Vernacular Visualization Practices in a Citizen Science Project

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Jaime Snyder
University of Washington Seattle

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Jaime Snyder
University of Washington
Seattle, WA, USA
jas1208@uw.edu

ABSTRACT
Vernacular visualizations are visual representations of information created by and for non-expert users, in contrast to those developed by experts for specialized audiences. Research looking at everyday design practices and the democratization of innovation indicates that deeper understanding of non-expert design practices has a positive impact on technology development. This qualitative study focuses on the creation, use and dissemination of vernacular visualizations in a citizen science project. Findings from this research (1) map visualization practices in an established citizen science project, (2) contribute to theoretical understanding of the ways in which vernacular visualization practices support data-rich collaborative and coordinated work, and (3) suggest ways in which visualizations and visual resources can be evaluated in terms of their abilities to enrich coordination and communication in these contexts.

Author Keywords
Vernacular visualization; Data science studies; Everyday adaptive design; Visual practices; Citizen science.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Visual representations are critical tools for understanding a world that is increasingly described in terms of data. The field of information visualization has produced dynamic and interactive systems for producing complex visual representations. The web provides a platform to access these tools at an unprecedented level, and open data initiatives are flourishing. As a result, an increasingly diverse group of people are seeing, using and making visual representations of data in a broad range of contexts [18]. In response to this, Viégas and Wattenberg [56] coined the term "vernacular visualization" to describe visual representations of information that are created by and for non-expert users in contrast to those developed by expert system builders for specialized audiences. Vernacular visualization practices are pragmatic and enable a range of interrelated tasks, such as communicating complex ideas to diverse audiences, educating the public, and stirring debate [9, 17, 39]. In spite of the increasing availability of visualization tools to non-expert audiences, significant attention has only recently turned to understanding the ways in which vernacular approaches differ from more formalized visualization practices [cf. 18, 39], particularly in terms of the infrastructures they require, the communicative activities that they facilitate, and the range of skills used by non-experts to create meaningful visual representations [47, 48]. Similar to other DIY design practices, understanding non-expert visualization design practices provides opportunities for expanding practical approaches to problem solving, fueling innovation [19, 57], and developing new literacies [53], while highlighting the value of openly sharing expertise and information [27].

To begin to explore the role that vernacular visualization practices play in data-rich collaborative and coordinated work contexts, this study focuses on the creation, use, and dissemination of visual materials in citizen science. Citizen science projects are informal learning experiences that provide the public with opportunities to engage in authentic science activities. Volunteers perform discrete tasks that contribute to science initiatives, typically involving collecting or analyzing large sets of data. Citizen science projects often depend on the engagement of a diverse set of stakeholders ranging from subject matter experts to members of the general public. Within citizen science, visual representations of information have been used to communicate findings to the general public, to recruit and train volunteers, and to enable volunteers to engage with science in meaningful ways. While the roles of visual information in formal science contexts have been widely explored [e.g., 26, 30, 31], visualizations and visual practices in the informal science learning vernacular of citizen science have not yet been investigated.

A participant observation study conducted with the University of Washington's Coastal Observation and Seabird Survey Team (COASST) explored three primary research questions:

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- What are key vernacular visual practices in the COASST citizen science project?
- What role do these practices play in COASST's collaborative and coordinated work?
- What criteria have been used to evaluate the success of visualizations and visual representation practices in this domain?

Findings from this research (1) map the role and importance of visualization practices in an established citizen science project, (2) contribute to theoretical understanding of the ways in which these vernacular visualization practices support heterogeneous communities of practice performing data-intensive work such as those that contribute to many citizen science projects, and (3) suggest ways in which visualizations and visual resources can be evaluated in terms of their abilities to enrich coordination and the doing of science in these contexts.

BACKGROUND

Vernacular design practices

At first glance, many traditional New England barns might seem identical and homogeneous; however, architectural historian Hubka [19] has shown that further inspection reveals rich and diversified adaptations made by owners as the result of situated and evolving needs. Innovation in contexts like this occurs through repurposing and re-contextualizing existing materials and ideas. According to Hubka and others who study vernacular design practices [13, 19, 40, 46, 57], if taken into consideration, these adaptations, modifications, hacks, and augmentations can provide a valuable source of insight to professional designers regarding situated and longitudinal user requirements.

Embedded in the notion of vernacular or everyday design practices is the idea that in day-to-day contexts, individuals sometimes choose to make design choices that differ in form or format from those vetted by experts. As Viégas and Wattenberg [56] point out, vernacular and formal or expert design contexts often reflect divergent resources, requirements, evaluation criteria and final outputs [cf. 44, 46]. Importantly, a vernacular designer is not an apprentice who is aspiring to attain expertise in a professional domain; the vernacular designer is already an expert in his or her own local context and situated needs. The vernacular designer performs design activities in order to address specific needs related to that local context [13].

Within the domain of human-computer interaction, Thomas Moran defines "everyday adaptive design" as "pervasive activity engaged in by people as they adapt resources at hand to their everyday lives" [32]. According to Moran, adaptive design occurs after technology has been designed and built, during set-up, installation, training, maintenance, upgrades, repair, and reconfiguring. Implicit in acknowledging the work of vernacular or everyday designers is the notion that manufacturers (i.e., experts or formally trained designers) and users (vernacular designers) approach the innovation process using distinctly different knowledge, skills, resources, and practices [19, 57].

It has been over a decade since Moran advocated everyday adaptive design practices as a "worthwhile focus for design research" [32]. In that time, studies of everyday adaptive design have shown the benefits of expanding the domain of technology design research to include the potentially idiosyncratic and highly individualized activities of non-expert communities. For example, Wakkary and Maestri [58] and Bardzell, Rosner, and Bardzell [2] looked at localized design work to explore the ways in which quality is assessed in the absence of formal evaluation procedures and heuristics. Tanenbaum et al. [53] highlight the ways in which maker communities have created demand for new types of tools and literacies. Torrey, Churchill, and McDonald's work looking at the online search practices of crafters [54] reveals that the process of "learning how" can be used to expand models of information-seeking behavior to accommodate the blend of material and virtual experience involved in many types of craft tutorials.

Work in this area also provides important reminders that as sociotechnical practices unfold in the real world, systems (and the activities they were designed to support) do not remain static [51], supporting Moran's claim that exploring the theory and practices of adaptive design will help interactive system developers "to develop design methods, adaption techniques, and 'pliant' technologies to support adaptive design" [32]. In this sense, everyday or vernacular design practices are entwined with sociotechnical perspectives on infrastructure and articulation work [43]: understanding the tasks and adjustments that need to be made in order to keep a system functioning for a given purpose by a particular audience is an important resource for future system design [41, 42, 50].

The vernacular of citizen science

Citizen science projects enable participants to be involved in science activities and, in many cases, to be active collaborators in scientific research across a broad range of fields from conservation biology to molecular physics. These projects differ from more formal approaches to scientific practice and learning in that they are typically volunteer based, do not generally require specialized knowledge to begin participating (though training may be part of the experience), and take place outside of traditional lab or classroom settings [3, 23, 45]. Examples include counting and documenting wildlife (e.g., Cornell's eBird program, University of Washington's COASST project), identifying specific features and patterns of interest in large datasets (e.g., Adler Planetarium and Oxford University's suite of Zooniverse projects), and building and deploying DIY environmental tracking devices (e.g., PublicLab.org).

Within citizen science projects, visual practices take a number of different forms. Information visualizations are used to explore data, explain scientific procedures, and disseminate information about research impact to the public. For example, the National Geographic FieldScope visualization tool and eBird's suite of data exploration tools allow participants to see the accumulative effect of their data collection efforts through interactive visualization interfaces. Other projects, such as COASST, require participants to use a visual reference guide to identify wildlife and to submit visual evidence (e.g., photographs) and measurements to verify data. Zooniverse's GalaxyZoo project provides tools that allow participants to explore and analyze extant visual data [22].

In formal scientific practice and formal science education, visualization practices are performed within relatively structured analytic activities (e.g., statistical comparisons, pattern seeking, model construction) with specific desired outcomes (e.g., objective conclusion, valid data reduction, functional understanding of a thematic framework) [1, 28, 37]. In citizen science contexts, learning outcomes are less clearly defined and can emerge over time, resources can be difficult to obtain and sustain, and the challenge of recruiting and retaining a diverse population of participants looms large [3]. Visualization practices in citizen science often develop as part of larger educational (as opposed to purely scientific) programs and produce outputs intended to serve multiple roles within a project (e.g., providing accurate representations of data, educating volunteers about scientific principles, communicating findings to the public to encourage support).

Developing tools that support these engagements can require significant investment of time and resources. While many different types of scientific visualizations have been shown to make positive impacts in formal STEM education [12], there has been only limited study of these techniques in informal science learning contexts [7, 52, 61]. Core teams do not typically include individuals with specific expertise in information visualization system design, graphic design, or visual literacy. Those visualizations that are created are often done by non-expert designers in response to situated needs.

Exploratory interviews with representatives of five established citizen science projects confirmed three primary justifications for the suitability of this domain for a study of vernacular visualization practices. First, visualizations (e.g., data visualizations, visual evidence, and visual training materials) are important to the success of many citizen science projects. Second, program organizers feel that they could be making even better use of visualization technologies and techniques. Third, in spite of the fact that many visualization tools and resources are developed "in-house," few teams include dedicated visualization specialists.

Professional and skilled vision

Visual tools and materials deployed in citizen science projects have the potential to help participants "see like a scientist," cultivating what anthropologist Charles Goodwin refers to as *professional vision* [14]. The process of acquiring professional vision involves learning how to recognize the "objects of knowledge" associated with a craft or profession. This means learning to recognize what is important, signaling or indicating this importance as part of the professional practice, and having the ability to recreate or represent information that is salient to practitioners in ways that make sense to that group. Grasseni [15] discusses similar practices of *skilled vision* in the context of cattle breeding aesthetics, involving a constant training of attention. Skilled vision is situated, contextual, and material, and involves an apprentice-like experience to acquire.

Vertesi [55] highlights a similar process in the context of NASA's Mars Exploration Rover team. These scientists perform distributed coordination on Earth to determine how and where to move robots located on Mars. Vertesi highlights the visual work involved in learning the behaviors and idiosyncrasies of the robots, including performing physical gestures that emulate the anatomy and articulation of the robots (i.e., "becoming the robot") and constraining field and depth of vision to imitate the rover's optic system (i.e., "seeing like a rover"). For this distributed team, professional or skilled vision enables them to cultivate a functionally similar understanding of the ways in which the robots move and observe, essential for the successful coordination of their movements.

METHOD

Coastal Observation and Seabird Survey Team (COASST)

This qualitative field study focuses on the Coastal Observation and Seabird Survey Team (COASST), a citizen science project based at the University of Washington's College of the Environment. This program has engaged coastal residents in monitoring the health of beaches from the Pacific coast of the U.S. to the Commander Islands in Russia. Morbidity of seabirds can be a useful indicator of the overall health of marine ecosystems. COASST participants collect structured and detailed data (Figure 1) regarding beached bird carcasses in their area. Beach surveys are conducted on a monthly basis and observation records are uploaded to a project database through a web portal. COASST provides its cumulative dataset to the scientific community as an open access resource. (COASST recently launched a similar program to monitor marine debris such as nets, plastic, and other types of garbage. This study focused on the more mature seabird monitoring program.)

The COASST project was selected as a site for this study because of its strong reputation as an established citizen science project with a rigorous data collection and management process, the extensive work project organizers have conducted in-house to develop a robust set of visual resources to support the project, and the team's willingness

Figure 1. Photo documentation of beached birds. Photo credits: (Clockwise from upper left) J. Thompson/COASST; D. Cotton/COASST; T. Schulz/COASST; G. Webb/COASST.

to engage with this research. COASST participants are trained to gather and share visual evidence of field observations using a systematic protocol and image-rich field guide. These custom-made reference materials have been designed and optimized by the COASST team over 17+ years of trial and error in the field, with minimal assistance from professional designers. Data visualizations generated from the COASST dataset are regularly used in public presentations, scholarly publications, and outreach programs. COASST program organizers have also expressed an interest in and commitment to enhancing their visualization activities in the future.

The core COASST team includes approximately seven people, including an executive director, a science coordinator, a manager of participant engagement, a data verifier, a postdoctoral researcher, and graduate students. In addition, the COASST project engages a fleet of interns and last, but certainly not least, approximately 800 volunteer participants (referred to with affection and respect as COASSTers) who make monthly observations of over 450 coastal beach sites along the Pacific shore. Through funded research projects, COASST also collaborates with research teams from other institutions.

Data collection and analysis

Data collection for this study included interviews with key COASST stakeholders, participant observation, and document analysis over the course of 10 months [49]. A set of three focusing questions, adapted from cultural studies of visual practices, guided iterative observation and analysis: What things are being made visible? How are these things being made visible? And what are the implications of this visibility for the citizen science project (e.g., required resources, sustained engagement, technical skills training)? Field notes from observations and transcripts of interviews were compiled for analysis, along with photographs, video recordings, and example documents.

Interviews and Observations

Most of the day-to-day activities of managing and running the COASST project take place in a suite of offices on the UW campus. From these offices, members of the staff coordinate and manage a steady stream of data and documentation sent daily by volunteer participants. Undergraduate interns work during the academic year and over the summer to help enter data, prepare volunteer materials, assist in trainings, and conduct their own research projects. Graduate students and postdoctoral researchers use these data to address research questions related to environmental science and marine biology.

The voluntary and public nature of citizen science is well suited to active researcher engagement. Over the course of 10 months, observations of a series of organizational and administrative activities were conducted, including: approximately 11 weekly team meetings, each lasting 1-2 hours; an all-hands meeting for a collaborative funded research project; three 6-hour volunteer participant training sessions, including informal interactions with new trainees and experienced COASSTers returning for a “refresher” training; and the filming of a series of short training videos at a local beach.

Participant observation [49] for this study involved two types of experiences. I participated in several discussions about the design, redesign, and dissemination of visual resources. These conversations generally took place before, during, and after meetings and involved most members of the core team. I also took part in a training session as a volunteer participant. Training sessions occur on a roughly monthly basis at locations all along the Pacific coast, from California to Alaska (excluding the coast of British Columbia). During each 5-6 hour session, attendees are introduced to general citizen science principles, the COASST project, and procedures for making detailed observations of beached birds. I attended two training sessions in communities along the northern Oregon coast and one in coastal Washington.

In addition to these observations, a total of 7 semi-structured interviews (approximately 1 hour each) were conducted with the project’s director (2 interviews), citizen science coordinator, participant engagement manager, data verifier, postdoctoral researcher, and a COASST graduate student. Interview transcripts and field notes were iteratively analyzed throughout the course of data collection using inductive grounded techniques [5].

Direct access to COASST volunteers was limited to informal engagement during training sessions. COASST project organizers were understandably protective of the time of active volunteers, balancing the needs of their own program evaluation activities (such as surveys of new and continuing volunteers to assess learning) with their support for this study. However, project organizers have very high contact with COASSTers, putting an extraordinary amount of effort into understanding and crafting the volunteer experience. Many details about the volunteer experience, including summaries of feedback and reception of materials, were provided during staff interviews and through observations of training sessions.

Document analysis and tool inventory

Visual documents were collected and analyzed as products of dynamic sociotechnical activities [36]. For example, the process of observing, identifying, and documenting beached birds is supported through a highly visual field guide and protocol handbook (discussed further below). Observations are recorded using a detailed datasheet that includes visual icons. Beached birds are also documented through a series of digital photographs. Data visualizations, in both draft and final form, were collected. The span of this study intersected with a major effort to redesign the COASST database. As a result, most of these documents experienced a revision cycle during the time that observations were conducted. In addition to examining these visual artifacts, an inventory of digital and analog tools that play a role in vernacular visual practices was compiled in order to better understand the technological infrastructure that supports data practices in this citizen science project.

FINDINGS

Cassin's Auklet wreck

In the autumn of 2014, thousands of dead Cassin's Auklets began washing up on the Pacific coast from California to British Columbia. These small blue-footed seabirds are common in the North Pacific and nest on offshore islands. COASST volunteers were among the first to encounter unusually large numbers of Cassin's Auklet carcasses turning up on mainland shores and quickly found themselves on the front lines of documenting a major environmental anomaly.

Wrecks, or large quantities of dead birds washed ashore, can occur for a number of reasons, including natural fluctuations in the availability of food, unusually large breeding years, or other environmental factors such as oil spills or climate change. COASST and other related scientific and citizen science efforts are working to establish normative baselines and models that can help conclusively determine the cause of events such as the Cassin's Auklet wreck. (Since this wreck, there have been other large mortality events involving marine seabirds: for example, the Common Murre wreck of 2015-2016 and, as of August 2016, an alarming number of Rhinoceros Auklets washing up on Pacific beaches.) Making careful, accurate, and well-documented observations of the scope and nature of morbidity is an essential first step in that scientific process.

COASST relies on a dedicated group of volunteer participants to observe, document, and submit evidence of beached birds to a centralized repository. On average, COASSTers need about 10 minutes to document a single bird, including making careful measurements of specific body parts; recording details about location, weather, and condition of the carcass by filling in 24 fields on a datasheet; and taking photographs using a standardized protocol.

In the case of a mass mortality event the size of the Cassin's Auklet wreck, individual volunteers, who typically record less than ten bird carcasses on any given survey, were faced with carefully documenting hundreds of birds washed up on their beach on any given day (Figure 2). The unprecedented scale of the Cassin's Auklet wreck tested both the resolve of volunteers and the ability of the COASST protocols and data management procedures to respond to this rapid increase in scale. In the next sections, the ways in which visual resources and practices played a role in supporting COASST's response to this wreck will be used to illustrate some of the key aspects of vernacular visual practices in this domain.

Figure 2. Documentation of beached birds during Cassin's Auklet wreck of 2014-2015. Photo credit: J. Forsythe/COASST.

COASST data collection

Visual keys

A core aspect of the COASST volunteer participant training session is a hands-on introduction to *Beached Birds: A COASST Field Guide.* The guide was designed and compiled by Todd Hass and Julia Parrish and is a highly visual reference manual that assists COASSTers in identifying species of bird carcasses. Parrish[1], director and PI of the project, explained that when the first versions of the field guide were designed, they asked themselves, "How do you create a set of tools that allow non-experts to

[1] Actual names used with permission.

identify with high certainty what is in front of them in a way you can teach them in a very short period of time?"

Parrish and her team were keenly aware that most of the people who would be signing up to participate as COASST volunteers would not be experts, or even birders. Further, existing bird identification references were not useful in this situation. Typical live bird field guides focus on providing users with information about the silhouette, song, habitat, and other behavioral characteristics of animals, assuming that birders will have only a fleeting glimpse of their subject [8, 29]. Dead birds are different. When a carcass washes up on a beach, it might be far from typical nesting or breeding grounds, decomposed, missing body parts, or bleached or discolored from exposure to the elements.

Motivated by a desire to maximize the quality and quantity of data being collected by volunteer participants, the COASST team created their own field guide. They felt confident that volunteers would be able to tell that a carcass was a bird (as opposed to another type of animal or just a pile of feathers); that people would be willing to pick up a bird carcass (after donning protective gloves) in order to examine it more closely; and that it would be possible to teach people to make a few standard body measurements (i.e., morphometrics) with a fair amount of precision and accuracy. These assumptions served as the basis for the design of the guide, as well as the training curriculum.

Parrish and Hass designed the procedure for identifying a bird's species to begin with a series of illustrated forced-choice questions that ask volunteer participants to match specific parts of a bird carcass with drawn images supported by explanatory text (Figure 3a and 3b). While traditional dichotomous keys used in biological sciences to identify organisms are often simply text based, the COASST keys are highly visual with targeted text annotations corresponding to specific observable features of bird anatomy. The guide blends hand-drawn illustrations (designed and created by multiple project staff and students), with icons, photographs, and verbal descriptions of visual features in order to create unambiguous representations of the bird species that COASSTers are most likely to encounter on their beaches. Training activities provide new recruits with opportunities to examine many different specimens of bird parts (such as feet, wings, bills, and occasionally a fully intact carcass) and walk through the process of using the guide to reach a conclusive identification of a bird's family and species.

For example, the version of the COASST field guide for the lower 48 states in the U.S. includes descriptions of 55 different species and begins by guiding participants through the process of identifying birds starting with a *foot key* (Figure 4a). Parrish explained that feet were chosen because early COASST studies indicated that on the beaches where the project began, this was the body part that tended to last the longest before decomposing across all types of bird carcasses. However, when the project expanded to include

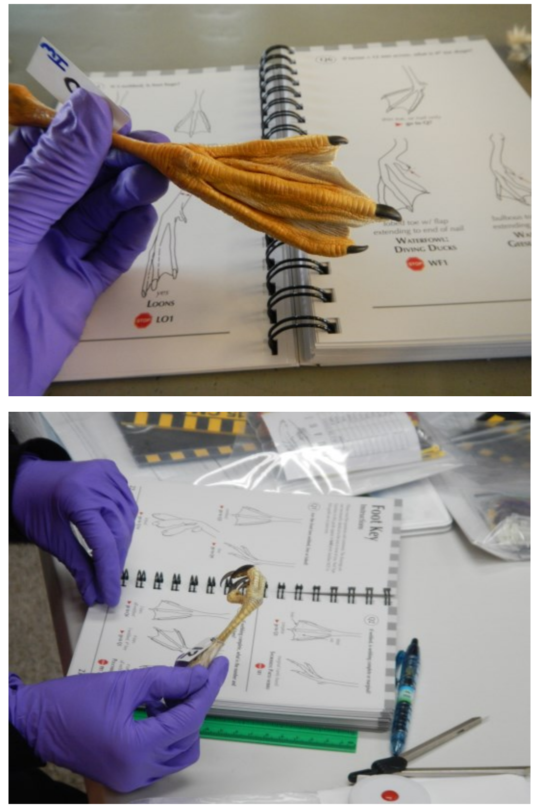

Figure 3a (top), 3b (bottom). COASST training materials. Photo credit: J. Snyder.

the shores of Alaska, Parrish and her team need to create a special guide for that region because not only are there significantly different species of birds along that part of the coast, but on these beaches, feet do not last as long as wings. So this guide begins a with a *wing key*.

Whether starting with feet or wings, working through the initial steps of the field guide leads to a family key (Figure 4b) or directly to a species page (Figures 5a and 5b). Life-sized drawings of bills and heads (see Figures 5a and 5b, lower right corners) provide additional confirmation of species identification. Other details included on the species page include graphs of encounter or overall population rates and a checklist to make sure that COASSTers have followed identification protocols without skipping steps.

As is the case with other types of atlases [8, 29], the vernacular designers of the field guide have discovered that each type of representation affords distinct opportunities in terms of what can be presented to the viewer. Line drawings can be excellent for highlighting salient details and muting differences that are not relevant to the process of identification. However, they can also be highly idealized, at times quite stylized, and unrealistically simplified. While photographs reflect what a COASSTer might actually see on the beach (including decomposition, natural lighting conditions, and scale), they can also be challenging to use as tools for identification because salient anatomical details could be obscured or occluded. Due to

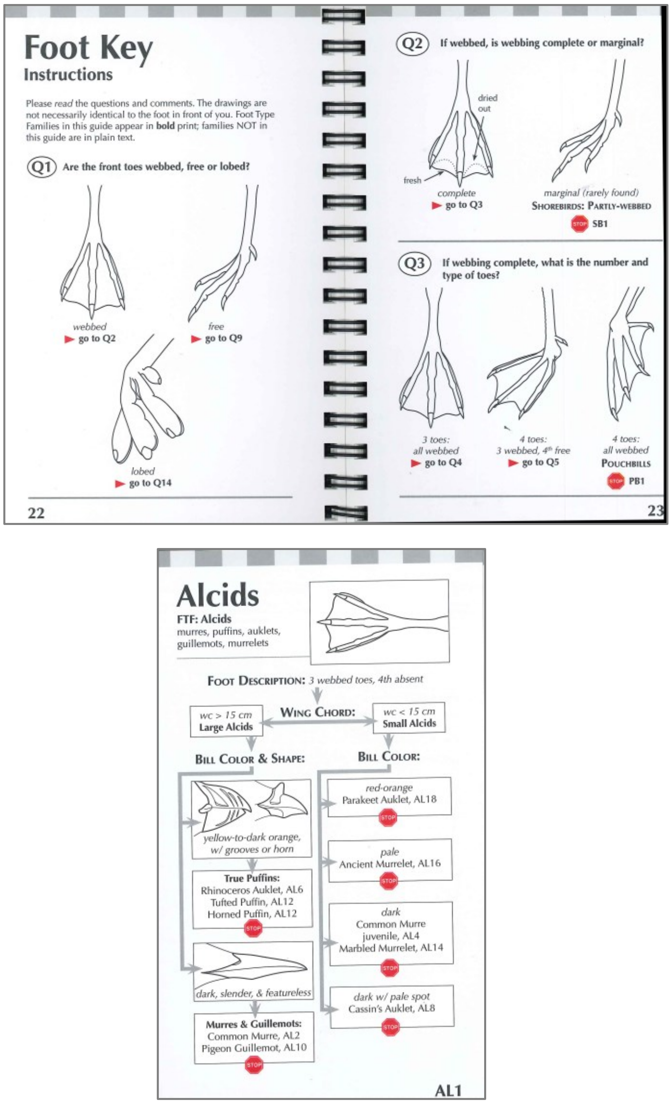

Figure 4a (top), 4b (bottom). Example pages from COASST field guide, including foot key (top) and bird family page (bottom). Image credit: COASST.

subtle individual differences between birds of the same species, it can also be difficult to know which parts of the specific bird being shown are most relevant when trying to identify another bird of the same species. The value of the COASST field guide lies in the compilation of multiple complementary types of visual representation.

Data quality

Accurate species identification is essential to maintaining the high quality of COASST data. Using these visual keys, participants are able to follow a highly deductive process, resulting in COASSTers accurately identifying a bird carcass to the species level ~83% of the time. The various forms of visual representation in the field guide help to train new COASSTers to focus on those aspects of the animal's form that will help them most when identifying the species of a bird.

The field guide also plays an integral role in maintaining the quality of data over time. The foot and wing keys were designed to be used with each and every observed bird, whether the first encounter for a new volunteer or the 300th encounter of an experienced COASSTer. The goal is not to leave the guide behind after training, but to use it as a perpetual checklist for the data collection process, similar to a pilot's pre-flight checklist. The visual cues highlighted by illustrations, icons, and photographs ensures that the participant is observing, measuring, and recording the information that is needed to maintain the quality of the database. Shortcuts are not an option.

Changes to the field guide

As noted, Parrish and her team looked at the creation of the protocol, illustrations, and layout of the field guide as part of their research design process in order to get more data and better data. Although a design firm was brought in to help integrate the design, Parrish described this as a highly collaborative process that involved going "back and forth with them until the guide was both correct and to the visual standard I wanted." Parrish and the COASST staff have retained strong control of the visual design and content of the guide.

The field guide was originally created as a set of individual pages in the FreeHand vector graphics software application. Over time these files have been migrated to a consolidated Adobe InDesign file using a combination of digital and manual techniques including automated imports and tracing of original files. The field guide has been revised periodically over the 17 years of its use, with changes addressing the material aspects of its presentation (e.g., waterproof paper, spiral versus three-ring binding, adjustments to page layouts) as well as its contents. Content changes include: breaking the guide into Lower 48 and Alaska versions as the COASST project has expanded; expansion of the foot key to include types not in the guide but occasionally found by COASSTers; and replacing an encounter rate graph (i.e., how frequently a species has been observed over time) in the Alaska guide (Figure 5a, upper right corner) with population and conservation information including icons representing the most prevalent threats to each species (Figure 5b, upper right corner).

Transforming situated observation to abstract data

As a matter of best practice, the COASST protocol is methodical and requires close visual and physical examination of each beached bird that is encountered. Through the mediation of the visual field guide and accompanying datasheets, COASSTers experience each bird carcass first as a visceral and material encounter with the bird, then as an increasingly abstracted data-driven representation. The successful navigation of this transition from situated observation to abstracted record is a vital aspect of the citizen science process and, in the case of COASST, is greatly supported by the visually-enabled field guide.

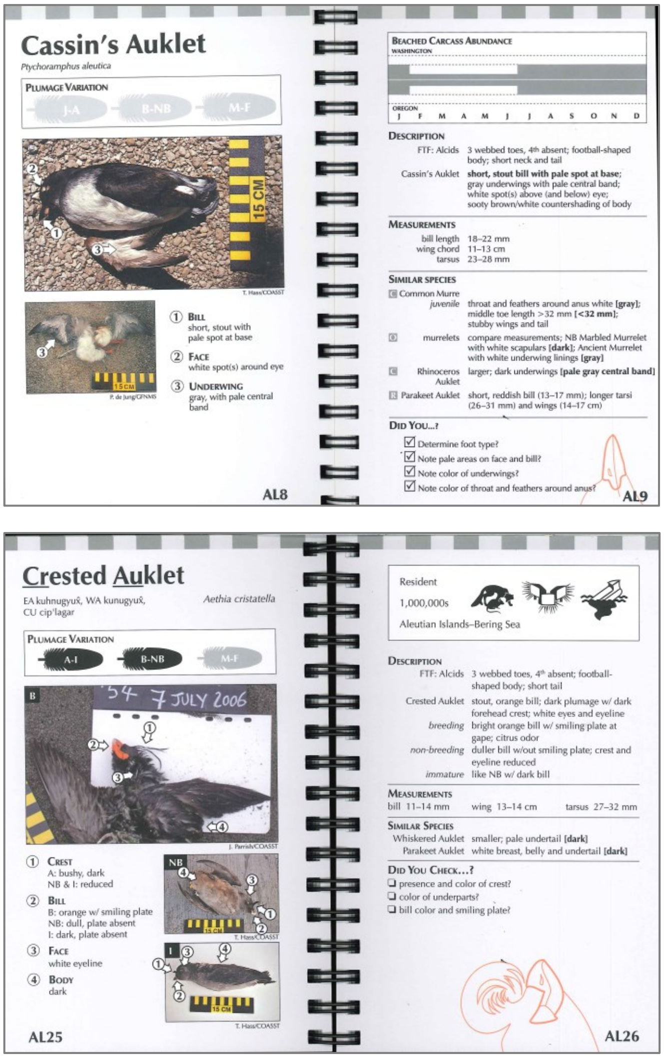

Figure 5a(top), 5b(bottom). Example pages from COASST field guide, including species page from Lower 48 guide (top) and species page from Alaska guide (bottom). Image credit: COASST.

There is a very close relationship between the visual field guide and the datasheet used to record observations. The datasheet, in turn, has a direct relationship to the structure of the COASST database. This chain of correspondences was evident as the COASST database underwent a recent upgrade. COASST staff took great pains to reverse engineer the new database fields to match the datasheet; the fields were also meticulously compared to the visual keys in the field guide.

The recent Cassin's Auklet wreck presented distinct challenges to COASSTers as they performed this important transition from material observation to abstracted data point. Clearly documenting and verifying each bird involved a tremendous amount of work that was distributed across both the volunteer participants and the COASST staff. When scaled to the degree required to respond to the wreck, the careful, visually-centered data collection protocol took an emotional toll on volunteers. In recounting surveys from that period, COASSTers mentioned being overwhelmed, and COASST staff described being concerned about volunteer burnout because wreck events can be "crazy making." In response to this event, new protocols were devised that enabled COASSTers to more efficiently batch process beached birds during wrecks (Figure 2); however, these changes still require most birds to be handled at least once in order to arrange the carcasses for photo documentation, discussed next.

Data verification

Photo documentation plays an important role in the COASST data verification process. Photographing the bird carcass is the last stage of the on-site protocol. As described in the COASST Protocol manual: "COASST uses your photographs to verify identifications, as well as to prove that a particular species was found at a particular location. If COASST data are ever used in a court case, these photographs are essential evidence" [6, p. BB-36].

Visual evidence

Volunteer participants are given detailed instructions for how to photograph beached birds, and special tools, including a ruler and an erasable chalkboard, are included in the survey kit provided to all volunteers (Figure 6). COASSTers are advised to "pose" carcasses so that identifying species characteristics (as described in the field guide) are visible. Instructions also include guides for what to write on the erasable slate, how to position the ruler in order to provide a reference for scale and color balancing, and suggestions for naming digital files to make photos easy to match with datasheets. While COASST will provide volunteer participants a digital camera if needed (with a small deposit), most individuals use a smartphone or have their own equipment.

Photographs are sent to the COASST data management team by email, via a cloud-based repository like Dropbox, by loading the images onto a flash drive and mailing that, or by sending in a hard copy of their datasheets. With the help of a team of interns, each photograph is matched with its corresponding datasheet and all information is entered into

Figure 6. Documentation of beached Cassin's Auklet. Photo credit: C. Moses/COASST.

a database (including photos). A bird expert on the COASST staff performs the substantial task of using the measurements, datasheet notes, and photographs to verify each observation and species identification. In a “non-wreck” year, the project will verify ~7,000 carcasses; during a wreck event that number can easily double. While significant effort has gone into making this process as efficient as possible, visual confirmation using the photographs can still be a bottleneck in the data management process, especially during a wreck event.

Data validation

As Wiggins and He point out, “Validation is critical to ensuring the usefulness of citizen science data by establishing its quality” [60, p. 1548]. COASST is distinct among citizen science projects in the rigor that project organizers bring to verifying data, and it is well known for the high quality of its dataset. Like the field guide, the photographs provide a bridge between a palpable experience of the coastal environment and mathematical models of an ecological system that rely on the accuracy of underlying data.

The photograph serves as evidence of both the observation itself (the bird really did exist) and the various metrics that were used to identify the bird (it really did look like that). When COASSTers take photographs of beached birds as part of their survey procedures, they contribute to the stable transition from physical observation to abstracted data. Once the photograph is submitted to the COASST data management team, it is used by subject matter experts, along with the datasheets and measurements, to corroborate and verify the bird’s species. The photos also help the staff bird verifier to provide feedback to COASSTers regarding the quality of their documentation and the accuracy of their identifications. This process establishes a high degree of trust in the COASST data that has positive implications for the types of scientific analysis that can be performed with it.

Shared visual experiences

The photographs are also used during the formal COASST training alongside physical specimens of bird feet, wings, and bills. Some of these images are also made available to the public through the COASST blog, presentations delivered to both scientific and general audiences, and through the media (for example, a story about the Cassin’s Auklet wreck on the National Geographic website [59]). *What’s Washed In*, a semi-monthly e-newsletter, highlights examples of recent bird observations made by COASSTers. The photographs provide mini-tutorials on particularly challenging identification problems, birds that are difficult to disambiguate because of subtle distinguishing characteristics, or birds that might be local to a specific region and therefore might not be as familiar to COASSTers.

While these mini-tutorials do help to increase the quality of data by providing COASSTers with additional information and training, they also serve as a means to develop community across geographic regions. Volunteers often meet others from their area during the initial training session, and many develop a strong local COASSTer community. The photographs in the e-newsletter are a means of extending these communities to the broader COASST collective. Individuals can see the work of others and be reminded of the scope of project. This is an important way of retaining participants, especially during events like the Cassin’s Auklet wreck.

The photographs also serve as a reminder to the COASST scientists working in the lab. One researcher described the importance of occasionally referring to the photographs of the beached birds while performing analyses of the abstracted data associated with wrecks:

There is one beach in Alaska where there were 6,000 birds in December…and that creates a big bubble [in the data visualization] that definitely doesn’t convey the same meaning as seeing the actual photo of the beach and there’s just piles and piles, and piles of birds….You lose some of that impact…and there is definitely a disconnect there. Like, I just see it as numbers until I see the image and then I’m like, oh that’s big, yeah.

Analysis and dissemination

Data visualizations are most often created in-house by project researchers, using tools such as R, Inkscape, and PowerPoint, with input from the rest of the COASST team. They are typically generated as part of the analytic process (i.e., seeking patterns in the data, testing hypotheses, understanding the scope of data across time and geographic space); in order to communicate findings to the scientific community; and to share updates and information with the general public.

Scientific analysis

Up until this point, the directional flow of data through the COASST infrastructure has been described as moving from beach to lab. A great deal of effort and energy has been put into converting those physical, material observations of bird carcasses to discrete, verifiable data points. Once the data have gotten to the point of analysis and modeling by the research team, there is a high degree of consistency across the dataset in spite of it being compiled by several hundred volunteer participants distributed across 450+ beaches over the course of 17 years. As scientific conclusions are being drawn from the data, the current switches and data (in the form of visualizations and reports) begin to flow back out towards the public. While the creation of visualizations as a means of data analysis is not that different from other scientific practices, the final design and dissemination of data visualizations has a high degree of dependency on the practice of citizen science in the COASST project.

Adaptive design

Project organizers make efforts to represent scientific findings in ways that will be comprehensible and meaningful to broad audiences. As analyses solidify, more attention is paid to the story being told by the images. During the Cassin's Auklet wreck, the immediacy of the event compressed this transition. As researchers were trying to develop robust algorithmic models to support a hypothesis regarding the timing and cause of the bird die-off, the public was also clamoring to hear from the experts why alarming numbers of tiny blue-footed bird carcasses were showing up on their favorite beaches. Analytic activities and storytelling became more tightly integrated.

This can be seen in a series of data visualization examples provided by COASST from the approximately 20-month time period from the beginning of the Cassin's Auklet wreck in autumn 2014 to the preparation of scientific findings about that event in spring 2016.

Created in December 2014 and distributed through a report to COASSTers and on the COASST blog, Figure 6 shows regional baselines over the last 7-10 years (orange circles), current encounter rates (blue circles), and locations of beached birds (Pacific coast line map on right side of image) observed during the last three months of 2014 with the scale designed to accommodate a relatively large encounter rate in December. Geographic areas are defined based on internal COASST delineations used for organizational purposes.

Figure 7 uses a similar design and was created a month later for a presentation to the Audubon Society. In response to the unfolding wreck event, this data visualization shows not just verified observations (September through December) but also unverified counts shown in purple (January estimates) including COASST data not yet vetted and data from other bird monitoring programs (Beach Watch and BeachCOMBERS). Photos of a live Cassin's Auklet and a beached bird were also added to the presentation.

The relatively unusual decision to show unverified data and the choice to present data from other projects (collected using different protocols) reflects the anomalous nature of the wreck event and the adaptive design practices of the COASST team. COASST's reputation for high-quality data and extensive experience tracking seabirds made Parrish and her team the go-to source of information about the wreck; however, the bottleneck of data verification was being acutely felt by COASST staff. Their solution was to devise a visual encoding that would enable them to share the information they had without making premature claims about its accuracy.

Finally, fourteen months later, with COASST finally caught up on the process of verifying observations and findings from analyses providing a foundation for interpretation of events, Figure 8 was created for public presentations (a modified version will also appear in a scientific publication). As a result of having more information about the magnitude and geographic scope of the wreck event, adjustments were made to the overall scale of graphic

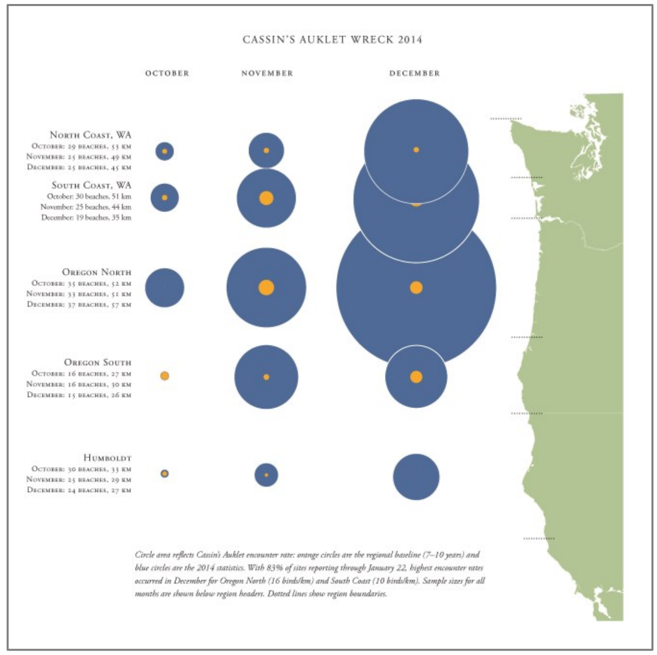

Figure 6. Data visualization depicting the known geographic scope and magnitude of the Cassin's Auklet wreck as of December 2014. Image credit: COASST.

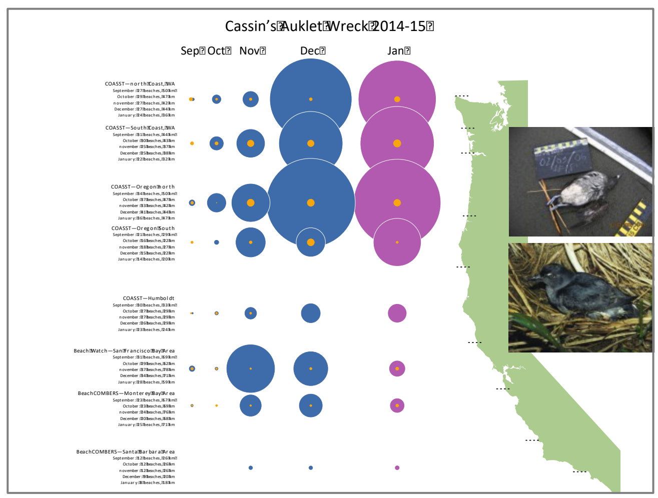

Figure 7. Data visualization depicting the known geographic scope and magnitude of the Cassin's Auklet wreck as of February 2015. Image credit: COASST.

elements and observations were mapped to more standardized geographic areas based on latitude.

As illustrated by these data visualizations, one of the biggest challenges faced by the COASST team during wreck events is how best to communicate the scope of each event in ways that are easily understood by diverse audience. This type of visualization problem is complex. None of the members of the COASST team are specifically trained in visual design, graphic principles, or information visualization heuristics. However, years of facilitating

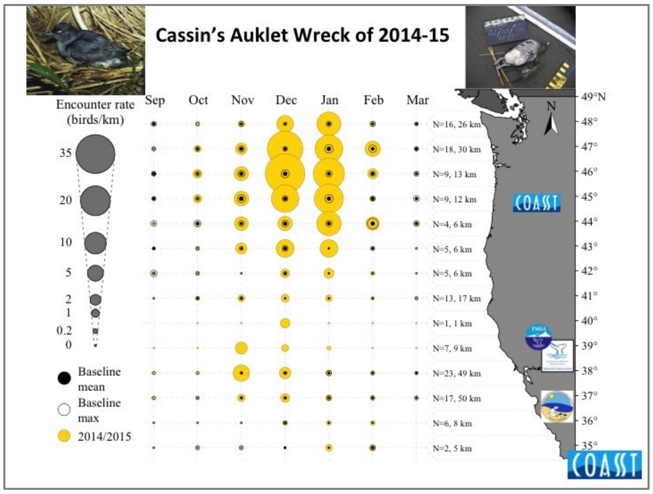

Figure 8. Data visualization depicting the known geographic scope and magnitude of the Cassin's Auklet wreck as of May 2016. Image credit: COASST.

communication between the general public, scientific communities, conservation organizations, environmental activists, and government agencies has produced a strong sense of what works and what does not in terms of presenting complex information. While COASST organizers believe that visualizations are vital for conveying this information, they also recognize that each potential audience has distinct needs, expectations, and evaluation criteria.

Data communication practices

A significant amount of time before, during, and after meetings was devoted to looking at iterations of visualizations generated by COASST researchers. These images included exploratory passes through historical data in order to identify anomalies or previously unidentified wreck events; output from a range of statistical techniques used to explore different types of patterns over time; supporting documentation for emerging models to explain the Cassin's Auklet wreck; and attempts to convey complex stories about ecological change over time to lay audiences for use in public talks about the wreck.

Conversations around these visualizations tended to flow from highly specific scientific language to more generalized questions about communicative clarity. Experienced members of the team used the visualizations to teach students about the mechanics of data representation, pointing out specific visual features in order to flag potential errors or limitations in statistical models. They also pointed out visual encodings that might be confusing or opaque to specific audiences, using the images as tools to convey to junior researchers the importance of clear and unambiguous communication even in the context of complexity.

The COASST data visualizations also provide a basis for "data stories" shared with potential volunteers during COASST training sessions. This is considered an important part of integrating individuals into the COASST community by providing them with evidence of the scientific work that is enabled by consistent and careful observations. Great care is given to selecting visualizations and stories that convey a sense of the scope and impact of the scientific work being done by COASST without bogging down new trainees with too much jargon or detail. This is a specific instance of that reversal of flow: the visualizations created in the context of scientific work are then brought back to the volunteers to support the recruiting and training of new participants in the COASST project, which in turn will enable more observations to be made and more data to enter the system.

DISCUSSION

The COASST study points to some of the important roles that vernacular visualization practices can play in providing support for coordinated work, communication practices, and data infrastructures. The observational and organizational structure provided by visual resources and practices in the COASST project are essential tools for facilitating the flow of information and data among stakeholder groups, performing as infrastructure to support the doing of citizen science. However, observations of visual practices deployed in the doing of citizen science raise a host of questions about the nature and value of understanding vernacular visualization practices for CSCW and HCI researchers:

- Where do the boundaries of data visualization work lie? Should *all* of the COASST practices discussed here be considered visualization? Is there a broader range of visual practices that should be considered when supporting coordinated work? What is at risk by considering a more holistic set of data-driven visual practices when supporting coordinated activities?
- Are these vernacular designers doing something different from professionals or are they just not as well trained? What is the boundary between expert and non-expert? How can the practices of vernacular designers be advanced without assuming that they need or want the same skills or training as professionals? Are there specific tools that can better support the work of these designers?
- If a visualization does not follow prescriptive best practices established in one domain, does that mean it is useless in all contexts? What does it mean for a visualization to work "in the wild" as opposed to in the lab? Are there vernacular literacies that need to be accounted for when thinking about visualization curricula and tools?

This discussion uses material from the COASST study to explore ways in which answering questions like these can contribute to the design and development of innovative technologies to support collaborative and coordinated practices.

A broader vision of visualization practice

One of the key ways that COASST project organizers have scaled data consistency across time (17+ years), space (thousands of kilometers of coastline), and context (scientific and lay audiences) is by using visual representations like the field guide and photographic documentation to synchronize data collection, management, analysis, and dissemination. As Latour describes in his discussion of immutable mobiles [cf. 28], visual representations of information provide a portability of vision and judgment that enables multiple stages of verification and confirmation. For COASST, this has contributed to an extremely high-quality dataset documenting thousands of miles of coastline over several years, in addition to providing a meaningful experience for thousands of citizen scientists. While the form and format of many COASST visual representations extend beyond conventional information visualization charts and graphs, visual practices are deeply tied to their collaborative data practices.

Visual representations provide the means to maintain the structural integrity and functional stability of the data as it moves through its life cycle within the COASST project. The field guide not only entrains the attention and observations of individuals on the beach, but it also serves as a guide for the design (and redesign) of data entry interfaces and the COASST database. When improving the interface used by COASSTers and interns to enter data through the web-based portal, the COASST data management team referred back the field guide, comparing the step-by-step series of forced-choice observations made by COASSTers with the information being asked for through the new interface. The visual comparisons at the heart of the field guide informed the design of data fields and helped to remind the data management team what the COASSTers see when they are conducting a survey. The data fields within the database were evaluated to ensure that they would be both recognizable to the COASSTers and create a comprehensive representation of each recorded instance of a beached bird.

Outlining this process highlights the broad range of vernacular visual practices that are deeply embedded in the COASST data lifecycle. In extending well beyond activities typically associated with visualization work, this process challenges the siloed approach to visualization research often taken in academic domains [9], in favor of more inclusive and contextualized consideration of any activity that involves or generates a data-informed visual representation [10]. In this way, the richness of the COASST case encourages future work that continues to explore a range of visual activities associated with collaborative data practices, including both formal and informal techniques and literacies, in order to better understand the ways in which the process of representation influences what we do with data.

Evaluating vernacular visualizations

Embedded in the notion of vernacular practices is the idea that in non-expert contexts, individuals sometimes choose to make data-informed visual representations that differ in form or format from those vetted by expert information visualization practitioners. Vernacular and expert design contexts are often defined by divergent design requirements, evaluation criteria, and final outputs [19]. Viégas and Wattenberg use the word (or tag) cloud to illustrate these potential differences: “A tag cloud is truly a ‘vernacular’ technique – one that does not come from the visualization community, and that violates some of the golden rules of traditional visualization design” [56, p. 52]. While experts dismiss the word cloud for having “glaring theoretical problems” [56, p. 51], for many lay audiences, word clouds are enormously popular, support social engagement and are highly accessible [16]. This example points to potential disparities in criteria used by expert and non-expert audiences for not only evaluating the usefulness of different types of visualizations, but for design choices regarding the form and format of those representations. It also signals potentially different relationships with aesthetics, credibility, storytelling, and other practices associated with the representation.

In order to begin to explore these differences, one of the questions asked at the onset of this study concerned learning more about the ways in which COASST organizers assessed the effectiveness and value of visual resources and practices. This question proved to be more complicated to answer than anticipated.

For COASST, evaluations are typically grounded in formal protocols for assessing general environmental science learning outcomes [23], which are often a requirement of funding agencies like the National Science Foundation (NSF). When asked explicitly about the ways in which visual resources were evaluated, project organizers said that they did not do as much evaluation as they wanted and highlighted this as an important area of future work.

In comparison to their efforts to assess the COASST program as a whole, this is certainly true. However, there were a number of ways in which the project team responded to user needs, iterated on existing designs, and relied on visual resources to communicate and maintain the quality of data. These activities fell outside of what they considered “evaluation,” but nonetheless still provided insights regarding how visualizations were being received by different audiences. For example, one of the ways in which the visualizations included in training materials have been refined over the years is by paying attention to the type and quantity of questions received during a training session. A visualization that provoked too many of the wrong type of question was altered or removed. In this way, evaluation of visual resources was not entirely absent, but grounded in vernacular design practices that have evolved in response to lived experience.

At the beginning of this study, it was anticipated that visual artifacts were being used to prime and train volunteer participants to "see like a scientist," similar to mechanisms of professional and skilled vision discussed above [14, 15] and in accord with the mission of many citizen science programs that seek to educate the general public about science practice. Given this context, it is reasonable to expect that the value of a visualization could be assessed by measuring how well it helps COASSTers do science.

However, while visual representation of information does play an important role in the training of participants to make scientific observations, it also serves other important roles related to coordinating activities from beach to lab. The COASST visual field guides not only enable participants to see *like* a scientist, but they also enable participants to see *for* scientists by helping to keep hundreds of human sensing instruments (i.e., COASSTers) calibrated as they walk the beaches of the Pacific coast year in and year out. Law and Lynch [29] provide a related and rich description of the relationship field guides, lists, and calibrated vision have for birders. And data visualizations enable participants to see *along with* scientists in the lab, as in the case of the unfolding of the unprecedented Cassin's Auklet wreck event. Visual storytelling plays a significant role in COASST's work.

Within the COASST project, the type of "education of attention" [15] is not seen as interchangeable with the type of training a student of marine biology or environmental science receives. Here we see a slight departure from apprenticeship models of professional and skilled vision, where an individual is in training to acquire the visual tools and interpretive frameworks of an expert. A new COASST volunteer is not exactly trained to see like a scientist, but is trained to see *like a COASSTer* and in doing so becomes an essential member of a (citizen) scientific team. The cultivation of skilled vision provides the volunteer participant with a clear and distinct identity within the project team.

Orr highlights similar dynamics associated with heritage museums where skilled vision cultivated by long-term engagement with sites through docent work and other activities grants volunteers access to the museum social world [35]. Related, Vertesi's work examining the ways in which embodied visualization is used by the Mars Rover team highlights the role of visual salience and situated cues that contribute to the formation of a shared disciplinary schema [55]. Aspects of Grasseni's notion of skilled vision are also closely related to this type of identity work, highlighting the sense of belonging that comes from learning to see (i.e., recognize, notice, appreciate, interpret, discern, disambiguate) through eyes that have been calibrated to a specific practice [15]. While all of these identity-building activities rely on visual representation, none of the outcomes are easily evaluated or measured.

Reflecting a growing appreciation for these issues, there has been discussion within the academic information visualization community regarding the inadequacy of traditional approaches to evaluation, like time error, to measure the full range of activities associated with working with visual representations of information [25]. As a result, information visualization researchers have introduced a range of techniques for measuring a wider spectrum of the user experience, including: grounded approaches that lead to a situated understanding of contextual aspects of use (e.g., [21, 38]; reflections on the visualization design process (e.g., [4, 33]); placing focused attention on insight generation (e.g., [34, 62]) and sense-making processes (e.g., [11, 24]) over task completion; and evaluating the impact of a visualization on narrative interpretation (e.g., [20, 44]). This call by academic information visualization researchers for expanded evaluation techniques resonates with the vernacular work of COASST, highlighting an opportunity for CSCW to bridge these domains by focusing on the collaborative, communicative, and coordinated practices that seem to motivate many vernacular visualization practices.

CONCLUSION

Research looking at everyday design practices and the democratization of innovation indicates that deeper understanding of non-expert practices (in this case, referring to the practices of those not trained in information visualization or graphic design) can have a positive impact on technology development by introducing new, pragmatically driven approaches to coordinated work and communication among diverse communities of practice. This study has shown that vernacular visualization practices are a means for communicating, coordinating, and maintaining the quality of data within projects with diverse sets of contributors. Further, the adaptive design activities of the project organizers in this study are a rich resource for devising new approaches to the evaluation of systems, informal learning, and communication.

By focusing on non-expert visualization designers, this research surfaces opportunities for empowering individuals to engage with data on their own terms. Findings from this study, focused on one community of practice, provide empirical and methodological support for future comparative studies of vernacular visualization design practices. The cumulative results of this work will contextualize limitations of existing public-facing data tools and infrastructure and enhance requirements for new tools, while at the same time shedding light on new forms of data, visual, and technical literacies.

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