Best Practices for Community-based Observing: A National Workshop Report

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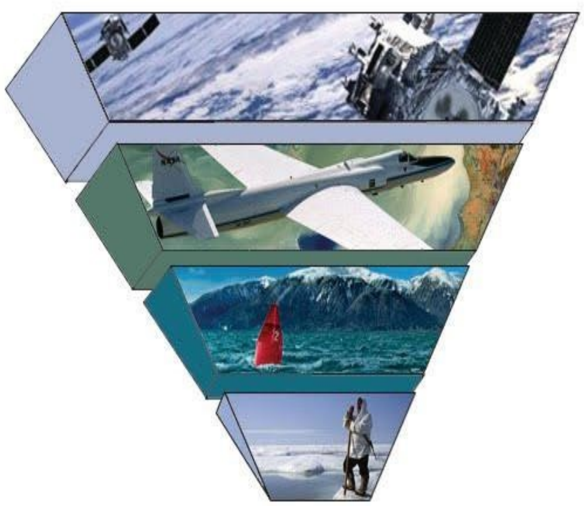
1. INTRODUCTION

Nationally, there is increasing interest in the use of citizen-acquired environmental change observations but a science of CBO is not well developed. As part of this science, toward producing fair, equitable, reliable and interoperable data, we need to systematically assess how CBO can be co-developed by communities on the ground and users that range from response agencies and policy makers. The purpose of this report is to give the reader insight into a range of community-based observing (CBO) types as well as understand their appropriate applications and trade-offs. In order to protect and serve both communities and agencies on the ground, and to ensure that they are equipped with the best possible tools to respond to both chronic and acute change, it is necessary to critically evaluate and develop best practices for the suite of activities that fall under CBO.

Several conceptual pluralities exist about what CBO is, the types of activities that fall under it, and the appropriate uses of each of them. Additionally, misconceptions about the types of communities that are involved in CBO have led to the intersection of the terms "traditional ecological knowledge" (TEK) and CBO, with the implication that mostly indigenous communities are engaged in these kinds of activities. The contributions of CBO to Arctic observing and residents, in particular, have been well stated (Johnson et al. 2015; Alessa et al. 2015) and highlight the need to more clearly articulate how CBO can connect with broader observing networks (Figure 1) – this report aims to help fill this gap.

Figure 1. *The integration of CBO into broader systems of environmental change observatories spans satellite observing, airborne observing, terrestrial and marine instrumentation networks, and human observing networks. Data needs to be interoperable if efforts are to contribute substantially to a global understanding of change. Since all communities, to a greater or lesser degree, are embedded in a globalized and teleconnected world, such an understanding is critical to provide place-based contexts to preparedness and adaptive responses that can sustain livelihoods and allow communities to thrive*.



Currently, terms and meanings concerning community based observing networks (CBONS), community based monitoring (CBM), citizen science (CS), and community observer blogs (COB) activities are often used interchangeably. However, each constitutes a different type of CBO with different structures, protocols, data types, assurances, and inter-operability (see Figure 2). They also represent different levels of engagement or participation with communities (Danielson et al. 2009). Each type of CBO has a valuable role, fill different needs, meet different objectives, and has its own strengths and weaknesses.

In this report, we address CBO broadly, in part as a result of a workshop held on October 4-5, 2015 at the University of Washington, and in part as a reflection of broader conversations with communities, organizations, agencies, and academics. It is important that the reader understands that in many parts of the U.S. and the world there are resident communities who may or may not be "Indigenous" and who could effectively engage in CBO. More specifically, we assert that CBO is a set of processes that hinge on the knowledge of place, rather than race. This report is the first of an anticipated three-report series that outlines a science of community based observing, initially supported by investments from the National Science Foundation and subsequently from the Department of Homeland Security Science and Technology Directorate (DHS S&T), the Environmental Protection Agency, and the National Oceanographic and Atmospheric Administration.

Workshop Purpose

The October 2015 "Best Practices" workshop held in Seattle was intended: to establish a taxonomy, application context, and a framework for best practices within a typology. Our ultimate goal is to ensure that communities, practitioners, and agencies will have access to the best available science and knowledge about CBO, including data interoperability, so as to minimize liabilities and maximize its use and products for on-the-ground applications; and to ensure that community engagement in any type of CBO results in the highest possible quality data/information while ensuring desired cultural and personal (e.g., privacy) protections.

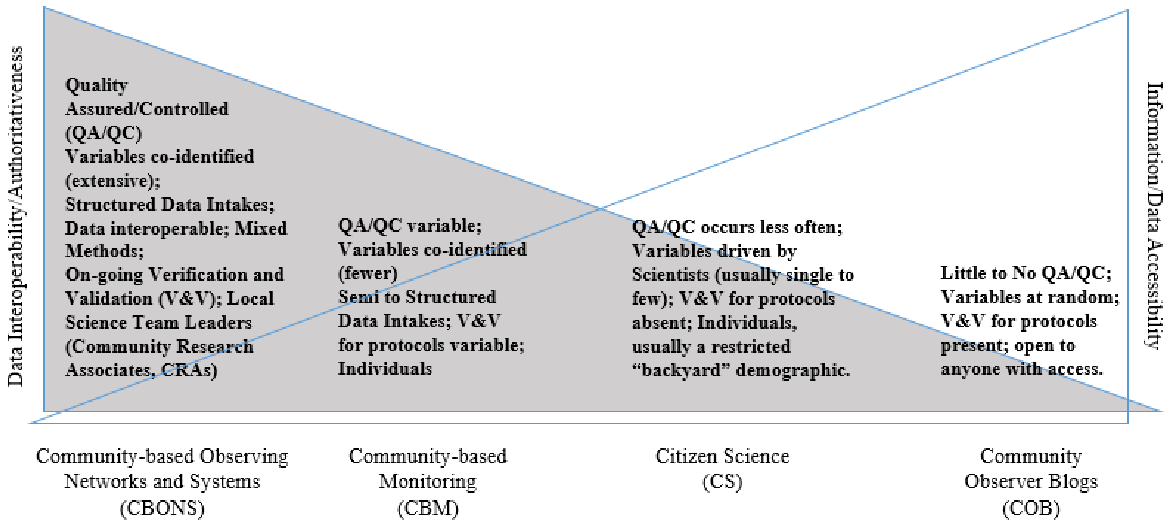
One of the authors of this report was involved, as a Principal Investigator, in an NSF-funded workshop on community-based monitoring that took place in Anchorage, Alaska in 2013. However, it did not achieve the desired level of precision in terms of Best Practices (Sigman et al. 2013). The latest workshop was held in response to the increased interest from federal agencies in community-based observing (CBO) and citizen science, in particular. While CBO, including citizen science, attempts to both engage the public and acquire high quality data on a range of variables, there have been uncertainties and concerns raised about rigor, standardized protocols, data accuracy, interoperability, and security.

Inputs from broader CBO-engaged communities were solicited after the conclusion of the Best Practices Workshop since our goal is to build a *science of CBO* so that it may be applied broadly in diverse settings. These broader concepts and ideas have been incorporated as well.

A Typology of Community Based Observing

CBO, writ large, has been articulated as a component of a system of observing and monitoring activities which range from satellite to buoy/met station instrumentation to individuals engaging in daily activities on the ground (Figure 1; Alessa et al. 2015b). The range of CBO efforts vary in their structure, data types, utility, and appropriateness for use and application (Figure 2). Since CBO involves people, and because a range of decisions could be based on information collected, it is critical that the trade-offs for each are understood. Failure to develop a given type of CBO appropriately could lead to significant vulnerabilities, ranging from inaccurate assessments of decision outcomes to deliberate and malicious manipulation of data in order to bias outcomes or cause harm. CBO has other benefits, both to observing systems broadly, as well as to communities whose inclusion in these systems brings to them a voice in characterizing global and environmental changes that could affect them. During the workshop, we developed a typology of CBO types and assigned a set of initial characteristics to them, these characteristics are dynamic and should not be viewed as final (Figure 2).

Figure 2. *An initial typology of community-based observing approaches.*



A Note on Different Ways of Knowing

This report approaches CBO as a set of distinct processes with different roles, ranging from systematic, structured, and networked observations intended to detect patterns over large areas in space and time to opportunistic observations of unusual environmental events that can be used to request the attention of subject experts, who can respond to the concerns of individual community members (Sigman et al. 2013). It does not address traditional ecological knowledge (TEK) specifically, because CBO relies on local and place based knowledge (LPBK), in which TEK may or may not be embedded. TEK has a range of definitions that generally encompass "a local and holistic set of knowledges, integrating the physical and spiritual into a worldview or 'cosmovision' that has evolved over time and emphasizes the practical application of skills and knowledge" (Indigenous Peoples' Restoration Network, SER 2015). TEK carries with it a sense of sacredness and cultural specificity that cannot be casually incorporated into activities such as CBO. The very essence of local Indigenous communities, both within and outside the Arctic, are encapsulated in TEK; it defines how we come to be, who we are, and how we define our relationships with the world. Because of this, when developing a science of community based observing, TEK must stand on its own, and should be included only at the discretion of each community who holds it. It is a mistake to conflate TEK with LPBK, since the latter provides key insights into the characteristics of a location without risking the inadvertent misuse of a culture's sacred knowledges.

Similarly, our experiences with CBO, in particular with community-based observing networks and systems (CBONS), is that communities already contain individuals with extensive training and a level of knowledge that is comparable to that derived from western academic degrees, even if these are not represented by an official piece of paper and represent a different way of understanding the world than western science (Barnhardt and Kawagley 2005). For example, in the Community-based Observing Network for Adaptation and Security (CONAS) and the Community-based Observing Network for Situational

Awareness (CBON-SA; see Section on CBONS below), we consider these individuals as equals to western academic peers and remunerate them accordingly. However, remuneration writ large remains an unresolved issue that is addressed at the end of this report. There is also an increasing practice of recognizing these contributions in publications (see, for example, Huntington et al. 2013; Alessa et al. 2015a). The formation of community science steering committees (CSSC), that is, representatives of communities that are part of a regional CBON and who have oversight of the protocols used and the use and publication of CBON data, has proven to be a very successful vehicle for addressing protocols, data, and the sharing of information (c.f., Alessa et al. 2015a, 2015c). In our opinion, one cannot assume that community members will not understand western science concepts and methods, but successful collaboration may require the development of a shared language that places information in culturally appropriate contexts. Stereotyping and homogenization occurs commonly, not just with Indigenous communities, but across rural and marginalized communities throughout the U.S. and globally. It serves to sustain the divide between "us" and "them," and leads to an approach to scientific partnerships that are necessarily condescending and often patriarchal. Indigenous, rural, and other subsistence-bound communities are characterized by a plurality of values and knowledges, much like any other group of people. A tendency for scientists to treat community practitioners with unwarranted sensitivity because of preconceptions about traditional cultures, or to assume that they are not competent to deal with rigorous methods and approaches, is inherently flawed and intellectually indefensible.

Knowledge contributed by LPBK can advance place-based adaptation by elucidating vulnerability to environmental change and exploring appropriate adaptive actions and interventions (Collings 2011, Ford & Pearce 2012, IPCC 2014, Pearce *et al.* 2009, Riedlinger 2001, Tremblay *et al.* 2007). Beyond expanding data availability, other important aspects of including the "human" in Arctic observing networks include: 1) placing environmental change in a social context (Alessa et al. 2015); 2) shaping policies toward greater relevance to those affected (Ford *et al.* 2010, Mahoney *et al.* 2009, Meek *et al.* 2008); 3) more equitable power sharing by co-producing knowledge (Gearheard & Shirley 2007); 4) contributing to an understanding of social processes that relate to use of natural resources (Wolfe *et al.* 2007); 5) providing alternative perspectives of ecological change (Berkes *et al*. 2007); 5) guiding scientific inquiry (Carmack & MacDonald 2008), and; 6) capacity and relationship building (Pearce *et al.* 2009).

By developing clear definitions, taxonomies, and contexts for the application of the range of CBO activities we can: a) realize opportunities to add value to the spectrum of existing observatories in the U.S., which are currently limited in terms of both coverage and range of variables observed; b) ensure that the best available science is used, resulting in appropriate applications of CBO; and c) reduce vulnerabilities, e.g., the acquisition of data which may be inaccurate or which has been purposefully manipulated in order to be misleading (spoofing). Ultimately, individual communities may initiate and sustain CBOs of any type, for their own purposes. This allows communities to retain full control of protocols, language(s), and data sharing agreements. However, when communities enter into partnerships with federal agencies, the latter often have specific mandates to meet certain conditions that revolve around the 'best possible/available science.'

Currency and expertise

It is important to consider who has relevant expertise in a local community for any given CBO effort. Community based monitoring or citizen science, where instruments are operated by local community members versus Community Based Observing Networks where individuals who are highly knowledgeable about the system as a whole and make observations in context (in Indigenous communities these are often those who hunt and fish for a living) differ in the characteristics of the individual observer. Local expertise and knowledge is highly valuable, but not every resident is an expert. For example, with CBONS the observers are recognized within the community as expert observers. In other CBO efforts, for example observer blogs, rely on an open pool of input, with broader geographic coverage but also a range of expertise. Community-based observations, and TEK specifically, have been compared to fuzzy logic, which employs heuristic rules. Fuzzy logic enables people, regardless of locale, to successfully navigate ecological complexity (Berkes & Berkes 2009) and provides flexibility for people to adapt and thrive in natural environments (Turnbull 2000). Expert fishers have been shown to use heuristic rules to process ecological knowledge (weather, fish behavior, 'folk oceanography', etc.) to make decisions related to fishing (Grant & Berkes 2007). Nonetheless, there is likely to be some uncertainty present as understanding ecosystems is a complex process and observations of the environment are seen through the filter of human perception. While these studies make specific reference to TEK we argue that they are not unique to Indigenous populations but apply more broadly to place-based local knowledge or community-based observations generically.

The type of observer is critical. Gearheard *et al.* (2010) compared wind data with observations at Clyde River, Nunavut, Canada and found little correspondence between observations and instrumented data. Alessa *et al.* (2007) found differences between perceptions of change in water quality and quantity of younger observers compared to middle-aged and older observers in western Alaska, finding that accuracy increased with age. Ambrose *et al.* (2014) found that expert fishers were more highly attuned to environmental changes in marine species than were elders or expert hunters.

More broadly, an innovative program called the Good Judgement Project found that certain individuals possess inherent cognitive qualities that allowed them to filter out personal biases in such a way as to provide high degrees of accuracy in observing events and forecasting their consequences; speaking to the need for structured networks, their data also showed that forecasts of consequences were more useful to communities when observers were linked through communication. Observers who are capable of placing system changes in a specific context (for e.g., "within" or "outside" "normal ranges") can help, for e.g., federal agencies design more effective preparedness and response programs (Bone et al. 2011).

A distinction is noted between traditional ecological knowledge (TEK) and local place-based knowledge (LPBK), with TEK being dependent on holistic, spiritual, traditional experience and knowledge, while LPBK emphasizes life experiences of the observer and may or may not include an oral tradition or spiritual values passed on from one generation to the next. People with experience and expertise can assist even if they are not Indigenous – the emphasis in CBO is on LPBK rather than TEK. This is partly because many community members have extensive knowledge of their local environment even if not indigenous, but also because some TEK is not readily shared or appropriate for monitoring or observing programs (Hi'iaka Working Group 2011). By focusing on LPBK, CBO programs can collect relevant data from any community observers willing and able to participate while avoiding inappropriate use of cultural or intellectual property. Additionally, the type of partnership with the observer/community comes into play: are they observing as part of regular activity or are they going out on a regular "route" so that observing is solely for the purpose of the CBO; are they paid for their efforts or is observing done on an opportunistic/voluntary basis were remuneration is supplemental?

Patterns of observing

The CBO continuum highlights differences between patterns, predicated on one-time observations of phenomena, and those which involve repeat visits to the same locations to measure a pattern of change over time or to produce a time-series. If protocols are structured well, monitoring can yield data that are longitudinal, more interoperable with other observing systems, and more useful in detecting and understanding patterns. One-off observing, by comparison, does not support measurement of longitudinal change and is primarily used for instantaneous assessment of phenomena (e.g., something the observer considers unusual).

A Note on Legal Requirements for Best Available Science

One of the considerations that needs to take place when federal agencies are deciding on what type of CBO to leverage for acquiring data relevant to their mission areas is the legal requirement of using "sound science." The requirement does not require using the highest level of detail in all situations. Rather, the best available science should be used to provide results with an acceptable confidence level appropriate to the level of detail needed to inform decisions. In the case of maritime security, for example, it would be necessary to develop protocols, quality assurances, validation, and protections that allow the decisions made, and their outcomes, to carry the highest likelihood of success while minimizing the risk of loss of life and infrastructure. The use of networks, versus individual observers, in this case is more amenable to the detection of patterns and abnormalities that warrant response.

Implicit in this is a set of protocols, data assurances, quality controls, and interoperability that is defensible under scrutiny or even legal challenge. As importantly, the security of our nation's resources and citizens, at all levels, relies on authoritative, high-fidelity data and information. Recent studies have identified potential vulnerabilities in CBOs that utilize social media due to the potential to suggest trends where none exist or to cause concern where none is warranted (HCI 2011). Having said that, COBs can provide an invaluable "help line" to connect community concerns with experts who can verify or refute observations, such as is the case with the Local Environmental Observers (LEO) program (see the Section on Community Observer Blogs below).

A Note on Data Interoperability for CBO

Interoperability in the context of CBO can be defined as properties of cyberinfrastructure that allow CBO to work and share with other information products or systems, present or future, without unintended restrictions. Achieving interoperability is a critical issue for CBO data that are intended to be used and understood in concert with other data (e.g., instrumented climate observations) and is a multifaceted issue that includes technical, semantic, legal, and geopolitical concerns to name a few. Technical interoperability relates to how data are encoded and transported, and the data formats and structures that are used. Semantic interoperability refers to how we define and label concepts including the language used, ways of communicating, and ways of thinking. Understanding terms and related concepts across cultural and disciplinary boundaries and different worldviews is critical to linking different knowledge domains for CBO, and ultimately achieving interoperability. There are many other aspects of interoperability including whether data can be ethically shared (e.g. privacy issues), legally shared or shared under national or international agreements. These issues are not new, however broader discussion and action in the area of "open data" is changing how data are and will be shared.

2. TYPES OF COMMUNITY BASED OBSERVING (CBO) EFFORTS

Community Based Observing Networks (CBONS)

CBONS are distributed arrays of people in communities throughout a region who are able to make regular observations on their environment, acting as human sensors and documenting their observations in the context of hunting, fishing, or other livelihood activities (Alessa et al. 2015b, 2015c). CBONS are built on an explicitly defined network of communities so that observations from multiple communities can be scaled up to provide regional-level perspectives and inter-community sharing on issues such as species distributions or phenology. An example of a CBONS is the community-based observing network for adaptation and security (CONAS) that spans the Bering Sea (Alessa et al. 2015a). The CONAS network is a partnership between researchers and eight Alaskan and Russian communities for collecting systematic observations on environmental and global change and developing Adaptive Capacity Indices (ACI) for the region. Another effort, the community-based observing network for situational awareness (CBON-SA) integrates community-based observing in the Bering Sea, Chukchi Sea, and Beaufort Sea with maritime observation and security in the Arctic. The strength of CBONS is based on the recruitment and vetting of a cohort of observers to provide high fidelity and quality assured data – long-term residents of a region whose awareness of the environment and quality of observing is known and trusted in their communities and by researchers. Observers do not adopt a different set of activities but rather incorporate structured observing into their customary activities.

Advantages of CBONS:

- standardized protocols are developed that emphasize quality assurance and quality control;
- trends in observation are possible due to repeat observations and continuous monitoring;
- data collection protocols are designed to support interoperability with other instrumented networks, and purposefully structured to augment the spatiotemporal coverage of other networks;
- support is established for community-based science teams under the oversight of steering committees of community representatives;
- observations are placed in a social/situational context;
- partnerships are developed between local community representatives, academic researchers, and government agencies, where the variables of concern are collectively determined for a common purpose;
- observers make decisions about where and when to observe based on tacit and implicit knowledge and familiarity with the region.

Disadvantages of CBONS:

- it takes considerable time to establish a network of communities and establish data flows due to the requirement to vet and train observers and community coordinators and modify protocols to accommodate local contexts;
- data is not immediately available due to error checking, interoperability requirements, QA/QC procedures, and community approval processes;
- significant funding is required to support training and remuneration of observers and development of data collection protocols.

Community Based Monitoring

Community-based monitoring (CBM) efforts are scientific observing networks and projects that have a community-based component built into them. CBM is typically based on using scientific instrumentation and imagery for monitoring, with local community observations integrated as additions. Good examples of CBM include: the seasonal ice zone observing network (SIZONET) that operates on the northwest coast of Alaska, which was originally designed as a physical sea-ice monitoring project supported by instrumentation and which has since been augmented with the observations of local sea-ice experts (Eicken 2014; Druckenmiller et al. 2009; Mahoney et al. 2009), and; the Bering Citizen Sentinel program.

Advantages of CBM:
- data collection protocols can support interoperability with both instrumented data and data from other observing networks;
- standardized protocols allow for the implementation of quality assurance and quality control measures;
- detection of trends is possible due to repeat observations and continuous monitoring;
- CBMs make use of existing community experts;
- CBM integrates instrumented observations and local community observation.

Disadvantages of CBM:
- requires significant funding to provide equipment and gear, and to support training and data collection protocols;
- observing network design is primarily led by scientists;
- observations are generally restricted to relatively few, usually biophysical phenomena, such as those related to flora, fauna, water quality, environmental toxicology, or forest carbon stocks.

Citizen Science

Citizen Science efforts involve the engagement of volunteers from the public in the systematic measurement or observation of specific phenomena, typically using physical instrumentation or a standard scientific observation protocol (Pocock et al 2014; Sigman 2015). Citizen science projects vary widely in scale and in the nature of the phenomena observed or measured, so that some efforts may involve a network of individuals or a sampling network of multiple individuals, although this is a feature of the sampling protocol rather than an explicit effort to network communities or observers. Citizen Science projects are typically contributory; that is, the project is initiated and directed by scientists, with volunteers contributing data. Collaborative projects are possible when they are strongly shaped by volunteer participants. A long-running and successful citizen science program is the coastal observation and seabird survey team (COASST) that has been operating in the Pacific Northwest since 1998 (University of Washington 2015). The COASST project has been working with citizen volunteers to collect data on birds, marine debris, and human activity on Pacific beaches for more than 17 years.

Advantages of Citizen Science:
- can be a cost-effective way of gathering data, especially across broad spatial and temporal scales;

- have strong educational benefits by directly engaging people with their local environments;
- if data is collected using standardized protocols, then QA and QC is possible, and high-quality data is often acquired, and;
- the detection of rare events is possible across broad spatial and temporal scales.

Disadvantages of Citizen Science:

- participation is likely to be reduced when protocols are overly complex or demanding;
- volunteers need to be recruited, and the self-selection of observers may lead to bias in observations (for example, when volunteer's locations aren't representative of spatial heterogeneity);
- projects are not typically collaborative, so they often lack community engagement in the project design;
- data can be unstructured or poorly structured, requiring complex approaches to analysis, and;
- significant time and resources are required to support and retain volunteers through the life of a project.

Community Observer Blogs

Community observer blogs (COB) are online portals that provide a two-way communication mechanism for members of the public to report environmental observations from their local area and to receive reciprocal feedback from the portal manager (Alessa et al. 2015b). Such observer blogs have the benefit of being open conduits for anyone to report observations or quality control consists of a data manager who vets posting. An example of a successful observer blog is the local environmental observer (LEO) program operating in Alaska (ANTHC 2015). In LEO, community members from all over Alaska upload observations of 'unusual' environmental phenomenon, from odd wildlife sightings to built-environment disruption from global change processes; experts in various environmental processes are able to give direct feedback to the observer and explain or ask additional questions about specific observations. Observer blogs generate reports via an open, organic array of individuals leading to the possibility of regional coverage and two-way communication. While observer blog entries may be vetted by a moderator, they do not involve extensive QA-QC and they are not conducive to resolving trends. Observer blogs are open to any interested individual with access to the portal or social media, depending on the structure of the blog, and training is not necessary. Postings are often reviewed and explained by scientific experts who do not reside in the community itself, thus removing expertise from a local place-based context and delegating it elsewhere.

Advantages of Observer Blogs:

- easy acquisition of observations;
- no training is required for observers, since anyone can be an observer and this allows insights from diverse perspectives;
- all observations are considered valid, and;
- broad geographic coverage is possible at a very low cost.

Disadvantages of Observer Blogs:

- quality assurance and quality control does not occur in any true sense, and instead a blog acts as a means for posting community observations and concerns that can then be addressed by experts;
- no standardized protocols;
- relies on Western scientists for explanation of reported observations, i.e., operates as a helpline;
- observations can be taken out of context, and;
- the singular nature of observations means that trends in phenomena are not identifiable or resolvable.

3. A SET OF BEST PRACTICES

Issue 1: Ontologies, Typologies, Identities, and Applications

Community-based observing (CBO) is comprised of continua of approaches, methods, applications, and efforts (Figure 2). These differences are important for understanding the applicability of a particular CBO project and for developing and assigning best practices; that is, best practices will vary according to the type of CBO involved. Nonetheless, every CBO project has merit and fulfills some valuable, and varied, purpose. CBO can be distinguished on the basis of different features, including: methodological approaches; extent of integration with other observations; the intended use and application of the CBO; the motivation and origination of the CBO; the type of expertise necessary to support the effort and the relative emphasis on monitoring versus observing.

Motivation and origins

CBO can be essentially community-driven (described as having a bottom-up motivation), agency-driven (or top-down motivation), or a combination of both. For example, agencies monitor variables defined by law, policies, or mandates, whereas communities may have very different priorities or concerns than those prescribed in such mandates. Even if a particular CBO is primarily community- or agency-driven in origins, how it actually works in practice may be very different. It is important to recognize that the priorities of communities and the priorities of scientists are sometime but not always well aligned. In CBO efforts that are genuine partnerships, it is essential for communities and scientists to take the time to gain each other's trust so that alignment of purpose can occur.

Methodological approach

CBO spans approaches that support strong data interoperability and authoritativeness but restricted accessibility (e.g., community-based observing networks and systems (CBONS)), to those that provide highly accessible information but offer less data interoperability (e.g., observer blogs). Community-based monitoring (CBM) and citizen science lie between these endpoints on this continuum.

Integration of observations

In any CBO effort, it is important to determine whether there is an intent by the community or agency to use the community-based data or observations with data from other work. If so, does the local community or agency want to link, or mediate[1], the data into a common system (e.g., a database or knowledge system)? Perspectives vary with respect to whether local communities want additional levels of data or would permit the integration of community-based data with other observing data; some communities collect data for themselves, while others wish to integrate knowledge with other communities. CBO can never be forced on a community.

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[1] In data science, "data mediation" refers to the process of translating data from the format arising from original collection to a form usable by other applications, either manually or through mapping with data models.

Working with Local Communities

It is important to understand the different protocols that exist for any given type of CBO effort, but also to recognize that each has value in an overall portfolio of understanding environmental change. Conversely, communities on the ground should also recognize that the influences of globalization and market economies that affect them may require a set of approaches that carry specific constraints. Honest communication and an articulation and acceptance of trade-offs is required by all involved for successful and equitable CBO.

There will be core Best Practices that apply across CBO efforts. However, each CBO project must be sensitive and adaptive to the specific realities of each community it is engaged with. If CBO is to be viewed as a partnership, then a genuine relationship and trust is needed between local community and researchers, including the articulation of expectations for communication and reciprocity on both sides. The language used in organizing and managing a CBO is very important, and also in communicating and reporting observations. Clear data management, protection and sharing protocols must be developed with communities on the ground. The development of a good communications plan for external participants and the local community is essential. It is often assumed that such respect, trust, and protections only apply to Indigenous communities. However, every community, particularly those with very close resource-livelihood relationships (e.g., subsistence and mixed economies), has a culture to which these concerns apply (Shamah and MacTavish 2009). We strongly emphasize the need to consider "Place Not Race" in CBO in order to avoid the conflicts and pitfalls of racial biases in any directions. LPBK is not limited to indigenous communities in somewhat the same way that western scientific knowledge is not limited exclusively to white men. It is useful to consult the Ethics components for research activities involving Alaska Natives as laid forth in the Alaska Native Science Commission's documents, as well as those outlined by the NCAI Policy Research Center. Other protections for communities not covered by these, and other minority group umbrella organizations (e.g., NAACP, NHMA), fall essentially under Institution Review Board (IRB) oversight. Ultimately, the relationships of researchers with the communities themselves will drive the effectiveness, and success, of CBO.

Some Best Practices – Types of Community-based Observing

In order to build a coordinated and cooperative observing system across the CBO continuum it is necessary to know which data exist:

1. Determine which type(s) of observing the activity supports.
2. Why is the activity necessary?
3. Who are the data for and how will they be used?
4. What data will be collected and by whom?
5. How will the data collection procedures be structured so that they can be used by the intended users?
6. Do the data fill specific gaps in observing system needs, and if so, these should be specified.

Issue 2: Quality Assurance

Quality assurance and quality control (QA/QC) are the external and internal processes followed to ensure that observing methods and resulting data meet predetermined standards

(Chapman 2005, USGS 2015). Quality assurance can be defined as the set of activities designed to ensure that the CBO meets specified requirements for the quality of methods and data based on standards external to the CBO, including review of the activities and quality control processes (Chapman 2005, USGS 2015). Quality control is the assessment of quality of the observing system based on internal standards and procedures established to control and monitor quality (Chapman 2005, USGS 2015). Data collected from CBO are appropriate for different purposes depending on how well data quality is assured. The plurality of CBO efforts (see Figure 2) and the unique elements that an observer may bring, depending on the type of CBO, will influence the type and the nature of quality assurance. Observer blogs are more amenable to communities who wish to retain their own independent methods of recording observations without the constraints of standardized protocols. Particularly robust protocols are those which are co-developed by both the local community and researchers, i.e., CBONS, for diverse decision-making purposes where consequences of poor decisions are greater (e.g., harm to subsistence habitat or catastrophic loss of access to resources). Paramount to this flexible standardization is data management with formal sharing and protection protocols that are controlled by the local community. The drawback to this kind of structure is that agencies may not have access to the comprehensive suite of observations as quickly as they might like.

Calibration and ground-truthing of data are essential. This can be done in a variety of ways: a) training people in interview methods; b) providing professional development opportunities (which may actually refine data collections protocols); and c) making comparisons of observing data with instrumented data. Toward this, a meta-analysis of variables which are more or less amenable to different kinds of CBO is currently underway and is expected to be published in 2016. For an example of a calibration study, please refer to Ambrose et al. (2014).

Audience, Purpose, Message

The target audience for the data generated by a CBO, the central purpose or mission of a CBO, and the intended message to arise from a CBO will be important considerations in defining quality assurance of data. The type of effort within the continuum of CBO activities (Figure 2) will provide the primary basis for determining: a) the range of variables observed or monitored; b) the quality control and assurances needed; and c) the forms and means by which results are disseminated and data are archived and protected.

Who decides?

Quality assurance is defined by different people in different ways, and who makes decisions on quality assurance will be an important factor in setting quality assurance protocols. It is important that quality assurance is examined and discussed by all parties to a CBO, and that protocols are agreed on and implemented collaboratively. Depending on the type of CBO, other terminology might be preferred. For example, the "value" of the data to communities and other end users, or the "fitness of purpose," may be appropriate phrases in certain contexts. Community-based review may be on the basis of approval through community representatives, such as a traditional or Indian Reorganization Act (IRA) Council or a City Council. Data interoperability, or the utility of data in addressing a range of broad challenges or issues, should be carefully considered, with the trade-offs of 'stand-alone' data clearly understood by the observer community itself.

Open or restricted data?

A transparent data policy for CBO and the accompanying push to make data publicly available does not necessarily ensure strong quality assurance. If a CBO effort does follow an open data policy, decisions have to be made on whether to release data with caveats pending rigorous quality assurance and quality control, or to wait for rigorous QA/QC before releasing data. Observer blogs, where one-off observations are often made, allow information to be viewed almost immediately. On the other hand, a local community may wish to restrict data release, release data through password protected access, or allow only community-specified audiences to have immediate access to information. Such a structure has been extremely useful in community-to-community data sharing, where lessons learned or advance warning of phenomena are desired to improve adaptive responses.

Metadata requirements

Minimum requirements for metadata, the description and characterization of the data, should provide clarity and transparency about data collection processes. Metadata is essential for CBO efforts.

Some Best Practices – Quality Assurance

1. Users of a CBO should be involved in setting metadata and observing parameters.
2. Consistent data gathering and ground-truthing protocols should be used.
3. Data quality techniques should be appropriate for the type of data, e.g., quantitative vs. qualitative data will require different techniques.
4. CBO processes, goals, and data collection should be transparent.
5. Development of trust and a relationship with a CBO local community is crucial.
6. CBO processes and data gathering should be reproducible.
7. A balance will be required among data quality (QA and QC), speed of collection and release, and the costs for a CBO.

Issue 3: Data Interoperability

During the planning phase of a CBO project the question of data interoperability and access need to be answered. Some projects are designed solely for the use of the communities collecting observations, while others are intended for use outside of the community or even across international borders. The next steps should be to determine products for the data and the types of software they are built to support, while keeping in mind the needs of the local community. Communities in remote areas often struggle with bandwidth and software issues. Though it is in the best interests to strive for 'sharing' of data to avoid the repetitiveness of research efforts in the same community, access privileges to older data sets can be useful for analysis. Sharing data helps drive the adoption of standard protocols, which then further facilitates sharing.

Interoperability has different meanings:

1. technical interoperability refers to the language that a data browser or interface uses;
2. structural interoperability refers to the ability of different datasets to be handled within a common spreadsheet or relational database;

3. semantic interoperability refers to common definitions, language, and terminology used for observed phenomena;
4. and legal interoperability refers to licensing protocols and permission to use software and data.

Technical interoperability relates to fundamental elements such as how data are encoded and transported, data formats, and structures. In the not so distant future, exchange data between a PC and a Macintosh computer was a challenge. Similarly, it was difficult to exchange data represented in different languages (e.g. English, Chinese). Base level standardizations have addressed most of these issues. The format of data (e.g. different GIS file formats) can limit interoperability, particularly if the format used is proprietary and closed. While still present, this problem is being addressed through the development of translation tools and web-based services that can share data in a standard way regardless of the storage format. If data have compatible encoding and format, but do not have the same structure (e.g. how tables are designed in a relational database), then inoperability will be limited or impossible. Mediation tools that can modify structure and new approaches to structuring data such as "linked open data" are providing new opportunities for structural interoperability, however it remains a challenge.

Language is more than a way of communicating, it is a way of thinking and is deeply connected to knowledge. Understanding terms and related concepts across cultural and disciplinary boundaries and different worldviews is critical to linking different knowledge domains (e.g. indigenous, western scientific), and ultimately achieving interoperability. Semantic interoperability is a socio-technical issue requiring analysis using a trans-disciplinary approach. While there are new technologies and standards emerging under the label of the "semantic web", there are still many challenges and opportunities related to developing knowledge and terminology models that can sufficiently represent different types of knowledge and observations.

Some Best Practices – Data Interoperability

1. CBO projects should explore cooperative collaborations with other observing systems and develop data interoperability where possible.
2. Data interoperability can be enhanced by developing data collection and data access protocols that are transparent.
3. CBO projects should identify core data for the effort and focus efforts for data interoperability on that core data.
4. Both qualitative and quantitative data should be acknowledged as legitimate; each is valid even if it represents a different type of knowledge.
5. Local experts and knowledge holders should be engaged early in the process of developing data structures and metadata standards for any CBO project.

A Note on Remuneration of Observers

Remuneration of observers continues to be an issue in the Arctic in particular because of the limited range of economic options available to communities. Thus, time spent observing is time spent away from other activities that sustain lifestyles in communities. A range of remuneration types is used. In many communities, depending on the partners and dialogue, there is also an understanding that participation in observing gives communities a voice in characterizing the global and environmental changes that affect them, often directly. It also puts more emphasis on local control of resources, such as training and equipment that could be put in place to help communities respond to acute events, such as an oil spill or maritime disaster with survivors, rather than stand-by as events unfold. In general, remuneration is expected and is a meaningful reflection of the parity of community experts and knowledge holders.

Summary of Best Practices for CBO

1. For CBM and CBONS, the variables that will be observed/monitored should be co-developed and coordinated with participating communities. This includes each step in the design, including developing the data collection protocols, developing and approving technology to be utilized, and structuring the community-managed science teams that conduct monitoring and observing.
2. Remuneration, comparable to that provided to other scientific practitioners, is justified and necessary for some types of CBO (CBONS and some CBM). Individuals cannot be expected to act as true partners in CBO without some agreed upon compensation.
3. CBO should be designed with the goal of achieving real or near-real time observations.
4. For CBM and CBONS, careful design of the network of observers will lead to more accurate detection of patterns of change and anomalous observations.
5. Data interoperability protocols must be built into CS, CBM, and CBONS at the outset of a system's design, and a repository should be identified in order to house, protect, and manage data (e.g., the Exchange for Local Observations and Knowledge in the Arctic – ELOKA, and the SERVIR global observation product catalog, or some comparable system). If it is part of the CBO design, community data controls should be clearly described and followed without exception.
6. Observations should be organized, if possible, using spatial architectures such as the Alaska Ocean Observing System (AOOS), Emergency Response Management Application (ERMA), and other similar platforms.
7. For CBONS in particular, data quality assurances, controls, and interoperability standards need to be designed to the methods of the particular decision system it is intended to support. Ideally, data interoperability standards should be designed for universal coherence across databases.

4. PROPOSED ACTIVITIES TO INCORPORATE CBO IN NATIONAL EFFORTS

It is tempting to view the Arctic as a singular and unique region for the development and application of CBO. However, because CBO is particularly useful when reliant on a partnership with individuals and communities with Local Place Based Knowledge (LPBK), it has potential for systematic applications nationwide. In some cases, this potential may be greater when the potential consequences of environmental change to population centers are considered. It is likely that leveraging CBO, in a systematic and structured fashion, will greatly enhance our abilities to characterize change with a high resolution across diverse social, ecological, and technological system settings. As importantly, implementing CBO will allow for these environmental changes to be placed in local contexts; through partnerships and co-development of CBO protocols, enhance the adaptive capacity of communities on the ground to respond to a suite of changes. The workshop initiated a series of actions that will build CBO into national efforts and mandates. Three of these are briefly described below.

Activity 1 – Contributions to the United States GEOSS Program

Community based observing, unlike other observing protocols, often incorporates "user-context" into the process of making observations. CBONS are primarily distinguished from instrument-based monitoring by their focus on variables of greatest interest and impact to specific communities (Johnson et al. 2015). It has been noted that the results from this form of observing are variably shared beyond the community, often by design through data protections reflecting cultural concerns and the potential for misuse by outside users (Johnson et al. 2015). The Summative GEOSS Evaluation (GEOSS 2015) found that GEO, during its first 10 years, was largely successful in including satellite-based programs, but had mixed results in its efforts to integrate *in-situ,* or ground-based, observations. The Evaluation also concluded that GEOSS is far from realizing its vision of being *user-driven*.

Combining the strengths of Sustaining Arctic Observing Networks (SAON), an international effort to coordinate and support observing and monitoring needs in the Arctic which grew out of the International Polar Year (IPY) of 2007-08, and GEO will make a significant contribution toward developing a sustained, integrated Arctic observing system that is part of a larger global system. In this context, the accelerated development of CBO in the Arctic, facilitated in part by relationships formed during the IPY between community members, social scientists, and biogeophysical researchers, provides an opportunity to develop a template for implementing CBO around the globe. The GEOSS vision and approach may, in turn, provide added-value to SAON and Arctic CBO projects by linking their observations and information (e.g., that which is available through the Atlas of Community Based Monitoring) to the GEOSS Portal and other global databases. Such linkages, which often serve to connect seemingly disparate communities, may provide opportunities to explore new applications for CBO; for example, through tailored approaches to inform or integrate with scientific modeling. As new international, collaborative polar initiatives get underway, such as the Year of Polar Prediction (YPP), a closer connection between SAON and GEO, framed in part by a shared desire to advance CBO, will serve to strengthen and grow lessons-learned and partnerships formed during the IPY. This opportunity comes at an appropriate time in the evolution of GEOSS. The GEO Strategic Plan 2016-2025 has shifted the defined societal benefit areas (SBAs) toward more information-user domains. These proposed new SBAs include Biodiversity and Ecosystem Sustainability, Disaster Resilience, Energy and Mineral Resources Management, Food Security and Sustainable Agriculture, Infrastructure and Transportation Management, Public Health Surveillance, Sustainable Water Resources Management, and Urban Development. Within all of these areas, Arctic CBO could play a role in defining user needs and demonstrating the societal and scientific value of utilizing local observations and local knowledge together with satellite-based or instrument-based observations at larger scales.

The workshop concluded with a recommendation to form a CBO Community of Practice (CoP) within GEO, with an initial priority focus on the Arctic. It was felt that this would most appropriately follow an organized effort by the GEO Community (e.g., coordinated by the GEO Secretariat) to gather expressions of shared interests from GEO Member States and Participating Organizations. A CoP could leverage and integrate the critical mass that now exists in Arctic CBO with observing systems that are within the scope of GEOSS. Here, SAON efforts to understand and document the state of Arctic observations, particularly CBONS, would be a valuable contribution for the CoP to understand how CBO can develop and support shared interests. Established best practices and applications could then be transferable to regions outside the Arctic, especially where GEO's local community engagement and capacity building efforts have shown significant progress, such as the regions served by the SERVIR Program and its growing number of regional hubs. Such an effort could address shared resources and efforts to create infrastructure to unite data producers and users. This will result in improved interoperability and the application of local and ground-based data. A CBO CoP may also advance understanding of how and where traditional and local knowledge can best interface with scientific monitoring to improve our understanding of social-ecological systems.

Activity 2a –Engagement with Communities for Improved Preparedness: CBO and the National Response Framework

Members of communities express on-going concern that they are ill-prepared and ill-equipped to be first responders in a range of challenging scenarios resulting from global change and natural or manmade disasters. Conversely, response agencies such as the U.S. Coast Guard, value the safety of citizens as a paramount value. The National Response Framework (NRF) relies on a component of community engagement for preparedness. This engagement is not limited to the arctic, nor to Indigenous communities, but rather extends nationally to a range of community types.

Under the NRF, the Federal Emergency Management Agency (FEMA) sets out five overview areas (prevention, protection, mitigation, response, and recovery) under five key theme areas (engaged partnerships, scalability, flexibility, adaptability in implementation, and integration among the frameworks). The recent decision by Shell Oil Corporation and other oil and gas entities to indefinitely suspend operations in the Arctic highlights the need to focus on these areas and other aspects of de-centralized, community-based observing, preparedness, and response. This is because Shell and other corporations have historically provided much of the critical response support in remote regions, and we must now develop an alternative set of models for ensuring safety and security in America's Arctic.

The NRF often uses the phrase 'engage the whole community,' which specifically refers to policies concerned with: a) planning; b) public information and warning; and c) operational coordination. This phrase seems to anticipate the incorporation of CBONS into the NRF.

Incorporating CBONS would enhance available information by adding a range of data streams and on-the-ground validation to supplement existing streams. It would also reduce costs, raise awareness within communities participating in the observing network, and place observations into a social context, which would increase accuracy in forecasting opportunities or undesirable events. Additional values of CBONS lie in their use to guide targeted preparedness, planning, workforce, and skills development. For example, in the Arctic, where data streams are limited and we are often "blind" during certain seasons, CBONS will be of particular utility. This model is readily transferable to other parts of the United States, particularly in the sparsely populated but infrastructure-heavy American West. The role(s) of CBO in enhancing preparedness was discussed in the context of connecting on-going awareness of change, as monitored by the community in concert with other forms of observing, to enhance capacities to respond to either slower, chronic changes or rapid, acute changes (e.g., emergencies). Engaged partnerships can be considered as working relationships that are sustained by regular communication and active support between response agency leaders and local-level organizations and individuals. We also propose that policies formalizing the incorporation of community based observing networks (CBONS) and the establishment of an integrated response framework (IRF), focusing on the maritime domain, will accomplish many of the goals of both the National Strategy for the Arctic (NSAR) and the NRF.

Use of such a system will enhance observation networks and preparedness, as well as response entities and actions. These elements will come together to create a whole that respects the enormous diversity in the Arctic and acknowledges that shared arctic geography requires different approaches to and policies concerning collective response. A comprehensive framework requires the use of a social-ecological and technological systems (SETS) based approach focusing on key indicators with simple, robust, and accessible models for interactions that allow us to better Predict Actionable Critical Events (PACE) as a form of a regional, community-centered, early-warning system (Figure 3).

Activity 2b. Developing a Community-Centered Forecasting Tool: Predicting Actionable Critical Events (PACE)

During the workshop several arguments for the inclusion of CBONS in the NRF, the USCG Concept of Operations (CONOPS), and the Arctic Strategic Plan were advanced in order to propose a system for predicting actionable critical events (PACE), so that communities on the ground can better prepare for their actuality and be more likely to mount rapid and successful responses. Such a framework, the equivalent of an 'early warning system,' could better enable local and regional responses around an "Observe-Prepare-Respond" paradigm. Preparedness is defined as the use of observing system outputs to derive awareness of potential critical events and the forecasting of their emergence, leading to a rapid but organized response. Observing and preparation are consequently the foundations for response, which we describe as any systematic and proactive set of actions to address critical events (Figure 3).

Figure 3. *The basic four elements of an effective early warning system as laid out in the United Nations International Strategy for Disaster Reduction. CBONS can play a role in the Risk Knowledge and Monitoring and Warning Service by directly connecting communities to critical changes that may be occurring as well as by placing warnings of these changes, if necessary, in a context that is appropriate to locale. Over time, through revisiting components of the NRF, better preparedness can be developed that links back to the ability to detect changes/events ahead of their occurrence (PACE).*

Risk knowledge	**Monitoring and warning service**	**Dissemination and communication**	**Response capability**
Systematically collect data and undertake risk assessments Are the hazards and the vulnerabilities well known? What are the patterns and trends in these factors? Are risk maps and data widely available?	*Develop hazard monitoring and early warning services* Are the right parameters being monitored? Is there a sound scientific basis for making forecasts? Can accurate and timely warnings be generated?	*Communicate risk information and early warnings* Do warnings reach all of those at risk? Are the risks and the warnings understood? Is the warning information clear and useable	*Build national and community response capabilities* Are response plans up to date and tested? Are local capacities and knowledge made use of? Are people prepared and ready to react to warnings?

By formally incorporating CBONS into the NRF, the challenges of communicating warnings may be met halfway since communities will have greater control of and buy-in to information regarding emerging changes that could potentially impact them, either positively or negatively. Ultimately, a re-consideration of CBONS as part of a range of observation, planning, and response frameworks will also elevate the diversity and skills within remote communities in the Arctic (see Table 1, below, for what kinds of data might be integrated in this manner). Increasing the human capacity to respond across such a vast region could greatly assist responding agencies and build improved trust between the public and government resulting in a more resilient Arctic.

Activity 3: The Arctic CBO Coalition

A significant outcome from the workshop was strong support for developing institutions to strengthen collaborations and partnerships across existing Arctic CBONS. There was also support for exploring the deployment of CBONS to geographical areas outside the Arctic. It was determined that a coalition of networks would be desirable and that such a network would be useful for advancing the science of CBO. The goals of a network of CBONS would include: a) creating a coordinated community of practice; b) describing best practices and standards for community-based science and observing; c) describing the ethical basis and standards for the integration of scientific. Such an endeavor could take place under the SAON (Sustaining Arctic Observing Networks) umbrella and help leverage the range of observing networks as reflected in Figure 1, above.

Table 1. *Data types across a range of observing platforms, including CBONS, which can potentially be integrated with products of other observing systems (c.f. Figure 1). Potential indicators and sub indicators that can contribute to predicting actionable critical events (PACE).*

Type of Sensor	Indicator	Sub Indices
Satellite/Remote Sensing	Sea ice	Extent, velocity, quality, pattern (scaled to rate and density)
	Marine debris	Bulk, diffuse, rigid, unknown
	Roads, building, and ports	Coastline infrastructure, connectivity and proximity for evac to nearest permanent facility
	Shipping patterns (AIS visible) Marine Vessels (AIS invisible)	Baseline, irregular, proximity to habitat/infrastructure, other vessels
	Phytoplankton and marine algae	Variation from baseline, pattern, density, types
	Oil / petrochemicals	Location, density, velocity, aggregation
	Wetland drying / surface drying	Rates, substrata
	Greening / browning (NDVI)	Rates, types of vegetation, proximity to habitat; relative to wetland drying/substrata
	Phenology	Increased uncoupling (wildcard)
	Ocean temperature	Higher, lower, phenologically disjunct
	Coastlines	Erosion (rates & patterns), proximity to habitat, proximity to infrastructure, sedimentation
Buoy / Meteorological Station	Ocean temperature	Higher, lower, phenologically disjunct
	Salinity	Higher, lower, pattern
	Microbes	REQUIRES FURTHER DISCUSSION
	Oil / petrochemicals	Location at unfamiliar places, density, proxy indicators through oiling of wildlife, velocity, aggregation
	Precipitation / hydrology	Increase, decrease, rate (e.g., drought/flood), proximity to infrastructure
	Phenology	Increased uncoupling
	Species distributions / biodiversity	REQUIRES FURTHER DISCUSSION
Community-Based Observing	Marine transit patterns (unfamiliar) Marine State	Pattern, occurrence, proximity, behavioural features (e.g., debris); wave height, patterns, tidal range/surge.
	Fauna - familiar	Frequency, body condition (e.g., lesions), behaviors
	Fauna – unfamiliar	Occurrence, distribution, behavior
	Flora – familiar	Frequency, productivity, location, condition
	Flora –unfamiliar	Occurrence, distribution
	Community Capacity Human consequences-anticipated	Human capital, diversity/demographics, infrastructure, equipment, training, access, contingencies. REQUIRES FURTHER DISCUSSION
	Coastlines	Erosion (rates & patterns), proximity to habitat, proximity to infrastructure, sedimentation

and community goals; and d) developing data and metadata standards necessary to facilitate the sharing of knowledge between and among researchers and communities. The network of networks will be a place where existing CBONS, as well as institutions and communities interested in establishing new CBONS, can exchange information, support each other in individual and collective goals, and discuss the extension of the CBON model to new knowledge and geographic domains. The Research Coordination Network (RCN) program of the National Science Foundation was discussed as the likely program under which such a network of CBONS would be formed.

The RCN program is a mechanism used by the National Science Foundation to advance fields of study or create new research initiatives, and funded RCNs function by creating networks of scientists and stakeholders across disciplinary, institutional, and even national borders. This latter part is critical, since the existing Arctic CBONS span three nations, many domains, and are supported by several agencies, universities, and many indigenous communities. The proposed CBONS-RCN is conceived as a member-supported body, which would include representatives from all existing CBONS in the Arctic as well as interested researchers, policy makers, and land managers across the continental US. The stated intention of the RCN would be to support and extend the current efforts of member networks and also to expand CBONS science into new areas and types of observing networks. Working Groups would be established to discuss, at a minimum, the following topics: coordination between CBONS; developing and refining the theory of integrated social-ecological science underlying community-based science; describing best practices and standards for creating and extending CBONS; proposing ethical guidelines for integrating science and community objectives; developing data and metadata standards, including recommendations for archiving and sharing data; engagement with a broader research and resource management community; and integrating educational curricula and community-based observing. Ultimately, the CBONS-RCN will serve the CBONS community by holding yearly meetings and workshops for practitioners and theorists to collaborate and learn from each other, and it will further the scientific agenda by producing detailed plans for deployment of CBONS in new domains and publications formalizing and extending the science of CBO more broadly.

5. ADDITIONAL MATERIAL

Note

This report is the first in an anticipated series of three. Subsequent reports will refine protocols and activities within each type of CBO. The reader is encouraged to review the Literature Cited for further details or contact the Workshop Chair through the Center for Resilient Communities: crc@uidaho.edu.

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