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Introduction

AN UNLIKELY JOURNEY INTO CITIZEN SCIENCE

Darlene Cavalier

The American shad is Philadelphia's fish. Like the far more celebrated salmon, shad live their adult lives in cold, salty ocean waters and swim back to freshwater rivers and streams only to spawn. They're tasty like salmon, too, if bonier and less fleshy (the fish's Latin species name, Alosa sapidissima, means "most delicious fish"). Unlike salmon, though, shad can undertake their freshwater return migration several times in their lives — they are a most determined little fish. Shad were once so plentiful in the Philadelphia region that the Lenape Indians could hunt the fish in the Schuylkill and Delaware rivers with bows and arrows, and the shad industry provided the name for Fishtown, one of Philadelphia's archetypal neighborhoods. Philadelphians like me take pride in the shad's hardiness and history—they fed our country's Founding Fathers, after all, and were a dietary staple of city residents for generations.

By the mid-20th century, however, the people who lived along Philadelphia's rivers — many of whom depended on shad for their livelihoods — noticed that the shad were not migrating upriver as they had before. They were being hampered by twin human-produced barriers, one chemical and the other physical. The industrialization that powered the city's prosperity had created a river system that was one of the most polluted in the country. Reportedly, the stink was so bad that military pilots were told to ignore the smell as they flew thousands of feet overhead. Meanwhile, as pollutants like phosphorous depleted oxygen levels in the rivers, a series of dams blocked migration routes; they established walls through which the shad couldn't pass and couldn't leap in their desperate attempts to reach their spawning grounds upstream. Fishermen and other locals did not know all the details at the time, but they observed declining fish

numbers with great concern, knowing that the disappearance of the shad would affect their own economic and cultural survival.

Those citizens used what they did know about their environment, however, to guide their observations and inform their collection of data about local shad populations. With their findings, they were able to form hypotheses about the causes of the shad decline and communicate them to policymakers to encourage action in cleaning up the rivers. It was a process that sounds an awful lot like science and science-based policymaking.

I am inordinately fond of the shad, and perhaps I identify with the fish a little too closely. But how could I not? They are stubborn, persistent, maniacally focused creatures, and a legacy of a city I have called home for decades. It took a long, long time before the efforts of all those concerned citizens began to reverse the shad's fortunes — and only in very recent years has there been some real ground for optimism. Yet the shad's story provides a shining (albeit at times smelly) example of what can happen when non-professionals become involved in a scientific problem near and dear to their hearts. In some ways, their story mirrors that of my own journey and that of the field to which I have become dedicated: citizen science.

This book is intended to demonstrate the value and vitality of citizen science, and its terrific potential for involving many more everyday people in a dynamic and responsive scientific enterprise. This book is also addressed to people like me: those who, as young students, were not especially interested in dissecting frogs or working out physics problems, and had little desire to become professional researchers or engineers — but who, as adults, find themselves drawn to science, and more than a little curious as to how it shapes the world we live in. In some people, maybe, that interest shows itself as an itch to read about theories on the origins of the universe, or the search for unknown worlds or undiscovered species. Maybe it's a hunger to know more about what lies behind the ever-rising tide of technological wonders. Maybe the urge is for all things environmental: to know more about climate change or biodiversity or simply what kinds of birds are nesting in the backyard. Or perhaps it's a quest for greater clarity about the billions of federal tax dollars being spent on scientific research. There are a great number of us with such interests, and citizen science opens up a way for us all to become more involved in following our passions into the realms of research and policymaking.

In the diversity of projects described throughout this volume, the term "citizen science" encompasses a range of activities and involvement on the part of the public, a range large enough to include amateurs searching for hidden galaxies and middle school students documenting microbes culled from their belly buttons. Citizen scientists are often driven by an unending passion, whether to protect a species they care about, to speak up for people suffering from diseases or toxic exposures, or to watch over an ecosystem nearby. As Caren Cooper and Bruce Lewenstein illustrate in Chapter 2, citizen science encompasses at least two main pursuits. One involves citizens voluntarily contributing observations

and data to scientists, who then use this information in research. The other encompasses democratic participation in science and science policy, to ensure that it meets the needs and concerns of citizens. These are not mutually exclusive pursuits; indeed, one naturally engenders the other.

Because of this, citizen scientists can serve in a wide range of roles. Sometimes they are an educated volunteer researcher, collecting data, recording observations, and performing basic analyses. These roles can be especially useful on projects that are difficult to automate, where the human eye can make rapid work of complex problems. While these kinds of involvement have historically often been in one-time or context-specific roles, citizen scientists today can be involved in dozens of projects around the world. Sometimes, for instance, citizens are more active in designing and developing projects from the outset. For others, citizen science may mean a lifetime of government lobbying with science-based data. On other occasions, they're involved in research that would have been impossible a decade ago — like launching cube satellites into orbit.

All these components of citizen science increasingly overlap — that is, engaged citizens participating in scientific research desire a greater voice in how that research is conducted and what goals that research seeks to achieve. My own journey to citizen science certainly bears this out.

Swimming Upstream

I grew up in a blue-collar family, in a part of Pennsylvania where not many folks had the chance to go to college, or even the expectation that they should. I liked school well enough, and I got decent grades, but I was never particularly interested in my science classes. Our science teachers and the speakers they occasionally brought in—ostensibly to motivate us—seemed mostly to address only the handful of kids who were demonstrably smart and already science-oriented, leaving the rest of us to search for other passions to define us. In my case, those passions were the very non-scientifically taught disciplines of dancing and cheerleading, and I spent every waking classroom moment practicing routines under my desk.

All that practice paid off. After getting into Temple University's communications program, I made it onto the school's competitive cheerleading squad my freshman year. That provided me not only with excitement — I traveled the country and cheered at some thrilling games, including an NCAA playoff game at the University of Nevada Las Vegas — but also with an unlikely career start. In part because I needed to pay my way through college, in my senior year I landed a professional cheerleading gig with the Philadelphia 76ers, and for the next three years I got to share a court (or at least the sidelines) with Charles Barkley and Hersey Hawkins.

That was pretty much an evening job, though. During the day I worked for a company called Media Management, which performed administrative and mar-

keting work for a variety of clients. One of those clients happened to be the popular science magazine *Discover*, and one of my tasks was to help with the newly inaugurated *Discover Magazine* Technology Awards program. The task at hand was chiefly organizational: I had to come up with suitable nominees for the various award categories, encourage them to apply, and then shepherd the submission of forms and supporting materials. But in the process I had to read through a mind-boggling variety of journals and magazines about everything from software design to medical research to environmentalism.

Not only did I learn a lot about recent scientific and technological developments, but I also interacted with the people at the heart of some truly amazing scientific research and cutting-edge technologies. Granted, my interaction with these titans was from a chair in the mailroom and often consisted simply of checking with them about missing information in their applications. But the innovators I spoke with — probably assuming I had some sort of influence on the $100,000 awards — were incredibly open and responsive to my requests for details about their work. All of which I found fascinating — as did my fellow cheerleaders, when I would talk to them in our dressing room about what I'd learned. That last fact may surprise most people, who do not readily associate cheerleaders with an interest in science. It did not in the least surprise me.

Before too long, my obvious interest helped me move out of the mailroom and into the classroom. I took over the Educator's Guide for *Discover*, reading the magazine cover to cover each month and translating the information into a form suitable for school use. I discovered (no pun intended) that the magazine, written for a general, nonprofessional audience and highlighting the most exciting developments in science and technology, was conceptually perfect for kids learning about science. It was perfect for my education, too: in learning more about how *Discover*'s writers and editors rearticulated complex material for broad understanding, and in how I could further explain it to teachers of young enthusiasts, I grew increasingly confident in navigating a once alien landscape.

Less than three years later, the magazine was bought by the Disney Company, and when I was hired by Disney and moved to their headquarters in New York City my responsibilities expanded considerably. They now included running the *Discover Magazine* Technology Awards, for which I'd been stuffing envelopes earlier. Eventually I became Senior Manager of Global Business Development for Walt Disney Publishing Worldwide, specializing in development and strategic marketing. This isn't meant to be a boast or even a recounting of my résumé. I mention it because my experiences at Disney opened my eyes to the fact that one of the important factors in the company's success was the partnerships and synergies they developed with others — a model that would eventually become enormously useful to me, and to the field of citizen science.

In my new role heading up the *Discover* Awards, I garnered a lot of corporate support for the program, and it became a significant annual event for both Disney and the scientific community. The Awards grew to become Disney's largest publishing event—the "Academy Awards of Science." There were thousands

of applications and nominations, as well as annual two-week-long exhibitions and shows at Epcot Center. The role of celebrity judges grew impressively and included luminaries from Apollo 11 astronaut Buzz Aldrin to magicians Penn & Teller, and from the famed physicist Freeman Dyson to the inimitable Ray Charles. Through the Awards and supporting science-themed roundtable discussions, I met F. Story Musgrave, the only astronaut to have flown missions on all five space shuttles and best known as the "fixer" of the Hubble Space Telescope; intriguingly, he was also a high school dropout who became a heart surgeon before becoming an astronaut. I met Marvin Minsky, co-founder of MIT's Media Lab and often referred to as the "father of artificial intelligence." I worked closely with astronaut Sally Ride, the first American woman to enter space, and Dean Kamen, the inventor of the Segway. Personally and professionally, it was a high point in my life, and interacting with some of the top scientific minds in America nurtured a deep love for science, a love that had been kindled just a few short years earlier.

It was inevitable, I suppose, that as that passion took greater hold of me, I began to wonder why it was so long in coming. What was it about my science classes in grade school that failed to inspire me in the way that conversations with professional scientists did? Perhaps it was the outdated "demonstration science" that passes for science education (which Robert Dunn and Holly Menninger eloquently critique in Chapter 3). Maybe, too, more insidious forces were at work: I had just assumed that science was intended for the geeky boys in my class—unaware of the subtle social pressures that girls receive, pushing us away from careers in science, technology, engineering, and math (STEM). Whatever the reason, I was grateful that I no longer saw science as something meant only for others. But I was the beneficiary of a series of truly fortuitous events. What about all the others like me who weren't so lucky?

It took a number of years with Disney before I had a conversation with an editor at *Discover* that changed my life. Over time my career had become very corporate — a daily march of business meetings and PowerPoint presentations — and I was telling the editor, Marc Zabludoff, how much I missed the work at *Discover*, educating the magazine's millions of readers about the ways science and technology impacted their lives and shaped the future. The editor interrupted my waxing nostalgic: "Do you think we really educate people? Or do we merely entertain them?"

He went on: "What do you think our readers can actually do with the information we give them? The opportunities for non-scientists to participate in anything having to do with science in a meaningful way are nil. People who aren't going to be scientists are excluded from the very start — after teaching the basics, science classes in schools are not geared toward kids who aren't planning to go into the sciences professionally. So we entertain people with the latest research and breakthroughs, but there's not much the average person can do with that information, is there?"

"But isn't a scientifically literate population important?" I objected. Don't we

stress STEM education in school and fret that our students are falling behind other countries in science education? What is the point, if the scientifically literate can't engage with the research that impacts our future? How (as Lily Bui insightfully inquires in Chapter 4) can media like *Discover* add value to the way citizens discover, assess, and even produce scientific information? Can't people like me, who aren't career scientists but are fascinated by science, participate meaningfully in the scientific enterprise—a huge and vital enterprise, I should emphasize, that's paid for in significant part by our tax dollars?

Marc was goading me, but he knew what I was really bemoaning—I had grown more comfortable with scientists, but I still felt I was little more than a tourist in the world of science. I wanted a place of my own. Claim one, he told me. "If you can figure out where you fit here, you'll figure this out for millions of people."

I took him up on his challenge. I applied to a graduate program at the University of Pennsylvania and dove into science history and sociology. I was especially eager to learn how science policy worked, since policy is critical for shaping what and how research is done in this country and because it seemed to offer an opening for non-scientists like me to get involved.

Through readings guided by Professor Susan Lindee, I started to understand how many lay people, like me, came to "find science." For many it was through the familiar path of activism — a response to a medical condition or disease outbreak or a local environmental concern. People who had a vested interest were quick to absorb technical information and take action. The environmentalists, notably, also organized communities to gather and share data and frequently called into question the ability of industry and government to place the interests of people first.

But at the time, 2004, the term "citizen science" (as coined by Cornell University's Rick Bonney) was still new. An internet search yielded very little of relevant interest. Apart from Cornell's Lab of Ornithology's small database of bird projects, there was no searchable listing of activities that allowed non-professionals the chance to be involved in scientific pursuits. That would soon change — new tools were being developed that would boost the citizen science movement enormously. Fuelled by the internet, data processing software, and the ubiquitous use of cell phones, it would become significantly easier to connect people to formal and informal research projects. Yet just a dozen years ago, it was still quite difficult to find these opportunities.

Among my more memorable projects in graduate school was a paper I wrote on the rise and fall of the U.S. Office of Technology Assessment (OTA), which provided Congress with objective analyses of important issues in science and technology from 1972 to 1995. Throughout six administrations, both Republican and Democratic, this small agency provided Congress with unbiased information about a host of critical scientific, technological, and environmental issues — from acid rain to radioactive waste storage, from solar power to AIDS

prevention — before being shut down during the days of Newt Gingrich's reign as Speaker of the House. I probably read every OTA report the office produced during its 23 years of existence, and many of the recommendations for reopening it after Congress shut it down. The OTA proved to be a very influential creation, and a number of other countries, especially in Europe, modeled their own technology assessment institutions on it. Yet it was defunded here, despite much critical acclaim for its work, and without any true input from the public on its worthiness.

For my master's thesis I expanded on the issues raised by the demise of the OTA, exploring how average citizens can engage with the complexities of national science policy, and how they can voice their knowledge and values on an equal footing with acknowledged experts. It was then that I first truly encountered that remarkable group of people known as citizen scientists and the barriers they were trying to tear down.

Through their grassroots, bottom-up efforts, they were aiding research by tagging butterflies, monitoring water health, keeping an eye on bird migratory patterns, and looking for new galaxies. But when it came to engaging in policy-making decisions, they were shut out. The forces against them were considerable, coming from politics and industry. But there was also strong resistance from the scientists themselves.

Scientists and other experts seemed to fear that the lay public, largely lacking formal science education, could not grasp technical concepts as they relate to policy. By and large, they concluded that unless people possessed credentialed scientific expertise, they should be excluded from any discussion of how research into such topics as, say, synthetic biology, biomedicine, alternative energy, or climate change should be funded or applied.

To my mind, this was wrongheaded, and not just because a democratic government is supposed to represent the will of its citizens. I thought it incredibly important for all interested people to be involved in such decision-making because we live in a society in which science and technology are major drivers of social and economic change — that's why we invest huge sums of money in them. The changes brought about by science and technology can be responsive to society's needs and meet the enormous challenges confronting all of us. Opening up the process of how scientific resources are allocated and assessed, or at the very least making these processes more transparent, struck me as an obvious win-win: citizens would be more knowledgeable about the science being done in their name, scientists and policymakers would be able to better anticipate challenges and do some risk assessment before they rolled out new policies, and the societal benefits of our research and development investments would be vastly improved.

I had expected the resistance I experienced from politicians I met with in those days. Newt Gingrich, for example, offered the usual talking points for the demise of the OTA under his watch: that it merely represented bloated government,

that it couldn't offer neutral assessments, and that if he needed a technological analysis he could call the appropriate people himself. He viewed the OTA as simply a unidirectional source of potentially biased analysis, rather than as a way of engaging constituents in science policy for the edification of both policymakers and the public.

But I was disheartened when in years to come I encountered a similar lack of understanding by scientists. Speaking with me at an event on citizen engagement, for example, was an official representative from a professional science association, who was ostensibly presenting in support of such lay participation. Before the event, though, she leaned over to me to say: "By the way, you're completely misguided." She elaborated, arguing that there was already a system in place for citizen input once a bill has been posted, called the "public consultation period," when people could provide comments to the bill. In her eyes, there was no need for upstream public engagement of the sort that I advocated, especially with a population that isn't particularly scientifically literate. Never mind the fact that research by the University of Michigan's Jon Miller found the scientific literacy of U.S. adults is relatively high compared to other developed nations!

Changing the Current

That moment was really the start of my citizen science advocacy, and it has shaped all my activities since. Ten years ago, I started pushing to reopen the OTA, which I thought had the most potential to bring together the public and scientists in shaping science policy. I supported efforts by professional science organizations such as the Union of Concerned Scientists and members of Congress, including Rush Holt, then a Representative from New Jersey (and current CEO of the American Association for the Advancement of Science). However, unlike the stated aims of such OTA supporters, my goal was to embed mechanisms for public participation in the policymaking process. To be clear, that was not their primary goal at that time.

I founded the Science Cheerleaders, a group of more than 300 current and former professional cheerleaders from the NFL, NBA, and other sports leagues who are pursuing science and engineering careers. From personal experience, of course, I knew that there were a large number of sympathetic minds in this group. I also knew that they offered a terrific opportunity to overturn stereotypical perceptions about the exclusivity of the scientific world. With the support of professional sports leagues, media partners like NBC Sports, the National Science Foundation, Pop Warner youth leagues, and scientific stars like Why Science? author Dr. James Trefil, the Science Cheerleaders have become the "superheroes of science" both on- and offline. At the same time, the cheerleaders inspire everyday citizens to connect with science — especially young women who may be considering STEM careers — and work to empower people to weigh in on important science policy discussions.

I created a portal on the Science Cheerleaders website for projects with which citizen scientists could become involved. The combination of the cheerleaders sparking excitement about science with a set of projects that were open to enthusiastic citizens would, I thought, create a process to unite the citizen's desire to be heard and valued, the scientist's growing interest in the public's involvement, and government's need to garner public support. Eventually I imagined these inspired citizens getting more involved in policy conversations and expressing their values and knowledge in influential ways.

To bring more attention to Science Cheerleaders and the citizen science portal, I wanted to mix up the kinds of projects that people could participate in on the site and expand beyond what is traditionally thought of as citizen science. Not that counting birds or bees or monitoring water quality weren't important—far from it. But I wanted to demonstrate the field's incredible diversity to professional scientists, policymakers, and most importantly, to everyday citizens who weren't yet sure how to become involved in science. So the site posted projects in fields as varied as archaeology, astronomy, biology, cybersecurity, epidemiology, gaming, geography, geology, programming, and zoology, among others.

When the number of projects we were posting became unmanageable for hosting on the Science Cheerleaders site, I launched SciStarter.com as a platform fully dedicated to discovering, organizing, and participating in citizen science projects. I wanted to make it easy and fun for people to get involved in projects ranging in commitment from one-off events like swabbing for microbes in Project MERCCURI (an extravagant acronym for Microbial Ecology Research Combining Citizen and University Researchers on the International Space Station) — which David Coil uses as an illuminating case study of citizen science in microbiology in Chapter 6 — to long-term coastal monitoring programs. And the site seems to be meeting a need for engaging people in science and technology. With the help of a network of contributors and media, government, and academic partners, the platform currently hosts more than 1,600 projects and events with more than 50,000 citizen scientist participants and more joining all the time.

Yet even as SciStarter rapidly grew and matured, there still remained the problem of getting the public's voice to be better included in policymaking. I was intrigued by the advances other countries like Denmark and the United Kingdom had made on this front, including inaugurating methods of citizen participation and stakeholder engagement in assessing emerging technologies and science-related issues like climate change. Was something like that possible in the United States?

To answer these questions, I joined forces with Arizona State University's Consortium for Science, Policy & Outcomes, the Woodrow Wilson Center for Scholars, the Museum of Science Boston, and the Loka Institute to found the Expert & Citizen Assessment of Science & Technology (ECAST) Network in 2010. As a collaborative endeavour between academia, informal science educators, and policy partners, ECAST has been instrumental in bringing citizens and experts

together to inform and improve decision making on science and technology issues. Our most recent success was in hosting a forum on NASA's Asteroid Initiative, which provided NASA administrators with public perceptions, aspirations, and concerns about the agency's space mission through dialog with a diverse group of informed citizens. Other federal agencies, including the National Oceanic and Atmospheric Administration and the Department of Energy have since enlisted ECAST and together, with SciStarter, we are forging new opportunities for people to move between citizen science and "citizen science policy." Mahmud Farooque's logic model in the final chapter illustrates this vision.

My aim in all this — in the creation of Science Cheerleaders, SciStarter, ECAST, and this book — is ultimately to empower ordinary people to contribute to science, and for their voices to be influential in ongoing science policy debates. It is to cast a wide net through the Science Cheerleaders, to provide opportunities to actually do science through SciStarter, and to move people to contribute to related science policy discussions and shape science through ECAST. Citizen science projects give people confidence in their involvement in science, so it's vital that projects connect with people's diverse interests and values in ways that can lead to more profound engagement. This is especially true when citizens seek to change the status quo — scientific, social, or otherwise — as in the powerful social movement-based citizen science that Gwen Ottinger describes in Chapter 5.

There is already broad agreement that our educational priorities for our children must include a greater emphasis on STEM subjects, and I naturally fully support all efforts to encourage this. But I and other citizen science advocates — and many professional scientists — think that concerns about scientific literacy and the influence of public values on science policymaking should be the start of the conversation, rather than the end. There is increasing opportunity today for scientists and policymakers to inform a curious public about the work that they do, rather than assume few would be interested in it or capable of understanding it. But convincing the scientific community and policymakers that the public should be invited to participate in research and decision-making activities is only part of the equation. Convincing the general public — those without an obvious, immediate stake in the outcome of the policy decision — to get involved is still a substantial challenge. Yet I believe that change is coming.

This is not simply the pie-in-the-sky hope of an enthusiastic science cheerleader. Those shad fishermen who worried about declining fish stocks in the Delaware and Schuylkill rivers could see the impact that pollution, overfishing, and dam construction was having on their livelihoods. But more importantly, they could measure this impact by counting the ever-smaller number of fish that were moving upstream to spawn. These weren't just people with hunches; they were citizen scientists with data.

By communicating these observations to policymakers, the shad fishermen provided evidence to support the passage of the Clean Water Act in 1972. Polluting industries were forced to clean up their acts, and fish-blocking dams were altered

or removed. Fishery managers placed restrictions on the shad catch, and hatchery operations have released millions of young shad into the rivers. Citizen science-influenced policy helped achieve changes that reflect society's shared priorities and values. The shad that once played such a foundational role in both Philadelphia's ecosystem and economy are slowly returning.

That's the kind of profound change I know citizen science can incite.

Further Reading

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