientist
Dr. Tracy Collier, moderator

Question: Do you think your science enterprise is meeting the needs of the management and policy community from their point of view - not your point of view.

Scott Phillips (Chesapeake Bay) answered no, but they are trying.

Dr. Ted Sommer (Bay-Delta): "Part of the issue is a lot of the information they get from us is fairly negative gloom and doom stuff. One of the reasons they know who we are is that we create problems for them. Some of us are doing our best to try and change that and communicating more in the way of solutions. We have some ways to go in this."

Dr. Bill Labiosa (Puget Sound) also had a mixed answer. "There are certain aspects of ecosystem recovery where I think we are doing a pretty good job of meeting needs but as soon as you go up a level, is there a science enterprise meeting the needs of Puget Sound recovery? I would have to answer, what science enterprise? We really aren't working at the integrated regional science enterprise-level at this point." We haven't really progressed much beyond our individual agency missions and needs in terms of science and monitoring.

Dr. Scott Redman (Puget Sound) had two answers. "The first one is, no, we don't satisfy the managers and the policy makers interests because we hear the question, for instance, how much should we do, where and when?" he said. "This is a complex system so the science community is not feeling obliged to answer the question that way so there's a disconnect. Then I would say, yes, we're meeting their expectations is because they're more convinced that we know what needs to be done than the science community is. They're not so worried about working in the face of uncertainty."

John Hortness (Great Lakes): "From the Great Lakes perspective I think I would agree. Especially under the Great Lakes Restoration Initiative (GLRI) [123], I think a lot of them think they know what needs to be

[123] Great Lakes Restoration Initiative. https://www.glri.us/index.html

done and don't need the science. What we've had to evolve over time is to get the managers to understand that they don't have the entire story and that they do need to bring in the science to help them inform as they move forward and adaptively manage. Part of it is I don't think they've asked the right questions, or are willing to ask the right questions. I think we're getting there over time."

Dr. Nick Aumen said it depends on the topic. When litigation required establishment of a phosphorous water quality standard, the science was funded by the federal and state governments and the sugar industry - about $70 million spent over seven years to do the background science to establish the phosphorous standard. "With other issues that are pressing right now, I'd say no," he said. "For example, invasive species. We can't tell you what to do with Burmese pythons. I'm not sure we'll ever be able to. No on climate change. We're not there yet on the science, in terms of certain things."

Dr. Aumen said that another successful effort was with the endangered cape sable seaside sparrow. They developed a Data Viewer[124] for their Everglades depth estimation network that the Fish and Wildlife Service could use. "We took six months to do it; we dropped everything and worked on that and they love it. It really helped to shape what came out of a recent jeopardy opinion."

Dr. Denise Reed said it depends on whether or not they think they are achieving success, which is defined as getting projects on the ground and making a difference in the landscape. She acknowledged that Louisiana doesn't always have the best reputation for spending money wisely. "A lot of the money that I showed on the slide this morning, while it's available - the check's not written yet. A lot of the entities that are the trustees of the Natural Resource Damage Assessment (NRDA)[125] money, they are going to be looking for project proposals that are founded on science. They are going to be even more sensitive to the potential for politically based decision making as opposed to scientifically based decision making, just because it's Louisiana."

Dr. Reed noted that it's a definite yes for the 2012 Coastal Master Plan, but this may not be so for the 2017 Coastal Master Plan.[126] "We put climate change in it in a big way. That red map [showing the effects of sea level rise on coast] is not going to be very easy for them to deal with," she said.

The next hurdle is when these big projects go into permitting, as the NOAA and other agencies will be looking at the scientific basis for what's being proposed. "I think at that point they're going to recognize the value added that we've provided, but that's yet to be proven," she said.

Question (Dr. Peter Goodwin): In that last round, several of you mentioned the uncertainty in these systems. We're always going to have that uncertainty. From your perspective as leading scientists, what can you put in place to support agency directors, the people making the decisions, to give them some of the backing to help them make these very, very difficult decisions in the face of uncertainty?

Dr. Nick Aumen said this has been an ongoing discussion with their lead policy person. "Her view on that is the way scientists look at uncertainty is very different from the way managers look at uncertainty. She said, 'most of that stuff you say is uncertain, but there's plenty of information from which I can make decisions on.' "The dialogue has to happen in the way we couch uncertainty. We're going to do that with the management community on our work on climate change and modeling precipitation. We're never

[124] EverVIEW Data Viewer. Joint Ecosystem Modeling. https://www.jem.gov/modeling
[125] Natural Resource Damage Assessment (NRDA). http://eli-ocean.org/gulf/nrda/
[126] 2017 Coastal Master Plan. Coastal Protection and Restoration Authority (CPRA). http://coastal.la.gov/2017-coastal-master-plan/

going to be 100 percent certain on forecasting. We're finding common language that we can use that makes sense to managers and that scientists can live with that will communicate that better."

Dr. Collier turns next to Scott, and notes, "I think you were saying from your perspective managers can handle more uncertainty than we think they can."

Dr. Scott Redman (Puget Sound): "Well I think they seem to be. They don't share the same understanding of the uncertainties, or maybe they're just comfortable with that level of uncertainty. The other thing I thought of in hearing the question was having project proponents and reviewers talk about the likelihood of success. Then rolling that up to what's the likelihood of success of the entire plan, the portfolio of action. I think there's some room there that we could try to bring in some kinds of uncertainty."

Scott Phillips (Chesapeake Bay) said they try to present the information in terms of strengths and weaknesses so they can get an idea of how those might affect a particular option. "That helps them, perhaps, narrow down what they feel more comfortable with; we try to say it in that context."

Dr. Denise Reed (Louisiana Coast) said the best way they communicate that is through fairly simple scenario analysis. "The general approach is 'hope for the best, but plan for the worst' kind of thing. The key message is that we really try not to say that there are any guarantees. I think it's really about how we communicate our findings and what the results are." Dr. Reed said that often in a public meeting, people on the other side are expecting guarantees. "Our job is to educate the managers that that's infeasible from both sides."

Dr. Ted Sommer (Bay-Delta) said that it helps to have a moderately broad group of people weigh in on the issue. "It's less effective when one of us goes to one of our managers or directors and says something, whereas with the Interagency Ecological Program, it makes a difference when you have nine agency groups all saying, 'Yeah, there's uncertainty but this is what looks like it's worth doing.'"

Jon Hortness (Great Lakes) agreed that having broad group coming together with the same agenda helps. He also said they sometimes take a portfolio approach if there are several potential projects that could address a specific issue. "Some may be real high risk but high reward; others may be relatively low risk, so maybe you don't get quite as much bang for the buck, but you have a pretty good confidence level that it will succeed. We look at it from that portfolio view of several different levels of uncertainty."

Dr. Denise Reed (Louisiana Coast) recalled that in the work she has done in the Bay-Delta, there were situations where the discourse was tense over decisions where the foundation for the decision was a statistical analysis, such as OMR flows and turbidity habitat for smelt. "There's a very complex, statistical analysis that's foundational for the decision. Inherent in our understanding of statistics is that you can quantify the uncertainty around that. I do think that in several circumstances we get ourselves in trouble by kind of relying on the line and not the scatter around it. We have to be careful about that. I wonder if any others have kind of major decision points within their programs that rely on specific statistical analysis that are then subject to endless scrutiny. I think it's perhaps not the way to go to begin with."

Dr. Josh Collins (Bay-Delta) said he has had the experience where an interdisciplinary group of scientists having a coherent perspective addressed people with the authority to make real decisions. "We're

asking them to make trade-offs. Their decision was not based so much upon statistics, but it was based upon their willingness and ability to manage the uncertainty in front of them within their budgets and get to the next step. They were willing to make a step forward without a forever commitment, but to try something a little further together. It was really decisions based upon a common professional agreement more than anything legal or very binding… It's having the numbers but not relying on them so much because they don't translate one to another. The rectification from one unit of measure to another seems to be something that's borderline emotional."

Dr. Bill Labiosa (Puget Sound) said they are often asked questions framed from the engineering perspective, but there are certain aspects of the system where it is definitively not an engineering problem. "Complex adaptive systems are inherently unpredictable. It's not, do I have uncertainty in my prediction; it's that complex adaptive systems just cannot be predicted over the time frames of adaptation. My point being that we have to figure out how to talk about uncertainty in a useful way in these contexts. We still have a State of the Sound report that tells the legislature how ecosystem recovery is progressing in the context of the paradigm that they hold - the engineering paradigm… I would argue we have to figure out how to answer back within the complex adaptive systems paradigm in a useful and clear way. Uncertainty has multiple interpretations in the complex systems paradigm."

Question: What science tools would be really useful for your system, and how would those be useful across other systems?

Dr. Nick Aumen (Everglades) said they have an effort called Joint Ecosystem Modeling[127] that's an attempt to take some of these complex ecological models, bring them down to the level of a desktop viewer than anybody in any agency or entity can use to solve complex problems. The cape sable seaside sparrow viewer they developed took the needs of the Fish and Wildlife Service and put that into a desktop application. "It draws on very complex background information but makes it so it's very usable. I think there's some approaches like that that can be used as examples across some of these programs."

Scott Phillips (Chesapeake Bay) noted that a lot of the models that are developed don't do a good job of transferring this information across different ecosystems. "If we had a more collective approach saying we need ecological models to look at species groups A and B, and develop that as a consortium that we can apply that model in any of these coastal systems, we'd be so much further along. That's what I see as a big limitation. Whether it's a model or a web service or a web viewer, there's too much individual effort in a particular system and not enough collective approach on this."

Scott Redman (Puget Sound) said that some of the models from the Chesapeake sound very similar to some of theirs and he thinks he could learn from them. "I was inspired by hearing about their goal teams and how those are interdisciplinary, where the scientists and the people making management decisions are working together. We implement that sort of thing. We tend to do it on a more ad hoc than standing committee basis… The other is synthesis. We've tried things like that; we have taken a 700-page document and brought it all the way up to a two-page management implications document but we haven't, even in our own system, replicated that through time and through all the topics."

Dr. Denise Reed (Louisiana) said that she uses the EverView[128] system which was developed in the Everglades and is an example of something that could be more widely used. She also said that

[127] Joint Ecosystem Modeling. https://www.jem.gov/
[128] EverVIEW Data Viewer. Joint Ecosystem Modeling. https://www.jem.gov/modeling

conceptual models could also be of great utility if they could come together and have a common way of approaching them. Dr. Reed also noted that there's a lot of good work on synthesis and report cards across different systems. "It happens more through professional networking than it does through organized dialogue amongst enterprises."

Dr. Collier noted that in his experience in systems where there are many stressors, science synthesis is important for distilling the issues down to something that people can understand. "My view is we don't have many systematic ways to do that across systems. We haven't come up with a way. I think each of these systems, the more stressors that they've got to deal with, they've got to have a better way of achieving the synthesis."

Dr. Nick Aumen said that the Everglades is a multifaceted system with a lot of stressors. They developed conceptual ecological models for all of the systems. They also started out with 960 indicators and were able to pare that down to 14. He acknowledged it was a lot of work. "In the end, we used the phrase, 'get the water right." That has four elements: quality, quantity, timing, and distribution. When folks go to Congress to sell that, that's an easy message, even though underneath it is a tremendous complexity of things. If you have a theme you can focus on that's very understandable and you can put it down in that and convey that consistently and effectively, it really pays off."

Dr. Ted Sommer (Bay-Delta) pointed to the need to develop a nexus to the social sciences. He noted that it is relatively easy for the water supply folks to quantify the effects of a loss of water supply or for flood control folks to quantify the effects of a food. "What we don't do a good job is quantifying the value of a lot of the other resource issues that we deal with; therefore, we don't have a way to have a dialogue about trade-offs; we don't have a way to quantify what the costs of inaction are. It's easy to look at habitat restoration and see this is going to cost a billion dollars. What we don't quantify is what the cost of inaction is."

Question: In your experiences, have any of you utilized any structured decision making efforts in your particular systems?

Dr. Bill Labiosa (Puget Sound) said they have tried to use Structured Decision Making (SDM).[129] It's a resource-intensive process if the program routinely uses it, and there are many contexts in which it could be applied. They have ended up using it, but in an incomplete way. "One is a prioritization of our recovery plan at a fairly course scale. We used a combination of expert elicitations but within a prioritization framework that frames the question as a decision. The problem that we ran into is when you approach the decision makers about expressing preferences across programs and major issues, they don't want to do that; they wanted the science panel to take a first crack at expressing their preferences for them. That was a tough hurdle to get over so we decided to split the problem into a number of cases so that we didn't have to impose our own values into the prioritization exercise. This generated more than one set of prioritized actions, grouped by major issues. Multiple lists of priorities are still useful but we can't compare across them without some expression of importance from the decision makers.

"Another example is a pressures assessment we did for Puget Sound recovery where we tackled the uncertainty using techniques from the decision analysis literature; we treated uncertain variables using Bayesian probability theory[130] and used expert elicitation to create an analysis that could be updated as

[129] Structured Decision Making Fact Sheet. 2008. U.S. Fish and Wildlife Service. https://www.fws.gov/science/doc/structured_decision_making_factsheet.pdf

[130] Bayesian probability theory. Bruno A. Olshausen. March 1, 2004. http://redwood.berkeley.edu/bruno/npb163/bayes.pdf

more information comes in; it could also be plugged into a decision analysis later to allow us to prioritize between the stressors. It's a tool that's there for the using but… we can't get the decision makers, necessarily, to express preferences in the way that we need to take it to the next level," continued Dr. Labiosa. "Perhaps part of the problem is the way we're approaching it. I think we need to approach the decision-makers differently, frame the problem in a more useful way. Maybe a decision analyst shouldn't be running the process. Keep that guy in the other room while emissaries get the needed information in a more palatable way."

Dr. Josh Collins (Bay-Delta) noted that he's experienced problems when developing a structured system for a particular permit, such as the USACE 404 permit and a system for evaluating potential compensatory mitigation sites in the watershed context. "It sounds good, but once you do that, you'll find out that they've locked down and run the seven metrics they chose the first time and they won't consider any more," he said. "Once you meet the requirements that the manager wants, they want to use the same system over and over and over again, even if they move it 1,000 miles. Managing uncertainty is keeping the uncertainty in front of people. Having group decision around data and enabling them to make another decision to move forward but not the final decision. Just keep advancing the debate. I've come to the conclusion that these structured decision support tools are about advancing public debate more than actually solving something, just keeping it going," continued Dr. Collins. "The big question is what's the biggest step you can take and what data do you need to take that step and get to the next one?"

Dr. Nick Aumen (Everglades) then had two examples to share. The first was when the Loxahatchee National Wildlife Refuge was very concerned about Burmese python. The python hadn't arrived yet, and the manager of the refuge wanted to know how much resources should he invest in keeping the python out of the refuge? So they convened a structured decision making process with experts over the course of four days, and in the end, the decision was that it wasn't worth the investment; the population model showed it's going to be there no matter what. "The manager was saddened by the news, but also very appreciative of and felt like a well justified decision that that's not where the priority money should be spent right now for their resources. I thought that was a very good application."

However, they convened a similar process for another invasive species, again a four-day structured decision making workshop with senior managers from state and federal governments. "I won't tell you all the outcomes of it but the downside of that exercise was that the managers said, 'Don't ever invite me to one of these again.' They said, "Not that we didn't appreciate the process and the deliberation, but we could have arrived at that decision in half a day rather than four days.' Whatever we end up doing, the managers' view of that is it's a useful process but it's got to be applied very carefully. Don't do it across the board, do it on really important tough problems."

Scott Redman (Puget Sound) said they were inspired by watershed scale work that had been done in the Willamette Valley in Oregon, so they tried using their version of structured decision making to the sub-Puget Sound efforts called Local Integrating Organizations (LIOS)[131]. With the help of a social scientist, they designed a process and guidance for how these groups could go through a structured decision making process in building their local ecosystem recovery plan. Very few were willing to pilot, but they did find some that did. "We were overlaying structured decision making over these frameworks of open standards for the practice of conservation and integrated ecosystem assessment. It worked pretty well."

[131] Local Integrating Organizations (LIOS). Puget Sound Partnership. http://www.psp.wa.gov/LIO-overview.php

Scott Phillips (Chesapeake Bay) said they brought in consultants who were well-versed in structured decision making, and they found that it might be useful for individual topics where there is a clear decision maker such as water quality and EPA. However, they found that with a lot of outcomes, there isn't a clear decision maker because so much is done by consensus. "They said, 'I can come up with some options for you, but since you need so much consensus between federal and state agencies I don't know if you're ever going to work it out.' That was a limitation we saw."

Question: All of your systems have something to do with the federal government. For Florida you mentioned one of the big advantages you had there was a FACA exemption. What are two ideas for things that would make management of your system, or the science of your system, much easier in terms of changes in federal policy or administration?

Dr. Nick Aumen (Everglades) noted that Florida government is subject to the Sunshine Law, which prevents the deals being cut in the smoke-filled back rooms, but at the same time, it creates hurdles to communication between science and policy makers. His colleague Jayantha Obeysekera has a governing board of nine people, he can't brief the board members at the same time. He has to do nine separate briefings, because if two or more of them are in the same room at the same time it has to be a publicly noticed meeting and an agenda published; it's a real challenge.

However, pooling budgets is goal of his. Where there are common purposes and goals, especially in the area of declining budgets or at least flat funding, if they could agree to pool budgets and govern science that way, they could make more progress. "We're not there yet in the Everglades. I'm not sure if other places are able to do this yet. It doesn't have to be your whole budget for science but get each entity to dedicate a small portion, or some significant portion, and have that governed by an inter-agency group where you're really building on the strengths and capabilities of those individual people."

Jon Hortness (Great Lakes) said that the efforts on Asian carp are coordinated at a regional level; the agencies bring their resources and their funding to the table and they determine at that time how they will address that.

Scott Phillips noted that after the Chesapeake Bay Executive Order 13508[132], they worked hard to come with a strategy and a role of each of the federal agencies; they then identified where the gaps were. They went to the Office of Management and Budget (OMB) to describe those gaps and the need for a pooled budget concept. Unfortunately, the OMB could not figure out how to work with a pooled budget. "They just said, 'We'll do a piece in this department, a piece in that department.' It defeated the whole purpose of trying to come up with a pooled budget and be able to collectively say how we could use that money."

Dr. Denise Reed (Louisiana) acknowledged the problems that can be encountered when working with the federal government, particularly the USACE, in getting them to be on the bigger team. "If you're not in the federal agencies, they kind of just ignore you. What about the rest of the people that have an interest in this system? I'm not sure what would have to change there. I think it's the bureaucracy within which they live. I think it's more than just budgeting. It's about our money and your money and that's not good. It's really about our issue. ... Stu Applebaum used to show that slide of leave your hat at the door. Well maybe that worked at some points but I don't think it really works all the time."

[132] Chesapeake Bay Executive Order. http://executiveorder.chesapeakebay.net/page/About-the-Executive-Order.aspx

Dr. Collier then turned it back to Jay Lund, who asked the original question. "From your perspective, how would you like to see the federal government be a better partner?"

Dr. Jay Lund pointed out that these problems are all bigger than any one agency. To some degree, the state agencies are no different than the federal agencies. "The problem doesn't care about our agencies; the problem doesn't care about the territoriality that has been established in enabling legislation and the budgets. I think it's just a really interesting problem that should be kicked upstairs, at least a little bit. One problem we have here a lot in doing science is permits … getting permits with endangered species to do science. That's a problem at the federal level that prevents us all from being able to do science in this system."

Jon Hortness (Great Lakes) said that as the Great Lakes Restoration Initiative (GLRI) evolved, some had inherent expectations that they would receive funding for them to do work, but as the second action plan developed, not everyone got the money as expected and there was some tension on those issues. "What it finally came down to was the federal agencies as a group made it a point to say, 'these are the priorities that we have come up with; these are the directions that we have determined we need to take. If that doesn't fit with the way you think you need to do your work, you have the base program to do your work as well.' They're not easy conversations. They're difficult conversations but I think we've addressed that to some degree. I don't think we're there yet but it has come up several times and we've gotten past some of that."

Dr. Josh Collins (Bay-Delta) said that in California, federal money hasn't come from pooling budgets, but instead from intense lobbying. It was intensive lobbying to get Water Resources Development Act (WRDA) funding for science in the bay that lasted nearly seven years. There is a water quality improvement fund which is a special allocation that came about through the efforts of Senator Dianne Feinstein; the money goes through the EPA's estuary program to about 150 recipients, some of which is for science. In Tahoe, President Clinton sold off some federal lands around Reno and Las Vegas and used the proceeds to fund the Tahoe Regional Planning Agency to do science. "I think it takes political pushing, actually, to get special allocations that can persist for some length of time. That's one way that I've seen fairly large amounts of money flow to different regions of this state that persisted for more than a decade."

Scott Redman (Puget Sound) said that there's a lot of promise that the Puget Sound will get to the point of having an interagency task force and working groups. "Just getting to that place would be helpful. I'm very intrigued by the Interagency Ecological Program (IEP).[133] A question for Ted Sommer is, what works and what could work better with IEP?"

Dr. Ted Sommer (Bay-Delta) said, "We do a good job developing a broader voice to get policy back. We do compare resources and strengths and I think that helps us leverage, avoid overlapping, and wasting too much. We're not very good, necessarily, at doing collaboration as we'd like. There are certain pots of money that have certain flavors or colors with different agencies. Some of those are just plain hard to put in a common pot and be used by everyone. One of the bigger needs we have is a funding source that the group, as a whole, could use more clearly. The last thing I'll mention is outreach. There are a lot of organizations that do a whole lot better job of outreach than we do. We have a long way to go with sharing our data and getting our data out to the public."

[133] Interagency Ecological Program. California Department Water Resources. http://www.water.ca.gov/iep/

Question: In the science process, since many of our issues come out of litigation and much of that litigation is about how the science is done, how do you engage those stakeholders who don't necessarily have the resources to participate but could have the resources to litigate in development of science that's collaboratively developed and implemented?

Dr. Nick Aumen (Everglades) said the workshops that they've used in their two major restoration efforts have been successful. They held workshops where anyone could come in and put an idea or concept on the table, and the scientists and engineers would review the proposal, come back and say why it would or would not work. "In the end we developed a consensus alternative that's now just recently been authorized by Congress. I don't want to say this is an easy process. It was extremely labor intensive and also very expensive. It took agency employees weeks of their time dedicated just to this process… I would think many of those folks that were most opposed to this before would say this process to date has been the best way to bring them into the mix."

Dr. Denise Reed (Louisiana Coast) said that there are often multiple ways of doing things. One might agree to pursue a number of different paths together and understand what those different paths, what the different assumptions were, or the different approaches were, and the pros and cons, and illuminations that those different paths might pursue. It's also important to have some sort of external review to ensure credibility of the analysis; not necessarily peer review, but some sort of external eyes. They used over-the-shoulder reviews quite successfully. "You also have to be careful that you are doing something which has scientific merit and credibility and is going to stand the test of some third party looking at it. I think talking is good and collaborating is good but that's not the whole process. The outcome should be the solid science, not just the collaboration."

Question: About the role of citizen science and traditional ecological knowledge, are the other systems are making systematic use of those things? We are in Puget Sound, for example.

Jon Hortness (Great Lakes) said that in the Great Lakes, they are trying that but they haven't gotten there yet. It's especially an important component with the tribes and the First Nations and traditional ecological knowledge. "We're just starting that conversation… at the federal level we are trying to determine what does that look like and how do we incorporate it."

Dr. Josh Collins (Bay-Delta) recalled how when they were working on the historical ecology reconstruction, they realized they were drawing pictures of somebody else's landscape, so they invited indigenous people in to interpret the landscape. "I began to understand that there was a cultural landscape. We are now trying to figure out how we build cultural story and cultural understanding into the landscape maps," he said. "Frankly, one of the things we're discovering is that the whole landscape is so rich with cultural understanding that there's nothing left out. We began thinking we'll do this in order to redirect roads away from cultural resources, but it's all a cultural resource."

Dr. Collins added that there are two tribal people getting their PhDs in environmental science who are managing this duality between their way of understanding the environment through 12,000 years of trial and error with western experimentation. "I think it's a very rich thing to explore. We're trying to, we're just beginning. Nowhere near where you are with First Nation people but we're not shying away from it around California. We're starting to look into it."

Question: A lot of the science enterprises to me seemed to be about these large scale broad monitored programs, which I think are great. As you're starting to get some of these large-scale restoration projects on the ground, how are you meshing the project specific monitoring with the broad scale, more ambient monitoring? Are you tying into those mechanisms that you were monitoring? Are they still specific to the project?

Dr. Denise Reed (Louisiana) said that while monitoring is important, monitoring should not be considered science as it's just data collection. “I don't think that's science; it's not science until you use that data in some kind of analytical process,” she said. “We have to be really careful, especially when we think about the funding for science, that that science is actually advancing knowledge, not collecting data. They are not the same thing.” Dr. Reed referenced Dr. Sommer’s earlier slide showing the large amount of funding spent for compliance monitoring of the state and federal projects. “If I were you in IEP, I'd carve off that money and put that in a separate pot and then say, "Okay, we're going to learn something with the rest of the money. We might lean on that data but that data collection that has to be done to comply with the project should not be considered funding for science."

Scott Redman (Puget Sound) said it’s best to remember the question they are trying to answer. It’s something they are struggling with. They haven’t really invested in monitoring in a while. “We are getting to grow towards effectiveness assessment but it's a challenge. The programs who invest money, do they have questions about their investments? That's kind of our answer.”

Dr. Josh Collins (Bay-Delta) said he wouldn’t carve data collection away from science, but he does believe in science turning data into information. “It's an essential step and without that, I don't think data has much value at all. It's the minimum amount of science.” Effective monitoring and ambient assessment in order to show effectiveness and permanence across projects has become important. “That's the way to judge the effectiveness of whole policies, in fact, and programs. Is the Clean Water Act effective? You have to have projects, to some extent, monitor in a way that's consistent with an ambient monitoring program so you can compare projects to each other, to themselves over time, and to ambient conditions. The two go hand in hand.”

Jon Hortness (Great Lakes) then gave two examples of where monitoring has been part of the science and not just status indicators. He said that in the Great Lakes, they have both long-term ambient monitoring for status and trends as well as project or topic specific monitoring that is more focused on effectiveness and adaptive management (GreatLakesMonitoring.org[134]). One example is monitoring the effectiveness of the agricultural BMPs to see if it changes the amount of nutrients running off the field. The monitoring data is put into models by USGS and NRCS modelers, and used to inform decisions on where and types of BMPs to place in specific areas. Another example is the connected wetlands which are the coastal wetland areas where the lake meets the nearshore. Monitoring has been important to determine where they can gain the most impact on specific wetlands. They use monitoring, modeling, and then analyze that across the entire system, looking for other high impact areas for additional wetlands to start to recover.

Dr. Josh Collins (Bay-Delta) added that with performance monitoring, they know it can’t be done in all the projects. “So we do try to pick what we think are representative areas so we can transfer and translate that information to other projects that are in a similar hydrogeomorphic setting.”

[134] GreatLakesMonitoring.org. https://greatlakesmonitoring.org/

Scott Redman (Puget Sound) noted that the Puget Sound Vital Signs[135] include human well-being vital signs, so they will be relying on both objective data collection by the Bureau of Labor, the GDP from natural resource industries, and others, but also on subjective surveys of people's well-being, their sense of place, cultural practice, and other factors. "Those will just be data streams; we'll need the social scientists to help us make sense of that."

Dr. Nick Aumen (Everglades) said that monitoring and data are a very important component of science; it's a three-legged stool: monitoring, research, and modeling. "I would challenge anybody to do a good model without data. I would also challenge someone in climate change. Where would we be without some of the long-term data we've collected that helps inform where we're going to go in the future?" he said. "The answer is that there needs to be a balanced approach; it needs to be the right combination. If you indeed put all of your information or your money into collecting data points you certainly are not going to advance the science. The problem we all face is when budget cuts happen, what goes first?" Oftentimes, it's research, the modeling, or predictive work; compliance monitoring usually can't be cut as it's mandated. "The challenge we face is getting the education to the point of where from resource management that there's equal recognition importance of all three legs of that stool."

Dr. Denise Reed (Louisiana Coast) had the last word. She agreed that effectiveness monitoring is important. "It's compliance monitoring that is a permit condition or something like that; that should not be part of the science enterprise, the science budget. It should be a resource that the science enterprise can lean on but if the project doesn't go ahead without that monitoring, that's not the same thing."

Panel 1: Science Strategies in Large Programs

Panel 1 Presentation: International Examples: Effective Science Strategies

Dr. Clifford Dahm, Lead Scientist, Delta Stewardship Council

Dr. Clifford Dahm began with some background information on international efforts at managing ecosystems. The International RiverFoundation[136] gives an annual prize of $300,000 Australian dollars for outstanding management of river basins worldwide. The Lake Eyre Basin in Australia received the award in 2015; the River Rhine, particularly the lower Rhine, won the prize in 2014. The River Thames and its recovery from some very serious degradation was the winner for 2010. The Danube River was the winner for 2007; the Sha River in China won the award in 2006, and the Mekong River was awarded the prize in 2002.

"The awards have, in many cases, identified some excellent programs where you could look for successful science strategies," Dr. Dahm said. "These are international examples of where smart people have developed interesting and important programs, and are doing really good things."

In North America, the Willamette River won the award in 2012. "One of the things that I've always admired about the Willamette River program is their wonderful planning atlas that they completed in 2002, which is a guide to the kinds of restoration and basin level management that they've done. It reminds me very much of some of the things that San Francisco Estuary Institute is doing with their historical ecology, and then bringing that up to how we might use that kind of information in management issues here in the Bay Delta."

[135] Vital Signs. Puget Sound Partnership. http://www.psp.wa.gov/vitalsigns/
[136] International RiverFoundation Riverprize. http://riverfoundation.org.au/our-programs/riverprize/

During his tenure as the Delta Lead Scientist from 2008 to 2012, Dr. Dahm had the opportunity to give a plenary talk in Japan at the Ecology and Civil Engineering Society of Japan. The Society has an annual meeting with about 1,000 people in attendance. “It was impressive to me how much river restoration, basin restoration, and coastal management goes on in Japan,” he said. “I bet it is comparable dollar-wise to what we do here in the United States. One of the reasons why it's comparable dollar-wise is that these are very built environments, and so they have this society where they link civil engineers with people who are doing ecological research and restoration because it is a very difficult thing to do within these built systems and it's expensive. Yet, they've committed a lot of resources to do, for example, things for their anadromous fish populations for example or some of their fresh water aquatic mussels. There are some really interesting examples from that part of the world.”

Dr. Dahm then highlighted the Healthy Waterways Partnership in Southeast Queensland. “In 2007, I was doing quite a bit of work on the Rio Grande River basin in New Mexico and I had become very interested in some of the issues of science monitoring and science decision making,” he said. “I had heard a number of presentations at international and national meetings about this Healthy Waterway Partnership that was going on in South East Queensland. I was very impressed with some of the things that were presented, and I said, ‘this would be a great place to do my sabbatical.’”
In addition, his interest at that time was moving more towards the study of intermittent rivers, which make up approximately half of the river networks worldwide. “They are understudied systems, and the Australians, particularly in Outback Australia, had really focused on studying these intermittent systems,” he said. “I wanted to have the opportunity to combine those two efforts.”

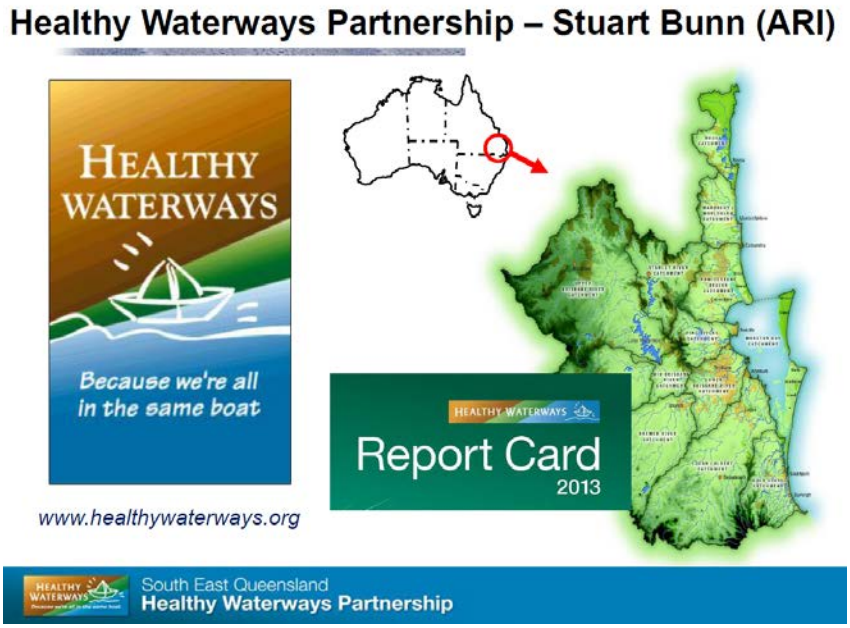


Figure 82, Slide 2

“One of the things that I really liked about the Healthy Waterways Partnership was not only the monitoring program and the science program that they had developed, but also the communication program that they had developed,” said Dr. Dahm.

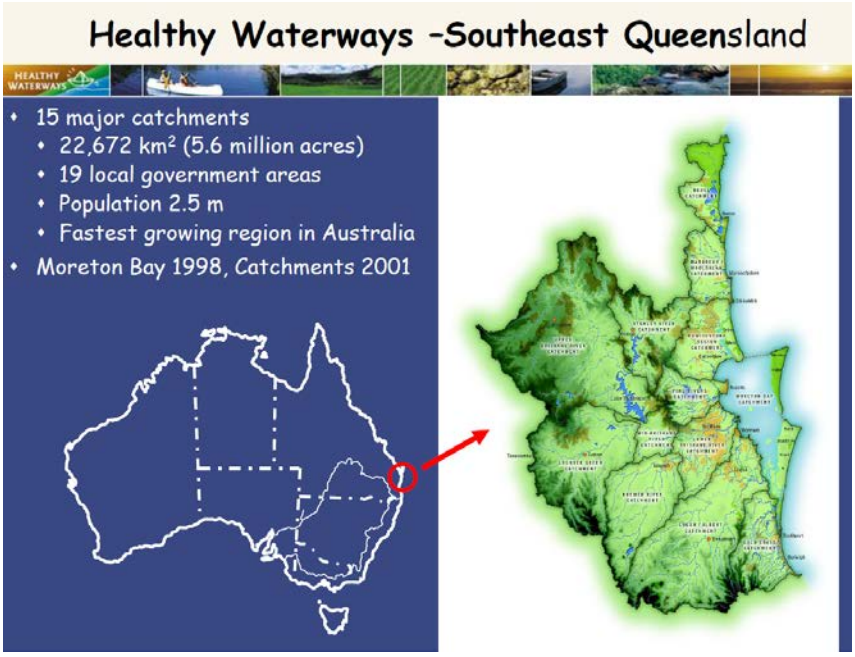


Figure 83, Slide 3

The area under study in Southeast Queensland is comprised of 15 major catchments, about 23,000 square kilometers and 2.5 million people in one of the fastest growing parts of Australia. It includes a lot of different jurisdictions who contribute to a fund that actually pays for the research and monitoring. One of the iconic parts of this area of South East Queensland is Moreton Bay, which is a focus of recreation and tourism.

"There were growing problems within the bay," Dr. Dahm said. "They had problems with sediment, with increasing turbidity within the system, and with nutrients and nitrification. They also had problems with the loss of some of their beneficial sea grasses that were in the estuary. These were the drivers that basically caused them then to start this program."

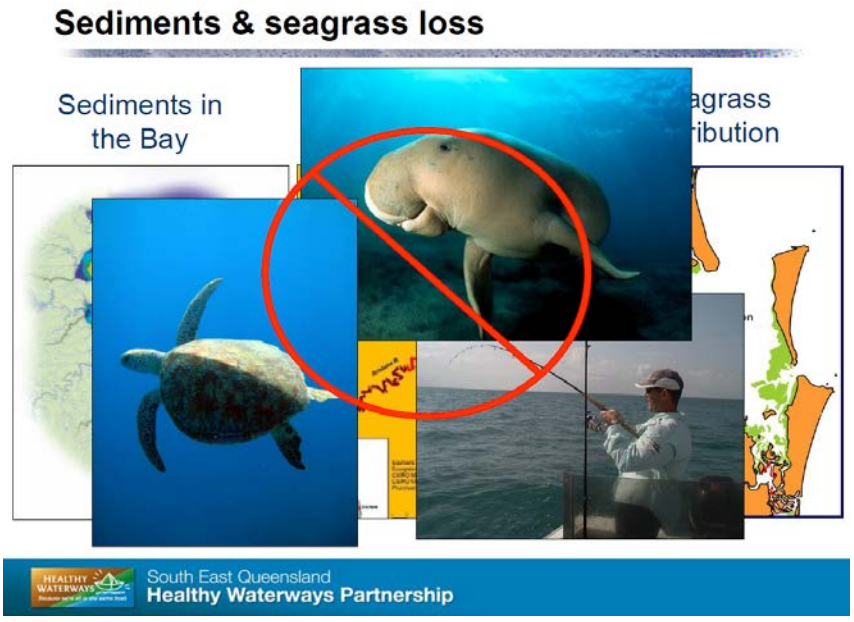


Figure 84, Slide 4

The program was initiated in the late 1990's; there were concerns for the iconic species in the Moreton Bay ecosystem, such as the dugong (a marine mammal in the family of manatees), turtle, and the sports fishery. They initially developed a monitoring program of all the catchments to identify the sources of sediment derived from within the catchments. "One of the things they did was use models and modelling to help them understand the dynamics of the sediments within these catchments," he said. "It became quite clear that the vast majority of the sediments were coming from a fairly small part of the landscape; 30 percent of the landscape was contributing more than 70 percent of the sediments."

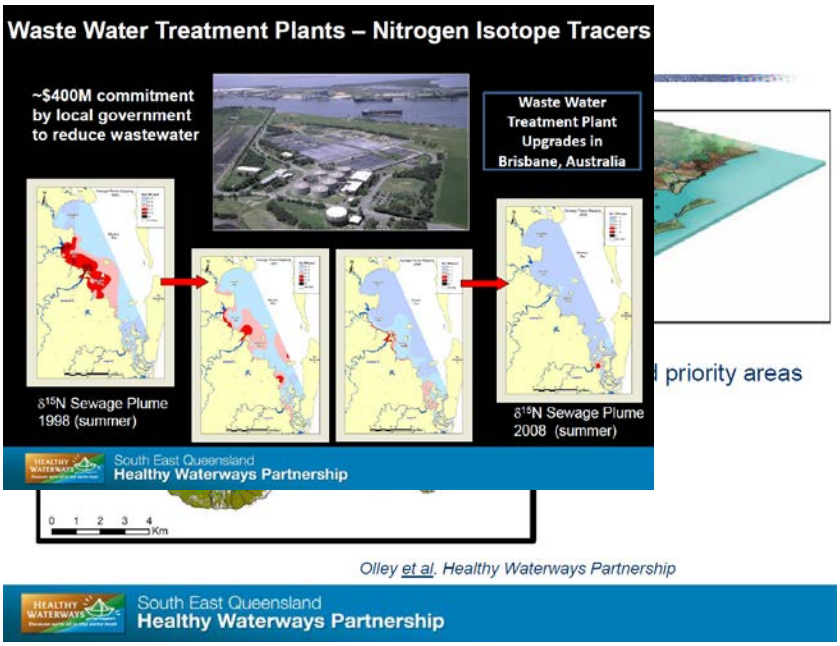


Figure 85, Slide 5

The next question that generated some direct research was, 'how much of the sediment that is getting into this bay is coming from sediment that is associated with active river channels, versus how much of it was associated with row crop agriculture, versus how much of it was associated with incision and arroyo formation. What were the sources of sediment?' That work pinpointed the vast majority of sediment which was coming from a subset of the overall catchment and was derived from sediment that was in the active channel. "These are active channels that were incised, and there were a lot of banks falling in erosion," Dr. Dahm said.

The monitoring program that was set up then allowed them to get an idea of the amount of material coming in from various catchments. Much of the movement of this material was very much event driven, such as with tropical storms, and this kind of information then directed the focus of their restoration efforts to the most heavily degraded stream systems.

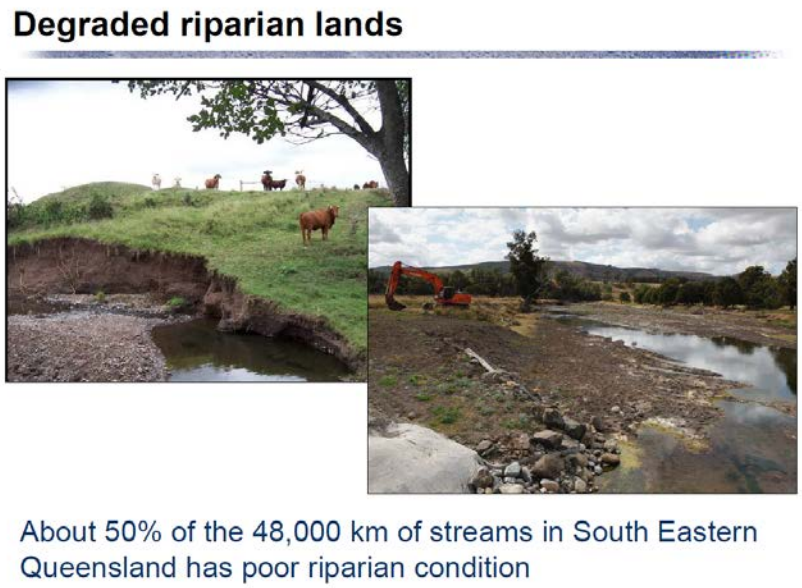


Figure 86, Slide 6

They initially started with some pilot experiments in some areas that they knew were problematic; about 50 percent of the 48,000 km of streams in South Eastern Queensland had poor riparian conditions. They implemented a program of a combination of replanting, getting the grazing animals out of the system, and some re-contouring, and they had some success in getting revegetation back in some of the highly eroded systems.

Early on, they also realized that one of their main problems from a nutrient loading perspective was point source inputs, mainly the wastewater treatment plants associated with the greater Brisbane area; a number of these plants that

were identified as being sources. “They used some very interesting and innovating tools to actually figure out how much of the nutrient, particularly the nitrogen, was getting into the various aquatic plants within Moreton Bay by using a stable isotope tracing technologies,” said Dr. Dahm.

“The stable isotope tracing technologies allowed them to basically look at the condition for the upgrades to the plant. They then invested about $400 million in upgrading a variety of these plants,” said Dr. Dahm. “Then as these plants were upgraded, you can see that the effluent point source inputs that can be traced with the N15 stable isotope nitrogen signal were largely removed from the system by a decade later.”

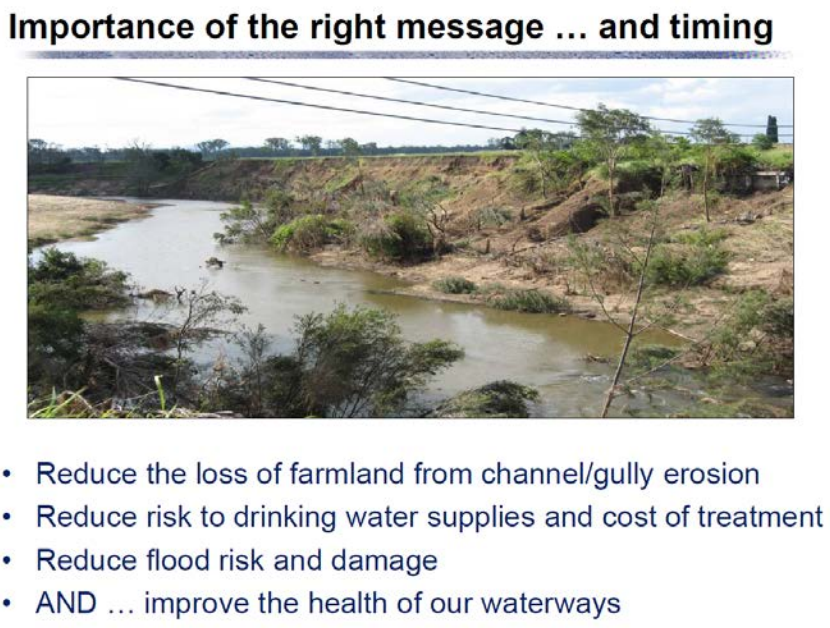


Figure 87, Slide 9

“Some of the things that I think this program did very well were the importance of getting the right message out and timing that message,” said Dr. Dahm. “There was a very active communication program to convince the agricultural interests that reducing the loss of farm land and enhancing the functioning of these ecosystems by basically reducing channel and gully erosion was one of the important things that should be invested in. They also sold the idea that by reducing the sediment sources, there was going to be a significant cost savings in the amount of money that was spent on getting drinking water ready for the population there. It also reduced flood risk and damage, and it improved the overall health and viability of the waterways.”

They had some fairly dramatic examples. Australia’s Millennial Drought ended in the Brisbane area in 2008, and they experienced some fairly substantial floods. “A lot of these restored watersheds did a whole lot better than the ones that had not been fully restored, so there is certainly a monetary payback that they could actually quantify from having healthy waterways and improved waterways in different parts of the catchment,” said Dr. Dahm.

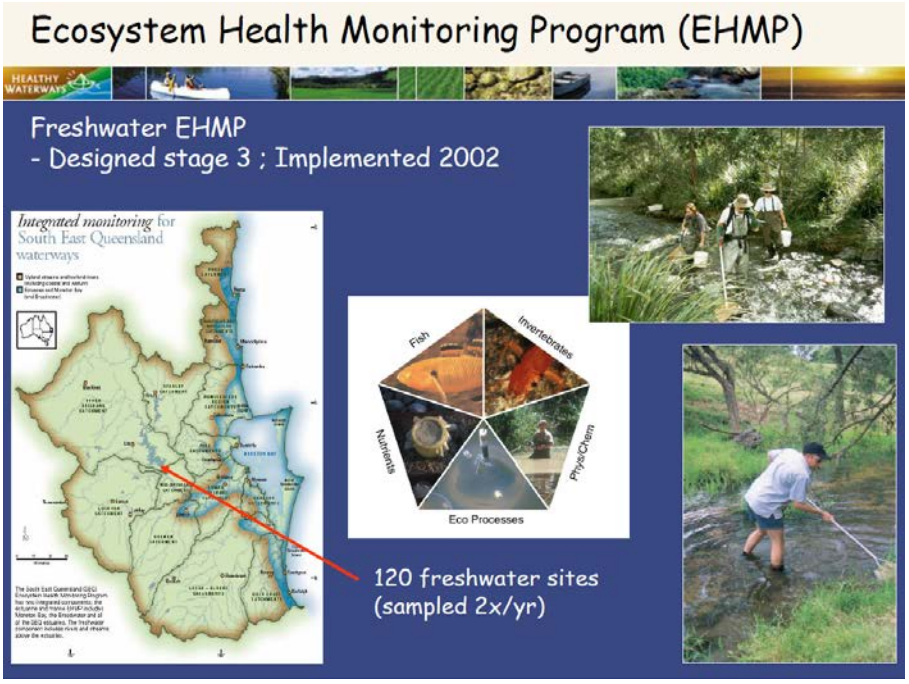


Figure 88, Slide 11

They also set up a very effective Ecosystem Health Monitoring Program, which was designed in stages. The first phase of the program studied and focused on Moreton Bay; that was developed and implemented in 1998 - '99. There was then a development of a similar kind of monitoring program that focused on all 15 major catchments that was implemented in 2001-2002.

"It's basically an integrated evaluation program that utilized five compartments: a fish community analysis; invertebrate community health and bio-indicator measurements; nutrients and nutrients effects on primary producers; ecosystem processes such as rates of primary production and rates of nutrient uptake; and then physical and chemical measurements of the system," said Dr. Dahm. "Each one of those sides of the pentagram produced a series of measurements. Those measurements were then scored and each of those five areas received a 20-point score ranging from 0 to 20. Then the information on this was reported out in a very effective communication campaign; this is one of their report cards that they issue annually."

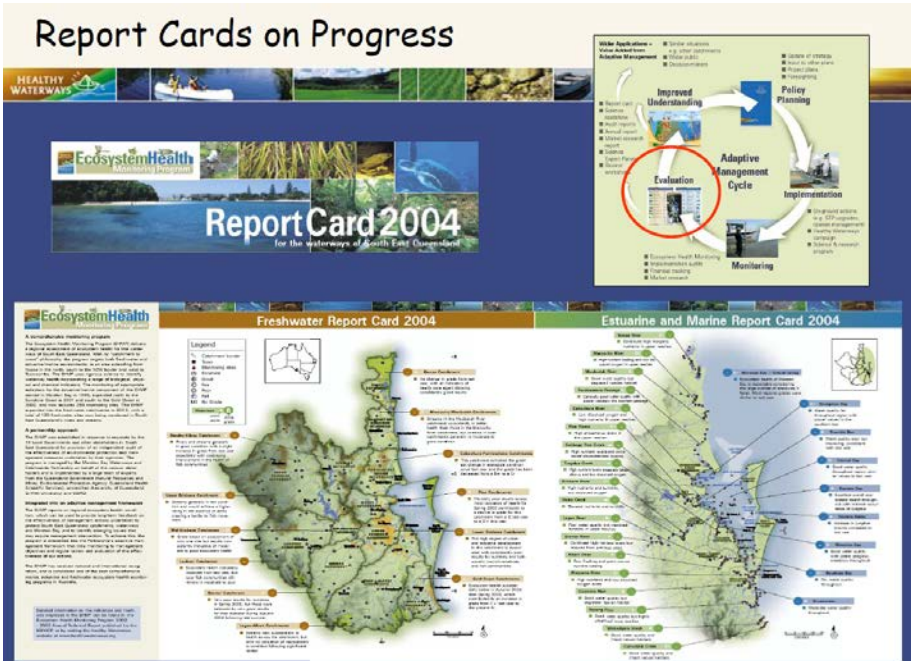


Figure 89, Slide 12

The report cards are given out at various locations around the overall basin. Dr. Dahm attended one meeting where there were 100-150 people – the press, local government representatives, and those who were involved with the monitoring. "It was a big deal," said Dr. Dahm. "That meeting basically allowed the people there to hear how their catchment was doing, and it also in many cases allowed them to help get the resources

necessary to do the improvements and to try to improve the score if their score wasn't up to snuff with some of the other systems." The program is underpinned by an adaptive management program that has now been active for almost two decades. That adaptive management program has gone full circle - so it has gone through all the planning and all the other implementation, the analysis, the evaluation, the communication, decision making, and then the modification.

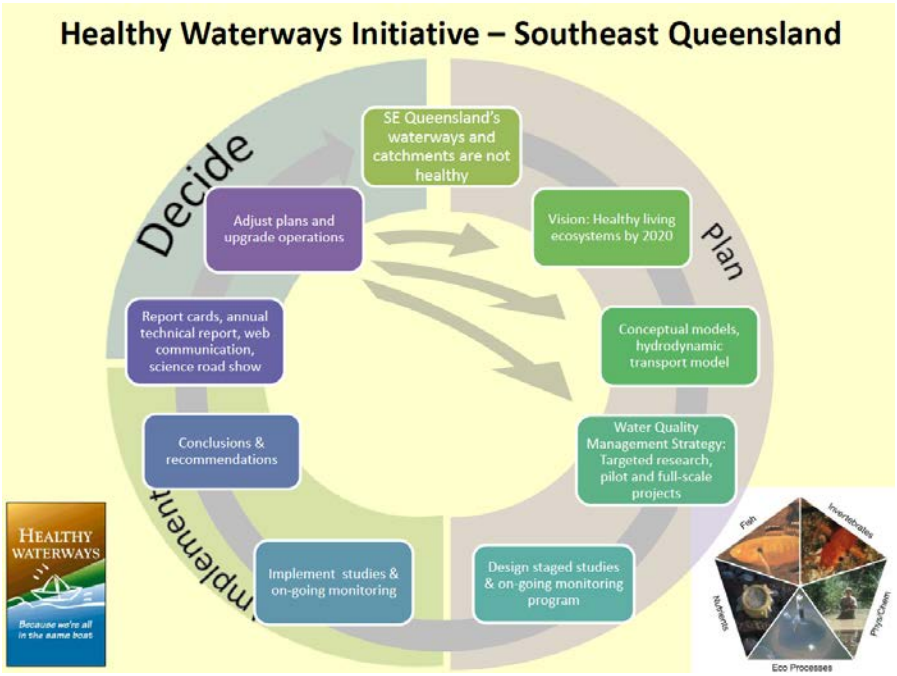


Figure 90, Slide 13

Dr. Dahm presented a graph of how they were doing adaptive management in Australia, noting that it is quite similar to the graphic that's part of the Delta Plan. "They took some of the ideas that we've developed and actually made examples of very concrete things that they've done in Australia associated with this Healthy Waterways Partnership," he said.

Dr. Dahm concluded by saying that they have one of the most effective communication programs that he's ever seen linked to their evaluation and monitoring program. "It is targeting all levels of the population: there are things for kids, high school students, and adult, continuing education. There's a series of study guides, and then there's this report card that they report out on," he said. "Here's a place where I think adaptive management has worked, and I think it's been around long enough that's it's been shown its value and its efficacy. It's a nice international example of some of the things we're talking about here."

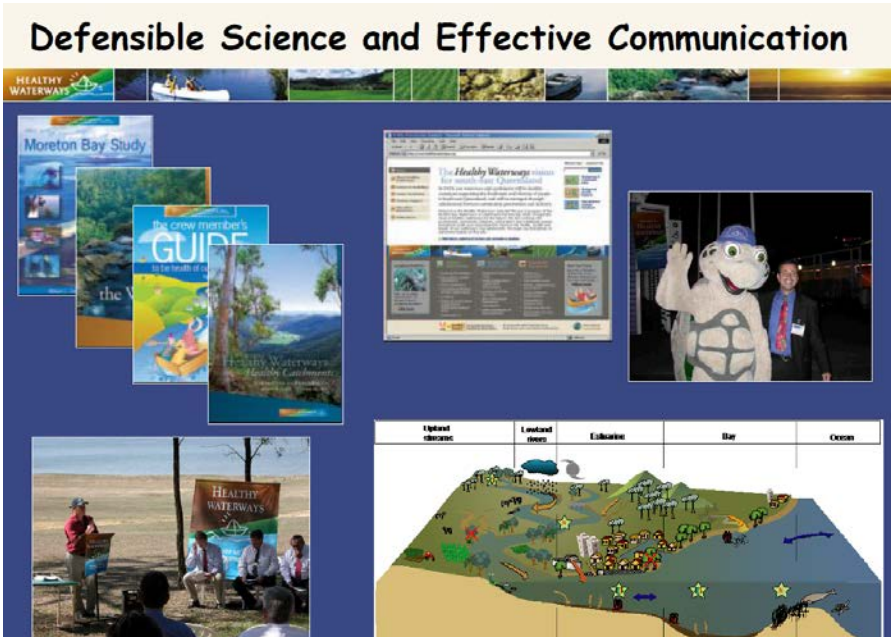


Figure 91, Slide 14

Question and Answer

Question: The monitoring program that they were implementing; were the scores based on a reference site, or were the scores based on a threshold of achieving certain goals or functions at a certain score level?

Dr. Dahm: "The program had 120 locations that are sampled twice a year. The samples are collected for a variety of parameters. Each one of those five areas has at least five metrics that they are measuring within the system. Then they use the measurements themselves to score; it grades from zero, poor quality, to four, good quality, and then that is how the information gets summed up into the overall grade that the site gets."

"They basically have criteria that are written up for each one these metrics, so, for example, if it were suspended sediment level, they would have a threshold that would be zero, a threshold that would be one, a threshold that would be two, a threshold that would be three, a threshold that would be four. Each one of the metrics has a range that sets the score."

"They have in some parts of the catchment things that they consider to be reference-like, so they, in some cases, we use a reference. In some cases, they also have long enough-term data that they can actually look to a baseline. They use a bit of both: both reference conditions and baseline conditions."

Question: It seems like there could be a very strong role for citizen science in this. Could you speak to any role that citizen science plays in Australia?

Dr. Dahm: "Fairly substantive, in that the 120 sites where they're doing the measurements and making the determinations to give the grades also then get adopted by school systems. Then they actually use these systems for actually getting kids out into outdoors, and in some cases actually in some of the monitoring programs."

Panel 1 Discussion

Panelists:

Dr. Clifford Dahm, Lead Scientist, Delta Science Program
Scott Phillips, USGS Chesapeake Coordinator
Dr. Steve Brandt, Professor at Oregon State University; member of the Delta Independent Science Board
Dr. Denise Reed, Chief Scientist, Water Institute of the Gulf
Dr. Steve Lindley, Director, Southwest Fisheries Science Center, NOAA Fisheries
Dr. Nick Aumen, USGS Regional Science Advisor, Southeast Region
Moderator: Jay Lund

What is important in developing science strategy for a basin, and how can a strategy be made adaptable?

DR. NICK AUMEN, USGS Regional Science Advisor, Southeast Region, began by noting two key elements that have served the Florida Everglades well:

1. **Interagency FACA exemption**. Federal Advisory Committee Act (FACA) prohibits federal agencies from interacting with the public when they are receiving public comments; having that barrier removed through an exemption improves ability to receive stakeholder input. "I think the Act was created for good reasons, but having that out of the way for the purposes of what we're trying to do with ecosystem management and restoration, I think, is really important," Dr. Aumen said. The Florida Everglades received FACA exemption through enabling legislation in the

Water Resources Development Act of 1996 that established the South Florida Ecosystem Restoration Task Force.[137] The Gulf Restore program also has FACA exemption.

2. **Provide structure for interagency interaction.** Need a framework that has a leadership role and connects at senior management level at federal, State, and local government level. Sometimes there are framework constraints by law, or there may be litigation issues that inhibit collaboration, but a framework similar to the Task Force in the Everglades can help. "Whoever or whatever entity is the leadership of that has effective connections both higher up the chain and lower down the chain, because in the end you need an advocate that goes all the way back to the administration and the Congress to advocate for particular things." When science enterprises are therefore empowered, it is then possible to leverage and pool substantial resources. "For example, we have a political direction in Florida right now that's against a lot of big public investments, tax increases, or anything like that but we were able through effective collaboration to get the governor of Florida to commit $90 million to building another set of bridges over Tamiami Trail to restore flow to the Everglades at a time where no new money was being put anywhere else," Dr. Aumen said. "We came up with some unusual partners, including the Florida Department of Transportation, and that in turn, forced the park service, who has not had a major infrastructure project like that in decades, to put up a match. It's a $150 million project co-funded by the Department of Transportation from Florida and the National Park Service, and that's moving forward because of the structure that was put in place." "Having that structure in place and a group of entities that are willing to talk to each other, do the hard work to overcome barriers, it sets a good stage if you do that right at the beginning," Dr. Aumen said. "None of this is easy … sometimes it just takes a lot of hard, hard work, and a lot of talking, and inter-personnel interactions, and perseverance, and not taking no for an answer."

DR. STEVE LINDLEY, Director, Fisheries Ecology Division, Southwest Fisheries Science Center, NOAA Fisheries

Besides working in the Central Valley with threatened and endangered anadromous salmon, the NOAA Southwest Fisheries Science Center is also heavily involved in the management of the California Current Large Marine Ecosystem (CCLME)[138], which can be thought of as an ocean basin. The work they do in the California current comes from the Magnuson-Stevens Fishery Conservation and Management Act of 1976[139] and a lot of that Act is responsible for the effectiveness of conservation, Dr. Lindley said. "The California Current, which is relatively well organized, has had successful outcomes in that we've turned around a lot of fisheries which were overfished and in terrible condition, and many of those are now in good shape or on track to being so shortly."

1. **Have clear goals and objectives.** Their goals and objectives are defined mathematically based on theories of population dynamics and ecosystem science. Fisheries management in the U.S. has developed over the last century to be a science based, stake-holder driven, formal process. There are five week-long meetings per year that include representatives from state and federal governments, tribal governments, industry, and non-government organizations; they get around a table and hash things out in a very structured way. They are guided by comprehensive and up to date fisheries management plans, and an ecosystem plan that is more nascent, but in development, he said. "Those plans, how they're put together and what's contained in them is remarkably well-defined in the Magnuson Act itself, which has 10 national standards for how these things are to be done, which are laws," he said. "What those national standards do really

[137] South Florida Ecosystem Restoration Task Force. http://evergladesrestoration.gov/content/tf.html
[138] California Current Large Marine Ecosystem (CCLME). https://www.integratedecosystemassessment.noaa.gov//regions/california-current-region/about.html
[139] Magnuson-Stevens Fishery Conservation and Management Act. http://www.nmfs.noaa.gov/sfa/laws_policies/msa/

defines how science is to be done and organized, and that includes things such as what is the best scientific information available, how to deal with uncertainty and transparency, and extensive and comprehensive peer review, which is really critical to the acceptance of the science that comes out. There are also science and technical advisory committees that are stocked with some of the best minds in the nation on these panels."

2. **Modeling is a central activity:** There are well-developed models for fishery stock assessment; they make use of common software tools and a common theoretical basis. "That is really central to organizing the data that is collected and is brought to bear on the questions. These models can also be used to evaluate the value of bringing in new data or what would happen if we were to curtail collecting certain kinds of data."
3. **NOAA has a well-defined role in fisheries management.** "It makes it pretty easy to know what we need to be doing there," Mr. Lindley said.
4. **Strong national leadership:** Scientists at higher levels of NOAA think broadly about the fisheries management and ocean management issues that are shared across the nation and across the world; they write policy documents and papers that filter down through the ranks. They are currently working on incorporating climate effects and ecosystem considerations into fisheries management; an ecosystem-based fisheries management policy or a roadmap; and a climate action science strategy with a Regional Action Plan. "I think we're very successful, and it's in a bit of a contrast to what we do in the San Francisco Bay Delta, which is much more amorphous and involves attending many meetings," he said. "We can't even really begin to attend them all and still do any science like that. It's much more ad hoc and challenging."

The Magnuson-Stevens Fisheries and Conservation Act was enacted in 1976. "It'd be hard to think you need a better law to be operating under, but those can, at least in some periods of our American history, be written, and maybe we'll have that again," said Dr. Lindley.

DR. DENISE REED, Chief Scientist, Water Institute of the Gulf

1. **Get the right people to do the work (and this may not be the people that you have):** Dr. Reed noted that it is fundamental that a science strategy creates a process to get the right people to actually advance the scientific understanding of the system, which may be different than those currently involved. Dr. Reed said she'd been reflecting on budgets, and thinking that a lot of the money is going to staff time. "I'm really wondering how much goes to science and moving the knowledge forward eventually that occurs as a result of that money," she said. "I think that principle is something that a new program starting from scratch could really build on."
2. **Identifying what research is needed, as well as identifying good approaches to achieve those research needs.** Dr. Reed said that the Restore Act and the Louisiana Coastal Master Plan seeks to identify research needs and best approaches to achieve research needs. To identify research needs, the Centers of Excellence adopted a process that solicited input from the top (state level) and bottom (university community) and general public (on-going) – and the resulting product was a very long list structured around issues the state has identified as important. "We have this combination of top down and bottom up," Dr. Reed said. "It hasn't necessarily been pretty because what we've ended up with is a very, very long list. There's a very, very long list structured around issues that the state's already said is very important, but the individual topics could look fairly scattered." Going forward, the research funding will be organized around the input received from this wide audience, which is critical in order to receive innovative ideas from scientists that are actually doing the work – rather than just agency staff. "The key thing is that we're then going to put the R.F.P. out on the street and see what good ideas we get back. What research ultimately gets funded is a combination of those two things intersecting."

3. **Processes and strategies need to be set up to allow for creativity, innovation, and new ideas to be put into the process.** "It is about the people that do the work and can actually best contribute, as opposed to necessarily the people that you have on your staffs," she said. "I think that's a really important thing."
4. **Attract the best and brightest.** "This is not about money for Louisiana researchers," said Dr. Reed. "This is about money to solve problems in Louisiana, and if the researchers have ideas, they can efficiently work in Louisiana, and can provide some constructive input, then I think that is definitely worthwhile. Setting up mechanisms to get the best and the brightest across the country and across the world working on these large scale ecosystems is a really important component of any science strategy."

DR. STEPHEN BRANDT, Professor at Oregon State University; Chair-elect of the Delta Independent Science Board

Dr. Stephen Brandt provided some insights based on his efforts at the NOAA Great Lake Environmental Research Lab for designing an effective science strategy for the Great Lakes and his work in the Chesapeake Bay and Gulf of Mexico. Four key elements are critical:

1. **Identify what the big problems are.** This is not the responsibility of the science community per se, pointed out Dr. Brandt. "Scientists can be involved, which would be science informed, but really you need to develop a comprehensive approach with stakeholder involvement. The stakeholders really need to agree that these are the big issues because without that there won't be money for it eventually." Dr. Brandt recalled how in the Great Lakes, there were 1500 participants comprised of state and federal agencies and other stakeholders that took one year to develop five key priority areas and then obtained congressional support ($500 million annually). "What motivated the people was that the congressional delegation said, 'we're not going to give you any big hunks of money unless you have a priority set and everybody agrees to it,'" he said. "Money is a big motivator and that managed to get it done and get done on time. This eventually involved half a billion dollars a year of new money. So you need to identify what those key issues are that everyone agrees to."
2. **Identify what the science priorities are relative to addressing those issues.** Science-informed forecasting on the key issues is critical in that it forces linkages between drivers and outcomes, rather than explanatory science. "I'm going to suggest that the science, on a big scale, should be focused towards forecasting, even ecosystem forecasting, rather than explanatory science," Dr. Brandt said. "I think that forces the linkages of the key drivers to the key outcomes." Weather is good example as it is very valuable for management purposes. "In the Great Lakes, salmon is stocked on an annual basis on a massive level that supports a $4 billion fishery. It used to be stocking levels were based on hatchery capacity. Now it's evolved to the stage that the stocking level in Lake Ontario this year was cut back by the state and federal agencies because forecasting models said there wouldn't be enough food supply three years down the road when these fish reach maximum consumption capability. To get the fisherman and to get the agencies to agree to reduce stocking level based on science, which means ultimately there'll be less fish to be caught and less income to the state, is huge, but it took a massive effort of science as well as stakeholder engagement."
3. **A formal structure for interagency collaboration**: The Great Lakes Restoration Initiative (GLRI) Interagency Task Force[140] provides decision-making authority and funding ability to enact the science enterprise – it is critical to have high-level management participation. It is also critical to have a lead agency – in Great Lakes the USEPA ensures action. "You want to have decision makers who can speak on behalf of the agency and can devote resources and people to solving particular

[140] The Great Lakes Restoration Initiative. https://www.glri.us//actionplan/index.html

problems," said Dr. Brandt. "That's a very high level thing, but that's the kind of level it needs to be to be effective." Dr. Brandt also emphasized that there needs to be a lead agency that takes the lead and the responsibility, in the Great Lakes the US EPA ensures action.

4. **Once the problems and the key science ecosystem forecasting program have been identified, you need to get a jumpstart the enterprise.** It is critical to rally collective effort on an initiative to get the work going. For example, The Chesapeake Bay Program developed a 3D hydrodynamic water quality model which led to calculations of nutrient reduction needed to achieve Water Quality objectives. In the Great Lakes the "International Field Year for Lake Erie"[141] was a concerted effort where all the agencies started collection of nutrient loading affected algal blooms and fish production, which then informed forecasting models of how reduction efforts could influence loading and subsequently algal blooms and fish production. Dr. Brandt said, "An interdisciplinary effort was started to look at how nutrient loading into that lake affected the dead zones, harmful algal blooms, and fish production for the purpose of forecasting how nutrient reloading, nutrient reduction and nutrient reloading would impact those things."

Dr. Brandt noted that in the Bay-Delta, many of these components already exist. "I think we've already identified the issues, called the coequal goals, and we have some structures available that could very easily make things happen."

SCOTT PHILLIPS, USGS Environmental Scientist; Coordinator of the USGS Priority Ecosystems Science program for the Chesapeake Bay

1. **You need to have a systems approach.** "I think you really need to be looking at the estuaries of the delta and the contributing watersheds together when you come up with your science strategy, because they're all interconnected, so trying to have a broader strategy looking at all those pieces would be valuable," he said.
2. **You need to be thinking about your audiences.** It is also important to define the audience – who should the strategy influence (congressional, state funding) – and calibrate the message so that each audience group understands what they are getting out of it and how they can advocate through their own funding mechanisms. Mr. Phillips noted that, "While your strategy needs to hit the two big issues that you guys already have, you need to be able to tailor your messages so each of those audiences understand what they're getting out of it. We have a pretty strong science strategy from the Chesapeake, but we really have to message it differently depending if we're sitting down to the congressional staff, or one of our state partners, or even the tribes. You really have to say, "This is how you can contribute, and this is how your contribution in San Francisco will also make your agency look good," and they'll then be willing to really advocate for you and try to get funding for their own mechanisms, as well as try to advocate for other funding mechanisms."
3. **Try to keep your science strategy at a very high level.** And finally, the strategy should be kept high-level; agencies are already working together in some fashion – so the strategy should show at a high level where working well, what needs improvement, and what isn't working well. "You're just trying to write a strategy and general direction; you'll have plenty of time for implementation and action plans afterwards," he said. "I think what others are going to want to see when they walk in here are the science entities that are sitting in this room are working together in some sort of fashion… If you can have a matrix of issues versus science, you can pretty quickly say where your green light sections are, what you're doing well to address an issue, and look at those as your early successes that you want to focus on to show that you can get different entities to work together." To obtain new money from congress, it is critical to

[141] The International Field Years on Lake Erie (IFYLE). https://www.glerl.noaa.gov/pubs/fulltext/2006/20060048.pdf

show where the successes are to demonstrate organizational ability and efficiency, and where steps are being taken to ensure better resource alignment.

DR. CLIFFORD DAHM, Lead Scientist, Delta Science Program

1. **Have clear goals and objectives.** "If you have clear goals and objectives, things seem to flow well from that."
2. **Have a well thought out, long-term sustainably funded monitoring and evaluation program.** "I view the monitoring, if done right, as a very important part of the research program," he said.
3. **The need to couple modeling with synthesis, analysis, and communication.** "If you invest in that modeling, synthesis, analysis, communication component, then you actually have the opportunity to complete your adaptive management cycle. The program has a better chance of being successful, and I think you can generate the will for long term support."

Dr. Jay Lund described a paper on the history of hydraulic modeling in the Netherlands, ""*Strong, Invincible Arguments"?: Tidal Models as Management Instruments in Twentieth-Century Dutch Coastal Engineering*"[142]which chronicled the evolution of models for flood planning. Jay emphasized organization of effective science around construction of "invincible arguments" for diverse stakeholders and decision makers. "I think that's part of the organization of effective science is to make invincible arguments to these diverse stakeholders and decision makers, so that's it's not deniable and that implies a lot of credibility in the good workmanship that has been applied and the organization," he said.

Question and Answer

Question: It was interesting to hear ecological forecasting or forecasting mentioned. It's one of the first times we've really heard that term. I'm wondering if the panelists would comment on the importance of that as a framing construct for a large system. Are there constraints that keep you from getting there, and what those might be?

Scott Phillips (Chesapeake Bay) said that forecasting is important for looking at future conditions that they are trying to manage towards, in terms of both the impacts of land change and climate variability. Forecasting is also important in a scenario context. "We really need to evolve the science to not look at the root causes as much, because they've been studied pretty heavily, but what are the different ecological outcomes we might get from different management interventions. People can see which intervention might have a particular outcome, then you can start to look at which ones do we really want to try to pursue."

Dr. Steve Brandt said he's a strong supporter of the concept of ecosystem forecasting; it has been used in N.O.A.A. as an organizing principle for at least a decade or more. As an organizing principle, it makes you think about the drivers and the outcomes. It's the difference between asking 'do striped bass eat Delta smelt in the Delta?' or 'How will a doubling of striped bass impact smelt?' "It's a whole different concept that requires you to take the physical environment into account… It really requires you to look at it from a more multi-disciplinary perspective." It's not trying to be operational like the weather service; it's constructing science to do it in a way that is valuable to managers. "I think if you talk to managers, they're more likely to want to know what might happen rather than what did happen."

[142] Cornelis Disco and Jan van den Ende. (Jul., 2003). "Strong, Invincible Arguments"?: Tidal Models as Management Instruments in Twentieth-Century Dutch Coastal Engineering. Technology and Culture. Vol. 44, No. 3 pp. 502-535. https://www.jstor.org/stable/25148159?seq=1#page_scan_tab_contents

Dr. Nick Aumen said they have always used hydrologic modeling for forecasting, especially when selecting restoration alternatives. Recently, they've been using a lot of ecological models such as single species models, vegetation models, and tropic level models in the evaluation of different restoration alternatives. They also did an exercise where they picked a climate change scenario and used that as input to the regional water management model; the outputs produced were then given to a whole suite of ecologists who were asked to use that scenario and tell them what it would mean to their ecological system. "We're really getting to the point where we're bringing the ecological forecasting up to the level of what we've had the hydrological forecasting up to, at least in south Florida."

Dr. Denise Reed said forecasting absolutely essential and should be what the science strategy is about. In a system where there are knobs to turn and challenging real-time dynamics, there's a role for the near-term forecasting model which would be from week to month and the longer term predictive. "They don't have to be the same level of resolution. You have different kind of needs. I think we're all on the same page here, that modeling and this way of using these tools to bring our science together to the management need seems very obvious in these other systems."

Question: For science strategy what are the elements of an invincible argument, and are the scientists the ones that should be making that, or do you need to essentially translate that to somebody else who has to make it?

Dr. Denise Reed noted that there are key pieces of scientific information that are the "backbone" for a successful science enterprise. For example, in Coastal Louisiana, showing projected land-loss in 50 years was critical for showing what will happen unless actions were taken. Because the projection is a science-based forecast – it was credible and motivated action "If we don't do something, then science is telling us that something really bad is going to happen, which is going to be a stimulus for action. Then the onus is on science to say, 'If you take this action, how is that map going to change.' I think there are some real linchpin scientific products in some of these systems that really are the backbone of the restoration programs - not just the science strategy but the restoration programs."

Dr. Steve Lindley pointed out that publication in a peer-reviewed journal can make for an invincible argument, for better or for worse; once contentious analyses are published, people tend to move on from them, even maybe sometimes when they shouldn't.

Dr. Nick Aumen added that having good quality people by attracting the best and brightest; having high quality science, which in part means having well-designed approaches to science and experiments; and peer-review and publication of articles.

Dr. Steve Brandt said experience and proven results are the best way to do it. If you make predictions that hold true, stakeholders will take note; the more reliable the models become, and the more they become the accepted way of looking at it. With respect to his example of cutting the stocking in Lake Ontario, that only came about because they predicted something similar decades ago, and it did result in smaller catches and smaller fish. "It took many years for those forecasts to be accepted as this is what's going to happen. That's what they're telling us, and this happened, so now we have to do something about it. I think continually proven results are the way the stakeholders begin to accept the science."

Question: What happens when the invincible science proves to be wrong in some respect? What's your communication strategy when the science that is basis for management decisions proves to be wrong in some respect?

Richard Roos-Collins noted that the Clean Water Act of 1973 required that all waters be swimmable, fishable, and drinkable by 1983 based on testimony that did not include non-point sources. What can the enterprise do when the basis for management decisions proves to be wrong?

Science evolves - Dr. Denise Reed noted that incorporating new information is a critical part of the scientific process; clear articulation of assumptions must be made up front in management contexts. "That is the thing that allows us to move forward without this perfect knowledge - to move forward on what we do know and not be paralyzed by what we don't know."

Dr. Reed then added a comment on peer review, pointing out that everyone probably knows of papers that they think are fundamentally wrong that have gone through the peer review process. It's a way of doing it, but it's not infallible, she reminded. *Consensus* across scientists and across publications is a much better way of ensuring invincibility. "I think that consensus across scientists and across a number of peer reviewed journals is much, much more important that then individual peer review of one particular story. I think climate change probably is the best example of that, where the consensus is about the bigger picture that makes it much more powerful and for me an invincible argument, as opposed to an individual paper that might be peer reviewed on a specific aspect."

Dr. Clifford Dahm agreed and noted that another way that science can be self-regulating to some extent is if studies can be replicated in multiple locations. He gave a specific example of the Hubbard Brook Experimental Forest, which was looking at the effect of clear cutting on nutrient transport into the waterways. They found that when they cut the forest in New England, there was massive amounts of nutrient loss, but these results were not replicated in other locations in North America; more than half showed very little nutrient transport. It was then that they began to get into the mechanistic reasons why these things were happening. "Having a group of people from multiple locations gives us an opportunity to look at how other systems function and to test whether the ideas of our systems work well in these other systems. Cross system experimentation is, I think, another way that science is self-correcting."

Dr. Nick Aumen agreed that science is not invincible; there are numerous examples where something has appeared in peer-reviewed literature, which was rebutted, sometimes multiple times. "I think good scientists love that in a way because it advances science. Certainly there are times when things head the wrong direction, and that to me, is the key to adaptive management because you're going to learn as you do, and you're going to figure out that wasn't the right way, so let's head a slightly different way."

Question: The Role of Uncertainty in Forecasting?

Jayantha Obeysekera noted that the terms "invincible" and "forecasting" could diminish in some ways the role of uncertainty in prediction. As an example, like Lake Okeechobee in the late 90's, "The lake had been higher for five years, and there was a lot of push to drain the water out of the lake. We let three feet of water go, and then in the middle of that action, we were in a hundred-year drought. The public did not let us forget that. In terms of forecasting, you have to be wrong only one time and your credibility goes down. Hydrologists distinguish between near and long term uncertainty – they used 'forecasting' for describing near-term expectations where they had some confidence in the results, and "predictions" for long-term projections that have probabilities. Is it a good idea to promote these concepts which will diminish some of the role of uncertainty in the whole process?"

Dr. Nick Aumen recalled that the executive director of the district lost his job based on that decision to lower the lake; he also noted that that wasn't the result of any output of an ecological or forecasting model but it was a decision made on best professional judgment and just an ill-timed move. "I think that any ecological modeler will say that uncertainty is a really important element of it… it's really important communicate to the decision makers that uncertainty associated with that."

Dr. Steve Lindley pointed out that the Magnuson Act requires scientists and managers to consider uncertainty; there is a formal process for this of being more conservative when forecasts are less certain as a way to buffer against that. "I think also it's just very important to realize that predictions about the future are very difficult to make. People probably shouldn't be penalized terribly when they get wrong what's going to happen with ecosystems, which are inherently unpredictable. We do need to be monitoring carefully what happens and adjusting the models that were using to forecast when they don't work, which would usually be the case."

Dr. Denise Reed noted that the NOAA Office of Water Prediction and their National Water Model[143] is doing a great job nationally in providing water prediction outcomes to support decisions. While reservoir operations are not included yet, they have 2.5 million predictive points for all the streams across the United States- which is a large improvement on the 14,000 stream gauging stations. The grand challenge now for the Weather Service is the 30 to 90-day weather forecast which would provide enormous contributions to water managers across the country. Coastal Louisiana is looking forward to working with NOAA OWP and more broadly, science enterprises should seek collaborations with other efforts to collectively advance modeling. "There were some really big developments out there that we need to kind of recognize that we're not working in isolation of."

Dr. Steve Brandt said that in his view, ecosystem forecasting is a more conservatively structured way to do the science, because you have to be more careful in forecasting things. You can also do things in a probabilistic forecasting way, as the weather service does where you don't get a 100 percent chance of anything; that says up front that things may not turn out the way that they're being forecast. "Some would use the term forecasting and prediction interchangeably. I'm not so sure… I think forecasting makes it more formal and makes you think that you really have to think about it more precisely." Jay Lund agreed and noted that there are ways in decision analysis to characterize various levels of uncertainty to arrive at an optimized decision given various potential impacts and data imperfections.

Question: Characterizing Uncertainties in Human Behavior?

Bill Labiosa noted that in Puget Sound, some of the greatest uncertainties are associated with human behavior. "For example, in flood plains there is a high degree of confidence from the engineering aspect on what the outcomes will be, while the human population that is living there refuses to change their behavior. I'm just trying to imagine the invincible argument being the thing that you employ in this situation." A good science strategy should include an understanding of human behaviors and an appropriate system of incentives or penalties to influence behavior.

Dr. Steve Brandt said that involving the stakeholders from the beginning and getting their buy-in up front on the problem is really important. Stakeholder engagement is also an important component of the ongoing effort. "Having that continual engagement is one way to keep the open dialogue."

[143]NOAA. Office of Water Prediction. http://water.noaa.gov/

Question: Balancing Long term and Immediate Needs in Enterprise Design?

Quite often the policy makers are fighting fires every day. They live in a very difficult world compared to most scientists. To what degree, how can you design and manage the science programs so you can address a lot of those immediate needs that they have every day, with the need for longer term perspective, longer term foundational development understanding of the system?

Dr. Nick Aumen said that in a previous position where he oversaw a large research group, their advice was to plan that 25 percent of scientists' time would go to 'brush fires' – those immediate issues that arise because of outside forces such as political forces, natural forces, or natural disasters - whatever that was going to drive 25 percent of your time and you just have to build that in. At the USGS, part of the mission is to be looking far ahead. "I don't think I'm doing my job well unless I think about what I think our partners need five and ten years from now."

Dr. Steve Lindley said that at NOAA, there are three people at the national level whose job it is to basically think big thoughts about ecology and fisheries assessment, as well as social sciences. They engage with managers as well as the people who work in the field. "They do have the time to step back and think about what are the emerging issues that are going to be the brush fires 10, 20 years from now."

Dr. Clifford Dahm said that the Delta Science Program, a portion of the budget is allocated for "directed actions", ensuring there are resources available for pressing human or nature events. Dahm emphasized that it is critical to defend budget allocation (10-25 percent) for unanticipated events. "It's a hard thing, though, to defend in your budgets, but it's critical if you're going to be able to respond to these events which are going to always happen."

Scott Phillips pointed out that synthesis can play an important role. When an issue comes up, there's often a lot of existing information; it can just be a matter of pulling it together quickly and having that capacity where people can use their best professional judgment to try to inform some of the decisions that might be needed to be made in a short manner.

Dr. Steve Brandt noted that even some granting programs can do this; Sea Grant has a pilot project program where they can get money out the door in a few days; likewise, the National Science Foundation (NSF) has Grants for Rapid Response Research (RAPID) Program.[144]

Question: Structure Science Strategy Input Processes

Ted Sommer noted that several of the panelists identified the need for input for science strategy to be top-down, bottom-up, also stake-holders obviously is right on target, but not much about was talked about who uses that information and how. Although Denise did mention there was a concern that maybe some of the existing staff may not be the right ones to use it. I wasn't sure if that was conflict of interest, different skill sets, independence?

Dr. Denise Reed clarified that science enterprises must be deliberate in creating processes to attract the best and the brightest; in practice this means bringing in multi-disciplinary and different skillsets, from the private sector for example, which can bring in new and creative ideas – as opposed to just career agency scientists. This is particularly helpful for new, short-term challenges that may require expertise

[144] National Science Foundation (NSF) Grants for Rapid Response Research (RAPID) Program. http://www.nsf.gov/pubs/policydocs/pappguide/nsf09_1/gpg_2.jsp#IID1

that existing staff do not have. "I think that the idea of getting the best and the brightest is the key thing, and having a process that can bring in the right people to do the job. Having the right people and the right magnitude with the right skill sets available when there are emergencies coming - that doesn't always happen within the structure of a kind of F.T.E. process."

Dr. Nick Aumen said that it's a struggle within the USGS; if they hire a permanent person, it's a 30-year commitment to whatever skill set that person has, so those decisions must be made carefully. However, he noted that things have changed; probably half the staff at the science centers are either term positions or contractors, which gives them the ability to change directions and bring in new expertise. He also noted that almost all the science centers have a pre-arranged contract with a staffing agency, where he can go to a contractor, identify a person, and have them working the next day. "It's really important to have ways to be able to adjust because if you lock in, you are locked in."

Question: Best Practice in Data Management Across Agencies and Stakeholders

Jay Lund asked the panel for some examples of practices for data sharing, modeling, collection, and monitoring in efforts that are shared across agencies and partners. There are some examples in South Florida of an integrated modeling center where several agencies came together in one location with their staff to do this kind of work. What are your thoughts on these community technical efforts and their management administration?

Dr. Denise Reed said that after the oil spill, B.P. put $500 million into the Gulf of Mexico Research Initiative. They set up a competitive grants program, and one of the things they established as requirement for receiving funding were very rigorous data management standards, and a very rigorous process for release and public access of data through the Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC).[145] "On the Gulf coast, the emphasis on this by that particular program elevated everybody. Everybody now does that, and all of the money that is flowing to science as a result of the Deep Water Horizon is now rising to that bar." This is becoming more common across agencies, for example NOAA's ERDDAP is a data server that gives users a simple, consistent way to download subsets of scientific datasets in common file formats and make graphs and maps.[146] In addition, NOAA's National Centers for Environmental Information (NCEI)[147] host and provide public access to environmental data. Linking grant funding requirements to use of database standards are critical in elevating professionalism in data management.

Scott Phillips agreed that community modeling or monitoring and having set standards or requirements for comparable information are a really important foundation. In the Chesapeake, they co-locate to achieve that. For example, in the Chesapeake Bay Program office, only a quarter of the staff are US EPA staff – the rest are from different agencies and universities, and this really helps in making progress in data management and integrated modeling. "There's a lot of benefit to have community involvement, and if you can to co-locate them in one spot, they can really make a lot of progress."

Dr. Clifford Dahm said that when he was involved with a long term ecological research program which started in 1980, and about 15 years in, they decided that data management was critical to the success of that program. They put in standard protocols; the National Ecological Observatory Network[148] requires

[145] Gulf of Mexico Research Initiative. Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC). https://data.gulfresearchinitiative.org/
[146] NOAA. ERDDAP. https://coastwatch.pfeg.noaa.gov/erddap/index.html
[147] NOAA. National Centers for Environmental Information (NCEI). https://www.ncei.noaa.gov/
[148] National Ecological Observatory Network. http://www.neonscience.org/

use of data management standards, and in California, the Open and Transparent Water Data Management Act (AB 1755)[149] will also help motivate use of data management standards.

Dr. Steve Lindley pointed out that federal agencies are now required to make all of their data available online to the public. A group in NOAA has developed ERDDAP[150] which is a software tool that provides a searchable database of over 9,000 datasets that has allowed for easy portability in data sharing. "It's basically a magic transformer of all kinds of data types that is fairly easy to use and other people run that on top of their other systems. It can gather data from around the world, and make it readily available to people. It's really pretty easy to do, and I would offer their assistance to anybody who wants that."

Question: Guidance for Business Models for Co-Location of Public, Private, Academic Collaboration
Lauren Hastings followed-up on the challenge to develop co-location for integrated modeling - one of the issues in the California Bay-Delta system is that top notch modelers are actually working for private consulting firms. One of the issues that we've been exploring is a business model that would allow for that kind of interaction of the private consulting firms with agencies and academics.

Scott Phillips said that while they do have some people co-located, there are others who are located elsewhere. They address that by holding a two-day modeling meeting every quarter where technical experts come in, talk about progress and what needs to be done next.

Dr. Denise Reed said she doesn't understand why getting the private sector to work with agencies is a problem. She emphasized the need for a clear understanding up front the terms and conditions around intellectual property, and once that is defined, then it is possible to develop the business model. There is a push to work in the open-source, free software environment – and once that baseline is set, it becomes much easier to progress in the agreement. With universities, getting master contracts and agreements established up front enables readiness and nimbleness for emergencies. "By getting contracts, arrangements, and master agreements, and negotiating the terms and conditions up front so when there is an emergency you can move the money fast; then you're both ready so that you can be nimble."

Panel 2: Governance and Adaptive Management

Panel 2 Presentation: Impact of regulations on science

David Wegner, Water, Energy, and Transportation Committee at U.S. House of Representatives, former Senior Staff

On the issue of adaptive management and regulations and how they interact with each other, Mr. Wegner said his perspective is shaped by three things: his academic training as a scientist and an engineer; by those he has come in contact with and learned from; and in learning by doing. He said it's hard to try and explain the concept of adaptive management to a congressman or senator when they are more interested in other topics. "But that was part of the deal," he said. "You had to be able to interact and try to explain concepts that, to us, we can at least spell it, but try to explain something blank that internally within politics is hard."

[149] The Open and Transparent Water Data Management Act (AB 1755). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1755
[150] NOAA. ERDDAP. https://coastwatch.pfeg.noaa.gov/erddap/index.html

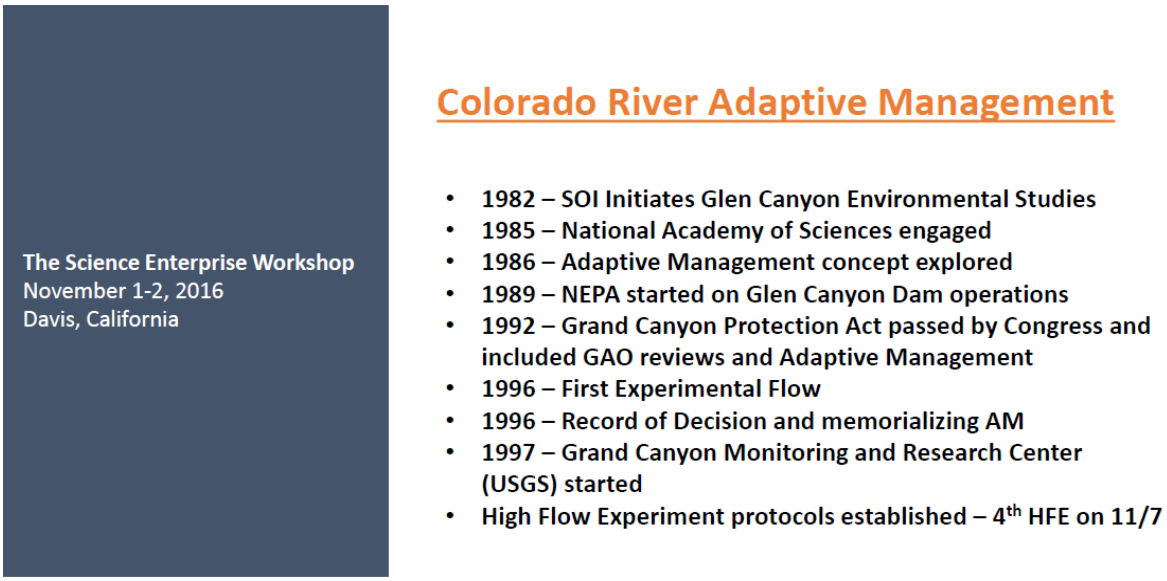


Figure 92, Slide 4

Back in the early 1980's, they began a process at Glen Canyon Dam in the Colorado River at the request of the Secretary of the Interior where they started to explore the elements of adaptive management, although at the time, they didn't know what to call it. In 1985, the Secretary funded the National Academy of Sciences $200,000 to stand up the Water Science and Technology Board and one of the first tasks they were given by Mr. Wegner was to explore the concepts of adaptive management at Glen Canyon Dam.

Mr. Wegner said it was one of the smartest decisions he made as they brought in science and a high-level science review at an early stage. "It was hard," he said. "We hadn't been doing really good science, but the academy made us become better scientists in the peer review continual process of moving through it."

It is important to engage with the stakeholders from the beginning, Mr. Wegner said. "Early on, we had a very select group of stakeholders; they were the water districts, they were the people who run power out of Glen Canyon Dam, and they were some of the boaters in the Grand Canyon, who didn't have a very vocal voice at that time - they became very vocal because they had this unique platform," he said. "When you take a Grand Canyon trip, you have people on your boat for anywhere from 7-21 days and they could instill in people's minds the importance of what was happening with the operation of the dam. Every guide that I knew in the Grand Canyon had post cards in his box on his boat that he would give his clients, his passengers, and they would write letters. They would send post cards into Congress. That's what got Congress engaged in this."

It's also important to get the politicians engaged as well. "I was able to get Congressman George Miller and Senator John McCain, and a few others interested in the Grand Canyon and that went a long way to helping this along," Mr. Wegner said.

He then emphasized some of the topics and issues brought up on the first day of the Science Enterprise Workshop. "Science is an investment," he said. "Science is advancing knowledge, not just collecting data. A lot of times we go out there to collect data just to collect data, but we really have to use that to advance the science."

Stakeholders and their involvement are critical, but not all stakeholders are created equal, Mr. Wegner said. Traditional environmental ecological knowledge is important. "Dealing with tribes, we had 8 Native American tribes who were engaged," he said. "You have to deal with tribes in a whole different level than you deal with your other stakeholders. You have to spend time at the chapter houses; you have to spend time with the leaders educating them on the process."
The role of a federal regulatory agency is different than that of a federal data agency. "A regulatory agency has a whole different set of requirements in how they do business versus a federal agency who just does business collecting data," said Mr. Wegner.

Managing uncertainty and risk is an ongoing effort for all of us, Mr. Wegner said. "Developing a common language is important; you have to have some common terminology that you're consistent with as you explain your process," he said. "Open dialogue and the sharing of data are critical."

Adaptive management and water resource management as well as the complex and dynamic nature of ecosystems require a robust approach and understanding of four key overlapping factors:

- Scientific – factors causing species to go into decline – what actions might mitigate, halt or reverse
- Managerial – how might a variety of actors and stakeholders plan, finance, implement, and coordinate actions
- Cultural – what values of an ecosystem are important to various stakeholders
- Political – what stakeholder values are in play and how might they be addressed, reconciled or played off of

In terms of regulations and adaptive management, the first thing is to determine the relationship of the regulations and policy to the issues. "Is it guidance? Is it there for restrictions (such as the Endangered Species Act issues), or is it process directed?" Mr. Wegner said. "It's important to understand what that regulation is and what its potential impacts may be on your particular process or studies. It's also important to understand what the limits and sideboards are."

"Educate the regulators and the stakeholders continuously. It's important you have a dialogue with agencies like the Fish and Wildlife Service, the National Marine Fisheries Service, or the Corps of Engineers," he said. "I have found from my experience that the more dialogue that you do with both the regulatory side and with the stakeholder side, you can get a common understanding of where the challenges are."

Lastly, determine where the points are when lack of action will lead to possible court intervention – know the playing field. It's important for everyone to understand which regulations are show stoppers and which require additional guidance or process. "There is a trigger where the points are where lack of action will potentially lead to litigation," Mr. Wegner said. "Everybody needs to know where that threshold is. Is it the loss of a certain number of beaches in the Grand Canyon? Is it the numbers of chinook salmon fry that are coming through? You have to know where your thresholds are so you can work through them and understand them."

Federal agencies present their own challenges. “We had 26 federal agencies that have water in their mission statements, so there are 26 silos that are out there, each with their own directive and their own funding base,” he said. “There are a very limited number of bridges that exist between those 26 silos, and part of the job is trying to figure out how to get people to share it.”

There are challenges of getting authorizing legislation such as the Water Research Development Act (WRDA) bill is versus getting appropriation legislation or funding, Mr. Wegner said. “We can do all kinds of WRDA bills, but if you don't have appropriations following up behind it, that's just a lot of words on paper,” he said.

The Federal Advisory Committee Act (FACA)[151] requirements add time and effort, Mr. Wegner said, noting that Dr. Nick Aumen has explained the importance of getting a FACA exemption if you can.

Streamlining permits is difficult although not impossible to do, but you have to understand agency cultures, Mr. Wegner said. “Dealing with the Corps of Engineers and the way they think is different than dealing with the Bureau of Reclamation and how they think, versus dealing with the Fish and Wildlife Service and how they think,” he said.

Mr. Wegner then gave an example from when he was responsible for coordinating the response from the Hill to Hurricane Sandy; the hurricane had come through Long Island and breached a couple of outer dunes on Long Island and the Fire Island National Seashore Area. “We were trying to get out there to protect the people and get the dunes rebuilt,” he said. “The National Park Service said, ‘It's a wilderness area folks, you can't take any piece of equipment in there to rebuild the dune.’ The congressman from Long Island said, ‘I've got 50,000 poor people that are the service people to all those Wall Streeters who live on Long Island, who live there and they are directly exposed if we get a next storm,’ versus the Fish and Wildlife Service who said, ‘We have plover and we have some endangered plants.’ The point here is that each of those cultures, you have to understand how they operate and work.”

While permits for streamlining difficult issues is hard, but not impossible, pooling budgets with the agencies is real challenge because of Office of Management and Budget, Mr. Wegner said. “There is no other way to get around it,” he said. “We have to do a better job of educating OMB and changing some of their philosophy.”

Knowing when to engage a public process with the federal agencies is critical, he said. The WRDA 2014 bill laid out a new process for how projects are proposed and moved forward. The ban on earmarks has totally changed the way projects are initiated. “The point here is that congressional cycles come in flows,” he said. “They go in 2 years, 4 years, 6 year cycles and you have to know where those windows of opportunities are.”

Mr. Wegner noted that in the 114th Congress alone, there are 28 pieces of legislation that have adaptive management in the legislation. “I can guarantee you if you go to talk to the staff who wrote that legislation, they're not going to have clue one what it really means,” he said. “Again, it's important for us to communicate on these issues.”

[151] Federal Advisory Committee Act (FACA). U.S. General Services Administration. https://www.gsa.gov/portal/category/21242

Additionally, NEPA and ESA often include forms of adaptive management in them, either in the terms in the record of decision, or in the reasonable and prudent alternatives. "It's there; we have to do a better job of explaining what it is, but it can be done," he said. He noted that the Congressional Research Service wrote a report, Adaptive Management for Ecosystem Restoration: Analysis and Issues for Congress[152], has been effective in helping to educate the public.

Mr. Wegner said that five elements came out of this:

- **Leadership of adaptive management initiatives is needed at all levels**, and requires nurturing and educating along the way.
- **Stakeholder representation, involvement, and support are important**. You need to include all initially and let them decide who participates.
- **Clear and concise decision rules need to be articulated right from the very beginning**. They need to be articulated, they need to be followed, and you must watch the currents.
- **Milestones and objectives are important;** check in points are critical as are reporting results. These must be articulated so people know when they're going to be reaching thresholds or reporting results.
- **The balancing of flexibility and certainty:** You need to manage expectations and abilities, as well as understand and communicate risk.

Mr. Wegner then concluded with some personal observations, based on his 30+ years of experience. "Leadership is critical; you have to build this leadership; you have to nurture it; you have to mentor it; and you have to make sure that they understand the process and protect you," he said. "Stakeholders have a limited capacity to how much science they can handle without results. You have to feed them along the way and show them some positive or negative results, as the case may be, from what the science is producing."

An entrepreneurial mindset is needed. "In my opinion, a traditional agency manager put into schooling up and running an adaptive management program is doomed to fail if they don't understand that they have to be willing to think on their feet," he said. "They can't just depend upon checking the box. Every program has to have some folks who always are thinking kind of outside the box, they're always challenging you for what you do."

"People who get the program to the adaptive management door are likely not the people who are going to carry it forward," Mr. Wegner said. He gave an example from the Grand Canyon Monitoring and Research Center, which came after they had done the Glen Canyon program. "They have a whole new set of bureaucracy, a whole new set of ways they do business, and a whole new set of how they get their dollars and their finances in order to run the program. So keep that in the back of your mind that you have really different sets of people and their mindsets on how they do it."

Periodic independent review is critical, Mr. Wegner said. "The smartest thing you can do is have independent review come in and periodically assess what you're doing - People who don't have a dog in the fight, but are willing to tell you what you may not want to hear, but need to hear."

"No science program is sacred," Mr. Wegner said. "It might work great for 20 years and you should look at what you can carry forward, but no science program is, on its own, sacred. You have to look at how that science is done over time."

[152] Adaptive Management for Ecosystem Restoration: Analysis and Issues for Congress. https://www.everycrsreport.com/reports/R41671.html

Lastly, Mr. Wegner said to think of an adaptive management in terms of modules. “There's only so much you can market or sell to an administrator, or a decision maker, or a politician on the first go around, so you build in modules and you continue to build in modules as you go down the road,” he said.

Panel 2 Discussion

Panelists

Jon Hortness, US Geological Survey, Supervisory Hydrologist
Felicia Marcus, Chair, State Water Resources Control Board
Jayantha Obeysekera, South Florida Water Management District, Chief Modeler
Richard Roos-Collins, Water and Power Law Group
Dave Wegner, Water, Energy and Transportation committee at U.S. House of Representatives, former Senior Staff
Carl Wilcox, California Department of Fish and Wildlife, Policy Advisor to the Director for the Delta

Question and Answer

Jessica Law began the panel discussion with the following question:
Question: Uncertainty in decision-making. How is adaptive management framed from your perspective and those that you advise or work with?

Dave Wegner shared his perspective from experience in working with members of Congress. First, it is critical to frame adaptive management to members of congress in ways they understand, such as potential advantages, new regulatory impacts, funding, or political risk. As an example – members of Congress do not necessarily recognize the value of the National Academy of Sciences, had to educate on the specific risks NAS helps mitigate and the value of it. In terms of communication, it is important to develop relationships with champions in DC. “They don't know our language; they don't know the value of science, they know it in terms of risk and what they are going to be learning,” said Mr. Wegner. “In terms of having to make decisions, that may mean millions of dollars; it may mean a new regulation that they will get hammered over; or it may mean that they're going out on a limb for one reason or another, politically. You have to able to frame it, "What can this do for you?”

Jon Hortness spoke about his perspective from a federal agency as part of the Great Lake Restoration Initiative (GLRI). Federal agencies have not always agreed on what adaptive management is, and it is really difficult to define especially for a large ecosystem and given different agency authorities and missions. “When you start branching out into an ecosystem, it’s much more difficult,” he said. “Really getting all the federal agencies with the different authorizations, different inherent thoughts, needs, and wants and how they want to deal with things makes it much more difficult. We're still in the stage of really trying to identify, ‘What do we really define adaptive management as at that large scale and how do we put that forward in a large ecosystem restoration effort?’”

Carl Wilcox said, “From a policy maker perspective, adaptive management is hope that the status quo can be changed in some way. That hope is always in the perspective of the beholder. Certainly in the context of what we do in the Delta, as it relates to water management and resource management, adaptive management is like a panacea that everybody can get better together,” he said. “I don't know that that's necessarily the case, but it's what we pursue to be able to clarify the issues and how we manage things, and hopefully manage them in a better way.” During the drought, we have managed for one species – and need to recognize going forward that water management decisions touch the entire ecosystem and **all** stakeholders. The Water Board is dealing with this directly in the Update to the Water

Quality Control Plan. Ultimately, the plan will touch all stakeholders in the state – and are making progress in reaching some stakeholders, while have challenges with others. Adaptive management is critical for meeting Co-Equal Goals and for the state as a whole.

Richard Roos-Collins noted that "the only constant in life is change" – and he pointed to how Dr. Garrett Hardin deals with uncertainty in his work on the Tragedy of the Commons. Those who propose change, will face skeptics and opponents who talk about the risk of change – and what the skeptics and opponents do not do is acknowledge the risks and consequences of doing nothing. Dr. Hardin says, "But we can never do nothing. That which we have done for thousands of years is also action. It also produces evils. Once we are aware that the status quo is action, we can then compare its discoverable advantages and disadvantages with the predicted advantages and disadvantages of the proposed reform, discounting as best we can for our lack of experience."[153] "How I think of adaptive management is in the context of what we do, which could include nothing," he said. "In that context, I'll recommend one thing that tends to work. That is clarity on who, what, when, where, and how, and a clock drives decisions. It is essential that the decision rules for adaptive management include a clock. It's also critical that the decision rules include accountability for who makes the decision." As an example, as part of the re-licensing settlement with a hydropower dam on the Roanoke River, they had to take into account that the downstream ecosystem (cypress and tupelo swamp) had a thousand-year life-cycle – and needed to incorporate regeneration efforts associated with peak release decisions along that extremely long time horizon. So, they introduced a structured adaptive management program with three phases. The first seeks to test the hypothesis that existing release operations over 5 years do not affect regrowth – if proved that they do, the second phase initiates with an operations adjustment, and if it is shown to impact, then move into the next phase and so-forth. The phases provided a clear performance-based standard for operations management, and a structure for who and how scientific research would be conducted in a way that was acceptable to the different agencies (NOAA NMFs, state department of Fish and Wildlife, and others).

Jayantha Obeysekera provided some thoughts from his experience at the South Florida Water Management District[154] where they have been implementing adaptive management over ten years. As a classic example, they sought to de-channelize the waterway in the Kissimmee River. Early on, they began with experimenting with weir construction to divert water into the old river sections which have been abandoned; they quickly realized through modeling and monitoring that the weirs would not work. So, they removed the weirs and proceeded with back-filling the channel and restore the river back to its original form. More broadly, a 1983 paper "Lessons learned from the first decade of adaptive management in comprehensive Everglades restoration"[155] identifies five key principles: 1) legislative and regulatory authorities are critical for funding and implementation; 2) integration of adaptive management activities into agency framework ensures roles and responsibilities are clearly understood; 3) applied science framework is critical to establish a pre-restoration ecosystem reference condition; 4) clear identification of uncertainties that pose risks to meeting restoration goals (such as decision matrices); and 5) independent external peer review of an adaptive management program provides important feedback. Continual review, such as what the National Academy of Sciences (NAS) is providing is critical for balance along the way. "There's a new paradigm because of climate change itself leads into deep uncertainty situations where the models don't agree, the outcomes don't agree, and you can't

[153] The Tragedy of the Commons. Garret Hardin. 1968. http://www.garretthardinsociety.org/articles/art_tragedy_of_the_commons.html
[154] South Florida Water Management District. https://www.sfwmd.gov/
[155] LoSchiavo, A. J., R. G. Best, R. E. Burns, S. Gray, M. C. Harwell, E. B. Hines, A. R. McLean, T. St. Clair, S. Traxler, and J. W. Vearil. 2013. Lessons learned from the first decade of adaptive management in comprehensive Everglades restoration. Ecology and Society 18(4): 70. http://dx.doi.org/10.5751/ES-06065-180470

even predict the probabilities of what could happen," he said. "There's a whole new area of science that's coming out in situations of dealing with deep uncertainty that I think is something we need to communicate to decision makers to get them to think about how to make decisions in this new paradigm."

Felicia Marcus noted that it is critical to think about the long-term legacies that settlements have, and the structure that is needed at the outset to ensure they are able to last over time. Scientists and policy makers need to be able to communicate. A good example of when stakeholders came together and were able to get passed just talking about uncertainty ranges is the Santa Monica Bay Restoration Plan. They built a successful framework based on balanced stakeholders, regular reporting, transparency, accountability (periodic review), and established a higher authority in the case of goals not being achieved. As an example of what has not worked, the Salton Sea shows what can happen if it is poorly constructed. The 2002 agreement was linked to 15 years of releases from the Colorado River, but the Sea has receded and there is no plan in place because the agreement did not require regular check-ins. The settlement did not include periodic review – so it is unable to deal with water reductions. So need long-term programs with periodic check-ins, governance structure, and give them a framework that enables trust, verification, and rigorous accountability. "In the case of the Bay Delta, we have gone far too long without updating the standards," she said. "As you know, we're totally open to all kinds of agreements that can do much more than we can ever order, but we're going to have to come up with a structure that people have some faith in, considering that we're 20 years out of date and there are challenges there."

Question: State and federal agency coordination. How some of the regions have managed coordination across agencies, what are the implications for science cooperation and coordination? How can region-specific restoration visions be best support by state and federal agency leadership?

Richard Roos-Collins noted that coordination is better than the alternative – and that it is obviously a great to have an organizational structure, periodic reporting, a funding strategy, etc. – but the risk is that it's such a shared responsibility that decisions aren't made. So, it's critical to have a single point of authority for decisions within each agency's regulatory boundary. As an example, the Department of Interior completed the Environmental Impact Statement (EIS) in 2012[156] on the removal of Klamath Dam. The statement was completed in only two years after the agreement and represented an extraordinary synthesis of over 50 studies from researchers across the country. DOI managed to structure a team with meaningful leadership (staff directly under the deputy director) and designated the lead scientist to be from the USGS. Leadership was able to clearly communicate assumptions, uncertainties, and conclusions that worked well across multiple agencies and stakeholders. "Essentially, they adopted a communication strategy consistent with what Dr. Reed recommended in a prior panel, which is, 'State your assumptions. State your uncertainties. Rely on probabilities. Then reach conclusions.' That's my recommendation for coordination," he said.

Jon Hortness noted that in the Great Lakes, the federal agencies have coordinated local lake partnerships that include membership from each of the states. These local lake partnerships are charged with identification of local needs and to generate a list of priorities, goals, and strategies to achieve those goals. Then, when federal agencies undertake their funding processes and review the local needs, while not all of the priorities receive resources – the decisions are informed by the local needs. "That's one mechanism that has worked fairly well in most of the states, although I wouldn't say it's worked well

[156] Klamath Basin Water Issues. https://klamathrestoration.gov/

in all," he said. "Each of the states has their own partnership. Some are very engaged and have meetings like this annually; they talk about priorities and they talk about needs. Others aren't quite as engaged, aren't quite as functioning well. It's hit or miss on how that works, but I think in the Lakes where it works well, it does work really well."

Carl Wilcox noted that in the California Delta there is an immense amount of effort to coordinate among the state and federal agencies that are involved in management of the state and federal water projects. Throughout the drought – managers have intensified efforts to coordinate and in some cases have met weekly. On the science side, the Interagency Ecological Program (IEP)[157] has gradually started to define better decision-making processes through annual and multi-year work plans. Through the Collaborative Science and Adaptive Management Program (CSAMP),[158] seeks to facilitate collaboration on priorities linked to Biological Opinions (BiOps). While there is a lot of uncertainty in the system – there are some phenomena that are well understood. For example, salmon survival is low in the Delta from the San Joaquin system, and rather than continuing to study it, perhaps our resources should be focused on constructing a science plan that would assess the impact of different management actions. The Delta Smelt Resiliency Strategy[159] is a good example of a concrete set of actions which address a suite of stressors that can be assessed over time. "In my experience, working in the Delta with the Bay Delta Conservation Plan, there are lots of ideas, but never any actions to take," he said. "Now, we're confronted with the need to take actions and do things to see if they work and what their affecting. It's not perfect, but at some point you have to start doing things and moving along."

Jayantha Obeysekera noted that in the Everglades, there was a cost-share agreement between the USACE and the Water Management District that helped enforce coordination across agencies. Again, the South Florida Ecosystem Restoration Task Force has legislative authority, which provided the 14 State, federal, tribal, and local agencies the obligation to coordinate science, adaptive management, and restoration implementation.[160] Independent peer-review from the National Academy of Sciences was also fundamental, as well as stakeholder engagement provided by the Water Resources Advisory Commission that gives local and regional interests the opportunity to offer input. In general, having multiple ways of coordinating efforts in science enterprises is valuable in complex systems.

Dave Wegner says that adaptive management is starting to become understood in Congress (about 28 bills have adaptive management embedded within the legislation). "Adaptive management, if done correctly, can become a force to help managers make better decisions," he said. "It can be a force so that science is included in the decision process. It needs to continue to be nurtured and managed along the way. I think that's the challenge that all of us are faced with here. I would say it's even more important, because of the issue of climate change." For large ecosystem enterprises, adaptive management could be the mechanism that provides members of Congress the cover needed in order to invest in these systems. In the example of the Klamath Dam Removal EIS undertaking, while the team did a great job of bringing together a vast amount of information – it was not coordinated well with congress along the way; so there was no appetite to pass legislation to implement a settlement agreement (which is why the current effort does not depend on congressional approval, instead it is

[157] Interagency Ecological Program. Department Water Resources. http://www.water.ca.gov/iep/
[158] Collaborative Science and Adaptive Management Program (CSAMP). Delta Stewardship Council. http://deltacouncil.ca.gov/docs/collaborative-science-and-adaptive-management-program-csamp
[159] DELTA STEWARDSHIP COUNCIL: Update on the Delta smelt resiliency strategy. Maven's Notebook. Oct 2016. https://mavensnotebook.com/2016/10/12/delta-stewardship-council-update-on-the-delta-smelt-resiliency-strategy/
[160] South Florida Ecosystem Restoration Task Force. http://evergladesrestoration.gov/content/tf.html

undergoing a "de-licensing" process through FERC that will receive public comment).[161] It is critical to engage both sides of the aisle along the way to ensure that politicians have the right information and buy-in to the process.

Felicia Marcus noted that for the agencies that work in the California Delta, there is need for collective ownership of everyone's mission. During the drought, when individual agencies made decisions based on their unique mission – it meant that no broad objectives were met. However, there have been improvements since the 1990s where there was ClubFed/Calfed, where coordination was not as successful. During the current drought, there has been gradual improvement in cross-agency coordination. Emergency Orders enable accelerated action when there is no time to build legislation. For longer-term solutions that must deal with risk and uncertainty, it is critical to nurture relationships at the State and federal legislature. Broadly there is need to build the support across agencies and recognize all missions, critical to have rapport. "It's an issue of being able to translate into real accessible language what you're trying to do, why, and why doing it this way might actually yield result and end the endless rhetorical badminton that can characterize these issues," she said. "A lack of clarity is your worst enemy when you're trying to convey that we should be doing something either risky or different, in the context of a legislator or a regulator."

Judah Grossman at The Nature Conservancy asked the following question,
Question: How can we introduce "permission to fail" into agency decision making?

Felicia Marcus talked about her effort to create an awards program for taking risk at EPA. It had to be a calculated risk that was well-thought out, and then failed. There weren't any participants, and over time – was able to educate managers on the intent of the award and foster a sense of when risk-taking is a justified action within an adaptive management framework.

Richard Roos-Collins noted that it is okay to fail if thought has been put into subsequent scenarios to mitigate failure. As an example, the Waterboard in the 1990s decided to allocate water between the Mono Lake/creeks and supply water to users. Unfortunately, the Waterboard did not understand how to restore the degraded creeks that had been dry over fifty years. The Waterboard requested a plan, which resulted in a hearing - which was going nowhere. So, the Waterboard gave the parties a limited amount of time to resolve the dispute, and if not resolved – they would approve the settlement. This motivated the parties to reach agreement on a restoration plan after over 20 years of litigation.

Jayantha Obeysekera noted that it is business-as-usual to penalize people for failure, and for senior management to say, 'it's okay to fail, but we'll shoot you!' "I think it's okay to fail if you tell the decision makers all the potential up front, and ideally use all probabilities," he said. "I really like the idea of rewarding risk taking. We don't have enough."

Dave Wegner provided a case study of how to make risk-taking work. In 1994, efforts were gearing up to test some of the hypothesis that had come out of research on flow releases in the Grand Canyon and where sediment would and would not go – and began experimental high flow release that bypassed the Glen Canyon Dam. There was broad concern from variety of stakeholders; dam operators would not receive as much flow revenue for the year, water districts and users were worried that weren't able to receive their allocations, Secretary of Interior had political concerns, and environmental groups

[161] Removal of Klamath Dams Would Be Largest River Restoration in U.S. History. KQED. Oct 2016. https://ww2.kqed.org/news/2016/10/24/removal-of-klamath-dams-would-be-largest-river-restoration-in-u-s-history/

threatened lawsuits. So, they reframed how the science would be undertaken, communicated it to the press about the calculated risk - or how they had characterized the general parameters for the action and potential impacts, and it is part of the adaptive management plan for bank creation. "Climate change is likely going to throw all that in a whole different perspective because of changing water temperatures, we have exotic species coming in, and a whole variety of other things going on in the reservoir. The fact is that we had to take a risk, and that risk resulted in some results that have been used in other dams and other places around the country and around the world. Adaptive management is a process. You learn from it and you move forward with it."

Question: "Modular" Adaptive Management

Dave Wegner commented that compartmentalizing risk, or structuring risk within modules. The Grand Canyon Protection Act was a piece of legislation that that brought together various components that had been developed over time with bi-partisan support from the ground-up. In the 2007 NEPA compliance, high-flow experiments are now recognized legally. It is critical to understand who is making the decisions and what their risk threshold is, and then integrate various components**. "**It's figuring out who is making the decisions, understanding how far you can push them along this line of decisions, and then working to get there, and then building on the next as you go along," he said.

Jayantha Obeysekera emphasized the value of "dynamic adaptive policy pathways"[162] which is becoming an alternative to robust decision making in order to deal with climate change. "The idea is that you make short-term commitments, but have a framework for shifting those policies or actions along the way at some point in time," he said. "Those short-term solutions may hit a tipping point, but you have the framework to shift to another action." The Dutch do this well with an optimization model that incorporates uncertainties related to climate change, land use, cause-effect relations, and policy efficacy, to identify the most promising pathways. An Integrated Assessment Meta Model provides an ensemble of possible futures and candidate pathways.[163] The value of this approach is that it ensures short-term actions do not preclude long-term options.

From an investment point view, given that agencies and stakeholders have limited time and money, Richard Roos-Collins noted that a modular approach understands which issue is best dealt by adaptive management (or greatest uncertainty) versus what can be resolved in the initial decision. In the Roanoke example, there were significant threatened and endangered anadromous populations in the systems, but USFWS and NMFs agreed that the by-pass flow, fish passage, and certain other issues could be resolved in the settlement without the need for adaptive management. This ensured that there were funds available for investments in the areas with the least understanding – i.e. the long-term relationship between flows and downstream riparian restoration.

In terms of modularity, Carl Wilcox noted that there a number of actions that are called for within the biological opinions for thestate and federal projects (CVP, SWP); there are 82 actions in the NMFs BiOps for winter-run/spring-run, steelhead, and green sturgeon – and not many have been evaluated in terms of their efficacy or feasibility. The CDFW permit for the SWP hinge on restoration in the Delta, and there hasn't been much progress. This means that it is impossible to know if the permit requirement actually

[162] Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. Global Environmental Change, 23(2), 485-498. http://www.sciencedirect.com/science/article/pii/S095937801200146X

[163] Kwakkel, J.H., Haasnoot, M. & Walker, W.E. (2015). Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world. Climatic Change 132: 373. doi:10.1007/s10584-014-1210-4 http://link.springer.com/article/10.1007/s10584-014-1210-4

works. While the Yolo Bypass Restoration experiment is a good example of coordinated action with up-stream diverters and various agencies that seems to have had a positive response in food web productivity, it is not directly required by the permit. "I think that points to the need to actually do things as opposed to just study, and study, and study," he said. "We're never going to resolve those necessarily, unless we take actions to test the underlying assumptions about them. I think it's important to go back … and simplify things to, 'What are the real issues you're confronted with? What is your objective here and how do you do something about it?' And test that as you go forward."

Question: Legislative and executive tools.

Jessica Law asked for some examples of program-specific legislation (such as the Water Resources Development Act, Task Forces) that have been used to do the types of science needed to support the various ecosystem programs. Where the tools are essential?

Jon Hortness noted that for the Great Lakes, the Great Lakes Water Quality Agreement[164] with Canada drives most of the work that happens. Periodic stakeholder engagement ensured that the effort continues to be relevant locally and at the congressional level. "They have a concerted effort every year to go to the Hill, meet with their congressmen, talk about Great Lakes issues, and work through that," he said. "It's an ongoing, constant strategic effort by the stakes and stakeholders to do that."

Carl Wilcox noted that the California Water Action Plan[165] has simply and clearly provided a guide for CDFW and other agencies on what needs to be done on water statewide; how to run grant programs and where to focus on issues. CDFW is reviewing the Water Quality Control Plans for the Bay-Delta, which will decide how much water is available for the Bay-Delta ecosystem balanced with the State's economy and people's lives. Other actions like the Executive Orders on the drought facilitated agency ability to take fast action to manage water. It is important to bear in mind that many of these actions have been supported by the current administration – and it will be important to carry them forward. As a cautionary example, there was a lack of commitment to CalFED. "The Delta Reform Act provides good guidance, although there's some ambiguity associated with it on how we should be moving forward and what our objectives are," he said. "There are 2 basic objectives and 1 modifier, protecting the Delta as place. It's pretty clear what we're supposed to be about. We may not agree about what water supply reliability means necessarily or what ecosystem restoration means. I think we have these two things out there that we're trying to achieve, and ultimately, it's coming to some resolution on decisions. Without that clear legislative guidance, it would be even more difficult."

Dave Wegner emphasized the need to know your tools; there are certain legislative processes that provide the opportunity to incorporate adaptive management (the Water Resources Development Act (WRDA)[166]) and authorization. Under the incoming administration, there will likely be new initiatives to deal with drought (Feinstein) – be prepared to join those initiatives. Broadly, there will be other opportunities that are unexpected; the Deepwater Horizon spill did bring some benefits, and enterprises need to be nimble enough to use disasters to call attention from the federal agencies for a new approach (Hurricane Sandy enabled the USACE to develop a new approach that incorporated climate change). For California, it could be floods and droughts – how can these situations be used to gain knowledge and respond in way that better leverages funding and capacity. "We have to make sure as a group of scientists and managers that we use these opportunities, not to just throw money at a problem, but also to use it to gain knowledge, so that we can do a better job, especially as climate

[164] Great Lakes Water Quality Agreement (GLWQA). US EPA. https://www.epa.gov/glwqa
[165] California Water Action Plan. California Natural Resources Agency. http://resources.ca.gov/california_water_action_plan/
[166] Water Resources Development Act. https://en.wikipedia.org/wiki/Water_Resources_Development_Act

change is staring us down," he said. "We have to be able to leverage our dollars, we have to be able to leverage our capacity - our intellectual human infrastructure, to do the best we can with the now limited dollars that we are getting from the federal entities."

Felicia Marcus emphasized the need for credible backstop authorities. For example, the Sustainable Groundwater Management Act (SGMA) was structured in a way that enabled the locals to be the responsible through the creation of Groundwater Sustainability Agencies (GSAs); if, however the GSAs are unable to form plan, then the State will come in and be the backstop – it is important to have durability over time. "Coming up with a credible backstop that gives you things short of the nuclear option to make the point and feel a pinch and keep moving, I think, is a really important tool and construct to put into any kind of adaptive management framework that's going to have durability over anything over a year," she said. "The players will change and you need to have something set in stone where there's credible action on the part of somebody."

Panel 3: Funding and Resource Allocation

Panel 3 Presentation: Program development and resource allocation related to the Gulf Coast Ecosystem Restoration Council

Dr. Alyssa Dausman, Science Director for the Gulf Coast Ecosystem Restoration Council

Dr. Alyssa Dausman began by reminding everyone that the Deepwater Horizon (DWH) oil spill happened six years ago. Eleven lives were lost, a tragedy for those families as well as a tragedy to the ecosystem.

Figure 93, Slide 3

When environmental contamination occurs, the Natural Resources Damages Assessment (NRDA)[167] identifies responsible parties who pay damages to restore the wildlife habitat and other resources that were injured as a result of the spill, as if the spill had not occurred. There are Clean Water Act fines so the EPA is involved, and there are criminal and civil penalties that are assessed that typically go to the oil spill liability trust fund.

[167] NOAA. What is a Natural Resource Damage Assessment? http://oceanservice.noaa.gov/facts/nrda.html

Figure 94, Slide 4

In the case of the Deepwater Horizon oil spill and the gulf, the Restore Act[168] of 2012 was passed that was an amendment of 22 pages to the end of the transportation bill. That Act took the civil penalties (but not the criminal penalties) when they were settled, and said, 80 percent is going to go to the Restore Act to gulf coast restoration trust fund and basically back to the gulf and the rest will go the Oil Spill Liability Trust Fund.[169] The Oil Spill Liability Trust Fund's managed by the Coast Guard. It's to be used for other future oil spills where ever they occur or especially if they can't find a responsible party.

Figure 95, 5

Dr. Dausman then presented a chart showing the funding and how it is distributed. The civil penalties that were redirected are at the bottom on the left. The responsible parties that were assessed criminal penalties are listed at the top. Dr. Dausman noted that criminal penalties were assessed against not only BP, but the owners of the platform and others that were responsible for a part of the disaster. The criminal penalties were distributed via plea agreements as per the

[168] About the RESTORE Act. RESTORETHEGULF.GOV. https://www.restorethegulf.gov/history/about-restore-act
[169] Oil Spill Liability Trust Fund. U.S. Coast Guard. https://www.uscg.mil/npfc/About_NPFC/osltf.asp

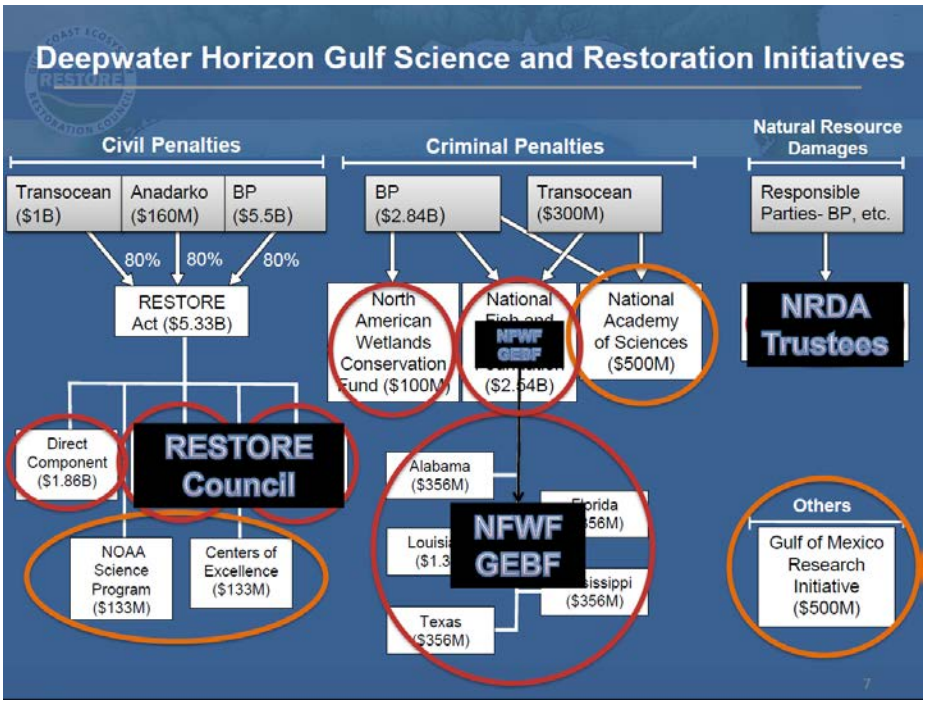


Figure 97, Slide 7

courts. The Natural Resource Damage Assessment is shown at the far left, which is where the majority of the money is going.

Over $8 billion was set aside with over half of that is going to the state of Louisiana, which was impacted the most from the spill. The Gulf of Mexico Research Initiative[170] was a voluntary initiative where BP put $500 million out for an RFP process to do research as a result of the spill. The Restore Act created five 'buckets' of funding; the Restore Council has two buckets: the council component is bucket two and it oversees the spill impact component bucket three, which is money that goes to the state for restoration. There are other restoration pots of funding, such as for science. All the pots have different hooks and tweaks associated with them, so you can't just pull money from a pot because there are missions associated with each.

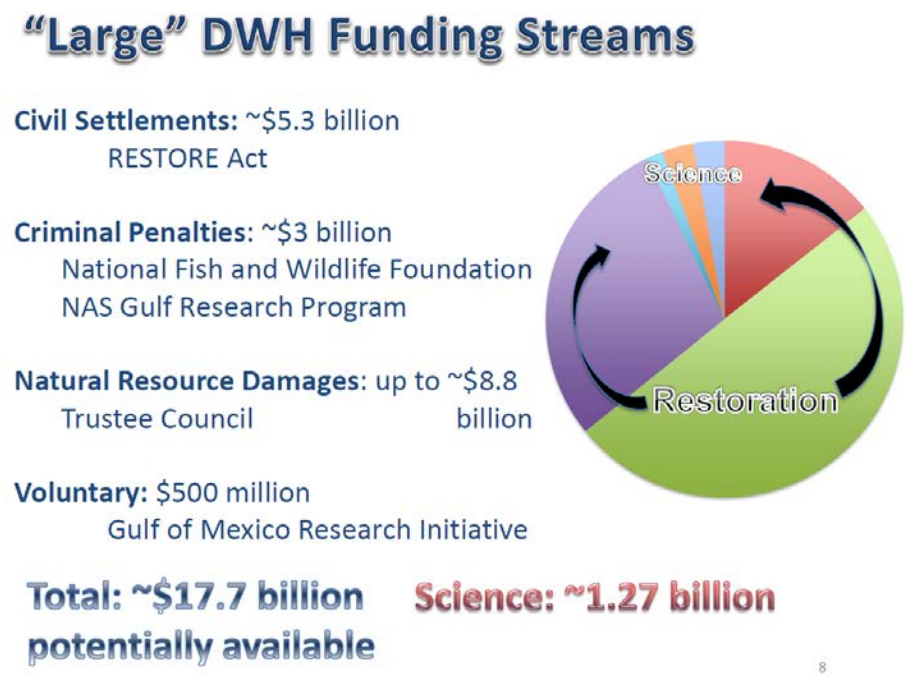


Figure 98, Slide 8

The big restoration players are the Restore Council, the NRDA Trustee council, and the Gulf Environmental Benefit Fund, which pays money and sends it to the Gulf states. The Deepwater Horizon Funding stream makes nearly $18 billion available. About $1.3 billion of that is going towards science but not necessarily science to support restoration; some of that is for exploratory research.

[170] Gulf of Mexico Research Initiative (GoMRI). http://gulfresearchinitiative.org/

Figure 99, Slide 11

The Restore Council is an independent federal entity established by the Act in 2013 that doesn't fall under the Department of Interior or the Department of Commerce. The Council is comprised of the Governors of the Gulf states (Alabama, Florida, Louisiana, Mississippi and Texas); the Secretaries of Agriculture, Army, Commerce, Homeland Security, Interior, and Administrator of the EPA. The chair of the council is selected by the state, recommended by the president, and the president appoints. If somebody's not happy with the chair, that can be changed by the state. The states each get one vote and all of the feds together get one vote, so it's six votes even though there are eleven members.

The Restore Council is charged with restoring the resources that were injured by the spill without regard to geographic location. There are four priority criteria specified in the Act for selecting projects and programs: The greatest contribution to restoring and protecting resources; large-scale; contained in existing restoration plans or programs; and restore long-term resilience to areas most impacted by the Deepwater Horizon oil spill.

Dr. Dausman pointed out that one of the criteria is contained in existing restoration plans, and recently the Council announced they were giving money for two projects proposed in the Louisiana Master Plan.

Another important component in the Restore Act is that all of the projects and programs are to be based on the best available science; the Act contains a definition for what is; the Council has some commitments, goals, and objectives that they set forth in their comprehensive plan.

Figure 100, Slide 12

The Restore Council issued their first comprehensive plan was in 2013; the plan has just been updated. During the public comment phase, they received over 65,000 public comments. The Council is expected to finalize the plan in December of 2016. The Council's plan is not as detailed as the Louisiana Coastal Master Plan; they don't select projects and programs. The plan provides the framework for how things are prioritized and how commitments are made; they make some science commitments in the comprehensive plan. One of the commitments they make is a commitment to implement or improve science-based adaptive management.

There are a number of overarching challenges, none of these are particularly new, noted Dr. Dausman. There are issues with coordinating across numerous programs with different missions, and no matter how much money there is, it's never enough and it is a balancing act between science wants and needs. It is helpful to stress the difference between *useful* science and *usable* science – it is important to have science that is usable for managers. In addition, decision-makers must be educated on why science investments are important for the future and where there are win-win scenarios.

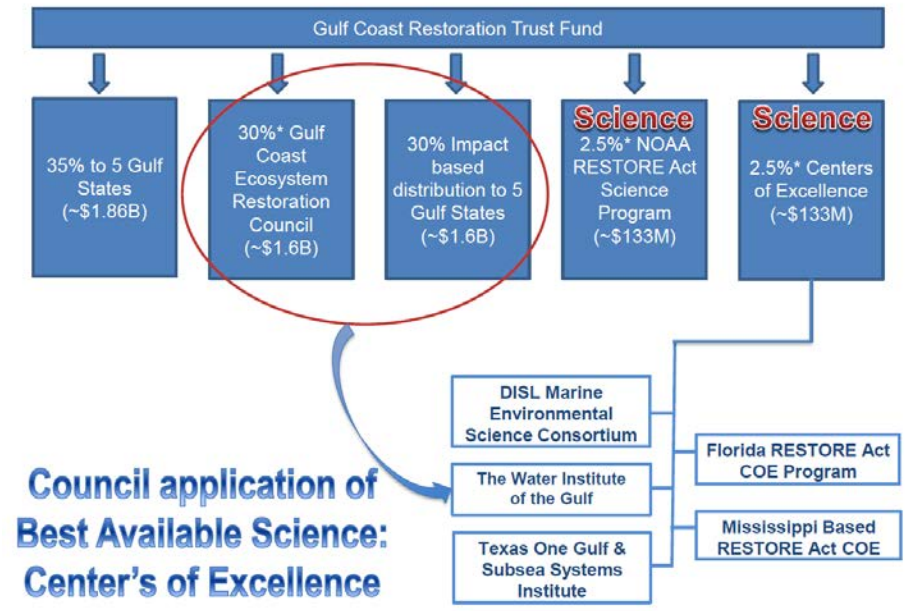


Figure 101, Slide 16

The general Council philosophy, being a federal agency, is that they are very small, lean and mean. They operate on less than 5 percent overhead, and try to avoid duplication of

efforts or support processes that aren't working. A central question that they ask is how can they change business so that they are being more effective with the money that they have and build on existing capacities? The Restore Council invests in best available science. The Centers of Excellence which exist in each of the Gulf states represent a "capacity nexus" as each of the Centers provide an essential line to academics and other universities.

Figure 102, Slide 17

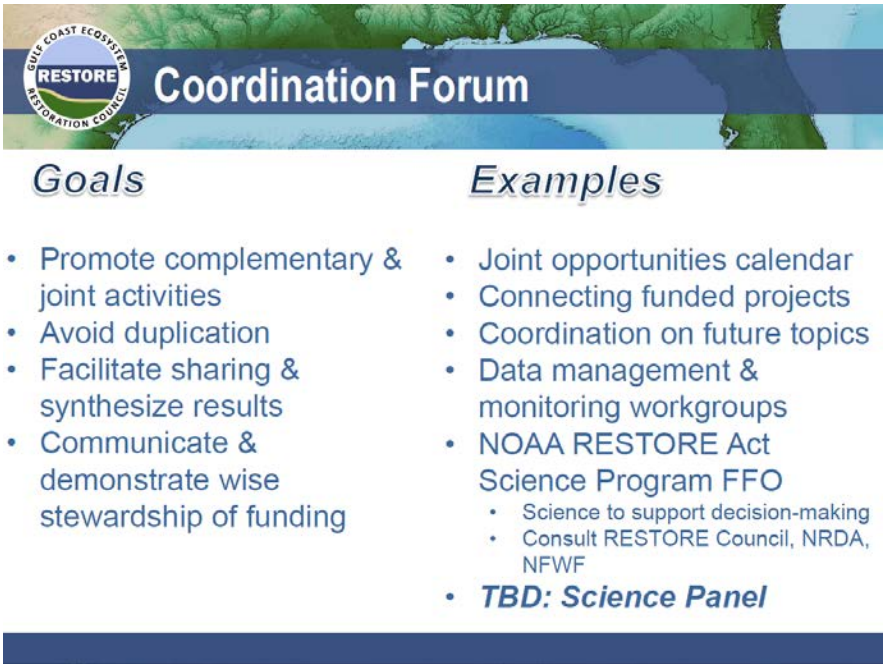


Figure 103, Slide 19

They have started implementing some coordination structures. On the state and federal side, there are similar efforts to leverage "management coordination structures" through workgroups comprised of relevant members from different agencies on subjects like monitoring. To reach the broader stakeholder interests, a Community of Practice on Monitoring was created to include NGO input.

There is also a Science and Restoration Coordination Forum that NOAA Science Program runs; the goals of the coordination forum are to promote complementary and joint activities, avoid duplication, facilitate sharing and synthesize results, and to communicate and demonstrate wise stewardship of funding. They have been working to get different groups to start to work together; for example, the Natural Resource Damage Assessment (NRDA)[171] program did a FFO to fund science tools for management to help managers make better

[171] Natural Resource Damage Assessment (NRDA). http://eli-ocean.org/gulf/nrda/

decisions. They are also interested in a Science Review Panel that could be used by other DWH settlement recipients.

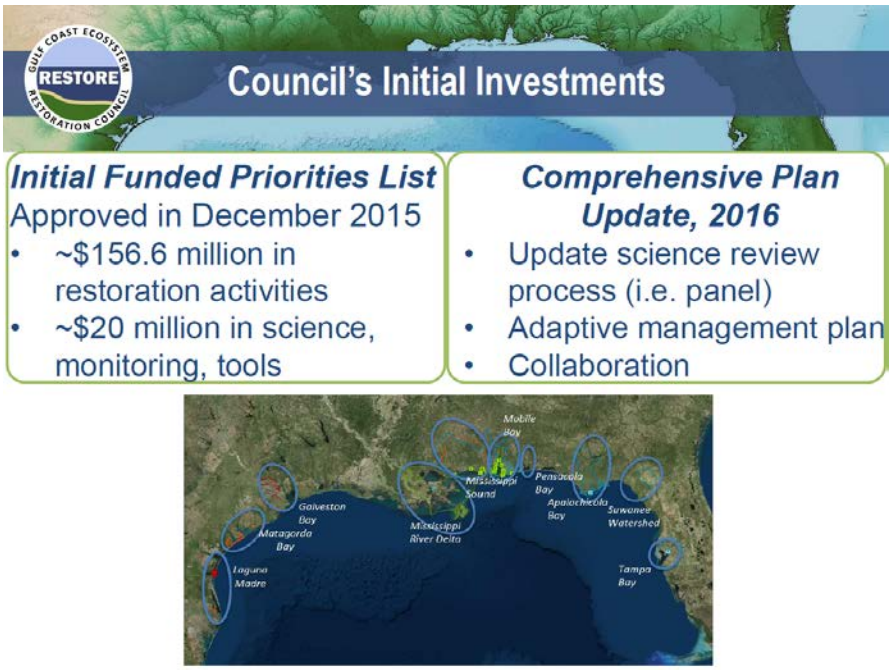


Figure 104, Slide 20

With the Council's initial investment in December of 2015, they approved over $150 million for restoration activities, and $20 million for science monitoring and tools.

In the comprehensive plan update that the Council will be voting on in December, the science review process was updated to incorporate the science review panels, and committing to an adaptive management plan.

In terms of collaboration and in the spirit of moving from cooperation to coordination to collaboration, the council is sponsoring some workshops next year.

Dr. Dausman then concluded with three main points; building on capacity, balancing wants and needs, and moving from coordination to collaboration.

Figure 105, Slide 22

Panel 3 Discussion

Panelists

Alyssa Dausman, Science Director, Restore the Gulf
Peter Goodwin, Former Delta Lead Scientist, Director of Center for Ecohydraulics Research, University of Idaho
Stephanie Johnson, Senior Staff Officer, National Academy of Sciences
Scott Phillips, USGS Chesapeake Coordinator
Denise Reed, Chief Scientist, Water Institute of the Gulf
Lisa Wainger, Professor, University of Maryland
Josh Collins, Lead Scientist, San Francisco Estuary Institute (SFEI)

Erin Foresman introduced the panelists, and began with several observations from Day 1 of the workshop: funding levels vary substantially for each of the six systems, funding for science is difficult to distinguish from program-wide investments, and when able to – it is generally a very small portion (~7 percent). There was agreement for need for long-term funding for science, and some debate on differences between "compliance" monitoring, long-term monitoring, assessment, and investigative science.

Question and Answer

Question: Proven strategies to fund science

Josh Collins began with the observation that as a non-governmental organization, he thinks about fundraising for basic and applied science. Applied science is in the service of place-based ecosystem management. Given the partners in research, which are generally state/federal agencies and academic partners, the research that is undertaken is in response to carefully constructed questions. After that, generally seeking to fundraise for capacity building (always entrepreneurial - public, private, philanthropic and usually 3-5 year contracts or grants) and development of tools and hiring staff. Generally dynamic. "Where I am, capacity building is always entrepreneurial," he said. "It's getting the money where ever you can. It's government, private sector, philosophic grants, and contracts. It's 2 years, 3 years, 5 years off. You hire people, you get seed money, you build things, you get going. Sometimes it takes, sometimes it doesn't. Base funding is the idea that we've got something that seems to be useful, it's usable, it's getting used, it's being used by multiple agencies. No one of them can fund it; they don't want to fund each other. How do we get a collective body of money that will service all the clients, agencies, our clientele, or partners through this program application of science? That is almost always in my experience hinged to permitting." As a result, the tools are built for permit compliance. Science funding is built into permit compliance.

Peter Goodwin provided some science funding lessons learned from other scientific disciplines. The National Science Board which oversees the National Science Foundation produces a periodic report, the National Science and Engineering Indicators[172], and it provides some insights on historical science investments. In 1980s, most of the funding went to the National Institute for Health (NIH). Part of the reason why is that they went to Congress and said they cured cancer. This was a compelling statement (or brand), and they received support. As another example, in the 1990s, a lot of funding went to support the Laser Interferometer Gravitational-Wave Observatory (LIGO) – which was set up to test the hypothesis about space-time fabric of the universe. It failed, and so the physics community went back collectively to congress and asked for more sensitive equipment – they were successful and gravitational waves were discovered. It captured national attention and pride.

[172] National Science and Engineering Indicators. https://www.nsf.gov/statistics/2016/nsb20161/#/

In general, there are some common traits that successful science investment efforts share; first there is a "big vision" (moon, cancer, gravity); second, the scientific community comes together and speaks with one voice; third, there is a champion on the political side (Rockefeller has been a great advocate of science), as well as a champion from the different agencies (chairs or secretaries). Fourth, consistent pressure to fund scientific research (Texas Universities), and fifth, need a proof of concept. Finally, need effective communication (NASA and Mars Rover).

In terms of private funding - Lisa Wainger provided some thoughts on funding from three motivational angles: legal, economic, and social-institutional. "In terms of the legal structures to motivate people to want better science, there's a basic strategy here of you give them something painful to do, unless they can demonstrate they can achieve the same performance in some other way," she said. "You motivate them to build a science that will let them find a more innovative solution." As an example of legal and economic motivation, in the Chesapeake Bay – a dam operator, Exelon Power, was notified that it needed to renew its permit on the Susquehanna River. Given that the dam stopped holding sediment, the operator started to fund research on what could be the most cost-effective ways to get in compliance. Similar examples for science investment exist through requesting Natural Resources Damages Assessment (NRDA).[173] On the restoration side, it important to create the ability to "pay for performance" which brings science into the funding model. As an example, in the Bay there is an impervious surface tax, or a"Rain Tax"/stormwater management fee that is a flat fee per property owner or on surface square footage.[174] Entities can avoid the fee if they are able to demonstrate that they have reduced their stormwater runoff flow. On the social-institutional side, behavioral motivations take many forms from incentives to threats. As an example, the Delmarva Land and Litter Challenge[175] brings together the medium-sized CAFOs which are motivated to find cost-effective solutions.

Question: Funding for long-term monitoring versus academic/investigative science

"I do think that we've been challenged in identifying longer-term sources and money to fund investigative, innovative, idea-driven science," said Dr. Reed. "Perhaps the challenge there is how that produces something which is usable in the end." Readiness is critical, both in ability to respond to disasters (such as Katrina, Hurricane Sandy, DWH spill) and in linking research interests to response needs. These are areas that are sometimes outside of the traditional academic funding avenues. There is great interest in "coastal green infrastructure" and the question of whether coastal restoration can actually mitigate sea-level rise/storm-surges risks. The attractiveness is that in general it's much cheaper than grey infrastructure – but need to characterize efficacy/reliability. Research community should be ready and able to respond. Another pot of money includes the National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund (GEBF)[176] has $1.2 billion in funds that needs to be spent on river diversions or barrier island restoration – as they start to draw down those funds, they have agreed to set aside small portion, or percentage, for adaptive management. This is innovative in that they are trying to think about how can set aside specific money for research needs.

Josh Collins cautioned that "repackaging" projects in a way that is more marketable (ie green infrastructure) plays upon concerns and interests, which may be over-promising the benefits before

[173] NOAA. What is a Natural Resource Damage Assessment? http://oceanservice.noaa.gov/facts/nrda.html
[174] The Facts About Polluted Runoff and Maryland's Stormwater Utility Fees. Chesapeake Bay Foundation. http://www.cbf.org/about-cbf/offices-operations/annapolis-md/the-issues/annapolis-maryland/the-issues/stormwater-fee#rain-tax
[175] 'Land and Litter' group proposes plan for Delmarva poultry manure. Chesapeake Bay News. http://www.chesapeakebay.net/blog/post/land_and_litter_group_proposes_plan_for_delmarva_poultry_manure
[176] National Fish and Wildlife Foundation (NFWF). Gulf Environment Benefit Fund (GEBF). http://www.nfwf.org/gulf/Pages/home.aspx

there is a robust, science-based understanding what will happen. It is important to have a multi-disciplinary assessment of projects before they go forward, otherwise failure can result in the entire effort being thrown out.

In addition, Collins noted there is great need to invest in information technology, or data management, as a critical part of science. For example, there are agencies that need to conduct quality assurance on evidentiary data– but are unable to do this because of the costs associated with QA/QC. Another example includes data that multiple agencies need to use and share, but there is not fiduciary mechanism to pool resources to develop and maintain a data platform. The recently passed AB 1755 The Open and Transparent Water Data Act,[177] for example, is housed within one agency (DWR), and that could mean that not all agencies will exactly trust the information that comes out of it. Our goal is to use technology in a cross-program, cross-agency way – and need to overcome the challenge of individual funding. Somehow we have to keep apace of technological invention and progress and pool resources development and maintenance. "Around information technology, there is a huge opportunity to be innovative about marketing, about paying for tools, how to keep them useful, and what is the fiduciary mechanism for both accounting for the cost and who is paying for what, and making sure there's QA/QC of the data being used," he said. "The innovative possibilities are there, but accountability is yet to be proven."

Erin Foresman agreed and noted the challenge in the California Delta in transitioning a monitoring system that is using technologies and equipment that are over 20 years old – and there is a big need to evolve the program.

Question: How do we evolve our science programs to support resource system goals? What are methods for making science programs efficient and strategic?

Stephanie Johnson noted that National Academy of Sciences, Engineering, and Medicine (NAS)[178] was chartered by the government to be an independent, non-governmental organization to provide scientific advice to the nation. As an example, NAS can provide valuable outside, independent review of programs which is useful to show funders a credible evaluation of the program over time. As an example, NAS provided a review of a 2002 Park Service Everglades science program, and Congress was interested in cutting funding for it. The review proved to be critical – it noted that the science program needed to incorporate peer review and stakeholder engagement. Overall, however, the evaluation found that the Park Service science program had value and was worth investing in, even if some improvements to the program were needed, because the Park Service ultimately held the responsibility of being the steward of that land and needed this science to support their stewardship responsibilities. In the Everglades, NAS has provided a bi-annual review of the program since 2004, and it has provided a critical long-term perspective through an external committee. These "outsider insights" can help overcome conflicts, for example scientific uncertainty was proving to be a barrier in restoration activities. The external committee recognized these stakeholder conflicts, and were able to recommend a series of incremental steps using science to address those uncertainties and resolve the problem.

Stephanie also noted that building capacity in science communication is important – and collectively, all of the science enterprises should think about how to elevate and advance scientific communication. For example, in the Everglades when funding for a monitoring program was substantially reduced, the scientists were upset while the managers were pleased with the outcome. "There was this conflict

[177] AB-1755 The Open and Transparent Water Data Act. California Legislative Information. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1755

[178] National Academy of Sciences, Engineering, and Medicine (NAS). http://www.nationalacademies.org/

because there was a lack of communication," she said. "The independent panel tried to get in the midst of it, and they couldn't even understand what the cost versus the benefits of that cut were because the scientists felt like monitoring is inherently valuable. They were not able to articulate the value of what was being cut, and what was being lost." NAS understands that the value of building science communication skills be built at all levels of an enterprise – and has developed an award program for science communicators.

Scott Phillips noted that strategically, it's important to be ready for changes that expect to occur. For example, preparing information for political administration transitions that clearly articulates issues, the context and planning efforts, and the subsequent resource needs is critical. In the Chesapeake Bay, there was a need for additional monitoring stations in the upper watershed in order to detect performance changes after mitigation activities were initiated there. The program sought an independent review which evaluated tradeoffs and eventually provided information for an improved plan which included monitoring equipment in the upper watershed. When managers were able to understand the value of estuary monitoring and the roll the upper watershed played in the basin from the report, the rational was provided for funding and resources.

Lisa Wainger noted that an economic perspective provides the connection between information needed to inform managers on what actions are most effective in meeting a water quality objective. Valuation of ecosystem services (green versus gray infrastructure) is a common question, and it is critical to identify the types of research that are needed to provide the scientific basis of relative efficacy. "People come to me a lot and say, 'We want to value all of the ecosystem services of the green infrastructure,'" she said. "I say, 'Who's decisions are you trying to influence?' They usually say, 'Private property owners.' I say, 'I think you might be more successful if you showed that it worked as well as the gray infrastructure and that you're not asking people to take a bigger risk with green.' That's really what prevents them. Of course they can see it's prettier, and they'd rather have the birds than the concrete. It's the risk that's driving that decision. Alternatively, if you're trying to influence the people who might be providing grant money, then they do want to know social benefit. They want to know what society is getting back for this investment of public dollars."

In the Chesapeake Bay Program, the governance structure includes an independent review board called Scientific and Technical Advisor Committee (STAC),[179] which is comprised of 36 independent multi-disciplinary scientists from a variety of agencies, and they are tasked with evaluating long-term programmatic risks like climate change.

Denise Reed noted that STAC has an innovative structure in that while it is independent, it at the same time also includes "insider" scientists from the same agencies that are working on the program. This structure could have benefits in adapting to change. Stefani Johnson agreed that having knowledgeable reviewers helps when detailed input is needed. In parallel, it is complimentary to have NAS panels which can provide high-level strategic review which can identify support systems need to obtain goals. Peter Goodwin noted that in the Delta, the National Research Council (NRC) will periodically provide an external, heavy-hitting review - and the Delta Independent Science Board (ISB) provides a closely-engaged review panel. Josh Collins noted that when consider adaptive management, it's important to revise goals as needed – and science helps establish goals and the methods to measure progress and revisit the goals as appropriate. This means a periodic review is critical to inform resource allocation. Erin Foresman noted that it is very challenging for the Interagency Ecological Program (IEP) re-allocate

[179] Scientific and Technical Advisor Committee (STAC). Chesapeake Bay Program. http://www.chesapeake.org/stac/

resources. Much of the program focuses on compliance monitoring and it is not necessarily available for re-allocation. Scott Phillips emphasized that when the value of both the estuarine and upper watershed monitoring was considered, they were able to find additional resources.

Question: What is the case for science funding?

Denise Reed began with the observation that science can provide the information to folks out of bind. In particular, there are approaches to identify the value of information – or narrowing the uncertainty. "When you get into the details of some of these decisions, and you're really struggling to think about the need for science, sometimes uncertainty seems to be a distraction from that. I actually think that you can turn that around. If you can describe the uncertainty around the decision, then you can actually make a case for the value of narrowing that uncertainty through science."

Peter Goodwin noted that if able to characterize the worst case scenario and consequences of what will happen if don't do anything, that makes a compelling case for doing the research. Secondly, it is possible to leverage funding. "One agency steps up, starts doing science around a certain issue and it affects a lot of other folks. Other people start contributing to that source of funding. Suddenly, you find you have a lot of different groups taking ownership and interested in those outcomes. Building the science community through leveraging different funding sources I think is also very possible."

Peter Goodwin cautions that it's dangerous to rely entirely on disaster related funding, it tends to distract from long-term system goals – a diversity of funding sources should be cultivated. Denise clarified that understanding extremes, particularly in these coastal systems, are linked to long-term goals. Peter agreed and that it is a balance that must take into account limited staff resources.

Lisa Wainger noted that the value of information can be sold as a way to save money. "Don't spend money on stuff that's not working. Find the stuff that is working. I also think you have to remind them of when you save the money. That's where communication comes back in." She noted that they have their own newspaper, the Bay Journal.

Stephanie Johnson noted that critical to be able to be accountable to the public for how well public funds are spent. "There are some systems that do that extremely well. Chesapeake Bay has a wonderful system where they have a website that the public can find out how all of the different indicators are doing. Other systems really struggle with communicating with how well they are doing. Other systems struggle to even find the money to monitor to even be able to find out how well they're doing."

Alyssa Dausman noted that NGOs and advocates have been helpful in providing a sense to the elected officials of what is important – they received 60,000 comments requesting a science review panel. It is also critical to engage and lobby DC, success is linked to targeted communications with clear messaging on how science is usable to elected officials. "I work on a lot of politicians that are on election cycles. 'If you invest in the science we're going to help your restoration project be more successful and you're going to look better. You might get reelected because you're going to look better.'"

Scott Phillips agreed and noted that science investments ultimately help decision makers do their job more effectively in two ways – 1) identifying where projects can have most benefit and 2) monitor to see whether obtained desired benefit.

Josh Collins noted that it's important to sell science to make progress on challenging technical problems, provide accountability and credibly show how using tax monies to delivering on mission and why

decisions were made in the way they were. “There are two major endeavors of our species that account for change so well that we can reverse it. One is the law. Where every decision is accounted for in writing, it is archived, and kept, and you can refer to it; it's called a case study. The other is science, where through publication we keep track of what we think is right and wrong, or likely or unlikely. Because of that accountability of ourselves through those processes, we can reverse our decisions and explain why we're reversing our decisions. That's a piece of accountability; you need science to explain why you're going to change your mind and account for that, and then get the money to keep going in a different direction.”

Question from Anitra Pawley at Department of Water Resources on how have dealt with long-term funding challenges – for much of their work, they rely on bond funding which cannot be put into an endowment funds. So, while able to do the restoration – there is no funding to do long term monitoring or management over time. Josh Collins noted that in California, it is possible to create Joint Powers Authorities (JPAs) among agencies where money can be place there and grants them fiduciary authority. In addition, JPAs are allowed to charge the agencies a subscription/membership/user fee for program they belong to. Another option is to establish a Public Service Corporations within agencies, which enable them to move money in different ways than is possible through normal budget processes. The central question is establishing who will be the fiduciary agent and what the legal options are to move money across programs.

Panel 4: Legitimacy, Co-Production, and Communication

Panel 4 Presentation: Perceptions of science in the San Francisco Bay Area

Dr. Mark Lubell, Director of the Center for Environmental Policy and Behavior, UC Davis

The focus of Mark Lubell’s presentation was the perceptions of science and political knowledge in the Delta and other estuaries he has been studying.

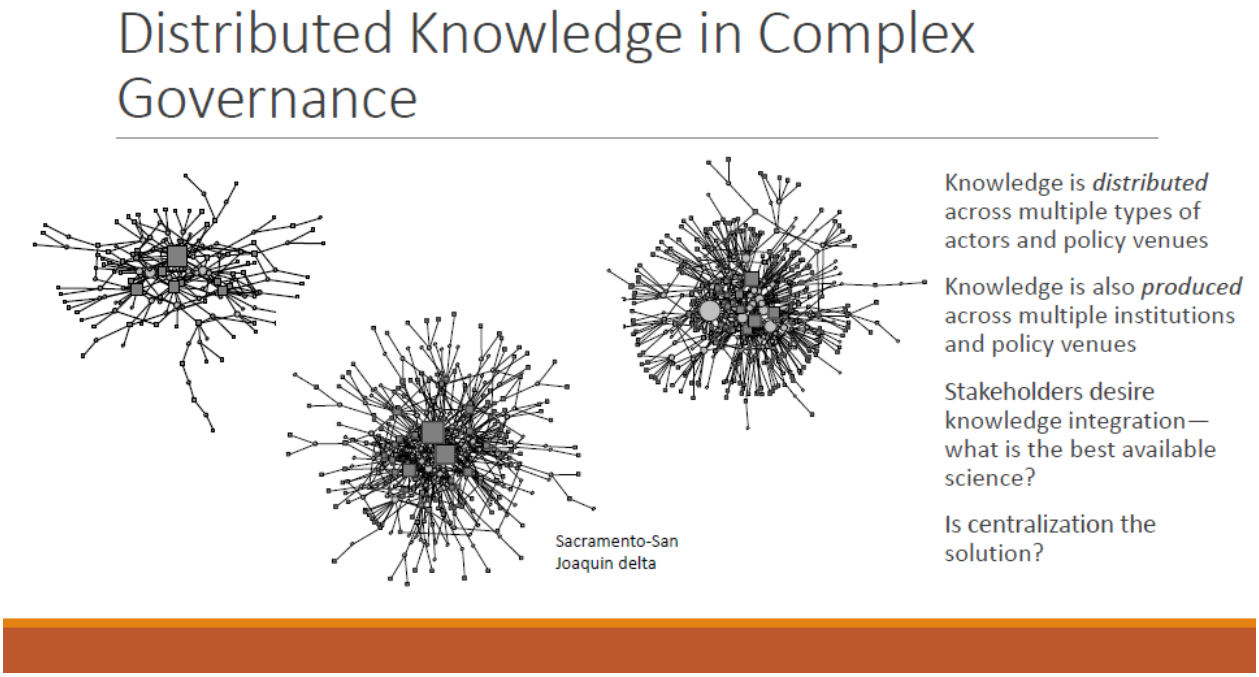


Figure 106, Slide 3

"Governance is messy," began Dr. Lubell, presenting diagrams of the structure of the networks from the Parana Delta in Argentina, the Sacramento-San Joaquin Delta and Tampa Bay. The squares represent the public policy venues in which people are interacting and the circles represent the actors. "The point of this research that we're doing is that all of the systems are messy," he said. "You won't find a large-scale or even a small-scale system that doesn't have this messy governance system that's happening."

"From the knowledge and science perspective, you have to realize that in these systems, the knowledge is distributed across these actors and venues," he said. "There are people that know things and organizations that know things across the system, and it's not usually just one place where you're going to find the scientific information or other sorts of information you need. You also have to realize is that knowledge is produced in multiple places in the system. People are doing research, either applied or basic, in all these different places in the system. The thing you have to do is figure out how to manage the knowledge across the system from a systems perspective, including trying to figure out what is the best field of science, where with all these different stakeholders, what is the best available science you have to look for?"

Dr. Lubell said that a lot of people initially will say the answer is to make the science centralized – to have one place for all of the knowledge to be held, for all of the knowledge to be produced. "That's is often a knee jerk reaction, but I want to make sure that we push back against that to some extent and realize there are probably some benefits to having the knowledge distributed across the system," he said.

He presented the diagram for the Bay Delta. "There's science being produced and knowledge being produced across these different factors in different ways," he said. "How do you integrate across them?"

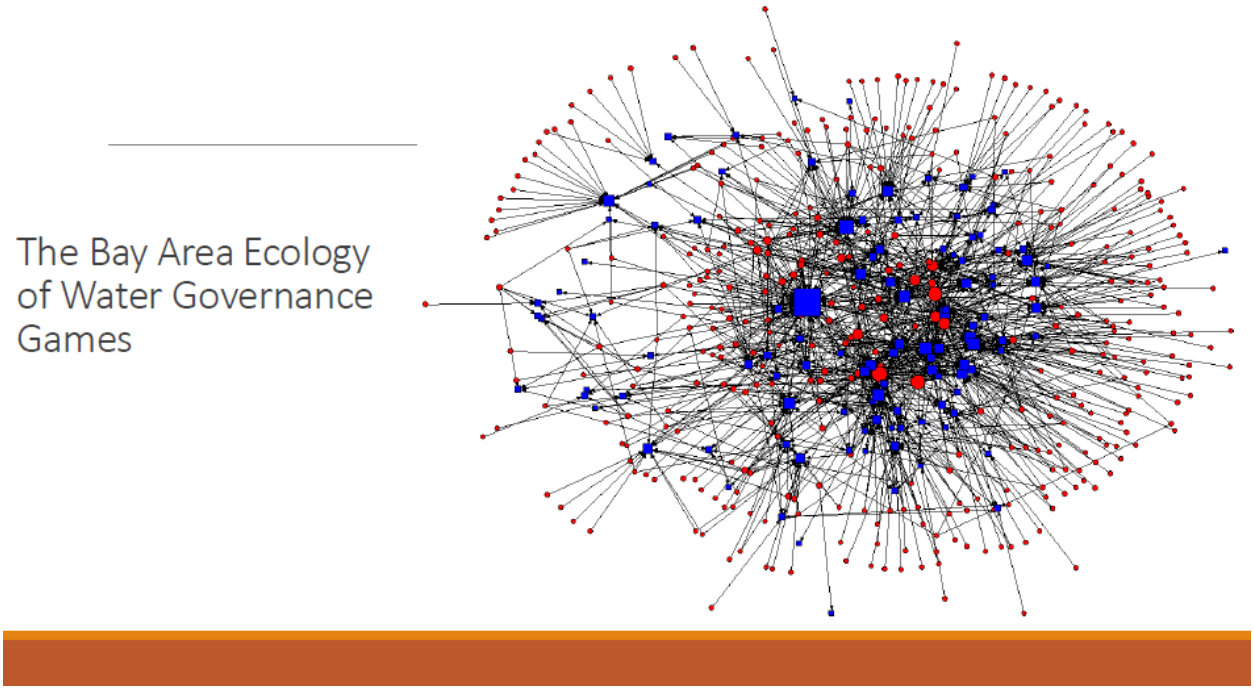


Figure 107, Slide 4

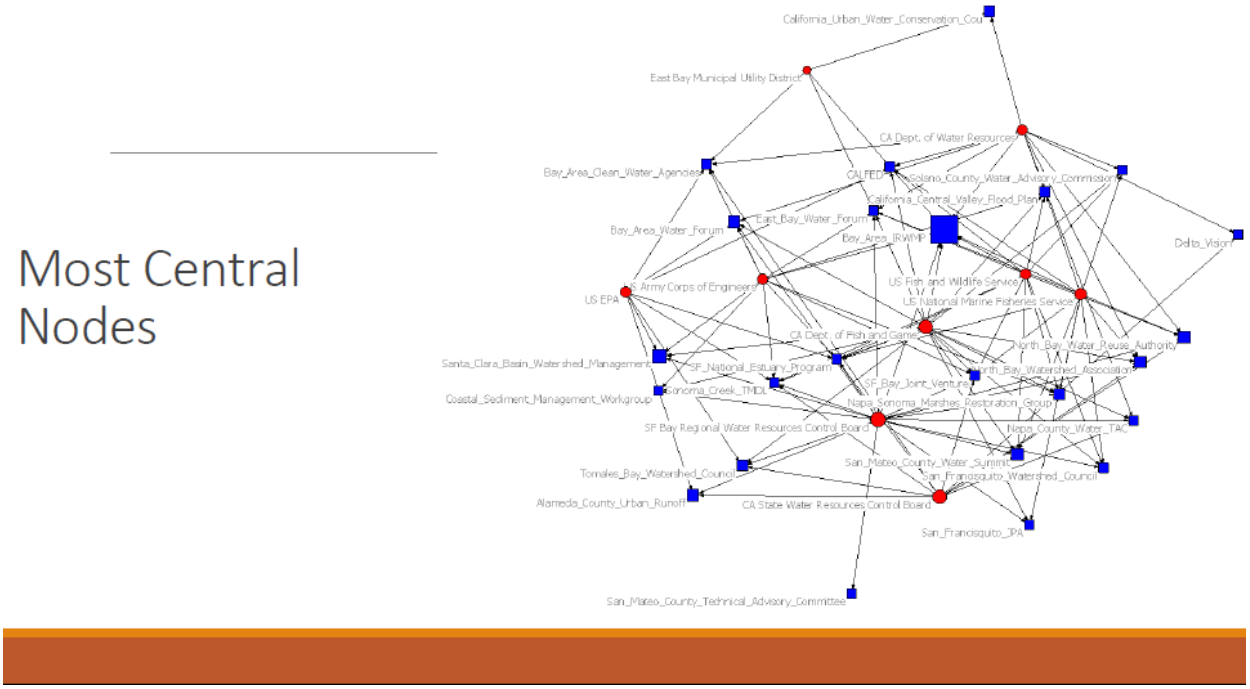


Figure 108, Slide 5

In doing his research, Dr. Lubell conducts surveys stakeholders and asks them questions about conflict and about their perceptions of science. He noted that the squares in the diagram are the venues. "We asked every stakeholder we could in Tampa Bay and Argentina and Delta and some other places, when they participated in those venues, how much conflict did they see? We asked them, within a particular

venue such as the Delta Stewardship Council or CALFED, would they say that most decisions that there are mutual gains, that there is cooperation, win-win solutions if you want? Or getting better together? Or are there trade-offs that you have to make? Is there some sort of zero sum game? That gives you an indicator of how much conflict is occurring in the system."

Perceived Policy Game Payoffs Across Sites

Site	Number of Games >2 Actors	Percent Mutual	Percent Trade-Offs	Percent Zero-Sum
Parana 2010	26	51.5%	38.3%	10.1%
Parana 2012	13	58.8%	35.8%	6.4%
Tampa 2012	46	68.2%	20.6%	11.1%
California 2012	52	51.9%	24.1%	24.0%

Figure 109, Slide 7

He then presented some of the results from the surveys. In terms of Tampa versus California, how much cooperation is there? "If you look in Tampa, 68 percent of the people that answered these surveys are saying that there's mutual gains compared to only 51 percent in California; 24 percent of the people in California are saying zero-sum. That's where the conflict is occurring. There is more conflict in California."

Dr. Lubell then contrasted that to Parana, Argentina, which is a developing country with weaker institutions, noting that there are a lot of trade-offs. "Why that exact pattern is there, we're not quite sure but we have some ideas."

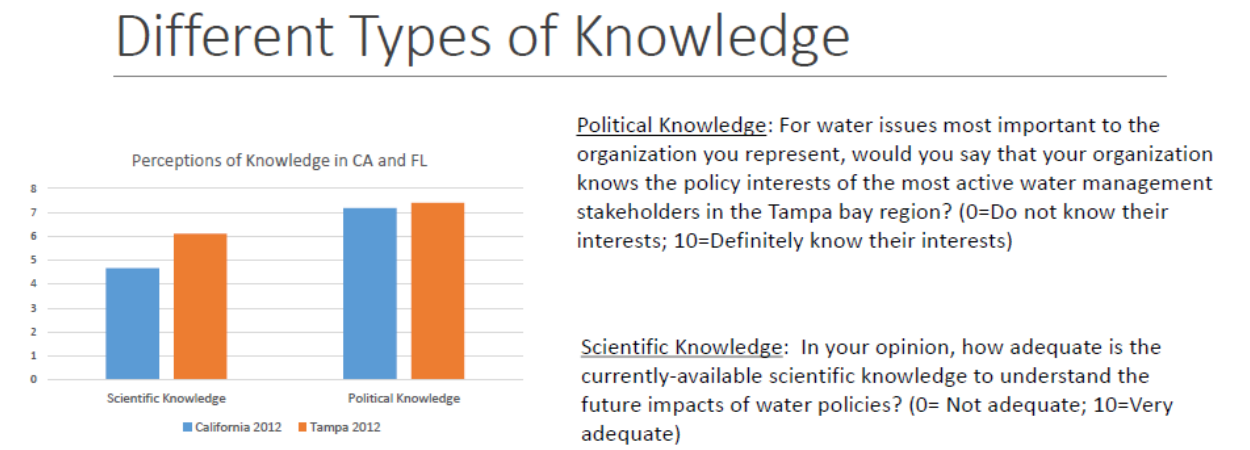


Figure 110, Slide 8

He presented survey results from California and Tampa for the question, how much political knowledge is there and how well do they understand the interests of the other actors? “One point to make here is that scientific knowledge is not the only relevant type of knowledge in these sorts of systems; political knowledge and local knowledge is important too,” he said. “Political knowledge here means understanding the interests of all the actors,” he said. “When you have these collaborative forums with various sorts of people participating, understanding the interests and who is going to benefit and experience costs from different policies and what their policy preference are. It's crucial to be able to make agreements.”

One of the survey questions asked, how adequate is the scientific knowledge? “Interestingly enough, if you look at California, on the scientific knowledge part, they give a lower score than Tampa,” he noted. “There's probably some link to the conflict there.”

Political Knowledge Matters Most for Policy Process (in weak institutional settings?)

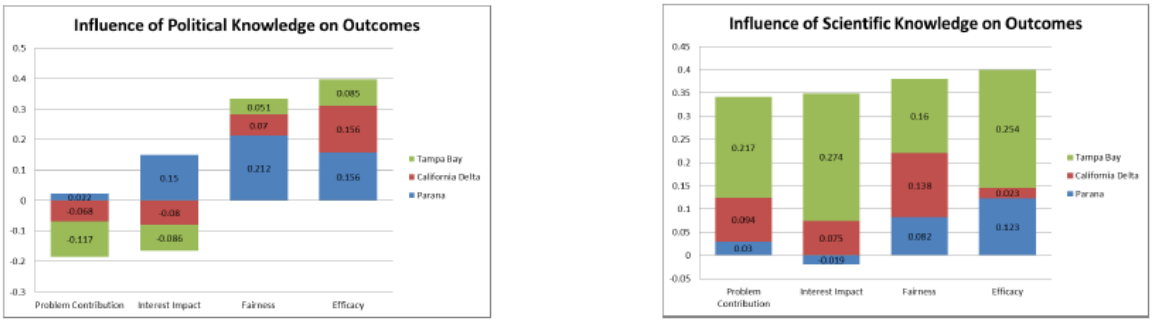


Figure 111, Slide 9

Dr. Lubell then presented a graph showing how much influence a particular type of knowledge has on outcomes. "People who think that they know the interest well, they are more likely to rate the fairness and efficacy of governance processes more highly," he said. "This political knowledge really has more of an influence on the process part of things while scientific knowledge … has more of an influence on a broader range of outcomes, and is particularly strong in Tampa where there is more agreement on the science."

Dr. Lubell noted that scientific knowledge doesn't have much of an influence in the Parana Delta at all but political knowledge does. "We think there may be something going on between the context in developing countries which has political knowledge and weaker institutions; the political knowledge might come first actually and the scientific knowledge might come second. We don't know for sure, because we only have three case studies, and we need more comparisons."

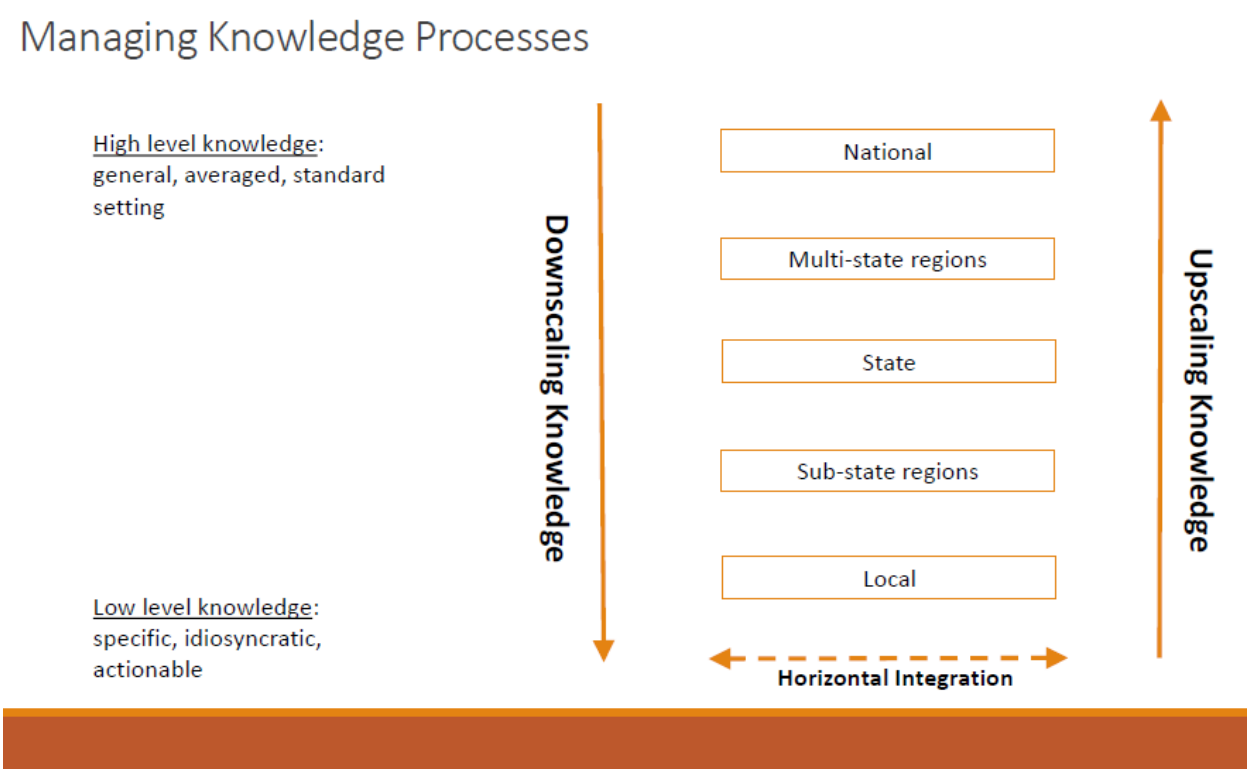


Figure 112, Slide 10

So how do you manage knowledge in these sorts of systems? How do we think about co-production of science? What's the role of academic institutions? How can we think about effectively doing this? "There are a couple things to say here," he said. "One is that I think you need to think of science from both a down-scaling knowledge and an up-scaling knowledge and horizontal integration as well. The down-scaling knowledge part means taking something like what is the best available science around sea level rise or climate change, and moving that down to the local level, because at the local levels, you have very specific requirements and specific circumstances. If sea level rise is going to be 50 centimeters in San Francisco Bay, how much does that matter in Marin County or in the coast vs the inland vs San Mateo County? That's more of a local question where the science hits the ground."

"At the same time, there are things going on at the local level - maybe local knowledge or some process that we need to integrate up and average to get a better understanding of the more global phenomenon," he continued. "We have to constantly be giving this up-scaling, down-scaling knowledge and then integrating across agencies, integrating across geographies, which is one of the things I think this conference is good for is integrating some of these ideas across geographies."

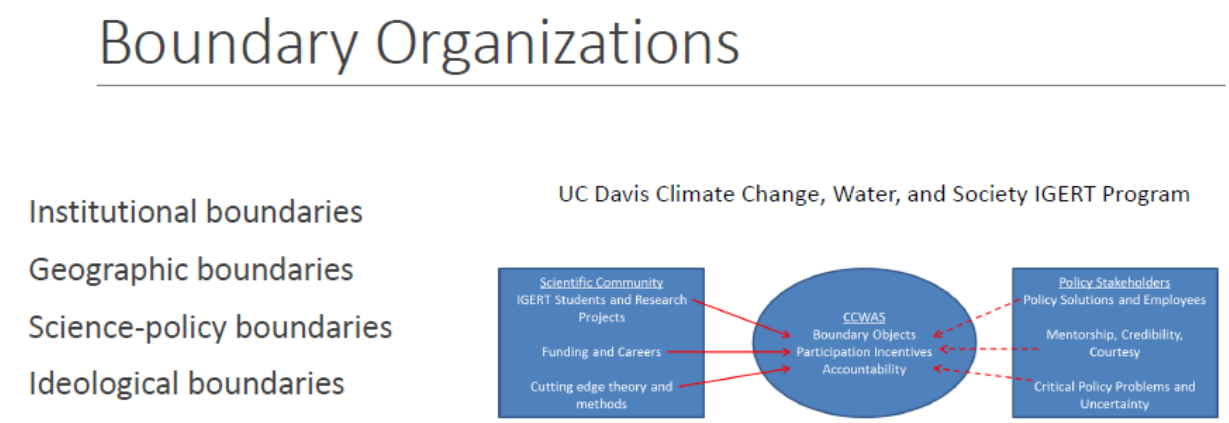


Figure 113, Slide 11

Boundary organizations are a type of organization that can be important. "A lot of our concepts and I think a lot of the organizations in which you folks work in fit into this role of boundary organizations where an organization takes the explicit strategy of trying to expand boundaries and connect knowledge across boundaries; those boundaries might be institutional, they might be geographic; they might be the science-policy divide, or they might be across different ideological boundaries, interest group communities, developers vs environmentalists, and that sort of thing."

Boundary objects are things that are produced by the organization such as scientific reports. Then there are incentives for participation on both sides. "For example, if you're going to have academics participating in the science production, you can't imagine they're just going to do it for free on their own altruistic standpoint; they need some sort of incentive," Dr. Lubell said. "The same for the stakeholder side."

Accountability means whatever the products are, they have to meet the goals and be accountable to the goals of both sides. "Through the UC Davis Climate Change Water and Society Integrative Graduate Education Research Traineeship (IGERT) Program[180], we tried at least to think about the entire graduate training program as creating students as the boundary objects in a sense that they are capable of expanding across these boundaries of science and policy in doing science that can help do this integration between climate, water, and society to fulfill a need to address these sorts of problems."

Dr. Lubell then gave his conclusions. "Governance systems are messy," he said. "You have to manage the different types of knowledge across them. It's not only the scientific knowledge that matters. The

[180] Climate Change Water and Society (CCWAS) Integrative Graduate Education Research Traineeship (IGERT) Program. UC Davis. http://ccwas.ucdavis.edu/

comparison part is key. How much knowledge exists? How much scientific agreement exists or political knowledge exists that varies across context? How much it matters actually seems to vary across contexts, according to our research. Science seems to be having more of an effect on perceptions of policy in Tampa and less of an effect of perceptions of policy in the California Delta. Boundary organizations are at least one idea. I don't think they're the only idea, but one I think promising idea, toward doing this knowledge management. We're up-scaling, down-scaling knowledge and integrating it across the system."

Panel 4 Presentation: Credible Science in a Complex World

Dr. Denise Lach, Director of School of Public Policy, Oregon State University

Denise Lach's presentation focused on three models of ways to think about the issues that have been discussed at the workshop. "One of the first things we try to think about is, where does credibility in science come from?" began Denise Lach. "We think about credibility, we think about salience, and we think about legitimacy. And those are three different ways of thinking about what we're doing."

She then defined the terms: Credibility is this idea that the science that we do is accountable to other scientists, such as peer review. Salience is the idea that it's relevant and timely. Legitimacy is the idea that we think the process that's being used to develop the knowledge is reflective of people's concerns.

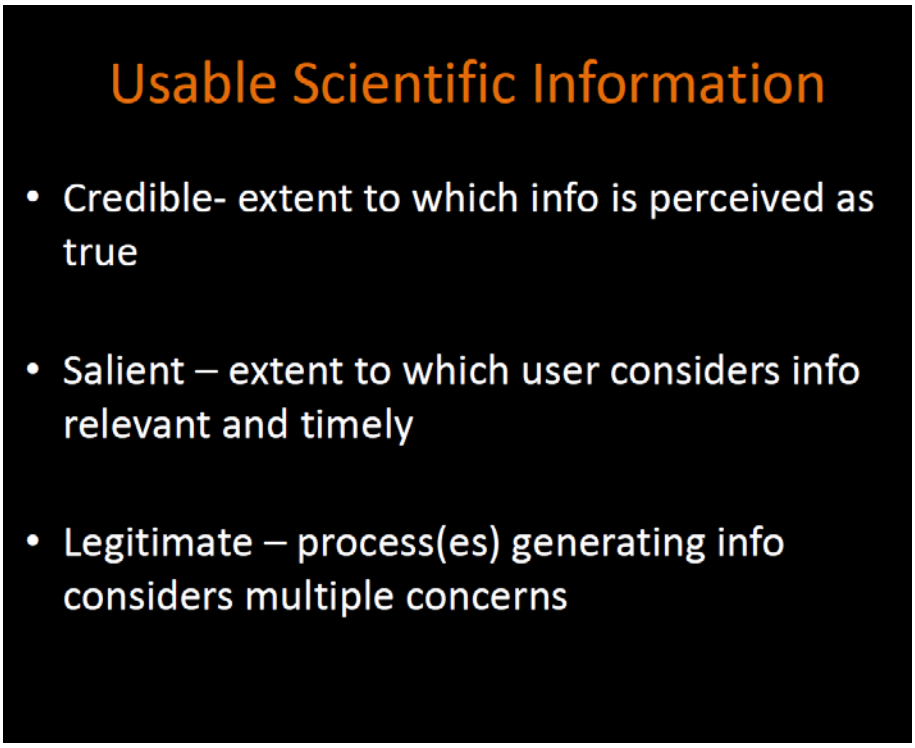


Figure 114, Slide 3

"The interesting thing in policy is those three variables: credibility, salience, and legitimacy are often contradictory to each other," she said. "We can do credible science, but it might not be very salient, because it's not timely and it's not relevant. We can do legitimate science, and it might not be credible. There's this trade-off between these ideas when we're working in these large systems where we have different interests. We have these ideas of credibility, salience, and legitimacy."

Ms. Lach then addressed the idea of how people make decisions. "The psychologists have been doing research a long time on how people make decisions and what's considered when people are making decisions," she said. "Most of us who are scientists think that knowledge and information is really critical to decision makers. It's really not. It is really not important for most people who are making decisions. One of the biggest

variables in decision making are the constraints that people have on the actions they can take, and people are really aware of the constraints that they have to take."

Ms. Lach does a lot of work with climate scientists, and one of the worst things that individuals can do is get on a plane and fly to a conference, but climate scientists fly all over the world over and over again. "When I ask them, 'Why do you do that? You know it's bad,'" she said. "They know the science. They understand it. They say, 'I have to do it. It's my job.' Those are the barriers. Those are the constraints."

When we think about the role of science and the role of knowledge in changing people's behavior, what we have to understand is that what we're really trying to do is help them find ways for them to change the constraints that they perceive on their behavior. "It's not giving them information to go out and do the right thing; that doesn't help most of us," she said. "What we have to have is information about how do we remove the constraints on our behavior."

The other tool that anthropologists have been working on a long time is called Grid-group Cultural Theory[181]; the idea is that all of us have these very deep belief structures in us that come from somewhere but we're not quite sure where, because people and families have very different belief structures, Ms. Lach said. "The belief structures are based on how much you believe the group is important versus the individual. It's also based on how much you believe that there are external controls on your life versus that you are personally responsible for your life."

A two by two quadrant can then be created that shows that people are either connected to the group and rules or they're connected to individuals and no rules.

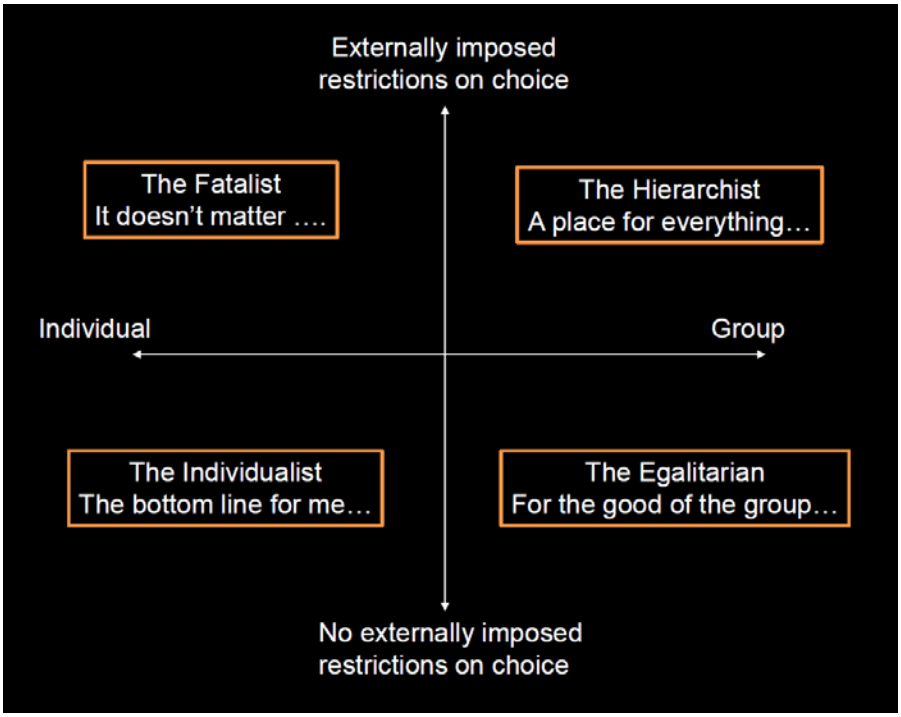


Figure 115, Slide 5

Ms. Lach said that there are three active approaches to worldview. "The first is the hierarchist, and this is a person who believes that the group makes the decisions and those decisions, rules, and practices are all important. All of those things that agencies are really good at are in that hierarchical worldview," she said. "Opposite in the quadrant are libertarians who believe that individuals are what's important, and no one should be able to tell you what to do, and there aren't any external constraints. The other

[181] Mamadouh, Virginie. "Grid-Group Cultural Theory: an Introduction." GeoJournal, vol. 47, no. 3, 1999, pp. 395–409. www.jstor.org/stable/41147316.

active quadrant are egalitarians who think that decisions should be made by consensus, that we're all good, that we're all well-meaning, and that the group is important, and it's really important to take everybody's beliefs into consideration."

The fourth quadrant are the fatalists, which is the inactive quadrant. "It's basically, 'I'm all by myself. Nobody cares about me. There's no way to be connected to anything,'" she said. "Mostly fatalists don't participate. When they do and they're in your department, they can be really difficult to work with."

Anthropologists have looked at this all over the world, she said. "These four worldviews out there are everywhere in the world, and every one of us has an affinity to one of these perspectives," she said. "It's interesting because the hierarchists and the libertarians work pretty well together; they can usually co-exist. Neither of them can co-exist with those egalitarians, because it's all kumbayah all the time; we're going to try to find a win-win solution every single time; libertarians and hierarchists say, 'Man, that's not going to happen.'"

"Holling, an ecologist, took a look at this and he thought, 'This is really interesting,'" Ms. Lach continued. "Along with the anthropologists, the ecologists said, 'Maybe this has something to do with the way we think about nature' and sure enough, it does."

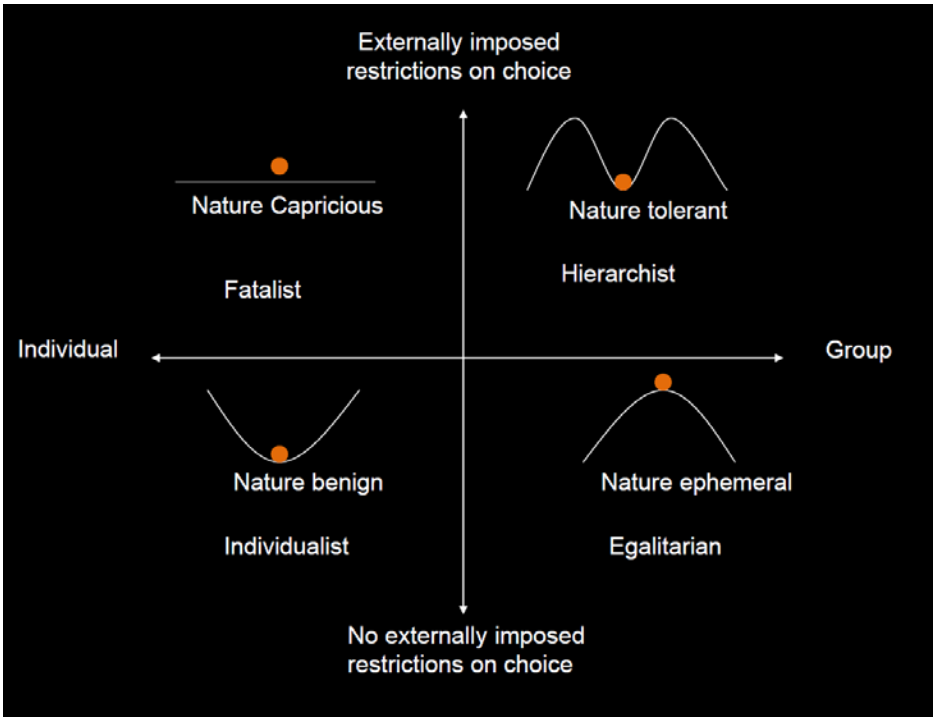


Figure 116, Slide 6

The egalitarians, who are all about group process, also believe that the environment is very fragile and it needs to be protected from human behavior at all costs, and everything that we do is a danger to the environment, she said. "I would say there are a lot of academic scientists who have this worldview who are egalitarians and feel that nature is very fragile," she said. "Libertarians feel that the environment is very robust. There really isn't anything that humans can do to upset the environment, and if it does, we're all out of here anyway, so it doesn't matter. Hierarchists believe that their environment can be managed and that it's somewhat fragile, but we can put sideboards up, and we can manage it with rules and processes and procedures."

Everyone has these different worldviews, and we all work in organizations that are pretty amenable to the worldviews that we have. "What's interesting is that when you come together in these large basins, it's important to realize that people are coming in with these worldviews and the way they think about

organizations, the way they think about decisions, and the way they think about the environment," Ms. Lach said. "These are very implicit biases that we all bring to the decisions and to the places that we work. This is very robust research from the social scientists."

We used to be able to think about really elegant solutions, engineering solutions, or solutions where we would fix something forever and it would stay that way. "We know that with complex systems, that's not possible and it if you think about these different worldviews, you also know that's not possible, because everybody comes with a different expectation about what a good decision looks like."

Those that are studying these things have found that there are what they call 'Clumsy Solutions.'[182] "People don't like that idea, but the idea is that you find solutions that really appeal to all three of those active worldviews," Ms. Lach said. "What can you give those egalitarians who think that nature is very fragile? What can you give to the hierarchists who believe that if there are rules, processes, procedures, and chains of command, that we can manage it? What do you give to the libertarians who are convinced that if I can make money off of this if you just let me alone? How do you balance those three different worldviews? I know you've probably had these conversations in these stakeholders' meetings where you're thinking, 'What the hell are they talking about?' These things are ingrained in our heads, and we don't even realize that we have them; it's really easy to talk to other people who share in that worldview, and it's almost impossible to talk with people who don't share that same view."

"I think that that credibility, legitimacy, and salience are all important for making decisions, but knowing that they're also in conflict as you move forward with them, as well as the idea that we have these different worldviews."

Social science has a lot of theories and approaches out there that are pretty well researched, and they're researched across multiple cultures and across multiple countries. "There are some ways to think about the ways that we can use this when we're approaching some of these scientific problem solving situations that we're finding ourselves in these giant basins," she said.

Ms. Lach then turned to the concept of "Post-normal science."[183] "The idea with post-normal science is that as the stakes get high and the uncertainty gets high, normal science in the Thomas Kuhn sense of the word is really not very useful," she said. "One of the first things that we do is we move into this idea of professional consultancy. The IPCC, for example, is a perfect example of professional consultancy where we're bringing all these experts together. As someone said earlier, 'this consensus by all these egalitarian scientists is a real sign that we have some agreement on the science.' We don't really have agreement on social science. We really don't understand climate science yet, but we have this consensus in this professional consultancy role."

[182] Hartmann, T. March-19-2012. *Wicked problems and clumsy solutions: Planning as expectation management.* Planning Theory Vol 11, Issue 3, pp. 242 – 256 10.1177/147309521244042. http://journals.sagepub.com/doi/abs/10.1177/1473095212440427

[183] Silvio O. Funtowicz, Jerome R. Ravetz, Science for the post-normal age, Futures, Volume 25, Issue 7, 1993, Pages 739-755, ISSN 0016-3287, http://dx.doi.org/10.1016/0016-3287(93)90022-L. (http://www.sciencedirect.com/science/article/pii/001632879390022L)

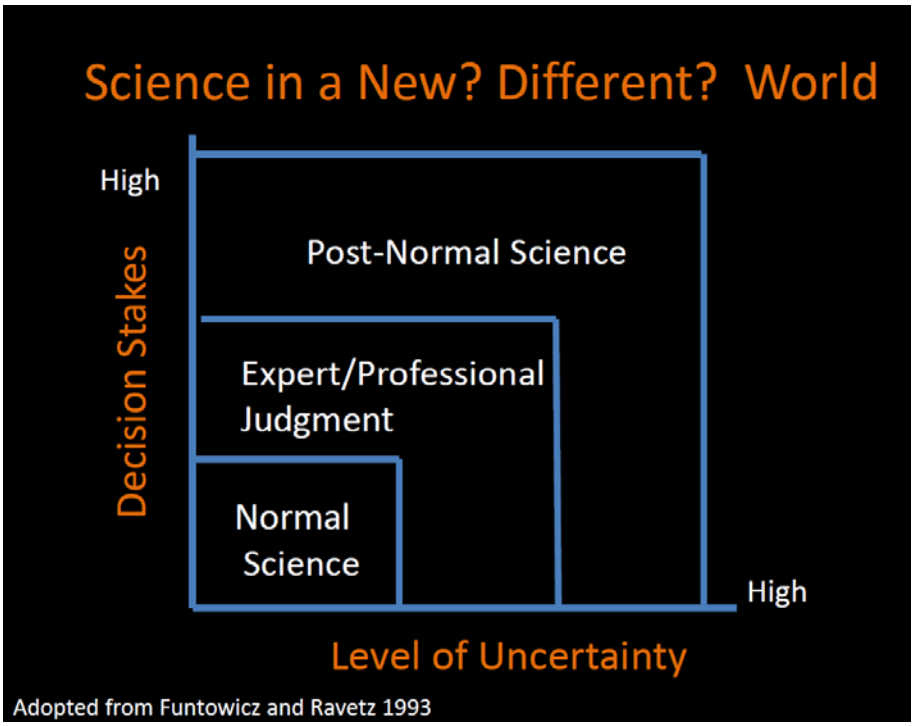


Figure 117, Slide 8

If you go even further out on scale with the uncertainty and stake issues, you get to a place where you're looking at post-normal science," Ms. Lach said. "In post-normal science, the real difference there is that we extend the peer group - the people who make decisions about whether or not the science is credible, legitimate, and salient - to other people, to other stakeholders," she said. "There are a lot of different techniques for doing that. One of this is this idea of coproduction, but there are other strategies like consensus conferences and watershed councils." "Each of them is built on one of these different worldviews on how the world works," she continued. "They're more or less amenable to different groups, but there are different strategies that social scientists are looking at that they're comparing across different environmental problems. That would be another possible technique to be thinking about what that post-normal science looks like in a world that's filled with uncertainty."

"We've talked a lot about uncertainty here," Ms. Lach concluded. "Like uncertainty, there are just a lot of things that we don't know and to be able to say that as scientists puts us in a different realm of uncertainty."

Panel 4 Discussion

Panelists

Dr. Nick Aumen, USGS Regional Science Advisor, Southeast Region
Dr. Ken Currens, Manager of Conservation Planning; Northwest Indian Fisheries Commission
Dr. Denise Lach, Professor and Director of School of Public Policy, Oregon State University
Dr. Mark Lubell, Professor and Director, Center for Environmental Policy and Behavior
Dr. Jayantha Obeysekera (Obey): Chief Modeler, South Florida Water Management District
David Wegner, Former Senior Staff at Water Energy and Transportation Committee, U.S. House of Representatives

Panel moderator Rainer Hoenicke began the panel discussion by noting that reflecting on Dr. Lach's definition of legitimacy. "I think there's a real desire, especially in a very contentious environment, to elevate that level of legitimacy," he said. "Especially in systems with strong resource conflicts, we often have institutions and stakeholders where they view each other's science to be outcome driven and illegitimate."

Question and Answer

Question: "How would you balance this three-legged stool of credibility, salience, and legitimacy? How have you encountered this balance setting in your area?"

Dr. Nick Aumen said that we're all human, and in spite of being scientists, we view what other people do through our own lens that we create; we are informed by our world experiences, our scientific background, the political background, and the social background. If a stakeholder who has a strong desire for a particular outcome produces science, no matter what or how good that person is as a scientist, he's always going to view that through that lens, at least initially. This in part what scientists are trained to do: to be critical and skeptical. "I think it's part of the construct and the integration of all these different viewpoints of stakeholders. It's just part of working in these very complex systems; you have to factor it in almost daily in the work that you do, but in the end, good science stands on its own," said Dr. Aumen. "When it ends up down to the wire either in front of a judge or in the court of public opinion, those processes have to work their way through. People have to make their own judgments, and that's happened in the Everglades time and time again."

Dr. Ken Currens works the Northwest Indian Fisheries Commission,[184] a support organization for 20 western Washington Treaty Tribes. Through a series of court cases, it has been determined that the Indian tribes have a right to fish, hunt, and gather as they always have; this is a right as opposed to a privilege, and cannot be restricted by state agencies. The court cases have also determined that the state of Washington has an obligation to protect the habitat that sustains those treaty rights. And the court has also ruled that the tribes have a right to manage the resources. For fishery management, they have a system of jointly producing the science and management between the federal and state government and other folks; there is increasing involvement by the tribes as they have developed more expertise and have become more involved in management issues.

Dr. Currens then described how he frames discussions for legislators. He tells them that five things need to be done: We have to get the right science, meaning that we're bringing the breadth of science to the problem at hand. We have to get the science right, meaning we have to credible, legitimate and salient science. We have to get the right people, which means a broad group that includes all the people that have a stake in it. We've have to get the people right, which means we have to get the participation right; the process needs to be run so it's inclusive. And don't ask the scientists to give you an analysis that you need to understand later, he said, explaining this means don't think about who does it but about what we do. Good decisions come from analyzing and deliberating; scientists can do the statistics and can run the modeling, but the policy folks need to be there, because if the analysis of the problem is not framed right at the beginning, the scientists won't give an answer that's useful to them. A process of analysis and deliberation needs to occur, and it has to be repetitive and recursive. "I've been through this a number of times," Mr. Currens said. "When we do this, we have legitimate science and we get to a solution. When we don't, we will get to the solution… but that solution is going to be driven by lawsuits. We'll get there - it's just a different way to get there."

Dr. Jayantha Obeysekera said that the integrity of the team is very important. He has an established team of people working on models that has established recognition and creditability in their work; the team does high quality unbiased research, and backs that credibility up with publications. He warned that sometimes modelers or scientists could potentially be used inappropriately to build consensus

[184] Northwest Indian Fisheries Commission. http://nwifc.org/

among stakeholders. “That could be good in some settings, but in an iterative process, I think we have to be aware of that fact so that we don't lose that credibility that we have there.”

David Wegner said that from his perspective from working in Washington, when people come in to talk about an issue, he first determines their credibility by considering their relationship to the issue and if they will have information that will add value to the process. He then considers their legitimacy, and tends to view those to whom the issue something that is personal to them or that they have a responsibility to their constituents as more legitimate then the paid lobbyists looking for billable time. On the salient point, he considers whether the information they are going to provide will help educate, provide information they haven’t heard before, or can be used in a forum to help make a better process.

A good scientist who has the ability to communicate is a huge commodity. “Most scientists are very good at collecting data, analyzing data, going through the process of science, but the ability for a scientist to communicate, that is something that we need to do a much better job at, because the issues that are facing us as a society - these issues of climate change, of complex ecosystem issues, they are only going to get worse,” said Mr. Wegner. “We have to be able to discern the issues, take out the fluff around the edges, get to the real points, and be able to articulate those in a clear, responsible manner.”

Dr. Denise Lach said that much of the science is in a ‘black box’ to other scientists who don’t know the models or the algorithms as well as the decision makers, and stakeholders; that makes legitimacy hard for most people because they don’t really understand. Scientists need to find ways to involve people in opening that black box of the model or the algorithm or the data collection or the monitoring process. Dr. Lach’s research makes a distinction between the general public and the attentive public: the general public doesn’t understand and aren’t usually the ones showing up at the hearing, while the attentive public do attend hearings and are usually very knowledgeable about the systems, the rules, and the policy. “Opening up the black box of the science that we do to that attentive public increases legitimacy of the decisions that we're trying to make about very uncertain systems that are being driven by processes that we don't understand, and while we're being asked to make big decisions about big systems in a time when the world is changing around us as quickly as it possibly can.”

Ken Currens then addressed Ds. Lach’s comments on post-normal science that she made in the introductory presentation. He recalled how he was asked recently after giving a talk on resilience theory, when we pass these thresholds and we’re in a new regime, we say that the system will self-organize or will reorganize in to something else. What is that going to mean for the tribes in the face of climate change?’ “I don't know what that will be, but what I can tell you is the uncertainty is high, and the stakes are huge, which is why we're in the post-normal box. That's why we're saying this has to be broadened. This has to be about participation.”

Question: Dr. Reiner Hoenicke asked Dr. Lubell about his research in the Parana Delta in Argentina. “You pointed out that they started with more of the political aspects rather than more of the scientific aspects. Can you tie that in ... Was there kind of a sign or a tendency for people to actually strive for the legitimacy aspect of it?”

Dr. Mark Lubell noted that political knowledge is relevant, because in order to understand the legitimacy of science, you need the understand the political interests of the individuals that are producing it. In the case of Parana and other developing countries where institutions are weak, what the researchers think happens is that there are constant attempts to solve problems and bring knowledge, and without institutions like the Delta Independent Science Board or the Delta Stewardship Council, they get

together for a bit and then it falls apart. “That's why the political knowledge seems to be the more important thing early on, because they have to figure out what are the interests of the people at the table. Once they get that down, then they can start thinking about how are they going to start understanding what's going on in the system. Getting the political part right might be something to do first - not positive yet though.”

Dr. Reiner Hoenicke noted that what he heard in the panel discussion so far was that co-production is important as it is a determining factor for generating legitimacy and credibility, although he acknowledged that coproduction with stakeholder engagement from beginning to the end of the decision process can be cumbersome and time consuming, which could be in conflict with saliency because it takes time. “To me it sounds like at this point in the evolution of our thinking, it really is a must to have that coproduction element built right in to the three-legged stool in some way.”

Question: We have heard in earlier discussions that when dealing with ecosystem problems, it’s important to understand what the problem is, and then define the objective or what you are trying to accomplish with the process. Do the things that you're talking about with regard to credibility, legitimacy, and salience of the science also apply to those elements of the equation?

Dr. Denise Lach said yes, definitely; one of the first places to start with coproduction is to gather needs and goals from a wide perspective as that contributes to the legitimacy of moving forward. “If people were asked their opinion or asked their needs, asked their wants, it starts the process of forming the scientific questions, which lead to the legitimacy, because people feel like their concerns are being heard.”

Dr. Nick Aumen agreed. In the workshop series that went for about nine months, everyone was involved in developing the path forward. Workshop participants, some of them citizens, could draw out a plan and they could go ask a modeler for technical help; the modeler’s opinion was trusted by the participants because the relationship had been built over time. “To get there takes a lot of interaction, takes a lot of work, and takes a lot of talking one on one. It just doesn't happen automatically. It takes a tremendous amount of energy and input, but it pays off big dividends.”

Dr. Ken Currens recalled how in the presentation that Joel Baker gave on the outcomes in the Puget Sound, one of the things that came out was the groups that had been most successful had somebody who could not only talk to policymakers, but was trusted by them. “That takes work, work that most of us don’t do, but it’s absolutely essential.”

In response to trusting agencies, Dr. Denise Lach asked why would anyone trust a government agency? Trust means that the other person's looking out for your best interests, and government agencies and organizations don't do that. There is trust in relationships with individuals inside those organizations. But what we want from agencies is reliability, transparency, and competence; Ds. Lach said that’s not the same thing as trust.

Question: You mentioned ‘clumsy solutions’ … That sounded like an interesting idea to me so I was hoping you could say a little more about that.

Dr. Denise Lach answered by saying that in planning and engineering, they are often looking for an elegant solution – the most efficient, most effective, and the easiest solution for the problem, but often in large and complex systems, there aren’t any elegant solutions, and if a solution is forced, that when

legitimacy is lost and lawsuits are filed. Instead, it's thinking about putting together solutions that address multiple needs. She gave an example of small communities in Southern California whose water supply is controlled by Metropolitan. In the drought when their supplies were constricted, they had to practice demand management. So many communities came up with a strategy to give everyone enough water to live on at a small price which appeals to the egalitarian, and charge more for those who used more which appeals to the libertarians, and then the hierarchists were collecting data and sharing it with water users, so they were getting comparative data of their use with neighbors use, block use, and neighborhood use, which started a competition to use less water. "All of the sudden, they're not so worried about water supply in these towns. They're coming up with clumsy things. There wasn't a perfect answer, but there were these different modules. It's responding to these different needs that people have, these different worldviews that people have."

Question: I wanted ask about the boundary organizations. Ken talked about recursive analysis and deliberation. To me, that sounded like co-production. I'm wondering about opening the black box. I'm wondering anyone would want to talk about boundary objects like those recursive processes or what opening the black box looks like?

Dr. Mark Lubell defined a boundary object as a model, a scientist, a report, a visualization - some piece of science that is useful to all of the actors who are participating in the organization. Using models as an example, the boundary organization is the place where models are developed that are useful to both actors. "You could say that for scientists, it may be something that advances the basic science, but for the policy maker, it's salient to a particular question at a particular time."

Question: Dr. Hoenicke asked to what extent are academic institutions playing a role as boundary organizations, but also in the process of legitimacy and coproduction. "What experiences has the panel had with incorporating academic institutions in this whole three-legged stool?

Dr. Nick Aumen said that academic institutions are important in the Everglades, having done some of the work that set some of the boundaries of the problems they're facing now; the challenge always has been the connection between the academic world, the government world, and the policy world. He recalled how two professors at area universities spent a lot of time going to agency and public meetings, but it paid off in the end as they received funding for research at their respective institutions. "They worked hard in connecting themselves with what we were trying to do, and that's hard to do. We don't have a good system for that. A young faculty member at almost any institution can't devote that kind of time. We're trying to think of better ways to make sure when they come to us with work that's well thought out, and that they are connected well."

Dr. Jayantha Obeysekera agreed that academic institutions have a role to play, as they have the ability to look at creative non-traditional approaches which adds value to what the agencies do; they can also bring graduate students to look at problems that others don't have time or resources for. They are also thought of as unbiased. He acknowledged that sometimes timing can be an issue, as is sometimes the lack of ability to come up with actionable science. "One of the drawbacks is how to get them to produce the science that will lead to some decision making."

David Wegner said that with his work on the Colorado River, the inclusion of academic research into the process was needed as they brought in new perspectives as well as new blood into the process. He also noted how when he started the program in the Grand Canyon, they had eight Native American Tribes who had a cultural affinity to the canyon, but knew nothing about traditional ecosystem and

environmental knowledge from the tribes. He went out and spent time with the tribes to learn their perspective. Out of that, they spun up a training program and got some young Hopi women interested in studying hydrology at Northern Arizona University, and today, one of them is an assistant regional director for one of the agencies. "To me, we have a responsibility when we're within the agencies to help not only further science, but further people, so they get opportunities to continue to expand. With that, we reap benefits that are uncountable at this point."

Dr. Mark Lubell noted that some universities are finding ways to create institutions at the university. He gave the Center for Watershed Science[185] at UC Davis as an example of an institution that does go out and try to engage in policy; there is some funding for these activities, and symbolic rewards. "At the level of the individual professor, or faculty member, there is often that trade off, which if we're not publishing and that sort of thing, that becomes problem for us… We also have to remember that the incentives of a university professor are to try to pursue and publish basis research. To create a space where that can happen, we can do science to help solve the problem, but we can also publish it and do things we need to count the beans that are being counted by the university."

Question: One thing that really wasn't touched on a whole lot was conflict resolution… What if you have two equally credible organizations that are coming to some fairly different places just looking at the science? Do you have any thoughts on mechanisms for conflict resolutions in matters of science?

David Wegner said that was built into the Adaptive Management Program. When dealing with a lot of complex issues, professional facilitation of the difficult issues is important, so that everybody gets some say in the discussion. "What I found by bringing in professional facilitators on not every issue, but those that we knew were going to be contentious in the end and making sure we did that facilitation dialogue process right; then having an ability to go into some conflict resolution, some mediation on issues that we just weren't going to be able to make a cut and dry answer on, to make sure that we followed process. That doesn't mean we get to exactly the same point we started out to get to, but at least people felt like they were involved, were listened to, and were part of the process."

Dr. Jay Lund noted that remarks earlier today were that in order to do a legitimate study, you have to get all the stakeholders involved all along the way; he commented that if they had to do science that way for every project, not a lot of science would get done. However, he acknowledged that it's a very important way to do some science. "Do you have any thoughts about the mix of different ways of doing science across a science enterprise to in a broad scale that advance the amount of territory you can explore and the overall legitimacy of the overall enterprise rather than just one particular study?

Dr. Denise Lach said that's what the model of post-normal science is about. If the problem is one where the stakes are relatively low and there's relative amounts of certainty that can be found, then regular, positivistic science that gets you an answer can be done. "It's when you go out to these places where the stakes get really high and the uncertainty gets really magnificent that you need to do these more inclusive processes that bring legitimacy to places where we don't get answers. I think we have to admit that there are places in our science enterprises now where we will not get answers. We're looking for solutions, but we're not going to get answers."

Dr. Jay Lund agreed, noting that the when the complexity and the breadth of these controversies is sufficiently large, there needs to be a lot of the lower level, exploratory science that might be done by

[185] Center for Watershed Science. UC Davis. https://watershed.ucdavis.edu/

individual investigators or small groups - even combat science could be useful in that situation. “Then for a few things, you can muster the big enterprise where it's all inclusive and completely collaborative, but in order to make the collaborative science activities successful, it helps a lot to have established some understory to that so you can be more efficient about it and more direct about it.”

Dr. Denise Lach clarified that post-normal science doesn’t mean that you don’t do professional consultancy or normal science; in fact, you have to do it all. “In some of these cases, if we don't take the time upfront to do the collaborative coproduction, we're going to pay the price on the other end in court. Do we spend the time upfront or do we spend the time at the back end? I think it all washes out, but I think it's more fun at the front end than at the back end.”

Dr. Jayantha Obeysekera said that in his experience, the leadership of the science enterprise needs to make sure that there's always a critical mass for that long term research as there’s going to be pressure to divert resources to big projects or brush fires. When he was doing modeling for his group, there was a lot of pressure to give up on the new model they were developing in order to do the immediate modeling needed for restoration. “I realized that there was a need for that tool ten years down the road, and I was able to maintain the critical mass. You can see the results today. But I think it's very hard to do both... Unless the leadership buys into it, it's hard to commit.”

Dr. Ken Currens then added that he has been the one advocating the broad participation approach, but of course they move between doing normal science and post-normal science, depending on the question.

Closing Remarks

Dr. Clifford Dahm, Lead Scientist, Delta Stewardship Council

Dr. Clifford Dahm then closed the two-day workshop with his thoughts, noting that this event was important because it brought together science and policy makers, which is critical to long-term success. It’s also been an opportunity to learn about six complex, very interesting systems that participants can take away information from to help everyone do science in their own sites, he said.

Key messages were the importance of communication, how modeling underpins strong science and decision making, and that social sciences must be embraced and integrated into the science and complex systems. He also heard that peer review is important to the credibility of science.

Dr. Dahm recalled how 21 years ago as a program director of the National Science Foundation, they started a program called Water and Watersheds. “We said that there were three elements to be a successful proposal. It had to have the physical sciences, it had to have the biological sciences, and it had to have the social sciences. We got 636 proposals in for a competition that could at best fund 20, which is just to give you an idea of how much pent up desire there was to make that happen. I know we're still wrestling with how to combine the social sciences, physical sciences, and biological sciences. Progress is being made, and I'm seeing progress being made at meeting like this.

Dr. Dahm said that he’s been asked several times how things have changed since his first tenure as lead scientist that ended in 2012, and in these last fourteen months? “One of the things I will say is there are clear signs in many of these sites that we're moving from the endless planning that we've been doing

towards implementation, learning, decision making, and maybe even adaptive management. I think that's a clear moving forward."

Before the workshop, Dr. Dahm visited John Fleck, a science writer for the Albuquerque Journal and now on the faculty at the University of New Mexico. He has written a book which was recently published called, 'Water is for Fighting Over and Other Myths about Water in the West.'[186] "One of the things that he lays out in this book is a promising record of cooperation, and he also feels that often the good things are obscured by the crisis narrative that we hear about water in the western United States," Dr. Dahm said. "I was chatting with him and was telling him about the workshop, and I said, 'I'm sorry you can't be there. You've written about most of the folks on the Colorado in your book.' I asked him, 'What about the Delta, the California Delta?' He looked at me and said, 'Now that's a tough nut to crack.'"

[186] Fleck, J. 2016. *Water is for Fighting Over and Other Myths about Water in the West*. https://islandpress.org/book/water-is-for-fighting-over

Panelists & Credits

In alphabetical order:

Nick Aumen, USGS. Regional Science Advisor, SE Region. Research interests include nutrient biogeochemistry, microbial ecology, wetland restoration, linking science and policy.

Joel Baker, University of Washington. Chair in Environmental Science. Director of the Center for Urban Waters. Research interests include contaminants, aerosol chemistry, contaminant transport in estuaries, modeling, food webs, and water quality.

Steve Brandt, Oregon State University, Professor. Delta ISB. Research interests include fish ecology, management of marine and freshwater ecosystems, food webs, fish bioenergetics, underwater acoustics, and coastal hypoxia.

Mike Chotkowski, USGS, Bay-Delta Science Coordinator, Pacific Region. Research interests include marine and estuarine fish ecology, ichthyology, science planning, and policy.

Tracy Collier, NOAA Fisheries, Division Director for NW Fisheries Science Center. Delta ISB. Research interests include environmental toxicology and chemistry, assessing oil spill impacts, and harmful algal blooms.

Josh Collins, San Francisco Estuary Institute, Chief Scientist. Research interests include landscape ecology, regional ecological planning, mapping/assessing stream and wetland ecosystems, restoration, and monitoring.

Ken Currens, NW Indian Fisheries Commission, Manager of Conservation Planning Program. Research interests include conservation strategy and planning, population genetics, risk assessment, science communication, and policy.

Cliff Dahm, Delta Stewardship Council, Lead Scientist. Research interests include aquatic ecology, nutrients, climatology, and restoration

Alyssa Dausman, Restore the Gulf, Science Director. Research interests include restoration, groundwater, water quality, saltwater intrusion, modeling, and monitoring.

Randy Fiorini, Delta Stewardship Council, Chair. Research interests include water resources policy, agriculture, and local and state governance.

Erin Foresman, USEPA, Environmental Scientist. Research interests include environmental policy and science, ecology, wetlands, NEPA, CWA, water quality, and permitting.

Peter Goodwin, University of Idaho, Director-Center for Ecohydraulics Research. Former Delta Lead Scientist. Research interests include ecohydraulics, sustainability, modeling river and estuarine flows, sediment transport, and geomorphic evolution.

Rainer Hoenicke, Delta Stewardship Council, Deputy Executive Officer of Delta Science Program. Research interests include ecology, limnology, water quality, landscape restoration planning, decision-support tools, and policy.

Jon Hortness, USGS Liaison to the USEPA Great Lakes National Program Office, USGS Coordinator for the Great Lakes Restoration Initiative. Research interests include river and watershed modeling, surface/ground-water interactions, flood and drought analyses, and in-stream flow criteria.

Stephanie Johnson, National Academy of Sciences, Senior Staff Officer. Research interests include contaminant hydrogeology, water quality, science and practice of restoration, science communication, and policy.

Bill Labiosa, USGS, Regional Science Coordinator, Northwest Region. Research interests include modeling, ecosystem recovery, and decision support.

Denise Lach, Oregon State University, Professor, Director of School of Public Policy. Research interests include environmental natural resource sociology, applied sociology, program evaluation, organizational sociology, and water conflict resolution.

Jessica Law, Delta Stewardship Council, Delta Plan Interagency Implementation Committee (DPIIC) Coordinator. Research interests include land use planning, facilitation, communications, ecology, and water resources policy.

Steven Lindley, NOAA Fisheries, Southwest Fisheries Science Center. Director, Fisheries Ecology Division. Research interests include ecosystem manipulations, capture-recapture, telemetry, trophic dynamics in tidal environments, and modeling.

Jeff Loux, UC Davis Extension. Chair of Science, Agriculture and Natural Resources. Research interests include sustainable urban planning and design, water resources policy, community engagement and collaboration, sustainable transportation, water resources, GIS, and environmental law.

Mark Lubell, UC Davis, Professor. Director, Center for Environmental Policy and Behavior. Research interest include water management, sustainable agriculture, adaptive decision-making, climate change policy, and policy/social network analysis.

Jay Lund, UC Davis, Director of the Center for Watershed Sciences. Delta ISB. Research interests include system analysis, economics, water management, and policy.

Jayantha Obeysekera, South Florida Water Management District, Chief Modeler. Research interests include modeling, restoration, hydrology, hydrodynamics, and water quality.

Felicia Marcus, SWRCB, Chair. Policy interests include water quality, drinking water, and water rights policy.

Scott Phillips, USGS, Environmental Scientist, Coordinator of the USGS Priority Ecosystems Science (PES) program for Chesapeake Bay. Research interests include hydrogeology, modeling, and nutrient loading.

Scott Redman, Puget Sound Action Team (Partnership), Program Manager. Research interests include toxic contaminants, marine shoreline habitats, and collaborative approaches to science and management.

Denise Reed, Water Institute of the Gulf, Chief Scientist. Research interests include coastal restoration and planning, role of human activities in coastal systems, sea-level rise, adaptive management, and modeling.

Richard Roos-Collins, Water and Power Law Group PC, Principal. Research interests include law and complex cases involving multiple parties.

Ted Sommer, DWR, Lead Scientist. Research interests include aquatic ecology, floodplain ecology, native fish restoration, and salmonid biology.

Lisa Wainger, University of Maryland, Professor. Research interests include regional-scale ecological and economic modeling, invasive species, environmental economic indicators, and GIS-based landscape analysis.

Dave Wegner, Water, Energy and Transportation committee at U.S. House of Representatives, former Senior Staff. Research interests include fluvial geomorphology, GIS, pacific salmon dynamics, aquatic ecology, vegetation dynamics, and science policy.

Carl Wilcox, DFW, Policy Advisor to the Director for the Delta, Bay-Delta Regional Manager. Research interests include ecology, conservation, fisheries, natural resources, and policy.

Workshop Planning Committee:

The workshop would not have been possible without the hard work of the workshop planning committee:

Co-chair: **Jessica Law**, Delta Stewardship Council

Co-chair: **Mike Chotkowski**, USGS

Cliff Dahm, Delta Lead Scientist

Jay Lund, Delta Independent Science Board

Tracy Collier, Delta Independent Science Board

Rainer Hoenicke, Delta Stewardship Council

Kate Anderson, Delta Stewardship Council

Amanda Bohl, Delta Stewardship Council

Lindsay Correa, Delta Stewardship Council

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Peter Goodwin, University of Idaho

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Proceeding Report:

Chris Austin, Maven's Notebook

Kate Anderson, Delta Stewardship Council

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Nina Abdollahian, USGS

Megan Brooks, Delta Stewardship Council

Martina Koller, Delta Stewardship Council