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Insight

Collaborative research to inform adaptive comanagement: a framework for the He'eia National Estuarine Research Reserve

Kawika B. Winter[1,2,3,4], Yoshimi M. Rii[1,2], Frederick A. W. L. Reppun[1,2], Katy DeLaforgue Hintzen[2,5], Rosanna A. Alegado[5,6], Brian W. Bowen[1], Leah L. Bremer[7,8], Makena Coffman[9], Jonathan L. Deenik[10], Megan J. Donahue[1], Kim A. Falinski[11], Kiana Frank[12], Erik C. Franklin[1], Natalie Kurashima[13], Noa Kekuewa Lincoln[10], Elizabeth M. P. Madin[1], Margaret A. McManus[6], Craig E. Nelson[5,6,14], Ryan Okano[15], Anthony Olegario[15], Pua'ala Pascua[16], Kirsten L. L. Oleson[3], Melissa R. Price[3], Malia Ana J. Rivera[1], Kuulei S. Rodgers[1], Tamara Ticktin[17], Christopher L. Sabine[6], Celia M. Smith[17], Alice Hewett[18], Rocky Kaluhiwa[19], Māhealani Cypher[20], Bill Thomas[21], Jo-Ann Leong[1], Kristina Kekuewa[22], Jean Tanimoto[21], Kānekoa Kukea-Shultz[18], A. Hi'ilei Kawelo[23], Keli'i Kotubetey[23], Brian J. Neilson[15], Tina S. Lee[21,24] *and* Robert J. Toonen[1]

ABSTRACT. Globally, an increasing recognition of the importance of ecosystem-based management (EBM), Indigenous resource management (IRM), and Indigenous-led research and management is emerging; yet, case studies within scholarly literature illustrating comprehensive application of these theories and philosophies are scarce. We present the collaborative management model for the He'eia National Estuarine Research Reserve (NERR) as a contemporary Indigenous Community and Conserved Area (ICCA) that has synergistically operationalized these principles, as well as one that approaches research as a reciprocal collaboration with the Indigenous people and local community (IPLC) of place. The He'eia NERR was designated in 2017 through a process led by IPLC members in Hawai'i. This research framework is aimed at informing EBM within social-ecological systems. It, therefore, serves as an example of a program designed to demonstrate and provide practical solutions for adaptive resource management. The framework of the He'eia NERR embraces the values, perspectives, and IRM strategies that have been foundational for the people of the Pacific to thrive sustainably in the context of limited resources for millennia. As a program, the He'eia NERR aims to build bridges between coexisting worldviews as a means of informing policy in the realms of conservation and sustainability. We do this by weaving together conventional and Indigenous science to collaboratively develop research and collaboratively produce new knowledge. We examine these issues through the lens of holistic ecosystem services that consider both the reciprocal benefits that humans provide to nature as well as the full range of existential benefits that humans gain from nature. Research collaborations between the He'eia NERR and its partners (University of Hawai'i, state and federal agencies, and Indigenous-led NGOs operating in the community) are grounded in Indigenous and local knowledge (ILK) with applications that will guide a future of enhanced ecosystem services in a changing world.

Key Words: *ecosystem-based management (EBM); Indigenous and community conserved area (ICCA); Indigenous and local knowledge (ILK); Indigenous people and local community (IPLC); Indigenous resource management (IRM); Indigenous science; National Estuarine Research Reserve System (NERRS); reciprocal collaboration*

INTRODUCTION

The conventional discourse in environmental science and conservation biology has portrayed humans as separate from nature and has depicted human actions as inherently disruptive to healthy ecosystem function (e.g., Soulé 1985, Terborgh 2004). However, these conventional notions of conservation are philosophically founded, at least in part, in racist perspectives that viewed native people as blights on nature that needed to be purged in order to attain a pristine wilderness (Kashwan 2020). These foundational philosophies have subsequently led to institutional approaches to conservation that aim to restrict human presence in an attempt to create pristine nature separate from human influence. Such an approach, however, often happens at the expense of displacing Indigenous people (Guha 1989, Nelson and Callicott 2008). Reactional approaches, such as fortress conservation, which holds that biodiversity protection is best achieved by creating protected areas in which ecosystems can function in isolation from human disturbance, serve to perpetuate the perceived need to protect nature from humanity (Wilshusen et al. 2002). Although this has been cited as a rationale for creating nature reserves across the globe, the end results of such approaches often fall short of overall conservation goals (Laurance et al. 2012, Dominguez and Luoma 2020).

In contrast to conventional thinking, disciplines such as Indigenous studies and political ecology challenge mainstream

[1]Hawai'i Institute of Marine Biology, University of Hawai'i at Mānoa, [2]He'eia National Estuarine Research Reserve, Hawai'i, [3]Natural Resources and Environmental Management, University of Hawai'i at Mānoa, [4]Hawai'i Conservation Alliance, [5]University of Hawai'i Sea Grant College Program, [6]Department of Oceanography, University of Hawai'i at Mānoa, [7]University of Hawai'i Economic Research Organization, University of Hawai'i at Mānoa, [8]Water Resources Research Center, University of Hawai'i at Mānoa, [9]Institute for Sustainability and Resilience, University of Hawai'i at Mānoa, [10]Tropical Plants and Soil Sciences, University of Hawai'i at Mānoa, [11]The Nature Conservancy, Hawai'i , [12]Pacific Biosciences Research Center, Kewalo Marine Lab, University of Hawai'i at Mānoa, [13]Natural and Cultural Resources, Kamehameha Schools, [14]Daniel K. Inouye Center for Microbial Oceanography: Research and Education, [15]Division of Aquatic Resources, Department of Land and Natural Resources, Hawai'i , [16]Center for Biodiversity and Conservation, American Museum of Natural History, New York, [17]School of Life Sciences, University of Hawai'i at Mānoa, [18]Kākoʻo ʻŌiwi, [19]Koʻolaupoko Hawaiian Civic Club, [20]Koʻolau Foundation, [21]Office for Coastal Management, National Oceanic and Atmospheric Administration, Honolulu, Hawai'i, [22]Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration, Hawai'i, [23]Paepae o He'eia, [24]Lynker LLC

conservation strategies by centering people as an inseparable part of nature (Escobar 1998, McGregor et al. 2003, Adams and Hutton 2007, Berkes 2018). Indigenous peoples have histories spanning millennia across a vast majority of Earth and have managed landscapes that allowed human societies and nature to thrive together (Denevan 1992, Zimmerer 2006, Robbins et al. 2015, Garnett et al. 2018). Though our current geological age, the Anthropocene, is defined as beginning when the collective activities of humans influenced earth systems (Crutzen 2006, Lewis and Maslin 2015), and the global market economy is the primary contributor to anthropogenic climate change (IPCC 2018), it is critical to acknowledge that not all human activity negatively affects biodiversity and ecosystem function; Indigenous peoples being the prime example of that alternative notion (Berkes 2018, Winter et al. 2020*a*). Many Indigenous resource management (IRM) strategies and practices are intended to enhance ecosystem processes (e.g., productivity) and services, including biodiversity and species abundance, as a means to increase system resilience (Berkes 2018, Winter et al. 2020*a*). Therefore, Indigenous peoples and local communities (IPLCs) that perpetuate these practices provide valuable examples for examination (Ban et al. 2018, Eckert et al. 2018, Howitt 2018). Additional research into such approaches can inform policy and management actions to meet contemporary challenges.

Conservation and sustainability policies are often contextualized in terms of ecosystem services, yet that framing has been criticized for depicting a one-way flow of benefits to humans and for characterizing human-nature interactions as transactional (Schröter et al. 2014). Rather than abandon the ecosystem services framework, we advocate for a more holistic and relational definition of ecosystem services that acknowledges reciprocal human-nature relationships and encompasses the full range of existential benefits, such as cultural, psychological, physiological, spiritual, aesthetic, recreational, socioeconomic, and natural aspects (Pascual et al. 2017). Adopting a holistic approach aligns with other comprehensive views that describe the reciprocal relationships between people and ecosystems, as embraced by various cultures, IPLCs in particular (Comberti et al. 2015, Winter 2020*a*), and with scholarship advocating for a more dynamic view of ecosystem services in multiple decision-making policy arenas (cf. Chan et al. 2016, Pascua et al. 2017, Díaz et al. 2019). Furthermore, a more holistic interpretation of ecosystem services provides a viable lens through which we can examine both conservation (e.g., habitat loss and extinction) and sustainability (e.g., food and energy systems, and climate adaptation) issues, as well as their interactions. With this intersection in mind, much remains to be learned from the cultural paradigms of isolated island cultures, societies, and civilizations who either thrived or failed, in the context of bounded resources and invasive species, based on the sustainability of their management practices. Examples of sustainable island management practices in this context include Rapa Nui (Hunt and Lipo 2011) and Hawai'i (Abbott 1992, Jokiel et al. 2011, Kurashima et al. 2019), the latter being the focus of this paper.

Over the past forty years, considerable effort has been undertaken to restore the health and function of Hawaiian social-ecological systems (IUCN 2016, Chang et al. 2019*a*, Winter et al. 2020*a*). These efforts have been undertaken by local communities reclaiming agency over Indigenous legacy lands and re-establishing their connections to the land in the face of urbanization (McGregor-Alegado 1980, Goodyear-Ka'ōpua et al. 2014, Kubota 2018). More recently, applied research on diverse topics such as habitat and biodiversity protection (Friedlander et al. 2002, Jokiel et al. 2011, Burnett et al. 2018), core watershed function (Winter and Lucas 2017), agroecology (Lincoln et al. 2018, Winter et al. 2018*a*, Kurashima et al. 2019), aquaculture (Summers 1964, Kikuchi 1976, Costa-Pierce 2008), fisheries management (Poepoe et al. 2003), coral reef health (Bahr et al. 2015), community engagement (Matsuoka et al. 1998), and Indigenous resource management (Kurashima et al. 2018, Winter et al. 2018*a*, *b*) have supported such community efforts.

Despite the growing body of research and local-level examples demonstrating the viability of human-in-nature approaches to conservation, policies at multiple levels of government have yet to fully embrace this approach (Sterling et al. 2017). Thus, collaborative partnerships between resource managers and researchers are necessary to conduct applied research (Gavin et al. 2018). In Hawai'i, collaborative partnerships can inform policies guiding the restoration and adaptive management of Hawaiian social-ecological systems (sensu Winter et al. 2018*b*) in the context of these modern challenges (Ayers et al. 2018). The Hawaiian concept of *'āina momona* (Kamakau 1976, Andrade 2008), meaning a state of sustainable resource abundance, has increasingly become central to this discussion (Chang et al. 2019*a*, *b*).

Contextualizing ecosystem-based management research within Hawaiian social-ecological systems

Like other Pacific Island cultures, Hawaiian society developed IRM norms centered on natural resource limitations inherent to living on high volcanic islands (Fisher 2015). Seminal publications in the realm of Hawaiian IRM have synthesized the broad array of Native Hawaiian authors who documented Indigenous philosophies and practices in the Hawaiian language during the 19th and 20th centuries (Handy et al. 1992, Maly and Maly 2003). These works highlight foundational elements of Hawaiian IRM, such as the inseparable connection between people and place, the connection between the mountains and the sea, the importance of stratified land divisions that facilitate decentralized resource management, and the roles that sacred designations of places and species played in ensuring a sustainable abundance of resources. Hawaiian IRM (hereafter, Hawaiian resource management) adaptively managed the population dynamics and connectivity of key resource species at the habitat level (Winter et al. 2018*b*), and employed various forms of ecomimicry (sensu Winter et al. 2020*a*) such as habitat engineering in agroecology systems, which mimics natural disturbance regimes to increase the productivity within landscapes, to attain the state of *'āina momona*. The Hawaiian civilization that persisted under this system was one of the resource-bound, island societies documented to live sustainably for centuries while maintaining a large human population (Kittinger et al. 2011, Bahr et al. 2015, Winter et al. 2018*a*), even in the face of geometric population growth (Dye and Komori 1992).

Notably, there is no evidence of significant decline in marine resources throughout the centuries preceding colonization

(Kittinger et al. 2011). Occasional famine has been noted in the precolonial period and linked to temporary climatic shifts (Dye and Komori 1992, Chinn et al. 2014, Winter et al. 2018*b*). Local declines in fish stocks were, however, documented during the colonial period. For example, severe deficiency of fish observed in the 19th century was attributed to ineffective management (Ellis 2004). Cumulatively, these data suggest that states of resource abundance can be tenuous and susceptible to unpredictable changes in environment, and further that careful management of resources is required to prevent overharvest, and to persist through and rebound from episodic changes in climate. In contrast to the vast majority of the prior millennium, in which 1.2 million people could have been sustainably fed without imported resources (Abbott 1992, Kurashima et al. 2019), Hawai'i's current population of 1.4 million people imports over 90% of its food, a notably unsustainable scenario (Jokiel et al. 2011, Loke and Leung 2013). This supports the notion that much can be learned from Indigenous and local knowledge (ILK) when it comes to sustainability in the context of limited resources.

Over the past 150 years, market-based approaches to resource management, born from a worldview that sees humans as separate from nature, have replaced the island-adapted practices of an IRM model that is based on the relationship between people and place (Winter et al. 2018*b*). This period coincided with substantial declines in ecosystem services (e.g., abundance of key resource species) that are most obvious around urban population centers (Jokiel et al. 2011); a trend observed throughout the Pacific region (Johannes 1978). The observable decline in ecosystem services, experienced over the lifetimes of individuals raised in the tradition of *ʻāina momona*, has prompted many community-based groups to revitalize IRM and re-establish it as a solution to issues of sustainability (Minerbi 1999, 2001, Andrade 2008). This has been tangibly accomplished by creating contemporary Indigenous and community conserved areas (ICCAs; sensu Berkes 2009*a*) that are supported by collaborative management agreements with government agencies (e.g., Delevaux et al. 2018). In these continuing efforts, communities seek to learn from the past to better manage natural resources. Thus, the global movement toward ecosystem-based management (EBM; Rodriguez et al. 2011) is particularly welcome and familiar among Pacific Islanders, who have managed resources accordingly to thrive within social-ecological systems for millennia (Winter et al. 2020*a*). The basic premises of EBM are to: prioritize the health and function of the entire ecosystem over the needs of any individual activity or special interest group; be place-based with natural boundaries; account for multiple interactions, and how human actions both within and outside the place can influence or be influenced by management; integrate the concerns of the environment, society, economy, and human institutions; consider humans as part of the system and maintain access to the broad array of ecosystem services; and provide a mechanism for participation and coordination among all responsible entities (McLeod and Leslie 2009). Despite widespread consensus on the general tenets of EBM, questions remain about what exactly constitutes EBM as an explicit adaptive management strategy to increase a holistic set of ecosystem services. This has presented challenges for the attempts to create policy that supports the implementation of EBM through existing governance and economic structures (Levin and Möllmann 2015, Prellezo and Curtin 2015). The goal of this concept paper is to establish a framework for the collaborative development of research and the subsequent collaborative production of new knowledge that can inform policy and practice regarding adaptive EBM in Hawai'i and beyond, using the He'eia National Estuarine Research Reserve (NERR) as an illustrative case.

On language and terminology

Globally, Indigenous languages play an important role in biodiversity conservation (Maffi 2005, Gorenflo et al. 2012, Wilder et al. 2016). The same is true in Hawai'i where Hawaiian language terms are essential to discussions around IRM and EBM to convey nuances in meaning to IPLCs that are not sufficiently characterized by English language translations. For example, although the Hawaiian word *pono* lacks a suitable direct English language translation, *pono* can be interpreted as referring to actions that are appropriate, correct, balanced, and deemed necessary by traditional standards in the Hawaiian culture (Gould et al. 2019). Hawaiian language terminology is increasingly being incorporated within collaborative management plans and policies between Native Hawaiians and both federal and state agencies (e.g., the Papahānaumokuākea Marine National Monument Management Plan). The He'eia NERR also uses Hawaiian terminology in reference to Indigenous perspectives and management practices to convey those nuances, and is committed to doing so in a way that honors the terminology and that protects against cultural appropriation meant to suit outside interests. The He'eia NERR research framework, therefore, requires some working knowledge of a Hawaiian worldview and of traditional standards in Hawaiian culture.

Furthermore, the words tradition/traditions/traditional are used herein to refer to customary cultural norms and values in Hawai'i, and the traditional and customary practices of Native Hawaiians protected in the state constitution and other bodies of law (Akutagawa et al. 2016*a*, *b*). Although we recognize the history associated with such terminology and its use as tools of colonization to inhibit the evolution of Indigenous cultures, in Hawai'i, it is currently the commonly accepted terminology among IPLC members. We use this terminology where appropriate while acknowledging that traditional practices are adaptive and evolve over time.

Collaborative management in the He'eia National Estuarine Research Reserve

Comanagement efforts between IPLCs and government agencies have not always been successful, especially where government agencies have imposed designations that restricted human activity first, and then attempted to engage IPLCs in comanagement as a secondary process. Examples of this are some Marine Protected Areas (MPAs) and National Parks (Coombes and Hill 2005, Singleton 2009, Ross et al. 2011). However, there is a range of comanagement approaches that includes "cooperative management," "community-based management," and "collaborative management," with each iteration existing on a scale of a power differential between communities and government. Of these, we advocate for collaborative management that empowers IPLCs, and that mutually honors both Indigenous and conventional knowledge systems and approaches (Tipa and Welch 2006). This form of comanagement has long-been recognized as an effective approach to conservation and sustainability (Carlsson and Berkes 2005,

Berkes 2009*b*). The long-term success of collaborative management arrangements, however, relies heavily on the design process; for instance, recognizing the importance of free, prior, and informed consent from IPLCs in advance of implementing human activity regulations or restrictions, and ensuring that equitable collaborative management is indeed a primary goal of the management area.

In He'eia, on O'ahu Island, Hawai'i, in the context of a larger Hawaiian renaissance (Gon and Winter 2019), an Indigenous-led contingent set out to engage government entities to support the creation of a contemporary ICCA through a collaborative management agreement. Native Hawaiian elders (*kūpuna*) and other community leaders advocated for a collaborative management model that would support the IPLC's interests, and they selected the National Estuarine Research Reserve System (NERRS) as the one best structured for those purposes (Hawai'i Office of Planning 2016). The NERRS is a network of coastal sites designated to protect and study estuarine systems, established through the Coastal Zone Management Act. Each reserve is collaboratively managed by a state agency that acts as a program administrator, and the Office for Coastal Management (OCM) within the National Oceanic and Atmospheric Administration (NOAA). Unlike NOAA's sanctuary designation, a type of MPA which typically identifies no-take marine protected areas, the reserve designation does not necessarily regulate human activity within its reserve boundaries. Rather, it is a collaborative management arrangement that operates within existing state laws and local ordinances. The He'eia NERR is unique in the national system specifically because its designation process was IPLC driven and was undertaken to support an existing ICCA. It, therefore, represents a true collaborative management effort that engages the IPLC of place rather than one that is limited to an agreement between federal and state governments.

The He'eia NERR was designated in Hawai'i in 2017 as the 29th reserve in the national system, with the state partner being the University of Hawai'i at Mānoa (UHM). The University of Hawai'i system, as a designated Land Grant, Sea Grant, and Space Grant Institution, has a committed responsibility to public service and outreach. The He'eia NERR, as a part of that system, operates within this context. It has no regulatory purview over land or sea itself, but its site partners have committed to collaboratively managing this area, which covers 560 hectares (1385 acres; Fig. 1). The Reserve is organizationally administered through the Hawai'i Institute of Marine Biology (HIMB), which itself is a part of UHM's School of Ocean and Earth Science and Technology (SOEST). The He'eia NERR is physically located in the region of Ko'olaupoko, in a place traditionally called Ka-waha-o-ka-manō, but now commonly referred to as Kāne'ohe Bay. There are several ecosystem-scale habitats (including forests, streams, wetlands, riparian areas, an estuary, and coral reefs) within the He'eia NERR boundaries. The reserve is situated within a community of mixed human demographics with more than two-thirds of these being IPLC residents born in Hawai'i. This local community is composed mainly of Native Hawaiians and the descendants of immigrants from Western Europe, North America, and the Asia-Pacific region (Hawai'i Office of Planning 2016).

Native Hawaiian self-governance is not legally recognized by either federal or state governments, but the He'eia NERR has designed pathways for Native Hawaiians to participate in the governance of the reserve. Native Hawaiian representation in the collaborative management agreement is formally held by Hawaiian-led, nonprofit organizations operating within the larger region, and those who demonstrate their management authority through active stewardship practices within the boundaries of the reserve specifically. This collaborative management agreement exists between the seven entities who led the designation process for the reserve (Table 1), each of whom is now recognized as an official collaborative management partner and plays a role in the reserve governance via a seat on the reserve's advisory board. Although not a resource managing entity in and of itself, the He'eia NERR facilitates collaborative management among its site partners and provides support for restoration efforts. Its role within this context is to lead and conduct research in collaboration with the IPLC of He'eia in a larger effort to inform adaptive comanagement among the site partners in the reserve. There are several examples from around the globe of IPLCs participating in collaborations aimed at better understanding how ILK, along with ancestral perspectives, technologies, and practices, can contribute to solving various problems that threaten the health, function, and resilience of the social-ecological systems in which they live (Kirkness and Barnhardt 2001, CIDA 2002, Fisher and Ball 2003, ISE 2006, Berkes 2009*b*, CTKW 2014, Smith 2015). The He'eia NERR serves as a model of such a collaboration, with its designation process being led by the IPLC of the associated place. Salient issues in the overlapping realms of conservation and sustainability have been at the forefront of these collaborations. The various outputs of He'eia NERR will contribute to a growing body of knowledge about adaptive comanagement across the United States and around the world.

Fig. 1. The boundaries of the He'eia National Estuarine Research Reserve (NERR) in the region of Ko'olaupoko on the Island of O'ahu.

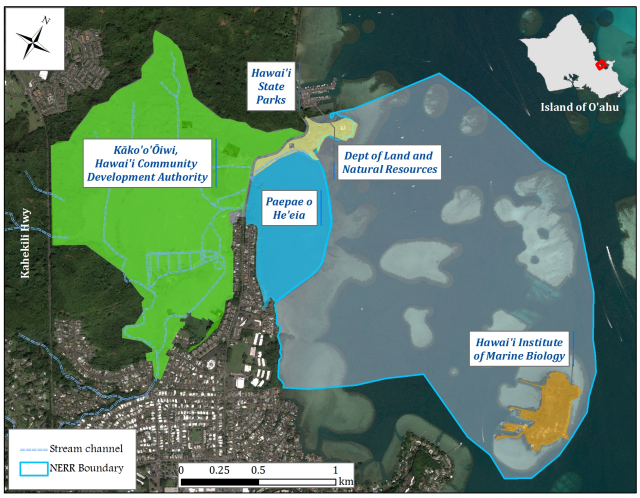


Table 1. The seven collaborative management partners of the Heʻeia National Estuarine Research Reserve and their respective organizational classifications. Each of these site partners holds a seat on the Heʻeia NERR's Advisory Board, and thus plays a role in the reserve's governance.

Collaborative management partner	Organizational classification	Focus and scope
Koʻolaupoko Hawaiian Civic Club	Hawaiian-led, nonprofit organization	Civic engagement within the region
Koʻolau Foundation	Hawaiian-led, nonprofit organization	Community-based efforts within the region
Kākoʻo ʻŌiwi	Hawaiian-led, nonprofit organization	Restoration of sustainable Indigenous agro-ecology in the reserve
Paepae o Heʻeia	Hawaiian-led, nonprofit organization	Restoration of sustainable Indigenous aquaculture in the reserve
Hawaiʻi Institute of Marine Biology (HIMB)	Research unit of University of Hawaiʻi at Mānoa (UHM)	Research and training in tropical marine biology, biodiversity, and conservation (physically located within the reserve)
Department of Land and Natural Resources (DLNR)	Agency within the State of Hawaiʻi government	Management (rules, regulations, and enforcement) of lands and waters outside of urban, residential, and agricultural areas
Hawaiʻi Community Development Authority (HCDA)	Public entity created by the Hawaiʻi State Legislature	Establishes plans for community development districts (holds the title to the land upon which Kākoʻo ʻŌiwi operates)

A FRAMEWORK FOR COLLABORATIVE RESEARCH IN HEʻEIA

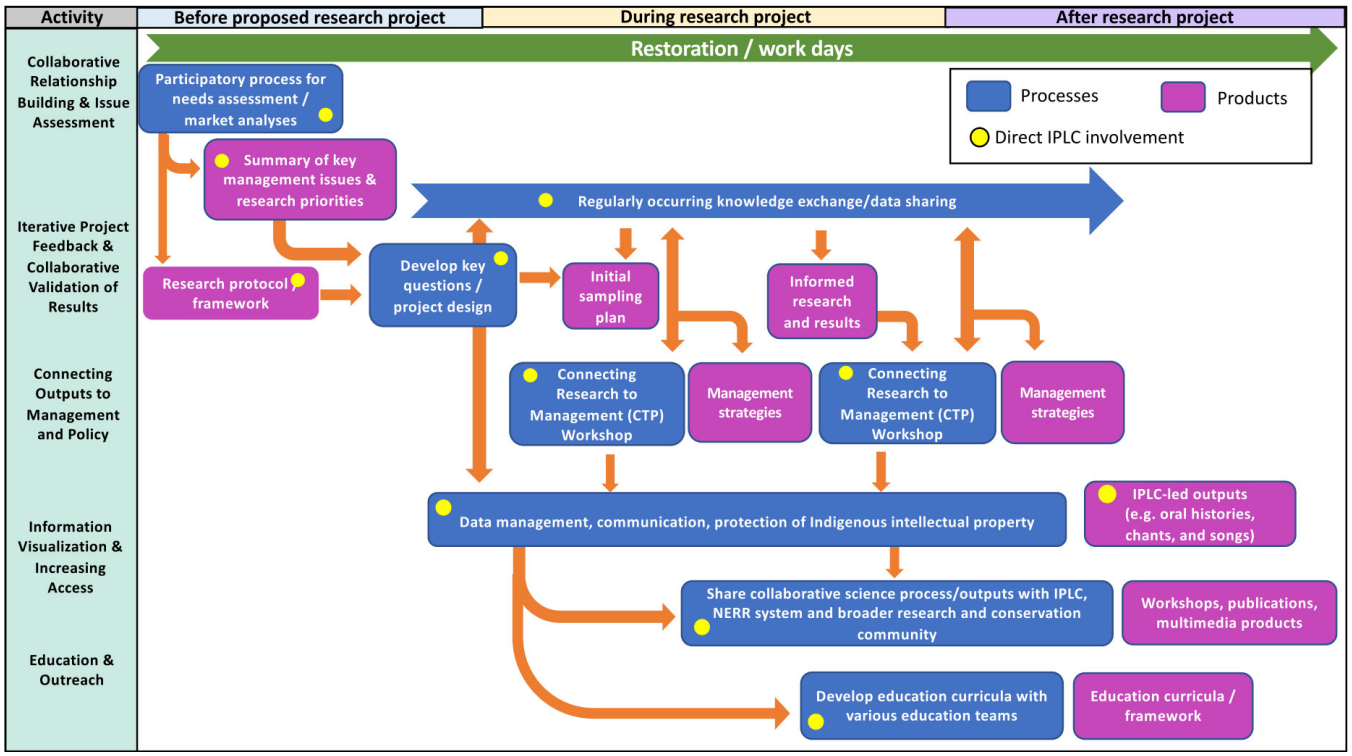
Contextualizing Heʻeia NERR's collaborative research framework

In the inaugural phase of the Heʻeia NERR, the fundamental question for its research program is: What are the most effective EBM strategies that contribute to the resilience and integrity of estuarine ecosystems considering anthropogenic drivers in the context of sociocultural and environmental factors? This question can be addressed by assessing a suite of ecosystem services. Research stemming from this question must weave modern technologies, tools, and information together with ancestral ones based on deep and ancient ties to the *ʻāina* (land) and born from Indigenous science that is encoded within ILK. We seek creative and collaborative research and management strategies to return food security, resilience, and sustainable resource stewardship to the hands of the community, thereby serving as an example of effective EBM in the twenty-first century.

However, the aspirations of the Heʻeia NERR are contextualized against the challenges and conflicts between IPLCs and researchers in Hawaiʻi (e.g., Alegado 2019), which are similar to those experienced by other IPLCs around the world. Accordingly, the Heʻeia NERR's research framework and associated guidelines align, in many ways, with both the letter and the spirit of those produced previously for researchers working with IPLCs (e.g., Kirkness and Barnhardt 2001, CIDA 2002, Fisher and Ball 2003, ISE 2006, CTKW 2014, Smith 2015) in that they honor the rights of Indigenous people and the perspectives of IPLCs. Although the context for the genesis of the Heʻeia NERR's framework shares similarities with place-based programs in other parts of the world, it contains some things not found in all IPLCs. For instance, as may be the case in many other IPLCs, Indigenous self-governance in Hawaiʻi is complicated by centuries of colonization, including the illegal overthrow of the Hawaiian Kingdom in 1893 and subsequent ramifications (Beamer 2014). As a result, there is no legally recognized, sovereign Indigenous entity representing Native Hawaiians and there are no nation-to-nation agreements like those that exist in other places. That said, certain Native Hawaiian rights still exist as originally codified under the Kingdom of Hawaiʻi. For instance, traditional and customary practices and the lands and waters on which they depend are protected by the State of Hawaiʻi Constitution and have been repeatedly reaffirmed by precedent set in case law (e.g., Akutagawa et al. 2016*a*, *b*). This provides a strong rationale for collaborative management and a collaborative research framework. Furthermore, the decades-long Hawaiian Renaissance (Chang et al. 2019*a*, Gon and Winter 2019) has resulted in new generations of graduate-level IPLC researchers in the biological, physical, and social sciences. This has allowed IPLC researchers to influence how research is conducted from within institutions, whether it be universities, government agencies, or nongovernmental organizations. The establishment of the Heʻeia NERR and this associated concept paper itself are notable achievements of that movement because they represent changes in policy and action that have resulted from doing work with IPLCs rather than within them (Smith 2013).

Accordingly, the goal of the Heʻeia NERR is to practice and promote responsible stewardship through collaborative management in manners that are consistent with Native Hawaiian values. It also conducts innovative research, in collaboration with its collaborative management partners, to contribute to broader understandings of sustainable ecosystem-based management within social-ecological systems. As such, the Heʻeia NERR aims to examine the effects of two fundamentally different management strategies relating to ecosystem services: (1) conventional ecological restoration techniques developed out of contemporary study of biological sciences in the modern era; and (2) IRM strategies informed by ILK (including Indigenous science) along with associated philosophies and practices. Both strategies seek to integrate concerns about the environment, society, economy, and human institutions, but focus on different aspects. In the former, ecological restoration is typical of contemporary conservation projects in which the primary goal is to restore a damaged or degraded ecosystem to a pre-existing state by using prehuman conditions as the starting point for restoration design (SER 2004). However, this strictly ecological focused approach, often advocated for by government agencies, falls short of the full tenets of EBM, which requires explicit consideration of humans as part of the ecosystem. Furthermore, this strictly ecological approach tends to lead to conflict between conservationists and IPLC members. The strategies associated with Hawaiian social-ecological systems, which characterizes the latter, are part of an EBM approach employed for centuries prior

Fig. 2. Schematic showing He'eia NERR's reciprocal collaboration process for researchers proposing a research project with Indigenous peoples and local communities (IPLC). Before proposing a project, researchers must develop a relationship with He'eia by engaging in restoration and work days. Then together with the IPLC, researchers must align their research interest/question with the needs and issues prioritized by the IPLC. Iterative feedback is crucial during and after the project through regular knowledge exchange meetings and Coastal Training Program (CTP) workshops to inform products and management strategies. Outputs and products will be IPLC-led and seek to protect Indigenous intellectual property.



to European contact (Jokiel et al. 2011, Bahr et al. 2015). The essential premise of this approach is to manage resources in a manner that optimizes multiple ecosystem services (defined holistically) in the context of a reciprocal relationship between people and nature (Winter et al. 2020*a*), which are encapsulated in Native Hawaiian values.

A values-based design for reciprocal collaboration in research

Researchers often aim to engage ILK held in IPLCs for various reasons (Tengö et al. 2017). However, collaborative studies initiated with and by IPLC members (i.e., in mutual agreement between researchers and IPLC members) can more effectively engage ILK than studies initiated by researchers alone (Smith 2013, Ban et al. 2018, David-Chavez and Gavin 2018, Kūlana Noi'i Working Group 2018). Reciprocal collaboration is a viable pathway for researchers to engage with IPLCs. Reciprocal collaboration has been defined as the ability to share ideas and perspectives in an open and trusting environment in which common goals are created through a collaboratively generated process (Johnson 2008). We add that reciprocal collaboration is also purposefully designed to be mutually beneficial to both researchers and the IPLC of place. However, any discussion of a research framework for reciprocal collaboration must be prefaced by ethical practices and values rooted in the Indigenous and local cultures of the area, with reciprocity and equity in mind (Kūlana Noi'i Working Group 2018). The Native Hawaiian community's sense of *kuleana*, to promote relationships to place and resilience of place, is held strongly. A sense of *kuleana* also exists regarding the revitalization of traditional and customary practices in an effort to restore and maintain a state of *'āina momona*. Thus, there are broad community and policy interests in sustainable resource management. Therefore, the He'eia NERR research program seeks to learn from and inform individual and collective *kuleana*, and to inform policy as it relates to adaptive management strategies for healthy and sustainable social-ecological systems. However, guiding principles for doing so are needed.

Guiding principles for a research framework centered on reciprocal collaboration

A fundamental goal of the He'eia NERR is to engage in reciprocal collaboration with the IPLC of the Ko'olaupoko region in a manner that equitably benefits both the community and researchers by recognizing and seeking to correct power disparities. Such an approach necessitates a *pono* framework for engaging in collaborative management and conducting collaborative research (Berkes 2009*c*, Bennett et al. 2019) within the designated boundaries of He'eia NERR (Fig. 1) and within the larger region of Ko'olaupoko. In this regard, research

conducted within and/or otherwise supported by the Heʻeia NERR should align with the priorities of the IPLC, and it should operate within a process deemed *pono* by the community. The Heʻeia NERR's framework for reciprocal collaboration, therefore, is built on a fundamental question and consists of a set of guiding principles for collaborative endeavors between researchers and IPLCs. This framework includes a list of research priorities identified by the community (see our reciprocal collaboration process for researchers and IPLC before, during, and after a proposed research project; Fig. 2).

Equally important are culturally attuned processes of acquiring free and informed consent prior to initiating research projects (cf. FAO 2016, Kūlana Noiʻi Working Group 2018). A general framework for research standards in Hawaiʻi, "Kūlana Noiʻi" (Kūlana Noiʻi Working Group 2018), was developed through a partnership led by the University of Hawaiʻi Sea Grant College Program and Kuaʻāina Ulu ʻAuamo (KUA), in consultation with Paepae o Heʻeia and the Heʻeia NERR. The Kūlana Noiʻi provides guidance for building and sustaining reciprocal collaborations and long-term relationships between researchers and IPLCs. The standards articulated therein are intended to be flexible guidelines adaptable to a range of different communities and to reflect the perspectives and responsibilities of both researchers and communities in the context of equitable and mutually beneficial research partnership. The Kūlana Noiʻi calls for researchers to engage with the community of their study area early and often in the research process. The framework for approaching (both proposing and conducting) research in the Heʻeia NERR (Fig. 2), as modeled by initial research conducted therein (Bremer et al. 2018*a*, Möhlenkamp et al. 2019, Winter et al. 2020*a*; Box 1) builds off the Kūlana Noiʻi guidance. The framework for reciprocal collaboration used in the Heʻeia NERR has four main guiding principles: (1) conducting culturally appropriate research; (2) collaboratively developing research; (3) collaboratively producing new knowledge; and (4) informing policy through sharing of collaboratively produced knowledge.

1. Conducting culturally appropriate research

Indigenous approaches to resource management provide invaluable insight into sustainable management practices because they document techniques that have been tested and demonstrated as effective over the course of centuries (Ban et al. 2018, Reyes-Garcia et al. 2019). Successful collaborative research projects with Indigenous communities are built on a firm understanding of and respect for reciprocal human-nature relationships. It also operates within the sense of place for those communities, including their genealogical ties to the landscape and biodiversity. In biocultural conservation and restoration efforts, this means conducting research that acknowledges the interconnected relationship between people and nature across both landscapes and seascapes (Poe et al. 2016). This foundation enables an approach that honors the views of that culture regarding life forms, places, and relationships that are sacred, ultimately strengthening and perpetuating these interconnected relationships (Kimmerer 2011, Smith 2013). Humility is required, as is an acceptance that research in academic institutions should be conducted in the context of knowledge accumulated over the course of generations in a single place (Tengö et al. 2017).

Heʻeia NERR advocates that the key to gaining humility and respect for reciprocal human-nature connection is to foster relationships between people from different worldviews, thereby creating opportunities for exchange of ideas and knowledge between IPLCs and researchers not familiar with the place or the people. We mandate all of our multilevel researchers, from undergraduate interns, graduate research assistants and fellows, to senior university researchers, to first and foremost develop a relationship with Heʻeia as a place by attending community work days and participating in *kilo* (observation, deep understanding of various natural phenomena; see Fig. 2's collaborative relationship building and issue assessment activity). Through spending physical and spiritual time at the place and with people of the place, researchers can start to frame research questions in a specifically Hawaiian context (e.g., *kaulana mahina*, the Hawaiian lunar calendar) and begin to think in terms of developing dual fluency of two often contrasting worldviews. Working side by side with IPLCs also helps to break down systemically imposed structures of hierarchy and establish personal relationships of trust.

2. Collaboratively developing research

Collaboratively developing research with the IPLC of place will align research questions with community priorities in ways that will cultivate trust, foster relationships, build capacity, and allow community partners to better understand their social-ecological system and pursue their own research questions (Laursen et al. 2018). In fundamental research (often cast as basic versus applied research), it can be challenging to align questions with community priorities. However, as long as the research is not deemed harmful by the community and the researchers follow cultural protocols of giving before taking, then fundamental research can align with the intentions of ensuring that research is beneficial to the social-ecological system rather than extractive. In terms of larger, more complex questions (e.g., ecological interactions), efforts must be made to ensure that research contributes positively to community values and priorities. This alignment is built on mutual respect and an understanding of questions that community members have for their own place. It is facilitated by research practices and methods that provide both community members and researchers with decision-making power through each stage of the research process, particularly in refining research questions, goals, and proposal development. In some instances, formal processes including memoranda of understanding between outside researchers and community partners can be useful to clarify expectations, garner collective agreement surrounding collaborative processes, and improve accountability (Minkler 2004). Such an agreement is already in place among the comanagement partners of the Heʻeia NERR.

Far too often IPLC partners are engaged only after a research project has been designed and funded, and then researchers are surprised to encounter pushback from the community. This is entirely possible even under NOAA's standard, end-user driven approaches to collaborative research (Yaffee and Wondolleck 2010). Only by engaging community partners in all aspects of research, with equal power in decision-making processes, can a project be truly community based. Seeking funding for research projects or otherwise engaging stakeholders from universities, research institutions, and government agencies should take place only after community support is achieved and the community has had the opportunity to shape research questions and objectives (see Fig. 2, Iterative project feedback activity). Researchers,

Table 2. The priority research topics identified for the inaugural phase of the He‘eia National Estuarine Research Reserve via participatory processes that included researchers, collaborative management partners, and IPLC members. Contextual descriptions for each priority research topic is included.

Priority Research Topic	Contextual Description
Historical Ecology	What and when were the major ecological regime shifts in Hawai‘i, how did these shifts affect ecosystem services, and how can historical ecology inform restoration and management of contemporary Hawaiian social-ecological systems?
Habitat Health	What are the spatial and temporal variability of physical and biogeochemical processes at the foundation of healthy watersheds, including a thriving wetland, productive Hawaiian aquaculture systems, and diverse coral reef ecosystems? How does restoration and maintenance of agroforestry, wetland agro-ecology, and novel forest types affect water quality, erosion control, nutrient cycling, carbon sequestration, and other ecosystem services?
Biological Indicators	What are the effects of Indigenous resource management on native species richness and abundance within local-scale habitats in the context of Hawaiian social-ecological systems?
Restoration of native species	How does the removal of terrestrial and/or marine invasive species affect ecosystem services and other indicators of healthy Hawaiian social-ecological systems, such as the presence of native biodiversity?
Well Being and Human Health	What are the sociocultural, educational, and economic aspects of ecosystem services, including biocultural indicators of human health and wellness at collective human scales (e.g., families and communities)? How does restoration of Hawaiian social-ecological systems help to control microbial contaminants detrimental to human and animal health?
Economics	How can Indigenous resource management be adapted to contribute to robust and resilient community-based, circular economies in a modern context?
Climate Change	What are the effects of changing climate conditions (e.g., intensified storm events, sea-level rise, eutrophication, ocean acidification) on healthy habitat functioning and ecosystem services? How does restoration of Hawaiian social-ecological systems promote resilience?
Scalability of Indigenous Resource Management	How can Indigenous resource management and the restoration of Hawaiian social-ecological systems in He‘eia address issues of conservation and sustainability in Hawai‘i and in other systems?

working in places or with resources (e.g., freshwater) that are stewarded by IPLCs, are far more likely to succeed if they follow such an approach. Within He‘eia NERR, collaborative management partners are working together to develop site-specific research protocols that include: (1) an establishment of relationship and respect with place (e.g., through individual relationships or through community work days); (2) transparent communication between researchers and IPLC members regarding specific details of the proposed research (e.g., duration, infrastructure, resources needed, etc.) with understanding that the methodologies will change iteratively through discussion; (3) relatability of research that benefits IPLC organizational goals and mission; and (4) inclusion of IPLCs in formal agreements to determine how data and knowledge generated from research in the places they steward is used (Kūlana Noi‘i Working Group 2018).

Research in Kāne‘ohe Bay, prior to the establishment of the He‘eia NERR, serves as an important example of belated or nonexistent engagement of IPLCs in research. Much of the research historically conducted in the area has been held within the scientific community and lacks a direct relationship to the questions that IPLC members have for their own place. This has led to strained relations between the IPLC and researchers, and a growing sense of negativity toward institutional science. The He‘eia NERR endeavors to realign scientific research with community interests and support mutually beneficial community-researcher partnerships identified through a participatory process with comanagement partners of the He‘eia NERR (see Fig. 2, Issue assessment activity). This ongoing iterative process has thus far involved public meetings and focus-group conversations facilitated by the He‘eia NERR Coastal Training Program (CTP), which seeks to contextualize research, recognize the value of expertise and knowledge systems not rooted in academic systems, and to guide the use of site-specific research protocols. In addition, the reserve’s CTP and education programs have conducted their own data collection, consisting of individual and group interviews, to inform needs assessments and market analyses that will guide the reserve’s training and education programs. The themes identified through these reports further inform the reserve’s current understanding of the IPLCs research priorities. We have categorized the emergent research questions under the context of ecosystem services gained or recovered through restoration via contemporary and Hawaiian IRM strategies (Table 2).

We acknowledge that although these questions are important during the inaugural phase of the He‘eia NERR, we intend to evaluate the focus of these questions frequently in consultation with the comanagement partners as initial research results become available, and as restoration and maintenance efforts evolve (see Fig. 2, Collaborative validation of results activity). Site-specific guidelines outlining the process of obtaining permission and opening dialog between researchers and IPLC members are being developed and adapted in the He‘eia NERR. Researchers interested in engaging in collaborative research are encouraged to establish relationships with IPLC members and with the place, then work with IPLC to collaboratively design projects that align with the reserve’s priority topics (Table 2; Fig. 2).

3. Collaboratively producing new knowledge

The outputs of projects that have been collaboratively developed between researchers and IPLCs constitute new knowledge that can be incorporated in both conventional and Indigenous knowledge systems. Just as the research itself was collaboratively

designed, the new knowledge coming out of it should be collaboratively produced via a process that includes collaborative validation, not only to check for accuracy, but also to confirm that Indigenous intellectual property is protected and that the information can be shared with broader audiences (see Collaborative validation of results and Information visualization activities in Fig. 2). Workshops (conducted by the He'eia NERR CTP) provide opportunities for communication between IPLCs and researchers throughout the research project, to promote iterative feedback on research methods, practices, and applicability to management strategies (see Fig. 2, Connecting outputs to management and policy activity). Products should be developed to share results in a way that aligns with the communication preferences of the collaborating IPLC members, such that the community, as a whole, will not only have access to, but will also understand and use the information (cf. as described in Pascua et al. 2017, Bremer et al. 2018*b*; see Fig. 2, IPLC-led outputs product). Inclusion of community collaborators in project outputs and dissemination processes creates an opportunity for IPLC members to contribute their unique knowledge and expertise to interpret results and shape conclusions, which contributes to higher quality research products.

Research outputs should increase access of the local communities to information in a broad sense (See Fig. 2, Increasing access and Education and Outreach activities). To increase access in the short term, He'eia NERR's education program develops curriculum based on current research, specifically targeting local students and educators. To increase community access to information, and the means to produce it, in the long term, the reserve builds the capacity of the next generation of local researchers through college-level classes and internships that facilitate student-driven research. Student-driven research has thus far helped to answer practical management questions and drive development of the reserve's long-term monitoring program (Buskey et al. 2015). By closely intersecting research efforts with education goals, He'eia NERR increases IPLC access to the physical location and research products while creating career pathways for local youth.

An aspiration of the He'eia NERR vision is that the results of the various research projects conducted in the reserve will be communicated in a form that protects Indigenous intellectual property and that honors the intellectual contributions of community collaborators, such as Indigenous people, cultural practitioners, and local elders (*kūpuna*) of the area. This can be done by inclusion of IPLC on research products with their prior informed consent, advocating for fair, equitable, and inclusive policy regarding authorship and acknowledgements to honor all individuals who contribute to the collaborative design and collaborative production of new knowledge. Potential models include the authorship guidelines developed by the Diversity of the IndoPacific Research Coordination Network (DIPnet) and the Equity in Author Order Protocol (Liboiron et al. 2017), from which He'eia NERR is in the process of developing its own authorship guidelines in collaboration with collaborative management partners.

Just as there are important scientific guidelines for data collection and dissemination, so too are there important ethical guidelines and best practices for information sharing, especially when reporting results outside of the community. When working with IPLCs there must also be special attention paid to locally or culturally sensitive information with regard to the people and places that are potentially impacted. One of the roles of IPLC collaborators is to determine what and how findings are reported outside of the community. For example, community members reasonably object to the public sharing of sensitive information such as the exact GPS coordinates of favored fishing spots or information on the abundance and availability (i.e., biomass) of culturally valued species being shared publicly. However, they could be more amenable to describing a general geographic region or aggregated ecological data for scientific publication. Once feedback and sharing permissions are received, the results reported to broader audiences should be done in a manner that honors the data sharing wishes and intellectual contributions of all those involved in the research.

4. Informing policy through sharing of collaboratively produced knowledge

As we find ourselves at the dawn of the Anthropocene and a 6th global mass extinction (Lewis and Maslin 2015), societies urgently seek solutions that address climate change in the context of habitat degradation and loss, as well as the overextraction of natural resources, while supporting larger populations (Mora et al. 2018, IPCC 2019). It is imperative to engage ILK in this process (Grossman 2008, Nakashima et al. 2012, Burkett 2013). Prioritizing applied research to focus limited time, energy, and resources on identifying positive and negative drivers of ecosystem services will inform adaptive comanagement in site-specific contexts. The He'eia community, however, also maintains connections to a broader web of organizations and partners leading place-based efforts to restore Hawaiian social-ecological systems across the archipelago. The collective impact of these efforts contributes to policy (e.g., laws, rules, and regulations, government initiatives, and/or strategic plans) at all levels of government. By sharing and analyzing applied, place-based research across these networks, we hope to inform policy, specifically in the realms of conservation and sustainability, to address larger-scale problems and structural issues inhibiting restoration of social-ecological systems. Ideally, such research syntheses should highlight sustainability solutions in a global context (Díaz et al. 2019). Doing so is especially important with regard to aligning efforts to improve local-level well-being with international policy, such as the UN Sustainable Development Goals (Sterling et al. 2020). Although we recognize the value of fundamental discipline-specific research (i.e., basic, conceptual, or theoretical explorations), the He'eia NERR advocates for interdisciplinary, policy-oriented applied research that views humans as part of the ecosystem. He'eia NERR facilitates collaborative development of such research through CTP workshops that facilitate knowledge exchange among researchers, IPLC members, stakeholders, resource managers, and decision makers.

The He'eia NERR provides one such model for conducting and otherwise supporting policy-oriented research, informed by IRM and ILK, to guide the adaptive comanagement within He'eia and inform related efforts in other communities. As we continue to more deeply understand the regional variations in the original design, structure, and function of Hawaiian social-ecological

systems, we can better gauge which approaches can be resurrected and adapted on larger scales in the 21st century. The data provided from various case studies throughout Hawai‘i, like those from Mo‘omomi on the Island of Moloka‘i (Friedlander et al. 2002, Poepoe et al. 2003), and from both Hā‘ena on the Island of Kaua‘i and Ka‘ūpūlehu on Hawai‘i Island (Winter and Lucas 2017, Burnett et al. 2018, Delevaux et al. 2018, 2019, Winter et al. 2020*b*), as well as initial studies conducted within the He‘eia NERR (e.g., Bremer et al. 2018*a*, Möhlenkamp et al. 2019), can inform policy and adaptive comanagement throughout Hawai‘i. These case studies, in conjunction with contributions that represent a broader synthesis of such thinking (Matsuoka et al. 1998, McGregor et al. 2003, Winter et al. 2020*a*), can illuminate how Hawaiian social-ecological systems can be a model for managing human-in-nature systems, particularly in terms of EBM, as well as for human well-being (Price and Toonen 2017, Gon and Winter 2019).

Box 1: Following guidelines for reciprocal collaboration in research: a case study in research that informs policy regarding sustainable development in Hawai‘i

1. Conducting culturally appropriate research

Since 2013, Rosie Alegado has partnered with Paepae o He‘eia (POH) to understand the microbial ecology of He‘eia Fishpond. As part of building strong relationships to the people and place, all members of her group participate in community work days and have contributed to educational programming at He‘eia Fishpond. Because of this established relationship of trust POH asked Alegado to serve as an informal research coordinator for He‘eia Fishpond in 2016. Her lab collaboratively designed their sampling regime to be consistent with practitioner monitoring sites and to align with the *kaulana mahina* (moon/tidal phases). Alegado’s research hypotheses are based on Indigenous knowledge drawn from Hawaiian language primary sources and kūpuna (elders) of the area. Alegado also partners with POH to host biannual Fishpond Science Nights that bring together IPLCs and members of the University community to share food and exchange knowledge.

2. Collaboratively developing research

To support their biocultural restoration efforts in an Indigenous aquaculture system (including the removal of invasive mangrove trees), POH and the University of Hawai‘i Sea Grant College Program identified a funding opportunity that required water quality monitoring as part of their restoration plan. Paepae o He‘eia reached out to long-time research partner, Alegado, for assistance. The result was an applied research project that met a grant deliverable narrowly, while informing POH’s restoration strategy broadly. A research question was collaboratively developed around understanding and characterizing the environmental changes that resulted from the massive restoration efforts. Sampling sites were chosen together by researchers and IPLC practitioners who possessed relevant ILK, and timing and frequency of sampling was adjusted in consultation with the IPLC members leading the project. Paepae o He‘eia staff were full participants in data collection and analysis alongside Alegado lab members.

3. Collaboratively producing new knowledge

Novel biological proxies to human health indicators regarding water quality were identified, through a collaborative process, to ensure protection of sensitive data. Subsequently Alegado’s group produced new molecular markers for these novel proxy indicators. Once completed, the research was published with the IPLC members, who contributed their intellectual property in the design process, as coauthors (e.g., Möhlenkamp et al. 2019). Research results were also presented to the public at He‘eia Fishpond Science Nights.

4. Informing policy in the realms of conservation and sustainability

As a result of this study, government agencies have a better understanding of the connection between removal of invasive mangrove and improvements to water quality. This restoration project is now held up as a model for sustainable development in policy circles, especially those around the state-sanctioned Hawai‘i Green Growth initiative and the Sustainable Hawai‘i goals.

Fig. 3. An aerial view of He‘eia Fishpond, the largest Indigenous aquaculture system in He‘eia, which covers approximately 36 hectares (88 acres) of the estuary and is stewarded by Paepae o He‘eia (a comanagement partner in the He‘eia NERR). It is estimated to be approximately 800 years old, and, after falling into disrepair and being inundated with invasive mangroves for several decades, has been the focus of biocultural restoration efforts since 2001. Photo credit: Keli‘i Kotubetey.

CONCLUSIONS

Indigenous people and local communities seek to decolonize the systems that influence their lives and to aspire to implement creative, place-based solutions to restore self-sufficiency at the community level. The He‘eia NERR represents a step toward achieving that vision, in part, by facilitating adaptive comanagement within an ICCA, and by having IPLCs play a

leading role in identifying problems, collaboratively developing research, collaboratively producing new knowledge, and influencing policy. This program joins many others in different regions around the world as the vanguard of efforts to change the way research is conducted and shift paradigms that drive how communities operate and thrive in a larger context. It supports the growing recognition that conventional science should not be extractive of IPLCs, but can engage in reciprocal collaboration with Indigenous science and other forms of ILK in support of the global movement toward more sustainable and resilient communities.

This concept paper establishes a framework for engaging in collaborative management within an ICCA and guidance for conducting collaborative research with IPLCs. The latter, in particular, is embodied by a fundamental question, a list of our initial phase of research priorities, and guiding principles and protocols emphasizing reciprocal collaboration, iterative engagement, and increasing access. The results of such research will inform adaptive comanagement between IPLCs and government agencies that incorporate new knowledge by weaving Indigenous and conventional knowledge systems. This can further be used to fill knowledge gaps and influence policy initiatives in Hawai‘i such as the Sustainable Hawai‘i initiative and the Hawai‘i Green Growth initiative. This research can also help the University of Hawai‘i at Mānoa to fulfill its expressed commitment of being a foremost Indigenous-serving institution and of advancing sustainability.

As Hawai‘i, and He‘eia specifically, revitalizes and adapts ancestral engineering and Indigenous approaches to adaptively managing social-ecological systems, the lessons learned here can be exported on a global scale. This model addresses global issues including habitat restoration, endangered species recovery, and sustainable food systems, all of which supports cultural revitalization and broader conceptualizations of resilience in the 21st century. In this regard, the He‘eia NERR is uniquely positioned to contribute to the ongoing debate about best practices for EBM within the paradigm of social-ecological systems.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/11895

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Data Availability:

There is no relevant data nor code underlying the findings described in this manuscript.

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