COMMUNICATING SCIENCE AMID ENVIRONMENTAL CONTROVERSY: HOW SCIENTISTS INTERACT WITH POLICY IN THE SAN FRANCISCO BAY-DELTA

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ABSTRACT

In controversies over environmental management, participants often call for policies based on the best available science. However, environmental controversies are rarely simply disputes over scientific knowledge; instead, they are driven by stakeholders' conflicting interests and values. In this context, science often becomes a part of the political dispute, used and interpreted differently by different actors in the policy process. Scientists, therefore, face the challenge of communicating their research to non-scientific audiences—such as stakeholders, policy makers, and the general public—in a highly politicized context. This essay examines how scientists perceive their role in the policy process and how they navigate the intersection of science and policy in the San Francisco Bay-Delta, a region that has been the site of decades of scientific research and controversy over environmental management. This essay examines three cases: the CALFED Science Program, which built a policy-neutral body of research to support a collaborative planning process in the Bay-Delta that began in 2000; the interdisciplinary Bay-Delta policy reports which scientists from the University of California, Davis and the Public Policy Institute of California (PPIC) have published from 2007 to 2013 in reaction to policy failures; and a series of radio stories and interactive web maps that the San Francisco Estuary Institute (SFEI) produced in 2012 with KQED, a San-Francisco-based public media station, to communicate their research to a general California audience. These cases show how scientists in the Bay-Delta have struggled with the tension between communicating their research in a way that is salient to policy discussions and maintaining their legitimacy within scientific and policy communities. They also show an increasing political sophistication among scientists in the Bay-Delta as they have continued to engage in the policy process and an expanding scale of engagement, from working directly with the policy community to communicating about Bay-Delta ecology and policy with the general public. These approaches, while different, complement each other, demonstrating how scientists can communicate their research in a variety of ways depending on their relationship to the policy community.

THESIS SUPERVISOR: Judith Layzer, Associate Professor of Environmental Policy

TABLE OF CONTENTS

COMMUNICATING SCIENCE AMID ENVIRONMENTAL CONTROVERSY: HOW SCIENTISTS INTERACT WITH POLICY IN THE SAN FRANCISCO BAY-DELTA

INTRODUCTION

Most scientists are not trained as politicians. In cases of environmental controversy, however, the act of communicating their research can become political. As Center for Research on Aquatic Bioinvasions founder Andrew Cohen put it, "people go into science to remove themselves from politics. That's what I wanted, but it didn't work out that way" (Cohen 2013). Many environmental scientists and engineers conduct research that is directly relevant to political disputes over environmental management, and they often find that they have to navigate the political context of science in policy to communicate their research with non-specialist audiences, such as policy makers, stakeholders, and the general public. Such communications can be challenging for a number of reasons. Environmental conflicts often entail clashes of parties with competing interests or values that cannot be solved by rational, scientific analysis alone, and parties to a dispute may use "combat science" to support their arguments or undermine the scientific basis for policy change. Scientists therefore must navigate a political battlefield in which they struggle to communicate their findings in ways that are salient to policy discussions yet maintain trust in their findings. To make matters more difficult, scientists generally have not have been trained in public relations, and they typically are not rewarded professionally for interpreting their findings to non-scientific audiences.

Within this context, it is important to ask: how do scientists perceive their role in the policy process, and how do they navigate their roles at the intersection of science and policy in environmental controversies? What constraints and pressures do they face, and how can they be more effective in contributing to more informed policy discussions? Science communication matters, because environmental controversies are shaped by the natural processes scientists

study. In planning to reduce vulnerabilities to natural hazards and mitigate risks, or to reduce the negative impacts human developments have on the natural environment, it is important to understand the causes and consequences of natural hazards and environmental problems. In such cases, we expect our policymakers to make decisions informed by science. But most policymakers are not scientists. Instead, they are consumers of scientific information, which they must interpret and may choose to heed or ignore. At the same time, policymakers are unlikely to enact policies for which there is little public support. Furthermore, strategies to mitigate environmental harms may require the cooperation of individuals, such as property owners, which would require them to have confidence in the scientific basis for those policies. In turn, this makes communicating research to non-scientists an important challenge for environmental scientists if they want their research to have an impact on how we manage the environment.

There are a number of potential roles for environmental science in the policy process. Scientific research can contribute toward problem definition (Kingdon 1995) and the development of causal stories (Stone 1989). By identifying or improving our understanding of the physical, chemical, or biological processes by which natural hazards or environmental problems occur, scientists help identify and inform our understanding of a policy problem. Scientific research can also help policymakers understand why a problem is occurring and what the potential consequences are. Environmental scientists often contribute to a basic understanding of an ecosystem, which can be useful in establishing a "baseline," often necessary for regulatory or management practices. Scientific research also can play an important role in evaluating potential solutions to environmental problems: how effective is a particular action expected to be? In the regulatory context, scientific knowledge often plays a role in designating regulatory thresholds, such as acceptable levels of contaminants in a waterway or the minimum

population of a species that would trigger regulatory action. These decisions, while often informed by some scientific rationale, also require non-objective value judgments about acceptable levels of risk to humans or the environment (Layzer, 2012).

However, it is important to recognize that environmental policy is not a simple, rational process of applying scientific knowledge. It is tempting to think that if only policy makers understood the science behind an environmental problem, they would make better policies. But Litfin (1995) argues that the relationship between science and policy is not so straightforward; many environmental policy disputes are trans-scientific problems that require decisions beyond rational analysis. "The modernist fallacy wrongly assumes that scientific and technical knowledge can provide an objective body of facts from which policy can be generated" (Litfin 1995, 15). Litfin argues that scientists do not just communicate their knowledge to lay audiences. Instead, they act as "knowledge brokers," interpreting and framing their findings. In this process of interpretation, scientists exercise subjective judgments shaped by their social contexts. Lynn (1986) also questions the assumption that scientists are neutral experts by showing how individual scientists' political and social values affected their views on acceptable levels of exposure to environmental risk. Translating scientific observations into policy recommendations requires subjective value judgments that are not apolitical.

Environmental science can often become a political battleground in disputes that are really about participants' values or economic interests. According to Layzer (2012), nearly all environmental disputes may seem to revolve around technical questions but actually are conflicts over values, such as environmentalism or economic growth. For this reason, "environmental policy conflicts are rarely resolved by appeals to reason; no amount of technical information is likely to convert adversaries in such disputes." Participants rarely support their positions with

value-laden arguments, instead framing their positions in technical terms (Layzer 2012, 2). Ozawa (1996) describes how actors in environmental conflicts often use science as a tool of persuasion, with research used politically on both sides of an issue. This forces scientists into a political role they may not want to take. The result can be combat science, in which stakeholders promote scientific arguments that support their interests or discredit scientific research that challenges their interests (Service 2003; Taylor and Short 2009).

The politicization of science poses a particular challenge for scientists, who are expected to remain as objective, impartial observers, both by the scientific community and society at large. Scientists derive cultural legitimacy from their image as objective researchers (Nelkin 1995). For this reason, scientists avoid discussions of values, even when they necessarily employ subjective judgments to interpret their research for policy purposes (Litfin 1995). Because the language of political debate is much less reserved than that of science, scientists struggle to communicate their research with the public in a clear, compelling way. Porder (2004) describes the conflict between scientific culture, which prizes caution and avoids overstatement, and the culture of public relations, in which scientists' language seems weak and uninteresting. Many scientists avoid strong normative statements about the implications of their research. When debates call for a simple, press-savvy message, or when they veer away from questions of pure science into questions of values, scientists fear damaging their reputations among other scientists and the general public (Mooney 2010). The cultural expectation of scientific objectivity constrains the culture of science communication, which makes it difficult for scientists to express their research in ways that are clear and relevant in public debates.

The uncertainty of scientific knowledge also makes it difficult to explain to the public. Scientific knowledge is uncertain and provisional, since any theory could be disproved by future

research (Popper 1965). In some cases, scientists struggle to maintain the nuance and uncertainty of their research when journalists simplify it for a story (e.g., Nordhaus 2011). In other cases, opponents of a policy approach overstate the level of uncertainty of the science underpinning it. In the United States, conservative think tanks have funded numerous studies to challenge environmental science, "manufacturing uncertainty" to undermine support for environmental regulations (Michaels and Monforton 2005; Jaques et al. 2008).

There is a basic conflict between the pressure on scientists to communicate their research in an objective, apolitical way and the political battlefield in which science interacts with policy. How can scientists communicate effectively when they are expected to communicate uncertainty and nuance that other policy actors do not? And how can scientists provide a clear, policy-relevant message while maintaining their neutrality? Cash, et al (2003) argue that for science to be most effective in shaping social responses to environmental problems, it should not only be credible, but also salient and legitimate; it should be relevant to the needs of decision makers but also trusted as unbiased and fair in its treatment of divergent views and interests. However, there is a contradiction between the objectivity from which scientists derive their cultural legitimacy and the judgment needed to craft salient policy messages. This contradiction, between saliency and legitimacy, is one of the primary challenges that scientists face in navigating the boundary between science and policy.

This study asks how scientists perceive their role in the policy process, and how they navigate the intersection of science and policy given this political context. To answer these questions, I chose to study the San Francisco Bay-Delta, because it is a region where scientists have a long history of conducting research and engaging with the policy community. The Bay-Delta is also an area where the relationship between science and policy is particularly important.

The region is a major hub for California's water supply. It is also a complex and fragile landscape, heavily altered by human use and development. Over the past few decades, this region has been the site of conflict between environmental, agricultural, and urban interests, as the area's water resources face increasing stress and the potential extinction of fish species (Layzer 2008; Hanak et al. 2012). The region's farms and towns are also vulnerable to flooding and land subsidence (Ingebritsen and Ikehara 1999). Because the cities around the Bay-Delta's edges are some of the fastest-growing cities in California, the area faces substantial development pressure, which will exacerbate environmental pressures and exposure to natural hazards in the region (Lund et al. 2008). Climate change also threatens to exacerbate pressures on the Bay-Delta by increasing the risks of flood and drought from sea level rise, changing precipitation patterns, and the decline of the Sierra snowpack (Layzer 2008; Cloern et al. 2011).

Because of the region's complex natural hazards, as well as over three decades of environmental disputes, the San Francisco Bay-Delta has been the subject of many scientific studies. Scientists from universities, the United States Geological Survey (USGS), and other government agencies have studied the Bay-Delta since the 1960s, making it one of the best-understood estuaries in the world. But it is unclear of the extent to which this research has been communicated to stakeholders or how effective these communications have been. We do know that in policy discussions, stakeholders often say that we do not know enough about the Bay-Delta to change management policies (Moyle 2013).

To better understand how scientists in the San Francisco Bay-Delta have communicated their research to non-scientists within the context of the region's political controversies, I interviewed scientists conducting research in the region, science communications staff, and science journalists. I also reviewed scientific reports, policy white papers based on scientific

research, and public-facing communications, such as fact sheets and news accounts of environmental science and management issues in the Bay-Delta. I found that many scientists have explicitly engaged in discussions about their research with the policy community or the general public. In the three cases I examine in this paper—the CALFED Science Program (starting in 2000), the policy-focused collaboration between the University of California, Davis Center for Watershed Science (CWS) and the Public Policy Institute of California (PPIC) (2007 to the present), and the San Francisco Estuary Institute's public-facing work with KQED (a local public radio and television station) in 2012—the overall story of scientists' approach to communicating their research in the Bay-Delta is one of increasing political sophistication. Scientists have adjusted their strategies to adapt to changing political circumstances and past political failures. They have also struggled with the conflict between salience and legitimacy in a variety of ways. How different scientists have attempted to reconcile this tension is partially informed by their affiliations and their sense of their role in the policy process. Although each of these cases depicts a different approach to the relationship between science and policy, these scientists' strategies complement each other, showing how scientists have built upon previous communications work.

GEOGRAPHY, HISTORY, AND ENVIRONMENTAL CONFLICT IN THE SAN FRANCISCO BAY-DELTA

Environmental policy disputes in the San Francisco Bay-Delta have been shaped by the region's unique geographic setting and history of development. The Bay-Delta encompasses approximately 1,000 square miles and is home to more than 400,000 residents at the confluence of the Sacramento and San Joaquin Rivers. Approximately 60 percent of California's precipitation travels through this system, draining from the Sierra Nevada to the San Francisco Bay (Ingebritsen and Ikehara 1999; Kallis et al. 2009). The Bay-Delta is a tidal estuary system,

with fresh water flowing from the Sierra Nevada towards the San Francisco Bay and salt water from the Pacific Ocean flowing inland due to ocean tides. In a typical year, the Bay-Delta experiences cool, wet winters and hot, dry summers, leading to fluctuating water flows and Delta salinity. California's climate varies from season to season and year to year, however, with extremely wet or dry periods (Whipple et al. 2012). This variability supports a landscape of great diversity, with a variety of ecosystems and habitat types. The Delta's native species have adapted to live in this variable environment.

The History of Bay-Delta Development and Environmental Decline

Prior to European colonization of California in the late eighteenth and early nineteenth centuries, the Bay-Delta was home to a population of around ten thousand Native Americans, who appear to have moved seasonally to take advantage of different natural resources and to avoid flooding (Whipple et al. 2012). Intensive European-American settlement of the Bay-Delta began in the early- to mid-nineteenth century. After the California Gold Rush brought an influx of new Americans to the state in 1849, many settlers moved to the Delta, attracted by its potential for agricultural production and its strategic location as a shipping hub between the Sierra Nevada and the San Francisco Bay.

These new settlers rapidly reshaped the landscape to a state dramatically different from its early-nineteenth century environment, building dikes and levees to straighten shipping routes and reclaim wetlands for agriculture (Whipple et al. 2012). Hydraulic mining in the Sierra Nevada created massive flows of sediments and mining waste into the Bay-Delta. This debris created a legacy of contamination by mercury and other heavy metals that affects water quality into the present. The debris also exacerbated flood risks, which became particularly pressing in the winter of 1862, when a series of severe storms flooded the central Delta for over a month (Hanak et al. 2011; Dettinger et al. 2012). In an effort to encourage scouring and transport of

hydraulic mining sediment through the Delta, engineers designed levees at the rivers' edges to design narrow, deep river channels (Hanak et al. 2011). Farmers and Delta communities then built up to the levees' edges, leaving little room for floodplains. Once these reclaimed lands were converted from anaerobic wetlands to aerobic farmland, the peat in the soil began to decompose, which led to land subsidence at a rate of approximately four inches per year. Parts of the Bay-Delta are now more than twenty-five feet below sea level (Ingebritsen and Ikehara 1999). The landscape of the Bay-Delta today was largely shaped during this period, with over 70 subsiding islands, or tracts of reclaimed land surrounded by levees.

The transformation of the Bay-Delta's landscape in the nineteenth and early twentieth centuries was the consequence of decentralized efforts by farmers, municipalities, and local reclamation districts (Hanak et al. 2011). The most significant large-scale, centrally organized alterations to the Bay-Delta ecosystem began in the 1930s with the Central Valley Project (CVP), a federal water project to construct several dams, reservoirs, diversion canals, and pumping stations to transport water from the Sacramento and San Joaquin Rivers to the Central Valley (Layzer 2008; Hanak et al. 2011). In the 1960s and '70s, the State of California constructed the similarly ambitious State Water Project (SWP), another system of dams and canals to export water from the Sacramento-San Joaquin Delta to the Central Valley and to support urban growth in the southern San Francisco Bay and Southern California (Hanak et al. 2011; Layzer 2008). The primary motivation for the SWP was to support growth in California's agricultural economy and urban development in water-constrained parts of the state. Beginning in the 1930s, the federal and state governments took a more active role in flood control, as well, with the construction and improvement of levees by the U.S. Army Corps of Engineers. Today,

the state and federal governments jointly manage approximately 1,100 miles of earthen levees in the Delta.

By the time the SWP began operations in the 1960s, the Delta's ecological health was deteriorating noticeably, as the combined diversions from the CVP, SWP, and individual Delta farmers led to an overall diversion of up to 60 percent of the fresh water flowing through the Sacramento and San Joaquin Rivers every year (Layzer 2008). The cumulative impacts of decades of habitat transformations—the conversion of what was once 700,000 acres of tidal wetlands into a network of rock-lined, leveed channels; the input of contaminants from legacy mines and urban and agricultural runoff; and the dramatic reduction of fresh water into the Delta—led to a collapse of native fish species, such as the Delta smelt, an endemic fish species found nowhere else, and the Chinook salmon (Hanak et al. 2011). The passage of federal and state environmental laws—including the National Environmental Policy Act (NEPA) of 1969, the California Environmental Quality Act (CEQA) of 1970, the Clean Water Act (CWA) of 1972, and the federal Endangered Species Act (ESA) of 1973—gave the growing environmental movement legal leverage to force the state and federal governments to pay attention to the Delta's ecological decline.

The Delta's ecological decline and the increasing legal leverage of environmental interests led to a period of conflict over water use and water quality in the Delta. Meanwhile, environmental activists focused on the San Francisco Bay became increasingly interested in the health of the overall Bay-Delta system. As Bill Davoren, who founded the Bay Institute in 1981, put it, "Save the Bay [a San Francisco Bay environmental advocacy organization] was working on the bay as a bathtub, but no one was looking at the faucet" (quoted in Walker 2007, 117). In 1978, as the SWP continued to increase its extractions, California's State Water Resources

Control Board (SWRCB) attempted a series of regulations to protect water quality in the Delta, which faced a series of lawsuits by water users and environmentalists. In 1982, a ballot measure to build a peripheral canal that would allow water exports to southern California to bypass the Delta entirely failed, defeated by an unlikely alliance of Delta farmers and environmentalists (Hanak et al. 2011).

The situation worsened throughout the 1980s and became a political crisis in 1986 when the courts ordered a review of the effects of diversions (Hanak et al. 2011; Walker 2007). A six-year drought from 1987 to 1992 exacerbated conflicts over water allocation between environmental and economic interests (Sommer et al. 2007). The National Marine Fisheries Service (NMFS) listed the Sacramento River's winter-run Chinook salmon as a threatened species in 1989, upgrading it to endangered in 1994. The Chinook salmon run in the Sacramento River had decreased from 100,000 fish in 1940 to fewer than 500 in 1989. In 1993, the U.S. Fish and Wildlife Service (USFWS) listed the delta smelt as a threatened species, after its population declined by over 90 percent (Hanak et al. 2011).

During this time, scientists were increasingly concerned that the state's water policy did not sufficiently address the combination of factors contributing to the Bay-Delta's decline: the loss of over 90 percent of historical wetlands, the channelization of the Delta's waterways, the industrial and agricultural pollution, the proliferation of invasive species, and the diversion of freshwater inflows to the system (Layzer 2008). The disputes over water management in the Delta came to a head in 1992, when the U.S. Environmental Protection Agency (EPA) disapproved the SWRCB's export-friendly water quality plan (Hanak et al. 2011). In October of that same year, Congress passed the Central Valley Project Improvement Act (CVPIA), which

declared environmental protection a purpose of the CVP and allocated 800,000 acre-feet of water to fish and wildlife (Layzer 2008).

As the federal government became more active in California water policy, the state sought ways to cooperate with federal regulators to reach a resolution that would be favorable to California water users (Layzer 2008). In December 1994, the state and federal governments signed the Bay-Delta Accord, which developed a new water plan and established the CALFED Program. CALFED was an ambitious attempt to solve the disputes over water allocation and environmental management in the Bay-Delta in a comprehensive way, following a collaborative adaptive management model in which state and federal agencies, water users, and environmental stakeholders would collaborate to find solutions that would satisfy all parties. CALFED's motto was "getting better together," suggested that they would be able to solve the region's environmental problems without imposing costs on any stakeholder (Layzer 2008). In 2000, twenty-four agencies signed the CALFED Record-of-Decision (ROD), which addressed compliance with environmental regulations, ecosystem restoration, and water supply reliability (CALFED Bay-Delta Program 2000; Kallis et al. 2009). The ROD established a science program to support and synthesize independent, peer-reviewed scientific research about Bay-Delta ecosystem processes—an attempt to incorporate better science into policy-making by creating an independent, credible body to support scientific research. With the science program, CALFED's intent was to counteract the dominance of combat science sponsored by interested parties in the Delta's disputes (Taylor and Short 2009).

Initially, CALFED was well funded, with a budget of $3 billion, but the program's ambitions fell short in implementation. The stakeholders in the CALFED process failed to reach agreement on substantial policy changes, and the environment of the Bay-Delta continued to

deteriorate. Around 2000, four pelagic fish species—the delta smelt, longfin smelt, striped bass, and threadfin shad—began to decline in abundance, in what became known as the Pelagic Organism Decline (Sommer et al. 2007). This decline of several fish species at once, both native and introduced, suggested a systemic decline in ecosystem functions rather than an isolated threat to a single species. In 2005, the population of the Delta smelt collapsed further, making manifest the stakeholders' failure to improve environmental quality in the Bay-Delta. (In 2008, the delta smelt would be elevated to endangered status.) Frustrated at the lack of tangible results from the CALFED process, the Schwarzenegger administration ordered two reviews of CALFED and launched a Delta Vision Blue Ribbon Task Force in 2005 (Layzer 2008).

Based on the recommendations of the Delta Vision Blue Ribbon Task Force, the California Legislature passed the Sacrament-San Joaquin Delta Reform Act (Delta Reform Act) in 2009, which ended CALFED and created a Delta Stewardship Council to manage the Delta with "the coequal goals of providing a more reliable water supply to California and restoring and enhancing the Delta" (California Department of Water Resources 2009). The Delta Stewardship Council is a decision-making body of seven appointees tasked with developing a new Delta Plan and Bay-Delta Conservation Plan (Delta Stewardship Council 2010).

Kallis et al. (2009, 641) argue that after the failure of CALFED's consensus approach, "[s]takeholders in the Bay-Delta have reached the painful realization that they cannot have it all." However, the "coequal goals" of the Delta Reform Act suggest that the Delta Stewardship Council is still expected to satisfy the interests of all water users and protect the environment, a task that may prove impossible. In March of 2013, the Delta Stewardship Council released the first seven chapters of the Draft Bay-Delta Conservation Plan; the complete document is expected to be up to 17,000 pages long and will propose water conveyance via a new peripheral

canal as well as large-scale ecosystem restoration (Bay Delta Conservation Plan 2013; Whipple 2013). The length of the document suggests the complexity of the task ahead; it also suggests that only those most invested in the process will review more than a portion of it. As Alison Whipple, an ecological researcher for SFEI, commented, "you can't conceive or digest that" (Whipple 2013).

There are several reasons why the Bay-Delta's natural environment and policy setting will change substantially in the future. Sea level rise, climate change-related changes in precipitation patterns, and the decline of California's snow pack will increase long-term flood risk to the Delta's islands. Climate change will also change water temperature and salinity, further stressing fish habitats (Cloern et al. 2011; Mount et al. 2012; Hanak et al. 2011). Meanwhile, the federal and state governments are increasingly unwilling to fund expensive levee and water infrastructure projects, including maintenance. Hanak et al. (2011) argue that this confluence of trends will make substantial change in the Bay-Delta inevitable. For them, the relevant policy question is how to manage this change to avoid catastrophic outcomes to the environment or the state's economy.

The Bay-Delta's Diversity of Scientists and Stakeholders

Not all scientists working in the Bay-Delta are alike. Taylor and Short (2009) group scientists in the Bay-Delta into two categories: research scientists and management scientists. In their schema, research scientists work to produce fundamental research to understand a system, whereas management scientists typically producer and use knowledge to inform management actions (Taylor & Short, 2009: 676). Research scientists typically are employed by universities, whereas most management scientists work for resource management agencies. The USGS is an example of a government agency that is culturally similar to a university due to its focus on fundamental research (Taylor and Short 2009, 679). The USGS has no regulatory or

management authority, but instead conducts research that other agencies may use in their policy development (Ingebritsen 2013; Gordon 2013; Pressfield 2013). USGS scientists are forbidden from taking explicit policy stances by the agency's mandate in order to protect the agency's long-term credibility and "ensure...that the public trust is met" (USGS 2011). In addition to the research scientists and management scientists that Taylor and Short (2009) describe, there is a third category of scientists conducting research in the Bay-Delta: advocacy scientists. These scientists typically work for environmental non-profits or as consultants to stakeholder groups, such as farmers, water districts, or environmental activists. Their research often has a more explicit policy agenda.

Because of the complex, multifaceted nature of the environmental problems and natural hazards in the Bay-Delta, the scientists and engineers workign the Bay-Delta come from many different specialties. Because there are so many researchers from so many different disciplines doing policy-relevant research in the Bay-Delta—hydrologists, seismologists, geophysicists, fish biologists, invasive species biologists, chemists, and engineers, among others—it is not enough for each of these researchers to communicate their research alone. There is a need for scientists to understand what other specialists in other disciplines are doing and how that relates to their work. There is also a need for someone to create synthesized explanations for the policy community and other interested audiences to understand how different scientific processes in the Bay-Delta interact.

There are also multiple potential audiences for science communication that are relevant to the policy process. These include what USGS biologist Janet Thompson referred to as "client agencies," or resource management agencies that directly apply USGS data collection and research in their management activities (Thompson 2013). Another important audience is the

policy community, including legislators, legislative aides, and policy-level staff at environmental regulatory and management agencies. Many of the scientists interviewed in this study spoke of directing communications at the policy community, with the stated goal of ensuring that policy makers who are making decisions about the Bay-Delta are well-informed about the scientific processes that shape the region.

A third audience is the public. Although most members of the public do not have direct decision-making authority over Bay-Delta management, they do affect policy through the political process. State and local politicians pay attention to opinion among their constituents, so the public's knowledge and opinions about the Bay-Delta may affect their decisions. Public opinion can also have a direct impact on Bay-Delta management policies when measures are on the state ballot, such as when California voters rejected a proposal to build a peripheral canal around the Bay-Delta in 1982.

The public is not monolithic. Justin Pressfield, chief of communications for the Western states at the USGS, stated this clearly: "I don't ever just have this giant blob that I call the general public. Everything we do is targeted to specific audiences.... Anyone in communications who isn't looking at who would be most impacted by this study, and why do we want to impact them, is doing it wrong" (Pressfield 2013). Specific USGS publications about the Bay-Delta may be targeted at Suisun Marsh duck hunters or mining companies or salt pond owners. But, as Pressfield explains, many Californians are stakeholders in the Bay-Delta, whether or not they are aware of it. "If you're talking about a broader ecosystem, then you would want to talk to all users of water from the Bay-Delta, which you know is a lot bigger than the surrounding communities to the Bay and the Delta. Now all of a sudden you're talking about all of the farmers in the

Central Valley and water users even as far away as L.A., and you're talking to South Bay residents" (Pressfield 2013).

The level of salience of an issue affects the extent to which public opinion influences policy. If most people are not aware of an issue, or do not perceive it as a problem, then policies will be much more likely to be shaped by those with a direct interest in the outcome. There is currently very little knowledge of the Bay-Delta among California residents. In 2012, a statewide voter poll showed that 78% of respondents did not know about the Bay-Delta or had never heard of it (Probolsky Research 2012; Miller 2012). Matthew Weiser, a science and environment reporter for the *Sacramento Bee*, explained, "it's not well understood by most people, even though it's in the heart of California. Most people in California drive around it. They don't drive through it. A lot of people don't even know it exists" (Weiser 2013). Lauren Sommer, a reporter for KQED's Quest Science Program, had a more personal anecdote, since she grew up in the San Francisco Bay Area but had no knowledge of the Bay-Delta. "I didn't know that much about the Delta before I started covering environmental issues in California. So that does influence me, that I could grow up 45 minutes away and not know anything about that place. That means that most Californians don't know anything about the Delta" (Sommer 2013).

Environmental Reporting in the New Media Landscape

Recent structural changes in the economics of the news industry have affected Bay-Delta scientists' ability to communicate their research to general audiences. The traditional news media, which generally serves a universal audience with policy-neutral news, is a less significant source of scientific information than it used to be. In the past decade, several local newspapers in California have gone out of business; others have significantly reduced their staff. Science and environment beats, often seen as niche coverage, have been especially hard-hit. Matt Weiser,

from the *Sacramento Bee*, described the situation he has seen since he began covering the Bay-Delta in the mid-1990s:

> One thing that's changed is that there's just a lot fewer journalists covering the things I write about. There used to be a reporter at every paper in Northern California that was well versed on Delta issues and water issues, and now it's me and one other reporter at the Stockton Record.... Having more reporters reporting on these things was a competitive environment. You had a bunch of different reporters covering these issues, and one of them would come out with a story that was new to me, and it would drive the issue forward, for the public and for decision makers. And that just doesn't happen as much anymore. (Weiser, 2013)

Weiser believes this has created a less-informed public, as well as scientists and government officials who have less experience interacting with the media.

Agency science communication staff also noticed these changes. Leslie Gordon, Public Affairs Specialist for the USGS, explained how science journalists are generally easier to work with on a story than generalist reporters, because they already have background knowledge. Today, though, "there are fewer and fewer science and environmental reporters.... As news staffs are being downsized, they've got just one non-specialist reporter who will do it all." As a result, Gordon says, "we do a lot of our own storytelling... We are going sometimes directly to the public with new social media, because there are fewer reporters" (Gordon 2013). The USGS has developed a variety of blogs, and they maintain Facebook and Twitter profiles to disseminate information. However, these typically will only reach audiences who are already interested in environmental science, so they may not be as effective as traditional news coverage as a way to engage the interest of new audiences.

Ellen Hanak, Co-Director of Research at PPIC, also noted that communications about Bay-Delta policy are increasingly occurring in specialty forums, rather than the news media. "What happens is that the water world in California has a lot of communication networks.... So information still gets around fairly well, there are just different formats for that. But you could

ask what the implications are for reaching the broader public. It's maybe harder than it was before. So people are probably more likely to be getting information from more advocacy-oriented sources to the extent that they care about water" (Hanak 2013). The disappearance of general-audience, policy-neutral venues for communicating Bay-Delta science poses a challenge to expanding public awareness of the region and the issues it faces. It makes it harder for scientists to communicate their research with people who do not already take an interest in the region or identify themselves as stakeholders.

CASE STUDIES: THE POLITICAL EDUCATION OF BAY-DELTA SCIENTISTS

The San Francisco Bay and estuary system has a long history as the site of interdisciplinary scientific research. The USGS and other state and federal agencies have been conducting research on topics such as water quality, levee stability, and ground deformation since the late 1960s (Jacobs et al. 2003). The following three cases do not comprise a comprehensive history of science communications efforts in the Bay-Delta. Rather, they reflect the political education of research scientists over the past two decades as they have interacted with environmental policy development. These cases also show that one of the biggest challenges in communicating and interpreting policy-relevant science is figuring out how to engage effectively with the policy community while maintaining one's perceived legitimacy. Each group of scientists featured below emphasizes their independence but struggles with the tension between their expected objectivity and the need to interpret their knowledge in a way that can inform policy. They are under tremendous pressure to be perceived as objective so that they can maintain their scientific authority and perceived legitimacy in the policy debate, as well as their reputation within their own scientific fields. However, much of their work is not value-neutral; whether or not they make explicit policy recommendations, these scientists are making

implicit value judgments about environmental values, such as whether protecting species from extinction should be a goal. How scientists approach this dilemma depends partly on their institutional affiliations, and partly on the role they strive to play in the policy process.

These three cases show an increasing level of political sophistication among scientists in the Bay-Delta as scientists continue to navigate the line between science and policy. In the first case, the CALFED Science Program was created in 2000 to complement and support the CALFED policy process by developing a body of credible, policy-relevant research and a non-adversarial setting in which scientists, policy makers, and stakeholders could discuss Bay-Delta science. The CALFED Science Program explicitly incorporated scientists into the policy making process while maintaining a policy-neutral stance—a position which was contradictory, but which helped the scientists maintain legitimacy within the scientific and policy communities. This legitimacy was necessary to support the CALFED policy process. Although CALFED did not lead to substantial changes in environmental policy, the CALFED Science Program did increase scientific knowledge of the Bay-Delta and policy makers' understanding of the science. It also established a base of research and relationships between researchers and policy makers that aided future science and policy efforts in the Bay-Delta.

The second case explores how an interdisciplinary team of scientists at the University of California, Davis collaborated with PPIC, a non-partisan policy think tank, to respond to CALFED's failure to change policy. This interdisciplinary team began releasing a series of policy white papers in 2007, as CALFED came to an end. The PPIC and UC Davis team maintained a claim to scientific independence and objectivity but explicitly addressed the policy implications of their research to make recommendations about the Bay-Delta's future. Their claim to scientific objectivity contradicted their aggressive policy statements, but their

willingness to take a stand played a useful role in organizing discussions about the future of the Bay-Delta and research priorities. In this case, the PPIC and UC Davis scientists staged a policy intervention based on their analysis of the science. Although their approach to policy is different, their work relied on the research base that the Science Program provided, showing some continuity between these cases. Their approach was much more explicitly political than that of the CALFED Science Program, trying to change the policy process from outside rather than supporting it from within.

In the first two cases, scientists focused their communications on the policy community rather than communicating with the public. Both the CALFED Science Program and the PPIC collaboration saw general outreach as beyond their scope. By contrast, the third case explores an attempt to communicate complex ecological and management information originally developed for state resource management agencies to a broader audience. In 2012, the San Francisco Estuary Institute (SFEI), an ecological research non-profit, produced a detailed report on the historical ecology of the Sacramento-San Joaquin Delta, reconstructing knowledge about the pre-European landscape of the Bay-Delta and its history of alteration over time. In addition to providing a 480-page report to the California Department of Fish and Wildlife (CDFW) and the Ecosystem Restoration Program (ERP), SFEI staff also embarked on a multi-month collaboration with KQED's Quest Science Program—a Bay Area public radio show about science and the environment—to create a series of radio stories and interactive materials that explain Bay-Delta history, ecology, and management issues to a broader public audience. Rather than engaging the public in the existing political debate about managing the Bay-Delta, these stories provide educational background on the region, its history, and the dilemmas policy makers face in restoring its environment. These stories are not apolitical, however; they have the potential to

increase the number of people who take an active interest in Bay-Delta policy. By providing an engaging portrait of this unique landscape, stories like these may build a case for why people should care about the Bay-Delta's environment.

The CALFED Science Program: Science Supporting Policy Development

The CALFED Science Program began in 2000 as an attempt to create a forum for science that could support CALFED's policy process. The program's founders sought to develop credible science that would have legitimacy with Bay-Delta stakeholders and be salient to policy makers, echoing Cash et al (2003) (Taylor and Short 2009). The program was a response to the acrimonious policy debates and litigation that preceded the creation of CALFED in the 1990s, when many stakeholders complained about "battlefield science," or political debates dominated by advocacy science produced and promoted by conflicting stakeholders. CALFED sought to address this problem by creating the Science Program as an independent entity whose mission was to improve the use of science to inform management decisions (Taylor and Short 2009). More specifically, the program's goals were to increase scientists' understanding of "human and natural systems" in the Bay-Delta, to "integrate best available scientific understanding and practices throughout CALFED," to provide CALFED decision makers with "authoritative and unbiased" descriptions of the state of scientific knowledge, and to "establish and improve communication between science, management, and public communities" (Jacobs et al. 2003, 34).

The Science Program pursued these goals through a suite of actions: it instituted a grant program to fund research in the Bay-Delta, attracting scientists from academia and non-profits; it held annual conferences on the state of Bay-Delta science and organized interdisciplinary workshops on controversial scientific topics; and it created a new open-source online journal, *San Francisco Watershed and Estuary Science*, which disseminated peer-reviewed science relevant to the Bay-Delta (Layzer 2008; Luoma 2013). The creation of an online journal was

especially useful in the context of the Bay-Delta because most agencies and stakeholder groups did not have access to academic journal subscriptions (Luoma 2013). *San Francisco Watershed and Estuary Science* provided a new forum for publicly sharing peer-reviewed scientific knowledge among research scientists, management scientists, advocacy scientists, policy makers, and stakeholders.

The CALFED Science Program aimed to provide relevant and "policy-neutral" advice for decision-makers (Luoma 2013). In this way, the Science Program was an attempt to create a scientific institution with an explicit link to policy makers. However, the advice the program created avoided advocacy of specific policies in an attempt to avoid the combat science prevalent in Bay-Delta policy discussions. In reality, this task was full of contradiction: advice implies judgment about the viability or wisdom of different options, which requires some value judgment. The Science Program navigated the contradictory goals of using science to inform the policy process while acting as an independent voice outside of the policy community by focusing on community-building and facilitation between scientists and policy makers. Samuel Luoma, the CALFED Science Program's first lead scientist, cast his role as one of an independent facilitator:

> That job was created to be right in the middle of the policy world. So the key word for that job was not 'lead scientist,' it was '*independent* lead scientist.' The science program was created as an independent entity equal to the executive director of CALFED, communicating...with the agencies, the university people. I think the best description of that job is facilitation of communication between the entire science community, the regulatory community, which are the agencies, and the policy community, which are the stakeholders as well as the legislature. (Luoma 2013)

Clifford Dahm, the lead scientist for CALFED and the Delta Stewardship Council's Science Program from 2008-2012, described the job similarly: "really, the lead scientist position is not so

much a doing research as a synthesizing, integrating and communicating research position…to be an independent broker of scientific information" (Dahm 2013).

The CALFED Science Program's staff recognized the potential tension between their central role in policy development and their ostensible policy neutrality but stressed that this neutrality was necessary to foster trust in the collaborative decision-making process:

> Another contradiction between science and policy is that science gains credibility through independence from the policy arena, but policy changes only when it is supported by a champion or cause.... CALFED follows a model that suggests that advocacy in policy is best supported by a science apparatus that provides as much relevant information as possible but leaves advocacy to policy makers and other arenas such as litigation.... In the CALFED program, debates fueled by alternative values are minimized. A science arena where advocates can find grounds for agreement is presumed to be the most conducive to successfully linking science and policy. (Jacobs et al. 2003, 39)

Although the CALFED Science Program staff may have recognized the contradiction between their ostensible neutrality and their role in the policy process, their primary goals were to establish trust in the science and to establish a productive dialogue about environmental management. For that, program staff believed it was best to refrain from statements that could be perceived as political. Essentially, their choice to maintain policy-neutrality was a political decision; they believed that this was the best way to constructively support the policy process and make sure policy makers had a better understanding of the natural processes that were driving the environmental management issues they were struggling with.

The staff of the CALFED Science Program focused on creating a trusted knowledge base and a forum to increase mutual understanding among policy makers and stakeholders (Jacobs, et al. 2003). To achieve this, they strove to create venues for non-confrontational engagement among parties: "we didn't want to get in arguments about scientific so-called fact. That can destroy a collaborative situation. Our job was to calm the waters, to use science as a vehicle to establish trust for people" (Luoma 2013). As a result, the Science Program avoided issues that

could cause policy negotiations to break down due to disagreements over science, such as developing a holistic model of the Bay-Delta system (Layzer 2008). Instead, the Science Program organized workshops and other venues to explore areas of scientific uncertainty constructively: "If everyone agrees that water flows downhill, you're not going to have a workshop on it.... The workshop arguments are always about the areas of greatest uncertainty. So arguing about who's right is rarely constructive, and it does not develop trust" (Luoma 2013).

The Science Program also recognized that, to improve the link between science and policy, it needed to do more than provide new forums for communicating science. It was also necessary to produce different kinds of science. The program's grant program and expanded dissemination of peer-reviewed research increased the diversity of credible scientific viewpoints studying the Bay-Delta and facilitated greater information sharing and synthesis between research. As Luoma explained,

> You can't have a policy-science interface without new science.... Watching things over time, I just became convinced that if the agencies had all of the money the science was only going to progress in a certain way. There had to be a mix of university science, agency science, and stakeholder science, and somehow you've got to mix those things and make those people interact.... But the progress of your science is narrower and more inhibited if all of the money goes to a few agencies or all the money goes to just the universities, because they've each got their view of the world. You really want a multi-dimensional view of the world. (Luoma 2013)

The Science Program's research grant funding increased the number of academic researchers studying the Bay-Delta. This funding encouraged scientists from California universities to study the region's environment, establishing their presence in the Bay-Delta research community (Luoma 2013). The Science Program also encouraged agency scientists and stakeholder scientists who did not have much experience publishing in peer-reviewed journals to publish in *San Francisco Watershed and Estuary Science*, increasing communication between different groups of scientists who previously were not communicating with each other (Luoma 2013).

The CALFED Science Program was generally considered successful at substantially increasing the scientific and policy communities' understanding of the Bay-Delta ecosystem and at increasing mutual understanding among stakeholders and agencies (Anonymous 2013; Luoma 2013). It also was successful at bringing academic researchers into the region, increasing the number of independent, well-respected researchers studying its environment. When the CALFED planning process broke down, the state polled stakeholders about which aspects of the program should be preserved or dismantled. No one recommended cutting the science program (Luoma 2013). It was generally considered the most successful part of the CALFED experiment.

Although the Science Program was successful in creating better understanding of Bay-Delta science among policy makers and stakeholders, it did not lead to substantial changes in environmental management practices in the Bay-Delta. Changing policy may not have been the primary goal of the CALFED Science Program, but it was an implicit goal. Presumably, the Science Program facilitated conversations between stakeholders and interpreted science to policy makers so that CALFED would be able to reach agreements at least partially informed by scientists. The fact that CALFED did not substantially change Bay-Delta management led Science Program staff to conclude that it is important to "look... beyond the creation of mutual understandings and at the capacity to integrate and apply that knowledge in management situations" for actually changing environmental policy (Taylor and Short 2009, 675).

Luoma argues that we may also be asking too much when we expect a program like the CALFED Science Program to help solve policy deadlocks:

> Science can only do so much. Science doesn't react well to crisis. There's got to be [research] ongoing, and you can shift some of that to crisis, but you can't continually redirect science to the next crisis and get anything at all... So in terms of responding to crisis, there will always be people who say that science didn't help us in that regard. But that's a fundamental limitation of science. (Luoma 2013)

In other words, we should not expect better scientific knowledge and better understanding of the science by policy makers alone to solve political or ecological crises. Instead, the value of a robust science program should be in the long-term benefits of continuous research and monitoring. However, Luoma's statement seems to contradict the whole purpose of the CALFED Science Program, which was created to guide CALFED's crisis-driven policy effort. From Luoma's statement, it is not clear what the role of science should be in attempting to address an ecological crisis. Long-term research and monitoring could incrementally increase our understanding of the ecosystem over time, providing us with basic knowledge that can help us respond when ecosystems collapse. Or it could help us avoid ecological crises through adaptive management. However, both of these scenarios still require political and institutional support to implement policy responses, which requires strong relationships and trust between scientific and policy communities.

The existence of a science program to support, facilitate, and communicate policy-relevant scientific research in the Bay-Delta has outlived CALFED, preserved in the Delta Reform Act of 2009. CALFED Science Program staff consulted on the enabling legislation that established the Delta Stewardship Council, creating the Delta Science Program modeled on the CALFED Science Program. Clifford Dahm, the CALFED lead scientist at the time, remained in the job past his expected term to oversee the transition to the Delta Science Program (Dahm 2013). One change Dahm and his staff did pursue was to strengthen lines of communication between the science program and decision-makers: the science program now shares an office with the Delta Stewardship Council and has a dedicated time to report to the Council at every Council meeting. Dahm described the Delta Science Program's success in interpreting scientific information for the Council, although his language is less ambitious than that of the CALFED

Science Program's creators: "we did a few things well...I think we provided timely information to decision makers...I think we were pretty effective in constituting a body of experts that the council could go to for advice...They also are a go-to group when some entity or organization issues a document. They are often asked to evaluate the scientific integrity of that document" (Dahm 2013). In general, Dahm was surprised by how engaged the Delta Stewardship Council has been with the Science Program:

> One of my surprises was the really strong interest in getting good scientific information into the decision making or the planning process that I ran into with almost all of the decision makers and policy makers that I interacted with in California. There was a legitimate and real interest in understanding the science well enough to utilize it in the planning and decision making process.... I thought I might run into a lot more resistance from the people I was communicating with. (Dahm 2013)

In addition to informing policy makers, the CALFED Science Program and the Delta Science Program have had another lasting legacy: they have supported the production of a new base of scientific knowledge that has changed the nature of science used in policy discussions. Much of the policy analysis that the PPIC and the UC Davis Center for Watershed Sciences staff began to publish in 2007 was based on the scientific research that the CALFED Science Program funded from 1997 to 2006 (Luoma 2013; Hanak 2013). Luoma stated that he is optimistic about the long-term impact of the science program model in creating a more informed policy environment: "If you really look at what the existing regulations are and what the lawsuits are about, it's a different world than it was 30 years ago. It's really more sophisticated. That doesn't mean people quit arguing. It doesn't solve the arguments. But managing water isn't about solving problems, it's an ongoing journey" (Luoma 2013).

One thing the CALFED Science Program did not do was end arguments over science in the Bay-Delta. Although these scientists were able to support independent research and facilitate

constructive conversations about areas of uncertainty, they were only one small part of the Bay-Delta science and policy community. Stakeholders continued to produce their own research to support their interests, continuing the culture of combat science (Moyle 2013; Hanak et al. 2012; Lund 2013). The Science Program also did very little outreach to the broader public, focusing on the existing policy and stakeholder communities (Luoma 2013). Because of this, they did not change public perceptions of the nature of the conflict in the Bay-Delta. In 2009, the Ecosystem Restoration Workshop Panel submitted a report to the CALFED Science Program that included an anecdote about a conversation with a Sacramento taxi driver, arguing that public opinion matters (Teal et al. 2009). The authors argued that science program needs to do a better job educating the public about what ecological restoration in the Delta is and why it is valuable. However, that would require a dramatically different communication strategy.

PPIC and CWS Launch a Multidisciplinary Intervention

The CALFED Science Program increased scientists' knowledge about the Bay-Delta ecosystem and the physical, chemical, biological, and human processes that threatened it. However, by 2005 it was clear that CALFED had failed to apply this knowledge to address the environmental issues confronting the Bay-Delta. Meanwhile, the environmental crisis continued, with the Pelagic Organism Decline and the 2005 crash of delta smelt populations. As the Schwarzenegger administration began to evaluate the future of the CALFED program, a new partnership emerged in Bay-Delta science and policy between the PPIC and a number of earth sciences, biology, and engineering professors at the University of California, Davis. This collaboration took a much different approach to the relationship between science and policy in the Bay-Delta. Whereas the CALFED Science Program consciously maintained its neutrality to work directly with the policy process, the PPIC and UC Davis authors chose to explicitly address the policy implications of Bay-Delta science and criticize current policy from outside. By

framing the Bay-Delta as an impending crisis, with change inevitable, they also avoided framing their argument in terms of environmental values. Their analyses also directly challenge political actors who try to stall action by manufacturing uncertainty by laying out well-supported arguments based on the substantial body of research from decades of Bay-Delta science. Their recommendations for how to reorganize the Bay-Delta policy discussion were a kind of policy intervention, drawing on the research CALFED Science Program had supported but arguing for policy change in the wake of CALFED's collapse.

The collaboration between the PPIC and the UC Davis researchers represents an alliance between two groups dedicated to a rational policy model, or the assumption that better knowledge will lead to better outcomes. PPIC's mission is to inform public policy through research, synthesis, and policy analysis. They do not support or recommend specific policies or political parties, maintaining their independence as a source of legitimacy. Ellen Hanak, co-director of research for PPIC, described the organization's mission: "We're a non-partisan, non-advocacy group that was created to provide solid, rigorous, research-backed information to contribute to the decision-making process in California" (Hanak 2013). PPIC's partner on this project, the UC Davis Center for Watersheds (CWS), is an interdisciplinary research center with a focus on applied environmental science, "dedicated to the interdisciplinary study of critical issues in watershed science–with a focus on the sustainable and cost-effective restoration and management of stream, lake and estuarine ecosystems" (CWS 2013). Interestingly, the CWS takes a more explicit policy stance in their mission statement than the PPIC, a policy think tank, by stating that sustainable ecosystem restoration and management are their goals.

PPIC and CWS researchers chose to intervene in the Bay-Delta policy discussion in reaction to what they saw as a political and ecological crisis. PPIC decided to research possible

policy solutions in the Bay-Delta in 2005 because of the breakdown in the CALFED process. As Ellen Hanak put it, "it became pretty clear by 2005 that it was really one of the major water management challenges, and it was really emerging as a crisis again. Things were starting to fall apart at that point" (Hanak 2013). PPIC chose to pursue Bay-Delta policy research in an interdisciplinary manner and began collaborating with researchers from the CWS. CWS scientists were also reacting to the breakdown of communications between scientists, agencies, and stakeholders in the Bay-Delta. As Jay Lund, a hydrological engineer and associate director of the CWS, explained, "it seemed to us on the Delta...that all of the public policy conversations...had gotten completely mired and confused, and they were just at each other's throats really to no good purpose, and it seemed like it might be just about the time when people might be desperate enough to listen to what a bunch of professors had to say" (Lund 2013).

The first product of this collaboration was *Envisioning Futures for the Sacramento-San Joaquin Delta*, published in 2007 (Lund et al. 2007). The authors of this report formed an interdisciplinary team whose goal was to synthesize the current state of scientific knowledge with economic analysis to explore the policy implications of environmental and economic trends in the Bay-Delta. This report goes far beyond synthesizing and communicating the science of the Bay-Delta ecosystem; it is more of a policy white paper. The authors were Jay Lund; William Fleenor, a research engineer in UC Davis' department of Civil and Environmental Engineering; Jeffrey Mount, a geology professor at UC Davis; Peter Moyle, a UC Davis fish biologist; Richard Howitt, a UC Davis professor of Agricultural and Resource Economics; and Ellen Hanak. In addition to the disciplinary diversity of the named authors, *Envisioning Futures* is the product of a larger, more multidisciplinary consultation process. The authors conducted a series of technical workshops and discussions over nine months, which convened a larger group of

academic, agency, and stakeholder scientists. Many of these workshop participants, especially government scientists, were not comfortable putting their names on the final document, but they did participate in a "not-for-attribution way" by sharing information and providing feedback on drafts (Hanak 2013). A group of scientists and policy experts peer-reviewed the final report.

The final product, a 147-page report, analyzed the ecological and economic impacts of nine potential futures for the Bay-Delta, based on the broad management strategies of maintaining the Delta as a freshwater system (the continuation of water export and flood management policies begun in the 1930s), managing the Delta with continuing water exports but with greater sensitivity to fluctuating environmental conditions, or substantially reducing water exports. The authors purposely analyzed a wider range of potential policy solutions than were under serious policy discussion at the time of the report's publication because they believed that the existing discussion under CALFED had only considered a narrow band of politically acceptable solutions that would not solve the Delta's long-term problems (Lund et al. 2007). They wanted to take the discussion beyond its existing political boundaries.

Although *Envisioning Futures* does not advocate a specific set of policies, its authors do make strong statements about the policy implications of their research and explicitly eliminate policy approaches whose economic or ecological costs they find unacceptable. From the beginning of *Envisioning Futures*, the authors state that the current management regime in the Bay-Delta is not ecologically or economically stable in the long-term, and that California must fundamentally rethink Delta policy. They argue that California policy makers must adjust policy to better align with new scientific understanding of the Bay-Delta as a complex mosaic of ecosystems that vary spatially and fluctuate over time:

> To address the problems of the Delta's native species, a fundamental change in policy is needed. A Delta that is heterogeneous and variable across space and time

> is more likely to support native species than is a homogeneously fresh or brackish Delta. Accepting the vision of a variable Delta, as opposed to the commonly held vision of a static Delta, will allow for more sustainable and innovative management. This is a legal and political necessity as much as it is an ecological one. (Lund et al. 2007, viii)

The authors conclude that the current management strategies of maintaining the Delta as a freshwater ecosystem and relying on weak levees for flood protection will not work in the long term, saying that "the current management of the Delta is unsustainable for almost all stakeholders" (Lund et al. 2007, xvi).

Stressing that substantial change in the Delta is inevitable was a politically savvy way to frame the argument in *Envisioning Futures*. Layzer (2012, 560) argues that stories are more likely to gain public and political attention in the context of an impending crisis. By framing the change in the Delta as an economic necessity as well as an ecological one, they avoid accusations that they value the environment over economic considerations. However, this analysis would be a powerful tool for advocates of environmental protection, because PPIC and CWS developed their argument based on scientific and economic analysis. By framing *Envisioning Futures* as a response to crisis, the authors also provide a compelling rationale for why having a policy discussion about the Bay-Delta is necessary, even if it is politically difficult.

The authors also criticized the central tenet of the CALFED planning process that "everyone would get better together," arguing that the policy discussion about the Bay-Delta must include a discussion of trade-offs: "[g]oing forward, Californians will need to recognize that the Delta cannot be all things to all people. Tradeoffs are inevitable. The challenge will be to pursue an approach that yields the best outcomes overall, accompanied by strategies to reasonably compensate those who lose Delta services" (Lund et al. 2007, ix). Echoing the sentiment that CALFED had produced better knowledge of the Bay-Delta but had failed to improve Delta management, they suggested that "now we are all 'getting worse together'" as

status-quo policies lead to continued environmental degradation and economic vulnerability (Lund et al. 2007, xvii).

The PPIC / CWS partnership is neither policy-neutral nor value-neutral. Its authors start from the position that public policies should emphasize the protection of native species, and that a healthy, functioning Delta ecosystem should be a policy goal. In fact, one of the reasons *Envisioning Futures* was so influential In their economic analyses, they also make assumptions about what level of expense for flood protection or economic costs of lost water exports would or would not be acceptable. However, the authors from PPIC and CWS believe that this more explicit policy analysis does not conflict with their roles as unbiased researchers. Hanak stressed that the authors are nonpartisan and unbiased because they were not working for anyone or advocating for any specific position. She also stressed that their report was peer-reviewed and that they would never withhold findings for political reasons, as some advocacy groups may do. For Hanak, maintaining independence was crucial, but it did not mean the group could not explore the policy implications of their research:

> We pretty jealously guard our independence in terms of what we'll say about this. We try to be helpful to the conversation and not too destructive. So we try to be measured in terms of how we talk about things, but we don't shy away from coming to pretty strong conclusions if we think that's warranted. And nobody's off-limits in terms of what they may or may not like to hear. (Hanak 2013)

Lund framed his view of the group's independence similarly, stressing that they did not work for any government agency or stakeholder group. "We will work with anyone, but we will work for nobody," he explained (Lund 2013).

Independence and objectivity are not the same thing, of course. The PPIC and CWS may claim legitimacy as policy actors due to their independence, but their analyses are not objective. On the contrary, the fact that PPIC and CWS are independent may actually allow them to express political judgments that researchers who are affiliated with government agencies cannot, because

they are not speaking for anyone but themselves. Lund argued that it was appropriate for academic scientists to take a more active role in the policy discussion: "given our position, it seemed like the responsible thing to do." He continued that different scientists may conceive of their role in policy debates differently:

> There's lots of different doctors, too. There's doctors that you go see, they do their little technical thing, and they give you advice on your little problem. But the well-being of society requires that there are doctors who do not only that,...but they come together and say something about health policy and public health. I think both roles are important for scientists...And I can understand why some...don't want to engage in the public conversation. It's messy, it's ugly, and you don't get paid for the time you spend doing it. But somebody's got to do it. If public university professors aren't willing to do this, then that's pretty sad. (Lund 2013)

Lund and Hanak both believe that *Envisioning Futures* was effective at reshaping the conversation about the Bay-Delta. They evaluate their efficacy based on feedback from policymakers and the ways their work has been explicitly incorporated into subsequent legislation. Their goal was to synthesize existing scientific and economic knowledge to shape a more informed discussion of policy alternatives, and they had a clear impact on the public conversation. Both Lund and Hanak stated that the timing of the report was excellent and captured the California water policy community's attention just as the state was rethinking CALFED (Hanak 2013; Lund 2013). The report directly informed upcoming legislation: "If you look at the 2009 legislative package that passed, some of the findings are pretty much direct quotes from some of our work in terms of laying out the problem" (Hanak 2013). The findings of the Sacramento-San Joaquin Delta Reform Act (2009) do sound very similar to the overall message of *Envision Futures*; they begin by stating that "[t]he...Delta watershed and California's water infrastructure are in crisis and existing Delta policies are not sustainable. Resolving the crisis requires fundamental reorganization of the state's management of Delta watershed resources." However, the act's focus on the "two coequal goals" of reliable water supplies and

environmental restoration suggest that the California legislature may not be as willing as the PPIC to discuss the need for trade-offs.

The PPIC and CWS have continued to collaborate on in-depth, multidisciplinary reports on the science and policy of the Bay-Delta. In 2008, the same group of authors and an additional fish ecologist from UC Davis, William Bennet, released a follow-up report, *Comparing Futures for the Sacramento-San Joaquin Delta* (Lund et al. 2008). Like *Envisioning Futures*, *Comparing Futures* begins with the assertion that the status quo in the Bay-Delta is unsustainable, and substantial ecological and economic changes are inevitable. Therefore, policy makers should consider how to manage change effectively. *Comparing Futures* then builds on the analysis in *Envisioning Futures* to analyze the environmental and economic implications of four potential policy approaches identified as potentially viable in *Envisioning Futures*: continuing the current approach of through-Delta freshwater exports, building a peripheral canal, a mixture of a canal and through-Delta exports, and ending all water exports from the Delta. Their analysis focuses on the impact of each scenario on ecosystems and California's water supply, how climate change may affect the system, and the governance and financial reforms necessary to help California make "strategic decisions about the Delta given the uncertainties about ecosystem and climate effects" (Lund et al. 2008, 3). The authors also argue that policy makers should not require scientific certainty to make management decisions: "Our analysis does not provide perfect clarity, but perfect clarity should not be needed to select a strategy to solve an urgent problem" (Lund et al. 2008, 4).

In 2011, the same group of PPIC and UC Davis researchers partnered with Ariel Dinar, an environmental economist from UC Riverside, and Brian Gray and "Buzz" Thompson, law professors from UC Hastings and Stanford Law School, respectively, to publish a 430-page book

on California water policy, *Managing California's Water: From Conflict to Reconciliation* (Hanak et al. 2011). This comprehensive analysis of the history and current issues of California water policy from a biological, geological, engineering, economic, and legal perspective discusses the Delta in depth because it is the hub of California's water system. This analysis is useful for situating the Bay-Delta within the broader context of California's water system. This book also synthesizes more recent information about ecological processes in the Bay-Delta. Among their recommendations, the authors discuss the state of scientific research to support decision-making, arguing that combat science and poorly organized scientific research that lacks integration in the Bay-Delta have hurt the state's ability to develop effective policies (Hanak et al. 2011).

In 2012, the PPIC and CWS researchers released two shorter, more digestible reports: *Where the Wild Things Aren't: Making the Delta a Better Place for Native Species* (Moyle et al. 2012) and *Aquatic Ecosystem Stressors in the Sacramento-San Joaquin Delta* (Mount et al. 2012). These reports both attempt to frame the complexities of Delta ecology in ways that provide guidance for policy action. *Where the Wild Things Aren't* addresses a central question for ecological restoration in the Delta, which many previous science and policy discussions, including CALFED, have failed to address: what would a "restored" Delta look like? Because the Delta has been so dramatically altered by human actions over the past 150 years, return to the past landscape is impossible. Therefore, Moyle et al. (2012) use the concept of reconciliation ecology (see Lundhold and Richardson 2010) to propose a vision for what a new Delta ecosystem, actively managed to be functioning habitat for native species, may look like. *Aquatic Ecosystem Stressors* is a shorter report with a more direct, management- and policy-oriented goal: to organize the complex set of ecosystem stressors in the Delta in a way that is more

understandable for a policy audience. By simplifying the discussion of ecosystem stressors, Mount et al (2012) may also hope to discredit advocates who stall against policy action by claiming the ecosystem is too complex and poorly understood.

In 2013, PPIC published another report that is a direct challenge to political actors who try to undermine environmental policies in the Bay-Delta by over-emphasizing uncertainty or scientific disagreement. In *Scientist and Stakeholder Views on the Delta Ecosystem*, Hanak et al (2013) surveyed 122 scientists and 240 policy makers and stakeholders in the Bay-Delta about the relative importance of different ecological stressors and the potential effectiveness of proposed policy responses. They found that there was a high degree of consensus within the scientific community, which included both academic and research scientists. (This consensus may be due in part to the relationships forged by the CALFED Science Program.) They also found a moderate amount of agreement among stakeholders; as the non-rational model of policy making would predict, the largest divergences from scientific consensus were among stakeholder groups whose economic interests conflicted with the science. As the authors explain, "[s]cientific uncertainty, and the inability of the scientific community to address it and effectively communicate what *is* known, frustrates decisionmakers…Uncertainty has become a rationale for resisting inconvenient measures to address stressors, and it has encouraged the use of competing scientific opinions in the courtroom" (Hanak et al. 2013). With this survey, the PPIC and CWS are trying to combat combat science. They are showing which views on Delta science are marginal, and why some stakeholders have a financial interest in perpetuating confusing over ecological science.

The goal of the CWS and PPIC researchers was to organize the public conversation about the Bay-Delta, but to do that they focused mostly on California's water policy community:

legislators, resource management agencies, and various stakeholder groups (Hanak 2013). Their primary tools were the reports they released and a number of workshops they organized. Their focus was not on communications and outreach with the general public. Although their reports are clearly written, they are too long and complex for outreach purposes. They are meant for analysts, legislative aides, and interested stakeholders, not the general public.

The authors did complement their policy communications with more digestible materials for the public, but these materials were argumentative rather than educational. Their goal was to communicate their policy recommendations to a wider audience. In 2009, the authors accompanied the release of *Comparing Futures* (Lund et al. 2008) with a series of editorials in California newspapers. They tailored each editorial to the issues salient to the newspapers' local communities, focusing on the vulnerability of urban water supplies in the *San Diego Tribune* and emphasizing flood risks due to levee instability, changing precipitation patterns, sea level rise, and earthquakes in the *Sacramento Bee* (Hanak and Lund 2009; Lund and Hanak 2009). These editorials target their messages to their audiences, but they both stress that radical change in the Bay-Delta is inevitable, and the legislature must take a strong leadership role due to stakeholders' inability to reach agreement. They also advocate action despite uncertainties and express a concern that scientific uncertainty has been used to stall change. As with the PPIC's longer reports, the authors frame their arguments in terms of inevitable change and economic pressures, rather than environmental values.

For an approachable, online presence, Moyle, Hanak, Lund, and Mount maintain the California WaterBlog (with the tagline "a biologist, economist, engineer and geologist walk into a bar..."), which analyzes California water policy and Bay-Delta restoration issues in a clearly written way that is accessible to audiences without intimate knowledge of Delta ecology or the

intricacies of water policy (California WaterBlog 2013). In a February 2013 blog post titled "Ten realities for managing the Delta," Peter Moyle repeats many of the central conclusions from *Comparing Futures* and *Where the Wild Things Aren't* in a clear, accessible way, explaining that the Delta ecosystem "cannot be restored to look or function as it did at some idyllic point in the past" and that the Delta should be managed for variable conditions to improve native species' chances of survival. Moyle's essay is practical, rather than emotional, in tone, arguing based on "realities" rather than environmentalist values.

Moyle (2013) also repeats the message that scientific uncertainty should not be used to prevent change: " 'We need better science,' or, 'We don't know enough,' are common rationales for staying the course on Delta management. In reality, the Delta is part of the world's most studied aquatic ecosystem." If science can't inform environmental policy in the Bay-Delta, then where can it? Together, PPIC and the Center for Watershed Sciences have spoken out to make sure that the broad body of knowledge scientists have produced over decades of research in the Bay-Delta will have a greater role in future policy discussions. In doing so, they have also created a compelling argumentative basis for environmental advocates to push for policy change.

SFEI and KQED: Expanding The Audience For Environmental Science

The CALFED Science Program and the PPIC and CWS collaboration were both effective at expanding understanding of Bay-Delta science in the policy community, but neither focused on communicating their research beyond those already engaged in the discussion of what to do in the Bay-Delta. As Teal et al (2009) illustrated with their story of the Sacramento taxi driver, at least some of the scientists involved in these projects recognized that this was a shortcoming. By contrast, SFEI has produced materials about the Bay-Delta for broader public education as well as the policy community. These materials are different than PPIC's editorals, because they are educational, rather than argumentative. But creating them is still a political act: SFEI is building

the foundation for a more interested and informed public, and it is creating a new argument for why Californians should care about the Bay-Delta's environment.

SFEI is a non-profit that conducts environmental research and monitoring in the San Francisco Bay and Delta. It has a long history of working on the boundary of science and policy in the San Francisco Bay Area. A precursor to SFEI, the Aquatic Habitat Institute (AHI), was founded in 1986 to synthesize existing information about water contaminants to better inform the contentious water quality debates in the estuary at the time. In 1993, AHI reorganized as SFEI to conduct independent research and to study the estuary system in a more holistic fashion. Today, SFEI conducts research for several resource management agencies in topic areas including contaminants, invasive species, historical ecology, and conservation biology (SFEI, 2013). Like the CALFED Science Program and PPIC, SFEI values its independent reputation, although SFEI's work is under contract to specific clients (Whipple 2013). SFEI is also relatively new to Delta science, since most of their previous studies have focused on the San Francisco Bay; Whipple believes that this gives them the ability to offer a fresh perspective on Delta science, without being associated with previous policy debates (Whipple 2013).

In *Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process*, ecologists and historians from SFEI combined ecological research with GIS analysis and archival research to construct a complex and detailed portrait of how Delta ecosystems functioned prior to European-American settlement and the history of their subsequent alteration (Whipple et al. 2012). This report is the first phase of a larger project, Delta Landscapes, that aims to create tools to understand what a functioning landscape in the Bay-Delta would look like (Whipple 2013). SFEI prepared this report for the California Department of Fish and Game and the Ecological Restoration Program (ERP), under contract to

the Department of Fish and Game (now the Department of Fish and Wildlife (CDFW)). The goal of the report was to understand the historic ecosystems of the Delta and to provide information for restoration managers and policy makers to make more informed decisions about how to restore the ecosystem and protect native species. The authors stressed that the intent of the report is not to recreate the past Delta, which would be impossible, but to better understand what a functioning Delta landscape would look like (Whipple et al. 2012). Similar to the PPIC reports, SFEI's research depicts a geographically and temporally variable Delta. SFEI provides historical documentation, such as historic maps, photographs, and travelers' accounts, to support this view. Whipple et al. (2012) split the Delta into three main regions: the North Delta, Central Delta, and South Delta, which functioned differently historically and should be considered for different ecosystem functions in future restoration projects.

At 480 pages, *Sacramento-San Joaquin Delta Historical Ecology Investigation* contains a lot of scientific and historical detail. However, SFEI designed the report to be useful to a variety of users with different levels of engagement with the document (Whipple 2013). The primary audiences for the report were CDFW and ERP resource managers, but SFEI also wanted the broader messages of the report to be useful for higher-level policy makers, such as the Delta Stewardship Council, and for Delta stakeholders. Whipple explained that the report is as large as it is because they needed to include all of their data for those who want to review it: "you don't want to present what you've synthesized without backing it up, to let people explore for themselves and see what you're saying and why" (Whipple 2013). However, Whipple and her colleagues organized the report to help readers focus on what was most necessary to them. The report's executive summary includes a section on the report's management implications, which Phil Isenberg, the chair of the Delta Stewardship Council, told the authors was particularly useful

for him to understand its implications for the Bay-Delta Conservation Plan (Whipple, 2013). The report has separate sections for the North, Central, and South Deltas, so that resource managers can focus on their areas of interest.

SFEI also used the graphic layout of the report to make it more approachable. The report integrates maps of past and present Delta landscapes, graphics, and historic photos to create a visually compelling document. According to Whipple, "the other big component of the report that's different from a lot of the other reports that come out is our beautiful graphic design... I think it really engages people in ways that your typical report doesn't, necessarily. Also, the beautiful old maps from the 1850s are really engaging to people, and the old photographs. It is a way for people to jump in" (Whipple 2013). This is in contrast to many of the publications from PPIC and the CALFED Science Program, which had a much simpler, text-based layout.

SFEI worked to make their report approachable for a variety of management, policy, and stakeholder audiences, but the report itself probably would not have reached a wider audience without additional outreach. Very few people who are not already interested in the Bay-Delta would read the full report, even if it is pretty. The SFEI team expanded the report's reach, however, by working closely with a local science reporter to produce a series of public-facing news stories and materials for a state-wide and national audience. The reporter was Lauren Sommer, a science and environment reporter for Quest Science, a science show that produces television and radio stories for KQED, a San Francisco-based public media station. Sommer had interacted with SFEI before, interviewing Robin Grossinger, the head of SFEI's historical ecology division, for previous stories. In 2012, she expressed an interest in the upcoming Delta historical ecology report. Sommer and the SFEI authors recognized that this report had the

potential to generate compelling stories and to provide a new perspective on the Bay-Delta for California residents (Whipple 2013).

Through this collaboration, Sommer produced a three-part series, "California's Deadlocked Delta," which explores the complex set of issues facing the Bay-Delta and potential solutions that scientists and policy makers have proposed. The first story, "California's Deadlocked Delta: Can it Be Fixed?," provides historical context for controversies over fish management and water exports (Sommer 2012a). In the second story, "California's Deadlocked Delta: Can We Bring Back What We've Lost?," Sommer visits the Delta with Whipple and Grossinger to explore the history of landscape alteration and what knowledge of past ecosystems can contribute to future restoration projects. Sommer anchors the story with compelling images: descriptions of a vast tule wetland from a duck hunter who got lost on a cold night in 1850 and the story of Liberty Island, which flooded due to a levee breach in 1997 and has become a state restoration project (Sommer 2012b). The third story—"Is Carbon Farming the Future?"—is a more speculative piece, exploring one proposal for addressing land subsidence and flood risks by replainting thule wetlands as tradeable carbon offsets. In the story, Sommer uses this proposal to explain the processes driving Delta land subsidence and flood vulnerability and to show potential solutions (Sommer 2012c). These radio stories initially aired on KQED's Quest Science, but they were successful enough to be picked up for national syndication on NPR's Morning Edition.

These stories were accompanied by an interactive mapping feature that allows readers to explore the historical ecology of the Delta, view historic photographs, and explore contemporary restoration projects in an easy-to-use web browser (Sommer et al. 2012). The maps and photographs provide a comelling way to pin these stories to the geography of the place in a way that radio stories alone do not. This is especially useful since the majority of Californians do not

even know where the Bay-Delta is, let alone what it looks like or what species it supports. NPR's national audience is even less likely to be familiar with the place.

The collaboration required SFEI and Sommer to go beyond their traditional roles as scientists and journalist. Sommer and SFEI worked together on the series, sharing drafts back and forth. For Sommer, working *with* the scientists was an "out of the box thing to try" (Sommer 2013). The goals of the two groups were different, so the final product needed to meet both groups' expectations. The SFEI researchers wanted to communicate a complex ecological study, whereas Sommer's goal was to "find one little thing that can teach me something larger," an engaging detail that can pull NPR's audience into the "really wonky" issue of the Bay-Delta Conservation Plan (Sommer 2013). Because these stories would be broadcast nationally, Sommer needed to record a story that would also be compelling to a national audience (Sommer 2013). According to Whipple,

> that was a learning experience for all of us: for Lauren to be willing to work with me at a level that typically reporters don't with scientists...I think we both ended up spending a lot more time on it than we originally thought we might, but to be able to come to that point where...I feel like enough of the scientific detail and accuracy is in there, and hopefully Lauren thought that there was enough of a story there to really engage people without muddying it with uncertainty. (Whipple 2013)

This collaboration was also unique because for SFEI this research was still a work in progress, the first phase of a larger Delta research project. For scientists it can often be difficult to decide when to communicate their research, as Whipple articulates: "You know, it's a fine balance of the scientists wanting to tuck in and ignore everybody and for a year or two do your research and then come out with a beautiful, polished product, but you're not necessarily going to be very relevant, and the time to influence things may have passed by" (Whipple 2013). In May 2012, when the KQED series aired, the Delta Stewardship Council was in the process of finalizing the Bay Delta Conservation Plan (BDCP), over 10,000 pages long, which would be

released in March 2013. It was a time when SFEI's research would be particularly salient to policy makers, and the KQED reports would create a context for future stories about Bay-Delta policy as the BDCP became public. Because online stories are accessible long after they air on the radio, these stories will remain a resource for people to explore the context of the Bay-Delta as new developments occur (Sommer 2013). Future stories about the Bay-Delta can link back to these stories to provide context.

One notable result of SFEI's collaboration with KQED is that the public-facing materials they created for NPR's audience also became a valuable resource for the agency staff, policy makers, and stakeholders in the Bay-Delta. By producing an interactive map that was easy to use and compelling to explore, they created an opening to have new conversations with stakeholders based on a perspective other than the "water wars" narrative that often dominates stakeholder conversations (Whipple, 2013). SFEI have also received feedback that the interactive map has been valuable for scientists and resource managers: "an interactive map of our data was not a deliverable that we had in our contract with the Department of Fish and Game...but it really was and is a valuable tool for scientists and managers in the area to use now. It's a quick way, they don't have to have GIS, they don't have to know how to create the pretty symbols...they can just use the web browser" (Whipple, 2013). It is tempting to think of policy reports as relevant to policy makers and news graphics for the general public, but policy makers also consume the news, and an easy-to-use interface meant for the public may also help the policy makers better access the report's findings.

As a collaboration between SFEI and KQED, "California's Deadlocked Delta" shows how scientists and journalists can work together to produce a rich, nuanced series of news stories and interpretive materials for the general public, despite the financial limitations of today's

media environment. This is an important goal, because one way to change the conversation about environmental management in the Bay-Delta is to bring new participants into the conversation. By portraying the Delta as a rich and fascinating ecosystem in the Bay Area media, SFEI may capture the interest of California voters who care about the environment but had never heard of this place before. (San Francisco is a particularly liberal media market, so this may be a savvy communications strategy.) Lauren Sommer said that one of her rubrics for producing a broadly compelling story is to ask, "why would my grandmother care?" (Sommer 2013). Perhaps SFEI hopes to make more Californians know and care about the Bay-Delta, too. Stories like "California's Deadlocked Delta" have the potential to teach the public why environmental policy in the Bay-Delta is so complicated, but also why it is important. More public knowledge alone will probably not lift the Delta's policy deadlock, but it can complement the more policy-focused communications that the CALFED Science Program, PPIC, CWS, and SFEI have all produced.

CONCLUSIONS AND RECOMMENDATIONS

This study shows how different scientists have navigated the challenges of communicating their research with the policy community and the broader public in the context of environmental controversy in the San Francisco Bay-Delta. The cases here show how research scientists in the Bay-Delta have learned to engage more effectively with the policy process and have learned how to craft more salient messages while retaining scientific legitimacy among their peers and the public. They also show an expanding scale of engagement, from working directly with the policy community to communicating about Bay-Delta ecology with the general public. Overall, the story of these three cases is one of the political education of the Bay-Delta's scientific community since 2000, as they have continued to engage with the policy process. These scientists also built off of each other's successes and acted to improve upon their

shortcomings. PPIC and CWS benefitted from the scientific research and community understanding that the CALFED Science Program had created in the early 2000s even as they took a much more aggressive approach to interpreting the policy implications of Bay-Delta science. SFEI developed its research to inform a resource management and policy audience, but its scientists also worked to reach beyond those already engaged in the process by producing materials for general public, as well. Each of these groups filled a new communications need.

There are several related topics I did not research for this paper. I did not evaluate how particular messages were received by their audiences; nor did I interview policy makers, stakeholders, or other Californians about their perceptions of Bay-Delta science. Although understanding how audiences interpret these communications is an important element of this story, such an investigation was beyond the scope of this project. I also did not study the extent to which science communication in the Bay-Delta may be more the product of two-way relationships between scientists and their audiences, rather than one-way broadcasts. One direction for future research would be to study how the longer-term relationships that scientists, policy makers, and other members of the public may develop over time affect the way that their understanding. Many of the scientists I interviewed for this essay have worked in the Bay-Delta for decades. Have they developed better strategies to communicate their research, or do Bay-Delta residents, stakeholders, and policy makers just know or trust them more after decades of interaction? If the longevity of scientists' engagement in the region does affect their ability to engage with policy makers and other stakeholders, then it would be important to examine how their long-term knowledge and relationships can be transferred to new scientists as current environmental scientists near retirement.

It can be discouraging to realize that scientists have been conducting research in the Bay-Delta since the 1960s, and they have actively engaged with policy in the region for decades without substantially changing the political deadlock over environmental management. This fact seems to support the hypothesis that the arguments in the Bay-Delta are not rational arguments about scientific knowledge, but entrenched conflicts between competing values and economic interests. The survey of scientists and stakeholders that Hanak et al (2013) conducted also suggests that stakeholders diverge from scientific consensus primarily on issues where the implications of the science are in conflict with their financial interests. If so, then it is unlikely that a more persuasive scientific argument would change their minds.

But finding that the conflict over environmental management in the Bay-Delta does not follow the rational model of policy development is hardly a surprise. The question it prompts is: if environmental policy is not a rational, technical process, but rather a battlefield of environmental values and economic interests, then what is the role of science in environmental debates? Why should scientists continue to dedicate their time and hard work to communicate their research to non-scientists? Why should they go to political forums to explain their research or engage with policy makers and stakeholders at all? Does science communication have any impact on the policy process?

I believe science communication does matter to environmental policy, even if the mechanisms by which scientists interact with policy are less clear than the rational model suggests. Environmental science still has a crucial role to play in defining the nature of environmental problems as we continue to develop and create new stresses on our ecosystems. Environmental scientists can also provide the basis for compelling arguments for the environment, developing the data and analysis that allow environmental advocates for

environmental protection to make arguments based on the consequences of environmental degradation rather than just an appeal to environmental values. This can be especially compelling when melded with economic analysis, as the PPIC and CWS collaboration did. Environmental educational materials, like SFEI's beautiful maps and historic photos, can also engage new audiences on an emotional level as well as an intellectual one. Although not all news consumers share the same values, some may become interested in the Bay-Delta policy process by learning about the place. Many environmental scientists came to their work out of a fascination with the ecosystems they study, and it can be effective to share that feeling with others.

My advice to future scientists in the Bay-Delta and similar settings is not to shy away from engaging with the policy community or the general public. It may be difficult, and the outcomes may not be clear, but the scientists in the Bay-Delta have provided an important role, providing information and analysis that has informed legislation and litigation, if not always the opinions of those with the most entrenched interests. Some of these scientists' approaches to communication produced unexpected benefits: most significantly, the CALFED Science Program provided the scientific foundation and fostered the relationships that PPIC, CWS, and SFEI all benefited from in their own policy engagements.

Scientists also should not be afraid to address the policy implications of their research to the extent they are able. The balancing act between maintaining scientific legitimacy and communicating salient analysis to policy makers and the public will remain one of the most difficult challenges that scientists face in policy disputes, and how they navigate this tension will necessarily be constrained by their employment or affiliations. Although scientists face strong pressures to remain objective, they should not cede the interpretation of their research to interested parties who undermine it for political ends.

In this paper, I focused on how scientists communicate their research in the context of environmental controversy, but the burden of political learning should not fall solely on the Bay-Delta's scientists. Policy makers and the general public have a responsibility to become more sophisticated consumers of scientific information, as well. Combat science is politically effective partly because many people do not have enough knowledge of environmental science in the region to evaluate the validity of competing claims. But most importantly, policy makers and members of the public, like many of the scientists in the Bay-Delta, erroneously cling to the rational model of policy making, waiting for "better science" to solve the region's problems. Instead, participants need to recognize that resolving the Bay-Delta's policy deadlock will require California legislators or voters to make decisions that not all stakeholders support. One of the main problems in the Bay-Delta is that no one in a position of authority seems willing to admit that trade-offs in the Bay-Delta are inevitable, that there is no sustainable way for all stakeholders to get what they want. Until decision makers acknowledge this reality, there is only so much that science can do.

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