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# Collaboration Across Worldviews: Managers and Scientists on Hawai'i Island Utilize Knowledge Coproduction to Facilitate Climate Change Adaptation

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**Abstract**
Complex socio-ecological issues, such as climate change have historically been addressed through technical problem solving methods. Yet today, climate science approaches are increasingly accounting for the roles of diverse social perceptions, experiences, cultural norms, and worldviews. In support of this shift, we developed a research program on Hawai'i Island that utilizes knowledge coproduction to integrate the diverse worldviews of natural and cultural resource managers, policy professionals, and researchers within actionable science products. Through their work, local field managers regularly experience discrete land and waterscapes. Additionally, in highly interconnected rural communities, such as Hawai'i Island, managers often participate in the social norms and values of communities that utilize these ecosystems. Such local manager networks offer powerful frameworks within which to co-develop and implement actionable science. We interviewed a diverse set of local managers with the aim of incorporating their perspectives into the development of a collaborative climate change research agenda that builds upon existing professional networks utilized by managers and scientists while developing new research products. We report our manager needs assessment, the development process of our climate change program, our interactive forums, and our ongoing research products. Our needs assessment showed that the managers' primary source of information were other professional colleagues, and our in-person forums informed us that local managers are very interested in interacting with a wider range of networks to build upon their management capacities. Our initial programmatic progress suggests that co-created research products and in-person forums strengthen the capacities of local managers to adapt to change.

**Keywords** Adaptation · Climate change · Collaboration · Knowledge coproduction · Manager · Knowledge forms · Knowledge network · Resilience · Worldview

## Introduction

As ecosystem processes continue to shift worldwide at unprecedented rates resulting from human influences such as climate change, land-use change, and invasive species, there is a growing call for actionable science to mitigate these impacts and solve complex real-world problems (Asrar et al. 2013). Actionable science is science that can be used by decision makers and end users, such as natural resource managers, cultural resource managers, and policy professionals (henceforth collectively refered to as managers; Asrar et al. 2013; Beier et al. 2017). Creating actionable science and promoting awareness of end products, however, is not effective if the science is not getting used. One approach to promote the use of science in management and policy decisions is through knowledge coproduction. Knowledge coproduction is the collaboration between researchers and managers in all aspects of a project, including the development of research questions, study design, analysis, and ultimately the dissemination and application of the results (Meadow et al. 2015; Beier et al. 2017). While some studies refer to knowledge systems,

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partners, or stakeholder collaboratives (Cash et al. 2003; O'Brien and Selboe 2015; Beier et al. 2017), we utilize the term knowledge network to refer to the collective group of professionals that employ a knowledge coproduction process (Dilling and Lemos 2011; Bidwell et al. 2013; Parris et al. 2016).

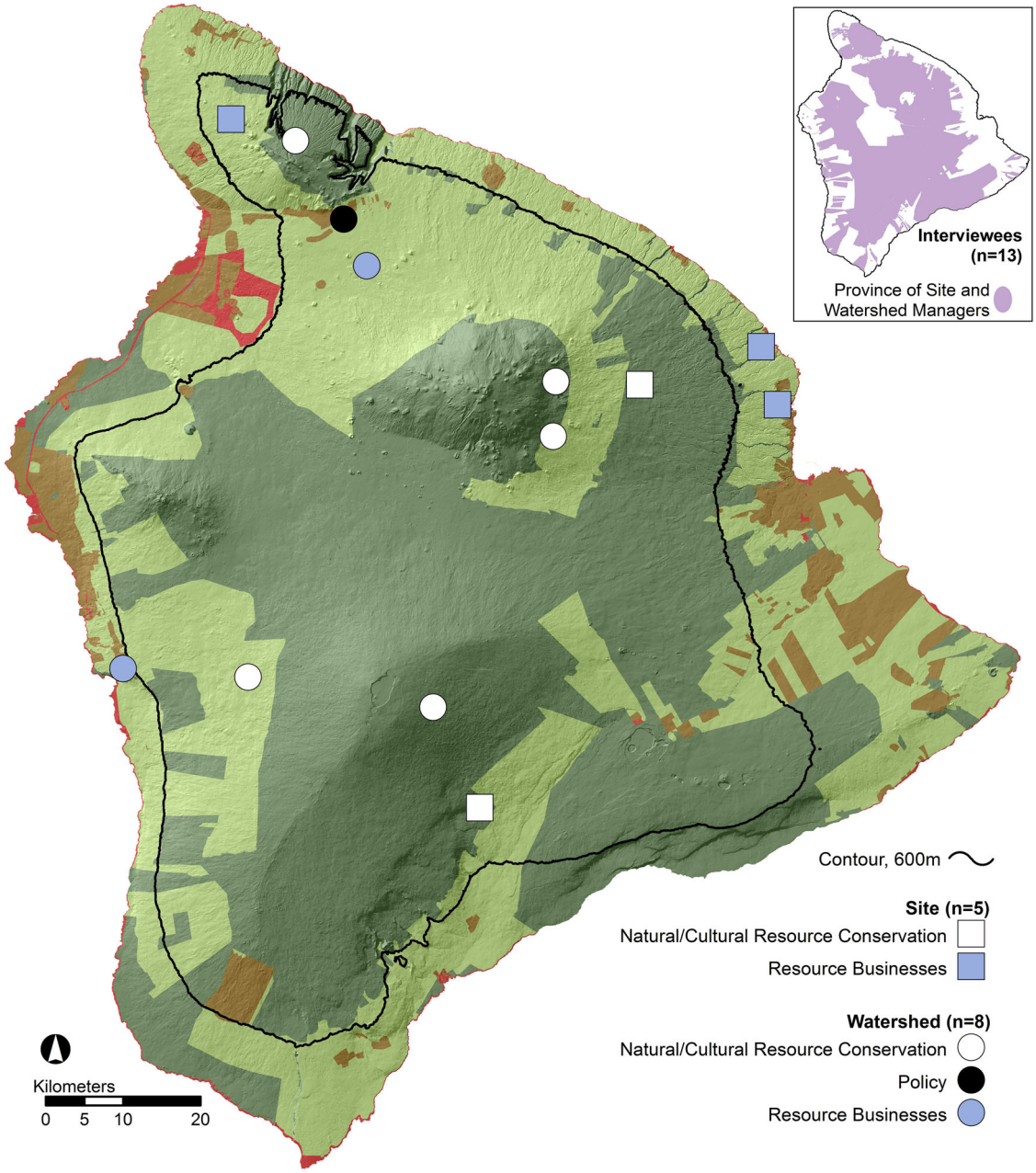
Due to perceptions of increased saliency, credibility, and legitimacy resulting from managers' involvement and their vested interest in research products, the knowledge coproduction process provides an effective mechanism through which to increase the likelihood of developing and implementing actionable science (Meadow et al. 2015; Beier et al. 2017; DeCrappeo et al. 2018). Yet manager engagement processes, such as knowledge coproduction, are highly underutilized and not well documented (Meadow et al. 2015; Kruk et al. 2017). Demonstrating knowledge coproduction in action, at both a project and programmatic level, addresses an existing knowledge gap (DeCrappeo et al. 2018). This paper, therefore, reports on the initial progress of an exploratory knowledge coproduction program developed within a university-community interface setting.

DeCrappeo et al. (2018) contend that developing forums where managers and researchers regularly interact increases the use of actionable science. Participatory methods, such as interviews, focus groups, and needs assessments are key to both identifying, and eventually engaging with, a knowledge network (Reed et al. 2009). While the tools and approaches utilized in knowledge coproduction vary widely, all methods share in common the central tenets of iterative, two-way collaboration and building long-term trust (Meadow et al. 2015). For example, in Hawai'i and other island communities in Oceania, researchers have collaborated with local leaders and community organizations as co-facilitators of heritage management (Genz et al. 2009; Kawelu and Pakele 2014). These research projects successfully establish collaborations based on in-person, two-way interactions among all network members, which develops the foundation for growing trust (Meadow et al. 2015). Similarly, in the field of natural resource management, ancient aquaculture practices are being restored at He'eia Fishpond on the island of O'ahu through a non-profit organization that unites university research networks directly with elders' long-standing knowledge of traditional land management practices (Hufana 2014:17–20).

The knowledge coproduction process fundamentally involves the integration of distinct worldviews (O'Brien and Selboe 2015: 8) and complementary knowledge forms, such as traditional ecological knowledge alongside knowledge derived from research science practice (Ingold 2011; Berkes 2012). Bridging distinct worldviews within a knowledge network stimulates wise reasoning (Brienza and Grossmann 2017) and rests on the recognition and effective integration of diverse ways of knowing, such as rational, analytical knowledge forms, and experiential, visceral knowledge forms (Dampney et al. 2002; Ingold 2011; Brown et al. 2012; O'Brien and Selboe 2015; van der Linden et al. 2015). At He'eia Fishpond on O'ahu, for instance, experiences in re-building the ancient fishpond wall combined with scientific experiments allows managers and researchers with diverse worldviews to work collaboratively, collectively address knowledge gaps, integrate diverse perceptions and practices, and thereby increase managers' capacities to adapt to complex socio-ecological challenges on the ground (Heifetz et al. 2009; Hufana 2014:17–20; O'Brien and Selboe 2015; Rist et al. 2016).

Interacting directly with the environments they oversee on a regular basis, managers' knowledge can be critical in actively developing and utilizing climate science for preserving natural resources (Dilling and Lemos 2011; Brown et al. 2012; Amel et al. 2017). Brown et al. (2012) point out that local managers function as "custodians of context" in the socio-ecological systems in which they are embedded. Their stewardship rests, in part, on integrating knowledge that is embodied–sensory experience, intuition, and perception of the environment. For example, Ingold (2011: 21) contends that the process of collecting and exchanging information does not increase our knowledge base. Rather, it is the capacity to situate information and understand its meaning within the context of direct experience that transforms information into knowledge. Informed by their regular experiences in their specific landscapes, local managers are often immediately and regularly accountable to a well-defined extent of land and/or water. Within highly interconnected rural communities, such as on Hawai'i Island (see study area section), this place-based context is taken a step further in that local managers also interact regularly with and are, thereby, accountable to the human communities that utilize the resources within the areas they manage. Such factors offer an interconnected setting within which to develop a program to efficiently implement actionable science that builds upon existing knowledge networks.

The Pacific Islands Climate Adaptation Science Center (PI-CASC) is one of eight U.S. Department of the Interior regional Climate Science Centers partnering with natural and cultural resource managers to develop science products promoting socio-ecological adaptation to climate change (Beier et al. 2017). The University of Hawai'i at Hilo (UH Hilo) arm of the PI-CASC university consortium is focused on building upon existing local relationships between researchers and managers to co-develop actionable science that addresses climate change with the aim of strengthening local managers' resilience and adaptive capacities through change. To achieve this end, managers and UH Hilo faculty, staff, and graduate students are engaged in an exploratory new knowledge coproduction program, called the Manager




| | Agriculture | Conservation | Open Area | Developed | All Classes (km²) |
|---|---|---|---|---|---|
| **Sea Level to 600 meters** | 18% | 8% | 1% | 5% | **32% ( 3,337.6)** |
| **Higher than 600 meters** | 22% | 45% | 0% | 1% | **68% ( 7,092.4)** |
| **Shore to Summit** | **40%** | **53%** | **1%** | **6%** | **100% (10,430.0)** |

**Fig. 1** County of Hawai'i General Plan Land Use Pattern Allocation Guide (current as of 2012) with centroids of land managed by interviewees, site (squares) and watershed (circles) scales, by manager type on Hawai'i Island, Hawai'i. 12 managers were islandwide or greater and are, therefore, not depicted in specific locations on this map. Inset showing area (63% of island acreage) managed by interviewed site- and watershed-scale managers. Data courtesy of interviewees, County of Hawai'i, State of Hawai'i Planning Office, and National Oceanic and Atmospheric Administration

Climate Corps (MCC; http://hilo.hawaii.edu/pi-casc/), to respond to a wide range of local ecosystem management needs. As we come to the end of the first cycle of funding through the PI-CASC, we share our program development process and the goals we aimed to achieve. Our first goal in this paper is to report the results of needs assessment interviews with managers across Hawai'i Island that initiated the MCC. Our second goal is to report the MCC's

current progress in utilizing these interviews to facilitate a diverse knowledge network on Hawai'i Island that strengthens the capacities of local communities to adapt to change through manager-driven research projects and interactive forums.

## Study Area

Hawai'i Island is a remote island encompassing 10,430 $km^2$ in the Central Pacific and rising from sea level to over 4200 meters (13,780 feet) in elevation (Fig. 1). The heterogeneous terrain is characterized by climate variability that drives a unique diversity of ecosystems and biota within close proximity. Trade winds and resulting orographic rainfall and cloud formation interact with a temperature inversion layer and island topography to form an island resembling a miniature continent (Juvik and Juvik 1998).

Climate change threats involve a wide range of impacts across the Hawaiian Islands. Some of these impacts include sea level rise (Marra et al. 2012; Leong et al. 2014; Reynolds et al. 2015) and an increase in storm intensity (Chen and Chu 2014; IPCC 2014) with decreasing and variable annual rainfall (Chu and Chen 2005) threatening human infrastructure and communities (IPCC 2014). Examples of climate change impacts on human communities include inundating storm and waste water systems (Rotzoll and Fletcher 2012; Habel et al. 2017), increasing coastal erosion (Vitousek et al. 2010; Fletcher et al. 2012; Anderson et al. 2015), threatening traditional Hawaiian cultural sites and cultural practices along the coast (Vitousek et al. 2010; Marrack and O'Grady 2014), and causing potential human health risks through shifts in near-shore water chemistry and bacteria levels (Strauch et al. 2014). Climate change will also impact ecological systems through increasing reef acidification (Anthony et al. 2008), shifting groundwater flows (Rotzoll and Fletcher 2012) altering nutrient flux into coastal and near-shore systems, increasing wildfire size and occurrence (Trauernicht et al. 2015; Frazier and Giambelluca 2016), altering forest community composition through invasive species colonization (Vorsino et al. 2014; Camp et al. 2018), and altering the distribution and abundance of native forest bird populations due to a rising mosquito-avian disease line (Atkinson et al. 2014; Liao et al. 2015; Paxton et al. 2016).

The majority of Hawai'i Island is zoned as agricultural or conservation lands (Fig. 1). Due to the rural nature of Hawai'i Island, individuals managing small landscapes or seascapes collectively have a disproportionate impact beyond the size of individual areas they manage, particularly in the lower elevation landscapes largely zoned for agriculture (Fig. 1). For instance, the 2012 Census for Agriculture in Hawai'i from the U.S. Department of Agriculture, National Agricultural Statistical Service (www.agcensus.usda.gov) revealed that of the 7000 farms and ranches in the state of Hawai'i, 4282 of these are on Hawai'i Island, and, of these, over half (2610 farms and ranches) range in size from one to nine acres. Additionally, a recent comprehensive state of Hawai'i mapping effort recognized that small producers are vital to sustaining the state's rural agricultural economy and, therefore, included farms and ranches down to three acres in size (Melrose et al. 2015; Perroy et al. 2016). Human communities within this rural island matrix are highly localized and interconnected, collectively experience a wide range of climate regimes, and are characterized by extensive histories of indigenous Hawaiian and immigrant cultures (McMillen et al. 2017).

# Methods

## Manager Selection

To create a foundation for UH Hilo manager-driven climate research efforts, we conducted a needs assessment of local managers to guide subsequent knowledge coproduction networking and research collaborations. We selected managers who are directly and regularly accountable to explicit areas of land, water, and the surrounding communities that utilize the managed natural resources. We targeted managers within a range of local spatial scales. At our largest scale, we selected interviewees whose positions are primarily focused on Hawai'i Island in its entirety, though two managers selected at this scale secondarily concentrate on the Hawaiian archipelago. Our smallest management scale was approximately five acres, which was included to incorporate the perspectives of small-scale managers in a largely rural landscape.

Similar to Tribbia and Moser (2008), we defined manager occupations broadly to include issues on safety, environmental protection, public infrastructure, and development of both terrestrial and marine resources. We pursued managers who experience effects of climate change in their local environments. This broad focus included a variety of organizations such as county, state and federal government, non-government organizations (NGO), and private land managers.

## Interviews

To understand individual managers' worldviews, staff within our MCC program at UH Hilo initially interviewed managers in different organizations and sectors who had a strong previous connection with us. Utilizing referrals from the first set of interviewees, we then identified additional individuals to interview. These pre-existing relationships enabled us to consistently locate individuals who were

**Table 1** Interview questions

| |
|---|
| (a) What is the personal and professional pathway that led you to your current position? |
| (b) How long have you been in your current position? |
| (c) Has the area you manage changed over the time you have held this position (stakeholders, policies, numbers of users on the land you manage, etc)? |
| (d) How have the above changes influenced or shifted the way you manage? |
| (e) Is your site affected by the ocean? If so to what degree? (e.g., not at all, some what, greatly) |
| (f) Is your site affected by mauka (upslope) activity? (e.g., not at all, somewhat, or greatly) |
| (g) Do you use science as a tool to help manage your area? In what way? |
| (h) Will the ability to adapt to change be important in your management area in the future? |
| (i) Is climate change science involved or considered in the development of your management plans? If so, to what degree and what are your sources for such information? |
| (j) What types of information, training, or products regarding resiliency and adaptation in the face of climate change impacts would be useful to you? |

interested in and comfortable in sharing their perspectives transparently. Rather than an exhaustive survey of individuals, this snowball sampling approach enabled us to locate, engage, and build upon existing professional networks (Browne 2005).

Using this snowball method, we conducted 25 semi-structured interviews in the summer of 2015 that involved a total of 29 different individuals. Four of the interviews involved two managers simultaneously. This made it difficult to effectively separate the integrated perspectives. Therefore, we treated each of these four interviews as a singular expression of perspectives.

To elicit managers' perceptions, values, needs, information sources, and the professional networks, we conducted semi-structured interviews based on 10 questions. These questions were sent in advance (Table 1), allowing the interviewee time to consider the subject matter of our inquiries. The interviews ranged in length between 30 min and 2.5 h. The questions were intentionally open-ended, and not all questions were covered in each interview to allow the conversation to develop according to the interviewee's priorities and perspectives. Each interview was at the manager's preferred meeting place with the exception of one phone interview. The interviews were audio recorded and transcribed.

We applied grounded theory to our interview transcripts to analyze key themes. This qualitative approach places significant emphasis on the interviewee's stated perceptions and experiences (Glaser and Strauss 1967; Hussein et al. 2014; Charmaz 2015). Rather than searching for pre-conceived concepts, this approach allows for the emergence of themes. Using line-by-line coding and memo writing, we coded and outlined specific themes identified from the interviews, summed themes according to the number of managers who described a given theme during the interview, and organized all themes within broader context categories. Additionally, we classified the type of manager (e.g., safety personnel; Fig. 2a, Appendix 1) and scale of areas managed according to spatial scale and the level of direct resource interaction (i.e., degree of connection with natural resources and human communities regularly affiliated with those resources; Fig. 2a).

### Developing Manager-based Research Projects

Our interview and analysis methodologies were exploratory in nature and focused on improving our understanding of managers' experiences and perspectives so that we could develop research projects in collaboration with university faculty and local managers. After completing the analysis of interviews, we invited all interested UH Hilo faculty and a selection of interview participants to attend a campus workshop in early 2016 led by our MCC team to discuss the interview results and identify faculty interested in collaborating with managers. We then released a formal university-wide call for research proposals to develop actionable science products with managers to address climate change impacts. Once research projects were selected and initiated, our program staff facilitated meetings involving all project partners and interacted regularly with graduate students, faculty advisors, and managers to ensure sustained in-person collaboration. Lastly, to support the newly established research projects and further build on knowledge networks, we planned and participated in forums to showcase each project while building awareness and skills in knowledge coproduction and to engage multiple knowledge forms across program and additional networks in attendance.

## Results

Our interviewees manage a geographic range across Hawai'i Island in roughly equal percentages of coastal and mountain systems (Fig. 1). The native species rich high-elevation systems are largely zoned for conservation land use, while the lower elevations are dominated by non-native species and have mainly centered on human land use (Fig. 1). The interviewees expressed wide-ranging management perspectives on native ecosystems (terrestrial and marine), traditional cultural sites and homelands, marine recreation, open ocean harvesting and transport, near-shore safety, ranching, agriculture, county- and community-based management, fire hazards, and invasive species.

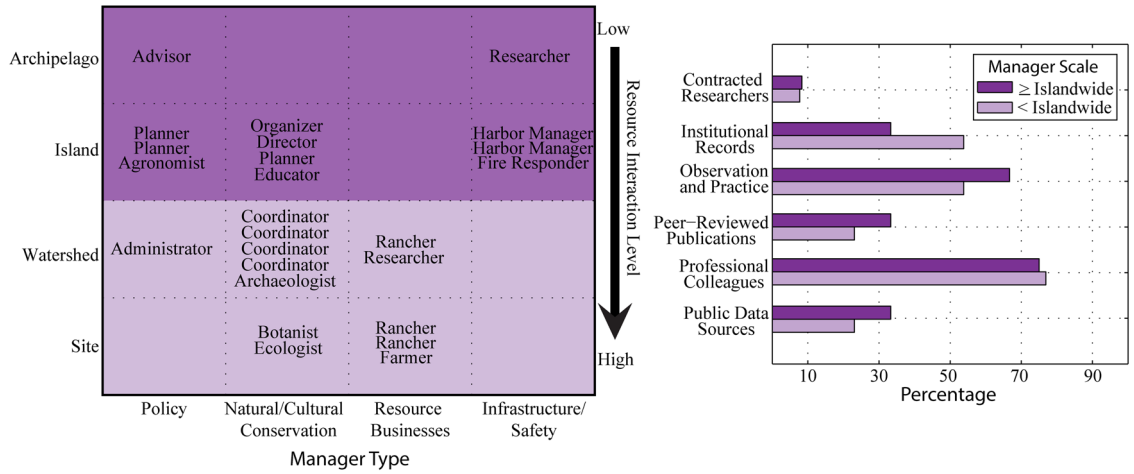



**Fig. 2** **a** Spatial representation of managers interviewed and **b** their knowledge sources as discussed in their interviews. 12 managers were focused on areas islandwide or greater, and 13 were focused on areas smaller than Hawai'i Island

We identified five broad categories from the interviews. Participants primarily discussed knowledge sources, goals, challenges, needs, and climate concerns. Each of these categories contained several sub-themes (totaling 46). A majority of interviewees identified the following sub-themes as important: (1) utilizing professional colleagues for information; (2) utilizing direct observation or practice; (3) investing in sustainable communities; (4) restoring and conserving traditional sites and ecosystems; and (5) increasing capacity for networking with other professionals.

## Interview Themes

### Knowledge sources

There were two main types of knowledge sources cited by participants. Nineteen managers described professional colleagues (e.g., scientists and local experts) as their most common source of knowledge (Fig. 2b). Anecdotal observations and field experiences were mentioned as a common source, as well as institutional records. These records include experimental field designs from unpublished techniques, collection of personal weather data to guide ranch practices, and the evaluation of restoration methods in remnant native ecosystems.

### Goals

The most common goals mentioned by managers are shown in Table 2. Directed by personal, business, or agency mandates, 16 of the 25 interviews explicitly stated a goal of working toward sustainable local communities. Our focus during the interview process was not to differentiate between the interplay of professional and personal motivations behind such responses. Though human communities were the overall priority, preserving natural communities was often described as a fundamental element of sustainability. The intersection between natural and human systems was also expressed in the second most common goal. Managers described this goal as the conservation and restoration of natural landscapes that sustain human communities and cultural, historical, and archaeological sites. Managers strive to involve communities directly in the lands and waters they manage by supporting recreation, restoration efforts, and food acquisition to increase personal experience, investment, and, ultimately, value in protecting natural resources. As an example of food acquisition, one interviewee operates a small family ranch primarily to allow the ranchers' children to "learn more about raising their own food and eating their own food. Men are butchering, wives make hamburger, and the kids help".

### Challenges

The bulk of the interviews focused on discussing challenges managers faced (Appendix 1, Fig. A1.1b). Impacts of environmental hazards such as invasive species, fire, and extreme weather events were universal issues for managers. For example, invasive species replace high quality forage for livestock, outcompete native species on reefs, create a public nuisance (e.g., little red fire ants), and threaten property and human health (e.g., downed non-native *Falcataria moluccana* tree limbs in hurricane winds). Invasive species can also alter fire return intervals and severity by increasing fuel loads and risk to human safety, infrastructure, and erosion. Other challenges included deficits of operational resources (e.g., money, staffing, site access, infrastructure, and sufficient information) and restrained efforts due to social and political pressures. Complications to efforts occurred when archaeological sites spanned more

**Table 2** Top five goal categories and examples expressed in manager interviews

| Goals | Examples |
|---|---|
| (a) Sustainable communities | Increasingly utilizing local goods and services |
| | Renewable energy projects, particularly wind power |
| (b) Conservation and restoration of natural landscapes that sustain human communities | Ranch and farm lands; promoting traditional Hawaiian farming practices |
| | Native ecosystem restoration efforts that are vital to traditional Hawaiian practices |
| | Sustainably harvested local timber |
| | Protecting sacred sites for native Hawaiian practice |
| | Restore and protect native Hawaiian archaeological sites |
| | Restore and protect historic sites |
| (c) Outreach | Teach sustainable resource use through community organizations |
| (d) Community-based management | Increasingly involving local and native Hawaiian perspectives in management plans |
| | Community watch programs that control poaching and unsustainable resource use |
| (e) Community involvement in managed lands/waters | Small group food acquisition such as hunting, fishing, gathering, hobby farms/gardens |
| | Recreation |

than one political boundary; pollution and sediment from landowners affected downstream occupants; conflicts developed between conservation and farming and ranching; and urban development degraded agricultural lands. One common bureaucratic pressure was the constant shifting of priorities from administrative and politically influenced offices, leaving many field managers pursuing perpetually fluctuating agendas.

### Needs

Managers expressed a strong need for increased networking opportunities across a diversity of professional disciplines and organizational levels. Traditional Hawaiian biogeographic land units, called ahupua‘a, were often suggested as management models within which to nest this networking interest across ecosystems (McGregor 1996). Additionally, managers mentioned a need to obtain knowledge from scientists that is usable in both subject scope and spatial-temporal scale, particularly in relation to climate change impacts.

### Climate science

Although climate change research did not play a prevalent role in the day-to-day operations of most managers, societal awareness of climate change impacts did. A number of managers recently became aware of climate change influences due to increased discussions of this topic within their professional networks and within popular culture. They expressed interest in learning how these impacts were predicted to affect their managed areas in the near future and desired assistance in prioritizing locations of high vulnerability to near-term impacts. Extreme weather events were of most concern. Managers made it clear that they would greatly benefit from information regarding localized shifts in storm frequency and intensity, sea level rise projections, and future temperature and rainfall regimes so they could plan to mitigate these impacts on cultural sites, reefs, and land.

## Uniting Manager and Researcher Networks

The knowledge coproduction workshop at UH Hilo was well attended with representation from diverse fields: anthropology, ecology, environmental economics, environmental engineering, geography, Hawaiian studies, marine sciences, and sociology. We presented the idea of collaboration and the goals of knowledge coproduction between faculty and local managers. Four managers described their programs and research needs related to climate change and adaptation. Roundtable discussions explored possible collaborative research projects, future workshops, and coursework development at the university. As a result of this workshop, MCC staff surveyed adaptation coursework at UH Hilo and began consulting with faculty members who are developing a professional master’s degree track within the Tropical Conservation Biology and Environmental Science (TCBES) graduate studies program at UH Hilo. Working with the TCBES executive committee has also led to MCC staff facilitating a graduate seminar on natural

resource management that engages local managers as weekly speakers.

### Initiation of Knowledge Coproduction

An additional direct result from the workshop was the UH Hilo PI-CASC funding of four research projects including five graduate students scheduled for completion in spring of 2018. Statements of interest received from faculty immediately after the workshop were thoroughly examined according to rigor of actionable research content and level of manager collaboration. Full proposals were requested from a subset of interest statements, and four proposals (involving five graduate students) were ultimately funded through the MCC. Each project incorporated knowledge coproduction and originated from ideas expressed in our interviews that were further developed during the faculty-manager roundtable discussions in the workshop. Research topics included: adapting to climate change impacts within traditional Hawaiian loko i'a (fishpond) systems by investigating marine and upslope (groundwater shifts) impacts; developing sustainable agriculture methods that buffer climate change impacts by utilizing invasive species management practices; projecting *Staphylococcus aureus* levels in near-shore recreation environments through predicted increases in storm intensity; and estimating coastal erosion rates of different substrate types around Hawai'i Island.

### Interactive Networking Forums

In August 2016, MCC staff and members of the research and management networks developed a three-night, four-day intensive climate change camp, bringing together a wide array of managers, scientists, and graduate students (https://hilo.hawaii.edu/pi-casc/ClimateChangeBootCamp.php). Knowledge coproduction, multiple ways of knowing, and place-based management were themes of the event. The camp took place outdoors amid rare, endemic forest species and showcased the four manager-led graduate projects as collaborative examples to other attending manager networks. The group discussed current and near-future needs for adapting to local climate change impacts. Post-event surveys indicated strong interest in advancing knowledge networks as mechanisms to build local capacities of resiliency, adaptation, and sustainability in the face of climate change. A film was produced from the four-day immersion experience and screened in 2017 at five local, regional, and national annual meetings involving different organizations to share the networking experience, including the Rising Voices symposium in Boulder, CO (April 13–15) and the National Adaptation Forum (May 9–11).

During the spring and summer of 2017, the MCC participated in three interactive knowledge coproduction forums at local, regional, and national conference sessions that involved both scientists and managers, including the University of Guam Island Sustainability Conference in Tumon, Guam (April 18–21), the National Adaptation Forum in St. Paul, MN (May 9–11), and the Hawai'i Conservation Conference in Honolulu, HI (July 18–20). These forums utilized a variety of formats (panels, small group discussions, slide presentations, and film) and were opportunities for managers, policy professionals, community leaders, graduate students, and researchers to interact in person. The MCC developed the forums in Tumon and in Honolulu. The MCC graduate projects were showcased as on-the-ground examples of knowledge coproduction within each forum. Drawing diverse backgrounds, the forums were unique opportunities for researchers and stakeholders to develop relationships, deepen understanding across worldviews, and expand their networks.

## Discussion

The MCC's program development process suggests that harnessing influential capacities of human behavior within person-to-person and person-to-nature relationships is a useful method for creating actionable science toward adaptation and resilience within manager-driven knowledge networks. Research in psychology has shown that humans do not make decisions according to predominantly or exclusively rational, analytical capacities. Rather, human behavior is more profoundly based upon intuitive affective (emotional) capacities that are driven by experience, group norms, values, perceptions, and intrinsic motivations that collectively define one's identity or worldview (Jones et al. 2011; Kahan et al. 2012; van der Linden et al. 2015; Jones et al. 2016; Amel et al. 2017). For instance, Kahan et al. (2012) make clear the powerful influence of personal interest, beliefs, and communal ties in their study which found that the sectors of society most scientifically literate and most proficient at technical reasoning are also the most culturally polarized regarding the severity of climate change impacts and their causes. Additionally, most scientists do not have formal training in communicating effectively to the lay person about topics such as climate change (Hassol 2008). For instance, Amelung et al. (2016) studied the "Summaries for Policymakers" (SPM) produced by the Intergovernmental Panel on Climate Change (IPCC 2014) and found the SPM to be unreadable to non-scientists, making it less effective in decision-making capacities. They recommended using approaches that convey salient information without adding detailed data. More centered on understanding of climate science in the Pacific, Cvitanovic et al. (2016) interviewed people from agencies and universities who had experience in food security in the Pacific

islands and concluded that there was a breakdown in knowledge exchange and issues with trust between scientists and Pacific islanders. They recommended participatory research such as knowledge coproduction, with particular attention to local experts, to increase the efficacy of climate adaptations. Complementing Cvitanovic et al. (2016), we interviewed managers focused on Hawai'i Island to better understand their needs. We took it one step further by building upon existing local professional networks to develop knowledge coproduction efforts within them.

Universities can increase local resilience and adaptive capacity in the context of climate change by progressively addressing the worldviews of the people who live and work in nearby lands and waters through the knowledge coproduction process (O'Brien and Selboe 2015). Our needs assessment of field managers was a first step to initiate a knowledge coproduction program focused on climate change adaptation across Hawai'i Island. Similar to Carrier et al. (2012), our initial programmatic steps gathered information from different manager sets (Appendix 1). Both Carrier et al. (2012) and our needs assessment concluded that natural resource managers in Hawai'i have a strong interest in opportunities to collaborate across disciplines and organizations.

Van der Linden et al. (2015) pointed out that local, personal, and present experiences and perceptions are critical drivers of human behavior and decision making. These perspectives are substantiated by our needs assessment, which revealed that managers collectively spend far more time focused on immediate or near-future events and projects than considering long-term scenarios that may occur in the next 50–100 years. For instance, ranchers described adjusting seasonal grazing rotations according to short-term weather patterns on the scale of weeks to months. Many managers we interviewed mentioned the need to be prepared for short-term severe events such as hurricanes, earthquakes, tsunamis, and fires. Our interviews also indicate that very few managers regularly utilize scientific data directly through peer-reviewed literature. Rather, person-to-person communication within their available knowledge networks is used to obtain information and resource support (Fig. 2b). We therefore suggest that broadening knowledge networks of local managers fundamentally increases their capacity to achieve sustainability goals (e.g., through extension services and programs such as the MCC).

Working from the foundation of manager interviews, the MCC is engaging in its second phase of development, which is to utilize the place-based experiences of local managers to advance UH Hilo research products, event programming, coursework development, and degree programs, which are all focused on directly supporting local manager networks through growing knowledge networks. The four MCC-funded graduate research projects have completed the first year of their two-year projects. Because these projects are funded for a finite time, we made sure all graduate students and their manager counterparts had established a relationship before the onset of the students' research. For example, one graduate student interned at a county department and worked closely with the managers now involved in the student's project. This prior relationship has been beneficial in maintaining trust as roles between managers, faculty, and graduate students have shifted. As the student transitioned into the leadership role in the graduate project, the existing manager and faculty relationships allowed the student to move the project forward rapidly, including building a graduate committee and efficiently developing a sound research proposal. Regular meetings and sustained interactions among MCC, community members, managers, faculty, and graduate students have helped to specify and advance the roles of each group participant.

Though the UH Hilo MCC graduate student research projects have not yet developed actionable science products, the project meetings and interactive forums utilized by managers, graduate students, and faculty have increased the likelihood that products will be readily applied at scales appropriate to the managers' needs. Some examples of project deliverables are: an analysis of historical rates of shoreline change and predictions of future impacts under rising sea level scenarios to inform county shoreline setback policies; predictions of how future shifts in hydrology may affect productivity at traditional fishponds; and a study of invasive species mulch applied to crops to aid the control of invasive forest canopies which threaten infrastructure during extreme wind events. The final study may also help local farmers mitigate climate change impacts through the utilization of sustainable composting practices. As part of the MCC program, all five graduate students within the four research projects have presented their work amongst managers and researchers within interactive forums at conferences and been highlighted in local media. These interactions allow the students to showcase their collaborative projects and receive valuable feedback from managers and researchers working elsewhere. These opportunities build stronger bridges between the university environment and local communities across the Pacific region, offer additional insight into developing actionable products for managers, and can be used as examples for other university communities and managing organizations.

Fundamental to decision making, the norms and values of local communities across Hawai'i Island are place-based and, therefore, may be distinct from worldviews in other locations (McMillen et al. 2017). In light of this, although some themes from our manager assessments will likely resonate with managers in other locations, we suggest that the iterative process of knowledge coproduction is equally,

if not more, widely applicable to other locations. A critical component to this process is focusing on sustained relationships between end users and those who intend to create actionable science. As resource manager networks increasingly engage with the TCBES graduate program at UH Hilo, through manager-driven research, coursework involving managers, and the new professional masters degree track within TCBES, relationships between local managers and research faculty will continue to grow into the long-term. The process of building and strengthening relationships must be a sustained priority above a stand-alone dataset, toolkit, software package, idea, or needs assessment in a given window of time (Beier et al. 2017). It is clear that natural resource managers in Hawai'i and the broader Pacific are drawing from their local worldviews to confront the emerging challenges of climate change. We argue that developing collaborative approaches between academic institutions and local professional networks increases managers' adaptive capacity to address climate change issues.

## Conclusion

Building resilient, adaptive, and sustainable communities requires shifting from a focus on data distribution and technical problem solving to creating stronger in-person relationships with each other, with basic life essentials (food, water, and shelter), and with other species (Abram 1996; Amel et al. 2017). When founded in the meaningful acknowledgement of diverse worldviews, in-person knowledge networks can lead to behavior change and more effectively address adaptive challenges (Adger et al. 2009; Heifetz et al. 2009; O'Brien and Selboe 2015; Amel et al. 2017; Brienza and Grossmann 2017). If knowledge producers aim to significantly influence human behavior (i.e., action), it is imperative that they directly and iteratively engage the worldviews of interdisciplinary research teams, field managers, policy professionals, cultural practitioners, and local communities, while engaging the full range of knowledge forms that guide human decision making within such knowledge networks. Our knowledge coproduction program on Hawai'i Island attempts to address climate change impacts by developing collaborative research efforts and recognizing and supporting knowledge exchanges through in-person networking opportunities. If we are to create adaptive and resilient communities, a transformation of science, management, and society is required well beyond simply adapting to climate change (O'Brien and Selboe 2015; Amel et al. 2017; Beier et al. 2017). Climate change adaptation is an entry point for much broader and deeper social transformation, which can begin by making seemingly small yet potent steps. In this paper we report on a program development process attempting to support such transformation through the facilitation of collaborative knowledge networks.

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## Compliance with ethical standards

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Conflict of interest** The authors declare that they have no conflict of interest.

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