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Community-based Strategies for Strengthening Science and Influencing Policy: Vernal Pool Initiatives in Maine

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Community-based Strategies for Strengthening Science and Influencing Policy:

Vernal Pool Initiatives in Maine

by Jessica S. Jansujwicz and Aram Calhoun

Abstract

Scientific research is not having the impact it could and should have on natural resources conservation. Rather than conceptualize and conduct research in isolation, we need new approaches to identify and investigate problems in coordination with stakeholders, policymakers, and others who would benefit from the research. By supporting partnerships between researchers and the public, citizen science creates new opportunities for stakeholders to interact with scientific experts. This process of public collaboration with scientists has far-reaching implications for science, management, and policy. Drawing on two decades of work on vernal pool management strategies in Maine, we illustrate how citizen science and engaged research helped bridge the science-policy gap. As scientists, we learned from diverse stakeholders at multiple levels of decision making, and this feedback led to improvements in our citizen science programs, gradual adaptations to our scientific research process, and locally based, innovative vernal pool policy initiatives.

SETTING UP THE PROBLEM

Great, cutting-edge research that advances the scientific community's understanding of urgent and important problems is done every day. It is highlighted in scientific journals, and it advances scientific knowledge. But does this research have an impact on policy?

Policy change is vitally important, but it does not happen simply because scientists have studied an issue (Silka 2017). As scientists, we have seen that science frequently *does not* have the impact it should have on policy. There is widespread recognition of the growing gap between the production of scientific knowledge and societal action, particularly in natural resources conservation (Fox et al. 2006; Hall and Fleishman 2009; Knight et al. 2008; Meffee, Ehrenfeld, and Noss 2006; Reyers et al. 2010), which highlights the need for new approaches to link scientific knowledge, stakeholder decision making, and on-the-ground conservation outcomes (Jansujwicz, Calhoun, and Lilieholm 2013). Increasingly, we recognize that conceptualizing and conducting research in isolation does not work and that scientists need to identify research issues in communication with stakeholders, policymakers, and others who would benefit from the research. This recognition leads to a greater emphasis on conducting research so that it gets used (Clark et al. 2016).

Citizen science offers a potential solution to bridge the gap between science and policy by changing the way science is produced and used in conservation and management decisions. As a participatory model that encourages public engagement in scientific research (Irwin 1995), citizen science provides a practical approach to link science with societal needs and improve outcomes for both human and other natural systems. A broad range of initiatives falls under the rubric of citizen science, so it is useful to identify a unifying principle: By supporting partnerships between researchers and the public, citizen science creates opportunities for stakeholders to interact with scientific experts, and this process of public collaboration with scientists has far-reaching implications for science, management, and policy. A key aspect (and one that is not widely discussed) is the ability of citizen science programs to engage a broader network of stakeholders (i.e., beyond the volunteer citizen scientist). Casting a wider net over the stakeholder groups allows

more diverse perspectives to inform decision making at multiple levels of governance and at multiple points in the research and policy process (Jansujwicz, Calhoun, and Lilieholm 2013).

Engagement of diverse stakeholders at multiple levels of social structure (i.e., government agencies municipal officials, landowners) is important: What might be easily embraced as a goal by one stakeholder group may not necessarily resonate with others. For example, at a landscape scale, the importance of wetland conservation in reducing flood risk, enhancing biodiversity, and providing education and recreational opportunities is now widely recognized and reflected in codified conservation action. Yet, individual landowners who might be looking to sell or enhance their properties might find land use and regulatory restrictions around wetlands to be cumbersome, intrusive, expensive, and confusing. Benefits realized at a regional or landscape level do not necessary accrue to the individual landowner or citizen. This tension between planning and management objectives at different scales (i.e., concerns over private property rights and societal rights) often exacerbates or ignites fear, misunderstanding, and frustration for decision makers and those affected by the decisions. To more effectively balance these concerns and meet diverse management objectives, it is necessary to understand decision trade-offs at multiple levels. Understanding the perspectives of stakeholders is a critical first step towards integrating important information and communication needs into conservation and management approaches. Positioned at the nexus between science and society, citizen science can foster a better understanding of stakeholder needs (Jansujwicz, Calhoun, and Lilieholm 2013), and when used in innovative ways, can "make our lives—individually and collectively—better" (Silka 2017: 91).

In this article, we draw on almost two decades of work in Maine with citizen science and stakeholders focused on management strategies for vernal pools to illustrate one approach that helped span the gap between knowledge and outcomes. We share what we, as university scientists, learned from diverse stakeholders and how this feedback led to improvements in our citizen science program, gradual adaptations to our scientific research process, and ultimately to innovative vernal pool policy initiatives. Our purpose is to provide an exemplary case for how citizen science can be mobilized to meet multiple objectives of diverse stakeholder groups at different levels of social structure.

A web comic by Laura Bollert with Kris Hoffmann

The UMaine Vernal Pool Team has produced a new, comical way to learn about the animals that live in these small wetlands. The free, inspirational, and educational comics are available on the Of Pools and People webpage (http://www.vernalpools.me/comic/).

The following questions inform our discussion:

- What did we learn from different stakeholders at each stage of the process, and how did this feed into the design and implementation of our program?
- How did each level of decision maker inform incremental changes in vernal pool conservation policy?
- What gaps and policy or management implications remain, and how can they be better addressed by citizen science?

In answering these questions, we first provide a brief description of vernal pool conservation and citizen science in Maine. We then discuss lessons learned about two simultaneous and important aspects of citizen science (Cooper 2016): (1) producing reliable knowledge of what can be done to address conservation and development decisions around vernal pools and (2) developing and maintaining social capital (networks and relationships) critical for putting this new knowledge to use. Using these "two interlocking keys" of citizen science as a framework (Cooper 2016: 11), we discuss how the perspectives, concerns, and information needs of the different decision makers involved in community-based vernal pool conservation planning informed the process and influenced policy outcomes at key decision points in the policy-making process. While we draw on a specific example of vernal pool conservation planning in Maine, lessons learned from our experiences are transferable to the conservation of other small natural features on private lands (see Hunter et al. 2017).

VERNAL POOLS AND CITIZEN SCIENCE IN MAINE

Vernal pools in the northeastern United States are small, seasonal wetlands that occur in forested landscapes. Pools typically fill with snowmelt or runoff in the spring and provide critical breeding habitat for amphibians and invertebrates and important resting and foraging habitat for a number of rare and endangered species in Maine (Calhoun and deMaynadier 2008). While vernal pools are unique ecosystems that perform important functions at the landscape scale (Cohen et al. 2016), protecting pools is a challenge for natural resource managers because they are small, ephemeral, occur predominantly on private land (Baldwin and deMaynadier 2009), and are difficult to identify remotely (DiBello et al. 2016).

Historically, vernal pools in New England only received attention on a case-by-case basis by government agencies charged with protecting wetlands. Numerous federal and state agencies weighed in on project proposals resulting in an overlapping and confusing regulatory process. Gradually, as more became known about vernal pools and their critical role in the landscape, new approaches to address their long-term sustainability emerged. Today, Maine has one of the most comprehensive and stringent measures for protecting vernal pools in northeastern North America (Mahaney and Klemens 2008). Under the Maine Natural Resources Protection Act (NRPA), which provides for the regulation of wetlands and other important natural resources (38 MRSA §§ 480-A to 480-Z), a subset of ecologically outstanding vernal pools are designated as "significant wildlife habitat." Beginning in 2006, Maine adopted a definition for identifying significant vernal pools (SVPs) (Significant Wildlife Habitat Rules, Chapter 335, Section 9 under NRPA) based on the abundance and presence of vernal pool indicator species—fairy shrimp, wood frogs, and blue-spotted and spotted salamanders—or use by state-listed threatened or endangered species. An SVP includes the pool and adjacent terrestrial habitat within a 250-foot radius around the pool from the high-water mark. This proactive management of vernal pools evolved slowly, taking more than 10 years to address the regulatory gaps for their protection (Jansujwicz and Calhoun 2010). Throughout this history, citizen science played an important role in raising awareness of vernal pools and informing policy change. Foundational projects include the Very Important Pool (VIP) program and Maine Vernal Pool Mapping and Assessment Program (VPMAP).

The VIP program was initiated in 1999 by the Maine Audubon Society to inventory vernal pools statewide. This outreach program collected data on pool-breeding amphibians and their reproductive behavior in pools in southern, central, and northern Maine for five years (see Calhoun et al. 2003 for a summary). The VIP program's goals were (1) to raise the profile of vernal pools through statewide citizen participation, (2) to engage the news media to make vernal pools a household word and a resource of interest, thus bringing home the importance of these small wetlands to the public, and (3) to gather baseline inventory and assessment data on vernal pools that could help scientists, regulators, and legislators understand the resource and craft a definition of vernal pools and SVPs.

The Maine Vernal Pool Mapping and Assessment Program (VPMAP) followed eight years later in 2007. When the Maine State Legislature passed the vernal pool law in 2007, vernal pools were not mapped, and this posed a significant challenge for regulatory compliance. In response to the need to know where vernal pools and specifically SVPs persisted in the local landscape, the University of Maine and Maine Audubon Society jointly initiated VPMAP, which was designed to reduce uncertainty in development proposals by offering landowners a free assessment to determine whether a potential

vernal pool (PVP) met the biological criteria for significance under NRPA. Significance, used to identify SVPs, is determined by threshold egg mass counts of pool-breeding amphibians during the peak breeding season in the spring, or by the presence of fairy shrimp or an endangered or threatened species. PVPs are first identified remotely by aerial photography, but then require field assessments in the spring by a citizen scientist, consultant, agency biologist, or other qualified individual to determine whether they meet the biological criteria of an SVP. Organizers of VPMAP worked collaboratively with interested local towns to map and conduct ecological assessments of vernal pools on public and private land using trained citizen scientists. The goals of VPMAP were (1) to develop a map of vernal pools and particularly SVPs with the goal of submitting data to the state database, (2) to provide towns with a map and data on pools for use as a decision-making tool in planning and development activities, and (3) to raise public awareness of the value of vernal pool resources by educating citizens through hands-on engagement in pool assessment and documentation.

Emerging Lessons from Citizen Science in Maine

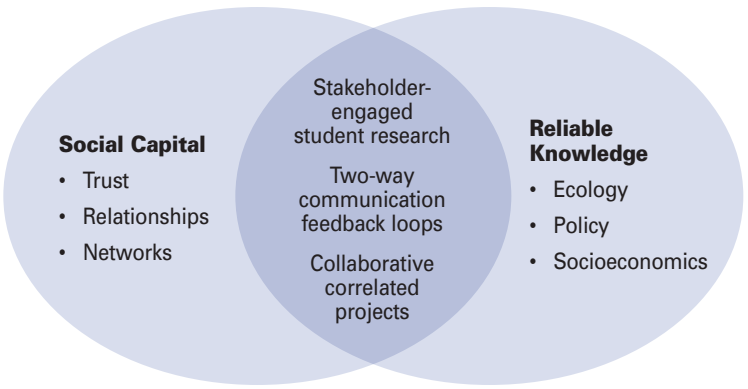
In the following sections, we share our experiences with the VIP program and VPMAP. We discuss how our research and community-based citizen science involved the people who would ultimately use the research results; how we involved them in identifying the problems, tailoring data collection to reasonable goals; and how we as a team developed and sustained feedback loops that ultimately built local capacity to enhance stakeholder communication and long-term impact on land use decisions. We share the success we achieved, but also identify the challenges we faced in the implementation of our citizen science programs and in acceptance of the data for policy making at the local, state, and federal level. We offer examples of how we, as scientists, work with citizens and policymakers and how we involve students in our research and community engagement activities. We use the two citizen science projects as the foundation for this discussion because the partnerships, cutting-edge research, and innovative policy initiatives were outcomes that emerged from these community-based initiatives. The outcomes of VIP and VPMAP illustrate how community-based citizen science can build relationships at the local and state level, enhance data-collection activities, and lead to real policy impacts. Accordingly, our discussion is organized around Cooper's (2016) conceptualization of citizen science as simultaneously creating reliable knowledge of what can be done and social capital to make it happen (Figure 1).

Building Knowledge to Identify and Address Conservation and Management Challenges

Most New England vernal pools occur on private lands, which introduces an interesting mix of stakeholders including multiple scales of government, diverse resource-management organizations, and heterogeneous landowner and development community interests (Calhoun et al. 2014). As a consequence of these ownership patterns and patchwork of regulatory mechanisms governing vernal pools in Maine, we realized that key stakeholders at multiple governance levels would be essential to identify opportunities for vernal pool conservation and to address management challenges.

Identification of knowledge gaps and management constraints was an iterative process. New issues were continuously identified as understanding of the resource improved, as stakeholder knowledge needs evolved, and as more stakeholders became relevant to decision making. Here citizen science played a dual role: it offered a platform for the identification of new challenges to bridging the science-policy gap, and it fostered development of new approaches to vernal pool conservation that built upon a strong base of citizen participation and involvement. In our Maine example, each

FIGURE 1: **Two Interlocking Keys for Vernal Pool Citizen Science Outcomes**



Source: Cooper (2016)

iteration of problem identification and policy change was reflected in changes to the citizen science model. Our efforts in vernal pool citizen science were built upon previous models, but adapted to meet new stakeholder priorities, management realities, and emerging resource concerns. This evolution involved almost two decades of collaborative work. Early vernal pool conservation efforts were initiated in direct response to problems identified at the federal and state level: federal regulators had called upon Maine to improve its poor record in regulating small wetlands, including vernal pools, but the state and the public knew little about the resource, making progress a regulatory and public relations challenge (Calhoun et al. 2014). Citizen science through the VIP program helped fill these gaps. Important outcomes of the VIP program included citizen scientists trained to conduct vernal pool assessments; data on more than 400 vernal pools; dozens of workshops, newspaper and magazine articles, radio and television programs, and a manual, *The Maine Citizen's Guide to Locating and Documenting Vernal Pools* (Calhoun 2003). The VIP program also motivated scientific research. Five master's and five doctoral students produced data on life history needs of pool-breeding amphibians, two state-listed species of turtles depending upon pools, and amphibian responses to forestry practices (see Baldwin, Calhoun, and DeMaynadier 2006a, b; Joyal, McCullough, and Hunter 2001; Lichko and Calhoun 2003; Oscarson and Calhoun 2007; Patrick, Calhoun, and Hunter 2007; Vasconcelos and Calhoun 2004, 2006). Information collected helped regulators come to terms with the science of vernal pools and explore mechanisms to fulfill legislative mandates to define pools and determine significance (Jansujwicz and Calhoun 2010).

While the VIP program (in combination with student research) was instrumental in filling initial data gaps and in bringing vernal pools into the public lexicon, it was perhaps most influential in identifying emerging issues and concerns. As the important functions and values of vernal pools became better known, the problem definition shifted from determining significance and raising awareness to identifying appropriate management measures that would facilitate on-the-ground conservation outcomes that were based on the emerging science.

The next phase of citizen science reflected a larger paradigm shift from top-down reactive management to an emphasis on local-level planning decisions. While federal pressure played a role in motivating regulatory approaches to vernal pool conservation, regulatory compliance was ultimately the responsibility of local managers and private landowners. In grappling with the 2007 SVP regulations at the local level, the actions (and reactions) of different stakeholders highlighted new issues. First, vernal pools were not mapped, and most towns did not have the expertise and capacity to identify vernal pools, much less SVPs, in their jurisdictions. Second, while based on the best available science but tempered with politics, the regulations were highly controversial. Landowners feared that the regulations would restrict what they could do with their property, and the added expense and delay of having to hire a contractor to survey potential pools in the spring only added to their frustration. This regulatory backlash threatened to derail conservation efforts. New conservation approaches were needed to alleviate the burden on local towns and private landowners and to reduce public fear and misunderstanding of the new regulations. As the new rules on vernal pool rolled out and tensions mounted, stakeholders and researchers identified the need for stronger partnerships and engagement at the municipal level. Citizen science was introduced as a potential tool to fill this gap.

While sharing similar goals with the VIP program, VPMAP included additional public outreach and encouraged more municipal involvement. Ecological assessment and data collection was still a priority; however, the program placed a greater focus on decisions at the municipal and individual landowner scale. As described earlier, VPMAP was designed to create a town-wide vernal pool database for use by municipal planners to guide development within their jurisdiction. VPMAP more specifically addressed landowners' needs by providing a less expensive and more accessible method to learn about potential vernal pools on their properties.

Over three field seasons, VPMAP expanded on the VIP by engaging 10 Maine towns, incorporating years of research into web-based support for volunteers, and closely coordinating with state agencies to meet their data needs. The VPMAP addressed emergent issues and achieved important outcomes, particularly with respect to data collection, education, and stakeholder-engagement activities (discussed in more detail later in this article and in Jansujwicz, Calhoun, and Lilieholm 2013; Jansujwicz et al. 2013). However, VPMAP also exposed underlying tensions that continued the iterative cycle of problem identification.

The culmination of this second and most recent phase of citizen science identified recurrent challenges to pool conservation. On the one hand, stakeholders continued to be concerned about the limitations of the state legislation (i.e., regulating less than a quarter of all pools and regulating an inadequate amount of key amphibian habitat around each pool). On the other hand, there were concerns about perceived excesses (i.e., regulating too many pools and adjacent uplands and infringing on private property rights) (Calhoun et al. 2014; Jansujwicz et al. 2013). Vernal pool regulations once again became the subject of intense political scrutiny and the target of attempted rollbacks with the goal of allowing increased development activity associated with vernal pools. This ushered in a new phase of adaptive management and focus on producing local alternatives. Maps produced by VPMAP served as a catalyst for considering vernal pool tradeoffs at the local scale, and municipal participants in VPMAP, state officials, and university researchers began to discuss how to effectively conserve vernal pools given the current political and social context. Emerging from discussions with citizen scientists and other town participants, it was clear to us that economic issues needed to be addressed before pool conservation efforts could reach a new level. Passive maps and voluntary approaches would not be enough to conserve pools using a local, landscape-level approach that would both conserve pools and invite economic growth and vitality.

Effective conservation is an adaptive and iterative process, and citizen science provided a pathway for addressing stakeholder needs and identifying new issues.

Our team took this to heart, and the feedback provided by our program partners led to another research grant that funded five doctoral students to study vernal pool ecology and the economics of conservation of poolscapes in developing landscapes from 2013 to the present. It also inspired the formation of a diverse stakeholder group to address alternative conservation mechanisms for vernal pools that would be locally based and address economic issues on private land. The stakeholder group—made up of participants from the development community, academia, state and federal agencies, and municipal officials—met for more than six years and developed a Maine Vernal Pool Special Area Management Plan (VP SAMP) that provides a solution to challenges highlighted by citizen scientists and municipal officials (see Calhoun et al. 2014; Levesque, Calhoun, and Bell 2017; Levesque et al. 2016 for more details). The VP SAMP was accepted by federal and state agencies and provides a voluntary alternative mitigation mechanism for developers and landowners to conserve vernal pools in rural areas through remuneration to rural citizens for pool conservation. This remuneration is funded by developers who are having an impact on vernal pools in designated growth areas. This local in-lieu-fee program tailored to pools and run at the local level could not have developed without our strong citizen science programs and Maine's culture of local participation in natural resources issues.

Reflecting on the iterative process of identifying challenges, building new knowledge, and adapting strategies, it is interesting to note that citizen science played an important role in negotiating the needs of decision makers at multiple governance levels. While federal- and state-level entities initially identified the problem, once lack of data and resources was identified as an issue and citizen science identified as possible solution, the process moved to the local level where scientists worked collaboratively with towns. Working with towns to train citizen scientists and collect data on privately owned lands, we identified larger planning issues and regulatory pushback that when translated back to the federal and state levels served to (re)initiate discussions on how to address emerging issues through research and better communication. Effective conservation is an adaptive and iterative process, and citizen science provided a pathway for addressing stakeholder needs and identifying new issues.

Building Social Capital for More-Adaptive Solutions

Cooper (2016: 11) defines social capital as "the social networks, cohesion, and individual investments in community that make democracy work better." Building social capital by engaging the community can increase public support for conservation (Schwartz 2006). Engaging partners in community-based projects may not only strengthen social capital, but also enhance

scientific capacity and inclusiveness of local decision making (Whitelaw et al. 2003). At the same time, stakeholder engagement in citizen science varies widely. Developing and sustaining programs that match different stakeholder needs in terms of type and degree of engagement is, therefore, a challenge.

General categories of citizen science occur along a continuum by degree of public participation outlined by Gray et al. (2017):

- Contributory projects—usually scientist designed where the public is included mainly in data collection.
- Collaborative projects—structured by scientists where the public is provided opportunities to collaborate on project design and in data collection and analysis.
- Cocreated projects—more democratic partnerships where the public is actively engaged with all steps of the scientific process.

Like the majority of citizen science projects (Bonney et al. 2009), the VIP project falls squarely into this first category, VPMAP contains elements of the first and second categories as measured by the degree and nature of stakeholder engagement, and VP SAMP falls squarely into the third category. In reflecting on our engagement, we learned that as our model of citizen science transitioned from contributory to collaborative and cocreated, our stakeholder engagement became richer and more complex as challenges and solutions increased in complexity. In navigating this complexity with citizen science, important benefits emerged. This included stronger stakeholder relationships, new models of stakeholder-engaged student research, and a better understanding of stakeholder expectations and resultant policy implications (Table 1).

The relationships we developed with participants at local, state, and federal levels were a notable benefit of our engagement with citizen science. These projects provided a unique opportunity for us, as researchers, to work with various stakeholders on an issue of common concern. Working in the community allowed us to hear firsthand the reactions of different stakeholder communities to the vernal pool regulations and to consider their viewpoints and information needs as the project progressed. For example, we learned about more effective ways to communicate with different constituents (i.e., email and web networks, creation of fact sheets and streamlined data-collection forms) (Jansujwicz, Calhoun, and Lilieholm 2013). Channels open for communication changed over time from top down to jointly managed. As challenges increased, we changed the strategies for engaging stakeholders from gathering general information on pools and educating the public to providing base maps and static information to towns and landowners to a living-solutions action that provides economic benefits to citizens. This transition was well supported by prior engagements (and programs such as VIP and VPMAP) that engendered trust (Levesque, Calhoun, and Bell 2017).

Students and student-led research projects were critical for engaging stakeholders and sustaining their attention. Numerous students contributed to project continuity and exemplified our long-term human resource and financial investment in the local community and natural resources. VIP, VPMAP, and SAMP all used students to collect data and interact with stakeholders. Students met with agencies, towns, and private landowners; their research topics were informed by stakeholder requests and ranged from detecting post-breeding movement patterns of blue-spotted salamanders to understanding private landowner perceptions of vernal pools. Although specific projects wrapped up and students graduated, the continuous influx of students and the staggering of research projects meant that there was a sustained boots-on-the-ground presence. For over

TABLE 1: **Evolution of Vernal Pool Citizen Science, Research, and Policy in Maine**

Project	Type	Goal	Research	Policy
VIP	Contributory	Data collection Education	Ecological	Reactive
VPMAP	Contributory/ Collaborative	Data collection Education Planning tools (static map)	Ecological/ Human Dimensions	Regulatory and community-based
VP SAMP	Cocreated	Planning tools (local alternatives)	Human-Natural Coupled Systems	Voluntary, local, adaptive

15 years, a cadre of dedicated graduate and undergraduate students waded through vernal pools with citizen scientists, met with landowners, participated in meetings with federal and state agencies and town planners, and attended legislative hearings in our state capital. We shared data collected and lessons learned with stakeholders and peers through personal connections, a user-friendly website, and academic papers. This model of student research attracted stakeholders from many different backgrounds and age groups in hands-on conservation in their own backyards and exposed students to interdisciplinary stakeholder-engaged research.

Through our work with federal, state, and local community stakeholders, we learned that groups and individuals had different reasons for engagement, levels of commitment, and expectations of the process and outcomes. This, in turn, made managing roles and expectations a challenge, particularly in communicating expectations related to workload and availability of outcome data (Jansujwicz, Calhoun, and Lilieholm 2013), but it also made the results deeper, richer, and ultimately, more resilient (McGreavy et al. 2016). We learned important lessons about difficulties with training citizen scientists and getting data back from them, with gaining access to private property, and with following up with participating landowners and towns after the significance data was collected. Continuous interaction with stakeholders enabled us to understand where process bottlenecks occurred and where better communication was needed. Stronger stakeholder relationships helped overcome obstacles and contributed to a stronger base of social and political capital that built the foundation for collaborative and cocreated projects.

NAVIGATING CHANGE AND FUTURE CITIZEN SCIENCE

If there is one constant in our experiences with citizen science and vernal pool conservation planning in Maine, it is change. Natural resources conservation is dynamic—new knowledge emerges, stakeholders' needs change, and (in an ideal scenario) policies adapt. As our example illustrates, citizen science programs are similarly dynamic. Our community-based citizen science evolved slowly, continuously shaped by the influx of new ecological knowledge and stakeholder input. In the early iteration (VIP program), citizen science was used to support the development of science-based policies, particularly the vernal pool definition and rules. In the next phase (VPMAP), citizen science was used as a community-based strategy to navigate the challenge of regulating natural resources on private property. With VP SAMP, the foundation of the first two programs provided the social and political capital that allowed us to assemble a diverse stakeholder group familiar with VIP and VPMAP and vernal pool issues and that was committed to moving policy to local control.

Strong social capital was critical to the parallel evolution of our scientific research, citizen science, and vernal pool policy. Continuous, face-to-face, and hands-on interaction between our research team, community, and regulatory stakeholders created the trust and networks needed to get things done. Just as our work has, on a practical level, increasingly involved working with partners, on a theoretical level, much of it is increasingly framed in terms of "human-natural coupled systems." One of the moves that conservation science has made is to conceive of, approach, and analyze conservation problems within this framework because natural systems often aren't best studied alone. Nature doesn't exist in isolation. This framework points to the possibility that much is to be gained by recognizing that human systems and natural systems are interlinked. We have embedded our citizen science work within this broader framework. An important consequence is that the theory and practice of what we do is coordinated, thus allowing for science and action to move together in ways that have the potential to enhance both. And we are seeing this happening in how citizen science has created and sustained relationships and feedback loops in the science and policy process, leading to better on-the-ground outcomes for people and pools.

But there is more work to be done. As we transition into the next phase, we recognize that, despite notable advances, our research is not having the impact it could and should have on the local community. New approaches are needed to empower communities and encourage citizens to engage not only in data collection, but also in processing, analyzing, and applying new information (Kennedy 2016). Excited about the role citizen science can play in this transition, our team is turning attention to the use of technology as a way to support increased usability and timing of data collection and sharing so that stakeholders receive the information they need when they need it in a form they can use it. Leveraging technology to increase responsiveness (in collaboration with stakeholders) will better support

planning in a rapidly changing ecological, social, and political environment and may ultimately bring us closer to bridging the science-policy gap in natural resources conservation.

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