# Summary of the Literature

# for an

# Alaska Community-Based Monitoring
# Best Practices Workshop

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## Executive Summary

We reviewed and summarized reports and articles published in scientific journals related to the effectiveness and success of programs involving community members in environmental monitoring activities. We decided to use the term Community-Based Monitoring (CBM) as an "umbrella term" for the purpose of an Alaska workshop to encompass on-going monitoring activities that have also been called citizen science, observing networks, public participation in scientific research, community-based research, and community-based participatory research. What all of these activities share is a collaboration between professional scientists and non-scientist stakeholders from recognizable, but diverse, communities.

While CBM is an umbrella term, it is also a sub-set of the other, broader terms because they encompass all types of research, particularly research that is hypothesis-driven, while CBM focuses on monitoring to detect significant environmental changes.

In general, the degree of involvement of community members in CBM activities varies along a spectrum from solely the collection of data and information to involvement in every aspect of program initiation, planning, implementation, and evaluation. The degree to which scientists or communities drive CBM programs, however, affects the quality of community participation.

In Alaska, the communities engaged in CBM are particularly diverse, and include subsistence hunters, K-12 teachers and students, political entities (e.g., villages, towns, cities, etc.), people who live in the same geographic area, and people who have common interests (e.g., birding, commercial fishing) or common concerns (e.g., clean water, the status of fish and wildlife populations or species).

CBM programs have already made substantial contributions to ecological understanding and many programs have incorporated local and/or traditional knowledge, particularly in the Arctic. CBM has the potential for beneficial outcomes at multiple levels: individual participants, communities, including the scientific community; natural resource management systems; and the social-ecological systems in which human and their institutions are recognized as playing an integral role.

Successful CBM programs begin with a clearly-articulated purpose shared by all participants, clear and measurable objectives, the results and outcomes desired, and a recognition of what will constitute success.

Implementation of the project required standardized or documented methods for collecting data or gathering observations and other types of information, recruiting and training (and often re-training) community participants, and evaluating success. Participating scientists require reliable, useful, and well-managed scientific data, observations, and other types of information. Traditional and local observations, gathered and managed in culturally-appropriate ways, also contribute to the desired understanding.

Sustaining CBM programs is a challenge, especially for those that rely on volunteers and/or require on-going funding. Scientist and community participants in CBM often have different objectives, motivations, and rewards; and this difference must be recognized and addressed to sustain participation. Observation networks usually depend on paid observers. Other strategies to sustain participation by community monitors or observers include ongoing feedback to community participants, recognition of individual efforts, and appreciation and acknowledgment of community contributions.

The need to establish and maintain two-way communication that is frequent and timely

throughout program planning and implementation was stressed as critical to program success, and to building relationships and establishing trust. This communication has often been accomplished effectively by combining "state of the art" electronic communication technology and with other means appropriate to the community.

## Introduction

We reviewed and summarized the literature that existed in the form of reports and peer-reviewed scientific publications related to the effectiveness of programs which fit our definition of Community-Based Monitoring (CBM) for the purpose of a statewide workshop in Anchorage, Alaska, held on April 1-2, 2014. The workshop was designed to bring together a growing community involved in the practice of CBM in Alaska with interested funders and potential end-users of community-collected data to develop guidelines and best practices in the following:

1) validating existing best practices in CBM and the application of data and information to resource management in Alaska, across the Arctic, and beyond;

2) articulating outcomes for both scientist and community member participants;

3) designing successful projects that:
    a. use methods and technologies that are locally and culturally-appropriate,
    b. sustain participation,
    c. manage data and other community-based observations and provide appropriate QA/QC and access, and
    d. develop and sustain timely two-way communications between scientists and community members;

4) evaluating success.

Information gained through this process was used to develop the agenda for the workshop. Likewise, the organization of the literature summary reflects the workshop agenda.

## Background and Definitions

A CBM handbook developed for the Arctic Council group Conservation of Arctic Flora and Fauna (Gofman, 2010) defined CBM as "the direct involvement of local community members in monitoring, either through their participation in collaborative monitoring efforts, or by training and contracting local workers to carry out monitoring projects" (Fernandez-Gimmenez et al., 2008) or more simply, as "the gathering of information by local residents over a period of time." The handbook provided "lessons learned" for six types of CBM activities: 1) citizen science involving the operation or maintenance of scientific instruments and/or recording of data such as phenology; 2) "sentinel" (patrol) activities in which community members make place-based observations and record various elements of their local environment, 3) the use of humans as sensors by surveying the perceptions of local residents of the status and changes in the environment, 4) journaling to record personal accounts of the observed environment on a regular basis over a period of time, 5) maintenance monitoring (e.g., recording data from beach clean-ups), and 6) group meetings that are organized for local residents to share and report on observations over a specific period of time.

CBM is thus an umbrella term that encompasses a diversity of on-going monitoring projects and programs in Alaska that involve community members. While CBM is an umbrella term itself, it is also a sub-set of other broader terms such as "observing networks," "public participation in research (PPSR)," "community-based research," and "community-based participatory research (CBPR)." These terms encompass all types of research, particularly research that is hypothesis-driven. Because CBM is a sub-set, however, this review draws on the "best practices" in the literature on all of these types of activities with consideration of their relevance to CBM.

In addition to Arctic and other Alaskan communities, activities considered CBM in Alaska engage a diversity of communities united by interest or environmental concern such as subsistence hunters, K-12 science teachers and their students, tribal members, birdwatchers, and shellfish farmers. The programs vary greatly in design and goals, however, depending on the type of community involved. What they all have in common is a collaboration between professional scientists or other users of data and other forms of information (e.g., natural resource managers) with non-scientist stakeholders from recognizable, but diverse, communities who collect or gather the data, observations, or other types of information. The degree of involvement of the community members varies along a spectrum from solely the collection of data and information to involvement in every aspect of program initiation, planning, implementation, and evaluation.

Citizen science has been defined as follows: "for North America, citizen science typically refers to research collaborations between scientists and volunteers, particularly (but not exclusively) to expand opportunities for scientific data collection and to provide access to scientific information for community members." (Cornell Lab of Ornithology, n.d.)." The term has generally been used to describe data-collection projects that are large-scale and involve the public in data collection. Bonney et al. (2009a) reviewed citizen science and described it in terms of the integration of members of the public into science, but they also included specific and measurable goals for public education as one of the components. Gofman (2010) explicitly included citizen science activities as one type of CBM activity, but also identified other CBM activities that ranged from the use of humans as sensors, in which perceptions of the status and/or changes of the environment by local residents were surveyed, to group meetings organized for local residents to share and report on observations over a specific period of time.

"Observing networks" is another term used to describe CBM activities. In the Arctic, the term "observing" is often preferred to the term "monitoring," to avoid the perception that the monitoring plays a regulatory function (Gofman, 2010). CBM efforts in Alaska often involve paid observers to contribute local observations to observing networks that also include the scientific instruments deployed to collect data remotely, including satellites, buoys, and other types of sensors; and the agencies and researchers who deploy and them. To be relevant to Alaska communities that include Alaska Natives, the observational framework requires a design that is responsive to the context of traditional knowledge systems about the local environment.(The term "Traditional Ecological Knowledge (TEK)," "Traditional Environmental Knowledge (TEK)," or "Traditional Knowledge (TK)" distinguishes knowledge with a time-depth based on multiple generations and provides a context for observations made in "real time."

It is often considered with other types of local knowledge or LTK. Some scientists use the terms LTK and TEK interchangeably.)

PPSR is defined broadly as an over-arching category that includes citizen science, volunteer monitoring, and other forms of organized research in which members of the public engage in the process of scientific investigations: asking questions, collecting data, and/or interpreting results (Cornell Lab of Ornithology, n.d). Shirk et al. (2012) described the common element of collaborations involving PPSR as "explicitly engaging the public in the research process to produce science-based knowledge." and "aiming explicitly to contribute to scientific research and/or monitoring."

The term "community-based research" has been used in a similar manner to PPSR, but the term implies that the community has a role greater than that of data collection or the contribution of local observations. In Alaska, the term usually refers to the role of organized communities (villages, towns, etc.) in identifying community concerns and being engaged in research that is relevant to them. Community-based participatory research (CBPR) is a term used in the literature that emphasizes a partnership approach to research and equitable involvement of community members and researchers in all aspects of the research process and in which all partners contribute expertise and share decision-making and ownership. The "bidarki" project that examined the role of natural and social factors on is an example of a project with full participation by the communities of Port Graham and Nanwalek, including co-authorship by community members of both scientific reports and articles and the book, *Imam Cimiuciq: our changing sea* (Salomon et al., 2011).

We decided to use the term CBM as one that focuses specifically on monitoring but was inclusive with respect to methods, the types of information collected or gathered, and a wide range of desired outcomes for both science and community participants.

## The Spectrum of Collaboration

Bonney et al. (2009b) and Shirk et al. (2012) distinguished three predominant types of public engagement in PPSR projects, based on their review of case studies and synthetic work in conservation management, informal education, community-based forestry, and volunteer monitoring:

1) Contributory projects, which are generally designed by scientists and for which members of the public contribute data;

2) Collaborative projects, which are generally designed by scientists and for which members of the public contribute data but may also help to refine project design, analyze data, or disseminate findings;

3) Co-created projects, which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all of the steps of the scientific process.

Danielson et al. (2009) reviewed monitoring projects throughout the world and classified the degree of community involvement in terms of projects that were: externally driven and professionally executed, externally-driven with local data collectors, collaborative with external data interpretation, collaborative with local data interpretation, or locally autonomous.

Although a number of Alaska Native communities participate in the collection of scientific data, the degree to which project design is cooperative and takes into account Native knowledge and ways of knowing varies considerably. At one end of the spectrum, tribal governments and organizations are involved in the prioritization of monitoring needs to address local environmental concerns and community members are trained to collect scientific data using rigorous data collection protocols (e.g., water quality monitoring projects, biological sampling from marine mammals by hunters). Native Elders may be involved in the determination of "natural indicators," empirical observations that correlate with specific ecological phenomena and complement scientific data collection, such as those developed for salmon run timing and abundance for the Yukon River (Moncrieff and Bue, 2012). At the other end of the spectrum, monitoring efforts are designed and implemented cooperatively (including sharing, interpretation, and application of results) with attention to the incorporation of both scientific data collection methods and traditional knowledge and knowledge systems (e.g., the Sea Ice and Walrus Outlook( SIWO) project that involves cooperative monitoring by hunters and wildlife managers of sea ice conditions relevant to walrus in the Northern Bering Sea and southern Chukchi Sea regions).

## Benefits of CBM

A wide variety of benefits have been documented or identified as potential benefits of CBM. Several researchers found that community-based monitoring is more cost effective than traditional monitoring methods, i.e. instrument data collection (Danielsen et al., 2005, Danielsen et al., 2007, Mahoney et al., 2009), and that social and political capacity is also strengthened. The inclusion of community members in monitoring has proven to lead to increased conservation efforts and interventions on behalf of the community, as well as increased awareness and interest within the community of their local environment and potential detrimental effects of climate change (Andrianandrasana et al., 2004, Noss et al., 2005, Danielsen et al. 2007, Tremblay et al., 2008; Brubaker et al., 2011). These increases in interest, in combination with lowered operating costs, allow community-based monitoring to be a fairly sustainable observation method that supports local capacity building through local knowledge inclusion and recognition (Becker et al., 2005, Danielsen et al., 2005, Hovelsrud et al., 2007).

Collaboration with communities can provide an effective approach to evaluating community vulnerability and adaptive capacity in a way that ensures that knowledge, experiences, and opinions of the community are adequately captured as a foundation for culturally- appropriate adaptation strategies (Nichols et al., 2004, Hovelsred et. al., 2007, Pearce et al., 2009). Within other collaborative vulnerability assessments that have already been established, key social factors were highlighted as impetuses for undertaking such studies including: changes in social-ecological systems; limited economic opportunities within communities; and threats to identity and well-being (Hovelsred et al., 2007). Gaps within the current literature on vulnerability and adaptation have also been found, including: an uneven geographic spread of studies; limited focus on indirect effects of climate change including economic, health, and cultural vulnerabilities; and limited research on determinants of adaptive capacity such as social networks or access to financial resources (Ford et al., 2012), all of which can be strengthened through increased community collaboration. Community collaboration is also needed in terms of strengthening biodiversity monitoring and conservation management at the local level (Danielsen et al., 2005).

Dickinson et al. (2012) reviewed the current state of citizen science as a tool for ecological research and public engagement. They described the opportunities for non-professionals to engage in authentic research to collect important baseline data and to monitor mortality of particular populations or species, helping to identify threats to native species and to people. They considered citizen-science projects to be a natural fit for scientific endeavors with important environmental or public-policy implications, regardless of the degree of community involvement, provided that they engage the affected populations from the start. Building upon the assumption that participation in scientific research creates authentic learning experiences, citizen science is also a powerful way to generate ecological knowledge, inquiry, and place-based nature experiences for the public. They (Dickinson et. al., 2012) reviewed and summarized distinctive contributions of citizen science to ecology that have already been documented in the areas of landscape ecology, macro-ecology and climate change, urban, agricultural, and residential ecology; finding rare organisms, tracking invasions, and detecting irruptions and species declines. They also concluded from their review that citizen science augmented traditional research programs, layered question-driven research onto existing monitoring programs, and spurred statistical innovations arising from the challenges of working with large, heterogeneous datasets. They noted a further strength of citizen science research in its potential to address conservation problems across the entire range of a species.

Krupnik et al. *(*2011) described local observations contributed in the context of community-based research as one avenue to bring the voices of the people to the decision-making table. Their participation can offer unique perspectives to the scientific community and encourage knowledge exchange between the two systems (Ericsson et al., 1999; Nichols et al., 2004; Danielsen et al., 2005, Mahoney et al., 2009) which could help lead to more informed and relevant decision-making and policy recommendations (Danielsen 2007; Hovelsrud et al., 2007; Pearce et al., 2009). Data collected at the local scale can be a powerful tool in the hands of community leaders for use in policy-making and resource protection (Danielsen et al. 2010). Additionally, this knowledge exchange and collaborative relationship has been shown to strengthen relationships between local/community members and the science community as well as other governmental agencies, which may help avoid future conflict when issues arise (Danielsen et al., 2007, Hovelsrud et al., 2007, Brook et al., 2009, Pearce et. al., 2009).

Ultimately, CBM has the potential to lead to joint or co-management of environmental resources (Laidler et al., 2008). Many co-management systems are in place in Alaska that incorporate elements of CBM. Fourteen separate co-management systems regarding the management of marine mammals alone exist in Alaska (MMC, 2008). Community members engage in monitoring activities such as gathering bio-samples of their harvest, conducting population counts, administering surveys, participation in marking and tagging of wildlife and/or participation as an expert in a sentinel-type program (MMC, 2008). A review of three long term co-management agreement in the Canadian Arctic concluded that positive social and ecological outcomes are more likely through the co-production of knowledge (Armitage et al., 2011).

In Alaska, CBM engages a diverse group of people, including Alaska Natives who make valuable contributions of Local and Traditional Knowledge. This is not the case in most citizen science projects nationally, but Pandya (2012) believes that citizen science can bridge this gap if it offers an opportunity for communities and people to participate in science, rather than simply serving as recipients of outreach efforts. He defined the most effective programs as those that engage community members as active participants in every aspect of the science process: defining the research questions, collecting and analyzing data, and translating scientific insights into policy decisions and actions. Such programs connect scientific questions and practices to community priorities, values, and norms and have the potential to broaden participation not only in citizen science projects but also in science in general.

Thornton and Scheer (2012) reviewed the collaborative engagement of Local and Traditional Knowledge and science in marine environments, documenting the use of marine LTK to provide historical and contemporary baseline information, suggest stewardship techniques, improve conservation planning and practice, and to resolve management disputes. They found 56 species-specific studies that collected LTK, including those on fish, marine mammals, seabirds, lobster, and turtles. They summarized the type of LTK collected as falling into the categories of: 1) current abundance and spatial distribution of species, 2) migratory or seasonal movements, 3) sightings, 4) stranding incidents, 5) health of the species, 6) size of the species, 7) life history, 8) stock structure, 9) key habitats, 10) spawning and nursery areas, 11) past abundance, 12) behavior, 13) reproduction-related behavior, 14) feeding behavior, 15) effect of physical environment (lunar periodicity, shifting climate), human-animal interactions and effects. The Alaska and Arctic species that were the focus of the research included beluga whales, bowhead whales, seals, cod, gaddid fish, Arctic char, herring, geese, and eiders. Numerous other studies had a broader focus, including assessments of environmental change. LTK is also being used to understand the resilience and adaptive capacity of communities in response to the impacts of climate change. Other types of CBM data and observations being collected in Alaska include water quality measurements, sea ice conditions in relation to marine mammal observations, unusual occurrences of a species, unusual weather events, symptoms of disease in marine mammals, beached birds, and marine debris accumulations to plan beach clean-ups.

The framework document for the Circumpolar Biodiversity Monitoring Program (CBMP) (Petersen et al., 2004) recognized the importance of CBM in the Arctic which is inhabited by a number of indigenous and other local peoples who live in communities that rely heavily on natural resources and who have developed strong ties and a deep understanding of nature.

Local observation may provide the basis for scientific discovery and discussion (Huntington and Fox, 2005). One of the larger benefits of community-based observing networks, which also services the scientific community as a whole, is the widening of the base of knowledge upon which climate change research may be drawn (Berkes et al., 2007). Local observations of change offer a different type of data, on the local scale, that can't be replicated by instruments and which may add depth to scientific instrument data. Community-based observing networks are holistic in nature, as opposed to the more common reductionist scientific research approach to collecting data. Local observations often focus on how changes affect well-being, so they can provide society a more in-depth understanding of community vulnerability to climate change impacts (Ford et al., 2006). The effective documentation of changes at the local scale can be used as an early warning system for detecting environmental change with significance to society, as well as contributing to an increase in our understanding of human adaptation to those changes (Fidel et al., 2014). Community-based observing networks can be an extremely valuable scientific tool especially in remote, data-poor regions experiencing rapid climatic change.

## Motivation for Participants

The sustained participation of community members and local observers is critical to CBM success. Much of the literature on motivation has focused on voluntary participation. Gearhard and Shirley (2007), however, working with indigenous communities in Canada, emphasized that effort needs to be focused on providing benefits, such as training opportunities and employment, to increase local participation in research activities.

Motivation to volunteer to participate in citizen science projects often involves a desire to participate in an authentic scientific investigation, and a desire to learn more (or have their children learn more) about the ecological setting they live in (Evans et al., 2005). In projects targeting adults and families, citizen science volunteers tend to be a self-selecting group of people already interested in social-ecological issues (Evans et al., 2005). Citizen science programs within school settings tend to engage a greater diversity of participants with a range of skills, knowledge and relationships with their environment (the international GLOBE monitoring program, for example) than programs that do not engage schools (Evans et al., 2005).

Rotman et al. (2012) presented findings of a study of motivational factors affecting participation in ecological citizen science projects. They found that the factors motivating citizen scientists shifted over the course of their involvement. They used Batson's (2002) framework of four motivational factors – egoism (i.e., self-interest or self-identity), collectivism, altruism, and principalism – and found that both scientists and volunteers described some form of self-interest or self-identity as their primary motivation for engagement, but the types of personal goals for each group were different. Volunteers wanted to do something that would satisfy their personal needs and would interest and educate them through their participation, while scientists wanted to promote their careers. Other motivational factors came into play for the volunteers during their decisions to sustain their participation, but not for scientists. For volunteers, egoism was satisfied through attaining attribution and recognition from the scientists. Collectivism and altruism proved more motivating to the volunteers after their initial engagement. Collectivism was achieved by the scientists giving group feedback to the volunteers, and also through community involvement and advocacy. Altruism was achieved by aiding scientists in data collection (and rarely, data analysis) processes. Scientists did identify altruism (i.e., public education) as a secondary motivator after egoism, but for them it was tied to the need for scientific data and the need to publish. The one significant different between volunteers and scientists was in their perception of collectivism – volunteers saw it as being just as important as other motivational factors, while the scientists indicated that working with volunteers would not be greatly beneficial to the scientific community as a whole.

In one study of an online citizen scientist project, they (Rotman et al., 2012) found that scientists were primarily motivated to participate as an opportunity to facilitate large-scale data collection and they used the data in peer-reviewed publications. Scientists' altruistic notion of contributing to the common good through educating the public was a secondary motive for some, but many failed to recognize an initial interest that volunteers had in scientific problems as their primary motivation and downplayed the need for attribution and recognition as important to volunteers. The volunteers were motivated to sustain their participation by recognition, but initially in awe of scientists and aware that the scientists were wary of their level of commitment and quality of work.

## Other Factors Affecting Participation

Shirk et al., (2012) analyzed the relationships between public participation in the three types of PPSR projects and the observed outcomes in five synthesis studies. They concluded that the degree to which the public participates in the research process, as well as the quality of participation, is closely related to the range and types of outcomes achieved. The degree of participation is related to the extent to which individuals are involved in the process of scientific research: from asking a research question through analyzing data and disseminating results, which supported Pandya's (2012 ) recommendations concerning participation of communities typically underrepresented in science. The quality of participation is related to the extent to which a project's goals and activities align with, respond to, and are relevant to the needs and interests of the community participants. They summarized their review of the five synthesis studies as follows:

> In general, contributory projects are associated with robust scientific research outcomes and content knowledge gains, whereas co-created projects have demonstrated success in affecting timely policy decisions and enhanced resource management capacity of communities. These cases also reveal trade-offs regarding the resources and capacity needed to achieve outcomes of interest. For example, although co-created projects are driven and organized to a large degree by communities, they may actually involve as much if not more input, resources, and commitment by scientists than would a contributory project.

They asserted, however, that the documented outcomes of the PPSR projects, regardless of type, were more attributable to design choices regarding quality of participation (whose interests were being served) than they were to the degree of participation. They concluded that "projects must, therefore, reflect carefully on, and design deliberately for, the interests that sustain participation and yield the full range of desired outcomes for both science and the public in each specific programmatic context."

Shirk et al.(2012) acknowledged that the scientific process was common to the three different types of collaborations, and thus, subject to trade-offs related to the degree and quality of public participation and scientific rigor. Jordan et al. (2012) recommended that citizen science projects strike a balance between data collection to be accomplished and meeting learning goals, both of which need to be clearly defined by citizen science program leaders and scientists. If learning goals are a priority, then that should be reflected in the activities of participants, and these goals should be stated explicitly.

Pandya (2012) also emphasized aligning research and education with community priorities, planning for co-management of the project, incorporating multiple kinds of knowledge, and disseminating results widely.

## Planning and Implementing CBM Programs

Several frameworks have been developed to guide and organize the design and implementation of CBM and related citizen, community, or public participation in research (see Appendix 1). After reviewing these frameworks and others for program planning and management, we concluded that key elements in designing effective CBM programs include: 1) articulating a statement of purpose shared by all participants; 2) goal statement or statements; 3) objectives (which may differ for scientist and community participants); 4) outcomes at appropriate levels (e.g., for individual participants, for science, for resource management systems, for social-ecological systems); and 5) methods for collection of data or gathering of observations or other types of information, data management, evaluating results, assessing program success, and communication.

**Definitions**
**Purpose:** The “why we are doing this” statement. The purpose statement for community-based environmental monitoring projects generally relate to one or more of the following contexts:

a) detecting what changes are occurring

b) determining which changes are of concern to a community

c) determining responses the community is planning and/or initiating to changes

d) determining the consequences to or trade-offs for different outcomes of changes

**Goals:** Qualitative statement(s) about what we will strive to achieve in the future (that describe characteristics or qualities of what we strive to achieve)

**Objectives:** How much will be accomplished and when, in quantitative – or measurable - terms. S-M-A-R-T objectives are Specific, Measurable, Achievable, Realistic, and Time-specific.

**Outcomes:** Desired benefits at appropriate levels for the project or program. Examples of levels include science, individual participants, communities, resource management systems, the “good of society,” and/or social-ecological systems (e.g., resilience of ecosystems, including humans and human cultures and societies)

## Evaluating Outcomes

One of the greatest challenges to evaluating the success of CBM programs lies is in the need for clear communication about the outcomes desired by the collaborating scientists (or other information users) and by the community who will participate in collecting data, making observations, or gathering information. Gofman (2010) described monitoring outcomes primarily in terms of collected data and quantitative and qualitative databases. By their nature, citizen science and PPSR also focus on the collection of scientific data and usually evaluate success in those terms, but many have also defined success for the community participants in terms of learning or environmental engagement or action. School-based and informal education programs typically require “learning outcomes” stated in terms of what the individual learner will gain in terms of knowledge, skills, or understandings.

Bonney et al. (2009b) recommended that the impacts of citizen science projects be measured not only in terms of scientific contributions (e.g., numbers of papers published in peer-reviewed journals, size and quality of citizen science databases*)* but also that the impacts be measured in terms of scientific literacy outcomes (e.g., duration of involvement of project participants, improved participant skills for conducting science, increased participant interest in science as a career). They focused on literacy outcomes through an evaluation of selected projects in each of the three categories along the spectrum of involvement by adapting a framework for evaluating informal education projects (Friedman, 2008). The evaluation categories in the rubric were those of developing understanding and knowledge, enhancing engagement or interest, improving skills, changing attitudes, and changing behavior.

Phillips (2014) reviewed outcomes from PPSR projects and found that more than 70% were evaluated in terms of the satisfaction of the participants with respect to learning and becoming engaged in environmental issues, many were evaluated with respect to the quality of scientific data produced, but very few were evaluated for the accomplishment of tangible conservation outcomes such as acres of habitat restored, increased in conservation behaviors, or the outcome of a policy decision.

Dickinson et al. (2012) also described citizen science as a means of achieving broader impacts of ecological research through educational materials for participants. A number of other researchers focused on participant outcomes, particularly in terms of learning outcomes evaluated in formal and informal education contexts. Zoelick et al. (2012) distinguished between formal and informal science education programs in terms of learning outcomes. When engagement of both citizens and scientists is focused on shared goals of gathering and interpreting data that addresses a research question, a "win-win" scenario is created, where increased citizen participation in all phases of a project might result in both improved learning and better research outcomes. Learning in informal settings (e.g., improved attitudes towards science, understanding of scientific principles) may be difficult to describe and quantify, but this might be acceptable if the participants are volunteers, feel they are learning something, and continue to volunteer. Bonney et al. (2009b) concluded, however, that the learning from participation in citizen science projects was more robust for adult volunteers who explored their own questions.

Zoelick et al. (2012) worked with teachers and students in a project at Acadia National Park. They found that meeting the needs of scientists, teachers, and students required recognizing that those needs were different. The balance between learning and science goals can become a trade-off rather than a "win-win," due to the constraints on time and logistics and the need to achieve specific learning outcomes in the context of standards-based K-12 education. In the formal education setting, educational goals must take precedence, which can mean that scientific goals are not realized.

In their experience in Acadia National Park, teacher professional development and student learning was needed at the outset of the project. Students also needed help interpreting the data and both teachers and students needed additional support to undertake basic scientific work even though they valued the engagement in a real and complex project. The questions of interest to the scientists were not aligned with student learning outcomes specified in state educational standards. The researchers addressed teacher and student needs through regular online and occasional in-person access to scientists to help in shaping questions aligned with student learning outcomes. They also provided professional development at summer institutes for teachers, which focused on helping students develop appropriate research-oriented questions and make sense of data. They also took care to avoid the students' perception that because their questions were different from those of the scientists and volunteers in an informal science setting, that their work had less value.

## Outcomes in the Framework of Social-Ecological Systems

Community-based monitoring is a social learning tool that has been proposed for promoting social-ecological resilience and adaptability (Ford et al., 2012, Jordan et al., 2012). Education acts as an interface between ecological knowledge and environmental stewardship for the public at large (Krasny and Tidball, 2009a). In an ideal scenario, the more a person or community learns about a socio-ecological problem, the more they will be able to act to solve it. The more they act on an issue, the more they learn and know about it, stimulating further action. This learning has been posited to help foster the resilience and sustainability of social-ecological systems by promoting attributes such as social capital diversity, improved ecosystem services, and learning through experience (Fazey et al., 2007, Krasny and Tidball, 2009, Kofinas, 2009, Tidball and Krasny, 2010). Formal and informal educational institutions such as K-12 schools, universities, or environmental education agencies can stimulate learning that leads to changes in human behavior and direct improvement of ecosystem structure and function (Tidball and Krasny, 2011). Further, educational institutions can enhance individuals' or societies' understanding that they themselves are agents of change (Krasny, 2009). The actual tools or mechanisms that educational institutions can use to help foster these sorts of resilience-building feedbacks, however, remain understudied.

Within a social-ecological resilience framework, the learning that results from participation in CBM increases human capital by providing new skills and knowledge to both community members and scientists through collaborative action and dialogue. Citizen science volunteers have demonstrated gains in understanding of scientific topics and processes and improving their ability to perform scientific tasks (Turnbull et al., 2000, Brossard et al., 2005, Jordan et al., 2011). Scientists' participation in citizen science projects gained new insights into the dynamics of the study system, and improved their public communication skills (Dickinson et al., 2012). CBM can also build social capital such as social networks and trust between scientists, land managers and the public (Backstrand, 2003, reviewed in Jordan et al., 2012). Numerous high quality interactions between scientists and volunteers, such as face-to-face trainings and sustained dialogue greatly improve the reciprocal learning experience that citizen science can provide (Feinsinger et al., 1997, Evans et al., 2005). These best-practices for scientist-volunteer interactions could help maximize the social capital outcomes that CBM produces.

The identification of documented and potential outcomes of citizen science projects is relevant to CBM. Jordan et al. (2012) reviewed citizen science outcomes and concluded that participation has the potential for gradual shifts in the way people think, their skills for solving social-ecological problems, and what they value. Local stewardship actions have commonly been documented as arising as a result of learning from participation. Citizen science also has the capability to influence adults with influence on the social-ecological system right now and at broader spatial scales (Henderson, 2012). Citizen science, and thus CBM, has the potential to produce not only gradual shifts, but also large rapid changes to foster resilience in social-ecological systems. This could immediately translate the new knowledge gained from the data collected into stewardship policies. Overall, the social-ecological systems model integrates the multi-faceted benefits of CBM (educational, scientific, political, etc.) into the overarching purpose of enhancing the resilience and adaptability.

## Role of Communication

In the development of a community-based observing network, particularly in indigenous communities, a number of communication practices have been shown to lead to a more successful and sustainable network, either singly or in combination. First, two-way communication needs to be established and maintained with community members (Laidler et al., 2008, Pearce et al.,2009) so as to encourage the involvement of the community in research design and development (Laidler et al.,2008, Mahoney et al.,2009, Pearce et al., 2009). This allows the community to identify areas of concern that should be addressed through observation efforts (Tremblay et al., 2008) and better ensure that the methods of observation are simple and locally/culturally appropriate (Mahoney et al., 2009), leading to a more sustained network (Danielsen et al., 2005). Local training in monitoring and reporting should be given to the community members (Hovelsrud et al.,2007, Tremblay et al., 2008, Brooket al., 2009), including training in operating data collection instruments (Mahoney et al., 2009). Finally, either after the completion of the project or during, it is important that the community has easy access to the data and the results (Hovelsrud et al.,2007, Pearce et al., 2009).

Gearheard and Shirley (2007), working with indigenous communities, highlight the critical need for trust and rapport, resulting from early and frequent communication between scientists and community members. Similarly, Pearce et al. *(*2009) emphasize the importance of early and on-going communication, involving communities in research development, facilitating employment and training opportunities and communicating findings effectively. Several researchers addressed communication strategies appropriate for projects and programs that involve scientists and Alaska Native or other indigenous communities. Traditional academic papers can be restructured to better represent different accounts of reality (Watson and Huntington, 2008), outreach and K-12 education can be designed to be culturally-responsive (Sigman et al., 2014), and workshops can be co-sponsored by LTK holders and structured for shared understanding based on different viewpoints (Huntington et al., 2002). Bonny and Berkes (2008) described the knowledge systems of northern people as based on oral tradition and teaching through stories and the guided development of practical skills. Hence, the most appropriate method of communicating indigenous knowledge would be direct interaction with knowledge holders, through workshops, hearings, meetings, and on-the-land excursions. Books, videos, atlases, audio recordings, CDs, and websites are currently being used to communicate in ways that build cross-cultural understanding.

Communications technology is revolutionizing school, community and public participation in science. Dickinson et al. (2012) reviewed the “state of the art” of communications technology in community-based research and monitoring. They found that Internet and geographic information system (GIS) enabled web applications allow participants to collect large volumes of location-based ecological data and submit them electronically to centralized databases. The ubiquity of smartphones, the potential for digital validation of questionable observations, and the development of infrastructure for creating simple online data-entry systems provide added potential for initiating projects quickly, inexpensively, and with stringent criteria to ensure data entry. These same web-based tools are democratizing program development, allowing for the creation of data-entry systems for community-based programs that arise. Such empowerment means that resource management decisions, and the data that drive them, are more likely to be in the hands of the people who will be affected by the outcomes.

## Other Best Practices

Moller et al. (2009) described the need for both a strong mandate from the community at large and active leadership from within the participating community as necessary for research partnerships that include LTK to succeed, which is also relevant to sustainable CBM partnerships. They advised that project design would therefore need to not only be cognizant of these attitudes but also take steps to engage them by creating a new space for knowledge coproduction, co-learning, and co-management. Thornton and Scheer (2012) identified the advantages of stable bridging institutions such as the Alaska Eskimo Whaling Commission to build trust and engage communities in all stage of research in the context of shared interest in project objectives, settings (i.e., seascapes), and outcomes, as well as providing ongoing financial support.

Gofman (2010) cautioned that every component that goes into the design of a CBM program needs to be specific to a particular region, culture, community needs, science needs, and government regulations, among other considerations. She points out that several long-term monitoring projects are successful with modest funding and a manageable size, which makes them adaptable, however many of these have substantial involvement of government agencies who provide substantial in-kind financial support. A project's ability to provide regular and community-relevant results is another important factor in long-term success. Larger projects can produce better organized and higher quality data, and other products such as books and films. Starting small, as a pilot, and expanding slowly is a recommended strategy.

## Challenges

Monitoring of natural resources has become increasingly important, and various international agreements, such as the Millennium Development Goals and national legislative frameworks of many countries rely on adequate knowledge of trends in species and habitats to make informed policy decisions. Despite these agreements and frameworks, however, monitoring often receives low priority because it is difficult and expensive to coordinate. Externally-driven monitoring in which professional researchers outside the area of interest set up, run, and analyze the results that has been funded by a remote agency has been criticized as expensive to sustain over time and reliant on skills that are not local. Linking monitoring to decisions of local people may help make monitoring more relevant locally and hence sustainable (Danielson et al., 2005), however, the realities of Alaska in terms of the area to be covered and the remoteness of many communities resembles those of developing countries who require approaches that are simple, cheap, and require few resources (Danielson et al., 2009).

Rotman et al. (2012) characterized the relationship between citizen science and professional scientists. They described citizen science as having a longstanding tradition of assistive participation of volunteers in scientific endeavors, but emphasized that scientists, who are educated, trained, and placed within a hierarchical academic world, are sometimes wary of letting others, who do not have the credentials they do, into their research. As a result, a large number of peer-reviewed publications on citizen science have been dedicated to validating datasets collected by citizen scientists against similar datasets collected by professional scientists (Kery et al., 2010, Munson et al., 2010, Gollan et al. 2012). Citizen scientists and community participants in general, without formal training or credentials, challenge the pattern of the academic world. In many cases, although volunteers are allowed to take part in scientific processes, they are limited to distributed data collection and limited analyses, and excluded from later phases of the research, in a way that prevents complete collaboration. Benz et al. (2013) reviewed PPSR outcomes and found a related challenge in demonstrating explicit project outcomes for both science and education in PPSR projects which he concluded had resulted in "legitimate criticisms along with some misunderstandings concerning their utility."

Gearman and Shirley (2007) examined common challenges in the Canadian Arctic when conducting collaborative research. Although the laws governing research in Alaska are different, some challenges are common. Similar to the challenges for volunteers engaged in citizen science and PPSR programs, unequal power relationships exist among scientists and Arctic indigenous communities and these often characterize research activities. This may lead to debate about the acceptable impacts and how much the community benefits from the research. The appropriate research methodology that balances local expectations with research needs may also be a source of contention.

Other challenges exist to the establishment of CBM programs involving indigenous communities, especially in terms of forming community-researcher relationships and incorporating the two knowledge systems. These challenges include: cultural differences, poor relations, financial limitations, time constraints (Pearce et al., 2009, Ford et al., 2012), concerns over intellectual property, reliability of information, issues of subjective/biased data and differences in language, concepts, and terms (Nichols et al., 2004). Also, compared to work accomplished by professional scientists, CBM programs or community-based observing networks can yield a higher degree of variance in the data collected, a challenge that can be mitigated through strict methodology (Danielsen et al., 2005). An awareness of past practices in western science is also recommended so as to ensure there is more local inclusion in the research process as to better reduced the occurrence of “research fatigue” (Ford et al., 2012).

Although participation by Alaska Natives is substantial in Alaska, Pandya (2012) concluded that, in general, participation in citizen science does not reflect the demographics of the U.S. Individuals from groups that have been historically underrepresented in science (e.g., American Indians/Native Alaskans, Latinos, African-Americans) participate less than majority groups and affluent participants outnumber the less affluent. One barrier for indigenous people is in the scientific approach itself, which can be regarded as incomplete and reductionist in way that contrasts with more integrative indigenous world views (Riggs, 2005, Levine et al., 2009) or as divorced from social and ethical considerations (Levine et al., 2009). Research on diversity in science suggests another key hurdle to broader participation is a disconnect between the norms and priorities of the research community and the values, aspirations, and cultures of many historically underrepresented communities.

## Other Resources

Bonney et al. (2009b) published a report that helped define the field of citizen science and developed understanding about the broad educational impacts of various citizen science models. Bonney et al. (2009a) produced a citizen science toolkit, the website citizenscience.org, best practices for data management (McEver et al., 2007; McEver et al., 2011).

A conference on PPSR was held on August 4 and 5, 2012 in association with the Ecological Society of America’s 97th Annual Meeting in Portland, Oregon. The papers presented at that conference were published in a special issue of *Frontiers in Ecology and the Environment*, a journal of the Ecological Society of America. Several were reviewed in this paper. Additional information about and results from the conference can be found at www.citizenscience.org.

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## Models for Community-Based Monitoring Program Design

Bonney et al. (2009a) provided a model developed with input from participants in a 2007 citizen science conference to fulfill goals for recruitment, research, conservation, and education in citizen science projects:

1. Choose a scientific question.
2. Form a scientist/educator/technologist/evaluator team
3. Develop, test, and refine protocols, data forms, and educational support materials.
4. Recruit participants.
5. Train participants.
6. Accept, edit, and display data.
7. Analyze and interpret data.
8. Disseminate results.
9. Measure outcomes.

The final step in the model involves measuring project outputs and outcomes to ensure that both scientific and educational objectives have been met.

Shirk et al. (2012) recommended the use of the W.R. Kellogg Foundation's (2004) format for outcome-oriented logic models to develop desired outcomes and impacts at the beginning of the project design process for all three different types of PPSR. A critical feature of this design process is to start with the end in mind in terms of the yield of specific and measurable project outcomes. They also noted that the process could also be used to reflect on the accomplishments of on-going projects and address goals in new ways by adding complementary participation outcomes that deliberately address specific outcomes.

This model distinguishes between outcomes, typically measured within one-three years of project implementation, and impacts, which are measured over a longer period of 4-6 years and defined in terms of sustained changes, e.g., an improvement in human well-being through conservation of natural resources. They listed three different types of outcomes for PPSR projects that have been documented – ones related to science (e.g., trends in species ranges, distributions, abundances, and diversity), ones related to individual participants (e.g., increased understanding of the process of scientific research, opportunities to deepen their relationship with the natural world), and ones relate to socio-ecological systems (e.g., improved relationships between communities and resource management agencies, improved resource management strategies). Examples of desired impacts included a knowledgeable and empowered citizenry, resilient human and natural communities, and responsive science. The recommended design process involves considerations, and often negotiations, related to the desired degree and quality of public participation.

Jordan et al. (2012) developed a framework which aligned three types of outcomes: individual learning, programmatic, and community-level. They described these types of evaluations as having the potential to ultimately increase the chances of project success and contributing to socioecological system resilience.

Zoellick et al. (2012) developed a logic model for scientists and educators to come together with different needs and inputs and collaborate during program design and implementation, and then diverge, focusing on different outputs and seeking different outcomes. They recommended the inclusion of a third party (e.g., a university) that understands the needs of scientists and educators to facilitate collaboration (Houseal, 2010). The model suggests that program design and evaluation must place equal emphasis on scientific outcomes and learning outcomes. In most cases, however, each outcome will be evaluated differently.

Jordan et al. (2012) summarized key considerations in establishing and evaluating learning outcomes for participants in citizen science projects. The recommended establishing broad, abstract goals, then developing an evaluation plan that ensured that: 1) learning goals are aligned with project outcomes (and vice versa), 2) learning outcomes are well-articulated, and 3) both are attainable through identification of relevant indicators (measures of success for achieving desired outcomes (Phillips et al., 2012). Jordan et al. (2012) recommended S-M-A-R-T (specific, measurable, attainable, relevant, and timely) learning outcomes.

Pandya's (2012) general framework for planning "place-based, culturally-relevant, community-driven" projects included: 1) aligning research and education with community priorities (desired actions may include community action and policy changes), 2) planning for co-management of the project (e.g., community leaders serving on oversight or advisory meetings, regular informal interactions between scientists and local community members), 3) engaging the community at every step (e.g., providing training and/or employment, grants to community groups, coauthored publications or curricula, briefings for decision-makers), 4) incorporating multiple kinds of knowledge (i.e., traditional knowledge, historical accounts, participant observations), and 5) disseminating results widely (in both scientific publications and in other appropriate venues and language to meet community priorities).

CAFF (Gofman, 2010) developed a CBM handbook subtitled Lessons from the Arctic which summarizes types of CBM, CBM monitoring methods, and a process for project development.